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Nanotunnels and pull-aparts: Defects of exsolution lamellae in alkali feldspars

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ABSTRACT

We have studied defects associated with flat, lens-shaped perthitic albite lamellae in alkali feldspars using SEM and TEM. In orthoclase phenocrysts from the Shap granite, Cumbria, NW England, bulk composition $Or_{70.20}Ab_{29.05}An_{0.85}$, no dislocations were found even in optically "fresh" parts of grains. Instead, dissolution inferred to be localized on edge-dislocation loops has created tiny "nanotunnels" typically <10 nm in diameter. Some nanotunnels are facetted, confirming that they were produced by fluid-feldspar reactions in the cooling intrusion. A second type of defect is also developed: tiny cracks crossing albite lamellae that we call "pull-aparts," parallel to the (001) or the (010) cleavages. We found similar nanoscale features in perthitic feldspars from Antarctic granulite-facies gneisses and Brazilian charnockites.

In the Shap feldspars, the Pericline-twin composition plane (the rhombic section) is close to the high albite position, explicable only if the *T* effect of the ~1% An in the feldspars is taken into account for commencement of coherent exsolution. The orientation of the Pericline twins was fixed shortly after coherent exsolution began. Previous work has indicated that edge dislocations would start to form during cooling at ≤400 °C, so that nanotunnels form at still lower *T*. Dry heating experiments were carried out to establish the stability of the defects and the homogenization behavior of the exsolution lamellae. Na ↔ K exchange is rapid on heating above the coherent solvus and chemical homogenization of lamellae is complete after 24 h at 700 °C. In contrast, nanotunnels persist for >148 h at 1000 °C and >5748 h at 700 °C. Below the coherent solvus, exsolution lamellae thin on heating, leaving nanotunnels stranded in the orthoclase matrix. Microtextures related to Si-Al ordering patterns in the framework, such as Albite twins, are not eliminated, forming ghost-like lamellar strain patterns in chemically homogeneous feldspar. The presence of nanotunnels in optically "fresh" alkali feldspars shows that not only granites but also granulite-facies rocks have been pervasively affected by fluids at low *T*. Both nanotunnels and pull-aparts have important implications for feldspar reactivity in the upper crust, for ^{18}O exchange, and for transport of ^{40}Ar both in nature and in laboratory step-heating.

Keywords: Electron microscopy, alkali feldspar, high-temperature studies, fluid phase, diffusion