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A low-aluminum clinopyroxene-liquid geothermometer for high-silica magmatic systems

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Abstract

Several geothermobarometric tools have focused on clinopyroxene due to its prevalence in igneous rocks, however clinopyroxene produced in high-silica igneous systems is high in iron and low in aluminum, causing existing geothermometers that depend on aluminum exchange to fail or yield overestimated temperatures. Here we present a new clinopyroxene-liquid geothermometer recommended for use in natural igneous systems with bulk $SiO_2 \geq 70$ wt%, which contain clinopyroxene with Mg# ≤ 65 and $Al_2O_3 \leq 7$ wt%.

$$T\left(°C\right) = 300\begin{bmatrix} -1.89 - 0.601\left(X_{\mathrm{CaTs}}^{\mathrm{Cpx}}\right) - 0.186\left(X_{\mathrm{DiHd}_{2003}}^{\mathrm{Cpx}}\right) + 4.71\left(X_{\mathrm{SiO_2}}^{\mathrm{liq}}\right) + 77.6\left(X_{\mathrm{TiO_2}}^{\mathrm{liq}}\right) \\ +10.9\left(X_{\mathrm{FeO}}^{\mathrm{liq}}\right) + 33.6\left(X_{\mathrm{MgO}}^{\mathrm{liq}}\right) + 15.5\left(X_{\mathrm{CaO}}^{\mathrm{liq}}\right) + 15.6\left(X_{\mathrm{KO_{0.5}}}^{\mathrm{liq}}\right) \end{bmatrix} \quad (1)$$

The new geothermometer lowers calculated temperatures by ~85 °C on average relative to Putirka (2008, Eq. 33) and reduces the uncertainty by a factor of two (standard error of estimate ±20 °C). When applied to natural systems, we find this new clinopyroxene-liquid geothermometer reconciles many inconsistencies between experimental phase equilibria and preexisting geothermometry results for silicic volcanism, including those from the Bishop Tuff and Yellowstone caldera-forming and post-caldera rhyolites. We also demonstrate that clinopyroxene is not restricted to near-liquidus temperatures in rhyolitic systems; clinopyroxene can be stable over a broad temperature range, often down to the solidus. An Excel spreadsheet and Python notebook for calculating temperature with this new geothermometer may be downloaded from GitHub at http://bit.ly/cpxrhyotherm.

Keywords: Geothermometer, clinopyroxene, high-silica