Barren Halite Zones in Potash Deposits Carlsbad, New Mexico

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ABSTRACT

Barren zones in ore, called "salt horses," are locally abundant in the potash beds of the Carlsbad district of southeastern New Mexico. Detailed mine mapping has provided information on the character and origin of some of these features.

In the area studied, the ore zone contains three ore members, each about 2.5 feet thick, separated by orange halite marker beds. The ore members contain clear halite, red and milky sylvite, traces of sulfate minerals, and gray clay. The marker beds contain disseminated orange polyhalite and red or milky sylvite.

The salt horses are irregular in size and shape. In plan, their width ranges from 1 to 350 feet; their length from 15 to over 550 feet. In cross section, the widths generally decrease from the lowest to the highest ore member, giving the salt horses a domal form. Salt horses limited to the bottom ore member are commonly associated with small anticlines. The beds in the salt horses are thinner than the equivalent beds in ore. The contacts between salt horses and ore are sharp. The color of the clay changes from gray in ore to brown in salt horses. Pods and lenses of langbeinite, leonite, kainite, recrystallized halite, and recrystallized sylvite occur in ore near the salt horses. The disseminated polyhalite of the marker beds is locally concentrated into intergranular seams and pods.

The observed features seem best explained by assuming that NaCl-saturated brines containing Ca, Mg, and SO_4 *entered the ore zone from below and formed salt horses by the selective leaching of sylvite. This process caused thinning of the beds, the precipitation of langbeinite, leonite, kainite, and halite, the transfer of hematite pigment from red sylvite to the clays, and the recrystallization of halite, sylvite, and polyhalite.*

INTRODUCTION

The Carlsbad potash district is located 15 miles east of the city of Carlsbad in southeastern New Mexico. The district covers an area of approximately 1200 square miles within which six companies are presently producing potassium salts. Production from the district began in 1931, and during the past 33 years 225 million tons of ore have been mined.

Intermittent barren zones, called "salt horses," occur locally in the main sylvite ore horizon of the district, designated the First Ore Zone by the U.S. Geological Survey. The ore zone is normally composed of an intergrowth of halite and sylvite, but in salt horses the sylvite is absent. This paper discusses the results of underground mapping in an area containing salt horses at the mine of the International Minerals and Chemical Corporation.

The regional geology of the Permian rocks of west Texas and southeastern New Mexico has been described by many authors. Perhaps the most comprehensive discussion was published in 1942 by P.B. King. Detailed discussions of the Salado evaporite formation and the potash deposits it contains are, however, rare. The broad regional stratigraphy of the evaporites was described by J. E. Adams in 1944. C. L. Jones presented a more detailed description of the evaporite stratigraphy and mineralogy of the Carlsbad district in 1954. A description of the mineralogy of potash drill cores is contained in a bulletin by W. T. Schaller and E. P. Henderson (1932). J. C. Dunlap (1951) published the results of mine mapping in the Fifth Ore Zone at the mine of the International Minerals and Chemical Corporation.

The presentation of this paper was made possible through the interest and permission of the International Minerals and Chemical Corporation, in particular Dr. F. C. Kruger, Vice President of the Mining and Exploration Division, and Dr. D. L. Everhart, Chief Geologist. We gratefully acknowledge the cooperation and assistance of the personnel at the Carlsbad operation, managed by Mr. S. A. White.

REGIONAL GEOLOGY

The Permian strata of west Texas and southeastern New Mexico are composed of chemical sediments deposited from epicontinental seas and lesser amounts of clastic rocks derived from adjacent land masses. King (1942, p. 665) and others have divided the area into several provinces on the basis of changes in the thickness and types of sediments. The principal sedimentary provinces are shown in Fig. 1. The Carlsbad district is located on the north edge of the Delaware basin, a pronounced negative area throughout Permian time. This basin was separated from the Midland basin to the east by the Central Basin Platform. Though the platform was submerged throughout most of Permian time, it apparently subsided less than the adjacent basins and therefore received a thinner layer of sediments. The shelf area to the north of the Carlsbad district also has a thinner Permian section than the basins and contains a higher percentage of clastic rocks.

The abundance of marine fossils, algal reefs, and finally evaporites in the Upper Permian rocks demonstrates clearly that the area was in at least intermittent contact with the ocean. The deposition of gypsum, anhydrite, halite, and potash salts near the end of Permian time has been

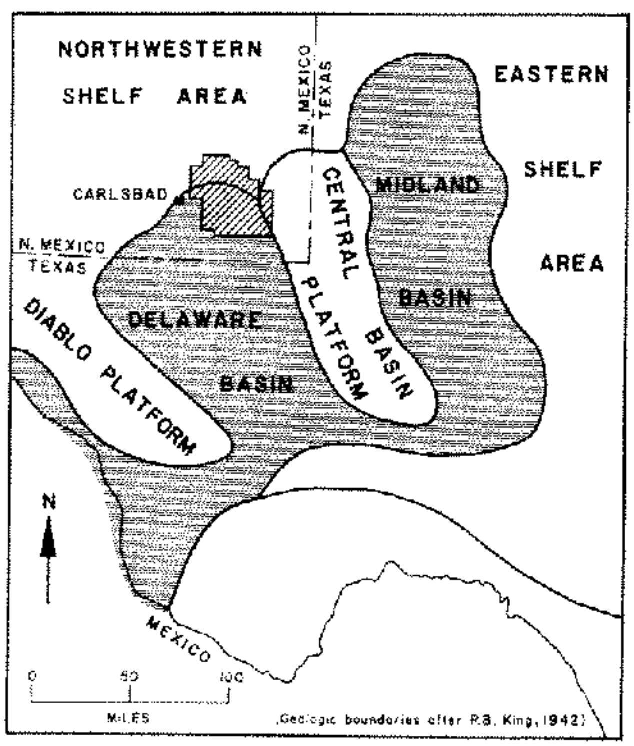

Figure 1. Location map of the Carlsbad potash district.

logically interpreted to indicate that evaporation exceeded the combined influx of ocean and terrestrial waters. This may have been accomplished by a restriction of the connection with the open ocean, which is presumed to have been southwest of the Delaware basin.

The basin margin area through the central part of the Carlsbad district marks the transition from the thick basin sediments on the south to the thinner sequence on the shelf (Fig. 2). This marginal area also corresponds to the position of the buried Capitan reef which developed around the margin of the Delaware basin prior to the deposition of Upper Permian evaporites. Note that potash mines occur both north and south of the margin area, indicating that the distribution of potash was not restricted by the reef. The International Minerals and Chemical Corporation mine is within the Delaware basin.

The rocks of the Permian system are divided, from oldest to youngest, into four series: Wolfcamp, Leonard, Guadalupe, and Ochoa. The rocks of the upper Guadalupe and Ochoa series in the Carlsbad district are shown schematically in Fig. 3. The Guadalupe series in the basin margin area is represented by the Capitan formation. The formation is composed of massive algal limestone and fore-reef talus and attains a maximum thickness of 2,100 feet. It gives way to bedded limestones both on the shelf and in the basin. Overlapping the Capitan formation, but limited to the Delaware basin, is the Castile formation of lower Ochoan age. This formation is composed of calcite-banded anhydrite with halite and anhydrite beds becoming more important toward the north edge of the basin and in the upper part of the formation.

The Salado formation overlies the Castile in the basin and upper Guadalupian limestones on the shelf. It is an essentially continuous sequence of salt with minor anhydrite, polyhalite, and detrital beds. Within the potash district its depositional thickness increases from 1,000 feet on the shelf to 2,000 feet in the basin. Along the western edge of the district the entire halite section has been removed by subsurface erosion. The portion of the Salado formation containing the First Ore Zone is shown in expanded form on the right side of Fig. 3. The halite intervals are composed of coarse- to fine-grained clear halite, with variable amounts of disseminated clay and polyhalite. The polyhalite beds are generally brick red, massive, and fine-grained. The anhydrite bed is gray, medium- to fine-grained, and generally banded.

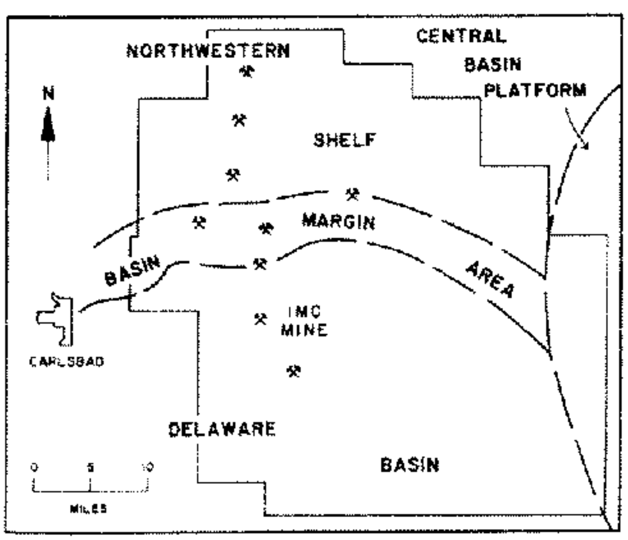

Figure 2. Index map of the Carlsbad potash district, showing locations.

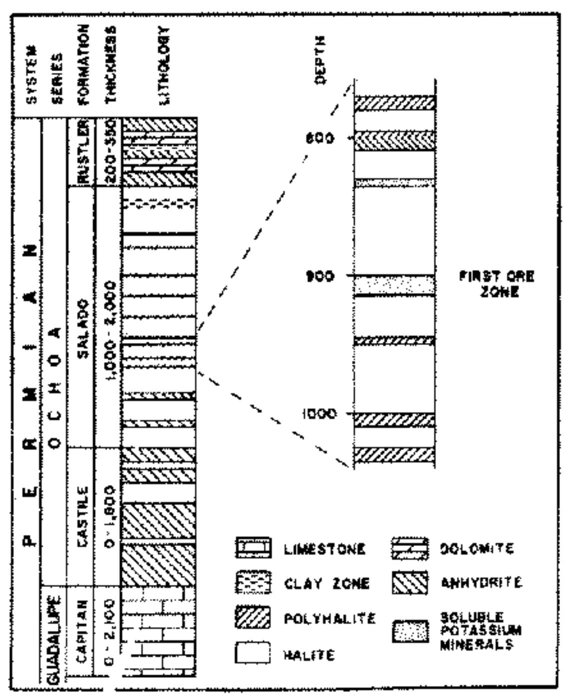

Figure 3. Schematic columnar section of the Carlsbad potash district.

FIRST ORE ZONE

The First Ore Zone is normally between ten and fifteen feet thick and is bounded both above and below by clean halite rock. The ore zone contains more clay than the average halite rock though it is not evenly distributed throughout the bed. The upper 2 or 3 feet of the ore zone contains 5-10% brown clay with two prominent clay partings. At the bottom of the ore zone is a poorly defined clay-rich interval 1 or 2 feet thick. Both of these clay-rich intervals are usually barren of sylvite or only weakly mineralized.

A generalized section of a mine face in the ore-bearing central portion of the First Ore Zone is shown in Fig. 4. The ore zone may be conveniently divided into six persistent beds which result from the alternation of two rock types. The first rock type is compose of fine- to medium-grained clear halite with disseminated orange polyhalite. These beds are remarkably free of clay. The disseminated polyhalite imparts an orange color to the rock and the beds are referred to as orange halite marker beds.

The second rock type is sylvinite in which the essential minerals are halite and sylvite. The halite is clear, medium- to coarse-grained, and generally subhedral to anhedral. The sylvite is medium- to coarse-grained, anhedral, and milky to deep red in color. The red color is due to very fine-grained hematite within the sylvite crystals. Most sylvite grains have milky centers and red rims. The percentage of red sylvite in a crystal tends to increase with a decrease in grain size. Gray clay occurs within the ore members in discontinuous seams, as clots within halite crystals, and as disseminated clay between the halite and sylvite grains. Accessory minerals found in the ore beds include polyhalite, leonite, kainite, kieserite, langbeinite, quartz, and talc. Though leonite, kainite, langbeinite, and kieserite are locally abundant, all the accessory minerals combined rarely exceed 10% by weight of the bed.

Three sylvite ore members, each two to three feet thick, are designated upper, middle, and lower members in the following diagrams. The ore members are overlain by orange halite marker beds that range from 4 to 12 inches in thickness. Gray clay seams are commonly found along the upper or lower edges of the marker beds.

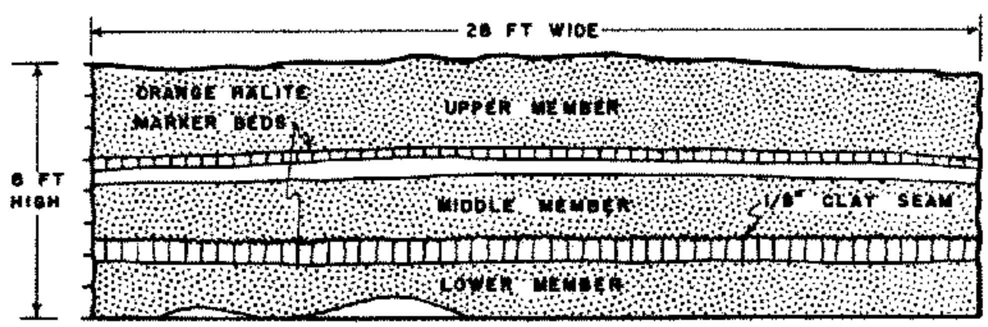

Figure 4. Mine face in normal ore.

SALT HORSES

An area measuring about 1000 feet by 750 feet was selected for study in a portion of the mine in which salt horses are particularly abundant. A series of cross sections of mine faces from this area will illustrate the progression from normal ore to completely barren salt. The mine faces are 28 feet wide and from 7 to 10 feet high.

As an advancing mine face approaches a salt horse, pods of recrystallized, coarsely-crystalline white sylvite and halite begin to appear in the ore. Clay seams and the contacts between marker beds and ore members appear to localize the recrystallized pods, as shown in Fig. 5.

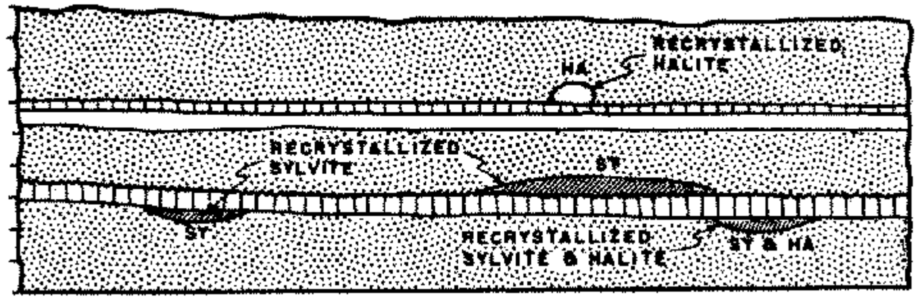

Figure 5. Ore face near a salt horse.

In a traverse from ore to waste, salt horses usually appear first in the lower ore member as shown in Fig. 6. The contacts between ore and barren salt are usually sharp and exhibit a wide variety of shapes.

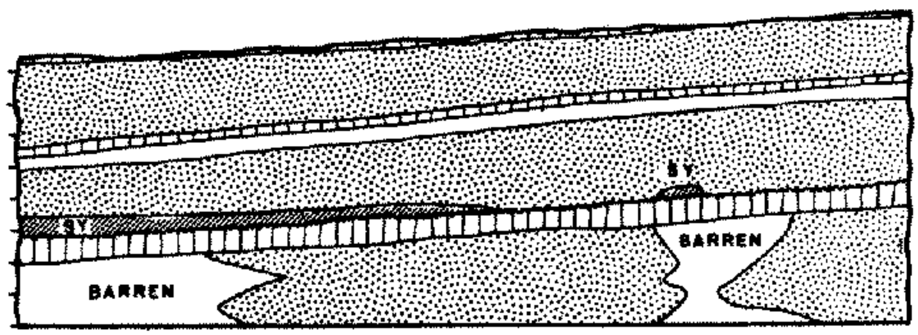

Figure 6. Salt horse in lower member.

Figure 7 shows a salt horse that has affected both the lower and middle ore members. Low-grade sylvite mineralization occurs over the top of the salt horse. A small anticlinal fold 1/2 foot high and 8 feet wide is associated with the salt horse.

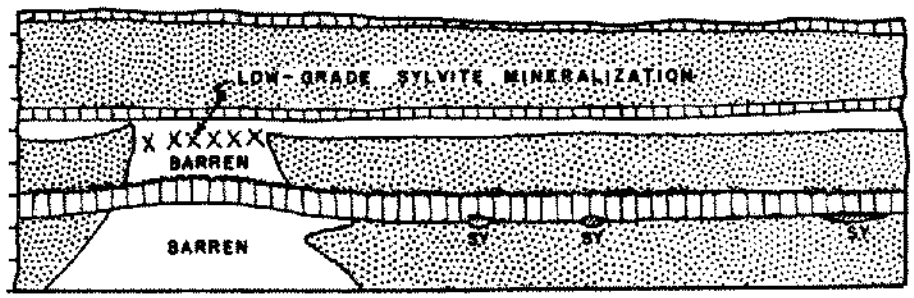

Figure 7. Salt horse in lower and middle members.

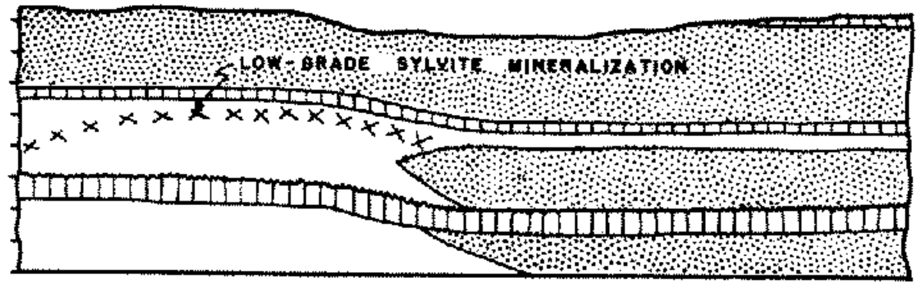

Figure 8. Salt horse in lower and middle members.

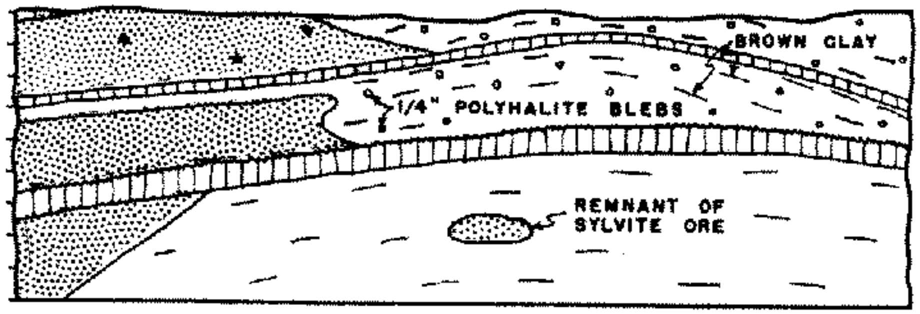

Figure 9. Salt horse in lower, middle, and upper members.

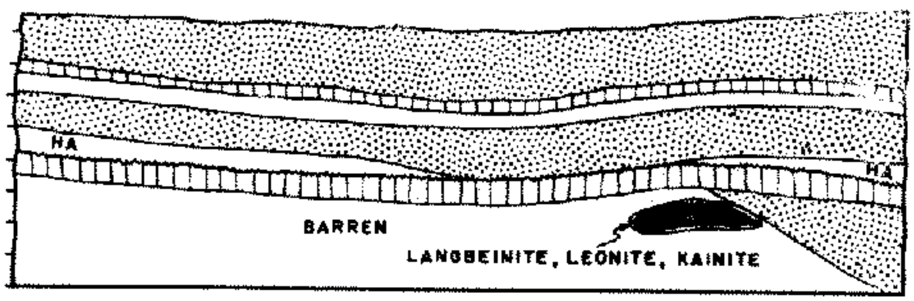

Figure 10. Sulfate pod on edge of salt horse.

A similar type of salt horse affecting the lower and middle ore members is shown in Fig. 8. This horse is also associated with an anticlinal fold having a height of about 1 foot.

Figure 9 shows a salt horse that affects all three ore members. What appears to be an isolated remnant of sylvite ore occurs in the barren part of the lower member. Also conspicuous in Fig. 9 are 1/2 inch blebs of polyhalite and stringers and clots of brown clay which are disseminated in the salt horse. This salt horse is associated with an anticline 2 feet high and over 30 feet wide. A pronounced thinning of the middle member is seen at the right side of the section. The thickness of the middle member in ore at the left side of the section is about 2 1/2 feet. In the salt horse at the right side, the middle member is only 1 foot thick.

Pods of potassium-bearing sulfate minerals, such as langbeinite, leonite, and kainite, commonly occur near salt horses or along the contact between ore and waste. Such an occurrence is illustrated in Fig. 10. Note that the recrystallized halite is localized by the clay seam overlying the lower orange marker bed.

In addition to disseminated blebs, polyhalite was also found locally in a 1-inch thick red seam in the lower orange marker bed, shown in Fig. 11. Note that the red polyhalite seam overlaps ore in the lower member by only a few feet. Brown clay and recrystallized halite also appear

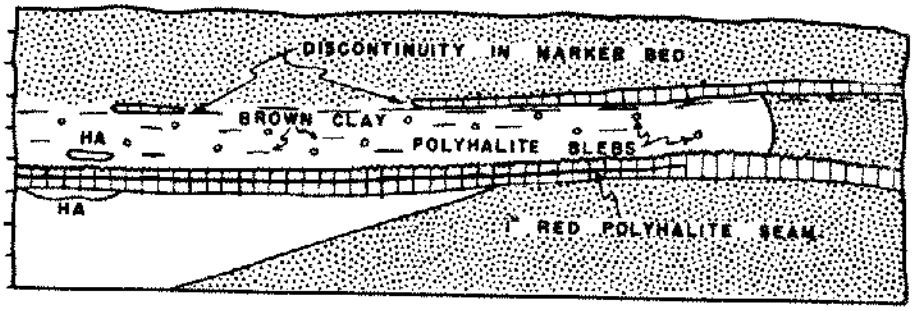

Figure 11. Polyhalite and brown clay in salt horse.

in this salt horse. The discontinuity in the thin orange marker bed is not related to the salt horse because similar interruptions are also found in normal ore.

A second example of red polyhalite in the lower orange marker bed is shown in Fig. 12. Here, again, the polyhalite seam overlaps ore by only 2 feet.

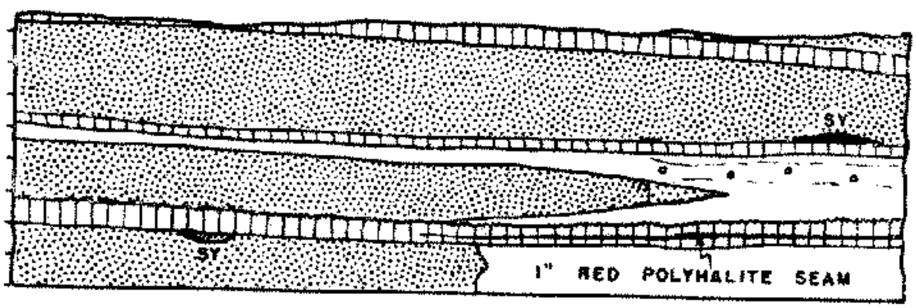

Figure 12. Polyhalite and brown clay in salt horse.

A map of the salt horse area was prepared by combining the results of numerous cross sections of mine pillars (Fig. 13). The beds in the area strike N 62° E and dip 3 1/2° to the southeast.

Salt horses in the upper member usually overlie salt horses in the middle and lower members. Likewise, salt horses in the middle member commonly overlie salt horses in the lower member. Features that are apparent from a study of the map are:

1. Salt horses are most extensive in the lower member, constituting about 50% of the mapped area. Salt horses in the middle member cover 40% of the mapped area, those in the upper member, 25%.
2. There is an approximate concentric arrangement of salt horses in the three members.
3. The shapes of salt horses in the upper and middle members are irregular. Salt horses in the lower member also have irregular shapes, but show a tendency to have fingerlike extensions that strike easterly. A narrow, wormlike salt horse extends east-west across the mapped area for a length of 700 feet. Near the center of the mapped area it approaches a width of 300 feet.

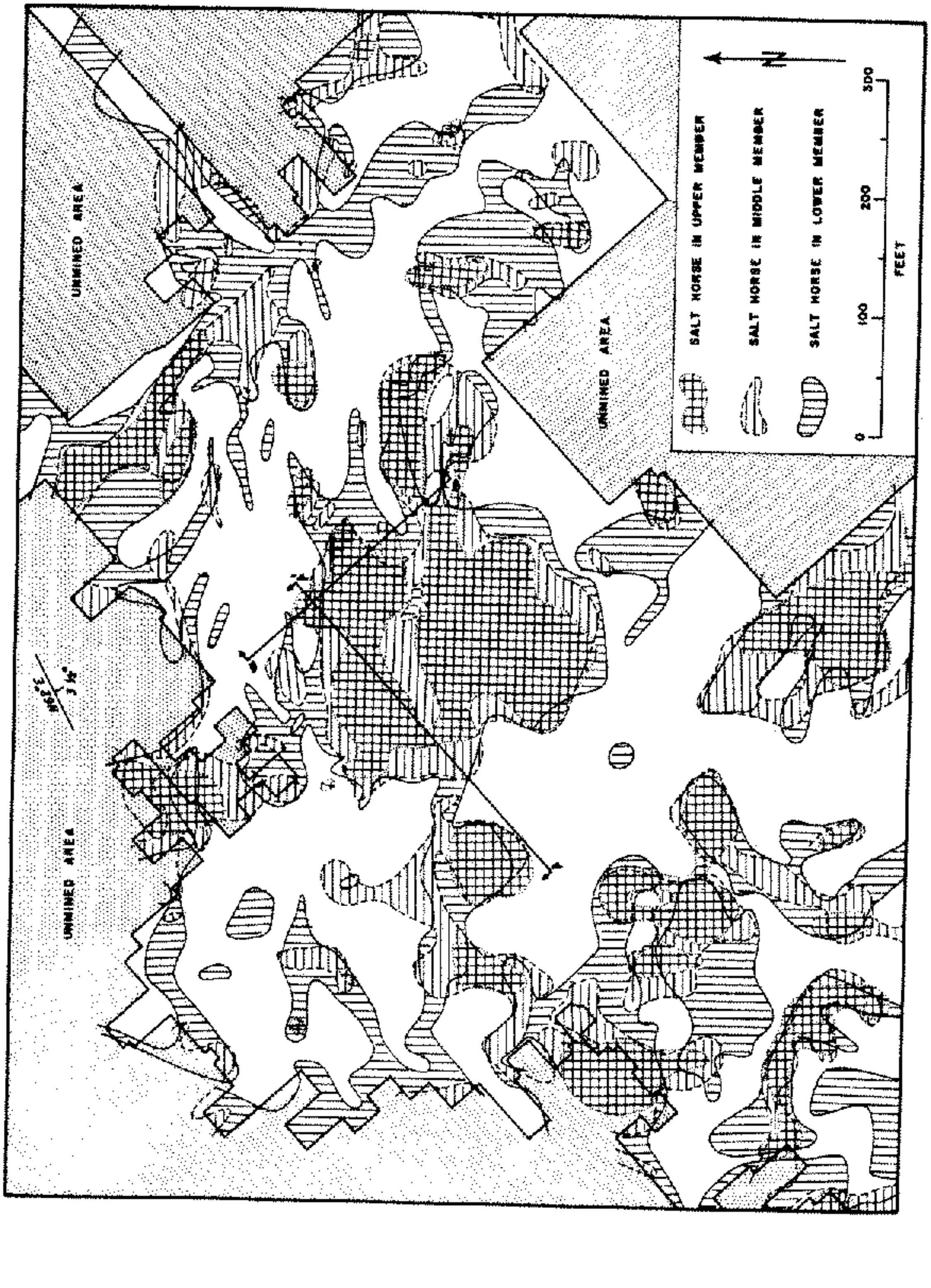

Figure 13. Map of salt horse area.

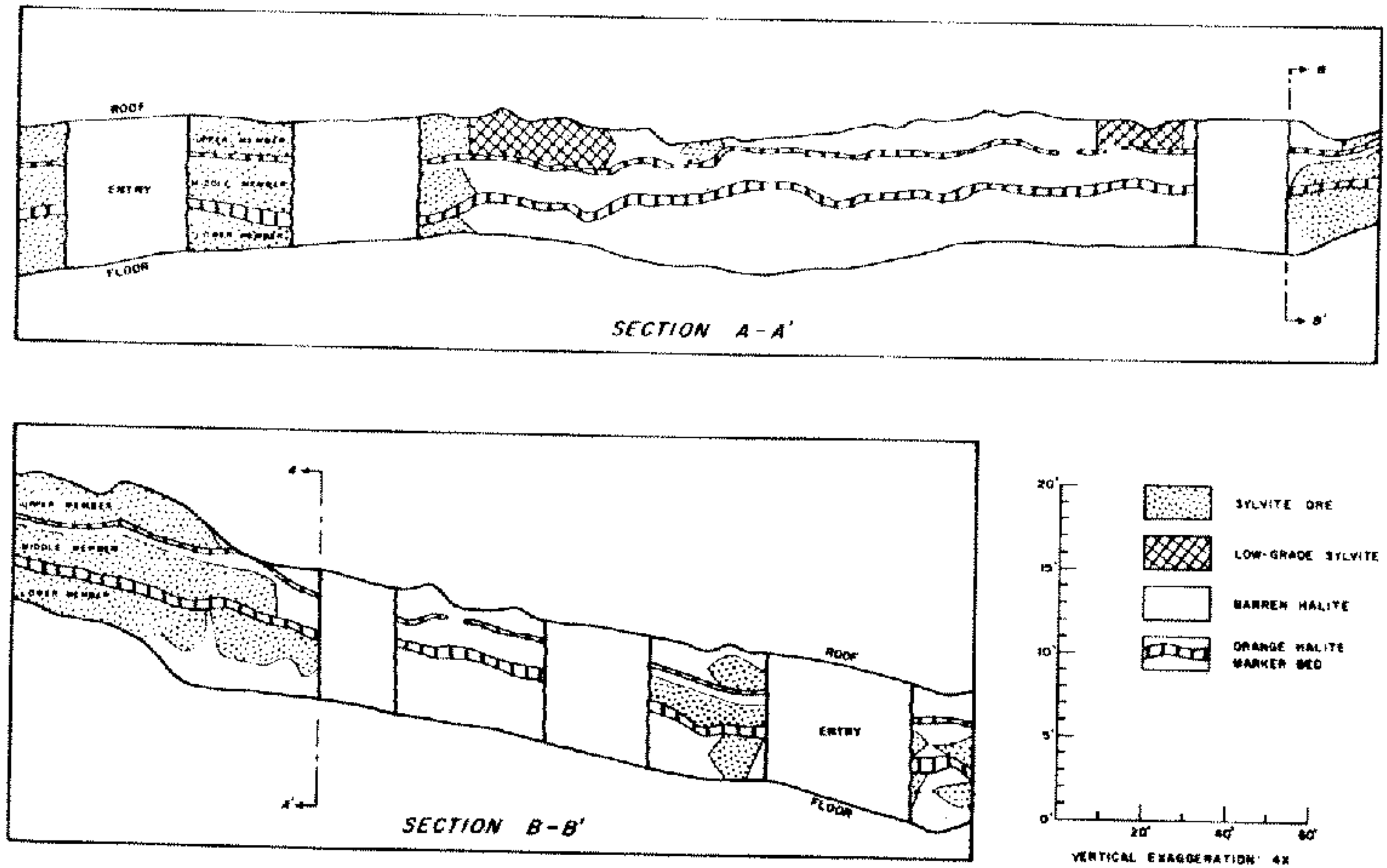

Figure 14. Sections through large salt horse.

4. The horizontal dimensions of salt horses in the area range from 1 foot to over 300 feet.
5. Inclusions of sylvite ore surrounded by barren salt appear at several places on the map.

Two cross sections, labeled A-A' and B-B' on Fig. 13, were drawn through the large salt horse near the middle of the area (Fig. 14). To emphasize any possible relation between folding and the large salt horse, the vertical scale on sections A-A' and B-B' was exaggerated 4 times. The contortions of the bedding and the mine workings are therefore greatly amplified. A study of these cross sections reveals that:

1. There is no large fold associated with the large salt horse. Several small folds with heights of 1/2 to 1 foot occur within the salt horse.
2. There is a good correlation between small folds and ore-waste contacts.

DISCUSSION

The features characteristic of salt horses and the ore zone adjacent to these barren areas have now been described. In our opinion the origin of these features can be best explained by the proposition that after the ore zone was deposited, sylvite was selectively leached by upward-moving brines undersaturated with respect to KCl. The features which appear to support this interpretation are explained as follows:

1. Continuity of stratigraphy. Orange halite marker beds, thin clay seams, and other small stratigraphic units persist relatively unchanged through both ore and barren salt. If salt horses were primary depositional features, we would expect discontinuities to appear in the strata.
2. Cross-cutting nature of salt horses. The contacts between the salt horses and ore cut across the strata abruptly, suggesting that the contacts are younger than the ore members.
3. Domal shape of salt horses. The concentric arrangement of salt horses, with a decrease in size from the lower to the upper member, suggests that the invading brine came from below the ore zone. The occurrence of diffuse ore-waste contacts and low-grade sylvite mineralization above some salt horses probably indicates the brines had become nearly saturated with sylvite and were unable to completely leach the sylvite.
4. Sulfate minerals. The occurrence of lenses and pods of sulfate minerals near the base of the ore zone also argues for unsaturated brines rising through the ore. Any brine derived from the evaporite section below the First Ore Zone would be unsaturated with respect to KCl since the First Ore Zone is the lowest occurrence of appreciable sylvite mineralization. The brine would have become saturated, however, with respect to halite and polyhalite. When the brine was exposed to the base of the ore zone, therefore, it dissolved sylvite and precipitated potassium-bearing sulfate minerals. The sulfate minerals most commonly observed are leonite, kainite, and langbeinite.
5. Recrystallized halite and sylvite. Pods and lenses of recrystallized halite and sylvite are closely associated with the salt horses. Some of these pods cut across both orange halite marker beds and normal sylvite ore, and are obviously post-ore in age.
6. Remnants of sylvite ore in barren salt. Local inclusions of normal sylvite ore in masses measuring 1 to 50 feet across are best explained as portions of ore that have escaped the leaching action of the salt horse brine.
7. Association of anticlines and ore-waste contacts. The close correlation between salt horses and small anticlines has been demonstrated with the cross sections, but the reasons for the observed association are not clearly understood. One interpretation is that the folds existed before the salt horses were formed and were preferred loci for salt horse development. Another interpretation is that the folds and salt horses formed simultaneously in response to the pressure and leaching action of upward-moving brines.

8. Thinning of strata. Equivalent stratigraphic units are thicker in ore than in salt horses. An explanation for the thinning associated with salt horses is that the leaching of sylvite diminished the volume of the ore members.

9. Brown clay in salt horses. The ore members contain hematite-bearing sylvite and disseminated gray clay. In salt horses, however, the clay is commonly brown and has a higher iron content than the gray clay. With the leaching of sylvite, the hematite is transferred to the clay, imparting a brown color.

SUMMARY

A brief resume of the development of a salt horse will serve to summarize our interpretation of the information gained in this study.

We believe that the ore zone was deposited as the lower, middle, and upper members, separated by orange halite marker beds.

Compaction induced by the weight of overlying sediments squeezed interstitial brine from the polyhalite-bearing salt strata beneath the ore zone. Brine released by the conversion of gypsum to anhydrite may also have been important. The bulk of these brines probably escaped by migrating up-dip along clay seams or along the base of less permeable beds. Locally, however, they passed upward and penetrated a potash ore zone.

It is likely that the brines were saturated with respect to halite and polyhalite, but unsaturated with respect to sylvite because sylvite does not occur in significant amounts below the ore zone. The rising brines were probably warmer than the rocks they invaded because they came from a greater depth.

Where the brine encountered an ore zone, a salt horse began to form in the lower member. As more brine was introduced, the salt horse grew laterally and upward, and penetrated the middle and upper members. The ultimate size of the salt horse depended on the amount of brine that flowed across the ore-waste contact.

The polyhalite, langbeinite, leonite, and kainite blebs, pods, and lenses that are associated with the salt horse represent the reaction of a halite and polyhalite-saturated brine with sylvite. The pods and lenses of recrystallized sylvite and halite were perhaps caused by cooling of the brine as it moved out through the ore along clay seams, bedding planes, and grain boundaries. The process of salt horse formation caused a thinning of the beds. After the rising and laterally-spreading brines became saturated with sylvite and cooled to the same temperature as the surrounding rocks, they escaped through the overlying rocks without leaving any signs of their passage.

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