REPORT OF INVESTIGATION

UTAH GEOLOGICAL AND MINERAL SURVEY

REPORT OF INVESTIGATION NO. 202

UGMS INVOLVEMENT WITH PARADOX BASIN REPOSITORY SITING: A REVIEW OF UGMS ACTIVITIES ASSOCIATED WITH THE DEPARTMENT OF ENERGY'S EFFORTS TO EVALUATE AREAS WITHIN THE PARADOX BASIN AS SUITABLE FOR A HIGH LEVEL NUCLEAR WASTE REPOSITORY

by
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PREFACE

This Report of Investigation consists of four reports that summarize different aspects of the Utah Geological and Mineral Survey's (UGMS) review of the U.S. Department of Energy's (DOE) program to evaluate several areas in the Paradox Basin as suitable for a high-level nuclear waste repository. This document brings together most of the technical comments and other concerns that the UGMS geologists and Utah's Geology Work Group raised regarding DOE's program. These reports were written over a two-year period of time as part of the UGMS responsibility to review DOE activities. Editorial standards have not been entirely adhered to because of the different conditions, purposes, and audiences for which the reports were originally written. They have been edited to a limited extent for clarity, although, extensive changes in text have been avoided. Section I, "Summary of Utah Geological and Mineral Survey Geologic and Hydrologic Concerns, Paradox Basin High-Level Nuclear Waste Program", provides an overview of UGMS activities and comments from 1979 to November 1984. Section II, "Geologic Issues, High-Level Nuclear Waste/ Paradox Basin", provides an overview for the lay person or decision maker of the geologic concepts to be considered when evaluating the disposal of high-level nuclear waste in the Paradox Basin. Section III, "Comparison of Adequacy of Geologic/Geohydrologic Data at the Nine Potential High-Level Nuclear Waste Repository Sites", is a comparison of the perceptions of the six state geologists in evaluating the adequacy of data collected in each of their states for siting a high-level nuclear waste repository. Section IV, "Utah Geological and Mineral Survey Comments on the Draft Environmental Assessment, Davis Canyon Site, Utah," contains the UGMS and Geology Work Group concerns with the repository siting processes and the information base used in the Environmental Assessments.

Numerous concerns are raised in these four reports relative to the suitability of the Davis Canyon and Lavender Canyon sites for a high-level nuclear waste repository and the adequacy of the data upon which the DOE based major decisions. Many of these concerns have not been resolved to the satisfaction of the UGMS. This Report of Investigation is intended as a permanent record outlining the UGMS activities relating to the evaluation of proposed high-level nuclear waste repository sites in the Paradox Basin and comments made by the UGMS and Geology Work Group on documents prepared by the DOE and DOE contractors.

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Section I

Summary of Utah Geological and Mineral Survey Geologic and Hydrologic Concerns, Paradox Basin High-Level Nuclear Waste Program

by

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Utah Geological and Mineral Survey

November 1984
(Revised March 1985)

This paper was prepared in response to a request from Utah's Office of Planning and Budget. It has been edited slightly since its original submission.

Summary of Utah Geological and Mineral Survey
Geologic and Hydrologic Concerns
Paradox Basin High-Level Nuclear Waste Program

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ILLUSTRATIONS

SUMMARY OF UTAH GEOLOGICAL AND MINERAL SURVEY (UGMS) INVOLVEMENT WITH THE DEPARTMENT OF ENERGY (DOE).

Policy Development

UGMS has been actively involved with the Paradox Basin repository program since 1981 when the Governor's Nuclear Waste Task Force was formed and Genevieve Atwood appointed as a member. Genevieve Atwood has since been involved with the succeeding policy groups (Utah Office of Nuclear Waste and the Policy Work Group). One of the subgroups established in 1981 by the Task Force was the Geology Work Group, which Atwood chairs and for which Sandra Eldredge provides staff support. Eldredge has also been a member of the Repository Technical Review Group.

As part of the various policy groups, Atwood has: helped draft proposals to DOE; visited the Nevada Test Site; made trips to DOE in Columbus; looked at the files/data at the Woodward-Clyde Consultants (WCC) facilities with Don Mabey (UGMS) and Juline Christofferson (Governor's Office); and written two papers with Sandra Eldredge (a policy paper briefing for Senator Hatch, Norman Bangeter, and Wayne Owens and a paper comparing the adequacy of data available at all nine potential candidate sites).

Contacts with individuals/groups outside of UGMS (other than DOE, ONWI, USGS, WCC) include: Genevieve Atwood, as a member of the American Association of State Geologists, has attended three meetings where the topics involved nuclear waste disposal, numerous speeches on the issue including to the American Institute of Mining Engineers and the Kansas Geological Survey, and speeches by Sandra Eldredge to various groups including a class at the University of Utah.

UGMS-USGS Cooperation

UGMS and USGS have always maintained good communications. UGMS and USGS have reviewed each other's reports. The USGS did the initial work evaluating the United States salt basins. In the Paradox Basin, the USGS performed numerous studies in the Salt Valley anticline. Geologic studies and investigations on the salt characteristics are continuing in the Paradox Basin by the USGS. UGMS is well informed of USGS activities in Paradox Basin and Robert Hite's work there. Some ongoing activities include work on organic geochemistry from samples from GD-1, ER-1, and other petroleum test holes in Paradox Basin and work on the amount of hydrocarbons already present in the evaporite sequence and the potential amount that additional heating would generate. USGS has also written an evaluation and comparison of the potential repository sites which was shared with us. The USGS is also conducting a Basin and Range concurrent study, developing scenarios to assess the area's potential for disposal of high-level nuclear wastes.

UGMS studies and document reviews

UGMS geologists have carried out various geologic investigations in the Paradox Basin over the last several years. These studies, which are non-duplicative and parallel to the DOE investigations, have enabled UGMS to become familiar with the Paradox Basin geology. The projects included:

A 1979 study of mineral potential of the Paradox Basin in Utah and Colorado under contract to ONWI to help evaluate the salt beds as possible waste repository sites. Several UGMS geologists participated in the project, although most of the compilation was the work of Harvey Merrill. All mineral commodities of the Paradox Basin were investigated and it was found that of those, the oil, gas, and potash were ones which could have a conflict with waste disposal in that they are in the salt-bearing section of the Paradox Formation. Four specific areas (Gibson Dome, Elk Ridge, Lisbon Valley anticline, Salt Valley anticline) were studied in more detail. Gibson Dome and Elk Ridge were found to have little mineral potential. According to the report, the potash at Gibson Dome has a low economic potential rating as it is at least 3,000 feet deep and oil and gas drilling in the area has so far been unsuccessful. Subsurface structures may yet be found but it was felt that there is not a strong potential for future oil and gas development. The report found no potential for potash in the Elk Ridge area because it is outside the basin where potash had been deposited millions of years ago. Elk Ridge was rated as having only a fair potential for oil and gas, based on unsuccessful oil tests with no oil and gas shows; however, there could be possibilities of favorable subsurface structures. The results of the study were published in October, 1979 in UGMS Report of Investigation 143, Mineral Resource Inventory of the Paradox Salt Basin, Utah and Colorado.

Keith Clem, petroleum geologist, made a thorough study of petroleum resources in the Utah portion of the Paradox Basin. The study includes an individual oil and gas field report and a presentation of the regional structure. Sixty-three individual petroleum fields were identified and each are represented by data outlining the nature of the petroleum reservoir, along with its geology, structure, and location. The study is published as UGMS Bulletin 119, Petroleum Resources of the Paradox Basin, April 1984.

Hasan Mohammed, uranium geologist, conducted an investigation of active and inactive uranium mines in the basin. The texts of his reports are presently in editorial review and probably will be published as a UGMS special studies on the geologic, petrologic, and mineralogic study of uranium deposits of the Cutler Formation, Cane Creek - Indian Creek area, and the geology of active uranium mines (1982) in parts of Paradox Basin in southeastern Utah.

J. Wallace Gwynn, Chief, Minerals Section, studied the lithologic characteristics of the salt as evidenced by the salt core from GD-1. Gwynn studied sections of the core, evaluated Woodward-Clyde's analyses and reviewed much of Hite's work. He has written a draft "Report on the Stratigraphy of the Paradox Formation - Gibson Dome No. 1 Boring Location" which has recently been reviewed by Hite of the USGS. After revisions, this report will go the UGMS review board for probable release as a UGMS Report of Investigation.

Gwynn also studied the mining conditions encountered at the Texasgulf-Cane Creek Potash Mine near Moab and related them to the potential mining conditions at Gibson Dome. In the conclusions, Gwynn states that possible problems anticipated with the construction of the proposed shafts and repository facilities at Gibson Dome would include salt movement at repository depth, warm working temperatures, and the presence of some methane in the interbeds. The study is published as UGMS Report of Investigation No. 184, Mining Conditions and Problems Encountered within the Texasgulf-Cane Creek Potash Mine near Moab, Utah; and Potential Mining Conditions at Gibson Dome, Utah.

Hellmut Doelling, Senior Geologist for Geologic Mapping, began stratigraphic investigations of Paradox Basin structures as a means of determining the rates and geologic age of salt-induced deformation (UGMS Open File Report 29) in 1980. That study revealed a significant lack of information in the understanding of the region's geologic history. It also pinpointed the Salt Valley anticline area as a representative place for intensive study because it exposes the entire post-salt stratigraphic column in an area where salt deformation has taken place. Doelling's initial work indicated that movement of salt did not take place at an even rate of growth as previously postulated by many geologists. He had clear evidence of movement of salt after the Chinle Formation and there are even indications of localized salt movement in recent times. In the last year and one-half, Doelling has addressed the problems of salt movement and the mechanisms influencing the rate of movement in the Paradox Basin. He has mapped in detail the Salt Valley anticline. His work will be published as eight quandrangles at 1:24,000 scale and compiled onto a single 1:50,000 scale sheet that will be jointly published with the National Park Service. His report will also be published in two forms: a short pamphlet to be included with the map, and a large, more technical report that defines the detailed stratigraphy of the Salt Valley anticline. A section by Jack Oviatt on the Quaternary history of the Salt Valley Anticline and surrounding areas is also included. A progress report is available, UGMS Open-File No. 30, Geologic Studies of the Salt Valley anticline, October 1982 and an article is published in UGMS Survey Notes, Summer 1982, entitled "History of Paradox Salt Deformation as Related to Nuclear Waste Isolation" by Genevieve Atwood and Hellmut Doelling.

Gary Christenson, Site Investigations geologist, undertook a study of Quaternary deposits in Montezuma and Recapture creeks in southern San Juan County, to evaluate the erosional history of this part of the Paradox Basin. His results, which generally corroborate Woodward-Clyde findings, will be published in a UGMS Special Studies.

William Lund, Chief, Site Investigations Section, investigated geologic hazards along proposed railroad routes to Davis and Lavender Canyons. Seven potential types of geologic hazards were identifed and results of the field reconnaissance showed that potential geologic hazards exist along all three routes identifed at that time by Bechtel as potential railroad corridors. The results are published in UGMS Report of Investigation No. 177, Geologic Review of Proposed Rail Access Alternatives, Gibson Dome Nuclear Waste Terminal Storage Study Area, Utah, November 1982.

UGMS Consultants

In the spring of 1982, UGMS contracted a consultant to review the hydrology program in Paradox Basin. Robert Dingman - who previously worked with the USGS in various hydrology positions (Assistant Chief Hydrologist for Scientific Publications and Data Management; Regional Hydrologist in Atlanta, Georgia; District Chief of the Water Resources Division in New York; District Chief of the Water Resources Division in Kansas; Chief of field party in Chile for seven years; geologist with the Water Resources Division in Maryland for three years; and geologist with the Water Resources District in North Dakota for three years) and who currently works with a hydrologic consulting firm (Tetra Tech International, Inc.) and consults as an individual - evaluated the proposed 1982-1983 drilling and exploration program and helped identify areas where the UGMS could further review the program. Dingman raised many serious questions concerning the hydrology program. The exchange of written questions and responses with DOE was not adequate to address our concerns, so the "Aqua Summit" was convened as an informative, scientific meeting where many of the concerned geologists present who have worked in the Paradox Basin for various agencies (USGS, WCC, DOE, etc.) could share their views. This meeting accomplished the UGMS objectives of defining discrepancies between the USGS and the DOE regional hydrologic models, defining the most immediate data gaps that could be filled, and setting priorities for additional studies.

Dingman left for Oman in spring 1984 to work on ground water resources there for a year. He recommended two people whom he considered very experienced in geohydrology who could help with further review of the hydrology program: Ken Vanlear, Consultant for Office of Surface Mining, Washington, D.C., and I.S. Papadopulos, USGS. These people have been referred to the Office of Planning and Budget as well as two other local geologists who were recommended by Harry Goode: James Hood (SLC) and Reed Mower, Fairview, UT. Both Hood and Mower are retired USGS geologists/ hydrologists.

Geology Work Group

The Geology Work Group reviews DOE documents and acts as a sounding board for geologists technical judgements. The members of the Geology Work Group are: Thure Cerling, geochemist, University of Utah; Gregory Francis, petroleum geologist, Wexpro; Peter Huntoon, structural geologist, University of Wyoming; Jeffrey Keaton, engineering geologist, Dames & Moore; Robert Norman, petroleum geologist, Buttes Gas and Oil, Moab; Howard Ross, geologist/geophysicist, UURI-ESL; Harry Goode, hydrogeologist; Charles Hunt, retired USGS geologist; Williamm Lee Stokes, professor emeritus University of Utah; and David Tillson, consulting geologist. The group meets when the need arises for review. Members act as advisers to the UGMS on technical aspects of the program and have conducted presentations on various geologic topics. In addition to numerous reviews of DOE/ONWI, Woodward-Clyde, USGS, and other reports over the years, various members of the Geology Work Group have provided specific reviews and recommendations depending on their expertise. Some of these include a study by Gregory Francis of the negatives of original logs from GD-1, ER-1, and Kubat wells and reviews of tests performed in GD-1; valuable studies previously performed by Peter Huntoon who has worked extensively in the area and continues to provide recommendations for further studies, one of which is to establish discharge points in the Dark

Canyon area; Charles Hunt has brought up many concerns about the geologic integrity of areas near the Gibson Dome sites including the possiblity of shear planes in the salt extending from The Grabens beyond the Monument upwarp and under the sites, sinkholes in The Grabens, near-by salt movement, and reaffirming concerns for methane hazards on which William Lee Stokes has commented extensively and DOE is aware; Stokes has also raised many concerns about the inadequacy of DOE's studies of flooding in Davis and Lavender Canyons and has questioned the potential of a possible alternative area around the Fremont Embayment; and Howard Ross has reviewed geophysical studies in the area and kept UGMS informed of ONWI's Geologic Review Group of which he is a member. It would be difficult to attribute to each of the members the various reviews/comments since 1981 (if the Policy Review Group wants such a listing, Sandra Eldredge can be contacted for specifics). The bulk of this paper reiterates concerns and issues raised by members of the Geology Work Group and UGMS staff.

UGMS and the Geology Work Group have organized and attended various meetings with representatives from the USGS, DOE, ONWI, Bechtel, Woodward-Clyde Consultants, and other individuals. In addition to numerous Geology Work Group meetings and participation in state meetings, some of the more notable meetings were:

February 17 & 18, 1982 - WCC came to UGMS to update us on their activities. A concern was raised at this time about the adequacy of the screening process and we subsequently requested a rescreening of the Paradox Basin. In particular, there were questions about all of Colorado being eliminated and Stokes raised questions about the potential west of the Colorado River.

April 7, 1982 - Robert Hite briefed UGMS/Geology Work Group on USGS activities in the Paradox Basin. This included Salt Valley investigations and properties of salt at Paradox environments of deposition.

October 1, 1982 - In response to a UGMS/Geology Work Group request that WCC rescreen the Paradox Basin to search for any areas which may have been overlooked in the initial screening, WCC rescreened using the criteria they had established for repositories (depth, thickness, etc). The only areas (other than the four areas already chosen) which satisfied their criteria were ultimately unfavorable due to their locations in narrow canyons. One area some geologists are still interested in is the "Fremont Embayment" area.

July 6 & 7, 1983 - "Aqua Summit" was a two day meeting organized by the UGMS/Geology Work Group of experts representing various agencies, including USGS, WWC, DOE, ONWI, INTERA Environmental Consultants, Inc., DOE's Geologic Review Group, and other interested parties. Geohydrologic issues - the lack of information, data discrepancies, the planned drilling program and questions on the possible need to drill in Canyonlands National Park, plans for additional studies, and updates on WWC and USGS studies - were discussed. Recommendations from this meeting included: (1) drilling a borehole cluster 1 to 2 miles downgradient of GD-2, (2) sampling springs in Cataract Canyon (which was done later that fall by WCC), (3) drilling an array (at least 3 points) of holes 4 to 5 miles apart downgradient of GD-2 to establish potentiometric surface - locations dependant on results from (1), and (4) needed for studies in The Needles area to determine rates, directions, and processes of deformation. These recommendations are discussed in more detail in the following pages.

Executive Summary

Geohydrologic data is very limited in the Paradox Basin. Only one borehole was drilled for the program in the vicinity of Gibson Dome. It is an inadequate base for DOE assumptions and models. Much more information is needed on ground-water flow paths and velocities, recharge and discharge areas, and solute transport velocities before the geohydrology in the Davis Canyon and Lavender Canyon areas can be adequately assessed. At this time the UGMS questions the validity of geohydrologic comparisons of the potential repository sites due to the limited and noncomparable types and amount of data available.

There are several seismology issues which need to be resolved including river-triggered seismicity, mining-induced seismicity, Colorado lineament, Shay graben fault system, and the maximum credible earthquake.

Some host rock characteristics are of concern and need to be addressed. The geomechanical/geochemical properties of the salt cycle in which the repository would be constructed (salt 6 or salt 9) need to be evaluated for site specific information. The effects of carnallite and other impurities in the salt need to be assessed because of their potential impacts on repository operations. DOE will have to satisfy the state's concerns about methane hazards which could be encountered during mining. And localized salt movement, which could result from the waste's thermal expansion, is of concern.

Geologic hazards, including flooding, slope stability, seismicity and faulting, expansive soil and rock, collapsible soil, erosion and sedimentation, and ground water, exist along transportation routes and some potentially exist at the proposed repository sites. DOE does not adequately address these hazards. A major concern which has been raised consistently over the years is the issue of flash floods, both along transportation routes and at the Davis Canyon and Lavender Canyon sites.

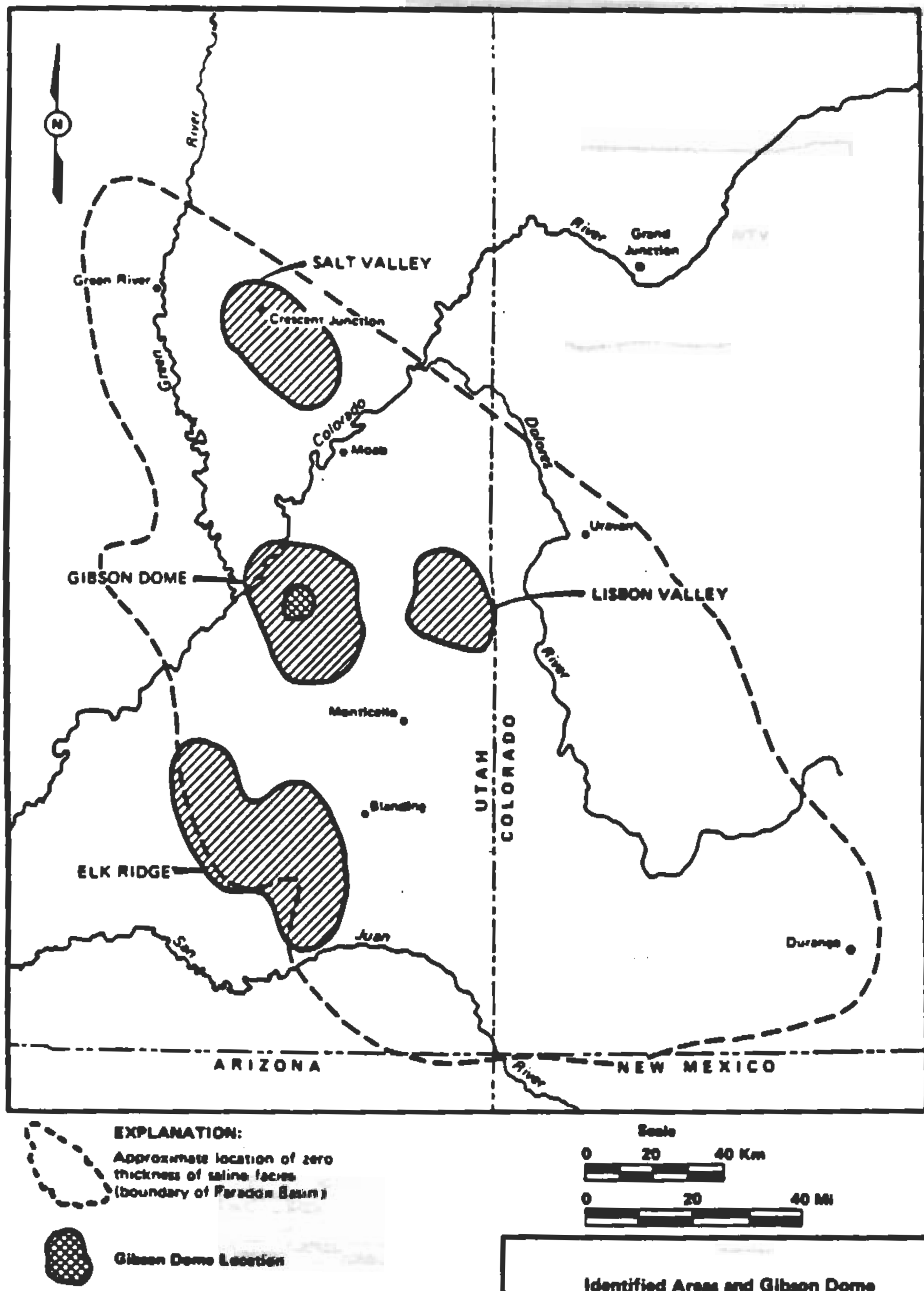
Several geologists have been concerned that "better" sites in the Paradox Basin have been overlooked due to the initial screening process. Upon request, Woodward-Clyde rescreened the Paradox Basin. WCC used the same criteria and the depth limitations resulted in elimination of large areas of the basin and any other potential areas were further deleted from consideration due to locations in narrow canyons. Small areas may exist which could satisfy the criteria. Elk Ridge was determined by Woodward-Clyde to be the only other alternative area. UGMS/Geology Work Group have geologic concerns about that location including loss of circulation, oil and gas shows, and salt of minimum thickness.

There are various inherent problems, including language and definitions, with the DOE guidelines and the Environmental Assessments that make reviews of these documents difficult.

DOE has not yet indicated what the plans will be for a Test and Evaluation Facility (TEF). A TEF will be important for developing site specific and repository operations information. We don't know if DOE plans to construct one. If one is constructed, we are concerned that the facility may be located at an area other than the one chosen for the repository.

At this time, based upon feedback from state geologists, UGMS does not believe that it is technically sound to compare the Paradox Basin sites with any other sites due to lack of information. Comparisons will be inadequate due not only to the lack of geohydrologic data, but also because of the varying amounts and types of data available (or not available) at all nine of the potential candidate sites.

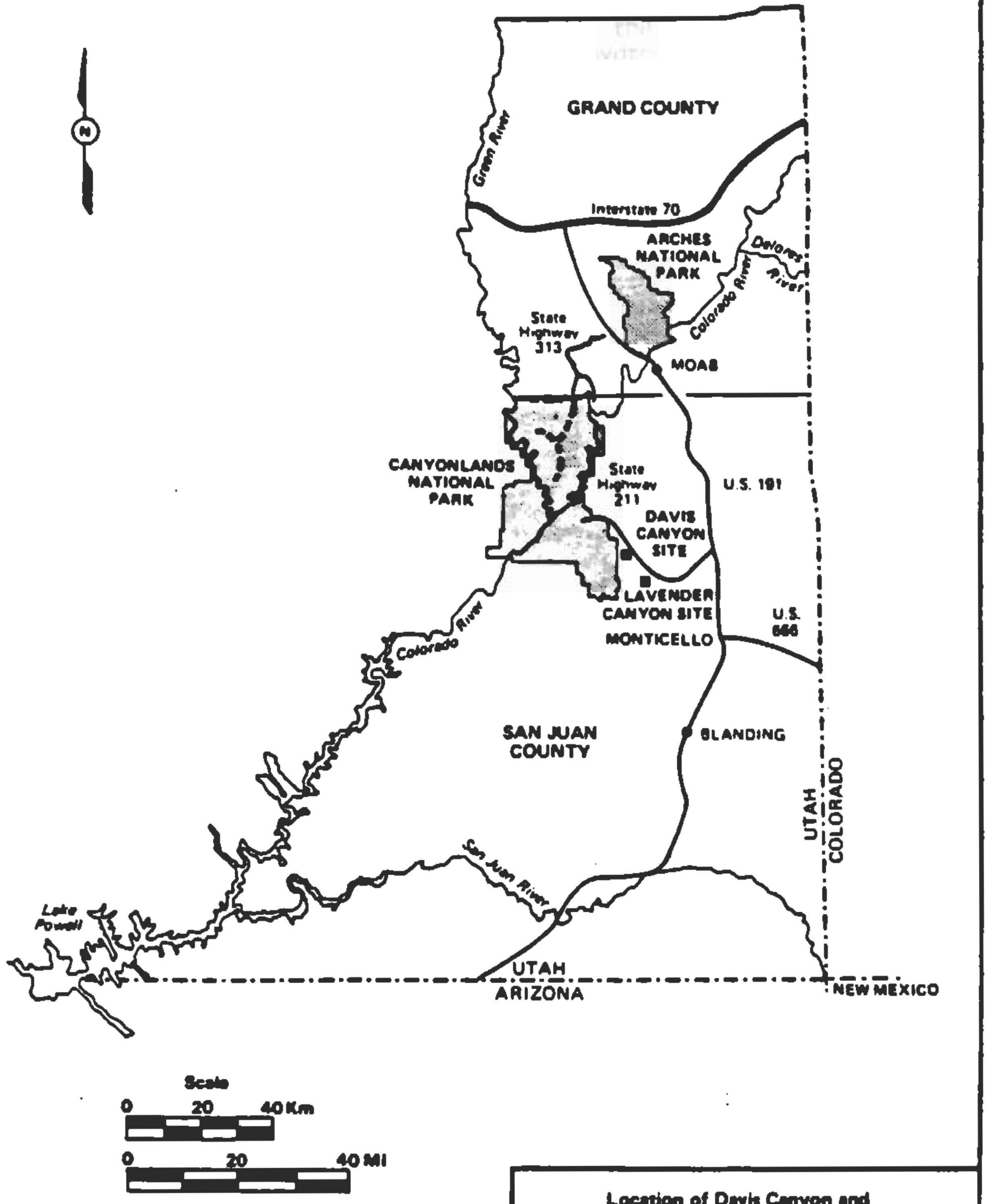
If a Utah site is chosen for site characterization, it will be necessary to oversee the scope of the work and the quality of all the geologic activities and to provide time and consideration for geologists' input into the program.



Source: BGI and WCC, 1982b, ONWI-291, Figure 3-1, p. 3-24

Identified Areas and Gibson Dome Location in the Paradox Basin

Figure 1-1.



Source: BGI and WCC, 1982b, ONWI-291, Figure 3-1, 3-25

Location of Davis Canyon and Lavender Canyon Sites San Juan County, Utah

Figure 2-1.

Issues

I. GEOHYDROLOGY. Geohydrologic data is very limited in the Paradox Basin. There is relatively little information about the upper hydrostratigraphic unit and there is even less information on the lower hydrostratigraphic unit. Therefore, modeling has been based on very little data and on many assumptions. Further studies to define the geohydrology are required in geophysics, geochemistry, stratigraphy, water chemistry, geomorphology (salt dissolution in The Grabens and in Beef Basin), and recharge/discharge/water balance. Main hydrologic issues which need to be resolved are ground-water flow paths and velocities, recharge and discharge areas, and solute transport velocities. DOE plans to resolve these issues in the site characterization phase although it is difficult now to assess whether the particular activities will adequately resolve the geohydrologic issues to the satisfaction of the state. Despite the fact that DOE says they will resolve these issues during site characterization, this information should be available now before the decision is made on which sites to characterize.

1. Recharge and discharge areas need to be identified for each hydrostratigraphic unit. Woodward-Clyde has previously indicated that discharge from the lower hydrostratigraphic unit may occur in Marble Canyon and the Little Colorado River Canyon in north-central Arizona. Peter Huntoon argues that discharge occurs at 1/5 the distance from the proposed repository site along east-west extensional faults southwest of the site such as along the Imperial fault zone, faults in Dark Canyon, faults at Mill Crag Bend, etc. Woodward-Clyde has sampled some springs at low water level in Cataract Canyon. We are presently waiting for those results. In addition to these sampled springs, further studies are recommended to help establish this potential discharge area along the faults. Structures that control points of discharge should be identified, such as faults/fractures, edge of the salt mass, and other stratigraphic controls. Flow rates should be estimated and the water quality should be characterized. Several of the springs are permanently under Lake Powell and some of these might be identified from references in early literature.

In addition to studies in these potential discharge areas, investigations of near-surface ground-water movement in The Grabens should be done to determine if there is any discharge from The Grabens into the Colorado River.

2. To further establish flow paths and velocities, it was previously recommended (via a group consensus in the 1983 "Aqua Summit" with UGMS, Geology Work Group, ONWI, DOE, USGS, and WCC representatives present) to drill a cluster of holes 1 to 2 miles downgradient of GD-2. This cluster (3 boreholes within a few hundred feet of each other) is referred to as GD-16 in DOE plans. The state considered this information of great importance to the EA and therefore wanted the information before the EAs were issued. At the time, it was felt the drilling of GD-16 A, B, and C and triangulating with GD-3 and GD-1 would provide the minimum of information necessary for understanding flow gradients and velocities in the Gibson Dome area. The drilling of these holes would yield valuable information and would provide a basis for planning additional boreholes if Davis or Lavender Canyon sites are chosen for site characterization.

It was also recommended to drill an array (at least 3 points) of holes 4 to 5 miles apart and downgradient of GD-2 to establish the potentiometric surface in the area. Hole location and distance would depend on results from GD-16 tests.

3. Dissolution areas need to be investigated. In the vicinity of Davis and Lavender Canyons, the known dissolution areas are Lockhart Basin and Beef Basin and potential dissolution areas are the Shay graben complex and The Needles. Although these dissolution areas are discussed in the EA and are recognized as needing more studies, the concerns are not adequately addressed. In the discussion of dissolution, only nearby histories were somewhat examined and no real discussion was held on "worst-case" areas as exemplified by the Salt Valley anticline, Castle Valley, Moab anticline, Fisher Valley, and Lisbon anticline. Only the local past was discussed, but not the potential for future dissolution. The local past is important but so is the regional past and there is plenty of evidence that dissolution was very active during Pleistocene time throughout the region. In table 6-11 of the EA, DOE found the following favorable condition at Davis and Lavender Canyon sites: "The nature and rates of hydrologic processes operating within the geologic setting during the Quaternary period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years." The basic assumptions are that climatic fluctuations will not exceed those over the past 500,000 years, and the maximum change that may occur is a return to full-glacial climates of the late Pleistocene. These assumptions appear reasonable, and calculated rates of surficial processes represent long-term averages and include the effects of cyclical climate change from glacial to interglacial climates. However, effects of climate change on ground-water systems and the dissolution of salt is less well-known and, as stated, more data are required. Dissolution and concurrent salt movement are now proven to have occurred at Salt Valley less than 500,000 years ago, and at an increased rate. This could imply the potential for rapid rates of dissolution at other areas.

Also, the potential for dissolution nearer to the Davis and Lavender Canyon sites needs to be studied. While DOE limits evidence of significant dissolution to within the site as a potentially adverse condition (EA, 6.3.1.6.4), UGMS is concerned that if dissolution is occuring outside the site and is moving toward the site, the isolation capabilities of a repository could be adversely affected. Another concern is that there could be dissolution in the subsurface even if there is no surface representation of it. Unexposed breccia pipes and other anomalous features need to be identified. Brine pockets and active dissolution features could be identified by local resistivity surveys. The absence or presence of these features should be identified near the PBH.

4. The Needles is a potential dissolution area. The rate, direction, and process of deformation in The Needles area is not defined. DOE currently has plans to drill GD-4 and GD-14 and perform detailed surface mapping and age dating of fracture filling to help provide some information on this area. We are concerned that although the Monument upwarp appears responsible for blocking the eastward migration of the grabens, it may not have any effect on the eastward development of the shear planes in the salt.

To determine dissolution, it was suggested (from "Aqua Summit") to conduct geophysical surveys and drill a hole closer to the graben system which must be cored and then if breccias are found, the end of the dissolution front must be located. On the current (5/23/83) DOE planned activities map, GD-14 is the closest to the graben system. It has been suggested to move that hole closer to The Needles, however there are limited areas available for drilling due to the proximity of park boundaries and the existing Wilderness Study Area.

6. Beef Basin is another probable dissolution feature. Originally, the planned holes located there were to help establish regional flow directions. Since the basin probably is a dissolution feature, it therefore may not be a representative location for regional flow information. Holes planned in that area for definition of regional flow gradients should be relocated. For specific Beef Basin information it has been suggested to drill a hole in the basin as opposed to the crest of the anticline where holes are located now. Holes in the syncline, where there is less salt, would provide more information on the degree of thinning and the changes in salt characteristics with distance from the anticline uplift. Mapping and dating Quaternary deposits have also been recommended.

7. It has also been recommended to locate a borehole on the axis of Hatch syncline (Harts Draw drainage) to identify whether subsurface flow paths are following surface topography.

8. Shay graben is most probably a deep-seated feature extending through the salts and into the Leadville Formation. It is not known if salt dissolution is taking place along the faults or if the faults represent a vertical hydrologic connection between the upper and lower aquifers.

9. UGMS has received plans for GD-16 A, B, and C on which some comments have been made. Robert Dingman (consultant under contract with the UGMS) has suggested drilling either 16A or 16B down to the Leadville Formation so the hole could be used in conjunction with 16C and perform aquifer tests. The use of an observation well would increase the accuracy in the determination of the hydrologic coefficients of the permeable zone.

10. The salt is overpressured, therefore any water movement would be away from the salt. While it is most likely that escaping radionuclides would be carried by groundwater down to the Leadville Formation, there is a possibility of leakage upwards to the Elephant Canyon Formation. This needs to be studied further (possibilities, discharge points, etc.)

11. Fractures and joint patterns need to be investigated and mapped. These features are very important as they could provide conduits for ground-water flow.

12. More studies are needed on the Pinkerton Trail Formation. This formation is of concern because during drilling of ER-1, there was a substantial loss of circulation. This formation could be highly fractured.

13. The pressure changes, reservoir characteristics, and impacts on regional flows should be identified and analyzed at the Lisbon Valley oil fields. If the regional equilibrium has been disturbed, its equilibration

resolution may take thousands of years and affect the region including the Gibson Dome area. These studies could also serve as analogues if pumping were to occur closer to the repository if a field was discovered.

14. Solute transport velocities need to be evaluated. This would involve drilling a cluster of holes fairly close together once the groundwater directions were known.

15. If Davis Canyon or Lavender Canyon is chosen for site characterization activities, it will be important to thoroughly review DOE's activity plans and to see detailed plans for the proposed boreholes. We have suggested that each hydrologic borehole penetrate and test the lower hydrological unit. We are continually hearing about different plans and locations for boreholes and it is difficult to assess the adequacy of the drilling program. UGMS/Geology Work Group have made a number of recommendations on this issue and we are not sure how/if these recommendations would be reflected in DOE's program.

II. SEISMOLOGY/GEOPHYSICAL STUDIES. Seismology issues which still need to be resolved include river-triggered seismicity, mining-induced seismicity, Colorado lineament studies, further evaluation of the Shay graben fault system, and the maximum credible earthquake. Most of these issues are recognized by Woodward-Clyde as needing resolution.

1. River-triggered seismicity. Need to assess whether seismicity is river-induced and the nature of the mechanism.

2. Mining-induced seismicity. Need to address the potential hazards to man and facilities underground during construction.

3. Colorado lineament. Need to asses the tectonic and seismogenic implications of this extensive fault system. Some geologists disagree on the orientations of the fault system.

4. Shay graben. At present, only one trench on the north fault is planned because of the lack of gravel pediments on the south fault. If any Quaternary deposits are found on the south fault they should be trenched and mapped in detail in order to date the most recent movement on the fault. If field investigations encounter other deposits, mineralogies or physical or chemical conditions that will allow dating of the south fault, then a date should be obtained. Seismic lines are needed across Shay graben.

5. The Lisbon Valley fault should be analyzed and the last movement dated.

6. Earthquake potential and maximum credible earthquake. More studies on Capitol Reef seismicity and further definition the Colorado Plateau stress province. Need to determine if Basin and Range extension and deformation occurs any closer to the Paradox Basin than Capitol Reef. Woodward-Clyde notes that continued analysis of focal mechanisms from earthquakes within the Colorado Plateau will be of value in evaluating these issues.

7. Local uplift, subsidence, and folding should be discussed more in the EA.

8. Seismic work planned in the Gibson Dome area will need to be reviewed. Previously, Geology Work Group members had commented on the scheduling of some of the activites and DOE did change some of the original plans. This work still needs to be done (sesmic surveys, electromagnetic surveys, tiltmeters, etc). If structural complexities are observed from seismic lines in either Davis or Lavender Canyons, then 3-D seismic coverage may be required to prove the area acceptable for an exploratory shaft.

III. HOST ROCK CHARACTERISTICS.

1. Salt 6 (or salt 9 if this cycle is chosen as the repository horizon) should be cored whenever encountered to determine the variability of the salt sequence from area to area. Coring from the upper contact through the repository horizon selectively in the rest of the salt section should also be done. The geomechanical and geochemical properties of the salt need to be fully evaluated.

2. Carnallite, a hydrated mineral which could pose problems to repository performance, was present in salt 6 in GD-1. The effects of carnallite on a repository are not known and will have to be studied. There is a lack of carnallite and potash information. Important features such as the carnallite zone(s) and any other changes in saline mineralogy should be noted as these are very important data to be used in the overall evaluaton of a Gibson Dome site.

3. The effects on migration of brine from other impurities in the salt need to be addressed (this was omitted in BMI/ONWI-538, A Study of Thermal-Gradient-Induced Migration of Brine Inclusion in Salt: Final Report, Technical Report). For example, what would be the effect of the red iron oxide coloration in most of the Gibson Dome salts and the periodic bands of anhydrite that cut the salts at Gibson Dome.

4. If carnallite is found in salt 6 at the site and if it is found to have detrimental effects, then salt cycle 9 will be the alternative host horizon according to the EA. Salt cycle 9 is 173 feet deeper and is a thinner salt cycle. The salt available within cycle 9 does not provide as much of a buffer zone between the repository and the interbeds (non-salt lithologies). We question if it is known that salt cycle 9 does not contain carnallite. While there is some data available for salt cycle 9, many of the chemical and geomechanical evaluations thus far are only performed on salt cycle 6. Portions of the EA may have to be revised if salt 9 is chosen. The salts may have different physical and chemical problems requiring repository design modification. Many studies will be needed on salt 9 if this is chosen for the repository horizon.

5. Hydrocarbons are present in the Paradox Basin evaporites and the potential for associated hazards for an underground facility has been recognized as an issue at the Gibson Dome location for some time. Although DOE believes that "utilizing existing mine safety technology would provide adequate protection for workers from hydrocarbon hazards in a shaft or repository," more assessment of this issue is needed.

6. Salt flowage has created structural features in Paradox Basin such as Salt Valley anticline, Lisbon Valley anticline, Moab Valley anticline, Lockhart Basin, Beef Basin, etc. Although most of the salt flowage took place in the geologic past, local salt movement is ongoing at present. The Gibson Dome area of Paradox Basin is less disrupted by salt flowage features than the northeastern section and there is no evidence to show ongoing salt movement in the vicinity of Gibson Dome. Nevertheless, localized salt movement will result from the thermal expansion caused by the repository waste. It is not known how extensive or by what mechanism this movement will take place.

IV. GEOLOGIC HAZARDS exist along transportation routes and some potentially exist at the repository site. During a reconnaissance field investigation of Bechtel's original three potential railroad routes into Davis and Lavender Canyons, William Lund (UGMS) identified seven potential types of geologic hazards: flooding, slope stability, faults and seismicity, expansive soil and rock, collapsible soil, erosion and sedimentation, and ground water. Potential geologic hazards exist along all three routes. Further definition of those hazards and planning for their mitigation will be necessary. DOE does not adequately address geologic hazards along railroad corridors and highway routes in the EA. For example, DOE does not include any information on the transportation systems effect on ground-water recharge and discharge areas. While DOE appears to be aware that geologic hazards exist along proposed rail and highway routes, DOE apparently feels that the risk can be mitigated given enough money (UGMS feels that given the money, it probably is technically feasible). Table 6-10 in the EA shows the transportation route costs to be roughly 10 times that for any other site under consideration. DOE does not consider this a disqualifying characteristic for the Paradox Basin sites.

In the analysis of favorable conditions related to transportation (EA, 6.2.1.8.3), DOE establishes five conditions regarding favorability of access to the Paradox Basin sites. Of the five, only two were found to be favorable, and on that basis DOE concluded that generally favorable conditions for access exist. One of the three unfavorable conditions was the presence of geologic hazards.

In the EA (6.2.2.2.3 Conclusion), DOE states that the proposed highway and railroad routes do not impose safety hazards significantly different from those associated with transport in other regions of the country. It is difficult to believe that building and operating a railroad through some of the most rugged country in the United States is no more hazardous than building and operating a railroad on the Great Plains of Texas.

1. Flooding, or more specifically the hazard associated with flash flooding, is glossed over as a barely significant consideration in transportation routes. Examination of the canyons along any of the proposed routes shows that such an assumption is in error and deserving of re-evaluation.

Flooding studies done for the potential repository sites in Davis and Lavender Canyons are inadequate because they are based almost exclusively on models and make virtually no use of field observations. Field evidence such as measurements of the largest water-carried boulders in the Davis Canyon cul-de-sac, a century of photographic records of canyonlands landscape, and C-14 dates for logs resting in highest potential flood locations, mapping late Holocene alluvial deposits, dating flood plain vegetation, might be able to give a better description of localized events. Another suggestion was to employ a mathematical model, such as the Richfield Quadrangle Series 2^{o} map for Utah which shows flash floods over the past 100 years. Not all available information was utilized. Historical records, such as "Resource data for Utah, Part I, Surface Water Records" were not used. One report recorded a flood dated 8/28/71 at a gaging station in Indian Creek, 1/2 mile south of Kelly Ranch where 2330 cfs was recorded for an area of 31.2 square miles above the gage station. Bechtel reports a large flood in 1957 at Indian Creek of 3120 cfs but for a much larger watershed of 257 square miles. The difference in the damage potential between these two floods is substantial. Some other studies have indicated a shift in the rainfall pattern from winter to summer rains between the years 1000 and 1300, accompanied by cycles of rapid downcutting of stream channels and rapid deposition of silt.

2. Other questions not previously asked of DOE include:

To what extent do the hazards affect each of the currently proposed routes?

What studies are proposed to further identify the hazards?

What effect would construction of the rail corridors, particularly the necessary flood control structures, have on local/regional erosion and sedimentation patterns?

What effect would construction of each of the proposed railroad corridors have on ground water along their routes? Particularly the effect of tunnel construction on springs and seeps. Will there be a resulting negative effect on wildlife/livestock grazing?

Considering the high probability of flash floods along all proposed railroad corridors, to what extent are the waste containers capable of being overturned/carried along in flood waters without rupturing?

Of all of the railroad routes being considered, we do not know which ones are more seriously being looked at by DOE. It is hard to evaluate specific conditions when so many routes are under consideration. We will need to see detailed plans of the preferred routes and the proposed mitigation techniques.

V. ALTERNATE SITES.

Another issue has been the possibility of existing alternative sites in the Paradox Basin. The Geology Work Group encouraged evaluation of sites other than Gibson Dome and met with Woodward-Clyde Consultants in October 1982 to discuss this issue. Woodward-Clyde rescreened the basin, including the Colorado portion, using criteria established for repositories and concluded there are no other alternative sites except Elk Ridge. The screening yielded a few potential areas in anticlines, but upon further evaluation, these areas were judged unacceptable because they are located in narrow canyons. It is possible, based on the regional screening process, that small areas (maybe 10 square miles) which satisfy the criteria do exist in Paradox Basin. A few geologists still feel there is a possible location in the Fremont Embayment (Happy Canyon) area. Although the salt may be too deep except in a narrow canyon bottom, it was suggested that this be further investigated and to obtain existing seismic lines which run across that area which would provide information pertaining to basement faulting and corresponding salt thickness (12/6/82 memo). To our knowledge, nothing more has been done in this area.

A related concern is that DOE considers Elk Ridge to be an acceptable alternative site in Paradox Basin. However, it is the general opinion of the majority of the Geology Work Group and some staff of Woodward-Clyde Consultants that Elk Ridge is not an acceptable alternative site based on three factors: (1) loss of circulation in the Pinkerton Trail Formation while drilling ER-1, (2) oil and gas shows in the core, and (3) salt of minimum thickness.

VI. PROBLEMS WITH THE GUIDELINES.

In reviewing the DOE guidelines we raised many concerns of which quite a few remain unaddressed. Since DOE is evaluating sites against the guidelines, we would like to discuss some of our concerns not previously mentioned.

EA, 6.3.1.1.4(2) "The presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment" is a potentially adverse condition. This condition should take into account that there could be potable water with treatment. We don't think it is a valid assumption that saline water is not a potential resource and will never be developed. Any quality of water may become valuable as desalination techniques using solar power are developed and other uses of low-quality water develop.

Data sheet PA2 C makes the assumption that "Outside the host rock the most likely pathways for transport of radwaste radionuclides away from a breached repository are the presently existing aquifers. Only aquifers containing nonpotable water will be considered because usable aquifers are part of the accessible biosphere." According to the guidelines, any ground water within the controlled area is not considered part of the accessible environment. This is in conflict with the above statement. UGMS has previously commented that all ground water should be considered part of the accessible environment.

VII. PROBLEMS WITH THE ENVIRONMENTAL ASSESSMENTS.

In addition to all of the issues discussed in this paper, there are a few other items worth mentioning that make the review of the EA difficult. DOE inconsistently uses terms and does not adequately define some terms. "Site", "geologic repository operations area (GROA)", "area", and "disturbed zone" are used inconsistently and are therefore confusing. This becomes a concern when criteria are applied to distances from the "site" or "GROA" etc.

The issue of potable water was discussed previously under problems with DOE guidelines. DOE discusses the potentially adverse condition 6.3.1.1.4(2) and says that no potential ground-water sources are reported or suspected along ground-water flow paths to the accessible environment because of the high salinity of the ground water in the Pennsylvanian formations. The gound-water flow paths to the accessible environment cannot be limited to the Pennsylvanian formations. The Leadville Limestone, which would provide the likely flow path, is a Mississippian formation and the Elephant Canyon (another potential flow path) above the Paradox Formation is a Permian formation. The entire stratigraphic section should be discussed.

In 6.3.1.1.3(7), a condition that "all formations along probable flow paths contain non-potable saline ground water in the site vicinity..." is favorable and DOE says that the first water-bearing unit above the salt is the Honaker Trail with a salinity of approximately 120,000 parts per million. Table 3-10 indicates that the Elephant Canyon Formation has 3,650 milligrams/liter of total dissolved solids. The Elephant Canyon, which is the unit above the Honaker Trail, is the potential flow path above the salt. What is considered potable water and what is considered treatable water?

VIII. TEST AND EVALUATION FACILITY

The Nuclear Waste Policy Act authorizes, but does not require, DOE to provide for the construction, operation, and maintenance of a Test and Evaluation Facility (TEF). "Its purpose is to provide a facility to carry out confirmatory and technology development activities and to provide an integrated demonstration of the technology for mined geologic disposal of nuclear wastes" (Mission Plan, p.2-8). The TEF would be valuable for developing extensive site specific information, verifying the repository final design, confirming site performance, and developing and demonstrating repository operations technology. We were originally concerned that a TEF would be constructed at a site other than the one chosen for the repository. Specifically, we've had concerns that DOE may use WIPP as the TEF for any of the salt sites. This is not acceptable because conditions at the salt sites differ significantly so that a TEF should be required at whichever site is chosen. In the April 1984 Mission Plan, DOE concluded that a TEF located separately from a candidate repository site is not required. DOE also states that it is uncertain that any data from a colocated TEF will be required. We are concerned that current geophysical methods and the exploratory shaft are not adequate for complete evaluation of the characteristics of salt at a potential repository site. It still is of concern because DOE is not clear about whether or not a TEF will be constructed or where it would be located.

IX. LACK OF INFORMATION FOR ADEQUATE COMPARISONS.

Based upon discussions with other state geologists, UGMS does not believe it is technically sound to compare the Paradox Basin sites with any other sites due to lack of information. The data on which DOE bases its geohydrologic assumptions relies heavily on one DOE-drilled hole in the area (3.5 miles northeast of the Davis Canyon site and 6 miles north of the Lavender Canyon site). This is such a limited data base that it is difficult to arrive at adequate geohydrologic assumptions and models. In addition to this specific lack of geohydrologic data, there are varying types and amounts of data available (or missing) for the 7 other potential sites in the nation. To try to compare all these sites with limited data and different types and amounts of data will be very difficult. All sites have particular weaknesses that are difficult to compare and therefore the selection process will involve some subjective comparisons.

X. SITE CHARACTERIZATION.

If a Paradox Basin site is chosen for site characterization, it will be necessary to see detailed work plans for studies ONWI and subcontractors plan to perform. Monthly work plans and schedules of future field studies must be communicated to the state. Establishing a weekly or biweekly reporting procedure with WCC during drilling and testing would be valuable.

The Geology Work Group was concerned that not all of the activities planned in ONWI-301 would take place (this was during the review of ONWI-301 when it was intended that the activities dicussed in the report would be conducted during the "location" phase of the program and before site characterization). UGMS has asked DOE for an absolute "minimum program" for field activities which must be undertaken to resolve the geologic and hydrologic issues at Gibson Dome. A document which clearly outlines the work planned would be invaluable in the state's reviews. UGMS must be informed and up to date on all activites and plans. Adequate review periods are essential. Meetings with DOE/ONWI and Woodward-Clyde personnel would be essential to be kept abreast of activites and plans and to be able to provide some input into the plans and activities during site characterization.

XI. ADDITIONAL QUESTIONS/COMMENTS.

1. How will the repository be monitored? Monitoring will be a very difficult procedure as will guarantees on the integrity of monitoring devices. Should boreholes, e.g. GD-16, be kept open as possible monitoring wells? Monitoring wells will be needed where a repository is sited and the fewer wells drilled and abandoned in the plume area, the better the chances are of preventing the development of man-made conduits.

2. Will the properties of the salt to be used for backfill change when salt is stored on the surface? How will the non-halite components (clays, shales, carbonates) and carnallite affect the system when used as part of the backfill? Is any other backfill material (other than salt) being considered?

3. What are the results from the November 1983 spring sampling in Cataract Canyon by Woodward-Clyde?

4. We have recommended that an analysis of failure paths be done. There is a Sandia Report available for the Nevada site, "Scenarios for Consequence Assessments of Radioactive-Waste Repositories at Yucca Mountain, Nevada Test

Site" which describes hypothetical sequences of events and processes that might conceivably allow radioactive material to escape from a repository. This type of analysis would be valuable for the Utah sites as well as for the other sites.

5. It is not known if salt consolidation and fracture healing will be as effective and as rapid (or more rapid) as predicted, or if these processes could be retarded by differences in salt creep characteristics or repository conditions. Is there a concern that a time delay may exist between the salt consolidation and possible water entering the system in the first years, i.e., via pathways made by the shafts?

6. If Utah is chosen for site characterization, there will be a need for expert reviews of the engineering, geochemical, and geomechanical aspects of the program. Geochemical studies will be needed on heat reactions with salt, interbeds, waste package, and brine. Fluid migration needs to be evaluated. Exploratory shaft and repository designs will have to be studied.

Section II

Geologic Issues
High-Level Nuclear Waste/Paradox Basin

by

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September 27, 1984
(Revised March 1985)

This paper was prepared in response to requests from political candidates and decision makers for a paper on geologic issues to be considered in high-level nuclear waste disposal siting in the Paradox Basin. These statements do not necessarily represent state policies. The original paper has been edited considerably for style and has had minor changes in content to respond to comments and suggestions from reviewers.

Geologic Issues
High-level Nulcear Waste/Paradox Basin

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THE NUCLEAR WASTE PROBLEM

The need to find a permanent solution to the high-level nuclear waste disposal problem has been apparent since the use of nuclear power began over 30 years ago. Currently the wastes from commercial operations are stored temporarily at the power plants in water-filled pools. In order to assure the public that waste products from nuclear power can be disposed of safely and permanently, federal laws dictate that DOE provide facilities to isolate these wastes for as long as the wastes remain hazardous. The goal of the DOE program is to contain the waste in a limited area underground until radioactive elements decay to levels that will pose no significant threat to people or to the environment. EPA guidelines consider 10,000 years to be a reasonable period of isolation. Because some radionuclides remain hazardous beyond this time frame, some geologists believe that 100,000 years should be the time frame for isolation. The UGMS prefers the longer time frame of 100,000 years although it is difficult, if not impossible, to predict or "guarantee" performance over such a time frame . If adequate studies are done, it should be possible to define and test a repository site and environment that scientists will agree upon as capable of keeping radionuclides from the accessible environment for 10,000 years.

A fundamental question which is not raised is whether the goal of nuclear waste disposal by deep geologic burial is a wise national policy. Nuclear waste is a resource and the present program may be burying as much as 80% of the energy value of the original fuel rods. The option of safe, monitored surface or near-surface storage until technology evolves to safely handle the materials has not been given equal priority as an alternative to permanent disposal.

Even if the geology at Gibson Dome is proven to be favorable, there are many other factors to be considered. One such factor is the concern of many geologists that the repository's engineered performance will be adequate to contain the high-level nuclear waste as long as has been projected by its designers. Other non-geologic issues not discussed in this report are: Canyonlands National Park, cultural resources, transportation routes, and economic impact on the region. Some of these issues may prove to be more important to decision makers than the geology of the site.

The state can benefit from the repository program, especially during the investigations stage, by maximizing the geologic data collected and the knowledge obtained of the region's resources and characteristics. Federal megaprojects collect valuable information that can increase our knowledge about the state's geology, mineral resources, and hazards at federal expense so long as other values are not sacrificed. If a major scientific investigation were to be launched to fully understand the geologic environment in the Paradox Basin for nuclear waste disposal, it could address fundamental scientific issues that might lead to eventual development of the state's mineral resources and economy. University research is a likely recipient of such funding as well as state agencies. One of our concerns is that the information collected for public entities often does not become part of the public domain because it is archived with the project and is not readily available to the public. For instance, much of the basic data collected by DOE subcontractors on maps, photos, or in notes has not been made available as part of the review process.

GEOLOGIC ISSUES, GENERAL

1. Geologic barriers are the key components of the isolation system because engineered barriers (the form of the waste, the waste container, the repository design) cannot guarantee long-term waste containment with present technology. Thus, when the engineered barriers fail, only geologic barriers isolate the waste from the environment until the radionuclides have decayed to acceptable levels of radioactivity.

2. The engineered aspects of a repository need continuing theoretical and experimental research, development, and testing to achieve containment of the radionuclides beyond their hottest period. In the 1982 proposed numerical criteria by the Nuclear Regulatory Commission, it was proposed that the waste packages have no release of radionuclides for 1,000 years. Technology and assumptions concerning disposal are evolving rapidly so that research and development need to be strongly supported.

3. If geology is relied upon for waste isolation, then the entire geologic environment needs to be fully evaluated. Rock types, hydrologic settings, geochemical characteristics, and geometry of the rock units provide different types of barriers. The "best" geologic environment will be the environment with the largest number of effective, independent, and multiple barriers. (The DOE program has a strong reliance upon technology and a single host rock, whereas recent thinking by many geologists emphasizes multiple geologic barriers). Defining the total geologic environment is not easy and requires intensive field studies and sophisticated modeling. Many geologic environments appear simple but detailed studies disclose complications that are potential weaknesses. Concentrated study of an area is as likely to disqualify, as to favor, a site. Such detailed studies also greatly add to the information base (resources, hazards, etc.) of that region.

4. Ground water is the likely pathway for radionuclides to escape to the environment. Except for human intrusion or catastrophic events (e.g. volcanic eruption), the most likely way that radionuclides will reach the environment is by dissolution of the waste and ground-water transport of the radionuclides in solution into an aquifer or into a surface discharge area. Because ground-water flow paths and flow velocities are critical to understanding escape routes into the environment, these measureable hydrologic characteristics must be understood and be amenable to modeling. Presently these characteristics are not defined at any of the sites, particularly the Paradox Basin sites. Without this information in hand, the sites cannot be adequately compared.

5. It would be premature at this time to decide which site is geotechnically best for a repository. Even so, based on the partly-defined regional characteristics, general geologic principles, and the very limited site-specific information in hand, it appears that the geologic environment at the Hanford site is the least favorable of the nine sites and the geologic environment at Nevada is the most favorable. New information could show the site is unacceptable, but UGMS believes that the general geologic conditions at Nevada look good for a repository at this time.

GEOLOGIC CHARACTERISTICS OF THE SITES OUTSIDE OF UTAH

Basalt, volcanic tuff, and salt are the three different rock types being considered to host the first repository and nine sites have been studied (seven in salt, one in basalt, and one in tuff). There are advantages and disadvantages for each of the sites being considered. There are more detailed additional advantages and disadvantages that could be added to this listing. This is not a comprehensive analysis. Various conditions at the different sites carry different amounts of importance at each site, and it is difficult to weigh the factors. At this time, there are varying types and amounts of data available at each site. We want to restate that, based on the information in hand, the DOE cannot adequately compare the sites. This section is meant as a rough overview of the sites for individuals who are unfamiliar with the general conditions at each site.

Sites under consideration

Hanford Reservation, Washington - Basalt; one potential site at Hanford, Washington, federally administered land including surface storage areas for military nuclear waste.

Nevada Test Site - Volcanic tuff; one potential site at Yucca Mountain, partly located on the Nevada Test Site, partly on BLM land, and partly on Air Force administered land.

Gulf Coast Salt Domes - Domed salt; three potential sites, two in Mississippi and one in Louisiana.

Palo Duro Basin, Texas - Bedded salt; two potential locations in western Texas.

Paradox Basin, Utah - Bedded salt; two potential sites on dominantly federal and state lands -- Davis Canyon and Lavender Canyon, Utah.

Hanford Reservation

Perceived Advantages:

1. Basalt theoretically has good characteristics as a host rock so long as the critical horizons are not fractured. However, most basalt horizons have joints and fracture planes and are subject to additional fracturing. Geochemists working on Hanford basalts believe the basalts have geochemical conditions that favor long canister life and slow waste dissolution. Basalt contains constituents that may retard radionuclides along their pathway.

2. If discharge were to occur into the Columbia River, the river's large volume is considered advantageous by some for reduction of radionuclide concentrations and doses.

3. Considerable federal support has already been invested at Hanford to identify the geologic, hydrologic, and geochemical conditions. Numerous scientists, engineers, and their staff have worked on defining the characteristics of the site.

Perceived Disadvantages:

1. The site has significant technical problems. Waste containment at Hanford is particularly dependent on engineering because the geologic environment does not provide multiple or independent barriers, and the host rock, which is meant to provide adequate protection, may be subject to failure.

2. Abundant ground water of good quality is present in shallow aquifers in the area of the proposed site. In fact, the proposed repository lies between major aquifers. Future drilling to develop this resource could cause human intrusion into the geohydrologic system. Also, the potential for oil and gas below the basalts is not understood.

3. Unpredictable fracture zones and complex intertonguing horizontal features complicate the geohydrologic system. It has not been adequately characterized, and it is difficult to characterize without drilling because of the opaqueness of the basalts to geophysical tests.

4. The host rock consists of relatively thin layers of impermeable basalt bounded by highly permeable basalt. Sufficient thicknesses of quality basalt may not exist where DOE expects them. If the impermeable zone becomes fractured, ground water will circulate and interact with the waste.

5. The rocks themselves are under considerable horizontal stress and tend to fracture, thus creating pathways for water migration. Major vertical fractures may exist and allow for interconnections among units.

6. The host rock has a relatively high ambient temperature (57°C). The basalt will be difficult to mine due to temperature gradients, rock pressures, and the rock type itself. When combined with the heat created by the waste canisters, mining will require extensive cooling for working conditions.

Nevada Test Site

Perceived Advantages:

1. The proposed repository horizon is in the unsaturated zone, more than 500 feet above the water table and about 1200 feet below the land surface. Therefore, there is virtually no water at the repository level. Engineers claim that if water were to enter the system, it could be diverted away from the canisters. Without water at the canisters, geochemical reactions will be greatly reduced.

2. The host rock is extensively fractured. A highly fractured permeable host rock is favorable above the water table because it keeps the repository drained. (It is unfavorable below the water table because it allows migration of ground water through the repository). Should ground water enter the site, its flow would be downward.

3. Ground-water flow times are slow and the hypothetical flow path is toward a ground-water low in the Death Valley area. Water in the area is not extensively developed.

4. Water vapor driven by heat from the repository would tend to create a zone of higher saturation away from the canisters and deposit materials which would tend to further isolate the repository.

5. The host materials (volcanic rocks) have a thermal history that can be used to predict their behavior when heated by waste.

6. The presence of certain minerals (zeolites) and clays provides a high capacity to adsorb many waste radionuclides.

Perceived Disadvantages:

1. It would be difficult to characterize the unsaturated fractured rock. Ground-water modeling has not been done.

2. Yucca Mountain has relatively complex geologic structures including numerous faults. Ground shaking from earthquakes, or possibly from nuclear weapons testing, could be a problem.

3. Limited, relatively good quality ground water is present in aquifers below the site and could be developed in the future.

4. Recent volcanic activity suggests possible reoccurrences that could present potential problems.

5. There are a few "unknowns" at the site; what would be the effect of glacial activity or wetter climatic conditions should they return over the next many thousand years; and what is the mineral resource potential in the vicinity.

Salt sites in general

There are advantages and disadvantages of conditions at each salt site. There are also some advantages and disadvantages of salt when compared to other host material.

Perceived Advantages:

1. The mere existence of salt is an indication of a lack of ground-water flow. Many salt units have been unaffected by ground-water flow for tens to hundreds of millions of years. This is the reason why salt has been the preferred host rock for nuclear waste for almost 30 years. Salt has been considered closest to a complete natural containment and scientists have assumed radionuclides could be released only by human intrusion or through some naturally disruptive event, such as water intrusion from some source outside the repository.

2. The salt sites are the least likely sites to be intruded in search for ground water in the future because of the water's high salinity content below the repository level.

3. Salt's high thermal conductivity tends to dissipate heat.

4. Salt is naturally plastic. It flows rather than fractures and is capable of "self-healing" cracks which might develop in it or have developed in it in the past. Thus, it seals off potential pathways of ground-water flow.

5. Domestic salt resources are large. There is essentially no potential for depletion of the nation's resource base of salt.

6. Salt has been mined underground for decades. It can be mined easily at relatively low cost and the mining technology is well developed.

7. Bedded salt is predictable in thickness, location, and general chemistry.

8. Bedded salt areas that have remained undisturbed for tens to hundreds of millions of years are indicative of long-term integrity and lack of dissolution, although geologic conditions can change.

Perceived Disadvantages:

1. Salt is soluble in unsaturated water. Where water can circulate through or along salt, dissolution can be initiated.

2. Salt, because of its low shear strength, is plastic and can flow. At depth or under high temperatures this can cause engineering and safety problems. Once salt starts to mobilize it tends to move at geologically fast rates and is difficult to control or stop. Salt creep increases with repository depth, temperature, and with certain characteristics of different types of salt.

3. Water contained in rock salt tends to migrate toward a heat source. The brine (salt water) is corrosive and certain brines, particularly those with a high magnesium content, are highly corrosive. Potential coupling of water moving towards the heat source and vapor moving away, and the interaction with heat is not well understood. The chemical and physical properties of the waste canister and the effects of interaction with the brine need more definition.

4. Salt, when compared to basalt or tuff, is less effective in chemically retarding radionuclide travel, although the clay layers in salt sequences and regional shale sequences could significantly retard radionuclides.

5. Certain salt sequences contain impurities that can present methane hazards or can contain limited quantities of water. Brine pockets in salt sequences are difficult to identify.

6. Potash, oil, and gas are commonly associated with salt deposits, so there is potential for human intrusion into the repository or surroundings.

Gulf Coast Salt Domes

Perceived Advantages (in addition to the general salt characteristics previously noted):

1. The Gulf Interior Region is relatively free of earthquakes, although ground shaking from those earthquakes which do occur can be significant.

2. The domed salts contain less brine than bedded salts.

3. The domed salts contain fewer impurities than bedded salts.

Perceived Disadvantages (in addition to the general salt characteristics previously noted):

1. The local geohydrology is complex and difficult to model. Although the regional geohydrology is more predictable, the regional flow system becomes very complex and unpredictable near the salt dome structures.

2. The shape of the repository horizon is difficult to predict because of faulting and deformation of the original beds. Salt domes are the result of salt being forced upward sometimes through thousands of feet of sedimentary strata. This deforms the salt layers dramatically. Domes are also limited in size and some of the smaller domes may require a two-level repository design.

3. The hydraulic properties of the rocks in the areas are, as yet, not defined.

4. The potential for dissolution has not been evaluated. The differential movement caused by thermal expansion in only one area of a dome is not understood.

5. A very large number of test holes will probably be needed to fully characterize the local geohydrology and geometry of the site. These could jeopardize the site's waste-isolation capability.

6. A number of holes have been drilled in the past and not all of them are located. These present a potential for unrecognized pathways for radionuclide travel.

7. Domes are limited in number and are relatively easy to locate, making them likely targets for future human intrusion for exploitable resources (oil, gas, sulfur, and ground water). The domes are also attractive as sites for underground storage of oil, gas, and other fluids.

8. Climatic changes and sea level fluctuations could increase the possibility of exhumation of the salt domes.

Palo Duro Basin, Texas

Perceived Advantages (in addition to the general salt characteristics previously noted):

1. The Palo Duro Basin is relatively free of earthquakes.

2. The salt beds, although not thick, and other major rock units are quite extensive and are more predictable than at the other sites (except Paradox Basin sites). Also, there is considerable lateral flexibility choice where to locate a repository.

3. The surface topography is essentially flat and would not restrict construction of surface facilities nor pose flooding problems.

Perceived Disadvantages (in addition to the general salt characteristics previously noted):

1. The local geohydrology in the Palo Duro Basin has not been well-defined.

2. The Ogallala aquifer is used extensively in this basin. It is located above the salt beds and withdrawal might affect the hydrologic system. The technology for sealing the shaft will have to cope with this problem. A dissolution front associated with the Ogallala aquifer is located in the Palo Duro Basin but is quite distant from the potential sites.

3. There appear to be hydrologic connections between ground-water systems and salt beds in the Palo Duro Basin.

4. Although the locations under consideration are not associated with hydrocarbon production, there is potential for continued oil and gas exploration.

5. The Palo Duro Basin salt appears to have a greater brine content than the bedded salt in Utah, however the Texas brines could be less corrosive.

GEOLOGIC CHARACTERISTICS OF GIBSON DOME, UTAH

Perceived Advantages (in addition to the general salt characteristics previously noted which include: salt's high thermal conductivity; high plasticity and ability to "self-heal" fractures; ability to be mined easily and at low cost; predictability in thickness, location, and general chemistry; history of having remained undisturbed for millions of years; absence of ground-water flow; and the high salinity of ground water below it):

1. The Paradox Basin is relatively free of earthquakes.

2. The salt beds are extensive and the stratigraphy (layers and types of rock units) appears to be relatively easily characterized if sufficient geophysical and geologic work is done.

3. The Paradox salt is stronger than either the Palo Duro bedded salts or Gulf Coast dome salts (so it could be easier to excavate underground and it would creep less, however, tension cracks would take longer to heal).

4. The Paradox Basin salt strength decreases least with increases in temperature.

5. The brine content appears to be less than in the Palo Duro Basin, although greater than at the Gulf Coast salt domes.

Perceived Disadvantages (in addition to the general salt characteristics previously noted which include: that salt dissolves in unsaturated water; that salt mobilizes at depth; that water contained in salt tends to migrate toward a heat source; that salt is the least effective when compared to basalt and tuff in chemically retarding radionuclide travel; that certain salt sequences contain methane hazards; and that resources of oil, gas, and potash are commonly associated with salt deposits):

1. Very limited site specific hydrologic and geologic information has been collected for the two Utah sites. Neither the local nor regional hydrology has been defined. Flow paths, flow velocities, recharge areas, and discharge areas are not known.

2. Localized salt flowage and dissolution have occurred in many areas in Paradox Basin, including some areas similar to Gibson Dome. It has not been shown that such features do not exist in the vicinity of Gibson Dome.

3. A methane hazard may exist at the site. Oil and gas shows occur in the interbeds between salt layers. An explosion at the Cane Creek Mine near Moab killed 18 miners in 1963.

4. Some of the Paradox salt beds contain the mineral carnallite which could release limited amounts of water under certain conditions. The amount of water, its migration, the effects on the canister, potential for salt movement, and the transport of radionuclides is not understood.

5. There is very little flexibility in locating a repository in the Gibson Dome area. Only a few wide canyons provide sufficient space. The salt under the mesas is subjected to too much pressure from the overlying rocks to be mined as a repository. Narrow canyons are not suitable because of access, flooding problems, and differential rock pressures.

6. There could be potential for human intrusion in the area for oil, gas, and potash.

7. Potential flooding hazards could affect some of the surface facilities.

8. The potential for brines at the site and their geochemistry have not been adequately characterized for corrosive properties. There is a high magnesium content in the Paradox brines which could produce corrosion problems with the waste package.

Unresolved geologic issues at Gibson Dome

Each of the disadvantages of the Paradox Basin sites should be studied in detail.

1. Lack of Geologic Information. The details of the geology and hydrology in the area should be well enough understood to compare the sites with other potential sites. Later on, any site's characteristics should be shown to be excellent for a repository. Salt flowage, dissolution, faults, fractures, and fluid migration remain to be studied. The geohydrologic regime is not sufficiently defined. Recharge areas, flow paths, velocities, and discharge areas must be identified before transit time for radionuclide migration can be estimated and modeled.

2. Salt Movement and Salt Dissolution. The Paradox Basin contains thick salt beds which were deposited over 300 million years ago. Because salt is less dense than the sandstones, shales, and other rock units above it, it flows and is forced upward in order to reach equilibrium. Also, since salt and some other sedimentary rocks can be dissolved, collapse features can form. Salt movement has created structural features in Paradox Basin such as Salt Valley anticline, Lisbon Valley anticline, Moab Valley anticline, Fisher Valley anticline, Lockhart Basin and Beef Basin. Localized areas of salt movement occur as breccia pipes, collapse features, or small domes. Although most of the salt flowage took place in the distant geologic past, localized salt movement is ongoing at present. The Gibson Dome area of Paradox Basin is less disrupted by salt flowage features than the northeastern section, and there is no evidence to show ongoing salt movement in the vicinity of Gibson Dome. However, there is no evidence to show that the potential for salt dissolution is not present near the repository. A limited amount of localized salt movement will result from the thermal expansion caused by the repository waste. It is not known how extensive or by what mechanism this movement will take place.

Areas of salt movement relatively near Gibson dome include:

* The Grabens extension zone, located 12 miles from the proposed repository site in Davis Canyon, where a 2000-ft-thick section of rock above the Paradox salt is gradually sliding towards the Colorado River. The faults in this section of rocks could provide hydraulic connection between the surface water, ground water, and the top of the salt. It has not been conclusively shown that Gibson dome is beyond the eastern theoretical limit of the zone of sliding and associated fracturing.

* The Gibson Dome sites are a few miles from the axis of Gibson Dome and Indian Creek syncline which show thinning and thickening of salt. Thinning and thickening in the past can indicate a potential for similar movements in the future depending on future geologic conditions.

* The sites are 13 miles from Lockhart Basin which is an active dissolution collapse structure. How dissolution has occured at Lockhart Basin and the rate of dissolution are not known.

* The sites are 11 miles from the Shay graben complex. Shay graben is an area where ground water may reach the salt along faults and therefore is a potential dissolution area. It hasn't been established how Shay graben affects ground-water flow paths and rates.

* The sites are 18 miles from Beef Basin which is probably a dissolution collapse structure. This feature is not well understood.

* The Dark Canyon fault complex and other extensional faults and associated fractures in the floors of Cataract Canyon, lying between 23 and 38 miles southwest of the Davis Canyon site, are thought by some investigators to be discharge points for ground water in the lower hydrostratigraphic unit (the lower hydrostratigraphic unit underlies the salt sequences). This is 120 miles closer than Marble Canyon in Arizona which DOE investigators have identified as the discharge area.

3. Overpressured salt. The salt in the Gibson Dome area has been compressed by the overlying rock units. Water or other fluids will tend to escape from the salt units and move away from the salt (either downward or upward). This overpressuring also indicates low permeability of the salt which is a positive attribute, but the outward movement of water requires that geohydrologic information be collected on the units above and below the salt. At present it is not known where the contaminated water would go and how fast it would travel.

4. Data collection and proximity to Canyonlands National Park. Considerable hydrologic and geologic information can be collected from outside the boundary of Canyonlands National Park, however, this information could also indicate a need to perform additional studies inside the park, such as collection of data from hydrologic wells. If the park was not located where it is, the ideal data collection program would have included studies within the area presently designated as Canyonlands National Park.

CONCLUSIONS

1. The main unresolved substantive geotechnical issue at Gibson Dome is the lack of understanding of the regional and local hydrology. The hydrologic and geologic information now available for the Gibson Dome sites does not establish either Davis Canyon or Lavender Canyon as an unacceptable site. At the same time, there is insufficient geologic data and analyses to show that either site is acceptable, let alone an excellent site. There is no geologic or hydrologic basis on which to conclusively support a decision to either endorse or oppose Utah as a site for the repository at this time. However, this lack of adequate data provides justification for several policy positions, such as: opposing the DOE selection process, opposing nomination of the Utah site, or justifying further work to define the sites' conditions. Of course, there are many non-geologic issues also to be considered in such deliberations.

2. The best interests of the State of Utah and the United States in assuring that a geologically acceptable site is selected will be served by obtaining as much geologic, hydrologic, and other types of information as early as practical in the selection process. In the selection process: (1) the geologic data bases will vary considerably among sites, (2) much data can be collected without even sinking a shaft, including subsurface tests in existing drill holes, (3) many questions concerning geologic suitability cannot be answered in the screening phase and must wait until in-place experiments are made after sinking a shaft (site- characterization phase), (4) the process is not designed to identify the "best" site but to identify an acceptable, surely safe, site, and (5) all sites have particular weaknesses that are difficult to compare and therefore the selection process involves some subjective comparisons.

3. In general, the quality of the geologic and hydrologic information collected by DOE subcontractors in Utah appears quite good. Certain inaccuracies have been identified by state agencies and individuals and brought to the attention of DOE. Our concern is that not enough information has been collected and that the existing information has therefore been interpreted beyond its applicability. It is the state's position that DOE has not made a good faith effort to collect this data.

5. Based on its general geologic environment and only based on the incomplete information in hand, the Nevada site appears to have a relatively favorable geologic environment for a repository location.

APPENDIX

Additional Studies (This should not be interpreted as a complete list.)

1. In order to determine ground-water flow directions and velocities, boreholes will have to be drilled, some near or in Canyonlands National Park.

2. In order to determine potential discharge areas from the lower hydrostratigraphic unit, areas such as along faults in Dark Canyon and surrounding areas should be investigated.

3. In order to determine a "worse case scenario" which would involve flow up a shaft from the salt to an aquifer with a faster flow velocitiy than the underlying Leadville Formation, studies are needed on the Elephant Canyon Formation. The flow direction of the Elephant Canyon is estimated to be to the northwest. The northwesterly distance to the Colorado River (which is a discharge area for the Elephant Canyon) is 12 miles. If the flow was in a more northerly direction, then the shortest flow path could be to Indian Creek 6 miles to the north.

4. In order to define further the geohydrologic regime, the Molas and Pinkerton Trail Formations (below the salt and above the Leadville Formation) should be studied further as these can be very permeable units.

5. In order to determine if fractures provide pathways within and from the Paradox Formation, deep seismic profiles are needed to map the Precambrian basement and the continuity of salt horizons. The basement profile and extent of faulting in formations beneath the salt is not known. The structure of the Leadville Formation could affect the rate of ground-water flow. This will be difficult to determine.

6. In order to determine if deep ground water is discharging from The Grabens into the Colorado River, near-surface ground water movement needs to be investigated in The Grabens.

7. In order to determine if dissolution is occuring in The Needles and the cause and rate of the dissolution, geophysical surveys and drilling of holes will be needed.

8. In order to determine the cause, the rate, and direction of salt dissolution in Lockhart Basin, boreholes will have to be drilled and further geophysical studies done. The question must be answered of why dissolution occurred there and could such conditions occur closer to the Gibson Dome sites.

9. In order to determine solute transport velocities, studies should be conducted which would involve close multiple well clusters (10 to 30 feet apart) at hydrologic well sites.

10. In order to define the dissolution in Beef Basin, at least one borehole should be drilled in the center of Beef Basin. GD-14 and GD-4 are located on the crest of an anticline where they will hit salt; close to the center of the basin some of the upper section of the salt could be missing. Packer tests should be run in this hole. Holes will be needed in Beef Basin in order to better define regional ground-water flow as well.

11. In order to determine how hydrocarbons in the interbeds would react to heat, geochemical studies on heat and interbed reactions are needed.

12. In order to determine how fast The Grabens are developing, profile studies on the alluvium in The Grabens, particularly near the river, should be performed. The Bishop ash may provide an age-dating mechanism.

13. In order to determine the rates of depostion, profile studies in the Indian Creek syncline should be performed to see how deep the Quaternary alluvium is and coring should be done to look for the Bishop ash.

14. In order to determine if there has been recent movement along the Shay graben faults, trenching of Quaternary deposits should be done across those faults.

15. In order to determine the strength and mining attributes of the salt, rock mechanic properties of salt cycle 6 (and salt cycle 9 since it is being considered as an alternative potential repository horizon to salt 6) need to be investigated more.

16. In order to more fully assess potential pathways, joints and faults will have to be delineated, mapped, and potential discharge areas field checked.

17. In order to better understand the regional geologic setting, a multitude of studies could be done to help define the stability of the site. These would include studies on:

*Basin and Range - Colorado Plateau transition zone

*Thermal evolution of the basin

*Regional uplift

*Tectonic response of multilayers to the stress/strain of the Monument Upwarp

*Colorado Lineament

*Mining-induced seismicity

*River-induced seismicity

Section III

Comparison of Adequacy of Geologic/Geohydrologic Data at the Nine Potential High-Level Nuclear Waste Repository Sites

by

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(Revised March 1985)

This paper was prepared in response to UGMS concerns and in cooperation with the Governor's High-Level Nuclear Waste Policy Work Group. The content has changed since the original draft version in December 1984, based on comments and suggestions from the other states' reviewers.

Comparison of Adequacy of Geologic/Geohydrologic Data at the Nine Potential High-Level Nuclear Waste Repository Sites

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ABSTRACT

The Department of Energy (DOE) is currently studying nine potential sites in five regions of the country for the first underground repository which will store high-level nuclear waste. The geologic data available for the nine candidate repository sites were compared by the Utah Geological and Mineral Survey in a preliminary review based on state geologists' opinions. The resulting matrix shows major deficiencies in the adequacy of data upon which to make reasonable comparisons among sites. For virtually all the geohydrologic issues, insufficient information exists on which to make numerical (quantitative) comparisons or even on which to rank the sites. For other issues, such as rock characteristics and tectonics, it was found that there is insufficient information on which to make numerical comparisons but that the sites could be ranked. For some geologic issues, such as site geometry (depth, thickness), erosion rates, existing boreholes, and travel rates in the host rock, numerical comparisons as well as ranking of the sites is possible. The inability to compare sites quantitatively primarily is due to insufficient information available at the sites, unequal amounts of data available for the various sites, and different types of data collected at the sites. Some issues, almost by definition, cannot be compared quantitatively. For these issues, such as climatic changes and human interference, the information appears highly subjective and uncertain.

Much more information is needed in order to quantitatively compare the geologic and geohydrologic characteristics of the sites, and a significant amount of information is needed now to be able to even rank the sites.

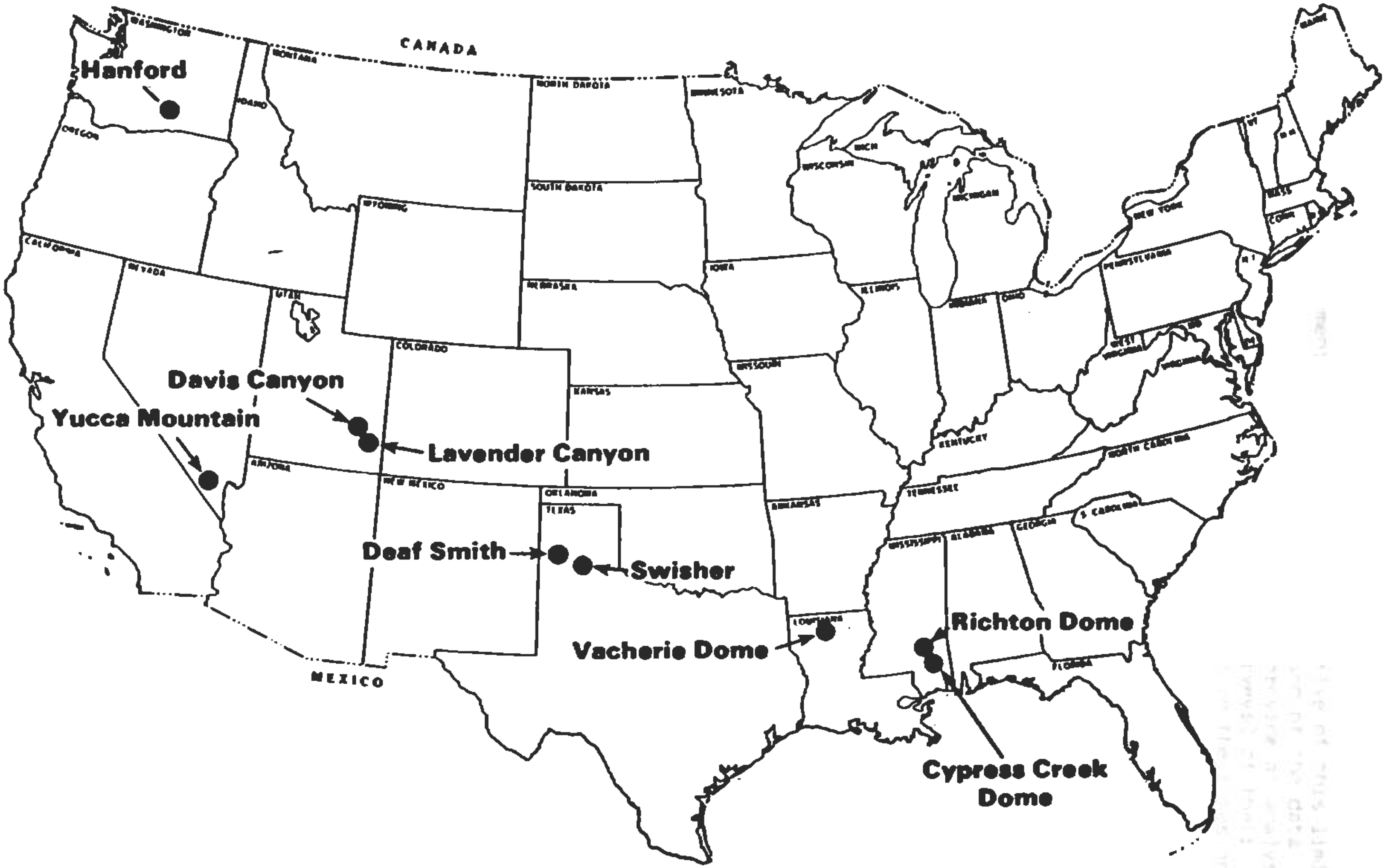
OBJECTIVES

Two general types of concern have been expressed about the information used by the DOE to assess the potential of nine candidate sites for permanent disposal of high-level nuclear waste. One concern reflects uneasiness about the quantity and quality of available information, or its "adequacy". The other type reflects concerns that the geologic characteristics of the site will pose problems in licensing decisions or present problems in waste isolation.

The State of Utah, in past letters and testimony, has expressed both types of concerns with respect to the geologic and hydrologic data available for the Paradox Basin sites. Utah's High-Level Nuclear Waste Policy Group asked the Utah Geological and Mineral Survey to evaluate the comparability of available data currently being used by the Department of Energy to assess the geologic conditions at the nine candidate sites. The objective of this brief study was to compare the quality and quantity of available geologic and geohydrologic data, identify technical issues of concern to the states, identify types of additional information needed to further characterize the geology and geohydrology of the sites, and to assess whether reasonable comparative evaluations can be made based on existing data. The adequacy of data was evaluated for geologic conditions related to waste isolation, not for licensing.

The evaluation of the adequacy of data and the concern for waste isolation

Figure 3-1. **POTENTIALLY ACCEPTABLE SITES FOR FIRST REPOSITORY**



issues are qualitative judgements. It was not the objective of this limited review to prepare a scientific, court-defensible comparison of the data existing for each site. The purpose of the study is to provide an analysis by the states' geological advisors (the state geological surveys) of their confidence in the adequacy of the data being used to compare the sites and the particular concerns about the geologic and geohydrologic factors at their state's sites.

METHODOLOGY

To compare the quantity and quality of data available for the nine potential repository sites, UGMS devised a chart which: lists the geologic and geohydrologic issues included in the DOE Environmental Assessments; lists the degree of concern expressed by the state geologic surveys for each geologic issue at their sites; rates the adequacy of data as perceived by the state geologic surveys; assesses if the data appears adequate for comparisons; and identifies types of additional information needed before comparisons can be made. UGMS staff who have been working in the Paradox Basin filled in the chart and then discussed each state's column with the respective state geological survey. The state geologist of each potentially affected state (Louisiana, Mississippi, Nevada, Texas, Washington) was contacted and either he or his designee discussed the chart with the UGMS staff. The information shown represents the state geologists' or designees' impressions of the geologic data available for their state's potential repository locations, with some modification by UGMS in order to present the evaluations consistently with respect to the intent of each issue.

For use in this chart, the nine candidate sites were grouped into five areas: Utah (Davis Canyon and Lavender Canyon sites in the Paradox Basin), Texas (Deaf Smith County and Swisher County sites in the Permian Basin), Gulf Coast Salt domes (Vacherie Dome in Louisiana, and Richton and Cypress Creek domes in Mississippi), Washington (Basalt Waste Isolation Project at Hanford), and Nevada (Nevada Nuclear Waste Storage Investigations site). The information represented on this chart for the Gulf Coast salt domes mainly reflects data available for the Richton Dome in Mississippi. Although the three Gulf Coast salt domes differ considerably - each dome's characteristics are different and the amount of data available for each dome differs - many of the concerns can be applied to all three domes, thus for the purposes of this chart the three domes were grouped together.

These five areas represent the 4 different types of geologic media being investigated by DOE for the first repository: bedded salt (Utah and Texas), dome salt (Gulf Coast), basalt (Washington), and tuff (Nevada).

The "geologic issues" are those listed in the DOE Environmental Assessment outline. A few additional questions were added because they are of interest to the state geologists. These are: what is the "worse case" scenario for fastest ground-water flow; is the regional regime well documented and understood; is the local regime well documented and understood; and what is the distance to the potential discharge area.

The state geologists were asked to express their degree of concern for each geologic characteristic as it relates to waste isolation. Most of the data at the sites indicates that the geologic conditions at the sites will meet the minimum criteria in the DOE guidelines for choosing sites for the site characterization phase. That does not necessarily mean that the state geologists believe the issues are not ones to be worried about as potential problems. If the state geologist feels the conditions are not a problem, or are favorable, for nuclear waste disposal then the "degree of concern" was rated "OK". The evaluation is based on the professional judgement of the geologists and the current knowledge of the particular conditions; in some cases, although they may rate a condition as "OK", they did note that the data to support that assumption were not adequate. To provide some sort of consistency for sometimes subjective opinions, we based the evaluations on the conditions and time frames as outlined in the DOE guidelines. For example, concerns about the time for the dissolution front to reach the disturbed zone were based on the 10,000 year time frame, which for Utah and Texas were evaluated as "OK". If the geologic condition was thought to be a potential problem, it was rated as "could be a concern" or "is a concern". Some geologists wanted to add a fourth category of "critical concern" to adequately describe their anxieties. For simplicity's sake, we stayed with three categories.

The state geologists were then asked to assess the quantity and quality of the available data at their sites. The "adequacy of data" was rated on a scale of 1 to 10, with 10 being the most adequate. It was decided to rate the "adequacy" of data rather than the "quantity and quality" of data when it became apparent that quantity did not necessarily reflect the adequacy and quality did not necessarily correlate with quantity.

The next column distinguishes between data adequate for quantitative (numerical) comparisons and data adequate for ranking comparisons. Some states argue that the data for the sites should be able to be compared quantitatively. Some individuals have argued that only ranking comparisons are necessary at this time. The DOE is required to apply the data for each site only to the criteria/conditions in the guidelines. It is not clear how the sites will be compared among each other, particularly if virtually all the geologic conditions for all the sites meet the guideline's criteria.

The last column identifies types of additional information needed before comparisons can be made. This listing is not a detailed analysis of what is needed at each site, but rather a generic identification of types of additional data needed.

FINDINGS

In several key areas there is insufficient information on which to base either ranked or quantitative comparisons. The types of information and the quantity and quality vary considerably among sites:

Utah

The DOE data collected in Utah appears credible, however the data are very limited. Much more regional and site-specific information is needed before comparisons can be made.

Texas

Considerable regional data is available in the Permian Basin, although questions remain concerning the geohydrologic regime. Much more information is needed for site-specific issues.

Gulf Coast

The amount and type of information collected for the Gulf Coast salt domes differs for each dome. Fewer data are available for Richton Dome and Cypress Creek Dome in Mississippi than for Vacherie Dome in Louisiana. A moratorium for data collection has been in effect in Mississippi since 1980 and there has not been any geologic work at Vacherie Dome since 1981. The data that are available are very limited and come mostly from existing wells.

Nevada

Considerable data have been collected at the Nevada Test Site, however, there is still a need for many more studies, especially in the areas of geohydrology and tectonics.

Washington

Considerable amounts of regional information have been collected for the Basalt Waste Isolation Project (BWIP), however, the conclusions drawn from these data were interpreted quite differently by DOE's contractor than by the NRC, USGS, and the State of Washington. Many of the data are now being verified by the DOE contractor.

For a few geologic characteristics, quantitative comparisons could be made among salt sites. For other geologic conditions, it was possible to quantitatively compare all the sites, or all but one of the sites. For several issues, only ranking comparisons could be made. In many cases, neither ranking nor quantitative comparisons could be made due to insufficient information. In examining each of the geologic issues listed, the following observations can be made from Table 1.

Rock Characteristics

Most of the sites can be ranked in the rock characteristics' categories. However, there is insufficient information to quantitatively compare the sites except for site geometry (depth, thickness, and areal extent). The depth to the host rock at the Nevada Test Site is difficult to compare with the other sites because the Nevada Test Site is proposed to be located above the water table. Site specific studies are needed to further define rock characteristics.

Climatic Changes

It is difficult to compare the effects of climatic changes on waste isolation among the sites given the widely differing scenarios and uncertainty in predicting future climates. More data may not resolve these difficulties.

Erosion

Rates of erosion and the potential for exhumation can be compared quantitatively among the sites with the current data in hand. Additional Quaternary studies would further define the geomorphic processes.

Dissolution

Dissolution applies only to the salt sites. At each salt site the mechanism of the dissolution process varies considerably and is not well understood. There are different types of concerns at the domed salt sites than at the bedded salt sites. Each site needs much more additional site-specific and regional information in order to understand the rates and the mechanism of the dissolution process. Although the degree of concern is rated "OK" at the Utah and Texas sites for the time it would take the dissolution front to reach the disturbed zone, based on the 10,000 year time frame and the geologic data in hand, the data available at each site to fully assess all of the potential dissolution hazards is very inadequate. For this reason, the possibility that local salt dissolution could be present at these sites raised the degree of concern to "could be". Even though there are variances in the degree of concern among the sites, no quantitative or ranking comparisons can be made among any of the sites due to insufficient information.

Tectonics

Insufficient information exists for the Gulf Coast salt domes, Nevada Test Site, and Hanford to assess faulting and earthquake risks. At best, the sites can be ranked in comparison. Additional information is needed; seismic monitoring is continuing at some sites while monitoring needs to be installed at the Gulf Coast domes, Nevada, and locally at Hanford.

Human Interference

The data available for oil and gas and mineral resources can be used to rank the states now, although the oil and gas potential is not known well at the specific sites and more information will be needed. It is far more difficult to guess the future use of industrial and mineral resources and the ranking of these would be subjective. The potential for usuable ground water, oil and gas, and mineral resources can never be compared quantitatively. It is difficult even to rank the sites for potential usable ground water or potential for human activities that could affect ground-water flow. The data is adequate for quantitative and ranking comparisons relating to existing boreholes.

Salt Pile Management

This issue could be a concern at all of the salt sites. Salt pile management is addressed in more detail for the Utah and Texas sites than the Gulf Coast dome sites. There is insufficient information to attempt ranking the three sites.

Geohydrology

Most of the available data for all sites is inadequate for comparison of geohydrologic issues. Much more information is needed, both in regional extent and locally. In some cases there are questions as to how adequately the geohydrologic regime can ever be well-documented, understood, and modelable without endangering the integrity of the repository. Utah and Texas were rated "OK" for expected ground-water travel rates and travel times based on professional geologic judgement; this considers that travel rates and travel times are slow and long enough to meet the 10,000 year time period. It is clear that such a rating would not be true for a 100,000 year time frame. Another concern which is not evident from this chart, because the reference is to expected ground water travel times, is that undetected fractures or faults could short circuit the flow paths at the Utah site. It should be noted that the next column indicates that the adequacy of data to support these assumptions is very low at all sites, again indicating that much more information is needed. Because all state surveys have concerns about the geohydrology at each site, we added a few other geologic issues, such as the "worse case" scenario. Although Nevada is rated "OK" for a number of geohydrologic issues, the repository would be located in the unsaturated zone and more information is needed to fully assess the geohydrologic concerns even at this site. All sites need much more site-specific information in order to be able to make more reasonable comparisons.

In summary, the types and amounts of data vary at each site and difficulties exist in trying to compare the sites using these data. Not much work has been done in Utah, Texas, or the Gulf Coast after the area characterization phase, some of which occurred back in 1981. Utah and the Gulf Coast states are particulary dissatisfied with the data used to chose site locations, let alone using the same data to compare sites. Geohydrology appears to be the most inadequate for comparative purposes and is the issue of greatest concern to the state geologists when examining waste isolation because ground water is the most likely conduit by which radionuclides could escape to the environment. At the salt sites, dissolution is the next most critical issue and has an equally poor data base for site evaluations and comparative purposes. Some of Nevada's greatest concerns are the potential for earthquakes and volcanic activity (ground water is a concern if the long flow paths have been short circuited by fractures or faults). Tectonic issues are of concern at the Gulf Coast salt domes, and at Hanford and Nevada where more information is needed to evaluate the repository's response. Potential for future human interference needs to be further evaluated before comparisons can be made concerning the potential value of natural resources.

Table 1. Data Comparison (1 of 5)

GEOLOGIC ISSUE	DEGREE OF CONCERN -OK -could be a concern -is a concern					ADEQUACY OF DATA (1-10, 10=most adequate)					DATA ADEQUATE FOR Quantitative Comparison	DATA ADEQUATE FOR Ranking Comparison
ROCK CHARACTERISTICS	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV		
Depth to Host Rock	could be concern	OK	OK	could be concern	OK	3	4	3	1	5	All sites except Nevada	All sites except Nevada
Thickness of Host Rock	OK	could be concern	OK	could be concern	OK	4	5	3	2	5	All sites	All sites
Areal extent of Host Rock	OK	OK	is a concern	could be concern	OK	5	5	1	3	5	All sites	All sites
Rock Mechanic Properties	could be concern	could be concern	could be concern	is a concern	could be concern	5	5	5	5	7	Insufficient information	All sites
Thermal Properties	OK	OK	OK	could be concern	OK	8	8	8	5	8	Insufficient information	All sites
Mineability	OK	OK	could be concern	is a concern	could be concern	10	9	7	2	8	Salt sites	All sites
Homogeneity	could be concern	could be concern	could be concern	could be concern	OK	7	7	3	4	8	Insufficient information	All sites

TYPES OF ADDITIONAL INFORMATION NEEDED: Site specific information: detailed geophysical studies; detailed examination of boreholes; tests for methane/gas potential; tests on core to characterize rock mechanic properties; in situ tests on stress; theoretical and experimental tests to identify potential of host rock to become fractured; hydrofracture tests; detailed core logging; petrographic analysis; borehole geophysics; and geologic history and evolution of the region, including its thermal history.

CLIMATIC CHANGES	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV	Quantitative Comparison	Ranking Comparison
Effects of climatic changes on waste isolation	OK	could be concern	could be concern	OK	could be concern	8	8	6	8	8	Can never compare quantitatively	Difficult

TYPES OF ADDITIONAL INFORMATION NEEDED: Continue Quaternary studies; regional Quaternary studies; detailed soil studies; studies to correlate dissolution rates and salt movement with Quaternary processes and climates; theoretical models of changed climatic conditions.

EROSION	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV	Quantitative Comparison	Ranking Comparison
Rate of erosion (exhumation)	OK	OK	could be concern	OK	could be concern	7	7	5	8	7	All sites	All sites

TYPES OF ADDITIONAL INFORMATION NEEDED: Continue Quaternary studies: dating deposits, terraces.

GEOLOGIC ISSUE	DEGREE OF CONCERN -OK -could be a concern -is a concern					ADEQUACY OF DATA (1-10, 10=most adequate)					DATA ADEQUATE FOR Quantitative Comparison	Ranking Comparison
DISSOLUTION	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV		
Time for dissolution front to reach the disturbed zone	OK	OK	could be concern	N/A	N/A	1	3	1	—	—	Insufficient information	Insufficient information
Diapirism/Salt movement	could be concern	OK	could be concern	N/A	N/A	2	4	1	—	—	Insufficient information	Insufficient information
Local salt dissolution	could be concern	could be concern	could be concern	N/A	N/A	1	2	1	—	—	Insufficient information	Insufficient information

TYPES OF ADDITIONAL INFORMATION NEEDED: Regional and local information needed to determine dissolution areas, rates, directions, and causes: detailed mapping of salt dissolution features boreholes to locate and define dissolutin fronts; boreholes in other suspected dissolution areas; geophysical surveys; investigate for salt dissolution features including breccia pipes in the site vicinity; verify salt flowage by drilling and trenching Quaternary sediments; define salt movement associated with thermal expansion; geologic studies to define the relationship between geologic structures, salt dissolution, diapirs, and salt movement.

TECTONICS	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV	Quantitative Comparison	Ranking Comparison
Tectonic and igneous activity in Quaternary												
Folding	OK	OK	OK	OK	OK	9	9	8	8	9	All sites	All sites
Faulting	OK	OK	could be concern	is a concern	is a concern	4	6	3	5	4	Insufficient information	All sites
Uplift/Subsidence	OK	OK	is a concern	OK	could be concern	6	6	4	6	6	Insufficient information	All sites
Igneous Activity	OK	OK	OK	OK	is a concern	10	10	10	8	6	Can never compare quantitatively	All sites
Earthquake Risks	OK	OK	could be concern	is a concern	is a concern	7	7	3	7	5	Insufficient information	All sites

TYPES OF ADDITIONAL INFORMATION NEEDED: Regional and site-specific information: continue regional seismic surveillance; continue microseismic monitoring at local areas; determine location, geometry, and age of folds, faults, and fractures with geologic mapping; geophysical surveys; mapping and dating Quaternary deposits; hydraulic fracturing in boreholes; studies to further assess earthquake risks.

Table 1. Data Comparison (3 of 5)

GEOLOGIC ISSUE	DEGREE OF CONCERN -OK -could be a concern -is a concern					ADEQUACY OF DATA (1-10, 10=most adequate)					DATA ADEQUATE FOR Quantitative Comparison	DATA ADEQUATE FOR Ranking Comparison
HUMAN INTERFERENCE	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV		
Usable Ground Water	could be concern	could be concern	could be concern	is a concern	could be concern	7	7	7	7	7	Can never compare quantitatively	Difficult
Oil and Gas	could be concern	could be concern	could be concern	could be concern	could be concern	4	6	5	4	2	Can never compare quantitatively	All sites
Mineral Resouces	could be concern	OK	could be concern	OK	could be concern	6	9	9	9	3	Can never compare quantitatively	All sites (totally subjective)
Existing Boreholes	OK	could be concern	is a concern	could be concern	could be concern	9	4	2	7	10	All sites	All sites

TYPES OF ADDITIONAL INFORMATION NEEDED: Regional resource potential: obtain data from new boreholes; mapping for resource potential; studies of the geologic history of the regions.

GEOLOGIC ISSUE	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV	Quantitative Comparison	Ranking Comparison
Human Activities affecting ground-water flow	OK	could be concern	could be concern	is a concern	OK	4	4	4	8	7	Can never compare quantitatively	Insufficient information

TYPES OF ADDITIONAL INFORMATION NEEDED: Document existing or planned projects and model effects of proposed or hypothetical projects; studies of the migration of fluids into, from, and within the regions.

GEOLOGIC ISSUE	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV	Quantitative Comparison	Ranking Comparison
SALT PILE MANAGEMENT	could be concern	could be concern	could be concern	N/A	N/A	2	2	1	--	--	Insufficient information	Insufficient information

TYPES OF ADDITIONAL INFORMATION NEEDED: How will the salt pile be managed; how much salt will be stored on the surface; how will the properties of the salt used as backfill change after being on the surface; where will the excess salt be disposed of.

Table 1. Data Comparison (4 of 5)

GEOLOGIC ISSUE	DEGREE OF CONCERN -OK -could be a concern -is a concern					ADEQUACY OF DATA (1-10, 10=most adequate)					DATA ADEQUATE FOR Quantitative Comparison	Ranking Comparison
GEOHYDROLOGY	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV		
Expected ground-water travel rate in the host rock horizon	OK	OK	OK	is a concern	OK	4	4	4	2	2	All sites	All sites
Expected ground-water travel time in the host rock horizon	OK	OK	could be concern	is a concern	OK	4	4	2	2	2	Can never compare quantitatively	Insufficient information
Expected ground-water travel time outside the host rock along the expected flow path	OK	OK	could be concern	is a concern	OK	2	3	2	2	2	Insufficient information	Insufficient information
*Worse-case scenario-fastest ground-water flow	is a concern	could be concern	could be concern	is a concern	could be concern	1	1	1	1	1	Insufficient information	Insufficient information
*Is the regional regime well-documented and understood?	could be concern	could be concern	could be concern	is a concern	OK	2	4	4	2	7	Can never compare quantitatively	All sites
*Is the local regime well-documented and understood?	is a concern	is a concern	is a concern	is a concern	is a concern	1	2	1	1	2	Insufficient information	Insufficient information
*Distance to potential discharge area	OK	OK	could be concern	is a concern	could be concern	1	3	1	1	5	Insufficient information	Insufficient information
Surficial hydrologic processes: effect of potential for flooding	OK	OK	could be concern	OK	could be concern	3	7	5	8	3	Can never compare quantitatively	All sites
Degree of complexity of local stratigraphic, structural, and geo-hydrologic features of site	OK	OK	is a concern	could be concern	could be concern	3	3	2	2	5	Can never compare quantitatively	Utah and Texas
Potentiometric head differences	could be concern	could be concern	N/A	could be concern	N/A	2	4	--	3	—	Utah and Texas	Utah and Texas
Presence of potable or irrigation ground water along flow paths	could be concern	could be concern	could be concern	is a concern	could be concern	2	4	3	8	4	Can never compare quantitatively	Difficult

Table 1. Data Comparison (5 of 5)

GEOLOGIC ISSUE	DEGREE OF CONCERN -OK -could be a concern -is a concern					ADEQUACY OF DATA (1-10, 10=most adequate)					DATA ADEQUATE FOR Quantitative Comparison	Ranking Comparison
GEOHYDROLOGY	UT	TX	GC	WA	NV	UT	TX	GC	WA	NV		
Presence of joints/ fractures/faults as potential ground-water pathways	could be concern	could be concern	is a concern	is a concern	is a concern	2	4	2	2	3	Insufficient information	Insufficient information
Geochemical effects on sorption	OK	OK	OK	could be concern	OK	4	4	4	4	4	Can never compare quantitatively	Insufficient information
Stability of mineral assemblages under expected repository conditions	could be concern	could be concern	could be concern	could be concern	OK	2	2	2	6	4	Insufficient information	Salt vs. non-salt
Ground-water interaction with waste container	is a concern	is a concern	is a concern	could be concern	could be concern	2	2	2	4	4	Insufficient information	Salt vs. non-salt

TYPES OF ADDITIONAL INFORMATION NEEDED: Regional and site-specific information: series of deep hydrologic test well clusters to determine flow paths, velocities, transmissivities; analyze in more detail all hydraulic head and hydraulic conductivity data; hydrologic tests in holes to determine vertical flow and lateral flow; drilling specifically to identify flow in fractures, fault zones, and dissolution features; determine recharge and discharge areas; determine solute transport velocites; further work on modeling techniques; assess and map joints; in situ testing in boreholes; data on thermal and chemical properties of minerals in the host rock; mineralogical studies; further study of sorptive characteristics of rock types; monitor existing wells; measure direct brine migration rates; research and development of waste container and interaction with water and heat; geomorphic studies of maximum flooding events; survey flood history.

*Not in the EA's

Section IV

Utah Geological and Mineral Survey Comments on the Draft Environmental Assessment, Davis Canyon Site, Utah

by

Sandra N. Eldredge
edited by Genevieve Atwood
Utah Geological and Mineral Survey

February 1985
(Revised March 1985)
(Revised July 1985)

These comments were prepared as part of Utah's review of the Draft Environmental Assessment for the Davis Canyon Site (December 1984). The original set of comments has been edited for clarity and for style. There have been minor changes in meaning, including the addition of comments that had not been received in time for the initial review.

February 20, 1985
Revised March 1985
Revised July 1985

Utah Geological and Mineral Survey Comments on the Draft Environmental Assessment, Davis Canyon Site, Utah

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February 20, 1985
Revised March 1985
Revised July 1985

MEMORANDUM

TO: Jack Wittman
Assistant Program Manager
High-Level Nuclear Waste Office, State of Utah

FROM: Sandra Eldredge
Utah Geological and Mineral Survey

SUBJECT: Draft Environmental Assessment, Davis Canyon Site, Utah (Dec. 1984)

Attached are comments on the draft EA for Davis Canyon. These comments were prepared by the following UGMS geologists: Don Mabey, William Lund, Gary Christenson, J. Wallace Gwynn, Hellmut Doelling, Keith Clem, Genevieve Atwood, and Sandra Eldredge; and by members of the Geology Work Group. When the word "we" is used, it refers to the geologists at UGMS. The comments are arranged by chapters and sections, starting with the EA's Executive Summary. Some comments are editorial, some are on specific items and others refer to general issues. The major issues and concerns are discussed in detail in other topical papers and are referred to throughout this review. To familiarize the reader with those papers, they are authored by: (1) Bruhn; (2) Chan; (3) Duffy & Hall; (4) Parry & Morrison; (5) Willett & Chapman; and (6) Zeisloft.

Some general comments on the EA are:

There is a substantial lack of data for the Davis Canyon and Lavender Canyon sites. We cannot agree with many of DOE's conclusions in the EA due to this limited information base.

Several important assumptions, concerning especially the geohydrologic characteristics in the vicinity of Davis and Lavender Canyons, are based on only one observation well (GD-1).

DOE appears to assume a favorable evaluation unless information to the contrary has been collected. It allows the lack of data to be interpreted as a favorable condition, whereas the EA reviewers agree that often the lack of information is not sufficient to allow a "favorable" rating. The burden of proof should rest with the DOE to show favorable evidence rather than for others to prove unfavorable conditions.

In some cases, such as in the area of geochemistry and geophysics, available data was not used by the DOE. Even more surprising, some of those data were prepared by DOE contractors.

Because some of the geophysical data is "proprietary", DOE has not presented or made public the basis for some of the assumptions made. This is unacceptable. The quality of the basic data cannot be evaluated, the processing methods cannot be checked and the interpretations verified. Alternate interpretations cannot be attempted. Most geological or geophysical information can be interpreted in more than one way, based on the skill and past experience of the interpreter. This is particularly true with gravity and magnetic data. Our concerns are increased because DOE appears to have ignored the resistivity data which do not support their conclusions (Daniels, 1982; Watts, 1982). All data used to prepare the EA should be available to the state and to others.

Executive Summary

2.2.3, p.6 In the selection of Davis Canyon over Lavender Canyon as a preferred site, DOE did not evaluate some potential distinguishing factors between the sites such as the effect of cliff loading in the narrow canyons or the hazard of flash flooding.

2.2.5 In determining the suitability of the Davis Canyon site for site characterization, DOE concludes that the evidence does not support a finding that the site is not likely to meet all of the guidelines. DOE found that the site is suitable for characterization, but we cannot come to the same conclusion based on the information presented in the EA. There is not enough information to arrive at their conclusions. This illustrates a general problem with the data and the EA evaluations.

2.2.6 DOE switched the Davis Canyon and Deaf Smith names in its proposal to nominate Davis Canyon.

3. The Site, p.9 The rocks beneath the site also consist of evaporites.

3., p.9 DOE mentions that the 100-year floodplain in Davis Canyon encroaches on a portion of the land needed for the repository. As we have mentioned previously, we are concerned with more than a 100-year event and DOE should address this. Previous reports by Bechtel (1982) have delineated the 500-year flood plain. Geomorphic evidence in the vicinity of the sites should be analyzed to determine the types of events that have occurred in the past.

3., p.9 The Elephant Canyon Formation is capable of producing 30 gallons of potable water per minute on the average. How variable are the calculations?

3., p.9 DOE states there is a vertical downward hydraulic gradient from the upper to the lower aquifer. This is a general assumption, but there have been mixed results on hydrologic tests in the middle hydrostratigraphic unit.

3., p.9 "Ground-water flow for the upper and lower hydrostratigraphic units is to the west or northwest." This must be a misprint because DOE, Woodward-Clyde, and USGS project the flow direction for the lower unit to be to the west or southwest.

4. Effects of site characterization, p. 12 DOE says after site characterization the site would be reclaimed. What is meant by "reclaimed"? Can the site be reclaimed?

5. Regional and local effects of repository development, p.15 The proposed method of excess salt disposal is placement in an offsite mine. This needs to be addressed in more detail. Water flow and ground stability could be problems in underground mines.

5., p.16 DOE refers to the proposed rail lines crossing "hilly" terrain. Probably a more appropriate description would be rugged terrain.

6. Evaluations of site suitability, p. 18 DOE does not expect dissolution to adversely affect waste isolation. We disagree with DOE's evaluation because there is very little information on which to base the conclusions. Dissolution concerns are discussed in greater detail in Chan, and Morrison & Parry.

6.2, p. 19 "Preliminary assessments of engineered-barrier performance under realistic but conservative assumptions indicate that the EPA's limit on the release rate to the accessible environment would be met at the Davis Canyon site." We question this conclusion. How well is engineered-barrier performance known?

6.3.3, p. 20 DOE states that the host rock at the Davis Canyon site affords significant flexibility in repository location. We question the term "significant" when factors such as the potential carnallite zones, the possibility of thinning, thickening, and folding in the salt beds, and the narrow canyons and associated "mesa effect" are considered.

6.3.3, p. 20 We agree with the statement that, "creep around, and the stresses induced on, the overpack could pose difficulties in retrieval, as could brine migration toward the canister." That there could be problems presents a real concern. No data on brine migration are available for the Paradox Formation (p. 3-69).

Chapter 1

1.3.2.2 In discussing the stratigraphic sequence at Davis Canyon, DOE states that the sequence includes a few relatively low-yielding aquifers that generally contain poor-quality water. This appears to contradict the Executive Summary's statement that the Elephant Canyon Formation water is potable.

Chapter 2

In evaluating the preferred Paradox Basin site, other possible differentiating factors between Davis and Lavender Canyons which DOE did not discuss are the potential for flooding and the effect of cliff loading.

Table 2-4, Rationale for not disqualifying the sites.
Dissolution. DOE states there is no evidence of past or present salt dissolution apparent at the sites. This may be true of surface observations, but at the same time there is no positive evidence to assure us that dissolution is not taking place without surface expression, and there is no assurance that dissolution will not occur at the site within 10,000 years.

Hydrology. DOE states that limited, small flows of ground water are expected to enter the shaft from strata above the salt and that control of such small flows into a shaft under these geologic conditions is well within standard engineering practices. We are concerned that the shaft will provide a conduit for ground water entering the system and become a pathway. How will DOE control these "small flows"?

Chapter 3

3.2 Geologic Conditions

3.2.1 Regional Geology

This section appears adequate.

3.2.2 Geomorphology

3.2.2.1 Physiography. DOE overlooked joints and joint-controlled drainage (see Zeisloft for more discussion) even though the DOE's contractor had studied these features. This is a good example of where DOE does not use or present data collected for the program.

3.2.2.2 Erosion. It should be noted that differential rates of erosion can occur along joints (see Zeisloft for further discussion).

3.2.2.3 Paleoclimate. This section appears adequate.

3.2.3 Stratigraphy

DOE does not adequately address salt flowage.

Figure 3-6, p. 3-13, shows the stratigraphic column with the geologic and tectonic history to the right divided into phases. Phase 2 indicates that the Paradox Basin and salt anticlines formed simultaneously during the times of deposition of the Hermosa and Cutler Groups. This presentation leaves the impression that salt anticline activity (salt flowage) ended with the Permian. Studies at Salt Valley anticline indicate that salt flowage in the salt anticlines continued well into the Jurassic and locally continues to the present (Doelling, UGMS). The problem is aggravated by statements made on p. 3-14, last paragraph: "Most of the salt flowage occurred during Permian time." Not only Permian, but post-Paradox Formation Pennsylvanian rocks (Honaker Trail) and Triassic rocks are missing in several of the anticlines. Thick Cutler sections were deposited in the troughs created by the salt movement into the anticlines. However, the Cutler is less than 15,000 feet thick except along the Paradox Basin-Uncompahgre Highland boundary. Part of the Cutler along the border is Pennsylvanian in age as well. The Triassic and Glen Canyon rocks as well as the Cutler Formation are thicker in the troughs showing that the salt was active at these times. Figure 3-8 perpetuates the same error by showing only the Cutler, and not the Triassic and Jurassic formations, to be thick in the troughs . Salt will flow at any time when suitable tectonic or loading stresses are placed upon it. The salt would flow today if those conditions existed. DOE needs to look at the regional salt movement in Paradox Basin as well as the data generated locally around GD-1.

3.2.3.2 In addressing site-specific stratigraphy, DOE did not consider the facies changes that can occur in the units (see Chan and Zeisloft for discussion).

p. 3-26 In discussion of the Leadville Limestone it is important to note that the top of the Leadville developed karst topography (Molas Formation). Karst features can contribute to ground-water flow paths (see Zeisloft for discussion).

Figures 3-17 and 3-18 are incomplete. It would be helpful if a cross-section line were placed for figure 3-18 on figure 3-17, to show how close to the repository or what position the repository has with respect to the diagram. The location of the repository should also be shown on figure 3-18 to indicate its position with respect to the tectonic elements.

3.2.4 Paleontology

This section appears to be covered adequately.

3.2.5 Structure and Tectonics

A section on jointing should be included. This is a very important concern and is commented on in detail in Bruhn and Zeisloft.

3.2.5.1 Faulting. It is not possible to tell the importance DOE has attached to the interpretation of the "proprietary" geophysical data from the Gibson Dome area. It appears to be the basis for conclusions on faulting, and this is unacceptable because the interpretation must be accepted on faith. Examples where proprietary geophysical data were used or appear to have been used to prepare the EA include:

> The first paragraph of section 3.2.5.1 makes two specific references to conclusions based on the reflecton data, and the second paragraph makes one reference.
>
> The degree to which the reflection data were used to prepare figures 3-13, 3-14, and 3-15 cannot be determined. Figure 3-13 shows faults that probably were interpreted from the reflection data. All figures show details in contouring that suggest information was used other than that provided by the drill holes. The statements on no faults or folds in the last paragraph of section 3.2.5 may be based partly on the reflection proprietary data that is not available for state review and inspection.
>
> The section showing The Needles fault zone is consistent with the reflection interpretation but probably not based upon it.
>
> Figure 3-19 is based on the reflection data as is the discussion in the next-to-last paragraph of section 3.2.5.1.
>
> Reference is made to gravity and magnetic data in sections 3.2.5.1 and 3.2.5.2. Because some published gravity and magnetic data are available in addition to the proprietary data, we cannot tell what conclusions are based on the proprietary data.
>
> References to faulting in the first paragraph of section 3.2.5.6 appear to be based on the reflection data.

3.2.5.2 Seismicity. The data available to base conclusions is somewhat scarce for the Gibson dome area.
Induced seismicity needs to be addressed in greater detail (see Chan).

3.2.5.3 Igneous Activity appears to be adequately covered.

3.2.5.4 Uplift, Subsidence, and Folding. This section does not have much information on local uplift, subsidence, and folding. More discussion is needed.

p. 3-49 DOE recognizes that there may be inter- and intra-stratal folding within the evaporite section at the site and that there is insufficient information to do more than speculate about the folding. It should be noted here that DOE did not cite a study prepared for DOE by J. Daniels of the USGS entitled "Hole-to-surface Resistivity Measurements at Gibson Dome (drill hole GD-1), Paradox Basin, Utah", open file report 82-320. The study indicates there could be folding and thinning and thickening of the salt in the immediate vicinity of GD-1. The folding, thinning and thickening of the salt beds need more investigation. Geophysical work could add a considerable amount of subsurface detail.

3.2.5.5 Salt Flow and Diapir Development. The discussion does not demonstrate that local salt features or incipient diapirs do not exist in the Gibson Dome area, instead it only implies that "unfavorable" information does not exist. Salt features are often local and subtle and, unless a specific program has been designed to show their presence or absence in a given area, conclusions cannot be drawn that such features do not exist.

3.2.5.6 Dissolution. DOE's assessment of dissolution is inadequate. The EA statement "If dissolution does occur in the bedded salt part of the basin, this process appears possible only in the areas where the normal, low permeability stratigraphic sequence of the Hermosa Group has been disrupted, such as in Lockhart Basin, where faults disrupt the Mississippian strata beneath the evaporite section," is misleading. Geologists propose other ways by which dissolution can occur, including: through fractures and faults above the salt where places such as The Needles are most likely undergoing dissolution (Hite, Doelling); via the karst zone at the top of the Leadville Formation (Zeisloft); and discharge of overpressured fluids from depth (Parry & Morrison). Also, the statement quoted above appears to contradict where DOE, in section 3.2.5.1, p. 3-36, interprets Lockhart fault as a tensional feature resulting from collapse of the Lockhart Basin instead of the cause of collapse (dissolution). If this is the case, then what is the mechanism for dissolution in the Lockhart Basin?

The timing and the mechanisms for salt dissolution throughout the Paradox are not well known. Salts found in waters in the formations above and below the Paradox Formation could be derived from dissolution. There is some evidence that the salts in the Leadville Formation water are derived from the Paradox Formation although it is not known where this dissolution may be occurring. This section on dissolution only discusses Lockhart Basin and Beef Basin. There are other areas of probable dissolution in the vicinity of Davis Canyon such as The Needles and the Shay graben complex (DOE does discuss these areas later, but they should be mentioned here as well). Comments on dissolution concerns are elaborated in further detail in Chan, Parry & Morrison, and Zeisloft.

3.2.6 Rock Characteristics

3.2.6.1 Geomechanical Properties. Several rock mechanic properties were studied at GD-1, however different properties may be present at the Davis Canyon site (see Bruhn).

In situ stress and temperature measurements are not fully evaluated and are not available specifically for the Davis Canyon site (see Bruhn).

3.2.6.2 Thermal Properties. Temperature measurements are not fully evaluated and are not available specifically for the Davis Canyon site.

A discussion is needed of thermal expansion and potential for salt movement.

"When a heat source is placed in a salt deposit, water trapped in salt has a tendency to move up the termal gradient." Brine migration could be a serious problem in a repository (see Zeisloft and Parry & Morrison) and, as DOE notes, data are not available on brine migration in the Paradox.

3.2.6.3 Natural Radiation apppears to be adequately stated.

3.2.7 Geochemistry

3.2.7.1 Host Rock Chemical Properties and 3.2.7.2 Hydrochemistry. Parry & Morrison have addressed this brief section in more detail. Most comments will be more applicable to the geochemistry section in chapter 6.

3.2.8 Mineral Resources

3.2.8.1 Hydrocarbon Resources. Evaluations leave the opinion that the potential for oil and gas is poor to fair around the site, however the Paradox Basin has definite potential for more discoveries. The DOE evidence may even support the area as a good location to test (see Zeisloft for further discussion).

3.2.8.2 Other Resources have not been completely covered. Resource potential and reserves of the uranium mines is not fully assessed.

Also, it is not known what the economic potential is for potash near the site.

3.3 Hydrologic Conditions

3.3.1 Surface Water

3.3.1.4 Flooding. DOE recognizes flood stage data are limited in the Gibson Dome area and that no streamflow data are available for the Davis Canyon area. We have commented previously that flooding studies done for the potential repository sites in Davis and Lavender canyons are not complete and do not make use of all of the available evidence. They are based almost exclusively on models and make virtually no use of field observations. Investigations of modern and paleohydrologic conditions from channel characteristics (vegetation, bed material size) and Holocene alluvial deposits could yield useful information to either verify or refute the calculated flood levels. These types of geologic investigations are also valuable in assessing debris-flow and mudflow hazards, which have not been addressed in the EA. Such phenomena are potentially as destructive to surface facilities as are floods.

3.3.2 Ground Water

3.3.2.1 Hydrology and Modeling. For additional and detailed comments on modeling see Willett & Chapman. There are very serious concerns with the modeling efforts in the Gibson Dome area.

Table 3-10, p. 3-128 does not explain the reason for the higher dissolved solids in the Elephant Canyon, Honaker Trail and Leadville formations. This could indicate vertical movement of water up and down from the Paradox

Formation. This hypothesis is not developed or refuted in the text. Aquitards may persist between units, but local facies changes in rocks and subsurface faults and fractures allow movement of water between units. Whether such conditions exist at the repository location needs to be investigated. Local conditions may be quite different than the regional conditions presented in the EA due to these facies changes, fractures, or dissolution features which may allow for vertical migration of water. Studies near Salt Valley anticline (Doelling, UGMS) indicate that units, especially as they approach salt anticlines, undergo facies changes that can affect their transmissivities. In addition, the structural framework, as deciphered from the drillhole intercepts at Lisbon oil field, indicates that there are sub-salt faults that do not pass through the salt, and that some faults extend upward from the salt that do not reach the surface (see Chan, Parry & Morrison, and Zeisloft for further discussion).

p. 3-131 In discussion of the Pinkerton Trail Formation, the problems encountered while drilling (lost circulation) in this formation in the Elk Ridge location should be discussed. DOE assumes that the Pinkerton Trail will act as an aquitard in the vicinity of Davis Canyon. However, this formation could be highly fractured (see Zeisloft, Parry & Morrison, and Duffy & Hall for further discussion) and needs more characterization.

Information on joints is needed in the area of the site because they could provide ground-water pathways to and from the salt (see Duffy & Hall and Zeisloft).

Discrepancies exist on where the hydrostratigraphic units receive recharge and where they discharge. More information is needed (see Duffy & Hall). Although the report was referenced, not much information was used from a USGS report by Weir, et al., "Reconnaissance of the Geohydrology of the Moab-Monticello Area, Western Paradox Basin, Grand and San Juan Counties, Utah."

Correlation of hydraulic properties over large distances cannot be assumed as confidently as correlating stratigraphy over large distances. The EA infers that these correlations are an acceptable practice. Not only is this a risky practice for correlating hydraulic properties, but the stratigraphy in the area is such that, with possible abrupt facies changes, it is hard to predict over large areas as well (see Chan, Zeisloft, Duffy & Hall). The problem that many geologists have with the EA's attempt to predict the geologic conoitions at the site is that some assumptions are based on a single observation well, GD-1, which is 3 to 4 miles distant from the Davis Canyon site (and farther from the Lavender Canyon site).

Much more geohydrologic information is needed. Ground-water flow paths and velocities are not known. Vertical hydraulic gradients are variable as well. With the salt units being overpressured, flow will move away from the salt, either up or down.

Chapter 4

4.1.1 Field Studies

Why doesn't the DOE propose more resistivity surveys as part of the site characterization activities? Resistivity anomalies are associated with both the salt and the brines; using combinations of surface and down-hole surveys the resistivity structure could be mapped in considerable detail. Some geophysical work has been done by the USGS, of which some has not been used in the EA (see the discussion of section 6.3.1.6 in this paper), and these studies have observed that more electrical work could increase data density and extend the survey area.

Plans to characterize the ground water flow paths should include flow path scenarios in the Elephant Canyon Formation as well as in the Leadville Formation. The emphasis of the field activities is to characterize the Leadville Formation, which is a likely ground-water flow path. However, the EA does not adequately address the other possible flow paths such as upward to the Elephant Canyon Formation and then northwestward.

No activities, other than trenching Shay graben, are planned to directly characterize geologic hazards, and geologic-hazard delineation is not listed as a secondary goal of the other programs, such as geologic mapping.

Figure 4.4 indicates locations of proposed field activities in the Davis Canyon area. Boreholes in the immediate vicinity of the Davis Canyon site are denoted by DC. Should these all be designated LC to indicate lower hydrostratigraphic unit test wells (which are in the explanation but do not appear on the map therefore implying that none of the boreholes will go into the lower unit)?

On the same map the location of DC-2 is not consistent with locations on previous maps. DC-2 is located in Corral Pocket and previously a hole was located north of there. What are the reasons for some of these locations?

What is the purpose of DC-5? This hole location has not shown up on any previous maps that we are aware of.

It has been suggested in the past to locate a borehole on the axis of Hatch Syncline (Harts Draw drainage) to identify whether subsurface flow paths are following surface topography.

The Beef Basin boreholes are located along the crest of the anticline. In order to get more information on the degree of thinnning and the salt characteristics, it has been recommended to drill those holes in the syncline. Also, since the basin is probably a dissolution feature, it would not be a representative location to help establish regional flow directions. To define the regional flow patterns, additional boreholes would probably be required in this area, but outside of the basin.

Chapter 5

5.1.3.4 Salt disposal. Section 5.1.3.4.8 assumes mine disposal as a representative method of salt disposal. It is not clear whether DOE is considering only evaporite mines or also considering hard rock or underground coal underground mines. Many mines have problems with ground-water flows and ground stability. The mines identified by Stearns-Roger, in a memo dated March 4, 1983, are an evaporite mine in Wyoming 300 miles away from Davis Canyon and a zinc mine, uranium mine, and coal mines in Colorado 100-200 miles away. It is not clear why Utah mines were not identified.

5.1.5.3 Active Monitoring. Postclosure monitoring requirements have not been established yet by the NRC. In this section, DOE briefly hypothesizes that if monitoring were required, some technical staff and a building at the site would remain. The level of ongoing activities could be considerably greater. In chapter 4, the EA indicates that some of the site-characterization boreholes will be used for monitoring during the postclosure period. Duffy & Hall question wheter these holes will monitor radionuclide transport if such transport is concentrated along fractures which may not be intercepted by the boreholes. The wells in the downgradient direction (southwest and west in the lower unit) from the site are few and the distance between them is considerable.

Another concern is could the monitoring wells be potential pathways for radionuclides to reach the accessible environment?

Monitoring will have to be addressed further.

5.2 Expected Effects on the Physical Environment. This section emphasizes the repository's effect on the environment, but does not consider the environment's effect on the repository. Geologic hazards could impact the repository's operation. Of particular concern are the effects of flash floods and slope stability on transportation/utility corridors. Conversely, the construction of such corridors may have an adverse effect on shallow ground-water resources supplying springs and seeps used by wildlife and range cattle.

The EA does not consider a concern that the drilling and removal of salt for a repository could create a pressure sink toward which fluids would tend to flow. The mine conditions would be at approximately atmospheric pressure compared to the higher pressures of the undisturbed host rock.

5.3 Expected Effects of Transportation and Utilities. This section does not address the transportation systems effects on ground-water recharge and discharge areas.

<u>Chapter 6</u>

<u>6.2.1.8 Transportation Guideline</u>. Geologic hazards along railroad corridors are not adequately addressed.

In the analysis of favorable conditions, there are nine favorable conditions listed. One of those nine (1. Availability of access routes from local existing highways and railroads to the site which have any of the following characteristics...) is divided into five subconditions, two of which are the only ones that address, to a limited extent, geologic hazards. These two favorable subconditions, (i) cuts, fills, tunnels, or bridges are not required and (ii) routes are free of sharp curves or steep grades and are not likely to be affected by landslides or rock slides, are not found to be present. However, the fact that these favorable subconditions are not present does not affect the DOE's evaluation that the favorable condition (1) is present in Paradox Basin.

In the analysis of potentially adverse conditions only one condition out of the four considers geologic hazards (terrain such that landslides, rock slides ... will be encountered along access routes to the site).

DOE finds that all four potentially adverse conditions are present and three of the nine favorable conditions are found to be present. The conclusion is reached in the EA that the evidence does not support a finding that the site is not likely to meet the qualifying condition. This appears to be too optimistic. Some risks can be mitigated, which increases the cost roughly 7 to 20 times that for the other sites under consideration except

Yucca Mountain (see page 7-90). However, other geologic hazards could present dangers that may not be easily mitigated. Flash flooding is one of the most significant geologic hazards to be considered in building a railroad in the Gibson Dome area and this hazard is accorded little consideration in the EA. Canyons are narrow and steep with abundant evidence of past flood activity. Other potential hazards along railroad corridors identified by William R. Lund, UGMS, include slope stability, faults and seismicity, expansive soil and rock, collapsible soil, erosion and sedimentation, and groundwater (see Attachment A).

6.3.1.1 Geohydrology. For additional and more in-depth comments on geohydrologic issues see Duffy & Hall and Willett & Chapman.

6.3.1.1.1 Qualifying Condition. Geohydrologic assumptions are based on available data which is very limited. Uncertainties exist and many concerns arise out of this lack of data (see Willett & Chapman, Duffy & Hall).

DOE assumes the stratigraphic correlations between boreholes widely spaced apart in this area can be done with a fairly high confidence. Not only do geologists question the confidence level because of local facies changes (Chan, Zeisloft), but this cannot be applied with the same degree of confidence to hydraulic properties (Duffy & Hall).

The EA analysis indicates no evidence from GD-1 of dissolution in the site vicinity. However, the indication of no dissolution at GD-1 cannot be transferred to Davis Canyon. Dissolution can be a localized phenomenon and can only be investigated by testing the area in question.

There is no discussion of the Pinkerton Trail Formation. At the Elk Ridge location DOE subcontractors lost circulation when they attempted to drill through this formation. The high probability that the Pinkerton Trail is fractured and the lack of information on this formation indicates a need for more studies. DOE statements should not assume positive attributes unless they are indicated by information specific to Davis Canyon.

The EA does not consider the potential for flow upward to the Elephant Canyon Formation because the EA only evaluates expected conditions. However, there is a concern that flow could travel upwards. There is not enough data to determine flow paths. The salt is pressured and flow would tend to escape from the salt either up or down. The shaft could provide such a pathway.

There is no discussions of possible subsurface faults, joints, or local facies changes. These could greatly increase ground-water travel time.

Also of concern is our need to better define the permeability of the bounding clastic interbeds (see Zeisloft).

6.3.1.1.2 Analysis of Favorable Conditions

Condition (1) "Site conditions such that the pre-waste-emplacement ground-water travel time along any path of likely radionuclide travel from the disturbed zone to the accessible environment would be more than 10,000 years." DOE finds the condition to be present. Note here that the guideline refers to any path of likely radionuclide travel. Again, we argue that the path scenario upward to the Elephant Canyon needs to be looked at. The EA evaluates only a flow path/travel time via the Leadville Limestone.

Travel times for the upper or lower hydrostratigraphic units could be within the 10,000 year travel time frame if fractures, joints or other discrete hydraulic features such as dissolution conduits provided shorter pathways (see Duffy and Hall). The Leadville Limestone is also susceptible to dissolution, particularly where these rocks are fractured and faulted (Huntoon, 1985). The resulting increased permeability from these various features and the potential of closer proximity to the discharge areas (as close as the Cataract Canyon area, Dark Canyon area, and Imperial Fault zone where extensional faults are present) could very likely result in travel times less than 10,000 years.

Condition (2) "The nature and rates of hydrologic processes operating within the geologic setting during the Quaternay period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years." DOE finds the condition to be present. The basic assumptions are that climatic fluctuations will not exceed those of the past 500,000 years, and the maximum change that may occur is a return to full-glacial climates of the late Pleistocene. These assumptions appear reasonable, and calculated rates of surficial processes represent long-term averages and include the effects of cyclical climate change from glacial to interglacial climates. However, effects of climate change on ground-water systems and the dissolution of salt are less well-known and, as stated, many more data are required to define the correlation of dissolution and wetter climate conditions. More investigations are also needed to identify additional dissolution features. Dissolution has occurred in Salt Valley during the last 500,000 years, and the rate may not have been constant. This could imply increased rates of dissolution at other areas.

Condition (3) The EA finds that the site cannot be easily characterized with reasonable certainty and we agree.

6.3.1.1.3 Analysis of Potentially Adverse Conditions

Condition (3) We concur that the condition is present that the presence of stratigraphic or structural features could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system. Joints should also be included as potentially adverse features.

<u>6.3.1.2 Geochemistry</u>

6.3.1.2.1 Qualifying Condition

Not all of the available data were used in the EA in evaluating geochemical conditions. Parry & Morrison believe that neither the data used nor the data not used support the conclusion that the Qualifying Condition for Geochemistry is present or can be reasonably expected. Significant information is lacking on dissolution and this could pose a real problem at the site (see Parry & Morrison for detailed discussion). And, admittedly, site-specific geochemical information has not been obtained.

6.3.1.2.2 Analysis of Favorable Condition

(1) "The nature and rates of the geochemical processes operating within the geologic setting during the Quaternary period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate waste during the next 100,000 years." DOE states that a

favorable condition is present. We disagree based on insufficient information regarding dissolution. There are some very serious concerns about the possibility of dissolution breaching the site in either Davis or Lavender canyons (see the comments on dissolution in section 6.3.1.6).

In the analysis of both the Favorable Conditions and Potentially Adverse Conditions (6.3.1.2.3), Parry & Morrison elaborate on their concerns with the EA analyses including potential for dissolution, the composition of ground waters, the presence of organic materials and the unknown effects on radionuclide transport, altered mineral assemblages, and uncertainties of the waste package lifetime (see Parry & Morrison for detailed discussion).

6.3.1.3 Rock Characteristics

The potential for thermal expansion initiating salt flowage has not been addressed. This is of concern because once salt is mobilized, it tends to continue to move. It is not known how extensive or by what mechanism this movement will take place.

6.3.1.3.3 Analysis of Favorable Conditions

In considering the thickness of salt cycle 6, DOE should have used a USGS report by J. Daniels "Hole-to-surface Resistivity Measurements at GD-1..." which indicates that folding, and thinning and thickening of the salt may be present at GD-1. Also of concern, and not mentioned by DOE, is that carnallite may be present and, if so, it limits the total thickness of usable salt 6.

Condition (2), p. 6-91 "The coefficient of thermal expansion for Paradox Basin is ..." should read "for Paradox Basin salt is ..." Also, in the same paragraph, the EA fails to say what the predicted consequences will be due to a higher axial thermal expansion of salt compared to rocks in overlying strata. Will this cause problems or potential for fracturing and additional flow paths?

6.3.1.3.4 Analysis of Potentially Adverse Conditions

Condition (2) The EA states that "potential for deleterious effects in host rock properties caused by thermal dehydration of carnallite minerals present in salt cycle 6 is not apparent, as discussed in Section 3.2.7.1." In Section 3.2.7.1, it is only indicated that salt cycle 6 probably contains lower concentrations of carnallite in the geologic repository operations area than in GD-1. This inference is based on Hite's (1982) report which outlines a general area of the potash depositional limits. However, as the EA indicates, even though the site appears to be outside of Hite's potash depositional limit, the limit is not precisely defined (see p.3-27) and carnallite could be present at the site. So, there is a potential for the presence of carnallite in salt 6 at the site. Information is not presented on the effects (deleterious or otherwise) of carnallite on repository performance. That the effects of carnallite on repository performance are not known has been stated before in previous drafts of the EA.

Condition (3) New fractures may be created as well as existing fractures being opened from thermal uplift.

In conditions (2) and (3), although the EA recognizes thermal uplift as a means of enlarging fractures in strata overlying the repository as well as the increased potential for ground-water movement, Zeisloft questions the relation of the enlarged fractures and increased gound-water movement to the pervasive jointing in the proposed sites (see Zeisloft for further discussion).

6.3.1.4 Climatic Changes

p. 6-97, the EA mentions the effect of climatic change on dissolution and concludes there are no such effects, explaining that the change in the rate of hydrologic flow should be negligible even if the precipitation rate were doubled. Evidence at Salt Valley anticline indicates that dissolution activity has occurred during the past Ice ages (Doelling, UGMS). Such dissolution may not have occurred at Davis Canyon, but a future climatic change coupled with local problems of structure and stratigraphy could potentially make trouble.

The presentation of relevant data is, for the most part, adequate in terms of documenting past climate changes. Assumptions regarding future conditions such as a return to glacial climates are supported by evidence, although the evidence is not cited. Similarly, the effects of climatic warming caused by the build-up of CO_2 from burning of fossil fuels were not presented.

6.3.1.4.2 Analysis of Favorable Conditions
The analyses shoulo take into account that much of the dissolution activity in the past occurred during the past Ice ages (see above discussion).

6.3.1.5 Erosion

The presentation of relevant data incudes long-term stream downcutting rates calculated from the geologic record, but does not include data from modern sediment yield of streams and rates of erosion based on reservoir filling in the area. Also, stream down-cutting is the only facet of erosion considered, and the possibility of the retreat of scarps and cliffs through mass wasting is not considered. The analyses of conditions (favorable, qualifying, etc.) are supported by the data presented, although this additional data should have been cited. Much of these data were compiled and considered by Woodward-Clyde, and do not alter the conclusions of the EA.

6.3.1.6 Dissolution

6.3.1.6.1 Qualifying Condition
The information the EA presents with respect to dissolution in the Paradox Basin is very limited and very inadequate. The EA alludes to this on p. 6-135 (in the postclosure system guideline section) "Uncertainty with regard to the qualifying condition results from a lack of site-specific information." Although the evaluation is that there is no indication of Quaternary-age dissolution at the site, several geologists familiar with the Paradox Basin are concerned that there is no indication of no dissolution occurring in the site vicinity. p.6-105 "A major assumption of this discussion is that if these characteristics [surface features, anomalous seismic reflection patterns, and the absence or partial absence of salt as indicated on borehole geophysical logs] are absent in an area, as they are in the site, no salt significant (sic) dissolution has occurred." However, as is admitted in the EA, there is data limitation in the sparse distribution of wells, there is limited seismic reflection coverage, and surface mapping data are limited because of the scarcity of Quaternary deposits at critical locations in the geologic setting.

The EA does not make reference to several geophysical studies performed in the Gibson Dome area, some of which were funded by the DOE. These were not used by the DOE and there is concern that some of the data did not support DOE's conclusions. One such study was performed by the USGS (Daniels), "Hole-to-surface resistivity measurements at Gibson Dome (drill hole GD-1), Paradox Basin, Utah". The investigations indicated possible folding, and thinning and thickening of the salt units at GD-1. Another study ignored in the EA is a USGS report by Raymond D. Watts, "Interpretation of Schlumberger DC Resistivity Data from Gibson Dome-Lockhart Basin Study Area, San Juan County, Utah". In this study, some small conductive anomalies which could indicate presence of brine were detected at Harts Draw and Harts Point. It is noted in the report, however, that these were single-station and therefore somewhat uncertain. Other conductive anomalies were discovered, although the depth is often difficult to determine and the study area was limited. Also, a previously unknown solution feature was detected in the vicinity of Troughs Springs Canyon - about 6 miles northeast of Lockhart Basin. As stated in the report, the data are inadequate and significant anomalies could have been missed. The report recommends that more geophysical work, specifically electrical work is needed, not only to clarify the Hart's Draw and Hart's Point anomalies, but also to provide better coverage of the Davis Canyon area.

There are other potential dissolution collapse features near the Davis Canyon site which the EA should address, such as the Chesler Canyon fault zone 11 miles west, and the Salt Creek Pocket/Squaw Flat area 5 miles northwest (Huntoon, 1985).

Not discussed in the EA are: facies changes may be a strong controlling factor of potential dissolution; widely-spaced data points may not detect dissolution features that are present (see Chan for further discussion); dissolution can occur along joints and faults; the repository may open fractures; the consequences if water entered the repository via the shaft; salt dissolution features may be ephemeral in nature (see Parry & Morrison) and may be difficult to detect.

Already identified dissolution features nearest the repository site are Lockhart and Beef Basins. The Needles and the Shay graben complex have been identified as potential dissolution features. Huntoon and others are concerned that additional dissolution features have not yet been identified. The EA states that, "Quaternary or present dissolution activity in both Lockhart and Beef Basins is also not known at this time." DOE does not clarify that the timing and mechanisms of dissolution are not well known and that dissolution is a localized phenomena and it is not unlikely that some dissolution at Lockhart and Beef Basins took place during Quaternary time. For instance, on page 6-104, the EA states that "Faults with sufficient displacement to juxtapose Paradox Formation salt against the Leadville Limestone aquifer are known to underlie Lockhart Basin and are probably related to the dissolution there." The EA refers to section 3.2.5.1 to document this statement, however the evidence presented in 3.2.5.1 is contradictory, indicating that the Lockhart fault may be a tensional feature resulting from collapse of Lockhart Basin rather than a cause of the collapse (see Parry & Morrison for more discussion). If the fault did not cause dissolution, then what is the mechansim for dissolution in Lockhart Basin? Thus, the timing and mechanism of dissolution are not known, however it is clear that dissolution has taken place and could have taken place in or continued into the Quaternary.

6.3.1.6.2 Analysis of Favorable Condition

"No evidence that the host rock within the site was subject to significant dissolution during the Quaternary Period."

The evaluation is that this favorable condition exists because no surface representation of dissolution is present at the site. However, there is also no evidence to show that dissolution has not or is not occurring within the site.

6.3.1.6.3 Analysis of Potentially Adverse Condition

"Evidence of significant dissolution within the geologic setting ... such that a hydraulic interconnection leading to a loss of waste isolation could occur."

The evaluation is that the potentially adverse condition exists. We agree and would add to the statement, p.6-106, "no evidence of dissolution ... has been identified in the site" with "however, the evidence is incomplete and past dissolution could have existed and the potential for future dissolution may exist."

We agree that the potentially adverse condition is present, especially since, as stated in the EA, there is insufficient information to conclude that hydraulic interconnection could not occur in the near future.

6.3.1.6.4 Analysis of Disqualifying Condition

"The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution as predicted on the basis on the geologic record, would result in a loss of waste isolation."

The DOE's evaluation is that the evidence does not support a finding to disqualify the site on the indication that there is no dissolution within the site and on a model of dissolution rates from the nearest known dissolution area. However, unidentified dissolution features may exist closer to the site than the known dissolution area, and the calculations in this model are based on rates in the Texas Palo Duro Basin which may not be representative of the Paradox Basin (see Chan for further discussion). The timing and mechanisms for dissolution are not known in the Paradox Basin and, hence, assumptions and models based on a set of data for dissolution of a particular process and timing may not apply to conditions in the Paradox which may be highly localized. Before DOE applies a model to Paradox conditions, they should identify the processes at work.

The DOE evaluation did not consider that dissolution occurred more rapidly during the Pleistocene (Doelling, UGMS) and a significant climatic change or a small tectonic disturbance within the projected 10,000 year time frame could increase or instigate localized dissolution (see discussions above for other factors omitted in this evaluation).

Because the EA assumes a 10,000 year restriction in the disqualifying condition, it ignored the potential for dissolution within 100,000 years that could adversely affect the repository. The DOE applies the 100,000 year condition to some geohydrologic and geochemical conditions where dissolution is a factor (see 6.3.1.2.2 discussed on a previous page).

More data is needed on water analyses from the Leadville Limestone and Honaker Trail Formations to determine whether the brine in these formations is from dissolution. Although some reports suggest the brine is derived from dissolution of the Paradox Formation, this is not well documented. If it is from dissolution, it is not known whether it is occurring only along the basal contact of the sequence or from within it.

6.3.1.7 Tectonics

The tectonic relationships are addressed only on a regional scale.

Bruhn feels that the possiblity of a "characteristic earthquake" of large magnitude on the Shay graben fault zone needs to be addressed (see Bruhn for more details).

6.3.1.7.4 Disqualifying Condition on page 6-112, the DOE evaluation cites Shay graben and The Needles as unlikely sources for seismic problems. The EA does not discuss that dissolution occurring at these locations could possibly cause faulting and attendant seismicity, especially during a more humid climatic cycle.

The DOE does not address induced seismicity adequately. Although mining-induced seismicity is mentioned in the EA, there are other geographic areas and types of induced seismicity which need to be addressed, such as the injection or withdrawal of fluids including petroleum, and the effects on seismicity (see Chan for more discussion). For instance, the possible impacts associated with the withdrawal of fluids at Lisbon Valley have not been evaluated in the EA.

6.3.1.8 Human Interference and Natural Resources

p.6-115 "Based on the lack of untested structures within the site vicinity, and the lack of structures that are elsewhere associated with commercial accumulations, the probability of significant quantities of oil and gas being discovered within the site is judged to be low." This statement is not accurate. Instead, the evidence supports that the area has good potential for testing. Favorable formations and oil shows are present. Only test holes can prove out that there is no resource at Davis Canyon (see Zeisloft for additional discussion).

The Potentially Adverse Condition (4) should include the above discussion in the evaluation.

6.3.2 Postclosure System Guideline

6.3.2.5 The DOE conclusion that the potentially adverse conditions that exist could be compensated for by the existing favorable conditions appears to be highly subjective, particularly when some of the evaluations are based upon subjective judgements (such as the evaluations regarding dissolution).

6.3.3 Preclosure Technical Guideline

6.3.3.1 Surface Characteristics. This guideline concerns conditions that are important to the ease and cost of constructing, operating, and closing a repository. The DOE concludes for the qualifying condition that one of the two favorable conditions is not present and the one potentially adverse condition is present. The EA further states "Primary concern is in regard to the construction of railroad and highway access to the site in the evaluation of the favorable condition. While the condition was not found to be present, transportation corridors, both rail and road, have been built in similar areas throughout the western United States." The DOE has not discussed the risks of constructing transportation corridors through such terrain.

It is recognized on p.6-139 the the construction of the access road and railroad through the rugged terrain will be difficult and expensive. "However," the DOE goes on to say, "standard practice in the design and construction of these routes will allow potential sources of hazard such as steep grades, sharp switchbacks, and slope instability to be mitigated." We question this conclusion, especially since not all hazards are adequately addressed. Of particular concern are the effects of flash floods.

6.3.3.2 Rock Characteristics. In section 6.3.3.2.3, the EA states for the first time that if the carnallite zone is present, it could limit the flexibility of siting the repository with respect to depth. Not mentioned is that the presence of carnallite combined with the possibility of local thinning, thickening, and folding (Weir, 1983) could limit the thickness of the usable salt.

A previous data sheet (PA3 G) states that "Repository horizon selection to avoid carnallite is presumed." Not mentioned is that the carnallite profile in GD-1 shows about 30 feet of carnallite present near the top of salt 6 and approximately 60 feet of carnallite present near the bottom of the salt cycle. Therefore, a repository in salt 6 would probably be forced to deal with the carnallite and any related problems.

The EA does not discuss that if the carnallite in salt 6 is found to have detrimental effects, then salt cycle 9 will be the alternative host horizon, although this was mentioned in the earlier drafts of the EA and the data sheets. Salt cycle 9 is 173 feet deeper and is a thinner salt cycle. The salt available within cycle 9 does not provide as much buffer zone between the repository and the interbeds (non-salt lithologies). Also, potash was found to be present in salt cylce 9 at GD-1 and therefore may be present in salt 9 at the repository site The EA does not discuss the possibility of carnallite being present in salt 9 at the site.

In this section the EA recognizes, and we concur, that the following potentially adverse conditions could be present: salt creep will necessitate extensive maintenance of the underground openings during repository operation and closure; retrieval will be difficult due to salt creep and brine migration; and brine pockets and gas pockets could compromise the safety of the workers.

6.3.3.4 Tectonics. In section 6.3.3.4.2, the DOE concludes that the favorable condition (maximum earthquake shaking for Davis Canyon is not considered significantly less than values that have generally been allowed for nuclear facilities) is not present. On the next page in the conclusion for the qualifying condition, the EA makes a contradictory (and incorrect) statement that the favorable condition is present.

6.4.2.4 Preliminary System Performance Assessment. 6.4.2.4.1 "The total volume of brine that can reach the package is limited because brine migration ceases when thermal gradients from emplaced waste no longer exist." The DOE does not discuss when thermal gradients will not longer exist, and there seems to be some debate on this subject.

6.4.2.6.1 Geologic Processes. The EA discusses dissolution rates in the section on climate. Again, we reiterate our previous concerns related to dissolution (see discussion in this paper on dissolution, section 6.3.1.6).

Chapter 7

The most serious problem we have with the rankings is that when data is not available for a site, that lack of data is not considered unfavorable. Thus, if a site does not have unfavorable information, it is considered to be favorable, but it is quite possible that data would expose the presence of adverse or disqualifying conditions. The amount of data available for the sites is unequal and the types of data available at the sites varies, thus making comparisons difficult and subjective.

7.2.1.3 Rock Characteristics

p.7-26 The EA evaluates the sites against the potentially adverse conditions of thermally induced fractures; the hydration or dehydration of mineral components; brine migration; or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation. The EA states that the Davis Canyon site has the potential for fracturing and brine migration. Additionally, it should be pointed out that the site also has the potential for mineral hydration or dehydration, a condition discussed for the Texas sites but not discussed for the Davis Canyon site.

7.2.1.6 Dissolution

The evaluations are too general due to the lack of data.

7.2.1.8 Human Interference

p.7-50 The EA states that the Davis Canyon site contains some resources (uranium, vanadium, potash) but fails to include the potential for oil and gas.

7.3.2.1.3 Transportation (see attachment A by W.R. Lund)

p.7-90 "The cost of building rail access to the Yucca Mountain site would be high because of the distance (85 miles) and the need to construct a bridge. The construction of both rail and road access to the Davis Canyon site would be difficult and costly because of the distance and the rugged terrain." Davis Canyon and Yucca Mountain sites are significantly more costly than the other sites. The distance projected for the rail access is 37 miles for the Davis Canyon site, as compared to the 85 miles at the Yucca Mountain site. The EA includes a bridge for only the Yucca Mountain site and does not acknowledge the same for the Davis Canyon site although the representative railroad route to Davis Canyon, as indicated on figure 6-1, p.6-53, crosses the Colorado River near Potash and requires the construction of a bridge. In addition the EA states, p.7-90, under subcondition iii, that "the route to Davis Canyon would require tunnels, cuts, fills, and bridgework of significant proportions." The presentations for each condition should be more consistent.

p.7-93 DOE concludes that potentially adverse condition 2 (a terrain that might lead to hazardous conditions along access routes to a site) is present only at the Davis Canyon site. "The rugged terrain at this site would result in access routes with steep grades and sharp curves and the potential for disruption by rock falls and landslides." As commented on previously in this paper, there are even more hazards than what the EA indicates at the Davis Canyon site including flash floods as the most significant ommission.

p.7-95 We agree that the Davis Canyon site contains very difficult terrain in which to construct a railroad, increasing both the costs and the hazards.

7.3.3.1.1 Surface Characteristics

We agree that there are concerns with the surface characteristics at the Davis Canyon site because of the absence of flat terrain and the potential for flooding at the site. The EA has omitted discussion of the possibility of other hazards at the site such as rock fall.

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ATTACHMENT A

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GEOLOGIC HAZARD REVIEW OF THE DRAFT EA, DAVIS CANYON

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6.3 SUITABILITY OF NOMINATED SITE FOR DEVELOPMENT AS REPOSITORY AGAINST GUIDELINES REQUIRING SITE CHARACTERIZATION 6-75 6.3.3 Preclosure Technical Guideline, 10 CFR 960.5-2-8 6-135

Probably the most telling comment that can be made concerning geologic hazards in the Davis Canyon Draft EA is that the term "geologic hazard" does not appear in the EA text. Sections 3.2 GEOLOGIC CONDITIONS AND 3.3 HYDROLOGIC CONDITIONS do discuss some geologic hazards (seismicity, long-term erosion, subsidence, flooding), but the coverage is general in scope. Section 4.1 SITE CHARACTERIZATION ACTIVITIES outlines the geologic and hydrologic studies that would be conducted during site characterization. No activities, other than trenching Shay Graben, are planned to directly characterize geologic hazards, and geologic-hazard delineation is not listed as a secondary goal of any of the other programs, such as geologic mapping. The section on REPOSITORY CONSTRUCTION ACTIVITIES makes no mention of geologic hazards for either onsite or offsite development, and section 5.2 EXPECTED EFFECTS ON THE PHYSICAL ENVIRONMENT emphasizes the repository's effect on the environment, but does not consider the environment's effect on the repository.

The proposed Davis Canyon repository site is located in some of the most rugged terrain in the western United States. Rapid erosion associated with uplift of the Colorado Plateau has produced high mesas and steep-walled canyons that commonly exhibit hundreds and even thousands of feet of vertical separation over short horizontal distances. The arid climate of the Paradox Basin has limited development of vegetation producing large areas of barren or near barren landscape. The rugged topography, sparse vegetation, and large number of geologic formations with varying physical characteristics combine to produce geologic hazards that could have a significant effect on the repository and particularly on transportation corridors.

A field reconnaissance of proposed rail access alternatives to Davis and Lavender Canyons by the Utah Geological and Mineral Survey (Lund, 1982) identified seven potential geologic hazards that could adversely affect railroads in the Paradox Basin. Those same hazards are applicable to road and utility corridors and could affect operations at the repository, depending on final selection of the site boundaries. The seven hazard types identified were:

1. Flooding
2. Slope stability
3. Faults and seismicity
4. Expansive soil and rock
5. Collapsible soil
6. Erosion and sedimentation
7. Ground water

Flooding

Steep narrow canyons occupied by ephemeral streams are common throughout the Paradox Basin. Such terrain, when combined with limited vegetative cover and a climate typified during the summer months by brief intense periods of rainfall, creates a major flash-flood and debris-flow hazard. The rapid rise of water, its high velocity, and the sediment and debris carried with it make flash floods particularly destructive to the works of man. The frequency of such events is difficult to determine since they depend on the vagaries of the weather and characteristics of individual watersheds. However, by way of example, Moab experienced 26 damaging flash floods between 1897 and 1978, and Monticello had 10 between 1906 and 1965 (State Division of Comprehensive Emergency Management, 1981). It is expected that measures to mitigate flash-flood hazard would be a major cost item along all transportation and utility corridors.

Although not as widespread, overbank flooding along the flood plain of the Colorado River could present a hazard to portions of transportation/utility corridors.

Slope Stability

Considerable topographic relief, characterized by vertical cliffs, is typical of the terrain to be crossed by any transportation or utility corridors to Davis Canyon. Mass wasting, principally rockfalls and debris slides, is a common phenomenon on natural slopes throughout the Paradox Basin. Such processes may adversely affect transportation and utility corridors that are located too close to a cliff or that cross naturally unstable ground. Large numbers of rockfall deposits were observed during the reconnaissance of the proposed rail alternatives. Because of the rugged topography, numerous man-made cuts will be required along corridor rights-of-way. The stability of the cuts in weak, jointed, or fractured rock or in unconsolidated material such as talus will have a direct impact on the operation and maintenance of the corridors.

Seismicity and Faulting

The Paradox Basin is generally recognized as an area of low seismic activity; however, the potential effect of a moderate earthquake (M_L 5.0-6.0 on the repository and transportation/utility corridors should be considered. The principal danger would be from ground failure associated with ground shaking. Additionally, corridor rights-of-way may cross faults whose state of activity is unknown, and may be capable of surface displacement. Those same faults, whether active or not, are of concern because of their influence on cut-slope stability and tunnel excavation.

Expansive Soil and Rock

Bedrock formations that include varying amounts of shale and claystone crop out across the Paradox Basin. Those rock types and the soils derived from them contain clay minerals with the capacity to absorb water and swell when wetted. Swelling causes many shales and claystones to slake (crumble and disintegrate) when exposed to air and moisture in a fresh cut. The large volume change produced in some materials makes them unsuitable for use in engineered fills and may result in damage to foundations, utilities, and roadbeds. Where encountered in tunnels shale may "squeeze" making excavation costly and difficult. A careful evaluation should be made of the shrink/swell potential of rocks and soil wherever fine-grained sedimentary rocks occur along transportation/utility corridors or on the repository site.

Collapsible Soil

Collapsible soils are low-density materials that undergo a volume reduction when wetted or subjected to heavy loads. They are commonly associated with mudflow and debris-flow deposits on young alluvial fans and with recent flood-plain deposits along streams. Such deposits occur within the Paradox Basin. Collapsible soils are also associated with weathered shale bedrock. The geologic formation most often associated with such soils in Utah is the Mancos Shale which does not crop out in the study area. However, the extent to which collapse-prone soils have developed from shale formations in the Paradox Basin is not known, and should be investigated wherever site facilities or transportation/utility corridors cross areas underlain by shale bedrock. The principal hazard from collapse-prone soils is differential settlement of foundations, embankments, and roadbeds.

Erosion and Sedimentation

Increased erosion and associated sedimentation may result from construction of the repository and associated transportation/utility corridors. Activities such as stripping vegetation, modifying natural drainages, building flood-control structures, and earth-moving activities will alter the natural rate of erosion and deposition. Potentially adverse effects could range from relatively minor long-term maintenance problems to total distruction of a corridor section or related facility. Sediment deposition can block culverts, increase flood damage, and reduce the capacity of flood-control structures.

Ground water

High ground-water conditions may occur along corridor rights-of-way adjacent to the Colorado River. Shallow ground water affects the bearing capacity of saturated soils and may necessitate the use of special foundation and roadbed designs. Hydrostatic pressure caused by rapidly fluctuating ground-water levels can crack foundations and buckle roadbeds. Permanent lowering of ground water can result in consolidation of previously saturated soil horizons producing differential settlement at the ground surface. Shallow ground water also influences the response of foundation soils during an earthquake and their potential for liquefaction.

Although not a safety or reliability issue, the possible effect of construction activities on springs or ground water seeps along or adjacent to corridor rights-of-way should be considered. Most springs in arid portions of southeastern Utah are in delicate balance with their environment. Disturbance of their recharge areas by construction activity may result in significant changes in discharge. Such changes could have a negative impact on wildlife and grazing.

The results of UGMS studies in the Paradox Basin show that potential geologic hazards exist which may affect the safety of waste transport and the operation/maintenance of a repository site. None of the identified hazards appear sufficiently serious to remove the Davis Canyon site from consideration as a nuclear waste repository. However, further definition of the hazards and planning for their mitigation will be necessary. The type and extent of mitigation required may prove a significant factor in determining the cost of establishing a disposal site. Apparently some of those costs have been recognized by the DOE, since their estimate for constructing transportation facilities to Davis Canyon is roughly ten times greater than for other sites under consideration. Based on this review of the Davis Canyon Draft EA, it is apparent that geologic hazards were not considered a valid criteria for evaluating the suitability of a site for a nuclear waste repository. The attitude seems to persist on the part of the DOE that geologic risks can be mitigated if enough money can be spent, which is probably true if the final cost of the repository is considered no object.