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Direct observation of crystal defects by combined electron backscatter diffraction and electron channeling contrast imaging

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In geological materials the presence and multiplication of dislocations is indispensable to accommodate larger amount of strain by continuous creep processes, possibly controlling large-scale tectonic processes. To fully understand the deformation behavior of the lithosphere it is therefore essential to analyze the nucleation, structure and arrangement of dislocations. So far the direct observation of crystal defects has been performed by transmission electron microscopy (TEM), limiting observations to the size of a thin foil. In this study we use electron channeling contrast imaging (ECCI), partly under controlled diffraction conditions, allowing us to analyze bulk samples. ECCI is a method using backscatter electrons in high-resolution scanning electron microscopy, which allows the direct observation of crystal defects. In combination with electron backscatter diffraction (EBSD) and the simulation of channeling pattern we have the control of diffraction conditions as well as additional information on crystal distortion.

The concept of brittle precursors triggering the nucleation of ductile shear zones has been focus of many studies ranging in size from centimeter to kilometer. Herein we focus on a study on pyrite showing clear dependence of brittle and ductile deformation mechanisms on a micrometer scale. By combining EBSD and ECCI we observed deformation structures including (i) intracrystalline micro cracking accompanied by minor crystal rotation, (ii) sealing of micro cracks resulting in low-angle grain boundaries (often build up by dislocations tracing 0001), which are partly decorated by nano inclusions, (iii) the nucleation of dislocations at crack tips and (iv) the reactivation of (possible) mode I cracks as mode III cracks accompanied by the nucleation of dislocations and crystal plastic behavior resulting in the development of complex dislocation structures and low-angle grain boundaries. Similar structures can be observed along sheared grain boundaries. EBSD maps reveal an increase in misorientation towards micro cracks consistent with a greater dislocation density along cracks observed by ECCI.