

EXPERIMENTAL INVESTIGATION OF TITANIUM STABILITY IN NATURAL SAGENITIC PHLOGOPITES FROM FENNOSCANDIAN LAMPROPHYRES

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Shoshonitic (calc-alkaline) lamprophyres are mafic lamprophyres containing feldspar as a matrix phase, which typically occur in late- to post-orogenic tectonic settings. Precise knowledge of the pressures of both magma generation and dyke emplacement can be of great benefit for developing models of orogenic evolution. However in cases where mantle and lower crustal xenoliths are lacking, options for determining source pressures and temperatures are severely limited. Several shoshonitic lamprophyre dyke swarms are found in the margin between the Palaeoproterozoic Svecofennian Domain and the Archaean Karelia Craton. The dykes intrude large-scale normal fault structures within a NW-SE trending palaeosuture at ca. 1790 Ma, indicative of a change from a compressional to an extensional tectonic regime (WOODARD, 2010). These dykes contain abundant Ba- and Ti-rich mica, both as a phenocrystic and matrix phase. Mica (biotite or phlogopite) phenocrysts occur as castellated grains, with a core-to-rim increase in Mg# and ubiquitous sagenitic texture. Sagenitic texture refers to the occurrence of needle-like inclusions of rutile or titanite, in this case exclusively titanite, occurring parallel to (001) of the host biotite in preferred crystallographic orientation (e.g., SHAU *et al.*, 1991). Using the phlogopite-melt Ti- and Ba-partitioning thermobarometer (RIGHTER & CARMICHAEL, 1996), matrix phlogopite indicate crystallisation at 1000–1150°C and 0.2–0.3 GPa, corresponding to emplacement at 7–10 km depth (WOODARD & BOETTCHER, 2010). This is in good agreement with previous depth estimates from this area (NIIRANEN, 2000). Thermobarometry from the phenocrysts imply PT conditions as high as 1200°C and 6.2 GPa, well beyond the calibration range of the method, albeit in a linear trend (WOODARD & BOETTCHER, 2010).

Many studies have shown that Ti solubility in phlogopite increases with temperature (e.g., ROBERT, 1976; ARIMA & EDGAR, 1981; ESPERANCA & HOLLOWAY, 1987), implying that sagenitic texture could form as a result of exsolution of the Ti-rich phase at lower temperatures. However, some experiments have shown a decrease in Ti solubility with temperature, which is most likely a result of complex substitutions coupled with other trace elements, most notably Ba (e.g., GUO & GREEN, 1990; RIGHTER & CARMICHAEL, 1996). Ba solubility in phlogopite decreases with pressure but increases with both temperature and coupled Ti substitution (GUO & GREEN, 1990). In order to form sagenitic titanite by exsolution, the picture

is further complicated by the stability Ca in phlogopite. Experimental studies have shown that like Ti, Ca solubility in phlogopite increases with temperature (OLESCH, 1979). Ca-rich phlogopite associated with orthopyroxene was interpreted as a prograde phase in ultrahigh pressure rocks (LI *et al.*, 2011), implying that Ca solubility may also increase with pressure.

For this study, we selected natural sagenitic mica phenocrysts from Fennoscandian shoshonitic lamprophyres for experiments in an attempt to reverse the exsolution process. Experiments were conducted in a piston cylinder apparatus over a range of temperatures (800–1100 °C), pressures (1–2.5 GPa) and time (30–160 h) at Natural History Museum, Oslo. Preliminary results indicate that at the highest temperatures, titanite inclusions only became larger and more rounded. Across the whole temperature range at low pressure, breakdown of titanite resulted in crystallisation of perovskite at grain boundaries. Finally, at the highest pressures and moderate to low temperatures, titanite inclusions decreased in size or disappeared altogether with no evidence of formation of new Ti- or Ca-bearing phases. While additional experiments are needed over a greater range of pressures, the successful reversal of the exsolution process implies that these phenocrysts crystallised at high pressures and moderate temperatures.

References

- ARIMA, M. & EDGAR, A.D. (1981): Contributions to Mineralogy and Petrology, 77: 288–295.
- ESPERANCA, S., & HOLLOWAY, J.R. (1987): Contributions to Mineralogy and Petrology, 95: 206–216
- GUO, J. & GREEN, T.H. (1990): Lithos, 24: 83–95.
- LI, X.P., YANG, J.-S., ROBINSON, P., XU, Z.-Q. & LI, T.-F. (2011): Journal of Asian Earth Sciences, 42: 661–683.
- NIIRANEN, T. (2000): Master's Thesis, University of Turku, Turku, Finland.
- OLESCH, M. (1979): Bulletin de Minéralogie, 102: 14–20.
- RIGHTER, K. & CARMICHAEL, I.S.E. (1996): Contributions to Mineralogy and Petrology, 123: 1–21.
- ROBERT, J.L. (1976): Chemical Geology, 17: 213–227
- SHAU, Y.H., YANG, H.Y. & PEACOR, D.R. (1991): American Mineralogist, 76: 1205–1217.
- WOODARD, J. (2010): Ph.D. Thesis, University of Turku, Turku, Finland.
- WOODARD, J. & BOETTCHER, I. (2010): Mineralogica – Special Papers, 37: 65–66.