

PARTIAL MELTING OF THE MARTIAN MANTLE: EFFECT ON REDOX STATE AND MAGMATIC CARBON *John R. Holloway (Depts. of Chemistry and Geology, Arizona State University, Tempe AZ 85287)*

Overview: The strong partitioning of ferric iron relative to ferrous iron into the melt during partial melting of spinel or garnet peridotite mantle results in transport of oxygen to the surface. The effect is enhanced in a graphite-bearing mantle. Carbon in the mantle is transported to the surface as dissolved carbonate regardless of its presence as graphite or carbonate minerals. The oxidation state of SNC's is shown to be consistent with a graphite-bearing mantle.

Introduction: Much is now known of the major element phase stabilities in a SNC model martian mantle [1] but little is directly known about the mantle oxidation state (ferric iron/ferrous iron ratio), or the abundance and form of carbon in the mantle. The oxidation state of some SNC's has been inferred to be close to that of the quartz-fayalite-magnetite assemblage [2], but those meteorites represented surface or near-surface magmas and may not necessarily indicate the state of the mantle. Evidence for carbon in the martian interior is based on accretion models [3] and the presence of CO₂ in the atmosphere. The purpose of this paper is to present models for the fate of iron and carbon species during partial melting of an SNC based mantle composition, and use the results of those models to place some constraints on the evolution of the martian mantle.

Model components: The relationship between the ferric/ferrous ratio in a silicate melt and oxygen fugacity (fO₂) is known as a function of melt composition, temperature and pressures up to at least 1.5 GPa [4]. The solubility of CO₂ is known in basaltic composition melts in the same pressure range [5]. The stability of graphite relative to crystalline carbonates at mantle conditions is a function of fO₂ [6], with carbonates stable under more oxidizing conditions. The calculations presented here assume that the fO₂ in the partial melt source region is lower than needed to stabilize crystalline carbonates, so graphite is the stable phase. The only chemical components important to the model are the total iron contents of mantle [3] and melt [7], and the initial ferric/ferrous ratio in the mantle (taken as a starting point from terrestrial data [8]). The model calculations for graphite-melt equilibria follow the description given in [9]).

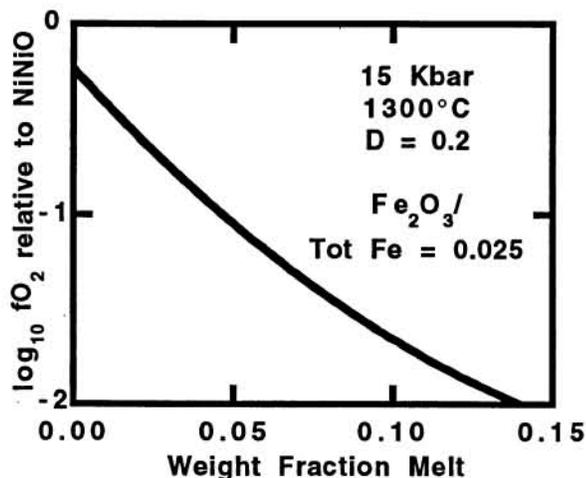
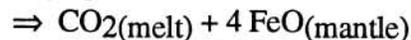
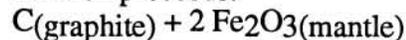


Figure 1. The change in oxygen fugacity with degree of melting.

fO₂ decreases. The effect of partial melting on fO₂ is shown in Fig. 1.

Results: The results are illustrated for an initially subsolidus mantle at a pressure of 1.5 GPa. Melting is assumed to begin at 1300°C and isothermal conditions are assumed for the calculations over the first 15% of melting (melt fractions, F from 0 to 0.15 wt. %). In actuality the melting would probably be polybaric and polythermal, but that would have only a small effect on the results. During partial melting the following reaction proceeds:



producing CO₂ in the melt and consuming Fe₂O₃ until redox equilibrium is reached. In the process of this reaction running to the right ferric iron is reduced so that the

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The changes in the ferric/ferrous ratios of melt and residual mantle are shown in Fig. 2.

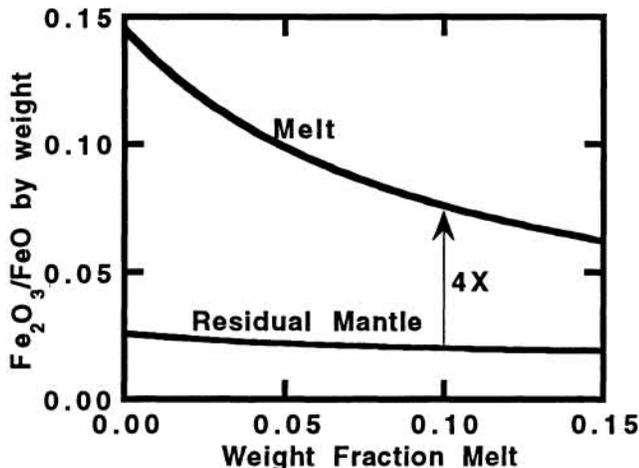


Figure 2. The change in ferric/ferrous ratios in residual mantle and partial melt as a function of the degree of melting.

The effects of partial melting will be qualitatively the same in a carbon-free mantle, and have the important conclusion that partial melting decreases the ferric/ferrous ratio of the residual mantle. Thus continued partial melting over time will make a mantle more reducing unless a processes exists to reintroduce oxygen to the mantle. On Earth the process of subduction does just that, but any such process seems to be missing on Mars. If true, the consequence is that the martian mantle has been progressively reduced during its history with the consequence that the amount of magmatic CO_2 decreases with time because the amount of dissolved CO_2 in magmas is proportional to f_{O_2} as shown in Fig. 3. If the melts shown in Fig 2 at 1.5 GPa rise to the surface without fractionation they would

have oxygen fugacities ranging from QFM -0.5 at $F = 0$ to QFM -1.5 at $F = .05$. Fractionation tends to increase ferric/ferrous ratios and SNC's appear fractionated [10]. Therefore it appears probable that fractionation of graphite-saturated primary magma is consistent with f_{O_2} determined for SNC's.

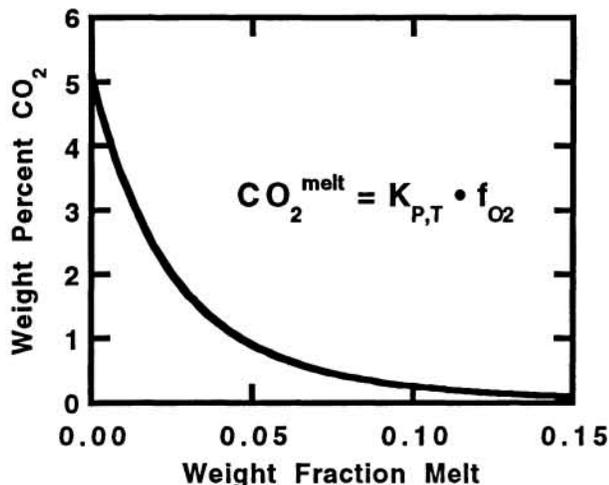


Figure 3. Dissolved carbonate content of the melt as a function of degree of melting.

References: [1] Bertka, C. M. and J. R. Holloway (1988) *Proc. LPSC 18th*, 723-739, Cambridge University Press, ____ (1994) *CMP* 115, 313-322. ____ (1994) *CMP* 115, 323-328. Bertka, C. M. and Y. Fei (in press) *Proc. Internat. Workshop on Intermarsnet. 2*. Stolper, E. M. and H. Y. McSweem, Jr. (1979) *GCA* 43, 1475-1498. 3. Dreibus, G. and H. Wanke (1985) *Meteoritics* 20, 367-382. ____ (1987) *Icarus* 71, 225-240. 4. Gudmundsson, G., et al. (1986) *EOS* 69, 1511. Kress, V. C. and I. S. E. Carmichael (1991) *CMP* 108, 82-92. 5. Holloway, J. R. and J. G. Blank (1994) *Rev. Mineral.* 187-230, MSA, Washington, D. C. 6. Eggler, D. H. and D. R. Baker (1982) *High Press. Res. Geophysics*, 237-250, Tokyo, Japan. 7. Longhi, J. and V. Pan (1989) *LPSC 19th*, 451-464, Treiman, A. H. (1993) *GCA* 57, 4753-4767. 8. Canil, D., et al. *EPSL* 123, 205-220. 9. Holloway, J. R., et al. (1992) *Eur. J. M.* 4, 105-114. 10. Wadhwa, M., et al. (1994) *GCA* 58, 4213-4229.