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The Middle Devonian Strata of Southern Illinois

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ABSTRACT

The Middle Devonian rocks have long been a major source of oil in the Illinois Basin. These rocks are exposed in southern Illinois in a small area along the Mississippi Valley in the extreme southwestern part of the state. In the outcrop area they have a strikingly different composition from equivalent strata in the deep part of the basin. Except for a thin basal transgressive sandstone, the outcropping section consists largely of shallow-water carbonates that are exceptionally pure at the base and become shaly upward. The pure carbonates (Grand Tower Limestone) are extensive throughout the basin, whereas the overlying shalier carbonates and interbedded shale (Lingle and Alto Formations) appear to grade eastward into shale only a few miles east of the outcrop area. The shale is divided into black shale (Blocher Shale) below and gray shale (Sweetland Creek Shale) above.

Facies and thickness variations are related to shallowing of the water over positive areas, the Sparta Shelf on the west and the Sangamon and Vandalia Arches on the north, the sinking Wittenburg Trough on the south side of the Sparta Shelf, and the deeper water of the Illinois Basin east of the DuQuoin Monocline.

The Lingle Limestone is subdivided into four members, the Howardton Limestone Member at the base, the Tripp Limestone Member, the Misenheimer Shale Member, and the Walnut Grove Limestone Member. All except the Misenheimer are new. A widespread oolite bed in the Walnut Grove, named the Rendleman Oolite Bed, is also new. These units, with distinctive geophysical key beds in the Sweetland Creek Shale, permit detailed tracing of Middle Devonian strata across the Illinois Basin.

INTRODUCTION

The Middle Devonian rocks of southern Illinois have been productive of large quantities of oil. They contain both reservoirs and source rocks, and a knowledge of their complex lateral variations is important in the search for new production, in the study of methods for secondary and tertiary production from partially depleted fields, and in the use of the reservoirs for storage of natural gas. Extensive drilling in the Illinois Basin has provided a large amount of geophysical data and many well samples and has made it both possible and timely to gain a greater understanding of Middle Devonian stratigraphy.

The Middle Devonian strata of southern Illinois, in general, are shallow-water carbonates in the lower part and shale in the upper part. They range in thickness from nothing at the west to about 400 feet in the deep part of the Illinois Basin. The lowermost unit within this section, the Grand Tower Limestone, is considered in more detail by Meents and Swann (1965). The younger formations, given more detailed consideration in this report, are the Lingle Formation, Alto Formation, Blocher Shale, and Sweetland Creek Shale.

The purposes of the investigation are to determine the thickness and distribution of the formations at and beneath the Middle-Upper Devonian boundary of southern Illinois and to study the lithologic changes both vertically (stratigraphic) and laterally (facies) within and between the formations. Of particular importance are the relations between the lower units of the New Albany Shale Group and the upper units of the Middle Devonian carbonate sequence.

The study is limited to the Middle and Upper Devonian strata of east-central and southern Illinois (fig. 1). The significant relations of the shale versus limestone facies are located south of the Vandalia Arch. Moreover, the carbonates to the north of the arch contain little or no silt and clay, and, therefore, their interpretation requires a different approach that is beyond the scope of this study.

Previous Work

The outcrop area of Devonian formations in southwestern Illinois and southeastern Missouri has been intensively studied. Investigations encompassing the entire Devonian section include those of Keyes (1894) and Croneis (1944) in southeastern Missouri and Savage (1920a, 1920b) and Weller (1944) in southwestern Illinois. Savage (1920a, 1920b) lists many fossils. Orr (1964) describes the type Lingle Formation and type Alto Formation sections and their conodont faunas. Grimmer (1968) describes the megafauna of the shale in the Lingle Formation.

Regional correlations are discussed by Savage (1910, 1920a, 1920b, 1925), Cooper et al. (1942), Cooper (1944), Weller (1944), and Collinson et al. (1967). The report by Collinson et al. is the most inclusive as well as most recent.

The subsurface Devonian stratigraphy of southern Illinois is summarized by Workman (1944). Workman and Gillette (1956) studied the New Albany Shale throughout its extent in Illinois. Warthin and Cooper (1944) discuss Middle Devonian formations. All of these reports are based primarily on sample studies. Several recent studies use geophysical logs in conjunction with samples and/or conodont data. Schwalb (1955) describes the Geneva Dolomite. Whiting and Stevenson (1965) delineate the Sangamon Arch of west-central Illinois and describe the Middle Devonian stratigraphic relations around the arch. Meents and Swann (1965) describe

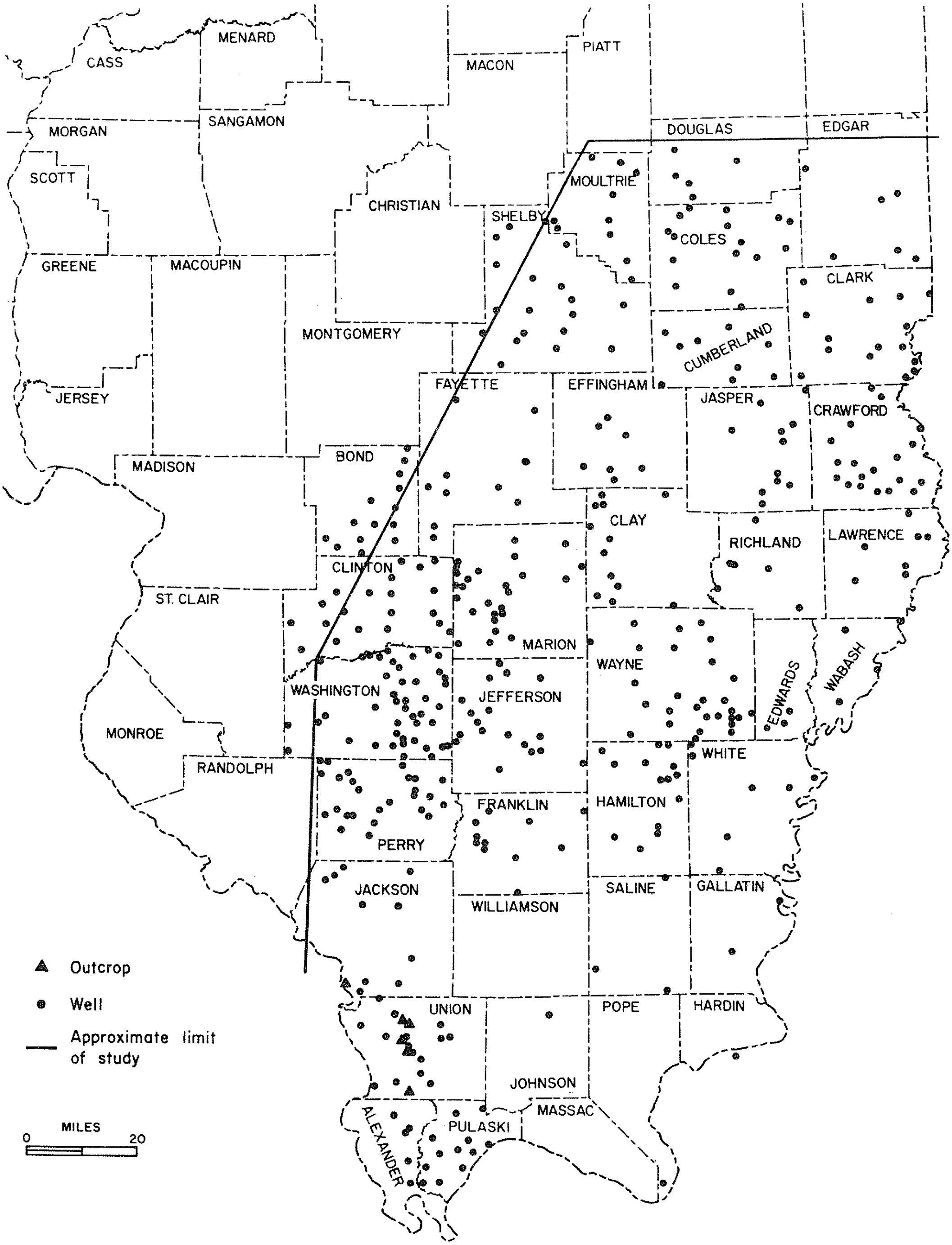

Fig. 1 - Location of area studied and distribution of datum points.

the Grand Tower Limestone of southern Illinois. Collinson et al. (1967) summarize knowledge of Devonian stratigraphy throughout the north-central states using geophysical and sample data in the subsurface. James (1965) studied the Sweetland Creek Shale of western Illinois using samples and conodonts.

Methods of Study

In this study most of the outcrops of southwestern Illinois were examined. Geologic sections that contain type sections of new units are given in Appendix B. The available chip samples from wells in the outcrop area and selected chip samples from wells elsewhere in southern Illinois were studied. Except where more than one well record is available within a section, every available geophysical log, core description, and sample description was examined (fig. 1). Forty of the wells were used in the cross sections (fig. 2). The list of wells used in compiling the cross sections is given in Appendix A.

Between drill holes in the cross sections, formation and member contacts at facies boundaries are shown by vertical lines—"vertical cutoff." Sloping lines between drill holes indicate thickening or thinning without evidence of facies relation.

Distinctive, readily traceable, features or positions on geophysical logs are called "key beds" in this report.

Acknowledgments

The writer wishes to express his deep gratitude to the late David H. Swann of the Illinois State Geological Survey, who suggested the topic and gave much help in solution of the problems. This report is based on a doctorate thesis at the University of Illinois. Ralph L. Langenheim, Jr., thesis advisor, gave constructive criticism in all phases of the study. Albert Carozzi, Carleton A. Chapman, C. John Mann, and R. D. Seif, of the University of Illinois, and Elwood Atherton, Charles W. Collinson, Wayne F. Meents, and H. B. Willman, of the Illinois State Geological Survey, critically read the manuscript and gave many helpful suggestions.

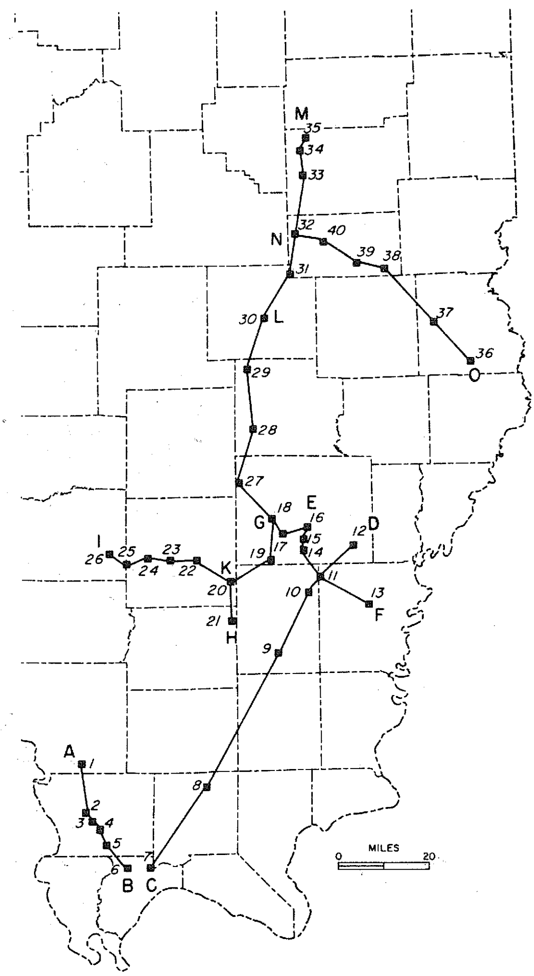

Fig. 2 - Lines of cross sections. Wells listed in Appendix A.

GEOLOGIC SETTING

The complex facies and distribution patterns of Middle Devonian sediments were influenced by two positive features that must not have been very far above Middle Devonian sea levels—the Sangamon Arch in central Illinois and the Sparta Shelf in southwestern Illinois (fig. 3). A northeastward extension of the Sparta Shelf into easternmost Illinois, inferred from thinning of Middle and lower Upper Devonian units, is called the Vandalia Arch. In the southeast, the Moorman Syncline represents the area of maximum subsidence. In the southwest, the Sparta Shelf was truncated by the Wittenberg Trough, a narrow, elongate structure, which was persistently negative during Middle and Late Devonian time.

Sparta Shelf

The broad wedge-shaped area in southwestern Illinois where Middle Devonian strata are absent (fig. 3) was recognized as a spur of the Ozark Uplift by Workman and Gillette (1956) and was formally named the Sparta Shelf by Meents and Swann (1965). The shelf is bounded on the east by the eastern slope of the DuQuoin Monocline and on the south by the Wittenberg Trough. It gradually merges northward into the depositional basin. The DuQuoin Monocline extends southward several miles beyond the eastern end of the Wittenberg Trough, thus effectively separating the trough from the deeper portion of the Illinois Basin to the east.

Wittenberg Trough

The Wittenberg Trough (Meents and Swann, 1965) is partially preserved in isolated fault blocks along the Ste. Genevieve-Rattlesnake Ferry Fault that extends more than 70 miles from Ste. Genevieve County, Missouri, to Union County, Illinois (fig. 3).

The Wittenberg Trough has had a long and complex history. It first subsided late in early Devonian time, which resulted in preservation within the structure of Lower Devonian strata that in areas adjacent to the trough were truncated prior to Middle Devonian time. Deposition continued through Middle Devonian and into Late Devonian. The trough was greatly deformed by post-Mississippian deformation (Meents and Swann, 1965). At the eastern end of the fault in northern Union County, the axis of the depositional trough turns southward, which indicates that the southern extremity of the DuQuoin Monocline formed a barrier between the trough and the deep part of the Illinois Basin to the east.

Sangamon Arch

The Sangamon Arch (Whiting and Stevenson, 1965) is a low, broad, northeast-southwest trending structure that extends from east-central Missouri into east-central Illinois (fig. 3). The structure was a positive area during the Middle Devonian.

Vandalia Arch

Workman and Gillette (1956) defined the Vandalia Arch on the basis of stratigraphic relationships of Mississippian strata, but the arch influenced the thickness and facies of certain Middle Devonian units. The arch trends northeast-southwest, parallel to and approximately 50 miles south of the Sangamon Arch. To

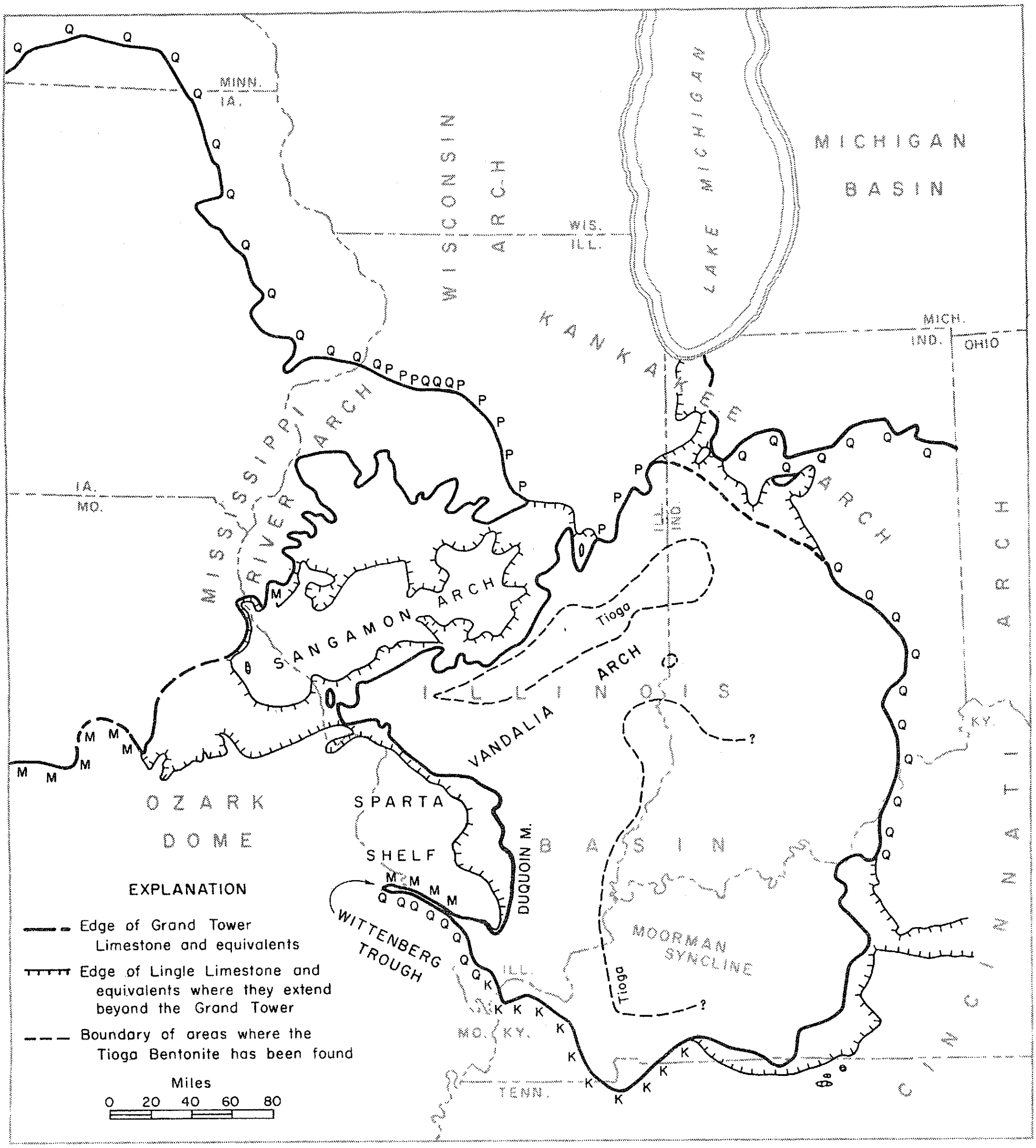

Fig. 3 - Distribution of the Grand Tower and Lingle Formations and correlative units and their relation to major structures (modified after Meents and Swann, 1965). The age of the formations truncating the Grand Tower is indicated by a letter: Q=Quaternary, K=Cretaceous, P=Pennsylvanian, M=Mississippian and Upper Devonian.

the west, the Vandalia Arch merges with the Sparta Shelf in the Clinton County area (T. 2 and 3 N., R. 1 W.); it extends eastward to the Indiana line in Edgar County (about T. 12 N.).

STRATIGRAPHY

Classification

The Middle and Upper Devonian strata of southern Illinois are dominated by carbonates in the lower part and argillaceous rocks in the upper part. The carbonates are the uppermost part of the Hunton Limestone Megagroup (Swann and Willman, 1961), which contains strata as old as lowermost Silurian. Shale of the upper part belongs to the lowermost part of the New Albany Shale Group, the lowest unit within the Knobs Shale Megagroup, which includes Upper Devonian and Mississippian (Kinderhookian and Valmeyeran) strata.

The carbonate units are the Grand Tower Limestone (below), the Lingle Formation, and the Alto Formation (fig. 4). The Grand Tower Limestone, originally defined by Keyes (1894), includes relatively pure carbonate strata between the base of the Dutch Creek Sandstone Member and the first occurrence of argillaceous limestone. The Grand Tower Limestone overlies the major pre-Middle Devonian erosion surface, the sub-Kaskaskia unconformity (Sloss, 1963). The first occurrence of argillaceous limestone in southwestern Illinois corresponds with the first occurrence of fossils correlative with the Hamilton Group fauna of New York (Meents and Swann, 1965) and the zone of abundant Microcyclus, a button-shaped solitary coral. The Grand Tower Limestone occurs south of the Sangamon Arch.

In the southwestern Illinois outcrop area, the Grand Tower Limestone is overlain by shaly limestone and calcareous shale that is very poorly exposed. In the southern part of the outcrop area, Savage (1920a) referred these rocks to a lower shale unit (Misenheimer Shale) and an upper limestone unit (Lingle Limestone). He thought that the shale pinched out northward so that the Lingle Limestone rested directly on the Grand Tower Limestone at the Grand Tower type locality in the northernmost part of the outcrop area. Weller (1944), however, considered the shale to be too poorly defined to differentiate and included it within the Lingle Limestone Formation. This was followed by Orr (1964) and Meents and Swann (1965).

Cooper et al. (1942) and Cooper (1944) distinguished the Misenheimer Shale from the Lingle Limestone in the Lingle type area on the basis of megafossils but considered the fossils of the Lingle Limestone at the Grand Tower type locality to be older than those of the Misenheimer Shale. For this reason, Grimmer (1968) traced the Misenheimer Shale from the southernmost outcrop area to the northern outcrop area. He tentatively assigned the Missouri term St. Laurent Limestone to the lower limestone, the Misenheimer Shale Member of the Lingle Limestone to the middle shale, and the Lingle Limestone to the upper limestone.

The name Lingle Formation has been long accepted for the limestone overlying the Grand Tower Limestone and overlain by the Sweetland Creek Shale or Alto Formation, and its use is continued here. The term St. Laurent Limestone in Illinois is rejected because as used in its type area in Missouri, it includes the Alto Formation (Dake, 1918; Weller and St. Clair, 1928; Collinson et al., 1967). The term Misenheimer Shale is retained as a member of the Lingle Formation. Three new members of the Lingle Formation are named in this report (fig. 4). The Howardton

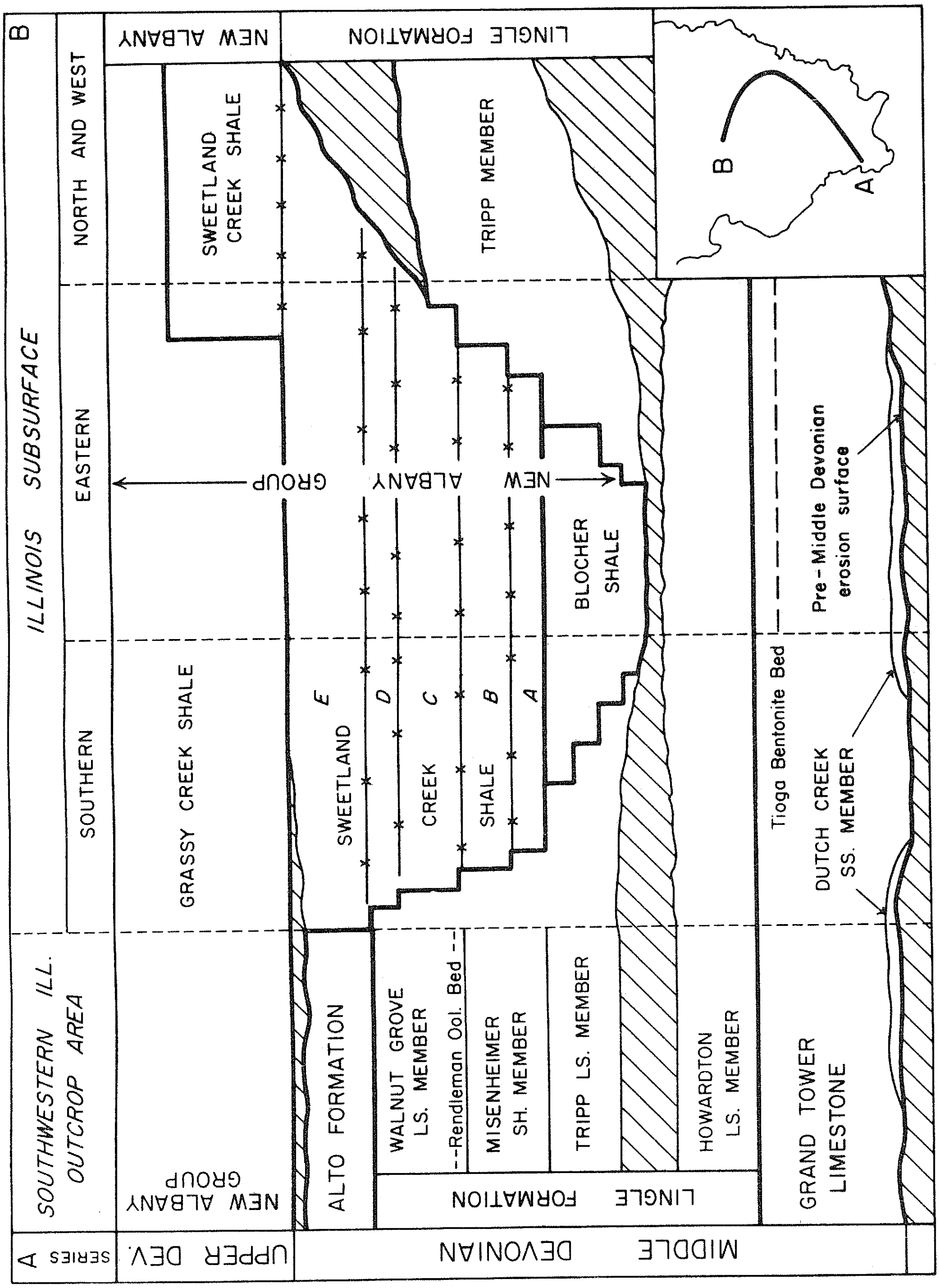

Fig. 4 - Diagrammatic chart showing stratigraphic relations and correlations of Middle Devonian and early Upper Devonian units in southern Illinois.

Limestone Member (at the base) is overlain by the Tripp Limestone Member. The Walnut Grove Limestone Member (at the top) overlies the Misenheimer Shale Member. An oolite bed within the Walnut Grove Limestone in the outcrop area is here named the Rendleman Oolite Bed (fig. 4).

The Alto Formation consists of strata overlying the limestone of the Lingle Formation and underlying the shale of the New Albany Group, as originally defined by Savage (1920a). The formation, however, is restricted to the southwestern Illinois outcrop area and is not extended into the southern Illinois subsurface, as Workman (1944) and Meents and Swann (1965) suggested.

Two lower formations of the New Albany Shale Group are included in this study—the Blocher Shale and the Sweetland Creek Shale. The Blocher Shale is the carbon-rich black shale that is the lowermost unit in the type area of the New Albany Shale Group in Indiana (Campbell, 1946; Lineback, 1968; Collinson et al., 1967). Because this report, as well as that of Collinson et al., is based on electric log studies, it disagrees in some respects with that of Lineback, who picked the top of the Blocher Shale in southern Indiana on the basis of well cuttings and placed the boundary somewhat higher stratigraphically. The Blocher Shale is present only in the southeastern part of the area of this study, and apparently is in facies relationship with the Tripp Limestone Member of the Lingle Formation to the west (fig. 4).

The Sweetland Creek Shale rests on the Blocher Shale to the east and the carbonates of the Lingle Formation to the west. The Sweetland Creek Shale was named by Udden (1899) for exposures in southeastern Iowa, and the term was used in western Illinois for many years. Workman and Gillette (1956) discontinued the use of the term Sweetland Creek in Illinois. In southern Illinois, Meents and Swann (1965) differentiated a dominantly gray shale unit from the overlying black shale in the New Albany Group and referred to it as the "unnamed shale." James (1965) and Collinson et al. (1967) reinstated the term Sweetland Creek and extended it to include the "unnamed shale" in southwestern Illinois. The Sweetland Creek is a facies of both the overlying Grassy Creek Shale and underlying Lingle Formation and is continuous from southeastern Iowa to southernmost Illinois.

Correlation

The correlation of the Devonian strata of the outcrop areas of southwestern Illinois with adjacent states, New York, and Europe is shown by Collinson et al. (1967), who give the ranges of both megafossils and microfossils. Conodont faunas from some of the southwestern Illinois Middle Devonian sections are described by Orr (1964). Megafossils are listed by Savage (1920a, 1920b) and Grimmer (1968).

Both the megafossil and microfossil evidence indicates that the Grand Tower Limestone correlates with parts of the Onondaga Group of New York and that the Lingle Formation correlates with the Hamilton Group of New York. Only the older portion of the Lingle Formation is present in the southern Illinois subsurface. Approximately the upper half of the outcropping Lingle Formation grades into the Blocher Shale and the Sweetland Creek Shale (fig. 4).

Conodonts in the Alto Formation of southwestern Illinois are considered by Collinson et al. (1967) to be latest Middle Devonian in age.

GRAND TOWER LIMESTONE

The Grand Tower Limestone is the oldest Middle Devonian formation of southern Illinois. Resting on the pre-Middle Devonian erosion surface, the formation is largely pure limestone and dolomite, although at almost all localities the basal parts contain isolated sand grains or lenses of sandstone called the Dutch Creek Sandstone Member. The Grand Tower Limestone consists mainly of fossiliferous limestone south of the Vandalia Arch, dolomite on the arch, and lithographic limestone north of the arch.

The type section of the Grand Tower Limestone (fig. 5), as designated by Keyes (1894) and illustrated by Meents and Swann (1965, p. 5, fig. 2), is in the Devil's Bake Oven, Sec. 23, T. 10 S., R. 4 W., Altenburg Quadrangle, Jackson County, Illinois. In the type section the formation is 157 feet thick. The lower 52 feet consists of sandstone at the base overlain by medium- to coarse-grained, cross-bedded, light-colored, crinoidal limestone, the lower part of which is sandy. The upper 105 feet consists of medium-grained, darker colored, crinoidal limestone as well as fossiliferous, fine-grained to lithographic, dark-colored limestone.

The type section of the Grand Tower Limestone is atypical. A few miles to the south and east of the type section the Grand Tower is only two-thirds as thick and is similar to the lower 52 feet at the type section. The lithologies in the upper 105 feet of strata at the Bake Oven appear restricted to the western portion of the Wittenberg Trough. On the basis of macrofossil evidence, Cooper (personal communication) suggested that rocks equivalent to the upper dark limestone at Devil's Bake Oven do not crop out south of the Bake Oven.

In southernmost Illinois, the Grand Tower Limestone can be traced from the outcrop to the subsurface with little hesitation (figs. 6 and 7). Farther north, however, correlation becomes difficult where the overlying Howardton Member of the Lingle Formation loses a significant part of its argillaceous content and where the Grand Tower changes from limestone to dolomite (fig. 5). Correlation there is aided by the occurrence of the Tioga Bentonite Bed, 10 to 30 feet below the top of the Grand Tower Limestone (Meents and Swann, 1965). The Tioga Bentonite is less than 1-foot thick and is readily recognized in geophysical logs throughout a large area in eastern Illinois (fig. 3).

Thickness and distribution

In the outcrop region, the Grand Tower Limestone is thickest at the type section (157 feet). Eastward, it thins abruptly to less than 50 feet over the southern extension of the DuQuoin Monocline (fig. 5). Southward, the formation thins toward its shoreline in T. 16 S., Pulaski County, Illinois.

In subsurface the Grand Tower Limestone ranges in thickness from 0 along the flanks of the Sparta Shelf to greater than 250 feet in the Moorman Syncline of southeastern Illinois (fig. 5). Stratigraphic relations indicate that the distribution of the limestone has been changed little by subsequent erosion. Therefore, figure 5 shows essentially the primary depositional extent of the unit.

The distribution reported here is not significantly different from that shown by Meents and Swann (1965, fig. 3), except in Jefferson, Perry, and Washington Counties along the eastern side of the Sparta Shelf. In those counties they show a thick tongue of Grand Tower extending westward onto the Sparta Shelf for 30 miles. The greater part of these strata is referred herein to the Lower Devonian Backbone Limestone, thus restricting the Grand Tower Limestone to east of the Sparta Shelf.

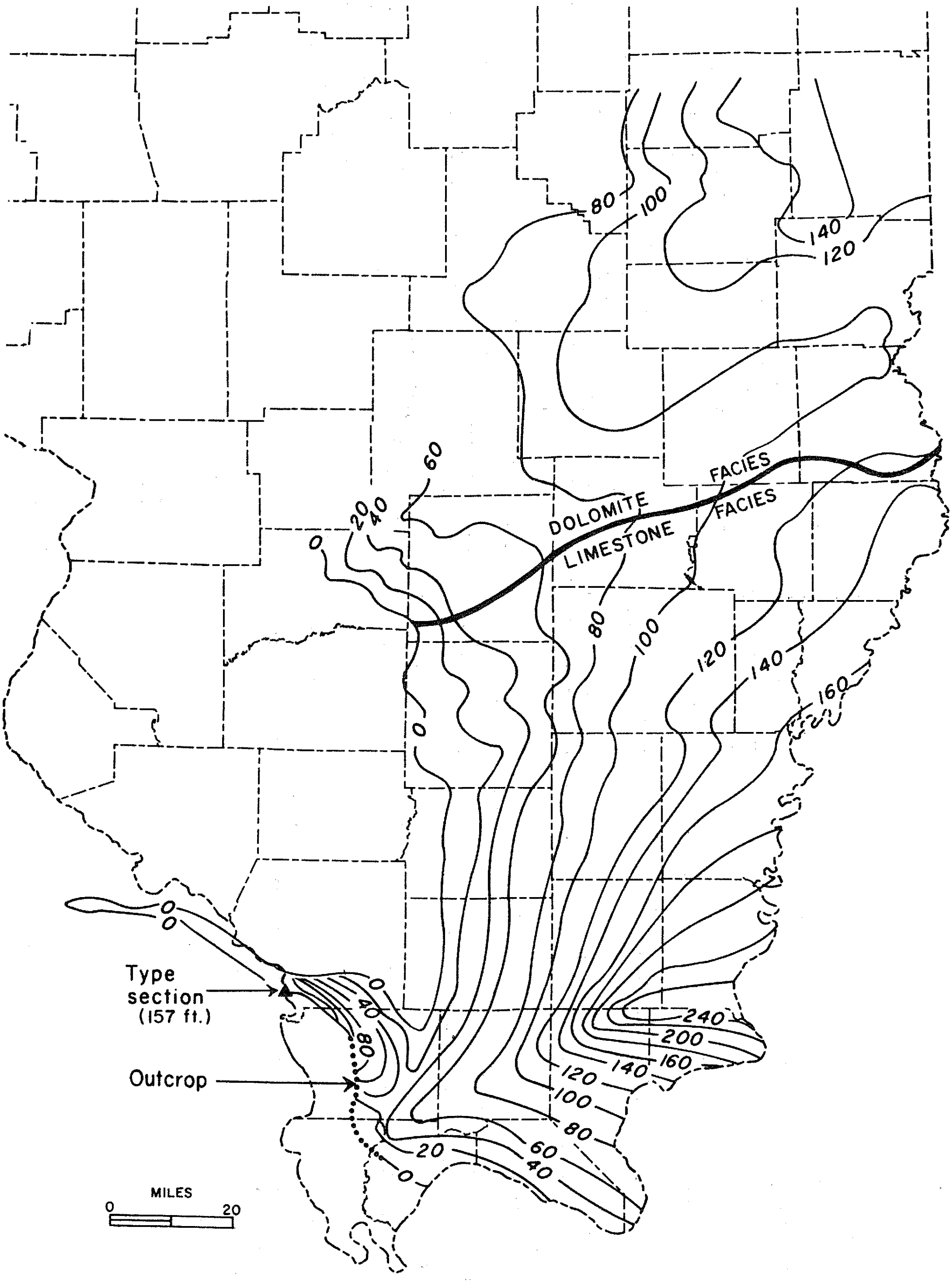

Fig. 5 - Thickness of Grand Tower Limestone.

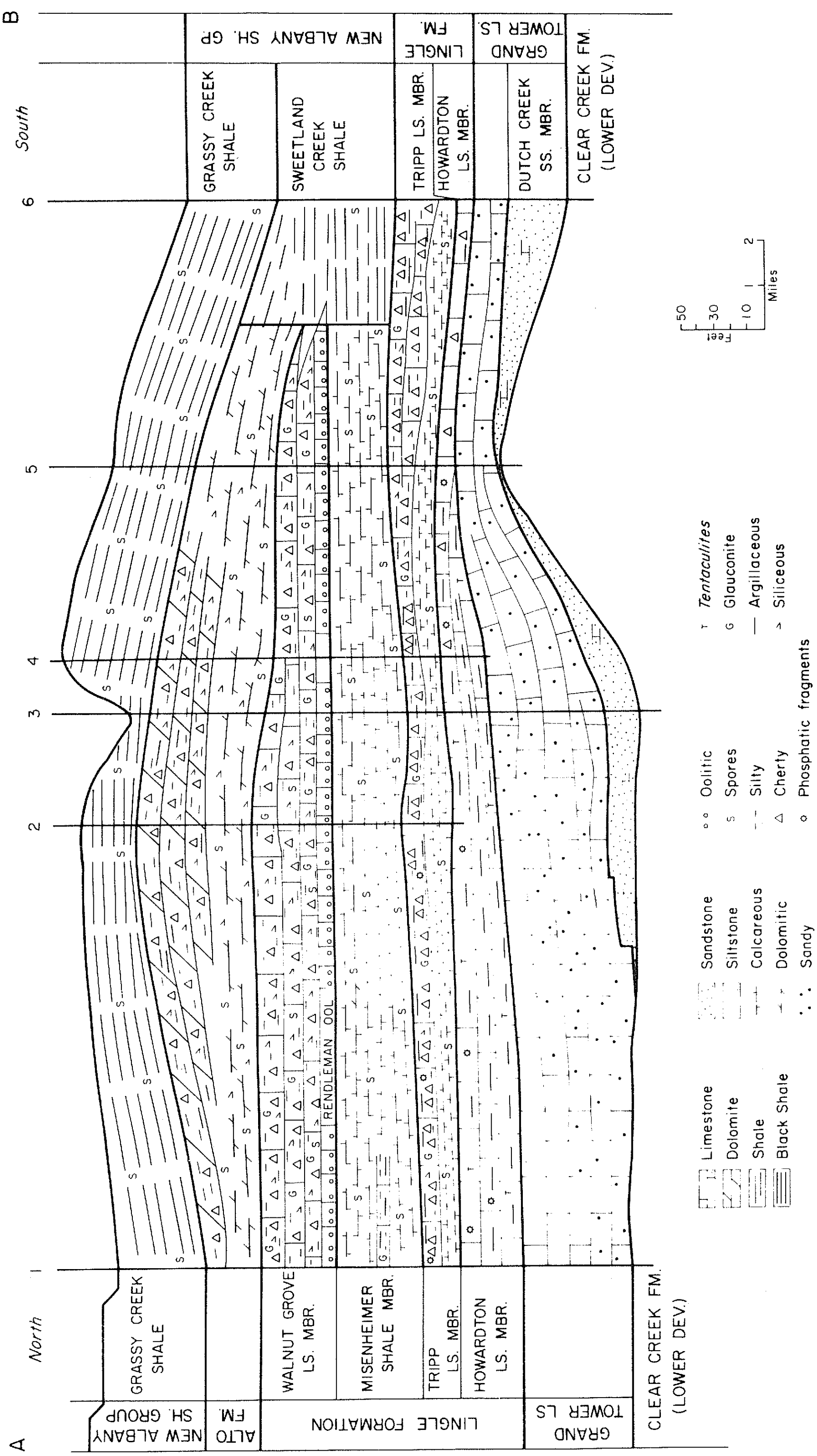

Fig. 6 - North-south lithology cross section A-B in southwestern Illinois outcrop area. Location shown in figure 2.

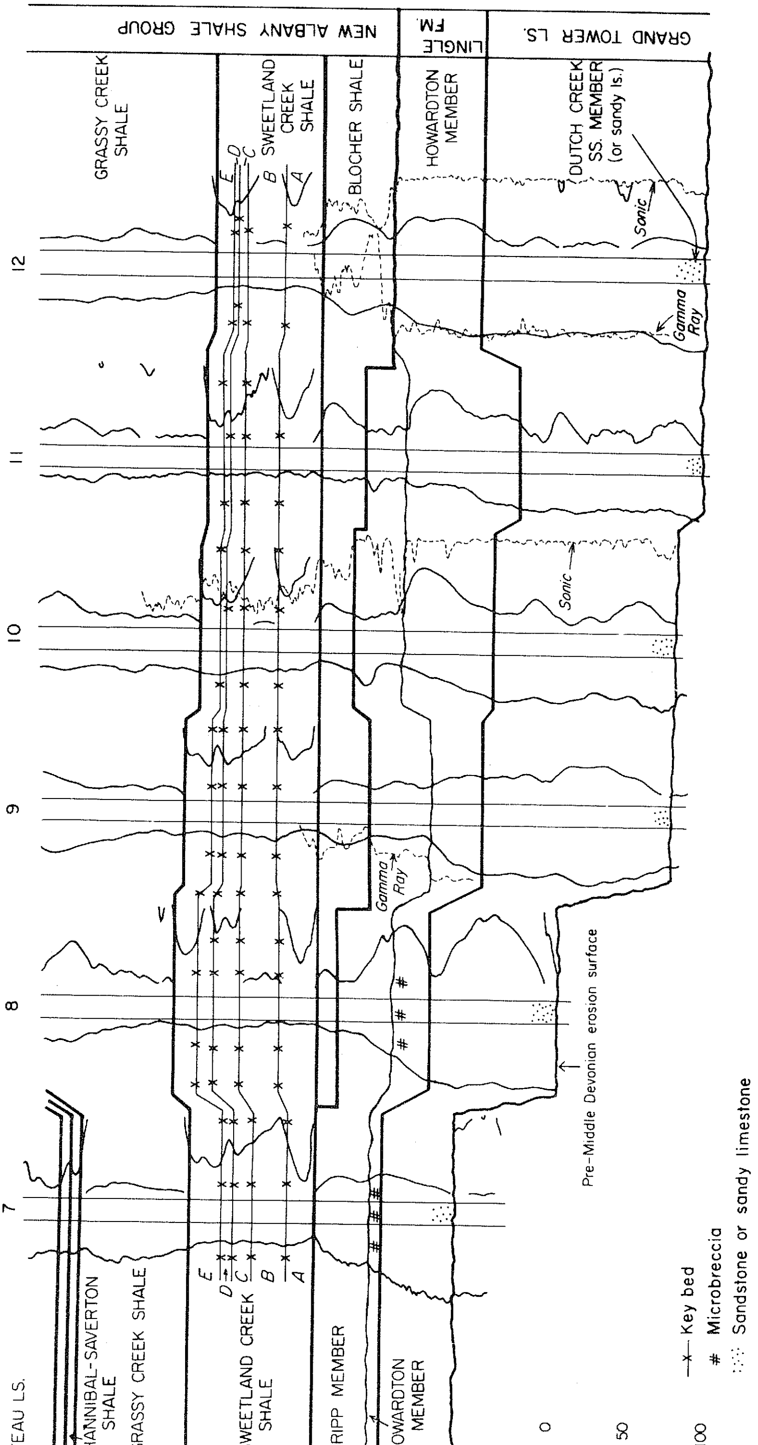

Fig. 7 - Southwest-northeast geophysical log cross section C-D from southwestern Illinois to eastern Illinois. Location shown in figure 2.

This interpretation is based on (1) the absence of sand at the base of the tongue, (2) tracing key beds within both the Lower Devonian and the Middle Devonian, (3) lithologic similarity of the limestone with that of the Backbone Limestone, and (4) the occurrence in a core in the lower part of the tongue of two Lower Devonian guide fossils, Eodevonaria and Acrospirifer murchisoni.

The Grand Tower Limestone has the Dutch Creek Sandstone Member or sandy limestone at its base over almost its entire extent; very few exceptions occur. Meents and Swann (1965) showed a small sand-free area east of the Sparta Shelf, but subsequent study has shown the sand to be there.

Lithology

The Grand Tower Limestone is uniformly fossiliferous, light colored, and nearly pure carbonate. Except for the basal Dutch Creek Sandstone Member, insoluble residue characteristically amounts to less than 5 percent and consists of angular to subrounded quartz grains ranging in size from coarse silt to coarse sand. Limestone textures range from lithographic through coarse grained to microbreccia.

In the dolomitic area over the Vandalia Arch, the formation consists of dark, sandy, crystalline dolomite (the Geneva Dolomite Member) at the base and lighter colored, laminated dolomites above (Schwalb, 1955; Meents and Swann, 1965). Only the latter are in contact with the overlying Lingle Formation. The laminated dolomites are gray, yellow to tan, fine-grained dolomite. Insoluble content in these strata is identical to that of the limestone facies. Carozzi and Textoris (1967) interpreted equivalent laminated dolomites of the Indiana outcrop area as deposits in a supratidal, penesaline, low-energy environment.

Geophysical characteristics

In the limestone area the geophysical characteristics of the Grand Tower Limestone are quite consistent (figs. 7-14). The rather low porosity of the limestone produces uniformly high electrical resistivities, neutron responses, and sonic velocities. Electrical resistivity logs characteristically have slightly lower resistive zones at the top, middle, and base (fig. 7, well 11). Except for the Tioga Bentonite Bed, the spontaneous potential is uniformly high-negative, and the natural gamma radioactivity is uniformly low.

In the dolomite area the electrical resistivities, neutron responses, and sonic velocities are all low in response to the higher porosities. The spontaneous potentials and natural gamma radioactivities are comparable to those of the southern limestone area.

LINGLE FORMATION

In the southwestern Illinois outcrop area, the Lingle Formation was defined by Savage (1920a) to include the strata from the Microcyclus Zone at the base to the base of the silty dolomites or dolomitic, silty limestones of the Alto Formation. The type section designated by Savage is near Lingle School, in Sec. 26, T. 13 S., R. 2 W., Union County. Recent studies by Grimmer (1968) and wells in the area indicate that only a small portion of the formation is exposed at this locality. Nowhere in southwestern Illinois is the Lingle Formation completely exposed in one

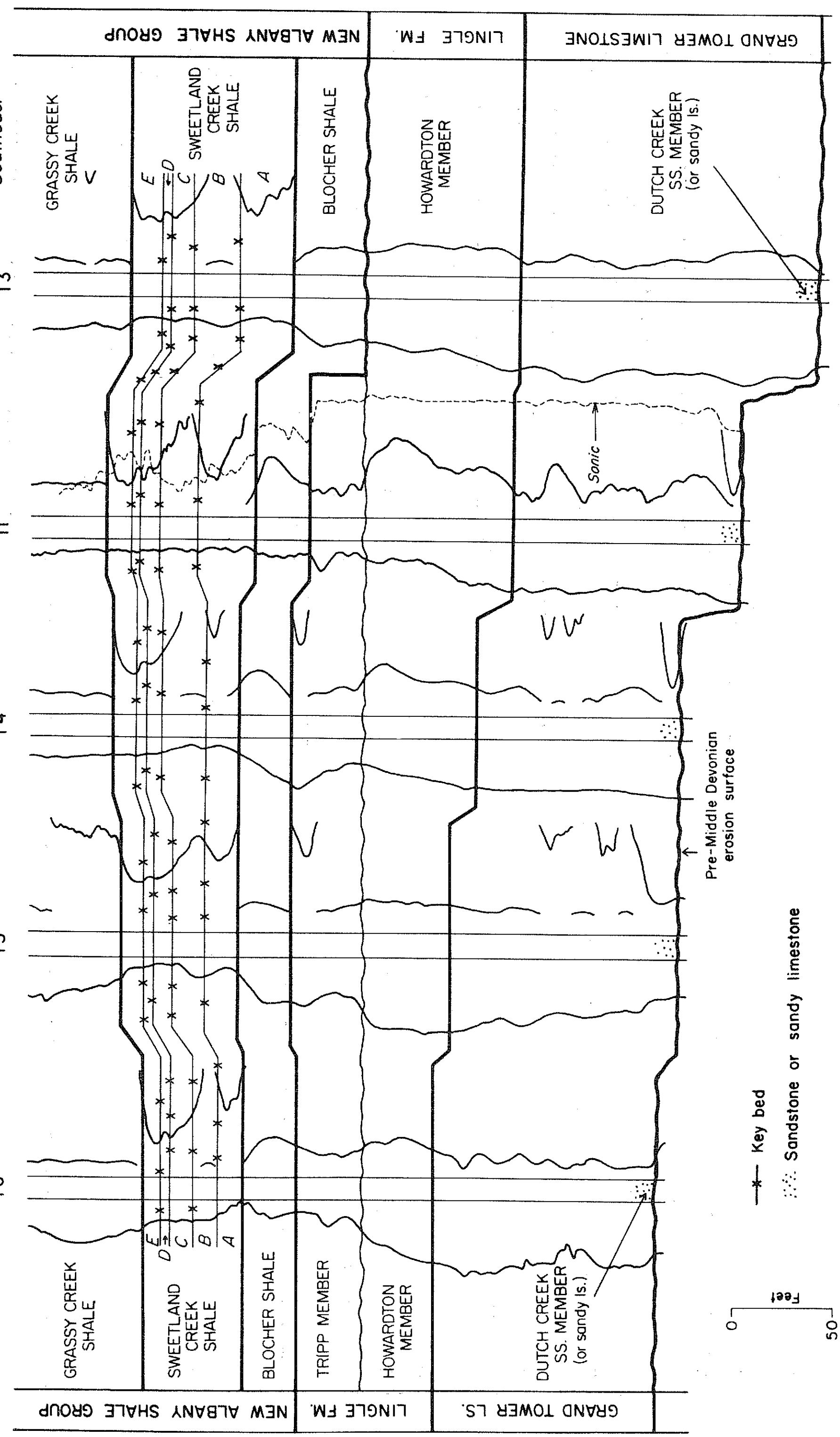

Fig. 8 - Southeast-northwest geophysical log cross section E-F in eastern Illinois. Location shown in figure 2.

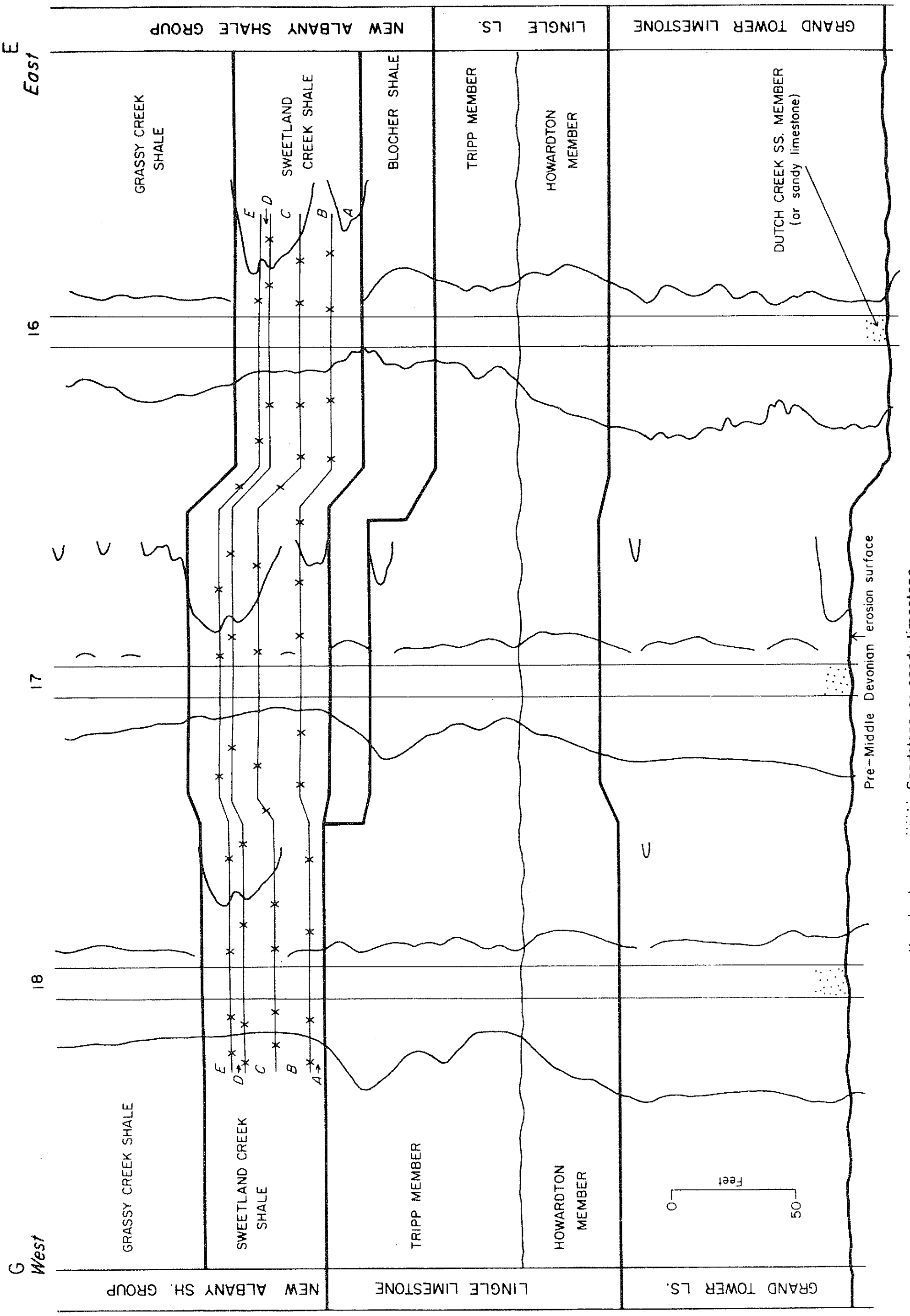

Fig. 9 - East-west geophysical log cross section G-E in eastern Illinois. Location shown in figure 2.

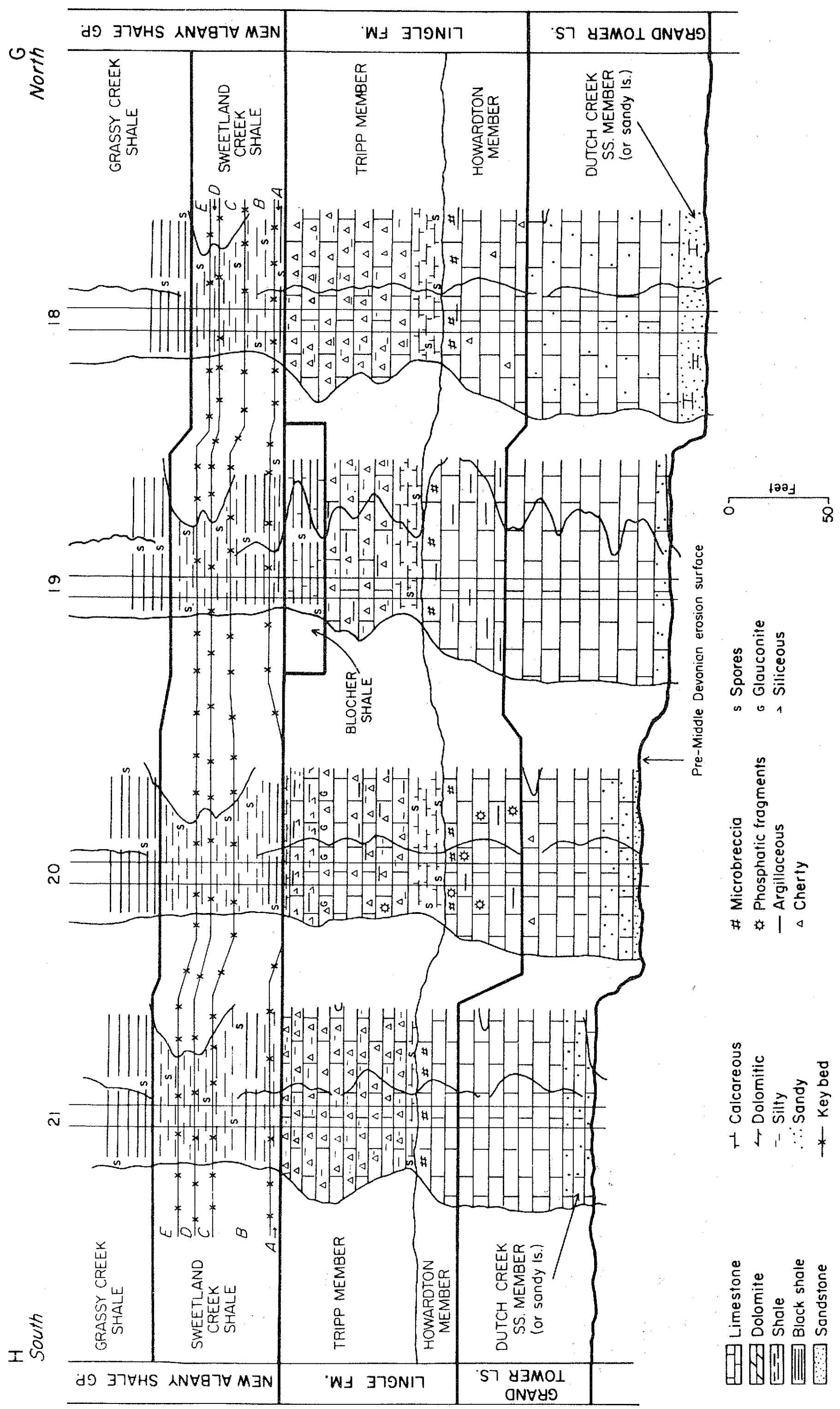

Fig. 10 - North-south lithology and geophysical log cross section H-G in eastern Illinois. Location shown in figure 2.

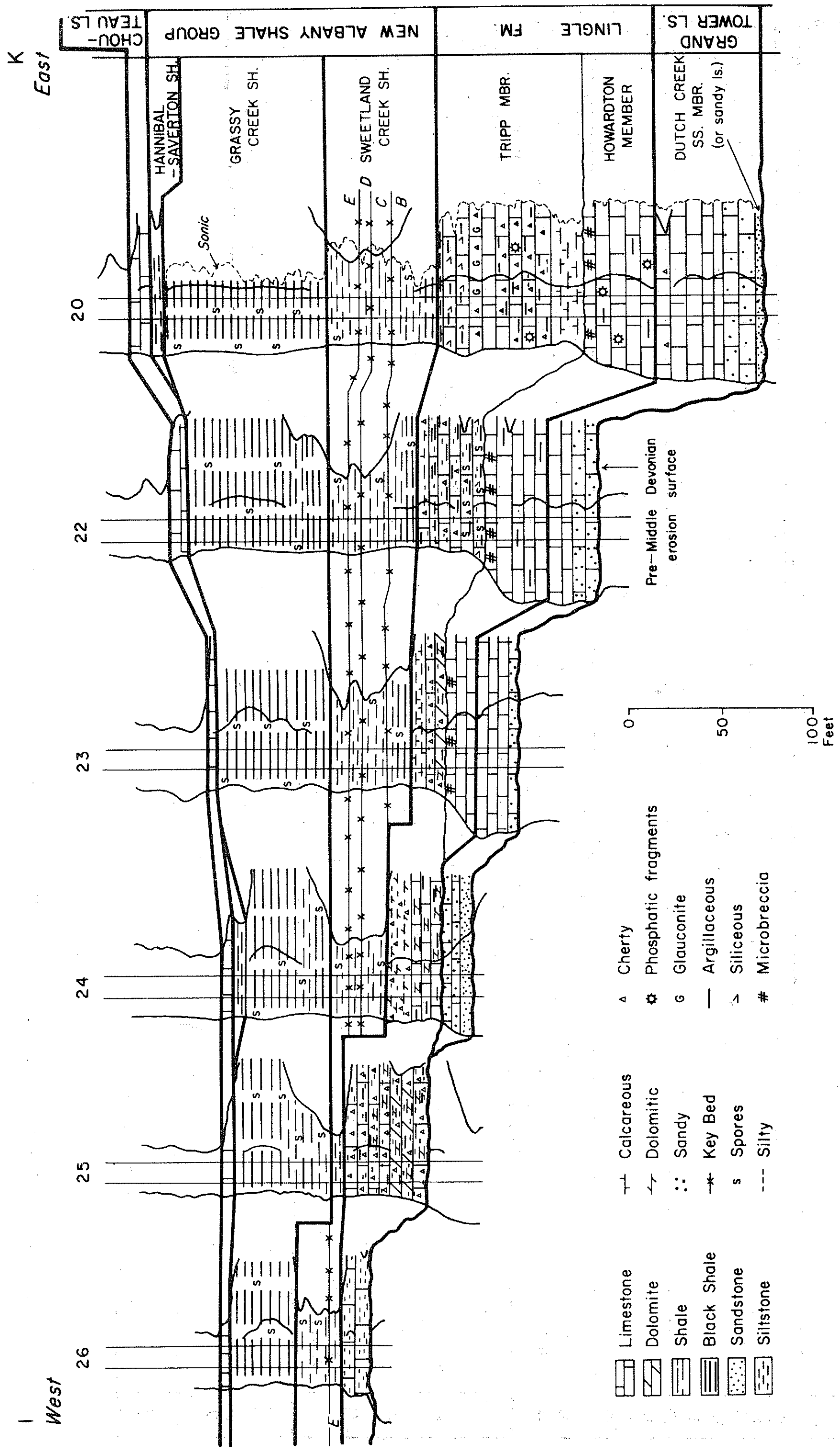

Fig. 11 - East-west lithology and geophysical log cross section I-K in central Illinois. Location shown in figure 2.

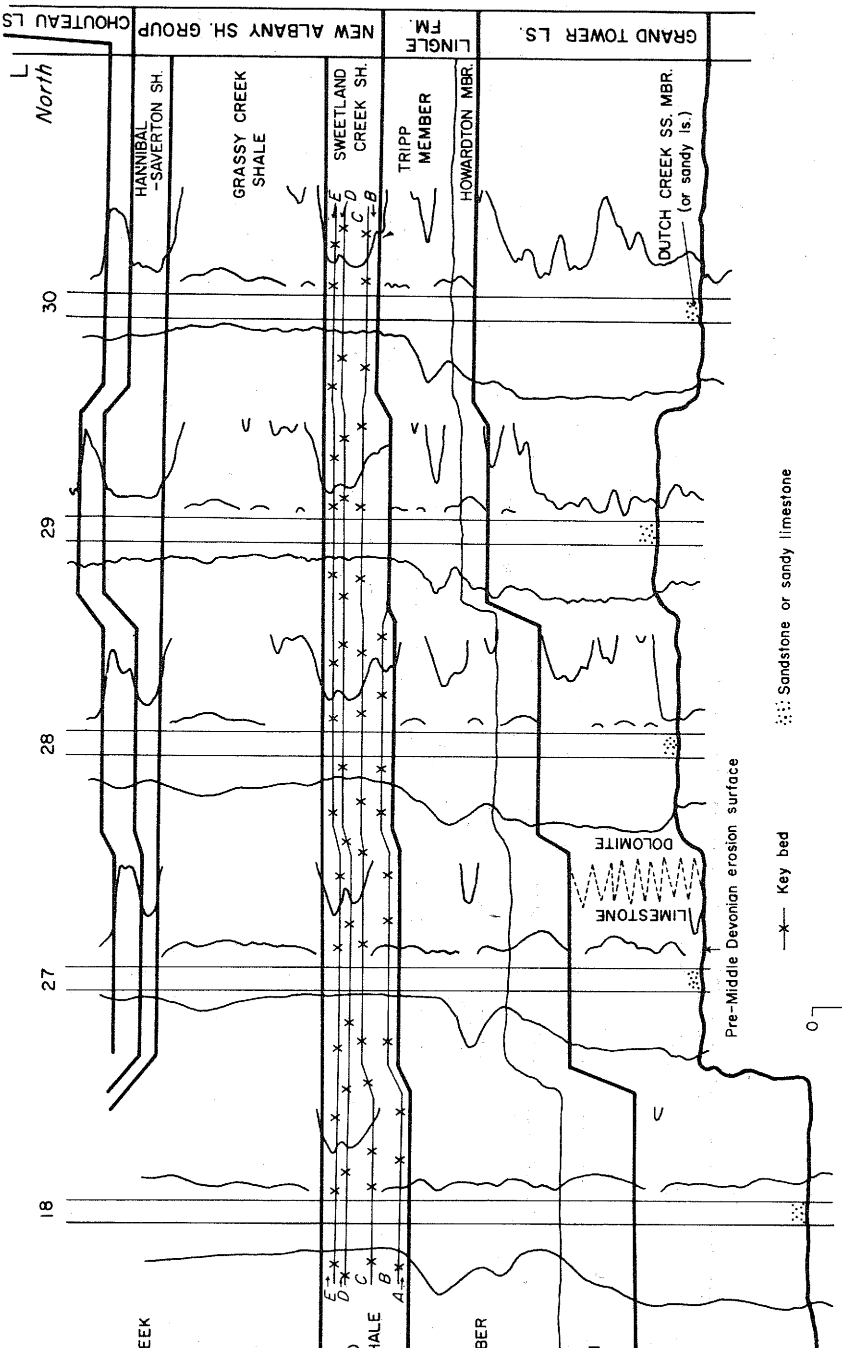

Fig. 12 - North-south geophysical log cross section G-L in central Illinois. Location shown in figure 2.

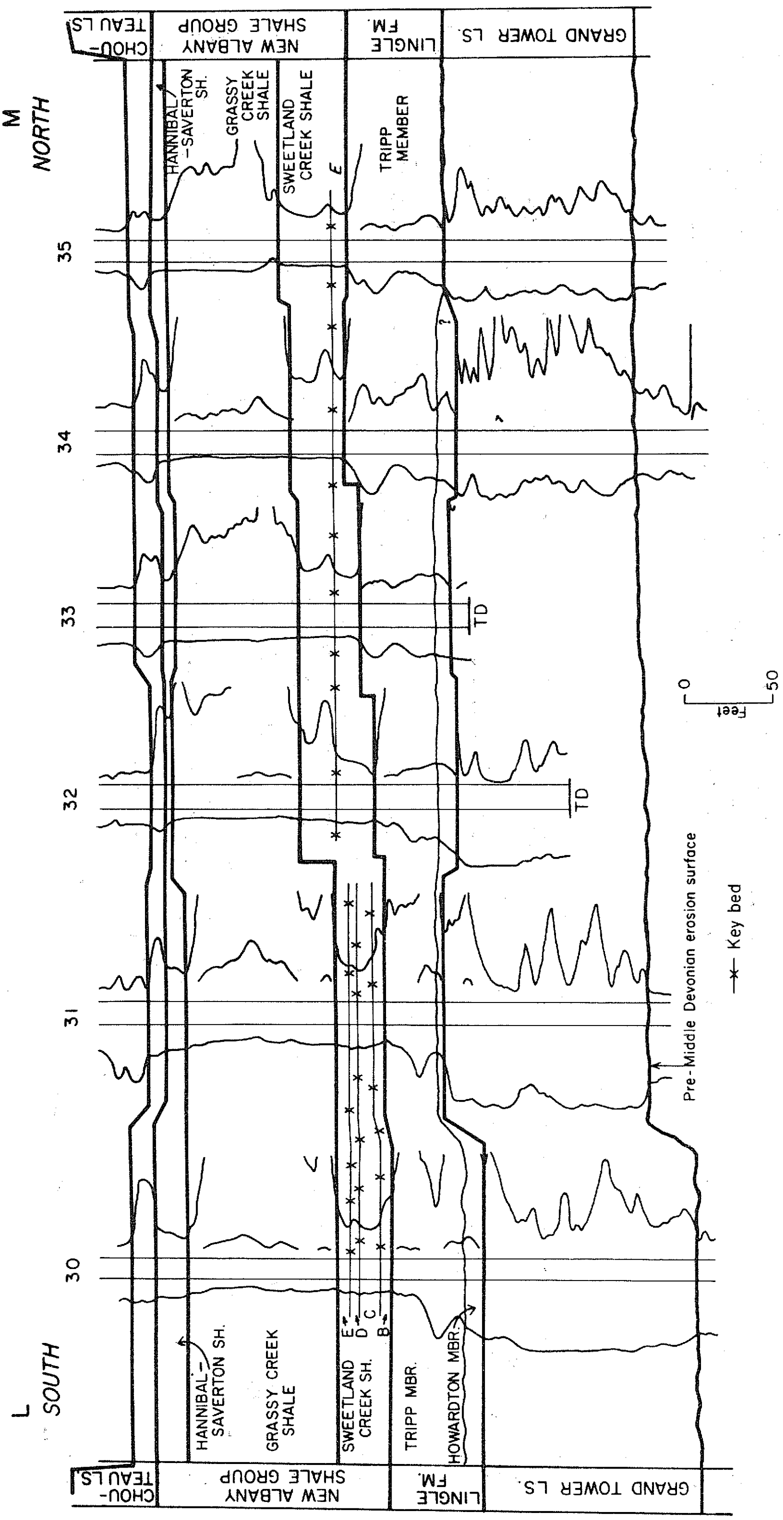

Fig. 13 - North-south geophysical log cross section L-M in central Illinois. Location shown in figure 2.

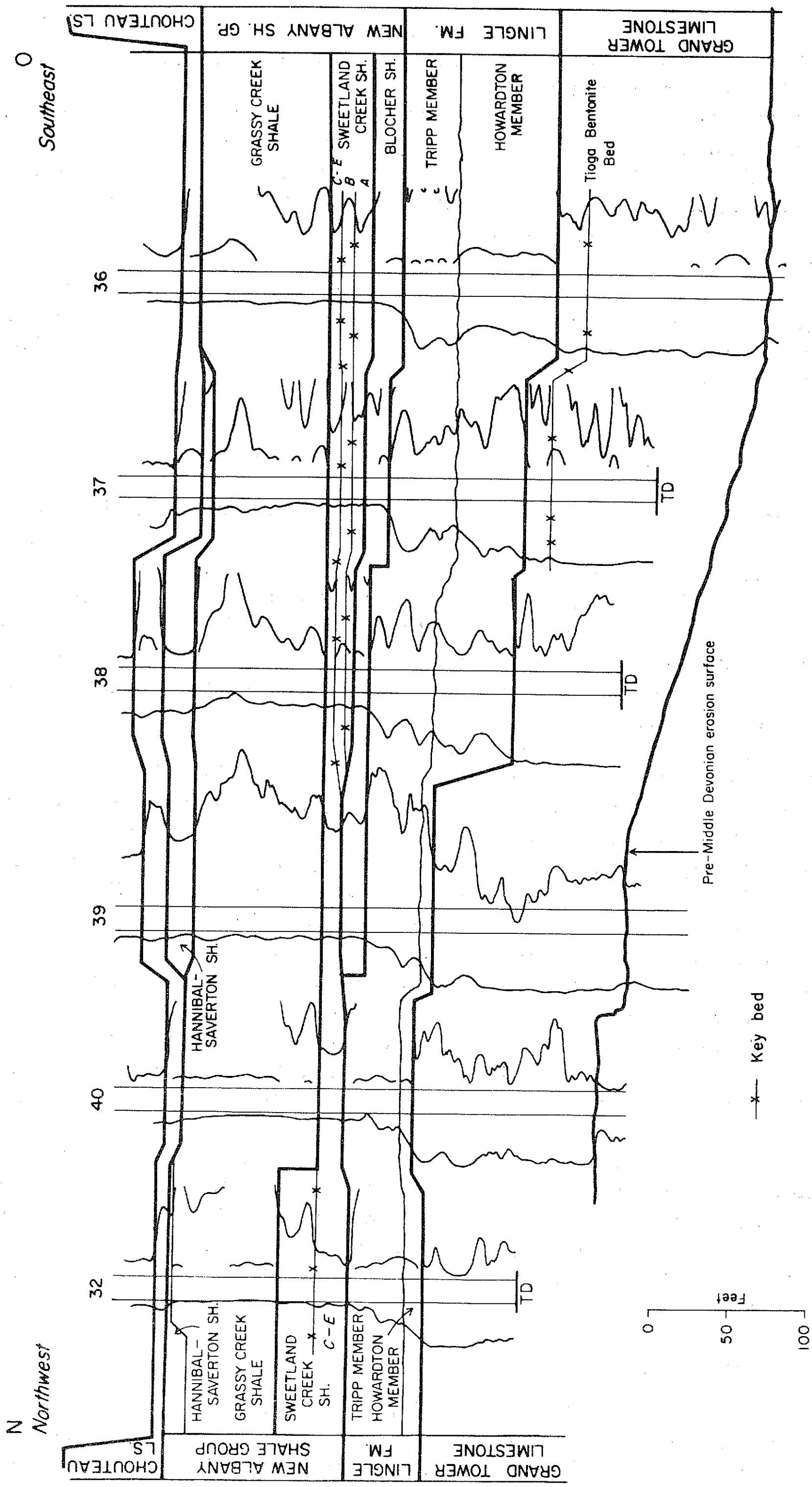

Fig. 14 - Northwest-southeast geophysical log cross section N-O in eastern Illinois. Location shown in figure 2.

outcrop, although the section 3$\frac{1}{4}$ miles west of the village of Cobden, in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ Sec. 34, T. 11 S., R. 2 W., Union County, is complete except for several covered intervals, presumably of shale.

The Lingle Formation (fig. 6) includes the Howardton Limestone Member at the base and the Tripp Limestone Member, Misenheimer Shale Member, and Walnut Grove Limestone Member at the top. An oolite bed near the base of the Walnut Grove Limestone Member is called the Rendleman Oolite Bed. The Misenheimer Shale Member is the only previously named unit.

Only two members of the Lingle Formation extend more than 20 miles eastward from the outcrop. These are the Howardton and Tripp Members, the lower two members of the formation. The Misenheimer Shale and Walnut Grove Members are facies of the dark gray and black shale to the east and are only distinguishable in and near the outcrop region.

Howardton Limestone Member

The name Howardton Limestone Member is here proposed for the lowermost member of the Lingle Formation. The type section (Geologic Section 1) is in the north face of an abandoned quarry in Backbone Ridge, north of Grand Tower, in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 23, T. 10 S., R. 4 W., Jackson County. The unit is named for the town of Howardton, 2 miles east of the type section. The type section consists of 33 feet of argillaceous, brown-gray (wet and fresh), fossiliferous, fine-grained limestone. Shaly partings are abundant. Fossils include solitary corals, brachiopods, and crinoids.

In outcrop, the Howardton is differentiated from the underlying Grand Tower Limestone by (1) its moderate argillaceous content versus the relatively pure limestone of the Grand Tower, (2) a zone in which Microcyclus is relatively abundant at the base of the Howardton Member, and (3) the Hamilton fossils in the Howardton versus the Onondaga fossils in the Grand Tower. The lower boundary of the Howardton coincides with the original Grand Tower-Lingle contact (Savage, 1920a, 1920b; Weller, 1944; Cooper et al., 1942; and Cooper, 1944).

The Howardton Member is less argillaceous and silty than the overlying Tripp Limestone Member, which contains spore-bearing, calcareous shale or very silty and argillaceous limestone, especially at the base. At the top of the Howardton Member a distinctive, calcareous, intraformational microbreccia consisting of pebble-size or smaller, irregularly shaped, light-colored limestone fragments of diverse texture in a dark, fine-grained, calcareous matrix forms a useful and widespread marker bed.

In subsurface, in the southern part of the study area, the Howardton Member is differentiated, as in the outcrop area, on the basis of argillaceous content. It becomes less argillaceous northward and northwestward until it can be differentiated from the Grand Tower Limestone only by cores and geophysical logs (figs. 11 and 12). As in the outcrop area, the member characteristically contains the intraformational microbreccia at its top.

Thickness and distribution

The Howardton Member ranges in thickness from 0 along the flanks of the Sparta Shelf to more than 110 feet in southeastern Illinois (fig. 15). The distribution in the southernmost part of the area nearly duplicates that of the Grand Tower

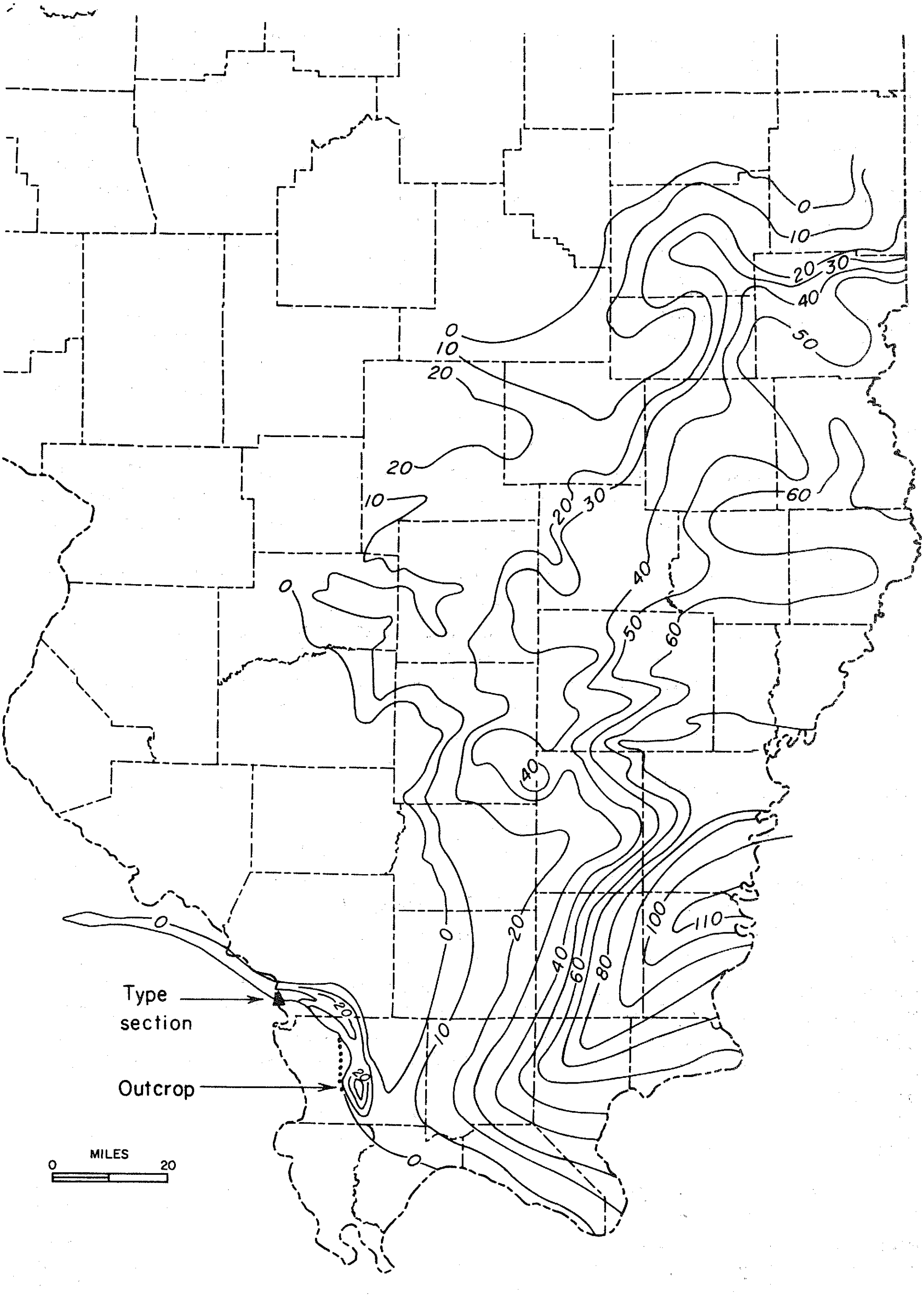

Fig. 15 - Thickness of Howardton Limestone Member.

Limestone. To the north, however, the Howardton pinches out onto the Vandalia Arch, whereas the Grand Tower continues to thicken northward (figs. 13 and 14). The occurrence of the Tioga Bentonite Bed both north and south of the arch, 10 to 20 feet below the Grand Tower Limestone top, supports the interpretations shown in figures 13 and 14.

Lithology

The limestones of the Howardton Member are fossiliferous and fine to coarse grained. Fine-grained limestone is the most abundant. Lithographic texture, which is common in the overlying Tripp Limestone, is extremely rare. Silt and clay are present in shale partings and are disseminated in the limestone. Microbreccia, although present lower, is most abundant at the top of the unit, especially near its pinch out to the north and west. Fossils, which are nearly always present, include brachiopods, corals, crinoids, stromatoporoids, and *Tentaculites*.

Phosphatic material, in the form of angular to subrounded pellets, bone fragments, or fish scales occurs in association with the microbreccia near the top. These are disseminated through approximately 5 feet of strata. The phosphatic material is a lag deposit associated with an unconformity that is probably equivalent to the unconformity at the base of the Beechwood Member of the North Vernon Limestone of Indiana (Butts, 1915; Dawson, 1941; Patton and Dawson, 1955; Bluck, 1966).

The occurrence of calcareous intraformational microbreccia, stromatoporoids, and calcareous breccia at the top of the Howardton Member over the western and northern areas suggests very shallow conditions and, also, probably unconformity (fig. 4). Chert is rare but is found in the deeper portions of the basin. Glauconite is extremely rare.

Geophysical characteristics

With the exception of natural electrical spontaneous potential, the geophysical properties of the Howardton Member are similar to those of the Grand Tower Limestone in its southern area. Nowhere is the clay content high enough to affect significantly the natural gamma radiation, electrical resistivity, sonic velocity, or neutron response. In fact, electrical resistivities tend to be slightly higher in the Howardton Member than in the underlying Grand Tower Limestone. The spontaneous potential, however, characteristically grades from high-negative at the base to more positive values at the top, forming an inflection point at the base of the unit (figs. 7-14). This inflection point is the Lingle-Grand Tower contact. As shown in cores, it marks the lowest occurrence of significant amounts of clay and silt.

Stratigraphic relations

As shown by Meents and Swann (1965), the Lingle-Grand Tower contact in the deeper basin area is conformable and gradational. However, in the western and northern areas, where the formations are thinner, the contact is abrupt and perhaps slightly disconformable. In contrast to opinions expressed by previous workers (for example Meents and Swann, 1965; Workman, 1944), sandstone or concentrations of sand grains do not occur at this stratigraphic position, except on the Sparta Shelf where the Dutch Creek Sandstone Member converges with the top of the Grand Tower Limestone (fig. 11).

In the west, toward the Sparta Shelf, and in the southwest, the Howardton Member has about the same distribution as the Grand Tower Limestone. Toward the north, however, the Howardton Member probably pinches out far south of the Grand Tower Limestone, although the stratigraphic relations are not clear. To the northwest, the contact is poorly defined and some strata included in the Grand Tower Limestone may be equivalent to the Howardton Member.

Although the contact is somewhat irregular in outcrops and in cores, apparently little erosion occurred, as shown by the occurrence of the Tioga Bentonite Bed 10 to 20 feet below the contact over a broad area in southeastern and eastern Illinois. Farther west, also, the Howardton Member overlies the Grand Tower in a large area. A slight disconformity may appear near the pinch out of the units. but thinning of the Grand Tower is a result of overstep and shoreward convergence of successive units more than of post-Grand Tower erosion.

Tripp Limestone Member

The name Tripp Limestone Member is here proposed for the argillaceous, silty, cherty limestone member of the Lingle Limestone between the Misenheimer Shale Member above and the moderately argillaceous Howardton Limestone Member below. The type section (Geologic Section 3) is an outcrop on the south side of Kratzinger Hollow, about 1 mile northwest of Jonesboro, in the N$\frac{1}{2}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 23, T. 12 S., R. 2 W., Union County, Illinois. The upper 17 feet of the member is exposed in the type section (fig. 16) (Grimmer, 1968, p. 410). Nearby wells indicate the total thickness of the member to be about 22 feet. The member is named for Tripp School, about 200 yards northwest of the type section.

The Tripp Member may be exposed also in the N$\frac{1}{2}$ NE$\frac{1}{4}$ Sec. 34, T. 11 S., R. 2 W., but the strata are badly disturbed and definite identification could not be established. No exposure of the basal contact was found.

In southwestern Illinois, the Tripp Member is characterized in its lower half by very argillaceous and very silty limestone or very calcareous shale that characteristically contains a number of large spores. The upper half of the member is marked by somewhat shaly, cherty, dolomitic, glauconitic limestone.

Thickness and distribution

The Tripp Limestone Member thickens from its pinch out on the Sparta Shelf to a maximum thickness of over 80 feet in south-central Illinois. In eastern Illinois, it grades laterally to the Blocher Shale (figs. 16, 20, and 21). To the west and north, the Tripp everywhere overlaps the Howardton Limestone Member.

The thickness of the Tripp Member is irregular (fig. 16). The unit is thickest (over 80 feet) immediately west of the facies change with the Blocher Shale and is moderately thick (30 to 40 feet) along the north side of the facies change. North and west from these areas the unit does not thin toward the Sparta Shelf and Vandalia Arch as the other units do, but, instead, it thickens along an arcuate belt that extends from T. 5 S., R. 1 E. (west-central part of the area), through T. 4 N., R. 1 W., and to T. 16 N., R. 10 W. (northeastern part of the area). This belt of thickening is in juxtaposition with the zero line of sub-units A and B at the base of the Sweetland Creek Shale. Approximately the upper 20 feet of the Tripp Limestone Member in this belt may grade into the Sweetland Creek Shale.

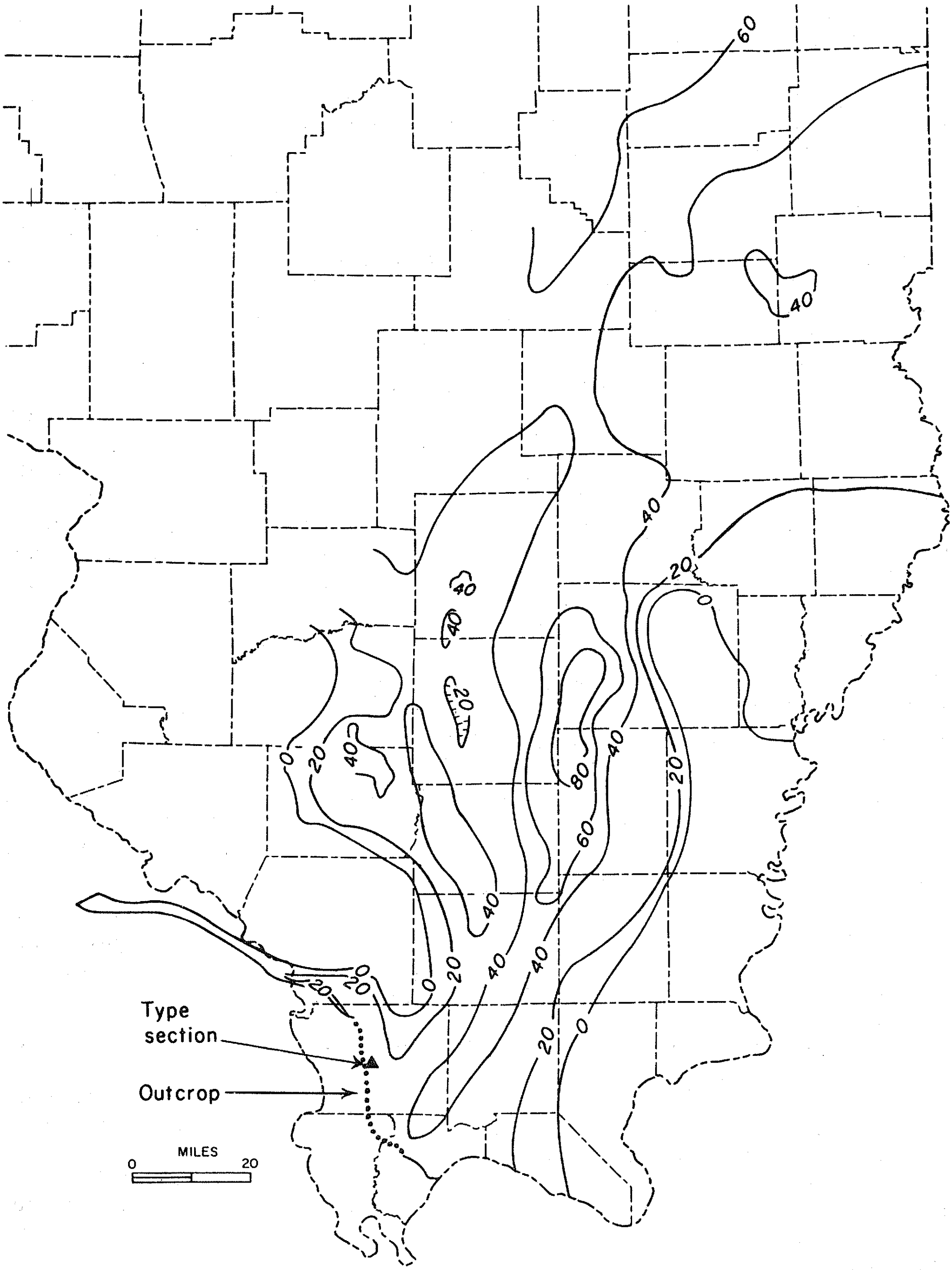

Fig. 16 - Thickness of Tripp Limestone Member.

Lithology

The lithology of the Tripp Member is heterogeneous, including limestone, dolomite, chert, siltstone, and shale.

Limestone.– The Tripp Member is dominantly limestone, ranging from light to dark gray and light brownish gray to dark brownish gray. The limestones generally are argillaceous and silty, with a few containing as much as 30 or 40 percent insoluble residue. In the north and west, however, terrigenous detritus is completely lacking in some beds. The limestones range from sublithographic to coarse grained and brecciated. Nonfossiliferous, sublithographic to fine-grained limestone is more common toward the east and southeast, toward the Blocher Shale, and also north of the Vandalia Arch. Fossiliferous coarser grained limestones occur to the west and over the Vandalia Arch where quartz sand grains are also an important constituent. Fossils include crinoids, brachiopods, and corals.

Two oolitic limestone beds occur in the westernmost and northernmost parts of the area—one approximately 10 feet from the top of the member and the other near the middle. The upper bed is extensive and consists of 1 mm or smaller oolites in a light brown, sublithographic to fine-grained, calcareous matrix. It is present immediately north and west of the limits of Sweetland Creek sub-units C and D and occurs where the Tripp Member thickens. This situation is comparable to that in the outcrop area where the Rendleman Oolite Bed has a facies relation with the Sweetland Creek Shale. Although the northern oolite bed is nearly contemporaneous with the Rendleman Oolite Bed, they are separated by the Sparta Shelf and cannot be traced directly to one another.

Dolomite.– Partial dolomitization of the limestone is widespread, but dolomite occurs within the Tripp Member only on the eastern edge of the Sparta Shelf. In that area, dolomite comprises one-half of all the unit and is as much as 30 feet thick. The dolomite is characteristically dark brownish gray and very fine to finely crystalline.

Chert.– Chert is an important constituent, mostly as nodules. Chert beds are present, most noticeably in Wayne and Clay Counties (T. 2 S. and 4 N., R. 5 to 7 E.). The chert ranges from light gray to blue-gray to gray, and locally constitutes as much as 30 percent of the unit.

Glauconite and phosphates.– Glauconite is abundant in the northern and western parts of the area. Glauconite and chert are diagnostic of the Tripp Member. Phosphate pellets have an irregular distribution. In two or three outcrops, a bed of phosphate pellets occurs near the middle of the unit.

Shale.– Shale is most abundant at the top and the base of the Tripp Limestone Member. Only near the facies contact with the Blocher Shale is the shale at the base abundant enough to appear in chip samples. In that area, the basal unit is 10 feet or less of dark brownish gray, very calcareous, spore-bearing shale. Farther west, the basal shale becomes so well interbedded with limestone that it is recognized only in geophysical logs and cores. This shale or shaly limestone is a key bed within the Lingle Formation because it can be traced on geophysical logs from southernmost Illinois to some distance north of the Vandalia Arch in central Illinois.

The shale at the top of the Tripp Limestone Member marks the transition to the overlying or adjacent Blocher Shale. It has a maximum thickness of about 5 feet and contrasts with the black shale of the Blocher by being very calcareous or very dolomitic, gray or dark gray, and reacting geophysically like the underlying units.

Geophysical characteristics

Because of its lithologic heterogeneity, the geophysical properties of the Tripp Limestone Member are quite variable (figs. 7-14). In general, neutron response, sonic velocities, and electrical resistivities tend to be high, but are more variable and average lower than in the underlying Howardton Member. Natural electrical spontaneous potential tends to be high-positive but differs considerably from place to place, especially where dolomite or chert beds are plentiful (figs. 10 and 11). Natural gamma radiation is slight to moderate and exhibits the most consistency (fig. 7).

Although some units within the member exhibit geophysical properties that can be traced for a few tens of miles, only the basal shaly unit of the member is recognizable over most of the area. This key bed is evident on all of the geophysical traces. On electric, sonic, and neutron logs it is represented by a persistent but subdued notch. The spontaneous potential of the key bed is on the shale line (high-positive), and, over most of the area, it is the oldest stratum within the Middle Devonian sequence that exhibits this high-positive spontaneous potential. The gamma radiation of the key bed is moderate. All geophysical properties show the shaliness to be sharply defined at the base but gradational upward. Shaliness within the Tripp Member decreases to the north and west, and the key bed becomes less well defined in those directions.

Stratigraphic relations

The widespread occurrence of the phosphatic, calcareous microbreccia, which commonly marks the top of the Howardton Member, followed by the abrupt increase in shaliness characteristic of the base of the Tripp Member, suggests a widespread regression and subsequent transgression of the Middle Devonian sea.

The Tripp Member overlaps the Howardton Member and the Grand Tower Limestone, and the disconformity merges on the Sparta Shelf with the pre-Middle Devonian erosion surface. Between the Sangamon Arch in central Illinois and the Vandalia Arch farther south, the Grand Tower Limestone extends beyond the Howardton Member and is overlapped by the Tripp Member (figs. 11 and 13), but the nature of the contact is obscure.

Misenheimer Shale Member

The Misenheimer Shale Member of the Lingle Limestone consists of approximately 50 feet of dark gray, calcareous, spore-boring shale overlying the Tripp Limestone Member and overlain by the Walnut Grove Limestone Member. The shale was named by Savage (1920a), who classified it as a formation and designated an exposure in the SW$\frac{1}{4}$ Sec. 26, T. 13 S., R. 2 W., as the type section. Weller (1944) and others considered the Misenheimer Shale to be discontinuous and not traceable, and the name was abandoned. Grimmer (1968) and the writer have succeeded in tracing it throughout the southwestern Illinois outcrop area, and it is reinstated as a member of the Lingle Formation. Grimmer (1968) suggested the locality used here for the type section of the Tripp Limestone Member as the principal reference section of the Misenheimer Shale.

Thickness and distribution

The Misenheimer Shale occurs only in the outcrop area of southwestern Illinois (fig. 17). The member is more than 50 feet thick in the Wittenberg Trough and its southern extension, and it is 10 to 30 feet thick near the area where it grades to the Sweetland Creek Shale. Like the Tripp Member, the thickness of the Misenheimer Shale is not as strongly influenced by the Wittenberg Trough and the DuQuoin Monocline as are some of the lower units.

Lithology

The Misenheimer Shale is generally a dark gray, dark olive gray, and gray-brown, spore-bearing shale. Limestone and chert lenses are rare. Glauconite is rare but does occur northwest of the outcrop belt. Grimmer (1968) and Savage (1920a, 1920b) reported a sparse fauna.

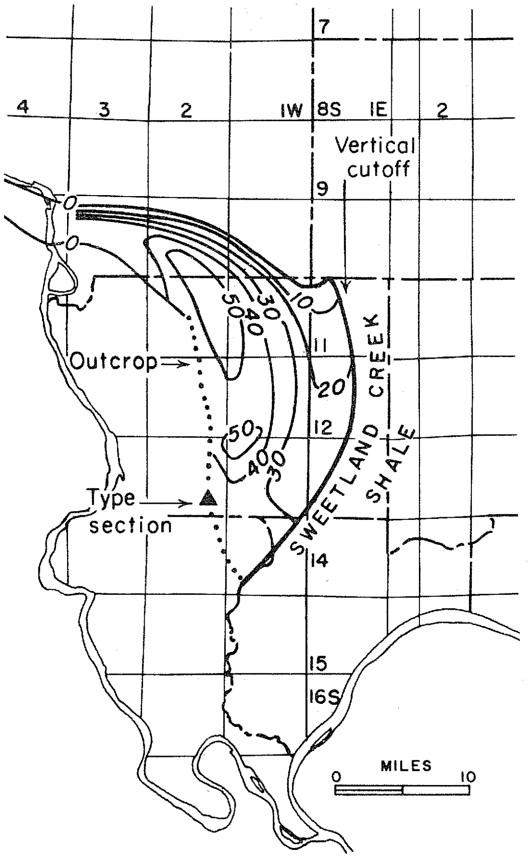

Fig. 17 - Thickness of Misenheimer Shale Member.

Stratigraphic relations

The contact of the Misenheimer Shale with the underlying Tripp Member is abrupt but conformable. Grimmer (1968, fig. 3) considers the upper contact to be at the lowermost cherty bioclastic limestone, which includes some shale, in the overlying member. The writer considers the upper contact at most localities to be marked either by the Rendleman Oolite Bed or bioclastic limestone at the base of the Walnut Grove Limestone Member. A short distance to the east of the outcrop area, where the overlying Walnut Grove Limestone is not present, the Misenheimer Shale grades laterally into the Sweetland Creek Shale (fig. 17).

Walnut Grove Limestone Member

The uppermost limestone member of the Lingle Formation is here named the Walnut Grove Limestone Member. It consists of approximately 40 feet of cherty, very silty, glauconitic, spore-bearing, fine-grained, fossiliferous limestone. It is 29 feet thick in the type section (Geologic Section 2), an outcrop in a small tributary to Clear Creek, 2 miles south of Alto Pass, in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 22, T. 11 S., R. 2 W., Union County, Illinois (fig. 18). The outcrop is near the top of a gully, 1500 feet north of the sharp bend in the road near the center of the NW$\frac{1}{4}$ Sec. 27.

Thickness and distribution

The Walnut Grove Limestone Member occurs only in the southwestern Illinois outcrop area (fig. 18). It ranges from over 50 feet thick in the west, along the outcrop belt and in the Wittenberg Trough, to less than 10 feet west of the facies line of vertical cutoff (fig. 18). The thicker portions of this unit correspond to the shape of the trough and its southern extension.

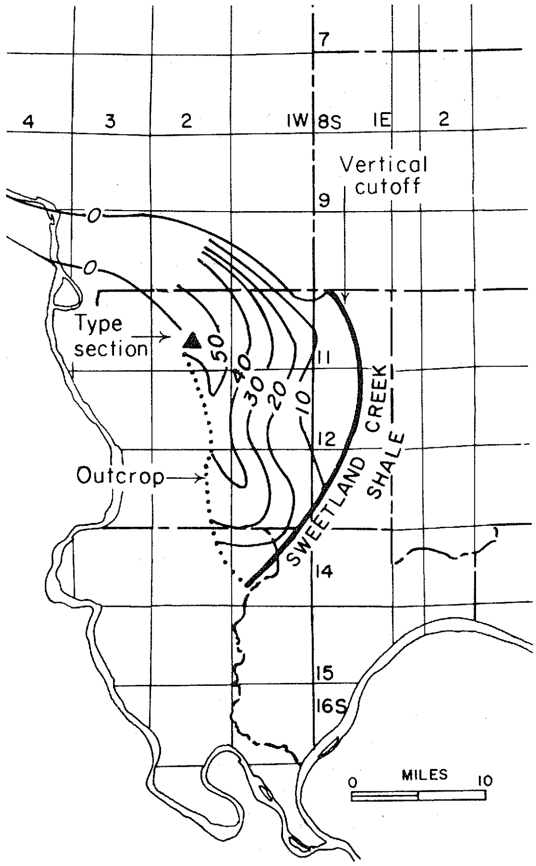

Fig. 18 - Thickness of Walnut Grove Limestone Member.

Lithology

The Walnut Grove Member consists mainly of dolomitic, silty, cherty limestone. The limestone is generally fine grained and fossiliferous. A single bed of very coarse-grained, bioclastic limestone occurs at the base. Fossils include crinoids, corals, brachiopods, and spores. The silt and clay content of the limestones ranges from 10 to 40 percent. The bioclastic limestone is free of silt and clay but contains fine to medium, subrounded quartz sand grains. Nodular chert is blue-gray to gray and ranges from 5 to 30 percent. Glauconite is abundant and characteristic. The limestone locally is interbedded with spore-bearing, very dark brown, calcareous shale.

The Walnut Grove Limestone Member appears to grade laterally into the Sweetland Creek Shale a few miles east of the outcrop belt. Its contact with the underlying Misenheimer Shale Member is at the base of a relatively pure, very coarse-grained, bioclastic limestone that generally lies directly beneath the Rendleman Oolite Bed. In general, the limestone is purer than the isolated limestone beds, which locally occur in the underlying shale. The upper contact of the Walnut Grove is sharply defined; the glauconitic, cherty limestones of the Walnut Grove are readily distinguished from the basal dolomitic siltstone of the Alto Formation.

Rendleman Oolite Bed

An oolite bed near the base of the Walnut Grove Limestone Member is the most significant key bed within the Lingle Formation in the outcrop area. The bed occurs at all of the several significant Lingle Formation exposures and in most of the wells in this region. The bed is here named the Rendleman Oolite Bed and the type section is part of the Walnut Grove type section in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 22, T. 11 S., R. 2 W., Union County, Illinois (Geologic Section 2). The name is derived from the Rendleman School, 1 mile east of the type section.

The Rendleman Oolite Bed is about 18 inches thick. It consists of ooliths in a fine-grained limestone matrix. Coarse-grained matrices occur but are rare. The ooliths are poorly sorted and have a maximum diameter of 1 mm. The fine-grained matrix is light brown-gray to brown-gray and approaches a lithographic texture. The fine-grained matrix indicates quiet water sedimentation, which suggests that the oolites are allochthonous and were derived from nearby shoal areas located to the east on the southern extension of the DuQuoin Monocline or to the west on areas that have since been eroded.

ALTO FORMATION

The Alto Formation, overlying the Walnut Grove Limestone Member, consists of over 70 feet of silty limestone and dolomitic or calcareous siltstone. Savage (1920a, 1920b) designated the type section as an exposure in Sec. 34, T. 11 S., R. 2 W., Cobden Quadrangle, Union County, Illinois. The best exposed section is in the center of the N$\frac{1}{2}$ NE$\frac{1}{4}$ NE$\frac{1}{4}$ Sec. 34. In the subsurface near the outcrop belt, the formation is composed of two units: a lower dolomitic siltstone and an upper silty cherty dolomite. The Alto Formation, like the underlying Walnut Grove Limestone Member of the Lingle Formation, is restricted to the southwestern Illinois outcrop area (fig. 19) and, like it, appears to grade eastward into the dark gray and black shales of the Sweetland Creek.

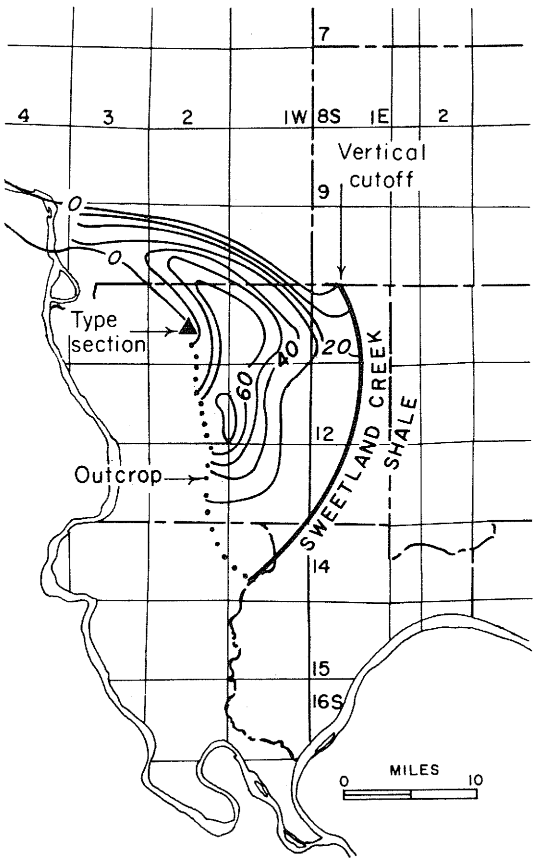

Fig. 19 - Thickness of Alto Formation.

The Alto Formation is thickest (over 70 feet) in the southern extension of the Wittenberg Trough and gradually thins in all directions. The formation consists of dolomitic and calcareous shale in the lower half and calcareous shaly dolomite in the upper. The shale resembles that of the Misenheimer Shale. The dolomite is generally medium to coarsely crystalline at the top, grading downward to finely crystalline. The color ranges from gray to dark gray-brown. Nodular chert is abundant, especially in the upper dolomite, and is white, gray, and black. The lower shale locally contains glauconite and spores. Savage (1920a, 1920b) reported a sparse fauna. Orr (1964) reported an extensive conodont fauna from the type section, which Collinson et al. (1967) interpreted as youngest Middle Devonian.

BLOCHER SHALE

The name Blocher Shale was introduced by Campbell (1946) for the lowermost carbon-rich, calcareous, or dolomitic black shale in the New Albany Group in the southeastern Indiana outcrop. Lineback (1968) and Collinson et al. (1967) traced the formation across Indiana into Illinois. Lineback, using lithologic criteria, showed the formation to be somewhat thicker locally than did Collinson et al., who used geophysical criteria. This report, also using geophysical criteria, in general follows Collinson et al.

Thickness and distribution

The Blocher Shale is present in Illinois in a belt 50 miles wide along the southeastern edge of the state (fig. 20). The shale is over 80 feet thick in the Moorman Syncline in southeastern Illinois, and it thins more gradually to the north than to the west (fig. 21).

Lithology

The Blocher Shale consists of brown-black to black, somewhat calcareous or dolomitic, pyritic, fissile, spore-bearing shale. The black color, which is diagnostic of the unit, results from a high content of carbon derived from plants (Lineback, 1968).

Geophysical characteristics

The Blocher Shale is best defined on sonic, neutron, and gamma ray logs. Electrical resistivity is high, and natural spontaneous potential is high-positive, similar to units below and above. In terms of neutron response, gamma radiation, and sonic velocity, the unit is intermediate between noncalcareous shale and pure limestone. These properties also consistently indicate a higher carbonate content at the top than at the base of the shale.

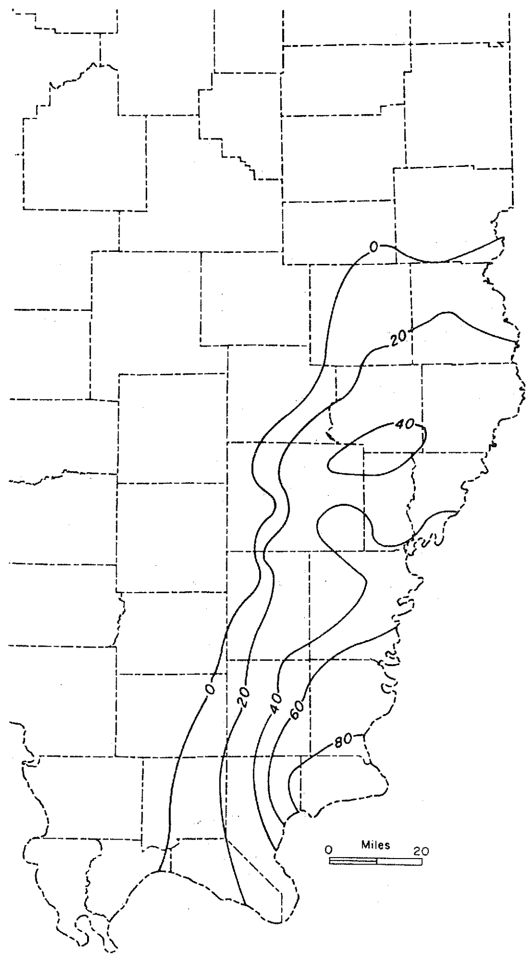

Fig. 20 - Thickness of Blocher Shale.

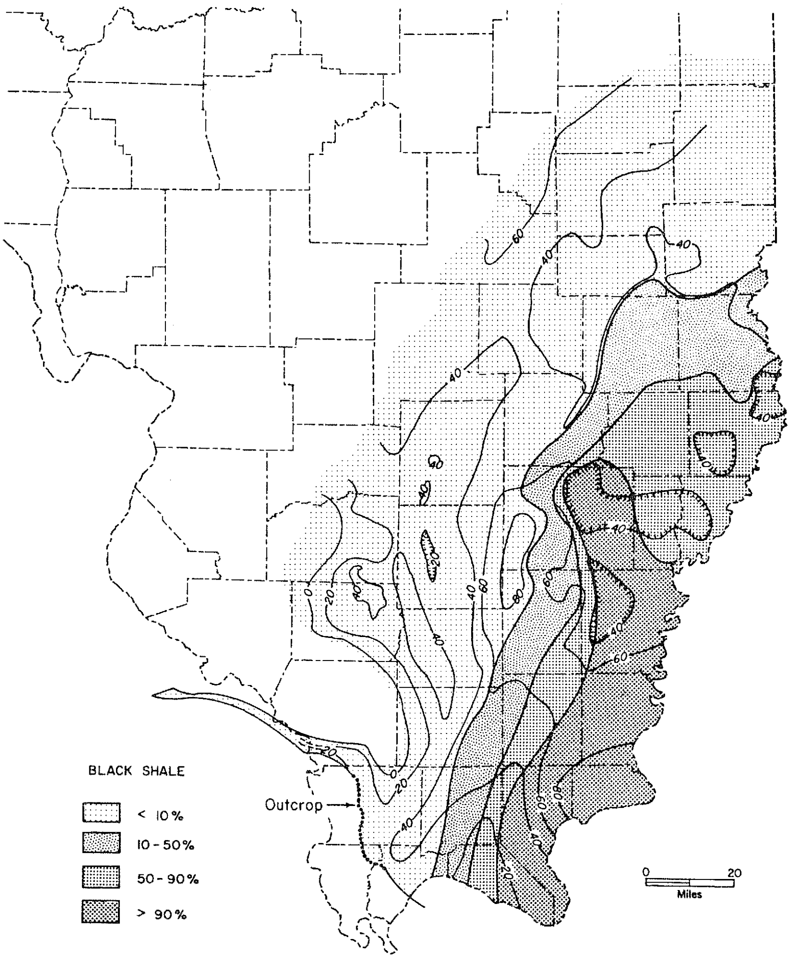

Fig. 21 - Combined thickness of Tripp Limestone Member of the Lingle Formation and the Blocher Shale and the percentage of black shale.

Stratigraphic relations

Through much of south-central Illinois the Blocher Shale appears to grade laterally into the Tripp Limestone Member. The change is quite abrupt in the south-central area but more gradual to the north (figs. 7, 8, 9, 14, and 21). In both regions, however, the area of shale deposition expanded with time so that the Blocher Shale transitionally overlaps the Tripp Limestone Member in a belt 20 to 40 miles wide. Blocher-type shale within the Tripp Limestone Member is most abundant near the top and base. In the Blocher, limestone beds are relatively common toward the top. The lithologic distinction between the two units is not only one of limestone versus shale, but of carbon-poor versus carbon-rich. Lineback (1968) reports as much as 50 percent carbonate in the Blocher Shale in Indiana. The intermediate geophysical characteristics of the unit in terms of shale versus limestone support this viewpoint.

SWEETLAND CREEK SHALE

The greenish gray shale at the base of the New Albany Shale Group was named Sweetland Creek Shale in southeastern Iowa by Udden (1899), but the name was discontinued in Illinois by Workman and Gillette (1956). James (1965) traced the unit from the type area to southern Illinois, and Collinson et al. (1967) extended the term to southern Illinois. Tracing of key beds shows that the Sweetland Creek Shale in western Illinois is younger, for the most part, than the Sweetland Creek to the southeast (fig. 4). These key bed correlations show that to the southeast the gray shale of the type Sweetland Creek grades to the black shale of the Grassy Creek (figs. 11-13) and that the Sweetland Creek Shale of the southeastern area either grades laterally to the Tripp Limestone Member or thins over it to the north and west.

Thickness and distribution

In southern Illinois the Sweetland Creek Shale ranges from over 200 feet thick in the Moorman Syncline area of southeastern Illinois to its pinch out on the southern part of the Sparta Shelf (fig. 22). It averages 20 feet thick in the area north of the Vandalia Arch. These thickness changes mostly result from lateral thinning toward the basin margins. However, thickening from central to northern and western Illinois is along the line of vertical cutoff where the Sweetland Creek Shale thickens at the expense of the Grassy Creek Shale.

Lithology

The Sweetland Creek Shale, in the deeper part of the basin, consists of brownish black to dark gray shale. The formation becomes lighter colored upward. Differences in color and organic content between the Sweetland Creek and the underlying Blocher Shale are so subtle that the units are difficult to distinguish on the basis of samples. To the north and west, the dark gray gives way to gray and green-gray.

Geophysical characteristics

For the most part, the Sweetland Creek Shale has geophysical properties typical of noncalcareous, low-organic shale. The sonic velocities and neutron

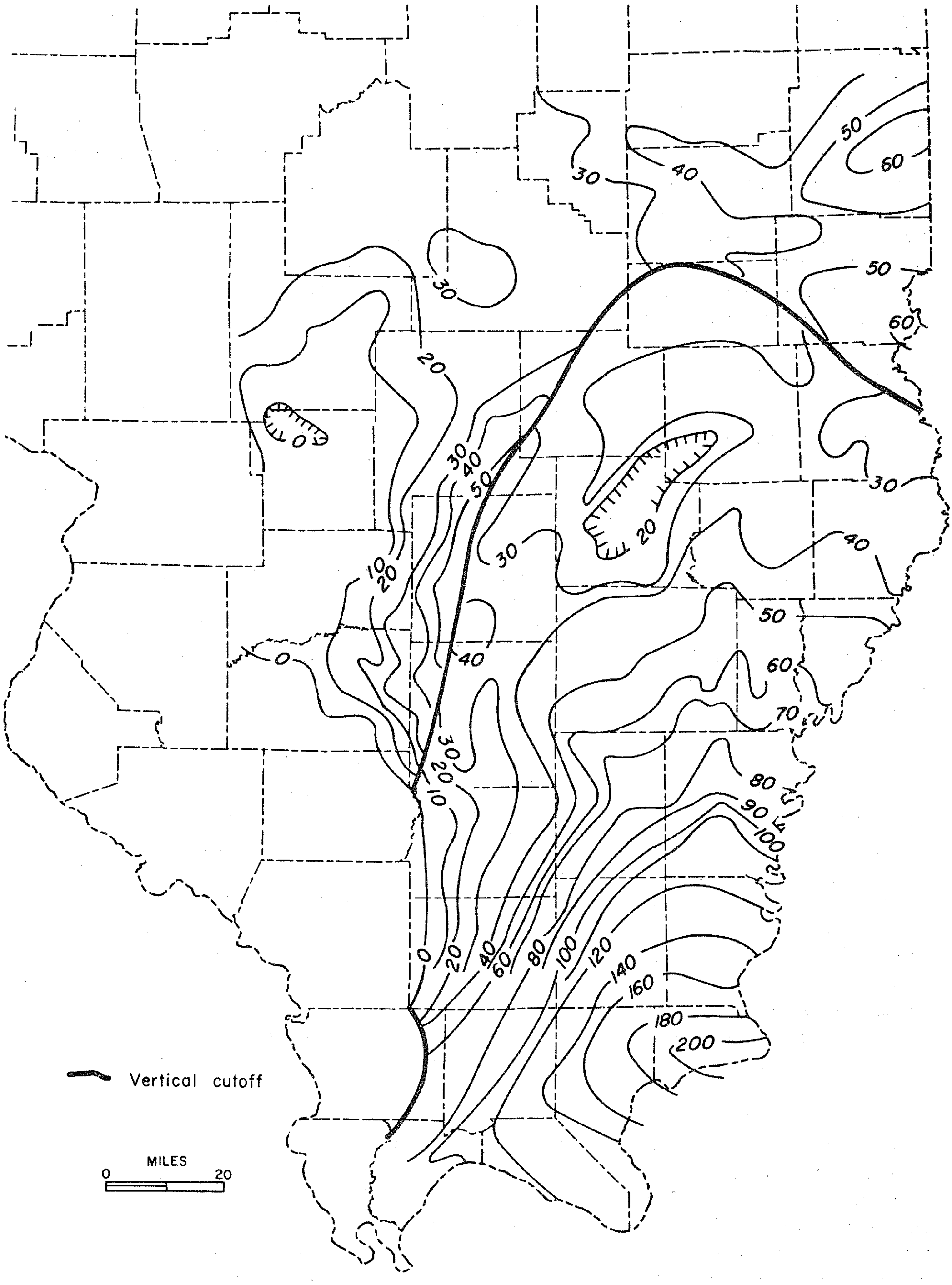

Fig. 22 - Thickness of Sweetland Creek Shale. The northern vertical cutoff is where the Sweetland Creek thickens northward and westward at the expense of the Grassy Creek Shale (figs. 4, 11, and 13); the southern vertical cutoff is where the Sweetland Creek grades laterally into the Lingle and Alto Formations (figs. 4 and 6).

response are low, natural gamma radiation is high, and natural electrical spontaneous potential is high-positive. The electrical resistivity is irregular but is dominantly low.

Irregularities in electrical resistivity within the Sweetland Creek are so uniform throughout the study area that it is possible to trace approximately a dozen key beds for many miles. These key beds are boundaries of alternating high- and low-resistive units. They also appear on the sonic, neutron, and gamma ray logs. The more resistive units show slightly lower neutron response, slightly lower sonic velocities, and slightly higher natural gamma radiation than the less resistive units. Key beds are used to differentiate six sub-units; the five lower sub-units are labeled A through E on the cross sections. The upper sub-unit consists of the strata that grade laterally to the Grassy Creek Shale (figs. 7-14).

Stratigraphic relations

In southwestern Illinois the Sweetland Creek Shale is interpreted as grading laterally into the Lingle and Alto Formations and, therefore, is not present in the outcrop area. Farther north, on the Sparta Shelf, the uppermost part of the unit overlaps Middle Devonian carbonate strata and is present in most of western Illinois. On the southern, more active, part of the Sparta Shelf, the shale pinches out (fig. 22).

As shown by geophysical logs, the Sweetland Creek-Blocher contact is abrupt; the high carbonate and organic contents of the Blocher Shale markedly contrast with the lesser amounts of those components in the Sweetland Creek Shale. The lowest unit within the Sweetland Creek Shale (sub-unit A) thins noticeably from east to west in the area of Blocher Shale occurrence, apparently because of internal thinning within sub-unit A rather than facies relations with the Blocher Shale (figs. 8 and 9).

Subsurface stratigraphic relations between the Sweetland Creek Shale and the Lingle Formation are very complex. Each succeeding Sweetland Creek Shale sub-unit overlaps the underlying one (fig. 23); also, each sub-unit thins toward its pinch out to the west and north. Conversely, the Tripp Limestone Member thickens, and an oolite bed, which may correlate with the Rendleman Oolite Bed, appears near the top of the member immediately west and north of the pinch out of the younger Sweetland Creek sub-units (figs. 16 and 23). Thus, the Sweetland Creek Shale, in part, may have a facies relation with the Tripp Limestone Member. In some areas a facies relation is supported by a transition zone; in others, the contact is sharp.

In the area of the oolite occurrences and to the west and north, the contact becomes unconformable and is marked by scattered occurrence of the Sylamore Sandstone (Workman and Gillette, 1956). Although the Sylamore Sandstone overlies Middle Devonian rocks in many areas in central and western Illinois, it occurs only sporadically in the study area. It commonly consists of St. Peter-type quartz sand cemented by pyrite, calcite, and dolomite. It overlies the Tripp Limestone Member of the Lingle Formation in the northeastern part of the area, and it occurs as a thin, sandy shale or clayey sand on top of the Alto Formation in the outcrop area in southwestern Illinois. In subsurface, the Sylamore is difficult to distinguish and consequently is not indicated in the cross sections.

Although the evidence is not entirely conclusive, the Sweetland Creek Shale in southwestern Illinois appears to have a facies relation with the Misenheimer Shale and Walnut Grove Limestone Members of the Lingle Formation and

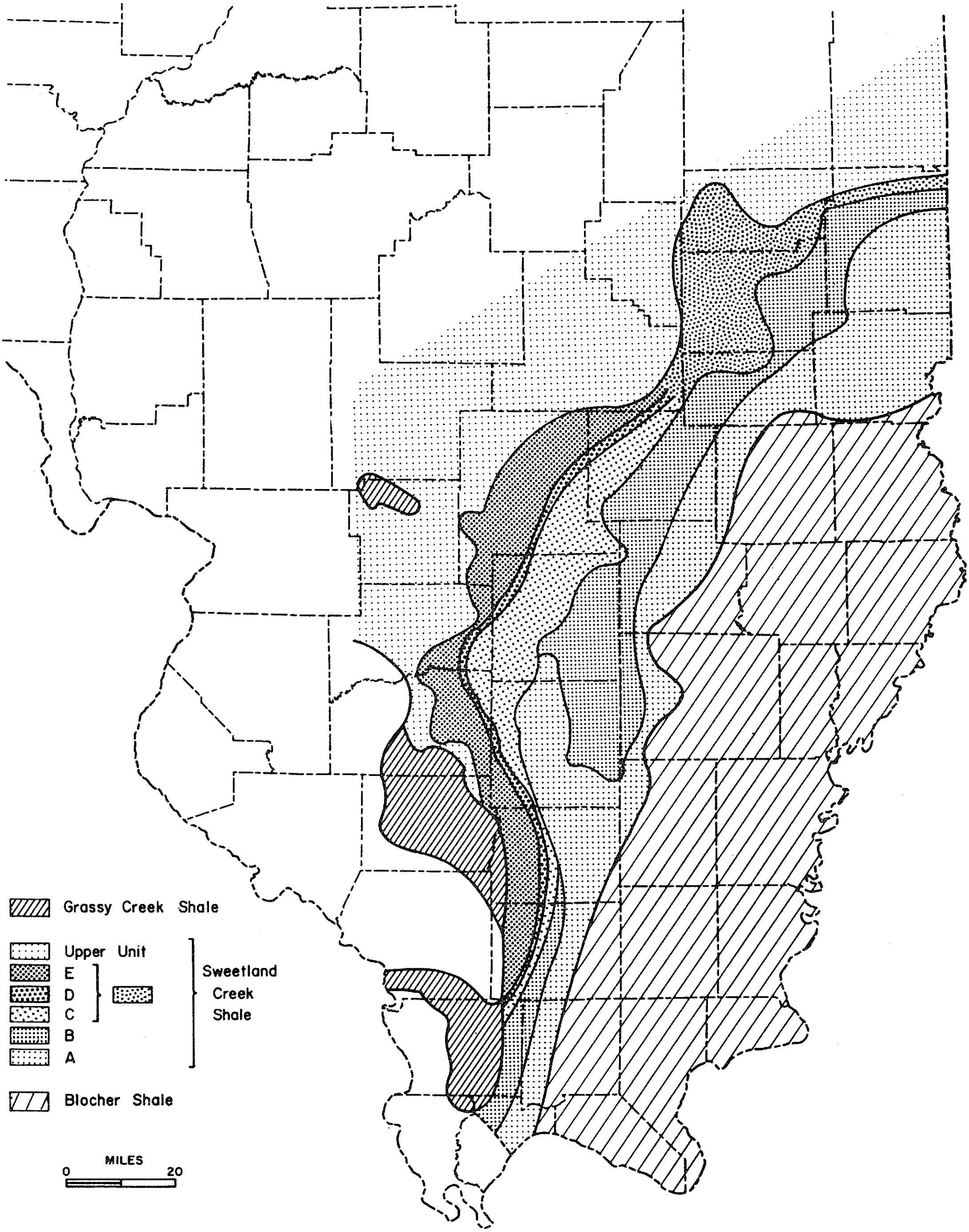

Fig. 23 - Units in contact with the top of the Middle Devonian limestones.

with the Alto Formation. This gradation results from the addition of carbonate in southwestern Illinois, which "dilutes" the eastward-derived clay and very fine-grained silt. The terrigenous detritus within these units is identical. The position of the zone of transition (figs. 17, 18, 19, and 22) is not accurately known, but the carbonate content of the strata is already low at the east side of T. 11 and 12 S., R. 1 W., just 6 miles east of the outcrop.

In addition to a gradational contact with the Grassy Creek Shale, the Sweetland Creek Shale grades laterally into the lower part of the Grassy Creek Shale in central Illinois. A vertical cutoff, in the area of transition, extends in a semicircle, convex toward the north from the west-central part of the study area to the northeast part (fig. 22). About 20 feet of strata are involved in the facies change from black shale with high carbon content in the south to lighter colored gray and green-gray shale with low carbon content to the north and west. The change is well defined by low resistivity to the north and west and high resistivity to the southeast. The facies boundary is arbitrarily drawn where the strata involved exhibit off-scale electrical resistivity (on the 0 to 100 ohms m^2/m scale) (figs. 11 and 13).

GEOLOGIC HISTORY

Beginning with sandstone and sandy limestone at the base of the Grand Tower Limestone, deposition during the Middle Devonian was characterized by two important transgressions and one important regression. The Dutch Creek Sandstone Member at the base of the Grand Tower Limestone marks the initial transgression over the pre-Middle Devonian erosion surface. In southern Illinois this unconformity is the base of the Kaskaskia Sequence and is associated with a craton-wide emergence. The transgression was accompanied by shallow-water carbonate deposition south of the Vandalia Arch, dolomite on the arch, and lithographic limestone between it and the Sangamon Arch. The only terrigenous detritus within the Grand Tower Limestone is fine to coarse, rounded sand grains of the St. Peter type derived from the Ozark uplift to the west. The carbonate shelf environment extends into the Wittenberg Trough where subsidence allowed the accumulation of an abnormally thick sequence.

The carbonate shelf was subsequently invaded by mud derived from the Appalachian area to the east. The Howardton Limestone Member at the base of the Lingle Formation shows the same carbonate microfacies as the Grand Tower Limestone, but mud and very fine-grained silt are added. Quartz sand deposition was confined to areas north of the Vandalia Arch, except along the western side of the Wittenberg Trough in a locality that was well isolated from the deeper basin to the east. The Howardton Member is a regressive deposit, with the unconformable upper surface marked by a calcareous intraformational microbreccia.

A limestone-producing oxygenated environment existed to the west during deposition of the Tripp Limestone Member and an organic-rich reducing environment lay to the east, producing the Blocher Shale. Abundant chert and sublithographic limestone in the Tripp Limestone Member in the zone of transition contrasts with fossiliferous limestone to the west and calcareous shale to the east, reflecting a lateral change from oxygenated conditions to a reducing environment.

Although the lighter color of the shales of the Sweetland Creek Shale indicates lower organic content, these shales contain virtually no carbonates. Carbonates are only present shoreward to the west, where the shales intertongue with the upper strata of the Tripp Limestone Member. These carbonates are shallow-water types and mark shoal areas. The youngest Sweetland Creek Shale overlapped the upper carbonates of the Tripp Member and was deposited on pre-Middle Devonian strata.

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APPENDIX A

List of Wells Used in Compiling Cross Sections

1. Lambert No. 1 Hagler, Sec. 28, T. 10 S., R. 2 W., Jackson County, Illinois.
2. Sturdevant No. 1 State Pond Land, Sec. 14, T. 12 S., R. 2 W., Union County, Illinois.
3. McRauer No. 4 City of Jonesboro, Sec. 25, T. 12 S., R. 2 W., Union County, Illinois.
4. Landers No. 1 Dillow, Sec. 31, T. 12 S., R. 1 W., Union County, Illinois.
5. Rigney No. 1 Hileman, Sec. 21, T. 13 S., R. 1 W., Union County, Illinois.
6. Vaughn No. 1 Ragsdale, Sec. 18, T. 14 S., R. 1 E., Pulaski County, Illinois.
7. Mid-Continent No. 1-A Herren, Sec. 12, T. 14 S., R. 1 E., Pulaski County, Illinois.
8. Benedum-Trees No. 1 Cavitt, Sec. 24, T. 11 S., R. 3 E., Johnson County, Illinois.
9. Texaco No. 2 Hicks-Russell Comm., Sec. 27, T. 6 S., R. 6 E., Hamilton County, Illinois.
10. Mitchell No. 1 Snead Comm., Sec. 14, T. 4 S., R. 7 E., Hamilton County, Illinois.
11. Nation No. 2 McIntosh, Sec. 31, T. 3 S., R. 8 E., White County, Illinois.
12. Collins No. 1 Harris Comm., Sec. 28, T. 2 S., R. 9 E., Wayne County, Illinois.
13. Taylor No. 1 Winter, Sec. 36, T. 4 S., R. 9 E., White County, Illinois.
14. Horton No. 1 Cuthbertson, Sec. 33, T. 2 S., R. 7 E., Wayne County, Illinois.
15. Beard No. 1 Atteberry, Sec. 21, T. 2 S., R. 7 E., Wayne County, Illinois.
16. Weinert No. 10 McPherson, Sec. 3, T. 2 S., R. 7 E., Wayne County, Illinois.
17. Peake No. 1 Feathers, Sec. 14, T. 2 S., R. 6 E., Wayne County, Illinois.
18. Texaco NCT-1 No. 5 Fuhrer, Sec. 28, T. 1 S., R. 6 E., Wayne County, Illinois.
19. Texas No. 1 Draper, Sec. 8, T. 3 S., R. 6 E., Wayne County, Illinois.
20. Sun No. 1 Aydt, Sec. 1, T. 4 S., R. 4 E., Jefferson County, Illinois.
21. Brehm No. 1 Hutchcraft, Sec. 24, T. 5 S., R. 4 E., Franklin County, Illinois.
22. Athene No. 1 Williford-Bosworth, Sec. 10, T. 3 S., R. 3 E., Jefferson County, Illinois.
23. Magnolia No. 1 Jones, Sec. 10, T. 3 S., R. 2 E., Jefferson County, Illinois.
24. Magnolia No. 7 Eubank-Winesburgh, Sec. 1, T. 3 S., R. 1 E., Jefferson County, Illinois.
25. National Assoc. No. 1 Schemming, Sec. 18, T. 3 S., R. 1 E., Jefferson County, Illinois.
26. Ohio No. 1 Sawyer, Sec. 33, T. 2 S., R. 1 W., Washington County, Illinois.
27. National Assoc. No. 1 Bookout, Sec. 18, T. 1 N., R. 5 E., Wayne County, Illinois.
28. White No. 1 Colclasure, Sec. 23, T. 3 N., R. 5 E., Clay County, Illinois.
29. Cooperative No. 1 Vangeison "A," Sec. 15, T. 5 N., R. 5 E., Clay County, Illinois.
30. Wiggins No. 1 Genaust, Sec. 18, T. 7 N., R. 6 E., Effingham County, Illinois.
31. National Assoc. No. 3 Krogmann, Sec. 31, T. 9 N., R. 7 E., Cumberland County, Illinois.
32. Robison No. 1 Young, Sec. 8, T. 10 N., R. 7 E., Cumberland County, Illinois.
33. Duncan No. 9 Oliver, Sec. 2, T. 12 N., R. 7 E., Coles County, Illinois.
34. Carter No. 1 Cobb, Sec. 10, T. 13 N., R. 7 E., Coles County, Illinois.
35. Sanders No. 1 Daily, Sec. 25, T. 14 N., R. 7 E., Coles County, Illinois.
36. Drake and Dome No. 1 Maxwell, Sec. 3, T. 5 N., R. 12 W., Crawford County, Illinois.
37. Ohio No. 1 McKee, Sec. 29, T. 7 N., R. 13 W., Crawford County, Illinois.
38. Wilson No. 1 Rue, Sec. 27, T. 9 N., R. 10 E., Cumberland County, Illinois.
39. Tri-Apco No. 1 Holsapple, Sec. 16, T. 9 N., R. 9 E., Cumberland County, Illinois.
40. Slagter No. 1 Layton, Sec. 20, T. 10 N., R. 8 E., Cumberland County, Illinois.

APPENDIX B

Geologic Sections

1.—Backbone North Section

North face of abandoned quarry, 350 feet northwest of the road through Backbone Ridge, NE¼ NE¼ SE¼ Sec. 23, T. 10 S., R. 4 W., Jackson County, Illinois (Altenberg 7½-minute Quadrangle). Description based in part on samples collected by W. W. Hallstein in 1949. The upper 10 feet is poorly exposed. Type section of Howardton Limestone Member of Lingle Formation.

	Thickness (feet)
Devonian System	
Lingle Formation	
Tripp Limestone Member	
Shale, grayish brown to dark grayish brown, very calcareous, few spores, fossiliferous (brachiopods)	1.5
Limestone, very fine grained, grayish brown to dark gray, very argillaceous, very silty, partly leached; contains many spores	7.0
Shale, very calcareous, grayish brown; contains abundant spores	0.5
Limestone, very fine grained, light brownish gray, silty, argillaceous, partly leached	1.0
Total Tripp Member	10.0
Howardton Limestone Member	
Limestone, fine grained, brownish gray, argillaceous, silty; contains silicified corals, some phosphatic fragments	1.0
Limestone, fine grained, brownish gray, slightly argillaceous, silty; contains silicified corals	.5
Limestone, fine grained, some pelletoidal, brownish gray, silty	1.5
Limestone, fine grained, light brownish gray to brownish gray, silty; contains silicified corals, few phosphatic fragments	3.5
Limestone, fine grained, gray to brownish gray, silty to sandy, fossiliferous	1.0
Limestone, very fine grained, to sublithographic, slightly argillaceous, gray to brownish gray; contains thin shale partings	2.0
Limestone, fine grained, fossiliferous, brownish gray, silty, argillaceous; contains thin shale partings	5.0
Limestone, fine grained, fossiliferous, argillaceous, brownish gray; contains thin shale partings	2.5
Limestone, lithographic, brownish gray	0.5
Limestone, fine grained, fossiliferous, argillaceous, light brownish gray to brownish gray; contains thin shale partings	8.5
Limestone, lithographic, fossiliferous, dark gray to brownish gray; contains thin shaly partings	1.5
Limestone, very fine grained, fossiliferous, brownish gray, partly leached, silty, argillaceous; contains *Microcyclus*, thin shaly partings	5.5
Total Howardton Member	33.0
Grand Tower Limestone	
Limestone, fine grained, very fossiliferous, brownish gray, partly leached	2.0
Limestone, fine grained, silty to sandy, brownish gray, sparingly fossiliferous	6.0
Limestone, fine grained, gray to brownish gray, silty; contains white to light gray chert in upper 5 feet	7.0

	Thickness (feet)
Grand Tower Limestone (cont.)	
Limestone, fine grained, fossiliferous, light brownish gray, silty to sandy; contains some intraclasts	8.5
Limestone, bioclastic, fine-grained matrix; contains clasts, <u>Chonetes</u>.	
Total Grand Tower Limestone	23.5

Base of measured section is about 40 feet above base of quarry.

2.—Walnut Grove School Section

Outcrop near top of gully, on the south line, 1000 feet from west line, of Sec. 22, T. 11 S., R. 2 W., Union County, Illinois (Cobden 7½-minute Quadrangle). Type section of Walnut Grove Limestone Member of the Lingle Formation.

Devonian System	
Alto Formation	
Limestone, fine grained, very silty, glauconitic, irregularly thin to medium bedded; contains dark gray to black chert nodules	1.0
Covered	0.5
Chert, dark gray to black, and limestone, fine grained, argillaceous, silty	1.0
Covered	0.5
Chert, dark gray to black, and limestone, fine grained, glauconitic, very silty; contains abundant spores	1.0
Covered	6.5
Total Alto Formation	10.5
Lingle Formation	
Walnut Grove Limestone Member	
Limestone, fine to coarse grained, fossiliferous (biomicrite to biosparite), grayish brown, glauconitic, sandy, irregularly thin to medium bedded; contains abundant crinoids, brachiopods, and spores	.5
Limestone, fine grained, dark gray, silty, very argillaceous, glauconitic, irregularly thin to medium bedded	.5
Limestone, fine grained, fossiliferous, dark gray to dark grayish brown, glauconitic, dolomitic, irregularly thin to medium bedded; contains black chert nodules, abundant spores, and abundant sponge spicules in some beds	10.0
Covered	1.0
Limestone, fine grained, dark grayish brown, very argillaceous, very silty, sponge spicules, thin bedded to laminated	7.0
Covered	2.0
Limestone, fine to coarse grained, coarser toward top, fossiliferous, dark brownish gray, silty; dolomitic in lower 6 inches	1.5
Limestone, fine grained, dark brownish gray, very silty, irregularly thin to medium bedded; contains silicified fossils	1.0
Limestone, oolitic, brownish gray; oolites are 1 mm in diameter and less in fine- to coarse-grained matrix (Rendleman Oolite Bed)	1.5
Limestone, medium grained, crystalline, gray, glauconitic, very sandy, massive	4.0
Total Walnut Grove Member	29.0

	Thickness (feet)
Misenheimer Shale Member	
Shale, very calcareous, silty; contains spores	4.0+

Section below poorly exposed.

3.—Tripp School Section

Outcrop 200 feet south of the bridge on Illinois Highway 146, N½ NE¼ NW¼ Sec. 23, T. 12 S., R. 2 W., Union County, Illinois (Jonesboro 7½-minute Quadrangle). The strata dip about 5° to the east, and successively younger strata are exposed eastward along an abandoned roadcut. The Rendleman Oolite Bed is exposed in a gully, 400 feet southeast of the bridge and about 30 feet above the level of the road. Type section of Tripp Limestone Member.

Devonian System	
Lingle Formation	
Walnut Grove Limestone Member	
Limestone, fine grained, grayish brown, argillaceous, thin to thick bedded; contains small very dark gray chert nodules, few crinoids	4.0
Limestone, coarse to fine grained, very fossiliferous, gray to grayish brown, massive	2.0
Limestone, fine grained, dark brownish gray, very glauconitic, silty, thin bedded	.5
Limestone, oolitic, brownish gray, poorly exposed; oolites are 1 mm in diameter and less in fine- to coarse-grained matrix; base not exposed	.5
Total Walnut Grove Member	7.0
Covered	15.0
Misenheimer Shale Member	
Siltstone, olive-gray, very calcareous; grades to very calcareous at base; contains spores	6.5
Limestone, brownish gray, fine grained, silty; abundant black chert nodules	1.0
Covered	6.0
Shale, very calcareous, very dark gray, silty; contains spores	.5
Covered	1.5
Limestone, fine to coarse grained, brownish gray to dark brownish gray; fossiliferous (crinoids), silty; contains black chert nodules	1.0
Covered	3.0
Shale, calcareous, very dark grayish brown; basal contact gradational	17.0
Total Misenheimer Shale	36.5
Tripp Limestone Member	
Limestone, fine grained, very dark grayish brown, very silty, very argillaceous, unevenly thin bedded	2.0
Limestone, fine grained, fossiliferous, dolomitic, very silty, irregularly thin to medium bedded; contains blue-gray to brownish gray chert nodules	3.0
Limestone, fine grained, very dolomitic, dark grayish brown, silty, irregularly thin to medium bedded; contains blue-gray to brownish gray chert nodules	4.0
Limestone, fine grained, fossiliferous, dark grayish brown, dolomitic, very argillaceous, silty, massive to thick bedded; contains crinoids, Tentaculites, and phosphatic pellets at base	2.0

	Thickness (feet)
Tripp Limestone Member (cont.)	
Shale, very calcareous, dark grayish brown, argillaceous; contains black nodules of chert at top	6.0
Total Tripp Member	17.0
Covered	12.0
Howardton Limestone Member	
Limestone, poorly exposed, fine grained, fossiliferous (solitary corals including *Microcyclus* are common), grayish brown, argillaceous, silty; contact not exposed	0.5
Total Howardton Member	0.5
Grand Tower Limestone	
Limestone, fine grained, crinoidal, grayish brown to light brownish gray	3.0
Limestone, fine to medium grained, crinoidal, gray to brownish gray	2.0
Limestone, fine grained, very fossiliferous (crinoids and brachiopods abundant), grayish brown to light brownish gray	9.0
Limestone, fine grained, fossiliferous (crinoids very abundant), argillaceous. Base concealed at stream level	3.0
Total Grand Tower Limestone	17.0

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