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# Uniaxial compression of calcite single crystals at low temperature: insights into twinning activation and development

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E-twinning is a common plastic deformation mechanism in calcite. Previous experiments have shown that temperature, strain rate and confining pressure have negligible effects on twinning activation, the latter being mainly dependent on differential stress. Temperature is however reported to control the aspect of twin lamellae, with thickness exceeding 2-5 $\mu$m mostly at temperature above 200 °C. The critical resolved shear stress (CRSS) required for activation of twinning has been shown to be dependent on grain size and to be subjected to strain hardening: its value increases with the amount of strain accommodated and decreases with increasing grain size. This CRSS value may obey the Hall-Petch relation, but due to sparse experimental data the actual evolution of the CRSS with grain size and strain still remains a matter of debate.

Numerous experiments were carried out at high temperature to investigate gliding systems in calcite, but just few data are available on the plastic behavior of calcite crystals at low temperature, despite the fact that the latter may help understand deformation processes of carbonate rocks in sedimentary basins. New mechanical tests were carried out at room temperature on unconfined single crystals of calcite, with different sizes and crystallographic orientations. Uniaxial deformation was performed at controlled displacement rate, meanwhile the sample surface was monitored using optical microscopy (reflected light) and high resolution CCD camera. The retrieved macroscopic stress-strain behavior of the crystals was correlated with the surface observations of the deformation process. Specific characteristic events observed on the loading curve could be related to either micro-fracturing or twinning. We especially focused on the sequence of activation and thickening of the calcite twins. Our results show (1) the early onset of crystal plasticity with the activation of the very first isolated mechanical twins during the strain hardening stage, (2) the densification and thickening of twin lamellae during the final flow stress leveling stage. The latter accounts for most of the irreversible strain and corresponds to episodically fluctuating resistance, with strain hardening increments followed by equivalent stress drops related to twinning events. Thickening of twin lamellae occurs in two steps with increasing deformation. Our observations of thickening of twins at low temperature confirm recent results by Rybacki et al. (2013). The different values for the CRSS we obtained for the activation of isolated twins and for the onset of densification and thickening bring questions about the appropriate value to be considered when using calcite twin data for inversion purposes aiming at retrieving past stress orientations and magnitudes. On the other hand, we also observed micro-cracking events, suggesting either imperfections of sample geometry, or the need of complementary accommodation mechanisms due to twinning anisotropy. These observations highlight the importance of direct observations during mechanical testing in order to interpret mechanical data. At last, we did not see any clear crystal size effect on the CRSS values. More experiments on both single crystals and aggregates are needed to validate the latter observations.