



U.S. Department of Energy  
Office of Civilian Radioactive Waste Management



# Fluid Inclusions

Presented to:

**Nuclear Waste Technical Review Board**

Presented by:

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# Fluid Inclusion Studies History

- **In 1996, the State of Nevada scientists concluded that elevated temperature fluid inclusions (FI) in calcite were conclusive evidence of deposition from upwelling hydrothermal fluids**
- **The Nuclear Waste Technical Review Board reviewed the state scientist's work (Szymanski and Dublyansky) and recommended additional studies to assess the State's FI observations**
- **DOE funded a joint study with geoscientists from the State of Nevada, University of Nevada Las Vegas (UNLV), and the United State Geological Survey (USGS) as participants**



# Fluid Inclusion Study Objectives

- **Determine whether two-phase fluid inclusion assemblages (FIAs) indicating elevated temperatures are present in the host rock**
- **Determine the spatial distribution of elevated temperature FIAs**
- **Measure the range of FIA temperatures**
- **Establish a temporal framework of FIA formation by defining a paragenetic sequence and geochronology of associated minerals**
- **All data collection was from a shared set of participant collected samples**



# State of Nevada

- **State Conceptual Model Implications**
  - The proposed model implies that the vadose zone is occasionally subjected to an upward flux of heat and gas-charged fluid, in addition to being subjected to a small flux of infiltrating rainwater
  - The proposed model implies that the Exploratory Studies Facility minerals, some of which contain two-phase inclusions and yield elevated homogenization temperatures, represent entropy that has been produced and then lost as a series of hydraulic mounds set in the vadose zone. This allows for both ascending and descending flows in the vadose zone
- **Reference: *Scientific Status of the Lingering “Upwelling Water” Controversy in Light of the Joint UNLV/USGS/State of Nevada Research Project.*” Szymanski, J.S. and Dublyansky, Y.V. May 2001**



# USGS Conclusions

- **The FI assemblages are consistent with vadose zone formation**
  - No evidence supporting flooding of the unsaturated zone
  - The extremely sparse and heterogeneous distribution of the deposits is specifically inconsistent with flooding
- **Paces et al. conclude: *“The physical and isotopic data from calcite and opal indicate they formed from solutions of meteoric origin percolation through a limited network of connected fracture pathways in the unsaturated zone rather than by inundation from ascending groundwater originating in the saturated zone”***



# UNLV Conclusions

- **UNLV concludes:**
  - ***“Results from this study are not consistent with models requiring formation of secondary minerals in a saturated environment at Yucca Mountain”***
  - ***“Results, furthermore provide no evidence for the former presence of upwelling hydrothermal fluids”***
  - ***“Alternatively, results are consistent with infiltration of a cooling off tuff sequence by descending meteoric water”***
  - ***“This study demonstrates that the hypothesis of geologically recent upwelling hydrothermal fluids is untenable and should not disqualify Yucca Mountain as a potential nuclear waste storage site”***





# ● UNLV **Fluid Inclusion Publications**

- Manuscripts submitted to **Geochemica et Cosmochimica Acta**:
  - ◆ **“Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 1, Secondary Mineral Paragenesis and Geochemistry.”** Wilson, N.S.; Cline, J.S.
  - ◆ **Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 2, Fluid Inclusion Analyses and U-Pb Dating.”** Wilson, N.S.; Cline, J.S.

# ● USGS

- **Water-Resources Investigation Report (WRIR) 01-4049**
  - ◆ **“Ages and Origins of Calcite and Opal in the Exploratory Studies Facility Tunnel, Yucca Mountain, Nevada.”** Paces, J.B. et al.



# DOE Conclusions

- **State of Nevada Perspective: The State is withholding conclusions until review of the Cline, Wilson (UNLV) report**
- **Data and interpretations by both the DOE and UNLV scientists confirms that the conceptual model of descending percolation is accurate**
- **DOE may continue to examine secondary minerals in conjunction with other studies (e.g., waste package geochemistry, paleohydrology, transport, and others as applicable)**





# DOE Conclusions

(Continued)

- **The DOE concludes through this study, in conjunction with previous work, that the “upwelling waters” or “seismic pumping” hypotheses for the origin of secondary mineralization at the Yucca Mountain site have been adequately addressed and may be discounted**

