Sr Isotopes and trace element patterns in sub-calcic garnets: A perspective on diamond-bearing fluids?

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Sub-calcic garnets are typical xenocrysts in kimberlites. They are found as inclusions in gem quality diamonds and as such have implications for the diamond growing area. This study focused on eight xenocrystic sub-calcic garnet crystals from the Ekati property, Canada. We studied the trace element and REE patterns of the garnets as well as the Sr and oxygen isotopic composition in order to investigate their origin and the nature of associated metasomatism.

Chondrite normalized REE paterns are sinusidal, however, the slope of the curve varies (Nd/La= 1.7 to 70; Nd/Er = 1.9 to 48). The highest enrichment varies between LREE (Nd) and MREE (Eu). One crystal exhibits a pronounced Ce anomaly (Ce/Ce*=3.3). Garnets have highly radiogenic Sr ($^{87}Sr/^{86}Sr$= 0.710371 to 0.731198). Enrichment in radiogenic Sr is coupled with increased concentrations of Ce, Sr, Nd, Sm, Pr, Nb, La, Th and U. The radiogenic Sr is not supported by the low Rb content of the garnets. The high Zr/Yb and low Sr/Yb ratios of the less radiogenic crystals indicate interaction with a Zr-rich and low Sr agent. The O isotopic composition of the garnets varies between 5.23 and 5.42‰, with a broad positive correlation between $\delta^{18}O$ and La/Nd. The $\delta^{18}O$ values are higher than those of sub-calcic garnets elsewhere. The above features indicate that a radiogenic, Sr-rich agent and a HFSE-rich agent are involved in the metasomatic process.

We calculated the composition of possible metasomatic agents in equilibrium with the garnets using partition coeficents for carbonatitic, silicic and hydrous-silicic melts. Diamond-forming fluids show some similaries to the calculated metasomatic agents (positive Pb anomaly and negative Zr, Ti and Nb anomalis). However, REE concentrations in typical diamond forming fluids are much higher than those of the calculated matasomatic agent. Carbonatitic–silicic globules reported in lherzolitic clinopyroxene macrocrysts closely resemble the trace element composition of the garnet metasomatic agent. Phase equilibria experiments indicate that sub-calcic, Cr-rich garnets have recyrstallized from subducted Cr-rich protoliths. We propose that the garnets inherited an enriched Sr signiture from old subducted oceanic lithosphere and were affected by extensive metasomatism of an agent not very different from carbonatitic-silicic melts and diamond forming fluids.

Hf-W chronometry and the thermal evolution of asteroids

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Hf-W chronometry has widely been applied for dating the differentiation of asteroids and terrestrial planets [1] but its potential for dating meteorites and constraining the thermal evolution of asteroids has yet to be explored. We determined Hf-W metal-silicate isochrons for various ordinary chondrites and acapulcoites and obtained the following ages: ~3 Myr for the H4 chondrite Ste. Marguerite; ~10 Myr for the H6 chondrites Kernouvé and Estacado; ~6 Myr for acapulcoites Dhofar 125 and NWA 2775 (here Myr refers to time after formation of CAIs). These Hf-W ages are older than Pb-Pb ages for phosphates [2, 3] and pyroxenes [4] for the same or similar meteorites, indicating that the Hf-W closure temperature in these samples is higher than the ~780°C Pb-Pb closure temperature of pyroxenes. Hf-W ages therefore provide essential information on the earliest cooling history of meteorite parent bodies. Our new Hf-W ages combined with previously reported Pb-Pb ages for the same or similar meteorites [2-4] reveal that acapulcoites cooled more rapidly than H6 chondrites but similar to H4 chondrites. This suggests that either the acapulcoite parent body is smaller than the H chondrite parent body or that the burial depth of acapulcoites was shallower. Compared to H6 chondrites, acapulcoites were heated to higher temperatures (as is evident from the formation of FeNi-FeS melts) but cooled more rapidly, indicating that the acapulcoite parent body contained a higher amount of ^{26}Al and hence accreted earlier than the H chondrite parent body. Acapulcoites may derive from a body that accreted as early as the parent bodies of the magmatic irons (<1.5 Myr [5]) but was too small to efficiently retain the heat produced by ^{26}Al decay. Alternatively, the acapulcoite parent body might have accreted later than ~1.5 Myr but before accretion of the H chondrite parent body at ~3 Myr (as derived from the Hf-W age of Ste. Marguerite). The presence of relict chondrules in some acapulcoites suggests that the latter scenario might be more likely. The Hf-W data indicate that the early evolution of asteroids is largely controlled by the time of parent body accretion and hence the amount of ^{26}Al present. This most likely reflects increasing accretion times with increasing distance from the Sun, consistent with the heliocentric zoning of the asteroid belt [6].

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