Experimental Calibration of Hornblende as a Proposed Empirical Geobarometer

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The recent Eos report by Anderson [1987] reviewed prospects for using dated granitoid plutons as crustal nails in the reconstruction of descent or ascent of deformed crust during orogenic processes, if suitable geobarometers could be established. Hammarstrom and Zen [1986] and Hollister et al. [1987] have proposed an empirical geobarometer for calcalkaline plutonic rocks of tonalite and granodiorite composition based on the total Al content (Al) of calcic hornblendes. This proposition has generated considerable interest.

In a mineralogical study of five symmetamorphic calcalkaline plutonic complexes, Hammarstrom and Zen [1986] concluded that the linear relationship between Al2O3 of hornblende and pressure of crystallization, independently estimated from metamorphic assemblages in the country rock, could be used as an indicator of pressure of solidification.

Their empirical curve, reproduced in Figure 1, was based on data from samples that crystallized at 1.5–3 kbar and 7–10 kbar. Hollister et al. [1987] tested and confirmed the proposed hornblende geobarometer with data for hornblendes from nine additional calcalkaline plutons that filled the gap from 4 to 6 kbar, and then added points at the low- and high-pressure ends. Their curve differs slightly from that of Hammarstrom and Zen [1986], with a smaller estimated error (Figure 1). Both groups emphasized that the geobarometer was restricted to calcalkaline rocks with specific mineral assemblages and to hornblende that crystallized near the solidus for the granitoids. The empirical geobarometer lacked reliable experimental confirmation when published, as discussed by Hammarstrom and Zen with particular reference to Helé’s [1982] review of the phase relations and compositions of amphiboles produced in experimental studies of natural rocks.

We have new experimental data on hornblende compositions in a partly melted, vapor-absent tonalite that provides direct experimental calibration. This tonalite has been the subject of many previous experimental studies [see Huang and Wyllie, 1986].

Experiments were conducted in gold capsules in piston-cylinder apparatus at 16 kbar for durations of 1 day and 4–5 days, with negligible Fe loss to the capsule. Polished sections of experimental charges were examined with scanning electron microscopy, and mineral and glass compositions were analyzed by microprobe. The necessary long-run durations precluded use of an external oxygen fugacity buffer. We have evidence that the oxygen fugacity in the experiments is close to that of nickel-nickel oxide (NNO), and we believe that this is imposed by the iron-bearing components in the assemblage that is present...
The oxygen fugacity is consistent with that in the capsule at the conditions of reaction deduced by Hammarstrom and Zen [1986] for a garnet-tonalite. Amphibole compositions in near-solidus experiments are plotted including temperature and a standard deviation (2 σ) of 0.3% relative for Al calculated from replicate microprobe analyses of a compositionally homogeneous amphibole. The new calcic amphibole in the near-solidus 850°C experimental run plots very close to the empirical curve of Hollister et al. [1987]. Application of this geobarometer to the relict hornblende, with substantially lower Al contents, implies a pressure of solidification for the starting tonalite of being 10 kbar and 850°C, measured by electron microprobe.

At 10 kbar the subsolidus assemblage is that of a garnet-tonalite. Amphibole compositions in near-solidus experiments are plotted in Figure 1. Error bars are based on a ±5% error in the pressure measurement and a standard deviation (2 σ) of 0.3% relative for Al calculated from replicate microprobe analyses of a compositionally homogeneous amphibole. The new calcic amphibole in the near-solidus 850°C experimental run plots very close to the empirical curve of Hollister et al. [1987]. Application of this geobarometer to the relict hornblende, with substantially lower Al contents, implies a pressure of solidification for the starting tonalite of being 10 kbar and 850°C, measured by electron microprobe.

Our experimental results on hornblende provide the first direct calibration of the empirically defined geobarometer curve. Although many more experiments are required to establish the theory of the reactions that buffer amphibole compositions along various vectors [Thompson et al., 1982], the fact that this calibration fits the extrapolated empirical curve supports the reliability of the indirect approach involving estimates of the pressure of country rocks to derive an empirical curve for the pluses. The agreement between the two approaches enhances the prospect that granitoid pluses will prove to be extremely useful in tracking the rise and fall of deforming crust.

This research was supported by NSF EAR85-06857.

References


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