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Distribution and petrogenetic behaviour of trace elements in granitic pegmatite quartz

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The geochemical evolution of igneous quartz is almost entirely neglected in the geological community because, until recently, the low trace element concentration challenged the available analytical approaches. New advancements in the Laser Ablation ICP-MS (LA-ICP-MS) technique throughout the late 1990's radically changed this situation in both lowering the limit of detection and strongly reducing the matrix effect that previously posed serious obstacles for in situ analysis.

The igneous evolution and the petrogenetic links of granitic pegmatites are particularly difficult to study because strong modal zonation patterns and extreme grain-sizes prevent the sampling of representative whole-rock samples for chemical studies. The present study documents that the trace-element distribution in granitic quartz is highly sensitive to AFC processes in granitic melts and, therefore, efficiently record both the history and the evolution of the granitic pegmatites. More than 95% of the trace elements comprise Al, P, Li, Ti, Ge and Na in that order of abundance. Most samples comprise >1 ppm of any of these elements. The remnant 5% comprises K, Fe, Be, B, Ba and Sr, whereas the other elements are present at concentrations lower than the detection limit. Regarding the igneous evolution of K-feldspar, it may be concluded that K, Fe, Be and Ti are relatively compatible hence will obtain the highest concentrations in early formed quartz. P, Ge, Li and Al are relatively incompatible and generally obtain higher concentrations in quartz that formed at lower temperatures from more evolved granitic melts. The Ge/Ti, Ge/Be, P/Ge and P/Be ratios of quartz are strongly sensitive to the origin and evolution of the granitic melts and, like, e.g., the Rb/Sr and Rb/K ratios of K-feldspars, may be utilised in petrogenetic interpretations. Apparently, the quartz trace element ratios are better at distinguishing similarities and differences in the origin and evolution of granitic melts than the trace element ratios of K-feldspar. For example, the two pegmatite fields in Norway followed overlapping evolutionary trajectories when trace elements in K-feldspar were utilised to analyse the fields. However, when trace elements in quartz were utilised, it was evident, in agreement with recent studies, that the fields are distinctively different. It appears that the Ge/Ti ratio is most robust to subsolidus processes in the igneous systems, and thus should be preferred when interpreting petrogenetic processes in granitic igneous rocks.

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Granites and differentiation of the continental crust

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Granites are abundant constituents of the upper continental crust, but crustal differentiation reflects both magmatic and sedimentary processes. Granites are generated by both magma differentiation and/or melting of different crustal sources rocks. These may be difficult to unravel and so there are advantages in using non-generic classification schemes[1]. The Hf isotope stratigraphy of magmatic zircons from the Lachlan granites, for example, highlight the contribution of mantle derived magmas in the generation of these granites whose compositions have been closely linked to different inferred crustal source rocks (Kemp et al. in prep). Moreover, at least from the Late Archaean the formation of granites with < 70% SiO_2 require relatively high temperature melting reactions and hence direct heat input from mantle-derived magmas.

Post-Archaean granites are characterised by negative Eu anomalies, and relatively unfractionated MREE to HREE patterns, highlighting the role of plagioclase rather than garnet. The degree of Rb/Sr fractionation is constrained from the Rb/Sr ratios in the granite source rocks as inferred from model Nd ages. In many cases the Rb/Sr ratios of granites reflect those of their source rocks, and hence the degree of evolution of the latter. Igneous differentiation in the crust results in decreasing Eu/Sm (proxy for Eu/Eu*) and its effects may therefore be distinguished from those of weathering and erosion, where this ratio is unchanged. The changes in Eu/Sr relative to their Rb/Sr ratios in granitic magmas are much greater than those seen between estimates of lower, bulk and upper crustal compositions. This may highlight the difficulties in estimating such compositions accurately, or it may indicate differences in the D_{Eu} for plagioclase. The latter is highly sensitive to fO_2 and one interpretation is that the differentiation of the upper and lower crustal reservoirs largely took place under relatively low fO_2 conditions, as in the Archaean[1]. This is consistent with the old average age for the continetal crust of ~ 1.8 Ga. Finally, the best fit to the average composition of the upper continental crust is a mixture of intermediate to silicic arc magmas (high Sr, but lowTi and HFSE) and one third sediments (low Sr and Ti, but high HFSE) [1].

Reference

[1] Kemp, A.I.S. and Hawkesworth, C.J. (2003) Granitic Perspectives on the Generation and Secular Evolution of the Continental Crust, *Treatise on Geochemistry*, **3**, 349-410.