Metamorphic zoning in plagioclase from the Caledonides recording transient events

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In recent years, special types of chemical zonation in plagioclase have been observed in lower crustal rocks. Two microstructural types can be differentiated: 1) Anorthite-rich plagioclase arranged in a network pattern in intact, more albite-rich plagioclase, which has been termed "complex feldspar" by Mukai et al. (2014). 2) Polygonal plagioclase with asymmetric rims of higher anorthite content. Because an increase in anorthite content is the opposite of what would be expected from fractional crystallisation, Soda et al. (2020) termed this "reversely zoned" plagioclase. What is striking is that the original intermediate plagioclase composition, where it is preserved, is split into two new ones. Versions of these plagioclase types have been described from the Bergen Arcs in Western Norway (Kaatz et al., 2022; Mukai et al. 2014, Petley-Ragan et al. 2021) and Vesterålen in Northern Norway (Soda et al., 2020), both part of the Scandinavian Caledonides. In all cases, the development of the plagioclase seems connected to deformation and fluids. However, differences in secondary phases and grain morphologies point to slightly different origins and/or developments. Two main mechanisms for their formation have been suggested: exsolution and grain boundary migration (Mukai et al. 2014, Petley-Ragan et al. 2021) and two-stage metamorphism during which intermediate plagioclase reacts to Ab-rich plagioclase and secondary phases (Kaatz et al. 2022), which are later backreacted to An-rich plagioclase (Soda et al. 2020).

Here, we investigate early stages of such plagioclase microstructures in detail, using examples of lower crustal rocks from the southern part of Lofoten. Here, the plagioclase is almost free of inclusions, except for local concentrations of aluminosilicate needles. Microstructurally, there are gradual transitions from needle-type in the host rock to polygonal type in cm-scale shear zones. Using microstructural and compositional data (acquired by electron microprobe analysis) combined with local equilibrium thermodynamic modelling, we show that two-stage metamorphism under changing pressure conditions is a plausible explanation for the plagioclase zonation, and that such zonations can be the only remaining records of metamorphic events. With data from transmission electron microscopy and electron backscatter diffraction, we further elucidate the deformation conditions and the microstructural evolution of the plagioclase. Initial reaction was probably focused at high-stress areas in a deforming rock. The polygonal microstructures likely developed by grain boundary migration induced by gradients in both dislocation density and chemistry.

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