State of Nevada Briefing to Nuclear Waste Technical Review Board

Subject	Geochemical Concerns Regarding the Disturbed Zone at the Proposed Nuclear Waste Repository, Yucca Mountain, Nevada.
Date	June 26, 1989
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Definition of the Disturbed Zone

"the portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository." 10 CFR Part 60.2

NRC considers changes in permeability and porosity define the Disturbed Zone.

This ignores changes in state of the pore (and fracture) fluid and associated effects.

Geochemical Concerns Regarding the Disturbed Zone

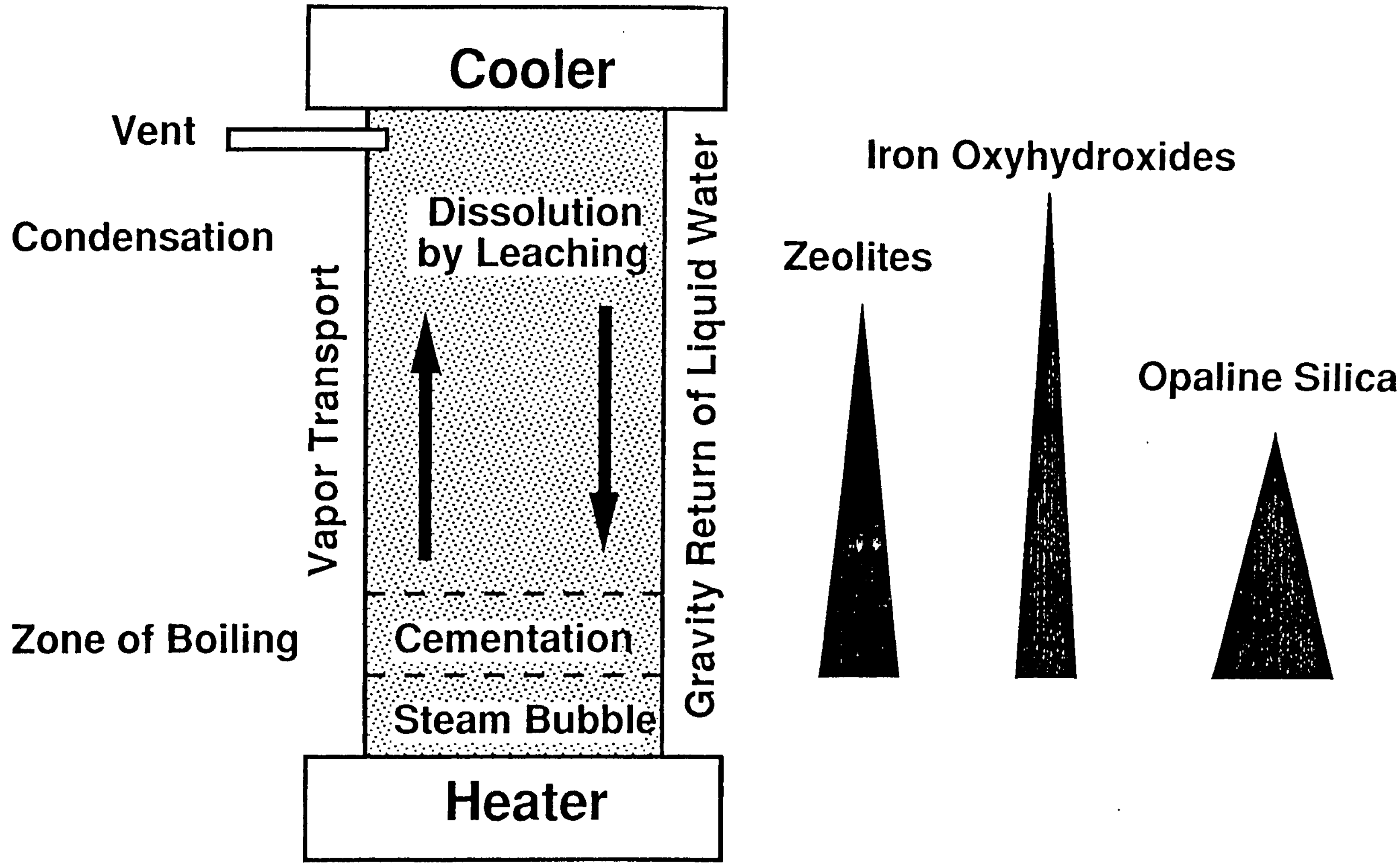
- Mass Transport (dissolution) in a Thermal Gradient
- Changes in Vadose Zone Water Chemistry:
  - Corrosion of Canisters
  - Leaching of Waste Forms
- Local Saturation Surrounding Dried Out Zone:
  - Perched Water Bodies above Repository
  - Saturated Fractures
- Thermal Fracturing of Repository Horizon Rock:
  - Boiling of Pore Water during Heating Phase
  - Massively Cemented Zones during Cooling

Vadose Zone, Yucca Mountain, Nevada

Hydrogeologic Unit	Thickness Range, m	Remarks
Tiva Canyon, welded	0 - 150	
Paintbrush nonwelded	20 - 100	Partially Zeolitic
Topopah Spring welded	290 - 860	Repository Horizon
Calico Hills nonwelded (vitric) Calico Hills nonwelded (zeolitic)	100 - 400	Potential Retardation ▼ Standing Water Level
Crater Flat unit: Prow Pass, Bullfrog, Tram members	0 - 200	

Mass Transport

Thermal Gradient Reactor Experiment



Changes in Vadose Water Chemistry within the Disturbed Zone

- **Boiling of Vadose Zone Water Produces:**

  High pH waters (pH jumps to 9 with small amounts of boiling, and is over 10 near dryness)
  Mineral Precipitates of Calcite, Amorphous Silica, Albite, and Talc

- **Condensation of Boiled Gases Produces:**

  Carbonic Acid Liquid with pH of 6 at 100°C (4.6 at 25°C)
  Series of Mineral Assemblages (when reacted with welded tuff) that include Alkali Feldspar, Zeolites, Hematite, Amorphous Silica, Laumontite, and Pyrophyllite.

Stability of Sorbing Minerals Example: Clinoptilolite

Stability of Clinoptilolite decreases with increasing
Temperature (=> Kaolinite)
Aqueous Al activity (=> Kaolinite ± Pyrophyllite)
Aqueous activity ratio of Na+/H+ (=> Albite)
Aqueous activity ratio of Ca2+/H+ (=> Calcite ± Epistilbite ± Scolecite)

Stability increases with increasing aqueous Silica activity.

CONCLUSION: Clinoptilolite will become unstable within the Disturbed Zone as boiling of vadose waters proceeds.

Redistribution of Water Within Disturbed Zone

Water in Topopah Spring matrix = Porosity * Mean Saturation
= 0.11 * 0.65
= 0.0715 (7.15% by volume)

Initial areal power density of 57 kw/acre, 95°C isotherm will reach maximum extent of 20m (10m above and below midline of repository) in approximately 90 years.

Volume of displaced liquid water = 2,000 acres * 20m * 0.0715
= 9,381 acre-feet

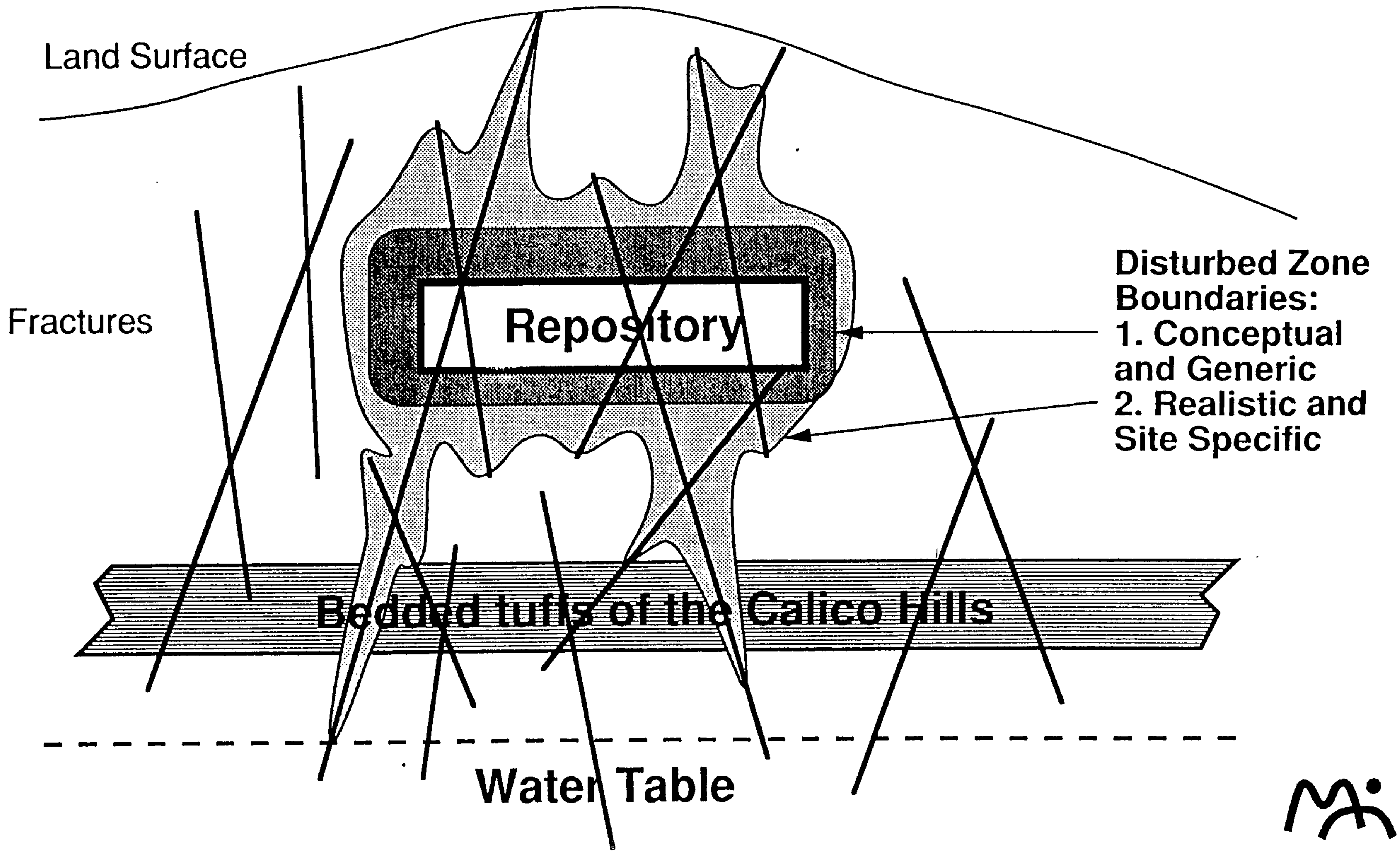
RESULT: Extensive envelope of fracture (and perhaps matrix) saturation totally surrounds repository. Recharge flux also accumulates.

A Site Specific, Realistically Defined Disturbed Zone

Is Required to be able to calculate:

- Travel Time
- Colloid and Particulate Transport
- Mineral Stability
- Changes in Vadose Water Chemistry

Schematic Diagram
Disturbed Zone Boundary



Conclusions Regarding the Disturbed Zone

- Significant Mass Transport may occur that could:
  - Affect the mechanical stability of the repository horizon
  - Cause local changes in permeability and porosity.
- Irreversible alteration of potentially sorbing minerals.
- Significant changes in Vadose Water Chemistry would affect
  - Corrosion rates of canisters, and
  - Dissolution rates of the waste form.
- Redistribution of water within and near the Repository by the thermal pulse may result in:
  - Thermal fracturing of repository-level host rock, and
  - Formation of locally saturated zones by condensation.

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VITAE

Don L. Shettel, Jr.

EDUCATION:

Ph.D., 1978, Pennsylvania State University, in Geochemistry and Mineralogy.
M.Sc., 1974, Pennsylvania State University, in Geochemistry.
B.Sc., 1971, University of Michigan, in Geology (with honors).

PROFESSIONAL EXPERIENCE:

Senior Geochemist, Treasurer, and Associate, Mifflin & Associates, Inc., Las Vegas, Nevada. As a technical consultant to the State of Nevada's Nuclear Waste Project Office, monitored and evaluated federal environmental assessment and site characterization efforts at the Yucca Mountain proposed nuclear waste repository. Conducted geochemical research on suitability of Yucca Mountain as the nation's first nuclear waste repository. Performed geochemical and hydrogeological modeling of vadose zone to determine extent of "disturbed zone." Oversaw development of quality assurance and quality control program for drilling and sampling of the vadose zone in the vicinity of Yucca Mountain. Reviewed technical documents of DOE and their subcontractors pertaining to the nuclear waste repository. 1986 to present.

Senior Research Geochemist, Reservoir Diagenesis Section, Exxon Production Research Company, Houston, Texas. Improved porosity prediction by investigating sandstone diagenesis by geochemical modeling (EQ3/6), isotopic methods, mass balance calculations, and microscopy. Developed model for carbonate cementation in sandstones based in part on stable isotope geochemistry and microscopy of sandstones from around the world. Established stable isotope laboratory for carbon and oxygen isotopic measurements on carbonates in rocks and calcareous microfossils that resulted in improved turn-around time and quality control of isotope analyses. Supervised and trained a technician to operate laboratory, 1982 to 1986.

Staff Geoscientist, Data Integration Group, Geology Division, Bendix Field Engineering Corporation, Grand Junction, Colorado. Improved uranium resource assessment by developing computer software and standardizing statistical analysis procedures for the interpretation and display of geochemical exploration data. Interpreted over 250,000 hydrogeochemical and stream-sediment samples consisting of over 5 million analyses and reported results. Combined solution-mineral equilibria computer models (PHREEQE and WATEQF) with standard interpretation techniques of geochemical data that aided uranium resource assessment. Supervised three professionals and one technician to develop and use software for interpretation of geochemical exploration data, 1978 to 1982.

Faculty Research Associate (Geochemistry Section), Arizona State University, Department of Chemistry, Tempe, Arizona. Designed and tested a mixing cell for performing calorimetry on geothermal brines, 1977 to 1978.

Research Assistant, Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania. Conducted hydrothermal experiments and stable isotope mass spectrometry that resulted in a new model for low 18-O magmas. Built fluorination line for oxygen isotopic analyses of silicates and trained other research assistants in its use which enabled completion of research. Developed computer software for geochemical calculations of fluid and isotopic equilibria and mineral stability, 1971 to 1977.

Assistant Field Geologist, Mineral Exploration Division, Humble Oil & Refining Company, Bangor, Maine. Conducted reconnaissance geologic mapping and geochemical and geophysical surveys that resulted in prospects for drilling, Summer1971.

PROFESSIONAL AFFILIATIONS:

American Association for the Advancement of Science
American Geophysical Union
Apple Programmers and Developers Association
Association of Ground Water Scientists and Engineers (a division of NWWA)
Computer Oriented Geological Society
Geochemical Society
International Association of Geochemistry and Cosmochemistry
International Association of Mathematical Geologists

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