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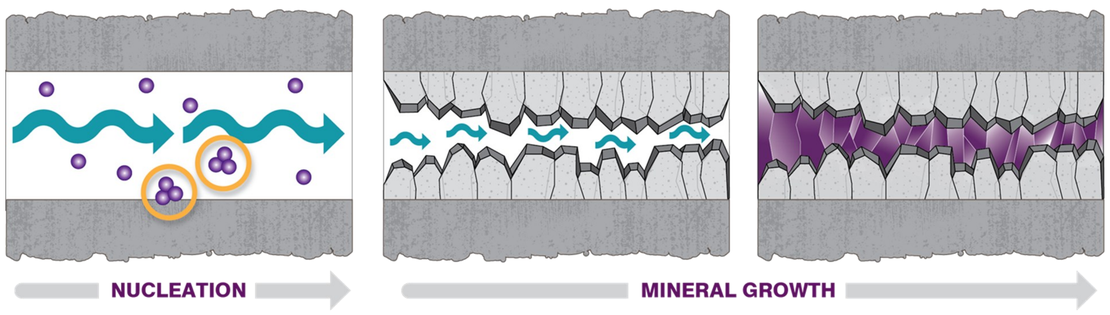
Using Electron Backscatter Diffraction to discover geothermal reservoir scaling controls

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INTRODUCTION

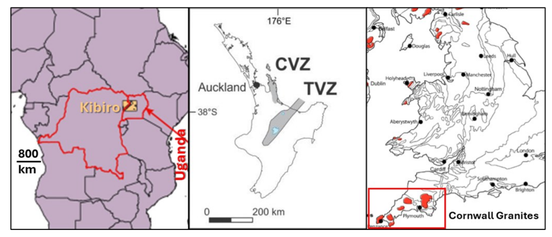
- Sustainable geothermal energy can rely on maintaining open fluid flow through fractured rock reservoirs.
- Mineral scaling can progressively block these fractures, reducing permeability and reservoir performance.
- Understanding how and where scaling minerals form is critical to predicting and mitigating these effects.
- This study uses of advanced correlative microanalytical techniques to examine natural geothermal scale samples from multiple geothermal sites around the World.



MATERIALS & METHODS

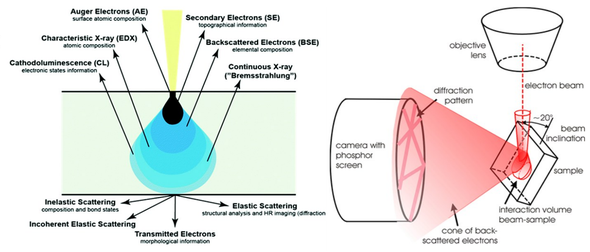
Sample of hydrothermal mineral veins from:

- Kibiro Geothermal Field, Uganda
- Taupo Volcanic Zone, New Zealand
- Coromandel Volcanic Zone, New Zealand
- Cornwall, United Kingdom



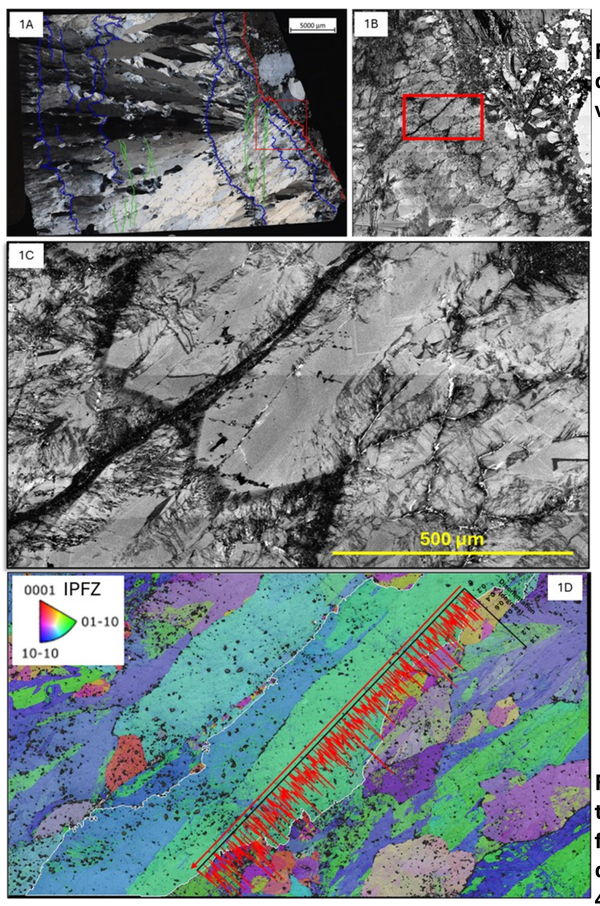
Combining methods for mineralogical analysis:

- Transmitted & reflected light microscopy
- Energy dispersive X-ray Spectroscopy
- Cathodoluminescence
- Electron Backscatter Diffraction



Allows us to combine optical, chemical, and crystallographic data together to identify signatures of mineral nucleation and growth mechanisms

GEOTHERMAL QUARTZ NUCLEATION CONTROLS



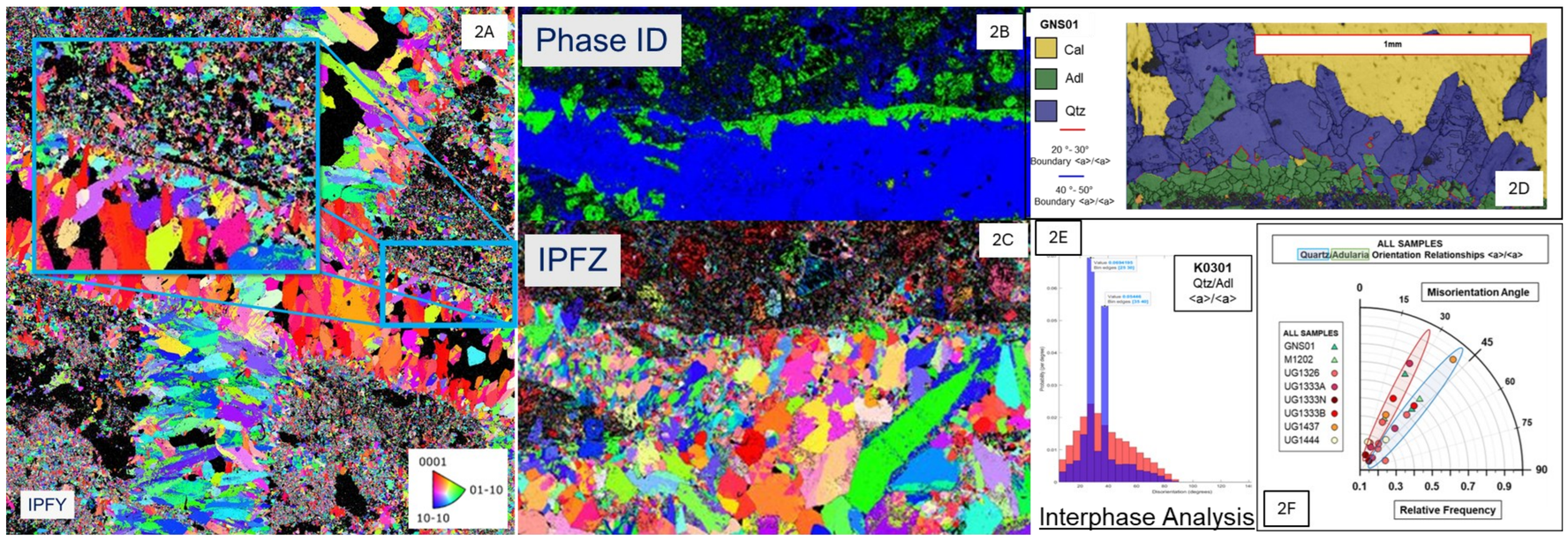
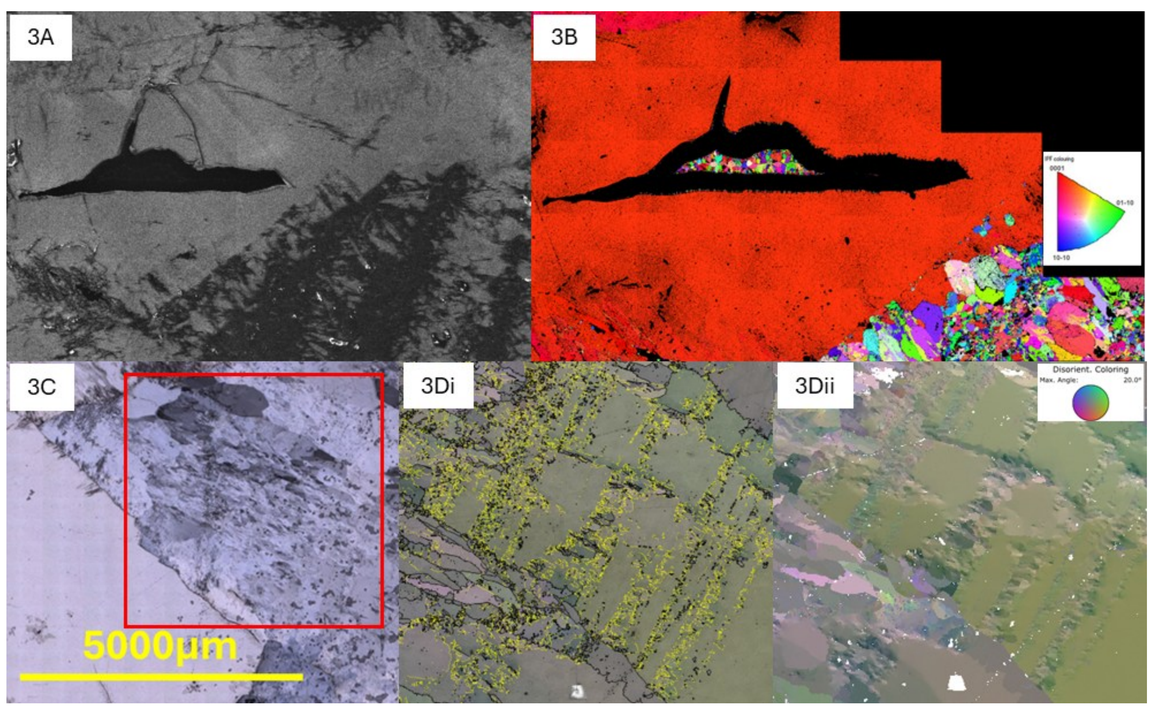


Figure 1. Geothermal quartz vein in Cornwall granites: A: XP light microscope image of hydrothermal quartz vein with lines colored for; fracture wall (red), stages of quartz mineralization (blue), late stage quartz veinlets (green); B: SEM CL image of hydrothermal quartz vein; C: Zoom in of SEM CL image of two stages of quartz vein development; D: EBSD image (IPFZ) overlaid with quartz crystal disorientation line.

Figure 2. A: EBSD (IPFY) map of intersecting quartz veins from CVZ showing preferred growth along c-axes from fracture walls. Zoom in (blue box) shows quartz crystal growth competition when fracture wall lined with jarosite (black layer). B: EBSD Phase ID map of a TVZ geothermal vein showing an initial adularia lining (green) followed by quartz infill (blue); C: EBSD (IPFZ) map of 2C showing random orientation of quartz crystals with a blocky morphology; D: EBSD Phase ID map showing quartz (Qtz)-adularia (Ad) interphase boundaries sharing common a-axes disorientation angles; E: Bar chart shows these a-axes disorientations are either 26° or 42°; F: Quarter rose diagram shows these quartz on adularia disorientations can be found in geothermal fields globally.

STAGED HYDROTHERMAL VEIN QUARTZ DEVELOPMENT



3A. SEM CL image showing large vein quartz crystal growth cross-cutting pre-existing banded finer-grained quartz vein textures. 3B EBSD map of 3A (IPFX) showing larger vein quartz crystal (red) potentially incorporating finer grained banded quartz into itself. 3C. XP photomicrograph of large hydrothermal vein quartz crystals with complicated internal extinction. 3Di and ii. EBSD maps of 3C; i) black lines mark boundaries between different large hydrothermal quartz crystals (>10°) ,yellow lines mark subgrain boundaries (<10°) within the larger crystals showing banded patterns; ii) is an average disorientation map that reveals a preserved original texture to hydrothermal quartz precipitation prior to large crystal development.

FINDINGS SO FAR

Correlative microanalysis can inform on silica/quartz nucleation and growth mechanisms.

Quartz nucleation is strongly affected by wall rock mineralogy such that:

- Heterogenous epitaxial nucleation can occur on appropriately oriented wall rock quartz.
- Progressive quartz nucleation and growth in veins is easier/faster (?) once the first layer is deposited.
- Heterogenous topotactical nucleation occurs when adularia is present in wall rock.
- Nucleation and growth of large quartz crystals is hindered by presence of jarosite on the fracture wall.

Quartz growth is affected by:

- Wall rock mineralogy - results in different macro quartz scale textures (euhedral vs. blocky).

EBSD highlights preserved banded microstructures in large hydrothermal quartz crystals suggesting that final hydrothermal quartz vein textures are not the initial ones

As such hydrothermal quartz crystallography and morphology likely evolves with time from precursor quartz and potentially amorphous silica deposits. This has implications for interpreting the conditions that starts silica scaling in hydrothermal reservoirs.

Correlative microanalysis can provide fundamental information on geothermal reservoir silica scaling mechanisms which in future may assist in the design of novel mitigation techniques or technologies.