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On the Nature and Distribution of Damage Surrounding Large Strike-Slip Fault Zones

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Fault damage zones are represented by both microfracturing of the rock matrix and by macroscopic fracture networks. The spatial distribution and geometric characterization of fracture patterns at various scales help to predict fault growth processes, subsequent mechanics and bulk hydraulic properties of a fault zone.

We studied strike-slip faults of various displacements that cut crystalline rock within the excellently exposed and exhumed Atacama Fault Zone, Northern Chile. Micro- and macroscale fracture densities within the damage zones of faults with displacements ranging over 3 orders of magnitude ($\sim$0.12 m – 5000 m) that cut through the same rock type have been characterized.

Multiple generations of microfractures are represented by fluid inclusion planes (FIPs), partially healed and open microfractures. FIPs show a log-linear decrease in density with perpendicular distance from the fault plane. These FIPs are in a predominantly mode I orientation and we interpret them to record a snapshot of fault history related to the passage of a migrating fault tip process zone. Microfracture densities fall to background levels at $\sim$0.12 m for the smallest displacement fault (0.2-2 m offset), $\sim$150 m for the medium displacement fault (200 m offset) and $\sim$200 m for the largest fault (5000 m offset). All faults appear to have a critical microfracture density independent of displacement. However, fault damage zone widths seem to scale with displacement, which is consistent with a post-yield fracture mechanics model. Later microfractures do not show a clear relationship of microfracture density with distance.

Macrofractures are a combination of shear and opening mode, but a significant proportion also occur at a high angle to the main fault trace, which may be related to dynamic loading or hydrofracturing with the greatest principal stress oriented at a high angle to

the fault trace.

We interpret the damage surrounding the faults studied accumulated as a result of process zone migration, geometrical irregularities on the fault plane and dynamic loading. Early fault damage zone width scales with displacement, and core structure becomes more complex with increased displacement.