GERMANIUM GEOCHEMISTRY OF MARTIAN ORTHOPYROXENES.

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Introduction: Germanium is an important cosmochemical element that provides information on volatile element depletion and core formation of planetary igneous rocks, due to their relatively constant Ge/Si ratio. Recent experimental studies show that Ge is volatile during magmatic processes [1-2]. Recent analytical work on Ge abundance in shergottites revealed evidence for volcanic outgassing of about half the original Ge inventory of shergottite magmas [3]. In contrast, Nakhlite-Chassignite meteorites do not show evidence for volatile Ge loss during magmatic processes [3], implying that the NC body is a sill emplaced at sufficient depth to avoid Ge degassing. Germanium is also one of a few elements (including Ni, Ir, etc.) that is enriched in impact breccias from meteoritic input. This aspect of Ge geochemistry has recently been employed to assess the pristinity of igneous-textured clasts in the martian polymict breccia, NWA 7533, that are not hosts for Ni or Ir, e.g., feldspar clasts [4]. Individual mineral clasts composed of orthopyroxene are abundant in the NWA 7533 polymict breccia [5]. Their chemical composition bears a remarkable similarity to the only known orthopyroxenite from Mars, ALH 84001 [5]. One of our goals is to determine whether igneous-textured clasts are primary igneous rock fragments or impact melts, and Ge plays a critical role in this exercise [6].

Samples and Analytical Methods: Polished thick sections of ALH 84001,147 and NWA 7533 were studied. Samples were analyzed with an Electro Scientific Industries New Wave™ UP193FX excimer laser ablation system coupled to a Thermo Element XR™ ICP-MS at the Plasma Analytical Facility at Florida State University following methods of [3].

Results: Major element compositions of orthopyroxenes from ALH 84001 are uniform in both coarse opx clasts and in opx grains from cataclastic zones (Mg#70; Fe/Mn~36). Germanium abundances in 8 opx grains averaged 1.00±0.5 ppm, compared with 1.08-1.14 ppm reported by [7]. Maskelynite has lower Ge ~0.4 ppm, and chromite has Ge~0.4 ppm. Chromite stringers from the cataclastic zones are compositionally identical to euhedral-subhedral chromites in ALH 84001. An opx crystal clast from NWA 7533 exhibiting no visible exsolution lamellae or zoning [5], RH9 in NWA 7533 ($En_{74}Wo_3$), is similar in Ge, Ni and REE abundances to opx from ALH 84001. Another opx clast that exhibits exsolution lamellae, RH 1 ($En_{58}Wo_9$), and is more evolved, is lower in Ge (~ 0.67 ppm).

Discussion: The formation of NWA 7533 opx-bearing clasts could include derivation from primary igneous rocks emplaced in the martian highlands or derivation from slowly-cooled impact melt sheets. Experimental work has shown that Ge abundances of pyroxenes are independent of the cation compositions, since Ge substitutes for Si on the tetrahedral site. Further, Ge abundances increase during magmatic fractionation in the nakhlite-chassignite body where Ge correlates inversely with Mg#. Thus, the Ge contents of primary igneous martian opx would be expected to be similar to that of cpx from chassignites (Ge~ 2 ppm), based on similar Mg#s. The Ge abundances of ALH 84001 opx and of several opx clasts from NWA 7533 reported in this study are a factor of two lower than that expected from the nakhlite-chassignite body. There are at least two possible explanations: existing experimental work [8-9] has not captured the full complexity of Ge partitioning between low-Ca and high-Ca pyroxenes, or the apparently plutonic opx grains in ALH 84001 and in NWA 7533 clasts were derived from magmas that outgassed Ge in shallow magma chambers. Neither of these two explanations is particularly satisfactory. Coincidentally, the Ge abundances of opx from ALH 84001 and the NWA 7533 clasts studied are similar to the abundances of Ge in chassignite olivine (~ 1 ppm). A less likely interpretation of the new opx data would derive the opx grains from olivines by a multi-step process of weathering, oxidation and subsequent impact melting to form opx+magnetite assemblages, as proposed for the matrix opx in NWA 7533 [10]. This interpretation does not seem consistent with the REE pattern and Ni-Co systematics of ALH 84001 opx that are compatible with an igneous origin.

References:

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