TEM-1033

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THICKNESS, CHARACTER, AND STRUCTURE OF UPPER PERMIAN EVAPORITES IN PART OF EDDY COUNTY, NEW MEXICO

By

C. L. Jones

October 1959

Trace Elements Memorandum Report 1033

60-83

This report is preliminary
and has not been edited for
conformity with Geological
Survey format and nomenclature.

CONTENTS

ILLUSTRATIONS

TABLES

THICKNESS, CHARACTER, AND STRUCTURE OF UPPER PERMIAN EVAPORITES IN PART OF EDDY COUNTY, NEW MEXICO

By C. L. Jones

ABSTRACT

Between Project Gnome site and the International Minerals and Chemical Corporation's plant site, in central eastern Eddy County, N. Mex., unconsolidated deposits of Quaternary age and redbeds of Triassic age attain a thickness of about 700 feet, and rest unconformably on evaporites of late Permian age. The upper Permian evaporites are 3,000 to 3,800 feet thick, and they are divided, in descending order, into the Rustler, Salado, and Castile formations. The Rustler is largely gypsum rock, the Salado is dominantly halite rock, and the Castile contains both anhydrite rock and halite rock. The salt and anhydrite beds of the Salado and Castile are intruded by narrow dikes of alkalic rock along which the evaporites are little altered. The sedimentary rocks have a generally southeastward regional dip, but locally are warped in gentle folds of low amplitude and fairly small lateral dimensions.

INTRODUCTION

This report summarizes existing subsurface data concerning the thickness, character, and structure of upper Permian evaporites in part of Eddy County, N. Mex. The area of particular interest lies in central eastern Eddy County between Project Gnome site, in the center of sec. 34, T. 23 S., R. 30 E. and the plant site of International Minerals and Chemical Corporation, in the SE$\frac{1}{4}$ of sec. 1, and N$\frac{1}{2}$NE$\frac{1}{4}$ of sec. 12, T. 22 S., R. 29 E. (fig. 1). Several drill holes (table 1) in this area penetrate the complete section of upper Permian evaporites. The evaporites and overlying rocks are described in this report in the order in which they are penetrated by the drill.

The plant site of the International Minerals and Chemical Corporation, which is about 11 miles northwest of Project Gnome site (fig. 1), comprises about 160 acres on which are located various facilities for hoisting, refining, storing, and shipping potash ores and the recovered salts. The ores are mined in underground workings that are from 650 to 900 feet below the surface and about 2,300 to 2,400 feet above the base of the upper Permian evaporites. The mine workings extend from the plant site northeastward to the northern part of sec. 31, T. 21 S., R. 30 E. and southwestward into sec. 26, T. 22 S., R. 29 E.

Project Gnome site (fig. 1) is underlain by about 3,600 feet of upper Permian evaporites (fig. 2) of which 1,203 feet were penetrated in the A.E.C. No. 1 drill hole (Moore, 1958). This drill hole is in the approximate center of sec. 34, T. 23 S., R. 30 E.

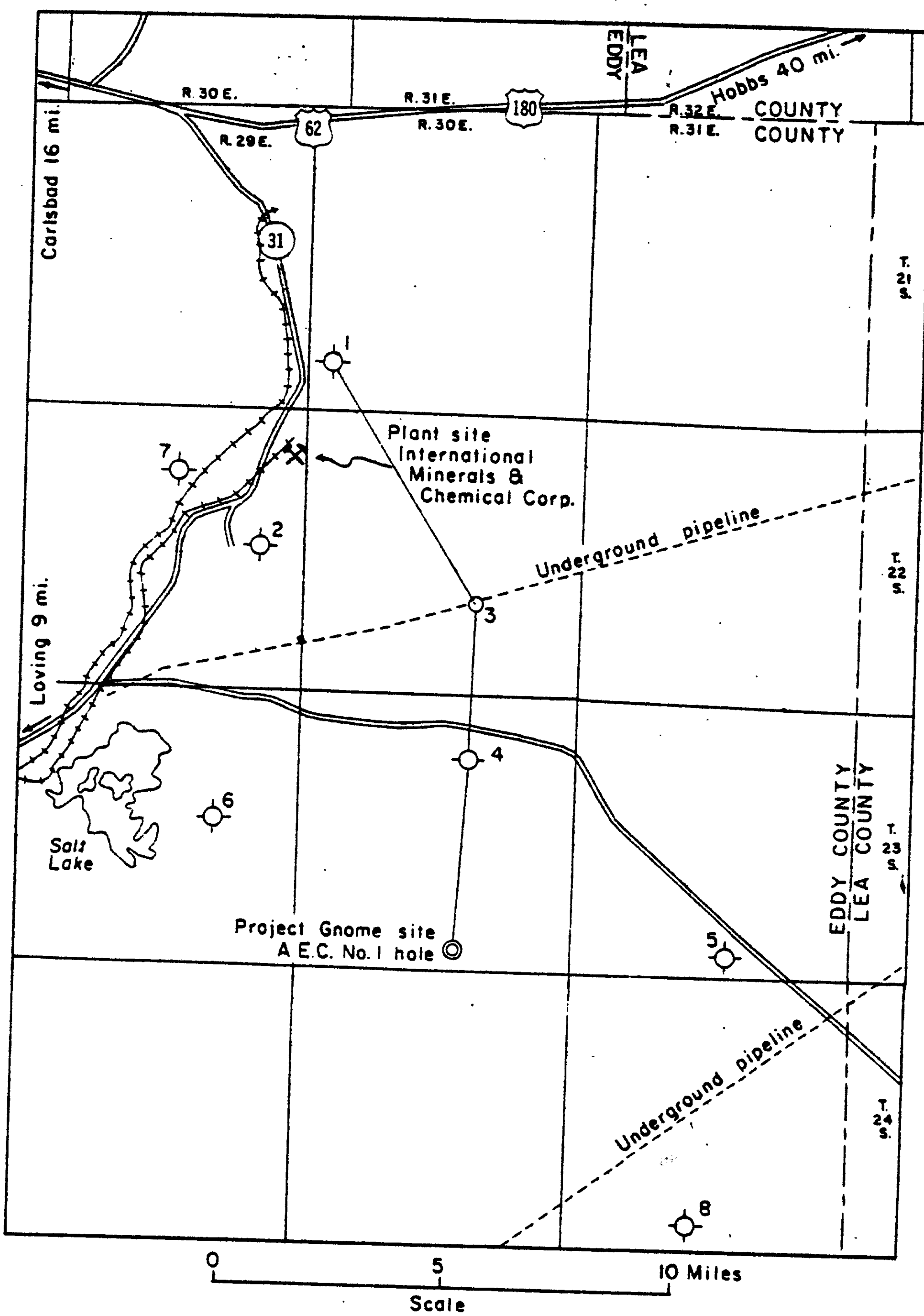


Figure 1.— Index map of part of central eastern Eddy Co., New Mexico, showing the location of the plant site of International Minerals & Chemical Corp. with respect to Project Gnome site, to drill holes listed in Table 1, and to line of structure section shown in Figure 2.

Table 1.--Index to drill holes

Company	Name of drill hole	Location: sec.	Location: T.	Location: R.	Altitude[1/] (feet)	Total Depth (feet)	Year [2/]	Remarks and type of logs
1. Stanolind Oil & Gas	No. 1 Duncan	SE¼SW¼ sec. 31	21 S.	30 E	3,320 (gl)	3,658	1934	Cable tool cuttings described and analyzed by R. K. Bailey[3/]
2. Ohio Oil	No. 1 Workman	SW¼SW¼ sec. 13	22 S.	29 E	3,047 (gl)	3,260	1927	Cable tool cuttings described by J. W. Vanderwilt and F. C. Calkins, and analyzed by R. K. Bailey and E. T. Erickson[3/]
3. Richardson & Bass	No. 1 Legg	NW¼NE¼ sec. 27	22 S.	30 E.	3,309 (df)	15,854	1954	Electrical resistivity radiometric, and caliper logs of hole
4. Wills, and others	No. 1 Montgomery	SW¼NE¼ sec. 10	23 S.	30 E.	3,129 (gl)	3,715	1935	Cable tool cuttings described and analyzed by R. K. Bailey[3/]
5. Continental Oil	No. 1 Gardner	NE¼SW¼ sec. 34	23 S.	31 E.	3,455 (gl)	4,410	1928	Cable tool cuttings described by J. W. Vanderwilt and F. C. Calkins and analyzed by J. J. Fahey[3/]
6. H. & W. Drilling	No. 1-X Fogarty	SW¼SW¼ sec. 14	23 S.	29 E.	3,003 (gl)	3,144	1937	Cable tool cuttings described by F. S. Grimaldi[3/]
7. H. & W. Drilling	No. 1 Danford	SE¼SE¼ sec. 9	22 S.	29 E.	3,246 (gl)	3,322	1937	Penetrated alkalic lamprophyre from 2,208 to 2,230 feet below surface. Cable tool cuttings described by R. K. Bailey [3/]

Table 1.--Index to drill holes -- continued

Company	Name of drill hole	Location			Altitude 1/ (feet)	Total Depth (feet)	Year 2/	Remarks and type of logs
		sec.	T.	R.				
8. R. L. Harrison	No. 1 Rowley	SW$\frac{1}{4}$NE$\frac{1}{4}$	24 S.	31 E.	3,459 (gl)	4,390	1948	Sample log prepared by Permian Basin Sample Laboratory

1/ gl ground level; df derrick floor

2/ Year completed or abandoned

3/ Unpublished records of U. S. Geological Survey

Data here presented were collected in the course of potash studies undertaken by the U. S. Geological Survey, and are made available to the Albuquerque Operations Office, U. S. Atomic Energy Commission at the request of that office.

The geology of the region of which the area is a part has been described by Adams (1944), Bretz and Horberg (1949), Dane and Bachman (1958), Dunlap (1951), Hendrickson and Jones (1952), Hughes (1954), Jones (1954), P. B. King (1942), R. H. King (1947), Kroenlein (1939), Lang (1935, 1937, 1939, and 1942), Mansfield and Lang (1935), Robinson and Lang (1938), Smith (1938), Schaller and Henderson (1932), and Udden (1924).

GEOLOGY

The sedimentary rocks of the area are, in descending order, Quaternary, Triassic, Permian, and Pennsylvania to Cambrian in age. All the rocks except those of pre-Permian age are exposed within or to the west and southwest of the area.

Quaternary rocks and deposits generally are thin, although locally they reach a maximum thickness of about 400 feet. They consist of alluvial deposits of clay, silt, sand, and gravel, playa deposits of gypsiferous and calcareous clay and silt with salt and gypsum, caliche, and loose, windblown sand. Below these surficial deposits lie the Pierce Canyon redbeds of Permian or Triassic age (Lang, 1935 and 1937). They attain a thickness of about 300 feet, and consist of thin bedded, reddish-brown siltstone, shale, and fine-grained sandstone.

Permian strata have a maximum thickness of about 13,000 feet. They consist, in descending order, of evaporites, sandstone, limestone, and interstratified sandstone, limestone, and shale (King, 1942, p. 550-613, and Hughes, 1954).

The evaporites, late Permian in age, reach a maximum thickness of about 4,900 feet in the Delaware basin--a large structural depression which includes the area of this report. The evaporites extend beyond the margin of the basin into the adjoining structurally higher Northwestern Shelf, where in places their thickness is less than 800 feet (Jones, 1954). The upper surface of the evaporites in the area between Project Gnome site and the potash mine is marked by both a sharp lithologic break and a structural break along which the strata are truncated and reduced in thickness. The evaporites rest conformably on, and probably grade fairly abruptly downward into fine-grained sandstone and interbedded limestone of the Bell Canyon formation of late Permian age.

The upper Permian evaporites of the area are divided, in descending order, into the Rustler, Salado, and Castile formations (Lang, 1935, 1937, and 1942; Adams, 1944; and Jones, 1954). The Rustler formation is composed dominantly of gypsum rock; the Salado formation is largely halite rock in the subsurface and gypsum rock in the outcrop; and the Castile formation consists of about two-thirds interlaminated calcite-anhydrite rock and one-third halite rock. The three formations have a total thickness of 4,440 feet in the subsurface type section (Lang, 1935), about 35 miles southeast of Project Gnome site. They average about 3,400 feet in the area between Project Gnome site and the potash mine, and range from about 3,040 to 3,840 feet in thickness (table 2).

Sedimentary rocks

Rustler formation

This formation ranges from 100 to 370 feet in thickness, and generally accounts for about one-eighth to one-twelfth of the thickness of the upper Permian evaporites. It is exposed at several places in the area; the outcrops consist largely of gypsum rock with relatively minor amounts of dolomite rock, siltstone, and fine-grained sandstone. Most of these rocks, as shown by holes drilled east of and down dip from the outcrops, are the hydrated and leached remnants of other rocks, such as anhydrite rock, halite rock, and argillaceous halite rock.

The formation is divided, in descending order, into the upper gypsum member, Magenta dolomite member of Adams (1944), middle gypsum member, Culebra dolomite member, and lower sandstone member (table 3). The lithic character and thickness given in table 3 applies only to the weathered part of the formation. All of the Rustler is weathered except in the eastern part of the area, where the gypsum members contain large relict masses of anhydrite rock. These remnants show evidence of the gypsification of anhydrite.

Table 3. Thickness and lithology of the members of the Rustler formation

Name	Thickness (feet)	Lithic character
Upper gypsum member	0-80	Gypsum rock: Massive, gray to white. Siltstone, claystone, and fine-grained sandstone, reddish-brown marked with gray reduction spots, form a poorly exposed layer, about 10 feet thick, 10 to 20 feet above base of member. This layer of clastic rocks shows evidence of abundant salt solution, collapse, and brecciation.
Magenta dolomite member of Adams (1944)	0-30	Dolomite rock: Thin-bedded, gray and magenta-colored, carries some silt and clay and has a cross-laminated structure. Most of the rock unit is cut by thin veinlets, up to one-half inch thick, of fibrous selenite.
Middle gypsum member	0-100	Gypsum rock: Massive, gray with red in lower part. Siltstone and claystone, reddish-brown marked with gray reduction spots, form a poorly exposed layer, about 5 to 10 feet thick, 8 to 15 feet above base of unit. Various parts of unit show evidence of salt solution, collapse, and brecciation.
Culebra dolomite member	15-35	Dolomite rock: Thin-bedded, light gray to buff-colored, has numerous, small, round and elliptical cavities lined with calcite crystals.
Lower sandstone member	90-180	Sandstone, claystone, and gypsum: Reddish-brown, argillaceous sandstone and light gray, calcareous sandstone with cross-laminated structure. Rare layers of olive green and maroon claystone, and massive, gray and reddish-brown, argillaceous gypsum.

Solution of salt has reduced the thickness of the formation so that at the surface the unit has only about two-thirds of its original sedimentary thickness. This reduction of thickness, however, is offset to some degree in the subsurface by an increase of thickness that accompanies the conversion of anhydrite rock to gypsum rock. These changes take place within the zone of weathering.

Salado formation

Conformably underlying the Rustler formation is a thick, lithologically complex deposit of salt known as the Salado formation (Lang, 1935). This formation, whose top lies 150 to 950 feet below the surface of this area, crops out in the Gypsum Plain of central southern Eddy County, about 20 to 25 miles southwest of Project Gnome site.

The Salado has an average thickness of 1,650 feet in the area of this report, but in the region its thickness ranges from about 200 to 2,450 feet. The formation is thinnest in the outcrop, where it is a solution breccia composed of brecciated and collapsed layers of gypsum rock separated by irregular seams and masses of reddish-brown and gray clay and silt containing fragments and blocks of red, gray, and white gypsum. The gypsum rock and intercalated clay and silt show evidence of abundant solution of salt, and in the subsurface, pass into a sequence of strata consisting largely of halite rock.

Between Project Gnome site and the potash mine, a layer of solution breccia lies between the top of the formation and the top of salt (fig. 2). The layer of solution breccia shows considerable range of thickness, from a few feet to as much as 150 feet. Although the solution breccia has the same general appearance as that exposed in the outcrop, the gypsum layers and fragments contain remnants of polyhalite rock, anhydrite rock, and glauberite rock, all of which show considerable gypsification. The breccia in a large part of the area is impregnated with brine containing as much as 200,000 ppm chlorine. This brine is formed by solution of halite rock in meteoric groundwater at the top of salt. The top of salt is an irregular surface that marks the change from weathered to unweathered rocks.

Below the top of the salt the Salado is composed of thin-layered, interstratified halite rock, argillaceous halite rock, sulfate rock (largely anhydrite and polyhalite rock with relatively minor amounts of glauberite rock and magnesite rock), and fine-grained clastic rocks (sandstone, siltstone, and claystone), whose average proportions are as follows:

Rock type	Percent
Halite rock	38.6
Argillaceous halite rock	45.0
Sulfate rock	12.5
Clastic rocks	3.9

The thin-layered halite and argillaceous halite rocks form thick members that are separated by layers of sulfate rock and clastic rock. The widespread layers of sulfate rock and clastic rock serve as stratigraphic markers. Some of them are identified by name, such as the Union anhydrite of local usage and the Vaca Triste sandstone of Adams (1944); other beds are identified by number. Numbering of stratigraphic marker beds was introduced by Smith (1938), and a modification of his system is used by most of the potash companies in the area. Some of the thickest stratigraphic marker beds and their names or numbers are shown on the structure section (fig. 2). Numerous other layers of equally wide extent are present in the formation; but are not shown on figure 2 or listed in table 2.

The lowermost salt layers in the formation tongue southward into anhydrite rock of the Castile formation (fig. 2).

Castile formation

The top of the Castile formation lies at depths ranging from about 1,450 to 2,750 feet below the surface of the area. The formation has an average thickness of about 1,500 feet in the area between Project Gnome site and the potash mine; its thickness ranges from about 1,300 to 1,600 feet.

The formation is composed of interlaminated calcite-anhydrite rock and subordinate halite rock and massive anhydrite rock. These rocks form laterally persistent lithic subunits, which in descending order are the upper anhydrite member, second salt member, middle anhydrite member, first salt member, and lower anhydrite member (table 2 and fig. 2).

The upper anhydrite member averages about 515 feet thick in the northern part of the Delaware Basin, but in the area of this report it ranges from about 290 to 840 feet in thickness. It consists of massive anhydrite rock that grades downward into interlaminated calcite-anhydrite rock near the center of the member. The second salt unit has an average thickness of about 230 feet in the region, and ranges from 165 to 330 feet in thickness. It is largely halite rock with scarce interbedded anhydrite rock. The middle anhydrite member, which generally has a thickness of about 120 feet, is composed dominantly of interlaminated calcite-anhydrite rock with minor amounts of limestone and anhydrite rock. The first salt member, which consists of halite rock with minor amounts of anhydrite, averages about 330 feet thick in the area. It gives place fairly abruptly downward to interlaminated calcite-anhydrite rock of the lower anhydrite member. This subunit generally is about 240 feet thick, although it ranges from 210 to 320 feet in thickness. The lower anhydrite member rests conformably on the interbedded sandstone and limestone of the Bell Canyon formation of late Permian age.

Igneous rocks

The evaporites of the Salado and Castile formations are cut by a northeastwardly trending system of narrow, steeply dipping dikes of alkalic rock (Jones and Madsen, 1959). A part of the system of alkalic dikes is exposed in the underground workings of the International Minerals and Chemical Corporation's mine, and was penetrated in the H & W Drilling Company, No. 1 Danford well (fig. 1 and table 1) between 2,208 and 2,230 feet below the surface. The igneous rock is a medium gray, porphyritic aphanite, exhibiting flow structure and a chilled border against the invaded salt beds. The rock consists dominantly of orthoclase and biotite with minor amounts of plagioclase feldspar, ilmenite, dolomite, and natrolite. The invaded salt beds are bleached and recrystallized to a depth of $1\frac{1}{2}$ inches from the contact with the intrusion. The salt beds and the alkalic rock contain epigenetic pyrite, polyhalite, and hydrocarbons that were introduced by aqueous solutions moving upward through fissures cutting the dike rock.

Structure

The dominant structural feature in the region is the Delaware Basin. This basin is a large, fairly steep-walled depression that underlies all of southeastern Eddy County and southwestern Lea County, New Mexico, and extends southward into Texas. Its northern rim lies a few miles north of the plant site of the International Minerals and Chemical Corporation and forms the southern margin of the Northwestern Shelf, which may stand as much as 1,800 feet above the level of the deepest part of the basin (Adams and Frenzel, 1950, p. 310).

The upper Permian evaporites of the area between Project Gnome site and the potash mine lie northwest of and up dip from the deepest part of the Delaware Basin. They have a generally southeastwardly regional dip of about 90 to 100 feet per mile. Locally, the strata are warped into small folds of low amplitude and lateral dimensions of a few thousand feet (fig. 2). No deep-seated faults are known that have vertical displacements of more than 20 feet in the evaporites in the area.

REFERENCES CITED

Adams, J. E., 1944, Upper Permian Ochoa series of Delaware Basin, West Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 1596-1625.

Adams, J. E., and Frenzel, H. N., 1950, Capitan barrier reef, Texas and New Mexico: Jour. Geology, v. 58, p. 289-312.

Bretz, J. H., and Horberg, L., 1949, Ogallala formation west of the Llano Estacado: Jour. Geology, v. 57, p. 477-490.

_____1949, Caliche in southeastern New Mexico: Jour. Geology, v. 57, p. 491-511.

Dane, C. H., and Bachman, G. O., 1958, Preliminary geologic map of the southeastern part of New Mexico: U. S. Geol. Survey, Misc. Geol. Inv. Map I-256.

Dunlap, J. C., 1951, Geologic studies in a New Mexico potash mine: Econ. Geology, v. 46, p. 909-923.

Hendrickson, G. E., and Jones, R. S., 1952, Geology and groundwater resources of Eddy County, New Mexico: New Mexico Bur. Mines and Min. Res. Groundwater Rept. No. 3, 169 p.

Hughes, P. W., 1954, New Mexico's deepest oil test: N. Mex. Geol. Soc., Guidebook, Southeastern N. Mex., 5th Field Conf., p. 124-130.

Jones, C. L., 1954, Occurrence and distribution of potassium minerals in southeastern New Mexico: N. Mex. Geol. Soc., Guidebook, Southeastern N. Mex., 5th Field Conf., p. 107-112.

Jones, C. L., and Madsen, B. M., 1959, Observations on igneous intrusions in late Permian evaporites (abs.): Geol. Soc. America Bull., v. 70, p. 1625-1626.

King, P. B., 1942, Permian of west Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 535-763.

King, R. H., 1947, Sedimentation in Permian Castile Sea: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 47-477.

Kroenlein, G. A., 1939, Salt, potash, and anhydrite in Castile formation of southeast New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1682-1693.

Lang, W. T. B., 1935, Upper Permian formation of Delaware Basin of Texas and New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 262-270.

_____1937, Permian formations of the Pecos valley of New Mexico and Texas: Am. Assoc. Petroleum Geologists Bull., v. 21, p. 833-898.

_____1939, Salado formation of the Permian Basin: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1569-1572.

_____1942, Basal beds of Salado formation in Fletcher potash core test, near Carlsbad, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 63-79.

Mansfield, G. R., and Lang, W. T. B., 1935, The Texas - New Mexico potash deposits: Univ. Texas Bull. 3401, p. 641-832.

Moore, G. W., 1958, Description of core from A. E. C. drill hole No. 1, Project Gnome, Eddy County, New Mexico: U. S. Geol. Survey TEM-927, 27 p., open-file report.

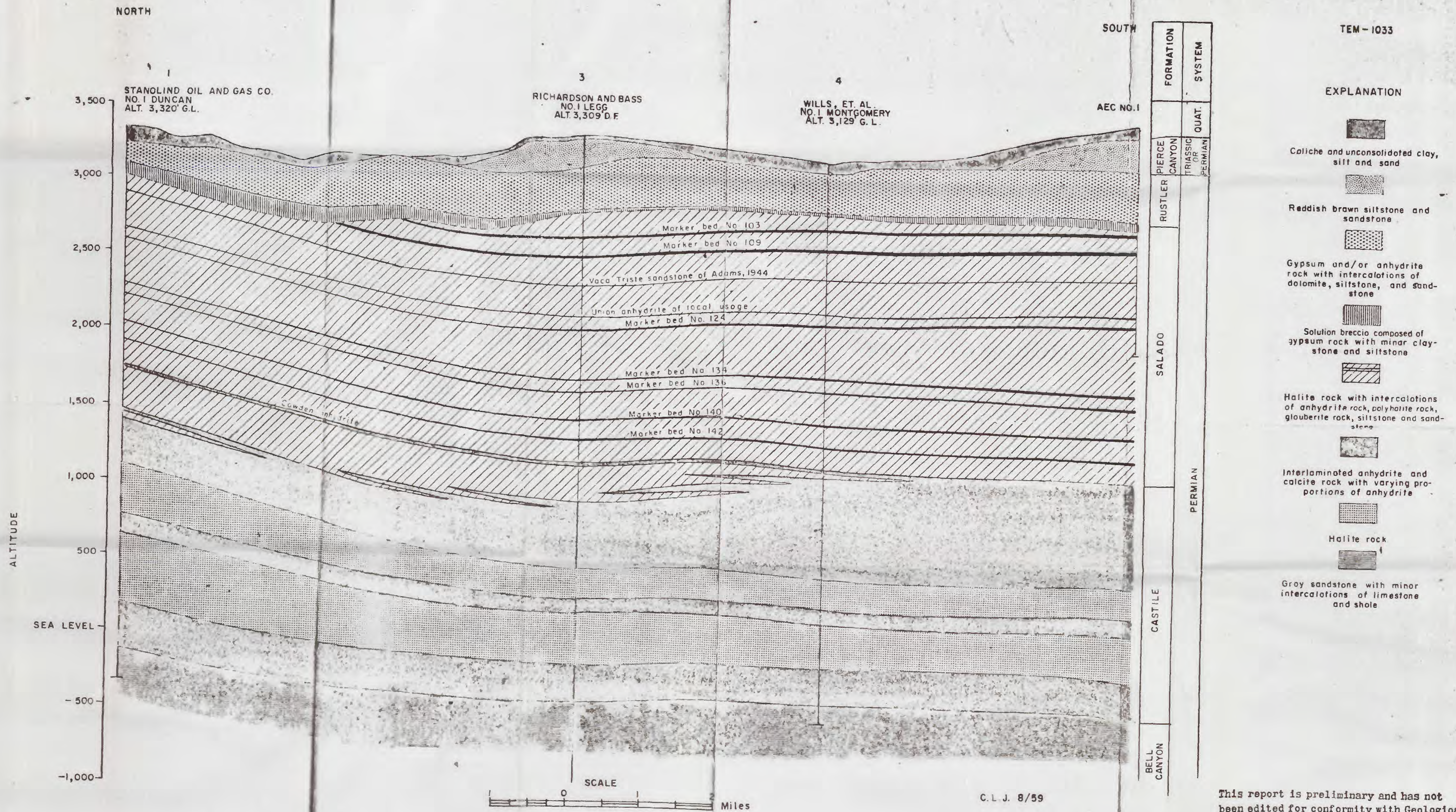
Robinson, T. W., and Lang, W. T. B., 1938, Geology and groundwater conditions of the Pecos valley in the vicinity of Laguna Grande de la Sal, New Mexico, with special reference to the salt content of the River water: N. Mex. State Engineer, 12th - 13th Bienn. Rept. 1934-38, p. 77-100.

Schaller, W. T., and Henderson, E. P., 1932, Mineralogy of drill cores from the potash field of New Mexico and Texas: U. S. Geol. Survey Bull. 833, 124 p.

Smith, H. I., 1938, Potash in the Permian salt basin: Ind. and Eng. Chemistry, v. 30, p. 854-860.

Udden, J. A., 1924, Laminated anhydrite in Texas: Geol. Soc. America Bull., v. 35, p. 347-354.

TEM-1033



This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature

FIGURE 2. GENERALIZED NORTH-SOUTH CROSS SECTION - INTERNATIONAL MINERALS AND CHEMICAL CORPORATION'S PLANT SITE TO PROJECT GNOME SITE.

U. S. Geological Survey

Table 2. Summary of geologic data obtained from holes drilled for oil

Name of formation and member	Hole No. 1 Depth (feet) From	Hole No. 1 Depth (feet) To	Hole No. 1 Thickness (feet)	Hole No. 2 Depth (feet) From	Hole No. 2 Depth (feet) To	Hole No. 2 Thickness (feet)	Hole No. 3 Depth (feet) From	Hole No. 3 Depth (feet) To	Hole No. 3 Thickness (feet)	Hole No. 4 Depth (feet) From	Hole No. 4 Depth (feet) To	Hole No. 4 Thickness (feet)
Caliche and unconsolidated clay, and sand	0	115	115	0	90	90	0	20(?)	20(?)	0	70	70
Pierce Canyon redbeds	-	-	0	-	-	0	20(?)	205	18[illegible](?)	-	-	0
Rustler formation	115	240	125	90	240	130	205	525	320	70	345	275
Upper gypsum member	-	-	0	-	-	0	205	285	80	70	100	30
Magenta dolomite member of Adams (1944)	-	-	0	-	-	0	285	300	15	100	120	20
Middle gypsum member	115	130	15	-	-	0	300	400	100	120	205	85
Culebra dolomite member	130	150	20	90	125	35	400	430	30	205	235	30
Lower sandstone member	150	240	90	125	240	115	430	525	95	235	345	110
Salado formation	240	1,940	1,700	240	1,724	1,484	525	2,430	1,905	345	2,082	1,737
Top of salt	343		-	320		-	530		-	360		-
Vaca Triste sandstone member of Adams (1944)	470 ± 10			430	435	-	1,010	1,015	-	780	785	-
Union anhydrite member (of local usage).	670 ± 5		-	600 ± 5		-	1,198	1,210	-	1,006	1,019	-
Castile formation	1,940	3,459	1,519	1,724	3,155	1,431	2,430	3,752	1,322	2,082	3,573	1,491
Upper anhydrite member	1,940	2,230	290	1,724	2,200	476	2,430	2,880	450	2,082	2,761	679
Second salt member	2,230	2,560	330	2,200	2,440	240	2,880	3,060	180	2,761	2,940	179
Middle anhydrite member	2,560	2,690	130	2,440	2,540	100	3,060	3,160	100	2,940	3,048	108
First salt member	2,690	3,140	450	2,540	2,895	355	3,160	3,500	340	3,048	3,340	292
Lower anhydrite member	3,140	3,459	319	2,895	3,155	260	3,500	3,752	252	3,340	3,573	233
Bell Canyon formation	3,459	3,658 (T.D.)		3,155	3,260 (T.D.)		3,752	? 15,854 (T.D.)		3,573	3,715 (T.D.)	
Total thickness of upper Permian evaporites (Rustler, Salado, and Castile formations).			3,344			3,045			3,547			3,503

Name of formation and member	Hole No. 5 Depth (feet) From	Hole No. 5 Depth (feet) To	Hole No. 5 Thickness (feet)	Hole No. 6 Depth (feet) From	Hole No. 6 Depth (feet) To	Hole No. 6 Thickness (feet)	Hole No. 7 Depth (feet) From	Hole No. 7 Depth (feet) To	Hole No. 7 Thickness (feet)	Hole No. 8 Depth (feet) From	Hole No. 8 Depth (feet) To	Hole No. 8 Thickness (feet)	Geologic age
Caliche and unconsolidated clay, and sand	0	35	35	0	10	10	0	40	40	0	190	190	Quaternary
Pierce Canyon redbeds	35	585	550	-	-	0	-	-	0	190	495	305	Permian or Triassic
Rustler formation	585	955	370	10	154	144	40	200	160	495	850	355	Permian
Upper gypsum member	585	649	64	-	-	0	-	-	0	495	565	70	
Magenta dolomite member of Adams (1944)	649	667	18	-	-	0	40	45	5	565	600	35	
Middle gypsum member	667	758	91	-	-	0	45	80	35	600	715	115	
Culebra dolomite member	758	782	24	10	39	29	80	105	25	715	740	25	
Lower sandstone member	782	955	173	39	154	115	105	200	95	740	850	110	
Salado formation	955	2,770	1,815	154	1,466	1,312	200	1,693	1,493	850	2,730	1,880	Permian
Top of salt	1,000		-	272		-	289			935			
Vaca Triste sandstone member of Adams (1944)	1,420	1,425	-	-		-	320 ± 5			1,180 ± 10			
Union anhydrite member (of local usage).	1,645	1,660	-	376	395	-	520 ± 10			1,420(?)			
Castile formation	2,770	4,320	1,550	1,466	3,055	1,589	1,693	3,122	1,429	2,730	4,330	1,600	Permian
Upper anhydrite member	2,770	3,465	695	1,466	2,217	751	1,693	2,140	447	2,730	3,570	840	
Second salt member	3,465	3,675	210	2,217	2,412	195	2,140	2,376	236	3,570	3,735	165	
Middle anhydrite member	3,675	3,757	82	2,412	2,505	93	2,376	2,491	115	3,735	3,845	110	
First salt member	3,757	4,090	333	2,505	2,843	338	2,491	2,860	369	3,845	4,090	245	
Lower anhydrite member	4,090	4,320	230	2,843	3,055	212	2,860	3,122	262	4,090	4,330	240	
Bell Canyon formation	4,320	4,410 (T.D.)		3,055	3,144 (T.D.)		3,122	3,322 (T.D.)		4,330	4,390 (T.D.)		Permian
Total thickness of upper Permian evaporites (Rustler, Salado, and Castile formations).			3,735			3,045			3,082			3,835	

No. 1 Stanolind Oil and Gas Co., No. 1 Duncan

No. 2 Ohio Oil Co., No. 1 Workman

No. 3 Richardson & Bass, No. 1 Legg

No. 4 Wills, and others, No. 1 Montgomery

No. 5 Continental Oil Co., No. 1 Gardner

No. 6 Hall and Wills Drilling Co., No. 1-X Fogarty

No. 7 H. & W. Drilling Co., No. 1 Danford

No. 8 R. L. Harrison, No. 1 Rowley

This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature