Petrogenesis of Fe-Ti-P-(Zr)-rich rocks and nelsonites in the Raftsund intrusion, Vesterålen-Lofoten AMCG suite, Northern Norway.

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The origin of Fe-Ti-P-rich rocks and nelsonites (SiO_2<10 wt%), predominantly found in mafic layered intrusions or anorthosites, has been debated. Fractional crystallization coupled with crystal sorting and/or magma mixing are the most commonly accepted processes suggested for these enigmatic rock types. Another process is silicate-liquid immiscibility. This mechanism has regained attention as a viable process in dry mafic tholeiitic systems. However, little is known about the petrogenesis of Fe-Ti-P-rich rocks found in monzonite and syenite. In this study we present unique occurrences of Fe-Ti-P-(Zr)-rich rocks and nelsonites, associated with the monzonitic to syenitic Raftsund intrusion, Northern Norway, that supports the silicate-liquid immiscibility formation model.

The Raftsund intrusion is a 35 x 70 km large batholith which belongs to the Lofoten-Vesterålen anorthosite-mangerite-charnockite-granite suite and was emplaced around 1800 Ma in migmatitic granulite facies gneisses. Conditions of emplacement, constrained by the QUILF equilibria (Markl et al, 1998), indicate that the suite was emplaced at 4-5 kbar, magmas were hot (800-920 C) and dry (ternary feldspar) at $aSiO_2$=1 and *f*O2=-0.6 FMQ. In this study, we focus on the Fayalite-Augite (Fay-Aug) monzonite which hosts cm-scale vein-like Fe-Ti-P-(Zr)-rich segregations and a 20 x 15 m large nelsonite pod. Fay-Aug monzonite consists of clusters of Fe-rich minerals including fayalite, augite, ilmenite, rare titanomagnetite and allanite, surrounded by a matrix of ternary feldspar. Locally the Fe-rich mineral clusters are strongly enriched in zircon and apatite. Thin rims of plagioclase, enriched in Fe, are present at the contact between the Fe-rich mineral clusters and the ternary feldspar. A previous study showed that silicate-liquid immiscibility is the likely process explaining these features (Coint *et al*., 2020). Segregations of Fe-Ti-P-(Zr)-rich rocks, displaying the same mineralogy as the Fe-rich clusters, occur at the contact with monzonitic enclave in a mingling zone. The composition of ilmenite and titanomagnetite in the segregation and the host Fay-Aug monzonite overlap, suggesting that the segregation of Fe-Ti-P-(Zr)-rich rocks derive from accumulation of Fe-rich melt along rheological boundaries. The origin of the nelsonite pod containing rounded enclaves of monzodiorite, is more intricate as Fe-rich melt produced by silicate-liquid immiscibility usually contains a minimum of 20-30 wt% SiO_2. The nelsonite, hosted by the Fay-Aug monzonite, is composed of titanomagnetite, ilmenite, apatite, mm-large skeletal zircon and sparse altered Fe-rich silicates. Ilmenite and titanomagnetite in the nelsonite are strongly enriched in elements such as Mg, Sc, Zr and Al, compared to the same minerals in the Fay-Aug monzonite and monzodioritic enclaves. Enrichements in elements that should behave both compatibly and incompatibly during fractional crystallization suggest that the nelsonite was also formed by silicate-liquid immiscibility. Fractionation of the Fe-rich melt is required to reach the composition of nelsonite and a Fe-silicate cumulate is expected. Such rocks crop out further north in the Raftsund intrusion.

Silicate-liquid immiscibility is a viable process in evolved dry alkalic ferroan magmas which can lead to local enrichment in accessory minerals such as zircon and apatite. Silicate-liquid immiscibility is also responsible for the formation of nelsonite rocks but requires differentiation of the Fe-rich melt.

References

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