August 22, 1999

Thin section description:

SPC00552502 CS: This specimen was collected from the damage zone of the Solitario Canyon fault at Sta 25+ 86.0. The thin section shows mineralized rock fragments (opal?) in a fine grained matrix, too fine grained to resolve optically. The matrix is brick red in plane polarized light and is responsible for the overall red color of the rock sample. Clast boundaries are of variable form but planar discrete grain boundaries predominate, indicating grain boundary sliding was a deformation mechanism.

~~SPC0053~~ MBG 8/22/99
SPC00543709D This specimen was collected from STA 25+ 37.36 in the ECRB. The specimen/thin section is a cataclasite. The clasts are heterolithic. There is an apparent absence of secondary minerals in this thin section. Eutaxitic foliation in clasts are randomly oriented.

Mary Beth Gray

MBG

August 24, 1999

Excerpt from Farrell et al, 1999: Farrell, D. A., A. Armstrong, J.R Winterle, D.R. Turner, D.A. Ferrill, J.A. Stamatakos, N.M. Coleman, M.B. Gray, AND S.K Sandberg, "STRUCTURAL CONTROLS ON GROUNDWATER FLOW IN THE YUCCA MTN REGION," CNWRA REPORT, SAN ANTONIO, TX, CNWRA, 1999

4.3 INFLUENCE OF FAULT ZONE DEFORMATION ON GROUNDWATER FLOW IN THE YUCCA MOUNTAIN REGION

4.3.1 Deformation Mechanism and Fault Width

Fault zone deformation in the upper crust produces a wide variety of textures that affect the overall permeability structure of the fault zone. Idealized faults consist of two textural zones (Sibson, 1977; Caine et al., 1996): a fault core in which the host rock is strongly deformed and altered and a surrounding damage zone in which the host rock may be brecciated or fractured (figure 4-6a). Depending on environmental conditions at the time of faulting, deformation of the core may include brecciation, cataclaysis, and mylonitzation. Fault gouge may or may not develop.

The deformation mechanism of the fault rocks is also an important feature of the faulting at YM. Brittle deformation mechanisms operate in these fault zones, and the details of the resulting textures bear directly on structural control of flow. First, the nature of deformation in the fault zones strongly governs if faults will narrow or widen with time. If the products of the deformation tend to produce fault rocks more resistant of continued cataclasis (what can be considered strain distribution and strain hardening) than their protoliths, then renewed faulting will tend to break the wall rock, and the fault zones will widen with time. In contrast, if the fault zone rocks are easier to deform as faulting renews (strain localization and strain softening), then deformation in the fault zones will tend to localize within a narrow portion of the fault zone. The result will be an intensely deformed fault core with no increase in fault zone width.

Fault zone architecture and related permeability structures may strongly control fluid flow into and out of the repository (e.g., Caine et al., 1996). Fault zones with grain-size reduction and mineral precipitation (by and large strain-softening mechanisms) generally contain core gouge zones with lower permeability and porosity than the adjacent protolith (e.g., Goddard and Evans, 1995; Caine et al., 1996). These faults would form barriers to flow. In contrast, faults with coarse-grained breccias and wide fault damage zones containing numerous subsidiary structures that bound the fault core gouge may have greater permeability and porosity than the protolith, thereby enhancing fluid flow (e.g., Chester and Logan, 1986). These faults would act as conduits to fluid flow. Faults commonly contain a less permeable core and a more permeable fault damage zone (Caine et al., 1996). Such fault zones have enhanced permeability parallel to the fault, but reduced permeability perpendicular to the fault.

Investigations of faulting at YM, especially studies of ESF faults, reveal that all these deformation processes and related features are present. Based on detailed field and microscope analyses of the ESF faults, four stylized fault types are recognized (figure 4-7). These four types essentially correspond to the four permeability fault zone structures defined in Caine et al. (1996). The discrete faults and shears (figure 4-7a) act like localized conduits. The minor faults with well-cemented fault zones (figure 4-7b) correspond to localized barriers. The Ghost Dance fault (figure 4-7c) corresponds to a distributed conduit. The Solitario Canyon fault (Figure. 4-7d) corresponds to a combined conduit-barrier.

Of the faults exposed in the ESF, only the Solitario Canyon fault has a well-developed fault gouge. The gouge is foliated, suggesting dip-slip motion on the fault. To assess the nature of the mineralogy in the gauge, a series of x-ray analyses were performed.[1] These included random powder-mount x-ray diffraction and oriented powder-mount x-ray diffraction runs. For the random powder mounts, the fraction of fault-rock material that passed through the 400 mesh sieve was placed inside a back-holding loader and inserted into the x-ray diffractometer. Results peak at 14.42 angstrom, indicative of clays (figure 4-8a).

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[1]Gouge specimen SPC00543707 collected at ECRB Station 25+85.1. Analyses were performed by Brad Jordan and Mary Beth Gray, Bucknell University, February 26, 1999.

August 24, 1999, continued

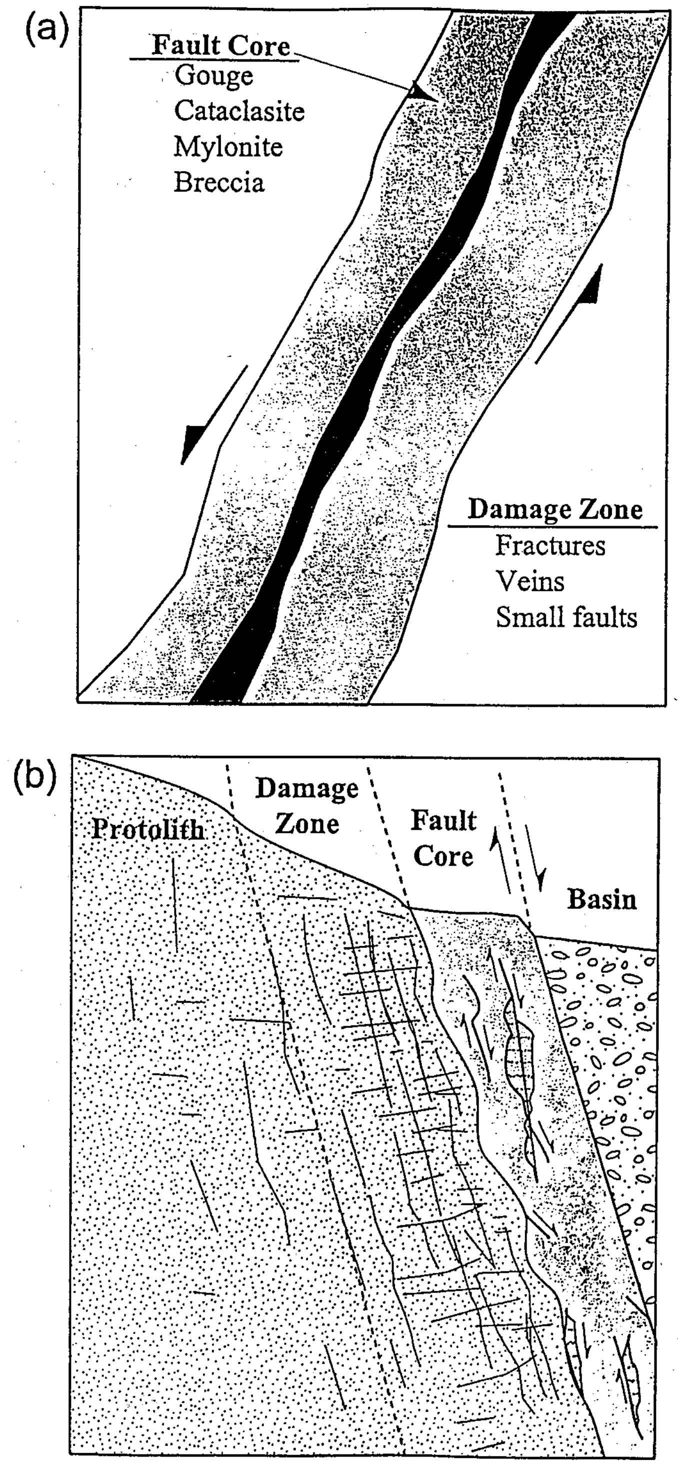


Figure 4-6. (a) Conceptual model of fault zone showing the fault core and surrounding damage zone; (b) diagram showing the fault zone of the Stillwater fault in Dixie Valley, Nevada (Seronot et al., 1998)

August 24, 1999, continued

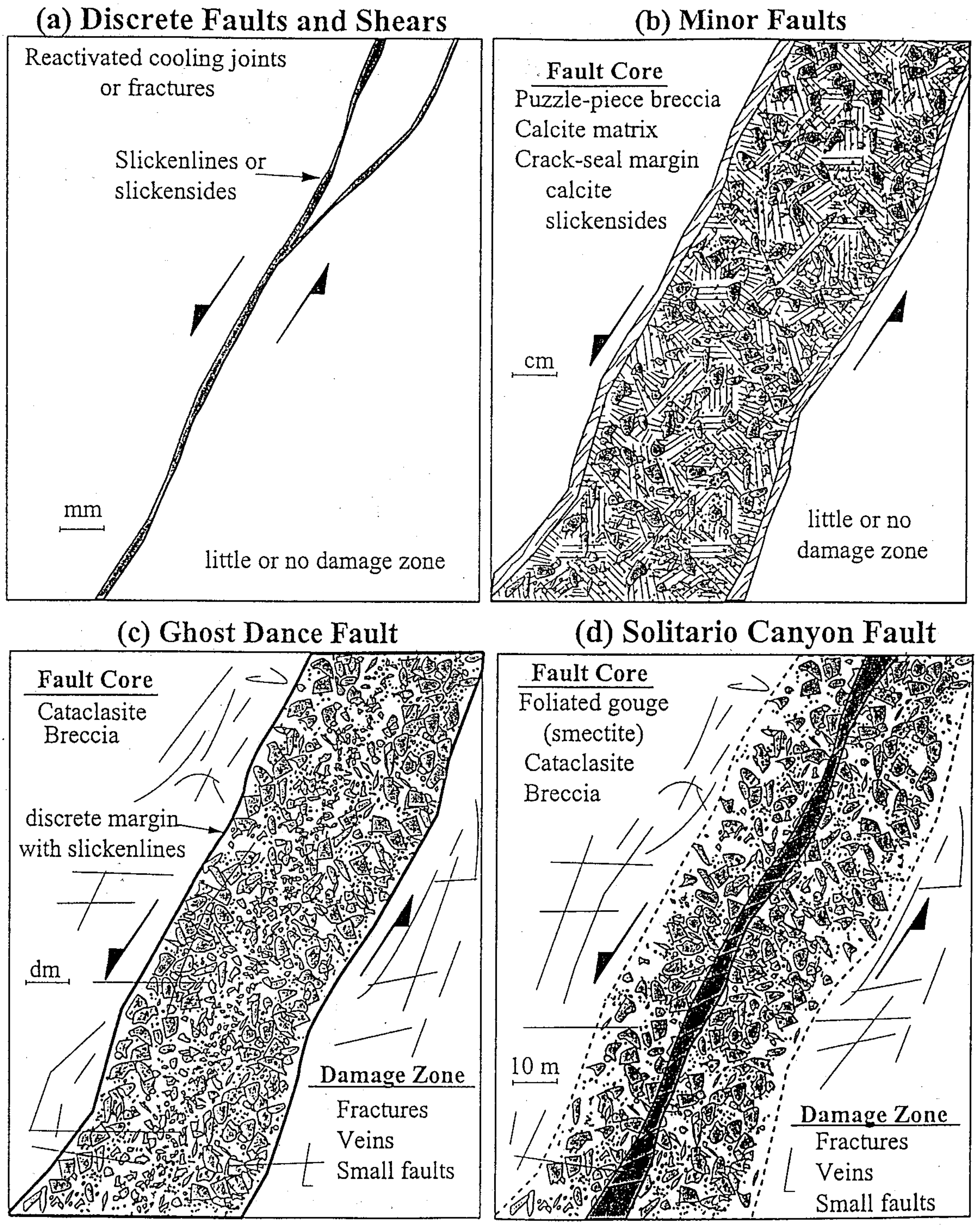


Figure 4-7. Types of fault zones observed from the exploratory shaft facility at Yucca Mountain; the four fault zones were identified from detailed field and laboratory studies of fault zone deformation.

August 24, 1999, continued

Three oriented powder mounts were prepared from the fraction of fault-rock sample that did not pass through the 400 mesh sieve. The mounts were prepared using the Millipore® FilterTransfer Method detailed in Moore and Reynolds (1989). The resulting x-ray diffraction pattern (figure 4-8b) shows a broad peak at 14.42 angstroms. One oriented powder was exposed to ethylene glycol vapors at 60°C for 4 hr in a closed container and analyzed. The resulting x-ray diffraction pattern showed a peak at 16.6 angstroms (figure 4-8c). Comparison of the air dried and glycolated x-ray patterns (figure 4-8d) shows the shift in peaks characteristic of smectites (Starkey et al., 1985). This result is significant because smectites form effective barriers to flow. If much of the fault surface of the Solitario Canyon fault contains a similar clay smear, then this fault would form a highly effective barrier to flow.

4.3.2 Crossing Faults

Extensional regions commonly develop two sets of steeply dipping normal faults with parallel strikes but opposite dips (Anderson, 1951), commonly referred to as conjugate normal faults. Intersecting and crossing conjugate normal faults are relatively common and range from micro- and meso-scale (e.g., Horsfield, 1980; Nicol et al., 1995; Watterson et al., 1998) to macro-scale features like those developed in many oil fields (Horsfield, 1980; Woods, 1988, 1992; Castagna, 1996). Crossing of conjugate normal faults produces a graben above a horst. Crossing faults play an important role in the development of permeability anisotropy in aquifers and reservoirs. At YM, faults and fractures represent the dominant permeability and potential fast pathways for groundwater infiltration, percolation, and flow in the fractured aquifers. Many of the surface traces collected in the vicinity of YM suggest crossing faults at depth. This is best exemplified by the intersection of the steeply-dipping to near-vertical Ghost Dance fault with the moderately west-dipping Bow Ridge fault.

The effects of crossing conjugate normal fault networks on the bulk permeability of the host aquifer or reservoir rock is to essentially enhance permeability parallel to the line produced by their intersection. This occurs whether the crossing-fault networks consist of permeability-reducing or permeability-enhancing fault zones (figure 4-9). If the fault cores become barriers to flow, then flow will be restricted to within each of the resulting fault blocks (figure 4-9a). Those blocks are elongated parallel to the crossing fault intersection, and thus flow will parallel the crossing fault intersection. In contrast, if the fault zones develop enhanced permeability relative to the host rock, then flow will likely follow the fault zones or the crossing fault intersection (figure 4-9a).

4.3.3 Summary of Implications of Fault Zone Deformation in Evaluating Structural Controls on Groundwater Flow in the Yucca Mountain Region

Because brittle fault zones are lithologically heterogeneous and structurally anisotropic, they can act as either barriers and/or conduits that can impede or enhance groundwater flow in both the SZ or UZ. The manner in which fault zones affect groundwater flow depends in large part on how the rocks within the fault zone were deformed. In an idealized fault, the fault zone is characterized by a fault core composed of gouge or cataclasite surrounded by a damage zone of highly fractured and brecciated wall rock. Permeability is reduced in the fault core and enhanced, at least initially, in the damage zone. In such faults, fluid flow would be heightened parallel to the fault zone, within the damage zone, and restricted along or across the core. In older faults, the damage zone may be cemented closed by subsequent mineral precipitation.

August 24, 1999, continued

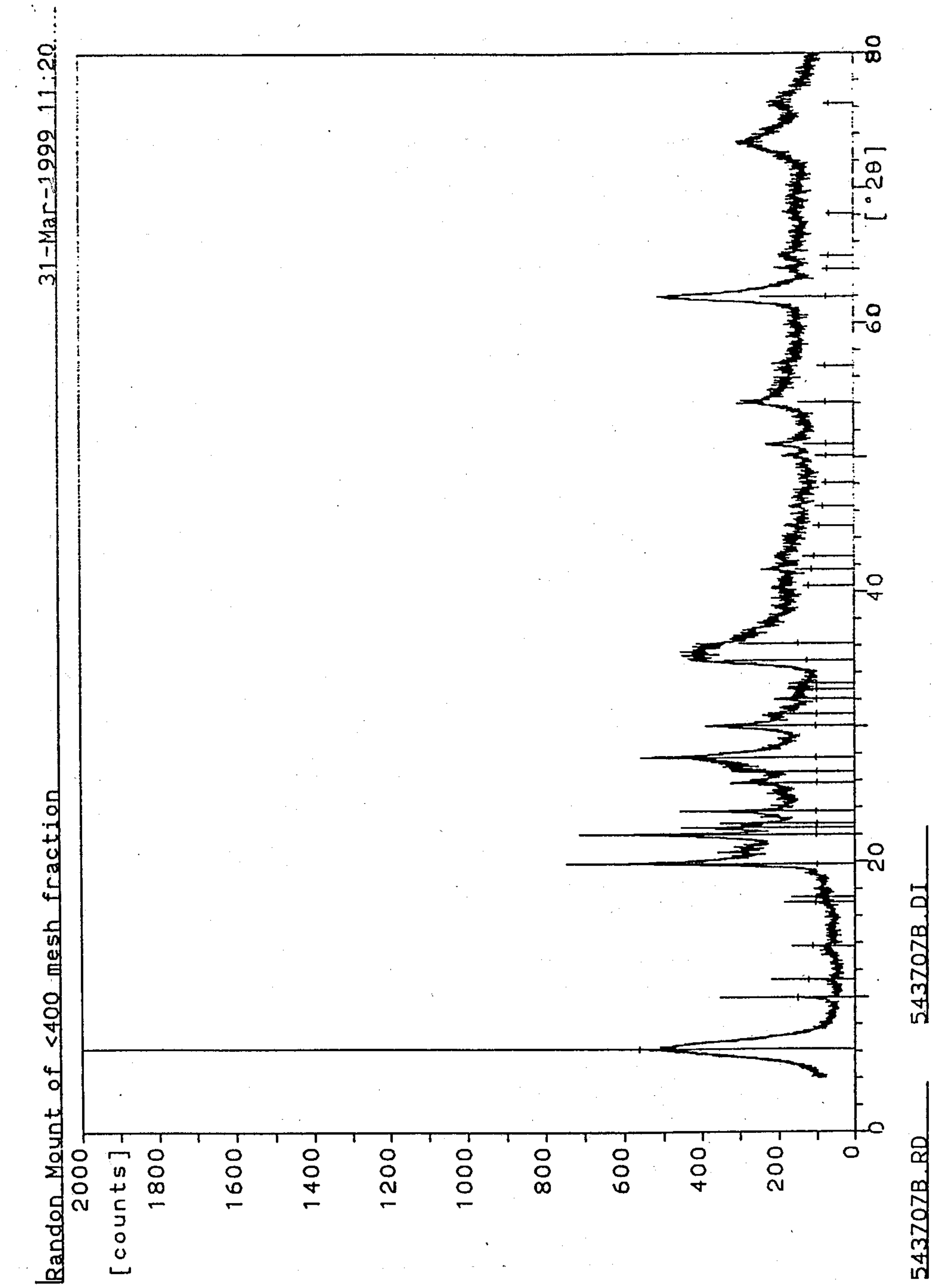


Figure 4-8a. X-ray results showing the clay mineralogy of the Solitario Canyon fault gouge (randon mount of <400 mesh fraction)

August 24, 1999 continued

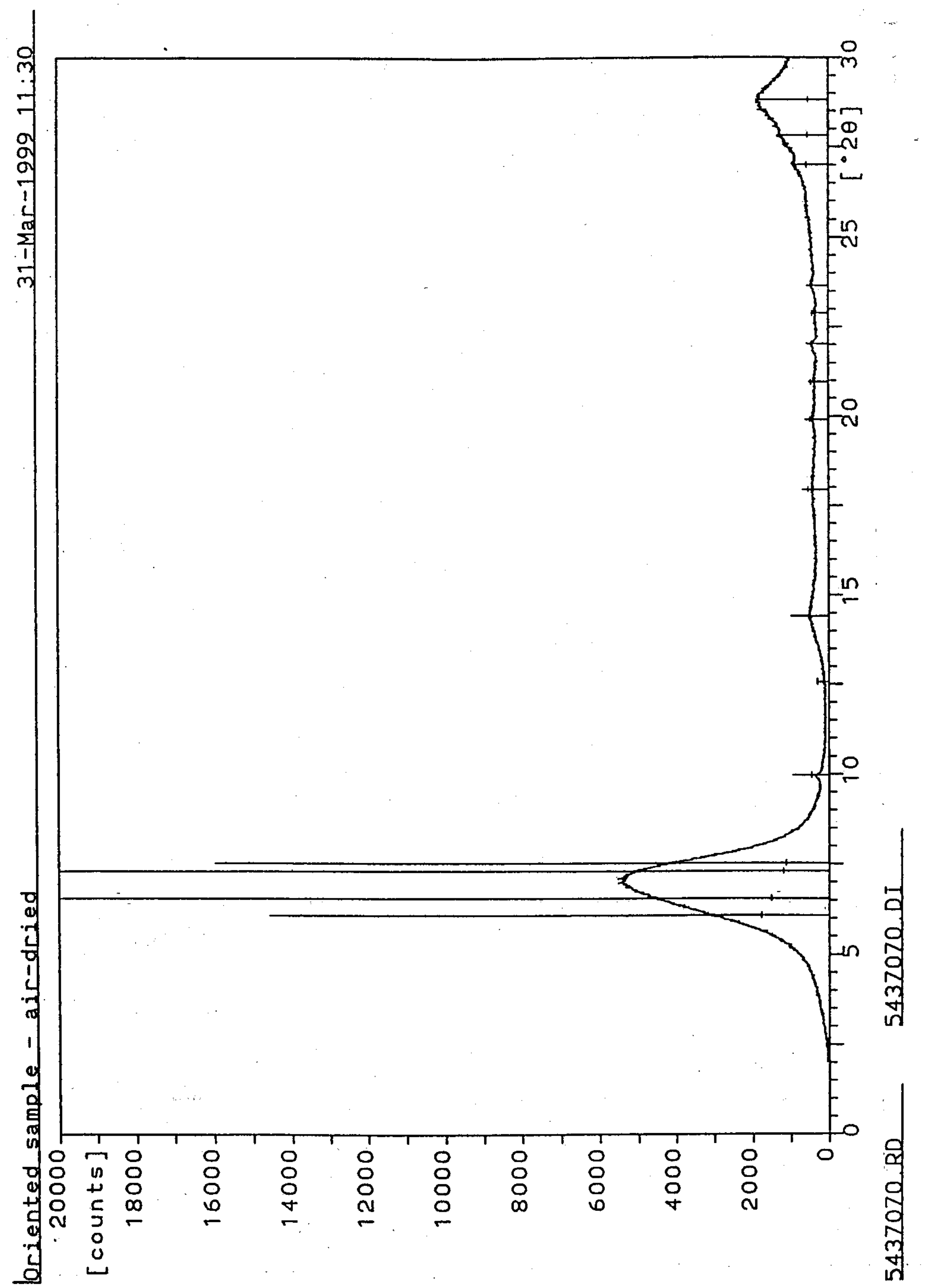


Figure 4-8b. X-ray results showing the clay mineralogy of the Solitario Canyon fault gouge (oriented sample: air-dried)

August 24, 1999 continued

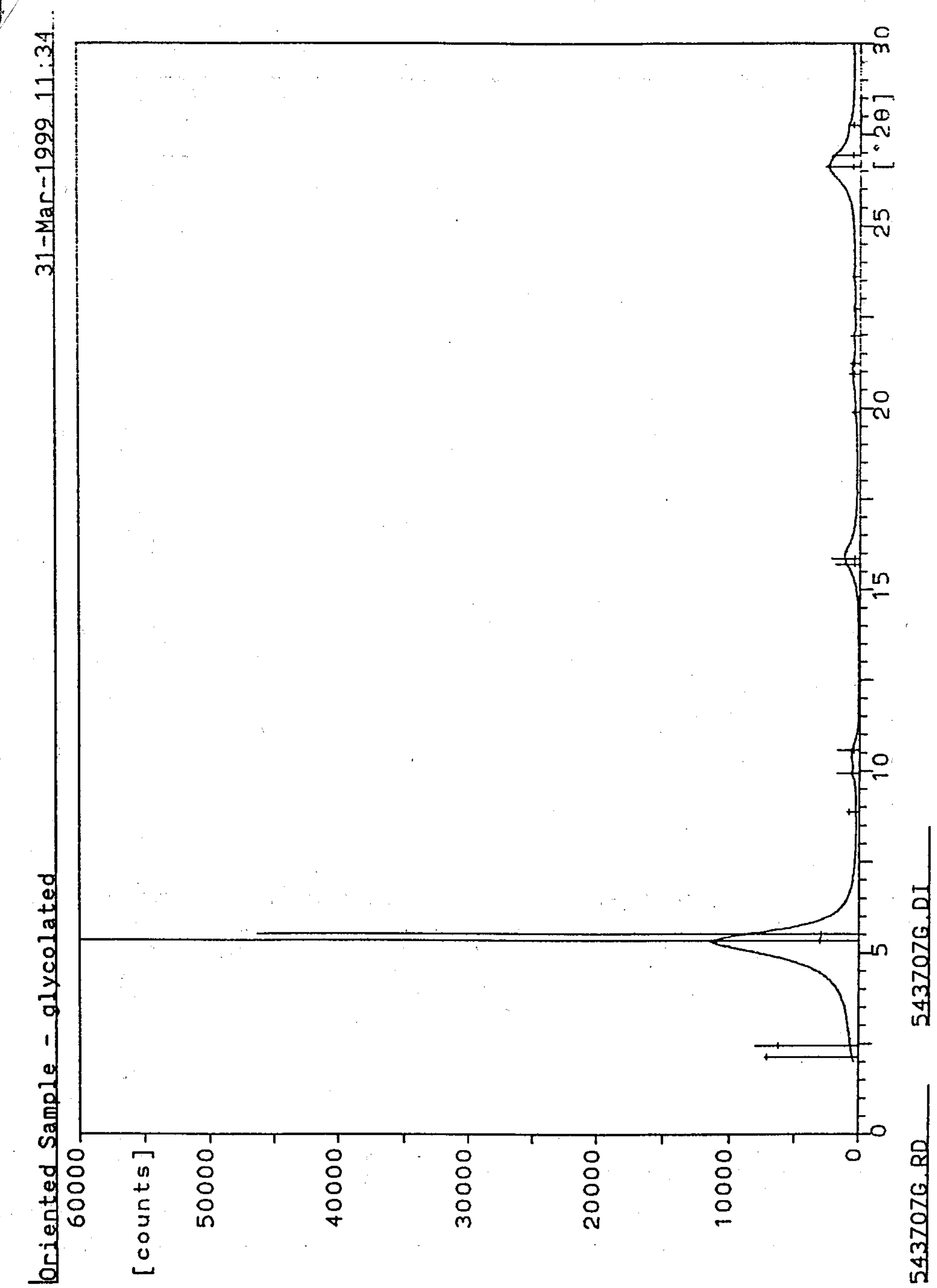


Figure 4-8c. X-ray results showing the clay mineralogy of the Solitario Canyon fault gouge (oriented sample: glycolated)

August 24, 1999, continued

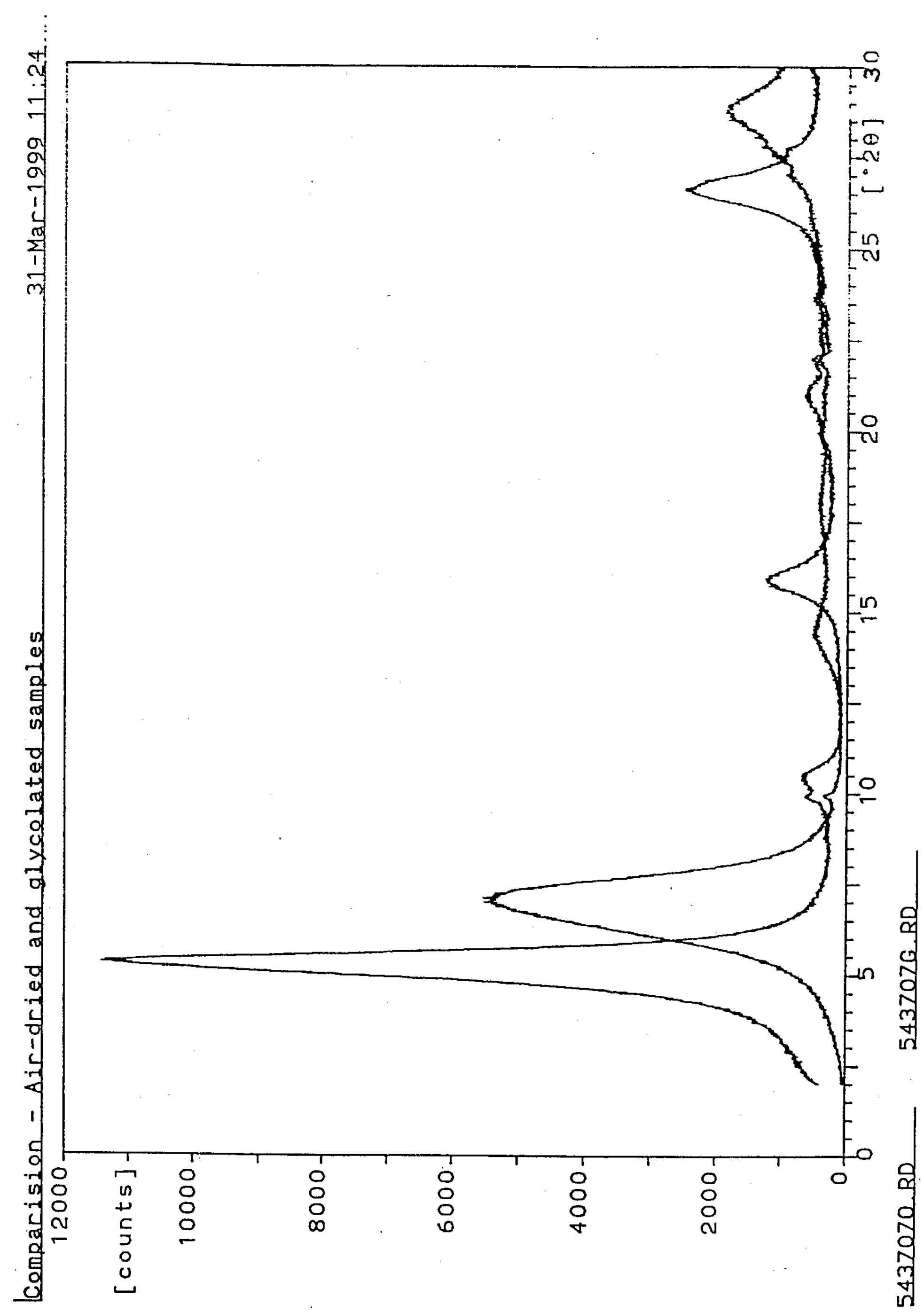


Figure 4-8d. X-ray results showing the clay mineralogy of the Solitario Canyon fault gouge (comparison: air-dried and glycolated samples)

August 24, 1999

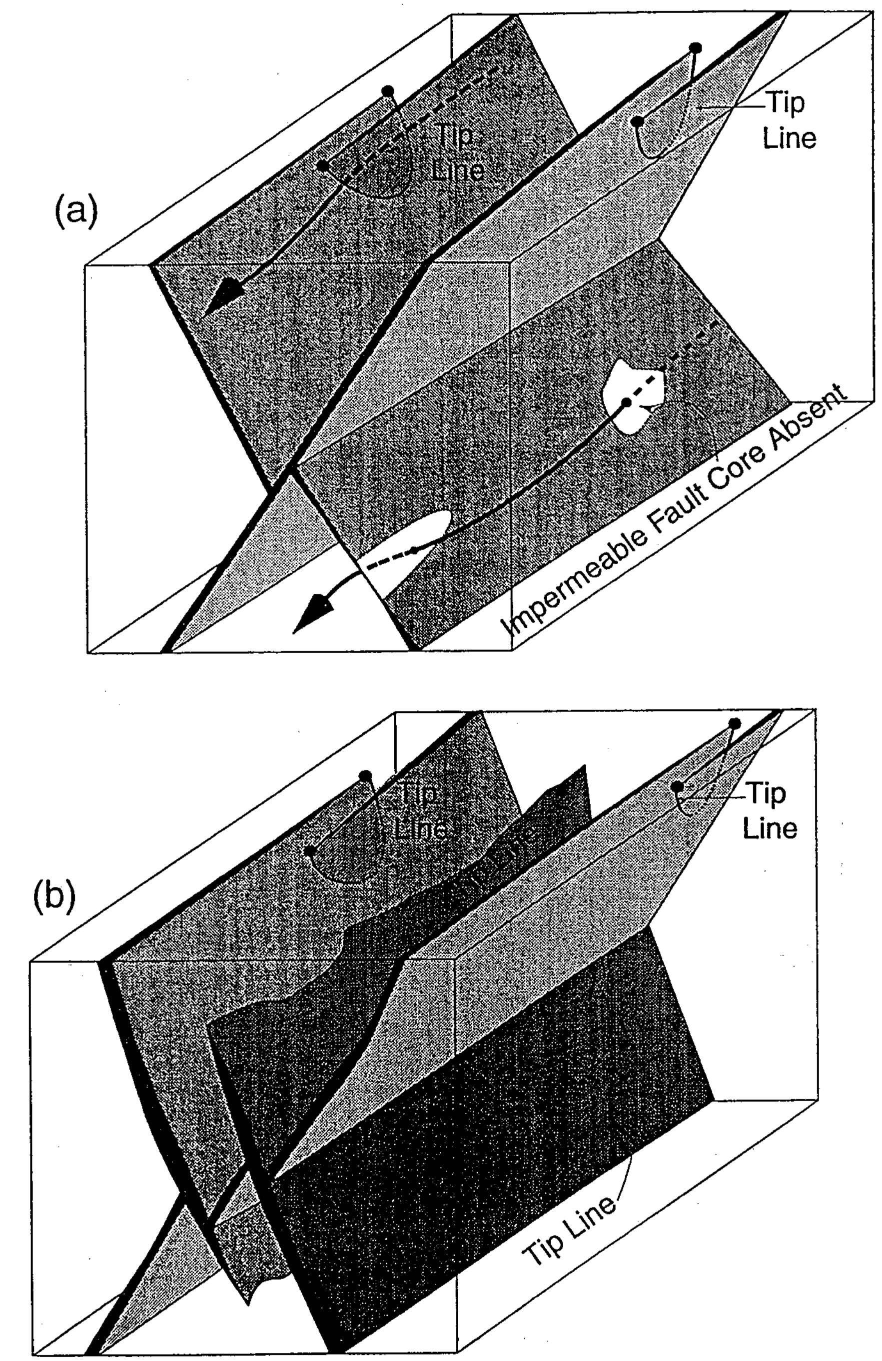


Figure 4-9. Schematic diagram illustrating effects of crossing conjugate normal faults on developing permeability anisotropy in rock where (a) fault zone deformation results in permeability decrease and (b) where fault zone deformation produces permeability increase

August 24, 1999

In nature, faults may contain all or only some of these deformation features. For example, in the ESF at YM, four fault types are identifiable based on these deformation characteristics. These four fault types match the generalized permeability fault types proposed by Caine et al. (1996). Of these the Solitario Canyon fault is most significant, because it is one of the few faults to exhibit a well-developed fault gouge at its core surrounded by large brecciated damage zones (13 m wide in the hangingwall and 3.5 m wide in the footwall), at least where it is exposed in the ECRB. X-ray analyses show that the fault gouge has been altered to a smectite clay, which would effectively clog the core and inhibit groundwater flow across the fault zone. In contrast, the large damage zones on either side of the Solitorio Canyon Fault would possibly enhance groundwater flow parallel to the fault, with little cross-fault communication of fluids. This observation could help explain the thermal anomalies at YM, where groundwater temperatures under the repository are significantly lower than those just west of the Solitario Canyon fault and in Crater Flat (Bredehoeft, 1997; Fridrich et al., 1994).

These effects of fault zones on groundwater flow are accentuated where faults form as conjugate pairs and intersect or cross each other (Ferrill et al., in review). Intersecting or crossing faults are common in extensional settings and tend to compartmentalize flow within the blocks bounded by the fault zones. This geometry establishes a permeability anisotropy, with maximum transmissivity parallel to the line of fault intersections. At YM, the faults dip moderately to steeply and strike generally north-south. Thus, permeability is enhanced along roughly north-south direction relative to all other directions. This trend is oblique to the northwest-southeast potentiometric gradient. Coupled with the effects of the regional stress field (Ferrill et al., 1999), the permeability anisotropy would therefore deflect groundwater flow into a more north-south orientation than current flow models that are solely based on the potentiometric data alone and assumptions of isotropic and uniform permeability.

Given the large uncertainties of the flow system in the SZ south of YM, incorporation and abstraction of these effects into YM flow models is recommended. For example and as discussed in section 4.1, fault zone permeability depends in part on the stress field. Increasing confining pressures (depth) alone substantially alters fault rock permeability (Evans et al., 1997). To understand these effects, additional constraints on fault zone properties at YM or appropriate analogs are necessary. Possible approaches to assessing fault zone permeability at YM that include:

- Mini-permeameter testing of fault core, damage zone, and host rock.
- Permeability plug testing of fault core, damage zone, and host rock under the different stress conditions indicative of the YMR following Evans et al. (1997).
- Fracman modeling of fault zone and numerical simulations of multidirectional fluid flow following Caine and Forester (1999).

The possibility that the SZ groundwater flow system is controlled to some degree by faults has important implications for YM repository performance. Groundwater flow enhanced along faults and restricted across faults could result in: (i) faster travel times from YM to the receptor group; (ii) reduced dilution of waters contaminated with radionuclides from YM; and (iii) localized flow of groundwater plumes contaminated with radionuclides from YM to the receptor group along discrete pathways.

MBL

August 24, 1999

Table 4.1. Aquifer properties estimated from the 1996 long-term pumping test

Well ID	Azimuth, θ	Distance from pumped well	Bulk Aquifer Transmissivity, T_e	Square-Root of Hydraulic Diffusivity, $\sqrt{D(\theta)}$
USW H-4	310°	2245 m	670 m^2/d	560 m d$^{-0.5}$
ONC1	327°	843 m	1340 m^2/d	416 m d$^{-0.5}$
UE-25 wt#3	161°	3526 m	1230 m^2/d	506 m d$^{-0.5}$
UE-25 wt#14	050°	2249 m	1330 m^2/d	820 m d$^{-0.5}$

Because of the considerable degree of uncertainty in the anisotropy ratio and direction obtained from this analysis, the degree of confidence in this horizontal anisotropy analysis should be regarded as low. This analysis does, however, indicate that a north-northeast orientation of horizontal anisotropy in the tuff aquifer near YM is certainly a reasonable conceptual model. It is also encouraging that the predicted 033° direction of maximum horizontal transmissivity is consistent with the maximum fault and fracture dilation tendency azimuth range of 025°–030° predicted by Ferrill et al. (1999b).

Mary Buckley

December 1, 1999

Excerpt from: Justus and Stamatakos (and 13 additional co-authors), "ISSUE STATUS RESOLUTION, REPORT: KEY TECHNICAL ISSUE: STRUCTURAL DEFORMATION AND SEISMICITY" REVISION 2, DWM, ONMSS, NRC REPORT. September, 1999.

Deformation Mechanism and Fault Width

Fault zone deformation in the upper crust produces a wide variety of textures that affect the overall characteristics of fault zones. Idealized faults consist of two textural zones, a fault core and a damage zone (Sibson, 1977; Caine, et al., 1996; Seront, et al., 1998). The fault core is a zone of high strain and accommodates most the fault displacement by flow in gouge, cataclasite, breccia, or mylonite. The surrounding damage zone is less deformed, accommodates less displacement, and may contain subsidiary structures such as veins, fractures, and minor faults (see figure 4-2).

Deformation mechanisms govern the behavior of the fault zone with time. At YM, the protolith (undeformed volcanic tuff) has undergone brittle deformation by cataclasis at shallow levels in the upper crust. Changes in deformation mechanisms with time and deformation, the presence of fluids in the fault zone, mineral transformations, and syndeformational mineralization affect the rheology of the fault zone that caused them to widen or narrow with increasing displacement. Two end-member possibilities exist. (1) If the products of the deformation produced fault rocks that inhibited continued cataclasis, then additional fault displacement would have caused the protolith to fracture, and the fault zone would have widened with time (i.e., strain harden). (2) In contrast, if the fault rocks became progressively easier to deform, then deformation would have localized within a narrow portion of the fault zone (i.e., strain localization or strain softening) resulting in an intensely deformed fault core with no increase in fault zone width. Investigations of faulting at YM, especially studies of ESF faults, reveal that all these deformation processes and related features are present (Gray, et al., 1998). Based on detailed field and microscope analyses of the ESF faults, four stylized fault types are recognized (figure 4-3). Of the faults exposed in the ESF, only the Solitario Canyon fault has a well-developed fault foliated gouge. The orientation of the foliation is indicative of dip-slip displacement on the fault. Detailed x-ray analyses of the Solitario Canyon fault gouge are given in Farrell, et al. (1999).

More general to YM are faults characterized by brecciation without development of fault gouge. A critical observation is that fault zones appear to narrow with depth from the surface to their subsurface exposures in the ESF. Wide fault zones at the surface, such as the exposure of the Ghost Dance fault zone at the UZ-7A drill pad that is more than 10 m wide, narrows to a meter or less in exposures in the ESF. The exact cause of this observed change in fault width is not known and is currently being investigated by ongoing SDS studies. Changes in fault width probably reflect differences in fault orientation and environmental conditions of faulting, including confining stress, lithology, and water content. These observations of fault zone width and character will be incorporated in revision of the SDS PA calculations of faulting to be presented as a supplement to this report.

MBG

December 1, 1999, continued

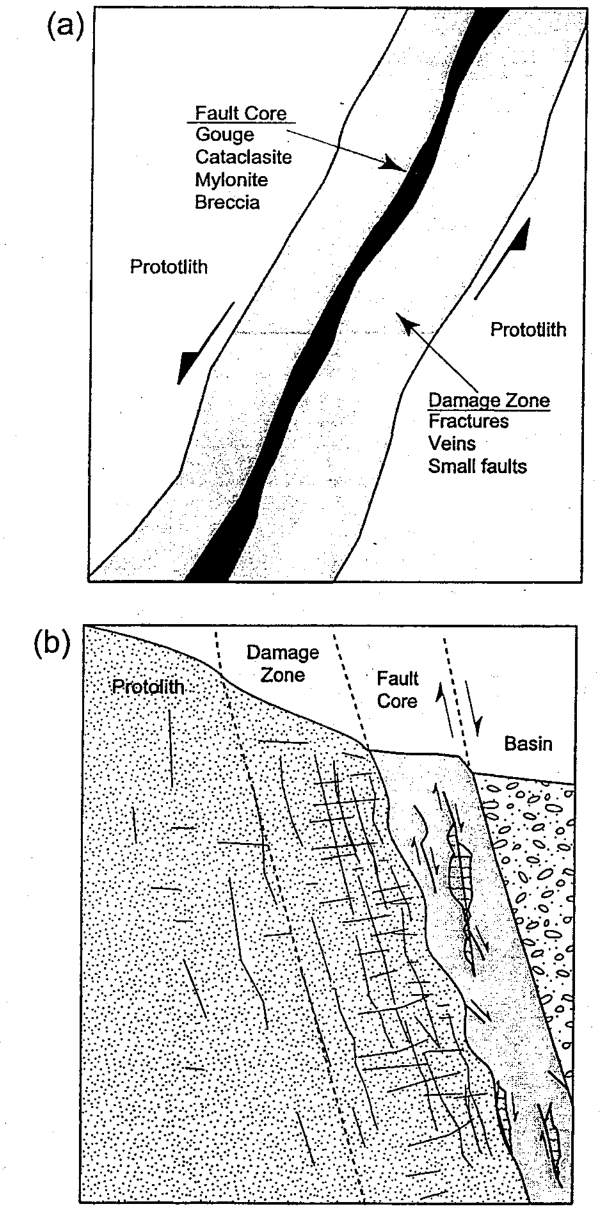


Figure 4-2. Definition of fault zone characteristics showing (a) conceptual model of fault zone showing the fault core and surrounding damage zone and (b) the Stillwater fault in Dixie Valley, Nevada (Seront, et al., 1998)

MBG

December 1, 1999 continued

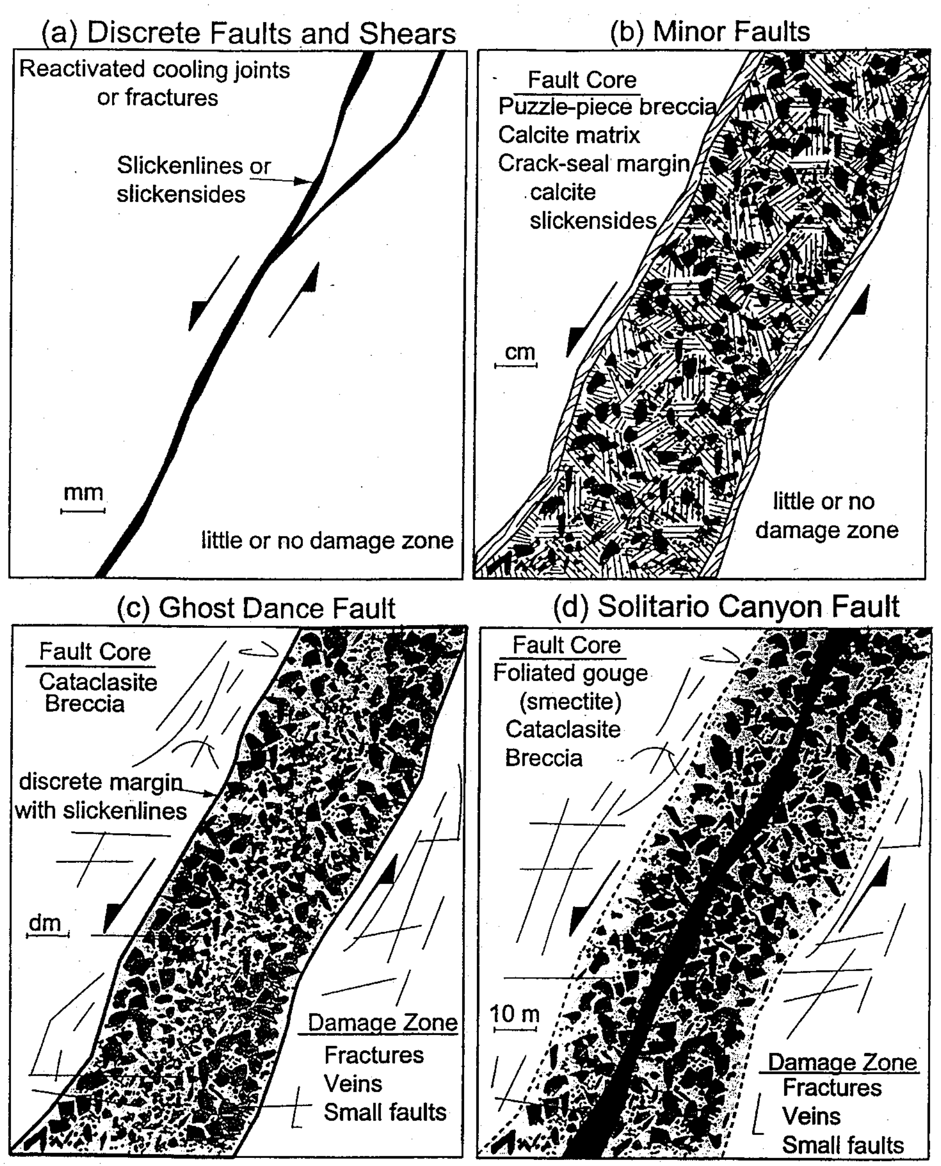


Figure 4-3. Types of fault zones observed from the Exploratory Studies Facility at Yucca Mountain. The four fault zones were identified from detailed field and laboratory studies of fault zone deformation (Gray, et al., 1998; Farrell, et al., 1999).

Mary Beth Gray

December 20, 1999

Below is a memo sent from Mark Evans regarding his universal stage analyses of thin sections I have provided. He describes his analysis of strain in calcite crystals in fault breccia.

Summary of Calcite Strain Gauge analysis of samples from fault zones in the Miocene volcanic tuffs at Yucca Mt., NV

Mark A. Evans, Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260

To date, only three samples (6 oriented thin sections) included an adequate number of twinned calcite grains to perform calcite strain gauge analysis. In general, total strain due to twinning is low (1.52 to 2.24%). The average twin width ranges from 1.08 to 1.61 microns, with a maximum of approximately 5 microns. Anything larger than 1 micron is considered to be a thick twin. This suggests that the twins formed when temperatures were greater than 200°C (talk to Dave Ferrill about this. I think a separate geothemometer is needed). In terms of strain directions, only one sample is oriented (SPC005398) and it gives a maximum shortening oriented approximately N-S and horizontal (see Figure 1). The calculated maximum stress direction (as calculated by Spang Numerical Dynamical Analysis (Groshong, 1972, 1974) is nearly the same, N-S and horizontal. This works out nicely with the orientation of the strike-slip fault (Figure 1). The other two samples are not oriented. However, they both give a horizontal maximum shortening direction (Figure 2). Maybe another sample or two will show that this is also oriented N-S.

MBG

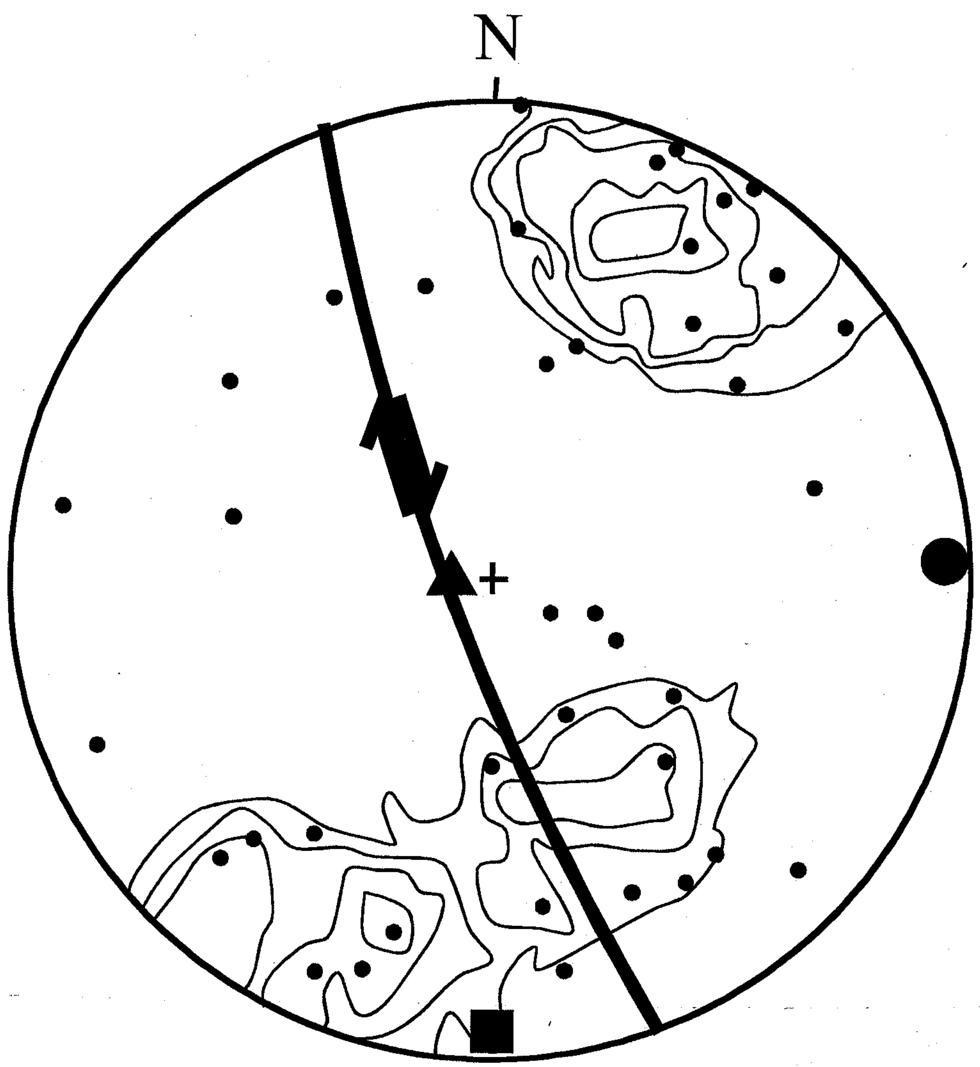
December 20, 1999, continued

Sample SPC005398, sections F and G from unnamed dextral strike slip fault.

m.A.E. typo Should read SPC00530198 MBE 5/5/05

This sample has a large number of calcite grains and provided excellent data. A summary of the data is as follows (all values reflect analysis after removal of 20% of the grains with the largest deviations from expected values (see Groshong, 1972; Evans and Groshong, 1991):

- Number of grains used is 39
- Extensions are: Minimum (square) = 0.975, Intermediate (triangle) = 1.009, and Maximum (circle) = 1.017
- Total distortion (J_2) due to twinning is 2.24%
- Average twin width is 1.43 microns
- Average twin density is 18.73 twins per millimeter
- Figure 1 is a lower hemisphere equal area stereonet showing the extension axes, calculated compression axes, contours of standard deviation (0.5, 1, 1.5, 2, and 2.5). Also shown is the orientation of the unnamed strike slip fault with dextral shear and horizontal slip lineations.

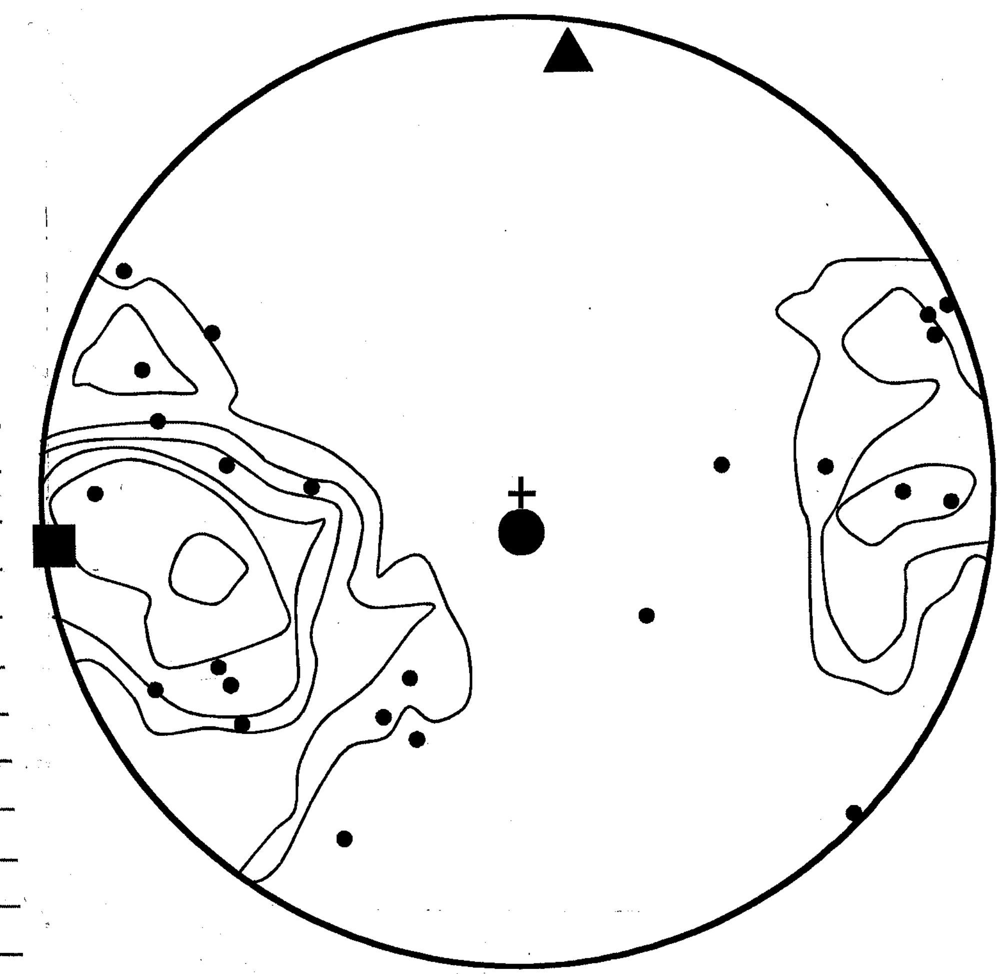


December 20, 1999, continued

Sample 02016200, sections A, B, C, and D from Drill Hole USW -G-1

This sample has a moderate number of large calcite grains and provided excellent data. A summary of the data is as follows (all values reflect analysis after removal of 20% of the grains with the largest deviations from expected values (see Groshong, 1972; Evans and Groshong, 1991):

- Number of grains used is 23
- Extensions are: Minimum (square) = 0.980, Intermediate (triangle) = 1.004, and Maximum (circle) = 1.015
- Total distortion (J_2) due to twinning is 1.78%
- Average twin width is 1.08 microns
- Average twin density is 23.30 twins per millimeter
- Figure 2 is a lower hemisphere equal area stereonet showing the extension axes, calculated compression axes, contours of standard deviation (1, 2, 3, 4, 5, and 6). This stereonet is not oriented with respect to north because the core was not oriented. North would be somewhere on the periphery.



December 20, 1999 continued

Sample 02016200, sections C and D from Drill Hole USW -G-1

This sample has a moderate number of large calcite grains and provided good data. A summary of the data is as follows (All data was used because of the small number of grains).

- Number of grains used is 18
- Extensions are: Minimum = 0.984, Intermediate = 1.003, and Maximum = 1.014
- Total distortion (J_2) due to twinning is 1.52%
- Average twin width is 1.61 microns
- Average twin density is 13.81 twins per millimeter
- No stereo net is provided for this sample (my program has crashed for some reason). It would look much like Figure 2 however.

Mary Beth Gray

Scientific Notebook 261 December 23, 1999

Entry: Mary Beth Gray
Project: 20-1604-471 Structural Deformation and Seismicity (SDS)
Experiment: Presentation at the 1999 Fall American Geophysical Union Meeting.
Purpose: Dissemination of information and interaction with others with similar scientific interests.

Abstract for oral presentation for the "Internal Fault Structure" Seismology / Tectonophysics Joint Session on December 16, 1999, American Geophysical Union Meeting in San Francisco, CA. Abstract published in EOS, Transactions of the American Geophysical Union v. 80, no. 46, p. F741.

Fault Behavior and Fault Zone Architecture in Miocene Volcanic Tuffs at Yucca Mountain, NV

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Information potentially subject to copyright protection was redacted from this location. The redacted material is from the reference information listed above.

December 23, 1999 continued

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the reference information on page 75 of this scientific notebook.

Mary Beth Gray

March 1, 2000

Scientific Notebook 261

Entry: Mary Beth Gray

Project: 20-1604-471 Structural Deformation and Seismicity (SDS)

Experiment: Inventory of all Yucca Mountain thin sections made by Mary Beth Gray.

Purpose: Documentation of thin sections, their sample localities, orientations and notes on preparation

Thin sections were made from samples collected in the field (within the Exploratory Studies Facility (ESF) and surface of Yucca Mountain) by Mary Beth Gray and John Stamatakos (CNWRA) and from core samples provided by the Sample Management Facility at the Nevada Test Site. Thin section ID numbers correspond directly to the ID sample numbers assigned by the Sample Management Facility for all samples collected in the ESF and from the cores. Samples collected from the surface of Yucca Mountain and adjacent areas were given sample numbers by John Stamatakos and/or Mary Beth Gray. In the case where multiple thin sections were made from a single rock chip, thin sections are differentiated by A, B, C, etc. at the end of the sample number. Box refers to the thin section storage box where each thin section can be found. Size refers to the dimensions of the glass slide used to make the thin section. I have made thins sections of two sizes: "small" (2.6 x 4.6 cm.) and "large" (5.0 x 7.5 cm.). The orientation column gives information on the orientation of the cut face affixed to the glass slide. The symbol ∥ is shorthand for "parallel to" and the symbol ⊥ is shorthand for "normal to". The locality column gives the sample location according to ESF meter markings, core markings and the core sample manifest, or the names of nearby surface features in the case of surface samples. The notes column contains information on orientation relationships between thin sections, special procedures used in preparation of the thin section, accidental damage to thin sections, transfers in custody of thin sections, and general notes on the condition of the thin section.

Thin Section ID#	Box	Size	Orientation	Locality	Notes
#02016217	1	small	∥core axis	USW G-2	
#02016216	5	large	∥core axis	USW G-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016215	5	large	∥core axis	USW G-2	
#02016214	5	large	∥core axis	USW G-2	
#02016213A		small	∥core axis	USW G-2	⊥ #02016213B, sent to Mark Evans, 8/17/99
#02016213B		small	∥core axis	USW G-2	⊥ #02016213A, sent to Mark Evans 8/17/99
#02016213C	5	large	∥core axis	USW G-2	∥#02016213B
#02016212A	5	large	∥core axis	USW VH-2	⊥ #02016212B
#02016212B	5	large	∥core axis	USW VH-2	
#02106211A	5	large	∥core axis	USW VH-2	cut parallel to #02016211B

MARCH 1, 2000, continued

#02016211B	5	large	‖core axis	USW VH-2	
#02016210	5	large	⊥ core axis	USW VH-2	
#02016209	5	large	‖core axis	USW VH-2	Hand sample shipped to John Stamatakos on 1/24/00
#02016208	5	large	‖core axis	USW VH-2	
#02016207A	7	large	‖core axis	USW VH-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016207B	7	large	‖core axis	USW VH-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016207C	7	large	‖core axis	USW VH-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016206	5	large	‖core axis	USW VH-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016205	5	large	‖core axis	USW VH-2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016204	5	large	‖core axis	USW VH-2	
#02016203A	5	large	‖core axis	USW G-1	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016203B	5	large	‖core axis	USW G-1	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
#02016202	5	large	⊥ core axis	USW G-1	
#02016201A	5	large	‖core axis	USW G-1	directly below #02016201B
#02016201B	1	small	‖core axis	USW G-1	directly above #02016201A
#02016200A		small	‖core axis	USW G-1	Sent to Mark Evans, 8/17/99, 02016200B is normal
#02016200B		small	‖core axis	USW G-1	Sent to Mark Evans, 8/17/99, 02016200A is normal
#02016198	5	large	‖core axis	USW G-1	
SPC00552506A	7	large	trans	ECRB 11+35.4	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552506B	7	large	long	ECRB 11+35.4	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552503A	6	large	⊥ fault	ECRB 25+86.2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552503B	6	large	⊥ fault	ECRB 25+86.2	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502AS	6	large	trans	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502BS	6	large	trans	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502CS	6	large	trans	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502E	6	large	long	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502F	6	large	long	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502G	6	large	long	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552502H	6	large	long	ECRB 25+86.0	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552501A		small	trans	ECRB 25+85.5	VAC. IMP. W/ EPOFIX; SENT TO M. EVANS 8/17/99
SPC00552501B	1	small	trans	ECRB 25+85.5	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552501C		small	long	ECRB 25+85.5	VAC. IMP. W/ EPOFIX; SENT TO M. EVANS 8/17/99
SPC00552501D	1	small	trans	ECRB 25+85.5	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00552500A	6	large	trans	ECRB 25+84.8	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY

MARCH 1, 2000, continued

SPC00543709A	1	small	‖709C &D	ECRB 25+37.36	STRIKE: 312, DIP: 78S, VAC. IMPR. W/ EPOFIX EPOXY
SPC00543709B	1	small	⊥ 709A, C &D	ECRB 25+37.36	STRIKE: 072, DIP: 23N, VAC. IMPR. W/ EPOFIX EPOXY
SPC00543709C	1	small	‖709A &D	ECRB 25+37.36	STRIKE: 312, DIP: 78S, VAC. IMPR. W/ EPOFIX EPOXY
SPC00543709D	6	large	‖709C &A	ECRB 25+37.36	STRIKE: 312, DIP: 78S, VAC. IMPR. W/ EPOFIX EPOXY
SPC00543708A	3	large	trans	ECRB 25+86.3	
SPC00543707A	3	large	trans	ECRB 25+85.1	
SPC00543707B	3	large	trans	ECRB 25+85.1	
SPC00543707C	2	small	trans	ECRB 25+85.1	
SPC00543706A	3	large	trans	ECRB 25+85.1	
SPC00543706B	3	large	trans	ECRB 25+85.1	
SPC00543704A	6	large	⊥ 704B	ESF 76+12.4	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00543704B	1	small	⊥ 704A	ESF 76+12.4	VACUUM IMPREGNATED WITH STRUER'S EPOFIX EPOXY
SPC00543701A		small	⊥ fault ⊥ B	ESF 76+17	sent to Mark Evans on July 31, 1999
SPC00543701B		small	⊥ fault ⊥ A	ESF 76+17	sent to Mark Evans on July 31, 1999
SPC00543701C	6	large	⊥ fault	ESF 76+17	
SPC00534025A	2	small	unoriented	alcove 6 00+85.5	
SPC00534025B	4	large	Long	alcove 6 00+85.5	
SPC00534024C	4	large	long	Ghost Dance	
SPC00534024B	2	small	trans	Ghost Dance	
SPC00534024A	2	small	trans	Ghost Dance	
SPC00534023	4	large	trans	ESF 62+08.0	
SPC00534020A		large	trans	ESF 67+87.2	destroyed
SPC00534020B	4	large	trans	ESF 67+87.2	
SPC00534020C	4	large	long	ESF 67+87.2	
SPC00534019C	2	small	long	ESF 79+09	CHIPPED
SPC00534019B	2	small	trans	ESF 79+09	
SPC00534019A	2	small	trans	ESF 79+09	
SPC00534017C	4	large	unoriented	ESF 76+17	
SPC00534017B	4	large	unoriented	ESF 76+17	
SPC00534017A		large	unoriented	ESF 76+17	Destroyed in prep
SPC00534016	4	large	unoriented	Split Wash	
SPC00534014A	4	large	trans	Dune Wash	
SPC00534014B	4	large	trans	Dune Wash	
SPC00534011	4	large	unoriented	Dune Wash	
SPC00534009C	4	large	trans	Diabolous Ridge	

MARCH 1, 2000 continued

SPC00534009B	4	large	trans	Diabolous Ridge	
SPC00534009A	4	large	trans	Diabolous Ridge	
SPC00534008	4	large	long	Diabolous Ridge	THICK
SPC00534007F	2	small	long	Diabolous Ridge	Sent to Mark Evans, 6/29/99
SPC00534007E	2	small	trans	Diabolous Ridge	Sent to Mark Evans, 6/29/99
SPC00534007D	4	large	trans	Diabolous Ridge	
SPC00534007C	4	large	trans	Diabolous Ridge	
SPC00534007B	4	large	trans	Diabolous Ridge	CATHODOLUM. STAINS
SPC00534007A	4	large	trans	Diabolous Ridge	
SPC00534005	4	large	trans	Bow Ridge	
SPC00534003	4	large	long	Bow Ridge	
SPC00534002B	4	large	unoriented	Bow Ridge	THICK
SPC00534002A	4	large	unoriented	Bow Ridge	THICK
SPC00534001A	2	small	trans	ESF 76+47	THICK
SPC00534000C	2	small	long	ESF 76+76.2	
SPCOO534000B	2	small	long	ESF 76+76.2	
SPC00534000A	2	small	trans	ESF 76+76.2	CHIPPED
SPC00530198G	2	small	trans	ESF 43+39	sent to Mark Evans, 6/29/99
SPC00530198F	2	small	long	ESF 43+39	sent to Mark Evans, 6/29/99
SPC00530198E	3	large	trans	ESF 43+39	
SPC00530198D	2	small	long	ESF 43+39	THICK
SPC00530198C	3	large	trans	ESF 43+39	
SPC00530198B	3	large	trans	ESF 43+39	CATHODOLUM. STAINS
SPC00530198A	3	large	trans	ESF 43+39	
SPC00530197B	2	small	trans	alcove 6 00+36	THICK
SPC00530197A	2	small	trans	alcove 6 00+36	THICK
SPC00530196	3	large	trans	alcove 6 01+52	
SPC00530195A	3	large	unoriented	alcove 6 00+97	
SPC00530195B		large	unoriented	alcove 6 00+97	destroyed during prep
SPC00530194C	2	small	long	alcove 6 00+97	
SPC00530194B	2	small	long	alcove 6 00+97	
SPC00530194A	2	small	trans	alcove 6 00+97	
SPC00530193D	2	small	trans	ESF 24+37.5	
SPC00530193C	2	small	trans	ESF 24+37.5	
SPC00530193B	2	small	long	ESF 24+37.5	
SPC00530193A	2	small	long	ESF 24+37.5	

MARCH 1, 2000, continued

SPC00530192E	1	small	trans	ESF 24+37	
SPC00530192D	1	small	trans	ESF 24+37	
SPC00530192C2	1	small	trans	ESF 24+37	
SPC00530192C1	1	small	trans	ESF 24+37	
SPC00520192A	1	small	long	ESF 24+37	
SPC00530191B	3	large	trans	ESF 19+42	POORLY IMPREGNATED
SPC00530191A	3	large	trans	ESF 19+42	POORLY IMPREGNATED
SPC00530190C	3	large	long	ESF 19+42	POORLY IMPREGNATED
SPC00530190B	3	large	trans	ESF 19+42	
SPC00530190A	3	large	trans	ESF 19+42	POORLY IMPREGNATED
JSTCA2	3	large		Prow Pass	
JSTCA1	1	small		Prow Pass	
JSSC2C	1	small		Prow Pass	CHIPPED
JSSC2B	1	small		Prow Pass	THICK
JSSC2A	1	small		Prow Pass	
JSLPPFC3A	3	large		Prow Pass	LITTLE PROW PASS FAULT
JSLPPFC3B	3	large		Prow Pass	LITTLE PROW PASS FAULT
JSLPPFC3C	3	large		Prow Pass	LITTLE PROW PASS FAULT
JSLPPFC2	1	small		Prow Pass	
JSLPPFC1	3	large		Prow Pass	LITTLE PROW PASS FAULT
JSLPPFA	1	small		Prow Pass	LITTLE PROW PASS FAULT
TLS4-9A	5	large		CRATER FLAT	
TLS4-9B	5	large		CRATER FLAT	
TLS5-16A1	1	small		CRATER FLAT	
TLS5-16A2	1	small		CRATER FLAT	
TLS5-15A	5	large		CRATER FLAT	
TLS5-A5B	5	large		CRATER FLAT	

I HAVE REVIEWED THIS SCIENTIFIC NOTEBOOK AND FIND IT ~~HAS~~ IS IN GENERAL COMPLIANCE WITH QAP-001 AND THERE IS SUFFICIENT INFORMATION SO THAT ANOTHER QUALIFIED INDIVIDUAL COULD REPEAT THIS ACTIVITY

H. Lawrence McKague
4/11/00

A COPY OF THIS NOTEBOOK WAS PROVIDED TO QA ON 4/11/00

H. Lawrence McKague

HLM

JUNE 30, 2000

ENTRY: Mary Beth Gray

Project: 20-1604-471 STRUCTURAL DEFORMATION & SEISMICITY

EXPERIMENT: CORRESPONDENCE RECORD.

PURPOSE: DOCUMENTATION OF REQUEST FOR ACCESS TO INFORMATION

Bret Leslie, 6/30/00 5:23 PM -0400, Fluid inclusion work 1

Date: Fri, 30 Jun 2000 17:23:26 -0400
From: Bret Leslie <BWL@nrc.gov>
To: arjun@ieer.org
Cc: mbgray@bucknell.edu, JSTAM@swri.edu
Subject: Fluid inclusion work

Dear Arjun,

As per your recent telephone call request, I am responding with some additional information. Until yesterday afternoon there was going to be a meeting (technical exchange, open to public) on July 12 and 13th on issues in the unsaturated zone at Yucca Mountain. I did not notify you earlier as I have been out on sick leave and I had heard the meeting might not occur. I think that the meeting would have been a good forum for discussion of the ongoing study of fluid inclusions at Yucca Mountain. This meeting has been canceled for now and is likely to be rescheduled for sometime in late August to September time frame. I will let you know when this meeting is rescheduled and the meeting logistics (location and whether the meeting will be available through video conference).

At the recent study group meeting (June 21) on fluid inclusions, Dr. Yuri Dublyansky approached Dr. Mary Beth Gray about obtaining splits of samples that Dr. Gray has studied. As you may recall, Dr. Gray is a consultant to the Center for Nuclear Waste Regulatory Analyses. Both Dr. Gray and Dr. John Stamatakos of the Center are acting on the behalf of the U.S. Nuclear Regulatory Commission in following the fluid inclusion studies. The focus of the Center's studies was to examine fault rock deformation as it relates to seismicity. The scope of their studies are outlined in a published abstract that I will send you in a Fax ("Fault Behavior and Fault Zone Architecture in Miocene Volcanic Tuffs at Yucca Mountain"). This abstract and another earlier abstract was provided to all meeting participants at the June 21 meeting. Some of the samples that Dr. Gray has investigated, using a technique that examines the thickness of calcite twins, suggest "elevated deformation temperature!
s." This "twinning" technique is independent of the fluid inclusion technique and sample collection and storage protocols for fluid inclusion samples were not followed for Dr. Gray's samples. The locations of these samples from within the Exploratory Studies Facility at Yucca Mountain was pointed out to the fluid inclusion study group almost a year ago. It is my understanding that only the USGS has investigated samples from the same location as Dr. Gray's samples. The USGS results have not yet been made available.

I have instructed that Drs. Gray and Stamatakos make sub-samples of their samples available to Dr. Dublyansky, to the extent possible. Many of their samples have already been cut into thin sections for the fault study. It is my understanding that they will contact Dr. Dublyansky and members of the study group sometime next week about the pending release of samples to Dr. Dublyansky. I have also instructed that they also include the sample locations of the samples that they plan to release to Yuri in the notification E-mail. With the sample locations all members of the study

JUNE 30, 2000, continued

Bret Leslie, 6/30/00 5:23 PM -0400, Fluid inclusion work 2

group would be able to obtain additional samples from the same location using the approved protocols for fluid inclusion samples. I have also requested that Drs. Gray and Stamatakos indicate in both the notification E-mail and in their formal transmittal of samples to Yuri (entire fluid inclusion study group will be copied on the transmittal letter) that the their samples were not collected according to!
the agreed upon protocol for fluid inclusion samples. In addition, Drs. Gray and Stamatakos will note that the samples were also not processed (stored and sawed) under the approved fluid inclusion protocol. They have also been instructed to require that Dr. Dublyansky, as a condition of release of the samples to him, note when presenting any fluid inclusion information obtained from these samples, that the samples were not collected according to the approved fluid inclusion protocols. This condition will be required of any investigator in the fluid inclusion study group that obtains subsamples from Dr. Gray's collection. Thus, any fluid inclusion results obtained from Dr. Gray's samples should not be considered as definitive.

I hope that this additional information addresses the points you raised in our phone conversation.

Sincerely,

Bret Leslie

US Nuclear Regulatory Commission
MS T-7C6
Washington, DC 20555-0001
(301) 415-6652
(301) 415-5398 fax
bwl@nrc.gov

MBG

July 17, 2000

Correspondence with Yuri Dublyansky regarding sample access.

kyoto_yuri@hotmail.com, 7/17/00 11:35 AM -0400, samples 1

To: kyoto_yuri@hotmail.com
From: Mary Beth Gray <mbgray@bucknell.edu>
Subject: samples
Cc:
Bcc:
X-Attachments:

Hi Yuri,

If my memory serves me, you are due to arrive at VPI on the 15th to work on fluid inclusions in Bob Bodnar's lab. You requested that I make some samples of Class B faults available for reconnaissance work on FIA microthermometry. I have discussed your request with John Stamatakos at the CNWRA and Bret Leslie at the NRC and they agree that we should provide our samples for your use, to the extent possible (the main limitation is what usable samples remain in my collection).

The NRC and the CNWRA also instructed me to notify you of the limitations of the samples I will send you.

I collected the samples for microstructural analyses. Therefore, I did not follow QA protocol for collecting samples for fluid inclusion microthermometry (no coolers, no temperature recorders, etc.). Furthermore, the samples were not stored or cut under conditions required for FIA microthermometry. It is therefore a condition of release of these samples that when presenting any fluid inclusion information obtained from these samples, you notify the intended audience that the samples were not collected according to the approved protocols. This condition will be required of any investigator in the fluid inclusion study group who may also wish to obtain subsamples from my collection. Thus, any fluid inclusion results obtained from my samples should not be considered definitive.

On the other hand, if the data yields intriguing results, you may may choose to resample my sites, according to FIA microthermometry protocols. I plan to send a detailed manifest with the samples identifying their ESF station locations. I cannot go underground until late fall, however, John Stamatakos would be able to join you anytime, if necessary, pending his schedule.

I have not yet sent a shipment of samples because a colleague of mine from U. Pittsburgh (Mark Evans) has some of my best samples. He has been away in Europe since mid-June and just arrived back last night. I have waited for him to return the samples so that I could send them to you. Mark completed the U-stage strain-twin analyses. He E-mailed me this morning and said he'd send the samples to me ASAP.

The majority of my thin sections are large format, better for doing microtextural analyses. Is Bob Bodnar's heating stage compatible with large format thin sections? If not, I'm afraid I'll have to wait to send small format sections to you. U-stage analyses require small format thin sections, so all of the thin sections I sent to Mark are small format and they constitute the bulk of my small format thin section collection.

Please call me or email so we can iron out what samples will work for you.

I look forward to hearing from you.

Mary Beth Gray

Mary Beth Gray

July 17, 2000

Fluid inclusion studies group correspondence for the purpose of transparency of procedures and providing equal access to samples.

Mary Beth Gray, 7/17/00 11:43 AM -0400, Fault rock fluid inclusions 1

X-Sender: mbgray@mail.bucknell.edu
Date: Mon, 17 Jul 2000 11:43:38 -0400
To: bubbles@vt.edu, william_boyle@ymp.gov, jwb@nrc.gov, jcline@nevada.edu, drew_coleman@ymp.gov, wld@nrc.gov, kyoto_yuri@hotmail.com, mbgray@bucknell.edu, bwl@nrc.gov, cjg1@nrc.gov, psj@nrc.gov, marilyn_kavchak@ymp.gov, sslevy@lanl.gov, bloux@govmail.state.nv.us, lundberg@nevada.edu, bdmarsha@usgs.gov, Alan_Mitchell@notes.ymp.gov, lneymark@usgs.gov, jbpaces@usgs.gov, peterman@usgs.gov, max_powell@notes.ymp.gov, jprice@nbmg.unr.edu, reiter@nwtrb.gov, roedder@shore.net, rotertj@nevada.edu, drunnells@shepmill.com, wbscott@usgs.gov, smiecins@nevada.edu, jstam@swri.org, stellanick@aol.com, stetzenb@nevada.edu, stuckles@usgs.gov, evt@co.clark.nv.us, jfwhelan@usgs.gov, nwilson@nevada.edu, szeee@govmail.state.nv.us
From: Mary Beth Gray <mbgray@bucknell.edu>
Subject: Fault rock fluid inclusions

Hi All, Yuri Dublyansky requested access to my samples at the June, '00, quarterly meeting. After consulting with the CNWRA and NRC, we have agreed to make samples/thin sections available for Yuri to conduct fluid inclusion microthermometry analyses. We wish to make it clear that any group who wishes to have similar access to our samples is welcome to do so. In the note sent to Yuri below, we point out some limitations of the results that may be obtained from our samples. These would of course apply to anyone who might wish to collect data from our samples.

Best wishes....

Mary Beth Gray

****

Hi Yuri,

If my memory serves me, you are due to arrive at VPI on the 15th to work on fluid inclusions in Bob Bodnar's lab. You requested that I make some samples of Class B faults available for reconnaissance work on FIA microthermometry. I have discussed your request with John Stamatakos at the CNWRA and Bret Leslie at the NRC and they agree that we should provide our samples for your use, to the extent possible (the main limitation is what usable samples remain in my collection).

The NRC and the CNWRA also instructed me to notify you of the limitations of the samples I will

MBG

July 17, 2000, continued.

send you.

I collected the samples for microstructural analyses. Therefore, I did not follow QA protocol for collecting samples for fluid inclusion microthermometry (no coolers, no temperature recorders, etc.). Furthermore, the samples were not stored or cut under conditions required for FIA microthermometry. It is therefore a condition of release of these samples that when presenting any fluid inclusion information obtained from these samples, you notify the intended audience that the samples were not collected according to the approved protocols. This condition will be required of any investigator in the fluid inclusion study group who may also wish to obtain subsamples from my collection. Thus, any fluid inclusion results obtained from my samples should not be considered definitive.

On the other hand, if the data yields intriguing results, you may may choose to resample my sites, according to FIA microthermometry protocols. I plan to send a detailed manifest with the samples identifying their ESF station locations. I cannot go underground until late fall, however, John Stamatakos would be able to join you anytime, if necessary, pending his schedule.

I have not yet sent a shipment of samples because a colleague of mine from U. Pittsburgh (Mark Evans) has some of my best samples. He has been away in Europe since mid-June and just arrived back last night. I have waited for him to return the samples so that I could send them to you. Mark completed the U-stage strain-twin analyses. He E-mailed me this morning and said he'd send the samples to me ASAP.

The majority of my thin sections are large format, better for doing microtextural analyses. Is Bob Bodnar's heating stage compatible with large format thin sections? If not, I'm afraid I'll have to wait to send small format sections to you. U-stage analyses require small format thin sections, so all of the thin sections I sent to Mark are small format and they constitute the bulk of my small format thin section collection.

Please call me or email so we can iron out what samples will work for you.

I look forward to hearing from you.

Mary Beth Gray

Mary Beth Gray
Associate Professor and Acting Chair
Department of Geology
Bucknell University

Mary Beth Gray

July 17, 2000

Response to providing sample access and transparency.

Robert Bodnar, 7/17/00 12:08 PM -0400, Re: Fault rock fluid inclusions

```
Date: Mon, 17 Jul 2000 12:08:51 -0400
From: Robert Bodnar <bubbles@vt.edu>
Subject: Re: Fault rock fluid inclusions
X-Sender: rjb@mail.vt.edu
To: Mary Beth Gray <mbgray@bucknell.edu>
Cc: william_boyle@ymp.gov, jwb@nrc.gov, jcline@nevada.edu,
        drew_coleman@ymp.gov, wld@nrc.gov, kyoto_yuri@hotmail.com,
        mbgray@bucknell.edu, bwl@nrc.gov, cjgl@nrc.gov, psj@nrc.gov,
        marilyn_kavchak@ymp.gov, sslevy@lanl.gov, bloux@govmail.state.nv.us,
        lundberg@nevada.edu, bdmarsha@usgs.gov, Alan_Mitchell@notes.ymp.gov,
        lneymark@usgs.gov, jbpaces@usgs.gov, peterman@usgs.gov,
        max_powell@notes.ymp.gov, jprice@nbmg.unr.edu, reiter@nwtrb.gov,
        roedder@shore.net, rotertj@nevada.edu, drunnells@shepmill.com,
        wbscott@usgs.gov, smiecins@nevada.edu, jstam@swri.org,
        stellanick@aol.com, stetzenb@nevada.edu, stuckles@usgs.gov,
        evt@co.clark.nv.us, jfwhelan@usgs.gov, nwilson@nevada.edu,
        szeee@govmail.state.nv.us
```

Mary Beth, Yuri, et al.:

I think it would be a great waste of time and effort to even look at these samples. Those of us familiar with fluid inclusions will not accept or believe any data that comes from samples not collected and prepared specifically for fluid inclusion analyses because we know how easy it is to modify the inclusions. All that can come from such studies is misleading information that will only serve to detract from the high-quality and scientifically rigorous studies that are being conducted on Yucca Mountain. This is, in my opinion, an example of poor science and should be discouraged at all costs. If anyone wishes to work on fluid inclusions in fault samples, new samples should be collected and prepared according to agreed upon protocols.

Bob Bodnar

Mary Beth Gray

July 17, 2000

Response to providing access to samples and transparency of procedures.

Yuri Dublyansky, 7/17/00 2:04 PM -0400, Re: Fault rock fluid inclusions 1

```
X-Originating-IP: [128.173.186.164]
From: "Yuri Dublyansky" <kyoto_yuri@hotmail.com>
To: bubbles@vt.edu, mbgray@bucknell.edu
Cc: william_boyle@ymp.gov, jwb@nrc.gov, jcline@nevada.edu,
        drew_coleman@ymp.gov, wld@nrc.gov, bwl@nrc.gov, cjgl@nrc.gov,
        psj@nrc.gov, marilyn_kavchak@ymp.gov, sslevy@lanl.gov,
        bloux@govmail.state.nv.us, lundberg@nevada.edu, bdmarsha@usgs.gov
Subject: Re: Fault rock fluid inclusions
Date: Mon, 17 Jul 2000 18:04:04 GMT
X-OriginalArrivalTime: 17 Jul 2000 18:04:04.0616 (UTC) FILETIME=[64D48080:01BFF019]
```

Bob, Mary Beth et al.:

I entirely agree with Bob: it would be a bad science if someone measured the fluid inclusion temperatures on samples which were not properly prepared and handled, and reported these results as reflecting the environment of calcite deposition.

The major purpose of my request to Mary Beth was to take a look at the fault calcite and make a judgement whether or not this type of material warrants further effort in trying to get fluid inclusion data.

I believe, it would be important and benefitial to get an independent corroboration or check on the "twin-width" thermometry. Fluid inclusions could potentially provide such independent assessment. However, since I did not examin samples in detail, I presently do not know whether or not the fault calcite is generally suitable for the FI studies; for instance, it might be so strongly twinned that no fluid inclusion survived. So, in requesting access to Mary Beth's samples I wanted to take a first look at the material and to decide whether I am going to resample these locations or I should just abandon this idea.

In my judgement, examining sections that already exist would not be a waste of time; instead, this might save time by helping to decide whether to start a new project or not. As opposed to a possible scenario than after you organized trip to the ESF, collected replicate samples, made fluid inclusion sections, you finaly found that the material is not suitable for fluid inclusion work.

Regards!

Yuri Dublyansky

Mary Beth Gray

July 19, 2000

Correspondence from Yuri Dublyansky regarding intended use of samples.

Yuri Dublyansky, 7/19/00 4:40 PM -0400, Re: samples 1

X-Originating-IP: [128.173.186.164]
From: "Yuri Dublyansky" <kyoto_yuri@hotmail.com>
To: mbgray@bucknell.edu
Subject: Re: samples
Date: Wed, 19 Jul 2000 20:40:50 GMT
X-OriginalArrivalTime: 19 Jul 2000 20:40:50.0972 (UTC) FILETIME=[A04805C0:01BFF1C1]

Hello, Mary Beth:

Sorry, it took some time for me to get back to you.

Yes, I would appreciate you sending me a few samples, and of course, I will respect all requirements that will be attached. I perfectly realize that fluid inclusion data obtained from samples that wete not properly (for this purpose) prepared and handled cannot be reliable. What I had in mind asking you for samples is to take a look at them, search for inclusions, and evaluate whether or not the resampling of these locations is warranted.

For this purpose, it does not really matter whether the samples are of large or small format. I do not plan to use your samples in the fluid inclusion stage, unless I can see extremely promissing FIAs and then I will have to cut a fragment of the section of ~5 mm in diameter aniway. (Of course I will consult with you before doing that).

As for the possible resampling, I greatly appreciate the willingness of John Stamatakos to accompany me. The whole thing will depend on two things: whether or not I will see the potential in repeating sampling and, most importantly, whether or not funds for that will be available.

Looking forward for seing your sections,

Sincerely,

Yuri

Mary Beth Gray

July 19, 2000

Request for sample localities.

Jean Cline, 7/19/00 5:52 PM -0400, Re: Fault rock fluid inclusions

Return-Path: <jcline@nevada.edu>
Received: from am-dew.nevada.edu (am-dew.nevada.edu [131.216.1.249])
by mail.bucknell.edu (8.10.1/8.10.1) with ESMTP id e6JLjYW30511
for <mbgray@bucknell.edu>; Wed, 19 Jul 2000 17:45:34 -0400 (EDT)
Received: from [131.216.26.30] (geo208a.lv-geo.nevada.edu [131.216.26.30])
by am-dew.nevada.edu (8.8.8/8.8.8) with ESMTP id OAA18812;
Wed, 19 Jul 2000 14:45:33 -0700 (PDT)
Message-Id: <103130302b59bd2cef071@[131.216.26.30]>
In-Reply-To: <v0422080db598d85a8629@[134.82.57.4]>
Mime-Version: 1.0
Content-Type: text/plain; charset="us-ascii"
Date: Wed, 19 Jul 2000 14:52:44 -0700
To: Mary Beth Gray <mbgray@bucknell.edu>
From: Jean Cline <jcline@nevada.edu>
Subject: Re: Fault rock fluid inclusions
Cc: nwilson@nevada.edu
X-UIDL: 221dc694677c9e19bd25fd7a87506736

Mary Beth,

A "sub group" of this project including Nick and Joel, Joe Whelan, Bob Bodnar and others will be visiting YM on Tuesday July 25. Re your message below, could you perhaps email Nick and provide him with some of the best localities of your class B faults by next monday. He could then look at these while visiting there and decide whether or not to collect some additional samples. Sorry about the short notice, but I just thought of this. I won't be going on this trip.

Thanks much,
Jean

MBG

July 20, 2000

Sample localities.

nwilson@nevada.edu, 7/20/00 5:57 PM -0400, Re: Fault rock fluid inclusions

```
        To: nwilson@nevada.edu
      From: Mary Beth Gray <mbgray@bucknell.edu>
   Subject: Re: Fault rock fluid inclusions
        Cc: jcline@nevada.edu
       Bcc: john Stamatakos, bwl@nrc.gov
X-Attachments:
```

Nick,

John provided some of our best localities at the first quarterly meeting. Here they are again:

ESF:

STA 43+39
STA 76+17
STA 19+42
STA 67+87.2
STA 87+85.2

Best wishes,

>Mary Beth

P.S. Jean, Would you like me to forward this message to the whole group or would you like to do this?

NICHOLAS WILSON, 7/20/00 6:41 PM -0400, Re: Fault rock fluid inclusions

```
X-Authentication-Warning: pollux.nevada.edu: nwilson owned process doing -bs
Date: Thu, 20 Jul 2000 15:41:19 -0700 (PDT)
From: NICHOLAS  WILSON <nwilson@nevada.edu>
To: Mary Beth Gray <mbgray@bucknell.edu>
Subject: Re: Fault rock fluid inclusions
```

Mary Beth

Thanks for the locations. I will bring the list with me on tuesday.

Cheers

Nick

MBG

July 26, 2000

Documentation that accompanied shipment of samples to Yuri Dublyansky.

July 26, 2000

Dr. Yuri Dublyansky c/o Dr. Robert J. Bodnar
Department of Geological Sciences
4040 Derring Hall
Virginia Polytechnic Institute and State University
Blacksburg VA
24061-0420

Yuri,

Enclosed are the samples you requested. This package contains 8 thin sections and four billets (rock chips). These materials are from two localities in the ESF. Each locality is represented by four thin sections and 2 billets in this shipment.

ESF Station 43+39: This site is represented by thin sections SPC00530198B, SPC00530198E, SPC00530198F and SPC00530198G and the billets from which thin sections SPC00530198F and SPC00530198G were cut. SPC00530198B and SPC00530198E are large format thin sections. SPC00530198F and SPC00530198G are small format thin sections. I conducted brief cathodoluminescence reconnaissance on SPC00530198B. I showed thin sections from this locality to the small working group on June 15, 1999.

ESF Station 76+17: This site is represented by thin sections SPC00534017B, SPC00534017C, SPC00543701A and SPC00543701B and the billets from which thin sections SPC00543701A and SPC00543701B were cut. SPC00534017B and SPC00534017C are large format thin sections. SPC00543701A and SPC00543701B are small format thin sections.

Please note that all of the billets from which these thin sections where cut were prepared using epoxies that require elevated temperatures to cure. If you decide to use any of these materials on the heating stage, I request that you cut fresh thick sections/chips from the enclosed billets rather than cut chips from the enclosed thin sections (I'd like to keep my thin sections intact). I make all of my own thin sections. None of them have cover slips and some of them may need further polishing. If you wish to further polish any of them you are welcome to do so. You are also welcome to attach cover slips. I use a thin layer of glycerin to improve the optics on uncovered thin sections. Saw blade cuts (nick marks) on the billets and thin sections indicate the orientation of the thin sections and billets. If you require orientation information, I would be happy to provide that.

MBG

July 26, 2000, continued.

As in my E-mail message of 7/17/00, the NRC and the CNWRA instructed me to notify you of further limitations of the samples I have enclosed.

I collected the samples for microstructural analyses. Therefore, I did not follow QA protocol for collecting samples for fluid inclusion microthermometry (no coolers, no temperature recorders, etc.). Furthermore, the samples were not stored or cut under conditions required for FIA microthermometry. It is therefore a condition of release of these samples that when presenting any fluid inclusion information obtained from these samples, you notify the intended audience that the samples were not collected according to the approved protocols. This condition will be required of any investigator in the fluid inclusion study group who may also wish to obtain subsamples from my collection. Thus, any fluid inclusion results obtained from my samples should not be considered definitive.

On the other hand, if the data yields intriguing results, you may choose to resample my sites, according to FIA microthermometry protocols. I stand ready to share other Class B sample localities should you desire to collect material from Class B faults. My colleague, John Stamatakos, remains willing to show you our best localities in the ESF.

Please do not hesitate to call me at (570) 577-1146 if you have any questions regarding these samples or localities.

Sincerely,

Mary Beth Gray
Associate Professor and Acting Chair

MBG

NOVEMBER 20, 2000

ENTRY: MARY BETH GRAY

PROJECT: 20-1604-471 STRUCTURAL DEFORMATION AND SEISMICITY

EXPERIMENT: ORAL PRESENTATION AT THE 2000 ANNUAL CONFERENCE OF THE GEOLOGICAL SOCIETY OF AMERICA MEETING IN RENO, NV. SESSION: T11: SECONDARY MINERALIZATION IN THE UNSATURATED ZONE AT YUCCA MOUNTAIN, NEVADA. GSA ABSTRACTS WITH PROGRAMS, V 32, N 7, P-A260.

PURPOSE: DISSEMINATION OF INFORMATION & INTERACTION WITH OTHERS WITH SIMILAR SCIENTIFIC INTERESTS.

POLYGENETIC SECONDARY CALCITE MINERALIZATION IN YUCCA MOUNTAIN, NV

GRAY, Mary Beth, Geol. Dept., Bucknell Univ., Lewisburg, PA 17837, mbgray@bucknell.edu; STAMATAKOS, J.A., and FERRILL, D.A., Center for Nuclear Waste Regulatory Analyses, SwRI, 6220 Culebra Rd., San Antonio, TX, 78238

Information potentially subject to copyright protection was redacted from this location.

The redacted material is from the information listed above.

Mary Beth Gray

I have reviewed scientific notebook 261 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook P. 82-95.

H Lawrence McKague 04/19/01

H. Lawrence McKague
GLGP Element Manager

HLMcK 04/19/01

June 7, 2001

All samples collected May 9 - 17, 2001 in the ESF AND ECRB were inventoried, unpacked, placed in labelled sample trays and properly stored.

The samples listed below were impregnated (in a vacuum chamber) with Struer's Epofix epoxy. Samples and epoxy were always at room temperature.

SPC 00552513
SPC 00552516
SPC 00552517
SPC 00552518
SPC 00552520
SPC 00552522
SPC 00552525 A
SPC 00552525 B
SPC 00552525 C
SPC 00552526
SPC 00566360

MBG
6/7/01

June 8, 2001

Vacuum impregnation of hand samples collected in the ESF/ECRB. Epoxy is Epofix, cured at room temperature.

The following samples were impregnated today:

SPC 00552510
SPC 00552515
SPC 00552519
SPC 00552521
SPC 00552523
SPC 00552524
SPC 00552527
SPC 00552528
SPC 00552529
SPC 00566352
SPC 00566353
SPC 00566354
SPC 00566356
SPC 00566357
SPC 00566358
SPC 00566359
SPC 00566362
SPC 00566363
SPC 00566365
SPC 00566366
SPC 00566369
SPC 00566370
SPC 00566371

ONE SAMPLE, SPC 00566368, was merely coated with Epofix. It was not placed in a vacuum chamber.

MBG 6/8/01

JUNE 14, 2001

CUTTING, POLISHING, AND MOUNTING OF ROCK CHIPS FROM SAMPLES ON PAGES 97 & 98. CHIPS WERE ORIENTED USING THE SAME METHODOLOGY AS ON PAGE 20. INSTEAD OF USING SAWBLADE CUTS TO MARK ORIENTATION, I USED INDELIBLE INK. I FOUND THAT THE SAW BLADE CUTS TOOK UP TOO MUCH AREA ON THE FINAL THIN SECTION IMAGE. INK MARKS WILL BE TRANSFERRED TO GLASS SLIDES BY INCRIPTION USING A DIAMOND SCRIBE WHEN CHIPS ARE AFFIXED TO GLASS SLIDES.

CHIPS PREPARED TODAY:

	ORIENTATION*	SIZE+
SPC 00552513	TRANSVERSE	SMALL
SPC 00552516A	TRANSVERSE	SMALL
SPC 00552516B	TRANSVERSE	SMALL
SPC 00552517A	TRANSVERSE	SMALL
SPC 00552517B	TRANSVERSE	SMALL
SPC 00552520	TRANSVERSE	SMALL
SPC 00552522A	UNORIENTED	SMALL
SPC 00552522B	UNORIENTED	SMALL
SPC 00552525AA	TRANSVERSE	SMALL
SPC 00552525AB	TRANSVERSE	SMALL
SPC 00552525C	TRANSVERSE	SMALL
SPC 00552526A	TRANSVERSE	SMALL
SPC 00552526B	TRANSVERSE	SMALL

* REFER TO PAGE 20

+ SMALL CHIPS TO BE MOUNTED ON 2.6 x 4.6 cm glass slides.

CHIPS WERE CUT, POLISHED, AND CLEANED AT ROOM TEMPERATURE. CHIPS WERE DRIED IN AN OVEN AT 40°C.

SPC00552518 & SPC00566636 were poorly epoxied & significant plucking occured during polishing. As a result cut surfaces were coated with Hillquist A/B epoxy & cured at 50°C

MBG 6/14/01

June 15, 2001

All chips listed on page 99 were mounted on June 14, '01 and cut off the glass slides today. MOUNTING EPOXY WAS HILLQUIST A/B epoxy, cured at 40°C overnight. SECTIONS WERE Then polished.

Chips prepared today:

	Orientation	Size
SPC 00566352	LONGITUDINAL	LARGE
SPC 00566369	TRANSVERSE	SMALL
SPC 00566356		LARGE
SPC 00566368	UNORIENTED	LARGE
SPC 00552521A	LONGITUDINAL	LARGE
SPC 00552521B	TRANSVERSE	LARGE
SPC 00552529A	LONGITUDINAL	LARGE
SPC 00552529B	TRANSVERSE	LARGE
SPC 00552524 A	UNORIENTED	SMALL
SPC 00552524 B	UNORIENTED	SMALL
SPC 00552515	TRANSVERSE	LARGE
SPC 00566354A	LONGITUDINAL	LARGE
SPC 00566354B	TRANSVERSE	SMALL
SPC 00566362	UNORIENTED	LARGE

CHIPS WERE POLISHED, CLEANED, & DRIED AT TEMPERATURES NOT EXCEEDING 40°C.

Mary Beth Carey
6/15/01

JUNE 17, 2001

All chips listed on page 100 were mounted on glass slides using Hillquist A/B epoxy. Epoxy cured at 40°C.

Mary Beth Carey 6/17/01

JUNE 18, 2001

The following chips were cut, polished, and dried in an oven at 40°C today:

Chips prepared today:

	orientation	SIZE
00552523A	unoriented	small
00552523B	unoriented (⊥ A)	small
00552525B	transverse	small
00552527	longitudinal	large
00552528	longitudinal	large
00566353A	unoriented	small
00566353B	unoriented	small
00566357A	transverse	large
00566357B	longitudinal	small
00566358	longitudinal	small
00566359	transverse	small
00566370	transverse	small
00566371A	transverse	large
00566371B	longitudinal	small

All chips listed on page 100 were cut from glass slides and thin sections were polished & stored properly.

Mary Beth Gray
06/18/01

JUNE 18, 2001

All chips listed on page 102 were dried for 8 hours at 40°C, then mounted to glass slides using Hillquist A/B epoxy cured at 43°C. The epoxy cured for 12 hours.

Mary Beth Gray 6/18/01

June 19, 2001

All chips listed on page 102 were cut off of glass slides and thinned.

Mary Beth Gray 6/19/01

I have reviewed scientific notebook 261 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook

H. Lawrence McKague 10/8/01

H. Lawrence McKague
GLGP Element Manager

HL McKague

August 30, 2002 4:00 PM.

I was requested to determine the nature of support in Class B fault rocks. Are the rocks clast supported or matrix (calcite) supported? To answer this question, I endeavored to digest the calcite in HCl and visually examine the remaining sample to establish the nature of support of the tuff fragments.

1 sample fragment of SPC00530198 was selected for digestion. It is Roughly 6 x 3 x 3 cm in size and is a rectangular prism. The sample fragment is labelled SPC00530198H. The specimen is a fragment of an oriented Class B fault rock that was vacuum impregnated with Epofix epoxy.

The sample fragment was placed in a Nalgene bottle filled with ~1 liter of pH=1 HCl at room temperature at 3:45 pm. The Nalgene bottle was placed on a hot plate & a magnetic stirrer was added to the bottle. The heating element was not turned on. The lid of the Nalgene bottle was placed loosely on top of the bottle.

Mary Beth Gray 8/30/02

~~August~~ MBG

September 1, 2002 7:30 PM.

Checked the pH of the solution and found that it was 1.32. No bubbles forming in the solution. Suspect the solution was saturated with respect to $CaCO_3$. Decided to discard solution and replace it. The fresh liter of pH≅1 HCl caused the specimen to effervesce. I returned the solution to the hot plate (heating element not turned on) and continued to stir the solution using a magnetic stirrer. Cap loosely placed on top of bottle.

Mary Beth Gray

Sept 2, '02 9:00 AM

Checked pH of solution — pH = 1.10.
Specimen is effervescing mildly.

Mary Beth Gray

@ 4:00 pm the pH ≅ 1.0 (using a test strip). The specimen is not noticably effervescing.

Mary Beth Gray

Sept. 3, '02 11:30 AM pH is ≅ 1.0 (using test strip)
Sample has broken into two pieces. Not noticably effervescing.

Mary Beth Gray

Sept 4, '02 3:00pm pH of solution is 1.30.
Sample is not effervescing. Discarded solution into a container filled with limestone aggregate. Solution did not effervesce. Presume solution is saturated with respect to Ca^{++}. Introduced 25 ml concentrated HCl (pH ~ 1.0) to digestion vessel. Some effervescence was noted.

Mary Beth Gray

Sept 8, 2002 10:15pm.

pH ≅ 1.0 (using test strip). No effervescence. I poured solution into waste container filled with limestone chips and the solution effervesced vigorously. This suggests that $CaCO_3$ was sufficiently depleted from the specimen in the digestion vessel so as to cause effervescence to stop. Suggests solution in digestion vessel did not saturate with respect to Ca^{++}. Acid digestion experiment now complete. I poured tap water into the digestion vessel (Nalgene bottle) several times to dilute remaining HCl on sample surface.

Mary Beth Gray

October 7, 2002

I examined the remnants of SPC00530198H. The sample is deeply etched and consists of silt size fragments — about 1/8 of total volume of original sample. Other fragments are larger diameter. The largest is 4 cm in largest dimension. Large fragments clearly show epoxy that holds together the sample. Also shows white translucent to opaque mineral in some spaces in between tuff clasts. This mineral is fairly abundant. Tiny crystals are too small to ID based on crystal form using a macroscope at 50x magnification. They do not fluoresce under shortwave UV lamp. It may be useful to collect samples of this mineral and ID using XRD.

Mary Beth Greeley

I have reviewed scientific notebook 261 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook. P. 106-110.

H. Lawrence McKague 10/9/02

H. Lawrence McKague
GLGP Element Manager

H. L. McKague 10/9/02

I have reviewed scientific notebook 261 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook

H. L. McKague 09/10/03

H. Lawrence McKague
GLGP Element Manager

H.L.McKAGUE
09/10/03

August 20, 2003

Several samples from USW-VH2, G1 and G2 were examined during the course of this study. These samples are listed on pages 77 and 78 of this notebook. USW-VH2, G1, and G2 drillholes and cores were made prior to the establishment of a QA program for drilling and therefore locations of these wells are not QA.

Some samples from these cores were used to conduct calcite strain and twin analyses. The results of these analyses are reported in Gray et al, "Fault Zone deformation in Welded tuffs at Yucca Mountain, Nevada". The types of data that were gathered from the faults in the drillhole cores did not depend upon a QA location and therefore we decided it would be appropriate to include these data (calcite twin thickness and strain data) in our manuscript for approval by the CNWRA and NRC.

Mary Beth Gray
8/20/03

I have reviewed scientific notebook 261 and find it in compliance with QAP-001. There is sufficient information regarding procedure used for conducting the research and acquiring and analyzing the data so that another qualified scientist could repeat the activity or activities recorded in this scientific notebook.

H. Lawrence McKague
GLGP Element Manager
Reviewed 10/24/03

HLMcK 10/24/03

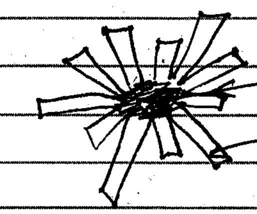
May 13, 2005.

The following sample descriptions were performed during the interval 5/2/1998 and 11/1/04. Transcribed from notes.

SPC00566356 – microtextures: Fibrous chalcedony & bladed calcite. Large patches go extinct at same orientation — Has this material been recrystallized? Some crack-seal textures and dust trails parallel to wallrock contact.

SPC00566362 – microtextures: big blocks of calcite go extinct at same orientation (max 1 cm). Weird general lack of twins. The few I see appear thin. Grainy texture – it's almost as if it's a micritic cement with a preferred orientation. Definitely Class B. Strange rosettes need explanation:

sketch.



parallel extinction
not pleiochroic
no color
0.1 mm length (avg)

SPC 00566362 – Sundance breccia/gouge.
Good intercrystalline fractures. Thin section isn't quite thin enough. Obvious chalcedony & blocky quartz. No calcite.

SPC 00552529 A & B – No calcite matrix, throughgoing fractures. Suggestions of chalcedony/quartz – needs thinning.

May 13, 2005 continued

SPC 00552528 – No calcite. Wallrock to fault rock transition – pretty descrete. Needs more thinning.

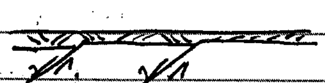
SPC 00566359 – No calcite present in matrix.

SPC 00566369 – vein fill with beautiful paragenesis. doesn't look like breccia at all. Needs thinning.

SPC 00566370 – I don't know the mineralogy of large blocky crystals in this section → quartz? Calcite present in small crystals. Chalcedony also present in clusters. Examine thinsection further – thin more.

SPC00552515 – One throughgoing fracture filled with Coarse calcite. One really large crystal (~1.5cm in diameter) nearly fills fracture. This plus field book description confirms Class B.

SPC 00566358 – A shear with a thin layer of secondary minerals.



This is a right-lateral fault. Coating of minerals is fibrous, chalcedony? The chalcedony doesn't appear to be ductilely deformed but is cross cut by minor shears.

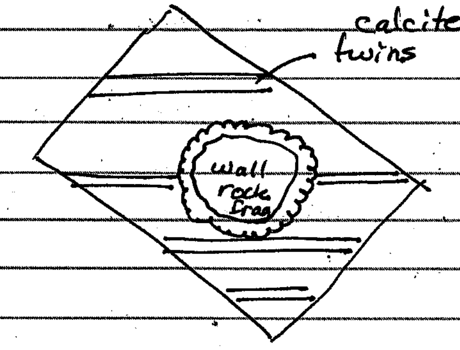
SPC 00552521A – Beautiful minor fault arrays. These show sense of shear, Fabric development corroborates. Note chalcedony but no calcite. Is this the missing link? i.e. the connection between Classes A, C & D?

SPC 00552527 – No calcite – not Class B. too thick.

SPC00552513 – Contains calcite – heavily mineralized. Need to study this one further.

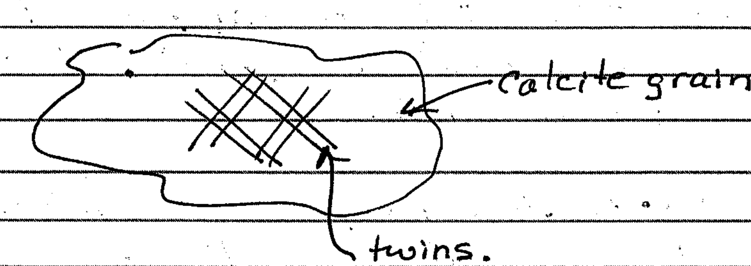
May 13, 2005 continued.

SPC00552516 A&B – Contains large crystals of calcite & also contains clasts of wall rock coated in opal/chalcedony.



SPC00552520 – Poor thin section – contains fragments of zeolitized tuff. Plucking severe. matrix unknown.

SPC 0055 25-22 A&B – Contains abundant large crystals of calcite. Beautiful twins. Strange core/rim structure. Cores look deformed & rims do not. What's going on?



SPC0055 25 23 A & B –
Large ~~pc~~ crystals of calcite. 5 mm max diameter in this thin section. Offset twins in section A.

SPC00552524 A&B – Maximum diameter calcite = 7mm. Non throughgoing twins. Some offset twins. The edge of the thin section looks like there might be some crack seal texture. Section B shows an awesome display of offset twins. Jig-saw puzzle texture.

May 13, 2005 continued.

SPC 00566368 – Abundant blocky calcite on perimeter of clast & also fracture fill within. Calcite deformation? Large crystals.

SPC 00566371A – Class B? Hw↑ lots of blocky calcite fills in pores? Calcite shows a least on case of offset twins. What is this lithology?

SPC 00534018 – this is a Class B fault zones – although calcite crystals a small – discernable twins. Zeolites and phenocrysts in wall rock.

SPC 00552525 C – Beautiful Class B fault rock – not a high percentage of calcite though. Mosaic of wall rock fragments.

SPC 00552526 A&B Small amounts of blocky calcite but definately constitutes matrix in this fault rock.

SPC 00566353 A&B Beautiful Class B breccia – big crystals of calcite enclosing wall rock clasts. Would make a nice photo.

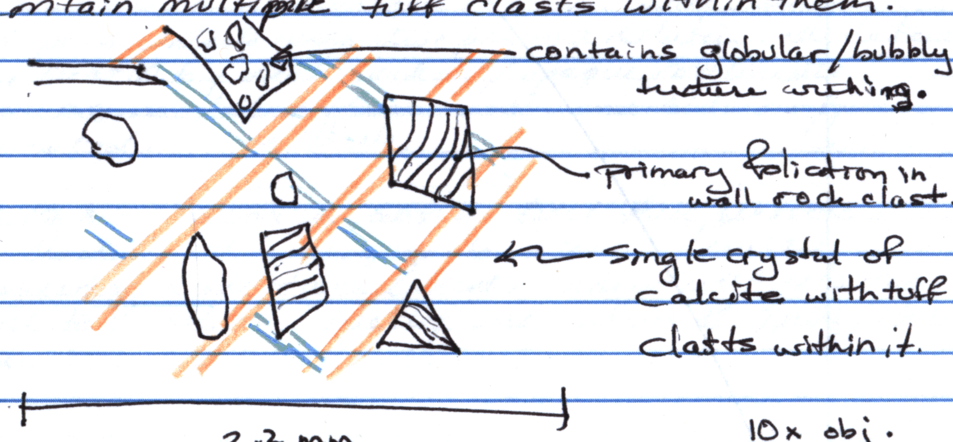
SPC 00566354 B&A Beautiful bladed calcite crystals with overgrowths / coatings of travertine(?) → Has ~~Fa~~ fibrous habit, clear, birefringent. Plus a blocky phase with twins (growth twins?). No obvious indicators of deformation.

May 13, 2005 continued

SPC 00566357 B. – Beautiful Class B fault breccia. 1mm diameter calcite crystals on average. 3mm diameter maximum. >> 50% calcite.

SPC 00530196 – this rock has a mixture of textures. Some highly angular fragments of single crystals and then some "globular" (rounded) clasts which have a foliation within. These rounded clasts are floating in a matrix and are subrounded to rounded and highly spherical to subspherical. The foliation within them looks primary – eutaxitic or flattening foliation with glass shards flattened in a wavy but discrete foliation. There are discrete discontinuities that cut across this thin section. "Knife sharp", they are intergranular. Perhaps these are small brittle fractures/faults.

SPC 00530198E – Impressive calcite mineralization in this thin section. The calcite crystals are huge and surround clasts of tuff. The calcite crystals are impressive in that they envelope individual clasts and contain multiple tuff clasts within them.



May 13, 2005 continued.

SPC 00530198A – Some very nice examples of calcite – clast textures that are reminiscent of "explosion" breccias. The clasts fit together as a jigsaw puzzle and foliations within them are sub parallel to clasts adjacent to them. Some nice images for photography.

Mary Beck Gray 5/13/05

May 13, 2005, continued.

Below are copies of notes on thin sections. These notes were taken on Sept 7, 1999.

Sept 7, 1999

#02016214 – too thick – some suspect calcite supported areas. (some translucent minerals at a minimum). Discrete sliding surfaces. crystal rich lithology phenocrysts are partially resorbed.

#02016215 – same.

#02016216 – discrete sliding surfaces with somewhat thick selvages or concentrated zones of opaques. no calcite too thick

#02016213C – huge patch of calcite – one crystal which supports many clasts of wall rock. Beautiful. too thick. Looked for 2 phase fluid inclusions but couldn't find any. Plenty of single phase gas or liquid inclusions. Could it be that the core exceeded ~50°C during drilling and homogenized all the gas bubbles?

#02016212B – orange red fine grained matrix supporting subrounded/subangular clasts. Some clasts have point contacts suggestive pressure solution indentations as indicated by some darker/opaque materials that are accumulated there and some clasts appear truncated. too thick.

#02016212A – same as above. both thin sections have clasts with intragranular veins. Veins are composed of some translucent mineral with xls too small to resolve. Relief indicative of quartz/chalcedony/opal.

#02016211B – too thick. Beautiful calcite crystals. Quite large. Possibly void filling. Some porosity evident within. Xls are of variable orientation. They don't look very deformed. No noticeable 2 phase inclusions.

May 13, 2005, continued

Sept 7, 1999

#0201 6211A – same as other but this one contains some noticeable twins (mechanical) too thick. Some opaque irregular "selvages" within clasts terminate against calcite.

#02016210 This thin section has very well expressed calcite mineralization. Xls are deformed (twinned) and of variable size. Clasts are remarkably rounded. "Selvages" are well expressed. Here selvages appear to truncate calcite as well as clasts. Intragranular veins.

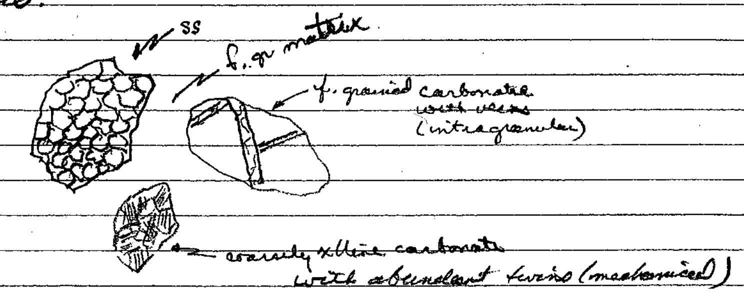
#02016209 Interesting lithology. laths of plagioclase feldspar are very abundant & small. Crudely aligned primary fabric. Very interesting fault zone. Thin, discrete and filled with calcite and chalcedony/opal. The opal is nearest the wallrock where present. chalcedony is fibrous and fibers are at a high angle to the fault plane. The chalcedony lines the wallrock/vein material interface. This lining is discontinuous and present on both sides of the vein material. The interior of the fault zone is blocky vein material (calcite?) Orange staining ("selvage") is present at interface between fault rock and wall rock. Mostly restricted to one side only. Not much apparent separation. One clump of phenocrysts is bisected by the fault zone and appears to have minor separation. Some opaques have crystallized along the interface too. Opaques and much chalcedony and opal is localized to one side of the discontinuity. That side is the <u>upper</u> surface of the fault zone.

May 13, 2005, continued

Sept 7, 1999

#02016208 – blebby patches of calcite – has the appearance of exsolution or resorption texture. Look up lithology for this fault rock. Much calcite. Origin? Texture?

#02016206 – some remarkable clasts in this thin section. Some clasts are cataclasites. Some have uniform sized wellrounded grains within. Monomineralic – uniaxial + [illegible] → quartz? These clasts are probably sandstone clasts. Rounded grains of quartz with quartz cement. Some quartz has undulose extinction but mostly undeformed. Other clasts are cataclasite and some clasts are large crystals of calcite – well deformed. These are either inherited from a deformed crystalline limestone or they are from new minerals in fault rocks.



suggestions of pressure solution selvages in matrix?

May 13, 2005 continued

On the following pages, is a table of my field observations and other locality information from other sources (referenced as appropriate) for each sample site in the ESF & Cross Drift in this study. Included in the Table is classification of fault zones where possible. Table was completed in 2003.

MBB
5/13/05

May 13, 2005, continued

Fault Zone and Related Feature Data.

Locality	Sample identification number	Lithostratigraphic unit	thermal/mech unit	Fault Zone Class	Orientation	Slickenlines	Separation	Core width	Notes	Levy et al. (1999) Cl-36/Cl data
		Mongano et al., 1999	Mongano et al., 1999		strike, dip angle & dip direction	trend, plunge				anomalous in bold
ESF 28+81.5	SPC00566356, SPC00566355, SPC00566354	Topopah - Tptpmn	Tsw2	A	153, 40N			3mm, 20 cm max	field photos	
ESF 35+92.5	none	Topopah - Tptpmn	Tsw2	A					050, 90 strike slip fault terminates against Sundance.	
ECRB 13+06	SPC00566358	Topopah - Tptpmn	Tsw2	A	285, 83N	284, 10		1 mm	shear	
ESF 15+66	SPC00566371	Topopah - Tptrn	TSw1	B	176, 69W		reverse dip separation			
ESF 16+19.2	SPC00566368	Topopah - Tptrn	TSw1	B	145, 87E		normal dip separation			982; "fracture"
ESF 19+36.5	SPC00566362, SPC00566363	Topopah - Tptpul	TSw1	B	300, 85S	299,09		25cm, 30 cm max	Drill Hole Wash A; field photos	
ESF 27+65	SPC00566357	Topopah - Tptpmn	Tsw2	B	322, 38N	346,17		11.5 cm, 20 cm max		
ESF 32+23.5	SPC00566353	Topopah - Tptpmn	Tsw2	B	085, 88N		normal dip separation			
ESF 43+39	SPC00530198, SPC00543700	Topopah - Tptpmn	Tsw2	B	160, 84W	160, 00; 170, 59*		3 cm, 10 cm max	USGS SPC00541297, related fractures: 200, 72W; 160,00 set predates 170, 59 set	
ESF 53+80	SPC00552526	Topopah - Tptpmn	Tsw2	B	330, 74W	240, 74	normal dip separation			
ESF 53+86	SPC00552525	Topopah - Tptpmn	Tsw2	B	215, 82W	031, 29		1.5 cm		
ESF 54+73.5	SPC00552524	Topopah - Tptpmn	Tsw2	B	133, 72S				at intersection with fault 235, 85E, norm sep.	
ESF 54+80.5	SPC00552522, SPC00552523	Topopah - Tptpmn	Tsw2	B	053, 84N		2.5 cm normal dip separation			
ESF 60+44	SPC00552516, SPC00552517	Topopah - Tptpmn	Tsw2	B	348, 80W		0.5 m reverse dip separation	2 cm, 5 cm max.	field photos	
ESF 67+46.5	SPC00552515	Tiva - Tpcpln	TCw	B	125, 81W	166, 76	8 cm normal dip separation	2.5 cm	field photos	
ESF 75+90	none	Tiva - Tpcpln	TCw	B	000, 81W	315, 78	30 cm right lateral strike separation and 45 cm normal dip separaton	3.5 cm core, no measurable damagezone	non-Q sample, confirmed Class B fault, joint 095, 70N appears offset by fault	

May 13, 2005 continued.

Fault Zone and Related Feature Data.

ESF 76+11.5	SPC00534018	Tiva - Tpcpmn	TCw	B	340, 80W		15 cm dip separation, 45 cm right-lateral strike separation	5.5 cm, 18 cm max		
ESF 76+12.4	SPC00543704	Tiva - Tpcpmn	TCw	B	343, 70W				same fault as ESF 76+11.5 but higher in ESF	
ESF 76+17	SPC00543701, SPC00543702, SPC00543703, SPC00534017	Tiva - Tpcpmn	TCw	B	167, 74W; 347, 70W; 356, 74W		norm dip	5 cm, 10 cm max.	USGS SPC00541298	
ESF 35+92.5	SPC00566352, SPC00552529, SPC00552528, SPC00552527	Topopah - Tptpmn	Tsw2	C	352, 81W; 345, 81W	352, 00; 344, 07			Sundance; field photos	**2840**; "fault breccia"
ESF 62+08	SPC00534022, SPC00534023	Topopah - Tptpmn	Tsw2	C	307, 82S	low and high plunge				
ESF 62+09	SPC00552521	Topopah - Tptpmn	Tsw2	C	140, 80W	230, 80; 140, 00; 146, 29	right lateral strike separation and normal dip separation			
ESF 62+70	SPC00552520	Topopah - Tptpmn	Tsw2	C	324, 87E	326, 35		7 cm		
ESF 63+22.5	SPC00552518, SPC00552519	Topopah - Tptpul	TSw1	C	342, 53W	252, 53	normal dip separation	10 cm, 15 cm max		
ESF 76+09	SCP00534019	Tiva - Tpcpmn	TCw	C	198, 75W	288, 75				
ESF 76+47	SPC00534001A	Tiva - Tpcpmn	TCw	C						
ESF 76+76.2	SPC00534000	Tiva - Tpcpmn	TCw	C	010, 69W					334 - 445; "breccia"
ECRB 4+99	SPC00552507	Topopah - Tptpul	TSw1	C	211, 64N			4 cm, 25 cm max; 2 m damage zone	left rib Ghost Dance?	
ECRB 11+35	SPC00566360	Topopah - Tptpmn	Tsw2	C					Sundance	
ECRB 11+35.4	SPC00552506	Topopah - Tptpmn	Tsw2	C	279, 70N	279,00			Sundance	
ECRB 11+35.5	SPC00566359	Topopah - Tptpmn	Tsw2	C	271, 80 N	271, 00		30 cm	Sundance	
ECRB 25+37.36	SPC00543709	Topopah - Tptpln	TCw	C	013, 80W				fault	
Alcove 5 01+00	none			C	200, 08W	030, 08	reverse dip separation		thrust	
alcove 6 00+36	SPC00530197			C	012, 87W	198, 65*	l.l. strike slip, norm dip slip	3 cm		
Alcove 6 00+74	none			C	012, 28E		reverse dip slip		thrust, cut across by normal fault: 000, 82,E	

May 13, 2005, continued.

Fault Zone and Related Feature Data.

alcove 6 00+84	SPC00543705			C	124, 14E		reverse dip separation		thrust	
alcove 6 00+85.5	SPC00534025			C			reverse dip		thrust	
alcove 6 00+97	SPC00530195			C	170, 71W			1.4m	Sundance	
Alcove 6 01+23.7	none			C	285, 46N	015, 46	reverse dip		thrust	
alcove 6 01+52	SPC00530196; SPC00534024			C	200, 83W; 024, 90		normal separation		Ghost Dance	
ESF 67+84.9	SPC00552512, SPC00552511, SPC00552510	Tiva - Tpcpln	TCw	D	164, 74W	221, 71	7 m minimum normal dip separation	30 cm, 5 cm damage zone	Dune Wash Western Splay	
ESF 67+85.2	SPC00534021	Tiva - Tpcpln	TCw	D	148, 85W		normal dip separation		Dune Wash	
ESF 67+87.2	SPC00534020	Tiva - Tpcpln	TCw	D					Dune Wash; field photos	475; "fault/graben"
ESF 67+89	SPC00552513, SPC00552514	Topopah - Tptrn	TSw1	D	355, 63W	275, 62			Dune Wash Eastern Splay; field photos	
ECRB 25+84.8	SPC00552500	Topopah - Tptpln	TCw	D	202, 57W		normal dip separation	foliated gouge 6 m, 2 - >8 cm thick	Solitario Canyon	
ECRB 25+85.1	SPC00543706, SPC00543707	Topopah - Tptpln	TCw	D	190, 60W; 193, 50W				Solitario Canyon	
ECRB 25+85.5	SPC00552501	Topopah - Tptpln	TCw	D	201, 65W				Solitario Canyon	
ECRB 25+86.0	SPC00552502	Topopah - Tptpln	TCw	D			norm dip separation		Solitario Canyon	
ECRB 25+86.2	SPC00552503	Topopah - Tptpln	TCw	D					Solitario Canyon	
ECRB 25+86.3	SPC00543708	Topopah - Tptpln	TCw	D	188, 58W				Solitario Canyon	
ECRB 25+87.5	SPC00552504	Topopah - Tptpln	TCw	D					Solitario Canyon	
ESF 16+12.4	SPC00566369	Topopah - Tptrn	TSw1	na						382; "cooling joint"
ESF 16+42.65	SPC00566365, SPC00566366	Topopah - Tptrn	TSw1	na	286, 90	286, 80	normal dip separation	4 cm	sheared cooling joint, no section	
ESF 16+44	SPC00566367	Topopah - Tptrn	TSw1	na					cooling joint with foliated gouge, no section	
ESF 24+37.5	SPC00530192, SPC00530193	Topopah - Tptpul	TSw1	na	040, 80E	041, 06; 059, 62; 130, 80 (HW up) ; 210,			cooling joint; 130,80 slickenlines	
ECRB 20+87	SPC00543710	Topopah - Tptpll	Tsw2	na					mineralized lithophysal cavity	
ESF 15+05.7	none	Topopah - Tptrn	TSw1	?					135, 82S terminates against 207, 74W	

May 13, 2005 continued.

Fault Zone and Related Feature Data.

ESF 16+02	SPC00566370	Topopah - Tptrn	TSw1	?					Sample insufficient to classify	
ESF 16+58.5	SPC00566364	Topopah - Tptrn	TSw1	?	214, 85W		normal dip separation		no section	
ESF 19+28.5	SPC00566361	Topopah - Tptpul	TSw1	?	321, 76W	321, 00		15 cm , 30 cm max	Drill Hole Wash B, left rib	
ESF 19+42	SPC00530190, SPC00530191	Topopah - Tptpul	TSw1	?	160, 85E				Drill Hole Wash B, field photos, right rib	2290; "breccia"
ESF 53+80	none	Topopah - Tptpmn	Tsw2	?	068, 90	vert slicks	normal dip separation		offsets a Class B fault (330, 74W, with dip slicks)	
ESF 59+75	none	Topopah - Tptpmn	Tsw2	?	212, 69W	302, 69	reverse dip separation		this fault offsets 320, 85E by 10	
ESF 59+84	none	Topopah - Tptpmn	Tsw2	?					325 striking r.l. faults offset 065 striking faults	
ESF 67+76.4	none	Tiva - Tpcpln	TCw	?	142, 79W	142,00				
ESF 75+35	none	Tiva - Tpcpln	TCw	?	339, 78W	249,78		9 cm core, 15 cm maximum		
ESF 75+62.8	none	Tiva - Tpcpln	TCw	?	058, 71W			3 cm core		
ESF 75+74.7	none	Tiva - Tpcpln	TCw	?	002, 73W		2.5 cm dip separation, left lateral strike separation	2 cm core, 4 cm max, no measurable damage zone	class B confirmed in the field only	
ESF 75+78	none	Tiva - Tpcpln	TCw	?	342, 73W			6 cm core, 7.5 cm damage zone		418; "breccia"
ESF 75+89	none	Tiva - Tpcpln	TCw	?	005, 79W		normal dip separation	15 cm		
ECRB 13+16.5	none	Topopah - Tptpmn	Tsw2	?	345, 90	345, 00	strike slip			
ECRB 13+17	none	Topopah - Tptpmn	Tsw2	?	160, 90	160, 00	strike slip			
ECRB 25+78	SPC00552505	Topopah - Tptpln	TCw	?					no section	

May 13, 2005 continued

Attached below is a CD containing a manuscript accepted for publication at the Journal of Structural Geology. We have yet to receive gallies of the manuscript from the journal.

Mary Beth Gray

Information Potentially subject to copyright protection was redacted from this location. The redacted material is a CD containing the Gray, et al. manuscript to the Journal of Structural Geology, accepted 01/27/2005.

May 13, 2005 continued.

On 1/27/05, I received notice from the Journal of Structural Geology that our manuscript was accepted for publication.

Tom Blenkinsop, 1/27/05 7:22 PM -0400, Your paper

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Date: Fri, 28 Jan 2005 09:22:15 +1000
Subject: Your paper
From: Tom Blenkinsop <thomas.blenkinsop@jcu.edu.au>
To: Mary Beth Gray <mbgray@bucknell.edu>
X-Proofpoint-Spam-Details: rule=opt-in_notspam policy=opt-in score=0 mlx=0 adultscore=0 adjust=0
engine=2.5.0-05012100 definitions=2.5.0-05012601
Status:
```

Mary Beth -

Please see my letter attached.

Tom

Tom Blenkinsop,
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Email Thomas.Blenkinsop@jcu.edu.au http://www.es.jcu.edu.au/
Tel. 617 4781 4318
Deformation Microstructures and Mechanisms in Minerals and Rocks:
FAX 617 4725 1501
http://www.wkap.nl/prod/b/0-412-73480-X

2004-02authb

May 13, 2005 continued.

Below is a copy of the attachment to the 1/27/05 email on the opposite page. Note typo in letter.

MBG

Journal of Structural Geology

30th August 2004 ← NOTE THIS IS A TYPO MBG

Dear Mary Beth,

Thank you for the revised version of your paper. I am glad to accept it for the Journal of Structural Geology. You should expect to receive the proofs in a few months.

I am assuming that you wish to have figures 5, 7 and 9 reproduced in colour: you will be billed according to the schedule below.

Yours sincerely,

Tom Blenkinsop

Charges for colour pages: first page US$/EUR 350, every following $/E 175.

received via email 1/27/05 from Tom Blenkinsop

Mary Beth Gray

5/23/01

I HAVE REVIEWED SCIENTIFIC NOTEBOOK 261 AND FIND IT IN COMPLIANCE WITH QAP-001. THERE IS SUFFICIENT INFORMATION REGARDING THE PROCEDURES USED TO CONDUCT THE RESEARCH AND TO ACQUIRE AND ANALYZE THE DATA SO THAT ANOTHER QUALIFIED SCIENTIST COULD REPEAT THE ACTIVITY OR ACTIVITIES RECORDED IN THIS SCIENTIFIC NOTEBOOK

[signature]

JOHN STAMATAKOS 05/23/05
MANAGER- GLGP