Evaporate Facies in Northwestern Ohio

by
F. G. Stehli, J. N. Namy,
and M. D. Aten
Western Reserve University

ABSTRACT

Sufficient well control is available in a large part of northeastern Ohio to permit correlation of and subdivision within the Salina section. Twelve subdivisions based on core examination and correlated by means of gamma ray, laterolog and sonic log events have been carried through a 15 county study area. Isopachous, structure and facies maps have been prepared from the data obtained. Salina deposition is found to show little correspondence to present structure and within the Salina individual zones of evaporite deposition occupy somewhat different basins. Facies maps based on the number of evaporite beds show that the maximum development is reached in the most subsident part of the Salina depositional basin that evaporite beds decrease toward the basin margin. Maps using a ratio of anhydrite/halite show greatest halite development in the axis of the depositional basin. Comparison of halite isopachs with total Salina isopachs and with structural maps suggest much loss of salt by solution in some areas.

INTRODUCTION

This study was undertaken in an attempt to learn more about the distribution, thickness and internal stratigraphy of the salt-bearing portion of the Silurian System in northeastern Ohio. The data employed in this work were derived primarily from gamma ray, laterolog and sonic velocity logs available commercially. Lithologic information needed for control was obtained from study of two cores and from available descriptions of a number of others.

The writers wish to express their appreciation to the many persons who aided in the study either through discussions or through the contribution of data. We particularly wish to thank Donald Richner and Donald Deardorff of the Diamond Alkali Company and E. Perry Bendler of the East Ohio Natural Gas Company, for help in obtaining materials, and H. F. Donner, J. M. Forgotson, Jr., J. F. Hall and C. F. Upshaw for valuable criticism of this paper.

PROCEDURE

In any study which considers the distribution and properties of a three-dimensional rock body over a significant geographic area, it is first necessary to develop a stratigraphic framework within which the accumulated data can be considered in their proper spatial and time relationships. Such a stratigraphic framework must be based on regional correlations of the best obtainable accuracy. Our primary correlations were established through the use of gamma ray logs, since logs of this type can be used to distinguish and correlate beds in an evaporite sequence. Correlations were effected by the development of small, roughly circular, traverses which could be closed as a check on consistency. The correlation framework was extended by tieing-in additional closed traverses. In cases in which the spacing of control did not permit this approach and required extrapolation of the correlation network over considerable distances, correlations were always made with all available nearby wells to ensure the highest possible degree of internal consistency.

The Diamond Alkali Jackson Street Brine Field Well #125 in Painesville township, Lake County, Ohio, was used as a subsurface reference section from which correlations were extended outwards. The salt-bearing section of the Cayugan was subdivided into twelve stratigraphic units (see Figure 1) which were correlated through much or all of the area of study. While all twelve units were correlated, wherever present, not all of them have been used for mapping purposes. Instead attention was focused primarily on those positions of the section in which the maximum development of evaporite occurred. In northeastern Ohio there are four main salt zones which are numbered sequentially from the top down. The first salt zone is defined as lying between horizons 2 and 3 (Figure 1), the second salt zone as lying between horizons 4 and 6, the third salt zone as lying between horizons 7 and 8, and the fourth salt zone as lying between horizons 10 and 13.

The exact relationship of horizon 1 to the top of the "Syracuse Formation" as recently defined by Alling and Briggs (1961) has not been determined definitely. However, horizon 1 was placed at the position of a gamma ray log marker which could be traced with considerable precision throughout the area. Exact correlation with the surface sections remains to be accomplished. The base of the "Syracuse" section may not correlate exactly with horizon 13 used to define the base of the section studied. Marker 13 is the position of the top of a thin shale overlying definite Niagaran dolomites in northeastern Ohio.

The stratigraphic framework used in this study is based on 47 wells distributed through 16 counties in northeastern Ohio, and two adjacent counties in northwestern Pennsylvania. Included within the area studied are two counties, Cuyahoga and Geauga, within which no satisfactory data were available to us.

The lithologic information required for facies studies was obtained from several sources. An excellent core from the reference well, the Diamond Alkali Jackson Street Brine Field Well #125, was made available by the Diamond Alkali Company, and was compared directly with sonic, gamma ray and laterolog records. This core, which covers almost the entire salt-bearing section, was taken from a well subjected to an extensive logging program and therefore was extremely valuable in relating the response of the various logs to particular rock types. A second core taken from the Morton Salt Company, C. E. Wilson, Well #1 in Milton township, Wayne County, covered only the upper portion of the salt-bearing section, but was nevertheless of considerable aid. A combination of gamma ray and laterolog records was found to be both useful and accurate in determining the presence of evaporite beds. Sonic logs of good quality permitted a distinction, within the evaporite beds, between salt and anhydrite.

Gamma ray logs, which provided data for structure and isopachous maps, were available for many wells and furnished good control. Sonic logs which are necessary to distinguish salt from anhydrite were available for relatively few wells so the control for facies maps was sparce. The area of greatest control for most of the maps lies in the region including Summit, Portage, Wayne and Stark Counties. Irregularities in the contouring which appear in this region on most of the maps are real but it should be remembered that the absence of similar irregularities in other areas may be due to diminished control in the sparsely drilled counties. Because of the scarcity of control in much of the map area proportional dividers were used to determine the location of contours as objectively as possible.

Limitations inherent in the available data have caused difficulty in the preparation of some maps. Structure maps were in general developed using well elevations given on the logs. Well elevations were not always available however, and in some cases where the well could be located with reasonable precision on topographic maps and where structural control was badly needed, elevations were obtained from the existing topographic control. In the preparation of isopachous maps, logs printed on three different scales (20 feet to the inch, 50 feet to the inch and 100 feet to the inch) were used. The precision with which the depth of a particular horizon could be determined varied with the scale of the log from $\pm$ 1 foot to $\pm$ 5 feet. The data used in maps indicating the number of evaporite beds present were taken, where possible, from combined gamma ray and laterolog records but in some areas gamma ray logs alone were used. In determining the number of discrete evaporite beds in any section no bed with a thickness of less than six feet

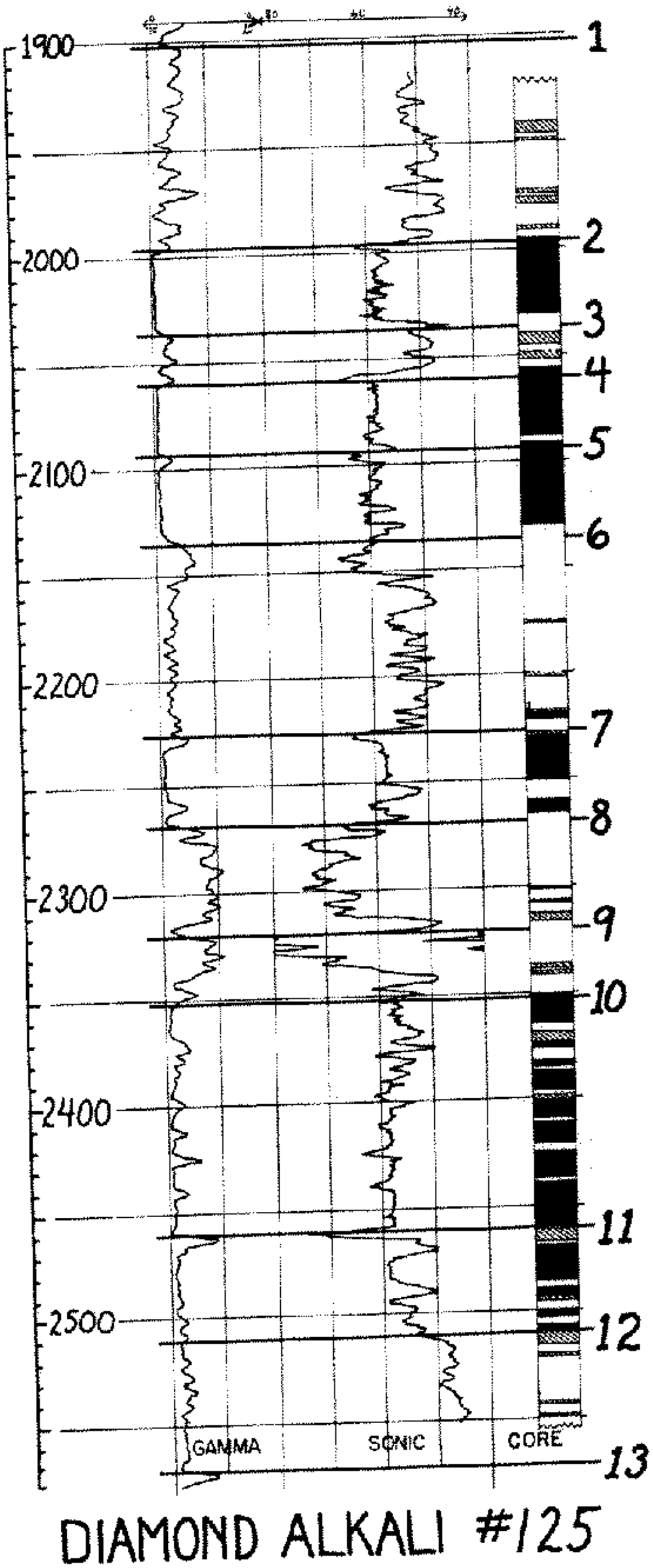
1900
2000
2100
2200
2300
2400
2500
1
2
3
4
5
6
7
8
9
10
11
12
13
GAMMA
SONIC
CORE
DIAMOND ALKALI #125

Figure 1.

was counted. On the reduced scale of some of the logs used, there is considerable subjectivity in determining whether or not a bed less than six feet thick is really an evaporite. To obtain as much objectivity as possible in these measurements, interpretations were made by three operators and an average figure was used.

Those maps which plot the ratio of salt to either anhydrite or all other lithologies present, are based primarily on sonic logs. Maps indicating the mining and brining possibilities in northeastern Ohio were made only as examples of quantitative exploration maps. The assumptions which were made in their preparation are fully described in a subsequent section.

RESULTS AND INTERPRETATION

All of the data obtained during the course of this study have been reduced to map form and are presented in Figures 2 through 17. The discussion which accompanies these maps will call attention to features which appear to have significance in terms of structural position, thickness distribution, facies relationships or depositional environments.

Figures 2 through 5 call attention to regional aspects of the "Syracuse Formation" (horizons 1 and 13) is shown, respectively, in Figures 2 and 3. These two maps are grossly similar in the form of the surface they display. Each indicates a surface sloping generally toward the southeast but exhibiting a change in trend from S.S.E. in the counties bordering Pennsylvania, to E.S.E. in the counties on the southern edge of the map area. In general, the structural surface seems to reflect the curvature in the trend of the folded Appalachians which lie to the south and east. Both maps differ in detail from the structural map on top of the highest salt as presented by Pepper (1947) and revised by Hall (this volume). The variations result mainly from the the fact that the uppermost salt does not always occur at the same stratigraphic horizon.

An isopachous map of the total "Syracuse Formation" (horizons 1 to 13) (Figure 4) indicates a regional thickness distribution which is significantly different from the structure maps (Figures 2 and 3). Within the map area, thicknesses reach a maximum in Mahoning and Columbiana Counties. From this region the beds may continue to thicken to the southeast but they definitely thin to the north, northwest, west and southwest. Thinning is most marked to the north and to the southwest where the section is reduced to approximately half in a distance of 65 and 52 miles respectively. Thinning is at a minimum along the northwest-southeast axis of the depositional basin where a 25% reduction in thickness occurs in a distance of roughly 65 miles.

The "Syracuse" depositional basin was elongated in a northwest-southeast direction and the most deeply subsident region lay in the southeast corner of the map area. Our use of a 50 foot contour interval permits considerable more detail than is shown by the 250 foot interval used by Alling and Briggs (1961) but the general form of the basin on each map is similar. To investigate the possibility that deviations between the structure and total isopachous maps might result from the solution of salt in certain regions a second isopachous map of the "Syracuse Formation" which excluded the four major salt zones, was prepared (Figure 5). Comparison of the two isopachous maps indicates that though they differ in detail they are grossly similar and that the discordance of the isopachous and structural maps represents a real difference between the basin of "Syracuse" deposition and the present structural basin.

We may now turn our attention to the internal stratigraphy of the "Syracuse Formation" and examine a series of four isopachous maps which summarize the thickness distribution of the four major salt zones present in northeastern Ohio. Figure 6 represents the thickness of rocks within the first salt zone. The pattern developed on the map is rather simple, suggesting a depositional basin elongated about an axis trending northwest-southeast and opening to the northwest. Both to the northeast and to the southwest the basin appears to shoal rapidly toward zero in Ashtabula County, and in the tier of Counties including Lorain, Medina, Wayne and Holmes. A comparison of the isopachous map of the first salt zone with that of the total "Syracuse Formation" (Figure 4) indicates that there is little relationship other than the northwest-southeast elongation of the basin. It should be recalled here, however, that Figure 4 indicates only the portion of the basin which received most sediments. In contrast, the isopachous map of the first salt zone, which represents primarily a single evaporite bed, may indicate the portion of the basin which contained the deepest waters during deposition of this particular unit and thus accumulated the high density

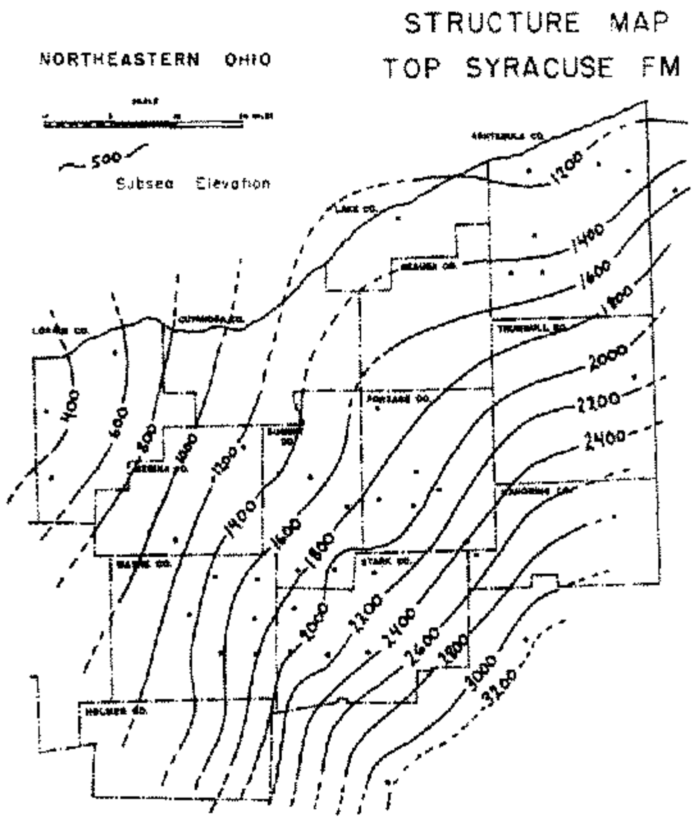

Figure 2.

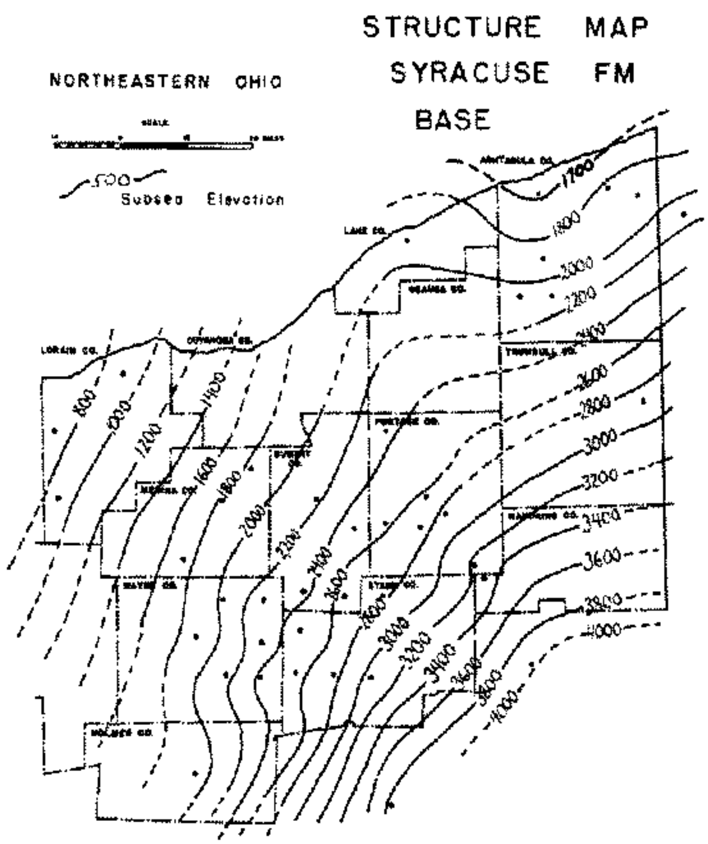

Figure 3.

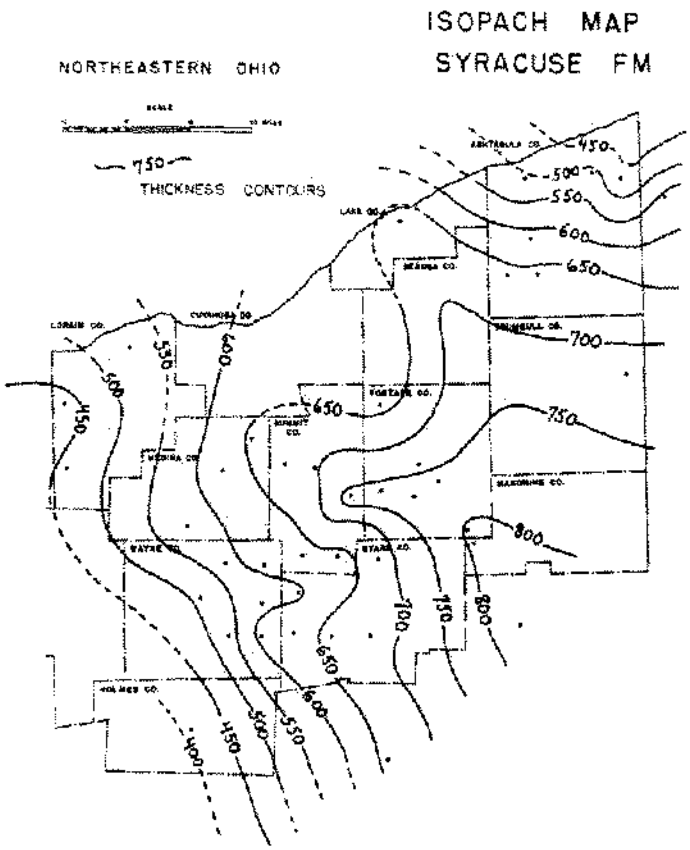

Figure 4.

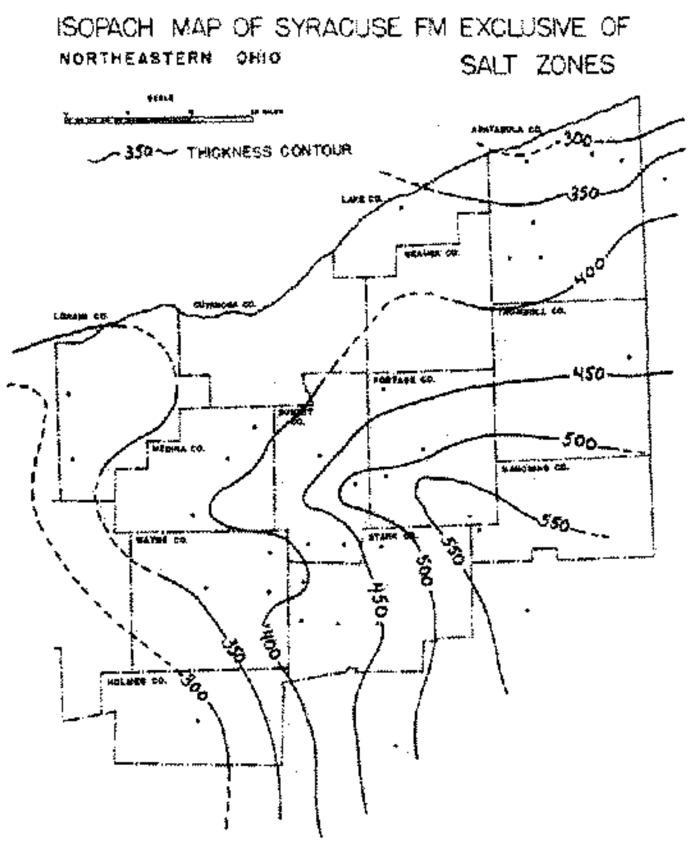

Figure 5.

brines from which salt precipitated. A second possible explanation of the discrepancy between the total isopach and the first salt zone isopach might be that the form of the depositional basin changed through time. The possibility that the discrepancy noted can be explained in the latter way may be checked as we examine isopachous maps for the remaining salt zone (Figures 7 through 9).

The isopachous map of the second salt zone (Figure 7) contrasts quite strongly with the map of the preceding interval and bears a general resemblance to the isopach of the total "Syracuse Formation." The second salt zone appears to reach maximum thickness along the general northwest-southeast trend of the basin, where a broad zone of widely spaced contours indicates an area of little change in thickness. Both to the northeast and southwest of this region, the section thins abruptly. Irregularities in the contours which occur in Stark, Wayne and Summit Counties represent real differences but their concentration in the area of greatest well control may be significant.

The isopachous map of the third salt zone (Figure 8) differs from the two preceding zonal isopachs in failing to indicate a dominant affinity either with a basin to the southeast or to the northwest. Instead, the map shows a relatively flat-bottomed prism of rock extending northwest-southeast through much of the study area but broadening considerably to the east in Tuscarawa, Carroll, Columbiana and Ashtabula Counties of Ohio and in Crawford County Pennsylvania. A rather extensive area of thinner section extends eastward from Wayne and Holmes Counties into Stark and western Columbiana Counties. Adjacent to this thin area on the northwest is a local area of unusual thickness in northeastern Wayne and southeastern Medina Counties. Apart from the anomalies mentioned, the section thins both to the northeast and to the southwest as is the case with the upper salt zones.

The isopachous map of the 4th salt zone (Figure 9) represents a more complex interval than those previously considered. The 4th salt zone consists of a number of thin evaporite beds rather than a few thick beds as is the case in the upper zones. Perhaps for this reason the isopachous map shows a more complex form than those of the preceding zones. During deposition of the rocks of the 4th salt zone, accumulation was least in the southern part of the map area (Tuscarawas County and adjacent Counties) and a region exhibiting a somewhat positive tendency seems to have extended northward through Stark County and into Summit and Portage Counties. Thinning to the southwest which is a feature of preceding maps appears minimal. A general thickening of the sediments seems to take place through Cuyahoga, Geauga, Lake and Ashtabula Counties, which suggests the 4th salt zone may reach its maximum thickness underneath Lake Erie. Somewhat irregular changes in thickness extend from eastern Ashtabula County, Ohio, into adjacent Erie and Crawford Counties in Pennsylvania. Along the eastern border of the map area there appears to be some indication of a relationship to the Appalachian basin. The rocks appear to thicken into northern Crawford County, Pennsylvania, and to thin rather abruptly into Erie County.

In summary of the four sonal isopachous maps it may be said that they exhibit a rather striking diversity. The only common feature seems to be the general northwest-southeast elongation of the basin. The fourth salt zone shows a pronounced relationship with a basin to the northwest and a suggestion of relationship with the area to the east as well. The third salt zone seems to show approximately equal relationships with areas to the northwest and southeast. The second salt zone clearly shows affinities with a basin to the southeast while the first salt zone shows, equally clearly, affinities with a basin to the northwest.

It seems that there was no clear-cut, progressive trend in the relationships with basins peripheral to the map area but rather a general and irregular tendency toward relationship with the basin to the southeast, the basin to the northwest, or both. Such variability within four zones all confined to a relatively small portion of the geological column, suggests that the basin of "Syracuse" deposition in northeastern Ohio was one of considerable instability. It is not implied that the mobility of the crust was anything more than that normal in cratonic areas. The suggestion is advance however, that while the isopachous map of the total "Syracuse" shows the region to the southeast to have accumulated the most sediment, the basin was an extremely shallow one. Differential compaction and minor amounts of crustal uplift or subsidence combined with a source of clastics, which lay predominantly to the east and southeast, acted in such a way as to change the location of the deepest water bodies within the basin through time, and thus cause the variability observed in the thickest salt accumulations for the four salt zones.

ISOPACHOUS MAP 1ST SALT ZONE

NORTHEASTERN OHIO

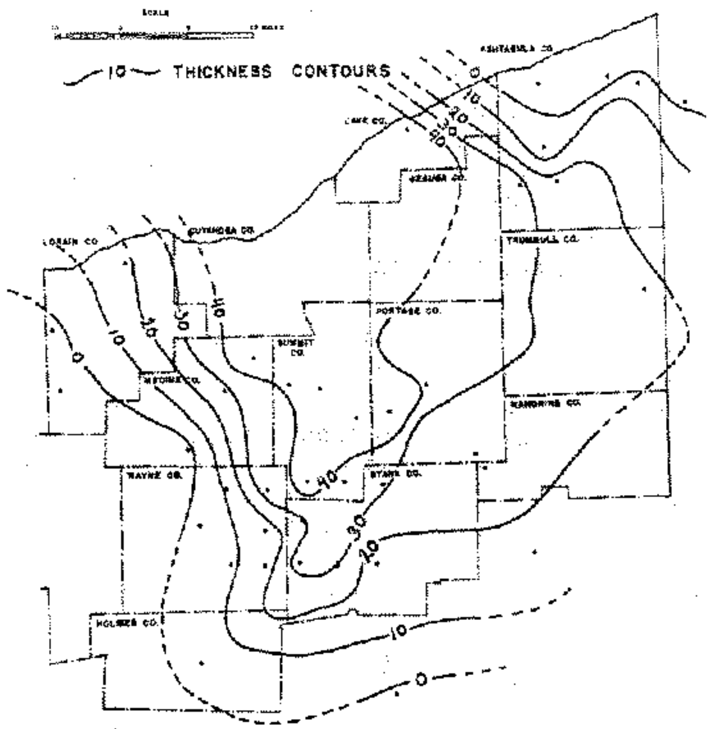

Figure 6.

ISOPACHOUS MAP OF 2ND SALT ZONE

NORTHEASTERN OHIO

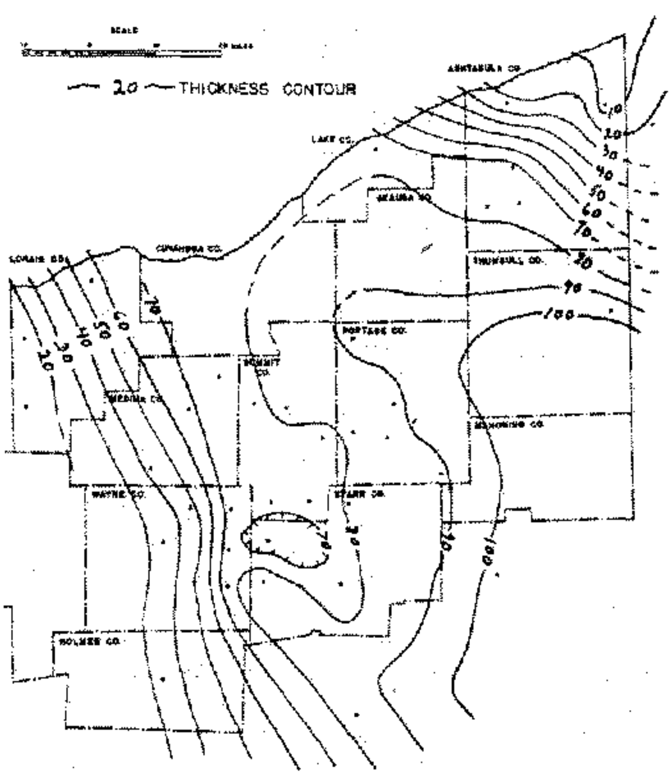

Figure 7.

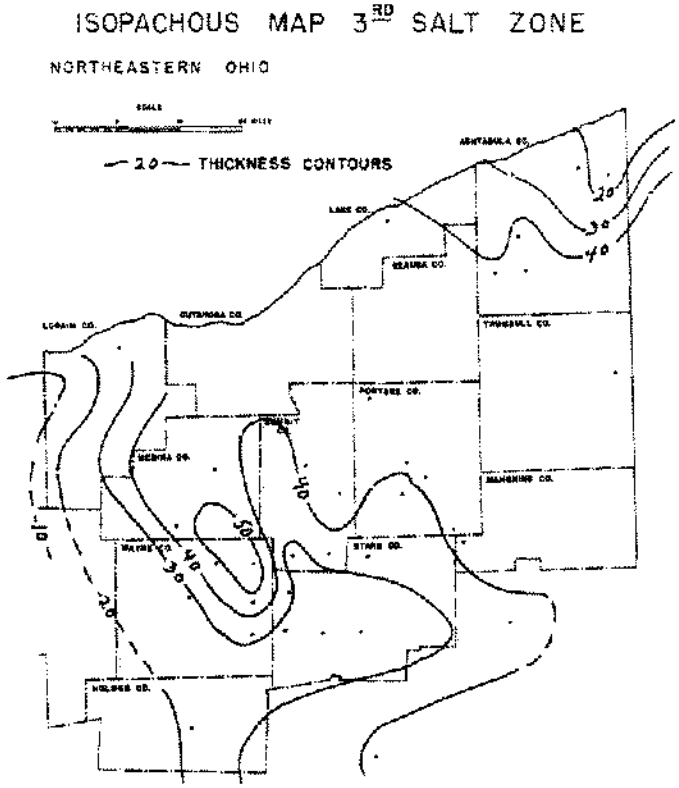

Figure 8.

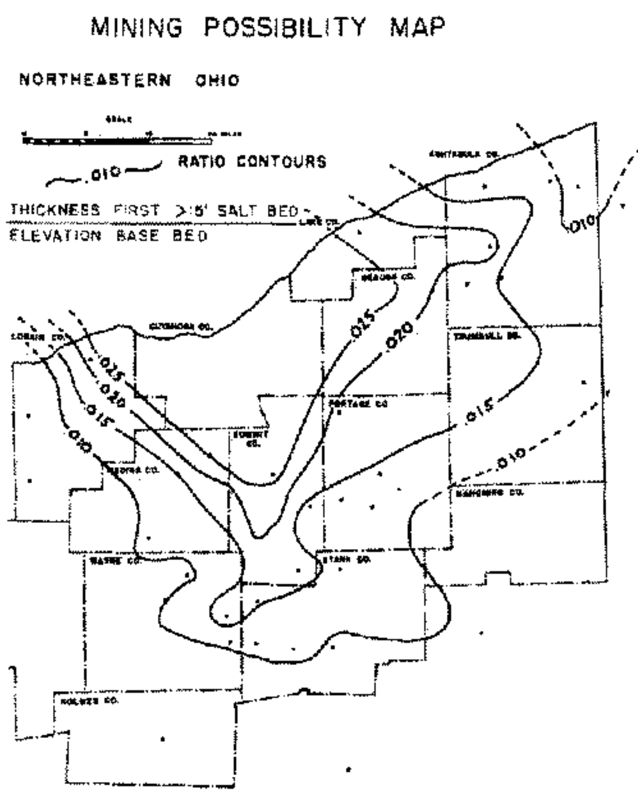

Figure 9.

Facies maps of the four salt zones provide further information on the relationship between salt and the total thickness of the "Syracuse." We may first examine the number of evaporites maps for the fourth salt zone (Figure 10). There is considerable subjectivity in the compilation of data for such a map and therefore it has been contoured on the basis of rather large class intervals instead of on incremental changes of one bed. Figure 10 shows a relatively simple pattern indicating the existence, through the central portion of the map region, of an E.S.E.-W.N.W. zone of maximum evaporite accumulation. Both to the northeast and to the southwest of this zone the number of evaporites tends to diminish. Within the limits of the available control it would appear that northeastern Ohio represented one single basin rather than a number of isolated basins, insofar as evaporite deposition at this time was concerned. In a single, simple basin, the areas of greatest evaporite accumulation should be those most persistently characterized by the deepest bodies of water. Dense brines developed by evaporation in the shallow regions of the basin, and heated there by insolation, should tend, despite their high temperatures, to exhibit a gravity flow toward deeper water. Here gradual cooling by upward transfer of heat should result in supersaturation and the precipitation of evaporites. It is therefore suggested that the central zone on the number of evaporites map (Figure 10) represents the region characterized by the deepest water during the deposition of the fourth salt zone. Comparison of this map with the isopachous map of the fourth salt zone (Figure 9) suggests some correspondence between the presumed deeper water areas and the regions of greatest sedimentary accumulation. The area previously mentioned as exhibiting a somewhat positive tendency in Stark, Portage, and Summit Counties appears to have a reduced number of evaporite beds. Somewhat greater accumulation of sediments occurred in Medina and Lorain Counties where an increase in the number of evaporite beds is also seen. In the northeast corner of the map, a thinning of the fourth zone is reflected in a decrease in the number of evaporites. It may be concluded for the fourth zone that the number of evaporite beds, and therefore presumably the depth of water, does correspond in a general way to the isopachous map and thus to the regions of greatest subsidence.

The number of evaporite beds occurring between the second and third salt zones is shown in Figure 11. This map serves not only to indicate the nature and distribution of evaporite beds, but to emphasize the fact that evaporite deposition was not confined to the four major zones. Comparison of Figure 11 with Figures 7 and 8, the isopachous maps of the second and third salt zones respectively, shows the closest relationship to be with the second zone since the number of evaporites increases to the southeast. It is true, however, that the region of greatest accumulation of evaporite beds lies considerably to the south of the region of greatest subsidence shown in Figure 7. The dotted contours shown in Figure 11 represent the number of salt beds included in the evaporite totals and indicate that the region accumulating the maximum number of salt beds was the same as that in which the maximum number of evaporite beds accumulated. Once more there is a suggestion that in a general way the most subsident regions are those which have accumulated the greatest number of evaporite beds and thus probably represent the areas of deepest water. It should be noted, however, that the region suggested as that containing deeper water for the fourth salt zone is not the same as that for the interval between the second and third salt zones. This fact may indicate that if deep water did persist in one area the water was probably not very deep anywhere in the basin.

A number of other facies maps showing primarily the relationships of salt and anhydrite within the different salt zones are presented in Figures 12-15. The data available for these different intervals were variable in both quantity and quality and it was therefore not possible to use exactly the same kind of facies map in all cases. Two maps represent ratios of anhydrite/salt, another is simply an isopachous map of the salt present in a single zone, and the last represents a ratio of non-salt/salt. Figure 12 presents an anhydrite/salt ratio map of the first salt zone. The control upon which this map is based was derived from sonic logs and examination of cores plus available descriptions of cores and is much more limited than that used in the preparation of the corresponding isopachous map (Figure 6). Within the limits of the control there is considerable agreement between the ratio map and the isopachous map. The ration supports the thesis that salt accumulated in the most subsident region, while in the less subsident regions, near the margin of the basin, anhydrite came to predominate. Since the salt producing brines should have been considerably more dense than those producing anhydrite, it is again suggested that the deepest water during the deposition of the first salt zone must have occurred in the region here shown as most subsident, i.e., parts of Summit, Portage, Lake and Cuyahoga Counties.

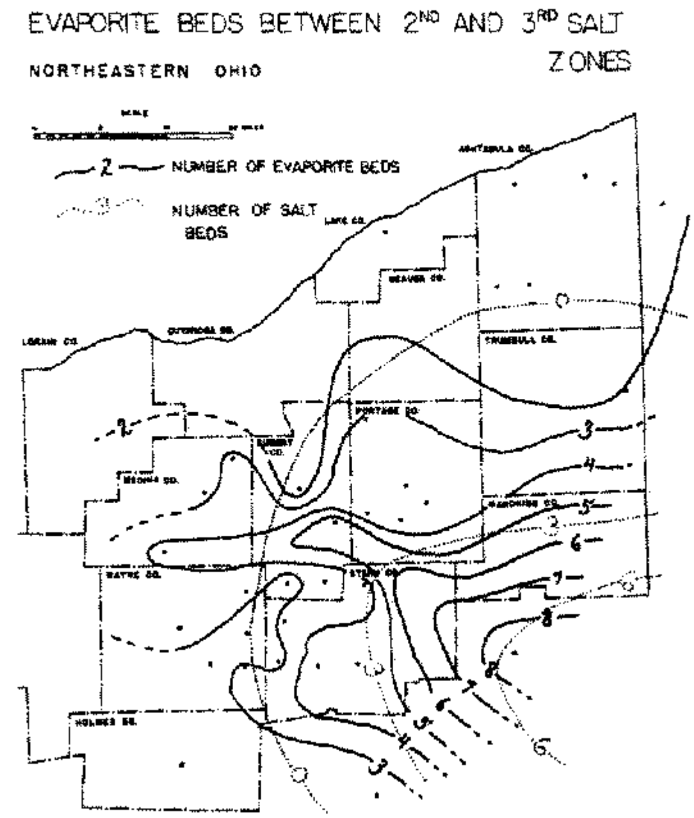

Figure 10.

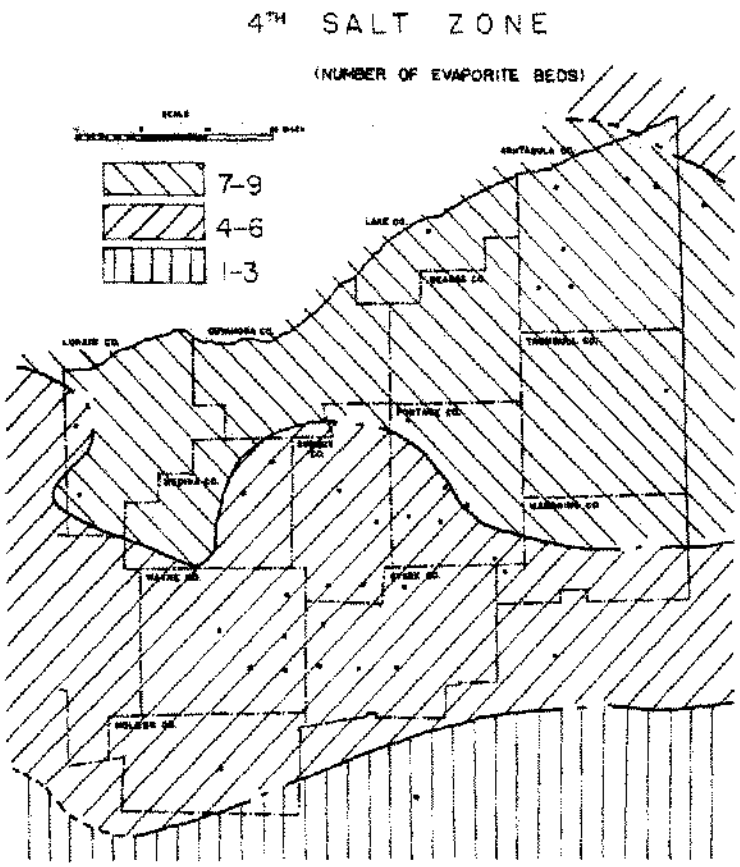

Figure 11.

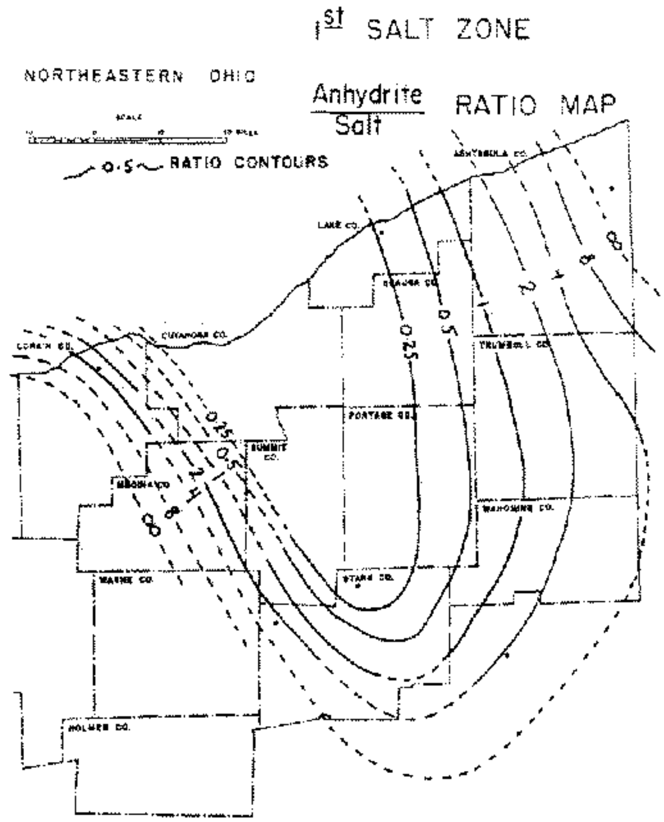

Figure 12.

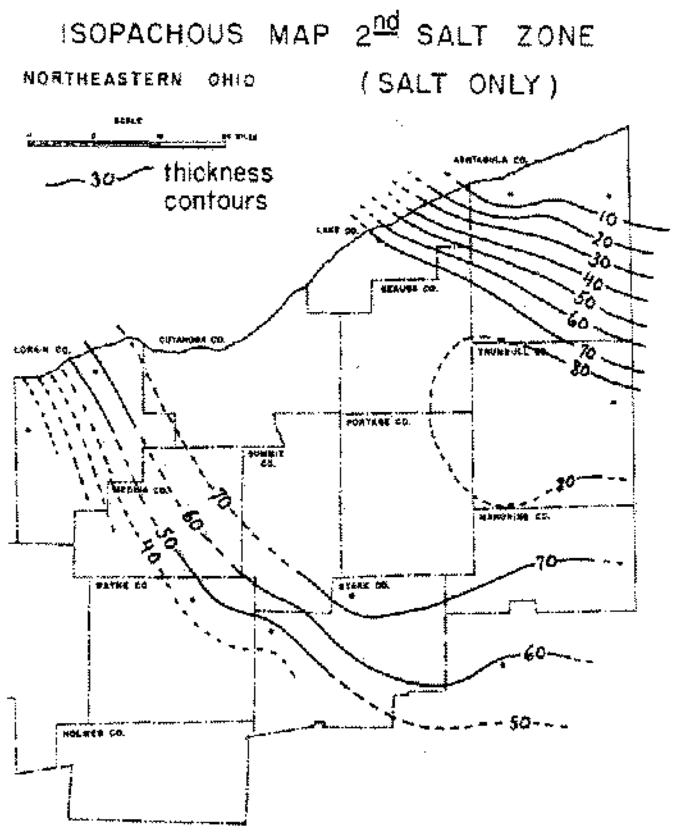

Figure 13.

Figure 13 presents an isopachous map of salt occurring within the second salt zone. This map indicates that the greatest volume of salt accumulated in a northwest-southeast trending basin which was apparently very flat-floored, though this characteristic may be due in part to the lack of control in Cuyahoga, Geauga, Portage and Summit Counties. In the southeast corner of the map, a decrease in the salt thickness is apparent in a region shown by the isopachous map (Figure 7) to be subsident. This situation is consistent with, but does not prove, the interpretation advanced by Alling and Briggs (1961) that normal marine sea water may have been entering southeastern Ohio by way of the Marietta Inlet. It could also be interpreted as indicating the existence here of slightly shallower water in which anhydrite rather than salt brines accumulated.

An anhydrite/salt ratio map of the third salt zone (Figure 14) suggests a pattern somewhat more definitive than that shown by the isopachous map (Figure 8). The greatest concentration of salt is in a region including Cuyahoga, Lake, Summit, Geauga, Portage and Trumbull Counties and corresponds to the more deeply subsident region shown in this area of the isopachous map. A departure between the trend of the ratio and the isopachous map is seen in the southeastern area, where the isopachous map suggests subsidence but the ratio map shows anhydrite rather than salt deposition. Once more this information seems to be consistent with the interpretation of Alling and Briggs (1961), that the Marietta Inlet to the south was providing normal marine sea waters from that direction or with the interpretation of an area of shallow water. While the isopachous map does not clearly suggest a relationship between northeastern Ohio and either the area to the northwest or the southeast, the ratio map suggests that the relationship, at least insofar as salt accumulation and probably water depth is concerned, was with the basin to the northwest during this interval of "Syracuse" deposition.

A map contoured on the value of a non-salt/salt ratio for the fourth salt zone is shown in Figure 15. The control is not extensive but is sufficient to indicate a region extending roughly northwest-southeast through Lake, Geauga, Ashtabula and Trumbull Counties in which salt deposition reached a maximum. To the northeast and southwest of this zone the quantity of salt decreases with respect to the non-salt beds. Comparison of Figure 15 with Figures 9 and 10, shows a correspondence of these two with the isopachous map of the fourth zone.

An attempt has been made in Figures 16 and 17 to demonstrate means by which the quantitative data available from well logs and core examination can be used to make exploration maps. Two maps have been produced, one indicating areas in which the brining possibilities are considered good, a second indicating areas in which mining possibilities are optimum. In each case certain assumptions have been made as a guide in accumulating data. It is not intended to suggest that these assumptions are necessarily the most desirable in any particular case nor is it intended to present these maps as definitively locating all promising areas for salt production. Instead the maps are intended as examples and are valid only if one subscribes to the conditions which are used in their development.

Figure 16 presenting the brining possibilities employs a ratio of $\left(\frac{\frac{x}{n}}{A}\right)$ in which x equals the total salt thickness in the upper three salt zones, n equals the number of salt beds present in the first three salt zones, and A equals the average structural elevation of the center of the salt beds with respect to sea level. Using these conditions we have developed a map which shows a relatively simple contour pattern and suggests that the most favorable zone for salt brining operations — considering, of course, only geological data -- lies in an area comprising the western half of Lake County, the northwest corner of Geauga County, the northern half of Cuyahoga County and the northeast corner of Lorain County. It should be noted that the control is poor, particularly in Cuyahoga, Geauga and Portage Counties, and it is quite possible that the ratio contours should extend somewhat farther to the southeast than shown. This map would appear to eliminate from consideration the area in Milton township of Wayne County in which the Morton Salt Company is currently operating a successful brine field but it must be recalled that this field is not producing from the first three salt zones as a whole, but only from the second salt zone, and that to correctly compare the potential of this area with others, conditions different from those used in Figure 16 would be required.

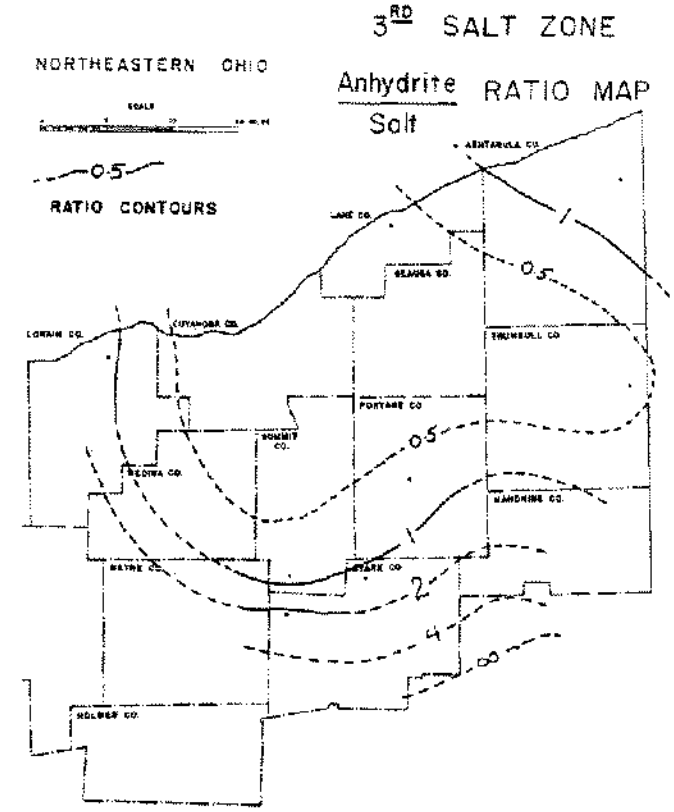

Figure 14.

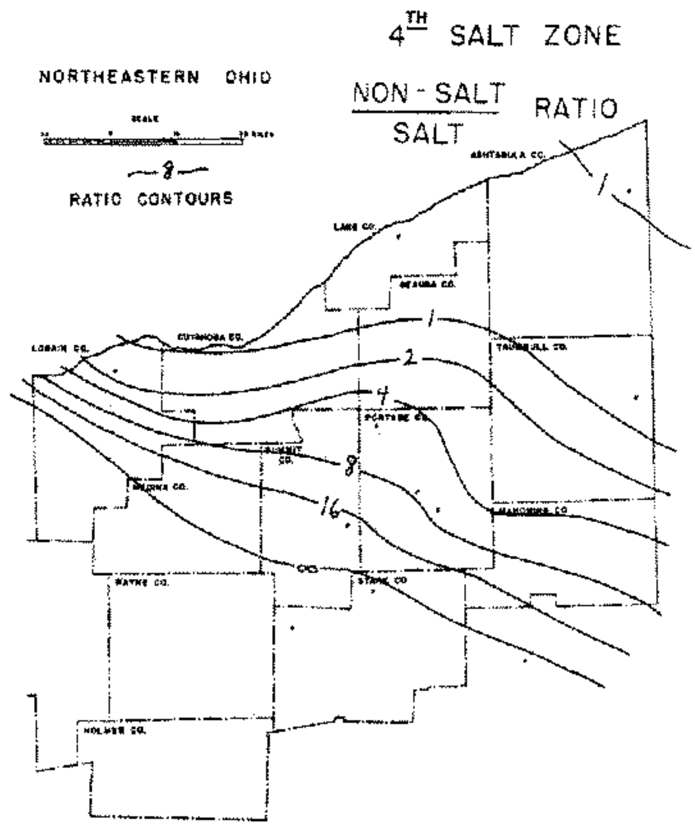

Figure 15.

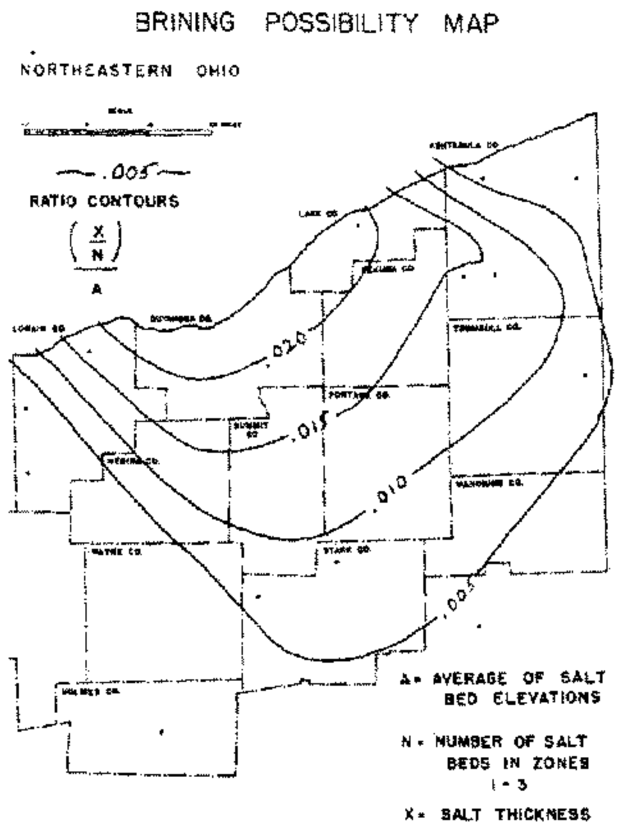

Figure 16.

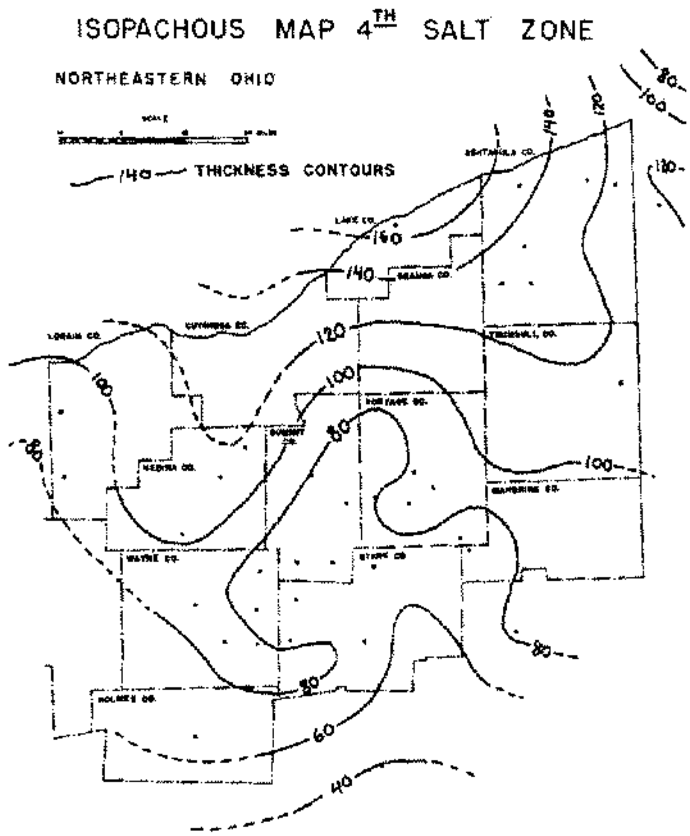

Figure 17.

A map indicating the mining possibilities for northeastern Ohio is presented in Figure 17. Once more conditions are involved in the construction of this map which may not apply to exploration problems other than the specific one considered here. This map (Figure 17) is based on the ratio values of the thickness of the first salt bed having a thickness greater than 15', divided by the structural elevation of the base of the salt bed relative to sea level. The map developed from these data indicates that an area relatively favorable for salt mining operations extends through most of Lake, all of Cuyahoga, the northern part of Geauga, the northwestern part of Summit, the northeastern part of Medina and the northeastern portion of Lorain Counties. Within this region, areas having the lowest elevations would be most favorable. The map suggests that generally the most favorable areas for mining exist farther west than those currently being exploited in the vicinity of Painesville. The new mine being developed by the International Salt Company at Whiskey Island would appear to be located in a very favorable position. Once more it should be stressed that only geological data are considered in the development of this map which thus does not take into account economic factors such as the cost of transportation or of land purchase.

SUMMARY

Comparison of total "Syracuse" isopachous map with regional structure maps shows a significant discordance indicating that the basin in which "Syracuse" deposition occurred was somewhat dissimilar to the present structural basin. Examination of the internal stratigraphy of the "Syracuse Formation" shows that isopachs of the different salt zones are quite variable. It is concluded from this evidence that while deposition took place in a cratonic area that was relatively stable, minor changes in subsidence, accumulation of sediments and compaction, caused frequent changes in the form of the basin, as indicated by zonal isopachous maps. Sufficient quantitative data are available in the form of well logs and cores to permit the development of simple but quantitative facies maps. Maps based both on the number of evaporites present in the salt zones and in one case in a section between two major salt zones, and those based on ratios of salt to other components in the stratigraphic column, show less complex patterns than those indicated by the isopachous maps.

It is believed that the areas exhibiting the greatest number of evaporite beds and the highest proportion of salt in the evaporite sequence probably represent the areas characterized by deepest water during deposition. If this be the case, the topographic as well as the structural basin of "Syracuse" deposition varied in position through time. While quantitative lithological data are still sparse in this region due to the relatively infrequent use of logging programs adequate for interpretation of lithology within the salt section, it is possible to produce quantitative exploration maps. When designed for the particular problem in hand, these maps can be quite useful in locating areas which are geologically favorable for exploitation either by mining or brining methods.

REFERENCES

Alling, H.L., and Briggs, L.I. (1961), Stratigraphy of Upper Cayugan Evaporites; Amer. Assoc. Petroleum Geologists. Vol. 45, p. 515-547.

Pepper, J.F. (1947), Areal Extent and Thickness of Salt Deposits of Ohio; Ohio Journal of Science, Vol. 47, p. 225-239.