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This is one of many related papers that were included in the 1954 NMGS Fall Field Conference Guidebook.

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Note: Three abstracts containing material pertinent to the escarpment of the Sacramento Mountains have been accepted by the Geol. Soc. America in connection with the 1954 annual meetings in November. These will be printed in the December issue of the Bull. Geol. Soc. America, and are as follows: Otte, Carel Jr., Lower Wolfcampian deposition in the northernmost Sacramento Mountains; Pray, L. C. & Graves, R. M. Jr., Desmoinesian facies of the Sacramento Mountains; and Pray, L.C. & Otte, Carel, Jr., Age and Correlation of the Abo formation in south-central New Mexico.

THE OCCURRENCE AND DISTRIBUTION OF POTASSIUM MINERALS IN SOUTHEASTERN NEW MEXICO

by

C. L. Jones[2]

The closing epoch in Permian time is especially known for the extensive evaporite deposits that fill the Delaware Basin and extend across the Capitan reef zone for considerable distances over the shelf area. This epoch is represented by the strata of the Ochoa series, which includes the following formations:

Dewey Lake redbeds
Rustler formation
Salado formation
Castile formation

Extensive deposits of halite and anhydrite occur in each of the formations except the Dewey Lake, which does not contain evaporite deposits and which is composed entirely of red sandstone, siltstone, and minor amounts of shale. The Dewey Lake red beds form the protective cover that serves to retard the dissolution and removal of the soluble salts comprising the evaporite deposits of earlier formations of the Ochoa series.

Extensive evaporite deposits are found in older Permian formations; but unlike the evaporite deposits of the Ochoa series, the older deposits are restricted entirely to the back-reef or shelf area. The evaporite deposits of the Ochoa series are more extensive and are better known because of their economically important deposits of potassium minerals. As the potash deposits represent a special phase of the evaporite deposits, a brief description of the saline rocks should be presented before discussing the occurrence and distribution of the potassium minerals.

The Ochoa series is conformably underlain by strata belonging to the Guadalupe series and unconformably overlain by strata belonging to the Upper Triassic Dockum group. Outcrops of the Ochoa series are not representative of the thick sequence found in the subsurface. The Dewey Lake red beds appear to be entirely confined to the subsurface; and the outcrops of the Rustler, Salado, and Castile formations contain only the insoluble or more slowly soluble constituents. Wherever these formations have been exposed to weathering conditions during either pre-Dockum time or post-Triassic time, all the halite and a part of the anhydrite have been dissolved and removed by ground water and surface streams; the anhydrite remnants have been completely altered to gypsum. Thus the outcrops contain only the more in-

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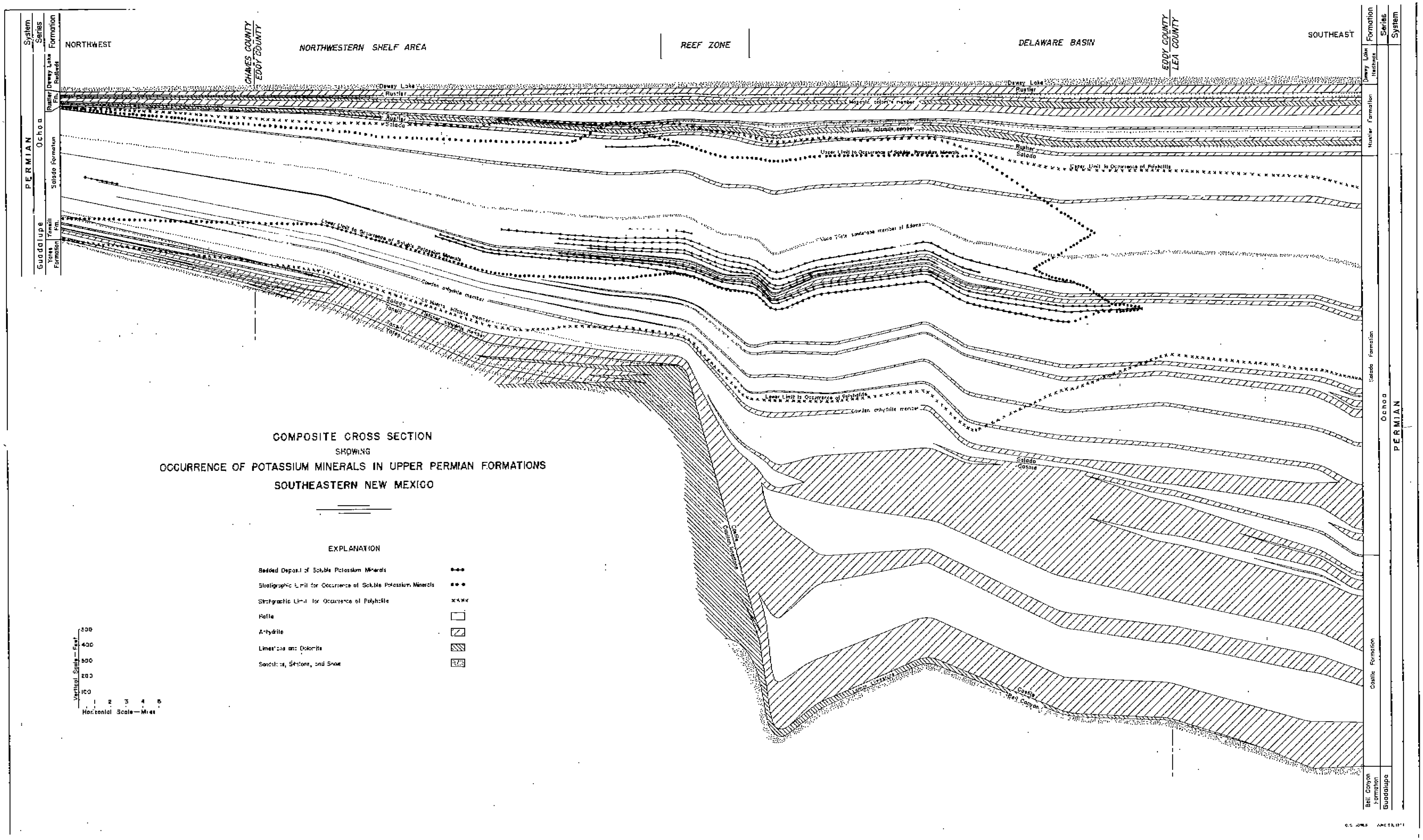

COMPOSITE CROSS SECTION
SHOWING
OCCURRENCE OF POTASSIUM MINERALS IN UPPER PERMIAN FORMATIONS
SOUTHEASTERN NEW MEXICO

soluble limestone, dolomite, gypsum, and clastics.

The descriptions and discussions that follow apply only to the formations as they exist in an unaltered state in the subsurface. The information presented herein has been obtained from exposures in mine workings, from drill cores and cuttings, and from study of electrical and radioactivity well logs. The composite cross section (Plate 1) is based entirely on information obtained from core test drilled for potash and from wells drilled for oil and gas.

The Castile is the oldest formation included in the Ochoa series. Except for a thin wedge overlapping the basinward margin of the Capitan reef zone, the formation is confined to the Delaware Basin where it conformably overlies the Bell Canyon formation of the Guadalupe series. The Castile formation is composed principally of anhydrite and halite with the halite definitely subordinate to the anhydrite in amount. Although of lesser importance, the halite beds are extensive and remarkably uniform in thickness in the northern and eastern parts of the Delaware Basin. The halite content is greatest in the deep part of the basin in front of the Central Basin platform.

Distinct differences in the lithology of the anhydrite can be used to divide the Castile formation into a lower banded unit and an upper massive unit. The banded unit is composed of alternating laminae of gray anhydrite and brown calcite in its lower part and alternating gray and brown anhydrite laminae in a thinner upper zone. Toward the margins of the Delaware Basin, a basal zone in the banded unit grade reefward into a laminated limestone. This basal limestone unit in turn appears to grade laterally into limestone of the Capitan (Newell, et al., 1953, p. 47). In the deep parts of the Delaware Basin, the banded anhydrite grades upward into massive, white anhydrite. Toward the margins of the basin, the upper part of the banded anhydrite grades laterally into the same type of massive, white anhydrite. A decrease in the thickness of the anhydrite of the Castile formation accompanies this marginal gradation from banded to massive anhydrite. This decrease appears to be due in part to depositional thinning, in part to lateral transition to halite of the Salado formation, and in part to an increase in the thickness of the basal laminated limestone. The lateral transition from anhydrite of the Castile to halite of the Salado is accomplished by means of depositional pinchouts of anhydrite tongues extending reefward from the core of massive anhydrite. The intercalated halite tongues thin basinward and pinch out in a southwesterly direction. They thicken reefward and coalesce in a northeasterly direction to form the basal halite strata in the Salado formation over the reef zone and on the shelf area.

Throughout most of the Delaware Basin area, the Castile and Salado formations are separable only on the basis of the significant lithologic difference. Whereas anhydrite is the most abundant mineral in the Castile formation, halite is the principal constituent of the Salado formation. Within the Salado formation, the halite occurs in the form of two very distinct types of strata. One type consists of a mixture of halite and clastics (principally clay-and silt-size particles of quartz and silicate minerals). The other type does not contain the clastic impurities. Both types of halite strata are present throughout the formation; individual strata in each group are very widespread laterally.

Many beds primarily composed of calcium and magnesium sulfate minerals are interbedded with the halite strata. Successive lateral changes in mineralogy are characteristic features of these strata. The composition of many sulfate strata, traced from the Delaware Basin into the shelf area, grades laterally from anhydrite ($CaSO_4$) to polyhalite ($2CaSO_4 . MgSO_4 . K_2SO_4 . 2H_2O$) and then to kieserite ($MgSO_4 . H_2O$). In other sulfate strata, the mineralogic change is from anhydrite to glauberite ($CaSO_4 . Na_2SO_4$) and then to polyhalite and kieserite. The sulfate beds are widespread members that serve as excellent stratigraphic markers. Two of them have received formal stratigraphic recognition. The Fletcher anhydrite member forms the base of the Salado formation over the Capitan reef zone and for some distance over the shelf area. The more widespread Cowden anhydrite member is 100 to 200 feet above the Fletcher and can be traced from the Delaware Basin onto the shelf area.

Thin shale seams are typical at the base of each sulfate stratum. The shale seams and a few sandstone and siltstone strata are prominent clastic members in the formation. Two widespread clastic members have been named. A prominent sandstone member that occurs about 100 feet above the principal potash deposits (see Plate 1) is the Vaca Triste member of Adams (1944). A less prominent clastic member that lies directly on or as much as 60 feet above the Fletcher anhydrite member over the reef zone and on the shelf area is the La Huerta siltstone member. The La Huerta siltstone member has not been recognized in the Delaware Basin. Adam's Vaca Triste member, however, is more widespread and can be traced from the Delaware Basin for considerable distances onto the shelf area. Three other clastic members, equally widespread and considerably thicker than the Vaca Triste member of Adams, are present in the upper 150 to 200 feet of the Salado formation. These upper clastic members, in leached outcrops containing remnants of the Salado and Rustler formations, comprise the so-called basal red beds of the Rustler formation.

Throughout the Salado formation, the principal lithologic types are repeatedly associated in a type of rhythmic depositional cycle that consists of a clastic stratum, a sulfate, a halite, and a mixed halite-clastic stratum in an ascending order. Gradational contacts are characteristic of the change from one lithology into the succeeding lithology in this depositional sequence. The top of the mixed halite-clastic stratum marks the end of one sedimentary cycle and the beginning of another cycle. In areas where data is available from mine exposures and from closely spaced core-drill holes, there is no evidence of an interruption in sedimentation within the sequence or between the sedimentary sequences. These stratigraphic sequences range from about 2 feet to 30 feet in thickness.

The Salado formation overlies the Capitan limestone and its back-reef equivalent, the Tansill formation, with apparent conformity. Over the Capitan reef zone and on the shelf area immediately behind the reef zone, the Fletcher anhydrite member forms the basal member of the Salado formation, and the Salado-Tansill contact can be placed at the change from this anhydrite to the limestone or dolomite of the Capitan and Tansill formations. A short distance onto the shelf area, however, the Tansill formation changes from a predominantly carbonate facies to an evaporite facies containing both anyhdrite and halite. As the evaporite facies of the Tansill does not differ significantly in lithology from the Salado formation and there is no evidence of an interruption in sedimentation at the close of Tansill time, the Salado-Tansill contact is obscure. The two formations are separable on the basis of a clastic member which forms a continuous stratigraphic marker traceable from the carbonate facies in the reef zone to the evaporite facies on the shelf area, The top of this clastic member is used on the cross section (Plate 1) as the contact between the Salado and Tansill formations.

In contrast to the great diversity in lithologies and formations that underlie the Salado, the formation is conformably overlain both in the Delaware Basin and on the shelf area by a single lithologic unit – the Rustler formation. Anhydrite and halite are the principal constituents of the Rustler formation, and just as in the Castile formation, anhydrite is the dominant constituent of the strata comprising the Rustler formation. Unlike the Castile formation, however, the Rustler formation contains two dolomite members and several siltstone and sandstone members that form remarkably persistent stratigraphic markers. The halite is intercalated within the anhydrite and clastic members. The highest halite member lies about 30 feet below the top of the formation; and the lowest halite member, about 10 to 15 feet above the base. The other halite members form a medial zone within the formation. Within the area of the Delaware Basin, the halite members represent about half the total thickness of the Rustler formation. The halite members thin reefward and pinch out on the shelf area.

In an article describing the Ochoa series J.E. Adams (1944, p. 1614) first used the term "Magenta member" as the name for the upper dolomite member, and the term Culebra for the lower dolomite member. Adams credits W.B. Lang with proposing both terms. The two members, which are excellent stratigraphic markers, are used to indicate the dolomite members of the Rustler formation on the cross section (Plate 1).

The Rustler formation is conformably overlain by the Dewey Lake redbeds. The red beds of the Dewey Lake are in sharp contrast to the evaporites of the earlier formations of the Ochoa series. The contact between the upper anhydrite member of the Rustler formation and the red beds of the Dewey Lake is the datum for the composite cross section. Additional description of the Dewey Lake and younger formations in southeastern New Mexico, or of the changes produced in the compositions and structural relationships among the evaporite deposits by weathering in post-Permian time, are not within the scope of this article. The cumulative effect of the geologic processes active in post-Permian time is the partial destruction of the evaporite deposits and the contained potassium minerals.

The principal potassium minerals, in order of decreasing abundance in the evaporite deposits, are polyhalite, sylvite, carnallite, langbeinite, kainite, and leonite. Other potassium-bearing minerals occur only in minor amounts; and then, only in association with the principal potassium minerals. The composition of the principal minerals is as follows:

Polyhalite	$2CaSO_4 . MgSO_4 . K_2SO_4 . 2H_2O$
Sylvite	KCl
Carnallite	$KCl . MgCl_2 . 6H_2O$
Langbeinite	$K_2SO_4 . 2MgSO_4$
Kainite	$KCl . MgSO_4 . 3H_2O$
Leonite	$K_2SO_4 . MgSO_4 . 4H_2O$

There are significant differences in the stratigraphic and areal limits of each of the principal potassium minerals. A discussion of the differences in the distribution of individual minerals would add needless detail to this brief summary. The soluble potassium minerals – sylvite, carnallite, langbeinite, kainite, and leonite – however, have many features in common in regard to their distribution and occurrence. For this summary, the distribution and occurence of these soluble minerals are discussed as a group. The distinction that has been made on the cross section (Plate 1) within the stratigraphic boundaries for the occurrence of polyhalite and the soluble potassium minerals illustrates some of the changes encountered in a study of the distribution of the various potassium minerals.

Plate 1. Composite cross section showing occurrence of potassium minerals in southeastern New Mexico.

The stratigraphic limits indicated for polyhalite and the soluble potassium minerals include all types of deposits and all forms of mineral occurrences. The indicated limits are based on the identification of the minerals in core samples. The lateral changes in the distribution were established by tracing widespread and easily identified marker beds. Not all the marker beds within the Salado and Tansill formations are shown on the composite cross section – only those that best illustrate the principal changes in the distribution of the potassium minerals and the shelfward decrease in the thickness of major units within the two formations.

Polyhalite occurs throughout a greater stratigraphic interval, and is more widespread in distribution, than the soluble potassium minerals. As may be seen on the composite cross section, this difference in mineral distribution is very pronounced in some areas; from one area to another there can be considerable changes in the relative positions of the stratigraphic limits for the distribution of the minerals. However, one change that is common to the distribution of polyhalite and the soluble potassium minerals is the progressively lower stratigraphic occurrence of the minerals in a shelfward direction. The lowest occurrence of the potassium minerals ranges from high in the Salado formation in the Delaware Basin area to low in the Tansill formation on the shelf area. This occurrence is very remarkable for no potassium minerals have been found in the Castile formation, which is one of the major and best known evaporite deposits in southeastern New Mexico; yet, the potassium minerals are found in the Tansill formation, which is better known for its basinward gradation into the Capitan limestone. The variations in mineral distribution can be attributed to existing differences in chemical equilibrium throughout the seas in late Permian time. Deposition of the potassium minerals started first on the shelf area in Tansill time; and with basinward changes in equilibrium conditions in later Tansill and Salado time, the base level of potassium mineral deposition moved basinward and progressively higher in the evaporite deposits. The occurrence of potassium minerals in the Rustler formation is to be expected for there are no really significant differences between the lower part of the Rustler formation and the upper part of the Salado formation and no evidence of an interruption to sedimentation at the close of Salado time.

The potassium minerals occur in the evaporite deposits as:
(1) accessory minerals; (2) stratified deposits in the sulfate strata; (3) bedded deposits in the mixed halite – clastic strata; and (4) vein or lens deposits that have replaced or displaced the strata.

The halite strata and many of the sulfate and clastic members of the evaporite formations contain, as one of their characteristic features, minor or accessoray amounts of the potassium minerals. This type of mineral occurrence is referred to as the accessory occurrence of the potassium minerals. All the potassium minerals occur as accessory minerals in the strata of the Salado formation; but polyhalite, sylvite, and carnallite are more widely distributed than the others. These three minerals are also the only potassium minerals that have been found in the Rustler and Tansill formations. Throughout the southeastern New Mexico area, the accessory occurrence is the most extensive form of occurrence for potassium minerals.

The stratified deposits in sulfate strata are another type of potassium mineral occurrence that is almost as widespread and extensive as the accessory occurrence. However, polyhalite is the only potassium mineral that occurs as a stratified deposit in these strata. The soluble potassium minerals, where present, occur either as accessory minerals or as vein deposits. The stratigraphic positions of the strata containing the polyhalite deposits are not indicated by a specific symbol on the cross section because the strata are numerous and widely distributed throughout the formations. Most of the anhydrite members or marker beds, which are found between the stratigraphic limits indicated for the occurrence of polyhalite, contain significant concentrations of the mineral in the form of stratified deposits. In such an occurrence, polyhalite comprises a type of mineral – or litho-facies in the sulfate members of the Rustler, Salado, and Tansill formations. The polyhalite facies or stratified deposits are very extensive; some can be traced from the Delaware Basin area for considerable distances onto the shelf area. Polyhalite is present in the other types of strata – the halite, the mixed halite-clastic, and the clastic strata – only as an accessory mineral or as an easily identified vein deposit.

The third type of potassium mineral occurrence – the bedded deposits of the mixed halite-clastic strata – is not very widespread. The bedded deposits have been found only in the Salado formation where the known occurrences for this type of potassium mineralization are limited to two areas – a small area in southern Chaves County and a much larger area that includes parts of eastern Eddy and western Lea Counties, N. Mex. The stratigraphic positions of the bedded deposits are indicated by a distinct symbol on the cross section (Plate 1). In the Eddy and Lea County area, there are 5 major deposits and about 10 deposits of lesser importance. The stratigraphic positions of only a few of the lesser deposits could be indicated on the cross section because of the relatively small vertical scale on the section. These minor deposits are separated from the more extensive deposits by relatively thin stratigraphic intervals. With the exception of one bedded deposit, which occurs from 50 to 75 feet below the top of the Salado formation, the deposits are concentrated in a medial zone in the formation.

The bedded deposits probably are best described as an internal zone or area within certain mixed halite-clastic strata that contain the soluble potassium minerals in significant concentrations. They consist of a mixture of halite, a minor amount of clay, and one or more of the soluble potassium minerals. Polyhalite, where present in this type of deposit, is always a minor constituent. Effective geologic controls for the accumulation and localization are clearly indicated, for the bedded deposits are found in only a few of the many mixed halite-clastic strata in the Salado formation. The factors affecting the localization are not known, and speculation about them is not within the scope of this summary.

The bedded deposits of the mixed halite-clastic strata are the potash deposits of past and present economic importance. These deposits contain sylvite and langbeinite in sufficient quantity and purity to constitute minable ore bodies. The lowest bedded deposit in the Eddy County area (see Plate 1) is being mined by all operating companies for its sylvite content. The sylvite ore recovered from this deposit is the principal source of the potash produced in southeastern New Mexico. The International Minerals & Chemical Corp. is the only one of the five operating companies that mines langbeinite ore. The langbeinite ore is recovered from stratigraphically higher deposits.

The vein or lens deposits are the least extensive of the four types of potassium mineral occurrence. Polyhalite, sylvite, and carnallite are the only potassium minerals that have been found in this type of mineral occurrence in the Salado formation. No potassium minerals have been found in vein or lens deposits in the Tansill formation; and carnallite is the only potassium mineral that occurs in the Rustler as a vein deposit. These deposits are mostly very small; few veins or lenses have been found that have dimensions in excess of 10 feet. The majority have a maximum dimension of less than 4 feet. The contacts between these secondary deposits and the saline strata are clearly defined, and a cross-cutting relationship is always apparent.

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