Supporting Information for **Crouch and Evans** (2023 - TEKTONIKA)

Shallow Composition and Structure of the Upper Part of the Exhumed San Gabriel Fault, California: Implications for Fault Processes

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Crouch et al Supplemental files

The supplemental files 1, 4, 5, 6, and 7 are stored at https://digitalcommons.usu.edu/all_datasets/193/, downloadable from Evans-20220502T171206Z-001.zip.

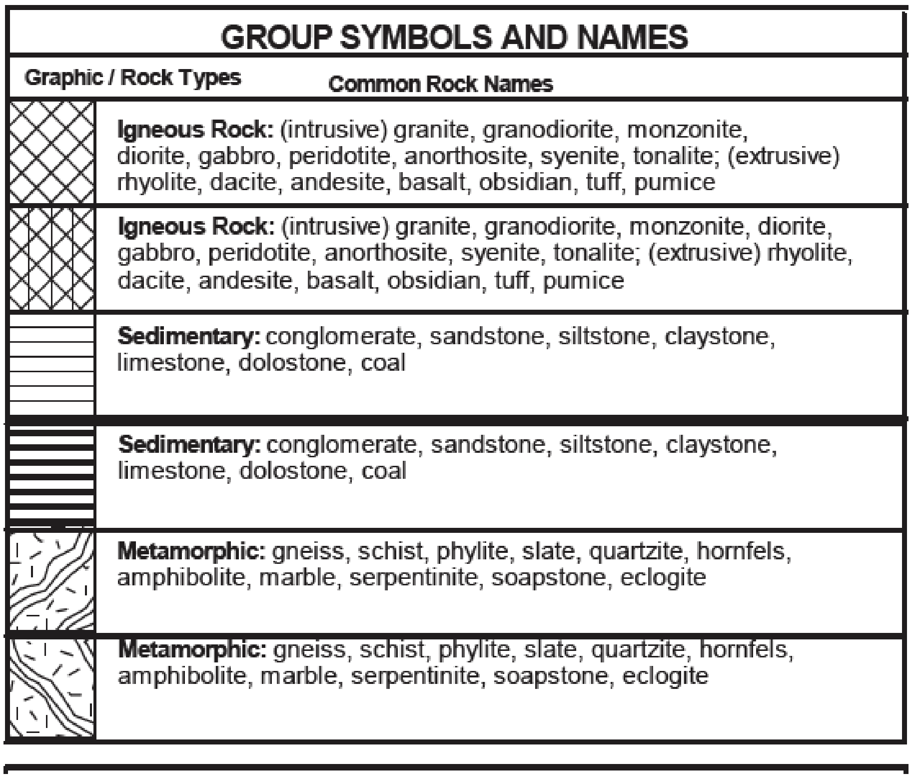
Supplemental File 1. Overview of the geometry and samples of the San Gabriel fault (SGF) sampled by the ALT-B2 drill core and the data collected from the drill core. Appendix A Data Overview at the data repository cited above includes:: Overview, Fault Geometry, Drill Core, Field Samples, Thin Sections, XRD, Geochemistry, and XRF Maps. The overview lists the drill core samples collected and the drill core box number they were collected from, the names of the thin sections and XRF maps associated with the drill core, and the names of the XRD and whole-rock geochemistry data associated with the drill core. The fault geometry lists the drill core and associated core box number, the upper and lower measured depths limits of the drill core samples in ALT-B2 (in meters), the measured distance of the samples from the main SGF along the measured depth of the ALT-B2 borehole, and the horizontal distance of the sample from the SGF trace. Descriptions of other sheets are detailed in the other appendices.

Supplemental File 2. Core description data. The data for the interpretation of the core data are shown here, from the work of Kleinfelder Associates in the draft Geotechnical Data Report for Tunnel Feasibility, Angeles National Forest (Kleinfelder). Drilling at Core Hole ALT-B2 in 2016 used HQ rods and core barrel; HWT over casing was advanced to 53.4 feet during the first three days of drilling. Drilling fluid loss was managed throughout the drilling of ALT-B2 through the use of mud additives. Core Hole ALT-B2 was advanced to a total depth of 1,617.8 feet measured along the inclined core hole. Details of the core logging is provided in Xxx. Project geologists used Caltrans methodologies and nomenclature. Onsite and in storage core log data are reported as:

Depth – measured in feet, from the drill collar.

Depth – in meters, the depth in feet x 0.3048.

Lithology Rock compositions were identified in the field according to the classification shown here.



GROUP SYMBOLS AND NAMES	
Graphic / Rock Types	Common Rock Names
	Igneous Rock: (intrusive) granite, granodiorite, monzonite, diorite, gabbro, peridotite, anorthosite, syenite, tonalite; (extrusive) rhyolite, dacite, andesite, basalt, obsidian, tuff, pumice
	Igneous Rock: (intrusive) granite, granodiorite, monzonite, diorite, gabbro, peridotite, anorthosite, syenite, tonalite; (extrusive) rhyolite, dacite, andesite, basalt, obsidian, tuff, pumice
	Sedimentary: conglomerate, sandstone, siltstone, claystone, limestone, dolostone, coal
	Sedimentary: conglomerate, sandstone, siltstone, claystone, limestone, dolostone, coal
	Metamorphic: gneiss, schist, phylite, slate, quartzite, hornfels, amphibolite, marble, serpentinite, soapstone, eclogite
	Metamorphic: gneiss, schist, phylite, slate, quartzite, hornfels, amphibolite, marble, serpentinite, soapstone, eclogite

Figure S2.1. Rock descriptions used in the core logging.

Recovered core (Rec. %) - [Length of core/core barrel length] x 100

Rock Quality Designation (RQD %)

$$\%RQD = \frac{\Sigma(length\ of\ core\ pieces\ ''\ 102\ mm)}{total\ length\ of\ core\ run}$$

RQD	rock quality descriptor
90-100%	Excellent
75-90%	Good
50-75%	Fair
25-50%	Poor
0-25%	Very Poor

Run Hardness

Abbreviation	Grade	UCS (MPa)[1]	Field Test
VS	Very Soft	0.25 – 1.0	Indented by thumbnail
S	Soft	1.0-5.0	Crumbles under firm blows of a geological hammer, can be peeled by a pocket knife.

MS	Moderately Soft	5.0-25	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of a geological hammer.
MH	Moderately Hard	25-50	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow of a geological hammer.
H	Hard	50-100	Specimen requires more than one blow of a geological hammer to fracture it.
VH	Very Hard	100-250	Specimen requires many blows of a geological hammer to fracture it.
EH	Extremely Hard	>250	Specimen can only be chipped with a geological hammer.

UCS – unconfined compressive stress

Run Weathering

Abbreviation	Descriptor	Criteria
U	Unweathered	No evidence of chemical/mechanical alteration; rings with hammer blow.
SW	Slightly Weathered	Slight discoloration on surface; slight alteration along discontinuities; <10% rock volume altered.
MW	Moderately Weathered	Discoloring evident; surface pitted and alteration penetration well below surface; weathering “halos” evident; 10-50% rock altered.
HW	Highly Weathered	Entire mass discolored; alteration pervading most rock, some slight weathering pockets; some minerals may be leached out.
D	Decomposed	Rock reduced to soil with relict rock texture/structure; generally molded and crumbled by hand.

Fracture Density

Abbreviation	Descriptor	Criteria (spacing in ft and cm)
U	Unfractured	None
VSF	Very slightly fractured	>3ft (91.44 cm)
SF	Slightly fractured	1-3 ft (30.48-91.44 cm)
MF	Moderately fractured	4 -12 in (10.16-30.48 cm)
IF	Intensely fractured	1-4 in (2..54-10.16 cm)
VIF	Very Intensely fractured	< 1 in. (2.54 cm)

Spacing

Abbreviation	Descriptor	Criteria
VW	Very wide	6.5-20ft (1.98 – 6.096 m)
W	Wide	2- 6.5ft. (60.96 cm – 1.98 m)
M	Moderate	8 in-2 ft.(20.32 – 60.96 cm)
C	Close	2.5-8 in. (6.35 – 20.32 cm)
VC	Very close	1-2.5 in. (2.54 – 6.35 cm)
EC	Extremely close	< 1in (2.54 cm)

Dip (°)

Fracture dips (Figure S2.2) were determined by measuring the angle between the core axis and the fracture plane (Figure S2.2A). The same configuration was used to measure the orientation in the inclined hole, and no correction was made in the data for the hole geometry, so for the ALT B2 hole the dip angle is the core axis – fracture angle.

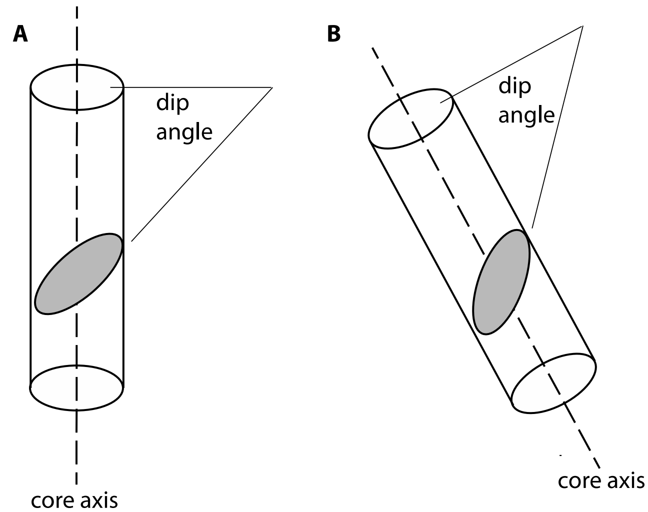


Figure S2.2. Geometry of the fracture dip measurements.

Aperture

Abbreviation	Descriptor	Criteria inches (mm)
T	Tight	< 0.4 (1)
O	Open	0.04 – 0.2 (1-5)
W	Wide	>0.20. (>5)
He	Healed	0

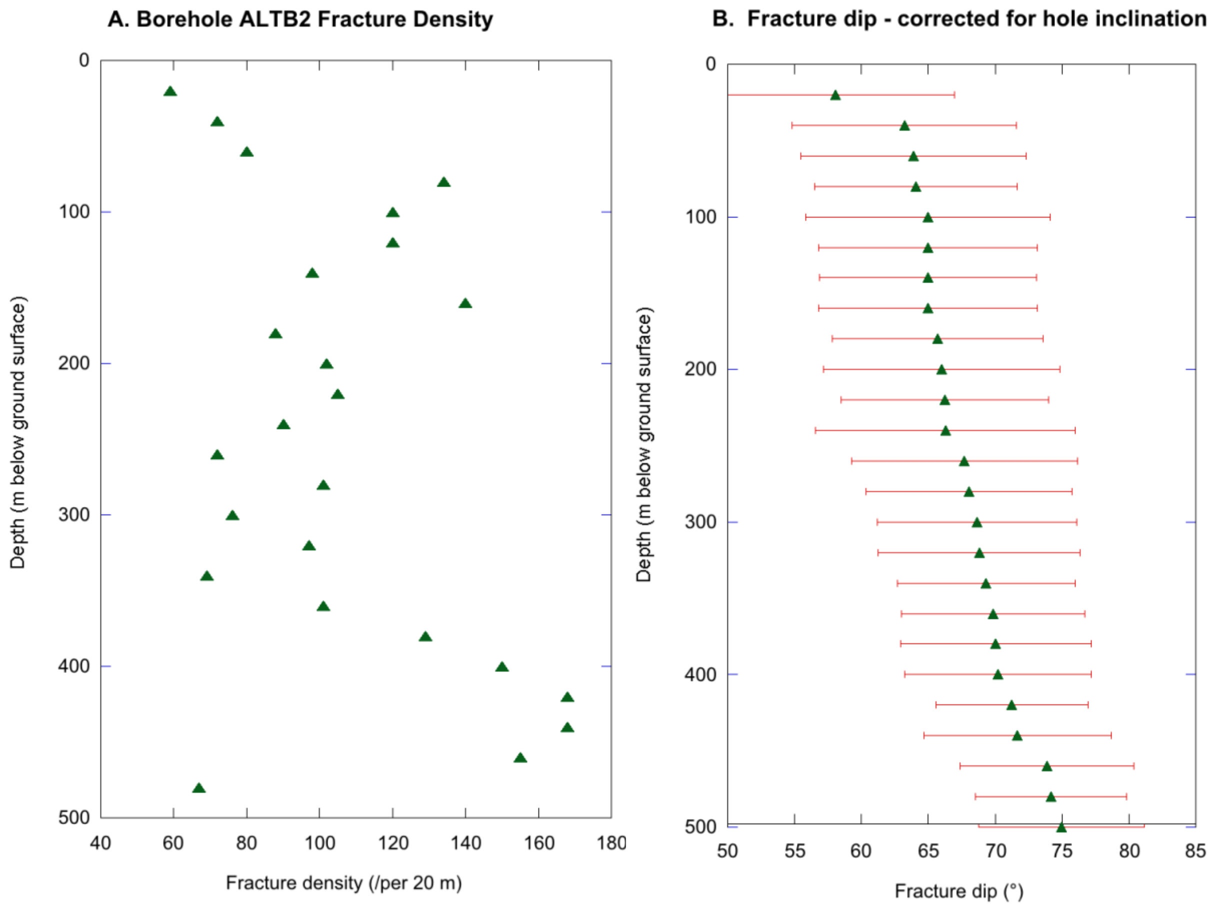


Figure S2.3. Summary of Fracture data for the ALT-B2 borehole. Depth is measured along the inclined borehole. A. Fracture density (#/20 m interval) shows increases in fracture densities near the upper part of the borehole between 100 and 200 m (See Figure 3) and the lower principal slip surface at ~ 450 m. . B. Fracture dips, corrected for the borehole geometry, increase with depth.

Depth section (m)	Fracture density #/20 m	Mean dip (°)	dip std deviation (±)
20	59	58.0	8.9
40	72	63.2	8.4
60	80	63.9	8.4
80	134	64.1	7.6
100	120	65.0	9.2
120	120	65.0	8.2
140	98	65.0	8.1
160	140	65.0	8.2
180	88	65.7	7.9
200	102	66.0	8.8
220	105	66.2	7.8
240	90	66.3	9.7
260	72	67.7	8.4
280	101	68.1	7.7
300	76	68.6	7.4
320	97	68.8	7.5
340	69	69.3	6.6
360	101	69.9	6.9
380	129	70.0	7.1
400	150	70.2	7.0
420	168	71.3	5.7
440	168	71.7	7.0
460	155	73.9	6.5
480	67	74.2	5.7
500		74.9	6.2

Table S2.1. Data for fracture density and fracture dips in the ALLT-B2 borehole.

Crouch et al. Supplemental File 3

Descriptions of outcrops of the San Gabriel Fault, east-southeast of the ALT B2 borehole where samples were collected. Data from Evans, J. S. Caine, and photos from D. Forand and J. Jacobs, 2004.

Site LT1

This is site 7 of Anderson, 1983, approximately 373796E, 3801566N, UTM zone 11N, approximately 3. 5 km ESE of the drill site (Dibblee and Ehernspeck, 1991). The steep southwest-dipping fault zone here consists of a southern strand called the De Mille fault, with a thin zone of Eocene Martinez Formation sedimentary rocks that appears to be in a fault sliver, faulted next to the Cretaceous Josephine Granodiorite. The San Gabriel Fault lies ~ 250 m to the north, where amphibolites of the Mendenhall Gneiss lie on the north side of the fault and granodiorite is south of the fault. The fault zone here is a 1-4 cm thick black, dark brown, aphanitic cataclasite to ultracataclasite, sometimes referred to as 'flinty fault rock in older literature (Ehlig, written comm., 1990). The Martinez Formation here consists of a polymict conglomerate and red coarse-grained sandstone. The granodiorite is altered and intruded by mafic dikes. A subsidiary fault zone in the sedimentary rocks. ~ 5 m from the fault core is weakly to strongly foliated and foliated shaly zones appear in places to be injected into the host conglomerate.

Site LT2

Site 8 from Anderson et al., 1983 – near the "earthquake" country site of the USFS picnic area (UTM 372895 E, 3802000N, UTM zone 11N). Proterozoic Mendenhall Gneiss to the north and Cretaceous light-colored Josephine Granodiorite to the south. The gneiss here is a quartz -plagioclase-biotite-actinoiite gneiss retrograded to greenschist facies. The fault is a 1-5 cm thick dense, aphanitic, black cataclasite to ultlracataclalsite. See Figure 5 of the text for annotations of the sample localities.

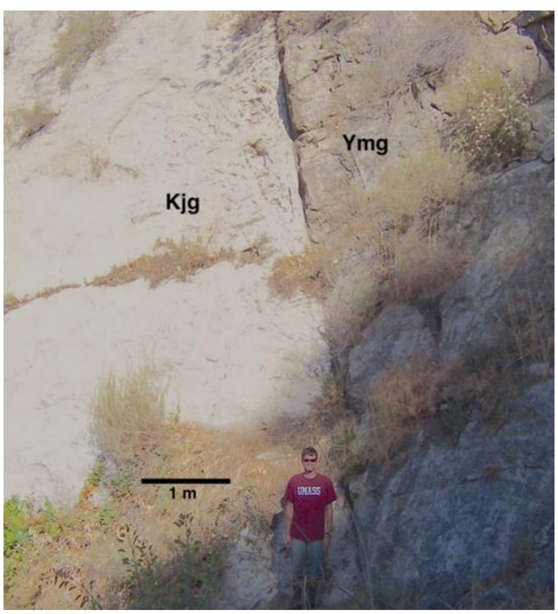


Figure S 3.1. View to the WNW of the narrow fault core of the north-dipping San Gabriel fault at site LT2.

Site BT1

This is Anderson et al., 1983, site 10, along the Big Tujunga road, (UTM 385560E, 3795870N, 11N). The fault zone here comprises a zone 70-80 m thick of numerous faults, mapped as offsetting granodiorites (Dibblee and Minch, 2002). The outcrop is strongly weathered and fault zone consists of numerous fractures and altered rocks.

Site BT2

This is near site 11 of Anderson et al., 1983, in the area from (383825 E, 3795888N to 384560E, 3796415 Nm UTM zone 11N). The fault here juxtaposes two gneissic units (Figure S3.2) and is a 1-5 m thick zone with highly deformed anastomosing foliated sheared rocks with curviplanar slip surfaces (Figure S3.yy). In places the fault one contains sulfides and gypsum. Within the fault zones brecciated felsic clasts are polished and striated.

A **B**

Figure S3.2. A. View to the north west of the San Gabriel site at Site BT2. B. Steep north-dipping. fault consists of a foliated zone 1-5 m thick, with no visible thin cataclasite zone.

Site BT4

This is the Anderson et al. (1983) site 14, UTM 11 N 388686 E, 3794075 N, near the Fusier Canyon on the Big Tujunga road. The steep north-dipping fault zone is up to 2 m wide, indicated by the double arrows in Figure S3.3) consisting of foliated, sheared rocks with a 5-10 cm thick cataclasite to ultracataclasite zone zone (Figure S 3.3). The fault juxtaposes K-feldpsar+biotite+hornblende granodiorite (Kgrdb), with chloritic alteration, on the northwest side of the fault against a felsic altered granodiorite on the southeast side of the fault (Kgr). The foliated sheared rock contain Fe- and chlorite-coated slip surfaces.

A B

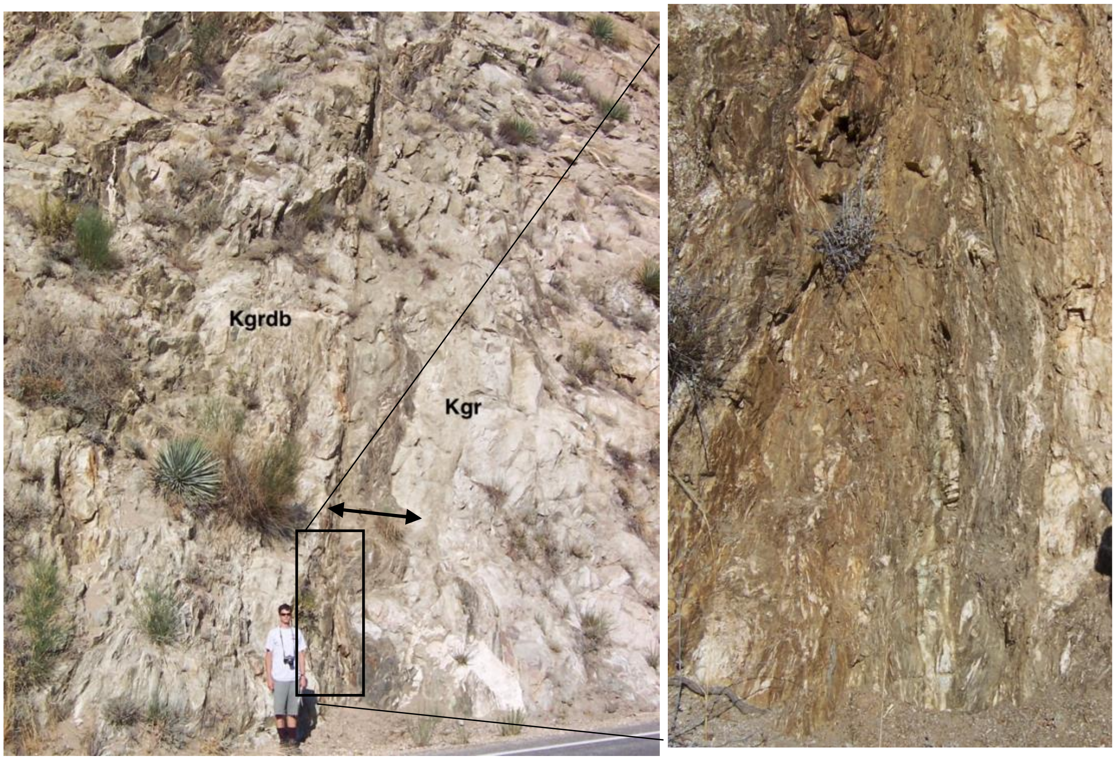


Figure S3.3. View of the east of the San Gabriel fault at site BT4. A. Fault zone consists of a 2-5 cm thick ultracataclasite zone on the west (left) side of the zone. B. Fault core with ultracataclasite and intensely sheared brown innermost damage zone, with sheared gray zone.

Supplemental File 4. This file contains photos and descriptions of drill core from borehole ALT-B2. The file **ALT-B2 Core Photos** is a PDF with compiled images of bisected core, both dry and wet. Samples are oriented with measured depth along the borehole, with the upper and lower limits of the samples listed in meters and feet. Drill core samples were epoxied prior to their bisection. A complete list of samples, sample length (in both ft and m), measured depth along borehole ALT-B2, sample type, sample description notes, horizontal distance from the principal slip surface of the San Gabriel Fault, and year the sample was collected (in 2017 by C. Studnicky and 2019 by K. Crouch) is found in the excel spreadsheet **Appendix B_ALT-B2 Core Descriptions.** The total amount of drill core collected is calculated in meters and feet, and the amount of core in the subcategories of protolith, damage zone, and principal slip zone is listed (in m).

The associated folder **Core Pictures** contains the raw images of the epoxied and cut drill core samples with scale bars and color references. Images include both wet and dry samples. Photos and brief descriptions of drill core collected by C. Studnicky in 2017 are in PDF **Appendix B_DrillCorePhotos_2017.**

Supplemental File 5. Photos of outcrop samples from the Little Tujunga Canyon and Big Tujunga Canyon field sites. **Appendix C Field Sample Photos** contains compiled images of dry outcrop samples, with scale bar. Samples were collected by J. S. Caine in 1993 and prepared by J. P. Evans in 1994. Associated folder **Field Sample Photos** contains raw images of the outcrop samples.

Supplemental File 6. Descriptions and photomicrographs of thin sections from drill core from borehole ALT-B2 and outcrop samples from the Little and Big Tujunga Canyons. **Appendix D_Thin Sections** contains photomicrographs from drill core from borehole ALT-B2 and outcrop samples from the Little and Big Tujunga Canyons, in plane polarized and cross polarized light. Thin sections were scanned using an Epson Perfection Pro scanner. **Appendix D_ALT-B2 Thin Section Descriptions** contains thin section size, type, lithology, distance from the main trace of the San Gabriel fault (in m), and description notes of samples from the drill core. Thin sections from the Little and Big Tujunga Canyons were created in 1994 by J. P. Evans at USU.

Raw images of the thin sections are contained in the folder **Thin Section Scans**. Subfolders with that folder include ALT-B2 Thin Sections, Big Tujunga Thin Sections, and Little Tujunga Thin Sections. Image labels read as drill core number followed by .1, .2, etc. if there were multiple thin sections in one drill core samples.

Supplemental File 7. X-ray diffraction (XRD) data. **Appendix F_XRD Data** excel spreadsheet details sample name, sample measured depth along ALT-B2, sample type, and major, minor, and present minerals. Samples from core were analyzed at the USU Geosciences X-ray Diffraction Lab using the PANalytical X'Pert PRO XRD Spectrometer with monochromatic Cu K-α radiation. XRD data files are in folder **XRD Data.**

Supplemental File 8. Rock mass rating values. The RMR_{1989} values (Bieniawski, 1989) are determined by combining the following six parameters into a rating score summarized in the table. These parameters are:

1. Uniaxial compressive strength of rock
2. The RQD value
3. Discontinuity spacing
4. Discontinuity conditions
5. Groundwater conditions
6. Discontinuity orientations

σ

σ

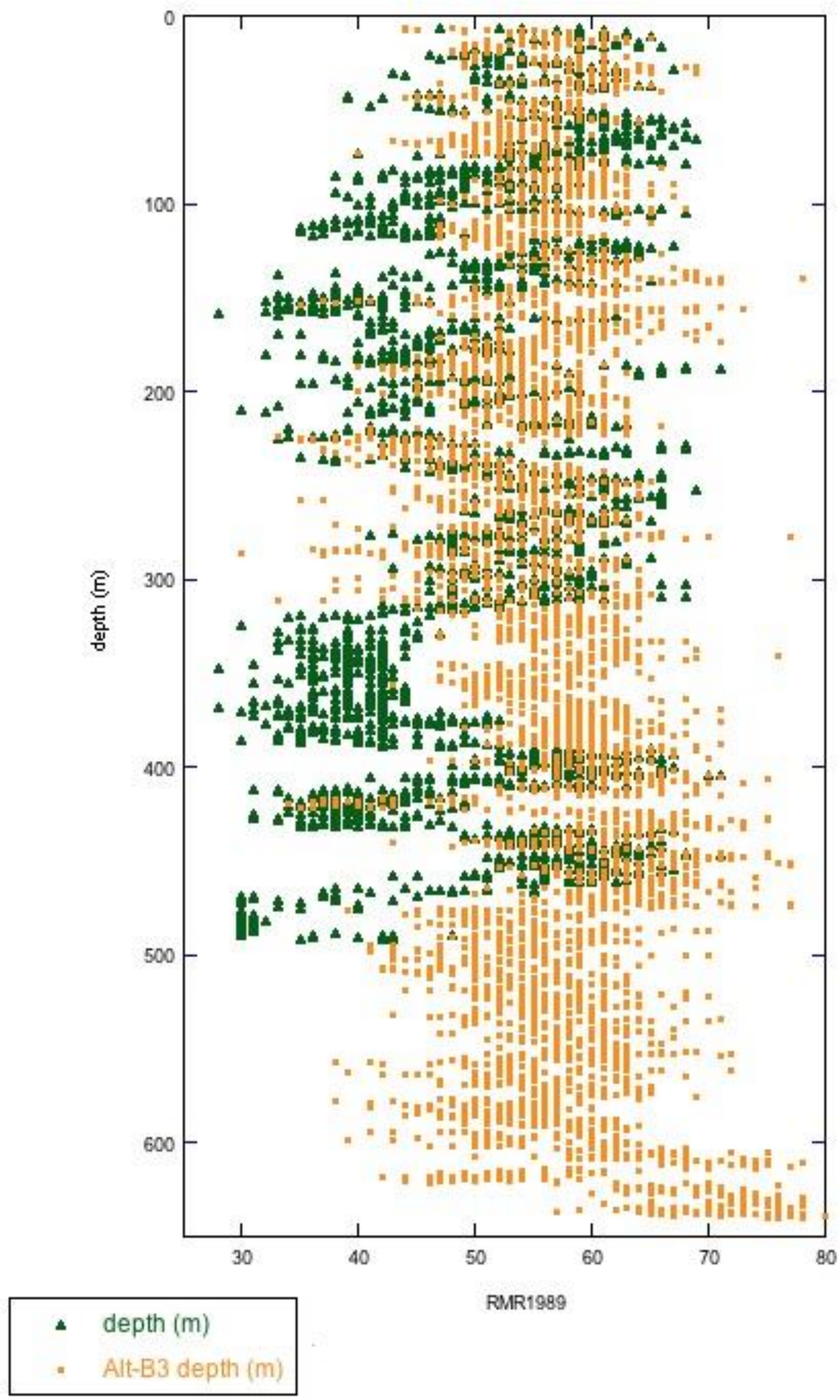


Figure S 8.1. RMR_{1989} values for the ALT B2 and ALT B3 boreholes. The ALT B3 borehole was drilled into relatively un faulted rocks ~ 1 km south of the San Gabriel Fault.