Calcic amphibole thermobarometry in metamorphic and igneous rocks: new calibrations using high-breakdown point and efficient MM-estimators

J.F. Molina[1], J.A. Moreno[1, 2], A. Castro[3], C. Rodríguez[3], G.B. Fershtater[4]

1: Departamento de Mineralogía y Petrología, Universidad de Granada, Campus de Fuentenueva 18002 Granada, Spain

2: Department of Geology and Natural Resources, Institute of Geosciences, University of Campinas - UNICAMP, 13083-970 Campinas, SP, Brazil

3: UA Petrología Experimental, CSIC-Universidad de Huelva, Facultad de Ciencias Experimentales, 21071 Huelva, Spain

4: IGG Russian Academy of Science, Ekaterinburg, Russia,

Abstract

Dependencies of plagioclase/amphibole Al-Si partitioning, $D_{Al/Si}^{plg/amp}$, and amphibole/liquid Mg partitioning, $D_{Mg}^{amp/liq}$, on temperature, pressure and phase compositions are investigated employing robust-to-outlier regression methods based on high-breakdown point and efficient MM-estimators. A database with 92 plagioclase-amphibole pairs —temperature range: 650-1050 ºC; amphibole compositional limits: $Ti_{23O}^{amp} > 0.02$ and $AlVI_{23O}^{amp} > 0.05$ — and 148 amphibole-glass pairs —temperature range: 800-1100 ºC; amphibole compositional limits: $CaM4_{23O}^{amp}/\left(CaM4_{23O}^{amp} + NaM4_{23O}^{amp}\right) > 0.75$ — compiled from experiments in the literature was used for the calculations (amphibole normalization scheme: 13-CNK method).

A significant dependence of $D_{Al/Si}^{plg/amp}$ values on pressure, temperature, Al fraction in T1-site, X_{Al}^{T1}, and albite fraction in plagioclase, X_{Ab}, was detected, being a barometer derived as (Eqn. B1):

$$P(kbar) = \left(8.3144\ T(K)\ ln\ D_{Al/Si}^{plg/amp} - 8.7\ T(K) + 23376\ X_{Al}^{T1} + 7578\ X_{Ab} - 11302\right)/(-274)$$

(precision: ±1.5 to ±2.3 kbar; expressed at 1s level).

For $D_{Mg}^{amp/liq}$ values, it was found a significant dependence on temperature and $X_{Ca}^{liq}/\left(X_{Ca}^{liq} + X_{Al}^{liq}\right)$ ratio (glass composition expressed as anhydrous mole fraction of cation components) that led to the pressure-independent thermometer (Eqn. T1):

$$T(℃) = \frac{71975 - 11896\ \ ln\left[X_{Ca}^{liq}/\left(X_{Ca}^{liq} + X_{Al}^{liq}\right)\right]}{8.3144\ ln\ D_{Mg}^{amp/liq} + 58} - 273$$

(precision: ±35 to ±45 ºC).

The calibrated barometer is suitable for a large diversity of amphibole-plagioclase-bearing assemblages from metamorphic (amphibolites and mafic granulites) and igneous

(metaluminous granitoids to gabbros) rocks, whereas the amphibole-liquid thermometer is applicable to alkaline and subalkaline systems.

The calibrated expressions yield P-T estimates consistent with those obtained with widely used barometers and thermometers, being possible to extend the use of the amphibole-plagioclase barometer to quartz-free and/or garnet-free assemblages.