USGS-OFR-85-229 USGS-OFR-85-229

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DISSOLUTION OF HALITE AND GYPSUM, AND HYDRATION OF ANHYDRITE TO GYPSUM, RUSTLER FORMATION, IN THE VICINITY OF THE WASTE ISOLATION PILOT PLANT, SOUTHEASTERN NEW MEXICO

By

R. P. Snyder

Open-File Report 85-229

Prepared in cooperation with the
Albuquerque Operations Office
U.S. Department of Energy
(Interagency Agreement E(29-2)-3627)

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey stratigraphic nomenclature. Company names are for descriptive purposes only and do not constitute endorsement by the U.S. Geological Survey.

Denver, Colorado
1985

Copies of this Open-File Report
may be purchased from

Open-File Services Section
Branch of Distribution
U.S. Geological Survey
Box 25425 Federal Center
Denver, Colorado 80225

PREPAYMENT IS REQUIRED

Price information will be published
in the monthly listing
"New Publications of the Geological Survey"

FOR ADDITIONAL ORDERING INFORMATION

CALL: Commercial: (303) 236-7476
FTS: 776-7476

CONTENTS

FIGURES

DISSOLUTION OF HALITE AND GYPSUM, AND HYDRATION OF ANHYDRITE TO GYPSUM, RUSTLER FORMATION, NEAR WASTE ISOLATION PILOT PLANT, SOUTHEASTERN NEW MEXICO

By

R. P. Snyder

ABSTRACT

Data from selected drill holes spaced at intervals of 1.5 to 15 km (5,000 to 50,000 ft) in southeastern New Mexico demonstrate a progressive removal of halite by dissolution, hydration of anhydrite to gypsum, and removal of gypsum by dissolution in the Permian Rustler Formation. Thickness of the Rustler decreases as halite is removed, but increases after complete removal due to the hydration of anhydrite to gypsum.

INTRODUCTION

The U.S. Department of Energy (DOE) has selected a site in southeastern New Mexico for the development of a Waste Isolation Pilot Plant (WIPP). The site (fig. 1), 40 km (25 mi) east of Carlsbad, is to be used as a test area for the underground storage of military radioactive waste in bedded salt (halite). Evaporites, mostly halite and anhydrite, constitute the major rock types at the WIPP site to a depth of about 1,280 m (4,200 ft).

Circulating ground water has removed halite, and thus has caused concern about the integrity of the stored waste. The Rustler Formation of Permian age is the uppermost unit at the site that contains evaporites. In addition to halite and anhydrite, the formation also contains two dolomite beds that are known aquifers.

More than 70 holes (Mercer, 1983, p. 7) have been drilled on or near the WIPP site to study the structure, stratigraphy, lithology, and hydrology of the area. The data for this study are from five of these holes plus one hole drilled for the U.S. Bureau of Land Management (BLM) southwest of the site. Lithologic descriptions of the units penetrated were obtained from cores and cuttings supplemented by interpretation of geophysical logs.

LOCAL STRATIGRAPHY

The Rustler Formation conformably overlies the Salado Formation and is in turn overlain by the Dewey Lake Red Beds, all of Permian age. The Dewey Lake Red Beds are the youngest Permian rocks in southeastern New Mexico and consist of laminated to thin bedded, reddish-brown siltstones interbedded with minor claystones and fine- to medium-grained sandstones. These deposits represent tidal flat or very shallow water deposits. Veins of secondary selenite occur in most of the formation except near the top. These veins are mostly parallel to the nearly horizontal bedding, but there are numerous veins cutting the bedding at various angles. Occasional vertical veins have been noted in cores. According to Powers and others (1978), the thickness of the Dewey Lake Red Beds "varies.... from about 167 m (550 ft) a few miles southeast of the site to 30 m (100 ft) a few miles to the southwest." Near the center of the WIPP site the thickness is 148 m (487 ft).

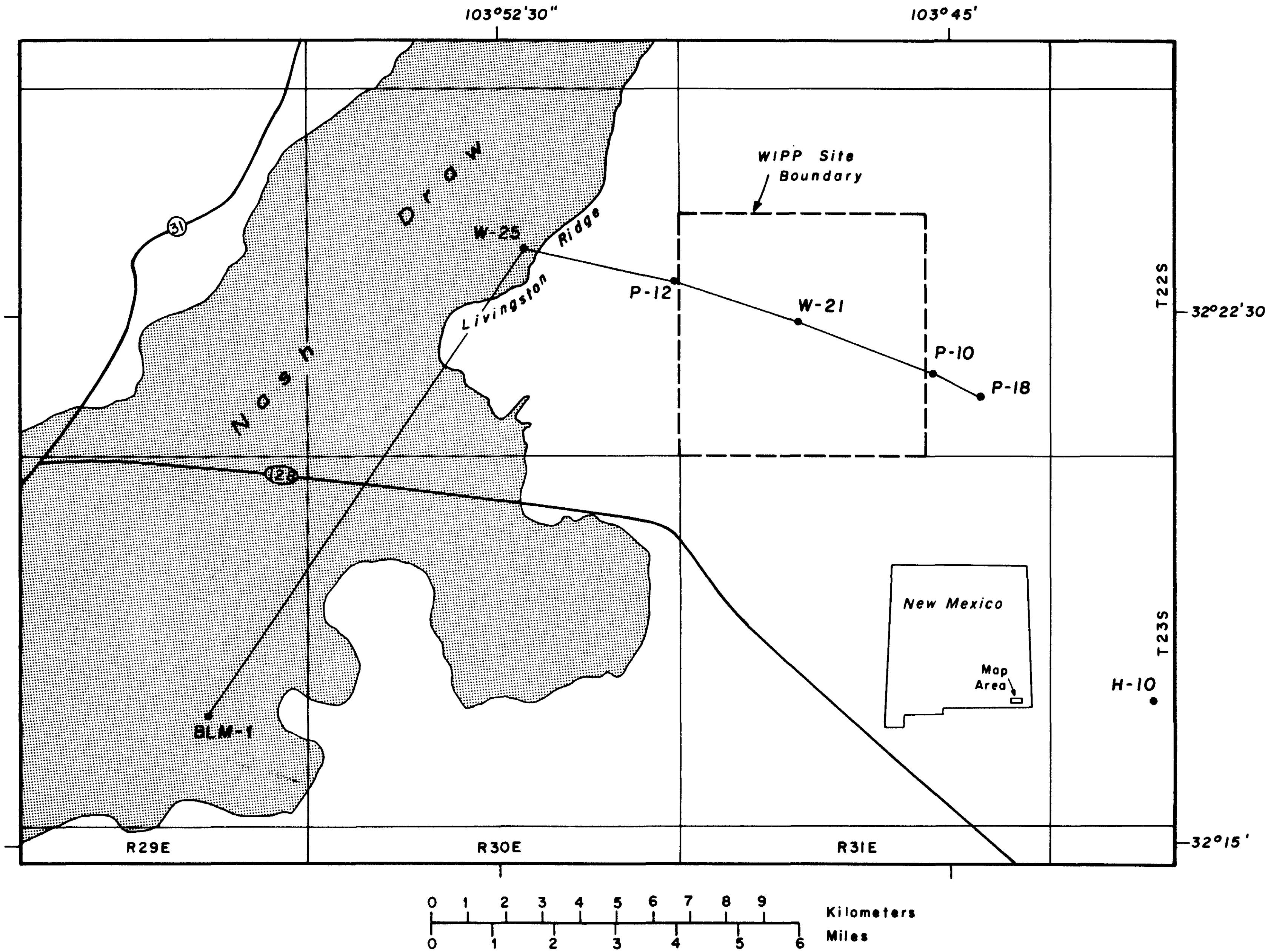

Figure 1.-- Location of Waste Isolation Pilot Plant (WIPP) site, southeastern New Mexico, and line of section shown on figure 2.

The Rustler Formation is the youngest Permian unit containing evaporitic rocks in southeastern New Mexico. A more detailed description of the formation is given in the section, "Stratigraphy and Lithology of the Rustler Formation."

Underlying the Rustler Formation is the Salado Formation, a 610-m-(2,000-ft-) thick sequence of halite and lesser amounts of anhydrite, polyhalite, siltstone, sandstone, and potash-bearing minerals. Much of the halite is transparent to translucent, but is commonly tinted light-gray, reddish-orange, or reddish-brown depending on which of the lesser constituents are included with the halite.

STRATIGRAPHY AND LITHOLOGY OF THE RUSTLER FORMATION

The Rustler Formation is 94.5 m (310 ft) thick near the center of the WIPP site (Jones, 1981), but varies in thickness from 140.8 m (462 ft) on the east side of the site to less than 45.7 m (150 ft) in the BLM-1 hole to the southwest. West of the BLM-1 hole, the Rustler has been completely removed. Bachman (1984, p. 16) cites field evidence 8 km (5 mi) northeast of Carlsbad and also 77 km (48 mi) south-southwest of the WIPP site that indicates removal of the upper Rustler Formation, including the Magenta Dolomite Member, occurred before or during Triassic time. This report discusses progression from west to east of a "dissolution front" in the Rustler Formation, and the effect of this progression on the thickness and lithologic character of the formation.

The Rustler Formation consists of five members, from oldest to youngest they are; (1) a unnamed lower member, (2) the Culebra Dolomite Member, (3) the Tamarisk Member, (4) the Magenta Dolomite Member, and (5) the Forty-niner Member. Vine (1963) was the first to propose this five-fold division.

Complete unaltered thicknesses of all members of the Rustler Formation are found only east of the WIPP site where thick overlying sedimentary rocks protect the upper part of the formation from direct penetration by surface water. West of the WIPP site, the Rustler is exposed at the surface; expectably all halite has been removed, and all anhydrite near the surface has been hydrated to gypsum. The following descriptions of the members of the Rustler Formation are derived mainly from drill hole P-18, which penetrated a complete unaltered section of the Rustler Formation, on the east side of the WIPP site (fig. 1).

The lower unnamed member consists of laminated to massive dark-gray siltstone about 21 m (70 ft) thick overlain by 23 m (75 ft) of alternating beds of halite, dark-gray and reddish-brown siltstone, and light- to medium-gray anhydrite. Secondary halite commonly fills fractures in the lower siltstone bed.

The Culebra Dolomite Member, a 6 to 9.1 m (20 to 30 ft) thick finely crystalline vuggy dolomite overlies the unnamed lower member. The vugs are diagnostic of the Culebra, and may have been formed by gas bubbles during or shortly after deposition (Vine, 1963, B-14). The vugs in some drill holes contain halite or gypsum. The Culebra is one of two known aquifers in the Rustler Formation near the WIPP site. Mercer (1983, p. 60) suggests that direction of ground-water movement in the fractured Culebra Dolomite is affected by directional differences in hydraulic conductivity (anisotropy), and that the regional direction of flow may show little or no relationship to localized direction of flow. The contours on the potentiometric-surface map (Mercer, 1983, fig. 17) show a southward flow trend in the vicinity of the WIPP site.

The Tamarisk Member, 179 feet thick, which overlies the Culebra Dolomite, is composed of two anhydrite layers separated by a thick section of halite and minor siltstone. On the east side of the WIPP site and further east, the Tamarisk contains a 1.2 to 1.5 m (4 to 5 ft) thick bed of polyhalite ($K_2Ca_2Mg(SO_4)\ 2H_2O$) near the middle of the halite unit. I do not know whether this polyhalite is ubiquitous in the unaltered evaporites, but my study of gamma-ray and sonic logs from many drill holes east and south of this area indicates that no polyhalite is present where all halite has been removed from the Tamarisk Member.

The Magenta Dolomite Member, about 6 to 9.1 m (20 to 30 ft) thick, overlies the Tamarisk Member. Whereas the Culebra Dolomite is a chemically precipitated rock, the Magenta is a fluvial unit that contains minor crossbeds as well as some laminae of anhydrite and dolomite. The distinct purplish-red color (magenta) and the laminae identify this member whether in core samples, cuttings, or outcrop. This member, like the Culebra, is also an aquifer; to the southeast of the WIPP site, in drill hole H-10, transmissivity in the Magenta is low (0.01 ft^2/day), but to the west (drill hole W-25) where a great deal of dissolution has occurred in the underlying Tamarisk, transmissivity is much higher (375 ft^2/day; Mercer, 1983). Between these two extremes, the transmissivity varies according to the amount of dissolution of halite and hydration of anhydrite in the underlying Tamarisk. I believe that the removal of halite and hydration of anhydrite have caused vertical movement of the rocks below the Magenta Dolomite, and this movement has caused fracturing of the dolomite. Mercer (1983, fig. 20) shows on a potentiometric-surface map that the direction of water flow in the Magenta Dolomite Member is westward across the WIPP site.

The Forty-niner Member, 150 feet thick, composed of two thick, light- to medium-gray anhydrite beds separated by a reddish-brown silty halite unit is the uppermost of the Rustler members. Directly overlying the Forty-niner are the Dewey Lake Red Beds. The Forty-niner Member differs markedly in color and lithology from the overlying Dewey Lake Red Beds. Despite this, the units appear to be conformable (Bachman, 1983). Jones (1973, p. 24), however, describes the contact as "an unconformity of slight discordance."

DRILL-HOLE DATA

Lithologic units and correlations derived from the drill-hole data are shown on figure 2. The five holes on the WIPP site were drilled as part of a geologic study of the WIPP area; the BLM hole to the southwest (BLM-1) was drilled on behalf of the Bureau of Land Management as part of a study of the water resources of the Carlsbad potash area (Geohydrology Associates, Inc., 1979).

Drill cuttings were generally too homogenized to be useful so gamma-ray, density, and neutron logs, as well as core from drill hole W-25 were used to identify lithologic units. Although drill hole P-18, on the east side of the

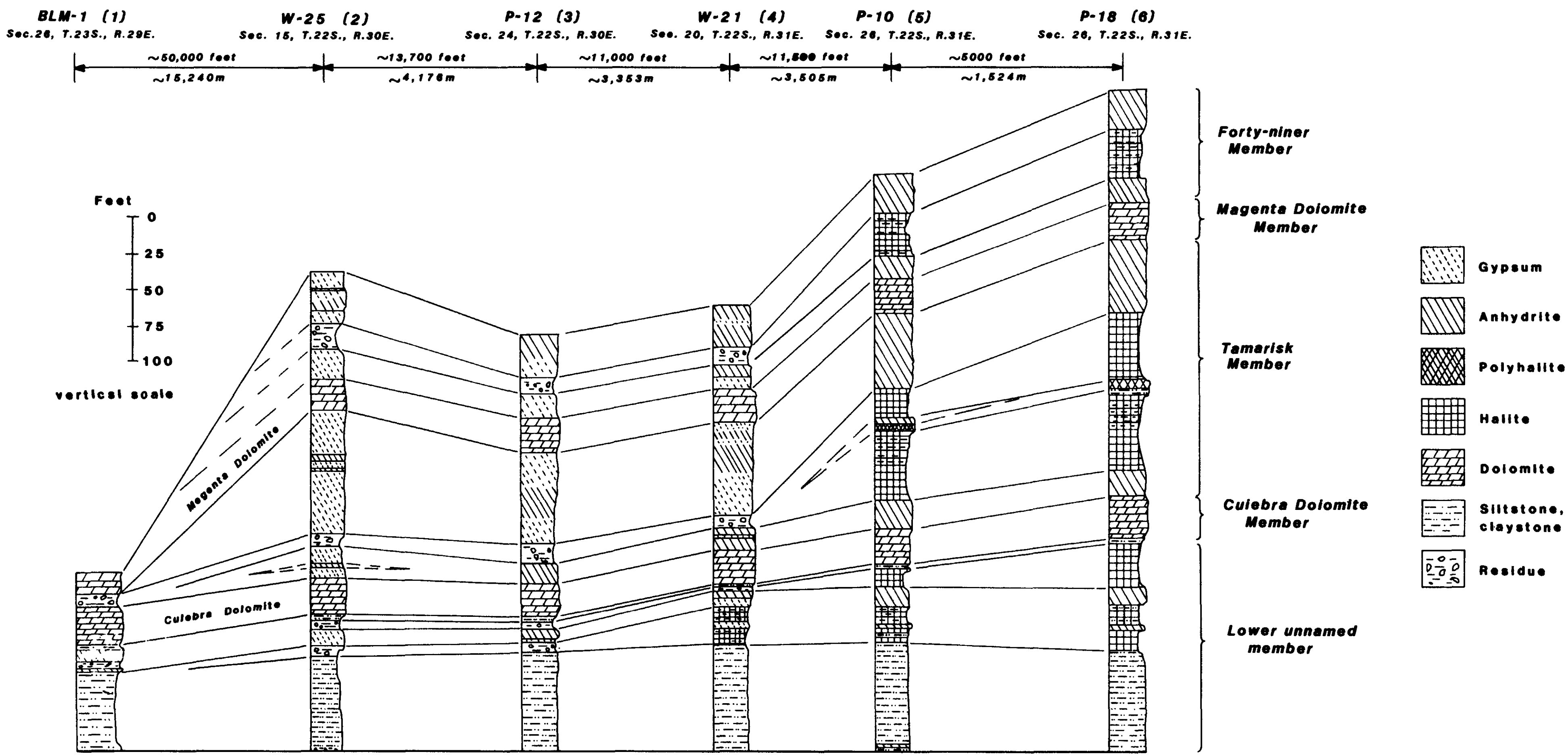

Figure 2.--Columnar cross section across WIPP site showing lithologic correlations of units in Rustler Formation.

WIPP site, penetrated a nearly complete section of unaltered Rustler Formation, slightly thicker unaltered sections of the Rustler are present to the east. I believe, however, that the increase in thickness is attributable to thicker beds, rather than additional ones.

Figure 3 matches lithologic and geophysical logs from hole P-18. The logs are from Jones (1978). Gamma-ray logs record natural radiation in rocks; curve deflections to the left indicate low radiation, deflections to the right indicate high radiation. Anhydrite, gypsum, and halite are rocks characterized by low radiation; clay, siltstone, dolomite, polyhalite, and silty halite are rocks characterized by high radiation. Potassium-40 is the major source of the radiation. On the density log, higher density rocks cause a deflection to the left, lower density rocks cause a deflection to the right. The neutron log measures hydrogen, and thus, in effect, the presence of water; deflections to the left show less water, deflections to the right more water. The geophysical logs on figure 3 show relative, not actual values.

The unnamed lower member of the Rustler in drill hole P-18 shows no alteration of anhydrite to gypsum and only minor amounts of residue are present, the result of halite dissolution. Evidence of dissolution of halite or hydration of anhydrite also is missing from the Tamarisk and Forty-niner Members. Drill hole P-18 is one of two drill holes on the WIPP site in which halite is present in the Forty-niner Member (Jones, 1978). The Magenta and Culebra Dolomite Members maintain their normal thickness, but commonly they do not thin unless they are exposed to surface erosion. Hydraulic tests in P-18 across the Culebra show a transmissivity of 0.001 ft^2/day (Mercer, 1983, p. 105); the Magenta was not tested. I believe that the very low transmissivity value for the Culebra indicates that the unit contains few or no open fractures. Such fractures would result from the settling of the Culebra onto underlying dissolution residue in the lower unnamed member.

Drill hole P-10 is about 1,524 m (5,000 ft) west of P-18. The three halite beds in the unnamed lower member thin westward (fig. 2). The two upper anhydrite beds of the lower unnamed member show no evidence of hydration on the geophysical logs (Jones, 1978). In the Tamarisk Member, both halite units thin westward, the anhydrites show no hydration effects, and the polyhalite bed is overlain by a thin anhydrite bed. The halite and anhydrite beds in the Forty-niner Member show neither dissolution nor hydration. Hydraulic tests were not run in drill hole P-10, so I lack evidence of possible fracturing of the dolomite members.

In drill hole W-21, about 3,505 m (11,500 ft) west of P-10, each of the three halite/anhydrite bearing members show evidence of dissolution and hydration. About half the halite in the unnamed lower member has been removed, and the anhydrite beds are partly converted to gypsum. The halite in the Tamarisk and Forty-niner Members has been completely removed, leaving only silt and clay residue; and much of the anhydrite has been altered to gypsum. The polyhalite bed, represented in drill holes P-10 and P-18, is missing from the Tamarisk Member in this hole. Thickening of anhydrite beds as they alter to gypsum is apparent in the Tamarisk and Forty-niner Members (fig. 2). Vine (1963) described a massive siltstone in Forty-niner Member outcrops found west of Livingston Ridge. Jones and others (1960) identified this siltstone as dissolution residue.

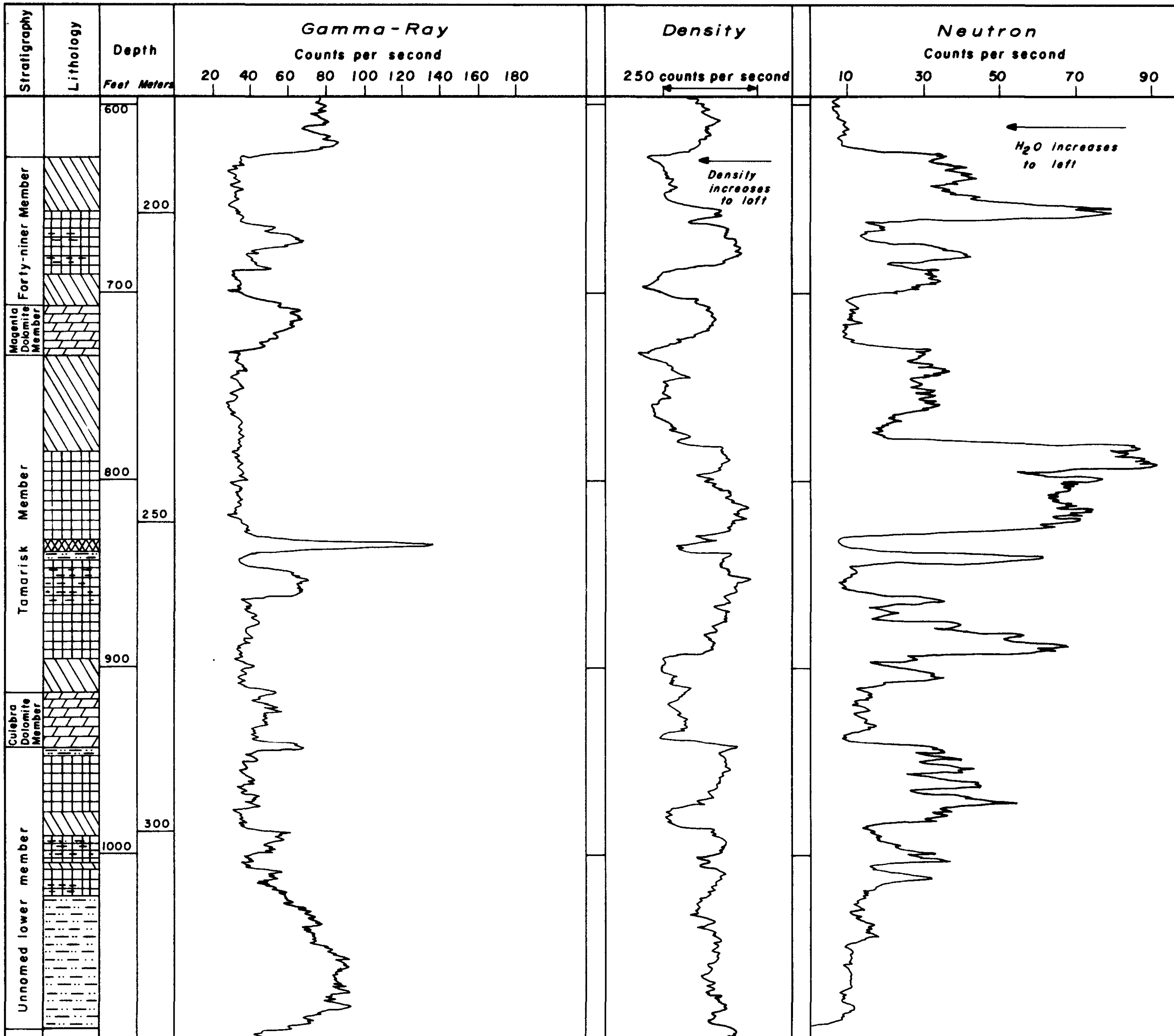

Figure 3.--Comparison of part of lithologic and geophysical logs in the Rustler Formation, drill hole P-18. (Logs from U.S. Geological Survey, Water Resources Division, published in Jones, 1978; see figure 2 for explanation of symbols.)

In drill hole P-12, 3,353 m (11,000 ft) west of W-21, geophysical logs indicate that all the halite in the Rustler Formation has been removed, leaving behind a silty residue; and more than half the anhydrite in the three non-dolomite members has hydrated to gypsum with an accompanying volume increase expressed as a thickening of the former anhydrite beds.

From drill hole P-18 to drill hole P-12 (fig. 2), the Rustler Formation thins westward. The loss of halite more than offsets any thickening caused by the hydration of anhydrite to gypsum. Approximately 4,176 m (13,700 ft) west of P-12 is drill hole W-25, located in Nash Draw, 9.6 to 19.2 km (6 to 12 mi) west of the center of the WIPP site. Bachman (1981, p. 5) believes that Nash Draw was formed in part by erosion, but in part by the dissolution of the underlying evaporites. The Rustler Formation in drill hole W-25 is thicker than in P-12. Only about 4.6 m (15 ft) of anhydrite remains in the Rustler; all the rest, as much as 35.7 m (117 ft) of anhydrite, has been altered to about 54.3 m (178 ft) of gypsum, a volume increase of about 52 percent.

Approximately 6.2 km (10 mi) southwest of W-25, in drill hole BLM-1, the Rustler is only about 37.2 m (122 ft) thick as a result of both erosion and dissolution of halite. The basal siltstone of the unnamed lower member, and the Culebra Dolomite are unchanged in thickness, but the Tamarisk Member has been reduced by dissolution to 2.4 m (8 ft) of residue. The Magenta Dolomite Member, now on (or) near the surface, has been partly eroded, and the Forty-niner Member is completely gone. Mercer (1983) reports that about 11 km (7 mi) northwest of the WIPP site (beyond the area shown on fig. 1), the Culebra Dolomite is near the surface along the Pecos River. The Rustler Formation continues to thin westward as a result of erosion, and finally is eroded away in the vicinity of the Pecos River.

An isopach map of the Rustler Formation (fig. 4) shows a general pattern of dissolution of halite and hydration of anhydrite. On the east and progressing westward for about 3.2 km (2 mi) the formation thins. In this area only halite is being removed, generally from the Forty-niner Member. Figure 4 divides the WIPP area into four zones; from east to west they are: (1) no halite dissolved from Rustler Formation, (2) halite dissolved from Forty-niner Member, (3) halite dissolved from Tamarisk Member, and (4) halite dissolved from lower unnamed member. In the first two of these zones the Rustler Formation thins progressively westward, but in the third and fourth zones the formation thins and thickens depending on how much anhydrite has altered to gypsum.

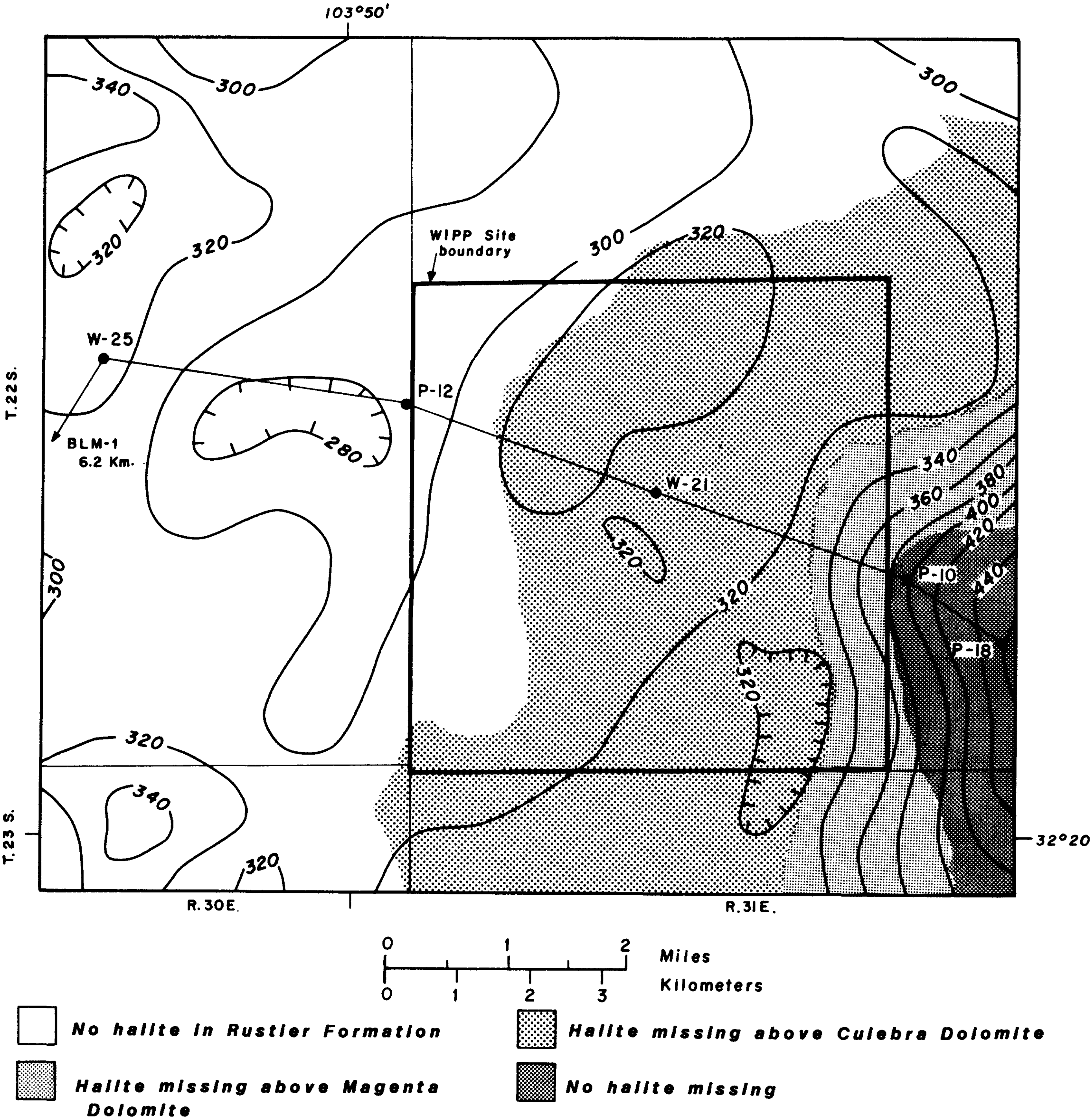

Figure 4.--Isopach map of the Rustler Formation in the vicinity of the WIPP site showing dissolution zones. (Hachures indicate closed lows.)

CONCLUSIONS

As one progresses westward across the WIPP site there is both a progressive dissolution of halite and a gradual hydration of anhydrite to gypsum. Seemingly, halite from the uppermost member, the Forty-niner, is removed first, followed by removal of halite from the middle Tamarisk Member, and then finally from the unnamed lower member. The intervening dolomite members are not directly affected by these processes, but as halite is removed from below each of them, the dolomites settle and fracture and transmit ground water more readily. At some stage in the removal of halite, possibly when the dissolution reaches a point where the anhydrites settle and crack allowing ground water to flow through them, the anhydrites begin hydrating to gypsum. This process tends to thicken the formation even though halite is being removed. The mutual interaction between these two processes results in an erratic thickening and thinning of the Rustler Formation as seen on the isopach map (fig. 4).

The increase in transmissivity in the Magenta and Culebra Dolomite Members seems to "feed upon itself;" fracturing increases as more halite is removed and more anhydrite alters to gypsum, more ground water moves through these aquifers removing more halite and altering more anhydrite. Eventually all the gypsum formed is also removed by dissolution. The final stage is reached when the dolomites are exposed at the surface with only a few feet of dissolution residue between them. Because about 168 m (550 ft) of younger rocks overlie the Rustler Formation at the center of the WIPP site (Jones, 1981), it appears that some part of the Rustler will remain for some time.

The "dissolution front," moving west to east in the Rustler Formation is not a straight line or even a smooth curve as is shown on figure 4; but rather inroads are made in each of the evaporite members and eventually any small islands of non-dissolution are removed. The fairly smooth lines dividing the four dissolution zones on figure 4 are interpolated between drill holes.

REFERENCES CITED

Bachman, G. O., 1981, Geology of Nash Draw, Eddy County, New Mexico: U.S. Geological Survey Open-File Report 81-31, 8 p., 4 plates, 1 fig.

_____1984, Regional geology of Ochoan evaporites, northern part of Delaware Basin: New Mexico Bureau of Mines and Mineral Resources Open-File Report 184, 24 p.

Geohydrology Associates, Inc., 1979, Water-resources study of the Carlsbad potash area, New Mexico: Report for Bureau of Land Management, Denver, Colorado, Contract Number YA-512-CT8-195.

Gonzales, J. L., and Jones, C. L., 1979, Geological data, in Basic data report for drill hole WIPP 25 (Waste Isolation Pilot Plant--WIPP): Sandia Laboratories Report SAND79-0279, p. 4-26.

Jones, C. L., 1978, Test drilling for potash resources, Waste Isolation Pilot Plant Site, Eddy County, New Mexico: U.S. Geological Survey Open-File Report 78-592, 2 vols., 431 p.

_____1981, Geologic data for borehole ERDA-9, Eddy County, New Mexico: U.S. Geological Survey Open-File Report 81-469, 46 p., 3 figs.

_____1973, Salt deposits of Los Medanos area, Eddy and Lea Counties, New Mexico, with sections on Ground-water hydrology by M. E. Cooley and Surficial geology by G. O. Bachman: U.S. Geological Survey Open-File Report USGS-4339-7, 69 p.

Jones, C. L., Bowles, C. G., and Bell, K. G., 1960, Experimental drill hole logging in potash deposits of the Carlsbad District, New Mexico: U.S. Geological Survey Open-File Report 60-84, 25 p.

Jones, C. L., and Gonzales, J. L., 1980, Geological data for borehole WIPP 21, in Basic data report for drill hole WIPP 21 (Waste Isolation Pilot Plant--WIPP): Sandia Laboratories Report SAND79-0277, p. 6-18.

Mercer, J. W., 1983, Geohydrology of the proposed Waste Isolation Pilot Plant site, Los Medanos area, southeastern New Mexico: U.S. Geological Survey Water-Resources Investigations Report 83-4016, 113 p.

Powers, D. W., Lambert, S. J., Shaffer, S. E., Hill, L. R., and Weart, W. D., eds., 1978, Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) site, southeastern New Mexico: Sandia Laboratories Report SAND78-1596, 2 vols.

Vine, J. D., 1963, Surface geology of the Nash Draw quadrangle, Eddy County, New Mexico: U.S. Geological Survey Bulletin 1141-B, p. B1-B46.