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Limited channelized fluid infiltration in the Torres del Paine contact aureole

Guillaume Siron[1,2,*], Robert Bodner[1], Lukas Baumgartner[1,†], Benita Putlitz[1], and Torsten Vennemann[3]

[1]Institute of Earth Sciences, University of Lausanne, CH1015 Lausanne, Switzerland
[2]WiscSIMS, Department of Geosciences, University of Wisconsin-Madison, Madison, Wisconsin 53706, U.S.A.
[3]Institute of Earth Surface Dynamics, University of Lausanne, CH1015 Lausanne, Switzerland

Abstract

The metamorphic rocks from the Torres del Paine contact aureole (Patagonia, Chile) show field, petrographic, and geochemical evidence for small amounts of igneous fluid infiltration due to the solidification of the granite complex. Hydrogen isotope ratios (D/H) in the contact aureole first decrease while approaching the intrusion and subsequently increase toward the granite contact. Initial decrease with metamorphic grade is due to preferential loss of the ^{2}H isotopes due to Rayleigh fractionation during prograde dehydration reactions. The infiltration of high-δD fluids from the intrusion increases δD within the last 150 m. In contrast, ($^{18}O/^{16}O$) ratios show no systematic changes, indicating that neither oxygen loss by Rayleigh fractionation nor oxygen exchange by fluid infiltration was significant enough to dominate original variations seen in the oxygen isotope ratio of the protolith. Calculated volume of fluid using the position of the hydrogen isotope exchange front gives a relatively low time-integrated fluid flux of about 4 m^3/m^2 at the contact for the igneous fluid. These small amounts of fluid flux are in agreement with whole rock oxygen isotope data that are not affected in the contact aureole. Chlorine content of metamorphic biotite crystals, in contrast to oxygen isotopes, supports infiltration of igneous fluids. Indeed, relatively high-Cl concentrations in biotite were measured in some samples close to the intrusion (up to 0.2 wt%), while chlorine concentrations in biotite are constant everywhere else in the entire contact aureole, having low concentrations (0.01–0.06 wt%). The absence of a well-marked Rayleigh fractionation trend in Cl concentrations with increasing metamorphism is surprising since chlorine strongly fractionates into the fluid. This is best explained by slow diffusive exchange of chlorine in biotite in the cooler outer aureole. Hence recrystallization of biotite would be required to modify its Cl composition. Biotite grains from samples close to the intrusion with high-Cl content also have lower Ti content (0.4 pfu) than biotite (0.5 pfu) from other samples containing biotite with lower Cl content located at the same distance from the contact. Since Ti content in biotite is a function of temperature, this is a good indication that magmatic fluid infiltration started post peak, early during cooling of the metamorphic rocks. Episodes of fluid flow appear to have been nearly continuous during cooling as evidenced by numerous retrogression textures, such as secondary muscovite (above 470 °C) or chlorite + muscovite intergrowth after cordierite or biotite (slightly below 470 °C). This might be related to crystallization of subsequent batches of granites or the onset of minor fluid convection during cooling of the aureole. Nevertheless, only minor secondary muscovite has been found, and fresh cordierite is present throughout the aureole confirming small amounts of fluid infiltration.

The time-integrated fluid flux computed from the hydrogen isotope exchange front is two orders of magnitude lower than values computed for metacarbonate in many other contact aureoles, suggesting low permeabilities of pelitic rocks. In conclusion, Cl contents and hydrogen isotope compositions of hydrous minerals provide a sensitive tool to identify small fluid-rock interaction events, much more sensitive than oxygen isotope compositions of the whole rock or minerals.

Keywords: Hydrogen isotopes, oxygen isotopes, Cl content, fluid flow, Rayleigh fractionation, Torres del Paine, fluid-ro interaction ck