Questa Baseline and Pre-Mining Ground-Water Quality Investigation 6: Preliminary Brittle Structural Geologic Data, Questa Mining District, southern Sangre de Cristo Mountains, New Mexico

Prepared in Cooperation with the New Mexico Environment Department

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U.S. Geological Survey

Introduction

The field data presented in this Open File Report were collected in the vicinity of the Red River Watershed and ground-water basin (RRW) by the author primarily during autumn of 2002. The data were collected as part of a U.S. Geological Survey investigation of the geological and hydrogeological conditions in the vicinity of the southern margin of the Questa Caldera, northeastern New Mexico (Lipman and Reed, 1989 and Figure 1). The data include detailed outcrop scale measurements, observations, and descriptions of lithology and geologic structure within and around a well exposed and mineralized Tertiary caldera. Fault zone and fracture network geologic and geometric properties such as orientation, composition, mineralization and alteration, density, length, width, etc. were recorded and numerous rock samples were collected. Explanations of the methods used in this characterization are provided below and can be found in (Caine and others, 1996; Caine, 2001a, b, c; Caine and Tomusiak, in press).

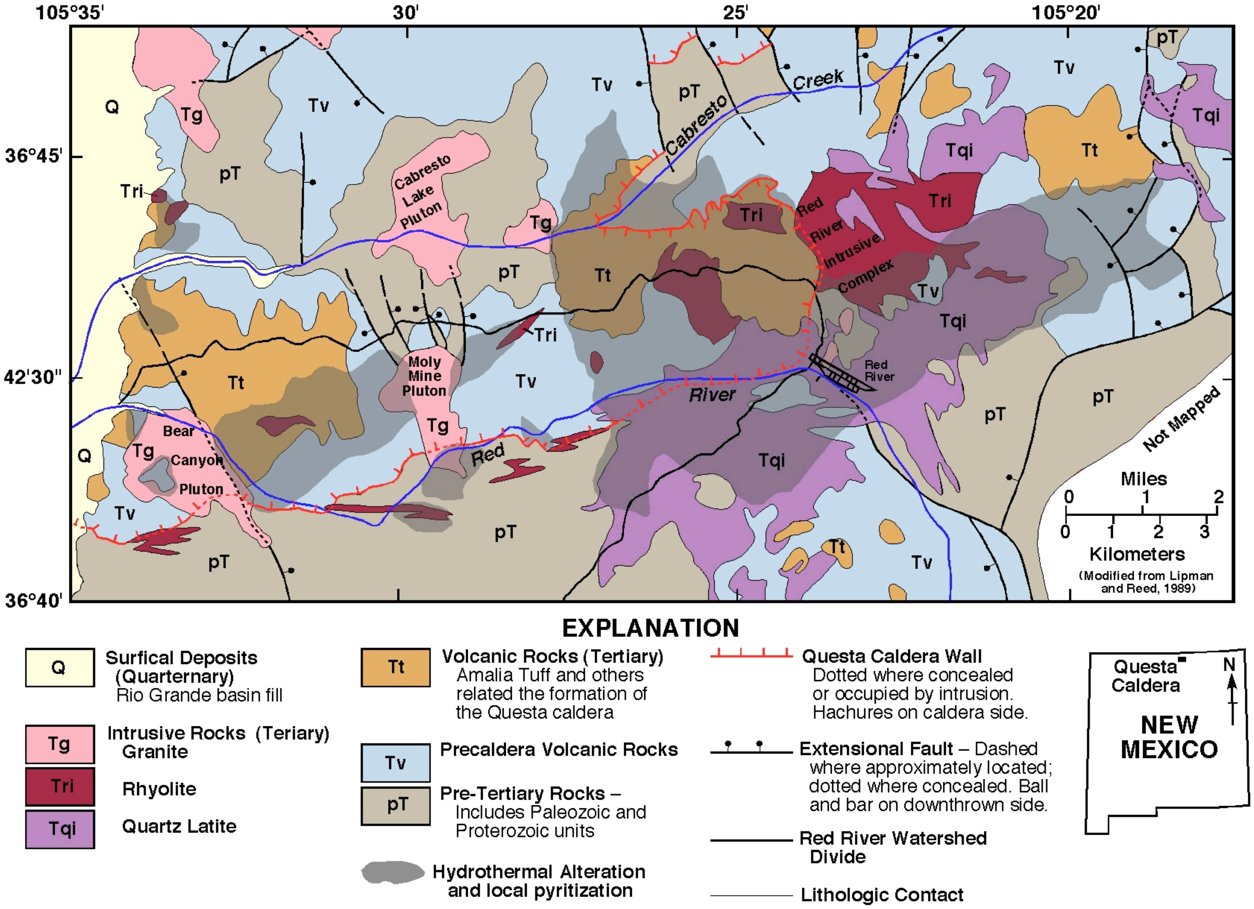

Figure 1: Simplified geologic map of the southern portion of the Questa Caldera in the vicinity of Red River, New Mexico modified from Lipman and Reed, 1989. The individual rock types shown are a starting point for conceptualizing what might be hydrologically significant units or domains in the study area. Note that the areas impacted by hydrothermal alteration are shaded transparent gray.

The purpose of this Open-File Report is to provide the raw field data from this investigation. Interpretation of this data will be reported in future publications. The field data were tabulated into a computer spreadsheet program and are shown below. The spreadsheet file is available upon request from the author and it is suggested that it be obtained for any use of the data. The data will be used to characterize the geologic and geometric properties of fracture networks and fault zones related to episodes of tectonism, volcanism, and magmatism that occurred in the various rock units from Precambrian though Tertiary times. Characteristics of these structures will likely provide insight into the potential affects that they may have on the present-day hydrogeology of the northwestern Red River ground-water basin and watershed (Figure 1).

The central portion of the Red River watershed is underlain by fractured Tertiary volcanic and intrusive rocks that cut Precambrian metamorphic rocks (Figure 1). A long geologic history of tectonism has resulted in the development of extensive and complex brittle structures in all lithologies. Due to the typically low primary permeability of crystalline rocks, the brittle structures found in the region are thought to have largely controlled paleo-fluid flow and mineralization, as well as present day ground-water flow and storage. These rocks were mineralized by extensive hydrothermal alteration and pyritization at least in part related to Tertiary emplacement of granitic plutons. The mineralization also resulted in precious and base metal deposition (Meyer and Foland, 1991). The most significant economic mineral is molybdenite. It has been intermittently mined from underground and open pit workings for over three quarters of a century to the present day. Both the interaction of natural surficial processes with acid-sulfate altered bedrock and mining activities have liberated metal and acid loads to surface and ground waters. The reader is referred to existing publications for details regarding Questa caldera geology, history, and environmental impacts (Carpenter, 1968; Clark, 1968; Rehrig, 1969; Lipman, 1988; Meyer and Leonardson, 1990 and 1997; Meyer and Foland, 1991).

Collection of Fracture Network and Fault Zone Data in the Field

Overview

Fracture network and fault zone characterization data were collected in the central portion of the RRW (Figure 2). The purpose is to better document and characterize fracture network and fault-related hydraulic heterogeneities that potentially exist in this segment of the ground-water basin and watershed as well as to answer a few fundamental questions about the complex, crystalline bedrock aquifer system that underlies the RRW: (1) what are the types, densities, and interconnections of brittle structures – joints, faults and, fault zones, and what might their potential hydraulic nature be (for example, open versus mineral-filled fractures and open versus gouge-filled fault cores)? (2) How do these brittle structures vary between major individual lithologies? (3) How do brittle structures vary from one major lithology to another? (4) How might these structures and other geological heterogeneities control the occurrence, transport, and fate of naturally-occurring and mining-related constituents, primarily acid and metal loads, in local and regional surface and ground waters?

Several approaches have been used to characterize the physical features of fracture networks and fault zones in the field and to attempt to infer their potential affects on bedrock hydrogeology. These include (1) aquifer hydraulic tests and numerical modeling with discrete fracture network modeling schemes (Anna and Wallman, 1997; Jones and others, 1999); (2) fracture network data collection from outcrops, pavements, and tunnels (Sweetkind and others, 1997) and the subsequent numerical modeling of hydraulic parameters based on the outcrop data (Caine and Tomusiak, in press); (3) analysis of mineralized and altered fracture networks as indicators of the systematics of paleoflow in an aquifer (Taylor and others, 1999); (4) borehole televiewer logging

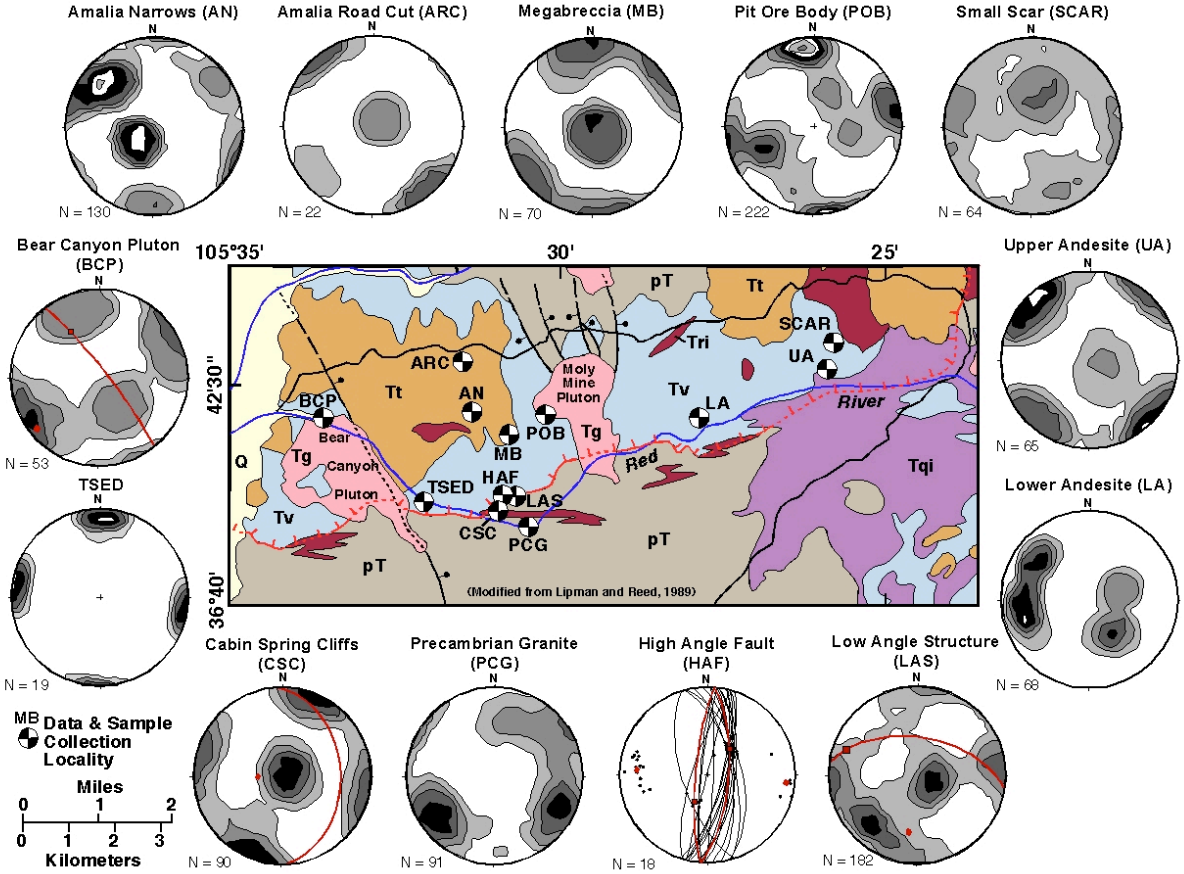

Figure 2: Cutout of the southwest section of the simplified geologic map of the Questa caldera shown in Figure 1 (modified from Lipman and Reed, 1989). Fracture network and fault zone data-collection localities are shown (BCP = Bear Canyon Pluton, AN = Amalia Narrows, ARC = Amalia Road Cut, MB = Megabreccia, TSED = Tertiary Sediments, HAF = High Angle Fault, LAS = Low Angle Structure, CSC = Cabin Spring Cliff, PCG = Precambrian Granites, POB = Pit Ore Body, LA = Lower Andesite, UA = Upper Andesite, SCAR = Small Scar Outcrop). Zones of hydrothermal alteration shown in Figure 1 have been removed for clarity. Poles to fractures are shown and contoured on equal-area nets using the Kamb method. All contour intervals are 2□ and N = the number of fractures measured. Mean great circles for fault plane orientations and their mean poles are shown in red. All plots were generated with the computer program "Stereonet" by Allmendinger (1995).

and flow metering (Paillet and Pedler, 1996); (5) lineament analyses (Bryant and others, 1975; Mabee and others, 2002); and (6) environmental tracer analyses (Abelin and others, 1991). Many studies, however, only address one of two major components of the needed information for comprehensive ground-water resource evaluation in fractured rock at the watershed-scale. An exception is from work at Mirror Lake, New Hampshire (Barton, 1996; Hsieh and Shapiro, 1996; Tiedeman and others, 1998). These components include either field-based characterization of the structural, lithologic, and geometric properties of fracture networks and fault zones as well as the shape and size of the geologic domains or bodies in which they exist (typically from the borehole to outcrop to aerial photographic / map scales) or aquifer hydraulic testing to directly measure hydraulic parameters from such features (typically at the scale of individual to multiple boreholes). The following briefly describes the field data collection techniques used in the RRW study that comprises the first of these components. The intention is that these data will ultimately be used to help interpret the results of aquifer hydraulic tests and other hydrologic and modeling investigations.

Outcrop Selection and Random Fracture Network Data Collection in Representative Outcrops

Geologic maps (Lipman and Reed, 1989; Meyer and Foland, 1991) and field reconnaissance during the 2000 and 2001 field seasons were used to select representative exposures of the dominant lithologies. Thirteen suitable localities with 17 outcrops were chosen for characterization, data, and sample collection. Natural outcrops with length scales of at least 30 meters and exposures of at least two nearly orthogonal faces were sought. By taking measurements on two nearly orthogonal faces, fractures that were subparallel to one face were captured on the second face thus reducing bias generated from the orientation of the measurement face. Measurements were collected using a modified scanline sampling method (Caine, 2001c; Caine and Tomusiak, in press). Typically several scanline pairs were analyzed at each locality. A graduated tape, or "scanline" was stretched across the outcrop face and where practical, scanlines were set up at near right angles to major fracture sets to further avoid scanline-fracture set orientation bias. For each fracture that intersected the tape position (from which spacing and density are derived), orientation, trace length, an estimate of aperture, degree and type of mineralization, shape, roughness, termination and any indicators of timing relationships (for example, crosscutting and offset of other fracture sets) were recorded. These parameters form the basic fracture data reported in the spreadsheet below. Rock type, 'unit' contacts, compositional layering, indications of structural position in larger scale structures, foliations and a variety of lineations were also recorded at each locality.

Data Format and Contact Information for Additional Copies

Raw field data were entered into a spreadsheet computer program and formatted with all pertinent information regarding outcrop location, geology, date, comments, samples, and photographs taken. Measured orientation data for each fracture encountered on a scanline were tabulated into an individual data column in the spreadsheet to facilitate calculations and transferability into other computer codes. Other data are reported in other columns and text boxes throughout the spreadsheet. In order to collect field data rapidly numerous abbreviations were used in the field notes. These are listed below.

Contact Jonathan Caine, U.S. Geological Survey, jscaine@usgs.gov.

Abbreviations Used in the Data and Spreadsheet

~ = approximately, alt = alteration, and = andesite, aps = aperture, avg = average, blk = black, carb = carbonate, cm = centimeter, cnt = contact, crg = clay-rich gouge, ddz = distributed deformation zone, dfs = down from south (s), east (e), north (n), west (w), etc., dir = direction, dz = damage zone, elev = elevation, esp = especially, fe = iron, flt = fault, frac(s) = fracture, fw = footwall, hor = horizontal, jnt = joint, ldz = localized deformation zone, lin = lineation, m = meter, mm = millimeter, mn = manganese, na = not available or collected, NM = New Mexico, no = number, oc(s) = outcrop(s), ox = oxide, PC = Precambrian, porph = porphyry, prop =

propylitic, rhy = rhyolite, rot = rotated, RS = Riedel shears or fractures, rx = rocks, sed = sedimentary, sh = shale, sst = sandstone, stdev = standard deviation, surf = surface, T = Tertiary, TL = trace length, trunc = truncated, vol = volcanics, vert = vertical, wp = waypoint, xls = crystals. Note: GPS Map Datum = WGS 84. Most other abbreviations are standard.

Measurement Localities

Location and elevation data is taken from a hand-held Geographic Positioning System receiver and from U.S.G.S. topographic maps (Questa and Red River, U.S.G.S., 7.5 minute quadrangles). UTM coordinates are in continental U.S. Zone 13. Latitude and longitude format is: degrees minutes seconds. Scanlines were collected from multiple elevations at each locality, thus one representative location is reported for all scanlines measured at each locality.

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Acknowledgments

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Questa Fracture, Fault Zone, Lithologic, and Sample Data

Collected and Compiled by Jonathan Saul Caine, U.S. Geological Survey, Autumn, 2002

Abbreviations Used in This File: ~ = approximately, alt = alteration, and = andesite, aps = aperture, avg = average, blk = black, carb = carbonate, cm = centimeter, cnt = contact, crg = clay-rich gouge, ddz = distributed deformation zone, dfs = down from south (s), east (e), north (n), west (w), etc., dir = direction, dz = damage zone, elev = elevation, esp = especially, fe = iron, flt = fault, frac(s) = fracture, fw = footwall, hor = horizontal, jnt = joint, ldz = localized deformation zone, lin = lineation, m = meter, mm = millimeter, mn = manganese, na = not available or collected, NM = New Mexico, no = number, oc(s) = outcrop(s), ox = oxide, PC = Precambrian, porph = porphyry, prop = propylitic, rhy = rhyolite, rot = rotated, RS = Riedel shears or fractures, rx = rocks, sed = sedimentary, sh = shale, sst = sandstone, stdev = standard deviation, surf = surface, T = Tertiary, TL = trace length, trunc = truncated, vol = volcanics, vert = vertical, wp = waypoint, xls = crystals. Note: GPS Map Datum = WGS 84. Most other abbreviations are standard.

entry			orientation		lin			intensity			
no	**outcrop wp**	**outcrop description**	**strike**	**dip**	**lin**	**dir**	**feature**	**count**	**length (m)**	**rock type**	**comments and coordinates**
1	**1008022a**	hi ridge silicified and(?)	none				sample			silicified breccia	sample at top western edge of small scar

GPS Coordinates (UTM 13s)		GPS elev	GPS error
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
460683	**4063555**	**9526**	**17**

entry no	outcrop wp	outcrop description	strike	dip	lin	dir	feature	count	length (m)	rock type	comments and coordinates
2	**1008023**	top west edge small scar	036	72	86	dfn	slip surf			white alt tuff	weak lin
			228	18			sub horizontal flow(?) boundary				photos 4 and 5
			156	78	90		slip surf				sample c
		high small scar oc	324	44			fractures	9	0.6		
			035	70				8	0.6		
			126	87				5	0.6		
			360	82				8	0.6		
			274	80				12	0.6		
			242	82				10	0.6		
			053	90				14	0.6		
			154	66				8	0.6		
			178	60				9	0.6		
			341	90				8	0.6		
			016	46				10	0.6		
			011	45				6	0.6		
			002	55				6	0.6		
			249	83				5	0.6		
			154	79				5	0.6		
			071	63				7	0.6		
			267	83				8.125	0.6		
			226	28			**average intensity**	**13.5**	**per meter**		
			021	68			**n**	**17**			
			300	86							
			098	40							
			124	53							
			101	34							
			103	36							
			181	85							
			114	27							
			106	31							
			085	39							
			024	70							
			011	68							
			130	89							
			098	36							
			146	24							
			310	7							
			091	18							
			041	90							
			036	78							
			255	81							
			231	46							
			272	52							
			341	6							
			004	81							
			093	44							
			164	87							
			115	72							
			240	74							
			272	53							
			006	88							
			140	87							

General Notes

- random data collection
- all sets have similar spacing except for low angle set that has ~ 1/0.3m
- only fracs with tl ~>2m counted
- photos 4,5 9,10, ocs where photos 1-3 were taken in scar
- sample c
- most fracs fe ox coated
- apertures ~1mm or less but a few are weathered to ~1cm
- many joints terminated against others
- TLs are tough to obtain ~avg 1m but many ~1 decameter and few ~3m

GPS Coordinates (UTM 13s)		GPS elev	GPS error
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
460767	**4063514**	**9475**	**28**

				120	23							
				028	36							
				241	48							
				140	33							
				321	30							
				024	84							
				104	30							
				085	72							
				217	71							
				248	63							
				115	23							
				090	24							
				177	84							
				170	87							
				243	58							
				242	86	**n=**	**65**					
3	**1008023a**	top west edge small scar		036	72	86 dfn		slip surface			white alt tuff	weak lin
4	**1008023b**	top west edge small scar		none				sample			fe ox frac coating in white alt tuff	
5	**1008023c**	top west edge small scar		156	78	90		slip surf sample			white alt tuff	
6	**1008024**	and ridge above treatment plant		none				outcrop			prop alt and porph	
	upper		set 1	283	83			fractures			Tand	
	andesite			074	88				6	1		
	outcrop			069	90				9	1		
				249	85				8	1		
				244	82				6	1		
				243	82			**average intensity**	**7.25**	**per meter**		
				070	70							
				040	76			• set 1 TLs				
				044	80			max ~ 2m, min ~ 0.1m, avg ~ 0.5m, stdev ~1.3				
				040	81							
				038	70							
				047	88							
				046	68							
				041	86							
				044	87							
				049	70							
				216	86							
				210	83							
				221	87							
				213	86							
				209	85							
				218	64							
				223	80							
				048	62							
				216	86							
				038	82							
				036	69							
				044	68							
				040	84							
				042	75							
				040	90	**n=**	**31**					
			set 2	320	86			fractures			Tand	
				308	82				7	1		
				328	64				9	1		
				307	76				9	1		
				134	80				8	1		
				312	78			**average intensity**	**8.25**	**per meter**		
				324	78							
				313	88							
				306	76			• set 2 TLs				
				312	76			max ~ 3m, min ~ 0.1m, avg ~1m, stdev ~2.1				
				311	76							
				310	85							

General Notes

- photos 11 and 12
- random collection by visualized, arbitrarily labeled sets
- andesite porphyry is highly weathered and rich in pyrite
- fractures are fe oxide stained
- 3 major near orthogonal frac sets with short fracs between main sets
- no visible slip surfs
- all fracs have similar spacing and TLs that are highly truncated into one another

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
460628	**4062932**	**8856**	**9**

	306	82		
	309	90		
	304	78		
	316	78		
	314	82		
	309	79	**n=**	18

low angle se set	233	26			fractures
	202	16			
	125	40			
	252	28			
	231	20			
	106	26			
	147	32			
	256	10			
	093	19			
	269	18			
	235	27			
	216	24			
	194	45			
	130	22			
	026	10			
	202	30			
	221	19	**n=**	17	

6	1	Tand
5	1	
5	1	

average intensity 5.33 **per meter**

- low angle se set TLs
  max ~1m, min ~ 0.1m, avg ~<1m, stdev ~0.64

7	1008024a	and ridge above treatment plant		none			sample	prop alt and porphyry	
8	1009021	base main pit rhy porph		060	62	73 dfw	slip surf	rhyolite porphyry	very weak lin
				160	76	60 dfs	small fault	rhyolite porphyry	strong lin
	last bench above base of main pit		subsidiary fault data	342	65		subsidiary frac in small flt from photo 19	rhyolite porphyry	
				336	74		"		
				347	54		"		
				327	60		"		
				342	50		"		
				340	66		"		
				321	52		"		
				330	70		"		
				328	48		"		
				225	58		"		
				196	60		"		
				201	64		"		
				192	36		"		

- small fault subsidiary fractures have an average intensity of ~ 14/0.2m or 70 per meter and an average TL of ~0.14m, aps ~<1mm, curviplanar

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
454529	**4062025**	**8747**	**13**

subhorizontal set	354	36	fractures	rhyolite porphyry
	340	51		
	062	27		
	319	44		
	332	34		
	323	47		
	354	22		
	348	18		
	332	42		
	340	46		
	341	60		
	339	42		
	343	35		
	342	44		
	342	53		
	332	58		
	341	54		
	334	44		
	334	56		
	335	57		

- scanline intensity of major fe oxide draining fractures
- scanline trend = 340
- measured from nw to se

position (m)		
0.0	*differences*	*differences stats*
1.9	1.9	mean
4.1	2.2	1.7
5.2	1.1	std dev
6.3	1.1	0.81
7.3	1.0	median
9.5	2.2	1.5
11.1	1.6	min
12.0	0.9	0.8
13.1	1.1	max
14.4	1.3	3.6
18.0	3.6	variance
19.2	1.2	0.66
20.0	0.8	kurtosis
21.8	1.8	1.5
25.2	3.4	n
26.9	1.7	18
28.4	1.5	

nnw set	160	70	fractures	rhyolite porphyry
	166	80		
	165	77		

- nnw set TLs ~ > 5 m

nnw set intensities

General Notes

- most fracs are quite planar, have regular orients, and cut min grains and are likely natural. blast related fracs have radial patterns but blasting and excavation may have impacted natural frac intensity and length in a minor way
- although TL is exceptionally hard to measure most fracs appear to truncate into others at ~ 5m +/-. fracs fully cut the outcrop and even if they jog about and link with other fracs result in an effective hydraulic length on order of the size of the outcrop that is ~ 5m high and ~10m long
- most fracs have apertures <1mm. a few weathered and free face fracs have apertures >1cm
- frac spacing appears uniform (enhanced baecher?)
- fractures collected randomly by set and set unassigned
- only fracs > 1m were measured

			• nnw set TLs ~ > 5 m					
	167	78			8	1		
	162	78			5	1		
	169	80			9	1		
	158	80			7	1		
	155	75			6	1		
	170	58			6	1		
	148	76			7	1		
	151	82			6	1		
	158	76			5	1		
	168	70			7	1		
	169	76		**average intensity**	**6.6**	**per meter**		
	165	76		**n**	**10**			
	165	78						
	167	74						
	161	76						
	165	67						
	162	80						
	166	81						
ene set	080	84	fractures				rhyolite porphyry	
	087	80			**ene set intensities**			
	079	76	• ene set TLs ~ > 5 m		11	1		
	082	76			7	1		
	088	78			8	1		
	098	52			6	1		
	080	74			9	1		
	110	51			4	1		
	100	68			5	1		
	070	74			4	1		
	085	78			4	1		
	076	90			5	1		
	086	79			4	1		
	070	50		**average intensity**	**6.09**	**per meter**		
	092	67		**n**	**11**			
	071	78						
	091	71						
	101	76			**sub hor set intensities**			
	082	84	• sub hor set TLs ~ > 5 m		7	1		
	085	74			9	1		
	092	72			8	1		
	095	85			9	1		
	267	88			6	1		
	090	78			5	1		
	080	81			5	1		fe ox
	079	74			6	1		fe ox
	086	74			4	1		fe ox
					6	1		
random unassigned fractures	080	80	fractures		5	1	rhyolite porphyry	• "random" frac data are from sets that are less prominent than subhor, nnw, ene sets, have lower intensity and TLs ~ <2m
	100	63			5	1		
	178	50			8	1		
	085	81			9	1		
	189	40		**average intensity**	**6.57**	**per meter**		
	191	32		**n**	**14**			
	300	65						
	228	87						
	054	85						
	145	70						
	205	35						
	202	54						
	165	26						
	196	35						
	180	20						
	192	40						
	197	43						
	201	42						
	173	22						
	110	24						
	100	46						
	263	89						
	272	90						

- photos 14, 15, 16 outcrop face looking east
17 point emanation of fe oxide stain

- three dominant ~ orthogonal sets ~ nnw, ene, sub hor

- probably natural only long fractures measured
photo 20 is a blast fracture with radial pattern

- several of the fe oxide stained fracs are small faults and some are veins with pyrite

- small faults show sub cm offset but there is high intensity fracturing and damage along these

- photos 18 and 19 - damage along these structures that might be important for flow - note moly paint

- photos 21, 22, 23 sun shot of main face and orthogonal fracs

- photo 24 looking ne at ew outcrop face that is south
of wp1009021 about 200m. these outcrops likely show distribution of near surface conductive and mineralized fractures

			170	45			
			139	30			
			145	85			
			200	30			
			201	34			
			173	23			
			358	37			
9	**1009021a**	base main pit rhy porph	171	67	sample	rhyolite porphyry	microcracks, note fe ox stain
10	**1009021b**	base main pit rhy porph	180	78	sample	rhyolite porphyry	also frac face
11	**1009022**	oc south of 1009021 next main bench	015	90	orient of oc face	rhyolite porphyry	
			113	37	fractures	rhyolite porphyry	
			050	77			
			289	23			
			355	88			
			178	70			
			353	78			
			295	60			
			350	78			
			347	75			
			280	70			
			094	43			
			350	82			
			257	77			
			290	60			
			351	82			
			255	18			
			270	81			
			187	80			
			107	42			
			258	82			
			013	87			
			091	39			
			359	74			
			355	90			
			297	52			
			356	84			
			111	25			
			057	84			
			082	78			
			076	78			
			260	44			
			002	83			
			355	81			
			110	26			
			300	44			
			106	26			
			044	76			
			083	80			
			322	74			
			006	81			
			082	89			
			108	34			
			327	60			
			324	63			
			130	42			
			079	80			
			119	40			
			336	58			
			285	73			
			341	70			
			068	82			
			346	90			
			116	36			
			021	87			
			154	84			

General Notes

- randomly collected orientation data for check on consistency with WP1009021.
- frac intensity, TLs, spacing, apertures are similar
- photo 25 looking s at oc face
- many fracs are developed with clotty moly and many of the se show evidence for minor amounts of slip (weak striations) with little visible offset

GPS Coordinates (UTM 13s) east (m)	**north (m)**	**GPS elev (ft)**	**GPS error (+/- ft)**
454691	**4061987**	**8656**	**25**

				245	90						
				264	38						
				030	82						
				027	83						
				120	35						
				110	36						
				070	90						
				309	39						
				074	69						
				326	16						
				330	26						
				076	88						
				190	66						
				282	54						
				071	86						
				234	89						
				147	60						
				350	79						
				244	89						
				158	50						
				160	42						
				120	40						
				112	38						
				273	18						
				091	61						fe ox
				358	90						fe ox
				072	80						
				007	90						
				094	71						
				345	43						
				271	54						fe ox
				298	52						
				342	90						
				182	60						
				250	20						
				157	37						
				089	86						
				299	70						
				275	70						fe ox
				087	88						
				206	64						
				035	70						
				018	68						
				220	41						
				182	28						
				290	57						
				095	70						fe ox
				277	56						fe ox
				325	44						
				082	83						fe ox
				283	62						fe ox
				286	73						fe ox
				088	76						fe ox
				078	84						fe ox
				355	80						
				070	86						fe ox
12	**1009024**	channel ocs by road		217	87	56 dfsw	small fault			Tsed	• epidote and fe ox stain related to PL and localized in flt core with a network of "riedel" dz fracs w an avg orient of 028/78. looks to be hi k, core ~ 3cm
13	**1009024**	channel ocs by road		028	78		avg dz riedel fracs			Tsed	
14	**1009024**	channel ocs by road	e-w set	091	83		fractures	9	1	Tsed	
				086	80			10	1		
				090	85			14	1		
				086	84		**average intensity**	**11**	**per meter**		
				099	90		• e-w set TLs				
				098	87		max ~2m, min ~0.1m, avg ~1.5m, stdev ~1.34				
				091	83						
				093	72		• e-w apertures ~<1mm but up to 2cm at weathered oc face				

General Notes

- stream cut outcrops with n-s joints
- photo 26 looking south at oc
- Tsed fine green and purple sst and sh w very poor exposure of bedding

	095	65				
	092	70				
n-s set	001	90	fractures	6	1	Tsed
	017	84		3	1	
	007	85		5	1	
	007	87		7	1	
	012	84		4	1	
	186	86	**average intensity**	**5 per meter**		
	196	86				
	190	88				
	358	89	**joint zone intensity ~**	7	0.23	
	185	87	**average intensity**	**30.4 per meter**		

- n-s set TLs
  full length of oc ~4 to 5m
- n-s apertures ~<1mm except where weathered then ~up to 2cm
- n-s spacing ~uniform except in jnt zones ~ 1/4 m

- many fracs are coated with epidote
- several small intrusions cut oc
- all frac set spacing ~uniform
- many n-s fracs are pyrolusite (mno) dendrite coated
- volcaniclastic "clots" make this unit appear chaotic
- many small plumose joint surfaces w ~vertical axes possibly indicating rotation?
- fracs other then e-w and n-s are present but are rather chaotic, ~<0.3m TLs, and intensities ~ >10/m and are likely due to weathering

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
452001	**4060174**	**7738**	**26**

15	**1009024a** channel ocs by road	306	52	sample	Tsed	sample orient

16	**1009025** large e-w outcrops w steep faults	photos

General Notes

- binocularlizing shows steep n-s trending normal flts that form conjugate sets. a few offset mafic sills/dikes up to ~ l meter.
- photos 28-32 looking n at these flts

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453585	**4059858**	**7840**	**na**

17	**1010021** top and easternmost ocs above cabin spring	226	82	biotite foliation	PC prop alt granite to granodirite

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453982	**4060286**	**8838**	**110**

18	**1010022** sub hor strs at upper eastern most cliffs	004	2	sub hor str	T volcanics (rhy porph)
	small fault traverse west to east **0.0m**	217	86	frac and oc west edge	T volcanics (rhy porph)
		130	82	avg orient for chaotic generally vertical flow banding	
		005	86	fractures	T volcanics (rhy porph)
		013	82		
		324	80		
		324	78		
		060	81		
		271	16		
		059	90		
		001	84		
		284	66		
		013	87		
		102	72		
		328	78		
		214	89		
		173	06		
		197	22		
		324	05		
		325	80		
		161	08		
		125	05		
		153	05		
		356	89		
		320	81		
		005	85		

Notes on Fracs at 0.0m

- randomly collected from n-s and e-w faces
- frac networks appear to not be related to flow fabric as they have different orients and fracs cut the flow bands
- all sets have ap ~<1mm with rather uniform spacing
- se vertical set: avg intensity ~12/m, avg TL ~1.5m, highly truncated and well linked, planar
- nnw vertical set: avg intensity ~15/m, avg TL ~1.5m to 2m, planar, similar to se set
- low angle set: avg intensity ~11/m, avg TL ~2m, curvi planar, similar to se set
- ne vertical set: avg intensity ~9/m, avg TL ~2m, planar, similar

General Notes

- two main sub horizontal structures w possible breccias and weak slip surfaces
- rotated fault hypothesis suspect -- looks like some kind of flow boundaries
- numerous vertical (~070/90) flow bands in light gray intrusive rocks that cut PC as noted by J. Meyer but structures appear intrusion related
- PC and Tvol are both pervasively fractured at <0.1m scale
- outcrops cut by small hi angle N-S extensional faults with <1m offset as seen from road
- extensional faults show no gouge in cores, there are many open features, and cut sub hor structures

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453918	**4060256**	**8789**	**33**

	317	81				
	003	86				
	316	80				
	158	07				
	305	03				
	324	15				
	315	11				
	057	04				
	065	90				
	074	90				
	058	88				
	052	90				
	289	90				fe ox
	286	84				fe ox
	226	88				
	035	80				
	037	83				
	211	06				
	270	05				
	000	01				
	352	14				
	252	16				
	282	19				
	248	16				
	283	14				
	355	87				
	234	80				
	346	90				
	310	78				
	302	80				
	014	82				
	186	84				
	240	85				
	261	82				
	328	86				
	004	85				
	015	81				
	131	90				
	140	89				**Notes at 7.2m**
7.2m	187	75	90	hi ang flt slip surf	T volcanics (rhy porph)	• photo 2 0.17cm offset of sub hor str by hi ang small conjugate flt - top down to the west
	329	70		conjugate small flt		
				Small Fault Intensity (P10) • ~ 9 faults per 43.8m or 0.205 faults per meter		• photos 3 and 4 close ups of uncemented breccia flt core with highly local damage • dz open fracs at intensity of <1/cm (photo 6) • pl is pervasively fractured and locally at a similar intensity (photo 5) • pervasive n-s frac fabric cuts flow layers but are also bounded by these layers as seen in truncation length that is proportional to layer thickness • this is a zone (~1m wide) with apparent dilatant zones possibly indicating that these features formed at the near surface • flt related fracs in fw dz are up to 0.3 m wide showing extensive dilatancy
frac data at 7.2m	210	90		fractures	rhyolite porphyry	• randomly collected fracture data
	216	83				
	014	80				
	300	52				
	298	48				
	213	78				
	013	84				
	006	80				

	032	77				
	200	84				
	174	90				
	215	76				
	214	84				
	222	70				
	008	79				
frac data at 10.0m	281	84		fractures	rhyolite porphyry	• randomly collected fracture data between two small flts • this interfault block shows subhorizontal flow layering • layer bounded frac intensity ~ 1/cm, TL ~ 1 to 5 cm, ap ~<1mm • thorough going frac intensities ~1/0.3m, TL >1m, ap ~<1mm
	019	10				
	156	80				
	098	84				
	287	87				
	172	80				
	059	87				
	131	83				
	296	14				
	197	90				
	143	79				
	076	10				
	018	08				
	342	06				
	233	84				
	287	87				
	025	08				
	076	11				
	326	10				
	359	14				
	167	80				
	169	87				
	112	90				
	171	84				
	107	90				
	124	88				
	156	78				
	104	90				
	172	84				
	155	74				
	351	16				
	225	80				
	158	80				
	237	88				
	345	04				
	291	12				
	099	80				
	111	79				
	226	80				
	284	87				
	271	58				
	221	77				
	129	02				
	245	09				
	104	90				
11.1m	138	76	17 dfe	strike slip surf w weak lin	rhyolite porphyry	little offset (~<5m), photo 8
15.6m	348	76		>20m long continuous shear zone with no slip surfaces (ddz)	rhyolite porphyry	• ~20 cm wide zone of damage that is open and dilatant
16.7m	195	82	80 dfs	slip surf in small fault with exposed tip, top down to west	rhyolite porphyry	• strike parallel tube like intersection zones would likely be open at least 100 m below the surface if not more
	178	64		main fracture at tip		• photos 9, 10
29.0m	178	88	90	slip surface with no visible offset, TL ~20m+	rhyolite porphyry	
33.2m	298	60		small flt / fracture zone, no lineations, ~TL 6m	rhyolite porphyry	• small fault with polished and striated slip surf and 3cm wide breccia core in rhyolite porphyry with a pod of PC granodiorite
40.1m	276	68	78 dfse	small flt and slip surf	rhyolite porphyry	• flt soles out at sub hor structure which is about 10m higher than at 7.2m (not same str? Corrugated?)

			43.8m	023	82	76 dfsw	small flt and slip surf at end of oc			rhyolite porphyry	• slip surf undulates from 90 to 82 degrees indicating potential for dilatant related permeability
19	**1010022a**	main rot flt oc					sample			slip surf and breccia	collected at 10.10.02 2 7.2m
20	**1010023**	base of cabin spring rhy cliffs	fracture data	290	86		**e-w vert set intensity**	3	1		
				188	87			2	1		
				186	07			4	1		
				110	82			5	1		
				211	25		**average intensity**	**3.5**	**per meter**		
				216	24						
				109	34		• e-w vert set TLs ~>6m ~ oc dimension				
				118	33						
				104	28						
				117	84						
				020	90		**n-s vert set intensity**	4	1		
				114	82			3	1		
				034	90			3	1		
				226	22		**average intensity**	**3.33**	**per meter**		
				068	06						
				116	75		• n-s vert set TLs ~>6m ~ oc dimension				
				113	69						
				132	12						
				034	74						
				104	76		**sub hor set intensity**	3	1		
				229	19			4	1		
				190	80			5	1		
				098	82			3	1		
				115	74		**average intensity**	**3.75**	**per meter**		
				197	78						
				114	15		• sub hor set TLs ~>6m ~ oc dimension				
				096	14						
				093	20						
				114	04						
				200	79						
				203	90						
				106	84						
				046	05						
				299	82						
				059	08						
				010	80						
				116	82						

General Notes

- many small vertical n-s faults with intense damage zone related open fracs as found in 1010022
- there are also curved subhorizontal fracture zones with no visible offset. these may be incipient faults or possibly flow boundaries that are intensely fractured
- a series of e-w cliff face parallel joints have max intensity of ~3/10m with trace TL ~>20m
- a few pods of Precambrian granite are in intrusive contact with the rhyolites suggesting this cliff is an intrusive margin
- photo 14 looks east at a small block where fracture data was collected – this shows the max observed frac intensity
- fracture data collected randomly and perpendicular to each set
- fracs are joints, planar, ~uniform spacing, with apertures <1mm with a few up to 5cm
- frac data collected on face oriented 196/80 (photo 14)

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453539	**4059963**	**7947**	**46**

21	**1010023a**	base of cabin spring rhy cliffs			sample			rhyolite porphyry	
22	**1010023b**	base of cabin spring rhy cliffs	102	90	sample orient			rhyolite porphyry	
23	**1010024**	base of cabin spring rhy cliffs	284	86	flt related fracture data			fled rhy porph	
			102	83					
			106	88	• randomly collected frac intensity data. Intensities are similar for all sets	8	0.2		
			105	90		10	0.2		
			107	84		8	0.2		
			009	77		10	0.2		
			159	80	• TL ~ average 1m and highly linked/truncated	13	0.2		
			304	84		12	0.2		
			337	90		15	0.2		
			332	82		11	0.2		
			023	84		9	0.2		
			349	80		15	0.2		
			194	88	average	11.1	0.2		
			010	84	**average intensity**	**55.5**	**per meter**		
			030	81					
			032	80					
			329	86					

General Notes

- first major fracture zone along cliff from oc at 1010023 (~100 m east)
- photo's 15 and 16 show fw dz
- flt zone is a network of faults with very small offsets (ddz like small structure)
- fw damage is ~1.4m wide
- no primary slip surface observed but main frac has TL >12m
- flt appears top down to the east
- no sign of cementation in this structure

026	80
329	86
320	82
295	52
304	56
290	86
177	16
296	82
110	79
306	52
089	76
004	90
284	88
306	56
295	57
200	85
018	85
140	10
310	52
287	22
197	13
178	09
191	13
230	06
279	12
197	14
223	04
049	18
357	10
356	09
352	82
297	70
180	74
170	68
187	73
176	75

- this damage is dominantly dilatant
- fracs are planar to curviplanar, apertures <1mm to ~3mm and OPEN
- fracture data was randomly collected

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453573	**4059972**	**7970**	**28**

fault intensity traverse at base of cabin spring rhy cliffs

358	64		main flt/fracture at 0.0m
350	64		flt bounded dz at 4.1m
349	70		flt/frac zone at 12.3m
110	86		flt/frac zone at 16.1m
192	74		flt/frac zone at 22.2m
190	80		flt/frac zone at 23.3m
202	55		flt/frac/shattered zone at 25.9m
350	72		major flt/frac zone at 34.9m
186	65		conjugate fracs
344	72		conjugate fracs
347	76		small flt at 42.5m
356	80		major flt/frac zone at 47.3m
002	56	62 dfs	LDZ at 62.9m and 1010025
180	80		small flt at 66.9m end of traverse

rhy porph for all below

fault locations (m)	*differences*
0.0	
4.1	4.1
12.3	8.2
16.1	3.8
22.2	6.1
23.3	1.1
25.9	2.6
34.9	9.0
42.5	7.6
47.3	4.8
62.9	15.6
66.9	4.0

differences stats

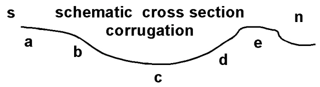
mean
6.1
std dev
3.97
median
4.8
min
1.1
max
15.6
variance
15.80
kurtosis
2.5
n
11

General Notes

- west to east traverse for fault intensity
- traverse starts at 1010204 = 0.0m
- all flt s are extensional
- at 16.1m and 22.2m the zones are 0.3 to 0.5m wide and the TLs extends as far as I can see ~>30m
- at 23.3m the flt/frac zone is similar to the previous zones but is only ~0.1 to 0.2 meters widened soles out into a 2m wide shatter zone
- the flt/frac zone at 34.9m is the one found at the base of the large curved structure seen in the cliff photos
- at 42.5m this is the first flt that cuts the sub horizontal dike
- at 47.3m this is the major flt/frac zone at the base of the large "cave" seen in the cliff photos. its base flowers out to ~ 6m wide!
- flt at 62.9m has ~1.5m top down to the east offset with a central ~0.2m crush zone and crg core. the core shows punky green clay ~3 to 5mm wide.
  very little subsidiary damage.
- no low angle fault observed
- no biotite in groundmass, possible pyrite, some fracs flts appear to have mn oxide and black stain but no good dendrites were observed, host rock possible granophyre

24	**1010024a**	base of cabin spring rhy cliffs		110	90		sample			frac rhy porph	first fracture zone, fw dz, microcracks
25	**1010025a**	base of cabin spring rhy cliffs					flt rx sample at end of traverse			flt core	
26	**1010025b**	base of cabin spring rhy cliffs					flt rx sample at end of traverse			green clay	
27	**1010025c**	base of cabin spring rhy cliffs					flt rx sample at end of traverse			flesh alt rx	
28	**1010025d**	base of cabin spring rhy cliffs					host rx sample ~1m into fw			rhy porph	
29	**1011021**	main hi ang flt by rot flt		007	67	71 dfnw	slip surf point a on profile				
				346	58	76 dfnw	slip surf point b on profile				
				357	66	78 dfnw	slip surf point c on profile				
				015	71	65 dfnw	slip surf point d on profile				
				007	64	68 dfnw	slip surf point e on profile				
				006	72	67 dfnw	randomly collected slip surf data				
				194	89	65 dfnw					
				018	74	61 dfnw					
				162	66	67 dfnw					
				002	85	72 dfnw					
				013	77	61 dfnw					
				186	84	59 dfnw					
				184	83	64 dfnw					
				197	75	68 dfnw					
				002	70	61 dfnw					
				351	68	63 dfnw					
				345	65	68 dfnw					
				015	76	50 dfnw					
				012	72	58 dfnw					
				165	39		face of 2cm high step on slip surf				
				238	78		biotite foliation in PC granite			biotite granite	
			n-s set with e and w dips	003	90		randomly collected frac data from fw dz ~6m from core	6	0.5	biotite granite	
				010	90			4	0.5		
				009	82			5	0.5		
				186	80			4	0.5		
				341	75			5	0.5		
				175	88			5	0.5		
				160	76			4	0.5		
				012	68			6	0.5		
				335	78			4	0.5		
				155	80			5	0.5		
				349	90		average	4.8	0.5		
				001	87		**average intensity**	**9.6**	**per meter**		
				002	70						
				007	80						
				325	82						
				355	88						
				320	90						
				170	52						
				158	52						
				152	64						
				154	40						
				316	81						
				156	54						
				316	90						
				330	84						
				320	86						
				335	77						
				328	84						
				325	86						
				002	64						
				232	64						
				004	68						

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453629	**4059946**	**8101**	**na**

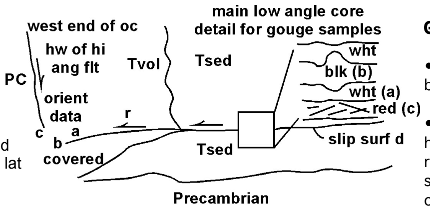


General Notes

- fw is precambrian granitic bio, plag, qtz gneiss with moderate foliation and does not appear as beaten up as Tvol and Tsed flts rocks
- high angle flt shows highly polished and striated slip surface that is highly silicified and highly corrugated photos 1 and 2
- slip surface corrugation data
wave length = 0.6m, amplitude = 8cm
- photo 3 groove at point e on profile
- major steps on slip surfs indicate displacement is top down to the east
- slip surfaces demark beginning of fw dz which is 3.4m wide here and composed of small offset pods of PC granite
see photo 7 looking sw
- flt core is not completely exposed (photo 8) but there is a 0.3m wide breccia zone with Tvol (?) clasts (sample 1011021b)
- frac intensity was collected on a set by set basis but all are similar so they are averaged together
- all fracs have TLs to the extent of the oc ~3m, planar, all crosscut but do not displace one another, apertures are <1mm
- PC to the west is in intrusive contact with Tvol then Tsed outcrops - cannot see contact
- dug out the core to reveal a plastic, black and fe oxide gunk that is foliated parallel to the strike of the core (sample d = plastic stuff and sample c = solid stuff). there could be organics in this material as are there is root material (date organics?). could indicate paleoflow of fe rich fluids in the core
- photo 11 looks n at x-section of fw dz fracs
- PC granitic rocks extend over 100m down canyon

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453673	**4060291**	**8652**	**107**

		e-w steep set	074	72			randomly collected frac data from fw dz ~6m from core		
			069	63					
			090	69					
			087	70					
			092	59					
			101	56					
			094	58					
			100	62					
			091	76					
			081	87					
			086	64					
			093	64					
			094	62					
			082	75					
			099	56					
			090	54					
			082	60					
			093	50					
			089	72					
			086	70					
			089	72					
		e-w low angle set	272	12			randomly collected frac data from fw dz ~6m from core		
			294	26					
			295	22					
			262	31					
			268	38					
			292	34					
			239	16					
			272	38					
			294	32					
			260	35					
			269	28					
			271	31					
			290	32					
			286	34					
			285	28					
			280	20					
			285	24					
			275	14					
			274	24					
			274	20					
			264	16					
			265	16					
30	**1011021a**	main hi ang flt by rot flt					sample from corrugated slip surf	silicified slip surf	
31	**1011021b**	main hi ang flt by rot flt	007	76			sample orient	crg?	
32	**1011021c**	main hi ang flt by rot flt					sample	flt core fe rich gunk	organically derived?
33	**1011021d**	main hi ang flt by rot flt					sample	flt core fe rich gunk	organically derived?
34	**1011021e**	main hi ang flt by rot flt					sample		
35	**1011022**	main rot flt oc	117	25	16	271	low angle slip surface that steps to west		
			266	60	8	dfw	qtz polished and striated slip surf at a, steps=left lat		
			280	36	7	dfn	slip surf at b		
			115	82	46	dfn	slip surf at c		
			212	16	16	262	slip surf at d		
			086	68			frac data from upper plate Tsed		
			320	66					



General Notes

- main exposure of the low angle structure/fault zone below and east of 1011021
- photo 12 clearly shows that the low angle flt cuts the high angle flt possibly indicating episodic deformation and reactivation. it is also possible that the high angle fault soles into the low angle fault and they are actually part of a contemporaneous system?
- photos 12-19 are of the area shown in sketch
- photos 20-22 looking north at phacoidally cleaved crg in core of low angle flt/structure that is 5cm wide and shows right lateral shear sense

				314	41						
				322	40						
				319	37						
				280	88						
				324	60						
				335	61						
				338	62						
				336	24						
				328	56						
				165	55						
				320	68						
				185	72						
				090	20						
				151	86						
				290	66	48 dfse	slip surf in Tsed				
				253	12						
				020	85						
				026	84						
				230	16						
				014	85						
				263	17						
				324	54						
				292	71						
				115	80						
				300	68						
				312	76						
				337	76						
				320	67						
				290	55						
				082	52						
				304	69						
				315	62						
				314	82						
				241	90						
				075	72						
				326	61		conjugate fracture				
				173	76		conjugate fracture				
				073	70		conjugate fracture				
36	**1011022a**	main rot flt oc					fault core sample			white crg	flt core of rot flt, fine SC fabric, red, blk, white clay
37	**1011022b**	main rot flt oc					fault core sample			blk crg	flt core of rot flt, fine SC fabric, red, blk, white clay
38	**1011022c**	main rot flt oc					fault core sample			red crg	flt core of rot flt, fine SC fabric, red, blk, white clay
39	**1011023**	amalia narrows		150	78		eutaxitic foliation			amalia tuff	
				148	78		eutaxitic foliation			amalia tuff	
				139	76		eutaxitic foliation			amalia tuff	
				143	64		eutaxitic foliation			amalia tuff	
			nne steep set	023	80		fractures	5	0.2	amalia tuff	
				023	79		• nne steep set TLs	8	0.2		
				025	81		~1m, planar, smooth, aps ~<1mm	9	0.2		
				027	80			6	0.2		
				031	71			7	0.2		
				050	61			6	0.2		
				056	66		average	6.833	0.2		
				055	72		**average intensity**	**34.2**	**per meter**		
				056	72						
				050	62						
				054	62						
				034	75						
				035	68						
				031	76						
				030	77						
				022	76						
				026	83						
				030	78						
				026	84						

- fracture data is randomly collected in the upper plate in Tsed matrix (there are medium sized boulders here too)

- this upper plate, esp in Tsed, is hydrothermally altered with extensive epidote coatings, veins, and clots

- regardless of low angle fault zone/structure and potential clay rich core barrier to flow the upper plate fractures and high angle faults are dominantly n-s striking and show many open structures and wrt groundwater flow should not be a major impediment to south directed flow esp given the north to south topographic gradient

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453745	**4060261**	**8818**	**16**

General Notes

- photos 25 - 29 aluminum precipitates on orthogonal fracture networks stained with fe oxides (gibsite? and jarosite?)

- recent rain (~2.5in) has soaked this area

- popcorn-like hollow films appear to have diffused from central crack forming a lower layer and reflects surface tension phenomena

- frac data collected randomly by set

- all sets mutually cross cutting with no macroscopic offset

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453030	**4062074**	**8860**	**43**

			023	80				
			018	86				
			021	83				
			020	86				
		nw-se set	127	76	fractures	8	0.2	amalia tuff
			155	79	• nw steep set TLs	8	0.2	
			167	44	~0.3m, semi- planar, rough,	5	0.2	
			128	76	aps ~<1mm	6	0.2	
			097	60		5	0.2	
			101	65		3	0.2	
			094	74	average	5.833	0.2	
			166	68	**average intensity**	**29.2**	**per meter**	
			136	78				
			134	64				
			332	86				
			143	72				
			149	70				
			150	76				
			145	71				
			147	77				
			152	71				
			146	60				
			319	84				
			143	70				
			326	80				
		low angle set	317	24	fractures	6	0.2	amalia tuff
			329	26	• low angle set TLs	8	0.2	
			328	26	~1.5m, planar, smooth,	11	0.2	
			328	24	aps ~<1mm	16	0.2	
			329	24		5	0.2	
			325	23		6	0.2	
			327	24		7	0.2	
			331	16		18	0.2	
			320	24		10	0.2	
			331	24	average	9.667	0.2	
			334	20	**average intensity**	**48.3**	**per meter**	
			318	16				
			320	24				
			323	26				
			327	24				
			321	23				
			322	24				
			329	26				
			322	21				
			325	24				
		other sets	040	60	fractures			amalia tuff
			054	66				
			042	58				
			046	43				
			037	46	possible columnar joints			amalia tuff
			050	72				
			273	76				
		bruce data	291	22	frac data from block across stream			amalia tuff
			301	17				
			289	24				
40	return to amalia narrows		036	56	frac data			
			295	21				
			294	18				
			315	16				
			304	14				
			285	12				
			316	54				
			273	70				
			279	71				

General Notes

- return to amalia narrows on 10.13.02
- random collection of fracture data from southeast side of stream
- focus is on conjugate fracture geometry of sets in oc
- all fracs except conjugates have similar properties as those in stream bed
- conjugate sets have:

- random collection of fracture data from southeast side of stream
- focus is on conjugate fracture geometry of sets in oc
- all fracs except conjugates have similar properties as those in stream bed
- conjugate sets have:

intensities ~4/m to 5/m

TLs ~2 to 3m

planar and slightly rough

apertures ~<1mm

tips do not offset one another ~ contemporaneous in time

106	54
111	56
269	88
194	86
197	84
205	90
200	90
265	68
054	49
000	56
001	54
009	53
245	66
034	57
055	52
077	82
045	50
043	51
052	52
043	50
194	80
192	78
305	20
283	70
195	78
042	49
076	38
047	50
042	56
280	14
302	16
277	85
272	73
042	56
268	82
275	75
286	80
282	73
272	80
250	80
040	53
049	54
276	80
036	60
326	16
273	74
185	82
182	76
052	60
330	67
050	84
283	76
281	77

41	**1011023a**	amalia narrows			sample			solid foam-like crust	aluminum (?) precipitate
42	**1011023b**	amalia narrows			sample			amalia tuff	look for microfractures
43	**1012021**	main rot flt oc return to 1011022	300	68	frac data from upper plate Tsed dz			Tsed	
			006	90					**General Notes**
			051	66	• up plate Tsed lo ang set TLs ~1.2m to 3m, curviplanar, smooth, aps are all over the map, mutually cross cutting and cut by small flts				• all fracture data randomly collected
			320	66		7	0.5		
			322	67		8	0.5		• photos 31 - 34 stretching deformation in main low angle structure
			316	66		6	0.5		
			061	84	average	7	0.5		• photos 35 - 37 whole view of exposure looking nw
			063	88	**average intensity**	**14**	**per meter**		
			312	81					• photo 38 looking n at upper plate dz
			075	72	• up plate Tsed nnw set TLs ~7 to 8m greatest observed but as low as 1m, planar to curviplanar, smooth, aps are all over the map, mutually cross cutting and cut by small flts, other sets similar to lo angle set above	9	0.5		
			173	80		4	0.5		• 14.1m top to the east minimum throw measured in gully from west top of PC granite to east top of PC granite

			• up plate Tsed nnw set TLs			
			~7 to 8m greatest observed but as			
092	81		low as 1m, planar to curviplanar,	16	0.5	
323	64		smooth, aps are all over the map,	9	0.5	
321	71		mutually cross cutting and cut by	11	0.5	
163	90		small flts, other sets similar to lo	13	0.5	
160	72		angle set above	4	0.5	
168	78			6	0.5	
177	74			3	0.5	
220	24		average	8.333	0.5	
216	20		**average intensity**	**16.7**	**per meter**	
200	16					
227	25					
216	14					
238	16					
274	24		main low angle structure along clay seam			flt rocks
240	20					
268	10		randomly collected frac data from			
281	27		rhyolite dike in upper plate dz			
275	25					
248	20					
154	16					
157	22		• up plate Trhy lo ang set TLs			fine rhyolite
158	16		~2 to 3m, curviplanar, smooth,			
123	17		aps ~<1mm, mutually cross cutting			
135	17		and possibly related to flow strs	6	0.5	
172	72			4	0.5	
351	20			4	0.5	
358	64			5	0.5	
315	72		average	4.75	0.5	
322	70		**average intensity**	**9.5**	**per meter**	
250	80		• up plate Trhy n-s set TLs			
298	77		~4 to 5m, curviplanar, smooth,	11	0.5	
178	82		aps ~<1mm, mutually cross	12	0.5	
281	80		cutting with no offset, and	8	0.5	
041	62		possibly related to flow strs,	13	0.5	
250	71		other sets essentially same, intensity	7	0.5	
092	46		gets higher closer to the fault	18	0.5	
084	38		average	11.5	0.5	
130	33		**average intensity**	**23**	**per meter**	
120	18					
166	70					
167	78					
165	75					
302	64					
303	66					
301	70		upper plate dz fractures			
299	64		~ 5m east of PC granite			
203	80		flow banding in Trhy			rhyolite
172	58					Tsed pod of conglomerate
296	56					
188	64					
188	58	90	slip surface	5	0.5	lo and set
262	53			3	0.5	
258	59			4	0.5	
019	59		average	4	0.5	
341	90		**average intensity**	**8**	**per meter**	
177	55	74 dfn	slip surface			
166	80			7	0.5	
290	52			10	0.5	
017	12			6	0.5	
340	24			3	0.5	~ slip surf intensity
333	37		average	6.5	0.5	
159	85	75 dfn	slip surf **average intensity**	**13**	**per meter**	
165	60	62 dfn	slip surface			
269	72	66 dfw	slip surface			
349	65	88 dfs	slip surface			
192	38	78 dfn	slip surface			

angle structure

- photos 35 - 37 whole view of exposure looking nw

- photo 38 looking n at upper plate dz

- 14.1m top to the east minimum throw measured in gully from west top of PC granite to east top of PC granite

- PC granite and Tsed have been propylitically altered and Trhy appears relatively unaltered. at the low angle structure there appears to be overprinting (?) argillic alteration from the intrusion of Trhy(?)

General Thoughts on This Outcrop

- Tsed appears to be intruded by Trhy and has left "septa" of Tsed sitting between Trhy dikes

- Trhy appears to have intruded along the PC Tsed original HORIZONTAL contact

- there are remnant pods of Tsed between Trhy and PC granite

- at the east end of the outcrop the PC granite and Tsed
contact is higher than at west end and the "fault" disappears

- these observations refute or complicate low angle fault model... this might simply be an unrotated major detachment fault?

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453918	**4060256**	**8789**	**33**

- upper plate and hi ang hw dz Tsed pod
lo ang set TLs
~2 to 3m ~ extent of oc, curviplanar, smooth, aps all over the board, mutually cross cutting with no offset

- upper plate and hi ang hw dz Tsed pod
n-s sets TLs (both similar)
~2 to 3m ~ extent of oc, curviplanar, smooth, aps all over the board, mutually cross cutting with no offset

General Notes for PC granite lower plate

- most fractures are coated with black - brown mn coatings
- 0.3 - 0.7 cm clusters of rhombohedral carbonate (?) crystals in vuggy black stained near vertical fracture
- fracture spacing approximated by a uniform distribution
- at lower part of gully the high angle fault appears to be tipping out and there is PC on PC granite with primarily curviplanar slip surfaces

			007	90	52 dfn	slip surface	randomly collected fracture data				
			172	31	48 dfn	slip surface	from lower plate dz and high angle				
			151	64	46 dfn	slip surface	flt hw dz in PC granite				
			005	73	48 dfn	slip surface					
		e-w set	286	82		TLs ~5m ~ extent of oc, planar,		4	1	PC granite	
			282	82		mutually cross cutting w no offset,		3	1		
			279	77		aps ~<1mm		3	1		
			284	80				2	1		
			276	81				2	1		
			270	84				**2.8 per meter**			
			108	82							
			086	90							
			082	76							
			086	82							
			259	80							
		n-s set	156	80	27 dfn	slip surface		4	1	PC granite	
			352	86		fractures		3	1		
			187	84		TLs ~5m ~ extent of oc, planar,		3	1		
			360	90		mutually cross cutting w no offset,		4	1		
			001	75		aps ~<1mm		**3.5 per meter**			
			326	83	8 dfs	slip surface					
			358	78							
			013	86				**~14 per meter near fault**			
			346	47							
			004	78							
			009	73							
			351	80							
			000	76							
			354	82							
			353	78							
			269	82	28 dfe	slip surface					
			047	49							
			347	58							
			060	47							
			032	52							
			030	58							
			029	56							
			031	53							
		low angle set	214	12		fractures		5	1	PC granite	
			229	11		TLs ~3 to 5m ~ extent of oc,		4	1		
			233	19		planar, mutually cross cutting w		4	1		
			287	90		no offset, aps ~<1mm		4	1		
			280	84				4	1		
			274	74				**4.2 per meter**			
			291	46							
			202	16							
			270	22							
			260	37							
			068	20							
			017	22							
			050	24							
			072	44							
			094	48							
			169	18							
			150	26							
			175	24							
			159	35							
			180	28							
			175	25							
			172	20							
			194	20							
			204	22							
44	**1012021a**	main rot flt oc				sample				red crg	flt core of rot flt, fine SC fabric, red, blk, white clay
45	**1012021b**	main rot flt oc	311	74		sample orient				rhy	~1.5m above main rot flt and PC granite

46	**1012021c** main rot flt oc		043	53	sample orient			pc granite	~3.5m below main rot flt
47	**1012021d** main rot flt oc				sample			slip surf	lower plate slip flt surf
48	**1012021e** main rot flt oc				sample			Mn(?), carb(?) xls	hw dz of hi ang flt in pc at frac data collection site
49	**1012021f** main rot flt oc				sample			Tsed flt rx	lower plate plastically(?) deformed Tsed lo ang cnt
50	**1013021** latite flows and mega breccias							blk stained amalia tuff	
		low angle set	214	06	fractures	9	0.5		
			165	03		8	0.5		
			215	07	TLs ~4 to 5m ~ extent of oc, curviplanar, mutually cross cutting w no offset, aps ~<1mm	6	0.5		
			278	07		11	0.5		
			271	09		10	0.5		
			261	10		10	0.5		
			220	15		9	0.5		
			280	06	average	9	0.5		
			260	10	**average intensity**	**18**	**per meter**		
			277	07					
			219	07					
			238	09					
			033	06					
			250	06					
			259	05					
			218	07					
			226	10					
			250	11					
			229	12					
			232	14					
			228	14					
		e-w set	034	36	fractures	9	0.5		
			046	40		9	0.5		
			064	36	TLs ~0.5m and smaller, truncated by low angle set at ~ 70%, rough and curviplanar, mutually cross cutting w no offset, aps range across the board	7	0.5		
			075	73		8	0.5		
			080	80		8	0.5		
			082	80		7	0.5		
			089	79		10	0.5		
			081	64	average	8	0.5		
			075	86	**average intensity**	**16**	**per meter**		
			273	88					
			287	90					
			089	84					
			093	85					
			267	88					
			084	72					
			112	81					
			265	67					
			260	72					
			253	83					
			270	82					
			066	68					
			064	60					
			072	76					
			068	56					
			070	76					
			283	78					
			072	76					
			069	74					
		nnw set	311	80	fractures	5	0.3		
			328	78		5	0.3		
			322	86	TLs ~0.5m and smaller, truncated by low angle set at ~ 70%, rough and curviplanar, mutually cross cutting w no offset, aps range across the board	4	0.3		
			138	78		4	0.3		
			147	88		3	0.3		
			338	73		6	0.3		
			325	82		4	0.3		
			333	86	average	4	0.3		
			336	78	**average intensity**	**13.3**	**per meter**		

General Notes

- fracture data collected randomly by set on west side of road
- rocks are highly stained by black precipitate (mn oxide?)
- photo 44 looking west at outcrop
- look for conjugate geometries in orientation data
- photos 45 and 46 megabreccia (?) blocks with chaotic fracturing

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
453804	**4061600**	**9840**	**27**

			334	64				
			331	90				
			327	80				
			328	82				
			331	85				
			142	84				
			149	90				
			144	80				
			314	84				
			309	82				
			305	84				
			112	83				
51	**1013021a**	latite flows and mega breccias	330	65		sample orient	blk stained amalia tuff	orient parallel to nnw fracs
52	**1013022**	amalia on nw-most mine property road cut	196	09		randomly collected fracture data	amalia tuff	
			137	16				
			147	14				
			126	10				
			093	06				
			111	06				
			162	10				
			225	86				
			233	82				
			230	84				
			228	90				
			225	90				
			232	84				
			315	70				
			321	74				
			327	79				
			324	70				
			215	76				
			220	82				
			064	88				
			074	85				
			075	82				

General Notes

- road cut of amalia is very clean and data was collected here as a check consistency with orientations at the amaila narrows

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
452821	**4063164**	**9672**	**15**

53	**1013023**	western pc road cut	066	86	8 dfs	slip surface	PC granites
			078	82	7 dfs	slip surface	
						riedel fracs indicate sinistral slip	
			331	60		fractures	
			334	60			
			108	61			
			286	80			
			336	66			
			246	77			
			093	48			
			189	75			
			298	14		biotite foliation	
			090	55		fractures	
			091	55			
			189	58			
			190	57			
			169	70			
			316	86			
			316	75			
			318	67			
			205	77			
			320	76			
			197	76			
			192	82			
			181	62			
			186	49			
			190	78			

General Notes

- roadcuts on NM 38, western most oc
- fracture data collected randomly
- pervasive epidote, chlorite, and possible pyrite alteration
- photos 54 and 55 looking north at north-south trending fracture intersections
- 196/54 large, west dipping set on lefthand side of open triangle in photo
- 160/46 large, east dipping set on righthand side of open triangle in photo
- fractures are mutually cross cutting

intensities ~12/m to 2/m

TLs run extent of the road cut ~3 to 5m

trunc ~ 20 to 30 percent

apertures ~<1mm

generally planar and smooth

			265	55				
			272	56				
			254	26				
			266	33				
			202	71				
			314	55				
			329	82				
			198	66				
			196	54				
			160	46				
			279	30				
			313	56				
			254	80				
			351	59				
			284	67				
			094	51				
			083	53				
			205	70				
54	**1013023a**	western pc road cut	254	80	sample orient			PC granites
55	**1014021**	Tandesite valley oc by NM 38						
		moderate angle e-w set	243	31	fractures	2	1	Tand
			225	27		3	1	
			230	38		7	1	
			260	38	**average intensity**	**4**	**per meter**	
			238	24				
			206	27	TLs ~1 to 2m, rough, planar,			
			257	42	mutually cross cutting w no offset,			
			236	33	aps ~<1mm, ~uniform spacing			
			232	38				
			230	44				
			222	52				
			234	55				
			223	44				
		moderate angle ne-sw set	016	70	fractures	6	0.5	Tand
			036	70		3	0.5	
			043	67		4	0.5	
			045	70	average	4.3	0.5	
			038	69	**average intensity**	**8.7**	**per meter**	
			038	58				
			038	66	TLs ~1 to 2m, smooth, planar,			
			042	72	mutually cross cutting w no offset,			
			039	66	aps ~<1mm, ~uniform spacing			
			024	55				
			030	60				
			038	67				
		moderate angle nnw-sse set	320	62	fractures	5	0.5	Tand
			356	58	TLs ~1 to 2m, smooth, planar,	4	0.5	
			330	62	mutually cross cutting w no offset,	4	0.5	
			341	61	aps ~<1mm, ~uniform spacing	4	0.5	
			352	64	average	4.3	0.5	
			353	64	**average intensity**	**8.5**	**per meter**	
			359	65				
			355	64				
			351	67				
			351	65				
			335	76				
			350	76				
			349	61				
			355	62				
		randomly collected data	356	64	fractures			Tand
			352	78				
			030	70				
			334	80				
			358	66				

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
454189	**4059608**	**7872**	**26**

General Notes

- tertiary andesite outcrop a few 10s of meters north of NM 38
- prop altered oc with subhedral relatively unweathered pyrite xls
- fracture data randomly collected by set
- joint or fracture zones occur in this oc
- photos 60 and 61 look n at oc
- trace lengths censored by extent of outcrop which is about 2x2x2 m

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
457911	**4061871**	**8250**	**31**

				356	58				
				164	34				
				160	28				
				163	30				
				025	57				
				036	66				
				252	55				
				359	76				
				228	44				
				236	47				
				325	55				
				265	30				
				250	33				
				036	56				
				330	70				
				154	42				
				057	50				
				153	26				
				165	26				
				157	32				
				148	41				
				157	30				
				168	26				
				158	28				
56	**1014021a**	Tandesite valley oc by NM 38		058	47	sample orient			Tand
57	**1014022**	eastern pc road cuts		310	74	biotite foliation			PC granites
				160	78	quartz vein sets			PC granites
				136	80	small brittle fracture zone			PC granites
			ne-sw, n dipping set	218	66	fractures	5	1	PC granites
				202	56	TLs ~4 to 5m, smooth, planar,	3	1	
				217	54	mutually cross cutting w no offset,	4	1	
				221	68	aps ~<1mm, ~uniform spacing	3	1	
				216	69	**average intensity**	**3.8**	**per meter**	
				215	71				
				206	73				
				212	72				
				219	76				
				214	84				
				216	78				
				225	82				
				222	81				
				217	86				
				215	82				
			nw-se, e dipping set	333	70	fractures	7	1	PC granites
				337	68	TLs ~4 to 5m, smooth, planar,	5	1	
				346	79	mutually cross cutting w no offset,	3	1	
				342	70	aps ~<1mm and up to ~1cm,	5	1	
				338	63	~uniform spacing	3	1	
				333	67	**average intensity**	**4.6**	**per meter**	
				300	62				
				328	64				
				326	60				
				323	80				
				320	74				
				338	68				
				330	63				
				318	69				
				326	64				
			w to nw-e to se, w dipping set	145	76	chlorite coated fractures	5	1	
				142	58		3	1	
				137	88	TLs ~2 to 6m, smooth, planar to	2	1	
				156	80	curviplanar, mutually cross cutting	2	1	
						w no offset, aps ~<1mm and up to			
						~1cm, ~uniform spacing			

General Notes

- roadcuts on NM 38, eastern most oc
- fracture data collected randomly by set
- pervasive epidote, chlorite, and possible pyrite alteration
- photo 62 looks n at oc and 63 looks n at small brittle fracture zone
- fracture TLs censored by extent of outcrop which is ~5m tall here
- fracture parameters in this road cut are similar to those in natural outcrops above road cut
- 2 small fault zones are found on the east side of the road cut. these are primarily fracture zones with no visible offset and also show mn stain within the fault related fractures that have an average intensity of ~ 10 to 12 per 0.3m or ~36.7/m
- numerous wide aperture quartz veins near fault zones.
these are up to 2m wide and trend nnw and dip e.
- some quartz veins show extensive high intensity fracturing within 0.1m of either side of vein -- evidence for preexisting fault -related damage or vein emplacement damage? intensity ~ 10 to 12 per 0.2m or ~55/m

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
454282	**4059631**	**7890**	**18**

			149	70		TLs ~2 to 6m, smooth, planar to curviplanar, mutually cross cutting w no offset, aps ~<1mm and up to ~1cm, ~uniform spacing	3	1	
			112	38			2	1	
			100	32			6	1	
			129	78		**average intensity**	**3.3**	**per meter**	
			118	71					
			115	50					
			098	70					
			103	61					
			110	58					
			112	60					
			136	72					
			148	70					
			138	71					
			144	70					
			148	56					
			146	65					
58	**1014022a**	eastern pc road cuts	331	63		sample			PC granites
59	**1014022b**	eastern pc road cuts	094	73	16 dfs	slip surf sample w mn stain and sinistral shear sense			PC granites
60	**1014023**	bear canyon road side crag	322	83	44 dfs	slip surf with top down to e by RS			bear canyon granite
			222	22		fractures			bear canyon granite
			230	30					
			226	25					
			236	35					
			234	39					
			228	35					
			250	40					
			255	36					
			229	38					
			251	36					
			242	32					
			249	30					
			317	71					
			321	56					
			349	68					
			345	53					
			350	60					
			329	62					
			328	66					
			325	70					
			305	74					
			303	66					
			309	75					
			312	69					
			158	80					
			155	76					
			154	78					
			162	78					
			155	80					
			157	82					
			169	80					
			159	76					
			158	82					
			168	58					
			148	82					
			157	79					
			152	55					
			151	81					
			074	67					
			076	67					
			069	73					
			072	72					
			070	70					
			077	72					
			053	68					

General Notes

- road cut in bear canyon pluton on n side of NM 38
- photos 64 and 65 looks nw at small fault zone that offsets low angle joints therefore joints came first
- note 1x1m carpenters rule to be used for measuring photo intensity and trace lengths at outcrop scale
- fracture data collected randomly
- road cut shows pervasive fracturing at macro scale (>10m) and submacro scale (<0.1m)
- many fractures at both scales are part of conjugate sets with near vertical acute bisectries and may reflect deformation related to damage zone in range front extensional fault
- submacro fractures have ~ intensities of 10 to 12 per 0.2m or ~55/m
- photos 66 and 67 looking ne at e-w steep nne lower angle fracture sets on a sse outcrop face around the corner from photos 64 and 65

GPS Coordinates (UTM 13s)		**GPS elev**	**GPS error**
east (m)	**north (m)**	**(ft)**	**(+/- ft)**
449856	**4061956**	**7555**	**18**

			075	68			
			070	56			
			051	64			
			053	70			
			068	74			
			071	72			
			072	78			
			080	70			
60	**1014023a**	bear canyon road side crag	055	71	sample	bear canyon granite	look for microfractures

END