Abstract

A Cautionary Note on Amphibole Geobarometry [†]

José F. Molina ^{1,*}, Aitor Cambeses ¹, Juan A. Moreno ², Irene Morales ¹, Concepción Lázaro ¹, Pilar Montero ¹ and Fernando Bea ¹

¹ Department of Mineralogy and Petrology, University of Granada, 18010 Granada, Spain; aitorc@ugr.es (A.C.); iremoral@ugr.es (I.M.); clazaro@ugr.es (C.L.); pmontero@ugr.es (P.M.); fbea@ugr.es (F.B.)

² CICTERRA, CONICET, Universidad Nacional de Córdoba, Córdoba X5016CGA, Argentina; jmoreno_2@ugr.es

* Correspondence: jfmolina@ugr.es

[†] Presented at the 2nd International Electronic Conference on Mineral Science, 1–15 March 2021; Available online: <https://iecms2021.sciforum.net/>.

Citation: Molina, J.F.; Cambeses, A.; Moreno, J.A.; Morales, I.; Lázaro, C.; Montero, P.; Bea, F. A Cautionary Note on Amphibole Geobarometry. *Environ. Sci. Proc.* **2021**, *6*, 17. <https://doi.org/10.3390/iecms2021-09346>

Academic Editor: Paul Sylvester

Published: 25 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>)

The classical Al-in-hornblende barometer has been very successful in determining the depth of intrusion of the metaluminous cordilleran granitoid plutons that bear the buffering assemblage at near solidus conditions: hornblende-biotite-plagioclase-orthoclase-quartz-sphene-two Fe-Ti-oxides (or one Fe-Ti oxide + epidote)-melt-vapor (e.g., [1–3]).

Ridolfi et al. [4] and Ridolfi and Renzulli [5] derived empirical amphibole-only barometric expressions that could be potentially applied to a larger number of phenocrystic assemblages from volcanic rocks. However, Erdmann et al. [6] claimed that these barometers are inaccurate and can give untenable estimates.

A graphical barometer based on the partitioning of Al and Si between amphibole and plagioclase was derived by Fershtater [7] using amphibole–plagioclase compositional pairs of rocks from the Urals. More recently, Molina et al. [8] calibrated an empirical expression based on experimental data that can be applied to igneous and high-grade metamorphic rocks.

In order to compare the reliability of amphibole-only and amphibole–plagioclase barometry, in this work, we test the performance of the expressions of Ridolfi and Renzulli [5] and Molina et al. [8], using an experimental data set compiled from the literature that has been recently published by Molina et al. [9].

In accordance with Erdmann et al. [6], the test reveals unsustainable pressure estimates with the amphibole-only barometric expressions from Ridolfi and Renzulli [5]. In contrast, the amphibole–plagioclase barometer from Molina et al. [8] performs well and yields a precision better than 1.7 kbar for the Qz-Amp-Pl and Ol-free-Cpx-Amp-Pl assemblages, with the amphibole compositions having >1 apfu (23O; normalization to 13-CNK) Al, 0.05–0.27 apfu Ti, and <1.07 apfu Fe³⁺.

Supplementary Materials: The supplementary file is available online at <https://www.mdpi.com/article/10.3390/iecms2021-09346>.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

References

1. Hammarstrom, J.M.; Zen, E. Aluminum in hornblende: an empirical igneous geobarometer. *Am. Mineral.* **1986**, *71*, 1297–1313.
2. Schmidt, M.W. Amphibole composition in tonalite as a function of pressure: an experimental calibration of the Al-in-hornblende barometer. *Contrib. Mineral. Petrol.* **1992**, *110*, 304–310.
3. Anderson, J.L.; Smith, D.R. The effects of temperature and fO_2 on the Al-in-hornblende barometer. *Am. Mineral.* **1995**, *80*, 549–449.
4. Ridolfi, F.; Renzulli, A.; Puerini, M. Stability and chemical equilibrium of amphibole in calc-alkaline magmas: an overview, new thermobarometric formulations and application to subduction-related volcanoes. *Contrib. Mineral. Petrol.* **2010**, *160*, 45–66.
5. Ridolfi, F.; Renzulli, A. Calcic amphiboles in calc-alkaline and alkaline magmas: thermobarometric and chemometric empirical equations valid up to 1130 °C and 2.2 GPa. *Contrib. Mineral. Petrol.* **2012**, *163*, 877–895.
6. Erdmann, S.; Martel, C.; Pichavant, M.; Kushnir, A. Amphibole as an archivist of magmatic crystallization conditions: problems, potential, and implications for inferring magma storage prior to the paroxysmal 2010 eruption of Mount Merapi, Indonesia. *Contrib. Mineral. Petrol.* **2014**, *167*, 1016.
7. Fershtater, G.B. Empirical hornblende-plagioclase geobarometer. *Geokhimiya* **1990**, *3*, 328–335.
8. Molina, J.F.; Moreno, J.A.; Castro, A.; Rodríguez, C.; Fershtater, G.B. Calcic amphibole thermobarometry in metamorphic and igneous rocks: New calibrations based on plagioclase/amphibole Al–Si partitioning and amphibole/liquid Mg partitioning. *Lithos* **2015**, *232*, 286–305.
9. Molina, J.F.; Cambeses, A.; Moreno, J.A.; Morales, I.; Montero, P.; Bea, F. A reassessment of the amphibole-plagioclase NaSi–CaAl exchange thermometer with applications to igneous rocks. *Am. Mineral.* **2021**, *106*, 782–800.