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Oxygen fugacity of martian basalts from electron microprobe oxygen and TEM-EELS analyses of Fe-Ti oxides

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ABSTRACT

The stoichiometry of titanomagnetite spinel in the martian basaltic meteorites is assessed using quantitative analysis of oxygen measured by electron microprobe and electron energy loss spectroscopy in the transmission electron microscope. The spinels are stoichiometric within the errors of the techniques, enabling the calculation of oxygen fugacity with confidence. The oxygen fugacity is calculated using the Ghiorso-Sack and Ca-QUIlF models, which also yield estimates of temperature. The oxygen fugacity of the martian basalts increases from 3 log units below the QFM buffer for QUE 94201 to QFM – 1.8 for EETA 79001 (both lithologies), to QFM – 1.0 for Shergotty, Zagami, and Los Angeles. Dar al Gani 476 spinels contain significant $MgAl_2O_4$ and $FeCr_2O_4$ components, complicating the use of Fe-Ti oxide models. The oxygen fugacity of Dar al Gani 476 is estimated to be 1.5 log units below QFM, on the basis of the Ghiorso-Sack model. The absolute error on the oxygen fugacity estimates is ± 0.5 log units; however, a consistent electron microprobe analytical routine was applied to all of the basalts, and the relative uncertainty is closer to 0.2 log units. Oxyexsolution has occurred in QUE 94201, but reconstruction of pre-exsolution titanomagnetite compositions permits the calculation of oxygen fugacity. Subsolidus reactions involving oxides and adjacent Fe-rich silicates are documented and the use of the Ca-QUIlF model for calculation of oxygen fugacity from these phases is discussed.