How large are tectonic deviations from lithostatic pressure in a continent-derived, lithologically heterogeneous Alpine UHP nappe (Koralpe-Saualpe-Pohorje Complex, Austria and Slovenia)?

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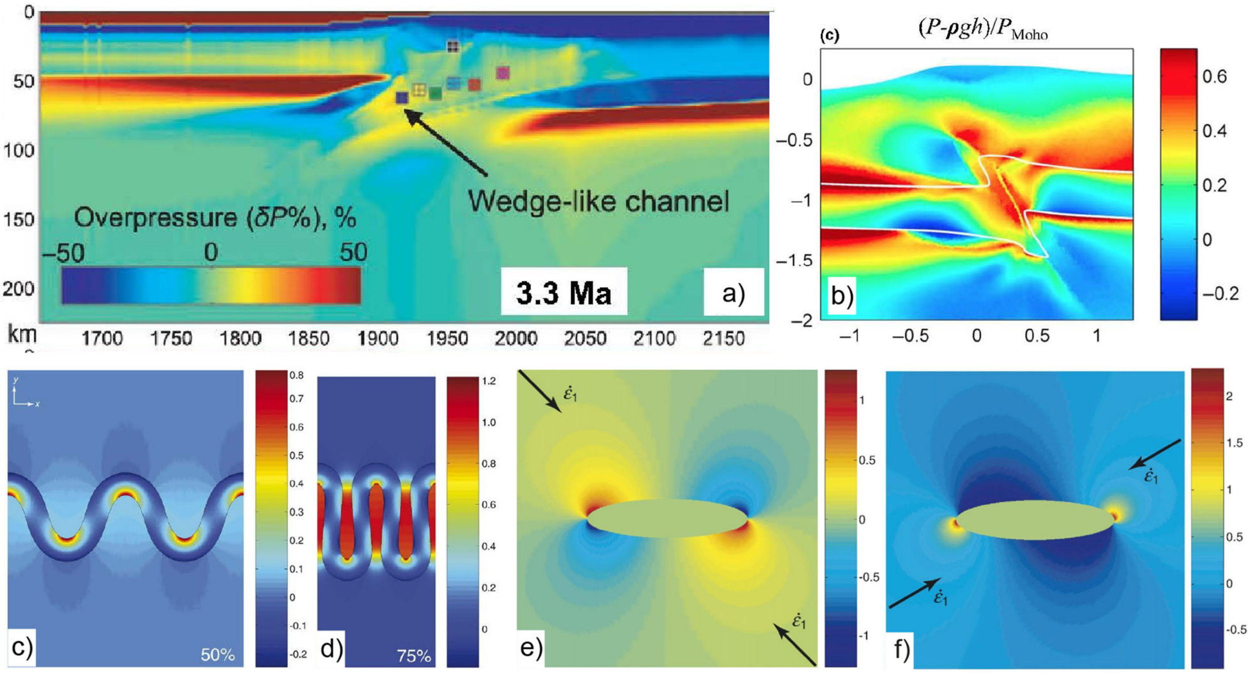
The Alps comprise a relatively high proportion of tectonic nappes that contain (U)HP rocks. In most of the Alpine (U)HP nappes, and in particular in those which are derived from continental crust, both the metamorphic and structural record of (U)HP conditions is limited to some lenses of a certain rock type (usually eclogite, garnet peridotite, or micaschist) embedded in a different host rock (usually orthogneiss, paragneiss, or micaschist). The highest pressures determined within a nappe are commonly supposed to indicate the maximum burial depth by assuming that pressures were close to lithostatic. Recently, however, several numerical studies demonstrated that in deep parts of the orogenic crust, tectonic deviations from lithostatic pressure may become significant (up to some tens of percent of the lithostatic pressure) if the strength contrast between different lithologies is high enough.



Numerical modelling results of tectonic over- and underpressures. ***a)*** *Distribution of tectonic over- and underpressures in a subduction zones (Li et al., 2010, J. metamorphic Geol. 28, 227-247; Gerya, 2015*, J. metamorphic Geol. 33, 785-800*). At the position of the blue marker point, the overpressure amounts to c. 300 MPa.* ***b)*** *Overpressure in a weak crustal-scale shear zone (Schmalholz & Podladchikov, 2013, Geophys. Res. Letters 40, 1-5; Gerya, 2015*, J. metamorphic Geol. 33, 785-800*). The colour coding indicates overpressure normalised against the initial lithostatic pressure at the Moho.* ***c&d)*** *Tectonic pressure within and next to a rigid layer that is becoming folded (Schmalholz & Podladchikov, 1999, Geophys. Res. Letters 26, 2641-2644; Mancktelow, 2008, Lithos 103, 149-177). The tectonic pressure is normalised against* $|2\mu_{layer}\dot{\varepsilon}_{XX}|$ *(normal flow stress) for a viscosity ratio 1:50.* ***e&f)*** *Tectonic pressure around a rigid elliptic inclusion and its matrix in a non-uniform stress field (Schmid, 2005, Geol. Soc. Spec. Publ. 245, 421-431; Mancktelow, 2008, Lithos 103, 149-177). The tectonic pressure is normalised against* $|2\mu_{matrix}\dot{\varepsilon}_{XX}|$ *(normal flow stress) for a viscosity ratio 1:10. Note that the pressure in the inclusion is everywhere the same and that the orientation of the inclusion with respect to the principal shortening axis (labelled) determines the distribution over over-and underpressure in the matrix. Significant tectonic pressures occur at the scale of the inclusion*

They may particularly occur near the boundaries between rock types differing in viscosity by an order of magnitude or more (see reviews by Mancktelow, 2008, Lithos 103, 149-177; Gerya, 2015, J. metamorphic Geol. 33, 785-800), e.g. near the hinges of folded eclogite layers or eclogite lenses embedded within gneiss or micaschist.

Unambiguous field evidence supporting the concept of tectonic over- and underpressure is still very sparse if not lacking. We will carry out a systematic study of peak pressures undergone by different lithologies at the scale of an Alpine nappe, specifically the Austroalpine Koralpe-Saualpe-Pohorje Complex that reached UHP conditions during the Eo-Alpine orogeny in the early Late Cretaceous. Like most other Alpine continent-derived (U)HP units, this unit is mostly composed of orthogneisses, paragneisses, and micaschists. HP and possibly UHP conditions were reported from volumetrically subordinate eclogite bodies of the Koralpe-Saualpe and Pohorje units, respectively (e.g. Schorn & Stüwe, 2016, J. metamorphic Geol. 34, 147-166; Janák et al., 2004, Tectonics 23, TC5014), and locally also from their metasedimentary host rocks (e.g. Herg & Stüwe, 2018, Austrian J. Earth Sci. 111, 1-17; Janák et al., 2015, J. metamorphic Geol. 33, 495-512).

We will apply Raman spectroscopy of quartz inclusions in garnet (RSQI) to determine pressures. This method has the advantage of being an equilibrium-independent barometer that utilises the shift of quartz peaks in Raman spectra as a function of the pressure preserved in quartz grains entrapped within garnet host grains (e.g. Ashley et al., 2014, Comput. Geosci. 66, 155-157). Another advantage of RSQI barometry is that it may detect pressure conditions of quartz overgrowth by garnet other evidence of which is not available (e.g. Groß et al., 2020, Tectonics 39, e2019TC005942), either because the rock chemistry is not sensitive enough to mineralogical phase changes or because the mineral assemblage was completely overprinted during later tectono-metamorphic stages. The RSQI barometric analyses will be complemented by zirconium-in-rutile thermometry that will allow us to account for the temperature-dependant elastic partial relaxation of quartz inclusions in garnet.

Our sampling strategy will follow a twofold approach. First, we will sample individual eclogite lenses and, if available, eclogite layers and their host rocks folded under HP conditions. This smaller-scale approach will serve to test whether or not structurally controlled tectonic pressure variations that are predicted to occur particularly around rigid inclusions in a weak matrix and near the hinges of rigid folded layers neighboured by weak ones can be observed on natural examples. Second, we will sample eclogites and garnet-bearing metasediments along a North-South profile from the Koralpe into the Pohorje unit. The sampling sites of metasediments will be chosen far enough away from eclogite bodies so that structurally controlled pressure variations are avoided as much as possible. This second, nappe-scale sample set will serve for verifying the existence of a regional gradient with southward increasing maximum pressures in the eclogites that is suggested by the existing literature data and for checking whether a similar gradient exists in the metasedimentary rocks. Our hypothesis is that it does exist, because the Koralpe-Saualpe-Pohorje Complex acted as a coherent unit that was subducted towards the South during Alpine orogeny. If the metasediments also yield a southward increase of peak pressures, the absolute peak pressure values and their North-South gradient may either be the same for eclogites and metasediments, in which case significant tectonic pressure variations induced by a rheological contrast between eclogite lenses and their host rock would be disproved, or show variations that, if systematic, can be interpreted in terms of tectonic pressure variations induced by different rheological and deformation behaviour of different rock types in the subduction zone.

The project is directly relevant to Research Theme 3 of the SPP (Rock trajectories and deformation during mountain building) because tectonic pressure variations from lithostatic may have to be taken into account when restoring maximum burial depths of nappes from local findings of (U)HP metamorphic rocks. The maximum burial depths, combined with age data, are essential pinpoints for developing kinematic models and these are, in turn, the major criterion for assessing which of the many existing numerical dynamic models are or are not applicable to specific tectonic units. Kinematic models also serve for estimating the amounts and rates by which nappes moved in the Alpine subduction zone. These data may again be used for quantifying relative plate motions in plate tectonic models.