7th Orogenic Lherzolite meeting
from 30 September to 4 October 2024
in Oviedo, Asturias, NW Spain
field trip to the *Cabo Ortegal massif*, Galicia

Meeting: OCT 2 - 4 Pre-conference excursion: SEP 30 - OCT 1

Stability and chemistry of rutile and titanite in metamafic rocks

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Rutile and titanite are valuable petrochronometers, since both can be dated using U-Pb and Zr concentrations are calibrated as geothermometers. In order to use these minerals as tracers of crustal gradients, a better understanding regarding their stabilities is required, as well as the development of single-grain barometry. Previous experimental studies using MORB compositions (Liou et al, 1998) established that titanite is more stable at LT-LP and rutile at HP (> 12 kbar). Despite these, the natural occurrence of rutile at LP (< 12 kbar) and titanite at HP (> 20 kbar) indicates strong uncertainties on our current understanding about their stabilities in mafic lithologies, particularly under conditions typical of subduction zones. To understand their phase stabilities and how their chemistries may reflect their peak P-T conditions, we conducted a set of experiments using piston-cylinder apparatus and we studied the chemistry of rutile and titanite using a set of metamafic rocks with MORB composition (Pereira et al., 2023), which experienced variable P-T metamorphism, by EPMA and LA-ICPMS.

We present the results of a set of 30 experiments that were conducted under water-saturated conditions, using a cold pressure-seal capsule technique, with pressures ranging between 12 and 23 kbar, and temperatures between 400 and 750 °C (Fig. 1A). We tested multiple starting materials, with bulk rock powders yielding different Ti/Ca values, and resourcing to mineral seeds to work as nuclei for mineral overgrowth (e.g. rutile, titanite, kaersutite, wollastonite). Due to the challenging LT experiments, equilibrium is not attained, but dissolution and precipitation features are often observable (Fig. 1B). We show that when Ti/Ca is high (0.20), titanite seeds become unstable and start reacting with the basalt bulk rock powder while rutile is stable, even at lower pressures (14 kbar), and when Ti/Ca is low (0.15), titanite seeds appear metastable, even at high pressures (19 kbar) and low temperatures (< 600 °C). This is in agreement with petrological observations recorded in some natural samples (i.e. peak titanite reported in blueschist and low-T eclogite rocks; Vitale Brovarone et al., 2011). We found that water content as well as Ti/Ca ratios appear to influence the stability of these Ti-phases in mafic systems, influencing the stable Ti-phase at HP conditions (Fig. 1C). Additionally, we present mineral chemical results for rutile and titanite from metamafic rocks formed at HT-LP and LT-HP metamorphic conditions. In our rock dataset, we found rutile stable in ocean-floor amphibole-bearing gabbros, formed at low pressures (< 2 kbar). These pressure conditions are lower than experimental constraints suggest for rutile stability, which is formed during retrograde reactions due to excess Ti released from Ti-amphiboles. Rutile is also found in eclogitic metagabbros from the Western Alps and can be chemically distinguished from LP rutile. Blueschist metagabbros from the Western Alps and eclogitic metabasalts from Corsica have titanite stable instead of rutile. High-pressure titanite from these metamafic rocks exhibits La depletion and low La/Sm_N values, distinct from titanite from amphibolite-facies mafic rocks. We compare our mineral chemical data with literature data and propose La/Sm_N or Nb together with Yb and V to distinguish HP titanite from titanite formed under other P–T settings, and Nb/V to distinguish LP from HP metamafic rutile.

These new experimental results can be used to better constrain the stabilities of rutile and titanite at subsolidus conditions in mafic systems, while our new trace element systematics can be particularly useful in provenance studies tracing metamorphic gradients using detrital minerals.

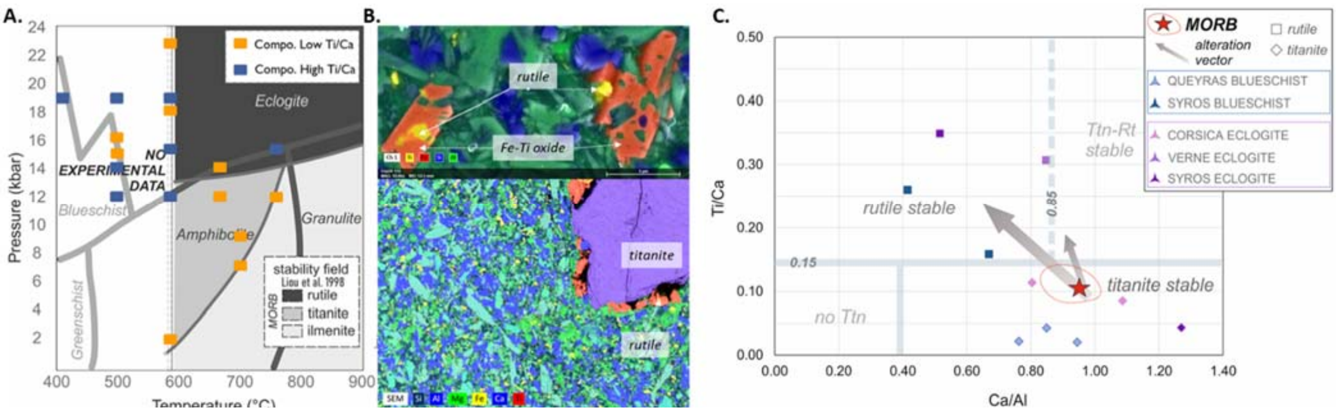

Figure 1. Stability of rutile, titanite and ilmenite, A. in terms of P-T space based on publish and new experimental petrology; B. EDS-SEM maps of mineral phases of experiments depicted in A., and C. as a function of Ti/Ca and Ca/Al bulk-rock composition (Pereira et al., 2023).

References

Liou, J. G., Zhang, R., Ernst, W. G., Liu, J. & McLimans, R. 1998. Mineral parageneses in the Piampaludo eclogitic body, Gruppo di Voltri, western Ligurian Alps. Schweizerische Mineralogische und Petrographische Mitteilungen 78, 317–335.

Pereira, I., Bruand, E., Nicollet, C., Koga, K. T., & Vitale Brovarone, A. 2023. Ti-Bearing Minerals: from the Ocean Floor to Subduction and Back. Journal of Petrology, 64(7), egad041 https://doi.org/10.1093/petrology/egad041

Vitale Brovarone, A., Groppo, C., Hetényi, G., Compagnoni, R. & Malavieille, J. 2011. Coexistence of lawsonite-bearing eclogite and blueschist: phase equilibria modelling of Alpine Corsica metabasalts and petrological evolution of subducting slabs. Journal of Metamorphic Geology 29, 583–600. https://doi.org/10.1111/j.1525-1314.2011.00931.x

Acknowledgments

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