



Geochemical tools in discriminating rival petrogenetic processes in granitoid suites: a case on the Los Pedroches Batholith, Iberian Massif, Spain

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The Los Pedroches Batholith (LPB) is one of the largest Variscan batholiths in Spain, consisting of two main rock lithotypes: biotite \pm amphibole granodiorites and cordierite-bearing monzogranites. Both rock types constitute separate, fairly homogeneous plutonic bodies along a WNW trend, extending over a length of more than 250 km with a maximum width of 30 km. All the LPB granitoids were emplaced within a short time span, at about 312 Ma. Epizonal emplacement, mainly in a non-metamorphic Namurian series, and other field relationships provide reliable constraints on the sequence and time of emplacement, and show that the monzogranitic group postdates the granodiorites.

Mineralogical differences between the above groups are conspicuous; granodioritic rocks contain plagioclase with intermediate to calcic cores (up to An₅₅) and only interstitial K-feldspar. In contrast, monzogranites contain cordierite, large K-feldspar megacrysts, white mica (mostly secondary) and more sodic plagioclase. It is apparent that the batholith can be straightforwardly interpreted as consisting of two plutonic series.

Geochemical evidence, however, is more ambiguous or even confusing. Regarding major- and trace-element geochemistry, these tend also to show separate geochemical trends, at least for selected elements, although some variation diagrams seem to reflect a single trend. More importantly, isotopic data on the LPB rocks yield analogous Rb-Sr and Sm-Nd signatures. This has led us to consider the possibility that, despite of the mineralogical differences between the two main rock types in the batholith, both rock

suites could have been formed by fractional crystallization, or a more complex AFC process. This possibility may also be supported by the fact that some 'intermediate' leucogranodioritic rocks have been found in small areas in the LPB.

This apparent paradox can be solved by a more detailed geochemical study, carefully integrated with field, petrographic and mineralogical data. Accordingly, we show that 'intermediate' leucogranodioritic rocks are geochemically related to the granodiorites, not to monzogranites. On the other hand geochemical evidence, including HFSE elements, mass-balance calculations, geochemical modelling and REE variation, is inconsistent with interpretations based on a single magma series, because the geochemical gap between leucogranodiorites and monzogranites cannot be explained. We conclude that two separate parental magmas are needed to account for the genesis of granodioritic and monzogranitic rocks. The evenness of the isotopic signatures indicates that the two series were generated from a single crustal segment by progressive partial melting. This is consistent with the available experimental data.

A second 'paradoxical' aspect of the LPB lies in the microgranular enclaves. These are abundant in the granodioritic suite, apparently showing similar features to microgranular enclaves in many granitic rocks worldwide. Accordingly, they have been interpreted as reflecting magma mixing processes. In some instances, granodiorites have been directly interpreted as hybrid rocks, in view of the occurrence of abundant microgranular enclaves.

A closer study of enclaves, however, shows a number of features that do not fit the mixing model. Enclaves are mostly subangular, generally lacking chilled margins; lobate contacts are rare and enclave-host contacts are generally sharp.

Enclaves are more mafic and more basic than their hosts, exhibiting much lower SiO_2 and higher MgO , FeO and compatible element contents, which superficially fits the magma mixing model. However, and also as in other instances, the microgranular enclaves in the LPG exhibit very similar isotopic, chemical and mineralogical compositions with respect to their host granitoids. In other areas, this has been commonly interpreted as a result of homogenization, either during or after the mixing process.

Again, a closer geochemical study of enclaves reveals inconsistencies of the mixing hypothesis. Apart from the above chemical features, enclaves in the LPB granodiorite are also enriched in Rb, Zr, Hf and P, and often depleted in CaO and Sr. On the other hand, variation trends of enclaves and hosts show reverse slopes in a number of significant cases. We interpret the enclaves as cognate, most probably formed from their host granitoids by kinetically induced, accelerated crystallization of ferromagnesian minerals (particularly biotite) related to rapid cooling.

We also suggest that our interpretation for the LPG enclaves could be applied to microgranular enclave/host rock relationships in other areas, especially where independent evidence (isotopic, mineralogical and textural) for magma mixing or restite unmixing are scarce. In all these cases, microgranular enclaves are not relevant to petrogenetic processes at the granite source. However, we suggest that they can constrain emplacement processes, as they indicate rapid cooling during magma ascent or emplacement at shallow levels in the crust. As a further example, we show that enclaves in the monzogranitic series in the LPB, although scarcer than in the granodiorites, can be explained in the same way, in view of their close mineralogical and isotopic similarity to their hosts and their geochemical features.

The use of geochemical tools to solve petrogenetic problems in the LPB is a good example of what we believe to be a general rule. Apart from analytical errors, geochemistry is a very powerful tool, that provides essential, unequivocal information to those having carefully assessed petrological problems in terms of field study, mineralogy and old-fashioned petrography. In contrast, geochemistry often tends to produce confusion if these geological constraints of the problem are only superficially addressed.