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Insights into past tectonism from authigenic quartz

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Supplementary Information

The Supplementary Information includes:

- Sample Description
- Analytical Procedures
- Figure S-1
- Supplementary Information References

Sample Description

Poorly consolidated clastic samples were collected from outcrops at Wilhelmøya, the northwestern Barents Shelf, Svalbard (Fig. S-1). The samples belong to the Svenskøya Formation of the Wilhelmøya Subgroup and are of Late Triassic to Early Jurassic (Rhaetian to Toarcian) age. The GPS coordinates of the sample location are 79°04'05.7"N 20°43'47.6"E.

The detailed diagenetic history of the units is published in Haile *et al*. (2019), including fluid inclusion data.

Analytical Procedures

Identification of recycled quartz grains were first carried out using optical microscopy on conventional thin sections, identifying dust rims and rounded cements. Fluid inclusions can also be identified during this stage, and these can be analysed also using a conventional optical microscope equipped with a heating/cooling stage to obtain homogenization and freezing point temperatures. This was not done in the present study.

SEM X-ray elemental mapping

The same thin sections were then analysed with a Hitachi SU5000 field-emission gun scanning electron microscope (FEG-SEM) after being carbon coated. To distinguish quartz grains from other sedimentary grains, the imaging capability of the SEM was combined with elemental mapping by energy dispersive X-ray spectroscopy (EDS). The instrument was run using an acceleration voltage of 15 kV and a working distance of 10 mm. Quartz was easily separated from other grains as it is the only mineral phase (if polymorphs and amorphous silica phases are included) consisting only of Si and O.

Cathodoluminescence (SEM-CL)

The next procedure after identifying the quartz grains was the identification of recycled quartz grains based on their cathodoluminescence (CL) spectra and microtextural characteristics. This was accomplished using SEM-CL imaging. The images were acquired using an acceleration voltage of 12 kV and a working distance of 13 mm. The images typically show authigenic cements with low luminosity (dark colours) whereas detrital quartz appear brighter. Using the recorded images, the number of recycled grains (*R*) were point counted.

CL-RGB

Finally, SEM-CL red-green-blue (RGB) intensity imaging was applied in order to obtain the geochemical/tectonic fingerprint of the grains. SEM-CL RGB colour images were generated by combining three visual primary colour bands of data (red, green, and blue filters). Data acquisition and fine-tuning of the RGB images were conducted using the Delmics Odemis software. The blue and red channels of the RGB spectra contain information on the number and types of crystal defects and incorporated chemical impurities. These are in turn a consequence of the physio-chemical conditions during cement growth and the growth rate of the cement (Götze *et al.*, 2001). Because of this, we can differentiate between multiple quartz overgrowth generations formed during different physio-chemical conditions. A cement that appears red may typically be hydrothermal (diagenetic), whereas one that appears dark blue-brownish is typically diagenetic.

Supplementary Figure

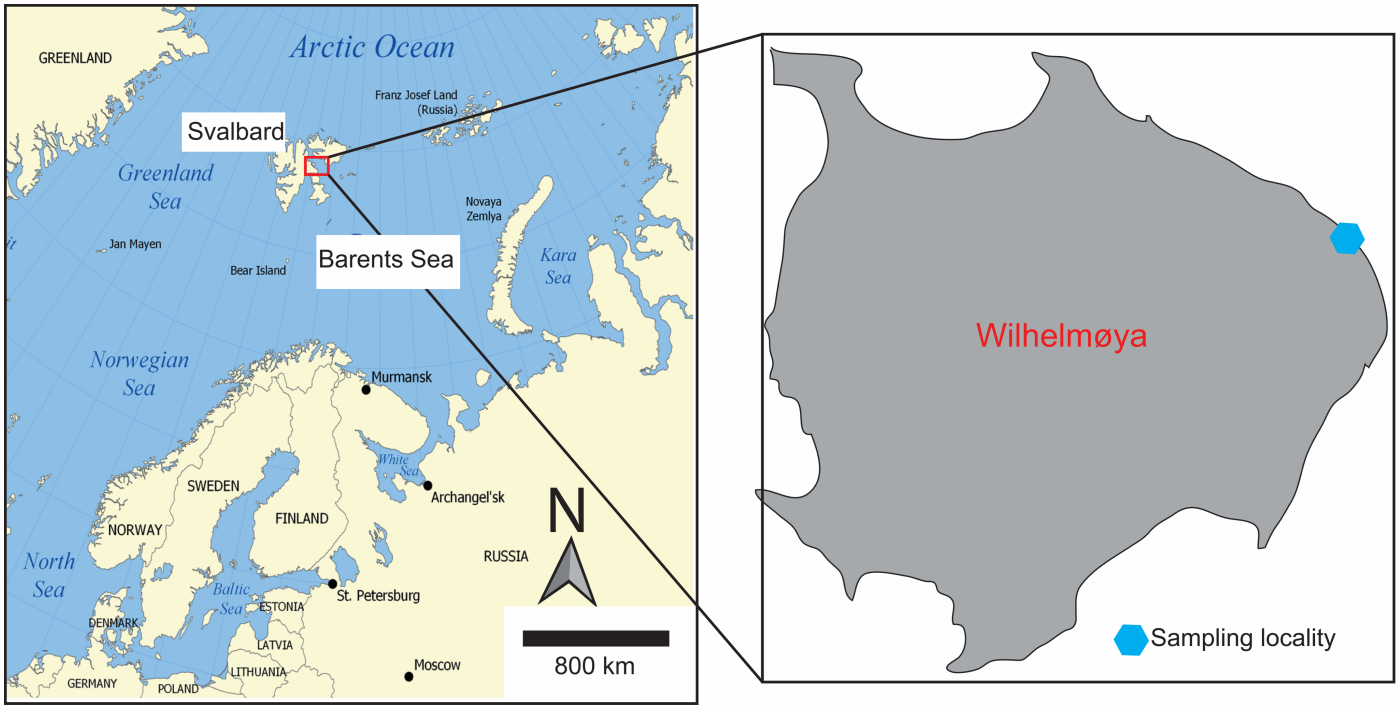

Figure S-1 Simplified geological map illustrating the sampling location (blue filled hexagon). Modified form Haile *et al*. (2019).

Supplementary Information References

Götze, J., Plötze, M., Habermann, D. (2001) Origin, spectral characteristics and practical applications of the cathodoluminescence (CL) of quartz- a review. *Mineralogy and Petrology* 71, 225–250.

Haile, B.G., Czarniecka, U., Xi, K., Smyrak-Sikora, A., Jahren, J., Braathen, A., Hellevang, H. (2019) Hydrothermally induced diagenesis: evidence from shallow marine-deltaic sediments, Wilhelmøya, Svalbard. *Geoscience Frontiers* 10, 629–649. doi: 10.1016/j.gsf.2018.02.015.