U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: NATURAL ANALOGUE MINERAL STUDIES AT YUCCA MOUNTAIN

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RENO, NEVADA
APRIL 16-17, 1991

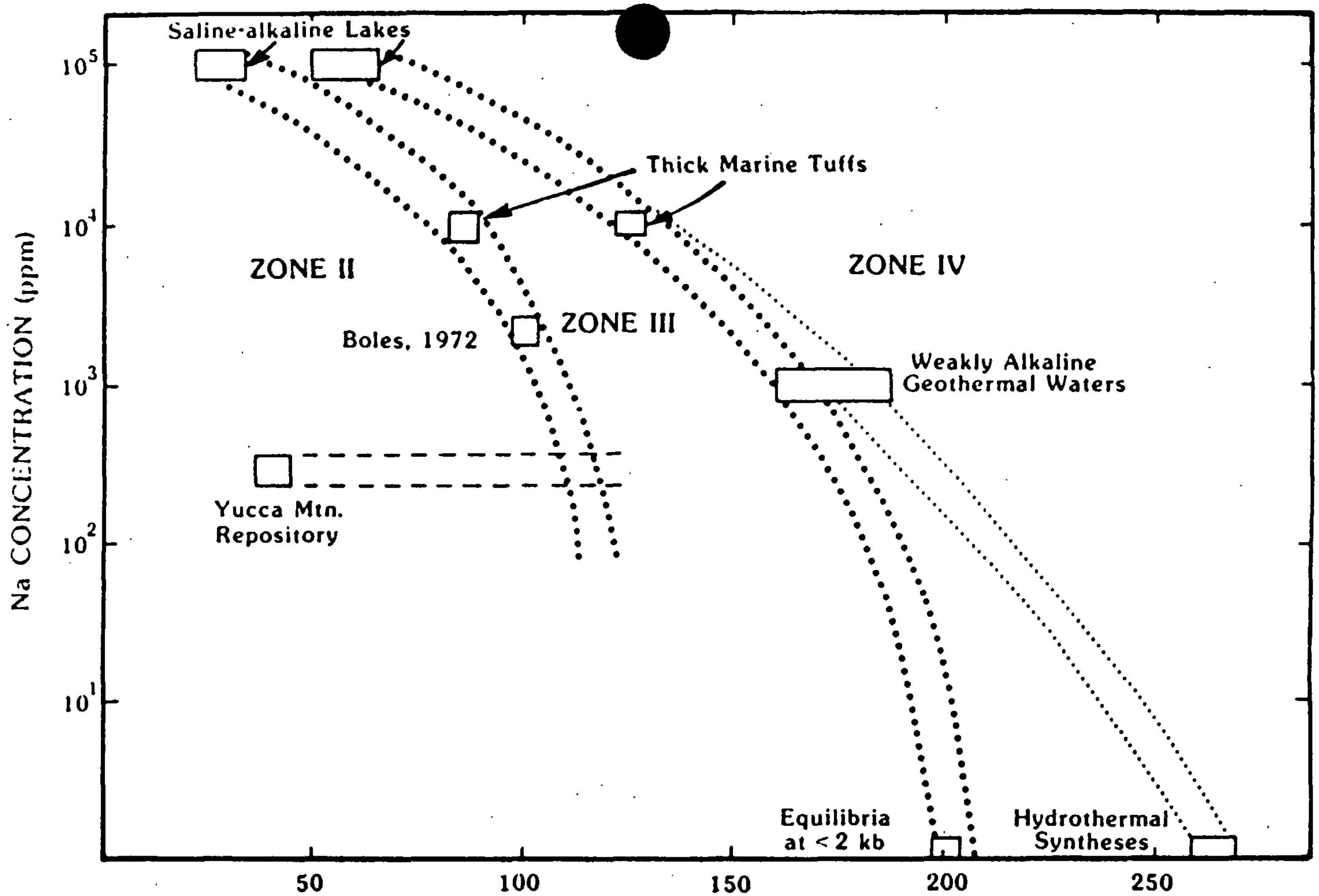
INFORMATION DESIRED FROM NATURAL ANALOGUES

- **Because of low temperatures and long reaction times, it is difficult to obtain useful information in the lab**

- **Need to understand the long-term behavior of minerals in a repository environment**

DIFFICULTIES WITH ANALOGUES

- **Defining past conditions**
- **Locating representative conditions**
- **Identifying representative mineral assemblages**



—Plot of Na concentration vs temperature for reactions bounding zeolite zones (after Iijima 1975). The lowest temperature and concentration field is for the assemblage alkali clinoptilolite + silica + H_2O and corresponds to Zone II (fig. 1). The reaction of this assemblage to analcime + quartz + H_2O is delineated by three data points: temperatures of saline alkaline lakes, those of thick marine tuffs, and the laboratory experiment of Boles (1972). The reaction of the assemblage analcime + quartz + H_2O (Zone III) to albite + quartz + H_2O is bounded by four data points: saline alkaline lakes (e.g., Mariner and Surdam 1970), thick marine tuffs (Iijima and Ohwa 1980), weakly alkaline geothermal waters (e.g., Honda and Muffler 1970) and some laboratory experiments (e.g., Liou 1971; Saha 1959). The composition of water from drill hole J-13 in Jackass Flat is plotted at the approximate ambient temperature of possible repository horizons at Yucca Mountain.

From: Smyth, J. R. (1982)

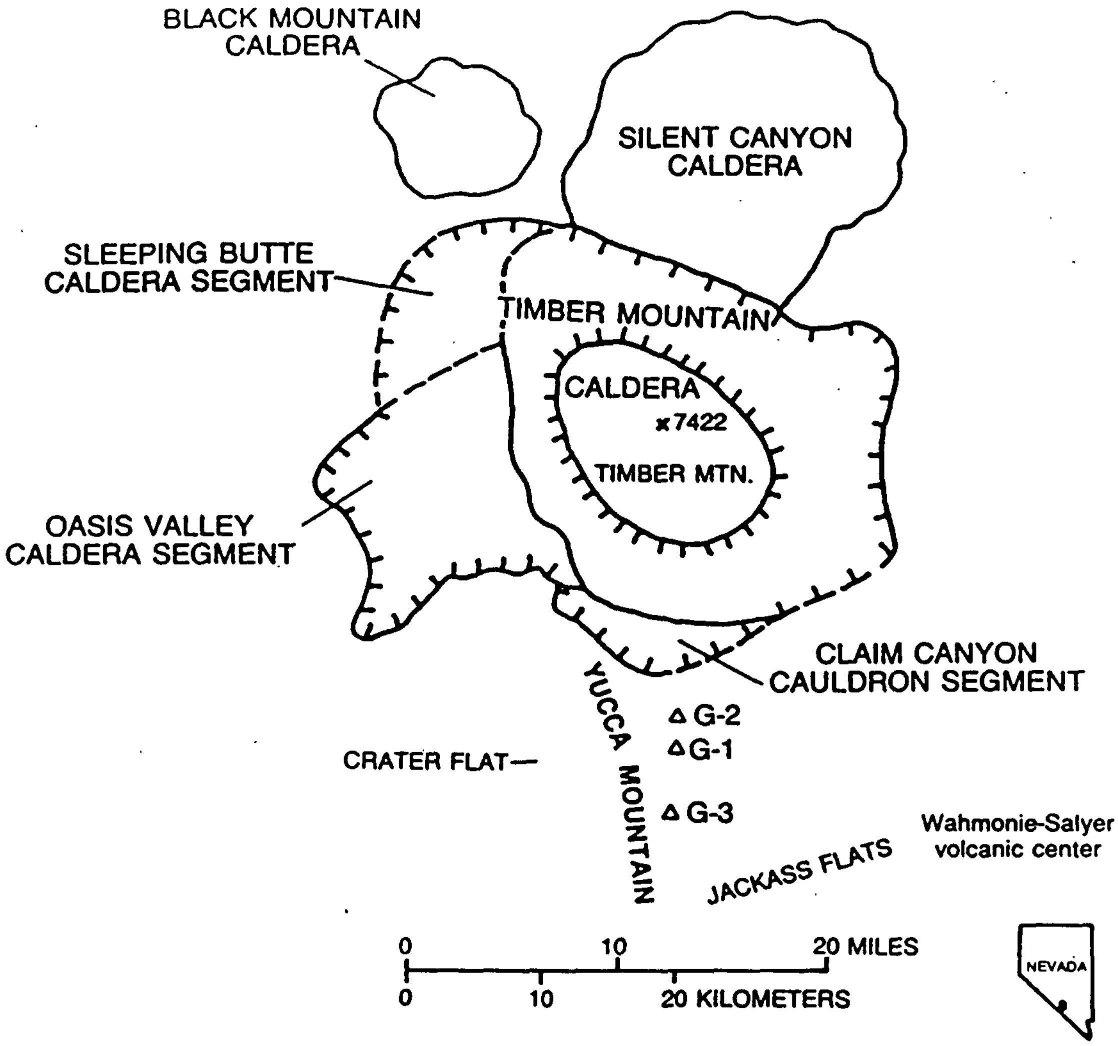
YUCCA MOUNTAIN AS A NATURAL ANALOGUE TO REPOSITORY-INDUCED ALTERATION

- **Use illite/smectite transformation to determine paleogeothermal gradients--estimate maximum temperatures to which minerals in drill holes have been subjected**

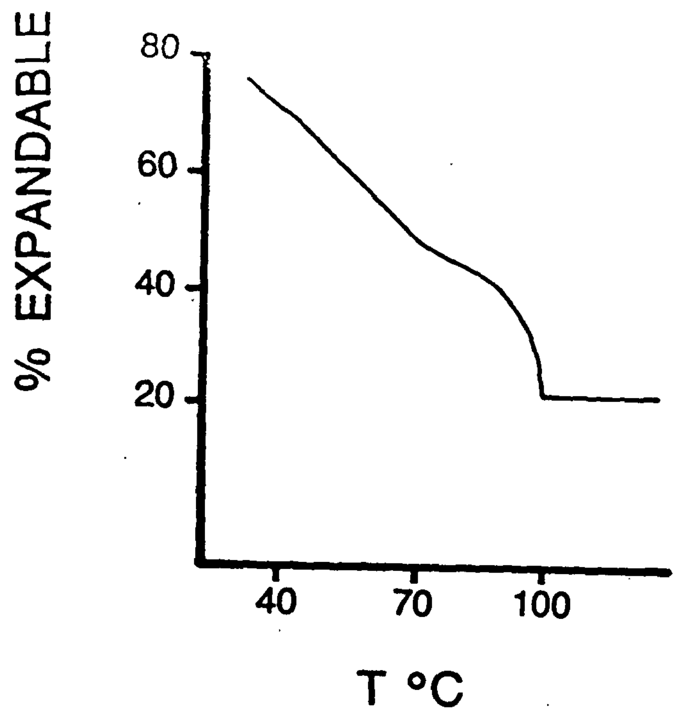
- **Use fluid inclusion homogenization temperatures from secondary minerals**

- **Use K/Ar dating of illite/smectites to determine timing of alteration**

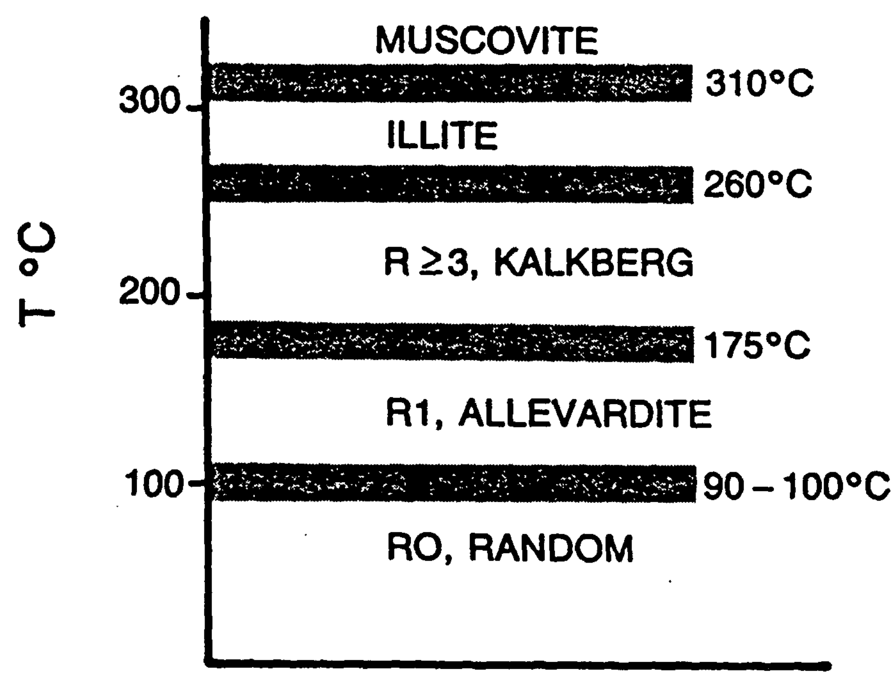
- **Determine apparent <u>long-term</u> stabilities of minerals in YM tuffs**



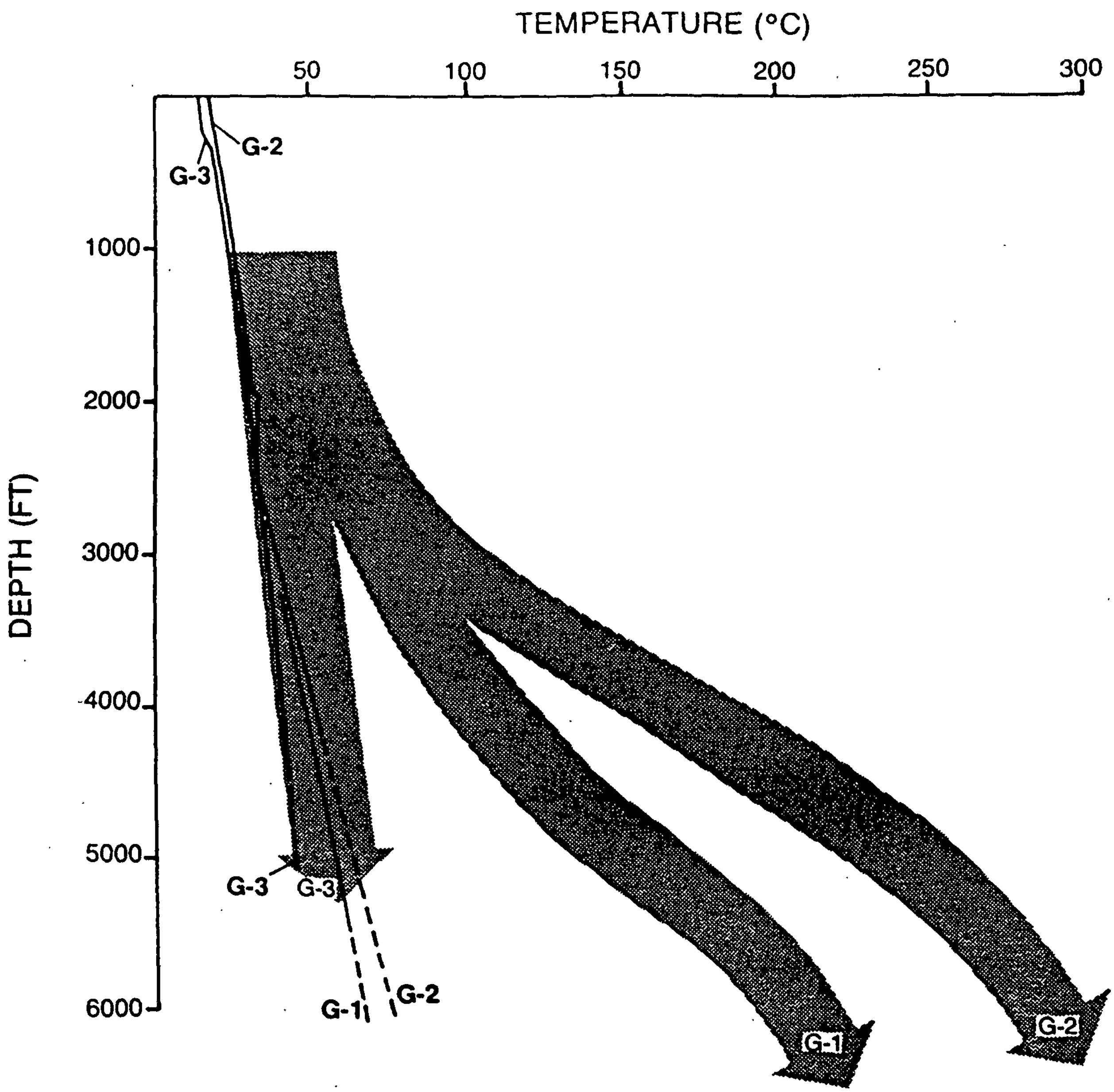
Southwestern Nevada volcanic field, Nye County, Nevada, showing the location of the Timber Mountain caldera and other volcanic centers with respect to Yucca Mountain from Byers et al. (1976). Heavy lines with hatchure marks to the inside represent the approximate outer limit of the Timber Mountain-Oasis Valley caldera complex, including the Sleeping Butte and Claim Canyon segments (dashed where indefinite). Heavy lines with hatchure marks to the outside represent the periphery of the Timber Mountain resurgent dome. Drill cores USW G-1, G-2, and G-3 are shown.



Relationship between expandability and temperature for illite/smectites from a Gulf Coast well (Perry and Hower 1970).



Relationship between temperature and extent of smectite-to-illite reaction (Hower and Altaner 1983).



Schematic paleotemperatures for USW G-1, G-2, and G-3 estimated from clay mineral reactions and fluid inclusion data (broad, arrowed lines) with the present-day measured temperature profiles from Sass et al. (1983) (solid narrow lines).

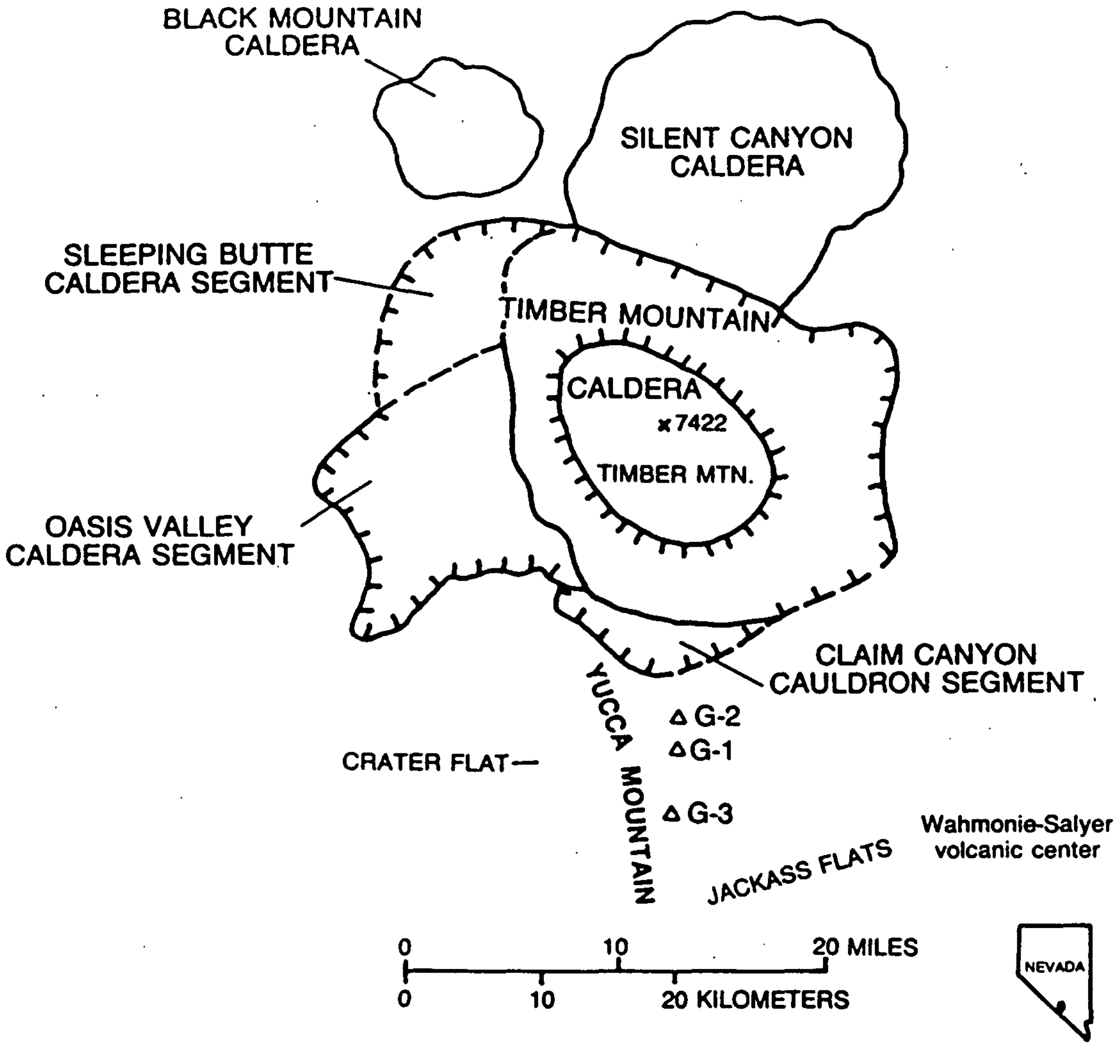
FLUID INCLUSION DATA FOR G-2

Sample	Mineral	Homogenization T (°C)
G2-5379	Calcite	94-115
G2-5762	Calcite	147
G2-5820	Calcite	202-239

SUMMARY OF I/S K/Ar AGES (Ma)

smectites (R0)	10.9±0.5
	10.0±0.4
R1 I/S	10.0±0.5
	10.2±0.5
	11.5±0.6
R≥3 I/S	11.0±0.6
	10.9±0.6
illite	11.0±0.6
average	10.7±0.8 Ma

The Timber Mountain-Oasis Valley calderas were most active between 11.5 and 11.3 Ma, and intracaldera lavas were erupted ~10.7 Ma.



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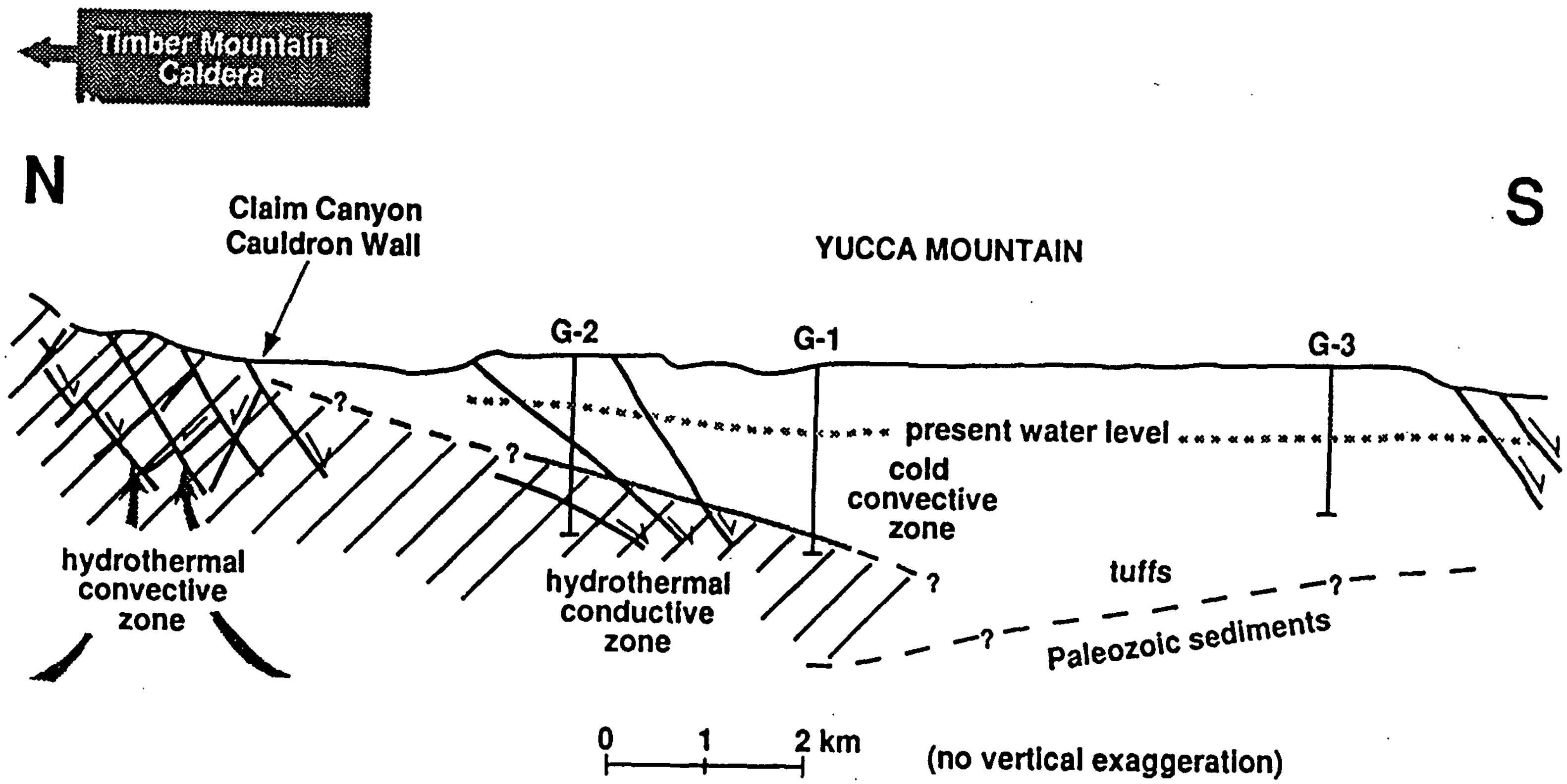
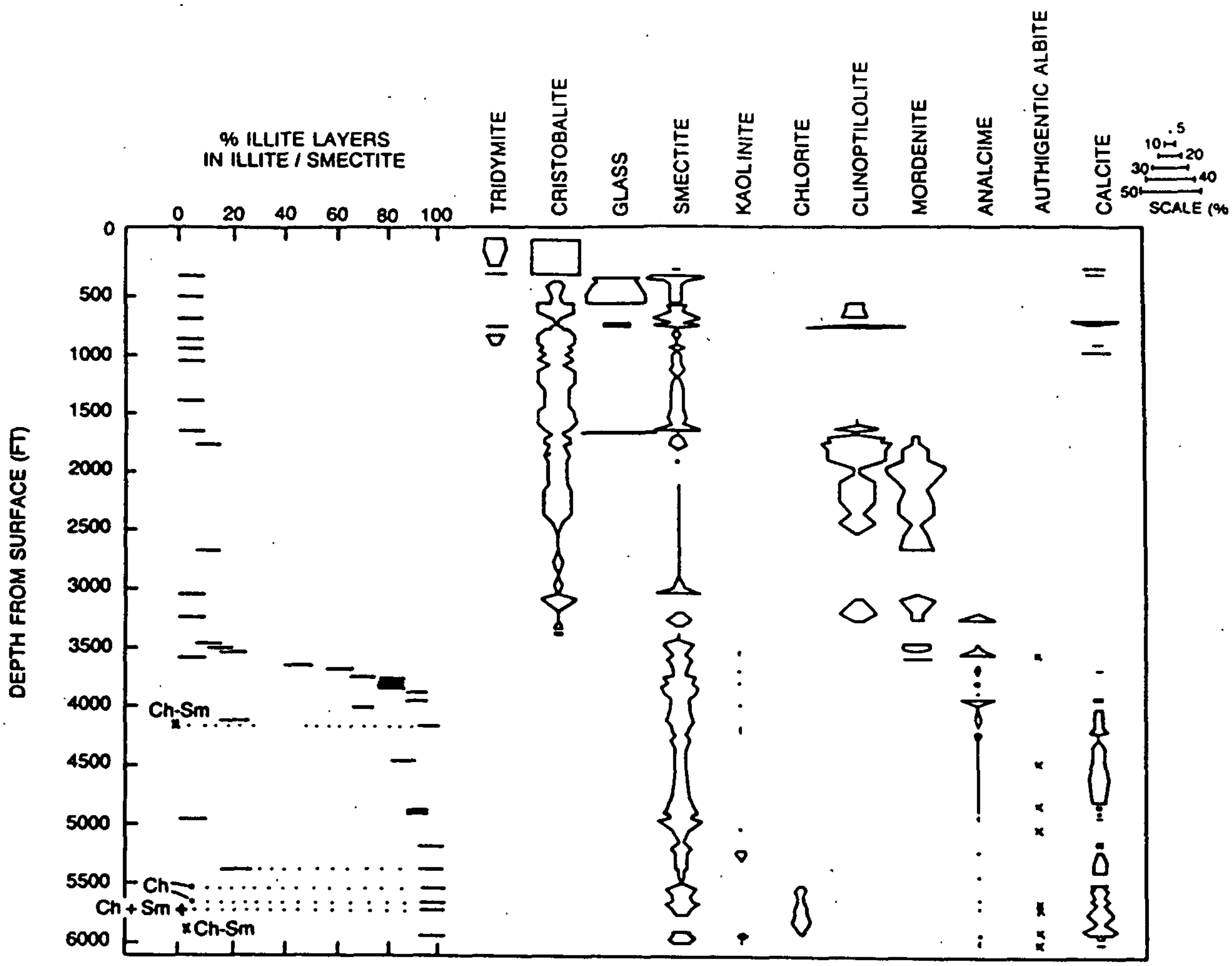
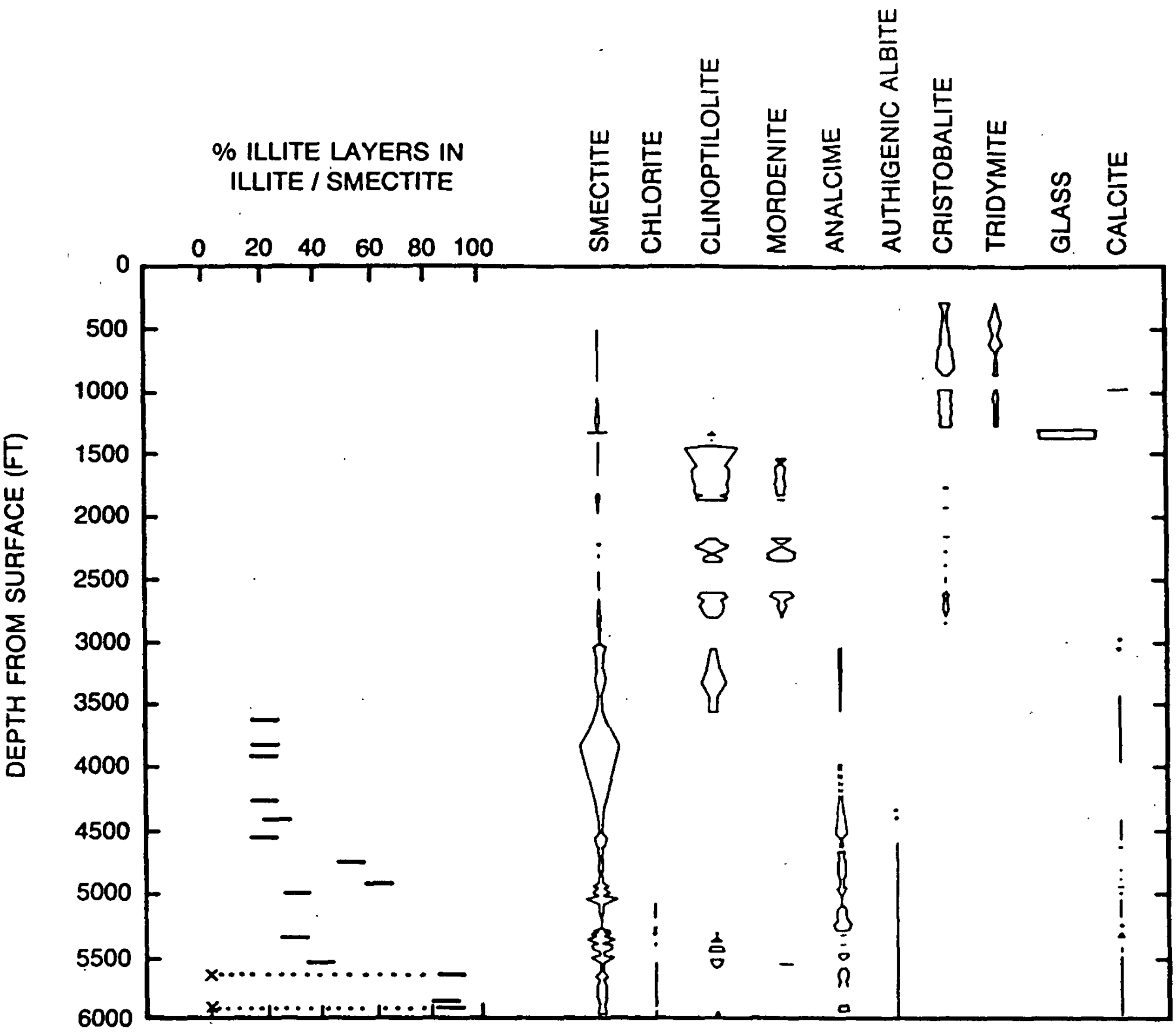
Reconstruction: 11 Ma Hydrothermal System at Yucca Mountain

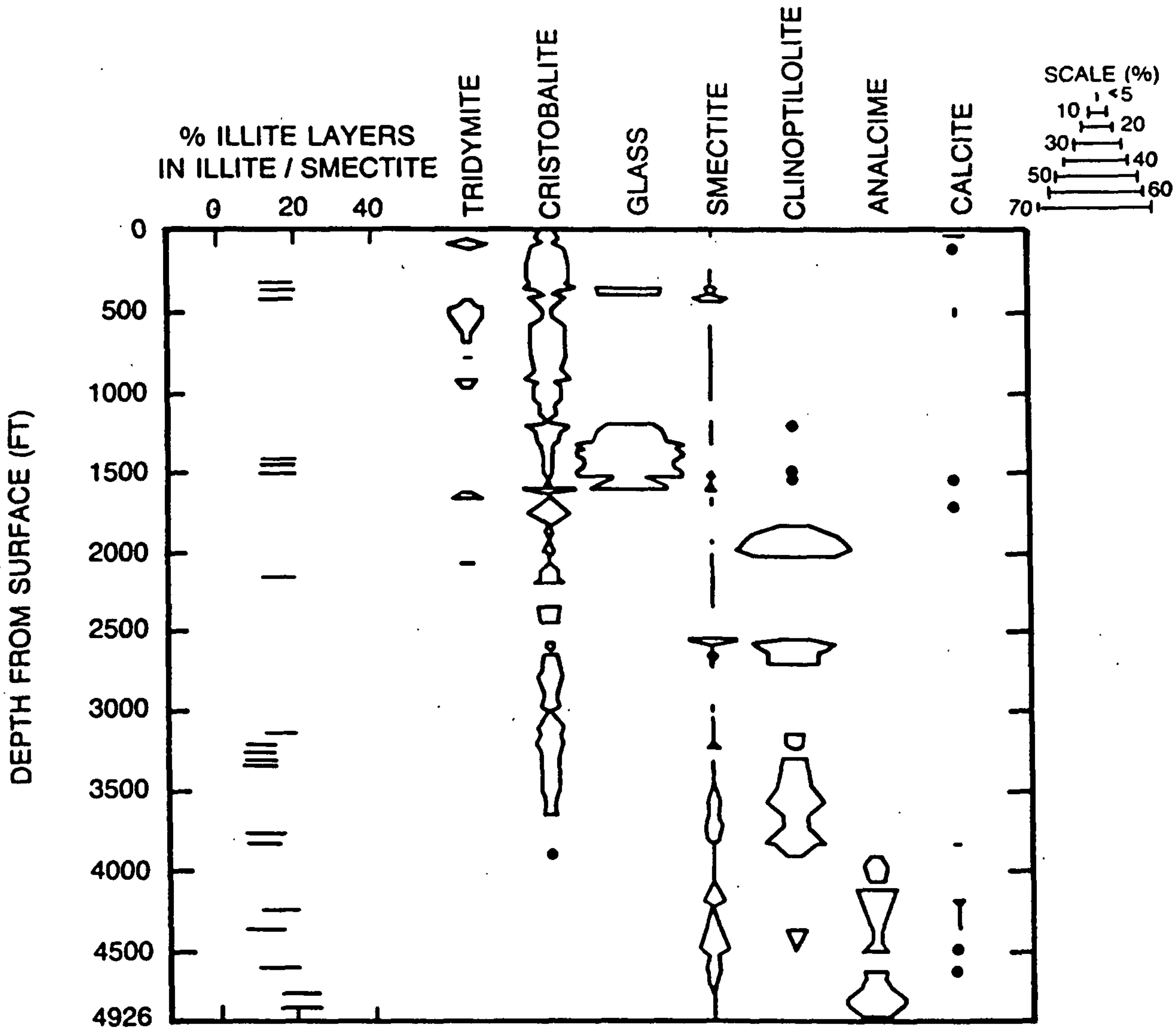




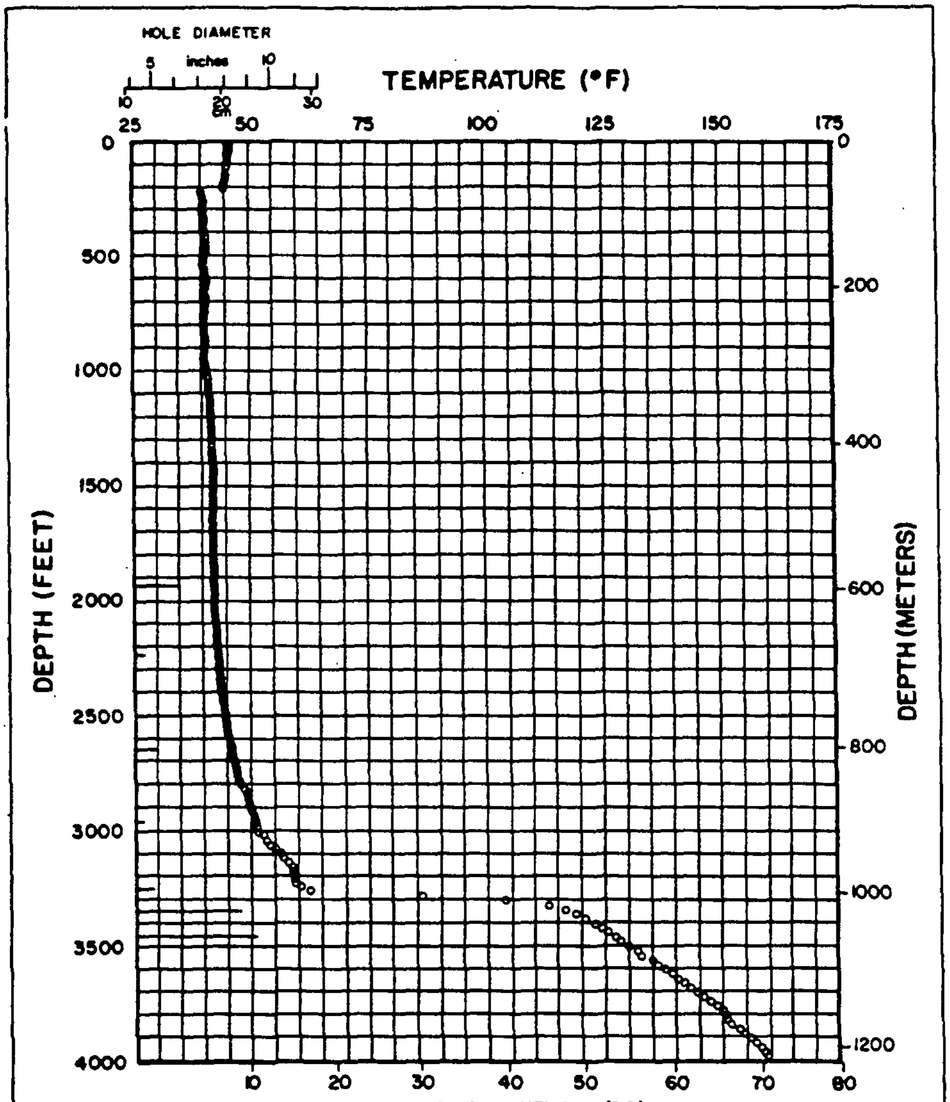
Mineral and glass abundances compared with clay mineralogy in drill core USW G-2 determined by x-ray diffraction. Occurrences of authigenic albite were determined by optical examination and are not quantitative. Dotted horizontal lines connecting clay minerals indicate that the phases are coexisting. An "X" signifies the occurrence of randomly interstratified chlorite/smectite, a "+" signifies the occurrence of chlorite + smectite, and a """ denotes the presence of chlorite.



Mineral and glass abundances compared with clay mineralogy in drill core USW G-1 determined by x-ray diffraction. Occurrences of authigenic albite were determined by optical examination and are not quantitative. Dotted horizontal lines connecting clay minerals indicate that the phases are coexisting.



Mineral and glass abundances compared with clay mineralogy in drill core USW G-3 determined by x-ray diffraction. Authigenic albite was not found in this drill core. Depths below 914 m (3000 ft) in this figure are corrected for drill-hole deviation such that the total depth is shown as 1501 m (4926 ft) rather than 1533 m (5031 ft).



Temperature-depth plot for core hole GEO N-1 with the idealized caliper log depicted along the left edge. Note the washouts over the interval 549 to 1046 m, which are depicted as straight horizontal lines.

From: Swanberg & Combs (1986)
EOS, p. 579.

CONCLUSIONS

- **A hydrothermal system existed beneath the north end of Yucca Mountain ~11 Ma.**

- **The alteration timing and distribution is consistent with a Timber Mountain volcanism association.**

- **The paleogeothermal profiles are consistent with a change from a meteorically-cooled (convective) zone to a conductive zone with depth.**

- **Apparent long-term thermal stabilities of minerals in YM tuffs:**
  --clinoptilolite ~100°C
  --mordenite ~130°C
  --analcime 175-200°C
  --cristobalite 90-100°C in G-2, lower in G-3
  --reactions in GU-3 appear to be water-chemistry dominated

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