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Strain rate dependent activation of slip systems in calcite marbles from Syros (Cyclades, Greece)

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The activation of certain slip systems in calcite has been experimentally proven to be highly temperature dependent, but also the strain rate plays an important role on the activation of the dominant slip system. In this study, observations from a flanking structure (i.e. shear zone) that developed under lower greenschist-facies conditions, in an almost pure calcite marble (Syros Island, Greece) are presented. The shear zone is characterized by a strain gradient from the slightly deformed tips ($\gamma \sim 50$) to the highly strained centre (γ up to 1000) while the host rock is moderately deformed ($\gamma \sim 3$). During the shear zone development, the strain gradient coincided with a strain rate gradient with strain rate varying from 10^{-13} to 10^{-9} s^{-1}. The studied outcrop thus represents the final state of a natural experiment and gives us a great opportunity to get natural constraints on strain rate dependent mechanical behaviour in a calcite marble. Detailed microstructural analyses have been performed via optical microscopy, electron microscopy, electron backscatter diffraction mapping and transmission electron microscopy, on samples from the highly strained shear zone and the host rock. The analyses show that the calcite microfabric varies depending on position within the shear zone, indicating activation of different deformation, recrystallization mechanisms and slip systems at different strain rates. Up to strain rates of $\sim 10^{-10}$ s^{-1} the marble deformed exclusively within the dislocation creep field, showing a change in recrystallization mechanism and dominant active slip system. While the marble preferentially recrystallized by grain boundary migration at relatively low strain rates ($\sim 10^{-13}$ s^{-1}), subgrain rotation recrystallization seems to be the dominant mechanism at higher strain rates ($\sim 10^{-12}$ to 10^{-10} s^{-1}). At higher strain rates ($\sim 10^{-9}$ s^{-1}), the recrystallization mechanism is bulging, resulting in the development of an extremely fine grained ultramylonite (average grain size ~ 3 μm) accompanied by a switch in deformation mechanism from dislocation creep to a combined deformation by grain boundary sliding and dislocation activity. Constraints on dominant active slip system depending on deformation strain rate have been made by a combination of misorientation analyses and viscoplastic self-consistent modelling.