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Stress and Temperature Dependence of Calcite Twinning: New Experimental and Field Constraints

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In low-grade metamorphic terrains at temperatures $< 300^{\circ}$C e-twinning of calcite is common. The amount and width of e-twins have been suggested to indicate stress and temperature representing robust paleopiezometers and geothermometers.

To evaluate the stress- and temperature dependence of e-twins in calcite we have performed a series of deformation experiments on specimens of Carrara marble in the semibrittle field. 14 experiments were performed at 100-400 MPa confining pressure and T $< 350^{\circ}$C in a Paterson-type gas deformation apparatus. 7 samples were deformed in axial compression test at strain rates from 10^{-4} -10^{-6}s^{-1}. 7 samples were deformed in torsion tests to shear strains γg 1.8. After testing, thin sections of all samples were prepared for optical inspection of twin density and twin width.

Calculations of shear stress based on the percentage of twinned grains (Jamison and Spang, 1976) significantly underestimate the applied stress, whereas below 170 MPa the twin density piezometer suggested by Rowe and Rutter (1990) yields too high stresses. Based on measured twin density (between $\approx$10 and 800 twins/mm at stresses up to 450 MPa) we propose an empirical paleopiezometer for which the square root of twin density increases linearly with applied stress. This correlation is likely associated with the development of dislocation cells in response to twin nucleation and growth. The piezometer is independent of strain for $\gamma < 1.8$ at temperatures up to 350°C.

To infer paleotemperature from the width and morphology of twins (Burkhard, 1993; Ferrill et al., 2004) we also measured twin width using a U-stage. Preliminary results show that the amount of thin twins (≤ 1 μm) decreases continuously with increasing temperature, whereas thick twins (> 1 μm) increases with temperature. This may indicate that strain incompatibility at grain boundaries is less for high temperature and low strain rate, respectively. The experimentally deformed samples were compared to naturally-deformed low-grade calcite rocks from different fault zones. From optical thin sections of 20 samples, deformation temperatures were estimated based on twin width and compared to other geothermometers (fluid inclusion analysis, vitrinite reflection, conodont colour alteration index). The data indicate a good correlation for peak temperature conditions, but considerable scatter below about 250°C.