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SALT DEPOSITS OF LOS MEDAÑOS AREA, EDDY AND LEA COUNTIES, NEW MEXICO

By

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With Sections on

Ground Water Hydrology

By

M. E. Cooley

and

Surficial Geology

By

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CONTENTS

	Page
Abstract	1
Introduction	2
Acknowledgments	5
Geology	5
General features	5
Permian System	7
Castile Formation	7
Salado Formation	10
Lower member	14
McNutt potash zone	15
Upper member	17
Rustler Formation	21
Dewey Lake Redbeds	24
Triassic System	25
Tertiary and Quaternary Systems	27
Mid-Tertiary lamprophyre dike	29
Structure	31
Conclusions and recommendations	34
References	37
Ground-water hydrology, by M. E. Cooley	41
Introduction	41
Occurrence of ground water	42
Movement of ground water	49

CONTENTS--Continued

	Page
Chemical quality of the ground water	53
Acknowledgments	55
References cited	56
Surficial geology, by George D. Bachman	57
Introduction	57
Description of mapped surficial units	58
Dewey Lake Redbeds	58
Ogallala Formation of Pliocene age	59
Caliche of Quaternary age	61
Sand	61
Surficial indications of dissolution	62
References cited	67

ILLUSTRATIONS

		Page
Figure 1.	Map showing location of Los Medaños area, southeastern New Mexico	3
2.	Geologic map of pre-Tertiary bedrock, Los Medaños area, Eddy and Lea Counties, New Mexico	in pocket
3.	Geologic sections of Los Medaños area	in pocket
4.	Logs of subsurface sections of the Castile Formation, Los Medaños area	in pocket
5.	Logs of subsurface sections of the Salada Formation, Los Medaños area	in pocket
6.	Logs showing lithology of select intervals in Salado Formation, Los Medaños area	in pocket
7.	Contour map showing depth to Salado salt, Los Medaños area	in pocket
8.	Logs of subsurface sections of the Rustler Formation, Los Medaños area	in pocket
9.	Logs of subsurface sections of post-Rustler rocks, Los Medaños area	in pocket
10.	Contour map showing structure at base of Castile Formation, Los Medaños area	in pocket
11.	Contour map showing structure at base of Salado Formation, Los Medaños area	in pocket

		Page
Figure 12.	Map of tract for exploratory drilling of Salado salt beds, Los Medaños area	in pocket
13.	Map showing water table and potentiometric contours in formations above the Salado Formation and the locations of water wells	in pocket
14.	Map showing structure at base of Culebra Dolomite Member of the Rustler Formation, Los Medaños area	50
15.	Map showing structure at the base of Santa Rosa Sandstone, Los Medaños area	51
16.	Map showing specific conductance of water in wells determined mainly during a field inventory in September and October 1972	54
17.	Surficial geologic map of Los Medaños area	in pocket
18.	Map showing areas of depressions in Los Medaños area	63

Table

TABLES

		Page
Table 1.	Summary of rock units of latest Permian (Ochoan) and younger age, Los Medaños area, Eddy and Lea Counties, New Mexico	6
2.	Hydrous evaporite minerals found in potassic rocks of the McNutt potash zone, Los Medaños area, Eddy and Lea Counties, New Mexico	16
3.	Chart of the hydrology of the formations above the Salado Formation	44
4.	Records of wells in Los Medaños area, New Mexico	45

SALT DEPOSITS OF LOS MEDAÑOS AREA,
EDDY AND LEA COUNTIES, NEW MEXICO

By

C. L. Jones

ABSTRACT

The salt deposits of Los Medaños area, in Eddy and Lea Counties, southeastern New Mexico, are being considered for possible use as a receptacle for radioactive wastes in a pilot-plant repository.

The salt deposits of the area are in three evaporite formations: the Castile, Salado, and Rustler Formations, in ascending order. The three formations are dominantly anhydrite and rock salt, but some gypsum, potassium ores, carbonate rock, and fine-grained clastic rocks are present. They have combined thicknesses of slightly more than 4,000 feet, of which roughly one-half belongs to the Salado. Both the Castile and the Rustler are richer in anhydrite and poorer in rock salt than the Salado, and they provide this salt-rich formation with considerable protection from any fluids which might be present in underlying or overlying rocks.

The Salado Formation contains many thick seams of rock salt at moderate depths below the surface. The rock salt has a substantial cover of well-consolidated rocks, and it is very little deformed structurally.

Certain geological details essential for waste-storage purposes are unknown or poorly known, and additional study involving drilling is required to identify seams of rock salt suitable for storage purposes and to establish critical details of their chemistry, stratigraphy, and structure.

INTRODUCTION

The salt deposits of Los Medaños area, in southeastern New Mexico, are being mapped and studied by the U.S. Geological Survey on behalf of the Division of Waste Management and Transportation, U.S. Atomic Energy Commission. The purpose of this work is to provide the Atomic Energy Commission with geologic data to be considered along with other factors in locating and evaluating a potential site utilizing the salt deposits of the area as a receptacle for radioactive wastes in a pilot-plant repository.

Los Medaños area is in the eastern outer fringes of the broad Pecos River valley at the latitude of Carlsbad, N. Mex. (fig. 1). It comprises about 335 square miles of desolate sand hills, straddling a low divide between Nash Draw to the west and San Simon Swale to the east. Nearly all parts of the area are covered by dune sand, which is stable to semistable over large sections. The vegetation is sparse and is chiefly mesquite and coarse grasses. New Mexico State Route 128 crosses the southwestern part of the area; roads in other parts are few and primitive.

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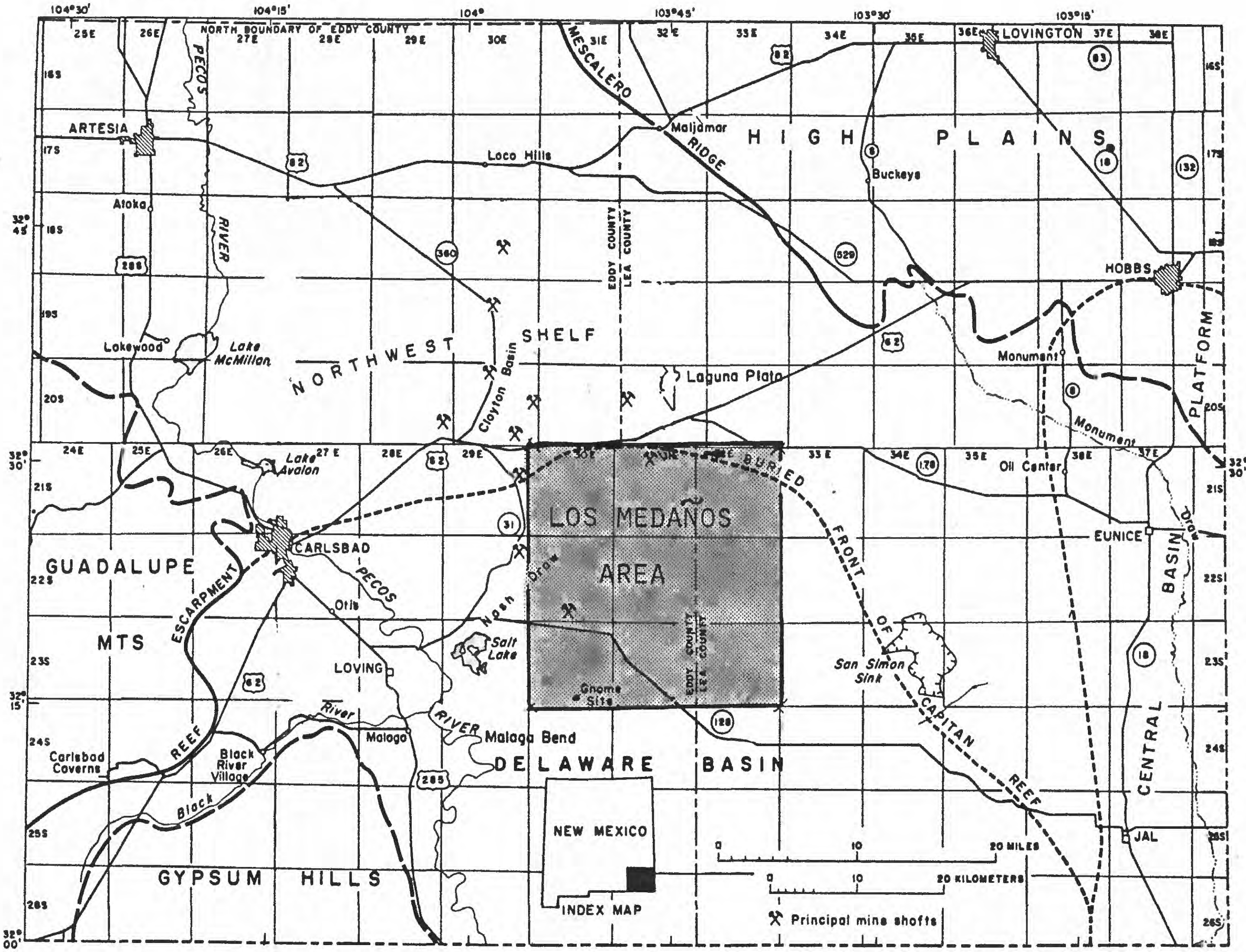

U.S. Geological Survey
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This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

FIGURE 1,-LOCATON OF LOS MEDAÑOS AREA, SOUTHEASTERN NEW MEXICO.

The present report supplements an earlier study of southeastern New Mexico by the U.S. Geological Survey (Brokaw and others, 1972) with detailed data on the stratigraphy and structure of the salt deposits and overlying rocks in Los Medaños area. Select data are summarized in a geologic map of the pre-Tertiary bedrock (fig. 2) and a series of cross sections (fig. 3) and contour maps (figs. 7, 10, and 11) that show the structure at different levels between the base and top of the salt-bearing formations and the depth to the main salt deposit of the area. The lithology and stratigraphic details of the salt-bearing formations and overlying rock units are shown in a series of correlated stratigraphic sections (figs. 4, 5, 6, 8, and 9). Finally, some geologic and other factors of significance in evaluating one particular tract for a more detailed, in-depth study are summarized on figure 12.

The data presented in this report were obtained, in part, from geophysical logs of boreholes drilled in exploration for petroleum and, in part, from lithologic and driller's logs of other boreholes drilled in the area. The geophysical logs contain the most reliable information, so that lithologic and driller's logs were used in the present study only in areas where geophysical data were lacking. The use of geophysical logs in the study and analysis of salt deposits and other evaporites has been discussed by several authors (Jones and others, 1960; Alger and Crain, 1966; Edwards and others, 1967; Tixier and Alger, 1967) and is not within the scope of this report.

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R. S. Fulton, Regional Mining Supervisor, U.S. Geological Survey, Carlsbad, N. Mex., was of great assistance in making available records of boreholes drilled on public lands in Los Medaños area.

GEOLOGY

General features

The sedimentary rocks and surficial deposits exposed in Los Medaños area range in age from Late Permian to Quaternary. Exclusive of Tertiary and younger rocks, the oldest rocks crop out in the western part of the area, and progressively younger rocks are exposed eastward. Upper Permian rocks surface almost one-half of the pre-Tertiary terrane, and Upper Triassic rocks cover the remaining area. The Lower and Middle Triassic Series and the Jurassic System are not represented, and, although rocks of Cretaceous age were deposited in the area, they have been removed by erosion.

The pre-Tertiary terrane of Los Medaños area is surfaced chiefly by red beds of Late Permian and Late Triassic age and, to a lesser extent, by evaporites of Late Permian (Ochoan) age. A summary of the evaporites, red beds, and younger rocks of the area is presented in table 1. As much as 12,500 feet of preevaporite Permian and older Paleozoic rocks have been penetrated by drilling but are not described in this report. The depth to the basement of Precambrian granite on which the Paleozoic rocks were deposited is estimated from geologic mapping by Foster and Stipp (1961) to be between 16,500 and 19,500 feet.

Table 1.--Summary of rock units of latest Permian (Ochoan) and younger age, Los Medaños area, Eddy and Lea Counties, New Mexico

Age		Rock Unit	Thickness (feet)	Description
Quaternary	Holocene	Mescalero Sand	0-15	Dune sand, uniformly fine-grained, light-brown to reddish-brown
				UNCONFORMITY
Quaternary	Holocene	Caliche	0-5	Limestone, chalky, includes fragments of underlying rock
				UNCONFORMITY
Quaternary	Pleis-to-cene(?)	Gatuna Formation	0-375	Sandstone and siltstone, poorly indurated, dominantly reddish-orange
				UNCONFORMITY
Terti-ary	Plio-cene	Ogallala Formation	20-60	Sandstone, fine- to medium-grained, tan, pink, and gray, locally conglomeratic, and typically has resistant cap of well-indurated caliche
				UNCONFORMITY
Triassic	Late Triassic	Chinle Formation	300-800	Mudstone shaly, reddish-brown and greenish-gray, interbedded lenses of conglomerate, and gray and reddish-brown sandstone
Triassic	Late Triassic	Santa Rosa Sandstone	212-245	Sandstone, medium- to coarse-grained, commonly cross-stratified, gray and yellowish-brown, contains conglomerate and reddish-brown mudstone
				UNCONFORMITY
Permian	Ochoan	Dewey Lake Redbeds	505-560	Siltstone and sandstone, very fine to fine-grained, reddish-orange to reddish-brown, contains interbedded reddish-brown claystone, small-scale lamination and cross-stratification common
				UNCONFORMITY
Permian	Ochoan	Rustler Formation	280-490	Anhydrite and rock salt with subordinate dolomite, sandstone, claystone, and polyhalite
Permian	Ochoan	Salado Formation	1,200-2,310	Rock salt with subordinate anhydrite, polyhalite, potassium ores, sandstone, and magnesite
Permian	Ochoan	Castile Formation	30-1,830	Anhydrite and rock salt with subordinate limestone

The distribution of Permian and Triassic formations in the pre-Tertiary terrane of Los Medaños area is shown on figure 2. The contacts on the map are generalized and their location is approximate. The contacts have been drawn on the basis of projected altitude of intersection of individual formation boundaries with the land surface.

Permian System

All the salt deposits and other evaporites of Los Medaños area are in the Ochoan Series of Late Permian age. The Ochoan is entirely of marine origin, but it has two unlike parts--a thick lower section of evaporites and a thin upper section of red beds. The lower section includes, in ascending order, the Castile, Salado, and Rustler Formations; whereas the upper section is made up of the Dewey Lake Redbeds. Together the four formations have a maximum thickness of 4,600 feet, of which slightly more than 4,000 feet is predominately evaporites. The evaporite section is largely anhydrite and rock salt, but it includes some fine-grained clastic rocks and a series of evaporites that range in composition from calcitic limestone to complex potassium ores. Among the three evaporite formations, the Castile and Rustler are richer in anhydrite and carbonate rock than the Salado, and they form protective barriers that have served long and effectively to retard the upward or downward movement of meteoric ground water into the salt-rich Salado Formation.

Castile Formation

The term Castile was originally applied by Richardson (1904) to evaporites lying between the Bell Canyon and Rustler Formations, but it is no longer used in that sense. Present usage of the term follows that proposed by Lang (1935, p. 268) who restricted the name Castile to the lower part of the original evaporite formation and introduced the name Salado for the upper part. The lithologic criterion used to differentiate one formation from the other is a predominance of anhydrite in the Castile and a predominance of rock salt in the Salado. In addition, the Castile is characteristically more thickly bedded than the Salado. The Castile overlies the Bell Canyon Formation conformably in the southern and central parts of Los Medaños area, and overlaps the Upper Permian Capitan Limestone and Tansill Formation in the northern part of the area (fig. 3).

The Castile Formation underlies Los Medaños area at depths ranging from 1,700 feet near the northwest corner of the area to 3,600 feet near the southeast corner. As developed in this area, the Castile is a very typical basinal evaporite showing great lateral continuity of individual rock units, a well-formed lamination in most units, and a marked paucity of terrigenous debris. In general, the formation is composed of as much as 1,830 feet of anhydrite and rock salt with subordinate limestone, but it is readily separable into three informal members by a salt-rich zone 200-400 feet above the base (fig. 4). The threefold division includes: a lower member composed chiefly of anhydrite, a middle member composed chiefly of rock salt, and an upper member composed chiefly of anhydrite. The three members are discrete, readily distinguished lithologic units throughout the southern and central parts of the area, but northward they merge into a single wedgelike mass of anhydrite that thins rapidly to a narrow tongue at the north edge of Los Medaños area (fig. 3).

The lower member of the Castile Formation is a well-stratified evaporite consisting of laminae of gray anhydrite and brownish-gray limestone in regular, rhythmic alternation. Some beds of laminated dark-gray and brownish-gray limestones, a few inches to several feet thick, are present at wide intervals in the lower and middle parts of the member, and there are a few thicker beds of massive gray anhydrite at long intervals. The member is 200-240 feet thick along the southern border of Los Medaños area, but it thickens northward and reaches a thickness of at least 400 feet before merging with other members of the Castile to form a single unbroken mass of anhydrite in the northern part of the area (fig. 3).

The middle member of the Castile Formation is predominately rock salt, but it includes some thin to thick beds of interlaminated anhydrite and limestone. The member ranges in thickness from about 560 feet near the southern margin of Los Medaños area to as much as 1,200 feet in deformationally thickened masses in the Culbertson & Irwin 1 Murray well (figs. 3 and 4) and elsewhere in the central part of the area. The member terminates northward by grading laterally into, and intertonguing with, anhydrite.

The upper member of the Castile Formation is composed chiefly of anhydrite laminated by calcitic limestone and, to a lesser extent, of massive anhydrite, rock salt, and carbonate rock, including both magnesite and dolomite. The member includes a northwardly thinning tongue of anhydrite that overlaps the Capitan Limestone and Tansill Formation in the northern part of Los Medaños area (fig. 3). The main body of the member is 600-700 feet thick at the south end of the area. It thins rapidly northward and is as little as 170 feet thick in the central part of the area. The northward thinning is attributed to a transition involving a stratigraphic descent in the top of the member as beds of anhydrite give way laterally to rock salt of the Salado Formation (fig. 4). The transition is accomplished partly by direct gradation from anhydrite to rock salt, and partly by pinch out of anhydrite beds between tongues of rock salt.

The contact between the Castile Formation and the overlying Salado Formation is conformable and gradational, but, nevertheless, is generally rather sharply defined as the horizon at which dominant anhydrite below gives way to rock salt.

Salado Formation

The Salado Formation was named by Lang (1935, p. 267) to include the upper, salt-rich part of the Castile Gypsum of Richardson (1904, p. 43) The Salado is readily distinguished by the characteristic alternation of thick seams of rock salt with much thinner seams of anhydrite, polyhalite, and glauberite (fig. 5). The Salado is the principal salt formation of Los Medaños area, and it contains rock salt and potassic evaporites throughout the area. The depth to the formation is as shallow as 175 feet at places along the west side of the area, but it increases eastward to almost 1,700 feet near the southeast corner of the area and to slightly more than 2,000 feet near the northeast corner.

The Salado Formation is generally between 1,700 and 1,900 feet thick in Los Medaños area. Nevertheless, its thickness ranges from as little as 1,200 feet near the northeast corner of the area to as much as 2,310 feet in deformationally thickened masses in the central part of the area. At places along the west side of the area, the thickness of the formation varies somewhat erratically owing to local solution and removal of rock salt in the upper part of the formation. Elsewhere, most variations in thickness of the Salado are probably depositional, and where the formation is thickest it seems to be more thickly bedded.

The Salado Formation is composed of rock salt, anhydrite, and potassium rocks with varying amounts of other evaporites and fine-grained clastic rocks. Rock salt constitutes about 85-90 percent of the formation except in the western part of the area where percolating ground water has dissolved and removed some of it. The next most abundant rock in the formation is anhydrite. The remainder of the formation is chiefly polyhalite and other potassium-rich rocks with subordinate glauberite, magnesite, sandstone, and claystone.

The rock salt in the Salado is composed of halite and clayey halite in discrete layers ranging from an inch to several feet in thickness (fig. 6). The two rock types differ primarily in that the halite is free of detrital debris and the clayey halite characteristically contains this debris in significant but typically small amounts. The detritus is chiefly quartz and clay, including illite, chlorite, and a corrensite-type of swelling, regular mixed-layered clay mineral (Grim and others, 1960). In general, the detritus-bearing clayey halite is mostly brown and tan; it is moderately crystalline but somewhat porous with a scattering of small cavities or vugs filled with clay and other detritus; and it either lies between seams of claystone or has a layer of halite below and a seam of claystone above. The halite is typically reddish orange; but its color grades to amber, gray, and white. It is generally somewhat more coarsely crystalline than the clayey halite.

Common to both the halite and the clayey halite in the rock salt of the Salado are traces to very minor amounts of polyhalite and anhydrite. Locally, glauberite is present in small amounts, and there are several of potassium and magnesium minerals, including sylvite, carnallite, kieserite, and several other equally exotic evaporite minerals that occur in small to large amounts in seams of rock salt in the middle and upper parts of the formation. Other constituents of the halite and clayey halite include traces to very minor amounts of brine and gas that fill microscopic to very small cubic and rectangular cavities in grains of halite and other evaporite minerals. Less common, but more notable in other respects, are much larger cavities or pockets that contain halite-saturated brine and nitrogenous gas confined under pressure sufficient to produce "blow-outs" when encountered during drilling operations.

The seams of anhydrite and polyhalite, which alternate with rock salt in all sections of the Salado, are very persistent but highly variable in composition (Jones, 1954, p. 109; Jones, 1972, p. 195-196). Lateral replacement of anhydrite by polyhalite is common, and nearly all seams show one or more stages of replacement between an initial slight development of polyhalite in the lower and upper parts of the seam to complete elimination of anhydrite by polyhalite. Locally, anhydrite and polyhalite give way laterally to glauberite, and polyhalite in the middle and upper parts of the Salado is replaced by hartsalz consisting of a coarsely crystalline mixture of anhydrite, kieserite, and carnallite.

Close examination of the Salado in drill cores and geophysical logs of boreholes in Los Medaños area and vicinity reveals that rock sequences show a regular order of succession. A typical sequence, repeated many times between the base and top of the formation, involves a change from claystone upward through anhydrite or polyhalite and halite to clayey halite capped by claystone (fig. 6). In other sequences the change is from halite to clayey halite capped by claystone. Boundaries between individual members of a rock sequence are gradational, but those along the lower and upper sides of the individual sequences are corrosion surfaces that form sharp, clear-cut breaks in the evaporite section but, nevertheless, are laterally persistent and convergent northward. The rock sequences represent a fundamental sedimentation unit or evaporite cyclothem, and they are believed to record discrete periods of influx and subsequent precipitation of calcium sulfate and sodium chloride during desiccation of sea water or an initially dilute brine. The ubiquitous claystone is thought to be a residue concentrated during dissolution of clayey halite by inflowing sea water or dilute brine.

The Salado Formation is divided into three members (fig. 5), but more subtle divisions can be made, for the beds are very persistent. In fact, the persistence of individual beds is the prime basis for the system of numbering individual seams of anhydrite and polyhalite which was introduced by geologists of the USGS (U.S. Geological Survey) (Jones and others, 1960, fig. 1) and is widely used by mining companies in the Carlsbad potash field. The numbers used in the USGS system to designate some seams of anhydrite and polyhalite in selected parts of the three members of the Salado are shown on figure 6.

The threefold division of the Salado used herein includes: an unnamed lower member, a middle member known locally as the McNutt potash zone, and an unnamed upper member. The three members are about equally rich in rock salt, anhydrite, polyhalite, and fine-grained clastic rocks, and they are generally similar in all but one major respect. The lower and upper members are generally poor in sylvite, carnallite, and other potassium- and magnesium-bearing minerals, and the McNutt potash zone is generally rich in these minerals and accounts for the large and extensive deposits in the potash field.

Lower member.--The lower member of the Salado Formation is almost entirely an alternation of thick seams of rock salt and thinner seams of anhydrite and polyhalite. Magnesite in thin bands, laminae, and ragged knots forms a carbonate-rich zone in the lower part of most anhydrite and polyhalite seams. Seams and partings of claystone underlie the anhydrite and polyhalite seams; the claystone caps layers of clayey halite in the rock salt. There are also a few beds of very fine grained halitic sandstone, a few inches to a foot or so thick, near the base and top of the member. Insofar as has been determined by drilling, the member is completely free of carnallite and other hydrous potassium and magnesium evaporite minerals in all parts of Los Medaños area, but the upper part contains traces to small amounts of these minerals several miles to the north of the area.

The lower member averages about 1,050 feet in thickness in the central part of Los Medaños area, but locally it is as much as 1,350 feet thick in deformationally thickened masses. Southward the lower 240-300 feet of the member grades by intertonguing into the upper part of the Castile Formation, and the thickness of the member decreases to between 785 and 950 feet along the south side of the area. Northward the member thins to 430 feet near the northeast corner of the area. The decrease of thickness in this instance seems to be due to beds missing at the corrosion surfaces that truncate individual rock sequences, as well as to thinning of all beds northeastward.

McNutt potash zone.--The McNutt potash zone is another salt-rich member of the Salado Formation. However, unlike other members of the Salado, the McNutt contains potassic rocks rich in sylvite, langbeinite, and hydrous evaporite minerals (table 2). The potassic rocks occur at

Table 2.--Hydrous evaporite minerals found in potassic rocks of the McNutt potash zone, Los Medaños area, Eddy and Lea Counties, New Mexico.

Mineral	Formula	Weight (percent H_2O)
Carnallite	$KMgCl_3 \cdot 6H_2O$	38.9
Schoenite	$K_2Mg(SO_4)_2 \cdot 6H_2O$	26.8
Kainite	$KMgClSO_4 \cdot 3H_2O$	21.7
Bloedite	$Na_2Mg(SO_4)_2 \cdot 4H_2O$	21.5
Leonite	$K_2Mg(SO_4)_2 \cdot 4H_2O$	19.7
Loeweite	$Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$	13.8
Kieserite	$MgSO_4 \cdot H_2O$	13.0
Polyhalite	$Ca_2K_2Mg(SO_4)_4 \cdot 2H_2O$	6.0

short to long intervals in seams of rock salt scattered through nearly all parts of the McNutt zone. They are the obvious lithologic feature by which the McNutt is distinguished, yet they are absent locally and, at best, probably comprise only 3-5 percent of the member in the most potassium-rich sections of Los Medaños area.

Apart from the potassic rocks, the McNutt presents virtually the same aspect as other members of the Salado. Thick seams of rock salt alternate with thinner seams of anhydrite and polyhalite. There are partings of claystone beneath most anhydrite and polyhalite seams and above layers of clayey halite. A bed of very fine grained halitic sandstone, a foot or so thick, occurs in clayey halite at the top of the member.

The thickness of the McNutt potash zone ranges between 422 and 483 feet in the southwest part of Los Medaños area, but it decreases northeastward to slightly under 300 feet in the northeast part of the area. The decrease in thickness northeastward is attributed to thinning of beds, as well as to truncation of beds along the corrosion surfaces that sharply separate rock sequences in the McNutt. As a rule, where the member is thinnest it seems to be more thinly bedded and to have fewer beds.

Upper member.--The upper member of the Salado consists of rock salt, minor anhydrite and polyhalite, and two persistent beds of very fine grained, halitic sandstone, which are, respectively, 30-40 feet and 110-150 feet below the top of the unit. Claystone underlies seams of anhydrite and polyhalite, and coats the upper surfaces of clayey halite layers in the rock salt. Most parts of the upper member are generally free of hydrous evaporite minerals, but, nevertheless, some intervals of rock salt and other rocks in the upper 130-180 feet of the unit commonly contain traces to very small amounts of carnallite and kieserite over practically the entire northern half of Los Medaños area.

Of particular interest is the occurrence of carnallite at the top of the upper member. The carnallite forms a major deposit of potassic rock that extends over a wide section in the northern part of Los Medaños area and much of the region immediately to the north. The deposit is the only one known to occur in the upper member of the Salado, but is not restricted to the unit. It extends irregularly upward into sandstone of the overlying Rustler Formation.

In the eastern half of Los Medaños area, the upper member of the Salado Formation is 510-590 feet thick in the south and thins to between 430 and 480 feet in the north. The thinning northward seems to be partly depositional and partly erosional, for the member is more thinly bedded in the north and contains fewer beds. Many seams of anhydrite, polyhalite, and other evaporites are only about three-fourths as thick as at the south end of the area. Beds of halite and clayey halite are missing beneath many of the corrosion surfaces that separate rock sequences in the unit.

In the western half of Los Medaños area, variations in thickness of the upper member are fairly complex and large. Their complexity and size are believed to reflect a combination of geologic factors involving mostly(1) gradual thinning northward in response to changes in deposition patterns during the Ochoan Epoch, and (2) rapid thinning westward in response to changes in subrosion[1/] patterns during the Pleistocene and earlier parts of the Cenozoic Era. The northward thinning of the member involves a fairly small reduction in thickness from 520 to 590 feet at the south edge of the area, to 450-510 feet at the north edge. In contrast to this modest change, the westward thinning of the member involves as much as a fourfold reduction in thickness in a distance of 4-6 miles, and the member is as thin as 150-170 feet at places along the west side of the area. This small thickness is considered to include the residue or remnants of at least a 450- to 500-foot-thick section of rock from which soluble salts (no doubt chiefly halite) have been leached by percolating ground water. The section of rock from which salts have been leached decreases in thickness eastward and feathers out in the area immediately east of Nash Draw. Insofar as can be determined from drilling records, the featheredge of the residual materials marks the easternmost extent of subrosion of the upper member of the Salado Formation at any time during the present or past. Its position is shown on figure 7 and is labelled "edge of subrosion." It divides Los Medaños area into two parts--an

1/The term subrosion, as used in southeastern New Mexico and elsewhere, is an all-inclusive name for the wide combination of dominantly subsurface processes of hydration, thinning, subsidence, solution, and removal of halite, anhydrite, and other rocks that invariably accompany the invasion of evaporite formations by meteoric (dilute) ground water.

eastern section in which the upper surface of Salado salt coincides with the upper surface of the formation, and a western section in which the upper surface of Salado salt is separated from the upper surface of the formation by a section of rock from which soluble salts have been leached. The depth to the upper surface of salt is least west of the edge of subrosion and is greatest east of the edge.

In all parts of Los Medaños area, where the upper member of the Salado is thinned by subrosion, the section of rock between the upper surface of salt and the upper surface of the formation is composed of clay with crudely interlayered seams of broken and shattered gypsum and fine-grained sandstone. The clay is considered to be a subsurface saprolite or residue concentrated through dissolution of clayey halite and other clay-bearing evaporites by percolating ground water. The gypsum is clearly the hydrated remnant of anhydrite and polyhalite seams, for it commonly contains ragged and embayed masses of anhydrite and polyhalite, and, also grades laterally into anhydrite and polyhalite. The clay, gypsum, and sandstone comprise a fairly distinct saprolitic unit that thins out eastward by grading into, and intertonguing with, rock salt and the other precursory rocks from which it originated. The saprolitic unit thickens westward and crops out locally along the Pecos River west of Los Medaños area. The unit is generally assigned by geologists mapping areas along the Pecos River (Lang, 1938, p. 84; Kelley, 1971, p. 24) to the lower member of the Rustler Formation, but this practice should be discontinued, for the saprolitic unit is clearly part of the Salado Formation.

Despite the somewhat extended discussion of subrosional thinning and related saprolitic debris in the upper member of the Salado, no great salt instability or active solution of salt is implied. Rather, the reverse seems clearly indicated, and the whole situation appears to be highly stabilized and of long duration, with very little or practically no subrosion since the Pleistocene or, perhaps, even earlier. Estimates prepared by Bachman and Johnson (1973) indicate that the rate of salt removal during subrosion may amount to as much as 0.5 foot per 1,000 years. This rate suggests that roughly 1 million years would be required to reduce 450-500 feet of the upper member to a saprolitic debris, and that subrosion in the western part of Los Medaños area has a long history extending back at least as far as mid-Pleistocene time. Other considerations, however, suggest that its history is even longer and may have a mid-Tertiary beginning.

In both the western and eastern sections of Los Medaños area, the Salado Formation is overlain conformably by the Rustler Formation. The contact between the two formations is rather sharply defined as the horizon at which dominant rock salt below gives way to a 35- to 55-foot-thick unit of fine-grained sandstone that is generally dolomitic in the basal few feet. This sandstone unit is recognized as readily in the outcrops along the Pecos River as in the subsurface of Los Medaños area.

Rustler Formation

The Rustler Formation, named by Richardson (1904), is the only salt-bearing formation that crops out in Los Medaños area. The formation is exposed only in inliers scattered here and there between dune fields and caliche-covered stretches in Nash Draw, but it surfaces as an unbroken stretch of pre-Tertiary terrane, about 1-8 miles wide, which extends along almost the entire west side of the area. The outcrops in Nash Draw are decidedly poor for any study that requires precise information on the lithology, thickness, or specific chemical or physical properties of the formation, and, as previously noted by Vine (1963), it is impossible to piece together a meaningful stratigraphic section from study or mapping of outcrops.

As typically exposed in outcrop, the Rustler is a broken and somewhat jumbled mass of gypsum with minor dolomite and a few crude seams of virtually unconsolidated sands and clays. The rocks are porous, friable, and loose-textured, and all are strongly jointed, cavernous, and locally brecciated. Stratification is obscured or completely obliterated, and the attitude of bedding can rarely be determined with any degree of confidence. The considerable deformation attests to the removal of much soluble material by percolating ground water and to the saprolitic nature of the debris exposed in outcrop.

Eastward, in the subsurface of central and eastern Los Medaños area, all the gypsum in the Rustler gives way to anhydrite and minor polyhalite, and the sands and clays grade into sandy and clayey rock salt. At depths of 900-1,000 feet, the Rustler is largely an alternation of thick seams of rock salt and anhydrite (fig. 8). A persistent seam of polyhalite occurs near the middle of the formation and, insofar as has been determined, it is the only hydrous evaporite rock of any great extent or major importance in the stratigraphy of the formation. Thin to thick units of sandstone and claystone form a significant part of rock salt seams in the lower, middle, and upper parts of the formation. There are also two persistent beds of dolomite which are, respectively, 100-150 feet and 200-250 feet above the base of the formation. The lowermost of the two dolomite beds is known as the Culebra Dolomite Member and the uppermost as the Magenta Dolomite Member (Adams, 1944, p. 1614).

With the eastward--downdip--change in composition from gypsum to anhydrite and rock salt, the thickness of the Rustler also changes rather significantly. The thickness ranges between 280 and 300 feet near the area of outcrop in the western part of Los Medaños area, but increases eastward to 490 feet near the southeast corner of the area, and to 385 feet near the northeast corner. The increase ranges in amount between 105 and 160 feet and provides a crude measure of the minimum thickness of rock salt that is missing in the area of outcrop. The difference in formation thickness between the southeast and northeast corners of the area is probably depositional in origin, for the formation is more thickly bedded in the southeast where it is thickest.

The Rustler Formation is separated from the overlying Dewey Lake Redbeds by a sharp lithologic break, which represents an abrupt change from anhydrite deposition to deposition of sandstone and shale. The anhydrite below the break is free of sand and clay, and it ranges erratically in thickness from 18 to 32 feet. There is no indication of northward thinning, such as that common to most, if not all, rock units in the Rustler and underlying Salado Formations, and it would appear that the contact between the Rustler and Dewey Lake is an unconformity. The discordance and hiatus is probably not very great.

Dewey Lake Redbeds

The term Dewey Lake was applied somewhat belatedly by Page and Adams (1940) to a rather distinct red bed formation for which the name Pierce Canyon had been proposed by Lang (1935). Nevertheless, the term Dewey Lake was more widely accepted by geologists, and it has been adopted for use by the U.S. Geological Survey. As used herein, the Dewey Lake Redbeds include all the rocks previously described as the Pierce Canyon Redbeds by Lang (1935) and Vine (1963), and it may include most, if not all, rocks to which the name Tecovas has been applied by some geologists in southeastern New Mexico and parts of western Texas (Dickey, 1940; DeFord and Lloyd, 1940; Bates and others, 1942; Garza and Wesselman, 1962).

The Dewey Lake rims the north and east sides of Nash Draw, but only partial thicknesses near the center and top of the formation are exposed. Other parts of the formation are mantled by blankets of dune sand and caliche. Nevertheless, the Dewey Lake covers a considerable section of the pre-Tertiary terrane in Los Medaños area. It is bound on the west by gypsiferous residue of the uppermost anhydrite seam in the Rustler Formation and on the east by coarse-grained clastic rocks of the Santa Rosa Sandstone of Late Triassic age.

The Dewey Lake is differentiated from other formations by its lithology, distinctive reddish-orange to reddish-brown color, and sedimentary structures. The formation consists almost entirely of an alternation of siltstone and very fine grained sandstone in beds a few inches to several feet thick, but there are a few beds of claystone in its lower and upper parts. Individual beds are persistent, and the formation is readily separable into several sequences alternately richer or poorer in sandstone (fig. 9). Many beds are horizontally laminated, and there are commonly small-scale cross-lamination and ripple marks in other beds.

The Dewey Lake thins from southeast to northwest in Los Medaños area. The formation ranges between 540 and 560 feet in thickness in the Cruz and Triste Draw oil fields, but it is only slightly more than 500 feet thick at the Kerr-McGee mine. The northwestward thinning is attributed to pre-Late Triassic erosion after the red beds had been tilted southeastward. The contact with the overlying Santa Rosa Sandstone is considered to be an angular unconformity of low angle.

Triassic System

Triassic rocks in Los Medaños area are included in the Dockum Group of Late Triassic age. The Dockum is entirely of continental origin and consists of dominantly fine sediments of broad flood plains and coarse alluvial debris. It surfaces the pre-Tertiary terrane throughout the eastern half of the area but is only partly exposed in escarpments at the Kerr-McGee mine and near the northwest corner of the area and in a few fairly small inliers separated by wide stretches of dune sand.

Local subdivisions of the Dockum Group are the Santa Rosa Sandstone (Darton, 1922) and the Chinle Formation (fig. 9). The Santa Rosa forms the lower part of the group and is 212-245 feet thick. It consists, for the most part, of cross-stratified, medium- to coarse-grained, gray to yellow-brown sandstone, but includes both conglomerate and reddish-brown mudstone. The contact with the overlying Chinle Formation is conformable and is at the change from sandstone of the Santa Rosa to shaly mudstone of the Chinle. The Chinle is dominantly reddish-brown shaly mudstone interspersed with some greenish-gray mudstone and minor lenses of sandstone and conglomerate. It reaches a maximum thickness of about 800 feet near Hat Mesa gas field in the northeastern part of the area, where it is overlain unconformably by the Ogallala Formation of late Tertiary age.

The Dockum Group in Los Medaños area and vicinity has been subjected to at least three major periods of erosion. These are: (1) post-Late Triassic to Early Cretaceous,(2) post-Cretaceous to late Tertiary, and (3) post-late Tertiary. No rocks of Jurassic age are known to occur in the area or any other part of southeastern New Mexico, but there are good reasons to infer from paleogeology and other considerations that the Jurassic Period was a time of erosion and removal of the Dockum. Rocks of Cretaceous age are also unknown, yet some almost certainly were deposited by Early Cretaceous seas which advanced northward across southeastern New Mexico. Small outliers, crevasse deposits, and other remnants of Lower Cretaceous rocks are found lying unconformably on the Capitan, Tansill, and Castile Formations near Carlsbad Caverns (Hayes, 1964, p. 37-38; Lang, 1947, p. 1472), on the Salado Formation near Black River Village, on the Rustler Formation a few miles northeast of Carlsbad, N. Mex., and on the Chinle Formation at many places to the north and east of Los Medaños area (Ash and Clebsch, 1961, p. D139). The deposition of Lower Cretaceous rocks was followed by uplift and eastward tilting of the region and by erosion of Cretaceous and Triassic rocks to form an eastward-sloping surface on which alluvial debris accumulated late in the Tertiary Period. The third and final period of erosion began near the close of the Tertiary and has continued intermittently until the present.

Tertiary and Quaternary Systems

Tertiary and younger alluvium, caliche, and dune sand cover the surface of nearly all parts of Los Medaños area and lie unconformably on older rocks. Local subdivisions include the Ogallala Formation of Pliocene age, the Gatuna Formation of Pleistocene(?) age (Lang, 1938), an unnamed caliche formation of Holocene age, and the Mescalero Sand of Holocene age (Darton, 1928).

The Ogallala Formation is exposed in outliers in the northeastern, central, and southeastern parts of Los Medaños area. The formation is as much as 60 feet thick and consists of dominantly fine- to medium-grained, tan, pink, and gray, calcareous sandstone interspersed with lenses of conglomerate and capped by a rather resistant layer of well-indurated caliche. Insofar as has been determined from study and mapping of outcrops (Bachman and Johnson, 1973), the Ogallala has totally escaped deformation related to subsidence, and it clearly marks the end of regionally important periods of evaporite subrosion in mid-Tertiary or earlier times. During these periods salt was leached from the Rustler Formation and parts of the underlying Salado Formation over a wide section extending southeastward from northern Nash Draw through central Los Medaños area into San Simon Swale (Brokaw and others, 1972, fig. 12).

Among the post-Tertiary rocks in Los Medaños area, the Gatuna Formation is the thickest and the least extensive. The formation ranges erratically in thickness from 0 to 375 feet. It consists of very poorly consolidated, reddish-orange sandstone and siltstone interspersed with conglomerate, and is a typical bolson deposit filling steep-walled valleys or troughs cut chiefly, and rather deeply, into the Dewey Lake and Rustler Formations. The Gatuna is overlain unconformably by an unnamed caliche formation, and it seems to be the last sedimentary deposit of any local or regional geological significance to accumulate prior to the start of downcutting by the Pecos River and attendant changes in the circulation of meteoric ground water. The unnamed caliche formation is composed of rather chalky, earthy limestone, as much as 5 feet thick, containing considerable clay, sand, and broken fragments of the underlying bedrock. The

Mescalero Sand, which overlies the unnamed caliche, is a wide-spread deposit of uniformly fine-grained, light-brown to reddish-brown dune sand, having a maximum thickness of about 15 feet.

Mid-Tertiary lamprophyre dike

A near vertical lamprophyre dike is inferred to intrude the Salado Formation and older rocks that underlie Nash Draw and the Maroon Cliffs in the northwestern part of Los Medaños area (fig. 3). The dike is not exposed at the surface, but its presence at depth seems clearly indicated by two separate occurrences, about 10 miles apart, of a near vertical, northeast-trending lamprophyre dike--one in mine workings located about 3,500 feet beyond the west edge of Los Medaños area and the other in mine workings about 2,600 feet beyond the north edge of the area. The two occurrences are considered to be parts of one continuous lamprophyre dike, but the possibility of being separate dikes in a series of en echelon dikes cannot be excluded. Despite the uncertainty concerning precise relationships, the two occurrences are clearly part of a series of occurrences of lamprophyre dikes that extends northeastward almost 80 miles from the Gypsum Hills in southern Eddy County near the New Mexico-Texas State line to the Vacuum oil field south of Buckeye in central Lea County, N. Mex. The strong northeast trend of these dikes parallels that of the crevasses and joints in carbonate rocks of the Capitan and Tansill Formations near Carlsbad Caverns and are filled with quartzose sandstone and conglomerate of Early Cretaceous age.

From one occurrence to the next, the lamprophyre dike is strikingly similar in appearance, composition, structure, and most other respects. The dike is typically only a few inches to a foot or so thick, but it is almost 15 feet across at its widest point in the Kerr-McGee mine. In general, the lamprophyre is a medium-gray to grayish-black, fine-grained porphyritic rock having a chilled border and a rather poorly developed flow structure (Jones and Madsen, 1959). It contains corroded phenocrysts of andesine, pseudomorphs of siderite and antigorite after pyroxene, and a scattering of amygdules, as much as about 2 mm (millimeters) across, filled with halite, siderite, calcite, and natrolite. The groundmass consists of dominantly orthoclase with appreciable biotite partially altered to vermiculite, and minor ilmenite, apatite, anatase, and pyrite. Intersecting near-vertical and subhorizontal fissures in the dike are commonly halite-bearing, but locally contain polyhalite, anhydrite, and minor pyrite, dolomite, quartz, and crystalline hydrocarbon. The intruded rock salt is recrystallized for as much as three-fourths of an inch from the margin of the dike and, in many places, contains pockets of methane and other gases introduced under pressure. Locally the lamprophyre dies out laterally and vertically in a vein of polyhalite that contains minor dolomite and pyrite along with a little crystalline hydrocarbon.

A mid-Tertiary date for intrusion of the lamprophyre dike is indicated by an age of 30±1.5 m.y. (million years) obtained by Urry (1936) on drill cuttings from the Texas Co. 1 Moore well located about 3 1/4 miles northeast of the Kerr-McGee mine.

Structure

The structure of Los Medaños area is basically simple and the rocks are, for the most part, only slightly deformed. Nevertheless, the rocks have been tilted, warped, eroded, and subroded, and discrete structural features can be recognized. These include: (1) structural features of regional extent related to Permian sedimentation,(2) intraformational folds of limited extent related to "down-the-dip" movement of salt under the influence of gravity and weight of overburden, and(3) subsidence folds related to warping and settling of rocks to conform with the general shape and topography of the surface of salt in areas of subrosion.

The principal structural features in the subsurface of Los Medaños area are two composite structural and sedimentary units--the Delaware basin on the south and the northwest shelf on the north--which subsided unequally throughout much of the Ochoan and earlier parts of the Permian. The hinge zone, or line of separation between the two units, is marked by the fairly narrow, arcuate belt of Capitan Limestone, which has long been considered an ancient carbonate reef (Lloyd, 1929; Crandall, 1929). This belt of carbonate rock passes through the northern part of Los Medaños area, and its steep fore-edge forms the rather pronounced, south-facing monocline shown on the cross sections (fig. 3) and map of the structure at the base of the Castile Formation (fig. 10). South of this flexure the main structure is a rather gentle homoclinal dip of no more than about 2° southeastward. The regional dip is interrupted here and there by slight ridges and troughs, and there is a fairly pronounced, southeastwardly plunging trough at the foot of the monoclinal flexure in the northern part of the area.

As may be seen from a comparison of structural features shown on figure 10 with those on figures 2 and 11, the structure of rocks in Los Medaños area changes with depth and tends to become more complex upward. In addition, the strong monoclinal flexure that is so much in evidence at the base of the Castile Formation disappears upward in the section and is not present at any level above the top of the formation. At the same time, however, it should be noted that the rather gentle homoclinal dip southeastward is maintained throughout the section with little or no change in direction or amount of dip from one level to the next. This feature should be emphasized rather strongly, for the general uniformity in direction and amount of dip is practically the only structural feature that is common to all levels in the section.

At intermediate and other levels in the section, the structure is generally more uneven than at the base of the Castile Formation, and minor folds are somewhat more prominent. Salt and anhydrite in the middle member of the Castile are crumpled in sharp intraformational folds that appear to die out northwestward up the dip and to become more pronounced southeastward down the dip. Spatially the intraformational folding of the salt and anhydrite appears to be confined to a single long northwestwardly trending belt, about 3-4 miles wide, that more or less coincides in trend and extent with the prominent southeastwardly plunging trough at the base of the Castile. The folding has resulted in some buckling and downwarping of rocks in the Salado Formation, and it has uplifted the Salado and other rocks as young as the Chinle Formation in a fairly broad arch that trends northwestward across the area. The exact age of the deformation is unknown; it can be dated only very broadly as post-Late Triassic to pre-Pliocene. Specific considerations concerning minimum thickness of overburden required to initiate salt movement suggest that the deformation may have occurred during or shortly after the period of regional tilting that followed the deposition of Cretaceous rocks. The deformation almost certainly had to occur before any great thickness of Cretaceous rocks was removed by erosion.

The structure at the level of the pre-Tertiary terrane shown on figure 2 is the most complex of all. It includes most features apparent at lower levels in the section plus the additional feature of subsidence folds that combine the total effect of all the warping and settling of rocks to conform with the topography of the upper surface of salt in areas where subrosion has taken place. The subsidence folds contribute considerably to the general unevenness of the structure at practically all levels above the upper surface of salt in central and western Los Medaños area, and they rather noticeably disrupt and otherwise modify the homoclinal dip southeastward and the continuity of the northwestwardly trending arch related to post-Cretaceous salt deformation. The folds are clearly post-Cretaceous but may have formed during mid-Tertiary or earlier time, for some are clearly pre-late Tertiary in age. They extend into areas where the Ogallala Formation of late Tertiary age has escaped deformation related to subsidence, but where other rocks above the Rustler-Dewey Lake contact have subsided 90-130 feet.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of available geological information, the salt deposits of Los Medaños area seem in many ways to constitute a suitable receptable for use in a pilot-plant repository for radioactive wastes. The deposits have thick seams of rock salt at moderate depths, they have a substantial cover of well-consolidated rocks, and they have escaped almost completely undamaged long periods of erosion. The deposits are only slightly structurally deformed, and they are located in an area that has had a long history of tectonic stability. Certain other essential geological details, however, are unknown or only poorly known at best, and more study involving the drilling of bore-holes to obtain cores of rock salt is required to(1) identify specific seams of rock salt that might be most suitable for waste-storage purposes, and(2) establish critical details of their chemistry, mineralogy, stratigraphy, and structure.

Consideration of all factors relating to Los Medaños area suggests that additional investigations involving the drilling of test holes could be conducted most profitably within or in the vicinity of the tract shown on figure 12. This tract seems to be in one of the more stable parts of Los Medaños area. It has a high degree of isolation from populated areas and, as indicated on figure 12 by the individual rays that connect producing oil and gas wells and mines with its arcuate segmented margin, all places within the tract are 5 miles or more from any center of industrial activity. In addition, the tract has a rather low density of boreholes that completely penetrate the salt deposits, and the complete history of drilling in the area is known from the records maintained by Federal and State agencies.

The geology is another important factor that points rather strongly to the particular tract shown on figure 12 as being a prime area for further study. Within the tract and much of the surrounding area, the Salado Formation is largely, if not entirely, free of subrosional debris, and any and all rock deformation related to subrosion is confined stratigraphically to the Rustler and higher formations. Furthermore, the depth to Salado salt is as shallow as 750 feet and at no place within the tract is it any more than about 1,500 feet (fig. 7). Another favorable factor is the presence of as much as 1,500-2,000 feet of Salado salt above a depth of 3,000 feet. With this amount of salt thickness available at rather moderate depths, a wide combination of options can be exercised in selecting a potential site or some particular sequence or group of salt beds to serve as the receptable or storage unit for radioactive wastes in a pilot-plant repository.

That all of the Salado Formation is intact must be strongly emphasized, for it means that virtually all parts of the formation can be considered in the search for a suitable receptable for radioactive wastes. From among all the seemingly limitless possibilities available, four groups or sequences of salt beds stand out as being most worthy of consideration in this search. The sequences of particular interest include the 139-136 and the 133-128 sequences in the lower member of the formation, the 124-Union sequence in the McNutt potash zone, and the 115-109 sequence in the upper member of the formation (fig. 6). The 133-128 sequence probably has the best overall combination of lithology and bedding chracteristics, and its anticipated longevity as estimated from the combination of salt cover, overburden thickness, and distance from edge of subrosion is considerable (fig. 12). The 133-128 sequence should be considered the prime target for close examination in any drilling program that might be started in the area.

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GROUND-WATER HYDROLOGY

By

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Introduction

An inventory of the existing and abandoned wells and all water data noted in the drilling of potash and oil and gas tests was completed in October 1972. The inventory showed that few water wells are in Los Medaños area (Los Medaños area defined as to include four townships--T. 21 S., R. 31-32 E., and T. 22 S., R. 31-32 E.). Only one water well, which supplies water to stock, is within 5 miles of the four-corners, the common point of the four townships. In order to obtain some control on the ground-water hydrology, the inventory included the water wells in the adjacent row of townships that surround Los Medaños area. The water-well inventory included measurements of the water level in the well and the depth of the well in order to identify the stratigraphic unit(s) that yields water to the wells (tables 3 and 4). Information obtained by the well inventory is contained in table 4. Only a minor amount of information concerning the hydrology was obtained from inspection of logs of potash, oil, and gas tests; this information is not included in this report. Data concerning results of drill-stem tests and other tests of the strata below the Salado Formation were not analyzed.

Occurrence of ground water

In the formations above the salt-bearing Salado Formation, the Santa Rosa Sandstone supplies much of the water to stock wells in Los Medaños area and adjacent townships. The Rustler Formation yields greater quantities of water to wells than does the Santa Rosa Sandstone (table 3), but much of the water in the Rustler contains excessive dissolved material to be of use for most purposes. The water in the Santa Rosa Sandstone appears to form a multiple aquifer system with that in the lower sandstone beds of the Chinle Formation and with the Dewey Lake Redbeds and Rustler Formation. This aquifer system supplies water to wells throughout the area, although the amount of water obtained differs from place to place. Yields from the Santa Rosa Sandstone, sandstone beds in the Chinle Formation, and the Dewey Lake Redbeds probably are less than 10 gpm (gallons per minute) and perhaps most are less than 5 gpm. The yields from the Rustler Formation are greater and, in places in Nash Draw and at the Gnome site, the formation yields more than 50 gpm to wells. Most of the water withdrawn by wells that penetrate the Rustler Formation probably is from the Culebra Dolomite Member and perhaps the Magenta Dolomite Member.

In the northern and eastern parts of the area shown on figure 13, the shaly strata that constitute most of the Chinle Formation separates the water in the Santa Rosa Sandstone and the lower sandstone beds in the Chinle Formation from that present at shallow depths in the surficial deposits and in the upper sandstone beds of the Chinle Formation. In several places water in the surficial deposits has been encountered at depths of less than 50 feet below the land surface. Yields from the surficial deposits and from the upper sandstone beds of the Chinle Formation usually are exceedingly small--only a few gallons per minute. At several locations three or four wells have been drilled close together in order to obtain a reliable water supply--this indicates a low yield and problems of well construction.

Table 3.--Chart of the hydrology of the formations above the Salado Formation

Water-bearing formation or zone	Distribution of water wells completed in the formation or zone	~~Con~~currence of water and brief description of hydrologic characteristics	Specific conductance1/ (in micromhos at 25° C)
Surficial deposits	Along the northern and northeastern boundary of ~~the~~ Los Medaños area.	In the lower few feet of the deposit, mainly in the lows cut into the underlying Chinle Formation; wells yield only a few gallons per minute.	460 - 2,200 feet
Chinle Formation	Mainly in the adjacent townships northeast and east of ~~the~~ Los Medaños area.	In thin sandstone beds that have a low permeability; wells yield only a few gallons per minute.	1,300 - 7,600 feet2/
Santa Rosa Sandstone	Main water-bearing unit in the central and eastern parts of ~~the~~ Los Medaños area and in the townships chiefly to the east.	In sandstone beds that have a low permeability; most wells yield less than 10 gallons per minute.	Mainly 540 - 850 feet
Rustler Formation	Main water-bearing unit west and southwest of ~~the~~ Los Medaños area.	Culebra Dolomite Member and perhaps the Magenta Dolomite Member are the chief water-yielding units of the formation; some water is from the gypsiferous part of the formation lying mainly above the Culebra Dolomite Member; yields of wells range from a few gallons per minute to more than 100 gpm obtained during pumping tests at the Gnome site.	2,200 - 15,000 feet
Basal solution breccia zone	No water wells penetrate this zone.	No items concerning water noted during drilling of potash, oil, or gas tests.	-------------------
Salado Formation	No water wells penetrate this formation.	No items concerning water noted during drilling of potash, oil, or gas tests.	-------------------

1/ Includes specific conductances obtained from Cooper and Glanzman, 1971; Hendrickson and Jones, 1952; and Nicholson and Clebsch, 1961.

2/ Includes water probably contaminated from oil and gas operations.

Table 4.--Records of Wells in the Los Medaños Area, New Mexico

Compiled by

F. P. Lyford and M. E. Cooley

1972

Explanation

Owner or name: The owner of, or name used at time of visit.
Altitude: From topographic maps.
Depth of well: All depths of wells were obtained in 1972; all depths to water in the wells measured in 1972 or before are listed; R, reported depth; P, pumping level; <, less than.

Geologic source: QTs, surficial deposits; Trc, sandstone beds in the Chinle Formation; Trsr, Santa Rosa Sandstone; Pdl, Dewey Lake Redbeds; Pru, Rustler Formation above Culebra Dolomite Member, including Magenta Dolomite Members; Prc, Culebra Dolomite Member of Rustler Formation.
Field specific conductance: Measurements made in 1972; T, water from stock tank; C, possible contamination from nearby oil tests or potash operations.
Power, use, and remarks: Name enclosed in quotation is local name of well.

Location number	Owner or name	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well casing (inches)	Water level: Depth below land surface (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Geologic source	Field specific conductance (micromhos at 25°C.)	Power, use, and remarks
19.32.34.424	--	3560	260	--	Dry	9-22-72	<3300	QTs, Trc, Trsr(?)	--	Unused; 3 wells at this locality; no access for entering casing in the other 2 wells.
19.33.26.244	Mark Smith	3609	--	6	90.58	9-25-72	3518	QTs, Trc(?)	2200	Electric Submersible; stock.
			101R	--	92.90	7- 1-54	3516	QTs, Trc(?)		
26.244a	Mark Smith	3609	101	--	90.93	9-25-72	3518	QTs, Trc(?)	--	--
19.34.31.131	Mark Smith	3620	53	6	Dry	9-25-72	<3567	QTs	--	Unused; 2 ft. of water in bottom of hole--probably does not represent true water level.
31.232	Larry Hughes	3632	120R	6	--	9-25-72	--	QTs, Trc(?)	2700	Windmill; stock; "Hardin Well", no access to enter casing.
20.31.13.412	--	3440	30	6	1.12	9-18-72	3439	QTs	2200	Unused.
15.130	--	3460	105	6	62.10	9-18-72	3398	QTs(?), Trsr	--	Unused.
15.130a	--	3460	79	6	63.39	9-18-72	3397	QTs(?), Trsr	--	Unused; 5 wells at this location of which only 1 is an operating well.
			70(?)	6	63.05	12-22-48	3397	QTs(?), Trsr		
15.130b	--	--	--	--	--	--	--	QTs(?), Trsr	4000TC	Windmill; stock.
16.240	--	3460	110(?)	--	61.18	12-22-48	3399	QTs(?), Trsr	--	Unused; 2 wells at this location.
20.32. 1.312	Wm. Snyder	3510	20	6	Dry	9-22-72	<3490	QTs	--	Unused; deepest of 4 wells at this location, all wells are dry.
			30		21.80	7- 1-54	3488	QTs		
18.233	Freeport Sulphur Co.	3460	400	8	89.20	3-24-54	3371	Trsr	--	Test hole(?); unable to locate in 1972.
24.333	--	3555	67	5	37.67	9-11-72	3517	QTs	--	Unused.
24.333a		3555	--	--	--	--	--	QTs(?)	740	Windmill; stock.
27.144	Joel Frey(?)	3545	30	--	23.67	9-18-72	3521	QTs	--	Unused; no casing present.
					12.30	6-11-54	3533	QTs		
30.142	--	3505	--	--	9.94	6-11-54	3495	QTs	--	Destroyed; unable to locate in 1972.
36.214	Bingham	3585	--	--	P43.88	9-18-72	3541	QTs	2000	Windmill; stock; 3 wells at this location, at Bingham ranch, well pumping estimated at 2 gallons per minute.
			60	7¼	46.60	6- 6-55	3538	QTs		

Table 4.--Records of Wells in the Los Medaños Area, New Mexico--Continued

Location number	Owner or name	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well casing (inches)	Water level: Depth below land surface (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Geologic source	Field specific conductance (micromhos at 25°C.)	Power, use, and remarks
20.33. 4.432		3555	4		Dry	9-22-72	--	QTs		Unused.
15.221	--	3580	--	4	336.10	4-20-55	3244	Trc(?)	--	Destroyed(?); unable to locate in 1972.
18.123	--	3521	249	6.5	245.58	9-25-72	3275	Trc	--	Unused.
21.111	--	3536	49	6	36.90	9-25-72	3499	QTs	--	Unused.
24.124	D.C. Berry	3630	680	12	405.15	9-22-72	3225	Trc, Trsr(?)	1500T	Windmill; stock; "West Windmill", watersand at about 300 feet as reported by driller.
20.34. 4.444	--	3633	200	8	P174.08	10- 2-72	3459	Trc	7600C	Windmill; stock; "Robert's Well", old oil test drilled before 1930.
14.133	--	3648	230	--	190.25	10- 2-72	3458	Trc	4000C	Windmill; stock.
17.334	Mark Smith	3640	220(?)	8	P129.68	10- 2-72	3510	Trc	4000C	Windmill; stock; "City Service Well", possibly oil test.
			200	--	140.00	7- 1-54	3500	Trc		
22.224	D.C. Berry	3655	220	12	196.49	10- 2-72	3459	Trc	4000C	Windmill; stock; "North Well", old oil test.
34.432	D.C. Berry	3770	96	6	89.50	10- 2-72	3680	QTs	520	Windmill; stock.
21.30.18.333	Wayne Cowden	3220	156	6	129.54	9-25-72	3090	Pru	--	Unused.
			176	6	124.32	4-15-59	3096	Pru		
22.423	Wayne Cowden	3180	130	6	111.50	9-25-72	3068	Pru	--	Unused.
			220(?)	6	104.55	4-15-59	3075	Pru, Prc		Unused.
21.31. 1.131	Matthews	3580	30R	6	20.80	9-18-72	3559	QTs	930	Windmill; domestic & stock; at Campbell Ranch.
1.241	Matthews	3600	--	--	--	--	--	--	--	"Grave Well".
2.221	Matthews	3570	35	--	29.80	9-18-72	3540	QTs	--	Windmill; stock.
7.331	--	3350	367	14	192.10	9-14-72	3158	Pru, Prc(?)	3500	Unused.
13.244	--	3600	68	6	Dry	9-13-72	<3532	QTs, Trc	--	Unused.
18.411	Cowden & Smith	3310	--	6	158.32	9-14-72	3152	Pru	2200T	Windmill; stock; "New Well".
					P158.80	4-15-59	3151	Pru		
30.421	Kerr-McGee(?)	3300	176	6	Dry	9-25-72	<3124	Pru	--	Unused.
21.32. 6.111	Allred	3598	54R	--	44.00R	9-18-72	3554	QTs	1400	Windmill; domestic & stock; at Allred Ranch; 2 wells at this location.
21.33. 2.231	Texaco(?)	3810	1150R	--	--	9-22-72	<3230	Trsr	--	Unused; could not pass tape below 580 feet in 1972.
2.422	D.C. Berry	3785	120R	--	107.20	6-28-54	3678	QTs	--	Unused; at Berry Ranch.
2.420	D.C. Berry	3770	94	6	79.58	9-22-72	3690	QTs	750	Windmill; stock.
2.420a	D.C. Berry	3770	--	10	72.85	6-28-54	3697	QTs	--	Windmill; stock.
4.434	D.C. Berry	3805	147	--	129.66	10- 2-72	3675	QTs(?), Trc	900	Unused.
4.434a	D.C. Berry	3805	127	--	Dry	10- 2-72	<3678	QTs(?), Trc	--	Unused.
18.114	D.C. Berry	3890	150	--	140.75	9-12-72	3749	QTs	500T	Windmill; stock.
18.114a	D.C. Berry	3890	175	--	142.88	9-12-72	3747	QTs	--	Unused.
			--	--	143.00	6-21-54	3747	QTs		
18.123	D.C. Berry	3855	--	--	--	9-12-72	--	QTs(?)	460T	Windmill; stock.
18.123a	D.C. Berry	3855	145	8	117.30	9-12-72	3738	QTs	--	Unused.
18.131	D.C. Berry	3895	11	--	Dry	9-12-72	--	QTs	--	Unused.
25.421		3670	67	--	56.58	9-22-72	3613	QTs	1100T	Windmill; stock; "West Well".
28.124	San Simon Ranch	3688	210	8	179.00	9-22-72	3509	Trc	1300T	Windmill; stock; "Standard Wells", 3 wells at this location.
			224	7¼	179.50	6-30-54	3508	Trc		

Table 4.--Records of Wells in the Los Medaños Area, New Mexico--Continued

Location number	Owner or name	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well casing (inches)	Water level: Depth below land surface (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Geologic source	Field specific conductance (micromhos at 25°C.)	Power, use, and remarks
22.30. 5.431	Int. Potash	3120	225	14	53.25	9-19-72	3067	Pru, Prc(?)	15,000	Unused.
			--	14	66.45	4-14-59	3054	Pru, Prc(?)		
			--	--	87.45	5-18-49	3033	Pru, Prc(?)		
5.443	Int. Potash	3110	--	14	57.08	4-14-59	3053	Pru, Prc(?)	--	Unused; plugged back to 13 feet in 1972.
			--	14	68.00	5-18-49	3042	Pru, Prc(?)		
6.344	Int. Potash	3145	--	--	110.30	5-20-49	3035	Pru, Prc(?)	--	--
6.424	Int. Potash	3150	--	24	112.40	5-18-49	3038	Pru, Prc(?)	--	Unused; could not measure in 1972.
6.444	Int. Potash	3140	176	22	92.40	9-19-72	3048	Pru	10,000	Unused.
					117.33	5-18-49	3023	Pru		
7.244	Int. Potash	3110	58	12	Dry	9-19-72	--	Pru	--	Unused.
					85.72	5-18-49	3024	Pru		
7.311	Int. Potash	3134	250R	12	105.95	5-18-49	3028	Pru, Prc	--	Destroyed(?), apparently covered by salt tailings.
8.241	Int. Potash	3155	180	24	104.80	4-14-59	3050	Pru, Prc(?)	--	Unused, plugged back to 35 feet in 1972.
			--	--	115.05	5-18-49	3040	Pru, Prc(?)		
10.311	Mark Smith & Sons	3135	68	6	63.70	9-12-72	3071	Pru	2200	Unused; at Crawford Ranch.
			67	6	60.73	2-19-59	3074	Pru		
			--	--	55.95	12-23-48	3079	Pru		
20.120	Mark Smith & Sons	3076	10	5	Dry	9-19-72	--	QTs, Pru	--	Unused.
			129	5	72.96	2-19-59	3003	Pru, Prc(?)		
30.240	--	3000	75	8	33.98	12-17-48	2966	Prc	--	Windmill; stock; destroyed by 1972.
32.111	Mark Smith & Sons	3010	35	6	32.70	9-19-72	2977	Pru	--	Unused.
			108	6	45.24	2-19-59	2965	Pru, Prc		
33.212	Duval	3164	265R	--	183.70	2-25-56	2980	Prc	--	Mine shaft test.
22.31.15.130	Mark Smith & Sons	3460	--	--	144.07	9-12-72	3316	Trsr(?), Pdl	1600	Windmill; stock.
			--	6	P158.20	2-19-59	3302	Trsr(?), Pdl		
15.130a	Mark Smith & Sons	3460	--	--	145.50	9-12-72	3314	Trsr(?), Pdl	1600	Unused.
			167	12	150.87	2-19-59	3309	Trsr(?), Pdl		
22.32.14.323	--	3717	380	--	367.80	9-13-72	3349	Trsr	540T	Jenson Jack; stock; "Comanche Wells".
14.324	--	3720	380(?)	--	370.40	9-13-72	3350	Trsr	520T	Windmill; stock; "Comanche Wells".
22.33. 5.321	--	3650	10	6	0.0	9-22-72	3650	--	300	Windmill; stock; well on edge of Dagger Lake.
13.231	San Simon Ranch	3515	490	6	388.05	9-21-72	3127	Trc	2600	Windmill; stock; "Rogers Well".
13.231a	San Simon Ranch	3515	400	6	388.05	9-21-72	3127	Trc	--	Windmill; stock.
20.244	--	3602	--	--	--	--	--	--	--	Unable to locate well in 1972.
23.30. 2.444a	James Bros.	3250	315	7	257.73	9-20-72	2992	Prc	5000	Windmill; stock; "Little Windmill", well 444 destroyed.
			318	7	260.75	5- 1-59	2989	Prc		
6.424	James & Briones	2980	--	6	0.0	9-20-72	2980	--	--	Unused; "Nash Well", area flooded by lake.
			30R	6	6.45	8-19-58	2974	QTs		

Table 4.--Records of Wells in the Los Medaños Area, New Mexico--Continued

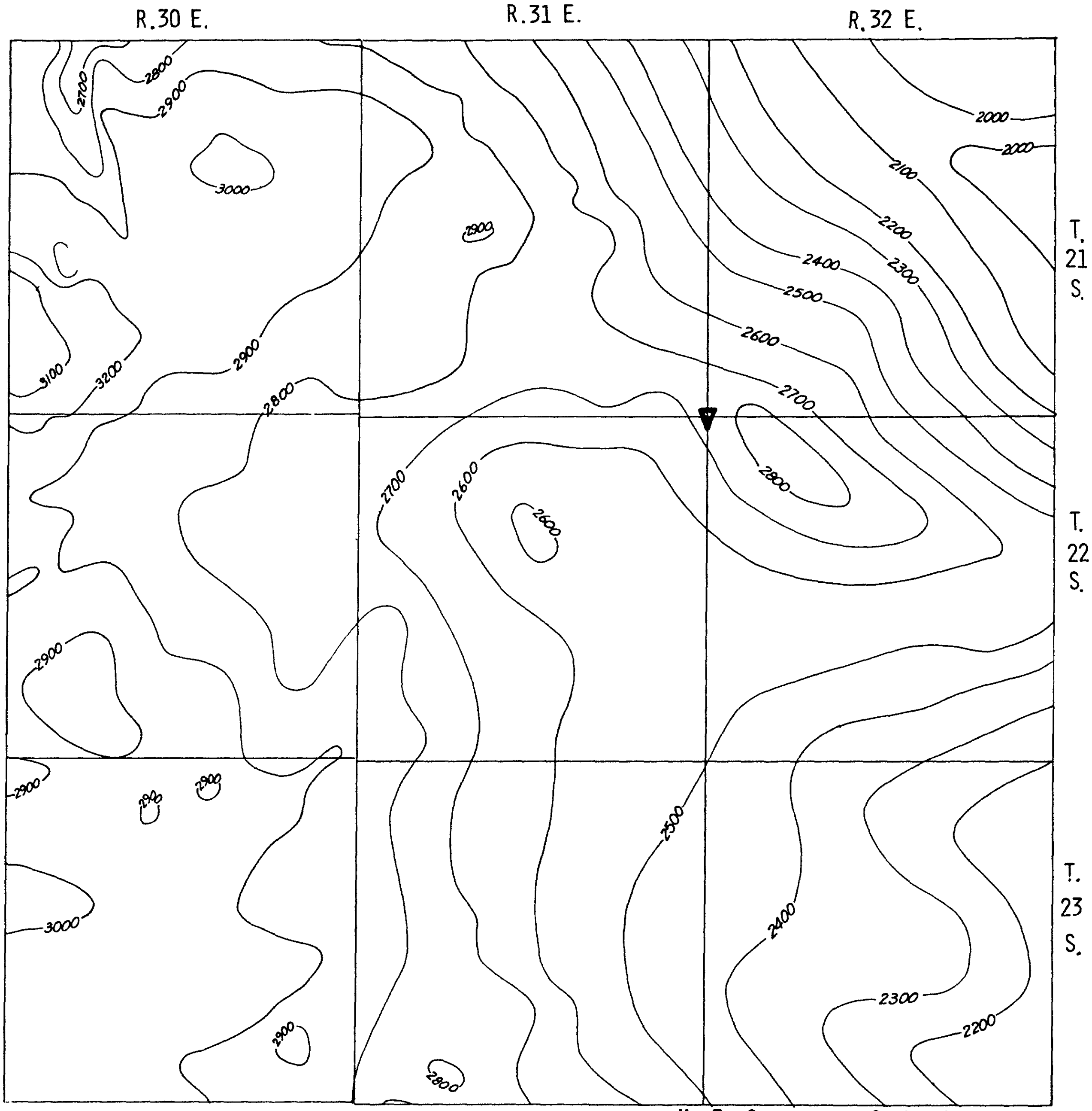
Location number	Owner or name	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well casing (inches)	Water level: Depth below land surface (feet)	Water level: Date of measurement	Water level: Altitude above mean sea level (feet)	Geologic source	Field specific conductance (micromhos at 25°C.)	Power, use, and remarks
23.30.19.123	James & Briones	3045	--	7	68.55	9-20-72	2976	Prc	3000T	Windmill; stock.
			92	7	69.10	4- 7-59	2976	Prc		
21.122	James & Briones	3165	--	5	--	9-20-72	--	Pru, Prc(?)	5000	Windmill; stock; "Indian Well", no access for water level measurement.
			204	5	179.25	4- 6-59	2986	Pru, Prc(?)		
22.234	--	3210	244	--	227.32	9-20-72	2983	Pru, Prc(?)	--	Unused.
33.244	AEC	3438	696	--	--	--	--	Pru, Prc	--	Abandoned; at Gnome Site, plugged 6-25-69, USGS No. 5.
34.133	AEC	3413	518	--	433.91	9-25-72	2979	Pru, Prc	--	Observation; at Gnome Site, USGS No. 4.
					433.67	12-12-61	2979	Pru, Prc		
34.133a	AEC	3413	--	--	427.03	9-25-72	2986	Pru, Prc	--	Unused; at Gnome Site, USGS No. 8.
34.234	AEC	3401	568	6	415.70	4-14-62	2985	Pru, Prc	--	Observation; at Gnome Site, USGS No. 6, drld to 1499' & plugged back to 568'.
34.234a	AEC	3402	563	6	418.10	4-16-62	2984	Pru, Prc	--	Observation; at Gnome Site, USGS No. 7, drld to 1507' & plugged back to 563'.
34.324	AEC	3426	567	--	441.67	9-25-72	2984	Pru, Prc	--	Observation; at Gnome Site, USGS No. 1.
					442.40	9-22-60	2984	Pru, Prc		
23.31. 6.320	James	3300	213	8	144.72	2- 4-59	3155	Pdl	--	Windmill; domestic.
6.320a	James	3300	400R	--	--	--	--	Pdl, Pru	--	Windmill; domestic; tape will not pass 222 feet in 1972.
6.444	James	3310	--	6	106.35	9-20-72	3204	Pdl	--	Windmill; domestic.
			168	6	105.65	2- 4-59	3204	Pdl		
7.222	James	3310	124	10	94.40	2- 4-59	3216	Pdl	--	Unused.
7.222a	James	3310	98	5	Dry	2- 4-59	<3212	Pdl	--	Unused.
7.240	James	3315	138	4	94.67	4- 2-59	3220	Pdl	--	Destroyed(?); did not locate well in 1972.
7.240a	James	3315	--	6	62.27	9-20-72	3253	Pdl	1500	Windmill; stock.
7.310	James	3295	--	--	--	--	--	--	--	--
17.310	James	3305	--	--	--	9-20-72	--	Pdl, Pru	3500	Windmill; stock.
			354	--	110.84	2- 4-59	3194	Pdl, Pru		
26.340	James	3451	--	6	250.47	9-20-72	3201	Pdl	3500	Windmill; stock.
			361		P256.90	2- 4-59	3194	Pdl		
29.113	James	3335	--	4	139.90	9-20-72	3195	Pdl	3500	Windmill; stock.
			223	4	138.43	3-26-59	3197	Pdl		
23.32. 3.311	James	3660	550R	8	--	9-13-72	--	Trsr	1300T	Windmill; stock.
3.311a	James	3660	--	10	204.18	9-13-72	3456	Trsr	--	Unused.
21.241	James	3680	550R	8	500.00R	4-13-59	3180	Trsr	--	Jenson Jack; stock; "Clifton Well".
21.241a	James	3680	515	--	480.75	9-21-72	3199	Trsr	650	Windmill; stock.
			550	6	510.00R	4-13-59	3170	Trsr		
23.33.12.312	San Simon Ranch	3530	388	12	351.45	9-21-72	3179	Trsr	1000	Windmill; stock; "Allred Well".
17.423	--	3702	650(?)	8	504.40	9-21-72	3198	Trc(?), Trsr	850T	Submersible; stock; "Graham Wells".
26.421	--	3645	173	6	165.15	9-21-72	3480	Trc	--	Windmill; stock; "Tip Top Wells".
26.421a	--	3645	189	6	P184.00	9-21-72	3461	Trc	1300	Windmill; stock; "Tip Top Wells".
26.424	--	3635	--	--	--	--	--	--	--	--
28.334	Brinninstool	3675	544(?)	--	500.00R	11-27-53	3175	Trc(?), Trsr	--	Windmill; stock & domestic; at Brinninstool Ranch, 2 wells at this location, tape will not pass 220 feet in either well.

Movement of ground water

Los Medaños area is astride a structural and topographic high that forms the drainage divide between the Pecos River and San Simon Swale. The structural high is well shown by contours drawn on the Culebra Dolomite Member of the Rustler Formation (fig. 14), the Santa Rosa Sandstone (fig. 15), and other strata below the Culebra Dolomite Member. These contours show an anticline that plunges generally southeastward across the central part of the area. This anticline is the dominating structure in the area and is the principal control on the movement of ground water in the multiple-aquifer system consisting of the Santa Rosa Sandstone and associated formations.

The eolian sand mantle restricts the development of internal stream channels and external drainage from Los Medaños area. Few stream channels extend beyond the boundaries of the area except along the western border where drainage is into Nash Draw. Most of the few short channels that are present in the area are along the flanks of the ridge known as The Divide.

Recharge to the water-bearing formations is from precipitation that falls directly on the few outcrops or on the widespread mantle of dune sand and caliche. The small part of the precipitation that is not evaporated or transpired may percolate downward through the dune sand and caliche into the underlying strata. Part of the precipitation collects into shallow temporary ponds that occupy



∇ Center of four corners area.

Compiled by M. E. Cooley and C. L. Jones, 1972

0 1 2 3 4 5 Miles

Contour interval is 100 feet.

Figure 14.--Structure at base of Culebra Dolomite Member of the Rustler Formation, Medonos area.

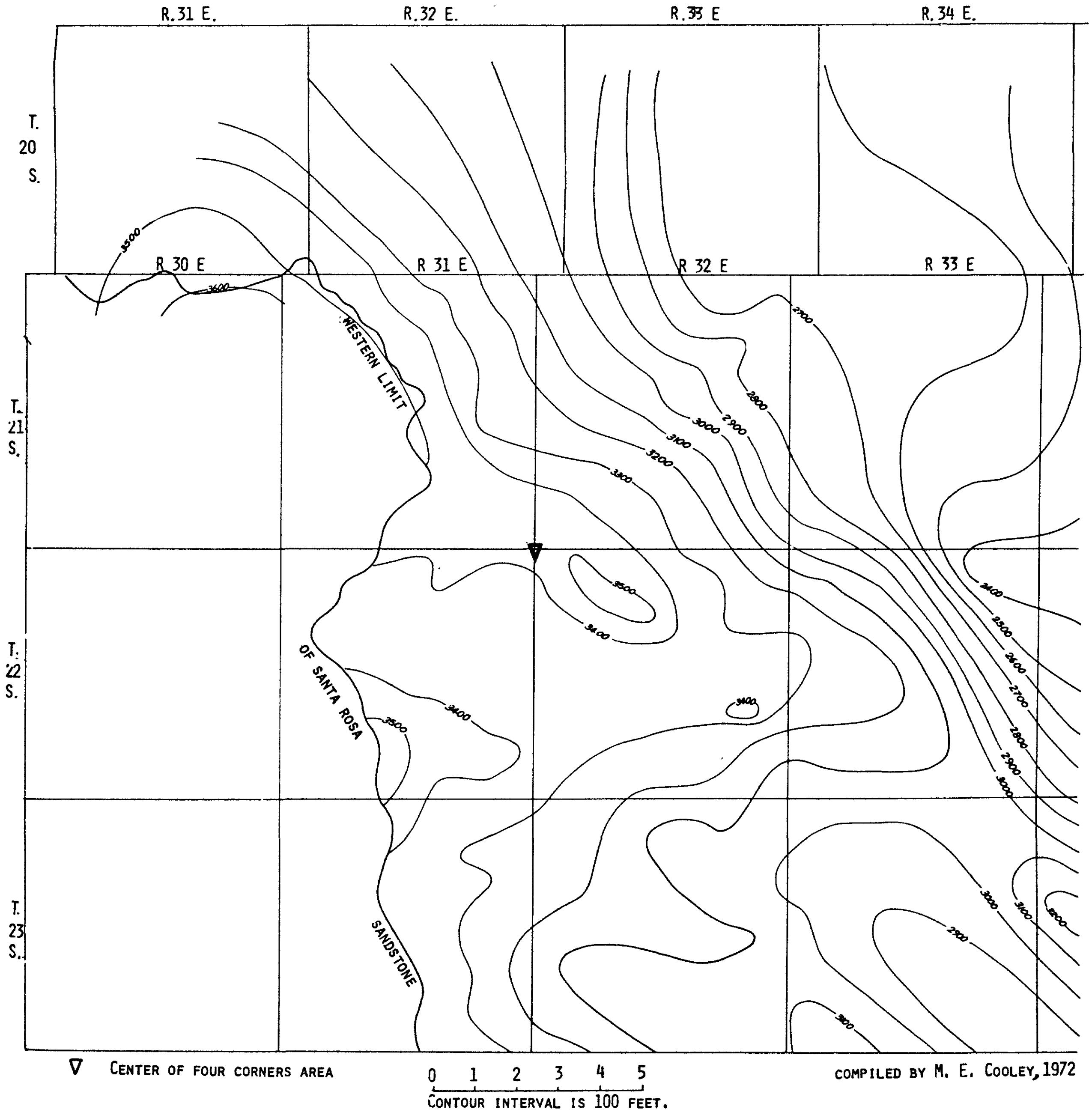


FIGURE 15.--STRUCTURE AT THE BASE OF SANTA ROSA SANDSTONE, LOS MEDAÑOS AREA.

depressions and sink structures. Water that recharges the surficial deposits in the northwestern part of the area is prohibited from moving downward into the Santa Rosa Sandstone anu underlying formations by the thick shales of the Chinle Formation.

Stated simply, the movement of ground water in the multiple-aquifer system is away from Los Medaños area--westward and southward (fig. 13) toward the Pecos River and eastward into San Simon Swale. From the high area near the "four-corners," water in the Santa Rosa Sandstone and lower sandstone beds in the Chinle Formation moves generally eastward and southeastward toward the San Simon Swale. Westward from the four-corners the water moves generally toward Nash Draw and southward to beyond Bootleg Ridge. The multiple-aquifer systems seems to be best developed in the western half of the area where the water moves downward as well as laterally from the Santa Rosa Sandstone into the Dewey Lake Redbeds and the Rustler Formation. Downward movement is restricted by the amount of salt that may be present in the Rustler Formation and the thick salt sequence that forms the Salado Formation. How well developed the hydraulic connection of the multiple-aquifer system between the Santa Rosa Sandstone and Dewey Lake Redbeds and the redbeds and the Rustler Formation is cannot be determined from the available hydrologic information. Some mixing of water among these formations is indicated by the chemical quality of the ground water. On the basis of meager evidence the quality of water in the upper part of the Dewey Lake Redbeds and in the Santa Rosa

Sandstone tends to be similar and, in places, the quality of water in the lower part of the redbeds and in the Rustler Formation is also similar.

Chemical quality of the ground water

During the 1972 field inventory, the water in the wells was tested to determine the amount of specific conductance (table 4), and selected samples of the water were taken for chemical analysis; the results of the chemical analyses are not included in this report. Figure 16 shows the general distribution of the specific conductance of the well water obtained from the field inventory and from available chemical analyses. An approximation of the amount of dissolved solids in parts per million of the water is obtained by multiplying the specific conductance by 0.6.

Figure 16 shows that the best water in terms of specific conductance or dissolved solids content occurs near the recharge (outcrop) area of the Santa Rosa Sandstone. Here the ground water usually has a specific conductance of less than 1,000 micromhos. The water becomes progressively poorer in quality as the water moves eastward toward San Simon Swale. The highest amount of dissolved material is in the water from wells completed in the Rustler or the lower part of the Dewey Lake Redbeds. The water in the surficial deposits in the northeastern part of the area shows local differences in the chemical quality where the specific conductance ranges mostly between 1,000 and 2,000 micromhos. The high specific conductances shown in the northeastern corner of figure 16 may represent, in part, contamination by oil and gas operations.

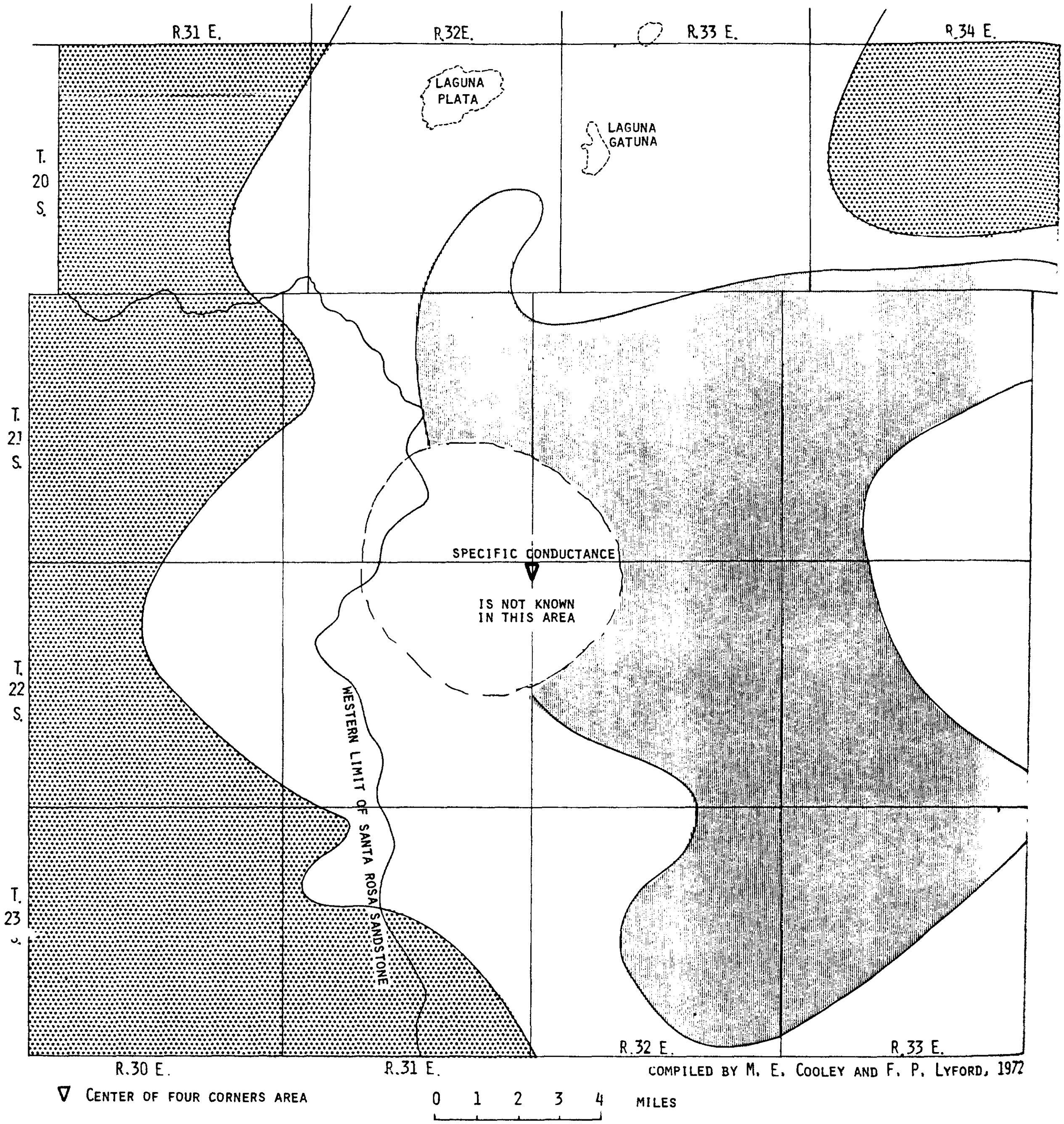
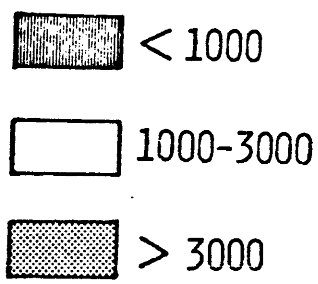


FIGURE 16.--SPECIFIC CONDUCTANCE OF WATER IN WELLS DETERMINED MAINLY DURING A FIELD INVENTORY IN SEPTEMBER AND OCTOBER 1972.

Acknowledgments

During the period of data collection generous assistance was provided by W. E. Hale, U.S. Geological Survey, and by F. P. Lyford and G. E. Welder of the subdistrict office in Roswell. Data on oil and gas tests were obtained from the New Mexico State Bureau of Mines and Mineral Resources. Water data from potash drilling was obtained from R. S. Fulton, Regional Mining Supervisor, U.S. Geological Survey, Carlsbad, N. Mex.

EXPLANATION



FIELD SPECIFIC CONDUCTANCE IN MICROMHOS AT 25°C

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SURFICIAL GEOLOGY

By

George O. Bachman

Introduction

The project area is located about 30 miles east of Carlsbad, N. Mex., and includes four townships (T. 21-22 S. and R. 31-32 E.) in Eddy and Lea Counties.

It is an area of sandhills covered by mesquite and associated plants of the Chihuahuan vegetation type at the northern end of the Chihuahua Desert. Altitude ranges from 3,300 to 3,900 feet above sea level. Local relief is low and usually does not exceed 20 feet; however, along the west side of Hat Mesa and The Divide, relief is about 50 feet. Rainfall is sparse and averages less than 10 inches per year. Most land within the project area is public domain and is used for cattle grazing. Traces of exploration for petroleum are widespread and pipelines from oil fields in the region cross the area. Potash is being produced from mines to the north and west.

Access is by pipeline roads and by roads built to drill holes and stock tanks. Many of these roads have been surfaced by caliche, but four-wheel-drive vehicles are necessary for access to most of the area.

Previous work has been done in this area by Nicholson and Clebsch (1961) and Vine (1963). The western portion of the accompanying geologic map (fig. 17) is from Vine (1963, pl. 1) with only minor modifications.

Description of mapped surficial units

Dewey Lake Redbeds

The oldest rocks exposed in the project area are the Dewey Lake Redbeds of Late Permian (Ochoan) age (fig. 17). These rocks consist of thin-bedded (average thickness less than 1 inch) shale, siltstone, and fine-grained sandstone. They are light to moderate reddish brown. There are some greenish-gray partings that average about 1 inch thick, and light-greenish-gray reduction spots that range from one-sixteenth inch to more than one-half inch in diameter are common in some beds. The sandstone beds are usually thinly laminated (laminae about one-quarter inch thick). Bedding is even and regular but some laminae show crossbedding. Ripple marks with amplitudes of less than 1 inch are common.

The best exposures of Dewey Lake Redbeds in the area are at the north end of Nash Draw. Other isolated exposures are present southwest of The Divide. All these exposures are poor and only a few tens of feet of the formation have been observed during the present work. Vine (1963, p. 19) estimated that the formation is 200-250 feet thick in the Nash Draw quadrangle. The Dewey Lake is overlain with apparent disconformity by the Santa Rosa Sandstone of Late Triassic age.

The U.S. Geological Survey has assigned the Dewey Lake Redbeds to the Permian Ochoan Epoch. Vine (1963, p. 21) noted a disconformity between the Dewey Lake and the overlying Triassic Santa Rosa Sandstone. Some constituents of the Dewey Lake are related to the underlying Permian beds, but it is here suggested that the Dewey Lake of southeastern New Mexico may actually be Triassic in age.

Santa Rosa Sandstone and undifferentiated rocks of Triassic age

The Santa Rosa Sandstone of Late Triassic age overlies the Dewey Lake Redbeds with apparent disconformity. The contact between these two formations is covered in the project area, but it may be seen in the northern part of the Maroon Cliffs and about 2 miles west of the Maroon Cliffs (Sec. 35, T. 20 S., R. 30 E.; Vine 1963, p. 21). In the project area a belt of exposures of Santa Rosa Sandstone is present northeast of Nash Draw and along the west side of The Divide.

The Santa Rosa Sandstone consists of moderate-reddish-brown to yellowish-brown conglomeratic sandstone, siltstone, and shale. Bedding is strongly cross laminated. Individual beds are lenticular and weather to form weak ledges. Constituents of the sandstones include coarse subangular sand grains and pebbles of rock fragments with occasional fragments of petrified wood. As the Santa Rosa is poorly exposed, its total thickness is not known. About 20 feet of sandstone and conglomeratic sandstone is exposed along the west side of The Divide but these beds may belong to the Chinle Formation. Vine (1963, p. 25) indicated that about 50-70 feet of the formation is present in the northern part of Nash Draw.

Ogallala Formation of Pliocene age

Considerable attention was given the Ogallala Formation while mapping in the project area because several criteria for distinguishing this formation from other stratigraphic units were observed. Previous generalized maps of the region (Dane and Bachman, 1965; Nicholson and Clebsch, 1961) have not restricted the Ogallala Formation as has been done during the present study.

The Ogallala Formation forms the caprock of Hat Mesa and The Divide and was not observed below an altitude of about 3,550 feet. It consists of gray to yellowish-gray sandstone and conglomerate overlain by caliche. On the northern part of Hat Mesa the sandstone is light yellowish gray, friable, fine to medium grained, well sorted, and about 10-15 feet thick. On the south part of Hat Mesa the total formation is about 15 feet thick, moderate yellowish gray, and consists of conglomerate cemented by silica. On The Divide the Ogallala is about 25 feet thick and includes about 10 feet of conglomerate at the base overlain by about 15 feet of caliche.

Caliche of the Ogallala Formation is a distinctive travertinelike calcium carbonate. It is dense, light gray to white composed of concentrically laminated fragments that range from less than one-half inch to more than 2 inches in diameter. Space between these fragments is filled with structureless or, in places, laminated limestone. The weathered surface apears "algal" or pisolitic in places. However, these concentric laminae probably are not the result of organic activity but indicate repeated generations of inorganic solution and reprecipitation. The caliche is sandy and has been precipitated in porous spaces between sand grains; therefore, individual sand grains appear to "float" in the caliche. The Ogallala caliche probably formed as a part of a soil profile that developed on the High Plains surface either during or after deposition of the Ogallala Formation.

Caliche of Quaternary age

Caliche of Quaternary age caps some topographic surfaces below The Divide and Hat Mesa. This caliche is light gray to white and composed of calcium carbonate. At many places it has precipitated in fractures and other porous spaces in bedrock of Permian or Triassic age or in unconsolidated sand of Quaternary age. Usually the caliche occurs as flat-lying beds 1 to 5 feet or more thick, but at places the beds dip at least 80-100 feet per mile. This caliche differs from the caliche in the Ogallala Formation in that laminar structures are absent, it is less dense, and has an overall fractured appearance. Many small joints and sheets are common. This caliche, like that of the Ogallala Formation, is sandy and has been precipitated in the porous spaces in sandstone.

Sand

Blow sand of Quaternary age blankets much of the area. At places it forms conspicuous dune fields that have been mapped separately, but in general it is a sheet deposit that usually rests on caliche. At many places the blow sand consists of two parts. At the base is a moderate-brown slightly consolidated eolian sand. This is overlain by light-brown to light-yellowish-gray unconsolidated sand. These may represent separate periods of wind activity but exposures of the oldest deposit are so limited aerally that they could not be mapped separately. In trans-Pecos Texas a similar sequence of Quaternary sand has been described (Huffington and Albritton, 1941). There the oldest sand was named the Judkins and the younger sand the Monahans. It is believed that the two sand units cannot be mapped separately in the project area.

The eolian sand was probably derived from Ogallala sands that extended far to the west and overlapped parts of the Guadalupe Mountains by the close of Ogallala time. These deposits were largely alluvial and were the result of streams draining eastward from the Rocky Mountain region. During Pleistocene time these deposits were eroded and extensively reworked. The widespread sands in this area are the last remnants of many cycles of erosion of those Ogallala deposits.

Surficial indications of dissolution

The project area is bordered by two major depressions, Nash Draw along the west and San Simon Swale on the east (fig. 18). Both of these surface features have long been regarded as the result of dissolution of salt, gypsum, and anhydrite in the subsurface. There is much local evidence for collpase into subsurface cavities along these depressions. Sink holes are common along the length of Nash Draw, both within the draw and along adjacent ridges. San Simon Sink is a prominent landmark within San Simon Swale about 20 miles southeast of the project area. Quaternary caliche dips towards these major depressions along their margins. These dips may have developed as a direct result of slumping or they may be the result of reprecipitation and deposition along a subsiding surface, or they may have been developed from deposition on an original or sloping surface.

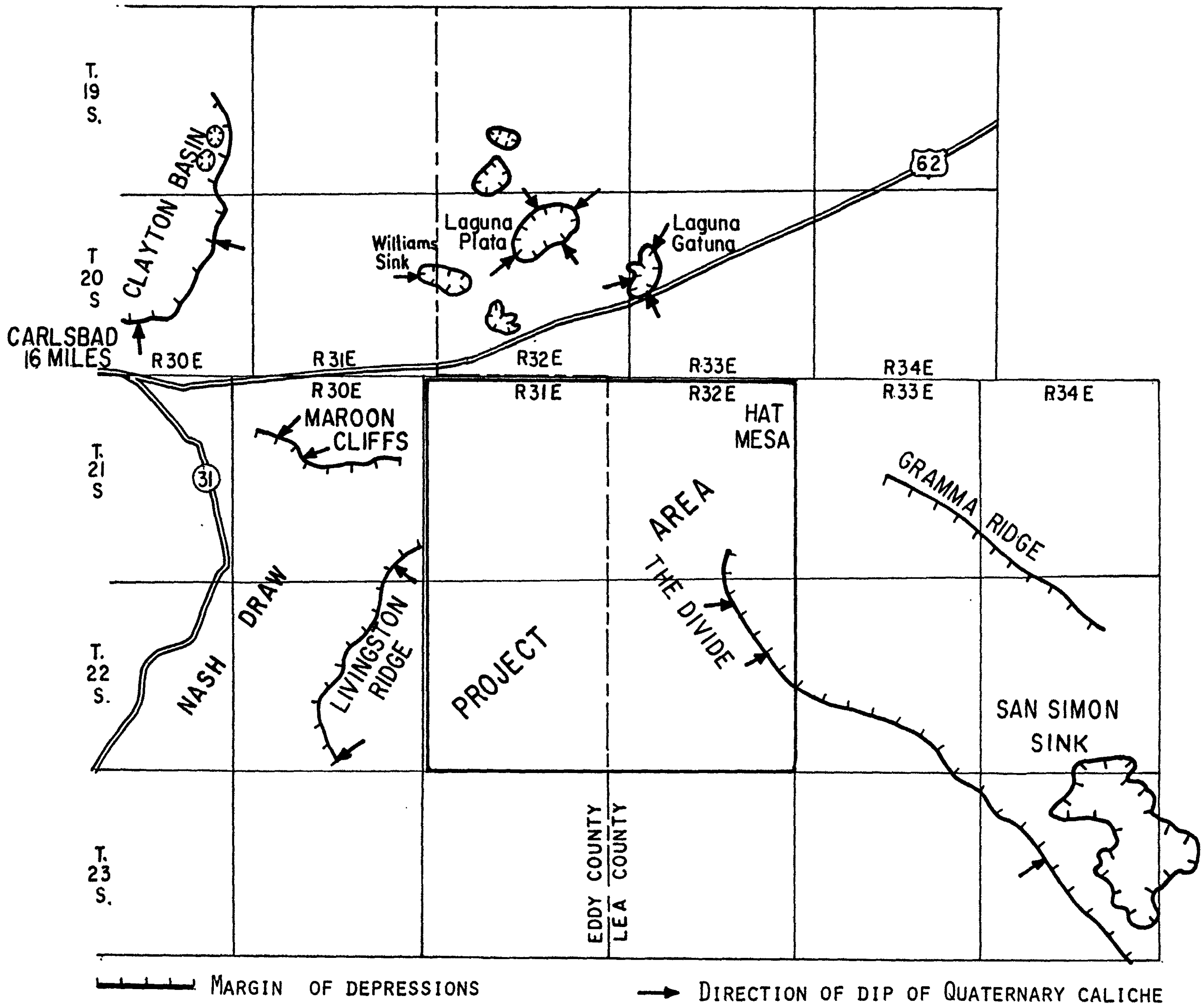

FIGURE 18.--AREAS OF DEPRESSIONS IN LOS MEDAÑOS AREA, NEW MEXICO

Depressions that exhibit internal drainage have developed on both the Pliocene and Quaternary caliche surfaces in and adjacent to the project area. Some of these are also related to subsurface dissolution of soluble rocks but others have an entirely different origin and are the direct result of surface phenomena. In the Clayton basin area, northwest of the project area, are numerous basins, sinks, and lakes that are believed to be the result of subsidence.

Within the project area, evidence of subsidence as a result of subsurface dissolution occurs only locally along the margins of Nash Draw and San Simon Swale. Along Livingston Ridge on the east side of Nash Draw caliche dips toward Nash Draw. Additionally, adjacent to Nash Draw in the northwestern part of the project area (Sec. 4, T. 21 S., R. 31 E.) several small sink holes may be related to subsidence. East of The Divide at some localities the Quaternary caliche dips eastward toward San Simon Swale.

North of the area those depressions such as Laguna Plata, Laguna Gatuna, Williams Sink, and other unnamed depressions are probably surface deflation structures resulting from erosion phenomena commonly found in arid regions. Subsurface evidence indicates that little or no solution has occurred in the underlying salt beds present in the Rustler Formation. Some of these, such as Laguna Plata and Williams Sink, have been filled with playa deposits and Laguna Gatuna has been partially covered by blow sand. Other surface depressions in the project area are also not believed to be related to subsidence. On the northern part of Hat Mesa and on The Divide shallow depressions with internal drainage are present on the Ogallala caliche. These depressions range from a few tens of feet to more than 500 feet in diameter and may be as much as 15 feet deep. They are generally oriented northwesterly. Caliche adjacent to these depressions does not dip toward the depression but is flat lying.

It is believed that these depressions are the result of dissolution of the surface between longitudinal sand dunes that once rested on the High Plains (Ogallala) surface. Similar depressions are present throughout the extent of the Ogallala caliche surface along the boundary of New Mexico and Texas. The longitudinal dunes developed at some time after the close of Ogallala time and before the major erosional cycles of late Pleistocene time began. The dunes formed during a period of persistent, dry, southeasterly winds. Between these dunes plants obtained a foothold and developed an acidic environment that dissolved the underlying calcareous caliche, making it possible for the wind to scoop out linear depressions between the dunes.

It is probable that Pleistocene erosion may have followed some of these linear dune features. San Simon Swale was a major drainage feature during Pleistocene time and is oriented generally parallel to these features; however, there is no indication that major drainage is following these features today.

There are no surficial indications of present dissolution of soluble rocks in the subsurface within the project area. However, there is a suggestion that some dissolution occurred in the area before Ogallala (Pliocene) time. Logs of an oil test drilled on The Divide indicate that some dissolution of the underlying Permian Rustler Formation has taken place (C. L. Jones, written commun., 1973). As there is no indication of collapse of the Ogallala Formation in this area, it is assumed that the dissolution occurred before the Ogallala was deposited.

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