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The Structure of Seismogenic Faults in Crystalline Basement

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Fault zone structure over a wide range of scales strongly influences earthquake mechanics, including the sites of earthquake nucleation and arrest, co-seismic strength and slip distribution, and the amount of energy expended during frictional heating and creation of wall-rock damage. The importance of multi-scale fault heterogeneity necessitates an integrated approach to understanding fault zone structure. Methods of digital data acquisition such as terrestrial laser-scanning (ground-based LIDAR) and differential GPS (D-GPS) represent spatially precise techniques of capturing and quantifying the structure of exhumed fault zones. Importantly, they allow the hierarchical nature of fault-zone structure to be explored within one spatially-referenced model.

Here, we use LIDAR and D-GPS, together with photogrammetric methods and field analysis, to investigate the structure of a seismogenic fault zone exhumed from $\sim$10km depth. We focus on oblique-slip cataclasite- and pseudotachylyte-bearing fault networks belonging to the Gole Larghe Fault Zone (GLFZ) in the Italian Alps. The GLFZ is hosted in granitoids of the Adamello batholith, containing a strong pre-existing joint set, and is exposed in continuous, glacier-polished outcrops for distances of tens to hundreds of metres.

Fractures outside the GLFZ are represented by joints and sheared joints formed predominantly at temperatures >500°C, whilst fractures inside the fault zone are represented by cataclasite- and pseudotachylyte-bearing fault strands active at 200-300°C. The transition from 'wall rock' to 'fault zone' is marked by an abrupt increase in macroscopic fracture density, in contrast to the gradual increases in fracture density observed in the damage zones of other large faults in crystalline basement e.g. the Punchbowl Fault, California, and the Caleta Coloso Fault, Chile. Both joints outside the GLFZ and faults inside the GLFZ are best described by log-normal spacing distributions. '1st-order' fault strands that accommodated metres to tens of metres of displacement have spacing distributions and mean spacing values that are similar to joints outside the fault zone. Overall, faults inside the GLFZ are strongly clustered, reflecting clustering of minor faults around 1st-order fault strands. However, minor faults preferentially occur on the northern side of 1st-order faults (in the local footwall block), suggesting an asymmetric damage distribution within the GLFZ that cannot be explained by lithological variations. One explanation for the asymmetric damage distribution may be that propagating earthquake ruptures preferentially follow one of the boundaries between a pre-existing joint cluster and relatively intact host rock due to stiffness contrasts. We use our observations to comment on the development and behaviour of seismogenic fault systems in areas containing strong pre-existing anisotropies.