Formation of zircon + titanite from igneous zirconolite in a high-pressure metamorphosed syenodiorite

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Lower continental plates in collisional settings are subject to tectonic burial at high pressures and elevated temperatures. However, metamorphic recrystallisation is largely steered by the influx of hydrous fluid linked to deformation. At deep crustal levels, shortage of hydrous fluid allows anhydrous bedrock to remain unreacted (metastable), preserving all or part of the original mineral assemblages and textures. Low-silica rocks that contain primary zirconium oxides (*e.g.*, baddeleyite) preserve these accessory phases in a metastable state. Where hydrous fluid has been introduced, however, metamorphic reaction involving silica in solution may transform e.g., igneous baddeleyite to metamorphic zircon (Beckman & Möller, 2018). Thus, accessory minerals record the metamorphic behaviour and the onset of metamorphic recrystallisation.

The eastern boundary of the Sveconorwegian Orogen in Scandinavia is characterised by steep, N–S trending, non-penetrative ductile deformation and low-T amphibolite-facies metamorphism (Möller & Andersson, 2018). The granitic 1.7 Ga bedrock hosts variably deformed 1.2 Ga syenite with minor anorthosite and related mafic rocks (Söderlund & Ask 2006). An investigated occurrence of orthopyroxene syenodiorite has an unusual Zr-rich igneous mineral assemblage, including Zr-bearing Fe-Ti oxides and accessory baddeleyite, zircon, zirconolite, and srilankite. Where the rock is recrystallised, metamorphic zircon + titanite intergrowths have formed at the expense of igneous zirconolite. The metamorphic reactions were triggered by the influx of hydrous fluid and deformation, causing the breakdown of the (metastable) igneous minerals to form a metamorphic assemblage (Bt + Pl + Ep + Ttn + Ilm ± Grt + Qtz). The breakdown of zirconolite and formation of metamorphic zircon and titanite can be described by the simplified reaction:

$CaREEZr_2Ti_3FeO_{14} + 5\ SiO_2 + 2\ CaO_{\textit{(in hydrous solution, from anorthite breakdown)}} \Longrightarrow 2\ ZrSiO_4 + 3\ CaTiSiO_5 + [0.5\ REE_2O_3 + 0.5\ Fe_2O_3]_{\textit{(into epidote minerals)}}$

Thermobarometric calculations, using the compositions of the main metamorphic minerals (*i.e.*, Bt + Pl + Ep + Grt), indicate that the metamorphic assemblage equilibrated at 620 ± 21°C and 12.0 ± 0.9 kbar. The high-pressure conditions are consistent with tectonic burial to depths ~40 km, in a setting that has been compared to the Indian Lower Plate underthrusting Eurasia beneath the Himalaya (Möller & Andersson, 2018).

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