Geophysical Research Abstracts
Vol. 16, EGU2014-4867, 2014
EGU General Assembly 2014

Estimation of local effective bulk (LEB) by micro-mapping; implications for equilibrium phase diagram computed for migmatites

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Metamorphic rocks often display mineral assemblages indicating local thermodynamic equilibria, even though the minerals involved grew sequentially, at different times and over a range of P-T (pressure-temperature) conditions. At thin section scale two or more mineral assemblages are commonly observed. Micro-structural or textural criteria are used to assess their stability, and forward thermodynamic models allow P-T conditions of local equilibration to be derived. The predicted P-T range of the stability fields of each assemblage and the computed proportion and composition of minerals are sensitively dependent on the bulk rock composition assumed in modeling. The XRF-measured composition of a sample may serve as a good approximation of the local bulk composition of all equilibrium assemblages. However, it is well known that this hypothesis is not valid for (1) rocks that experienced strong fluid-assisted metasomatism, (2) rocks showing a high proportion of zoned minerals, and for (3) heterogeneous rocks showing different domains with different mineral assemblages. In such cases, the concept of LEB (local effective bulk) is essential, and the question is how to determine the LEB composition.

We explore the possibility to derive suitable LEB by means of standardized microprobe X-ray images, using the program XMapTools (Lanari et al. 2014). For chemically heterogeneous samples, these LEB allow us to model (using Perple_X, Connolly, 2009) the stable mineral assemblages for each domain and to obtain reliable P-T estimates. To demonstrate the utility of this approach, we investigated metapelites showing evidence of partial melting from a xenolith whithin the Marcabeli pluton, El Oro Complex, Ecuador. Migmatites are good candidates, as they usually show complex mineral patterns resulting from prograde melt producing reactions, subsequent melt migration, and retrograde reactions. For example, the separation of melt from its residuum occurring near the peak temperature may produce a local melt redistribution (at mm to cm-scale) involving important changes affecting the local present-day chemical composition.

Four domains are identified in a migmatite sample studied in detail: A residuum domain made of cordierite + biotite + plagioclase + spinel, which is predicted to be stable at P-Tmax conditions of 750 $\pm$ 50°C and 2 $\pm$ 1 kbar. In the leucosome (plagioclase + K-feldspar + quartz + biotite + orthopyroxene) three sub-domains show different mineral assemblages. Domain-specific equilibrium assemblages in the computed P-T diagrams show that these three assemblages reflect three compositionally differentiated domains, each with different melt fractions, though coexisting at equilibrium near P-Tmax conditions.

Connolly J.A.D. (2009) The geodynamic equation of state: what and how. Geochemistry, Geophysics, Geosystems 10:Q10014 DOI:10.1029/2009GC002540.
Lanari, P. et al. (2014). XMapTools: a MATLAB©-based program for electron microprobe X-ray image processing and geothermobarometry. Computers and Geosciences. 62, 227-240.