A REVIEW

OF THE

DOE SITE SCREENING IN BEDDED SALT
PARADOX BASIN, UTAH
PALO DURO BASIN, TEXAS

Robert L. Johnson
Martha W. Pendleton
Ellen Quinn
Robert J. Wright

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INTRODUCTION

Purpose of Trip

Between May 11 and May 21, 1981, members of the Nuclear Regulatory Commission (NRC) technical staff undertook a survey of studies being conducted by the Department of Energy (DOE) in bedded salt, relative to a location for the safe disposal of high-level radioactive waste. This work is part of DOE's National Waste Terminal Storage Program.

The trip was one of a series to survey DOE investigations for the siting of a high-level waste repository. The purposes were:

1. To familiarize the NRC staff with the geology of the salt basins now under study.

2. To survey, from a licensing perspective, the nature and thrust of the DOE-sponsored investigations.

3. To develop technical knowledge that will assist in the preparation of various NRC documents.

It should be noted that the trip was not intended as an evaluation of salt for suitability as a waste repository; nor was it part of any current licensing action by NRC.

Organization of Trip

The bedded salt investigations are focused in two areas: the Paradox Basin in southeast Utah and the Palo Duro Basin in the "panhandle" region of Texas. Accordingly, the NRC trip was divided between the two basins with the following schedule:

May 11, Denver, CO. Discussions with the U.S. Geological Survey.
May 12, Moab, UT. Discussions of investigations in the Paradox Basin.

May 13-14, Moab, UT. Field visit to Paradox Basin study areas.

May 15, Denver, CO. Paradox Basin core storage facility; discussions with U.S. Geological Survey.

May 18, Austin, TX. Discussions of investigations in the Palo Duro Basin.

May 19-20, Amarillo, TX and vicinity. Field visit to Palo Duro Basin study areas.

The work in both regions is coordinated by DOE's prime contractor, Battelle Memorial Institute's Office of Nuclear Waste Isolation. The main investigators are:

Paradox Basin

Woodward-Clyde Consultants
U.S. Geological Survey
Bechtel National Inc.

Palo Duro Basin

Texas Bureau of Economic Geology
Stone and Webster Engineering Corporation

The NRC participants in the trip were:

Robert L. Johnson	Stratigraphy
Martha Pendleton	Structural geology
Ellen Quinn	Groundwater modeling
Robert J. Wright	Geologic exploration

In addition, under NRC consulting and technical assistance contracts, the group was joined by:

Paul Fenske (Paradox Basin only)	Hydrology, Desert Research Institute, Reno, NV
Robert Guzowski	Geology, Sandia National Laboratory, Albuquerque, NM

Organization of the Trip Report

The body of this report is divided into three parts.
Part A discusses the significant features of the Paradox Basin.
Part B provides similar information for the Palo Duro Basin.
Part C provides NRC observations on technical aspects of the repository investigation program, as observed in both basins.

DOE Salt Screening Program

As the plans have been described to the NRC, the DOE expects to select, during 1983, a site in salt for an exploratory test facility. Shaft sinking is expected to start there in late 1983. This site will be selected after a choice has been made, during 1981, between the Paradox Basin and the Palo Duro Basin. Then, during 1982, a selection will be made between the candidate basin and dome salt. The selected site that is nominated in 1983 for the exploratory test facility should, therefore, be the preferred choice among all bedded salt and dome salt candidates.

Part A Paradox Basin

STUDY AREAS

At the present stage of investigations in the Paradox Basin, four areas, in southeast Utah, have been selected for further study (Figure 1). From north to south, and not necessarily in order of preference, these are:

Salt Valley
Lisbon Valley
Gibson Dome
Elk Ridge

The choice of these areas is the result of a systematic screening process based on a number of criteria developed by the Office of Nuclear Waste Isolation (ONWI). Broadly speaking, the criteria fall into two groups: geologic and environmental. The screening process is well documented in a group of three ONWI documents, dated November 1980.

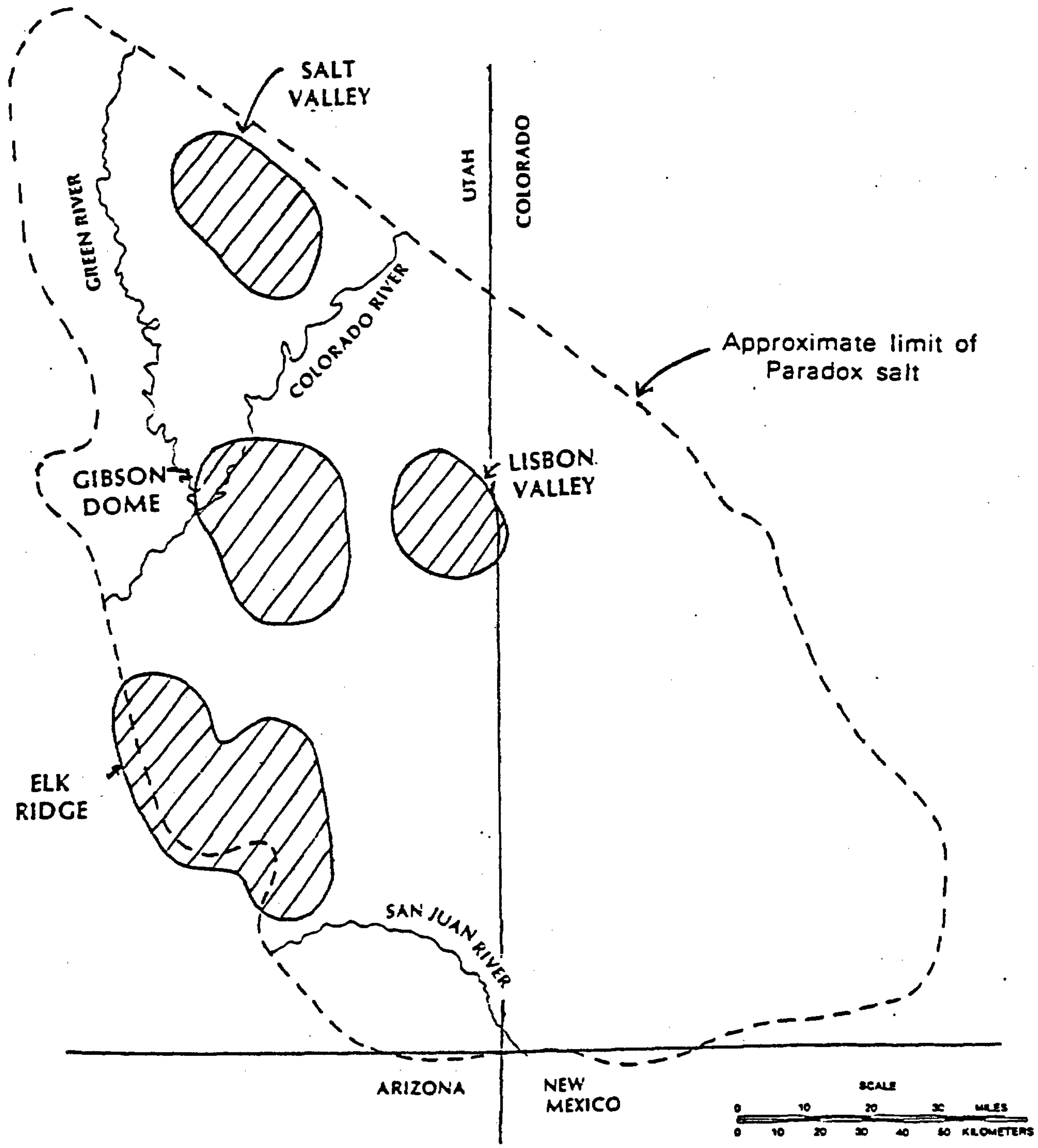
ONWI-92 (1980a) provides a description of regional geology, based on a literature and field work by ONWI contractors. ONWI-68 (1980b) provides general information, taken from published sources, on various aspects of environmental concerns. ONWI-36 (1980c) draws on ONWI-92 and ONWI-68 and on a group of screening criteria (summarized on pages 40 and 41 of ONWI-36) to identify the four study areas mentioned above.

No one screening criterion can be singled out as being more important than others because a study area must satisfy each criterion. However, one criterion--site geometry--is of particular note because it is of particular relevance at all locations. Site geometry involves two screening factors:

1. Depth to saline facies - favorable thickness is between 1,000 and 3,000 feet.

2. Thickness of saline facies - favorable thickness is more than 1,000 feet.

The acceptable range for depth and thickness of salt is grounded in the requirements for repository design. This subject is discussed further in the section on repository design.



Modified from: ONWI, 1980c

Figure 1. Location Map Showing Study Areas in the Paradox Basin

STRATIGRAPHY

Stratigraphic and Lithologic Setting

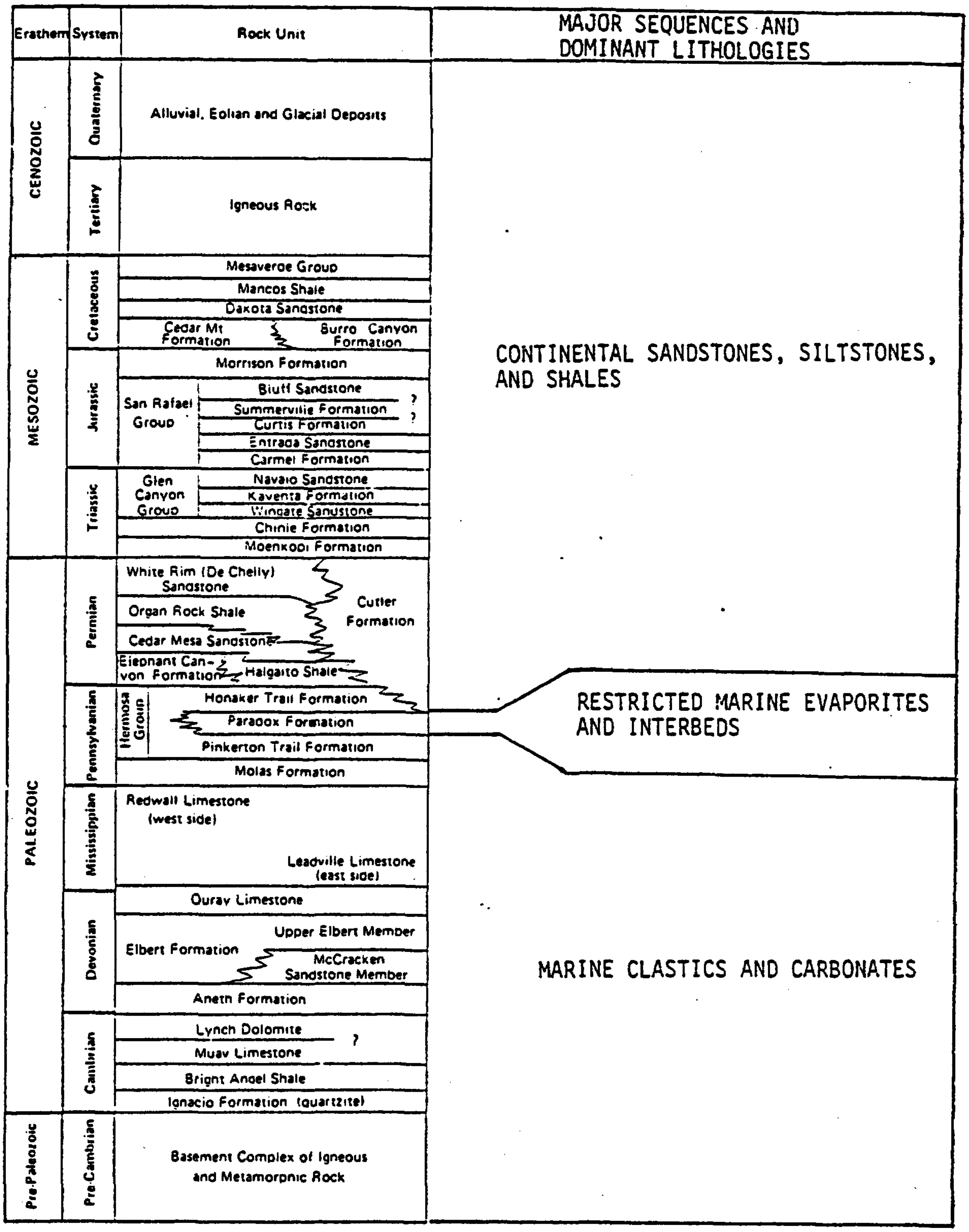
The Paradox Basin boundary is defined, for investigation purposes, as the line of zero salt thickness (Figure 1). The Paradox Basin is about 200 by 100 miles in dimension and contains a thick wedge-shaped sequence of sedimentary rocks ranging from about 6,000 to 18,000 feet thick. Figure 2 illustrates the three major rock sequences deposited predominantly in 1) marine, 2) restricted marine, and 3) continental environments. The corresponding rock types are 1) clastics, limestone, and dolomite; 2) evaporites, dolomite, and clastics; and 3) sandstone, siltstone, and shale respectively. Lateral gradation from one rock type to another is common within the basin. Numerous periods of erosion or nondeposition are also evident.

In the lowest rock sequence, the Leadville Formation is a significant unit, due to the high porosity and permeability of the dolomites and solutioned limestones. These rocks make up the only significant aquifer beneath the evaporites, and are also potential hydrocarbon reservoir rocks. Separating the Leadville aquifer from the evaporites is shale and impervious limestone of the Pinkerton Trail Formation.

The potential repository host rock is the salt-bearing evaporite sequence making up the Paradox Formation of Middle Pennsylvanian age (about 285 million years before present). Maximum thickness is about 6,000 feet, but in the salt anticlines the evaporites are up to 14,000 feet thick due to flow thickening. The depth of the salt is variable ranging from depths of 2,500 to 15,000 feet below the surface, with a 6,000 foot average. Locally, in salt anticlines, salt can be about 500 feet deep.

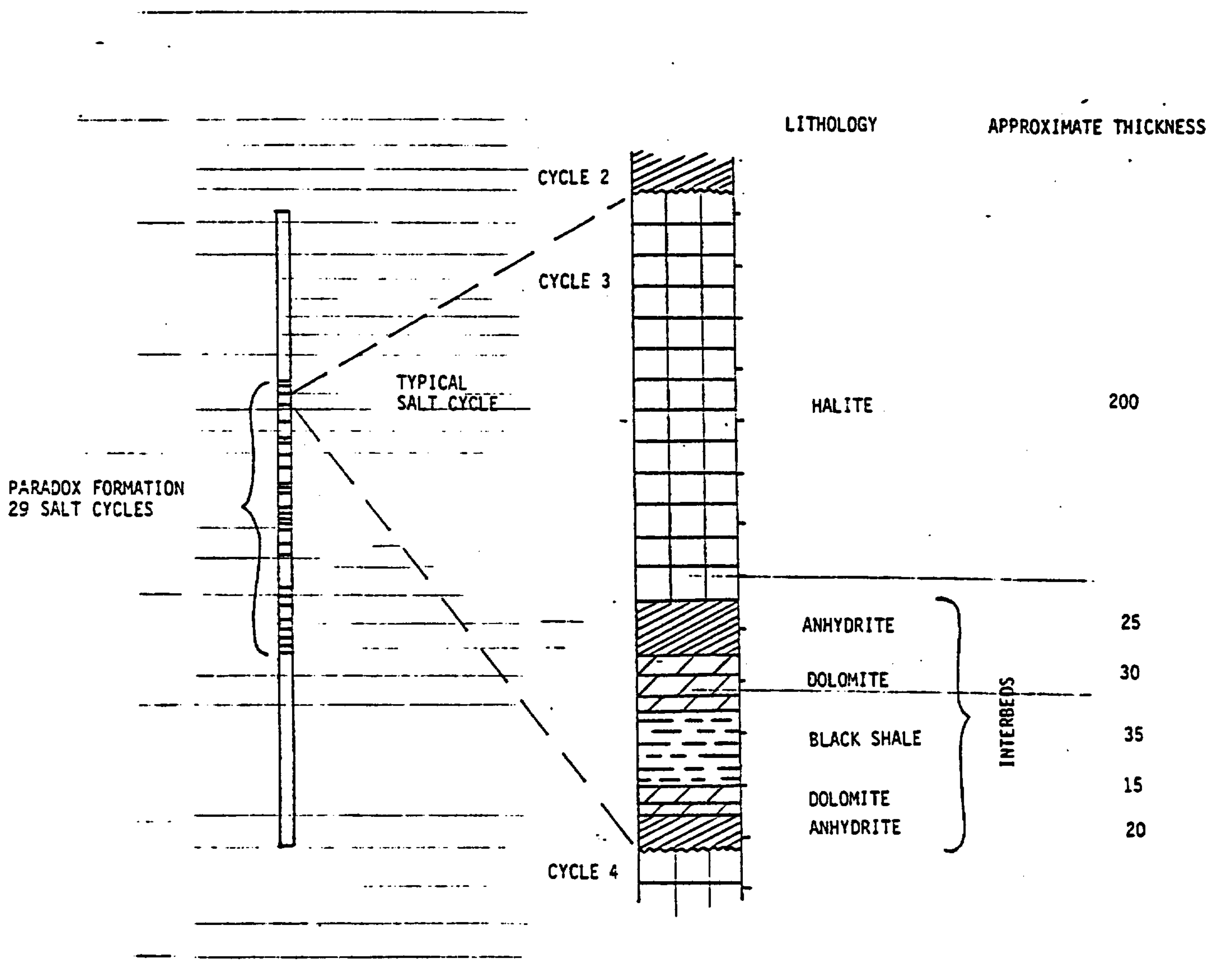
The evaporite sequence is not homogeneous in composition but is composed of at least 29 evaporite cycles deposited in a restricted, high salinity body of water. Adequate characterization of the various lithologies, their thicknesses, areal extent and relationships to adjacent lithologies are necessary for repository design considerations. Figure 3 illustrates the typical sequence and lithologies (lithofacies) making up one cycle. Variations exist between cycles and laterally within a cycle. This results in a different thickness and proportion of each lithofacies, as well as a departure from the ideal order of lithofacies. The salt (halite) of the cycle varies in thickness from 20 to 800 feet with 100 feet being average. Potash zones (sylvite and carnallite) are found near the top of some salt units. Insoluble minerals make up, at most, 5 percent of a salt unit, forming bands of finely disseminated anhydrite or anhydrite partings up to 3 inches in thickness.

Within a single cycle, interbeds of dolomite, black shale and anhydrite underlie each salt unit. The dolomite contains quartz silt, and flows of brine and/or oil and gas have been observed here. The black shale of the cycle can contain up to 50 percent carbonate and 10 to 15 percent organics. Oil and gas may be found in this unit.



Modified from: ONWI, 1980a

Figure 2. Stratigraphic Column Showing Major Rock Sequences in the Paradox Basin



Modified from: Hite and Lohman, 1973

Figure 3. Typical Salt Cycle in the Paradox Basin

In the clastic sequence overlying the Paradox Formation, dolomites and shales are important, low permeability units separating the evaporites from the thick sequence of sandstones and siltstones above, which make up a regional aquifer. The thickness and lithology of this clastic sequence is variable within the basin.

Finally, Quaternary sedimentary deposits are also significant to repository investigations because they may record the most recent processes affecting the region--such as uplift, faulting, erosion, salt dissolution collapse, and climate changes. Windblown and stream clastics are common Quaternary materials and are variable in their areal extent. A complete Quaternary record does not exist, and the ability to date and correlate deposits is very limited.

A large volume of the rocks overlying the Paradox Formation has been removed by late Tertiary and Quaternary erosion. The dramatic erosional features, such as high-relief, deep canyons with steep walls and entrenched meanders, result result from a combination of mechanically weak zones in the rock section combined with rapid tectonic uplift. Studies of Quaternary deposits indicate vertical erosion rates of about 0.8 feet/1000 years and scarp retreat rates of about 0.8 to 1.8 feet/1000 years. These rates may vary geographically, and for short periods of time, rates could be higher.

Stratigraphic Investigations

The stratigraphic data base in the Paradox Basin results from surface mapping of extensive exposures of the rocks overlying the Paradox, together with the subsurface mapping of scattered drill hole information (geophysical logs, etc.) and some purchased seismic survey data. The drill hole information is from exploration for uranium in the clastics overlying the evaporites, potash within the evaporites, and oil and gas in the carbonates beneath the evaporites. Study area investigations have included detailed surface mapping, and drilling one stratigraphic hole at Salt Valley and one at Gibson Dome. About 4,000 feet of caprock and salt core was recovered from the Salt Valley Anticline. About 600 feet of core into the evaporites was recovered from Gibson Dome. A deep continuous core through the evaporites and into the Leadville is currently being drilled at Elk Ridge.

The sparce subsurface data base seems adequate to understand the cyclic nature of the evaporites on a regional scale. The evaporite cycles have been under study for years, making their identification in one hole and correlation between widely spaced holes in undeformed areas fairly certain. Identification and correlation can, however, be difficult in anticlines where flowage has contorted the evaporite units (see Structural Geology section). Confident identification and correlation is a result of the uniform, predictable nature of the cycles and included units, together with evidence provided by lithologic sequence patterns, distinctive geophysical log signatures, insoluble residues, and bromine content.

Microstratigraphy is being developed from the pattern of anhydrite partings or bands within a salt unit. This technique has been used in potash mining to locate and maintain a position within a particular salt unit. This aids in

avoiding interbeds above or below the salt bed which might adversely effect mining.

In contrast to the sparce subsurface information, there are extensive surface exposures of the units overlying the evaporites. Observing and mapping these exposures yields an unusually extensive regional geologic record that is useful in identifying features which, if present, might be adverse to repository performance, such as faults and collapse structures due to dissolution.

STRUCTURAL GEOLOGY

Tectonic Setting

The Paradox Basin is a northwest trending Pennsylvanian depositional basin located in the relatively stable Colorado Plateau Province (Figure 4). In general, sedimentary strata are horizontal to gently dipping, but broad anticlines, abrupt monoclines, salt anticlines and domes, and igneous domes modify the otherwise simple structure. Deposition of the Paradox Formation was controlled by pre-Pennsylvanian structural relief. Northwest trending Precambrian basement faults formed northwest trending fault block highs with intervening lows. Thick sediments were deposited in structural lows, most notably in the Uncompahgre Trough parallel to and southwest of the Uncompahgre Uplift (Figure 4).

The structures that affect the Paradox Formation become more complex toward the Uncompahgre Uplift. Within the Uncompahgre Trough salt anticlines developed in response to regional compression and differential loading of sediments (as in the Salt Valley and Lisbon Valley study areas). Southwest of the Uncompahgre Trough, the salt is relatively undisturbed with gently dipping homoclines, anticlines, and structural domes (as in the Elk Ridge and Gibson Dome study areas).

Regional uplift of the Colorado Plateu was initiated in late Tertiary and is continuing today at a slow rate. Preliminary Quaternary studies have not identified areas of differential uplift within the Paradox Basin.

Salt Anticlines

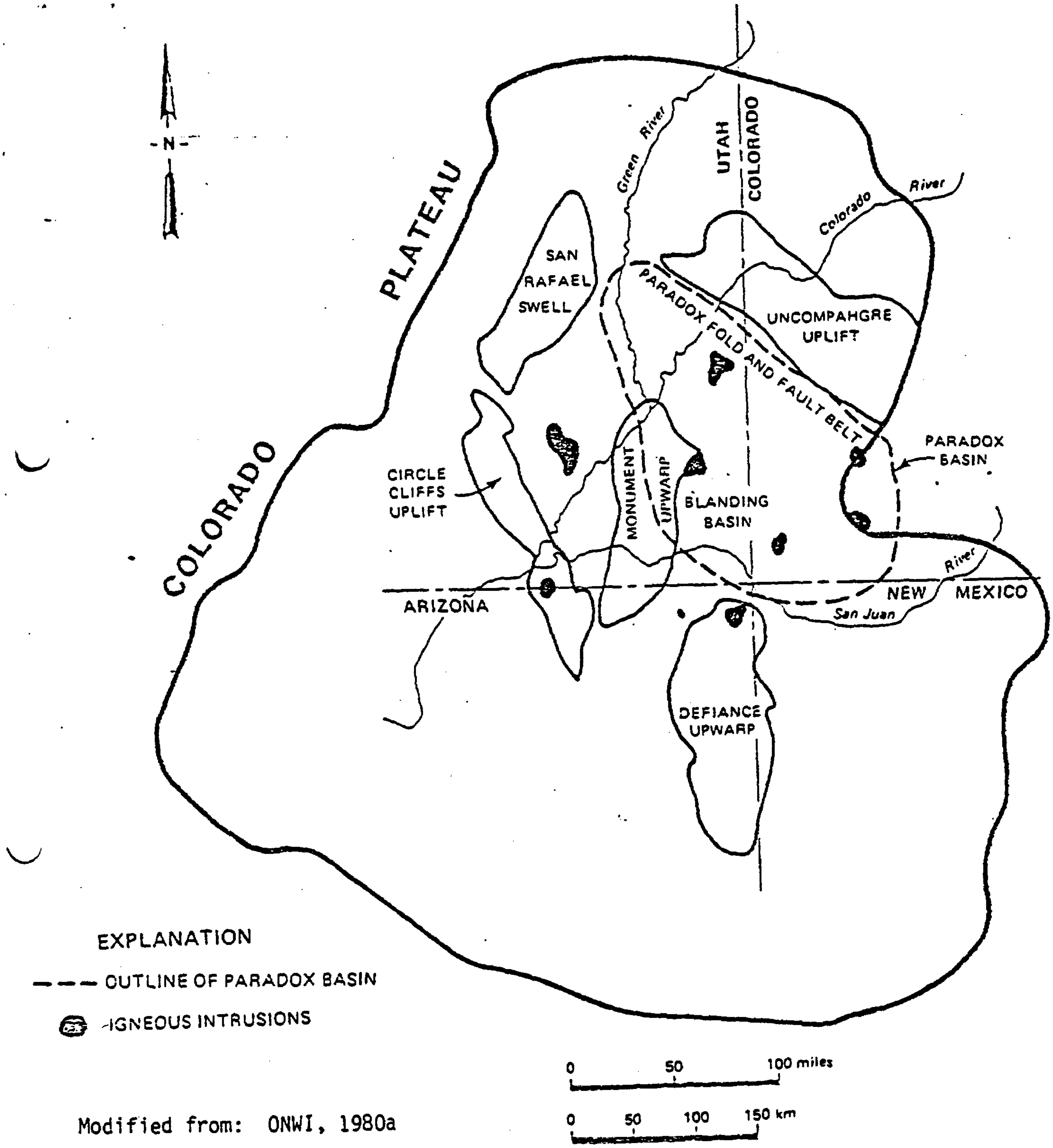
Post mid-Pennsylvanian time, salt flowage from synclinal areas into the adjacent anticlines was triggered by regional compression and differential loading from thicker sediment accumulation in synclinal areas. Within the Uncompagre Trough, progressive flowage of salt continued from synclines to adjacent anticlines through Jurassic time until most of the source had been exhausted.

In some salt anticlines, the salt pierced the overlying strata; elsewhere, no piercement occurred. Growth of the anticlines has locally affected the structure, thickness, and lithofacies of the overlying clastic rocks.

During the early Tertiary, regional compression associated with the Laramide Orogeny may have reactivated some salt flowage. In addition, normal faults and grabens developed along the crests of the salt anticlines. A second period of collapse occurred in mid to late Tertiary, concurrent with uplift of the Colorado Plateau. Increased erosion removed a thick Cretaceous section breaching some anticlines along the crest and initiating rapid solution of salt along the crest.

Faulting

Pre-salt basement faults are northwest and northeast trending, steeply dipping and generally have normal displacement. The top of the bedded salts in the



Modified from: ONWI, 1980a

Figure 4. Generalized Tectonic Map of the Paradox Basin

Paradox Formation masks these deep seated faults and they have no apparent surface expression. The basement faults are potential structural traps for hydrocarbon accumulation and potential locations of salt dissolution. Northwest trending normal faults occur along the flanks of the salt anticlines parallel to the axis of the anticlines. These faults developed as the result of flowage and solution of underlying salt and/or tensional release. Within the salt in salt anticlines, normal, reverse, and thrust faults have been identified.

Notable surface faults include the Needles Fault Zone, and the Moab and Lisbon Valley Faults. The Needles Fault Zone is thought to be the result of collapse following solution or flowage of the underlying salts. Individual grabens with this structural complex are up to 300 feet deep and up to 1,200 feet wide. The Moab and Lisbon Valley Faults are northwest trending normal faults also attributed to solution and collapse and/or flowage of underlying salt. The Moab fault may also be interpreted as a tensional fault that is younger than the Moab Anticline.

No minimum age has been established for surface faulting in the Paradox Basin. Quaternary faulting has been noted in alluvial deposits in Castle Valley, Sinbad Valley, Fisher Valley, and the Paradox Valley.

Seismicity

Because of low population density, the historic seismic record is incomplete. The available data indicate that the Paradox Basin is characterized by low historic seismicity. Seismic activity is recognized in two areas peripheral to the Paradox Basin: 1) the western margin of the Colorado Plateau along the Intermontane Seismic Belt and 2) southeast of the Paradox Basin along the Rio Grande Rift. Ongoing work includes micro-seismic networks in the region to refine the historic record. Preliminary focal plane solutions indicate eastwest maximum compression and strike slip motion along northeast or northwest trending faults. Attention is also being given to the problem of induced seismicity related to mining.

HYDROGEOLOGY

Hydrogeologic Setting

The Paradox Basin is a stratigraphic rather than a hydrogeologic basin. The precipitation in the lower elevations averages six to eight inches per year with variations reflecting topography. Tree ring analysis has shown that the local climate has remained fairly constant for the last 600 years. While the regional geology has been well established from the mappable units, the ground water movements are less well known.

Three hydrogeologic units are recognized: an upper unit containing the Upper Paleozoic through Tertiary beds; a middle unit containing the evaporite beds of the Paradox Formation (middle Pennsylvanian) and the lower unit containing the lower Pennsylvanian and Mississippi strata. The boundary of the lower unit is not known since little information exists about the continuity of flow paths below the Mississippian strata. Within the basin, the salt layer acts as a buffer zone causing the upper and lower systems to act independently; outside the basin, a connection between the aquifers is more likely.

The upper aquifer system is recharged by surface waters in the following areas: the Book Cliffs to the north, the Uncompahgre Uplift to the northeast, the San Juan Mountains to the southeast, and the Monument Upwarp to the south-east. Other areas of local recharge include the Abajo Mountains in the south-west and the LaSal Mountains in the east. The principal discharge points for the upper aquifer are: the Green River, the San Juan River, the Colorado River. Locally, some discharge occurs at small streams. In the southern portions of the region, flow is toward the major rivers; the presence of the Abajo and LaSal Mountains causes relatively steep gradients along their flanks. One hole has been drilled for hydrologic testing in the southern section. A downward gradient exists at this location.

Flow from the northern and eastern section of the region is generally to the southwest toward the Colorado River, but the flow in this region is affected by the presence of salt anticlines trending northwest-southeast.

Investigations around the Salt Valley Anticline have shown that this structure is a barrier to flow. Water flowing southwest off the Uncompahgre Uplift is forced to move either southeast or northwest along the trend of the adjacent syncline. The water flowing southwest along the synclinal trough has a shorter pathway to the Colorado River, but slower flow rates and a decreased gradient are present along this path, because the thickening of beds along the flanks of the anticline has resulted in increased transmissivity. In this area, potential exists for vertical connection between the lower and upper aquifers since the salt is absent in the syncline due to flowage; head measurements have shown that an upward gradient exists.

The principal source of information about the aquifer properties is from holes drilled for oil and gas exploration. Nine holes have been drilled as part of the DOE study to determine the hydrologic character of the caprock of the Salt

Valley anticline. The caprock has very low permeability and conductivity and the water present contains very little total dissolved solid. The caprock does not appear to provide a shortened pathway for water flow across the anticline, but instead could act as a seal against water movement.

Flow in the lower aquifer system is principally to the southwest, reflecting a large, laterally continuous aquifer with a primary discharge location in Arizona. Some of the potentiometric surface maps show the possibility of some recharge in the LaSal and Abajo Mountains. One theory proposed is that the intrusion of these laccoliths, and the associated faulting, has provided a pathway for downward fluid migration and an interconnection between the upper and lower aquifers across the evaporites. The existence of a connection has not been determined and would require additional investigations.

The distribution of head values in the lower aquifer appears to show a reentrant along the Colorado River. Several explanations have been suggested for this phenomena, including: (1) possible vertical connection of the lower aquifer to the river; (2) increased fracturing below the river, resulting in a more permeable zone; and (3) an illusion of vertical connection due to the distribution of recharge areas. The amount of disturbance of the flow system, the association with surface faulting, and the resulting dissolution rate have not yet been determined.

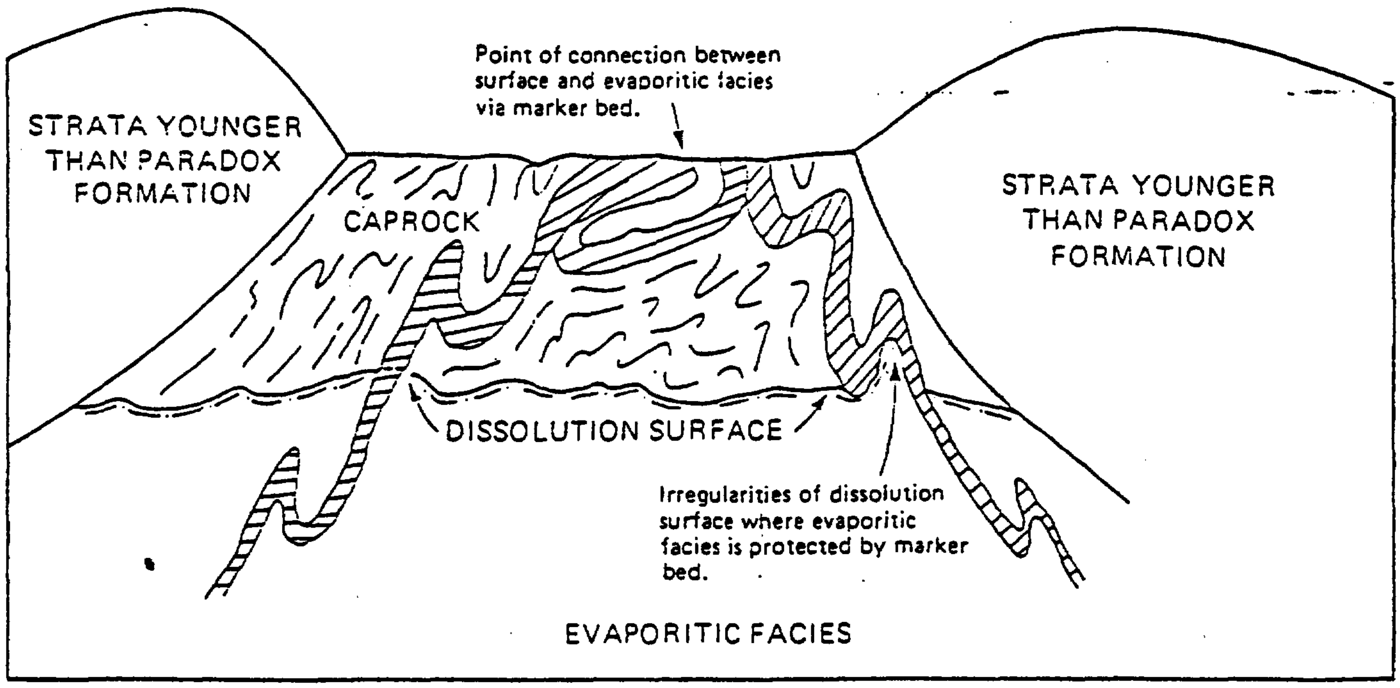
Computer modeling studies have not been applied to the conceptual model of ground water flow since the project is still in the regional characterization phase. Information on aquifer properties is still being collected; a test hole in the Elk Ridge area is currently being drilled. This hole will allow testing of both the upper and lower aquifer.

Dissolution

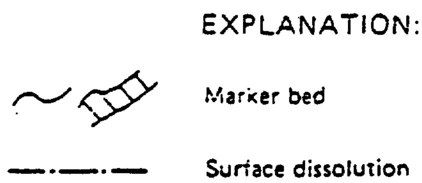
The Paradox Basin salts are confined by aquitards above and below. The impervious nature of the confining rocks appears to protect the salt from dissolution. There is no evidence, in well log data, of extensive loss of salt. Dissolution, however, has occurred along the crest of some salt anticlines, in places along the margin of the basin, and also adjacent to some faults.

Along some anticlinal crests, the salt was dissolved forming a caprock of insoluble residue. Dissolution may have been initiated during the Permian, when anticlinal areas had only a thin veneer of sediments on their crests, and may have continued, in places, until the salt was capped with impervious sediments of the Morrison Formation (late Jurassic). A second period of dissolution was initiated in the Miocene when regional uplift of the Colorado Plateau accelerated erosion which breached the anticlines. Dissolution and caprock formation is still an active process in places.

In the Salt Valley Anticline, data from geophysical logs indicate that dissolution is active along the crests of the anticline but not along the flanks (Figure 5). This observation has not been verified with core. Although contorted interbeds continue from the salt up into the caprock, there is no evidence, to date, that these interbeds serve as a hydraulic connection between caprock and salt.



Schematic cross section through a breached anticline showing relationships between caprock, evaporitic facies, and marker beds.



Modified from: ONWI, 1980a

Figure 5. Diagrammatic Cross Section Through Salt Valley Anticline

To the east of the northeast trending Lockhart fault, the Lockhart syncline forms a circular structural basin. No salt was encountered in a borehole in the center of the Lockhart syncline. This syncline is interpreted to be a collapse depression resulting from dissolution of a large volume of salt. This suggests that there may be areas of local salt dissolution that resulted from faulting in the Leadville limestone which places this aquifer in contact with the salt. Outcrops of gypsum along the San Juan River at the southern margin of the basin and south of the confluence of the Colorado and Green Rivers may indicate that some dissolution has occurred at the margin of the basin and/or adjacent to ground water discharge points. Rates of dissolution and controlling mechanisms have not been studied.

MINERAL RESOURCES

Mineral resources of the Paradox Basin have been studied as part of the regional characterization investigations, with emphasis on the four study areas. These vary considerably in interest for mineral resources.

The greater Lisbon Valley district, including the study area and its environs, has seen significant production of uranium and oil, with lesser values in natural gas and copper. Six hundred million dollars worth of uranium ore has been produced, and mining at a modest level continues. The Lisbon oil field was discovered in 1960 and has since yielded 43 million barrels of crude from a reservoir in the Leadville limestone. One small field has yielded 100,000 barrels of oil from an interbed in the Paradox Formation. These discoveries have stimulated exploration, which is mainly directed to units below the salt.

No mineral production has been reported from the three other study areas -- Salt Valley, Gibson Dome and Elk Ridge. Beds of low-grade potash have been identified by drilling at Salt Valley and Gibson Dome and these may be resources for the future. Elk Ridge is outside the limit of potash deposition in the Paradox Basin.

REPOSITORY DESIGN

A conceptual design for a repository in dome salt was prepared in 1979 (Bechtel National Inc. 1979). Because of the similarity of functions and features to a repository in bedded salt, the dome salt design is used to conceptually illustrate a repository in bedded salt.

The conceptual design provides for one transfer shaft for radioactive waste and four other shafts for men, materials and ventilation. Surface structures would occupy an area of about 400 acres. When completed, the underground waste emplacement area would extend over about 2,000 acres (3 square miles). The assumed storage level is about 2,000 feet below surface.

Two of the key geologic screening specifications are related to engineering requirements. These specifications are:

1. Depth to the saline facies should be in the range of 1,000 to 3,000 feet.

2. Thickness of the saline facies should be 1,000 feet; reason - the probability is high that at least one salt bed exceeds 100 feet in thickness.

A comparison of the conceptual design parameters and the screening requirements suggests a noteworthy discrepancy: whereas the design is for a storage level at 2,000 feet below surface, the screening requirement permits consideration of a host rock at depths up to 3,000 feet. There is also a second special design problem in the Paradox Basin: the Salt Valley and Lisbon Valley require special engineering analyses due to location on salt anticlines. These two matters are discussed in the following paragraphs.

Depth to Salt

An important property of salt, in underground openings, is its tendency to creep under stress. The stress is mainly the result of loading due to the weight of overlying rocks. The effects of creep on an underground opening is to cause convergence of roof, floor and sides. Unless checked, the ultimate result is closure of the opening.

The lithostatic stress field is highly dependent on depth below surface but the depth/stress relationship is far from linear. Wagner (1980) points out that "the depth of the repository appears to be very influential in determining the amount of closure" (page 34) and that "an increase in 500 feet of repository depth increases the floor to roof closure by approximately a factor of two" (page 33). This suggests that the rate of closure at 3,000 foot depth would be four times that at 2,000 feet.

It is unlikely that a repository design suitable for 2,000 foot depth would be similar to one at 3,000 feet. Among the considerations are (1) the effect on room and pillar sizes; (2) the effect on extraction ratios; (3) the methods of holding closure of long-lived haulageways within acceptable limits; and (4) the effect upon retrieval schemes.

It is true that some mines in salt are operated at depths of up to 4,000 feet (England). However, many components of a mine are designed for a limited useful life, compared with the longer term requirements of a repository. A number of reports between 1971 and 1978 on a repository in salt have favored depths less than 3,000 feet (U.S. AEC, 1971; Kans G.S., 1972; Gera, 1972; Johnson and Gonzales, 1978; San 78-1596, 1978). Furthermore, experience in the Texas Gulf Sulphur mine at Moab, Utah (the single mine in salt in the Paradox Basin) shows the importance on mine planning of salt creep at about 3,000 foot depth (Wieselmann, 1968).

Until the suitability of a 3,000 foot depth has been demonstrated by conservative engineering analysis for the Paradox Basin, the use of 3,000 foot as a screening specification must be viewed as questionable.

Interbeds in Salt Valley and Lisbon Valley

The Salt Valley and Lisbon Valley study areas present unusual and particular design problems. These two localities are in salt anticlines, where the salt has flowed from the flanks into the center of the structures. As a result, the center contains a thickened salt section, estimated to be at least 11,000 feet in Salt Valley and 8,000 feet in Lisbon Valley. This compares with the normal 6,000 feet thickness of the undisturbed salt section.

Due to flowage, the beds are contorted, with irregular folding of the salt units and the interbeds (dolomite, black shale and anhydrite). The room and pillar repository layout in salt of an anticline would result in openings that are partly in salt and partly in interbeds. Drilling at Salt Valley indicates that the interbeds make up 15 percent of the total salt section.

The presence of interbeds in the repository host rock raises particular engineering concerns that require assessment before the Salt Valley and Lisbon Valley study areas can be properly evaluated. One matter is the presence of hydrocarbons in the interbeds, especially the black shales: many of the shales contain methane; the Texas Gulf Sulphur Inc. potash mine operated as a gassy mine under the mining regulations; a methane explosion in the mine caused loss of lives; and a one-well oil field in Lisbon Valley yielded 100,000 barrels of oil from an interbed zone. A second matter is ground support. Some interbed rocks may be stronger than salt, but the shale is known to be weak. In the Texas Gulf Sulphur mine steel arch supports were necessary in this rock. For repository design in a salt anticline special attention will be needed to control of natural gas and to ground support in weak rocks.

On the other hand, there may be some advantages in a location in a salt anticline. Some interbeds (e.g. dolomite) may be stronger than salt. Also, a salt anticline may offer a greater range of depths to salt than a bedded salt site. Careful engineering analysis is needed.

CORE MANAGEMENT

In the Paradox Basin, a 4,000 foot borehole in Salt Valley and a 6,000 foot borehole in Gibson dome have been completed. Core management by the U.S. Geologic Survey (GS) and Woodward-Clyde Consultants (WC) is proceeding under the WC quality assurance plan. At the drill site, core is removed from the core barrel, boxed, marked with depth, and transported to Moab for detailed logging. Samples to be put aside for hydrologic testing are sealed at the drill site. After detailed stratigraphic logging in Moab, the core is shipped to Denver for storage and testing.

At the core facility in Denver, samples of core are distributed for testing to 1) GS and WC and 2) other organizations involved in repository investigations after approval of a testing plan. Samples that are shipped out of the core facility for testing are photographed and any unused part of the core is returned to the facility after testing. At the core facility, a small composite sample is taken of each two feet of core by grooving the core along the vertical axis and collecting the shavings. Analyses completed in Denver include x-ray diffraction (whole rock), insoluble residue, optical (as necessary), fluorescence, bromine, and hydrocarbon. Hydrologic, geotechnical, and mineral analysis is completed by WC in California. No provision has been established to retain a continuous sample of core as a permanent record or reference core.

Part B Palo Duro Basin

STUDY AREAS

Within the Permian salt region that extends from western Kansas south and west through parts of Oklahoma, Texas and New Mexico, the DOE investigations are concentrated in the Panhandle of Texas. Here, two basins are potentially favorable for waste isolation - the Palo Duro and the smaller Dalhart. For the purposes of this report both basins are embraced within the name Palo Duro, unless separate mention is made of Dalhart.

Screening criteria for the Palo Duro Basin are generally similar to those in the Paradox Basin, although some differences are evident. Briefly stated, some of the key criteria for selection of a study area are:

Salt depth - 1,000 feet to 3,000 feet
Salt thickness - 70 feet minimum with less than 15 percent interbeds
Absence of dissolution
Separation from known deposits of oil and natural gas
Adequate lateral extent of salt

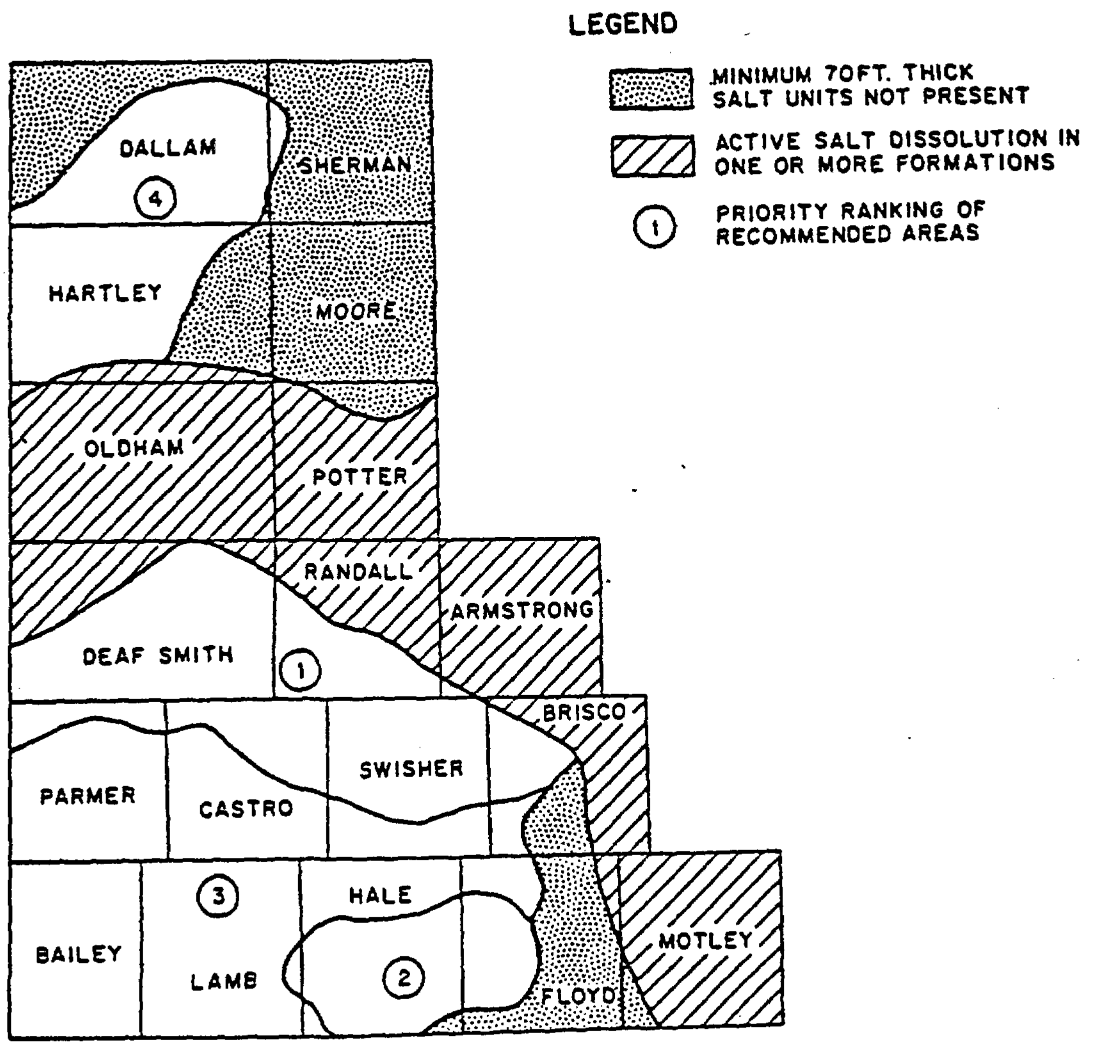
Application of these tests to the Palo Duro Basin has yielded four recommended study areas (Figure 6), which have been ranked by priority for further study.

Area 1 is underlain throughout by three target salt beds; a fourth bed is present in places.

Area 2 has the thickest target bed outside Area 1.

Area 3 has one target bed throughout, and a second is represented in places.

Area 4, which is in the Dalhart Basin, is underlain by a single target bed of minimum thickness near maximum allowable depth.



FROM: Stone and Webster, 1981

Figure 6. Location Map Showing Study Areas in the Palo Duro and Dalhart Basins

STRATIGRAPHY

Stratigraphic and Lithologic Setting

The Palo Duro and Dalhart Basins are two of five subbasins making up the Permian Basin defined by the line of zero salt thickness in Figure 7. The Palo Duro Basin is about 175 by 60 miles (EW by NS) in dimension and the Dalhart Basin is 60 by 75 miles (EW by NS). About 9,000 to 11,000 feet of sedimentary rocks are within these basin areas, respectively.

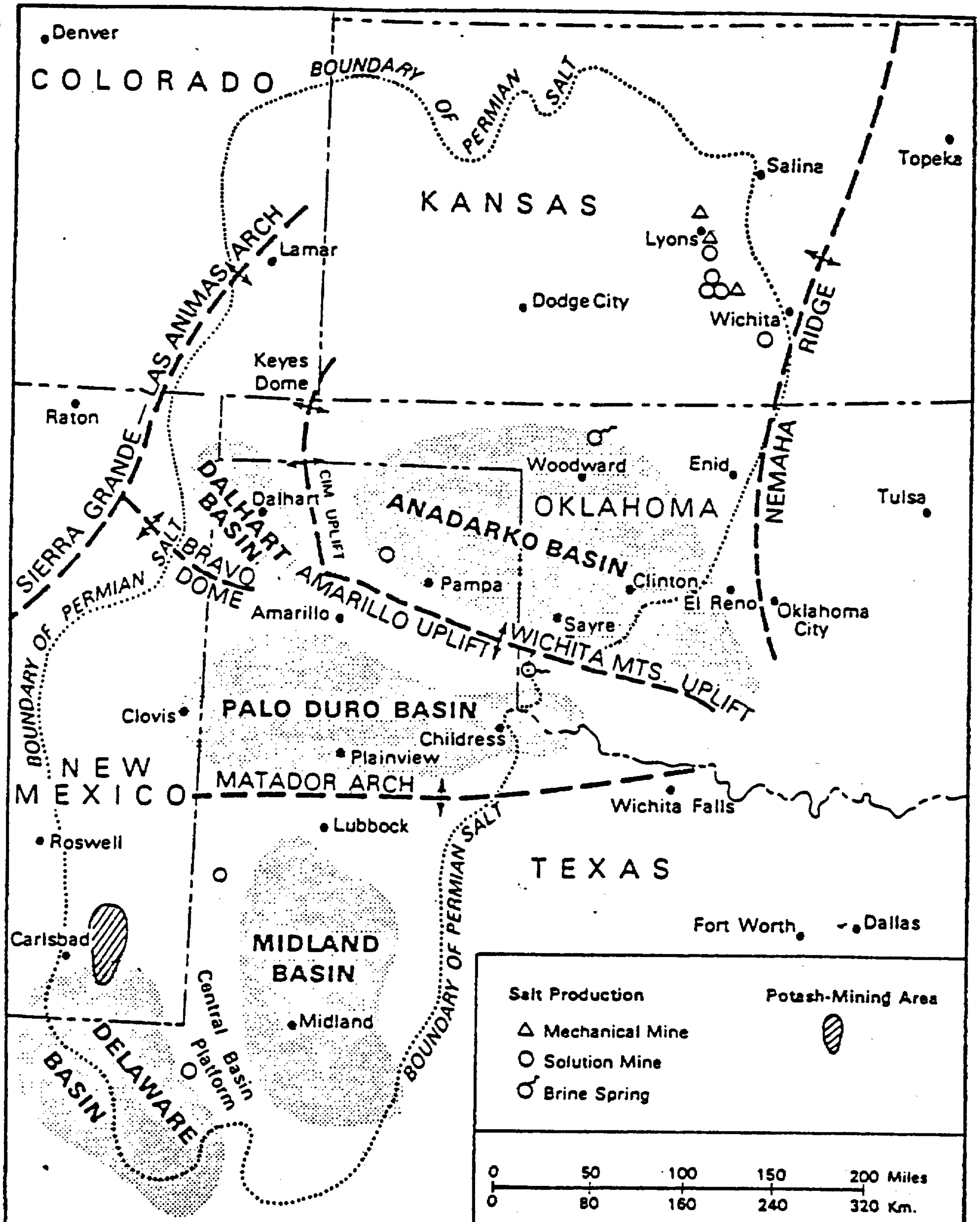
The complete sedimentary column can be separated into three major sequences: 1) pre-Permian marine carbonates and clastics, 2) Permian evaporites and clastics, and 3) post-Permian continental clastics (Figure 8). The Permian evaporite sequence contains the salt beds of interest for a repository. This sequence records a regional retreat of marine conditions which prevailed during much of the Paleozic, followed by continental deposition dominating from late Paleozoic to the present. This change of environments resulted in lateral and vertical variability of rock types and numerous unconformities in response to erosional or nondepositional periods.

The Pennsylvanian dolomites, sandstones, and shales near the top of the pre-Permian sequence underlie the evaporites and are important to studies of groundwater flow and hydrocarbon resources. Many of these units are brine aquifers and are potential reservoirs for hydrocarbons. The deep shales under proper conditions can be source rocks for hydrocarbons.

The Permian (250 to 280 million years before present) evaporite and clastic sequence is of interest for a potential repository. This sequence ranges from 5,000 to 7,000 feet thick and about 1,000 to more than 5,000 feet from the surface to the top of the salt. It represents a transition from dominantly marine to continental deposits. Typical of this transitional sequence are numerous lithologic cycles of varying scales resulting in horizontal and vertical lithologic variability. Changes in sea level, climate, and clastic source area were the dominant controls on shifting depositional environments. Adequate characterization of the various rock types (lithofacies), their thickness, areal extent, and relationships to adjacent lithofacies are important in repository design considerations.

Five major cycles have been identified within the evaporites and are shown in Figure 8. Generally each cycle has a basal section dominated by chemical precipitates (i.e., carbonate, anhydrite, and halite) which is overlain by predominantly continental clastic redbeds. The percentage of each lithofacies within the cycles is variable. These cycles were deposited in a coastal system consisting of a shallow shelf, salt flats (sabka) and alluvial fan plains above sea level and north of the marine basin.

Seven major salt units are identified within these major cycles (Figure 8). Parts of each salt unit satisfy the screening criteria: they are between 1,000 and 3,000 feet deep and contain more than 70 feet of net salt. (Net salt refers to the total thickness of relatively pure salt as interpreted from geophysical well logs and excludes anhydrite/gypsum, carbonate, and clastic interbeds).



FROM: Johnson, D. S. and Gonzales, 1978

Figure 7. Generalized Tectonic Map of the Palo Duro Basin

ERA	SYSTEM	SERIES	GROUP	FORMATION	MAJOR CYCLES	MAJOR SEQUENCES AND DOMINANT LITHOLOGIES
CENOZOIC	QUATERNARY			RECENT FLUVIAL AND LACUSTRINE DEPOSITS		POST-PERMIAN CONTINENTAL CLASTICS
	TERTIARY			OGALLALA		
	CRETACEOUS		DAKOTA			
				FREDRICKSBURG		
MESOZOIC				TRINITY		
	JURASSIC			MORRISON		
				EXETER		
	TRIASSIC		DOCKUM	TRUJILLO		
				TECOVAS		
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE		PERMIAN EVAPORITES AND CLASTICS
				ALIBATES		
		GUADALUPE	ARTESIA/ WHITEHORSE	SALADO salt	5	
				YATES		
				SEVEN RIVERS salt		
				QUEEN/GRAYBURG		
				SAN ANDRES/BLAINE salt	4	
		LEONARD	CLEAR FORK	GLORIETA salt	3	
				UPPER CLEAR FORK salt		
				TUBB	2	
				LOWER CLEAR FORK salt		
				RED CAVE	1	
			WICHITA			
		WOLFCAMP				
	PENNSYLVANIAN	CISCO				PRE-PERMIAN MARINE CARBONATES AND CLASTICS
		CANYON				
		STRAWN				
		ATOKA/BEND				
		MORROW				
	MISSISSIPPIAN	CHESTER				
		MERMAL				
		OSAGE				
	ORDOVICIAN		ELLENBURGER			
	CAMBRIAN		UNNAMED SANDSTONES			
	PRECAMBRIAN					

Modified from: Stone & Webster Engineering Corporation, 1981

Figure 8. Stratigraphic Column Showing Major Cycles in the Palo Duro Basin

Within any of the five major cycles are minor or second order cycles. An idealized cycle is shown in Figure 9; however, these cycles can have different orders and percentages of each lithofacies. Each minor cycle, like each major cycle, represents a shift from marine to continental conditions through time. Dolomite, anhydrite, and clastics (red beds) are the major lithofacies or interbeds which are associated with the salt, both vertically and laterally. There is a wide range of thickness of both the salt beds and the interbeds over the complete evaporite sequence with beds ranging from inches to hundreds of feet. Any one salt bed can extend for many miles before thinning and intertonguing with another lithofacies. Salt beds are divided into a massive-banded salt and chaotic-mudstone salt lithofacies. The massive-banded salt is 85 to greater than 95 percent pure salt, commonly in beds of about 3 to 10 feet thick. These beds are separted by organic-rich bands which are one to six inches thick. The chaotic-mudstone salt contains fifteen to twenty percent or more mudstone (clay and silt sized clay minerals and quartz). The clastic, or red bed, lithofacies contains predominantly red to brown sands, silts, and clays. All of these lithofacies grade laterally and vertically, causing changes in salt purity.

The third sequence, post-Permian continental clastics, consists primarily of Triassic sandstones and shales (Dockum Group) and Tertiary sands and gravels (Ogallala Formation). Respectively, the range in thickness of these units is 300 to 400 feet and 200 to 500 feet. Both of these units are aquifers, the Ogallala (the upper unit) providing the major groundwater input to the active salt dissolution along the Caprock Escarpment and Canadian River. Finally, Quarternary deposits of loess, dune sand and alluvium are very thin and limited in extent. A complete Quaternary record does not exist, and the ability to date and correlate deposits is very limited.

Erosion is a rapid, active process in the Palo Duro Basin along the edges of the High Plains (Caprock Escarpment) and along the canyons cutting into the High Plains. Geomorphologic studies are continuing to refine rates of denudation and scarp retreat from limited data. Preliminary denudation values range from about 0.8 to 1.2 mm/yr over the basin while scarp retreat ranges from about 1 to 2 cm/yr along the Canadian River to 11 to 18 cm/yr along the Caprock Escarpment. Scarp retreats and salt dissolution processes interact and affect each other.

Stratigraphic Investigations

The stratigraphic data base in the Palo Duro and Dalhart Basins is primarily derived from the well logs from petroleum exploration in units underlying the salt. Over 2,000 data points have been used to construct and interpret subsurface maps and cross sections. For the Ogallala aquifer a much more extensive data base is developed from water well logs. Only limited information has been gained from the surface exposures along the Caprock Escarpment and the canyons cut into the High Plains. These exposures are restricted to the upper Permian red beds and overlying Triassic and Tertiary clastics.

Thus far, DOE investigations have drilled two coreholes in the Palo Duro Basin through the Permian salt units to a depth of about 4,000 feet. Two additional

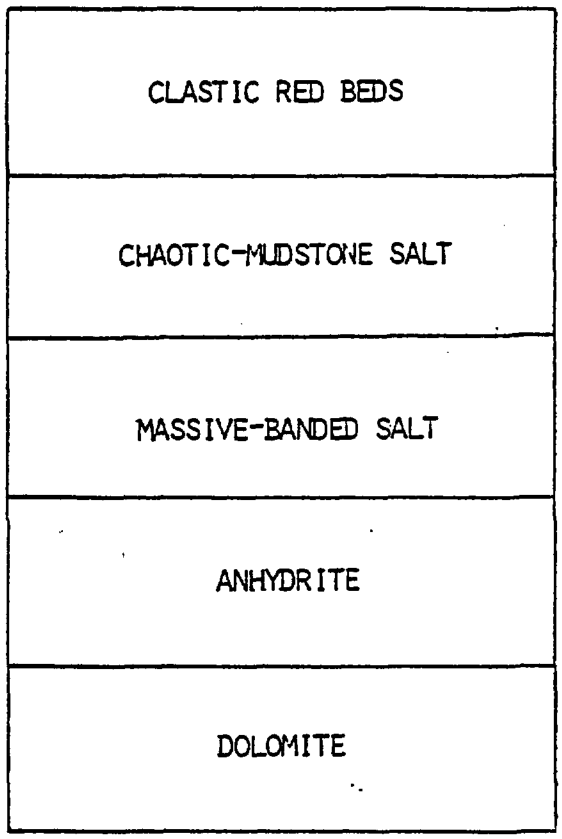


Figure 9 Idealized Salt Cycle in the Palo Duro Basin

holes will soon be drilled to provide core and testing. One hole will be drilled through the evaporites and into the Pennsylvanian and the other will penetrate a salt dissolution zone east of the Caprock Escarpment.

The two existing cores have been valuable for calibrating lithofacies identified in the core to geophysical logs (e.g., gamma ray, sonic neutron porosity, and caliper). This has enabled a refined lithofacies interpretation of petroleum exploration logs. Salt purity has also been determined from log interpretation.

Ongoing studies with an emphasis on lithofacies analysis and a well developed understanding of paleodepositional environments of the Permian evaporites have provided a systematic interpretation of both vertical and lateral variations in rock types, salt quality, and thickness of units. This approach is working toward a sound basis for predicting the rock types and their properties using a minimum of drill holes.

STRUCTURAL GEOLOGY

Tectonic Setting

The east-west trending Palo Duro Basin is located within a large Permian salt basin which is subdivided into variously oriented smaller basins and uplifts (Figure 7). The Palo Duro Basin is bounded by the Matador Arch to the south, the Amarillo Uplift to the north, and the Bravo Dome to the northwest. These features developed largely as the result of Pennsylvanian tectonism. Major downwarping and sedimentation occurred during the Permian, resulting in a thick accumulation of sediments in the basins. Mildly deformed to undeformed Permian and post Permian rocks indicate that tectonic activity had largely subsided by the end of the Permian. Although minor subsidence is continuing at the present, the Palo Duro Basin is considered tectonically quiescent.

Ongoing structural and tectonic studies are focused on developing and verifying a structural/tectonic model of the Palo Duro Basin. Basement structure is being analysed with particular attention to the Amarillo Uplift, a prominant structural discontinuity and location of seismic activity. Existing baseline data include well logs, regional gravity, geophysical profiles, and fracture studies. Preliminary conclusions indicate that the Palo Duro Basin is a low within an uplifted basement block defined by high angle, reverse faults that bound the Amarillo Uplift and the Matador Arch.

Seismicity

The historic seismic record is largely non-instrumental in the Palo Duro Basin. This limited data base indicates that the basin is characterized by low historic seismicity. Earthquakes greater than intensity V (MM) are rare in the region. Some seismic activity is coincident with the Amarillo Uplift.

Future work will include micro-seismic networks to refine the current understanding of seismicity in the Palo Duro Basin.

HYDROGEOLOGY

The Palo Duro Basin is located in a semi-arid environment which receives an average of 18-23 inches of rain per year. Two major drainage basins, the Canadian River Basin and the Red River Basin, are located in the study region. A small portion of the Bravo River Basin is also located in the region. The basin contains several reservoirs which supply approximately 100,000 acre-feet to the cities near the Canadian River and 12,000 acre-feet to cities near the Red River. Two aquifer systems, the shallow fresh water aquifers and the deep basin units, are separated by the Permian salt units.

The principal aquifer in the pre-Permian section above the salt is the Tertiary Ogallala Formation. This is the primary water source supplying over 90% of irrigation water in the Palo Duro. The Ogallala is a fluvial sequence generally deposited unconformably on Permian and Triassic rocks. Ground water in the unit is usually under unconfined conditions although locally confined conditions can exist. Flow is generally to the east-southeast. Because of the fluvial origin of the Ogallala, there is much vertical and lateral variation in grain size, sorting and hydrologic properties. Transmissivities reported range from 20,000 to 130,000 gpd/ft while the coefficient of storage ranges from 1.4×10^1 to 9×10^3. The saturated thickness can vary from a few feet to more than 500 feet and well yields have been reported from 100 gpm to 2000 gpm. Locally, the Quaternary alluvium and eolian deposits overlying the Ogallala may produce significant amounts of water but commonly they serve as recharge areas for the Ogallala. Similarly, the Cretaceous may provide water locally, but is not a contributor on a regional scale. The Triassic Dockum Group is the only other significant aquifer in the region. It contains fluvial deposits up to 760 feet thick. Wells in the formation have pumped 300-700 gpm while springs have flows up to 1500 gpm. The quality of water is very variable, with some areas having dissolved solids too high even for irrigation.

Recharge occurs through vertical leakage between aquifers, infiltration of precipitation and underflow. The amount of recharge from infiltration to the Ogallala has been estimated to be significantly less than one inch per year. The recharge is inhibited, in part, by the caliche and clay soil. Some recharge may occur through the playa lakes in the area, but the amount of recharge from this source is unknown. The final area for recharge is in drainageways cutting the Ogallala. Here water is able to percolate into the Ogallala through the permeable stream beds. The system discharges naturally through springs and through evapotranspiration, but the most important form of discharge is through pumping. The water pumped from the Ogallala is much more than the recharge.

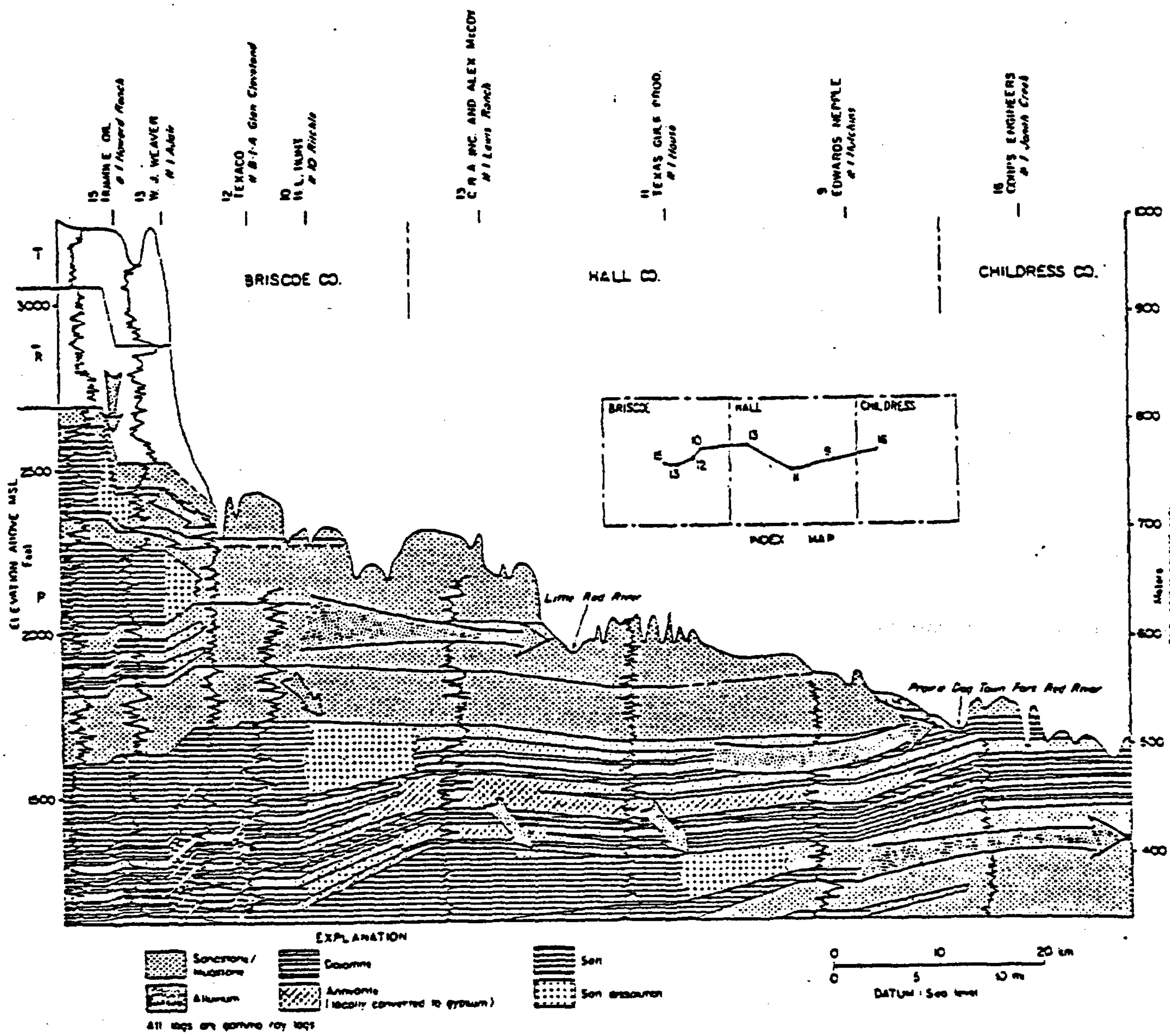
The flow systems in the formations below the Permian salt are poorly known. Generally, there is agreement that flow is from west to east and that the head distribution is controlled by facies changes. The deep aquifers do not appear to be affected by the topography because of the overlying "buffer zone" of salt. Vertical interconnection between the lower units exists possibly through faults, joints, or unconformities. The deep aquifers are at a higher head than the upper units but seepage is expected to be very slow due to the thick intermediate salt zone.

Dissolution

Numerous features such as sink holes, salt pans and seeps, saline springs, and micro-faulting indicate that salt dissolution is an active process along the northern margin and the central section of the Palo Duro Basin. Zones of active dissolution have been identified under and east of the High Plains Escarpment and beneath the Canadian River Valley and are thus closely coincident with the High Plains Escarpment. Salt dissolution at shallow to moderate depths is related to the location of major streams. Current work indicates that salt dissolution occurs primarily through back-wasting instead of vertical down-wasting (Figure 10). An inclined dissolution front occurs at the updip limit of salt beds. Fresh water, percolating vertically through the permeable Ogallala Formation and continuing through fractures into the underlying Dockum Group, dissolves salt and moves it laterally to discharge points. Depth to active dissolution is generally less than 1,000 feet.

Paleodissolution has also been noted in the Palo Duro Basin. In the eastern and northern Texas Panhandle, regional subsidence and structural deformation of Permian and younger sediments has resulted from salt dissolution. Major stratigraphic thinning from downsection solution of salt has been documented in the Salado and Tansill formations. North of the Canadian River, as much as 75 m (250 feet) of subsidence has occurred as the result of salt dissolution. Fracturing, folding, and chimneys of collapse breccia have been identified in areas of paleodissolution. In the Palo Duro Basin, dissolution has probably been active from late Tertiary through the present.

Ongoing studies are aimed at developing a conceptual model of groundwater movement as it relates to salt dissolution in the region to evaluate the impact of salt dissolution on repository siting. Some computer modeling has been done on the Caprock Escarpment in the northern section of the region, an attempt to represent the dissolution seen in the area. This information, combined with data on escarpment retreat, should provide a better understanding of expected dissolution rates. Horizontal dissolution rates along the eastern Caprock Escarpment range from 0.03 to 8.17 cm per year.



FROM: Gustavson, T. C., et al, 1980

Figure 10. Conceptual Ground Water Flow Model for the High Plains and Rolling Plains Region

MINERAL RESOURCES

Generally speaking, the potential for mineral resources in the Palo Duro Basin is low. The outlook for potash or uranium discoveries is unpromising, but somewhat better for oil and gas.

Although located in a productive part of Texas, little oil and gas has been discovered in the basin. A one million barrel field is known about thirty miles northwest of Amarillo. There is some production along the east margin of the basin, and production is considerable on the arches that bound the basin: the Amarillo Uplift to the north and the Matador Arch to the south. The major potential for oil and gas is from reservoirs beneath the salt units.

Studies of oil and gas potential indicate that many potential reservoirs and possible source rock and traps exist in the Palo Duro Basin; however, the amount of organic carbon matter deposited in the rocks is on the low side for major hydrocarbon accumulation. Furthermore, the organic material in the sediments probably did not reach temperatures necessary to generate oil and gas from all types of organic material present. Most likely only the source rocks at greatest depth in the basin center contain organic material which could generate hydrocarbons under the moderate temperature of that depth.

REPOSITORY DESIGN

The conceptual repository design used in the Palo Duro Basin is the same as that for the Paradox Basin, viz Bechtel National, Inc. 1979.

The section on repository design in Part A of this report, dealing with the Paradox Basin, discusses two matters in which site screening lacks support from engineering analysis: (1) the depth of salt and (2) potential problems related to interbeds. These matters also apply to the Palo Duro Basin, and in this basin there is also a third matter: salt thickness.

Depth of Salt

The Palo Duro Basin screening criteria call for an allowable host-rock depth of 1,000 to 3,000 feet, based on Brunton, G. D. et al., (1978). The referenced paper states that mining experience indicates that salt creep is excessive and hazardous below the 3,000 foot depth (page 7). However, no engineering analysis is provided to support this selection of maximum favorable depth. As previously discussed (page 24), the chosen conceptual design is for a depth of 2,000 feet, and no engineering basis has been presented for acceptability of 3,000 feet.

Effect of Interbeds

Interbeds in the Palo Duro Basin do not contain black shale, and have less natural gas, as compared with the Paradox Basin. They consist primarily of dolomite, anhydrite, and clays or silts. The interbeds may be stronger or weaker than the salt, and this must be taken into account where openings in the interbeds are planned. The interbed strength has a bearing on the thickness of salt that should be provided above the repository roof to provide stability; this, in turn affects the minimum acceptable thickness of the salt.

Thickness of Salt

The thickness of salt necessary to house a repository calls for several engineering design and geologic judgements. These include: the strength of the interbeds, particularly those within and above the salt; the needed thickness of salt above the repository opening; the variability of salt thickness within the repository area; the lateral continuity of thickness; and the amount and type of impurities in the salt.

In the Palo Duro Basin a screening requirement is "at least one individual salt unit having a minimum thickness of 70 feet (including no more than 15 percent of interbedded non-salt lithologies)." We have no reason to challenge this criterion. On the other hand there appears to be no justification from engineering analysis or design parameters and no explanation of the use of 70 feet in the Palo Duro Basin and 100 feet in the Pardox Basin. Furthermore, it is unclear whether the purity (percent mud) of the salt that is acceptable for design has been taken into account during screening.

CORE MANAGEMENT

Two 4,000 foot bore holes have been drilled in the region of interest. Prior to coring each run, PVC pipe is inserted into the core barrel to minimize mechanical damage to the core during drilling. The core, enclosed in PVC pipe, is then extruded from the core barrel and cut into 6-foot lengths. At the drill site, some core is extruded briefly to note zones of core loss and then replaced in the PVC pipe. After sealing both ends of the pipe, the core is transported by truck to Austin for detailed logging, analysis, and storage.

In Austin, the PVC pipe is split and the core is logged and photographed. In zones where the salt is at least fifty feet thick, a three foot section of core is sealed and set aside for rock mechanics, thermal, chemical, and waste interaction studies. The remaining core is cut lengthwise into two pieces. One piece is set aside as a reference sample for the core library, and the remaining two-thirds of the core is set aside for sampling. Salt cores are sealed in plastic bags to minimize dissolution and efflorescence.

To date, analysis on the Palo Duro Basin core have been aimed at lithologic, hydrologic, and potential resource studies. Analyses include fluid content, porosity, permeability, evaporite residue, fluid inclusions, hydrocarbon, petrography, uranium and molybdenum, copper, and multi-element analysis.

PART C OBSERVATIONS

This section of the trip report contains comments on technical aspects of the site screening program in the Palo Duro Basin and the Paradox Basin as viewed from the licensing perspective. The following matters are discussed below:

1. Site screening process
2. Use of proposed 10 CFR 60
3. Salt depth criterion
4. Engineering design
5. Drill core management
6. Hydrologic studies
7. Hydrologic modeling

1. Site Screening Process

As we understand the present (May 1981) plans, DOE expects to select a site in salt where shaft sinking for underground testing will begin in CY 1983. This salt site will be selected by a choice between the Palo Duro Basin and the Paradox Basin by the end of CY 1981, to be followed in 1982 by a choice between the selected basin and dome salt.

From the technical standpoint, we find it difficult to envisage a selection procedure for choosing between two basins, or between a basin and dome salt. Since the ultimate objective is a licensable site, the selection standards should be based on site-specific technical criteria of proposed 10 CFR 60, and these place heavy emphasis on the characteristics of the site. Perhaps what is meant is that the best site in the Palo Duro Basin will be compared with the best site in the Paradox Basin, the chosen site in bedded salt then to be compared with a chosen salt dome. If this is correct, it could be advisable to consider all sites at one time and choose from all possibilities in both bedded salt and dome salt. Three advantages can be seen:

a. Each site would be reviewed at a single time by a single group of individuals using a single set of selection standards.

b. One-time selection would help to assure that comparable information is available on each site.

c. Salt Valley and Lisbon Valley, two of the study areas in the Paradox Basin, present a special problem: they have some features of both dome salt and bedded salt. These locations could be better evaluated on intrinsic merit if matched against both bedded salt and dome salt sites.

2. Use of Proposed 10 CFR 60

The geologic criteria now used in site selection (for example, ONWI-36, 1980C) are drawn from a variety of sources. More consistent application of the criteria by which the sites will ultimately be evaluated (i.e., the technical criteria of proposed 10 CFR 60) would sharpen the standards used in site selection. Also, it

would tend to focus work more on technical licensing needs and less on scientific goals. Finally, it would help ensure that the present investigations are developing the kinds of information that will be necessary for licensing attention.

3. Salt Depth Criterion

Because of its tendency toward plastic deformation, salt presents special problems in rock mechanics. Under the current screening criteria, a maximum depth of 3,000 feet is considered to be acceptable, from the standpoint of maintenance of an underground opening without collapse due to lithostatic loading (ONWI-36, 1980c, p. 42). However, the reference conceptual design used in the bedded salt studies (BNI, 1979) was developed for a depth of 2,000 feet. The effect of the 3,000-foot depth on such matters as ground support, size of openings, extraction ratio, the useful life of openings and the approach to retrieval needs clarification. One DOE study (Wagner, 1980) suggests that the rate of closure at 3,000 feet may be four times that at 2,000 feet. Until conservative engineering analysis demonstrates the feasibility of a repository at 3,000 feet, the 3,000 foot siting criterion cannot be considered as demonstrably valid. A number of reports between 1971 and 1978 have favored depths less than 3,000 feet (see page 24).

4. Engineering Design

The need for integration of design requirements and siting criteria is noted in the preceeding paragraph. The interaction between design and siting studies is also needed elsewhere. For example, the Salt Valley and Lisbon Valley study areas present a special evaluation problem. Drilling shows that the salt beds here are contorted due to flowage, and that interbeds of dolomite, black shale and anhydrite constitute part of the salt section. Some of the interbeds contain methane, which proved hazardous at the Texas Gulf Sulphur potash mine near Moab. The normal room and pillar repository layout (e.g., BNI, 1979) would result in openings that are partly in interbeds. The Salt Valley and Lisbon Valley study areas can not be adequately evaluted, in site screening, without an engineering analysis of the effect of interbeds on repository design.

5. Drill Core Management

Three comments can be made about the management of core taken from boreholes in the sudy areas.

a. All core should be logged geologically, especially with respect to fractures, immediately upon recovery from the core barrel. This is important from two standpoints: (i) some fractures are apt to be developed during transport to the field office, and these can be identified only if the core is first logged at the drill site; (ii) from the quality assurance standpoint, logging at the site provides a safeguard against the effects of possible loss or mix-up of core during handling and transport to the field office.

b. The requests for samples of core come to the project offices from many investigators with different interests and different needs for samples. All requests may be valid, but they need to be rationalized against the finite amount of core and judged in the light of both today's and tomorrow's interests. There are several needs in both the Palo Duro Basin and the Paradox Basin: (i) an integrated core testing program, which will satisfy the information needs of both geology and engineering and ensure proper sequencing of nondestructive and destructive tests; (ii) controlled distribution of core in keeping with the testing program; and (iii) parallelism between PDB and PB test activities, so that comparable information is gathered.

c. Normal industry practice suggests that a certain portion of the entire core from key boreholes is retained for future reference. In the Palo Duro Basin and Paradox Basin investigations, some sections of core, particularly in the proposed repository host rocks, have been totally distributed to investigators. A policy is needed to ensure that a portion of the entire core from key holes is held for future review.

6. Hydrologic Studies

In the Palo Duro Basin, emphasis to date has been placed on modeling the upper aquifer system in the area of the Caprock Escarpment as an aid in the analysis of regional dissolution. In the Paradox Basin, attention to date is focused on the regional flow systems in hydrogeologic units above and below the salt.

Some differences in thrust of the hydrologic studies in the two basins are expectable, but the variance in approach may pose a problem during the site screening process because comparable information may not exist.

7. Hydrologic Modeling

During previous discussions with ONWI, the principal codes planned for use in performance assessment have been identified: PATHS, VTT, GETOUT FE3DGW MMT, and PABLM. However, the investigators in Palo Duro Basin and Paradox Basin present modeling analyses and plans for future work using other codes. The NRC would like, as soon as possible, to be made aware of the codes planned for use during site characterization so benchmarking can be done. In addition, the relation between modeling efforts by contractors and by ONWI should be clarified so that NRC has a clear understanding of the planned use of modeling to support geologic conclusions and performance assessment. If the site characterization report submittals include conclusions about geologic processes based partially or completely on modeling, it is appropriate that codes used on the project are consonant with those of the ONWI modeling program.

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