

Assessing the relative production rates of cosmogenic ^3He and ^{21}Ne in olivine, pyroxene and quartz

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Currently used methods to derive cosmogenic ^3He and ^{21}Ne production rates (P_3 and P_{21}) for pyroxenes based on their major element composition yield inconsistent exposure ages by up to 40% (Niedermann *et al.*, 2007), indicating a substantial flaw in our knowledge on production systematics of the noble gas isotopes, in spite of a general agreement of the models with experimental determinations of P_3 in olivine and P_{21} in quartz. However, $P_3(\text{ol})$ has never been directly compared to $P_{21}(\text{qz})$, probably because these minerals do not coexist in mineralogical equilibrium.

A rock of basaltic-andesitic composition sampled from a Pleistocene lava flow on the Puna plateau in NW Argentina, south of the Salar de Antofalla at 3660 m elevation, contained a quartz xenocryst from crustal contamination ~3 cm in size as well as olivine and pyroxene phenocrysts. Although the sample is not from a well-defined surface location (the exposure geometry may have changed during degradation of a lava tube), it provides the opportunity to study the ratios of P_3 and P_{21} in olivine, pyroxene and quartz. The resulting $P_3(\text{ol})/P_{21}(\text{qz})=7.80\pm 0.55$ and $P_3(\text{px})/P_{21}(\text{qz})=8.00\pm 0.62$ are ~30% higher than the value obtained by comparing the experimental P_3 in olivine (~116 at $\text{g}^{-1} \text{a}^{-1}$) to the experimental P_{21} in quartz (~19 at $\text{g}^{-1} \text{a}^{-1}$). The difference is similar to that resulting from different methods to calculate P_3 and P_{21} from major element composition. A difference of 10% at most might be assigned to unfavorable irradiation conditions, if the quartz xenocryst was located at the very bottom of the sampled rock during most of the exposure. But still the results would imply $P_3(\text{ol})$ ~20% higher or $P_{21}(\text{qz})$ ~20% lower than the values usually assumed. The determinations of cosmogenic ^3He and ^{21}Ne in our sample are robust since they are based on a value of 7.9 R_A for the magmatic $^3\text{He}/^4\text{He}$ ratio and an atmospheric trapped Ne composition. Any reasonable different assumption could only increase the P_3/P_{21} ratios.

The comparison of cosmogenic ^{21}Ne in olivine (Mg-rich) and pyroxene (Mg-poor) may, in principle, be used for an experimental determination of the $P_{21}(\text{Mg})/P_{21}(\text{Si})$ ratio. Our present data indicate a value of ~3.4, but with a large uncertainty of 30-50% which critically depends on the uncertainty of the $^{21}\text{Ne}(\text{ol})/^{21}\text{Ne}(\text{px})$ ratio. We hope to obtain a more accurate result by analyzing Ne in olivine and pyroxene from a well-defined surface sample.

Reference

Niedermann S., Schaefer J.M., Wieler R. and Naumann R., (2007), *Earth Planet. Sci. Lett.*, doi: 10.1016/j.epsl.2007.03.020.

Hydrothermal alkali and oxygen-isotope exchange in alkali feldspars controlled by dissolution-precipitation mechanisms

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The re-equilibration mechanisms of solid phases in hydrothermal fluids are only poorly understood. Depending on the prevailing conditions a sequence of fluid-induced dissolution-precipitation or solid state processes may take place. In the present study, we have investigated the re-equilibration of albite in the presence of a fluid phase. For this, we have experimentally treated a natural albite crystal in an aqueous KCl solution at 600°C and 2 kbars. To trace the exchange between mineral and fluid, the aqueous KCl solution was enriched with ^{18}O (95 atom %). The major aim of this study was the characterization of the chemical and physical properties of the K-feldspar reaction rim that is known to form during the interaction of albite with an aqueous KCl-rich fluid under the chosen conditions (Labotka *et al.* 2004). Transmission electron microscopic investigations have shown that the interface between the pristine albite and the K-feldspar product phase is sharp on a nano-scale, with a strong diffraction contrast difference between both phases, suggesting a defect-rich K-feldspar product. A porous zone also evolved near the interface. Existing crystallographic orientation as well as twinning in the albite is preserved in the K-feldspar reaction rim. Powder X-ray diffraction analyses revealed a change from triclinic Al,Si ordered albite structure to an Al,Si disordered monoclinic structure in the K-feldspar. Furthermore, Raman spectroscopy has been applied to map the mass frequency shift of the Si-O-Si bending vibration near 476 cm^{-1} in the K-feldspar due to the incorporation of ^{18}O . The frequency of this mode shifts to about 457 cm^{-1} in K-feldspar formed in ^{18}O -enriched solution, reflecting a high enrichment of ^{18}O in the K-feldspar lattice. In the K-feldspar formed in ^{18}O -enriched solution the highest frequency shift was found close to the interface, which coincides with an enrichment of the orthoclase component close to the interface, as revealed by electron microprobe measurements. This indicates that the higher frequency shift close to the interface results from chemical changes rather than from a higher ^{18}O content. An important observation is that there is no gradient in the frequency shift that could be related to diffusion of ^{18}O .

We propose that the new data are fully consistent with an interface-controlled dissolution-precipitation mechanism that operates at an inward moving replacement front.

Reference

Labotka, T.C., Cole, D.R., Fayek, M., Riciputi, L.R., and Stadermann, F.J. (2004) Coupled cation and oxygen-isotope exchange between alkali feldspar and aqueous chloride solution. *American Mineralogist*, **89**, 1822-1825.