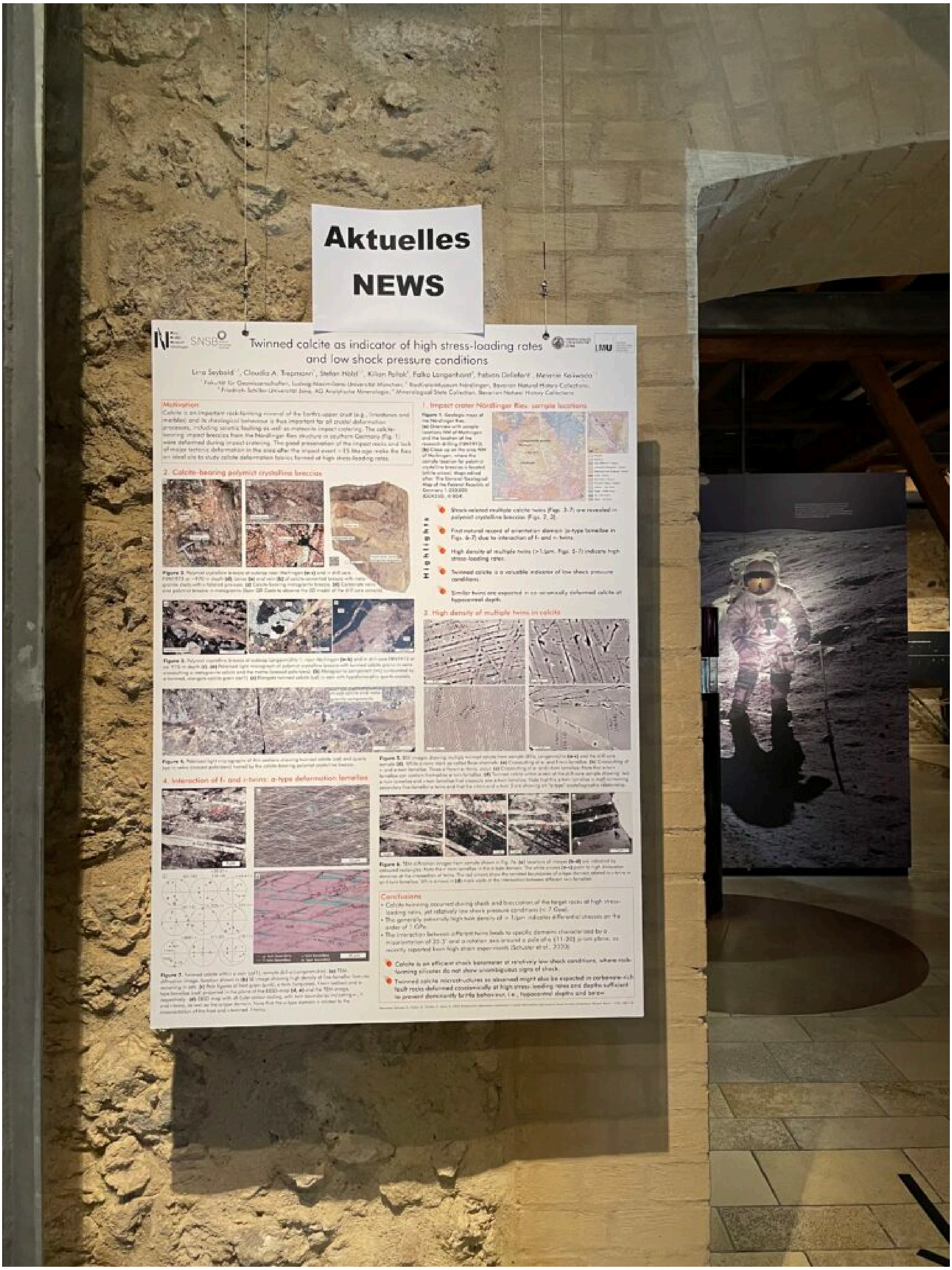
Aktuelle Riesforschung auf der Meteoritical Society Konferenz

Für alle die neugierig sind zu erfahren, an was wir aktuell forschen, gibt es jetzt einen kleinen Einblick zu sehen. Im Museum hängt unter „Aktuelles“ ein Poster, das wir auf der diesjährigen Konferenz der Meteoritical Society präsentiert haben. Es geht dabei um spezielle mikroskopisch kleine Strukturen in dem Mineral Calcit. Dieses Mineral ist der Grundbaustein von Kalksteinen, die die Schwäbische Alb bedecken und die auch von dem Asteroiden getroffen wurden, der vor 15 Millionen Jahren mit seinem Einschlag den Rieskrater bildete.

Der untersuchte Calcit zeigt sogenannte Zwillinge (engl. Calcite twinning), die durch die Stoßwelle entstanden sind, die die Gesteine im Untergrund beim Einschlag durchdrang. Die Zwillinge im Calcit sind in den Ausläufern der Stoßwelle entstanden, wo die Energie der Stoßwelle schon gedämpft war. Andere bisher untersuchte Minerale, wie z.B. Quarz, zeigen in diesem Bereich keine Veränderungen mehr durch die Stoßwelle, sodass sich heute nicht erkennen lässt, ob sie von der Stoßwelle betroffen waren oder nicht. Anhand unserer Untersuchungen ist das nun auch in diesem Bereich möglich. Calcit ist ein auf der Erde weit verbreitetes Mineral das aber auch in Meteoriten, Asteroiden und auf dem Mars gefunden wurde. Damit könnte die Untersuchung dieses Minerals in Zukunft also auch andernorts spannende Erkenntnisse ergeben.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Twinned calcite as indicator of high stress-loading rates and low shock pressure conditions

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Motivation

Calcite is an important rock-forming mineral of the Earth's upper crust (e.g., limestones and marbles) and its rheological behaviour is thus important for all crustal deformation processes, including seismic faulting as well as meteorite impact cratering. The calcite-bearing impact breccias from the Nördlinger Ries structure in southern Germany (Fig. 1) were deformed during impact cratering. The good preservation of the impact rocks and lack of major tectonic deformation in the area after the impact event ~15 Ma ago make the Ries an ideal site to study calcite deformation fabrics formed at high stress-loading rates.

1. Impact crater Nördlinger Ries: sample locations

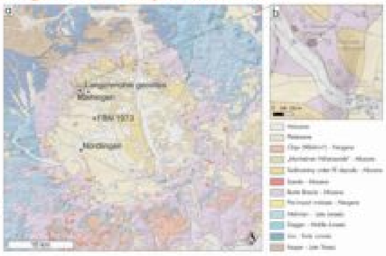

Figure 1. Geologic maps of the Nördlinger Ries. **(a)** Overview with sample locations NW of Maihingen and the location of the research drilling (FBN1973). **(b)** Close up on the area NW of Maihingen, where the sample location for polymict crystalline breccias is located (white arrow). Maps edited after: The General Geological Map of the Federal Republic of Germany 1:250,000 (GÜK250), © BGR.

Highlights

- Shock-related multiple calcite twins (Figs. 3-7) are revealed in polymict crystalline breccias (Figs. 2, 3).
- First natural record of orientation domain (a-type lamellae in Figs. 6-7) due to interaction of f- and r- twins.
- High density of multiple twins (>1/µm, Figs. 5-7) indicate high stress-loading rates.
- Twinned calcite is a valuable indicator of low shock pressure conditions.
- Similar twins are expected in co-seismically deformed calcite at hypocentral depth.

2. Calcite-bearing polymict crystalline breccias

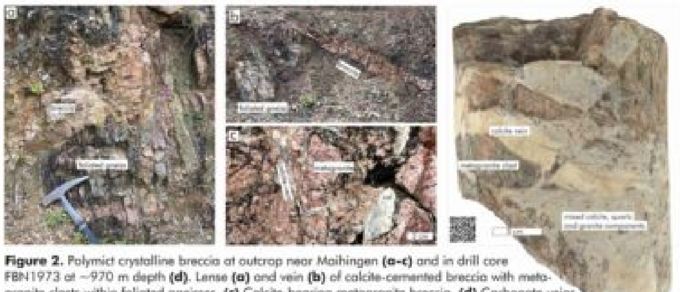

Figure 2. Polymict crystalline breccia at outcrop near Maihingen **(a-c)** and in drill core FBN1973 at ~970 m depth **(d)**. Lense **(a)** and vein **(b)** of calcite-cemented breccia with metagranite clasts within foliated gneisses. **(c)** Calcite-bearing metagranite breccia. **(d)** Carbonate veins and polymict breccia in metagranite (Scan QR Code to observe the 3D model of the drill core sample).

Figure 3. Polymict crystalline breccia at outcrop Langenmühle 1, near Maihingen **(a-b)** and in drill core FBN1973 at ca. 970 m depth **(c)**. **(a)** Polarized light micrograph of polymict crystalline breccia with twinned calcite grains in veins crosscutting a metagranite calcite and the matrix (crossed polarizers). **(b)** Metagranite component (mc) surrounded by a twinned, elongate calcite grain (cal1). **(c)** Elongate twinned calcite (cal) in vein with hypidiomorphic quartz crystals.

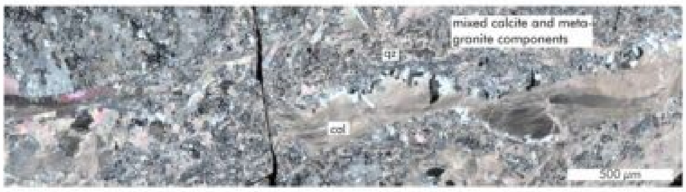

Figure 4. Polarized light micrographs of thin sections showing twinned calcite (cal) and quartz (qz) in veins (crossed polarizers) hosted by the calcite-bearing polymict crystalline breccia.

3. High density of multiple twins in calcite

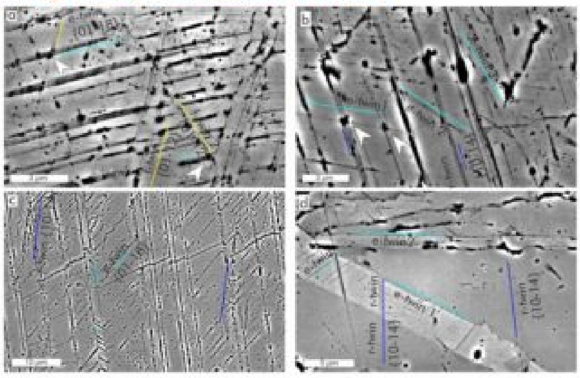

Figure 5. BSE-images showing multiply twinned calcite from sample JB2b, Langenmühle **(a-c)** and the drill core sample **(d)**. White arrows mark so-called Rose-channels. **(a)** Crosscutting of e- and f-twin lamellae. **(b)** Crosscutting of r- and e-twin lamellae. Three different e- twins occur. **(c)** Crosscutting of e- and r-twin lamellae. Note that e-twin lamellae can contain themselves e-twin lamellae. **(d)** Twinned calcite within a vein of the drill-core sample showing two e-twin lamellae and r-twin lamellae that crosscuts one e-twin lamellae. Note that this e-twin lamellae is itself containing secondary fine-lamellar e-twins and that the r-twin and e-twin 2 are showing an "a-type" crystallographic relationship.

4. Interaction of f- and r-twins: a-type deformation lamellae

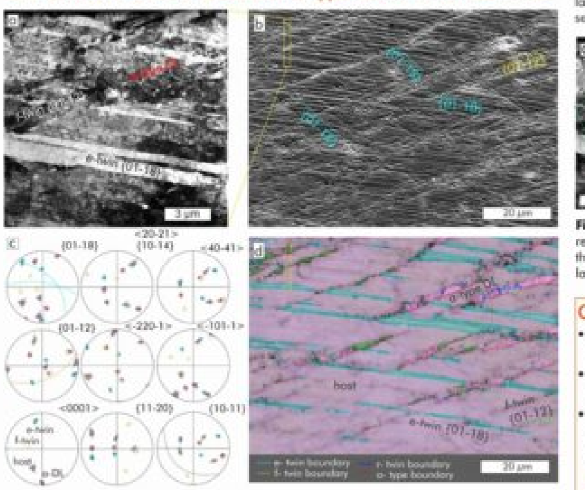

Figure 7. Twinned calcite within a vein (cal1), sample Jb2-a (Langenmühle). **(a)** TEM-diffraction image, location shown in **(b)** SE image showing high density of fine-lamellar features occurring in sets. **(c)** Pole figures of host grain (pink), e-twin (turquoise), f-twin (yellow) and a-type lamellae (red) projected in the plane of the EBSD-map **(d, e)** and the TEM-image, respectively. **(d)** EBSD map with all Euler colour coding, with twin boundaries indicating e-, f- and r-twins, as well as the a-type domain. Note that the a-type domain is related to the misorientation of the host and r-twinned f-twins.

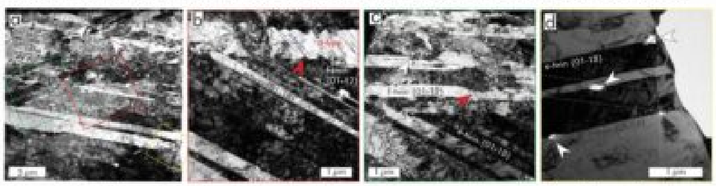

Figure 6. TEM-diffraction images from sample shown in Fig. 7a. **(a)** locations of images **(b-d)** are indicated by coloured rectangles. Note the r- twin-lamellae in the a-type domain. The white arrows **(a-c)** point to high dislocation densities at the intersection of twins. The red arrows show the serrated boundaries of a-type domain related to r-twins in an f-twin lamellae. White arrows in **(d)** mark voids at the intersection between different twin lamellae.

Conclusions

- Calcite twinning occurred during shock and brecciation of the target rocks at high stress-loading rates, yet relatively low shock pressure conditions (< 7 Gpa).
- The generally extremely high twin density of > 1/µm indicates differential stresses on the order of 1 GPa.
- The interaction between different twins leads to specific domains characterized by a misorientation of 35.5° and a rotation axis around a pole of a {11-20} prism plane, as recently reported from high strain experiments (Schuster et al., 2020).

- Calcite is an efficient shock barometer at relatively low shock conditions, where rock-forming silicates do not show unambiguous signs of shock.
- Twinned calcite microstructures as observed might also be expected in carbonate-rich fault rocks deformed coseismically at high stress-loading rates and depths sufficient to prevent dominantly brittle behaviour, i.e., hypocentral depths and below.

References: Schuster, R., Habler, G., Schafler, E., Abart, R., 2020. Intragranular deformation mechanisms in calcite deformed by high-pressure torsion at room temperature. Mineral. Petrol., 114(2), 105-118.


MetSoc
2022