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Olivine from planetary basalts: Chemical signatures that indicate planetary parentage and those that record igneous setting and process

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ABSTRACT

The systematics of Mn-Fe, Ni-Co, Ti, Cr, and V in olivine from 13 basalt suites from the Earth, Moon, and Mars were studied by electron and ion microprobe techniques. The results demonstrate that chemical signatures in olivine can be related to: (1) planetary parentage, where differences are the result of initial accretional ratios, source compositions, and oxygen fugacity; and also (2) igneous setting and process, where differences among basalt suites within a planet are a consequence of specific redox conditions in tectonic settings, differing melt compositions, and changes in element partitioning resulting from crystallization sequences and mineral modes. Manganese-Fe systematics indicate planetary parentage where the Mn/Fe ratio in olivine increases with increasing distance from the Sun (with the exception of the Moon, which can be explained). This sequence could be the result of initial Mn/Fe accretional ratios from the start of the solar system. Igneous processes such as differing melt compositions and crystallization sequences cause differences in the Mn/Fe ratios of olivine in basalt suites from the same planet. Nickel-Co and Ti systematics show that planetary signatures result from source-region differences among the three planets. For example, the lunar source regions are depleted in Ni and enriched in Ti, as compared with the Earth and Mars, and these characteristics are reflected in the olivine compositions. The differing partitioning behavior of Ni, Co, and Ti in planetary olivine suites is a result of crystallization sequences and initial melt compositions of the basalts during crystallization. Chromium concentrations in olivine result from differing oxygen fugacities and phase stabilities in the source regions of the three planets, whereas V concentrations in olivine are mostly a consequence of the different overall redox conditions on planetary bodies. Both Cr and V show igneous process signatures owing to different melt compositions, crystallization sequences, and modal mineralogy. Perhaps the most important conclusion from this study is that olivine in planetary basalts records information not only about igneous setting and process but planetary parentage as well, making the study of comparative planetary mineralogy an exciting way to gain new insights into basalt petrogenesis.