APPRAISAL OF THE
ENVIRONMENTAL ASSESSMENT
DOCUMENTS OF
LAVENDER AND DAVIS CANYON SITES,
SAN JUAN COUNTY, UTAH

PREPARED FOR
STATE OF UTAH
OFFICE OF PLANNING AND BUDGET
HIGH LEVEL NUCLEAR WASTE PROJECT
BY

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I INTRODUCTION

This report will serve as an appraisal of the geologic aspects of the Environmental Assessments (EA's) of Lavender and Davis Canyons, San Juan County, Utah. The subject EA's were prepared by the U.S. Department of Energy (DOE) as part of the process of evaluating the suitability of sites for the development of repositories, per the Nuclear Waste Policy Act of 1982.

The work has been done for the State of Utah Office of Planning and Budget, High Level Nuclear Waste Project. The objective has been to provide the state with a technical basis on which to judge the EA's prepared by the DOE. It is significant to note that probably well over one hundred man-years provided the basis for the EA's and that the few man-weeks of this study can only be a brief review.

The project is located in the western portion of the Paradox Basin (Figure 1).

Following a discussion of the findings of my geologic work in the course of this study, I will review the EA's relative to my findings and past experience. To close, my conclusions will be given.

II GEOLOGY

A. Surface Geology -

Introduction -

A moderately detailed (1 inch = 2000 feet) surface evaluation of the Lavender and Davis Canyon proposed repository sites was considered essential to the EA evaluation. This was especially so since the conclusions on which the EA's were based apparently were arrived at from the basis of regional geology, seismic studies (not available to the State of Utah), and remote sensing studies. This present study benefitted greatly by superb color air photos graciously loaned by the Monticello, Utah, office of the U.S. Bureau of Land Management (BLM). Those air photos (at a scale of approximately 1.8 inches = 1 mile) provided the basis for mapping formational contacts and structural features, via a magnifying stereoviewer and film overlays. Areas of approximately 11 square miles and 9 square miles were mapped at Davis and Lavender Canyons respectively. The geologic mapping data are presented as Plate 1.

Stratigraphy -

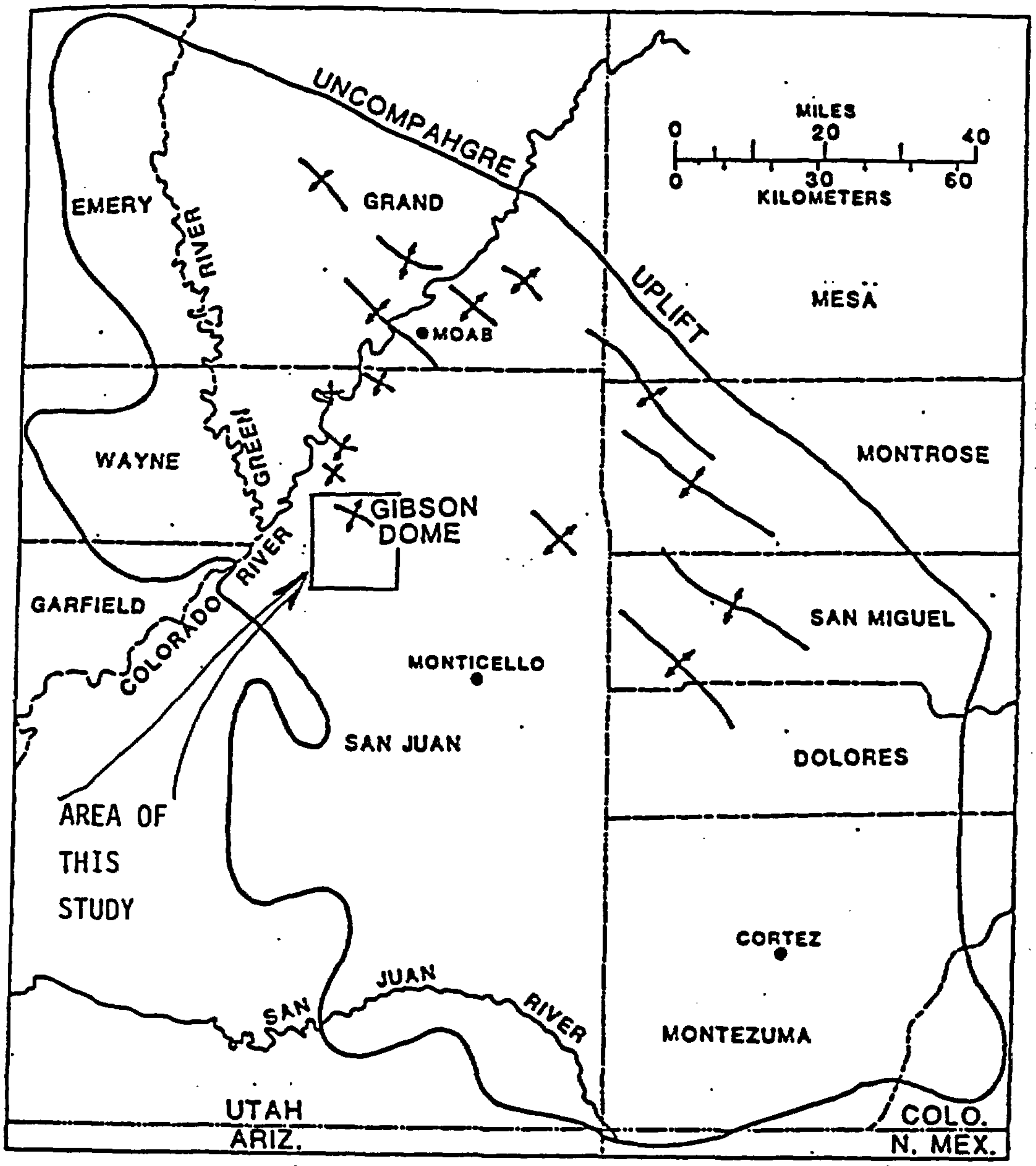


Figure 1. Index map of the Paradox Basin showing salt anticlines and limits of halite and potash in the Paradox Member of the Hermosa Formation. Modified from Hite, 1982.

The stratigraphy of the area has been amply described in the professional literature and will not be repeated in detail here. Very simply, strata exposed in the areas of detailed study (Figure 2) ranged from the Cedar Mesa Formation of the Permian Cutler Group to the Triassic Kayenta Formation. The Cedar Mesa was exposed in the southern and/or western portions of the areas mapped, where erosion has exposed older rocks. The Organ Rock Formation is present over wide areas of the lower slopes of both areas, although widely masked by a thin veneer of colluvial and wind blown material (the mapping of which was not relevant to this evaluation). The Triassic Moenkopi Formation forms the narrow, upper slopes bordering all of the canyons. It is somewhat more resistant to erosion than the Cutler units beneath. Unconformably overlying the Moenkopi is the Moss Back member of the Triasic Chinle Formation. The Moss Back forms the prominent benches throughout the mapped areas; examples are the flat-topped features from which the North and South Six Shooter Peaks arise. Above the Chinle is the Triassic Wingate Formation which forms the spectacular vertical cliffs of the narrow ridges separating the canyons, as well as the Six Shooter Peaks themselves. The youngest unit present, excluding the Quaternary Alluvium, is the Triassic Kayenta Formation which is the resistant protection for the underlying Wingate. Quaternary age alluvium is present in the drainage bottoms. These distinctive stratigraphic units in an arid environment provide well exposed formational contacts.

Structural Geology -

The structural simplicity of the area (1-4 dips to the east and northeast) belies the stresses which the area must have undergone. All of the stratigraphic section is extensively jointed, although the jointing is more visible in the more competent units. The jointing readings shown on Plate 1 are each representative of several joint measurements taken over broad areas. It should be emphasized that the joints on Plate 1 do not depict even 1% of the actual joints, which occur every 5-40 feet throughout the area. The dominant joint direction is northeasterly (N30E to N60E) with a secondary joint set to the northwest. It is important to note that the jointing is prominant in outcrops immediately adjacent to, and within, the proposed surface facilities. Such jointing is well developed throughout the region, including areas of recharge, up-dip at higher elevations which typically receive more precipitation.

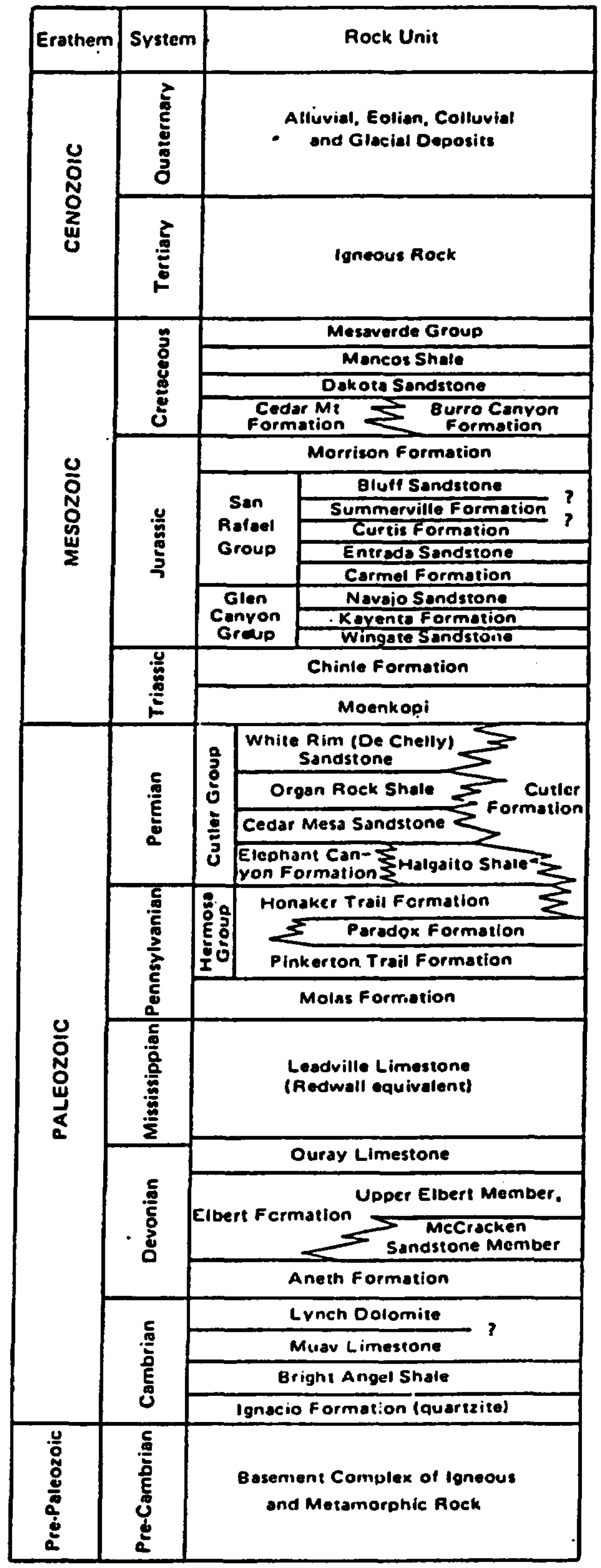


Figure 2. Stratigraphic column.

Modified from Woodward-Clyde Consultants, 1982.

Photographs of typical jointing were obtained in the course of the field study. Their locations are shown by a Photograph Location Map (Figure 3); Figures 4 through 7 depict those joints. Figures 4-A and 5-A illustrate the serrate edges of the more resistant cliffs in the Davis Canyon area caused by jointing. In addition, the upper-left quadrant of Figure 4-A shows the pervasive nature of the jointing, and that the jointing does not occur only along the erosional edges of cliffs. Figure 4-B is a close up of jointing in 4-A. The same joint-controlled, cliff-edge erosion occurs in the Lavender Canyon area as shown by Figure 6-A. An example of jointing further down in the section is shown by Figure 6-B. The existence of prominent joint sets elsewhere in the region is documented by Figure 7 which depicts joints to the southwest of the Davis Canyon site and east of the Lavender Canyon site.

The dominant northeast direction of joints measured in the project area is no coincidence. The primary structural grain over a large portion of the Candidate Area is northeasterly. The Colorado lineament, is a northeast trending fault zone through this portion of the Colorado Plateau which dates back to the Precambrian (Warner, 1978). Many regional structures can be related to crustal weakness resulting from the Colorado lineament, including the remarkably linear trend of the Colorado River just west and northwest of the study area, the left-lateral off-sets of the salt anticlines to the east (Hite, 1975), and Lockhart Fault bounding the northwest side of the Lockhart Basin dissolution collapse feature. The relationship of jointing to the circulation of water and subsequent erosion, on a regional basis, is evident in the distribution of drainages in and around the area (Figures 2-5) including Lavender and Davis Canyons. I call special attention to the drainages on either side of Harts Draw and Indian Creek. The concept of canyon systems being determined by the arrangement of joints is well established in classical geomorphology (Lobeck, 1939 - especially pages 29 and 487); Lohman (1974) also discussed the erosional effect of jointing (pp. 63 and 79).

There are no surface faults mapped within the areas I studied (Plate 1) according to Detterman (1955), Hackman (1955) and Huntoon, and others (1982). During the course of my field studies, I recognized no faulting. I did, however, find two rocks, each 6-8 inches across, which suggest faulting.

The first was a nearly white, banded rock of all crystalline calcite.

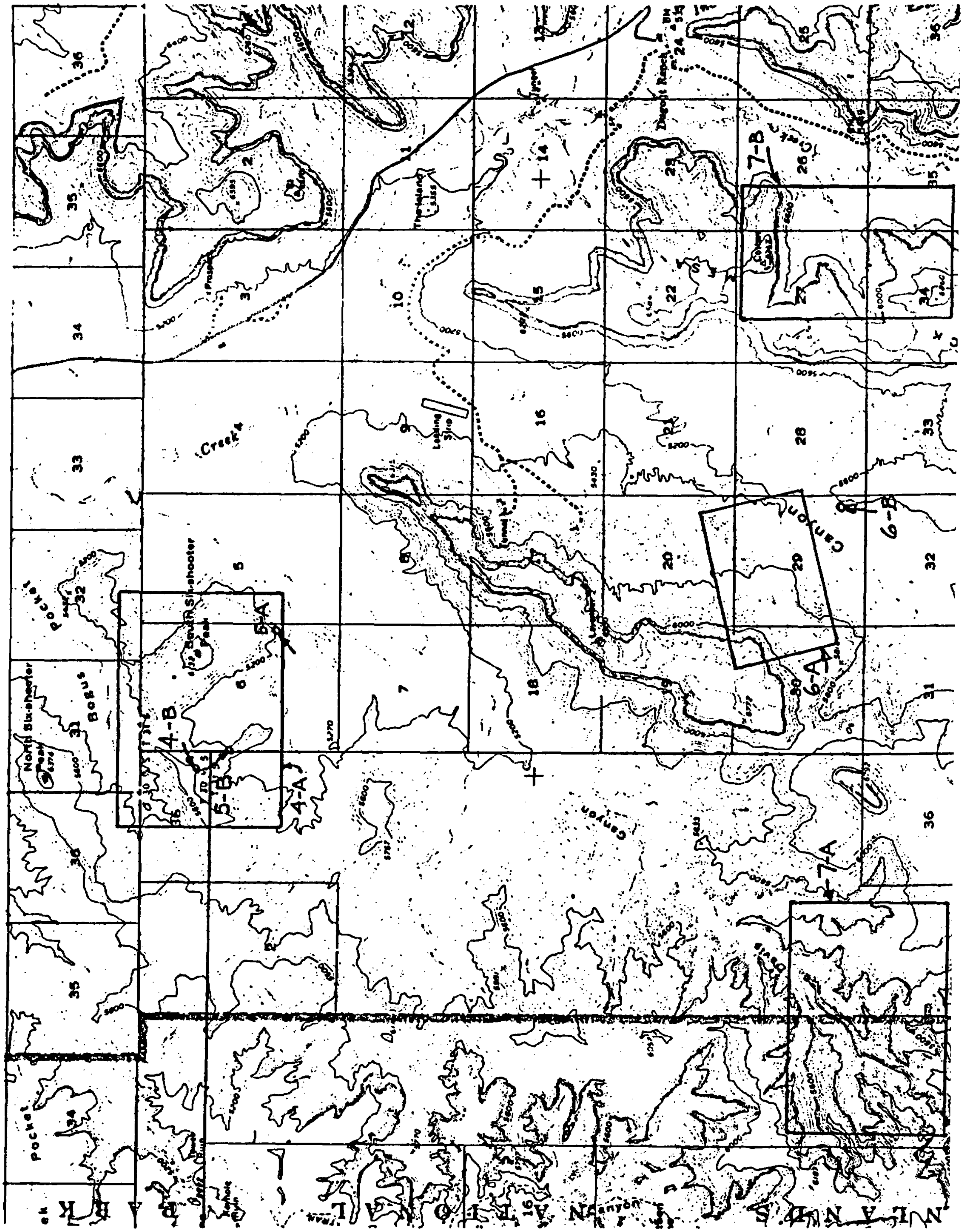
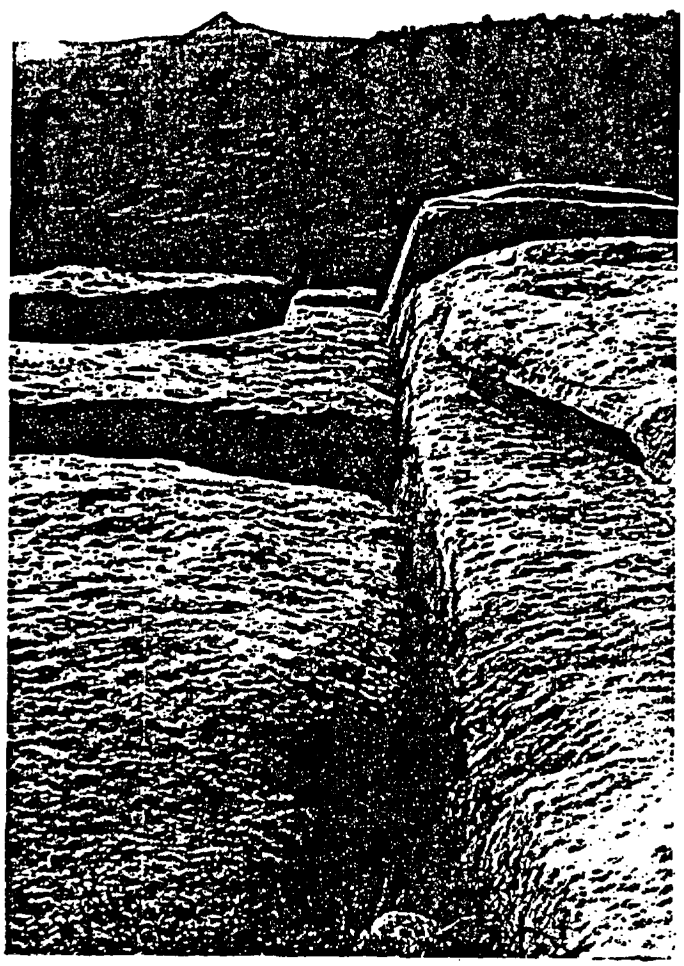


Figure 3. Photograph Location Map.

A.

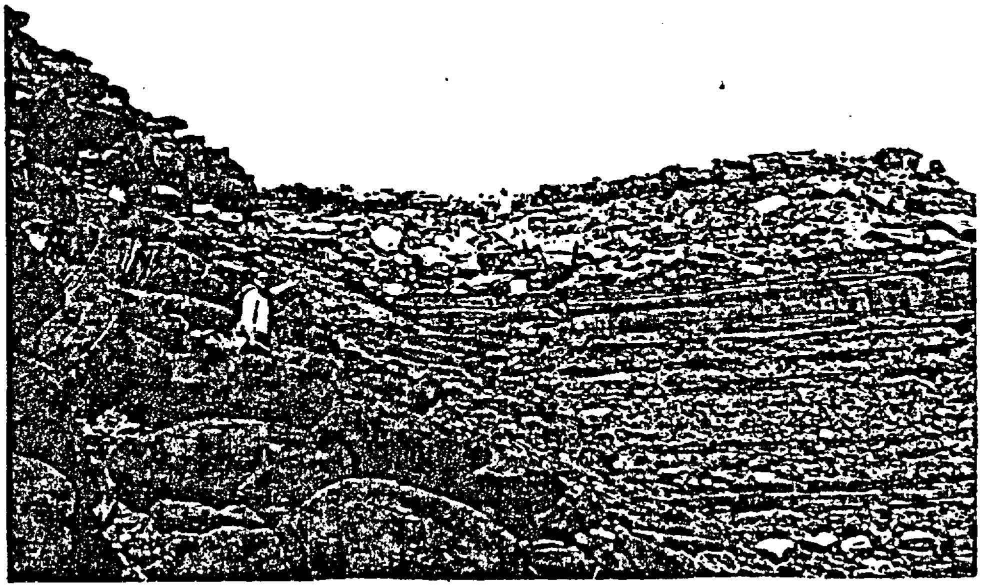
A. Enlarged portion of air photo used in surface mapping. Joints evident throughout South Six Shoot platform. Note especially rectilinear joint pattern in upper left quadrant of picture, and along the cliff edge (blue arrow).

B.



B. Close up of jointing at clif edge just beyond point of left arrow in photo A, above.

Figure 4. Davis Canyon jointing.



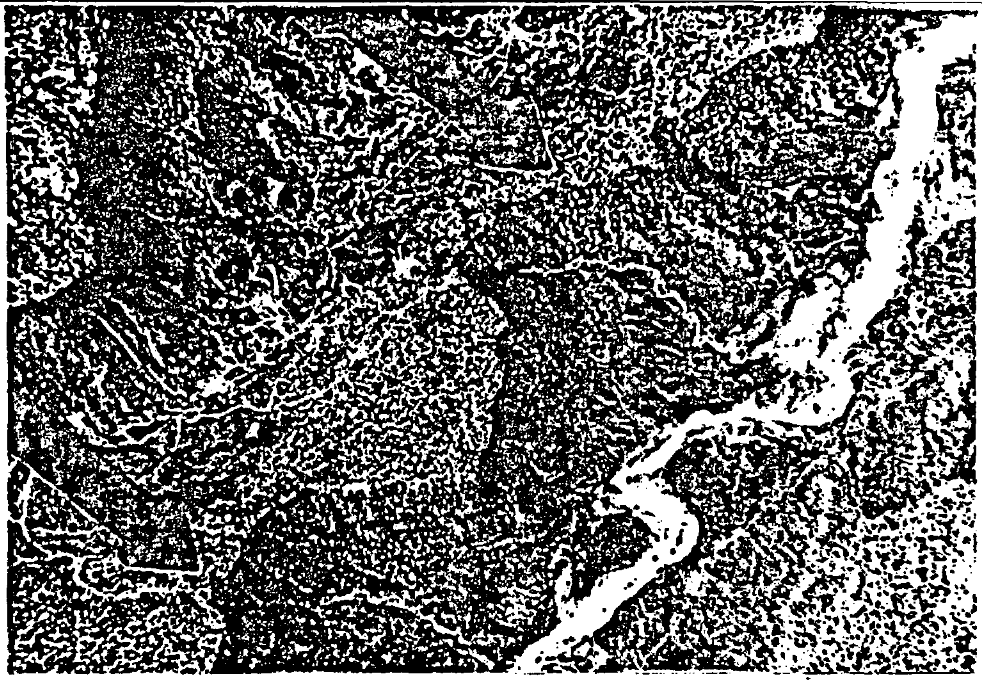
A.

B.

Figure 5. Davis Canyon jointing.

A. Prominent Moss Back jointing on skyline, on south end of South Six Shooter platform. Jointing is also evident in Moenkopi (mid-picture); and in the Organ Rock in foreground, although much rounded by erosion.

B. Prominent Moenkopi jointing on narrow ridge one mile west of South Six Shooter Peak.



A.

B.

Figure 6. Lavender Canyon Jointing.

A. Enlarged portion of air photo used in surface mapping. Serrate edge of Moss Back cliff gives evidence of extensive jointing.

B. Rectangular joint-bounded blocks in upper-most Organ Rock along east side of proposed Lavender Canyon Site.

A.

B.

A. Cedar Mesa sandstone landforms which are controlled by jointing occur in the upper stretches of Davis Canyon.

B. Wingate sandstone erosion controlled by jointing in Cottonwo Canyon, 2 miles due east of the Proposed Lavender Canyon Site.

Figure 7. Nearby, regional examples of joint-controlled erosion. (Both enlarged from air photos used in surface mapping.)

Such a lithology is typically deposited from solution in an open space, resulting in a vein filling. The second piece is composed largely of coarsly crystalline calcite, with the addition of numerous angular chips of reddish brown chalcedony. The arrangement of the chalcedony strongly suggests recurrent movement (i.e., brecciation) during the formation of the rock. This rock also suggests that it originated as an open-space filling. Both rocks were found in Bogus Pocket (Plate 1), but neither was found in place.

Following my return from the field it became evident that sub-surface structural maps of McCleary (1983) show a northeast-trending fault coincident with North Six Shooter Peak in the Pinkerton Trail and older formations; that fault also appears on the isopach map of the Paradox Formation. Is it possible that the erosion of the northeast-trending Bogus Pocket is fault controlled? Can such a fault be found by intensive field examination?

Evidence of salt dissolution was not found in Lavender or Davis Canyons. Such evidence might include the collapse of à central area with faulting, or inward dipping of the surrounding strata, breccia pipes or bleaching of a broad area of generally reddish brown slopes and cliffs. By contrast, the dip of beds and their continuity was very uniform.

There was no evidence of land slide or slump activity in this arid area.

B. Subsurface Geology -

Introduction -

The character of the subsurface geological setting was established by traditional structural and isopach map methods based on geophysical logs of oil and gas exploration tests. A significant contribution to the project came from the files of the State of Utah, Oil, Gas and Mining Division. Those files provided copies of well logs (Table 1), the locations and elevations of the wells, drill stem test (DST) data, comments on hydrocarbon shows and well histories. To suppliment that data base the files of the Utah Geological and Mineralogical Survey provided a limited amount of additional information on DST's and hydrocarbon shows.

It must be noted here that the following subsurface maps were prepared from geophysical logs from only 17 oil and gas tests. By contrast, the Department of Energy's contractors had available the logs plus substantial additional data. Those data included seismic reflection surveys (copies of

TABLE 1... -- WELL CONTROL

(those wells which provided geophysical logs for stratigraphic correlation)

1.	Flying Diamond	Lockhart Gov't. #1-3	2100' FNL/ 509' FWL	Sect.3-29S-20E
2.	Humble/Carter	Rustler Dome #1	2000' FSL/ 820' FWL	4-29S-20E
3.	G.E. Kadane & Sons	Rustler Dome #1	330' FNL/ 330' FWL	15-29S-20E
4.	Damson Oil	Rector Fed. #1	2060' FSL/ 330' FWL	5-29S-21E
5.	Husky Oil	Husky Fed. #6-15	2439' FNL/2344' FWL	15-29S-21E
6.	Union/Pure	Horsehead Unit #1	1980' FSL/ 660' FWL	18-29S-21E
7.	Reynolds Mining Corp.	Gibson Dome #1	1670' FNL/ 275' FEL	35-29 1/2 S-20E
8.	Belco Petroleum	Gibson Dome - State #1	2310' FNL/2471' FEL	2-30S-20E
9.	Union/Pure	Lost Canyon - USA #1	730' FSL/1910' FEL	19-30S-20E
10.	Pan Am. Petrol./Trident	Beef Basin #5	1125' FNL/2005' FWL	32-30S-20E
11.	Woodward-Clyde	Gibson Dome #1	660' FEL/ 660' FSL	21-30S-21E
12.	Pan Am. Petroleum	Beef Basin #1	2425' FSL/1800' FWL	7-31S-20E
13.	Gulf Oil	Hart Point-Fed. #1	1980' FNL/1980' FWL	8-31S-22E
14.	Chorney Oil	Hart Point-Fed. #1	368' FWL/2203' FSL	22-31S-22E
15.	Champlin Petroleum	Dugout Ranch-Fed. #14-22	660' FSL/ 559' FWL	22-31S-22E
16.	Champlin Petroleum	Dugout Ranch #21-2	481' FNL/1994' FWL	2-32S-21E
17.	Placid Oil Co.	USA #DU-2	2041' FWL/1717' FSL	5-33S-21E

which the DOE claims they cannot provide to the State of Utah -- Memo: Zeisloft to Kefer, 12-05-84), structural maps prepared by Petroleum Information (experts in the area) and photogeologic interpretations. This study was severly hampered by not having access to that seismic information and to a lesser extent the other data. As a result Plates 2 through 5 must be considered interim interpretations which are reasonable based on the available data. They should be refined if and when Utah can acquire copies of DOE's seismic data and interpretations.

Stratigraphy -

Of the formations present, the geometry of the total Paradox salt section and of salt cycle 6 were of primary importance. Plate 2 provides an isopach map of the total Paradox salt section. By my definition, that interval is the total thickness from the top of the uppermost salt cycle to the bottom of the lowest salt cycle. Since the study area is near the depositional edge of the saline basin the first salt encountered in drill holes varies across the area from salt cycle 2 to cycle 5 (Hite, 1960). Plate 2 clearly shows the excessively thick salt section which resulted in Gibson Dome. Salt cycle 6 individually exhibits an area of excessive thickness (Plate 3), but to a lesser degree than does the total Paradox salt interval shown on Plate 2. The linear zone of anomalously thick salt which constituted Gibson Dome is one of the lesser Salt Anticlines. Although there is currently no well control close to Davis or Lavender Canysons it is reasonable to predict that Salt cycle 6 at those two proposed repository sites would be thinner (less than 200 feet thick) than was encountered in the DOE exploratory well GD-1 at Gibson Dome.

Structural Geology -

The structural configuration of the Candidate Area could be demonstrated by making a corrected elevation contour map of any stratigraphic marker relative to sea level. The structure of that reliably identifiable horizon nearest to Salt cycle 6, and penetrated by the greatest number of drill holes would have the most value. To satisfy those requirements I chose the top of the Paradox Formation since it was penetrated in all wells used in this study (many oil and gas tests drilled only to the top of the salt). Plate 4 shows that the Paradox Formation structural configuration dips gently to the northeast closely following the trend of the Monument Upwarp. Anomalies on that surface are the Gibson and Rustler Domes. The strike of the structural contours at the Paradox Formation level closely parallel the depositional strike of the Paradox Basin and the strike of outcropping younger formations. The structural configuration on top of the Salt cycle 6 (Plate 5) is predictably similar to that of the top of the Paradox.

C. Petroleum Exploration Data -

Information derived from drillholes of the petroleum exploration industry reveals that 56 drill stem tests (DST's) were run in 14 of the 17 wells used in this study (see Table 2). The majority of those DST's were positioned to test porosity in the Leadville limestone, which typically produced moderate quantities of salt water with minor gas shows indicative of moderately developed porosity. Ismay and Desert Creek DST's likewise produced water, but in much smaller quantities; a slight gas show from the Ismay was tested only in the Chorney, Hart Point well. Drill stem tests within the Paradox salt section generally produced small quantities of drilling mud. An exception to that, however, was in the Reynolds Mining, Gibson Dome #1 well where a test of the interbed between Salt cycles 13 and 14 produced 100 ft. of free oil plus 480 additional feet of hydrocarbon-bearing fluid. Subsequent production testing of that interval, through perforated casing, produced 47.4 barrels of oil.

Although there is no commercial production of oil or gas in, or near, the Candidate Area, the number of DST's in the immediate area suggests that numerous oil and gas shows were encountered during drilling. The wide distribution of hydrocarbons in the Paradox Member has been noted by Hite and Lohman (1973) who state:

> "Oil and petroleum gases, primarily methane, are found in the Paradox Member by almost every well drilled in the Paradox basin."

Possibly the most significant bit of information to come out of the petroleum exploration records is from the Placid Oil, USA #DU-2. That drill hole reported porosity in the form of cavernous limestone in the upper Leadville Formation. That anomalous porosity may be an example of the karst surface discussed under regional stratigraphy, above. An alternate interpretation of the Leadville porosity in the Placid Oil test, (located on the north boundary of the Shay Graben) calls on the dissolution of the carbonate material by solutions passing from the graben boundary fractures.

TABLE 2 -- DRILL STEM TEST SUMMARY

WELL	FORMATION	DST (or other)	RECOVERY
Flying Diamond Lockhart Gov't. #1-3	mid-Leadville	4603 - 4665	3415' salt water
Humble/Carter Rustler Dome #1	top of Leadville	4193 - 4340	240' water cut mud
	upper Leadville	4200 - 4300	230' water cut mud
	mid Leadville	4334 - 4344	3730' black sulfer water
	Elbert	4905 - 5076	200' water cut mud
Kadane & Sons Rustler Dome #1	upper Leadville	4968 - 5013	1426' salt water; 2054' sulfer water
Husky Husky Fed. #1	salt cycles 2 and 3	4500 - 4687	90' drilling mud
	upper Leadville	7490 - 7675	453' gas cut mud; 420' slightly mud cut water
	mid Leadville	7667 - 7765	180' drilling mud 60' slightly gas and water cut mud
	mid Leadville	7775 - 7868	372' water cut mud 2271' very slightly gas cut water
	Elbert and McCracken	8214 - 8420	1083' water cut mud with a trace of g
Union/Pure Horsehead Unit #1	Molas	6359 - 6420	30' drilling mud
	upper Leadville	6420 - 6540	60' drilling mud and 4000' black salt water
	Elbert and McCracken	7131 - 7256	95' drilling mud
Reynolds Gibson Dome #1	interbed between salt 13 & 14	3487 - 3525	Production tested through perforation 47.4 barrels of oil
	interbed between salt 13 & 14	3481 - 3537	130' gas cut mud 350' highly oil cut mud, 100' free oil (gassy)
	upper salt 14	3527 - 3534	20' drilling mud
	mid salt 18	4165 - 4226	35' drilling mud
	Pinkerton Trail	5089 - 5097	3' drilling mud
	lower Leadville	5955 - 5974	190' water
Woodward, Clyde Gibson Dome #1	unknown	17 successful DST's run	not reported
Belco Gibson Dome - State #1	Cane Creek zone (clastic interval beneath salt 21)	4903 - 4955	5' drilling mud
Union Lost Canyon - USA #1	interbed between salt 19 & 20	3742 - 3807	15' drilling mud
	Pinkerton Trail	4103 - 4173	10' drilling mud
	upper Leadville	4428 - 4528	1120' salty sulfer water
	Elbert	5070 - 5215	20' drilling mud
Pan Am/Trident Beef Basin #5		reported "no shows"	
Pan Am/Trident Beef Basin #1		reported "no commercial shows"	
Gulf Hart Point - Fed. #1	upper Ismay	4409 - 4503	30' drilling mud
	lower Ismay	4584 - 4666	30' drilling mud
	Interbed between salt 13 & 14	5731 - 5762	315' highly gas cut mud
	Pinkerton Trail	7150 - 7261	50' drilling mud
	Pinkerton Trail	7147 - 7261	40' drilling mud
	Pinkerton Trail and Molas	7186 - 7301	25' drilling mud
	upper Leadville	7495 - 7568	720' highly gas & water cut drill. mu
	mid Leadville	7608 - 7628	400' muddy salt water
Chorney Hart Point - Fed #1	upper Ismay	4270 - 4375	310' very slightly gas cut drill. mud
	lower Leadville	7458 - 7564	2250' brackish sour water
	lower Leadville	7480 - 7564	2200' salt water
Champlin Dugout Ranch - Fed. #14-22	upper Ismay	4342 - 4404	180' water cut drilling mud 253' water
Champlin Dugout Ranch - Fed. #21-2	upper and lower Ismay	2998 - 3134	556' water
Placid USA #DU-2	Ismay and Desert Creek	2389 - 2703	2703' sulfer water

In either case, such cavernous porosity, up the hydraulic gradient from the Candidate Area, must be viewed with concern as it may reflect a path and/or mechanism for getting ground water into the Paradox evaporite section.

Limonitic alteration seen in the faulted blocks in the eastern extent of the Shay Graben further suggests anomalous fluid flow. The limonite is interpreted to be the result of recent oxygenated groundwater reacting with pyrite which had been deposited earlier in the fault-generated fracture porosity. Since much of the water tested from the Mississippian is sulferous, the present limonite may have once been pyrite generated by Mississippian fluids leaking via the graben system. The implication is that Mississippian water could have access to the Paradox salts via graben faulting, up-dip of the Lavender and Davis Canyon sites

D. Salt Tectonics -

The Paradox Member in the Paradox Basin is possibly best known as a result of the spectacular salt anticlines to the east of the Candidate Area (Hite and Lohman, 1973; Williams, 1964; Haynes, and others, 1972). These northwest-trending anticlines all exhibit a complex history of salt flowage, and in many cases diapirism and dissolution. The salt anticlines have been extensively described in the geologic literature (for example: Cater, 1970). The salt moved episodically from late Pennsylvanian time at least through the Jurassic, in the more prominent anticlines. In some small areas such as at Onion Creek in Fischer Valley (Colman, 1983) and on the Meander Anticline on the Colorado River the salt may still be actively moving.

In the area of this study the nearest salt anticline is Gibson Dome(Plates 2 through 5). It is only a slight swelling of the salt with no diapirism. In the immediate areas of Lavender and Davis Canyons there is no evidence of salt flowage, diapirism or collapse.

III Review of Environmental Assessments -

A. Introduction -

In the following part of this report the geologic aspects of the EA's will be discussed relative to the findings of this study and my experience in the Paradox Basin. Since the geology at the two proposed sites is very similar, my comments will apply to both Davis and Lavender Canyon sites. Comments which pertain to only one site will be so stated. For the convenience of all readers, these comments will follow the format of the

EA's. First I will discuss the geologic aspects of the site, Chapter 3, and secondly the adequacy of that information to meeting the siting guidelines, Chapter 6.

B. Review of Geologic Conditions -

3.2 - GEOLOGIC CONDITIONS -

3.2.1 Regional Geology - This introductory statement is adequately covered.

3.2.2 Geomorphology - This statement is adequately covered.

3.2.2.1 Physiography - The preparation of the EA has overlooked the obvious joint-controlled drainage which I have discussed above. This aspect should have been considered with regard to the manner in which erosion along jointing has modified the physiography of the area via a prominent northeast-trending orientation of the drainages.

3.2.2.2 Erosion - As mentioned in 3.2.2.1 above, the presence and influence of jointing was completely overlooked.

3.2.2.3 Paleoclimate - This section seems adequately covered.

3.2.3 Stratigraphy -

3.2.3.1 Regional Stratigraphic History of the Paradox Basin - This overview section is adequate. I take exception to the references to isopach maps developed by McCleary (1984). There is no way to evaluate the accuracy of those statements under the present posture of the DOE which does not allow them to provide to the State of Utah copies of the seismic data which contributed to the generation of those isopach maps.

3.2.3.2 Site Specific Stratigraphy - The EA statement (paragraph 2) that "The subsurface stratigraphy .... appears consistent and easily traceable for tens of kilometers surrounding the site" is at the same time true and very naive. Indeed, the gross formations can generally be traced for great distances. On the other hand, physical properties of those formations can change dramatically, within short distances. Since the deposits in question were virtually all deposited under marine conditions, one has only to envision the diversity of depositional environments on a sea floor to appreciate that properties such as porosity and permeability of a stratum can vary greatly in short distances. This is even more true along the edges of depositional basins, such as the case of Pennsylvanian deposits in the Paradox Basin.

This instance suggests that the EA's have taken a rather simplified approach to the various lines of documentation.

3.2.3.2.1 Surficial deposits -

through

3.2.3.2.13 Molas Formation - all brief descriptive statements are adequate.

3.2.3.2.14 Leadville limestone - The EA statement that "The top of the formation is an erosion surface is true but inadequate. It is well known (Armstrong and Mamet, 1976) that the erosion on the Leadville surface lasted long enough to produce karst topography and a deep red soil. It was even referenced in ONWI 290 (p. 4-4), but not in the EA. Karst features on the unconformable top of the Mississippian can be seen over widespread parts of the Rocky Mountains and represents a long lived hiatus. Further, the solution-enlarged joints, sinkholes and caves affect as much as the upper 150 ft. of the Mississippian and locally can contribute to groundwater flow paths. In the candidate area, present access of groundwater to that karst zone could be through the Salt Creek - Bridger Jack - Shay graben system. In the future, periods of higher precipitation could conceivably provide access of fresh water to the sub-salt strata via the grabens and the Mississippian karst zone.

3.2.3.2.15 Ouray Limestone -

through

3.2.3.2.19 Ignacio Formation - all adequately covered.

3.2.3.3 Thickness, Lateral Extent and Characteristics of the Host Rock - This section cannot be properly evaluated until the State of Utah receives the geophysical data requested from DOE. Projections of salt thickness are in the proper range, based on my subsurface studies, but there remain questions due to the scarcity of well control which can only be answered by having the same geophysical information that DOE has had.

Further, the presence of commercial deposits of potash cannot be ruled out with the present data base.

3.2.4 Paleontology - adequately covered.

3.2.5 Structure and Tectonics - adequate introductory statement.

3.2.5.1 Faulting - Again, I cannot concur with this section until it is reviewed in the light of the DOE seismic studies. A flag of caution must be raised for the Davis Canyon site in view of subsurface faulting reported by McCleary (1983) in the Paradox and older formations. If there truely are northwest-trending faults beneath the Davis Canyon proposed repository site, and if the Colorado Lineament is exhibiting reactivation (Wong, 1984), then the Davis Canyon site should not be considered for a nuclear waste repository.

3.2.5.2 Seismicity - This part of the Colorado Plateau is cut by the Colorado lineament, which provides an area of seismic activity in the Meanders Anticline area along the Colorado River. The seismic activity extends from the surface to depths of 11 miles (Wong, 1983, pg. 8). Microseismic activity within the candidate area has not been recorded for a long enough period to yield valid judgements.

3.2.5.3 Igneous Activity - adequately covered.

3.2.5.4 Uplift, Subsidence and Folding - adequately covered.

3.2.5.5 Diapir Development - adequately covered.

3.2.5.6 Dissolution - This aspect has not been adequately considered. The reported (McCleary, 1983) northeast-trending sub-salt faults in the Six Shooter Peak area could provide access of water to the lower Paradox salt cycles which could lead to dissolution and eventual collapse of the Davis Canyon site. A second means of providing access of water to the base of the salt section is via the karst zone at the top of the Leadville Formation, discussed above. Whether such dissolution could happen within the lift-time of the repository is highly speculative.

3.2.6 Rock Characteristics -

3.2.6.1 Geomechanical Properties - Rock mechanics is not part of my background, therefore, I will not comment on this section.

3.2.6.2 Thermal Properties - It is stated (pg. 3-89, para. 2) "that when a heat source is placed in a salt deposit, water trapped in salt has a tendency to move up the thermal gradient." This phenomenon has been documented at Project Salt Vault. Brine would migrate to the emplacement holes, (accumulation would be 2-11 quarts [Lavender 6-116, 5th draft] after 20 to 30 years) and contribute to the corrosion of the waste cannisters. This is a matter to be addressed by engineering of the cannisters.

3.2.6.3 Natural Radiation - adequately stated.

3.2.7 Geochemistry -

3.2.7.1 Host Rock Chemical Properties - adequately stated.

3.2.7.2 Hydrochemistry - This section seems reasonable treated. I question, however, why no water samples were collected from the Paradox salt section in drillhole GD-1.

3.2.8 Mineral Resources - The indroductory statement is adequate.

3.2.8.1 Hydrocarbon Resources - The EA glosses-over the oil tested from the Reynolds Mining Company, Gibson Dome #1 well. Indeed it tested 47 barrels of oil, but the EA neglects to say that the oil came from the salt section -- namely from the interbed between salt cycles 13 and 14.

Since there are only a small number of oil and gas tests closely surrounding the candidate site, I see no good reason to randomly sample a small number of drill stem tests (7 in the Paradox and 12 in the Leadville Formations) rather than evaluate them all (Lavender 3-101, para. 3). If there are many more drill stem tests of drill holes in close proximity to the site, then this is an inadequate assessment of potential hydrocarbon reserves.

3.2.8.2 Other resources -

3.2.8.2.1 Uranium/Vanadium - adequately covered. Additionaly, during the course of my field evaluations no favorable host lithologies, structure or mineralization were noted in the Moss Back (the primary uranium/vanadium host in the area).

3.2.8.2.2 Potash - Paradox cycle 18 as described in the Gibson Dome area, includes sylvite deposits which "are of sufficient thickness and grade to constitute minable deposits" (Hite, 1982), but "it is likely that they do not underlie Davis and Lavender Canyons". Those conclusions were based on rather wide-spaced drill hole data. Until site-specific drill holes are completed, the presence of economic deposits of Potash beneath Lavender and/or Davis Canyons cannot be ruled-out.

The economics of, and need for, potash over the life of the repository cannot be predicted. If those deposits are explored or exploited in the future, access of ground water to the repository is likely (Lavender 6-159, 5th draft, last para.).

3.2.8.2.3 Miscellaneous Minerals - adequately stated.

3.2.9 Soils - No comment; this is not my area of expertise.

C. Review of Guideline Assessment -

The following section will address the degree to which the information presented in chapter 3 meets the Siting Guidelines. For the convenience of the reader, the EA format will be followed.

6.3.1.1 Geohydrology - The basic premise here is that if there is a post-closure release of radionuclides from a repository it will be transported to the accessible environment by ground water. Thus the evaluation of the site is based on its geologic integrity relative to the transmission of groundwater, as specified in guidelines 10 CFR 960.4-2-1.

The discussion of Relevant Data is, for the most part, logical and complete. In attempting to establish the permeability and effective porosity of the host rock and its surroundings, data is presented which states that the permeability and porosity of buried halite is zero. That is acceptable, but there is no separation made between the salt bed and its bounding interbeds.

If the nuclear waste is to be buried in Salt 6, we need to know more of the permeability of the bounding clastic interbeds. It is through those interbeds that ground water could have access to Salt 6 especially if the more competent units (such as the interbeds) are jointed as they are on the surface.

The discussion of drill stem tests is inadequate as I have stated before.

I concur with the EA findings on climatic changes (pg. 6-96, Lavender), that a favorable condition is found.

In summary, the concerns I expressed in discussing the EA chapters 3 above are all applicable to the question of whether the geohydrologic conditions at Lavender and Davis Canyons meet the siting guidelines. Basically, I am concerned that DOE and its subcontractors have not considered some of the potential means of providing ground water circulation.

6.3.1.2 Geochemistry - I concur with the findings of this section.

6.3.1.3 Rock Characteristics - Thermal uplift as a means of enlarging fractures in strata overlying the repository as well as the increased potential for ground water movement are stated facts (p. 6-117). The DOE does not take this matter the next step, relating the enlarged fractures and increased ground water movement to the pervasive jointing in the proposed sites. If the ability of each joint to better transmit water as a result of thermal uplift is accepted, then I cannot accept this portion of the EA's which claims that the thermomechanical alteration of the rock mechanics will not significantly reduce the isolation characteristics of the host rock.

6.3.1.4 Climatic Changes - I concur with the findings of this section.

6.3.1.5 Erosion - The EA statement of this section is acceptable.

6.3.1.6 Dissolution - This section cannot be properly evaluated for accuracy and adequacy until the DOE makes available to the State of Utah the seismic data and interpretations on which this section is so heavily based.

6.3.1.7 Tectonics - I concur with the findings of this section.

6.3.1.8 Human Interference and Natural Resources - I concur with the findings of this section.

In summary this discussion of Chapter 6 of the EA's highlights aspects needing additional information and or analysis.

IV. CONCLUSIONS

In closing I would say that the majority of work presented by DOE in the EA's is accurate and complete. The exceptions have been well detailed earlier in this report. The inadequacies which are evident in Chapter 3 of the EA's could be resolved by the DOE:

1. making the seismic and related data available to the State of Utah.

2. performing geologic field mapping to become aware of the extensive jointing.

3. gathering and evaluating all data pertinent to the known karst surface on the top of the Leadville Formation, including the examination of cuttings and cores from oil and gas tests in the Candidate Area (many of which are available for sutdy at the Utah Geological and Mineralogical Survey).

4. considering the possible effects of the joints and karst features on hydrology as opposed to the strictly Darcian hydrologic evaluations to date.

5. researching and using all of the drill stem test data and not just a random sampling thereof.

V. BIBLIOGRAPHY

References cited -

Armstrong, A.K. and Mamet, B.L., 1976, Biostratigraphy and regional relations of the Mississippian Leadville Limestone in the San Juan Mountains southwestern Colorado: U.S. Geol. Sur. Prof. Pap. 985,25p.

Detterman, J.S., 1955, Photogeologic Map of the Carlisle - 10 Quadrangle, San Juan County, Utah; U.S. Geol. Surv. Map I-73.

Hackman, R.J., 1955, Photogeologic Map of the Carlisle - 15 Quadrangle, San

Juan County, Utah; U.S. Geol. Surv. Map I-76.

Haynes, D.D., Vogel, J.D., and Wyat, D.G., 1972, Geology, Structure and Uranium Deposits of the Cortez Quadrangle, Colorado and Utah: U.S. Geol. Surv. Map I-629.

Hite, R.J., 1960, Stratigraphy of the Saline Facies of the Paradox Member of the Hermosa Formation of Southeastern Utah and Southwestern Colorado; Four Corners Geological Society Guide book p. 86-89.

Hite, R.J., 1975, An unusual northeast-trending fracture zone and its relation to basement wrench faulting in northern Paradox Basin, Utah and Colorado: Four Corners Geological Society Guidebook, 8th Field Conference, p. 217-223.

Hite, R.J., 1982, Potash Deposits in the Gibson Dome Area, Southeast Utah: U.S. Geol. Surv. OFR Rpt. 82-1067, 8p.

Hite, R.J., and Lohman, S.W., 1983 Geologic Appraisal of Paradox Basin Salt Deposits for Waste Emplacement: U.S. Geol. Surv. open file report #USGS-4339-6, 75p.

Huntoon, P.W., Billingsley, G.H., Jr., and Breed, W.J., 1982, Geologic Map of Canyonlands National Park and Vicinity, Utah: Canyonlands Natural History Assoc'n.

Lobeck, A.K., 1939, Geomorphology - an introduction to the study of landscapes; McGraw-Hill Book Company, Inc., New York and London, 731p.

Lohman, S.W., 1974, The Geologic Story of Canyonlands National Park; U.S. Geol. Surv. Bull. 1327, 126p.

McCleary, J., 1983, Stratigraphic and Structural Configuration of the Navajo (Jurassic) through Ouray (Mississippian-Devonian) Formations in the Vicinity of Davis and Lavender Canyons, Southeastern Utah; Woodward-Clyde Consultants Topical Report, 39p. and 36 figures.

McCleary, J., Rogers, T., and Ely, R., 1983, Stratigraphy, Structure, and Lithofacies Relationships of Devonian through Permian Sedimentary Rocks: Paradox Basin and Adjacent Areas-Southeastern Utah: Woodward-Clyde Consultants Technical Report #ONWI-485, 148p.

Ohlen, H.R., and McIntyre, L.B., 1965, Stratigraphy and Tectonic Features of Paradox Basin, Four Corners Area; AAPG Bull. v. 49, no. 11, p. 2020-2040.

Warner, L.A., 1978, The Colorado lineament, a middle Precambrian wrench fault system: G.S.A. Bull., v. 89, p. 161-171.

Williams, P.L., 1964, Geology, Structure, and Uranium Deposits of the Moab Quadrangle, Colorado and Utah: U.S. Geol. Surv. Map I-360.

Wong, I., 1984, Seismicity of the Paradox Basin and the Colorado Plateau Interior: Office of Nuclear Waste Isolation Technical Report #ONWI - 492, 131p.

Woodward - Clyde Consultants, 1982, Geologic Characterization Report for the Paradox Basin Study Region, Utah Study Areas: Technical Report #ONWI - 290, v. I Regional Overview.

Other Pertinent References

Bechtel National, Inc., 1978, Regional Characterization Report for the Paradox Bedded Salt Region and Surrounding Territory; draft report prepared for Union Carbide Corp.; Nuclear Div., under subcontract administered by the Office of Waste Isolation, U.S. Dept. of Energy.

Cater, F.W., 1970, Geology of the Salt Anticline Region in Southwestern Colorado; U.S. Geol. Surv., Prof. Pap. 637, 80 p.

Coleman, S.M., 1983, Influence of the ONion Creek Salt Diapir on the late Cenozoic History of Fisher Valley, Southeastern Utah: Geology, v. 11, p. 240 - 243.

Hintze, L.F., 1973, Geologic History of Utah: Brigham Young University

Geologic Studies, v. 20, part 3.

Murray, R.L. 1982, Understanding Radioactive Waste; Battelle Press, Columbus, Ohio, 117 p.

Parker, F.L., Boegly, W.J., Bradshaw, R.L., Empson, F.M., Hemphill, L., Struxness, and Tanura, T., 1960, Disposal of Radioactive Wastes in Natural Salt: Four Corners Geol. Soc. Guidebook, p.33-42.

Trabalka, J.R., Eyman, L.D., and Auerbach, S.I., 1979, Analysis of the 1957-58 Soviet Nuclear Accident; Oak Ridge National Laboratory report #ORNL-5613, 79p.