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Quantitative estimates of reaction induced pressures: an example from the Norwegian Caledonides.

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Estimating the pressure and temperature of metamorphic rocks is fundamental to the understanding of geodynamics. It is therefore important to determine the mechanisms that were responsible for the pressure and temperature obtained from metamorphic rocks. Both pressure and temperature increase with depth in the Earth. Whereas temperature can vary due to local heat sources such as magmatic intrusions, percolation of hot fluids or deformation in shear zones, pressure in petrology is generally assumed to vary homogeneously with depth. However, fluid injection into veins, development of pressure shadows around porphyroblasts, fracturing and folding of rocks all involve variations in stress and therefore also in pressure (mean stress). Volume change during phase transformations or mineral reactions have the potential to build pressure if they proceed faster than the minerals or rocks can deform to accommodate the volume change. This mechanism of pressure generation does not require the rocks to be under differential stress, it may lead however to the development of local differential stress.

The Western Gneiss Region (WGR) is a basement window within the Norwegian Caledonides. This area is well known for its occurrences of HP to UHP rocks, mainly found as eclogite boudins and lenses and more rarely within felsic gneisses. Present observations document a regional metamorphic gradient increasing towards the NW, and structures in the field can account for the exhumation of the (U)HP rocks from ∼2.5 to 3 GPa. Locally however, mineralogical and geothermobarometric evidence points to metamorphic pressure up to 4 GPa. These locations present an example of local extreme pressure excursions from the regional and mostly coherent metamorphic gradient that are difficult to account for by present day structural field observations.
Detailed structural, petrological, mineralogical, geochemical and geochronological study at the Svartberget UHP diamond locality have shown the injection of transitional fluids from host rock felsic gneiss into a peridotite body and subsequent UHP metasomatism of the peridotite by these fluids. It thus provides direct evidence that the host rock gneiss was at higher pressure than the peridotite in order to drive the fluids into the ultramafic body.

Here we quantify with a numerical model the magnitudes of pressure variations due to volume change of reaction. We use the 2D geometry of the Caledonian orogen along a profile across the WGR at the start of UHP metamorphism. The effects of varying viscosity, temperature, activation energy, horizontal convergence rate and rate of reaction are investigated.
For typical effective viscosities of 10^{22} Pas and volume change of 13% per 100.000 years local pressure variations up to 1.5 GPa can be sustained. It can therefore be concluded that significant pressure variations can be maintained in rocks on the geological timescale. In the case of the WGR in Norway, it suggests that the local extreme pressure excursions from the coherent metamorphic gradient can be explained by the mechanism of pressure generation as a result of volume change of reaction.