FeTiMM: A new oxybarometer based on the partitioning of Fe and Ti between magnetite and melt

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Oxygen fugacity is an important thermodynamic parameter in magmatic systems because it exerts a first-order control on phase equilibria as well as on mineral–melt and fluid–melt partition coefficients of many elements. In this study we present a new oxybarometer that is based on the partitioning of Fe and Ti between magnetite and silicate melt. A series of experiments were done in cold-seal pressure vessels in order to determine the effects of temperature (800-1000 °C), pressure (1-5 kbar), oxygen fugacity (from ΔFMQ+0.7 to ΔFMQ+4.0), magnetite composition, and melt composition on the partitioning of Fe and Ti between magnetite and melt ($D_{Fe}^{mgt/melt}$ and $D_{Ti}^{mgt/melt}$). The starting material was a mixture of haplogranite glass or natural obsidian powder with variable aluminum saturation indices (ASI), and synthetic magnetite of 10-20 µm grain size. All samples were measured by means of LA-ICP-MS. The partition coefficient of Fe depends considerably on oxygen fugacity and temperature, but even more strongly on ASI, particularly in peralkaline melts. The strong dependence on melt composition precludes the application of this partition coefficient as a redox sensor, yet if one divides it by the partition coefficient of titanium (i.e., $D_{Fe}^{mgt/melt}/ D_{Ti}^{mgt/melt}$), both the temperature effect and most of the melt compositional effect are canceled out and the result becomes dominantly dependent on fO_2. Using this rationale we obtain the following equation from our data:

$$\Delta FMQ = (\log(D_{Fe}^{mgt/melt}/D_{Ti}^{mgt/melt}) - 0.015*ASI + 0.333)/(0.272*ASI + 0.121)$$

This simple equation reproduces 92% of our data points within 0.5 log units of the experimentally imposed fO_2. First tests of this calibration on previously published magnetite+ ilmenite-bearing experiments with 60≥wt% SiO_2 in the silicate melt reveal a very good agreement (mostly within less than 0.5 log units) between the fO_2 values calculated via FeTiMM and fO_2 values calculated via magnetite–ilmenite oxybarometry. In summary, the FeTiMM oxbarometer represents a simple and powerful new tool to determine oxygen fugacity in rhyolitic to andesitic magmas that lack ilmenite.