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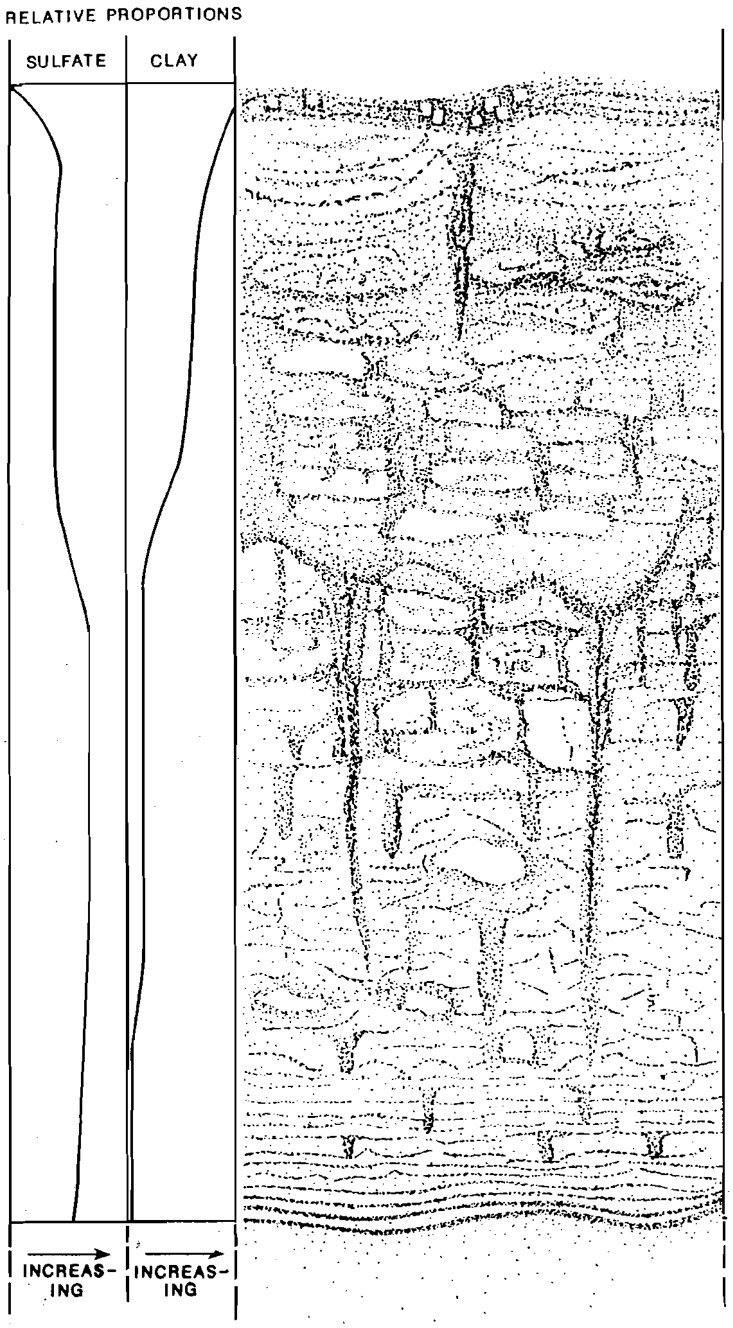
Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant



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GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WASTE ISOLATION PILOT PLANT

AUTHORS
Robert M. Holt--IT Corporation
Dennis W. Powers--IT Corporation

December, 1990

Any comments or questions regarding this report should
be directed to the U.S. Department of Energy
WIPP Project Office
PO Box 3090
Carlsbad, NM 88221
or to the Manager
Engineering and Repository Technology
Westinghouse Electric Corporation
PO Box 2078
Carlsbad, NM 88221

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EXECUTIVE SUMMARY

The air intake shaft (AIS) at the Waste Isolation Pilot Plant (WIPP) site was constructed to provide a pathway for fresh air into the underground repository and maintain the desired pressure balances for proper underground ventilation. It was up-reamed to minimize construction-related damage to the wall rock. The upper portion of the shaft was lined with slip-formed concrete, while the lower part of the shaft, from approximately 903 ft below top of concrete at the surface, was unlined. As part of WIPP site characterization activities, the AIS was geologically mapped.

The AIS was geologically mapped during the period from March 11, 1988 to November 14, 1989. The objectives of the geologic mapping were to: 1) provide confirmation and documentation of strata overlying the WIPP facility horizon; 2) provide detailed information of the geologic conditions in strata critical to repository sealing and operations; 3) provide technical basis for field adjustments and modification of key and aquifer seal design, based upon the observed geology; 4) provide geological data for the selection of instrument borehole locations; 5) and characterize the geology at geomechanical instrument locations to assist in data interpretation. All mapping activities were performed from a two deck galloway (work platform) and synchronized with shaft construction activities. The AIS was mapped according to the procedures described in WP 07-503, "Geologic Mapping of Shafts" (April 25, 1988) (Appendix B).

The entire shaft section including the Mescalero Caliche, Gatuña Formation, Santa Rosa Formation, Dewey Lake Redbeds, Rustler Formation, and Salado Formation to the WIPP facility horizon was geologically described. The shaft construction method, up-reaming, created a nearly ideal surface for geologic description. Small-scale textures usually best seen on slabbed core were easily distinguished on the shaft wall while larger-scale textures not revealed in core were well displayed. Previously undescribed textures were interpreted, and the AIS data were used to further refine depositional and post-depositional models of the units mapped.

The upper part of the Dewey Lake Redbeds displayed features consistent with Schiel's (1988) interpretation of the depositional environments. The geologic mapping data indicated deposition in a fine-grained, ephemeral fluvial system (Schiel, 1988). The lower part of the Dewey Lake, however, was depositionally a continuation of Rustler style sedimentation and accumulated in saline mud flat/mud flat environments. Most gypsum-filled fractures developed incrementally in response to unloading, while some Dewey Lake are syndepositional. Within the Dewey Lake, a cement change between carbonate and, possibly, anhydrite was observed at a depth of 164.5 feet. Perched water tables within the Dewey Lake may rest on this cement change. Above the cement change, the shaft surface was moist and displayed an efflorescent crust consisting of halite. The source of the halitic water is attributed to the muck-piles north and east of the AIS.

The features observed within the Rustler are consistent with those reported by Holt and Powers (1984, 1986, and 1988). Mudstones within the Rustler created a spalling hazard as several feet the mudstone had spalled out of the units and large slabs to desk-top size had to be scaled from the rib prior to mapping. Liner plate was installed over all Rustler mudstones. The surface of the lower part of the Rustler required extensive washing and scaling prior to mapping as Culebra and construction waters dissolved halite crystals and cements. Extensive vertical fluting was observed.

The AIS data from the Salado allowed the authors to add considerably to the understanding of the depositional and diagenetic history of the Salado. Unprecedented halite textural and fabric data was collected, characterized, and interpreted from the Salado. An idealized Salado halite sequence was constructed, and all Salado halite observed within the AIS fits partially or wholly into the idealized sequence. Complete Salado halite sequences consist of four lithofacies, in ascending order: 1) stratified mud-poor halite; 2) "podular" muddy halite; 3) "dilated" mud-rich halite; and 4) halitic mudstone. These lithofacies developed in four distinct depositional environments: 1) a mud-poor salt pan; 2) a "hummocky" salt pan; 3) a mud-rich salt pan; and 4) a saline mud flat.

Salado sulfate interbeds (including Markerbeds) displayed abundant previously undescribed textures and fabrics. Textural data from the AIS provided the basis for further interpretation of these interbeds. Salado sulfate interbeds were deposited in shallow saline lagoon environments following eustatically- or meteorically-driven, basin-wide flooding and freshening events (Lowenstein, 1982, 1983, 1988). Different hydrologic conditions produced three distinct types of sulfate interbeds within the Salado. The sulfate interbeds bounding the repository horizon may be laterally variable due to facies changes within the depositional environment. Geologic evidence of naturally occurring late-stage fluid migration or alteration within the halite of the Salado was not found. Mineralized and fluid-filled fractures occur within some sulfate interbeds within the Salado.

FOREWORD

There are times when we are fortunate in having the right experience to make the most of a rare or unique opportunity. We feel that mapping the Salado Formation in the Air Intake Shaft (AIS) was such an opportunity.

The Salado Formation in the AIS was not accessible for mapping for more than a year after the shaft drilling was completed. A crust of salt and spilled concrete (from the shaft liner installation) built up over this period, and a portion of the shaft wall had to be washed with a pressurized spray prior to mapping. After the mapping, the relatively smooth wall of the drilled shaft revealed a panoply of features and textures, developed from repeated subaerial exposure and synsedimentary dissolution, that had not been previously observed or described from any salt deposit. The clean, continuous exposure of these rocks through 1,300 feet of the Upper Salado has yielded a wealth of macroscopic detail that may not soon be available under any other conditions.

Since the time we mapped the Rustler Formation in the Waste Handling Shaft, we have maintained considerable interest in the various ideas about dissolution of evaporites, in general, and of the Ochoan Series, in particular. Each of us has made private trips to observe modern halite pan and other evaporite environments in the western and southwestern U.S. These experiences prepared us for the unusual opportunity afforded by the AIS mapping project.

We report the basic features and evidence from the Salado Formation which indicates that it was deposited and reworked extensively by syndepositional processes including subaerial exposures and reworking driven by fluctuating water tables. The idea that the Salado was exposed subaerially during its formation is not new. However, the extent of such exposure and the details described here are astounding; we have seen no equivalent reported anywhere. The information should be very valuable to other geologists examining evaporites. We anticipate publishing in scientific journals several papers based on the Salado and work in areas such as Death Valley.

The AIS study also provides a basis for evaluating the vertical and possibly lateral variability within the beds of the Salado, which are broadly homogeneous and laterally continuous, including units commonly exposed at the facility horizon. We believe that these units, now interpreted as having features caused by synsedimentary dissolution, will be much better understood. Specific features of these rocks can now be related to depositional models and very easily diagenesis that should aid the interpretation of such phenomena as the sources of fluids in these units.

As usual, we have had the pleasure of some good company while mapping in the shaft. In particular, we thank Mr. Mel Baldarrama for washing and sampling assistance; Mr. Norbert Rempe, who faithfully accompanied us and helped with observations, sampling, and photography, and arranged for video taping of the section; and the shaft crew who were admirably patient and maintained their good humor while we argued, pondered, and sat and described. We take sole responsibility for the results provided in this report, including their quality and accuracy.

Robert M. Holt　　　　Dennis W. Powers

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1.0 INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is a Department of Energy (DOE) research and development facility constructed to demonstrate the safe disposal of radioactive wastes derived from the defense activities of the United States. The WIPP project's mission consists of two parts. The first is to demonstrate the safe handling and disposal of transuranic (TRU) waste in bedded salt. The second is to provide a research facility for *in situ* examination of the technical issues affecting the emplacement of defense-related radioactive waste in bedded salt.

The WIPP facility is located approximately 26 miles east of Carlsbad, New Mexico, in an area known as Los Medaños (Figure 1). The underground portion of the facility is located at a depth of approximately 2,150 feet in the bedded salt deposits of the Salado Formation (Figures 2 and 3). An extensive program of site characterization and validation has been conducted for the past 14 years (1976-1990). The results of these studies are summarized in two WIPP geological characterization reports (Powers et al., 1978; Lappin, 1988), the WIPP "Safety Analysis Report" (U.S. DOE, 1980), and WIPP "Preliminary Design Validation Report" (Bechtel, 1983), and "Results of Site Validation Experiments" (Black et al., 1983). Geotechnical investigations at the site continue to refine further the understanding of the site-specific geology. The geotechnical activities in the air intake shaft (AIS) are part of this effort.

The AIS provides a pathway for fresh air to the repository to maintain air flow and the desired pressure balances. The shaft was upreamed to a final diameter of 20 feet 3 inches. Through the upper, concrete-lined portion of the shaft, the finished diameter is 18 feet from 0 to 471 feet and 16 feet 7 inches from 471 to 903 feet. The lower part of the shaft is unlined. Several less stable sections in the unlined portion have been covered with wire mesh and rock bolted for safety. The principal geotechnical activity in the shaft consisted of reconnaissance mapping and description of the entire geologic section. This was supplemented by detailed mapping of the entire circumference of the shaft areas of specific interest, including five sections of the Rustler Formation and the shaft keyway. During the mapping activities, various instrument locations were selected in cooperation with other investigators.

This report presents and discusses the data from the geologic mapping and description of rocks from the surface to the upper Salado Formation (mapped principally in the fall of

1988) and of the upper Salado Formation to the repository level (mapped in the fall of 1989). The Salado Formation is presented in more detail here (Appendices F and G) than in previous shaft mapping reports because the exposures in an upreamed shaft are superior to those in conventionally excavated shafts (waste handling and exhaust shafts). Our studies of modern saltpans allowed us to recognize and interpret previously undescribed textures and fabrics in the Salado. We include interpretations of these unique data in Appendices F and G. In addition, the construction history of the shaft is summarized, and several engineering geology characteristics are discussed.

1.1 SCOPE OF WORK

The detailed scope of work for mapping the air intake shaft was presented in the "Work Plan for the Geologic Mapping in the Air Intake Shaft at the WIPP Facility, Carlsbad, New Mexico" (dated March 4, 1988) (Appendix A). The objectives of the geologic mapping were to:

- Provide confirmation and documentation of strata overlying the WIPP facility horizon.
- Provide detailed information of the geologic conditions in strata critical to repository sealing and operations.
- Provide a technical basis for field adjustments and modifications of key and aquifer seal design, based upon the observed geology.
- Provide geological data for the selection of instrument borehole locations.
- Characterize the geology at geomechanical instrument locations to assist in data interpretation.

To fulfill these objectives, the following shaft activities were performed:

- Reconnaissance mapping of the entire geologic section from surface to the repository level.
- Detailed, 360° geologic mapping of identified zones of interest.
- Collecting geologic information in the vicinity of existing and proposed instrument locations.

The geology of the entire shaft was strip-mapped using reconnaissance mapping procedures. Five sections or intervals were identified as being of special interest and were mapped around the entire circumference of the shaft. These intervals were:

- The Dewey Lake Redbeds/Rustler Formation contact (from a map depth of 505-520 feet).
- The Forty-niner Member mudstone through Magenta Dolomite Member (from a map depth of 540-600 feet).
- The Tamarisk Member mudstone (from a map depth of 650-670 feet).
- The Culebra Dolomite Member and upper part of the unnamed lower member (from a map depth of 685-760 feet).
- The Rustler Formation/Salado Formation contact and the keyway interval (from a map depth of 820-915 feet).

1.2 METHODOLOGY

The AIS was mapped using two levels of mapping effort: (1) reconnaissance geologic mapping and (2) detailed, 360° geologic mapping. During reconnaissance mapping, a strip of the shaft wall was mapped, and a strip log of the geology was produced. During the detailed mapping, the entire circumference was mapped, and a 360° geologic log was produced. All of the shaft section was reconnaissance mapped, and selected intervals of interest within the lined section of the AIS were mapped in detail. All mapping activities were performed from a two-deck galloway (work platform) and synchronized with shaft construction activities. The AIS was mapped according to the procedures described in "Geologic Mapping of Shafts" (WP 07-503, April 25, 1988) (Appendix B). This procedure includes a description of the detailed and reconnaissance mapping procedures.

1.2.1 Reconnaissance Geologic Mapping

During reconnaissance geologic mapping within the AIS, the geology exposed in a 5- to 20-foot section of the shaft wall was cleaned, described, photographed, and if appropriate, sampled. Unusual geologic features visible outside of the cleaned area were also described. The south side of the shaft was mapped. Vertical control was established with a survey chain from a known reference point within the shaft. During the reconnaissance mapping of the lined section of the shaft, the zone to be mapped was cleaned at the start of each mapping exercise. In the unlined section of the shaft, the entire section was cleaned in two phases and then mapped. This allowed the surface of the shaft to dry so that brine inflow from markerbeds within the Salado could be distinguished from the water used for washing. After the shaft wall was cleaned, horizontal lines were spraypainted on the wall at five-foot intervals. The mapping units were defined and described by geologists, and the depths to and morphology of lithologic contacts and features were drawn on mapping forms. Photographs were taken as the section was mapped and described. When appropriate, oriented samples were taken and placed in labeled containers (Appendix C).

1.2.2 Detailed Geologic Mapping

The entire circumference of the shaft wall was mapped and described during detailed geologic mapping of several zones within the lined section of the AIS. In addition, 360° photographic coverage of the mapped intervals was provided. The level of descriptive detail provided during the detailed mapping equaled that of the reconnaissance mapping detail, except that the entire shaft surface was graphically described and photographed. The shaft wall was cleaned and a five-foot by five-foot grid was spray-painted on the wall around the circumference of the shaft. The point of origin for the vertical lines in the grid was along the southern-most point in the shaft. The horizontal lines were tied into known elevation reference points. The mapping units were established and described by the geologists on the mapping team, and the features and contacts were drawn onto a mylar form at a horizontal and vertical scale of one-inch to five-feet. The entire circumference was photographed after the grid had been painted on the wall.

2.0 CONSTRUCTION HISTORY OF THE AIR INTAKE SHAFT

The air intake shaft was raise-bored to a 20-foot 3-inch diameter by the Frontier-Kemper Constructors, Inc. Surface activities began on November 24, 1987. The pilot hole for the raise-bore was begun on December 4, 1987 and was completed as an enlarged hole on February 7, 1988. Shaft collar construction was completed by March 27, 1988, and raise-boring began on April 30, 1988. Raise-boring was halted on July 19, 1988, at a depth of 355 feet below the surface, because the rate of upreaming had dropped to about 1 foot/day from an initial rate of about 30 feet/day. An observation hole was drilled to the depth of the cutter head, and a video survey of the cutter head revealed damage to parts of the cutter head assembly. The observation hole was reamed to 36 inches in diameter, a 30-inch casing was installed, and Frontier-Kemper personnel manually replaced worn cutter heads. Raise-boring resumed on August 17, 1988, and was completed to the surface on August 25, 1988. The headframe was raised on August 31, 1988.

Shaft video surveys began on September 12, 1988. On September 14, 1988, the contractor began to install the liner plate, and geologic mapping began. Geologic mapping from the surface into the upper Salado Formation was completed November 8, 1988, and the last liner plate was installed November 9, 1988. A continuously-poured concrete liner was installed over the Rustler Formation and its overlying units. Slipforming began at a depth of 822 feet on November 21, 1988, and was completed on December 23, 1988. The construction contractor demobilized on April 17, 1989.

The installation of utilities, electrical lines, and water lines for in-shaft mapping and construction began on May 8, 1989. This work advanced sufficiently so that mapping of the Salado Formation could resume on September 20, 1989; mapping was completed November 14, 1989. Rock mechanics and hydrologic experiments and monitoring devices were emplaced in the shaft following geologic mapping. The construction history of the AIS is summarized in Table 1.

2.1 GROUND CONTROL

In the Rustler Formation and its overlying units, combinations of rock bolts, mesh, and liner plate were used for ground control. Liner plate was used for the following approximate depth intervals: 85-137 feet, 534.5-606 feet, 655-670 feet, 681-762 feet, and 791-811 feet. These areas were covered by the continuous-pour concrete liner. Rock bolts and mesh were used in small zones of the Salado, in the Vaca Triste Sandstone Member, and across some claystone/mudstone beds below sulfate marker beds.

TABLE 1

ABRIDGED CONSTRUCTION HISTORY OF THE AIR INTAKE SHAFT

Location:	Eddy County, New Mexico New Mexico Grid Coordinates y 499687.23, x 666270.00
Elevation:	Shaft Collar: 3410.0 feet MSL
Construction Contractor:	Frontier-Kemper
Pilot Hole Started for Raise bore:	December 4, 1987
Pilot Hole Completed:	February 7, 1988
Raise Boring Began:	April 30, 1988
Raise Boring Completed:	August 25, 1988
Liner Plate and Geologic Mapping Began:	September 14, 1988
Liner Plate Completed:	November 9, 1988
Slipforming Began:	November 21, 1988
Slipforming Completed:	December 23, 1988
Construction Contractor Demobilized:	April 17, 1989
Geologic Mapping Resumed:	September 20, 1989
Geologic Mapping Completed:	November 14, 1989

3.0 AIR INTAKE SHAFT GEOLOGY

The AIS provided a unique opportunity to describe the rocks overlying the WIPP repository horizon. The method of shaft construction, up-reaming, created a nearly ideal surface for geologic description. In contrast to the broken surface caused by explosives during conventional shaft excavation methods, the surface of the AIS was nearly smooth with only minor irregularities (tool marks) from the cutting head (up-ream bit). After cleaning, the level of detail visible on the shaft wall was akin to slabbed core. These high-quality, near outcrop-scale exposures in the AIS allowed us to recognize and describe features that had never before been reported in the various formations-encountered by the shaft. The reason for this is because many of the features were simply too large to be recognized in core samples without a previous knowledge of their existence (Death Valley Type textures and syndepositional caves in the Salado Formation; Dewey Lake-aged paleokarst in the Rustler Formation; and fluvial channel/bar complexes and large desiccation cracks in the Dewey Lake Redbeds). Other features were simply not well displayed in core (e.g., load textures and fine stratification in the siltstones and mudstones of the Dewey Lake Redbeds). Small-scale evaporite textures (eg., pseudomorphs after gypsum swallowtail crystals, smeared intraclast textures, and fluid inclusion zoning in halite) usually best seen on slabbed core were easily distinguished on the shaft wall.

Much of the new data presented here allows the refinement of previous interpretations, and we have interpreted the new data and related the new interpretations to the old (for Salado interpretations see Appendices F and G). The geologic mapping data allowed us to interpret, for the first time, the depositional setting of the lower part of the Dewey Lake Redbeds. The AIS data of the Salado allows us to add considerably to the current knowledge of the depositional and diagenetic history of the Salado, specifically the role of depositional and diagenetic fluids from the time of deposition to the present (Appendices F and G).

The geology of the AIS and its plenum excavation was intermittently described during the period from March 11, 1988, to November 8, 1989. The plenum excavation from the surface to a depth of 20 feet contained surficial dune sand, the Mescalero caliche, and the upper part of the Gatuña Formation. This interval was described on March 11, 1988. Shaft upreaming was completed on August 25, 1988. The upper 900 feet of the AIS (the concrete-lined portion of the shaft), containing the Gatuña Formation, Santa Rosa Formation, Dewey Lake Redbeds, Rustler Formation, and the upper 70 feet of the Salado Formation, were described between September 14, 1988 and November 8, 1988. The remainder of the shaft through the Salado

Formation was not lined and was described between September 20, 1989, and November 14, 1989.

The results of the geologic mapping are presented in descending order in this chapter. Interpretations of new and unique data are also discussed, and ground conditions at the time of mapping are reviewed. The detailed discussion of the depositional environments of the Salado from Appendices F and G is summarized.

3.1 MESCALERO CALICHE

The Mescalero caliche is an informal stratigraphic unit which derives its name from the Mescalero Plain. It began to form about 510,000 years ago as a pedogenic caliche on an aggrading eolian surface (Bachman, 1985). Many of the surface structures at the WIPP are founded on top of the Mescalero caliche. The AIS subcollar is founded below the Mescalero caliche.

The Mescalero caliche descriptions are from exposures in the AIS plenum excavation on March 11, 1988. In the AIS plenum excavation, the Mescalero Caliche is roughly ten feet thick with a well-defined upper surface and a very diffuse lower contact (Figure 4). In general, the overall degree of induration and the carbonate content decrease downward. The upper part of the Mescalero (the caprock) displays a well-developed laminar texture. Nodules and stringers of carbonate become more prominent downward, and the middle part of the caliche is dominated by these textures. Clastic material increases downward. Irregular zones containing sandstone are found toward the middle of the caliche and become larger and more prominent downward. The lower part of the caliche is dominantly a carbonate cemented sandstone. The sandstone is poorly sorted, moderately hard to very soft, and friable. Dark gray to black stains often bound irregular masses of well indurated sandstone. The caprock and nodules are very hard and dense while zones containing sandstone vary from well cemented and hard to poorly cemented and very friable. Uncemented zones of sand are locally present. The lower contact of the caliche with the Gatuña Formation is gradational.

3.2 GATUÑA FORMATION

The Gatuña Formation was named by Robinson and Lang (1938) for exposures in Gatuña Canyon on the east side of Clayton Basin. It is intermittently distributed through the Pecos River Drainage. Across the WIPP site area, the Gatuña occurs as a thin veneer of sandstone.

At the AIS, the Gatuña is 13 feet thick and consists of very calcareous, very friable, soft sandstone (Figures 4 and 5). The Gatuña is light red and mottled with dark stains. Carbonate occurs as stringers and concretions in probable rhizolithic structures. Clay-sized materials locally appear translocated. Some pebble-sized clasts of sandstone are probably derived from the underlying Santa Rosa Formation. The Gatuña overlies a sharp erosional contact on the Santa Rosa Formation.

3.3 SANTA ROSA FORMATION

The Santa Rosa Formation is part of the Late Triassic Dockum Group. Some authors (e.g., Bachman, 1987) feel that there is little basis for subdividing rocks of Triassic age in southeastern New Mexico and refer to Triassic rocks as the Dockum Group (undivided). For consistency across the site area, we have chosen to use the term Santa Rosa to describe rocks of Triassic age. The Santa Rosa occurs as an erosional wedge that pinches out west and south of the WIPP site.

At the AIS, the Santa Rosa is 25 feet thick (Figure 5). It consists of calcareous interbedded sandstone, siltstone, and claystone which is moderately well indurated to soft. The Santa Rosa consists of alternating sequences of channel deposits with fluvial bar sequences and, less commonly, mudstone or claystone. The channel sequences display abundant trough cross-laminae. The fluvial bar sequences exhibit planar laminae with low angle, tangential cross-laminae. Ripple cross-laminae often top the bar sequences. Fissile claystone is present as thin beds. Rip-up clasts occur locally. The contact between the Santa Rosa and the Dewey Lake Redbeds is sharp and erosional, with two feet of relief.

3.4 DEWEY LAKE REDBEDS

The Dewey Lake Redbeds are the uppermost of four Ochoan formations in the Delaware Basin. The Dewey Lake is assigned to the Permian, although this is somewhat arbitrary as it is not supported by radiometric dating or fossil evidence. The Dewey Lake was named by Page and Adams (1940), based on samples from the Penn Oil Habenstreit #1 Well, Glasscock County, Texas. The term "Dewey Lake" superseded the term "Pierce Canyon" originally proposed by Lang (1935) for redbeds in the Delaware Basin. The term "Pierce Canyon," however, was used as late as 1963 in Vine's (1963) descriptions of the Permian redbeds in Nash Draw. The U.S. Geological Survey later abandoned the term "Pierce Canyon" and adopted the term "Dewey Lake" because it was more widely accepted by geologists and "Pierce Canyon," as defined, included rocks of the Pleistocene Gatuña Formation.

The Dewey Lake conformably overlies the Rustler Formation on a regional scale (with local minor erosional relief) and underlies Late Triassic and younger rocks (Holt and Powers, 1988; Figure 5). The Dewey Lake thins to the northwest as the result of pre-Late Triassic erosion. The Dewey Lake is often assumed to be laterally equivalent to the Quartermaster Formation or Group of the Texas panhandle and Oklahoma (Hills and Kottlowski, 1983).

The Dewey Lake is characterized by its reddish-orange to reddish-brown color and varying sedimentary structures. At the WIPP site (as exposed in the AIS), the Dewey Lake is 476 feet thick and consists of interbedded reddish-brown fine sandstone, siltstone, mudstone and claystone (Figure 5). The Dewey Lake is distinguished from other redbed units by the presence of greenish-gray reduction spots, which are liberally sprinkled throughout the formation, and locally abundant fibrous gypsum-filled fractures. Its upper contact with the Santa Rosa Formation is sharp and erosional (Figure 6). The lower contact of the Dewey Lake with the Rustler Formation is sharp, with a minor amount of erosional relief (Figure 7 and 8). This contact is locally disconformable, but there is no evidence of a regional unconformity (Holt and Powers, 1988).

Miller (1955, 1966) provided the first interpretation of the depositional environments of the Dewey Lake. He postulated that the Dewey Lake was deposited as eolian material reworked in a shallow marine environment. Based upon the occurrence of gypsum, Hills (1972) suggested that the Dewey Lake was deposited in playa lakes.

On the basis of outcrop data from the northern part of Nash Draw, Schiel (1988) interpreted the depositional environments much differently. Schiel examined between 75 and 100 feet of stratigraphic section along the Maroon Cliffs in Nash Draw and identified and interpreted eight different lithofacies which displayed fluvial features. At the Maroon Cliffs, Schiel observed a fluvial architecture consisting of broad, winged channels, vertically stacked and laterally interfingering, filled with thin horizontal laminae within the Dewey Lake. Schiel interpreted the depositional environment of the Dewey Lake to be a fine-grained, ephemeral, fluvial system and envisioned the deposition to have occurred on a "broad, arid, and relatively featureless fluvial plain" with episodic transport of clastic material during really limited flash floods.

The entire Dewey Lake in the AIS was mapped and described; the shaft walls were smooth and, after washing, provided excellent exposures which allowed detailed description of sedimentary features. The sedimentological data collected from the AIS are superior to those collected from other shafts at the WIPP (Holt and Powers, 1984, 1986). In the following discussion, the data collected in the AIS are presented, and the relationship of the Dewey Lake to the underlying Rustler Formation is discussed, the origin and significance of gypsum-filled fractures is assessed, and the occurrence of brine in the Dewey Lake section of the AIS is examined.

3.4.1 Dewey Lake Redbeds In the Air Intake Shaft

The Dewey Lake Redbeds are 476 feet thick at the AIS. They consist primarily of interbedded siltstone, fine sandstone, mudstone, and claystone. They are characterized by abundant greenish-gray reduction spots and, below 164 feet, abundant fibrous gypsum-filled fractures. The Dewey Lake can lithologically be divided into an upper and lower sequence based upon sedimentary structures and grain size.

3.4.1.1 Upper Sequence of the Dewey Lake Redbeds

At the AIS, the upper 382 feet of the Dewey Lake consist of thinly laminated to cross-laminated sandstone and siltstone units interbedded with mudstone and local claystone (Figure 5). The majority of the upper part of the Dewey Lake consists of thin, foot-scale, fining-upward sequences within larger, broadly fining-upward packages (5 to 20+ feet thick). Thin fining-upward sequences usually show parallel laminae at the base which are overlain by ripple-sized cross-laminae or ripple-drift cross-laminae showing stoss and lee preservation (Figure 9). Some ripple sets are capped by mudstone or claystone drapes. The contacts between the different strata frequently show well developed load-casts (pillow structures) and flame structures (Figure 9). Shallow, wide, channel forms often cut across flat laminae and may have low-angle, tangential cross-laminae preserved on the channel margins (Figure 10). Channels deposits are often overlain by ripple-sized cross-laminae. A few channels are filled with trough cross-laminae. Nearly structureless thin beds of mudstone and claystone occur locally.

In the lower part of the upper sequence, rip-up clasts and burrows are common. Flat laminae may be contorted and disrupted by penecontemporaneous faulting. Prism-cracks to one inch deep are locally present.

Exposures from the upper part of the Dewey Lake in the AIS are very consistent with Schiel's (1988) descriptions of the Dewey Lake from Nash Draw. Schiel defined eight lithofacies within the Dewey Lake: (1) horizontally laminated siltstone, (2) structureless siltstone, (3) horizontally laminated (siltstone and fine sandstone) channel fill (channel width varied from 4 to 90 feet and depth varied from 1.5 to 20 feet), (4) micro-cross laminated siltstone with abundant climbing ripples, (5) interbedded siltstone and silty claystone couplets, (6) thinly interlaminated siltstone and claystone with convoluted bedding, (7) structureless silty claystone, and (8) cross-laminated fine to medium sandstone with tabular and trough cross-laminations. Schiel interpreted these lithofacies to have been deposited in a fine-grained, ephemeral fluvial system.

3.4.1.2 Lower Sequence of the Dewey Lake Redbeds

At the AIS, the lower 94 feet of the Dewey Lake consist mostly of siltstone and mudstone with some interbedded claystone and sandstone (Figure 5). It exhibits mostly flat to wavy laminae with rare cross-stratification. Granule- to small pebble-sized, rounded and tabular, siltstone and mudstone clasts are present above some erosional surfaces. Smeared and contorted laminae are locally abundant. Smeared intraclast textures (after Holt and Powers, 1988) occur with some disrupted strata. Dish-shaped laminae are often associated with prism cracks.

Prism cracks are abundant through this sequence; most are less than 2 inches deep, but some are up to 2 feet deep (Figure 11). Curled tabular clasts are often associated with prism cracks. Teepee structures are abundant between 15 and 20 feet above the Dewey Lake/Rustler Formation contact. Below some planar to wavy surfaces, the mudstone and siltstone displays a fabric similar to a packbreccia (after Morrow, 1982; Figure 12). Individual clasts and pieces of mudstone and siltstone are separated by mudstone-lined fractures. Individual clast size increases while fracture frequency decreases downward from the upper surface. This texture is often associated with prism cracks and smeared intraclast textures. We call this fabric a "crackle texture" because it is similar in appearance to the crackle glaze used on pottery. The "crackle texture" often occurs below planar surfaces where prism cracks originate.

Most of the strata show soft sediment deformation and disruption from slumping and penecontemporaneous fracturing and faulting (Figure 13). The resulting sedimentary structures are similar to those observed in periglacial sediments (Brodzikowski and Van Loon, 1985). This style of deformation decreases upward through the sequence.

The textures present within the lower part of the Dewey Lake are consistent with those formed in mud flat/saline mud flat environments. The general lack of bedform migration and channeling coupled with evidence of subaerial exposure suggest a low energy depositional system. Horizontal and subhorizontal strata were deposited primarily from sheet floods and shallow standing bodies of water. Delicate surface textures including teepees and desiccation cracks are preserved indicating that episodic flood-events were low-energy. Abundant sediment-filled desiccation cracks up to two feet deep and curled desiccation chips indicate long periods of subaerial exposure and suggest that the sediment accumulation rate was slower than the upper part of the Dewey Lake. Smeared intraclast textures suggest the former presence of evaporite minerals (e.g., Holt and Powers, 1988) in the lower part of this sequence. "Crackle" textures probably developed in the vadose zone as clays were translocated along surfaces created by sediment dewatering or the dissolution of efflorescent coatings. Local shallow channels occur near the top of this sequence signify a change to a low-energy fluvial system.

3.4.2 Relationship Between the Dewey Lake and Rustler Formation

The Dewey Lake Redbeds represent the transition from the dominantly marine-derived evaporites of the Rustler Formation to continental clastics during the end-stages of the Delaware Basin. No clear evidence of erosion and dissolution of the underlying evaporites complicate the understanding of this transition. A lack of a regional angular unconformity (Holt and Powers, 1988) suggests that the hiatus between the Rustler and Dewey Lake was very small. The geologic mapping of the AIS provide additional data concerning the lower part of the Dewey Lake which allowed the authors to more precisely reconstruct this transition.

The lower sequence is depositionally a continuation of the Rustler Formation. Like the mudstone/halite units within the Rustler (M-1/H-1, M-2/H-2, M-3/H-3, and M-4/H-4 of Holt and Powers, 1988), the lower part of the Dewey Lake is a saline mud flat/mud flat sequence following a desiccating upward saline lagoon (the uppermost anhydrite of the Rustler). In each case, deposition in Rustler salt pan/mud flat environments was halted by a transgressive or flooding event which resulted in deposition of sulfate or carbonate in a shallow lagoonal setting (Holt and Powers, 1988). This pattern did not continue because the Dewey Lake mud flat/saline mud flat sequence is overlain by a thick sequence of terrigenous clastic rocks deposited in low energy fluvial environments. The conditions suitable for rapid transgressive/flooding events did not continue during Dewey Lake time. The presence of an evaporite component in the Dewey Lake mud flat can be strongly inferred by the presence of smeared intraclast/laminae and "crackle" textures. Syndepositional slumping and penecontemporaneous faulting are attributed to dissolution of Dewey Lake evaporites and the development of small caves and collapse features in the upper Rustler. The upper part of the lower sequence represents the transition to a fluvial-dominated system.

3.4.3 Origin and Significance of Gypsum-Filled Fractures

With the exception of the upper portion, the Dewey Lake is characterized by locally abundant gypsum-filled fractures. Most of the fractures are filled with fibrous gypsum, although granular gypsum fracture fillings do occur in the upper portion of the Dewey Lake. In the AIS, gypsum-filled fractures are abundant below 164.5 feet. The fracture filling gypsum is fibrous indicating incremental growth. The fracture pattern and filling morphology is governed by the grain-size of the fractured host material, as discussed below.

3.4.3.1 Fracture Filling Gypsum

The gypsum fracture fillings are clear to white, fibrous, and both syntaxial and antitaxial (after Durney and Ramsey, 1973). Pieces of the wallrock material are sometimes found within the fracture filling. Most of the larger fibrous fracture fillings observed within the Dewey Lake appear to have a "suture" line which always parallels the fracture surface of the host material. The suture line is the site of a moderate to abundant amount of inclusion of wall rock material. Most of the fibrous fracture fillings are perpendicular to the fracture margin; however, some are tilted away from the perpendicular, and, in rare cases, they are sigmoidal. Fibrous fracture fillings result from overgrowth on individual crystals as the fracture opens in small increments. When the fracture initially opens, a void and a zone of low pressure is created. Intercrystalline or pore fluid migrates toward the site of low pressure. The pressure decrease coupled with newly created void space is conducive to mineral precipitation along the fracture surface. If the fluid is near saturation for a particular mineral, this pressure drop may drive the fluid to saturation, and precipitation may occur. If the wall rock and the fracture filling contain the same mineral, overgrowth upon grains or crystals of that mineral in the wall rock will occur and the fracture filling will be syntaxial (Durney and Ramsay, 1973). If saturation is reached and the wall rock does not contain the same mineral and nucleation of the new mineral occurs, the resulting fracture filling is antitaxial (Durney and Ramsay, 1973). The suture line is most visible in antitaxial fracture fillings because small pieces of the wall rock are included within the crystals during the initial fracturing and precipitation. The suture line parallels the fracture surface on the wall rock.

Once the initial fracturing and subsequent precipitation occurs, the fracture filling grows incrementally because the fracture filling mineral precipitates as overgrowths. These overgrowths are constrained by each other and grow competitively, perpendicular to the wall rock, creating a fibrous crystal habit. The fibrous habit is visually enhanced when the filling material consists of a mineral that is readily twinned (e.g., gypsum).

As fracturing continues, one side of the fracture filling and the wall rock separate. Fluids migrate to that point, and minerals precipitate at the contact between the wall rock and the filling material. Therefore, the youngest part of the filling is next to the wall rock, and the oldest part of the fracture filling is adjacent to the suture line. The width of the fracture filling on each side of the suture line is proportional to the number of reseparations along each side.

The morphology of the fibrous fracture filling reflects the stress field in which it was created (Durney and Ramsay, 1973). Fibers perpendicular to the fracture surface indicate that there was no displacement parallel to the fracture surface at the time of fracturing and subsequent filling. Fibers that are tilted from perpendicular indicate that displacement also occurred parallel to the fracture surface throughout the period of fracturing and filling. Sigmoidal morphologies develop when a small displacement occurs parallel to the fracture surface occurs after the initial fracturing.

3.4.3.2 Fracture Morphology and Origin

Within the Dewey Lake, sandstones and siltstones generally have fewer fractures than mudstones and siltstones. In sandstone and siltstone, fracture fillings are usually thick (up to two inches). Fractures are mostly horizontal to subhorizontal and parallel bedding planes or other linear syndepositional features (Figure 14). Subvertical to vertical fractures are less common and usually planar, crossing several depositional units. In the finer-grained rocks (mudstones and claystones), gypsum-filled fractures are usually more abundant and much thinner (rarely greater than one-half inch thick) than in the coarser-grained units (Figure 15). They are mostly subhorizontal, and sometimes subvertical. They are arcuate and frequently bifurcate. Planar fractures occur mostly along lithologic contacts.

The majority of the gypsum-filled fractures in the Dewey Lake are horizontal to subhorizontal. This fracturing is dissimilar to that associated with solution collapse (e.g., Middleton, 1961). In solution collapse breccias, clast separation vertically decreases to give way to a series of fractures, hairline fractures and cracks, and then undisturbed beds. Within WIPP shafts, fractures within the Dewey Lake are commonly, but not exclusively, horizontal. They occur in zones that are not well interconnected or continuous vertically. There is no apparent relationship between Dewey Lake fracturing and dissolution at the site area. A vertical to subvertical minimum principal stress is indicated by the horizontal to subhorizontal fractures. Although, variable fracture orientations suggest that the direction of the least principal stress was somewhat variable. The data are consistent with an unloading origin for Dewey Lake fractures. Differential unloading is probably responsible for the majority of fractures in the Dewey Lake.

Many of the fractures may have been filled with gypsum very early, possibly syndepositionally. Gypsum-filled fractures in a cobble-size rip-up clast of siltstone resting in a sandstone channel at a depth of 298 feet strongly suggest a syndepositional origin for at least some of the gypsum fracture fillings. The cobble contains two gypsum-filled fractures, one-fourth inch thick, which sharply terminate at the margin of the clast (Figure 16).

3.4.4 Origin of Perched Water Tables In the Dewey Lake

Moisture has been encountered within the Dewey Lake at several of the WIPP drillholes, and several stock wells south of the WIPP site are possibly completed in the upper Dewey Lake (Mercer, 1983). The cause and distribution of these perched aquifers within the Dewey Lake is not known. The geologic mapping of the Dewey Lake in the AIS has provided a possible basis for future assessment of these aquifers.

At the AIS, the Dewey Lake is cemented with carbonate above 164.5 feet. The coarse-grained units (sandstones and siltstones) are usually moderately hard, though a few are soft. The mudstones and claystones are soft and commonly fissile. Fractures are unfilled or filled with carbonate, and carbonate-filled fractures increase downward. The surface of the AIS wall in the Dewey Lake is moist down to 164.5 feet, and a halitic efflorescence is sometimes present on the shaft wall. At 164.5 feet, the cement changes from carbonate to a much harder material, probably anhydrite. The lower part of the Dewey Lake is well cemented, hard, and dry. Coincident with the cement change, fractures are filled with fibrous gypsum. The significance of this cement change is not clear, and its areal persistence is not known. Perched water tables within the Dewey Lake may rest on this cement change. The cement change may indicate the depth and extent of infiltration of recent meteoric water, though this certainly is not a unique interpretation.

This cement change may be recognizable on geophysical logs from the Dewey Lake. The geophysical logs from a drill-hole adjacent to the AIS (H-16; Mercer and Snyder, 1990) show an increase in compensated neutron porosity and an overall drop in bulk density in the vicinity of this cement change. If this cement change can be recognized consistently on geophysical logs in the vicinity of the WIPP, the cement change surface may be contoured and compared with known locations of perched Dewey Lake aquifers.

In the AIS, the presence of moisture in the uppermost section of the Dewey Lake is due to downward percolation of meteoric water through the poorly cemented clastic rocks. Halite dissolved into the water produced halite efflorescence on the shaft wall following evaporation. There is no source of halite within the overlying rocks, and halite muck-piles north and east of the AIS are the only source of halite above the Rustler Formation. The fluids observed at the AIS must have come in contact with halite at, or derived from, the muck-piles.

At the WIPP site, meteoric water probably infiltrates through the surface materials (dune sand and construction fill material) to the Mescalero caliche, where it moves downgradient off of the site or evaporates. When the Mescalero caliche and the Pleistocene and Triassic rocks have been disturbed by construction activities, this water can infiltrate along these newly created pathways into the underlying Dewey Lake. The water will infiltrate to the cement change surface and either stop or move down gradient. The impact of this process should be assessed with respect to shaft plugs and seals.

3.4.5 Summary of the Dewey Lake Redbeds

The Dewey Lake Redbeds at the WIPP site (as described in the AIS) consist of 476 feet of interbedded siltstone, fine sandstone, mudstone, and claystone. The Dewey Lake can be subdivided on the basis of grain size and sedimentary structures into 1) an upper sequence deposited from a fine-grained, ephemeral fluvial system (Schiel, 1988) and 2) a lower sequence deposited in saline mud flat/mud flat environments. Gypsum-filled fractures are abundant throughout most of the Dewey Lake and are at least partly syndepositional. The lower mud flat/saline mud flat sequence depositionally continued Rustler-style sedimentation. Conditions suitable for marine-derived flooding of the Delaware Basin were persistent through Rustler time (Holt and Powers, 1988), but did not continue through Dewey Lake time. The Dewey Lake represents a transition from the marine-influenced evaporite deposition of the Rustler to fluvial deposition on a broad, low-relief, fluvial plain.

3.5 RUSTLER FORMATION

The Rustler Formation is the youngest of three Ochoan evaporite-bearing formations in the Delaware Basin. Richardson (1904) named the Rustler for outcrops in the Rustler Hills, Culberson County, Texas. Lang (1939) clarified the term "Rustler" to stratigraphically define the interval between the Pierce Canyon Redbeds (an abandoned term, now recognized in part as the Dewey Lake Redbeds) and the Salado Formation. Lang (1939) (in Adams, 1944) recognized and named two laterally extensive dolomite units. The lower is named the Culebra Dolomite Member and the upper is named the Magenta Dolomite Member.

Vine (1963) introduced the fivefold stratigraphic subdivision of the Rustler (Figure 17) that is currently in use. Vine named the interval above the Magenta the Forty-niner Member and the interval between the Culebra and the Magenta the Tamarisk Member. The interval between the Rustler/Salado contact and the Culebra was not named and is referred to as the unnamed lower member. Holt and Powers (1988) further refined the Rustler stratigraphy by subdividing the Rustler into various informal units based upon their lithology (Figure 17).

The Rustler Formation is characterized by a variable lithology consisting of interbedded sulfates, carbonates, clastics, and halite. On the basis of mapping in the waste handling and exhaust shafts, cores, and geophysical logs, Holt and Powers (1988) evaluated the depositional environments and diagenetic history, including dissolution, of the Rustler in the WIPP area. They concluded that the Rustler was the depositional product of repeated transgressive events over low-relief salt pan and mud flat environments followed by desiccation to salt pan and mud flat environments. The transgressive events produced lagoonal conditions favorable to the subaqueous deposition of clastics (the lowermost siltstone and sandstone unit within the Rustler), carbonates (Culebra and Magenta Dolomite Members), and sulfates (anhydrite beds). Upward desiccation and shallowing, due to constriction of the lagoon toward the Rustler depositional center (15 miles south and east of the WIPP site), produced textural changes within the Rustler sulfates and ultimately led to deposition in salt pan and mud flat environments (the mudstone and halite units).

At the AIS, the Rustler is 309 feet thick. The features observed within the Rustler are consistent with those reported by Holt and Powers (1984, 1986, and 1988). The Rustler data collected during the mapping of the AIS are far superior to Rustler data from the other WIPP shafts due to the high quality of the shaft exposures. Features previously seen only in slabbed core were well displayed on the shaft wall. Some of the Rustler data collected in the AIS provide additional insight into the Rustler depositional and post-depositional alteration history. These data allow further refinement of the models presented by Holt and Powers (1988). The lithology of each of the five members is summarized below, and those features previously unreported are interpreted.

3.5.1 Forty-niner Member

The Forty-niner Member of the Rustler consists of two andydrite beds (A-5 and A-4 of Holt and Powers, 1988) which sandwich a thinner mudstone bed (M-4 of Holt and Powers, 1988) (Figures 17 and 18). The top of the Forty-niner Member occurs at a depth of 513 feet in the AIS, and its upper contact with the Dewey Lake Redbeds is sharp, undulatory, and erosional (Figures 7 and 17).

3.5.1.1 Anhydrite 5

The uppermost anhydrite (A-5) is 31 feet thick and shows wavy, thin laminae and laminae with some anhydrite pseudomorphs after gypsum swallowtail crystals (Figure 5). Stylolites parallel some laminae. A disrupted zone occurs between 517 and 521 feet on the south side of the shaft. This zone shows rotated boulder-sized clasts of anhydrite and soft sediment deformation of the laminae overlying and adjacent to the zone. Laminae overlying the zone are downwarped, while laminae adjacent to the zone are rotated into the zone. Red claystone lines some irregular surfaces in the disrupted zone. This zone directly underlies zones within the Dewey Lake that also show extensive soft sediment deformation. Most fractures are subhorizontal to subvertical and are filled with fibrous gypsum, although some subvertical fractures between 530 and 540 feet between 530 and 540 feet have a 1/16-inch aperture. The lower contact of A-5 occurs at 544 feet and is sharp.

The disrupted zone found within A-5 appears to have originated while the overlying sediment was still soft. Rotated blocks and soft-sediment shear suggest that the feature originated from the collapse of a small opening. This requires the removal of some volume of material, probably by dissolution. Soft sediment deformation of the material overlying and adjacent to the feature occurred in response to the collapse. No evidence of collapse of lithified material was found.

This feature developed before the surrounding sediments where lithified and under conditions where undersaturated fluids had easy access to the sediment. The transition between the end of Rustler deposition and the start of Dewey Lake deposition is the most likely time for both conditions to be met. As discussed in previous section (3.4), the Dewey Lake Redbeds are a depositional continuation of the Rustler. The lower Dewey Lake was deposited in a mud flat/saline mud flat environment which followed a desiccating upward sequence beginning with the deposition of A-5 in a saline lagoonal environment. As in Rustler time, periods of subaerial exposure and reworking of the saline lagoon sediments preceded the deposition of mud flat to salt pan sediments. This reworking was most prevalent along the margins of the Rustler depocenter where the water table fluctuated the most.

Schiel (1988) shows that a Dewey Lake depocenter is roughly coincident with the Rustler depocenter (Holt and Powers, 1988). The WIPP site lies on the margin of the depocenter for both units. During the transition time between Dewey Lake and Rustler deposition, the WIPP site area would have seen large fluctuations in the position of the watertable. Under these conditions, dissolution and reworking of Rustler sulfates probably occurred in the vadose zone. The disrupted zone is interpreted to have developed under vadose zone conditions while Rustler sediments were still soft. Red clay along some zones in this feature was probably infiltrated syndepositionally under vadose zone conditions.

3.5.1.2 Mudstone 4

As in the exhaust shaft (Holt and Powers, 1986), the Forty-niner mudstone, M-4, is subdivided into five units consisting of very fine sandstone, siltstone, and mudstone (Figures 5 and 18). In the AIS, M-4 occurs at a depth of interval between 544 and 558.5 feet. Overall, M-4 shows abundant well to poorly preserved, thin laminae to laminae with local ripple and accretionary cross-laminae. The strata are often slightly to very deformed and may be smeared. Granule-to pebble-sized clasts of siltstone and smeared intraclasts (as described in Holt and Powers, 1988) are common. Coarsely crystalline gypsum occurs in local laminae and thin beds. The units within M-4 are generally poorly indurated and soft.

3.5.1.3 Anhydrite 4

The lowermost anhydrite, A-4, within the Forty-niner Member occurs in the depth interval from 558.5 to 574 feet (Figures 5 and 18). It shows bedded nodular textures at the base and thin laminae to laminae intercalated with carbonate laminae from 565 to 570 feet. Strata become wavy to contorted and convolute upwards. Anhydrite pseudomorphs after gypsum swallowtail crystals are common between 560 to 570 feet, and some gypsum-filled subvertical fractures occur. The lower contact with the Magenta Dolomite Member is gradational.

3.5.1.4 Forty-niner Ground Conditions

The two anhydrites within the Forty-niner (A-4 and A-5) were well lithified and hard. The anhydrites showed no evidence of spalling. The Forty-niner mudstone (M-4) was poorly to moderately well indurated. Limited spalling was evident. The entire Forty-niner Member required washing prior to mapping.

3.5.2 Magenta Dolomite Member

The Magenta Dolomite Member of the Rustler Formation occurs in the depth interval from 574 to 599.5 feet in the AIS (Figures 5, 17, and 18). It is a regional marker within the Rustler and is considered to be an important hydrologic unit across the WIPP area.

The Magenta is a moderately well indurated, arenaceous, and gypsiferous dolomite that can be classified as a dolarenite. The dolomite grains are mostly silt to fine sand size. The Magenta is thinly laminated to laminated and contains gypsum nodules within some strata. Algal stromatolites occur within the lower five feet in the form of domes and hemispheriods. Wavy to lenticular bedding and ripple-cross laminae are abundant throughout the remainder of the Magenta. Overall, the size of sedimentary structures decreases upwards, although some very thin beds are present in the upper one foot. Both the upper and lower contacts are gradational.

During mapping, the Magenta produced only a limited amount of fluid into the AIS. After the Magenta section of the AIS was washed, all but one zone between 575 and 579 feet dried quickly. This zone remained moist and wet through the entire mapping exercise. The estimated inflow into the shaft was less than one gallon per minute.

3.5.2.1 Magenta Ground Conditions

The Magenta is well lithified and showed no evidence of spalling during shaft mapping activities. The surface was coated with dust which was removed by washing prior to mapping. The Magenta interval was covered with liner plate after mapping as required by contract specifications.

3.5.3 Tamarisk Member

Like the Forty-niner Member, the Tamarisk Member of the Rustler Formation consists of two anhydrite beds (Figures 5 and 17; A-3 and A-2 of Holt and Powers, 1988) which sandwich a thinner mudstone bed (Figures 5 and 17; M-3 of Holt and Powers, 1988). The top of the Tamarisk occurs at a depth of 599.5 feet in the AIS, and the base is at a depth of 686.5 feet (Figure 5).

3.5.3.1 Anhydrite 3

The upper anhydrite of the Tamarisk Member (A-3) is 56 feet thick and consists of anhydrite locally intercalated with carbonate interbeds (Figure 5). Thin claystone interbeds are present near the top and the middle of A-3. Subhorizontal and subvertical, fibrous, gypsum-filled fractures occur locally. The anhydrite is well lithified and hard. In the upper part of A-3, laminae-scale bedded nodular textures are abundant. Epitaxial crushed prism textures (Holt and Powers, 1988) occur in the middle of A-3; wavy and slumped laminae and thin beds with anhydrite pseudomorphs after gypsum swallowtail crystals are present in the lower part of A-3. Many of the sedimentary features in the lower part of A-3 show soft sediment deformation and slumping. In the lowermost few feet of A-3, beds of clast-supported, laminated anhydrite, and cobble and granule breccia are erosionally cross-cut by overlying beds of anhydrite. The lower contact of A-3 lies at 655.5 feet, is sharp, and has flame structures of material from the uppermost unit within M-3.

3.5.3.2 Mudstone 3

The Tamarisk Member mudstone (M-3) occurs within the interval from 655.5 to 665 feet (Figures 5 and 19). It is subdivided into three mapping units.

The upper mapping unit in M-3 is 2.5 feet thick and consists of anhydrite and gypsum interbedded with calcareous claystone. The unit displays thin laminae and laminae which become increasingly contorted upward. Claystone interbeds are possibly algal. Bifurcating, fibrous gypsum-filled fractures up to one inch thick are abundant. The lower contact is gradational.

The middle mapping unit within M-3 occurs in the interval from 658 to 659.5 feet. It consists of calcareous claystone in the upper one-half foot and argillaceous gypsum and anhydrite at the base. This unit is thinly laminated to laminated and shows extensive soft-sediment deformation at the top. Anhydrite and gypsum contain pseudomorphs after gypsum swallowtail crystals. The upper part of the unit is mounded and possibly algal. This unit contains abundant bifurcating, fibrous gypsum-filled fractures to two inches thick. The lower contact is sharp to gradational.

The top of the lower mapping unit within the M-3 interval lies at 659.5 feet. This unit consists of interbedded and intermixed claystone, mudstone, and siltstone which generally fines upward. The unit is mottled to laminated with alternating red and gray colors; red colors dominate at the base while gray colors are more prevalent toward the top of the unit. Local thin laminae to laminae are irregular, discontinuous, and often contorted, convoluted, or smeared. Laminae are often displaced slightly along shear surfaces. Smeared laminae and intraclast textures are most abundant in the middle and lower part of the unit. Broken, subhorizontal, laminae-scale, gypsum-rich zones found in the middle of the unit are laterally continuous around the circumference of the shaft. Anhydrite nodules up to one inch diameter are present in the lower half of the unit. The lower contact of this unit is sharp, erosional, and undulatory from 665 to 668 feet. At the lower contact, 24-foot wide by 2.5-foot deep channel is cut into the underlying anhydrite. The channel-fill consists of a clast-supported, rounded, gray siltstone, pebble conglomerate similar to the conglomerate in this stratigraphic position at borehole WIPP 19 (as described in Holt and Powers, 1988). The internal stratigraphy of the overlying section does not vary around the circumference of the shaft. This unit contains abundant small fractures showing slickensided surfaces and abundant fibrous gypsum-filled fractures to two inches thick.

The data from the M-3 interval at the AIS are consistent with data reported by Holt and Powers (1984, 1986, 1988). The shaft data provides an analogue for features described by Holt and Powers (1988) in the core from the borehole WIPP 19. Holt and Powers (1988) report a clast-supported siltstone in the M-3 interval at WIPP 19. At the WIPP 19 location, the lowermost anhydrite in the Tamarisk Member (A-2) is not present, and M-3 directly overlies the Culebra. Holt and Powers (1988) interpret the siltstone pebble conglomerate in the lower part of M-3 and the absence of A-2 at WIPP 19 to be the result of erosion and the development of channels into A-2 prior to and during the early stages of the deposition of M-3. The channel feature and siltstone pebble conglomerate described in the AIS developed in the same way.

Channeling and erosion on the upper contact of A-2 was reported from all shafts at the WIPP site (Holt and Powers, 1984, 1986). As the depocenter margins were subaerially exposed (Holt and Powers, 1988), the fluid base level dropped below the surface of the sediment, and A-2 was eroded. At WIPP 19, the base level dropped through the entire A-2 interval allowing all of A-2 to be eroded. The minimum water table drop at the AIS was much less as the channel is only 2.5 feet deep. Base level fluctuations were probably less at the AIS because it is closer to the Tamarisk depocenter than WIPP 19. This process was repeated at the Dewey Lake/Rustler transition and accounts for the development of paleokarst in the uppermost anhydrite (A-5) of the Rustler.

3.5.3.3 Anhydrite 2

The lowermost anhydrite within the Tamarisk Member (A-2) occurs within the depth interval from 665 to 686.5 feet (Figure 5). The anhydrite contains wavy, locally deformed thin laminae and laminae with occasional anhydrite pseudomorphs after gypsum swallowtail crystals and crushed prism textures. The anyhydrite is well lithified and hard. At a depth of 672 feet, A-2 is bisected by a 0.5 foot thick, undulatory bed of claystone. This claystone displays deformed thin laminae and contains fibrous gypsum-filled fractures to 1.5 inch thick. Below the claystone, the strata show soft sediment roll-over structures formed by sliding on a slope. The strata dip up to 20°. Algal structures are present near the base. The lower contact is sharp to gradational.

3.5.3.4 Tamarisk Ground Conditions

The anhydrites (A-2 and A-3) within the Tamarisk Member were well lithified and hard. Spalling was limited through the anhydrites within this section except for minor breakages along the contacts with the claystone. Tool marks from the upream-bit were prevalent in the anhydrite. Ground support (e.g., rock bolts and mesh, or liner plate) was not required through the anhydrites.

The Tamarisk Member mudstone (M-3) from 659.5 to 665 feet was poorly lithified, soft, and cohesive. Subvertical slickensided shear surfaces were abundant, and, in some cases, several feet of the mudstone have spalled out of the unit. Prior to mapping, large slabs of this claystone, some desk-top size, were scaled from the rib. Liner plate was installed over this zone prior to any in shaft work below the M-3 horizon.

3.5.4 Culebra Dolomite Member

The Culebra Dolomite Member of the Rustler Formation is the most transmissive hydrologic unit encountered by the AIS and is a really extensive markerbed within the Rustler. In the AIS, the Culebra occupies interval from 686.5 to 710.5 feet (Figures 5 and 20). The exposure of the Culebra within the AIS is far superior to exposures in other shafts and cores. The data collected from the Culebra in the AIS will be used by Holt, et al. (in preparation) to help create a more precise interpretation of the origin of the Culebra.

The Culebra is an argillaceous dolomicrite containing abundant open and gypsum-filled porosity. Portions of the Culebra are extensively fractured. The Culebra is divided into six mapping units which are described here from the top down. Although all mapping units make water into the AIS, the mapping unit between 694.5 and 700 feet (Unit 3a, Figure 20) produces more water than the others.

The uppermost mapping unit within the Culebra (unit 1, Figure 20) lies between 686.5 and 690 feet. It is an argillaceous dolomite which contains organic material (algal) near the top and base. Thin laminae and thin beds are mostly flat and are contained within fining-upward sequences 0.2-0.5 feet thick. The lower parts of these sequences often contain burrows. Cross-laminae occur in the upper 0.5 foot of this unit. The unit contains no vugs and few fractures. Short stratum-height subvertical fractures with synsedimentary brecciation are limited to the upper one to two feet of the unit. A synsedimentary fault with one foot of throw terminates near the middle of the unit, and the unit depositionally thickens over the downdropped section. The upper contact is sharp to gradational.

The second mapping unit from the top of the Culebra (unit 2, Figure 20) is much less disrupted and mechanically more competent than the underlying units. It occurs within the mapping depth interval from 690 to 694.5 feet and consists of locally organic, microcrystalline, argillaceous dolomite with internally structureless, parallel, thin laminae to thin beds. Large vugs are rare, and most large vugs are unfilled. Fractures are less abundant than in the underlying units, and most fractures are gypsum-filled, subvertical, and longer than those in underlying units. Some brecciation occurs along some fractures. Unlike the underlying units, the fracture pattern is not controlled by vugs, as large vugs are rare. Two synsedimentary faults with displacement less than one foot cross-cut the unit (Figure 20). The upper contact is gradational.

The third mapping unit from the top (unit 3a, Figure 20) visibly produces more water into the shaft than the other units because it is more extensively fractured. This unit occurs within the depth interval from 694.5 to 700 feet. Laminae and thin beds are flat, parallel, and sometimes contain microlaminae and thin laminae which may be discontinuous. Low-angle cross-laminae with possible ripple forms are rare. Strata are modified by possible bioturbation. Vugs texturally dominate the fabric within this unit as large (two to three inches), open, clay-filled, and gypsum-filled vugs are very abundant. Most of the vugs are partially to entirely clay-filled. This unit is characterized by a broken appearance as subvertical to vertical fractures are very abundant (spaced one-fourth to two inches), and are best characterized as a packbreccia (Morrow, 1982). These fractures are usually only a few inches long, irregular, open or gypsum-filled, and very thin (half of the fractures contain no gypsum filling). Most fractures connect vugs, and all vugs are interconnected by fractures. The upper contact of this unit is gradational to diffuse.

The fourth mapping unit (unit 3b, Figure 20), from 700 to 705 feet, displays distinct thin laminae to laminae, low-angle cross-laminae with low-relief hummocks, and local erosional scours to three inches deep. In places, the bedding appears wavy to lenticular. Vugs are abundant and become smaller downward. Most vugs are open or filled with clay; gypsum as a vug or fracture filling is much less common. The unit can be classified as a packbreccia (Morrow, 1982) due to extensive subvertical fracturing in between vugs. Vuggy porosity is present along some fractures. The upper contact is very diffuse.

The fifth mapping unit from the top of the Culebra (Mapping Unit 3c, Figure 20) occupies the interval from 705 to 710 feet. The upper contact is very diffuse and slightly undulatory over one foot. The undulations apparent at the lower contact are compensated within this unit. The dolomite displays flat to slightly wavy thin laminae to very thin beds with some low-angle cross-cutting relationships. Fractures are extensive, but less abundant than the overlying unit. Most fractures are subvertical. This unit contains locally abundant vugs, with fewer large vugs than the overlying units. Overall, this unit is less brecciated and disrupted than the overlying units.

The lower contact of the Culebra with the unnamed lower member lies at 710.5 feet along the south line of the AIS. This contact undulates over three feet in the AIS exposure. The lowermost unit (Mapping Unit 4, Figure 20) within the Culebra is 0.5 feet thick, and its upper contact parallels the lower contact of the Culebra. This unit consists of locally brecciated, thinly laminated to laminated dolomite. The strata parallel the upper and lower contacts.

3.5.4.1 Culebra Ground Conditions

Prior to mapping, the Culebra section was covered with a one-fourth to two inch thick build-up of rock flour from the upreaming operation. This flour consisted mostly of calcium sulfate derived from the Rustler anhydrites. The dust apparently stuck to the wet Culebra surface during shaft upreaming. This build up was scaled from the shaft wall prior to mapping the Culebra. Although the Culebra is highly fractured, only limited evidence of spalling was observed. The Culebra interval was covered with liner plate and the annulus between the rock and liner plate was grouted shortly after mapping activities were complete.

3.5.5 Unnamed Lower Member

The unnamed lower member of the Rustler Formation is 132.2 feet thick (Figure 5). It consists of interbedded siltstone, sandstone, halitic siltstone, halite, mudstone, and anhydrite (Figures 5 and 20). Holt and Powers (1988) subdivided the unnamed lower member into five informal stratigraphic units which at the WIPP site, in descending order, include: mudstone 2 (M-2), anhydrite 1 (A-1), halite/mudstone 1 (H-1/M-1), the transition zone, and a bioturbated clastic interval (Figure 17). For convenience, their stratigraphic subdivisions are used in this discussion.

3.5.5.1 Mudstone 2

The uppermost unit in the unnamed lower member is mudstone 2 (M-2). This unit directly underlies the Culebra Dolomite Member and occurs in the mapping depth interval from 710.5 to 716 feet (units 1 and 2, Figure 20). The lower half of M-2 is dominantly brown, while the upper half is mostly gray. The lower and middle part of M-2 consists mostly of mudstone displaying some laminae. Continuous, slightly deformed laminae to very thin beds of gypsum overlie mudstone displaying smeared intraclast textures in the lower part of M-2. In the upper gray portion of M-2, microlaminated, thinly laminated, and structureless mudstone overlies cobble-sized clasts of mudstone; subvertical slickensided surfaces are common. Gypsum-filled fractures, up to one-fourth inch thick, occur along some slickensided surfaces. Fibrous, gypsum-filled fractures to one inch thick occur with various orientations in the lower brown zone. The upper contact with the Culebra is sharp and undulatory over three feet, while the lower contact of M-2 is sharp with less than one foot of erosional relief.

3.5.5.2 Anhydrite 1

Anhydrite 1 (A-1) occurs within the mapping depth interval from 716 to 725.5 feet (unit 3, Figure 20). The anhydrite is microcrystalline and hard, displaying wavy to flat, thin laminae and laminae. Near the base, there are abundant one-foot tall halite pseudomorphs after gypsum swallowtail crystals. The lower contact is sharp.

3.5.5.3 Halite/Mudstone 1

The halite-bearing interval in the unnamed lower member is designated as halite/mudstone 1 (H-1/M-1) by Holt and Powers (1988). Where halite occurs in this interval, it is designated Halite 1 (H-1). In the AIS, H-1 occupies the mapping depth interval from 725.5 to 761 feet and is subdivided into seven mapping units (Figures 5 and 20).

Siltstone, mudstone, and halite are intermixed in varying proportions from 725.5 to 739 feet. This interval corresponds with Holt and Powers' (1988) upper halite-bearing zone (H-1c). The lower 0.5 feet of the mapping unit between 735 and 739.5 feet (unit 6, Figure 20) is included with the middle halite-bearing zone (H-1b) as it consists of relatively clean halite. Within H-1c, halite occurs as isolated crystals to crystal aggregates within a siltstone matrix. Halite margins with the matrix are usually planar (displacive) or irregular (synsedimentary solution). Siltstone occurs as irregular, thin interbeds and blebs. Smeared intraclast textures and rare wavy to contorted laminae are preserved within the siltstones. The upper 1.5 feet consist of siltstone at the base and mudstone at the top and include anhydrite nodules and anhydritic laminae.

Mud-poor halite and anhydrite occur in the middle halite-bearing zone (H-1b) within the depth interval from 739 to 743 feet in the AIS (Figure 20). This unit consists of interbedded halite and anhydrite. Halite occurs in the upper 0.5 feet, while anhydrite dominates from 739.5 to 741 feet. Halite is intercalated with wavy anhydrite laminae in the lower two feet.

Intermixed siltstone and halite occur between 743 and 761 feet (Figure 20). This interval is designated the lower halite-bearing zone (H-1a) by Holt and Powers (1988). Siltstone is the primary constituent in H-1a. The siltstone occurs as thin interbeds; blebs; incorporated material within halite; and irregular, discontinuous laminae. The halite content generally increases upward. Halite occurs as isolated crystals and crystal aggregates, many with displacive margins.

3.5.5.4 Transition Zone

The sandstones and siltstones within the interval from 761 to 772.5 feet are within the "transition zone" of Holt and Powers (1988) (Figure 5). This zone records the transition from a marine lagoonal environment to a saline mud flat/salt pan environment (Holt and Powers, 1988). It contains anhydritic and halitic, fine to medium, sandstone and siltstone. The siltstones and sandstones display thin laminae to very thin beds which are wavy to contorted near the top and become more flat downward. Some laminae and thin beds of anhydrite are enterolithic. Other textures include: disk-shaped laminae, teepee structures, and prism cracks. The sulfate content decreases downward. Cross-laminae and ripple forms become abundant and larger downward. Subvertical halite-filled fractures are two inches thick. The upper contact is gradational, and the lower contact is sharp and erosional.

3.5.5.5 Bioturbated Clastic Interval

The "bioturbated clastic interval" of Holt and Powers (1988) occurs in the depth interval from 772.5 to 821 feet in the AIS (Figure 5). This sequence consists of halite-cemented sandstone and siltstone exhibiting varying amounts of bioturbation. In the AIS, the "bioturbated clastic interval" is subdivided into three mapping units. The base of this sequence consists of a pebble lag containing invertebrate fossil fragments. Burrowing and evidence of bioturbation are abundant at the base and decreases upward. Upward, cross-stratification becomes common and larger. Wavy, thin laminae are locally numerous. Subvertical to vertical halite-filled fractures up to two inches thick are present. The halite fillings have been partly dissolved by Culebra and construction-related water.

3.5.5.6 Rustler-Salado Transition

At the AIS, the lowermost 1.2 feet of the Rustler consist of a thin (0.2 feet) basal anhydrite and one foot of halitic, very fine sandstone to siltstone exhibiting wavy to contorted thin laminae, laminae, and smeared intraclast textures (Figure 5 and 21). Holt and Powers (1988) suggest that this zone is depositionally more related to the Salado Formation than the Rustler. The thin anhydrite is an areally persistent marker in the WIPP area and is often included within the Rustler.

3.5.5.7 Unnamed Lower Member Ground Conditions

M-2 was poorly lithified, very soft, and cohesive. Prior to mapping, large slabs of mudstone and claystone spalled out of this interval. The Culebra and A-1 formed ledges that bounded the mudstone which was recessed back from the shaft wall. Closer inspection revealed that up to five feet of mudstone had spalled from below the contact with the Culebra. Water from the Culebra contacted this zone following excavation and decreased the strength of the mudstone along existing planes of weakness (slickensided surfaces). Prior to mapping this zone, large slabs were scaled from the shaft wall to ensure the safety of mapping personnel. This zone was covered with liner plate prior to any work below this zone.

The surface of H-1/M-1 required extensive washing and scaling prior to mapping because brine from the Culebra and shaft construction activities had extensively altered the shaft surface. Culebra waters drained along the shaft wall for a period of over four months from the time of excavation until mapping. In addition, the construction contractor used 136,000 gallons of brine to free the raise-bore cutting head. The combined effect of these different waters was the dissolution of halite crystals and cements from this section. Those areas consisting mainly of halite showed extensive vertical fluting caused by dissolution. The anhydrites acted as resistant units while the halite around them was dissolved. This was especially prevalent on the north side of the shaft where the majority of the 136,000 gallons ran down the shaft wall. The halite and halite cements were dissolved from the siltstones creating a highly unstable area. After scaling to halite-cemented siltstone, the surface of the halitic siltstone had a vertically fluted appearance. This zone was covered with liner plate to reduce the spalling hazard.

The "transition zone" and "bioturbated clastic interval" required some scaling as halite cements were dissolved by Culebra and construction-related fluids. Halite-filled fracture fillings were partially dissolved.

3.6 SALADO FORMATION

The Salado Formation of southeastern New Mexico and west Texas is the major domestic source of potash for fertilizers in the U.S. It is the second of three Ochoan evaporite-bearing formations in the Delaware Basin. The Salado consists of halite, anhydrite, and polyhalite with varying amounts of other potassium-bearing minerals. About 85-90 percent of the Salado is halite (Jones et. al., 1973). Beds of anhydrite and polyhalite alternate with thicker beds of halite throughout the Salado section. The Salado consists of nearly 2000 feet of evaporites in the subsurface within the eastern part of the Delaware Basin and only a few tens of feet of brecciated insoluble material at outcrops in the western part of the basin.

The term Salado was originated by Lang (1935) for the upper, salt-rich part of the Castile gypsum of Richardson (1904). The Salado is subdivided into three informal members: an unnamed upper member, a middle member locally designated the McNutt potash zone, and an unnamed lower member (Figure 22). Each of the members contains similar amounts of halite, anhydrite, and polyhalite (Jones, 1972) and are differentiated on the basis of other potassium and magnesium-bearing minerals. The upper and lower members generally lack these minerals, while the middle member (McNutt potash zone) contains a relative abundance of potassium and magnesium-bearing salts.

Individual beds within the Salado are often traceable for large distances. These areally persistent beds allow the middle and upper Salado to be subdivided on a much finer scale. A system of numbering areally extensive beds of anhydrite and polyhalite (markerbeds) was introduced by geologists of the U. S. Geological Survey (Jones et. al., 1960). The markerbed system is used extensively by mining companies in the Carlsbad potash district and by researchers at the WIPP for smaller-scale stratigraphic control.

The AIS penetrated 1,290 feet of the Salado, including all of the unnamed upper member and the McNutt potash zone and a portion of the unnamed lower member. The Salado was mapped in three phases. First, the keyway interval, the upper 60 feet, was mapped immediately following the geologic mapping of the Rustler (Figures 5 and 21). Second, three zones within the unlined section of the AIS presented a spalling hazard and were mapped prior to the installation of rock bolts and mesh (Figure 23). Finally, the remainder of the Salado was washed and mapped after the WIPP operating contractor had assumed control of the shaft (Figure 23, Appendix D).

The data collected from the Salado during the final phase of mapping were far superior to any data previously collected from WIPP underground excavations or core. The construction method provided a smooth surface, with only minor irregularities and tool marks, for description. The shaft wall was washed with fresh water which etched the surface of the salt and smoothed the irregularities created by the construction method. The surface created by the washing was akin to slabbed and polished core. Materials less soluble than halite exhibited positive relief which made the description of even small-scale, nearly microscopic fabrics, possible. Fluid-inclusion zoning within individual halite crystals was easily recognized. The shaft surface was allowed to dry for several days to weeks prior to mapping. This enabled us to recognize those zones in the Salado which make limited amounts of fluid and form weeps to be easily recognized. The shaft wall provided a large surface for description which allowed us to examine large, outcrop-scale features and textures, many of which have never before been recognized in ancient evaporites. Finally, we were able to describe the section without interruption for construction activities or other time constraints.

3.6.1 Salado Halite

Exposures of the Salado in the AIS showed abundant, previously unreported, large- and small-scale halite textures. Many of the large-scale textures are similar to features which occur at the Devil's Golf Course in Death Valley, California. We were able to recognize, describe, and interpret numerous previously undescribed halite textures and fabrics and place these features into stratigraphic context. A detailed discussion of Salado halite sequences is presented in Appendix F and summarized here.

Halite is the most abundant mineral in the Salado and occurs in thick beds intercalcated with thinner beds of polyhalite or anhydrite (Jones, 1972; Holt and Powers, 1984, 1986). Salado halite is rarely pure and usually contains trace and minor amounts of foreign material, including: clay, anhydrite, or polyhalite (Jones, et al., 1960; Jones, 1972; Jones et al., 1973; Powers et al., 1978; Holt and Powers, 1984, 1986). Halite crystal size and morphology varies considerably, and various large- and small-scale sedimentary structures are abundant throughout all of the Salado halite.

The Salado exposed at the AIS shows numerous cycles which are generally consistent with those reported by other workers (Schaller and Henderson, 1932; Jones, 1954, 1972; and Lowenstein, 1988). At the AIS, complete Salado halite sequences consist of clay-poor halite at the base grading upward into argillaceous halite. The vertical distribution of halite textures is largely consistent through all halite sequences whether they overlie a thicker sulfate unit or another halite unit. Clay content within most sequences increases upward and appears to be unrelated to the presence of underlying anhydrite/polyhalite beds.

The distribution of foreign material and sedimentary structures generally follows a distinct vertical pattern within an individual unit or several successive mapping units. We have constructed an "idealized" Salado halite sequence to represent the features and textures seen in most complete Salado Halite sequences (Figure 1, Appendix F). The sequence is subdivided into four major lithofacies. The lower two lithofacies are further subdivided on the basis of smaller-scale halite fabrics. Many of the sequences described in the AIS are incomplete (Figure 23) and do not contain all of the textural lithofacies summarized below.

The lower mud-poor section of the sequence is dominated texturally by an overall sense of horizontal to subhorizontal stratification and is named the "stratified" mud-poor lithofacies (Figure 1, Appendix F). It is subdivided into three zones with small-scale textures. The first zone is dominated by bottom growth halite textures including halite chevron, cornet, and cumulates and clay or sulfate laminae. The second zone shows abundant passive pore-filling halite cements in small dissolution pits and pores. The uppermost zone contains exhibits mostly expansive halite cement textures (displacive halite) mixed with various syndepositional solution textures and fabrics. These textures are consistent with deposition in a mud-poor salt pan.

The "podular" muddy halite lithofacies is characterized by lenses and pods of fine to medium crystalline halite (Figure 1, Appendix F). Generally, it is more argillaceous than the "stratified" mud-poor lithofacies. The "podular" muddy halite lithofacies is subdivided into two zones which laterally and vertically interfinger: 1) a zone dominated by expansive (displacive) halite cements and 2) a zone with few expansive cements. Few textures reflecting subaqueous deposition are preserved, and continuous strata are very rare. Dissolution pits, pipes, and pores are common. Textures within this lithofacies are similar to "hummocky" salt pan halite in the Devil's Golf Course in Death Valley, California.

In some cases, the upper few inches to feet of Salado sequences consist of argillaceous halite exhibiting abundant displacive halite cement fabrics (Figure 1, Appendix F). These rocks are placed within the dilated mud-rich halite lithofacies because displacive halite cements give a "dilated" appearance to the halite. Passive pore-filling halite cements are rare in this lithofacies.

Crude stratification is present, but is locally bisected by prism cracks and dissolution pits and pipes. These textures reflect deposition in a mud-rich salt pan.

The halitic mudstone lithofacies occurs at the top of our "idealized" sequence. It consists of halitic mudstone showing displacive/incorporative halite crystals and smeared intraclast textures (after Holt and Powers, 1988). Prism cracks and disk-shaped laminae may occur. Textures within the halitic mudstone lithofacies indicate deposition in a saline mud flat.

Uninterrupted Salado halite sequences record the vertical progression of environments: mud-poor salt pan - "hummocky" salt pan (similar to the Devil's Golf Course at Death Valley, California) - mud-rich salt pan - saline and mud flat (Figure 23, Appendix F). Salado halite sequences record the deposition and alteration of halite under variable water table conditions. Subaqueous deposition of halite alternated with vadose alteration as water table fluctuations created intermittent vadose zone conditions. Phreatic zone cements filled porosity below the water table. The frequency and duration of these water table drops rose with time as the basin desiccated.

Mud-poor salt pan halite was deposited following a first-order flooding event. Evaporation and reworking of existing halite increased salinity to halite saturation. Halite was accumulated until the basin was desiccated. When the water table dropped below the surface of the sediment, vadose zone alteration produced characteristic textures and fabrics. Second-order flooding events created intermittent subaqueous conditions, allowing further accumulation of halite. Vadose zone alteration increased with time as flooding events became less frequent. Long periods of deep water table conditions cycled with shallow water table and episodic saline lagoon conditions producing and preserving "podular" muddy halite in a "hummocky" salt pan environment. Vadose zone alteration intensified with time decreasing the overall relief across the basin. This allowed more efficient transport of clastic materials into the basin, and a mud-rich salt pan developed. Continued dessication of the basin moved laterally equivalent saline mud flat environments toward the depocenter.

3.6.2 Salado Sulfate Interbeds

Sulfate interbeds are important elements of vertical sedimentation cycles within the Salado. Earlier descriptions of these interbeds are of core and limited horizons within mine workings. The geologic mapping of these interbeds in the AIS provides continuous outcrop scale descriptions through the upper 1,200 feet of the Salado. Salado sulfate interbeds are discusse at length in Appendix G and summarized in the following discussion.

Numerous textures and fabrics occur within sulfate interbeds, many of which have never been described from the Salado sulfates. These textures reflect: 1) subaqueous deposition and alteration, 2) vadose alteration, 3) phreatic alteration, and 4) late-stage diagenesis.

Vertically oriented prismatic gypsum pseudomorphs, detrital gypsum pseudomorphs, algal stromatolites, subaqueously accumulated halite, slumping and collapse of gypsum sediment alon the lower contact with halite developed during shallow subaqueous conditions. Teepee structures, prism cracks, buckled and disrupted strata, and collapse textures in interbeds containing bottom growth halite developed during subaerial exposure and alteration of gypsum sediment. Displacive halite crystals, sulfate cements, passive pore-fillings, and the pseudomorphous replacement of gypsum by anhydrite, polyhalite, formed in the phreatic zone within the depositional environment. The only features within the Salado sulfate interbeds whic could be uniquely attributed to late-stage alteration were open and halite- sulfate-filled fractures.

Salado sulfate interbeds were deposited in shallow saline lagoon environments following eustatically- (Lowenstein, 1982, 1983, 1988) or meteorically driven, basin-wide floods. The bas of sulfate interbeds are time lines produced by dissolution, and the interbeds can be considered punctuated aggradational cycles (after Goodwin and Anderson, 1980). Different hydrologic regimes produced three distinct types of sulfate interbeds. Thin, isolated sulfate interbeds were deposited in low-volume, hydrologically isolated saline lagoons. Low-volume flooding events ma have been derived from minor eustatic changes or major rainfall/runoff events. Multiple thin sulfate interbeds separated by interbeds of halite with little or no subaerial exposure were deposited during periods of hydrologic fluctuation when closely spaced, hydrologically-related, low-volume flooding events repeatedly produced shallow, saline lagoon conditions. Large-volum saline lagoons which accumulated thick sequences of sulfate were produced and maintained following major eustatic changes. After the marine hydrologic connections were broken, these large-volume lagoons desiccated to halite saturation, and sulfate deposition ceased.

Considerable lateral variability exists within sulfate interbeds, including MB139, at both the regional and repository scale. Lateral variations can be related to the depositional and early diagenetic environments. Lateral variability may be an important control on the mechanical response of MB139 during repository closure. The type and degree of fracturing generated during repository closure and the orientation of those fractures will be controlled by the thickness of, depositional and alteration fabrics within, relief on the upper surface of, and mineralogical composition of MB139. When compared, the descriptions of MB139 in Borns (1985) and Jarolimek, et al. (1983) confirm considerable lateral variability within MB139 across the repository. The AIS sedimentological data from other sulfate interbeds within the Salado and the depositional models discussed in this report may be helpful in reconstructing the origin and distribution of lateral variability within MB139.

Brine was observed discharging into the AIS from some of the thicker sulfate interbeds. The surfaces of these interbeds were moist to wet and were marked by the accumulation of efflorescence crusts. The lower part of MB103 was as wet as the fluid producing zone within the Magenta Dolomite. Inflow occurred primarily along horizontal to subhorizontal bedding plane fractures in the lower part of some anhydrite beds, although interparticle flow was observed from the lower part of MB103 which consists of anhydritic dolomite. No significant flow was found from any polyhalite. The brine contained within the fractures could have been locally derived from clays. These pore fluids may have migrated under a newly created pressure gradient into the fractures as they opened.

3.6.3 Salado Ground Conditions

During the mapping of the AIS, most of the Salado section was well lithified and hard. Prior to washing, the surface was covered with a crust of halite-cemented mud and, once the concrete liner was emplaced, localized concentrations of concrete over-spill (Figure 24). Unstable zones in the vicinity of sulfate interbeds were meshed before work could be conducted below them.

Halite was dissolved and fluted along the north side of the shaft by water used during the construction of the shaft (Figure 25). Where the north side of the shaft deviated inward, this dissolution was extensive. Interbeds of sulfate were not dissolved and extended out into the shaft from the fluted halite up to two feet. These interbeds were scaled and covered with wire mesh. In some areas, the fluting of the halite along the north side of the shaft was so extensive that irregular fluted pieces of halite could be easily scaled. These zones were also meshed.

In several locations, fracturing was extensive within sulfate interbeds and their underlying claystones. Book-sized pieces of sulfate and claystone readily spalled from some of the zones (Figure 26). Fracturing and spalling anhydrite and claystone resulted from the strain induced by mechanical anisotropy between those materials and halite during shaft closure. The full circumference of the shaft was meshed in these areas.

Above the station back, anhydrite A and the halite between it and the station brow was extensively fractured (Figure 27). En-echelon fractures occurred in subhorizontal to subvertica zones. Some fractures showed apertures at the shaft surface of up to 1/4 inch. The lower p of this zone was also meshed.

Sulfate interbeds that did not present a spalling hazard at the time of mapping will probably fracture as the shaft closes. All sulfate interbeds should be periodically inspected and meshe as necessary. Fractures in the station area should also be monitored because fracturing and separation will continue.

4.0 CONCLUSIONS

The air intake shaft (AIS) was geologically mapped from the surface to the WIPP facility horizon during the period from March 11, 1988 to November 14, 1989. The entire shaft section including the Mescalero Caliche, Gatuña Formation, Santa Rosa Formation, Dewey Lake Redbeds, Rustler Formation, and Salado Formation was geologically described. The shaft construction method, up-reaming, created a nearly ideal surface for geologic description. Small-scale textures usually best seen on slabbed core were easily distinguished on the shaft wall, while larger scale textures not generally revealed in core were well displayed. During the mapping, newly recognized textures were interpreted in order to refine depositional and post-depositional models of the units mapped.

The upper part of the Dewey Lake Redbeds displayed features consistent with Schiel's (1988) interpretation of the depositional environments. The textures observed indicated deposition in a fine-grained, ephemeral fluvial system (Schiel, 1988). The lower part of the Dewey Lake, however, depositionally continued Rustler-style sedimentation and accumulated in saline mudflat/mudflat environments. Some gypsum-filled fractures within the Dewey Lake are interpreted to be syndepositional. Within the Dewey Lake a cement change between carbonate and, possibly, anhydrite was observed at a depth of 164.5 feet. Perched water tables within the Dewey Lake in the WIPP site area may rest on this cement change. Above the cement change, the shaft surface was moist and displayed an efflorescent crust consisting of halite. The source of the halitic water is attributed to the muck-piles of halite from the underground mining operations located north and east of the AIS.

The features observed within the Rustler Formation are consistent with those reported by Holt and Powers (1984, 1986, and 1988). Rustler sediments accumulated in marine lagoon, saline lagoon, saltpan, and saline mudflat environments (Holt and Powers, 1988). No evidence of late-stage dissolution was observed. Mudstones within the Rustler were spalling hazards and covered by liner plate. Halite cements were dissolved from the surface of clastic rocks in the unnamed lower number by construction-related waters and Culebra groundwaters.

The AIS geologic data from the Salado Formation added considerably to the understanding of the depositional and diagenetic history of the Salado. Unprecedented halite textural and fabric data was collected, characterized, and interpreted. From this data, an idealized

Salado halite sequence was developed. All Salado halite observed within the AIS fit partially or wholly into the idealized sequence. Complete Salado halite sequences consist of four lithofacies which are related to distinct depositional environments. Many textures not previously reported from Salado sulfate interbeds were recognized and described. Salado sulfate interbeds were deposited in shallow saline lagoon environments following eustatically- or meteorically-driven, basin-wide flooding and freshening events (Lowenstein, 1982, 1983, 1988). Different hydrologic connections with marine waters produced three distinct types of sulfate interbeds within the Salado. No geologic evidence of naturally occurring late-stage fluid migration or alteration within the halite of the Salado was observed. Mineralized and fluid-filled fractures within some sulfate interbeds are the only recognizable late-stage diagenetic alteration.

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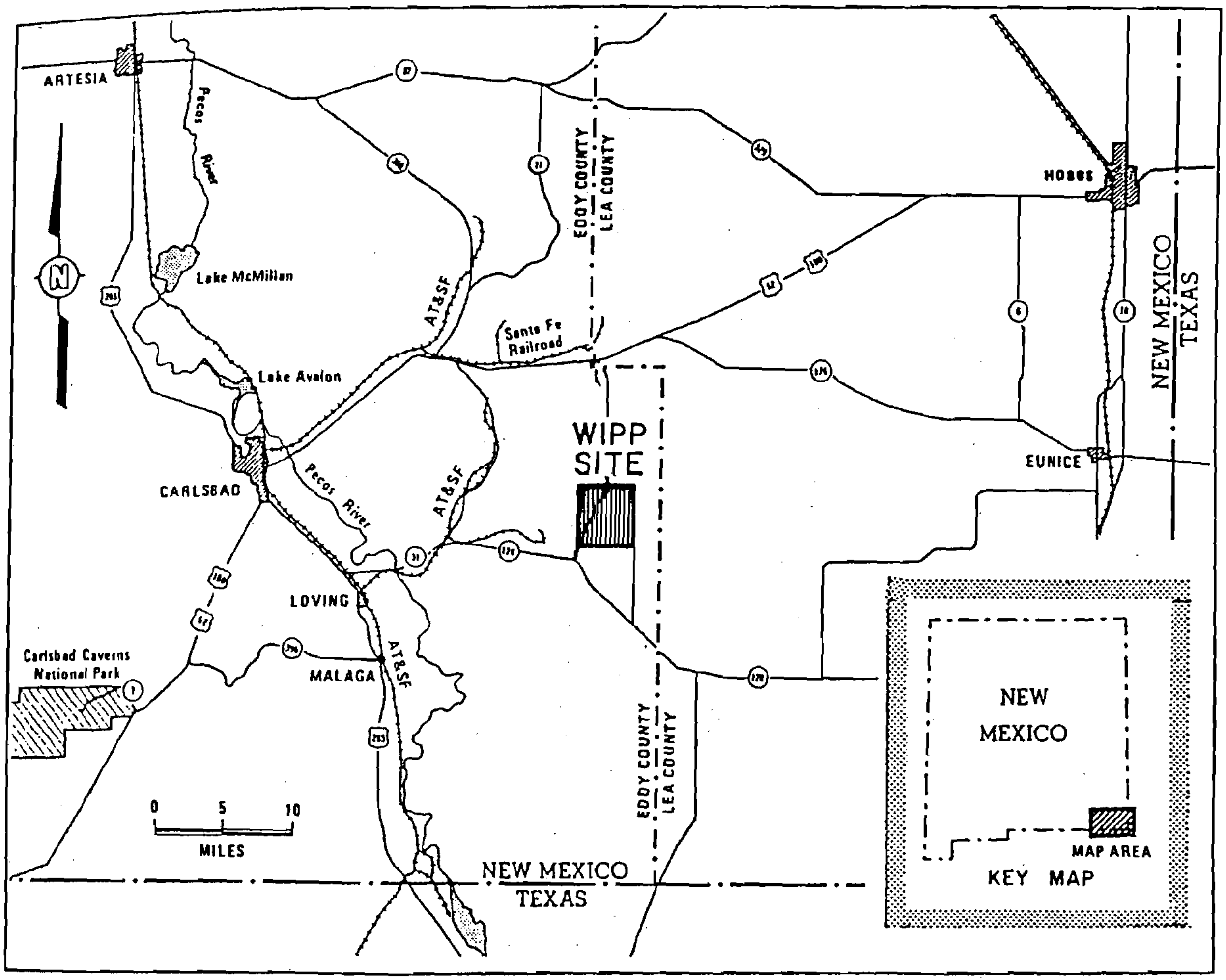
Figures


ARTESIA
Pecos River
Lake McMillan
Lake Avalon
CARLSBAD
Pecos River
AT&SF
AT&SF
AT&SF
Santa Fe Railroad
EDDY COUNTY
LEA COUNTY
WIPP SITE
HOBBS
EUNICE
NEW MEXICO
TEXAS
LOVING
MALAGA
Carlsbad Caverns National Park
0 5 10
MILES
EDDY COUNTY
LEA COUNTY
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MAP AREA
KEY MAP
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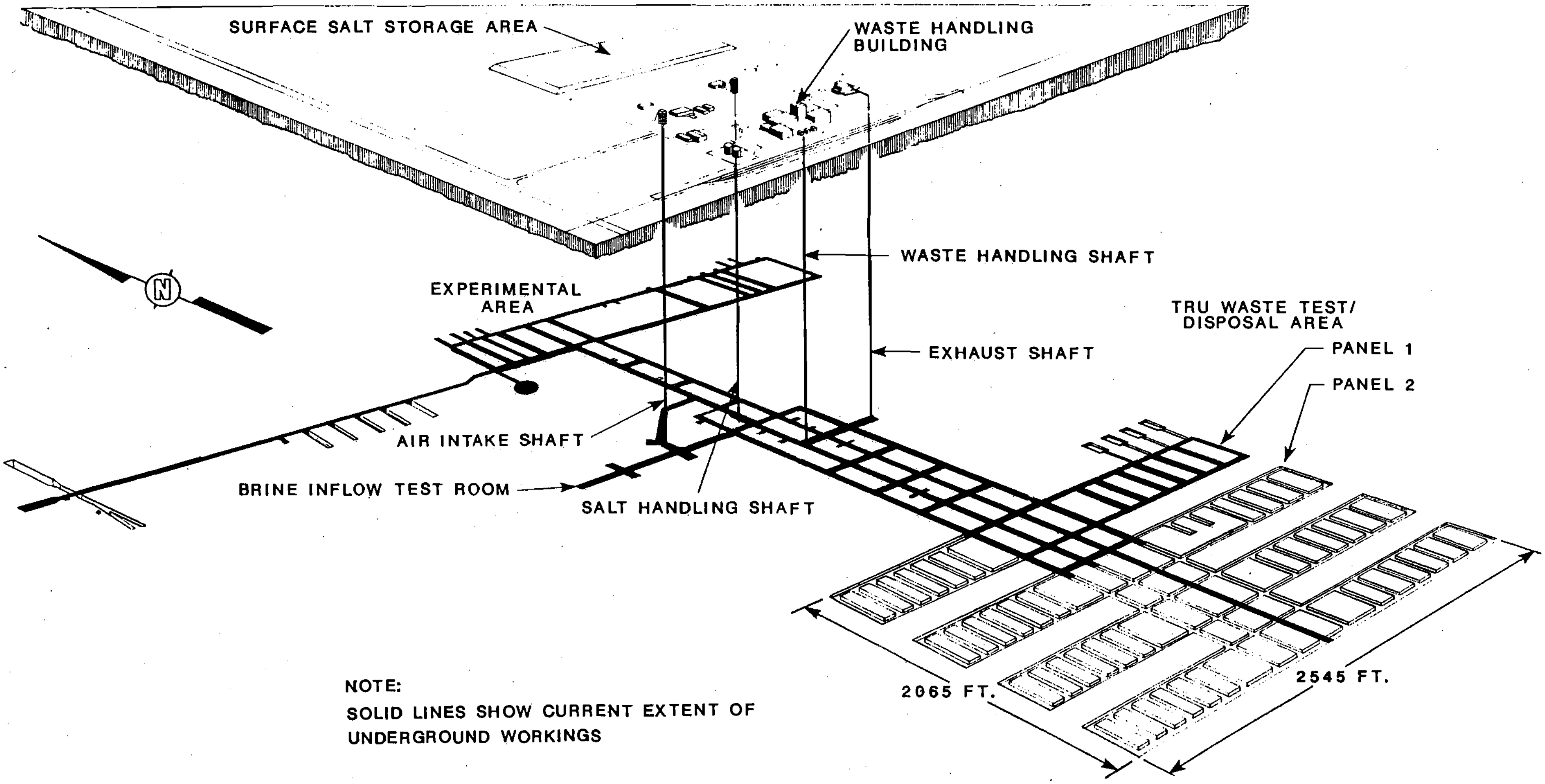
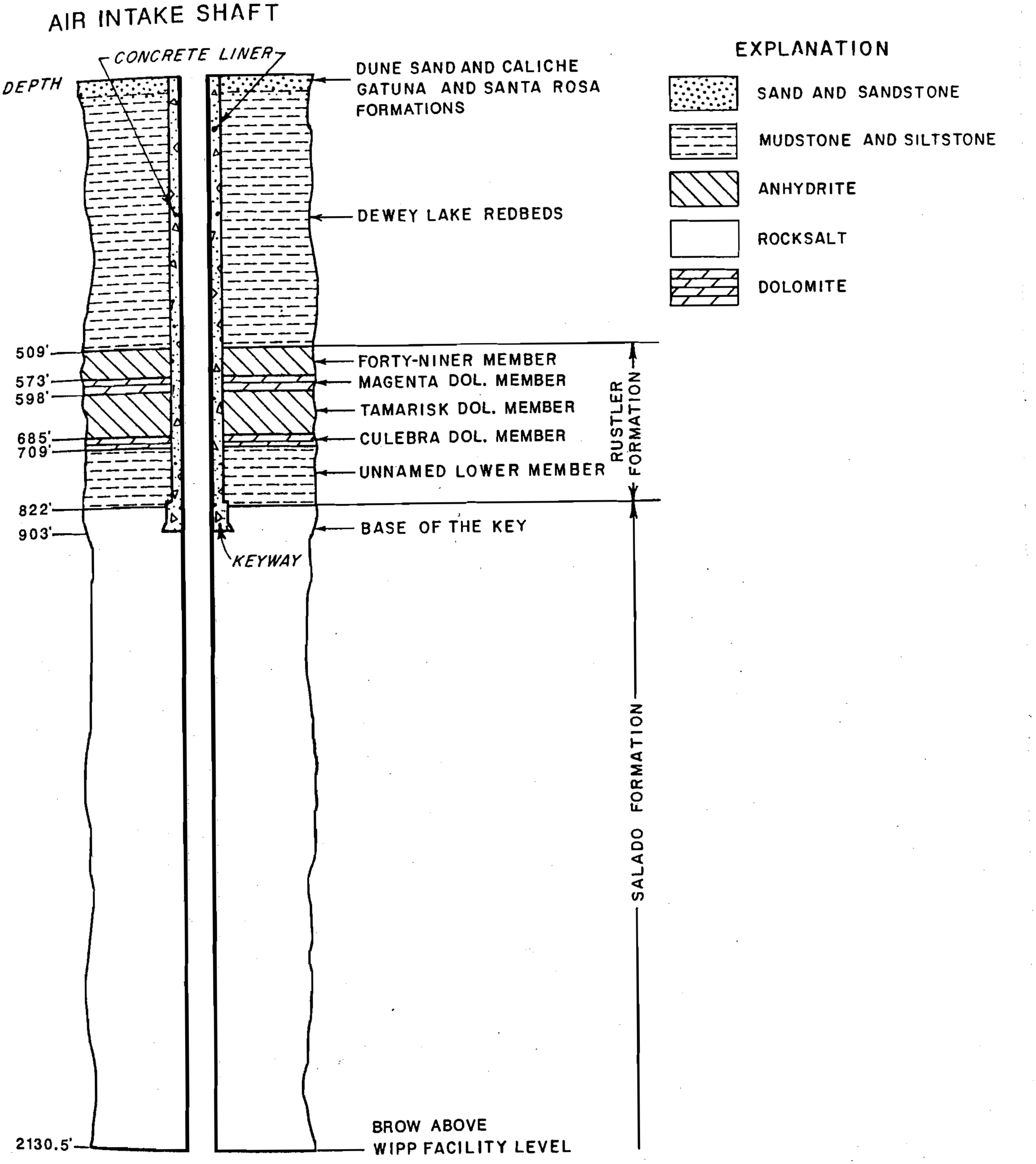


FIGURE 2 AIS LOCATION RELATIVE TO UNDERGROUND WORKINGS

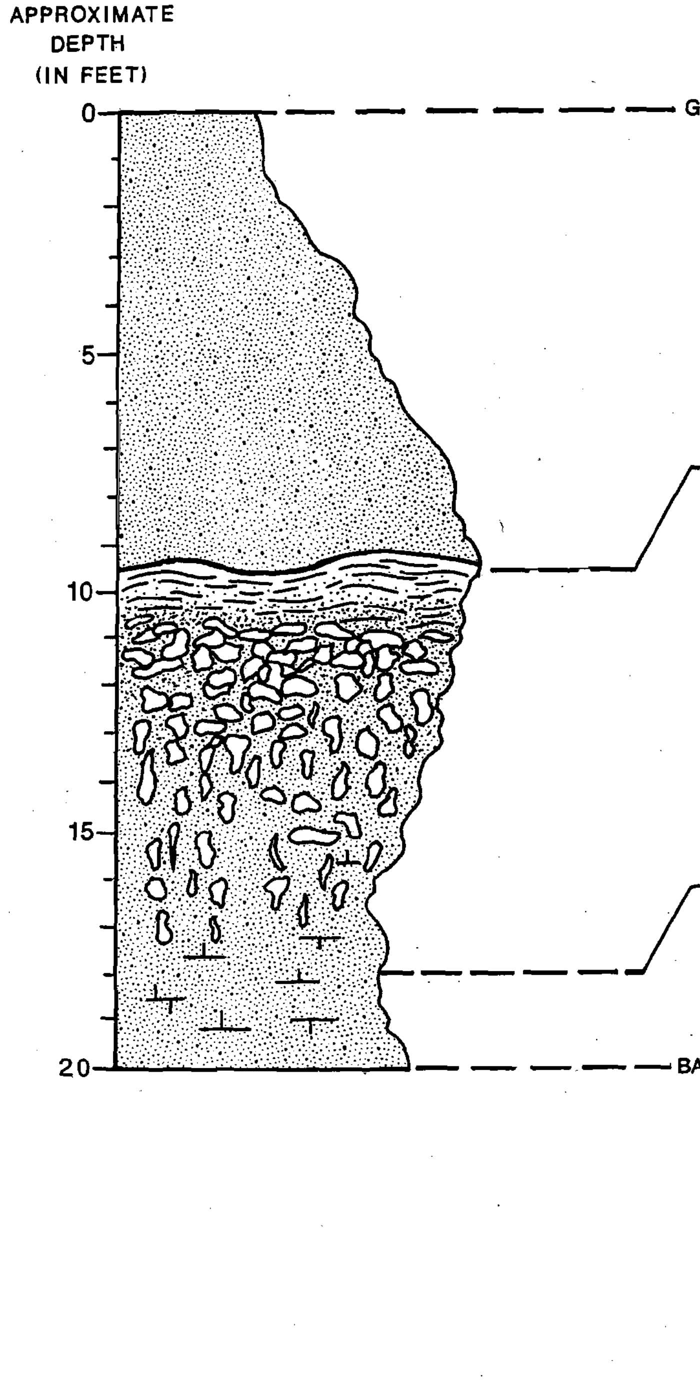


NOTES:

1 ALL ROCKS BELOW SANTA ROSA ARE PERMIAN IN AGE.

2 RUSTLER DEPTHS WERE MEASURED FROM SUBCOLLAR (18.5' BELOW TOP OF CEMENT). KEYWAY AND BROW WERE MEASURED FROM TOP OF CEMENT (ELEV. 3410' ABOVE MSL).

FIGURE [illegible]. GENERALIZED AIR INTAKE SHAFT STRATIGRAPHY



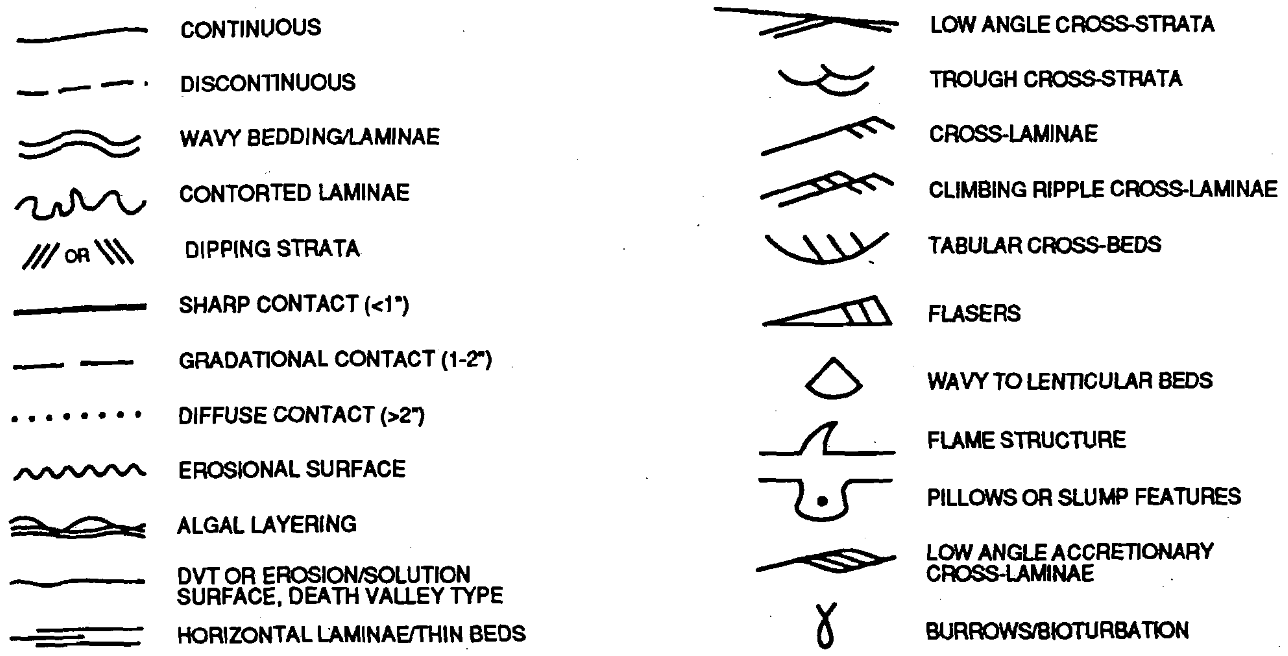
Mescalero Caliche	Caliche with sandstone and sand, color varies fro white (where mostly carbonate) to reddish-brow where mostly sand or sandstone; sand consists o very fine- to medium-sized sand grains, mostl quartz, some dark grains; strength variable fro hard to very soft with the carbonate-rich zones bein hard, locally very friable; the caprock is very hard massive; stringers of carbonate become mor abundant downward; middle portion of the calich contains abundant nodules, nodules become mor abundant downward; becomes less well indurate downward; lower portion consists predominantly o calcareous sandstone with some unconsolidate sand, these zones are often engulfed by whit (calcareous) zones; the base of the excavation is or near the lower (very gradational) contact with th Gatuna Formation.
Lowermost 1-2'	Sandstone, reddish-brown, slightly argillaceou very fine to fine sand sized grains, poorly sorte calcareous, induration variable from moderatel hard to very soft, mostly very friable, contains ligh colored carbonate and dark colored stains, consist of mostly quartz grains, upper contact diffuse.

FIGURE 5

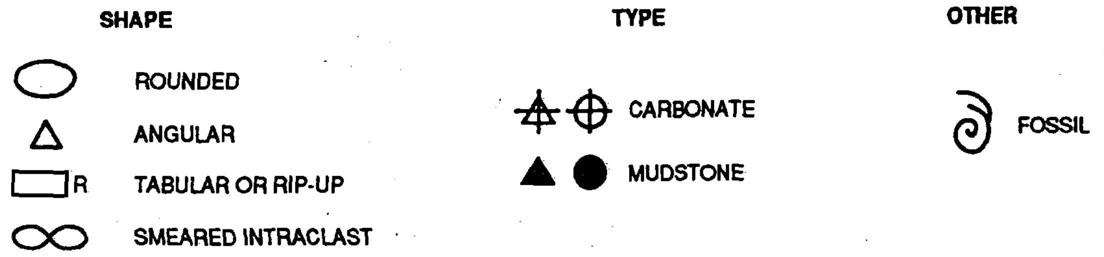
LITHOLOGIC LOG OF THE LINED PORTION OF THE AIR INTAKE SHAFT

EXPLANATION FOR FIGURES 5 AND 23

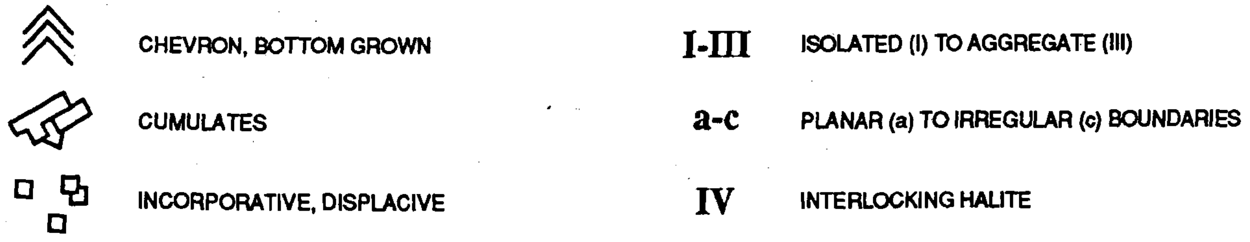
STRATIFICATION TYPES/PRIMARY FEATURES



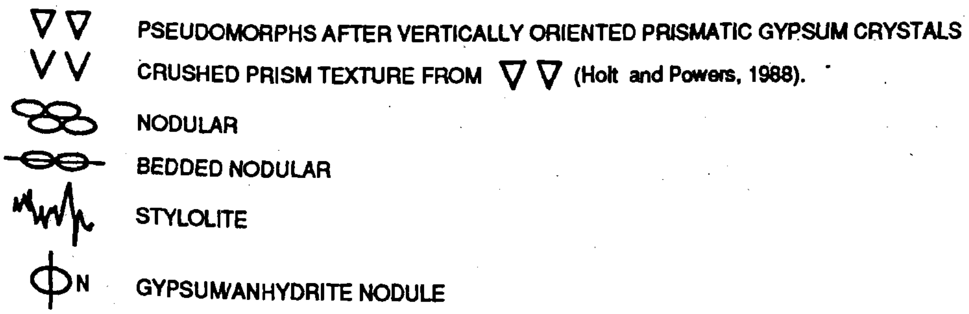
CLASTS



HALITE TEXTURES



SULPHATE TEXTURES



EXPLANATION (CONTINUED)

VUGS/MACROPORES

○V	OPEN VUG	ΦV	GYPSUM-FILLED VUG	⊕V	CALCITE-FILLED VUG	⊕N	HALITE-FILLED VUG

OTHER STRUCTURES

⅃⊏	BOXWORK FABRIC	△◁▶▷	BRECCIA
S	SMEARED LAMINAE		PACKBRECCIA (Morrow, 1982)
⊥⊥⊥	SUBVERTICAL FRACTURES		CRACKLE TEXTURE
//\	FAULT	—/—	SEDIMENTARY FAULT
≈≈	VADOSE-INFLUENCED BEDS		HALITE PODS
⅄⅄	TEEPEE-LIKE STRUCTURES	≋≋	DISH-SHAPED LAMINAE

SIDE NOTES/MODIFIERS

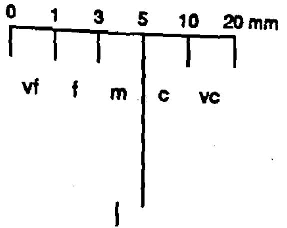
R	RIP-UP CLASTS	**E**	EROSIONAL SURFACE	**St**	ALGAL LAYERING
V	VUGS	**N**	NODULE	**S**	SLICKENSIDES
CF	CLAY-FILLED FRACTURES			**?**	POSSIBLE OR PROBABLE
DVT	DEATH VALLEY TYPE	┃	ZONE OF WEEPS	**e/s**	EROSION/SOLUTION SURFACE

LITHOLOGY

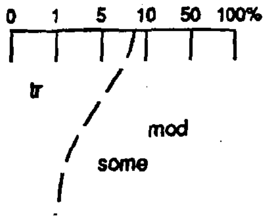
- - -	MUDSTONE/CLAYSTONE	— _ —	ARGILLACEOUS
▬	CLAYSTONE BED		
-·-·	SILTSTONE	—·—·	SILTY
⁙	SANDSTONE	·.·.	SANDY
▧	ANHYDRITE/GYPSUM	\\\\\\	SULFATIC
▦	DOLOMITE	—/—	DOLOMITIC
▤	LIMESTONE	—⊥—	CALCAREOUS
□	HALITE	+ +	HALITIC
▩	POLYHALITE	XX X	POLYHALITIC
⊏⊏⊏	LANGBEINITE		

SCALES/SYMBOLS HALITE/NON-HALITE COLUMN

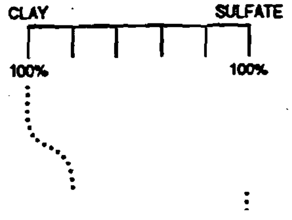
HALITE CRYSTAL SIZE

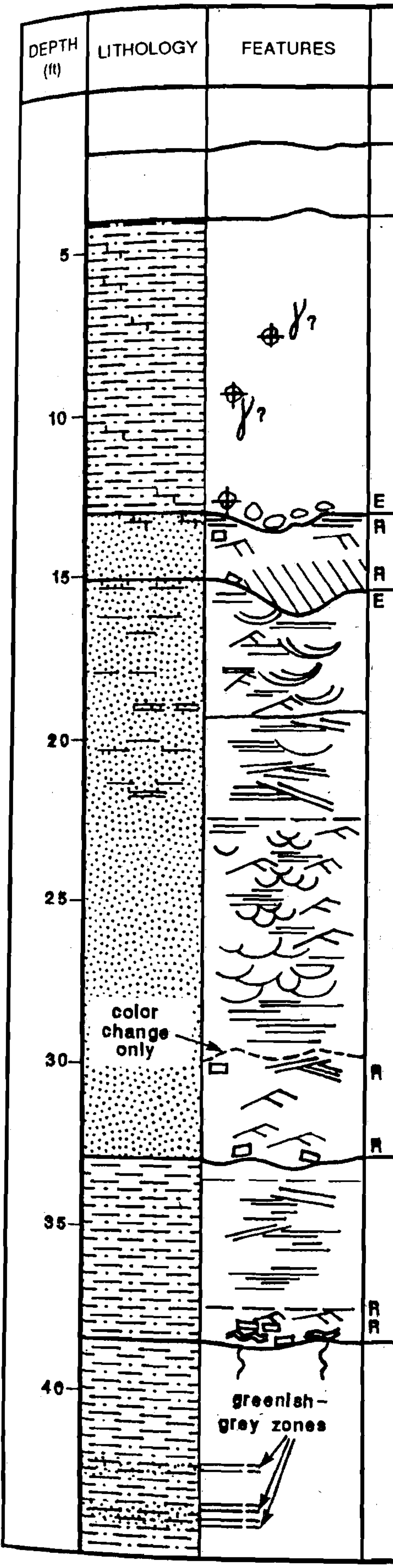


NON-HALITE CONSTITUENTS



RELATIVE PROPORTIONS NON-HALITE CONSTITUENTS





REMARKS

TOP OF SUBCOLLAR CONCRETE
BASE OF SUBCOLLAR CONCRETE

FILL MATERIAL, DARK REDDISH BROWN, MOTTLED; BECOMES LESS DISTURBED DOWNWARD.

GATUNA FORMATION - UNDISTURBED. SANDSTONE, LIGHT RED, MOTTLED, VERY CALCAREOUS, SLIGHTLY ARGILLACEOUS. VERY FINE SAND TO SILT-SIZED GRAINS, SUBANGULAR TO ROUNDED, ESTIMATED 80 PERCENT QUARTZ, 5 PERCENT MAFIC GRAINS, 15 PERCENT OTHER. CARBONATE STRINGERS GENERALLY ORIENTED SUBHORIZONTALLY, CARBONATE CONCRETIONS ARE POSSIBLE ROOT CASTS. SOME CLAYS AND ARGILLACEOUS MATERIAL ARE POSSIBLY TRANSLOCATED; POSSIBLE BIOTURBATION. UNIT LOCALLY CONTAINS CLASTS OF MORE CALCAREOUS, HARDER SANDSTONE (POSSIBLY REWORKED CALICHE CLASTS) AND GREENISH-GRAY CLASTS (POSSIBLY SANTA ROSA FM.). SURFACE OF UNIT IS LOCALLY MOIST AND EXHIBITS NaCl-RICH EFFLORESCENT CRUST; UNIT IS VERY FRIABLE, SOFT. BASAL CONTACT SHARP, EROSIONAL (2 FT RELIEF), OVERLAIN WITH COBBLE-SIZE RIPUPS OF UNDERLYING SANDSTONE AND GRANULE-SIZED RIPUPS OF DARK BROWN CLAYSTONE.

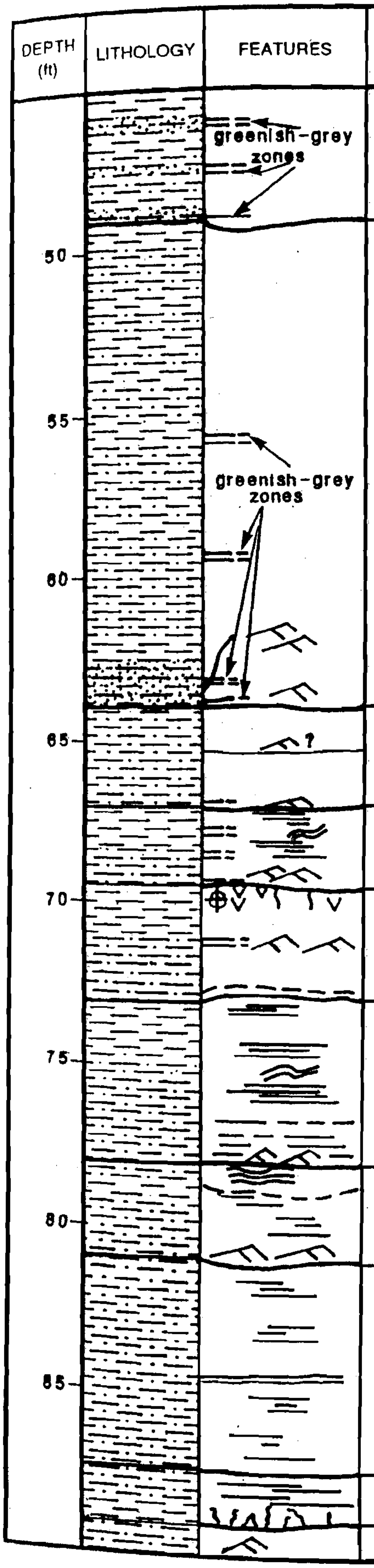
SANTA ROSA FORMATION. SANDSTONE, CALCAREOUS, RED; SILT TO FINE SAND-SIZED GRAINS, 80 PERCENT QUARTZ, 5 PERCENT MAFIC, 15 PERCENT OTHER, GRAINS SUBANGULAR TO ROUNDED. TABULAR CROSS-CUTTING BEDS UP TO 2 FT THICK; UPPER SURFACE BOUNDED BY HARD, VERY CALCAREOUS, VERY THIN BEDS AND CLASTS OF SANDSTONE; DARKER BEDS MAY BE CROSS-LAMINATED; LIGHTER INTERBEDS CONTAIN THIN LAMINAE TO LAMINAE OF CALCAREOUS SANDSTONE PARALLEL TO CROSS-CUTTING SURFACES: CALCITE-RICH UNITS CONTAIN RIPUP CLASTS OF DARK RED SILTSTONE, LOCAL COBBLE-SIZE RIPUP CLASTS OF WELL-CEMENTED SANDSTONE. VERY RARE SUBVERTICAL FRACTURES ARE FILLED WITH CALCITE, LOCAL STRINGERS POSSIBLY DEVELOPED ALONG FRACTURES; UNIT IS SOFT TO MEDIUM HARD. BASAL CONTACT SHARP, EROSIONAL RELIEF OF 2 FT.

SILTY SANDSTONE TO SILTSTONE, DARK REDDISH BROWN (10R3/6), WITH PALE OLIVE (10Y6/2) FROM 30 FT TO BASE; CALCAREOUS; FINE TO MEDIUM AT BASE TO FINE TO VERY FINE SAND GRAINS UPWARD; DOMINANTLY QUARTZ, 1-5 PERCENT MAFIC GRAINS; SOFT TO MODERATELY WELL INDURATED. THINLY LAMINATED TO CROSS-LAMINATED FROM 15-19 FT WITH LOCALLY ABUNDANT TROUGH CROSS-BEDS HAVING TANGENTIAL BOTTOMSETS, TROUGH .1-.3 FT DEEP AND 1 FT WIDE IN A CHANNEL BAR COMPLEX. PLANAR LAMINAE TO LOW ANGLE CROSS-LAMINAE (IN-CHANNEL BARS) FROM 19-22 FT IN SETS <.3 FT HIGH WITH LOCAL ARGILLACEOUS ZONES MARKING TOPS OF SETS. TROUGH CROSS-BEDS FROM 22-28 FT (CHANNEL DEPOSITS) IN SETS .4-.7 FT HIGH, DECREASING IN SIZE UPWARD TO .1-.3 FT SETS INTERBEDDED WITH THIN LAMINAE AND CROSS-LAMINAE. PARALLEL PLANAR, HORIZONTAL TO SUBHORIZONTAL, THIN BEDS TO LAMINAE FROM 28-30 FT, WITH SOME BROAD CROSS-CUTTING SETS (CHANNEL DEPOSITS); UNDULATORY, BUT SHARP, COLOR CHANGE AT ABOUT 30 FT CUTS ACROSS BEDDING; ZONE OF SMALL CLAYSTONE CLASTS (1/4" X 1") AT 30.5 FT; COARSENS DOWNWARD FROM FINE TO MEDIUM SANDSTONE FROM 30.5-33 FT, WITH MINOR SILT AND CLAY. SHARP, EROSIONAL BASE WITH ABOUT 6" RELIEF OVERLAIN BY A FEW REDDISH BROWN CLASTS.

SILTSTONE, ARGILLACEOUS, SLIGHTLY SANDY, FINING UPWARD TO SILTY CLAYSTONE; PALE OLIVE (10Y6/2) IN BASAL 1.5 FT, INTERBEDDED WITH AND OVERLAIN BY DARK REDDISH BROWN (10R3/6) TO VERY DARK REDDISH BROWN (10R3/3) AT TOP, SMALL, GREENISH REDUCTION SPOTS NEAR GRADATION TO CLAYSTONE; VERY CALCAREOUS. BEDDING UNCLEAR NEAR BASE, INTERBEDDED REDDISH BROWN LAYERS IN GREEN ZONE CONSIST OF CLAYSTONE AND CLAYSTONE CLASTS, SMALL (<.1 FT) RIPPLES NEAR TOP OF GREEN ZONE. ABOVE GREEN ZONE, MAINLY HORIZONTAL TO SUBHORIZONTAL LAMINAE WITH LOW ANGLE CROSS-CUTTING BEDS; SUBUNITS ARE UP TO 1 FT THICK, FINE UPWARD INTERNALLY. CLAYSTONE IS WET AND PROBABLY COLLECTING WATER IN OVERLYING SANDSTONE; VARIABLE SALT EFFLORESCENCE ON SHAFT WALLS; MODERATELY WELL INDURATED IN GREEN ZONE, WELL INDURATED TO SOMEWHAT FISSILE NEAR TOP. SHARP BASAL CONTACT.

DEWEY LAKE FORMATION. CLAYSTONE, SILTY AND SANDY, VERY DARK REDDISH BROWN (10R3/3), WITH GRAYISH GREEN (10GY5/2), SLIGHTLY MORE SANDY BEDS NEAR BASE AND GREEN REDUCTION SPOTS NEAR TOP. SLIGHTLY COARSER ZONES AND INTERBEDS ARE VERY CALCAREOUS, WELL INDURATED, AND USUALLY .1-.3 FT THICK AT .3 TO 1 FT INTERVALS. BASAL PART SHOWS FINING UPWARD CYCLES ABOUT .5-1 FT THICK AND INTERBEDDED SILTSTONE AND CLAYSTONE. VERTICAL TO SUBVERTICAL FRACTURES IN UPPER 1-2 FT ARE

AIR INTAKE SHAFT LITHOLOGIC LOG



REMARKS

SPACED 2-5 FT APART AND YIELD SOME WATER; MUCH OF UNIT IS MODERATELY TO POORLY INDURATED AND SLOUGHS 1-2" SLABS; UNIT DIPS ABOUT 2° TO THE NORTH; SURFACE SALT EFFLORESCENCE TO A DEPTH OF 45 FT. BASAL CONTACT IS SHARP.

INTERBEDDED REDDISH BROWN (10R3/5) CLAYSTONE AND SANDY SILTSTONE WITH SOME GRAYISH GREEN (10GY5/2) BANDING (<1") SPACED AT 1-2 FT OVER MUCH OF UNIT. SLIGHTLY CALCAREOUS OR DOLOMITIC IN LOWER 2 FT; UNIT SANDY AT BASE AND BROADLY FINES UPWARD; PROBABLE RIPPLE DRIFT CROSS-LAMINAE AT 62-63 FT, JUST ABOVE SANDY BASE. INTERBED SETS HAVE SHARP, SLIGHTLY UNDULATORY BASAL CONTACTS, FINE UPWARDS SLIGHTLY, AND DECREASE IN THICKNESS FROM 3-6+" IN LOWER PART TO 1-4" UPWARD. SINGLE FRACTURE FROM 62.5-64 FT STRIKES NS-SE, DIPS 70-80° NORTH, THIN CARBONATE FILLING, NO FLUID WEEP; BETTER INDURATED SILTSTONES HAVE VERTICAL TO SUBVERTICAL FRACTURES WHICH DO NOT USUALLY PENETRATE ADJACENT CLAYSTONES; UNIT MODERATELY WELL INDURATED. SHARP BASAL CONTACT. ROCK BOLT TEST AT ABOUT 60.5 FT.

SILTSTONE TO INTERBEDDED ARGILLACEOUS SILTSTONE AND SILTY CLAYSTONE TO CLAYSTONE IN FINING UPWARD SEQUENCE; REDDISH BROWN (10R3/5-4/5) THROUGHOUT, GREENISH REDUCTION SPOTS NEAR BASE. BASAL UNIT THINLY BEDDED TO LAMINAR WITH A FEW MICRO CROSS-LAMINATED BEDS. INTERBEDDED ZONE IS PSEUDOFISSILE TO RIPPLE CROSS-LAMINATED. UNIT IS MODERATELY WELL INDURATED, HARD CALCAREOUS ZONE 3" THICK OCCURS AT TOP OF BASAL SILTSTONE. BASAL CONTACT IS SHARP AND PLANAR.

SILTSTONE TO SILTY CLAYSTONE IN FINING UPWARD UNIT. STRUCTURELESS (?) 8" BASAL SILTSTONE IS OVERLAIN BY ARGILLACEOUS SILTSTONE 3" THICK WITH ABUNDANT RIPPLE CROSS-LAMINAE. UPPER 1.5 FT IS LAMINAR TO SLIGHTLY UNDULOSE BEDDING. TWO THIN GREENISH ZONES IN UPPER 2 FT. MEDIUM WELL INDURATED. SHARP BASAL CONTACT.

SILTSTONE TO SILTY CLAYSTONE SIMILAR TO 67-69.5 FT. UPTURNED ZONES OF BEDDING NEAR TOP MAY BE DESICCATION CRACKS 6"-1 FT HIGH. GRAYISH GREEN (10GY5/2) SILTSTONE WITH RIPPLED SURFACE AT MIDUNIT. VUGGY CALCITE AT TOP OF BASAL 8" SILTSTONE. MEDIUM WELL INDURATED. SHARP BASAL CONTACT.

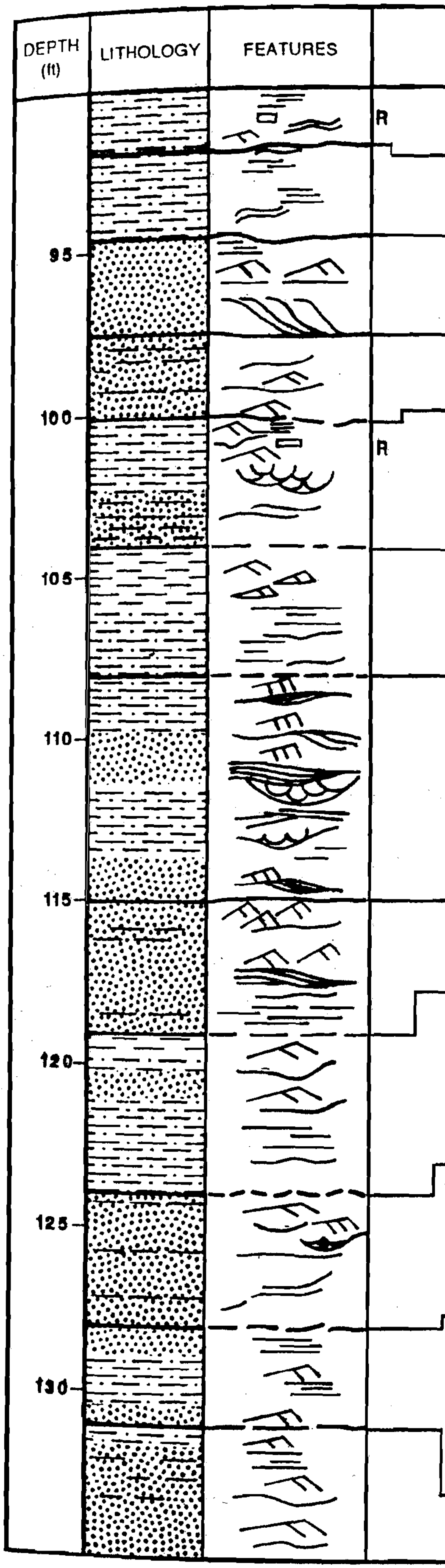
SILTSTONE TO SILTY CLAYSTONE SIMILAR TO 67-69.5, WITH TWO THINNER SILTSTONES AT AND NEAR BASE; REDDISH BROWN (10R3/5), WITH TWO THIN GRAYISH GREEN ZONES. SOME RIPPLE CROSS-LAMINAE IN BASAL SILTSTONES; UNDULATORY BEDDING TO LAMINAE AND THIN BEDS IN SILTY CLAYSTONE; SOME TABULAR INTRACLASTS IN SILTY CLAYSTONES. SILTSTONES ARE SLIGHTLY CALCAREOUS, WELL INDURATED. CLAYSTONES ARE POORLY TO MODERATELY WELL INDURATED. SHARP BASAL CONTACT.

SANDY ARGILLACEOUS SILTSTONE GRADING TO SILTY CLAYSTONE, REDDISH BROWN (10R3/5). FAINT BEDDING, LAMINAE AND POSSIBLY SOME MICRO CROSS-LAMINAE NEAR BASE, LAMINAR TO THINLY BEDDED AND SLIGHTLY UNDULOSE AT TOP. VERY WELL INDURATED. SHARP BASAL CONTACT.

SILTY CLAYSTONE WITH THIN SCATTERED INTERBEDS OF ARGILLACEOUS SILTSTONE, REDDISH BROWN WITH SCATTERED GRAYISH GREEN IRREGULAR ZONES. LAMINAR AND THIN BEDDING, SOME UNDULATORY SURFACES. ZONE OF POSSIBLE NODULAR CALCITE AT TOP. THIN SILTSTONES ARE CALCAREOUS AND WELL INDURATED, CLAYSTONE RANGES FROM POORLY LITHIFIED, SOFT, TO MODERATELY WELL INDURATED. SHARP BASAL CONTACT.

CLAYSTONE GRADING TO ARGILLACEOUS SILTSTONE, REDDISH BROWN (10R3-4/5), WITH ABUNDANT GREENISH REDUCTION SPOTS. LAMINAR TO THIN BEDDING WITH SLIGHT UNDULATIONS. BASAL 8" INTENSELY FRACTURED. POORLY INDURATED. SHARP BASAL CONTACT. ROCK BOLT TEST LOCATION.

SILTSTONE WITH MINOR INTERBEDDED CLAYSTONE FINING UPWARD TO ARGILLACEOUS SILTSTONE, LIGHT GREENISH GRAY (5G8/1) IN TWO ZONES NEAR TOP AND DOMINATES NEAR BASE, MODERATE BROWN TO REDDISH BROWN (5YR3/4 TO 10R3/5) UPWARDS. THINLY LAMINATED TO THINLY BEDDED WAVY STRATA WITH THIN (4-8") FINING UPWARD CYCLES



DRAPED WITH CLAYSTONE CONTAINING RIPUP CLAYSTONE CLASTS; SOME RIPPLE MARKS IN UPPER PART. LOCAL SUBVERTICAL FRACTURES WITH CALCITE FILLINGS. POORLY TO MODERATELY WELL INDURATED. SHARP BASAL CONTACT.

SILTSTONE WITH MINOR AMOUNTS OF INTERBEDDED CLAYSTONE, FINES UPWARD. MODERATE BROWN (5YR3/4) WITH VERY PALE GREEN (5G8/1) REDUCTION SPOTS. WAVY THIN LAMINAE TO THIN BEDS. MODERATELY WELL INDURATED, WET SURFACE. LOWER CONTACT SHARP.

SANDSTONE, MODERATE BROWN TO MODERATE REDDISH BROWN (5YR3/4-10R4/6), LOCALLY LIGHT GREENISH GRAY (5G8/1) NEAR BASE. 2 FT THICK SET OF CROSS-LAMINAE IN LOWER 2 FT; RIPPLE CROSS-LAMINAE AND LAMINAE IN UPPER 1 FT. CALCITE LINING IN LOCAL FRACTURES; MODERATELY WELL INDURATED. SHARP BASAL CONTACT.

SANDSTONE INTERBEDDED WITH MINOR AMOUNTS OF SILTSTONE AND CLAYSTONE; MODERATE BROWN (5YR3/4). INTERBEDS 2-8" THICK, SOME CHANNELLING ON UPPER AND INTERNAL SURFACES, LOCAL RIPPLE CROSS-LAMINAE. SHARP TO INDISTINCT BASAL CONTACT.

SILTSTONE INTERBEDDED WITH CLAYSTONE, SANDY NEAR BASE; FINES UPWARD; MODERATE BROWN TO MODERATE REDDISH ORANGE (5YR3/4 TO 10R6/6), INTERBEDDED LIGHT GREENISH GRAY (5G8/1) AT 104 AND 102 FT. SMALL CHANNELS (3" X 24") WITH TROUGH CROSS-LAMINAE, SMALL UPWARD FINING SEQUENCES WITH RIPPLED TOPS AND CLAYSTONE RIP-UP CLASTS, THINLY BEDDED TO LAMINATED NEAR TOP, MINOR TROUGH NEAR TOP. MODERATELY WELL INDURATED. GRADATIONAL LOWER CONTACT.

CLAYSTONE INTERLAMINATED WITH MINOR AMOUNTS OF SILTSTONE, FINES UPWARD, MODERATE BROWN WITH MINOR MODERATE REDDISH BROWN (5YR3/4-10R4/6). LOCAL LIGHT GREENISH-GRAY INTERBEDS AT 105.5, 107, 108 FT. MICROLAMINAE TO LAMINAE, WAVY, LOCAL RIPPLES WITH CLAY DRAPE, LOCAL ABUNDANT FLASERS OF RIPPLED SILTSTONE. MODERATELY WELL INDURATED, POSSIBLY SLIGHTLY FISSILE. GRADATIONAL BASAL CONTACT.

SANDSTONE AND SILTSTONE INTERBEDDED WITH MINOR AMOUNTS OF SILTSTONE; FINES UP. PALE REDDISH-BROWN TO MODERATE REDDISH BROWN (10R5/4-4/6) WITH LOCAL ZONES AND SPOTS OF LIGHT GREENISH GRAY (5G8/1). THIN LAMINAE TO THIN BEDS; STRUCTURES DOMINATED BY BAR AND CHANNEL FORMS; LOW ANGLE CROSS-LAMINAE ACCRETED ON BAR EDGES, SETS 2-3" BY 5+ FT, UPPER SURFACES OF BARS EROSIONAL TRUNCATING UNDERLYING STRATA, STRATA THICKEN OVER EROSIONAL DEPRESSIONS ON BAR TOPS, UPPER PARTS OF BARS SHOW SOME RIPPLE CROSS-LAMINAE; TROUGH CROSS-LAMINAE IN CHANNELS, SETS 3-4" HIGH. 1 FT DEEP CHANNEL NEAR 110 FT IS 5 FT WIDE, SHOWS TROUGH CROSS-LAMINAE AT BASE AND LOW ANGLE CROSS-LAMINAE (FROM LATERAL ACCRETION ON ADJACENT BAR) AT TOP. SHAFT SURFACE MOIST, HAS EFFLORESCENT CRUST. LOWER CONTACT SHARP.

SANDSTONE INTERBEDDED WITH MINOR SILTSTONE, MODERATE REDDISH BROWN (10R4/6). THIN LAMINAE TO LAMINAE, FLAT, OVERLAIN BY LOCALLY ABUNDANT CROSS-LAMINAE IN SETS 1/2-1" THICK; LOCAL PLANAR CROSS-LAMINAE LATERALLY ACCRETED ON BAR FORM. VERY WELL INDURATED. GRADATIONAL BASAL CONTACT.

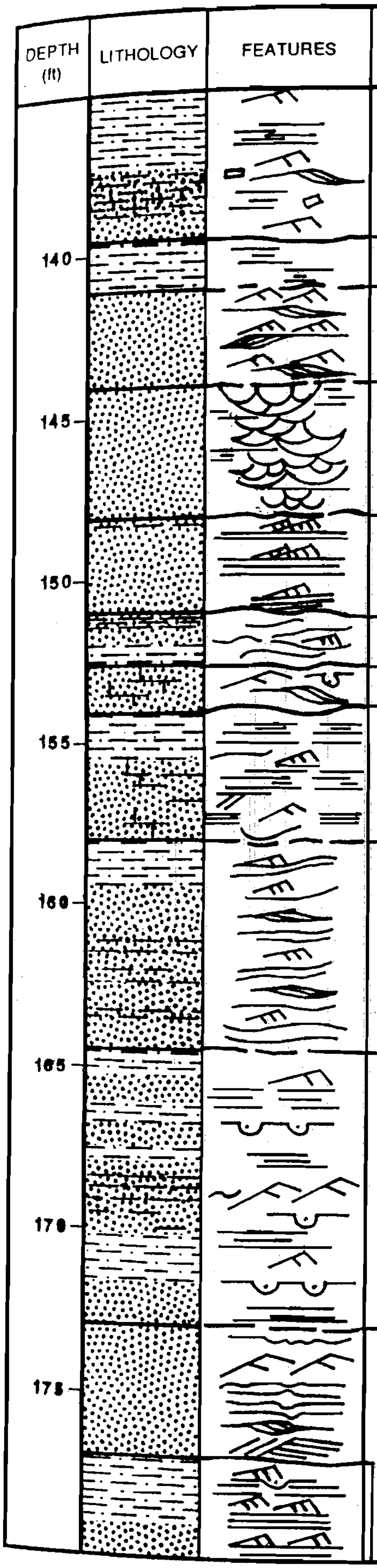
MUDSTONE AND CLAYSTONE WITH MINOR SANDSTONE, MODERATE BROWN (5YR3/4). THIN LAMINAE TO THIN BEDS, MOSTLY FLAT STRATA, SOME WAVY; LOCAL RIPPLE FORMS WITH CLAY DRAPE; SANDSTONE ZONES SHOW SOME RIPPLE CROSS-LAMINAE; TROUGHS/CHANNELS 2-4" DEEP BY 5+ FT LONG LOCALLY CUT INTO UNDERLYING UNITS, FILLED WITH SANDSTONE; SEQUENCES FINE UPWARD. LIGHT GREENISH GRAY (5G8/1) INTERBEDS ALONG SOME CHANNEL BOTTOMS AND BEDDING PLANES. ROCK NEARLY FISSILE, WEAK, SPALLS IN SOME AREAS. UNIT IS VERY FRACTURED WITH OPEN SUBVERTICAL FRACTURES SPACED 1-2", MOST TREND ABOUT EAST-WEST, MANY CALCITE LINED. SHARP BASAL CONTACT.

INTERBEDDED SANDSTONE AND CLAYSTONE, CLAYSTONE ALSO AT TOP; MODERATE BROWN TO MODERATE REDDISH BROWN (5YR3/4, 10R4/6). THIN LAMINAE TO THIN BEDS; LOCAL CHANNELS NEAR 125 FT ARE 2-4" DEEP BY 5+ FT LONG, FILLED WITH SANDSTONE WITH TROUGH-SHAPED LAMINAE AND SOME CROSS-LAMINAE; CLAYSTONE IS LOCALLY ERODED. SUBVERTICAL FRACTURES IN CLAYSTONE ARE OPEN TO CALCITE LINED. CLAYSTONE IS FISSILE AND WEAK, SANDSTONE MODERATELY WELL INDURATED. LOWER CONTACT IS SHARP TO GRADATIONAL.

SILTSTONE; UNIT GENERALLY FINES UPWARD FROM SANDSTONE AT BASE TO SILTSTONE, BECOMING SANDY AT TOP; MODERATE BROWN TO MODERATE REDDISH BROWN (5YR3/4, 10R4/6) WITH SOME LIGHT GREENISH GRAY (5G8/1) INTERBEDS AND REDUCTION SPOTS. THIN LAMINAE TO THIN BEDS, FLAT, WAVY; LOCAL RIPPLES AND RIPPLE CROSS-LAMINAE, RIPPLES MOSTLY ASYMMETRICAL, MANY WITH STOSS SIDE PRESERVATION, CLAYSTONE DRAPE ON RIPPLES; CROSS-LAMINAE SETS .25-.5" BY 1-3". FRACTURES AS ABOVE; DARK BLACK STAIN ON FRACTURES. UNIT MODERATELY WELL INDURATED. GRADATIONAL TO SHARP BASAL CONTACT.

SANDSTONE FINING UPWARD TO SILTSTONE, SIMILAR TO OVERLYING UNIT. STRUCTURES AND TEXTURES SIMILAR TO OVERLYING UNIT, BUT LESS FRACTURED. 4" THICK SANDSTONE-SILTSTONE SEQUENCE AT TOP. MEDIUM WELL INDURATED. GRADATIONAL BASAL CONTACT.

AIR INTAKE SHAFT LITHOLOGIC LOG



REMARKS

SANDSTONE AT BASE GRADING TO SANDY SILTSTONE AT TOP, SMALLER FINING UPWARD SEQUENCES WITHIN UNIT. MODERATE BROWN TO MODERATE REDDISH BROWN (5YR/3/4 TO 10R4/6) WITH LIGHT GREENISH GRAY (5G8/1) INTERBED AND REDUCTION SPOTS. THIN LAMINAE TO THIN BEDS, LOCALLY CROSS-LAMINATED, SHALLOW (<3") SCOUR TROUGHS, CROSS-LAMINATED RIPPLE SETS, LAMINAE WAVY AND CONTINUOUS, POSSIBLE DUNE-SIZED LATERAL ACCRETION SURFACES, LOW ANGLE CROSS-CUTTING RELATIONSHIPS, LOCAL RIPUP CLASTS. MINOR FRACTURES, CALCITE LINES SUBHORIZONTAL FRACTURES. UNIT SLIGHTLY CALCAREOUS, LOCALLY MODERATELY WELL INDURATED. SHARP BASAL CONTACT.

SILTSTONE, MODERATE BROWN (5YR3/4) WITH LOCAL LIGHT GREENISH GRAY (5G8/1) REDUCTION SPOTS. THINLY LAMINATED, FLAT. THIN, CALCITE-LINED FRACTURES ARE ABUNDANT. LOWER CONTACT SHARP TO GRADATIONAL.

SANDSTONE, MODERATE REDDISH BROWN (10R4/6) WITH MINOR MODERATE BROWN (5YR3/4), 4" THICK LIGHT GREENISH-GRAY (5G8/1) AT TOP, THIN LAMINAE TO THIN BEDS. CONSISTS OF REPETITIVE CHANNEL BAR PACKAGES; LOWER PART OF EACH CHANNEL BAR PACKAGE EXHIBITS TANGENTIAL LOW ANGLE CROSS-LAMINAE, SETS 2-3" THICK BY 4+ FT WIDE; UPPER PART RIPPLE CROSS-LAMINAE, SETS 1-3" THICK; COMBINED THICKNESS OF EACH PACKAGE 4-6". RARE VERTICAL CALCITE-FILLED FRACTURES TO 1/16" THICK. LOWER CONTACT GRADATIONAL.

SANDSTONE, MODERATE REDDISH BROWN (10R4/6). THIN LAMINAE TO THIN BEDS, WAVY. TROUGH CROSS-LAMINATIONS; ABUNDANT CROSS-CUTTING EROSIONAL TROUGHS AND CHANNELS (2-4" DEEP X 3-5+ FT LONG), LOWER CONTACTS SHARP AND EROSIONAL ON CLAYSTONE. CALCITE-FILLED FRACTURES ARE VERTICAL AND SUBVERTICAL TO SUBHORIZONTAL. SHARP BASAL CONTACT.

SANDSTONE, MODERATE REDDISH BROWN (10R4/6). 1" CLAYSTONE AT TOP. THIN LAMINAE TO THIN BEDS, FLAT TO SLIGHTLY WAVY; RIPPLE CROSS-LAMINAE (SETS TO 1" HIGH), LOCAL RIPPLE DRIFT CROSS-LAMINAE WITH STOSS SIDE PRESERVATION; RIPPLES (ANTIDUNES?) OVERLIE PLANE LAMINAE IN SEQUENCES 8-12" THICK. RARE SUBVERTICAL FRACTURES FILLED WITH CALCITE. MODERATELY WELL INDURATED. LOWER CONTACT SHARP, EROSIONAL, UNDULATORY.

SILTSTONE INTERBEDDED WITH SANDSTONE, MODERATE REDDISH BROWN TO MODERATE BROWN (10R4/6-5YR 3/4). SANDSTONE OCCURS IN LENTICULAR BEDS 5-10 FT ACROSS BY UP TO 8" THICK; SILTSTONE IS THINLY LAMINATED, LOCALLY WAVY TO FLAT; SANDSTONE CROSS-LAMINATED SETS TO 1/2", COSETS 1-2". SILTSTONE CONTAINS ABUNDANT CALCITE-FILLED FRACTURES OF VARIABLE ORIENTATION. UNIT CALCAREOUS, MODERATELY WELL INDURATED. MOIST EFFLORESCENT CRUST. LOWER CONTACT IS SHARP.

SANDSTONE, LIGHT GREENISH GRAY (5G8/1). CROSS-LAMINAE WITH TANGENTIAL BASES, SETS 3-4" BY 3-5+ FT, TOPPED BY RIPPLE CROSS-LAMINAE, COSETS ABOUT 8" THICK. LOCALLY SHOWS SOFT SEDIMENT DEFORMATION IN PILLOW STRUCTURES, PALEOCURRENTS TO NORTH. CALCAREOUS, MOIST, EFFLORESCENT CRUST. LOWER CONTACT EROSIONAL, 1.5 FT RELIEF.

SANDSTONE FINING UPWARD TO MUDSTONE WITH MINOR SILTSTONE, ARGILLACEOUS, MODERATE BROWN (5YR3/4) WITH REDUCTION AREAS OF LIGHT GREENISH GRAY (5G8/1). THIN LAMINAE TO THIN BEDS (BECOMING MORE COMMON DOWNWARD); WAVY STRATA, LOCAL SCOURS AND RIPPLE CROSS-LAMINAE, LOW ANGLE TANGENTIAL CROSS-LAMINAE SETS LESS THAN 1/2" THICK; CROSS-LAMINAE MORE ABUNDANT AT BASE, THIN LAMINAE TO THIN BEDS DOWNWARD; SILTSTONE OCCURS AS WAVY INTERLAMINAE AND RIPPLES (FLASERS); CLAYSTONE IS THINLY LAMINATED, WAVY, SOFT, MOIST WITH EFFLORESCENT CRUST. CALCITE-FILLED FRACTURES TO 1/16" THICK, SMALL DISPLACEMENTS, VARIOUS ORIENTATIONS. UNIT SOFT. LOWER CONTACT SHARP TO GRADATIONAL.

INTERBEDDED SANDSTONE, SILTSTONE, AND MUDSTONE, MODERATE REDDISH BROWN TO MODERATE BROWN (10R4/6 TO 5YR3/4) WITH LIGHT GREENISH GRAY (5G8/1) REDUCTION SPOTS. CONSISTS OF FINING UPWARD SEQUENCES 1-12" THICK WITH SANDSTONE AT BASE; ENTIRE SEQUENCE FINES UPWARD; THIN LAMINAE TO THIN BEDS, WAVY; LOW ANGLE TANGENTIAL CROSS-LAMINATED SETS LESS THAN 1" THICK, RIPPLE CROSS-LAMINAE. SUBVERTICAL FRACTURES WITH DISPLACEMENTS TO 1". MOIST. CALCAREOUS, NO GYPSUM. BASAL CONTACT SHARP TO GRADATIONAL.

SANDSTONE AND SILTSTONE, MODERATE REDDISH BROWN (10R4/6), LIGHT GREENISH GRAY (5G8/1) REDUCTION SPOTS AND ZONES. THIN LAMINAE TO THIN BEDS, FLAT TO WAVY; RIPPLE CROSS-LAMINAE. ABUNDANT SLUMP FEATURES. HARD UPPER CONTACT MARKED BY FIRST OCCURRENCE OF GYPSUM-FILLED FRACTURES. NON-CALCAREOUS, NOT MOIST. ABUNDANT GYPSUM-FILLED FRACTURES TO 2" THICK, SPACING: HORIZONTAL LARGE FRACTURES ARE 4-12" AND MOST ABUNDANT, VERTICAL SPACED 5+ FT. HARD. BASAL CONTACT GRADATIONAL.

SANDSTONE, VERY LIGHT GRAY (N8) TO MODERATE BROWN (5YR3/4). THIN LAMINAE TO THIN BEDS, MOSTLY FLAT, SOME WAVY; RIPPLES ABUNDANT, SOME RIPPLE CROSS-LAMINAE; LOCAL CLAY DRAPE OVER RIPPLES; CROSS BEDDED BELOW RIPPLES, LOW ANGLE FORESETS WITH

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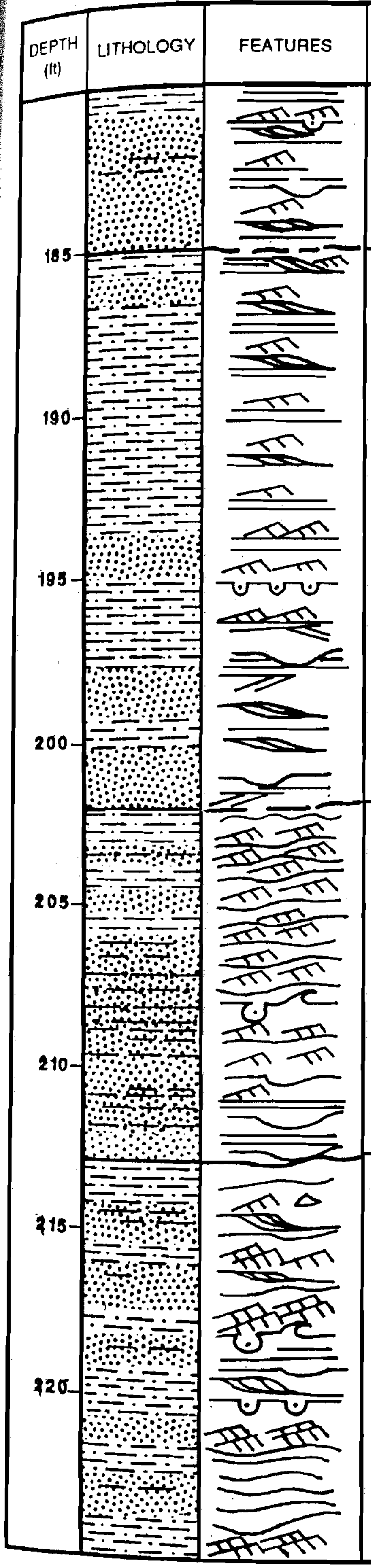
FIGURE 5



REMARKS

TANGENTIAL BASE AND SETS 3-8" THICK. ABUNDANT GYPSUM-FILLED FRACTURES TO 1/2" THICK, AVERAGE 1/8"; HORIZONTAL BIFURCATING FRACTURES SPACED 1-3"; SUBVERTICAL FRACTURES SPACED 2-5 FT. SHARP BASAL CONTACT.

SANDSTONE FINING UPWARD TO INTERBEDDED SANDSTONE AND SILTSTONE, MODERATE BROWN TO MODERATE REDDISH BROWN (5YR3/4 TO 10R4/6) WITH LIGHT GREENISH GRAY (5G8/1) BASAL CONTACT ZONE AND REDUCTION SPOTS. THIN BEDS TO THIN LAMINAE; SEQUENCES OF FLAT LAMINAE OVERLAIN BY RIPPLE LAMINAE AND RIPPLE CROSS-LAMINAE 2-8" THICK; FLAT LAMINATED SECTION IS LOCALLY ABSENT AND REPLACED BY STRUCTURELESS THIN BED; FLAT LAMINATED ZONE MAY CONTAIN LOW ANGLE CROSS LAMINAE WITH TANGENTIAL BASES; RIPPLE SETS TO 1" BY 4", COSETS OFTEN 2" THICK. LOCAL TROUGH-LIKE FORMS WITH LATERAL TO ACCRETION CROSS-LAMINAE DOWNWARD, SETS TO 4" BY 3+ FT, FLAT STRATA LOCALLY WAVY. LOCAL LOAD/PILLOW STRUCTURES, SOFT SEDIMENT DEFORMATION AT BASE OF RIPPLED ZONES. GYPSUM FILLED FRACTURES TO 2" THICK: HORIZONTAL SPACING 1-4 FT, VERTICAL SPACING 10+ FT, SUBVERTICAL 1-5 FT. LOWER CONTACT SHARP TO GRADATIONAL.

INTERBEDDED SILTSTONE AND VERY FINE GRAINED SANDSTONE, FINING UPWARD, MODERATE REDDISH BROWN TO MODERATE BROWN (10R4/6 TO 5YR3/4), WITH LIGHT GREENISH GRAY (5G8/1) REDUCTION SPOTS AND SUBHORIZONTAL ZONES. INTERBEDS OF ARGILLACEOUS SILTSTONE BETWEEN 192-194 FT; THIN LAMINAE TO THIN BEDS; CONSISTS OF SEQUENCES 6" TO 2 FT THICK OF FLAT TO WAVY LAMINAE OFTEN OVERLAIN BY LOW ANGLE TANGENTIAL CROSS-LAMINAE (SETS TO 3" THICK) OVERLAIN BY RIPPLE CROSS-LAMINATED SETS TO 1" HIGH; SEQUENCE MAY SHOW LATERAL RELATIONSHIPS WITH TABULAR FLAT LAMINATED ZONE ADJACENT TO ACCRETED UNITS WHICH ARE ADJACENT TO RIPPLE CROSS LAMINAE; RIPPLE CROSS-LAMINAE SETS TO 2", MORE ABUNDANT BELOW 194 FT; SCOURS WITH TROUGH FORMS ABUNDANT BELOW 197 FT. ALL TRANSITIONS USUALLY BOUNDED BY EROSIONAL SURFACES. PILLOWS, SOFT SEDIMENT DEFORMATION NEAR 195 FT. MORE INTENSELY FRACTURED THAN OVERLYING UNIT; GYPSUM-FILLED FRACTURES TO 2" THICK: HORIZONTAL SPACING 2" TO 1 FT (MOST ABUNDANT), VERTICAL FRACTURES 4-10 FT SPACING, SUBVERTICAL FRACTURES 6" TO 5 FT; IRREGULAR DISTRIBUTION OF FRACTURES IN UPPER 3 FT. GRADATIONAL LOWER CONTACT.

SANDSTONE INTERBEDDED WITH SILTSTONE AND MUDSTONE AS FINING UPWARD SEQUENCES 4" - 1 FT THICK; UNIT FINES UPWARD OVERALL. MODERATE BROWN TO MODERATE REDDISH BROWN (5YR3/4-10R4/6) WITH LIGHT GREENISH GRAY (5G8/1) REDUCTION SPOTS AND ZONES. THIN LAMINAE TO THIN BEDS; FLAT TO WAVY LAMINAE IN LOWER PART; RIPPLE CROSS-LAMINAE SETS TO 1-2" THICK BY 4-6" WIDE, TOPS OF SEQUENCES DRAPED WITH CLAY; SCOUR SURFACES ARE ABUNDANT IN LOWER RIPPLED PART OF SEQUENCE. SANDSTONE CONTAINS THIN TABULAR (1/4" BY 2") RIPUP CLASTS OF MUDSTONE. FINER GRAINED UPPER PART OF SEQUENCES BECOMES THICKER DOWNWARD. SOFT SEDIMENT DEFORMATION AS SMALL PILLOWS AND SOUTHWARD TRENDING FLAME STRUCTURES OCCUR IN SANDIER PARTS OF SEQUENCES. GYPSUM FRACTURES TO 1": HORIZONTAL SPACING 1"-4"; VERTICAL FRACTURES SPACED 3-10 FT, SUBVERTICAL 1-3 FT. LOWER CONTACT SHARP.

INTERBEDDED VERY FINE SANDSTONE AND SILTSTONE IN FINING UPWARD SEQUENCES GENERALLY 8" TO 2 FT THICK; UPPER 0.5 FT SILTSTONE; MODERATE BROWN (10R3/4). SMALL SCOUR CHANNELS TO 3" DEEP, FILLED WITH LOW-ANGLE CROSS-LAMINATED SETS 1-2" HIGH BY 10+" LONG WITH TANGENTIAL BASES, OVERLAIN BY LOW-ANGLE CROSS-LAMINATED SETS 1" HIGH AND PLANAR TO WAVY LAMINAE; OVERLAIN BY LOW-ANGLE CLIMBING RIPPLES (SETS 1" HIGH BY 6-10" LONG). LOCAL SEQUENCES WITH FLAT TO WAVY LAMINAE TO LOW-ANGLE TANGENTIAL CROSS-LAMINAE WITH SMALL SCOURS ARE OVERLAIN BY ZONES WITH SOFT SEDIMENT DEFORMATION (PILLOWS AND LOCAL FLAME STRUCTURES) OVERLAIN BY LOW-ANGLE CLIMBING RIPPLES. A REVERSAL OF THIS SEQUENCE OCCURS AT 220 FT. SILTSTONE AT TOP OF UNIT POSSIBLE OVERBANK DEPOSIT. LOCAL INTERNAL EROSIONAL SURFACES MAY HAVE 1+ FT RELIEF. GYPSUM-FILLED FRACTURES TO 2" THICK: HORIZONTAL 1/4-3" SPACING, VERTICAL 4-10 FT, SUBVERTICAL 1-5 FT. HARD, VERY WELL INDURATED. SHARP TO GRADATIONAL LOWER CONTACT.

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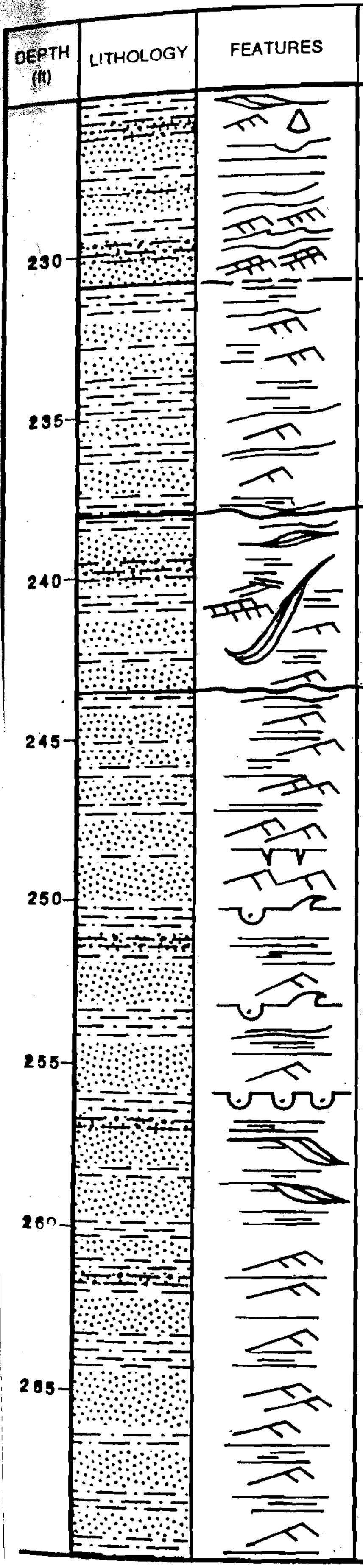
FIGURE 5

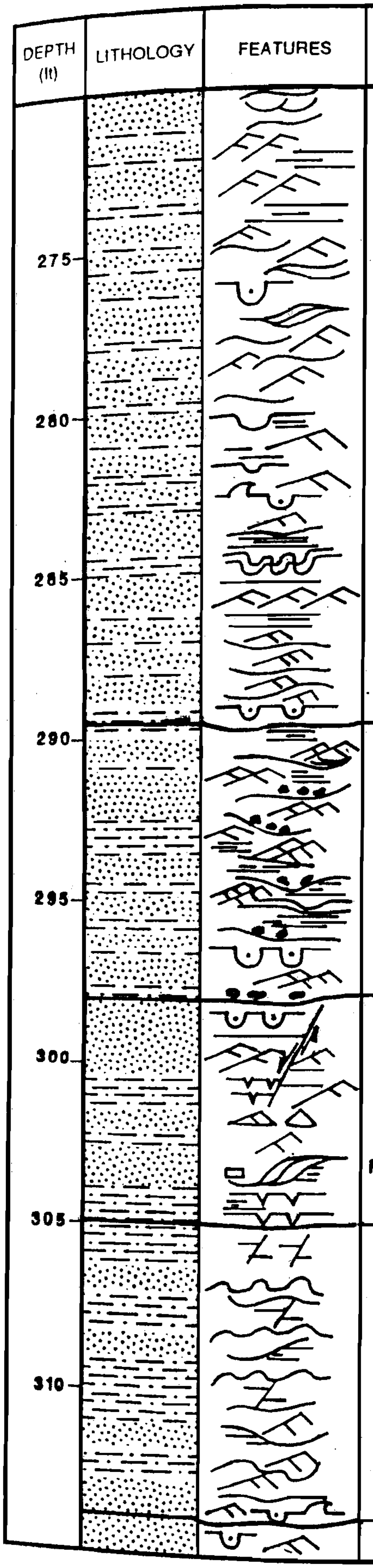


REMARKS

SILTSTONE WITH INTERBEDS OF SANDSTONE AND CLAYSTONE; REDDISH BROWN (10R4/4). THIN LAMINAE TO THIN BEDS; SANDSTONE OCCURS AS THIN BEDS WITH RIPPLE CROSS-LAMINAE; SURFACES ARE WAVY TO LOCALLY CONTORTED. UNIT FINES UPWARD OVERALL DUE TO FEWER COARSE GRAINED INTERBEDS. FRACTURES SIMILAR TO OVERLYING UNIT. HARD, VERY WELL INDURATED. LOWER CONTACT SHARP AND EROSIONAL.

SANDSTONE WITH THIN INTERBEDS OF SILTSTONE, MODERATE REDDISH BROWN (10R4/6). THINLY LAMINATED TO VERY THINLY BEDDED SILTSTONE. CHANNEL WITH 4 FT RELIEF. UPWARD SEQUENCE OF CROSS-LAMINAE WITH TANGENTIAL BASE, FLAT LAMINAE, CLIMBING RIPPLES (SETS 1/2" BY 3", WITH STOSS-SIDE PRESERVATION) AND CROSS-LAMINAE, FLAT LAMINAE WITH LOW ANGLE CROSS-LAMINAE WITH TANGENTIAL BASE ON SCOUR SURFACES. RARE HORIZONTAL FRACTURES TO 1" THICK, SUBVERTICAL FRACTURES SPACED 1-5 FT, VERTICAL FRACTURES SPACED 6"-10 FT. HARD, VERY WELL INDURATED. EROSIONAL BASAL CONTACT.

SANDSTONE INTERBEDDED WITH SILTSTONE AND ARGILLACEOUS SILTSTONE (NEAR TOP), MODERATE REDDISH BROWN (10R4/6). SERIES OF FINING UPWARD UNITS 6" TO 2 FT THICK; SCOURS ABUNDANT, 4" DEEP BY 6"-2 FT WIDE; ACCRETIONARY CROSS-BEDDING ON MARGINS OF CHANNELS NEXT TO BAR DEPOSITS; LOW ANGLE TANGENTIAL CROSS-LAMINAE INTERBEDDED WITH FLAT TO WAVY LAMINAE. SEQUENCES MOST OFTEN SHOW FLAT LAMINAE WITH LOW-ANGLE ACCRETIONARY CROSS-LAMINAE AT BASE; CROSS-LAMINATED RIPPLE AND CLIMBING RIPPLE SETS TO 1" HIGH FOLLOW; FLAT LAMINAE OR LOW-ANGLE CROSS-LAMINAE ARE COMMONLY OVERLAIN BY SOFT-SEDIMENT DEFORMATION IN LOCAL PILLOW STRUCTURES AND FLAME STRUCTURES SHOWING NORTHWARD SHEAR. SEQUENCES TOPPED BY FLAT LAMINAE OF SILTSTONE. POSSIBLE PRISM CRACKS (DESICCATION) IN UPPER PART OF UNIT. GYPSUM-FILLED FRACTURES TO 1" THICK, HORIZONTAL SPACING 3" TO 3 FT, VERTICAL SPACING 4-10 FT, SUBVERTICAL SPACING 1-10 FT. SHARP BASAL CONTACT.



REMARKS

SANDSTONE, VERY FINE GRAINED, INTERBEDDED WITH SILTSTONE AND SILTY CLAYSTONE, DARK REDDISH BROWN (10R3/4). UPPER .2 FT IS SILTSTONE. CONSISTS OF SEQUENCES FROM 4"-2 FT THICK OF SANDSTONE OVERLAIN BY SILTSTONE; SILTSTONE CLASTS OCCUR IN LAG DEPOSITS LOCALLY (SOME WITH WELL PRESERVED BEDDING). SEDIMENTARY STRUCTURES VARY BUT OFTEN EXHIBIT FOLLOWING SEQUENCE: AT THE BASE, PLANAR BEDDING (LAMINAR) OVERLYING SILTSTONE CAP OF LAST SEQUENCE, OCCASIONALLY OVERLYING LAG OF SILTSTONE PEBBLES, PLANAR LAMINAE MAY LOCALLY GRADE INTO LOW ANGLE CROSS-LAMINAE WITH TANGENTIAL BASES (ACCRETIONARY DEPOSITS), PLANAR LAMINAE COMMONLY OVERLAIN BY RIPPLE CROSS-LAMINAE (MOST CLIMBING AT HIGH ANGLES) WITH SETS TO 1.5" THICK; SMALL CHANNELS WITH TROUGH CROSS-LAMINAE OCCUR LOCALLY, 3-4" HIGH BY 1-2 FT WIDE; SOME SCOURS AND EROSIONAL SURFACES MAY EXHIBIT SILTSTONE PEBBLES TO COBBLES; LARGE CHANNELS HAVE SILTSTONE LAG WITH CLASTS TO COBBLE SIZE; CHANNELS USUALLY FILLED WITH PLANAR LAMINAE WITH SOME ACCRETIONARY SURFACES. ONE SILTSTONE COBBLE CONTAINS TWO GYPSUM-FILLED FRACTURES WHICH DO NOT EXTEND BEYOND CLAST. INTERBEDS OF FINE GRAINED SANDSTONE AT 296 FT, SOFT SEDIMENT DEFORMATION ABUNDANT. GYPSUM-FILLED FRACTURES TO 1" THICK. HORIZONTAL SPACING 8" TO 2 FT, VERTICAL SPACING 8" TO 10 FT, SUBVERTICAL SPACING 3" TO 2 FT. LOWER CONTACT SHARP TO GRADATIONAL, SOMEWHAT EROSIONAL.

VERY FINE SANDSTONE INTERBEDDED WITH SILTSTONE, DARK TO MODERATE REDDISH BROWN (10R3/4-4/6). THIN LAMINAE TO THIN BEDS; SILTSTONE INTERBEDS CONTAIN SANDSTONE FLASERS TO LENTICULAR BEDS. SILTSTONE INTERBEDS COMMONLY EXHIBIT ABUNDANT FILLED PRISM CRACKS 1-2" DEEP WITH A REGULAR SPACING; THE UPPERMOST 6" IS VERY DEFORMED BY SOFT SEDIMENT PILLOWS; SCOUR SURFACES, PLANAR TO WAVY LAMINAE, CLIMBING CROSS-LAMINAE SETS TO 1.5", ALL STRUCTURES ABUNDANT AND MORE DIVERSELY DISTRIBUTED THAN IN OVERLYING UNIT. RIPUP CLASTS OF SILTSTONE AND SANDSTONE OCCUR LOCALLY. PENECONTEMPORANEOUS FAULTING WITH 6" THROW DISSIPATED UPWARD AND DOWNWARD AND IS POSSIBLY ERODED AT TOP. GYPSUM-FILLED FRACTURES TO 1/2" THICK, MOST LESS THAN 1/8", GYPSUM LINING FRACTURES WITH SLIGHT DISPLACEMENTS SHOW ONLY STRAIGHT FIBERS, UNIT MUCH MORE EXTENSIVELY FRACTURED THAN OVERLYING OR UNDERLYING UNITS. SHARP BASAL CONTACT.

SILTSTONE WITH INTERBEDDED VERY FINE SANDSTONE, MODERATE REDDISH BROWN TO MODERATE BROWN (10R4/6 TO 5YR3/4), VERY LIGHT GRAY (N8) UNIT AT TOP. THIN LAMINAE TO LAMINAE; WAVY TO FLAT LAMINAE WITH LOCAL SCOURS AND LOW ANGLE CROSS-LAMINAE IN ACCRETIONARY DEPOSITS, LOCAL RIPPLE CROSS-LAMINAE; OVERALL STRUCTURE VERY WAVY WITH 1-2 FT AMPLITUDE, WAVELENGTH ABOUT 5 FT. UNIT VERY TO MODERATELY CONTORTED, SHOWS PENECONTEMPORANEOUS FAULTING AND SLUMPING ALONG SHEAR PLANES, SMALL FAULTS ALONG TOP OF UNIT, SLUMPING OR WAVY CONTORTIONS LESS PREVALENT UPWARD, VOLUME CHANGES ADJUSTED FOR BY SOME SLUMPING AND FAULTING. SOME ARCUATE GYPSUM FILLED FRACTURES TO 1" THICK, MOST LESS THAN 1/8". LOWER CONTACT SHARP, MARKED BY SOFT SEDIMENT DEFORMATION (PILLOWS AND FLAME STRUCTURES).

INTERBEDDED SANDSTONE WITH SILTSTONE, FINING UPWARD FROM MEDIUM AND FINE SAND IN LOWER 6 FT TO MOSTLY SILTSTONE AT TOP; MODERATE REDDISH BROWN TO MODERATE BROWN (10R4/6 TO 5YR3/4). CONSISTS OF FINING UPWARD SEQUENCES CAPPED BY SILTSTONE, EXHIBITING SMALL DESICCATION CRACKS. THIN LAMINAE TO LAMINAE, WAVY TO FLAT;

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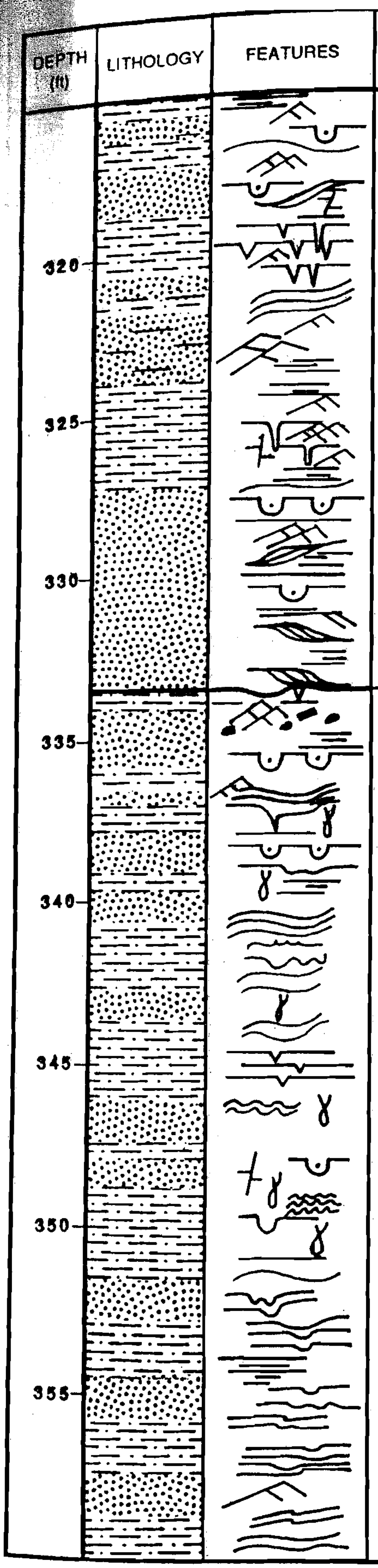
FIGURE 5



REMARKS

FLASERS AND RIPPLE CROSS-LAMINAE (SOME CLIMBING, MM SCALE IN SILTSTONES), EROSIONAL SCOUR SURFACES AND SMALL CHANNELS. BELOW 320 FT, SEQUENCES MORE REGULAR AND EXHIBIT PLANAR TO WAVY LAMINAE AND LOW ANGLE CROSS-LAMINAE OVERLAIN BY RIPPLE CROSS-LAMINAE (SOME CLIMBING). SILTSTONES NEAR TOP EXHIBIT DESICCATION CRACKS; LOCAL CLASTIC DIKES AND FILLED DESICCATION CRACKS ARE TO 1 FT DEEP; PENECONTEMPORANEOUS FRACTURES, FAULTING, AND SLUMPING WITH ABUNDANT PILLOW AND LOAD STRUCTURES SHOWING SHEAR. FRACTURES MORE REGULARLY SPACED TO 1" THICK, HORIZONTAL FRACTURES SPACED 6" TO 5 FT, VERTICAL AND SUBVERTICAL FRACTURES RARE. BASAL CONTACT SLIGHTLY UNDULATORY, SHARP TO GRADATIONAL.

INTERBEDDED SILTSTONE AND MEDIUM TO VERY FINE SANDSTONE; MODERATE TO DARK REDDISH BROWN (10R4/6-3/4). INTERBEDS OF MEDIUM SANDSTONE IN THIN FINING UPWARD SEQUENCES CAPPED BY CLAYSTONE SHOWING RIPPLE-DRAPE 1/2-2" THICK NEAR BASE OF UNIT, INTERBEDS ARE FINER GRAINED UPWARD. THIN LAMINAE TO LAMINAE, FLAT TO WAVY TO CONTORTED. LOCAL CROSS-LAMINAE PRESERVED. HORIZONTAL TO SUBHORIZONTAL BURROWS FROM 337-350 FT. UNIT VARIABLY DEFORMED BY SOFT SEDIMENT DEFORMATION AND FRACTURES: BROADLY DEFORMED AND WAVY FROM 337-345 FT, WAVY AND CONTORTED ON SMALLER SCALE FROM 345-360 FT, VERY CONTORTED WITH SLUMP FRACTURING 360-370 FT, LARGER AMPLITUDE DEFORMATION AND SHEAR ALONG PLANES WITH SLIGHT DISPLACEMENT WITH DECREASING DEFORMATION TOWARDS BASE OF UNIT, SOME PILLOW STRUCTURES 385-390 FT. ABOUT 5° DIP TO NORTHEAST NEAR BASE. VERY FRACTURED; MOST PARALLEL TO CONTORTED BEDDING. LOWER CONTACT SHARP.

AIR INTAKE SHAFT LITHOLOGIC LOG
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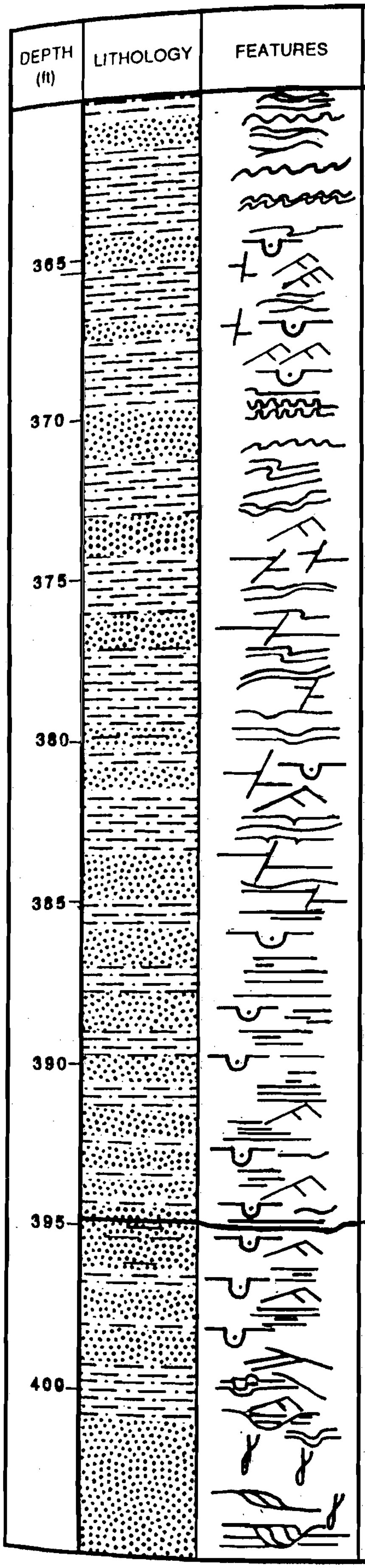
FIGURE 5



REMARKS

395-419 VERY FINE GRAINED SANDSTONE WITH INTERBEDDED MEDIUM SANDSTONE, SILTSTONE AND MUDSTONE; MODERATE TO DARK REDDISH BROWN (10R4/6-3/4), WITH PALE OLIVE (10Y6/2) SANDSTONE AS CHANNEL-FILLS. UPPER 3-4 FT CONSISTS OF 1/2"-3" THICK, THINLY LAMINATED TO VERY THINLY BEDDED, FINING UPWARD SEQUENCES WITH CLAY DRAPE OVER SEDIMENT STARVED RIPPLES AND LOCAL PILLOW STRUCTURES; MOTTLING FROM POSSIBLE BIOTURBATION NEAR THE BASE OF EACH SEQUENCE. BELOW 398 FT, PENECONTEMPORANEOUS SOFT SEDIMENT SLUMPING AND DEFORMATION ARE ABUNDANT AND STRATA ARE OFTEN CONTORTED; CHANNELS 2"-1 FT DEEP, 3-10 FT WIDE, FILLED WITH MEDIUM SANDSTONE CUT ACROSS THINLY LAMINATED VERY FINE SANDSTONE AND SILTSTONE; CHANNEL FILL SHOWS TABULAR TO TANGENTIAL LOW ANGLE CROSS-LAMINAE AS PROBABLE LATERAL ACCRETION DEPOSITS; SCOURS WITH LITTLE OR NO DEPOSITION BECOME COMMON DOWNWARD; MAY BE TOPPED BY THIN LAMINAE TO LAMINAE OF SANDSTONE; SCOURS AND CHANNELS MAY BE DEFORMED AND LOCALLY CROSS-CUT DEFORMED STRATA. BELOW 412, IRREGULAR PODS AND ZONES OF SANDSTONE SIMILAR TO SMEARED INTRACLAST TEXTURE BECOME COMMON, LAMINAE AND CLASTS ARE DEFORMED, GRANULE TO PEBBLE-SIZED CLASTS OF MUDSTONE AND SANDSTONE

AIR INTAKE SHAFT LITHOLOGIC LOG
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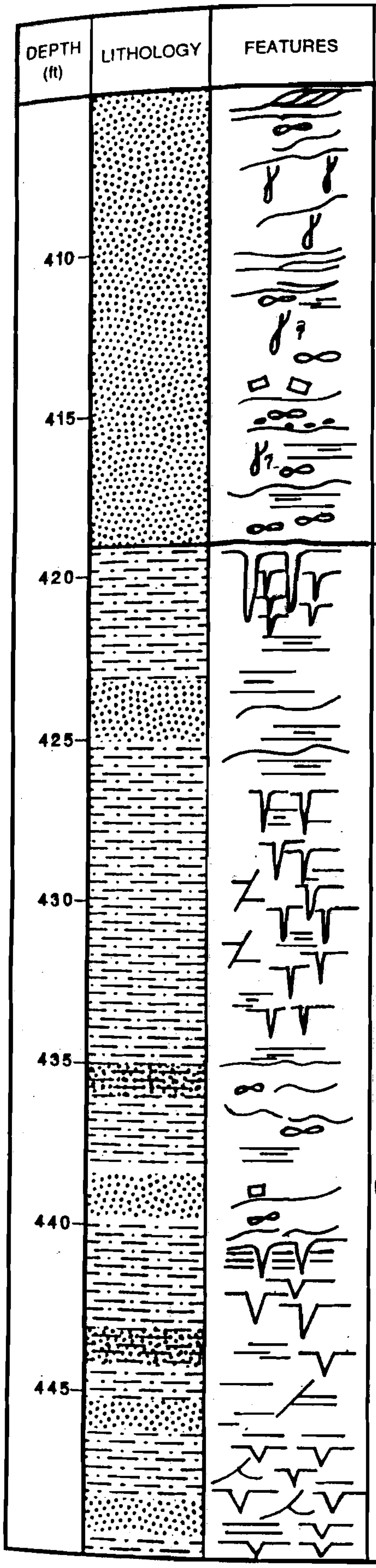
FIGURE 5



REMARKS

LOCALLY OVERLIE SCOUR SURFACES AND MAY APPEAR SHEARED AND DEFORMED. IRREGULAR, <1/16" THICK, GYPSUM-FILLED FRACTURES ARE ABUNDANT. FROM 411-417 FT WEDGE-SHAPED SLABS ALONG SLICKENSIDED GYPSUM-FILLED FRACTURES OCCUR ON THE NORTHWEST, SOUTHEAST AND SOUTH SIDES OF THE SHAFT, SLICKENSIDES SHOW VERTICAL MOVEMENT; FRACTURE SETS STRIKE N45°E, DIP FROM 45-90°N, GROUND SOUNDS HOLLOW. MODERATELY WELL INDURATED; LOWER CONTACT SHARP TO GRADATIONAL.

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SILTSTONE WITH SANDSTONE AND MUDSTONE; MODERATE TO REDDISH BROWN (10R4/6-4/3). SEQUENCE OF SUBUNITS VARY MAINLY IN DISRUPTION OF STRUCTURES; RANGE FROM THIN LAMINAE TO LAMINAE, FLAT TO DISCONTINUOUS AND DISTORTED WITH RARE POORLY EXPOSED CROSS-LAMINAE. UPPER 1 FT CONSISTS OF LAYERS OF DESICCATED SILTSTONE WITH ABUNDANT DESICCATION CRACKS (<2") TO 2 FT DEEP PRISM CRACKS; LOCALLY ABUNDANT GYPSUM-FILLED FRACTURES MAY SHOW DISPLACEMENT TO 3" AND SLICKENSIDED SURFACES. FROM 420-425 FT WAVY TO IRREGULAR DISCONTINUOUS THIN LAMINAE TO LAMINAE. FROM 425-434 FT IRREGULAR THIN LAMINAE TO LAMINAE OF SILTSTONE AND VERY FINE SANDSTONE INTERBEDDED WITH MUDSTONE AND SILTSTONE; SILTSTONE BEDS FINING UP TO ARGILLACEOUS SILTSTONE. ABUNDANT PRISM CRACKS TO 2 FT DEEP. ABUNDANT GYPSUM-FILLED FRACTURES 1/16", MOST SUBHORIZONTAL, SPACED 1/2"-2 FT, SUBVERTICAL FRACTURES TO 1/4" WIDE, SPACED 6"-1 FT. FROM 434-440.5 FT, MORE ARGILLACEOUS DOWNWARD, SMALL INTRAFORMATIONAL CLASTS OF MUDSTONE, IRREGULAR STRINGERS AND LAMINAE OF VERY FINE SANDSTONE, LAMINAE MORE IRREGULAR DOWNWARD (MUDFLAT SEQUENCES WITH IRREGULAR SMEARED LAMINAE TEXTURES FROM 434-440.5 FT). FROM 440.5-451, DESICCATION CRACKS TO 2 FT DEEP AND MANY DISH-SHAPED LAMINAE IN UPPER 4 FT. BELOW 445 FT, STRATA MORE REGULAR AND CONTINUOUS; TEEPEE-LIKE STRUCTURES ABUNDANT, SOME OVERTURNED, UP TO 1' HIGH, MOST 1/4-1/2" AMPLITUDE, ABUNDANT DESICCATION CRACKS TO 1" DEEP, POSSIBLE CURLED DESICCATION CHIPS. UNIT AS A WHOLE MORE COMPETENT THAN OVERLYING UNIT. BASAL CONTACT SHARP.

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AIR INTAKE SHAFT LITHOLOGIC LOG
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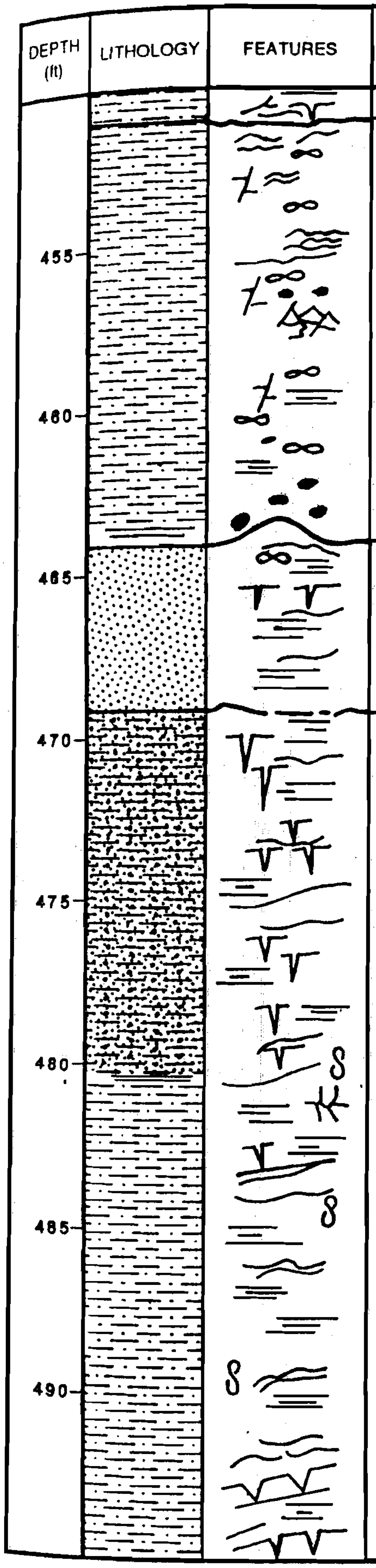
FIGURE 5



REMARKS

SILTSTONE INTERBEDDED WITH MUDSTONE AND SOME CLAYSTONE; MODERATE TO DARK REDDISH-BROWN (10R4/6-3/4), MUDSTONE MODERATE REDDISH ORANGE (10R6/6). LOCAL IRREGULAR AND DISCONTINUOUS THIN LAMINAE TO LAMINAE AND DESICCATION CRACKS. LOCAL GRANULE TO COBBLE-SIZED CLASTS OF MUDSTONE; CLASTS AND STRATA MAY SHOW SMEARED TEXTURE. FROM TOP TO 455 FT, SILTSTONE WITH MUDSTONE LAMINAE AND VERY THIN BEDS AND GRANULE TO COBBLE-SIZED CLASTS OFTEN SHOWING SMEARED INTRACLAST TEXTURE. AT 455 FT, IRREGULAR, GRADATIONAL TO SHARP EROSIONAL SURFACE. FROM 455-460 FT, LESS ARGILLACEOUS SILTSTONE DISPLAYS IRREGULAR DISCONTINUOUS STRATA, SMEARED INTRACLAST TEXTURES AND CRACKLE TEXTURES; MUDSTONE PRESENT AS LOCAL DISCONTINUOUS, IRREGULAR LAMINAE; CRACKLE TEXTURE SHOWS IRREGULAR ZONES AND CLASTS/PIECES OF SILTSTONE BOUNDED BY MUDSTONE LINED FRACTURES, LESS COMMON BELOW 457 FT. FROM 460-464.5 FT, TEXTURE DOMINATED BY LOCALLY SMEARED GRANULE TO SMALL PEBBLE-SIZED CLASTS OF SILTSTONE AND MUDSTONE AT BASE GRADING UP TO SMEARED LAMINAE TEXTURE. LOCAL NARROW (<1/16") ARCUATE, GYPSUM-FILLED FRACTURES, SOME DISPLACED TO 1". LOWER CONTACT SHARP, MARKED BY MUDSTONE.

VERY FINE SANDSTONE WITH SILTSTONE, MODERATE TO DARK REDDISH BROWN (10R4/6-3/4). THIN LAMINAE TO LAMINAE, MOST FLAT TO WAVY, SLIGHTLY CONTORTED. DESICCATION CRACKS TO 1/4" DEEP. SMEARED INTRACLAST TEXTURED DEVELOPED LOCALLY. LOWER CONTACT GRADATIONAL.

VERY FINE SANDSTONE WITH MINOR SILTSTONE AND MUDSTONE, MORE SILTY AND ARGILLACEOUS DOWNWARD. THIN LAMINAE TO VERY THIN BEDS; IRREGULAR, DISCONTINUOUS, FLAT, WAVY, LOCALLY CONTORTED. SOFT SEDIMENT DEFORMATION; SMEARED LAMINAE TEXTURE; CRACKLE TEXTURE OCCURS WITH SOME DESICCATION CRACKS, UP TO 2 FT DEEP. EROSION SURFACES AT 475, 480 FT. MAJOR STRATIFICATION AT 483, 493, 495, 506, 510 FT. MUDSTONE AT TOP OF SURFACE AT 475 FT. SOME DISH-SHAPED FEATURES IN LOWER 7 FT, MOST OVERLIE CONTORTED BEDS. EROSIONAL SURFACES DIP PARALLEL TO OTHER INTERNAL BEDDING. UPPER PART OF UNIT HAS ABUNDANT THIN FRACTURES, VERY DISCONTINUOUS, MOST SUBHORIZONTAL, SPACED 1-3", <1/16" WIDE. LARGE FRACTURES MORE ABUNDANT NEAR BASE AS ARE GYPSUM-FILLED FRACTURES IN IRREGULAR PATTERNS, MOST LESS THAN 1/16" WIDE, SPACED 1" FOR HORIZONTAL AND 3-4 FT FOR SUBVERTICAL FRACTURES. PENECONTEMPORANEOUS FOLDING NEAR BASAL CONTACT PARALLELS SHARP BASAL CONTACT WITH TOP OF RUSTLER FORMATION.

AIR INTAKE SHAFT LITHOLOGIC LOG
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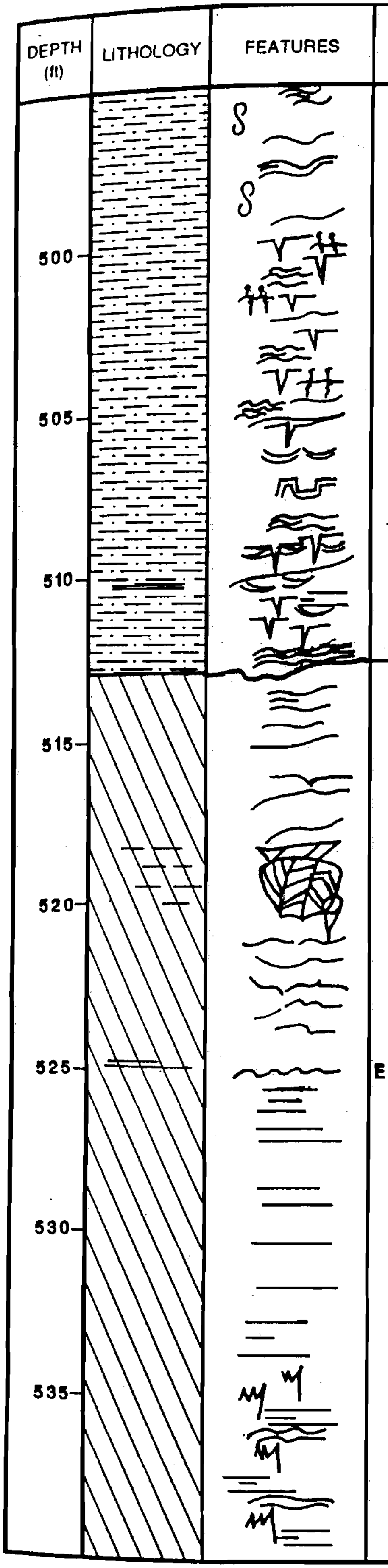
FIGURE 5



REMARKS

RUSTLER FORMATION.

FORTY-NINER MEMBER. ANHYDRITE, VERY LIGHT GRAY (N8), HARD (SEE FIG. 6 FOR DETAILED MAP). THIN LAMINAE TO LAMINAE, WAVY TO SLIGHTLY CONTORTED; POSSIBLE LOCAL RIPPLE MARKS; IRREGULAR CLAYSTONE ALONG EROSION SURFACE AT 524.4 FT, THINLY LAMINATED TO WAVY WITH STYLOLITES AT 1"-2 FT SPACING FROM 533-540 FT. SWALLOWTAIL GYPSUM CRYSTALS FROM 540-544 FT. DISRUPTED ZONE 517-521 FT, BOULDER SIZED CLASTS, LAMINAE DOWNWARPED TOWARD AREA OF DISTURBANCE, SOUTH SIDE OF SHAFT AS SOFT SEDIMENT DOWNWARPING IN DEWEY LAKE, CLAYSTONE ON IRREGULAR SURFACES IN ANHYDRITE, LOCAL ZONES OF GYPSUM, ALL PART OF POSSIBLE PALEO MICROKARST ON SURFACE OF FORTY-NINER MEMBER. GYPSUM-FILLED FRACTURES FROM 513-530 FT, HORIZONTAL SPACING 6"-1 FT, NO VERTICAL FRACTURES, SUBVERTICAL SPACED ABOUT 3 FT; OPEN FRACTURES TO 1/16" WIDE FROM 530-540 FT. SHARP BASAL CONTACT.

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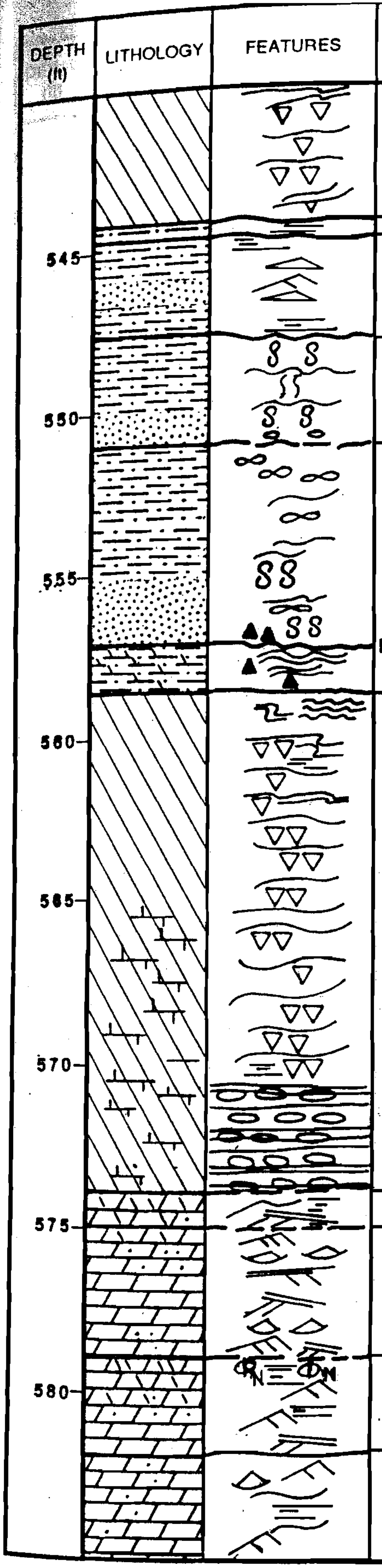
FIGURE 5



REMARKS

ARGILLACEOUS SILTSTONE; GREENISH GRAY (5G6/1). THIN BEDS OF COARSELY CRYSTALLINE GYPSUM NEAR TOP. POORLY PRESERVED IRREGULAR THIN LAMINAE. LOWER CONTACT IS REDUCTION/OXIDATION CONTACT. UNIT SOFT. CONTACT SHARP TO GRADATIONAL.

MUDSTONE INTERBEDDED WITH SILTSTONE AND VERY FINE SANDSTONE, PALE YELLOWISH BROWN (10YR6/2). SOME GYPSUM NEAR TOP IN COARSELY CRYSTALLINE LAMINAE TO THIN BEDS. SILTSTONE AND SANDSTONE OCCUR AS FLASER-LIKE INTERBEDS, VERY DISCONTINUOUS TO IRREGULAR; THIN LAMINAE TO LAMINAE, DEFORMED AND WAVY; POORLY DEFINED CROSS-LAMINAE, SOME RIPPLE SURFACES, LOCALLY SLIGHTLY SMEARED TEXTURE. BASAL CONTACT SHARP, EROSIONAL.

VERY FINE SANDSTONE TO SILTSTONE, MODERATE BROWN TO LIGHT BLUISH GRAY (5YR3/4-5B7/1). THIN LAMINAE TO LAMINAE, FLAT AND PARALLEL TO CONTORTED AND DISTORTED OR SMEARED, LOCALLY KINKED; LOCAL SANDSTONE PEBBLES; LOCAL LOW ANGLE CROSS-LAMINAE IN ACCRETION SURFACES. UPPER 1 FT VERY ARGILLACEOUS. SMEARED INTRACLAST TEXTURE DOMINATES AT BASE. SOFT. BASAL CONTACT IRREGULAR.

SANDSTONE AND SILTSTONE, BECOMING FINER AND MORE ARGILLACEOUS UPWARD. MICRO-LAMINATED TO LAMINATED, MORE ABUNDANT AT BASE, VERY DISCONTINUOUS, IRREGULAR, CONTORTED TO DISTORTED. SMEARED LAMINAE LESS DISTINCT THAN IN UNIT ABOVE, DOMINANT TEXTURE AT BASE; EXHIBITS SMEARED INTRACLAST TEXTURE; ANGULAR CLASTS OF SILTSTONE AND MUDSTONE WITH SMEARED INTRACLASTS AND LAMINAE AT BASE. GRADATIONAL BASAL CONTACT.

SILTSTONE, LIGHT BLUISH GRAY (5B7/1). THIN LAMINAE TO VERY THIN BEDS, VERY DISCONTINUOUS, CONTORTED TO WAVY, OVERALL STRATIGRAPHIC CONTINUITY WITHIN UNIT; INTERLAMINAE OF ANHYDRITE DECREASE UPWARD. LOCALLY CONTAINS GRANULE TO PEBBLE-SIZE SILTSTONE CLASTS. WELL INDURATED, MODERATELY HARD. SHARP BASAL CONTACT.

ANHYDRITE, MEDIUM GRAY TO WHITE (N5-9), MEDIUM TO FINELY CRYSTALLINE. BEDDED NODULAR FROM BASE TO 570 FT; INTERBEDS OF CARBONATE DECREASING UPWARDS, SPACED .5-1 FT FROM 570-565 FT; ANHYDRITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAILS TO 1/2" HIGH FROM 570-560 FT; THIN LAMINAE TO LAMINAE, SOME VERY THIN BEDS; LAMINAE TO MICROLAMINAE IN UPPER 2 FT; BEDDING WAVY TO CONTORTED AND CONVOLUTE UPWARD AND LESS CONTINUOUS. LOCAL ZONES OF MEDIUM TO COARSELY CRYSTALLINE GYPSUM. HEALED SUBVERTICAL FRACTURE ON NORTHWEST SIDE OF SHAFT NEAR 560 FT. HARD. GRADATIONAL BASAL CONTACT.

MAGENTA DOLOMITE. DOLOMITE AND GYPSUM, WHITE TO LIGHT BLUISH GRAY OR DARK GREENISH GRAY (N9 TO 5B7/1-5G4/1) (SEE FIG. 7 FOR DETAILED MAP). GYPSUM CONTENT INCREASES UPWARD. THIN LAMINAE TO VERY THIN BEDS, WAVY; ABUNDANT LOW ANGLE CROSS-LAMINAE, SETS TO 1/2" HIGH. GRADATIONAL BASAL CONTACT.

DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT SIZE. WAVY TO LENTICULAR BEDDING; LOW ANGLE CROSS-LAMINAE WITH ABUNDANT SETS 2" HIGH BY 6 "LONG; WAVY TO LENTICULAR BEDDING WITH LOW ANGLE CROSS-LAMINAE SETS TO 1/4" NEAR BASE. SURFACE WET. GRADATIONAL BASAL CONTACT.

DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). MAINLY SILT-SIZED GRAINS, SOME SAND-SIZED; COARSE-GRAINED, MORE GYPSIFEROUS, POROUS, BUT NOT WET. THIN LAMINAE TO LAMINAE; ABUNDANT CROSS-LAMINAE. LOW ANGLE CROSS-LAMINAE SETS 1/4-1/2", INCREASE IN SIZE AND BECOME INTERLAMINATED WITH LAMINAE CONTAINING PEBBLE-SIZED NODULES OF GYPSUM IN UPPER .5 FT. BASAL CONTACT GRADATIONAL.

DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT TO VERY FINE SAND SIZE. THIN LAMINAE TO LAMINAE, STRATA WAVY AT BASE BUT WITH MUCH LESS AMPLITUDE THAN IN UNDERLYING UNIT; ABUNDANT EROSIONAL/SCOUR SURFACES TO 2" DEEP; LOW ANGLE RIPPLE CROSS-LAMINAE SETS TO 1/2" HIGH, MOST 1/4", SETS INCREASE IN HEIGHT TO ABOUT 1" NEAR TOP. GRADATIONAL BASAL CONTACT.

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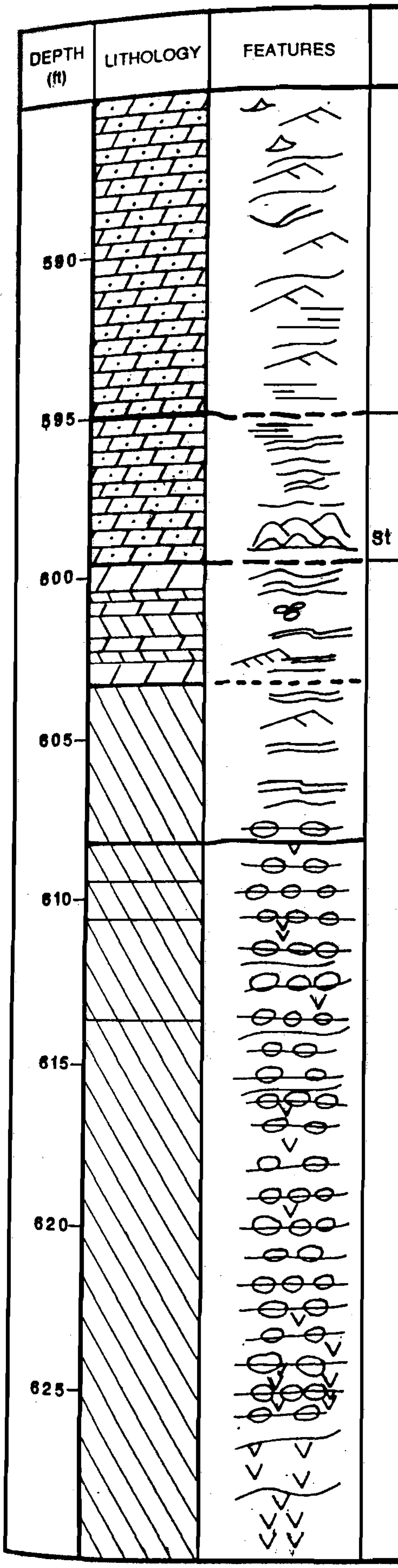
FIGURE 5



REMARKS

DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT TO VERY FINE SAND SIZE. UPPER PART THINLY LAMINATED, WAVY, DISCONTINUOUS. LOWER PART ALGAL WITH DOMES AND HEMISPHEROIDS. ABUNDANT GYPSUM FILLED FRACTURES IN WAVY PART, <1/2" THICK, MOST PARALLEL TO LAMINAE. GRADATIONAL BASAL CONTACT.

TAMARISK MEMBER. ANHYDRITE, GYPSIFEROUS NEAR TOP, INTERBEDDED WITH CARBONATE IN UPPER 4 FT; MICROCRYSTALLINE, VERY LIGHT TO MEDIUM LIGHT GRAY (N8-6). FROM 599.5-607 FT, GYPSIFEROUS ANHYDRITE SHOWS WAVY LAMINAE AND VERY THIN BEDS AND SOME NODULAR TO BEDDED NODULAR TEXTURES, STRATA DISCONTINUOUS AND CONTORTED LOCALLY, POSSIBLE ALGAL ORIGIN FOR SOME STRATA NEAR TOP, INTERBEDDED WITH CARBONATE ABOVE 603.5, CARBONATE CONTENT INCREASES UPWARD, LOCAL CROSS-LAMINAE. FROM 607-623 FT, LAMINAE-SCALE BEDDED NODULAR TEXTURE DOMINATES; SHOWS CRUSHED PRISM TEXTURE LOCALLY, CRUSHED PRISM TEXTURE BECOMES MORE ABUNDANT NEAR BASE. FROM 623-633.5 FT, EPITAXIAL CRUSHED PRISM TEXTURE ABUNDANT, STACKS TO 1 FT HIGH, HEIGHT OF INDIVIDUAL CRUSHED PRISMS TO 2" MAXIMUM AT BASE, HEIGHT DECREASES UPWARD AS MORE OF ORIGINAL VOLUME REDUCED. FROM 633.5-643 FT, THIN LAMINAE TO VERY THIN BEDS WITH ANHYDRITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAIL CRYSTALS TO 1" HIGH, AVERAGE HEIGHT 1/4". FROM 643-650 FT, WAVY AND LOCALLY SLUMPED THIN LAMINAE TO LAMINAE OF ANHYDRITE AND SOME CARBONATE. FROM 650-652 FT, THIN LAMINAE WITH ANHYDRITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAIL CRYSTALS. FROM 652-653, CLAST-SUPPORTED COBBLE BRECCIA OF THINLY LAMINATED ANHYDRITE, ZONE OVERLAIN BY EROSIONAL SURFACE WHICH CROSS-CUTS ANHYDRITE CLASTS. FROM 653-654 FT CLAST TO LOCALLY MATRIX-SUPPORTED ANHYDRITE GRANULE BRECCIA WITH LOCAL COBBLE-SIZED CLASTS OF ANHYDRITE, UPPER SURFACE EROSIONAL. FROM 654-655.5 FT THIN LAMINAE AND LAMINAE CONVOLUTED DOWNWARD, FLAME STRUCTURES OF UNDERLYING UNIT PENETRATE ZONE TO .5 FT, UPPER SURFACE EROSIONAL. MEDIUM DARK GRAY (N4) CLAYSTONE INTERBEDS: 1" THICK AT 607, 609.5, 611, 613, 637.5 FT AND 1/16" THICK AT 627. 1" INTERBEDS AT 611 AND 637.5 SHOW CLAYSTONE SQUEEZED UPWARD (TO .3 FT) INTO NEAR VERTICAL FRACTURES OVERLYING THE CLAYSTONE; CLAYSTONE SQUEEZED AROUND SOME ANHYDRITE AT THE BASE OF THE CLAYSTONE AT 637.5 FT; THIN LAMINAE OF CLAYSTONE AT 654 FT; CLAYSTONES OFTEN CONTAIN HORIZONTAL AND SUBHORIZONTAL FIBROUS GYPSUM-FILLED FRACTURES. GYPSUM-FILLED FRACTURES LOCALLY ABUNDANT, MANY FIBROUS. FROM 599.5-607 FT, SUBHORIZONTAL GYPSUM-FILLED FRACTURES SEPARATE STRATA, THICKNESS <1/8", SPACED 1/2" AT TOP, SPACING INCREASES DOWNWARD; SUBVERTICAL FRACTURES LESS COMMON, SPACED 2-10 FT. FROM 620-643 FT, SUBVERTICAL GYPSUM-FILLED FRACTURES MORE COMMON, MANY MAY ORIGINATE FROM AND A FEW MAY RADIATE FROM A SINGLE POINT ALONG CLAYSTONE INTERBEDS; OPEN FRACTURES (<1/32") LOCALLY OCCUR .2-1.5 FT BELOW CLAYSTONE INTERBED AT 637.5, 1 FT OF THESE FRACTURES IS OPEN BUT ALL GRADE TO GYPSUM-FILLED. FROM 643-650 FT, THIN GYPSUM-FILLED FRACTURES ABUNDANT: SUBHORIZONTAL FRACTURES SPACED 1-6" PARALLEL TO STRATA, SUBVERTICAL FRACTURES SPACED 6"-3 FT. UNIT HARD, WELL LITHIFIED. LOWER CONTACT SHARP TO LOCALLY GRADATIONAL, UNDULATORY AND IRREGULAR, MARKED BY FLAME STRUCTURES.

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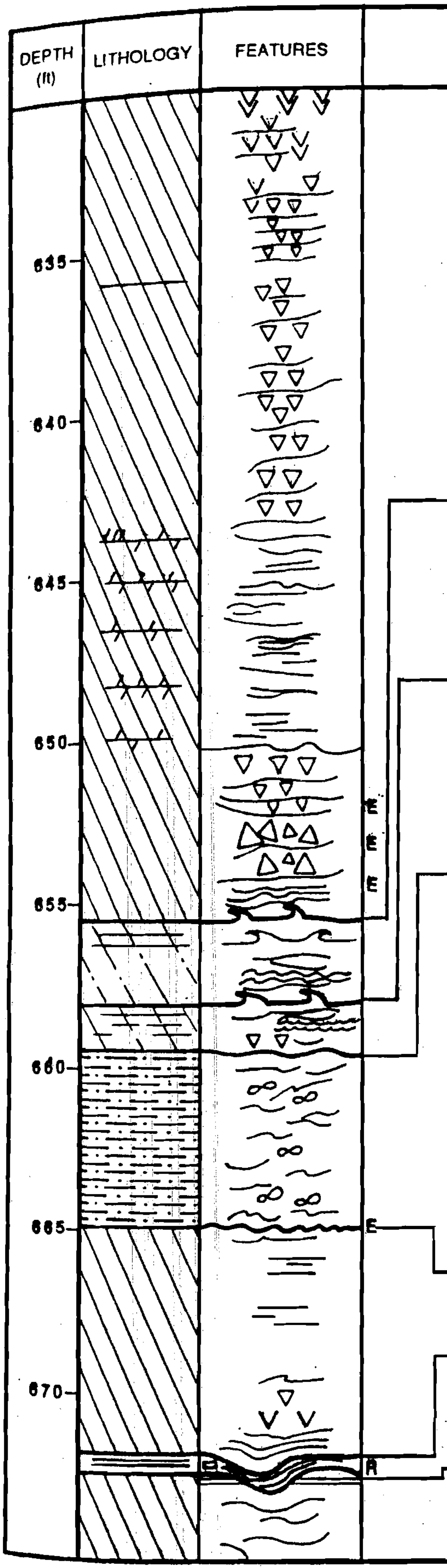
FIGURE 5



REMARKS

ANHYDRITE AND GYPSUM, VERY LIGHT GRAY (N8), INTERBEDDED WITH CLAYSTONE, LIGHT BLUISH TO DARK GREENISH GRAY (5B7/1-5G4/1). CLAYSTONE CALCAREOUS AT UPPER .5-.2 FT, CONTENT DECREASING DOWNWARD. THIN LAMINAE TO LAMINAE, WAVY TO UNDULATORY PARALLEL TO LOWER CONTACT BECOMING MORE DISRUPTED, CONVOLUTED UPWARD (SOFT SEDIMENT DEFORMATION); UPPER .5 FT VERY CONTORTED, WITH LOCAL FLAME STRUCTURES (NO BRECCIA); LAMINAE VERY DISTINCT IN CLAYSTONE (POSSIBLY ALGAL). CONTAINS ABUNDANT IRREGULAR BIFURCATING GYPSUM-FILLED FRACTURES TO 1" THICK, MOST SUBHORIZONTAL, FRACTURES DECREASING DOWNWARD. BASAL CONTACT GRADATIONAL.

CLAYSTONE, CALCAREOUS CLAYSTONE IN UPPER 3-5 FT; VERY ARGILLACEOUS GYPSUM AND ANHYDRITE AT BASE; LIGHT BLUISH TO DARK GREENISH GRAY AND VERY LIGHT GRAY (5B7/1-5G4/1, N8) (SEE FIG. 8 FOR DETAILED MAP). THIN LAMINAE TO LAMINAE; UPPER PART MOSTLY PARALLEL, WAVY, WITH SOME SOFT SEDIMENT DEFORMATION, CONTORTED INTO FLAME STRUCTURES AT UPPER CONTACT; LOWER PART DISRUPTED, DISCONTINUOUS. ANHYDRITE AND GYPSUM CONTAINS SWALLOWTAILS LOCALLY TO 1/4" HIGH. UPPER CLAYSTONE MOUNDED (POSSIBLY ALGAL), CONTAINS ABUNDANT BIFURCATING GYPSUM-FILLED FRACTURES, MOST SUBHORIZONTAL AND PARALLEL TO BEDDING, TO 2" THICK. LOWER CONTACT SHARP TO GRADATIONAL.

INTERBEDDED AND INTERMIXED CLAYSTONE, MUDSTONE, AND SILTSTONE, GENERALLY FINES UPWARD; LOCALLY SANDY NEAR BASE; SILTSTONE PEBBLE CONGLOMERATE FILLS 2.5 FT CHANNEL AT BASE. GRAYISH-RED TO MEDIUM BLUISH-GRAY (10R4/2, 5B5/1); UPPER .5-2 FT, MEDIUM BLUISH-GRAY, IRREGULAR LOWER CONTACT; ALTERNATING LAMINAE AND MOTTLED GRAYISH-RED TO MEDIUM BLUISH-GRAY BELOW UPPER ZONE. LOCAL THIN LAMINAE TO LAMINAE, IRREGULAR, DISCONTINUOUS, DISTORTED, CONTORTED TO CONVOLUTE OFTEN WITH SMEARED LAMINAE TEXTURE; LAMINAE OFTEN DISRUPTED BY ABUNDANT SMALL SOFT SEDIMENT DISPLACEMENT SURFACES; SMEARED INTRACLAST TEXTURE LOCALLY ABUNDANT; SMEARED INTRACLAST/LAMINAE TEXTURE MOST ABUNDANT IN MIDDLE AND BASE OF UNIT. LOCAL BROKEN, SUBHORIZONTAL, LATERALLY CONTINUOUS LAMINAE-SCALE GYPSUM-RICH ZONES IN MIDDLE OF UNIT. LOCAL ANHYDRITE NODULES TO 1" DIAMETER IN LOWER HALF OF UNIT. AT BASE OF UNIT ON EAST SIDE OF SHAFT, A 2.5 FT DEEP, 24 FT WIDE CHANNEL IS FILLED WITH MEDIUM BLUISH-GRAY SILTSTONE PEBBLE CONGLOMERATE; CONGLOMERATE IS CLAST SUPPORTED WITH ROUNDED CLASTS; REGULAR SECTION OCCURS ABOVE CHANNEL. SMALL PYRITE CUBES OCCUR IN BLUISH-GRAY ZONES, MOST ABUNDANT NEAR TOP. ABUNDANT SMALL FRACTURES WITH SLICKENSIDED SURFACES. ABUNDANT FIBROUS GYPSUM-FILLED FRACTURES TO 2" THICK WITH SLICKENSIDED SURFACES, MANY SHOW SIGMOIDAL FRACTURE FILLINGS, MOST ARCUATE. LOWER CONTACT SHARP, EROSIONAL.

ANHYDRITE, VERY LIGHT TO DARK GREENISH GRAY (N8-5G4/1). THIN LAMINAE TO LAMINAE; SOME ANHYDRITE PSEUDOMORPHS AFTER SWALLOWTAIL GYPSUM STRUCTURES SHOWING CRUSHED PRISM TEXTURE; LAMINAE CONTINUOUS AND WAVY AT LOWER CONTACT; POSSIBLY NODULAR AT TOP. HARD. SHARP, UNDULATORY CONTACT WITH 1.5 FT RELIEF.

CLAYSTONE, GREENISH BLACK (5G2/1). VARIES AROUND SHAFT TO 1 FT THICK. THIN LAMINAE TO LAMINAE, WAVY, SOFT SEDIMENT DEFORMATION; INTERBEDDED GYPSUM LAMINAE; RIPUP COBBLE OF UNDERLYING MATERIAL AT NORTH SIDE OF SHAFT. GYPSUM-FILLED FRACTURES TO 1.5" THICK, SUBHORIZONTAL WITH LOCAL SUBVERTICAL BIFURCATING FRACTURES. SOFT. LOWER CONTACT UNDULATORY 1-4 FT, SHARP.

ANHYDRITE, VERY LIGHT TO DARK GREENISH GRAY (N8-5G4/1). THIN LAMINAE TO LAMINAE WAVY, STRATA BECOME MORE CONTORTED DOWNWARD, LOCALLY EROSIONALLY TERMINATED; SMALL (<1/8") SWALLOWTAIL FEATURES; ALGAL STRUCTURES DOMINATE AT BASE. LARGE SCALE EROSION SURFACE ABOUT 2 FT FROM TOP SHOWS 1 FT RELIEF WITH

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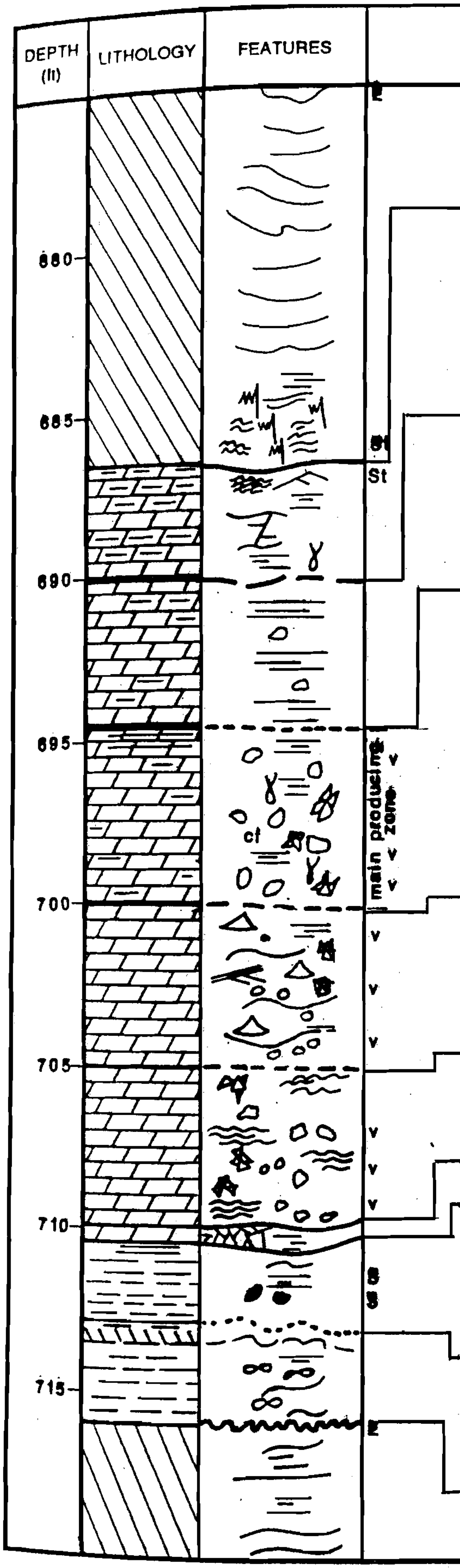
FIGURE 5



REMARKS

OVERLYING AND UNDERLYING SURFACE; FORMS LOCAL ROLLOVER STRUCTURES FROM SOFT SEDIMENT DEFORMATION ALONG A SLOPE, DIPS TO 20°. LOWER 2 FT OF UNIT VERY STYLOLITIC. HARD. LOWER CONTACT SHARP TO GRADATIONAL.

CULEBRA DOLOMITE MEMBER. DOLOMITE, ARGILLACEOUS, LOCALLY ORGANIC-RICH (ALGAL) AT TOP AND BASE, LIGHT OLIVE GRAY (5Y6/1) (SEE FIG. 9 FOR DETAILED MAP). THIN LAMINAE TO THIN BEDS; CROSS-LAMINAE IN UPPER .5 FT; CONSISTS OF FINING UPWARD SEQUENCES .2-.5 FT THICK WITH BURROWS IN LOWER PART OF SEQUENCES. SYNSEDIMENTARY FAULT WITH 1 FT THROW TERMINATES NEAR MIDDLE OF THIS UNIT, UNIT DEPOSITIONALLY THICKENS OVER DOWNDROPPED SECTION. UPPER 1-2 FT SHOWS SHORT, SMALL FRACTURES WITH SYNSEDIMENTARY BRECCIA, MOST SUBVERTICAL AND LIMITED TO INDIVIDUAL STRATA. A FEW WITH FIBROUS GYPSUM-FILLINGS TO 1/4". CONTAINS NO VUGS. LOWER CONTACT GRADATIONAL.

DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), MEDIUM CRYSTALLINE, ARGILLACEOUS, LOCALLY ORGANIC-RICH. THIN LAMINAE TO THIN BEDS, PARALLEL BEDDING "RAILROAD TRACKS"; RARE LARGE VUGS, MOST OPEN; BEDS INTERNALLY STRUCTURELESS. PROBABLE BRECCIA ALONG SOME FRACTURES. CONTAINS LONGER SUBVERTICAL AND VERTICAL FRACTURES FILLED WITH GYPSUM. LOWER CONTACT GRADATIONAL TO DIFFUSE.

DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), ARGILLACEOUS, MEDIUM CRYSTALLINE. LOCAL THIN LAMINAE TO MEDIUM LAMINAE. FRACTURES NOT RELATED TO STRATA BUT ARE ASSOCIATED WITH VUGS; WITHIN SOME LAMINAE AND THIN BEDS, THIN BEDS LOCALLY EROSIONALLY TERMINATED. STRATA PARALLEL, FLAT; SOME LOW ANGLE CROSS-LAMINAE WITH POSSIBLE RIPPLE FORMS; THIN LAMINAE LOCALLY DISCONTINUOUS. POSSIBLE BIOTURBATION. ZONE PRODUCES MOST OF CULEBRA FLUID; UNIT IS CHARACTERIZED BY BROKEN APPEARANCE; VERY VUGGY AND BROKEN, ABUNDANT VUGS TO 2-3" DIAMETER, SOME FILLED WITH GYPSUM AND SOME WITH CLAY, SOME HAVE BOTH; MOST HAVE IRREGULAR MARGINS DUE TO DISSOLUTION OF CARBONATE; ABUNDANT IRREGULAR THIN (<1/16") FILLED AND OPEN FRACTURES INTERCONNECTING ALL VUGS. MOST FRACTURES ARE SUBVERTICAL TO VERTICAL. CLAY-RICH INTERBEDS NEAR TOP, MOST VUGS CLAY-FILLED. ABOUT 50 PERCENT OF FRACTURES ARE UNFILLED. SUBVERTICAL FRACTURES VERY ABUNDANT, SPACED 1/4-2", MOST VERY DISCONTINUOUS. UNIT ACTUALLY PACKBRECCIA (MORROW, 1982). GRADATIONAL BASAL CONTACT.

DOLOMITE, LIGHT OLIVE GRAY (5Y6/1). BEDDING MORE DISTINCT BELOW 700 FT, LAMINAE TO VERY THIN BEDS; LOW ANGLE CROSS-LAMINAE WITH LOW HUMMOCKS, LOCAL EROSIONAL SCOURS TO 3" DEEP, MAY APPEAR WAVY TO LENTICULAR. VUGS MORE ABUNDANT AND SMALLER DOWNWARD, FREQUENCY DECREASES SIGNIFICANTLY BELOW ABOUT 705 FT; VUGGY POROSITY DEVELOPED IN SUBVERTICAL FRACTURES; MOST VUGS OPEN OR FILLED WITH CLAY, GYPSUM AS FRACTURE OR VUG FILLING MUCH LESS COMMON. ABUNDANT DISSOLUTION OF CARBONATE. UNIT IS A PACKBRECCIA (MORROW, 1982). GRADATIONAL BASAL CONTACT.

DOLOMITE, LIGHT OLIVE GRAY (5Y6/1). THIN LAMINAE TO VERY THIN BEDS. LESS BRECCIATED AND DISRUPTED THAN OVERLYING UNIT; FEWER LARGE VUGS, LAYERING FLATTER, LESS WAVY THAN OVERLYING UNIT; SOME LOW ANGLE CROSS-CUTTING RELATIONSHIPS. FRACTURES LESS ABUNDANT THAN IN OVERLYING UNIT, BUT STILL ABUNDANT, MUCH MORE CONTINUOUS, MOST SUBVERTICAL. ABUNDANT MICROVUGS. GRADATIONAL BASAL CONTACT.

DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), ENTIRE UNIT UNDULATORY. THIN LAMINAE TO LAMINAE. LOCALLY BRECCIATED. SHARP BASAL CONTACT, UNDULATORY OVER 3 FT.

UNNAMED LOWER MEMBER. MUDSTONE AT BASE TO CLAYSTONE AT TOP, MEDIUM BLUISH GRAY TO BROWNISH GRAY TO DARK GREENISH GRAY UPWARD (5B5/1-5YR4/1-5GY2/1) (SEE FIG. 9 FOR DETAILED MAP). MICRO TO THIN LAMINAE TO STRUCTURELESS, WAVY, SOME CONTORTED AND VERY IRREGULAR TO DISCONTINUOUS. GRAY CLAST TO COBBLE SIZE IN LOWER MIDDLE PART OF UNIT. SLICKENSIDES COMMON. GYPSUM-FILLED FRACTURES OCCUR LOCALLY TO 1/4" THICK ALONG SLICKENSIDED SURFACES. YELLOW STAINS ON SOME FRACTURES. SOFT. LOWER CONTACT MARKED BY DISTINCT COLOR CHANGE.

MUDSTONE, MODERATE BROWN (5YR3/4) WITH MEDIUM BLUISH GRAY (5B5/1) INTERLAMINAE; CONTAINS SEVERAL VERY THIN BEDS TO LAMINAE OF DISCONTINUOUS GYPSUM, .5-1 FT BELOW, AND PARALLEL TO, UPPER CONTACT. SMEARED INTRACLAST/LAMINAE TEXTURE BELOW SULFATE INTERBEDS WITH A HINT OF HORIZONTAL STRATIFICATION. LOCALLY ABUNDANT GYPSUM-FILLED FRACTURES TO 1" THICK WITH VARIOUS ORIENTATIONS. LOWER CONTACT SHARP, EROSIONAL.

ANHYDRITE, VERY TO MEDIUM LIGHT GRAY (N8-6), MODERATE PINK ZONE (5R7/4) 1 FT BELOW CONTACT; COVERED WITH GROUT, MOST DETAIL OBSCURED. MICROCRYSTALLINE. THIN LAMINAE TO LAMINAE; STRATA MOSTLY FLAT, LAMINAE WAVY. POORLY EXPOSED. LARGE

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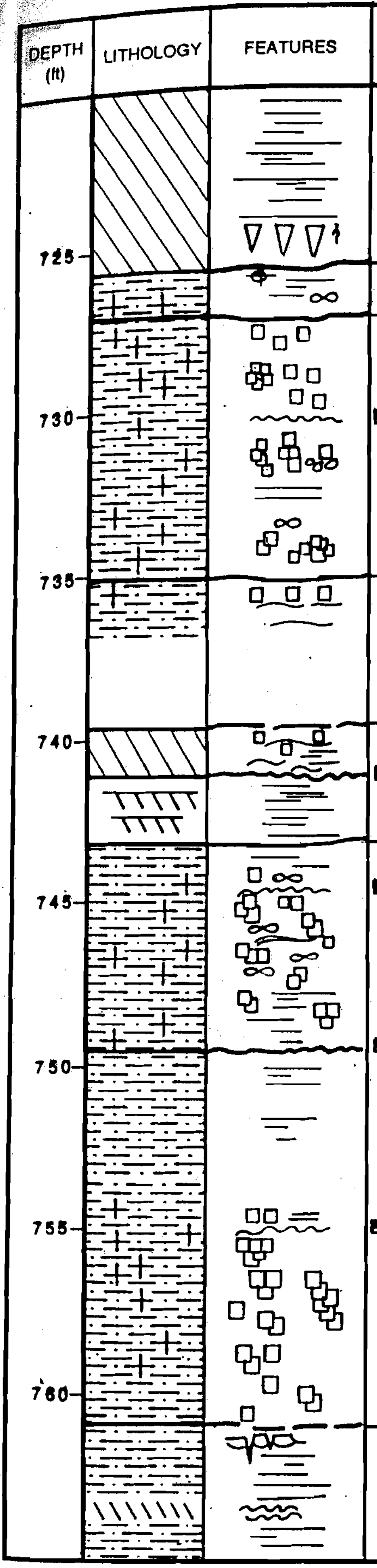
FIGURE 5



REMARKS

HALITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAIL CRYSTALS TO 1 FT HIGH NEAR BASE. LOWER CONTACT SHARP.

SILTSTONE (BASE) TO MUDSTONE (TOP), GRAYISH BROWN TO GRAYISH RED (5YR3/2-10R4/2), UPPER .5-.2 FT IS GRAY (5G6/1). HALITE CEMENT NEAR BASE, ANHYDRITE CEMENT AT TOP. LOCAL THIN LAMINAE; ANHYDRITE OCCURS AS IRREGULAR INTERBEDS AND NODULES; HINT OF SMEARED INTRACLAST/LAMINAE TEXTURE. SHARP TO EROSIONAL BASAL CONTACT MARKED ALSO BY INCREASE IN SALT CONTENT.

SILTSTONE AND HALITE, MODERATE BROWN (5YR3/4), ZONES OF GREENISH GRAY (5GY6/1). LOCAL THIN LAMINAE OF SILTSTONE; CLEAR INCORPORATIVE HALITE OCCURS AS ISOLATED AGGREGATES OF CRYSTALS TO 1" ON A SIDE, CONCENTRATED BETWEEN 727.4-729 FT, CRYSTALS MAY BE DISPLACIVE; SILTSTONE BED AT EROSIONAL SURFACE AT 730 FT IS ABOUT .5 FT THICK; BELOW 730 FT, HALITE OCCURS WITH SILTSTONE, SILTSTONE OCCURS AS BLEBS AND DISCONTINUOUS INTERBEDS MARKING EROSIONAL SURFACES; HALITE CONCENTRATION DECREASES IN LOWER .2-.5 FT; SILTSTONE SHOWS SMEARED INTRACLAST/LAMINAE TEXTURE; BELOW 730 FT, MOST HALITE ORIGINATED AS OVERGROWTHS ON HALITE CRUST; SILTSTONE INTERBEDS DISCONTINUOUS; WITH EXCEPTION OF AN IRREGULAR HORIZONTAL ZONE NEAR 732 FT AND THE SILTSTONE INTERBED AT 730 FT, HALITE IS THE DOMINANT CONSTITUENT. LOWER CONTACT SHARP AND EROSIONAL.

HALITE, CLEAR, WITH SILTSTONE, MODERATE BROWN (5YR3/4). INCREASING CLAY AND SILTSTONE CONTENT UPWARD TO SILTSTONE AT TOP. MOST SILTSTONE OCCURS IN UPPER HALF OF UNIT AS THIN STRINGERS AND BLEBS, CONTENT INCREASES UPWARD. LOWER .5 FT MOSTLY CLEAR HALITE, INTERLOCKING CRYSTALS (HALITE CRUST). HARD. BASAL CONTACT SHARP TO GRADATIONAL.

ANHYDRITE, MEDIUM CRYSTALLINE; VERY TO MEDIUM LIGHT GRAY (N8-6). THIN LAMINAE, WAVY, FLAT TO PARALLEL IN UPPER .5-1 FT; LAMINAE LOCALLY DISCONTINUOUS. IRREGULAR ZONES OF HALITE, SOME DISPLACIVE CRYSTALS, HALITE INCREASING UPWARD. HARD, STANDS OUT AS RESISTANT UNIT. LOWER CONTACT SHARP AND EROSIONAL; LAMINAE WITHIN UNIT DRAPE CONTACT.

HALITE WITH INTERLAMINATED ANHYDRITE, ANHYDRITE CONTENT INCREASING DOWNWARD, CLEAR TO WHITE. VERY THIN TO THIN BEDS, FLAT TO SLIGHTLY WAVY; CONTAINS THIN ARGILLACEOUS LAMINAE DOWNWARD WITHIN ANHYDRITE. BASAL CONTACT SHARP, EROSIONAL.

HALITE WITH MUDSTONE AND SILTSTONE (TOP, UPPER 1 FT); HALITE CLEAR, MUDSTONE AND SILTSTONE LIGHT BROWNISH GRAY (5YR6/1). MUDSTONE OCCURS AS STRINGERS; .5 FT THICK SILTSTONE WITH EROSIONAL BASE OCCURS BELOW UPPER CONTACT, HAS DISPLACIVE HALITE CRYSTALS TO 1/4" WITH SMEARED INTRACLAST/LAMINAE TEXTURE. REMAINDER OF UNIT MAINLY HALITIC SILTSTONE; LOCAL THIN LAMINAE TO VERY THIN BEDS, IRREGULAR TO DISCONTINUOUS; SMEARED INTRACLAST/LAMINAE TEXTURE. LOCALLY THINLY BEDDED, ANHYDRITIC NEAR TOP. SOME HALITE AGGREGATES, MOSTLY DISPLACIVE TO SMALL AGGREGATES, CRYSTALS TO 1/2" ACROSS. LOOSE TO HARD DUE TO RECENT DISSOLUTION OF HALITE DURING SHAFT CONSTRUCTION. BASAL CONTACT GRADATIONAL TO SHARP, EROSIONAL.

HALITE AND SILTSTONE, CLEAR HALITE, SILTSTONE LIGHT BROWNISH TO GREENISH GRAY (5YR6/1-5GY6/1); HALITE COARSELY CRYSTALLINE, TO 1/2". UPPER PART SHOWS WELL DEVELOPED VERY THIN TO THIN BEDS WITH HALITE INTERLAMINAE; STRATA LESS WELL DEVELOPED IN MIDDLE PART, CONTAINS IRREGULAR SMALL BLEBS OF SILTSTONE; AT ABOUT 755, .5-.2 FT SILTSTONE OCCURS ON TOP OF EROSIONAL SURFACE, CONTAINS 1/4" DISPLACIVE CRYSTALS, IRREGULAR LAMINAE; BELOW 755 FT, HALITE IS ISOLATED TO AGGREGATES, CRYSTALS TO 1/2", CONTENT AND SIZE DECREASE DOWNWARD. GRADATIONAL BASAL CONTACT.

FINE TO MEDIUM SANDSTONE TO SILTSTONE, ANHYDRITIC, HALITIC; VERY LIGHT TO LIGHT BROWNISH GRAY TO GRAYISH RED (N8-5GY6/1-10R4/2). THIN LAMINAE TO LAMINAE, WAVY TO CONTORTED, LOCALLY DISCONTINUOUS; BELOW 763 FT, BEDDING IS FLATTER; SOME LAMINAE TO VERY THIN BEDS OF ANHYDRITE ARE ENTEROLITHIC; SOME TEPEE STRUCTURES AND DISC-SHAPED LAMINAE; POSSIBLE DESICCATION CRACKS. UPPER .5 FT SLIGHTLY HALITIC, NEXT 1.5 FT VERY ANHYDRITIC, BELOW 763 FT ANHYDRITE CONTENT DECREASES DOWNWARD. LAMINAR TO VERY THINLY BEDDED GRAY ZONES OCCUR, MORE ABUNDANT; BELOW

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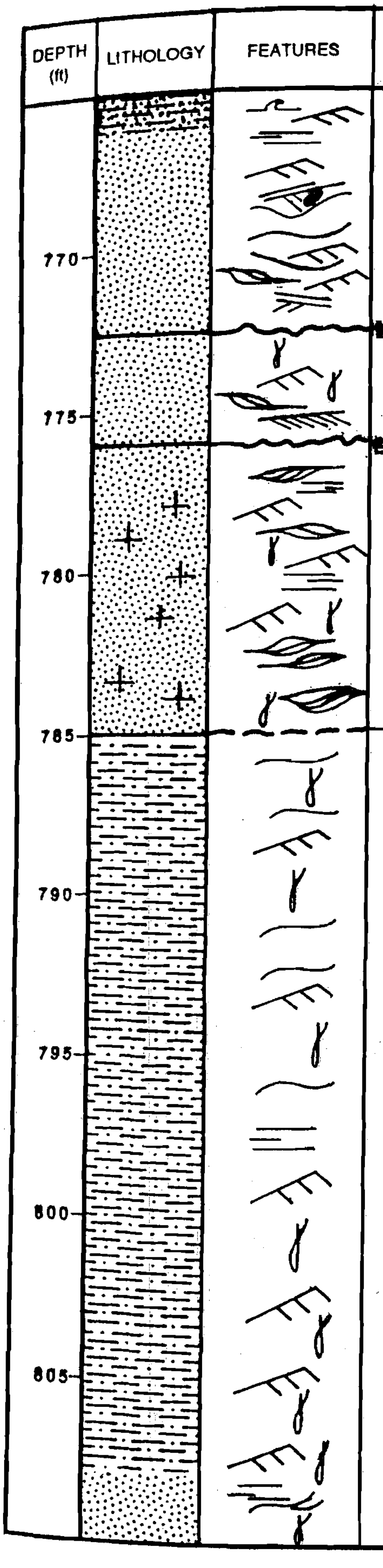
FIGURE 5



REMARKS

767 FT, LOCAL FLAME STRUCTURES. MAINLY SANDSTONE FROM 765 TO BASE; SOME LOW ANGLE ACCRETIONARY CROSS-LAMINAE, SETS TO 2" HIGH ON MARGINS OF CHANNELS .2 FT DEEP BY 5 FT WIDE; SMALLER FLAT LAMINAE AT TOP, RIPPLE CROSS-LAMINAE AND RIPPLE FORMS BECOME MORE COMMON DOWNWARD; RIPPLE FORMS AND RIPPLE CROSS-LAMINAE INCREASE DOWNWARD, AS DOES SET SIZE TO 2"; LATERAL ACCRETION LOW ANGLE CROSS-LAMINAE SETS TO .4 FT HIGH. MANY SUBVERTICAL HALITE-FILLED FRACTURES TO 2" THICK, SPACED 2-4 FT. LOWER CONTACT SHARP, EROSIONAL, UNDULATORY.

SANDSTONE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5GY6/1). THIN LAMINAE TO LAMINAE WITH ABUNDANT CROSS-LAMINAE; SIZE INCREASES DOWNWARD TO DUNE-SIZE CROSS-BEDDING WITH SCOUR BASES; PLANAR CROSS-BEDDING AT BASE WITH RIPPLES TO 2" CROSS-LAMINAE AT TOP; LOCAL SCOURS; SOME BURROWING. HARD. EROSIONAL BASAL CONTACT.

SANDSTONE, GREENISH GRAY (5GY6/1). THIN LAMINAE TO RARE LAMINAE; CROSS-LAMINAE TO CROSS-BEDDING COMMON, SETS TO .5 FT; CROSS-BEDS PLANAR; LOCAL TROUGHS TO .2 FT DEEP; SCOUR SURFACES COMMONLY OVERLAIN BY TANGENTIAL CROSS-BEDDING; SOME EQUIDIMENSIONAL RIPPLES AND RIPPLE CROSS-LAMINAE, SETS TO 1"; FLAT TO WAVY LAMINAE; SOME BURROWING. ABUNDANT SUBVERTICAL TO VERTICAL HALITE-FILLED FRACTURES TO 1" THICK, DISSOLVED OUT AT SURFACE OF SHAFT. MODERATELY HARD, PROBABLE HALITE CEMENT. GRADATIONAL BASAL CONTACT.

MEDIUM SANDSTONE, PROBABLE HALITE CEMENT; MODERATE BROWN (5YR3/4) AT BASE FINING UPWARD TO ARGILLACEOUS SILTSTONE, GREENISH TO BLUISH GRAY (5GY6/1-5B6/1). LOWER .1 FT CONTAINS CLASTS AND PEBBLES OF SILTSTONE WITH FOSSIL FRAGMENTS (INVERTEBRATES). SEDIMENTARY STRUCTURES SMALLER THAN IN OVERLYING UNIT; LOW ANGLE RIPPLE CROSS-LAMINAE WITH FLAT TO WAVY THIN LAMINAE. BIOTURBATION MORE EXTENSIVE DOWNWARD. CONSISTS OF BIOTURBATION ZONE OVERLAIN BY RIPPLES, OVERLAIN BY BIOTURBATION, ETC.; VERY LITTLE STRATIFICATION PRESERVED DOWNWARD; BURROWS SUBHORIZONTAL. ABUNDANT CLOSELY SPACED SUBVERTICAL TO VERTICAL FRACTURES, SOME FILLED WITH HALITE TO 1" THICK; SLABS 2-6" THICK SCALE OUT; FRACTURES INTERSECT FORMING WEDGES. HALITE FRACTURE FILLINGS DISSOLVED AT SHAFT SURFACE FROM CULEBRA WATER. MODERATELY HARD. CONTACT EROSIONAL AND SHARP, UNDULATORY OVER 1 FT.

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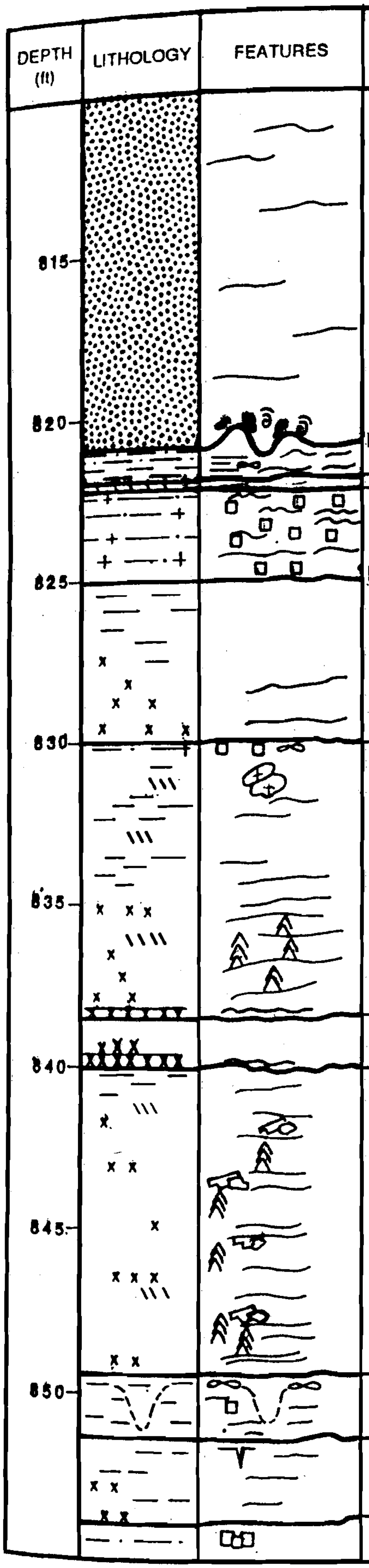
FIGURE 5



REMARKS

SILTSTONE TO VERY FINE SANDSTONE, HALITE CEMENT; MODERATE BROWN (5YR3/4). THIN LAMINAE TO LAMINAE, WAVY TO LOCALLY CONTORTED, DISCONTINUOUS; SOME SMEARED INTRACLAST/LAMINAE TEXTURE. MODERATELY HARD. BASAL CONTACT SHARP.

ANHYDRITE, LIGHT BROWNISH GRAY TO LIGHT GRAY (5YR6/1-N7); MEDIUM CRYSTALLINE (SEE FIG. 10 FOR DETAILED MAP). PARTIALLY LAMINATED. HARD. LOWER CONTACT SHARP.

SALADO FORMATION. HALITIC SILTSTONE, MODERATE BROWN (5YR3/4) WITH INTERLAMINAE OF GREENISH GRAY (5G6/1) SULFATE. HALITE CONTENT INCREASES DOWNWARD, SMALL DISPLACIVE CRYSTALS TO 1/8", MOST ABOUT 1/16". IRREGULAR THIN LAMINAE TO LAMINAE NEAR TOP ARE LESS DISTINCT DOWNWARD. EROSIONAL CONTACT AT 824 FT AND BASE OF UNIT.

HALITE, CLEAR, WITH POLYHALITE, MODERATE REDDISH ORANGE (10R6/6) AND CLAY, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). HALITE MEDIUM TO COARSELY CRYSTALLINE, MODERATELY POLYHALITIC AT BASE, MODERATELY ARGILLACEOUS AT TOP. CLASTIC MATERIAL AS BLEBS, POLYHALITE AS BLEBS AND STRINGERS. LOWER CONTACT SHARP.

HALITE TO HALITIC MUDSTONE (UPPER .5-.3 FT); HALITE MEDIUM TO COARSELY CRYSTALLINE. ARGILLACEOUS ZONES FROM 831.5-832.5 AND 833.5-834.5 FT WITH ABUNDANT DISCONTINUOUS SUBHORIZONTAL STRINGERS OF MODERATE BROWN (5YR3/4) CLAYSTONE; LOCALLY POLYHALITIC (MODERATE REDDISH ORANGE, 10R6/6) AS DISCONTINUOUS AND INTERCRYSTALLINE STRINGERS; SOME WHITE (N7) ANHYDRITE. MOSTLY CLEAR BELOW 835 FT, THIN TO MEDIUM BEDS; LOCAL CLEAR, VERY COARSELY CRYSTALLINE HALITE; UPPER HALITIC MUDSTONE WITH ABUNDANT DISPLACIVE CRYSTALS TO 1", WITH SMEARED INTRACLAST TEXTURE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). LOWER CONTACT MARKED BY .1-.3 FT THICK POLYHALITE BED, VERY UNDULATORY AT SMALL SCALE. LOWER CONTACT SHARP.

HALITE, CLEAR, LOCALLY BLUE; VERY COARSELY CRYSTALLINE, TO 6" ON SIDE; LOWER .5" SLIGHTLY POLYHALITIC, MODERATE REDDISH ORANGE (10R6/6); LOWER .1-.2 FT CONSISTS OF POLYHALITE. LOWER CONTACT SHARP, SLIGHTLY UNDULATORY.

HALITE; THIN TO MEDIUM BEDS WITH IRREGULAR STRINGER OF POLYHALITE, MODERATE REDDISH ORANGE (10R6/6) AND ANHYDRITE; SLIGHTLY ARGILLACEOUS IN UPPER 1 FT. HALITE CLEAR, MEDIUM TO COARSELY CRYSTALLINE. BEDDING 3-6" THICK; STRATA WAVY. SEQUENCES OF VERTICALLY ORIENTED HALITE OVERLAIN BY CUMULATES; ZONES OF COARSE CLEAR HALITE. LOWER CONTACT SHARP.

ARGILLACEOUS HALITE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1), LOCAL PITS WITH CLEAR HALITE. CLAY OCCURS AS BLEBS AND IRREGULAR STRINGERS, INCREASES UPWARD. HALITE DISPLACIVE, INCORPORATIVE. SMEARED INTRACLAST/LAMINAE TEXTURES AT TOP. LOWER CONTACT SHARP AND EROSIONAL.

HALITE, POLYHALITIC, MODERATE REDDISH ORANGE (10R6/6), CLEAR TO WHITE HALITE. INTERCRYSTALLINE POLYHALITE AND AS IRREGULAR DISCONTINUOUS SUBHORIZONTAL STRINGERS. RARE STRINGERS OF MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1) CLAY. POSSIBLE PRISM CRACKS NEAR TOP. LOWER CONTACT SHARP.

HALITE AND SILTSTONE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). HALITE CLEAR, INCORPORATIVE; MEDIUM TO COARSELY CRYSTALLINE, TO 1" ON SIDE, LOCALLY

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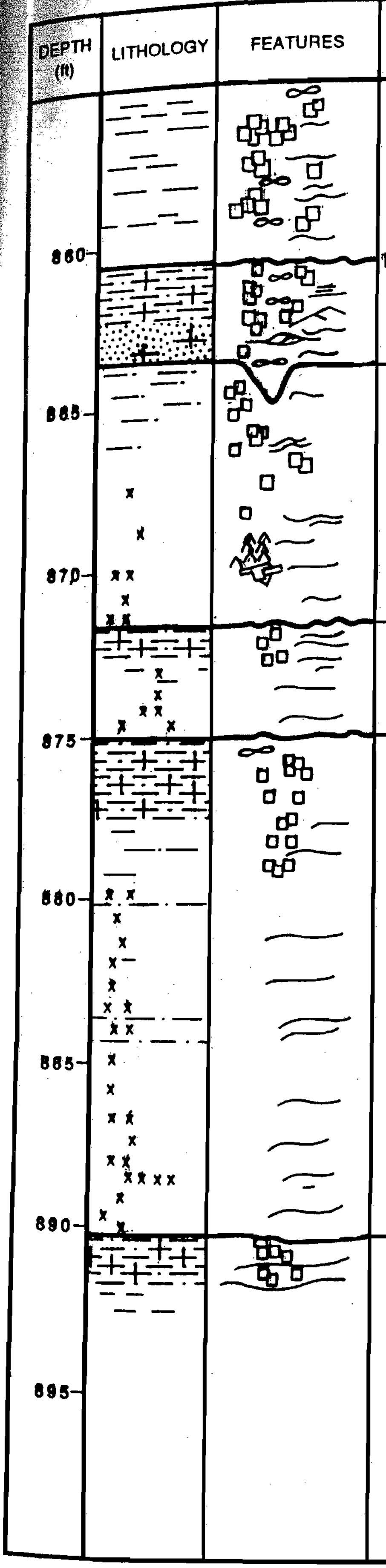
FIGURE 5



REMARKS

DISPLACIVE. BEDDED; POORLY DEFINED IRREGULAR ZONES OF SILTSTONE WITH SMEARED INTRACLAST/LAMINAE TEXTURE. EROSIONAL LOWER CONTACT.

SILTSTONE TO VERY FINE SANDSTONE, HALITE CEMENTED, MODERATE BROWN (5YR3/4) WITH MINOR GREENISH GRAY (5G6/1). THIN LAMINAE TO LAMINAE; SOME SMALL (<1/4") CROSS-LAMINAE; LAMINAE ARE IRREGULAR TO DISCONTINUOUS; LOCAL SMEARED INTRACLAST/LAMINAE TEXTURES; SOME SCOURS WITH LOW ANGLE CROSS-LAMINAE; RARE SMALL (<1/4") DISPLACIVE HALITE CRYSTALS; HAS SCOUR/DISSOLUTION TROUGH 1.5 FT DEEP AT WEST AND EAST SIDE OF SHAFT. SHARP BASAL CONTACT.

HALITE, WHITE TO TINTED LIGHT RED (5R6/6); MEDIUM TO COARSELY CRYSTALLINE, CLOUDY; SOME VERY COARSE CLEAR; ABUNDANT SILTSTONE AT TOP, DECREASING DOWNWARD. IRREGULAR DISCONTINUOUS STRINGERS/LAMINAE AND BLEBS TO COBBLE-SIZE WITH DISPLACIVE CRYSTALS TO 1", CONTENT DROPS GREATLY BELOW 868 FT. POLYHALITE CONTENT INCREASES DOWNWARD, AS DISSEMINATED MATERIAL AND IRREGULAR SUBHORIZONTAL STRINGERS. BELOW 868 FT, BECOMES THIN TO MEDIUM BEDDED. BOTTOM GROWN HALITE OVER HALITE CUMULATES WITH POLYHALITE. LOWER CONTACT SHARP.

HALITE, CLEAR OR WHITE TO LIGHT OR MODERATE RED (5R6/6-4/6). UPPER .5 FT IS SILTSTONE WITH HALITE CONTENT DECREASING DOWNWARD CONTAINING INCORPORATIVE AND DISPLACIVE CRYSTALS. REMAINDER, MEDIUM TO COARSELY CRYSTALLINE; MEDIUM BEDDED WITH BLEBS OF POLYHALITE. LOWER CONTACT SHARP.

HALITE, ARGILLACEOUS AT TOP AND POLYHALITIC AT BASE, AND SILTSTONE. HALITE CLEAR TO WHITE TO TINTED LIGHT RED (5Y6/6). ARGILLACEOUS UNITS MODERATE BROWN (5YR3/4). HALITE MEDIUM TO COARSELY AND VERY COARSELY CRYSTALLINE, SOME VERY COARSELY CRYSTALLINE. CLAY CONTENT DECREASES DOWNWARD. THIN LAMINAE, IRREGULAR, DISCONTINUOUS IN UPPER 1 FT WITH SMEARED INTRACLAST/LAMINAE TEXTURE AND DISPLACIVE/INCORPORATIVE HALITE. BELOW 879 FT, SILTSTONE OCCURS AS IRREGULAR, DISCONTINUOUS STRINGERS. POLYHALITE MODERATELY ABUNDANT AT BASE, DECREASES UPWARD AS IRREGULAR DISCONTINUOUS STRINGERS AND BLEBS, ALSO RIMS HALITE CRYSTALS. IRREGULAR THIN TO MEDIUM BEDS DELINEATED BY POLYHALITE BELOW 883 FT. SHARP BASAL CONTACT.

HALITE, WHITE TO CLEAR TO TINTED LIGHT RED (5R6/6) AND ARGILLACEOUS HALITE, MODERATE BROWN (5YR3/4). MEDIUM TO COARSELY CRYSTALLINE; ARGILLACEOUS TO SILTY IN UPPER PART, DECREASING CONTENT DOWNWARD. LOCAL SILTSTONE INTERBEDS.

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 22 OF 22

FIGURE 5

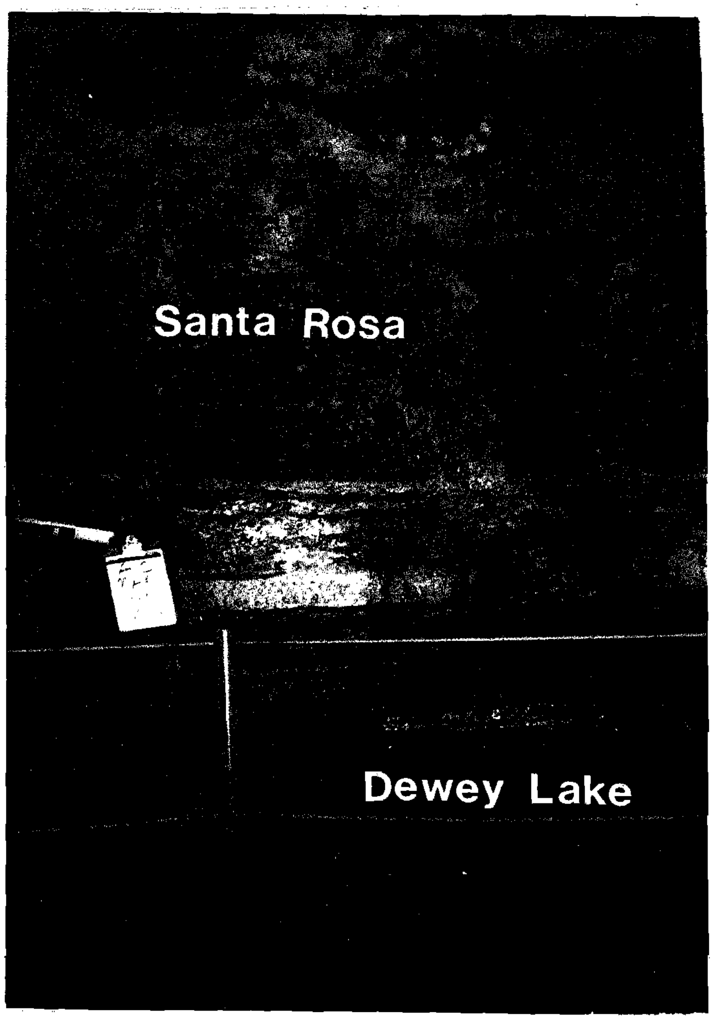
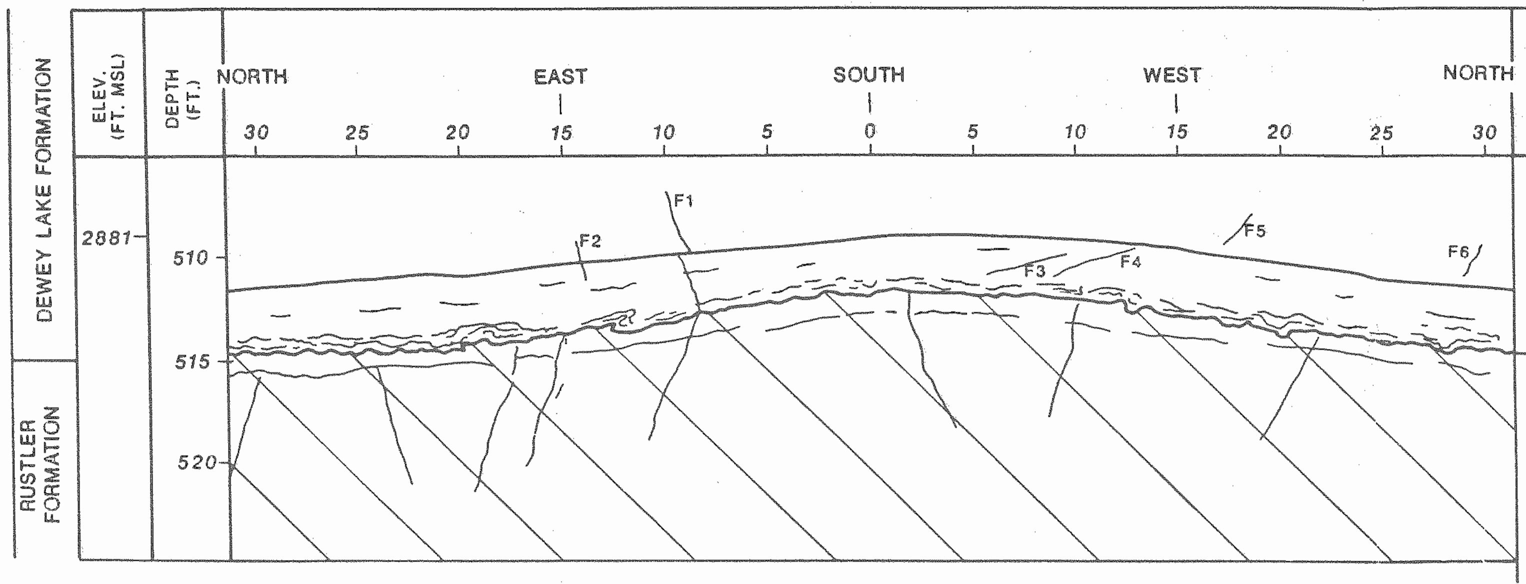


Figure 6
Santa Rosa/Dewey Lake Redbeds contact in the air intake shaft.



LITHOLOGIC DESCRIPTION

VERY FINE SANDSTONE WITH MINOR SILTSTONE AND MUDSTONE. MORE SILTY AND ARGILLACEOUS DOWNWARD. THIN LAMINAE TO VERY THIN BEDS; IRREGULAR, DISCONTINUOUS. FLAT, WAVY, LOCALLY CONTORTED. SOFT SEDIMENT DEFORMATION; SMEARED LAMINAE TEXTURE; CRACKLE TEXTURE OCCURS WITH SOME DESICCATION CRACKS, UP TO 2 FT DEEP EROSION SURFACES AT 475, 480 FT. MAJOR STRATIFICATION AT 483, 493, 495, 506, 510 FT. MUDSTONE AT TOP OF SURFACE AT 475 FT. SOME DISH-SHAPED FEATURES IN LOWER 7 FT, MOST OVERLIE CONTORTED BEDS. EROSIONAL SURFACES DIP PARALLEL TO OTHER INTERNAL BEDDING. UPPER PART OF UNIT HAS ABUNDANT THIN FRACTURES, VERY DISCONTINUOUS, MOST SUBHORIZONTAL, SPACED 1-3", <1/16" WIDE. LARGE FRACTURES MORE ABUNDANT NEAR BASE AS ARE GYPSUM-FILLED FRACTURES IN IRREGULAR PATTERNS, MOST LESS THAN 1/16" WIDE, SPACED 1" FOR HORIZONTAL AND 3-4 FT FOR SUBVERTICAL FRACTURES. PENECONTEMPORANEOUS FOLDING NEAR BASAL CONTACT PARALLELS SHARP BASAL CONTACT WITH TOP OF RUSTLER FORMATION.

RUSTLER FORMATION.
FORTY-NINER MEMBER. ANHYDRITE, VERY LIGHT GRAY (N8), HARD. THIN LAMINAE TO LAMINAE. WAVY TO SLIGHTLY CONTORTED; POSSIBLE LOCAL RIPPLE MARKS; IRREGULAR CLAYSTONE ALONG EROSION SURFACE AT 524.4 FT, THINLY LAMINATED TO WAVY WITH STYLOLITES AT 1"-2 FT SPACING FROM 533-540 FT. SWALLOWTAIL GYPSUM CRYSTALS FROM 540-544 FT. DISRUPTED ZONE 517-521 FT, BOULDER SIZED CLASTS, LAMINAE DOWNWARPED TOWARD AREA OF DISTURBANCE, SOUTH SIDE OF SHAFT AS SOFT SEDIMENT DOWNWARPING IN DEWEY LAKE. CLAYSTONE ON IRREGULAR SURFACES IN ANHYDRITE, LOCAL ZONES OF GYPSUM, ALL PART OF POSSIBLE PALEO MICROKARST ON SURFACE OF FORTY-NINER MEMBER. GYPSUM-FILLED FRACTURES FROM 513-530 FT, HORIZONTAL SPACING 6"-1 FT, NO VERTICAL FRACTURES. SUBVERTICAL SPACED ABOUT 3 FT; OPEN FRACTURES TO 1/16" WIDE FROM 530-540 FT. SHARP BASAL CONTACT.

NOTES

1) THIS INTERVAL WAS MAPPED 10/1/88.
2) DEPTHS ARE RELATED TO SHAFT SUBCOLLAR, 18.5 FEET BELOW TOP OF CEMENT.
3) ELEVATION IS BASED ON SURVEY OF CONTACT AND RELATED TO LOCAL MONUMENTS AND 1927 NORTH AMERICAN DATUM.
4) INTERNAL BEDDING IS DIAGRAMMATIC ONLY; STANDARD GEOLOGIC SYMBOLS ARE NOT USED TO ENHANCE CLARITY OF FIGURE.

FRACTURE NOTES

F1-6 ALL 1/2" WIDE.

EXPLANATION

— SHARP CONTACT
〰 BEDDING (DIAGRAMMATIC)
/ F2 MAPPED FRACTURE

FIGURE 7

GEOLOGIC LOG OF CONTACT
DEWEY LAKE AND RUSTLER FORMATIONS
DEPTH 505 THROUGH 520 FEET
AIR INTAKE SHAFT

WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO

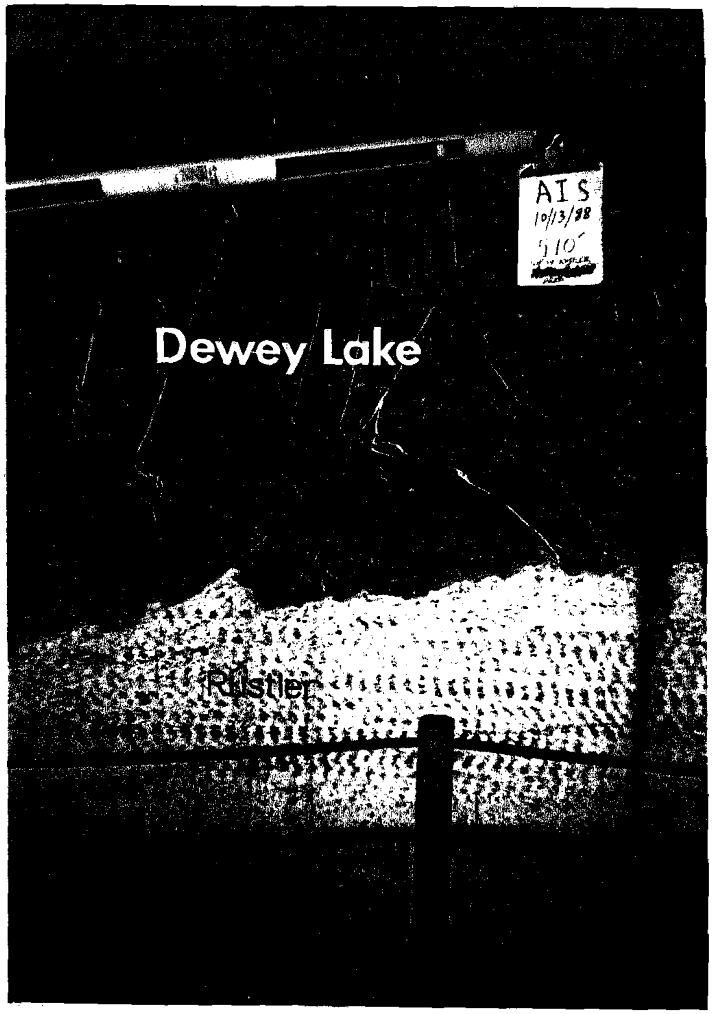
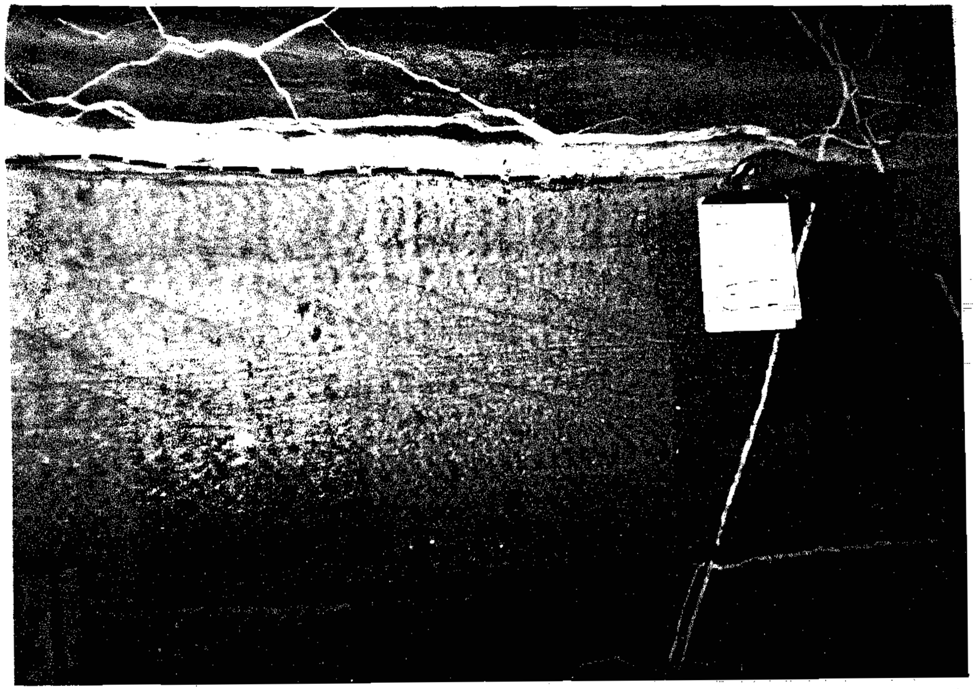
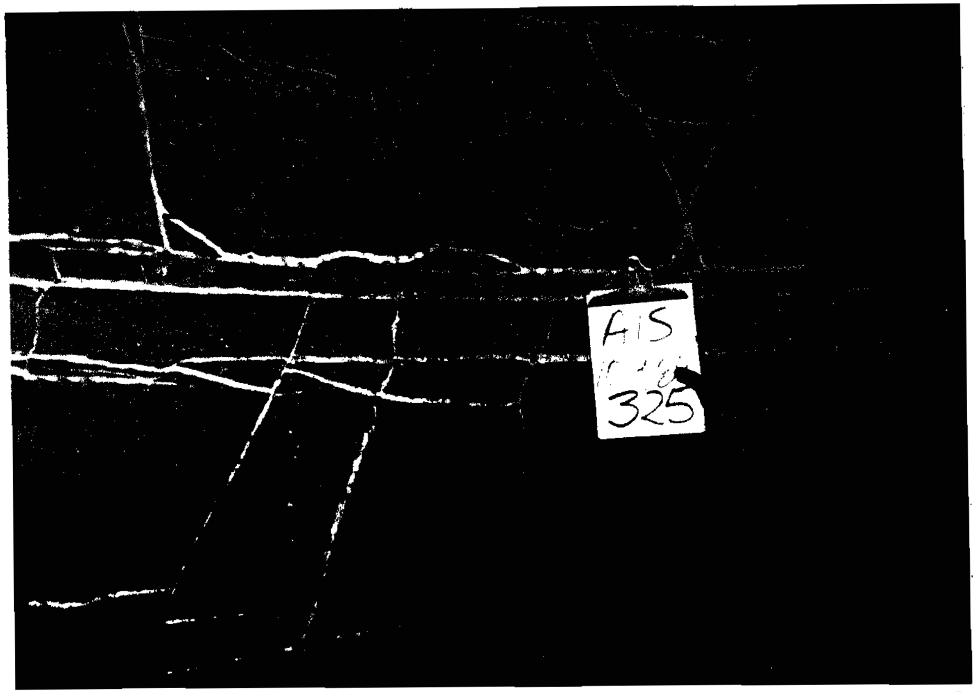


Figure 8
Dewey Lake/Rustler Formation contact in the
air intake shaft.



A

C



B

Figures 9A, 9B, and 9C
Dewey Lake Redbeds. Three examples of upward fining sequences consisting of very fine sandstone grading to siltstone at the top. A) Wavy to flat laminae at the base - ripple drift cross-laminae with stoss preservation - flat laminae at top. B) Two sequences with structures following same order as A) (Note pillow structures in sequence 2.) C) Sequence 1 shows flat laminae at base - ripple-scale cross-laminae with local clay flasers in middle - wavy to flat laminae at top with flame and pillow structures developed at base of sequence 2.

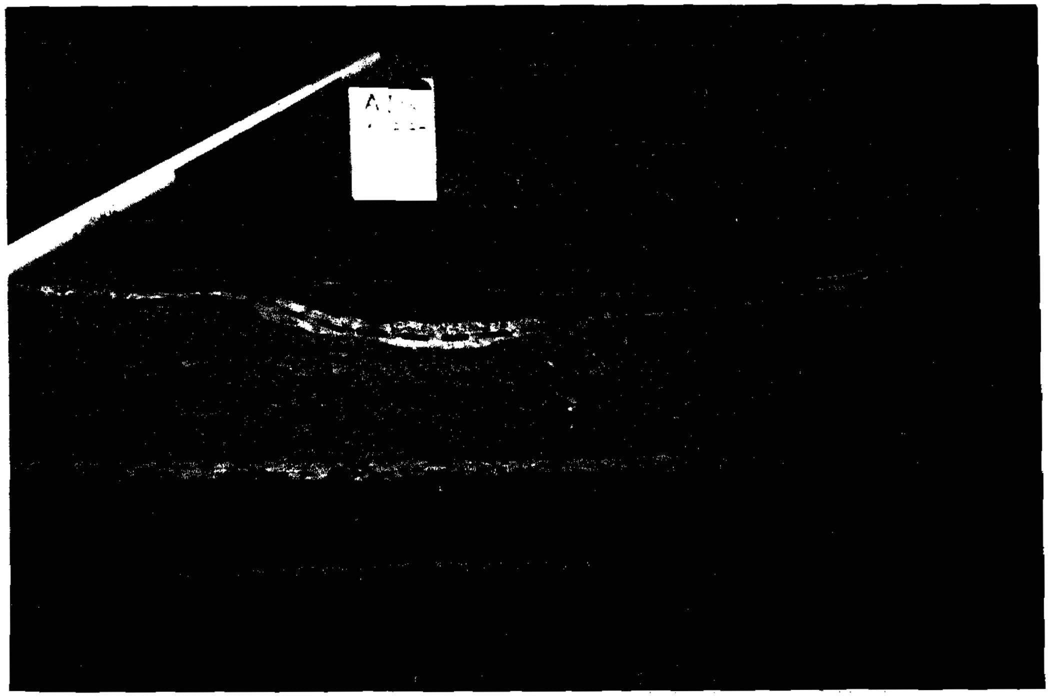


Figure 10
Dewey Lake Redbeds. Shallow channel with low-angle, tangential cross-bedding.

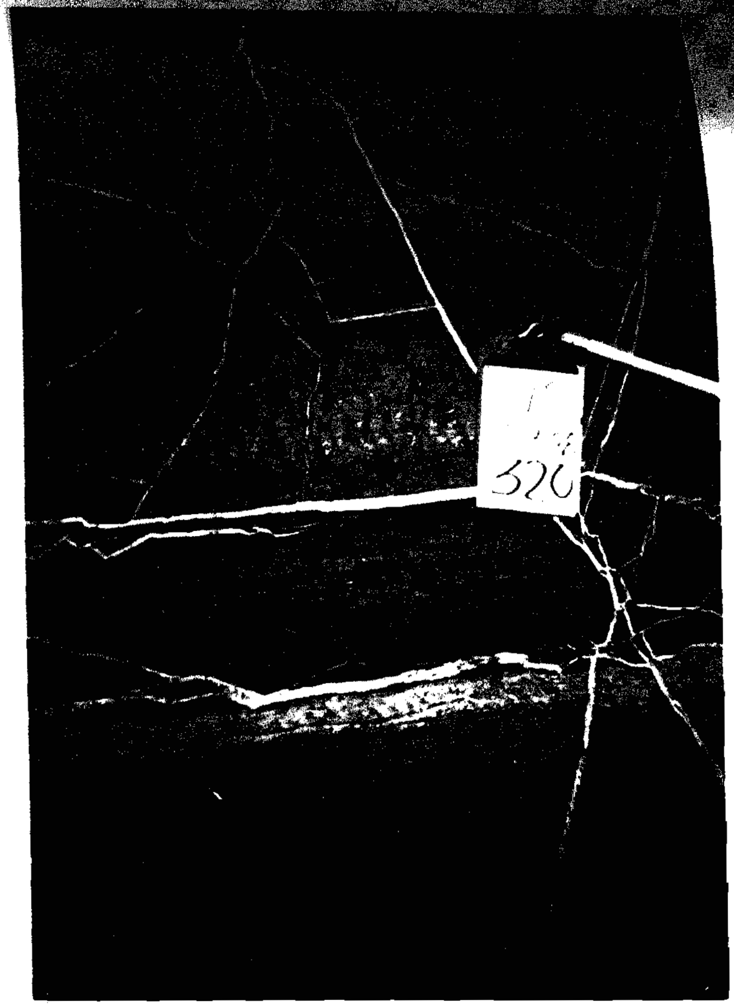


Figure 11
Dewey Lake Redbeds. Prism cracks in fine sandstone and siltstone. Ripple drift cross-laminae occur in the lower part of the photograph.

Figure 12
Dewey Lake Redbeds. "Crackle" texture in siltstone accentuated by wispy thin laminae of claystone. Vertical "ribbed" surface is from cutter heads on shaft bit.

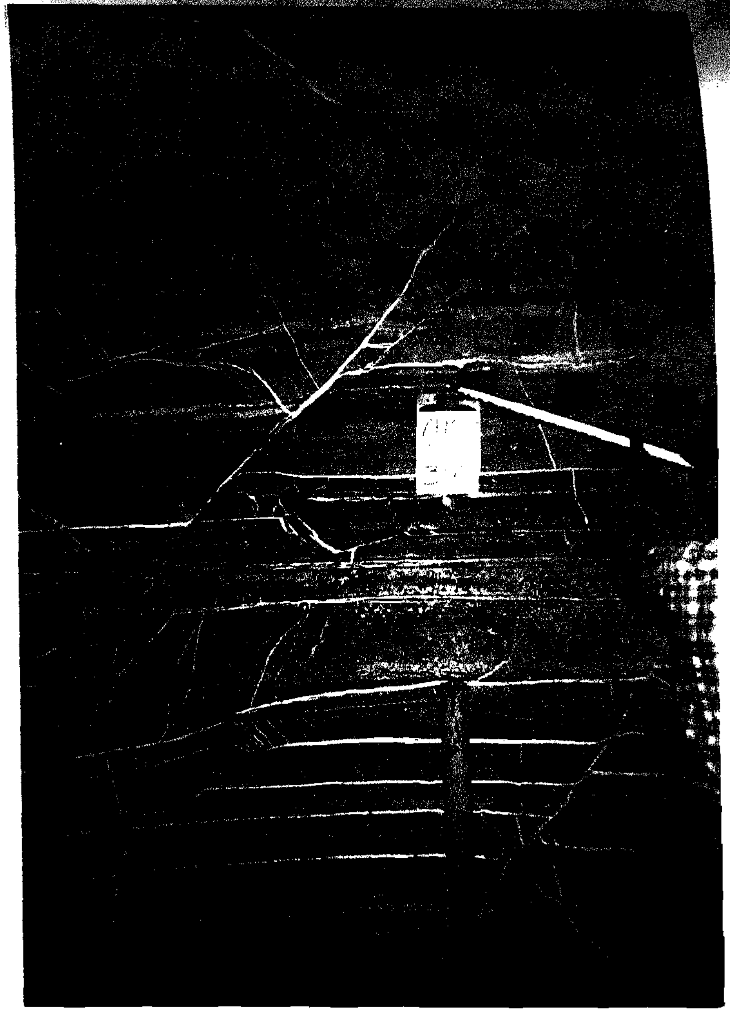


Figure 13
Dewey Lake Redbeds. Penecontemporaneous normal fault with 20+ cm displacement at the base and no displacement at the top (uppermost zone of rip-up clasts).

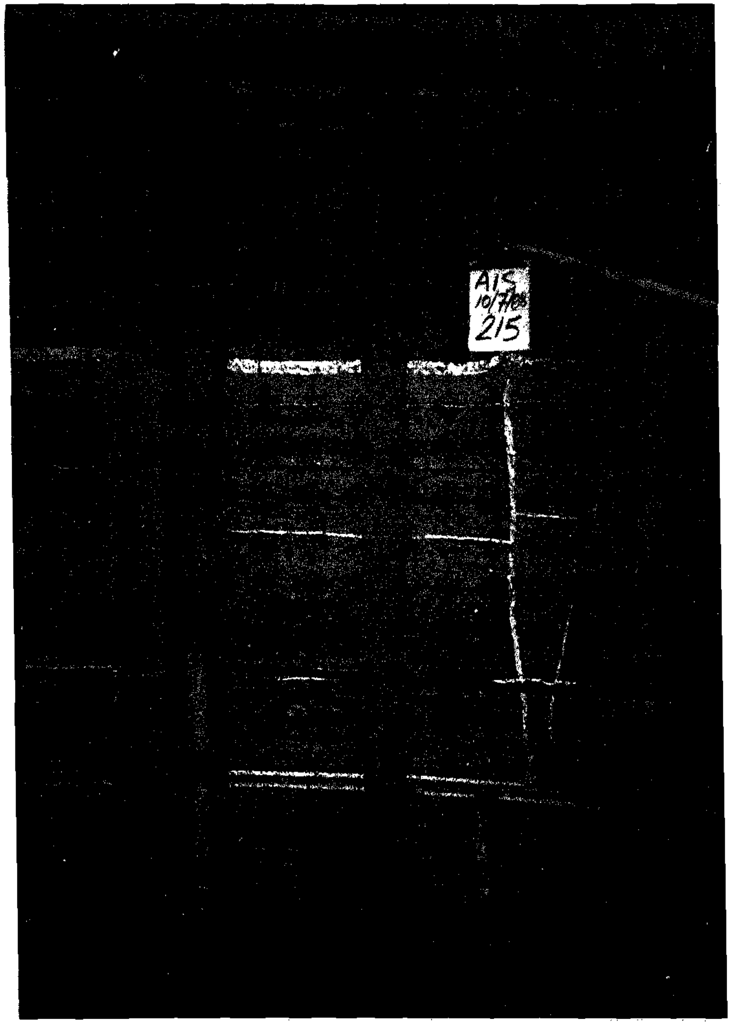


Figure 14
Dewey Lake Redbeds. Typical gypsum-filled fracture pattern in sandstone.

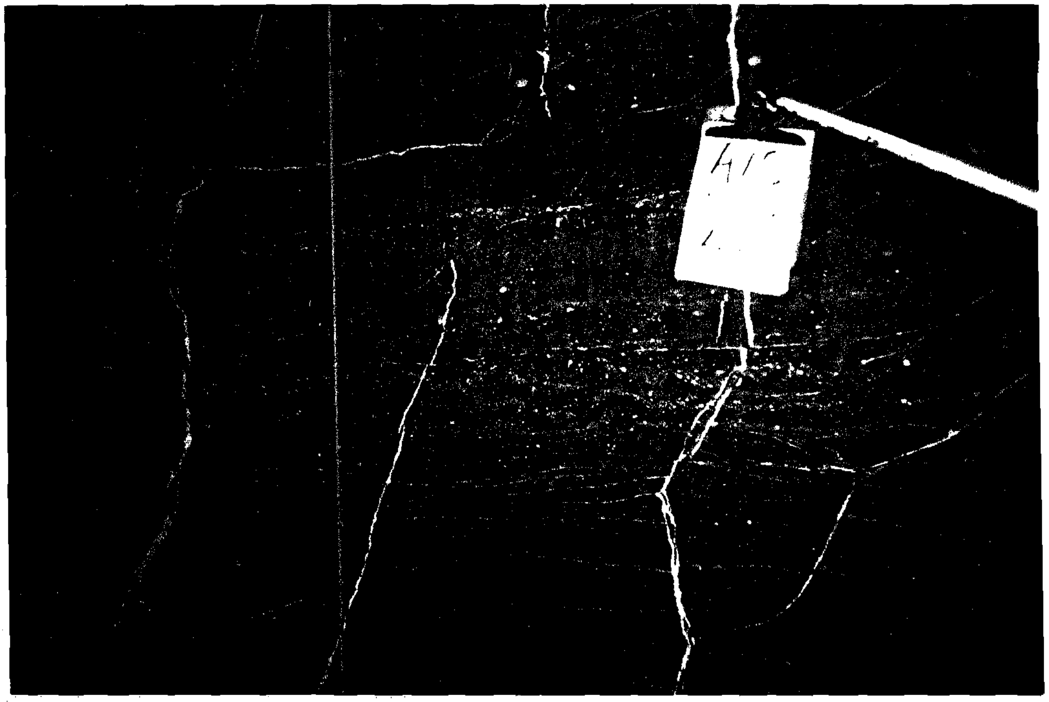


Figure 15
Dewey Lake Redbeds. Typical gypsum-filled fracture pattern in mudstone and siltstone.
(Note contorted strata near center of photograph.)

Figure 16
Dewey Lake Redbeds. Cobble-sized rip-up clast containing gymsum-filled fractures which terminate at the margin of the clast.

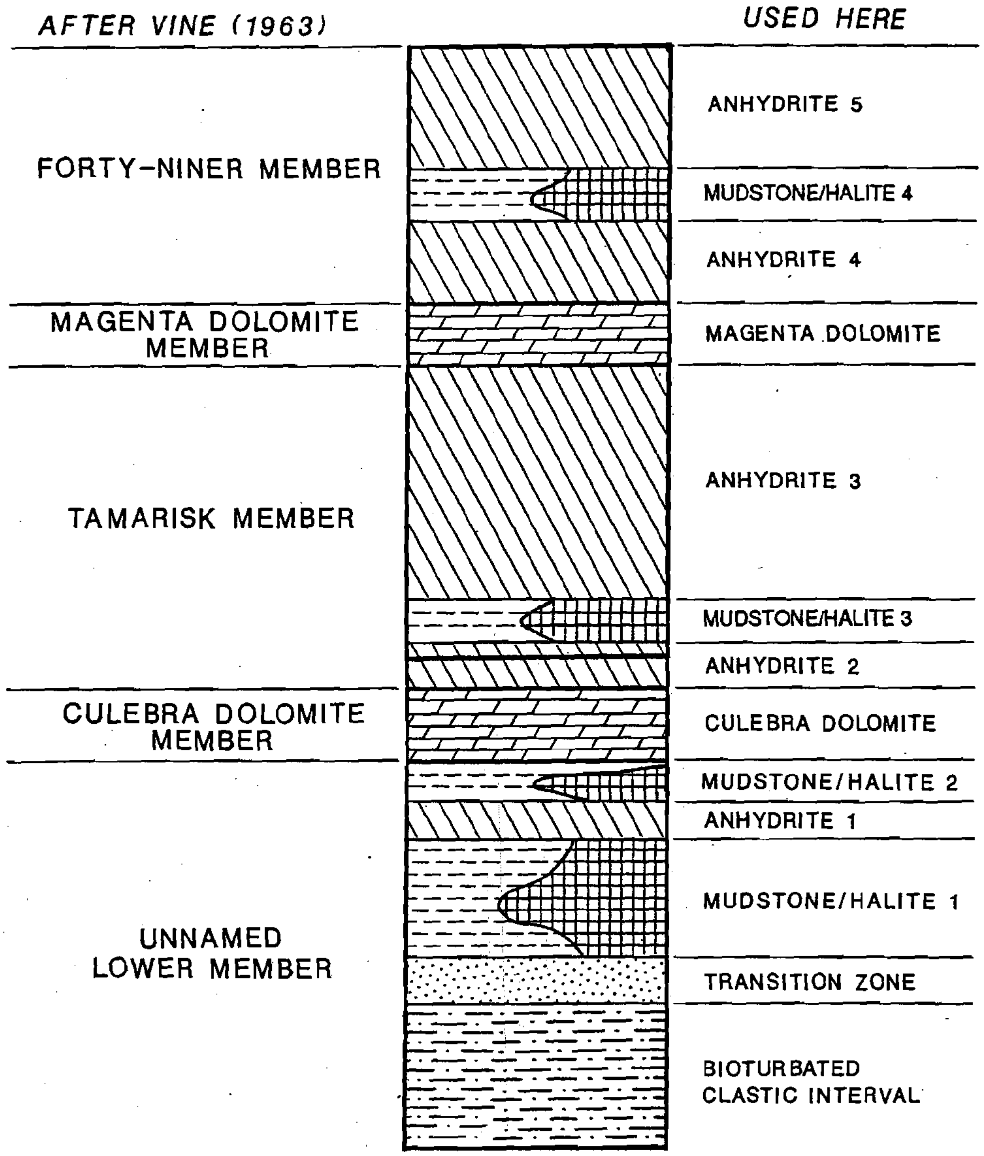
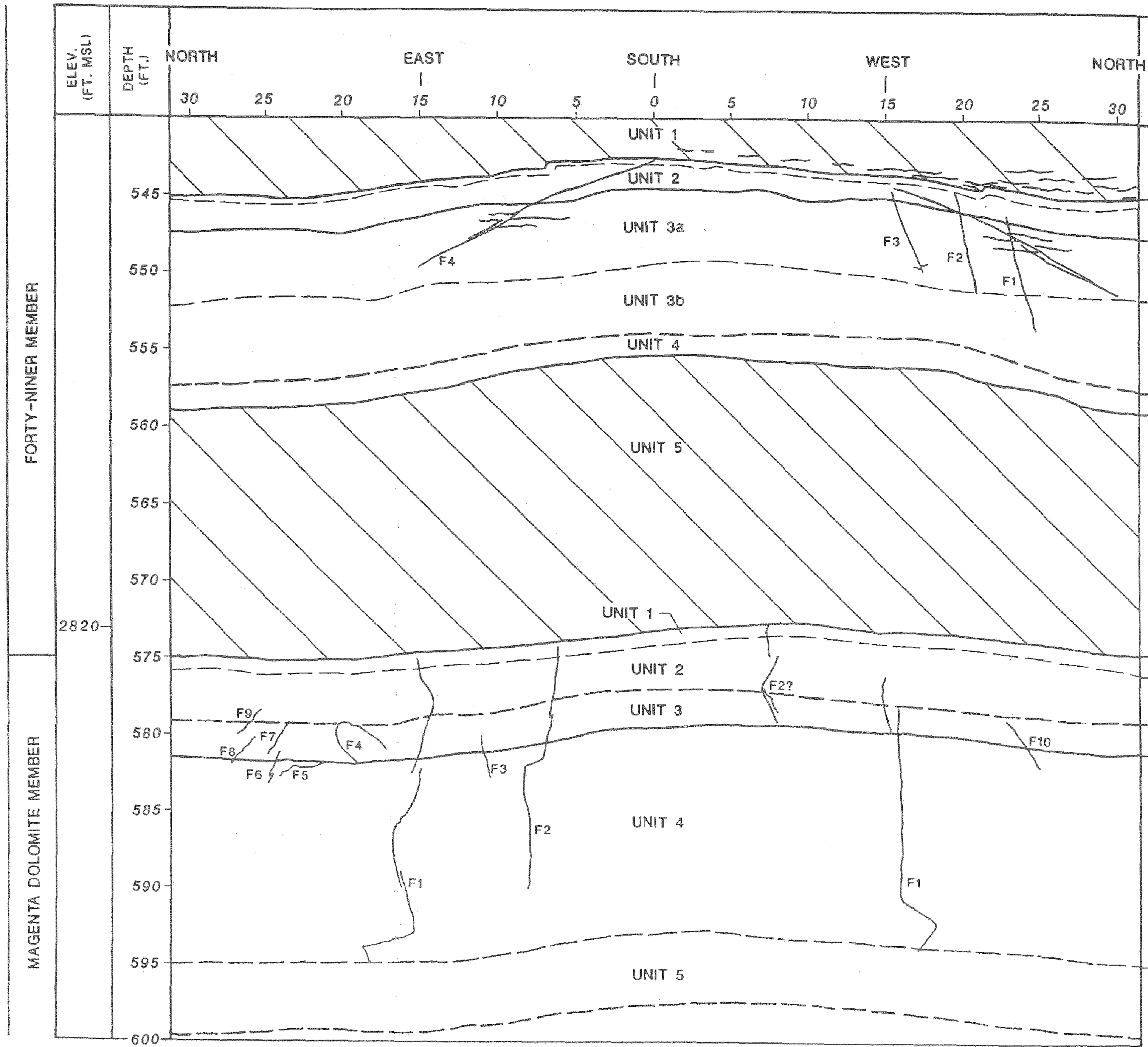


FIGURE 17 RUSTLER STRATIGRAPHY



	LITHOLOGIC DESCRIPTION
UNIT 1	ARGILLACEOUS SILTSTONE; GREENISH GRAY (5G6/1). THIN BEDS OF COARSELY CRYSTALLINE GYPSUM NEAR TOP. POORLY PRESERVED IRREGULAR THIN LAMINAE. LOWER CONTACT IS REDUCTION/OXIDATION CONTACT. UNIT SOFT. CONTACT SHARP TO GRADATIONAL.
UNIT 2	MUDSTONE INTERBEDDED WITH SILTSTONE AND VERY FINE SANDSTONE, PALE YELLOWISH BROWN (10YR6/2). SOME GYPSUM NEAR TOP IN COARSELY CRYSTALLINE LAMINAE TO THIN BEDS. SILTSTONE AND SANDSTONE OCCUR AS FLASER-LIKE INTERBEDS, VERY DISCONTINUOUS TO IRREGULAR; THIN LAMINAE TO LAMINAE, DEFORMED AND WAVY; POORLY DEFINED CROSS-LAMINAE, SOME RIPPLE SURFACES, LOCALLY SLIGHTLY SMEARED TEXTURE. BASAL CONTACT SHARP, EROSIONAL.
UNIT 3a	VERY FINE SANDSTONE TO SILTSTONE, MODERATE BROWN TO LIGHT BLUISH GRAY (5YR3/4-5B7/1). THIN LAMINAE TO LAMINAE, FLAT AND PARALLEL TO CONTORTED AND DISTORTED OR SMEARED, LOCALLY KINKED; LOCAL SANDSTONE PEBBLES; LOCAL LOW ANGLE CROSS-LAMINAE IN ACCRETION SURFACES. UPPER 1 FT VERY ARGILLACEOUS. SMEARED INTRACLAST TEXTURE DOMINATES AT BASE. SOFT. BASAL CONTACT IRREGULAR.
UNIT 3b	SANDSTONE AND SILTSTONE, BECOMING FINER AND MORE ARGILLACEOUS UPWARD. MICRO-LAMINATED TO LAMINATED, MORE ABUNDANT AT BASE, VERY DISCONTINUOUS, IRREGULAR, CONTORTED TO DISTORTED. SMEARED LAMINAE LESS DISTINCT THAN IN UNIT ABOVE, DOMINANT TEXTURE AT BASE; EXHIBITS SMEARED INTRACLAST TEXTURE; ANGULAR CLASTS OF SILTSTONE AND MUDSTONE WITH SMEARED INTRACLASTS AND LAMINAE AT BASE. GRADATIONAL BASAL CONTACT.
UNIT 4	SILTSTONE, LIGHT BLUISH GRAY (5B7/1). THIN LAMINAE TO VERY THIN BEDS, VERY DISCONTINUOUS, CONTORTED TO WAVY, OVERALL STRATIGRAPHIC CONTINUITY WITHIN UNIT; INTERLAMINAE OF ANHYDRITE DECREASE UPWARD. LOCALLY CONTAINS GRANULE TO PEBBLE-SIZE SILTSTONE CLASTS. WELL INDURATED, MODERATELY HARD. SHARP BASAL CONTACT.
UNIT 5	ANHYDRITE, MEDIUM GRAY TO WHITE (N5-9), MEDIUM TO FINELY CRYSTALLINE. BEDDED NODULAR FROM BASE TO 570 FT; INTERBEDS OF CARBONATE DECREASING UPWARDS, SPACED .5-1 FT FROM 570-565 FT; ANHYDRITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAILS TO 1/2" HIGH FROM 570-560 FT; THIN LAMINAE TO LAMINAE, SOME VERY THIN BEDS; LAMINAE TO MICROLAMINAE IN UPPER 2 FT; BEDDING WAVY TO CONTORTED AND CONVOLUTE UPWARD AND LESS CONTINUOUS. LOCAL ZONES OF MEDIUM TO COARSELY CRYSTALLINE GYPSUM. HEALED SUBVERTICAL FRACTURE ON NORTHWEST SIDE OF SHAFT NEAR 560 FT. HARD. GRADATIONAL BASAL CONTACT.
UNIT 1	DOLOMITE AND GYPSUM, WHITE TO LIGHT BLUISH GRAY OR DARK GREENISH GRAY (N9 TO 5B7/1-5G4/1). GYPSUM CONTENT INCREASES UPWARD. THIN LAMINAE TO VERY THIN BEDS, WAVY; ABUNDANT LOW ANGLE CROSS-LAMINAE, SETS TO 1/2" HIGH. GRADATIONAL BASAL CONTACT.
UNIT 2	DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT SIZE. WAVY TO LENTICULAR BEDDING; LOW ANGLE CROSS-LAMINAE WITH ABUNDANT SETS 2" HIGH BY 6 "LONG; WAVY TO LENTICULAR BEDDING WITH LOW ANGLE CROSS-LAMINAE SETS TO 1/4" NEAR BASE. SURFACE WET. GRADATIONAL BASAL CONTACT.
UNIT 3	DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). MAINLY SILT-SIZED GRAINS, SOME SAND-SIZED; COARSE-GRAINED, MORE GYPSIFEROUS, POROUS, BUT NOT WET. THIN LAMINAE TO LAMINAE; ABUNDANT CROSS-LAMINAE. LOW ANGLE CROSS-LAMINAE SETS 1/4-1/2", INCREASE IN SIZE AND BECOME INTERLAMINATED WITH LAMINAE CONTAINING PEBBLE-SIZED NODULES OF GYPSUM IN UPPER .5 FT. BASAL CONTACT GRADATIONAL.
UNIT 4	DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT TO VERY FINE SAND SIZE. THIN LAMINAE TO LAMINAE, STRATA WAVY AT BASE BUT WITH MUCH LESS AMPLITUDE THAN IN UNDERLYING UNIT; ABUNDANT EROSIONAL/SCOUR SURFACES TO 2" DEEP; LOW ANGLE RIPPLE CROSS-LAMINAE SETS TO 1/2" HIGH, MOST 1/4", SETS INCREASE IN HEIGHT TO ABOUT 1" NEAR TOP. GRADATIONAL BASAL CONTACT.
UNIT 5	DOLOMITE, LIGHT BLUISH GRAY TO DARK GREENISH GRAY (5B7/1-5G4/1). CLASTIC, SILT TO VERY FINE SAND SIZE. UPPER PART THINLY LAMINATED, WAVY, DISCONTINUOUS. LOWER PART ALGAL WITH DOMES AND HEMISPHEROIDS. ABUNDANT GYPSUM-FILLED FRACTURES IN WAVY PART, <1/2" THICK, MOST PARALLEL TO LAMINAE. GRADATIONAL BASAL CONTACT.

NOTES

1) UPPER SECTION WAS MAPPED 10/15/88.
LOWER SECTION WAS MAPPED 10/19/88.

2) DEPTHS ARE RELATED TO SHAFT SUBCOLLAR, 18.5 FEET BELOW TOP OF CEMENT.

3) ELEVATION IS BASED ON SURVEY OF CONTACT AND RELATED TO LOCAL MONUMENTS AND 1927 NORTH AMERICAN DATUM.

4) INTERNAL BEDDING IS DIAGRAMMATIC ONLY; STANDARD GEOLOGIC SYMBOLS ARE USED SPARINGLY TO ENHANCE CLARITY.

FRACTURE NOTES

UPPER UNIT:

F1	0-1/4" THICK; GYPSUM-FILLED, STRAIGHT FIBERS.
F2-3	GYPSUM-FILLED.

LOWER UNIT:

F1	1/2" THICK; GYPSUM-FILLED.
F2-5	1/4" THICK; GYPSUM-FILLED.
F6-9	1/8" THICK; GYPSUM-FILLED.
F10	1/4" THICK; GYPSUM-FILLED.

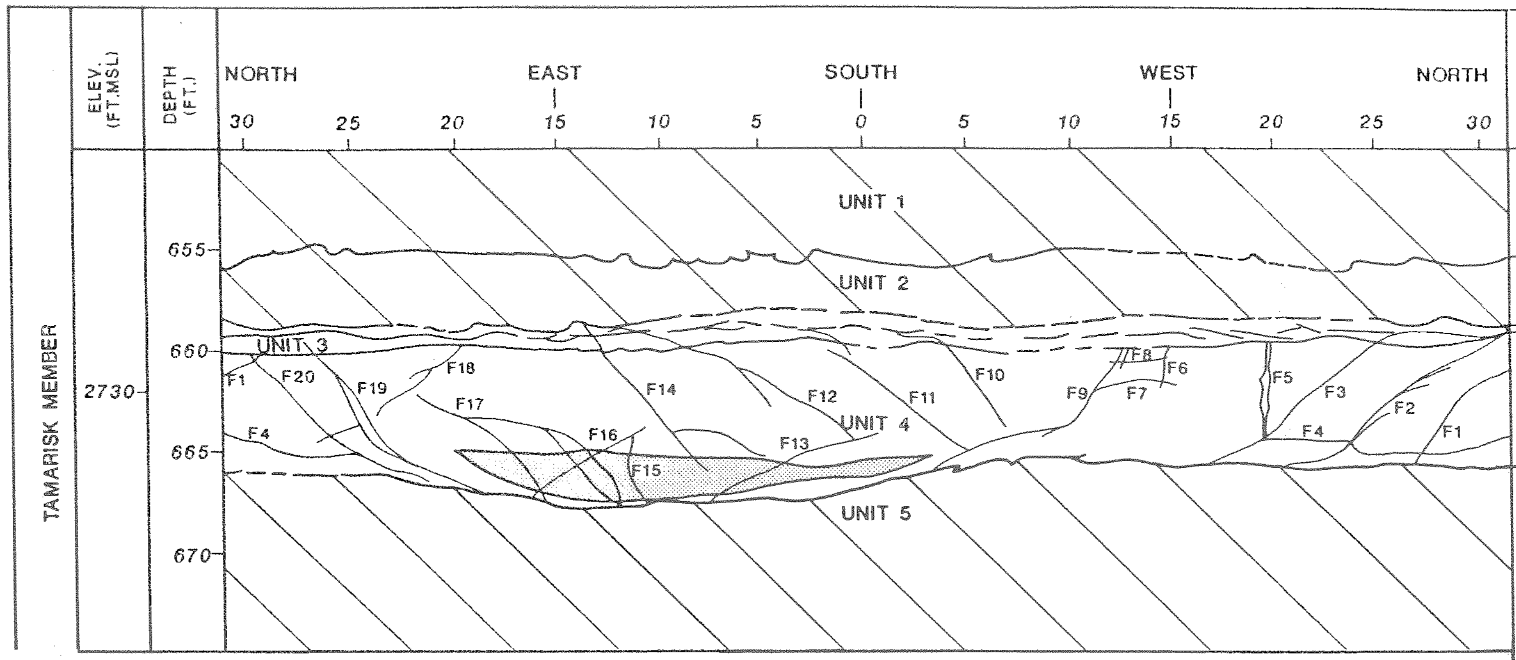
EXPLANATION

──	SHARP CONTACT
– – –	GRADATIONAL CONTACT (DEFINED WITHIN 2 INCHES)
⁄ F2	MAPPED FRACTURE

FIGURE 18

GEOLOGIC LOG OF
THE FORTY-NINER MEMBER CLAYSTONE AND
THE MAGENTA DOLOMITE MEMBER,
RUSTLER FORMATION
DEPTH 540 THROUGH 600 FEET
AIR INTAKE SHAFT

WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO



LITHOLOGIC DESCRIPTION

UNIT 1	TAMARISK MEMBER. ANHYDRITE; MICROCRYSTALLINE, VERY LIGHT TO MEDIUM LIGHT GRAY (N8-6). FROM 650-652 FT, THIN LAMINAE WITH ANHYDRITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAIL CRYSTALS. FROM 652-653, CLAST-SUPPORTED COBBLE BRECCIA OF THINLY LAMINATED ANHYDRITE, ZONE OVERLAIN BY EROSIONAL SURFACE WHICH CROSS-CUTS ANHYDRITE CLASTS. FROM 653-654 FT CLAST TO LOCALLY MATRIX-SUPPORTED ANHYDRITE GRANULE BRECCIA WITH LOCAL COBBLE-SIZED CLASTS OF ANHYDRITE, UPPER SURFACE EROSIONAL. THIN LAMINAE OF CLAYSTONE AT 654 FT. FROM 654-655.5 FT THIN LAMINAE AND LAMINAE CONVOLUTED DOWNWARD, FLAME STRUCTURES OF UNDERLYING UNIT PENETRATE ZONE TO .5 FT, UPPER SURFACE EROSIONAL. UNIT HARD, WELL LITHIFIED. LOWER CONTACT SHARP TO LOCALLY GRADATIONAL, UNDULATORY AND IRREGULAR, MARKED BY FLAME STRUCTURES.
UNIT 2	ANHYDRITE AND GYPSUM, VERY LIGHT GRAY (N8), INTERBEDDED WITH CLAYSTONE, LIGHT BLUISH TO DARK GREENISH GRAY (5B7/1-5G4/1). CLAYSTONE CALCAREOUS AT UPPER .5-.2 FT, CONTENT DECREASING DOWNWARD. THIN LAMINAE TO LAMINAE, WAVY TO UNDULATORY PARALLEL TO LOWER CONTACT BECOMING MORE DISRUPTED, CONVOLUTED UPWARD (SOFT SEDIMENT DEFORMATION); UPPER .5 FT VERY CONTORTED, WITH LOCAL FLAME STRUCTURES (NO BRECCIA); LAMINAE VERY DISTINCT IN CLAYSTONE (POSSIBLY ALGAL). CONTAINS ABUNDANT IRREGULAR BIFURCATING GYPSUM-FILLED FRACTURES TO 1" THICK, MOST SUBHORIZONTAL, FRACTURES DECREASING DOWNWARD. BASAL CONTACT GRADATIONAL.
UNIT 3	CLAYSTONE, CALCAREOUS CLAYSTONE IN UPPER 3-5 FT; VERY ARGILLACEOUS GYPSUM AND ANHYDRITE AT BASE; LIGHT BLUISH TO DARK GREENISH GRAY AND VERY LIGHT GRAY (5B7/1-5G4/1, N8). THIN LAMINAE TO LAMINAE; UPPER PART MOSTLY PARALLEL, WAVY, WITH SOME SOFT SEDIMENT DEFORMATION, CONTORTED INTO FLAME STRUCTURES AT UPPER CONTACT; LOWER PART DISRUPTED, DISCONTINUOUS. ANHYDRITE AND GYPSUM CONTAINS SWALLOWTAILS LOCALLY TO 1/4" HIGH. UPPER CLAYSTONE MOUNDED (POSSIBLY ALGAL), CONTAINS ABUNDANT BIFURCATING GYPSUM-FILLED FRACTURES, MOST SUBHORIZONTAL AND PARALLEL TO BEDDING. TO 2" THICK. LOWER CONTACT SHARP TO GRADATIONAL.
UNIT 4	INTERBEDDED AND INTERMIXED CLAYSTONE, MUDSTONE, AND SILTSTONE, GENERALLY FINES UPWARD; LOCALLY SANDY NEAR BASE; SILTSTONE PEBBLE CONGLOMERATE FILLS 2.5 FT CHANNEL AT BASE. GRAYISH-RED TO MEDIUM BLUISH-GRAY (10R4/2, 5B5/1); UPPER .5-2 FT, MEDIUM BLUISH-GRAY, IRREGULAR LOWER CONTACT; ALTERNATING LAMINAE AND MOTTLED GRAYISH-RED TO MEDIUM BLUISH-GRAY BELOW UPPER ZONE. LOCAL THIN LAMINAE TO LAMINAE, IRREGULAR, DISCONTINUOUS, DISTORTED, CONTORTED TO CONVOLUTE OFTEN WITH SMEARED LAMINAE TEXTURE; LAMINAE OFTEN DISRUPTED BY ABUNDANT SMALL SOFT SEDIMENT DISPLACEMENT SURFACES; SMEARED INTRACLAST TEXTURE LOCALLY ABUNDANT; SMEARED INTRACLAST/LAMINAE TEXTURE MOST ABUNDANT IN MIDDLE AND BASE OF UNIT. LOCAL BROKEN, SUBHORIZONTAL, LATERALLY CONTINUOUS LAMINAE-SCALE GYPSUM-RICH ZONES IN MIDDLE OF UNIT. LOCAL ANHYDRITE NODULES TO 1" DIAMETER IN LOWER HALF OF UNIT. AT BASE OF UNIT ON EAST SIDE OF SHAFT, A 2.5 FT DEEP, 24 FT WIDE CHANNEL IS FILLED WITH MEDIUM BLUISH-GRAY SILTSTONE PEBBLE CONGLOMERATE; CONGLOMERATE IS CLAST SUPPORTED WITH ROUNDED CLASTS; REGULAR SECTION OCCURS ABOVE CHANNEL. SMALL PYRITE CUBES OCCUR IN BLUISH-GRAY ZONES, MOST ABUNDANT NEAR TOP. ABUNDANT SMALL FRACTURES WITH SLICKENSIDED SURFACES. ABUNDANT FIBROUS GYPSUM-FILLED FRACTURES TO 2" THICK WITH SLICKENSIDED SURFACES, MANY SHOW SIGMOIDAL FRACTURE FILLINGS, MOST ARCUATE. LOWER CONTACT SHARP, EROSIONAL.
UNIT 5	ANHYDRITE, VERY LIGHT TO DARK GREENISH GRAY (N8-5G4/1). THIN LAMINAE TO LAMINAE; SOME ANHYDRITE PSEUDOMORPHS AFTER SWALLOWTAIL GYPSUM STRUCTURES SHOWING CRUSHED PRISM TEXTURE; LAMINAE CONTINUOUS AND WAVY AT LOWER CONTACT; POSSIBLY NODULAR AT TOP. HARD. SHARP. UNDULATORY CONTACT WITH 1.5 FT RELIEF.

NOTES

1) INTERVAL MAPPED 10/24/88.

2) DEPTHS ARE RELATED TO SHAFT SUBCOLLAR, 18.5 FEET BELOW TOP OF CEMENT.

3) ELEVATION IS CALCULATED BASED ON DEPTH DIFFERENCE TO SURVEYED ELEVATION AT TOP OF CULEBRA DOLOMITE MEMBER; SURVEY POINT IS RELATED TO LOCAL MONUMENTS AND 1927 NORTH AMERICAN DATUM.

4) INTERNAL BEDDING IS MAINLY DIAGRAMMATIC; STANDARD GEOLOGIC SYMBOLS ARE USED SPARINGLY TO ENHANCE CLARITY.

FRACTURE NOTES

MOST FRACTURES SHOW SLICKENSIDES AND ARE FILLED WITH SIGMOIDAL FIBROUS GYPSUM.

F1-3	2" THICK.
F4	1-2" THICK.
F5	1" THICK.
F6-8	1/2" THICK.
F9-12	2" THICK.
F13	1" THICK.
F14	2" THICK.
F15-16	1" THICK.
F17	2" THICK.
F18	1/2" THICK.
F19	2" THICK.
F20	1/2" THICK.

EXPLANATION

—— SHARP CONTACT

-·-·- GRADATIONAL CONTACT (DEFINED WITHIN 2 INCHES)

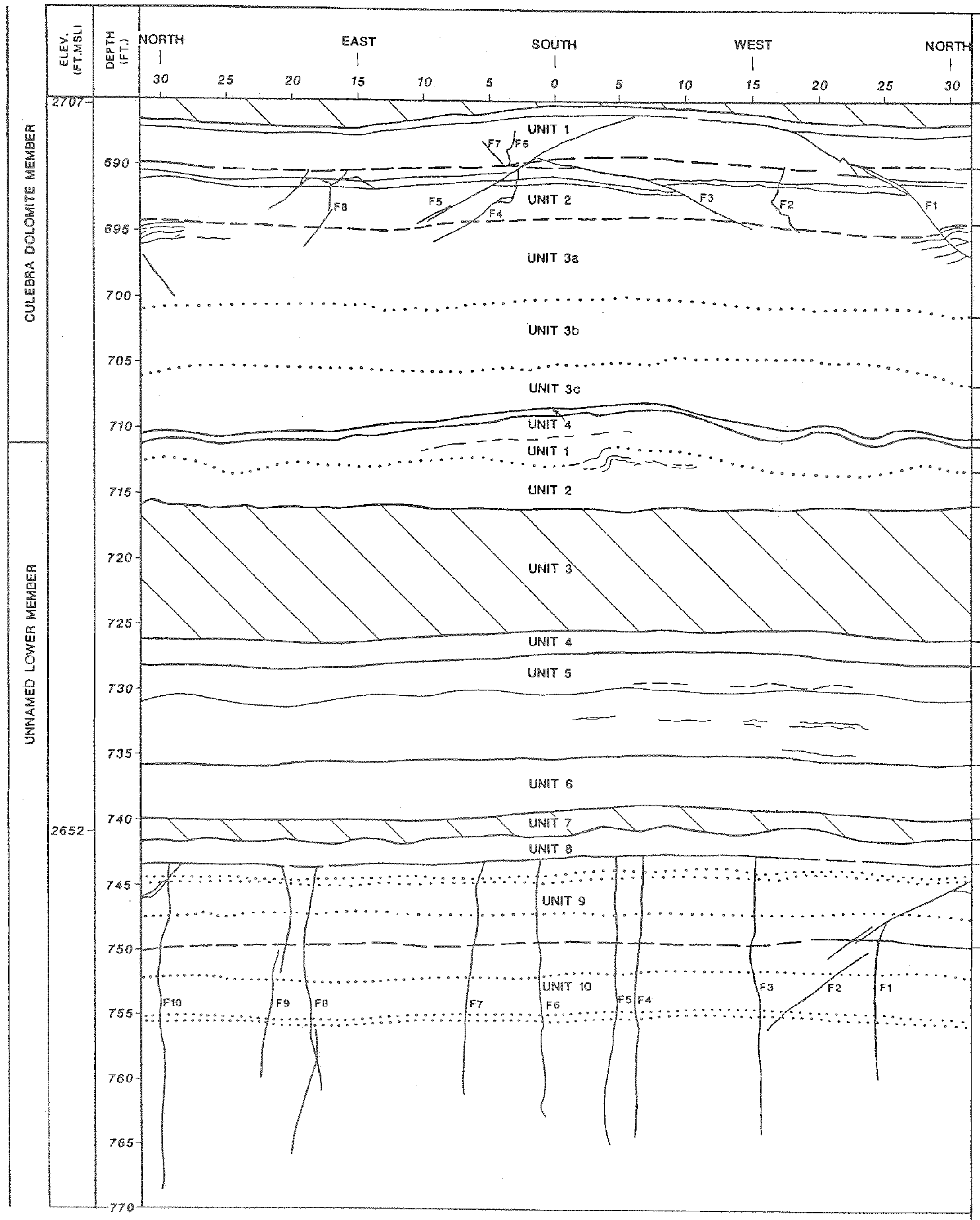
F7 MAPPED FRACTURE

CHANNEL WITH FILL

FIGURE 19

GEOLOGIC LOG OF THE TAMARISK MEMBER CLAYSTONE, RUSTLER FORMATION DEPTH 650-670 FEET AIR INTAKE SHAFT

WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO



LITHOLOGIC DESCRIPTION

UNIT 1	CULEBRA DOLOMITE MEMBER. DOLOMITE, ARGILLACEOUS. LOCALLY ORGANIC-RICH (ALGAL) AT TOP AND BASE, LIGHT OLIVE GRAY (5Y6/1). THIN LAMINAE TO THIN BEDS; CROSS-LAMINAE IN UPPER .5 FT; CONSISTS OF FINING UPWARD SEQUENCES .2-.5 FT THICK WITH BURROWS IN LOWER PART OF SEQUENCES. SYNSEDIMENTARY FAULT WITH 1 FT THROW TERMINATES NEAR MIDDLE OF THIS UNIT, UNIT DEPOSITIONALLY THICKENS OVER DOWNDROPPED SECTION. UPPER 1-2 FT SHOWS SHORT, SMALL FRACTURES WITH SYNSEDIMENTARY BRECCIA, MOST SUBVERTICAL AND LIMITED TO INDIVIDUAL STRATA. A FEW WITH FIBROUS GYPSUM-FILLINGS TO 1/4". CONTAINS NO VUGS. LOWER CONTACT GRADATIONAL.
UNIT 2	DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), MEDIUM CRYSTALLINE, ARGILLACEOUS, LOCALLY ORGANIC-RICH. THIN LAMINAE TO THIN BEDS, PARALLEL BEDDING "RAILROAD TRACKS"; RARE LARGE VUGS, MOST OPEN; BEDS INTERNALLY STRUCTURELESS. PROBABLE BRECCIA ALONG SOME FRACTURES. CONTAINS LONGER SUBVERTICAL AND VERTICAL FRACTURES FILLED WITH GYPSUM. LOWER CONTACT GRADATIONAL TO DIFFUSE.
UNIT 3a	DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), ARGILLACEOUS, MEDIUM CRYSTALLINE. LOCAL THIN LAMINAE TO MEDIUM LAMINAE. FRACTURES NOT RELATED TO STRATA BUT ARE ASSOCIATED WITH VUGS; WITHIN SOME LAMINAE AND THIN BEDS, THIN BEDS LOCALLY EROSIONALLY TERMINATED. STRATA PARALLEL, FLAT; SOME LOW ANGLE CROSS-LAMINAE WITH POSSIBLE RIPPLE FORMS; THIN LAMINAE LOCALLY DISCONTINUOUS. POSSIBLE BIOTURBATION. ZONE PRODUCES MOST OF CULEBRA FLUID; UNIT IS CHARACTERIZED BY BROKEN APPEARANCE; VERY VUGGY AND BROKEN, ABUNDANT VUGS TO 2-3" DIAMETER, SOME FILLED WITH GYPSUM AND SOME WITH CLAY, SOME HAVE BOTH; MOST HAVE IRREGULAR MARGINS DUE TO DISSOLUTION OF CARBONATE; ABUNDANT IRREGULAR THIN (<1/16") FILLED AND OPEN FRACTURES INTERCONNECTING ALL VUGS. MOST FRACTURES ARE SUBVERTICAL TO VERTICAL. CLAY-RICH INTERBEDS NEAR TOP, MOST VUGS CLAY-FILLED. ABOUT 50 PERCENT OF FRACTURES ARE UNFILLED. SUBVERTICAL FRACTURES VERY ABUNDANT, SPACED 1/4-2", MOST VERY DISCONTINUOUS. UNIT ACTUALLY PACKBRECCIA (MORROW, 1982). GRADATIONAL BASAL CONTACT.
UNIT 3b	DOLOMITE, LIGHT OLIVE GRAY (5Y6/1). BEDDING MORE DISTINCT BELOW 700 FT, LAMINAE TO VERY THIN BEDS; LOW ANGLE CROSS-LAMINAE WITH LOW HUMMOCKS, LOCAL EROSIONAL SCOURS TO 3" DEEP, MAY APPEAR WAVY TO LENTICULAR. VUGS MORE ABUNDANT AND SMALLER DOWNWARD, FREQUENCY DECREASES SIGNIFICANTLY BELOW ABOUT 705 FT; VUGGY POROSITY DEVELOPED IN SUBVERTICAL FRACTURES; MOST VUGS OPEN OR FILLED WITH CLAY, GYPSUM AS FRACTURE OR VUG FILLING MUCH LESS COMMON. ABUNDANT DISSOLUTION OF CARBONATE. UNIT IS A PACKBRECCIA (MORROW, 1982). GRADATIONAL BASAL CONTACT.
UNIT 3c	DOLOMITE, LIGHT OLIVE GRAY (5Y6/1). THIN LAMINAE TO VERY THIN BEDS. LESS BRECCIATED AND DISRUPTED THAN OVERLYING UNIT; FEWER LARGE VUGS, LAYERING FLATTER, LESS WAVY THAN OVERLYING UNIT; SOME LOW ANGLE CROSS-CUTTING RELATIONSHIPS, FRACTURES LESS ABUNDANT THAN IN OVERLYING UNIT, BUT STILL ABUNDANT, MUCH MORE CONTINUOUS, MOST SUBVERTICAL. ABUNDANT MICROVUGS. GRADATIONAL BASAL CONTACT.
UNIT 4	DOLOMITE, LIGHT OLIVE GRAY (5Y6/1), ENTIRE UNIT UNDULATORY. THIN LAMINAE TO LAMINAE. LOCALLY BRECCIATED. SHARP BASAL CONTACT, UNDULATORY OVER 3 FT.
UNIT 1	UNNAMED LOWER MEMBER. MUDSTONE AT BASE TO CLAYSTONE AT TOP, MEDIUM BLUISH GRAY TO BROWNISH GRAY TO DARK GREENISH GRAY UPWARD (5B5/1-5YR4/1-5GY2/1). MICRO TO THIN LAMINAE TO STRUCTURELESS, WAVY, SOME CONTORTED AND VERY IRREGULAR TO DISCONTINUOUS. GRAY CLAST TO COBBLE SIZE IN LOWER MIDDLE PART OF UNIT. SLICKENSIDES COMMON. GYPSUM-FILLED FRACTURES OCCUR LOCALLY TO 1/4" THICK ALONG SLICKENSIDED SURFACES. YELLOW STAINS ON SOME FRACTURES. SOFT. LOWER CONTACT MARKED BY DISTINCT COLOR CHANGE.
UNIT 2	MUDSTONE, MODERATE BROWN (5YR3/4) WITH MEDIUM BLUISH GRAY (5B5/1) INTERLAMINAE; CONTAINS SEVERAL VERY THIN BEDS TO LAMINAE OF DISCONTINUOUS GYPSUM, .5-1 FT BELOW, AND PARALLEL TO, UPPER CONTACT. SMEARED INTRACLAST/LAMINAE TEXTURE BELOW SULFATE INTERBEDS WITH A HINT OF HORIZONTAL STRATIFICATION. LOCALLY ABUNDANT GYPSUM-FILLED FRACTURES TO 1" THICK WITH VARIOUS ORIENTATIONS. LOWER CONTACT SHARP, EROSIONAL.
UNIT 3	ANHYDRITE, VERY TO MEDIUM LIGHT GRAY (N8-6), MODERATE PINK ZONE (5R7/4) 1 FT BELOW CONTACT; COVERED WITH GROUT, MOST DETAIL OBSCURED. MICROCRYSTALLINE. THIN LAMINAE TO LAMINAE; STRATA MOSTLY FLAT, LAMINAE WAVY. POORLY EXPOSED. LARGE HALITE PSEUDOMORPHS AFTER GYPSUM SWALLOWTAIL CRYSTALS TO 1 FT HIGH NEAR BASE. LOWER CONTACT SHARP.
UNIT 4	SILTSTONE (BASE) TO MUDSTONE (TOP), GRAYISH BROWN TO GRAYISH RED (5YR3/2-10R4/2), UPPER .5-.2 FT IS GRAY (5G6/1). HALITE CEMENT NEAR BASE, ANHYDRITE CEMENT AT TOP. LOCAL THIN LAMINAE; ANHYDRITE OCCURS AS IRREGULAR INTERBEDS AND NODULES; HINT OF SMEARED INTRACLAST/LAMINAE TEXTURE. SHARP TO EROSIONAL BASAL CONTACT MARKED ALSO BY INCREASE IN SALT CONTENT.
UNIT 5	SILTSTONE AND HALITE, MODERATE BROWN (5YR3/4), ZONES OF GREENISH GRAY (5GY6/1). LOCAL THIN LAMINAE OF SILTSTONE; CLEAR INCORPORATIVE HALITE OCCURS AS ISOLATED AGGREGATES OF CRYSTALS TO 1" ON A SIDE, CONCENTRATED BETWEEN 727.4-729 FT, CRYSTALS MAY BE DISPLACIVE; SILTSTONE BED AT EROSIONAL SURFACE AT 730 FT IS ABOUT .5 FT THICK; BELOW 730 FT, HALITE OCCURS WITH SILTSTONE, SILTSTONE OCCURS AS BLEBS AND DISCONTINUOUS INTERBEDS MARKING EROSIONAL SURFACES, HALITE CONCENTRATION DECREASES IN LOWER .2-.5 FT; SILTSTONE SHOWS SMEARED INTRACLAST/LAMINAE TEXTURE; BELOW 730 FT, MOST HALITE ORIGINATED AS OVERGROWTHS ON HALITE CRUST. SILTSTONE INTERBEDS DISCONTINUOUS; WITH EXCEPTION OF AN IRREGULAR HORIZONTAL ZONE NEAR 732 FT AND THE SILTSTONE INTERBED AT 730 FT, HALITE IS THE DOMINANT CONSTITUENT. LOWER CONTACT SHARP AND EROSIONAL.
UNIT 6	HALITE, CLEAR, WITH SILTSTONE, MODERATE BROWN (5YR3/4). INCREASING CLAY AND SILTSTONE CONTENT UPWARD TO SILTSTONE AT TOP. MOST SILTSTONE OCCURS IN UPPER HALF OF UNIT AS THIN STRINGERS AND BLEBS, CONTENT INCREASES UPWARD. LOWER .5 FT MOSTLY CLEAR HALITE, INTERLOCKING CRYSTALS (HALITE CRUST). HARD. BASAL CONTACT SHARP TO GRADATIONAL.
UNIT 7	ANHYDRITE, MEDIUM CRYSTALLINE; VERY TO MEDIUM LIGHT GRAY (N8-6). THIN LAMINAE, WAVY, FLAT TO PARALLEL IN UPPER .5-1 FT; LAMINAE LOCALLY DISCONTINUOUS. IRREGULAR ZONES OF HALITE, SOME DISPLACIVE CRYSTALS, HALITE INCREASING UPWARD. HARD, STANDS OUT AS RESISTANT UNIT. LOWER CONTACT SHARP AND EROSIONAL, LAMINAE WITHIN UNIT DRAPE CONTACT.
UNIT 8	HALITE WITH INTERLAMINATED ANHYDRITE, ANHYDRITE CONTENT INCREASING DOWNWARD, CLEAR TO WHITE. VERY THIN TO THIN BEDS, FLAT TO SLIGHTLY WAVY; CONTAINS THIN ARGILLACEOUS LAMINAE DOWNWARD WITHIN ANHYDRITE. BASAL CONTACT SHARP, EROSIONAL.
UNIT 9	HALITE WITH MUDSTONE AND SILTSTONE (TOP, UPPER 1 FT); HALITE CLEAR, MUDSTONE AND SILTSTONE LIGHT BROWNISH GRAY (5YR6/1). MUDSTONE OCCURS AS STRINGERS. .5 FT THICK SILTSTONE WITH EROSIONAL BASE OCCURS BELOW UPPER CONTACT, HAS DISPLACIVE HALITE CRYSTALS TO 1/4" WITH SMEARED INTRACLAST/LAMINAE TEXTURE. REMAINDER OF UNIT MAINLY HALITIC SILTSTONE; LOCAL THIN LAMINAE TO VERY THIN BEDS, IRREGULAR TO DISCONTINUOUS; SMEARED INTRACLAST/LAMINAE TEXTURE. LOCALLY THINLY BEDDED ANHYDRITIC NEAR TOP. SOME HALITE AGGREGATES, MOSTLY DISPLACIVE TO SMALL AGGREGATES, CRYSTALS TO 1/2" ACROSS. LOOSE TO HARD DUE TO RECENT DISSOLUTION OF HALITE DURING SHAFT CONSTRUCTION. BASAL CONTACT GRADATIONAL TO SHARP, EROSIONAL.
UNIT 10	HALITE AND SILTSTONE, CLEAR HALITE. SILTSTONE LIGHT BROWNISH TO GREENISH GRAY (5YR6/1-5GY6/1); HALITE COARSELY CRYSTALLINE, TO 1/2". UPPER PART SHOWS WELL DEVELOPED VERY THIN TO THIN BEDS WITH HALITE INTERLAMINAE; STRATA LESS WELL DEVELOPED IN MIDDLE PART, CONTAINS IRREGULAR SMALL BLEBS OF SILTSTONE; AT ABOUT 755, .5-.2 FT SILTSTONE OCCURS ON TOP OF EROSIONAL SURFACE, CONTAINS 1/4" DISPLACIVE CRYSTALS, IRREGULAR LAMINAE, BELOW 755 FT, HALITE IS ISOLATED TO AGGREGATES, CRYSTALS TO 1/2". CONTENT AND SIZE DECREASE DOWNWARD. GRADATIONAL BASAL CONTACT.

NOTES

1) INTERVAL MAPPED 10/26/88 - 11/1/88.

2) DEPTHS ARE RELATED TO SHAFT SUBCOLLAR, 10.5 FEET BELOW TOP OF CEMENT.

3) ELEVATIONS ARE BASED ON SURVEY OF CONTACTS AND ARE RELATED TO LOCAL MONUMENTS AND 1927 NORTH AMERICAN DATUM.

4) INTERNAL BEDDING IS MAINLY DIAGRAMMATIC; STANDARD GEOLOGIC SYMBOLS ARE OMITTED TO ENHANCE CLARITY.

FRACTURE NOTES

CULEBRA DOLOMITE MEMBER

F1	ABOUT 1' THROW.
F2-3	1/2" THICK, GYPSUM-FILLED.
F4	GYPSUM-FILLED.
F5	1/4" THICK; GYPSUM-FILLED.
F6-7	GYPSUM-FILLED.
F8	1/4" THICK; GYPSUM-FILLED.

UNNAMED LOWER MEMBER

F1-2	1" THICK; HALITE-FILLED.
F3-5	1/4" THICK; HALITE-FILLED.
F6	1/2" THICK; HALITE-FILLED.
F7-10	1/4" THICK; HALITE-FILLED.

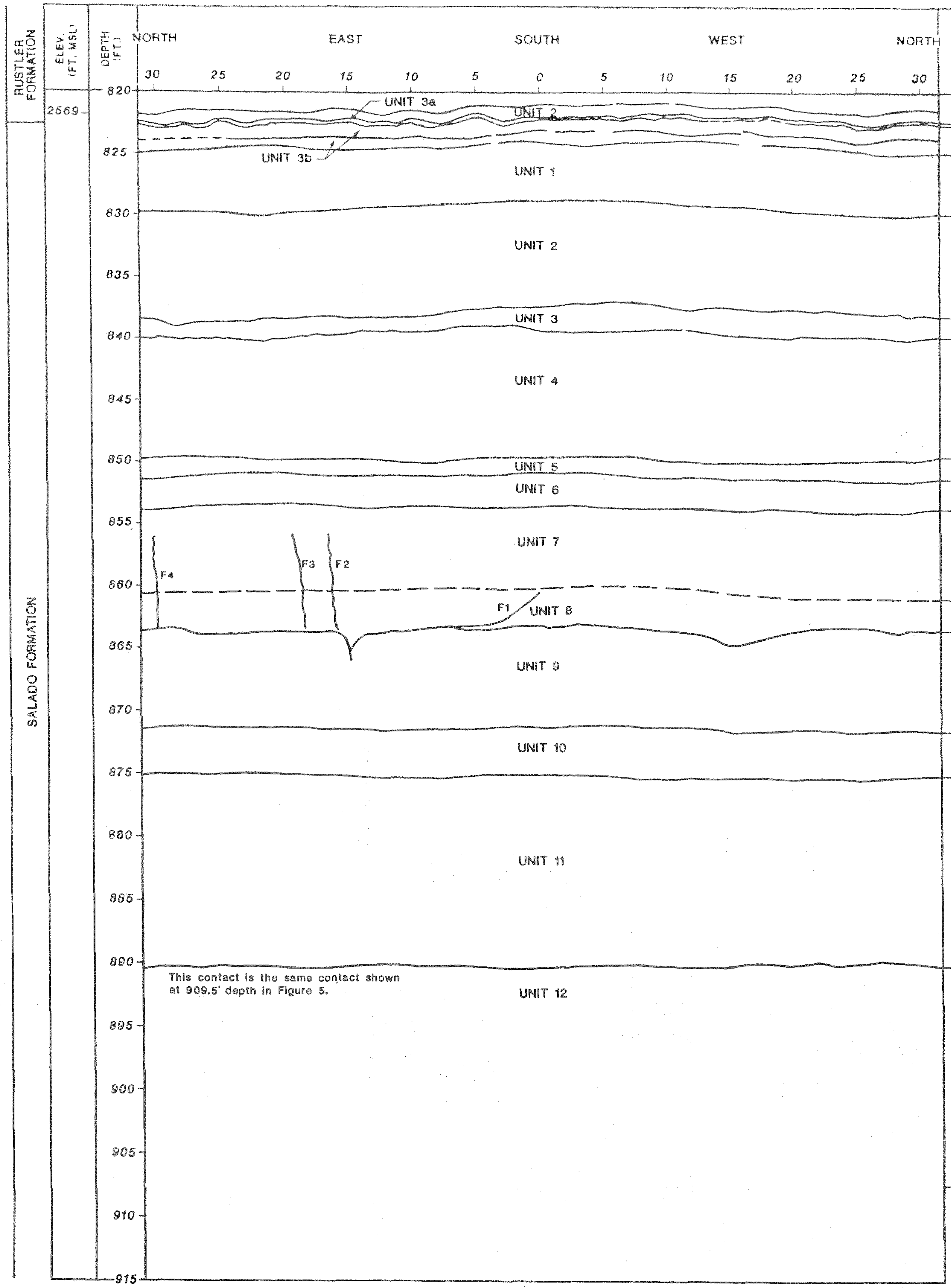
EXPLANATION

———	SHARP CONTACT
— — —	GRADATIONAL CONTACT (DEFINED WITHIN 2 INCHES)
········	DIFFUSE CONTACT (DEFINED WITHIN 6 INCHES)
F1	MAPPED FRACTURE

FIGURE 20

GEOLOGIC LOG OF CULEBRA DOLOMITE MEMBER AND UPPER PART OF UNNAMED LOWER MEMBER, RUSTLER FORMATION DEPTH 685 TO 760 FEET AIR INTAKE SHAFT

WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO



LITHOLOGIC DESCRIPTION

UNIT 2 SILTSTONE TO VERY FINE SANDSTONE, HALITE CEMENT; MODERATE BROWN (5YR3/4). THIN LAMINAE TO LAMINAE, WAVY TO LOCALLY CONTORTED, DISCONTINUOUS; SOME SMEARED INTRACLAST/LAMINAE TEXTURE. MODERATELY HARD. BASAL CONTACT SHARP.

UNIT 3a ANHYDRITE, LIGHT BROWNISH GRAY TO LIGHT GRAY (5YR6/1-N7); MEDIUM CRYSTALLINE. PARTIALLY LAMINATED. HARD. LOWER CONTACT SHARP.

UNIT 3b SALADO FORMATION. HALITIC SILTSTONE, MODERATE BROWN (5YR3/4) WITH INTERLAMINAE OF GREENISH GRAY (5G6/1) SULFATE. HALITE CONTENT INCREASES DOWNWARD, SMALL DISPLACIVE CRYSTALS TO 1/8", MOST ABOUT 1/16". IRREGULAR THIN LAMINAE TO LAMINAE NEAR TOP ARE LESS DISTINCT DOWNWARD. EROSIONAL CONTACT AT 824 FT AND BASE OF UNIT.

UNIT 1 HALITE, CLEAR, WITH POLYHALITE, MODERATE REDDISH ORANGE (10R6/6) AND CLAY, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). HALITE MEDIUM TO COARSELY CRYSTALLINE. MODERATELY POLYHALITIC AT BASE, MODERATELY ARGILLACEOUS AT TOP. CLASTIC MATERIAL AS BLEBS, POLYHALITE AS BLEBS AND STRINGERS. LOWER CONTACT SHARP.

UNIT 2 HALITE TO HALITIC MUDSTONE (UPPER .5-.3 FT); HALITE MEDIUM TO COARSELY CRYSTALLINE. ARGILLACEOUS ZONES FROM 831.5-832.5 AND 833.5-834.5 FT WITH ABUNDANT DISCONTINUOUS SUBHORIZONTAL STRINGERS OF MODERATE BROWN (5YR3/4) CLAYSTONE; LOCALLY POLYHALITIC (MODERATE REDDISH ORANGE, 10R6/6) AS DISCONTINUOUS AND INTERCRYSTALLINE STRINGERS; SOME WHITE (N7) ANHYDRITE. MOSTLY CLEAR BELOW 835 FT, THIN TO MEDIUM BEDS; LOCAL CLEAR, VERY COARSELY CRYSTALLINE HALITE; UPPER HALITIC MUDSTONE WITH ABUNDANT DISPLACIVE CRYSTALS TO 1". WITH SMEARED INTRACLAST TEXTURE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). LOWER CONTACT MARKED BY .1-.3 FT THICK POLYHALITE BED, VERY UNDULATORY AT SMALL SCALE. LOWER CONTACT SHARP.

UNIT 3 HALITE, CLEAR, LOCALLY BLUE; VERY COARSELY CRYSTALLINE, TO 6" ON SIDE; LOWER .5" SLIGHTLY POLYHALITIC, MODERATE REDDISH ORANGE (10R6/6); LOWER .1-.2 FT CONSISTS OF POLYHALITE. LOWER CONTACT SHARP, SLIGHTLY UNDULATORY.

UNIT 4 HALITE; THIN TO MEDIUM BEDS WITH IRREGULAR STRINGER OF POLYHALITE, MODERATE REDDISH ORANGE (10R6/6) AND ANHYDRITE; SLIGHTLY ARGILLACEOUS IN UPPER 1 FT. HALITE CLEAR, MEDIUM TO COARSELY CRYSTALLINE. BEDDING 3-6" THICK; STRATA WAVY. SEQUENCES OF VERTICALLY ORIENTED HALITE OVERLAIN BY CUMULATES; ZONES OF COARSE CLEAR HALITE. LOWER CONTACT SHARP.

UNIT 5 ARGILLACEOUS HALITE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1), LOCAL PITS WITH CLEAR HALITE. CLAY OCCURS AS BLEBS AND IRREGULAR STRINGERS, INCREASES UPWARD. HALITE DISPLACIVE, INCORPORATIVE. SMEARED INTRACLAST/LAMINAE TEXTURES AT TOP. LOWER CONTACT SHARP AND EROSIONAL.

UNIT 6 HALITE, POLYHALITIC, MODERATE REDDISH ORANGE (10R6/6), CLEAR TO WHITE HALITE. INTERCRYSTALLINE POLYHALITE AND AS IRREGULAR DISCONTINUOUS SUBHORIZONTAL STRINGERS. RARE STRINGERS OF MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1) CLAY. POSSIBLE PRISM CRACKS NEAR TOP. LOWER CONTACT SHARP.

UNIT 7 HALITE AND SILTSTONE, MODERATE BROWN TO GREENISH GRAY (5YR3/4-5G6/1). HALITE CLEAR, INCORPORATIVE; MEDIUM TO COARSELY CRYSTALLINE, TO 1" ON SIDE, LOCALLY DISPLACIVE. BEDDED; POORLY DEFINED IRREGULAR ZONES OF SILTSTONE WITH SMEARED INTRACLAST/LAMINAE TEXTURE. EROSIONAL LOWER CONTACT.

UNIT 8 SILTSTONE TO VERY FINE SANDSTONE, HALITE CEMENTED, MODERATE BROWN (5YR3/4) WITH MINOR GREENISH GRAY (5G6/1). THIN LAMINAE TO LAMINAE; SOME SMALL (<1/4") CROSS-LAMINAE; LAMINAE ARE IRREGULAR TO DISCONTINUOUS; LOCAL SMEARED INTRACLAST/LAMINAE TEXTURES; SOME SCOURS WITH LOW ANGLE CROSS-LAMINAE; RARE SMALL (<1/4") DISPLACIVE HALITE CRYSTALS; HAS SCOUR/DISSOLUTION TROUGH 1.5 FT DEEP AT WEST AND EAST SIDE OF SHAFT. SHARP BASAL CONTACT.

UNIT 9 HALITE, WHITE TO TINTED LIGHT RED (5R6/6); MEDIUM TO COARSELY CRYSTALLINE, CLOUDY; SOME VERY COARSE CLEAR; ABUNDANT SILTSTONE AT TOP, DECREASING DOWNWARD. IRREGULAR DISCONTINUOUS STRINGERS/LAMINAE AND BLEBS TO COBBLE-SIZE WITH DISPLACIVE CRYSTALS TO 1", CONTENT DROPS GREATLY BELOW 868 FT. POLYHALITE CONTENT INCREASES DOWNWARD, AS DISSEMINATED MATERIAL AND IRREGULAR SUBHORIZONTAL STRINGERS. BELOW 868 FT, BECOMES THIN TO MEDIUM BEDDED. BOTTOM GROWN HALITE OVER HALITE CUMULATES WITH POLYHALITE. LOWER CONTACT SHARP.

UNIT 10 HALITE, CLEAR OR WHITE TO LIGHT OR MODERATE RED (5R6/6-4/6). UPPER .5 FT IS SILTSTONE WITH HALITE CONTENT DECREASING DOWNWARD CONTAINING INCORPORATIVE AND DISPLACIVE CRYSTALS. REMAINDER, MEDIUM TO COARSELY CRYSTALLINE; MEDIUM BEDDED WITH BLEBS OF POLYHALITE. LOWER CONTACT SHARP.

UNIT 11 HALITE, ARGILLACEOUS AT TOP AND POLYHALITIC AT BASE, AND SILTSTONE. HALITE CLEAR TO WHITE TO TINTED LIGHT RED (5Y6/6). ARGILLACEOUS UNITS MODERATE BROWN (5YR3/4). HALITE MEDIUM TO COARSELY AND VERY COARSELY CRYSTALLINE. CLAY CONTENT DECREASES DOWNWARD. THIN LAMINAE, IRREGULAR, DISCONTINUOUS IN UPPER 1 FT WITH SMEARED INTRACLAST/LAMINAE TEXTURE AND DISPLACIVE/INCORPORATIVE HALITE. BELOW 879 FT, SILTSTONE OCCURS AS IRREGULAR, DISCONTINUOUS STRINGERS. POLYHALITE MODERATELY ABUNDANT AT BASE, DECREASES UPWARD AS IRREGULAR DISCONTINUOUS STRINGERS AND BLEBS, ALSO RIMS HALITE CRYSTALS. IRREGULAR THIN TO MEDIUM BEDS DELINEATED BY POLYHALITE BELOW 883 FT. SHARP BASAL CONTACT.

UNIT 12 HALITE, WHITE TO CLEAR TO TINTED LIGHT RED (5R6/6) AND ARGILLACEOUS HALITE, MODERATE BROWN (5YR3/4). MEDIUM TO COARSELY CRYSTALLINE; ARGILLACEOUS TO SILTY IN UPPER PART, DECREASING CONTENT DOWNWARD. LOCAL SILTSTONE INTERBEDS.

NOTES

1) INTERVAL MAPPED 11/6/88.
2) DEPTHS ARE RELATED TO SHAFT SUBCOLLAR, 18.5 FEET BELOW TOP OF CEMENT.
3) ELEVATION IS BASED ON SURVEY OF RUSTLER/SALADO CONTACT AND RELATED TO LOCAL MONUMENTS AND 1927 NORTH AMERICAN DATUM.
4) STANDARD GEOLOGIC SYMBOLS HAVE BEEN OMITTED TO ENHANCE CLARITY.

FRACTURE NOTES

F1	1" THICK; HALITE-FILLED.
F2-4	1/2" THICK; HALITE-FILLED.

EXPLANATION

——— SHARP CONTACT
– – – GRADATIONAL CONTACT (DEFINED WITHIN 2 INCHES)
F2 MAPPED FRACTURE

FIGURE 21

GEOLOGIC LOG OF THE RUSTLER-SALADO CONTACT AND THE KEYWAY AREA
DEPTH 820 TO 915 FEET
AIR INTAKE SHAFT

WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO

SYSTEM	SERIES	FORMATION	MEMBER
PERMIAN	OCHOAN	SALADO FORMATION	UNNAMED UPPER MEMBER
			McNUTT POTASH MEMBER
			UNNAMED LOWER MEMBER

FIGURE 22 SALADO STRATIGRAPHY

EXPLANATION FOR FIGURES 5 AND 23

STRATIFICATION TYPES/PRIMARY FEATURES

——	CONTINUOUS		LOW ANGLE CROSS-STRATA
— — — ·	DISCONTINUOUS		TROUGH CROSS-STRATA
≈	WAVY BEDDING/LAMINAE		CROSS-LAMINAE
∿∿	CONTORTED LAMINAE		CLIMBING RIPPLE CROSS-LAMINAE
/// OR \\\	DIPPING STRATA		TABULAR CROSS-BEDS
━━	SHARP CONTACT (<1")		FLASERS
— —	GRADATIONAL CONTACT (1-2")		WAVY TO LENTICULAR BEDS
········	DIFFUSE CONTACT (>2")		FLAME STRUCTURE
∿∿∿	EROSIONAL SURFACE		PILLOWS OR SLUMP FEATURES
≈	ALGAL LAYERING		LOW ANGLE ACCRETIONARY CROSS-LAMINAE
~	DVT OR EROSION/SOLUTION SURFACE, DEATH VALLEY TYPE		BURROWS/BIOTURBATION
═	HORIZONTAL LAMINAE/THIN BEDS		

CLASTS

SHAPE

⬭	ROUNDED
△	ANGULAR
▭R	TABULAR OR RIP-UP
∞	SMEARED INTRACLAST

TYPE

⌖ ⊕	CARBONATE
▲ ●	MUDSTONE

OTHER

	FOSSIL

HALITE TEXTURES

⋀	CHEVRON, BOTTOM GROWN	I-III	ISOLATED (I) TO AGGREGATE (III)
	CUMULATES	a-c	PLANAR (a) TO IRREGULAR (c) BOUNDARIES
□ □ □	INCORPORATIVE, DISPLACIVE	IV	INTERLOCKING HALITE

SULPHATE TEXTURES

▽ ▽	PSEUDOMORPHS AFTER VERTICALLY ORIENTED PRISMATIC GYPSUM CRYSTALS
V V	CRUSHED PRISM TEXTURE FROM ▽ ▽ (Holt and Powers, 1988).
∞	NODULAR
–∞–	BEDDED NODULAR
	STYLOLITE
ΦN	GYPSUM/ANHYDRITE NODULE

Sheet 1 of 32

FIGURE 23

EXPLANATION (CONTINUED)

VUGS/MACROPORES

⬭V OPEN VUG ⏀V GYPSUM-FILLED VUG ⌖V CALCITE-FILLED VUG ⊕N HALITE-FILLED VUG

OTHER STRUCTURES

┘┌	BOXWORK FABRIC	∆◁▷▷	BRECCIA
S	SMEARED LAMINAE	⧫	PACKBRECCIA (Morrow, 1982)
┴┬┴	SUBVERTICAL FRACTURES	⊿	CRACKLE TEXTURE
//Λ	FAULT	—/—	SEDIMENTARY FAULT
≈≈	VADOSE-INFLUENCED BEDS	◯ ◯	HALITE PODS
⋏⋏	TEEPEE-LIKE STRUCTURES	≋ ≋	DISH-SHAPED LAMINAE

SIDE NOTES/MODIFIERS

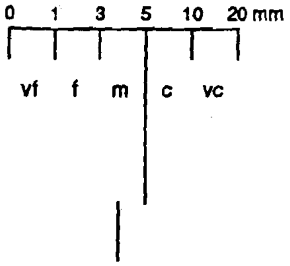
R	RIP-UP CLASTS	**E**	EROSIONAL SURFACE	**St**	ALGAL LAYERING
V	VUGS	**N**	NODULE	**S**	SLICKENSIDES
CF	CLAY-FILLED FRACTURES	┃	ZONE OF WEEPS	**?**	POSSIBLE OR PROBABLE
DVT	DEATH VALLEY TYPE			**e/s**	EROSION/SOLUTION SURFACE

LITHOLOGY

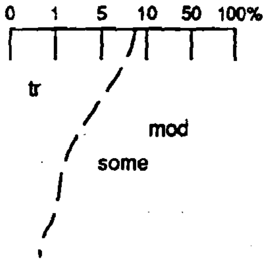
┄	MUDSTONE/CLAYSTONE	— — —	ARGILLACEOUS
▬	CLAYSTONE BED		
┄·	SILTSTONE	—·—·	SILTY
░	SANDSTONE	·.·.	SANDY
▨	ANHYDRITE/GYPSUM	\\\\\	SULFATIC
▱	DOLOMITE	—/—	DOLOMITIC
▦	LIMESTONE	—┴┬—	CALCAREOUS
▭	HALITE	+ +	HALITIC
▩	POLYHALITE	XX X	POLYHALITIC
⊔	LANGBEINITE		

SCALES/SYMBOLS HALITE/NON-HALITE COLUMN

HALITE CRYSTAL SIZE



NON-HALITE CONSTITUENTS



RELATIVE PROPORTIONS
NON-HALITE CONSTITUENTS

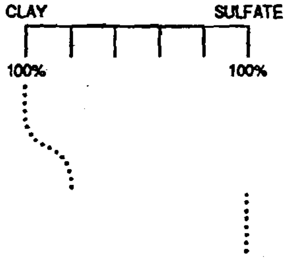


FIGURE 23

EXPLANATION
(Continued)

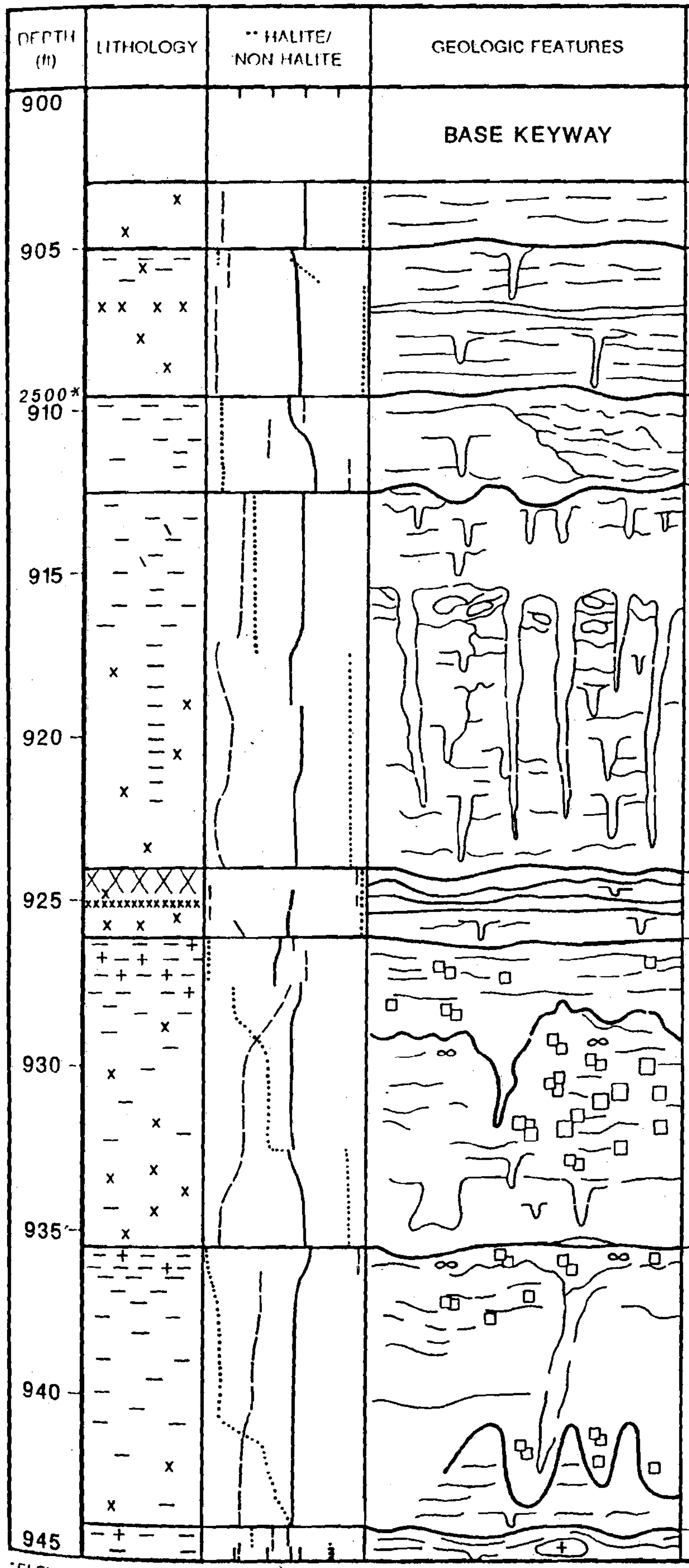
The following abbreviations used in Figure 23

abund = abundant
anhy = anhydrite
arg = argillaceous
BG = bottom grown
c = course
C = cement
cont = continuous
disc = discontinuous
DVT = Death Valley type
e/s = exposure/solution
f = fine
H = halite
irreg = irregular
lam = laminae
m = medium
mod = moderate
mod'ly - moderately
MP = macropores
P = primary
PAGS = pseudormorph after gypsum swallowtails
poly = polyhalite
poly'c = polyhalitic
pos = pile of sticks
reg = regular
sic = smeared interclast
tr = trace
v = very
vel = vertically elongate
VO = vertically oriented
w/, w/i = with, within

Note: The descriptions in Figure 23 are highly abbreviated and compressed from the descriptions presented in Appendix D, so that the feature could be presented at an appropriate

EXPLANATION
(Continued)

graphical scale (1" = 5'). The halite classification system discussed in Appendix E is used in Figure 23 and Appendix D. For fuller detail, the reader is referred to Appendix D. Because these descriptions are highly abbreviated and edited, many modifiers have been eliminated. For example, the rock described may include trace to abundant macropores; the abbreviated description lists this characteristic as "MP." More detailed descriptions of lateral and vertical relationships have been eliminated where they were deemed to be less important or if they are presented in the graphics that accompany this report. Contacts are not described for most units because the graphics illustrate scales and relationships.



REMARKS
(SEE APPENDIX FOR DETAILS)

H, tr poly; similar to below. Upper contact not observed.

H, tr poly, beds 2-5"; tr clay at upper contact. Poly as reg to slightly irreg thin lam to lam and disc stringers. VO MP; pits to 2' deep. F-c IV, tr P, BG textures, tr C.

Claystone and arg H, thin claystone in pits and over irreg DVT e/s surfaces; arg H between and crosscut by DVT surfaces; c-vc la and sic textures in claystone; f-c I-III a-c in arg H; f lc in uppermost claystone.

H, tr to mod poly and clay. DVT e/s surface with .5' relief divides unit at 917.5; pits to 8' deep at 915.5; lower poly zone contains translocated clay. Abund MP and interunit pits, multiple generations of solution and cementation. Poly occurs as lam to blebs to lining on displacive H. Abund C. Halite in polyzone is mainly m-vc IV, f IV near top, c-vc II-III a-c, c-vc I-III in pits. H in upper part mostly IIIa, tr b and zones of m-vc IV, some m-c I-IIa-b; abund irreg zones and pits of f IV near top; c-vc I-III in pits with poly and translocated clay. Pits to 1' deep. DVT e/s surface at top.

H, interbedded poly; thin lam of poly, some crosscutting over high relief; m I-IIa-b in lower lam. H, tr poly as thin lam and stringers. F-c IV; tr lam of f or m-c H; beds pf poly to c clear H to f-c cloudy H; tr P, probable BG textures mod C. Pits to 4"; irreg VO MP.

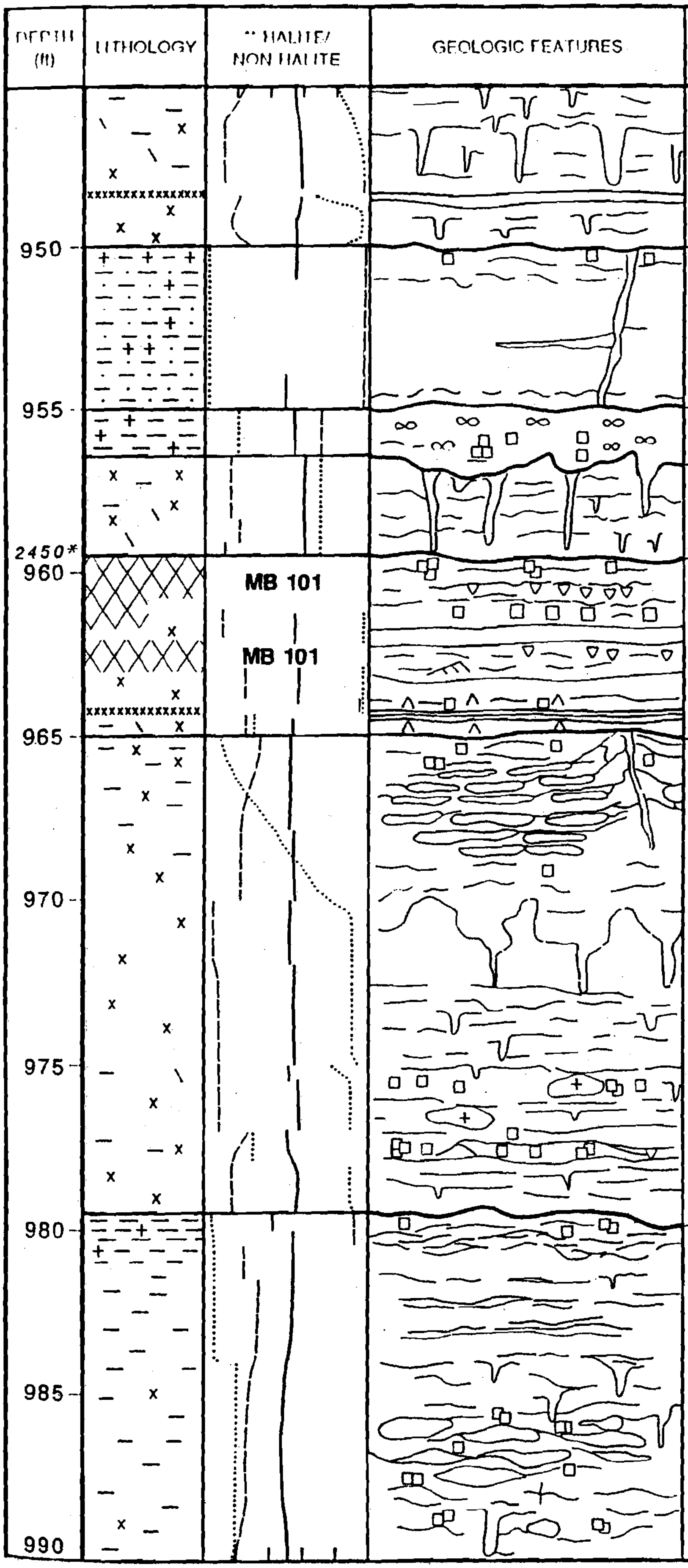
H, tr poly, tr to mod clay. Lower poly-rich and upper arg zones divided by DVT e/s surface at 929. Poly occurs as blebs, lam, and blebby linings around c-vc la. H in poly zone is m-vc IV, to f-m II-III b-c, c-vc I-IIIa; vc MP. Claystone as blebs to and lam with displacive H. Claystone has pits to 3', thin beds with zones of c IIIa, tr of bedding and abund m-c I-IIa. H in arg zone is m-vc II-IIIa-b, w/tr m-vc IV, and tr II-IIa-c; more II-IIIc and sic textures upward and c-vc I-IIa-b at top overlain by f-m I-IIa-c. Pits 6"-5+'.

H, mod to tr poly, tr to mod clay, zones of claystone in pits and upper .5-1+'. Divided into lower poly-rich zone and upper arg zone by DVT e/s surface with 2.5' relief; shows large troughs of arg H w/small poorly preserved pinnacles of poly-rich H. H in poly'c zone is f-c IV, f-c I-IIa-b, and tr IIIa-b in pipes; Poly'c zone is bedded, sequence of poly'c H to c H to f-m H w/tr P. Claystone zones with c-vc la in pits, blebs with displacive H and lam to thin beds. Rare v thin beds drape e/s surfaces. H in arg zones is c-vc I-IIIa w/b-c margins present upward, and zones of m-vc IV. Abund MP to 2" with displacive boundaries. Hint of strata, vc I-IIa, some sic in upper claystone.

*ELEV (ft m s l)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 5 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

DVT e/s surface. Interunit pits in poly'c zone to 6", pits at DVT surface to 1.5'. Poly occurs as lam, to blebs with displacive H margins, and POS texture and drapes/linings on H. H in poly zone: mainly m-c IV with zones of f H between m-c H and poly; tr to mod irreg MP (1-2"); vc C in MP. In arg zone: claystone occurs as stringers to v thin beds, and blebs with displacive margins. Large f-m MP. Pits to 6". H is m-c IV, vc in MP; IV at base of zone, I-IIIa-c in upper part.

Sandstone, silty, tr vc poikilitic H C; brown with local greenish-gray reduction; some sic in lower 1'. Tr to some f-m Ia-b, m at top; Tr m-c Ia, in upper .5'; tr to some f-m Ia-c at top. Hints of contorted strata in upper 1'.

Siltstone, brown; sic, irreg, poorly defined lam in upper .5'. M-f Ia-c, tr to some II-IIIb-c.

H, mod poly in poly'c zones; tr poly and clay in alternate zones. Poly occurs as blebs, lam, stringers. Claystone occurs as blebs, thin beds, and stringers. Displacive margins abund between H and poly, rare between H and claystone. Hints of strata and sic textures in claystones. I-IIa-b in poly blebs. V crude beds .3-.5' thick. H: m-c IV w/tr interstratified f-IV. F-c I-IIIb-c w/tr I-IIIa in poly and arg zones. Pits to 6" in unit, to 2' from upper DVT e/s surface.

Interbedded poly and H. H: tr poly; poly lam and lower interbed, tr clay as thin lam and stringers. Poly drapes vel H and lines H; some lam, stringers, and POS textures. H is m-c IV, some P(vel, BG textures), mod to tr to some C. Poly lam are contorted to reg, local halitic cross-laminae; interbedded with anhy. Zones of I-IIIb-c in upper interbed, also poly to anhy PAGS to 1/4". Middle interbed with H PAGS to 1/4".

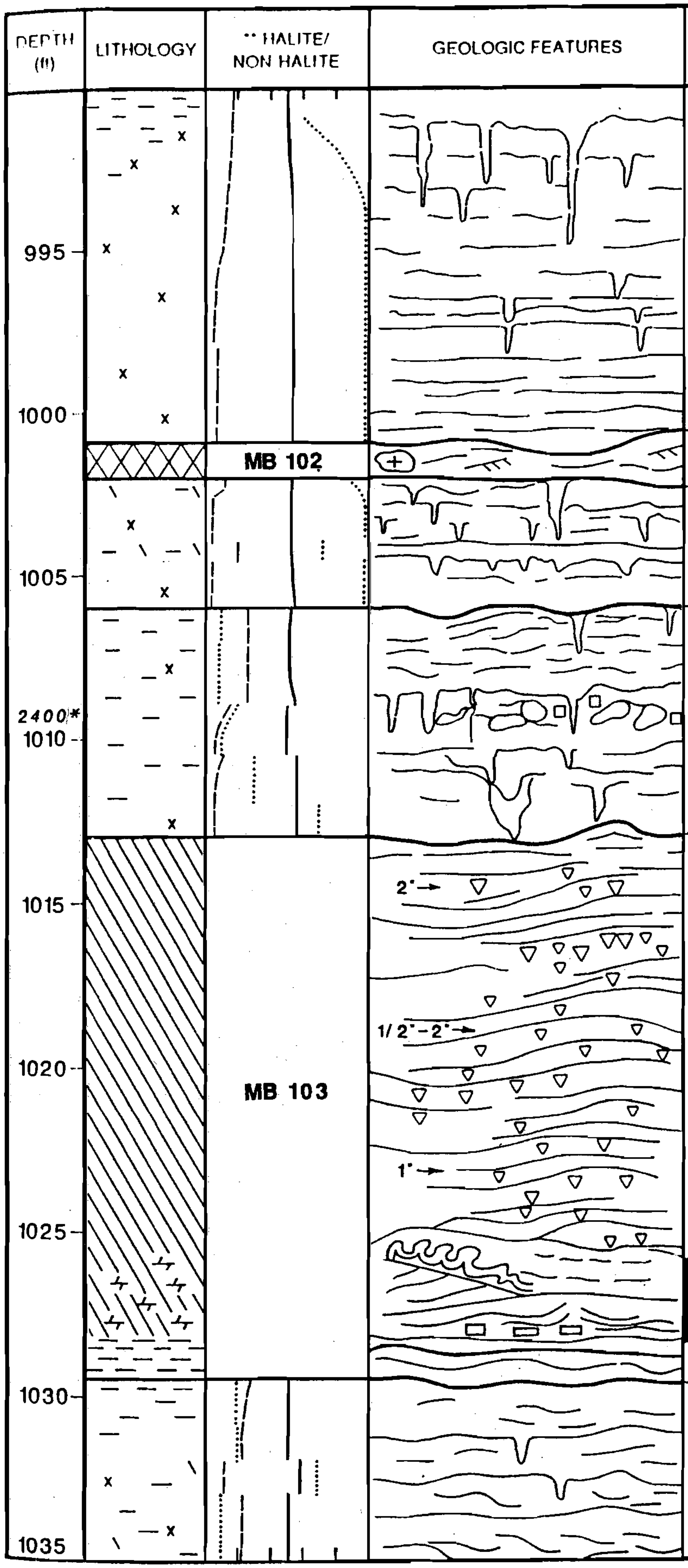
H, tr to some poly and clay, zones of claystone in upper part and at upper contact (.5+'). Divided by major DVT e/s surface at 970.5. Lower poly'c zone has crude to well-defined strata, pits from 6" in unit to 2.5' deep at DVT e/s surface. Poly as lam, stringers, blebs with displacive H, lining H, and as rare H drapes. VO MP rare to common. H in poly-rich zone m-c IV, vc in MP, f H occurs in beds of m-c to f or f-m to poly'c H or poly at top. Upper zone becomes increasingly arg upward to .5+'thick claystone. Irreg zones to pods of f IV. Crude beds to lam to thin beds of claystone over irreg e/s surfaces; sic textures. Claystone as blebs, "blebby" lam, and stringers with with displacive a-b H margins and incorporative f-m I-IIa-b. H in arg zone trends upward from m-c IV to f IV to I-IIIb-c in arg H; tr P, tr to some C in pods and MP. Tepee-like structure developed on polygon margin tilts strata up with 4-5" of displacement, polygon margin shows downward movement into clay pit, 3.5' deep. 6" pits in arg zone, 3+' deep pits originate at top.

H, tr poly, arg in upper part above 991; Poly occurs as lam to stringers, to blebs, with drapes over vel BG H; delineates well defined to crude thin to m beds. M-c IV with vel BG overlain by f IV; tr to major P (decreases upward), tr C (increases upward). Pits

*ELEV (ft m.s.l.)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 6 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

in lower part 6-12"; deep pits (to 9') from DVT e/s surface at 991'. Arg upper part in 5 zones: m-vc IV, tr f-IV, II-IIIa-b; m-c IV, zones and pods f IV, m-c I-IIIa-b; f-c I-IIIb-c, m-c IV, tr 1-IIa; f-c I-IIb-c, tr Ia; to f-m I-IIa, tr I-IIb. IV with f H abund in zones and pits in DVT zone. Local f-c I-IIIa-b in arg zones. Clay occurs as lam to blebs with displacive H margins, as irreg zones and beds to .1-.2' in upper 3', and abund sic textures.

Poly; crosslaminae in lower .2-.4'. Indistinct contorted strata, zones of H in upper part. Possible coated grains in lower part.

H, tr poly , tr clay and anhy. Poly occurs as lam, blebby lam and stringers, irreg blebs mostly in pits. Poly delineates thin to m beds. DVT e/s surface with 4" relief and pits. Clay as irreg disc lam. Pits to 1'. VO MP. H in sequences of f-c IV, f-m IV, poly-rich f. Tr P, mod C. I-IIIa-b in poly'c and arg zone 8.

H, tr to some clay with tr poly in lower part. Poly as blebs with displacive H margins and irreg stringers. Claystone occurs as lam delineating thin to m beds in upper part and blebs to lam, blebs in pits with abund displacive margins. F-c IV and zones of f-m IV; tr P, tr to abund c. F-m I-IIIb, m-c I-IIa-b in arg zones. Pits to 1', VO MP.

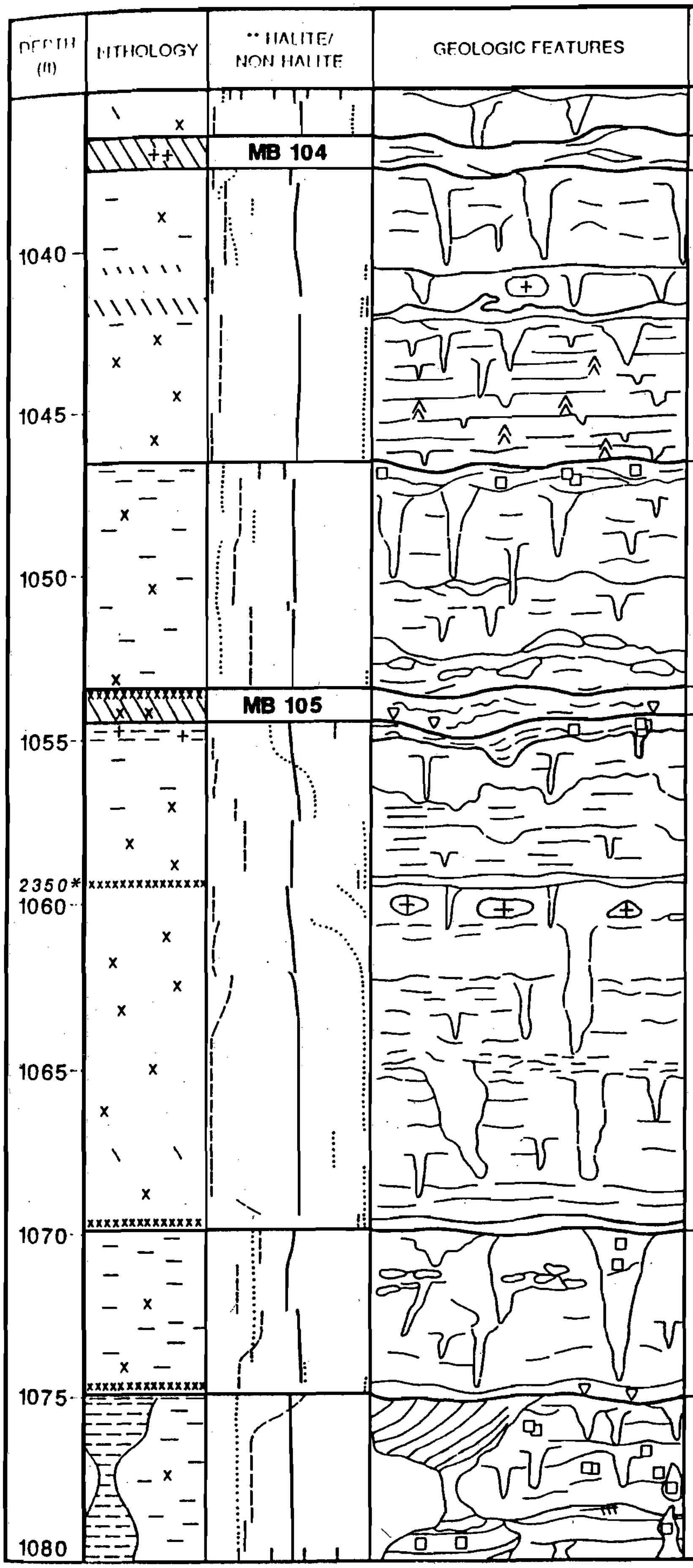
Anhy, lower part anhydritic dolomite; .5-1' laminated claystone at base with H-filled fractures. Weeps, moist surface in lower 4'. Ripup clasts at 1028, overlain by probable tepee structure. Lam and organic material in algal zone 1026-27. 1/4" H PAGS at 1025. Lam to v thin beds, parallel to convolute; abund H, rare anhy PAGS to 2". Upper contact marked by possible tepees.

H, tr poly, tr to some clay above basal 1-1.5'; tr anhy as lam, stringers, and blebs, some displacive H margins above 1034-35. Clay occurs as lam, blebs and irreg zones in topographic lows. Poly occurs as blebby lam, blebs with c displacive H (a margins). VO MP; pits 6"-1'. Abund DVT e/s surfaces marked by clay. C-vc IV w/f-c IV in arg zones; tr to some P, some C. M-c I-IIIb-c in lower arg zone to I-IIIa-b upward; f I-IIIb-c increases upward.

*ELEV (ft m.s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 7 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Anhy; lam; zones of IV under high relief; possible H pseudomorphs after gypsum clastic grains; strata contorted.

H, tr lam poly near base; .2-.3' anhy interbed at 1042, lam from 1039.5-1049.5; tr poly and clay in upper 2'. Poly in lower 2' with some BG H and lining H with POS textures, blebs with displacive H margins, lam and stringers above lower 2'; poly zones in pits. Anhy interbed structureless to laminated, irreg morphology around large MP with vc la H. Poly blebs with c displacive H in upper part. Tr clay in pits. H below anhy; f-c IV, tr vc C; beds of c IV, f-c IV, poly or poly'c IV; I-IIIb-c. H above anhy: m-vc IV w/some to tr P, some C; I-IIIb-c w/tr I-IIIa. H at top is tr f-m IV in pads and lenses. Large irreg MP, VO MP abund. Clay as irreg disc lam. Abund pits, deepest at upper surface.

H, mod'ly arg in lower 2', clay lam in .5' zone near top, tr to some clay. Mod to tr poly, as lam and stringers in lower part, irreg blebs, zones and "blebby" stringers in upper part; blebs with displacive H margins in pits. Clay in zones, lam, and v thin beds to .1', some f-m I-IIa-b in lows. Well developed pods and zones of f IV in lower part of unit. M-c IV, tr P, abund C; tr opaque f-m IV in pods to zones; f-m I-IIb-c, tr la in arg zones; equal m-c IV and f I-IIIb-c in upper 6". VO MP, irreg MP. Abund pits 6" - 3'. Claystone translocated into pits, w/f-vc I-IIIa-b. DVT e/s surface at 1050'.

Poly and halitic anhy, lam. Lower halitic anhy shows possible H PAGS. Some possible collapse. Possible H pseudomorphs after gypsum clastic grains. Irreg H-poor poly zones. Upper contact of anhy with poly shows possible loading, incipient pillows. Irreg zones of H near top of poly.

H, tr to some poly, arg and poly'c near top; halitic claystone at upper contact. Poly occurs as stringers to lam, some vertical crystal shapes and lines m la, blebs (some displacive H margins) in pits, POS textures, and poly boxwork from 1056.5-1059'. Tr anhydritic clay as stringers in pits. DVT e/s surface at 1056.5. Clay in upper part as lam and "blebby" lam, stringers, blebs, zones in topographic lows. Thin to m bedded below arg zone, delineated by poly. H sequence in beds: poly or poly'c H, clear c H w/tr P and C in MP, f-m cloudy H at top. F IV mod abund lower 2-3', 1061-1058, some f-m IV 1058-1055. VO MP. Pits abund, 6"-3'. Claystone at upper contact thickens over pits, contains m-c I-IIIa-b, lam, some sic and f I-IIIc texture in upper part. Tr to some P, mod C.

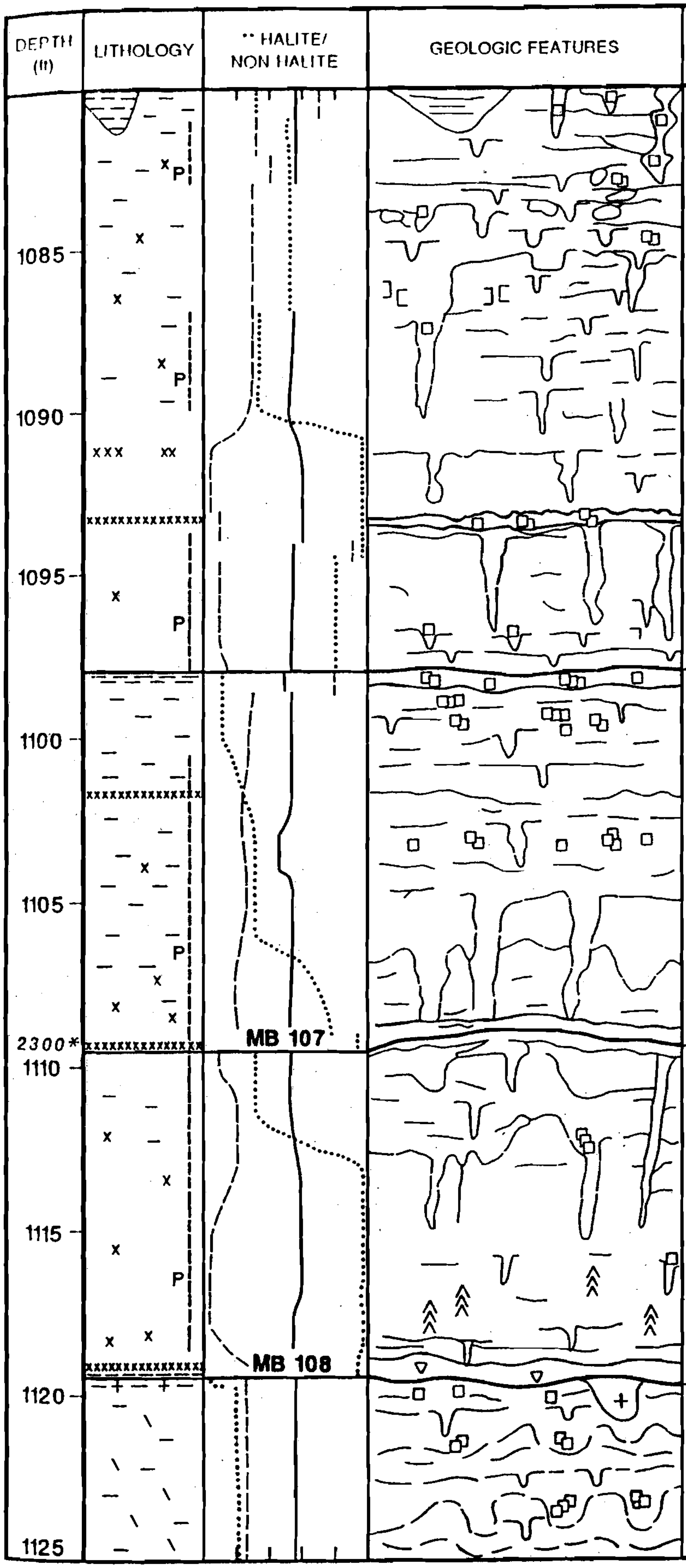
H, tr to some poly, tr to some clay in upper part. Arg H, some claystone in pits from upper contact. Pits 6"-4' deep. Poly .5' at base with zones of H, lam with H PAGS to 1/4". H generally m-c IV, some C, and f-m opaque IV in beds. Beds 4-12" delineated by "blebby" lam of poly. Poly granular, slightly arg, as blebs to stringers; some displacive H margins. Claystone blebs in pits with f-m I-IIIc and tr m-c I-IIa-b, tr gray clay infiltrated into pits. Irreg MP to 2".

H, tr to some poly from 1098-1091, tr to mod'ly arg in upper part with irreg zones of claystone. Poly

*ELEV (ft m s l) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 8 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

occurs as thin beds to blebs and "blebby" lam (as solution lag surfaces), and zones in pits with m-c I-IIa-b. H in poly zone m-c IV, w/vc IV in MP; tr P, tr C in MP. VO and irreg MP. From 1091-1087, f-c IV w/tr P and some C in MP and pipes; some f-m II-IIIb-c. Poly boxwork fabric above 1087, appears v disrupted by pits and MP. DVT e/s surfaces near 1085 with solution lag; collapse of bedded block into pit. H in arg zone: m-c IV w/tr P and tr to some C. Displace H above 1085 trends from m-c Ia-b to f-c I-IIIa-c (mainly b) to f-c I-IIIb-c upward. E/s surfaces topped by claystone w/m-c I-IIa-b. Claystone in topographic low shows ripples. Claystone w/m-c I-IIa, some irreg lam occur in irreg vertical zones. As no laterally equivalent claystone occurs these probably originated as infiltration mud transported in deep channels in pits or small caves; these zones cross-cut H strata are v irreg, and show no internal continuity with strata. Trough and parallel lam at upper contact. Upper 2' v arg w/claystone blebs. Abund pits l6"-2' deep. Claystone with ripple cross-laminae (1/4-2") cont with large pit of claystone. Pits originate in claystone at top.

H, some to tr poly; tr to some clay above lower 2'. Poly occurs as .2-.3' halitic bed at base w/collapse into underlying pit; thin lam to blebs in pits w/displacive margins. Clay occurs as lam to blebs with displacive H margins. Crude strata near middle of unit v/f-m I-III. Poly and clay translocated in pits. Pits 6"-3' deep, abund. VO MP rare, irreg MP abund. Zones of claystone with f-m I-IIIa-b. H: m-c IV, vc in MP; tr to some P, some C. Unit tends to II-IIIb-c w/tr Ia-c in arg/sulfate parts. F-m I-IIa-b in upper .5' claystone.

H, some to tr poly to about 1113, tr clay in upper 3' above DVT surface. Lower .5' of poly lam w/swallowtails and lam anhy and clay. Poly occurs as lam to blebs and zones with displacive H margins. In lower 2', POS textures and poly draping BG H. DVT e/s surface near 1113. Clay occurs as thin lam to blebs, many w/displacive H margins. Thin to m beds (2-10" thick) well defined at base to crude at top. M-vc I-IIIa in pits with poly. Abund pits to 5' deep, most 6" to 2'. Pits and MP rare in lower 2', abund upward. H is m-c and vc IV; major vel and P near base to tr P upward; tr C in MP near base to some C in VO MP and pits in arg. zone. M-c II-IIIb-c w/tr Ia-c in blebs and lam of clay and poly.

H, arg and trace poly'c to anhy'c in upper part, lam of anhy. Poly occurs as blebs, most translocated into pits. Clay occurs as lam to blebs and irreg zones, and translocated material in pits. Pits to 2+' deep. M-f I-IIb-c in claystone. Unit is m-c IV, tr f IV in lower part, m-c I-IIIb-c in arg zones. VO and irreg MP. Pit to 1' x 1.5' with clear halite at upper contact. M-f Ib in claystone at upper contact.

*ELEV (ft. m s l) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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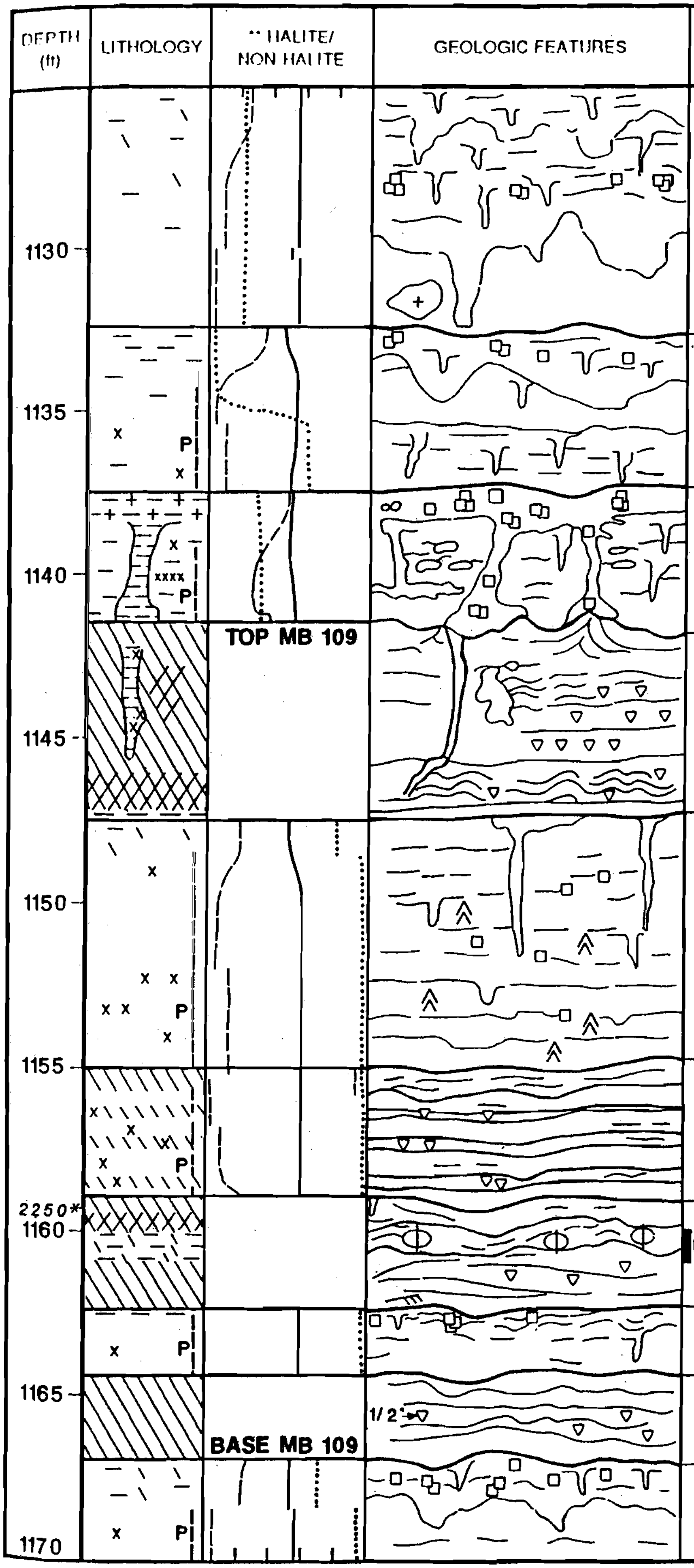
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H, tr poly below about 1135 in lower part, tr to some arg in upper part. Poly occurs as v thin beds to blebs and irreg zones (mostly in pits with displacive H margins), some with vc IV. Clay occurs as lam to blebs, irreg zones. DVT e/s surface divides arg and poly zones. Pits 2'-6". VO and irreg MP mod'ly abund, increasing upward. H is m-c IV, vc in MP. Poly'c zone tr to some P, tr C in MP; beds w/sequence poly'c H, c clear H, f-m cloudy H. Upper arg. zone mod P near base; f-m I-IIIb-c and m-c, tr vc I-IIIa-b.

H, tr to mod'ly arg upward, tr poly. Poly occurs as lam to blebs and zones with some m-vc Ib-c. Clay occurs as lam, zones in topographic lows, translocated pore fillings (w/m-vc Ia) in zones at lower contact, and blebs. Clay and poly infiltrated downward from DVT e/s surface. H: m-vc IV, some f from 1139-1140 at e/s surface. M-c I-IIIa-b, f I-IIIb-c w/f I-IIIa increasing upward in arg zone. Abund pits 6"-3' deep.

Anhy, basal claystone w/lam, poly in irreg zones and in lower 1.5-2'. H PAGS 1/8-2" high w/lam, possible H replacement of gypsum clastic grains, c H fills desiccation feature. Possible poly and anhy PAGS. Some H PAGS grade laterally w/i same lamina into poly or anhy PAGS. Lam wavy to convolute. Cross-cutting relationships near poly/anhy transition and near top. Upper 1-1.5' has abund H and "teepee" structures, porosity filled w/clay and H C.

H, some to tr poly upward, tr to some gray clay in upper 1'. Poly is granular and occurs as v thin beds to large blebs w/displacive H margins and m-c Ia. Thin to m beds delineated by poly. Clay occurs as lam, zones and irreg blebs w/m Ia. F-vc, mainly m-c IV; f H in upper 1'. Tr P and vel, mod to abund C. VO and irreg MP. Pits 6"-3+' deep.

H, thin beds of anhy, some poly. Interbeds are laminated, parallel to contorted, halitic. H in anhy interbeds: H PAGS to 1/2" high; zones of intermixed anhy and possible clastic H; zones of f H w/anhy are possible early replacement of gypsum grains. H: m-c IV, zones of f H w/sulfate. Tr P, some C. VO MP. Sulfate also as lam to blebs and POS textures. Pits to 4" deep in lower H interbed.

Anhy, mudstone w/anhy nodules in middle, and poly. Anhy lam, some cross cutting, slumping, and draping relief on lower contact. Small ripple cross lam. Anhy PAGS in upper half of anhy. Middle arg nodular zone has 1/8" anhy PAGS. Poly has lam w/abund small H and poly PAGS.

H, tr to some (upward) poly. Poly on dissolution surface and as blebs in pits. M-vc IV; tr to abund P, mod C. Irreg MP to 5". Pits to 6" near top.

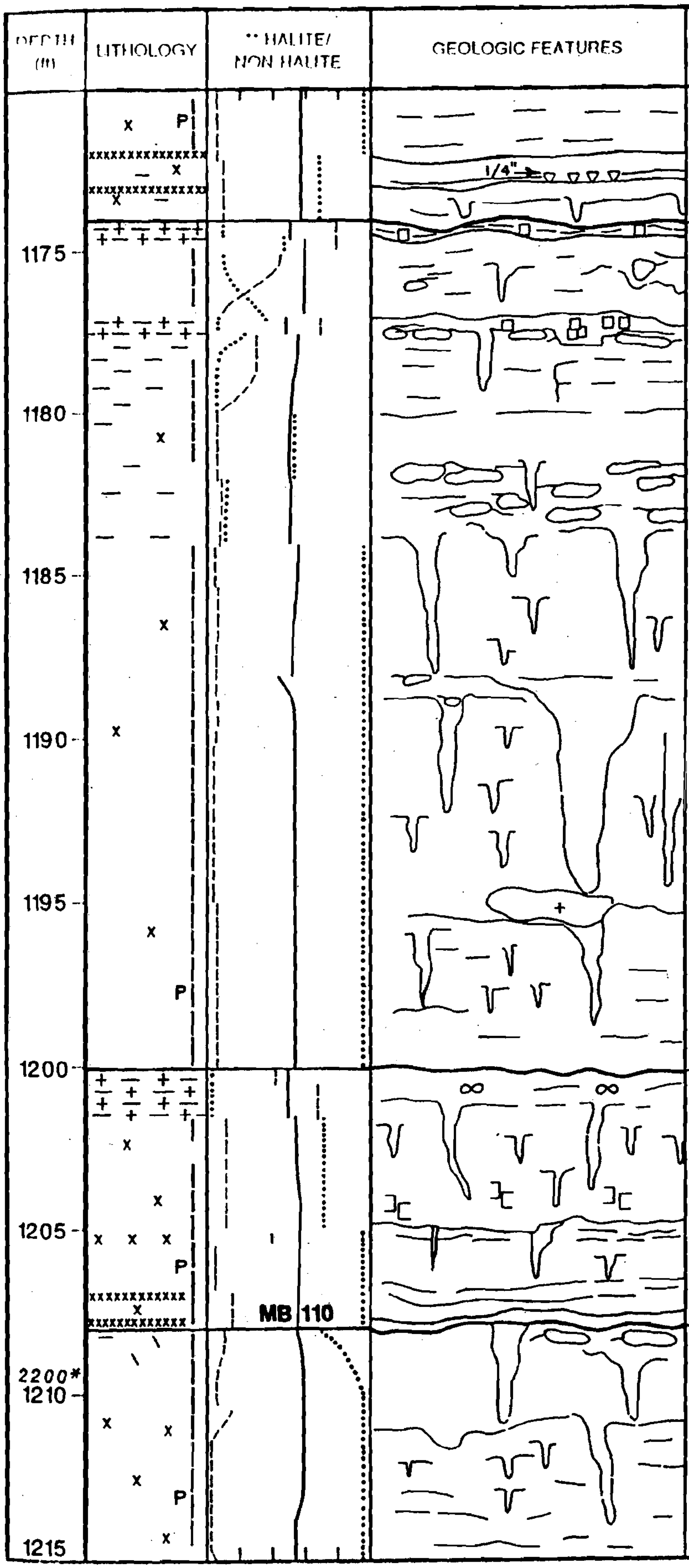
Anhy, lam, contorted to wavy; possible clastic H and H PAGS to 1" high.

H, tr poly and clay. Poly occurs as lam, stringers, irreg blebs (mostly in pits) and rare crude POS texture. Clay occurs as lam, stringers, and blebs. Anhy similar to poly in arg part, increasing upward.

*ELEV (ft m s l)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 10 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Blebs w/I-IIa. Middle part bedded; abund pits to 6" in upper part. VO to irreg MP. M-c IV, zones of f in upper part; beds of stratified sulfate to m-c to f IV. Pits with translocated material. Small swallowtails in lower poly.

H, tr poly, below 1174, brown arg zones above; zones of halitic claystone near top. Poly occurs as lam to blebs w/abund displacive H margins and m-vc Ia-b. Thin to m beds delineated by poly. Tops of poly-rich zones show deep pits; pits to 7-8'. MP. Clay occurs as lam to blebs. M-c IV, zones and pods of f H with DVT textures at upper e/s surfaces on tops of poly-rich zones and in pits. I-IIIa-b common in arg zones. Tr P, mod to abund C. Some box-work fabric. Claystone shows sic texture in upper gray zone, f Ib-c w/tr c-vc Ia and zones III-IV.

H, tr to some poly, tr to major clay. Thin to m beds delineated by poly. Poly occurs as thin beds to bleb-like zones 1"-3" thick with m-vc Ib. Poly translocated in pits to 3' deep. Clay occurs as stringers and blebs. M-vc IV, tr f throughout; m-c I-IIIa-b to f-m I-IIIb-c in upper 1.5'; tr to some P, and C. Abund irreg MP, also VO MP. Overlain by DVT e/s surface. Claystone contains sic textures.

H, tr poly in lower part, tr gray clay at top. Thin to m beds, strata not apparent above 1211'. Poly occurs as lam to H linings and POS textures near base. Higher, poly occurs as blebs with some lam; blebs as solution lags and in pits, show displacive H margins. Clay occurs as stringers and blebs. F-vc IV overall: m-c to 1214, m-vc to 1209, f-c to 1208; beds w/sequences poly'c H or poly to c clear H to m-c cloudy H; tr P, abund to mod C. VO and irreg MP mod to abund upward. Abund pits to 3' deep with translocated poly.

*ELEV (ft msl) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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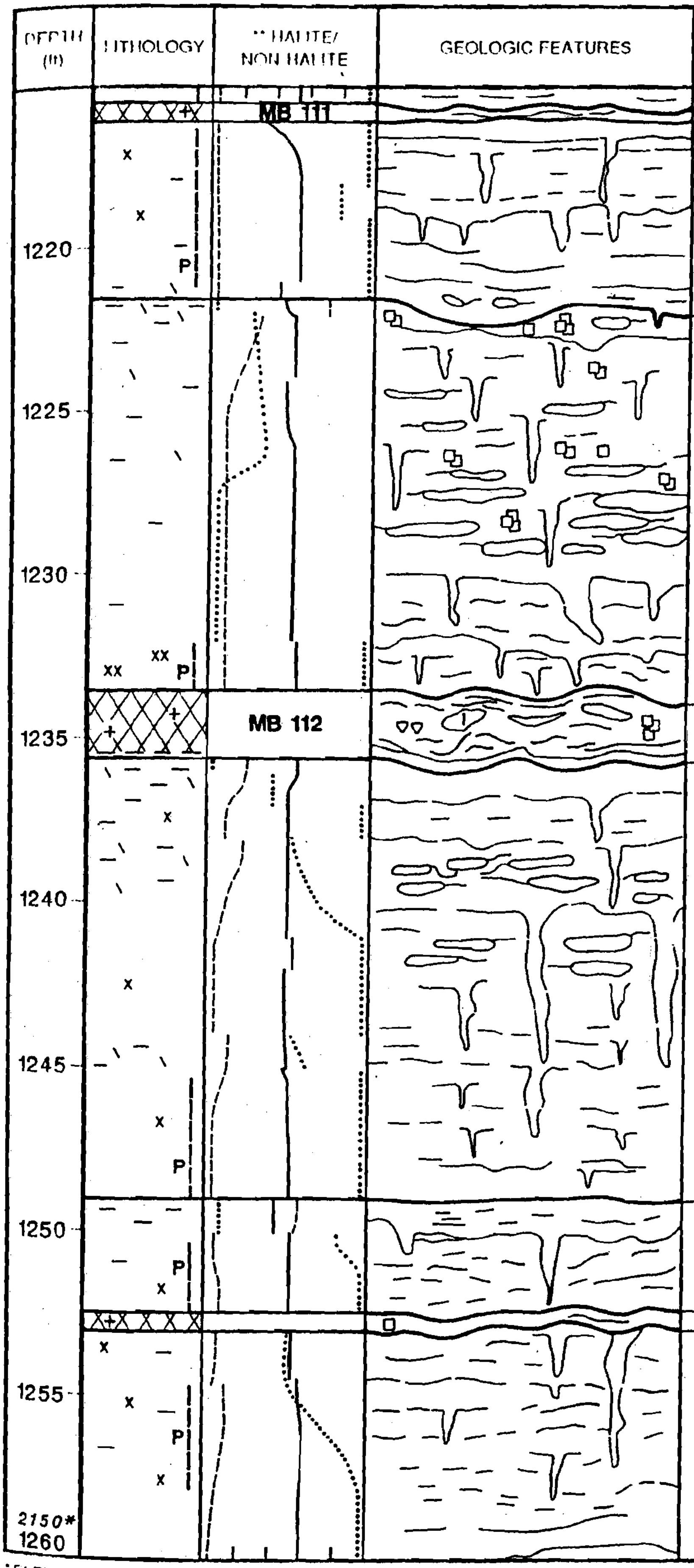
FIGURE 23



REMARKS (SEE APPENDIX FOR DETAILS)

Poly, m crystalline, H in lenticular zones parallel to strata. Lam to structureless.

H, tr poly, alternate zones w/tr gray clay and anhy. Poly occurs as lam to blebs and POS textures. Clay as thin lam and stringers, commonly with f IV. M-c IV, f-m near base, tr f at top; tr P, tr to some C. Abund VO to irreg MP. M to thin beds delineated by sulfate or clay. Sequences of poly'c H to c clear H to found in cloudy H. Pits 3"-2' deep with translocated material.

H, tr poly, tr to some clay above basal 2.5'. Poly occurs as lam to blebs with some displacive H margins, large blebs in pits with m la. Clay occurs as lam (many as e/s lag) to blebs w/f-m I-IIa-b. H in poly'c part: m-c IV, tr f; tr P and C. VO and irreg MP. H in arg part: m-c IV, zones and pods of f-m and f overlain by clay e/s lags, m-c I-IIa-b to 1227; f-m IV in pods w/f I-IIIb-c and m-c I-IIIa-b to 1224; m-c IV w/I-IIIa-b to 1222; f-m IV w/f-m I-IIIa-b and basal I-IIa-b to 1221.5; abund DVT textures; sic near top. Pits 6"-2' deep. Clay and poly translocated down in some pits. Tr f IV in some pits. Filled prism cracks to 4" deep at upper contact.

Poly, basal claystone w/lam, claystone shows gravity loading and slumping w/flame structures around pillows. H as probable PAGS in teepee-shaped zones of H, BG H with sulfate drapes, m-c III, zones of c-vc IV w/H drapes, m-c Ic. H zone boundaries w/poly are usually irreg and not planar. Poly lam contorted to convolute in hummocks on upper surface. H zones occur below hummocks. Strata thicken in troughs and thin over the hummocks. BG H in lenticular zones in upper troughs.

H, tr poly, tr to some gray clay and anhy w/gray clay at top. Pits 1-5' deep. M to thin beds, best defined near base, w/sequence f poly'c H to clear c H to cloudy m H w/tr f. Poly occurs as lam to blebs and zones in pits, H linings, POS textures; blebs have m I-IIa-b. Clay occurs as lam to blebs w/ f-m I-IIa. Poly and clay translocated into pits and some MP. MP abund; size decreases in upper 2'. M-c IV, some f to 1245, tr P; f-m IV in pods, m-vc in zones and m-f I-IIIc to 1237, tr to some P, tr-mod C; m-c IV w/I-IIIa to 1235.5. DVT textures abund in middle. Upper surface planed off by flooding.

H, tr poly to 1250, arg upper part. Poly occurs mostly as large blebs w/m-c Ia-b H. Clay as blebs to lam. Blebs abund upward w/I-IIIa-b. Local pits to 6". F-c IV, mainly m, pods f abund in upper 1.5'. Tr P, mod C. F-m I-IIa-b in upper 1.5'.

Poly, gray clay at base w/load features. Tr m-c Ia-b. Some contorted thin lam.

H, tr poly, tr clay in upper part. Poly as lam to blebs and zones translocated in pits and as solution lags. Clay as irreg lam over e/s surfaces and blebs and stringers. F-vc, mainly m-c IV, f near top and in pits. Tr P near base, mod C increasing upward. Some sequences poly or poly'c H (f) to clear H to poly'c H. Tr to abund VO and irreg MP. Pits to 3+' deep.

*ELEV (ft m s l) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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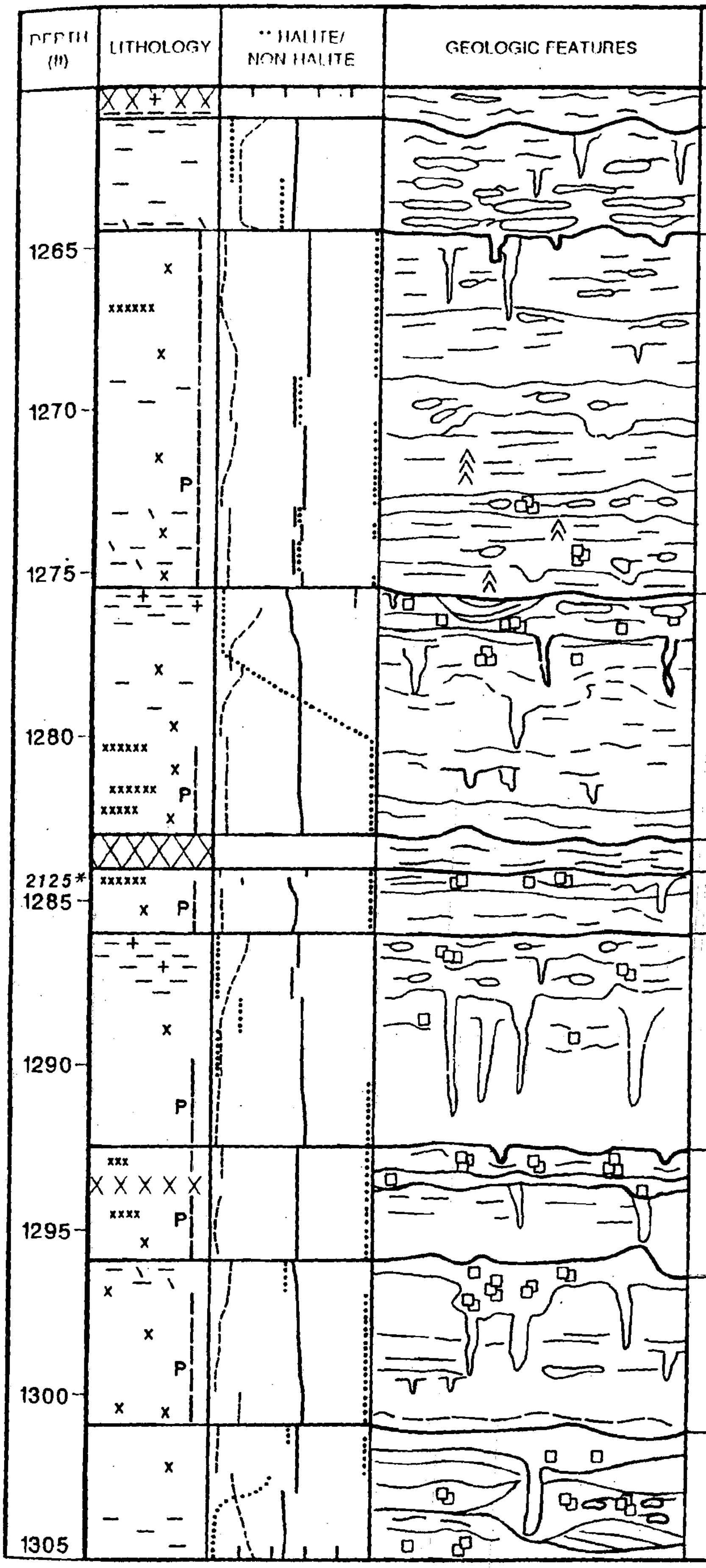
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Poly, tr H. Basal gray claystone. H as zones, some BG textures. Irreg contorted to wavy lam.

H, some to tr clay and poly, arg in upper 1.5'. Clay as stringers and thin lam. Poly as irreg blebs in pits w/displacive H margins. F-vc IV, w/abund f in zones and pods near base. Mod C. Abund MP. Claystone infiltrated into pits.

H, alternately tr poly and tr clay w/intervening DVT e/s surface. Poly occurs as thin lam, stringers, H drapes and linings, POS texture, and as blebs. F-vc IV, tr to some P and C; f IV in poly'c zones and as pods near base. Mod'ly abund MP, some VO. M-c I-IIa w/poly in some pits.

H, tr poly at base, arg to claystone at top. Poly occurs as lam to blebs (lags and translocated in pits w/m-c Ia). Clay occurs as lam, blebs and zones of blebs, some w/a-c margins, zones w/sic textures, translocated in pits. M-c some vc, IV to 1276.5, tr f near top, some IIIa-b, tr-some P, tr C increases up. Ib-c above 1276.5, some f II-IIIb-c, versus m-c IIIa-IV. Abund MP, VO near base. DVT e/s surfaces near top. Possible desiccation cracks filled w/H at upper surface.

Poly, halitic. Contorted to cross-cutting lam. H in zones, some lenticular, some Ia-IIIa-c.

H, tr to some poly. Poly occurs as lam to blebs, zones w/m-c Ia in pits, H drapes H, POS textures. M-c IV, zones of f, f-m I-IIIa-b. Tr P, mod C. Some MP.

H, tr poly; tr clay, increasing upward, claystone lam at e/s surface in upper 3'. Clay occurs as stringers, blebs, zones w/displacive H margins. Poly occurs as blebs (some displacive H margins) and POS textures. M-vc IV to 1290; f-c IV w/f in pods, f Ia-b, also I-IIIa-c. Some to tr P; tr to some C. VO MP.

H, tr poly; 5-6" bed of laminar poly w/lenticular H-filled voids m I-IIIa-c. Poly occurs as thin lam to blebs in pits, H drapes and linings, and POS texture. Mainly m-c IV, tr f near top and poly'c zones. Tr to some P, some to mod C. MP.

H, tr poly, tr clay at top. Poly occurs as lam to blebs. Clay occurs over DVT surface and in pits. M-c IV; f-c I-IIIa-c in upper 1'. Some to tr P; mod C. VO and irreg MP near DVT surface.

Arg H w/halitic claystone. Tr poly as thin lam to POS textures, displacive H margins. Clay occurs as lam, zones in topographic lows, blebs, incipient sic texture near base. Thin to m beds of H and claystone in lower 2'. M-c I-IIIa-b and f I-IIIa in lower 1.5'; f-c IV w/bases f-IV w/clay and I-IIIb-c disrupting beds near 1304. Clay occurs upward as stringers w/f and m-vc IV; I-IIa-c to f IV in zones and pods near top. E/s surfaces in middle.

*ELEV (ft m.s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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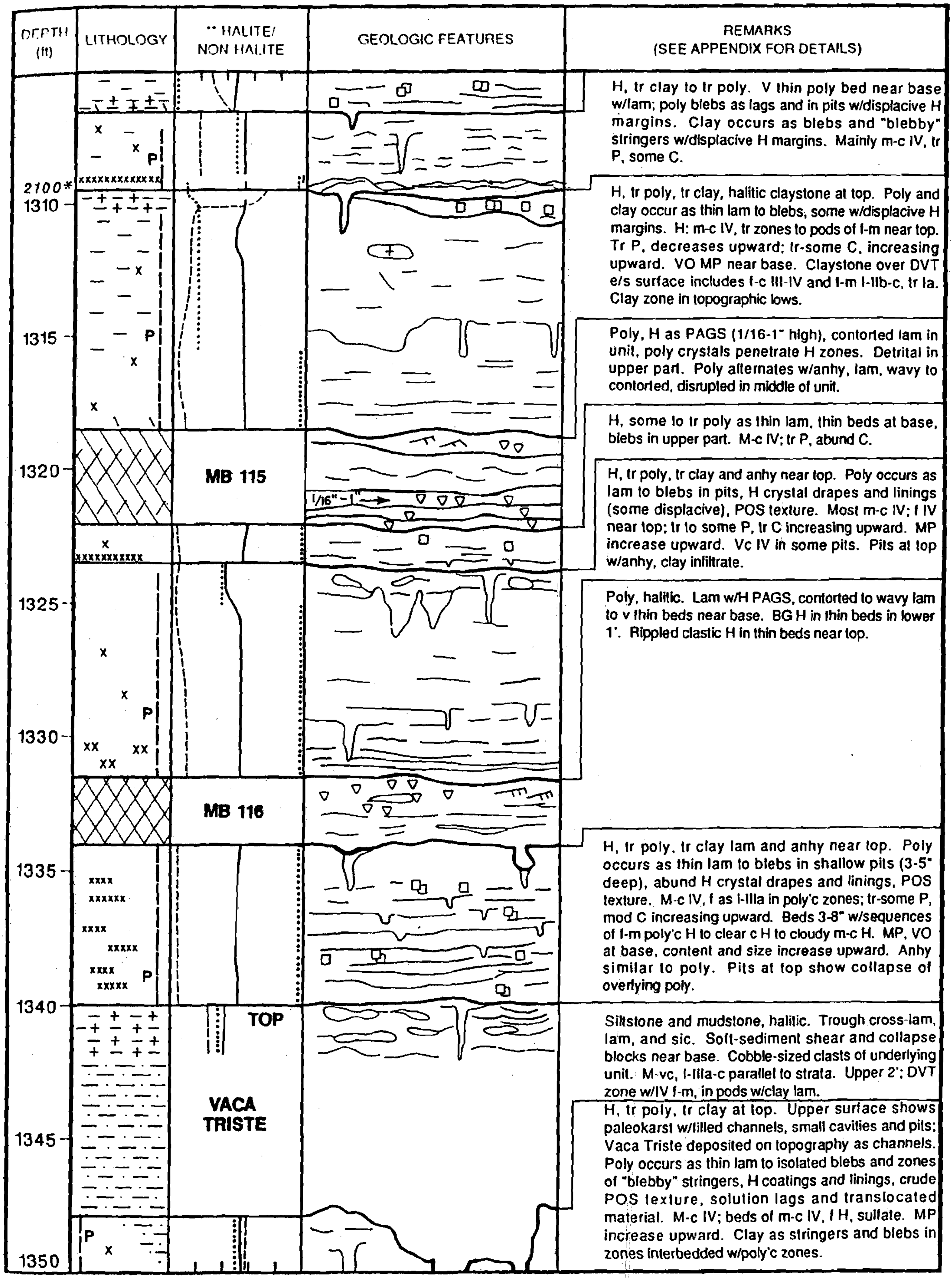
FIGURE 23



H, tr clay to tr poly. V thin poly bed near base w/lam; poly blebs as lags and in pits w/displacive H margins. Clay occurs as blebs and "blebby" stringers w/displacive H margins. Mainly m-c IV, tr P, some C.

H, tr poly, tr clay, halitic claystone at top. Poly and clay occur as thin lam to blebs, some w/displacive H margins. H: m-c IV, tr zones to pods of f-m near top. Tr P, decreases upward; tr-some C, increasing upward. VO MP near base. Claystone over DVT e/s surface includes f-c III-IV and f-m I-IIb-c, tr Ia. Clay zone in topographic lows.

Poly, H as PAGS (1/16-1" high), contorted lam in unit, poly crystals penetrate H zones. Detrital in upper part. Poly alternates w/anhy, lam, wavy to contorted, disrupted in middle of unit.

H, some to tr poly as thin lam, thin beds at base, blebs in upper part. M-c IV; tr P, abund C.

H, tr poly, tr clay and anhy near top. Poly occurs as lam to blebs in pits, H crystal drapes and linings (some displacive), POS texture. Most m-c IV; f IV near top; tr to some P, tr C increasing upward. MP increase upward. Vc IV in some pits. Pits at top w/anhy, clay infiltrate.

Poly, halitic. Lam w/H PAGS, contorted to wavy lam to v thin beds near base. BG H in thin beds in lower 1'. Rippled clastic H in thin beds near top.

H, tr poly, tr clay lam and anhy near top. Poly occurs as thin lam to blebs in shallow pits (3-5" deep), abund H crystal drapes and linings, POS texture. M-c IV, f as I-IIIa in poly'c zones; tr-some P, mod C increasing upward. Beds 3-8" w/sequences of f-m poly'c H to clear c H to cloudy m-c H. MP, VO at base, content and size increase upward. Anhy similar to poly. Pits at top show collapse of overlying poly.

Siltstone and mudstone, halitic. Trough cross-lam, lam, and sic. Soft-sediment shear and collapse blocks near base. Cobble-sized clasts of underlying unit. M-vc, I-IIIa-c parallel to strata. Upper 2'; DVT zone w/IV f-m, in pods w/clay lam.

H, tr poly, tr clay at top. Upper surface shows paleokarst w/filled channels, small cavities and pits; Vaca Triste deposited on topography as channels. Poly occurs as thin lam to isolated blebs and zones of "blebby" stringers, H coatings and linings, crude POS texture, solution lags and translocated material. M-c IV; beds of m-c IV, f H, sulfate. MP increase upward. Clay as stringers and blebs in zones interbedded w/poly'c zones.

*ELEV (ft m s l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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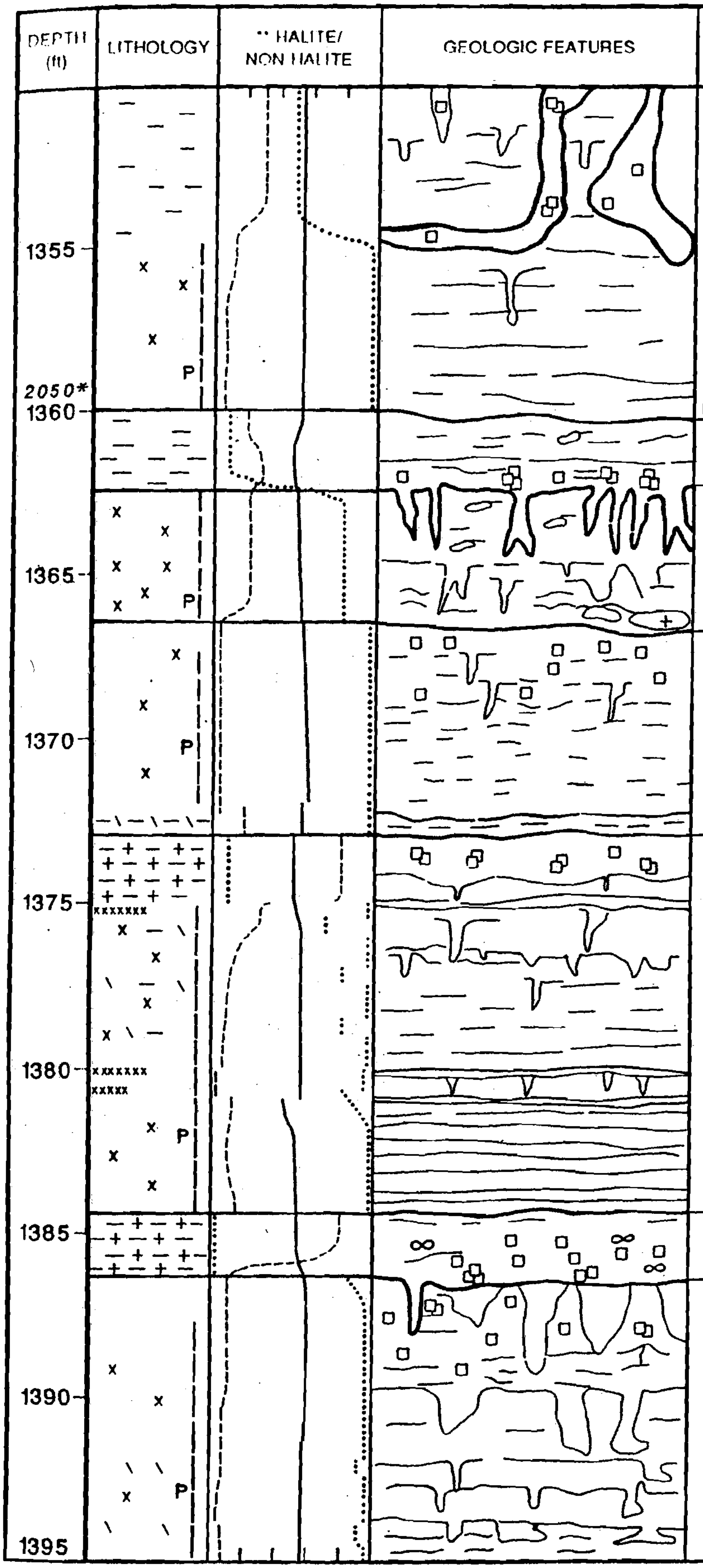
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H, tr clay, decreases near top. Clay occurs as blebs and lam sic in I textures. Abund f I-IIIb-c, some m I-IIa-b, in lower part; m-c, tr f, IV in upper 1'.

H, tr to some poly, similar to unit below 1373' w/more MP and abund pits. Poly lam, solution lag. F-c IV, tr P, c-vc in pits and MP, f at upper DVT surface and e/s surfaces. M beds of poly or poly'c f-m H, clear c H, f H. Clay infiltrated into pits and pores. Pits to 2.5+' deep.

H, tr poly. Poly occurs as thin lam to blebs, H crystal linings. Poly delineates m beds of m-c IV, tr of f IV, sulfate. Mainly m-c IV, m Ia-c in upper 1.5'. Tr P, tr-some C, tr triple junctions. Stringers of gray clay and anhy near base. Abundant MP. Poly and lam more cont upward. Clay and anhy lam at upper contact.

H, mod to tr poly, slightly arg zones, upper 1.5' arg H. Thin to m beds near base w/poly-rich zone at top of each. Above poly lam at 1380.5' and 1381', strata less well defined. In lower part, poly consists of lam to blebs, some w/displacive H margins and f-m Ia, H drapes and linings (some BG), and POS textures. Character changes at 1379. Below 1379, MP are small and VO, size increases upward. Pits and MP abund between poly beds at 1380.5 and 1381'. Below 1379', H is m-c IV, mod'ly abund P and some C at base, P decreasing upward and C increasing upward. Tr f over m-c IV with and under poly w/m-c IV. Arg zone 1381-1382 has abund f H. Clay consists of thin lam to zones w/m-f Ia. More disrupted above 1379 w/pits and MP. Clay increases upward, strata not recognizable, zones of varying composition distinguishable. Clay and poly more disseminated as blebs and stringers w/displacive H margins. f IV abund; m-c IV, some incorporative H. I-IIa-b in zones and blebs of poly and clay. Abund pits, large MP below 1376. Upper 1.5' mostly IIb-c w/some Ia-IIa and local IIIb.

Arg H to halite claystone w/sic texture. Thrusts w/4" throw at upper contact. Mainly f-m Ia-b w/m-c II-IIIa at base.

H, tr poly, tr clay, more arg above DVT surface at about 1390'. Langbeinite in pits and MP C, leonite in arg zones. Poly occurs as thin lam and stringers, drapes and linings on BG H, POS texture, blebs, and translocated blebs in pits. Clay occurs as thin lam and stringers. Poly and clay show displacive boundaries w/H and potash minerals. Beds w/sequence of poly'c m H to cH to f-m H. H: f-c IV, c as MP C. P, decreases upward. MP more abund upward. Pits to 1' deep in lower part, deeper and larger upward. F IV occurs in small zones. BG fabric most common near base. F IV in zones and pods, m-c I-IIa more common along and above DVT surface.

*ELEV (ft m.s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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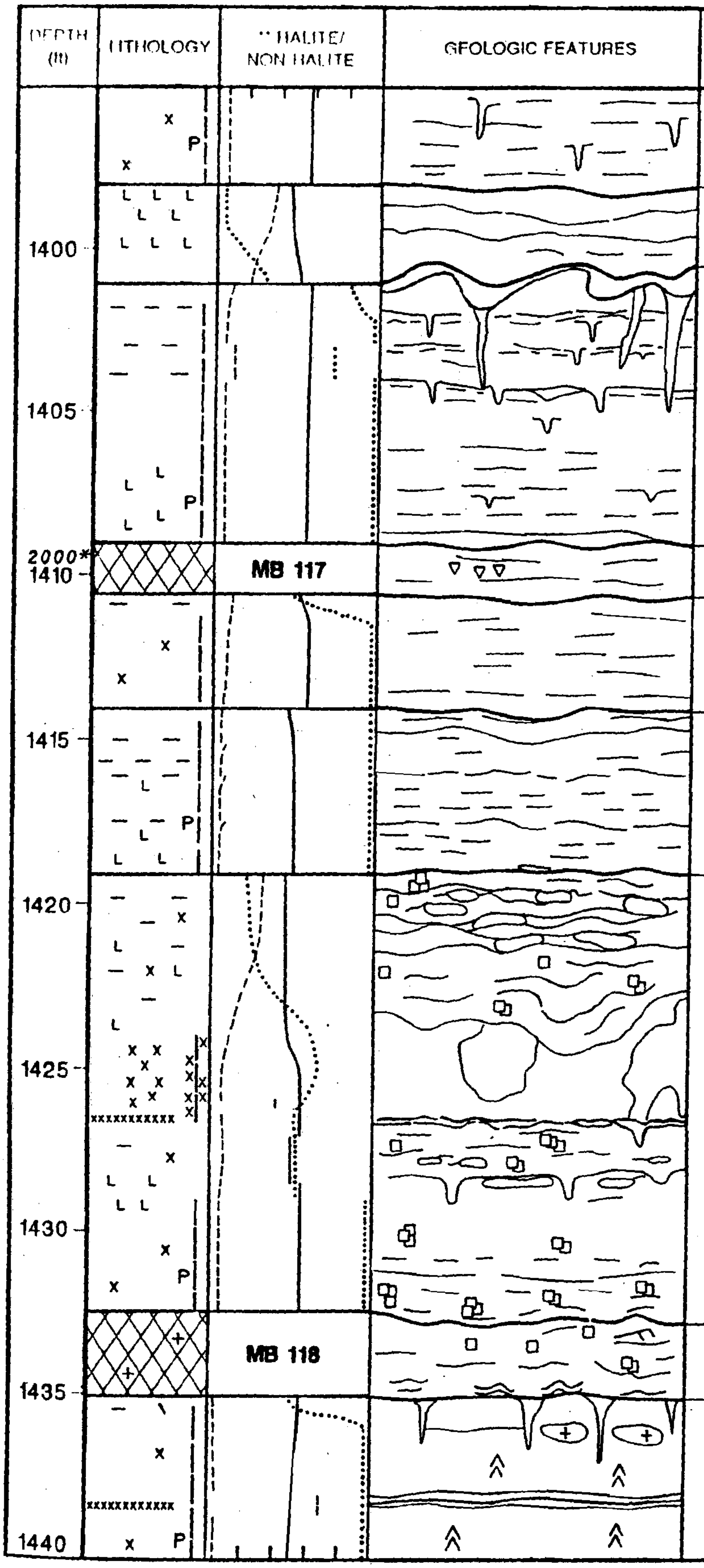
FIGURE 23



*ELEV (ft m s.l) **SEE EXPLANATION FOR SCALES

REMARKS
(SEE APPENDIX FOR DETAILS)

Arg H, poly'c, langbeinitic in irreg zones 1-4" in upper part. Poly as blebs, lag, stringers and POS. Two claystone beds: lower drapes irreg surface, thickens in lows, shows sic texture, infiltrated near pits; upper bed is associated w/langbeinite zones 1-4" across. Clay in H-rich zones occurs as stringers to blebs w/displacive or incorporative H. M-c IV to I-IIIa-b in lower 1'; II-IIIa-b w/tr I-IIIc in middle; f-m I-IIIb-c, tr m I-IIa, and some beds of m-c IV, in upper part. Langbeinite possibly pseudomorphed by leonite. Langbeinite partly displacive, abund near upper contact.

H, tr poly, tr langbeinite. Arg zones near e/s surfaces at top. Poly occurs as lam to blebs, POS, drapes on BG H. Clay occurs as thin lam. Clay box work 1403-1404', more disseminated upward. H is f-c, mainly m, IV; tr to some P, C. MP increase upward. Sequences of poly, c H, f poly'c H. Langbeinite in MP.

Poly, H (IV) zones. Thin lam, contorted to wavy, clay at base. Potash minerals in lenticular pore w/drusy lining of unidentified mineral. Poly PAGS.

H, tr poly as stringers, blebs and solution lags. F-m beds w/sequence poly, m-c IV, f H; tr to some P, tr C. Pods f IV near top. Possible langbeinite.

H, tr poly as thin lam, stringers, blebs as solution lags, POS and H crystal boundaries. Thin to m beds of poly, m-c IV, tr f IV; tr to some P, tr C and langbeinite in MP.

Divided into 5 parts:
part a: H, tr poly, tr clay at top. Poly occurs as blebs to lam, lags. Beds delineated by sulfate. F-c, mainly f-m, IV; tr to some P, cC in MP.
part b: H, tr poly and clay Poly occurs as blebs and stringers. Clay occurs as lam to blebs. M-c IV, abund C, f H in zones and pods, f I-IIIb-c in arg zones. Pods of displacive langbeinite.
part c: H, tr poly. Poly w/langbeinite at top. Poly occurs as blebs and stringers. M-vc IV, tr P, some C. Abund VO MP.
part d: disc 3' H w/tr poly as blebs, stringers, box work. Many generations of C in pits and MP. Zones and pods of langbeinite in pits and MP. E/s surface at top. M-c IV w/f H near top.
part e: H, tr poly and clay. Poly occurs in f IV, blebs, as solution lags. Clay occurs as lam (DVT surfaces) to blebs. F-m I-IIIb-c, sic textures. M-c IV w/f H in pods and zones. Possible pits. Tr langbeinite at top.

Poly, tr to v halitic upward. Zones of vc IV and m-c IIIb in lower part. Thin lam, low angle cross-beds and cross-lam. Zones of clastic/detrital H and m-c I-IIIa-b. III occurs in troughs of cross-lam. Zone of m-c IV w/interlam of poly in upper 4".

H, tr to major poly. Poly occurs as thin beds, blebs, and POS textures, drapes of crystals and surfaces. Drusy sulfate formed in open void. Beds about 4" thick of m-c to f H to poly. F-c IV; some P (tr vel?), tr to some C upward. Blocks of clay w/c-vc la in pits. Large MP.

AIR INTAKE SHAFT LITHOLOGIC LOG
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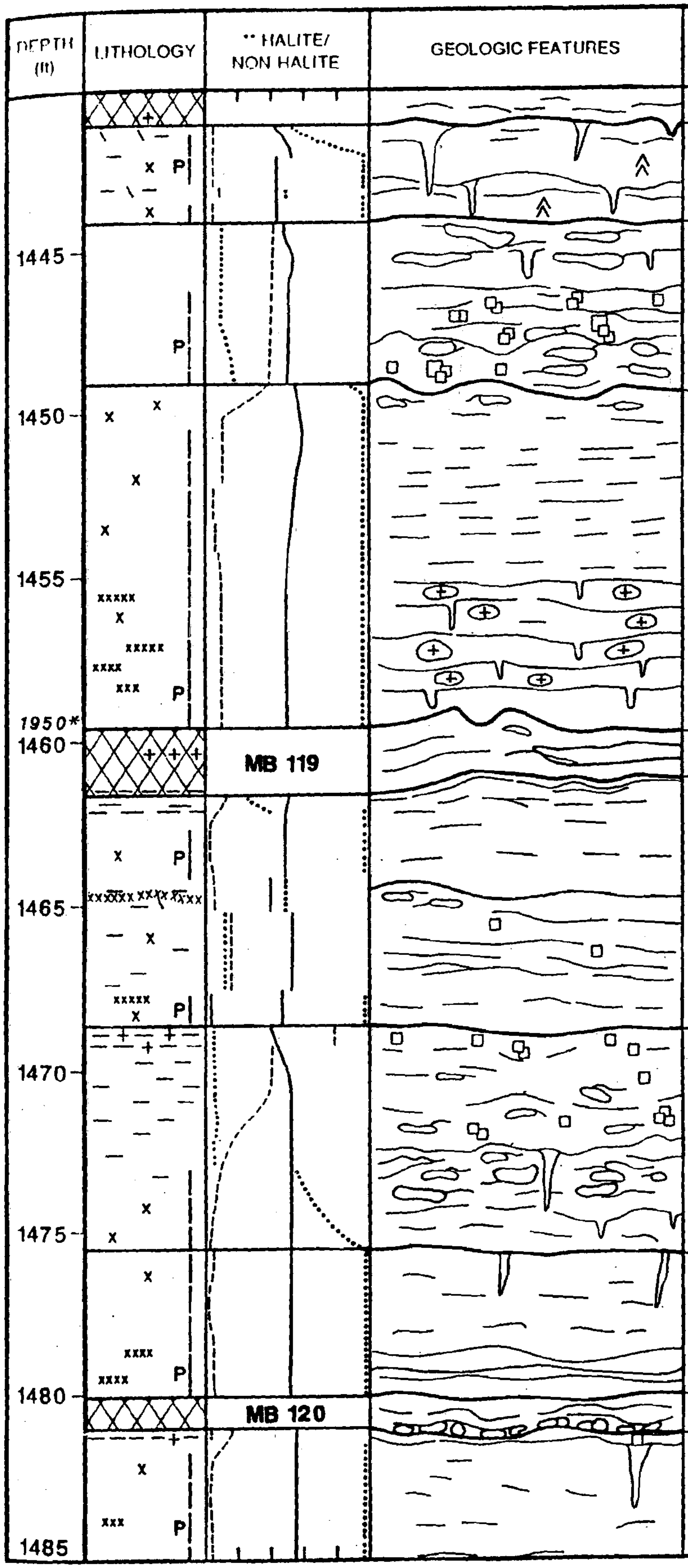
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Poly, some H. Lam, parallel to slight cross-cutting. M-c Ib near base, m-c Ic in middle.

H, lower 2' tr poly, tr anhy and clay in upper 1', tr clay 6" from base. Clay occurs as thin lam in discrete horizons. Anhy and poly occur as thin lam and stringers to blebs; some poly POS, H drapes. Thin beds, zones w/poly, m-c IV, f H sequence. H: f-vc IV, f H increase upward; tr to some P (BG) and tr C; tr VO MP. DVT e/s surfaces w/pits. F H, POS in pits.

H, arg. Lower part: clay in thin lam to blebs w/m-c I-IIIa-c, sic/lam texture. DVT surfaces. M-c IV, tr f H, some pods near top; tr P, abund C. Upper zone similar, less arg. F-m IV near top.

H, tr poly to some in upper 1'. Poly occurs as H crystal rims, POS, stringers to thin beds, zones in pits, boxwork pattern. Lower H: f-m IV w/sequences of poly, m-c IV, f IV; c-vc C in MP and pits. Tr to mod P (some BG), minor C. Some I-IIIb-c w/poly. Upper part: tr large poly blebs on dissolution surfaces and in pits. M-c IV w/zones of f; mod P (probable BG), mod C. Small MP. Thin to m bedded. Tr clay as thin lam and stringers. F III w/tr poly and some pods f IV near top.

Poly, H'c, basal claystone. Claystone has pods of poly in trough w/clay squeezed between pods. Claystone shows thin lam. Lower 6-8" of poly has lam delineated by claystone. Lenticular to tabular zones of BG H and m-cI in upper part. Possible clastic H near top. Upper surface undulatory over 8"; 4" high hemispheroids near top.

H, tr poly and clay, in zones. Poly occurs as thin lam to blebs. Clay occurs as thin lam and stringers. Most H is f-c IV; some beds of poly to m IV to f-m IV. Tr to some P and C. 1" poly at 1465. Clay lam at upper surface.

H to H'c claystone in 3 parts:
part a: tr poly and clay; f-c IV, pods f IV, tr P.
part b: tr to some clay, tr poly as lam and blebs. Tr P near base, abund C. M-c IV, f near top. DVT e/s surface at top. Thin clay lam, blebs near base.
part c: H'c claystone; thin lam. F-c I-IIIc; pods to lam of m-c IV. Reverse fault w/3" throw at top.

H, tr poly as lam, POS texture, and margins of m IV vel H. Some to mod P, abund to some C. F-vc IV, mainly m, zones of f H in middle. MP near top; poly lam at contact.

Poly, thin lam. Lam w/H show nodular texture at base w/claystone squeezed between nodules.

H, tr poly, tr clay at top. Poly occurs as thin lam to blebs outlining H crystals. M-c IV, tr P, some C. Thin beds defined by poly. MP near top. Clay lam to blebs at top; sic/laminae texture.

H, tr poly to 1490, decreases upward; arg from 1490, increasing upward. H below 1490 in m-c IV

*ELEV (ft. m s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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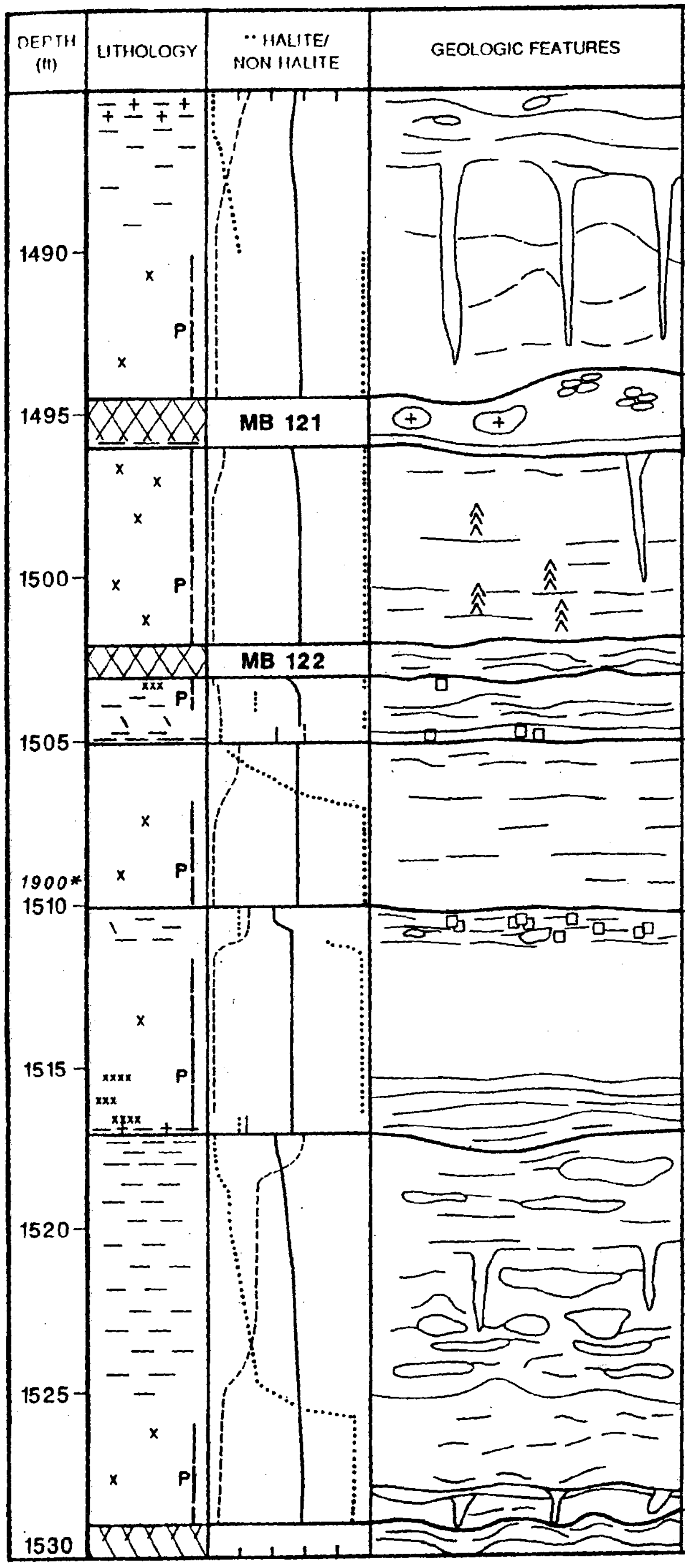
FIGURE 23



REMARKS
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w/tr to some P and C. Above 1487.5, H is interbedded w/arg H. H is m-c IV to l-IIIa-b; f IV in pods; l-IIa and m-c IV in upper 1'. Arg H to. Claystone near top shows thin lam to mod sic/laminae texture w/f-c l-IIIc. Upper arg zone shows dish-shaped strata. Some weeps.

Poly, w/zones of m-vc l-IIIb-c. H near base. Has 2-3" clay at base. Thin lam, wavy to contorted near base. Massive poly; displacive poly nodules developed w/i anhy. Incipient load structures w/clay near top. Possible langbeinite.

H, tr poly increasing upward. Poly occurs as thin lam to blebs and incipient boxwork. M-c IV, tr f H. Mod P, tr to mod upward C. MP more common upward. Pits filled prior to clay deposition.

Poly, lam. Thin shear zone 4" below top filled w/H.

H, tr poly w/some clay in basal zone and tr gray clay in thin middle zone; clay as thin lam and stringers in middle. Poly occurs as stringers, blebs, and irreg POS. F-m l-IIc near base. M-c IV; tr P, tr C. Ic at top. Disseminated poly at top.

H, tr poly, tr clay above 1507 as stringers and thin lam. H'c claystone w/f-m l-IIc at top. Poly occurs as thin lam, stringers and blebs; delineates thin beds w/sequence m-c (BG) IV to f-m poly'c H to thin poly residue. Tr to some P; tr to abund C upward. IIIb-c and f IV dominate below upper claystone.

H, tr poly and anhy, tr to some clay at base and top. Poly occurs as blebs, lag, thin lam and lam, delineates thin beds. Clay is lam and zones w/blebs, w/pods of m IV and some m-f l-IIIa-c, dominated by l-IIIc. F-c IV, tr P and C; beds w/sequences of poly, m-c IV, f-m IV w/tr poly. No pits.

Halite, in 3 parts:
part a: tr poly occurs as blebs, small blebs in f IV, thin lam to lam. Lamina of poly overlies pits. Poly lam locally coalesced into pit. F-c IV, f is more common near top. Tr P, some C. BG H near base. P decreases upward and C increases as MP become more abund.
part b: tr to some clay and poly. F IV w/tr poly in pods and zones bounded by clay. F IV zones surrounded by arg m IV, w/some m IIIa-c and l-c l-IIa-b. Clay occurs as lam and zones w/abund H and as isolated blebs. Mod'ly well developed DVT textures.
part c: arg H, tr to some clay, sulfate decreases upward. Zones and pods of m-c IV and IIIb. F-m l-IIa-b, incorporative. Claystone lam, incipient sic/lam texture. Parallel dissolution pits rare. H-filled (fibrous) fractures.

Anhy, gray (N6-N9), w/poly zones, slightly arg in lower 1-2". Subdivided into 6 zones:
a) clay, poly nodules w/displacive growth.
b) anhy, slightly arg. Thin lam and lam, parallel, cross-cutting near an algal(?) hemispheroidal feature. Incipient enterolithic textures.
c) black "sticky" clay, probably organic-rich, squeezed in and around displacive poly nodules;

*ELEV (ft. msl) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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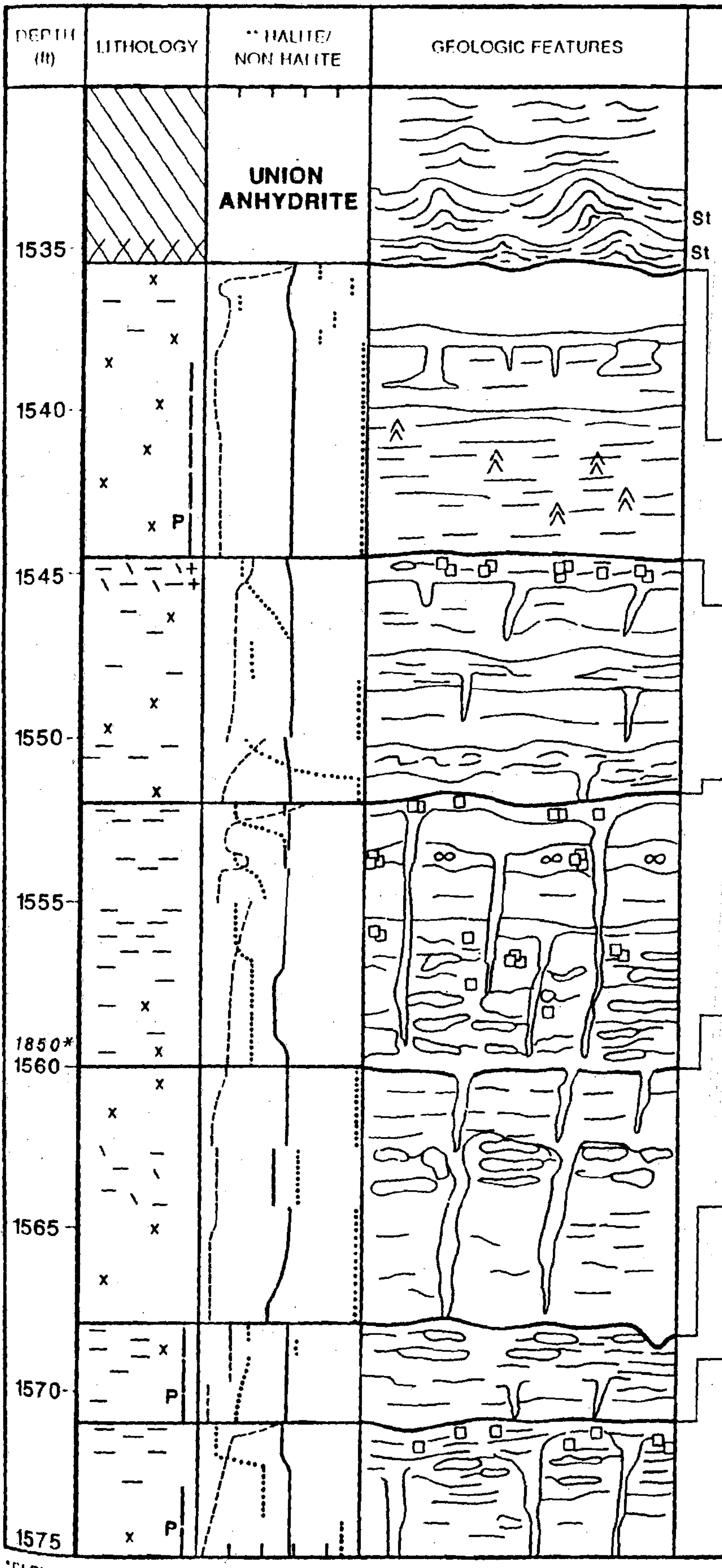
FIGURE 23



REMARKS
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squeezed into flame structures and subvertical fractures.

d) poly, lam, parallel to non-parallel, wavy to contorted, cross-cutting. Soft deformation. Lam hemispheroids are evenly spaced around the shaft. Slumping around these structures.

e) anhy. m lam, wavy to contorted, most semi-parallel, some cross-cutting relationships. Ripple forms w/o clear bedform. Slumping around small hemispheroids. Zones of probable clastic H.

f) poly, lam contorted to convolute, halitic. Desiccation cracks from top into unit 2' deep filled w/H.

Unit as a whole bears fluid. Weeps parallel strata and are v common around zones w/clastic H. Occurs also around fractures and at contacts.

H, poly'c, tr clay. Poly occurs as thin lam to irreg blebs. Thin beds w/sequence: m-c IV w/abund P and BG, f IV, poly lam or poly-rich zone. F-m IV, tr to mod P, tr C. Shallow pits; MP under pits have tr clay. Dissolution surface in upper part w/arg clay. Less P and more C at top w/no bedding. Poly at upper contact.

H, poly'c w/arg interbeds. Poly occurs as thin lam and disseminated blebs delineating thin to m beds in poly'c zones. Clay occurs as lam to zones w/f-c I-IIIa, c, may delineate thin to m beds. Arg zone at top contains pods and zones of m-f IV (DVT textures). F-c IV, mainly f-m, w/zones f H; tr P, tr to some C.

H, tr poly to tr to some clay in sequences w/arg H interbeds. H is f-vc IV w/m-c (tr P) dominant near base poly'c parts, more f in upper parts. F-m I-IIIb-c w/tr Ia in arg zones. Lower .5' arg lam. Next 2' is poly'c f IV w/abund DVT textures. DVT zone overlain by m IV zone w/thin lam of clay, tr poly interbedded on 1' scale w/halitic claystone w/I-IIIb-c. Pods of f H. Tr P, abund C. Claystone, thin lam w/some sic/laminae textures. Upper 2' contains thicker interbeds of similar claystone.

H, tr poly, tr clay in thin lam. Poly is disseminated in f IV, blebs along dissolution surfaces, in pits as solution lag. F-vc IV, mainly near base. Lower part shows MP and pits filled w/m-c. Middle shows mod to advanced DVT textures and e/s surfaces w/abund f H. Upper zone shows thin to m beds w/poly blebs delineating strata, m IV w/tr f dominates. Tr- mod C, some P, BG.

H, tr clay as lam, tr poly as blebs in f IV along dissolution surfaces. Thin to m beds delineated by clay lam. H stratified below upper 1'. F-m IV w/tr c as C, tr P near base, decreases upward. C locally abund. F H caps strata, more abund upward, in zones and pods in upper 1'.

H, tr poly, tr clay above 15745 increases upward. Poly is disseminated in f IV, blebs elsewhere. Clay is disseminated to lam and zones upward. F-c, mainly m, IV, tr to some P (tr vel) and C to 1573; pods to layers f IV to 1572; bedded m-c IV, tr P and C, w/f-c I-IIIc and tr Ia to top. Some c C in MP and pits, C increases upward. DVT textures near middle. Thin lam clay at top.

*ELEV (ft m s l)   **SEE EXPLANATION FOR SCALES

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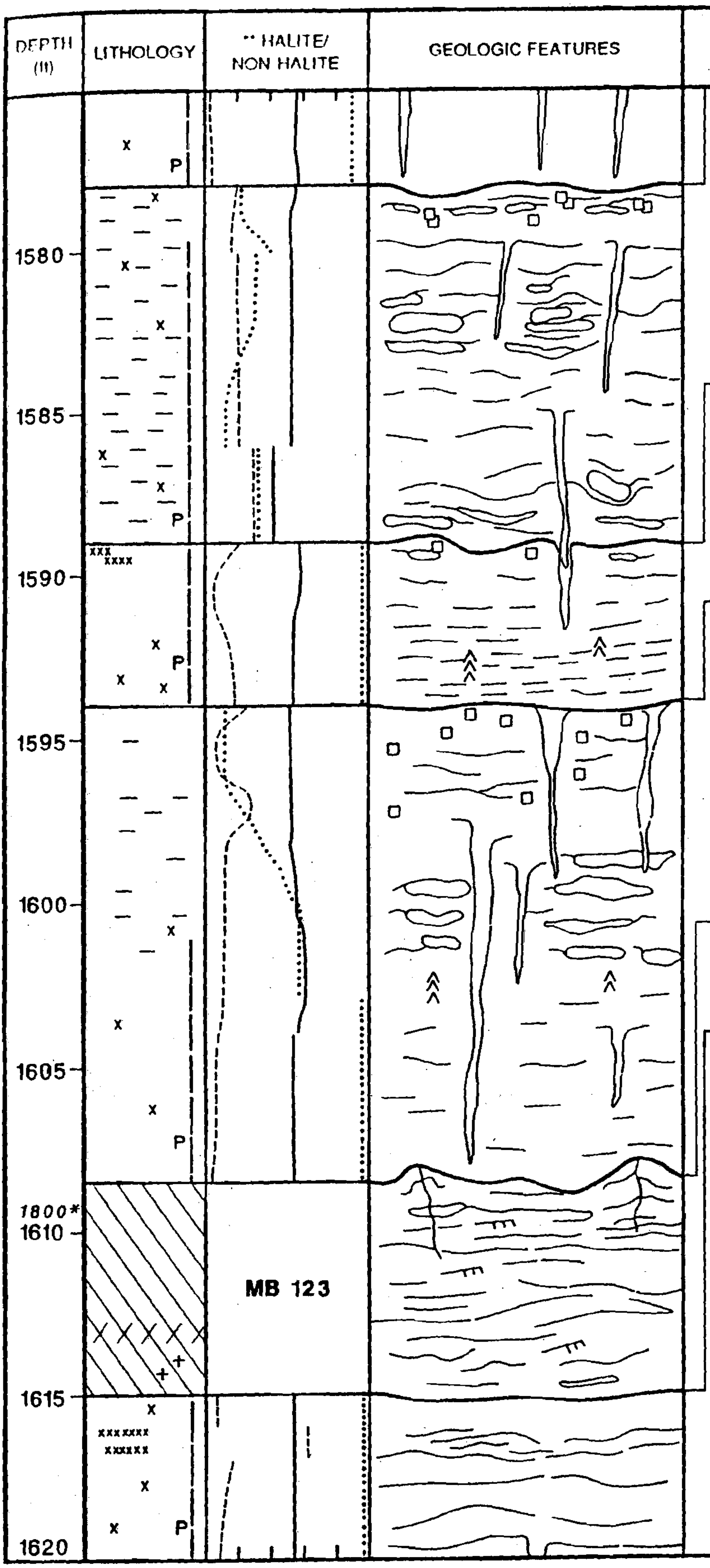
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H, tr to some clay and poly, incipient to mod/advanced DVT textures. Poly is disseminated in f H, blebs concentrated along e/s surface w/lag and in pits as translocated material. Clay occurs as lam to zones. F-m IV, w/some c C in pits and MP. Tr P, tr to mod C. F H is abund near base and middle of unit, w/i zones and pods w/i lower middle part of unit, and caps e/s surfaces near top. Lower middle dominated by m w/some c as C in abund MP and pits. Upper part shows stratified m H capped by f H or clay lam w/I-IIIc and tr Ia. F H fills pits - efflorescent H that survived. Pits show many episodes of reactivation.

H, tr poly and anhy. Poly occurs as thin lam to blebs showing some displacive H margins. Lower part mainly poly'c. Upper part contains some poly zones, disseminated blebs, and blebs concentrated w/i pits as translocated material. Poly delineates thin to m beds. M IV, w/some P (tr vel), some c; some f H near top. Vertical C and P BG. Mod to abund C in pits and MP. I-IIIc, tr Ia in poly near top. Pits reactivated during deposition of overlying unit.

H, in 3 parts;
a) poly'c m-c IV w/f H more common near top. Multiple episodes of DVT textures. Tr P (rare vel); tr C, abund in pits and MP. Poly occurs as thin lam and blebs translocated into pits. F H at top.
b) DVT texture zone - H, tr clay and sulfate. Clay as lam to zones and blebs, w/m-c IV, tr P, abund C in lower part. F-c IV H in zones and pods; poly occurs as blebs. Claystone w/I-IIIa-b, sic textures. 1' zones of clear IV w/abund C. Claystone in topographic lows.
c)H, some to tr clay. No DVT textures at base, minor textures at top. M-c IV w/f and clay lam; f Ic common, Ia rare in arg zone.

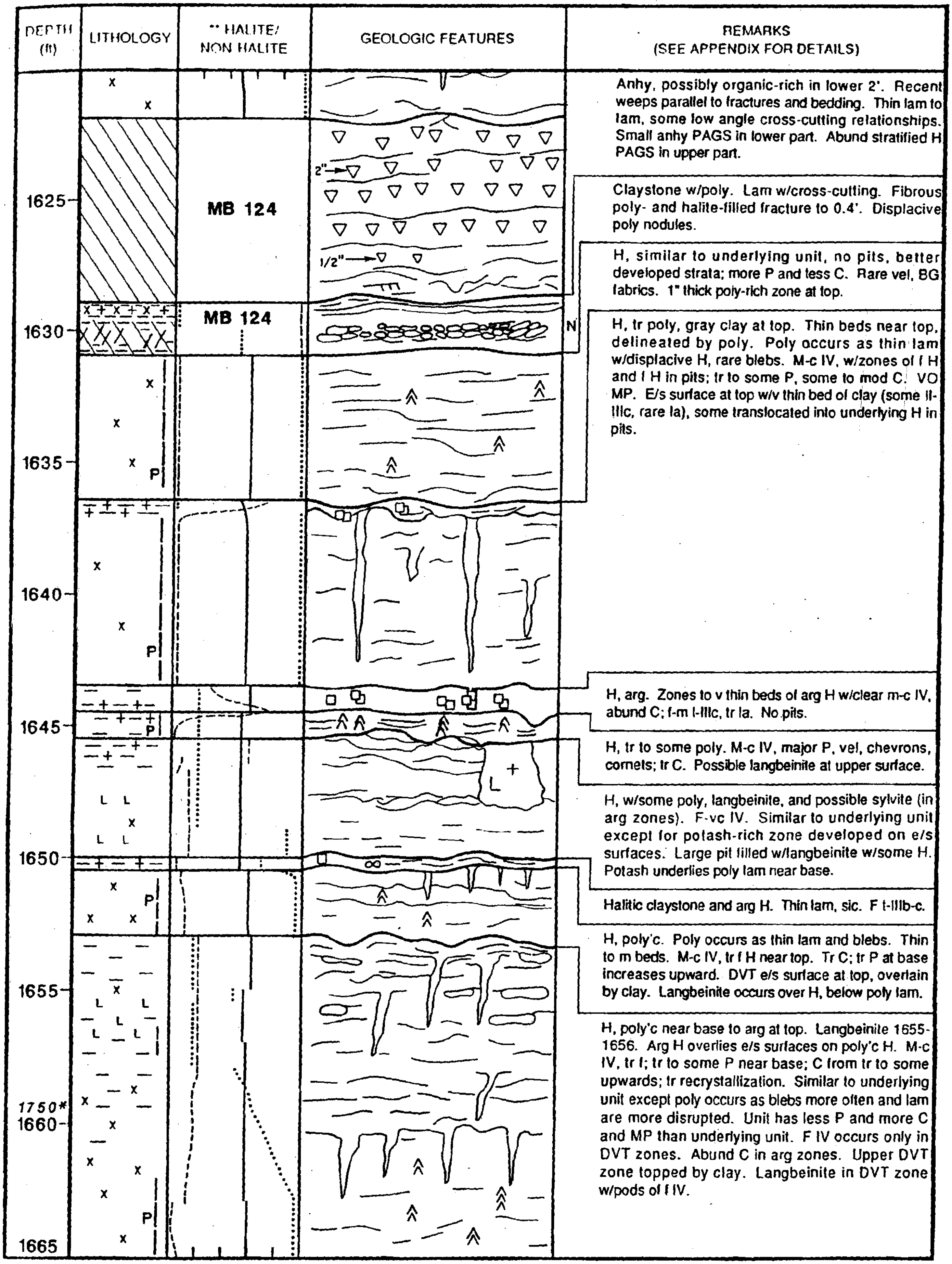
Anhy, w/poly, thin lam to lam, some cross-cutting and cross-lam. Several zones w/clastic H textures and cross-lam. Bedding disturbed. Teepee structures at upper contact.

H, tr anhy at base, tr anhy and poly upward; some sulfate 1616-1617. Lam; poly disseminated blebs. Sulfate delineates thin to m beds. M-c IV, w/vel H; some to mod P, tr to some C; BG planed off by sulfate lam, stratified f H.

*ELEV(ft. m s l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 20 OF 32

FIGURE 23



Anhy, possibly organic-rich in lower 2'. Recent weeps parallel to fractures and bedding. Thin lam to lam, some low angle cross-cutting relationships. Small anhy PAGS in lower part. Abund stratified H PAGS in upper part.

Claystone w/poly. Lam w/cross-cutting. Fibrous poly- and halite-filled fracture to 0.4'. Displacive poly nodules.

H, similar to underlying unit, no pits, better developed strata; more P and less C. Rare vel, BG fabrics. 1" thick poly-rich zone at top.

H, tr poly, gray clay at top. Thin beds near top, delineated by poly. Poly occurs as thin lam w/displacive H, rare blebs. M-c IV, w/zones of f H and f H in pits; tr to some P, some to mod C. VO MP. E/s surface at top w/v thin bed of clay (some II-IIIc, rare Ia), some translocated into underlying H in pits.

H, arg. Zones to v thin beds of arg H w/clear m-c IV, abund C; f-m I-IIIc, tr Ia. No pits.

H, tr to some poly. M-c IV, major P, vel, chevrons, cornets; tr C. Possible langbeinite at upper surface.

H, w/some poly, langbeinite, and possible sylvite (in arg zones). F-vc IV. Similar to underlying unit except for potash-rich zone developed on e/s surfaces. Large pit filled w/langbeinite w/some H. Potash underlies poly lam near base.

Halitic claystone and arg H. Thin lam, sic. F I-IIIb-c.

H, poly'c. Poly occurs as thin lam and blebs. Thin to m beds. M-c IV, tr f H near top. Tr C; tr P at base increases upward. DVT e/s surface at top, overlain by clay. Langbeinite occurs over H, below poly lam.

H, poly'c near base to arg at top. Langbeinite 1655-1656. Arg H overlies e/s surfaces on poly'c H. M-c IV, tr f; tr to some P near base; C from tr to some upwards; tr recrystallization. Similar to underlying unit except poly occurs as blebs more often and lam are more disrupted. Unit has less P and more C and MP than underlying unit. F IV occurs only in DVT zones. Abund C in arg zones. Upper DVT zone topped by clay. Langbeinite in DVT zone w/pods of f IV.

*ELEV (ft. m.s.l.)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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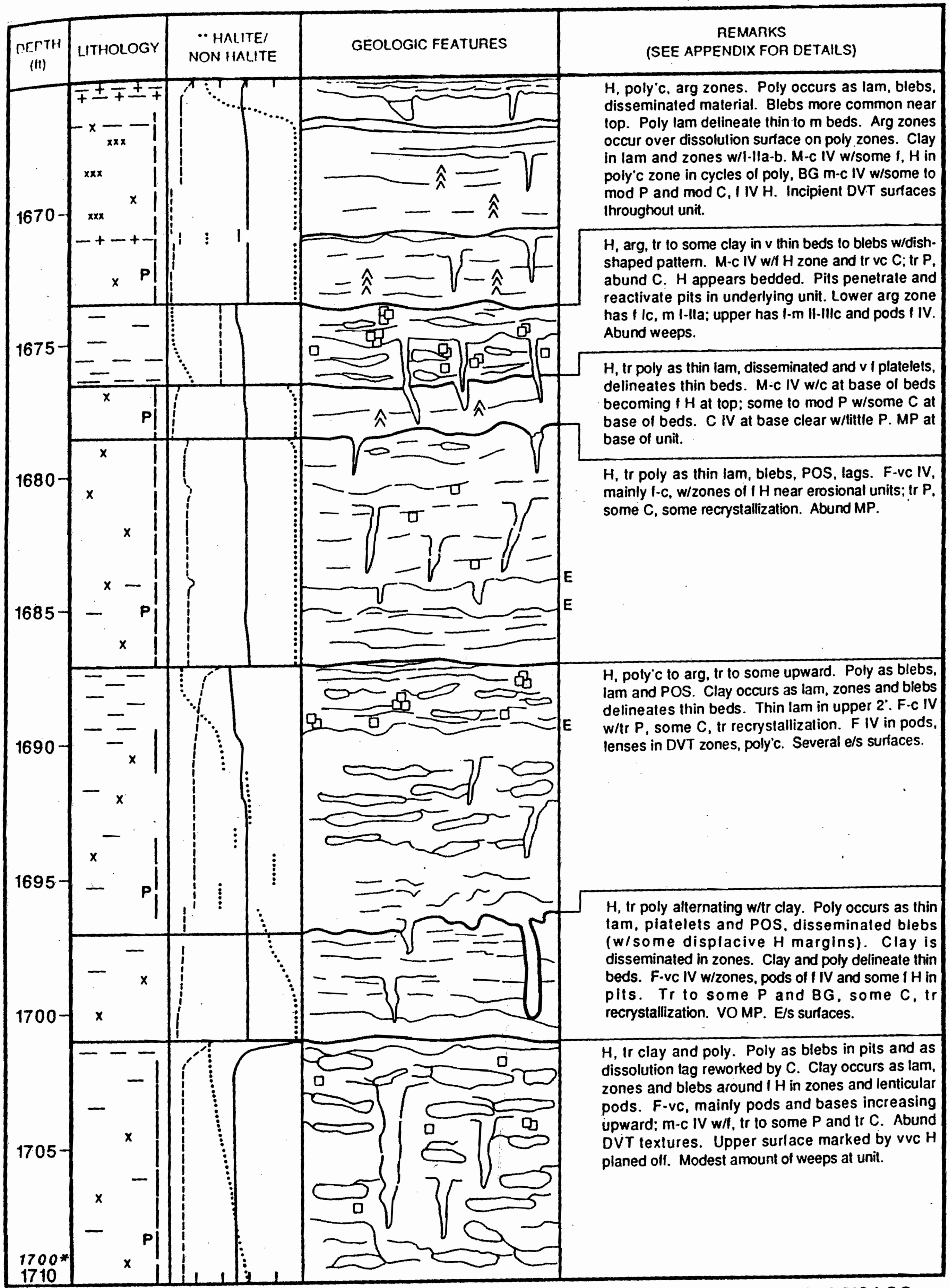
FIGURE 23



H, poly'c, arg zones. Poly occurs as lam, blebs, disseminated material. Blebs more common near top. Poly lam delineate thin to m beds. Arg zones occur over dissolution surface on poly zones. Clay in lam and zones w/I-IIa-b. M-c IV w/some f, H in poly'c zone in cycles of poly, BG m-c IV w/some to mod P and mod C, f IV H. Incipient DVT surfaces throughout unit.

H, arg, tr to some clay in v thin beds to blebs w/dish-shaped pattern. M-c IV w/f H zone and tr vc C; tr P, abund C. H appears bedded. Pits penetrate and reactivate pits in underlying unit. Lower arg zone has f Ic, m I-IIa; upper has f-m II-IIIc and pods f IV. Abund weeps.

H, tr poly as thin lam, disseminated and v f platelets, delineates thin beds. M-c IV w/c at base of beds becoming f H at top; some to mod P w/some C at base of beds. C IV at base clear w/little P. MP at base of unit.

H, tr poly as thin lam, blebs, POS, lags. F-vc IV, mainly f-c, w/zones of f H near erosional units; tr P, some C, some recrystallization. Abund MP.

H, poly'c to arg, tr to some upward. Poly as blebs, lam and POS. Clay occurs as lam, zones and blebs delineates thin beds. Thin lam in upper 2'. F-c IV w/tr P, some C, tr recrystallization. F IV in pods, lenses in DVT zones, poly'c. Several e/s surfaces.

H, tr poly alternating w/tr clay. Poly occurs as thin lam, platelets and POS, disseminated blebs (w/some displacive H margins). Clay is disseminated in zones. Clay and poly delineate thin beds. F-vc IV w/zones, pods of f IV and some f H in pits. Tr to some P and BG, some C, tr recrystallization. VO MP. E/s surfaces.

H, tr clay and poly. Poly as blebs in pits and as dissolution lag reworked by C. Clay occurs as lam, zones and blebs around f H in zones and lenticular pods. F-vc, mainly pods and bases increasing upward; m-c IV w/f, tr to some P and tr C. Abund DVT textures. Upper surface marked by vvc H planed off. Modest amount of weeps at unit.

*ELEV (ft. m.s.l.)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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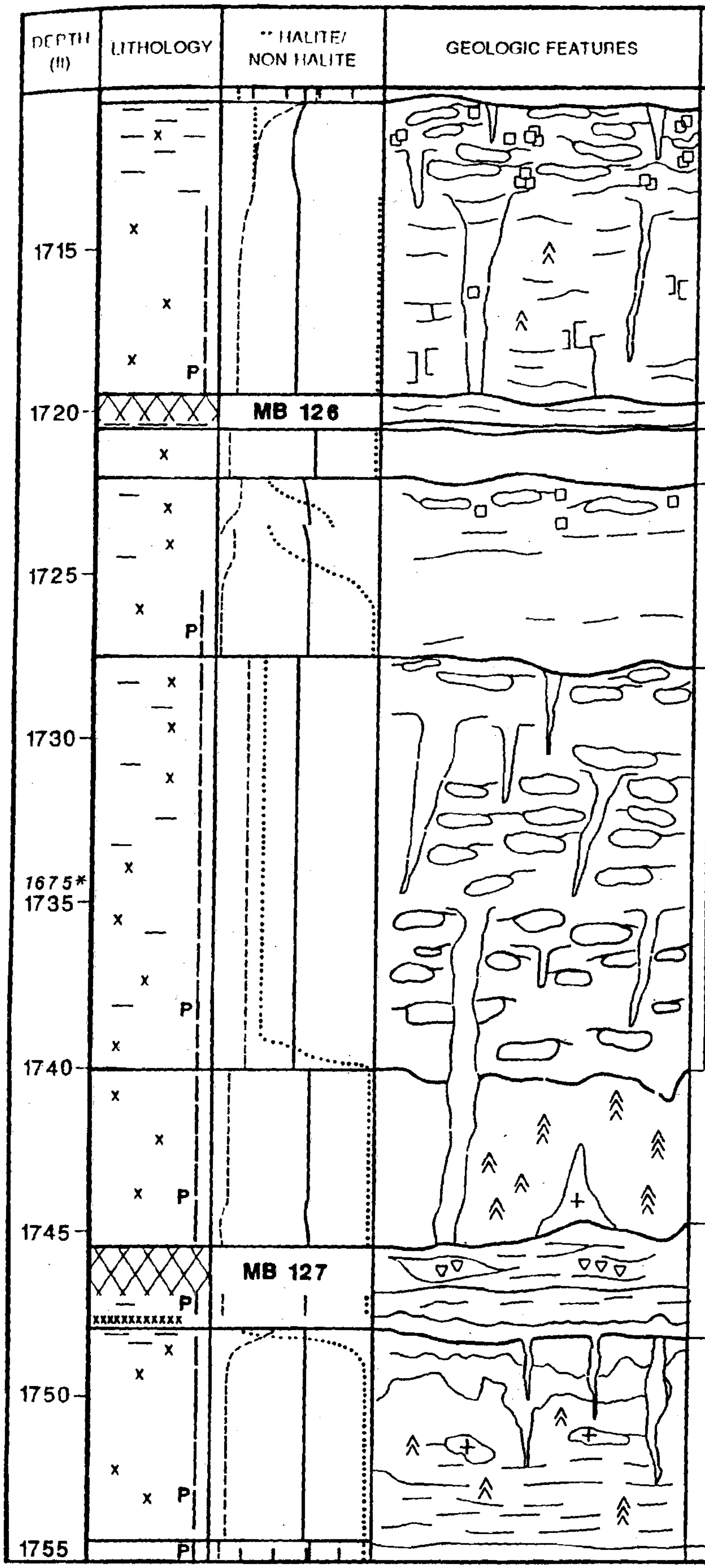
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H; poly'c lower part grading into arg reworked DVT upper part. Lower part: H, tr poly as thin lam, blebs, 1" zones w/abund displacive H, and zones of blebs w/displacive H in pits. Poly delineates v thin beds. Poly in pits and strata shows boxwork fabric. M-c IV w/f near top; tr to some P (vel) w/abund c. Upper part: more arg upward as lam and zones containing f-m I-IIIa-c. H occurs as arg zones of m-c IV w/displacive margins, tr P, abund C, and dish-shaped pods and zones of f-m H. DVT textures.

Poly, lam to thin lam; lower .2' clay.

H, tr poly as platelets and blebs; m-c IV, tr P and C. Upper surface planed off by dissolution.

H, tr poly and clay. Two sequences of tr poly to tr clay, increasing up. Poly occurs as blebs to lam, tr platelets near top. Clay as lam and blebs. M-c IV, zones and pods of f-m H in upper 1'; tr P, decreases upward. Abund C near base in MP.

H, tr clay and poly; clay occurs as lam, blebs and zones w/irreg boundaries w/H associated w/m IV. Poly is disseminated, as tr amounts in f IV, and as blebs in m IV. H occurs as f-c IV; tr P, C in arg zones around zones and pods of f IV. Pits from 1-10' originating throughout unit and penetrating underlying unit.

H, tr poly; poly occurs as thin lam and blebs (some w/displacive H margins), delineates v thin beds. M-c IV w/vc in MP at base. Abund P BG at base, decreasing upward. Zones of f H. Pits (about 1') from overlying unit.

Poly unit in 3 parts. .2' poly at base, lam, microcrystalline. 8" H, w/thin lam of poly, blebs m-vc IV, tr P and some C, displacive boundaries w/poly. Upper poly, lam to thin lam, slightly irreg to convolute, cross-cutting; stratified poly PAGS; possible polygonal cracks spaced about 3'; possible tepees.

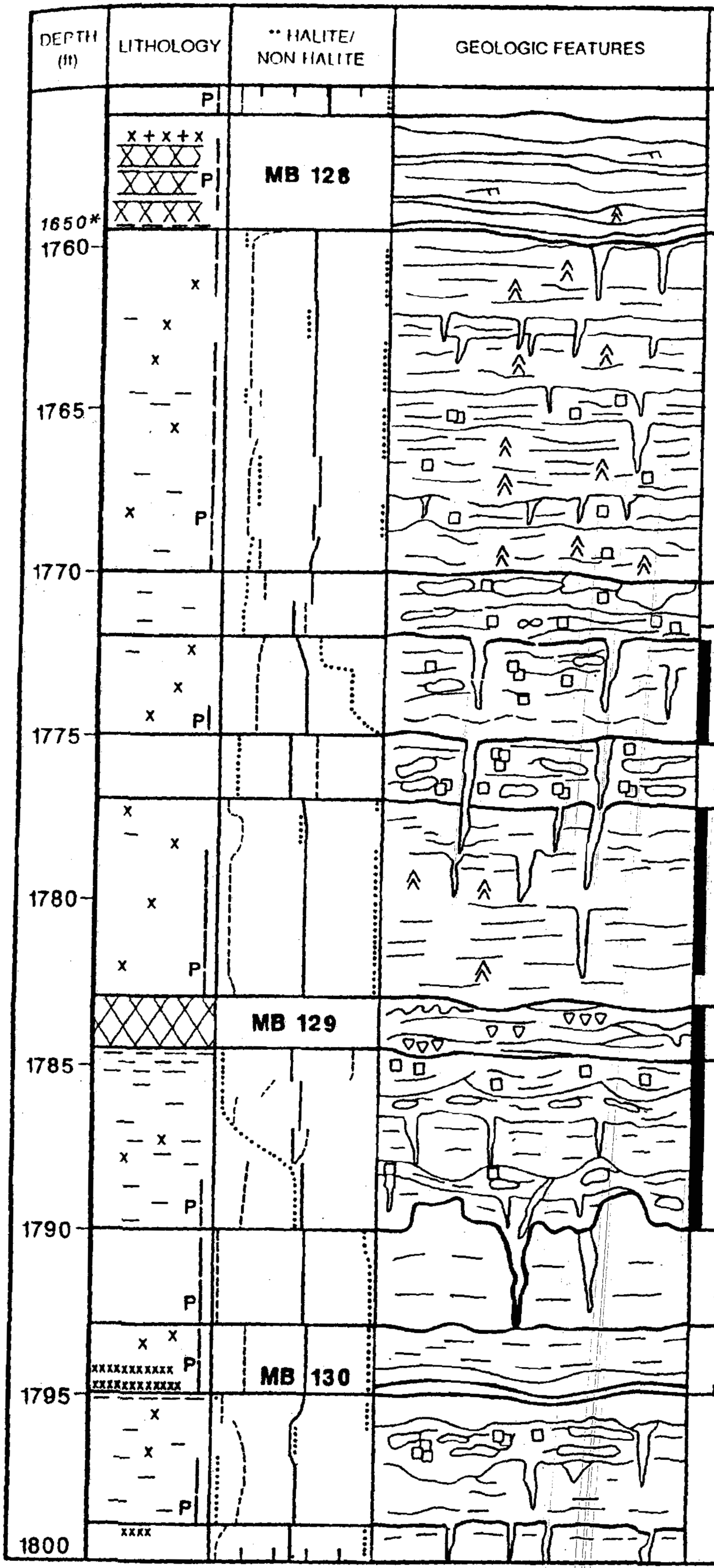
H, tr poly to 1749, tr to some gray clay in upper 1'. Poly occurs as thin lam, isolated blebs w/some displacive margins, POS and platelets, and crystal drapes. Mainly m-c IV w/vc in MP, f H in middle of unit w/disrupted poly textures. Some to mod BG, vel P at base, decreasing upward; tr C at base increasing upward. MP increase upward from middle of unit. Clay at top as thin lam.

H, tr poly and anhy. F-c IV, mainly m, some P, some C, v thin beds. Vertically aligned clear zones present, some BG textures; upper contact well defined by poly.

*ELEV (ft m.s.l.)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 23 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Interbedded poly and H. Lower 1-2" consists of claystone. Poly shows pillows, load structures into clay while soft. Poly occurs as v thin beds to thin lam, wavy to planar w/ripples to 1/2" high, H crystal drapes. F-c vel IV, w/abund P (vel, chevrons), some C.

Interbedded poly'c H and arg H. Poly'c H: eq to vel IV, f-c, mostly m, w/f H at tops of v thin beds; tr to mod P (BG, vel), tr to some C. Poly occurs as thin lam, blebs (w/displacive H margins), disseminated platelets and POS, H drapes. Poly delineates strata, well defined in upper units. Cycles of BG, f H, poly. Arg H: f-vc, mostly m IV, tr to some P (BG, vel), abund C. Clay occurs as thin lam and blebs w/tr to some displacive H. Some f H in upper units. Weeps in lowermost part.

Divided into lower and upper arg H. H, some clay in lower part; lam, tr sic texture. H occurs in pods and zones of m-c IV, w/poly POS and platelets and as f-m I-IIa-c. Fibrous H-filled fractures, to 1/4" thick. H, tr clay in upper part: lam and blebs. M-c IV; I-IIa-b. Irreg zones of H similar to lower unit. Weeps in pits.

H, tr poly to tr poly and clay. Clay occurs as lam and blebs. Clay lam delineate H strata. Poly occurs as abund POS textures, thin lam, and local blebs w/displacive H. F-vc, mainly m-c IV w/more f-m H near upper contact, some triple junctions, some C. Ia-c, II-IIIa in clay layers. Mod weeps in unit.

Arg H and H'c claystone, poly'c. Thin lower-lam, locally cross-cutting, local sic. H: f-m I-Ii-III a-c and in-c IV 2 tr P, in pods and stratified zones. Poly and anhyy in H pods as platelets, POS, blebs 4' pits at upper surface show downward translocation of clays, abundant weeps from pits.

H, poly'c, 1' arg zone near top. Poly occurs as thin lam, blebs w/displacive H margins, platelets (some POS texture). F-vc, mainly m-c IV, w/c-vc in pits, MP, and C; f H is abund in zones in upper part of the unit. Tr P, abund C. Arg zone has v thin beds in cycles: 1) clear c H w/clay lam, blebs; 2) m H w/abund P, some BG; 3) f H. F IV zones at top unit. Mod weeps.

Poly, H'c; lam to thin lam, undulatory to cross-cutting. Stratified poly PAGS; H PAGS. Abund weeps.

H, w/claystone interbeds. IV f-c, abund C, tr P. Lam claystone w/I-IIa-b, f-m. Abund dessication cracks and pits.

H, tr poly as lam and blebs w/some displacive H margins. E/s surface at top. Pits filled w/clear C. M-c IV w/vc C, possible MP, tr f H; tr to some P, some C.

H, poly'c. Poly as v thin beds at base, delineates v thin beds in H. Lam clay at base, blebs w/displacive H. Poly zones w/I-IIa-c. M-c IV, w/tr vc; some triple junctions, some P and C (I I PAGS in lower poly).

H, in 3 parts: a, b are arg; b, c poly'c. Clay lam. Poly disseminated, lam and blebs w/displacive H. Part a: m-c IV, tr to some P and abund C, Ia-c, minor f H in zones near top. Clay lag at top. Part b: zones, pods of poly'c f H w/dissolution margins, bounded by clay lam. Poly and clay lag at top. Part c: v thin beds delineated by poly lam. Top overlain by gray clay.

*ELEV (ft. m.s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
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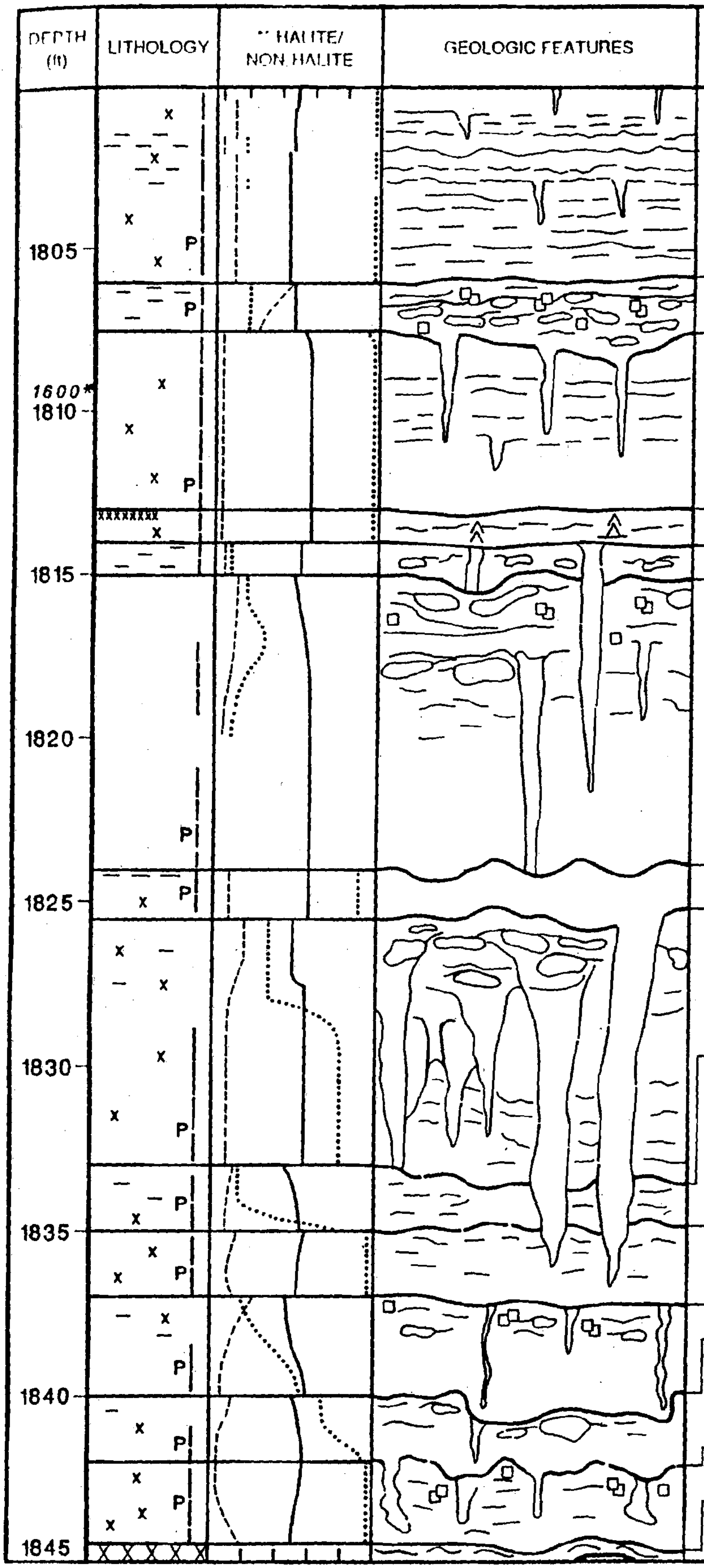
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H, poly'c, w/zones of clear H w/tr clay lam. M IV, w/some c-vc C, f H zones near erosional surfaces. Lam, blebs and zones of disseminated poly delineate v thin beds. Poly lag on some e/s surfaces. Tr clay in two zones. Poly lag at top e/s surface is overlain by clay lam of overlying unit. Tr P, some C, some triple junctions.

H, tr to some clay and poly upward. M-c IV, tr P, mod recrystallization; pods f IV; f-m I-IIc. Clay occurs as lam, blebs, is matrix. Poly is disseminated and platelets in POS texture.

H, tr poly. M-vc IV, w/zones and pods of f IV in poly'c zones and abund in upper 1'; tr to some P, some C. Poly in lam to disseminate blebs w/displacive H to discrete zones. Upper surface is capped by clay lam which thickens in lows. Poly lag near upper contact.

H, tr poly as zones, lam, blebs and drapes on BG H. M-vc IV, f H under each poly'c zone and at top; tr P; some C; some triple junctions.

H, tr clay and poly. Poly'c zone undulates over dissolution surface. Tr clay lam, solution lag. M-c IV w/f H in pods, zones. Tr P.

H, tr clay and poly above 1819. Clay increases upward. F-vc IV, mostly m-c, w/abund triple junctions, tr-some P. Tr I-IIa-c w/i arg zones. Pods and zones of f IV w/tr poly in upper 2'. Clay is disseminated to thin lam.

H, tr poly, tr clay at top; both as thin lam and disseminated. M-c IV; some P, and recrystallized. Tr insolubles at upper surface.

H, tr poly, tr to some clay upward as infiltrated material. Poly occurs as thin blebs and thin lam delineating v thin beds. M-c IV; tr to some P, some C. Pits filled w/m-vc IV w/P. F H pods, zones and claystone in upper part unit, some clay w/i f H. Clay lags at top. Multiple generations of pits overlap, unit shows v complex and advanced dissolution history.

H, tr clay lam and zones. M-c IV w/v c H in pits; f H pods and zones, f I-IIc near top. Tr P, BG near base; abund C. Large pit includes infiltrated poly.

H, tr poly as blebs to thin lam, displacive H margins. Some P (BG, vel); M-c IV. E/s surface at top is marked by poly.

H, tr clay increasing up, tr poly at top. M-c IV, w/irreg pods and zones of f H near top. Clay occurs as lam, tr I-IIa near top. Poly infiltrated 3' into pit. Upper e/s contact. Trace to some P.

H, tr clay and poly in upper part. M-c IV, vc C, w/f-c H near top. Clay lam around f H zones. Poly displaced downward in pits. Clay lag at upper surface.

H, tr poly, decreases upward. Poly lam delineate thin H beds. M-c IV, vc C, tr vel, tr P, some C.

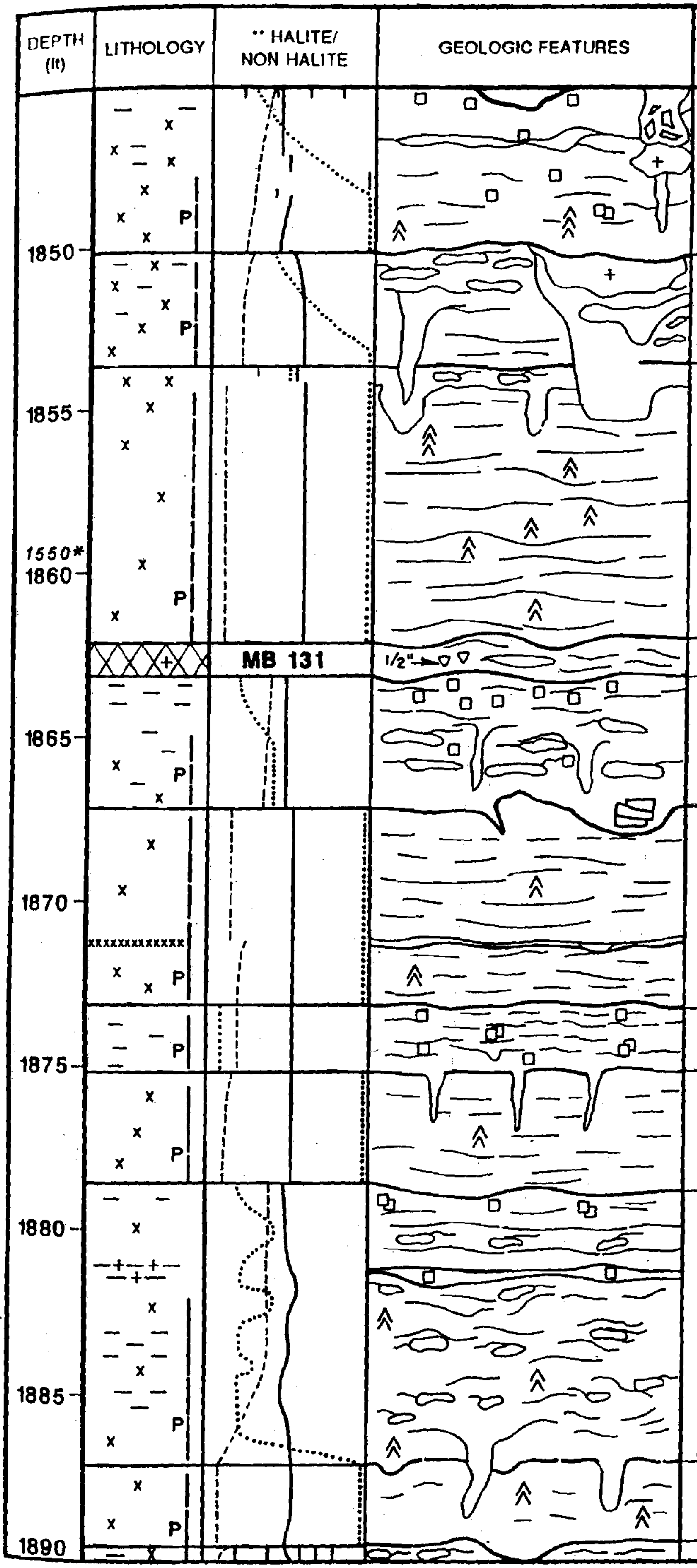
Poly, BG and clastic(?) H in lows, lam, slumped, contorted; sic texture. Slumped while soft.

*ELEV(ft m.s.l.)

**SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 25 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

H, tr poly to tr to some clay upward. Poly lam, outlines displacive H, thicker in paleolows. Large MP of clear vc H. M-c IV, some vc; I-IIa; tr P (vel), abund C. Pods and zones of f H in upper part bounded by dissolution surfaces. Clay occurs as irreg lam and deposits in lows. Overlying unit collapsed into void.

H, tr poly, tr clay; beds delineated by poly lam. Poly blebs near base and top. Arg at top, increases upward. Claystone occurs in zones, lam, infiltrated material along pipes and pits, shows sic textures. Lam to v thin beds surround dish-shaped pods and zones of poly'c H. Several episodes of pits, some cross-cutting. F-c IV, w/ultra c in pit; some P and C; Ia, Ic.

H, tr poly, tr poly and clay in upper 6". Poly lam delineate strata; lam in upper 3' show displacive margins w/H. M-c IV, abund vel, abund BG textures, many planed off by sulfate lam; some recrystallized zones. Abund P fluid inclusions; some c-vc C; internal sulfate parallel to H growth planes. Pods and zones of f-c poly'c H in upper 1'.

Poly, halitic; lam; clastic H w/i sulfate, also H PAGS. M-c IV, may include BG H.

H tr to some clay and poly. M-c IV, tr P, minor C; zones of f Ia and f IV in pods, pods w/Ia and Ic in upper 1'; some IIa. Clay, gray and brown, increases upward. Abund pods and lam to v thin beds delineated by thin poly lam. Poly platelets and POS. Fractures filled w/fibrous H near upper contact. Abund weeps.

H, tr poly. M-c IV; tr vel, some P and C. Beds delineated by poly lam; poly blebs and POS.

H, tr clay and anhy. M-c IV, tr P, abund C; abund I-IIa-b in muddy areas. Thin lam to thin beds. Sulfate occurs as platelets in POS texture.

H, tr poly; poly delineates lam to v thin beds; poly occurs as lam to micro lam near top. M-c IV, some vel, some to mod P textures; C increases upward. Poly slightly concentrated upward w/more displacive boundaries. H w/i pits is m-c IV w/tr infiltrated clay.

H, tr to some clay w/tr sulfate. M-c IV w/abund f IV in zones and pods, Ia-c in arg zones and lam, some IIIa-c; abund P (BG H) and C. Claystone lam to pods in lower part. Upper part lam to v thin beds. Irreg lam mark dissolution boundaries. Poly as blebs and lam infiltrated into dissolution troughs.

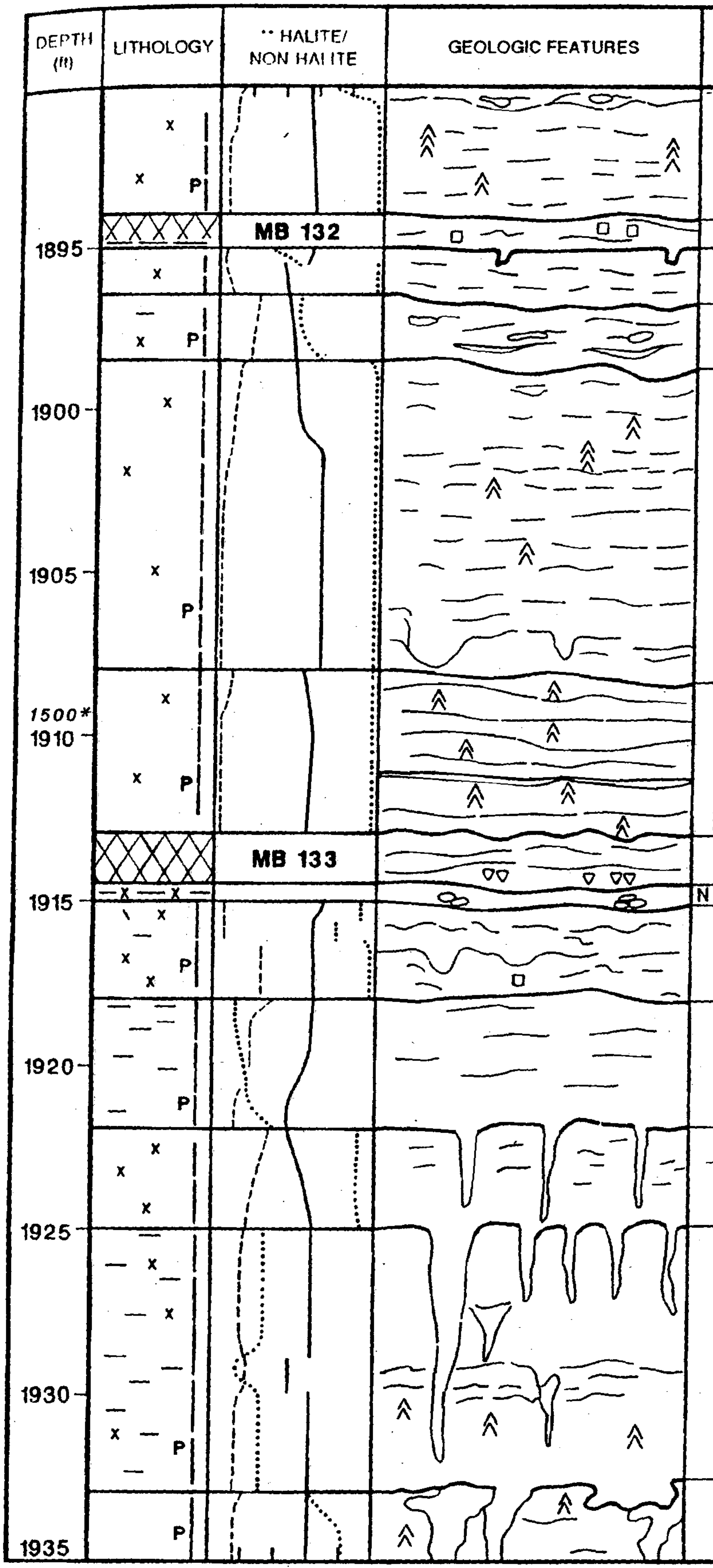
H, tr poly. M-c IV, some P (BG, vel, chevrons); abund C. Poorly stratified.

H, tr poly, tr poly and clay near top. M-c IV, some vc near top, some P (BG, vel, chevrons) and C. Rare lam, some blebs of poly. Clay distributed in upper part w/irreg pods and zones of f IV.

*ELEV (ft m.s.l) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 26 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Poly; some lam; clastic sand-size H, la-c H. Clay, poly at base. Brine inflow after washing.

H, tr poly in lower part, tr clay, and poly in upper. Lower part: f-c IV. Lam w/abund blebs of poly, some lb. Tr-some P; poly marks upper surface. Upper part: M-c IV, tr P. Tr poly blebs; arg top.

H; tr anhy and poly w/clay to tr clay upward. Interlaminated and v thinly bedded w/mudstone. F-c IV and IIIb; some P; some la. F H in pods and zones near top. Clay occurs in zones deposited in lows, some rotation. Tr poly disseminated in f H zones and some lam and blebs. Arg zones are dish-shaped.

H, tr poly. M-vc IV at base to f-c IV major P (BG, vel, cumulates) at base, decreasing upward, C present. Beds at base to lam at top delineated by poly lam. Lam to blebs upward.

H, tr poly. M-c IV, equant, some vel; major P (BG). v thin to thin beds, each topped by lam of poly w/lower boundary showing displacive H margins. Unit lacks intercrystalline poly. Sulfate lam at upper contact.

Poly, H in upper part as sand-size, clastic grains. Poly pseudomorphs after anhy. Lam to v thin beds in upper part. Possible ripups in lower part. Basal anhy w/poly PAGS. Possible algal lam in lower 1".

Claystone, v poly'c, as nodules nodules. Poly lam at top.

H, tr sulfate, tr clay and sulfate in zone. Abund thin lam and blebs of poly, displacive margins w/H. M-c IV, c-vc upper part, some to mod P (BG), some C. Clay as thin lam to blebs. Poly as stringers and blebs in upper .5'. Clay at top.

H, tr to some clay, tr poly. No dissolution pits or pipes; v thin to thin beds. M-c IV, f-vc upward; some displacive/inclusive H w/clay; some P, increases upward. Clay stringers, lam and blebs.

H, tr to some poly as stringers and blebs w/displacive H margins. No apparent strata. M-c IV, mod P decreasing upward, some inclusive H at top.

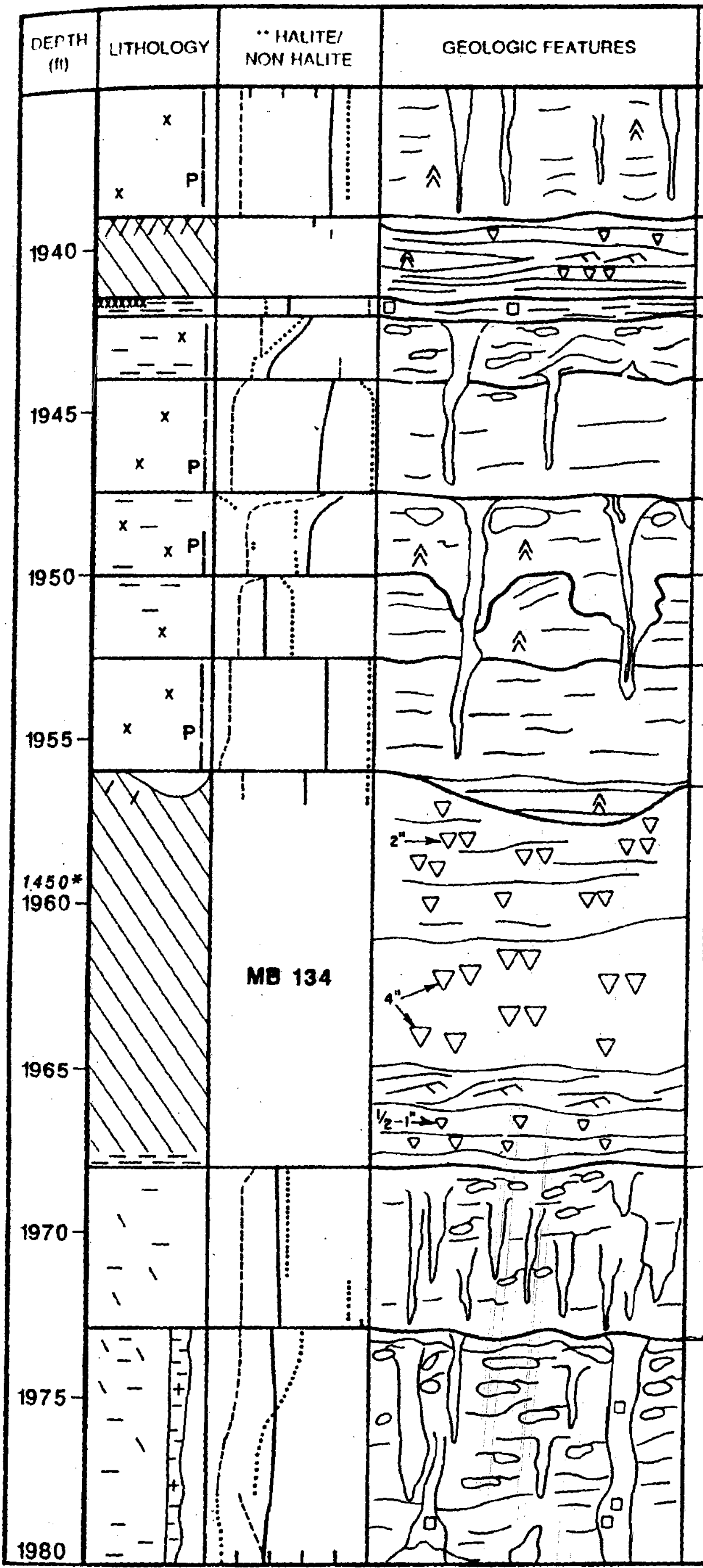
H, tr clay and poly. M-vc IV; w/f-c, IV in more arg zones, displacive and incorporative boundaries w/clay. Irreg arg lam near middle of unit. Some to mod P in lower part, some P in upper.

H, tr poly. M-c IV; mod to major P (tr vel), some C; displacive boundaries between poly and H. Some poly lam and blebs; v thin to thin beds. Pits and pipes filled w/c IV w/no P, some displacive H.

*ELEV (ft. m.s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 27 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Anhy; gray (N8-7); sequence from base: lam and cross-cutting lam; lam and H PAGS; H zone w/ripples; lam and swallowtail zone; upper rippled and structureless poly.

Claystone, gray; thin lam at top and bottom, c-vc Ib-c and IIIb. Overlain by thin poly.

H, v arg at base, tr clay and poly in upper part. F-m IV at base to m-c IV at top, pods of f IV w/MP; some vel. Lam to v thin beds of mudstone w/f I-IIa, concentrated in lows. Poly blebs and lam w/displacive margins w/H. Clay at upper contact.

H, tr poly. C IV, few vel, mod to major P, clear C; poly stringers, thin lam. Poly lam show some displacive margins w/H. Thin to v thin beds. Pipes filled w/vc IV, no P.

H, tr poly and clay to trace to some clay w/decreasing poly upward. M-c IV to vel c IV to pods of f IV in upper 6". Some P and C; displacive H. Thin to v thin beds. Poly lam. Pits and pipes filled w/c IV H w/tr clay.

H, tr poly to tr clay upward. Mainly f IV, c-vc in MP in original strata. V thin to thin beds, disrupted by syndepositional dissolution troughs, pits, and pipes. Some slumped strata. Dissolution voids filled w/c to v c H w/few P. Original strata: IV, tr poly lam and blebs; cloudy H, MP filled w/clear IV C w/some planar boundaries (grew in open pore). Clay on dissolution surfaces and w/i pipes and pits.

H, tr poly. Thin lam of poly delineate beds. M-vc IV, vel to equant w/i each bed; tr P (BG H at base), possible C. Poly lam show some displacive H. Upper contact marked by clay.

Anhy; H PAGS, clastic H in ripples ar cross lam. Thin lam to lam of anhy. Upper contact has 1' deep trough on south side of shaft w/beds of H w/anhy interlaminated w/c sand-size H. Anhy-rich lam show some I-IIIa. Some poly lam occur only w/i the trough. H is confined to the trough.

H, tr to some clay, tr anhy and poly. Clay and sulfate occur as blebs w/displacive margins to H linings, stringers, and lam. Claystone zones in pits. Pits and MP abund, abund C, decreases upward. C, blebs and H linings are most common in pits. M-c IV, vc in lower part, some f H in upper zones; some P. M-vc I-IIIa common in pits.

H, tr to some anhy, tr poly, tr to some clay; claystone in pits, pipes and caves. Beds in lower part delineated by anhy lam. H in lower part is f-c to f-m IV w/some C, some P in pits and MP. Upper part strata less well defined, zones of clay-poor DVT textures. M-c to f-m IV w/f H in zones and pods, tr P, abund C. Poly occurs as blebs and platelets in POS textures. Clay lines H, forms blebs w/displacive margins to thin lam to zones w/vc I-IIa in filled caves and pits. Anhy lines H crystals. Vc IV in large MP. Pits continue on both sides of shaft.

*ELEV (ft. m.s.l.) **SEE EXPLANATION FOR SCALES

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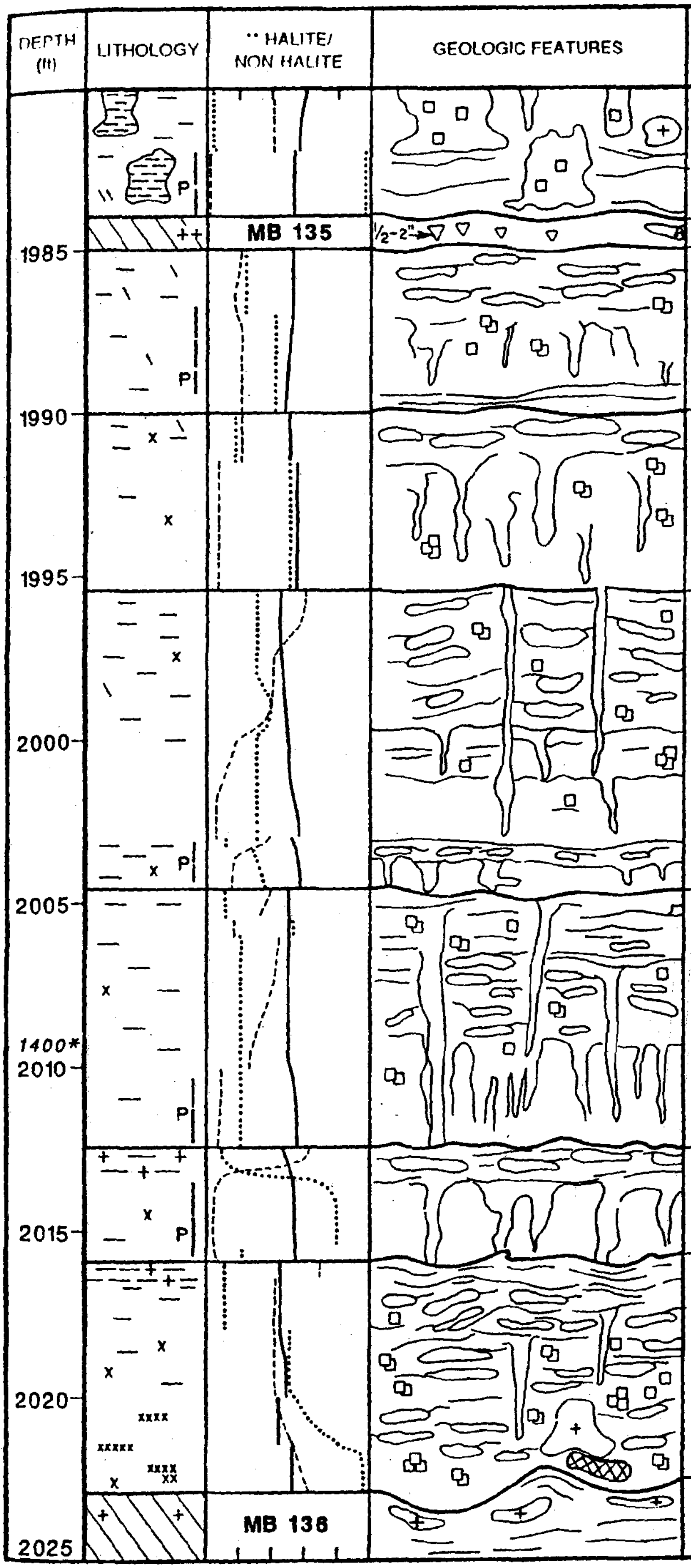
FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

Anhy, lower 1" organic-rich; lam, small H PAGS in middle. H in lows on upper contact overlain by anhy.

H, tr poly, tr to some clay. Poly blebs to lam w/displacive H. Anhy lines some H crystals. Thin clay lam and stringers, lines H crystals. F-m to f-c to m-c IV upward w/f H at tops of beds and in zones and pods near top. I-IIb-c in middle. Abund C, tr to some P.

H, tr poly, tr clay. M beds delineated by clay. DVT textures in upper 1.5' modified by C. Clay occurs as lam to stringers, on margins of C/displacive H in pits. Poly occurs as blebs to stringers and larger blebs in pits w/displacive boundaries. F-c, mainly m, IV w/some f H in lenses and pods in DVT zone. Abund MP. Abund C.

H, tr to some clay below 1999.5, some clay and tr sulfate above 1999.5. Lower part divided into 3 subparts consisting of clear H overlain by DVT zone and topped by DVT e/s surface. Upper part is a well developed DVT zone. Poly blebs w/i H and in claystone. Clay in lam, v thin beds, zones, blebs, w/f-c I-IIIa-b in C and pits. In lower part: clear H MP and C. M-c IV w/vc H in MP; abund C in DVT zones; zones and pods of m-c IV bounded by clay w/m-c I-IIIa-b. Upper part: "dish" fabric bounded by deep pipes. C abund w/m-c IV. Clays show m-c I-IIIa,b in C zones. Some dish-shaped zones and pods of f-m IV. Some claystone shows thin lam, possible cross lam, and sic textures. Some pit edges show f IV.

H, tr to some clay, tr to anhy and poly. Divided into upper DVT zone and lower zone w/pits modified by C. VO and irreg MP. Dish-shaped fabric in DVT zone. M-c III in C dominated zones; also m-c I-IIIa-b in pits and some C-rich zones. H in lower part m-c IV w/I-IIIa-b in pits w/clay or poly. Tr P; tr to some C. Poly occurs as blebs to linings on H crystals, w/m-c I-IIIa,b. Clay occurs in zones to v thin beds, w/f-c I-IIIa-b. H in DVT zone f-m IV in zones and pods, f IV in some pits, m-c IV in C-rich areas.

H, tr poly to some clay near top in pits overlain by DVT e/s surface. DVT textures w/some clay and claystone w/sic textures, pods and irreg zones of f-m IV, some c C. Poly stringers, crystal linings; displacive "a-type" boundaries w/H. Clay occurs in topographic lows and pits, as blebs to v thin beds. H in lower part m-c IV w/tr f H; some to tr P w/abund to mod C. VO and irreg MP. F-m IV in zones and pods in upper part, some c as C; m-f Ib at top, m-c I-IIa in pits.

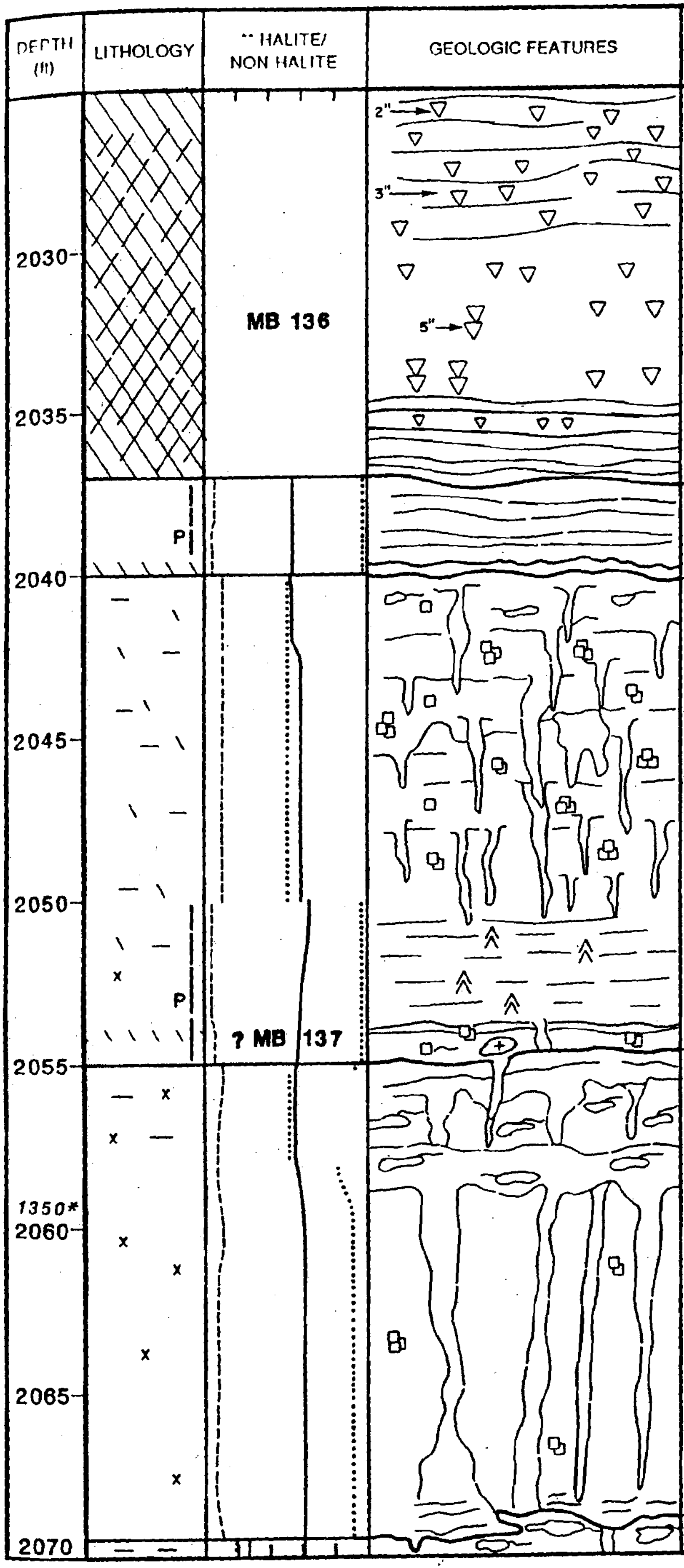
H, major to some poly, some clay, inc at top; tr anhy. Poly masses near base w/possible sic textures, m-c I-IIIa-b, f-m I-IIc, "a" type boundaries w/c-vc H, some f H. Poly also occurs as blebs w/displacive boundaries to lam in DVT zone. Dish-shaped thin beds to blebs of clay occurs around pods of f-m IV; pods and zones increase upward. Abund C, decreases upward. DVT textures pervasive. Thicker claystone zones near top, show incipient sic texture and thin lam, w/m-c (some f) I-IIa-c. M-vc IV in large MP.

Anhy and poly, halitic, arg in lower 6-8". Lower 1'

*ELEV (ft msl) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 29 OF 32

FIGURE 23



REMARKS
(SEE APPENDIX FOR DETAILS)

anhy'c, poly'c from 2035 to 2035.5. Poly occurs as PAGS, discrete lam in anhy. H zones w/i poly pseudomorphs and H PAGS. Unit has thin lam to v thin beds. Poly PAGS decrease upward. Poly occurs as clasts in anhy; c sand to granule-sized in poly lam zone. Upper part has lam to cross-lam, w/local .5' high hummocks/hemispheroids.

H, .1-.2' anhy at base, thin lam, possible organic material in lower 1", soft sediment deformation. Base of anhy slumped. Anhy contains m Ia-b and zones of m-c IIIa-b near top. Tr anhy and poly lam delineate thin to m beds w/sequence: anhy'c or poly'c f-m H, cloudy c H, clear c H. F-c IV. Some P, tr to some C. Tr to some VO and irreg MP.

H, tr sulfate below 2050, tr clay and sulfate above 2050. Tr poly in lower 1.5', anhy bed w/lam and c-vc Ia. Tr anhy throughout. Beds in lower part delineated by poly and anhy. Poly occurs as lam (w/II-IIIa-b in lower 1.5') blebs (w/m-c Ia). Anhy occurs as lam to blebs. Clay occurs as stringers to thin lam. F-c IV in beds w/sequence sulfate f-m H to cloudy c H to clear c H to clear f-m H; some P and C. Upper part f-m IV w/f-m H in zones and pods dominant above 2042, c-vc in pits and MP. Tr to some C in upper part; mainly II-IIIa-b in middle, f-m II-IIIa increases upward.

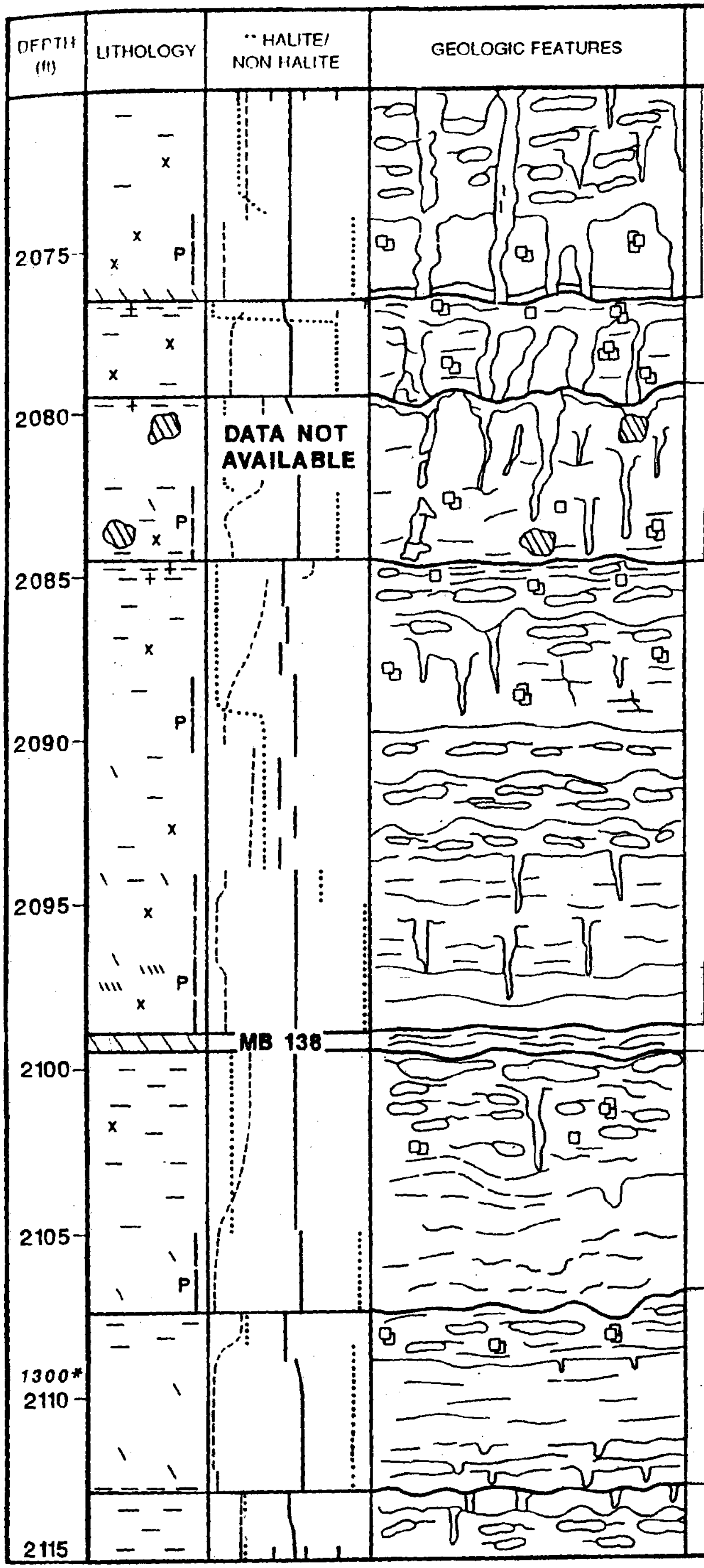
H, tr poly, and tr clay and poly above 2060. Poly occurs as blebs (w/II-IIIb), lines H crystals in pits. Clay occurs as lam to zones w/f-m Ia. M-f IV in beds below 2060, m-c IV and tr II-IIIb in pits and MP. Upper 5' has thin lam and stringers of clay around pods to beds of f-m IV. Abund C.

H, divided at 2074 into upper DVT zone and lower poly'c zone. Tr poly, tr clay in DVT zone; tr clay in pits in lower zone. Poly occurs as blebs (w/m-c II-IIIa-b) to stringers and H crystal linings. Clay occurs as lam (w/f-m IV-IIIb-c) to irreg blebs and zones (w/tr m I-IIa-b). H: m-c IV below 2074, f-m IV in pods in DVT zone. Tr to some displacive H C. Vc-c IV in pits and MP. DVT textures crudely horizontal; some POS. DVT e/s surface separates zones. Clay infiltrated pits at upper surface.

*ELEV (ft m s.l.) **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG
SHEET 30 OF 32

FIGURE 23



REMARKS (SEE APPENDIX FOR DETAILS)

H, tr poly to 2077.5, tr clay to claystone in upper 1', tr anhy in middle of unit. Poly and anhy occur as blebs to stringers (w/m-vc II-IIIb-c) and H crystal linings. Clay occurs as blebs and zones showing sic texture to thin lam (w/m-vc I-IIIa-b), zones and blebs in pits and pipes. Mainly m-c IV w/pods, lenses of f H in upper 1'; tr P, tr to some C. Abundant irreg MP. Translocated clasts (soft) of overlying anhy.

H, tr poly at base, tr clay anhy, poly upward; claystone at top. tr to mod clay. Poly and anhy occur as lam to blebby stringers w/I-IIIa-b; blebs and zones translocated into pits. Clay in unit middle is translocated, occurs as v thin beds at top to blebs and zones in pits and linings of H; f-c I-IIa-c at top. M-vc IV, w/I-IIa, marked by crystal linings, in pits. F IV in pods at top; v advanced DVT e/s surface. Abund C, tr P 1 pit has cobble-sized translocated clasts from 2076.

H, in four zones: a) thin to m beds, b) DVT zone, c) poorly defined strata, d) DVT zone. Poly and anhy occurs as lam to blebs, and crystal linings in MP. Lam often show displacive H contacts. Clays occur as blebs to lam and stringers infiltrated into pits forming boxwork fabric. Blebs w/displacive H margins abund in pits. Claystone in DVT zones shows disrupted thin lam. Part a: tr anhy, poly; tr clay at top. F-vc IV, tr P, tr-some c-vc C. Thin beds at anhy lam to m-c cloudy H to clear c H to f-m H. Part b: tr-some clay, tr anhy. F-m IV lenses and pods w/f-m II-IIIb-c and m-c I-IIa-b in arg zones. Middle zone of c-m IV C. Part c: tr clay and anhy, increase upward. F-vc IV, mainly m-c w/f IV at top; tr clay in boxwork, abund pits and pipes to 2'. Irreg and VO MP abund. E/s surface at top. Tr P, mod to abund C. Part d: tr to some clay, increasing upward, tr poly. Lenses and pods m-c and f-m IV to f IV to f-m I-IIa-c at top. DVT textures abund in top and bottom, middle shows abund C.

Anhy; wavy to slightly contorted, cross-cutting relationships. Clay at base.

H; lower zone w/tr anhy, upper DVT zone w/tr clay and poly. Lower part: m-c IV, w/tr f H on tops of m-c in zones associated w/anhy. Anhy occurs as stringers, "stringer-like" blebs, and planar H linings in MP. Tr P, abund C. VO and irreg MP. DVT zone: f-m IV in zones and pods, w/abund C (f-m II-IIIb-c) at base, decreases upward. M-c I-IIb in MP w/some Ib-a in f H in lam. Poly disseminated and as rare blebs. MP in lower part abund.

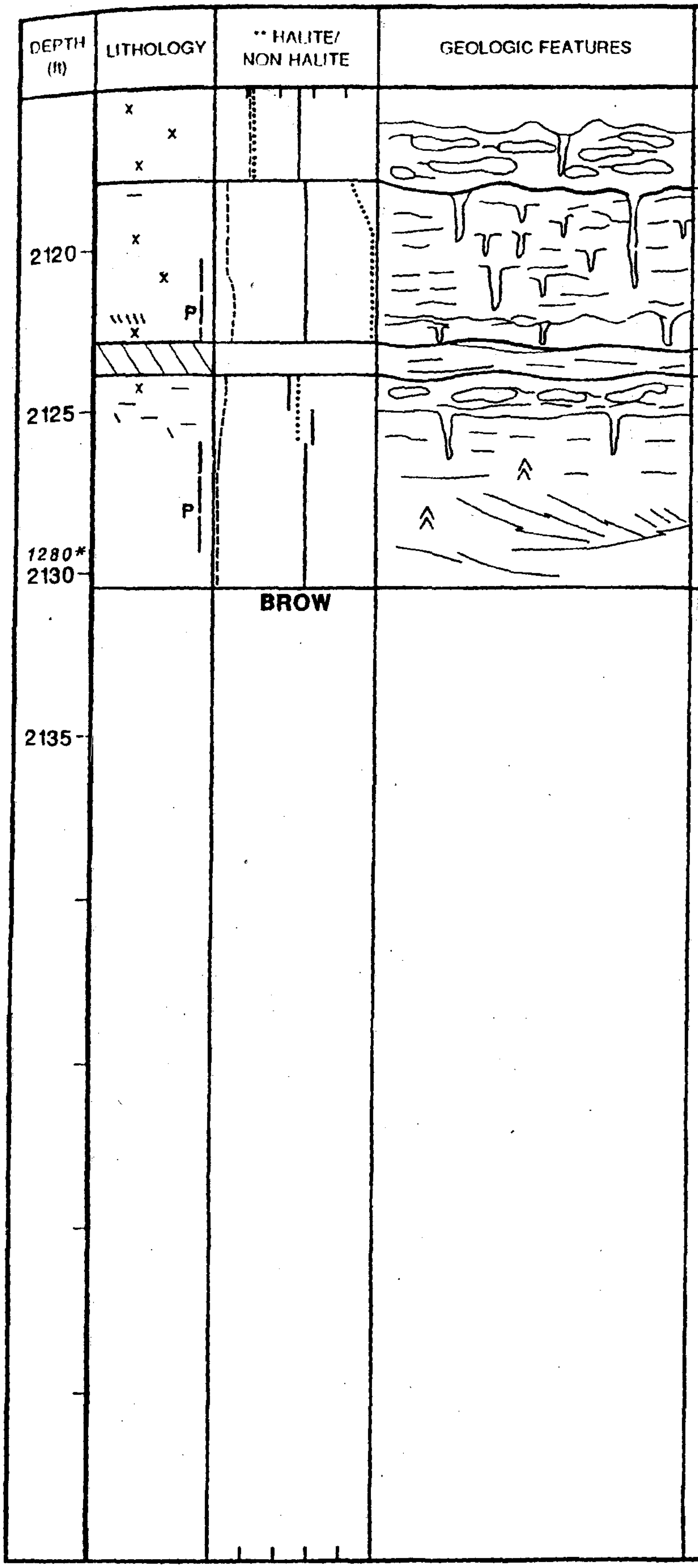
H, tr anhy in lower part, tr clay and poly in upper DVT zone. Anhy occurs as lam to blebby lam w/m-c Ia; stringers and H crystal lining in MP and pits. H in lower zone: m-vc IV, w/f H associated w/anhy over m-c in thin to m beds; some P (BG, chevrons, vel). Irreg and VO MP. Thin to m bedded. Upper DVT zone: clay occurs as thin lam to lam. Poly occurs as rare blebs and disseminated in m-f IV. F-m IV in zones bounded by clays and MP; f-m II-IIIb-c in clay zones. Large MP near upper contact.

H, tr clay and tr poly. DVT textures in 2 zones topped by DVT e/s surface. Clay occurs as irreg

*ELEV (ft. m.s.l.)   **SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG

SHEET 31 OF 32



REMARKS
(SEE APPENDIX FOR DETAILS)

stringers to lam, drapes and surrounds zones of f-m IV. Poly occurs as blebs to irreg lam, w/tr disseminated poly in m-f IV. Anhy at tops of e/s surfaces as lam to stringers. Middle has abund irreg MP. Pits and pipes w/c-vc IV and w/some f. H in DVT zones: f-m IV, w/some c in pits and pores. Upper and middle zones: m-c IV, w/some f H; some P and C.

H, tr poly, tr infiltrated clay. Thin to m beds delineated by poly. Pits 6" to 3+' deep throughout. Translocated poly in pits defines boxwork texture. Abund to rare irreg MP, abund VO MP. H: f-vc, mainly m-c IV, w/c-vc in MP, f H at tops of strata w/poly. Poly occurs as blebs w/rare displacive margins to lam. Lam of anhy near base w/some a-b H margins. Upper contact is DVT e/s surface.

Anhy, tr H, thin lam to lam, irreg to convolute. Possible detrital H. Clay at base, claystone lam. Contains fractured zones w/separations in middle to lower part (due to closure of drift).

H, tr anhy as thin lam to lam and translocated material in pits; tr disseminated clay in upper part as zones and lam to stringers in DVT zone. V rare blebs of poly. H below DVT e/s surface is f-vc m, IV, w/rare c-vc in irreg MP, c in VO MP. F H overlies c H in irreg zones; thin to m beds most obvious between 2125-2127. Upper 1' exhibits DVT textures. H is m-f IV, mostly f in zones, tr poly as lam to blebs. Local pits to 1' at DVT surface.

Excavated brow at facility level.

*ELEV (ft. m s.l.)

**SEE EXPLANATION FOR SCALES

AIR INTAKE SHAFT LITHOLOGIC LOG

SHEET 32 OF 32

FIGURE 23

Figure 24
Mud and halite crust on the surface of the shaft wall prior to washing.

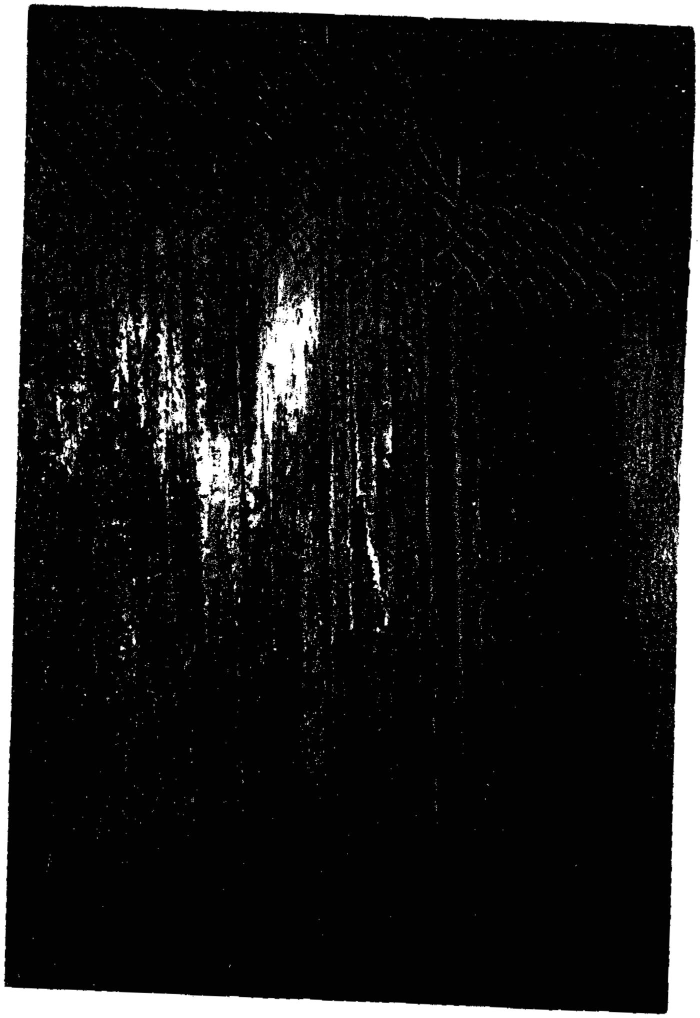


Figure 25
Fluted halite on the north side of the AIS

Appendix A

APPENDIX A
WORK PLAN FOR THE GEOLOGIC MAPPING OF THE AIR INTAKE SHAFT AT THE WIPP FACILITY, CARLSBAD, NEW MEXICO

WORK PLAN FOR THE GEOLOGIC MAPPING IN THE AIR INTAKE SHAFT AT THE WIPP FACILITY, CARLSBAD, NEW MEXICO

1.0 INTRODUCTION

The purpose of this work plan is to describe the upcoming geologic mapping activities in the air intake shaft and to provide background information for the planning of field activities. The air intake shaft is being constructed to provide additional ventilation to the WIPP facility. The shaft will be upreamed by the construction contractor to its full diameter. In the air intake shaft, a strip map of the entire shaft to total depth will be produced, along with detailed mapping in zones of interest. Geologic information will be gathered following the upreaming of the shaft to its full diameter and concurrent with the installation of ground support.

Information from the geologic mapping will be used to:

- Provide confirmation and documentation of strata overlying the WIPP facility horizon.
- Provide detailed information of the geologic conditions in strata critical to repository sealing and operations.
- Provide technical basis for field adjustments and modification of key and aquifer seal design, based upon the observed geology.
- Provide geologic data for the selection of instrument borehole locations.
- Characterize the geology at geomechanical instrument locations to assist in data interpretation.

For the purposes of geologic mapping the field procedures given in the Geologic Mapping Procedure for WIPP Shafts in the WIPP Geotechnical and Geosciences Procedure Manual (WP 07-503) will be followed.

2.0 SCOPE OF WORK

2.1 Premapping Activities

Prior to performing the geologic mapping in the air intake shaft, the following work items will be addressed:

- o Hazard training for shaft work for all personnel who will perform shaft mapping.
- o Familiarization with the geology overlying the facility horizon.
- o Preparation of geologic mapping procedures and forms for use in the shafts.
- o Coordinate with contractor personnel to establish both horizontal and vertical survey control.
- o Coordinate with contractor personnel to establish necessary working conditions: proper lighting, shaft wall access, galloway water, and safety (contract specified as utilities).
- o Coordinate with contractor personnel to arrange the timing of shaft mapping activities relative to on going contractor activities.
- o Check, clean, and procure supplies and equipment needed to support the shaft mapping activities.

Specific activities to be performed in the air intake shaft are described below.

2.2 Air Intake Shaft Geologic Mapping Activities

All in shaft activities related to mapping are designed, barring any unforeseen circumstances, to be performed in a total of 25 shifts or 200 hours of dedicated shaft time. This is the amount of dedicated shaft time specified for geologic mapping activities by the air intake shaft construction contract. All mapping activities will be performed on a cleaned shaft surface prior to any meshing or lining activities. Reconnaissance mapping, resulting in a strip log at a scale of 1 in. equals 10 ft. or 1 in. equals 5 ft., will be performed in the air intake shaft from the first available exposed bedrock down to the facility level. In addition to the reconnaissance mapping, detailed 360° geologic mapping at a horizontal and vertical scale of 1 in. equals 5 ft. will be made in zones of interest, including:

- Rustler Formation - approximate map depths from 538 to 850 ft.
- Rustler/Salado contact and the Shaft Key - approximate map depths from 850 to 900 ft.
- Any anomalous areas within the Dewey Lake Redbeds or the Salado Formation.

All geologic mapping will be performed in accordance with the Geologic Mapping Procedure for WIPP Shafts in the Geotechnical and Geosciences Procedure Manual (WP 07-503). Both the reconnaissance and detailed 360° geologic mapping will be supplemented with a photographic record of those areas mapped. Rock samples will be taken as deemed necessary.

2.3 Presentation of Mapping Results

The results of the geologic mapping effort will be summarized in a DOE/WIPP report to be published after the shaft mapping has been completed. Photographic coverage and other information will be presented as the project needs dictate.

3.0 PERSONNEL

All work described in this plan will be under the technical lead of Bob Holt and the administrative direction of the Geotechnical and Geosciences Department Manager. The reconnaissance geologic mapping and photo log effort will require a mapping team consisting of two geologists and one technician. Detailed 360° geologic mapping will require a mapping team of six people, including a minimum of two geologists. The actual field conditions will dictate how the mapping personnel will be scheduled. Support for the mapping effort and subsequent report will be provided by either on-site personnel or IT Corporation home office support, depending on availability and other project commitments.

4.0 SCHEDULE

Geologic mapping activities will begin as soon as the shaft is upreamed and shaft access is provided. According to the latest available Contractor's schedule, the air intake shaft will be accessible for mapping during the period from June, 1988 to September, 1988. Following the completion of geologic mapping activities, a final report of mapping results will be produced.

5.0 SAFETY

All personnel participating in the geological mapping in the air intake shaft will receive shaft specific safety and hazard training from the Westinghouse Industrial Safety Department. In addition to providing training, the Industrial Safety Department will determine the safety of shaft access. Once shaft mapping is underway, the geological mapping team will meet weekly to discuss safety issues and regularly interface with the Industrial Safety Department to verify the conditions, with respect to safety issues, of the zones to be mapped.

6.0 ADDITIONAL ITEMS

6.1 Galloway Utilities

Several galloway utilities must be supplied by the shaft construction contractor including: electricity, water, and compressed air. Galloway electricity will be required for lighting and, possibly, to operate rock sampling tools. Galloway water is needed to allow the mapping team to wash the shaft wall clean prior to mapping. Compressed air lines will be required if galloway electricity is unsuitable for the safe operation of sampling devices.

6.2 Survey Control

Both horizontal and vertical survey control is necessary for shaft mapping. Horizontal survey control can be established from contractor supplied tightlines. Vertical survey control will be established from known reference points provided by Westinghouse surveyors. The actual methods used will depend upon the field conditions.

7.0 QUALITY ASSURANCE

Quality assurance will be performed by IT Corporation under the direction of the Westinghouse Quality Assurance Department. All procedures and activities will be developed, approved, and controlled in accordance with WIPP procedure 15-101. Nonconformances and variances from the approved procedures will be documented according to the Westinghouse Quality Program Manual, Section XV and the IT Engineering Operations Quality Assurance Manual as ammended for the WIPP Project. To provide confidence in the final report, all data reduction, computer input, calculations, and figures will be independently verified by IT Corporation Quality Assurance. Audits will be conducted to insure compliance with the WIPP Quality Assurance Program.

Appendix B

APPENDIX B

WP 07-503 GEOLOGIC MAPPING OF SHAFTS

WASTE ISOLATION PILOT PLANT
WIPP

PAGE 1 OF 6

NO: 07-503 REV. 0 ISSUE DATE: 06-08-88

APPROVAL SIGNATURE:

PROCEDURE AUTHOR: R. Holt

TITLE: GEOLOGIC MAPPING OF SHAFTS

Information Only

1.0 SCOPE

This procedure defines the methods to be used for 360°, detailed geologic mapping and reconnaissance geologic mapping of shafts accessing the WIPP repository for which accurate geologic observations and fracture data are required. The general procedure described in this document involves cleaning the shaft wall, establishing both horizontal and vertical datums, and sketching to scale the lithologic and structural features observed. The geology in the WIPP shafts is mapped as part of a continuing effort to further characterize the rocks overlying the WIPP facility.

2.0 DEFINITIONS

Detailed Geologic Mapping - Mapping will consist of recording geologic information obtained by observation of the exposed surface on a mylar sheet, typically at a horizontal and vertical scale of one inch equals five feet. This information will provide a log depicting the shaft surface 360° around its circumference and a detailed description of the observed lithologies, lithologic features, and conditions. The log and accompanying description will indicate the location in the shaft, lithologies, lithologic contacts, geologic structures, and the general conditions of the walls.

Reconnaissance Geologic Mapping - Mapping will consist of recording geologic information obtained during the observation of an approximately five-foot wide strip of the exposed shaft surface on a vertical log, typically at a scale of either one inch equals ten feet or one inch equals five feet. A vertical strip log, depicting the geologic column observed in the shaft, will be created (Attachment 1). The log and accompanying description will indicate the depth in the shaft of the observed lithologies, lithologic contacts, and geologic structures.

3.0 REFERENCES

Holt, R. M., and D. W. Powers, 1984, Geotechnical Activities in the Waste Handling Shaft: WTSD-TME-038, U.S. Dept. of Energy, Carlsbad, New Mexico.

Holt, R. M., and D. W. Powers, 1986, Geotechnical Activities in the Exhaust Shaft: DOE-WIPP-86-008, U.S. Dept. of Energy, Carlsbad, New Mexico.

4.0 GENERAL

Geologic mapping of WIPP shafts will be performed as part of continuing site characterization activities. The activity will be performed in each shaft on uncovered and unlined rock surfaces. A block of dedicated shaft time will be required for this activity. Two levels of effort will be undertaken in the shaft:

(1) Detailed, 360° geologic mapping
(2) Reconnaissance geologic mapping

During the detailed geologic mapping, the entire shaft surface (360° around the circumference) will be mapped and described. The mapping team will consist of five to six people, with at least three professional geoscientists. Ideally, the team will be subdivided into three groups of two: one group will be responsible for the geologic mapping; the second group will provide the 360° photographic coverage; and the last group will take samples as necessary and provide general support.

Reconnaissance geologic mapping will be performed in those zones within the shaft that are not mapped in detail. A strip map of the geology observed will be created. The mapping team will consist of three people, two of which will be geoscientists. The following materials and equipment will be needed for geologic mapping in a shaft.

- Several cans of paint
- A 25-foot measuring tape scaled to tenths of feet
- A 100-foot (or longer) tape or surveying chain
- A 360° geologic mapping log sheet or a reconnaissance mapping log sheet
- Several pieces of gridded mylar
- Camera and film
- Chalkboard mounted on stadia rod
- Sample bags
- Waterproof marking pens
- Rock hammer

The lithologies and lithologic features will be described as they occur. Examples of description style may be found in Holt and Powers (1984 and 1986). Lithologic descriptions should include rock type, color, crystal/grain size, stratification type, minor constituents, structural features, and contacts.

In addition to mapping, photographic coverage of the mapping zone will be provided and samples will be taken as deemed necessary.

5.0 PROCEDURE

5.1 Detailed Geologic Mapping

1. The zone to be mapped will be cleaned as necessary.
2. Vertical control will be established with a survey chain from a known reference point within the shaft.
3. After the depth/elevation of the top of the mapping zone has been established, horizontal lines will be spray-painted at five-foot intervals around the circumference of the shaft.
4. Horizontal control will be established using either contractor supplied plumb lines or the alignment of the galloway or cage lines. A vertical line will be spray-painted along the south line of the shaft.
5. The shaft wall will then be painted with vertical lines at five-foot intervals both east and west of the south line along the circumference of the shaft.
6. Mapping units will be established by the geologists; their contacts and features will be measured to within a tenth of a foot from the grid lines and drawn on to the mapping log.
7. The geologist will then describe the mapping units and other geologic features on the blank sheets of gridded mylar.

8. Photographs will be taken after the grid has been established. An identifier, which gives the depth and location relative to the south line of the shaft, will be written on the chalkboard and included in each photograph.

9. Samples will be taken after the grid has been established. All samples will be uniquely identified and marked with an "up" arrow and an azimuth. They will be located on the field log, and their location will be recorded on their sample bag (Attachment 2).

att 2

10. The geologist will complete the log by filling in the contacts and structures using the appropriate symbols (Attachment 3) on the mylar sheets. At the completion of the shaft mapping efforts, the information obtained will be published in a DOE report.

att 3

5.2 Reconnaissance Geologic Mapping

1. Reconnaissance mapping should be performed on the same side of the shaft each time.

2. Vertical control will be established with a survey chain from a known reference point within the shaft.

3. The zone to be mapped will be cleaned as necessary and horizontal lines will be painted on the shaft wall at five-foot intervals.

4. Mapping units will be established by the geologists; the depths to their contacts and features will be measured to within a tenth of a foot from the horizontal lines and drawn on to the reconnaissance mapping column (Attachment 1).

att 1

5. The geologist will then describe the mapping units and other geologic features on the blank sheets of gridded mylar.

6. Photographs will be taken after the section has been mapped and described. An identifier, giving the depth of the photograph, will be written on the chalkboard and included in each photograph.

7. Samples will be taken after vertical control has been established. All samples will be uniquely identified and marked with an "up" arrow and an azimuth. Sample depth will be recorded on the strip log and will be written on each sample bag (Attachment 2).

att 2

8. The geologist will complete the log by filling in the contacts and structures using the appropriate symbols (Attachment 3) on the standard pre-printed mylar log sheets. At the completion of the shaft mapping efforts, the information obtained will be published in a DOE report.

att 3

157e+

ATTACHMENT 1
WP 07-503
Page 1 of 1

CORRECTED DEPTH

PRELIMINARY DEPTH

HORIZONTAL CONTROL

DEPTH IN FEET

EXPLANATION

1 INCH = 10 FEET
(HORIZONTAL AND VERTICAL SCALE)

WASTE ISOLATION PILOT PLANT
RECONNAISSANCE GEOLOGIC LOG
EXHAUST SHAFT

DEPTH ________ TO ________ FEET
BY ____________________
DATE ____________________

SAMPLE IDENTIFIERS

All samples taken during the shaft mapping activities will be permanently stored in the WIPP core storage library at the WIPP site for future reference. They will be cataloged in two parts: reconnaissance mapping samples and detailed mapping samples. In each case, the notation used for sample identification also describes the depth and, in the case of detailed mapping samples, the location of the sample with respect to the shaft wall. The notations are described below.

Reconnaissance Geologic Mapping Samples

The method of identification used for samples taken during reconnaissance geologic mapping is as follows:

ES24-466

The notation ES24 indicates that the sample is exhaust shaft reconnaissance geologic mapping sample number 24. The number 466 indicates that the sample was taken at the depth of 466 feet below the reference elevation.

Detailed Geologic Mapping Samples

Samples taken during detailed geologic mapping exercises are identified using the following notation:

ESM49-715/10' W. of S.

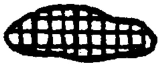
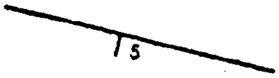
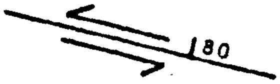
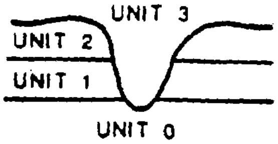
As above, the ESM49 indicates that the sample is the exhaust shaft sample number 49, and the number 715 corresponds with the depth in feet. In addition, 10' W. of S. indicates the location of the sample along the circumference of the shaft. This notation means that the sample location is ten feet west of the south line along the circumference of the shaft.

MAPPING SYMBOLS

Contacts between different rock types will be symbolized by:

Sharp contact identifiable within 0.05 feet or less;	————————
Gradational contact between 0.05 and 0.2 feet;	— — —
Diffuse contact between 0.2 and 0.5 feet;	• • • • • • • • • •

Clay features will be noted by:

Seams greater than 1/4 inch thick;	━━━━━━━━
Partings between 1/4 to 1/16 inch thick;	━ ━ ━
Breaks less than 1/16 inch thick;	━•━•━•
Discontinuous partings and breaks;	~ ~ ~
Spalling areas;	
Seep or seep line;	
Bedding showing attitude;	
Fault trace showing attitude and/or relative separation;	
Weep or patchy damp area commonly with 1/4 to 3/4 inch diameter knobs of finely crystalline halite	
Syn- or immediately post-depositional pits caused by dissolution and reprecipitation of the halite	

Grain/Crystal Size

The rock types in the Salado Formation will consist primarily of halite with lesser amounts of anhydrite and polyhalite. In order to provide a uniform classification of crystallinity, the following convention will be used:

coarse-crystalline - greater than 5 mm
medium crystalline - 1-5 mm
fine-crystalline - less than 1 mm

LIST OF REVIEWERS

Procedure Number: WP 07-503

Revision Number: 0

Procedure Title: Geologic Mapping of Shafts

Reviewer's Name	Department
T. Dillon	Mine Engineering
M. Werner	Construction
R. Youngman	QA
B. Johns	Safety
R. Matalucci	Sandia
M. Schulz	IT-ALB.

Appendix C

APPENDIX C

AIR INTAKE SHAFT SAMPLES

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/21/89	1959	2"	About 2 ft. below top of MB 134, thin zone of gypsum swallowtails.
9/21/89	1958	2"	Gypsum swallowtail 2 ft. below top of MB 134 at side of trough.
9/20/89	1957	1"	MB 134, southwest side of shaft.
9/21/89	1956	2"	Top of trough over MB 134, vertical growth textures and thin laminae.
9/21/89	1954.5	3"	1 ft. above base of mapping unit 1.
9/21/89	1953	3"	1 ft. below top of mapping unit 1.
9/21/89	1952	3.5"	4 in. above base of mapping unit 2.
9/21/89	1949	2"	Near top of unit 3.
9/21/89	1948	1.5"	8 in. below top of unit 3, in zone with more vertically elongate halite crystals
9/21/89	1947.5	3.5"	Middle of small "pod" of fine grained, equant, white halite, top of unit 3, immediately below clay.
9/21/89	1946	1.5"	Along side of channel.
9/21/89	1946	1.5"	Middle unit 4.
9/21/89	1944	2"	Basal part unit 5, halite with clay laminae, overlaps contact with 4.
9/21/89	1943	3"	Lower unit 5 on high point on residue at base unit 5.
9/21/89	1940	2"	Base of halite/anhydrite ripple unit 7.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/25/89	1863.8	2"	Gray clay zone, top unit 26, Ia, Ic.
9/25/89	1863.3	2.5"	Gray clay zone, top unit 26, Ia, Ic.
9/25/89	1863	1.5"	Gray clay zone, top unit 26, Ia, Ic.
9/25/89	1863	1"	Base polyhalite, miscellaneous hand samples.
9/25/89	1863	1"	Hand sample.
9/25/89	1863	1"	Base polyhalite, hand sample.
9/25/89	1862.5	3"	Polyhalite unit with probable swallowtails.
9/25/89	1858	2.5"	Top of vertically elongate halite truncated by thin polyhalite.
9/25/89	1857	2.5"	Vertically elongated halite in zone, truncated by polyhalite laminae.
9/25/89	1856.8	2"	Vertically elongate halite crystals truncated by polyhalite laminae.
9/26/89	1851	1.5"	Halite from pod of very coarse crystals.
9/26/89	1850	1.5"	Sample of pipe zone through polyhalitic halite into top unit 29.
9/26/89	1845.5	1"	Polyhalite included in halite.
9/26/89	1845	2"	Polyhalite with bottom grown halite.
9/26/89	1828	2"	Margin of polyhalite and halite and small solution pit (clear halite).
9/26/89	1827.5	2"	Unit 37, clay/polyhalite along side of larger solution channel.
9/26/89	1827	2.5"	Unit 37, clay residual on collapse block of fine halite.
9/26/89	1823.6	2"	Halite, recrystalized and cement.
9/26/89	1823.5	1"	Base unit 39, primary and recrystalized halite with polyhalite inclusions.
9/26/89	1823.5	1.5"	Halite.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/27/89	1813	1"	Top unit 41.
9/27/89	1813	1.5"	Top unit 41.
9/27/89	1811	2"	Lower unit 41, macropore/cement in clean halite.
9/27/89	1810	1.5"	Middle of unit 42.
9/27/89	1809.5	1.5"	Middle unit 42, top of slightly polyhalite halite.
9/27/89	1807.5	2"	Unit 43, base unit at clay/halite.
9/27/89	1807.3	1.5"	Unit 43.
9/27/89	1807.0	1"	Unit 43, middle of halite/clay accumulation with polyhalite flakes.
9/27/89	1806.7	1.5"	Middle unit 43, top of halite and brown clay with polyhalite flakes.
9/27/89	1806.5	1.5"	Middle unit, halite between brown clay and gray clay.
9/27/89	1806.3	1"	Middle unit 43.
9/27/89	1806.1	2"	Middle gray clay, unit 43.
9/27/89	1806	2.5"	Unit 43, top gray clay and base unit 44.
9/27/89	1805.5	2"	Transition unit 43-44.
9/27/89	1805	1"	Unit 44.
9/27/89	1803.5	1"	Middle unit 44.
9/27/89	1803	2"	Middle unit 44, halite and polyhalite transition to gray zone.
9/27/89	1802.6	1.5"	Middle unit 44, top of transition gray to orange.
9/27/89	1802.4	1"	Unit 44, halite/polyhalite.
9/27/89	1802.0	2"	Unit 44, halite/polyhalite transition up to gray.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/27/89	1800	1"	Top unit 44, lower end of polyhalite fill of solution pipe, 1 ft. below top of pipe.
9/27/89	1799.2	1"	Top unit 44, just below transition to 45, halite and polyhalite.
9/27/89	1799	2"	Top unit 44, transition to unit 45.
9/27/89	1799	2.5"	Top unit 44, top solution pipe filled with polyhalite and halite and transition to unit 45.
9/27/89	1794	1"	Near middle unit 46, halite and polyhalite.
9/27/89	1793.5	1"	Upper unit 46.
9/27/89	1793	1.5"	Top unit 46.
9/27/89	1790	1"	Unit 47 top, top polyhalite and halite.
9/27/89	1789	1.5"	Unit 48, clay, displacive halite, solution zone.
9/27/89	1788.5	1"	Unit 48, incorporative and exclusive halite in muddy unit.
9/27/89	1788	2"	Unit 48, clay and Ia, c, IV pods.
9/27/89	1785.5a	1.5"	Unit 48 top.
9/27/89	1788.5b	2"	Unit 48 base of "basin."
9/27/89	1785.2	2"	Unit 48, center of halite pods in clay in "basin."
9/27/89	1785a	1.5"	Unit 48 top, side of collapse/basin.
9/27/89	1785b	2"	Unit 48 top, center and bottom of claystone "basin."
9/28/89	1784	1"	Middle unit 49, MB 129, polyhalite with laminae.
9/28/89	1783.3	1.5"	MB 129, growth textures and pseudomorphs.
9/28/89	1783	1.5"	Top unit 49, growth textures, halite bottom growth, top of polyhalite.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/28/89	1771.8	2"	Unit 53, just above base unit.
9/28/89	1771.8	1.5"	Unit 53, lower part clay-rich zone.
9/28/89	1771.5	1"	Upper part of lower clay-rich zone.
9/28/89	1770.5	2"	Upper part of less clay-rich zone.
9/28/89	1770	2.5"	Top of unit.
9/28/89	1766.2	1.5"	Vertically elongate halite crystals
9/28/89	1766.2	1.5"	Vertically elongate halite crystals
9/28/89	1786.2	1.5"	Vertically elongate halite crystals
9/28/89	1765	3"	
9/28/89	1764.8	1"	
9/28/89	1764	1.5"	Base gray zone.
9/28/89	1763.8	2"	Top gray unit.
9/28/89	1762	1.5"	Fine halite, vertically elongate halite crystals, polyhalite.
9/28/89	1761.5	2"	Fine halite, vertically elongate halite crystals, polyhalite laminae.
9/28/89	1759.5	1"	Top unit, halite and vertically elongate halite crystals
9/28/89	1759	1.5"	Base polyhalite (MB 128?) laminar zone.
9/28/89	1758	2"	Vertically elongate halite crystals, over polyhalite.
9/28/89	1757	2"	Vertically elongate halite crystals and polyhalite laminae.
9/28/89	1756	2.5"	Top unit 55, vertically elongate halite crystals; polyhalite
9/28/89	1736	2"	3 ft. above base.
9/28/89	1714	2"	Halite and polyhalite.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/28/89	1713	2.5"	Polyhalite and clay at base of area with pods of fine halite.
9/28/89	1658	2.5"	Langbeinite pocket.
9/29/89	1657	2"	Solution zone on wall, sample for K mineralization.
9/29/89	1656.3	3.5"	Langbeinite zone.
9/29/89	1656.0	2"	Solution zone on wall.
9/29/89	1656	1.5"	Solution zone on shaft wall, langbeinite, first ore zone.
9/29/89	1655.5	3.5"	Upper unit 72, solution on shaft surface, langbeinite.
9/29/89	1655	2"	Solution zone on shaft surface, langbeinite.
9/29/89	1652	2.5"	Area of solution on shaft wall.
9/29/89	1650	1"	Langbeinite under polyhalite zone.
9/29/89	1649.5	1"	Minor amount of langbeinite.
9/29/89	1649	1"	Solution on shaft wall.
9/29/89	1630	1"	Fibrous halite polyhalite under MB124.
9/29/89	1630	1"	Base MB 124.
9/27/89	1627.3	2"	Bottom-grown gypsum about 1.3 ft. above base MB 124.
9/27/89	1627	1.5"	Bottom grown gypsum about 1.5 ft. above base MB 124.
9/27/89	1625	1.5"	MB 124.
9/27/89	1624	1.5"	MB 124.
9/27/89	1614	2"	MB 123.
9/27/89	1613.5	1.5"	MB 123.
10/4/89	1572.2	3"	Near top unit 87.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/4/89	1572	1.5"	Near top unit 87.
10/4/89	1571.5	2"	Near top unit 87.
10/4/89	1571	2"	Check for potassium mineralization.
10/4/89	1557	3"	Middle unit, check for translocation of clays.
10/4/89	1556	1.5"	Middle unit, check for translocation of clays.
10/4/89	1554	1.5"	Check clay translocation.
10/4/89	1553.5	2"	Check clay translocation.
10/4/89	1553	2"	Check for translocation of clays.
10/4/89	1545	2.5"	Clay/halite 1 ft. below 91/92 contact.
10/4/89	1544.7	2"	Immediately below sharp contact of 91/92.
10/4/89	1544.6	1.5"	Contact 91 on 92.
10/4/89	1544.5	1"	Top 91, base 92, sharp contact.
10/4/89	1544.4	2"	Base unit 92.
10/4/89	1544.4	1.5"	Base of 92.
10/4/89	1534.5	1.5"	Clay/carbonate and base of polyhalite.
10/4/89	1534	1"	Effluorescence.
10/4/89	1533.6	1.5"	Top polyhalite on side of "polyhalite hill."
10/4/89	1533	1"	Black clay and organics.
10/4/89	1533	2"	Middle of polyhalite section at base of sulfate, ripple/clasts?
10/4/89	1532.5	2.5"	Near base of anhydrite of unit 93, from local part of effluorescence
10/5/89	1532	2"	Union anhydrite.
10/5/89	1531.5	1.5"	Union anhydrite.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/5/89	1531.5	1"	Union anhydrite.
10/5/89	1531	2.5"	Union anhydrite.
10/5/89	1530	1.5"	Union anhydrite base of desiccation crack.
10/5/89	1529	1.5"	Union anhydrite at top, wavy, algal?
10/5/89	1500	3.5"	Primary, vertically elongate halite crystals
10/5/89	1499	1.5"	Vertically elongate halite crystals, polyhalite.
10/5/89	1496	1.5"	Sample from base MB 121.
10/5/89	1495.9	2"	Lower MB 121, from halite lens, check for langbeinite, KCl.
10/5/89	1495	1"	Base MB 121, polyhalite.
10/5/89	1494.8	1.5"	Lower MB 121, langbeinite? at arrow.
10/5/89	1494	2"	Upper MB 121, anhydrite polyhalite, nodular polyhalite?
10/5/89	1494	2"	MB 121, polyhalite and anhydrite.
10/9/89	1465	1.5"	Halite unit.
10/9/89	1464.7	1.5"	Halite bed.
10/9/89	1464.5	1.5"	Top of halite.
10/9/89	1464.2	1"	Top fine halite unit and thin polyhalite.
10/9/89	1461	1"	Base MB 119, hand sample.
10/9/89	1457a	2"	Sample of pore and cement for potassium values.
10/9/89	1457b	1.5"	Halite/polyhalite for potassium values.
10/9/89	1457c	2"	Halite for potassium values.
10/9/89	1444a	1.5"	Base unit 110, zone of vertically elongate halite crystals marked by drape of polyhalite skins, precursor to pile of sticks.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/9/89	1444b	1.5"	Base unit 110, vertically elongate halite crystals -transition from polyhalite draped to undraped.
10/9/89	1444c	1.5"	Base unit 110, higher solution concentration of pile of sticks.
10/9/89	1444d	2"	Base unit 110, vertically elongate halite crystals
10/9/89	1444e	1.5"	Base unit 110, vertically elongate halite crystals with polyhalite drape.
10/10/89	1434.5	.5"	Lower unit 113 (MB 118) from well lithifield lower 1 ft.
10/10/89	1434.5	1.5"	MB 118, ripple bedding?
10/10/89	1434	1"	MB 118, from flank of high - check for downward crystal growth.
10/10/89	1433.1	2"	Top unit 113, (MB 118) halite/polyhalite in "trough."
10/10/89	1433	1.5"	Top MB 118, halite and sulfate in "trough."
10/10/89	1428.5	2"	Halite and potassium sulfate.
10/10/89	1428	1.5"	Potassium-sulfates in gray clay-rich zone.
10/10/89	1426.8	2"	Solution pit w/halite and langbeinite.
10/10/89	1426.8	2.5"	"Cleaner" halite adjacent to solution pit with potassium minerals.
10/10/89	1426	1.5"	Potassium zone, polyhalite zone w/displacive halite and potassium minerals.
10/10/89	1426	3"	Potassium sulfate mineralization.
10/10/89	1426	1"	Thin polyhalite with displacive halite and langbeinite.
10/10/89	1425.5	1.5"	Gray zone and silty vug area.
10/10/89	1425.5	1"	Potassium-sulfate.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/10/89	1425.5	1"	Gray zone, langbeinite.
10/10/89	1425	3"	Just above large vug in solution pit.
10/10/89	1422	2"	Langbeinite in muddy halite in Death Valley Type solution.
10/10/89	1421.5	2"	Langbeinite in muddy halite along edge of Death Valley Type relief/solution area.
10/10/89	1421.3	2"	Random sample, upper unit 114 for potassium-mineralization.
10/10/89	1421	2.5"	Random sample from upper unit 114, check for langbeinite - slight chance.
10/10/89	1421	2"'	Upper unit 114, random sample to check for potassium mineralization.
10/10/89	1420.5	3"	Random sample for potassium-mineralization. Upper unit 114, probably langbeinite.
10/10/89	1420	1"	Upper unit 114, random sample from clay rich zone with pods of halite, check for potassium mineralization.
10/10/89	1419	3"	Unit 115 base and top 114, trace langbeinite on zone of solution pits.
10/10/89	1418.5	1"	Check potassium mineralization.
10/10/89	1417.5	2"	From "residue" laminae. Check for potassium-mineralization, none apparent.
10/10/89	1412	2.5"	Near surface vug. Check potassium mineralization.
10/10/89	1410	1"	Radial crystal in polyhalite near base sulfate unit. Hand sample.
10/11/89	1408.5	2"	Unit 118 base, polyhalite film on vertically elongate halite crystals.
10/11/89	1408	1"	11th ore zone.
10/11/89	1407.5	2.5"	11th ore zone, sample near vug, some langbeinite.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/11/89	1406.5	1"	Random sample, 11th ore zone, langbeinite - near solution vug.
10/11/89	1399.5	3.5"	11th ore zone, pseudomorphs-after langbeinite, zone of solution vugs.
10/11/89	1399.5	4"	11th ore zone, langbeinite in clay.
10/10/89	1399	2"	Just above solution zone with langbeinite.
10/11/89	1398.5	2"	11th ore zone, gray clay sample, check for any potassium minerals.
10/11/89	1398	3"	Zone with pseudomorphs after langbeinite.
10/11/89	1398	2"	Top unit 119, vuggy, from vuggy zone at contact, potassium-sulfate.
10/11/89	1398	1"	11th ore zone, displacive relationship of potassium-sulfate.
10/11/89	1398	3.5"	11th ore zone, top contact w/unit 120, note potassium-sulfate and possible displacive relationship to clay.
10/11/89	1398	2.5"	Top unit 19, 11th ore zone, sample gray clay between vugs.
10/11/89	1397	2"	Langbeinite in orange halite near solution pit.
10/11/89	1397	2"	Langbeinite in halite.
10/11/89	1396	2"	Zone of solution vugs, langbeinite in orange halite.
10/11/89	1394	2"	Langbeinite near solution vugs on shaft wall.
10/11/89	1394	2.5"	
10/11/89	1393.5	3"	
10/11/89	1392	1"	
10/11/89	1392	1.5"	

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/11/89	1389.7	2"	Ore zone.
10/11/89	1389.5	1.5"	
10/11/89	1389.5	1.5"	Ore zone.
10/11/89	1389	1.5"	
10/11/89	1388	1.5"	
10/11/89	1384.5	1"	Gray clay, hand sample.
10/11/89	1374	2"	Brown clay, hand sample
10/11/89	1346.5	1"	Stalactite on mesh at Vaca Triste.
10/12/89	1321.8	2"	Near base MB 115, gypsum swallowtails.
10/12/89	1320.5	2"	MB 115, porosity filled with halite and gypsum, crystal grown down from top pore.
10/12/89	1319	1.5"	MB 115, downward gypsum growth?
10/12/89	1319	2"	
10/12/89	1318.8	2"	MB 115, upward growth of gypsum and halite.
10/13/89	1235a	1.5"	Polyhalite unit.
10/13/89	1235b	2"	Side of collapse/subsidence feature.
10/13/89	1235c	2"	Halite/gypsum textures in remnant lens.
10/13/89	1235d	1.5"	Halite growth? in remnant lens.
10/13/89	1235e	1"	Halite lens in solution/collapse area.
10/16/89	1160	1"	Top unit 159, lower middle MB 109, nodular or clast zone.
10/16/89	1147.9	2"	Polyhalite zone in upper MB 109.
10/16/89	1147.4	1.5"	Polyhalite zone in upper MB 109, just above basal contact of polyhalite.
10/16/89	1147.0	2.5"	Polyhalite zone in upper MB 109, low part in slight folded zone.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/16/89	1146.9	2.5"	In polyhalite zone, from crest of crenulated zone.
10/16/89	1146	2"	Upper MB 109, from transition polyhalite - anhydrite, east sample.
10/16/89	1146	1"	Upper MB 109, west wall, transition polyhalite - anhydrite and truncation plane.
10/16/89	1146	2.5"	Upper MB 109, transition of polyhalite - anhydrite.
10/16/89	1145.5	1.5"	Upper MB 109.
10/16/89	1144.9	2"	Upper MB 109.
10/16/89	1144	1.5"	Upper MB 109.
10/16/89	1143.2	1"	Upper MB 109.
10/16/89	1143.2	2"	Upper MB 109, polyhalite blotch in anhydrite, near margin on right and base of sample.
10/16/89	1142.2	3"	Upper MB 109, margin of fracture w/polyhalite, clay, halite.
10/16/89	1142.2	2"	Upper MB 109.
10/16/89	1142	2"	Upper MB 109, clay infiltration into halite pseudomorph after gypsum.
10/16/89	1142	2"	Upper MB 109, dessication crack into sulfate with polyhalite, clay, halite, above 1142.2.
10/16/89	1142	2.5"	Upper MB 109 possible clay infilled pseudomorphs.
10/16/89	1141.9	2"	Upper MB 109, "collapse" zone between teepee or dessication cracks.
10/16/89	1141.5	1.5"	Upper MB 109, upper "collapse" zone between teepees or dessication cracks.
10/16/89	1140.5	1.5"	In pit.
10/16/89	1139.5	1.5"	In pit.

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
10/16/89	1138.8	1"	
10/16/89	1138	2"	Top unit.
10/17/89	1083	1.5"	From clay-filled pit.
10/17/89	1076	2"	From solution pit and channel with samples, hand samples.
10/17/89	1054	2"	Pseudosmorphs after gypsum, polyhalite zones.
10/17/89	1054	2"	Halite pseudomorphs after gypsum, polyhalite.
10/17/89	1029	2"	Basal MB 103, clast zone.
10/17/89	1029	2.5"	Basal MB 103, clast zone with gypsum growth.
10/17/89	1027	2"	From MB 103, zone yielding fluid.
10/17/89	1027	1"	MB 103.
10/17/89	1026.3	2"	From organic zone, yields fluid.
10/17/89	1025.8	2"	MB 103 top.
10/17/89	1025	2"	MB 103, swallowtail zone just above organic-rich zone.
10/17/89	1002	1.5"	Oolitic base of sulfate, MB 102.
10/17/89	980.2	2"	Displacive halite in red clay.
10/17/89	979.8	1.5"	Displacive halite in gray mud.
9/18/89	972	1" 179	From finer halite zone.
9/18/89	971	2.5"	
9/18/89	963	1"	MB 101 polyhalite, hand sample.
9/18/89	954.7	1.5"	Base unit 183.
9/18/89	954	1"	
9/18/89	953	2"	Poikiolitic halite cement

APPENDIX C

AIR INTAKE SHAFT SAMPLES
(CONTINUED)

DATE	DEPTH (FEET)	LENGTH OF SAMPLE	COMMENTS
9/18/89	952	1.5"	
9/18/89	951	2"	
9/18/89	926.3	1.5"	
9/18/89	926	1"	
9/18/89	925.5	2"	
9/18/89	925	1"	
1/14/89	2037.2	1"	Unit 15 base, MB 136.
1/14/89	2036.0	2"	Anhydrite with halite pseudomorphs after gypsum near base of unit 15. MB 136.
1/14/89	2035.5	.5"	Polyhalite in MB 136, top of sample at 2035.5 ft.
1/14/89	2027	1"	MB 136 halite, polyhalite pseudomorphs after gypsum.
1/14/89	2026	1"	MB 136, slabs scaled from wall.
1/14/89	2026.0	1"	MB 136, polyhalite grains in anhydrite.
1/14/89	2023.5	1.5"	MB 136 top.
1/14/89	1966.5	1"	No bag.
1/14/89	1965	1"	
1/14/89	1964	1"	
1/14/89	-	2"	Large slab, no depth or other data.
1/14/89	-	.25"	Small rock chip with up arrow, no other data, no bag.
1/14/89	-	.5"	Small rock chip with concrete on surface, no bag.
1/14/89	-	.5"	Large rock chip with salt crust on surface, no bag.

Appendix D

APPENDIX D

FULL DESCRIPTIONS FROM UNLINED PORTION OF THE AIS

NOTE: THE HALITE CLASSIFICATION DESCRIBED IN APPENDIX E
IS USED IN THESE DESCRIPTIONS

AIR INTAKE SHAFT
LOG DESCRIPTION

903-905	Halite, trace polyhalite; similar to unit below. Upper contact not observed.
905-909.5	Halite, with trace polyhalite, well defined thin to medium beds 2-5"; trace clay at upper contact. Polyhalite as regular to slightly irregular thin laminae to laminae and discontinuous stringers. Some VO MP to 1/2 x 2", local pits to 2' deep. Equant halite, fine to coarse, mainly medium to coarse, IV, trace primary, trace cement. Some probable BG textures. Upper surface sharp. Halite in sequences of polyhalitic halite to coarse clear halite to fine to coarse cloudy halite.
909.5-912.5	Claystone and argillaceous halite, claystone as irregular blebs and zones in pits and as mostly continuous blebby to 1/4-.5" thick drapes over irregular DVT exposure/solution surfaces with .5-1' irregular relief. Lower and upper .5" claystone, argillaceous halite occurs in middle of unit and is locally crosscut by DVT surfaces. Halite occurs as fine to coarse in the argillaceous halite and I-IIa coarse to very coarse in claystone; some fine SIC in uppermost claystone. Claystone locally shows incipient to moderate SIC textures. Clay mostly brown, trace gray at top. Upper contact sharp, undulatory over 4".
912.5-924	Halite, trace to moderately polyhalitic and argillaceous. Divided into an upper argillaceous zone and a lower polyhalite-rich zone by DVT exposure/solution surface at 917.5 with .5' relief; an advanced surface with many pits to 8' deep is at 915.5; lower polyhalitic zone is slightly argillaceous with clay in abundant pits, pipes and MP, clay translocated from above. Abundant interunit pits and MP show multiple generations of solution and cementation, irregular MP 2-6". Polyhalite occurs as irregular discontinuous to moderately continuous thin laminae, laminae, blebby laminae and stringers, irregular blebs, blebby crystal lining on displacive growth of halite. Cement with displacive relationships is abundant. Halite is generally equant, M-VC IV, with abundant irregular zones and pits of fine IV near top; coarse to very coarse I-IIIa-b, some II-IIIc in unit, coarse to very coarse I-III in pits with polyhalite and translocated clay. Clay and claystone in upper part occur as irregular claystone zones in pits, large to small blebs and blebby laminae, and blebby crystal linings of coarse to very coarse halite; clay is mostly brown with trace gray. Entire section shows abundant displacive growth. No strata. Halite mostly IIIa with a trace of b, and irregular, discontinuous zones of IV, coarse to medium,

with some to trace very coarse, some I-IIa-b, medium to coarse. Local pits to 1' deep. Upper surface irregular DVT exposure/solution surface, sharp and irregular with .5' relief.

924-926 Halite interbedded with polyhalite; polyhalite locally thinly laminated with some cross-cutting relationships developed over topographic highs; lower laminae show medium I-IIa-b halite. Halite, trace polyhalite as irregular moderately continuous to discontinuous thin laminae and stringers. Equant fine-coarse IV halite, trace irregular discontinuous subhorizontal interlaminae of fine or medium-coarse halite; polyhalite to coarse clear halite to fine to coarse cloudy halite. Trace primary, probably BG textures, moderate cement. Pits in lower part to 4"; VO MP 1/2 x 2", irregular, moderate to some; upper contact sharp, irregular over 4".

926-935.5 Halite, trace polyhalite, moderate to trace clay. Divided into a lower polyhalite-rich and upper argillaceous zones by DVT exposure/solution surface with a gradational to diffuse contact. Polyhalite occurs as blebs and blebby laminae, very discontinuous, irregular and blebby crystal linings around coarse to very coarse Ia. Halite in polyhalite zone is equant medium to very coarse IV, becoming fair to medium II-IIIb-c, coarse to very coarse I-IIIa, MP to 6" filling. Clay and claystone moderately abundant as large irregular blebs with displacive halite margins (a), irregular zones bounded by displacive margins often in deep pits, local blebby laminae with displacive margins. Claystone dominates above irregular DVT erosion/exposure surface with 2' relief at 929.0 with pits of claystone to 3', as irregular thin beds to 2" with zones of coarse IIIa, and claystone with trace of stratification and abundant medium to coarse, I-IIa.

Halite in argillaceous zone is mostly displacive I-IIIa, coarser to very coarse, some medium, with rare zones of IV, medium to very coarse. Medium to coarse II-IIIa-b, trace equant medium to course IV, and trace fine I-IIa-c in muddy zones; trends upward to more II-IIIc and SIC textures. Local pits 6"-5+'. Very halitic in upper part, coarse to very coarse I-IIa-b and trace I-IIc, overlain by f-ml-IIa-c with trace of Ib-c in dipping mudstone beds. Upper surface sharp, planar.

935.5-944 Halite, moderately to trace polyhalitic, trace to moderate clay, local irregular zones of claystone in pits and upper .5-1+'. Divided into lower polyhalite-rich zone and upper argillaceous zone by irregular DVT exposure/solution surface with 2.5' relief; shows large troughs of argillaceous halite with small poorly preserved pinnacles of polyhalite-rich halite. Polyhalitic zone is crudely to moderately well bedded (3-4");

beds with sequence of polyhalitic halite to clear coarse halite to fine to medium halite, br P. Poly occurs as in lower units with abundant reworking by displacive halite. Halite in polyhalite-rich zone is IV, mainly fine to coarse, with irregular zones of fine and fine to coarse I-IIa-b and trace IIIa-b in pipes; abundant MP to 2" with displacive boundaries locally. Clay and claystone occur in irregular zones with Ia, coarse to very coarse, in pits, large irregular blebs with abundant displacive boundaries and very irregular discontinuous laminae to thin beds (to 1/4" to 1') with displacive boundaries. Rare very thin beds to 1" drape erosional/exposure surfaces, are locally discontinuous. Halite in argillaceous zones is coarse to very coarse I-IIIa, some incorporative, with b-c margins present upward, and irregular zones of medium to very coarse IV, with displacive contacts with clay. Claystone in upper part. Claystone in upper part with hint of strata, very coarse Ia to 4", some sic textures. Upper surface sharp and undulatory over 6".

944-950 Halite, trace to moderate polyhalite, trace to moderately argillaceous. .2' thick polyhalite bed with some medium I-IIa-b at 948.5. Divided into upper argillaceous and lower polyhalite rich zones by moderately well developed DVT exposure/solution surface with .5' relief. Crude thin beds (2-8") in lower polyhalite zone, delineated by polyhalite, become less well defined upward. Interunit pits in polyhalitic zone to 6" with pits at DVT surface to 1.5'. Polyhalite occurs as local irregular, discontinuous thin laminae to laminae; irregular, very discontinuous stringers are common; irregular blebs, most with displacive margins; and POS texture and crystal drapes/linings on top of strata. Halite in polyhalite zone: mainly medium to coarse IV, range fine to very coarse, interstratified irregular zones or beds of medium to coarse halite to fine to medium halite to polyhalite or polyhalitic halitic; trace of fine to medium II-IIIb in polyhalitic halite. Trace to moderate upward irregular MP to 1-2"; very coarse cement in MP. In argillaceous zone: clay and claystone occurs as irregular stringers, very discontinuous irregular blebby very thin beds to 1"; irregular moderately continuous to discontinuous laminae and thin laminae, and blebs with displacive margins. Large MP irregular to 6" x 1' locally, shows probable interzone pits to 6". Halite is medium to coarse IV, with very coarse in MP; IV is most common at base of zone with some IV and mostly fine to medium IIIa-b with some c in upper part. Upper contact irregular over 2-4" , slightly undulatory, sharp to gradational due to later overgrowth of halite.

950-955	Sandstone, silty, halite cement, brown with local greenish-gray reduction; some sic in lower 1'. Mostly structureless, trace to some fine to medium Ia-b, medium at top, trace very coarse poikilitic halite cement. Trace of medium to coarse Ia in upper .5' with well-developed faces on top, irregular base; trace to some fine to medium Ia-c at top. Hints of contorted irregular stratification in upper 1'. Upper contact sharp, slightly undulatory.
955-956.5	Siltstone, brown, hint of stratification; sic, some irregular, poorly defined thin laminae and laminae (in upper .5'). Contains I and some II, mainly Ia-c, trace to some II-IIIb-c, mostly a with some b in medium to fine size. Upper surface undulatory, locally irregular over 2".
956.5-959.5	Halite, moderately polyhalitic in polyhalite-rich zones; trace polyhalite, trace clay in argillaceous zones. Polyhalite-rich zones alternate with argillaceous zones. Polyhalite occurs as blebs mostly, blebbly laminae, very irregular, discontinuous stringers and thin laminae, one regular continuous thin lamina near base. Clay and claystone occur as large blebs, large "blebby" laminae and very thin beds 1/4-1" thick which are very discontinuous with trace of some stringers. Abundant displacive margins between halite and polyhalite, rare between halite and claystone. Some zones, laminae and very thin beds show hints of strata and sic textures. Polyhalite blebs locally surround I-IIa-b. Clay is brown, some gray. Locally very crude and medium beds .3-.5' preserved. F-c I-IIIb-c with trace I-IIIa in polyhalite and clay-rich areas. Halite: medium to coarse equant IV with IV medium to coarse with trace interstratified fine IV, less common upward. Some to trace P upward unit contains intermittent pits to 6" and pits from upper contact to 2'; upper contact irregular over 1'. DVT exposure/solution surface is sharp.
959.5-965	Interbedded polyhalite and halite. Halite: trace polyhalite with local polyhalite interlaminae, lower interbed with trace gray clay as irregular, moderately continuous to discontinuous thin laminae and stringers. Polyhalite occurs as abundant crystal drapes over vel, and crystal linings; some regular to irregular, discontinuous to continuous thin laminae to laminae; irregular, discontinuous stringers, and local POS textures. Equant medium to coarse IV, some P (vel, BG textures, moderate to trace to some cement). No visible MP. Polyhalite is microcrystalline, thinly laminated to laminated, contorted to wavy to regular, local cross-laminae with sets <1" x 3-4" (locally halitic). Interbedded with some zones of anhydrite. Upper interbed contains some irregular zones of subhorizontal I-IIIb-c. Locally upper interbed with poly to anhydrite PAGS to 1/4". Middle interbed with halite PAGS to 1/4". Upper contact sharp, slightly irregular over 2".

965-979.5 Halite, trace to some polyhalite, trace to some clay, with zones of claystone in upper part, and claystone at upper contact (.5+'). Major DVT exposure/solution surface at 970.5 with 1-1.5' relief divides unit into argillaceous zone above DVT exposure/solution surface and polyhalitic zone below. Strata in polyhalitic zone: crude in lower 1' with very thin beds 1-2"; above lower 1' moderately well defined thin to medium beds to 975' (3-6" thick); above 975', crude thin to medium beds 3-6" thick, strata less well preserved up to DVT exposure/solution surface. Polyhalitic zone contains some 6" deep pits throughout section, with 1.5-2.5' deep pits originating at DVT exposure/solution surface. Polyhalite in polyhalitic zone: occurs as irregular moderately discontinuous to very discontinuous thin laminae and laminae; irregular, very discontinuous stringers; blebs rare below 975' become more common upward (but still only trace amounts), some show displacive margins; medium to fine halite crystal drapes (rare) and crystal linings near tops of strata, with some displacive boundaries. VO MP are rare below 975', some above 975' to 1" x4", irregular and large only below 975' to 6" x 1+', rare, and small to 2" common above 975'. Halite in polyhalitic zone is mainly medium to coarse IV, local very coarse in MP, fine IV occurs in sequences of clear halite, fine or fine to medium halite, polyhalite or polyhalitic halite. Halite has trace primary, trace to some cement. Argillaceous beds within polyhalitic zone have a range of displacive halite, mainly f-c I-IIIb-c. Upper zone becomes increasingly argillaceous upward to argillaceous halite in upper part with upper .5+' consisting of brown to gray claystone. Shows some crude DVT textures as irregular zones of trace polyhalite-rich fine IV, some pods from 967-968.5. Crude to absent medium beds (6-10" thick) below 967. Above 967, irregular to regular discontinuous laminae to thin beds 1/4"-.2' of claystone occur over irregular exposure/solution surfaces; claystone shows some irregular, wavy to contorted thin laminae to laminae and sic textures. Planar zone of claystone .3-.5' thick at upper contact. Claystone covered erosion/exposure surfaces are very irregular over 6", often cut and terminate zones of underlying halite. Clay and claystone in argillaceous halite mostly irregular blebs, very discontinuous irregular "blebby" laminae, and stringers; most all show displacive a-b margins. Claystone strata, zones and blebs contain incorporative fine* to medium, I-IIa-b*. Clay lines some fine halite. Halite in the argillaceous zone trends generally from medium to coarse equant IV upward to fine equant IV to displacive halite (fine to medium I-IIIb-c, trace medium I-IIa) in argillaceous halite to claystone. Trace primary, trace to some cement (some very coarse) in pods and

	macropores. Tepee-like structure developed on polygon margin tilts strata up with 4-5" of displacement, polygon margin shows downward translation into pit of clays, 3.5' deep. Argillaceous zone contains probable pits to 6" deep locally, with 3+' deep pits originating at top. Upper surface planar.
979.5-1001	Halite, trace polyhalite, argillaceous in upper part above 991. Polyhalite occurs as continuous to moderately discontinuous upward, regular to irregular, thin laminae to laminae; irregular discontinuous stringers become common higher, blebs irregular above 997', below 997' polyhalite commonly drapes over vertical bottom grown halite, crystal on coarse halite with displacive margins become common upward (absent to rare above 997'). Polyhalite delineates well defined to moderate to crude (upward) thin to medium beds (3-12"). Halite in polyhalitic zone is mainly equant to vertically elongate medium IV overlain by some fine to coarse; trace to major primary with vertical BG fabric in m-c IV, primary (decreases upward), trace cement (increasing upward). Blebs abundant in polyhalitic zone above 993 as are blebby laminae (discontinuous) with abundant displacive margins, 6-12" pits in lower part originate from within unit and deep pits (to 9') originate at DVT exposure/solution surface with 4" relief at 991'. Upper zone is increasingly argillaceous upward to claystone at top; contains local traces of polyhalite as irregular blebs, mostly in pits. Halite is in 5 broad zones; equant medium to very coarse IV with a trace of IV and II-IIIa-b and some II-IIIc in more argillaceous zones at base; equant m-c IV with zones and pods of fine IV and m-c I-IIIa-b and some f I-IIIb-c in more argillaceous zones; mainly f-c IIIb-c with trace I-IIa and incorporative growth, f-c IV; f-c I-IIb-c with trace Ia; to f-m I-IIa with some I-IIb in claystone, with fine halite abundant in irregular subhorizontal zones and pits in interval displaying DVT text (moderately advanced). Local I-IIIa-b, fine to coarse, in more clay-rich zones. Clay occurs as irregular moderately continuous to very discontinuous thin laminae, laminae and near top, irregular blebs with displacive margins and bleb-like discontinuous stringers. Claystone moderately abundant in upper 3' as irregular zones and beds to .1-.2', with abundant I-IIIa-b, with some c, fine to coarse, and local irregular pods of medium to coarse IV, claystone with hints of thin laminae and locally abundant sic texture. Upper 1' mostly claystone with sic texture in lower half and medium Ia in upper half. Upper surface is planar, slightly irregular, sharp.
1001-1002	Polyhalite, medium crystalline, crosslaminae sets to 1" x 3" in lower .2-.4'. Upper part has indistinct contorted strata, with irregular discontinuous zones of halite. Shows possible coated grains in lower part. Upper contact sharp with undulatory surface with 6" relief.

1002-1006	Halite, trace polyhalite, trace gray clay and anhydrite. Polyhalite occurs as irregular, moderately continuous to very discontinuous thin laminae, laminae, blebby laminae and stringers, with local irregular blebs, mostly in pits. Polyhalite delineates moderate to crude thin to medium beds 3-4". DVT exposure/solution surface with 4" relief and pits. Clay as irregular discontinuous thin laminae to laminae. Pits to 1' maximum. VO MP rare to 1/2 x 2", irregular rare to 1". Halite in sequences of fine to coarse equant, clear IV, fine to medium cloudy IV, polyhalitic fine IV or polyhalite. Trace to some primary, moderate cement I-IIIa-b in polyhalitic and argillaceous zones; medium to coarse Ic preserves. Upper surface sharp, irregular over 1", with slumping into some pits on a small scale. Sulfate crystal growth in cavity.
1006-1013	Halite, trace to some (upward) clay with trace polyhalite in lower part. Polyhalite occurs as irregular blebs with some displacive margins and very discontinuous irregular stringers. Claystone occurs as irregular moderately continuous laminae delineating 1-4" thin to medium bed in upper part and blebs and discontinuous to irregular blebby thin laminae to laminae, blebs in pits with abundant displacive margins. Local I-IIa-b, medium to fine in clay-rich zones. Fine to coarse equant IV and zones of fine to medium equant opaque IV; trace to some primary, trace to abundant cement. Fair to medium I-IIIb, medium to coarse I-IIa-b in argillaceous zones. Pits to 1'. VO MP abundant, 1 x 3", irregular 4-3". Upper contact sharp, irregular over 2", with local pits to 6". Clay brown with local gray.
1013-1029.5	MB103. Anhydrite, lower part anhydritic dolomite. .5-1' gray claystone at base is thinly laminated with subvertical 1/2-1" thick halite-filled fractures. Dolomite zone to 1025.5 shows abundant weeps and surface is moist (Figure 1). Thin zone of probable ripup clasts at 1028, overlain by probable tepee structure. Zone with laminae and wavy laminae and possible organic material in algal zone 1026-27. 1/4" halite PAGS at 1025. Upper part of anhydrite thinly laminated to laminated to very thinly bedded, most parallel, some wavy, contorted to convolute bedding; abundant halite and rare anhydrite PAGS to 2". Upper contact sharp, marked by possible tepees with 6"-1' relief.

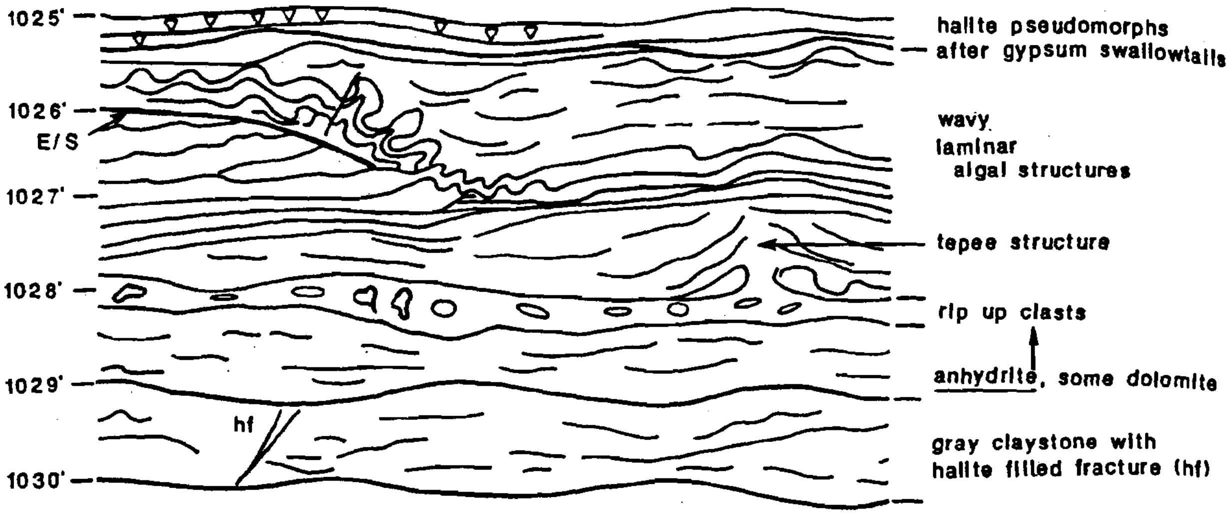


FIGURE 1 RIP UP CLASTS AND ALGAL STRUCTURES IN BASAL MB103

1029.5-1036.5	Halite, trace polyhalite, clay is trace to some above the lower 1-1.5'. Trace anhydrite as irregular thin laminae and stringers, discontinuous and blebs, with some displacive halite margins above 1034-35. Clay occurs as irregular thin laminae to laminae, discontinuous to moderately continuous, blebs and irregular zones in topographic lows. Polyhalite occurs as discontinuous irregular blebby laminae and blebs with displacive halite margins (coarse size, a type). Abundant displacive margins with sulfate and clay. Local VO MP 1 x 4", irregular to 2", pits locally 6" to 1'. Abundant DVT exposure/solution surfaces marked by clay with <6" relief (incipient). Coarse to very coarse equant IV with fine to coarse IV in argillaceous zones. Halite medium to coarse IV, trace to some primary, some cement. Medium to coarse I-IIIb-c in lower argillaceous zones to I-IIIa-b upward; fine I-IIIb-c increases upward. Upper contact sharp, irregular over 6".
1036.5-1037.5	Anhydrite; thinly laminated to laminated; halitic in irregular zones of IV and as possible pseudomorphs after gypsum clastic grains; strata contorted to very irregular. Halite zones very discontinuous, support topographic highs. Upper surface irregular, undulatory over .5'.
1037.5-1046.5	Halite, trace polyhalite near base; irregular anhydrite interbed at 1042", .2-.3' thick. Local anhydrite laminae to thin laminae from 1039.5-1049.5, trace polyhalite and clay in upper 2'. polyhalite in lower part: regular thin laminae to laminae, moderately discontinuous to continuous, planar; in lower 2' with some BG halite, lining halite crystals and local POS textures; irregular blebs with some displacive margins; irregular, discontinuous thin laminae to laminae and stringers above lower

	wave length < 5'. sharp. Polyhalite locally contains irregular zones of halite near top.
1054.5-1070	Halite, trace to some polyhalite, argillaceous and polyhalitic from about 1057.5 to top, .5' brown halitic claystone at upper contact. In polyhalitic zone, poly occurs as: irregular subhorizontal discontinuous stringers, thin laminae to laminae, in lower 1' shows some vertical crystal shapes and lines some medium Ia displacive halite as crude POS texture, irregular blebs (some with displacive margins) mostly in pits, irregular to discontinuous "blebby" laminae. Trace brown to gray (anhydritic) clay as irregular discontinuous stringers in pits. Polyhalite, as "blebby" laminae, very discontinuous and irregular and stringers and irregular blebs dominate upward. Incipient polyhalite boxwork texture from 1056.5-1059'. DVT exposure/solution surface with about 6"-1' relief at 1056.5. Halite in polyhalitic zone: generally fine to coarse equant IV, trace to some primary and to some cement. Clay in upper part as irregular discontinuous thin laminae and "blebby" laminae, stringers and blebs local irregular zones in topographic lows. Unit below argillaceous zone (below about 1057.5) is thin to medium bedded, crude to well defined, 3-6", delineated by polyhalite. Interbeds have general sequence of polyhalite or polyhalitic halite at base, clear coarse halite and trace to some primary and cement in macropores, overlain at top by fine to medium cloudy halite. VO MP to 1/2" x 2" and irregular MP to 6+", most about 1-2". Pits abundant, 6"-3' deep with translocated material. Fine IV moderately abundant in lower 2-3' and from 1058-1061. Some opaque fine to medium IV in beds or zone with clear medium. Upper contact sharp, slightly undulatory over 3" with a wave length of about 6'. Claystone at upper contact .5+' thick thickens to <1' over pits, contains medium to coarse I-IIIa-b in lower part, thinly laminated with some sic texture and fine I-IIIc in upper part (.1-.2""); brown clay with local gray. Trace to some primary, moderate cement.
1070-1075	Halite, trace to some polyhalite, trace to some clay in upper part. Has clay with halite and some claystone in pits originating at upper contact. Unit has moderate amount of pits 6"-4' deep. .5' polyhalite at base with irregular zones of halite, local thin laminae to laminae with possible halite PAGS to 1/4". Halite is generally medium to coarse equant IV, some cement in pores and pipes, and fine to medium opaque equant IV in nearly continuous beds. Moderately well to crudely medium bedded 4-12" delineated by "blebby" laminae of polyhalite. Upper 1' argillaceous. Polyhalite granular, slightly argillaceous. Occurs as irregular blebs and discontinuous irregular moderate to very discontinuous with some stringers. Local

blebs of claystone in pits with fine to medium I-IIIc and trace medium to coarse I-IIa-b*, trace gray clay infiltrated into pits. Polyhalite blebs show some displacive margins. Local irregular MP to 2".. Trace clay stringers locally. Upper surface planar, with pits.

1075-1098 Halite, trace to some polyhalite from 1098 to about 1091; becomes trace to moderately argillaceous in upper part with irregular zones of claystone. Polyhalite occurs as moderately continuous irregular thin bed .1-.2' thick at 1094, irregular moderately continuous but more often very discontinuous thin laminae to laminae, irregular stringers, irregular blebs with some displacive margins (mostly in pits and irregular "blebby" laminae (as solution lag surfaces, and zones in pits with medium to coarse I-IIa-c. Strata in polyhalite zone are very crude to not distinguishable, from fine to medium beds 2" - 1.5'. Halite in polyhalite zone medium to coarse IV, very coarse IV in MP. Trace primary, trace cement in MP. VO MP 1" x 2" are rare. Irregular MP to 3". Pits 6" to 2+'. From about 1091 to about 1087, halite is mainly fine to coarse equant IV, with trace primary and some cement in MP and some pipes; some fine to medium II-IIIb-c in irregular zones and argillaceous blebs. Fine to medium equant opaque IV in discontinuous beds to pods with zones of fine to coarse II-IIIb-c and some medium to coarse equant IV. Above 1087, unit becomes moderately well to crudely thin to medium bedded 4-8" with irregular laminae of polyhalite or clay delineating strata, local boxwork fabric present. Above 1087, polyhalite becomes partly argillaceous and occurs as irregular continuous to locally very discontinuous thin laminae and laminae, with abundant very discontinuous blebby stringers and blebs. Appears very disrupted by pits and MP, irregular to 3". Near 1085, DVT exposure/solution surfaces are present with polyhalite and clay laminae as continuous to very discontinuous laminae and local solution lag; collapse of bedded block into pit. Halite in upper argillaceous zone: generally medium to coarse IV with trace primary and trace to some cement. Displacive halite above 1085 trends from medium to coarse Ia-b to fine to coarse I-IIIa-c (mainly b) to fine to coarse I-IIIb-c upward. Laminae and blebs and blebby stringers show some displacive margins. Clay becomes more dominant (brown to locally gray) upward as irregular discontinuous stringers, blebs and irregular continuous to discontinuous laminae to thin beds of claystone. Exposure surfaces are topped by claystone, much of this claystone shows medium to coarse I-IIa-b. Claystone zone in topographic low shows rippling. Claystone with well developed medium to coarse I-IIa, some irregular strata (laminae to thin laminae) occur in irregular zones which are vertically aligned. As no laterally equivalent claystone occurs these probably originated as infiltration mud transported in deep channels in pits or small caves; these zones cross-cut halite strata and are very irregular and show no internal continuity with strata. They are, however, vertically interconnected; large zone at upper contact showing trough laminae and parallel laminae (Figure 2). Upper 2' very argillaceous with claystone blebs. Abundant pits 16"-2' deep. Claystone 2-6" continuous with large pit of claystone, ripple cross-laminae (1/4-2") with medium to coarse I-IIa. Upper surface sharp and undulatory of 3". Pits originate in claystone at top.

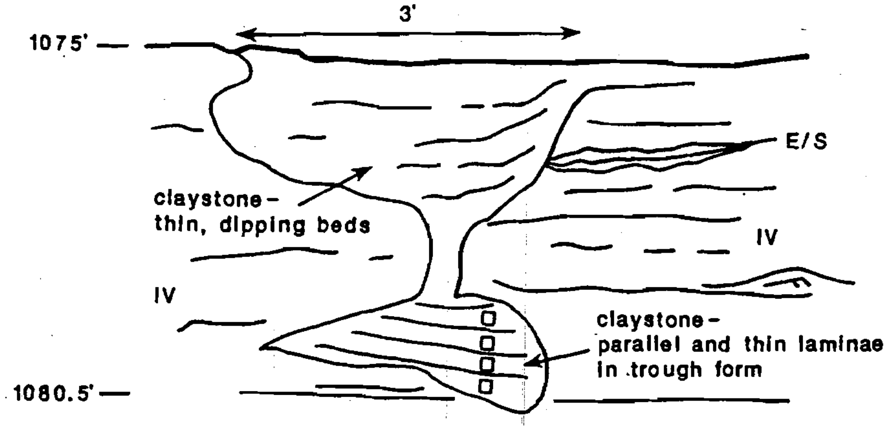
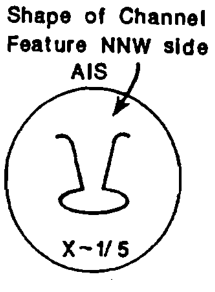


FIGURE 2 CLAYSTONE FILLING DEEP SOLUTION CHANNEL OR ORIGINAL SMALL CAVE, SOUTH SIDE AIS



1098-1109.5 Halite, some to trace polyhalite; above lower 2' trace to some brown with some gray clay. Polyhalite occurs as .2-.3' thick irregular halitic bed at base with collapse into underlying pit, irregular discontinuous thin laminae, laminae, stringers, and irregular zones and blebs in pits with displacive margins. Clay occurs as irregular very discontinuous stringers and blebs with displacive margins and less frequently irregular discontinuous to moderately continuous thin laminae and laminae and irregular zones. Crude strata locally preserved near middle of unit, 4" to 1' thick to medium beds with fine to medium I-III. Polyhalite and clay translocated in pits. Pits 6"-3' deep and abundant. VO MP rare, 1" x 3". Irregular MP locally abundant to 2-3". Local subhorizontal zones of claystone with fine to medium I-IIIa-b. Halite in unit is mainly medium to coarse IV, locally very coarse in MP. Trace to some primary, some cement in MP and pipes. Unit tends to II-IIIb-c with a trace of Ia-c in argillaceous and sulfate parts. Upper .5' claystone, brown with fine to medium I-IIIa-b mainly Ia. Upper contact sharp, planar, pits 6"-2'.

1109.5-1119.5	Halite, some to trace polyhalite from 1119 to about 1113, trace brown and gray clay in upper 3' above DVT surface. Lower .5' consists of laminated polyhalite at top with swallowtails and anhydrite at base with .1' thick anhydritic gray claystone within laminae. Polyhalite occurs as continuous, slightly irregular thin laminae to laminae in lower 2', to discontinuous irregular thin laminae, laminae, stringers, and irregular blebs and small zones with displacive margins, common in pits. In lower 2', POS textures and well developed crystal drapes showing BG halite occur. Some vertically elongate halite zones are planed off by polyhalite laminae. Irregular DVT exposure/solution surface occurs near 1113 with 1.5' relief. Clay occurs as irregular very discontinuous thin laminae, stringers and blebs, many with displacive (a-b) margins. Foreign material delineates thin to medium beds (2-10" thick) well defined at base to crude at top. Local medium to very coarse I-IIIa in pits with polyhalite. Contains abundant pits to 5' deep, most 6" to 2'. Some originate at upper contact. Pits and MP rare in lower 2', become abundant upward. VO MP to 1" x 3", irregular; MP to 4". Halite is medium to coarse and some very coarse IV, major vertically elongate and primary in lower 2' to some to trace primary upward with equant halite. Cement trends from trace in MP near base to some cement in vertical macropores and pits in argillaceous zone. Argillaceous zone exhibits medium to coarse II-IIIb-c with trace Ia-c in blebs and thin laminae of clay and polyhalite. Upper surface irregular with pits and collapse of overlying material, sharp.
1119.5-1132.5	Halite, clear in lower part, argillaceous in upper part; argillaceous part is trace polyhalitic, with discontinuous and irregular local thin laminae to laminae of anhydrite. Polyhalite occurs as irregular blebs, most showing translocation into pits. Clay occurs as irregular discontinuous to moderately continuous thin laminae and laminae (to 1/2"), horizontal to subhorizontal, delineating thin to medium beds 2-10" thick. Clay occurs in blebs and irregular zones, and translocated material in shallow pits. Pits occur locally to 2+' deep. Medium to coarse equant IV throughout unit, trace fine IV in clear parts in lower 2'; zones of medium to coarse II-IIIb-c, and very thin zones of fine to medium I-IIb-c, trace IIIb-c, in clay-rich zones. VO MP to 1" x 2" and local 2-3" irregular MP. Local clear pit to 1' x 1.5' at upper contact. Upper contact sharp, marked by .2' thick brown claystone with medium to fine Ib.
1132.5-1137.5	Halite, trace polyhalite below about 1135 in lower part, trace to some argillaceous in upper part. Polyhalite occurs as irregular, moderately continuous to discontinuous thin laminae to very thin beds (one at 1135.5), stringers, blebs and irregular zones; blebs and zones mostly in pits showing displacive margins, some with very coarse

IV. Clay occurs as irregular, discontinuous (becoming more continuous upward), thin laminae to laminae in upper 6", blebs, irregular zones; content increases from trace to moderate at top. Local laminae of claystone present near upper contact. Contact between argillaceous and polyhalitic zone is irregular over 2' DVT exposure/solution surface at about 1134 and above. Shows pits 2'-6". VO MP to 1" x 2", irregular to 2", moderately abundant, increasing upward. Polyhalitic zone shows trace to some primary, trace cement in MP; beds with sequence polyhalitic halite to coarse clear halite to fine to medium cloudy halite. Halite in unit is medium to coarse IV, with some very coarse in MP. Upper argillaceous part also shows fine to medium I-IIIb-c and medium to coarse, trace very coarse I-IIIa-b; moderate primary near base of argillaceous zone. Halite does not readily display MP in argillaceous part. Local gray clay near base of argillaceous zone. Upper surface sharp, slightly undulatory over 2".

1137.5-1141.5 Halite, trace to moderately argillaceous (brown and gray clay) and trace polyhalitic. Polyhalite occurs as irregular, moderate to very discontinuous thin laminae and laminae to 1" thick (all rare) and abundant irregular blebs and zones with b,c margins with halite. Some medium to very coarse Ib-c. Most blebs are small as dissolution lags (reworked) and translocated material into pits. Clay occurs as irregular discontinuous laminae, halitic claystone zones in topographic lows, translocated pore fillings in zones to 1' x 6" at lower contact, and blebs. In pore zones claystone may have medium to very coarse Ia (crystals to 2" on a side). Halite originally polyhalite-rich; clay infiltrated downward in abundant dissolution pits from DVT exposure/solution surface. Upper part is very argillaceous. Halite is fine to very coarse IV and a trace of primary halite with pods to discontinuous layer of fine IV from 1139-1140 near middle of unit at DVT surface. Clay-rich upper part has irregular zones and discontinuous laminae to thin beds of claystone with fine I-IIIb-c and medium to coarse halite I-IIIa-b; fine I-IIIb-c becomes more fine I-IIIa upward. Unit contains abundant pits 6" -3' deep showing infiltration of polyhalite and clay. Upper surface is sharp, slightly irregular over 1". Claystone locally shows sic textures.

1141.5-1147.5 Anhydrite and polyhalite in irregular zones and in lower 1.5-2'. Lower .1-.3' consists of gray claystone with irregular thin sulfate laminae, medium crystalline. Halitic, as halite PAGS 1/8-2" high within laminae, as possible halite replacement of gypsum clastic grains in local irregular, discontinuous zones, and as coarse halite filling voids associated with desiccation feature. Polyhalite and anhydrite may occur as PAGS, most small (1/3-1/4" high). Some zones of halite PAGS grade laterally (often within same lamina) into polyhalite or anhydrite PAGS. Laminae of polyhalite are laterally traceable within anhydrite. Strata thinly laminated to laminated, wavy to convolute to slightly contorted. Cross-cutting relationships are abundant near polyhalite/anhydrite transition and near top. Upper 1-1.5' shows abundant halite and displays "teepee" structures with abundant porosity filled with infiltrated black to gray clay and halite cement. Deposition occurred between tepees following their development. Swallowtails now filled with halite possibly collapsed. Large desiccation? prism crack with infiltrated black clay and halite cement (about 5' deep) with polyhalite alteration on margins of crack. Polyhalite-rich irregular zone adjacent, but not connected with polyhalite in crack - contains no halite, possibly more porous. Black clay laterally infiltrated into strata from crack. Upper contact sharp, irregular over 1' with abundant relief.

1147.5-1155 Halite, some to trace polyhalite upward, trace to some gray clay and anhydrite in upper 1'. Polyhalite is generally more granular than previously observed and occurs as very irregular moderately continuous to very discontinuous thin laminae to very thin beds (to .1' thick, maximum), irregular very discontinuous stringers, irregular small to large blebs, and irregular zones. Blebs and zones may show displacive margins and some contain medium to very coarse la. Moderately well to crudely defined thin to medium beds 2"-1' thick delineated by polyhalite. Halite is commonly in sequences of polyhalite or polyhalitic halite to clear coarse halite to medium-coarse cloudy halite. Clay occurs as irregular very discontinuous laminae to thin laminae, zones and irregular blebs often with a-b margins and local medium la within clay. Clay is gray. Fine to very coarse, mainly medium to coarse halite IV; fine IV occurs in pods and lenses in upper 1' with clay. Trace primary, some possible vertically elongate halite in polyhalitic zone; trace to moderate cement. VO MP TO 1" X 3" with irregular to 3". Pits with translocated polyhalite 6"-3+' deep. Upper contact planar wavy, undulatory (3" x 3-5'), sharp.

1155-1159 Halite with thin interbeds of anhydrite: .2-.3', .1-.2', .2-.3', and .5-.6' thick from bottom to top. Anhydrite interbeds are thinly laminated to laminated, parallel to wavy to contorted, medium crystalline, halitic. Halite in anhydrite interbeds: some irregular discontinuous thin beds to 1" thick of halite PAGS to 1/2" high; possible zones of intermixed anhydrite and halite with possible clastic texture; some irregular zones of fine halite with anhydrite are very irregular and discontinuous - possible early replacement of gypsum grains by halite. Halite: mainly medium to coarse IV, with local zones of fine associated with sulfate. Trace primary, some cement.

	Local VO MP to 1" x 3". Thin to medium beds well delineated by sulfate. Sulfate within halite interbeds is mostly polyhalite in lower part and anhydrite in upper part. Distinct polyhalite zone (0-1" thick) occurs in topographic low on top of first anhydrite interbed. Sulfate occurs as very continuous to moderately discontinuous thin laminae to laminae with rare stringers, irregular blebs and POS textures in lower halite interbed. Pits to 4" deep in lower halite interbed. Upper contact sharp, slightly wavy and irregular over 1".
1159-1162.5	Anhydrite at base and top gray mudstone with coalesced to isolated anhydrite nodules in middle, and polyhalite - thinly laminated to laminated with halite PAGS 1/8-1.5" high. Medium crystalline. Anhydrite: thin laminae to laminae with irregular and discontinuous laminae, most parallel, some low angle cross cutting relationships, local slumps, and deposition drapes lower contact. Laminae deposited on sides of topographic highs at lower contact slumped downward into troughs. Some small (<1/2" x 3") ripple cross laminae sets occur. Overall thickness of strata decreases from about 1/4" to about 1/16" at top. Small anhydrite pseudomorphs after bottom grown gypsum in some thicker laminae in upper half of anhydrite. Surface below nodular zone is irregular with some strata terminating at nodules. Argillaceous nodular part: clay content increases from moderately argillaceous anhydrite at base to anhydritic mudstone at top. Anhydrite occurs as well developed nodular material with possible bedded nodular textures in lower .1' and .1' thick zone in middle of unit which retains small 1/8" anhydrite PAGS. Above middle bedded nodular zone, clay content increases and nodules are isolated in mudstone. Below bedded nodular zone, nodules coalesce. Upper surface of argillaceous part is sharp, upper 1/4-1.5" of argillaceous zones shows thin laminae to laminae. Upper polyhalite-rich part has irregular thin laminae to laminae with abundant 1/8-1.5" halite and polyhalite PAGS.
1162.5-1164.5	Halite with trace to some (upward) polyhalite. Polyhalite occurs in irregular zone, subhorizontal, to 1/4-2" thick on dissolution surface and irregular blebs mostly in pits. Medium to coarse halite IV, trace very coarse as cement. Trace to possible abundant primary, moderate cement. I-IIIa-c near top. Irregular MP to 5". Pits to 6" near top. Upper contact irregular over 2", sharp.
1164.5-1167	Anhydrite, medium crystalline, thin laminae to laminae, contorted to convolute to wavy; with possible clastic halite and halite PAGS to 1" high. Upper surface sharp, very irregular over 2".
1167-1174	Halite, trace polyhalite, local zones with trace gray clay. Two upper 1/4" polyhalites and lower 1" polyhalite as irregular continuous strata near base. Polyhalite also

occurs as irregular moderate to very discontinuous thin laminae, stringers, irregular blebs (mostly in pits) and rare crude POS texture. Clay occurs as very discontinuous thin laminae to laminae, stringers, and blebs. Upper gray argillaceous part with anhydrite similar to polyhalite. Blebs with I-IIa margins, middle of unit crudely thin to medium bedded (2-6"). Abundant pits to 6" in upper part. MP trace to some moderate with VO MP 1/2-1" x 1-2", and irregular, rare to 2". Medium to coarse IV, with irregular zones and beds of polyhalitic halite to clear coarse halite to fine cloudy halite. Foreign material translocated down into pits. I-IIIa-b in upper 2', mostly I-IIb upward. Trace primary, trace to some cement in macropores. Upper contact irregular, anhydrite content increases to abundant in upper 2". Small 1/4" swallowtails in lower most polyhalite bed.

1174-1200 Halite, trace polyhalite below 1174; brown argillaceous zones above 1174; zones of halitic claystone near top, upper contact gray. Polyhalite occurs as irregular, moderately discontinuous to very discontinuous thin laminae and laminae, local irregular discontinuous stringers, irregular zones in pits with displacive boundaries, irregular blebs large to small (large mostly in pits) with locally abundant displacive margins and medium to very coarse Ia-b. Crude thin to medium beds (3-1") delineated by polyhalite. Tops of polyhalite-rich zones show deep pits. Abundant pits from 6" to 7-8' deep. MP vertically oriented from 1/2-1" x 1-3" to irregular MP 1" maximum. Clay occurs as irregular discontinuous to moderately continuous thin laminae to laminae, blebs, discontinuous irregular stringers - brown to gray. Halite is mainly medium to coarse IV with trace of fine IV in polyhalitic zones and trace of very coarse cement; local irregular subhorizontal zones and pods of fine halite with DVT textures at erosion/solution surfaces on tops of polyhalite-rich zones, and in pits as pit fillings. Trace to some primary; trace to major cement. Crude poly box-work fabric below 1184. DVT exposure/solution surfaces. Claystone shows sic texture in upper gray zone. Halite in argillaceous zone above 1184: irregular pods of fine to medium white opaque IV set in medium to coarse IV with I-IIIa-b from 1184-1182; medium to very coarse IV similar to lower part of unit from 1182-1180; medium to coarse IV, some I-IIIa-b with clay and ply in upper part, trace primary and cement, trace fine IV in pods from 1180-1177.5; medium to coarse I-IIIa-b and fine I-IIb-c from 1177.5-1177; from 1177-1174.5 is similar to 1177.5-1180; mainly fine Ib-c with trace of coarse to very coarse Ia, some III or IV in small zones from 1174.5-1174. Lower brown claystone on irregular DVT exposure/solution surface with 4" relief, material locally translocated down into pits. Upper surface sharp, irregular over 1".

1200-1208	Halite, trace to some polyhalite, zones with trace gray clay, very argillaceous br halite or halite claystone in upper 1.5'. Well defined at base to crude upward, t to medium beds (4-8" thick) delineated by polyhalite. Polyhalite occurs as irreg continuous laminae and thin beds 1/4-2" thick in lower 3'. Irregular continuous discontinuous thin laminae and stringers, "blebby" thin laminae and laminae, lo irregular bleb-like zones 1"-3" thick with medium to very coarse Ib. Polyhal translocated downward in abundant pits to 3' deep. Clay occurs as discontinuo irregular stringers and local blebs. Gray, trace brown clay in pits and near t Medium to very coarse IV, trace fine throughout; medium to coarse I-IIIa-b to fine medium I-IIIb-c in upper 1.5'. Trace to some primary, trace to some ceme Abundant MP irregular to 3", VO 1/2-1" x 1-2". Overlain by brown claystone zo Contact on irregular surface with 4' relief. DVT exposure/solution surface. Hali claystone shows sic textures. Upper surface planar.
1208-1215.5	Halite, trace polyhalite in lower part, trace gray clay at top. Moderately well crudely defined upward thin to medium beds (2-8"). Strata not apparent abo 1211'. Polyhalite occurs as irregular, discontinuous thin laminae to stringer crystal linings and POS textures in lower 2'. Above the lower 2', polyhalite most occurs as larger irregular blebs with some irregular discontinuous thin laminae an laminae locally. Blebs as solution lags and in pits, often show displacive margin Clay occurs as gray with some brown stringers and local blebs. Fine to very coars IV overall; medium to coarse to 1214, medium to very coarse to 1209, fine t coarse to 1208. Below 1210.5, shows sequences of polyhalitic or polyhalitic halit to coarse clear halite to medium to coarse cloudy halite. Trace primary, trace t some cement. MP moderate to abundant upward, VO 1/2-1" x 1-3", irregular to 4"; most common upward. Contains abundant pits to 3' deep with translocate polyhalite throughout unit. Upper surface sharp, marked by collapse of overlyin material into pits, slightly irregular over 1". Irregular zones of fine IV near top.
1215.5-1216	Polyhalite, medium crystalline, locally halitic as irregular to well defined lenticula zones 1/2" x 3" parallel to strata. Hints of laminae to structureless. Upper surface sharp to irregular over 2".
1216-1221.5	Halite, trace polyhalite, alternate zones with trace gray clay and anhydrite near base. Poly occurs as continuous to very discontinuous thin laminae to laminae, irregular discontinuous stringers, blebs mostly in pits and crude POS textures. Clay as irregular, very to moderately discontinuous, thin laminae and stringers, often associated with fine IV (in irregular zones). Mostly medium to coarse IV, with some fine to medium in basal zone and trace fine IV at top. Trace primary, trace abundant

to some cement in macropores and pipes. Some sequences of fine polyhalitic halite to coarse clear halite to fine and medium cloudy halite. Locally abundant VO MP 1/2-1" x 1-2" and irregular to 3". Unit moderately well to crudely medium to thin bedded (2-10" thick), delineated by foreign matter. Contains well developed pits 3"-2' deep with translocated material. Upper surface planar, sharp.

1221.5-1233.5 Halite, trace polyhalite. Trace to some clay above basal 2.5'. Polyhalite occurs as very discontinuous, irregular thin laminae and stringers and irregular blebs with some displacive margins, large blebs with medium Ia in pits. Clay occurs as irregular slightly continuous to very discontinuous laminae and thin laminae (many as solution/exposure lag), irregular discontinuous stringers and blebs. Blebs and small irregular zones showing fine to medium I-IIa-b. Halite in polyhalitic to 1232 part: medium to coarse IV, trace fine; trace primary, and cement. Shows VO MP 1/2-1" x 1-2". Halite in argillaceous part: medium to coarse IV, with irregular subhorizontal zones and subhorizontal pods of fine to medium overlain by clay solution/exposure lags, medium to coarse I-IIa-b in clay, to 1227; fine to medium IV in pods and beds with fine I-IIIb-c and medium to coarse I-IIIa-b between pods to 1224; medium to coarse IV with II-IIIa-b to 1222; and fine to medium IV with fine to medium I-IIIa-b and basal medium I-IIa-b to 1221.5. Clay in argillaceous part is brown to gray. Argillaceous part shows abundant DVT textures and solution/exposure surfaces. Pits 6"-2' deep are abundant throughout unit. Irregular macropores present to 3". Clay and poly translocated down in some pits. Rarely, fine IV occurs in some pits. Upper 1.5-5' shows sic textures. Filled prism cracks to 4" deep at upper contact. Upper surface planar, sharp, locally irregular over 1".

1233.5-1235.5 Polyhalite, microcrystalline, underlain by 1-3" thick gray claystone, medium to thinly laminated locally, upper contact of claystone with polyhalite shows gravity loading and slumping with some flame structures around incipient pillows. Halite occurs as probable PAGS in large (4" x 1' maximum) teepee-shaped zones of halite, possible BG halite with sulfate drapes, medium to coarse III, local irregular zones 4" x 8" of coarse to very coarse IV with no to few crystal drapes, local medium to coarse Ic. Halite zone boundaries with polyhalite are usually irregular. Some crystal linings within IV may be displacive. Polyhalite is mostly laminar; laminae are slightly contorted to convolute in hummock (Figure 3). Relief on upper surface great (6-8") between hummocks with about 7' wavelength. Irregular halite zones occur most often below hummocks and are smaller and less common in troughs. Polyhalite in troughs shows collapse and convoluted textures. Higher in the unit, strata thicken in troughs and thin over the hummocks. Some possible BG halite in concave upward lenticular zones in troughs near top of unit.

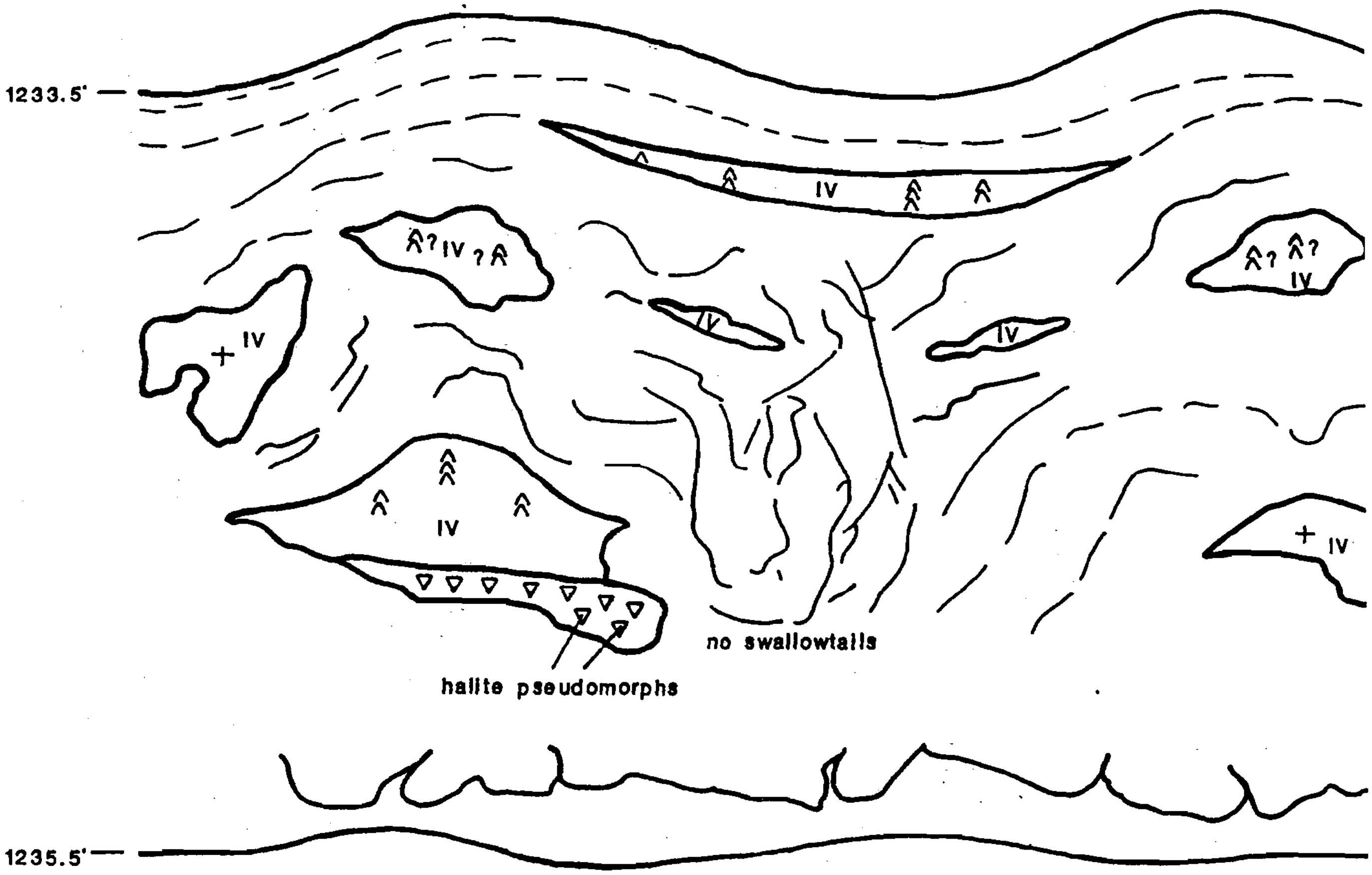


FIGURE 3 CONTORTED BEDS AND BOTTOM-GROWN HALITE IN MB112

1235.5-1249 Halite, trace polyhalite with local interzones with trace to some gray clay and anhydrite. Pits 1-5' deep. Upper surface sharp, planar, marked by gray clay. Shows crude to moderately well defined medium to thin beds locally 2-8" thick, best defined near base, with sequence of fine polyhalitic halite to clear coarse halite to cloudy medium halite with trace of fine. Polyhalite occurs as irregular continuous to discontinuous thin laminae and stringers, blebs and zones in pits, local crystal shapes and coating near base (linings, POS textures, locally blebs have medium I-IIa-b. Clay occurs as irregular discontinuous to continuous stringers, laminae and thin laminae, irregular zones, blebs with some fine to medium I-IIa. Both polyhalitic and argillaceous zones show downward translation in pits and some MP. MP abundant from small to large (4-5"). Mainly medium to coarse IV, some fine to 1245, trace primary; fine to medium IV in layers and pods, medium to very coarse in

	irregular subhorizontal zones and some medium or fine I-IIIc to 1237, trace to some primary, trace to moderate cement upward; medium to coarse IV with some I-IIIa to 1235.5. DVT textures abundant in middle of unit. Upper surface sharp with pits to 2' deep, irregular over 2". Planed off by flooding. MP size decreases in upper 2'.
1249-1252.5	Halite, trace polyhalite to 1250, some clay in upper argillaceous zone. Polyhalite occurs mostly as large blebs with medium to coarse Ia-b halite, similar to 1253-1260. Clay as blebs and blebby stringers, irregular discontinuous thin laminae to laminae. Blebs become abundant upward with I-II-IIIa-b with blebs. Local pits to 6". Fine to coarse IV halite mainly medium, fine to medium IV abundant in upper 1.5' as irregular pods and lenses. Trace primary, moderate cement. Fine to medium I-IIa-b in upper 1.5' in halitic claystone. Upper surface sharp, planar.
1252.5-1253	Polyhalite, medium crystalline with 1/4 to 1" thick gray clay at base with load features into clay. Trace medium to coarse Ia-b locally. Mostly structureless shows some irregular thin laminae with contortions. Upper surface sharp, irregular over 2".
1253-1260	Halite, trace polyhalite, trace brown to gray clay in upper part. Polyhalite as very discontinuous thin laminae to laminae, discontinuous stringers and irregular blebs and zones mostly in pits as translocated material, often as solution lags. Blebs small at base, large at top. Clay as irregular discontinuous laminae over exposure/solution surfaces and disseminated small blebs and stringers. Fine to very coarse, mainly medium to coarse IV, fine near top and in possible pits. Some sequences of polyhalite or polyhalitic halite (fine) to clear halite to polyhalitic halite. Trace primary near base, moderate cement increasing upward. Trace to abundant upward VO MP 1/2-1" x 1-3", and irregular MP to 3" near top. Moderate interunit pits and pits at upper contact to 3' deep. Upper surface sharp, irregular and undulatory over 3", marked by gray clay.
1260-1261	Polyhalite, medium crystalline, trace halitic. Underlain by 1/4-2" thick gray claystone. Halite as 1/2-1" continuous to discontinuous subhorizontal to horizontal zones, some with BG textures. Irregular contorted to wavy thin laminae to laminae. Upper surface sharp and irregular over 2".
1261-1264.5	Halite, some to trace clay and polyhalite, argillaceous in upper 1.5. Brown and gray in lower 1.5', gray in upper 2'. Clay as irregular discontinuous stringers and thin laminae, in pits as blebs with displacive margins. Polyhalite as irregular blebs in pits. Content of each decreases sharply upward. Fine to very coarse IV, with abundant fine in irregular subhorizontal zones and pods near base. Moderate cement. Abundant MP upward 1/2" x 1" to 2", not VO. Shows local pits to 1' deep abundant at upper surface. Upper surface irregular, very undulatory over 6",

marked by transition to gray claystone. Claystone infiltrated into pits.

1264.5-1275.5	Halite, alternately polyhalitic and argillaceous (all trace amounts) with intervening DVT exposure/solution surface. Pits to 1.5-2' deep with DVT exposure/solution surface relief to .5'. Polyhalite occurs as irregular continuous to very discontinuous thin laminae and discontinuous stringers, crystal drapes, linings, POS texture, and as irregular blebs mostly in pits. Polyhalite margins frequently displacive. Clay as irregular discontinuous subhorizontal stringers, translocated material, irregular blebs and blebby stringers - often associated with fine IV. Fine to very coarse halite IV, trace to some primary and vel, trace to some cement, fine IV mainly in polyhalitic zones and in pods to lenses in gray zones near base. Moderately abundant MP, some VO 1/2" x 1", others to 4". Medium to coarse I-IIa with polyhalite in some pits. Local BG fabrics with polyhalite drapes. Upper surface sharp with pits, irregular over 4". Local box work fabric in upper 2'.
1275.5-1283	Halite, trace polyhalite at base, slightly to moderately argillaceous upward claystone at top. Polyhalite occurs as irregular to continuous to discontinuous thin laminae and laminae with irregular stringers, irregular blebs (some as lags and some translocated downward in pits with medium to coarse Ia), some with displacive margins. Clay occurs as irregular discontinuous laminae, irregular blebs and zones of blebs, some with a-c margins, rare zones with sic textures, translocated in pits. Medium to coarse, some very coarse IV to 1276.5, trace fine IV near top of zone, some IIIa-b, trace to some primary, decreasing upward; trace cement in macropods increasing upward. Mainly Ib-c above 1276.5 with some fine II-IIIb-c, all surrounding lenses of medium to coarse IIIa to IV. Moderately abundant MP 1/2-1" x 1-2", VO near base, content increasing upward and become larger (to 3") with less vertical orientation. Pits to 1.5' deep. Local DVT exposure/solution surfaces near top. Upper halitic claystone shows crude thin laminae to laminae contorted locally convolute. Possible desiccation cracks filled with halite 2" deep at sharp upper surface, slightly irregular over 1".
1283-1284	Polyhalite, medium crystalline, halitic. Contorted to wavy to slightly convolute thin laminae to laminae, some with cross-cutting relationship. Halite occurs in irregular subhorizontal zones, some lenticular, some with Ia-IIIa-c textures. Upper surface sharp, irregular, undulatory over 6".
1284-1286	Halite, trace to some polyhalite. Polyhalite occurs as irregular, moderately continuous to discontinuous thin laminae to laminae and stringers; local blebs; and irregular zones with medium to coarse Ia in rare pits, and near top; halite drapes,

linings and crude to moderate POS textures. Medium to coarse IV, local irregular small zones of fine. Trace primary, trace to moderate cement. Fine to medium I-IIIa-b in polyhalite zone. Some macropores to 1". Upper surface sharp, wavy. Pits to 6".

1286-1292.5 Halite, trace polyhalite; trace clay, content increasing upward. Local irregular moderately continuous to discontinuous thin laminae and laminae of claystone marking exposure/solution surface in upper 3'. Clay also occurs as discontinuous irregular stringers, blebby stringers and small blebs. Clay zones may show displacive halite margins. Polyhalite occurs as irregular small blebs (some with displacive halite margins) and crude POS textures (only in upper part). Medium to very coarse IV with some to trace primary and trace to some cement in polyhalite zone to 1290. Above 1290, halite is fine to coarse IV, with fine mainly in pods and lenses 1287-1288, some fine to Ia-b upward, also I-IIIa-c, especially I-IIIc, increasing upward, trace to some cement in pores and pipes. Has VO MP 1/2-1" x 1-2". Shows pits to 3' deep. Upper surface sharp, slightly irregular over 1".

1292.5-1296 Halite, trace polyhalite; 5-6" thick bed of irregular to contorted laminar polyhalite containing crudely lenticular halite-filled voids to 1/2" x 3" (subhorizontal) with local medium I-IIa-c. Polyhalite occurs as irregular thin laminae, continuous to discontinuous, discontinuous irregular stringers, irregular blebs (some with displacive margins and medium to coarse I-IIa) in pits, and crystal drapes, linings, and POS texture. Fine to very coarse, mainly medium to coarse IV, trace fine near top and in polyhalitic zones. Trace to some primary, local BG textures with drapes. Some to moderate cement. Local small MP to 1". Upper contact irregular over 1", sharp. Local pits to 2+'.

1296-1301 Halite, moderate to trace polyhalite; irregular zone of polyhalite-poor halite with trace gray to brown clay at top. Polyhalite occurs as irregular, moderately continuous to very discontinuous thin laminae to laminae and stringers, locally occurs as irregular blebs some with displacive margins. Clay occurs in halite deposited over irregular DVT pitted surface with 1' relief and in pits to 1-2+' deep. Clay occurs as irregular discontinuous stringers and is continuous thin laminae at upper surface and blebs with irregular to rarely displacive margins (in pits). Mainly medium to coarse IV with local fine as displacive crystals near top of DVT surface on polyhalite zone and in polyhalite zones of thin sequences. Some to trace primary; moderate cement. I-IIIa-c, mostly about IIb in upper 1'; fine to medium has more irregular boundaries, medium to coarse more planar. VO MP 1/2-1" x 1-2"

	and irregular macropores near DVT surface (2-3"). Upper surface sharp, irregul over 3", marked by brown clay and laminae.
1301-1306.5	Argillaceous halite with local halite claystone; brown to locally gray. Tra polyhalite as irregular discontinuous to very discontinuous thin laminae ar stringers, rare "blebby" stringers (solution lags), blebs (rare) and very crude PC textures. Many displacive halite margins. Clay occurs as irregular discontinuo thin laminae and laminae, irregular discontinuous zones in topographic lows ar pits, irregular blebs with some displacive margins, zones of large blebs with n displacive margins showing ad reduction of halite volume; incipient sic textur (above water table), local stringers. Crude thin to medium beds (2-5" thick) of hali topped by claystone in lower 2'. Mostly medium to coarse I-IIIa-b and fine I-IIIa i lower 1.5'. Fine to coarse IV with lenses to beds of IV surrounded by clay and IIIb-c disrupting bedding near top of brown zone (1304'). Claystone zones nea base locally shows smeared intraclast/laminae texture. Upward in gray zones cla occurs as stringers, irregular, discontinuous, with fine and medium to very coars IV, mainly medium to coarse, with trace cement; local I-IIa-c to fine IV occurs i irregular zones and pods near top. Shows local pits to 2+' deep and DVT relief t 6+" with local surfaces of exposure/solution in middle of unit. Upper contac irregular over 1", sharp to gradational.
1306.5-1309.5	Halite, trace clay to trace polyhalite (upward). Polyhalite also occurs in irregula discontinuous very thin bed (about .1' thick) near base with very discontinuous irregular thin laminae near base and irregular blebs as solution lags and in pits with some displacive margins. Clay is gray at base and brown at top; occurs as small irregular blebs and "blebby" stringers (very discontinuous, locally showing displacive margins. Halite is medium to coarse IV to IIIb under thin polyhalite; most of unit is fine to very coarse, mainly m-c, IV with trace primary and some cement. Pits locally to 1', poorly defined upper contact; sharp, planar with local pits to 6".
1309.5-1318.5	Halite, trace polyhalite near base, trace clay in upper part, brown with some gray, gray halitic claystone at top. Polyhalite occurs as irregular discontinuous to continuous thin laminae, stringers, irregular blebs, some with displacive halite margins, blebs in pits. Clay occurs as irregular discontinuous thin laminae, irregular zones, blebs, many displacive halite margins. Halite: mostly medium to coarse IV, trace zones to pods of fine to medium IV near top, trace primary at base, content decreasing upward. Trace to some cement at base, increasing upward. Halite locally incorporates clay and may occur as IIIa with rare to some medium to coarse

	I-IIa. Local pits throughout, 4"-2' near top. VO MP locally near base 2" x 1" to 1" x 1/2". Upper greenish gray claystone zone above 1310 overlies DVT exposure/solution surface. Contains irregular subhorizontal zones of fine to coarse III-IV and mainly fine to medium I-IIb-c and trace Ia. Upper surface is sharp, irregular over 2". Clay zone in topographic lows.
1318.5-1322	Polyhalite, halitic as PAGS (1/16-1" high) in stratified irregular zones within contorted laminae in middle of unit with polyhalite crystals penetrating into halite zones. Detrital in upper part. Polyhalite alternates with anhydrite, thinly laminar to laminar, wavy to contorted locally disrupted in middle of unit. Upper contact sharp, wavy.
1322-1323.5	Halite, some to trace of polyhalite upward. Polyhalite occurs as irregular, discontinuous thin laminae in lower 4" with 12-2" irregular thin beds at base, disseminated blebs in upper part. Medium to coarse IV; trace primary, abundant cement. Upper contact sharp, slightly wavy.
1323.5-1331.5	Halite, trace polyhalite. Polyhalite occurs as regular to irregular continuous to discontinuous upward thin laminae and laminae (1/4-2" near base), irregular blebs in pits and crystal drapes and linings (some displacive), and POS texture. Content of polyhalite decreases upward. Fine IV in discontinuous beds to pods in upper 1.5'. Most medium to coarse IV, trace to some primary, trace cement increasing upward. BG halite near base of unit, less obvious upward. Pits from 8"-2' at top, and MP 1/2 x 1" (VO) to 3 x 1" increasing upward. Blebs show displacive margins. Upper contact irregular over 2" marked by pits with downward translocation of overlying polyhalite and anhydrite, gray clay infiltrate. Very coarse IV in some pits.
1331.5-1334	Polyhalite, medium crystalline, locally halitic, thin laminae to laminae with halite PAGS (1/3-1/2" high), with locally contorted to convolute to wavy laminae to very thin beds near base. Irregular BG halite in 1-2" beds in lower 1'. Halite as clastic rippled material in thin beds 1-2" thick near top. Upper contact sharp, wavy.
1334-1340	Halite, trace polyhalite with trace gray clay and anhydrite(?) near top. Polyhalite occurs as irregular moderately continuous to very discontinuous thin laminae and stringers, rare irregular blebs in shallow pits (3-5" deep), abundant crystal drapes and crystal linings, with local moderately well developed POS texture. Sulfate defines thin to medium beds (3-8"). Medium to coarse IV, fine as I-IIIa in polyhalite-rich zones; trace to some primary, moderate cement increasing upward. Beds show sequences of fine-medium polyhalite to clear coarse to cloudy medium-coarse halite. MP small 1" x 1/2", VO at base, content and size (to 2") increasing upward. Anhydrite similar to polyhalite. Trace gray clay as irregular laminae at top.

	Well developed pits 1' deep at top with downward collapse of polyhalite in overlying unit.
1340-1347.5	Vaca Triste Markerbed. Halitic siltstone and mudstone, reddish-brown, well to poorly cemented with halite. Contains halite and polyhalitic clasts (to cobble-size) derived from the underlying units. Laminae to cross-laminae (sets to 6" thick); sic texture locally; strata locally downward, soft sediment shear and clast translocation over channels and pits into underlying unit. Halite is medium to very coarse I-III a-c, locally aligned parallel to strata: Upper 2', contain fine IV in pods and irregular zones, exhibiting DVT textures. Upper contact sharp.
1347.5-1360	Halite, trace polyhalite, trace clay at top. Upper surface very irregular over 5'. Shows paleokarst with filled channels and small cavities 1-1.5' x 1-5' near top. Abundant pits penetrate upper surface with Vaca Triste deposited within irregular topography as channels. Polyhalite occurs as irregular moderately continuous to very discontinuous thin laminae and very discontinuous stringers, isolated irregular blebs and zones of "blebby" stringers, crystal coatings and linings, and crude pile of sticks texture, solution lags and downward translocated material. Medium to coarse IV with thin to medium beds (3-6") with sequences of medium to coarse IV, full halite, sulfate; increasing MP upward. Clay content trace increasing upward as irregular subhorizontal stringers and disseminated blebs in subhorizontal zones interbedded with polyhalite-rich zones. Medium to very coarse I-IIIa in claystone. Local interunit pits to 2'. Upper surface irregular with channeling (6' relief).
1360-1362.5	Halite, trace clay decreasing near top. Clay occurs as disseminated blebs and irregular moderately continuous laminae with local sic in I textures. Abundant fine I-IIIb-c in lower part with source medium Ia-IIa and some b near base. Mainly medium to coarse IV, trace fine IV, in upper 1'. Trace very coarse cement in lower part. Upper surface planar, sharp, slightly wavy.
1362.5-1366.5	Halite, trace to some polyhalite, similar to unit below 1373' with more MP and abundant pits locally originating from within unit and at upper surface. Polyhalite laminae locally more continuous. Strata poorly defined at top and bottom, more well defined from 1364-1365.5. Polyhalite concentrated as solution lag. Fine to coarse IV with coarse to very coarse in pits and MP; trace primary. Medium beds (4-8") of polyhalite or polyhalite fine to medium halite, clear coarse halite, fine halite. Fine IV locally at upper surface in pods and lenses and subhorizontal exposure/solution surfaces. Upper surface DVT surface with irregular exposure/solution surface with 6-10" relief. Gray and brown clay infiltrated into pits and pores. Pits to 2.5+' deep.

1366.5-1373 Halite, trace polyhalite. Polyhalite occurs as irregular, very discontinuous to moderately continuous thin laminae, irregular discontinuous stringers, irregular blebs and crystal linings to very discontinuous stringers. Medium to coarse IV with trace of fine underlying sulfate and overlying medium to coarse IV in irregular discontinuous subhorizontal zones. Trace primary, trace to some cement, tr triple junctions at 1372. Halite is medium Ia-b to Ia-c, closely spaced in upper 1.5'. Stringers of gray clay and anhydrite in 1/2" zone 6" from base. Abundant MP to 4" in diameter upward. No obvious pits, but a few vertically elongate MP 10" deep and 4" wide near top. Polyhalite and laminae more continuous upward. Polyhalite delineates crude medium beds to 10" thick, 4" minimum. Upper surface marked by 1-2" zone of gray clay and anhydrite in irregular thin laminae and stringers. Top contact sharp.

1373-1384.5 Halite, some to trace polyhalite. Shows several horizontal zones with trace of clay and anhydrite. Upper 1.5' argillaceous halite. Well defined thin to medium beds 3-5" thick near base with about 2+" polyhalite-rich zone at top of each bed. Above two polyhalite laminae at 1380.5' and 1381', strata become less well defined. In lower part, polyhalite consists of rare continuous to discontinuous irregular to moderately irregular thin laminae and laminae, mostly as discontinuous subhorizontal stringers, irregular blebs, some with displacive margins and containing fine to medium Ia, crystal drapes and linings (some showing BG) and crude to well developed POS textures. Above 1379 character changes. Below 1379, MP are mostly small 1/2" x 1" VO, size increases from base upward. Pits and MP to 6" deep abundant between two polyhalite beds at 1380.5 and 1381'. Below 1379', halite is medium to coarse IV with trace to some primary and trace cement at base with primary decreasing upward and cement increasing upward. Halite becomes fine to medium and argillaceous from 1382-1381 under polyhalite beds. Halite shows sequences of polyhalite medium halite to medium-coarse IV to medium (trace fine) halite. Above polyhalite beds, halite is medium to coarse IV with trace fine, trace to some primary, trace cement. Clay, gray to brown, consists of irregular stringers and discontinuous irregular to continuous thin laminae and zones with medium to fine Ia. Above 1379 becomes more disrupted with pits and MP. Overall, clay content increases upward, strata are not distinct, only broad zones of varying composition. Clay is more disseminated as is polyhalite as irregular blebs and stringers with displacive margins. Fine IV locally abundant. Most medium to coarse IV with some incorporative halite locally. Local I-IIa and b in zones and irregular blebs of polyhalite and clay. Abundant pits to 2+' deep and

	large MP to 4" below 1376. Upper 1.5' mostly IIb-c with some Ia-IIa and rare IIb-IIIb-c. Upper surface irregular over 1" to planar.
1384.5-1386.5	Argillaceous halite to halitic claystone, brown; with 2-3" of gray near top, brown at top. Shows thrust displacement with 4" of throw at upper contact (in two places). Upper surface sharp across this area indicating early origin. Mainly fine to medium Ia-b with medium to coarse II-IIIa at base. Claystone shows sic texture. Upper surface sharp, planar.
1386.5-1398	Halite, trace polyhalite trace clay. Langbeinite in lower part. Langbeinite apparently associated with pits and MP cements. Leonite (after langbeinite) from 1394-1395. Polyhalite occurs as very irregular, discontinuous thin laminae and stringers, crystal drapes and linings on BG halite, local crude to moderately well developed POS texture, blebs, and blebs translocated downward in pits. Gray clay occurs as continuous to discontinuous irregular thin laminae and stringers. Polyhalite occurs in zones, delineates well defined to crude thin to medium beds 3-6" with common sequence of polyhalite medium halite to coarse to fine to medium halite. Halite is mainly fine to coarse IV, with coarse mostly as cements in MP. Trace to some primary, including bottom grown halite, near base, decreases upward. Unit displays MP of various sizes in 2 main groups: 1) small 1" x 1/2" VO and 2) large to 4+" across. Pits to 1' deep as local features in lower part. Upward pits become deeper (to 2+' deep) and larger, MP become more abundant. Clay in trace amounts is translocated down in the larger pits. Clay mostly gray, local brown zones occur in upper 3'. In those more argillaceous zones, leonite (not langbeinite) occurs. Polyhalite and clay may show displacive boundaries with halite and potash minerals. At and below 1390, DVT surface developed with up to 2' relief in pits. Along this surface and above this surface, fine IV becomes more common in subhorizontal zones and irregular pods and medium to coarse I-IIa becomes more abundant. Above 1390, polyhalite occurs more often as irregular blebs, POS derived from collapse of displacive fabrics, and irregular zones with abundant medium Ia. Most polyhalite is solution lag, some reworked. MP become abundant in upper part as do irregular pits < 6" deep. Slightly argillaceous halite deposited in topographic lows around zones of slightly polyhalitic fine IV. Irregular discontinuous to continuous clay laminae (1/4-1/2") delineate crude stratification. Medium beds about 1' thick laterally discontinuous. Upper surface irregular over 1-3", sharp, erosional.
1398-1401	Argillaceous halite, langbeinite in upper bed in irregular zones 1-4" across (irregular shaped - dissolved out during dumping of water to free raise bit as clast of DL found in one pit). Locally polyhalitic as irregular blebs to solution lag in lower zone and

irregular blebs, very discontinuous stringers and crude POS texture. Blebs in lower part show local displacive halite a-b boundaries. Claystone occurs as 2 laminae to very thin beds 1/4-2" thick, lower bed contains less halite and drapes irregular lower surface, thickening in topographic lows; shows probable sic texture, is infiltrated downward in vicinity of pits. Clay brown at base and gray in upper 6-10". Clay in halite-rich zones occurs as irregular stringer and "blebby" irregular discontinuous thin laminae and local zones and blebs with displacive/incorporative halite. Halite in lower 1' is medium to coarse IV to IIIa-b upward. Middle part is mainly II-IIIa-b with trace I-IIIc. Upper gray part is f-m I-IIIb-c, trace medium I-IIa, and some beds of medium to coarse IV. Upper surface sharp, planar, with irregular thin laminae of gray clay. Langbeinite possibly pseudomorphed by hydrated sulfate form (leonite). Langbeinite appears partly displacive. Langbeinite abundant near upper contact.

1401-1409 Halite, polyhalitic, trace to moderately abundant potash minerals (langbeinite). Local clay-rich zones in vicinity of exposure surfaces. Polyhalite occurs as irregular discontinuous (upward) to continuous (downward) laminae to thin laminae and local stringers. Irregular blebs, some with displacive margins, as crystal boundaries showing BG, POS moderate to well developed. Clay occurs as irregular moderately continuous to slightly discontinuous thin laminae. Locally clay box work developed near 1403-1404'. Halite is fine to coarse IV, mainly medium; trace to some primary, trace cement. Thin beds with sequence polyhalite, coarse halite, fine polyhalite halite. MP <1" x 1/2", becomes more abundant upward. Local fine halite near top and on edge of large pit originating at upper surface. Possible pits 6" deep originate at clay-rich zones. Clay brown to gray. Local pits within polyhalite-rich zones. Clay becomes more discontinuous and disseminated upward. Langbeinite occurs mostly in MP. Unit upper surface is DVT erosion/exposure surface with 2+' relief; larger pits to 4+' deep originate at this surface; sharp.

1409-1410.5 Polyhalite, microcrystalline, locally halitic as discontinuous zones of IV 1/4-1/2" thick, 4-10" long, parallel to strata. Shows irregular thin laminae, contorted to wavy, with gray clay at base. Possible potash minerals in lenticular pore with drusy lining of unidentified mineral - possible open pore filled with potash mineral (Figure 4). Upper surface irregular over 6", sharp. Some possible polyhalite PAGS to 1/4" high.

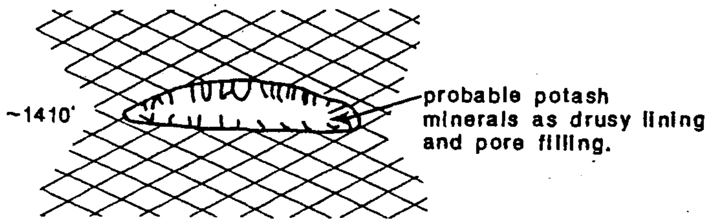


FIGURE 4 FILLED PORE IN POLYHALITE BED (MB117)

1410.5-1414	Halite, trace polyhalite. Polyhalite as irregular discontinuous stringers and irregular small blebs partly as solution lags. Polyhalitic zones delineate crude fine to medium beds (3-8") with sequences of polyhalite, medium to coarse IV, fine IV; trace to some primary, trace cement. Fine halite occurs in discontinuous pods, some in possible pits. Possible langbeinite. Fine halite abundant near top. Upper surface sharp, planed off, slightly wavy.
1414-1419	Halite, trace polyhalite. Polyhalite occurs as irregular very discontinuous thin laminae and stringers, local irregular blebs as solution lags, some with displacive boundaries, some incipient crude POS and irregular to planar crystal boundary material (some displacive), delineates thin to medium beds (3-6") with sequence polyhalite, medium to coarse IV, fine IV sequence lacks fine in upper part. Trace to some primary, trace cement in VO MP 1" x 1/2", langbeinite associated with MP. Gray clay accumulated on exposure/solution surface. Upper surface planar, with .2' relief,dissolved, sharp. Contains trace langbeinite in MP.
1419-1432.5	Divided into five parts: Part a: halite, trace polyhalite. Polyhalite consists of irregular blebs and stringer-like blebs, with some displacive margins, irregular, discontinuous to moderately continuous bleb-like laminae and thin laminae, some as probable lags showing displacive margins with halite (developed during later displacive growth). Moderately well to crudely thin to medium bedded (2-5"), delineated by sulfate. Fine to coarse IV, mainly fine to medium trace to some primary, coarse cement in MP. Trace to some VO MP. Upper surface irregular, gradational to sharp, marked by increase in clay content. Part b: halite, trace polyhalite and clay. Polyhalite occurs as blebs and irregular discontinuous stringers. Clay is gray and brown, occurs as rare very irregular, discontinuous thin laminae, mostly as irregular discontinuous stringers and blebs with displacive margins. Medium to coarse IV, abundant cement locally incorporating clay, fine IV in irregular subhorizontal zones and pods, fine I-IIIb-c in argillaceous zones. Zone contains isolated pods of langbeinite to 1" around, some

appear displacive; langbeinite washed out 3-4" back into rib. Upper surface gradational to sharp, marked by drop in clay content. Shows some probable pits within unit.

Part c: halite, trace polyhalite. Top marked by 1/2-2" zone of polyhalite with some langbeinite. Polyhalite occurs as irregular blebs and discontinuous stringers. Medium to coarse IV; trace very coarse, trace primary, some cement. VO MP moderately abundant (1" x 1/2"). 6"-1' deep probable pits with polyhalite blebs.

Part d: very discontinuous zone (laterally) to 3' thick of halite with trace polyhalite as irregular blebs and very discontinuous irregular stringers. Polyhalite locally shows incipient box work texture. Many generations of cemented pits and MP evident, some originating prior to development of DVT relief on upper surface of Part d. Contains zones and pods of langbeinite, mostly associated with pits and MP. Upper surface very irregular marked by exposure/solution surface with up to 2.5' relief. Medium to coarse IV with fine halite near top, abundant cement in small VO MP 1/2" x 1", and cement with gray tinted halite in larger MP.

Part e: halite, argillaceous, trace polyhalite. Polyhalite occurs as disseminated material in fine IV and isolated irregular blebs, some with displacive boundaries, as solution lags. Clay occurs as irregular discontinuous to continuous (marking DVT relief surfaces) thin laminae and laminae, isolated to disseminated zones and blebs. Contains fine to medium I-IIIb-c, locally shows sic textures. Medium to coarse halite IV with localized fine halite in irregular pods and zones. Halite shows abundant displacive margins with clay, mostly cement. Contains langbeinite. Upward, fine IV in pods and lenses becomes more common on top of medium to coarse. Possible localized pits. Upper surface planed off by dissolution, erosion, sharp, shows trace langbeinite.

1432.5-1435 Polyhalite, microcrystalline, halitic. Slightly halitic in lower part; very halitic above 1434. Halite in lower part occurs in isolated irregular subhorizontal zones of very coarse IV and medium to coarse IIIb. Contorted to wavy thin laminae in lower 4" and upper 3"; hint of thin laminae in middle of zone. Upper part shows crude laminated texture with probable low angle cross-beds and cross-laminae with sets 2-4" high and 6"-1' long. Strata partly delineated by halite-rich zones with probable clastic/detrital origin. Often associated with these zones are medium to coarse, I-II-IIIa-b, halite with displacive/angular to solution/irregular margins. These crystals also contain tube-like inclusions of polyhalite or anhydrite which originate from the margin of halite with the polyhalite as included material, replacement material, or "drusy" style cement grown into an open void. III halite often occurs in the troughs of cross-laminae. This halite may have been BG in topographic depressions similar to that in Nash Draw with margins accentuated by displacive growth after deposition of overlying material. I and II halite often disrupts and separates strata. Irregular horizontal zone of medium to coarse IV with irregular interlaminae of polyhalite in upper 4" (Figure 5). Upper surface is irregular, marked by irregular discontinuous polyhalite laminae, sharp.

1435-1440 Halite, trace to major polyhalite in lower part. Polyhalite occurs as well developed laminae and thin beds in middle of unit (1438-1438.5) and irregular discontinuous subhorizontal stringers, blebs and POS textures and crystal and depositional surface drapes. Some voids within polyhalite laminae show drusy style crystals with sulfate penetrating void and indicating open void at time of deposition. Polyhalite tops fine halite which overlies medium to coarse halite about 4" thick beds in upper part. Trace polyhalite in upper part is isolated irregular blebs and POS in subhorizontal zones parallel to strata. Fine to coarse mainly fine to medium with coarse increasing upward some primary (trace vertically elongate) rare chevrons; trace to some cement upward. Dissolution pits (to 2' deep) originate at upper contact and contain blocks of gray clay with coarse to very coarse Ia and general trace gray clay and anhydrite. Also some large MP occur in upper 1', horizontally aligned 3" x 1'. Upper surface planar, undulatory over 6", dissolution due to flooding planed off surface.

1440-1441 Polyhalite, microcrystalline, halite in irregular subhorizontal discontinuous laminae to 1/2" thick near base. Thin laminae, most poorly defined, parallel to low angle cross-cutting relationships, locally contorted to slightly wavy. Some medium to coarse Ib near base and medium to coarse Ic in middle. Upper surface irregular over 8", sharp.

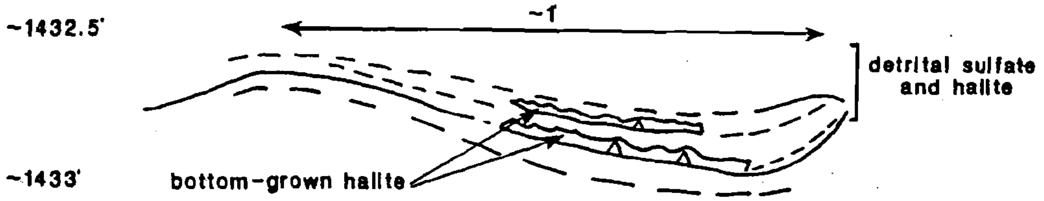


FIGURE 5 BOTTOM-GROWN HALITE IN LOW AREAS OF SULFATE BED (MB118)

1441-1444 Halite, trace polyhalite in lower 2', trace anhydrite and gray clay in upper 1', trace gray clay in 2-4" thick irregular subhorizontal zone 6" from base. Clay occurs as irregular, moderately continuous to very discontinuous thin laminae in discrete horizons. Anhydrite and polyhalite occur as irregular very discontinuous thin laminae and stringers with subhorizontal orientation commonly over irregular exposure/solution surfaces and subhorizontal stringer-like blebs. Unit shows crudely defined to moderately well defined thin beds (2-4"). Zones or beds of polyhalite, medium to coarse halite, fine halite or alternating polyhalite and medium to coarse halite. Locally contains narrow pits, 6" deep. Halite: mainly fine to medium IV, with fine halite increasing upward in local zones and subhorizontal zones, trace coarse and very coarse IV mainly as cement; trace to some primary, including vertically elongate and bottom-growth halite. Some rare VO MP (1/2" x 1"). Some polyhalite occurs as crystal boundaries and drapes but is poorly developed (due to thin granular nature of original drapes). POS texture localized under some of pits (Figure 6). Irregular DVT solution/exposure surfaces. Fewer primary textures and more cement in upper argillaceous zone. Pits originate at DVT exposure/solution surfaces. Some fine halite in pits. Pits in lower part developed of POS texture. POS texture occurs higher stratigraphically than zone with drapes - possibly due to BG of halite within pit and draping while deposition of sulfate occurs on higher sediment-water surface. Upper surface sharp, irregular with some pits (to 6" deep).

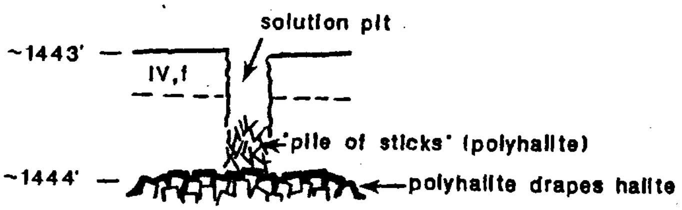


FIGURE 6 ACCUMULATION OF POLYHALITE 'PILE OF STICKS' IN SOLUTION PIT

1444-1449 Argillaceous halite: divided at 1446 into an upper gray part and a lower brown part. Lower brown part: clay in irregular very discontinuous thin laminae, stringers and blebs with displacive to irregular boundaries, and as irregular moderately continuous laminae 1/4-1/2" thick and irregular zones. Clay locally marks irregular DVT surfaces. Some claystone contains discontinuous irregular thin laminae and sic/laminae texture. Medium to coarse IV with a trace of fine halite; some fine halite in irregular subhorizontal pods near gray-brown contact; trace primary, abundant cement. Medium to coarse I-IIIa-c, mainly II-IIIb-c on claystone. Upper gray zone

	shows similar texture, but with less claystone. Mainly II-IIIb-c and equant IV; fine Ib-c in argillaceous zones; fine to medium IV dominated upper 6". Upper surface sharp, slightly irregular over 1", mostly planar. Some pits 6"-1' deep.
1449-1459.5	Halite, trace polyhalite to some polyhalite in upper 1'. Polyhalite occurs as irregular rims on halite crystals; poorly developed POS texture; incipient boxwork pattern; very irregular to irregular, and discontinuous thin laminae and stringers and well developed irregular thin laminae to thin beds 1/16-4" thick, spaced 4"-10", become more irregular and discontinuous upward. Polyhalite also occurs as irregular zones in pits 4"-10" deep. Lower halite is generally fine to medium, IV in beds less than 10" with fine halite at top and separated by polyhalite or polyhalite halite. Coarse to very coarse halite cement in MP 3" x 4" and pits 6-10" x 1-4". Trace to moderate primary halite features, minor cement. Hints of BG fabrics. Some I-IIIb or c with polyhalite. Upper part shows trace polyhalite as irregular large blebs often concentrated on dissolution surfaces and shallow (<1') pits. Halite: coarse to medium IV, with local subhorizontal zones of fine. Moderate primary, moderate cement. Local small MP. Shows probable BG fabrics. Crudely thin to medium bedded (3-5"). Trace brown clay as thin irregular, moderately discontinuous thin laminae and stringers. Abundant fine III with trace polyhalite and some fine IV in pods, lenses near top. Upper surface irregular DVT surface with 6"-1' relief.
1459.5-1461.5	Polyhalite, halitic locally. Gray claystone at base is 4"-6" thick, contains subhorizontal pods of polyhalite in trough. Pods resemble nodules as gray clay is squeezed in between pods. Claystone shows crude thin laminae. Lower 6"-8" of polyhalite is laminated (1/8"-1/2"), delineated by thin laminae (1/16") of gray claystone; discontinuous contorted thin laminae in upper polyhalite. Claystone content decreases upward. Upper part of polyhalite is lenticular to tabular zones "--2" thick and 1-15' long which are halitic, with halite showing bottom growth fabrics and medium to coarse I, coarse near top. Possible clastic halite near top. Discontinuous contorted thin laminae in polyhalite of upper part. Upper surface very irregular and undulatory over 8" with local 4" high hemispheroids near top. Relief present prior to deposition of unit as laminae in overlying unit do not show any deformation (Figure 7).

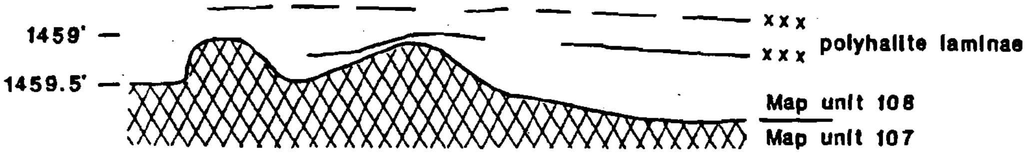


FIGURE 7 UNDEFORMED LAMINAE OF POLYHALITE
OVER RELIEF ON POLYHALITE BED

1461.5-1468.5 Halite, trace polyhalite and clay, zones vary in each. Polyhalite occurs as irregular moderately discontinuous to very discontinuous thin laminae and stringers. Isolated irregular blebs of polyhalite are disseminated in subhorizontal zones. Clay is brown to gray and occurs as irregular, very discontinuous thin laminae and stringers. 1" thick polyhalite bed at 1464. In polyhalitic zones, halite occurs in following sequence: discontinuous sulfate stringers; medium IV with abundant primary and some cement; fine to medium IV. Halite in overall unit: fine to coarse IV, mainly fine to medium trace primary and cement to 1467.5; find to coarse IV, mainly medium, trace Ib-c to 1465; fine to medium IV, mainly fine, trace coarse cement to 1464; fine to coarse IV, rare very coarse cement, fine IV mainly in polyhalitic halite to 1462; fine to coarse IV, mainly medium to coarse to top. Polyhalite becomes abundant near top of this polyhalite zone. Upper 6"-1' is argillaceous with irregular, slightly discontinuous thin laminae of gray clay. Upper surface sharp, undulates over 3".

1468.5-1475.5 Halite to halitic claystone in 3 parts:

Part a: trace poly and clay; fine to coarse IV, mainly medium, fine in small pods of white to gray equant IV; trace primary.

Part b: trace to some clay and trace polyhalite as irregular, discontinuous laminae and irregular blebs. Trace primary near base, abundant cement. Medium to coarse IV, fine near top. DVT erosion/solution surface at top is irregular over 4". Clay occurs as irregular very discontinuous to moderately discontinuous thin laminae and disseminated blebs (in medium to coarse IV near base. Clay mostly brown with some gray.

Part c: halitic claystone, brown with gray in upper 1-4" and local irregular zones in upper 1'. Gray reduction spots. Thin laminae are locally parallel, contorted to convolute. Halite occurs as fine to coarse I-IIIc (with trace of I-IIb) and local subhorizontal, discontinuous zones, isolated pods and discontinuous laminae (to 1") of medium IV with trace coarse. Upper surface sharp, planed off, marked by a small fault with about 3" throw showing a reverse displacement (Figure 8). The displacement breaks the polyhalite zone at base of unit but does not propagate.

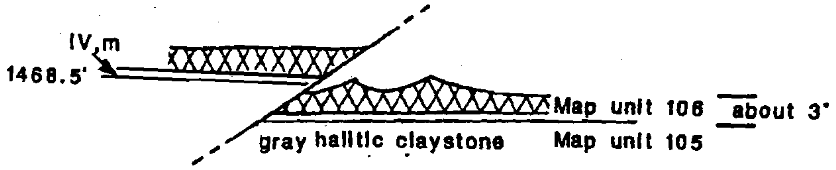


FIGURE 8 SMALL REVERSE FAULT

1475.5-1480	Halite, trace polyhalite. Polyhalite occurs as continuous laminae to thin laminae i lower 2' (spaced 3"-1') and at upper contact; local crude POS texture near base and polyhalite margins of medium IV vertically elongated crystals. Some primar with abundant to some cement. Fine to very coarse IV, dominantly medium, wit local subhorizontal zones of fine halite in middle zone with trace polyhalite. Dissolution pits to 2' deep originate at upper contact but are rare. Upper contact marked by 1/4-1/2" polyhalite laminae, sharp. Local MP about 1-2", near top.
1480-1481	Polyhalite, microcrystalline, hints of thin laminae. Local laminae with halite show nodular texture at base with gray claystone from lower 1/4" squeezed in between nodules. Upper contact sharp, undulatory over 1".
1481-1485	Halite, trace polyhalite, trace clay in upper 6". Polyhalite occurs as irregular thin laminae and discontinuous stringers with small irregular blebs outlining halite crystals. Medium to coarse IV, trace primary, some cement. Crude thin beds (2"-5") defined by polyhalite with sequence cloudy and clear halite to polyhalite and halite. MP to about 2"-4" near top. Dissolution pits originate at top to 3+' deep. Upper 6" contains coarse to very coarse IV to medium I-IIIc and gray clay as irregular continuous to discontinuous thin laminae to laminae and local small blebs; shows sic/laminae texture internally. Upper surface planar, sharp, marked by gray clay.
1485-1494.5	Halite, trace polyhalite to 1490, decreases above 1490; trace clay from 1490 increasing upward. Halite below 1490 is medium to coarse IV with trace to some primary and trace cement. Above 1487.5, halite is interbedded with poorly defined thin to medium beds (1-3" thick) of argillaceous halite. Halite is mainly medium to coarse IV to I-IIIa-b (mainly II-IIIb); fine IV increases upwards in pods and zones. Upper 1' has more coarse I-IIa and medium to coarse IV. Cement is more abundant in upper part. Clay is mostly brown with some subhorizontal gray zones near top. Argillaceous halite to claystone near top shows poorly defined thin laminae, convolute and incipient to moderate sic/laminae texture. Upper argillaceous zone shows crude subhorizontal strata with concave upward (dish) form. Polyhalite occurs as irregular blebs with local displacive halite margins - mostly disseminated. Local MP. Pits originate within argillaceous zone and penetrate 6+'. Upper surface sharp, undulatory, erosional, marked by gray clay laminae. Some weeps.
1494.5-1496	Polyhalite, microcrystalline, with irregular large zones of halite roughly 1' across near base directly under undulation. Has 2-3" gray clay at base. Upper part shows incipient load structures with clay. Thin laminae to wavy to contorted bedding near base. Remainder shows nodules of polyhalite and massive polyhalite. Nodules developed within anhydrite matrix, displacing wispy laminae. Contains possible

langbeinite. Medium to very coarse displacive halite I, II, IIIb-c occurs. Upper surface irregular, undulatory over 1'.

1496-1502 Halite, trace polyhalite increasing upward slightly. Polyhalite occurs as irregular continuous to discontinuous thin laminae and stringers in lower part, irregular blebs and disseminated blebs and stringers in upper part, and incipient boxwork with downward translocated blebs in middle where pits occur. Medium to coarse IV, trace fine halite in thin laminae and discontinuous horizontal zones. Beds with sequence polyhalite to vertically elongate and equant clear halite to trace fine halite. Moderate primary, trace to moderate upward cement. MP become more common upward and are 1-2" across. Pits originate at top surface and penetrate 4+'. Upper surface planar to slightly undulatory, sharp, planed off during flooding which deposited overlying gray clay. Pits filled prior to gray clay deposition.

1502-1503 Polyhalite, microcrystalline. Salmon pink. Thin laminae to laminae, wavy, locally contorted to convolute. Thin laminae-sized shear zone filled with halite 4" below top. Upper contact sharp, slightly undulatory.

1503-1505 Halite, trace polyhalite with some clay in thin basal zone and trace in thin middle zone. Clay is irregular discontinuous to continuous thin laminae and stringers. Polyhalite is irregular stringers, blebs, disseminated and concentrated on solution surfaces, and irregular, poorly POS developed. Fine to medium I-IIc in basal argillaceous zone. Medium to coarse IV; trace primary, trace cement Ic at top. Upper surface marked by increase of disseminated polyhalite, sharp, undulatory over 4".

1505-1510 Halite, trace polyhalite; trace clay above 1507. Clay as irregular discontinuous stringers and thin laminae. Upper 3-5" halitic claystone with fine to medium I-IIc. Polyhalite in lower part occurs as irregular discontinuous thin laminae, stringers and blebs. Delineates crude to poorly defined thin beds (1-4") (much more disrupted by shallow WT conditions than underlying unit, but very similar sequence). Halite fine to coarse IV, mainly medium. Beds show sequence of medium-coarse bottom grown IV to fine-medium with trace of polyhalite to thin polyhalite residue. Trace to some primary; trace to abundant cement upward. IIIb-c and fine IV dominate in upper 4" below claystone, with gray clay. Upper surface sharp, planar, erosional, marked by clay. No pits.

1510-1517 Halite, trace polyhalite and anhydrite, trace to some clay at base and top. Polyhalite occurs as slightly to very irregular, continuous to very discontinuous thin laminae and laminae, trace amounts of polyhalite delineate thin beds (1-3"). Continuous laminae in lower 1.5'. Polyhalite also occurs as irregular blebs, disseminated to solution lag near top. Clay in upper 1' is irregular discontinuous

laminae and zones with blebs, contains pods of medium IV and some mediur
fine I-IIIa-c, dominated by irregular (c) boundaries. Two zones separated by m
poor halite with abundant polyhalite blebs as solution lag. Fine to coarse IV, tr
primary and cement; units less than 8" show sequence of polyhalite, mediun
coarse IV with trace primary, fine to medium IV with a trace of polyhalite. No p
Upper surface erosional with brown clay. Unit contains irregular, moderat
continuous, thin laminae of gray clay in lower .5'.

1517-1529.5 Halite subdivided into 3 parts:

Part a: trace polyhalite to clay; polyhalite occurs as irregular blebs which
disseminated (trace displacive halite margins), disseminated material and sn
blebs in fine IV, irregular very discontinuous thin laminae and irregular m
continuous laminae (near base). 1-2" lamina of polyhalite overlies halite contain
pits which are regularly spaced. Polyhalite laminae locally coalesced (wh
cohesive) into pit. Fine to coarse, mainly medium, halite IV, fine is more comm
near top (irregular DVT surface). Trace primary halite some cement. BG textur
near base. Primary decreases upward and cement increases as MP become mc
abundant. VO MP 1" wide by 2-3". Upper surface irregular, locally gradation
showing DVT textures and relief.

Part b: trace to some clay and polyhalite; fine to halite IV with trace polyhalite
irregular pods and zones bounded by solution surfaces with gray and brown cla
Some zones of fine IV with subhorizontal orientation. Fine IV zones surrounded l
argillaceous medium to coarse IV with some medium III a-c and fine to mediu
I-IIa-b. Clay occurs as irregular discontinuous laminae and zones with abunda
halite and isolated blebs. Upper contact gradational to diffuse. Part b show
moderately well developed DVT textures.

Part c: argillaceous halite, trace to some clay, decreasing sulfate upwarc
Subhorizontal zones and pods of medium to coarse IV and IIIb. Fine to mediur
incorporative I-IIa-b within Part c. Claystone laminae to thin laminae, subhorizonta
irregularly contorted to convolute, showing incipient sic/laminae texture. Gray a
top, brown dominates the remainder. Upper surface sharp/erosional. Paralle
dissolution pits rare through unit, but occur locally and are 1-2' deep. Loca
subhorizontal to discontinuous fractures, 1/4" thick, filled with fibrous halite.

1529.5-1535.5 <u>Union Anhydrite:</u> anhydrite with local polyhalite zones, slightly argillaceous in lowe
1-2". Microcrystalline, gray (N6-N9). Subdivided into 6 zones, from bottom to top
(Figure 9):

Part a: gray (N7) clay and polyhalite nodules showing displacive growth.

Part b: anhydrite; gray to slightly tannish gray, possibly slightly argillaceous as broken surface is smooth, not very crystalline. Wavy to contorted thin laminae and laminae, some parallel, showing some cross-cutting relationships in the vicinity of an algal(?) hemispheroidal feature. Locally may display some incipient enterolithic textures.

Part c: upper surface marked by black "sticky" clay, probably organic-rich Part c. This black material has squeezed in and around polyhalite nodules which grew displacively. It has squeezed into apparent (in two dimensions) large flame structures in the vicinity of hemispheroid structures and into subvertical fractures intersecting the shaft 6-8" above the unit and intersecting the hemispheroid. Part c may be slightly organic-rich.

Part d: polyhalite; thin laminae to laminae, parallel to non-parallel, wavy to contorted, showing cross-cutting relationships; deformated while soft. Thinly laminaed to laminaed hemispheroids are developed within this part and are evenly spaced around the shaft. Material around these structures shows some slumping. Upper surface sharp, very undulatory, and slightly irregular.

Part e: anhydrite; micro laminae to laminae, wavy to contorted, most semi-parallel, showing some cross-cutting relationships. Ripple-shaped forms occur but without clear bedform migration. Small hemispheroids occur within anhydrite. Local slumping around hemispheroids is common, showing gravity sliding downward. Subhorizontal zones of probable clastic halite occur. Two zones, filled with clear halite, roughly parallel strata. The lower one shows sigmoidal shear shapes, and the halite contains angular pieces of anhydrite parallel to margins (floating in halite). Unit becomes more halitic in upper 1'. Upper surface irregular/undulatory, sharp.

Part f: polyhalite; contorted and convolute, thin laminae, halitic. Upper surface sharp, irregular/undulatory. Desiccation cracks from top into unit 2' deep filled with halite. Unit as a whole bears fluid. Weeps occur parallel to strata and are very common around those zones with clastic halite. Weeps also around fractures and at contacts between parts a, b, c, d, e; most abundant around a toe contact.

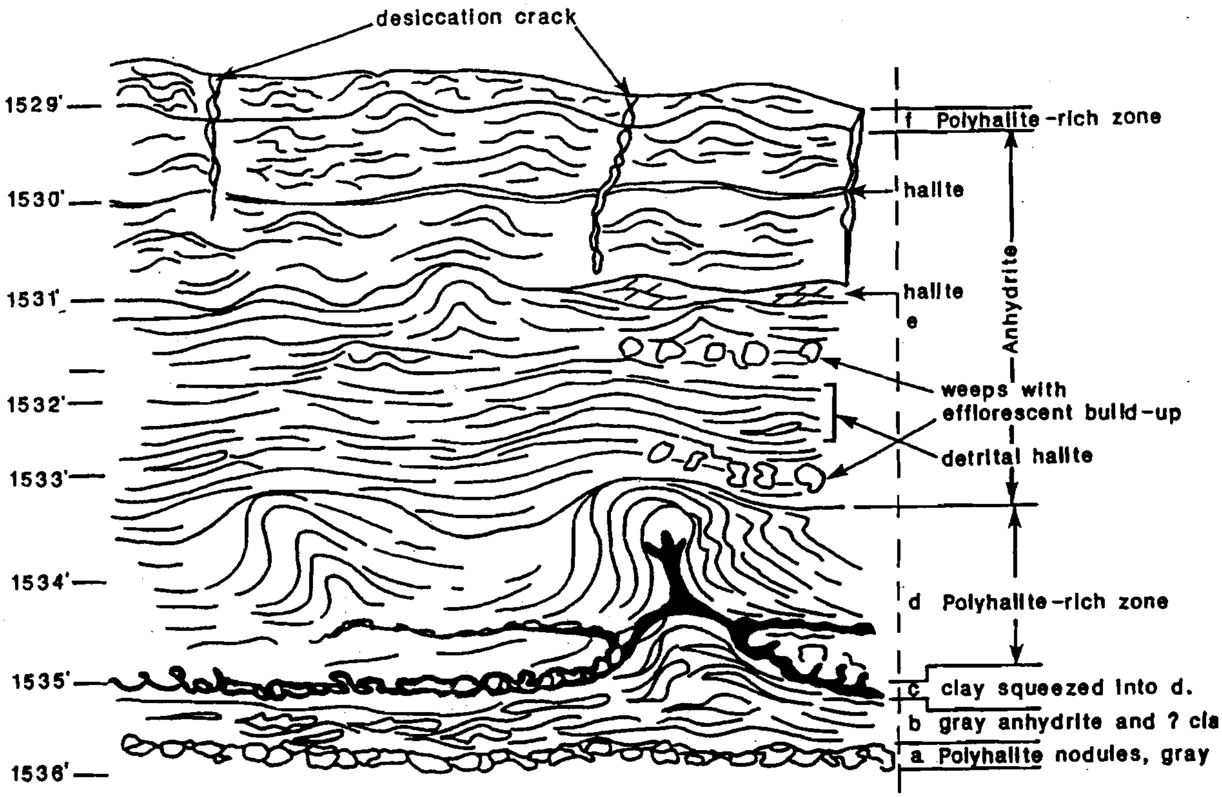


FIGURE 9 UNION ANHYDRITE

1535.5-1544.5	Halite, polyhalitic, trace clay in two zones in upper part. Polyhalite occurs irregular slightly discontinuous to very discontinuous thin laminae and isolate grouped irregular blebs in laminae-sized zones. Unit displays thin beds 2-4" t with following sequence: medium to coarse IV with abundant primary and BG, f IV, polyhalite laminae or polyhalite-rich zone. Generally fine to medium IV, trac moderate primary with trace cement. Shallow pits 6" to 1' and MP under pits h trace gray clay (infiltrated) in upper part. Dissolution surface in upper part w argillaceous clay. Upper 1' shows less primary and more cement with no beddi Irregular zone of polyhalite marks upper contact, sharp, irregular over 6".
1544.5-1552	Halite, alternating mud-poor (trace polyhalite) with argillaceous (trace polyhali interbeds (clay black to gray with trace to some brown). Polyhalite occurs irregular discontinuous thin laminae and disseminated small irregular blebs crud delineating thin to medium beds (2-4") in polyhalite-rich zones. Clay occurs as v irregular continuous to moderately discontinuous thin laminae, laminae, a subhorizontal zones with fine to coarse I-IIIc, rare I-IIIa. Clay may crudely deline thin to medium beds 2-3" thick, is locally translocated down in pits. Pits occ

	within unit and are 1-2' deep. Clay-rich zone at top contains irregular pods and subhorizontal zones of medium to fine IV (DVT textures). Unit is fine to coarse IV, mainly fine to medium, with zones of orange fine halite, trace primary and trace to some cement. Upper surface sharp, very planar.
1552-1560	Halite, trace polyhalite to trace to some clay upward in several sequences with argillaceous halite interbeds. Halite is fine to very coarse IV with medium to coarse (trace primary) dominating near base of polyhalitic parts and more fine IV in upper parts. Displacive halite in argillaceous zones mainly fine to medium I-III-c with trace Ia. Trace fibrous halite along edge of solution pipe near 1555. Lower .5' argillaceous, very discontinuous irregular clay laminae. Next 2' shows polyhalic fine IV with abundant DVT textures similar to DVT zone in underlying unit. DVT texture zone overlain by medium IV zone with irregular discontinuous thin laminae of clay, trace polyhalite interbedded on 1' scale with halitic claystone with I-II-IIIb-c. Zone shows local pods of fine halite. Halite in this zone shows trace primary, abundant cement. Claystone in irregular thin laminae, wavy to convolute, locally parallel with some sic/laminae textures. Upper 2' contains thicker interbeds of similar claystone. Most interbed margins poorly defined. Dissolution pits originate within unit and at its upper contact are filled with halite cements and translocated clays; pits at upper surface are filled with gray clay from overlying unit. Moderate effloresence in clay-rich part.
1560-1568	Halite, trace polyhalite, trace clay in rare, well developed, subhorizontal, thin laminae. Polyhalite occurs as disseminated material in fine IV and as isolated irregular blebs along planar dissolution surfaces near top and in pits as translocated dissolution lag. Lower part shows abundant fine IV with MP and dissolution pits filled with medium to coarse halite. Middle zone shows moderate to advanced DVT textures (clay poor) and irregular exposure/dissolution surfaces with abundant fine halite. Upper zone shows crude to poorly defined thin to medium beds 2"-1' thick with polyhalite blebs delineating strata. Fine to very coarse IV, mainly fine near base and in source other zones. Trace to moderate cement, some primary, showing BG. Upper surface irregular over 4" dissolution/exposure surface. Pits originating at upper surface and within unit to 6+'.
1568-1571	Halite, trace clay, trace polyhalite as irregular blebs in fine IV concentrated along dissolution surfaces. Clay mostly as irregular continuous to slightly discontinuous upward, thin laminae to laminae. Strata moderately to poorly defined in lower 2'; less well defined upward. Thin to medium beds (2"-1') delineated by clay laminae. Halite stratified below upper 1'. Brown clay with some gray zones. Fine to medium

	IV with trace coarse halite as cement, trace primary near base, content decre upward. Cements are locally abundant. Fine halite caps strata, and is abundant upward. In upper 1', fine IV is in lenticular to irregular subhoriz zones and pods. One pit at upper surface was deep x 6" wide. DVT textur upper 1'. Upper surface planar, slightly irregular; erosion with clay deposition surface.
1571-1578	Halite, trace polyhalite. Clay content increases from trace at 1574' to some at Polyhalite occurs as disseminated material in fine IV, and isolated dissemin irregular blebs elsewhere. Clay occurs as disseminated material and increasi well defined irregular to slightly continuous to moderately discontinuous laminae to laminae and irregular zones upward. Laminae fairly continuous in u 1'. Fine to coarse, mainly medium, IV, trace to some primary (trace vertic elongate) and cement to 1573'; zone of pods to layers of fine IV to 1572; strati medium to coarse IV, trace primary and cement, with fine to coarse I-IIIc and t Ia to top. Some coarse cement in MP and pits; cement increases upward. textures are abundant near middle and upper middle. Contains interunit originating within DVt texture zone to 5+' deep. Upper surface marked by thinly laminaed clay 1/2-2" thick deposited over planed off, slightly irreg dissolution surface. Clay is brown with some gray.
1578-1589	Halite, trace to some clay and polyhalite. Incipient to moderate/advanced textures. Polyhalite occurs as disseminated material in fine halite, irregular s (<1/4") to large (about 3") blebs concentrated along subhorizontal zo (exposure/solution surface with lag), and in pits as translocated material. occurs as irregular, slightly discontinuous to moderately discontinuous locally po defined, thin laminae to laminae and irregular zones. (Continuous thin laminae laminae partly as lags on irregular dissolution surfaces (or incipient DVT surfac and around irregular pods of fine). Clay mostly brown with some gray. Equant to medium IV, with some coarse halite as cements in pits and MP. Trace prim trace to moderate cement. Fine halite is abundant near base and upper middle of unit, occurs within disseminated irregular zones and pods within lower mid part of unit, and caps irregular subhorizontal exposure/dissolution surfaces n top. Lower middle dominated by medium halite with some coarse as cements abundant MP and pits. Upper part shows medium halite in crude strata capped fine halite or clay laminae with I-IIIc and trace Ia. In addition to the irregular po and zones (some showing dish-shaped beds near base), fine halite occurs fillings of some dissolution pits (efflorescent material that survived). Pits originate

various locations through unit and vary in depth from 1-8' and show many episodes of reactivation. Upper surface sharp to irregular and slightly gradational, irregular over 6".

1589-1594 Halite, trace polyhalitic and anhydrite. Polyhalite occurs as irregular moderately continuous to very discontinuous thin laminae, mostly subhorizontal, disseminated small blebs and irregular large bleb showing some displacive margins. Lower part mainly polyhalitic. Upper part contains some polyhalite aligned in subhorizontal zones and as locally disseminated blebs. Blebs in upper part are concentrated within dissolution pits as translocated material. Polyhalite delineates moderately well to poorly defined thin to medium beds 3-8" thick. Medium IV, mostly equant, some primary (trace vertically elongate), some coarse; some fine halite in upper 1.5'. Vertical cement fabric and BG primary fabrics. Cement moderate to locally abundant in dissolution pits and small MP 1" x 1/2". I-IIIc with trace Ia in polyhalite zone in upper 6". Interunit pits and pits 2'-4' deep originate from upper surface. Upper surface sharp to irregular, marked by increased polyhalite concentration; irregular over 6". Pits reactivated during deposition of overlying unit.

1594-1608.5 Halite subdivided into 3 parts:

Part a: polyhalitic medium to coarse IV to 1603 with fine halite more common near top. Upper surface subject to multiple episodes of DVT style textures. Trace primary, rare vertically elongate halite; trace cement, abundant in pits and MP (1"). Polyhalite occurs as irregular very discontinuous, thin laminae and irregular blebs locally transported downward in pits; interunit pits.

Part b: DVT texture zone halite, trace clay and sulfate. Clay brown to locally gray as irregular discontinuous to continuous thin laminae to laminae, irregular zones, and blebs - associated with medium to coarse IV, trace primary, abundant cement in lower part. Some displacive margins (mud-rich halite pan deposited in topographic lows on irregular erosion/exposure surface). Fine to coarse IV in irregular zones and pods, polyhalite occurs as irregular blebs in upper part. Claystone with I-II-IIIa-b showing sic textures. Zones about 1' thick laterally continuous of clear IV with abundant cement. Claystone in topographic lows.

Part c: halite, some to trace clay, no DVT textures at base, minor textures at top, medium to coarse IV with fine (1598-1597) and irregular clay laminae. Fine Ic common, Ia rare in argillaceous zone. Upper surface sharp, planed off during flooding.

1608.5-1615 Anhydrite with local polyhalite, gray to pink, thin laminae to laminae, most wavy, parallel, some show cross-cutting relationships, local cross-laminae. Several zones display clastic halite textures and cross-laminae. Bedding locally contorted to

	convolute (especially in polyhalite-rich area). Tepee structures at upper cont Upper contact sharp, undulatory over .5'.
1615-1622	Halite; trace anhydrite at base and trace polyhalite and anhydrite upward; sc sulfate 1616-1617. Thin laminae to laminae and disseminated polyhalite bl Sulfate delineates thin to medium beds (4"-1'). Medium to coarse IV, equant vertically elongate halite; some to moderate primary, BG locally planed of sulfate laminae; trace to some cement; locally stratified fine halite. Tr recrystallized halite. Upper surface planar, sharp, eroded by freshening. Som interunit pits with translocated sulfate.
1622-1629	Anhydrite, gray, microcrystalline, possibly organic-rich in lower 2'. Shows abun recent weeps parallel to fractures and bedding. Thin laminae to laminae, w most parallel, some low angle cross-cutting relationships. Shows some contor and convolution. Small anhydrite PAGS to 1/2" high in lower part. Abunc stratified halite PAGS in upper part to 2" high. Upper contact sharp, undulat slightly irregular over 4".
1629-1631	Claystone, gray; locally displays thin laminae which are distorted and disrup local cross-cutting relationships. Contains a 0.2'-0.4' thick fibrous halite polyhalite filled fracture near top. Pebble to granule sized polyhalite nodules wi displacive morphology interlock near the base, packing decreases upward. L fibrous halite filled fractures. Upper contact sharp undulates over 6".
1631-1636.5	Similar to underlying unit with better developed strata; more primary and l cement. Rare, vertically elongate BG fabrics. 1" thick polyhalitic zone at Upper contact sharp.
1636.5-1643.5	Halite, trace polyhalite, gray clay at top. Strata not apparent near base, crude beds (3-6") near top, delineated by polyhalite. Polyhalite occurs as very irreg very discontinuous thin laminae with displacive margins, rare small blebs. Med to coarse IV, with local irregular zones of fine and fine in small pits; equant, trac some primary with some to moderate halite cement. VO MP to 2" high x 1" w Some displacive halite near base; some II-IIIc, rare Ia in clay at top. Contains s interunit pits to 2' and deep pits from upper surface 6'. Upper surface is incip exposure/dissolution surface, with 1" very thin bed of gray clay, some transloc down into underlying halite in pits. Upper surface sharp, planar.
1643.5-1644.5	Halite, argillaceous, gray. Irregular zones and well defined laminae to very beds of argillaceous halite with clear halite. Medium to coarse IV, equ abundant cement; fine to medium Ic, some II-IIIc, trace Ia. No pits. Upper surf slightly irregular, dissolution surface.

1644.5-1645.5	Halite, trace to some polyhalite. Medium to coarse IV, major primary, vertically elongate, chevrons, cornets; trace cement. Upper surface undulatory, planar, tion - planar, marked by possible langbeinite.
1645.5-1650	Halite with some polyhalite, langbeinite and possible sylvite (in argillaceous zones). Fine to very coarse IV. Similar to underlying unit except for potash-rich zone developed on dissolution/exposure surfaces. Contains large pit 2.5' deep and about 1.5' wide filled with langbeinite with some halite. Upper surface irregular with possible dissolution lag and relief of 1'. Potash underlies polyhalite laminae near base.
1650-1650.5	Halitic claystone and argillaceous halite, brown with trace gray, deposited over irregular surface on underlying unit. Hints of thin laminae, irregular and distorted; sic. Fine I-II--III--c. Upper surface planar.
1650.5-1653	Halite polyhalitic. Polyhalite occurs as irregular continuous to discontinuous thin laminae and blebs. Unit poorly to well stratified as thin to medium beds (3"-1'). Medium to coarse IV, with trace fine halite near top. Trace cement; trace primary at base where poorly stratified, increases upward. Incipient irregular DVT dissolution surface at top; with shallow 6" pits; overlain by clay. Langbeinite occurs over halite, below polyhalite laminae.
1653-1665	Halite; polyhalitic near base to polyhalitic and argillaceous to argillaceous upward, all trace amounts. Langbeinite from 1655-1656. Argillaceous gray halite overlies irregular dissolution surfaces on polyhalitic halite. Medium to coarse IV, trace fine; trace to some primary in lower 3'; cement from trace to some upwards; trace recrystallized halite. Similar to underlying unit except polyhalite occurs as blebs more often and laminae are not as continuous - more disrupted. Unit has less primary and more cement and MP than underlying unit. Fine IV occurs only in areas subject to DVT reworking. Abundant cement in argillaceous zones. Upper irregular DVT relief to 1' topped by clay. Contains langbeinite in moderate DVT zone with pods of fine IV.
1665-1673.5	Halite, polyhalitic, argillaceous zones. Polyhalite occurs as irregular to very irregular continuous to discontinuous laminae and thin laminae, blebs, disseminated material. Blebs more common near top. Polyhalite laminae delineates well-defined beds near base to moderately well-defined near top, thin to medium beds 2"-1' thick. Gray clay-rich zones occur over irregular dissolution surface on polyhalite zones. Clay in continuous to discontinuous, very irregular laminae and thin laminae and irregular zones with I-IIa-b. Medium to coarse IV with some fine. Halite in polyhalite-rich zone occurs in cycles of polyhalite, medium to coarse IV with some moderate primary (vel, BG) halite moderate cement, overlain

	by fine IV halite. Unit displays irregular, incipient DVT dissolution surf throughout unit with pits to 1' deep.
1673.5-1676.5	Argillaceous halite, brown in lower 2', gray at top, trace to some clay. Clay o in thin contorted laminae, laminae, very thin beds, discontinuous to contin irregular to very irregular laminae, irregular zones and blebs with dish-sh pattern. Medium to coarse IV with local fine halite zone and trace very co cement; trace primary, abundant cement; halite in continuous to discontin subhorizontal zones. Unit has crude thin bedded appearance (2-5"). Eros contact between brown and gray is origin of dissolution pits which penetrate reactivate pits in underlying unit, with translocation. Brown zone contains fir medium I-IIa; gray zone has fine to medium II-IIIc and pods of fine IV. Local of very coarse halite in pit/pore near upper contact (in gray zones). Upper su wavy, slightly irregular over 4", erosional. Trace irregular polyhalite b Abundant weeps.
1676.5-1678.5	Halite; trace polyhalite as thin, very irregular and very discontinuous thin lam disseminated material, and very fine platelets, delineates crude to moderately defined thin beds (2-4") thick. Medium to coarse IV with some coarse at ba beds and fine halite at top; some to moderate primary (chevrons, cornets) some cement at base of beds. Coarse IV at base of unit mostly clear with primary. MP to 1" at base of unit. Upper surface slightly irregular to planar, p 2' deep (penetrating upper part of underlying unit) originate at contact, show material translocated downward (reactivated during deposition of overlying Upper surface planed off.
1678.5-1687	Halite, trace polyhalite; polyhalite occurs as irregular discontinuous to discontinuous thin laminae, blebs and platelets and local POS, occurs as locally. Fine to very coarse IV, mainly fine to coarse, with local irregular zon fine halite near erosional units; trace primary, some cement, trace to some junctions (recrystallization). Trace to some Ia-b in polyhalite. Locally abun dissolution pits to 1-3' deep originating at erosional surfaces (exposure). U surface is irregular over 6" with polyhalite dissolution lag, and 2' deep pits translocated polyhalite. Locally abundant MP.
1687-1697	Halite, polyhalitic to argillaceous, trace to some upward. Polyhalite as irre blebs, irregular very discontinuous laminae and local platelets and POS. occurs as irregular very discontinuous to continuous thin laminae and lami zones and local blebs. Delineates crude thin beds in medium to coarse IV (to Thin laminae (clastic, very irregular, contorted locally in upper 2'. Halite occu

	fine to coarse equant IV with trace primary, some cement, trace recrystallization. Clay is brown with local gray. Local fine IV in irregular zones (DVT), slightly polyhalitic. Above 1690; fine to medium I-IIIc with some medium I-IIIa. Local interunit pits to 2' deep. Unit contains several exposure/erosional surfaces. Upper surface planar, sharp, erosional.
1697-1701	Halite, slightly polyhalitic, alternating with trace clay. Polyhalite is fine grained, occurs as irregular discontinuous thin laminae, local platelets and POS, and disseminated blebs (with some displacive halite margins). Clay occurs as disseminated material along subhorizontal zones. Clay and polyhalite delineate thin beds to 8" thick, crudely to moderately defined. Fine to very coarse, mainly fine to coarse, equant IV with local subhorizontal zones of fine halite pods and some fine halite in pits to 1' deep. Trace to some primary and BG, some cement, trace recrystallization. Local VO MP to 1" high. Local irregular erosion/solution surfaces with 4" relief. Large pits at upper surface contain material infiltrated from overlying unit. Upper surface very irregular, sharp with .6' relief, solution surface.
1701-1710.5	Halite, trace gray and brown clay and polyhalite. Polyhalite as irregular blebs in pits and aligned parallel to strata as dissolution lag reworked by cement processes. Clay occurs as irregular subhorizontal laminae, irregular zones and local blebs around fine halite in subhorizontal irregular zones and lenticular pods. Fine to very coarse, mainly medium to coarse, IV with equant fine halite in pods, lenses increasing upward; trace to some primary, trace cement, some recrystallization. Trace coarse I-IIa, fine Ic. Shows abundant moderate to advanced DVT textures. Contains interunit dissolution pits to 5' deep. Some 2-3' deep. Upper surface irregular, marked by very very coarse halite clear zone about .2-.3' thick, planed off by erosion/dissolution. Modest amount of weeps at unit.
1710.5-1719.5	Halite; lower part (to 1713) polyhalitic grading into argillaceous reworked DVT upper part. Lower part: halite, trace polyhalite as irregular moderate to very discontinuous thin laminae and blebs and 1" horizontal zones with abundant displacive halite and zones of blebs with displacive halite in pits. Polyhalite delineates well to poorly preserved very thin beds 3-5" thick. Polyhalite in pits and strata show boxwork fabric. Medium to coarse IV with local fine halite near top; trace to some primary (vertically elongate) with trace cement. Upper part: becomes more argillaceous upward as irregular discontinuous thin laminae to laminae and zones locally containing fine to medium I-IIIa-c. Halite occurs as argillaceous zones of medium to coarse IV with displacive margins, trace primary, abundant cement, and irregular dish-shaped, pods and horizontal zones of

	fine to medium halite (slightly polyhalitic). Shows well developed DVT text Contains many large interunit dissolution pits to 1' wide and 6' deep transloc polyhalite lag material and clay downward. Upper surface planed o erosion/dissolution. Shows several pits.
1719.5-1720.5	Clay, gray, in lower .2'; upper part polyhalite, microcrystalline; laminae tc laminae contorted. Upper surface undulatory.
1720.5-1722	Halite, trace polyhalitic as platelets and blebs; medium to coarse, equant IV, primary and cement. Upper surface planed off by dissolution.
1722-1727.5	Halite, trace of polyhalite and clay. In two sequences of slightly polyhalitic hali slightly argillaceous halite increasing upward. Polyhalite occurs as irregular b and very discontinuous laminae, trace platelets near top. Clay occurs as irre laminae and blebs. Medium to coarse IV, upper 1' contains local irregular z and pods of fine to medium halite (moderate DVT textures in upper 1'); t primary, decreasing upward. Some la-c between halite pods; lc near Abundant cement near base in MP to 2". Upper surface planar, erosional. L pits to 2-3' deep.
1727.5-1740	Halite, trace clay and very slightly polyhalitic; clay occurs as irregular to irregular continuous to very discontinuous thin laminae and laminae, blebs, irregular zones; mostly irregular boundaries with medium IV halite. Polyh occurs as disseminated material within unit, as trace amounts in fine IV, irregular blebs in medium IV with mostly irregular boundaries with halite. H occurs as fine to coarse IV, equant, trace primary, mostly cement in argillace zones around irregular zones and subhorizontal pods of fine IV. Unit sho abundant DVT textures, moderate to advanced development. Has dissolution from 1-10' deep originating throughout unit and penetrating underlying (translocating material down). Upper surface is irregular, planed off by dissolutio
1740-1745.5	Halite, trace polyhalite; polyhalite occurs as irregular moderately discontinuous very discontinuous thin laminae and blebs (some with displacive margin delineates beds 2-6" thick becoming thinner upward. Medium to coarse IV w local very coarse halite in MP at base and wide dissolution pits (about originating in overlying unit, shows moderate to major primary BG at bas decreasing upward; local subhorizontal zones of fine halite. Abundant MP ne base, some to 1' x 1'. Upper contact very irregular, gradational, undulates ov 1.5'. Dissolution surface.
1745.5-1748	Polyhalite unit, in 3 parts; .2' polyhalite at base, laminaed, microcrystalline. halite, with irregular discontinuous thin laminae of polyhalite; local blebs of equa medium to very coarse, mainly medium to coarse IV, trace primary and son

	cement, shows displacive boundaries with polyhalite, sharp upper contact. Remainder is laminaed to thinly laminaed polyhalite, slightly irregular to convolute, showing cross-cutting relationships. Local possible stratified polyhalite PAGS to 1" high. Possible polyhalite cracks spaced about 3'. Possible tepees. Upper contact sharp, irregular over .5'.
1748-1754.5	Halite, trace polyhalite to 1749, trace to some gray clay in upper 1'. Polyhalite occurs as irregular to very irregular thin laminae; slightly discontinuous at base, become more discontinuous upward; isolated blebs with some displacive margins, POS and platelets, and crystal drapes. Mainly medium to coarse IV with local very coarse halite in MP, fine halite in middle of unit with disrupted polyhalite textures. Shows some to moderate primary subaqueous halite (BG, vel) at base with increasing shallow WT reworking upward. Minor cement at base increasing upward. MP occur from middle of unit, increase upward. Local interunit pits and relief indicating moderate reworking with moderate WT. Pits to 2-4' deep. Clay at top as thin irregular laminae. Abundant pits originate at top to 4' deep upper surface. Erosion with gray clay, planar.
1754.5-1756	Halite, clear to cloudy, trace (<1%) polyhalite and anhydrite. Fine to coarse IV, mainly medium equant, some primary, some cement, poorly defined very thin beds 3-4" thick. Vertically aligned clear zones present; some BG textures. Upper contact sharp, well defined by polyhalite.
1756-1759.5	Interbedded polyhalite and halite. Lower 1-2" consists of gray claystone overlain by polyhalite 4" thick. Polyhalite shows pillows and moderately well-developed loading structures into clay while soft. Polyhalite occurs as very thin beds (to 5") to thin laminae, horizontal and undulatory to slightly wavy, thin laminae, wavy to planar with ripples to 1/2" high. Fine to coarse vertically elongate IV, with abundant primary (chevrons, BG) and some cement in 3-5" very thin beds (all subaqueous). Contains irregular thin laminae of polyhalite and crystal drapes. Upper contact slightly irregular. Overall polyhalite content decreases upward in upper 1.5'.
1759.5-1770	Divided into interbedded polyhalic halite (b,d,f,h) and argillaceous halite (a,c,e,g,i). Polyhalitic/halite: equant to vertically elongate fine to coarse IV, mostly medium, with some fine halite at tops of very thin beds (common in d,f); trace to moderate primary (BG, vel) with trace to some cement. Polyhalite occurs as continuous to very discontinuous (most in b) thin laminae, blebs (with displacive margins in b), disseminated platelets and POS, and intercrystalline drapes. Polyhalite delineates crude (b) to well-defined very thin beds (1-3") in upper units. BG textures can be planed off and overlain by sulfate (indicating no subaerial exposure, increasingly common upward). Fine halite with POS indicate minor shallow WT exposure

(common in d,f,h). Shows repeated cycles of: BG halite, fine halite, polyha
varying amounts of fine halite and disruption of polyhalite. Tops of units (e
show dissolution pits to 1'; and pits occur locally within units.

Argillaceous halite: fine to very coarse IV, mostly medium or medium to
trace to some primary (BG, vel), abundant cement, equant. Some I-IIIa-c,
Ic, in argillaceous vaceous zones. Clay mostly gray, some brown. Clay oc
irregular continuous to moderately discontinuous thin laminae and blebs wi
to some displacive margins. Some fine halite in upper units (e,g). Mudc
show some dissolution pits within and at tops. Irregular upper contacts.
occur in lowermost part around irregular clay laminae and within halite adj
clay laminae.

1770-1772 Divided into lower and upper argillaceous halites.

Halite, some clay, in lower part; brown with minor gray, thin laminae to la
mildly to very contorted and irregular, with trace sic texture. Halite oc
laterally discontinuous (1"-2" thick), equant, mostly clear with polyhalite P
platelets and as I-IIa-c, fine to medium. Local subhorizontal fibrous halit
fractures, to 1/4" thick, laterally discontinuous. Upper surface sharp, grad
showing erosion and development of dissolution pits 2' deep into underlyi
showing translocated clay.

Halite, trace clay, in upper part: brown clay, irregular, moderately continu
discontinuous thin laminae, laminae and blebs. Halite is mainly medium to
IV. Halite contacts with clay are locally displacive (I-IIa-b). Irregular zones o
are similar to lower part. Upper surface sharp and erosional with pits <2
penetrating underlying part a.

Weeps in pits

1772-1775 Halite, trace polyhalite to trace polyhalite and clay upward. Clay is mostly
and occurs as irregular moderately continuous to discontinuous laminae ar
laminae (more continuous at top) and local blebs. Clay laminae delineate
thin beds (3"-4") at base to moderately well defined very thin beds (2"-3")
Polyhalite occurs as abundant POS texture in upper well stratified zone with v
amounts of separation between the platelets. Very discontinuous irregul
laminae, and local blebs with some displacive margins. Fine to very coarse, r
medium to coarse IV with more fine to medium halite near upper contact, ec
some triple junctions, trace polyhalite, some cement. Ia-c, some II-IIIa in
part; thin argillaceous beds show fine Ic and medium Ia. Contains several int
dissolution pits to 1' deep. Pits originating at top show downward translocat

	overlying material and are about 3' deep. Upper contact planar as dissolution surface, slightly irregular, sharp. Moderate weeps in unit.
1775-1777	Argillaceous halite and halitic claystone. Halite occurs as medium to coarse I-IIIa-c, and fine to medium IV in pods and irregular stratified zones. Shows clastic style stratification as thin laminae and laminae which are wavy, locally contorted, and slightly irregular with local cross-cutting relationships. Incipient to moderately well-developed SIC textures locally; syndepositional slumping. Polyhalite and anhydrite occurs as platelets, POS textures, and blebs within halite. Upper surface is the origination point for pits to 4' deep which shoe downward translocation of clays. Upper contact is erosional and overlain by clay laminae.
1777-1783	Halite, polyhalitic 1' thick argillaceous zone near top. Polyhalite occurs as irregular, moderately discontinuous thin laminae (more common near base), blebs often showing displacive margins (most common in dissolution pit fillings), and irregular thin (1/2-1") subhorizontal zones of platelets (some POS texture) and very small blebs (more common toward middle and top of unit). Fine to very coarse, mainly medium to coarse IV, with coarse and very coarse in pits and MP fillings and cements; fine halite is abundant locally in subhorizontal zones in middle and top part of the unit, within and associated with polyhalite zones of platelets and POS textures. Halite equant with trace primary, abundant cement. Argillaceous zone (mostly brown clay) is very thinly bedded (to 2+") with following repetitions: clear coarse halite with clay as irregular laminae and blebs with displacive margins; medium halite with abundant primary textures, some BG textures, very little clay; clay-poor fine halite. Upper polyhalitic zone shows more abundant fine halite in subhorizontal zones. Unit contains some dissolution pits and pipes originating from various horizons within the unit (1-3' deep). Pits at upper contact were reactivated during deposition of overlying unit as clay from overlying unit is translocated down into this unit. Upper surface irregular and erosional with polyhalite-rich zone as solution lag. Unit produces moderate amount of brine.
1783-1784.5	Polyhalite, medium crystalline, minor red halite; laminae to thin laminae, undulatory, locally slumped and slightly contorted showing cross-cutting relationships. Contains local stratified polyhalite PAGS. Halite as BG or as PAGS, also fills small sigmoidal separation at top of unit. Abundant weeps in unit.
1784.5-1790	Argillaceous halite, unit subdivided into 5 parts (Figure 10). A) Medium to coarse IV, trace primary, abundant cement with brown clay as irregular discontinuous laminae, blebs and zones with I-II a-b (with abundant displacive margins). Upper surface erosional with clay lag.

B) Halitic gray claystone with irregular pods of fine IV and I-IIa-b. Shows di
and slumped thin laminae and laminae. Upper surface erosional with clay la
C) Medium IV with some fine IV near top. Brown and gray clay as irr
disrupted laminae. Upper contact erosional with local brown clay solution lag
D and E) Both are similar to B with more slumping of strata and textures
separated by an erosional surface. Upper contact of E is sharp. Unit has ab
weeps.

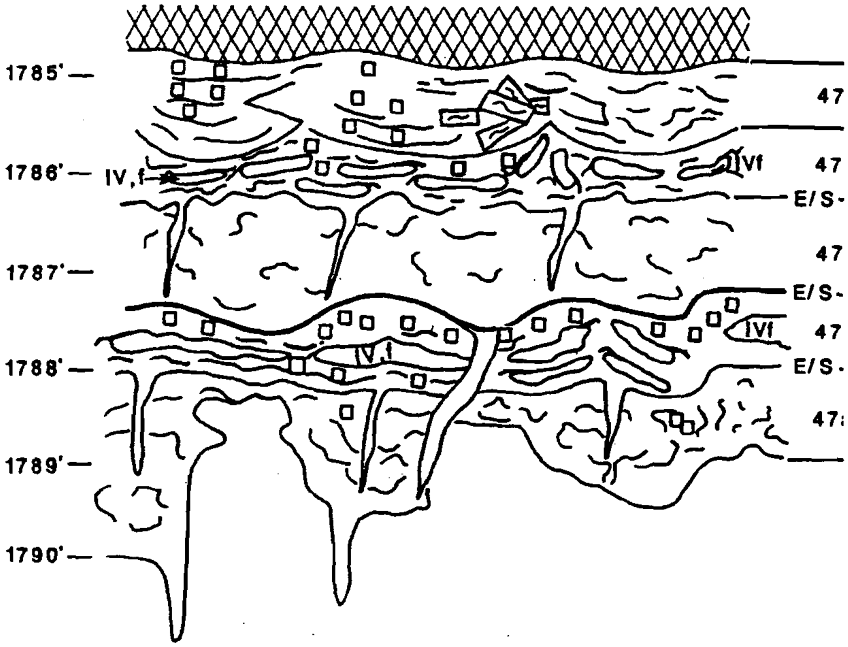


FIGURE 10 SOLUTION FEATURES AND EROSION/SOLUTIO
(E/S) SURFACES MAP UNIT 47

1790-1793 Halite, mostly clear with trace of polyhalite as irregular very discontinuous l
and blebs with some displacive margins and strata poorly defined. Upper s
very irregular over 1+'. Erosion/dissolution surface. Unit penetrated by pits
6"-1.5' and up to 2' deep filled with clear cement. Medium to coarse IV wi
coarse cement and pipe fillings, local possible MP, trace fine halite. Trace t
primary, some cement. Trace triple junctions, local displacive textures in pipe

1793-1795 Halite, polyhalitic, very thin bed at base (.1' thick) showing slumping on
contact (underlain by 1/2"gray clay laminae), elsewhere polyhalite occ
laminae to very thin laminae, laterally persistent and irregular, discontinuo
laminae to very irregular, and irregular blebs with some displacive halite m
Polyhalite zones locally contain I-IIa-c. Polyhalite zones delineate very thi

(.1-.2') in halite. Medium to coarse IV, equant, with trace very coarse; some triple junctions, some primary and vertically elongate halite and cement (halite PAGS in lower polyhalite). Upper surface irregular, shows dissolution lag of polyhalite locally, .5' relief.

1795-1799 Halite, subdivided into 3 parts: a and b argillaceous as irregular, slightly to moderately discontinuous thin laminae and laminae, brown with some gray in b. b and c polyhalitic as fine disseminated material, irregular very discontinuous thin laminae and blebs showing trace to some displacive margins - overall laminae occur in more continuous zones in c. Part a: medium to coarse IV, trace to some primary halite and abundant cement, some displacive margins (Ia-c) in more argillaceous zones, minor amounts of fine halite in small irregular zones near top (upper 4"). Upper surface of a is irregular, undulatory over .7', marked by clay dissolution lag. Pits to 2' deep originate at contact. Part b: contains irregular zones and lenticular pods of slightly polyhalitic fine IV with dissolution margins. Bounded by irregular subhorizontal laminae of clay. I-IIa-c between pods of IV. Upper surface irregular over 4", showing dissolution lag of polyhalite and clay, pits to 1' deep originate at contact, contact erosional. Part c: very thinly bedded (.1-.2') with irregular polyhalite laminae delineating strata. Fine to coarse IV halite. No pits. Upper contact marked by gray clay in overlying unit, erosional, planed off by dissolution.

1799-1806 Halite, mostly polyhalitic with 2 zones about .5' thick of clear halite with trace amounts of thin gray clay laminae. Contacts of each zone of clear halite indicate subaerial exposure relief. Halite consists of medium IV, with some coarse to very coarse as cements of pores and pits, and irregular zones of fine halite near each major erosionial surface. Polyhalite occurs as irregular thin, moderately to very discontinuous laminae, blebs and zones of disseminated polyhalite .1-.2' thick. Polyhalite laminae and zones delineate very thin beds (.2-.4' thick). Polyhalite also occurs on some erosion/dissolution surfaces as an insoluble lag. Clay occurs in trace amounts in two zones as irregular moderately discontinuous laminae locally translocated down in dissolution pits and pipes. Dissolution pits mostly shallow (about 1+') and originate on erosional surfaces within and at top of unit. Upper surface erosional/dissolutional, slightly irregular but planar on large scale, showing dissolution lag of polyhalite overlain by clay laminae of next overlying unit. Trace primary, some cement, some triple junctions.

1806-1807.5 Halite, trace to some clay and polyhalite upward; divided into 5 parts as shown i
Figure 11:

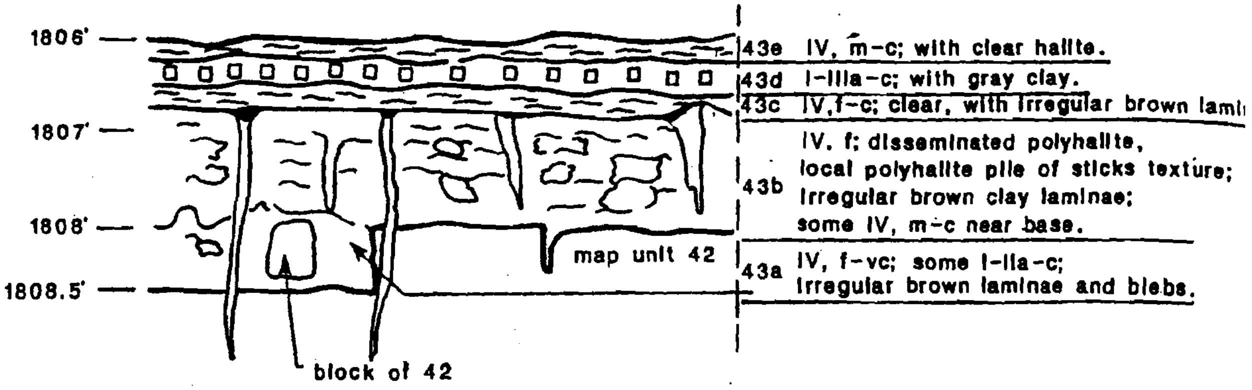


FIGURE 11 HALITE SOLUTION FEATURES

Medium to coarse IV, trace primary and moderate recrystallization; fine IV in pod
fine to medium I-IIc in more argillaceous parts. Clay occurs as irregular ve
discontinuous (in a,b,c) and moderately continuous (e) laminae, blebs, and is matr
material in d. Polyhalite occurs in b as disseminated concentrations and platelets
local POS texture. Pits originate in b and penetrate into upper surface of underlyi
unit (1-2' maximum penetration depth).

1807.5-1813 Halite, clear to white, medium to very coarse IV, with irregular zones and pods
fine halite, minor amounts within polyhalite-rich zones and abundant in upper
Halite is equant, shows some triple junctions; trace to some primary, some ceme
as crust cement, MP and dissolution pit fillings. Polyhalite in middle zone occurs
widely spaced very irregular and very discontinuous thin laminae and blebs wi
trace displacive margins with halite. Polyhalite in upper zones similar, but occurs
more discrete zones. Upper surface is erosional, sharp, shows relief to 1', ve
irregular, capped by persistent laminae of brown clay which thickens into pits a
filled relief. Polyhalite concentrated in variable (<1") zone near upper contact
dissolution lag. Unit penetrated by dissolution pits and pipes, moderately abunda
(spaced 1.5-3'), some at upper surface show reactivation during deposition
overlying unit. Pits vary in depth from .5' within middle zone to 3' when originati
at upper contact. A few pits originate in middle polyhalite-rich zone, but mo
originate at upper contact.

1813-1814 Halite, clear with trace polyhalite as irregular thin laminae, moderately continuous
very discontinuous, and blebs and incorporated drapes on BG halite - all showi

some displacive boundaries. Polyhalite zones vary from 1/8-4" in thickness and delineate crude to well developed very thin beds (2-6" thick). Medium to very coarse IV, with localized irregular zones of fine halite beneath each polyhalite-rich zone and at top, trace primary with some cements of crust, in MP, and pits; equant to irregular crystals with some triple junctions. Unit contains abundant pits spaced 1-2', many as deep as 2' showing infiltration of polyhalite into underlying unit. Upper surface erosional, planed off by freshening. Deposition of upper 0.1' follows.

1814-1815 Halite, trace clay, clear to white at base, .4' up from base a zone .05-.1' thick is slightly polyhalitic in very discontinuous irregular laminae; zone undulates irregularly (2") over dissolution surface. Upper .5' contains trace gray clay as irregular very discontinuous laminae. Medium to coarse IV with local fine halite near top of units in irregular zones, upper surface planar and erosional with local solution lag of gray clay as a thin lamina. Unit contains many evenly spaced dissolution pits some as wide as 6", most .5' deep. Several pits coalesce to form large pit 1' wide at top, 1.5' wide at base. Trace primary, some triple points.

1815-1824 Halite. Mostly pure below 1819: fine to very coarse, mainly medium to coarse, IV with abundant triple junctions and trace to some primary. Above 1819, trace clay and poly content increasing upward. Halite in upper part mostly medium to coarse IV with abundant triple junctions, rare primary and moderately abundant displacive margins with clay zones. Trace I-IIa-c within clay zones. Pods and irregular zones of fine crystalline IV present with trace polyhalite in upper 2'. Clay occurs as disseminated material, blebs and irregular, very discontinuous to moderately discontinuous thin laminae. Clay is translocated downward within dissolution pipes. Upper surface is irregular and sharp over .5' with clay dissolution lag. Clay is mostly brown, but local zones of gray occur. Large scale pipes originate within unit at its contact and from overlying unit. Many reactivate pre-existing pipes. Pipe depth varies from 3 to about 10'.

1824-1825.5 Halite, trace polyhalite, trace brown clay at top. Both mostly as thin laminae and isolated trace amounts. Medium to coarse equant IV; some primary cement, and recrystallized. Upper surface very irregular, trace concentration of foreign material. Dissolution surface planed off slightly prior to deposition of overlying unit. Surface irregular over .5'.

1825.5-1833 Halite, polyhalitic, becoming increasingly argillaceous upward; dissolution pits within unit and from above infiltrated clay into unit. Within intact section polyhalite occurs as thin blebs and thin laminae, very irregular and very discontinuous, delineating

	very crude very thin beds to .3'. Medium to coarse IV, equant, trace t primary, abundant clear and some cement. Polyhalite in dissoluti translocated and concentrated, have abundant displacive halite margins. Pi with medium to very coarse IV with local primary halite (indicating rapid gr open pore as large scale "drusy" cement). Pits contain polyhalite, transl down toward and into underlying unit, and clay as irregular, brown bleb abundant displacive margins, often vertically aligned along infiltration path. part of unit, when not dissected by dissolution pits, contains abundant fin pods and irregular zones surrounded by claystone and displays diss boundaries (with gray and brown clay). Clay also locally within fine halite. contact sharp to gradational, marked by clay dissolution lags; shows ir surface with about .5' relief. Entire unit dissected by many dissolution pits. M what is observed below the upper part was deposited as pit fillings. M generations of pits are evident and often overlap. Many of the pits originate unit or at its upper contact. Some originate with flooding prior to depos overlying unit and reactivate older pits. Entire unit shows very complex diss history with dissolution features dominating record and is advanced version textures.
1833-1835	Halite, trace polyhalite to trace gray and brown clay upward. Clay occurs irregular and very discontinuous laminae and thin laminae and in irregular Medium to coarse IV with very coarse halite in dissolution pits origina overlying unit, fine halite in irregular pods and zones bounded by irregular cl zones; trace fine I-II c near top in clay. Trace primary and BG halite near ba abundant cement and clear halite. Upper surface irregular with relief ab Contains dissolution pits to <1' deep very locally.
1835-1837	Halite, trace polyhalite, more near base and top. Occurs as blebs with som irregular, very discontinuous thin laminae showing displacive margins. Ab clear halite, some BG. Medium to coarse equant IV with trace vertically el halite. Upper contact irregular over 4". Dissolution surface (DVT), sh gradational, marked by increasing polyhalite. Unit penetrated by pits from ab
1837-1840	Halite, trace clay (brown and gray) increasing upward, trace polyhalite ne Medium to coarse IV, with irregular pods and zones of fine to medium halit top (upper 2'). Clay occurs as irregular thin laminae, very discontinuous contorted, trace displacive halite margins, I-IIa near top. Polyhalite has inf

	down 3' into a narrow pit. Pits penetrate from 2-3' and originate at upper surface. Upper contact is irregular with low relief, was planed by erosion/solution; marked by clay laminae. Local triple points in more pure halite; trace to some primary.
1840-1842	Halite, trace clay to very coarse polyhalite in upper part. medium to coarse IV, very coarse halite cement, with fine halite near top. Clay occurs as irregular discontinuous laminae around zones of fine halite. Fine material has some polyhalite laminae. Trace primary, some cement. Polyhalite displaced downward in pits. Pits to 5' deep. Upper surface irregular with .5' relief, and marked by irregular clay dissolution lag.
1842-1844.5	Halite, trace polyhalite, content decreasing upward in those zones bounded by dissolution pits. Polyhalite is thin laminae, very irregular and discontinuous and delineates crudely preserved very thin beds to laminae in halite. Medium to coarse halite IV, very coarse cement, equant with trace vertically elongate halite, trace primary and some cement. Polyhalite in dissolution pits. Laminar-like blebs with abundant displacive margins and laminae. Upper surface is very irregular with about 2+' of relief.
1844.5-1845.0	Polyhalite, contains clastic and BG halite in topographic lows; microcrystalline, thin laminae to micro-laminae, showing local slumping and contortion. Shows local incipient sic texture and slumping of soft sediment into existing large voids (1' x 2' maximum) after deposition.
1845.0-1850	Halite, trace polyhalite, trace to some clay upward. Polyhalite in lower 2.5' as irregular, very discontinuous thin laminae; locally outlines abundant displacive halite (I-IIa). Polyhalite is thicker in probable paleolow areas. Halite occurs mostly as displacive cements with local areas showing some very crude, very thin beds (to .2'). Unit is penetrated by abundant dissolution pits originating from various horizons. Contains large MP of clear, very coarse halite. Medium to coarse IV with some very coarse; local I-IIa with displacive margins, equant; trace vertically elongate halite, trace primary with locally abundant cement. Contains irregular pods and lenticular to tabular zones of fine halite in upper part bounded on top and sides by dissolution surfaces. Some halite in upper part is similar to lower 2.5' in polyhalite content and distribution. Most halite, however, is fine grained and polyhalite-rich with local subhorizontal clay-rich zones. Gray clay occurs as irregular laminae and irregular accumulations in topographic lows. Small dissolution pits to 2' deep originate within this upper part. Floods deposited overlying unit and eroded halite crust leaving only relict fine halite. Overlying unit collapsed into existing void after deposition (Figure 12). A large (2' x 1') crudely lenticular pore within unit is filled with clear halite.

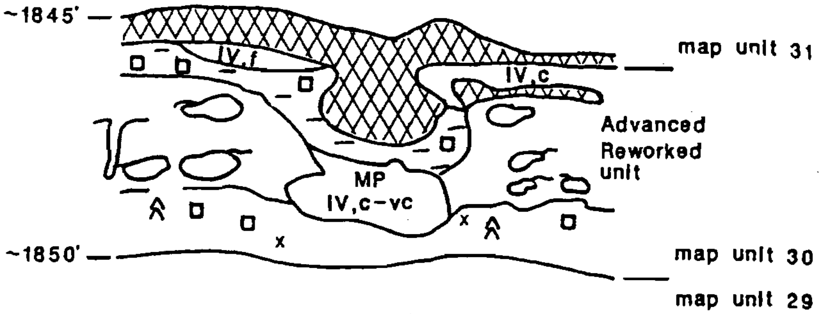


FIGURE 12 COLLAPSE AND MACROPORE FEATURES

1850-1853.5	Halite, trace polyhalite to trace clay upward. Crudely to moderately well defin polyhalite laminae to very thin beds (about 2") delineated by thin to micro lamin of polyhalite. Polyhalite laminae are irregular, very discontinuous at base and to becoming more continuous in middle part of unit. Blebs of polyhalite occur ne base and top. Clay content increases toward top. Claystone occurs in irregul zones overlying halitic zones, as infiltrated material along dissolution pipes and pit and is poorly laminated. Laminae to very thin beds (most 1/2", some 2") surrour dish-shaped pods and lenticular zones of polyhalitic halite. Clay zones sho discontinuous irregular thin laminae and local areas with incipient to moderatel well developed sic texture. Unit contains several large-scale dissolution pits a originating in upper 2'. Pits show general spacing over about 2'. Many penetrat into underlying unit with maximum penetration of 2' into underlying unit Penetration height varies from 3-5'. Unit shows several clear episodes of pi development (dissolution, infiltration and cement growth), some with cross-cuttin relationships. Large dissolution pit feature appears to occur where several pits coalesced (perhaps close to the intersection of polygon limbs; Figures 13 and 14); as the feature developed with time additional pits were included. Halite is fine to coarse IV, with ultra coarse halite in pit; equant irregular, some primary and cement. Local Ia and Ic.

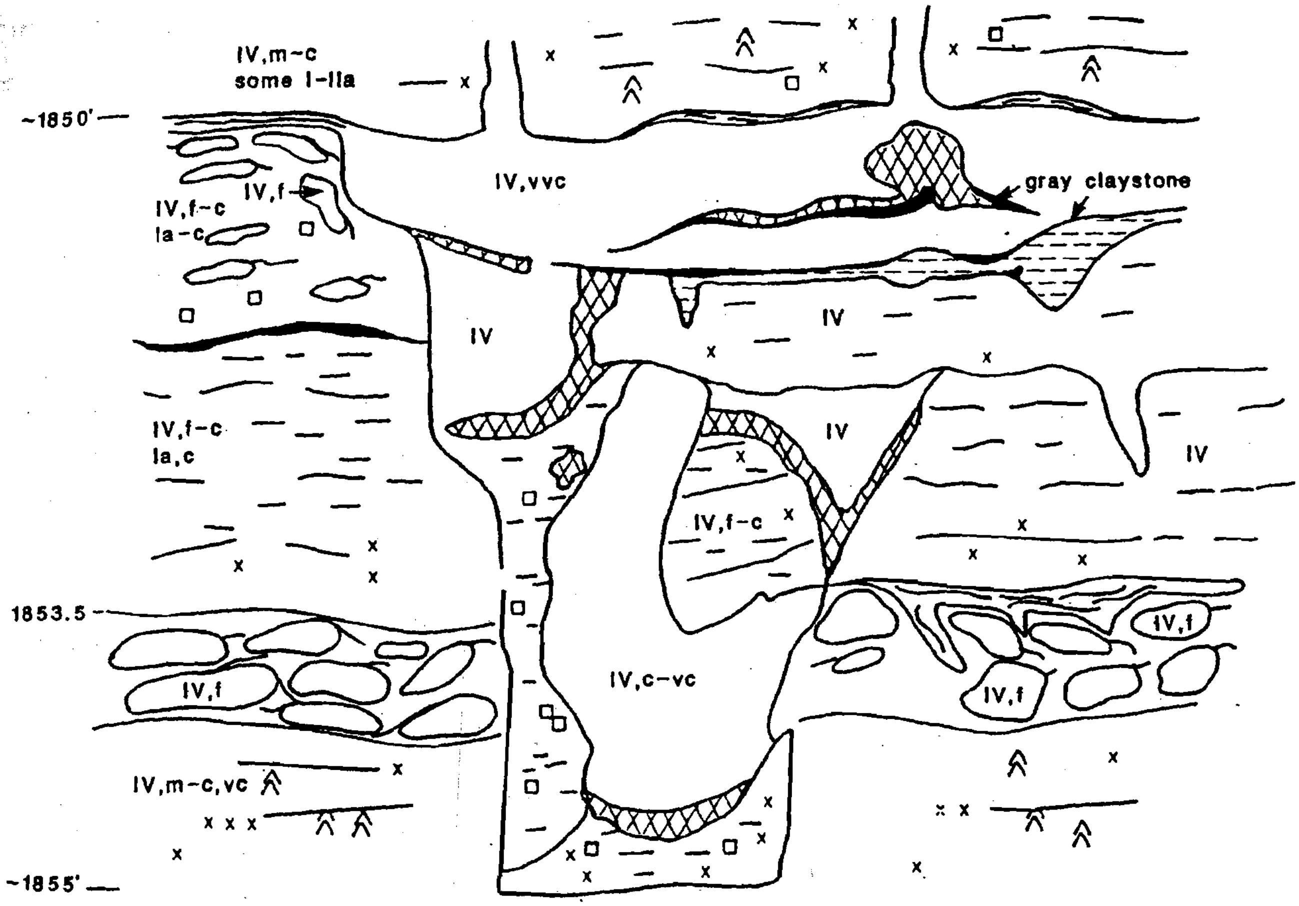


FIGURE 13 GENERAL LITHOLOGY OF MAP UNITS 28-30 AND COMPLEX SOLUTION FEATURE

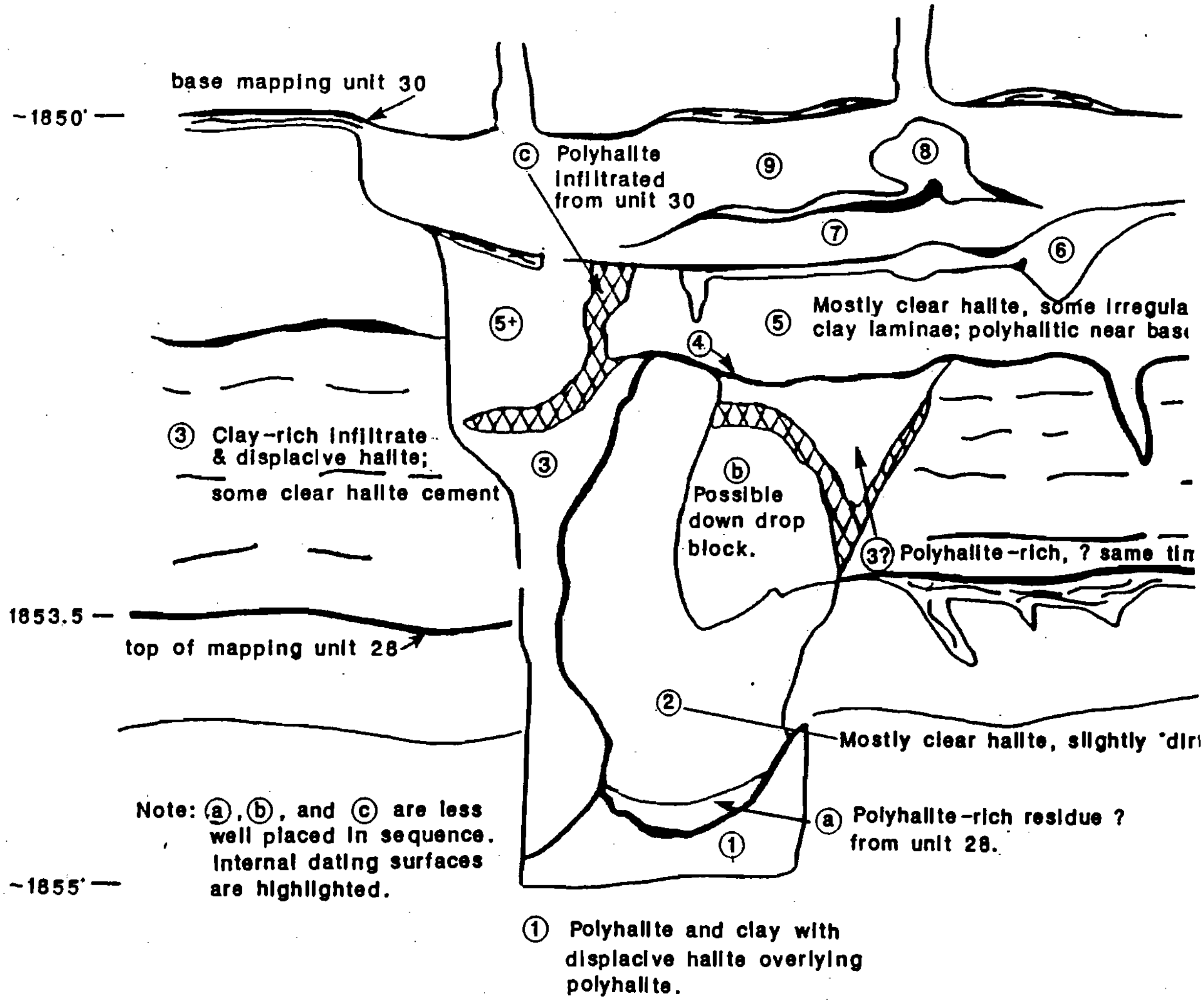


FIGURE 14 GENERAL SEQUENCE OF EVENTS (1–9) FORMING SOLUTION FEATUR

1853.5-1862 Halite, trace polyhalite, trace polyhalite and clay in upper 6" as laminae and th laminae, regular to slightly irregular, mostly continuous, delineating strata; very th to thin beds (.2-.8'). Polyhalite laminae become slightly irregular and mo discontinuous in upper 3', some showing displacive margins with halite. Medium coarse IV, abundant vertical elongate with some equant. Abundant BG texture many planed off by sulfate laminae. Abundant primary fluid inclusions with som cement (coarse to very coarse), halite crystals often show internal sulfate parallel t growth planes. Sharp planar upper contact with irregular dissolution pits and relie locally (to 1+' deep) completely cutting into unit. Small zones (1" x 3") possibl recrystallized. Upper 1' is argillaceous with discontinuous pods and zones of fine t coarse polyhalitic halite similar to the underlying material.

1862-1863	Polyhalite, halitic; laminae to thin laminae, irregular to slightly contorted; clastic halite within sulfate, contains partly replaced swallowtails to 1/2" high. Some medium to coarse IV within unit is possible BG halite. Upper contact is sharp, undulatory. Unit undulates over 1' around shaft.
1863-1867	Halite, trace to some clay and polyhalite. Medium to coarse IV, Trace to minor primary, minor cement zones of fine Ia and fine IV in pods and pods with some Ia and Ic in upper 1'; some IIa and Ic; equant. Clay (gray and brown) content increases upward, upper 1' dominantly argillaceous with no pods of sulfatic material. Pods of fine halite are abundant. Irregular zones of laminae to very thin beds are delineated by thin laminae of mostly finely crystalline polyhalite. Polyhalite platelets and "pile of sticks" texture show dissolution of cements. Interunit dissolution pits to 3' deep originate from different horizons. Upper surface of halite is sharp, irregular with dissolution planing. Overlain by gray clay containing bifurcating horizontal fibrous halite-filled fractures to 1" thick. Unit shows abundant weeps, some developing after washing.
1867-1873	Halite, trace polyhalite, decrease in upper two-thirds. Medium to coarse IV; equant with trace vertically elongate, some primary with good vertical growth; some cement present with some possible macropore filling. Moderately well to crudely defined very thin beds (.2-.4') delineated by very irregular to discontinuous thin laminae of polyhalite. Polyhalite forms local blebs, POS. Laminae are most continuous from 1870-1869.
1873-1875	Halite, trace clay and anhydrite. Medium to coarse IV, equant, trace primary, abundant cement; displacive growth is abundant in muddy areas with I-IIa-b textures. Crude very thin beds (.2-.3'). Irregular discontinuous laminae (to about 1/2") are persistent and define strata, irregular discontinuous thin laminae, and muddy zones with very thin beds. Sulfate occurs locally as platelets in POS texture. Upper surface is irregular with dissolution pits to 6" deep. Interunit pits do not occur.
1875-1878.5	Halite, trace polyhalite. Laminae to very thin beds with minor amounts of polyhalite delineating well defined strata; polyhalite occurs as irregular laminae to thin laminae near base and thin to micro laminae near top. Laminae become more irregular near top and occur within a wider, thicker zone and are more disseminated. Upper surface irregular, undulatory over about 4". Dissolution relief (Death Valley style). Well defined, narrow (<1" wide) dissolution pits uniformly 1+' deep, evenly spaced 3+' (probable dissolution of efflorescence from within polygonal crack during flooding event as halite within pit is mostly coarsely crystalline). Halite is medium to

	coarse IV, equant, some vertically elongate near base, some irregular. Som moderate primary textures; cement content increases slightly upward. Polyha concentrated slightly upward with more displacive boundaries. Fill wit polygon/dissolution pits is medium to coarse IV, equant, clear, <10% primary, tr gray clay (infiltrated from above).
1878.5-1887	Halite, trace to some clay mixed with trace sulfate. Medium to coarse IV with loc abundant fine IV in irregular zones and pods, Ia-c in claystone zones and lamin some IIIa-c locally. Abundant gray and brown claystone zones as irregular v discontinuous laminae to very thin bedded pods in lower part, laminae to very t bed scale. Mostly subhorizontal in upper part laminae to very thin beds. Loc abundant primary halite as BG chevrons and cement. Irregular laminae m dissolution boundaries. Polyhalite as blebs and irregular laminae locally infiltrat downward into dissolution troughs. Dissolution pits and troughs to 3' in lower p 1 penetrates underlying unit. Dissolution lowered material around well-cement core of dissolution pit bending laminae upward (Figure 15). Upper contact sha erosional, marked by clay, planed off by dissolution.

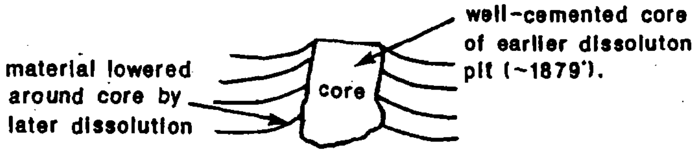


FIGURE 15

1887-1889.5	Halite, trace polyhalite. Medium to coarse IV, some primary (BG, vel, chevrons abundant cement. Sense of stratification very poor. Upper surface irregular wi dissolution pits penetrating into unit from overlying unit.
1889.5-1894	Halite, trace polyhalite, trace polyhalite and clay near top. Medium to coarse I equant, planar to irregular boundaries, some primary (BG, vel, chevrons) an cements. Fine halite is abundant in pods with some very coarse near to Irregular, very discontinuous laminae (rare) and some blebs of polyhalite. Gray wit some brown clay irregularly distributed in upper part around irregular pods an zones of fine IV. Upper contact sharp, marked by shallow 4" dissolution surfac No pits penetrate unit.

1894-1895	Polyhalite, microcrystalline, reddish orange; some laminae; clastic sand-size halite, contains Ia-c halite. Thin clay with polyhalite at base. Some efflorescent crust indicating recent brine inflow even after washing.
1895-1896.5	Halite, trace polyhalite in lower part, trace clay and polyhalite in upper part. Lower part: fine to coarse IV, equant crystals. Contains very irregular to discontinuous laminae with abundant blebs of polyhalite with some Ib. Trace to some primary. Upper surface sharp to irregular, marked by polyhalite. Upper part: medium to coarse IV, equant to irregular halite. Trace polyhalite as blebs; irregular zone of polyhalite (0-2" thick) at top (overlain by gray clay). Trace primary fluid inclusions. Some dissolution pits to 6".
1896.5-1898.5	Halite, trace anhydrite and polyhalite with clay to trace gray and brown clay upward. Interlaminated and very thinly bedded with mudstone. Fine to coarse IV and IIIb-c, equant, some primary fluid inclusions; some Ia halite. Fine halite occurs in pods and irregular zones in upper part. Gray (N6) clay occurs in irregular to discontinuous subhorizontal zones showing deposition in topographic lows, local zones show some rotation after deposition. Trace polyhalite is disseminated in fine crystalline zones and some irregular discontinuous laminae and blebs. Clay-rich zones are dish-shaped. Upper contact is irregular, partly planed off dissolution surface.
1898.5-1908	Halite, trace polyhalite. Medium to very coarse IV at base to fine to coarse IV at top, equant with some vertically elongate, planar to irregular crystal boundaries; major primary fluid inclusion zoning, BG halite, and cumulates at base, decreasing upward, cements present. Well defined beds at base to very thin beds to crude laminae at top marked by irregular thin polyhalite laminae. Laminae become more discontinuous upward with more blebs. Upper contact irregular to erosional.
1908-1913	Halite, trace polyhalite. Medium to coarse IV, equant with some vertically elongate, abundant planar boundaries, major primary fluid inclusion zoning, BG halite. Very thin to thin beds, each bed topped by laminae of polyhalite; lower polyhalite boundary commonly shows displacive margin with halite, contacts with laminae irregular, undulatory. Vertical BG halite textures are commonly capped by thin sulfate (indicating sulfate deposition on bottom; Figure 16). Polyhalite is abundant; unit differs from overlying unit above in lacking intercrystalline polyhalite. Upper contact sharp, marked by sulfate laminae.

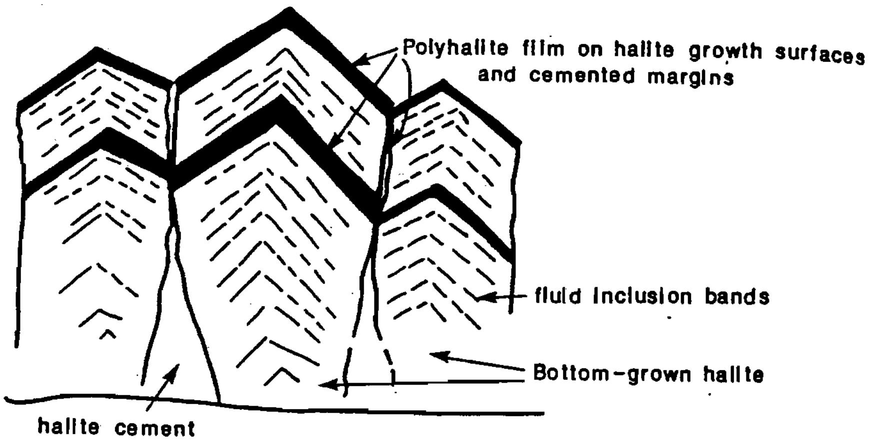


FIGURE 16 1908–1913

1913-1914.5	Polyhalite, microcrystalline, halitic in upper part as clastic coarse sand-size grains. Polyhalite probably pseudomorphs anhydrite. Laminae to very thin beds in upper part; possible ripups in lower part. Lower .3' consists of tan anhydrite with polyhalite pseudomorphs of swallowtails to 1" high. Thin laminae to laminae, possible algae in lower 1". Upper surface irregular, sharp.
1914.5-1915	Claystone, polyhalitic (about 40%), as nodules I-IIIc sulfate nodules. Laminae of polyhalite at top, upper surface sharp, wavy.
1915-1918	Halite, trace sulfate, zone with trace clay and sulfate. Abundant subhorizontal thin laminae and blebs, many displacive margins with halite. Medium to coarse IV with coarse to very coarse in upper part, equant to irregular vertically elongate, some to moderate primary BG halite near base, with some cement. Upper middle part of unit is argillaceous with trace clay as thin laminae, irregular, discontinuous, some blebs. Polyhalite in upper .5' polyhalitic as stringers and blebs. Erosional syndepositional relief on lower polyhalitic section is minor, pits 6-8" deep (low relief, shallow/moderate WT incipient). Similar surfaces on top of argillaceous section. Moderately thin or moderately well defined to crudely defined very thin beds. Gray (N6) clay. Upper contact sharp, erosional.
1918-1922	Halite, trace to some gray to brown clay, trace polyhalite. Very crude very thin to thin beds; no dissolution pits or pipes. Medium to coarse IV, fine to very coarse upward; equant, some displacive/inclusive halite in argillaceous zones; some primary, increases upward. Upper contact sharp, dissolution plane.

1922-1925	Halite, trace to some polyhalite as irregular, very discontinuous stringers and abundant blebs with some displacive halite margins. No obvious strata in unit. ?? Halite fills dissolution pits in underlying unit. Medium to coarse IV; Moderate primary at base, decreasing upward. Some inclusive halite at top. Polyhalite content increasing upward. Dissolution pits to 3' deep at top of unit. Upper contact sharp, well defined with pits.
1925-1933	Halite, trace clay (mostly gray, but some reddish brown) and trace polyhalite; unit appears gray. Medium to very coarse IV, with fine to coarse IV in more argillaceous zones, equant, local displacive boundaries (IIa) in mud. Some to moderate primary in lower part, some in upper part. Reddish brown laminae irregular to discontinuous in zone near middle of unit. Contains numerous dissolution pipes and pits 4-8' deep, many originate within unit, some at top of unit, and 1 pit penetrates from above and is filled with irregular polyhalite with displacive halite boundaries and equant to irregular coarse IV, with no primary. Upper contact sharp. No obvious strata.
1933-1939	Halite, trace polyhalite. Medium to coarse IV; equant with trace vertically elongate crystals, moderate to major primary, some cement, some displacive boundaries between polyhalite and halite. Contains some irregular and very discontinuous polyhalite laminae and blebs; very thin to thin beds, very poorly defined. Contains dissolution pits and pipes to 6' deep within unit, filled with coarse equant IV with no primary textures but some displacive margins of halite on polyhalite. DVT textures at top with about 1' relief, do not show well due to lack of change in materials. Upper contact gradational.
1939-1941.5	Anhydrite; gray (N8-7); see detailed description in Figure 17.

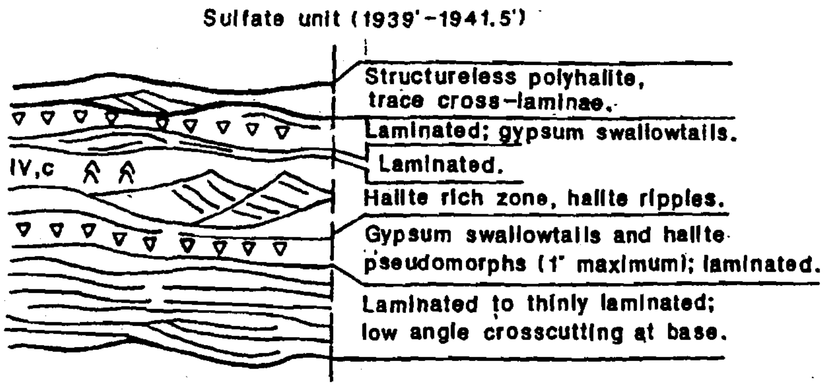


FIGURE 17

1941.5-1942	Claystone, gray (N6-7); thin laminae at top and bottom, contains coarse to very coarse Ib-c and IIIb halite. Overlain by 0-.2' polyhalite; upper contact sharp.
1942-1944	Halite, very argillaceous at base to trace clay and poly in upper part. Fine to medium IV at base to medium to coarse IV at top; local pods of fine halite with MP, most equant with some elongate. Contains laminae to very thin beds of mudstone with fine I-IIa, shows thin laminae, mudstone mostly concentrated in topographic depressions. Unit appears very disjunct. Polyhalite proportion increases upward. Isolated blebs and irregular laminae showing displacive margins with halite. Upper contact sharp, erosional with clay. Dissolution pits and pores originate in this unit with maximum penetration of 5' into and through underlying unit.
1944-1947.5	Halite, trace polyhalite. Coarse IV, equant with few vertically elongate, moderate to major primary fluid inclusion zoning with clear cements; contains polyhalite as stringers and well defined thin laminae which are irregular and discontinuous; are not dispersed throughout. Crude thin to very thin beds. Polyhalite laminae show some displacive margins with halite. Halite appears cloudy. Unit penetrated by dissolution pits and pipes from overlying unit. Pipes filled with very coarse IV, equant, no primary. Upper contact gradational to diffuse.
1947.5-1950	Halite, trace polyhalite and clay in lower part, trace to some (upward) clay with decreasing polyhalite in upper 1'. Mainly medium to coarse IV, to vertically elongate coarse IV, to pods of fine IV in upper 6". Some primary and some cement; displacive halite. Halite is more equant near base, more vertically elongate in coarse zone. Unit displays crude very thin to thin beds. Irregular and discontinuous thin laminae of polyhalite. Entire unit penetrated by dissolution pits and pipes 4-8' deep. Pits filled with coarse IV halite with minor concentration of gray clay. Detail of one of the its is presented in Figure 18.

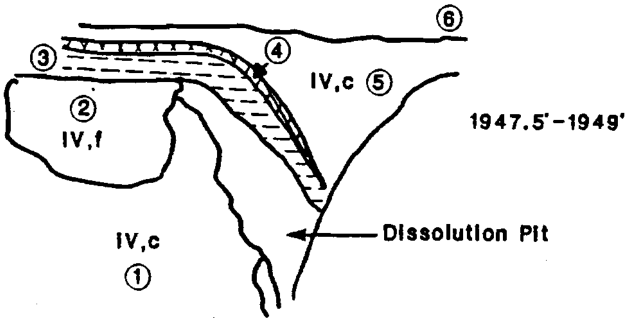


FIGURE 18

Sequence of events in Figure 18: 1) deposition of part 1, 2) deposition part 2, 3) dissolution DVT surface, developing to advanced stage, 4) flooding events plane off surface, introduce gray clay, dissolution causes collapse of gray clay into pipes created during event 3, 5) sulfate laminae deposited, 6) deposition of IV halite filling in topography, 7) minor flood planes off surface, 8) next unit deposited.

1950-1952.5 Halite, trace polyhalite to trace clay at top. Mainly fine IV, coarse to very coarse cement in MP in original strata. Crude very thin to thin beds, strata disrupted in places due to syndepositional dissolution, shows much syndepositional dissolution penetrated by dissolution troughs, pits, and pipes. Some strata tilted by slumping. DVT equivalent. Dissolution originating in this unit penetrates 4-6' into underlying unit. Moderately complete dissolution.

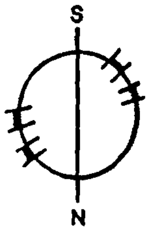
Original strata: Halite, slightly polyhalite; equant IV, discontinuous laminae and blebs of polyhalite, cloudy opaque halite with MP filled with clear cement. Cement is equant to irregular IV with some planar boundaries (cube growth in open space). Gray clay concentrated along dissolution surfaces and within pipes and pits, some within strata.

1952.5-1956 Halite, trace polyhalite. Crude very thin to thin beds with discontinuous irregular thin laminae of polyhalite. Polyhalite (5YR7/2). Minor amount of clay near top, trace throughout. Halite clear to cloudy. Medium to very coarse IV, average coarse; elongate to equant upward within each thin unit. Polyhalite laminae lower boundaries show some evidence of displacive growth of halite. Trace primary textures as fluid inclusion zoning, possible cements. Lower 1' of unit shows BG halite with no subaerial exposure. Remainder shows minor amounts of subaerial exposure with a shallow WT (no penetrations). Unit contains dissolution troughs originating in overlying units. Upper contact sharp to gradational, erosional with irregular concentration of gray clay (N6).

1956-1968 Anhydrite (MB 134); medium crystalline, halitic as PAGS to 4", locally shows clastic halite and ripples (to 1/2" high x 2"), and cross laminae. Anhydrite thin laminae to laminae, locally wavy, undulatory, slightly contorted. No swallowtails in upper 1'. Laminae containing anhydrite increase upward. Upper contact undulatory over 2", has 1' deep trough on south side of shaft. Trough contains thin to very thin beds of halite with interlaminated anhydrite and coarse sand-size halite. Primary halite shows vertical elongate crystals and BG halite. Anhydrite-rich laminae show some displacive I-IIIa halite. Some polyhalite laminae occur only within the trough. Sulfate laminae may be continuous and show draping onto margins of trough. Halite is confined to the trough. Polyhalite occurs at base of trough, but not on margin.

1968-1973 Halite, trace to some gray clay, trace anhydrite and polyhalite. Clay and sulfate occur as irregular blebs with displacive margins, crystal linings and irregular very discontinuous stringers and laminae, blebby laminae. Local irregular zones of claystone to 2" in pits. Pits and MP abundant, abundant cement textures. Cement textures most common in pits as are clay/anhydrite blebs and linings of clay and anhydrite on halite crystals. Mainly medium to coarse IV, some very coarse in lower part, some fine halite in upper zones that are not pits; some primary halite. Abundant cement near base, less common upward. Medium to very coarse I-IIIa common in pits. Upper contact planed off prior to deposition of overlying unit, sharp.

1973-1984 Halite, trace to some anhydrite, trace polyhalite, trace to some gray clay; claystone in pits, pipes and caves. Lower part shows well developed very thin beds to medium (1-5" thick) delineated by very thin, moderately continuous, slightly irregular anhydrite laminae. Halite in lower part is fine-coarse to fine-medium (upward) IV with some cement, some primary in rare shallow pits to 5" and rare MP to 1". Strata are less well defined in upper part, local zones of clay-poor incipient to moderate DVT textures. Medium-coarse to fine-medium (upward) IV in upper part with locally abundant fine halite in irregular zones and pods, trace primary, trace to some cement. MP and pits abundant. MP irregular to 5+", pits to 8'. Polyhalite occurs as irregular blebs, but mostly as well developed platelets in POS textures large to 1/2" x 1/16". Clay occurs as halite crystal linings, irregular blebs in pits with displacive margins, irregular discontinuous, thin laminae and stringers, irregular small zones 1-2" (in pits) and large irregular zones with I-IIa, very coarse (to 3") in caves and deep pits. Anhydrite lines some halite crystals. Cement textures abundant in pits and MP. Very coarse IV in a 1' MP near pits with clay. Cement textures are abundant outside pits. No clay source for large pit fillings obvious. Clay filled caves irregular to 2' x 2' and 1' to 6" wide pits clay-filled to about 10' deep (Figure 19). Gray clay laminae irregular, locally discontinuous 2-5" below upper contact. Upper contact sharp, planed off. Large pits continue on both sides of shaft.



Location of clay-filled pits up to 10' deep. (1973'-1983' depth)

FIGURE 19

1984-1985 Anhydrite (MB 135), lower 1" possibly organic-rich, medium crystalline, laminae to thin laminae, wavy to contorted, shows 1/2-2" high halite PAGS in middle of unit. Sharp undulatory upper contact sharp with halite deposited within lows and anhydrite deposited over halite (Figure 20).

Bottom grown halite deposited in topographic low areas; overlain by anhydrite. (MB135; 1984'-1985')

FIGURE 20

1985-1990 Halite, trace polyhalite, trace to some gray clay. Upper part shows incipient DVT textures. Polyhalite occurs as irregular blebs and "blebby" laminae with displacive halite margins, and irregular stringers. Anhydrite locally occurs as halite crystal linings. Clay occurs as subhorizontal irregular, discontinuous to moderately continuous thin laminae and stringers and halite crystal linings. Mainly fine-medium to fine-coarse to medium-coarse IV upward (with I-IIb-c in middle; trace to some primary; trace to some cement. Sequences of medium to coarse IV with fine halite at tops; fine halite in irregular subhorizontal zones and pods near top. Contains moderately abundant pits to 2' maximum. Shows incipient DVT textures near top. Upper contact sharp and over 4" is planed off by flooding and erosion.

1990-1995.5 Halite, trace polyhalite, trace brown and gray clay. Poorly defined beds about 1' thick delineated by clay. Upper 1.5 ' shows moderately developed DVT textures modified by cementation processes. Clay occurs as irregular very discontinuous to moderately discontinuous thin laminae to laminae (rare) and generally subhorizontal stringers; trace amounts of clay occur on margins of cement/displacive crystals in pits. Polyhalite occurs as small blebs, stringer-like blebs, and very discontinuous subhorizontal stringers (all strata modified by cement) and larger blebs with displacive halite boundaries in pits. Fine to coarse, mainly medium, IV with some fine to medium halite pods and lenses in DVT zone. Halite in DVT zone shows abundant cement fabrics with minimal fine IV (clay-poor DVT-zone). Unit shows abundant pits to 2.5+' deep and MP. Abundant cement. Upper surface sharp and planar.

1995.5-2004.5	Halite. Lower part (below 1999.5) divided into 3 subparts trace to some upward, trace polyhalite and anhydrite, each clear halite overlain by DVT zone topped by DVT exposure/solution surface. Upper part (above 1999.5) is a developed DVT zone. Polyhalite occurs as irregular blebs and stringer-like bl within halite and in irregular blebs and zones of claystone. Most polyhalite sh displacive "a-type" margins. Polyhalite is most common as material translocate pits. Clay occurs in irregular discontinuous thin laminae, laminae, very thin be irregular subhorizontal oriented zones, blebs. Clay is commonly associated fine to coarse I-IIIa-b in cemented zones and pits. In lower part: clear zone of each subpart shows abundant to moderate pits (t deep) and MP, and cement fabrics. Halite in clear zones is medium to coarse with very coarse halite in irregular MP (to 4"). Halite in DVT zones has abund. cement fabrics and halite occurs as irregular zones and small pods of medium coarse IV bounded by clay zones and laminae with medium to coarse I-IIIa-b. Upper part: shows well developed "dish" fabric with dishes bounded by deep pip (to 5+')(polygon fabric with tepees at boundaries). Cement zones locally abunda with medium to coarse IV. Clays show medium to coarse I-IIIa,b in cement zon Some irregular dish-shaped zones and pods of fine to medium IV occur. Sor claystone shows thin laminae, possible cross laminae, contorted and sic texture Some pit edges show fine IV (surviving efflorescence crust in polygon margi Upper contact sharp, locally graditional due to cement processes, irregular over DVT exposure/solution surface modified by flooding.
2004.5-2012.5	Halite, trace to some brown clay, trace anhydrite and polyhalite. Upper DVT zo and lower zone with pits are divided by irregular (over 6") cement-modified (makin contact less distinct) DVT exposure/solution surface. Pits abundant in lower pa moderate to some pits in upper part to 7' deep. VO MP to 1" x 3" and irregular to in lower part. DVT zone shows well developed DVT textures; claystone abundant and halite is limited. Dish-shaped fabric well developed in part of DV zone. Some pits in DVT zone show fine IV preserved within pit. Medium to coars III is present in cement-dominated zones, also medium to coarse I-IIIa-b is preser in pits and some cement-rich zones. Halite in lower part medium to coarse IV wit some I-IIIa-b in pits with clay or polyhalite. Trace primary; trace to some cemen Polyhalite occurs as blebs, "stringer-like" blebs, halite crystal linings, often wit displacive "a type" margins and medium to coarse I-IIIa,b. Polyhalite most commo in pits as translocated material and disseminated material disrupted by cements Clay occurs in irregular zones, irregular blebs, irregular discontinuous stringers

laminae and very thin beds, local displacive halite crystal linings. Commonly associated with fine to coarse I-IIIa-b. Halite in DVT zone mostly fine to medium IV in irregular subhorizontal zones and pods (small due to nearly complete syndepositional solution) with medium to coarse IV in cement-rich areas. Upper surface sharp, irregular, DVT exposure/solution surface with 4" relief.

2012.5-2016 Halite, lower part with trace polyhalite, trace to some brown clay near top in pits overlain by DVT exposure/solution surface with low relief; pits mostly originate at this surface (although pits also originate elsewhere) to 3' deep. Pits moderately abundant. Upper part shows moderately well developed DVT textures with brown clay and claystone, with sic textures, pods and irregular zones of fine to medium IV, some coarse cement. Polyhalite occurs as irregular discontinuous stringers, stringer-like blebs, small blebs and halite crystal linings. Most polyhalite has displacive "a-type" boundaries with halite. Clay occurs in irregular zones of claystone in topographic lows and pits, blebs, irregular discontinuous stringers and laminae to very thin beds. Irregular zones at top may have medium to fine Ib, medium to coarse I-IIa in pits. Blebs of clay often show "a type" displacive halite boundaries. Halite in lower part is medium to coarse IV with trace fine halite; trace primary, trace to some cement. Contains VO MP to 1" x 3-4", irregular MP 4". Abundant pits.

2016-2023 Halite, major to some polyhalite, some clay (gray at base, brown at top), increases at top; trace anhydrite. Polyhalite occurs in irregular masses to 2.5' x 1.5' (high) near base with possible sic textures, medium to coarse I-III-a-b, fine to medium I-IIc, some fine halite in pods. Most masses smaller (4" x 5" or less) and many display "a" type boundaries with coarse to very coarse halite. Polyhalite also occurs as irregular blebs with displacive boundaries, halite crystal linings, and very irregular discontinuous stringers and laminae in DVT zone. Clay occurs as material around irregular pods of fine to medium IV, discontinuous irregular thin beds to thin laminae (.2' - 1/8" thick), irregular masses and blebs. Cement textures decrease upward. Fine to medium IV occurs in pods and irregular zones, content increases upward as cement decreases. Pods and laminae to thin beds of claystone show general dish-shaped pattern upward. Medium to very coarse IV occurs in large MP irregular to 1' x 1.5' maximum. Pits common to 4'. DVT textures pervasive through unit. Thicker claystone zones become abundant near top and show incipient sic texture and thin laminae that are wavy to contorted, with medium to coarse (some fine) I-IIa-c. Upper surface is DVT exposure/solution surface, sharp with .5' relief.

2023-2037	Anhydrite and polyhalite (MB 136), microcrystalline, halitic, argillaceous in lower 6-8". Lower 1' anhydritic. From 2035 to 2035.5, unit is polyhalitic. Above 2035, polyhalite occurs as PAGS. Upward, polyhalite occurs as discrete laminae in anhydrite. Halite occurs as irregular zones within polyhalite pseudomorphs and as pseudomorphs after gypsum swallowtails. Unit has thin laminae to laminae to very thin beds (1/8-1"), wavy, most parallel, locally slightly contorted. Amount and size of polyhalite PAGS decrease up such that polyhalite content decreases. Polyhalite occurs as clasts in anhydrite; coarse sand to granule-sized in polyhalite laminae zone. Upper part laminated to cross-laminated, wavy with local .5' high hummocks/hemispheroids. Contact sharp and undulatory over 2+'.
2037-2040	Halite, .1-.2' anhydrite at base, thin laminae, wavy to slightly contorted, shows possible organic material in lower 1", local boudin-like soft sediment deformation. Base of anhydrite slumped over irregular contact. Anhydrite contains some medium Ia-b and irregular zones of medium to coarse IIIa-b near top of anhydrite. Upper surface of anhydrite very irregular. Halite contains trace anhydrite and polyhalite as irregular continuous to slightly discontinuous thin laminae and laminae which delineate 2-5" beds. Fine to coarse IV, in beds 4-8" thick in sequence anhydrite or polyhalitic fine to medium halite (or polyhalite laminae) to coarse cloudy halite to coarse clear halite to anhydrite or polyhalitic fine to medium halite. Some primary halite, trace to some cement. Trace to some VO MP to 1" x 2", irregular MP to 2". Upper surface sharp, slightly undulatory, planed off by flooding depositing overlying anhydrite.
2040-2055	Halite, trace sulfate below 2050, trace clay and sulfate above 2050. Trace polyhalite in lower 1.5', .1-.2' thick anhydrite bed (laminae irregular to contorted with coarse to very coarse Ia locally) at 2054. Trace anhydrite throughout, trace brown to gray clay above 2050. Well stratified in lower part, beds (3-5") delineated by polyhalite and anhydrite. Lower 1.5' shows moderate pits to 1+' and irregular MP to 5" and VO MP 1-2". Middle well stratified zone shows no pits or MP, dissolution at upper surface of each bed increases upward above 2050 and MP and pits increase. Abundant pits and MP in upper part; pits to 5+' and irregular MP to 1'. Polyhalite occurs as irregular moderately continuous to very discontinuous thin laminae to laminae (in lower 1.5', with II-IIIa-b) to "blebby" laminae and stringers, small blebs and stringer-like blebs, and larger irregular blebs showing some displacive margins of associated medium to coarse Ia. Local polyhalite linings of halite with displacive fabric in halite cements. Anhydrite occurs as irregular continuous to discontinuous thin laminated stringers and laminae, stringer-like

blebs. Clay occurs as irregular stringers, discontinuous laminae to thin laminae and in pits, blebs. MP and pits abundant in upper part with cement fabrics. Fine to coarse in beds in lower part with sequence fine to medium sulfatic halite to cloudy coarse halite to clear coarse halite to clear fine to medium halite; some primary halite (chevrons, vel) and some cement. Upper part medium fine to medium IV with fine to medium halite pods. Zones and layers dominant above 2042, and coarse to very coarse in pits and MP. Clay-poor DVT fabric in upper part. Clay and anhydrite translocated into pits. Some to trace cement in upper part with mainly II-IIIa-b in middle with fine to medium I-IIIa increasing upward. Upper surface planed off, DVT exposure/solution surface irregular of 3".

2055-2069.5 Halite, trace polyhalite, and brown to gray clay upper 5'. Polyhalite occurs as irregular blebs, with displacive halite margins (II-IIIb) and halite crystal linings most common in pits. Clay occurs as irregular discontinuous thin laminae to laminae, stringers, irregular zones with displacive fine to medium Ia. Mainly medium IV in host halite beds below 2060 with disseminated polyhalite and Medium to coarse IV and trace II-IIIb in pits and MP. Abundant large pits/pipes to 10+' and MP with coarse halite, 2' x 1'. Upper 5' contains irregular thin laminae and stringers of dark gray clay around zones, pods to beds of fine to medium IV. Abundant cement. Upper surface is DVT exposure/solution surface, irregular over .5'.

2069.5-2076.5 Halite, divided at 2074 into upper argillaceous DVT zone and lower polyhalitic zone. Trace polyhalite, trace clay in DVT zone; trace clay in pits in lower zone. Polyhalite occurs as irregular blebs with displacive halite margins (medium to coarse II-IIIa-b), irregular discontinuous stringers and halite crystal linings. Clay occurs as irregular discontinuous stringers to laminae to irregular blebs and zones with displacive halite margins (fine to medium IV-IIIb-c) and containing displacive halite (trace m I-IIa-b). Halite: medium to coarse IV below 2074, fine to medium IV in irregular subhorizontal pods in DVT zone. Trace to some displacive halite cement. Very coarse to coarse IV in pits and MP (delineated by linings of polyhalite). DVT textures show crude horizontal fabric; some POS textures. Upper and lower part separated by irregular DVT exposure/solution surface with .5' relief. Abundant pits (2+') and MP (6+"). Upper surface irregular DVT exposure/solution surface with .5+' relief; clay infiltrated into pits at upper surface.

2076.5-2079.5 Halite, trace polyhalite, to 2077.5; trace brown clay to claystone in upper 1'; trace anhydrite in middle of unit. Polyhalite and anhydrite occur as irregular blebs, very irregular and very discontinuous stringers, often associated with or containing displacive halite, mainly II-IIIb-c crystal linings to displacive cements. Clay occurs

	as irregular discontinuous stringers, irregular blebs and zones showing sic te local thin laminae with medium to very coarse I-IIIa-b at top and blebs concent in pits and pipes. Mainly medium to coarse IV with pods and lenses of fine upper 1'; trace primary, trace to some cement. Abundant MP irregular to 5+" pits and pipes to 2.5+'. Moderately complete DVT textures in upper 1'. Con clasts of overlying anhydrite translocated while soft. Upper surface planed c solution with 1" relief.
2079.5-2084.5	Halite, trace polyhalite at base; trace clay, anhydrite and polyhalite upw claystone at top; clay mostly brown, trace gray. Polyhalite and anhydrite occu very discontinuous, irregular, stringers and laminae, and blebby stringers, all abundant displacive halite margins (I-IIIa-b); irregular large to small blebs and h crystal linings, and irregular large zones with displacive crystals. Blebs irregular zones concentrated in pits as translocated material. Clay in unit midd mostly gray with brown as translocated material. Occurs as irregular, discontinuous stringers, thin laminae to laminae to very thin beds at top, irreg blebs, irregular zones in pits, halite crystal linings. Clay shows abundant displa (mostly type "a"), margins with fine to coarse I-IIa-b in mud at top. Mediu coarse IV, locally very coarse with I-IIa, marked by linings of clay in pits. Fine I irregular pods in DVT texture in claystone upper .5'; probably very advanced exposure/solution surface. Shows abundant cement, trace primary hal Abundant MP and pit/pipes with displacive halite growth (1 pit contains transloca cobble-sized clasts from base of second unit above this unit). Pits to 4+'. M 5+". Upper surface well developed irregular DVT exposure/solution surface, with relief.
2084.5-2099	Halite subdivided into four zones: a) well defined to moderately well defined thi medium beds 3-5" thick, b) DVT zone, c) poorly defined strata, d) DVT zone. Polyhalite and anhydrite occurs as irregular continuous to very discontinuous t laminae, laminae, stringers; blebs and halite crystal linings in MP. Laminae oft show displacive contacts. Blebs are locally translocated in pits. Clays occur irregular moderately continuous to discontinuous thin laminae, laminae a stringers locally infiltrated into pits forming boxwork fabric. Blebs with displaci halite margins (type "a-b") abundant in pits. Claystone in DVT zones show irregular discontinuous thin laminae, locally contorted and disrupted, some cros cutting relationships. Part a: Trace sulfate, trace clay at top. Fine to very coar IV, trace primary, trace to some coarse to very coarse cement. Thin beds wi sequence of anhydrite laminae to medium to coarse halite to clear coarse halite

	fine to medium halite. Abundant VO MP to 1" x 3" irregular locally to 4", pipes abundant to 2+'. Locally shows boxwork with clay in upper 1'. Part b: Trace to some clay, trace anhydrite. Fine to medium IV in lenses and pods with fine to medium II-IIIb-c and medium to coarse I-IIa-b in argillaceous zones. DVT zone with abundant DVT textures, shows abundant cement. Upper part and lower part show well developed DVT surfaces separated by irregular middle zone of coarse to medium IV cement. Part c: trace brown clay and anhydrite, increase upward. Fine to very coarse IV, mainly medium to coarse with fine IV at top; trace clay infiltrated into boxwork, and moderately abundant pits and pipes to 2'. Irregular MP 4-6", VO MP to 1" x 3", moderately abundant to abundant. Upper surface erosional/exposure surface, irregular over 6". Trace primary, moderate to abundant cement. Part d: trace to some clay, increasing upward, trace polyhalite. Lens and pods of medium to coarse and fine to medium IV to fine IV upward and fine to medium I-IIa-c at top. DVT textures abundant in top and bottom, middle is clear and shows abundant cement. Moderate argillaceous with irregular very discontinuous thin beds (to 1") of halitic claystone associated with DVT textures, upper .3-.5' mostly claystone. Upper surface nearly planar, planed off by erosion/solution.
2099-2099.5	Anhydrite (MB 138), medium crystalline, gray; well delineated thin laminae to laminae, wavy to slightly contorted, local cross-cutting relationships. 1" brownish gray clay at base.
2099.5-2107.5	Halite divided into lower zone, with trace anhydrite, and upper DVT zone with trace clay and polyhalite. Strata not well defined in either part. Lower part: mainly medium to coarse IV, with trace fine halite above medium to coarse halite in irregular discontinuous subhorizontal zones often associated with anhydrite. Anhydrite occurs as irregular very discontinuous stringers, "stringer-like" blebs, and planar crystal linings in MP. Trace primary halite, some cement. MP moderately abundant, VO to 1" x 3", irregular to 4". Rare well defined pits to .5'. contact with DVT zone irregular, gradational to diffuse due to cement processes. DVT zone: halite is fine to medium IV, in irregular subhorizontal zones and pods with moderately abundant cement (fine to medium II-IIIb-c) at base, content decreasing upward (mostly in poorly defined, multiply developed MP). Medium to coarse I-IIb in MP with some Ib-a in fine in laminae. Clay occurs in irregular, subhorizontal, moderately continuous to discontinuous, thin laminae to laminae subhorizontal; irregular blebs with displacive halite margins in MP. Polyhalite as trace disseminated material and rare blebs. Upper surface sharp, undulatory over 3". MP abundant in lower part.

2107.5-2113	Halite, trace anhydrite in lower part, trace brown clay and poly in upper DVT Anhydrite occurs as irregular moderately continuous thin laminae to lam stringers and blebby laminae locally with medium to coarse la and abunda margins, translocated blebs in pits with displacive "a" margins; very discontin stringers and "stringer" blebs, and crystal lining. Most common in MP and Halite in lower zone: medium to very coarse IV, with fine halite associate anhydrite over medium to coarse in subhorizontal zones in thin to medium some primary halite (BG, chevrons, vel) and some clear halite. Irregular MP VO to 1" x 3". Lower part has moderately well defined bedding (3-5"). Upper zone: clay occurs as brown, irregular, moderately continuous to very discontin thin laminae to laminae, mostly subhorizontal. Polyhalite occurs as irregular blebs and disseminated material in medium to fine IV. Halite is fine to medium irregular zones bounded by clays and MP, local medium to coarse in MP, m irregular to 6" x 3" maximum. Fine to medium II-IIIb-c in clay zones. Upper su irregular DVT exposure/solution surface with brown clay. Large MP near u contact filled with halite. Local pits to .5' near base.
2113-2118	Halite, trace clay and polyhalite. Strata absent to very poorly delineated. Exh DVT textures in 2 zones each topped by DVT erosion/solution surface with 6" r Brown (with some gray) clay as irregular stringers, moderate to very discontinu and thin laminae to laminae. Clay mostly drapes and surrounds zones of fin medium IV. Polyhalite occurs as irregular large to small blebs and rare ble discontinuous to irregular laminae, with trace disseminated material in mediu fine IV. Anhydrite mostly at tops of exposure surfaces as thin laminae to lami and very discontinuous and irregular stringers. Center zone contains abundant VO rare to absent, abundant irregular MP to 8". Dissolution pits and pipes 6 2.5', with clear coarse to very coarse IV. Halite in DVT texture zones: mainly to medium granular IV, with some coarse in pits and pores. In upper and mid zone medium to coarse IV, with some fine halite; some primary, some ceme Upper surface sharp, erosionally planed off, 1-1/2" thick brown (locally gray) cla contact.
2118-2123	Halite, trace polyhalite, trace gray clay infiltrated into pits and pores (from overly unit) in upper 1-2'. Unit displays moderately well-defined thin to medium beds (2 thick) delineated by polyhalite. Unit contains dissolution pits 6" to 3+' de throughout. Locally translocated polyhalite in pits gives poorly to moderately we defined boxwork texture. Contains irregular MP to 4" with coarse IV; MP rare upper part, abundant near base. VO MP to 1" x 3" moderately abundant. Hali

	fine to very coarse, mainly medium to coarse IV, with coarse to very coarse in MP, fine halite at tops of strata with polyhalite. Polyhalite occurs as irregular small blebs, with rare displacive halite margins, and as local stringers and laminae, very discontinuous and irregular near base. Contains discontinuous, irregular to moderately continuous laminae of anhydrite near base with some a-b margins. Upper contact very irregular over 6". DVT exposure/solution surface, sharp contact.
2123-2124	Anhydrite, gray, microcrystalline, slightly halitic, thin laminae to laminae (to 1/2"), irregular to wavy, most subhorizontal, locally convolute on small scale. Possible detrital halite. 1/8-1/4" gray clay at base with local laminae of brown claystone. Upper contact irregular, undulatory over 3", sharp. Contains fractured zones with separations in middle to lower part (due to repository opening).
2124-2130.5	Halite, trace anhydrite as irregular, moderately continuous to very discontinuous, thin laminae to laminae and translocated material in pits; trace brown and gray clay in upper part as material disseminated in irregular discontinuous zones and irregular, very discontinuous to moderately continuous, thin laminae to laminae and stringers in upper zone with DVT textures. Very rare blebs of polyhalite. Halite below DVT exposure/solution surface is medium, fine to very coarse, mainly IV, with rare coarse and very coarse in irregular MP to 5", coarse in VO MP to 1" x 2" (most common between 2127-2125), fine halite overlies coarse halite in irregular, slightly discontinuous subhorizontal zones; well-defined beds (3-5" thick) most obvious between 2125-2127. Halite contains trace polyhalite as irregular, very discontinuous stringers, laminae and blebs. Fine IV washed out very readily, during washing. Upper contact sharp, slightly undulatory. Local pits to 1' at DVT surface.

EXCAVATED BROW AT FACILITY LEVEL

Appendix E

APPENDIX E

A CLASSIFICATION OF MATRIX-RICH SALT PAN HALITE

APPENDIX E
A CLASSIFICATION OF MATRIX-RICH SALT PAN HALITE

1.0 INTRODUCTION

Halite crystals in rocks with varying amounts of matrix are often simply described as "chaotic mud/halite" because relationships are not obvious among crystals and the textures within these rocks can be quite complex. While this broad classification readily permits displacive/ incorporative halite in mud-rich sediment to be attributed to deposition in a saline mudflat or other environments with mud-rich sediment containing halite-saturated fluids (e.g., deep-water growth of displacive halite), it leaves little room for further dissection of the environment of deposition. This type of halite, particularly in core samples, may not appear to have any obvious textural pattern or distribution and is lumped into the broad category of "chaotic mud/halite" because useful macroscopic information is not obvious. We have examined both modern and ancient examples of "chaotic mud/halite," however, and found that the relationships of one halite crystal to another and the margins on the crystals can help us to more precisely interpret the origin of the rock and decipher some of the complex history.

We have developed an empirically-derived classification of halite in cores from, and underground exposures of, matrix-rich salt pan halite that describes the textural relationships. These textures imply certain genetic conditions that have become apparent through work with modern analogues as well as Permian evaporites of the Delaware Basin. The shorthand associated with these textures can be very simple and diagnostic.

Our examples of rock textures for this classification are derived from the Permian (Ochoan) Salado and Rustler Formations of southeastern New Mexico.

2.0 THE CLASSIFICATION

The two most important elements of our classification are the crystal to crystal relationships and the nature of the crystal margins with the matrix material (Figure 1). We have designated the crystal to crystal relationships by Roman numerals and the crystal margins/matrix relationships by lower case letters.

The simplest example to classify (Ia) consists of isolated halite crystals (I) each having planar margins (a). The Rustler Formation of southeastern New Mexico yields good examples of this texture (Holt and Powers, 1988, Figure 2). Careful inspection of these textures may reveal displacive margins, matrix incorporation, and skeletal continuations of the crystals in the matrix.

Matrix margins on isolated halite crystals may also be partially to completely irregular (Ib or Ic, respectively). Ib textures most commonly display irregular upper margins to the crystals, and these irregular margins may be crudely to very well aligned along a subhorizontal to horizontal plane. Ic halite has mostly irregular margins with the matrix. The Rustler Formation yields a good example of Ic textures (Figure 3).

Halite crystals sharing one face (II) are less common than textures where halite crystals share multiple faces (III). We have observed a number of II halite textures, but they are easy to visualize and are not illustrated here.

Textures with multiple shared halite faces (III) are quite common in cores and underground exposures of both the Rustler and Salado Formations (Figure 4). We note that irregular internal crystal to crystal boundaries are common, while planar internal boundaries are less common. External boundaries range from planar (IIIa) to more than 2/3 irregular (IIIc). Irregular outer margins of these textures may also be aligned along a subhorizontal to horizontal plane within core or outcrop.

We use the classification IV for dominantly interlocking halite rock. Matrix may be a smaller proportion of these rocks or, in some cases, the halite clusters may be relatively large, with many interlocking crystals. It is possible to use a,b,c matrix margin indicators for this texture.

Although we do not present specifics here, it is quite easy to provide a series of modifiers to the basic classification that provide a shorthand containing a large amount of information for descriptive purposes. We commonly use a term such as f-m Ia to incorporate a defined size range (fine to medium) for the halite crystal size. Many other modifiers can be defined and used.

These textures are best observed in cores if they have been slabbed in oil and lightly polished to bring out the halite features. This is even more important if the coring was done with under saturated mud.

3.0 GENETIC IMPLICATIONS

Isolated halite crystals with planar margins indicate displacive/incorporative growth within soft sediment under saturated conditions. For the most part, IIa and IIIa represent sediment that had additional nucleation points or that coincidentally had nucleation points that were closely spaced.

A, b, and c margins cover a spectrum ranging from undisturbed displacive/incorporative growth to considerable disruption of the crystal margins by solution. We commonly find the upper margins disrupted along a horizontal to subhorizontal plane that represents a former groundwater chemical boundary between saturated and unsaturated water or between phreatic and vadose zones. In the Rustler Formation, for example, we have found planar margins (I-IIIb) with subsequent epitaxial overgrowths above the plane, representing resumed displacive growth when the water table and/or zone of saturation rose respective to the plane. Internal margins, especially within III textures, are commonly irregular. These margins may represent earlier episodes of solution and regrowth or the boundaries of crystals grown into pore space. The pore space may be created by solution of halite; regrowth may occur on seed crystals that are remnants of the earlier generation of halite.

In these deposits, the environment for halite crystal growth and solution may have changed of many times, and the rock observed may only be interpretable in terms of the last event or last few events. Smith (1971), for example, believed that Triassic rocks in England may have undergone many series of growth and solution of halite in soft sediment that would disturb the sedimentary features; he called the process haloturbation. Holt and Powers (1988) proposed that this process resulted in textures, described from the Rustler Formation, called "smeared intraclasts" or "smeared laminae textures." These are the next logical step in the process, beyond forming "c" margins, where halite is completely removed and the soft sediment deforms. The panoply of halite characteristics and relationships utilized in this classification fit with other textural evidence and features in the Rustler and Salado Formation that reveal the extensive effects of changes in water table and saturation that affected the halite pan sediments.

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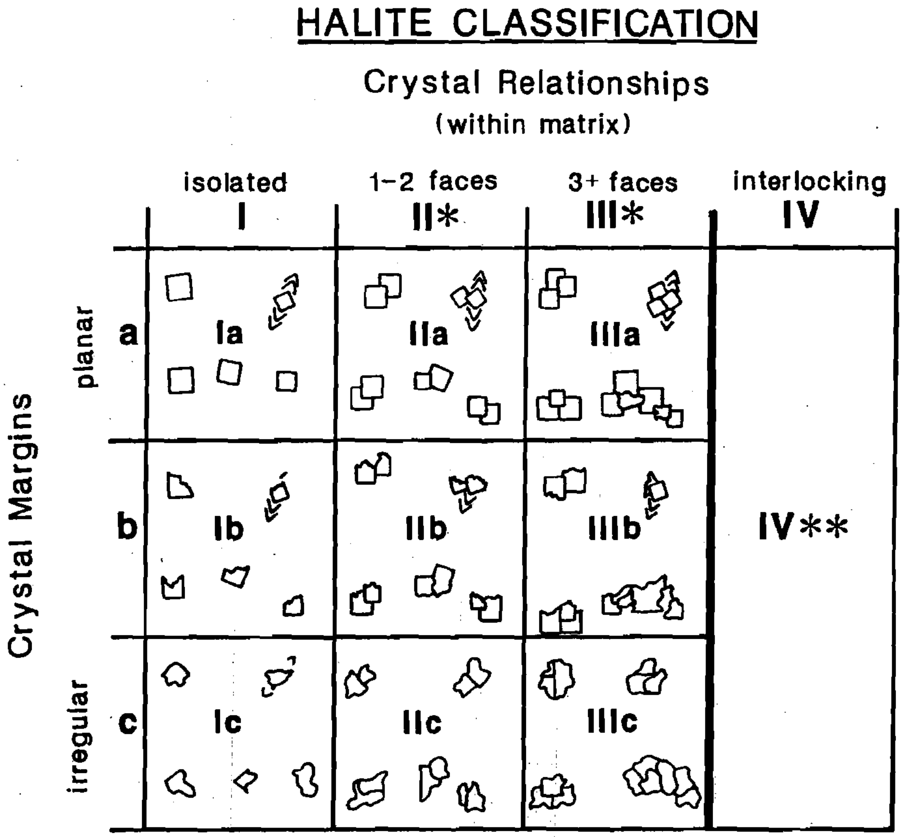
Smith, D. B., 1971, "Possible Displacive Halite in the Permian Upper Evaporite Group of Northeast Yorkshire," Sedimentology, Vol. 17, pp. 221-232.

APPENDIX E
FIGURES



* Internal boundaries may be more planar for growth of individual displacive crystals. Internal boundaries are more irregular with multiple solution/growth episodes and rapid growth into porosity.

** Interlocking textures in dominantly halite rock may exhibit a variety of margin relationships.

FIGURE 1 MATRIX-RICH HALITE CLASSIFICATION

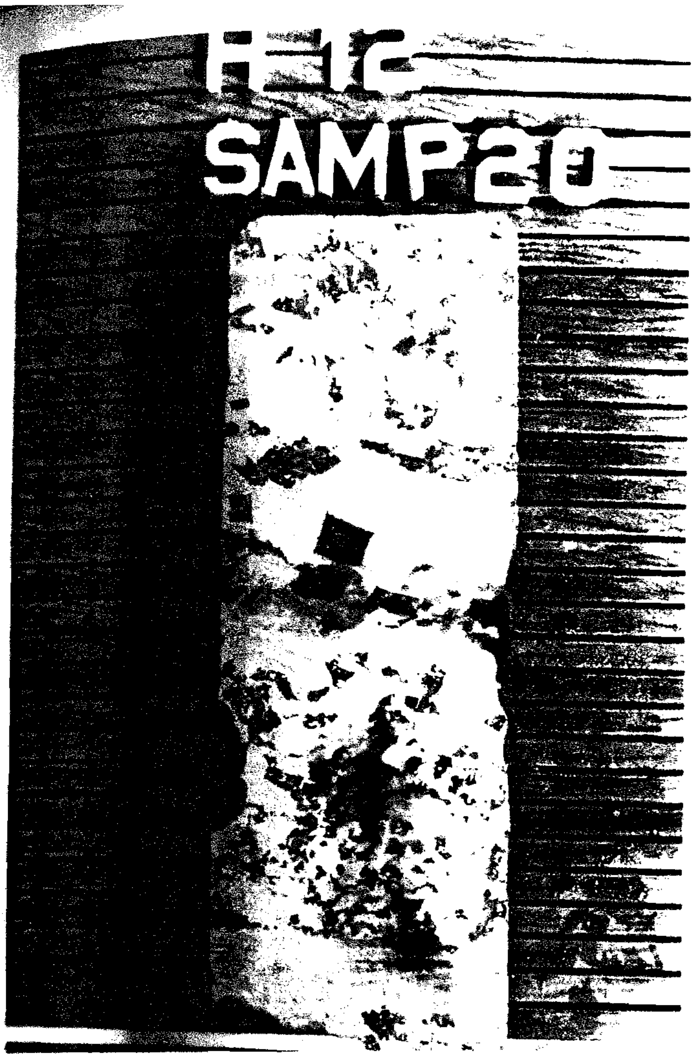


Figure 2
Isolated (I) Displacive Crystals of Halite with
Planar (a) Matrix Margins--Ia.
Rustler Formation. Core is 5cm across.

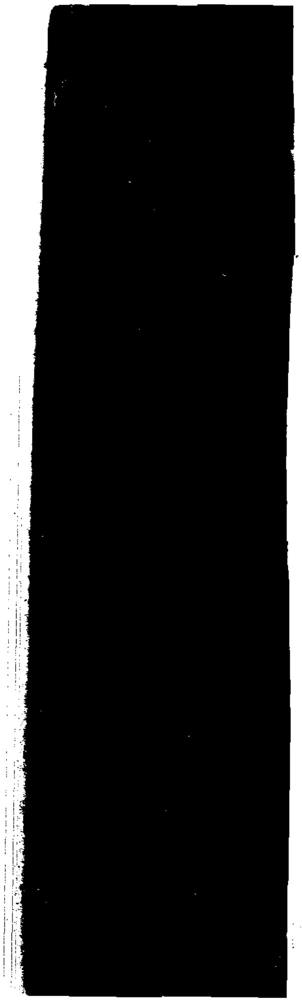


Figure 3
Isolated Halite Crystals with Irregular Matrix
Margins--Ic. Rustler Formation.
Core is 5cm across.

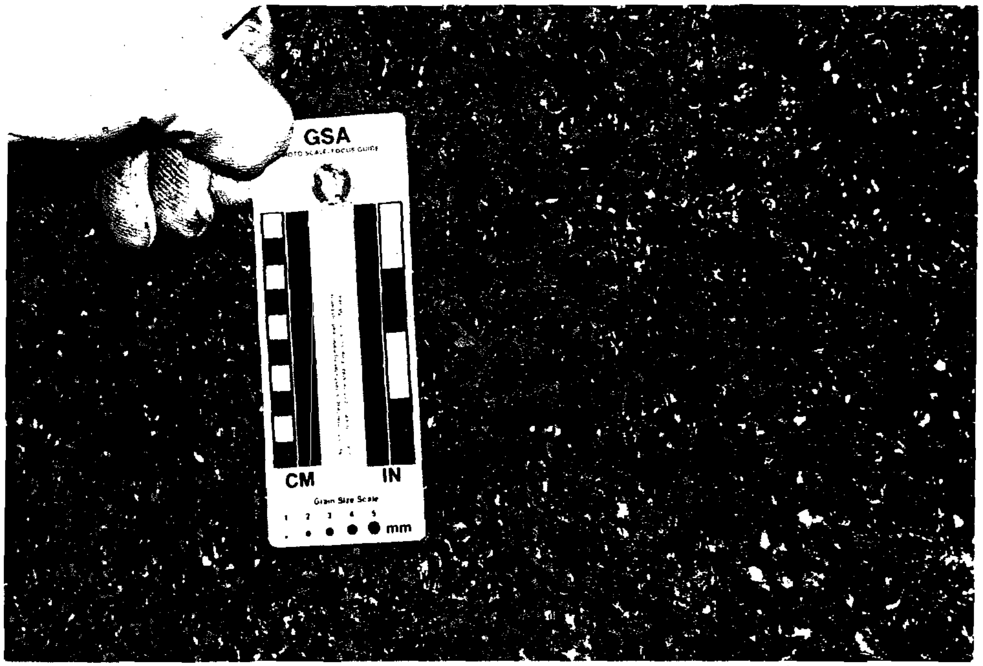


Figure 4
Halite with Multiple Shared Faces (III) and Planar (a) to Irregular (b)
Matrix Margins. Salado Formation.

Appendix F

APPENDIX F
SALADO HALITE SEQUENCES

SALADO HALITE SEQUENCES

1.0 INTRODUCTION

A sedimentological approach has been increasingly used in the study of ancient halite rocks. As studies of ancient halites have been largely limited to data collected from core and, occasionally, limited underground exposures, most modern and experimental halite analogues have been examined for textures and features which may be identifiable from core or thin-section (e.g., Shearman, 1970; Arthurton, 1973; Handford, 1982; Southgate, 1982; Sonnenfeld and Hudec, 1983; Lowenstein and Hardie, 1985; Casas and Lowenstein, 1989). Numerous investigators (e.g., Garrison, et al., 1978; Handford, 1981; Hovorka, 1983a, 1983b; Fracasso and Hovorka, 1986; Lowenstein, 1982, 1987, 1988) have used this approach to refine our understanding of the depositional systems of ancient halite rocks. Large-scale surface textures from modern halite deposits have been described by several investigators (e.g., Hunt and Washburn, 1960; Christianssen, 1963; Hunt, et al., 1966; Cooke and Smalley, 1968). Except for a few studies of large-scale halite textures from underground exposures (e.g., Tucker, 1981; Powers and Hassinger, 1985), these fabrics have been understudied in ancient halite deposits because they are difficult to recognize in cores and they are not expected to survive their depositional environments.

Exposures of the Salado in the AIS showed numerous, previously unreported, large- and small-scale halite textures. Many of the large-scale textures are similar to features which occur at the Devil's Golf Course in Death Valley, California (Holt and Powers, in preparation). Over 1,290 feet of the Salado was described. From these incredible exposures, we were able to recognize, describe, and interpret numerous previously undescribed halite textures and fabrics and place these features into stratigraphic context. To further refine the depositional model of Salado halite, we have constructed an "idealized" Salado halite sequence of lithofacies based upon our shaft data, interpreted the fabrics observed within Salado halite sequences based upon their relationship to paleo-water table position, and interpreted the depositional environments of the lithofacies within our idealized sequence.

2.0 SALADO HALITE

Cyclicity within the Salado was first described by Schaller and Henderson (1932) as the vertical succession of clay - anhydrite - polyhalite - halite and minor amounts of polyhalite - halite.

Jones (1954, 1972) reported cyclical units consisting of clay - magnesite - anhydrite, polyhalite or glauberite - halite - argillaceous halite capped with mudstone. Lowenstein (1988) recognized two types of depositional cycles within the Salado. Lowenstein's Type I cycle consists of 1) a basal mixed siliciclastic and carbonate (magnesite) mudstone, 2) laminated to massive anhydrite-polyhalite, 3) halite, and 4) halite with mud. His Type II cycle was an incomplete version of a Type I cycle consisting of halite grading to muddy halite. Lowenstein (1988) interpreted these cycles to represent a deposition in a shallowing upward, desiccating basin.

Lowenstein (1988) interpreted his Type I cycle to record basin shallowing and brine concentration, beginning with a perennial lake of marine origin. Carbonate precipitated from this lagoon first as the fluids were concentrated by evaporation and was followed by gypsum, and finally, halite was deposited from saline lagoon and salt pan environments. The Type II cycle was deposited in shallow-lake or lagoon and salt pan environments following terrestrially derived flooding. Lowenstein separated the halite in Type I cycles from the halite in Type II cycles because the Type II cycles were not underlain by anhydrite/polyhalite beds and the halite in Type I cycles contained little "terrestrial-derived siliciclastic sediment" except at the top. Type II cycles contained no features indicating prolonged subaqueous deposition or perennial lake conditions.

The Salado exposed at the AIS shows numerous cycles which are generally consistent with those reported by other workers (Schaller and Henderson, 1932; Jones, 1954, 1972; and Lowenstein, 1982, 1983, 1988). At the AIS, complete Salado halite sequences consist of clay-poor halite at the base grading upward into argillaceous halite. The vertical distribution of halite textures is largely consistent through all halite sequences whether they overlie a thicker sulfate unit or another halite unit. The clay content within most sequences increases upward and appears to be unrelated to the presence of underlying anhydrite/polyhalite beds. Many of the anhydrite/polyhalite units display evidence of subaerial exposure during and immediately following their deposition suggesting that post-sulfate halite was not deposited in a perennial lagoon. As we found little textural difference between halite sequences which overlie anhydrite/polyhalite beds or other halite sequences, we separate the halite sequences from underlying units and recognize only one cyclical pattern in Salado halites.

Halite is the most abundant mineral in the Salado and occurs in thick beds intercalated with thinner beds of polyhalite or anhydrite (Jones, 1972; Holt and Powers, 1984, 1986). Salado halite is rarely pure and usually contains trace and minor amounts of foreign material, including:

clay, anhydrite, or polyhalite (Jones, et al., 1960; Jones, 1972; Jones, et al., 1973; Powers, et al., 1978; Holt and Powers, 1984, 1986). Halite crystal size and morphology varies considerably, and various large- and small-scale sedimentary structures are abundant throughout all of the Salado halite. Numerous small-scale sedimentary textures and fabrics preserved within Salado halite are similar to those described by other investigators (e.g., Shearman, 1970; Arthurton, 1973; Hardie, et al., 1983; Lowenstein and Hardie, 1985). Other small-scale textures and fabrics from the Salado are newly reported here. They are usually distinguished by crystal size, morphology, primary fluid inclusion zoning, and relationship to foreign material.

The distribution of foreign material and sedimentary structures generally follows a distinct vertical pattern within an individual unit or several successive mapping units. We discuss the vertical succession of individual textures and construct an idealized Salado sequence to illustrate this pattern (Figure 1). All halite beds, in the 1,290 feet of the Salado mapped in the AIS, are complete or partially complete versions of our ideal sequence.

3.0 IDEAL HALITE SEQUENCE

We have constructed an "ideal" Salado halite sequence to represent the features and textures seen in most complete Salado halite sequences (Figure 1, 2, and 3). Many of the sequences described in the AIS are incomplete and do not contain all of the textural lithofacies and textural zones described in our ideal sequence. The sequence is subdivided into four major lithofacies on the basis of halite textures. Two of the lithofacies can be further subdivided into distinct zones showing characteristic smaller-scale halite fabrics.

The lower mud-poor section of the sequence is dominated texturally by an overall sense of horizontal to subhorizontal stratification and is named the "stratified" mud-poor halite lithofacies. It is subdivided into three zones with small-scale textures (Figure 1) dominated by 1) bottom growth halite, 2) passive pore-filling halite cements, and 3) expansive halite cements. The "podular" muddy halite lithofacies overlies "stratified" mud-poor halite and is characterized by lenses and pods of fine to medium crystalline halite. The podular muddy halite lithofacies is divided into 1) a lower zone with little expansive halite cements and 2) an upper zone dominated by expansive cement textures (Figure 1). The "dilated" mud-rich halite lithofacies overlies "podular" muddy halite and shows abundant fabric expansion due to displacive halite cements. The upper halitic mudstone lithofacies displays clastic deposition and alteration textures with displacive halite crystals. Neither the "dilated" mud-rich halite nor the halitic mudstone lithofacies is subdivided on the basis of small-scale halite textures.

3.1 STRATIFIED MUD-POOR HALITE (SMPH) LITHOFACIES

The stratified mud-poor halite (SMPH) lithofacies displays a well developed to very crude sense of horizontal stratification through the entire interval (Figure 4). Sulfate is common at the base and often decreases slightly upward. Clay is rare, but if present, it increases upward. Strata are often defined by thin laminae and laminae of sulfate. Irregular, discontinuous, subhorizontal solution lags become more abundant higher in the interval and may resemble depositional stratification (Figure 5). Dissolution pits, pipes, and macropores are rare at the base and become more abundant and larger upward. They are easily distinguished by their coarse, clear halite fillings. Pits, pipes, and macropores cross-cut strata and commonly include both clay and sulfate translocated from above (Figure 6). Much of the translocated material commonly shows displacive boundaries with the coarse halite pore-fillings (Figure 7). Toward the top, translocated material in dissolution pits and pipes cross-cuts solution lags creating a characteristic boxwork fabric (Figure 8). The upper surface of the SMPH lithofacies is a Death Valley Type (DVT) exposure/solution surface which may have up to four feet of relief and is often draped by an irregular solution lag (Figures 2 and 3).

The lowermost zone within the SMPH lithofacies displays small-scale, bottom-accumulated halite textures: chevron, cornets, and cumulates. Halite with primary fluid inclusion zoning is abundant. Chevron and cornet fabrics are often evident. Laminae to thin beds of vertical halite crystals displaying chevron and cornet fluid inclusion zoning are overlain by fine-crystalline cumulate halite. The cumulate halite often thickens and thins over the topography on the underlying bottom-grown halite. Erosional surfaces often mark the tops of strata by cross-cutting the underlying textures. The stratification is usually emphasized by slightly irregular thin laminae or laminae of anhydrite or polyhalite overlying the erosional surface. Within individual halite crystals zoned by fluid inclusions, sulfate may drape several growth surfaces, and some vertical crystals are partially to wholly outlined by sulfate (Figure 9). Near the top of the lower zone, very small pits and vertically oriented macropores occur. The contact with the passive halite cement zone is gradational.

The middle zone in the SMPH lithofacies shows abundant passive halite cements (Figure 10). Stratification becomes less distinct upwards as laminae of sulfate become increasingly disrupted and irregular. Halite laminae and thin beds become disrupted by small pits which penetrate one or more stratum. Crystals exhibiting primary fluid-inclusion zoning become less common, and clear, coarse passive pore-filling halite occupies pore spaces between crystals showing depositional fabrics. Vertically oriented and irregular small macropores become more abundant upward (Figure 10). Fine crystalline halite is moderately abundant in irregular subhorizontal to randomly oriented zones. Pile of sticks (POS) textures, consisting of sulfate flakes floating in a halite matrix, occur locally. Blebs of sulfate or, rarely, clay occur in pits and small-scale macropores (Figure 11). Clear halite cements are usually passive pore fillings, although some displacive boundaries with foreign material occur. The contact with the overlying expansive halite cement zone is gradational.

Displacive halite cement fabrics are prevalent in the zone of expansive halite cements (Figure 12). Both passive pore-filling cements and displacive cements are present, but displacive cements are more abundant. Blebs and "blebby laminae" of sulfate minerals become increasingly common upward in the sequence. Strata become very discontinuous, but a stratified sense is retained by horizontal and subhorizontal solution lags. Fine crystalline halite occurs locally. Clear, coarse halite is abundant, and primary fluid-inclusion zoning is rare. Blebs and crystal linings frequently show displacive margins with clear and incorporative halite. POS textures are common locally. Small-scale vertically oriented and irregular macropores are abundant. Clay occurs locally as blebs, some with displacive boundaries with halite and becomes more abundant upward. Solution lags are common at the upper DVT exposure/solution surface.

3.2 "PODULAR" MUDDY HALITE (PMH) LITHOFACIES

Above the DVT exposure/solution surface, the fabrics and textures change dramatically as irregular pods and lenses of fine to medium crystalline halite dominate (Figure 13). The interval displaying these irregular pods and lenses is designated the "podular" muddy halite (PMH) lithofacies. Two textural zones delineated by the relative proportion of expansive halite cements grade laterally and vertically within the PMH facies. The basal zone displays pods and lenses of fine to medium crystalline halite with a small amount of expansive halite cement (expansive halite cement-poor zone) (Figure 14). The upper zone exhibits many expansive cement fabrics with fewer and smaller lenses and pods of fine to medium crystalline halite (expansive halite cement-rich zone) (Figure 15).

Texturally, the expansive halite cement-poor zone is dominated by irregular lenses and pods of fine to medium crystalline halite containing irregular, discontinuous stringers, laminae, and solution lags of sulfate or clay. Zones with halite cement fabrics separate the lenses and pods. Solution lags cap some surfaces, and discontinuous clay laminae often occur between lenses and pods. Pits and pipes commonly cross-cut lenses and pods and often penetrate into the halite in the underlying SMPH lithofacies (Figure 16).

The expansive halite cement-rich zone contains mostly coarse halite-cement fabrics and relicts of finely crystalline halite pods and lenses. Usually, it is much more argillaceous than the cement-poor zone of vadose alteration. Displacive halite cements are abundant within this zone. Some irregular, discontinuous, crudely subhorizontal laminae to thin beds of claystone and argillaceous halite occur. Solution lags, pits, and pipes are common.

The small-scale textures in the zone with little expansive cement and the zone dominated by expansive cement are similar, but differ in proportions. As the proportion of halite with cement fabrics varies, so does the overall appearance of the unit. Generally, halite containing primary fluid inclusion zoning is rare. Clay is more abundant, and medium to very coarse halite cement fabrics dominate between pods of fine to medium halite. In the expansive cement-rich zone, displacive halite crystal boundaries with irregular, very discontinuous clay laminae and irregular blebs and zones are numerous, and isolated and aggregates of displacive and incorporative halite crystals abound. In the zone with less expansive cements, pods containing fine to medium crystalline halite often show solution lags, consisting of blebs and irregular discontinuous laminae and stringers of clay and sulfate, internally and at boundary surfaces, and individual pods frequently contain irregular macropores filled with coarse halite. POS textures are common within solution lags and in zones containing cement fabrics. Numerous clay solution lags exist on dissolution surfaces. Blebs, stringers, and irregular zones of clay and sulfate are translocated into some pits and modified by displacive growth of halite cements. Irregular zones, large blebs, and solution lags of clay show smeared intraclast (SIC) textures (Holt and Powers, 1988) and possible translocation fabrics (Figure 17).

3.3 DILATED MUD-RICH HALITE (DMRH) LITHOFACIES

In some cases, the upper few inches to feet of Salado sequences consist of halitic claystone exhibiting abundant halite cement fabrics (Figure 18). These rocks are placed within the dilated mud-rich (DMRH) lithofacies because displacive halite cements give a dilated appearance to the halite. Passive pore-filling halite cements are rare in this zone, while displacive and poikilotopic halite cements are abundant. Crude subhorizontal stratification is often evident but is extremely disrupted by displacive/incorporative cement fabrics. Some solution pits and prism-cracks are present. The argillaceous halite often displays crude, irregular, thin (1 to 3 cm thick) beds of halite which are discontinuous and disk-shaped. These beds often have displacive boundaries with the surrounding argillaceous material.

3.4 HALITIC MUDSTONE (HM) LITHOFACIES

The upper few inches to feet of Salado sequences may consist of halitic mudstone (HM lithofacies; Figure 19). This mudstone often contains isolated crystals and aggregates of fine to coarse displacive halite crystals and poikilotopic halite cements. The crystal boundaries with the mudstone may be planar to irregular. Thin laminae occur in some units, and smeared intraclast and smeared laminae textures (after Holt and Powers, 1988) are usually present. Prism cracks and disk-shaped laminae may occur. The mudstone slightly may drape underlying topography. The upper surface of the mudstone is ordinarily sharp and slightly undulatory.

4.0 INTERPRETATION OF SALADO HALITE TEXTURES

Textures and fabrics within Salado halite can be classified genetically as 1) subaqueous deposition textures (from a standing body of fluid), 2) vadose zone alteration products, and 3) phreatic zone alteration products.

4.1 SUBAQUEOUS TEXTURES

Subaqueous deposition and dissolution textures and fabrics are common in Salado halite (Figure 23 in Report). Many of the fabrics are similar to those described by other workers (e.g., Shearman, 1970; Arthurton, 1973; Hardie, et al., 1983; Lowenstein and Hardie, 1985). Depositional halite textures developed during subaqueous conditions include: bottom growth fabrics with chevron and cornet fluid-inclusion zoning in vertical medium to coarse halite crystals; fine crystalline layers of cumulate halite (Figure 20) (sunken rafts and hopper crystals); and rarely, sand-sized crystals reworked as traction deposits (sunken rafts and hoppers reworked into ripples). Sulfate or clay was deposited subaqueously and coevally with halite and draped and lined bottom growth halite crystals. Coprecipitated sulfate often outlined several growth planes within an individual halite crystal. Planar dissolution of halite resulted from freshening events in the standing body of brine. Dissolution planed both bottom-grown and cumulate halite parallel to the depositional surface. Sulfate or clay was introduced during these freshening events. Sulfate formed because cations were added by runoff and the salinity was decreased by dilution. Clays were introduced with runoff from the surrounding terrain. In the Salado, sequences of bottom-grown halite and halite cumulates are planed off parallel to bedding planes and are overlain by laminae of sulfate, anhydrite or polyhalite. These sequences show no evidence of vadose zone alteration. Repetitive sequences of bottom-grown halite--cumulate halite--sulfate laminae are common and reflect subaqueous deposition interrupted by minor freshening events.

4.2 VADOSE ZONE ALTERATION FABRICS

Most halite within the Salado shows the effects of some syndepositional alteration within the vadose zone. In the Salado, small-scale vadose zone fabrics are related to synsedimentary dissolution, hygroscopic alteration, and efflorescent crust development. Many are analogous to features we and others (eg. Hardie, et al., 1983; Lowenstein and Hardie, 1985) have observed in modern evaporite deposits, but some are unique to the Salado. Vadose zone alteration of salt pan halite takes place when a standing body of water is reduced and the water table drops below the surface of the sediment.

4.2.1 Synsedimentary Dissolution

Dissolution fabrics are a commonly preserved indicator of vadose zone alteration in the Salado. Most Salado shows some evidence of synsedimentary dissolution. In modern salt pans, water from flooding and precipitation dissolves halite from the vadose zone and percolates downward toward the water table. Near the surface, dissolution follows and porosity is developed parallel to depositional fabrics: vertically for bottom-grown halite and horizontally for cumulate halite (Figure 20) (Lowenstein and Hardie, 1985). Vertical pits and pipes are dissolved to the water table as vadose zone conditions persist (Figure 21). Irregular to subhorizontal pores develop just above the water table. As vadose dissolution continues, an irregular topography forms at the surface (Figure 22). The relief increases with time until a complex surface of spires and pinnacles develops (DVT morphology similar to the Devil's Golf Course).

Perhaps the most interesting and diagnostic textures developed during vadose dissolution of halite are those accentuated by insoluble sulfate or clay. When present, these textures are unique indicators of vadose zone dissolution. Vadose zone dissolution initially affects the uppermost depositional unit. This is usually a triplet with a sulfate or clay lamina at the base overlain by bottom-growth halite which is in turn overlain by cumulate halite (Figure 20). Sulfate crystal drapes and linings on bottom-grown halite crystals remain after the halite host is dissolved. This produces a characteristic fabric we call pile-of-sticks (POS), after its appearance on the washed surface of the AIS (Figure 11). If little or no sulfate intervenes between successive depositional sequences, vadose dissolution of halite may generate a significant solution lag consisting principally of sulfate POS. POS textures are present in all Salado halite lithofacies, except the HM lithofacies. Thin laminae and laminae of clay or sulfate also develop characteristic textures in response to vadose zone dissolution. Irregular, discontinuous strata may form over a dissolving surface or on relief generated by vadose zone dissolution (Figure 20). These strata in the Salado may thicken and thin over the existing topography. As planar dissolution occurs parallel to the surface of the salt pan and removes all or most halite from successive small-scale depositional sequences, clay or sulfate laminae are disrupted and translocated. The amount of disruption is proportional to the volume of halite removed. Flat to slightly irregular strata consisting of clay or sulfate are disrupted into irregular strata and stringers, isolated blebs, and ultimately, "blebby" strata (Figure 20). These blebs are often displacively reworked by phreatic halite cements.

Point dissolution along preferential permeability pathways within the vadose zone and results in vertical solution features (Figure 21). The most common of these are dissolution pits and pipes. Some of these develop after the dissolution of the efflorescent material in polygonal cracks. Others may originate in topographic lows where rainfall and runoff pond before infiltration. Pits and pipes mature during repeated small floods and rains. Other examples of point dissolution include macropores and collapsed macropores. These features develop at and above the water table. They are vuggy and cavernous porosity which is ultimately connected to the surface. Insoluble material is often translocated into pits and macropores and is usually displaced by phreatic halite cements. In the Salado, some pits and macropores show evidence of multiple episodes of solution, translocation of insoluble material, and displacive growth of halite cements.

If the water table remains below the surface for an extended period of time, point dissolution dominates the fabrics (Figure 21), and pits and pipes become accentuated such that the surface develops a hummocky relief. As hygroscopic alteration occurs (Section 4.2.2), surficial halite becomes finely crystalline and well consolidated, and porosity is reduced by overgrowths on the fine crystals. Insoluble material accumulates at the surface as a solution lag. Strata are disrupted by collapse and slumping following dissolution. As this process continues, the depositional fabrics and textures become unrecognizable. Characteristic irregular lenses and pods form, and the surface becomes a complex terrain of jagged spires, hummocks, and columns. These textures are preserved if the water table rises considerably and cement processes occur. Repeated fluctuations between shallow standing bodies of water and deep water table conditions may produce a thick section showing this texture. Within Salado examples of this texture, the amount of cement fabrics is proportional to the time of subaqueous or nearly subaqueous deposition of halite within the topographic lows between the spires and columns. Cement-rich versions of this texture show very small pods and lenses of fine halite.

4.2.2 Hygroscopic Alteration

Solution is not, however, the only process which occurs in the vadose zone. Material exposed at the surface is commonly subject to hygroscopic alteration, which reduces crystal size and causes some cementation. In modern halite pans, moisture is hygroscopically attracted to the halite in the evening when the humidity increases, evaporation decreases, and the sediment cools. This process is accentuated if dew is precipitated. The hygroscopic fluid dissolves a small portion of halite. The following day, as evaporation rates quickly increase and the relative humidity at the pan surface decreases, halite is reprecipitated rapidly as very fine crystals. If subaerial exposure continues, this alteration process becomes increasingly effective as the fine crystals offer a greater surface area, allowing more fluid to be hygroscopically attracted. The net result of this process is to decrease the overall crystal size of surficial halite with time. This process is very effective at the Devil's Golf Course in Death Valley, California, where nearly all surficial halite is finely crystalline and, in the hummocky zones "podular" muddy halite, well-cemented and hard. In the Salado, much of the fine-to-medium crystalline halite in pods in the PMH lithofacies may have originally been altered hygroscopically.

4.2.3 Efflorescent Crusts

Halite also forms as efflorescences within the vadose zone in salt pans. Efflorescent crusts are fine to microcrystalline and consist mostly of halite with minor amounts of other minerals. The efflorescence precipitates as water is evaporated from the capillary fringe. Efflorescent growth is self-perpetuating. Because capillarity is greater within the efflorescence than the host sediment, the efflorescence will build upon itself and may rise above the sediment surface. Efflorescent crusts are common along the margins of polygonal cracks in halite pans. Evaporation from the water table in halite pans is most efficient at the edges of polygons, because centers of polygons generally exhibit a lower vertical permeability and the polygonal margins provide a direct vertical connection to the water table. Efflorescence crusts probably develop synchronously with polygons. Once the efflorescence reaches the sediment surface, evaporation from the water table increases allowing further concentration of solutes in phreatic water and continued sediment cementation. In modern salt pans, pits through the surficial sediment to the water table often show the development of an efflorescence along the side of the pit. If the pit is small enough, a thin efflorescent crust may cover the opening. Efflorescences generally have a low preservation potential as they are usually dissolved by rainfall and runoff. A flooding event may totally dissolve an efflorescence from along polygonal margins producing dissolution pits and pipes. Fine-grained halite preserved along the margins of some pits within the Salado are interpreted to be relicts of an efflorescent crust.

4.3 PHREATIC ZONE ALTERATION

In modern salt pan environments, displacive and passive pore-filling halite cements precipitate in the phreatic zone, further altering subaqueous deposition and vadose zone fabrics. Phreatic dissolution is rare as groundwaters are extremely saline. In the phreatic zone, halite saturated brines preserve and overgrow salt pan halite. Voids and pores are filled by displacive and passive halite cements. This process is very effective in modern salt pans where all visible porosity is filled by the time the sediment is buried 45 m (Casas and Lowenstein, 1989). Saturated to oversaturated conditions are maintained in the phreatic zone as water evaporates from the capillary fringe. Capillary pathways to the surface are established when efflorescent crusts grow along polygonal margins. Once these efflorescences reach the sediment surface, evaporation from the water table and, consequently, halite cement growth becomes more efficient.

Phreatic zone alteration fabrics are dominated by slowly-grown, coarse, clear overgrowth and cement textures. Displacement and incorporation of soft clay or sulfate by cement halite is common. Very porous and weakly bonded subaqueous deposition fabrics can also be mechanically displaced and disrupted by displacive cement growth. Angular boundaries with clay or sulfate develop as halite crystals grow displacively. In the Salado, sediment incorporative halite with angular matrix margins are displacive phreatic cements. Clear halite cements passively fill some porosity generated by vadose zone alteration. In the Salado, clear halite within pores and pits are passive halite cements.

A crude correlation can be made between the amount of vadose zone dissolution and the style of phreatic cementation. Phreatic cements tend to be passive in more mechanically competent halite sediments with lower bulk porosities and displacive where extensive vadose dissolution has increased the porosity and lowered the mechanical competence.

Displacive phreatic cements may radically overprint depositional and vadose textures when porosity is high within the host sediment. The porosity provides room for displacive cements to grow. In bedded halite sediments, high porosity develops at the individual stratum or several strata scale during repeated episodes of vadose solution and subaqueous deposition. This occurs when the water table drops only a small distance below the surface of the sediment and halite is dissolved from the vadose zone. A stable water table position permits surficial vadose zone alteration to be extensive while pits and macropores develop within the vadose zone sediments. Displacive cements fill porosity and disrupt remaining primary deposition fabrics. In general, displacive phreatic cements are proportional to the amount of dissolution porosity generated in the vadose zone.

5.0 INTERPRETATION OF THE IDEAL SEQUENCE

Each Salado halite sequence contains part or all of our idealized sequence (Figures 23 and 24). The textures and features found within each lithofacies and subfacies can be attributed to either subaqueous deposition, vadose zone alteration, or phreatic zone alteration processes (Figure 46). Each process leaves a characteristic textural overprint. Upward through the ideal sequence, vadose zone and phreatic zone alteration textures become more abundant, at the expense of subaqueous deposition fabrics. The textures present within the lowermost lithofacies, stratified mud-poor halite, reflect subaqueous deposition. The "podular" muddy halite lithofacies show mostly vadose zone alteration fabrics. Both the dilated mud-rich halite and halitic mudstone lithofacies are dominated by displacive halite cements formed in the phreatic zone. Although the entire sequence records an increasing role of vadose zone and, consequently, phreatic zone alteration with time, intermittent subaqueous deposition must have occurred episodically through out this time for the sequence to accumulate vertically.

5.1 STRATIFIED MUD-POOR HALITE (SMPH)

The SMPH lithofacies retains an overall sense of near horizontal stratification. On a large-scale, this reflects subaqueous depositional processes. On a small scale, vadose zone and phreatic zone alteration increases upward indicating that intermittent subaqueous deposition was followed by longer and more pronounced water table drops.

The lowermost zone within the SMPH lithofacies displays abundant bottom-accumulated halite textures indicating nearly uninterrupted halite deposition from standing water. The base of this zone shows either extensive dissolution and planing of underlying halite, an uninterrupted transition from subaqueously deposited sulfate to subaqueously deposited halite, or subaqueous accumulations of halite over subaerially reworked halite or sulfate. The lowermost zone formed following first-order flooding event that produced the longest-lived uninterrupted standing body of water.

The middle zone contains moderate amounts of subaqueously deposited halite and small to large pits, pipes, and macropores filled with passive halite cements. The pits, pipes, and macropores developed during modest amounts of point dissolution and limited planar dissolution within the vadose zone. They were later passively filled by halite cements within the phreatic zone. Displacive halite cements are sparse in the middle zone as vadose zone solution created only small increases in the bulk porosity of the section. Water table fluctuations began to drive deposition and alteration processes during the accumulation of the middle zone. Intermittent second-order flooding events created standing bodies of water that deposited halite. Shallow and deeper water table fluctuations were of limited duration creating only incipient vadose zone alteration fabrics.

The uppermost zone is dominated by displacive halite cements and more extensive point dissolution fabrics. It shows limited subaqueous deposition textures. As the shallow water table conditions existed for longer periods, planar dissolution produced more advanced vadose zone alteration fabrics (eg., solution lags) and created extensive porosity for the displacive growth of halite cements. Point dissolution textures became more abundant as the duration of deep water table conditions increased. Intermittent subaqueous deposition continued, despite greater water table fluctuations and longer periods of vadose zone alteration. Deposition in the uppermost zone is culminated by a major drop in the water table position of extended duration. The vadose zone was altered extensively by point dissolution. An irregular, hummocky topography developed during extended point dissolution, and a lag of insoluble material accumulated on the upper surface.

All the textures and fabrics displayed within the SMPH lithofacies are consistent with those found within a mud-poor halite pan environment with intermittent subaqueous conditions followed by large and small fluctuations in water table position.

5.2 "PODULAR" MUDDY HALITE (PMH)

The PMH lithofacies displays pods and lenses of finely crystalline halite surrounded and bounded by planar and point solution textures and zones dominated by displacive halite cement fabrics. The pods and lenses developed during repeated long term exposure in the vadose zone. Textures and fabrics similar to Salado examples of PMH are found at the Devil's Golf Course in Death Valley, California. There, spires, pinnacles, and hummocks of argillaceous halite develop during the reworking of halite in the vadose zone along the margins of localized depositional centers (Holt and Powers, in preparation). Point dissolution creates the hummocky relief and vertical pathways to the water table, while planar dissolution lowers the overall relief and creates solution lags of insoluble materials on the irregular surfaces (Holt and Powers, in preparation). The textures and fabrics developed by these processes, DVT, are analogous to those in the Salado PMH lithofacies.

The Salado PMH lithofacies preserves ancient examples of DVT textures. Salado examples are preserved as the phreatic zone engulfs the lithofacies and saturated brines stop dissolution. The "podular" textures develop in response to extensive vadose alteration during long-lived, deep water table conditions. The preserved thickness results from the alteration of a considerably thicker original section.

Pits and pipes initially developed within halite in the vadose zone (Figure 21). Further dissolution widened these features creating an irregular topography consisting of spires, pinnacles, and hummocks. As vadose zone alteration continued, the relief was reduced by planar dissolution, and lags consisting of insoluble materials developed on exposed surfaces. Intermittent flooding events further reduced the topography and precipitated bottom-accumulated halite in topographic lows. Planar solution created high porosity within the bottom accumulated halite which was later filled by passive halite cements or altered by displacive halite cements in the phreatic zone. Hummocks, spires, and pinnacles tipped and collapsed enhancing the podular texture. Additional subaqueous halite accumulated over the surface following second-order floods, providing additional material for later alteration and continued development of a "podular" texture. The entire "podular" sequence records numerous episodes of subaqueous deposition followed by extensive vadose zone alteration with relatively deep water table conditions.

The PMH lithofacies was deposited in a salt pan subject to intense vadose zone alteration. The salt pan developed an irregular topography due to both point and planar dissolution processes within the vadose zone. We call this environment a "hummocky" salt pan based upon its surface expression. Hummocky salt pan halite is muddier than the underlying mud-poor salt pan halite because the mud concentration increases as halite is dissolved.

5.3 DILATED MUD-RICH HALITE (DMRH)

The DMRH lithofacies displays displacive halite cement textures, and it may show crude horizontal stratification. Displacive halite cements record extensive alteration within the phreatic zone. Halite accumulated subaqueously following intermittent flooding events. The water table fluctuated frequently, and planar dissolution in the vadose zone created high porosity within subaqueously accumulated halite. The mechanical integrity of the altered halite was low, and subsequent growth of displacive cements during phreatic conditions dilated the fabric. Large water table fluctuations were infrequent, as pits and pipes are rare and "podular" textures do not occur. Disk-shaped strata and prism cracks developed as the exposed surface broke into polygonal structures during subaerial exposure. The overall relief of the depositional environment was low, and flooding events were capable of carrying relatively large volumes of mud into the depositional environment. Layers of mud were broken and disrupted by repeated solution and displacive growth of halite.

Textures within the DMRH lithofacies are consistent with those formed in a mud-rich salt pan. Extensive subaerial exposure and vadose zone alteration was followed by displacive halite cement growth within the phreatic zone. Water table fluctuations were less pronounced, and the overall relief on the salt pan was less than the preceding hummocky salt pan.

5.4 HALITIC MUDSTONE (HM)

Textures within the HM lithofacies are consistent with those formed in saline mud flat environments. The HM lithofacies is characterized by displacive halite crystals within a mudstone matrix. Well developed to highly contorted strata and smeared laminae/intraclast textures indicate subaqueous deposition and vadose zone alteration. Halite crystals growing in the phreatic zone displaced mudstone strata. Halite repeatedly dissolved and precipitated to create the smeared laminae/intraclast textures (Holt and Powers, 1988). Mudstone free of displacive halite shows smeared laminae/intraclast textures indicating dissolution of soluble evaporite minerals, probably halite. In some cases, mudstone free of displacive halite may have accumulated as broad solution lags following the dissolution of halite down to, or near, the water table. Prism cracks and disk-shaped strata developed as the surface broke into polygons during subaerial exposure.

6.0 DISCUSSION

Uninterrupted Salado halite sequences record the vertical progression of environments: mud-poor salt pan - "hummocky" salt pan (similar to the Devil's Golf Course at Death Valley, California) - mud-rich salt pan - saline mud flat (Figure 23). Salado halite sequences record the deposition and alteration of halite under variable water table conditions. Subaqueous deposition of halite alternated with vadose zone alteration as water table fluctuations created intermittent vadose zone conditions. Phreatic zone cements filled porosity below the water table. The frequency and duration of these water table drops increased over time as the basin became increasingly desiccated.

Mud-poor salt pan halite was deposited following a first-order flooding event. Evaporation and reworking of existing halite increased the salinity to halite saturation. Halite accumulated subaqueously until the basin was desiccated. When the water table dropped below the sedime surface, vadose zone alteration produced characteristic textures and fabrics. Second-order flooding events created intermittent subaqueous conditions, allowing additional halite to accumulate. Vadose zone alteration increased with time as flooding events became less frequent. Long periods of deep water table conditions cycled with shallow water table and episodic saline lagoon conditions producing and preserving PMH in a "hummocky" salt pan environment. Vadose zone alteration intensified with time reducing the overall relief across the basin. This allowed more efficient transport of clastic materials into the basin, and a mud-rich salt pan developed. Saline mud flat environments moved laterally toward the depocenter, as desiccation continued.

7.0 CONCLUSIONS

Geologic mapping of the AIS provided us with unprecedented halite textural and fabric data fro the Salado. We were able to characterize and interpret many previously unreported textures ar fabrics and recognize their stratigraphic succession. Halite shows extensive vadose zone alteration textures that developed under variable water table conditions.

Each halite sequence within the Salado fits partially or wholly into an idealized sequence. Complete Salado halite sequences consist of four lithofacies that are related to distinct depositional environments. First, SMPH lithofacies formed in a mud-poor salt pan texturally dominated by subaqueous depositional fabrics. Second, PMH lithofacies displaying abundant vadose zone alteration textures developed in a "hummocky" salt pan similar to the Devil's Golf Course in Death Valley, California. Third, the DMRH lithofacies showing abundant displacive halite cement fabrics was deposited in a mud-rich salt pan. The HM lithofacies formed in a saline mud flat.

Halite sequences record the increasing desiccation of an intermittently flooded basin. Each complete sequence began with a first order flooding event that produced the longest-lived perio of subaqueous deposition. Numerous second order flooding events allowed subaqueous deposition to occur episodically throughout the accumulation of each sequence. Vadose zone alteration coupled with extensive phreatic cementation increased over time as the frequency of flooding events decreased. Ultimately, vadose zone dissolution lowered the relief across the basin allowing greater input of clastic materials. The accumulation of each Salado halite sequence was halted by another first-order flooding event.

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APPENDIX F
FIGURES

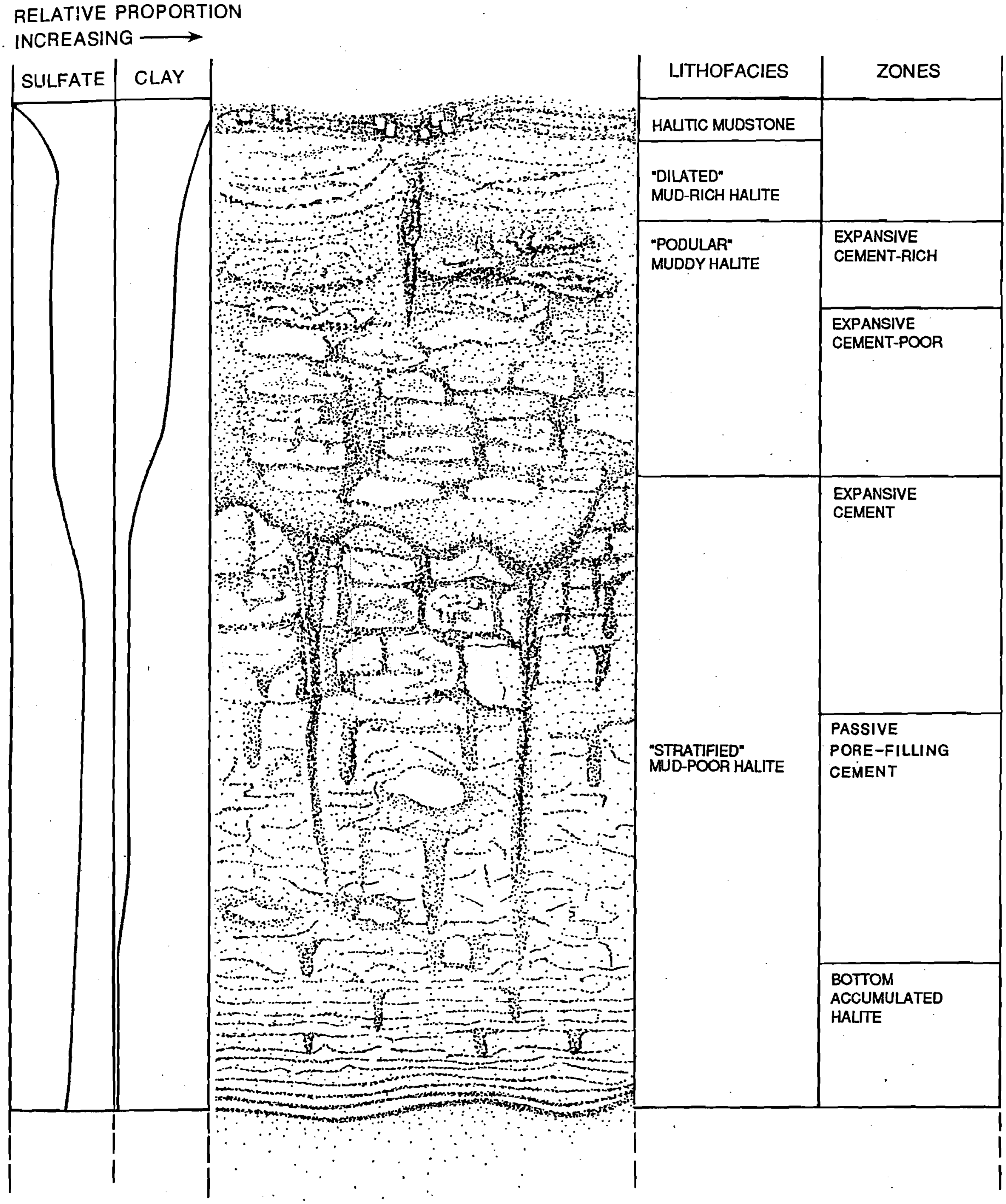


FIGURE 1 IDEALIZED SALADO HALITE SEQUENCE LITHOFACIES AND ZONES.

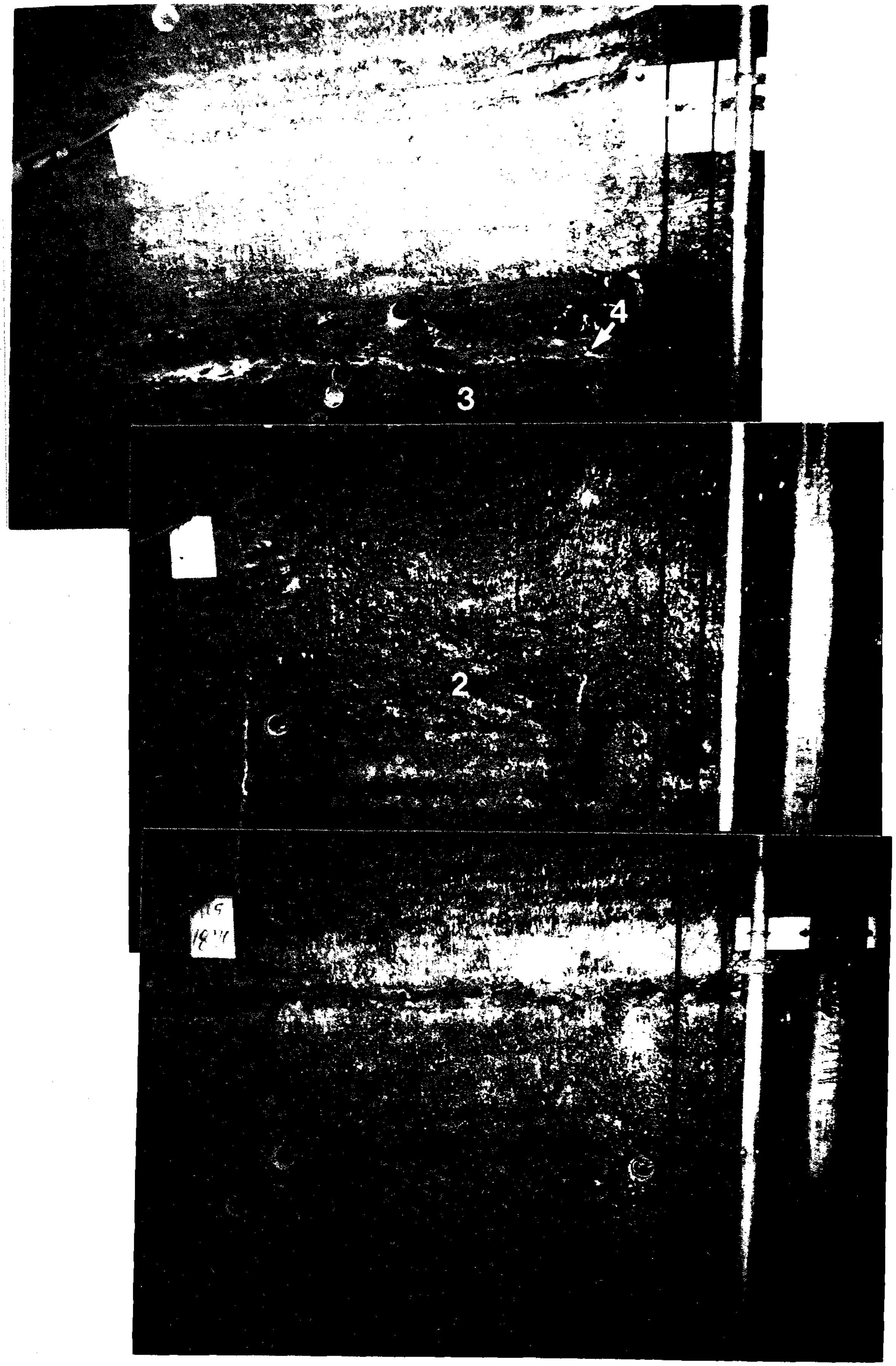


Figure 2
Photomosaic of a complete Salado sequence with the following lithofacies, upward from the base: 1) stratified mud-poor halite, 2) "podular" muddy halite, 3) "dilated" mud-rich halite, and 4) halitic mudstone.

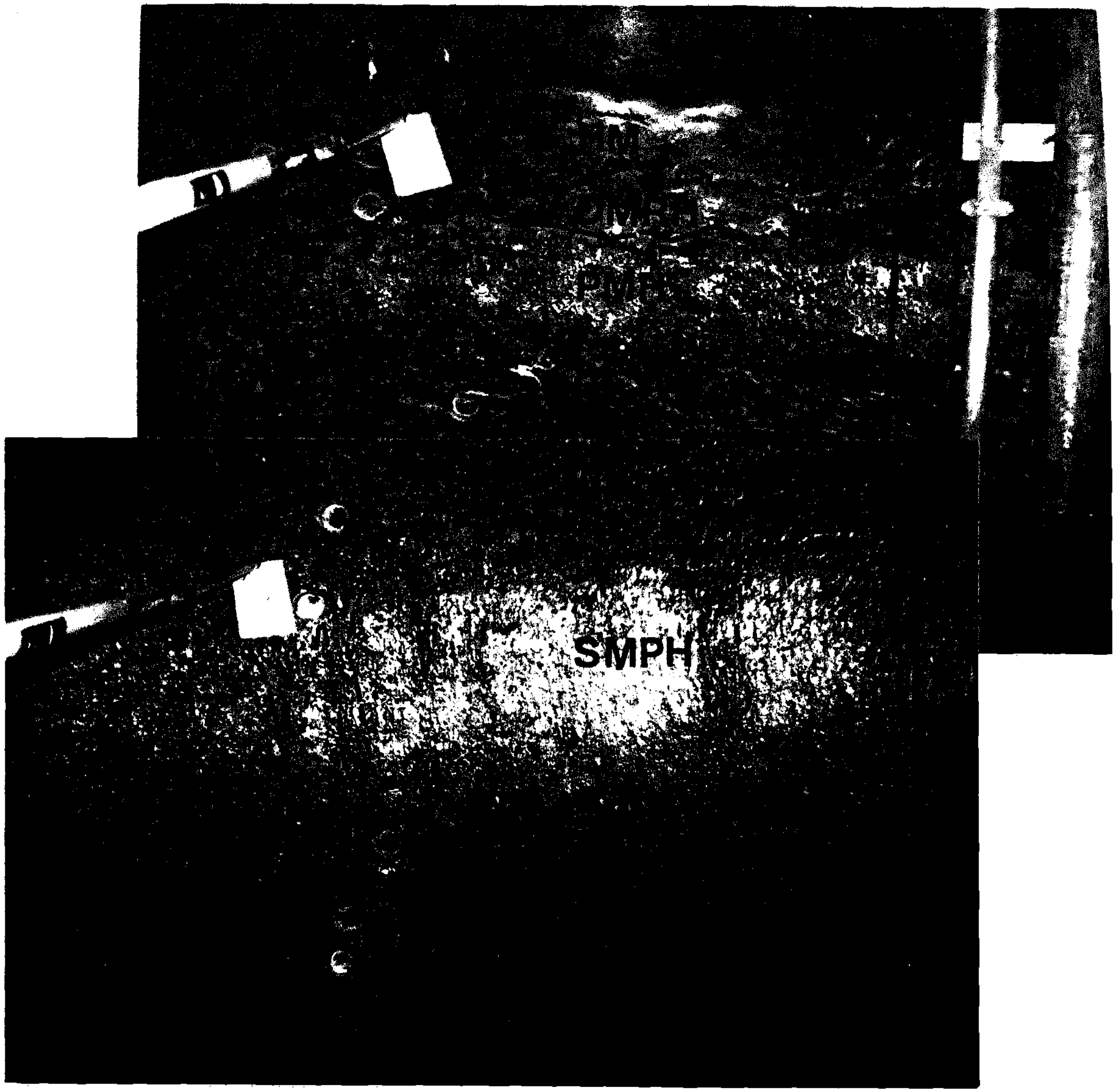


Figure 3
Photomosaic of a complete Salado sequence with the following lithofacies, upward from the base: stratified mud-poor halite (SMPH), "podular" muddy halite (PMH), "dilated" mud-rich halite (DMRH), and halitic mudstone (HM). (Note the large amount of relief present on and the dissolution pits originating from the Death Valley Type (DVT) exposure/solution surface between the stratified mud-poor halite and "podular" muddy halite lithofacies.)

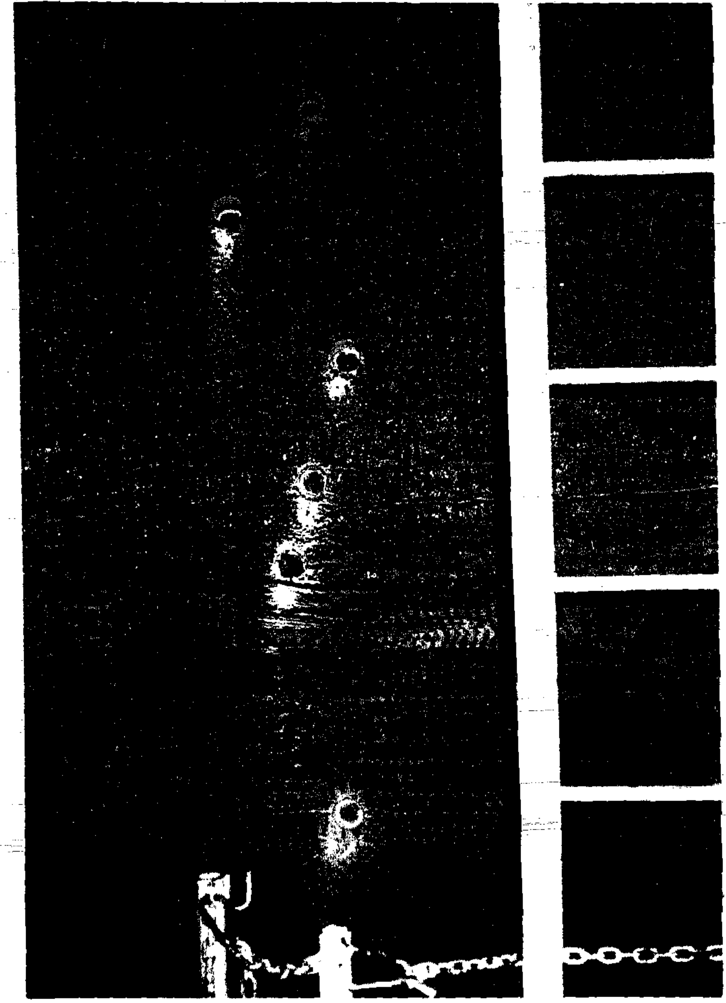


Figure 4
Stratified mud-poor halite intercalcated with laminae of polyhalite is subdivided into three textural zones: 1) bottom accumulated halite, 2) passive pore-filling cements, and 3) expansive cements.

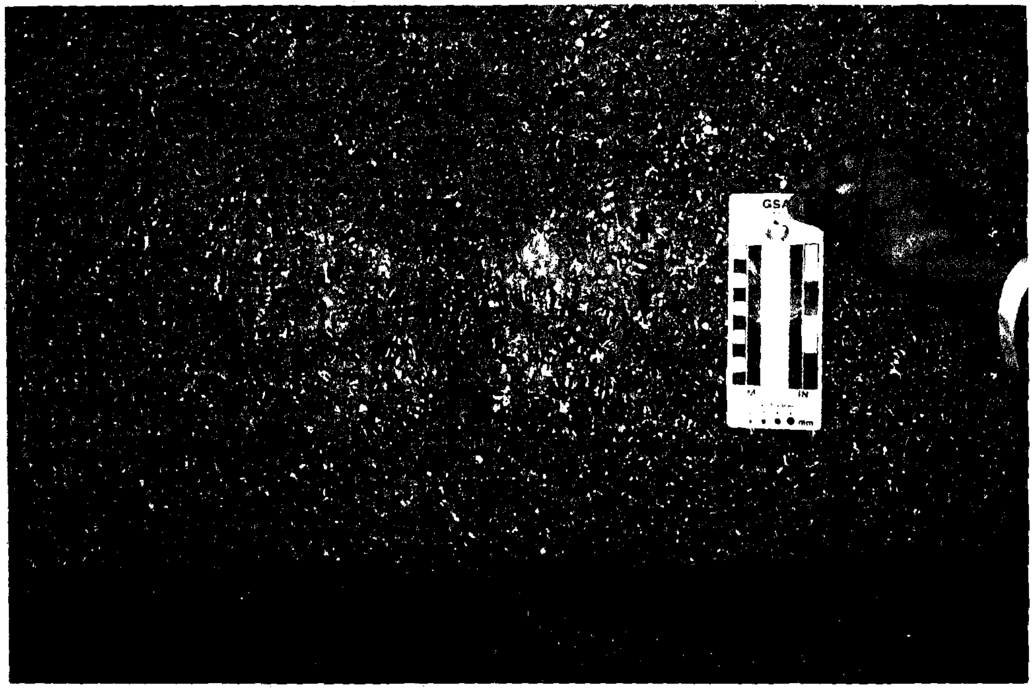


Figure 5
Polyhalite (orange blebs) and clay (light gray) solution lags (sl) on top of exposure/solution surfaces.

Figure 6
Dissolution pit with translocated polyhalite and displacive and passive halite cements.

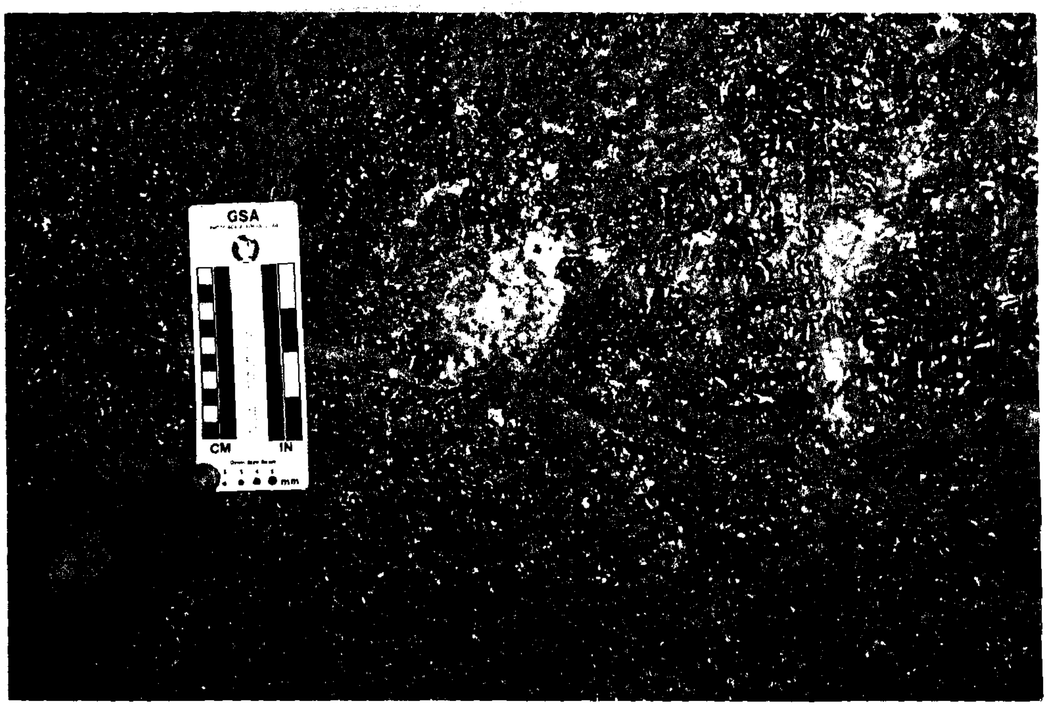
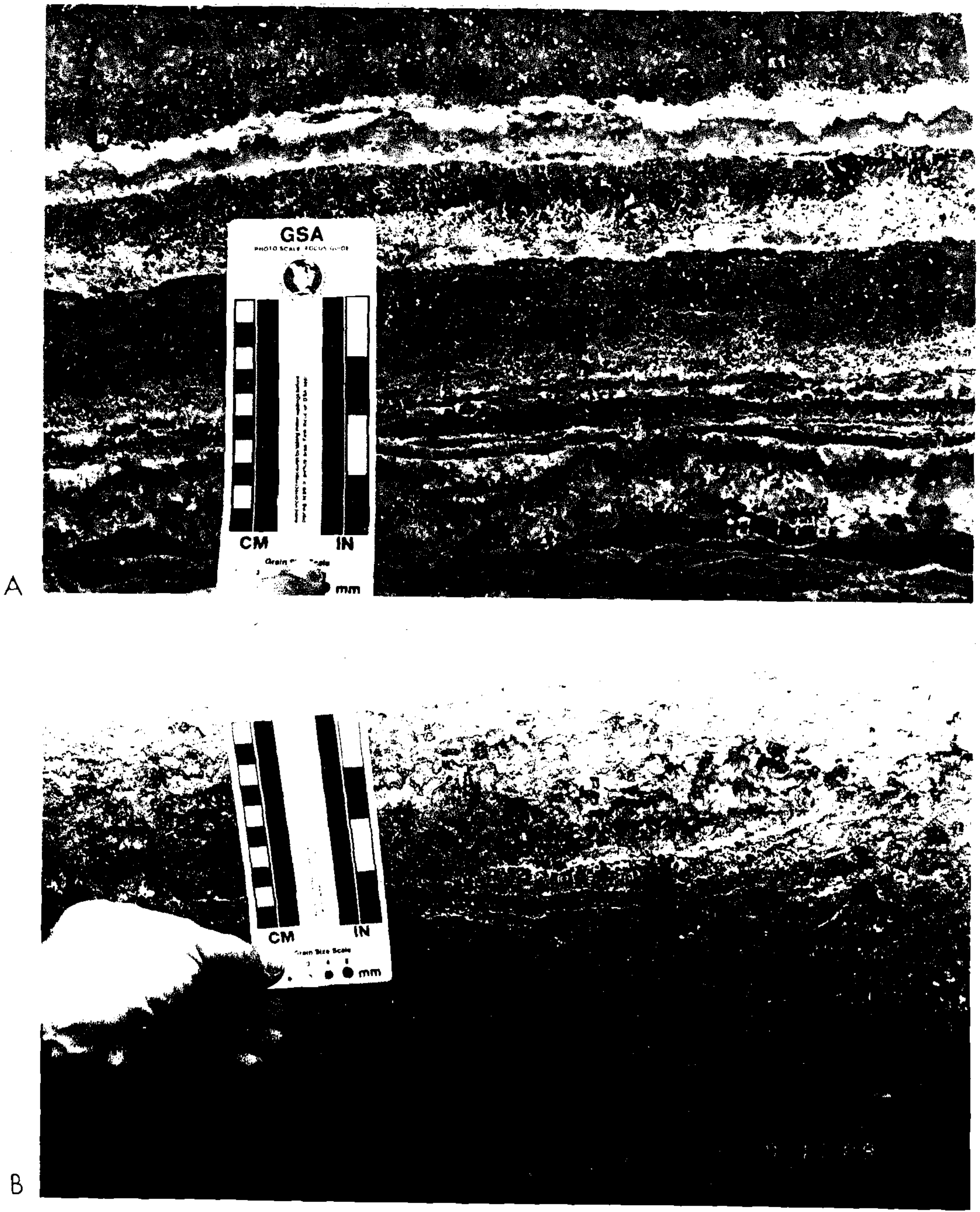


Figure 7
Very coarsely crystalline displacive halite cements and translocated material in a large solution pit.

Figure 8
Boxwork fabric formed by the intersection of horizontal polyhalite solution lags and translocated polyhalite pit/pipe fittings.



Figures 9A and 9B
Two examples (A and B) of halite crystal drapes and linings consisting of anhydrite after gypsum.

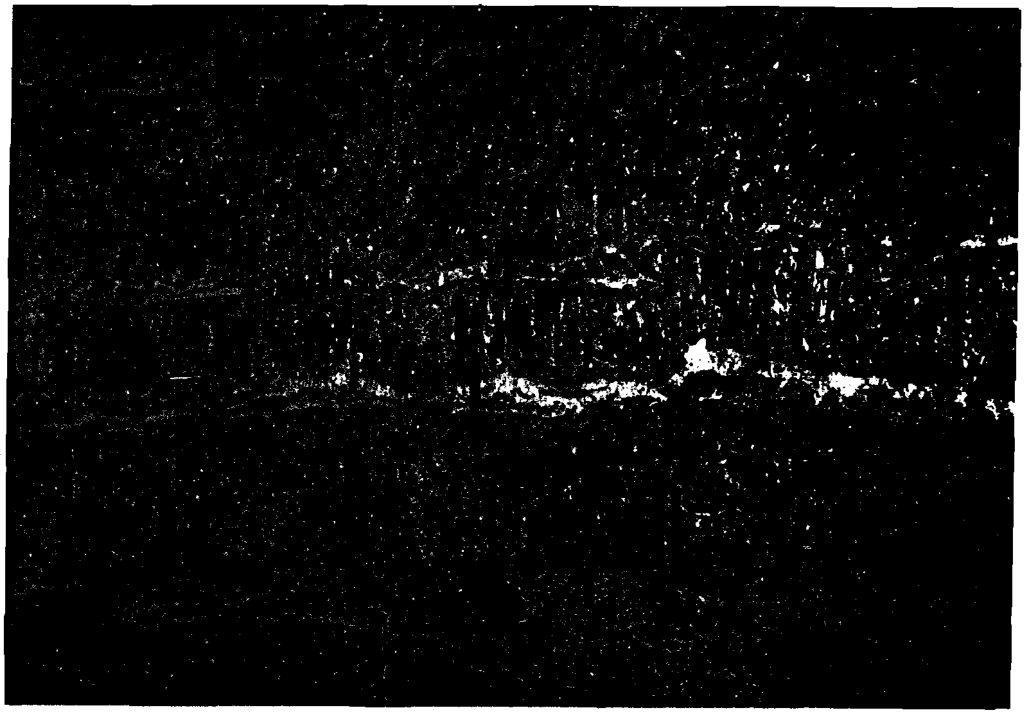


Figure 10
Small solution pits and irregular macropores developed in the stratified mud-poor halite lithofacies. Macropores are passively filled by coarsely crystalline halite. Polyhalite is translocated in some pits and macropores. (Arrows are approximately 10 cm long.)

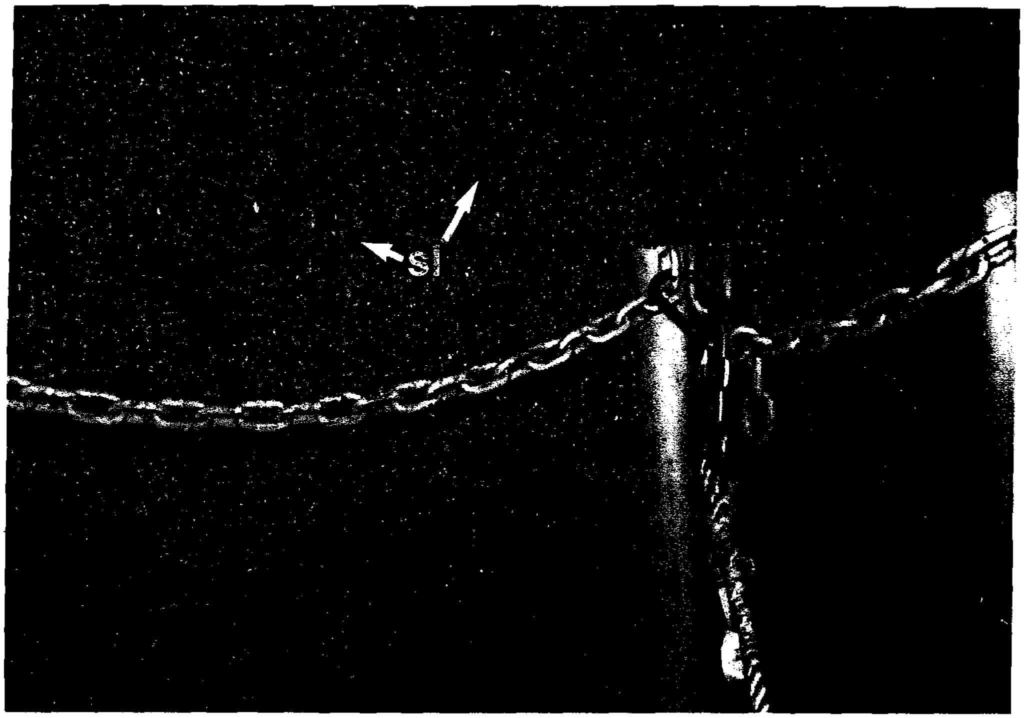
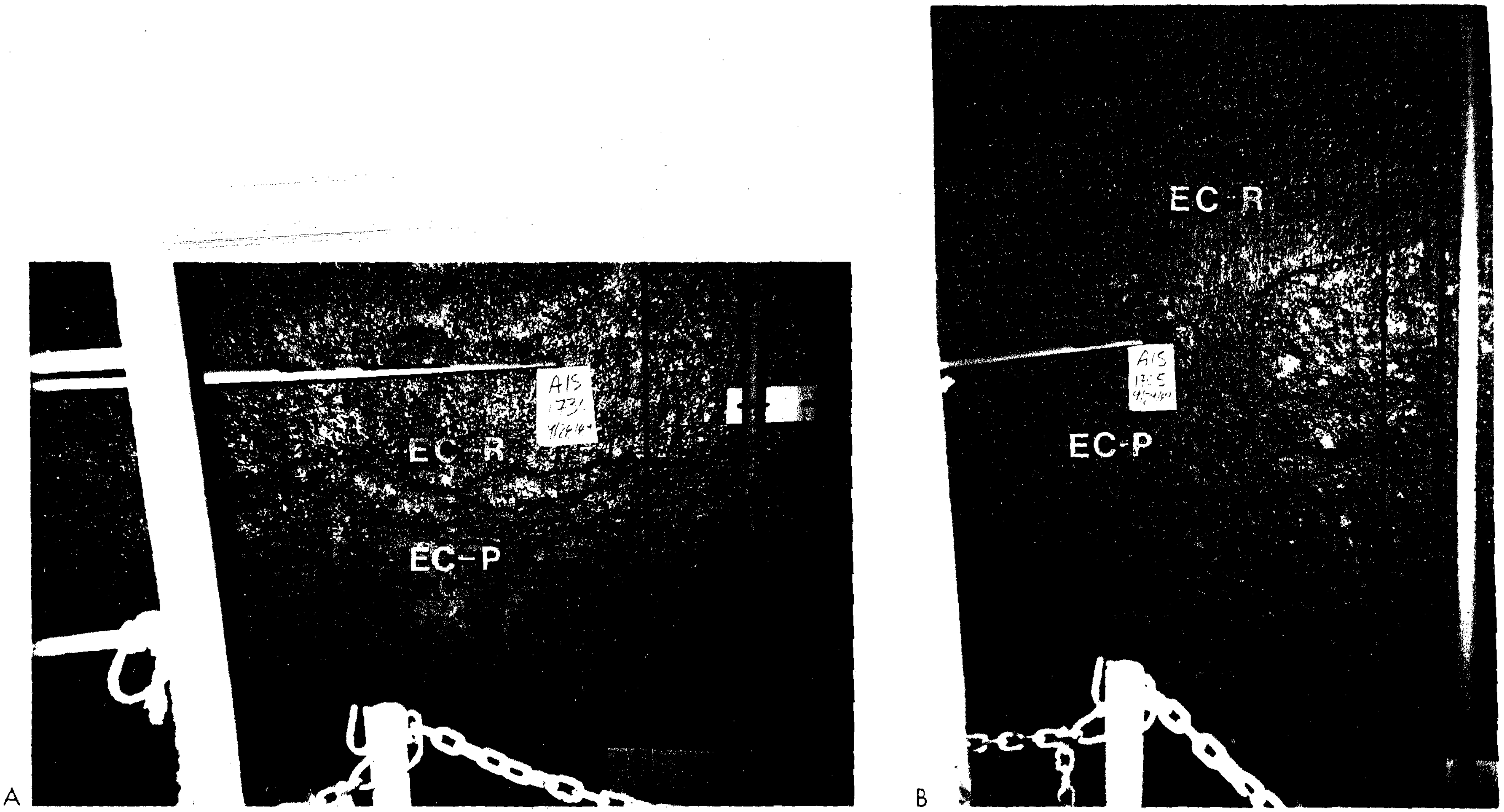
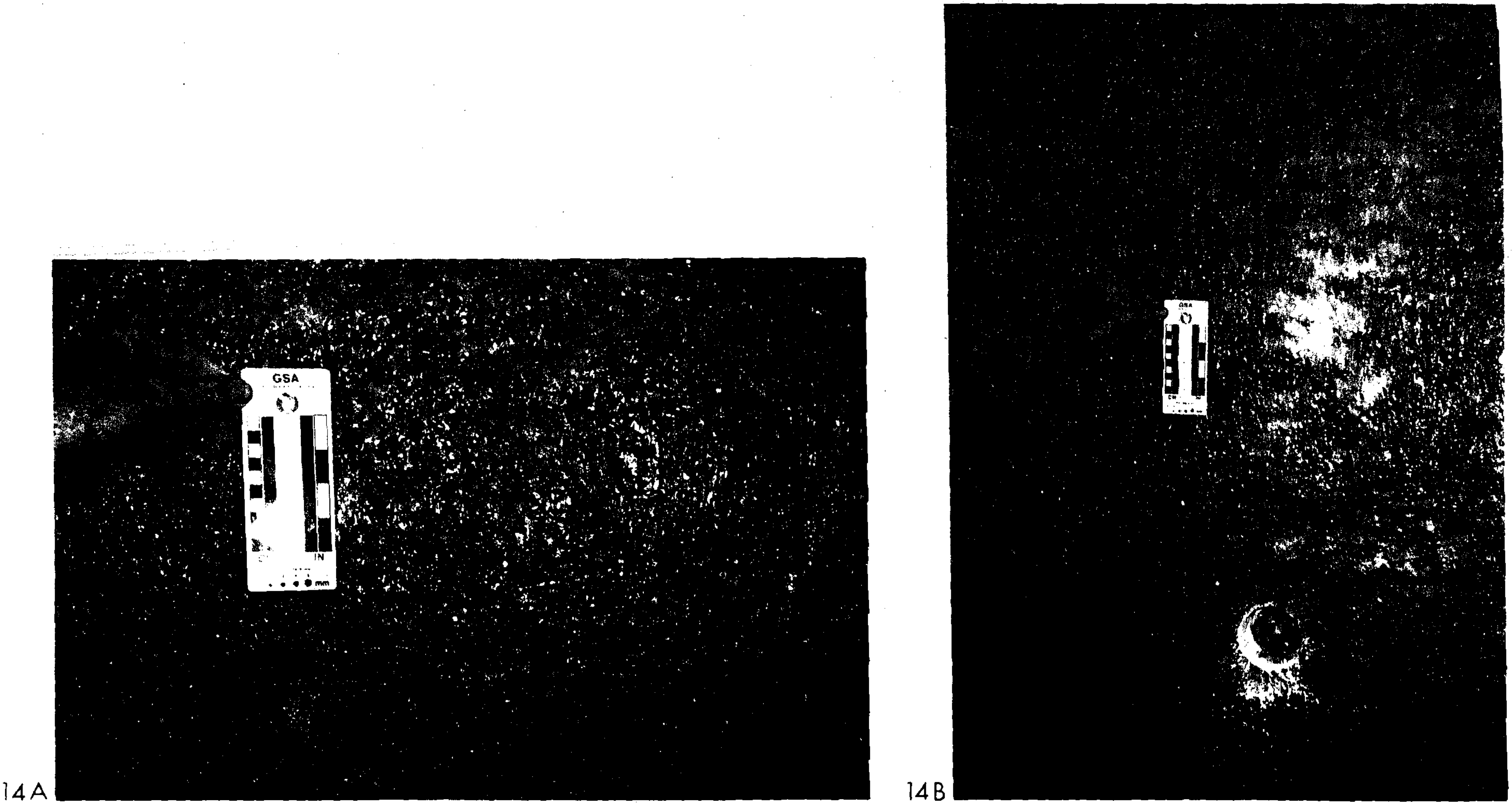


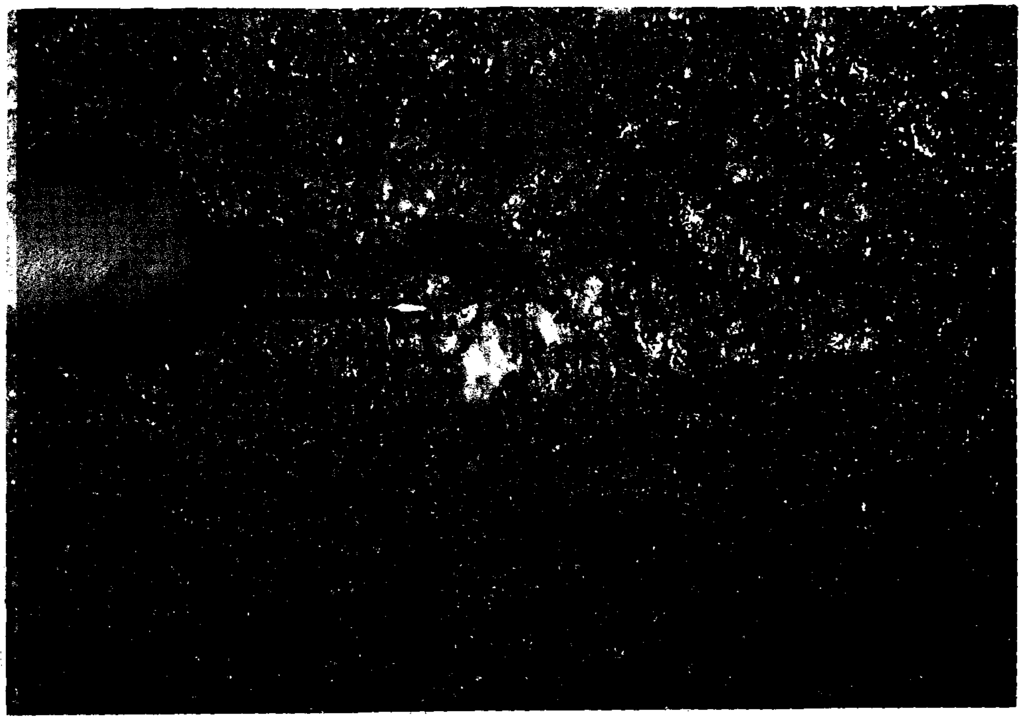
Figure 12
Zone of expansive cements in the stratified mud-poor halite lithofacies. The zone contains subhorizontal, irregular, discontinuous blebby laminae/solution lags (Sl) of polyhalite and dissemminated blebs of polyhalite with displacive margins.



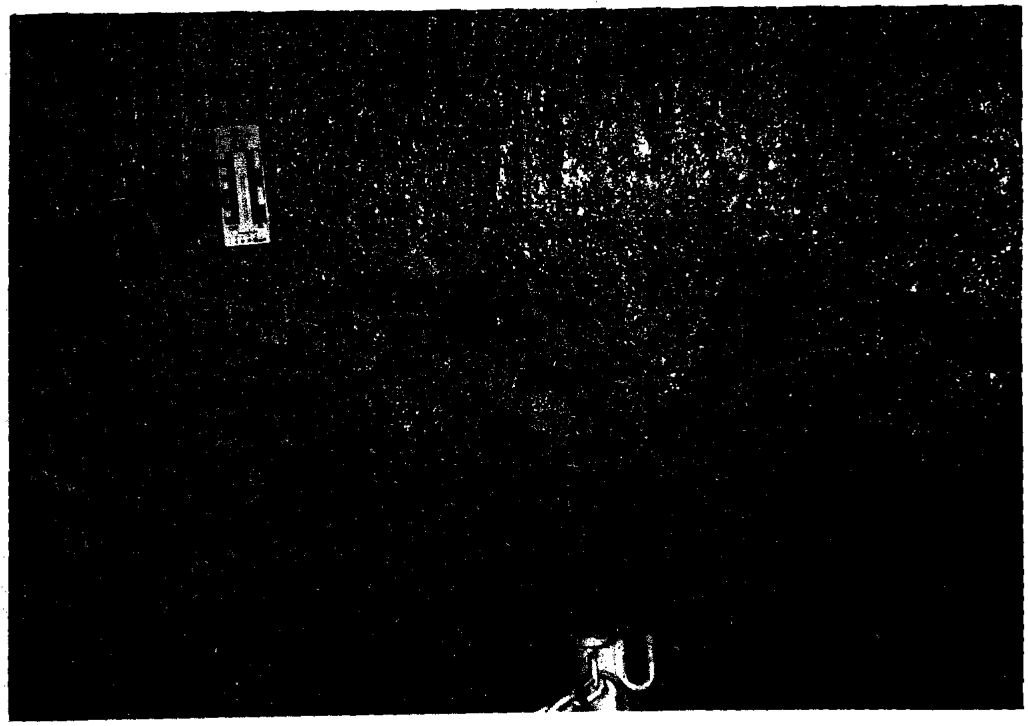
Figures 13A and 13B
"Podular" muddy halite lithofacies showing a lower expansive cement-poor (EC-P) zone and an upper expansive cement-rich (EC-R) zone. Irregular clay laminae and blebs are solution lags. A) Expansive cement-poor zone contains very little cement and is dominated by medium to finely crystalline halite. B) Expansive cement-poor zone contains a greater percentage of cements, including expansive cements. The pods are smaller, and the unit displays a large solution pit originating at the contact between the expansive cement-poor and expansive cement-rich zone. (Note: coarsely crystalline, clear halite [cements] reflects more light than fine to medium crystalline halite.)



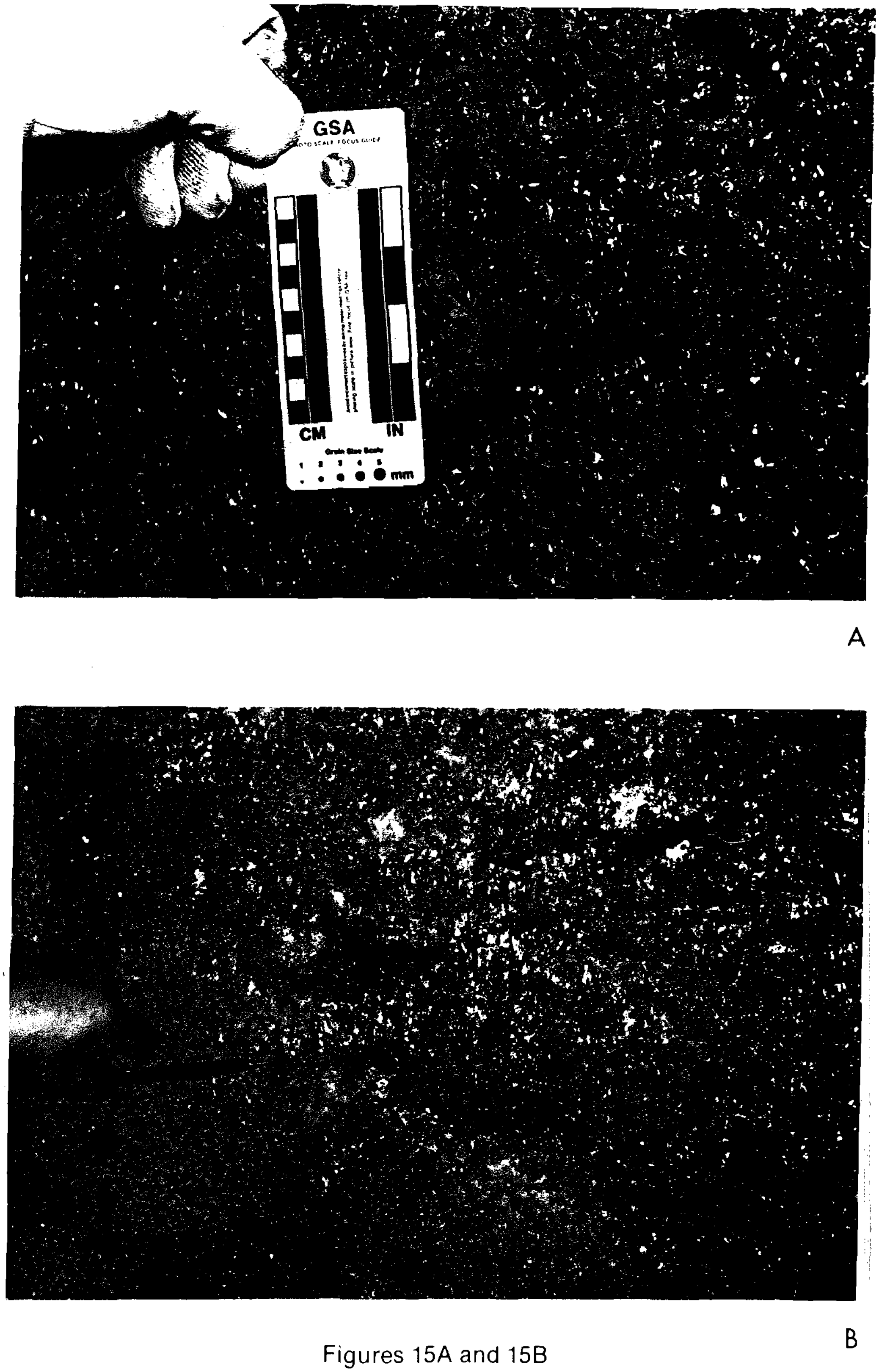
Figures 14A, 14B, 14C, and 14D
Four examples (A-D) of textural variations within the "podular" muddy halite expansive cement-poor zone. Irregular laminae of clay and blebs of clay and polyhalite are solution lags. (Note: coarsely crystalline, clear halite [cements] reflects more light than fine to medium crystalline halite.)



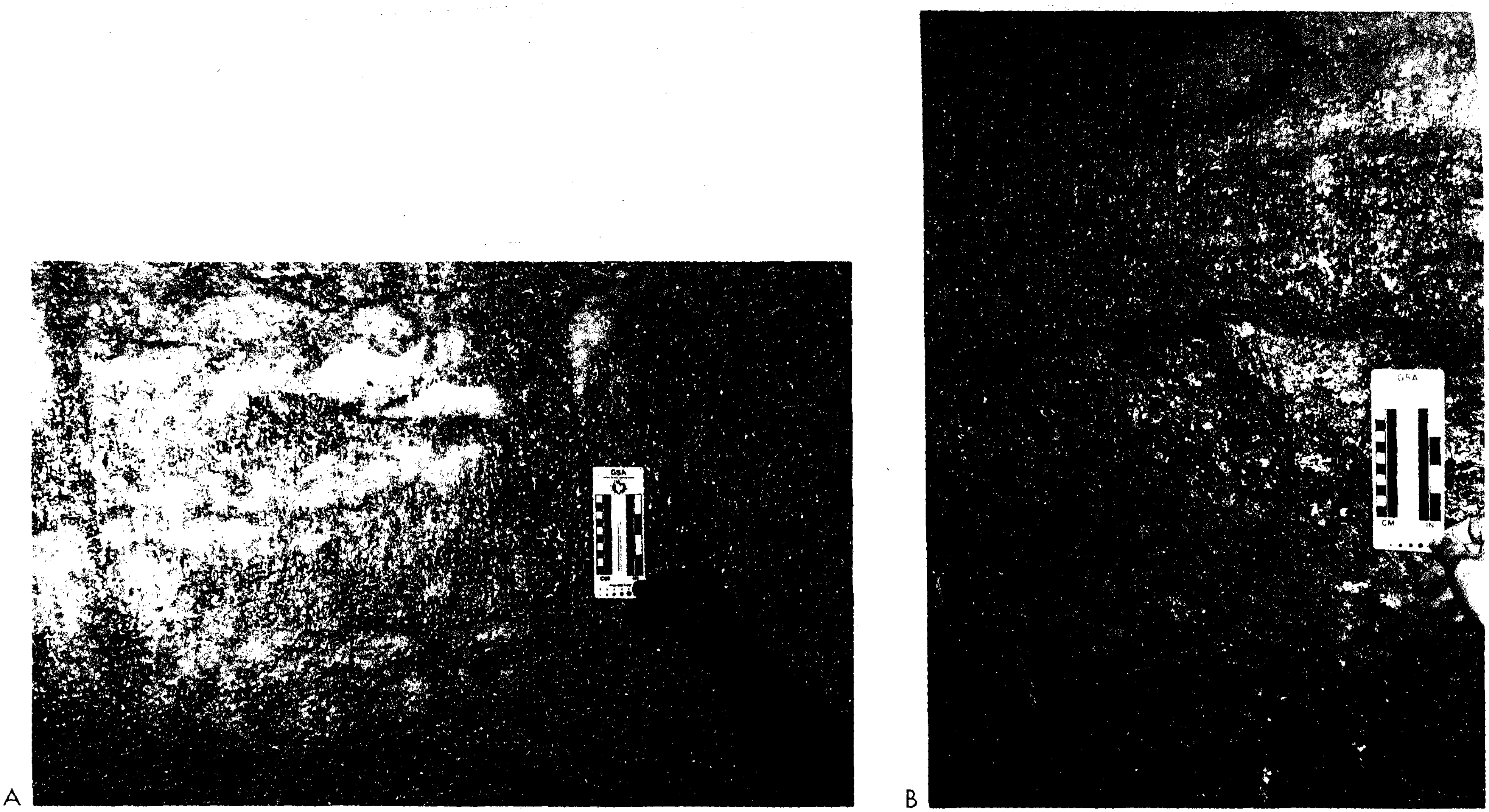
14 C



14 D



Figures 15A and 15B
Two examples from the expansive cement-rich zone in the "podular" muddy halite lithofacies. A) Coarse clear displacive halite cements with irregular blebs of claystone. Bleb boundaries are mostly planar due to expansive growth of halite cements in the phreatic zone. B) Medium to coarsely crystalline displacive halite cements with solution lags and blebs of clay.



Figures 16A and 16B
Solution pits and pipes through "podular" muddy halite. A) Slightly argillaceous "podular" muddy halite with little expansive cement with translocated material and coarsely crystalline passive and displacive cements in pipes. B) Very argillaceous "podular" muddy halite with a moderate amount of expansive halite cement.

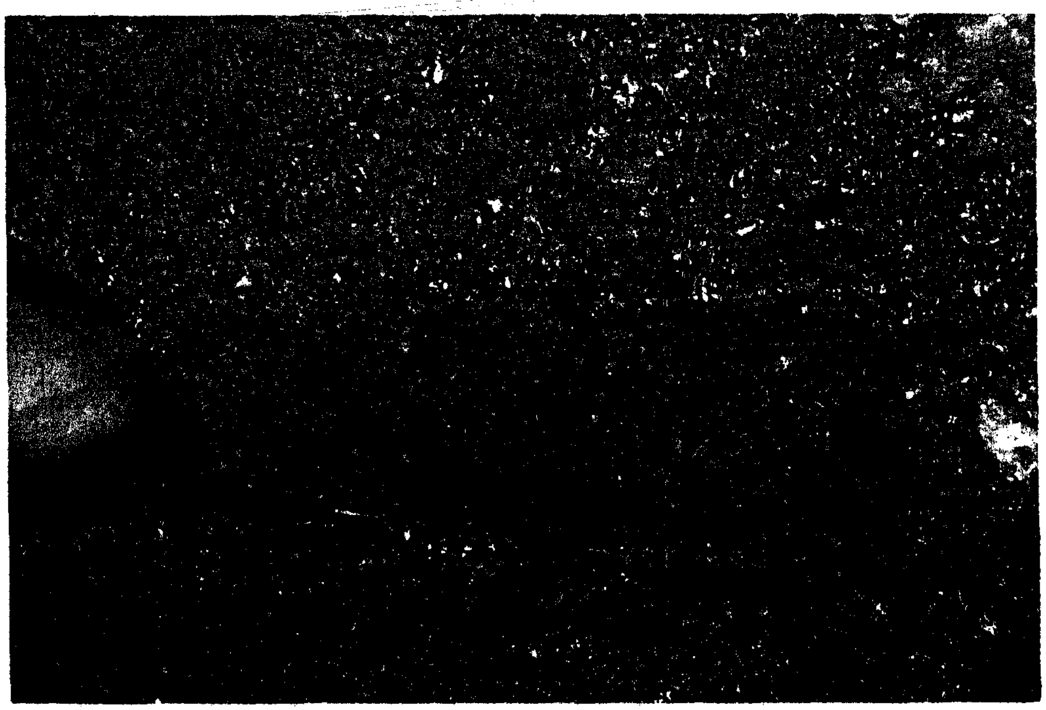


Figure 17
Irregular pod of mudstone in "podular" muddy halite lithofacies showing smeared intraclast (SIC) textures. Halite surrounding pod shows some planar boundaries with claystone blebs.

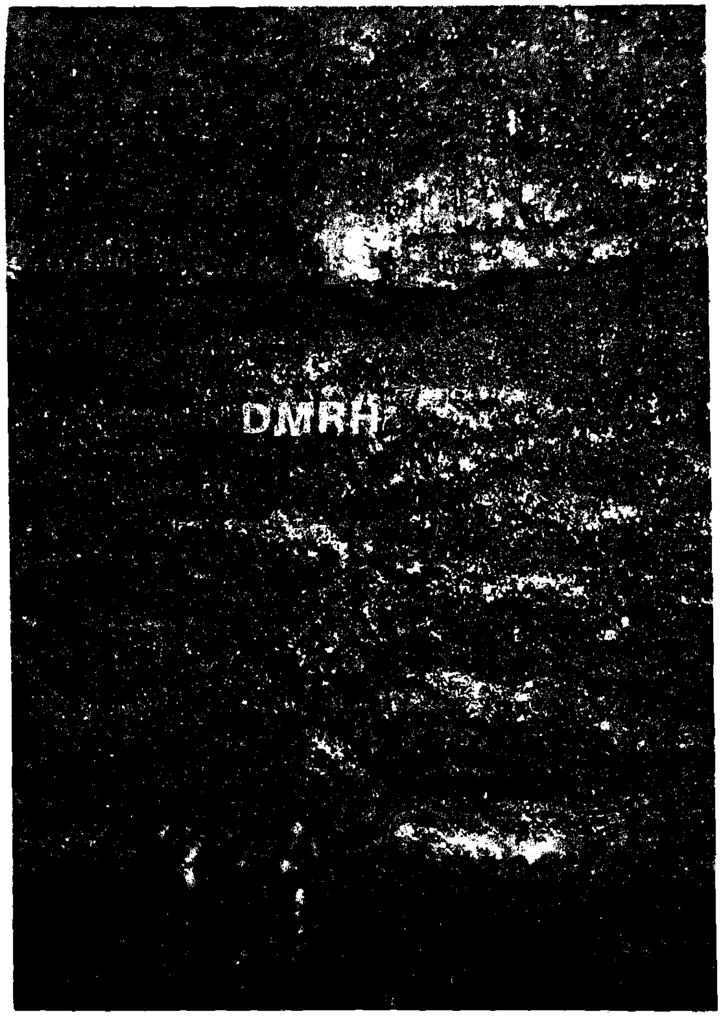
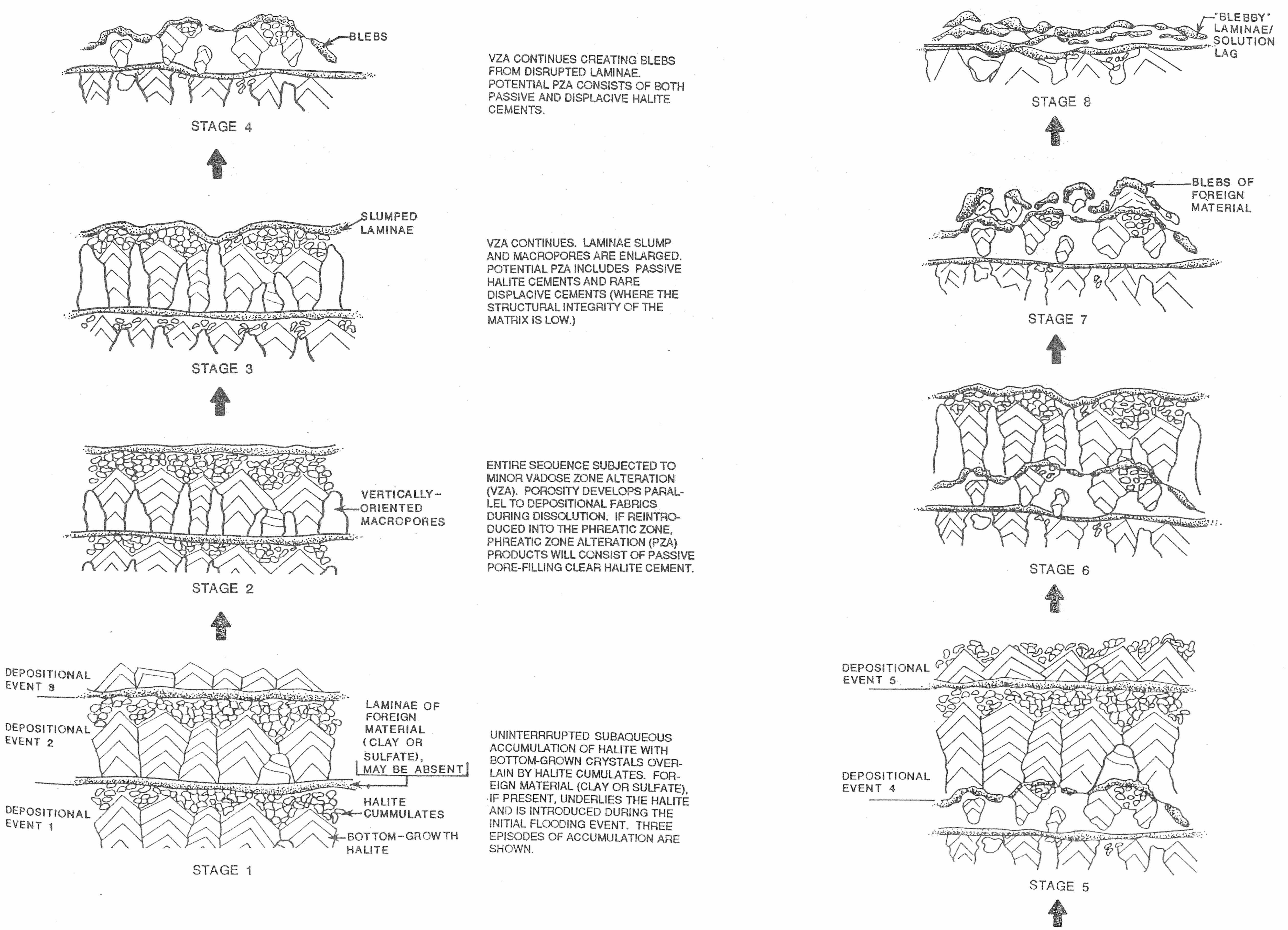


Figure 18
"Dilated" mud-rich halite (DMRH) lithofacies with aggregates of displacive crystals and irregular subhorizontal zones of halite showing displacive margins with clay.

Figure 19
Halitic mudstone lithofacies with isolated displacive halite crystals.



UNINTERRRUPTED SUBAQUEOUS ACCUMULATION OF HALITE WITH BOTTOM-GROWN CRYSTALS OVERLAIN BY HALITE CUMULATES. FOREIGN MATERIAL (CLAY OR SULFATE), IF PRESENT, UNDERLIES THE HALITE AND IS INTRODUCED DURING THE INITIAL FLOODING EVENT. THREE EPISODES OF ACCUMULATION ARE SHOWN.

ENTIRE SEQUENCE SUBJECTED TO MINOR VADOSE ZONE ALTERATION (VZA). POROSITY DEVELOPS PARALLEL TO DEPOSITIONAL FABRICS DURING DISSOLUTION. IF REINTRODUCED INTO THE PHREATIC ZONE, PHREATIC ZONE ALTERATION (PZA) PRODUCTS WILL CONSIST OF PASSIVE PORE-FILLING CLEAR HALITE CEMENT.

VZA CONTINUES. LAMINAE SLUMP AND MACROPORES ARE ENLARGED. POTENTIAL PZA INCLUDES PASSIVE HALITE CEMENTS AND RARE DISPLACIVE CEMENTS (WHERE THE STRUCTURAL INTEGRITY OF THE MATRIX IS LOW.)

VZA CONTINUES CREATING BLEBS FROM DISRUPTED LAMINAE. POTENTIAL PZA CONSISTS OF BOTH PASSIVE AND DISPLACIVE HALITE CEMENTS.

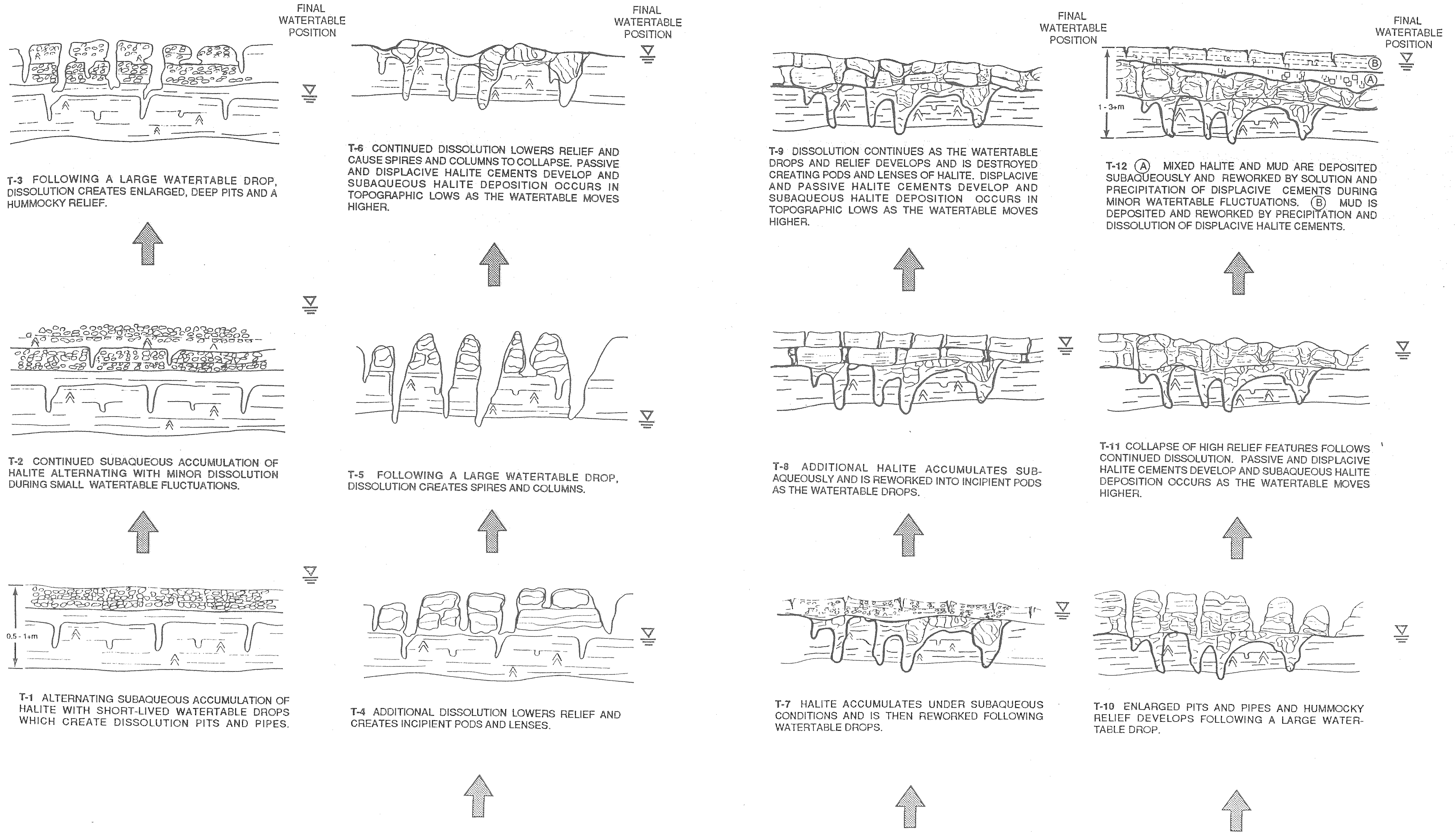
ADDITIONAL SUBAQUEOUS ACCUMULATION OF HALITE OVER DISRUPTED SEQUENCE.

VZA RESUMES. MACROPORES DEVELOP AND LAMINAE ARE DISRUPTED. BOTH PASSIVE AND DISPLACIVE CEMENTS MAY DEVELOP IF ALTERED IN THE PHREATIC ZONE.

VZA CONTINUES. NEW LAMINAE ARE BROKEN INTO BLEBS AND POROSITY CONTINUES TO DEVELOP. POTENTIAL PZA INCLUDES MOSTLY DISPLACIVE WITH SOME PASSIVE HALITE CEMENTS.

EXTENSIVE VZA REMOVES MOST HALITE AND INSOLUBLE FOREIGN MATERIAL IS REWORKED INTO "BLEBBY LAMINAE"/SOLUTION LAGS. POTENTIAL PZA PRODUCTS ARE MOSTLY DISPLACIVE HALITE CEMENTS.

FIGURE 20 DEVELOPMENT OF SMALL-SCALE SALADO HALITE FABRICS.



T-1 ALTERNATING SUBAQUEOUS ACCUMULATION OF HALITE WITH SHORT-LIVED WATERTABLE DROPS WHICH CREATE DISSOLUTION PITS AND PIPES.

T-2 CONTINUED SUBAQUEOUS ACCUMULATION OF HALITE ALTERNATING WITH MINOR DISSOLUTION DURING SMALL WATERTABLE FLUCTUATIONS.

T-3 FOLLOWING A LARGE WATERTABLE DROP, DISSOLUTION CREATES ENLARGED, DEEP PITS AND A HUMMOCKY RELIEF.

T-4 ADDITIONAL DISSOLUTION LOWERS RELIEF AND CREATES INCIPIENT PODS AND LENSES.

T-5 FOLLOWING A LARGE WATERTABLE DROP, DISSOLUTION CREATES SPIRES AND COLUMNS.

T-6 CONTINUED DISSOLUTION LOWERS RELIEF AND CAUSE SPIRES AND COLUMNS TO COLLAPSE. PASSIVE AND DISPLACIVE HALITE CEMENTS DEVELOP AND SUBAQUEOUS HALITE DEPOSITION OCCURS IN TOPOGRAPHIC LOWS AS THE WATERTABLE MOVES HIGHER.

T-7 HALITE ACCUMULATES UNDER SUBAQUEOUS CONDITIONS AND IS THEN REWORKED FOLLOWING WATERTABLE DROPS.

T-8 ADDITIONAL HALITE ACCUMULATES SUBAQUEOUSLY AND IS REWORKED INTO INCIPIENT PODS AS THE WATERTABLE DROPS.

T-9 DISSOLUTION CONTINUES AS THE WATERTABLE DROPS AND RELIEF DEVELOPS AND IS DESTROYED CREATING PODS AND LENSES OF HALITE. DISPLACIVE AND PASSIVE HALITE CEMENTS DEVELOP AND SUBAQUEOUS HALITE DEPOSITION OCCURS IN TOPOGRAPHIC LOWS AS THE WATERTABLE MOVES HIGHER.

T-10 ENLARGED PITS AND PIPES AND HUMMOCKY RELIEF DEVELOPS FOLLOWING A LARGE WATERTABLE DROP.

T-11 COLLAPSE OF HIGH RELIEF FEATURES FOLLOWS CONTINUED DISSOLUTION. PASSIVE AND DISPLACIVE HALITE CEMENTS DEVELOP AND SUBAQUEOUS HALITE DEPOSITION OCCURS AS THE WATERTABLE MOVES HIGHER.

T-12 Ⓐ MIXED HALITE AND MUD ARE DEPOSITED SUBAQUEOUSLY AND REWORKED BY SOLUTION AND PRECIPITATION OF DISPLACIVE CEMENTS DURING MINOR WATERTABLE FLUCTUATIONS. Ⓑ MUD IS DEPOSITED AND REWORKED BY PRECIPITATION AND DISSOLUTION OF DISPLACIVE HALITE CEMENTS.

FIGURE 21 DEPOSITIONAL MODEL FOR THE ORIGIN OF SALADO HALITE SEQUENCES.

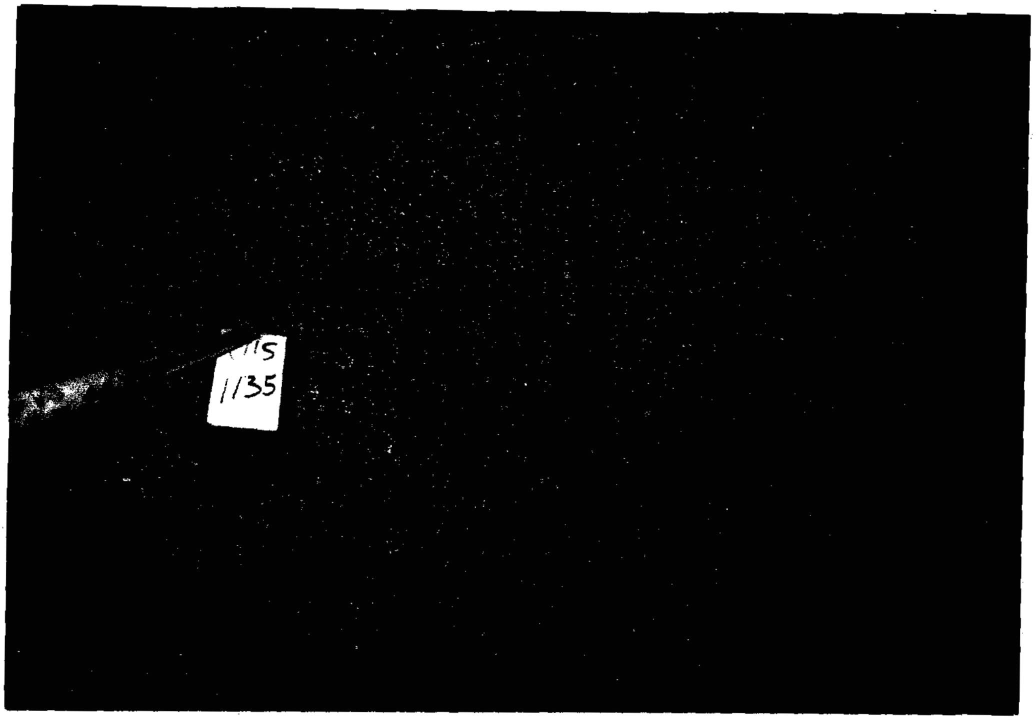
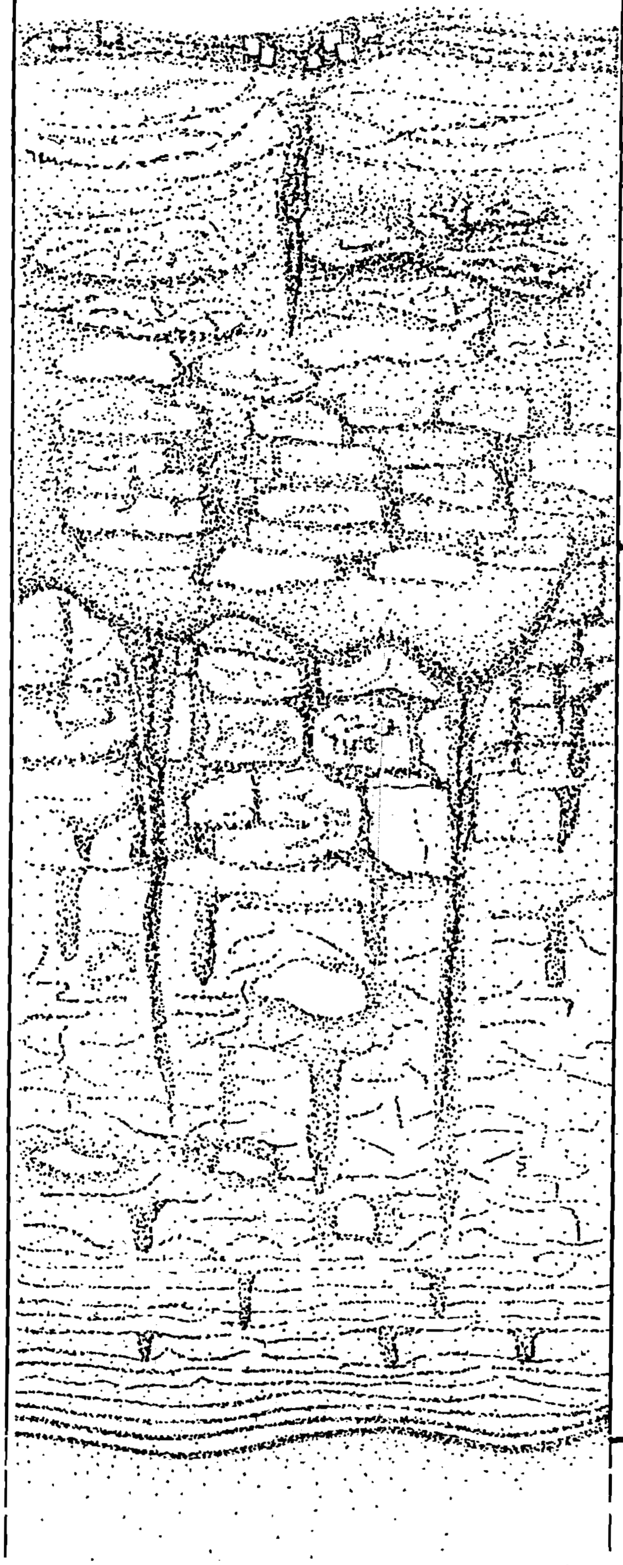


Figure 22
Death Valley Type (DVT) exposure/solution surface
with over 0.5 m relief.



DEPOSITIONAL ENVIRONMENT	PROCESSES
SALINE MUDFLAT	CLASTIC DEPOSITION EXTENSIVELY MODIFIED BY VZA AND DISPLACIVE PZA CEMENTS.
MUD-RICH SALTPAN	SUBAQUEOUS HALITE AND CLASTIC DEPOSITION ALTERNATING WITH EXTENSIVE VZA AND DISPLACIVE PZA CEMENTS.
HUMMOCKY SALTPAN	SUBAQUEOUS HALITE DEPOSITION ALTERNATING WITH VERY LONG PERIODS OF EXTENSIVE VZA WITH LARGE WATER TABLE FLUCTUATIONS. PZA MOSTLY CONSISTS OF GROWTH OF DISPLACIVE HALITE CEMENTS.
	SUBAQUEOUS HALITE DEPOSITION ALTERNATING WITH MODERATELY LONG PERIODS OF EXTENSIVE VZA WITH LARGE WATER TABLE FLUCTUATIONS. PZA MAINLY INCLUDES GROWTH OF DISPLACIVE AND LIMITED PASSIVE HALITE CEMENTS.
MUD-POOR SALTPAN	SUBAQUEOUS DEPOSITION OF HALITE ALTERNATING WITH SHORT PERIODS OF VZA WITH LARGE WATER TABLE FLUCTUATIONS AND LONGER PERIODS OF VZA WITH SMALL WATER TABLE FLUCTUATIONS. PZA INCLUDES GROWTH OF ABUNDANT DISPLACIVE AND SOME PASSIVE HALITE CEMENTS.
	SUBAQUEOUS DEPOSITION OF HALITE ALTERNATING WITH SHORT PERIODS OF VZA WITH INTERMEDIATE WATER TABLE VARIATIONS AND INTERMEDIATE PERIODS OF VZA WITH SMALL WATER TABLE FLUCTUATIONS. PZA INCLUDES MAINLY PASSIVE CEMENT GROWTH.
	SUBAQUEOUS DEPOSITION OF HALITE AND MINIMAL AMOUNTS OF VZA WITH SMALL WATER TABLE FLUCTUATIONS. LIMITED AMOUNTS OF PASSIVE PZA CEMENTATION.

FIGURE 23 SUMMARY OF SALADO HALITE DEPOSITIONAL ENVIRONMENTS AND PROCESSES.

Appendix G

APPENDIX G
SALADO SULFATE BEDS

SALADO SULFATE BEDS

1.0 INTRODUCTION

Thin, areally persistent interbeds of sulfate have long been recognized within the halite of the Salado Formation. Some sulfate interbeds were recognized as valuable stratigraphic markerbeds within the Salado and were numbered by geologists from the U.S. Geological Survey (Jones, et al., 1960); this numbering system has been used by many researchers for fine stratigraphic control within the Salado. As early workers (e.g., Schaller and Henderson, 1932; Page and Adams, 1940; Lang, 1942; Adams, 1944; Jones, 1954, 1972; Jones et al., 1960; and Brokaw et al., 1972) relied almost exclusively upon well cuttings, core, and geophysical logs for descriptive data from these interbeds, sedimentary texture data from the Salado were limited and the depositional environments of Salado sulfates were poorly understood. During the 1980's, several workers (e.g., Lowenstein, 1982, 1983, 1988; Jarolimek et al., 1983; Borns, 1985) used a comparative sedimentological approach to provide more precise interpretations of the depositional environments and diagenetic history of Salado sulfate interbeds. We have used a comparative sedimentological approach during this study to further expand and refine the understanding of these interbeds.

Sulfate interbeds within the Salado are considered by many (e.g., Schaller and Henderson, 1932; Jones, 1972; Lowenstein, 1982, 1983, 1988) to be important parts of vertical sedimentation cycles within the Salado. The depositional environments of these sulfates and their relationship to overlying and underlying halite interbeds provide a primary basis for understanding Salado sedimentation. Although some sulfate sedimentary features are reported from core (e.g. Schaller and Henderson, 1932; Lowenstein, 1982, 1983, 1988; Borns, 1985) and underground excavations (Lowenstein, 1982, 1983, 1988; Jarolimek et al., 1983), all of these studies focus upon limited stratigraphic sections within the Salado. The geologic mapping of the Salado in the AIS, however, provides continuous descriptions of outcrop-scale exposures through the upper 1,290 feet of the Salado. We describe many previously unreported textures, features, and lithologic associations from sulfate interbeds within the Salado, interpret newly described features, and refine existing models of deposition and diagenetic alteration of sulfate interbeds.

The hydrogeologic behavior of Salado sulfate interbeds is important for WIPP performance assessment and the plugging and sealing of the WIPP shafts and underground excavations. During the geologic mapping of the AIS, several thick sulfate interbeds were observed producing limited volumes of brine into the shaft. Discharge of brine from sulfate interbeds may be an important consideration for shaft plugging and sealing design if enough fluid is discharged into the shaft to affect the reconsolidation of crushed salt backfill. Sulfate interbeds immediately underlying and overlying the WIPP underground excavation may provide migration pathways for gas and brine from waste storage panels. Markerbed (MB) 139, the most important of these interbeds, is currently being characterized hydrologically. Data from sulfate interbeds in the AIS may provide the basis for a more precise conceptual hydrogeological model of MB139.

1.2 PREVIOUS WORK

Sedimentological data from Salado sulfate interbeds are limited. Schaller and Henderson (1932) first characterized the mineralogy of the Salado through core description and petrography. They noted that sulfates dominantly consisted of magnesite-banded anhydrite and polyhalite with occasional anhydrite, polyhalite, and halite pseudomorphs after gypsum crystals. Schaller and Henderson (1932) did not ascribe any sedimentological interpretation to the features they observed, although they did recognize pseudomorphs after gypsum crystals and replacement of sulfate by polyhalite.

Lowenstein (1982, 1983, 1988) macroscopically and petrographically examined the sedimentological textures and fabrics present in sulfate interbeds from the McNutt potash zone in cores and potash mine excavations. Lowenstein observed flat, wavy, crinkly, and contorted laminae of anhydrite or polyhalite alternating with laminae of magnesite-rich, sulfatic mudstone. Anhydrite, polyhalite, halite, and sylvite pseudomorphs after gypsum were described as vertically elongate prisms, some incorporating mud, originating from a common surface; cross-laminated grainstones with clear crystal fragments displaying gypsum morphologies; and layers of randomly oriented or horizontally aligned prisms or equant crystals.

Lowenstein (1982, 1983, 1988) interpreted the vertically elongate pseudomorphs after gypsum to be subaqueously-grown prismatic gypsum crystals. Cross-laminated grainstones and randomly-oriented or horizontally aligned gypsum pseudomorphs were interpreted to be reworked vertically-oriented, bottom-grown gypsum crystals. Lowenstein interpreted these features to be analogous to those found in modern marginal marine deposits and ancient gypsum interpreted as shallow subaqueous lagoonal deposits. Hundreds of carbonate-gypsum pseudomorph couplets were interpreted to indicate prolonged subaqueous conditions with repeated inflow of water, evaporative concentration, gypsum precipitation, and sediment reworking. Lowenstein (1988) stated:

> The anhydrite-polyhalite beds provide ample evidence of an origin in a shallow lake or lagoon not concentrated beyond gypsum saturation. The absence of subaerial exposure features suggest that this phase of evaporite sedimentation took place in a permanent brine body. (p. 599)

Lowenstein (1982, 1983, 1988) believed the sulfates were deposited shortly after a marine-derived influx of water and that the transition to halite deposition was without an intervening period of subaerial exposure.

Markerbed 139 (MB139) has been studied as part of WIPP site characterization activities. Jarolimek, et al. (1983) focused on explaining the undulations on the top of MB139 and quantifying the variation of the relief of MB139 (thickness, strike, and dip). Based on the exploratory shaft mapping (now called the construction and salt handling shaft) and core data, the undulations were attributed to localized bottom-growth of prismatic gypsum ("swallow-tail") crystals in clusters that created mound-like shapes at the upper surface of MB139. Thickness variations from 1.2 to 4.1 feet were reported for MB139 at the WIPP site.

In a later study, Borns (1985) used macroscopic core data from five closely spaced (greatest spacing was 13 feet) underground boreholes at WIPP to reevaluate the origin of undulations on the top of MB139; examine evidence of depositional and deformational history of the middle Salado; compare the mechanical responses of MB139 with the surrounding units; and qualitatively characterize the fluid history and future hydrologic potential of MB139. Borns observed the following sedimentary textures: irregular laminae, pseudomorphs after prismatic gypsum crystals ("swallowtails"), soft sediment deformation, and bottom-grown halite fabrics. Diagenetic features observed included mineralogic replacements and fractures. Borns discounted gypsum growth and late-stage deformation in favor of traction deposition of halite and channelling as a mechanisms for creating undulations on the top of MB139. Borns cited halite replacements of groundmass and pseudomorphs after gypsum with partially filled fractures as evidence of post-depositional fluid movement through MB139. Though MB139 was not exposed in the AIS, many other sulfates were examined, and they provide further background for interpreting MB139.

2.0 LITHOLOGY OF SULFATE INTERBEDS

At the AIS, interbeds of sulfate within the Salado consist of anhydrite, polyhalite, magnesite, and limited amounts of halite and other potash minerals at the AIS (Figure 23 in Report). Their thickness varies from 0.1 to 16.5 feet, and 75 percent of the sulfate interbeds range between 0.1 and 1.0 feet thick. The cumulative thickness of Salado sulfate interbeds is 124 feet at the AIS, roughly 10 percent of the section mapped; 54 percent of this thickness is contained within seven interbeds ranging from 6 to 16.5 feet thick. Thicker interbeds are usually underlain by gray magnesitic mudstone, ranging from less than 1 inch to 2 feet thick. Thinner interbeds may show planar or irregular upper and lower contacts, while thicker interbeds have planar lower contacts and undulatory upper contacts. Thinner interbeds are more likely to consist of polyhalite while thicker interbeds usually consist of anhydrite. Primary depositional and diagenetic alteration textures and fabrics are prevalent through most markerbeds.

2.1 PRISMATIC GYPSUM PSEUDOMORPHS

Pseudomorphs after prismatic gypsum crystals are common in sulfate interbeds and usually consist of anhydrite, polyhalite, or halite. They are associated with varying amounts of detrital material. The most characteristic gypsum pseudomorphs are vertically oriented prismatic crystal forms, a fraction of an inch to 8 inches high, with the c-axis oriented nearly perpendicular to stratification (Figures 1, 2, and 3). Some prismatic gypsum pseudomorphs are randomly oriented and show a disrupted fabric. Gypsum crystal morphologies range from acicular to twinned swallowtail shapes (Figure 1). They can occur as isolated crystals; radial clusters originating from a common point; groups of crystals originating from a single horizon forming a discrete stratum; or large, discrete or epitaxially overgrown, often laterally interlocking, prismatic crystals in a massive bed (Figure 2). The prismatic gypsum pseudomorphs often contain intercrystalline inclusions of laminated material parallel to and cross-cutting gypsum crystal faces. Individual laminae cross-cut many crystals and give a stratified sense to a more massive, interlocking, vertical crystal fabric (Figure 3). In some beds, larger crystals coalesce to form mound-like forms within sulfate interbeds. Randomly oriented zones and mounds of prismatic gypsum crystal pseudomorphs occur in some interbeds and may create relief on the upper contact. Vertically-oriented, prismatic gypsum pseudomorphs mostly occur in thicker sulfatic interbeds. AIS mapping recorded these textures in only 27 of 82 mapped interbeds. Large crystals are common in those interbeds greater than 1 foot.

2.2 DETRITAL TEXTURES

Detrital fabrics occur within all sulfate interbeds. Flat to wavy thin laminae to laminae are extensive and show local cross-cutting relationships. Ripple forms and ripple cross-laminae are found within some markerbeds (Figure 4). Rippled material consisting of anhydrite, polyhalite, and occasionally halite pseudomorphs detrital gypsum (Lowenstein, 1982, 1983, 1988). Although, detrital halite ripples also occur. Cross-laminae occur in only 13 of the interbeds mapped; most of these were thicker than 1 foot. Tabular rip-up clasts are present near the base of Markerbed 103, and coarse-sand to granule-sized clasts of polyhalite occur within an anhydrite matrix near the tops of Markerbed 136 and Markerbed 133.

Varying amounts of detritus occur with prismatic gypsum pseudomorphs. Strata containing prismatic gypsum pseudomorphs may be flat but most are wavy to contorted and slumped. Stacked parallel laminae containing prismatic gypsum pseudomorphs are often mound-like with the amplitude increasing upward until cross-cut by an erosional surface or stratum which thickens into a topographic low. More massive beds consisting of interlocking, vertically oriented prismatic gypsum pseudomorphs have detrital material interspersed in individual crystals and may contain irregular, discontinuous laminae to thin beds of detrital material.

2.3 ALGAL AND CRYPTALGAL FABRICS

Stromatolites and cryptalgal layering are found at the base and top of six sulfate interbeds exposed in the AIS. Thinly laminated to laminated hemispheroids occur near the base of MB103 and the Union anhydrite (Figures 5 and 6). Soft sediment deformation and displacement along shear planes commonly occur within the cores of the hemispheroids. Black, sticky, clay-sized material within some strata in these zones is possibly organic-rich. These stromatolites are classified as laterally linked hemispheroids (after Logan et al., 1964) and are similar to those reported from Rustler dolomites in the vicinity of WIPP (Holt and Powers, 1984, 1986, 1988). Stromatolitic forms also occur at the top of MB119 and MB136. These are generally similar to previously described stromatolites but may show some irregular and truncated margins with the overlying halite (Figure 7). Cryptalgal layering and mound-like algal biscuits (after Gebelein, 1969) containing crude fenestral-like halite-filled porosity occur near and at the top of MB115 (Figure 8). Cryptalgal layering is also found at the base of MB133. Some thicker interbeds display probable cryptalgal layering.

2.4 PRIMARY HALITE TEXTURES WITHIN SULFATE INTERBEDS

Halite is abundant within most sulfate interbeds mapped. Halite exhibiting primary or syndepositional fabrics, however, is less common, occurring in 28 of 82 interbeds mapped. Bottom-grown halite textures, exhibiting primary fluid inclusion zoning as chevrons or cornets and sulfate crystal-drapes are found within lenses and irregular zones bounded by sulfate (Figures 9 and 10). Halite zones are often truncated by sulfate showing collapse textures (Figure 11).

Displacive and incorporative halite crystals are found in some sulfate interbeds and may show either planar or irregular boundaries with the host material.

2.5 SOFT SEDIMENT DEFORMATION AND COLLAPSE TEXTURES

Soft sediment deformation and collapse textures are widespread within Salado sulfate interbeds. Either type of deformation may originate externally, at the lower contact, or internally, within the interbed. Soft sediment deformation includes slump features, soft sediment shear along planes, and load/pillow structures (Figure 12). Collapse structures originate at the base of interbeds and within interbeds adjacent to bottom-grown halite. In addition, smeared intraclast (SIC) textures (after Holt and Powers, 1988) occur within some interbeds.

The amount of soft sediment deformation within most sulfate interbeds varies and is usually greatest near the lower contact. It occurs most frequently in sulfate exhibiting detrital or algal textures and is moderately abundant within detrital sediment-rich occurrences of vertical pseudomorphs after prismatic gypsum crystals. Slumping and minor disruption of strata is common in sulfate interbeds and may texturally dominate in thinner interbeds. Shear planes exhibiting minor amounts of displacement are associated with slumping in some interbeds, particularly those containing algal stromatolites. Load structures are rare and occur only within thicker interbeds.

Several interbeds display collapse textures. The collapse may originate at the base of sulfate interbeds or in small to large zones within the interbeds. Textures vary depending upon whether collapse occurs within a narrow well defined zone or along a broader area. The degree of deformation is proportional to the amount of the displacement and its width. In broad, shallow depressions at the base of interbeds where strata are downwarped, separation and displacement of strata may occur, and clasts may be rotated slightly (Figure 13). In extreme cases, usually over pits at the lower contact, breccia clasts are rotated and slumped downward, and upward stoping is observed (Figure 14). Much of the collapsed material shows post-collapse soft sediment deformation and displacive halite crystals.

In some cases, sulfate interbeds may exhibit a smeared intraclast texture similar to that reported by Holt and Powers (1988) in mudstones from the Rustler Formation (Figure 15). Deformed or smeared intraclasts show no evidence of transport, and in some cases, irregular, poorly preserved, discontinuous laminae are present. The intraclasts and laminae appear to be squashed together while soft. Smeared laminae and intraclasts may be well preserved and distinct. In other cases, indistinct mottling is present. Occasionally, polyhalite may appear crudely structureless with hints of irregular intraclasts and laminae. The surface may appear lumpy or corrugated.

2.6 OTHER DISRUPTIVE TEXTURES

Other disruptive textures found within sulfate interbeds include prism cracks, teepee structures, and buckled strata. These fabrics usually occur at the tops of thicker interbeds, although, a probable teepee structure occurs near the base of MB103. Each of these fabrics may be associated with the others.

Prism cracks occur at the tops of thicker interbeds, including: MB 109, Union anhydrite, and MB127. Their depth ranges from a few inches to several feet (Figures 16 and 17). They are usually associated with porous (now filled with halite cement), disrupted to buckled strata and may be filled with translocated clay or sulfate and halite cements.

Teepee structures occur at the top of MB109, MB123, and MB127 and possibly in the lower part of MB103 (Figures 18 and 19). They show disrupted and upward buckled strata ranging from a few inches to nearly a foot in height. They may display a regular spacing along the tops of interbeds. Halite-filled voids occur between buckled strata. Sometimes, flat lying buckled and disrupted strata occur at the tops of interbeds (Figure 20). Upward buckling and overriding of individual strata characterize this fabric. Irregular voids between buckled strata are passively filled with halite and may show prismatic gypsum crystal pseudomorphs oriented downward from the top of the void. Minor amounts of collapse and infiltrated clay occur in some examples.

2.7 VOID FABRICS

Lenticular to tabular voids filled with halite are found in some sulfate interbeds. These voids lie parallel to flat, wavy, and contorted strata and generally retain the stratified appearance of the interbed (Figure 21). They may be isolated or clustered in groups which dominate the overall appearance of the interbed. These voids are sometimes associated with cryptalgal layering and algal stromatolites and minor amounts of soft sediment deformation. The halite void-filling rarely displays fluid inclusion zoning. Often, they contain pseudomorphs after prismatic gypsum crystals from originating from both the base and top of the void (Figure 22).

2.8 GYPSUM PSEUDOMORPHS

Although primary gypsum fabrics are widespread in all sulfate interbeds, gypsum is not found as it is replaced by halite, anhydrite, or polyhalite. Halite pseudomorphs after prismatic gypsum crystals are common, while halite pseudomorphs after detrital gypsum grains are rare. Both polyhalite and anhydrite are pseudomorphous after detrital and prismatic gypsum. Thinner interbeds usually consist of polyhalite while thicker interbeds consist mostly of anhydrite. Discrete, well-defined laminae of polyhalite or anhydrite may occur within a matrix consisting of the other sulfate mineral. Polyhalite is mostly confined to those areas which may have had extensive permeability shortly after deposition. It occurs along some prism cracks, along bedding planes adjacent to prism cracks, and as detrital layers between pseudomorphs of vertically oriented prismatic gypsum. In other cases, polyhalite pseudomorphs after prismatic gypsum crystals occur within an anhydrite matrix. Polyhalite and anhydrite in a single interbed may have a well defined or diffuse contact. Rare granule-sized grains of polyhalite are found with anhydrite pseudomorphs after detrital gypsum.

A well developed trough on the top of MB134 displays halite with polyhalite overlain by anhydrite laminae terminating at the trough margin (Figure 23). Within the trough, the first thin bed of halite is polyhalitic; it is overlain by alternating anhydritic and polyhalitic thin beds separated by polyhalite and anhydrite laminae. The lowermost polyhalitic halite extends only partly up the margin of the trough, and the contact between MB134 and this lowermost halite bed has been altered to polyhalite.

2.9 FRACTURES AND FRACTURE-FILLINGS

Many of the thicker sulfate interbeds display naturally occurring open and filled fractures. Open fractures occur only in anhydrite and usually parallel stratification. Many of these fractures were observed producing limited amounts of brine into the AIS. Filled fractures are usually subhorizontal and contain halite or polyhalite fillings.

3.0 INTERPRETATION OF TEXTURES

Textures within sulfate interbeds developed from depositional, early alteration, and late-stage diagenetic processes. Depositional fabrics within the interbeds reflect subaqueous accumulation, and some early alteration probably occurred subaqueously (e.g., soft sediment deformation, collapse following solution of underlying material, and replacement of sulfate). Prism cracks, weathered sulfate, teepee structures, and point solution of soluble minerals occurred in the vadose zone. Sulfate cements, displacive halite growth, and pseudomorphous replacement of sulfate occurred within the phreatic zone. Late-stage diagenetic fracturing and void-filling cement growth occurred after the sulfate was effectively hydrologically and chemically isolated from the depositional environment.

3.1 SUBAQUEOUS PROCESSES

Depositional textures generated by subaqueous processes are present in all sulfate interbeds within the Salado and indicate subaqueous accumulation in a shallow saline lagoon environment. Lagoonal conditions followed initial flooding over salt pan sediments and were maintained by episodic flooding (Lowenstein, 1988). Evaporation concentrated solutes in the lagoon, and gypsum was deposited. In Salado sulfate interbeds, textures indicating subaqueous deposition in sulfate interbeds include: detrital fabrics, pseudomorphs after vertically grown prismatic gypsum crystals, bottom-grown halite, and algal textures. The condition of the substrate at the time of deposition (ie. stable or collapsing) and the water depth are reflected by the type of textures preserved. Subaqueous alteration fabrics developed as salinity changed in the lagoonal waters. These early alteration fabrics resulted from low-salinity (e.g., soft sediment deformation and collapse due to planar solution of underlying halite) and high-salinity (e.g., replacement of sulfate in the presence of solutions concentrated by evaporation) conditions.

3.1.1 Detrital Fabrics

All sulfate interbeds within the Salado display detrital gypsum pseudomorph and carbonate textures and fabrics. Detrital laminae within the sulfate interbeds originally consisted of reworked gypsum crystals alternating with carbonate-rich mud (Lowenstein, 1982, 1983, 1988). These couplets of reworked gypsum pseudomorphs and magnesite-rich mud were deposited in response to repeated freshening in a saline lagoon-like environment (Lowenstein, 1982, 1983, 1988). Detrital material also occurs within and around prismatic gypsum crystals and provides support for more isolated crystals. Detrital gypsum was produced by mechanical reworking of bottom-nucleated crystals (Lowenstein, 1988). Lowenstein (1988) suggested that the carbonate-rich material originated as magnesite-rich mud deposited during minor freshening events. Some of the carbonate-rich layering in the sulfates may have originally consisted of algal material as suggested by cryptalgal layering. Cross-laminae developed under high-energy conditions when bedforms migrated acros a stable, not dissolving or deforming substrate. Both storm events and localized shoaling could have produced high-energy conditions. Cross-laminae are rare in thinner interbeds because ripples could not readily migrate over an irregular and, possibly, dissolving surface. Pebble-sized clasts of sulfate and carbonate were ripped up during subaqueous reworking of a subaerially exposed surface.

3.1.2 Prismatic Gypsum

Salado prismatic gypsum pseudomorphs resemble gypsum morphologies observed in modern shallow, subaqueous gypsum deposits (e.g., Schreiber, 1978; Arakel, 1980; Warren, 1982). In ancient sulfates, similar textures have been interpreted to indicate shallow, saline, lagoon-like environments (Vai and Ricci Luchi, 1977; Lowenstein, 1982, 1983, 1988; Holt and Powers, 1988). Gypsum nucleated and grew into a gypsum-saturated brine producing, vertically oriented prismatic crystals. Each of the different prismatic gypsum pseudomorph morphologies present in Salado sulfate interbeds reflects a unique set of depositional conditions and allows a more precise reconstruction of the subaqueous depositional environment.

Prismatic gypsum crystals occur at the sediment/brine interface in modern subaqueous gypsum deposits. They either overgrow existing gypsum crystal seeds or nucleate on the substrate and grow upward into the gypsum-saturated brine. Untwinned or "swallowtail" twinned gypsum crystal habits are the most common forms. Gypsum crystals grow faster along the c-axis and orient the c-axis vertically from the substrate, toward the chemical nutrient source. The size of these crystals, their general morphology, and their stratification style can be related to the substrate condition, volume of saturated fluid, and nucleation point or seed crystal distribution.

A stable substrate provides a platform on which larger, vertically oriented crystals can develop, and crystals tend to tip and slump if deposited on an unstable substrate (Warren, 1982). An actively dissolving substrate will not become stable enough for vertical prismatic gypsum to develop until the underlying soluble minerals are either removed or isolated from the overlying fluid by sediment accumulation or cement growth. Substrate stability partially depends on fluid depth. Mechanical reworking of existing gypsum and agitation of the substrate in shallow water may prevent or limit the accumulation of vertically oriented prismatic crystals. Also, low-volumes of brine are more readily diluted, destabilizing weaker substrates by dissolution and limiting the accumulation of bottom grown gypsum. Closely spaced prismatic gypsum crystals may create mounds on a disrupted, unstable substrate. Once gypsum crystals interlock horizontally and detrital gypsum has been cemented, the substrate is very stable and suitable for the growth of large vertical, prismatic gypsum crystals. Larger interlocking crystals can protect the substrate from minor dissolution events because solution affects only the upper surface of the interlocking crystals.

Prismatic gypsum crystals grow as a function of the availability of calcium and sulfate. This too is partly dependent on the volume of fluid present. Shallow brine in the basin will reach gypsum saturation much more quickly during evaporative concentration than will a larger volume in the source basin. Once gypsum saturation is reached and bottom growth of gypsum begins, minor freshening events in a low-volume lagoon dilute the water and gypsum growth ceases. If the dilution is significant, then newly precipitated gypsum will dissolve, perhaps destablizing the substrate. After a freshening event, a low-volume lagoon will quickly return to gypsum saturation after dissolution of gypsum on the substrate and evaporative concentration. Sequences of laminae and very thin beds containing small prismatic gypsum crystals are produced by repeated flooding and evaporation from a low-volume perreneal lagoon.

A larger volume of brine is less diluted during minor freshening events and more conducive to growing large prismatic gypsum crystals. With minimal interruptions, crystals may grow large enough to interlock and stabilize the substrate. Dissolution will only occur following larger influxes of less saturated water. Dissolution planes off the existing crystals leaving a flat, well-stabilized substrate supported by large, interlocking crystals. As the brine evaporates, the number of overgrowth sites are dominated by the existing crystals, and only a few crystals grow from the substrate.

Nucleation point or seed crystal distribution controls the density of prismatic gypsum crystals and affects the crystal and stratum morphology. A wide crystal spacing permits crystals to become well developed, while closely spaced, non-parallel crystals may interfere with one another producing deformation ridges and mounds (Warren, 1982). Once a hummocky or mounded topography develops on the substrate, crystal growth is augmented on the crests of mounds and restricted in the intermound troughs where crystals are more confined. This process may continue in overlying strata exaggerating the wavy to contorted appearance.

Once gypsum crystals begin to interlock, competitive growth overwhelms poorly-oriented crystals (those whose c-axis is not nearly perpendicular to the substrate), and vertical crystals continue to grow upward. If suitable conditions persist, all gypsum crystals will ultimately become parallel, and additional crystals will not nucleate. Continued overgrowths on these crystals will produce massive selenitic gypsum. These accumulations may develop internal stratification as detrital material drapes crystal faces or accumulates on planar solution surfaces. The detrital material is poikilotopically incorporated by overgrowths on the prismatic gypsum, and sediment-free prismatic gypsum grows above the newly incorporated material. Thick detrital material over prismatic gypsum crystals may limit poikilotopic overgrowth and a new set of unrelated crystals may precipitate. Epitaxial crystals develop where poikilotopic overgrowth through the sediment succeeds.

3.1.3 Bottom-Grown Halite

Bottom-growth halite within sulfate interbeds indicates that lagoonal waters reached halite saturation. Medium to very coarsely crystalline, bottom growth halite with chevron and cornet fluid inclusion zoning nucleated and grew from the substrate subaqueously. Salinity or calcium content fluctuated slightly, and sulfate precipated crystal linings and drapes which outlined and capped vertically oriented bottom growth halite. Larger freshening events decreased the salinity of the standing body of brine and dissolved newly precipitated halite from the top down in a planar fashion. Incomplete dissolution left small lenses of halite in topographically low areas. Sulfate deposited on this surface was disrupted and slumped by continued dissolution of the underlying halite.

3.1.4 Algal Features

Algae and algal features are common in modern subaqueous carbonate and evaporite deposits (eg., Logan, 1961; Gebelein, 1969; Kendall and Skipwith, 1968; Neumann, et al., 1970; Arakel, 1980) and indicate shallow subaqueous to intermittently wetted, subaerially exposed conditions. Although algal stromatolites in some ancient deposits do not always imply shallow conditions (e.g., Playford and Cockbain, 1969; Hoffman, 1974), the stromatolites observed within Salado sulfates can not be placed within a deep-water context. They occur within and bounded by rocks displaying unequivocal shallow-water and subaerial exposure features. As none of the stromatolites observed in the Salado display features uniquely attributable to subaerial exposure and the host rocks display textures and fabrics developed in shallow, saline water, they are interpreted as shallow subaqueous features.

Algal stromatolites and mats aggrade by agglutination and binding of algal sediment (Gebelein, 1969) and, therefore, require a source of detrital sediment to accumulate. Once in place, they may help to stabilize the substrate from erosion (Neuman, et al., 1970). Salado stromatolites display morphologies similar to modern subtidal stromatolites described by Gebelein (1969).

Gebelein (1969) reports that the morphology of subtidal stromatolites in Bermuda depends upon current velocity and sediment accumulation rate. Algal mats grow in higher energy areas, and mat thickness is inversely proportional to sediment movement. Algal biscuits and domes form in lower energy environments. Algal domes develop in areas with rapid sediment accumulation, while algal biscuits aggrade in areas protected from high rates of sediment movement. The degree of streamlining of algal biscuits and domes is proportional to current velocity and sediment movement. Both algal biscuits and domes accrete in the direction of the sediment source.

Salado algal mats, biscuits, and domes were accumulated in a shallow, saline lagoon with abundant detrital gypsum, and the morphology and stratigraphic position of these stromatolites was controlled by the current velocity and sediment load within the lagoonal environment. Algal mats and rare biscuits stabilized the upper surface of some sulfate interbeds. Higher energy conditions were produced by upward shallowing during evaporation, and algal domes were eroded as wave energy increased. The growth of these algal stromatolites was halted by a salinity increase to halite saturation which inhibited further algal growth, eliminated the source of clastic gypsum, and rapidly covered the stromatolites with bottom-grown halite. Deeper water and a high sediment load allowed algal domes to become well developed in the lower parts of two thick sulfate interbeds. Within some sulfate interbeds, cryptalgal layering occurs with vertical prismatic and detrital gypsum pseudomorphs.

Similar features have been reported from modern shallow gypsum deposits. In the Salt Flat Graben, Texas, algal material is interlaminated with both detrital and vertical prismatic gypsum (personal observations). Arakel (1980) reports the accumulation of interlaminated vertical prismatic gypsum and algal material in pools in Hutt Lagoon, Australia. Algal material accumulates during the freshening of the lagoon, and bottom nucleated prismatic gypsum crystals grow after evaporative concentration (Arakel, 1980). Kushnir (1981) observes a similar accumulation pattern for interlayered gypsum crystal mush and algal material in a coastal hypersaline lagoon in the southern Sinai. Interlayered gypsum and algal textures may not survive early diagenesis, as early diagenetic overgrowth on detrital and prismatic gypsum crystals and nucleation of additional crystals may destroy interlaminated algal and gypsum textures (Kushnir, 1981).

MB115 displayed well-developed algal stromatolites and locally abundant, halite-filled lenticular and tabular voids parallel to stratification. These voids may have developed after algal material interlaminated with detrital sulfate decomposed. These voids were preserved by early cementation of the sulfate host and passive pore-filling by halite. We have interpreted other examples of this void texture similarly.

It is likely that algae were more important during Salado sulfate deposition than revealed by stromatolitic forms preserved in cores and underground outcrops. Although the original carbonate phase in the magnesite-anhydrite couplets is unknown (Lowenstein, 1988), algae may have been an important component of carbonate-sulfate laminae. Diagenetic growth of gypsum coupled with compaction, dewatering, and chemical alteration in the presence of high magnesium brines may have radically decreased the preservation of algal textures in interlaminated Salado gypsum and carbonate.

3.1.5 Subaqueous Dissolution

The textures and mechanical processes affecting the gypsum-rich sediment during halite solution from underlying units were similar to those described in periglacial sediments by Brodzikowski and Van Loon (1985). In the early stages of sulfate accumulation, lagoonal-waters were undersaturated with respect to halite and dissolved halite from the underlying unit. Halite dissolution occurred in a crudely planar fashion from the top down. If dissolution proceeded slowly and was limited, gradual lowering and slumping of the sediment occurred with only local disruption of sedimentary structures. Mechanical anisotropy within the cohesive sediment resulted in slumped and disrupted strata. If the strain energy accumulated at the bedding plane contacts during flowage exceeded the threshold value of strength within the material, the sediment fractured, and the fractured fragments were displaced and rotated. Localized shear zones developed fractures in response to downward displacement. These processes continued until interstitial water was isolated hydrologically from the overlying lagoonal waters and became saturated with respect to halite and dissolution ceased.

3.1.6 Subaqueous Replacement

MB134 was diagenetically altered early and subaqueously by magnesium- and potassium-rich brines. The brine volume was reduced by evaporation until partial desiccation occurred. Topographically high areas on MB134 were subaerially exposed, and small pools of highly concentrated, magnesium- and potassium-rich brine were present in the topographic lows. In the topographic lows, sulfate at the sediment/brine interface was pseudomorphed by polyhalite coevally with the deposition of bottom growth halite. Holser (1966) described similar modern polyhalite pseudomorphs after gypsum developing from highly concentrated potassium and magnesium brines in the phreatic zone at Laguna Ojo de Liebre, Baja California.

At MB134, it cannot be determined whether polyhalite replaced gypsum or anhydrite pseudomorphs after gypsum. It is certain, however, that permeability of the sediment was low enough to prevent the highly concentrated brines from entering and altering the sulfate much beyond the rim of the localized surficial pools. Cements, either gypsum or anhydrite, could have lowered the permeability and prevented fluid movement away from the small pools. If gypsum was well cemented, it would have been difficult for enough calcium to enter the system for later volume-for-volume (pseudomorphous) alteration to anhydrite, especially after halite deposited in the overlying sequence had further reduced the vertical permeability. In a concentrating brine, anhydrite becomes the stable calcium sulfate phase long before polyhalite saturation is reached. This, and the rather poorly defined pseudomorphous textures, suggest that anhydrite was the precursor to the polyhalite. The alteration to anhydrite may have occurred before evaporation had totally desiccated the lagoon.

3.2 SUBAERIAL EXPOSURE AND VADOSE ZONE ALTERATION

Some Salado sulfate interbeds show clear evidence of subaerial exposure and alteration in the vadose zone. These textures developed after the sulfate-depositing saline lagoon was totally evaporated to subaerial exposure and water table conditions. The textures at the upper surface of sulfate beds interpreted to be the result of subaerial exposure include: bottom-growth halite in well defined topographic depressions with exposed margins, prism cracks, and teepee structures, and displaced and buckled strata with irregular voids. Point-dissolution textures internal to the sulfate beds also indicate subaerial exposure and alteration in the vadose zone. These textures include: smeared intraclast textures, collapse textures from point-style vadose zone halite dissolution.

3.2.1 Halite Accumulation in Small Pools

During very short subaerial exposure on the upper surfaces of some markerbeds, halite was precipitated from shallow pools in localized topographic low areas while the higher pool margins were subaerially exposed. Bottom-growth halite precipitated in a well developed trough on the top of MB134 from a pool of halite-saturated brine. Halite deposition was limited to the pool, and the halite was not subaerially exposed. Minor freshening of the pool resulted in the accumulation of thin laminae of sulfate which were also confined to the pool, as the sulfate laminae terminate at the margin of the pool. Repeated desiccation, resulting in subaqueous halite deposition, and freshening, resulting in sulfate deposition, filled the depression without any accumulation on the topographically higher pool margins.

3.2.2 Prism Cracks

Prism cracks developed during the initial desiccation of subaerially exposed sulfate surfaces. The depth of the cracks was controlled by the depth to the water table. Sulfate and clastic sediment were translocated downward into the prism cracks by downward percolating water. Prism cracks occur only at the upper surfaces of sulfate interbeds suggesting that desiccation only occurred prior to the deposition of halite in the overlying sequence.

3.2.3 Teepee Structures and Buckled Strata

Gypsum strata were dissolved, buckled and disrupted, ultimately into teepee structures, creating voids with drusy gypsum crystal linings and passive halite cements during continued subaerial exposure and alteration in the capillary fringe. Buckling did not occur subaqueously at a sediment/brine interface as numerous overgrowth sites exist for vertical growth of gypsum. Within the phreatic zone, overgrowth disrupted some sediment but was incapable of generating void space because the crystals grow displacively reducing existing porosity within the sediment. During subaerial exposure, the capillary fringe extended to the sediment-air interface if the water table was shallow and continued evaporation could concentrate solutes within the groundwater. Strata were buckled by the displacive growth of cements within the sediment creating void spaces between and crudely parallel to the strata. As subaerial exposure continued, strata in the capillary fringe were buckled into teepee structures by displacive addition of gypsum along the margins of polygons. Sulfate was dissolved by point dissolution when minor flooding occurred. Once the phreatic zone engulfed the voids, drusy gypsum lined the pores, and halite passively filled the voids after halite saturation was reached. Early void-filling halite cements prevented void fabrics from being compacted.

3.2.4 Smeared Intraclast Textures

Within sulfate interbeds, irregular zones of smeared intraclast textures (after Holt and Powers, 1988) developed following dissolution of displacive halite from the vadose zone. Displacive halite crystals grown under phreatic conditions were dissolved by meteoric water in the vadose zone. In some cases, the gypsum was repeatedly disrupted by the expansive growth and dissolution of halite as the water table rose and fell. Strata were smeared, disrupted, and fractured into soft clasts, probably in proportion to the number of growth and solution episodes.

3.2.5 Point Dissolution of Halite

Interbeds of halite were partially dissolved by point solution during vadose zone conditions. The sediment overlying the halite collapsed downward and deformed while soft. Cores of undissolved bottom-growth halite supported topographic high areas on the upper surface of the sulfate. This style of vadose zone alteration occurred in response to a rapid drop of the water table below the stratigraphic position of the halite. After some of the halite dissolved, the water table rapidly rose and preserved the remaining halite.

3.3 PHREATIC ZONE ALTERATION

Phreatic alteration process occurred below the water table. For our purposes, we also consider those processes which occurred within sediment overlain by a standing body of water to be phreatic. These processes include: the growth of cements and the volume for volume replacement of sulfate by anhydrite, polyhalite or halite.

3.3.1 Cementation

Overgrowth occurred on detrital gypsum crystals as indicated by euhedral gypsum pseudomorph morphologies within Salado sulfates (Lowenstein, 1988). These overgrowths were later replaced by anhydrite, polyhalite or anhydrite. We were unable to demonstrate that interparticle gypsum cements were present as no gypsum cement morphologies were preserved. Passive gypsum cements partially filled large voids within the sediment as drusy crystals grown from the edges of pores toward the center. After sulfate deposition ceased and halite deposition began, phreatic halite cements passively filled and preserved large open pores in more mechanically competent sulfate. In soft, poorly lithified sulfate, halite crystals grew displacively.

3.3.2 Gypsum Replacement

Most Salado sulfate observed in the AIS preserves primary sedimentary structures and shows no evidence of either expansive or implosive textures. This indicates that anhydrite, polyhalite, or halite pseudomorphously replaced gypsum within the sulfate interbeds on a volume-for-volume, not mole-for-mole, basis with no disruption of depositional fabrics.

Gypsum was not altered to anhydrite by simple dehydration during burial as the volume reduction associated with that reaction would have destroyed the fine-scale gypsum textures preserved in the sulfate (Holt and Powers, 1988). The geochemical system which produced anhydrite was chemically and hydrologically open as the volume-for-volume replacement of gypsum by anhydrite required the addition of extra calcium. The alteration of sulfate, either gypsum or anhydrite, to polyhalite required potassium- and magnesium-rich brines. This process also requires an open hydrologic and geochemical system. Holser (1966) described polyhalite pseudomorphing and cement gypsum grains within the phreatic zone in a tidal flats in Baja California.

Unlike anhydrite or polyhalite, halite usually replaces more coarsely crystalline gypsum, leaving the ground mass/matrix unreplaced. Halite probably replaced the gypsum crystals prior to, or synchronous with, the replacement of gypsum with anhydrite or polyhalite. Anhydrite pseudomorphs after coarse or fine gypsum consist of fine anhydrite crystals. If halite had replaced anhydrite, texturally there would have been little reason for the halite to have preferentially replaced anhydrite pseudomorphs after prismatic gypsum. Halite replacement woul have more readily occurred when the replaced material consisted of gypsum.

Gypsum sediments were the most hydrologically and geochemically open shortly after their deposition, before cements decreased permeability. Once halite began to accumulate over sulfate sediments, the vertical porosity was also reduced and the access of saline lagoon and ground water to the sediments became restricted. Casas and Lowenstein (1989) reported that porosity within modern salt pan halites was reduced by cementation to less than 10 percent within the first 10 m of burial and completely filled by the time they reach a depth of 45 m. Cement processes within halite pan deposits overlying Salado sulfate interbeds hydrologically anc geochemically isolated the interbeds. Once the sediments were buried and the porosity of the underlying and overlying halite eliminated, no appreciable fluid could access and extensively alter the sulfate interbeds.

Once saline lagoon or ground waters reached halite saturation, gypsum became unstable, and anhydrite became the most stable form of calcium sulfate. Sulfate sediments were hydrologically and geochemically connected to the lagoonal waters and ground waters until they became isolated by halite accumulation and cementation. The geochemistry of the pore fluids was controlled by the surface system. Anhydrite and polyhalite grew as interparticle cements and pseudomorphed detrital gypsum grains and crystals. Larger prismatic gypsum crystals required more time for anhydrite or polyhalite to pseudomorph. Halite precipitated as passive void-filling cements and displacive crystals. Unaltered gypsum, including the larger prismatic gypsum crystals, was replaced by halite. This reaction probably occurred after the system was more hydrologically and geochemically isolated from an outside calcium and magnesium source. Episodic changes in the chemistry of the surface system changed the chemistry of the groundwater producing different types of pseudomorphs (anhydrite, polyhalite, or halite). Gypsum was completely altered by the time sulfate interbeds were hydrologically isolated from the surface system.

In most modern evaporite deposits, the abundance of calcium, not sulfate, controls the accumulation of gypsum as the ratio of calcium to sulfate in the brines is less than one. Once sulfate deposition ceased and halite began to accumulate, gypsum was no longer the stable phase in the presence of the halite saturated waters and pseudomorphous replacement of gypsum by anhydrite or polyhalite required the addition of calcium. Calcium from carbonate-sulfate couplets and that associated with algal material may have been chemically cannibalized for the anhydrite. In the presence of magnesium-enriched brines, magnesite may have been an alteration product.

3.4 LATE-STAGE DIAGENETIC ALTERATION

Late-stage diagenetic alteration of Salado sulfate interbeds occurred after the interbeds were hydrologically and geochemically isolated from their depositional environment. The only features observed in Salado sulfate interbeds that can be uniquely attributed to late-stage diagenetic alteration are open and filled fractures. These fractures developed in response to stress-field changes related to unloading (Borns, 1985). Halite and sulfate fracture fillings grew both passively and incrementally as indicated by poikilotopic and fibrous morphologies. Anhydrite may have fractured more readily than polyhalite as interlocking polyhalite crystals may produce a better mechanical bond across bedding planes.

4.0 SULFATE DEPOSITIONAL ENVIRONMENTS

Sulfate interbeds within the Salado accumulated in a shallow, saline lagoon environment. Episodic, eustatically-driven, flooding events rapidly transgressed over salt pan deposits producing a basin-wide freshening to lagoon-like conditions (Lowenstein, 1988) and creating a time line. Underlying halite and sulfate dissolved and combined with evaporative concentration to increase the salinity of lagoon waters to gypsum saturation. Sulfate was deposited over salt pan halite in shallow, evaporatively concentrated perennial to ephemeral lagoons. Sulfate was deposited as vertical bottom-grown prismatic crystals. Prismatic gypsum was reworked and deposited as detrital material. Further evaporation drove the salinity of lagoon waters to halite saturation and, in some cases, totally desiccated the lagoon. Halite deposition marked the end of most sulfate accumulation. The volume of the initial flooding coupled with amount of secondary recharge to the lagoon controlled depositional textures, interbed thickness, and early alteration processes.

We have recognized three distinct types of sulfate interbeds within the Salado; each was produced by different hydrologic regimes. Hydrologically isolated low-volume floods resulted from minor eustatic changes or major, basin-wide rainfall and runoff. They were recorded by thin, isolated sulfate interbeds. Frequent hydrologically-related, low-volume floods repeatedly produced shallow, saline lagoons which quickly reached halite saturation. These lagoons deposited multiple thin sulfate interbeds separated by interbeds of halite with little or no subaerial exposure. Major eustatic changes produced and maintained large-volume, saline lagoon conditions allowing the accumulation of thick sulfate sequences.

4.1 THIN SULFATE INTERBEDS

Most sulfate interbeds within the Salado are less than two feet thick and separated from overlying and underlying sulfate interbeds by thick halite sequences showing considerable subaerial exposure. Most of these thin interbeds consist of polyhalite. Their lower contacts are often slightly to very irregular and their upper contact may mimic the lower contact. Detrital fabrics are abundant, and small vertical prismatic gypsum pseudomorphs occur frequently. Soft sediment deformation is common and usually originates at the lower contact. In rare cases, collapse at the lower contact has brecciated and translocated stratified sulfate downward. They display no unique evidence of subaerial exposure.

Thin sulfates were deposited following a low-volume, basin-wide freshening event. The water was quickly concentrated by evaporation and may have reached supersaturation. Numerous small prismatic gypsum crystals precipitated in response to the supersaturated conditions and were deposited over an unstable, dissolving substrate. Substrate relief from dissolution in this circumstance was greatest when a subaerially exposed surface was flooded. The collapsing substrate limited the size of prismatic gypsum crystals, helped to deter bedform migration, and caused soft sediment deformation and collapse. Rapid changes in salinity occurred as runoff and very small floods rapidly freshened the low-volume lagoon and further destabilized the substrate. Evaporation rapidly concentrated the waters back to gypsum saturation. Continued evaporation concentrated the waters to halite saturation, and sulfate deposition slowed or ceased. Once halite saturation was reached, anhydrite began to replace gypsum and cement existing porosity. If the waters were rich in potassium and magnesium, the rapid concentration to and above halite saturation may have limited alteration by anhydrite in favor of polyhalite. When this occurred, the porous gypsum sediment was pseudomorphed and cemented by polyhalite. Once halite accumulation began, gypsum was no longer deposited.

Some isolated low volume floods were probably the product of isolated small eustatic changes in sea-level. The hydrologic connection to marine waters was rapidly established and was maintained for only a short period of time. Others probably originated following large rainfall-runoff events. Floodwaters ponded creating shallow saline lagoons. Salinity changed rapidly within the small and isolated lagoon in response to evaporation and meteoric events. Once an isolated flooding event occurred, a considerable period of time elapsed before another basin-wide freshening event.

4.2 MULTIPLE SULFATE INTERBEDS

Interbeds containing bottom-growth halite and groups of two or more closely spaced thin sulfate interbeds separated by beds of subaqueously deposited halite with little or no vadose zone reworking are considered multiple interbeds. They are texturally similar to thin interbeds, although their lower contacts are usually more planar. If present, bottom-growth halite occurs in lenses or irregular zones bounded by collapse textures. Clay is commonly present below the first interbed and not the second. The halite between interbeds falls within the stratified mud-poor halite lithofacies (Appendix F) and shows mostly subaqueous deposition textures.

Like the isolated thin interbeds, multiple sulfate interbeds were deposited in a saline lagoon produced by low-volume, eustatically or meteorically controlled flooding events. Once gypsum saturation was reached in the lagoon waters, the first interbed was deposited. Additional evaporation produced halite. In some instances, the lagoon completely desiccated for a short time, and the vadose zone was altered by solution. Subaqueous halite accumulated quickly with little interruption until a second freshening event lowered the salinity of the lagoon. A second gypsum interbed was deposited as evaporation concentrated solutes. A standing body of water was usually present during the freshening event, and dissolution of halite produced planar contacts between the sulfate and halite. Planar dissolution halite was sometimes incomplete, leaving thin lenses of halite in topographic depressions on the underlying sulfate. Sulfate precipitated over these lenses. Slumping and disruption of sulfate sediments by irregular dissolution at the lower contact was limited creating a moderately stable substrate suitable for bedform migration and the deposition of vertical prismatic gypsum crystals. In some cases, many multiple interbeds were produced by repeated freshening events (five multiple interbeds occur within the MB109 complex).

If the vadose zone encroached on multiple interbeds, halite between sulfate interbeds dissolved, and the interbeds collapsed. If the dissolution was nearly complete, the multiple interbeds collapsed together with irregular cores of halite supporting topographic high areas covered by sulfate.

Multiple interbeds were the product of several closely spaced, eustatically or meteorically driven, freshening events. The hydrologic connection to a source of waters was quickly established, but not well maintained as indicated by halite interbeds between multiple interbeds. During the accumulation of multiple interbeds, flooding events were more common suggesting that the hydrologic or meteoric conditions responsible for flooding events were maintained.

4.3 THICKER INTERBEDS

Thicker interbeds are rare and usually display the greatest variety of depositional and alteration textures. They contain very little bottom-growth halite and consist mainly of anhydrite. Vertical prismatic gypsum pseudomorphs are usually abundant. Generally, large pseudomorphs interlock and form thick beds near the base while smaller pseudomorphs occur within individual strata upward. Well preserved and complex algal stromatolites are found at the base or top of some thick interbeds. Ripple-sized cross-laminae may occur near the top of these interbeds. Soft sediment load deformation is common in those areas not containing large, interlocking, vertically oriented prismatic gypsum crystals. Prism cracks, localized small-scale collapse textures, smeared intraclast textures, and teepee structures occur at the top of some thick interbeds. Voids filled with passive halite cement are rare. They are usually underlain by thicker beds of clay and show planar to slightly undulatory lower surfaces. The upper surfaces may show considerable relief generated by coalesced zones of prismatic gypsum crystals, teepee structures, algal stromatolites, and soft sediment deformation.

Large-volume, basin wide freshening events produced lagoon environments in which thicker, more varied sulfate interbeds were deposited. After a larger flood event, evaporative concentration occurred slower, and planar style dissolution affected the substrate. Carbonate-rich mud settled into laminae following the freshening event. The salinity of these relatively deep lagoons increased slowly as dissolution of underlying evaporites and evaporation concentrated solutes. Fine-grained prismatic gypsum was deposited on the substrate and reworked. In some cases, algae grew on the substrate trapping gypsum and carbonate sediment in stromatolitic forms. Gypsum sediment slumped and deformed when the underlying halite continued to dissolve. Vertical selenitic gypsum crystals were slumping following dissolution of underlying halite and disrupted by isolated storm events. Once the substrate stabilized, large vertical selenitic gypsum crystals competitively grew upward from the substrate and interlocked. As the lagoon shallowed, the size of vertical gypsum crystals decreased as the salinity fluctuated more frequently, and bedforms began to migrate. Near the end of the deposition of some thick interbeds, algal mats and stromatolites grew on and stabilized the gypsum substrate. In several instances the lagoon desiccated totally, producing prism cracks and teepee structures.

As the salinity of the lagoons could only decrease slowly, considerable time existed between anhydrite and polyhalite saturation. As a result, most gypsum was replaced and cemented by anhydrite. As halite deposition had begun prior to polyhalite saturation, most of the porosity within the thicker interbeds had been reduced by anhydrite and halite cements, and polyhalite only replaced the more porous sulfate (e.g., along dessication cracks, bedding planes, etc.).

Large-volume flooding events were probably produced by large eustatic sea-level changes. The resulting lagoons were hydrologically well connected or episodically reconnected to marine waters. Rapid changes of salinity could not occur as long as the hydrologic connection with marine waters was maintained. Additional fluids were supplied to the saline lagoons maintaining their volume. When sea-level dropped, the hydrologic connection was broken, and evaporation reduced the volume of water present in the lagoon allowing wider salinity variations.

5.0 HYDROGEOLOGY OF SULFATE INTERBEDS

Brine was observed discharging into the AIS from some of the thicker sulfate interbeds. These zones were identified and are marked on Figure 23 of the Report. The surfaces of these interbeds were moist to wet and were marked by the accumulation of efflorescent crusts (Figure 24). The lower part of MB103 was as wet as the fluid producing zone within the Magenta Dolomite (Figure 25).

Brine flowed in primarily along horizontal to subhorizontal bedding plane fractures in the lower part of some sulfate interbeds, although interparticle flow was observed from anhydritic dolomite in the lower part of MB103. No significant flow was found from any polyhalite due to the lack of bedding plane fractures and intergranular porosity. In units consisting of both anhydrite and polyhalite, bedding plane fractures occurred only in the anhydrite.

The brine contained within the fractures could be locally derived. As fracturing occurred, a pressure gradient must have been established between the newly created void and the pore fluids present in the underlying clays and other fluid-filled fractures. These pore fluids would migrate into the fractures in response to the newly established gradient. Once the fluid had fill the fracture, no further gradient would exist, and fluid would cease to move until another pressure gradient was established by additional fracturing or underground excavation (e.g., shaf construction). If this process occurred, the chemical signature of the fluids within the fractures would resemble those contained within the pore space of the clays.

6.0 LATERAL VARIABILITY AND MARKERBED 139

Jones et al. (1960), Jones (1972), and Jarolimek et al. (1983) describe considerable lateral variability in thickness and composition of sulfate interbeds within the northern Delaware Basin. To assess regional variability in sedimentary fabrics, we compared our shaft descriptions with those of Lowenstein (1988).

Lowenstein (1988) presents eight measured sections from the potash-district. Each of the sections partly or wholly incorporates the intervals between MB119 and MB124. Lowenstein describes laminae of anhydrite or polyhalite; laminae of magnesite-rich, sulfatic mudstone; and anhydrite, polyhalite, halite, and sylvite pseudomorphs after vertically oriented prismatic gypsum crystals and detrital gypsum. Lowenstein does not report bottom-growth halite within any of the sulfate interbeds he described. Because he observed no evidence of subaerial exposure, Lowenstein interprets the transition from sulfate deposition to halite deposition as subaqueous.

Our descriptions of the same interval in the AIS (Figure 23 of report) show that in the vicinity of the WIPP these interbeds are considerably more variable. Subaerial exposure is evident on the top of MB123, the Union Anhydrite, and MB121. In addition, bottom-growth halite occurs within MB119 at the AIS, and stromatolite features are present in the Union Anhydrite and MB119. These lateral variations suggest that a localized depocenter may have been located in the potash district during the accumulation of MB124 through MB119. As depocenter margins are often affected by a variety of process, they show abundant localized variability in depositional environments and sedimentary structures. It is likely that textures and structures within sulfate interbeds vary considerably across the WIPP area, if it was located on the margins of localized depocenters throughout the accumulation of the Salado.

A comparison of data from the WIPP site also indicates considerable lateral variability within sulfate interbeds. A four foot deep channel occurs on the top of MB136 in the exhaust shaft (Holt and Powers, 1986) but is not present within any of the other shafts. Jarolimek et al. (1983) reports large undulations on the top of MB139 in the exploratory shaft (now named the construction and salt handling shaft) supported by vertical prismatic gypsum pseudomorphs. Borns (1985) attributes undulations on the upper surface to traction deposits and reworking of sediments. Corehole data from the WIPP facility horizon and shaft data compiled by Jarolimek, et al. (1983) indicates that the thickness MB139 varies from 1.2 to 4.1 feet. The thickness and textural variations within MB139 are significant at the repository scale and are due to depositional processes.

The hydrologic performance of MB139 will be influenced by depositional variability. Lateral variability may be an important control on the mechanical response of MB139 during repository closure. The type and degree of fracturing generated during repository closure and the orientation of those fractures will be controlled by the thickness of, depositional and alteration fabrics within, relief on the upper surface of, and mineralogical composition of MB139. The AIS sedimentological data from other sulfate interbeds within the Salado and the depositional models discussed in this report may be helpful in reconstructing the origin and distribution of lateral variability within MB139.

7.0 CONCLUSIONS

Sulfate interbeds have been considered important elements of vertical sedimentation cycles within the Salado (Schaller and Henderson, 1932; Jones, 1972; Lowenstein, 1982, 1983, 1988). Until the geologic mapping of the AIS, these interbeds were only described from core and limited horizons within mine workings. We recognized and described many textures previously unreported from Salado interbeds. Pseudomorphs after vertically prismatic gypsum crystals and detrital gypsum, algal stromatolites, subaqueously accumulated halite, slumping and collapse of gypsum sediment along the lower contact with halite are interpreted as evidence of shallow subaqueous conditions. Textures interpreted to have originated during vadose zone alteration include: teepee structures, prism cracks, buckled and disrupted strata, and collapse textures in interbeds containing bottom-growth halite. Displacive halite crystals, sulfate cements, passive pore-fillings, and the pseudomorphous replacement of gypsum by anhydrite, polyhalite, and halite are interpreted to have formed in the phreatic zone within the depositional environment. The only features within the Salado sulfate interbeds which could be uniquely attributed to late-s alteration were open and halite- and sulfate-filled fractures.

Salado sulfate interbeds were deposited in shallow saline lagoon environments following eustatically- or meteorically-driven, basin-wide flooding and freshening events (Lowenstein, 1 1983, 1988). The base of sulfate interbeds are time lines produced by dissolution following basin-wide freshening, and the interbeds themselves can be considered punctuated aggrada cycles (after Goodwin and Anderson, 1980). Different hydrologic regimes produced three di types of sulfate interbeds within the Salado. Thin, isolated sulfate interbeds were deposited low-volume, hydrologically isolated saline lagoons. The low-volume flooding events which produced saline lagoons resulted from minor eustatic changes or major rainfall and runoff ev Multiple thin sulfate interbeds separated by interbeds of halite with little or no subaerial expo were deposited during periods of hydrologic fluctuation when closely spaced, hydrologically-related, low-volume flooding events repeatedly produced shallow, saline lagoon conditions. Large-volume saline lagoons which accumulated thick sequences of sulfate were produced and maintained following major eustatic changes.

The base of several of the thicker sulfate interbeds discharged brine into the AIS along subhorizontal fractures in anhydrite. Near the base of MB103, interparticle flow occurs, and shaft surface at the time of mapping was as moist as the fluid-producing zone in the Magent Dolomite.

Considerable lateral variability exists within sulfate interbeds, including MB139, at both the regional and repository scale. Lateral variations can be related to the depositional and early diagenetic environments. Lateral variability may be an important control on the mechanical response of MB139 during repository closure. The type and degree of fracturing generated within MB139 during repository closure and the orientation of those fractures will be controlle the thickness of, the depositional and alteration fabrics within, the relief on the upper surface and the mineralogical composition of the interbed. When compared, the descriptions of MB1 in Borns (1985) and Jarolimek et al. (1983) confirm considerable lateral variability within MB1 across the repository. The AIS sedimentological data from other sulfate interbeds within the Salado and the depositional models discussed in this report may be helpful in reconstructing origin and distribution of lateral variability within MB139.

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APPENDIX G
FIGURES

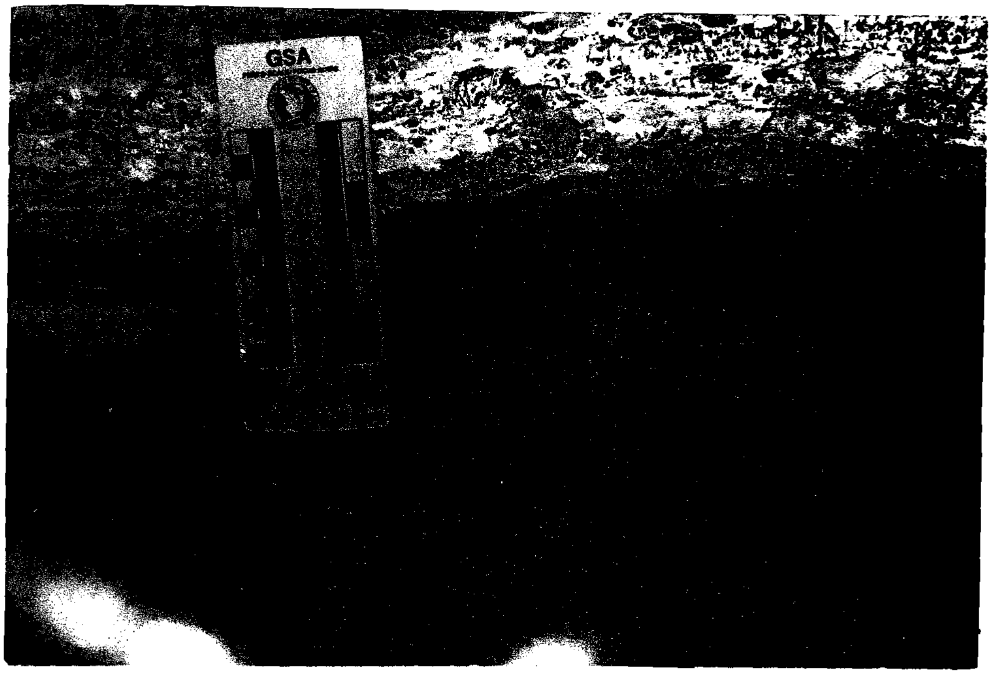


Figure 1
Small, vertically-oriented, halite pseudomorphs after prismatic gypsum crystals in anhydrite (light) and polyhalite (dark).

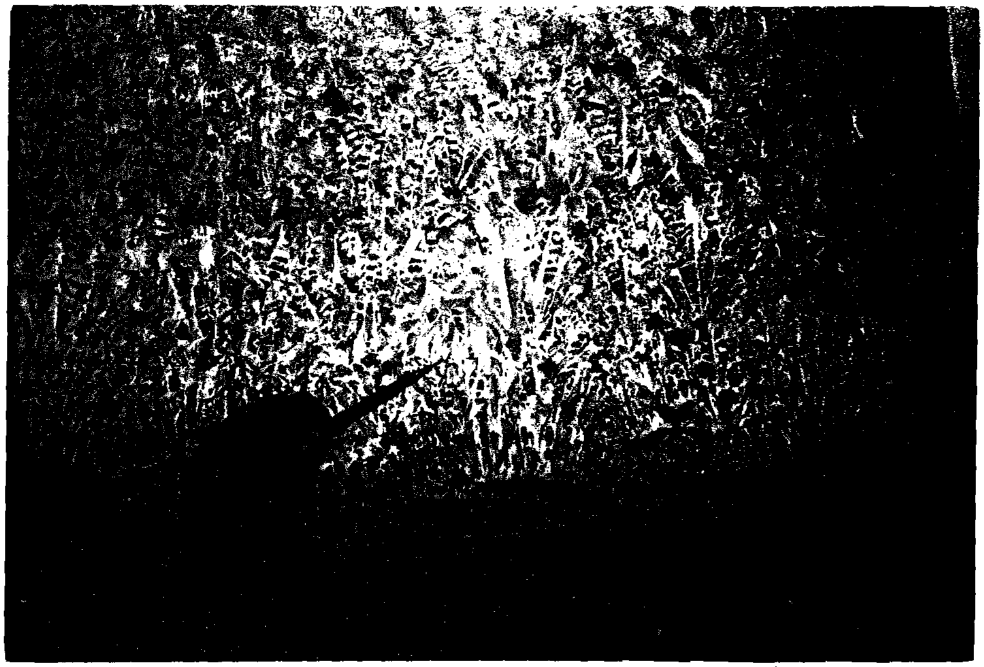


Figure 2
Large halite pseudomorphs after vertically-oriented prismatic gypsum crystals in an anhydrite matrix. Several of the gypsum pseudomorphs show epitaxial overgrowth.

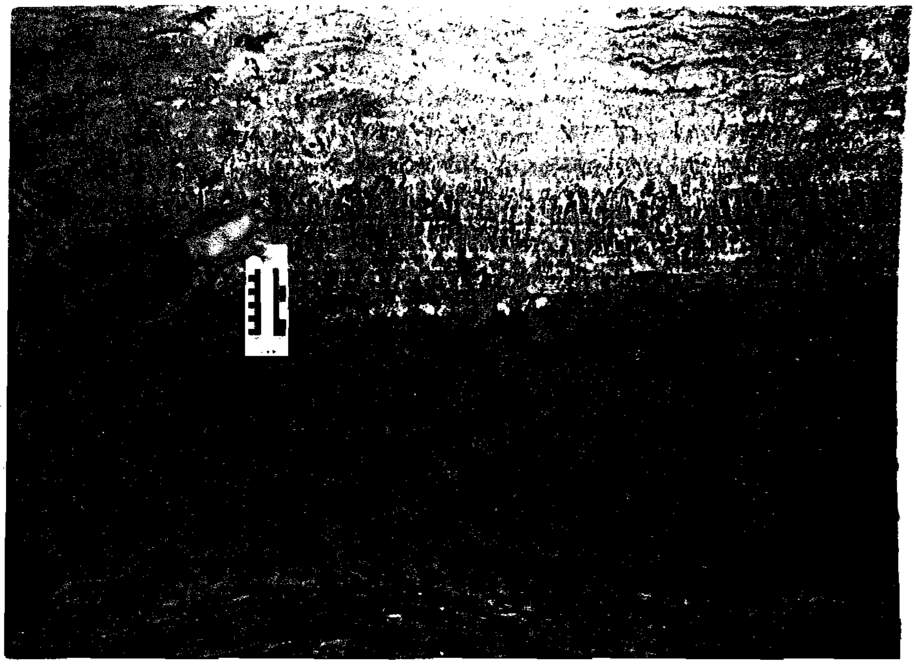


Figure 3
Anhydrite and halite pseudomorphs after vertically-oriented prismatic gypsum crystals cross-cut by anhydrite laminae.

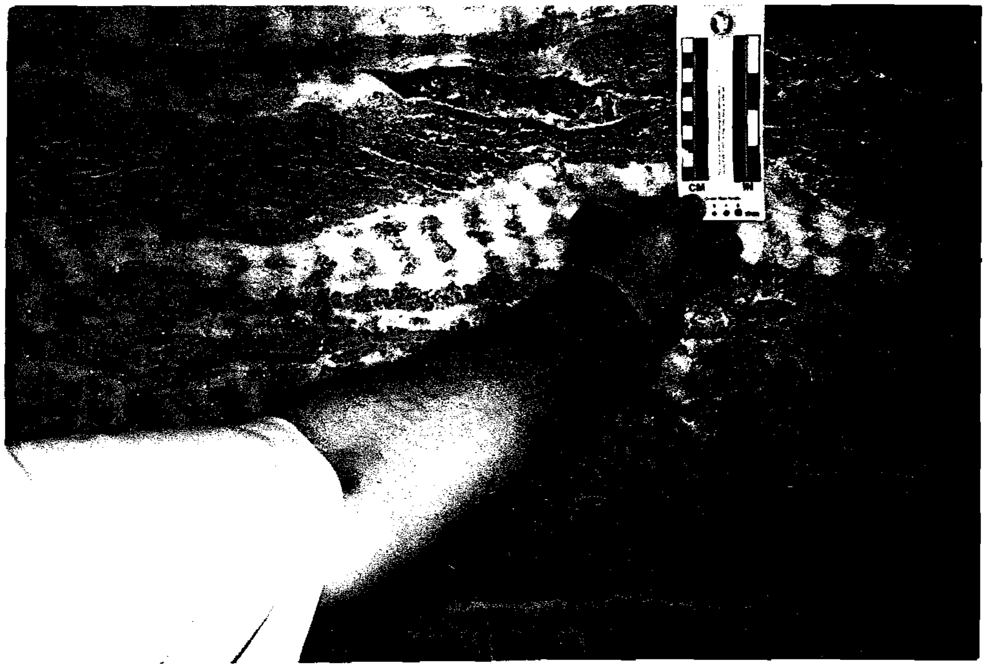
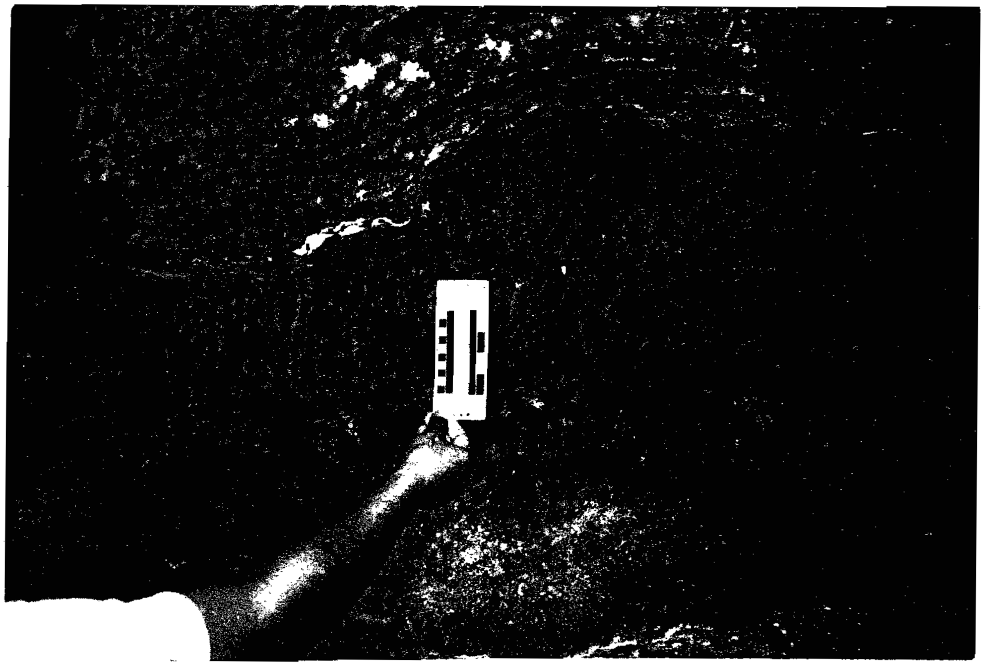


Figure 4
Cross-laminated halite and anhydrite pseudomorphs after detrital gypsum.

A

Figures 5A and 5B
Two examples (A and B) of stromatolitic hemispheroids at the base of the Union Anhydrite.



B

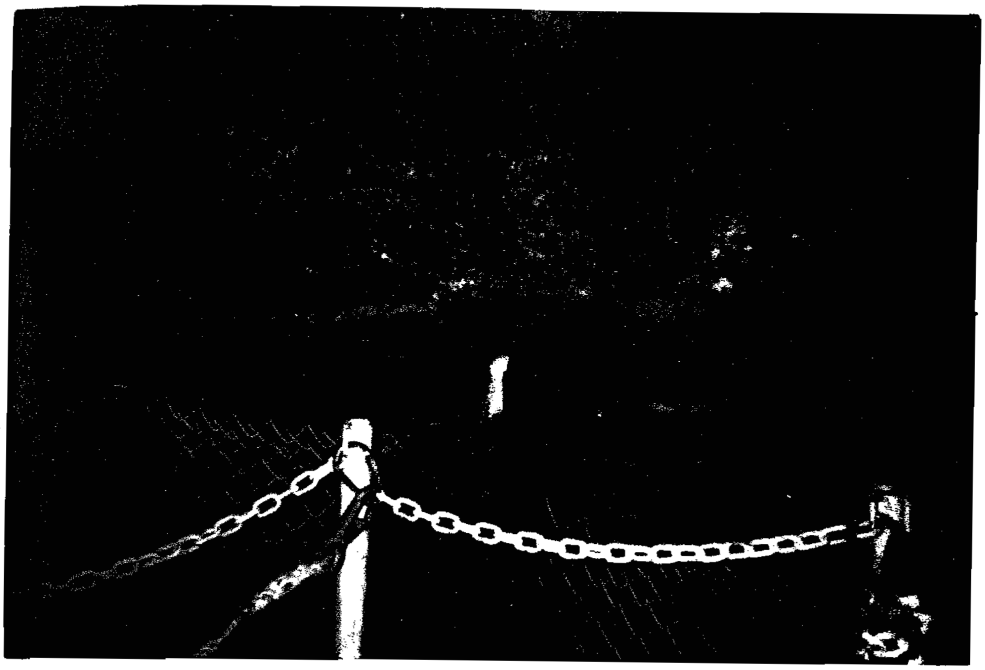


Figure 6
Deformed hemispheroidal stromatolites at the base of MB103.

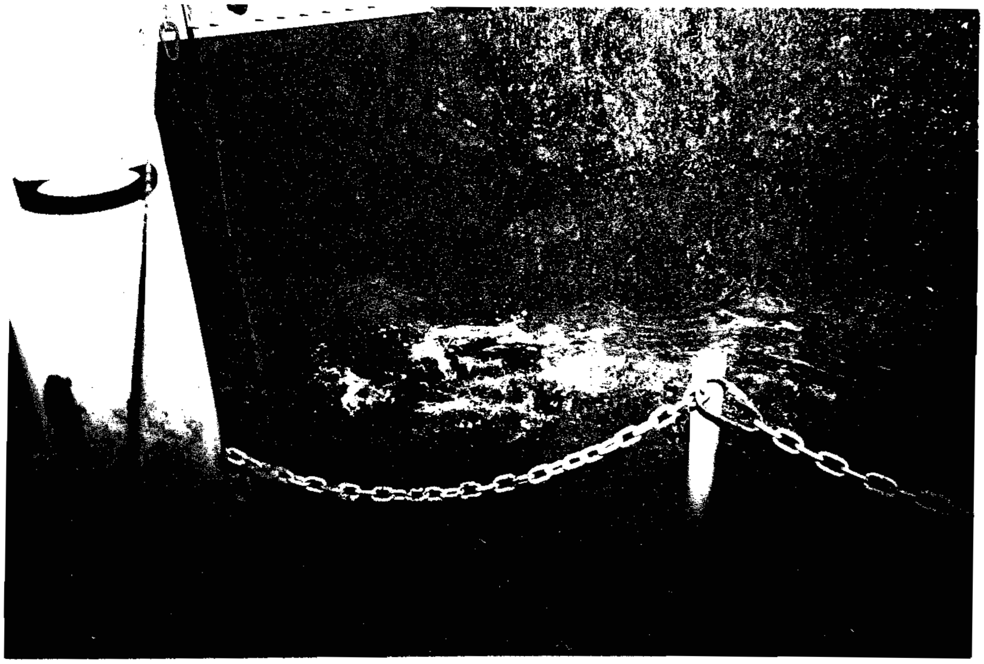


Figure 7
Eroded hemispheroids at the top of MB136.

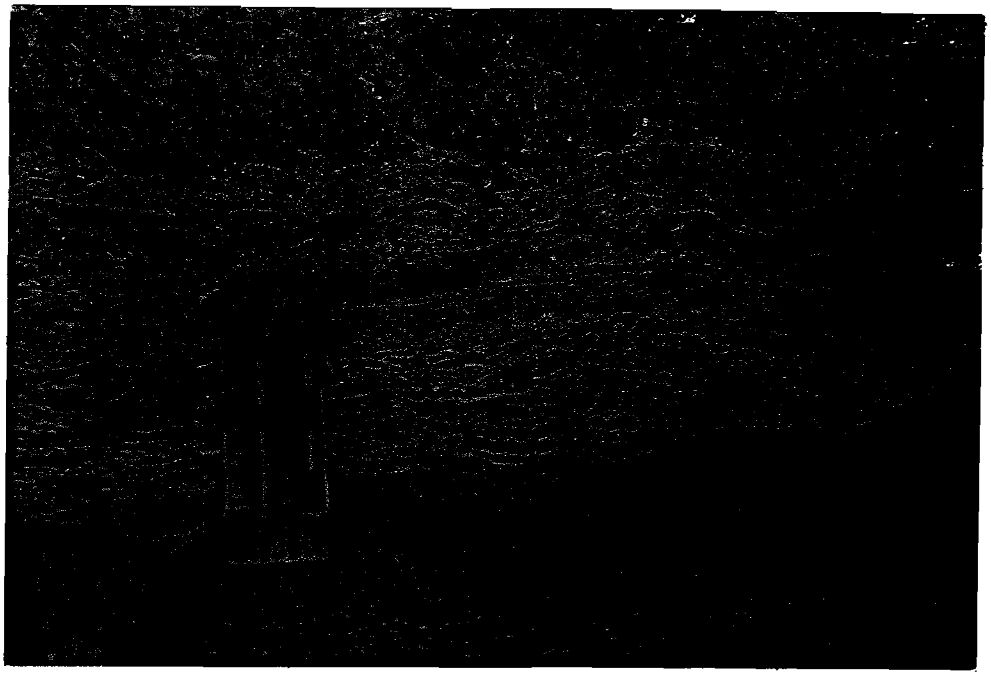


Figure 8
Algal mat and biscuit shaped stromatolites at the top of MB115.

Figure 9
A lens of bottom-growth halite within anhydrite.

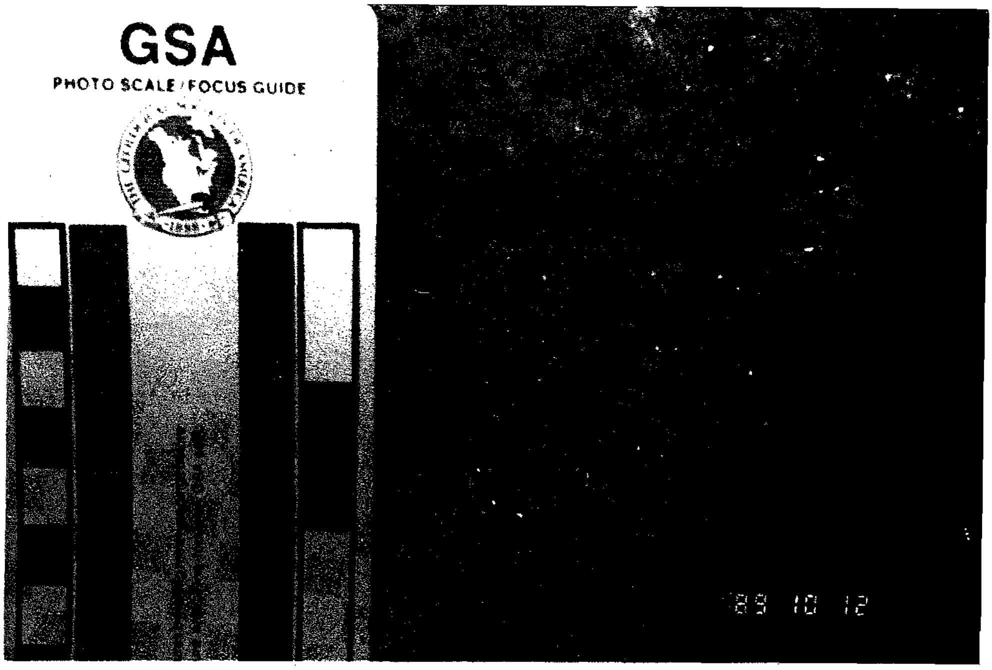


Figure 10
An irregular zone of bottom-growth halite showing sulfate drapes and crystal linings.

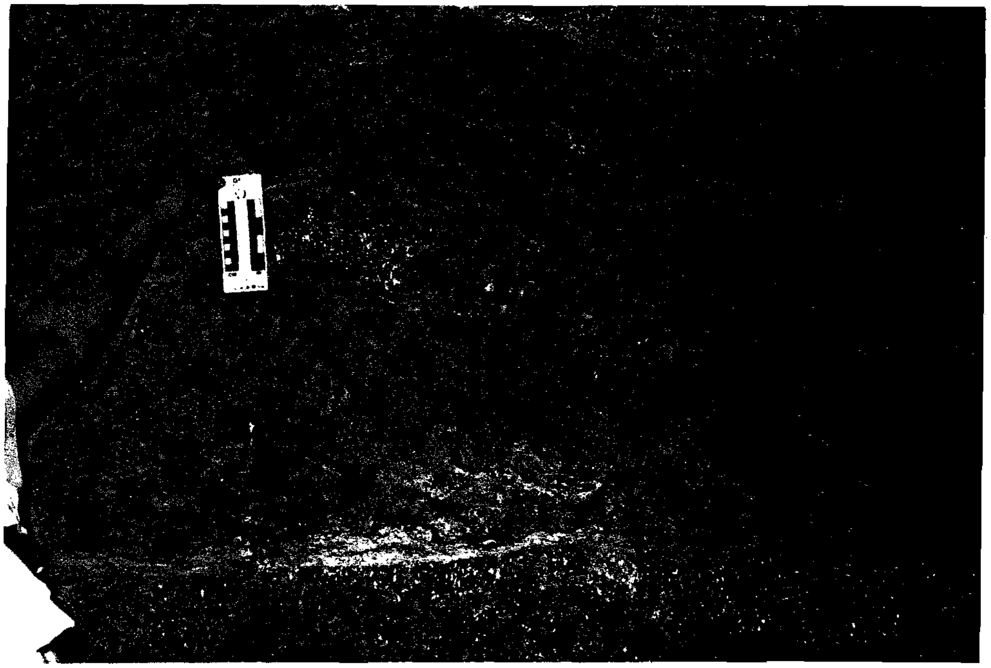


Figure 11
Collapse around irregular zones of bottom-growth halite in MB112. Halite cores support the topographic highs on the upper surface.

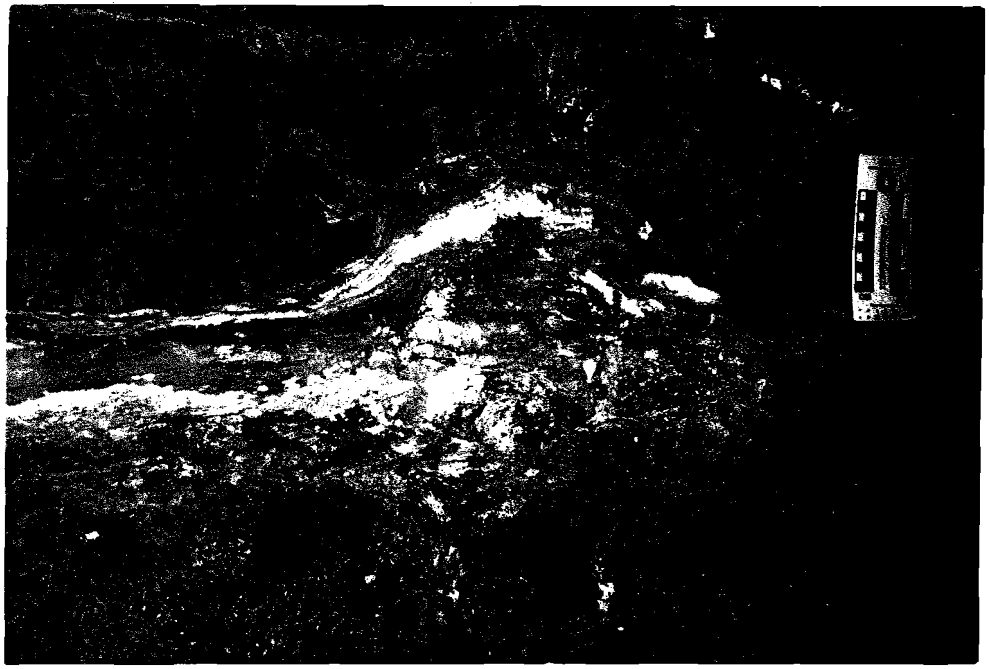


Figure 12
Load deformation in the form of pillow structures between the anhydrite (light) and polyhalite (dark).

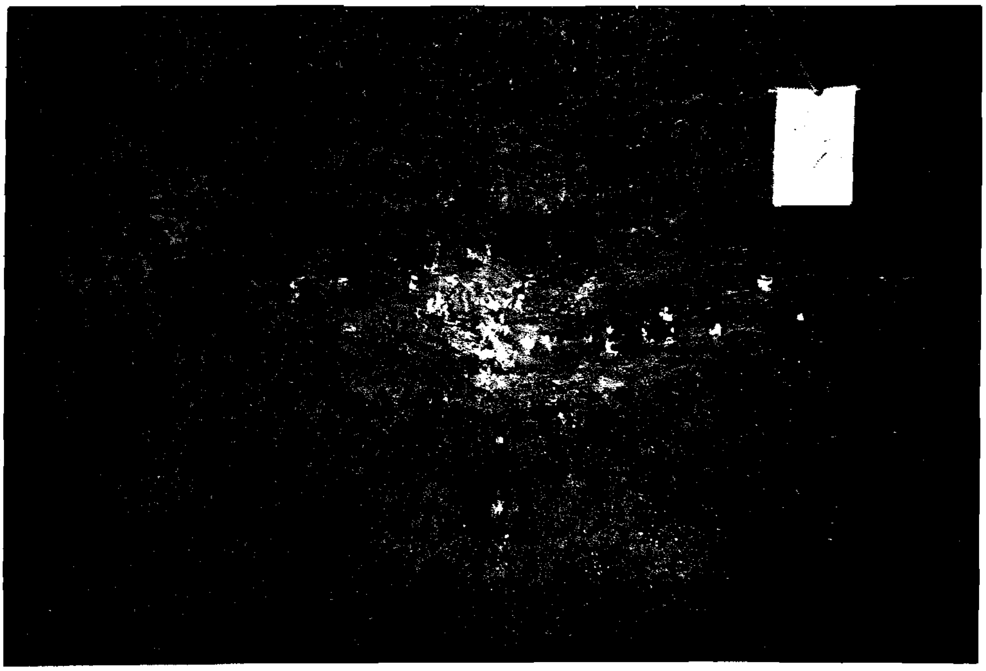
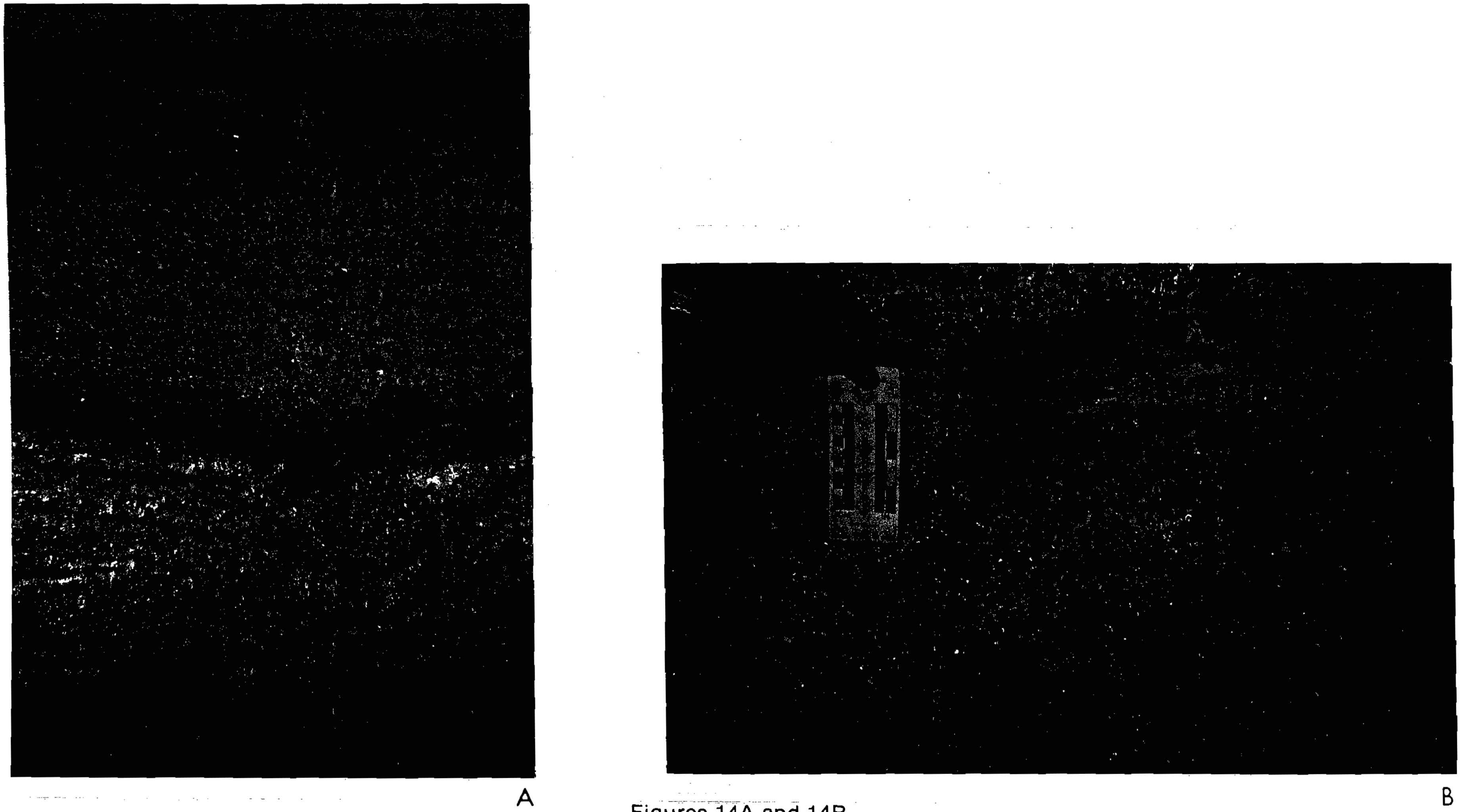
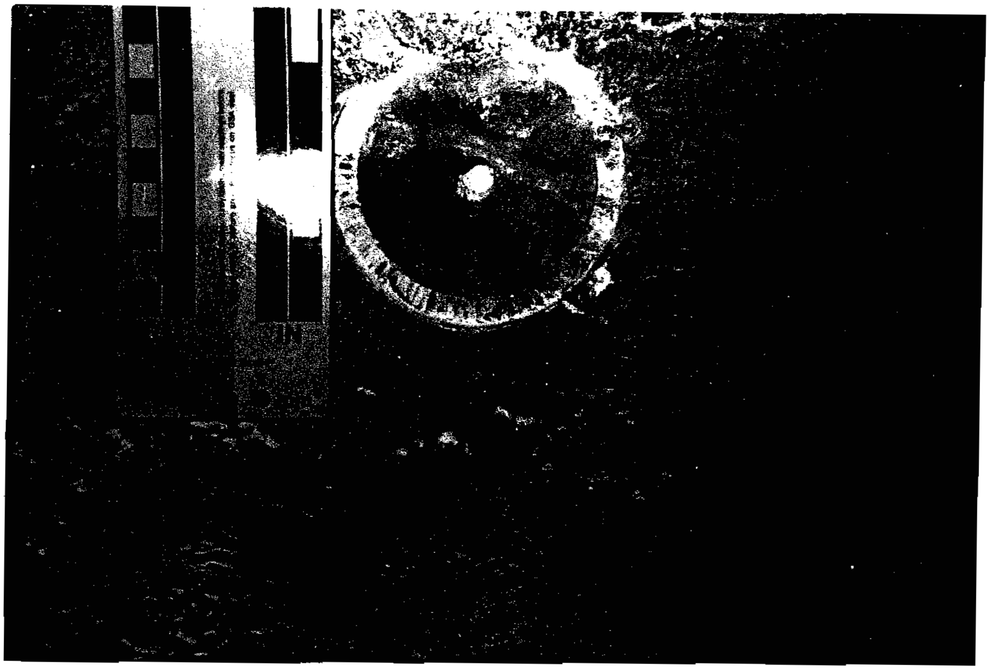


Figure 13
Collapse into a broad depression at the base of MB119.

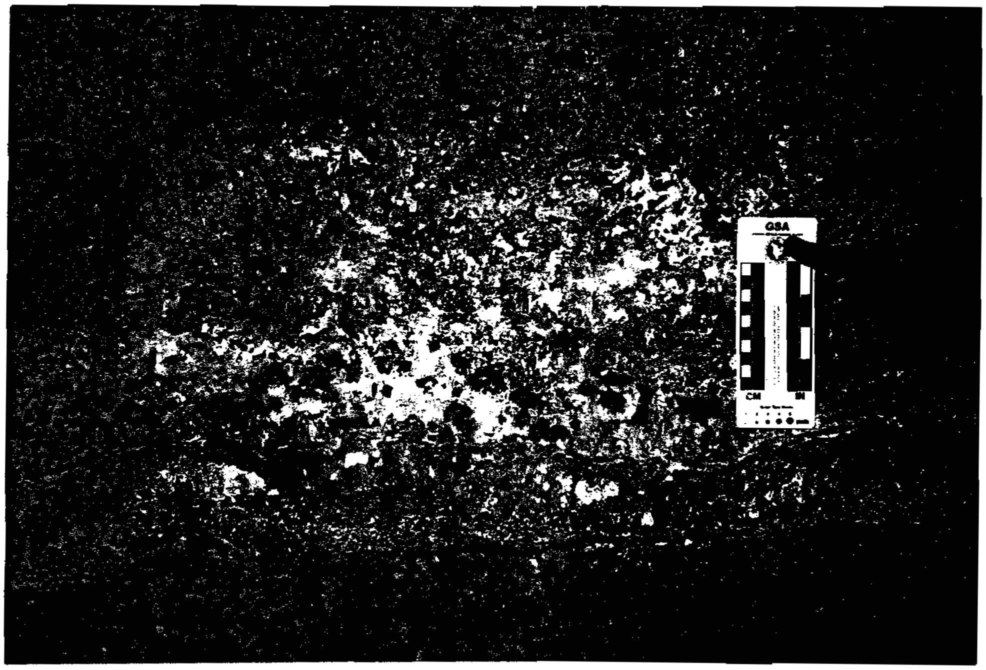


Figures 14A and 14B
Two examples (A and B) of downward collapse into pits at the base of sulfate interbeds.



A

Figures 15A and 15B
Two examples (A and B) of smeared intraclast textures. Example A shows downward collapse of the upper surface of halite filled voids in the lower part of the photo.



B

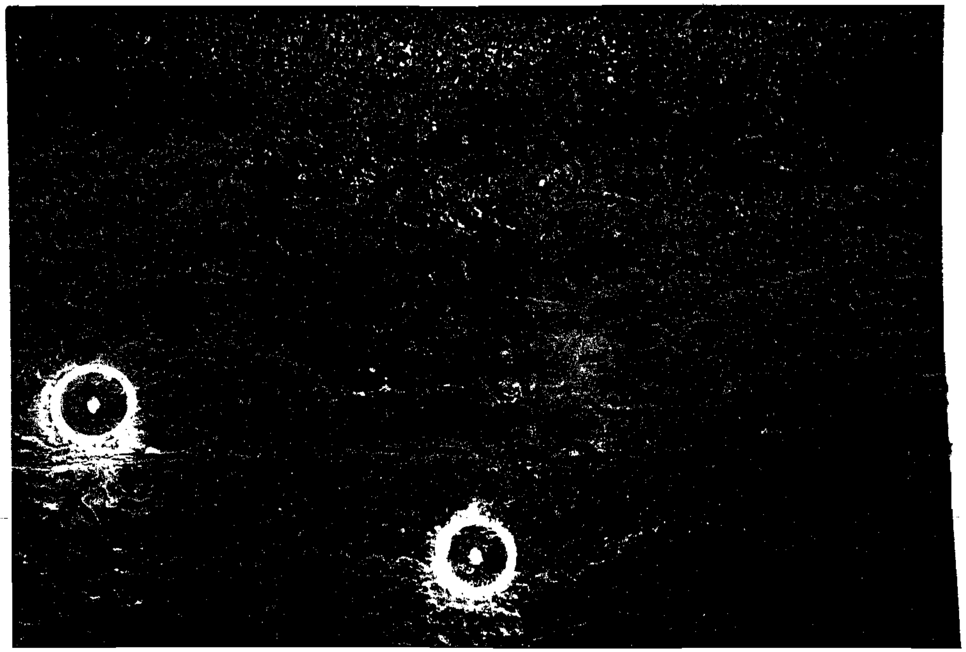


Figure 16
Shallow halite filled prism crack in anhydrite.

Figure 17
Deep clay filled prism crack in anhydrite with polyhalite (dark) occurring along and adjacent to the prism crack.

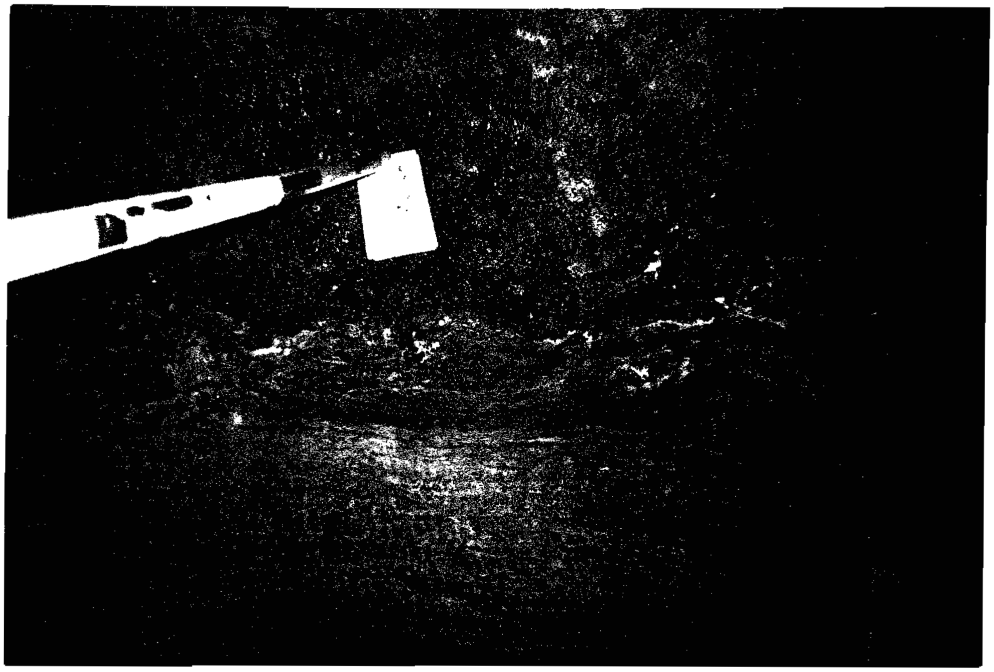


Figure 18A
Tepee structures on the top of MB109.

Figure 18B
Detail from one tepee structure.

Figure 19
Probable eroded tepee structure near the base of MB103.

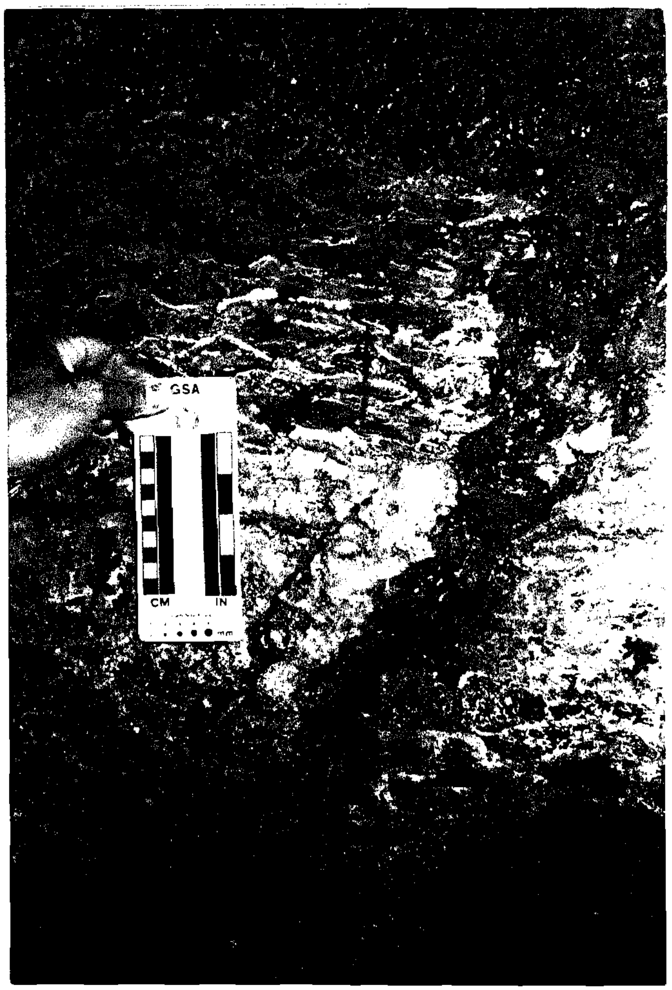


Figure 20
Buckled and displaced strata
near the top of MB109.

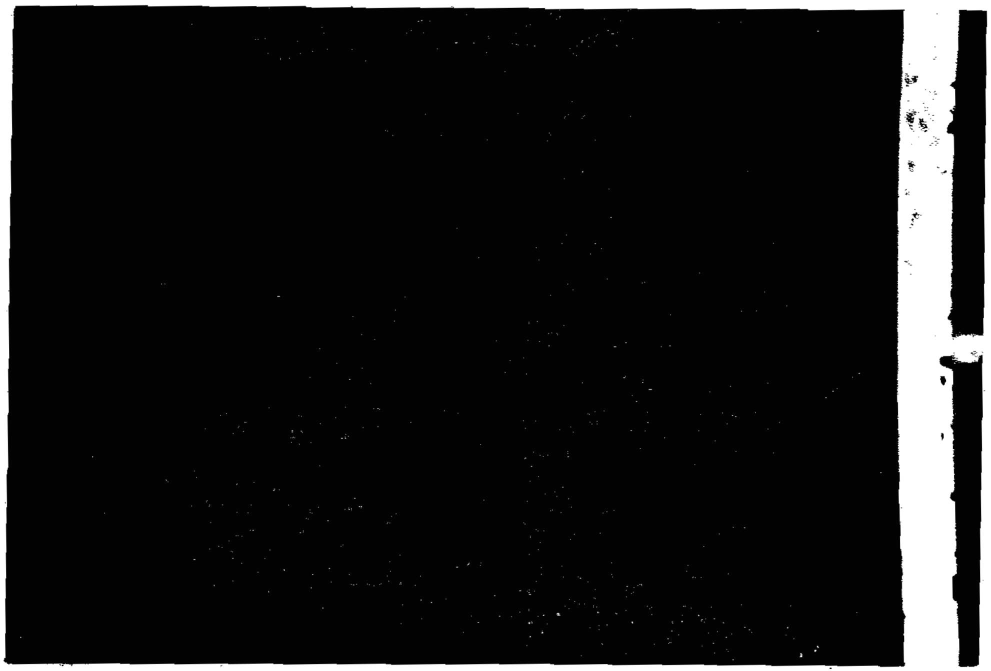
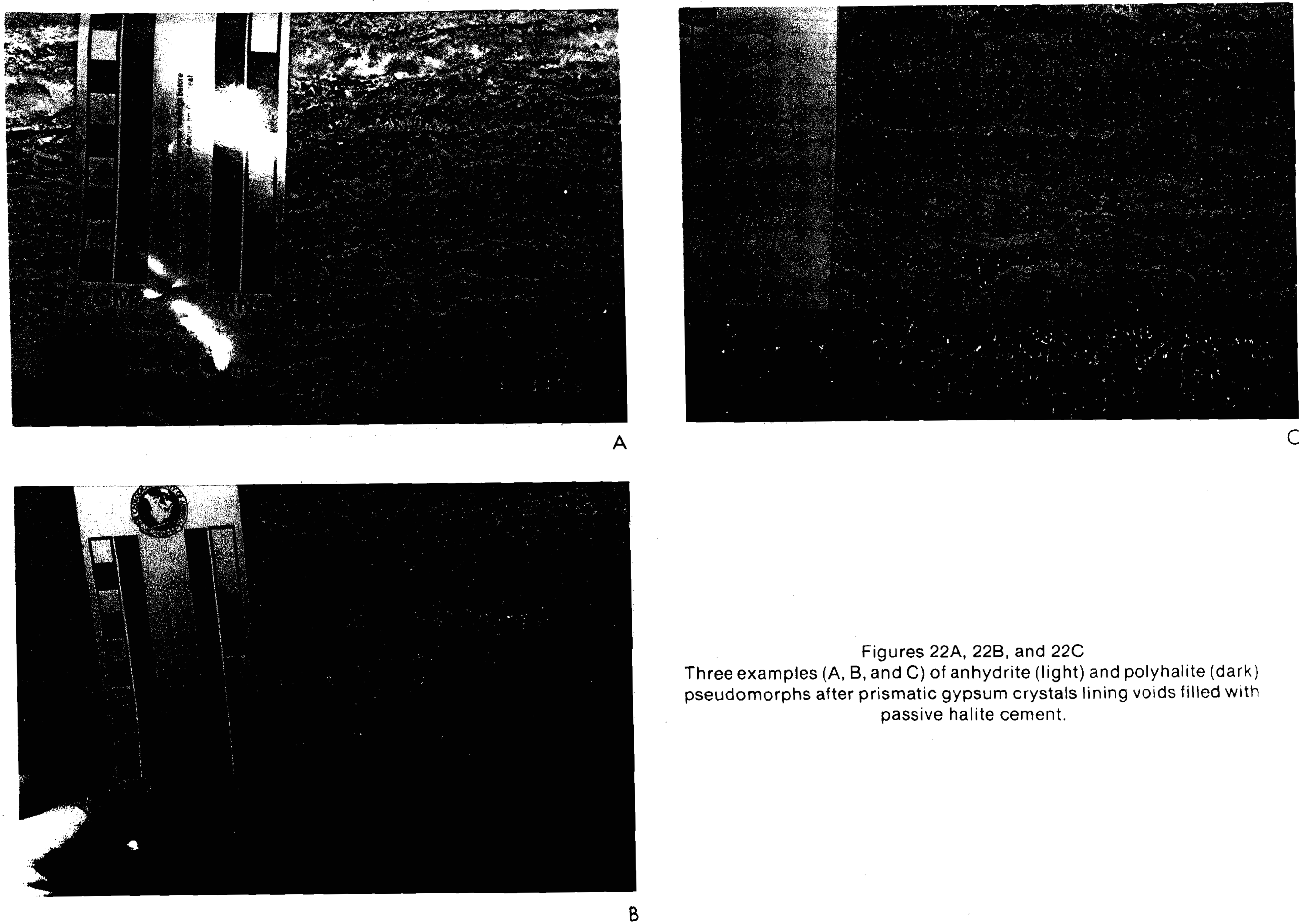


Figure 21
Lenticular zones parallel to strata passively filled with halite.



Figures 22A, 22B, and 22C
Three examples (A, B, and C) of anhydrite (light) and polyhalite (dark) pseudomorphs after prismatic gypsum crystals lining voids filled with passive halite cement.

Figure 23
A trough on the top of MB134 showing halite and sulfate (anhydrite and polyhalite) laminae terminating at the margin. The sulfate lining the lower part of the trough consists of polyhalite.

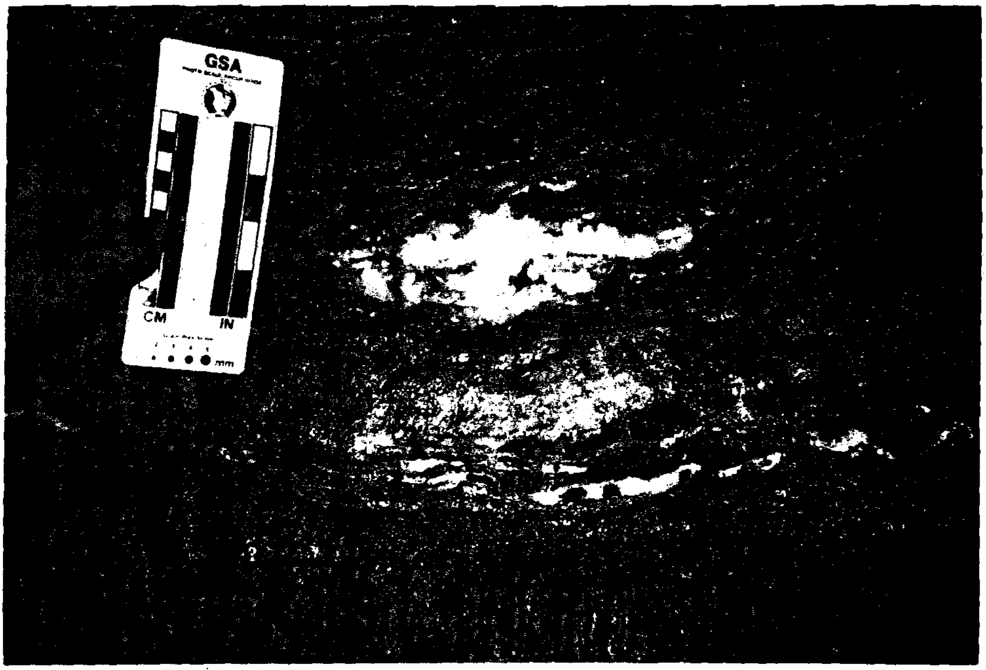


Figure 24
Weeps originating from horizontal fractures in anhydrite.

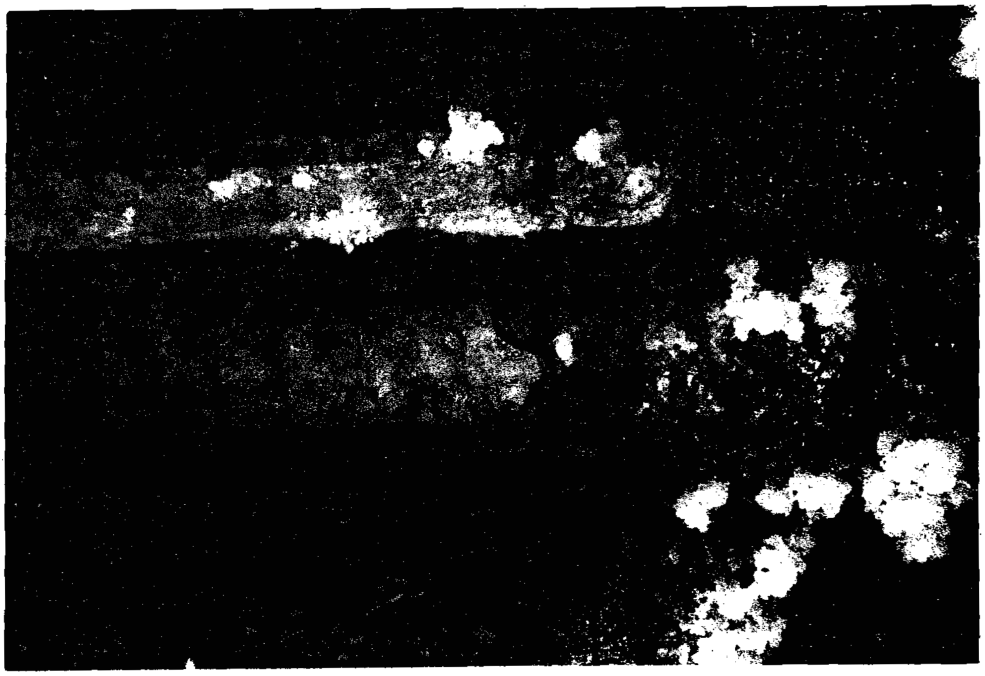


Figure 25
Weeps on the surface of MB103.