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Contamination in quartz dioritic magmas: is it best recorded in plagioclase, zircon or apatite?

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Diorites are usually the least evolved rocks in granitic suites and they occur as enclaves in more felsic hosts or form separate dykes. Granites are increasingly regarded as complex intermixtures of melts produced from isotopically distinct sources, both mafic and felsic [1], and diorites are potentially an important component in granite genesis, recording information on the more mafic end-member. Diorites and quartz diorites are often already contaminated and the contamination processes are observed both in isotopic diversity between rock samples and between individual minerals. The challenge is to unpick the information from isotopic and trace element data in different grains to characterize the nature of the contamination. Here we summarize chemical and isotopic data from plagioclase, zircon and apatite to see which processes and contaminants played an important role in the differentiation of dioritic magma in the Gęsiniec Intrusion, Sudetes, Poland. The Gęsiniec Intrusion was formed at ca. 300 Ma during late Variscan post-collisional extension [2]

The most reliable information on contamination comes from radiogenic isotopes and two systems measured routinely are Sr isotopes in plagioclase and Hf isotopes in zircon. In Gęsiniec, grains from three quartz diorite types were analyzed. The whole rock isotopic compositions are consistent with a contamination process as they vary for $^{87}Sr/^{86}Sr_{300}$ from 0.7069 to 0.7080 [2]. The contamination process is even more evident from $^{87}Sr/^{86}Sr$ variations in plagioclase ($^{87}Sr/^{86}Sr_{300}$ = 0.7069 – 0.7084, [2]) and Hf in zircon (εHf_{300} = -5.5 – 0). Variations in the Hf isotopic composition in zircon correlate with the minimum $^{87}Sr/^{86}Sr$ observed in plagioclase, but not with the whole rock isotopic ratios, which is consistent with both zircon grains and cores of plagioclase recording similar stages of magma contamination. Zircon is also characterized by increase in U, Th, Pb and Ce, when moving from the least to the most evolved quartz diorite type, and such correlations are again not observed in the whole-rock composition. The preferred interpretation of these correlations is early contamination by evolved, crust-derived magmas. Variations in $\delta^{18}O$ in zircon corroborate contamination by crust-derived, sedimentary material as $\delta^{18}O$ increases from 5.6 to 6.5‰ in the least evolved sample, to 6.2 - 9.4‰ in the most evolved one. The compositional variations in apatite does not follow those observed in zircon. Comparison between trace element contents in plagioclase and apatite indicate that crystallization of apatite was contemporaneous with crystallization of plagioclase rims. Apatite is characterized by ranges in trace element concentrations, and with the progress of crystallization, the apatite composition moves from those typical of I-type granites towards those typical for S-type [3]. Interestingly, compositions closest to the S-type granite field are observed in the sample with the most evolved whole-rock isotopic composition and the highest $^{87}Sr/^{86}Sr_{300}$in plagioclase rims.

Overall, the cores of plagioclase, and the zircons record earlier stages of magma differentiation than apatite. It is striking that the whole-rock compositions are more sensitive to the late stage of differentiation than the early one. The nature of the contaminant in the Gęsiniec intrusion appears to change during the crystallization of the magma and it could be a S-type granitic magma at the early stage and partial melts derived from granite at the later stage.

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