

Comparative planetary mineralogy: Pyroxene major- and minor-element chemistry and partitioning of vanadium between pyroxene and melt in planetary basalts

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ABSTRACT

Pyroxene grains from 14 basalt suites from the Earth, Moon, Mars, and Vesta were studied by electron- and ion-microprobe techniques. The results show that several elemental trends can be related to planetary parentage and crystallization conditions including paragenetic sequence and kinetics. Ferric iron (Fe^{3+}) systematics show that terrestrial pyroxene is enriched in Fe^{3+} compared with pyroxene from Mars due to higher oxygen fugacity (f_{O_2}) conditions on the Earth that produce more Fe^{3+} in basaltic melts. Low f_{O_2} conditions on the Moon and Vesta result in very little or no Fe^{3+} in pyroxene from these bodies. Terrestrial pyroxenes contain more Na than those from Mars, yet martian plagioclase contains more Na than terrestrial. This difference is because terrestrial pyroxene contains more Fe^{3+} and thus the acmite component ($\text{NaFe}^{3+}\text{Si}_2\text{O}_6$) is more important on Earth than Mars. Pyroxenes from the Moon and Vesta have very little Na, which can be attributed to the overall volatile-depleted nature of these bodies. All planetary pyroxenes show that Cr decreases with increasing fractionation because it is compatible in pyroxene, and in many basalts the crystallization of chromite depletes the melt in Cr^{3+} . The Mn/Fe^{2+} systematics in pyroxene show distinct trends for the planetary bodies in the order Vesta > Mars > Earth > Moon. These Mn/Fe^{2+} trends are most likely affected by the volatility of Mn relative to Fe, and thus there is an increase in the Mn/Fe ratio with increasing distance from the Sun, except for the Moon, which likely lost Mn during its giant impact origin. These same trends have been documented for olivine from the different planets, and this parameter as measured in basaltic silicates is a robust fingerprint of planetary parentage. Vanadium partitioning into planetary pyroxene grains is affected by oxygen fugacity, the availability of charge-balancing elements, basaltic crystallization sequences, and kinetics. Partitioning of V into pyroxene at low f_{O_2} conditions (i.e., Moon and Vesta) is seen to increase as the charge-balancing cation $^{\text{IV}}\text{Al}$ increases. Partitioning of V into pyroxene at relatively high f_{O_2} conditions (i.e., Earth and Mars) increases with increasing Na and $^{\text{IV}}\text{Al}$, which provide charge balance for incorporation of V^{4+} . Because of the above complexities, a V-valence oxybarometer as measured in planetary pyroxene grains is not likely to be robust.

Keywords: Vanadium, pyroxene, planetary basalts, partitioning, SIMS, microprobe