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Shock Induced Planar Deformation Structures in Quartz from the Ries Crater, Germany

W. v. ENGELHARDT and W. BERTSCH
Mineralogisches Institut der Universität Tübingen

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Abstract. Crystalline rocks from breccias of the Ries basin, Germany, contain highly deformed quartz. Various planar deformation structures could be observed and classified into five different types: (1) Decorated planar elements, (2) Non-decorated planar elements, (3) Homogeneous lamellae, (4) Filled lamellae, (5) Planar fractures. All these structures are parallel to crystallographic planes: $\{10\bar{1}3\}$, $\{10\bar{1}2\}$, $\{10\bar{1}1\}$, $\{0001\}$, $\{11\bar{2}1\}$, $\{11\bar{2}2\}$, $21\bar{3}1\}$, $\{51\bar{6}1\}$, $\{10\bar{1}0\}$. The most typical and most abundant planar structures are decorated and non-decorated planar elements parallel to $\{10\bar{1}3\}$ and $\{10\bar{1}2\}$. Planar fractures are parallel to $\{0001\}$ and $\{10\bar{1}1\}$ and form at lower stress levels, probably earlier than the planar elements.

Quartz containing planar elements, especially of the non-decorated type, has lower density, index of refraction and birefringence than normal quartz. This "quartz" is apparently a mixture of an amorphous phase and crystalline quartz, the amount of which can be calculated using average density or refractive index.

Comparison of planar quartz structures found in tectonites and those produced artificially under static or dynamic high pressure conditions demonstrates that Ries quartz closely resembles deformed quartz recovered from shock wave experiments. The planar structures found in Ries quartz have been formed by shock wave actions with peak pressures in the 100—400 kbar range.

Planar elements are explained to be traces of gliding processes during shock loading visible due to the fact that a high pressure phase (stishovite and/or a stishovite-like glass phase) has been produced along the glide planes. Upon pressure release most of the high pressure phase was transformed into an SiO_2-glass (diaplectic glass).

In comparison with experimental data the amount of residual crystalline quartz as well as type and orientation of planar structures in the quartz grains are clues to estimate the peak pressures responsible for these deformations. Shock waves with peak pressures exceeding about 400 kbar completely transform quartz into diaplectic SiO_2-glass.

Contents

1. Introduction

Planar deformation structures in quartz have been observed in brecciated rocks from many craters of suspected meteorite impact origin (MCINTIRE, 1962; BUNCH and COHEN, 1964; DENCE, 1964; DENCE, 1965; ENGELHARDT and STÖFFLER, 1965; STÖFFLER, 1966; CHAO, 1967; ENGELHARDT, 1967; ENGELHARDT, BERTSCH, STÖFFLER, GROSCHOPF, and REIFF, 1967; CHAO, 1968; ROBERTSON, DENCE and VOS, 1968; ENGELHARDT, HÖRZ, STÖFFLER and BERTSCH, 1968; CARTER, 1968; FRENCH, 1967). Several types of planar structures have been described using different terms such as deformation lamellae, planar features and cleavages. All types seem to be more or less different from deformation structures in quartz known from tectonites or artificially produced in low strain rate experiments. Deformation structures more similar to those from meteorite craters, however, have been found in shock loaded rocks from nuclear explosion sites (SHORT, 1966). Recently they also have been produced in shock wave experiments of known peak pressure (SHORT, 1968c; HÖRZ, 1968; MÜLLER and DEFOURNEAUX, 1968). Thus planar deformation structures in quartz developed to be a diagnostic criterion for shock wave action. They can be used to identify and distinguish meteoritic impact craters from volcanic structures on earth or other planetary bodies.

This paper presents a description of quartz with planar structures, collected in various breccias of the Ries basin. In addition, these types of planar structures are compared to deformation structures found in tectonites (Böhm lamellae) and those produced in the laboratory under low and high strain rates (static and dynamic conditions). The investigations in naturally shocked materials are restricted to 12 rock samples representative for shock metamorphism stages I and II. These samples were selected out of a large suite of rocks for detailed studies. No attempt is made to compare this quartz with quartz from other craters (see, e.g., the description of quartz deformation in Canadian craters by ROBERTSON, DENCE and VOS, 1968). This would imply a careful consideration of all geological and petrographic parameters and thereby exceed the scope of this article. However, the types of deformation structures found in the Ries are also commonly observed in other craters and the following description may be more general in its nature.

2. Petrography of the Investigated Rocks

Quartz with planar deformation structures is found in various breccias of the Ries (for a general description of Ries rocks see PREUSS, 1964; ENGELHARDT, 1967): they could be identified qualitatively in the suevite, in the crystalline