State of Nevada Briefing to the Nuclear Waste Technical Review Board (NWTRB)

Subject: Geochemical Concerns of the Proposed Nuclear Waste Repository, Yucca Mountain, Nevada

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Presenter: Dr. Maury E. Morgenstein

Title: Senior Geologist, Geochemical Program Manager

2700 East Sunset Road, Suite C25
Las Vegas, Nevada 89120

Telephone: (702)798-0402
Problem

To determine the Ability of the Surface Volcanic Tuffs to Isolate Radionuclides from the Accessible Environment.

Retardation Credit

- Retardation credit is needed for radionuclides that require isolation in the host rock in order for the Repository to meet Regulatory criteria. These radionuclides that require isolation are considered *Key Radionuclides*.

- Isolation can be accomplished by: Sorption, Precipitation, Ion Exclusion, and Diffusion mechanisms.
## Key Radionuclides

<table>
<thead>
<tr>
<th>Key Radionuclides</th>
<th>Mechanism of Possible Release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actinides*:</td>
<td></td>
</tr>
<tr>
<td>• Plutonium</td>
<td>Ground Water Travel</td>
</tr>
<tr>
<td>• Americium</td>
<td></td>
</tr>
<tr>
<td>• Neptunium</td>
<td></td>
</tr>
<tr>
<td>Technetium*</td>
<td>Ground Water Travel</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>Gas Transport</td>
</tr>
</tbody>
</table>

* After A.D. Kelmers, ORNL-WS 41476.
# Mineralogy-Related Parameters Necessary for a Retardation Barrier

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Suitable Mineralogy</td>
<td>Zeolites*, Clays, Fe &amp; Mn Oxyhydroxides</td>
</tr>
<tr>
<td>Mineral Stability</td>
<td>Ambient Temperatures, low Na water, high Silica activity</td>
</tr>
<tr>
<td>Mineral Accessibility</td>
<td>Open pores lined with suitable minerals in likely path of travel combine with:</td>
</tr>
<tr>
<td></td>
<td>• A significant volume of sorbing minerals</td>
</tr>
<tr>
<td></td>
<td>• Mineral crystals oriented so that sorbing crystal faces are exposed to passing liquids.</td>
</tr>
<tr>
<td></td>
<td><strong>This is a function of:</strong></td>
</tr>
<tr>
<td></td>
<td>• Crystal orientation</td>
</tr>
<tr>
<td></td>
<td>• No nonsorbing mineral overgrowths</td>
</tr>
</tbody>
</table>

* Sorbing zeolites such as clinoptilolite, mordenite, and heulandite.
Zeolite Stability

As the concentration of sodium in water that contacts clinoptilolite increases, the stability of clinoptilolite as a function of temperature decreases. Clinoptilolite converts to the nonsorbing zeolite analcime. Silica activity also affects clinoptilolite stability.

If the sodium concentration is held constant and at the level of J-13 water at Yucca Mountain, then the clinoptilolite conversion to analcime will probably take place at a temperature of about 90 degrees Centigrade. At temperatures between 60 and 90 degrees Centigrade, there would be a reduction of the clinoptilolite unit cell volume and therefore a partial loss of sorption capabilities, therefore retardation would be affected.

Heulandite is not stable in the present day Yucca Mountain saturated zone as indicated by recent studies by Los Alamos on J-13. Repository induced changes to Yucca Mountain will affect minerals that are presently stable.
## Other Parameters Affecting A Retardation Barrier

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</table>
| Mass Action Competition    | **Clinoptilolite Exchange Preferences:**  
Cs > K > Sr = Ba > Ca >> Na > Li  

**Mordenite Exchange Preferences:**  
Cs > K > NH4 > Na > Ba > Li  

**NOTE:** Cation exchange and thermal stability are both affected by cations present in the structures. |
| Colloid Formation           | Example: Actinide transport                                                                                                                                                           |
| Multiple Speciation         | Example: Actinides of various oxidation states.                                                                                                                                       |
| Fracture Flow Predominant   | Insignificant exposure to sorbing minerals. Low unit per unit residence time.                                                                                                         |
| Nonsorbing Radionuclides    | Most probably the actinides and Technetium.                                                                                                                                          |
| Soil Gas Circulation        | Known pressure differential in vadose zone create blowing wells - Radionuclide gas transport through open fractures and faults.                                                       |
If
- Sorption credit is to be taken

The Most Likely Path of Travel

Must Be:

- Geochemically Stable
- Composed of actively sorbing minerals
- A slow path of travel
If the Most Likely Path of Travel is:

**IF**

**Fracture Flow**
No sorption is expected because there are not enough sorbing minerals present along fracture pathways. Sorption credit is needed for site licensing.

**Matrix Flow**
Sorption is expected for non-key radionuclides. Transport is generally so slow that sorption credit for these radionuclides are not needed for licensing.

**Selective Matrix Flow**
(preferential pathways)
Limited sorption is expected for non-key radionuclides. Transport may be rapid and sorption credit is needed for licensing.

**A TENTATIVE CONCLUSION** might be that when sorption/retardation is really needed, it is not available and when it is not needed it is available on a limited basis.
Conclusions

The ability to determine whether or not there will be sufficient isolation of radionuclides from the accessible environment rests on the following concerns:

- Actinides do not appear to respond to sorption as a mechanism for retardation. Precipitation on the canisters or repository tuffs will depend upon unknown local conditions. Colloid formation is expected. It is doubtful that actinide retardation can be adequately characterized on a site-specific basis.

- Technetium is expected to stay in solution.

- Sorption of the other radionuclides (except actinides and vapor phase radionuclides) probably can be significant under idealized conditions at the Calico Hill Formation (below the proposed repository horizon) if the following conditions are met: There is no fracture flow, low sodium and high silica concentrations in the pore waters, and temperatures are at or below 60 degrees C. Transport by preferred channeling (selective matrix flow) may reduce sorption capacity by reducing exposure to sorbing minerals.

- Vapor phase radionuclide transport of C-14 is expected. No retardation mechanism has been identified yet.
Reference

EDUCATION:
Ph.D., 1974, University of Hawaii, in Geology and Geophysics.
M.S., 1969, Syracuse University, in Geology.
B.A., 1967, Queens College, City University of New York, in Geology,
New Mexico Institute of Mining and Technology (NMIMT).

PROFESSIONAL EXPERIENCE:
to present.
Consultant, Desert Research Institute, Water Resources Center, University of Nevada Sys-
Senior Geologist, Geophysicist, Director of Operations, Brim Partnership, placer gold mining
to present.
Affiliate Faculty of the Graduate School of the University of Hawaii, 1976-1979.
Consultant, State of Hawaii, Department of Land and Natural Resources, Division of State
Parks, 1977.
Aquatic Biologist, State of Hawaii, Department of Fish and Game, Honolulu, Hawaii, 1976-
1977.
Director of Research, Commercial Division, Pacific Analysis Corporation, Honolulu, Hawaii,
1976.
Assistant Oceanographer, University of Hawaii, 1975.
Assistant Researcher, Research Corporation of the University of Hawaii, 1974-1975.
Research Assistant, Research Corporation of the University of Hawaii, 1972-1974.
Lecturer - University of Hawaii, 1972.
Lecturer - Department of Geology, Rutgers University, NSF Summer Institute, 1967.
Teaching Assistant - Syracuse University, 1967-1969.
Assistant in Research, Lamont-Doherty Geological Observatory of Columbia University,

PROFESSIONAL AFFILIATIONS:
American Association for the Advancement of Science
Hawaii Association of Professional Geologists
International Association of Sedimentologists
Sigma Xi

PUBLICATIONS:
Blundy, J. D., R. G. Burns, and M. Morgenstein, Authigenic Minerals in Rhyolite Tuff at Yucca


Fan, P. F., M. Morgenstein, and W. Burnett, Clay Mineralogy and Geochronology, Semi-
CONSULTANT PUBLICATIONS:
Morgenstein, Fein, Andrews, Deepsea Ocean Mining for AMAX, Denver, Colorado.
Morgenstein, Kapuku Plan for Resource Management, State of Hawaii, for Department of Fish and Game.
Morgenstein and HMR archaeologists, various publications Geoarchaeology of Kaho'olawle, Maui County, Hawaii, for State of Hawaii, Department of Parks.
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Morgenstein, Micropaleontology and Chemical Stratigraphy for Paleotaro Fields, Oahu, for U.S. Army Corps of Engineers.
Morgenstein, Geoarchaeology, Chemical Stratigraphy, Micropaleontology, Hydration-rind Dating, various publications, Society Islands, Hawaiian Islands, Samoa, Easter Island, etc., Bernice Pauahi Bishop Museum, Honolulu, Hawaii.
Morgenstein, Geoarchaeology, Hydration-rind Dating, Micropaleontology with various archaeologists, various publications, Maui, Oahu, Hawaii, Molokai, Kauai, archaeological sites for U.S. Army Corps of Engineers and for State of Hawaii, Department of Parks.
Morgenstein, Uranium Mining, Grants, New Mexico Geologic and Sedimentologic Assessments with other geologists for Law firm in Hilo, Hawaii, Altman & Vanairsdale.
Morgenstein, Glass Hydration, Authigenic Mineralogy, Geochemistry Reports dealing with Yucca Mountain Proposed High-Level Nuclear Waste Repository, for DRI, University of Nevada System.
Morgenstein, Glass Hydration, Authigenic Mineralogy, Geochemistry Reports dealing with Yucca Mountain Proposed High-Level Nuclear Waste Repository, for State of Nevada.
Morgenstein, Reviews of various DOE and DOE contractors, NRC, USGS, and other publications and reports.

PATENTS:
2 U.S. Patents in Deep-Sea Mining Equipment, concepts:
1) Morgenstein, Elevator Apparatus; and
2) Andrews and Morgenstein, Concept of Full Mining System.