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Switching deformation mode during natural faulting in Carrara marbles.

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A study on meso- and microstructural features of a high angle normal fault observed in the Alpi Apuane NW Tuscany (Italy) is presented to document switching in the deformation mode during different evolutionary stages of a fault zone growth in naturally deformed Carrara marble. The studied fault was formed at c.3 Km of depth and belongs to structures related to the most recent deformation history of the Alpi Apuane metamorphic core (from c.4 Ma until now, Fellin et al. 2007; Molli, 2008). On the basis of deformation mechanisms and their chronology interpreted from cross-cutting relationships, different stages of the fault zone evolution have been recognized. An early stage of deformation (stage 1) was associated with extensional and shear veins now observable in both hangingwall and footwall blocks as part of the deformation zone developed at decameter-scale. Geochemical data indicate vein-development in a locally closed system where a "stationary" fluid phase migrates over meter scale distances (Molli et al., in press). During stage 2, a localization of the deformation, possibly in precursory coarse grained calcite/quartz shear veins of stage 1, took place. During this second stage crystal-plastic deformation affected areas at the head and along the hanging wall rim of fractures accommodating fault tip distorsions in a way recalling the mode-II geometry of stable crack propagation (Atkinson, 1987; Vermilye and Scholtz, 1993; Kim et al., 2004). Following pervasive cataclasis (stage 3) characterizes a plurimeter-wide dilational jog between two non-parallel main slip surfaces with brecciation and far-derived fluids channelling leading to significant geochemical alteration of the fault rocks with respect to the protolith (Molli et al., in press). Cataclastic deformation produced a grain size refinement and a decimetric thick fault core asymmetrically bounded by the upper main slip surface. Deformation was then localized within ultracataclasite of the fault core where diffusive-mass transfer mechanisms dominate microstructural development (stage 4). The fault growth ended by stage 5 associated with vertical shortening and development of slickolites at the contact hanging wall/main slip surface and microveins and stylolites within the fault core.
The study of naturally faulted Carrara marble reveals, therefore, switching in the deformation mode in terms of distributed vs. localized deformation styles and changing in deformation mechanisms. The two main stages of brittle deformation (stage 1 and 3) were associated with diverse types of fluids involvement and redistribution inducing: in stage (1) dilatancy possibly related to change in shear stress and/or mean stress during fault loading cycle and in stage (3) localized fluid-pressure inbalance possibly accompanying fast transfer of slip across the main slip surfaces with formation of implosion breccias in the dilational jog (Sibson, 1986). Rate-dependent mechanisms involving dislocations and diffusive-mass transfer allowed aseismic shearing flow during stage 2) and 4) and healing and sealing of the fault during stage 5).