NanoSIMS investigation of ^{36}Cl-^{36}S systematics in the early Solar System

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The ultimate nucleosynthetic sources of short-lived radionuclides (SLN) have important implications regarding the use of SLN as high-resolution chronometers for dating early Solar System events. If SLN originated from a stellar source(s) and were well mixed into the molecular cloud from which our Solar System was born, variations in abundances may reasonably be ascribed to passage of time. However, SLN produced by energetic particle bombardment might accommodate widely variable abundances with no chronological significance. The ^{36}Cl–^{36}S system ($t_{1/2}$ ~0.3 Ma) is a potential chronometer for dating halogen-rich phases in the early Solar System. Previous SIMS and NanoSIMS studies in sodalite from Ca-Al-rich Inclusions (CAIs) and chondrules in CV chondrites, yielded widely varying initial $^{36}Cl/^{35}Cl$ ratios ($(<1.6 \text{ to } 4)\times10^{-6}$). It is not clear if these results are due to temporal differences, disturbance to the ^{36}Cl-^{36}S system, or a heterogeneous distribution of ^{36}Cl. To investigate and better constrain the abundance and distribution of ^{36}Cl in the early Solar System and the utility of the ^{36}Cl–^{36}S system as a chronometer, we studied ^{36}Cl–^{36}S systematics in wadalite ($Ca_6(Al,Si,Fe,Mg)_7O_{16}Cl_3$), a Cl-rich secondary phase recently discovered in the Allende Type B CAI AJEF. Wadalite in AJEF occurs adjacent to melilite in veins associated with grossular, monticellite, and wollastonite. Anorthite in AJEF has $^{26}Al/^{27}Al$ ~5×10^{-5}, consistent with the canonical value. Cl−S isotope data were obtained using the LLNL NanoSIMS; Al-Mg and O isotopes in grossular associated with wadalite were measured on the UH Cameca ims 1280. The AJEF wadalite shows very large ^{36}S excesses (>200-fold) correlated with the respective $^{35}Cl/^{34}S$ ratios (as high as 2×10^6). The slope of the best-fit line through the data yields an inferred $^{36}Cl/^{35}Cl$ ratio at the time of wadalite formation of $(1.72\pm0.25)\times10^{-5}$. This slope is ~4−10 times higher than the inferred $^{36}Cl/^{35}Cl$ ratio in sodalite from the Allende CAIs. Grossular adjacent to the wadalite, with $^{27}Al/^{24}Mg$ as high as ~100, shows no resolvable excess of ^{26}Mg. Our Cl−S data in wadalite suggest ^{36}Cl production by energetic particle irradiation in a X-wind scenario and late incorporation of ^{36}Cl into CAIs via secondary alteration.

The growth of the continental crust: Isotopic constraints on timing and rates

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There has been a long-standing debate over the evolution of the volume of the continental crust. The two end–member models, (i) the steady-state model which assumes that a volume of crust equal to present volume was formed early in Earth history and maintained by recycling and growth and (ii) the crustal growth model (smooth or episodic) with little or no recycling over all of Earth history, are both unlikely to be correct. The very small volume of early (>3.5 Ga) Archean crust preserved today (less than 1% of the present continental volume) has been interpreted as indicating that crustal growth did not begin until about 4.0 Ga ago, before which the silicate Earth remained well mixed and essentially undifferentiated. However, the inferred initial ^{143}Nd isotope ratios of many early Archean rocks are higher than that of the bulk Earth implying that by 3.8 Ga ago the volume of the crust must have been as large as about 40% of the present value. When combined with measurements of ^{142}Nd this evidence points to a significant early silicate differentiation and early crust formation within the first 100 Myr of Earth’s formation. This evidence requires that all of the Hadean and most of the earliest Archean crust was recycled into the mantle. From about 3.0 Ga to the present, crustal growth appear to have dominated over recycling.