REPORT OF THE PANEL

ON

EVALUATION OF GROUND-WATER FLOW IN FRACTURES

AT

THE PALO DURO BASIN

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I. INTRODUCTION

The stated charge addressed in this report is to assess the relative importance of, and availability of data to evaluate the fracture contribution to ground-water flow at the Palo Duro Basin sites in Texas. In arriving at our conclusions, the panel has reviewed pertinent publications, has been presented information from various participating contractors, and has had an opportunity to question these contractors. On the basis of these inquiries, we have developed our own conceptual model of ground-water flow along with the possible relevance of fractures within this conceptual framework.

II. CONCEPTUAL MODEL

A. Overview

The salt sections and underlying Wolfcamp rocks of Permian Age are low permeability - low flux members at the Palo Duro sites. Meteoric water enters these formations at their western outcrop areas and thereafter moves in the downdip direction to eastern discharge areas. The hydrologic system in communication with meteoric recharge is relatively young, perhaps 12 to 15 million years. As a consequence, all formations still contain connate water that was trapped in the sediments during their deposition in Permian time. This conclusion is relatively well supported by the geochemical evidence, in particular the isotopic data presented by Knauth. The spatial distribution of this water is a reflection of the relative permeability of these rocks, with the Wolfcamp series being the most actively flushed in the western and central regions, but still containing connate water in the east. Based on very limited data, the salt section, in particular the #4 dolomite does not appear to be flushed at all in the central region, which supports the contention of low permeability, and low ground-water flow velocities, within the salt section rocks. Local hydraulic gradients, across individual members of the salt section may be upward or downward, although the main component of flow appears to be dominantly horizontal. The low (so called subnormal) pressures of the underlying Wolfcamp in combination with the higher heads in the Ogallala Formation and Dockum

Group assures a net vertically downward gradient across the rocks, resulting in a downward flow component. The net result is a downward movement in the low permeability salt with the horizontal flow occurring in the more permeable units below the salt horizon unless these formations are fractured and have significant secondary permeability.

The evolution of the flow system over time, in particular the subnormal pressure of the Wolfcamp, is uncertain at this time. There is a possibility that the salt section is still undergoing long-term, transient changes in pressure as the relaxation time of this low permeability section is much larger than the corresponding time for the more permeable Wolfcamp. This may account for the large gradient across the bottom of the salt section to the Wolfcamp where the difference in response time is so large that the Wolfcamp has continually approached a steady state flow regime much quicker (and possibly more or less independently) than the low permeability salt sections. The geologic events producing these transients would include regional uplift and tilt (10 to 15 x 10^6 years before present), incision of the Pecos River (about 2 x 10^6 years before present), and escarpment retreat (less that 1 x 10^6 years before present).

The major structural features include surface lineations and subsurface faults. The subsurface faults cut the basement rocks and sometimes extend into the base of the Permian horizon. These features do not appear to cut through the entire salt section. However, the relatively large number of surface lineations, observed across the basin, may correlate with the bedrock faults. No evidence has been presented that would suggest there are continuous features from basement to land surface. If they are continuous, it cannot be assumed that they constitute continuous, connected anomalously permeable pathways. However, the closed depressions at the base of the Ogallala Formation and Dockum Group may suggest that the lineations are connected across these formations. Consequently, the potential for a fault or disturbed zone to extend across the salt section cannot be discarded entirely, but it remains a low possibility, especially within individual beds of rather pure halite which do not readily sustain open fractures.

The unlikeliness (low probability) of permeable fractures transecting the salt section is further supported by studies by the Texas Bureau of Economic Geology in particular those of Hovarka. Detailed core studies indicate that these rocks contain numerous fractures, virtually all of which are apparently filled with secondary minerals, including halite. Fracture occurrence was greatest in the mudstone sections, the anhydrite, the carbonates, and the halite, respectively. The fractures are described as vertical or near vertical. As several such vertical veins were encountered, they are likely ubiquitous in the more brittle beds of the salt section. The fact that fractures heal or fill quite readily is supported by the geochemistry of the fluids in which minerals like halite precipitate in openings. Based on this evidence there is a very low probability that these internal discontinuities are continuous flow paths through the salt section. However, based on observations made in other parts of the Permian Basin (WIPP site) open fractures are noted in the Castille anhydrite, although they may be structurally controlled by processes responsible for salt anticline formation. No similar structures containing brine reservoirs are recognized in the Palo Duro Basin. For these reasons, the possibility for some open fractures in the salt section cannot be totally discarded, but appears to be a low probability given the limited, available data.

B. SUPPORTING EVIDENCE AND ISSUES

1. Lineaments

According to Collins and Luneau, 1985, zones of closely-spaced joints exist throughout Permian and Triassic strata in both Cap Rock Canyons and Palo Duro Canyon State park, several miles from the sites. Where exposed, these structures were observed to range from 10 to 40m wide and to extend to lengths of up to 0.75 kilometer or possibly farther.

The report indicates that the density of joints in these shear zones is about 10 joints per 2m for beds 0.5 to 3.0m thick. Away from zones of fracture concentration, joint densities are five joints per 2m for beds 0.5m thick.

Evidence for larger surficial lineation features is given by Finley and Gustavson (1981), and Gustavson and Budnik (1985). Structural features of post-Seven Rivers strata as well as segments of stream valleys (Tierra Blanca, Frio Draw and Palo Duro Creek) overlie and are parallel to a zone of apparent preferential salt dissolution. Tierra Blanca Creek and Frio Draw flow to the northeast in a broad topographic trough that overlies the dissolution zone causing thinning in Seven Rivers salt.

Tierra Blanca Creek flows parallel to the string of paleo topographic lows on the middle Tertiary erosion surface in eastern Deaf Smith County and vicinity. These three streams valleys are oriented oblique to the more regional drainage trend on the Southern High Plains, which is to the southeast.

Structure-contours on the base of the Ogallala Formation also show a series of "paleo topographic" lows and closed depressions on the Middle Tertiary erosion surface that overlie northeast structural and apparent dissolution collapse trends (Knowles et al, 1982). Gustavson and Budnik (1985) do not refer to these features as lineaments but the implication of these linear trends is that they might reflect pervasive structures seen at the land surface that have their origin in the underlying crystalline basement. Fault offsets in the basement that extend into shallower, near surface rocks are implied by Gustavson and Budnik (1985). However, similar controls on surface drainage and salt thinning might equally well be accounted for by crustal movements that induce fracture zone development in overlying rock without requiring propagation of faults to the surface.

It is certain that linear features are present at the land surface in the Deaf Smith - Swisher regions, and that shallow salt dissolution appears related to these linears. Extensive high angle faults are present in the crystalline basement that might be related to these surficial to near surficial linear features. However, drilling of one lineament (Detten No. 1) has not found evidence of increased fracturing, open or filled within brittle beds beneath these linear features. Hence, it has not been established if lineaments are underlain by zones of increased permeability when compared to immediately adjacent strata. During our June 3-7, 1985, briefing, Larry Picking of Stone and Webster reported that the Detten No. 1 well was intentionally drilled on one NE-SW linear oriented through what has been referred to as a lineament by the Texas Bureau.

Mr. Picking indicated that no out-of-the-ordinary structures, open joints, fluids occurrences or higher permeability values were noted in this deep test well when compared to other Stone and Webster deep test wells. However, zones of fracture concentrations defined by major lineaments 10 or so kilometer in length, may be only 10 to 100m wide and difficult to follow in drilling.

A test drilling program will have to be carefully designed during the Site Characterization stage to more fully address the concern of testing these narrow zones of potential fracture concentrations. Further, it would be unwise to select a potential repository site in such a manner that it had a high probability of being located on one or more major surface lineaments, or intersecting a subsurface structure.

Because such a structure could exist, the panel recommends that it be included as a low probability pathway in travel time calculations. However, the panel does not believe that such fracture zones would remain open within halite-dominated salt beds which appear to be forgiving, and the panel rejects such occurrence from its modeling recommendations.

2. Strata-Bound Dissolution and Breccia Pipes

Dissolution of Permian rocks has occurred in the Texas Panhandle and eastern New Mexico (Gustavson and others, 1980; Gustavson, and others, 1982; and Simpkins, et. al., 1982). Near surface dissolution in the vadose or phreatic zone develops caves, solution breccia, and accounts for the removal of salt. Such dissolution features appear to be abundant near the northern margin of the basin and above the upper zone of salt dissolution; hence, will not influence water flow from the repository to the top or bottom of salt.

Evidence for Permian salt dissolution was also presented that accounts for changes in bed thickness, insoluble residue distribution, and fractures observed in cores within the salt section. Such salt dissolution appears to be related to repeated salt water invasions of the evaporite basin during the Permian. No evidence was provided to suggest that detectable amounts of post-Permian ground waters have moved through more brittle beds within the salt section to enhance salt dissolution and to increase rock permeability.

Horizontal flow within brittle beds within the salt section may be enhanced by joints, fractures, or zones of fractures concentration but, only limited permeability data are provided to support or discount this possibility. No significant losses of salt appear to be related in intrastrata bound dissolution of the type reported in the Delaware basin.

3. Joints and Fractures

Data on the nature of fracture development are available from core descriptions and fracture identification logs (FIL). In general, several different investigators have concluded that the fractures are all filled with secondary minerals (including S. Horvoka from TBEG and

L. Picking from Stone and Webster). Where unfilled fractures appear in the core they appear to have been caused by drilling, core handling, and core storage. Strata overlying salt-bearing units exhibit vein fillings of gypsum, whereas strata fractures in or below the salt are filled with calcite and anhydrite. Fibrous gypsum is the main vein filling above the salt dissolution zone.

Studies of fractures and veins within core were conducted on strata located (1) below the salt zone, (2) within the salt zone, and (3) within the thin dissolution zone. As might be expected, the strata in the dissolution zone are more fractured than salt zone units. The core from this area contained from 30 to 50 percent more fractures, but they were all filled with calcite.

Units within the salt zone contain the lowest percentage of fractured core because fractures and veins almost always occur in thin mudstone, salt, and anhydrite interbeds. Fractures within the thicker salt sequence are rare (Collins and Luneau, 1985). They report that the fracture and vein percentage in core within the salt zone units are similar for all boreholes in the three counties whereas the frequency of fractures and veins in Wolfcamp core decreases away from the Bravo-Dome-Amarillo Uplift (site of DOE-Stone and Webster #1 Mansfield borehole).

The authors cite evidence for synsedimentary and post-compactional origins of joints. Some appear to be related to early burial but in close proximity to an overlying regime of evaporite deposition. The parallelism of vein orientation to regional structural trend as suggests that halite veins developed under the influence of the regional stress field (Collins and Luneau, 1985).

Information from TBEG descriptions indicated the fracturing in the Permian sequence was dominantly in the mudstones with approximately 10 percent of the total core containing fractures. No fractures were observed in the anhydrite and only minimal fracturing was observed in the halite. This is in contrast with the WIPP site where fractures have been observed in the anhydrite interbedded with Salado and Castille salt. All of the fractures intersected by the core in the Palo Duro area, were filled with calcite and no open fractures were observed.

Fracturing was observed in the Wolfcamp Group with approximately 10-25% of the unit containing fractures. Fracturing is nearly vertical with a NE-SW and NW-SE orientation appearing to be dominant. Fractures were also detected in carbonates where anhydrites had been formed, but these also were calcite filled.

At the Deaf Smith site, observed fractures trend in northeasterly and northwesterly directions and parallel basement structural trends that influenced the depositional thickness of selected Palezoic rocks (Gustavson and Budnik, 1985). The overall stress system indicates that the northeast trending fractures are more likely to be open, hence were likely to influence ground water and salt dissolution (Dutton et al 1982). The analysis of fault and salt dissolution movements in the exposed portion of the Wichita Uplift suggest a stress system with northwest trending, subhorizontal principal compression, and subvertical intermediate principal compression. In situ stress measurements following hydraulic fracturing of Permian strata in the Stone and Webster No. 1. Holtzclaw well in Randall County also indicates that regional northeast-southwest principal comprehensive stresses occur between N 40^{o} E and N 60^{o} E (Stone and Webster Engineering Corp., 1984; unpublished data reported in Gustavson and Budnik, 1985).

In summary, although open joints have not been detected thus far, allowance should be made for some open joints or fractures in modeling ground water flow velocities in the EAs. These joints and fractures are not visualized as being vertically or horizontally interconnected throughout or within all beds within a given stratigraphic unit. Halite beds should serve to isolate open joints in the vertical direction between brittle beds.

4. Experimental Evidence

Characteristics of salt with respect to its healing capabilities have been discussed to some extent in the literature related to salt mining and petroleum drilling experience in salt horizons. A recent laboratory experiment described by Tom Doe, OCRD, indicated salt has a definite healing ability. Mr. Doe also described a laboratory hydraulic fracture experiment where a salt block was hydrofractured. This experiment found the salt had a distinctly different mode of fracture origin versus consolidated rock such as limestone or sandstone. Salt does not appear to fracture in a distinct plane but tends to build a fracture from an initial point. It was interesting to note that after the fracture had been formed and the experiment stopped (Pressure reduced), no identifiable fracture planes or partings could be seen. Upon re-testing it was found the salt would recover to about 100 to 200 PSI of its original tensile strength after 12 hours of loading.

These experiments were conducted on essentially pure halite and indicate good healing characteristics. It is the feeling of the committee that more research is needed relative to the physical characteristics of the salt near the Palo Duro site. This salt is considered "dirty" containing considerable clay, and beds of mudstone which vary in thickness. It was found that dominant fracturing occurred in the mudstone/siltstone beds. Information should be collected on how the content of silt and other impurities within the salt affects the natural fracture resistance of salt (i.e., its brittleness) and the effect on the self healing ability of the salt. These are very important in analyzing fracture flow potential in the salt horizon.

5. Heads and Gradients

Because of the extreme variation in fluid density, as well as uncertainties associated with interpretations and measurements of fluid pressure and permeability distributions, the magnitude and direction of vertical gradients within the evaporite section are characterized by significant uncertainty. However, as mentioned previously, it is possible for the gradients to range from predominantly downward to slightly upward in some locations. The uncertainty in gradients should be considered in the probability analysis of travel times and pathways. This can be done by assigning several sets of expected pressure/density distributions to the cross-sections models, and by varying pressures randomly within their expected probability distributions.

East-west cross sectional (two-dimensional) models are useful for gross conceptual analysis of such major features as boundary conditions, vertical-leakage sensitivity, and under-pressuring phenomena in the Wolfcamp-Pennsylvanian units. However, these models should not be considered reasonable representations of the real flow system for pathway and travel time analyses because of the following limitations.

- The cross sections are generally not oriented along predominant gradient directions in either the upper or lower zones of flow.
- The gradient direction in the upper and lower zones of flow are widely divergent, and therefore cannot be adequately simulated by a two-dimensional cross section model.
- The models use fresh water heads which are inappropriate for determining three-dimensional vertical gradients, in a variable-density ground water.

The frequency of reference to these models in many publications and figures could mislead readers into an incorrect interpretation of the real flow system.

6. Geochemistry

Knauth presented a preliminary result of how chemical data from formation waters can be interpreted to yield information on the hydrodynamics of flow in the basin. He has defined zones of water chemistry in the salt sequence and deeper units in the eastern end of the basin based on features of the isotope chemistry. The ^{18}O and deuterium content of water sampled from within the salt sequence is enriched relative to present-day meteoric waters and suggests formation due to the evaporation of sea water. Water from beneath the salt sequence in the eastern end of the basin has a different isotopic character, but apparently also does not contain a meteoric component.

Recharge to the basin is generating a mixed meteoric-formation water along a mixing line between brines at the eastern end of the basin and present-day meteoric water recharging from the western end of the basin. Knauth has shown that this mixing not only controls the isotopic composition of the deep formation waters, but also the major ion content.

The chemical data for the salt sequence support the concept that the quantity of ground-water flow through these units is very small. However, as Kreitler pointed out, these observations and the pattern of fluid mixing within the Wolfcamp Series do not completely rule out the possibility of localized zones of ground-water leakage through the salt sequence. Nevertheless, the correspondence between the major ion and isotopic mixing patterns more strongly supports the concept that brings relatively lower salinity meteoric water from the edge of the basin around and under the salt sequence. Knauth argues that saline meteoric water moving through the salt sequence would not produce the observed patterns of mixing within the Wolfcamp Series.

III. TRAVEL TIME CALCULATIONS

The uncertainties inherent in the description of the geologic and hydrogeologic setting of the Palo Duro Basin and other sites means that estimates of travel time will also be subject to uncertainty. The panel believe that this uncertainty should be reflected in the way travel time assessments are made by developing a probability distribution on travel time. Presenting the data in this way not only characterizes the uncertainty but also helps to evaluate the probability of travel times of less than 1,000 or 10,000 years. We have not established criteria for use in qualifying a site based on travel time distribution. In general however, a very low probability of travel times of less than 1000 years should not disqualify a site, but provide guidance for site characterization.

At this stage of limited information, it is our contention that any site anywhere has some low probability that ground water will move a few kilometers in less than 1000 years. This is because such occurrences can be controlled exclusively by hidden geologic detail that may never be revealed and especially so in fractured rock.

A Monte Carlo technique is probably most appropriate for carrying out calculations of travel time. Realizations of the hydrogeologic setting can be generated from appropriate probability distributions for the important transport parameters and the basic system geometry. The travel times, which are estimated for each of the realizations in a complete Monte Carlo simulation, will ultimately provide a probability distribution in travel time. The modeling approach, developed by INTERA Technologies, Inc., for the Salt Repository Project, is based on such an approach and should be useful for the travel time calculations.

The model must adequately reflect hydrogeological conditions in a basin and represent all reasonable travel pathways. As the conceptual model

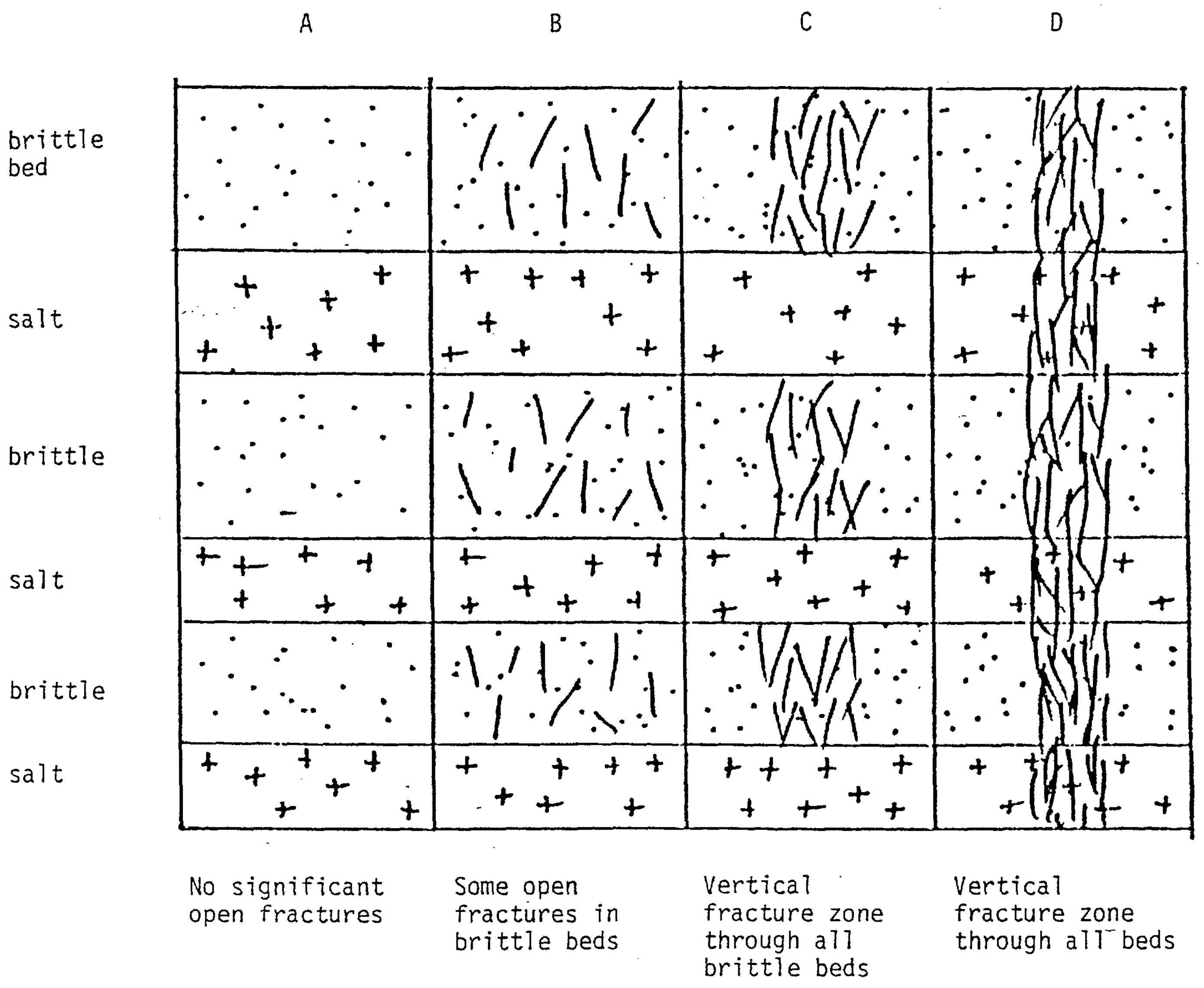

FIGURE 1. Hypothetical schematic fracture styles considered by the panel for ground-water flow in the evaporite section of the Palo Duro Basin.

of the Palo Duro Basin suggests, fluid probably flows in both fractured and porous rocks but is most likely dominated by porous flow. We would recommend that fracture flow be modeled as equivalent porous flow with an appropriate adjustment of effective porosity and possibly permeability. Values of effective porosity are thought to fall in range from slightly less than total porosity to a lower limit of 1×10^{-3}. Data are not sufficient to justify the use of network models for fractured flow.

Depicted in Figure 1 are simplified examples of fractured and porous flow conditions that could be included in a Monte Carlo model. We consider Case A, a condition of non-fractured porous flow to be the expected or the most probable condition in the Palo Duro Basin. Probability distributions on the hydraulic parameters should be sufficiently general to account for some dispersed, low intensity fracturing in what we term the brittle or non-salt units. This type of fracturing (depicted in Case B, Figure 1) should not necessarily be correlated between geologic units. Case C represents fracturing associated with structural discontinuities that may be propagated, from the basement, upward to the ground surface. More specifically, this fracturing probably involves fracture flow through the non-salt units and porous flow through the salt units (Figure 1 and 2). Travel times calculated along this pathway, if possible, should include times for movement along mainly porous pathways (Cases A and B) to the vertical discontinuities. The actual position of this vertical zone should be treated as a random variable. Because this total travel path is thought to occur infrequently in the Palo Duro Basin, its contribution to the overall travel time distribution should reflect this low probability of occurrence.

Case D (Figure 1) is a situation where conditions of fracture flow are propagated along the entire length of a structural discontinuity. From our examination of the available data for the basin, we do not feel that

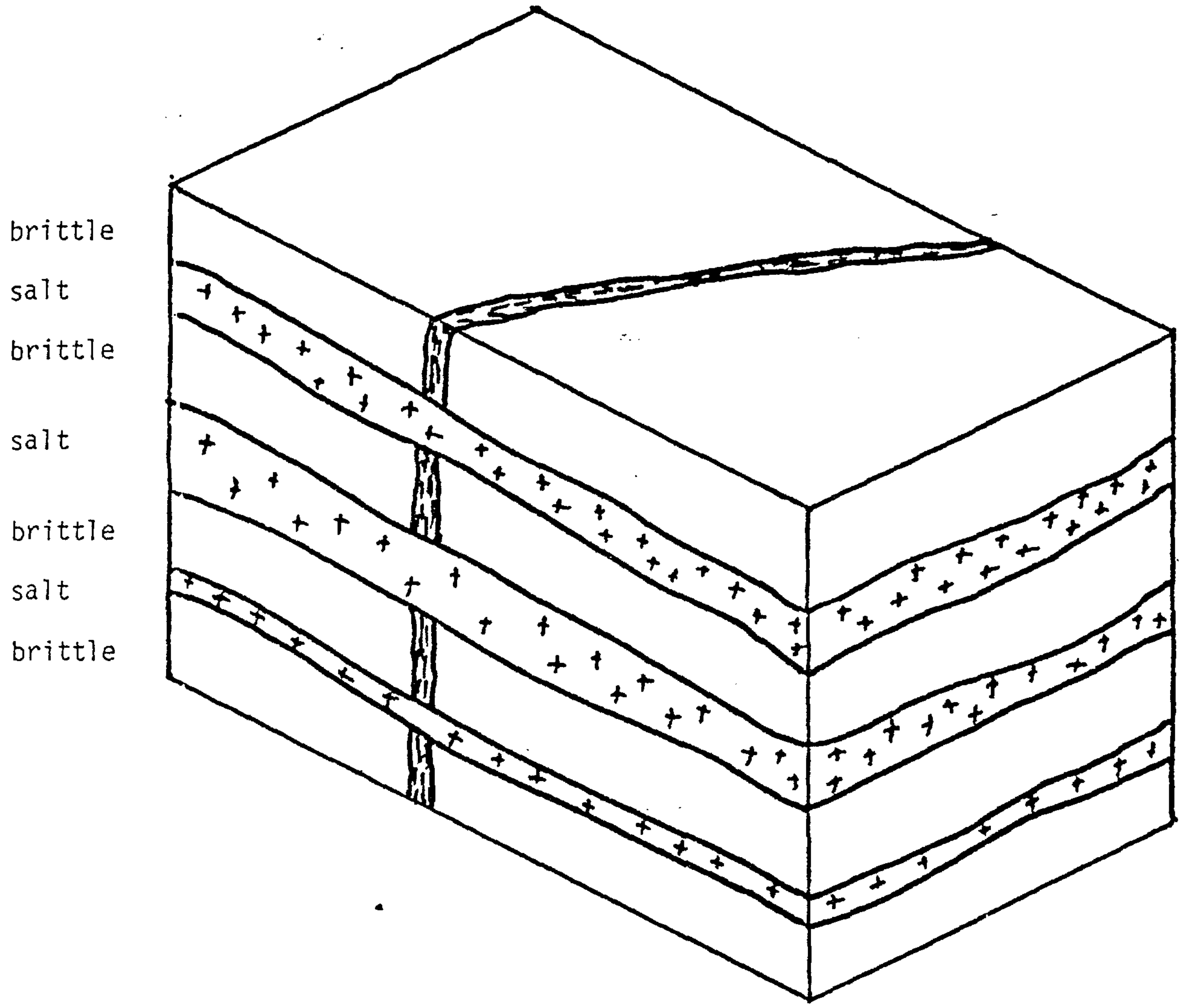

FIGURE 2. Schematic representation of hypothetical fracture zone propogating vertically through brittle beds only of the evaporite section, as represented in Case C of Figure 1.

a case can be made at this time for the existence of this kind of pathway in the basin. Thus, we would recommend that Case D not be included in the Monte Carlo analysis.

IV. CONCLUSIONS

There is no direct evidence that the regional ground-water flow in the Palo Duro Basin in the areas of Deaf Smith and Swisher Counties is significantly controlled by fractures which might have higher permeability or faster flow paths than the bulk rock porous permeability.

There are indirect suggestions that subsurface faults or surface lineament features might penetrate all or most of the stratigraphic sequence from basement to Dockum-Ogallala in some locations. However, the panel believes that these features are not likely to contribute to significantly shorter travel times than other pathways. This is because of the predominant evidence that fractures in the more brittle strata tend to be filled and that fractures in salt at depth tend to close and heal. However, because it is possible that these lineament features could have higher permeability and/or lower effective porosity, their potential effects on ground-water travel time should be analyzed in the EA with realistically conservative assumptions.

With current available information, the panel believes that the most likely ground-water pathway is as porous-media flow, through the bulk permeability and non-fractured, effective porosity of the stratigraphic units downward and laterally into the Wolfcamp series. A range of travel times can be estimated adequately by stochastic pathway analysis using known or expected distributions of pressure, fluid density, permeability, and effective porosity.

The conceptual model of the regional flow system indicates that ground-water fluxes and flow velocities through the evaporite sequence are very low. This model is consistently supported by independent lines of evidence from geochemical data, pressure and density distributions, permeability measurements, geologic and geophysical data, and modeling analysis. Although all the more brittle rocks in this system are fractured, the fractures are generally filled with secondary minerals, and the system appears to behave consistently, as an extremely low-permeability, low-flux porous medium.

V. RECOMMENDATIONS

The panel makes the following recommendations regarding ground-water travel time analysis in the Palo Duro Basin EA:

- The most probable flow path should be considered as porous medium flow through the sedimentary strata. However, because of the uncertainties, the porous flow paths and resultant travel time should be stochastically evaluated using realistic distributions for all the key parameters.

- A low-probability fracture-controlled pathway should also be considered. Some analyses should be carried out assuming a vertical lineament feature penetrating the sedimentary stratigraphic sequence in the vicinity of the repository which provides higher permeability and lower effective porosity in the more brittle rock units only, and porous media flow through the salts.

- Fracture fissure or fault generated hydrologic pathways through the halite-rich units salt should not be considered due to lack of credible evidence for their existence at this stage.

- Similar travel time calculations and analyses could be made for the Paradox Basin sites in Utah, which have a similar geologic setting.

Although the salt dome sites in Mississippi were not examined in any detail in this review; their hydrogeologic setting is considerably different than the Palo Duro or Paradox Basin environments and would warrant separate analyses.

- Site characterization plans should include some emphasis on characterizing location, extent and hydraulic significance of both lineament features on the surface and structural features extending from the basement.

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APPENDIX A

LETTERS OF CONCURRENCE

Richard R. Parizek, Ph. D.
Professor of Hydrogeology and
Consulting Hydrogeologist
751 McKee Street
State College, Pennsylvania
16803
July 5, 1985

Dr. James Tracy
Battelle Washington Operations
2030 M. Street, N. W.
Washington, D. C. 20036

Dear Jim:

I concur with the wording, findings and conclusions of the Second Draft Report prepared by the Salt Project Ground-water Modeling Panel. Corrections were made to this draft by phone on July 5, 1985. These should be included in the final report. They include spelling and similar other minor corrections. Paragraph four on page 4 (lines 7- 8) has a technical correction that must be included. It is an incomplete sentence as it now stands.

Very truly yours,

Richard R. Parizek

Richard R. Parizek, Ph. D.
Professor of Hydrogeology and
Consulting Hydrogeologist

RRP:ebp

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REFERENCE U S DEPARTMENT OF ENERGY
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CONTRACT DE AC02 83WM46656
FLUOR CONTRACT 839704-9-K014
M K WORK ORDER 1638

June 28, 1985

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Mr. James Tracy
Battelle
Project Management Division
Washington Operations
2030 "M" Street NW
Washington, D.C. 20036

Subject: Final Report on Fracture Flow Potential - Palo Duro Basin

Dear Mr. Tracy:

Enclosed is a final draft of the report prepared by the review panel, addressing the issue of fracture flow in the proposed Palo Duro Basin repository site in Texas.

This report reflects my professional opinion, based on the information presented and supplied by ONWI and various subcontractors.

Sincerely,

Leland L. Mink
Manager - Hydrologic Services

LLM/daB

Attachments

cc: P. W. McKie
R. W. Whiton
L. L. Mink
Project File
Reading File (w/o att)
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Groundwater Hydrologist
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June 27, 1985

James Tracy
Battelle
Project Management Division
2030 MStreet N.W.
Washington, D.C. 20036

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1985
BATTELLE
BPMD/BWO

Dear Jim,

Enclosed you will find the draft of the panel report. The report represents my professional opinions regarding the Palo Duro Basin site.

Sincerely,

Patrick Domenico

Patrick Domenico

ROUTING AND TRANSMITTAL SLIP Date 10/23/85

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July 5, 1985

Dr. James O. Duguid
Project Management Division
Battelle -- Washington Operations
2030 M St., NW
Washington, D.C.

Dear Jim:

Attached is the draft final report of the special panel to review groundwater flow through fractured Permian rocks of Palo Duro Basin, Texas.

I have reviewed the report as requested and indicated my final comments (all editorial in nature) directly on the text. The report accurately reflects my professional judgements and opinions regarding this issue and to the best of my knowledge accurately refelcts the consensus of the panel on the issue.

Sincerely,

Jack

John. B. Robertson
Vice president
Director of National
Ground Water Programs

JBR:slg
Enclosure