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Lateral Gradation of the Salem and St. Louis Limestones (Middle Mississippian) in Illinois

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ILLINOIS STATE GEOLOGICAL SURVEY

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LATERAL GRADATION OF THE SALEM AND ST. LOUIS LIMESTONES (MIDDLE MISSISSIPPIAN) IN ILLINOIS

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ABSTRACT

The dominant lithology of the Salem Limestone in Illinois is biocalcarene. The Salem thins from 500 feet (153 m) in Hamilton County to less than 80 feet (24 m) on the outcrop in Madison County. Part of this thinning is depositional, but in southwestern and south central Illinois the upper part of the Salem biocalcarene grades laterally into a fine-grained facies that includes dolomite and evaporites. The fine-grained facies is assigned to the St. Louis Limestone because its lithology closely resembles that of the St. Louis. Marker horizons on geophysical logs can be traced from the Salem into the St. Louis, and beds of biocalcarene occur in the lower part of the St. Louis in places, attesting to the lateral gradation of the facies.

Recognition of the lateral gradation of the upper part of the Salem into the lower part of the St. Louis explains the difficulties of previous workers who attempted to correlate the Salem-St. Louis boundary. As a result of this study, the boundary is placed at the top of the Salem biocalcarene and can be traced both by sample studies and by geophysical logs. The name Salem is continued for the biocalcarene facies and the name St. Louis for the fine-grained, dolomitic, and evaporitic facies. This nomenclature conforms to present outcrop usage and requires no nomenclatural changes.

INTRODUCTION

The Salem and St. Louis Limestones form the bulk of the upper part of the Valmeyeran (late middle Mississippian) limestones in the Illinois Basin. Together they are more than 1000 feet (305 m) thick near the center of the basin but thin towards the margins of the basin. The formations crop out extensively in southern Indiana and at places along the Ohio River (Hardin County) and the Mississippi River (Monroe and Madison Counties) in Illinois.

Many outcrop studies and several subsurface studies have been made in the past; however, the exact correlation of the boundary between the Salem and the St. Louis from Indiana to western Illinois had never been satisfactorily made. This study was initiated to improve the correlation, and it led to the discovery of the cause of some of the confusion. Subsurface studies using electric logs and sample studies from several hundred Illinois oil test holes show that the upper part of the Salem grades laterally into the lower part of the St. Louis along the west and north sides of the Illinois Basin. This facies change can also be recognized eastward in Indiana. Failure of previous workers to recognize or appreciate the significance of this lateral gradation has resulted in much confusion about the correlation of the Salem-St. Louis contact.

The outstanding lithologic characteristic of the Salem Limestone in its type section in southern Indiana and throughout most of its extent is the presence of rounded, broken fossil fragments and whole small fossils, commonly with oolite-like overgrowth, imbedded in a matrix that ranges from micrite to sparite. Cross-bedding is common on the outcrop. The lithology has been referred to as calcarenite (Pinsak, 1957; Baxter, 1960). It may also be called a biomicrite and biosparite (Folk, 1959). The term calcarenite is commonly used for any limestone composed of sand-size detrital calcite grains. To further distinguish the Salem and draw attention to the biologic origin of its detrital particles, this Salem lithology will be referred to in this report as biocalcarenite, meaning a limestone composed of sand-size fossils and fossil fragments. Most of the fossil fragments in the Salem are sand-size, but in places some are coarser grained (biocalcudite) or finer grained (biocalcilitite). Minor lithologies in the Salem include sucrosic dolomite, dolomitic limestone, fine-grained limestone, fossiliferous crystalline limestone, sandstone, chert, and evaporites (anhydrite and gypsum). The St. Louis Limestone in Illinois is characterized by fine-grained micritic to lithographic limestone, dolomite, crystalline limestone, fossiliferous limestone, chert, oolite, evaporites, and (on outcrop) evaporite breccias.

Even though some similar lithologies appear in the Salem and the St. Louis, each formation is characterized by its own dominant lithology. The Salem and the St. Louis can be recognized with confidence in most wells. Only in the zone of lateral gradation can the boundary between them not be distinguished consistently on a lithologic basis. In this zone, the use of electric log marker horizons is necessary. In most places the Salem can also be easily separated from the underlying Ullin Limestone. The Ullin is predominantly a biocalcarenite, which is commonly cross-bedded on the outcrop. The Ullin is composed largely of light-colored fragments of bryozoans and crinoids (Lineback, 1966). The Salem, in contrast, is darker colored and contains a greater variety of fossils, including gastropods and foraminifera in addition to crinoids and bryozoans. The fossil fragments in the Salem are more rounded than those in the Ullin and have oolite-like overgrowths. At places, fine-grained limestones or dolomites of the Salem overlie the Ullin. These lithologies are minor lithologies like those found higher in the Salem and are unlike those in the underlying Ullin. The St. Louis is not so easily separated on a consistent basis from the overlying Ste. Genevieve Limestone, and such separation was not attempted in this report.

This report is part of a continuing study of the Valmeyeran age rocks in the Illinois Basin. Some wells in Indiana and southern Illinois were studied in the preparation of the report, but its primary emphasis is on the lateral gradation of the lower part of the type St. Louis near the city of St. Louis into the upper

part of the Salem Limestone in the central part of the Illinois Basin. Formational boundaries have been changed in some of the illustrations of wells from previous works of the author (Swann, Lineback, and Frund, 1965; Lineback, 1966) as a result of restudying the lithologies involved.

Previous Work

The Salem and St. Louis Limestones have been extensively studied on surface outcrops for more than 100 years. The St. Louis Limestone was named by George Engelmann (1847) for the area of St. Louis, Missouri, on the west side of the Illinois Basin, and the Salem Limestone was named for the town of Salem, Washington County, Indiana, by E. R. Cumings in 1901. Ulrich (1904) is generally credited with restricting the name St. Louis to its present usage. Hall (1864), Weller (1908), and Weller and St. Clair (1928) studied these rocks in Illinois. Weller and Sutton (1940) compiled information on all Mississippian rocks around the Illinois Basin. Collinson and Swann (1958) and Baxter (1960, 1965) have provided detailed information on the Salem and St. Louis in the area of their outcrops in western Illinois. Pinsak (1957) presented cross sections of these rocks in the subsurface of Indiana, and Saxby and Lamar (1957) have described the gypsum and anhydrite deposits in these rocks in the subsurface of Illinois. The paleontology of the Salem and St. Louis has also been widely studied (Cumings and others, 1906). In recent years Rexroad and Collinson (1963, 1965) have attempted biostratigraphic correlation of the Salem and St. Louis by using conodonts. A preliminary version of the present report was given by Lineback (1970).

THICKNESS AND EXTENT

The area studied in detail includes the portions of south-central Illinois indicated in figure 1. In this area the combined thickness of the Salem, St. Louis, and Ste. Genevieve (not separated from the St. Louis for the purposes of this report) Limestones ranges from more than 900 feet (275 m) in White County to about 350 feet (107 m) in Madison County on the Mississippi River (fig. 2). The combined thickness of these units conforms to the structural pattern of the Illinois Basin. That is, they are thickest in the center of the basin, presumably because of greater subsidence there. The units thin towards the margin of the basin, where subsidence was less. The Salem Limestone is nearly 500 feet (153 m) thick in Hamilton County (fig. 3), and it thins to less than 200 feet (61 m) along the Mississippi River. The combined St. Louis and Ste. Genevieve are likewise thick (more than 500 feet, 153 m) in Hamilton and White Counties, and they thin westward to less than 200 feet (61 m) in the counties along the Mississippi River.

LITHOLOGY AND STRATIGRAPHY

Several cross sections (figs. 4-8) combining electric logs and sample studies have been constructed to show the distribution of lithologies in the Salem and the St. Louis in the study area. In White and Hamilton Counties, where the formations are thickest, the Salem Limestone consists predominantly of biocal-

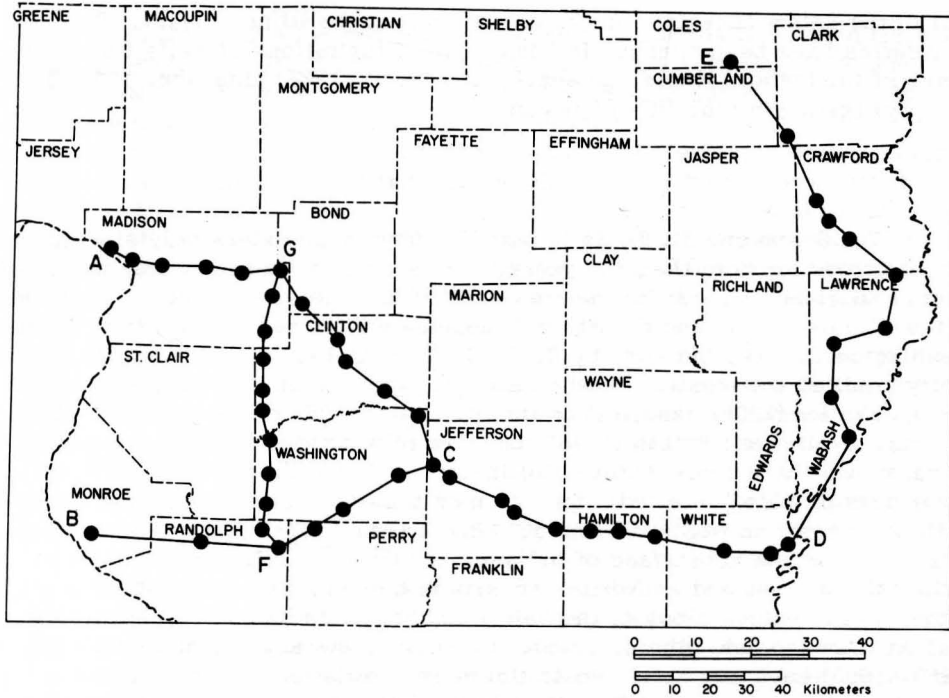


Fig. 1 - Map of south central Illinois showing locations of wells and outcrops used for cross sections (figs. 4-8).

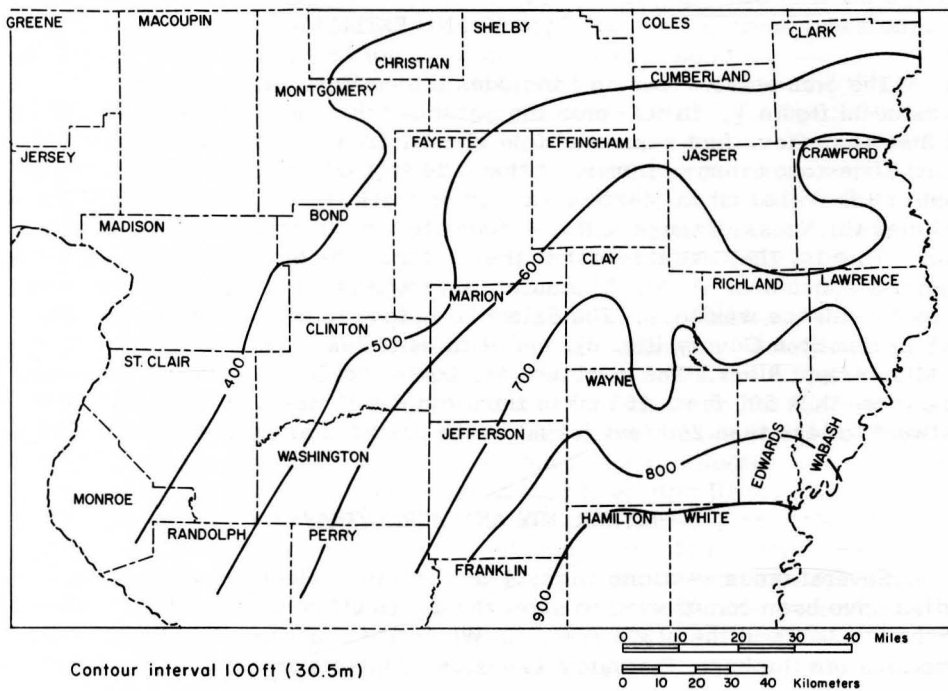


Fig. 2 - Combined thickness of the Salem, St. Louis, and Ste. Genevieve Limestones in south central Illinois.

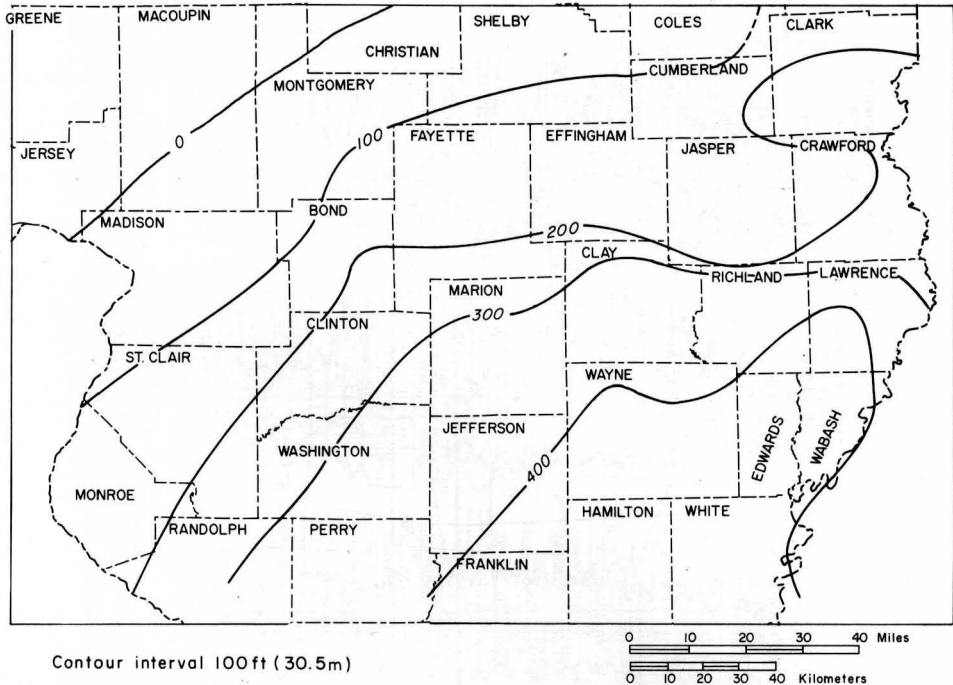
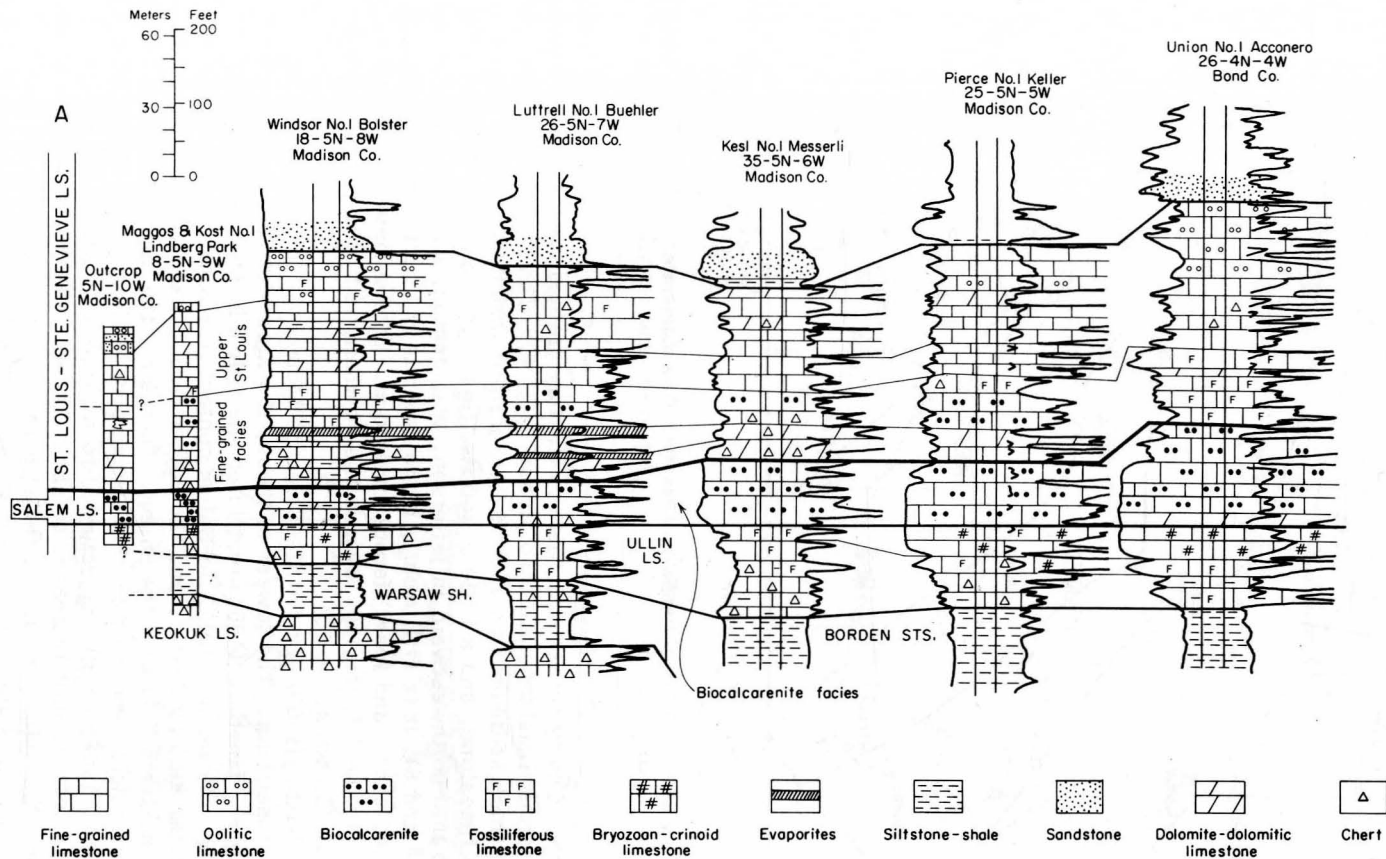


Fig. 3 - Thickness of the Salem Limestone (biocalcarenite facies) in south central Illinois.

carenite. Cherty limestone, fine- to medium-grained crystalline limestone, and fossiliferous limestone are also present (fig. 6). The St. Louis Limestone in the area of thick sediment consists of fine-grained limestone, cherty limestone, some oolitic limestone, and a little evaporite (figs. 4, 5, and 6). As the Salem begins to thin northwestward in Jefferson, Washington, and Clinton Counties (figs. 4 and 6), it is still mostly biocalcarenite but contains minor amounts of dolomite, chert, and fossiliferous limestone. This combination of lithologies persists to the Mississippi River in the southern part of the area (Perry and Randolph Counties, fig. 5).

Baxter (1960) divided the Salem in Monroe County (the west end of fig. 5) into four members. The lowest of these, the Kidd Member, included the Ullin Limestone. Lineback (1966) restricted the Salem in Monroe County by excluding the Ullin. However, the Ullin-Salem contact lies within and near the top of the unit called Kidd by Baxter, and the author (1966) inadvertently excluded the Salem part of Baxter's Kidd from the Salem. Therefore, the upper 14 feet of the Kidd Member is here removed from the Harrodsburg Member of the Ullin Limestone (Lineback, 1966, p. 39) and returned to its rightful place in the Salem. The thickness of this unit increases to about 22 feet in Baxter's (1960) type section. The name Kidd Member, as restricted herein, may be retained for this 14 to 22 feet and its equivalents in Monroe County. The Monroe County member names proposed by Baxter have not yet been used outside that county.



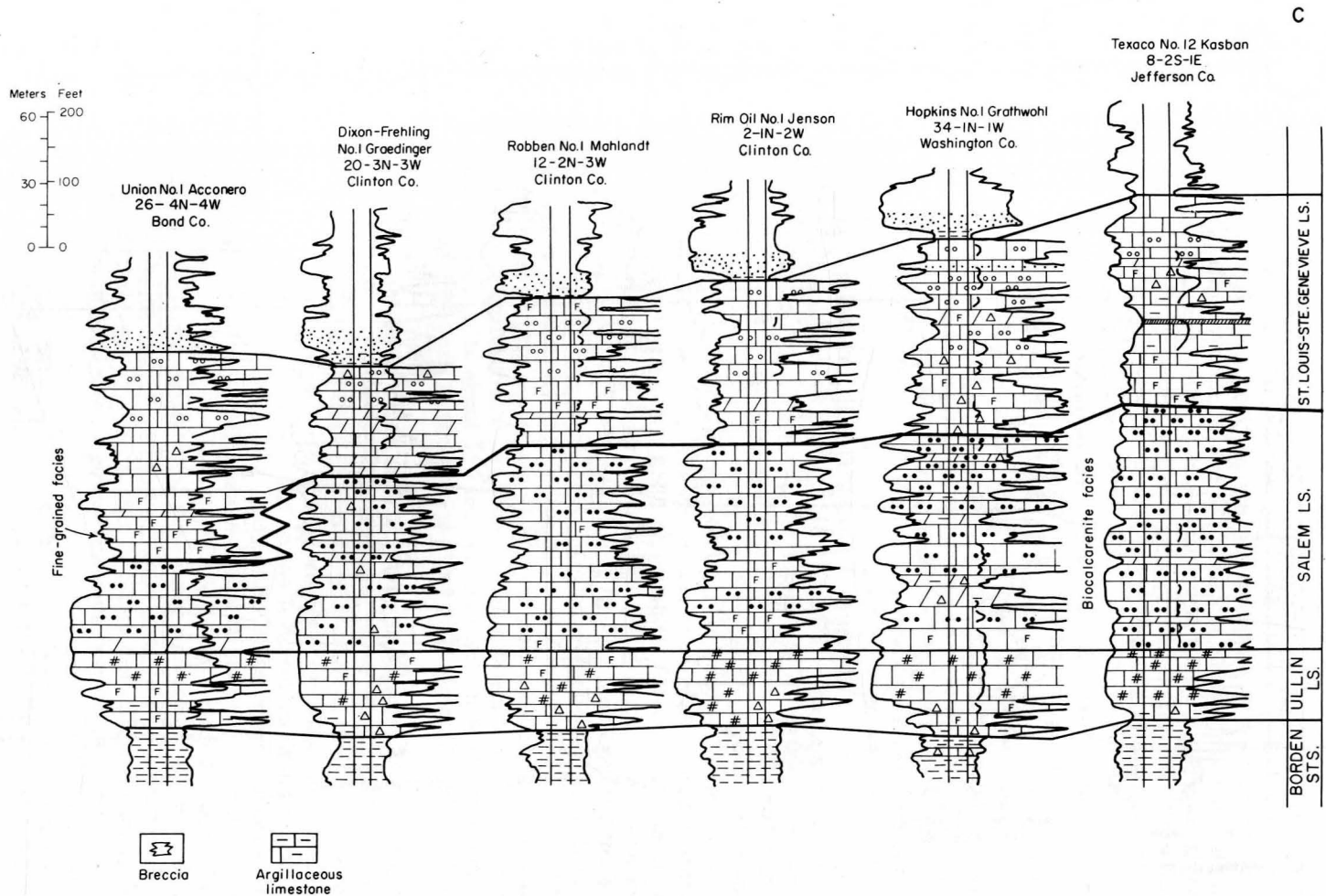


Fig. 4 - Electric log cross section A-C, extending from Madison County to Jefferson County. Index on figure 1.

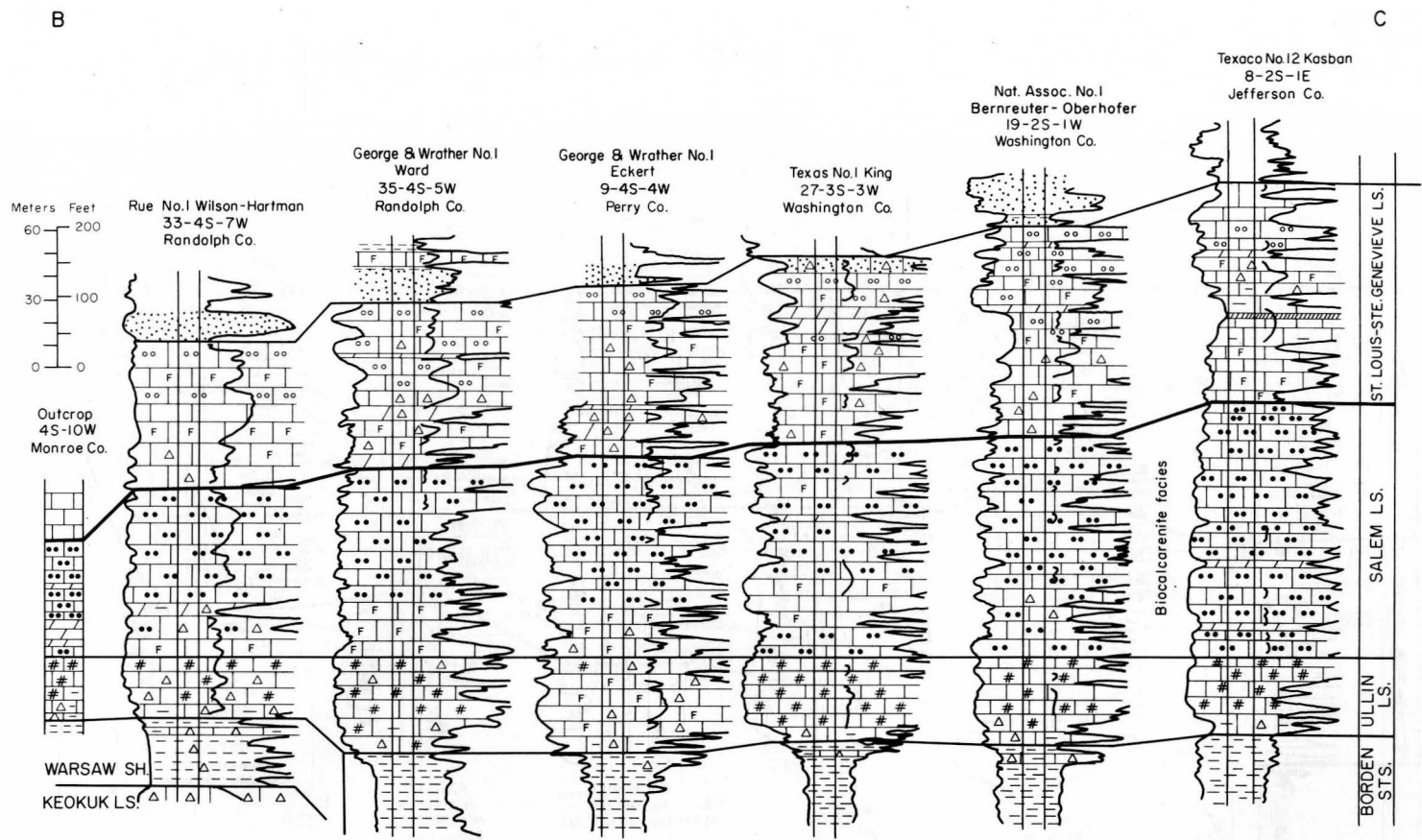


Fig. 5 - Electric log cross section B-C, extending from Monroe County to Jefferson County. Index on figure 1.

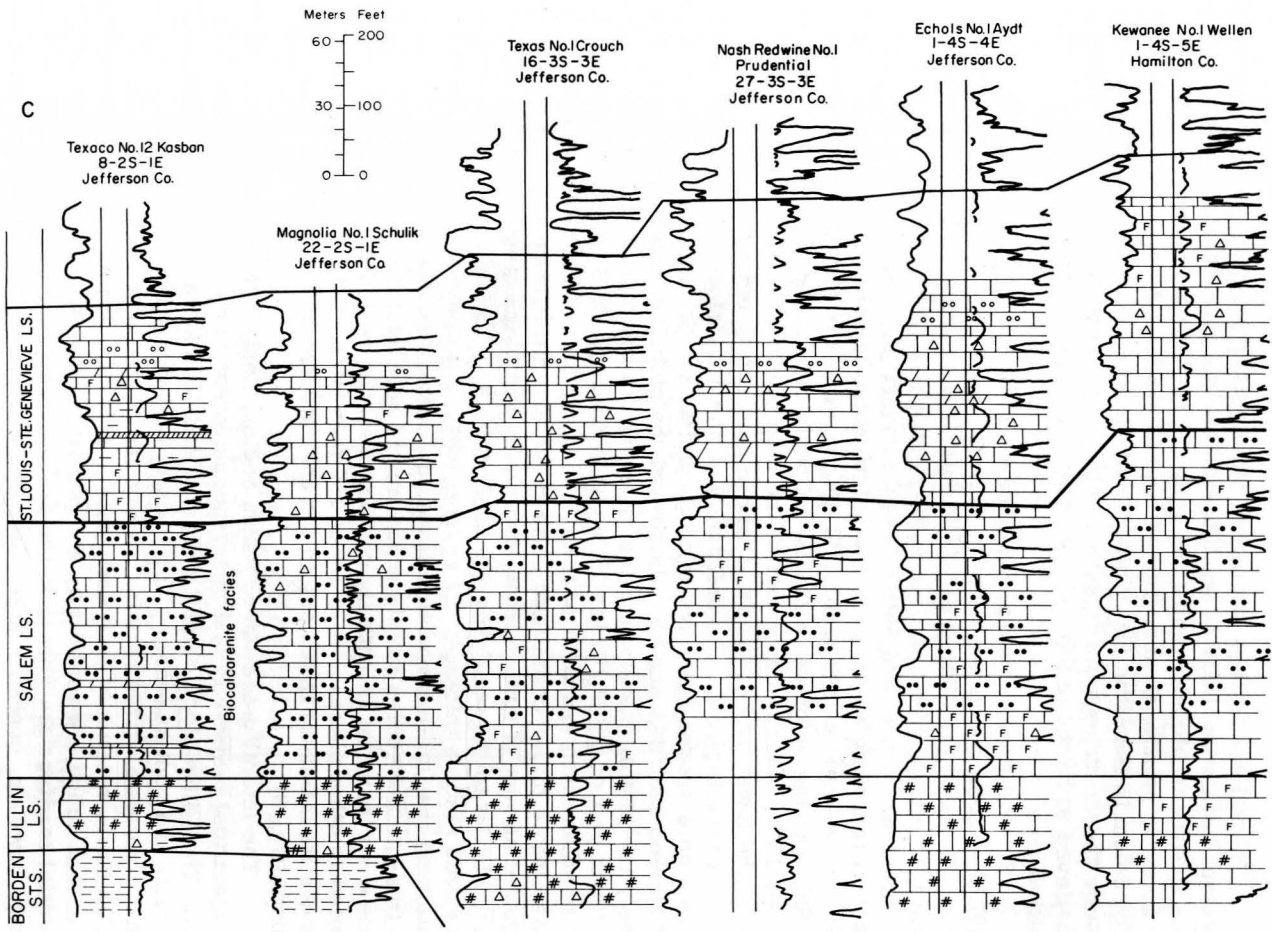
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The Salem, as thus defined in Monroe County, consists of biocalcarenic limestone with a few beds of argillaceous and dolomitic nature in the lower part and a mixture of biocalcarenic and fine-grained limestone in its upper part. The Salem in Monroe County (figs. 5 and 6) appears to be entirely equivalent to the Salem in Hamilton and White Counties although there is a marked thinning towards the west, especially as the outcrop is approached (fig. 5). This thinning is believed to be the result of depositional thinning in the direction of the Ozark positive area.

Several Illinois geologists (Baxter, 1960 and 1965; Weller and Sutton, 1940) have been concerned with the correlation of the Salem and St. Louis of Monroe County to the Salem and St. Louis of Madison County. Although the distance is short and there are intervening outcrops, the correlations have remained in confusion. Weller and Sutton (1940) suggest that "oolitic" beds in nearby Missouri that were assigned to the Salem might be equivalent to the St. Louis in Madison County. Baxter (1965) did not correlate his Monroe County members of the Salem to the outcrops in Madison County but indicated later (personal communication, 1972) that the upper part of the Monroe County Salem was probably equivalent to the lower part of the St. Louis in Madison County.

By tracing lithologic units through the subsurface, the author has had considerable success in correlating the Salem and St. Louis between Madison and Monroe Counties and has discovered the probable cause of the difficulties, namely the lateral gradation of the upper part of the Monroe County Salem into the lower part of the St. Louis in Madison County. In Bond and Clinton Counties and in areas north and west of them, the upper part of the Salem biocalcarenic grades into a facies containing some biocalcarenic limestone, but containing a greater amount of fine-grained limestone, sucrosic dolomite, chert, and evaporite, similar to the overlying St. Louis (fig. 4). In Madison County, the evaporite beds reach a thickness of several feet. For convenience, this facies, containing the fine-grained limestone, dolomite, and evaporite, is referred to as the fine-grained facies in this report and is here assigned to the St. Louis Limestone even though it is entirely contemporaneous with Salem biocalcarenic deposited in other places. It is about 150 feet (46 m) thick in Madison County and reaches its maximum thickness in the area studied of 250 feet (77 m) in Effingham County (fig. 9).

The lateral gradation of Salem and St. Louis lithologies is reflected by the electrical resistivity and spontaneous potential curves depicted by the electric logs. The Salem biocalcarenic (figs. 5 and 6) maintains a high average resistivity and contains many thick beds of high-resistivity limestone. The spontaneous potential curve remains steady and to the left, representing porous, and in this case, relatively pure carbonate. Beds of dolomite or argillaceous limestone that cause low resistivity and positive (curve to the right) spontaneous potential readings are sparse in the biocalcarenic facies. The St. Louis Limestone, however, contains more dolomite, evaporite, and impure carbonate units, and electric logs of the St. Louis have an irregular pattern that indicates rapid vertical changes in lithology. The logs of drill holes from Clinton County (fig. 4) show a lateral change in resistivity and spontaneous potential curves in the upper part of the Salem. The log from the Robben No. 1 Mahlandt well (fig. 4) shows a pattern more irregular in the upper half of the Salem than in the lower part, even where biocalcarenic is abundant. Towards the northwest, into Bond and Madison Counties, the biocalcarenic Salem lithology is confined to the lower



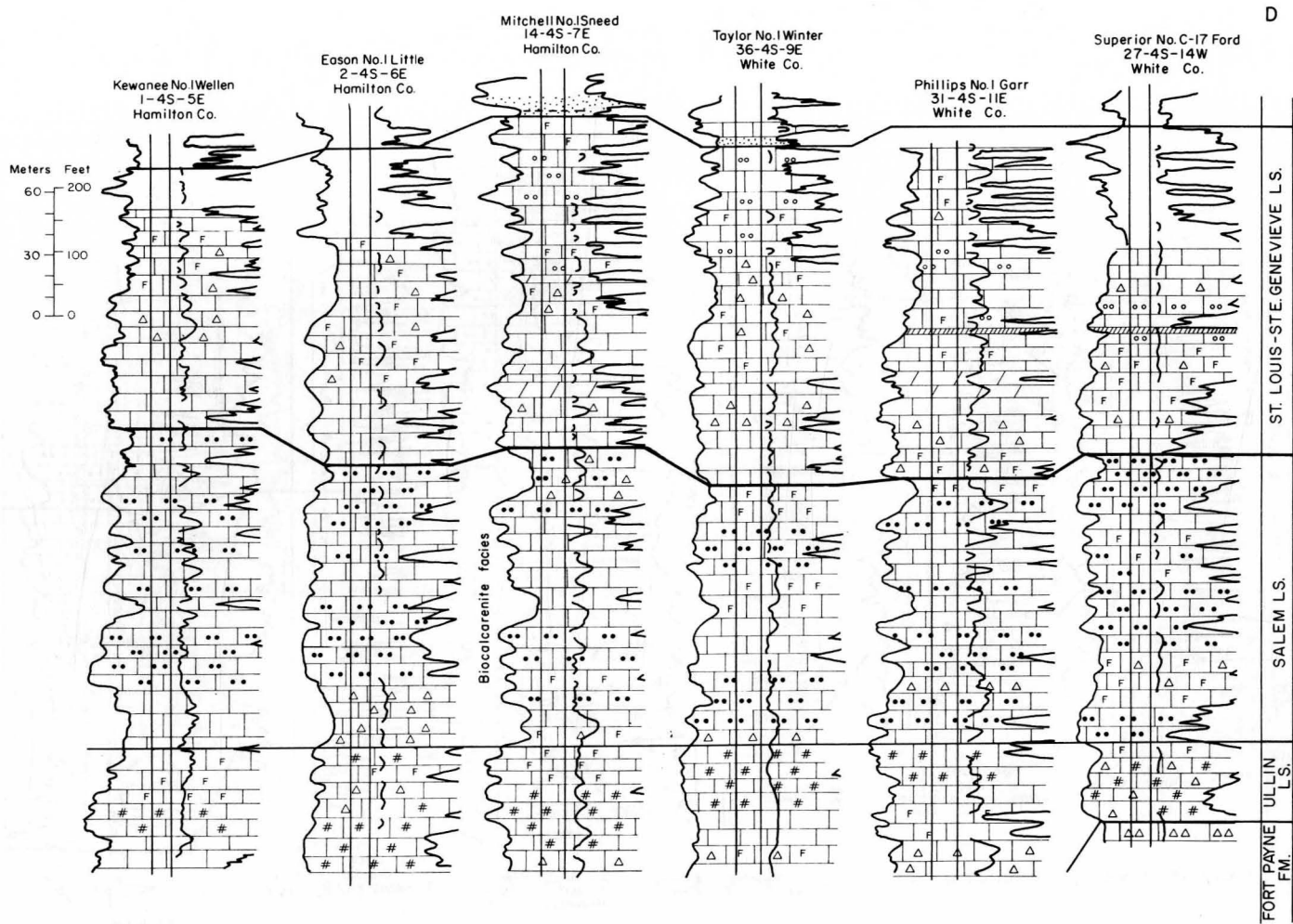
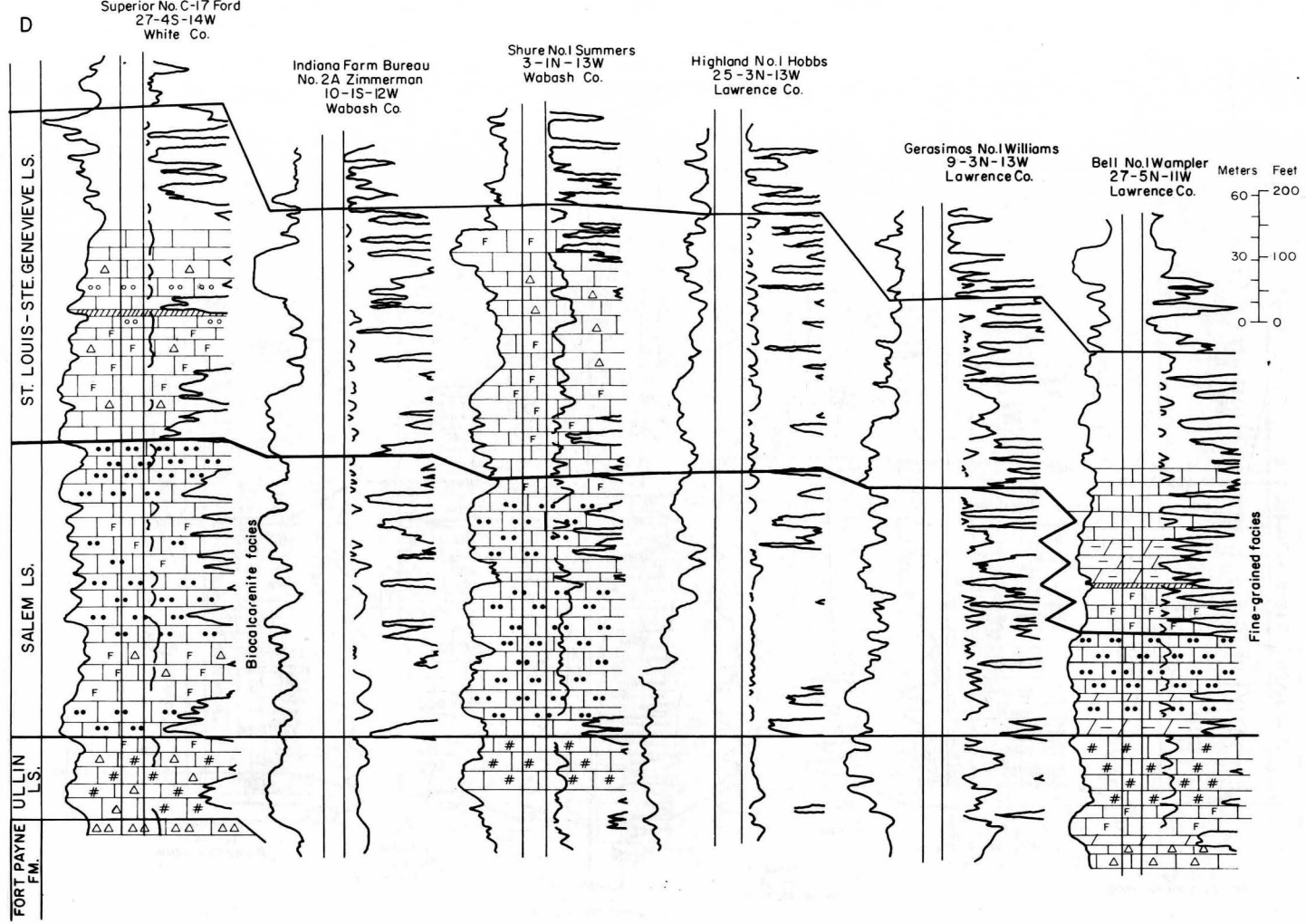


Fig. 6 - Electric log cross section C-D, extending from Jefferson County to White County. Index on figure 1.



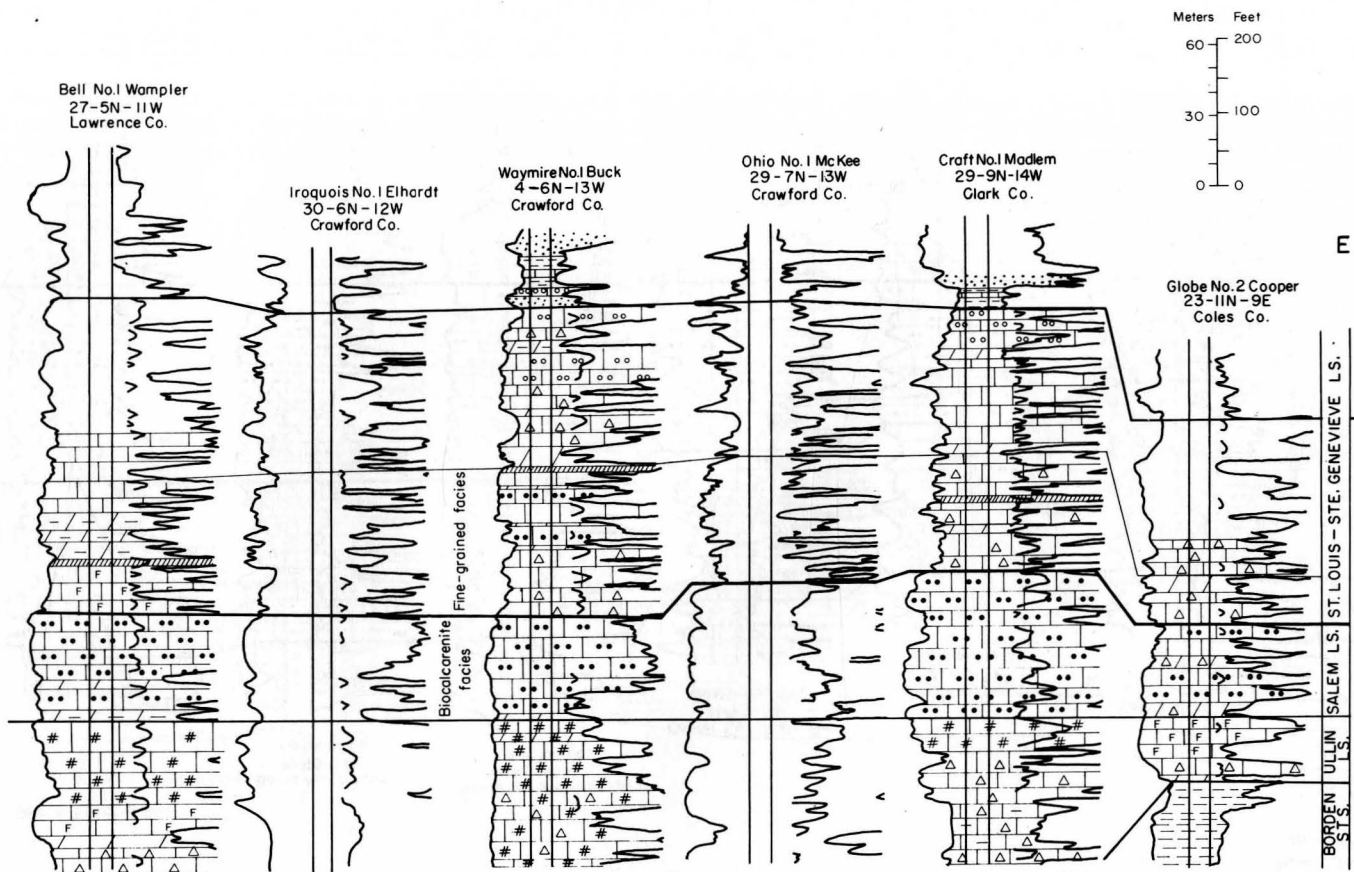
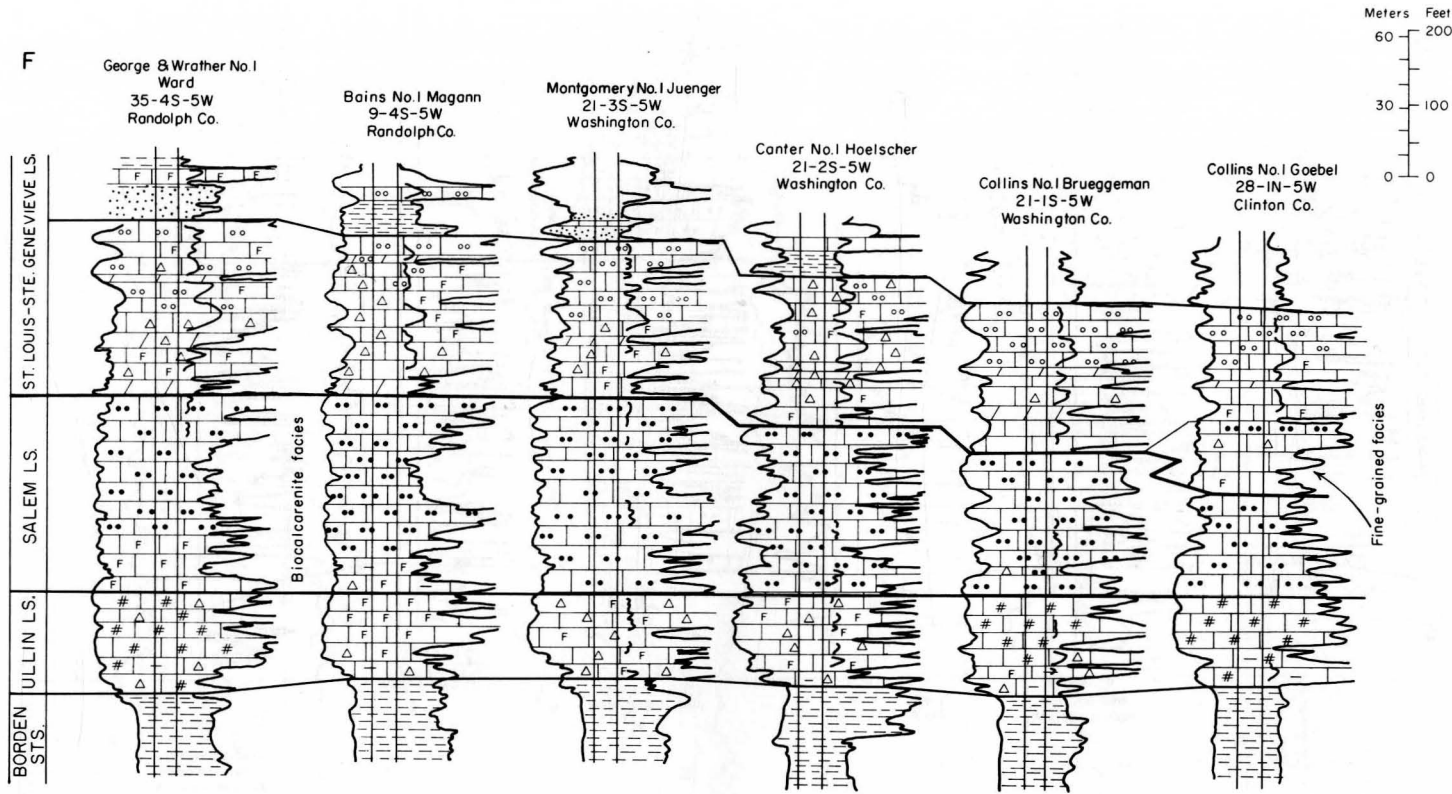


Fig. 7 - Electric log cross section D-E, extending from White County to Coles County. Index on figure 1.



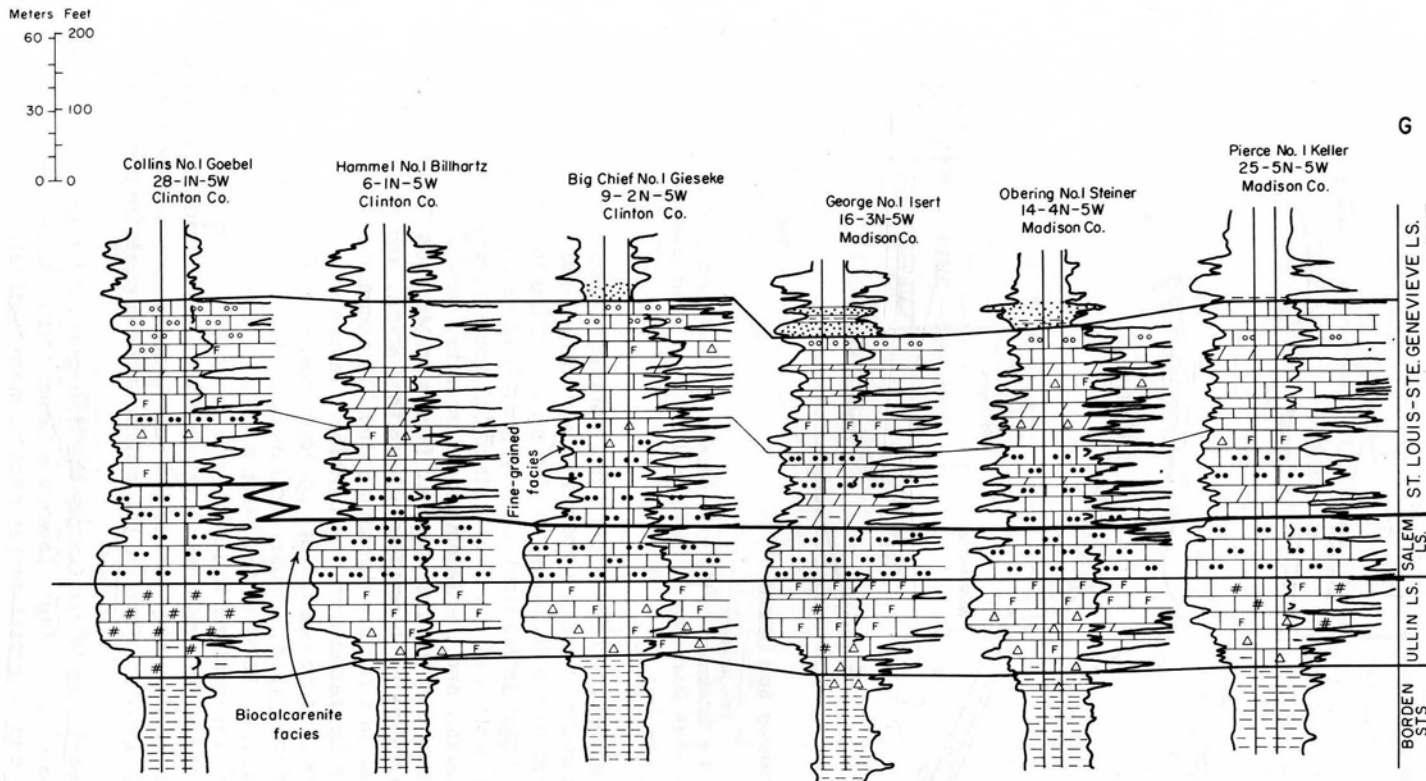


Fig. 8 - Electric log cross section F-G, extending from Randolph County to Madison County. Index on figure 1.

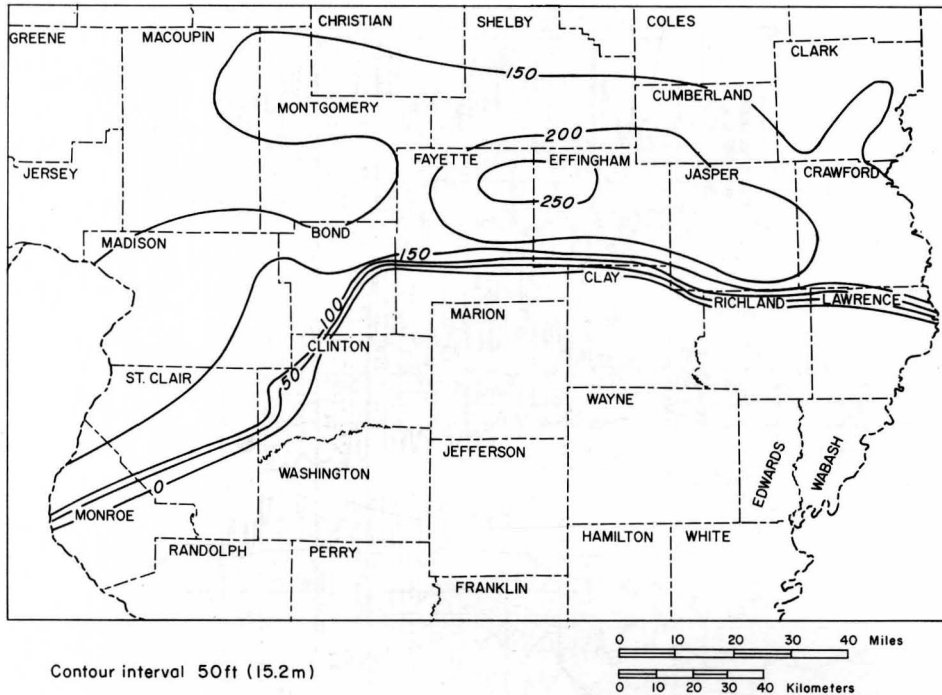


Fig. 9 - Thickness of the fine-grained facies of the St. Louis Limestone that is stratigraphically equivalent to the Salem Limestone.

part of the section; and the upper part, contemporaneous with biocalcarene deposition to the south, contains dolomite, evaporite, and fine-grained limestone similar enough to the St. Louis to warrant assigning these rocks to that formation. Logs of drill holes in Madison County (fig. 4) show the contrast between the electrical properties of the fine-grained St. Louis facies, which is equivalent to part of the Salem, and the Salem biocalcarene.

The fact that the fine-grained facies in Madison County is laterally continuous with the Salem biocalcarene farther south, and not merely St. Louis lithology deposited on a rapidly thinning Salem, is demonstrated by electric log marker beds that can be traced from one lithologic facies into the other. Additionally, the fine-grained facies of the St. Louis in places contains beds of biocalcarene like those of the Salem. Cross section F-G (fig. 8) shows the gradualness of the lithologic change. In southern Clinton County, the upper part of the Salem grades laterally into fine-grained lithologies that exhibit the typical vertically varying electric log of the fine-grained facies. In northern Clinton County, biocalcarene beds reappear in the upper part of the fine-grained facies without much effect on the electric properties, because the matrix of the biocalcarene is argillaceous or dolomitic.

Northward from White County the fine-grained facies replaces the upper part of the Salem in northern Lawrence County with the result that the resistivity and spontaneous potential curves become more vertically varied (fig. 7). North of Lawrence County, the fine-grained facies contains dolomite and evaporite beds at several levels. Biocalcarene beds reappear at places in the fine-grained facies in Crawford County, again attesting to the fact that this lithology is laterally gradational into the Salem.

The geographic distribution of facies in the same stratigraphic position as the Salem Limestone is shown by figure 10. The Salem biocalcarenite facies dominates the southern part of the area. The fine-grained facies of the St. Louis overlies the Salem biocalcarenite in a band across the central part of the area. North of Madison and Montgomery Counties, the biocalcarenite facies almost

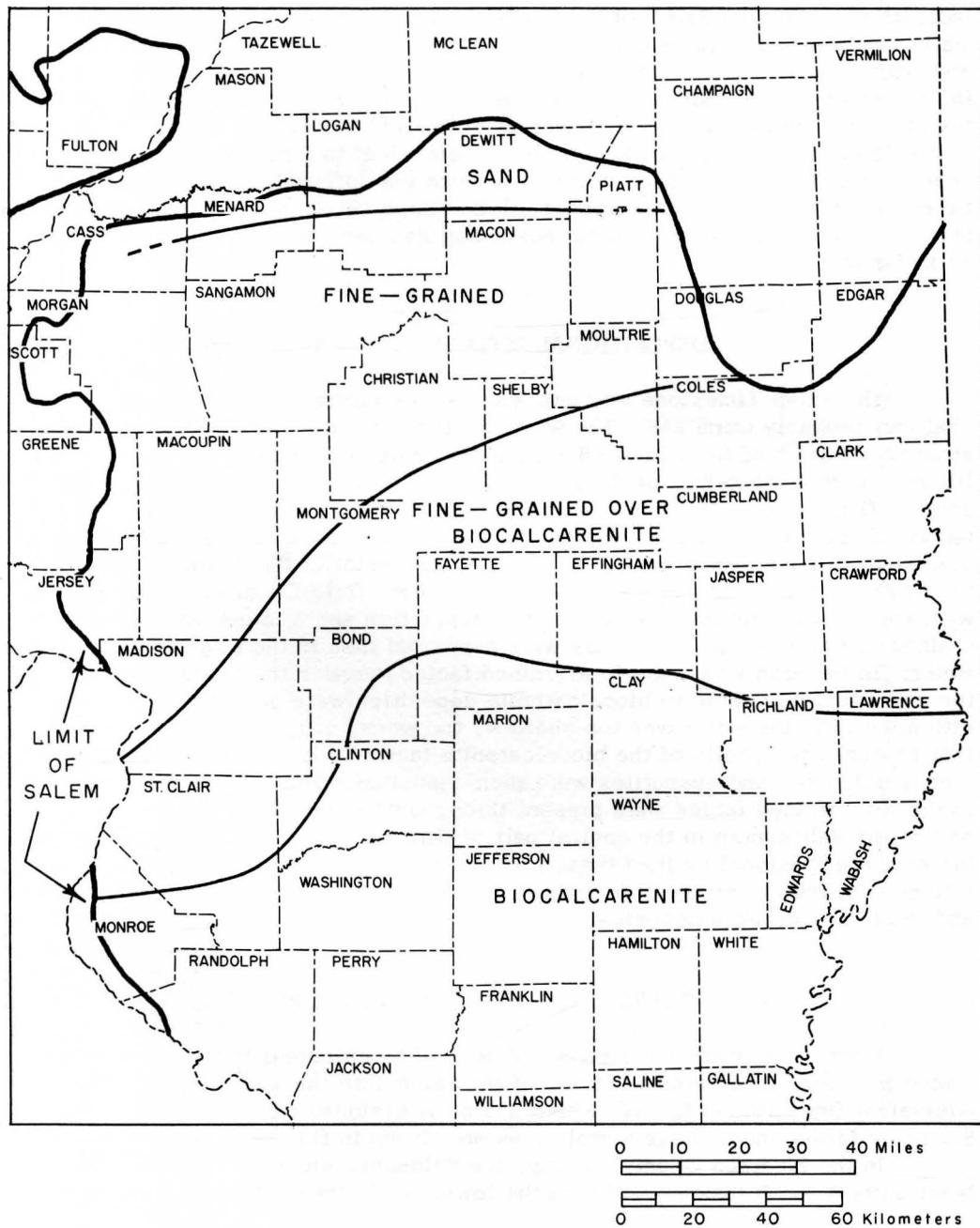


Fig. 10 - Facies of the Salem Limestone and laterally equivalent rocks.

entirely disappears and fine-grained limestone and dolomite dominate the rocks deposited contemporaneously with the biocalcarene facies. In southern Logan County (north of the main study area of this report), rocks equivalent to the Salem biocalcarene are sandy. Similar sandy rocks equivalent to the Salem were reported in extreme western Illinois by Collinson and Swann (1958).

Correlations between Illinois and Indiana made by the author strongly indicate that the type Salem of the Indiana outcrop, if traced by time parallel marker horizons, is equivalent only to the lower part of the Salem in Hamilton and White Counties, Illinois. The reason is that the upper part of the Salem in the center of the basin also grades laterally eastward into the lower part of the St. Louis just as it does northwestward towards Madison County. The top of the Salem in the Illinois Basin is about equivalent to Pinsak's boundary between the upper and lower St. Louis. Because the definition of the Salem is based on lithology, the stratigraphic relationships between the Salem and the St. Louis in the part of the Illinois Basin that has been studied can be shown, as in figure 11.

DEPOSITIONAL ASPECTS OF THE SALEM

The Salem Limestone was deposited in a structural basin containing a shallow, probably warm sea. The water depths probably conformed to the general structural pattern of the Illinois Basin, with the deepest water in southeastern Illinois nearest the center of the basin. The basin may have been open to the south. The water shallowed towards the west, north, and east margins of the basin. Depositional conditions were most favorable for the formation of biocalcarene limestone in a wide belt around the center of the basin; but near the center of the basin, as shown in Hamilton and White Counties, water depths were too deep for optimum biocalcarene deposition and a larger portion of fine-grained and crystalline limestones were deposited than in the slightly shallower water. In the area where the fine-grained facies overlies the biocalcarene, the conditions favorable to biocalcarene deposition were present early in deposition but later the water was too shallow, too warm, or too saline for the animals that produced the shells of the biocalcarene facies to live. Fine-grained limestone, dolomite, and evaporites were then deposited. The conditions favorable to the fine-grained facies were present throughout the deposition of the upper part of the Valmeyeran in the central part of Illinois. The sand that occurs near the northern erosional limit of these rocks may represent nearshore or beach deposition, thus indicating the shoreline of the sea in which the biocalcarene facies and related rocks were deposited.

CORRELATION AND NOMENCLATURE

Electric log marker horizons and beds of biocalcarene limestone can be traced from the biocalcarene facies of the Salem into the stratigraphically equivalent fine-grained facies, which has been assigned to the lower part of the St. Louis Limestone. These correlations are shown in figures 4, 7, and 8.

In the Madison County outcrop, the Salem biocalcarene is thin. At least units A and B (Baxter, 1965) of the lower St. Louis in Madison County are

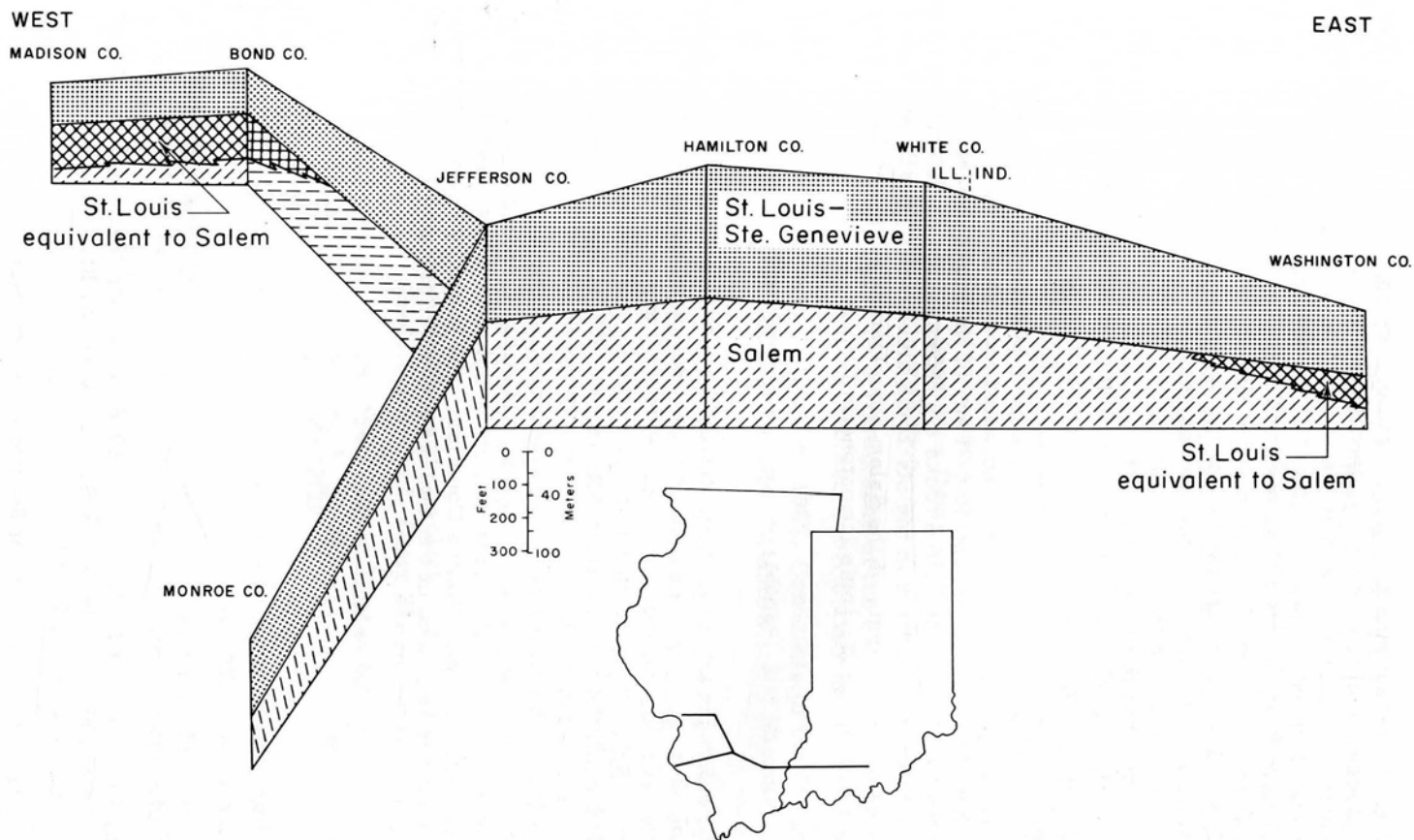


Fig. 11 - Diagrammatic cross section across the Illinois Basin showing the stratigraphic relationship between the Salem and St. Louis Limestones.

equivalent to the subsurface fine-grained facies, which grades southward into the Salem biocalcarenite. The fine-grained facies in the Madison County subsurface contains beds of gypsum that are absent from the outcrop. The outcrop contains beds of limestone breccia (unit C of the St. Louis and some beds in unit B) that have been interpreted as resulting from the solution of the evaporites and collapse of the superjacent and included limestone beds (Collinson and Swann, 1958). The lower part (unit C) of the upper St. Louis also grades laterally southeastward into the biocalcarenite facies, assuming that the breccia is correlated with the evaporites in the fine-grained facies.

The proof that the lower part of the St. Louis grades laterally into the upper part of the Salem of Monroe, Jefferson, Hamilton, and White Counties may help resolve many stratigraphic problems in the upper part of the Valmeyeran. The nomenclature on the Illinois outcrop need not be changed (with the exception of the previously mentioned base of the Salem in Monroe County), because it is based on lithology in accordance with accepted rock-stratigraphic practices. In reality there is no intrinsic need to call any of the rocks in Madison County, or anywhere else, Salem unless the rocks are recognizable as Salem on a lithologic basis. Most of the evaporites in the St. Louis discussed by Saxby and Lamar (1957) are lateral equivalents of the Salem biocalcarenite. Evaporites are rare in the upper part of the St. Louis Limestone in Illinois.

SUMMARY AND CONCLUSION

The Salem Limestone is characterized by biocalcarenite in its type area and throughout most of its subsurface extent. Because this facies is readily identifiable, lithologically distinct, and widely traceable, it is recommended that the name Salem be restricted to those rocks in this stratigraphic position that are dominantly of the biocalcarenite facies. Rocks laterally equivalent to the biocalcarenite facies that are fine-grained limestone, dolomite, and evaporite should continue to be called St. Louis Limestone. At the same time, it is recognized that the lower part of the St. Louis in Madison County and central Illinois is laterally equivalent to the upper part of the Salem in White, Hamilton, Jefferson, Perry, Randolph, and Monroe Counties. The boundary between the laterally grading formations is placed at the facies change as indicated in figures 4, 7, 8, 9, 10, and 11.

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