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Twinned calcite within polymict impact breccias from the Nördlinger Ries impact structure, Germany – shock effects and post-shock annealing

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Approximately one third of the worlds known impact structures are formed in carbonate-bearing target rocks. However, the response of their main constituent mineral, calcite, upon shock loading and unloading is still not well understood. Mechanical twins in calcite are described from natural impactites and shock experiments, yet, reliable indicators to distinguish these shock effects from the very common calcite twins generated in tectonites are missing. Here, we present scanning electron microscopic investigations of twinned calcite within calcite cemented brecciated gneisses from the Ries impact structure.

Calcite cemented brecciated gneisses occur at several outcrops of the Ries impact structure as well as in samples recovered from depth as low as 977 m in the research drilling 1973. At Maihingen, the polymict impact breccias contain shocked gneiss fragments and various generations of calcite in veins. The occurrence of rhombohedral PDFs in quartz from the gneiss fragments indicates shock conditions of >10 GPa. Coarse calcite grains, representing an early generation of calcite in the veins, show exceptionally fine-lamellar twins, indicating high stress and strain rates. The calcite twins show widths of < 0.5 μm , a high density of up to a few hundred lamellae per mm, and appear to crosscut each other, which has been suggested as a criterion for shock-induced twinning. Furthermore, a high density of sets of planar features occur associated and parallel to these twins, but along which no twin domains were resolved in the scanning electron microscope. Twin systems detected by EBSD measurements include e-twins, common also in calcite from tectonites, and another more rarely occurring twin system, characterized by a rotation axes parallel to <-2110> and a rotation angle of ca. 35°. A second generation of calcite without twins is represented by elongate palisade calcite, fine-grained aggregates and rims forming sutured grain boundaries surrounding twinned coarse calcite grains. EDS measurements show that these calcite grains contain up to 2.5 % Fe as well as traces of Mn, Mg, Si, Na and Al. In contrast, the coarse twinned calcite is almost pure CaCO_3 . Whereas the fine-grained aggregates and sutured grain boundaries indicate recrystallization, the palisade grains indicate precipitation from the pore fluid.

The twinned coarse calcite grains within the polymict impact breccias are interpreted to be shock induced. As coarse calcitic sedimentary target rocks are not known from the Ries area, they can

either represent pre-shock calcite veins within the gneisses or possibly marbles that were brecciated together with shocked gneisses during impact cratering. The second generation of calcite represents post-shock recrystallization and precipitation from a fluid.