INTRODUCTION

Numerous examples exist of the coupling of chemical reactions and diffusion in nature. Some of these include crystal growth–nucleation plus diffusion leading to Liesegang rings, oscillatory zoning in crystals, metamorphic differentiation, concretion growth, orbicular patterns, pseudomorphic replacement reactions, and formation of either hydration or dehydration rims. In general, these phenomena involve either the precipitation of a solid product on the surface of an existing grain, or the formation of a reaction zone that moves into a host crystal. Diffusional transport can occur across the newly formed coating or through the reaction zone.

Plagioclase feldspar in hydrothermally altered volcanic rocks commonly shows evidence for both cation and oxygen isotopic exchange, with preservation of the original grain habit and twinning in the albite–sericitic rims. For example, Cole et al. (2004) showed that oxygen isotopic patterns in altered plagioclase from the Rico, Colorado, paleohydrothermal system exhibit either hydration or dehydration rims. In general, these phenomena involve either the precipitation of a solid product on the surface of an existing grain, or the formation of a reaction zone that moves into a host crystal. Diffusional transport can occur across the newly formed coating or through the reaction zone.

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Alkali feldspars lend themselves to the experimental study of alteration because the complete Na-K solid solution series can be produced by cation exchange from structurally well-characterized, single-phase materials (e.g., Orville 1963, 1967). O’Neil and Taylor (1967) used this method in their classic study of oxygen isotope fractionation between alkali feldspars and Na-K chloride solutions. On the basis of optical and electron microprobe observations, they concluded that the mechanism of oxygen and cation exchange in their experiments involved fine-scale dissolution and redeposition in a thin film at the interface between the exchanged rim and unexchanged core. They observed that the replacement zone was porous, allowing enhanced communication between the fluid and the reaction interface. Porosity development in altered feldspars is not uncommon and can lead to increased surface area and surface roughness (Hodson 1989).

The nature of this microporous zone and communication across it has profound implications on the extent of equilibration of mobile species, including the light elements O, C, and H.

Despite numerous studies detailing the nature of Na-K exchange in anhydrous systems (e.g., Brady and Yund 1983; Christoffersen et al. 1983), a systematic study of the rates of pseudomorphic reaction-front replacement during hydrothermal cation exchange and associated isotopic exchange has not been conducted. We have begun a series of experiments in the alkali feldspar system to determine the correspondence between cation and isotope exchange and the growth of replacement fronts during reaction. In this study we document the exchange in Amelia albite with the aid of the Cameca NanoSIMS, which provides a remarkable compositional image of the reaction interface at the nanoscale.

METHODS

Hydrothermal experiments

Crystals of Amelia albite were crushed into powders that were repeatedly washed in deionized water and sieved to remove any ultra-fine particles (<1-2