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Insights into the redox history of the NWA 1068/1110 martian basalt from mineral equilibria and vanadium oxybarometry

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ABSTRACT

The NWA 1068/1110 martian meteorite contains megacrystic olivine and associated chromite set in a basaltic groundmass of pyroxene, maskelynite (shock-isotropized plagioclase), phosphates, ilmenite, and ulvöspinel. Spinel is compositionally zoned from chromian cores to titanian rims, and lacks the chromite-ulvöspinel miscibility gap. Co-crystallizing olivine + pyroxene + spinel and ulvöspinel + ilmenite assemblages were identified on the basis of compositional and textural criteria, and were used to determine the oxygen fugacity from the earliest to the latest stages of crystallization. Megacrystic olivine with earliest chromite and low-Ca pyroxene yield an oxygen fugacity 2.5 log units below the Quartz-Fayalite-Magnetite (QFM) buffer, whereas titanian-spinel rims, olivine rims, and co-crystallizing pyroxene yield QFM + 0.3 and groundmass ulvöspinel + ilmenite assemblages yield QFM + 0.5. Vanadium in spinel was examined to determine whether it would be sensitive to the changing redox conditions of the NWA 1068/1110 melt. Only small changes in V concentration were observed between spinel cores and rims; however, the relationship between V and Ti in spinel is consistent with an increase in the valence state of V from V^{4+} to V^{5+} in accordance with the increase in oxygen fugacity. Application of a quantitative version of the "V-in-chromite" oxybarometer results in an oxygen fugacity of QFM – 3, consistent with mineral equilibria results, although assumptions and uncertainties limit its application to circumstances where the parental melt V concentration is known independently of the redox conditions. Oxygen fugacity results and textural observations are strongly indicative of a xenocrystic origin for the olivine megacrysts and associated chromite, and lend support to a model in which martian basalt oxygen fugacity is determined by mantle-source redox conditions as opposed to assimilation of oxidized crustal material.

Keywords: Oxygen fugacity, oxybarometry, spinel, vanadium, partitioning, Martian, basalt