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THE BORDEN SILTSTONE (MISSISSIPPIAN) DELTA IN SOUTHWESTERN ILLINOIS

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ABSTRACT

The lower Valmeyeran Borden Siltstone in Illinois has the internal structure of a delta, with topset, foreset, and bottomset beds. Foreset slopes extend several miles and dip 30 to 90 feet per mile. The delta front progressed southwestward across southern Illinois in water 500 to 700 feet deep and filled a basin lying on the southeast side of a crinoidal-carbonate bank that is the Burlington-Keokuk Limestone. Borden sediment was carried by the Michigan River from the Canadian Shield region.

INTRODUCTION

A tongue-shaped subsurface body of the Borden Siltstone of early Valmeyeran (Middle Mississippian) age, 400 to 700 feet thick, extends southwestward across central and southern Illinois (fig. 1). Closely spaced rotary drilling near the western end of the tongue permits well to well tracing of many stratigraphic horizons within the Borden by means of electric logs. Nine selected horizons, designated A through I, have been mapped in an area comprising all of Clinton County and parts of St. Clair, Washington, Jefferson, Marion, Fayette, Bond, and Madison Counties. These horizons do not parallel the base and top of the formation, but slope from near the top to near the base in a general southwesterly direction. They demonstrate that the internal structure of the Borden Siltstone is that of a delta, with topset, foreset, and bottomset beds (fig. 2).

The Borden Siltstone is part of an extensive body of Kinderhookian and Valmeyeran clastic rocks extending eastward from Illinois into Indiana, Michigan, Kentucky, Ohio, Pennsylvania, West Virginia, and New York. These clastics were carried westward or southwestward into deep water by rivers that had their sources in the northern Appalachians and in the Canadian Shield.

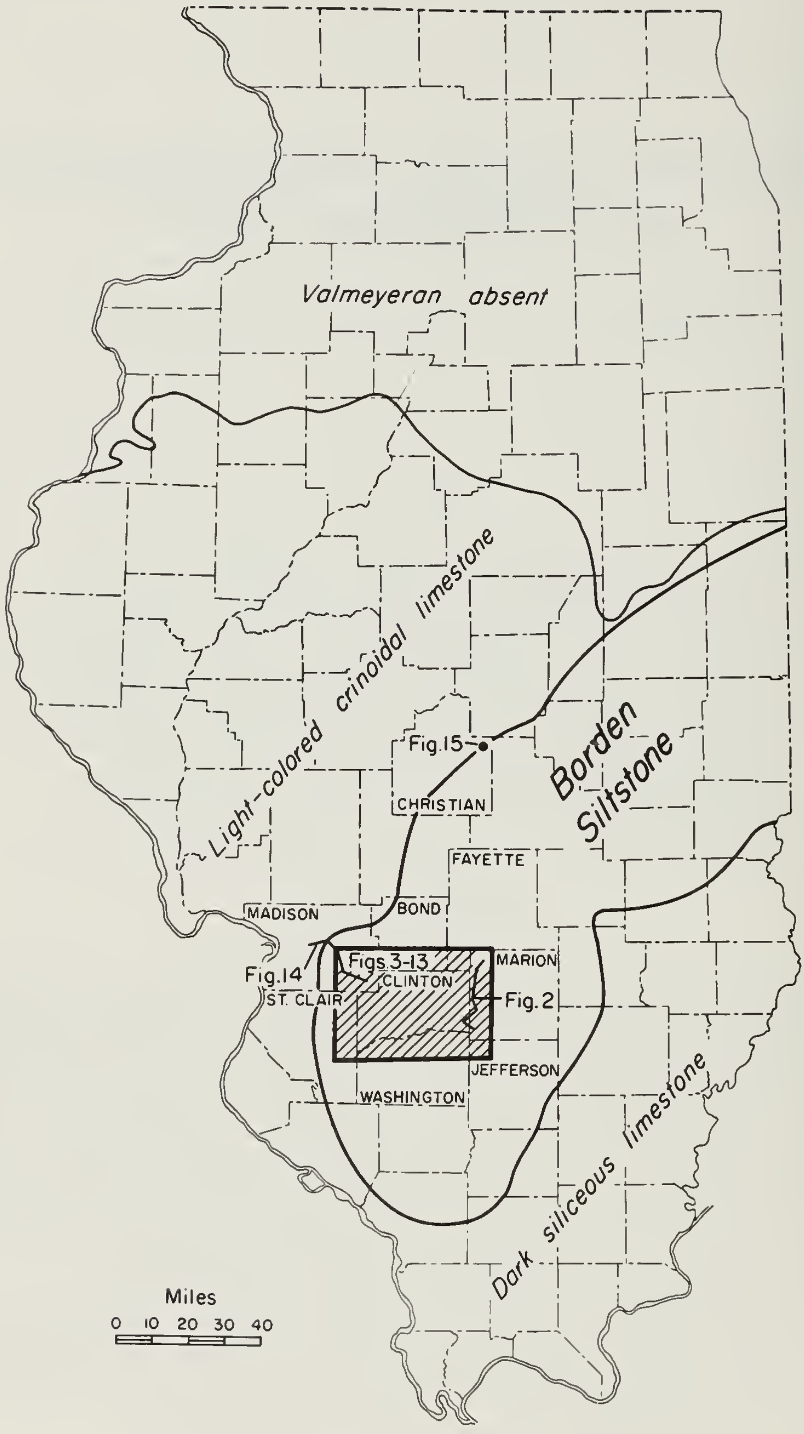


Figure 1 - Areal extent of the Borden Siltstone in Illinois.

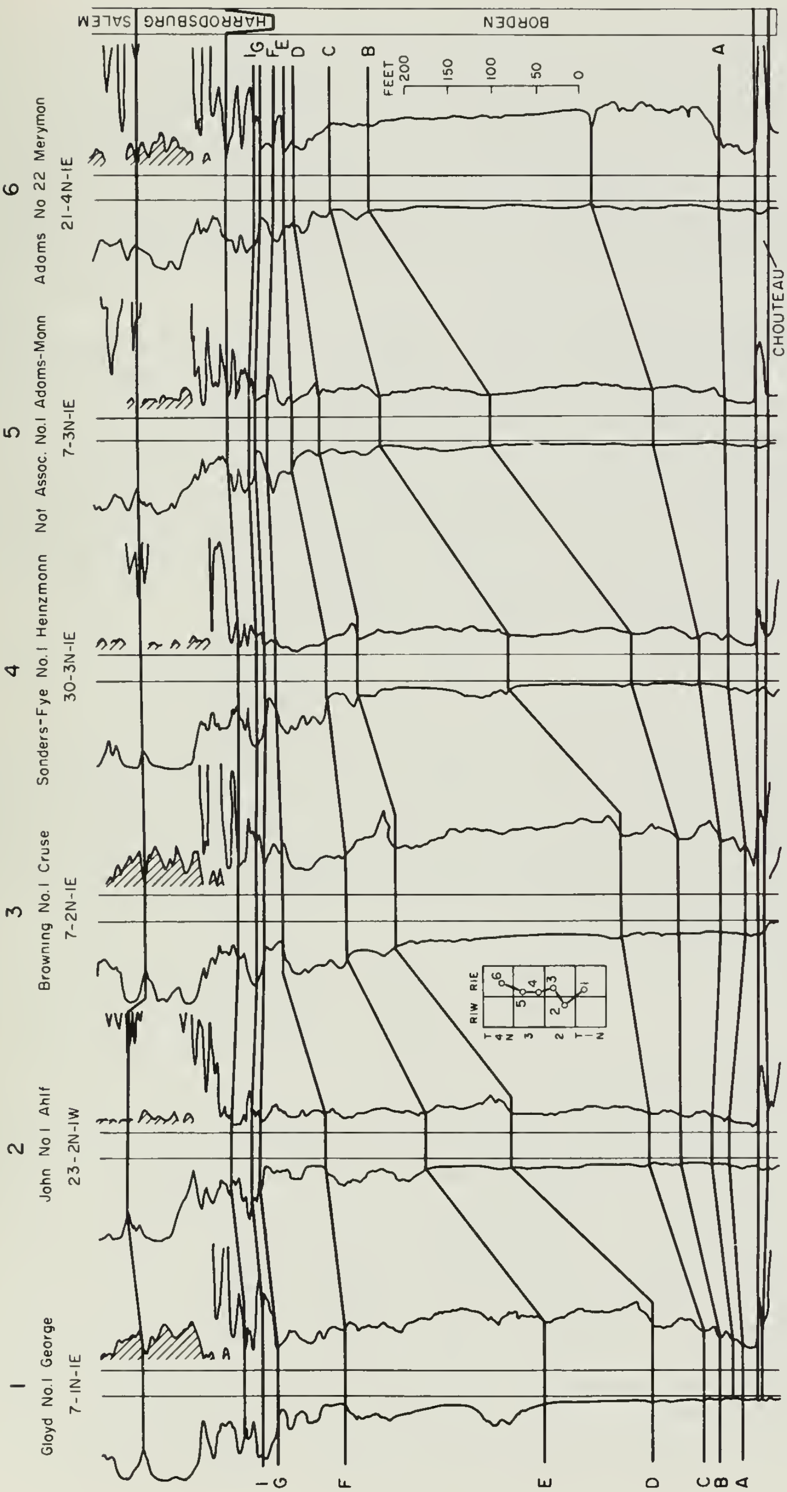


Figure 2 - Cross section in eastern Clinton (well 2) and western Marion (wells 1, 3-6) Counties showing the deltaic structure of the Borden Siltstone.

The Borden is exposed in central and southern Indiana and in Kentucky. It consists of siltstone and shale with some fine sandstone and crinoidal limestone. In Indiana the Borden is divided into a basal shale (New Providence) and a thicker upper siltstone that contains some cross-bedded channel deposits of fine-grained sandstone. Most of the Borden is sparsely fossiliferous, but in a few places fossils are abundant. Small crinoidal limestone bioherms occur.

The Borden generally rests on the Kinderhookian Chouteau Limestone, called Rockford in Indiana, but in small areas it overlaps onto the New Albany Shale and Silurian rocks. It is overlain by the Harrodsburg Limestone or by the Salem Limestone.

The Borden Siltstone extends westward to within a few miles of outcrops of the dominantly limestone, early Valmeyeran sequence near St. Louis. The siltstone is replaced within two miles by a sequence consisting of a basal red and green shaly limestone (Fern Glen) overlain by light-colored limestone (Burlington-Keokuk) overlain by shale with interbedded limestone (Warsaw). Southeast of the siltstone tongue, lower Valmeyeran rocks consist of dark-colored silty siliceous limestone (Fort Payne) resting on a relatively thin Springville (New Providence) Shale.

This report incorporates results from an unpublished thesis by Eugene Frund (1953), now geologist with Humble Oil and Refining Company, and work reported by D. H. Swann, Eugene Frund, and D. B. Saxby (1953).

INTERNAL STRUCTURE OF THE DELTA

The Borden Siltstone delta in Illinois is unique among described Paleozoic deltas because electric logs from closely spaced wells in several oil pools show that the siltstone has numerous traceable topset, foreset, and bottomset bedding planes. Classic internal delta structure has not been reported from other Mississippian deltas such as the Bedford delta of Ohio (Pepper, de Witt, and Demarest, 1954). Paleozoic deltas previously have been recognized by morphology, facies, and stratigraphic relations.

The Borden in Clinton County is essentially gray, calcareous or dolomitic siltstone that seems uniform from top to bottom except for a downward decrease in average grain size and a corresponding increase in clay content. However, subtle changes in grain size and clay and carbonate content produce irregularities in the resistivity and potential curves (fig. 2).

If wells several miles apart are compared, the slight variations in the electric log curves bear little resemblance to each other. However, where wells are closely spaced, dozens of these minor markers can be traced from well to well.

At numerous places, dip computations based on closely spaced wells show that the markers dip south, southwest, or west as much as 30 to 90 feet per mile with respect to horizons in overlying and underlying formations.

Nine electric log marker horizons, designated A through I (fig. 2), were selected for mapping. The character of each marker changes somewhat as it is traced for several miles. The markers are more distinctive and have higher relief in the middle and upper parts of the Borden. They fade to indistinct wiggles when traced down to the south or west into the shaly sections near the base of the Borden.

The Borden sediments were somewhat thicker and had correspondingly steeper slopes before post-depositional compaction. The foreset slope of the

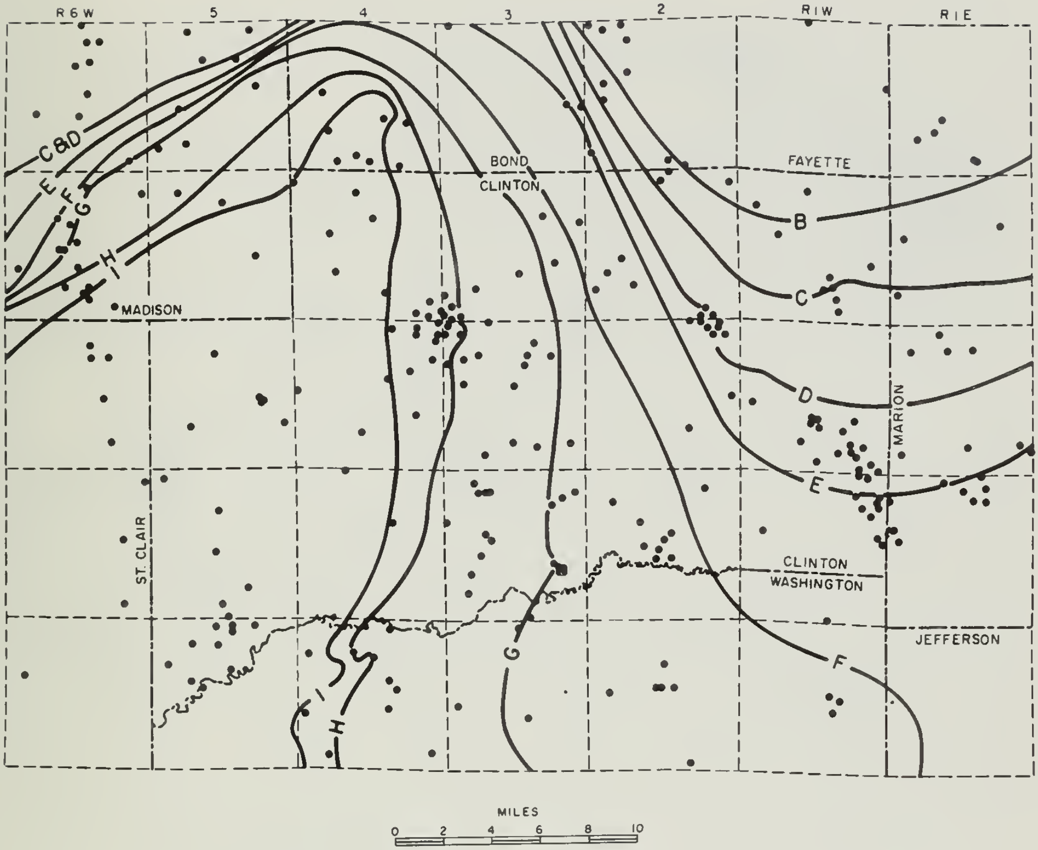


Figure 3 - Advance of the delta as shown by successive positions of the line where the Borden reached a cumulative thickness of 300 feet, taken from figures 5-12.

delta advanced from northeast to southwest in Clinton County (fig. 3). Areas of greatest accumulation migrated in response to shifts in active distributaries.

Horizon A represents the sea floor before the deltaic advance recorded here. The floor was relatively level over most of the map area, but in the northwest it rose to a high underlain by 200 feet of earlier Borden deposits. The Borden sediments below horizon A (fig. 4) probably include the toe of an earlier deltaic advance as well as the bottomset beds of the earliest stages of the advance described here.

The map of unit A-B (fig. 5) shows the first appearance of the main delta in the map area. Succeeding maps of units B-C through E-F record a southward extension of a major distributary, as shown by the shift of areas of maximum deposition (figs. 6-9). During deposition of unit E-F, the southward migrating distributary in eastern Clinton and western Marion Counties became overextended and

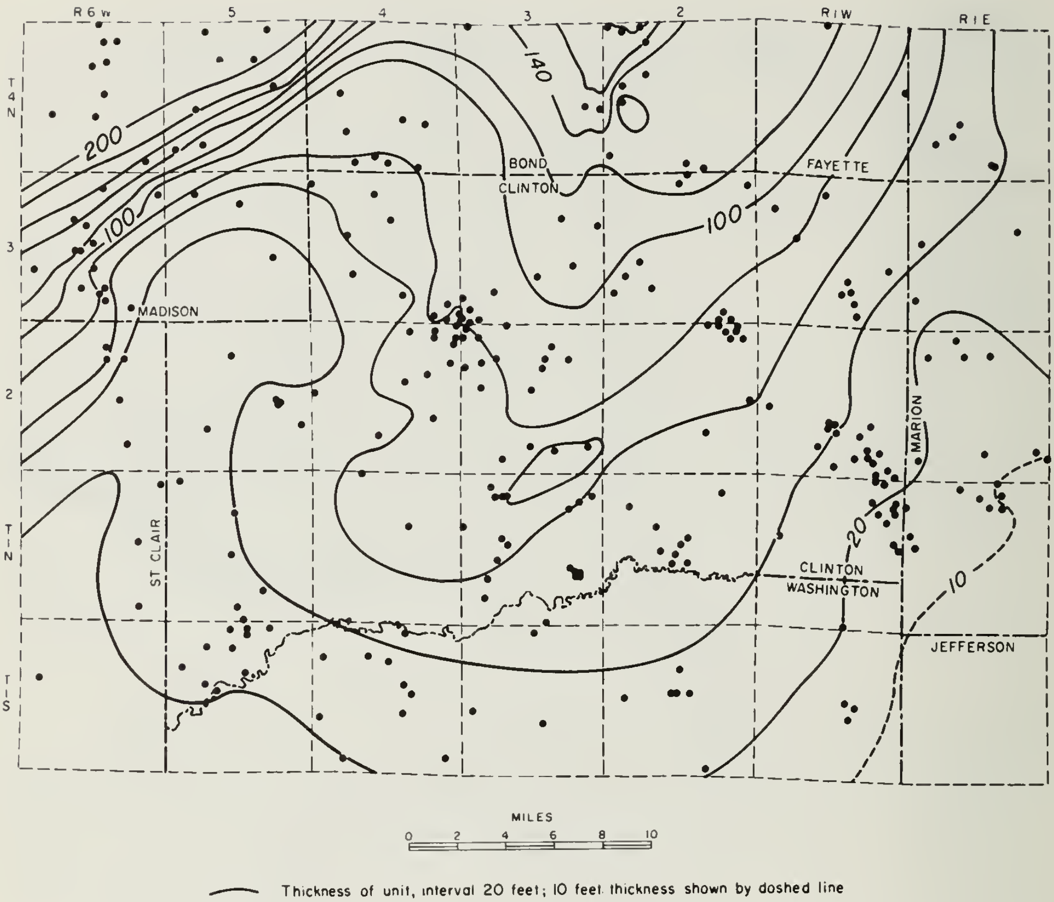


Figure 4 - Thickness of Borden sediment below horizon A.

ceased to be the major outlet in this area. Sediment was deposited by new distributaries farther west (T. 4 N., R. 3 W.) (fig. 9). Units F-G, G-H, and H-I show a westward growth of the delta front (figs. 10-12). At the time of horizon I there was still a narrow trough 400 feet deep in the western part of the area. The trough was filled by younger siltstone beds before the end of Borden deposition.

The delta continued to grow to the southwest and succeeding sediments were carried across Clinton County. At the end of Borden deposition, the top of the formation was a relatively horizontal surface. Thin beds of fossiliferous limestone in the upper part of the Borden indicate shallow water conditions. The Borden thins from east to west (fig. 12); this reflects less subsidence near the positive area of the Ozarks. The Borden also thins slightly over Silurian reefs, due to preferential compaction of the Silurian and Devonian non-reef sections during Borden time (fig. 13).

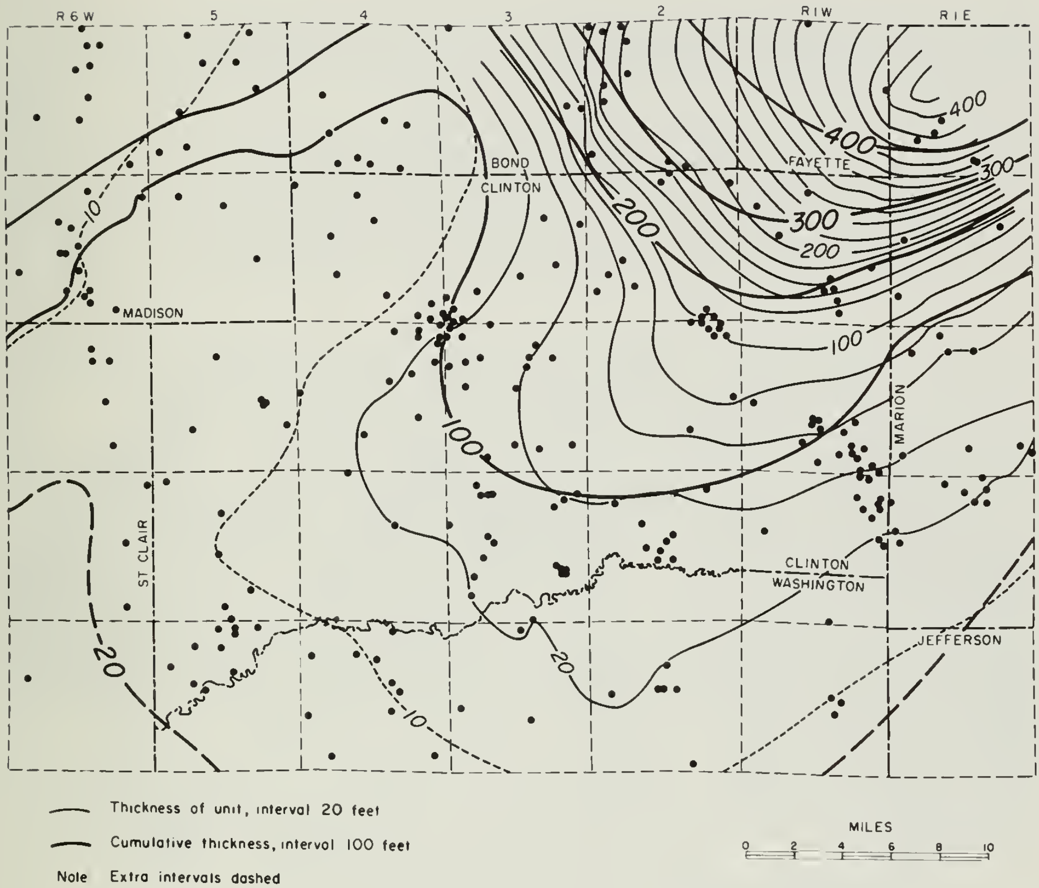


Figure 5 - Thickness of unit A-B and cumulative thickness from base of the Borden to horizon B.

Cumulative thickness maps of an advancing delta (figs. 5-12) are in essence submarine topographic maps. The difference in elevation between the top of the delta and its base is a measure of water depth. Compaction of the deltaic sediments has shortened the section by an unknown factor, perhaps 20 or 30 percent, and the water depth must be increased correspondingly. The cumulative thickness maps indicate that the water was 500 to 700 feet deep in front of the delta in eastern Clinton County.

Individual distributary channels were not traced in this study, but their existence may be inferred from the presence of cross-bedded sandstones in the Indiana outcrops. Limestone beds and bioherms in the Borden attest to favorable conditions for carbonate-producing organisms such as crinoids in submerged parts of the delta away from active distributaries.

The pre-compactional dips of the foreset beds in the Borden ranged from 0.4 degrees to a little over one degree, which is comparable to the dip of the foreset slope of the modern Mississippi River delta.

STRATIGRAPHIC RELATIONS OF THE DELTA

The tongue of Borden Siltstone in Illinois (fig. 1) is flanked on the northwest by the early Valmeyeran Fern Glen Limestone, Burlington-Keokuk Limestone,

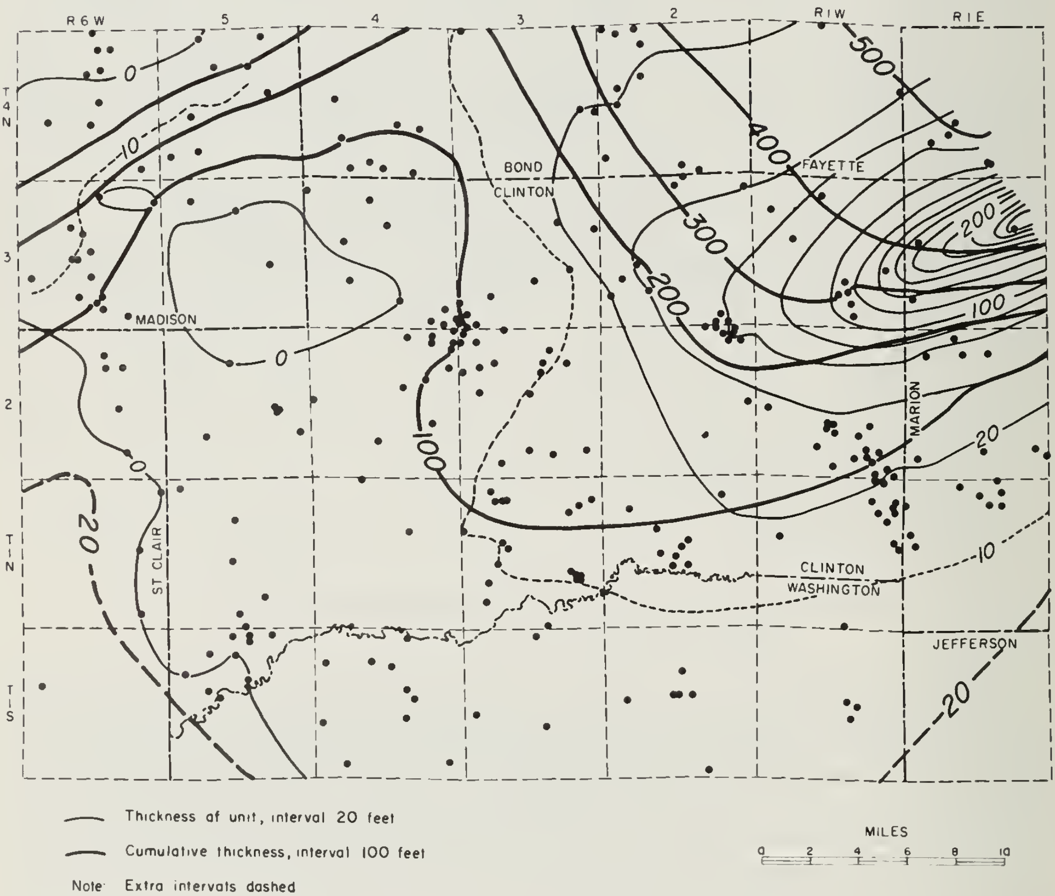


Figure 6 - Thickness of unit B-C and cumulative thickness from base of the Borden to horizon C.

and Warsaw Shale. The transition is abrupt and is generally completed in a belt no more than two miles wide that lies just northwest of the map area. Horizon A rises northwestward toward a point slightly above the base of the Warsaw (fig. 14). Its exact position cannot be traced to the edge of the siltstone body, but it is bracketed between other markers that can be traced farther west. Red and green shaly limestone and shale (Fern Glen), about 30 feet thick, can be traced directly into the lower part of the thick siltstone beneath horizon A along the western edge of the Borden tongue. Overlying the Fern Glen in the area of the cross section

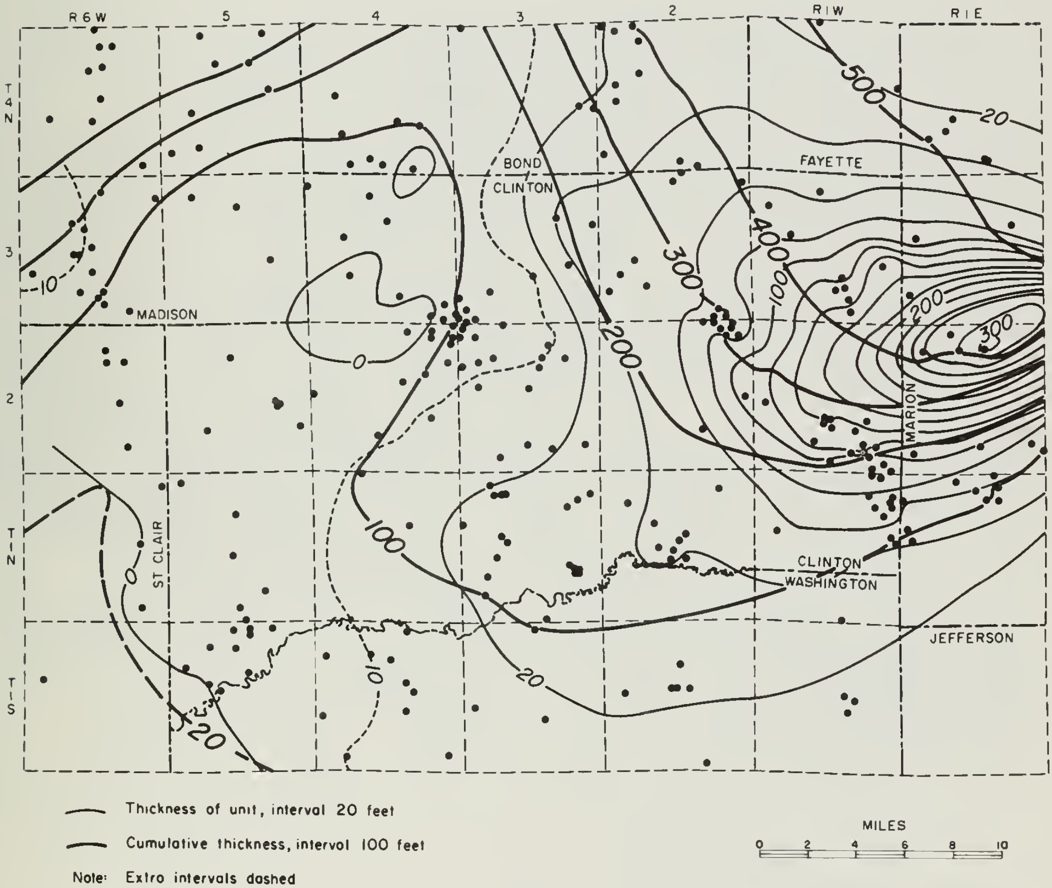


Figure 7 - Thickness of unit C-D and cumulative thickness from base of the Borden to horizon D.

(fig. 14) is a silty limestone unit about 50 feet thick at the base of the Burlington-Keokuk that can also be traced directly into the siltstone beneath horizon A.

Wells in Madison County and nearby areas are too widely spaced to show details of the change, but the Assumption Consolidated oil field in Christian County (fig. 1), 50 miles north of Clinton County, lies across the zone of change. Electric logs from wells less than 1000 feet apart in the Assumption Consolidated field show that the Burlington-Keokuk thins rapidly and underlies all but the lower 100 feet or less of the Borden Siltstone (fig. 15). The section from the Chouteau

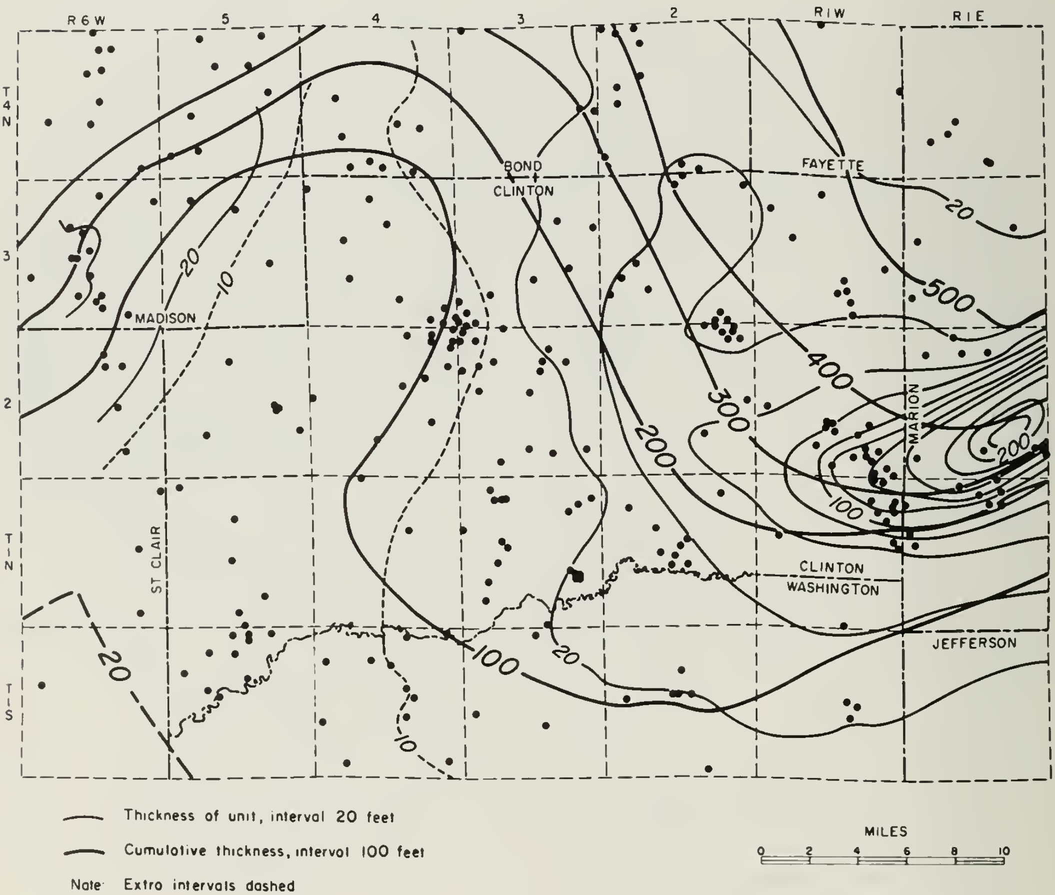


Figure 8 - Thickness of unit D-E and cumulative thickness from base of the Borden to horizon E.

to the top of the Keokuk thins southeastward from 300 feet to 100 feet in little more than a mile. All parts of the Burlington-Keokuk thin, but the greatest thinning occurs in the upper part. The Warsaw Shale and the Sonora Sandstone, which overlie the Burlington-Keokuk, are equivalent to all but the lower 100 feet of the Borden. The Burlington-Keokuk appears to have been a crinoidal carbonate bank that stood topographically 200 to 300 feet above the floor of the sea into which the Borden delta grew.

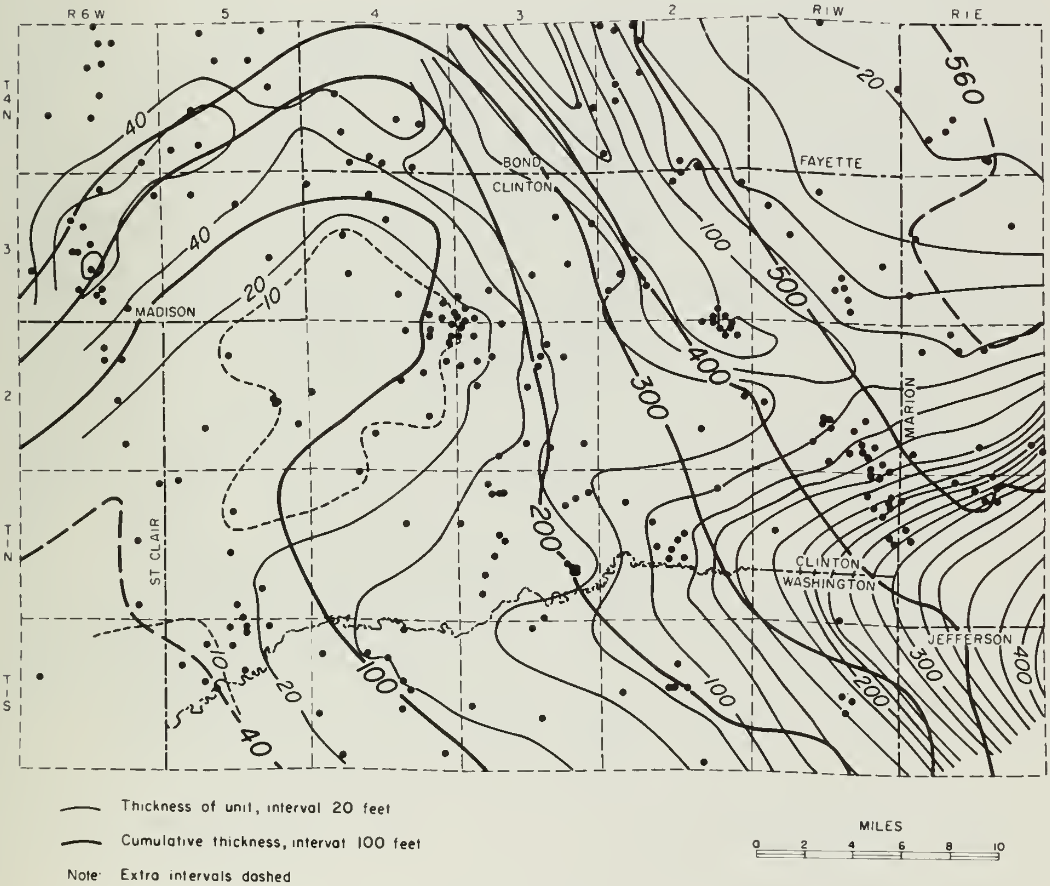


Figure 9 - Thickness of unit E-F and cumulative thickness from base of the Borden to horizon F.

In the area of detailed mapping, Borden sediments below horizon A thin from north to south (fig. 4). The lower part of the unit below horizon A was deposited before the full development of the crinoidal bank represented by the Burlington-Keokuk Limestone. It is equivalent to the Fern Glen and the silty phase locally present at the base of the Burlington (fig. 14). The middle part of the section beneath horizon A appears to grade laterally into the crinoidal bank. The upper part overlies the thinning edge of the crinoidal bank (figs. 14 and 15).

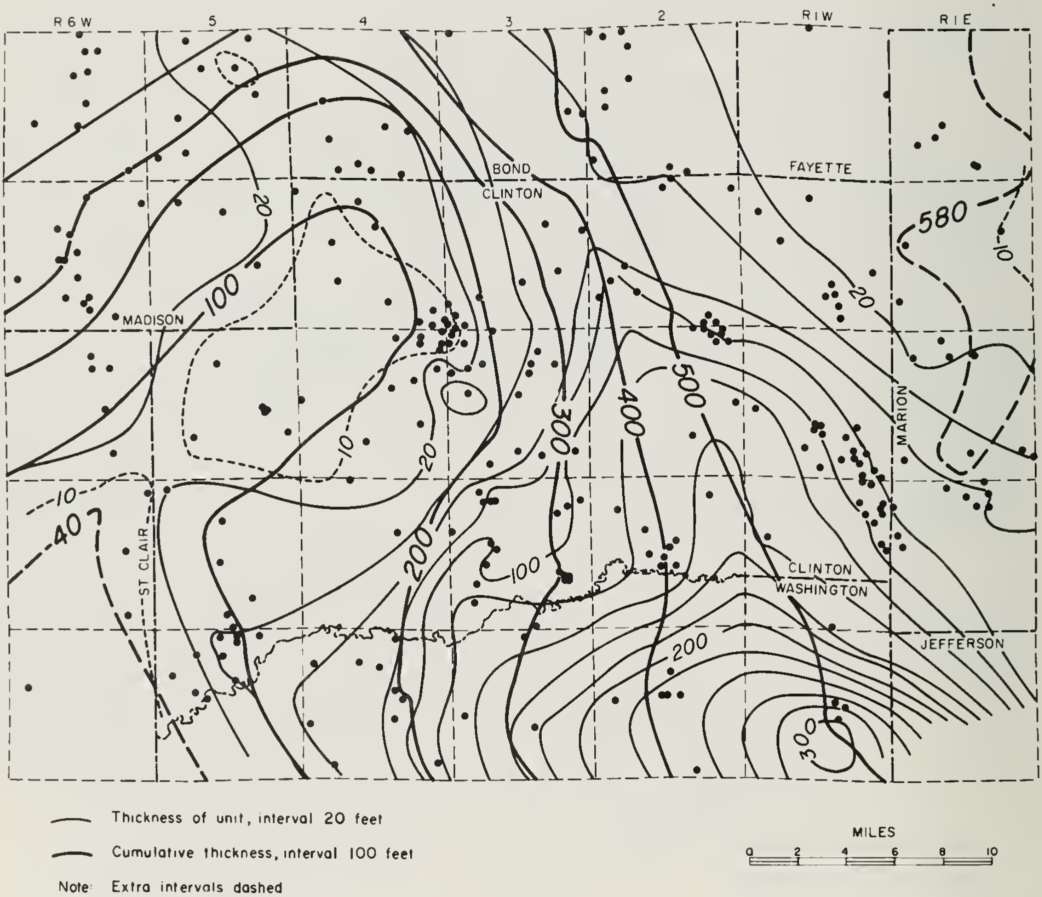


Figure 10 - Thickness of unit F-G and cumulative thickness from base of the Borden to horizon G.

A thick accumulation of siltstone beneath horizon A lies along the southeastern edge of the crinoidal bank in the northwestern part of the Clinton County area (fig. 4). These deposits are part of a delta tongue, the major part of which is north of the map area. The sediment may have been diverted southwestward by the topographically high crinoidal bank. Another possibility is that this siltstone, and succeeding accumulations along the front of the crinoidal bank, consists of sediment carried onto the top of the bank when the basin filled farther

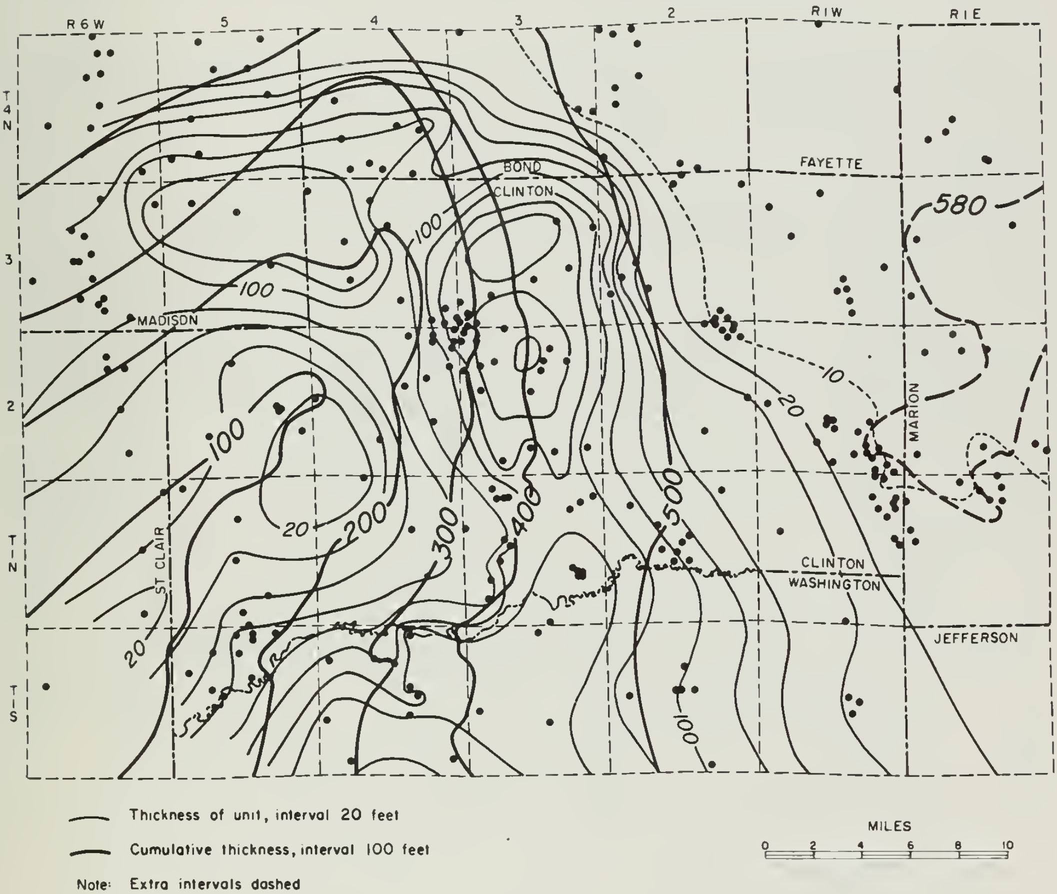


Figure 11 - Thickness of unit G-H and cumulative thickness from base of the Borden to horizon H.

north. Such sediment could have been transported southward by marine currents and waves in the shallow water over the bank and then dumped over the edge into deeper water.

SEDIMENT SOURCE AND TRANSPORTATION

In Kinderhookian and early Valmeyeran time, clastic sediments were carried by rivers west and south into the Appalachian, Michigan, and Illinois Basins.

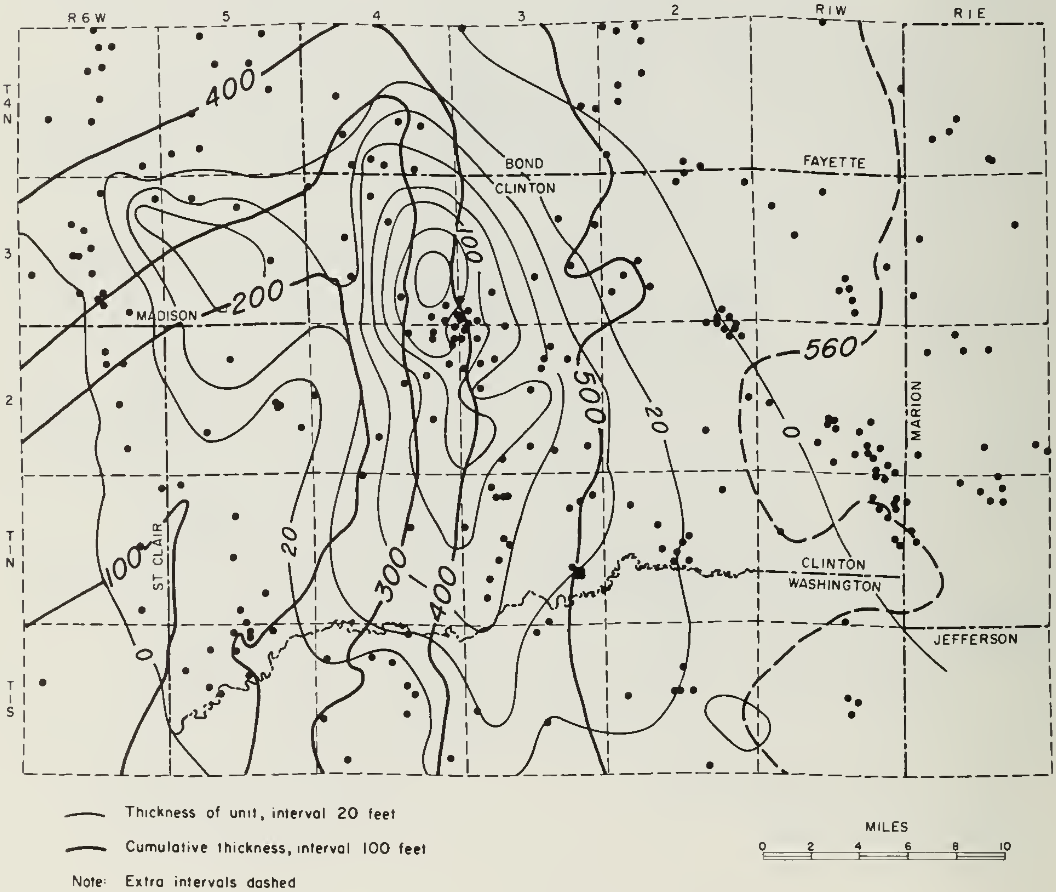


Figure 12 - Thickness of unit H-I and cumulative thickness from base of the Borden to horizon I.

The early Mississippian Bedford delta of Ohio was built of sediments that were derived from the northern Appalachians and carried southwestward by the Ontario River (Pepper, de Witt, and Demarest, 1954). Mountains in eastern Pennsylvania provided sediments that were transported northwestward across Pennsylvania and deposited in the middle Mississippian Pocono delta (Pelletier, 1958). The Borden clastics were carried southwestward across the Canadian Shield by the Michigan River (Swann, 1963, 1964). The Michigan River paralleled the Ontario River and repeatedly carried clastic sediments into the Illinois Basin during Mississippian time. The headwaters of the Michigan River may have been in rising mountains in the Franklin geosyncline area of northern Canada.

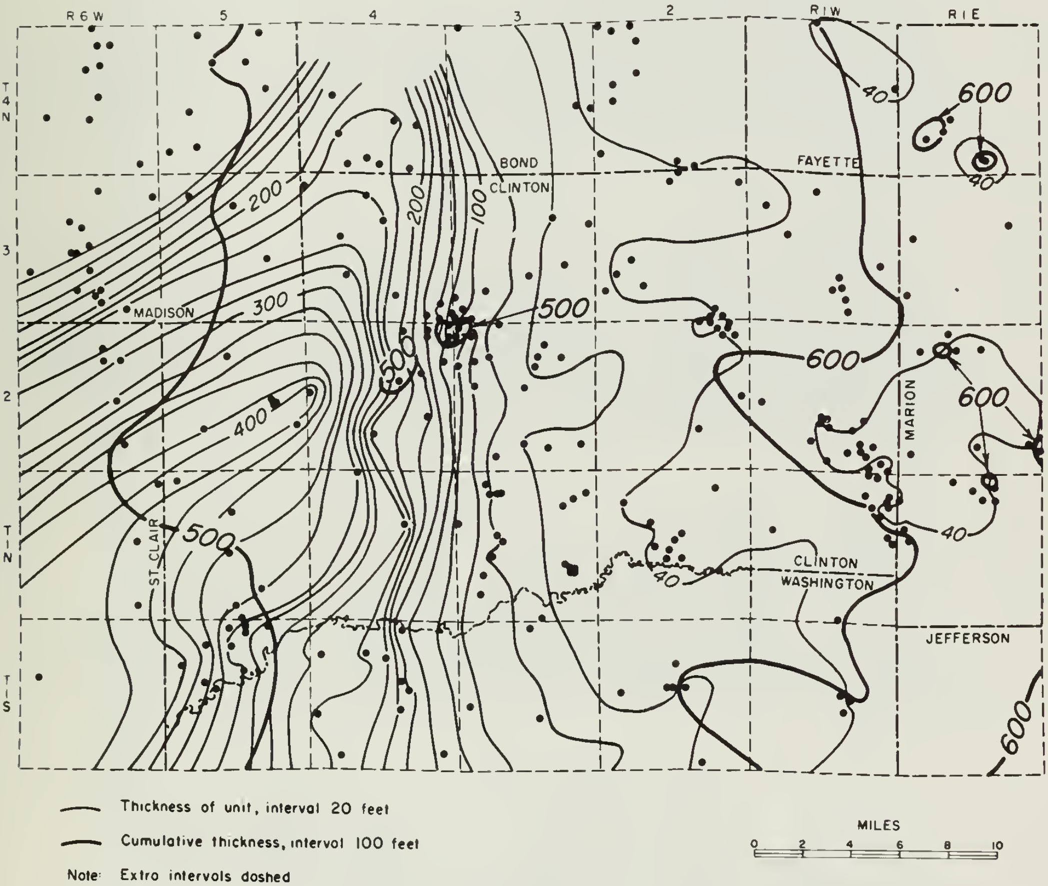


Figure 13 - Thickness of sediment between horizon 1 and the top of the Borden with cumulative thickness of the Borden, showing thinning over some Silurian reefs, e.g. in south part of T. 4 N., R. 1 E.

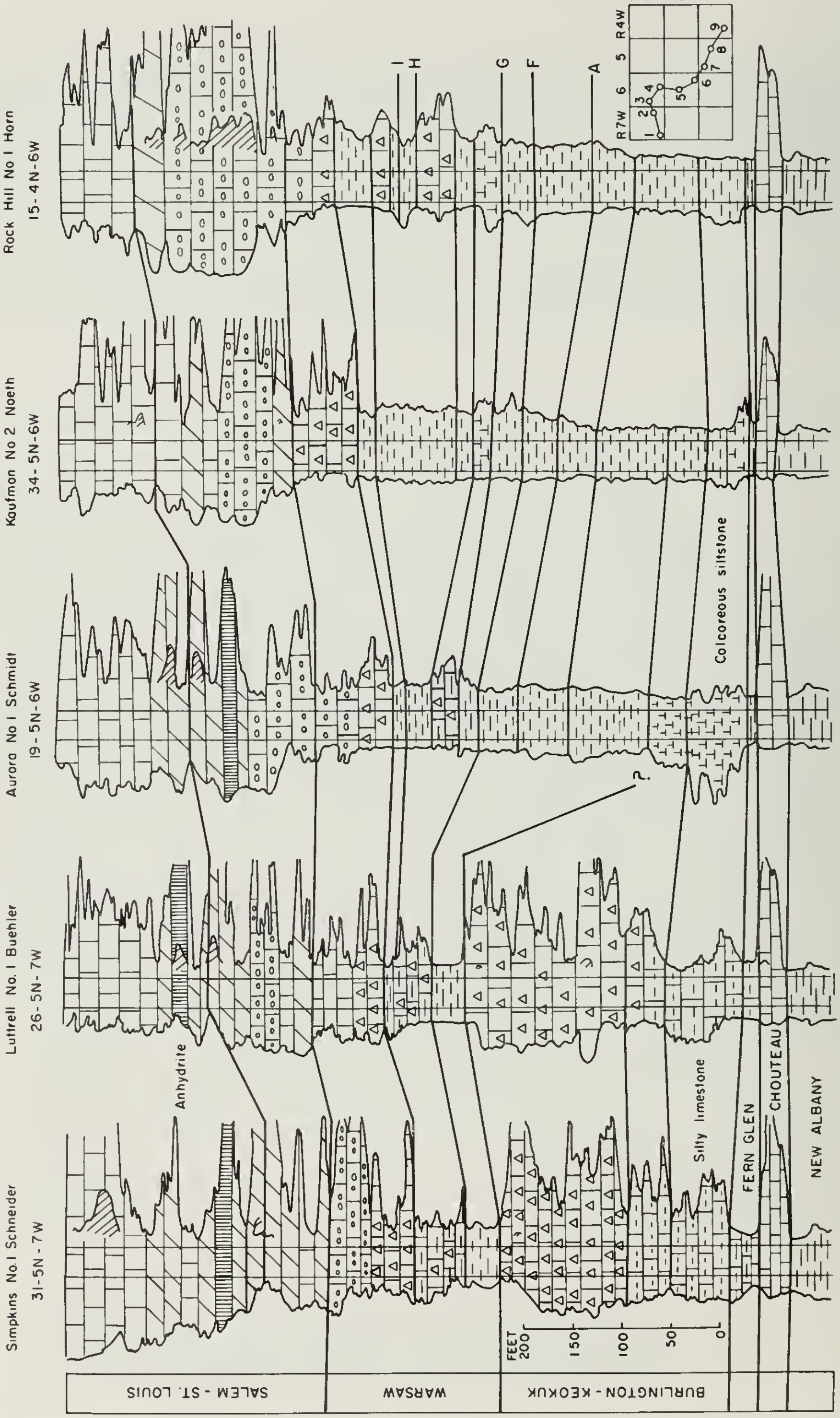
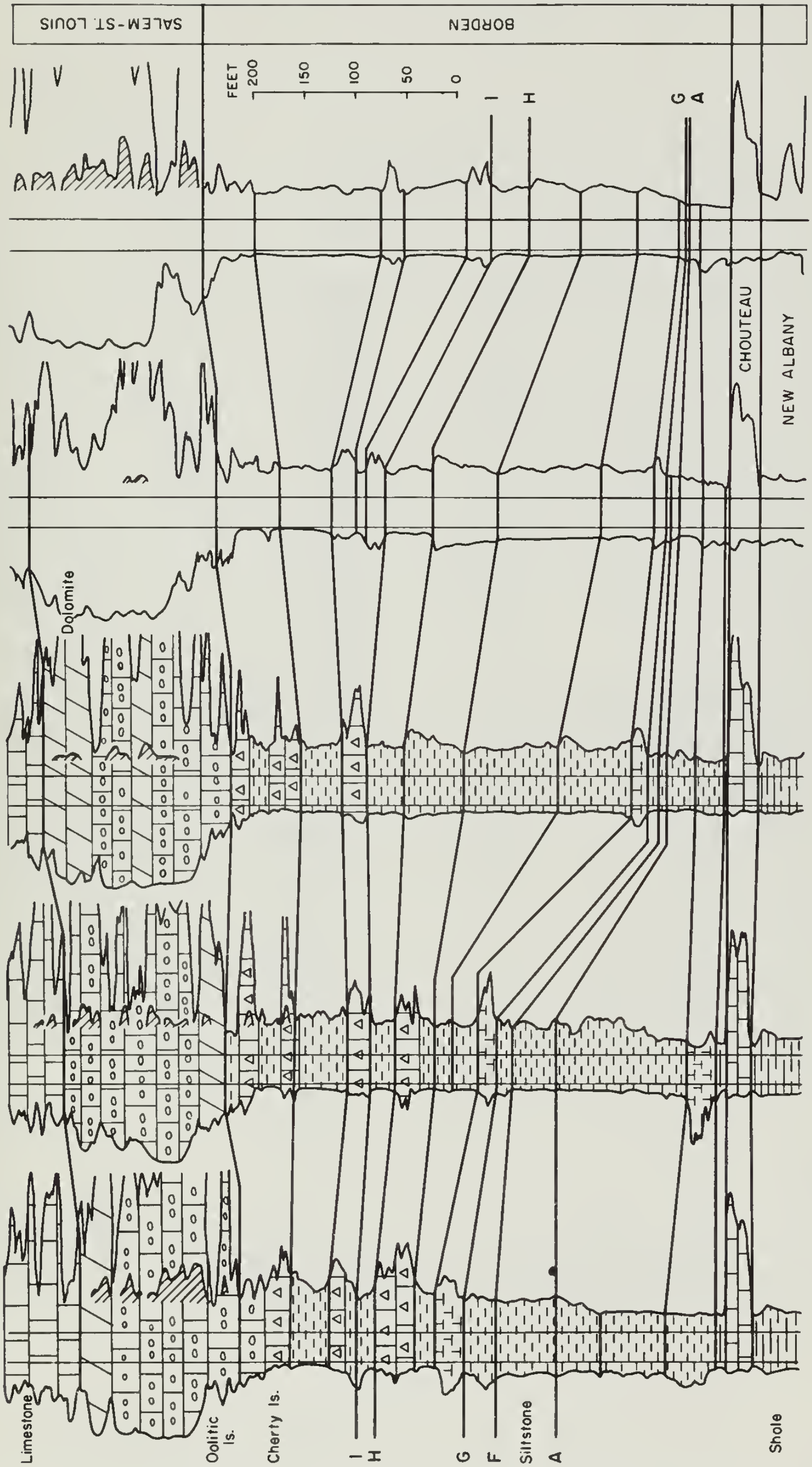


Figure 14 - Cross section in Clinton and Madison Counties showing relation of



the Borden Siltstone to the lower Valmeyeran sequence of Mississippi Valley.

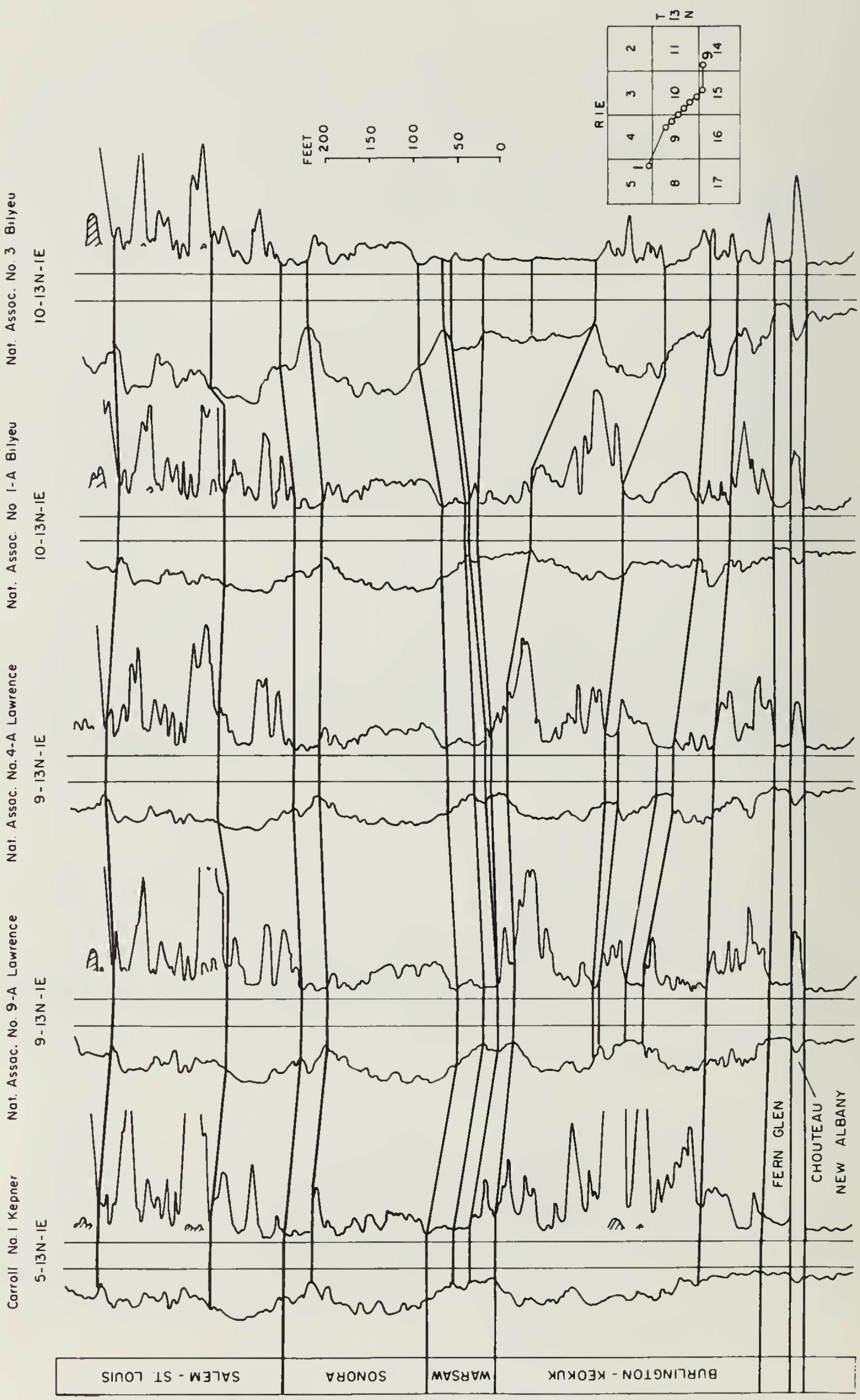


Figure 15 - Cross section in the Assumption Consolidated oil field, Christian County,

showing details of the relation of the Borden to the lower Valmeyeran sequence of Mississippi Valley.

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