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Crack Damage in Granite: Physical and Mechanical Consequences

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We investigate the effects of pervasive crack damage on the rupture processes of a fine-grained granite, under triaxial stress, in wet (H_20) and dry (argon gas) saturated conditions, at room temperature. Eight samples of La Peyratte granite (a granodiorite with an average grain size of 800 microns) were cored with an initial porosity of $<1\%$. Damage was introduced by heating four samples up to 700°C. These were then compared to the intact granite specimens. 4 samples were deformed at a constant strain rate of $2x10^{-6}$/s until brittle failure occurred. 4 other samples were deformed in creep conditions. During these 8 experiments, at each step, we recorded strains, elastic wave velocities and Acoustic Emissions (AE). Our main results are:

1. The brittle strength of the sample remained unchanged (approx. 500MPa deviatoric stress at 30MPa effective pressure), whether the sample was heat-treated or not. We did not observe any significant water weakening as well. However, the onset of dilatancy was observed at lower deviatoric stress in the heat-treated specimen than for the intact ones.

2. Acoustic emissions revealed useful in order to image the rupture processes. Indeed, AE locations and Focal mechanism were in good agreement with the post mortem analysis of sample. In intact specimen, failure occurred after a larger premonitory AE activity, while heat-treated specimen had a longer aftershocks activity. In creep conditions, we show that extreme damage localization is already initiated during the primary and secondary creep phases.

3. However, in all our experiments, we observed the development of an elastic fabric well before the onset of rupture. To be more precise, measuring the P wave velocities along two different horizontal travel paths – one perpendicular and one parallel to the eventual rupture plane, away from the nucleation zone – we showed that that both started to diverge as early as at 70% of the final rupture strength. This shows that quite early on during the experiment, the strain localization processes have started and the final fault orientation has already been selected.

4 In creep experiments, the heat treated rock sample with water is more sensitive to differential stress than the intact rock samples probably because of initial damage and the subcritical crack growth.

5 We investigated the crack density evolution of the 4 samples deformed at a constant strain rate both in hydrostatic and deviatoric stress. In hydrostatic condition, crack density decreased from about 0.5 to 0.2 for heat-treated samples while almost kept constant at 0.1 for intact samples. This means damage was significantly introduced by heating. In deviatoric situation, the thermal cracks decreased continually until to zero and random cracks increased until failure with increasing pressure.