Environment and Mechanics of Deposition of the Permian Hutchinson Salt Member of the Wellington Shale

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ABSTRACT

Sedimentary features, well exposed over large areas in Kansas salt mines, give excellent evidence of the environment and mechanics of deposition of the Hutchinson Salt. Additional, as well as substantiating information, can be obtained through the comparison of sedimentary features of the Hutchinson Salt with the Salina Salt of the Great Lakes region.

INTRODUCTION

An understanding of the depositional history of a sedimentary basin results from integration of results of regional studies with detailed studies of the individual units. Several regional studies of the Permian salt of Kansas are in progress: this study is concerned with the detailed analysis of a portion of the Hutchinson Salt of the Wellington Formation of Leonardian age. Consideration is given primarily to the bedded salt as exposed in mine sections on the assumption that variations in intensity and combinations of conditions would cause the majority of the varied salt-shale-anhydrite relationships seen in the salt section. Until such studies are fully integrated however, there is ample opportunity for misinterpretation of sedimentary features.

The cooperation and help of the Carey Salt Co., the Independent Salt Co., the American Salt Co., and the Frontier Chemical Co. is gratefully acknowledged. Mines were visited on numerous occasions, and mine and salt-analysis data were freely offered. Examination of cores was permitted by Frontier Chemical Co., and the results of core analyses and evaluation were made available. Mine and core samples were contributed by all companies. Appreciation is expressed not only to the management of these companies but also to the numerous employees who were always happy to lend a helping hand.

SALT IN KANSAS

Salt in Kansas occurs in seven Middle Permian units of Leonardian age (Figure 1), the unit attaining the maximum thickness and extent being the Hutchinson Salt of the Wellington Formation. This is the lowermost of the salt units.

The Hutchinson underlies a large area in southwestern Kansas and western Oklahoma and as yet undelimited area in the Texas Panhandle. (Figure 2.) In Kansas, the Hutchinson attains a maximum thickness of at least 700 feet, although throughout the greatest part of the basin in Kansas the thickness is 400 to 500 feet. This unit has been outlined in detail in Kansas by Kulstad (1961), and a detailed report concerning the Hutchinson is in preparation. Although the geologist in a state such as Kansas where there has been considerable drilling for oil is fortunate in having a wealth of information available in logs for regional studies, for detailed analysis and study of the salt section, mines and cores are necessary. Mines are presently operating (Figure 2) at Kanapolis, Lyons, and Hutchinson, and vertical and horizontal relationships and changes can be

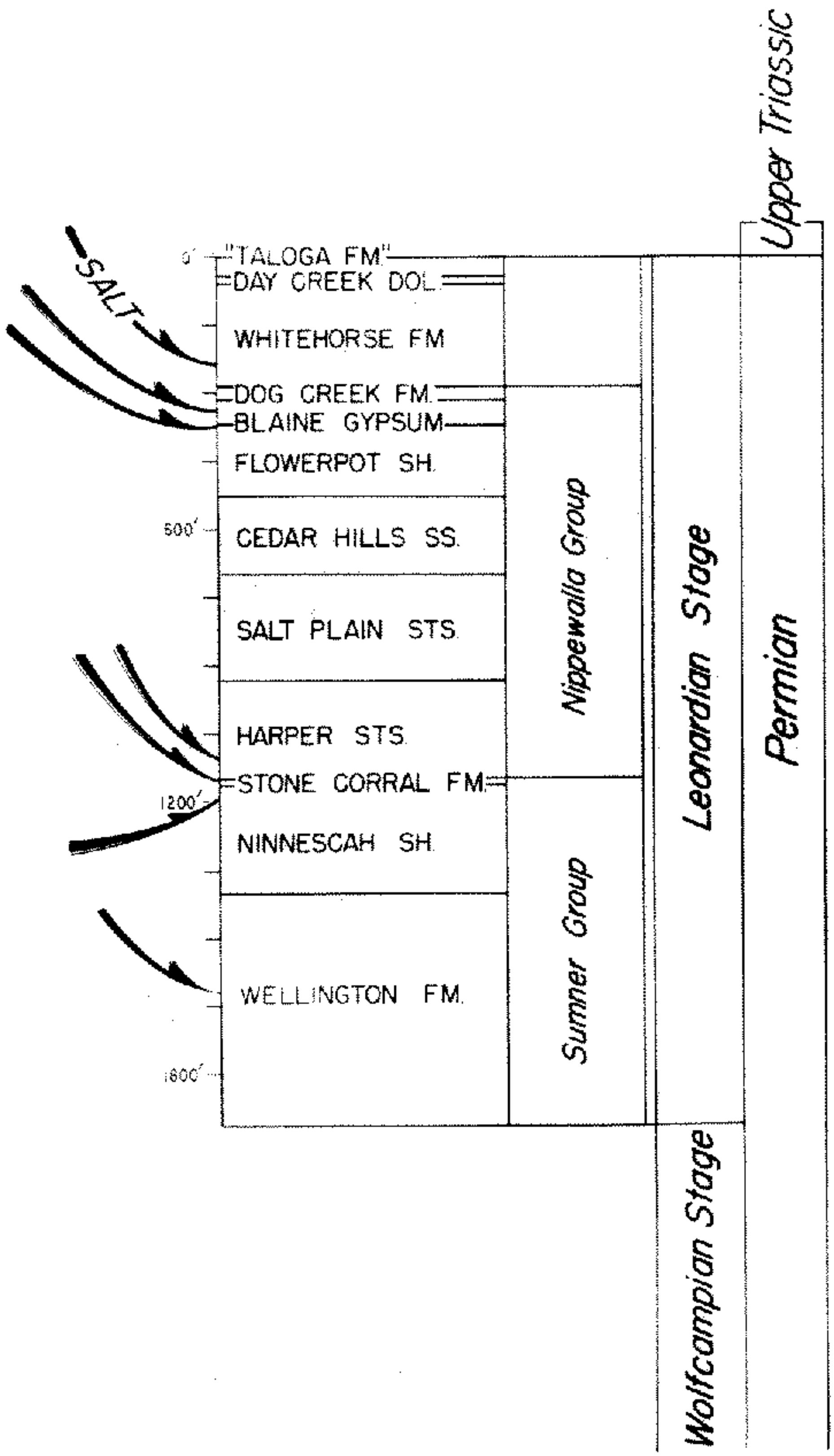

Figure 1. Distribution of salt beds in the Permian of Kansas.

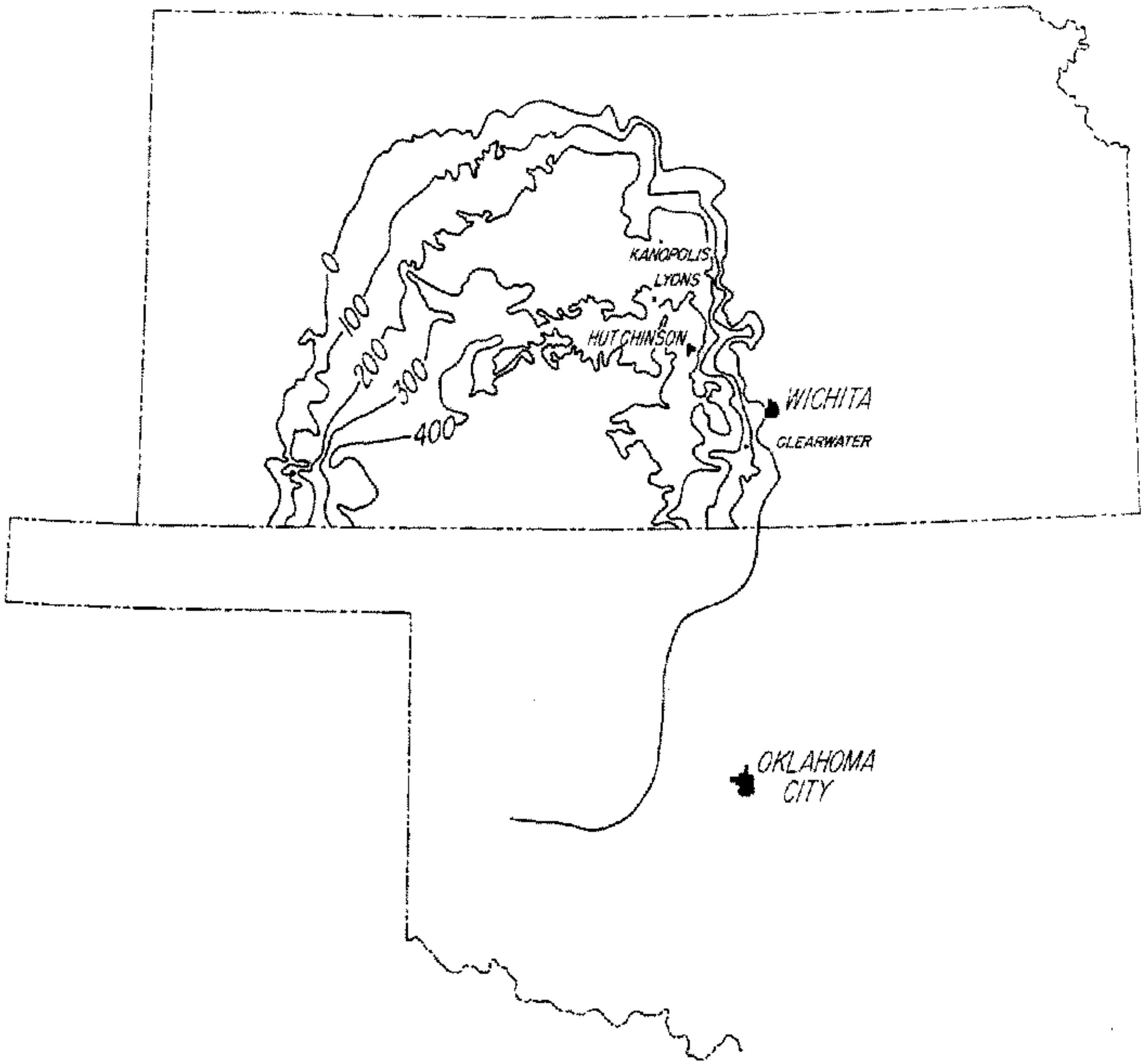

Figure 2. Generalized map showing the areal extent of the Hutchinson salt in Oklahoma and Kansas and the thickness of the of the salt in Kansas. Isopach interval, 100 feet. Modified from Kulstad (1959, pl. 1) and Jordan (1961, p. 272).

studied in the exposed salt sections. For examination of complete sections a core taken at the U.S. Naval Air Station near Hutchinson and several additional cores taken by Frontier Chemical Co. near Clearwater, Kansas, were available.

Along the western margin of the basin the salt is sufficiently deep to have been protected from solution by groundwater, but not so on the eastern margin, where the salt within 200 feet of the surface is marked by solution cavities and where collapse and distortion of the overlying sediments is noticeable. Although it has long been suspected that the salt was originally deposited over a larger area, only recently has an unconformity at the top of the Hutchinson on the eastern margin been proved by coring three holes near the margin of the basin (but west of the zone of solution) southwest of Clearwater, Kansas, along an east-west line and approximately 1.75 miles apart (Stricker, personal communication) (Figure 3). Excellent detailed logging and correlation definitely proves that the present eastward limit of the salt was not the limit of deposition, the present eastward limit being defined by erosion prior to deposition of the truncating shale. Along the unconformity there is no evidence of concentration of shale and anhydrite debris which might be suggestive of solution of salt by groundwater below the unconformity following deposition of the overlying shale. Without venturing too far on the basis of very limited information, it might be pointed out that this upper salt, now removed along the eastern margin of the basin, may have provided a possible source for the upper part of the Hutchinson salt.

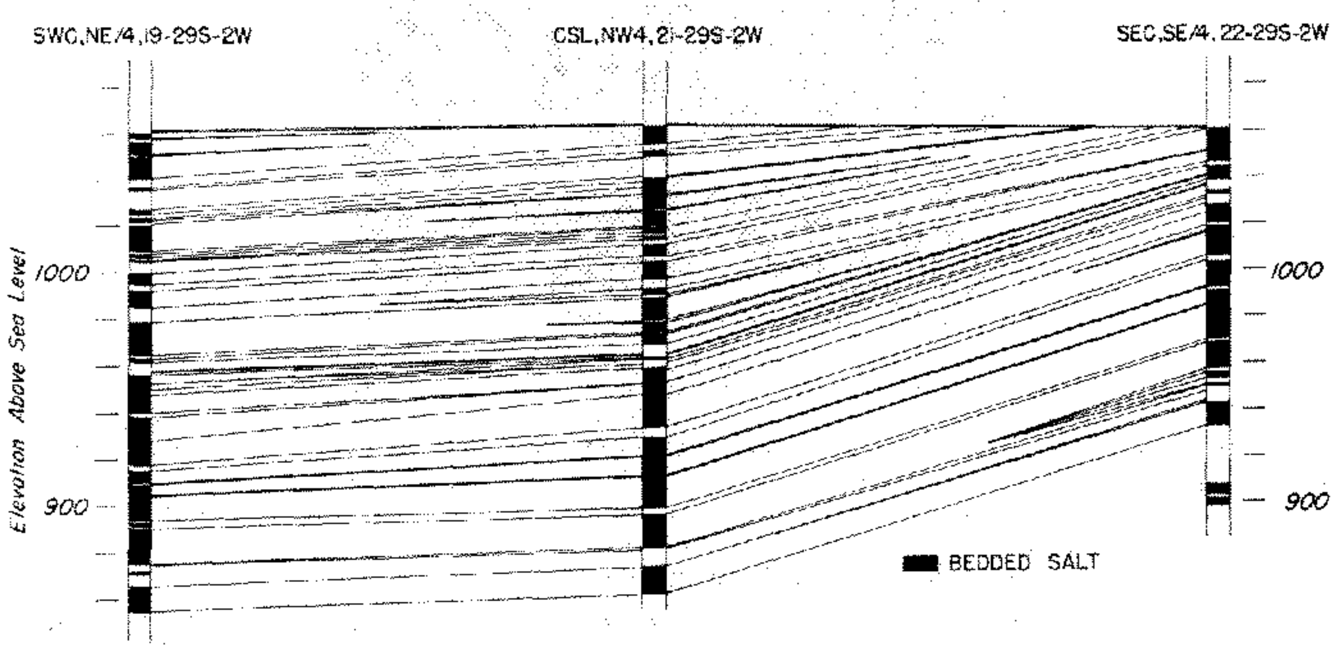

Figure 3. Generalized sections of cores showing the unconformity at the top of the Hutchinson salt, between 0.5 and 4.5 4.5 miles west of Clearwater, Kansas. Salt beds are shown in black. Modified from Stricker, report for Frontier Chemical Company.

COMPARISON OF N.Y., MICH., AND KANSAS BEDDED SALT AND PREVIOUS INTERPRETATION OF ENVIRONMENT OF DEPOSITION

By way of introduction, a comparison might be made between the mine sections at Detroit, Michigan, Retsof, N.Y., and Hutchinson, Kansas, and conclusions previously reached concerning environment of deposition of Michigan salt might be summarized inasmuch as they were used as a basis for study of Kansas deposits. In addition, substantiation of some conclusions was obtained from study of Kansas deposits. The value of each of these deposits in the determination of conditions of deposition lies in the lack of post-lithificational deformation and recrystallization as indicated by the non-disturbance of primary sedimentary features. In Kansas the major salt impurities are clay and anhydrite (Figure 4). The so-called "Jahresringe" are laminae primarily of clay or anhydrite spaced 0.25 and 3.0 inches apart. Salt crystals show considerable variance in size, in general, where crystals are small they are rich in fluid inclusions outlining hopper

Figure 4. Typical development of "jahresringe" on 10 foot working face, Hutchinson, Kansas mine, Carey Salt Company.

structures and where large they are generally clear. In Michigan the major impurity is anhydrite, which is also concentrated in laminae. As in Kansas, there is no regular spacing of the laminae, and the salt consists of both clear and cloudy crystals. In New York salt there is more uniformity of grain size (less than 0.25 inches) and "Jahresringe" are not developed. Layering can be recognized only as broad zones of lighter and darker material.

The previous study of the Michigan salt led to the conclusion that the so-called Jahresringe or seasonal layers do not indicate climatic changes but represent periods of influx of brine into the basin. With the addition of new brine to a basin in which salt is being deposited, calcium sulfate is first precipitated to form a lamina, this being followed by renewed precipitation of sodium chloride. Seasonal changes, it was believed, were shown by the layering of the clear and cloudy salt (Figure 5). The cloudy crystals contained liquid inclusions, which outlines pyramidal shaped hopper crystals that grew at the surface of the brine in the same manner in which grainer salt crystals are produced in grainer pans (Figure 6).

> "Crystal growth is effected by evaporation at temperatures below boiling in order to prevent turbulence and permit the formation of a thin surface film of high density brine. In this film the halite crystals begin to grow. As growth continues the cube tends to sink under its own weight although it is held at the surface by surface tension. Because only one cube face of the crystal is in contact with the high density film, growth takes place only along its edges. In this manner while the crystal sinks, growth continues upward and outward along these edges resulting in a hollow pyramid with its apex pointing downward. When the surface is disturbed the crystals are broken or swamped and sink.

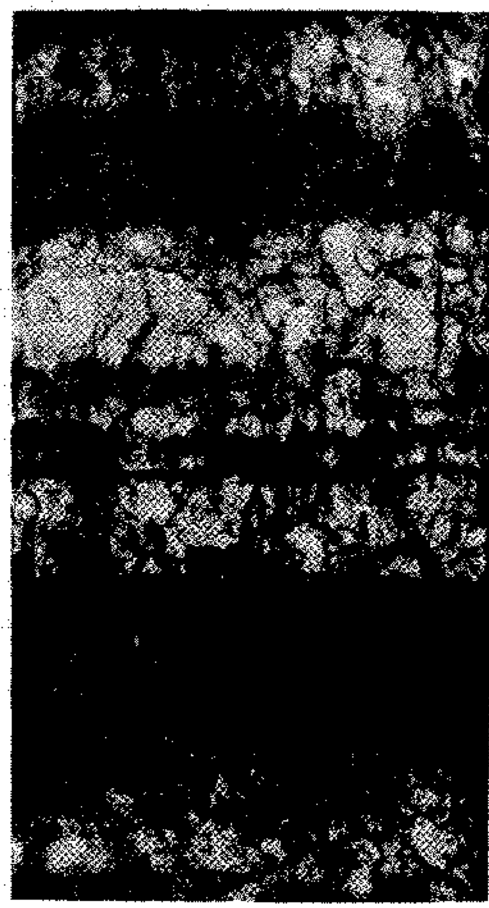

Figure 5. Section of core from the Salina salt (Silurian) of Michigan: G. Bradley No. 4 well, Newaygo County. Section shows layering of clear (inclusion) free) and cloudy (inclusion rich) salt. Section is 5.5 inches long.

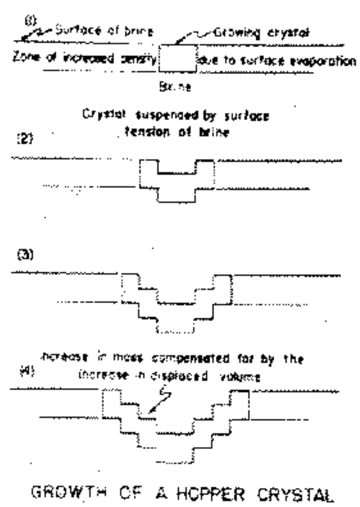

Figure 6. Schematic diagram showing method of growth of hopper crystals.

Growth of salt crystals at the surface of present day saline lakes and basins is not uncommon and the hopper crystals have been reported by Eardley (1938) in the salt mush along the margins of Great Salt Lake." (Dellwig, 1953, p. 730-731)

Such crystals are apparent in Michigan and Kansas salt deposits, and their presence is an indication of the minimal amount of recrystallization that has occurred. Layers of clear salt, on the other hand, resulted from crystallization in the bottom of the basin. Thus,

"alternation of bands of clear and cloudy salt is a seasonal function. During the warm periods halite, which is precipitated from the surface as pyramidal shaped hopper crystals, may go into solution so that a saturated, dense brine is developed on the bottom of the basin. Deposition of halite, after the establishment of equilibrium between halite crystals and the solution, then form a layer of cloudy, pyramidal hopper crystals. On cooling the brine becomes supersaturated and crystal growth takes place around hopper nuclei. Thus layers of pyramidal shaped hopper crystals represent deposition at which time the bottom layer of brine is saturated with sodium chloride, and layers of clear salt represent crystallization from a supersaturated brine due to a drop in temperature. This cycle may be interrupted by the addition of brine to the basin or by periods of unusual climatic conditions." (Dellwig, 1955, p. 107)

SIGNIFICANT FEATURES IN KANSAS SALT

It cannot be overemphasized that many of the features that have been studied and interpreted are features that have not been proved in depth, that is, they have been studied in mine sections but by their very nature cannot be studied in cores. Those features which are to be considered and which have some bearing on the environment of deposition are:

1. Layering of clear and cloudy salt, evidence of recrystallization, variations within the salt section.
2. Jahresringe (seasonal layering) or laminations of shale and anhydrite.
3. Interbedded thick shales and anhydrite and associated features.
    a. Mud cracks, ripple marks.
    b. Red salt, both in cracks and beds.
    c. Layering of shales and anhydrite, relationship of shales to salt, primary structures of shales.
    d. Polygons.

Layering of clear and cloudy salt

As in the deposits of Michigan, so also in the Hutchinson, is banding of clear and cloudy salt pronounced. No particular cyclic relationship is apparent between clear salt, cloudy salt, and shale and anhydrite. As previously postulated, the clear salt was produced during a period when basin waters were cooling seasonally, that is, it was crystallized from brine that became supersaturated by virtue of reduction in temperature. Although temperature change has only a small effect on solubility, this mechanism could develop thin layers of clear salt, but a relatively large is not unreasonable seasonal temperature change or great water depth would be required for deposition of thick layers. Inasmuch as thick layers of clear salt are common, an alternate explanation seems desirable. Recrystallization in the bottom of the basin may have been a function not of temperature change but rather of time. If salt was deposited at a relatively rapid rate there would be little opportunity for solution and recrystallization, whereas if salt was deposited at a slow rate, recrystallization in the bottom of the basin would result in an increase in size of crystals, destruction of the hopper structure, and development of clear salt. It is suggested that within the salt section there is no direct indication of seasonal changes in climate, although the rate of precipitation may reflect climatic changes. Climate could have been seasonal, but the lack of evidence of seasonal changes in the salt leaves open the possibility for nonseasonal climatic conditions at the time of deposition. Nonseasonal climate has been postulated in the midcontinent in Pennsylvanian time but no information is available concerning Permian conditions.

Jahresringe

As previously mentioned, it was originally postulated that these layers represented seasonal temperature changes that caused acceleration of deposition of anhydrite. Although argument may be presented supporting this postulate for those deposits in which the laminae are composed of anhydrite, it is difficult to extend this line of reasoning of salt deposits in which the laminae are composed of clay. In addition to laminae of clay, there are interbedded clay layers of various thicknesses, logically deposited under the same conditions as are laminae, the result of influx of sediment-bearing waters from the marginal areas of the basin.

The laminae are not uncommonly ripple marked. In gross relationship the laminae show near-perfect parallelism. In detail the anhydrite layers are more generally thin zones in which the anhydrite is dispersed and they reflect the expected irregularity of the basin bottom due to angularity of the crystals. Shale laminae, in contrast, generally are smooth or undulating and seem to have been deposited on a surface that was smoothed prior to deposition of the shale. In addition, shale beds that attain thickness greater than that of the normal lamina are generally interlaced with fractures filled with red salt.

Layers of anhydrite and layers of shale both represent periods of addition of water to the basin sea water and water from the adjacent land respectively. It should be recalled that the salt is contained within the Wellington shale and thus clay was exposed on the surface surrounding the salt basin. If fresh water were supplied from the adjacent land area, deposition of salt would be interrupted as a surface layer of fresh water spread over the basin, and if mixing took place, some solution and smoothing of the salt surface might precede settling of the clay and the associated carbonaceous material. Brine added to the basin would also interrupt precipitation of the salt, but if the brine were already concentrated almost to the point of salt deposition, initial deposition of anhydrite would take place without previous erosion of the bottom.

Thick interbedded shales and anhydrite

Shale and anhydrite occur in units of diverse thickness interbedded with halite and with one another without pattern. Undoubtedly the most striking feature of the shale beds is the universal development of mud cracks and their filling with red salt. (Figure 7.) These cracks are

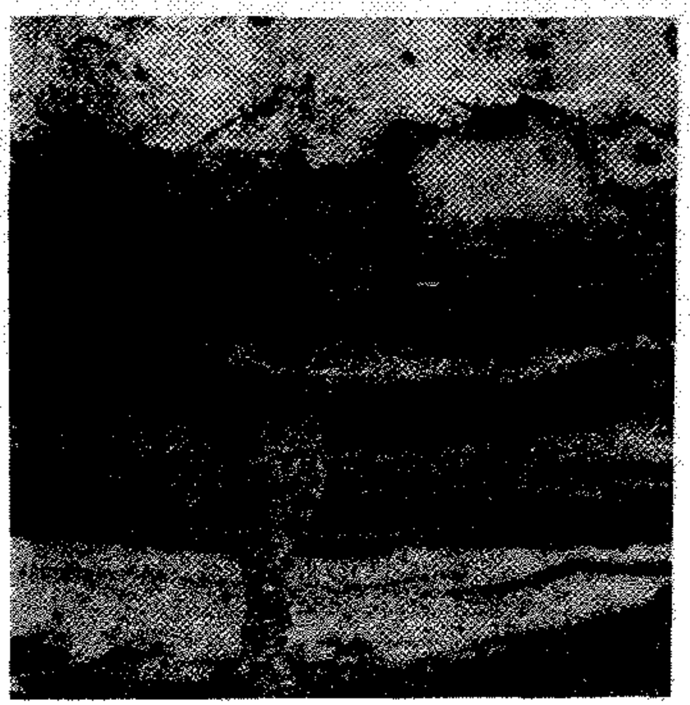

Figure 7. Vein of red salt filling mud crack. Red salt terminates upward against overlying anhydrite layer which in turn is overlain by salt. Vein is approximately 0.05 inches wide. Hutchinson, Kansas mine, Carey Salt Company.

associated with all shale beds, are more irregular than polygonal in pattern, and terminate upward or downward by pinching out or by abrupt truncation by salt or anhydrite. The dip of the cracks ranges from vertical to 40°, individual cracks changing in attitude over a distance of only a few inches. Where the cracks are inclined, the surfaces are polished and striated.

The red salt is not uniformly colored although dispersed clots and membranous masses give an overall impression of uniformity, especially in thin veins. Water solution of the salt yields a clear liquid and a water-insoluble red material. Chemical analyses report no potassium in the salt and about 23 percent ferric iron in the residue. The residue was examined by Ralph Reiser of St. Mary's College, Wichita, who identified bacteria and related organic forms. In a large part, at least, the precipitation of the iron is attributed to bacterial action. The residue is also found dispersed in zones of coarsely crystalline halite but there too is associated with a large quantity of dispersed clay clots or masses. In many veins a banding of red precipitate is to be observed parallel to the salt-shale contact (Figure 8), the iron-rich residue seemingly accumulating periodically rather than continuously. Generally a thin film of red iron precipitate overlies a thick shale layer. Vein salt is generally acicular, the crystals growing normal to the contact. Many of crystals are distorted, as is also the shale. Microfolds and faults attest to the force of crystallization exerted by the salt on the plastic, seemingly unlithified shale.

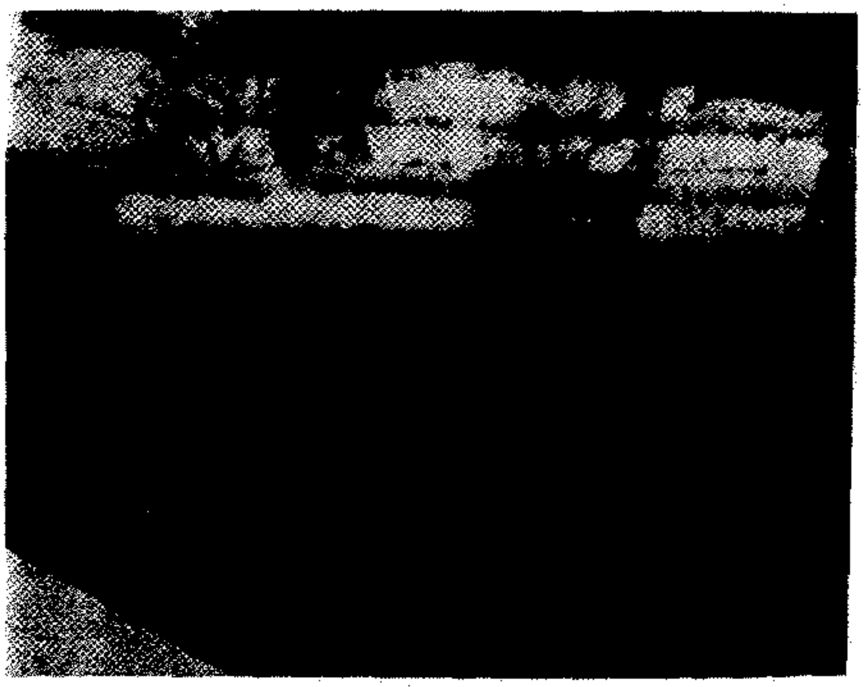

Figure 8. Vein salt in mud crack. Gray areas of vein are rich in iron, white areas are clear salt, black areas are clay. Vein is approximately 0.25 inches thick. Kanapolis, Kansas mine, Independent Salt Company.

Doubtless the shale (rich in iron) or the waters that carried the clays into the basin were the source of the iron. Although much of the iron was precipitated by bacterial action, some precipitation may have been effected by a change in chemical conditions, obviously related to an increase in salinity, inasmuch as the growth of salt in the mud cracks is closely associated with the reprecipitation of halite.

At Retsof, N.Y., red salt is associated with shale breccia zones, such zones resulting from solution of salt and subsequent collapse of overlying shale. Red precipitate is confined to these zones and is not found in normal bedded salt.

Thick shales show relatively poor stratification, and in some it is almost non-existent. Characteristic of the thick layers is a relatively smooth contact with the underlying salt, suggesting as in the case of the laminae that the surface had undergone erosion prior to deposition of the shale. This is not unreasonable, inasmuch as the shales were deposited from clay-bearing waters entering the margins of the basin, which waters could have been sufficiently dilute, even if intermixed with brine, to erode the subaqueously exposed salt layer. The occurrence of discontinuous layers or lenses of shale observed regionally in the salt section attests to the sweeping of the bottom by currents or waves. Excellent testimony of the movement of brine along the bottom of the basin is found in the development of ripple marks, which show particularly well where outlined by clay laminae.

Thick layers of anhydrite, on the other hand, do not generally show this smooth contact with underlying salt, and most are in contact with the underlying salt across an irregular surface reflecting the shape of halite crystals. Previously deposited salt did not dissolve, either because the added brine was concentrated or because it was not intermixed with the concentrated brine already in the basin.

Large scale polygons

A well-developed polygonal pattern is exposed in the roof of the Kanapolis mine. The polygons range in size from 3 to 10 feet, most being between 7 and 7.5 feet across. (Figure 9.) They are outlined by borders of anhydrite as much as 7 inches across and 2 inches thick. The polygons

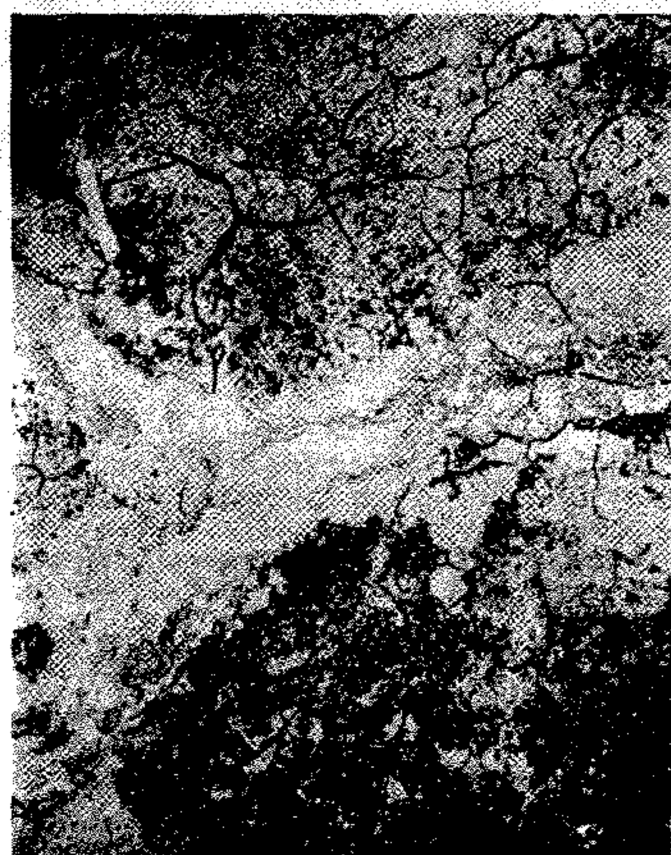

Figure 9. Section of roof, Kanapolis mine, Independent Salt Company. Broad, white bands are of anhydrite and outline polygons, parts of three of which are shown. Red salt shows as dark slashes within the polygons. Pencil taped to roof in upper left quadrant.

fill depressions in a shale bed (removed through mining). The pattern occurs at this level throughout the mine. Veins of red salt do not cut the anhydrite, but inclined fractures (extension of fractures filled with red salt in the clay) may extend through the anhydrite in the form of micro-faults. In detail the anhydrite shows considerable deformation (Figure 10) and intermixing with shale. It is proposed that the anhydrite was precipitated from the readvancing sea, as a more or

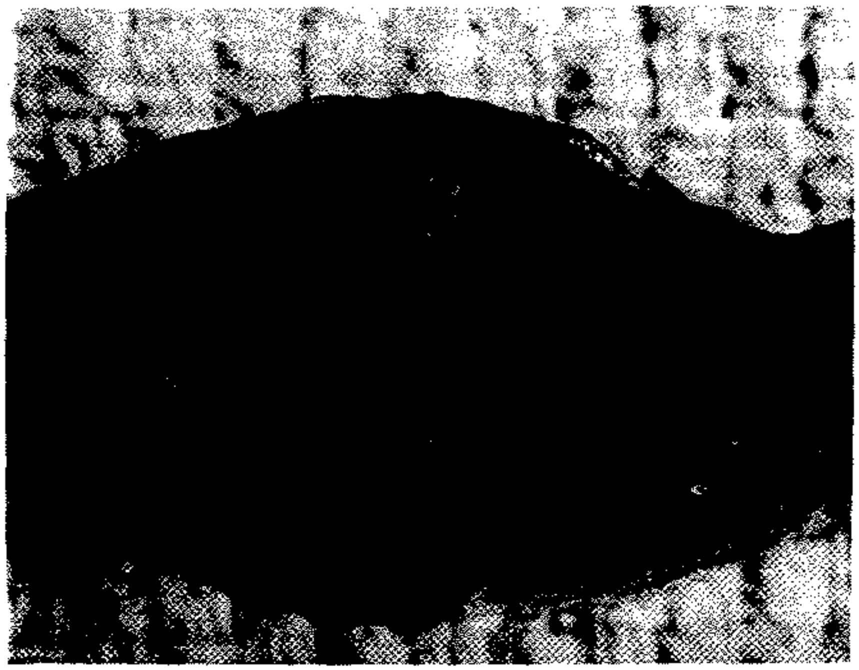

Figure 10. Section through anhydrite zone which outlines a polygon. Section shown is approximately 0.7 inches thick. Kanapolis, Kansas mine, Independent Salt Company.

less uniform layer. While still in the state of semi-lithification it was swept by bottom currents into the low areas outlining the polygons, where it was preserved by the deposition of the overlying salt. The pattern resembles the mud crack pattern observed in a desert area in Libya (Figure 11). The photograph vividly portrays the nature of the surface over which saline waters might be visualized as readvancing. In the early stages of evaporation (prior to deposition of halite) was precipitated the anhydrite that became concentrated in the troughs outlining the polygons.

CONCLUSIONS

The great variety and complexity of the relationships between salt, shale, and anhydrite is recognized. Many of these can be explained by variations in combination or intensity of conditions. Basically, frequent periodic subareal exposure of salt flats indicated by mud cracks and polygons suggests shallow basins in which the salt was deposited. Lack of potash minerals in the sequence, and also the deposition of anhydrite in the southern part of the basin at the time of deposition of halite to the north, suggest reflux as an operating mechanism; but frequent fluctuation of brine level suggests the possibility of modification or temporary interruption of the operation by the modification of the bar. Laminae of anhydrite indicate a periodic but sporadic addition of brine to the basin, whereas laminae of clay attest to the addition of fresh water from the adjacent land. The salt provides no positive evidence suggesting seasonal climates. Variations in the rate of deposition are indicated in the alternation of clear and cloudy salt.

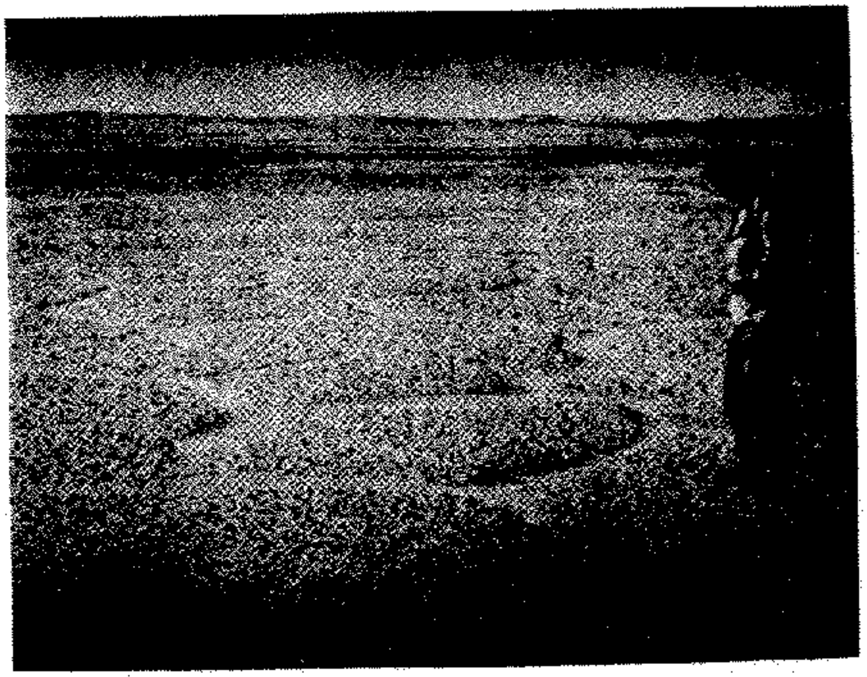

Figure 11. Polygon pattern on desert south of Nan En Namus, Libya. Photograph courtesy of G. Knetsch.

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