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New thermobarometers for martian igneous rocks, and some implications for secular cooling on Mars

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Abstract

Tests show that terrestrial mineral+liquid geothermobarometers are not well equipped for use on martian rocks, which tend to have much higher FeO and lower Al_2O_3. Here, we present new calibrations of thermometers and barometers using experimental data on martian samples from the literature. These new models recover *P-T* conditions with a greater accuracy compared to models calibrated using terrestrial compositions. We applied these new calibrations to primitive martian mantle-derived melts Yamato 980459 (Y98) and Northwest Africa (NWA) 6234 and several surface basalts (Gusev). Our new models yield similar *P-T* conditions for NWA and Y98 compositions of 1.4–1.7 GPa and 1500–1550 °C, which are close to estimates by most prior studies. Our models yield somewhat lower *P* estimates compared to Lee et al. (2009), apparently because our Si-activity model (from Beattie 1993) includes an Al_2O_3-correction (where lower Al_2O_3, as in martian samples, leads to lower *P* estimates). For Gusev basalt compositions, our new models yield *P-T* estimates of 1.0–1.3 GPa and 1340–1390 °C; furthermore, we also obtain $P = 1.03$ GPa and $T = 1340$ °C, for a Gusev composition from Monders et al. (2007), which comes very close to the Monders et al. (2007) estimate for multiple saturation, of 1.0 GPa and 1325 °C, derived from phase saturation relationships. Given the different ages of these meteorites, with Gusev at 3.65 Ga (Greeley et al. 2005) and Y98 at 4.3 Ga (Bouvier et al. 2005, 2008, 2009; Werner et al. 2014), their thermal contrasts may represent secular cooling of Mars. We estimate a mantle potential temperature difference of ~200 °C, with mantle potential temperatures of 1450 ±50 °C for Gusev and 1650 ±50 °C for Y98; this implies a cooling rate of 300 °C/Ga. This would appear to be a much more rapid rate of cooling compared to Earth, as may be expected by Mars' higher surface/volume ratio.

Keywords: Geothermobarometry, thermobarometry, martian meteorites, experimental petrology, martian geology, thermometer, barometer, Mars, petrology, SNC meteorites