Geophysical Research Abstracts
Vol. 13, EGU2011-13168-2, 2011
EGU General Assembly 2011

Investigating the Damage Pattern of Fault Zone Rocks by In-Situ Seismic Field Measurements and Laboratory Experiments

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Pulverized Fault Zone Rocks (PFZR) have been investigated in various studies at the San Andreas Fault describing their distribution and physical characteristics. These mainly crystalline plutonic or metamorphic rocks have been shattered in situ to the micron or finer scale while preserving most of their original fabric, but do not appear to have been subjected to significant shear strain. Field observations describe an asymmetry of the rock damage across the fault and also a decrease in damage with increasing distance from the fault. Recent favored theories include pulverized rock genesis by dynamic rupture propagation on bi-material interfaces in fault zones with different seismic velocities across the fault or the slip zone. In such cases, there is an incompatibility along the propagating rupture tip that can produce 'wrinkle-like' pulses and strong dynamic weakening. Rupture associated with wrinkle-like pulses may form asymmetric damage structures and shattered "pulverized rocks" on the high velocity side. If correct, such fault damage is directly generated by earthquake rupture.

Therefore, in order to correlate the seismic velocities of fault zone rocks of coseismic origin to their degree of damage, we investigated PFZR using in situ seismic field measurements and ultrasonic laboratory experiments. Shallow seismic velocity measurements were carried out using a 5kg sledgehammer source across a trace of the San Andreas Fault on different scales near Palmdale, California. A 350 m transect line and a high resolution 50 m profile were made running perpendicular to and crossing the 1857 Fort Tejon earthquake surface rupture. We collected data using linear arrays of 72 equally spaced 14Hz geophones connected to a 72 channel Geometrics recorder (1.75 Hz - 20 kHz). Ten stacked waveforms were recorded from sources located within 5m of each geophone, perpendicular to the array. Tomographic models produced from the two profiles show that the fault core does not seem to be associated with any detectable velocity perturbation. The 350 m profile shows a high velocity wedge on the pulverized side of the fault which matches results from a previous study and could be due to the asymmetric damage. Velocities of the high resolution 50m profile match those from the 350 m transect which leads to the assumption that there is an independence of scale on velocity suggesting that the zone of pulverized rocks has a lack of large scale macroscopic features.

Samples of the PFZR were taken at varying distances from the fault along the transects in order to measure seismic velocity at the smallest laboratory scale. The measured p-wave velocities are about a factor of 2 higher than the in-situ velocities, a dependence on scale seems to be present. The expectations of increasing seismic velocities with distance from fault (increasing velocity with increasingly intact rock) are not met. If at all, laboratory velocities show a slight decrease with increasing distance. Measurements of porosity inversely correlate with those observations.

We compare this data to laboratory velocity measurements made on samples from a similar transect across the Gole Larghe fault in the Southern alps, a fault zone exhibiting coseismic fault damage supported by the presence of pseudotachylytes. This fault shows a similar trend: there is a decrease in velocity with distance from the fault core. In these fault zone samples, however, microfractures are mineral-filled. Quantitative microstructure analysis will now be carried out on the San Andreas samples, in order to understand the role of pore collapse and healing that could influence the seismic velocity in these samples.