Geophysical Research Abstracts
Vol. 17, EGU2015-2686, 2015
EGU General Assembly 2015

Effect of crustal heterogeneities and effective rock strength on the formation of HP and UHP rocks.

Georg Reuber (1), Boris Kaus (1), Stefan Schmalholz (2), and Richard White (1)

(1) Johannes-Gutenberg University Mainz, Institute of Geosciences, Department of Chemistry, Pharmacy & Geosciences, Mainz, Germany (kaus@uni-mainz.de), (2) University of Lausanne, Switzerland

The formation of high pressure and ultra-high pressure rocks has been controversially discussed in recent years. Most existing petrological interpretations assume that pressure in the Earth is lithostatic and therefore HP and UHP rocks have to come from great depth, which usually involves going down a subduction channel and being exhumed again. Yet, an alternative explanation points out that pressure in the lithosphere is often non-lithostatic and can be either smaller or larger than lithostatic as a function of location and time.
Whether this effect is tectonically significant or not depends on the magnitude of non-lithostatic pressure, and as a result a number of researchers have recently performed numerical simulations to address this. Somewhat disturbingly, they obtained widely differing results with some claiming that overpressures as large as a GPa can occur (Schmalholz et al. 2014), whereas others show that overpressures of exhumed rocks are generally less than 20% and thus insignificant (Li et al. 2010; Burov et al. 2014).

In order to understand where these discrepancies come from, we reproduce the simulations of Li et al (2010) of a typical subduction and collision scenario, using an independently developed numerical code (MVEP2). For the same model setup and parameters, we confirm the earlier results of Li et al. (2010) and obtain no more than $\sim$20% overpressure in exhumed rocks of the subduction channel.
Yet, a critical assumption in their models is that the subducted crust is laterally homogeneous and that it has a low effective friction angle that is less than 7o. The friction angle of (dry) rocks is experimentally well-constrained to be around 30o, and low effective friction angles require, for example, high-fluid pressures. Whereas high fluid pressures might exist in the sediment-rich upper crust, they are likely to be much lower or absent in the lower crust from which melt has been extracted or in rocks that underwent a previous orogenic cycle.
In a next step, we performed several hundred numerical simulations to understand the effects of km-scale heterogeneities and material parameters on pressure magnitudes, using a model setup that is otherwise very similar to the one of Li et al. (2010). Results show that significant non-lithostatic pressures occur if (lower) crustal rocks are dry or if km-scale (nappe-sized) heterogeneities with dryer rocks are present within the crust. Overpressure magnitudes can be up to 1 GPa or 100% and in some cases rock assemblages are temporarily in the coesite stability field at a depth of only 40 km, followed by rapid exhumation to the surface. Tectonic overpressures can vary strongly in magnitude versus time, but peak pressures are present sufficiently long for metamorphic reactions to occur. The presence of heterogeneities can affect the crustal-scaled deformation pattern, and the effective friction angle of crustal-scale rocks (or the dryness of these rocks) is a key parameter that determines the magnitude of non-lithostatic pressures.

Our results thus reconcile previous findings and highlight the importance of having an accurate knowledge of the fluid-pressure, initial crustal structure and rock composition during continental collision. If rocks are dry by the time they enter a subduction zone, or are stronger/dryer than surrounding rocks, they are likely to develop significantly higher pressures than nearby rocks. This might explain the puzzling observation that some nappes have very high peak pressures, while juxtaposed nappes have much lower values, without clear structural evidence for deep burial and exhumation along a subduction channel of the high-pressure nappe. Our models might also give a partial explanation of why the reported timescales for high and ultra-high pressure stages of peak metamorphism are often very short.

References:

Burov, E., Francois, T., Agard, P., Le Pourhiet, L., Meyer, B., Tirel, C., Lebedev, S., Yamato, P., Brun, J.-

P., 2014. Tectonophysics. Tectonophysics 631, 212–250. doi:10.1016/j.tecto.2014.04.033

Li, Z.H., Gerya, T.V., Burg, J.-P., 2010. Influence of tectonic overpressure on P-T paths of HP-UHP rocks in continental collision zones: thermomechanical modelling. J Metamorph Geol 28, 227–247. doi:10.1111/j.1525-1314.2009.00864.x

Schmalholz, S.M., Duretz, T., Schenker, F.L., Podladchikov, Y.Y., 2014. Tectonophysics. Tectonophysics 631, 160–175. doi:10.1016/j.tecto.2014.05.018