Twinned Calcite in Polymict Breccias from the Ries Impact Structure – Brecciation and Mixing of Target Rocks

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Abstract: Although of prime interest, the way carbonates behave during impact cratering as well as the interaction between carbonate- and silicate-dominated components remain to date poorly constrained. We present twinned calcite in polymict breccias from the Ries impact structure sampled from the Langenmühle outcrop at the northwestern inner ring and cores of the 1973 research drilling (depths of 970 m) N' to the city of Nördlingen. The breccias comprise metagranite and calcite-rich clasts, which are cemented by a second generation of calcite. Calcite grains in clasts as well as calcite in veins and surrounding gneiss clasts show a high density of fine-lamellar twins of > 1 / µm observed by the scanning electron microscope (SEM)- based electron backscatter diffraction (EBSD) technique and widths < 0.5 µm (Fig. 1). Although, the critical shear stress for twinning of calcite is relatively low, this high density indicates high differential stresses of several hundred MPa to 1 GPa, applying the calcite twin paleopiezometer by Rybacki et al. [1]. Twin systems identified by EBSD include *e*-twins, *f*-twins, and *r*-twins in decreasing frequency, which can all be present in individual grains. Also, *a*-type boundaries, as described from experimentally deformed calcite [2], are observed. The twinned calcite at Langenmühle is mostly pure $CaCO_3$ with a tendency of higher MnO content in clasts (up to 1 wt. %) and lower MnO content in veins (< 0.5 wt. %), as indicated by energy dispersive x-ray sepectroscopy (EDS). A later generation of calcite without twins is present in veins with elongate palisade structures, as well as in growth rims forming sutured grain boundaries surrounding twinned calcite grains and in fine-grained aggregates within twinned calcite. EDS measurements show that these second-generation calcite grains can contain up to 2.5 wt. % FeO and < 1 wt. % MnO. Whereas the fine-grained aggregates and sutured grain boundaries indicate recrystallization, the palisade grains indicate precipitation from the pore fluid. Also quartz is found to form growth rims. Large hypidomorphic quartz crystals indicating precipitation in open space, intergrown with twinned calcite are mainly observed in the drill-core samples from 970 m depths.

The apparent close association of calcite with brecciation (twinned calcite within veins and twinned elongate calcite grains surrounding gneiss clasts) indicates mobilization and emplacement related to the formation of the polymict breccias, i.e., related to impact-induced brecciation and mixing. The calcite is interpreted to originate from the sedimentary bed rocks and especially in the case of the drill-core samples from pre-shock calcite veins within the gneisses. The not twinned calcite in growth rims and veins as well as quartz growth rims indicate precipitation from a $CaCO_3$--rich hydrous fluid (containing also some SiO_2) already within the mixed target rocks. In the polymict breccias, no microstructural evidence for melting and/or devolatilization has been identified. The calcite-bearing polymict breccias reflect the mixing of sedimentary and basement target rocks shocked to relatively low shock conditions, as no planar deformation features in quartz have been observed. The high density and fine-lamellar twins related to four different twin systems in one grain associated with cleavage cracks indicates high differential stresses on the order of several hundreds of MPa to 1 GPa, consistent with deformation processes related to brecciation and mixing of target rocks during impact cratering.

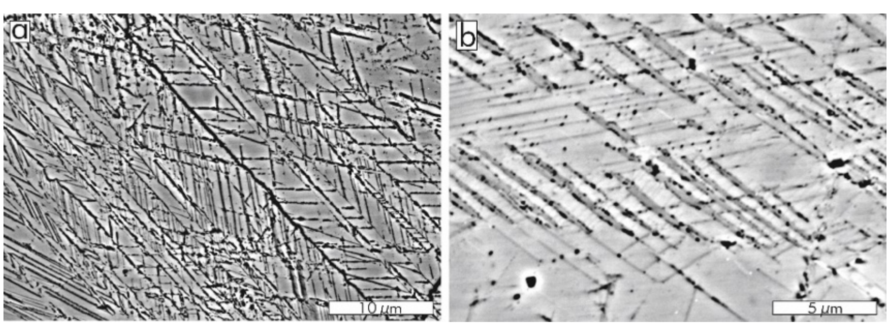

Fig. 1: *SEM images showing high density of fine-lamellar twins in calcite, sample JB2, Langenmühle, orientation contrast in (b).*

References:

[1] Rybacki et al. (2013) *Tectonophysics*, 601, 20-36, http://dx.doi.org/10.1016/j.tecto.2013.04.021.
[2] Schuster et al. (2020) *Mineralogy and Petrology* 114, 105-118, https://doi.org/10.1007/s00710-019-00690-y