Quartz dissolution and M-S-H cement precipitation in a high pH ultramafic system

Lisa de Ruiter[1], Håkon Austrheim[1], Anette Gunnæs[2] & Dag Kristian Dysthe[1]

[1] Physics of Geological Processes (PGP), The Njord Centre, Department of Geosciences/Physics, University of Oslo, Norway
[2] Centre for Materials Science and Nanotechnology, Department of Physics, University of Oslo, Norway

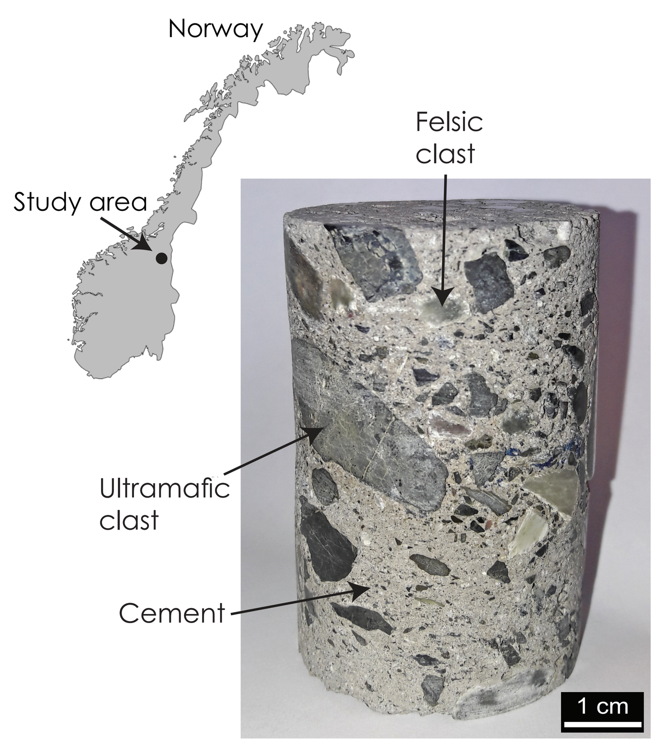
UiO : University of Oslo

l.d.ruiter@fys.uio.no

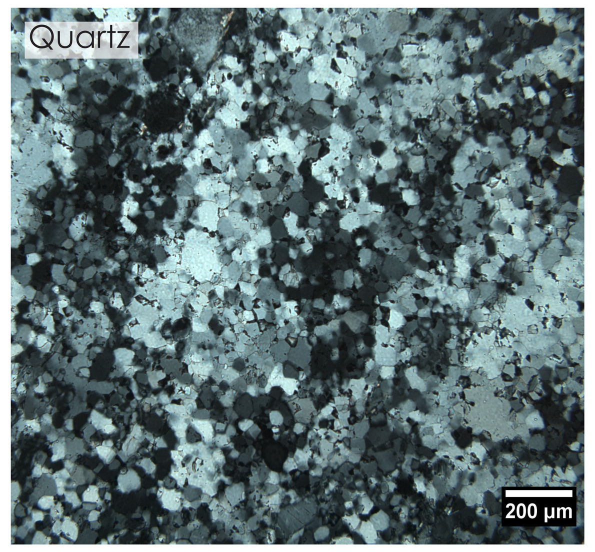
NJORD NANOHEAL

Introduction

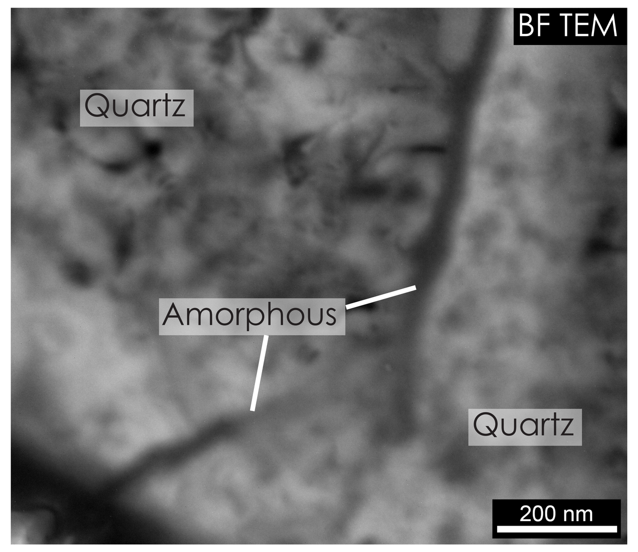
- **Magnesium silicate hydrate** (M-S-H) cement precipitates at the surface, forming a concrete-like rock with felsic (mainly quartz) and ultramafic clasts.
- The process occurs at the **Feragen Ultramafic Body**, a serpentinized peridotite and dunite massif covered with **felsic glacial till** deposits. Weathering of the serpentinite results in dissolution of brucite, leading to **Mg-rich, high pH (> 9) fluids**.
- These conditions result in extremely fast **quartz dissolution** followed by **cement precipitation**.
- We studied the concrete samples on μm- and nm-scale to obtain new insights into quartz weathering and the associated dissolution-reprecipitation reactions resulting in M-S-H cement.



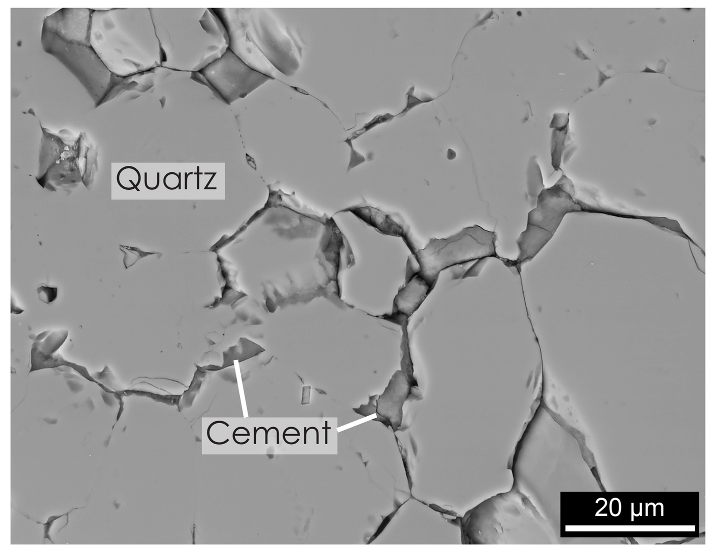
Quartz microstructures



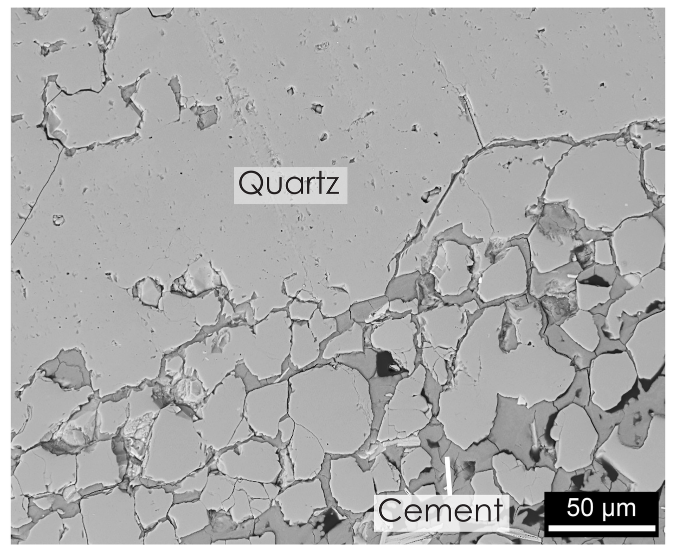
(1) Recrystallized with undulose extinction.



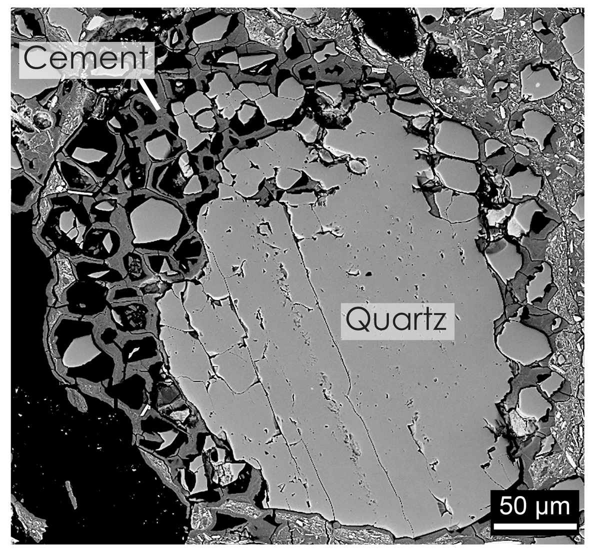
(2) Nm-scale intergranular amorphous silica layers.



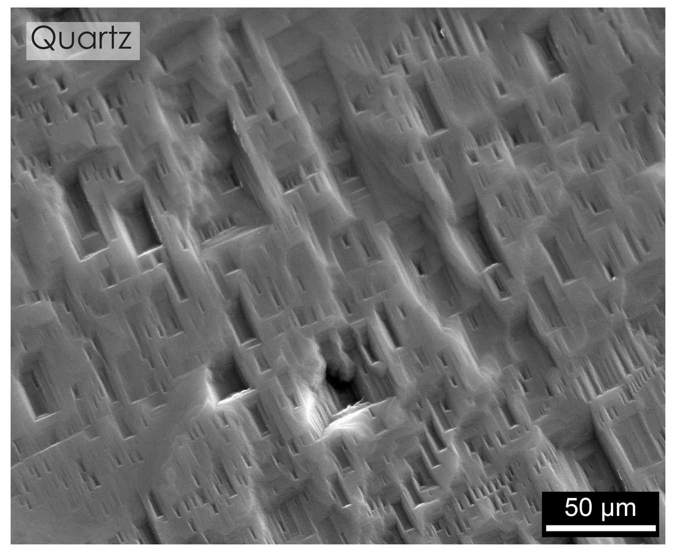
(3) Grain boundaries are replaced by cement first.



(4) Recrystallized quartz disintegrates.



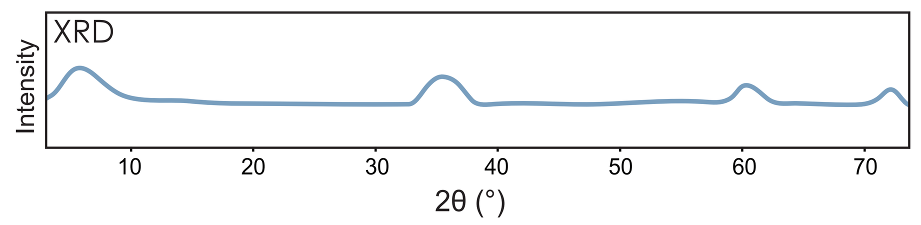
(5) Dissolution resulting in honeycomb pore spaces.

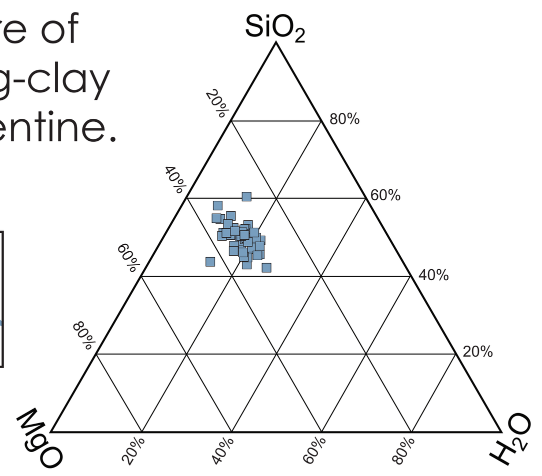


(6) Etch pits on the surfaces.

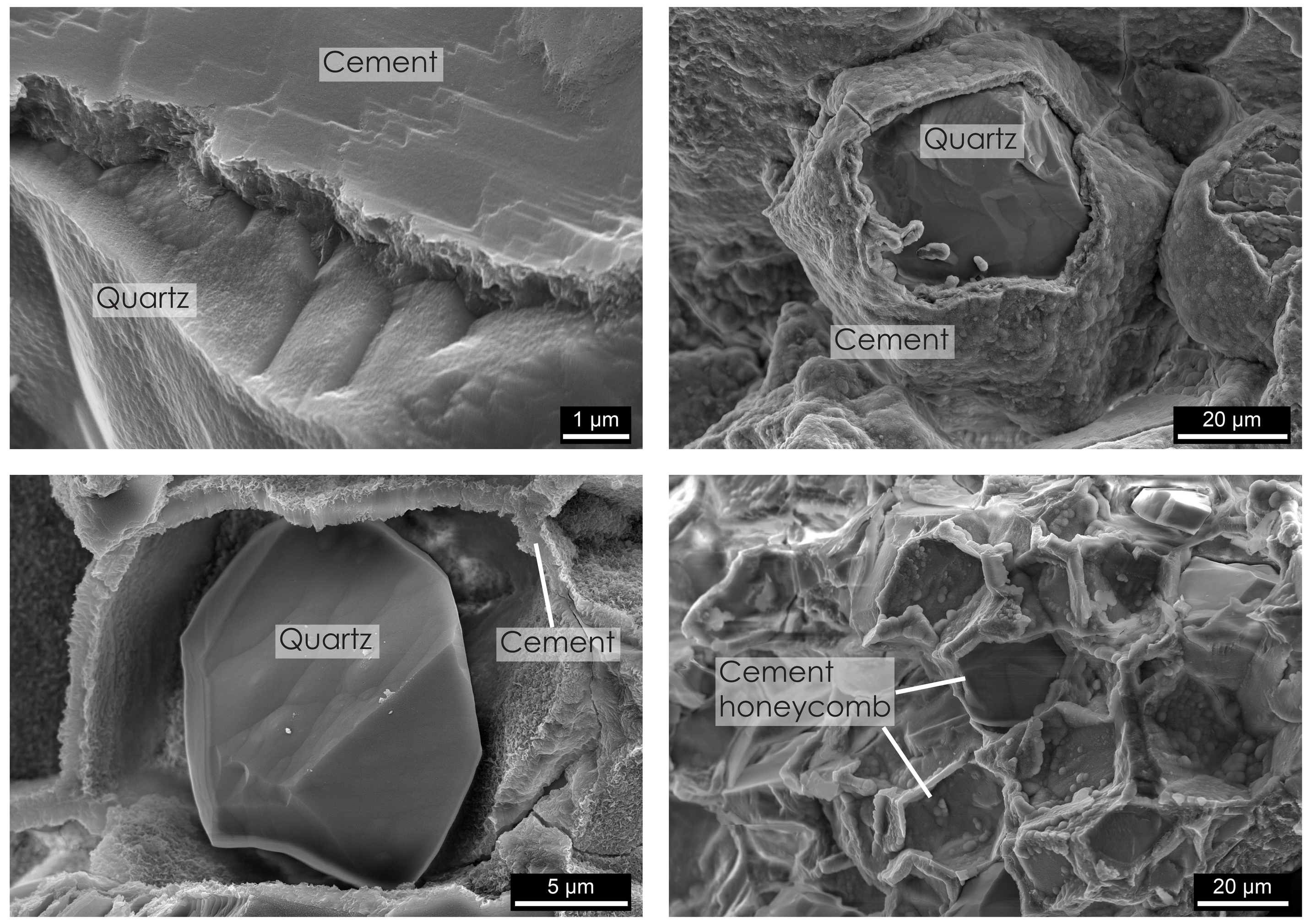
The cement

- $Mg_8Si_8O_{20}(OH)_8 \cdot 6H_2O$
- Forms when silica is released from quartz or amorphous silica in high pH, Mg-rich conditions.
- The XRD spectrum below indicates a mixture of nanocrystalline phyllosilicates related to Mg-clay minerals (kerolite and stevensite) and serpentine.



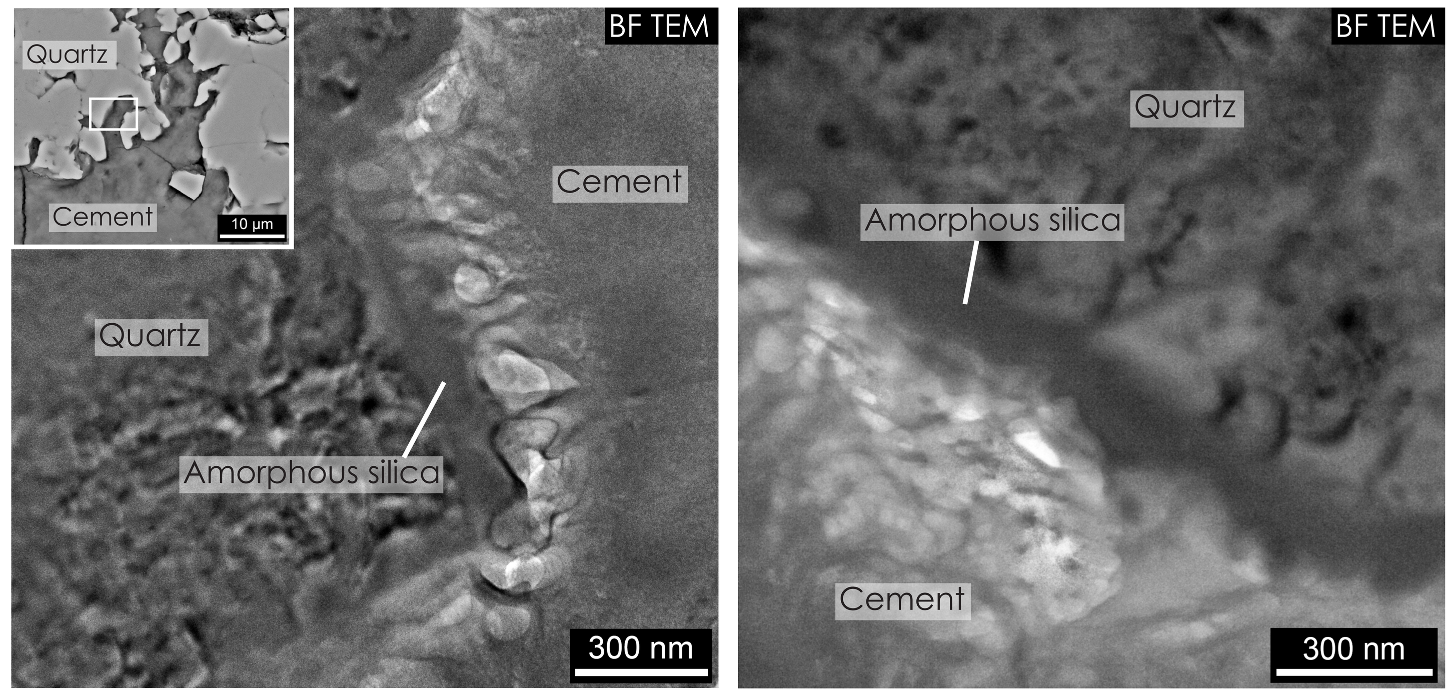


Honeycomb formation



- The cement forms a layer covering the dissolving quartz surface.
- A void often occurs between the quartz surface and the cement, probably because of tensional forces at the interface due to the shrinking or swelling of the hydrous cement.
- Undersaturated fluids can, as a result, more easily access the quartz surface and dissolution will continue without the precipitation of cement, leading to empty honeycomb cells.

Amorphous silica layer



- An amorphous silica layer of 100-200 nm is present around partly dissolved and replaced quartz grains.
- This layer is likely the result of dissolution-reprecipitation, as the fluid layer at the interface becomes saturated w.r.t. silica upon dissolution, even though the bulk solution is far undersaturated.
- The amorphous silica can subsequently react to cement under high pH, Mg-rich conditions. Repeating this process could lead to the complete replacement of quartz by cement.

CO_2-neutral cement

- We conclude that the fast quartz dissolution is associated with the precipitation of amorphous silica that subsequently reacts to cement in highly alkaline and Mg-rich conditions. This either leads to honeycomb structures or complete replacement.
- The natural cement is similar to man-made M-S-H cement, which is currently under investigation as a potential CO_2-neutral alternative for Portland cement and also for the encapsulation of nuclear waste.
- Our new insights and knowledge about natural M-S-H cement formation could therefore provide vital information for the development of synthetic environmentally friendly M-S-H cement.

References

- Hellmann R. et al., 2012. *Chem. Geol.*
- Brady P.V. and Walther J.V., 1990. *Chem. Geol.*
- de Ruiter L. and Austrheim H., 2017. *J. Geol. Soc. London.*
- Ruiz-Agudo E. et al., 2012. *Geology.*
- Velbel M.A. and Barker W.W., 2008. *Clays Clay Miner.*
- Zhang T. et al., 2011. *Cem. Concr. Res.*

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642976.