

REDOX SYSTEMATICS OF MARTIAN MAGMAS WITH IMPLICATIONS FOR MAGNETITE

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Introduction: Iron redox systematics of the high FeO shergottitic liquids are poorly known, yet have a fundamental control on stability of phases such as magnetite, ilmenite, and pyroxenes [1].

Experiments: We undertook experiments to constrain the Fe³⁺/Fe(tot) in high FeO glasses as a function of fO₂, melt P₂O₅, temperature and pressure. We also performed a series of sub-liquidus experiment between 1100 and 1000 °C and FMQ+0.5 to FMQ-1 to define magnetite stability. Experiments were performed at JSC in either the 1 bar gas mixing lab, or in a piston cylinder or multi-anvil presses in the high pressure experimental petrology lab.

Analyses: Run products were analyzed for Fe³⁺ and Fe²⁺ by either Mössbauer spectroscopy [2] or micro-XANES (x-ray absorption near edge structure) spectroscopy [3].

Results: One bar glasses equilibrated at FMQ-3 to FMQ+3 show a much lower Fe³⁺/Fe(tot) than terrestrial basalts at the same conditions (Figure 1). As melt P₂O₅ contents increase from 0 to 3 wt% (at fixed pressure, temperature and fO₂), Fe³⁺/Fe(tot) decreases from 0.07 to 0.05. Temperature increases between 1200 and 1500 °C cause little to no variation in Fe³⁺/Fe(tot). Pressure increases from 1 to 4 GPa cause a slight decrease in Fe³⁺/Fe(tot). The trends with pressure and temperature are in agreement with results of previous studies on terrestrial compositions [4-6].

Implications: Combining our new series of data allows derivation of an expression to calculate Fe³⁺/Fe(tot) for high FeO melts such as martian magmas.

$$\ln(\text{Fe}^{3+}/\text{Fe}^{2+}) = a \ln f\text{O}_2 + b/T + cP/T + dX\text{FeO} + eX\text{-Al}_2\text{O}_3 + fX\text{CaO} + gX\text{Na}_2\text{O} + hX\text{K}_2\text{O} + iXP_2\text{O}_5$$

This expression can be used to show that decompressed melts become slightly more oxidized at the surface (compared to 4 GPa).

Magnetite stability is suppressed by the lower Fe³⁺/Fe(tot) of the high FeO melts. Magnetite stability is a function of Fe₂O₃ and temperature and is stable ~50 °C lower than typical terrestrial basalt (Figure 2). Difficulty in producing magnetite as a liquidus phase in magmatic systems suggests either that many martian basalts are more oxidized, that the titanomagnetite only forms upon cooling below ~ 1000 °C at FMQ, or that the magnetite has a secondary origin.

References: [1] Carmichael, I.S.E., et al. (1974) *Igneous Petrology*, McGraw-Hill, New York, NY, 739 pp.;

[2] Morris, R.V. et al. (2008) *J. Geophys. Res.*, 111, E02S13, doi:10.1029/2005JE002584; [3] Bajt, S. et al. (1994) *GCA* 58, 5209-5214; [4] Kress, V.C. and Carmichael, I.S.E. (1991) *Contrib. Mineral. Petrol.* 108, 82-92; [5] Mysen, B.O. and Virgo, D. (1985) *Phys. Chem. Mineral.* 12, 191-200; [6] O'Neill, H.St.C et al. (2006) *Amer. Mineral.* 91, 404-412; [7] Toplis, M.J. and Carroll, M.R. (1995) *Jour. Petrol.* 36, 1137-1170; [8] McCoy, T.J. and Lofgren, G.E. (1999) *Earth Planet. Sci. Lett.* 173, 397-411.

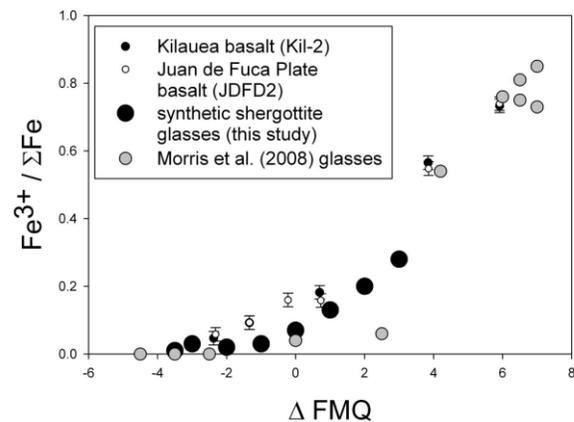


Figure 1: New results for glasses measured using Mössbauer spectroscopy illustrating that the shergottite composition remains low relative to terrestrial basalts such as mid ocean ridge (JDFD2) and Hawaiian (Kil-2) basalts (from [4]).

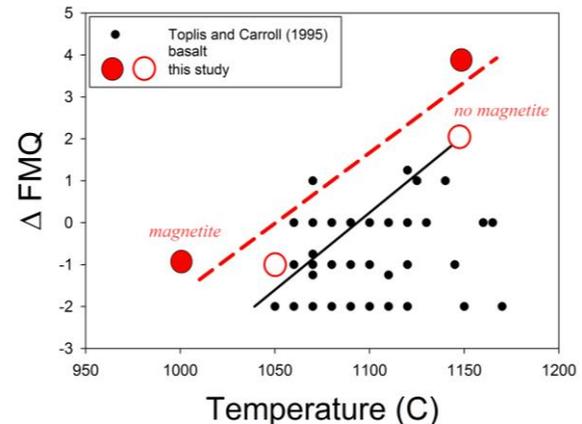


Figure 2: Comparison of magnetite saturation conditions (T and fO₂) for a terrestrial ferrobasalt [7] and a martian shergottite (this study and [8]). High FeO shergottite melts (dashed line) saturate magnetite about 50 °C lower than terrestrial basalt (solid line).