An Electron Backscatter Diffraction and Cathode-Luminescence Study of Microstructures in the Damage Zone and the Actively Creeping Core of the San Andreas Fault Zone

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Abstract

Using Electron Backscattered Diffraction (EBSD), we conducted a preliminary study on 6 core samples from the San Andreas Fault Observatory at Depth (SAFOD) between 3193-3311m Measured Depth. The selected samples represent areas of the fault zone in contact with the actively creeping Central Deforming Zone (CDZ) and Southwestern Deforming zone (SDZ), with one sample from within the CDZ. The samples were selected on the basis of containing significant pyrite, and evidence of multiphase calcite-vein-formation from cathodoluminescence (CL) imaging. EBSD results identify primary pyrite in the form of framboids, pyrite-cemented framboid aggregates and spherulitic pyrite overgrowths. Secondary (hydrothermal) pyrite forms a 15x7mm lenticular mass in one sample and records abundant evidence of core-and-mantle subgrain-rotation (SGR) deformation mechanisms in pyrite (Fig. 1), indicating elevated temperatures >400° C. We find a second generation of both plastically deformed and undeformed secondary pyrite that overgrows calcite-filled fractures in boudinaged Dauphiné-twinned-quartz clasts. Undeformed second-phase pyrite is also associated in the main secondary pyrite mass with calcite filled extension-fractures kinematically compatible with extension fractures in boudinaged quartz. Low-T pyrite cataclasis is also evident. Multiple generations of e-twinned calcite veins are revealed by CL (Fig. 1). The twin-density paleo-piezometry suggests differential stresses of 25-233 MPa, consistent with previous estimates and with the present-day temperature at the SAFOD. However, EBSD also reveals abundant evidence for dislocation-creep in calcite, commonly including the youngest veins in the samples. While dislocation creep deformation is possible in calcite at SAFOD depth, it would involve very high CRSS. Pyrite clearly records multiple episodes of formation and deformation during decreasing T from >400° C to present SAFOD conditions. Analysis of the deformation microstructures in this study also suggests a similar P-T history for calcite and quartz. Preliminary interpretation of the results in this study are: 1. SAFOD damage zone rocks close to SDZ and CDZ deformed, at least episodically, while being exhumed and 2: The deformation involved neo-mineralization and fluid overpressure events.

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Abstract Text:

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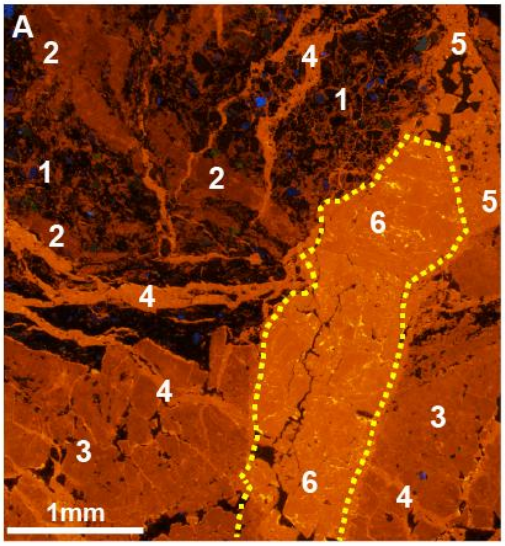
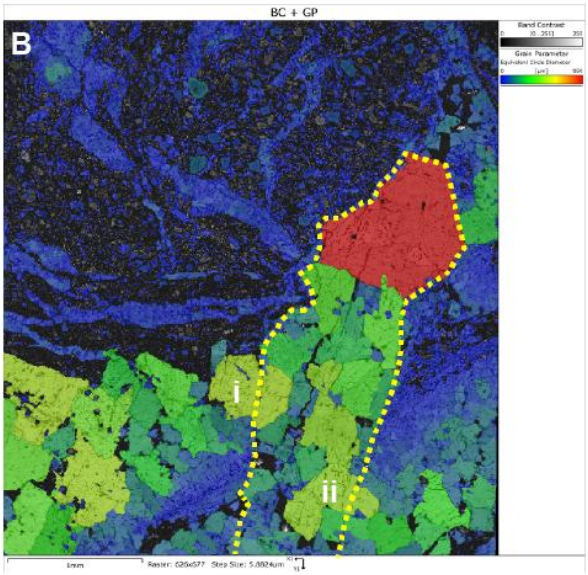
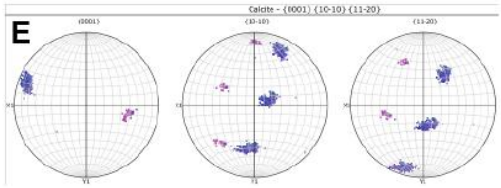


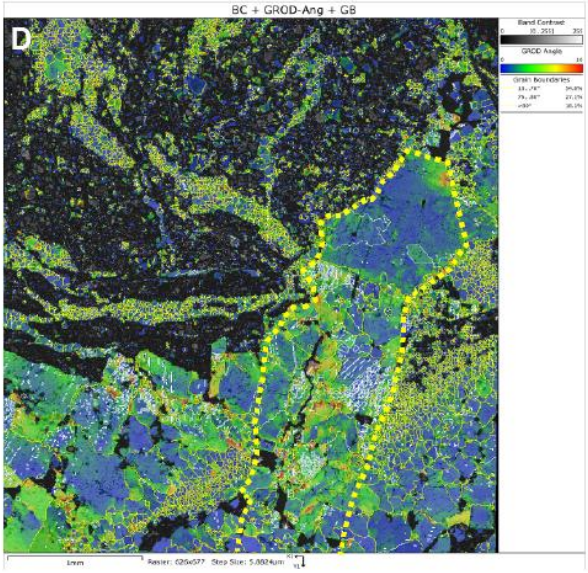


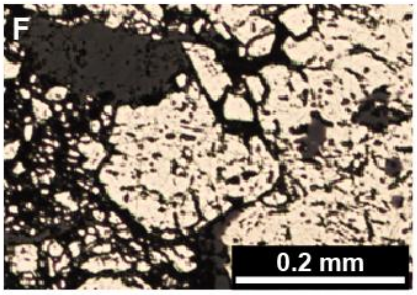
C

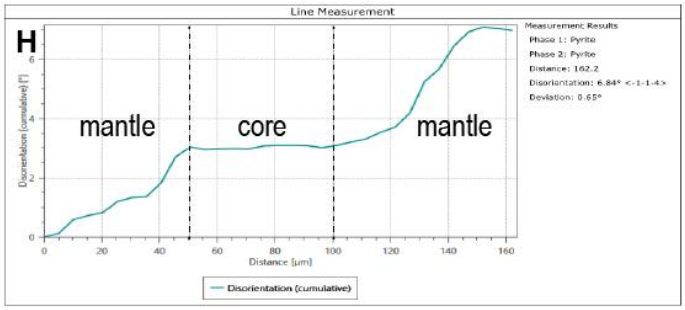
Summary of calcite grains, sizes and twins for 6 vein types

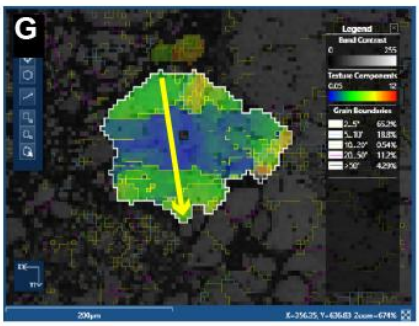
Gener-ation	Num	mean size (µm)	SD size (µm)	twin% num	twin% area
V1	655	18.4	5.6	0.8	1.5
V2	976	23.1	11.6	3.4	12.8
V3	1824	30.4	35.7	10.8	64.8
V4	388	22.4	9.6	7.5	16.9
V5	345	30.8	23.8	11.9	33.3
V6	96	63.6	81.0	34.4	90.3











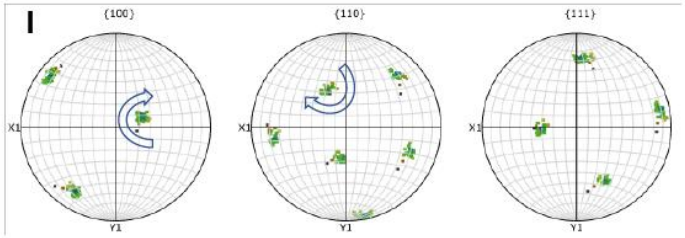


Figure 1. CL and EBSD data for multiphase calcite veins in sample G52-XZ (A-E) and SGR deformation of pyrite in sample G24XY (F-I). A - CL image with 6 vein generations, which from cross-cutting relationships are 1 oldest to 6 youngest. B - Grain size map with scale from 0-950 µm; grains labelled i and ii straddle the CL boundary between veins 3 and 6 indicating topotactic growth in vein 6. C - Table summarising calcite grain size and twinning for the 6 vein types - note general trend of increasing grain size and twinning %

Plain-Language Summary:
This presentation reports a study of the microstructures of three minerals (pyrite, calcite and quartz) in samples from the San Andreas Observatory at Depth (SAFOD) using advanced optical and scanning-electron microscope methods. Results reveal a complex episodic history of mineral formation and deformation involving decreasing temperature conditions during exhumation to the current depth (~3km) in the SAFOD. Each event involved fluid-overpressuring.

Session Selection:
T018. Initiation, Evolution, Structure, and Dynamics of Transform Fault Zones and their Complex Tectonics

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