Quartz Cement in Upper Jurassic Brora Formation Sandstone: What Electron Backscatter Diffraction Reveals about Microquartz Coatings*

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Abstract

The relationship between micro- and meso-crystalline silica cements in sandstones is highly significant because microcrystalline quartz cement is often cited as a mechanism for inhibiting subsequent mesoquartz cement, preserving porosity in oil and gas reservoirs. The Brora Sandstone (Upper Jurassic, Inner Moray Firth, NE Scotland) provides an excellent opportunity to study this relationship because microcrystalline cements co-exist with low-temperature mesoquartz cement; in some cases, even on the same grains.

This study combined the use of SEM techniques, including CL and EBSD, in order to address the occurrence, form, and crystallography of the silica cements and detrital sponge spicules. The study confirmed that dissolution of silica from sponge spicules provided a silica source internal to the sandstone. Spicule remnants are now composed of various forms of microcrystalline silica. The precipitation of microcrystalline quartz on detrital quartz sand grains occurred via two mechanisms: (1) some microcrystals are perfectly crystallographically oriented with the host quartz and probably grew on defect-free grain surfaces, while (2) other microcrystals grew initially with the same orientation as the host grain but became progressively misoriented relative to the host during growth. The second case represents bent crystals with the maximum misorientation being 4 degrees. It is likely that the bent crystals nucleated on screw dislocations at the surface of detrital grains. Subsequent mesoquartz cementation occurred only where microquartz was not misoriented with the substrate; where microquartz was misoriented, mesoquartz cement growth was inhibited. This study suggests that not all microquartz cement is capable of inhibiting mesoquartz cement and that inhibition results from small-scale misorientation effects rather than supersaturation effects.

Quartz cement in Upper Jurassic Brora Fm sandstone: what electron backscatter diffraction reveals about microquartz coatings

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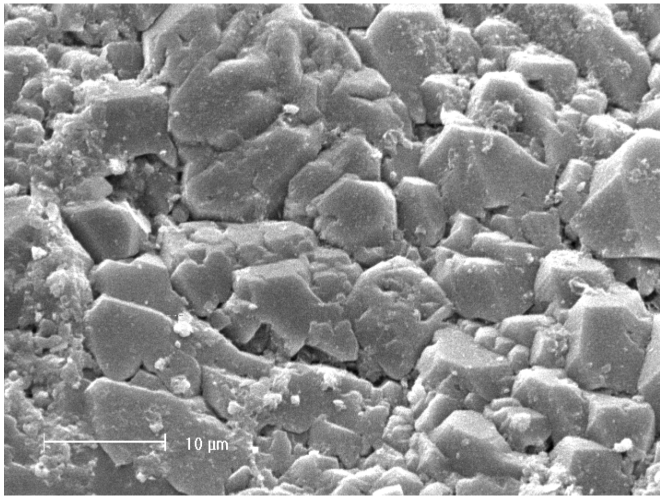
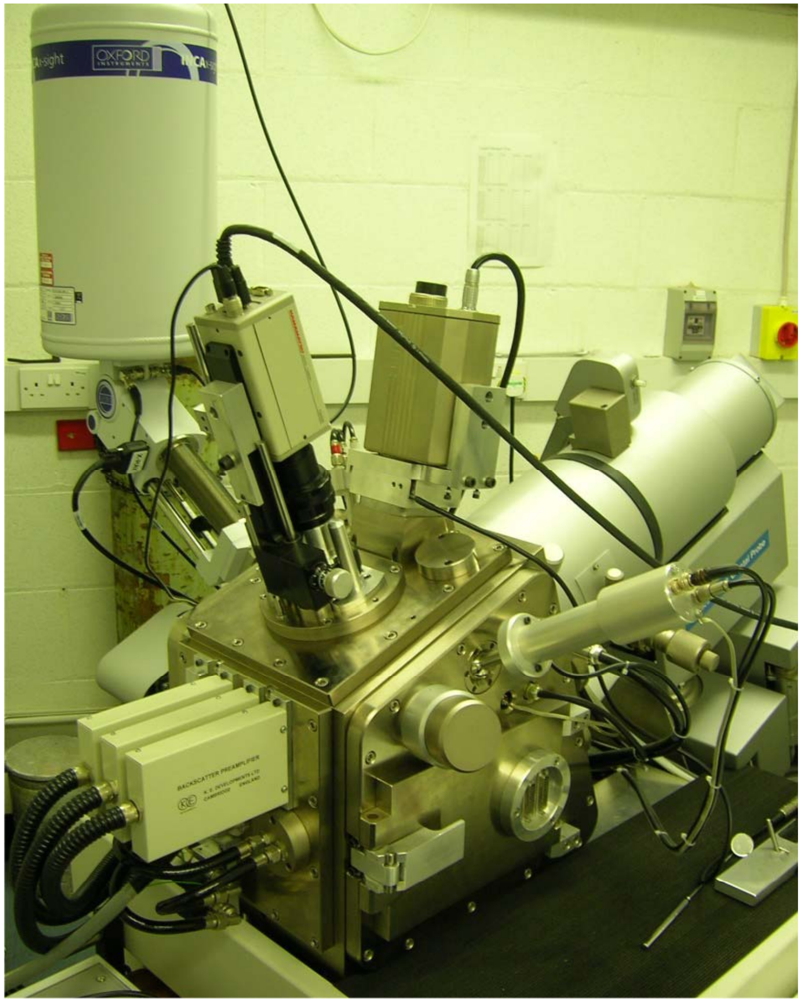


Electron backscatter diffraction (EBSD)

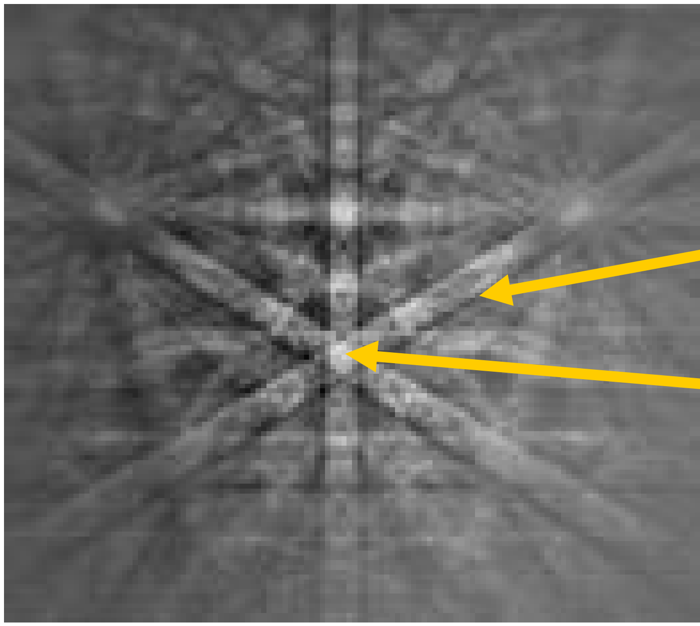
Using *automated* data collection from large, defined areas of polished sample:

- Exact orientation of 1 μm^2
- Crystallinity (e.g. quartz or opaline silica)
- Grain boundaries
- Subgrain structure
- Degree of misorientation



Electron backscatter diffraction

- Map crystallographic orientation from polished sections
- Any crystalline material (quartz, calcite, feldspar)
- Spatial resolution of 1 μm^2
- Can differentiate amorphous from crystalline SiO_2



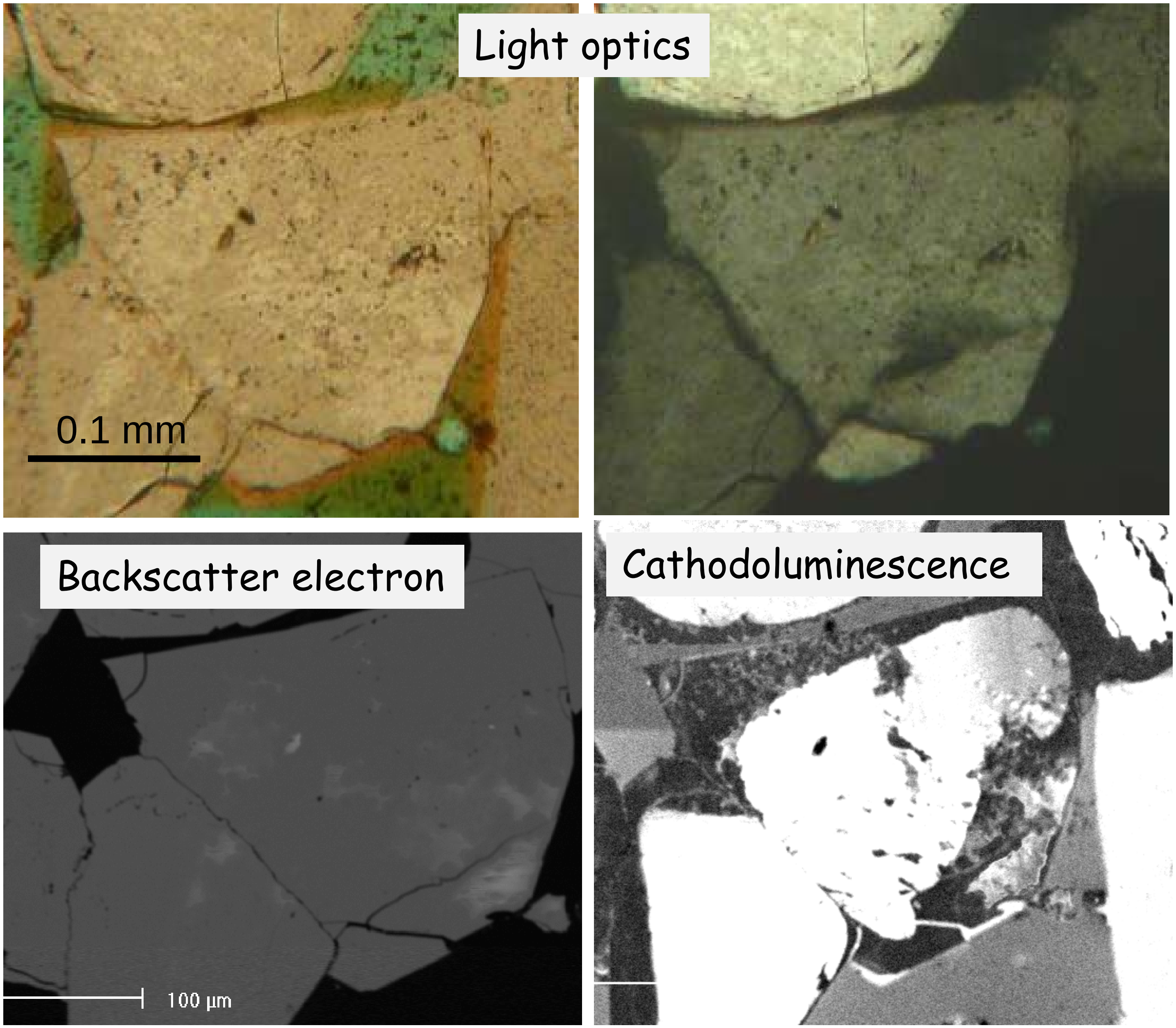
Pattern collected from 1 μm diameter spot

Lines due to crystallographic planes

Intersections of lines represent zone axes

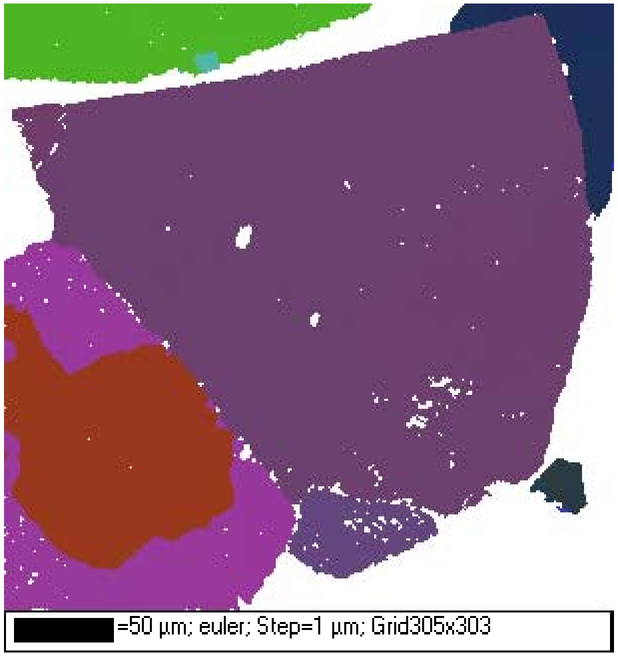
Reveals exact orientation of 1 μm spot within ±0.5°

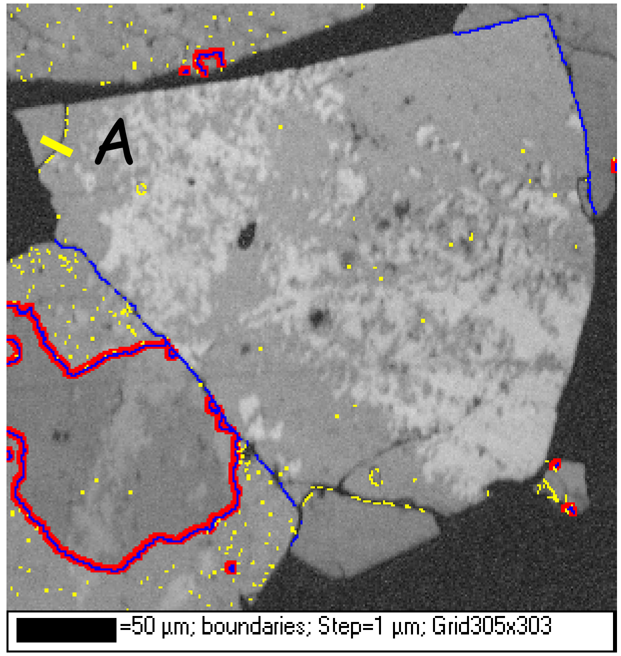
EBSD of quartz cement?

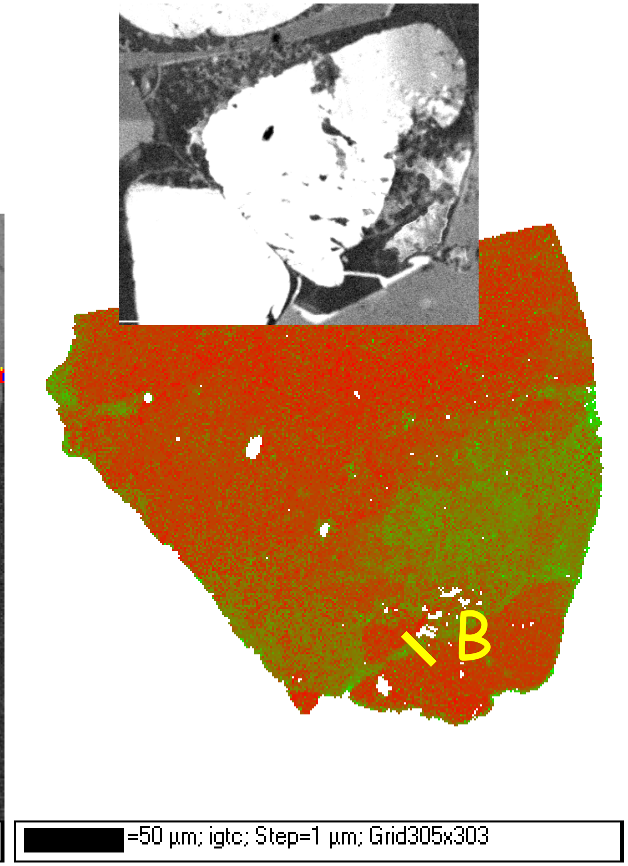


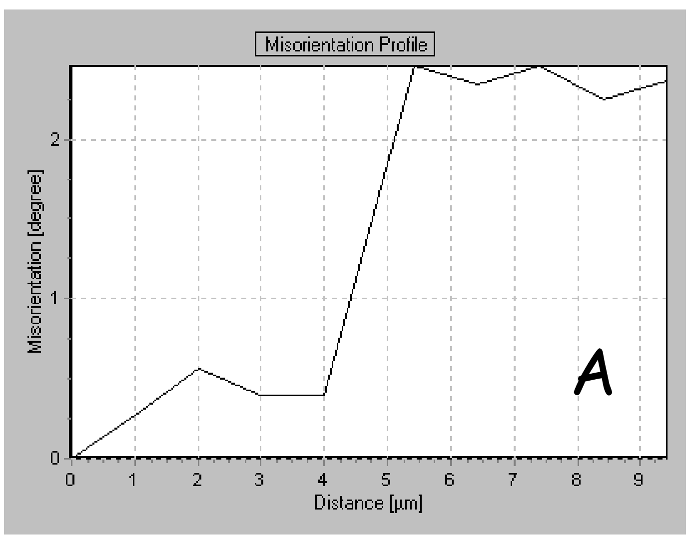
What does EBSD reveal about complex CL zoning in typical quartz cement?

EBSD of quartz cement?

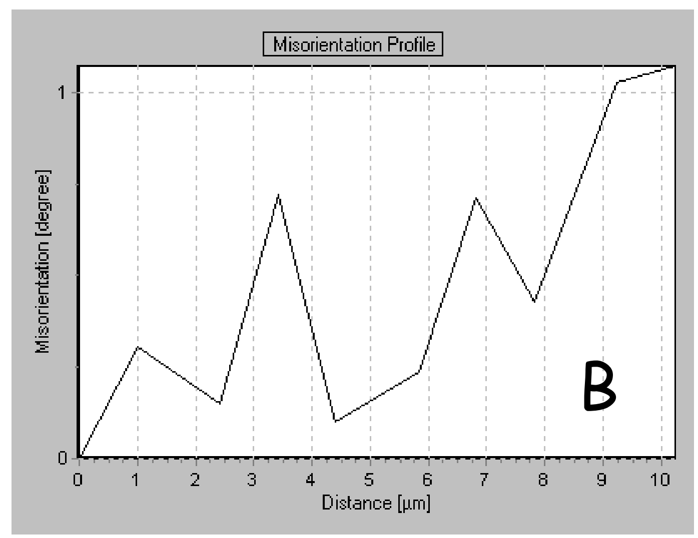








EBSD study of ordinary quartz cement not always revealing or useful

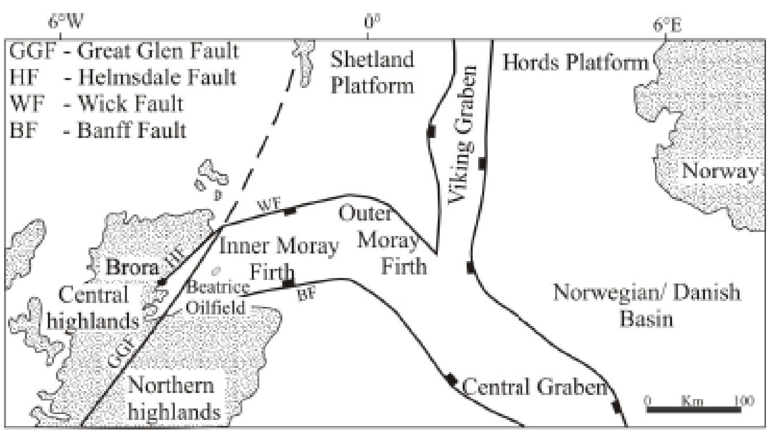


Microquartz cement in sandstones

Inhibits development of epitaxial normal quartz cement in some sandstones: good for reservoir quality

Poorly defined in the literature: crystal length (c-axis), crystal cross sectional area (⊥ to c-axis), crystal shape

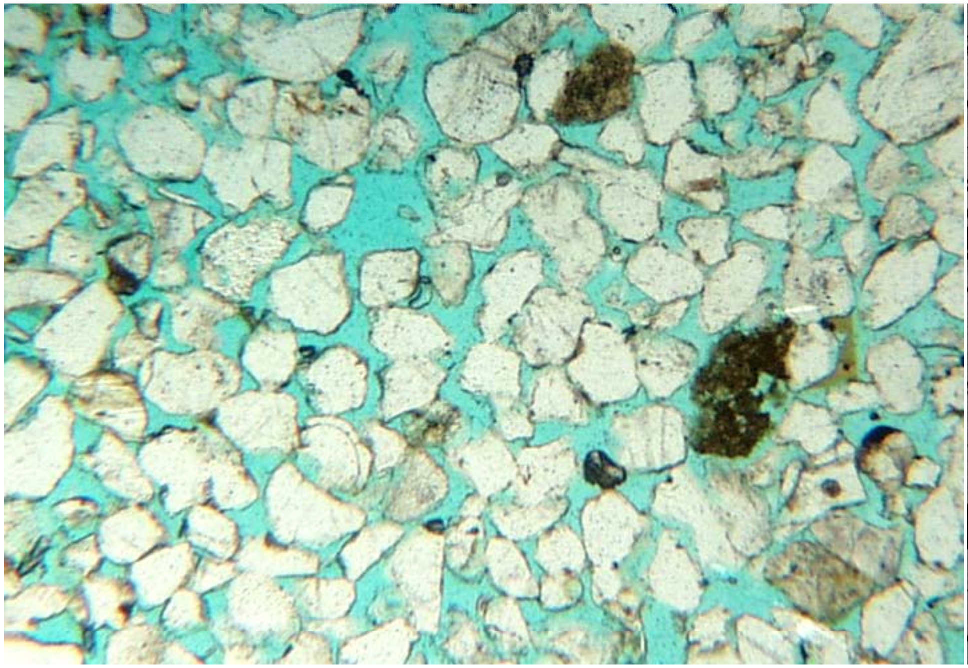
Brora Fm, Upper Jurassic NE Scotland chosen for study, rich in sponge spicules, analogue to many Central North Sea reservoirs (Buzzard, Tartan etc)

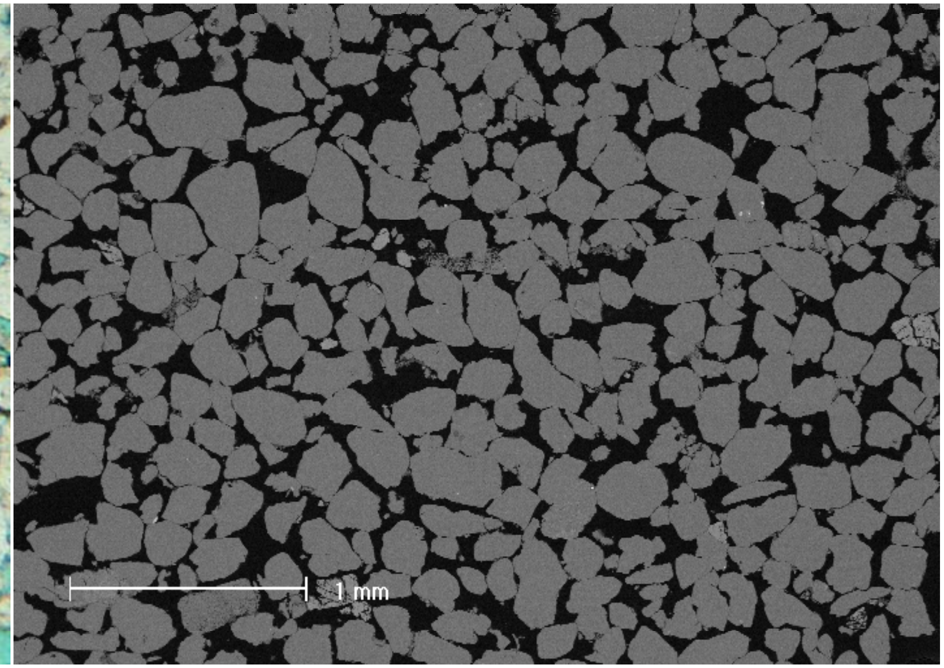


Submarine fan sandstone
Quartz arenite

Outcrop, max temperature pre-inversion ~60-70°C

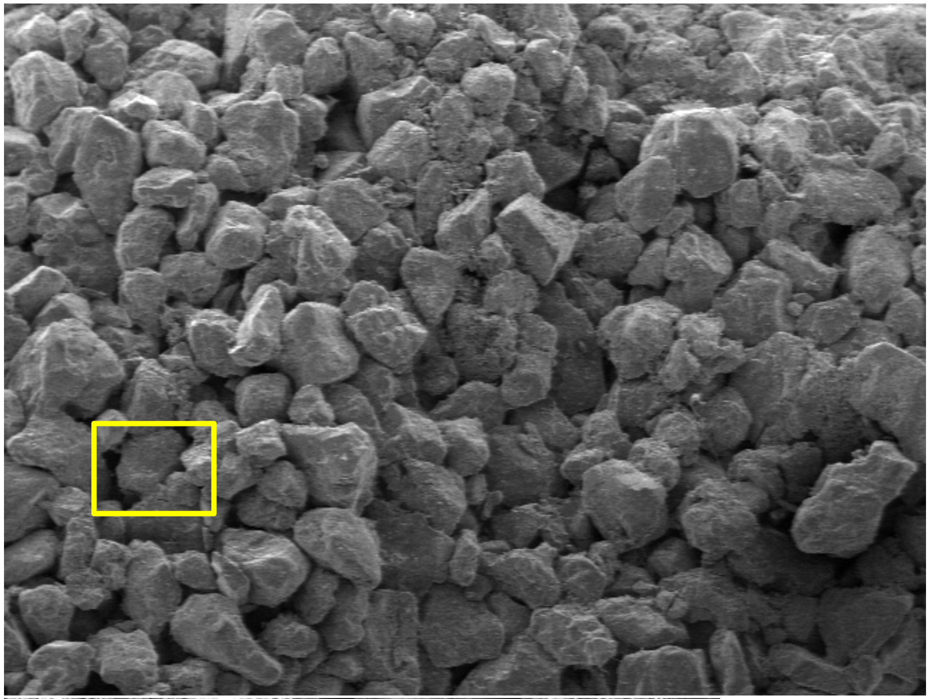
Brora Formation: porosity and packing

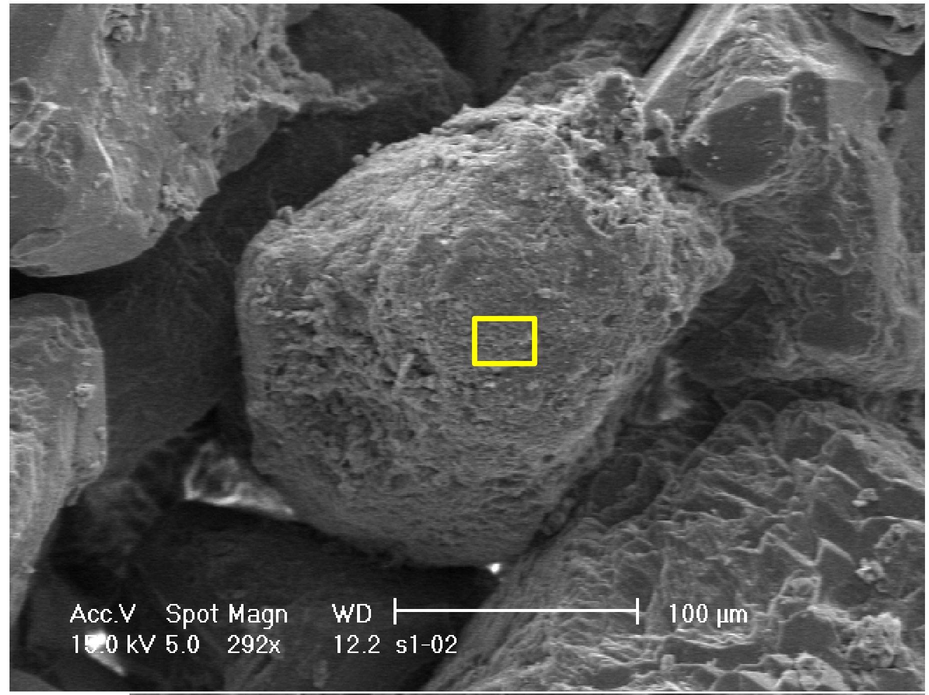


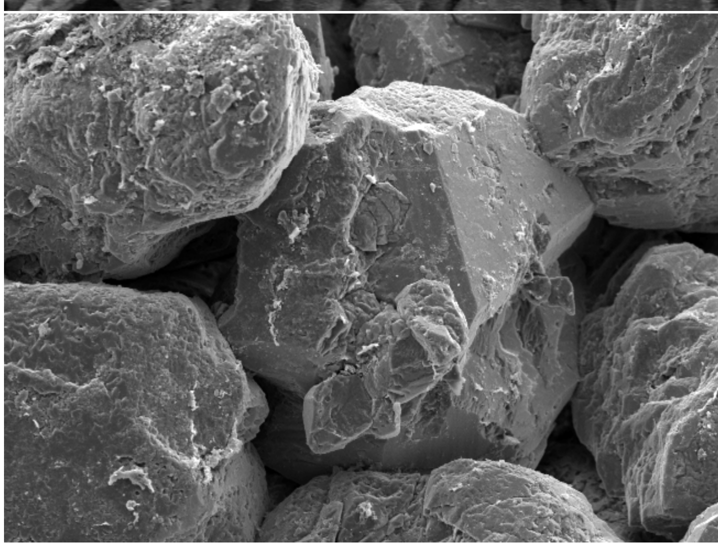


Poorly cemented, not well compacted, confirming lack of extensive burial and heating

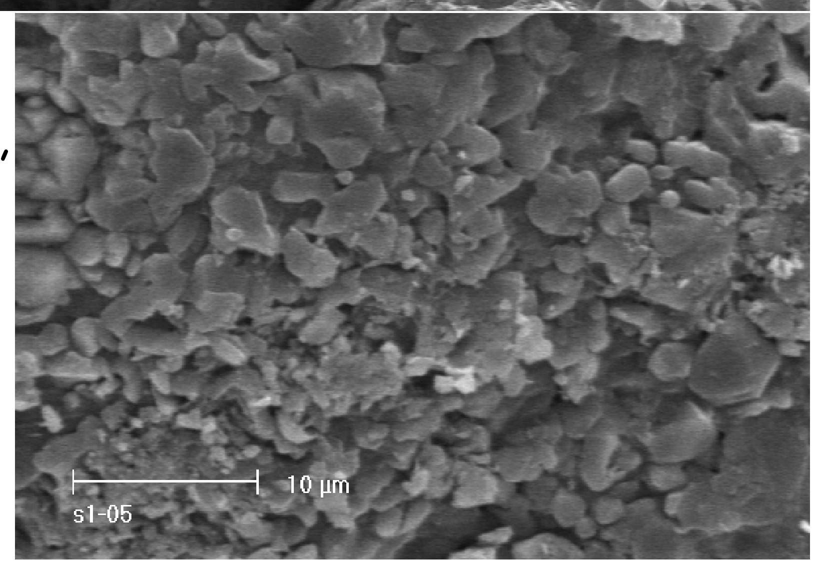
Brora Formation: SEM of grain coatings



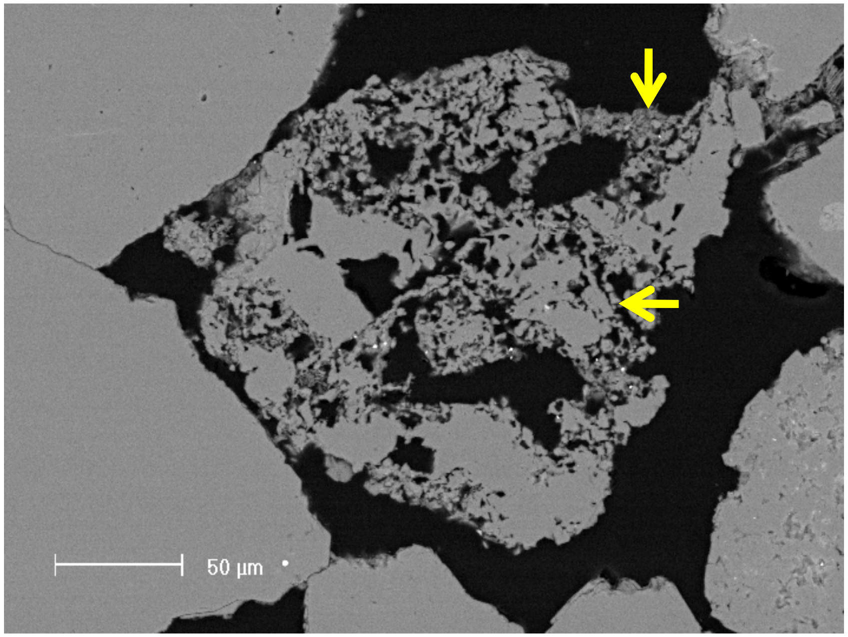


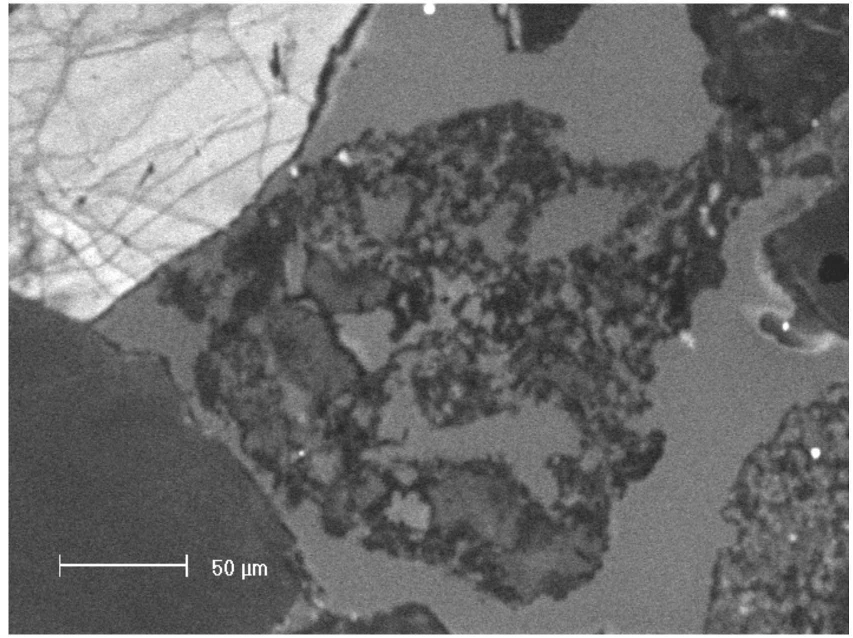


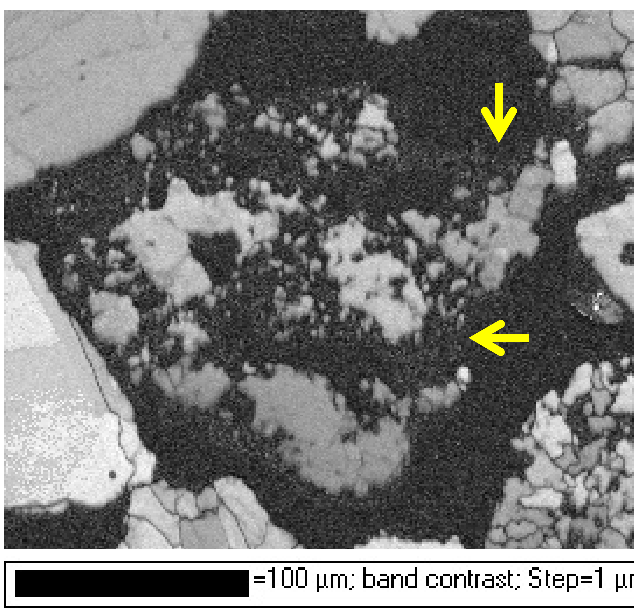
Grains coated by microquartz, though quartz cement locally present

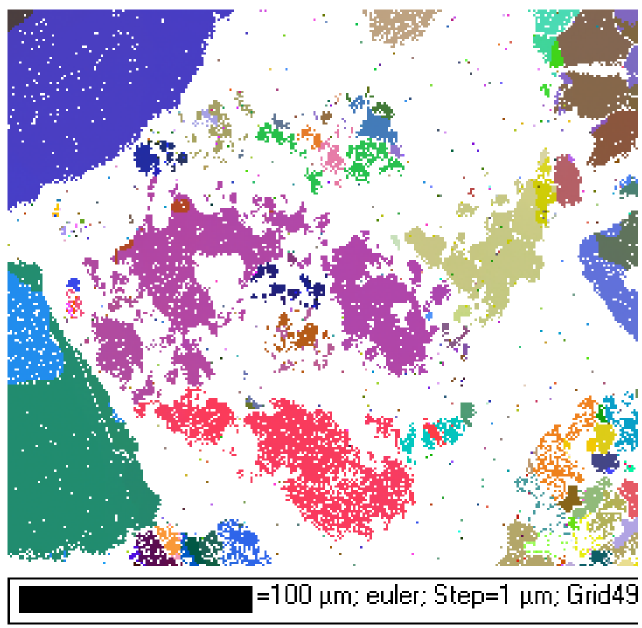


Brora Formation: sponge spicules - source SiO_2



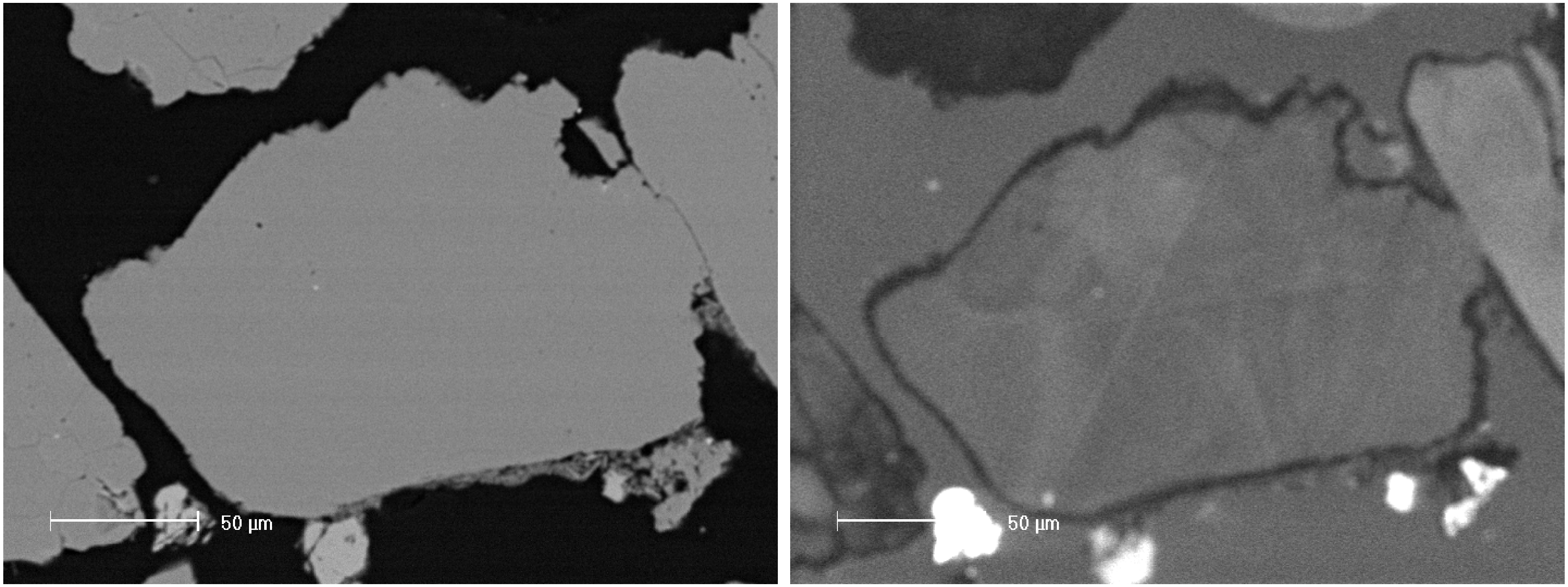






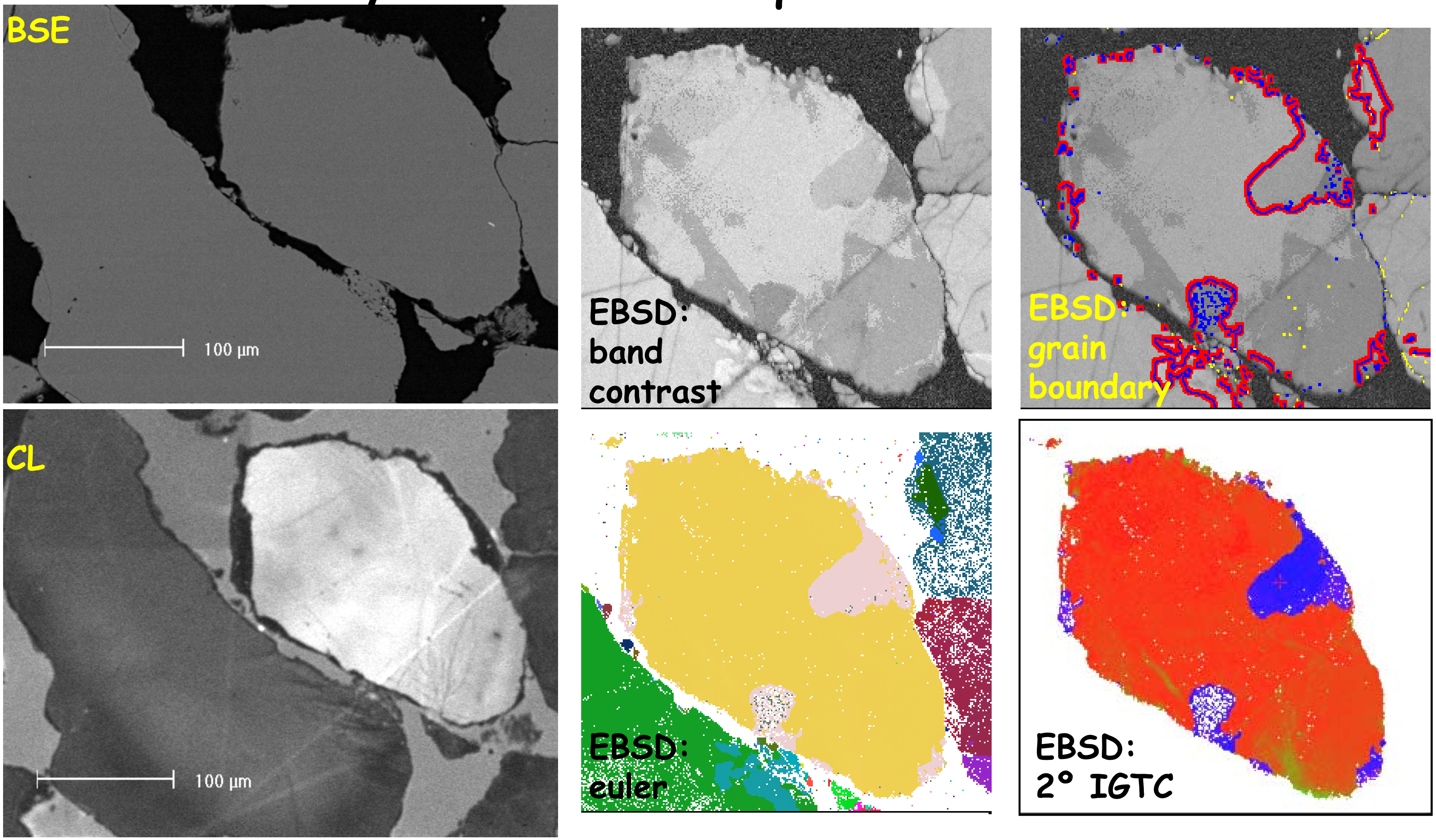
- Spicules: microporous
- Not all quartz: opal-A?
- Replaced by a number of quartz crystals

Cathodoluminescence of microquartz



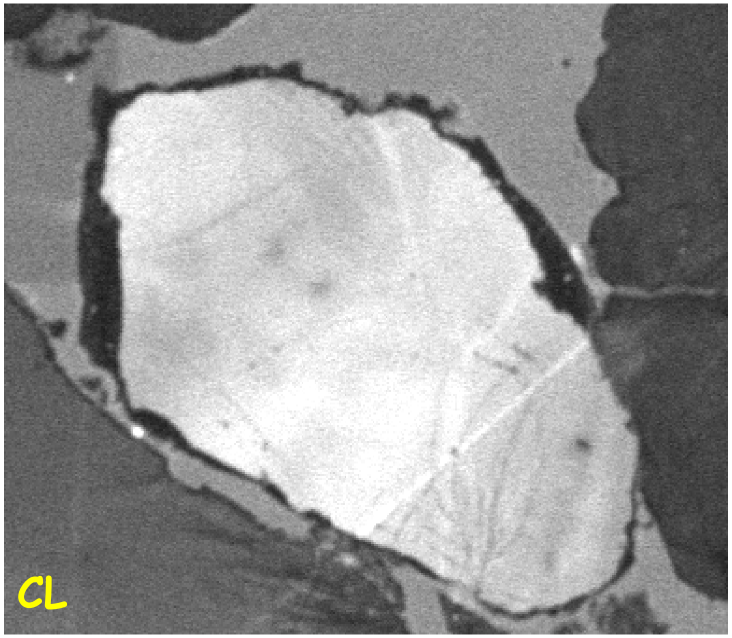
- Grains have irregular outline (like detrital sand grains)
- Grains have thin layer of poorly luminescent microquartz

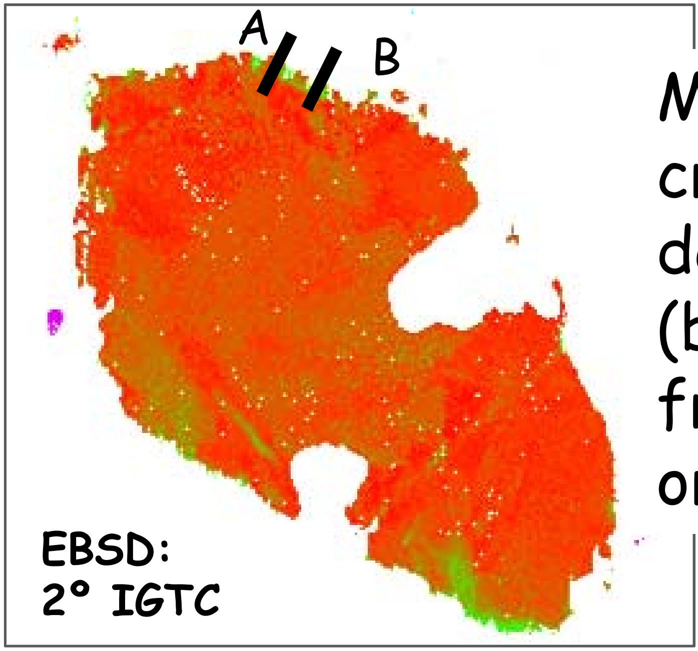
EBSD analysis of microquartz



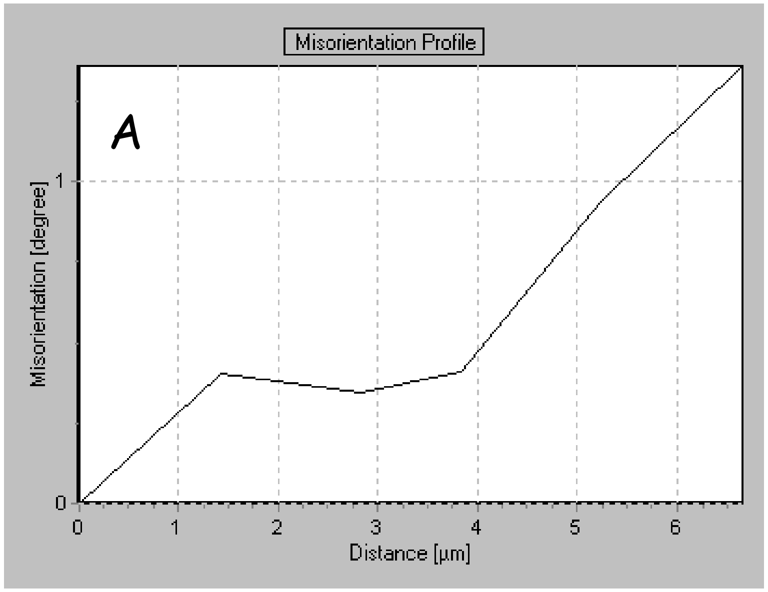
- EBSD shows that microquartz has orientation related to host, **but not exactly the same as host**

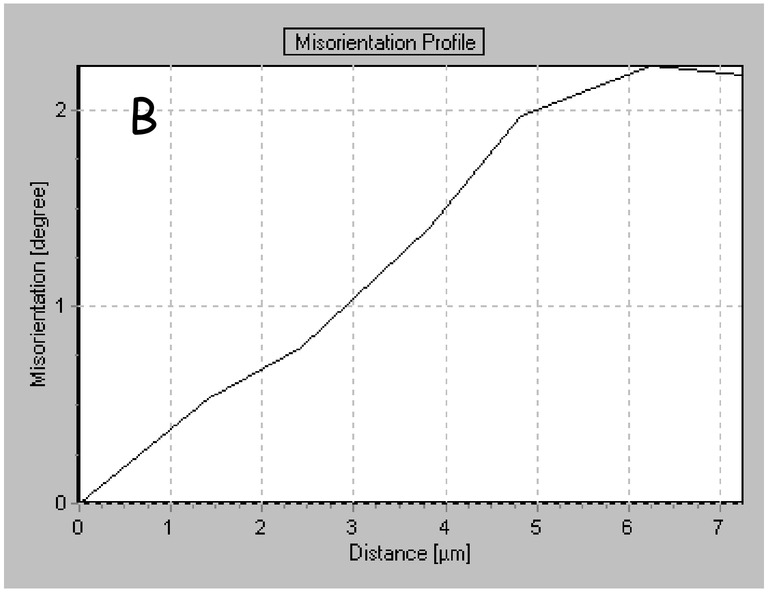
EBSD analysis of microquartz: misorientation



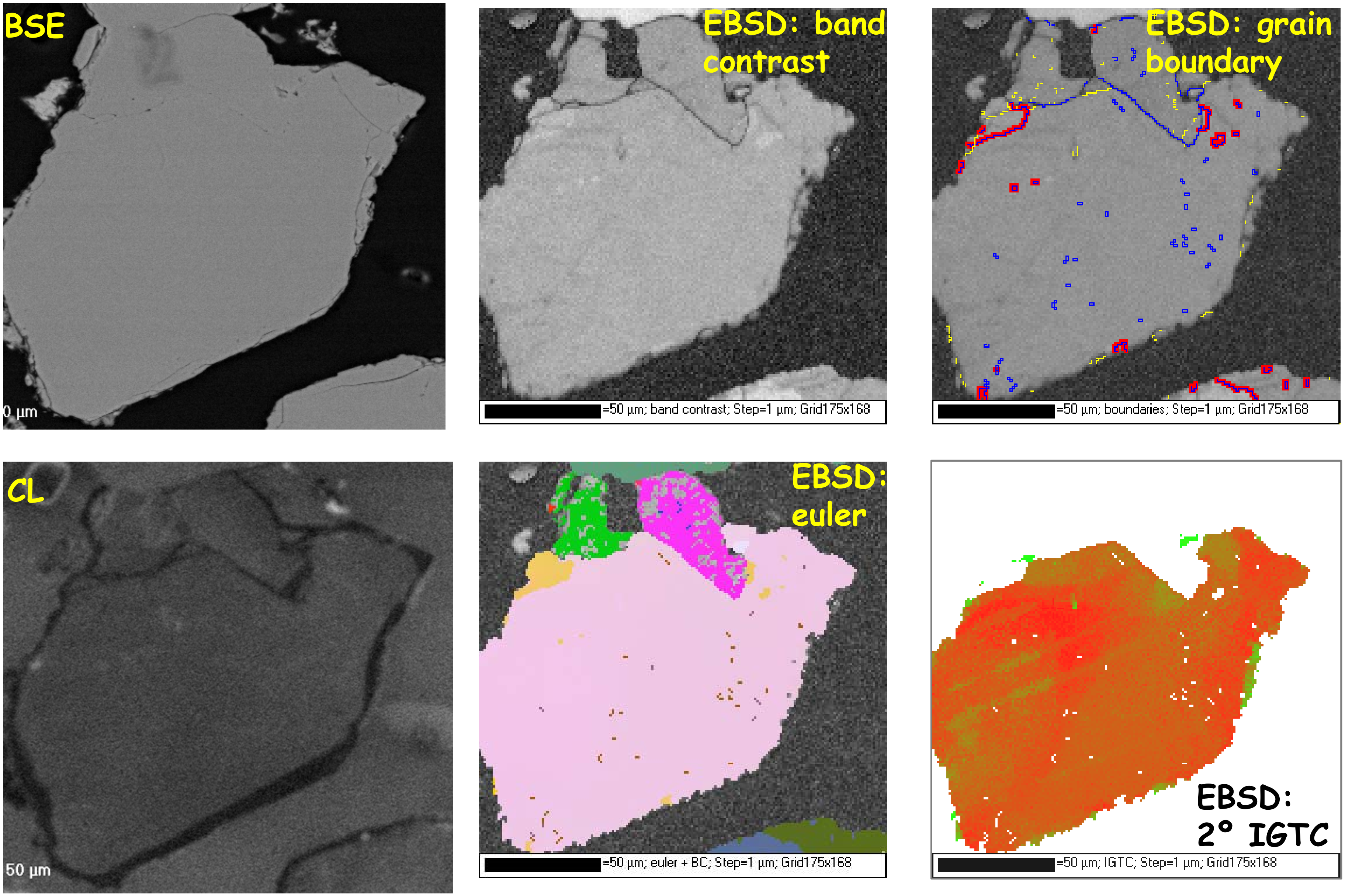


Microquartz crystals deviate (bend) away from host orientation

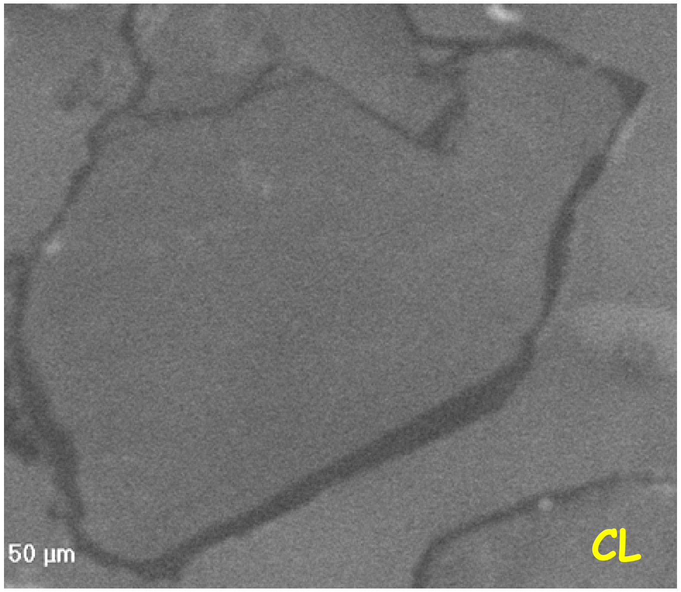


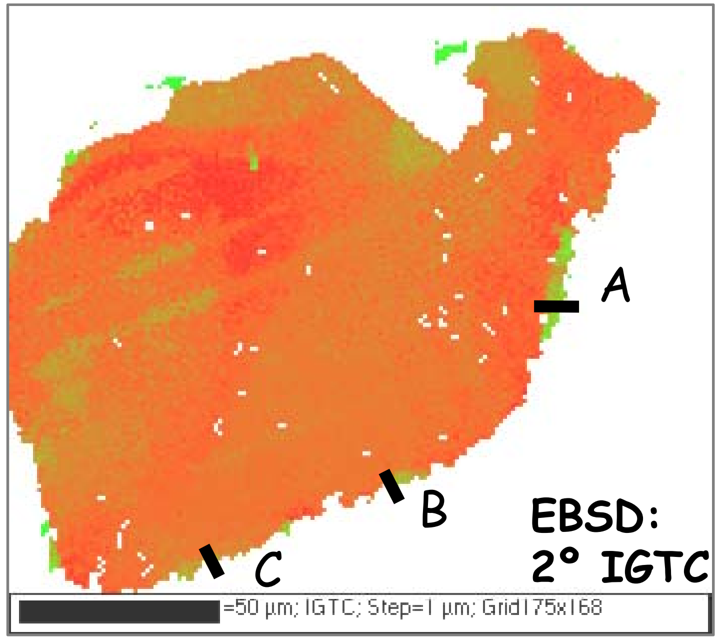


EBSD analysis of microquartz



EBSD analysis of microquartz: misorientation





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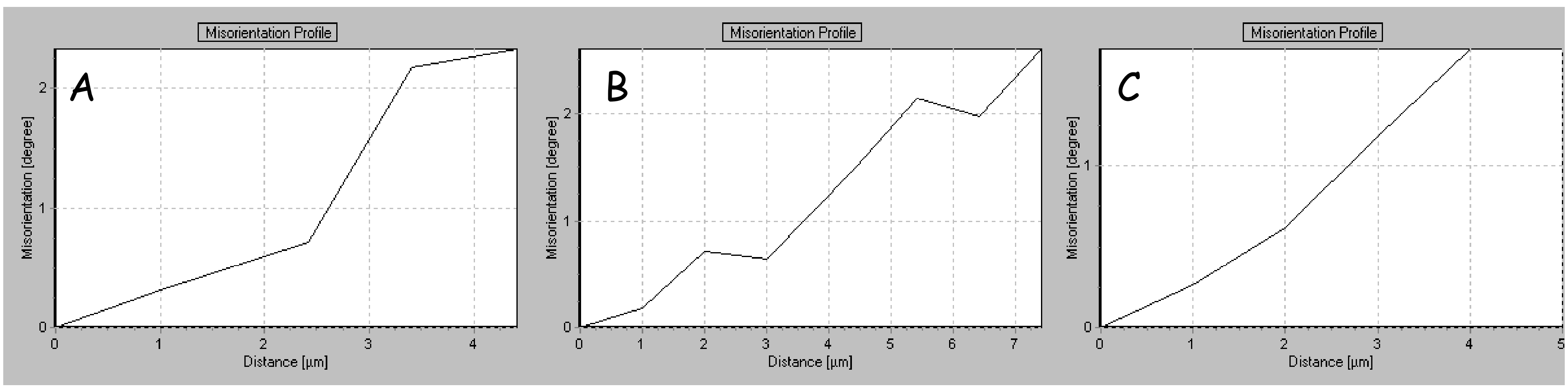


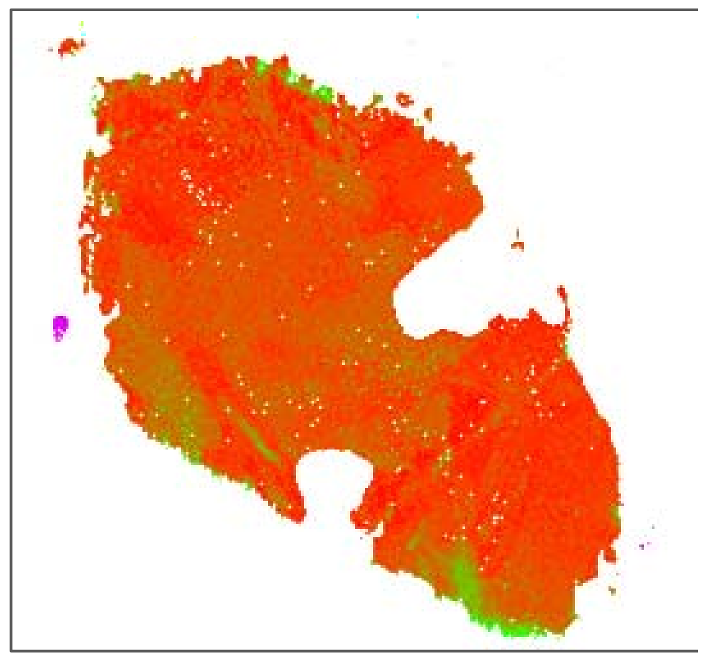
EBSD analysis of microquartz: conclusions

Sponge spicules still contain opaline silica (despite T_{max} of 60-70°C)

Microquartz sourced from sponge spicules

Microquartz seems to be truly quartz although *spotty* EBSD indexing hints some may actually be opaline

Microquartz cement shown (2nd case study) to be locally misoriented with respect to host grain



Inhibition of quartz cement may be result of misoriented microcrystals on grain surface