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Outcrop-scale pressure variations in the Monte Rosa Nappe, Western Alps, challenge the lithostatic pressure paradigm

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The Monte Rosa Nappe is part of the internal crystalline massifs of the Western Alps. It represents the southernmost European continental basement involved in the Alpine orogeny. It consists of a pre-Variscan paragneissic complex, intruded by a Permian granitic body[1].
The high pressure (HP) Alpine metamorphism is best preserved in the less deformed portions of the nappe. Here the metagranite consist of zoisite, phengite, and albite pseudomorphing igneous plagioclase, as well as phengite, garnet, and titanite partially replacing biotite. Jadeite has not been observed, despite the hydrous zoisite paragenesis. The metagranite locally grades into distinct 10 to 50 meters sized whiteschist bodies consisting of talc, chloritoid, and phengite. Locally these bodies contain kyanite and quartz ± garnet and carbonate. They represent zones of late magmatic hydrothermal alteration of the granite. Their mineralogy results from the Alpine HP metamorphism[2-3].
Calculations using the internally consistent thermodynamic database of Berman on the whiteschist composition result in a minimum pressure of 2.2 GPa for a temperature of 550 to 570 ˚C and a water activity close to 1. The Si in phengite barometer[4] was used to estimate the pressure in the metagranite. Assuming a water fugacity of one, a pressure increase is observed along a profile towards the whiteschist, from 1.05 GPa in the undeformed metagranite to 1.35 GPa in the metagranite closest to the whiteschist. This results in an apparent pressure difference of approximately 0.8 GPa between the metagranite and the whiteschist. A calculated water activity of less than 0.4 is required in the metagranite in order to reach the pressure of 2.2 GPa. It is hence critical to estimate the water fugacity independently. We developed white mica standards for H_2O content measurements using the SwissSIMS facility at the University of Lausanne. Accurate measurements of H_2O content in white micas by high temperature conversion elemental analysis (TC/EA) were challenging to do. In addition, a clear indication of a compositional matrix effect for white mica was observed for SIMS analyses. Nevertheless, preliminary results point towards high water fugacities registered by phengites in all metagranites, in agreement with the microstructural record and the lack of jadeite.
These results support a pressure variation in the order of 0.8 GPa between the undeformed metagranite and the whiteschist. Such pressure variation could be explained by large differential stresses in the metagranite. Large stresses are justified by field observations of large volumes of undeformed porphyritic metagranite surrounding the whiteschist bodies acting as a mechanically strong host for the weak whiteschist inclusions. Our results challenge the lithostatic pressure paradigm because (i) the pressure variation of 0.8 GPa occurs between the tectonically coherent whiteschist and metagranite, (ii) microstructural observations indicate no retrogression from jadeite to plagioclase and (iii) the high water fugacities do not support sluggish kinetics.

References

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