Pulverized Rock Along Faults of the San Andreas System and Garlock Fault in Southern California

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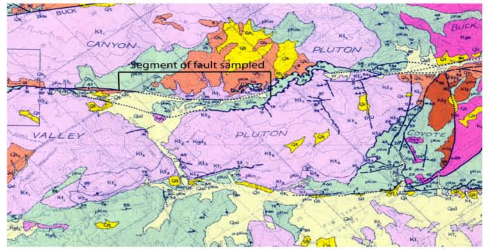
Abstract

We have described highly fractured and pulverized granitic rock at sites along the San Andreas, Garlock, San Jacinto, and Elsinore faults in southern California. XRF major and trace chemistry analyses demonstrate a lack of chemical weathering for most samples. This is confirmed by thin section analysis that shows intensely shattered crystal grains with little or no evidence of alteration near the fault core, and a decrease in damage outward. For at least the San Jacinto and Elsinore faults, these rocks have not been buried deeply during the timeframe since fault initiation (past 1.5-2 Ma), so we attribute this damage to near-surface processes (upper kilometer). At least at one of the San Jacinto sites, damage may be attributed to local structural complexity. Furthermore, where granitic dikes intrude foliated metamorphic rocks, only the granitic rock is pulverized suggesting that some intrinsic rock properties may influence damage production (or the lack thereof). We have analyzed the particle distribution of selected samples from several localities, including the classic Tejon Pass locality along the San Andreas fault. At Tejon Pass, pulverization is reported in the Tejon Lookout granite, with fracture textures dominant at the sub-micron scale. We collected additional samples from the same locality, as well as from along the Garlock fault on Tejon Ranch, also from the Tejon Lookout granite. All samples met the field criteria of pulverization - that is, the individual 1-2 mm-sized crystals can be recognized in the field but the granite (including quartz and feldspar) can be mashed with ones fingers and exhibits the texture of toothpaste. All samples were analyzed on a Horiba LA930 Laser Particle Analyzer and a Camsizer analyzer for complete particle distribution. We also analyzed the samples using the classical pipette method.

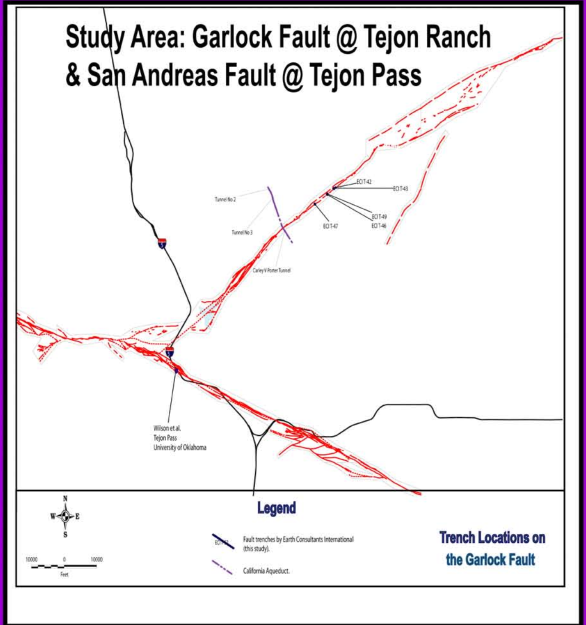
We find that the dominant particle size falls in the 31-125 micron range, much coarser than previously reported by Wilson et al. (2005), with >90% of the total sample falling in the >31 micron size range. We can reproduce the earlier results by slowing down the circulation speed on the analyzer, during which the coarser fraction drops out, thereby leaving only the fine fraction for detection. However, subsequent speeding up leads to a recovery of the original distribution. With the pipette method, which allows for a complete discrimination of each particle class range, we find a bimodal distribution with most of the sample in the coarse silt and sand fraction and the balance in the sub-micron fraction. We find that there is very little fine and medium silt-sized particles. These results indicate that pulverization is spatially associated with the active fault core and is likely the product of dynamic slip. However, the degree of damage does not appear to be as great as suggested in previous studies.

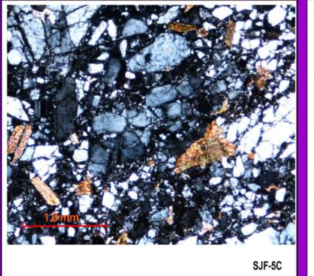
Study Area along the Clark strand of the San Jacinto Fault

Location of samples 1 through 10 for the White Wash pulverized granite locality. On the southwest side of the fault, the granite occurs as dike rock emplaced into Julian Schist (actually a gneissic schist in this area. The granitic rock is pulverized whereas the schist is mostly just fractured.

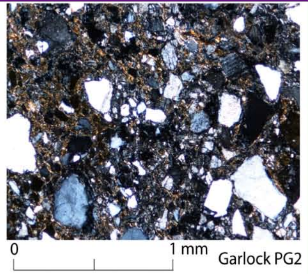


Geologic map (Sharp 1967) of the Clark strand of the San Jacinto fault, southern California. This map depicts the field area for the Horse Canyon, Whitewash samples.

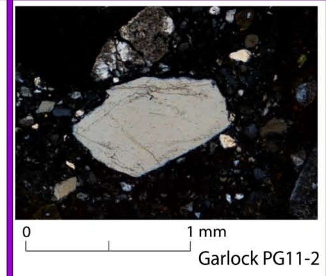




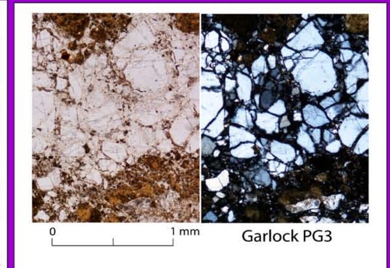
Severly fractured quartz and feldspar crystals, viewed in polarized light.



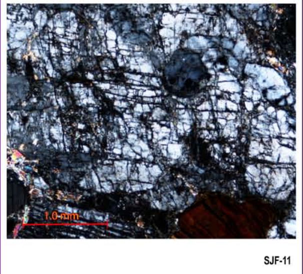
Pulverized quartz and feldspar crystals, viewed in polarized light.



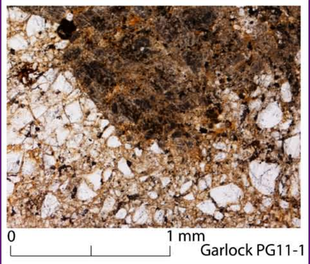
Relatively undamaged quartz grain in a pulverized matrix, viewed in polarized light.



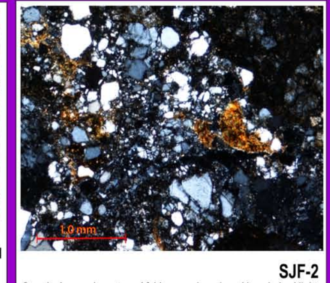
Fractured quartz crystal in plain light (left) and polarized light (right).



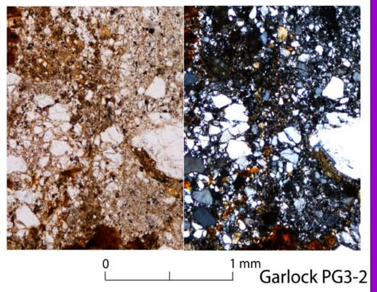
Throughgoing fractures in a quartz crystal, viewed in polarized light.

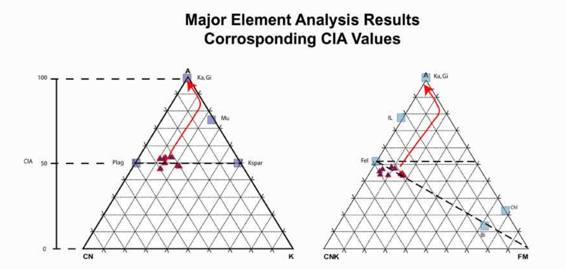


Severly damaged feldspar and quartz crystals, viewed in plain light.
(Note the feldspar crystal boundaries are still well defined.)

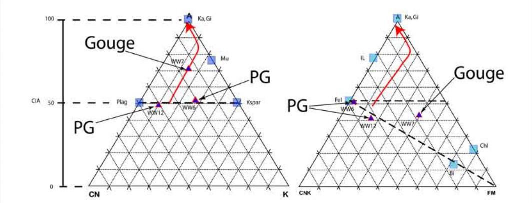


Severly damaged quartz and feldspar grains, viewed in polarized light.



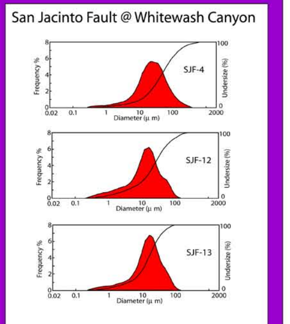


The ternary diagrams above demonstrate the major and trace element analysis and the resulting CIA values, determined though XRF. Chemical Index of Alteration (CIA) is a measure of the amount of weathering a particular rock has undergone. Our values are well within the range of unweathed granite . The red arrows are typical weathering trends for granitic rocks.

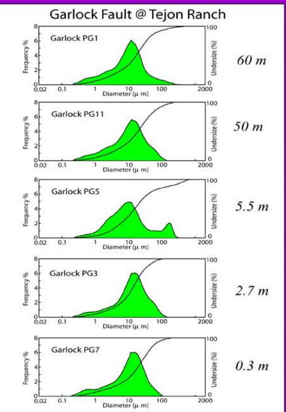


Whole rock chemistry of three of the San jacinto samples by XRF analysis. Samples 6 and 12 show no chemical alteration and have the signature of fresh granitic rock. Sample WW7 was taken from the fault core and is largely gouge - this sample shows a mix of weathered rock and unweathered rock. The fact that in the right plot, the sample falls off of the expected weathering trend from in situ weathering suggests that much of the altered material is derived from another source, possible from translocated clay of pedogenic origin.

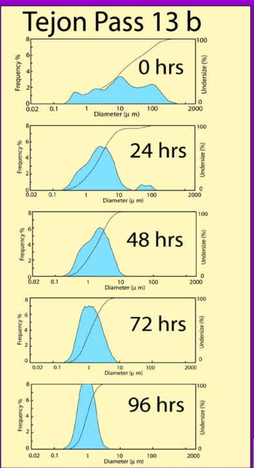
Horiba LA930 Lazer Particle Analyzer & the 96 Hour Run

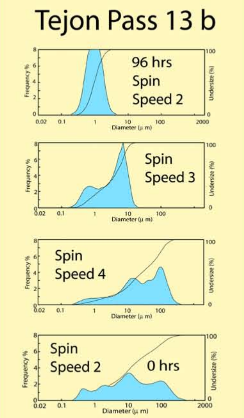


Passed through 63μ sieve



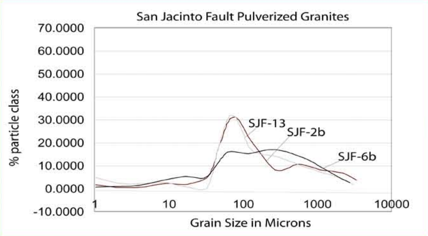
Results of particle size analysis using the Horiba XXXX Laser Particle Size Analyzer. The sample was first sieved through a 63m sieve, so note the apparent presence of material coarser than this fraction which is an artifact of the processing algorithm. The fine fraction below 31 m is also mostly an artifact of the the instruments processing algorithm, as demonstrated by conventional particle size analysis using the classical pipette method.

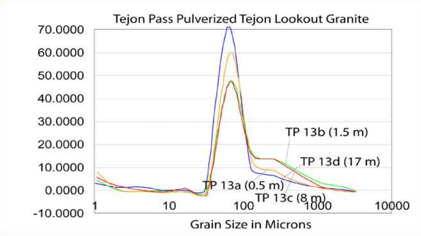


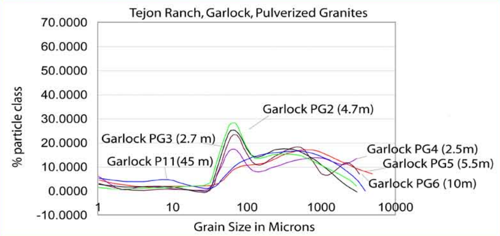


We took sample 13b (1.5m), from the classic Tejon Pass locality, and attempted to test earlier results that stated the importance of allowing a sample to circulate for several hours, in order to completely disaggregate grains with throughgoing fractures and produce a true particle sized distribution. In preparation we shook our samples for 24 hours to defloculate any clay minerals. The results, demonstrated above, show that when a sample is allowed to circulate at a low speed (<3 l/min), for several hours, silt sized particles tend to settle out, producing the incorrect particle distrubition. When the circulation speed was increased, we reaquired a result remarkably similar to the original, at 0 hours.

Results: Complete Particle Distributions







These plots depict a complete particle distribution of samples taken from the classic Tejon Pass locality, along the San Andreas Fault, samples taken from a strand of the Garlock Fault at Tejon Ranch and samples from the Clark strand from the San Jacinto Fault. Each sample was analyzed using pipette analysis on the silt and clay sized fraction, and mesh sieve analysis on the sand sized fractions. The data was combined to produce the distribution curves above.