Direct observation of dislocations nucleation in pyrite using combination of electron channeling contrast imaging and electron backscatter diffraction

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Crystal-plastic deformation is one of the main mechanisms to accommodate large amounts of strain within the lithosphere. Despite the importance of understanding dislocation nucleation and arrangement, the only widely accepted method for direct observation of dislocations in geological materials so far is transmission electron microscopy. Herein we present a first study using a combination of electron channeling contrast imaging (ECCI) and electron backscatter diffraction (EBSD) to visualize and analyze dislocations nucleating along micro-cracks and at their tips in a geo-material. The study focuses on a pyrite sample from the Detour Lake mine, a Neoarchean orogenic gold deposit located in the northwestern Abitibi district within the Superior Province, Canada. Maximum peak metamorphic conditions of 550°C, close to the brittle-ductile transition and pyrite being a semi-conductor, makes this the perfect study to test this new approach. The investigated sample shows a pyrite layer located at the margin of a sulphidized quartz vein within a mafic-volcanic host rock. The host rock is composed of quartz, albite, actinolite, chlorite, biotite and sulphide phases including pyrite. Additional quartz and calcite occurs in veins and sealed cracks. The matrix consists of fine grained quartz and albite often polygonal in shape, together with finely dispersed biotite defining the foliation fabric. The pyrite layer is strongly fragmented resulting in a jigsaw-puzzle like structure, which is built up of fragments ranging in size between 50 and 3000 µm. Brittle fractures are sealed by carbonates, quartz and chlorite. Different to the matrix, vein quartz reaches grain sizes up to a few millimetre in size and shows sutured grain boundaries together with small bulges. Undulatory extinction, deformation lamellae and subgrains are common. A variety of brittle to brittle-plastic deformation structures has been observed including: (A) intracrystalline-micro cracks, which are aligned en-echelon linking up in a relay style; (B) reactivated intracrystalline-micro cracks; (C) non-reactivated intracrystalline-micro cracks accompanied by a minor crystal-lattice rotation and a crystal-plastic zone; and (D) late brittle fractures cross cutting brittle-crystal plastic structures. Herein we focus on structures (B) and (C) which show a clear dependence of brittle and crystal-plastic deformation behavior on a micrometer scale. Stress concentration at the micro-crack tip appears to result in the emission of dislocations in the immediate vicinity of the tip. Furthermore, the reactivation of micro cracks is accompanied by the nucleation of dislocations and crystal-plastic behavior resulting in the development of complex dislocation structures and low-angle grain boundaries. EBSD maps reveal an increase in misorientation towards micro-cracks consistent with a greater dislocation density along cracks observed by ECCI.