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LETTER

Sulfides from martian and lunar basalts: Comparative chemistry for Ni, Co, Cu, and Se

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ABSTRACT

Here Mars and Moon are used as "natural laboratories" with Moon displaying lower oxygen fugacities (~IW-1) than Mars (~IW to FMQ). Moon has lower concentrations of Ni and Co in basaltic melts than does Mars. The major sulfides are troilite (FeS) in lunar basalts and pyrrhotite ($Fe_{1-x}S$) in martian basalts. This study focuses on the concentrations of Ni, Co, Cu, and Se. We chose these elements because of their geochemical importance and the feasibility of analyzing them with a combination of synchrotron X-ray fluorescence (SXRF) and electron microprobe (EPMA) techniques. The selenium concentrations could only be analyzed, at high precision, with SXRF techniques as they are <150 ppm, similar to concentrations seen in carbonaceous chondrites and interplanetary dust particles (IDPs). Nickel and Co are in higher concentrations in martian sulfides than lunar and are higher in martian olivine-bearing lithologies than olivine-free varieties. The sulfides in individual samples show very large ranges in concentration (e.g., Ni ranges from 50 000 ppm to <5 ppm). These large ranges are mainly due to compositional heterogeneities within individual grains due to diffusion and phase separation. Electron microprobe wavelength-dispersive (WDS) mapping of Ni, Co, and Cu show the diffusion trajectories. Nickel and Co have almost identical diffusion trajectories leading to the likely nucleation of pentlandite $(Ni,Co,Fe)_9S_8$, and copper diffuses along separate pathways likely toward chalcopyrite nucleation sites ($CuFeS_2$). The systematics of Ni and Co in lunar and martian sulfides clearly distinguish the two parent bodies, with martian sulfides displaced to higher Ni and Co values.

Keywords: Sulfides, troilite, pyrrhotite, Mars, Moon, basalts, trace elements