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DRILLING IN SABKHAHS OF THE DHAHRAN AREA

KINGDOM OF SAUDI ARABIA

by

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DRILLING IN SABKHAHS OF THE DHAHRAN AREA
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ABSTRACT

Eighteen holes were drilled by the Arabian Drilling Company (ADC) in Quaternary sabkhahs of the Dhahran area during the months of May and June, 1979.

The primary objectives of this drilling project were 1) to help locate potentially economic, shallow subsurface halite deposits and brines, 2) to help characterize the types of minerals found in sabkhahs of Saudi Arabia, and 3) to establish a relationship between brine chemistry, including saturation characteristics, and the existence of shallow evaporites.

It is not certain that the material recovered by ADC is representative of what is present in the subsurface. The majority of the samples extracted from a known halite body in Sabkhah Jayb Uwayyid contain more sand than halite and do not correspond to the results of previous drilling by ARAMCO. ADC was unable to recover a core sample of the halite deposit.

There is evidence that dolomitization has and possibly still is playing an important role in the diagenesis of the sabkhah sediments. There is also evidence that disseminated authigenic halite is present in many areas where bedded halite is not.

Testing halite saturation of the brine is not a reliable method of differentiating between disseminated and bedded halite. Groundwater saturation with halite was proved to be an essential but not sufficient condition for the occurrence of bedded halite.

No new halite deposits were discovered. Any further economic evaluation of the Dhahran area should concentrate on recovering good core samples from the halite deposit in Sabkhah Jayb Uwayyid.

INTRODUCTION

Sabkhahs of the eastern province of Saudi Arabia lie primarily in an area some 500 km long and 50 km wide (fig. 1) bounded by Kuwait on the north, the Qatar peninsula on the south, the Arabian Gulf on the east, and the interior escarpment on the west.

From 16 May to 26 June 1979 the Arabian Drilling Company (ADC) drilled 18 holes in Quaternary sabkhahs located within the western Arabian Gulf quadrangle, between lats 26°00' and 26°20 N and longs

49°50' and 50°10'E (fig. 2). Three major communities are located in this area: Dammam, the port city, Dhahran, the largest of the ARAMCO "camps", and al-Khobar, a commercial district.

The primary objectives of this drilling project were 1) to help locate potentially economic, shallow subsurface evaporite deposits, particularly halite, and brines, 2) to help characterize the types of minerals found in the sabkhahs of Saudi Arabia, and 3) to establish a relationship between brine chemistry, including saturation characteristics, and the existence of shallow evaporites.

Sabkhahs are a common evaporite environment. A sabkhah is generally described as a flat, fairly level, sandy, muddy or salt-encrusted surface that is occasionally inundated. Two primary prerequisites for the emergence of a sabkhah are 1) that the climate be arid and 2) that the mixing or exchange of groundwaters beneath the sabkhah with other diluting waters, be they marine or peripheral groundwaters, be restricted. Worldwide distribution of Holocene evaporites implies that an arid climate is essential but not sufficient for evaporite formation. Limited dilution of the sabkhah's saline groundwaters is of primary importance.

Sabkhahs may occur in either coastal or continental environments (Kinsman, 1969). Both are equilibrium geomorphic surfaces whose levels are determined by the local groundwater level. They occur where eolian sand supply is limited and hard rock lies below the groundwater table. Coastal sabkhahs are supratidal and commonly are a wedge of sediments overlain by a supratidal facies that itself is overlain by an eolian facies. The brines in coastal sabkhahs are most likely derived from the evaporation of percolating sea waters at the sabkhah surface.

Continental sabkhahs are located inland and are normally associated with areas of dune sand. They are equilibrium deflation-sedimentation surfaces situated approximately 1 m above the groundwater table (Kinsman, 1969). Brines are a result of large evaporation losses of water vapor at the surface. Groundwaters in peripheral dune areas may have very different ionic concentrations from the sabkhah brine. However, because the sabkhah surface is very near the groundwater table, evaporation of incoming groundwaters contribute to brine formation.

GEOLOGY

The dominant geological feature within the area of study is the Dammam dome, named after the major port city of the area, located off the northern edge of the dome.

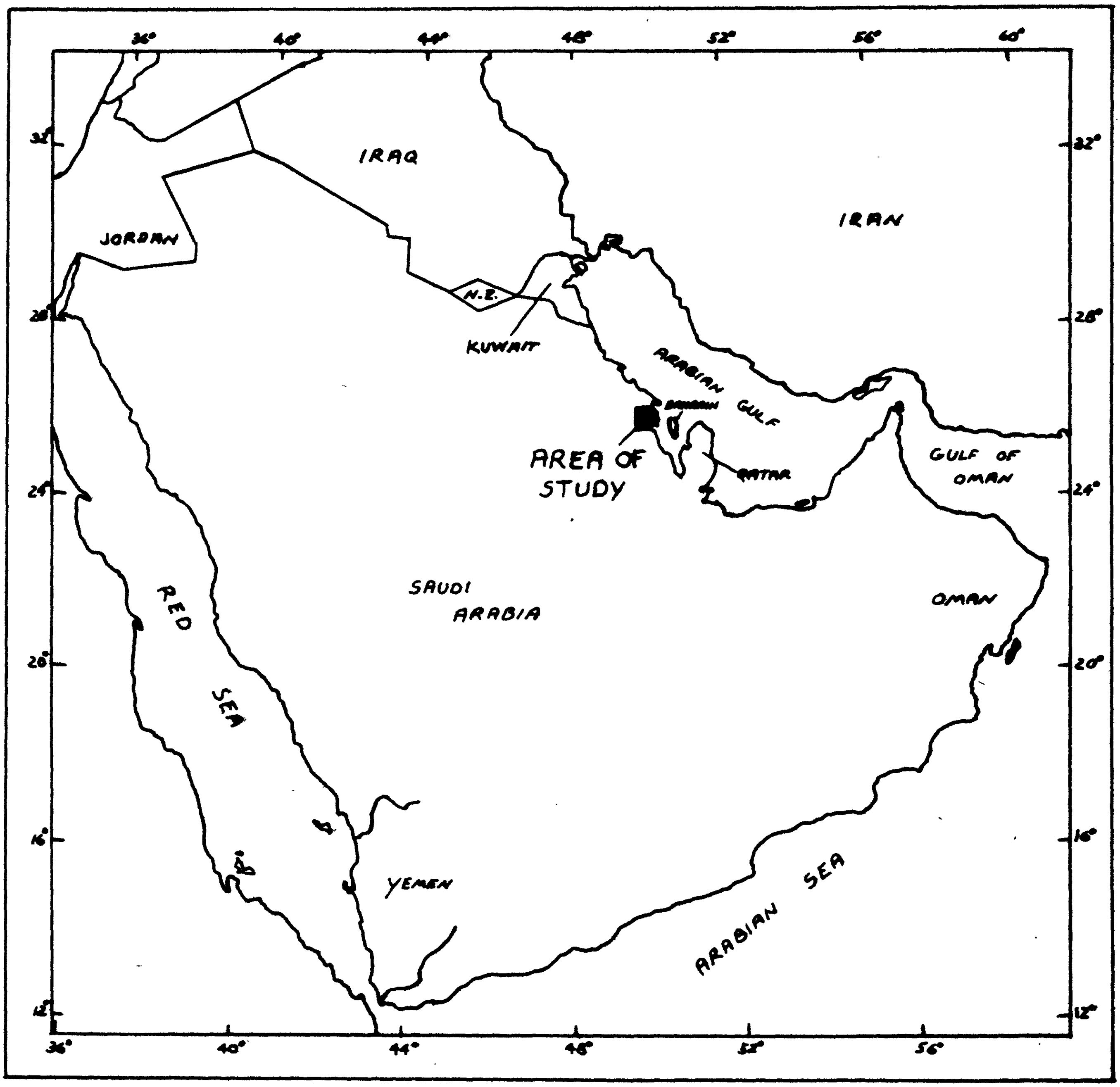

Figure 1.--Index map showing Arabian peninsula and area of study.

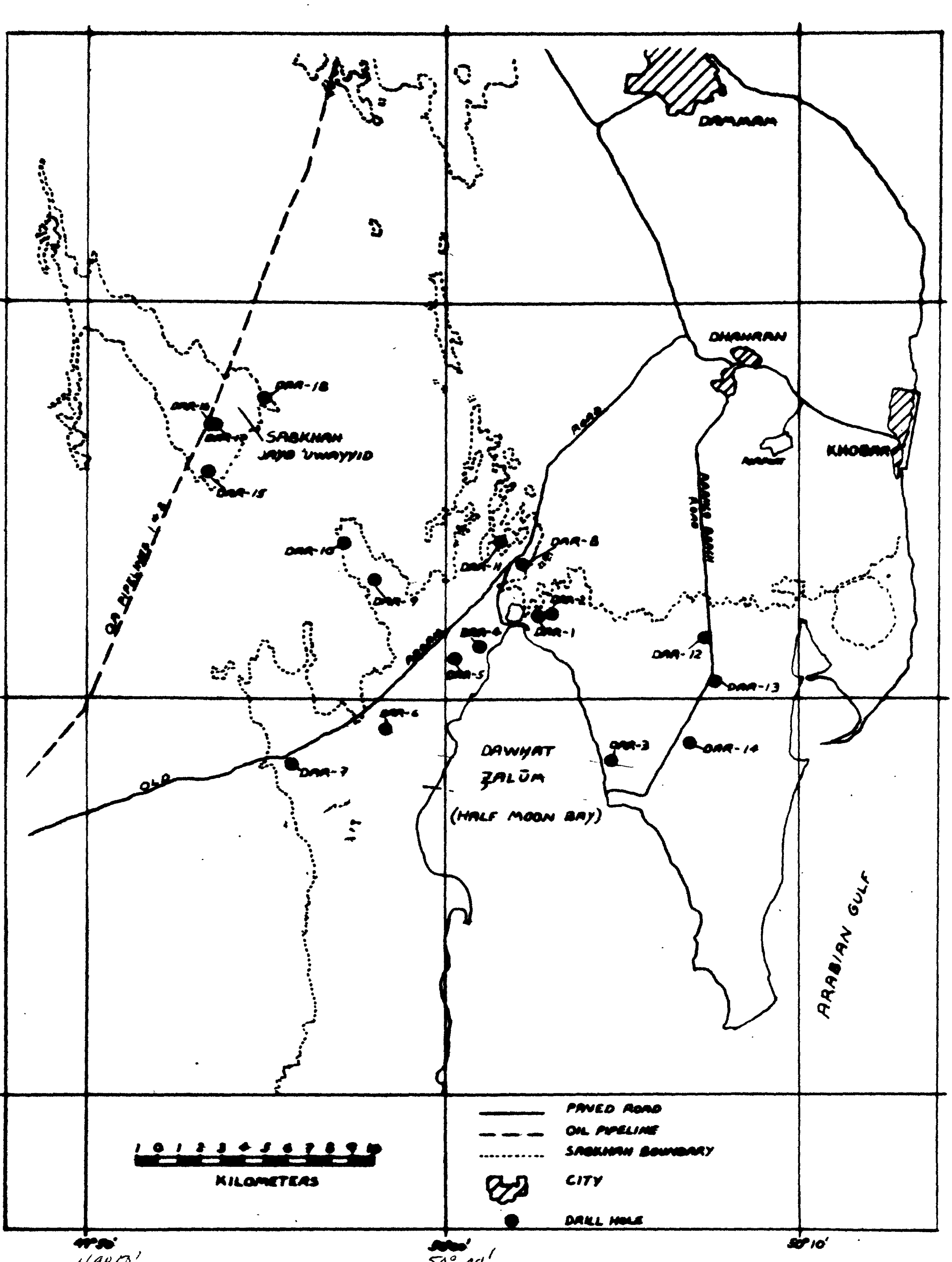

Figure 2.--Sample locality map showing location of drill holes in area of study.

The Rus Formation, early Eocene in age and the Dammam Formation, middle Eocene in age, crop out at the surface of the dome (Powers and others, 1966). The Rus consists primarily of limestone and marl. The Dammam Formation is composed of limestone and marl in the upper section and contains shale in the lower section. Both formations are fossiliferous, nummulite foraminifera being the dominant fauna.

The area consists, predominantly, of Quaternary eolian sand (Steineke, Harriss, Parsons, and Berg, 1958), commonly in the form of barchan dunes. Many Quaternary sabkhahs are present in both continental and coastal environments.

Three major halite deposits are known in the Dhahran area, all in sabkhah environments:

1) Sabkhah Jayb Uwayyid: subsurface deposit; 25 km west of Dhahran (Dimock, 1955)

2) Sabkhah al Qurayyah: surface deposit; south of Dawhat Zalum (Half Moon Bay) (Arnold, 1966)

3) Sabkhah Aba al-Hamam: surface deposit; 15 km south of Abqaiq. This is the only deposit being mined (Tleel, 1968).

Thickness of the surface halite deposits ranges from several centimeters to almost 10 m. The Sabkhah Aba al-Hamam halite is used by ARAMCO for the regeneration of zeolite beds in its water softening plants. Relatively small amounts are harvested for human consumption.

Drilling was done by ADC in the coastal and interconnecting continental sabkhahs peripheral to Dawhat Zalum and in Sabkhah Jayb Uwayyid. Most of these sabkhahs consist of a crust of salt, sand, and mud, the mud more prevalent in the coastal environments. In all cases the groundwater table is between 0.5 and 2.0 m below the surface. In several areas, particularly in the sabkhahs located on the peninsula immediately east of Dawhat Zalum, surface and near surface sediments are rich in gypsum crystals. They occur both as individual crystals and in crystal clusters. Crystal size may range from 5 mm to 15 cm in length.

Of the sabkhahs to be drilled, only Sabkhah Jayb Uwayyid is known to contain a halite deposit. It was discovered by ARAMCO during the 1954-55 field season while shot holes were being drilled by seismograph rigs. The sabkhah also possesses a fairly uniform salt crust up to 3 cm thick and is almost completely surrounded by peripheral dunes. The size and tonnage of the subsurface deposit were conservatively estimated at 11.2 million cubic meters and 26.3 million metric tons, respectively

(Dimock, 1955). To the writers' knowledge, no other drilling had been done in the area of the halite deposit in Sabkhah Jayb Uwayyid.

DRILLING

Eighteen holes were drilled in sabkhahs of the Dhahran area. The proposed drilling plan was:

1) Drilling would be to 10 m depth if no halite or consolidated material was encountered. If consolidated material was encountered the geologist would have the option of continuing the drilling to a maximum depth of 30 m.

2) If halite was encountered in the upper 10 m of sediment the hole was to be cored to 30 m.

3) Brine samples would be taken from each hole and samples of unconsolidated material would be taken every meter.

Drilling samples from each hole were initially inspected meter by meter under the hand lens by the geologist in the field and recorded in a log. Subsequently, log revisions were made as a representative sample from each stratigraphic unit was inspected under a stereo binocular microscope. Final detailed mineralogical analyses of representative samples from 23 stratigraphic units were made by the x-ray diffraction powder method.

A brine sample from each hole was obtained and tested for saturation with halite by acidifying the sample in concentrated hydrochloric acid. If a sample was saturated or nearly saturated by halite, a white precipitate would briefly appear when a drop of the acid was introduced into the brine.

RESULTS

The total thickness of sediments drilled was 233 m. The maximum depth reached was 20 m in hole DAR-3 while the minimum depth of drilling was 7 m in hole DAR-9.

The most common type of sedimentary material encountered in the drilling was unconsolidated quartzose sand. It is either tan or gray in color depending on the relative abundance of dark iron monosulfides, which transform to a lighter colored iron oxide upon oxidation.

The sands and mixed silts and muds are generally poorly sorted, subround, and calcareous. Calcite, dolomite and aragonite are common carbonate minerals.

Evaporite minerals are present within most of the quartzose sands. Fine-grained disseminated halite tends to be the most common evaporite mineral in most sediments. The bedded halite in Sabkhah Jayb Uwayyid is unique, however, and is found as granule- to pebble-size, euhedral crystals. Gypsum is present either as a cementing agent or as fine- to medium-grained euhedral crystals. Anhydrite commonly occurs as white, oval, fine-grained nodules.

Several reducing dolomitic clay units were penetrated during the drilling. A common clay mineral found not only in the clays but also in the sands is montmorillonite.

Marine fauna were present in more than 50 percent of the holes drilled. In some cases the shells and tests make up almost half of the volume of the sample. The dominant fauna in most cases appears to be nummulite foraminifera. Annelid tubes, pelecypods, and gastropods are also common. A more detailed description of the subsurface stratigraphy encountered in each hole is found in Appendix 1.

CONCLUSIONS

It is not certain that the material ADC recovered from each hole is representative of what is present in the subsurface. This fact was brought to the attention of the writers upon drilling in the area of the proposed halite deposit in Sabkhah Jayb Uwayyid. As described in the ARAMCO report by Dimock (1955), the halite bed is believed to be located approximately 2.8 to 4.3 m below the surface and to occur as a continuous bed 0.3 to 3.7 m thick.

Of the three holes drilled within the halite deposit, two (DAR-15 and DAR-16) produced samples that were composed of more sand than halite at the depth at which the halite bed is reported to occur. One of these, DAR-16, was located at approximately the same point where the ARAMCO drillers encountered a halite bed 2.8 m below the surface, having a thickness of about 1.8 m.

The ADC drillers were unable to recover any core from the three holes drilled in the bedded halite deposit. The unexpected material encountered in DAR-15 and DAR-16 may be a result of the drillers "pumping" out the fluid sand above the halite bed when the drill was actually within the halite body. Samples extracted from DAR-17, the third hole drilled within the deposit, correspond very closely to what the ARAMCO drillers have logged; however, no core of the halite was recovered.

Dolomitization, which is a very important process in sabkhah environments in relation to the occurence of diagenetic minerals, was evident in many of the sabkhahs that were investigated. In every analyzed drilling sample from the sabkhahs of the Dhahran area in which dolomite is present, aragonite, gypsum, and anhydrite are also present, either singularly or together. However, the converse is not true. This relationship tends to indicate that mineralogical diagenesis and dolomitization were, and possibly still are, active processes in these sabkhah environments. For a more detailed discussion of dolomitization in sabkhah environments see Butler (1969).

The granule to pebble size, euhedral halite crystals found in the drilling samples from Sabkhah Jayb Uwayyid are not found in samples from other holes. However, most of the drilling samples contain a considerable amount of fine-grained disseminated halite. In general, those samples that come from holes where the brine is saturated with halite contain more disseminated halite than those that come from holes where brine is not saturated. The additional halite may be due partially to the precipitation of halite from the brine as a result of desiccation of the sample. However, several samples that were not desiccated contained a moderate amount of disseminated halite, which indicates that authigenic halite was probably present in the sediments prior to desiccation. Testing halite saturation of the brine does not appear to be a reliable method of differentiating between disseminated and bedded halite. Groundwater saturation with halite was proved to be an essential but not sufficient condition for the occurrence of bedded halite.

No new halite deposits were discovered. Due to the lack of core recovery from the Sabkhah Jayb Uwayyid halite deposit, it is recommended that any further economic evaluation of the Dhahran area be concentrated on obtaining good core samples from this halite body.

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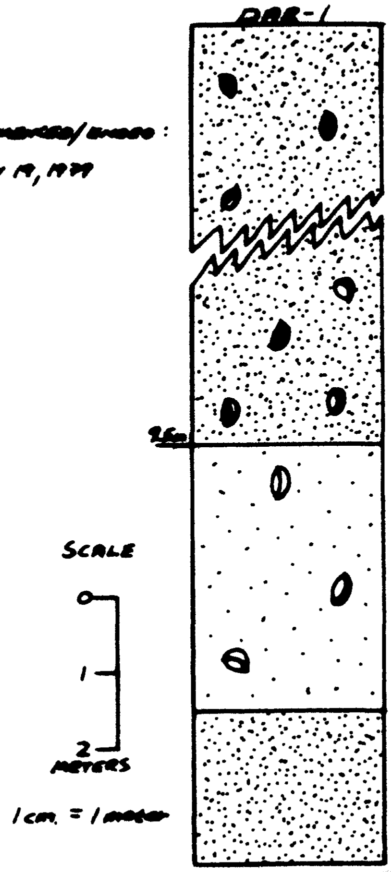
APPENDIX

STRATIGRAPHIC SECTIONS OF DRILL HOLES

DAR-1 through DAR-18

DATE DRILLING COMMENCED/ENDED:
MAY 16, 1979 / MAY 19, 1979



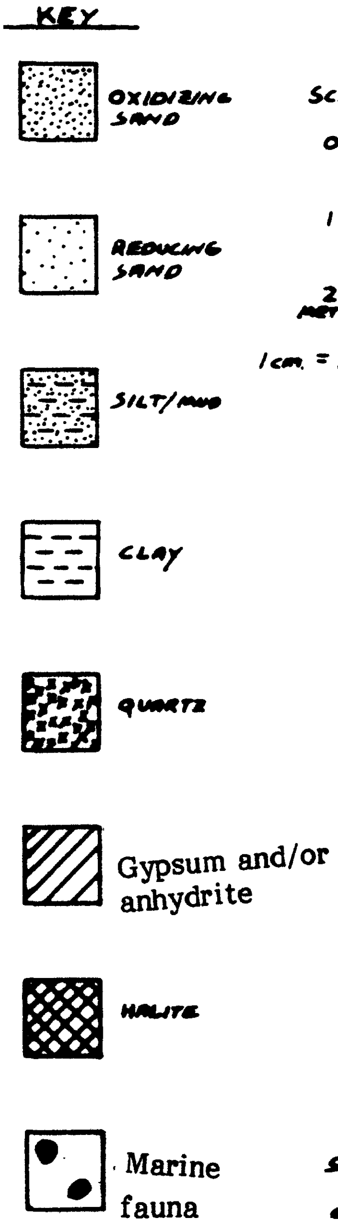
UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypods, gastropods, annelid tubes and nummulites(?). Disseminated halite cementing sand at depth.
MINERALOGY (8 m-9 m): Predominantly quartz with progressively lesser amounts of calcite, feldspar, halite, montmorillonite and gypsum.

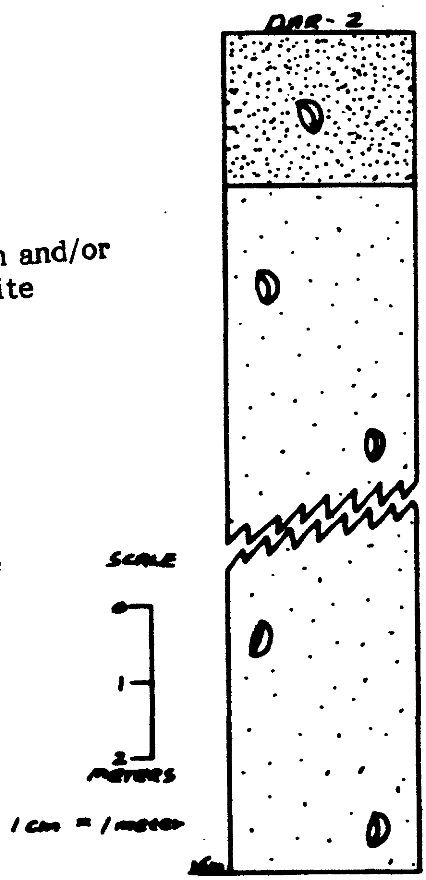
UNCONSOLIDATED REDUCING SAND: gray, fine- to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypods, gastropods, annelid tubes and nummulites(?).

UNCONSOLIDATED OXIDIZING SAND: brown, fine- to coarse-grained, poorly sorted, subangular to round, calcareous. Shells absent.

Brine not saturated with NaCl.

KEY



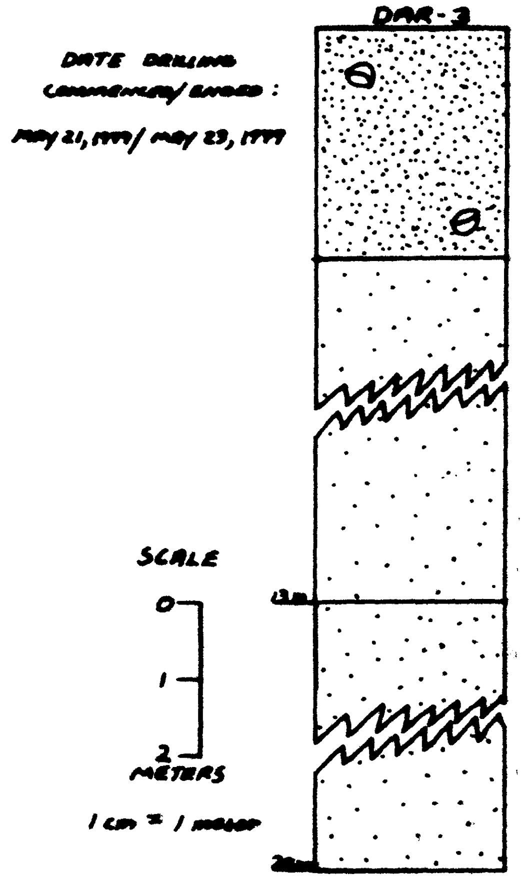


UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypods and gastropods.

UNCONSOLIDATED REDUCING SAND: gray, fine- to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypods.

DATE DRILLING COMMENCED/ENDED:
MAY 19, 1979 / MAY 20, 1979

Brine not saturated with NaCl.

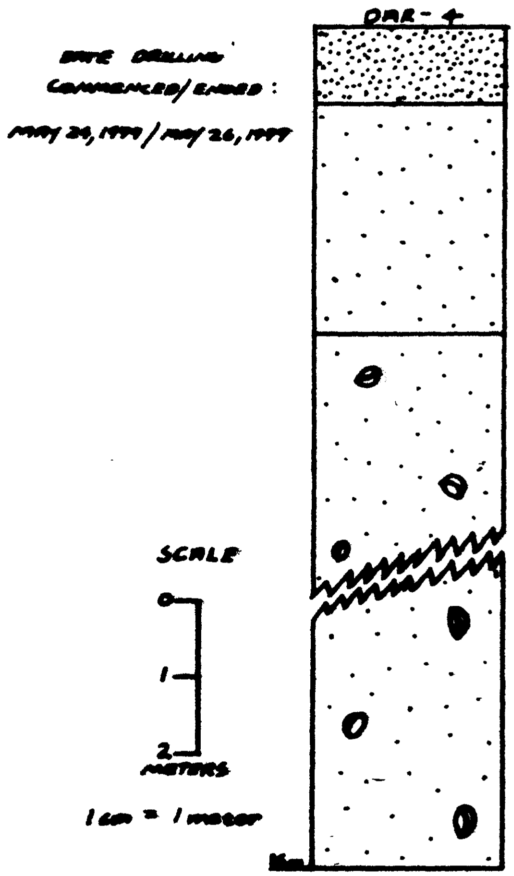


UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, angular to round, calcareous; containing few pelecypods and annelid tubes. Much disseminated halite, in places cementing sand.

UNCONSOLIDATED REDUCING SAND: gray, fine- to coarse-grained, poorly sorted, angular to round, calcareous. Considerable amount of halite present, possibly disseminated but sample was not desiccated.

UNCONSOLIDATED REDUCING SAND: Same as overlying unit described above but the color is here a dark olive green.
MINERALOGY (14 m–15 m): Predominantly quartz with progressively lesser amounts of feldspar, halite, calcite, gypsum and montmorillonite.

Brine not saturated with NaCl.



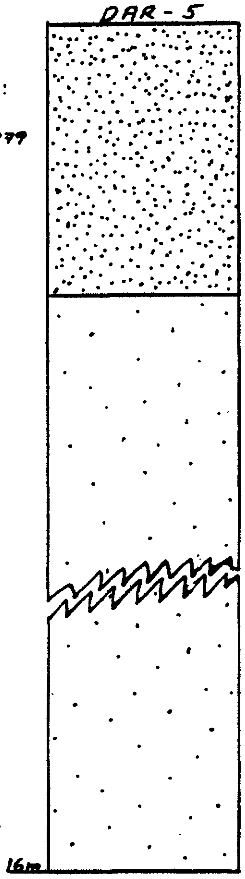
UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous.

UNCONSOLIDATED REDUCING SAND: gray, fine to coarse-grained, poorly sorted, subangular to round, calcareous.

UNCONSOLIDATED REDUCING SAND: gray-green, fine to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypods, gastropods, annelid tubes and nummulites (?). Also possible trace of pyrite (?)

Brine not saturated with NaCl.

DATE DRILLING COMMENCED/ENDED: MAY 26, 1979/MAY 27, 1979



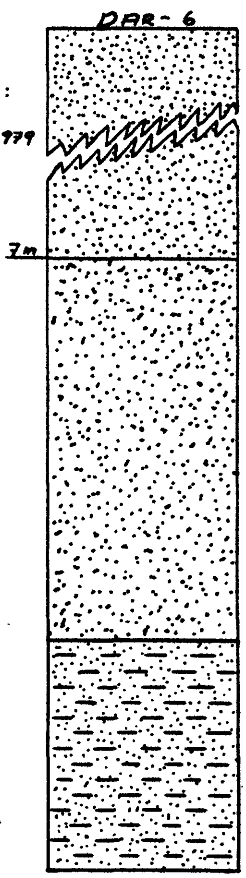
UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous

UNCONSOLIDATED REDUCING SAND: gray-green, fine to coarse-grained, poorly sorted, subangular to round, calcareous.
MINERALOGY (15m-16m): Predominantly quartz and feldspar with progressively lesser amounts of calcite, halite, aragonite, montmorillonite and gypsum.

SCALE
0
1
2
METERS
1 cm = 1 meter

Brine not saturated with NaCl.

DATE DRILLING COMMENCED/ENDED: MAY 28, 1979/MAY 29, 1979



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, angular to round, calcareous.

UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, angular to round, calcareous. Considerable amount of halite and salt-cemented sand.
MINERALOGY (11m-12m): Predominantly quartz and halite with progressively lesser amounts of illite, montmorillonite and calcite.

UNCONSOLIDATED OXIDIZING SILT/MUD: tan, calcareous, with sand-sized particles.
MINERALOGY (12m-13m): Predominantly quartz and halite with progressively lesser amounts of aragonite, illite, montmorillonite, gypsum, calcite and dolomite.

SCALE
0
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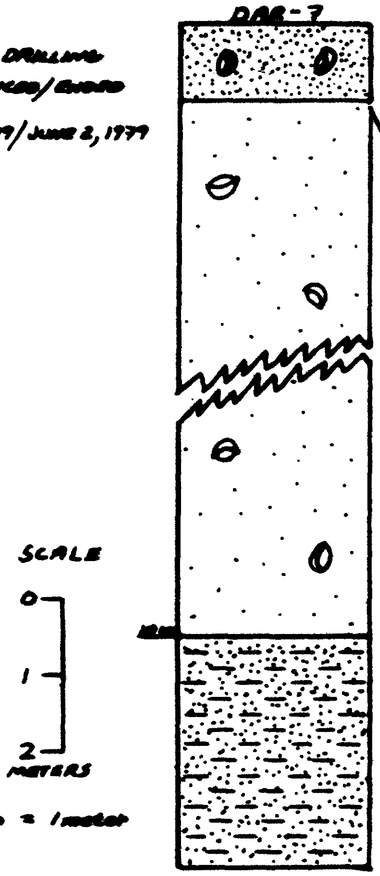
METERS
1 cm = 1 meter

Brine saturated with NaCl.

DATE DRILLING COMMENCED/ENDED

MAY 31, 1979/JUNE 2, 1979



UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, angular to round, calcareous; containing few gastropods, annelid tubes, pelecypod fragments and nummulites(?). Gypsum crystals and much disseminated halite present.

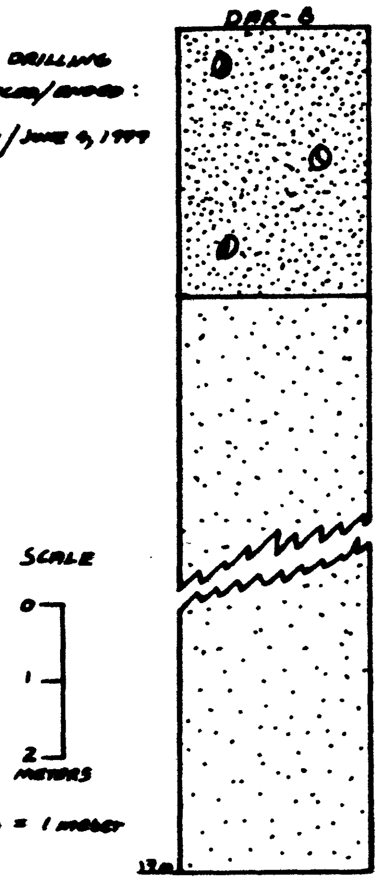
UNCONSOLIDATED REDUCING SAND: gray, fine- to coarse-grained, poorly sorted, subangular to round, calcareous; containing pelecypod fragments and gastropods.

UNCONSOLIDATED OXIDIZING SILT/MUD: tan, calcareous, with sand-sized grains.
MINERALOGY (11 m-12 m): Predominantly calcite and halite with progressively lesser amounts of quartz, mica-montmorillonite and aragonite.

Brine Saturated with NaCl.

DATE DRILLING COMMENCED/ENDED:

JUNE 3, 1979/JUNE 4, 1979



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, angular to subround, calcareous; containing pelecypods, gastropods, annelid tubes and nummulites (?).

UNCONSOLIDATED SEMIREDUCING SAND: dark tan, fine to coarse grained, poorly sorted, subangular to round, calcareous. Shells absent.

Brine Saturated with NaCl.

DAR-9

DATE DRILLING COMMENCED/ENDED:

JUNE 5, 1979/ JUNE 5, 1979

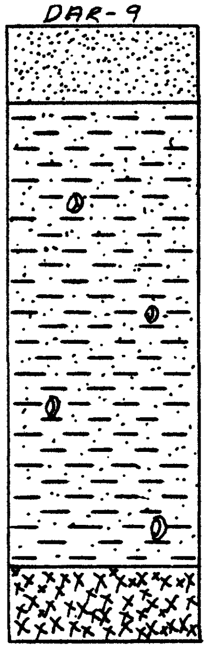
SCALE

0

1

2
METERS

1 cm = 1 meter



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous

UNCONSOLIDATED REDUCING SILT/MUD: gray, calcareous, with sand-sized grains; containing pelecypods, gastropods, annelid tubes, and nummulites (?)
MINERALOGY (5m-6m): Predominantly quartz and calcite with lesser amounts of halite, aragonite, feldspar, dolomite and montmorillonite.

QUARTZ: Vuggy, calcareous, with fine-grained euhedral quartz crystals
MINERALOGY: Quartz with a small amount of aragonite, dolomite and montmorillonite

Brine not saturated with NaCl

DAR-10

DATE DRILLING COMMENCED/ENDED:

JUNE 6, 1979/ JUNE 7, 1979

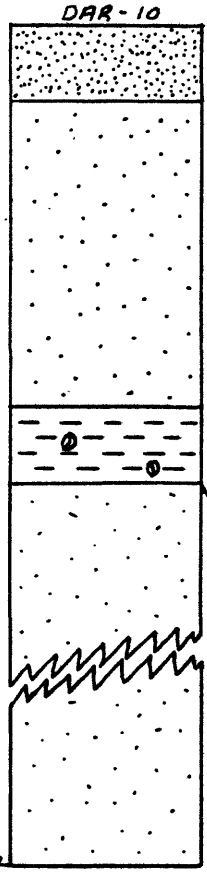
SCALE

0

1

2
METERS

1 cm = 1 meter



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous.

UNCONSOLIDATED REDUCING SAND: gray, silt-sized to coarse-grained, poorly sorted, subangular to round, calcareous.
MINERALOGY (1m-2m): Predominantly quartz with lesser amounts of halite, aragonite, calcite, dolomite, feldspar, montmorillonite and gypsum.

REDUCING CLAY: gray, calcareous, arenaceous, with fine-grained oval anhydrite nodules; containing pelecypods, gastropods and nummulites (?)
MINERALOGY: Predominantly calcareous material, ie. dolomite, aragonite and calcite, in order of decreasing occurance, with some halite, quartz and magnesite (?)

UNCONSOLIDATED REDUCING SAND: gray, fine to coarse-grained, poorly sorted, subangular to round, calcareous.
MINERALOGY (14m-15m): Predominantly quartz and feldspar with progressively lesser amounts of calcite, halite, montmorillonite.

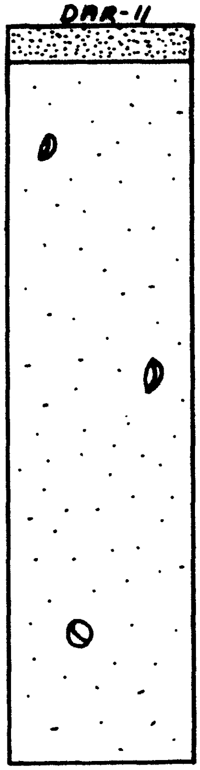
15m

Brine not saturated with NaCl.

DAR-11

DATE DRILLING COMMENCED/ENDED:

JUNE 12, 1979 / JUNE 12, 1979



UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, subangular to round, calcareous.

UNCONSOLIDATED REDUCING SAND: gray, fine- to coarse-grained, poorly sorted, subangular to round, calcareous, with much disseminated halite. Few shells throughout, mostly nummulites(?) increasing in quantity with depth.

SCALE

0

1

2

METERS

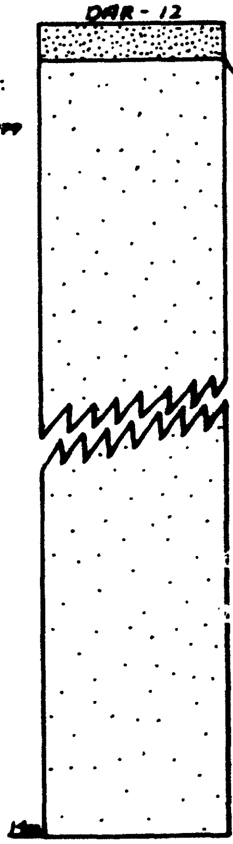
1 cm = 1 meter

Brine not saturated with NaCl.

DAR-12

DATE DRILLING COMMENCED/ENDED:

JUNE 13, 1979 / JUNE 13, 1979



UNCONSOLIDATED OXIDIZING SAND: tan, fine to very coarse-grained, poorly sorted, angular to round, calcareous. Much disseminated halite and very coarse-grained, subhedral to euhedral gypsum crystals. Some fine-grained oval anhydrite nodules present.

UNCONSOLIDATED REDUCING SAND: gray, fine to coarse-grained, poorly sorted, subangular to round, calcareous. Subhedral gypsum crystals and oval anhydrite nodules present.
MINERALOGY (13m-14m): Predominantly quartz with progressively lesser amounts of feldspar, calcite, halite, gypsum, aragonite, dolomite, and montmorillonite.

SCALE

0

1

2

METERS

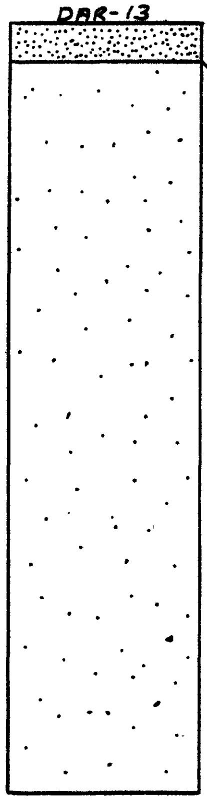
1 cm = 1 meter

Brine saturated with NaCl.

DATE DRILLING COMMENCED/ENDED:

JUNE 13, 1979/ JUNE 14, 1979

DAR-13



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous; fine-grained anhydrite nodules present.

UNCONSOLIDATED REDUCING SAND: gray, fine to coarse grained, poorly sorted, subangular to round, calcareous, with fine-grained anhydrite nodules.

SCALE

0
1
2
METERS

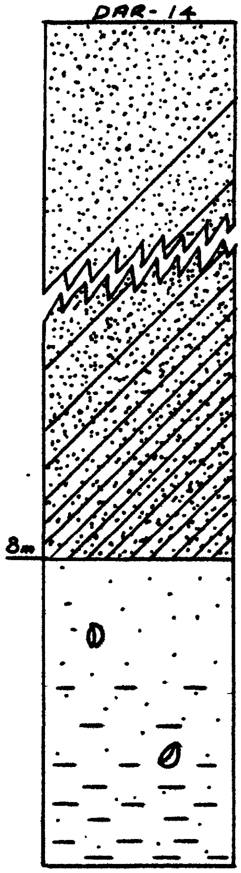
1 cm = 1 meter

Brine not saturated with NaCl.

DATE DRILLING COMMENCED/ENDED:

JUNE 14, 1979/ JUNE 14, 1979

DAR-14



UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, subangular to round, calcareous. Sand gypsum-cemented at depth.
MINERALOGY (3m-4m): Predominantly quartz and gypsum with progressively lesser amounts of halite, calcite, feldspar, aragonite and montmorillonite.

SCALE 8m

0
1
2
METERS

1 cm = 1 meter

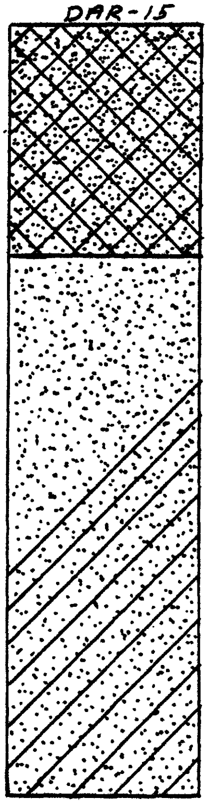
UNCONSOLIDATED REDUCING SAND: gray, fine to coarse-grained, poorly sorted, subangular to round, calcareous. Anhydrite nodules and much disseminated halite present. Occurance of gray clay material increases with depth. Few pelecypod fragments present.
MINERALOGY (9m-10m): Predominantly quartz with progressively lesser amounts of halite, calcite, feldspar, gypsum, dolomite, aragonite and montmorillonite.

Brine not saturated with NaCl.

DAR-15

DATE DRILLING COMMENCED/ENDED :

JUNE 19, 1979 / JUNE 20, 1979



UNCONSOLIDATED OXIDIZING SAND AND HALITE: tan, fine to very coarse grained, poorly sorted, angular to round, calcareous. occurance of euhedral halite increases with depth.
MINERALOGY (2m-3m): Predominantly halite and gypsum with progressively lesser amounts of quartz, feldspar and calcite.

UNCONSOLIDATED OXIDIZING SAND: tan, fine to coarse-grained, poorly sorted, angular to round, calcareous. Occurance of anhydrite increases with depth. Few large euhedral halite crystals present. many very minute tabular, rectangular halite particles adhering to larger grains.
MINERALOGY (9m-10m): Predominantly quartz, anhydrite and halite with progressively lesser amounts of feldspar, aragonite, calcite, gypsum and montmorillonite.

SCALE

0
1
2
METERS

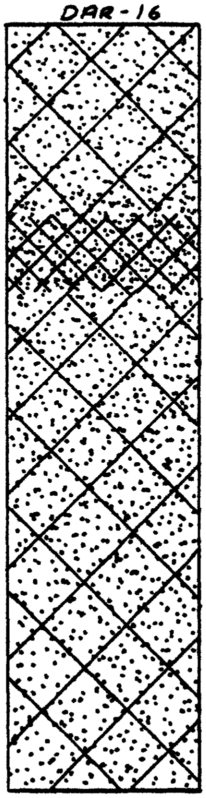
1 cm = 1 meter

Brine saturated with NaCl.

DAR-16

DATE DRILLING COMMENCED/ENDED:

JUNE 20, 1979 / JUNE 21, 1979



UNCONSOLIDATED OXIDIZING SAND AND HALITE: tan, fine to coarse-grained, poorly sorted, angular to round, calcareous. Crystalline halite occurs in varying amounts throughout, peaking in abundance around the 3.00 m level. Euhedral gypsum crystals and anhydrite nodules present,

SCALE

0
1
2
METERS

1 cm = 1 meter

Brine saturated with NaCl.

DATE DRILLING COMMENCED/ENDED:

JUNE 21, 1979/JUNE 21, 1979

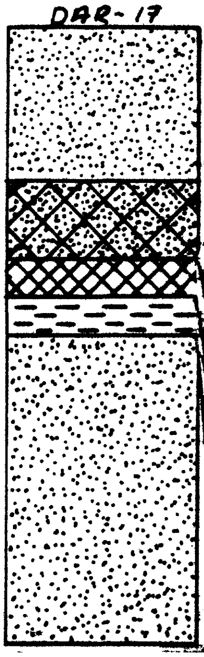
SCALE

0

1

2
METERS

1 cm = 1 meter



UNCONSOLIDATED OXIDIZING SAND: tan, fine to very coarse grained, poorly sorted, angular to round, calcareous. Considerable amount of very coarse-grained euhedral gypsum and halite crystals. Some anhydrite nodules present.

SALT-CEMENTED SAND: sand same as above. Gray-brown reducing clay present, containing euhedral halite and gypsum crystals.
MINERALOGY (2 m–3 m): Predominantly halite and quartz with progressively lesser amounts of feldspar, calcite and gypsum.

CRYSTALLINE HALITE & MINERALOGY: halite with some gypsum and possibly ulexite(?).

REDUCING CLAY: gray, calcareous, arenaceous, with a considerable amount of euhedral halite and gypsum crystals.
MINERALOGY: Predominantly quartz, gypsum and halite with lesser amounts of calcite, feldspar, illite, chlorite and montmorillonite.

Brine saturated with NaCl.

UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, angular to round, calcareous. Considerable amount of euhedral halite and gypsum crystals with some anhydrite nodules.
MINERALOGY: Predominantly quartz, with progressively lesser amounts of halite, calcite, feldspar, gypsum, dolomite and montmorillonite.

DATE DRILLING COMMENCED/ENDED:

JUNE 23, 1979/JUNE 26, 1979

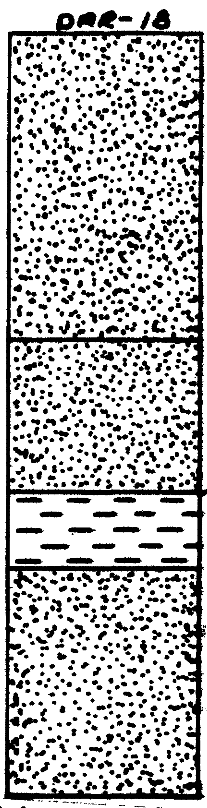
SCALE

0

1

2
METERS

1 cm = 1 meter



UNCONSOLIDATED OXIDIZING SAND: tan, fine- to coarse-grained, poorly sorted, subangular to round, calcareous. Some gypsum crystals present.

UNCONSOLIDATED OXIDIZING SAND: tan, very fine to coarse-grained, poorly sorted, subangular to round, calcareous. Anhydrite and gypsum present.

CLAY: pale green, calcareous.
MINERALOGY: Predominantly dolomite, montmorillonite, mica-montmorillonite and illite with lesser amounts of quartz and halite.

UNCONSOLIDATED OXIDIZING SAND: tan, silt-sized to coarse-grained, poorly sorted, subangular to round, calcareous. Gypsum crystals present.
MINERALOGY(9 m–10 m): Predominantly quartz with progressively lesser amounts of calcite, halite, dolomite, aragonite, montmorillonite and feldspar.

Brine saturated with NaCl.