# CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

## TRIP REPORT

**SUBJECT:** Trip Report for Busted Butte Rock Sampling and Observations of PTn on West Flank of Yucca Mountain (20.01402.861)

**DATE/PLACE:** May 22–23, 2000
Yucca Mountain, Nevada

**AUTHORS:** R. Fedors and J. Evans

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**PERSONS PRESENT:**

Randy Fedors of the Center for Nuclear Waste Regulatory Analyses and James Evans of Utah State University obtained rock samples from the Busted Butte facility, southeast of Yucca Mountain (YM), during a break in DOE mineback activities for the Phase 2 groundwater transport experiment. As time permitted, observations of outcrops of the nonwelded Paintbrush units (PTn) on the west flank of YM were also made during this trip.

**BACKGROUND AND PURPOSE OF TRIP:**

The nonwelded tuff units at YM play a prominent role in percolation through the unsaturated zone (UZ) to the repository and transport of chemical species below the repository to the water table. The PTn, which overlies the repository, is assumed by DOE to spatially and temporally dampen episodic pulses moving downward through the Tiva Canyon. Model simulations can readily show that a porous, permeable nonwelded tuff matrix (PTn) attenuates rapid, transient fracture flow from the Tiva Canyon tuff. Dampening of flow by the PTn is the basis for the steady state assumption used by the Department of Energy (DOE) in their three-dimensional (3D) site-scale UZ flow model. Primary heterogeneity or secondary discontinuities (e.g., fractures and faults), however, could lead to preferential flow paths through the PTn and into the Topopah Spring welded tuff below. The presence of bomb-pulse chlorine-36 below the PTn and the dilute chemical composition of the perched water suggest that some significant percentage of the episodic pulses follow fast pathways through the PTn. For fracturing and faulting, the PTn acts as an analog for the poorly exposed nonwelded Calico Hills Formation (CHn) at YM.

The CHn lies below the repository and acts as a barrier for radionuclide migration towards the water table. The nonaltered vitric portions of the CHn are capable of supporting matrix flow at rates above that of the current estimates of percolation. Radionuclides potentially moving through the matrix of the vitric CHn would be significantly delayed relative to movement through the fractures of densely welded tuff units because of slow advective rates and strong sorption within the vitric nonwelded matrix material. Approximately half of the repository footprint is underlain by a nonaltered, nonwelded vitric tuff. Whereas little fracture flow is predicted by the DOE 3D site-scale UZ flow model through the vitric CHn, flow bypasses the zeolitically altered CHn in fractures and faults with little delay in movement of radionuclides to the water table. The thermal pulse associated with the emplacement of radioactive waste in the repository has the potential to alter the vitric CHn to zeolites. The three to four order of magnitude reduction in permeability associated with zeolitization of the nonwelded vitric tuff would drastically alter the flow paths

below the remaining portion of the repository where vitric nonwelded tuff is currently present. Portions of the vitric CHn are as close as 45 m below the repository and DOE estimates that the may reach temperatures in the range of 65–85 °C after emplacement of waste.

The primary objective for this trip was to obtain samples of the vitric CHn from the Busted Butte facility for laboratory experiments designed to test DOE assumptions regarding the thermo-hydrologic response of the CHn. The samples will be geochemically and hydraulically characterized, heated to temperatures ranging from 65 to 85°C in water chemically matching the matrix water of the CHn, and recharacterized geochemically and hydraulically. A second objective for this trip was to observe features in the nonwelded tuffs (PTn and CHn) that might promote fast movement of water, such as fractures and faults that could lead to fast movement of water.

**SUMMARY OF ACTIVITIES:**

**Rock Sample Collection from Busted Butte Facility**

During the week of May 21–25, 2001, Los Alamos National Laboratory (LANL) and YM project (YMP) staff were analyzing the 4th mineback face and obtaining samples from the injection/collection area (figure 1). Each face is scraped by a front-end loader to a depth of about 30–40 cm. The tuff is extremely friable when dry. A soil coring device was used to collect samples (figure 2). Project scientists also used an ultraviolet light to observe the pattern of fluorescent tracers migrating through the rock below injection boreholes. The walls of the mineback area were wetted with a high-pH solution to bring the fluorescent tracers to the surface of the wall; ventilation in the Busted Butte facility rapidly dries out the rock. LANL staff assumes that the 20–30 cm core sampling depth is significantly beyond the drying front of the scraped faces.

While LANL staff were analyzing the 4th mineback face, sample locations on the north wall of the mineback were marked and YMP staff removed sample blocks for CNWRA laboratory testing. These samples were collected from a corner of the mineback area spatially removed from the LANL injection/collection area (figure 1) and are not likely to contain any of the injected tracers. Chain saws with carbide-tipped chains were used to cut four slots surrounding the marked locations and a metal pry bar was used to break the interior face of the block. Each block was approximately 9 in × 9 in × 9 in. Due to the friable nature of the rock, particularly when dry, plastic wrap and duct tape were used to completely envelop the sample blocks. The samples were packed with bubblewrap and shipped back in plastic coolers.

Four sample blocks (#1-4 of figure 3) were obtained from the basal Topopah Spring vitric tuff (Tptpv2, Tptpv1), which grades from partially welded to nonwelded as the CHn contact is approached. A thin (12–15cm) horizon of bedded tuff separates the Tptpv1 from the CHn. Four sample blocks (#5-8 of figure 3) were obtained from the CHn, both above and below a thin (10–12 cm) indurated ash layer. Plugs will be cut from the blocks for geochemical and hydrological characterization before and after experiments to alter the vitric material to zeolites. Two blocks (#9-10 of figure 3) were obtained for thin section observation of fault features, such as solution features or mechanical grain deformation, by James Evans of USU. Block 10 includes the indurated ash layer within the CHn.

**Matrix and Fracture Characteristics of the Nonwelded Tuffs**

Excellent exposure on the walls of the Busted Butte facility allowed for examination of small faults and fractures cutting the nonwelded Tptpv2, Tptpv1, and CHn. The bedded unit at the base of the Topopah Spring (Tpbt1) present at YM is thin to non-existent at Busted Butte where it will likely be grouped with the

Tptpv1 unit. For the hydrostratigraphic layering in the 3D site-scale UZ flow model, (i) Tptpv2 is model grid layer tsw39, (ii) Tptpv1 and Tpbt1 comprise model grid layer ch1, and (iii) the massive vitric or zeolitic CHn is divided into 4 model grid layers ch2, ch3, ch4, and ch5. For primary heterogeneity and fracture and fault characteristics, the PTn is treated as an analog for the poorly characterized CHn at YM.

Mined-out walls enabled observation of several small faults on an east-west striking face (figure 4) and a north-south access wall. The small faults in the excavation are normal faults with several centimeters of slip. They are marked by a distinct lighter color that appears as thin, white planar zones. The whiter color may be caused by leaching along preferential flowpaths along the discontinuities. The faults appear to have mutually cross-cutting relationships and have several centimeters of slip where they cross the primary layering the of bedded tuff and ash layers. Block samples collected from the wall appear to dry out quickly, leaving a moist trace along the fault surfaces. This suggests the small faults are able to retain moisture more readily than the matrix, likely due to the finer grain size associated with grain crushing on the fault plane. Because of the physics of UZ flow, the finer grain size along the fault would be associated with enhanced flux at the low percolation rates estimated for YM.

Preliminary observations of the distribution of fluorescent tracer on the injection/collection face of the mineback were made while the ultraviolet light was in place. The distribution was asymmetric below the high-flux, high-concentration lower injection borehole indicative of primary heterogeneity controlling flow in the matrix. The distribution was sporadic and faint above and below the upper, low-flux, low-concentration injection borehole. As highlighted by the fluorescence, a fracture along the corner of the mineback was traceable over a distance of almost 3 m. It was not clear whether the LANL staff observations were consistent with those noted here.

Two sites of the nonwelded sequence of the PTn on the western flank of YM were examined. At both sites, the basal Tiva Canyon vitrophyre (Tpcpv3,2,1), the Yucca Tuff (Tpy), the middle PTn ash fall and bedded unit (Tpbt3), and the Pah Canyon Tuff (Tpp) were exposed. The first site is the same as the measured section 4 of PTn of Moyer et al. (1995) in the northern portion of the repository. The second stop is the same as measured section 3 of PTn of Moyer et al. (1995) on line with the southern edge of the repository.

Fracture characteristics of the units are highly variable vertically in the sequence. As noted by Sweetkind et al. (1995, 1996), the more densely welded units exhibit the highest density of fractures. Uppermost in the sequence of exposures, the vitrophyre at the base of the Tiva Canyon and the Yucca Tuff vary in degree of welding from moderate to partial. The term "partially welded" is used by Moyer et al. (1995) and is intended to describe a degree of welding between nonwelded and moderately welded. Abundant vertical fractures are present in the Tpcpv2, Tpcpv1, and Tpy units. A small outcrop of the nonwelded bedded Tpbt4, which fits the light-colored, pumice-supported fallout description in Moyer et al. (1995) was only noted at the second site. The Tpy unit is massive with near-vertical fracture density variable in the range of 3-10 fractures/m (figure 5). There is a sharp contact with the Tpbt3 underlying the Tpy.

The six units of the nonwelded fallout and bedded Tpbt3 are also variable in their fracture character. Fractures in the pumiceous and poorly welded units (Tpbt3) are less abundant than in the partially welded sequences. Fractures are oriented dominantly with a north-south or east-west strike, and spacing in the upper units of the Tpbt3 is 20–50 cm. Notable in these outcrops, however, are some fractures and calcite-lined small faults that cut both the overlying densely welded sequences and the poorly welded tuffs. Figure 6 illustrates a fault and a set of calcite-filled fractures in the nonwelded fallout and bedded tuffs of Tpbt3. Both calcite-filled and other fractures cross the abrupt contact between the partially welded Tpy and the nonwelded Tpbt3, though generally they did not continue vertically downward in the Tpbt3 more than a

couple meters. The Pah Canyon Tuff, exposed at the base of the examined section, is a coarse, pumice-rich deposit with lithic fragments. Fractures in this sequence appear to be dominantly vertical and are polygonal in plan view

In the Busted Butte and the Yucca Mountain exposures, small faults are observed to offset the nonwelded units. The faults are marked by an apparent decrease in grain size. Noting the small area of observations, these faults could be occur at a density smaller than the grid size of the 3D site-scale UZ flow model. There was no evidence for focusing or funneling of water through the faults in the matrix surrounding the faults.

**OVERALL IMPRESSIONS:**

The logistics of working in the YM control area have greatly improved since the field trip in March 2001. During that trip, one day of work was lost due to the inability of YM project staff to find an escort and the lack of a clearly defined procedure for remote field access. During this trip, YM project staff facilitated CNWRA efforts by tying our work into a DOE work plan for Busted Butte. Also, YM project staff determined that no escort was needed for the observations of the PTn on the west flank of YM. While still following all safety procedures, YM project staff were clearly cognizant of needlessly delaying our efforts during all aspects of this trip.

**PROBLEMS ENCOUNTERED:**

None.

**PENDING ACTIONS:**

None.

**RECOMMENDATIONS:**

None.

**REFERENCES:**

Moyer, T.C., J.K. Geslin, and L.E. Flint. *Stratigraphic Relations and Hydrologic Properties of the Paintbrush Nonwelded Tuff (PTn) Hydrologic Unit, Yucca Mountain, Nevada.* U.S. Geological Survey Open-File Report 95-397. 1996.

Sweetkind, D.S., and S.C. Williams-Stroud. *Characteristics of Fractures at Yucca Mountain, Nevada: Synthesis Report.* U.S. Geological Survey Administrative Report Draft. 1996.

Sweetkind, D.S., E.R. Verbeek, J.K. Geslin, and T.C. Moyer. Fracture Character of the Paintbrush Tuff Nonwelded Hydrologic Unit, Yucca Mountain, Nevada. U.S. Geological Survey Administrative Report Level 4. 1995.

**SIGNATURES:**

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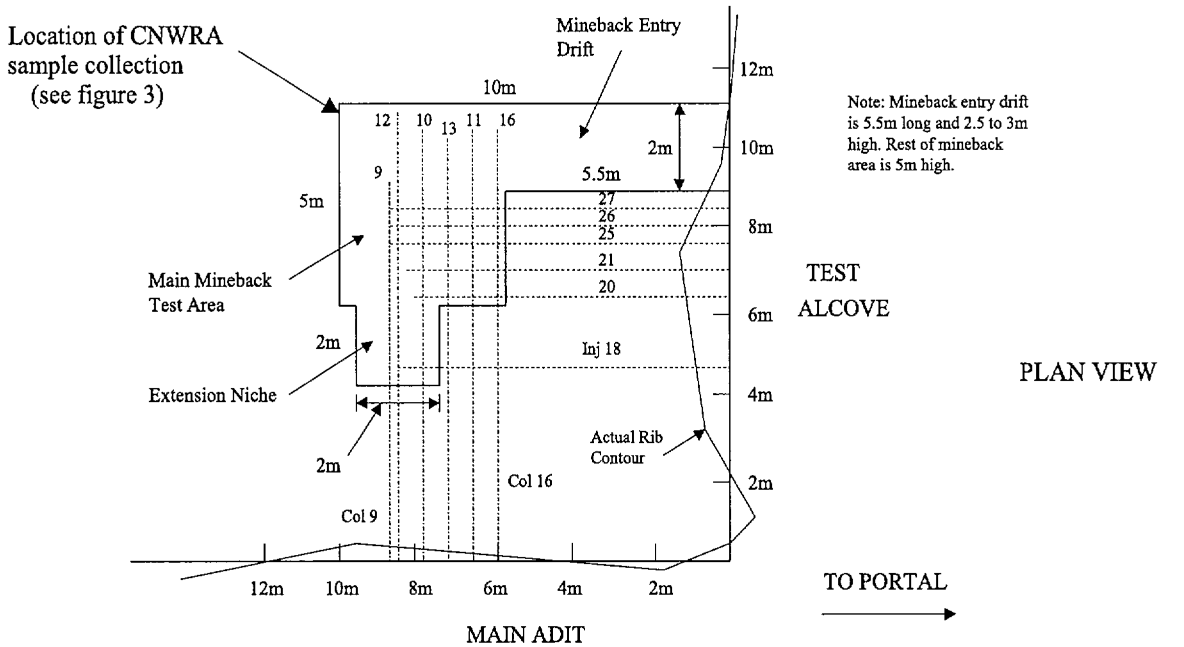


**Figure 1. Sketch of mineback program for Phase 2 experiment at Busted Butte. Sketch is modified from Yucca Mountain Project (YMP) sketch obtained from YMP staff.**

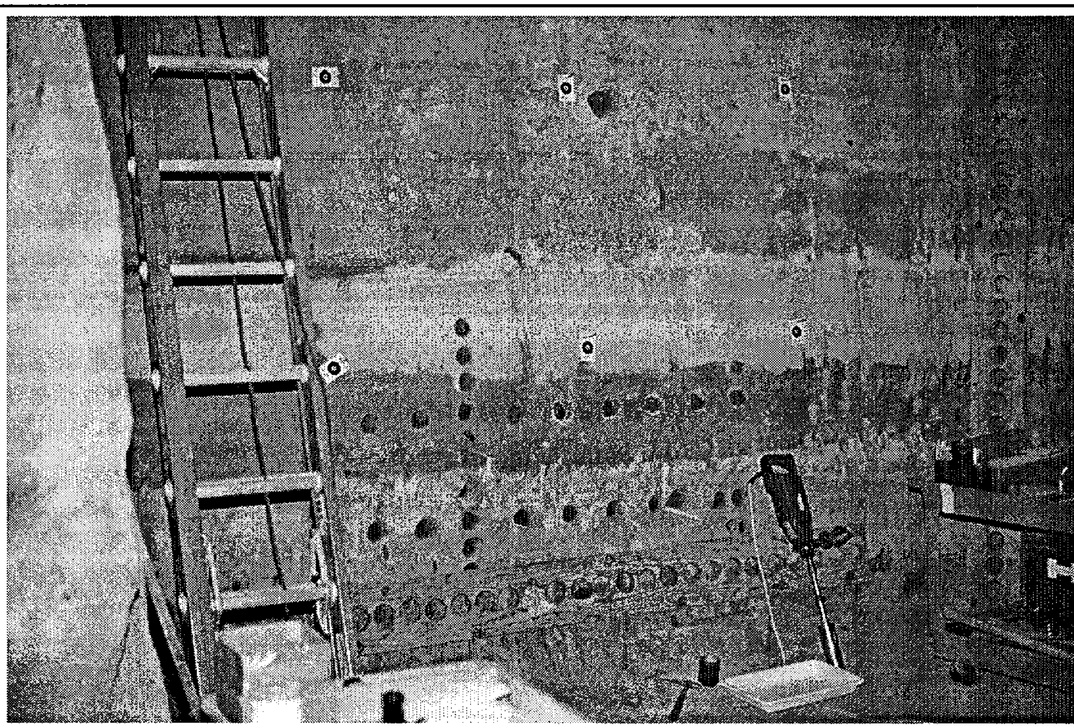

**Figure 2. Photograph of 4th face of mineback in Phase 2 test and power core sampler at the Busted Butte facility. Horizontal banding in the lower portion of the photograph is due to wetness variations caused by the recent removal of wood template used for core sampling.**

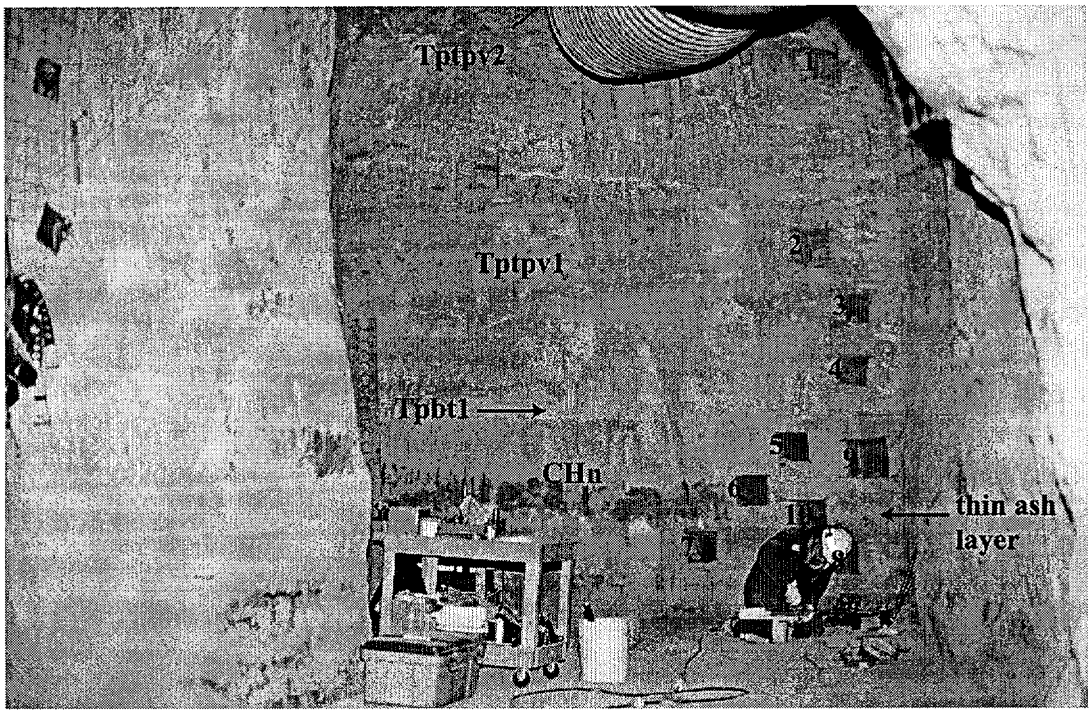


**Figure 3. Sample locations 1-10 from Busted Butte mineback wall (see figure 1). The labeled units are the basal nonwelded Topopah Springs vitric (Tptpv2 and Tptpv1) and bedded (Tpbt1) tuffs and the Calico Hills tuff (CHn).**

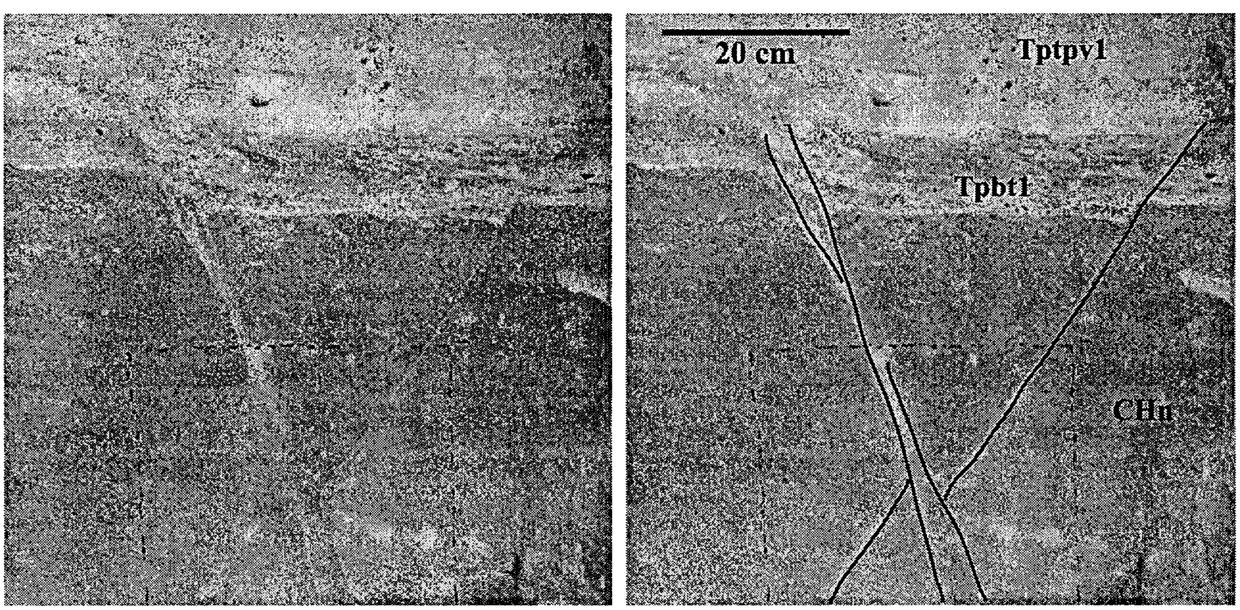


**Figure 4. Cross-cutting faults near the contact between the basal nonwelded Topopah Springs vitric (Tptpv1) and bedded (Tpbt1) tuff and the Calico Hills tuff (CHn). Faults are highlighted on righthand side photograph. Part of sample block 9 outline (see figure 3) is shown in photograph.**

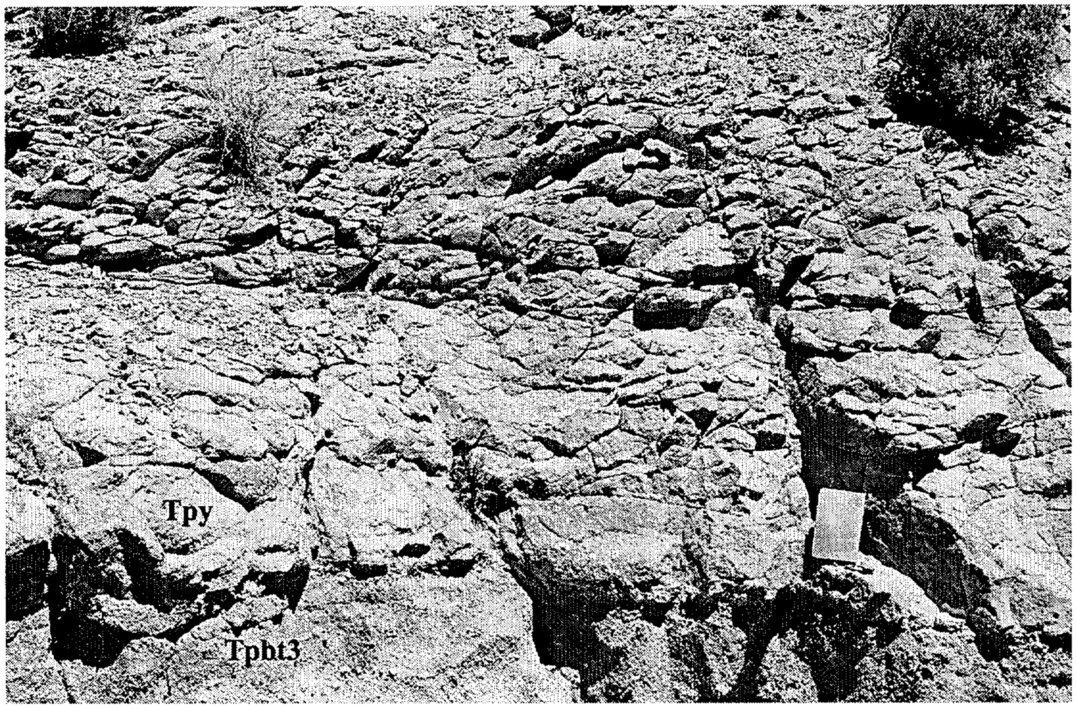


**Figure 5. Yucca Tuff (Tpy) contact with Pre-Yucca bedded tuff (Tpbt3). Note the extent of fracturing in the partially welded Tpy. The field notebook is 19 cm tall.**

a)

b)

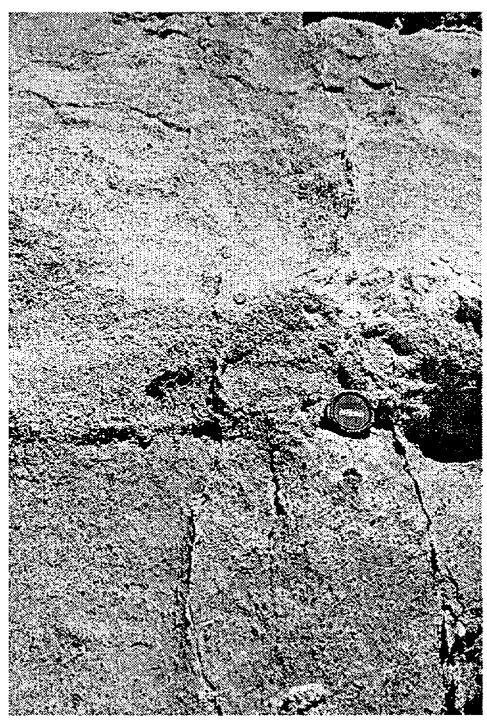

**Figure 6. Discontinuities in the nonwelded Pre-Yucca bedded tuff (Tpbt3): a) fault with leached, fined grained core, and b) fractures with caliche. The file notebook is 19 cm tall.**