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Using micro-scale evidence to understand regional-scale hydrothermal alteration of plutonic rocks

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Subsolidus re-equilibration of plutonic feldspars induced by hydrothermal fluids provides a valuable record of fluid-rock interactions that affect large volumes of the Earth's continental crust (Taylor, 1977). The effect of hydrothermal fluids has important implications for the interpretation of the present plutonic mineralogy and geochemistry. However, crustal hydrothermal activity is usually not accounted for unless stages of replacement can be identified or new minerals that are characteristic of fluid infiltration are formed. We have examined Scandinavian granitoids and the larvikite alteration to a rock locally known as tønsbergite, specifically focusing on feldspar replacement reactions, to gain a better understanding of the subsolidus re-equilibration of plutonic rocks with hydrothermal fluids. Scanning and transmission electron microscopy provide new microtextural and chemical insights into the subsolidus re-equilibration of alkali and plagioclase feldspars. In conjunction with Raman spectroscopy and electron probe micro-analysis, these techniques reveal that hydrothermal fluids have induced successive feldspar replacements in a variety of continental plutonic rocks enabling us to establish a relative timing between them. In both the granitoids and syenite examples the most prominent alteration is the albitisation of feldspar. Differing degrees of albitisation within a single grain can be distinguished. This implies that the albite was generated by an inhomogeneous fluid. Fine-grained mica (sericite) is closely associated with the albite porosity and can be observed in micron sized pores with scanning electron microscopy as well as in nanopores imaged by transmission electron microscopy. Textural and chemical observations as well as theoretical considerations based on thermodynamic equilibrium modelling suggest that the albitisation and sericitisation are directly linked and develop as a cogenetic alteration. Reddening is macroscopically recognisable in both samples and is especially prominent in the granitoids. This phenomenon is contemporaneously related to the appearance of K-feldspar which occurs at the expense of sericite. Transmission electron microscopy of the granitic feldspars reveals that the reddening is due to sub-micron sized hematite needles within feldspar nanopores. The textural classification of this alteration indicates that it occurred later than the albitisation and sericitisation. Consistently, porosity generation and the mechanism of dissolution and reprecipitation play crucial roles in the re-equilibration of plutonic feldspars in the presence of a fluid phase (Putnis, 2002). Although our understanding of the re-equilibration of plutonic rocks is limited to the studied areas, it is a logical progression that hydrothermal fluids could cause mineralogical and geochemical changes to larger volumes of the Earth's crust than is currently acknowledged. Furthermore, feldspar mineral fluid inclusions in the upper crust have been calculated to contain the same quantity of water as is incorporated in all hydrous minerals (Johnson & Rossman, 2004). Consequently, the interactions of hydrothermal systems with crustal plutonic rocks should be taken into closer consideration in future studies of their petrologic history.

References:
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