Geophysical Research Abstracts, Vol. 7, 05409, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05409

To what extent are granites representative of melt ?

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Interpretation of geochemical variations within granitic suites as the result of crystal fractionation is based on the common assumption that whole-rock compositions are representative of melt. However, if crystal fractionation is the likely process in granitic plutons (former magma chambers), we should expect the differentiation products to represent either residual melts, or cumulates, or mingling in various proportions. This will result in a high component of noise in the so-called "melt composition" data obtained from whole-rock analyses, which is commonly overlooked in granite magma petrogenesis. Our aim is to show from a case study that granites may not represent melt, but correspond to cumulate phases.

The Dolbel batholith (SW Niger) consists of several A-type plutons emplaced in low to medium grade schists under pressure estimated to be 5-6 kbar. The studied pluton consists of massive porphyritic granite in its centre, and of rhythmically layered granites at its periphery. A deformation gradient is observed close to the contact with the country schists. Structural data indicate that deformation is related to pluton inflation (Pons et al., 1995). The layered sequences are sub-vertical ($\geq 80^\circ$) and parallel to the contact of the pluton, suggesting that hydrodynamic sorting is probably negligible. Each sequence (when entire) comprises four layers, which consist of the following cumulus mineral phases, upwards: (i) hornblende ($0.37 < X_{Mg} < 0.54$); (ii) plagioclase ($An_{\leq 10}$) + hornblende; (iii) plagioclase + quartz + hornblende + diopside; and (iv) plagioclase + K-feldspar ($Or_{>96}Ab_{<4}$) + hornblende + diopside (X_{Mg} = 0.57). Accessories are ubiquitous and comprise titanite, magnetite (early ilmenite) and apatite. Minerals are euhedral and chemically zoned (orthocumulate). Intercumulus phases (*ca*. 25 vol.%) are quartz + plagioclase or quartz + plagioclase + K-feldspar. Retrograde phases are actinolite, epidote and carbonates.

Microstructures of cumulate minerals show that they consist of three parts consistent with trace element variations as illustrated from Ba and Sr contents in K-feldspar: (i) an oscillatory zoned core (Ba = 12 000 $\pm$ 1713 ppm, Sr = 4 000 $\pm$ 419 ppm); (ii) a periphery showing a regular decrease in Ba and Sr (Ba down to 3 800 ppm, Sr down to 2700 ppm); and (iii) overgrowths with constant Sr (2 500 ppm) and low Ba concentrations (down to 200 ppm). Overgrowths are in an intercumulus position suggesting that inflation-related compaction occurred in the last stages of growth. Growth can be considered to have occurred in three main episodes probably corresponding to different rheological thresholds (Vigneresse et al., 1996). The core with constant Ba and Sr concentrations is likely to have grown from a large volume of melt (open system, low crystal/melt ratio), whereas the periphery grew from a limited melt volume (closed system, higher crystal/melt ratio). Overgrowths grew from a small amount of residual melt depleted in Ba and Sr (closed system with very high crystal/melt ratio, i.e. below or close to the Rigid Particle Threshold as shown by the volume of intercumulus phases).

In the centre of the pluton, layering is absent and the massive granite consists of hornblende, plagioclase, K-feldspar and quartz in variable proportions. K-feldspar locally forms metre-sized accumulations ($>$ 90 vol.% K-feldspar) probably due to hydrodynamic sorting. Internal microstructures of hornblende and both feldspars are identical to those in the layered sequences. This strongly suggests that the granite-forming minerals are cumulate phases mingled in various proportions, probably as a result of convective movements. Major element mass balance calculations show that the composition of the granite samples does not correspond to the calculated melt composition.

These data show that all the granites (layered or not) consist of cumulus minerals and, therefore, are not representative of melt compositions. The massive porphyritic granites from the pluton centre consist of the same minerals as the rhythmically layered sequences but in variable proportions. Cumulus mineralogy varies from quartz + plagioclase to quartz + plagioclase + K-feldspar, with local accumulation of K-feldspar. Indeed, comparison of bulk compositions with the Qz-Ab-Or ternary diagram at P_{H20} = 5 kbar shows that the second, third and fourth layers can be equated to liquidus, cotectic and eutectic instantaneous solid compositions. We should add that the volume of melt removed during inflation-related compaction cannot be estimated, so that the amount of interstitial melt in the massive granites is unknown and is likely to be heterogeneous. Although this example represents an end-member situation, it shows that granites are not systematically representative of melt composition. Even though this may have limited consequences on major element compositions, it may significantly alter the fractional crystallization trace element pattern.

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