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Turbidites and Other Sandstone Bodies in the Borden Siltstone (Mississippian) in Illinois

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ABSTRACT

Deep-water turbidites and shallow-water sandstone bodies are found in the Borden Siltstone deltaic sequence of Valmeyeran age (Middle Mississippian) in central and east-central Illinois. The turbidites are composed of very fine-grained quartz sand that is well sorted, mineralogically mature, and graded. Turbidite sandstone bodies were formed when sand was carried by a river system into the delta environment that was normally characterized by deposition of siltstone and silty shale. The sand accumulated on the foreset slope of the delta off the mouths of major distributaries. It moved downslope, giving rise to turbidity currents that carried the sand across the gently sloping pro-delta plain.

Shallow-water sandstone bodies are present in the topset part of the delta sequence. These sandstones are not turbidites and exhibit shallow-water bedding features. Topset sandstone bodies were deposited during an influx of coarser clastics late in the deposition of the Borden delta.

INTRODUCTION

Discontinuous bodies of very fine-grained quartz sandstone are present near the base and near the top of the Borden Siltstone (Valmeyeran, Middle Mississippian) in central and east-central Illinois (fig. 1). The Borden Siltstone is a deltaic sequence (Swann, Lineback, and Frund, 1965; Lineback, 1966) with topset, foreset, and bottomset beds largely composed of siltstone and silty shale. The sandstone bodies found in the bottomset and topset parts of the delta were deposited during periodic influxes of coarser sediment.

Sandstone bodies in the lower part of the Borden are generally tongue or fan shaped and are often lobate. They may consist of a single sandstone bed in some

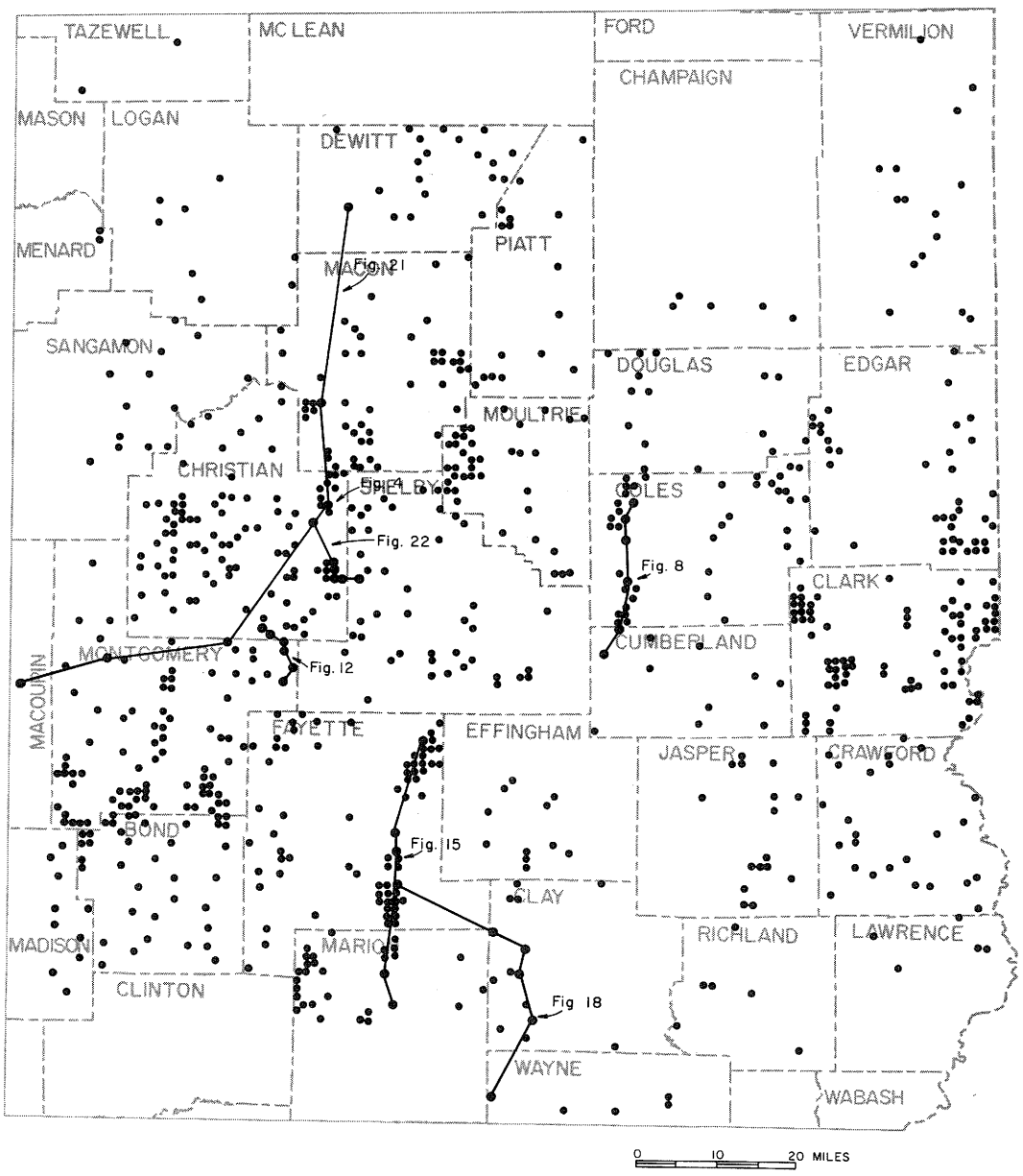

Figure 1 - Index map showing well control and the lines of electric log cross sections.

places, but in most places are a complex of several beds totaling up to 300 feet in thickness (fig. 2). The sandstone bodies are lenticular in transverse cross section, but a longitudinal cross section illustrates a significant aspect of the structure of these bodies. The bottom surface of the sandstone body slopes upward with respect to the base of the Borden in one direction and slopes downward, closer to the base, in the other. Downslope, the sandstone thins and pinches out. Upslope, the sandstone body may thicken, contain more fine-grained sediment, and grade laterally into siltstone in the middle of the Borden. The slope rises gradually at a low angle of 1 to 2 feet per mile to a position near the upslope end where the slope sharply increases to 40 feet per mile. The sandstones may be traced as high as 400 feet above the base of the Borden before disappearing into the upper part of the foreset slope of the delta.

The morphological form, stratigraphic position, and graded bedding of the bottomset sandstone bodies indicates deposition by turbidity currents that originated from localized sources on the foreset slope of the delta off the mouths of major distributaries. Turbidity currents deposited the sand bodies on the gently dipping bottomset pro-delta plain beyond the steep foreset slope. Some siltstone and shale beds in the Borden may also have been deposited by turbidity currents, but they are not distinguished by differences in grain size, as are the sandstone beds, and they cannot be readily distinguished in well records.

Most sandstone bodies have one main source or distributary mouth, but some have secondary sources from minor distributaries. Each sandstone body was deposited by a series of separate turbidity flows from the same distributaries. The successive positions of distributary mouths for stratigraphically higher sand bodies show the southward migration of the major distributaries and abandonment of previous channels during delta growth. Bottomset sandstone deposition was confined to the early stages of Borden deposition in Illinois, and sandstone is absent from the Borden south of Bond and Marion Counties.

Very fine-grained sandstone and coarse-grained siltstone beds are also present in the topset part of the Borden delta sequence and in the Warsaw Shale. The topset sandstones do not rise or fall significantly with respect to the top or the base of the delta sequence. They appear to have been deposited during a marine transgression across the topset plain after the delta had reached its maximum southward extent in Illinois. Topset sandstones show shallow-water bedding features and may grade laterally into limestone in places.

NOMENCLATURE

Sandstones near the base of the Borden in Clark County were named the "Carper sand" by Moulton (1926). The name Carper subsequently has been applied to all sandstones occurring in the lower quarter of the Borden Siltstone and in the Springville Shale (fig. 3). The Carper sandstones are oil reservoirs in several Illinois fields; in Fayette County, the Carper was studied by Stevenson (1964).

At least five major sandstone bodies with different areal distributions have been designated Carper sand or Carper sandstone. The name Carper is here retained as an informal oil-field term referring to any sandstone in the lower part of the Borden in Illinois. None of the individual sand bodies crop out in Illinois, and they are designated alphabetically in chronological order from oldest to youngest as Carper A through Carper E.

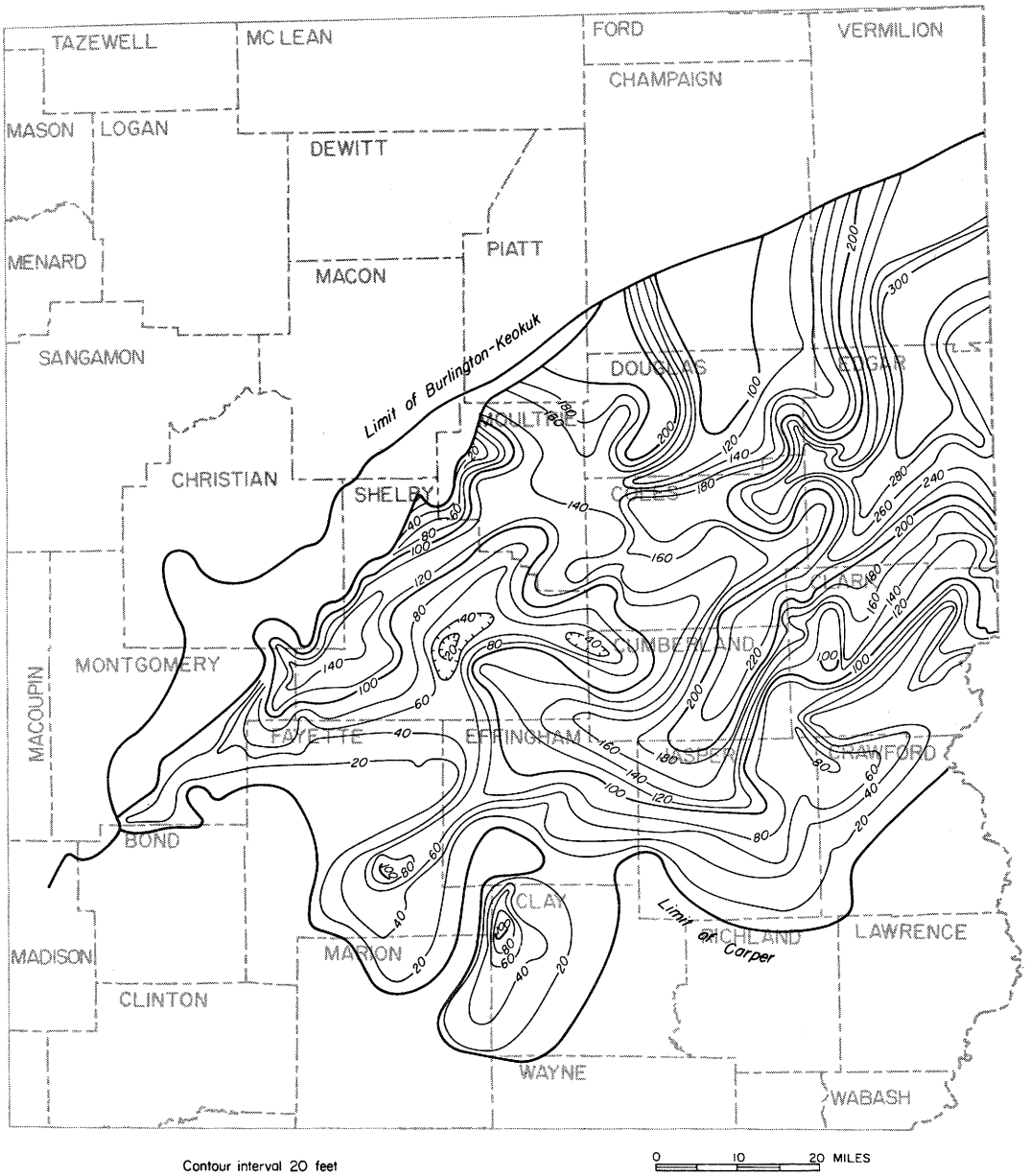

Figure 2 - Total thickness of the interval in the Borden Siltstone containing Carper sandstones.

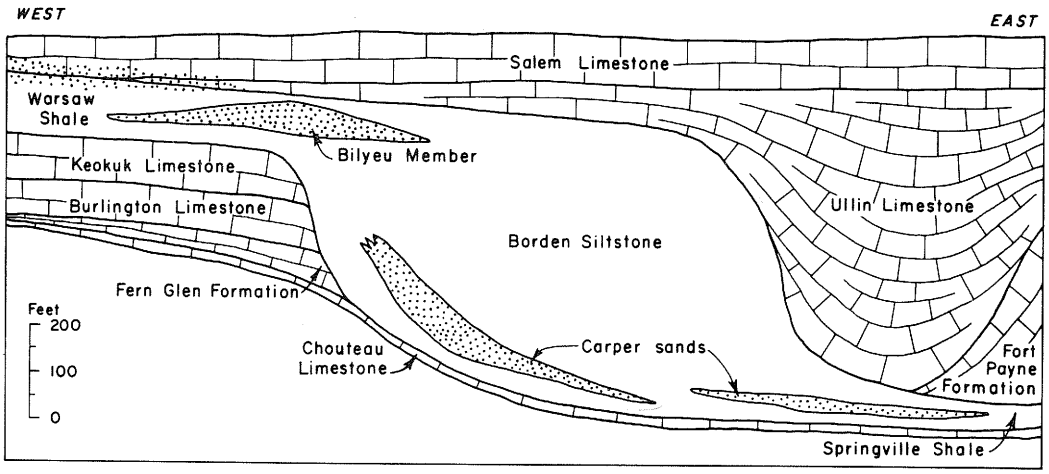

Figure 3 - Diagrammatic east-west cross section across central Illinois showing nomenclature of units studied.

Sandstone and siltstone present in the Warsaw Shale and in the upper quarter of the Borden Siltstone have been called the Sonora Sandstone, a name applied by Keyes (1895) to a sandy zone in the Warsaw Shale or Salem Limestone along the Mississippi River south of Nauvoo in Hancock County. The correlation of the topset sandstones of central Illinois to the Sonora is tenuous because of lack of intervening exposures and of well control.

One widespread topset siltstone unit in central Illinois is here formally named the Bilyeu Member. Because of the dual nomenclature of the deltaic sequence, the Bilyeu is a member of the Warsaw Shale northwest of the pinchout of the Burlington and Keokuk Limestones and a member of the Borden Siltstone southeast of the pinchout (fig. 3). The Bilyeu Member does not crop out and a type well is designated in the Assumption Consolidated field in Christian County, where the member is well developed. The type well is the National Associated Petroleum Company No. 1-A Bilyeu, Haldon et al. south, located in the $NW\frac{1}{4}$ $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 10, T. 13 N., R. 1 E., Christian County, Illinois (fig. 4). The electric log depth to the top of the Bilyeu Member is 1616 feet and to the base is 1718 feet, giving a thickness of 102 feet for the member. The logs and samples from this well are on file at the Illinois State Geological Survey. The name is taken from a small cemetery located in the $NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 33, T. 14 N., R. 1 E., about 2 miles north of the type well (Assumption 15-minute Quadrangle topographic map).

Sandstones and sandy carbonate beds are present above the Bilyeu Member in central Illinois. Some of these are included in the Warsaw Shale and others are shoreward sandy facies of the Ullin and Salem Limestones. Well control is too sparse to permit detailed study of sandstones above the Bilyeu Member.

LITHOLOGY

Carper sandstones are well sorted, very fine-grained quartz sandstones. The average quartz grain size varies from 0.07 to 0.09 mm. The quartz grains are angular

and may be somewhat elongate. A typical example of Carper contains 60 to 70 percent quartz, 25 percent sericitic matrix, 4 to 12 percent carbonate, 2 to 5 percent brown organic fragments, and small amounts of chlorite, glauconite, feldspar, clay, and pyrite. Some Carper sandstones contain more carbonate and sericitic matrix with correspondingly less quartz.

Individual beds of Carper are graded, but the difference in grain size is very small and cannot be seen in hand specimens. Thin sections of cores from two Carper beds in Illinois showed slightly coarser average grain size at their bases than at their tops. Carper beds are nonlaminated, and sole marks, characteristic of turbidites, have not been observed in cores. Sole marks are present on thin sandstone and siltstone beds near the base of the Borden in southern Indiana and in Kentucky (Kepferle, 1967).

The Bilyeu Member is generally a coarse-grained sericitic quartz siltstone, rather than sandstone. Cores of the Bilyeu show small-scale cross-bedding, burrows, and laminated bedding not found in the Carper sandstones.

Carper A

Carper A sandstone body, the original Carper of Moulton (1926), is the oldest, thickest, and covers the largest area of the five Carper sandstones. It is a complex of many individual sandstone beds. Carper A is over 300 feet thick in parts of Edgar and Vermilion Counties (fig. 5). The long axis of Carper A extends in a southwesterly direction across Edgar, Coles, and Cumberland Counties. The sandstone thins and pinches out in Jasper and Crawford Counties. Carper A extends eastward into northwestern Indiana, where most of the Borden Siltstone is composed of coarse-grained siltstone and fine-grained sandstone. Carper A represents an early stage of Borden deposition in Illinois during which the sediment was coarser grained than most later sediment. Sand of Carper A was deposited as a series of southward flowing turbidity currents originating from the mouth of a large distributary channel (fig. 6).

Irregularities in thickness of Carper A occur along the axis of the LaSalle Anticlinal Belt in Douglas,

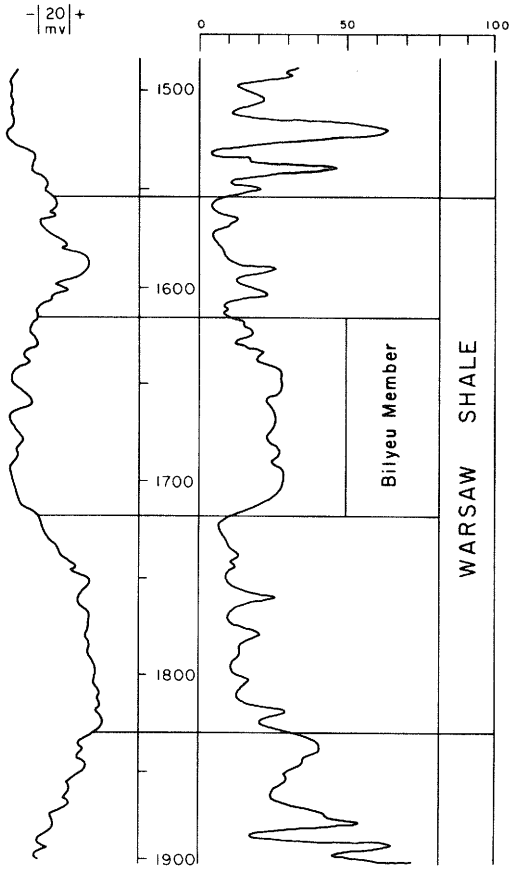

Figure 4 - Electric log of the type well of the Bilyeu Member. National Associated Petroleum Company, No. 1-A Bilyeu, Haldon et al. south, located in the NW¼ NW¼ SW¼ sec. 10, T. 13 N., R. 1 E., Christian County (fig. 1).

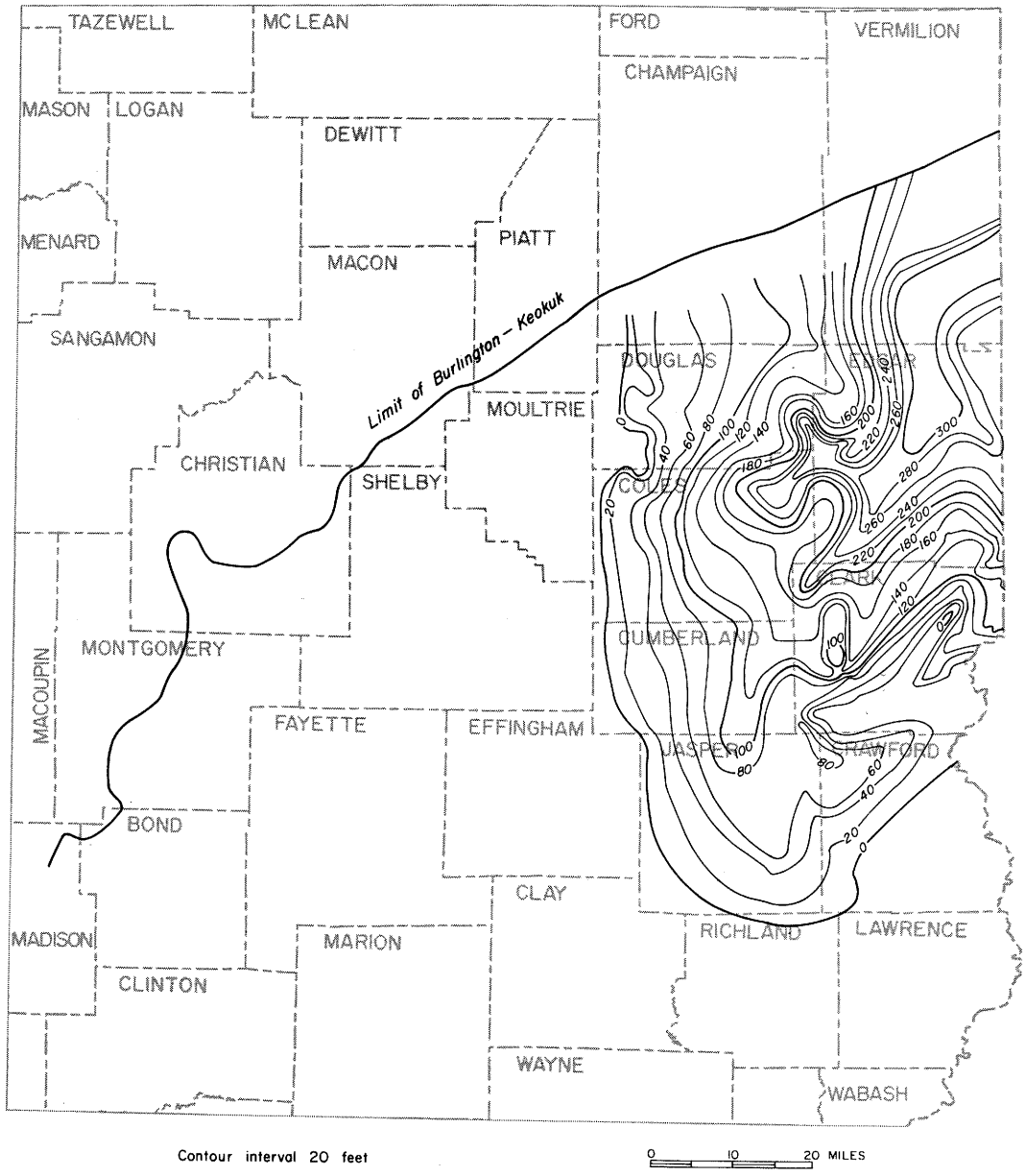

Figure 5 - Thickness of Carper A.

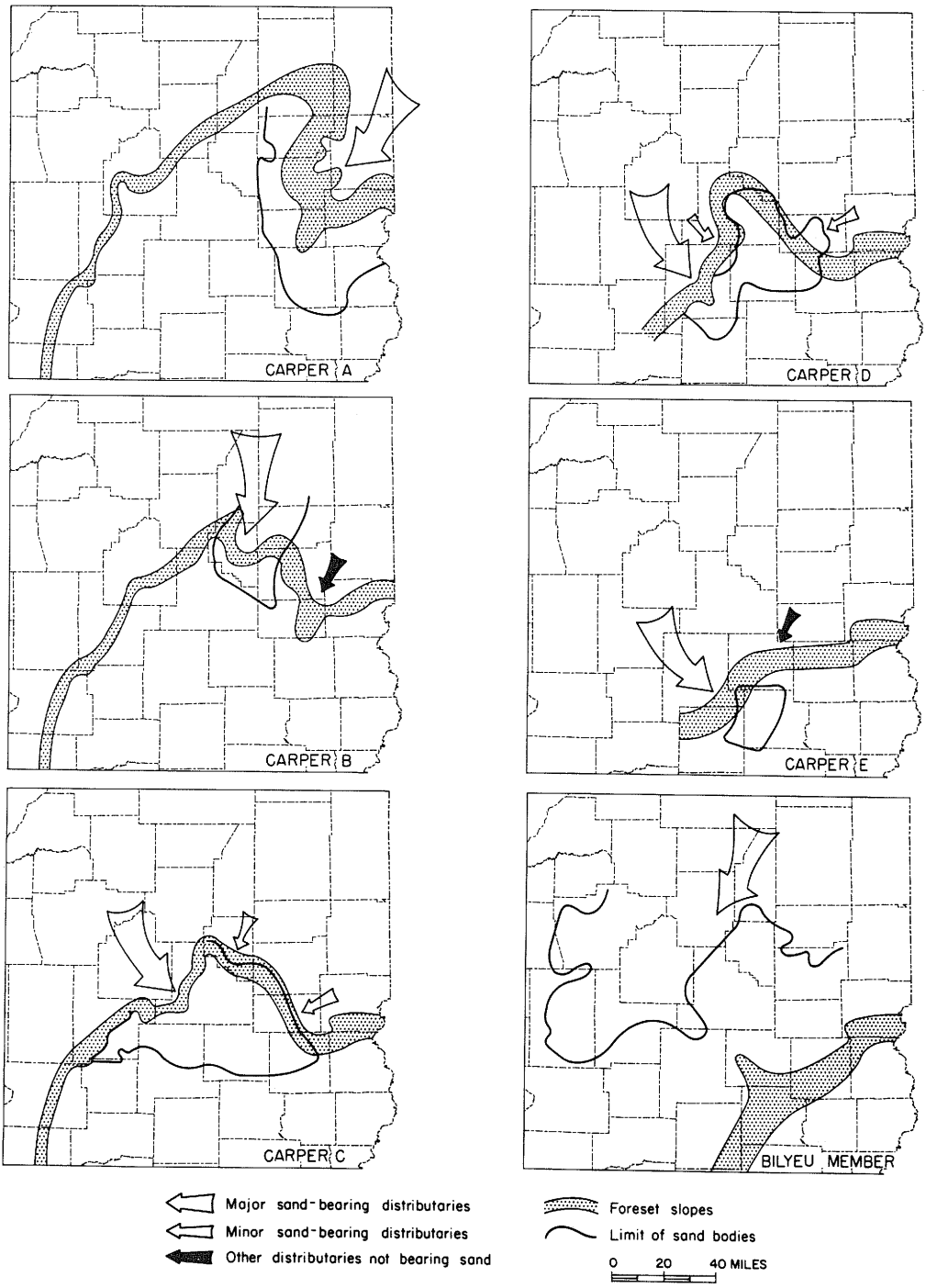

Figure 6 - Maps summarizing the positions of major and minor distributary outlets, the migration of distributary outlets, and the migration of the foreset slope of the Borden delta during deposition of the Carper sandstones and the Bilyeu Member.

Edgar, Coles, Cumberland, and Clark Counties. Structural uplift along the anticlinal belt resulted in highs over which thinner Carper sandstone was deposited. The Borden below Carper A is absent or very thin along the crest of the anticlinal belt, but thickens east and west of the crest (fig. 7). The surface upon which Carper A was deposited in Illinois was more or less flat, except for irregularities along the anticlinal axis and the presence of the escarpment to the north formed by the seaward edge of the Burlington-Keokuk carbonate bank. In contrast, later sandstone bodies show the topographic effect of foreset slopes of the Borden delta.

Carper B

The Carper B sandstone body lies adjacent to Carper A in Moultrie, Coles, and Douglas Counties. Carper B is difficult to separate from Carper A in some places but can be shown to overlie it (fig. 8). Carper B apparently represents deposition from a distributary that debouched into northern Moultrie County and may represent a westward shift of the major distributary channel. Sandstone beds of Carper B tend to be more massive and have fewer thick shale interbeds than the sandstones of Carper A. Carper B is over 250 feet thick in northern Douglas County (fig. 9) and thins south and west.

Borden sediment below Carper B thickens northwestward (fig. 10). Carper B rises in the section westward and disappears by lateral gradation into siltstones. Previous to deposition of Carper B, Carper A deposition to the east in Coles and Douglas Counties left a sharp topographic rise on the sea floor, marking the foreset slope of the delta. Carper B rose partway up that slope, probably under the momentum of turbidity currents.

Carper C

The Carper C sandstone body is a relatively thin unit that covers most of Shelby County and large parts of adjacent counties (fig. 11). Carper C is over 140 feet thick in places, and several individual lobes can be recognized. Carper C is an oil producer in the Louden pool, Fayette County, where it shows high resistivity and high spontaneous potential on electric logs. Where thin, Carper C consists of three or fewer sandstone beds, but where thick, it is a complex of many beds.

Carper C is thickest in western Shelby County and northeastern Montgomery County. Northwest of its area of maximum thickness, Carper C rises to the middle of the Borden and disappears by lateral gradation into siltstone (fig. 12). One thick lobe extends into northern Shelby County, another extends southeastward into the Louden pool in northeastern Fayette County. A third lobe extends southwestward across Montgomery County and abuts the escarpment formed by the Burlington and Keokuk Limestones along the Bond-Montgomery County line. Carper C extends eastward into Cumberland, Coles, and Moultrie Counties where it was deposited partway up the foreset slope formed in part by Carper A and B (fig. 13). Local thickening along the foreset escarpment may have resulted from piling up of successive flows against the topographic barriers or by deposition from the mouths of minor distributaries in Cumberland and Moultrie Counties that may be the much weakened sources for Carper A and B (fig. 6).

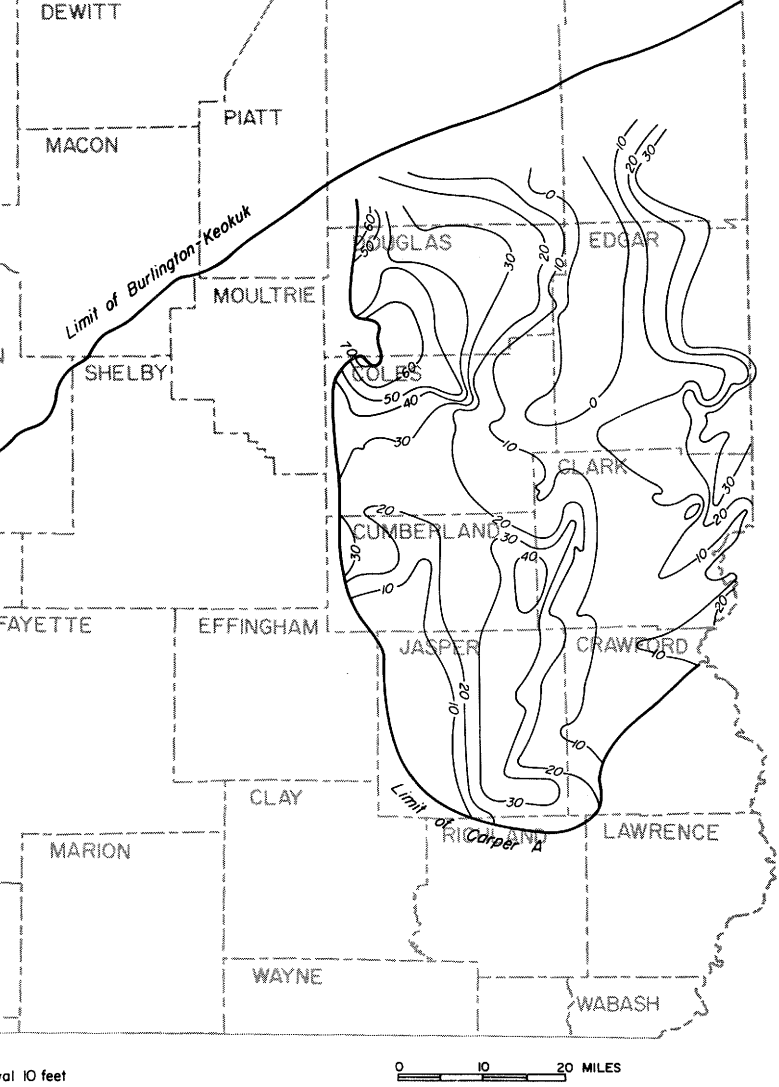

Figure 7 - Thickness of Borden below Carper A.

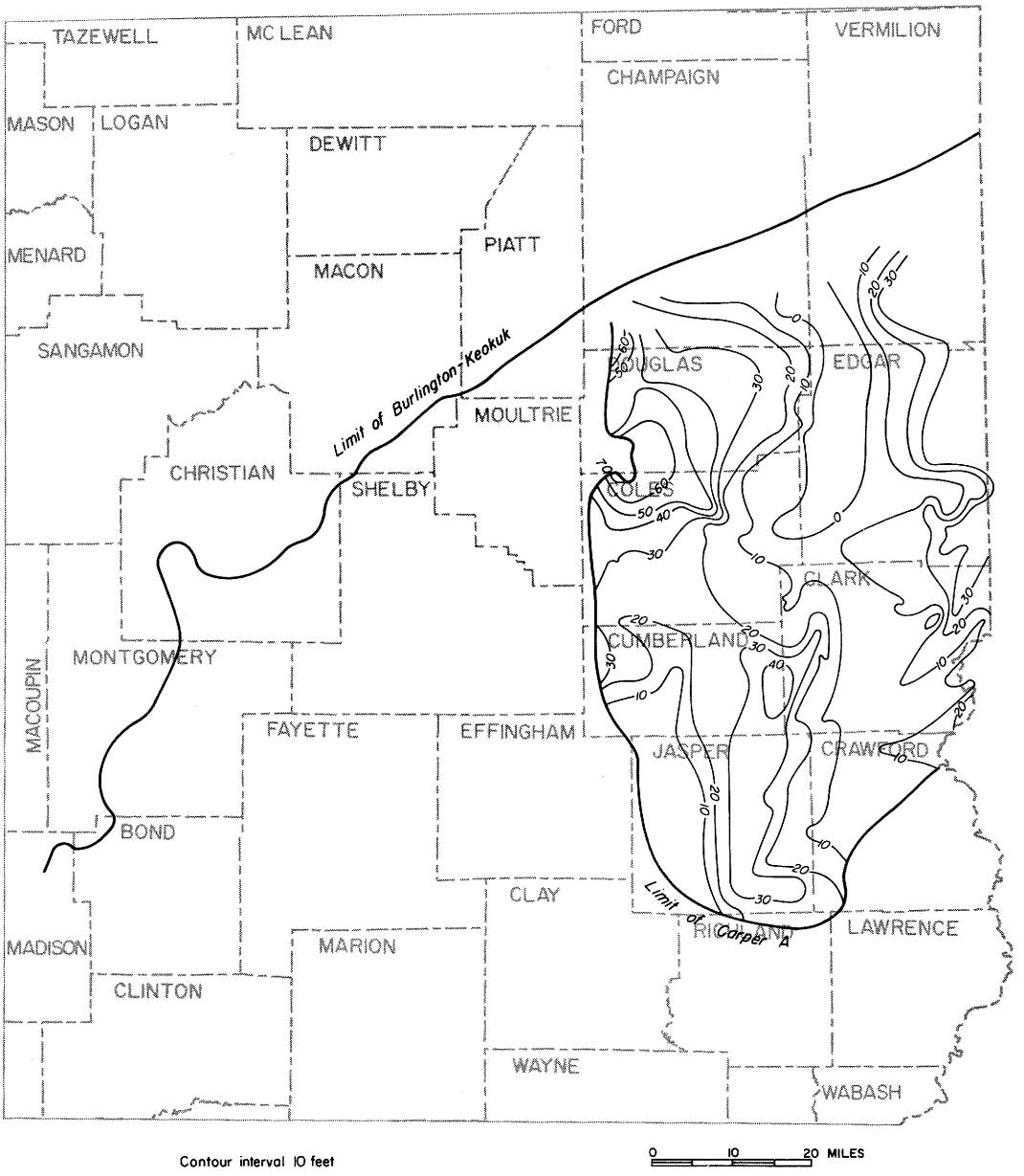

Figure 7 - Thickness of Borden below Carper A.

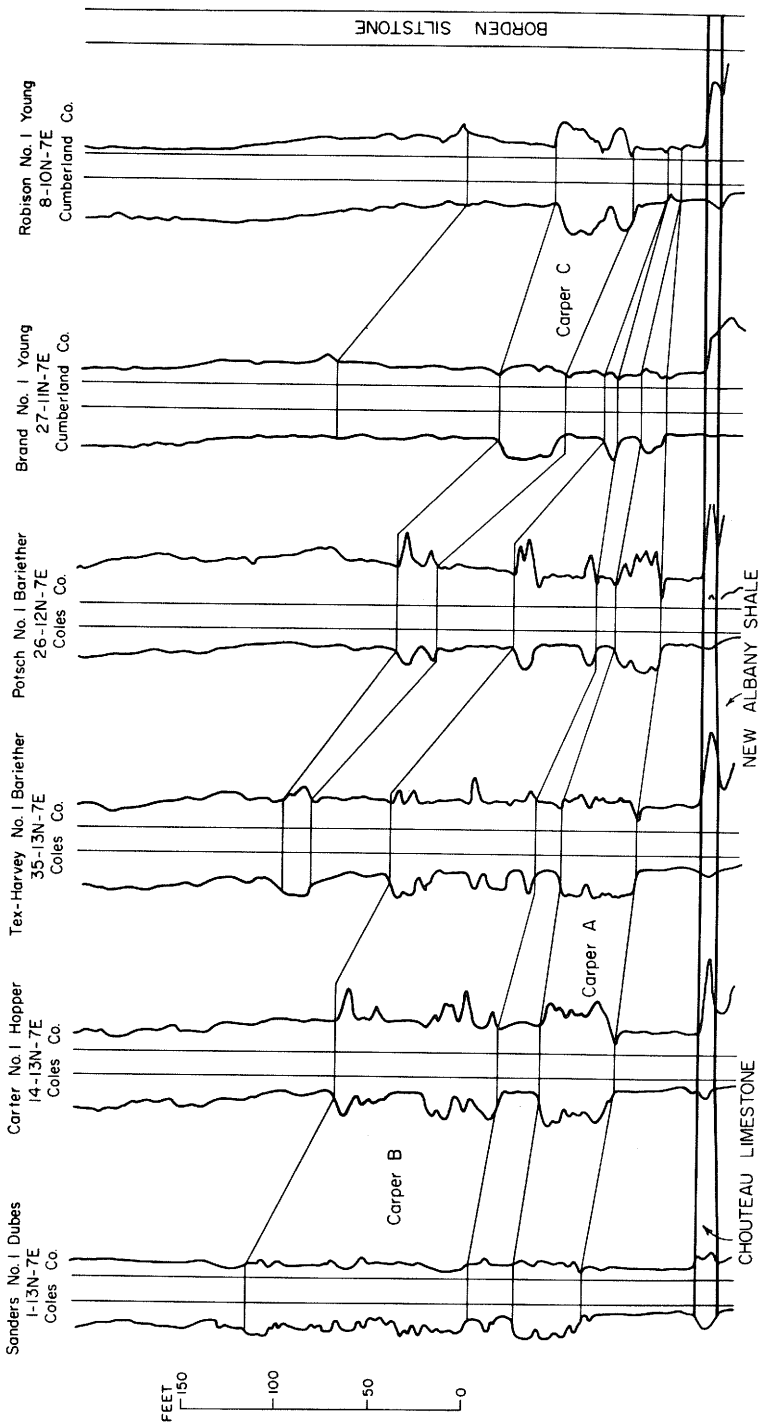

Figure 8 - Electric log cross section in Coles and Cumberland Counties showing the superposition of Carpers A, B, and C. (Index map fig. 1).

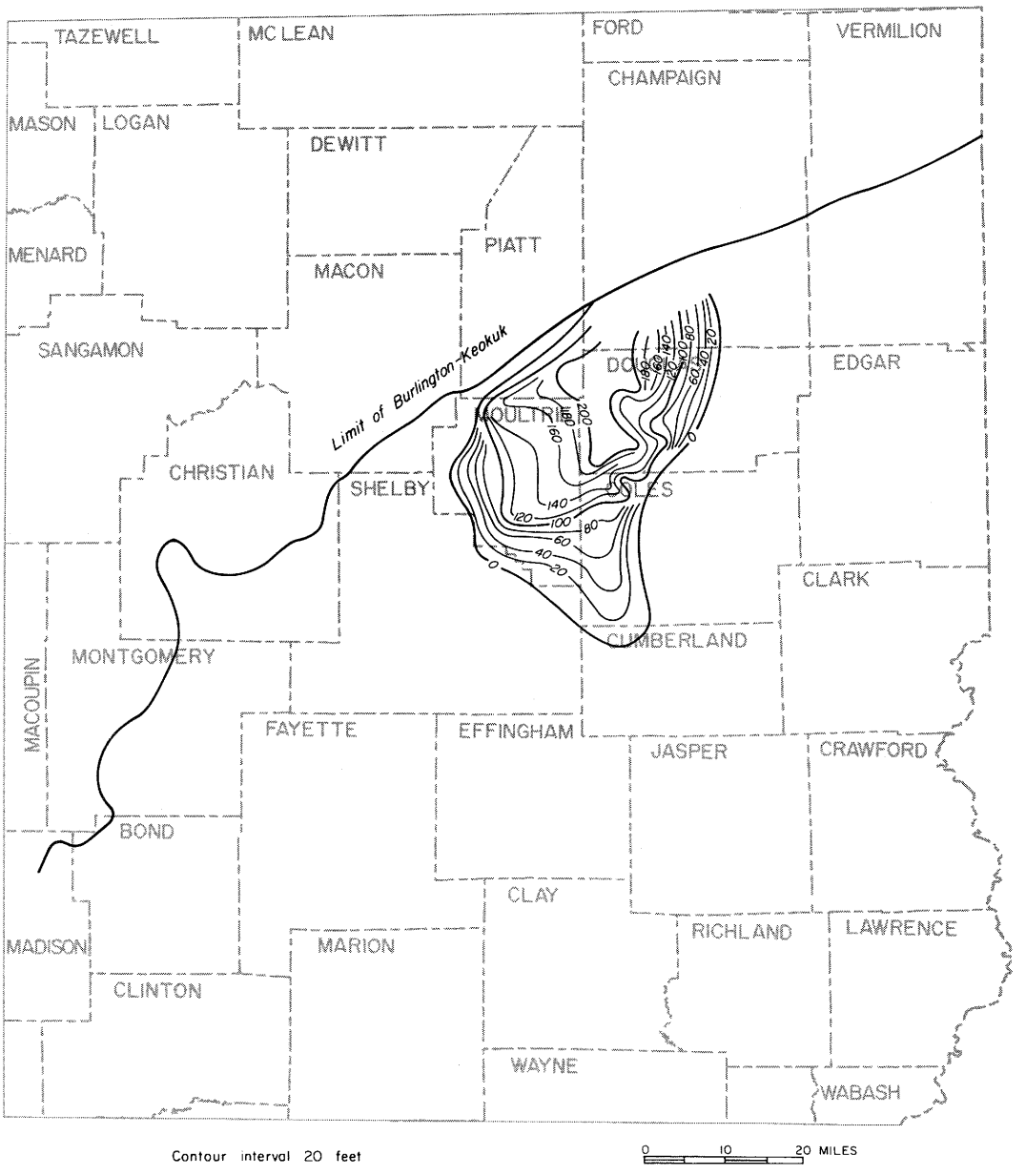

Figure 9 - Thickness of Carper B.

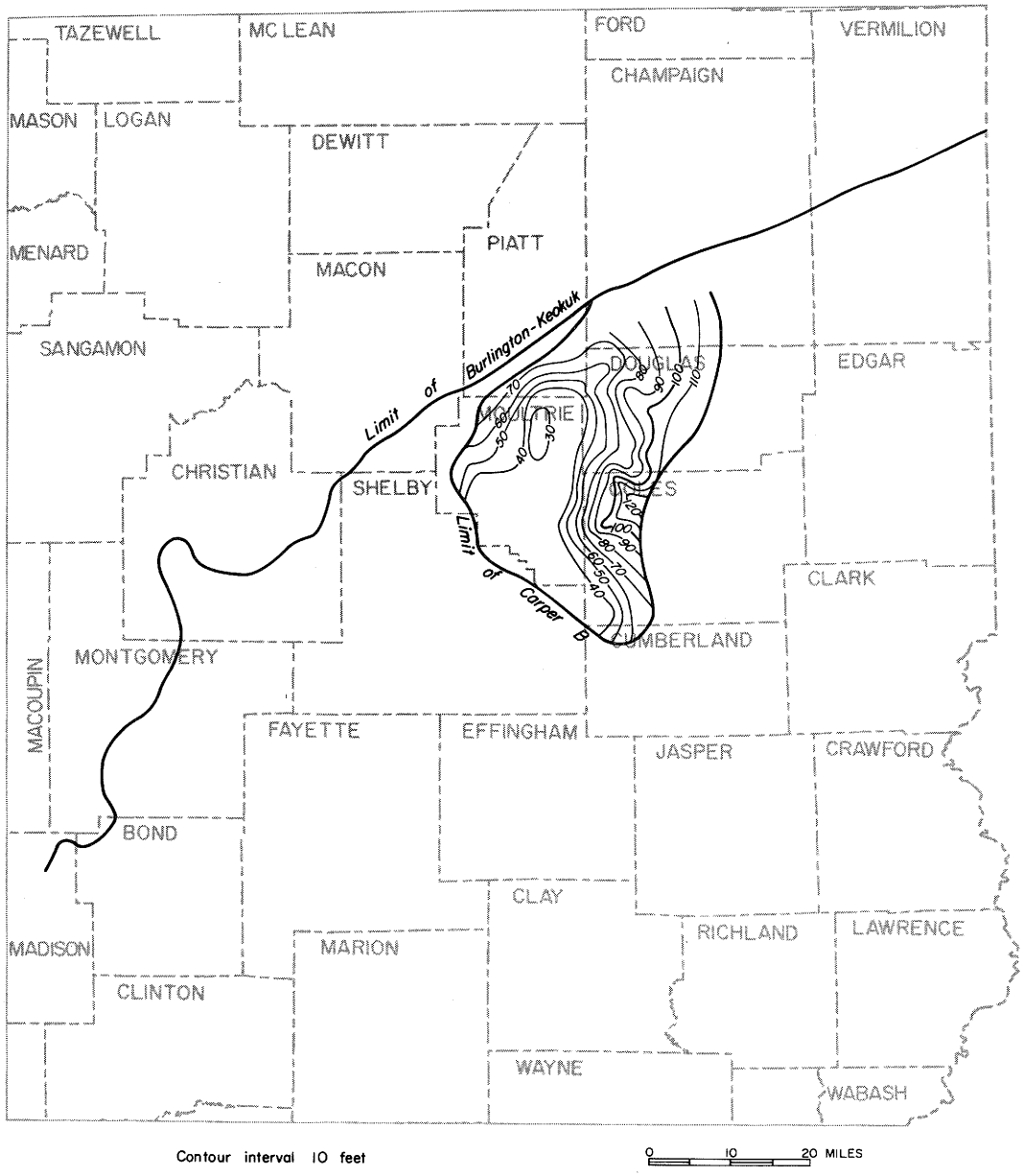

Figure 10 - Thickness of Borden below Carper B.

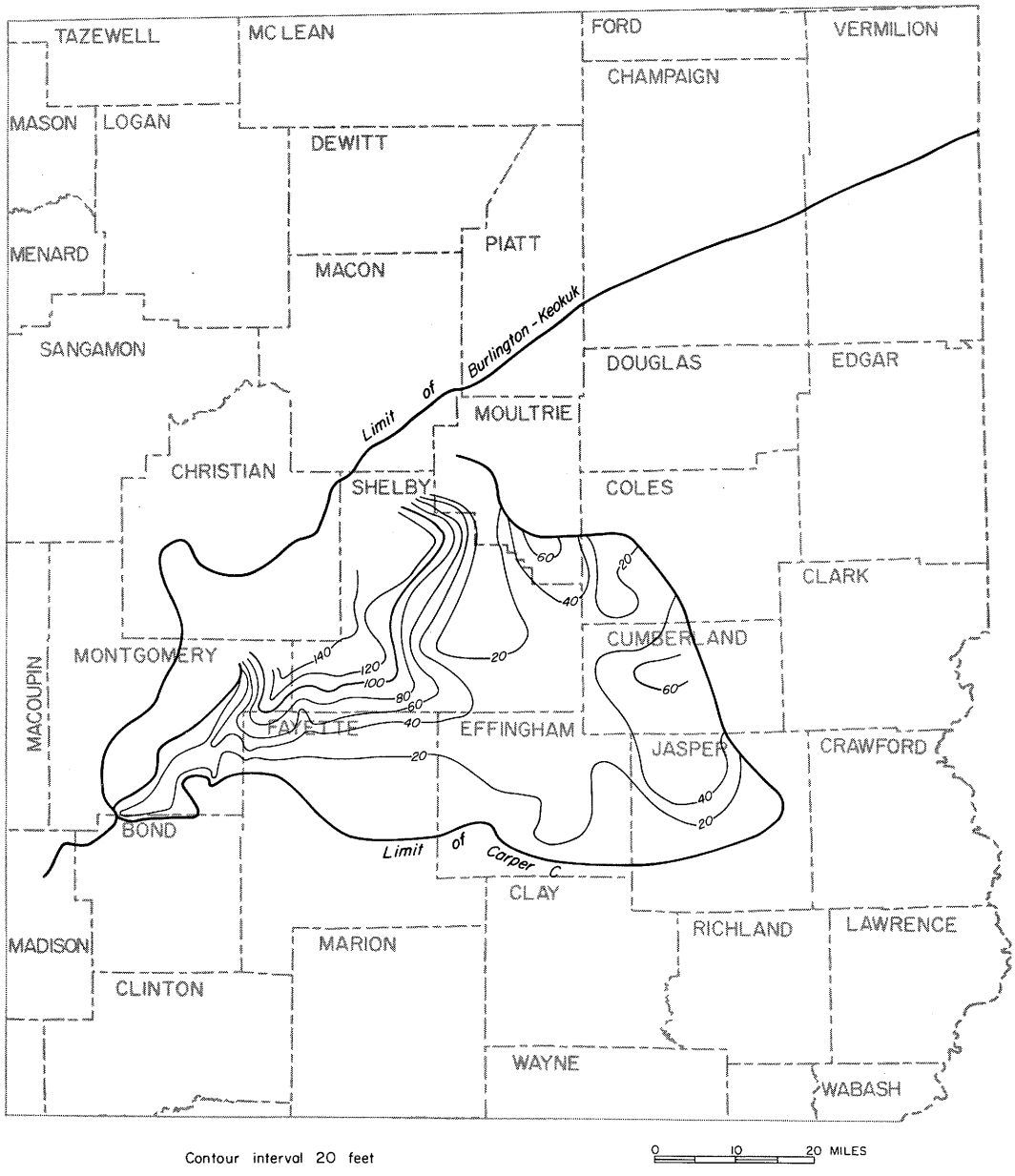

Figure 11 - Thickness of Carper C.

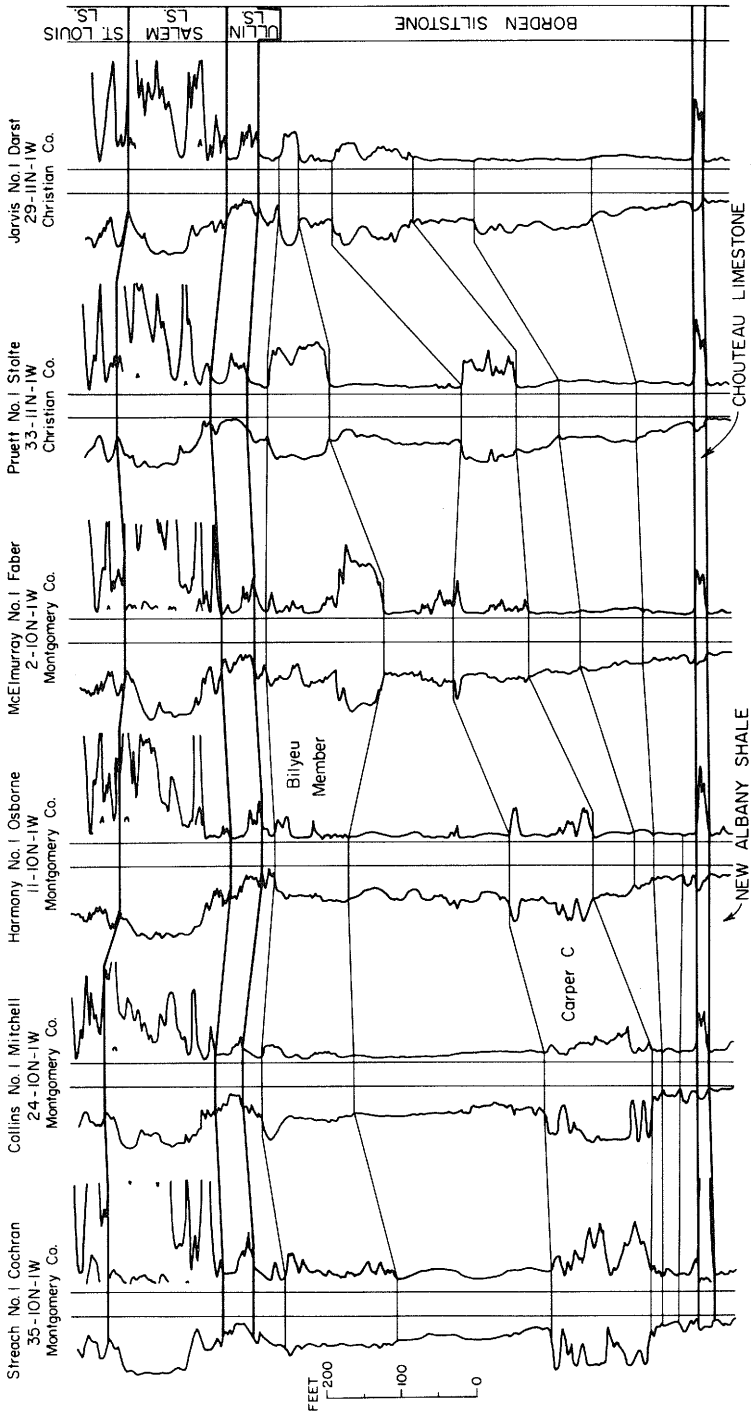

Figure 12 - Electric log cross section in Montgomery and Christian Counties showing Carper C rising in the foreset beds of the Borden delta. (Index map fig. 1).

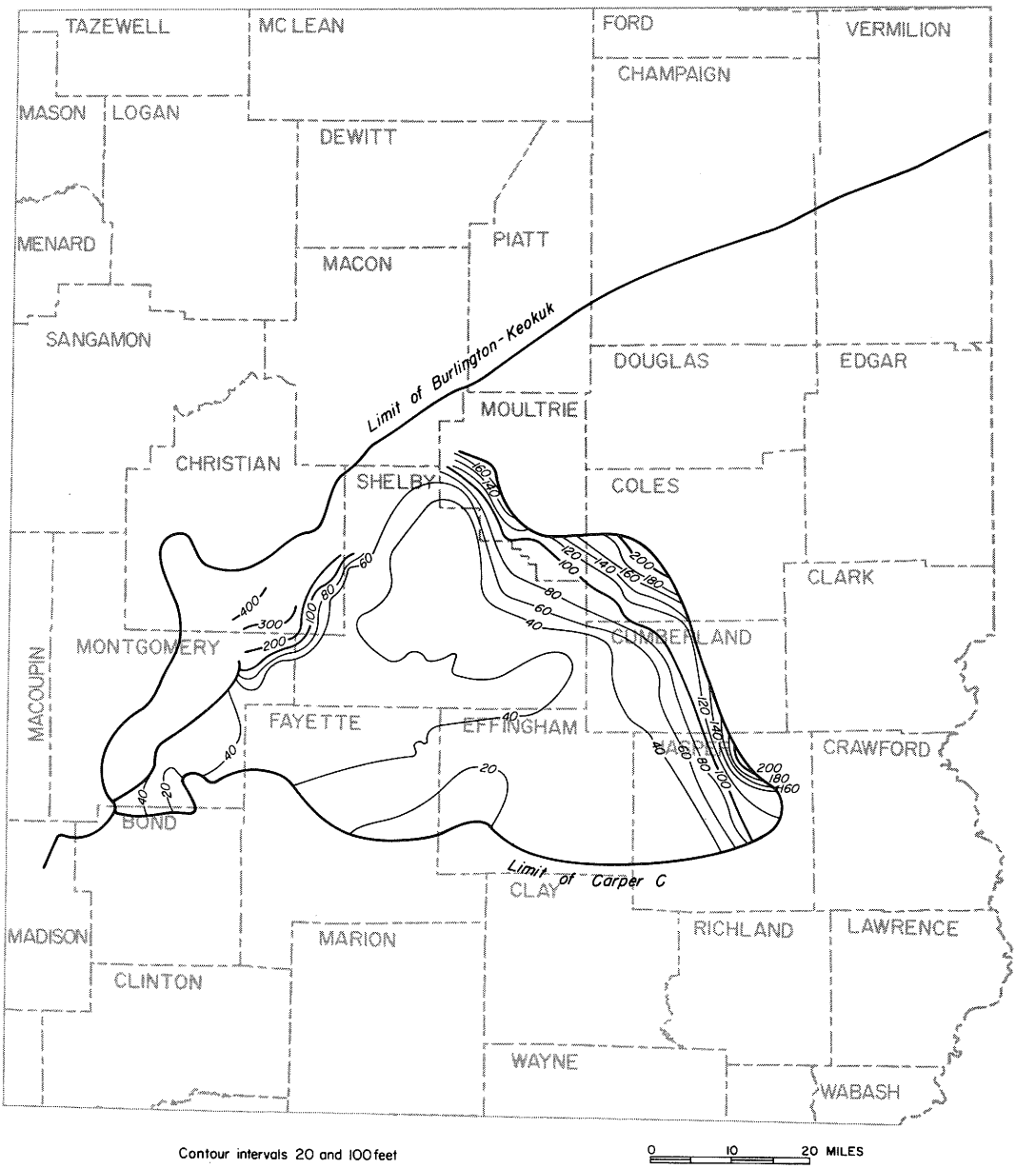

Figure 13 - Thickness of Borden below Carper C.

Carper D

The Carper D sandstone body is widespread in an irregular pattern across Fayette, Effingham, Shelby, Cumberland, and adjacent counties. It is generally thin and thickens notably only near its source (fig. 14). Carper D is an oil producer in the St. James, Wilberton, and St. Paul pools in Fayette County (Stevenson, 1964) and overlies Carper C of the more northerly Louden pool (fig. 15). In most places, Carper D has high spontaneous potential on electric logs, but low resistivity, indicating a higher content of silt and mud than the other sandstones. Where Carper D is thin, the resistivity is usually high.

Carper D is over 100 feet thick in southeastern Fayette County, and it is also thick in southeastern Shelby, in western Jasper, and in southern Cumberland Counties. The areas of thick Carper D are on or near the steep foreset slope of the delta (fig. 16). The main source of Carper D was a distributary mouth entering from the northwest; the sand spread southeastward across Fayette County (fig. 6). The other areas of thick Carper D originated from minor distributaries located on the delta front in southern Shelby County and in eastern Cumberland County.

Carper E

The Carper E sandstone body occupies a fairly small area in western Clay County and adjacent parts of Effingham and Marion Counties. Carper E thins rapidly eastward from its maximum of 110 feet (fig. 17). It has a more irregular spontaneous potential and resistivity than the other Carper sandstones and is a composite of several thick beds in most places. Carper E extends beyond the final foreset slope of the Borden delta in Clay County and below the Fort Payne Formation and Ullin Limestone (fig. 18). Carper E was deposited near the time at which the Borden delta reached its easternmost position in Clay County (fig. 19). A single distributary entering Clay County from the northwest was the source for Carper E (fig. 6).

The average grain size of the Borden decreases southward, and with the increased amount of shale, interruptions by coarser grained sediments ended. The absence of Carper sandstone south of Bond and Marion Counties indicates that the river system became less competent to transport coarse-grained sediment.

Bilyeu Member

The Bilyeu Member is thickest in an elongate band extending from DeWitt County through Macon County into eastern Christian County (figs. 20, 21). Eastward, it can be correlated with siltstone at the top of the Borden (fig. 22). The Bilyeu Member gradually thins to the southwest and west and extends as far as Montgomery and Macoupin Counties. The thickness of Valmeyeran rocks below the Bilyeu cannot be used as a reliable indicator of the topography on which the member was deposited because of the general westward and northward thinning of Valmeyeran rocks (fig. 23). However, the Bilyeu Member does not descend downward on foreset slopes in the Borden and is not known to be connected to any of the Carper sandstones. The member was not deposited until the Borden delta had extended southward as far as Clinton County, if not farther. It was deposited during an influx of coarser sediment from the northeast caused by a temporary rejuvenation of

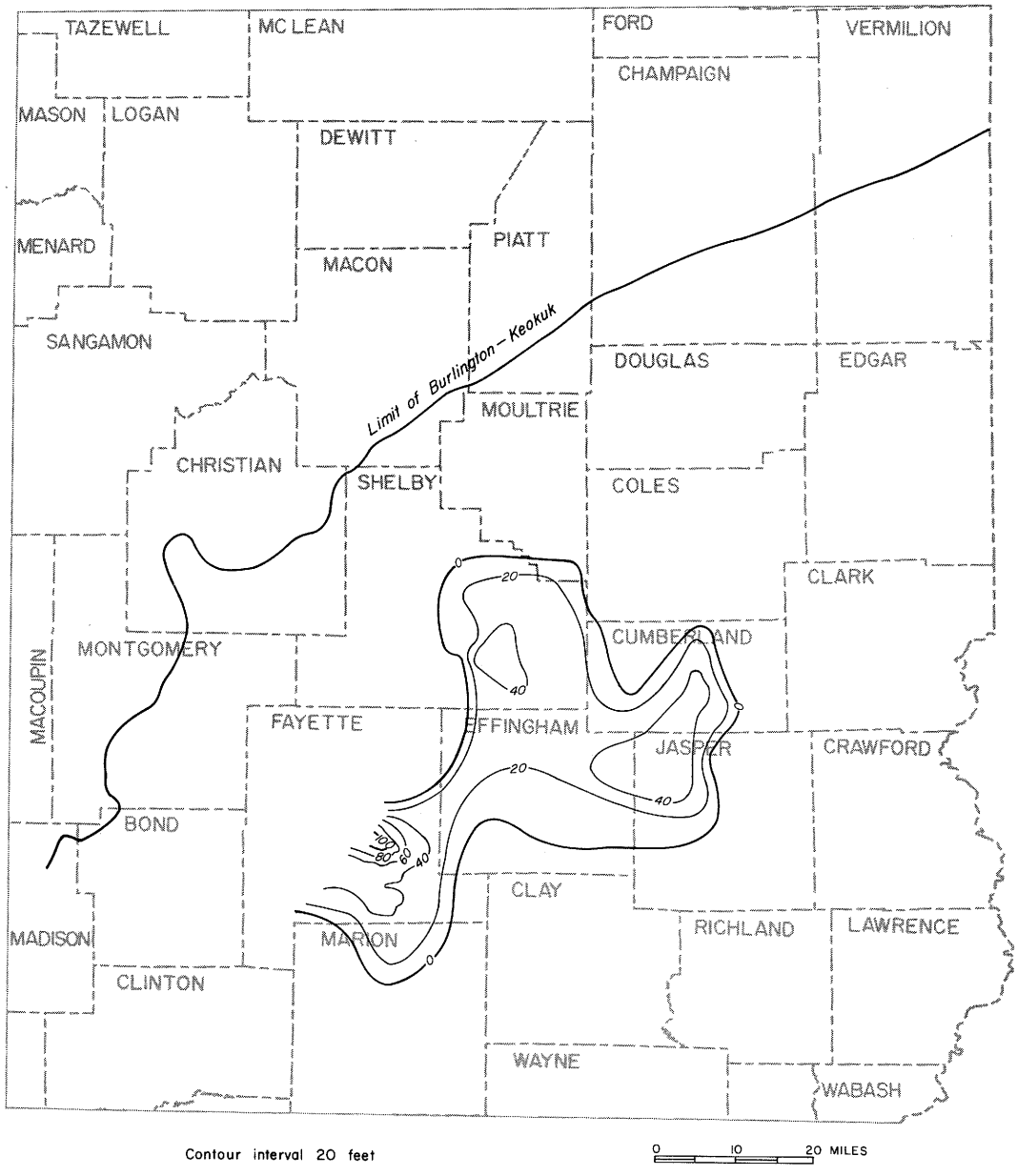

Figure 14 - Thickness of Carper D.

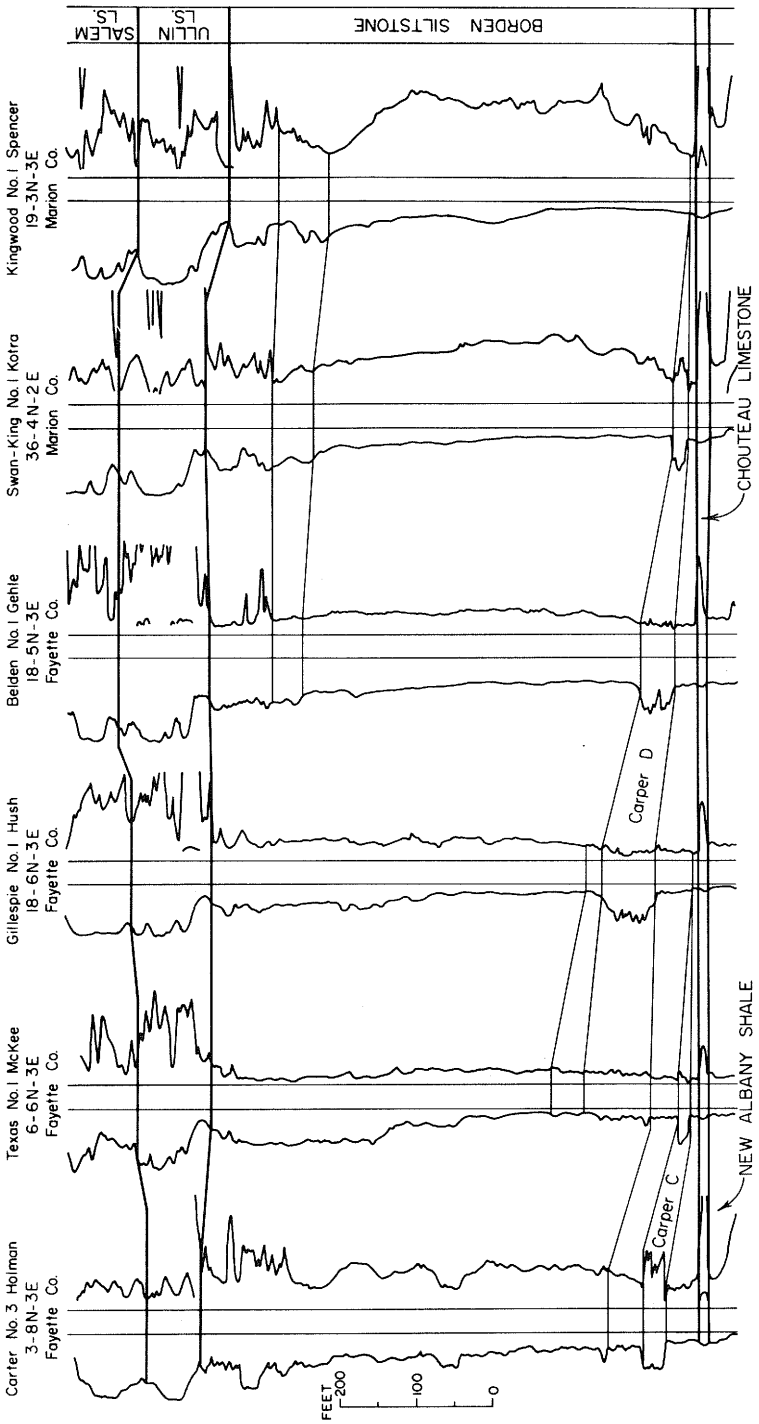

Figure 15 - Electric log cross section in Fayette and Marion Counties showing Carper D overlying Carper C and both pinching out southward. (Index map fig. 1).

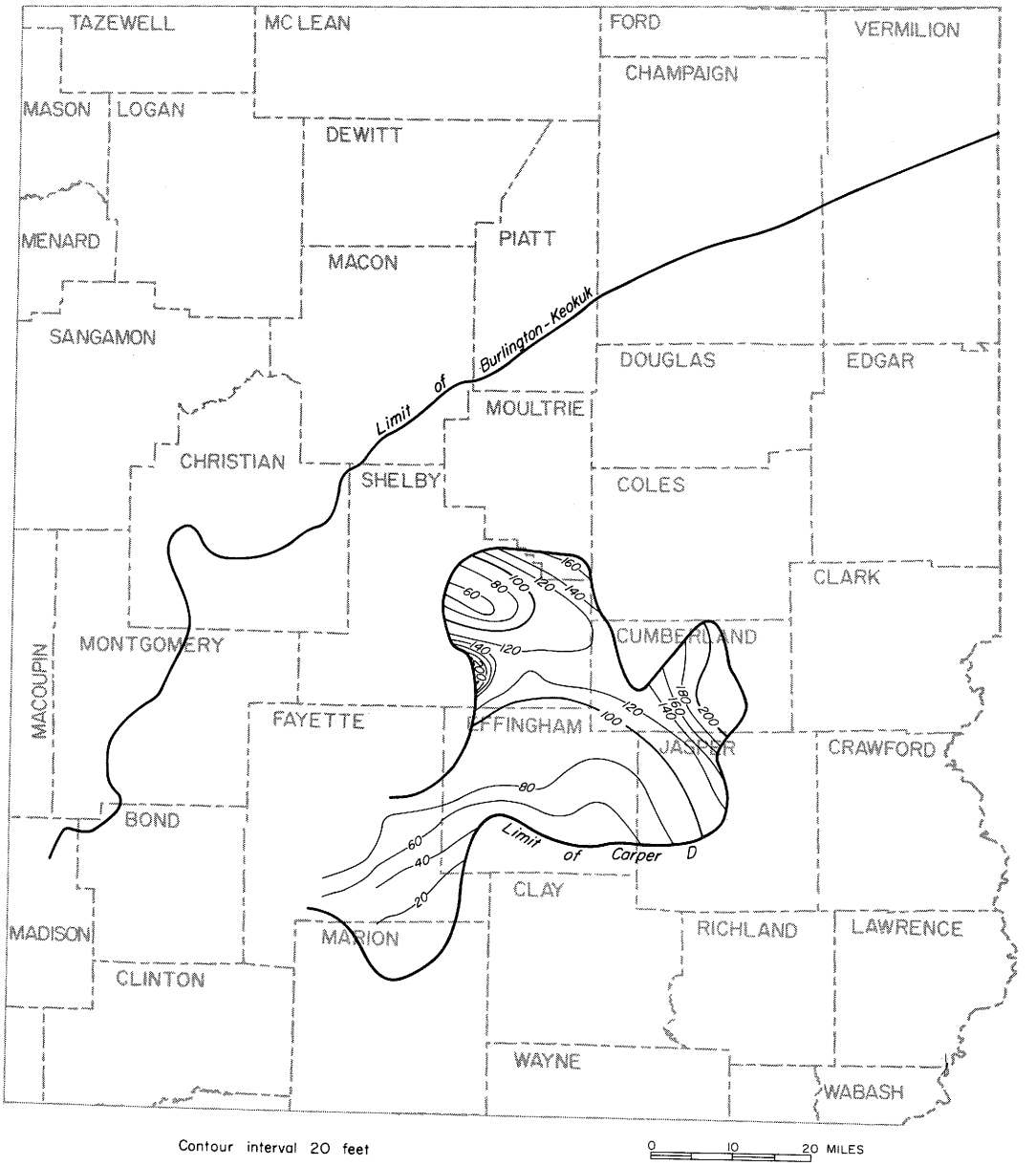

Figure 16 - Thickness of Borden below Carper D.

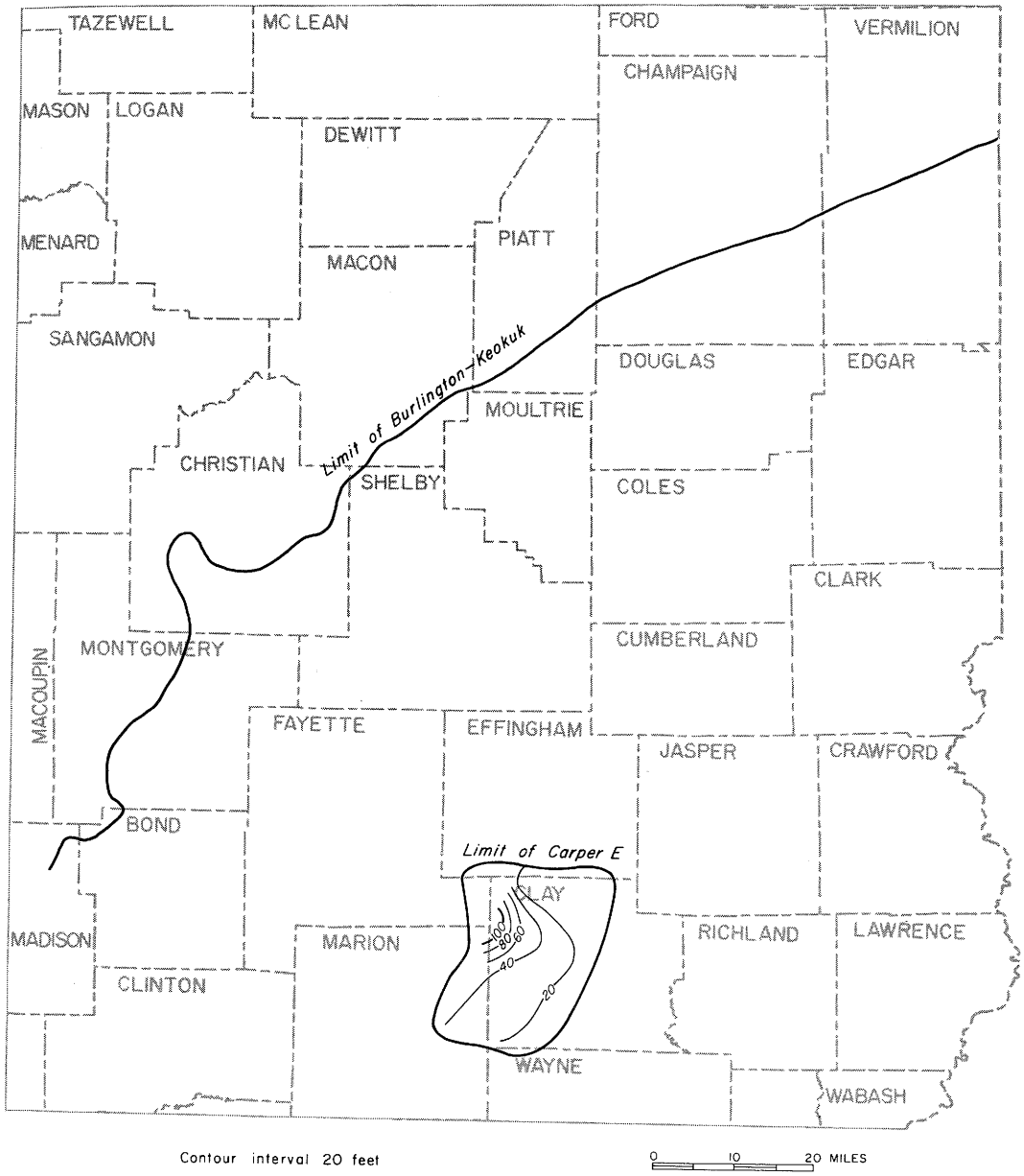

Figure 17 - Thickness of Carper E.

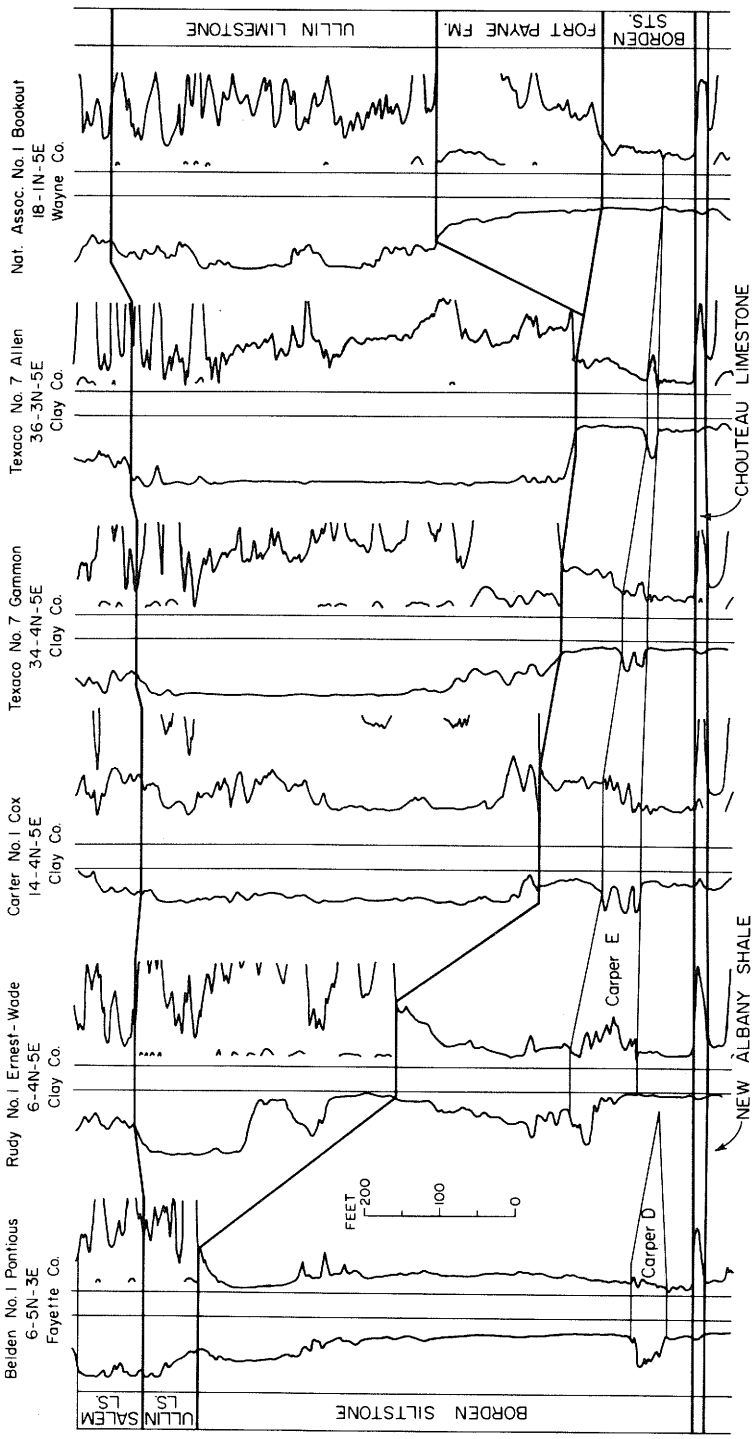

Figure 18 - Electric log cross section in Fayette, Clay, and Wayne Counties showing Carper E thinning southward and pinching out after extending beyond the last foreset slope of the Borden. (Index map fig. 1).

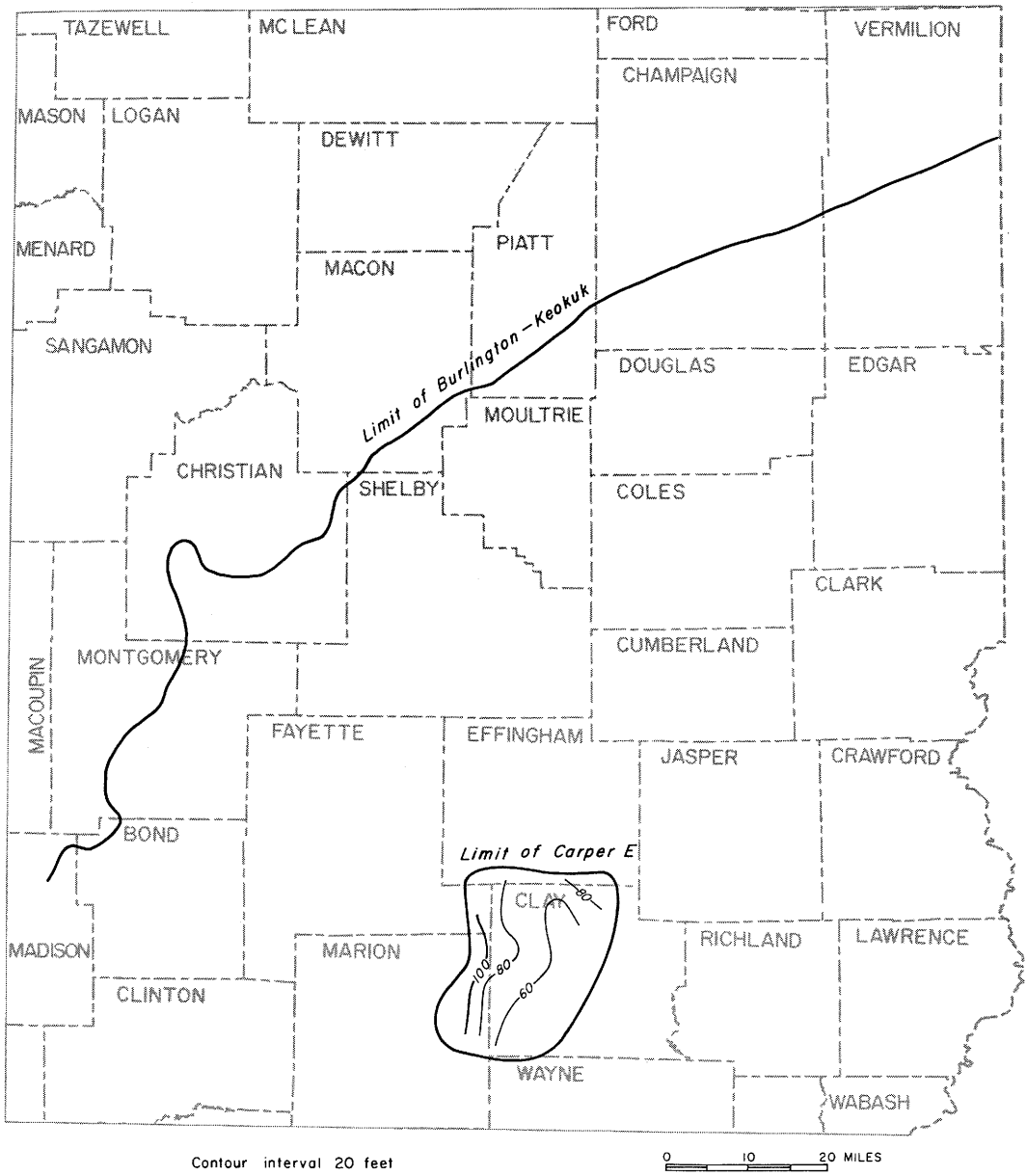

Figure 19 - Thickness of Borden below Carper E.

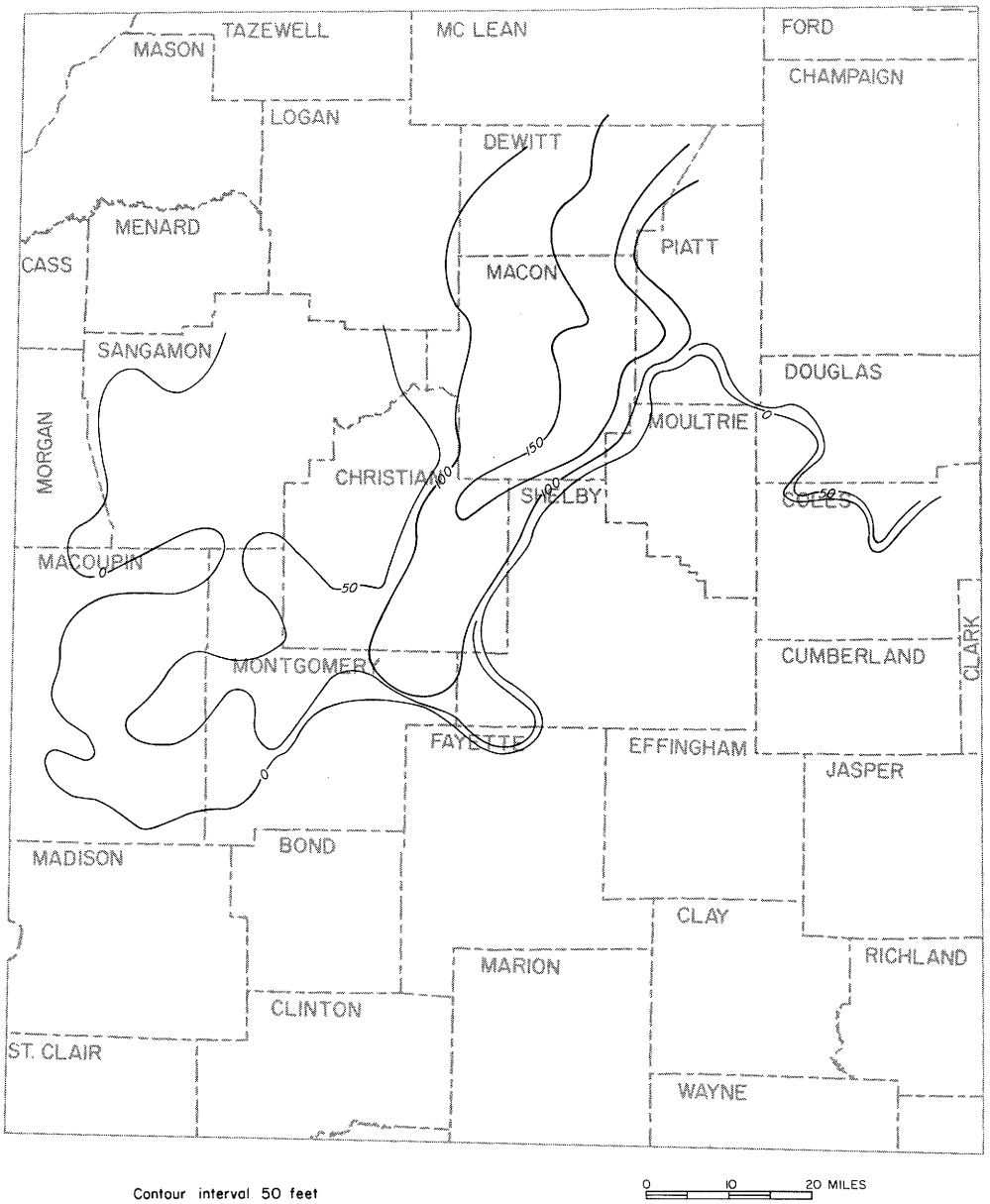

Figure 20 - Thickness of Bilyeu Member.

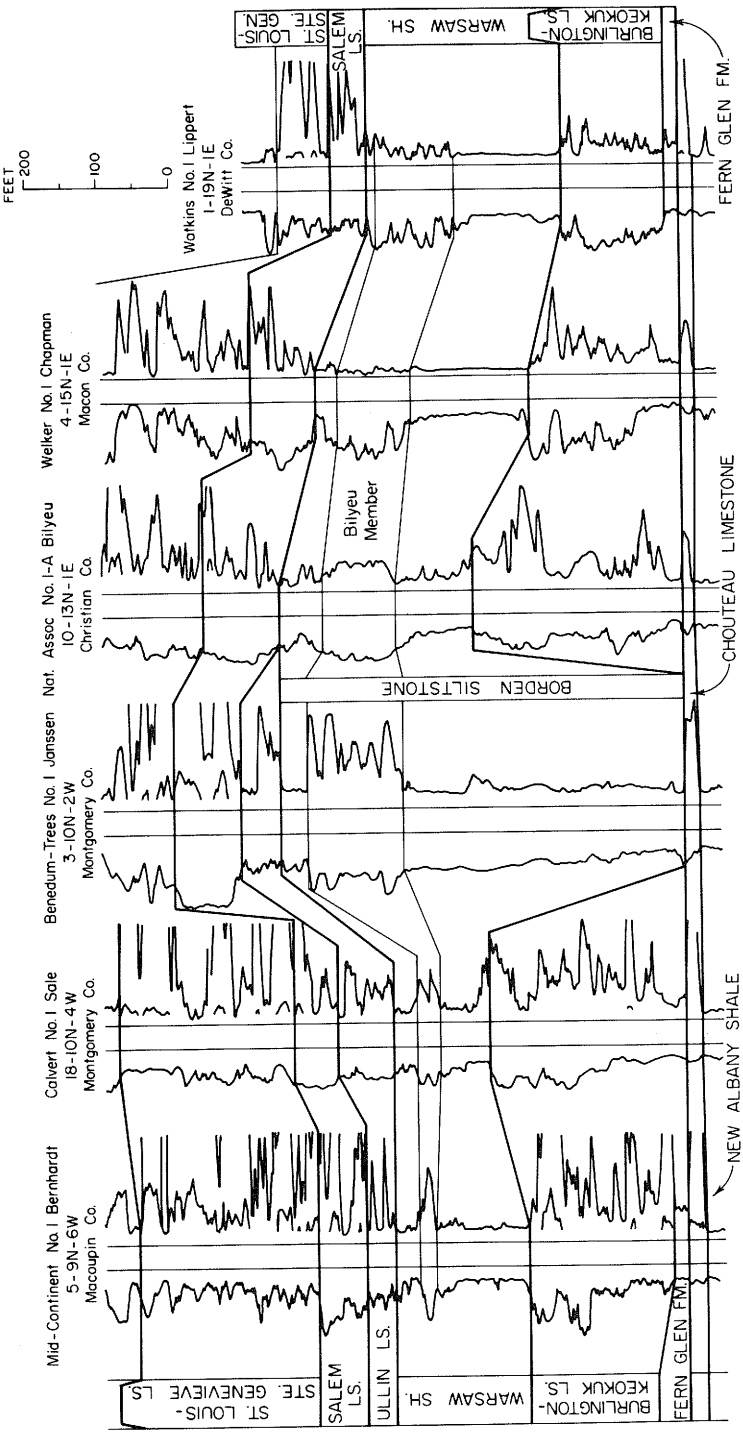

Figure 21 - Electric log cross section from Macoupin County to DeWitt County showing correlation and southward thinning of the Bilyeu Member. (Index map fig. 1).

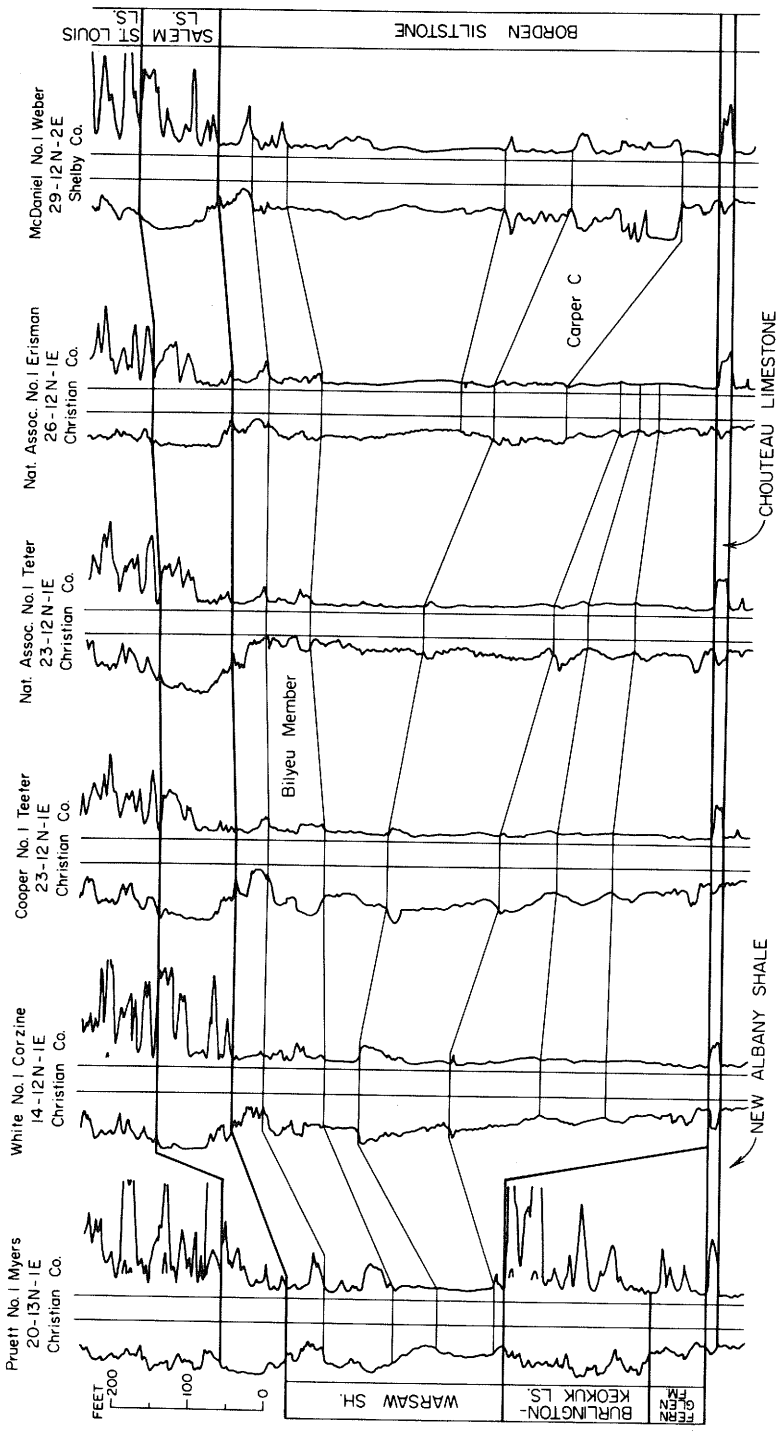

Figure 22 - Electric log cross section in Christian and Shelby Counties showing the correlation of the Bilyeu Member southeastward into the top of the Borden Siltstone. (Index map fig. 1).

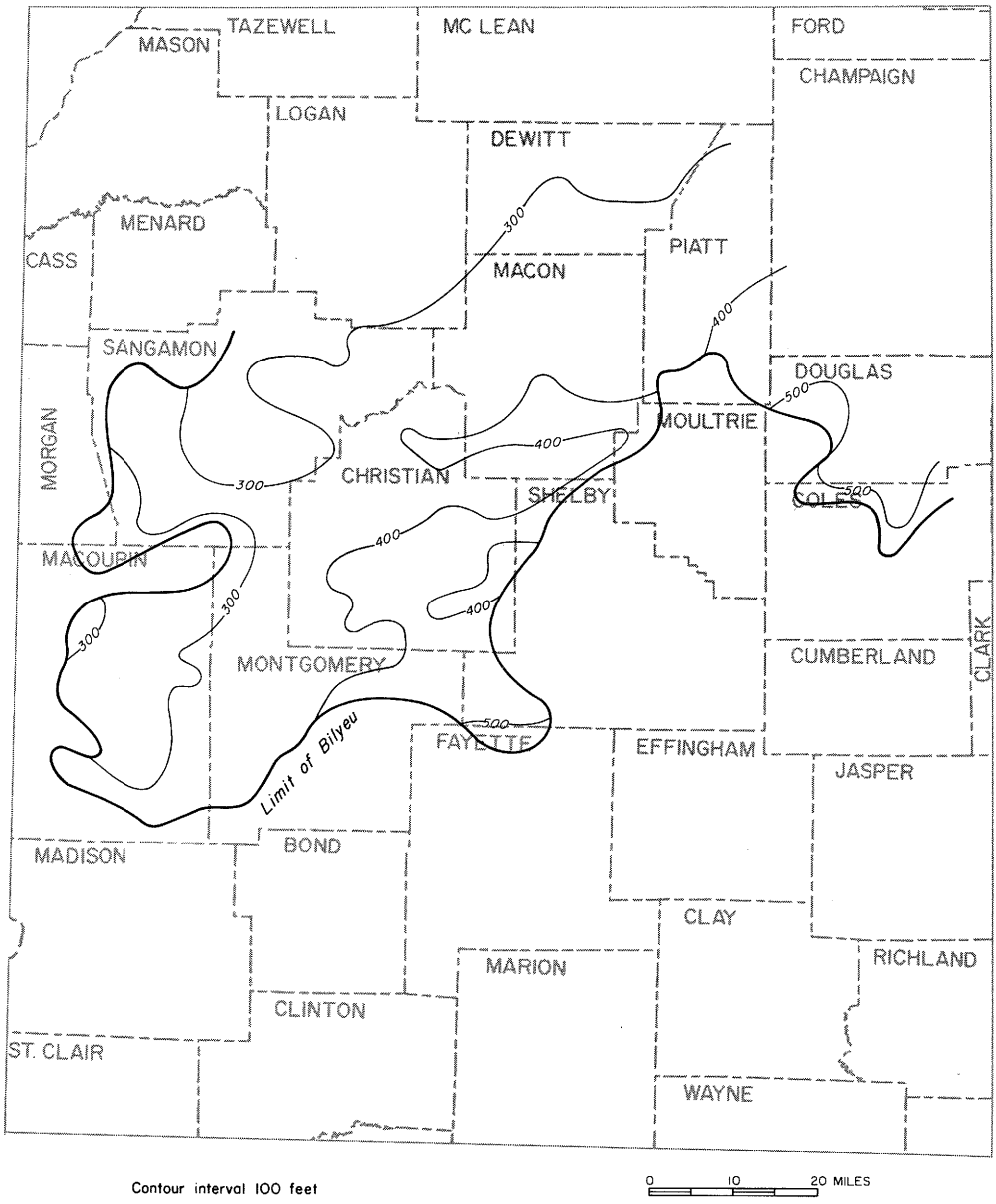

Figure 23 - Thickness of Valmeyeran rocks below the Bilyeu Member.

the source area or increase in stream competence near the end of Borden deposition in Illinois (fig. 6).

SUMMARY

The depositional events associated with sandstones in the Borden can be summarized as follows. The Burlington and Keokuk Limestones were deposited in shallow water in western Illinois. The eastern margin of the Burlington-Keokuk was an east-facing slope separating the shallow-water shelf from the deeper water basin to the east and south. Sand, silt, and mud of the Borden Siltstone were dumped into the deep-water basin by the delta distributary system of a major river entering Illinois from the northeast (fig. 6). Early Borden clastics deposited in Illinois were fine-grained sand and coarse-grained silt. Carper A sandstone was deposited during the early coarse-grained phase of Borden deposition. Foreset slopes of the delta complex had not reached Illinois when Carper A deposition began, but by the end of Carper A deposition, the foreset slopes extended into Douglas, Coles, Cumberland, and Clark Counties (fig. 6).

Carper B was deposited by a major sand bearing distributary that entered Piatt, Moultrie, and Douglas Counties from the north, west of the distributary that deposited Carper A (fig. 6). The distributary for Carper B passed across the top of the Burlington-Keokuk bank as the delta sequence overrode the carbonates to deposit the Warsaw Shale. Many subsequent distributaries passed across the area underlain by the Burlington-Keokuk, deposited silt on the carbonate slope, and extended that escarpment into the deep-water basin as a foreset delta slope. Silt and mud continued to be deposited by Carper A and Carper B distributaries after Carper B was deposited.

By the time of deposition of Carper C, the major distributaries had swung farther southwest and entered Shelby County from the northwest. Minor amounts of sand were received from Carper A and B distributaries during deposition of C.

Between the deposition of Carper C and D, silt and mud were deposited in Shelby and Fayette Counties from the northwest distributary, and its mouth migrated southeastward as the foreset slope was extended (fig. 6). Carper D was deposited during another outflow of sand from that same distributary mouth, and small amounts of sand were received from other minor distributaries in addition. Considerable silt and mud emanated from both the northwest and northeast distributaries between the deposition of Carper D and E (fig. 6). Carper E was deposited off the mouth of the northwest distributary, which had extended even farther southeast with the prograding foreset slope. After deposition of Carper E, mud and silt continued to be deposited and the delta was extended into southern Illinois. During a late stage of delta development, the Bilyeu Member was deposited from a northeasterly source in shallow water west of the main mass of the Borden delta.

The Carper sandstones were deposited on the lower part of the foreset slope and the pro-delta bottomset plain of the Borden Siltstone delta off the mouths of major distributaries. Sand deposition was not continuous, but was interspersed with increasing intervals of silt and mud deposition. Carper sandstones are well sorted, fine-grained, and mineralogically mature, indicating long transportation from the source area. The sandstones may have been deposited during periods of major floods of the river system or may be the result of tectonism in the source area. A combination of factors including uplift and increase in stream gradient and increase in water

volume by climatic or drainage basin changes may have increased the ability of the river system to move fine-grained sand to its outlets on the delta. After reaching the distributary mouths, the sand moved down the steep foreset slope as a turbidity flow and extended far across the deep-water bottomset pro-delta plain.

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