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POTASH RESOURCES IN PART OF LOS MEDAÑOS AREA OF EDDY AND LEA COUNTIES, NEW MEXICO

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ABSTRACT

Los Medaños area of eastern Eddy and western Lea Counties, New Mexico, is being considered for possible siting of a repository facility for experimental studies of nuclear-waste emplacement in salt beds of the Salado Formation of Permian age. The potential repository site encompasses about 29 square miles (75 square kilometres) of sandy terrain near the center of Los Medaños. The site is underlain by evaporite and red bed formations having an aggregate thickness of 4,462 feet (1,360 metres).

The Salado Formation, which is the main salt-bearing unit of the area, lies at a depth of 1,000 feet (305 metres). The formation is almost 1,970 feet (600 metres) of rock salt with prominent interbeds of anhydrite, polyhalite, glauberite, some widely spaced seams of fine-grained clastic rocks, and a few potash deposits containing sylvite and langbeinite. The potash deposits occur in salt beds 517-871 feet (158-265 metres) below the top of the formation. The lower half of the formation includes some salt beds which may be used for the experimental emplacement of nuclear wastes.

Most, if not nearly all, of the potential repository site is underlain by potash deposits that contain sylvite and langbeinite.

The deposits grade 12-13 percent K_2O as sylvite and 3-11 percent K_2O as langbeinite, and must be regarded as having economic potential for potassium minerals. There is considerable uncertainty concerning the full extent and total range in quality of the ores in the deposit, and subsurface investigation will be required to assess their potential.

INTRODUCTION

Since 1972 the U.S. Geological Survey has conducted a series of site evaluation studies in southeastern New Mexico for the Waste Management Division of the U.S. Energy Research and Development Administration. Some results of the studies include analyses of the geology and hydrology of selected areas (Brokaw and others, 1972; Jones, 1973, 1974a, 1974b), an examination of regional tectonics and its relation to salt stability (Bachman and Johnson, 1973), and discussions of Cenozoic erosion and sedimentation in the Pecos Valley and other sections of southeastern New Mexico (Bachman, 1973, 1974). On the basis of these studies, a tentative site for a repository or disposal facility for emplacement of nuclear wastes in bedded salt was selected near the center of Los Medaños area in Eddy and Lea Counties. Following this selection, borings were sunk to determine geologic conditions, to conduct hydrologic tests, and to obtain geophysical data and samples for physical property, mineralogical, chemical, and other investigations required for site evaluation purposes.

The present report on the potash resources in the area of Los Medaños repository facility is another in the series of site evaluation studies. The purpose of the report is threefold: to describe the potash deposits found by the site evaluation borings; to present an appraisal of the potash resources of the site; and to estimate the possible impact of a nuclear-waste facility on the resource situation in southeastern New Mexico and on the outlook for potash in the United States.

The drilling of Los Medaños repository site was carried out between March 18 and May 20, 1974, by a private contractor acting on behalf of the Union Carbide Corp., Oak Ridge, Tenn. Two borings were sunk. Table 1 gives the location, altitude, and other drilling data concerning the two site evaluation borings (boreholes 2 and 3), and includes data on some nearby borings (boreholes 1, 4, 5, 6, and 7) which penetrated the complete sequence of potash-bearing rocks. The tabulation is by no means a complete listing of borings in the area; shallow and deep borings for which geophysical data are lacking have been excluded.

As part of the drilling operations at the potential repository site, a radioactivity (gamma ray, neutron), density, and various other wireline logs were taken the full length of each boring. The wireline logs facilitated the identification and correlation of (1) potash deposits known to be present from earlier studies of Brokaw, Jones, Cooley, and Hays (1972, fig. 6), and (2) salt beds of possible use for experimental emplacement of nuclear wastes.

Table 1.--Partial list of boreholes that penetrate a complete sequence of potash-bearing rocks in the vicinity of Los Medaños repository site

[Altitude: kb, kelly bushing; gl, ground level. Geophysical data and other records: acs-gr, acoustic velocity-gamma ray log; cl, core lithology; den-gr, density-gamma ray log; dt/spl, drilling time/sample log; ftr, formation testing report; g-c, gamma-collar log; nl-gr, neutron lifetime-gamma ray log; ra, radioactivity log; son-gr, sonic-gamma ray log; tem, temperature log.]

Borehole number	Borehole name	Location	Altitude (feet)	Total depth (feet)	Geophysical data and other records
1	Skelly Oil Co. 1 South Salt Lake Unit	NW1/4 NW1/4, sec. 21, T. 21 S., R. 32 E., Lea County	kb 3,679 gl 3,658	14,690	son-gr
2	Union Carbide Corp. AEC 7	SW1/4 NE1/4, sec. 31, T. 21 S., R. 32 E., Lea County	kb 3,662 gl 3,654	3,918	acs-gr, cl, den-gr, dt/spl, ftr, g-c, ra, tem
3	Union Carbide Corp. AEC 8	NE1/4 NW1/4, sec. 11, T. 22 S., R. 31 E., Eddy County	kb 3,542 gl 3,533	3,028	acs-gr, cl, den-gr, dt/spl, ftr, ra
4	C. W. Williams, Jr. 1 Badger Unit	NE1/4 SW1/4, sec. 15, T. 22 S., R. 31 E., Eddy County	kb 3,496 gl 3,475	15,225	nl-gr
5	J. H. Trigg 1-18 Jennings	SE1/4 SE1/4, sec. 18, T. 22 S., R. 32 E., Lea County	kb 3,696	4,890	son-gr
6	Texas Crude Oil Co. 1-23 Wright	SE1/4 SE1/4, sec. 23, T. 22 S., R. 31 E., Eddy County	kb 3,596 gl 3,588	4,766	acs-gr
7	Ralph Lowe 1 Bass	SE1/4 SE1/4, sec. 19, T. 22 S., R. 32 E., Lea County	kb 3,620 gl 3,611	4,802	son-gr

Consecutive cores were taken through the lower 2,878 ft (877 m) of section in borehole 2 (table 1) and the lower 2,988 ft (911 m) in borehole 3. The cores included the complete sequence of potash-bearing rocks, as well as several salt beds worthy of further study for waste emplacement purposes. The cores were examined, and those found to contain potash deposits of possible economic importance were sampled and analyzed. The following sections of the text describe the results of the examination for potash; the results of the chemical and modal analyses are listed in tables 4a, b, and 5a, b (in pocket).

The potash deposits of interest in the present study occur near the stratigraphic center of the sequence of potash-bearing rocks at the potential repository site. The deposits were penetrated between the depths of 1,561 and 1,820 ft (476 and 555 m) in borehole 2 and at 1,522 and 1,767 ft (464 and 539 m) in borehole 3. The deposits are 1,099-1,453 ft (335-443 m) above the base of the main salt-bearing unit in the area. The basal 968-1,087 ft (295-331 m) of the unit contain salt beds of possible use for experimental emplacement of nuclear wastes.

Location and geography

The area being considered for possible siting of a nuclear-waste repository lies about 30 miles (50 km) due east of Carlsbad, N. Mex., in an area of eastern Eddy and western Lea Counties known as Los Medaños (fig. 1). The potential repository site in Los Medaños comprises parts

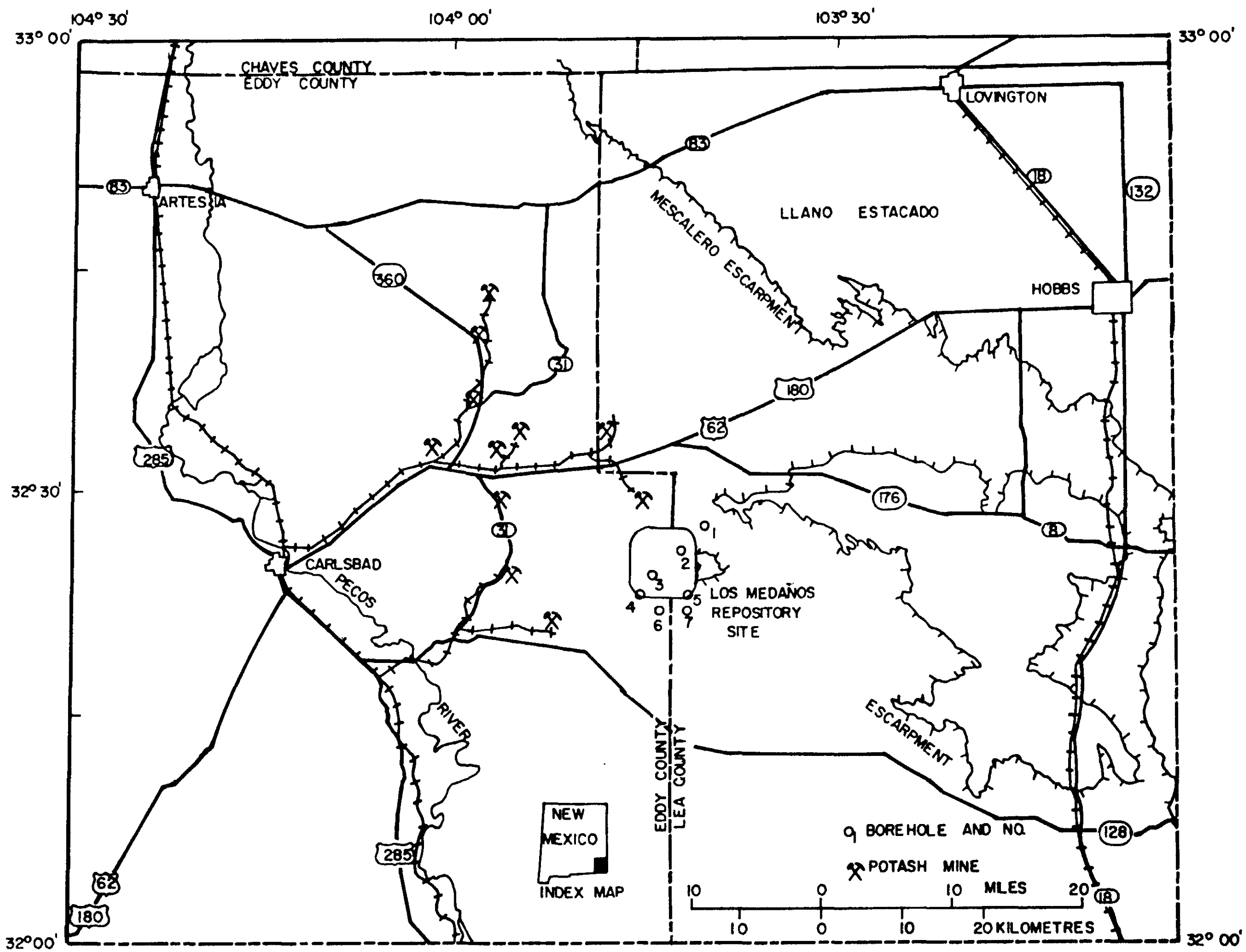

Figure 1.--Map of southeastern New Mexico showing location of potential repository site in Los Medaños.

of the southeastern one-quarter of T. 21 S., R. 31 E., the southwestern one-quarter of T. 21 S., R. 32 E., and northwestern one-quarter of T. 22 S., R. 32 E., and the northeastern one-quarter of T. 22 S., R. 31 E. The site includes a 3-mi^2 (7.7-km^2) area for repository-plant facilities and a buffer zone that extends 2 mi (3.2 km) in all directions from the perimeter of the plant area. The plant area and buffer zone total about 29 mi^2 (75 km^2). Approximately 85 percent of the land in the site is public domain; the remainder is dominantly State land with a sprinkling of patented land.

In its general relations, the potential repository site in Los Medaños is part of the broad plain that separates the Pecos River from the western edge of the Llano Estacado throughout southeastern New Mexico. Most of the surface of the plain is covered by loose, windblown sand, and the terrain is very hummocky, with a slight overall slope to the west. Vegetation is sparse and consists of mesquite, coarse grasses, and associated arid-climate flora of the Chihuahuan life zone. Land use is restricted to the grazing of cattle, but traces of exploration for mineral resources abound. Pipelines from nearby gas fields crisscross the site, and there are potash mines to the north and west. Roads are few and primitive, and access to most of the site requires use of "off-the-road" vehicles.

Acknowledgments

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DESCRIPTION OF THE ROCKS

At the two site evaluation borings in Los Medaños, the consolidated rocks penetrated range in age from Late Permian to Late Triassic. They consist mainly of Permian evaporites and red beds, but include some Triassic sandstone. The aggregate thickness of the formations in the borings is more than 3,950 ft (1,200 m), as shown in figure 2.

In addition to the rocks shown in figure 2, red beds of Triassic age are present in borings to the north and east of the repository site; sandstone and other rocks of Pliocene age cap nearby mesas; and a blanket of Quaternary caliche and dune sand conceals the bedrock at nearly all places.

SYSTEM	SERIES	FORMATION	MEMBER	SECTION	APPROXIMATE THICKNESS FEET	(METRES)	GENERAL CHARACTER
TRIASSIC	UPPER	Santa Rosa Sandstone			140	(43)	Sandstone interbedded with mudstone
PERMIAN	OCHOAN	Dewey Lake Redbeds			525	(160	Siltstone and very fine grained sandstone
		Rustler			330	(100)	Anhydrite (gypsum) interbedded with dolomite, siltstone, and sandstone
		Salado	Upper		490	(149)	Rock salt interbedded with anhydrite, glauberite, silty sandstone, and a variety of potassium-bearing rocks
			McNutt potash zone		370	(113)	
			Lower		1,100	(335)	
		Castile			>1,000	(>305)	Anhydrite and seams of rock salt

EXPLANATION

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This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

Figure 2.--Stratigraphic column of consolidated rocks penetrated by site evaluation borings sunk in Los Medaños area.

Permian rocks

The Permian System is represented in Los Medaños borings by the Ochoan Series, the uppermost of four provincial divisions of the Permian recognized in New Mexico. The Ochoan is predominantly rock salt and anhydrite, but includes a variety of potash ores and rocks of economic and scientific interest, as well as some limestone, dolomite, and fine-grained clastic rocks. It overlies shaly siltstone and associated limestone of the Guadalupian Series (Lower and Upper Permian), and is overlain unconformably by rocks ranging in age from Late Triassic to middle Pleistocene.

Castile Formation

The Castile Formation, named by Richardson (1904), is the oldest rock in the two Los Medaños borings. The top of the formation was penetrated at a depth of 2,914 ft (888 m) in borehole 2 and 2,975 ft (907 m) in borehole 3. A maximum of 1,004 ft (306 m) of Castile was drilled in borehole 2 without encountering older rock. It is estimated that an additional 740 ft (226 m) of drilling would have been required to reach the base of the Castile. The depth to the base is believed to be about 4,655 ft (1,420 m) at borehole 2 and about 4,450 ft (1,356 m) at borehole 3. The Castile may range in thickness from about 1,280 ft (390 m) to 1,740 ft (530 m).

The Castile is the least complex of the evaporites in the borings; it is chiefly anhydrite with a few interbeds of rock salt. Calcitic limestone is present in small amounts; materials of a terrigenous origin are missing. All the rock is sparingly bituminous and yields a fetid odor. It has a faint to conspicuous lamination or banded structure involving a color change, a difference in texture, or a rhythmic alternation of bituminous calcite and anhydrite, bitumen and anhydrite, or anhydrite and halite in layers a fraction of a millimetre to a few centimetres thick. The color of the rock ranges from white to dark gray, but becomes increasingly somber with increasing depth below the top of the formation.

The upper contact of the Castile is conformable, with lateral and vertical gradation from anhydrite to rock salt.

Salado Formation

Overlying the Castile Formation in the two Los Medaños borings is the Salado Formation which Lang (1935) defined and differentiated from the Castile gypsum of Richardson (1904). The Salado extends from a depth of 998 ft (304 m) to 2,914 ft (888 m) in borehole 2 and from 994 ft (303 m) to 2,975 ft (907 m) in borehole 3. The range in thickness is from 1,916 ft (584 m) to 1,981 ft (604 m). The top of the formation lies at an altitude of 2,664 ft (812 m) in borehole 2 and at 2,548 ft (777 m) in borehole 3.

The Salado Formation is the potassium-bearing evaporite encountered in the borings. It is also the most heterogeneous of the evaporites and consists of thick layers of rock salt interbedded with anhydrite, polyhalite, and glauberite. Partings and thin seams of mudstone are disseminated through the formation, and there are a few thin beds of halite-cemented sandstone at long intervals. Potash deposits containing sylvite, langbeinite, and a variety of magnesium-bearing minerals occur in salt beds near the middle of the formation.

At the base of the Salado are irregularly interbedded anhydrite and rock salt in a zone that is arbitrarily included with the formation. The anhydrite is identical with anhydrite in the underlying Castile Formation, whereas the rock salt is gray and anhydritic like that in the lower part of the Salado. The zone is 21 ft (6 m) thick in borehole 2, but thickens to 121 ft (37 m) in borehole 3, where some salt beds are as much as 18 ft (6 m) thick.

The Salado in the borings is divided into three members which are somewhat similar in lithology but differ significantly in economic importance (fig. 2). The lower member, 1,040-1,154 ft (317-352 m) thick, consists largely of rock salt, with less abundant anhydrite, polyhalite, and glauberite, as well as a few thin beds of fine-grained clastic rocks; it is medium to light gray in the lower part and decidedly red in the upper part. The middle member, known locally as the McNutt potash zone, is the ore-bearing section of the Salado from which potassium salts have been recovered from deposits rich in sylvite and langbeinite; it is 357-375 ft (109-114 m) of reddish-orange and brown rock salt with interbeds of red and gray polyhalite. There is a single bed of gray anhydrite in the lower part of the unit and a thin seam of silty sandstone at the top. The upper member of the formation, 468-504 ft (143-154 m) thick, is dominantly reddish-orange and brown rock salt with a few interbeds of red polyhalite, gray anhydrite, and brown sandstone.

The upper boundary of the Salado Formation in the borings is a sharp but conformable contact between rock salt and sandstone.

Rustler Formation

Resting on the Salado Formation in the two Los Medaños borings is 325-329 ft (90-100 m) of anhydrite, dolomite, and fine-grained sandstone termed the Rustler Formation by Richardson (1904). The depth to the top of the Rustler is 669 ft (204 m) in boreholes 2 and 3, but the altitude of the top is 119 ft (36 m) higher in borehole 2 than in borehole 3; the range in altitude is from 2,993 ft (912 m) to 2,874 ft (876 m).

The Rustler in the borings is divisible into a sandy lower part and an anhydritic upper part. The sandy lower part, 92-125 ft (28-38 m) thick, is dominantly very fine grained, silty sandstone, with less abundant anhydrite and rock salt; the sandstone is halitic and light to dark gray in its lower section and reddish brown and salt free in its upper section. The anhydritic upper part of the formation, 200-227 ft (61-69 m) thick, is largely gray anhydrite, with a few interbeds of reddish-brown clay and gray dolomite. The anhydrite is in fairly massive beds which have gypsiferous rinds along their lower and upper sides.

The upper contact of the Rustler Formation is sharp and is marked by a distinct change from gray anhydrite to reddish-brown mudstone. The contact is interpreted as an unconformity of slight discordance.

Dewey Lake Red Beds

Overlying the Rustler Formation in the two borings at Los Medaños is a red silty unit named the Dewey Lake Red Beds by Page and Adams (1940). The top of the Dewey Lake was penetrated by the bit at a depth of 120 ft (37 m) in borehole 2 and at 174 ft (53 m) in borehole 3; the altitude of the top ranges from 3,542 ft (1,079 m) in the first boring to 3,368 ft (1,027 m) in the second. The range in the thickness of the Dewey Lake is from 549 ft (167 m) in borehole 2 to 495 ft (151 m) in borehole 3, where the uppermost part is missing owing to post-Permian erosion.

The Dewey Lake Red Beds are a somewhat heterogeneous but very monotonous succession of reddish-orange to reddish-brown siltstone and very fine grained sandstone, with interbeds of dusky-red mudstone and siltstone. Most rock is evenly and thinly bedded, liberally sprinkled with greenish-gray spots, and irregularly intruded by horizontal and crisscrossing veins of fibrous selenite. Some beds are structureless, whereas others are either horizontally laminated or cross laminated. Many bedding surfaces carry shallow current or oscillation ripple marks. Silt-filled mud cracks occur at the top of many mudstone layers, and there are small chips and flattened pellets of mudstone in the basal part of many siltstone and sandstone layers.

Triassic rocks

Santa Rosa Sandstone

Resting unconformably on the Dewey Lake Red Beds in the borings at the potential repository site is the Santa Rosa Sandstone of Late Triassic age and named by Darton (1922). Only the lower 121-166 ft (37-51 m) of the Santa Rosa was penetrated. This part of the formation consists of fine- to medium-grained grayish-red to brown sandstone with some reddish-brown siltstone in the middle part. The sandstone is truncated by a nodular to laminar limestone, of middle Pleistocene age, informally named the Mescalero caliche by Bachman (1974, p. 31).

DESCRIPTION OF THE POTASH DEPOSITS

General features

Potash (K_2O) is widely and very abundantly distributed in evaporites of the Salado Formation. However, most of it occurs in beds of anhydrite, forming extensive deposits of polyhalite--a triple sulfate of potassium, magnesium, and calcium--which have considerable scientific significance but little or no economic importance. The remainder of the potash in the Salado forms much smaller deposits in salt beds where a variety of minerals containing the chloride or sulfate of potassium occur in crystalline mixtures with halite. Deposits of this type carry sylvite (KCl) or langbeinite ($K_2Mg_2(SO_4)_3$) as the potassium ore mineral, and are of great economic importance to New Mexico and the United States. The deposits have provided this country with slightly more than 105 million tons of potassium salts since the start of potash mining in southeastern New Mexico 45 years ago, and, insofar as has been demonstrated, they contain the bulk of our potash resources that are accessible and which are exploitable under existing economic conditions by means of established technological procedures or processes.

Deposits containing sylvite or langbeinite

In the area of the potential repository site, deposits containing sylvite or langbeinite occur exclusively within the McNutt potash zone of the Salado Formation (fig. 2). The deposits are scattered here and there throughout 259 ft (79 m) of McNutt in borehole 2 and 265 ft (81 m) in borehole 3. The mineralized interval carrying the deposits was penetrated between the depths of 1,516 ft (462 m) and 1,819 ft (554 m) in borehole 2, and the depths of 1,522 ft (464 m) and 1,778 ft (542 m) in borehole 3. The deposits at the bottom of the mineralized interval in the McNutt are only about 110 ft (34 m) deeper than the deepest potash mines in southeastern New Mexico.

The occurrence of potash deposits in the McNutt are summarized on figure 3 (in pocket). The figure is a stratigraphic diagram, extending from southwest to northeast across the potential repository site, on which the correlation and continuity of potash deposits between selected borings are interpreted. All the deposits shown on the diagram occur in salt beds. Most are fairly persistent, but are generally thin and weakly mineralized with potassium. Only a few contain as much potassium as the polyhalite-anhydrite rock which is intercalated here and there between beds of rock salt.

Stratigraphically, the potash deposits of the McNutt potash zone are restricted to a few mineralized salt beds termed "ore zones" by Jones, Bowles, and Bell (1960). In general the ore zones are laterally persistent beds of halite and argillaceous halite that locally contain complex assemblages of potassium and magnesium evaporite minerals. The ore zones occur at irregular, short to long, intervals in the McNutt, and are separated by generally thicker units of rock salt with interbeds of polyhalite-anhydrite rock. All are distinguished from other salt beds in the McNutt primarily by their stratigraphic position; the presence or absence of potash deposits is not a factor in their recognition on wireline logs of borings, in drill core, or in mine workings.

Among the 11 ore zones named by Jones, Bowles, and Bell (1960), only 5 contain potash deposits of proven economic importance. Sylvite-rich deposits in the 1st, 7th, and 10th ore zones have supplied virtually all the potassium chloride shipped from mines in southeastern New Mexico, and, insofar as has been determined, they contain the bulk of the unmined sylvite ore remaining in the region. Other deposits that contain sylvite ore locally are present in the 3d, 5th, 6th, 8th, 9th, and 11th ore zones. Potash deposits that occur in the 2d, 3d, 4th, and 5th ore zones are noted primarily for the occurrence of langbeinite, but only those in the 4th and 5th ore zones have been successfully exploited. Langbeinite is also present in economically significant amounts in some sections of the 1st and 10th ore zone deposits.

Petrography and mineralogy

The potash deposits that were intersected by the borings at the potential repository site are very distinctive rocks. They are decidedly colorful, with white and various shades of light to medium red, orange, and greenish gray predominating, and their margins are clearly marked by an abrupt change to the generally more somber grays and browns of the enclosing salt beds. The deposits are typically massive, somewhat coarsely crystalline, and fairly even grained, and they are mineralogically complex. All carry halite and one or more potassium minerals as major constituents, and there is at least one magnesium mineral present, as well as varying, but generally small, amounts of clayey and silty detrital materials--polyhalite and (or) anhydrite.

Table 2 lists 10 evaporite minerals that were found upon X-ray diffraction and petrographic examinations in the potash deposits at the potential repository site. Most of the minerals contain potassium. Two of them--sylvite and langbeinite--are recoverable from southeastern New Mexico potash ores by means of existing industrial processes, and they are the only constituents of the deposits that have a clearly established economic value. All the other evaporite minerals that contain potassium have very little, if any, economic importance, owing to the lack of viable methods of extracting potassium salts or of mineral utilization.

Among the various evaporite minerals that contain potassium and (or) magnesium, there are notable differences in their distribution in potash deposits of different ore zones. Aside from polyhalite, which is essentially ubiquitous, sylvite is probably the most pervasive. Sylvite occurs in the deposits of all ore zones above the 4th, and, in all of them, it is either the dominant or the only potassium ore mineral present. Carnallite is widely distributed in deposits in the 6th and other ore zones higher in the McNutt potash zone. Kieserite occurs in all deposits containing sylvite and carnallite, and makes up an appreciable part of the deposits in the 5th and 10th ore

Table 2.--Evaporite minerals of the potash deposits in Los Medaños borings

	Formula	Weight percent K_2O
	Ore minerals	
Sylvite	KCl	63.17
Langbeinite	$K_2Mg_2(SO_4)_3$	22.69
	Gangue minerals	
Leonite	$K_2Mg(SO_4)_2.4H_2O)$	25.68
Kainite	$KMgClSO_4.3H_2O$	18.91
Carnallite	$KMgCl_3.6H_2O$	16.91
Polyhalite	$K_2Ca_2Mg(SO_4)_4.2H_2O$	15.62
Kieserite	$MgSO_4.H_2O$	-----
Bloedite	$Na_2Mg(SO_4)_2.4H_2O$	-----
Halite	$NaCl$	-----
Anhydrite	$CaSO_4$	-----

zones. Kainite is closely associated with kieserite in the 5th ore zone deposit, and occurs with leonite and langbeinite in the potash deposits of the 3d and 4th ore zones. Langbeinite is sparingly present in the 5th ore zone deposits but is the potassium ore mineral of the 3d and 4th ore zone deposits. Bloedite, which lacks potassium (table 2), is the dominant constituent of the 2d ore zone deposit, and occurs with leonite and kainite in langbeinite-poor sections of the deposits in the 3d and 4th ore zones.

A detailed summary of the evaporite mineral content of the main potash deposits penetrated by the borings at the potential repository site is presented in table 3. The summary is based on modal calculations and the chemical data listed in tables 4a, b, and 5a, b, in pocket.

Resources

The two borings (boreholes 2 and 3, table 1) drilled at the potential repository site in Los Medaños intersected potash deposits in 9 of the 11 ore zones known for the occurrence of sylvite and langbeinite in southeastern New Mexico. Tables 6 and 7 catalog the distribution of the barren and mineralized ore zones in the two borings, and include an inventory of the mineralized zones, showing deposit thickness and tenor of ore. The deposits in four of the mineralized ore zones, specifically the 3d, 4th, 5th, and 10th ore zones, meet the minimum standards of thickness (4 ft (1.2 m)) and quality (10 percent K_2O as sylvite or 4 percent K_2O as langbeinite) used by the U.S. Geological Survey for classifying lands in the public domain as

Table 3.--Computed modes of the main potash deposits in Los Medaños borings (weight percent)

/Syl, sylvite; Lan, langbeinite, Leo, leonite; Kai, kainite; Car, carnallite; Kie, kieserite; Bloe, bloedite; Ha, halite; An, anhydrite; Poly, polyhalite. To convert from English to metric system multiply thickness and depth measurements by 0.3048. ---, not present./

Ore zone	Syl	Lan	Leo	Kai	Car	Kie	Bloe	Ha	An and Poly	Insoluble	Thickness (feet)	Depth (feet)
AEC 7 (borehole 2)												
10th	19.7	----	---	---	13.2	0.7	---	55.9	3.0	6.7	3.4	1634.5-1637.9
9th	12.8	----	---	---	17.3	.6	---	80.1	1.5	3.0	1.9	1650.0-1651.9
5th	20.3	0.3	---	8.7	----	10.8	---	55.4	2.9	.9	5.4	1736.5-1741.9
3d	----	25.6	5.1	5.5	----	----	2.4	58.3	1.5	2.1	4.5	1814.9-1819.4
AEC 8 (borehole 3)												
10th	21.6	----	---	---	6.7	20.1	---	44.8	0.9	6.0	5.0	1589.7-1594.7
9th	6.2	----	---	---	20.1	.9	---	70.8	.9	1.2	3.4	1604.3-1607.7
8th	18.9	----	---	---	5.1	.1	---	61.5	2.3	11.7	1.5	1636.6-1638.1
4th	----	48.5	2.2	2.6	----	----	0.3	43.8	.4	2.3	4.0	1753.4-1757.4
Stray	.3	11.2	---	.8	----	<.1	---	83.1	2.9	1.5	2.4	1761.0-1763.4

Table 6.--Deposit thickness and grade of ore in McNutt ore zones, AEC 7 (borehole 2), Los Medaños repository site (weight percent)

[Syl, sylvite; Lan, langbeinite; Leo, leonite; Kai, kainite; Car, carnallite. To convert from English to metric system multiply thickness and depth measurements by 0.3048. ---, not present.]

Ore zone	Depth (feet)	Thickness (feet)	K_2O distribution by minerals[1/]				
			Syl	Lan	Leo	Kai	Car
11th	1561.0-1563.0	2.0	[2/]1.6	---	---	---	[2/]0.4
10th	1634.5-1637.9	3.4	12.4	---	---	---	2.2
9th	1650.0-1651.9	1.9	8.1	---	---	---	2.9
8th	1682.3-1683.4	1.1	[2/]6.3	---	---	---	[2/]1.1
7th	1714.3-1719.1	4.8	[2/]2.0	---	---	---	[2/] .3
6th	1732.4-1734.9	2.5	[2/]1.1	---	---	---	[2/] .1
5th	1736.5-1741.9	5.4	12.8	<0.1	---	1.6	---
4th	1806.4-1807.2	.8	---	---	---	[2/] .5	---
3d	1814.9-1819.4	4.5	---	5.8	1.3	1.0	---
2d	1832.8-1836.1	0	---	---	---	---	---
1st	1846.1-1863.0	0	---	---	---	---	---

1/ Based on chemical and modal analyses listed in tables 4a, b.

2/ Estimate from core examination and radioactivity log.

Table 7.--Deposit thickness and grade of ore in McNutt ore zones, AEC 8 (borehole 3), Los Medaños repository site (weight percent)

[Syl, sylvite; Lan, langbeinite; Leo, leonite; Kai, kainite; Car, carnallite. To convert from English to metric system multiply thickness and depth measurements by 0.3048. ---, not present.]

Ore zone	Depth (feet)	Thickness (feet)	K_2O distribution by minerals[1/]				
			Syl	Lan	Leo	Kai	Car
11th	1521.8-1523.1	1.3	[2/]1.5	---	---	---	[2/]0.5
10th	1589.7-1594.7	5.0	13.6	---	---	---	1.1
9th	1604.3-1607.7	3.4	3.9	---	---	---	3.4
8th	1636.6-1638.1	1.5	11.9	---	---	---	.9
7th	1666.5-1671.0	0	---	---	---	---	---
6th	1681.9-1683.3	0	---	---	---	---	---
5th	1688.7-1697.0	0	---	---	---	---	---
4th	1753.4-1757.4	4.0	---	11.0	0.6	0.5	---
3d	1766.0-1767.0	1.0	---	[2/]3.4	[2/].6	[2/].5	---
2d	1781.9-1782.6	.7	---	---	---	---	---
1st	1796.0-1810.5	0	---	---	---	---	---

1/ Based on chemical and modal analyses listed in tables 5a, b.

2/ Estimate from core examination and radioactivity log.

valuable for potassium mineral deposits. Deposits in the four zones contain significant amounts of potash (K_2O) in the form of the mineral sylvite or langbeinite, and must be regarded as having an economic potential for potash.

Of the four ore zones containing potash in significant amounts, the 10th ore zone probably has the greatest economic potential. It is the shallowest of the four zones, carries sylvite as an ore mineral, and has been successfully exploited for a considerable tonnage of sylvite during the past decade of potash mining in southeastern New Mexico. Moreover, sylvite ore has been extracted from the 10th ore zone within 2 mi (3 km) of the potential repository site. In the two borings at the site. the range in deposit thickness is from 3.4 to 5.0 ft (1.0 to 1.5 m). The grade of ore is 12-13 percent K_2O (tables 6 and 7), but locally may exceed 14 percent if the carnallite in the deposit (table 3) gives way to sylvite in parts of the site untested as yet by drilling. The deposit in the two borings is not as rich in potash as the sylvite ore being mined from the 10th ore zone, but its potash content lies well within the 9-20 percent range in the grade of sylvite ore extracted from the 1st ore zone. Insofar as has been determined by drilling, the 10th ore zone deposit may underlie 90 percent or more of the site, and its thickness and grade of ore throughout 80 percent or more of its extent may equal or exceed the standards of ore thickness and quality used for mineral land classification purposes. If so, the 10th ore zone deposit within the potential repository site may contain about 165 million tons

(150 million metric tons) of sylvite ore and have a potash content (K_2O) of 16.5 million tons (15 million metric tons). This projection of possible potash resources is highly speculative; the degree of uncertainty is considerable.

In contrast to the 10th ore zone with its extensive deposit of sylvite ore, the 5th ore zone in the potential repository site almost certainly has a very limited potential for potash. This assessment seems required by the very presence of sylvite and its manner of occurrence in the ore zone. It must be noted that the 5th ore zone is known primarily for the occurrence of langbeinite. In the present instance, however, langbeinite is virtually absent, and its place is taken by sylvite, kainite, and kieserite (table 3). The sylvite and associated minerals are at the very top of the ore zone, whereas the langbeinite ordinarily occurs well below the top of the unit. The distribution and manner of potash occurrence in the ore zone suggest that the sylvite is not very widespread, and laterally gives way to langbeinite. Despite the uncertainty of deposit mineralogy and extent, borehole data (table 6) clearly shows that the 5th ore zone locally grades 12.8 percent K_2O as sylvite in an interval of 5.4 ft (1.6 m) thick. Furthermore, consideration of borehole data suggests that the deposit may underlie as much as one-third of the repository site, and that from one-tenth to one-third of its extent the thickness and grade of ore may equal or exceed the minimum standards used for mineral land classification purposes. The potash resources of the 5th ore zone may amount to 15.4 million tons (14 million metric tons) of sylvite ore containing 1.5 million tons (1.4 million metric tons) of potash (K_2O).

By practically any standards, the langbeinite-rich deposit of potassium minerals in the 4th ore zone (table 3) in this area must be regarded as having a considerable economic potential. Deposits in this ore zone are known for the occurrence of langbeinite ore, and they have long been successfully exploited for langbeinite at potash mines 6-7 mi (10-11 km) west of the potential repository site. Insofar as has been determined, the 4th ore zone deposit at the site is about equally rich as those now being exploited. As shown by the borehole data (table 7), the 4th ore zone deposit has a thickness of 4.0 ft (1.2 m) and grades 11 percent K_2O as langbeinite. The deposit thickness is comparable to that in many sections of existing mine workings, and the potash (K_2O) content is equal to the highest grades of langbeinite ore being mined. The depth to the deposit at the site is about 40 percent greater than that of the productive deposits, but this greater depth does not exceed the depth of existing mine workings from which sylvite ore is being extracted. The size of the deposit is unknown. However, from available data, the deposit may be inferred to occupy one-half to three-fourths of the area beneath the repository site. With the assumption that for two-thirds of its extent the deposit equals or exceeds the minimum standards of ore thickness and quality used for mineral land classification purposes, the 4th ore zone deposit may contain slightly over 88 million tons (80 million metric tons) of langbeinite ore and contain 3.5 million tons (3.2 million metric tons) of potash (K_2O).

Unlike the 4th ore zone, the deposit in the 3d ore zone (table 3) cannot be regarded as having a strong economic potential for potash at the potential repository site. There is no recorded production of langbeinite or sylvite ore from this zone, and the 3d ore zone deposits of potassium minerals are known to vary abruptly and erratically in thickness, grade, and mineralogy. Between the two borings sunk at the repository site, the 3d ore zone ranges in thickness from 1.0 to 4.5 ft (0.3 to 1.4 m), and in grade from 3.4 to 5.8 percent K_2O as langbeinite (tables 6 and 7). Borehole data suggest that the deposit may underlie as much as 50 percent of the site, and that throughout two-fifths or more of its extent the deposit may equal or exceed the standards of ore thickness and quality used for mineral land classification purposes. With this interpretation of deposit extent and quality, the potash resources of the 3d ore zone may total about 46 million tons (42 million metric tons) of langbeinite ore having a potash content of 1.9 million tons (1.7 million metric tons).

In summary, potash deposits in the 10th, 5th, 4th, and 3d ore zones at the potential repository site contain significant amounts of sylvite and langbeinite. It is inferred that the site may be underlain by 180 million tons (164 million metric tons) of sylvite ore and 134 million tons (122 million metric tons) of langbeinite ore. The potash ores may contain 23.5 million tons (21.3 million metric tons) of potash (K_2O). This tonnage of potash is equivalent to about a 4-year supply of potash at the present consumption level in the United States.

Table 8.--Summary of potash resources and production capacity of individual districts in North America

[Data in thousand short tons, K_2O. To convert from English to metric, multiply tons by 0.9072.]

District	Type of deposit	Type of operation	Annual production capacity1/	1973 Output2/	Reserves3/
		United States			
Carlsbad district	Crystalline rocks	Mines	2,550	2,232	308,600
Moab, Utah	Crystalline rocks	Solution (mined cavity)	200		63,000
Ogden, Utah	Great Salt Lake brine	Solution	130		91,000
Searles Lake, Calif.	Brine in surficial deposits	Solution	235	363	3,500
Wendover, Utah	Brine in surficial deposits	Solution	55		1,500
	Subtotal		3,170	2,595	467,600
		Canada			
Saskatchewan	Crystalline rocks	Mines	7,386	4,160	19,290,000
		Solution	938		35,825,000
	Subtotal		8,324	4,160	55,115,000
		North America			
	Total		11,494	6,755	55,582,600

1/ Data from Industrial Minerals, 1974, p. 13 and 18

2/ Data from U.S. Bureau of Mines, 1974, p. 126

3/ Data compiled from various sources

The tonnage is also equivalent to about 8 percent of the exploitable resources in southeastern New Mexico (table 8). It may represent about 5 percent of all exploitable domestic resources and about 0.04 percent of the resources in deposits currently being mined in the United States and Canada.

Deposits containing polyhalite

Potash deposits carrying polyhalite as their potassium mineral occur in beds of anhydrite termed marker beds by Jones, Bowles, and Bell (1960). The deposits underlie all sections of the potential repository site and are present in 35 of 52 beds of anhydrite scattered here and there through an interval of 1,242-1,273 ft (379-388 m) in the Salado Formation. Between the two borings sunk at the site, the depth to the polyhalite-bearing marker beds of anhydrite ranges from 1,070 to 2,367 ft (326 to 721 m). The thickness of the polyhalite-bearing rock in the marker beds ranges from a few inches to almost 13 ft (a few centimetres to almost 4 m). The rock is typically compact, somewhat finely crystalline, and white and grayish-pink to red. Much of it contains inclusions of halite and is banded with laminae of magnesite. The polyhalite content ranges from a few percent to more than 80 percent. Table 9 lists the results of chemical and modal analyses of four seams, or marker beds, of polyhalite-anhydrite rock.

Table 9.--Polyhalite and potash content of selected marker beds of polyhalite-anhydrite rock, borehole 2, Los Medaños repository site (weight percent)

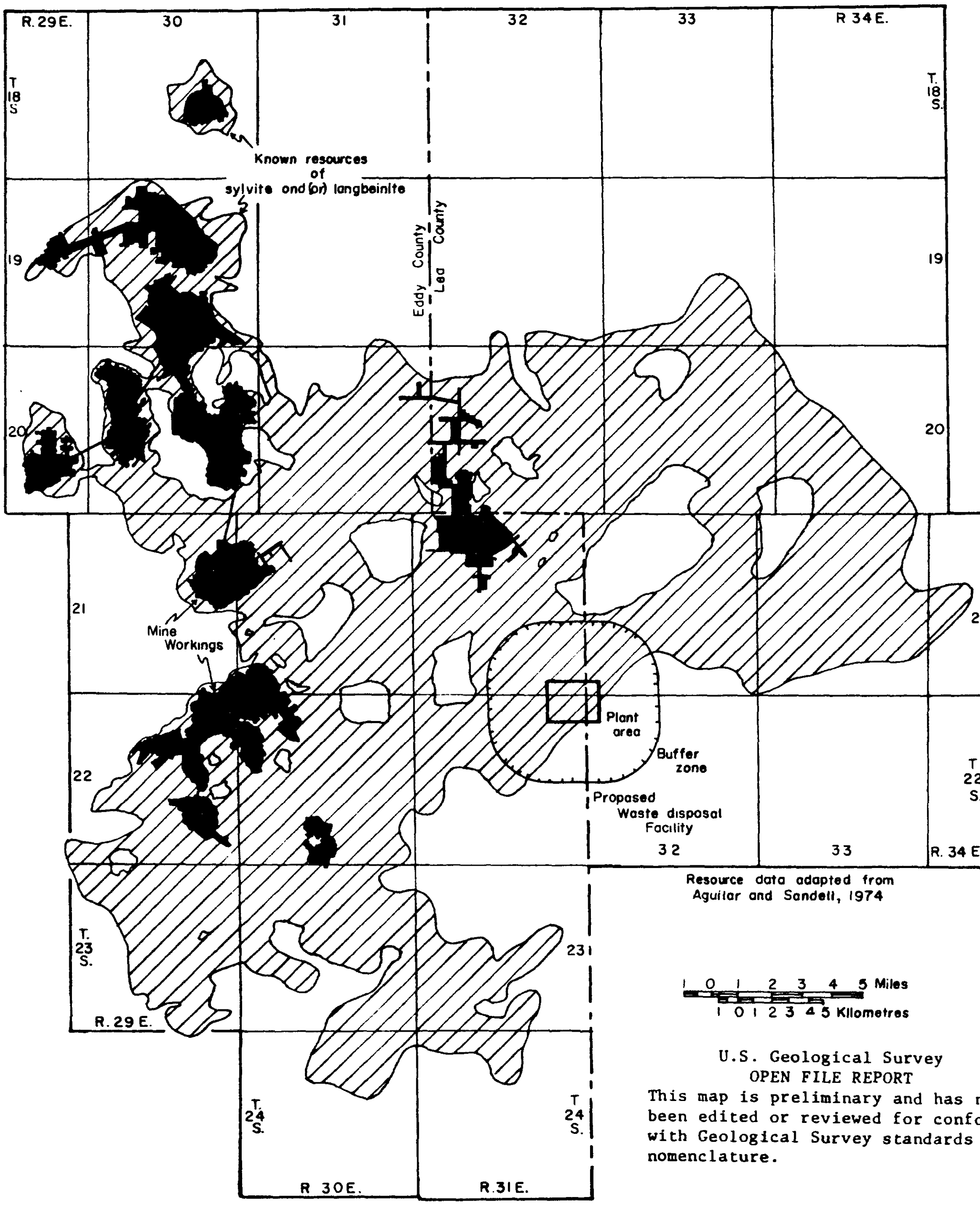
[To convert from English to metric system, multiply thickness and depth measurements by 0.3048]

Marker bed	Depth (feet)	Thickness (feet)	Polyhalite	Potash (K_2O)
114	1,447.9-1,450.5	2.6	80.7	12.6
123	1,774.8-1,780.7	5.9	70.9	11.1
136	2,157.9-2,164.9	7.0	62.0	9.7
140	2,299.6-2,312.2	12.6	61.3	9.6

The polyhalite-anhydrite rock of the Salado Formation is an untapped resource of potential, but unproven, value. Efforts to utilize the rock for the production of potassium sulfate have established experimentally successful procedures with little or no viable industrial application under existing economic conditions. The rock is potentially useful as a combination soil conditioner-fertilizer, but a lengthy program of testing and education would be required to establish its utility and value.

APPRAISAL OF RESOURCE SITUATION

Both geologically and geographically, Los Medaños repository site is part of the southeastern New Mexico potash field. This area of extensive potash deposits includes much of southern Eddy and Lea Counties between the Pecos River and the Llano Estacado, but only a fairly small part of it contains potash deposits of proven or potential economic value. Figure 4 (adapted from Aguilar and Sandell, 1974) shows the economically important section of the potash field and the extent of mine workings in the productive parts of the Carlsbad mining district. This section of the potash field is underlain by one or more potash deposits that contain sylvite or langbeinite in which the ore thickness and grade are believed to equal or exceed the standard of minimum thickness and quality of ore that is used to classify public lands as valuable for potassium mineral deposits. The Carlsbad district contains 86 percent of the potash production capacity in the United States and it has 65 percent of the potash resources that are exploitable by proven procedures or



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This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

Figure 4.--The Carlsbad mining district showing location of a potential waste-disposal facility and the distribution of mines and known resources of sylvite and langbeinite.

methods under existing economic conditions (table 8). Having an annual output of slightly more than 2.2 million tons (2.0 million metric tons) of potash, the mines in the district supply about 40 percent of all the potash consumed in the United States.

Insofar as can be foreseen, production of potash from deposits in the Carlsbad district should decline irregularly during the next decade and then stabilize significantly below the present production level. The resource base for potash production has been seriously eroded by extensive mining and it is no longer adequate to sustain the present high production. In addition, the resource base is not competitive with higher grade, more productive sources of potash in the Canadian province of Saskatchewan, and there will be a continuing loss of market to those sources. The disparity between grades of ore is considerable and has great economic significance. Between 2.5 and 3.0 short tons (2.3 and 2.7 metric tons) of sylvite ore are mined from the Canadian sources to produce 1 ton of potassium chloride product; whereas for the Carlsbad area, 4.5-6.0 short tons (4.1-5.4 metric tons) of sylvite ore are mined for each ton of product. The necessity of handling a larger tonnage of ore places a considerable economic burden on the production of potash in the Carlsbad area.

The potash deposits which underlie the potential repository site in Los Medanos are clearly part of the resource base for the potash industry in the Carlsbad area--and, therefore, the United States. However, the tonnage and range in quality of the potash ores are unknown. Available data indicate sufficient amounts of sylvite and langbeinite for the deposits to have an economic potential. Locally, the sylvite and langbeinite ores are similar, if not equal, in quality to some ores being mined only a few kilometres from the site, and they probably should be regarded as unproven, but potentially valuable, potash resources. They are clearly promising enough in mineralogy and tenor to warrant further investigation.

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Figure 3.--Correlated subsurface sections of McNutt potash zone, Salado Formation, Los Medaños area

Prepared by C.L. Jones
October 1974

Table 4a.--Analyses of potash ores and rocks in Union Carbide Corporation AEC 7 (borehole 2)

[Analyst: T. J. Futch. K_2O, potash; Ca, calcium; Mg, magnesium, Cl, chlorine; SO_4, sulfate. ---, not analyzed.]

Rock unit	Depth (feet) From To	Thickness (feet)	K_2O	Ca	Mg	Cl	SO_4	Water insoluble matter	Water loss 60°-200°C
			(weight percent)						
Marker bed 114	1447.9-1449.1	1.2	11.68	---	---	15.01	---	---	---
	1449.1-1450.45	1.35	13.41	---	---	8.66	---	---	---
11th ore zone	1559.8-1561.0	1.2	0.83	---	---	---	---	---	---
	1561.0-1563.0	2.0	4.46	---	---	---	---	---	---
	1563.0-1564.1	1.1	1.86	---	---	---	---	---	---
10th ore zone	1631.2-1632.0	0.8	1.94	0.44	0.52	57.52	1.90	0.08	0.97
	1632.0-1632.8	0.8	1.59	0.37	0.67	55.77	1.31	2.35	2.20
	1632.8-1634.5	1.7	1.90	0.33	0.83	56.75	1.46	0.07	2.34
	1634.5-1635.1	0.6	4.43	0.64	1.88	44.18	3.66	13.68	6.25
	1635.1-1637.0	1.9	19.01	0.44	1.24	48.93	2.54	4.71	4.05
	1637.0-1637.9	0.9	14.18	0.17	1.39	49.98	1.21	5.47	4.89
	1637.9-1639.1	1.2	2.65	0.59	0.67	55.56	3.14	0.90	0.96
9th ore zone	1645.1-1646.0	0.9	1.46	0.10	0.41	55.14	0.64	5.68	1.19
	1646.0-1650.0	4.0	3.31	0.31	0.99	56.05	2.01	0.21	2.28
	1650.0-1651.3	1.3	13.60	0.11	1.08	52.07	0.76	4.30	4.01
	1651.3-1651.9	0.6	5.60	0.14	2.73	49.77	0.65	5.14	9.04
	1651.9-1653.0	1.1	1.16	0.08	0.60	53.26	0.63	7.87	1.96
8th ore zone	1681.9-1682.3	0.4	1.46	---	---	---	---	---	---
	1682.3-1683.4	1.1	10.44	---	---	---	---	---	---
	1683.4-1684.1	0.7	2.04	---	---	---	---	---	---
7th ore zone	1712.8-1714.3	1.5	1.16	---	---	---	---	---	---
	1714.3-1717.3	3.0	2.52	---	---	---	---	---	---
	1717.3-1719.1	1.8	2.16	---	---	---	---	---	---
	1719.1-1724.4	5.3	0.83	---	---	---	---	---	---
5th ore zone	1732.4-1734.9	2.5	1.57	0.14	0.17	58.98	0.75	0.25	0.21
	1734.9-1736.5	1.6	1.86	0.49	0.19	57.65	2.44	0.09	0.15
	1736.5-1738.0	1.5	24.68	0.69	1.08	49.42	6.87	0.15	0.49
	1738.0-1739.4	1.4	20.45	0.49	1.44	49.49	7.43	0.16	0.52
	1739.4-1740.7	1.3	6.14	0.25	5.30	37.27	21.95	1.53	2.34
	1740.7-1741.9	1.2	6.43	0.08	4.32	40.90	16.87	2.00	2.74
	1741.9-1746.1	4.2	1.59	0.23	0.48	57.03	2.74	0.39	0.18
	1746.1-1751.0	4.9	3.10	0.80	1.30	50.26	9.07	1.42	1.41
	1751.0-1753.7	2.7	0.31	0.09	0.14	57.86	1.11	1.56	0.12
Marker bed 123	1772.6-1774.8	2.2	5.77	---	---	40.41	---	---	---
	1774.8-1776.0	1.2	13.56	---	---	5.30	---	---	---
	1776.0-1777.0	1.0	15.19	---	---	2.02	---	---	---
	1777.0-1778.3	1.3	15.35	---	---	0.91	---	---	---
	1778.3-1779.4	1.1	12.01	---	---	1.19	---	---	---
	1779.4-1780.7	1.3	0.61	---	---	8.38	---	---	---
	1780.7-1782.4	1.7	0.51	---	---	31.13	---	---	---
3d ore zone	1813.6-1814.9	1.3	0.83	0.52	0.14	57.93	2.55	0.41	0.06
	1814.9-1815.3	0.4	5.97	0.12	2.24	42.65	14.53	2.74	4.75
	1815.3-1816.1	0.8	1.34	0.45	0.49	55.84	3.49	1.64	0.34
	1816.1-1817.0	0.9	7.19	0.16	3.52	33.99	20.71	6.04	4.39
	1817.0-1818.4	1.4	12.83	0.15	6.41	26.38	38.84	0.57	0.06
	1818.4-1818.7	0.3	1.46	0.35	0.60	55.35	4.21	1.63	0.26
	1818.7-1819.4	0.7	13.76	0.08	6.94	24.22	41.57	0.68	0.26
	1819.4-1820.5	1.1	1.06	0.24	0.58	56.82	3.57	0.75	0.16
Marker bed 136	2156.7-2157.9	1.2	1.20	---	---	39.58	---	---	---
	2157.9-2159.1	1.2	9.84	---	---	4.26	---	---	---
	2159.1-2160.7	1.6	16.35	---	---	1.12	---	---	---
	2160.7-2161.9	1.2	12.67	---	---	3.49	---	---	---
	2161.9-2163.2	1.3	9.77	---	---	7.96	---	---	---
	2163.2-2164.9	1.7	2.10	---	---	1.75	---	---	---
Marker bed 140	2299.6-2300.1	0.5	0.07	---	---	5.86	---	---	---
	2300.1-2301.2	1.1	11.12	---	---	2.72	---	---	---
	2301.2-2302.2	1.0	9.11	---	---	1.61	---	---	---
	2302.2-2303.6	1.4	10.23	---	---	1.47	---	---	---
	2303.6-2305.0	1.4	11.47	---	---	6.28	---	---	---
	2305.0-2306.1	1.1	11.74	---	---	6.00	---	---	---
	2306.1-2307.2	1.1	13.88	---	---	3.42	---	---	---
	2307.2-2307.8	0.6	13.33	---	---	3.91	---	---	---
	2307.8-2308.3	0.5	12.44	---	---	1.88	---	---	---
	2308.3-2311.3	3.0	8.69	---	---	5.30	---	---	---
	2311.3-2312.2	0.9	0.51	---	---	15.08	---	---	---

Table 4b.--Computed modes of potash ores and rocks in Union Carbide Corporation AEC 7 (borehole 2)

[Syl, sylvite; Lan, langbeinite; Kai, kainite; Leo, leonite; Bloe, bloedite; Kie, Kieserite; Car, carnallite; Ha, halite; Poly, polyhalite; An, anhydrite. ---, not present; N.C., not computed.]

Rock unit	Depth (feet) From To	Thickness (feet)	Syl	Lan	Kai	Leo	Bloe	Kie	Car	Ha	Poly	An 1/	Water insoluble matter
							(weight percent)						
Marker bed 114	1447.9-1449.1	1.2	---	---	---	---	---	---	---	24.7	74.8	0.5	---
	1449.1-1450.45	1.35	---	---	---	---	---	---	---	14.3	85.7	---	---
11th ore zone	1559.8-1561.0	1.2	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
	1561.0-1563.0	2.0	Maximum of 7.0 percent KCl as sylvite and carnallite.										
	1563.0-1564.1	1.1	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
10th ore zone	1631.2-1632.0	0.8	1.2	---	---	---	---	---	4.7	91.0	2.7	0.3	0.1
	1632.0-1632.8	0.8	0.3	---	---	---	---	---	7.0	87.3	1.3	0.7	2.4
	1632.8-1634.5	1.7	0.2	---	---	---	---	---	8.5	88.0	2.1	0.2	0.1
	1634.5-1635.1	0.6	1.1	---	---	---	---	0.9	17.6	60.9	4.8	---	13.7
	1635.1-1637.0	1.9	26.2	---	---	---	---	0.6	11.4	52.9	3.3	---	4.7
	1637.0-1637.9	0.9	18.3	---	---	---	---	0.6	14.2	59.1	1.3	---	5.5
	1637.9-1639.1	1.2	3.2	---	---	---	---	2.1	3.0	87.2	0.8	1.7	0.9
9th ore zone	1645.1-1646.0	0.9	1.1	---	---	---	---	0.2	3.9	87.6	0.8	---	5.7
	1646.0-1650.0	4.0	2.3	---	---	---	---	0.8	8.7	85.1	2.3	---	0.2
	1650.0-1651.3	1.3	18.3	---	---	---	---	0.3	11.3	64.4	0.8	---	4.3
	1651.3-1651.9	0.6	0.7	---	---	---	---	0.5	30.3	62.4	0.5	---	5.1
	1651.9-1653.0	1.1	0.3	---	---	---	---	0.6	5.6	84.0	---	0.3	7.9
8th ore zone	1681.9-1682.3	0.4	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
	1682.3-1683.4	1.1	Maximum of 16.5 percent KCl as sylvite and carnallite.										
	1683.4-1684.1	0.7	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
7th ore zone	1712.8-1714.3	1.5	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
	1714.3-1717.3	3.0	Maximum of 4.0 percent KCl as sylvite and carnallite.										
	1717.3-1719.1	1.8	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
	1719.1-1724.4	5.3	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
5th ore zone	1732.4-1734.9	2.5	1.9	---	---	---	---	0.1	1.2	95.0	1.1	---	0.3
	1734.9-1736.5	1.6	2.0	---	---	---	---	0.1	0.2	93.4	3.7	---	0.1
	1736.5-1738.0	1.5	37.6	0.5	---	---	---	4.6	---	52.0	5.2	---	0.2
	1738.0-1739.4	1.4	30.8	---	2.4	---	---	6.0	---	56.9	3.7	---	0.2
	1739.4-1740.7	1.3	4.2	0.5	16.2	---	---	20.4	---	54.3	1.9	---	1.5
	1740.7-1741.9	1.2	4.1	---	18.9	---	---	13.5	1.1	59.1	---	0.3	2.0
	1741.9-1746.1	4.2	0.8	0.1	4.1	---	---	---	---	92.4	1.7	---	0.4
	1746.1-1751.0	4.9	0.2	4.6	5.3	---	---	---	---	81.5	6.0	---	1.4
	1751.0-1753.7	2.7	---	0.5	---	0.5	---	0.2	---	95.4	0.7	---	1.6
Marker bed 123	1772.6-1774.8	2.2	---	---	---	---	---	---	---	66.6	36.9	---	---
	1774.8-1776.0	1.2	---	---	---	---	---	---	---	8.7	86.8	4.5	---
	1776.0-1777.0	1.0	---	---	---	---	---	---	---	3.3	97.2	---	---
	1777.0-1778.3	1.3	---	---	---	---	---	---	---	1.5	98.3	---	---
	1778.3-1779.4	1.1	---	---	---	---	---	---	---	1.9	76.9	21.2	---
	1779.4-1780.7	1.3	---	---	---	---	---	---	---	13.8	3.8	83.2	---
	1780.7-1782.4	1.7	---	---	---	---	---	---	---	51.3	3.3	45.4	---
3d ore zone	1813.6-1814.9	1.3	0.2	---	---	---	---	---	---	95.3	3.5	0.2	0.4
	1814.9-1815.3	0.4	---	---	9.0	16.1	3.6	---	---	68.2	0.9	---	2.7
	1815.3-1816.1	0.8	0.3	---	3.8	---	---	---	---	91.0	3.0	0.2	1.6
	1816.1-1817.0	0.9	---	0.7	19.0	12.2	10.0	---	---	51.5	1.2	---	6.0
	1817.0-1818.4	1.4	---	52.6	---	2.8	0.3	---	---	43.5	1.1	---	0.6
	1818.4-1818.7	0.3	---	1.7	2.5	0.7	---	---	---	91.3	2.6	---	1.6
	1818.7-1819.4	0.7	---	57.5	0.4	2.1	---	---	---	39.8	0.6	---	0.7
	1819.4-1820.5	1.1	---	1.8	2.0	---	---	0.6	---	93.2	1.8	---	0.8
Marker bed 136	2156.7-2157.9	1.2	---	---	---	---	---	---	---	65.3	7.7	27.0	---
	2157.9-2159.1	1.2	---	---	---	---	---	---	---	7.0	63.0	30.0	---
	2159.1-2160.7	1.6	---	---	---	---	---	---	---	1.8	?	?	---
	2160.7-2161.9	1.2	---	---	---	---	---	---	---	5.8	81.1	13.1	---
	2161.9-2163.2	1.3	---	---	---	---	---	---	---	13.1	62.5	24.4	---
	2163.2-2164.9	1.7	---	---	---	---	---	---	---	2.9	13.4	83.7	---
Marker bed 140	2299.6-2300.1	0.5	---	---	---	---	---	---	---	9.7	0.4	89.9	---
	2300.1-2301.2	1.1	---	---	---	---	---	---	---	4.5	71.2	24.3	---
	2301.2-2302.2	1.0	---	---	---	---	---	---	---	2.6	58.3	39.1	---
	2302.2-2303.6	1.4	---	---	---	---	---	---	---	2.4	65.0	32.6	---
	2303.6-2305.0	1.4	---	---	---	---	---	---	---	10.4	73.4	16.2	---
	2305.0-2306.1	1.1	---	---	---	---	---	---	---	9.9	75.1	15.0	---
	2306.1-2307.2	1.1	---	---	---	---	---	---	---	5.6	88.8	5.6	---
	2307.2-2307.8	0.6	---	---	---	---	---	---	---	6.4	85.3	8.3	---
	2307.8-2308.3	0.5	---	---	---	---	---	---	---	3.1	79.6	17.3	---
	2308.3-2311.3	3.0	---	---	---	---	---	---	---	8.7	55.6	35.7	---
	2311.3-2312.2	0.9	---	---	---	---	---	---	---	24.9	3.3	71.8	---

1/ Includes magnesite.

Table 5a.--Analyses of potash ores and rocks in Union Carbide Corporation AEC 8 (borehole 3)

/Analyst: T. J. Futch. K_2O, potash; Ca, calcium; Mg, magnesium, Cl, chlorine; SO_4, sulfate./

Rock unit	Depth (feet) From To	Thickness (feet)	K_2O	Ca	Mg	Cl	SO_4	Water insoluble matter	Water loss 60°-$200^{\circ}C$
			(weight percent)						
10th ore zone	1589.1-1589.7	0.6	3.28	0.74	0.87	53.96	5.38	1.73	0.25
	1589.7-1591.7	2.0	10.54	0.06	7.06	33.57	28.25	1.21	0.17
	1591.7-1592.2	0.5	12.77	0.03	4.19	33.43	14.48	14.86	2.84
	1592.2-1594.5	2.3	19.08	0.22	1.51	46.49	3.49	8.42	3.29
	1594.5-1594.7	0.2	12.77	0.03	4.60	46.00	0.43	3.72	18.67
	1594.7-1595.5	0.8	2.16	0.52	0.78	54.23	2.56	4.46	1.61
9th ore zone	1603.2-1604.3	1.1	3.25	0.52	0.45	57.10	2.26	0.81	0.42
	1604.3-1606.0	1.7	7.84	0.30	1.91	54.03	0.87	0.59	6.24
	1606.0-1606.4	0.4	10.35	0.08	4.79	47.46	0.53	0.68	14.49
	1606.4-160 .7	0.6	3.73	0.33	1.61	54.86	1.85	0.65	4.62
	1607.0-1607.7	0.7	7.59	0.29	0.62	54.72	1.27	3.29	1.15
8th ore zone	1629.7-1630.4	0.7	2.23	0.44	0.54	53.12	2.48	6.87	0.85
	1630.4-1631.3	0.9	26.04	0.64	0.37	51.09	2.99	2.42	0.15
	1631.3-1631.8	0.5	3.99	0.42	0.81	46.84	1.95	15.05	2.80
	1631.8-1633.3	1.5	1.11	0.39	0.21	58.21	1.75	0.95	0.10
	1633.3-1634.8	1.5	1.88	0.50	0.19	57.31	2.03	1.63	0.13
	1634.8-1635.5	0.7	2.61	0.41	0.14	58.63	1.49	0.67	0.07
	1635.5-1636.6	1.1	2.61	0.47	0.12	58.21	1.85	0.86	0.08
	1636.6-1637.1	0.5	29.05	0.38	0.16	51.16	1.45	3.08	0.15
	1637.1-1638.1	1.0	5.20	0.30	0.75	46.84	1.55	15.98	2.79
	1638.1-1638.7	0.6	0.93	0.22	0.38	54.03	0.92	8.40	0.85
4th ore zone	1752.1-1752.7	0.6	0.52	0.10	0.17	58.63	0.78	1.93	0.14
	1752.7-1753.4	0.7	1.14	0.05	0.44	58.07	2.50	0.31	0.13
	1753.4-1754.0	0.6	6.78	0.08	3.34	43.14	20.07	0.20	0.14
	1754.0-1755.0	1.0	15.09	0.03	7.57	21.01	45.49	0.14	0.17
	1755.0-1756.7	1.7	16.76	0.05	8.34	14.87	49.93	2.32	1.30
	1756.7-1757.4	0.7	2.11	0.06	1.10	50.81	4.48	7.23	1.24
Stray between 4th and 3d ore zones	1761.0-1762.0	1.0	4.42	0.22	2.00	49.49	12.45	0.28	0.11
	1762.0-1762.3	0.3	3.66	0.37	1.69	50.54	11.06	4.98	0.32
	1762.3-1763.4	1.1	2.26	0.53	1.03	51.79	7.39	2.71	0.54

Table 5b.--Computed modes of potash ores and rocks in Union Carbide Corporation AEC 8 (borehole 3)

/Syl, sylvite; Lan, langbeinite; Kai, kainite; Leo, leonite; Bloe, bloedite; Kie, Kieserite; Car, carnallite; Ha, halite; Poly, polyhalite; An, anhydrite. ---, not present./

Rock unit	Oepth (feet) From To	Thickness (feet)	Syl	Lan	Kai	Leo	Bloe	Kie	Car	Ha	Poly	An	Water insoluble matter
			(weight percent)										
10th ore zone	1589.1-1589.7	0.6	4.9	---	---	---	---	4.7	---	85.1	1.0	2.0	1.7
	1589.7-1591.7	2.0	16.6	---	---	---	---	40.1	---	42.4	0.5	---	1.2
	1591.7-1592.2	0.5	18.5	---	---	---	---	20.8	6.2	36.7	---	0.1	14.9
	1592.2-1594.5	2.3	27.9	---	---	---	---	4.3	8.7	49.3	---	0.8	8.4
	1594.5-1594.7	0.2	6.4	---	---	---	---	0.5	51.6	38.4	---	0.1	3.7
	1594.7-1595.5	0.8	1.3	---	---	---	---	1.0	6.1	84.6	2.0	0.9	4.5
9th ore zone	1603.2-1604.3	1.1	4.1	---	---	---	---	---	0.9	90.7	3.2	0.3	0.8
	1604.3-1606.0	1.7	7.2	---	---	---	---	1.2	19.5	71.1	---	0.1	0.6
	1606.0-1606.4	0.4	2.0	---	---	---	---	0.5	53.8	42.8	---	0.3	0.7
	1606.4-1607.0	0.6	1.8	---	---	---	---	1.5	15.3	79.4	---	1.1	0.7
	1607.0-1607.7	0.7	9.9	---	---	---	---	---	6.3	78.5	1.8	0.2	3.3
8th ore zone	1629.7-1630.4	0.7	1.8	---	---	---	---	0.5	3.6	84.0	3.3	---	6.9
	1630.4-1631.3	0.9	39.5	---	---	---	---	---	2.1	51.9	4.6	0.1	2.4
	1631.3-1631.8	0.5	3.5	---	---	---	---	---	7.9	69.5	3.0	0.1	15.1
	1631.8-1633.3	1.5	0.8	---	---	---	---	---	1.2	94.6	2.6	0.2	1.0
	1633.3-1634.8	1.5	2.1	---	---	---	---	---	1.0	93.4	2.6	0.5	1.6
	1634.8-1635.5	0.7	3.5	---	---	---	---	---	0.9	93.4	1.6	0.7	0.7
	1635.5-1636.6	1.1	3.5	---	---	---	---	---	0.3	93.2	2.3	0.6	0.9
	1636.6-1637.1	0.5	45.3	---	---	---	---	---	1.1	48.2	1.7	0.5	3.1
	1637.1-1638.1	1.0	5.7	---	---	---	---	0.2	7.2	68.2	2.3	---	16.0
4th ore zone	1752.1-1752.7	0.6	0.4	---	0.8	---	---	---	0.7	96.0	0.8	---	1.9
	1752.7-1753.4	0.7	0.4	1.3	2.8	---	---	---	---	94.8	0.4	---	0.3
	1753.4-1754.0	0.6	---	26.1	1.2	2.0	---	---	---	70.8	0.6	---	0.2
	1754.0-1755.0	1.0	---	63.6	---	---	1.2	---	---	34.6	0.2	---	0.1
	1755.0-1756.7	1.7	---	67.6	1.2	4.6	---	---	---	24.2	---	0.2	2.3
	1756.7-1757.4	0.7	---	---	10.8	---	---	---	---	81.3	0.6	---	7.3
Stray between 4th and 3d ore zones	1761.0-1762.0	1.0	0.7	16.2	0.3	---	---	---	---	81.0	1.7	---	0.3
	1762.0-1762.3	0.3	0.3	12.9	0.6	---	---	---	---	83.0	2.8	---	1.0
	1762.3-1763.4	1.1	---	6.1	1.3	---	---	0.1	---	85.1	4.0	---	2.7