EEG-6

Geotechnical Considerations For Radiological Hazard Assessment of WIPP

A report of a meeting held on January 17-18, 1980

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CONTENTS

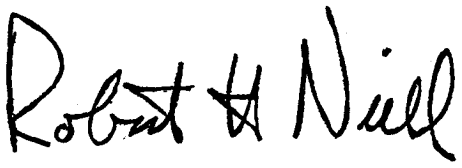
FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is no environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department – the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and other organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.



Robert H. Neill
Director

INTRODUCTION

To ensure consideration of all important pathways in the quantitative assessment of the radiological health risks to people from the proposed Waste Isolation Pilot Plant (WIPP), The Environmental Evaluation Group (EEG) arranged a meeting on January 17 and 18, 1980. The meeting, entitled "Geotechnical Considerations for Radiological Hazard Assessment of WIPP," was held at the Holiday Inn in Albuquerque, New Mexico.

Participants included thirty-five geologists, hydrologists, geophysicists and geochemists, who provided their views on the geologic and hydrologic mechanisms which might lead to the release of radionuclides from the WIPP repository. To help obtain a balance of views, the invitees included knowledgeable experts from Federal and State agencies, the National Academy of Science's WIPP Panel, the Governor's Advisory Committee on WIPP, several universities in the State, the mining industry and the Natural Resources Defense Council. A list of the participants and the agenda is contained in the Appendix.

As background information, each participant was provided in advance a notebook containing the agenda, list of invitees, a brief description of scenarios suggested as possible natural and man-made mechanisms leading to release of radionuclides form the repository, a summary of borehole data, selected illustrations from the Draft Environmental Impact Statement (DEIS) and the Geological Characterization Report (GCR), a list of questions or statements to indicate important areas for discussion, and copies of abstracts or reports of a few of the scheduled presentations. Two rapporteurs were designated for each of the scheduled technical sessions to provide a brief summary of the session. A tape recording of the proceedings was also available to assist the rapporteurs in finalizing the summary. The summaries of the rapporteurs are contained in Section I of this report.

Section II contains a summary, as viewed by the Environmental Evaluation Group, of the major issues discussed and which are considered important in assessing the radiological safety of the proposed repository. These issues reflect discussions of points brought out during several of the technical sessions, and also indicate EEG's views of future studies or assessments that are needed.

Section III contains a description of scenarios which have been suggested as possible mechanisms of breach of the nuclear waste repository and transport of the radioactive waste to the biosphere. These scenarios were included in the background information distributed to the participants in advance of the meeting. These scenarios, and other available information, will serve as the basis of EEG's work plan for the calculations of potential radiation doses to people.

The Environmental Evaluation Group is very grateful to the conferees for their assistance in the planning, technical presentations, discussions, the rapporteurs' reports, and subsequent comments on the results. We are particularly grateful to the U. S. Department of Energy for their support and cooperation.

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SECTION I

RAPPORTEUR'S SUMMARIES

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RAPPORTEUR'S SUMMARIES

For each of the scheduled technical sessions, two rapporteurs were designated to provide a brief summary of the session. A tape recording of the proceedings was also available to assist in the preparation. A draft of the summaries was distributed to the invited participants shortly after the meeting for their review and comments. The final summaries, as contained in this section, are based upon comments received.

SUMMARY OF GROUNDWATER HYDROLOGY SESSION

Prepared by
David L. Siefken
James K. Channell

Presentations

J. W. Mercer (USGS)

Mercer indicated that the two overriding concerns with the use of geologic media, particularly salt, as a means of waste disposal were the geologic stability of the site and host media and the hydrogeologic system as the pathway for potential releases. At the WIPP site, the Salado Formation is the projected host medium. The Bell Canyon Formation within the Delaware Mountain Group is the underlying aquifer of concern while the Rustler/Salado contact and two dolomite aquifers in the Rustler Formation are the overlying aquifers of concern. The Capitan Reef Formation also contains a significant aquifer.

The Hiss report is the primary source of potentiometric data for the Bell Canyon and Capitan Reef aquifers (Ref. 1). The Delaware Mountain Group and Capitan Reef aquifers intertongue, and the potentiometric surface in the Bell Canyon Formation indicates groundwater movement to the northeast into the Capitan aquifer in the area of study. Three deep holes (AEC-8, ERDA-10, and AEC-7) have been tested in the deep aquifer and the potentiometric levels agree, with some minor adjustments of potentiometric contours, with those in the Hiss report.

At the WIPP site, nineteen holes have been studied for hydrology. The Santa Rosa Formation, although an important aquifer elsewhere, has only two feet of lower sand saturated and provides very low yields of groundwater. The Dewey Lake Redbeds have minor amounts of perched water. The Magenta dolomite, the upper dolomite aquifer within the Rustler Formation, is characterized as a detrital dolomite which is impure and fractural. The Magenta

dolomite has a transmissivity value of approximately 10^{-2} ft^2/day near the site. The Magenta aquifer is brackish, with high sulfates, but provides the best quality groundwater at the WIPP site. Movement in the Magenta is from east to west and is considered as fracture flow.

The Culebra dolomite, the lower dolomite aquifer in the Rustler Formation, is a chemical dolomite which is vuggy and has a fracture permeability. The transmissivity of this unit near the WIPP site is 2-3 millidarcies (0.1 to 0.2 ft^2/day). Movement in the Culebra is from north to south and is considered to be fracture flow. Dissolved mineral content in the Culebra increases west to east.

At the Rustler/Salado contact, the transmissivity of 10^{-4} ft^2/day indicates a low flow rate and a low volume of flow near the WIPP site. Chemical analysis of water from this interval indicates 311,000 to 420,000 ppm TDS with sodium and chloride predominant and magnesium significant. Rustler salt beds are nearly absent to the west of the site and nearly fully present on the east side. Transmissivity in the two dolomite aquifers is greatest to the west and decreases to the east reflecting fracturing west of the site due to dissolution and slumping.

Relative heads at the site show decreasing potentiometric levels for the Magenta, Culebra, and Rustler/Salado contact aquifers. The head in the Delaware Mountain Group, corrected to fresh water equivalent, is nearly the same as the head measured at the Rustler/Salado contact. The measured head relationships indicate isolation between the aquifers.

To date, effective porosity measurements have not been made for any of the aquifers.

D. D. Gonzalez (Sandia Laboratories)

A tracer testing program starting with a two-well tracer test to the H-2 pad and possibly including tracer tests at 5 to 6 pads, is underway. The primary purpose of the two-well tracer tests is to quantify the effective porosity of the Culebra aquifer, and to determine dispersivity.

Several pads on the WIPP site, with 3 separate drill holes to the Magenta, Culebra, and Rustler/Salado aquifers are being used to determine potentiometric water levels. It is expected to take 1 to 2 years for water levels to stabilize in these wells.

The current modeling of the shallow aquifer is being revised to consider new boundary conditions to the north, west and south; the boundary to the east is difficult to define due to an absence of data. The model is also being expanded to include the Bell Canyon aquifer.

The flow path in the Culebra from the WIPP site to the Pecos River at Malaga Bend is approximately 15-17 miles long. This flow path extends about five miles south of the site, then west to Nash Draw and finally south to Malaga Bend. The travel time for water flow is estimated to be 5,000 to 40,000 years, based on varying the permeability inputs to the model. The first five miles of the flow path from the WIPP site represents 80% of the transit time to Malaga Bend due to the lower hydraulic conductivity at the site.

Hydrologic testing was performed in the Salado and Castile at 4 zones, which on the basis of reaction logs indicating porosity or presence of clay seams, have the potential to yield water. The four zones were at 1800 ft. (just below Rustler/Salado interface), at 2,300 ft. (within the Salado), at 3,000 ft. (Salado/Castile interface), and at 4500 ft. (just above the Delaware Mountain Group).

L. Gelhar (NM Tech)

Several potential problems exist concerning the role of the Delaware Mountain Group aquifer which is undersaturated upgradient. These problems include the following:

1) The tilting of the Delaware Basin on the west due to mountain building has created a gradient in the Delaware Mountain Group with flow of undersaturated water under the evaporite sequence, resulting in potential for dissolution from below.

2) The potential in the Delaware Mountain Group could lead to upward movement through the evaporites to above the level of the repository.

3) There is a question whether movement in the Delaware Mountain Group to the Capitan reef has resulted in the dissolution over the reef.

4) The effect of major climatic change on the potential in the Delaware Mountain Group may result in increased flow and increased potential for deep dissolution.

The recharge area for the Capitan Reef aquifer has been identified to the west with flow clockwise around the reef. The effect of "Submarine Canyons" on this flow is still unresolved.

In the DEIS, the uncertainty and range of input to the model has resulted in wide variances in the results of the modeling, e.g. Gelhar calculated pore velocities ranging from 0.02 to 4800 ft/year as extremes compared to 0.075 to 15 ft/year stated in the DEIS or 182 ft/yr at the Gnome site (Ref. 2). There are no field-determined inputs on transport parameters, e.g. dispersivity and distribution coefficient (Kd). Added to these limitations are problems with the calibration procedures. The sum total of those uncertainties and wide ranges for input data give no confidence in the results of the modeling.

Additional questions remain concerning the presence of water in the evaporite sequence, as illustrated by ERDA-6 and a brine reservoir encountered 3.5 miles southwest of the WIPP site. Unanswered questions include:

1) Where does the water come from?
2) What is the age of the water?
3) How is the water pressurized?
4) Why after 4 years of knowing of these brines haven't answers been provided to the previous questions?

Based on available information, Gelhar believes that the WIPP site does not meet several of the geological criteria set forth by the Panel on Geological Site Criteria, National Academy of Sciences (1978) including:

3.1.3 On host rock configuration (brine reservoirs, deep dissolution, salt flow)
3.3.1 On hydrologic transport (model uncertainties)
3.3.3 On hydrologic effect on climatic variability (recharge conditions, etc.)
4.1 Mineral resources.

In terms of geological conditions, it has not been established that the proposed WIPP site is favorable for long-term isolation of radioactive wastes.

Therefore, Gelhar concludes that a decision to proceed with underground construction at the WIPP site, as proposed in the EIS, would not have a sound scientific basis. Underground experimentation will do little to resolve the critical geotechnical issues.

For summary, questions remain in the following areas for the WIPP project:

1) brine reservoirs
2) deep dissolution

3) structural anomalies
4) conflict with mineral resources
5) gas generation by TRU wastes
6) regional, repository-induced deformation of salt by heat generation or stress changes induced by mining of the repository.

Discussion

Information presented in discussion periods during the meeting brought out the items listed below:

Well Pumping Rates

A two-well pump test of H-2 (on the site) produced a constant yield from the Rustler of 0.07 to 0.2 gallons per minute. The Rustler/Salado brine aquifer yields less than 0.01 gpm at this location but yields of 10 to 20 gpm can be obtained from this aquifer below Nash Draw.

Laguna Grande de la Sal

In answer to a question concerning shorter pathways to Laguna Grande de la Sol, Jones stated that a brine spring at the north end of the lake predates potash mining operations and is probably from the Rustler Formation since it is a gypsum water and the Rustler contains gypsum above the Culebra aquifer. Both the Salado/Rustler interface and Culebra aquifers flow beneath the lake and have potentiometric surface levels above the lake. The Magenta aquifer no longer exists at this point. Three wells (WIPP 26, 29, 32) are now being studied to determine if Rustler water could flow from beneath the site to Laguna Grande de la Sol.

Delaware Mountain Group Flows

Conflicting viewpoints were raised about the conclusion that DMG water flows to the northeast into the Capitan aquifer. The principal argument against this conclusion was the allegation that all cores

that all core date from the area indicates that the two aquifers are separated by thick anhydrite layers. There are geochemical differences in Bell Canyon and lower Capitan waters but this would not preclude a minor amount of mixing.

Distribution Coefficient (Kd) Measurements

In addition to the Kd values obtained from powdered aquifer samples (reported in the Geological Characterization Report), there have been column tests of an intact core, oriented for flow along bedding planes. Agreement between the two tests was within 10%.

Fracture Permeability

R. R. Parizek mentioned that methods exist whereby one can determine fracture density in joint-controlled Karst topography and then calculate expected rates of fracture and future fracture permeability in an aquifer. He believes this procedure may be useful for estimating future permeability changes in Rustler aquifers.

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1. Hiss, W. L. "Statigraphy and Ground-Water Hydrology of the Capitan Aquifer, Southeastern New Mexico and Western Texas", University of Colorado, Boulder, Ph.D. thesis, 1976.

2. Mercer, J. W. and Orr, B. R. Interim Data Report on the Geohydrology of the Proposed Waste Isolation Pilot Plant Site in Southeast New Mexico, (USGS Water Resources Investigations 79-98), July 1979.

SUMMARY OF SESSION ON DEEP DISSOLUTION AND BRECCIA PIPES

Prepared by
Frank E. Kottlowski
Marshall S. Little

Presentations

Dennis Powers (Sandia Laboratories)

Powers summarized the investigations of Sandia and others to characterize the dissolution features in the basin and, particularly, the WIPP site. These included studies of the geometry of solution features and methods to locate and characterize them. Powers discussed the results of resistivity and seismic methods which are two of the methods used in locating these solution features at depths of several hundred feet. These techniques have been used on known solution features such as Hills A and C, two known breccia pipes. Thirty-one areas were found by Sandia and industry surveys to have anomalous seismic response, but the area near the WIPP site indicated no solution features. Resistivity measurements revealed anomalies in the area of WIPP, but drillings, WIPP 19, 22, and 13 into the Salado failed to confirm deep dissolution features such as breccia pipes. It was concluded that such resistivity anomalies were due to unusually low resistivity in the Dewey Lake Formation. Powers also discussed drill holes made at several points off the WIPP site, such as Hill A, which revealed breccia to 810 feet; WIPP 32, eleven miles west of the WIPP site in Nash Draw, showed no brecciation in the upper Salado; WIPP 33 in a small sink nearer the site, found a normal stratigraphic section, and a high degree of permeability in the Dewey Lake and Rustler Formation. He described holes which have gone through the Castile, ERDA 6, AEC 7, AEC 8, ERDA 10, two holes which have gone through the lower anhydrite of the Castile, WIPP 11 and 13, and two holes which went through the lower Salado, ERDA 9 and WIPP 12. These holes were cored to determine if there is evidence of deep dissolution. Hill C is

also being cored to the depth of the mining horizon to determine some of the processes that occur in a breccia pipe.

George Bachman (USGS Retired)

Bachman discussed his studies of the regional dissolution and erosion features. He considered these features to be mainly due to karst development of three types:

1) Erosion by solution and fill
2) Karst mounds and regional breccia
3) Deep-seated breccia pipes

The only known breccia pipes in the area, according to Bachman, are those above the Capitan Reef and back reef facies. Although he accepted Anderson's theory as to the mechanism of formation of these features, he believed that they were probably formed about 600,000 years ago as a result of restrictions in the eastern reef aquifer flow leading to higher head potentials than exist today. Hill "C" is being cored to obtain further information as to their origin. He referred to the evaporite beds in the Castile as lenticular and believed that most of the dissolution of the salt beds on the western side of the basin occurred between Triassic and Ogallala or Gatuna time when the beds were much closer to the surface.

In reference to a cross section of the San Simon Swale, Bachman suggested that it is an elongated sink rather than a graben, as postulated by Anderson.

Forrest Miller said his personal experience leads him to agree with Bachman that anhydrite beds abut the Capitan Reef, and this is evidence that groundwater does not move from the Reef into the Castile.

Roger Anderson (UNM)

Anderson reviewed his evidence and the results of others to illustrate deep-seated dissolution which has occurred in the basin and is presently active. This included breccia pipes such as those at Hill A and C on the Reef top or margin, Reef margin depressions like the San Simon Sink, dissolution depressions along the Pecos River, and breccia chimneys in the basin as illustrated by the "Castiles." He also has correlated breccia beds and sonic logs in the Castile and Salado on the western side of the basin with undissolved salt beds to the east indicating a deep-seated type of dissolution has occurred in the lower Salado in the western and central part of the basin.

Other features which may be indicative of active deep dissolution according to Anderson, are replacement of anhydrite by halite in the core of WIPP 11, the brines and structural complexity of the "disturbed zone" northeast of the site, the absence of anhydrite layers in certain boreholes, and dissolution associated with San Simon and Bell Lake sinks.

Anderson described a model to explain the process of deep dissolution which he has verified in the laboratory. This model would involve an aquifer which provides unsaturated water flow through fractures in overlying impermeable beds into beds of evaporites. As salt is dissolved, the more saturated brine moves back into the aquifer and is replaced by more unsaturated water. The tilt of the basin gives the head necessary for water in the DMG aquifer and the Capitan aquifer to move up through fractures into the overlying salt beds, and laterally into the body of the evaporites.

In summary, Anderson believed the western dissolution to be relatively stable in comparison to the more active dissolution occurring in the east and northeast part of the basin. He cited Seager and Callender's recent work to show that quaternary faulting

at San Simon Swale is parallel to that found in the Salt Basin, just west of the western reef margin, and is probably tectonically connected. The presence of the quaternary faults in the San Simon Swale area was cited by Anderson as evidence for San Simon Swale being a graben. These tectonic implications may indicate that deep dissolution is younger than previously recognized or may occur through faults in the vicinity of WIPP. Anderson also concluded that the Delaware Basin was not a favorable one geologically owing to the advanced stage of dissolution and the applicability of the brine flow model.

Discussion

Bachman questioned Anderson's correlations of Triassic rocks in San Simon Swale, and believed the area is not a graben. There also seemed to be disagreement with Anderson's view of the "Castiles" as having originated as deep-seated breccia chimneys similar to those at Hills A and C. Others suggested that the amount of residue in the western part of the basin is insufficient to account for the extensive salt dissolution postulated by Anderson. Another noted that observed corings in the Capitan margin have failed to reveal an association of the Capitan with the DMG aquifer necessary for the deep-seated dissolution proposed by Anderson. In consideration of the disagreement concerning the presence of breccia pipes in the basin, it was suggested by some that perhaps some of these questionable features (such as "Castiles") should be cored to depths sufficient to resolve the question of their deep-seated origin. In reference to Anderson's contention that some of the dissolution features are dated at 50,000 to 100,000 years by Cenozoic fill, Hawley and Bachman believed older parts of the fill to be from the Ogallala or Gatuna formation.

There followed considerable discussion of the extent of active deep dissolution and its possible effect on the WIPP repository. On the one hand, Anderson and others considered deep dissolution

to be evident throughout the basin, and active in the east and northeast portion and possibly in the vicinity of WIPP. Others believed that available data does not indicate that artesian brine is evidence of active deep dissolution. It was also indicated that DOE plans to collect additional information on deep dissolution, brine reservoirs, and other questions through exploratory shafts including drifts, horizontal drillings and field experiments.

SUMMARY OF BRINE RESERVOIRS SESSION

Prepared by
Carla Wofsy
Rodney Ewing

Presentations

George Griswold (Tecolote Corporation)

Griswold described brine pockets which have been found in the Salado formation during potash mining operations, and brine reservoirs under artesian pressure which have been found in the middle of the Castile formation in deep well-drilling operations.

When brine is encountered in the Salado in potash mining operations, the reservoir is "bled"; i.e. allowed to flow into the mine until it is exhausted. Griswold gave estimated brine volumes in three mines as 190,000 gallons (PCA Mine, 17 miles from ERDA 9), 2500 gallons (Duval Nash Draw Mine, 5 miles from ERDA 9) and 15,000 gallons (Kerr McGee Mine, 10 miles from ERDA 9). In the discussion, Charles Jones mentioned another Salado brine occurrence in a potash zone well which bled for a longer time (30 days) than those occurrences listed by Griswold (7 and 14 days).

In the Castile, brine has been encountered in ten out of sixty (17%) deep drill holes in the area around the WIPP site shown on attachment 1. In nine of these holes, brine flowed to the surface at initial rates estimated between 660 and 20,000 barrels per day. The flow of 660 barrels per day was measured at ERDA 6 in a drill stem test and Griswold believes that the testing procedure led to an artificially low flow measurement. In AEC 7, brine and H_2S were found during a swabbing test. The brine did not flow at the surface.

With reference to the possibility that pressures in the ERDA 6 and Pogo brine reservoirs would tend to force the brines back

into the Reef, Griswold showed brine head calculations for four wells for which shut-in pressures had been measured (Pogo, ERDA 6, Belco and Gulf). These would suggest a flow to the south, away from the Reef, if the brines were interconnected.

Griswold believes that the methods currently being used to predict brine reservoir locations are inadequate. He pointed out that the newest Castile brine occurrence (Pogo, 1¼ mile north of ERDA 6) is associated with a syncline rather than an anticline and that Belco is not associated with the Capitan Reef. (Jones questioned the data base for concluding that Pogo was in a syncline.) In Griswold's view, brine reservoirs would present a "great danger" during waste emplacement but not after the repository was sealed. (Jonathan Callender and Roger Anderson believed that brine reservoirs could still cause problems after the repository was developed, especially if drilling occurred at a later time.)

Griswold suggested that the "disturbed zone" in the northern part of the proposed WIPP site is the best place to look for brine reservoirs and for evidence of deep dissolution. He believes these phenomena may be related.

Steven Lambert (Sandia Laboratories)

Lambert discussed brine reservoir geochemistry in relation to the geochemistry of other Delaware Basin waters. Lambert stated that waters from the Capitan, Santa Rosa Sandstone and Rustler aquifers are similar in geochemistry while waters from the Salado (potash zone), Bell Canyon (AEC 7, 8, ERDA 10) and the ERDA 6 brine reservoir each have a separate geochemical regime. Bell Canyon waters are high in calcium, and the ERDA 6 brine is sulfatic and calcium poor; the ERDA 6 brine appears to contain Na_2SO_4. The stable isotope analysis summarized in attachment 2 shows ERDA 6 water far from the meteoric field. The Capitan

waters and most of the Rustler waters analyzed are in or near the meteoric field.

In Lambert's view, this geochemical evidence does not support suggestions of:

1) The Delaware Mountain Group as a source of massive deep dissolution.
2) Existing dissolution conduits linking arbitrary parts of the basin.
3) "Pipeline connections" between brine reservoirs and the Capitan Reef.
4) A meteoric origin for brine reservoirs.

Lambert also discussed a dating technique using U-234/U-238 ratios. He used it along with stable oxygen isotope ratios to support the view that the ERDA 6 brine had been confined in the surrounding rock for a minimum of 600,000 to 1,000,000 years.

With regard to regional hydrology and recharge areas for the Capitan Reef and the Bell Canyon aquifers, Lambert used stable isotope analysis to conclude that:

1) There is no supply of water from the Capitan Reef aquifer to the Bell Canyon aquifer.
2) The supply of water for the Capitan Reef aquifer does not come from the Carlsbad Caverns area.

Additional information concerning the geochemical methods used and the conclusions reached can be found in Refs. 1 and 2.

Charles Jones (USGS)

Jones gave statigraphic locations and some geochemical information on Castile brine reservoirs, with a detailed case history of ERDA 6. He also presented a theory regarding the origin of brine reservoirs.

Brine reservoirs have been encountered in the Castile in the anhydrite II and III and the halite II layers. All of these brines are enriched in sulfate and certain trace elements (magnesium, potassium, lithium).

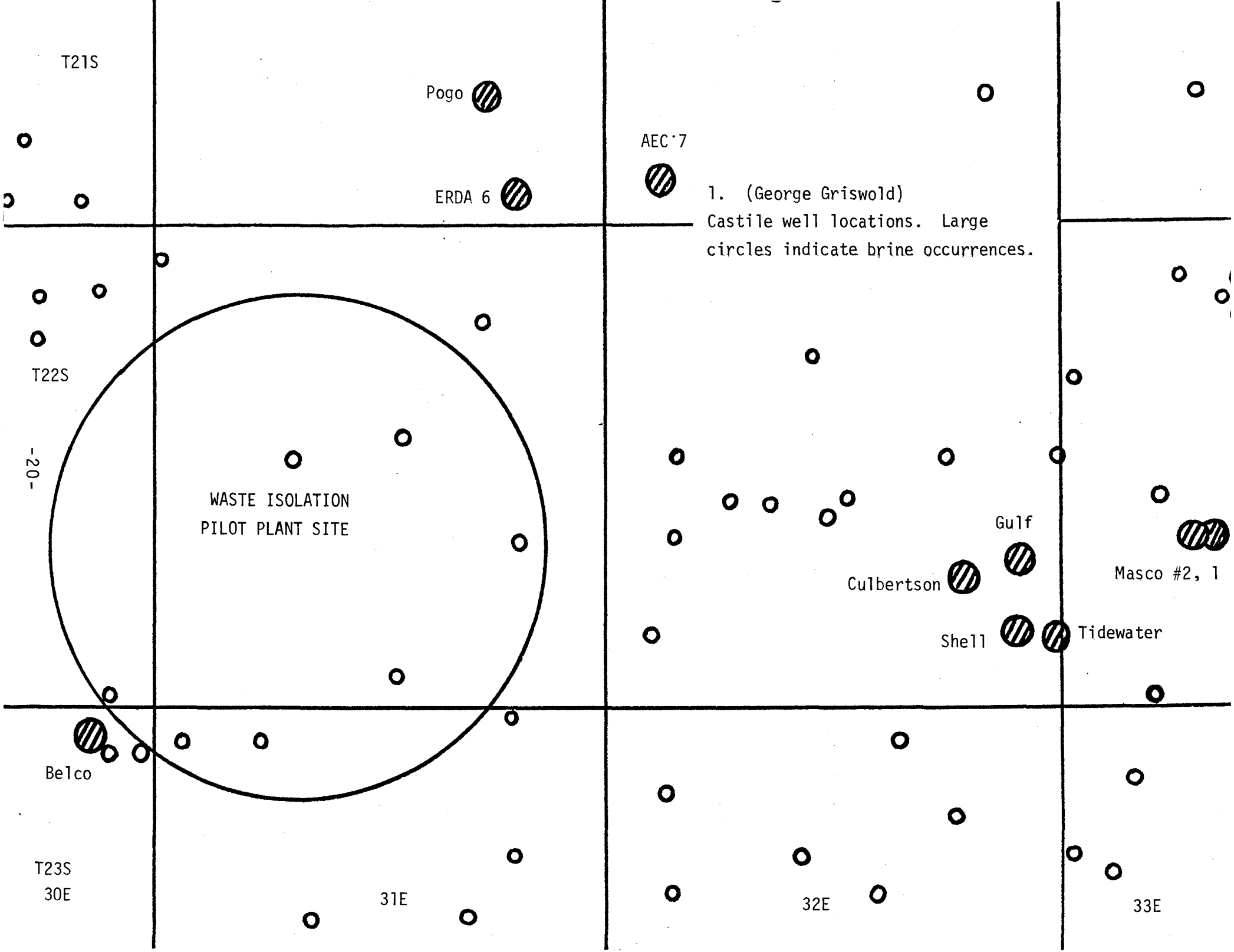
The brine reservoir at ERDA 6 is associated with a pronounced anticline which is evident in contours at the top of the Salado. Jones showed a schematic cross-section of ERDA 6 showing an anticlinal salt flow structure in the Castile with anhydrite III missing, halite II folding up into the Salado, anhydrite II raised and broken, and halite I thickened. He showed cores which showed effects of chemical reactions, and recrystallization, faulting and stretching.

Jones thinks that the Castile brines are residual Permian fluids (original formation fluids) which became trapped. He believes that the structural changes and fluid movement evident in the ERDA 6 core began in Castile time and persisted episodically in Salado time and Dewey Lake time. The ERDA 6 type brine has modified lower Salado and upper Castile geochemistry and is at equilibrium with the surrounding rocks.

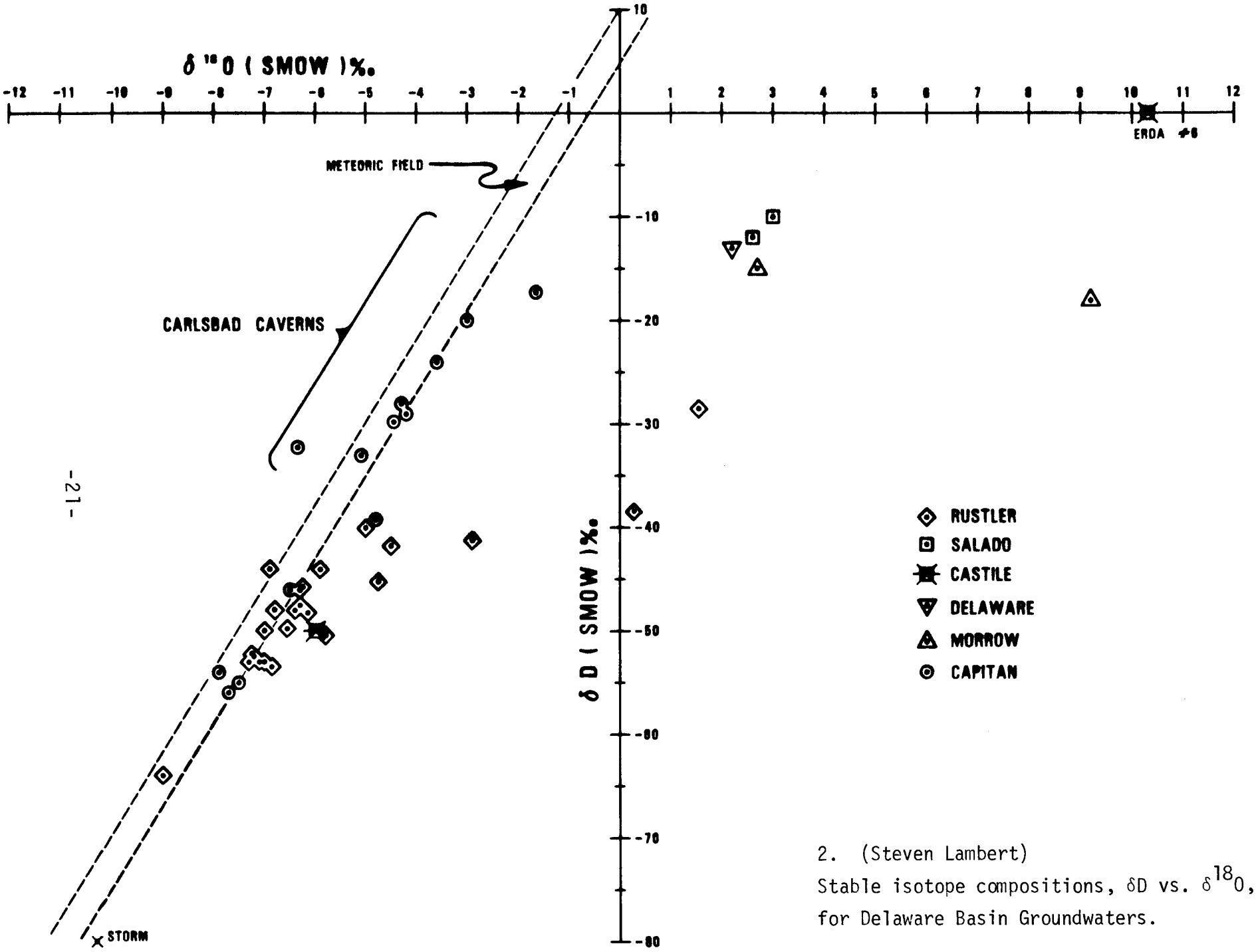
Discussion

Jones believes that the brines found at ERDA 6 and at Pogo are distinct, stratigraphically, but similar geochemically. Griswold believes that the brines in ERDA 6, Pogo and AEC 7 are all connected.

Anderson thinks microfolding of ERDA 6 rock is Cenozoic, since it follows the Cenozoic structural grain of the basin. He showed a core indicating that stretching took place after microfolding. This would suggest that the salt flow structure observed in the ERDA 6 core was formed much later than the Permian time suggested by Jones.



1. (George Griswold) Castile well locations. Large circles indicate brine occurrences.



2. (Steven Lambert)
Stable isotope compositions, δD vs. $\delta^{18}O$, for Delaware Basin Groundwaters.

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1. Lambert, S. J. The Geochemistry of Delaware Basin Groundwaters. (New Mexico Bureau of Mines and Mineral Resources Circular 159), 1978.

2. Barr, G. E., Lambert, S. J., and Carter, J. A. "Uranium Isotope Disequilibrium in Groundwaters of Southeastern New Mexico and Implications Regarding Age-Dating of Waters," Proceedings of the International Symposium on Isotope Hydrology, 1978.

SUMMARY OF SESSION ON OTHER FEATURES

(Includes faults, dikes, folds and diapiric structures)

Prepared by
William S. Twenhofel
Carla Wofsy

Presentations

Jonathan Callender (UNM)

Callender summarized the regional tectonic setting of the Delaware Basin with particular emphasis on the Rio Grande Rift and its tectonic history. The Rift is 100 km to the west of the Delaware Basin and is one of the greatest rift zones in the world. Within the Rift there is vertical displacement of the Earth's crust as great as 5 miles. The major disturbance of the Rio Grande Rift occurred 3 to 7 million years ago with crustal displacement, volcanism, erosion and sedimentation, and seismicity. The Rift is still tectonically active, although far less so than at the height of its activity. Between Carlsbad and the Rift, there are Quaternary faults believed related to tectonic activity within the Rift.

Callender suggested that the lack of faulting in post-Permian rocks of the Delaware Basin is not proof of tectonic stability. He postulates the thick salt rocks, because of their plasticity, may have masked out evidence of Quaternary faulting. Might not there be active faults below the salt?

The igneous dike that intruded the Salado salt of the Delaware Basin 32 million years ago is generally parallel to igneous structures in the Rift and Callender postulates that the thermal regime represented by the dike may have initiated salt mobilization in the Castile. He believes it is possible the Salado salt at the present time is near a state of critical instability.

Callender summarized his concerns:

1) WIPP is too close to the Rio Grande Rift.
2) If tectonism continues, it might create pathways for deep dissolution. In fact, such pathways already exist.
3) Other media than salt and other locations than the Delaware Basin should be considered.

He recommended further regional exploration as follows:

1) Seismic surveys to search for faults below the salt.
2) Characterization of sub-Salado aquifers.
3) Characterization of salt anticlines and salt domes within the Castile and Salado.

Larry Barrows (Sandia Laboratories)

Barrows summarized the geophysical exploration program used to characterize the WIPP site and surrounding region. The following techniques have been used:

1) Geophysical logs have been used for stratigraphic correlation and determination of rock properties.

2) Seismic reflection survey data have included industry data and contract surveys. These surveys have been used to search for faults and for subsurface correlation of lithologic and stratigraphic units.

3) Locations of earthquake foci and epicenters in the Central Basin Platform have been compiled from historical seismographic records and Sandia is monitoring its own seismographs, to assess the seismicity of the region.

4) Gravity surveys have been used to map the thickness of sediments in the Delaware Basin.

5) Aeromagnetic surveys have been used to map the igneous dike and to calculate depth to the basement rock,

6) Electrical resistivity surveys have been used to search for structural discontinuities and breccia pipes,

7) Subsurface radar is planned to be used in underground workings to map the edge of a breccia pipe (Mississippi Chemical mine).

Barrows described the use of geophysical techniques in combination with other procedures to investigate potential problems (e.g. breccia pipes and tectonic faults at the site). Based on a combination of surface geology, electrical resistivity surveys, seismic reflection surveys and well logs, it was concluded that there were no breccia pipes at the proposed WIPP site. It was also concluded that there were no deep-seated tectonic faults penetrating the Salado within a mile of the proposed repository site. This conclusion was based on evidence from surface geology, historical and present earthquake records, seismic reflection surveys, gravity surveys, aeromagnetic surveys and electrical resistivity surveys. Some fracturing was apparent in the Castile formation in the vicinity of WIPP but there was no evidence of displacement.

Discussion

Steven Lambert stated that the expected effects of the thermal pulse postulated by Callender are not seen in fluid inclusions or minerology of the rocks in the area. He cited a study by Roedder and Belkin which indicates that such effects should accompany a thermal pulse of such magnitude.

Wendell Weart stated that the tectonic events described by Callender have not adversely affected the WIPP site. If a repository had existed 35 million years ago at the WIPP site, it would have survived to the present time.

5) Perforating existing drill holes in Nash Draw at horizons of interest to obtain additional hydrologic information.

6) Constructing a verification shaft and drilling horizontally from the bottom to obtain additional data on room stability, thermal effects and repository horizon rock properties; horizontal drilling may concentrate on the disturbed zone, if the results of the geophysical surveys indicate that this would be useful.

Sandia has also proposed that ERDA 6 be reopened for the purpose of getting a good estimate of the brine volume, more geochemical information, and any additional clues as to structure and origin of brine reservoirs.

SUMMARY OF HUMAN INTRUSION SESSION

Prepared by
James K. Channell
Kenneth H. Olsen

Presentations

Wendell Weart (Sandia Laboratories)

Weart described the resources of potash, oil, natural gas, and distillate beneath the WIPP site. He believes most of the resources could be recovered safely with present technology. Specifically, there would be no hazard connected with normal potash mining and hydrocarbon drilling in Zone IV....Present thinking is not to permit solution mining or large water use in Zone IV. Sandia has told mineral lease holders it would be permissible to conduct deviated drilling from outside Zone IV to under Zone IV and to conduct straight drilling from within Zone IV.

The following points were made concerning consequences of human intrusion:

1) there are plans to model a scenario assuming interconnected potash holes that are filled with water;

2) the principal problems would occur if future generations drilled without knowledge of the repository;

3) the problem of drilling into a respository without knowledge of its existence would exist at every future site, whether it is presently known to have resources or not.

Frank Kottlowski (New Mexico Bureau of Mines)

Kottlowski believes potash mining and hydrocarbon drilling can be conducted in Zone IV without affecting the integrity of the site. Secondary and tertiary recovery methods for oil would have to be

monitored very carefully, if permitted. It is believed to be very unlikely that any unknown drill holes presently exist at the site.

Kottlowski believes it very unlikely that human intrusion would occur without knowledge of the repository. Also, he believes that any crews drilling into the site in 100 to 200 years would be more capable of handling radiation problems than we are now.

D'Arcy Shock (Consultant)

Shock discussed the early history of the art of horizontal hydrofracturing. He then presented data on hydrofracturing based on a project that he did during the 1960's between 4 wells in the north end of the Carlsbad potash reserve. The primary purpose of the experiment was to test the ability to use hydraulic fracturing along with solution extraction to perform a well to well extraction from thin-bedded potash deposits. The test was a success although the ore zone was not of commercial quality.

This experience suggests that activities carried out in the Salado formation are reasonably predictable and with proper engineering can be controlled.

Discussion

Gas Generation

The question was asked whether gas generated by decomposition of organics in buried wastes would pose additional problems in connection with human intrusion. This question was not directly answered; Weart's assumption is that the Waste Acceptance Criteria, when adopted, would require processing of the waste prior to burial to reduce gas producing material.

Resource Criteria

The point was raised that one of the main criteria (absence of

resources) used when explorations began for a Delaware Basin site in the early 1970's was now being ignored. Current thinking of Sandia and USGS is that the consequences of recovering (or not recovering) these resources should be the determining factor. No one expressed an opinion that the currently proposed policy of permitting conventional potash mining and hydrocarbon drilling in Zone IV would be hazardous. Concern was expressed about solution mining and secondary and tertiary oil recovery methods.

Gnome Site

The usefulness of data from the Gnome site was discussed. There is a continuing monitoring program from nearby wells and only tritium (used as a tracer in the detonation) has been detected. Also it would cost several million dollars to go back into the cavity at this time. A suggestion was made that this might be a good location to test the ability of geophysical techniques to detect cavities in the Salado formation.

Accidental Intrusion

Various opinions were stated concerning the likelihood that persons drilling in the repository area in future centuries would be unaware of the repository. Martin Tierney mentioned that the random probability of drilling into the WIPP site was only about 10^{-5} per well drilled in the Delaware Basin. The view was expressed (by two persons) that the probability of a connection forming between a brine reservoir in the Castile and the repository due to a fracture was even more unlikely than by a drilling accident.

SECTION II

DISCUSSION OF ISSUES

SECTION II

DISCUSSION OF ISSUES

This section provides a summary of the major issues which were discussed at the meeting, and, in the opinion of the EEG, are important in assessing the radiological safety of the proposed WIPP repository. The discussions of these issues may have occurred in one or more of the scheduled technical sessions. At the conclusion of each issue summarized in this section are EEG's recommendations for future studies or assessments.

GEOHYDROLOGY

Limitations of Available Information

Hydrologic Parameters

Sophisticated geohydrologic models have been developed for the WIPP site to model the scenarios involving radionuclide transport in groundwater flow through various aquifers and through connections between aquifers. Typically, a geohydrologic model analysis is most useful where a large number of pumped wells have provided a wealth of data concerning the characteristics of various aquifers. Even under such circumstances, a region can be modeled only to provide orders of magnitude parameters for groundwater management and future planning. At the WIPP site, nineteen holes have been used for hydrologic studies--many of these specially drilled for this purpose. Testing in these holes has provided a range of values, from which values for different parameters have been selected for use in modeling. These parameters are porosity, hydraulic conductivity, transmissibility, hydraulic heads and distribution coefficients.

The evaporite beds are generally tight formations with extremely low values for porosity, hydraulic conductivity and transmissibility. Still it is well known that water seeps along lithologic contacts and along fracture surfaces in mines in the Salado formation and other mines in evaporite deposits elsewhere. The migration of water in evaporites takes place mainly through slow dissolution along joints, bedding planes and other fracture surfaces. An estimation of "fracture permeability" is a difficult task due to the heterogeneous nature of fractures in a rock mass. Detection of solution conduits through which future migration of fluids may take place is not possible without ripping apart the whole formation. An estimation of fracture density and evolving future fracture permeability is possible on exposed

parts of an aquifer formation but this gives no clue to the already developed conduits along fractures in the subsurface. Only very approximate estimation of aquifer characteristics/ hydrologic parameters may thus be possible in evaporite sequences. It is important to understand these facts before making extensive use of hydrologic parameters obtained from limited testing in wells or from tests performed on rock samples. The calculations of water flow-times through a given path or of times for travel of certain radionuclides in an aquifer may be grossly inaccurate if they are based on assumptions of homogeneity in the rock mass, and if inappropriate average values are chosen for the parameters. For example, Gelhar calculated values of transit times (from the WIPP site through the Culebra aquifer to the Pecos River at Malaga Bend) that ranged from 15 to 5280 years by using the entire range of parameter values found in the Mercer and Orr report of 1979.

The possible range of distribution coefficient (Kd) values is also uncertain. Initially the values used at the site were determined by batch tests on powdered rock. More recent column tests have shown reasonable agreement with the batch tests. A need still exists to confirm these results with in situ measurements and to evaluate minimum Kd values that could occur from differing chemical forms of the various radionuclides or from characteristics of the rock and fluid.

Depth of Test Holes

Another limitation of the hydrologic testing program is in the depth of test holes. Hydrologic testing for the WIPP project has concentrated on aquifers in the Rustler (Magenta, Culebra and Rustler/Salado contact) or those lying above the Rustler (Dewey Lake and Santa Rosa formations). Hydrologic data in the Delaware Mountain Group has been obtained from only 3 wells (AEC-7, AEC-8 and ERDA-10).

DMG Flow

The Hiss report is the primary source of data for the characteristics of flow in the DMG aquifer (Bell Canyon). On the basis of work done by Hiss, it has been concluded that DMG water flows to the northeast into the Capitan aquifer. However, core data from the area indicates that the two aquifers are separated by thick anhydrite layers. There are geochemical differences in Bell Canyon and lower Capitan waters as well, but this would not preclude a minor amount of mixing between the two aquifers.

Need for Additional Information

In order to assess the WIPP site more comprehensively, and to obtain more reliable estimates of radionuclide releases, additional information is needed in the following areas of geohydrology.

a) Better definition of regional geohydrology through more field tests.
b) A clearer understanding of recharge areas for the Rustler and DMG aquifers.
c) Further refinements in Hiss' map of potentiometric surfaces in the Bell Canyon aquifer and its connection with the Capitan and/or San Andres aquifers.
d) The evaluation of hydrologic transit times from the WIPP site to man from existing or potential water well development in all aquifers near the site.

DEEP DISSOLUTION

Introduction

The sharpest differences of opinion in the geological characterization of the WIPP site appear to exist in the matter of deep dissolution. Some of the participants at the meeting who are familiar with the Delaware Basin interpret a number of geological features observed on the surface and in the subsurface as representing deep dissolution of evaporite beds. Another group of geologists, also having done extensive field work in the area, interpret the spatial relationship of certain geologic units as evidence for dissolution having resulted from surface erosional processes at different times in the geologic past. The main speaker favoring the idea of the presence of deep dissolution in the Delaware Basin was Roger Anderson. His ideas on deep dissolution are primarily based upon correlations of drill cores and sonic logs of wells, an interpretation of the hydrologic conditions in the area and a postulation of "brine density flow" as a mechanism for the formation of breccia pipes. George Bachman was the major speaker favoring an explanation of observed dissolution features as resulting from erosional Karst processes of dissolution on or near the surface. Following is a summary of the arguments for and against deep dissolution in the Delaware Basin, a summary of inconclusive discussions, and recommendations for resolving this question.

Arguments for Deep Dissolution

Anderson (1972, 1978, 1980) has correlated breccia beds and sonic logs in the Castile and Salado on the west side of the basin with undissolved salt beds to the east. He argues that since the correlations of lithologic and geophysical logs show that even the thinnest salt beds deposited in the eastern part of the basin once extended over most of the basin, the departures from full stratigraphic section have resulted from the removal of salt through

dissolution. According to him, other features which may be indicative of active deep dissolution are replacement of anhydrite by halite in the core of WIPP-11, the absence of anhydrite layers in certain boreholes, the dissolution associated with San Simon and Bell Lake sinks and the brines and structural complexity of the "disturbed zone" northeast of the site.

Anderson contends that the features which indicate localized deep dissolution, such as brine pockets, breccia chimneys, local anhydrite replacement, etc., should be visualized as advanced effects of larger patterns of regional deep dissolution. According to him, the dissolution front proceeds behind solution conduits and chambers and often leaves undissolved outliers behind. Anderson has identified regionally recognizable dissolution wedges in the southern part of Delaware Basin. He believes that the WIPP site is situated in a part of the basin which has not yet developed dissolution on a regional scale. However, according to him, there are sufficient features in the area which show the presence of deep-seated dissolution.

Anderson's model of deep dissolution in the Delaware Basin consists of "Brine density flow" mechanism. This mechanism invokes the rise of groundwater from the Bell Canyon formation to the overlying Castile and Salado formations due to differences in hydraulic head. According to the model, undersaturated water would dissolve salts from evaporite beds and the brine thus produced would flow downward due to higher density. More unsaturated water would rise to replace the brine and the process would become self-propelled, dissolving larger amounts of salt. Faults and fractures connecting the Delaware Mountain Group (DMG) formation with the Castile are assumed to be pathways for the ascending water.

Another possible supplier of water for this deep dissolution process on the eatern side of the Basin is the Capitan aquifer.

Anderson refers to fracturing near the Capitan Reef as a pathway for water to move laterally into the evaporites, and suggests that the eastern wedge of regional dissolution may have been initiated in this way. This is similar to the mechanism suggested by Maley and Huffington (1953).

At the meeting, Gelhar suggested that major climatic changes in the future could result in increased flow of the Delaware Mountain Group and an increased potential for deep dissolution. Anderson and Callender pointed to the similarity of the trend of Quaternary faults in the San Simon Swale area and those in the salt basin to the west. This similarity and other geologic data has been interpreted to correlate the San Simon Swale area faulting and graben formation with Quaternary faulting in the Rio Grande rift. Anderson has used this tectonic postulation to indicate that deep dissolution in the Delaware Basin is younger than previously recognized.

As specific evidence of deep dissolution near the WIPP site, Anderson, Griswold, and Gelhar pointed to the following features. Brine occurrences at ERDA-6, Pogo, Belco, AEC-7, Culbertson, Shell, Gulf, Tidewater, and Masco wells possibly indicate a connection between the reef or DMG aquifers. Breccia chimneys (hills A and C) on the Capitan reef, exhumed breccia chimneys or "Castiles" along the western margin of the basin and large dissolution depressions along the Pecos drainage were also offered as evidence for deep dissolution. Anderson referred to the missing Infracowden salt in the coring southeast of the site, and pointed out that four of the boreholes which have penetrated the Castile within 8 kilometers of the site have shown evidence of dissolution or brine movement.

Arguments Against Deep Dissolution

The chief argument against an active deep dissolution phenomenon in the Delaware Basin is that geologic mapping has accounted for

a substantial dissolution during Permian to Cretaceous periods. Bachman's objection to Anderson's hypothesis mainly rests on this premise. To understand the mechanism of previous dissolution of a large portion of the evaporites, the main question to be resolved is the timing of such dissolution process. If the solution occurred long before the development of present landscape, it could have occurred through surface erosion and dissolution. Bachman (1976) suggested that the basin was tilted as early as Jurassic time and this exposed the western portion to surface erosion. Hills (1968) believed the solution on the western side occurred during late Permian and Mesozoic time. Several investigators of the stratigraphy and tectonics of the Delaware Basin, including King (1949) and Maley and Huffington (1953) have attributed major tilting of the basin to late Tertiary period, and believed that solution on the western side occurred as a result of downward percolating surface waters. According to Anderson, the lower Salado has been the most dissolved horizon in the area and it is unlikely that pre-Cretaceous dissolution extended deep enough to affect a significant volume of lower Salado salt, even in the western part of the basin.

Other arguments against deep dissolution consist of questioning the validity of Anderson's "evidence." In this category fall the "Castiles," San Simon Swale "graben," and the presence of faults in the subsurface. Bachman does not believe that "Castiles" represent dissolution features with a deep-seated origin. Larry Barrows believes that the only "faults" under the WIPP site are some fractures in Castile formation with no evidence of displacement. Bachman believes San Simon Swale to be an elongated depression or sink rather than a graben.

Lambert concludes from his work on the geochemistry of waters from different aquifers in the area and from ERDA-6 brine reservoir that ERDA-6 brine does not have a communication with the Capitan Reef aquifers or other meteoric waters. In fact, the

results of dating techniques indicate to Lambert that the ERDA-6 brine has been confined for no less than 600,000 to 1 million years. Indeed, if an independent review of Lambert's geochemistry work could show that all known brine pockets around the site have no substantive connection with any of the existing aquifers in the Delaware Basin, the brine reservoirs would not be evidence of active deep dissolution.

Recommendations for Resolving the Question

The nature of evidence on either side appears to be primarily circumstantial and based upon deductive logic. The "hard facts" in Anderson's arguments for deep dissolution consist of a set of cores and logs from the southern part of the basin. The circumstantial evidence consists of some cores from holes near the WIPP site (WIPP-11, 12, 13, ERDA-10) and the brine reservoirs and breccia pipes. Anderson's model of brine density flow appears to work and is the best explanation to date of the origin of breccia pipes. However, a contention that deep dissolution has occurred on a massive scale and that its wedge or localized offshoots may have advanced close to the WIPP site is a major jump from meager facts through "possible" mechanisms to a hypothesis. In short, deep dissolution has almost definitely occurred in the past, but may or may not be active in the vicinity of the WIPP site.

The arguments against Anderson's hypothesis cannot be properly examined because they are not available in a "reviewable" coherent form. From what one is able to gather through verbal presentations made by Bachman, Jones, Lambert, et al, these are also based on circumstantial evidence or alternative mechanisms to explain observed features. In order to achieve a better resolution of these issues, at least the following steps should be taken.

1) USGS and Sandia Labs should provide the arguments against active deep dissolution in a reviewable scientific paper

format. Such a document should clearly show the data and its interpretations. Particularly, the geochemical evidence, the evidence from Gatuna and Mescalero Caliche formations and the evidence for an assumed age of uplift of Delaware Basin should be clearly presented and its relevance shown. When USGS/Sandia data and the interpretations are available as a written document, some decisions can be made with regard to the validity of the arguments for deep dissolution.

2) The DOE program of site investigation should include a more thorough investigation of several anomalous features near the WIPP site as discussed in the Rapporteurs' Reports, which have been pointed out by proponents of the deep dissolution idea. The results of such investigation should be presented to the scientific community in a reviewable paper.

3) The Department of Energy should assess potential consequences of deep dissolution and make the calculations available. The two possibilities that should be evaluated are:

   a) Movement of waste through a dissolution conduit to the upper part of the Capitan Reef aquifer, east or northeast of the site; and

   b) movement of waste down into the DMG.

It has been suggested that in both cases the waste would then move to the lower part of the Capitan Reef aquifer, then into the San Andres Limestone and into Texas. Information on the hydrologic properties of the formations, including locations of out-crop areas, transit times, and possible use by humans, is needed to perform these consequence assessments.

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BRINE RESERVOIRS

Introduction

The presence of pockets of highly mineralized water in the evaporite deposits of the Castile formation near the WIPP site is a fact, about which there is no disagreement. According to Griswold, smaller brine pockets are commonly found in the Salado formation as well. Specific examples of such occurrences and their estimated volumes are given in the Rapporteur's Summary of the "Brine Reservoirs" session. Brine under artesian pressure has been encountered in the Castile formation in nine out of sixty deep drill holes within ten miles of the WIPP site. The main questions to be resolved and on which there is considerable disagreement concern the origin and age of these brine pockets, their possible interconnection, association with geological structural features or with aquifers, volumes of pockets, volumes of brine per unit volume of reservoir rock, and the possibility of the presence of such reservoirs at the WIPP site. The following discussion attempts to focus on the facts and the interpretation of facts behind various views presented with respect to the existing and potential brine occurrences.

Important Questions

Geological investigators differ on the potential effects of brine reservoirs on WIPP. There appears to be a general agreement that if any one or a combination of the following specified conditions are met, it would require a serious consideration of the viability of the chosen site through a detailed analysis of the potential effects of these conditions on the proposed repository.

1) If a large brine pocket were located in the Salado formation at the WIPP site, at or near the repository horizon,
2) If a large, geopressurized brine reservoir were located in the Castile formation at the WIPP site,
3) If the known Castile formation occurrences near the WIPP area represented an interconnected reservoir.

4) If the occurrences represented a random feature unassociated with any structure which was identifiable by surface geophysical methods.
5) If the occurrences represented an effect of active deep dissolution.

The arguments and opinions of geologists who have studied the brine can be classified as either supporting or disagreeing with the view that brine pockets can have significant implications for WIPP site suitability. These arguments are presented below for Salado and Castile occurrences separately.

Salado Occurrences

According to Griswold, "Salt is never dry in bedded deposits," and the Salado formation is no exception. The Duval Nash Draw, Kerr McGee and PCA mines (5, 9 and 17 miles respectively from ERDA-9) have all encountered brine pockets (up to 190,000 gallons) at the McNutt Potash Zone (middle Salado) during mining operations. Griswold believes that the presence of brine pockets at or near the repository horizon could complicate mining and retrieval operations.

Larry Barrows anticipates that the subsurface radar technique can be used during mining to detect brine pools ahead of the mine face. Others argue that the limited size of Salado brine occurrences and the fact that these are not generally associated with gas and are not highly pressurized, suggest that these occurrences can be controlled even if encountered unexpectedly.

Castile Occurrences

The frequency of occurrence of brine in the Castile (10 out of 60 holes within 10 miles of WIPP site) has been cited as a factor favoring the possibility of such an occurrence at the WIPP site. In at least nine of these drill holes, the brine was associated

with hydrogen sulfide gas and was under artesian pressure. All of these wells were plugged before the brine flows were exhausted, so it is difficult to estimate the total volume or the size of chambers. Griswold believes that three wells northeast of the site (ERDA-6, Pogo and AEC-7) encountered the same reservoir. Anderson believes that microfolding, boudinage structures and stretching seen in the ERDA-6 core, places the age of deformation as late Cenozoic. He also believes that the brine reservoirs are too large to consist of original formation fluids. These ideas suggest that the brine reservoirs may be evidence of deep dissolution, supporting the view that the site is potentially vulnerable to deep dissolution and adding this long term threat to the danger of encountering a brine reservoir during mining for the repository.

According to Lambert, the brine from ERDA-6 has a geochemical regime which is clearly distinct from the Capitan, Bell Canyon and Rustler aquifers. In his view, at least this brine reservoir does not indicate a recent connection with meteoric water. From isotope dating, Lambert concludes that the ERDA-6 brine has been confined in the surrounding rock for a minimum of 600,000 to 1 million years. Jones believes that the Castile brines are remnants of original Permian formation fluids which became trapped at the time of deposition and have later come to equilibrium with the geochemistry of the host rock. Jones also believes that the brine occurrences at ERDA-6 and at Pogo are stratigraphically distinct. These views question the need to consider Castile brine occurrences as related to regional deep dissolution and provide an alternate explanation for these occurrences.

Geophysical Detection of Brine Reservoirs

Seismic reflection surveys have been used to look for possible brine reservoirs in the Castile formation. The idea is that

unknown brine reservoirs have been associated with anticlinal structures at the top of the Castile formation and anticlinal structures can be identified using seismic reflection data. There are two main points of disagreement regarding the use of this detection method at the WIPP site. First, Griswold and Anderson have given examples of brine reservoirs which they believe were not associated with anticlinal structures (Pogo and UNM Pokorney No. 1). Jones questions both examples; he does not believe that Pogo was in a syncline, as suggested by Griswold, and points out that the geological environment at UNM Pokorney No. 1 differs from that at WIPP, most notably by the absence of salt.

The second area of controversy involves the way in which seismic reflection data have been used to rule out the presence of brine reservoirs in the Castile at the WIPP site. Two anticlinal structures were identified in the northern portion of the WIPP site and boreholes WIPP 11 and 13 were drilled at or near these structures. Anderson and Chaturvedi believe that these boreholes were not drilled at the optimal locations, and WIPP 11 was not drilled to the appropriate depth, to detect brine reservoirs which might underly the anticlinal structures.

The other geophysical tool which Barrows considers promising as a means of detecting brine reservoirs is subsurface radar. The success of this method would depend on the particular characteristics of the site rocks. In very pure salt, domed and bedded, the detection capability of subsurface radar has been found to extend up to 1000 feet. At the WIPP site, the technique has not yet been tested. It is expected that the anhydrite layers between halite beds at the WIPP site will reduce the reach of subsurface radar. It appears likely that brine pools will be detectable near the mine workings (tens of feet). However, the use of subsurface radar in the Salado, at the repository horizon, is not likely to be a means of detecting a brine reservoir in or

below the top anhydrite layer (anhydrite III) in the Castile formation below the repository.

Potential Impact on the Repository

From the various facts and interpretations presented, it appears that the possibility of a brine reservoir being present at the WIPP site in the Castile or Salado formations cannot be ruled out. If the brine occurrences represent an advancing front of deep dissolution, the impact on the repository assumes a long range dimension. This question and its possible resolution is discussed in the section on Deep Dissolution. The intent here is to discuss more specific and shorter time range effects of the presence of a brine reservoir at the WIPP site.

Salado Brine

It is likely that Salado formation brine flows encountered during repository mining can be controlled so that areas in which waste has already been emplaced do not become flooded. The usual method for finding and controlling brine in potash mines is to drill relief holes during mining. On occasion the flow into a room is large enough so that the room is abandoned, but the mine continues to operate.

If a room were flooded during repository mining, it would be necessary to remove most of the water, in order to prevent later seepage into waste storage areas. Griswold believes that this would be difficult and costly, but that it could probably be done.

Castile Brine

If there were an artesian brine reservoir in the Castile formation below the repository, and a connection formed between the brine reservoir, the repository and the surface,

brine would flow to the surface and some of the waste could be brought to the surface with the brine. Griswold has suggested that such a connection could form during repository operations. He believes the pressure difference between a repository and an underlying geopressurized brine reservoir could open a pathway along an existing fracture, forcing a connection. According to Jones, the evaporite sequence below the repository horizon has long been an effective sealant to upward brine migration.

After repository closure, the most likely way for a connection to form between a brine reservoir, the repository and the surface would be through the drilling of an oil or gas exploration hole. The amount of waste carried to the surface would depend on whether a connection had existed between the brine reservoir and the repository, allowing mixing of the waste and brine, before the drillhole extended the connection to the surface.

Recommendations

EEG is performing the hazard analyses described below and recommends that DOE do the same. Detailed documentation should be provided.

Salado Brine

The likelihood and potential extent of water movement into a waste-filled portion of the repository, both during and after the operating lifetime of the repository should be evaluated. If it is determined that a sealed repository might contain large amounts of brine, then hydrologic breach and drilling scenarios should be evaluated under the assumption that some waste is mixed or dissolved in brine at the time of the breach. In the hydrologic breach scenarios, the waste/salt dissolution rate is an important determinant of nuclide concentrations in the Rustler aquifer and in the Pecos River. The assumption

that a portion of the waste is already in solution at the time of the breach might alter the scenario consequences significantly.

Castile Brine

Possible consequences of a connection between a brine reservoir, the repository, and the surface should be assessed and the plausibility of different sequences of events which might lead to such a connection should be evaluated. Consequences of a connection between a brine reservoir and the repository extending only as far as the Rustler aquifers are discussed in a draft of the final WIPP Environmental Impact Statement. EEG is currently reviewing this analysis.

HUMAN INTRUSION

Introduction

Significant reserves (presently economical) of potash, natural gas, and distillate exist at the WIPP site. In addition, there are oil resources (possibly economical in the future). There is an obvious concern that exploration through drilling for these resources. sometime in the future, may create a serious danger to the environment and life.

Wendell Weart described the proposed plans for resource exploition. Potash mining (other than solution mining) would be permitted in Zone IV. Hydrocarbons under Zone IV may be recovered either by direct drilling or by slant drilling from outside the Zone.

The following is a summary of primary concerns and unresolved questions on resource extraction and administrative control.

Drilling for Oil and Gas

Natural gas reserves are being exploited from several geological horizons in the vicinity of the WIPP site. No producing well is located on the WIPP site although there are two proven gas wells in Zone IV. Natural gas occurs mainly in the Morrow formation at depths of 13,000 to 15,000 feet. Exploitation of Zone IV is estimated to permit recovery of 36 percent of the reserves and 57 percent of the resources of natural gas on the site (DEIS, Table 9-12). While no concerns were expressed at the meeting about primary recovery methods in Zone IV, some have been expressed through written communications to EEG and at other forums. Concerns were expressed at the meeting about using secondary and tertiary recovery methods (which involve injection of fluids in the reservoir to force oil out of the pore spaces) without a more thorough evaluation of possible consequences.

These recovery methods are known to have induced seismic activity, subsidence or minor settlements at other locations. There was no discussion at the meeting about the consequences of permitting slant drilling to extract gas from under Zones I, II, and III. The draft of the Final Environmental Impact Statement refers to this possibility.

methods are known to have induced seismic activity, subsidence or minor settlements at other locations. There was no discussion at the meeting about the consequences of permitting slant drilling to extract gas from under Zones I, II, and III. The draft of the Final Environmental Impact Statement refers to this possibility.

Potash Mining

Potash mining is the major subsurface activity at present in the vicinity of the WIPP site and is expected to continue. It is estimated that mining for potash in Zone IV would permit recovery of about 73 percent of the Langbeinite and 100 percent of Sylvite reserves and 68 percent of Langbeinite and 78 percent of Sylvite resources present on the WIPP site (DEIS Table 9-12). While no objections were raised at the meeting concerning the proposed mining plan, several have been raised in writing or verbally before and after the meeting.

Extensive potash mining in Zone IV would leave large cavities in the Salado formation as close as 400 feet vertically and 1.5 miles horizontally from the stored waste. This could produce a preferential path for water movement in the evaporites, thus removing a portion of the natural geologic barrier. The resulting subsidence could produce fracturing in the overlying aquifer and adversely affect hydrology at the site. The mined out cavities may also become pathways for contaminated water from the repository following a breach.

Gas Generation

Presently packaged TRU wastes contain large amounts of organic material and if placed in the repository would be expected to generate considerable quantities of gas over a period of several centuries. Since present Draft Waste Acceptance Criteria does not forbid placing organic wastes in WIPP, it must be assumed that gas will be generated at the repository. This gas could be

a problem if a well were drilled into or through the repository.

Administrative Control

Much of the concern over human intrusion is due to the possibility that mining or drilling activity will be conducted at some time after administrative control is lost, by individuals who are either unaware of the repository or oblivious to the possible dangers. Differing opinions were expressed at the meeting about the likelihood of this happening. One school of thought is that no one will ever forget where the repository is or lose their fear of it. Proponents of this view mention societal institutions that have been controlled for hundreds of years. The opposite point of view is that people will get tired of looking after or thinking about a waste disposal site and will probably lose their fear of it. Furthermore, intrusions are more likely where resources exist. This viewpoint is supported by the fact that cases exist where control (and fear) of radioactive and hazardous waste disposal sites has been lost in a few years or decades. This type of intrusion may result in a breach of the repository and contaminants reaching the surface.

Recommendations

1) The DOE should publish detailed plans and restrictions on drilling for hydrocarbon resources at the site. The description should include:
   a) plans for regulating drilling and production outside of Zone IV;
   b) permissible drilling and production practices in and under Zone IV.
   c) whether secondary and tertiary recovery methods are being considered for Zone IV;
   d) possible use of slant drilling to recover natural gas or oil from beneath Zones I, II and III;
   e) the length of time over which drilling controls would be imposed.

2) The DOE should publish detailed plans and restrictions on mining of potash at the site. This description should include:
   a) whether solution mining would ever be permitted;
   b) whether any recovery inside of Zone IV would be permitted;
   c) whether shafts will be sealed when potash mines are decommissioned;
   d) the length of time over which mining controls would be imposed;
   e) whether any controls are to be imposed on mining outside of Zone IV.

3) Scenarios need to be evaluated for the following situations:
   a) a repository breach involving an abandoned potash mine in Zone IV, either as a source of water into the repository or as a pathway for migration away from it;
   b) drilling into a repository containing highly pressurized gas that has developed from decomposition of organic material in the wastes;
   c) an exploratory well striking a brine pocket below the repository. The brine ascends to the surface (being under pressure) and brings contaminants with it.
   d) appropriate breach scenarios for any additional exploration or mining activity that may be proposed (e.g. solution mining, secondary and tertiary aid recovery methods, and exploitation of Zones I, II and III).

SECTION III

RELEASE SCENARIOS

SECTION III

RELEASE SCENARIOS

This section contains a description of scenarios which have been suggested as possible mechanisms of breach of the nuclear waste repository and transport of the radioactive waste to the biosphere. These scenarios were distributed to the participants in advance of the meeting with the request that they be considered for possible modification or deletion as unrealistic and that any new plausible mechanisms be proposed at the meeting. Shortly after the meeting, these scenarios were distributed with a draft of the Rapporteurs' Reports to each of the participants for comment. Substantive comments were received on the scenarios from Roger Anderson, Steven Lambert, David Siefken, and Georgia Yuan. More broadly, views expressed in all of the sessions at the meeting bore on the plausibility and importance of various release scenarios. EEG's discussions of the major geotechnical issues, in Section II of this report, include EEG recommendations and plans for additional scenario analysis.

The scenarios with other available information will serve as the basis of EEG's work plan for the calculations of potential radiation doses to people.

A. SUMMARY OF DEIS LONG-TERM RELEASE SCENARIOS

Five repository breach scenarios were analyzed in the WIPP Draft Environmental Impact Statement (DEIS; section 9.5.1). Scenarios 1-4 all resulted in dissolution of the waste, passage of the waste into the Rustler aquifers, and passage through the Rustler to the Pecos River at Malaga Bend, 15 miles from the repository. Scenario 5 involved direct access by drilling.

Hydrologic Breach Scenarios

The following diagram from the DEIS may be helpful in understanding how the hydrologic scheme at the WIPP site was modeled.

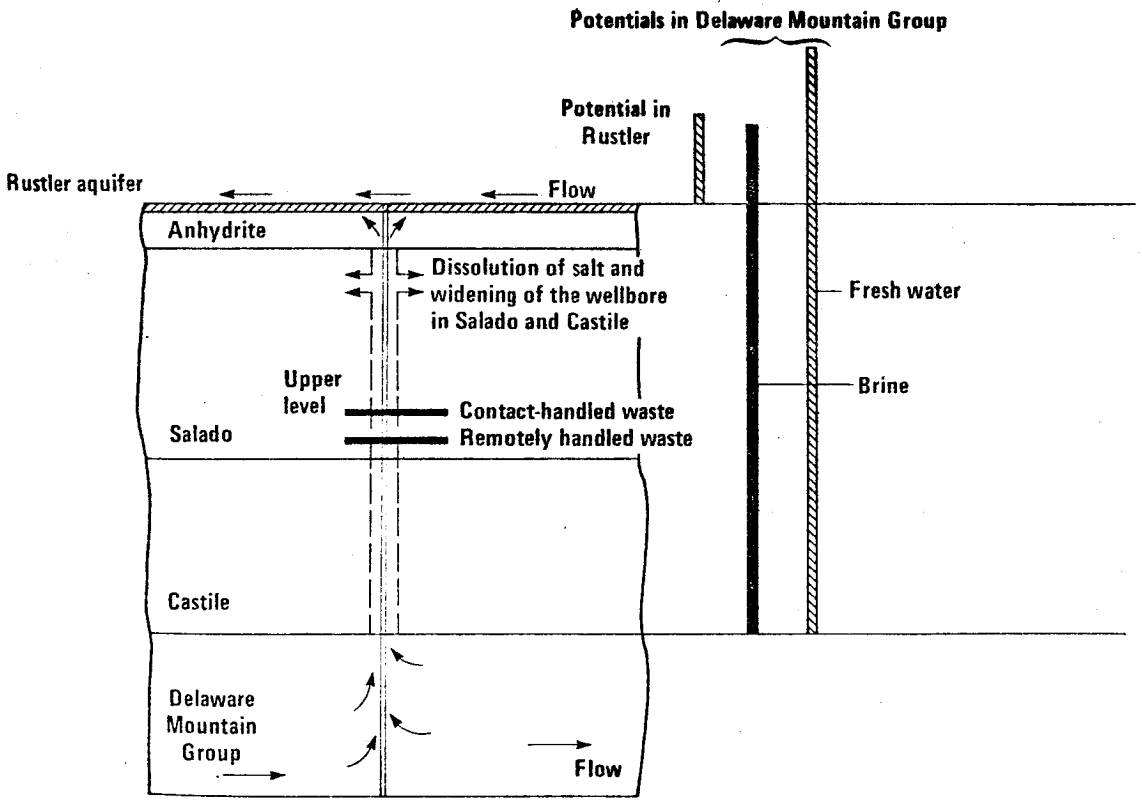

Figure 9-10. Schematic representation of scenario 1.

Scenario 1: A hydrologic connection was assumed to form between the Bell Canyon aquifer in the Delaware Mountain Group, below the repository, and the Rustler aquifer above the repository. Water flowed up from the Delaware Mountain Group, through the repository, into the Rustler. (See Figure 9-10, reproduced above.)

Scenario 2: Water was assumed to flow down from the Rustler into the repository through one opening (e.g. a shaft, borehole, fracture), then through the repository and back up into the Rustler through another opening.

Scenario 3: Water from the Rustler was assumed to enter the repository through a number of unconnected holes. Waste entered the Rustler by diffusion.

Scenario 4: Scenario 4 was considered to be a bounding case. The whole flow of the Rustler above the repository was assumed to pass through the repository and back into the Rustler. Equivalently, for modeling purposes, the repository was placed in the Rustler.

Assumptions Made for the Above 4 Scenarios

1. The waste was not considered to be in containers at the time of the breach.

2. The waste was assumed to leach or dissolve at the same rate as salt, and that rate was determined by the amount of salt required to saturate the water entering the Rustler after passing through the repository.

3. The flow path of the waste in the Rustler was to the Pecos River at Malaga Bend, 15 miles from the repository site.

Direct Access Scenario

Scenario 5: A drill shaft was assumed to penetrate a waste container. Samples were analyzed by drill crew members. Drilling mud and cuttings were left at the site in pits with surface areas of 720 square feet (oil or gas drilling scenario) or 144 square feet (mineral exploration scenario).

B. ADDITIONAL SCENARIOS

The following scenarios have been proposed by EEG, its consultants, or other groups commenting on the WIPP DEIS. EEG would like to know whether the hydrologic or geologic events described in these scenarios are plausible, and whether other events should be considered in designing meaningful radiological hazard scenarios.

1. Event: Breaching of the excavation workings by pressurized brine after installation of substantial quantities of waste.

   Causes:

   a) Penetration of a brine reservoir during excavation for WIPP.

   b) Structural overburden adjustments.

   c) Heat source effects.

   d) Collapse of underlying beds from previous or renewed dissolution.

   Result: A large flow of brine into the repository, rising to the surface and entering the local or Pecos River drainage and/or the Rustler aquifer.

2. Event: Hydraulic communication between the excavation for WIPP and the dissolution conduits connected to the Capitan Reef aquifer.

   Causes:

   a) Existing conduits NE and E of site already in communication with the Capitan Reef aquifer.

   b) Development of communication between the excavation and existing conduits from collapse of subjacent or underlying beds.

   c) Development of communication from renewal of dissolution.

   Result: Movement of brines into lower part of Capitan aquifer, transfer to San Andres limestone and escape from the basin (with possible effects on petroleum and gas exploration in Texas).

3. Event: Communication between excavation for WIPP and surface drainage, Rustler aquifer and Delaware Mountain Group aquifer.

   Causes:

   a) Collapse of existing dissolution pocket beneath site.

   b) Climatically induced renewal or development of a dissolution chamber beneath site.

c) Collapse due to retrieval of hydrocarbons beneath site.

d) Seismic activity, possibly induced by operation of repository or nearby mines.

Result: Movement of this fluid under artesian pressure to surface or down into Delaware Mountain Group aquifer with ultimate escape from the basin.

Note: This scenario is a variation on DEIS scenario 1, where water flows vertically from the Delaware Mountain Group to the Rustler horizon before moving laterally to Malaga Bend.

4. Event: Communication between the repository, a source of water, and reserves of potash, oil or natural gas.

Causes:

a) Communications between aquifers and repository, as in items 2, 3.

b) Communication between brine reservoir and repository, as in item 1.

c) Solution mining for potash after site control is lost.

d) Injection of water for secondary oil recovery.

Result: Dissolution of a fraction of the waste and contamination of retrievable resources.

APPENDIX

Premeeting Correspondence

List of Attendees

Agenda

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STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
320 E. Marcy Street
P. O. Box 968
Santa Fe, N.M. 87503
(505) 827-5481

October 18, 1979

To: Roger Anderson, University of New Mexico
Lokesh Chaturvedi, New Mexico State University
Stanley Davis, University of Arizona
Rodney Ewing, University of New Mexico
George Griswold, Tecolote Corporation
John Holloway, National Academy of Sciences
Frank Parker, National Academy of Sciences
D. T. Schueler, Department of Energy
William Twenhoeffel, U.S. Geological Survey
Wendell Weart, Sandia

As we discussed on the phone, I'm enclosing a tentative agenda to get your reaction to the thought of a two day meeting to consider the potential radiological health consequences of deep dissolution, breccia pipes, brine reservoirs and any other localized geological phenomena in the proposed WIPP site area.

The type of question we would like to ask is illustrated on the agenda. We want to ensure that all important geological pathways are included in our radiological health assessment of the proposed WIPP facility. From the standpoint of the EEG mission, it is essential that we don't discover two years from now that important geotechnical considerations were overlooked.

We are interested in your opinion about all aspects of the proposed agenda; for example:

1. choice of topics
2. allocation of time for topics
3. speakers to present various view points
4. chairmen for sessions
5. the speaker/discussion format
6. invitees.

We would like to make final meeting plans and send invitations at the beginning of November. If I have not heard from you by October 31st, I'll call for your comments.

Sincerely,

Carla Wojay for Robert H. Neill

Robert H. Neill
Director

RHN:sl

Enclosure

HEALTH & ENVIRONMENT department

"Equal Opportunity Employer"

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
320 E. Marcy Street
P. O. Box 968
Santa Fe, N.M. 87503
(505) 827-5481

December 20, 1979

Dear

You are invited to a 2-day meeting on January 17 and 18, 1980 on "Geotechnical Considerations for Radiological Hazard Assessment of WIPP."

The purpose of this meeting is to insure that all important geological pathways are considered in the quantitative assessment of the radiological health risks to people from WIPP. From the standpoint of the mission of EEG, it is essential that we don't discover two years hence that important geotechnical considerations were overlooked in our analyses of potential routes by which radioactive wastes could be introduced into the environment.

As you can see from the list of invitees, there will be representatives of the federal agencies and their contractors who have been studying these issues, together with several members of both the Governor's Technical Advisory Committee on WIPP, and the WIPP Panel, Committee on Radioactive Waste Management of the National Academy of Sciences. In addition, members of the Geology Departments from three New Mexican universities and several other outstanding people with particular knowledge in this area are being invited to attend.

The attached agenda was structured to provide an opportunity for hypotheses and analyses to be presented in a formal manner, with the bulk of the time allotted to questions, comments and discussion of the salient issues.

Background material for the conference will be transmitted next week. This will include a brief description of recent studies of the WIPP area, a summary of several scenarios which have been suggested as possible mechanisms for release of radionuclides from the repository, and a list of other geotechnical questions or problem areas which might be considered at the meeting as to their potential for release of radioactivity.

Please let us know if you can attend. We hope that your schedule will allow you to participate in this important meeting.

Sincerely,

Robert H. Neill

Robert H. Neill
Director

RHN:opg

Enclosures

GEOTECHNICAL CONSIDERATIONS FOR RADIOLOGICAL HAZARD ASSESSMENT OF WIPP

List of attendees for January 17, 1980

1. Roger Y. Anderson - UNM
2. Emery Arnold - NM Energy and Minerals Department
3. George Bachman - Independent
4. G. E. Barr - Sandia Laboratories
5. Larry Barrows - Sandia Laboratories
6. E. H. Beckner - Sandia Laboratories
7. Robert L. Bluntzer - Texas Department of Water Resources
8. Jonathan F. Callender - UNM
9. James K. Channell - EEG
10. Lokesh N. Chaturvedi, NMSU
11. Ken Clark, III - CARD
12. David Donaldson - Energy & Minerals Department
13. Sigmund L. Drellock, Fenix Scisson & USGS
14. Rodney C. Ewing - UNM
15. Roy W. Foster - Petroleum Recovery Research Center
16. Lynn Gelhar - New Mech Tech
17. John Gervers - WIPP Task Force
18. Carole Goetz - USGS
19. Don Gonzalez - Sandia Laboratories
20. George B. Griswold - Tecolote Corporation
21. Hubert Grossman - USGS
22. F. J. Gurney - Westinghouse
23. Don Hancock - Southwest Research & Information Center
24. John W. Hawley - Environmental Geology - State Bureau of Mines
25. Barbara J. Henson - USGS - Water Resources
26. Leslie R. Hill - Sandia Laboratories
27. G. L. Hohmann - Westinghouse
28. Russ Ives - USGS
29. Deidre Jeys - USGS
30. Charles L. Jones - USGS
31. Frank E. Kottlowski - New Mex. Bureau of Mines & Mineral Resources
32. Alan K. Kuhn - D'Appolonia/WIPP TSC
33. Steve Lambert - Albuquerque Tribune

34. Steven Lambert - Sandia Laboratories
35. Marshall Little - EEG
36. Ray Mairson - Westinghouse Electric
37. J. M. McGough - DOE
38. Jerry W. Mercer - USGS
39. M. L. Merritt - Sandia
40. Forrest Miller - Consulting Geologist
41. Jack Mobley - EEG
42. Peter Montague - Office of Technology Assessment (consultant)
43. Robert H. Neill - EEG
44. Kenneth H. Olsen - LASL
45. Gordon B. Page - Consultant to State Geologist
46. Richard Parizek - Penn. State University, NAS
47. Dennis W. Powers - Sandia Laboratories
48. D'Arcy A. Shock - NAS
49. Dev Shukla - D'Appolonia
50. David Siefken - U. S. Nuclear Regulatory Commission
51. Frank A. Swenson - USGS (Retired)
52. Denise Tessien - Albuquerque Journal
53. Martin Tierney - Sandia Laboratories
54. William S. Twenhofel - USGS
55. Wendell D. Weart - Sandia Laboratories
56. Marvin Wilkening - Governor's Advisory Committee
57. Jane Wells - USGS
58. Carla Wofsy - EEG
59. Robert J. Wright - Nuclear Regulatory Commission
60. Georgia Yuan - Natural Resources Defense Council
61. Fran Austin - KUNM University of New Mexico
62. Conroy Chino - ABC News
63. Ed Kelley - Mining and Minerals Division
64. Tim Hobbs - NM Mining and Minerals Division
65. Ken Balizer - NM Citizen Action
66. Hal Brice - KOB TV

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STATE OF NEW MEXICO

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AGENDA

GEOTECHNICAL CONSIDERATION FOR

RADIOLOGICAL HAZARD ASSESSMENT OF WIPP

January 17, 1980

8:00 a.m.	Registration		
8:30 a.m.	Welcome		Thomas E. Baca, Director, New Mexico Environmental Improvement Division, Health and Environment Dept.
8:45 a.m.	Purpose, Scope and Additional Agenda Items		Robert H. Neill, EEG Lokesh Chaturvedi, NMSU (Cochairmen)
9:00 a.m.	GROUND WATER HYDROLOGY	(1 hr. 15 min.)	David Siefken, NRC James K. Channell, EEG (Rapporteurs)
	Overview of new data	(15 min.)	J.W. Mercer, USGS
	State of knowledge; how accurately are the parameters known?	(15 min.)	Don D. Gonzales, Sandia
	Open questions	(15 min.)	Lynn W. Gelhar, NM Tech
	Discussion		All conferees (See Section 4)
10:15 a.m.	Break		
10:30 a.m.	SCENARIOS		
	Overview of scenarios, including those in WIPP Draft Environmental Impact Statement (DEIS)	(15 min.)	Carla Wofsy, EEG (See Section 2)

10:45 a.m.	DEEP DISSOLUTION AND BRECCIA PIPES (3 hr. 15 min.)		Frank Kottlowski, NM Bureau of Mines Marshall S. Little, EEG (Rapporteurs)
	Presentation	(15 min.)	Dennis W. Powers, Sandia
	Presentation	(15 min.)	George O. Bachman, USGS (See Section 5)
	Presentation	(15 min.)	Roger Y. Anderson, UNM (See Section 5)
	Discussion		All conferees (See Section 4)

Is deep dissolution occurring at or near the site and if so what could be the geological pathways and time frame in bringing radioactive waste to the surface? Are the data adequate to measure the significance of deep dissolution for the WIPP site? If not, what is required? Are breccia pipes present or can they develop at the WIPP site? How accurately can they be detected? Does Scenario 1 in the DEIS cover their importance in radionuclide transport adequately? What additional scenarios should be considered?

11:45 a.m. Lunch

1.00 p.m. DEEP DISSOLUTION AND BRECCIA PIPES, cont'd

Discussion

2:45 Break

3:00 p.m.	BRINE RESERVOIRS (2 hr.)		Rodney Ewing, UNM Carla Wofsy, EEG (Rapporteurs)
	Presentation	(15 min.)	George B. Griswold, Tecolote Corp.
	Presentation	(15 min.)	Steven J. Lambert, Sandia
	Presentation	(15 min.)	Charles L. Jones, USGS
	Discussion		All conferees (See Section 4)

	How well can brine reservoirs be detected with non-penetrative means? How can they bring waste to surface? Can brine reservoirs occur in the Salado? Can a connection form between a brine reservoir and the repository after the repository is sealed? If so, how?		
5:00	Recess		

January 18, 1980

8:30 a.m.	Rapporteur's summary of first day		
9:00 a.m.	OTHER FEATURES (2 hr. 30 min.)		W.S. Twenhofel, USGS Carla Wofsy, EEG (Rapporteurs)
	Presentation	(15 min.)	Jonathan F. Callender, UNM
	Presentation	(15 min.)	Larry Barrows, Sandia
	Discussion		All conferees (See Section 4)
	Can faults, dikes, synclines, anticlines, other geological features or combinations of features affect waste isolation in some way that has not yet been discussed? If so, what new scenarios should be considered? How accurate are current detection procedures?		
10:15 a.m.	Break		
10:30 a.m.	OTHER FEATURES, cont'd		
	Discussion		
11:45 a.m.	Lunch		
1:00 p.m.	HUMAN INTRUSION (2 hr.)		Kenneth Olsen, LASL James Channell, EEG (Rapporteurs)

	Presentation	(15 min.)	Wendell D. Weart, Sandia
	Presentation	(15 min.)	Frank Kottlowski, NM Bureau of Mines
	Presentation		D'Arcy A. Shock, Consultant
	Discussion		All conferees (See Section 4)

Can resource extraction or repository operations affect the geology and hydrology near the site? If so, how? For example, can repository operations or nearby mining operations affect seismic activity? Can mining activities near the site open new pathways for dissolution or increase dissolution rates? Can extraction of gas or oil below the site (at depths of 4,000 to 20,000 ft.) introduce new pathways for the release of radioactivity?

3:00 p.m. Break

3:15 p.m. Rapporteur's summary of second day

3:45 p.m. Final summary

4:30 p.m. Adjourn