Journal of Conference Abstracts
Volume 5(2), 202

Sr and Ar Isotopic Variations About a Lithologic Contact Near Simplon Pass, Switzerland: Implications for Diffusional Exchange and Geochronology

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A field study using Sr, Nd and Ar isotopic data from a site near the Simplon Pass, Switzerland, was conducted to constrain metamorphic fluid-rock exchange rates and bulk chemical diffusivities, and to ascertain their effect on geochronology and mineral equilibria. Sampling focuses on a lithologic contact between amphibolite and pelitic schist. Temperatures at the time of peak- to early retrograde metamorphic exchange were 500 C to 600 C. Sr and Nd isotope measurements in garnet porphyroblasts, bulk rock, and matrix minerals, (summarized in Baxter et.al. 2000) are used to deduce the bulk rock reaction rate, expressed in terms of the amount of solid reacted per gram of solid per unit time. The inferred rate, about 10^{-7}g/g/yr, is much slower than currently accepted estimates based on kinetic theory and lab experiments, and suggests that these rocks may not be able to accurately record the changing conditions of metamorphism. Furthermore, the data suggest that there was extensive post-garnet growth exchange of Sr (as well as other elements) across the contact, which severely compromises Rb/Sr garnet-whole rock geochronology within about 1 meter of the contact. Biotites from locations on both sides of the contact were also separated and analyzed by $^{40}Ar/^{39}Ar$. Biotites were sieved such that similar grain sizes (600-1000 micron diameter; coincident with natural grain size) were analyzed for each sample. $^{40}Ar/^{39}Ar$ plateau ages determined by laser heating of single grains (and bulk furnace heating of a few finer grained samples) vary from 11.30 ±0.05 Ma in the pelite to as high as 17.90 ±0.10 Ma in the amphibolite (Figure 1). Variation between individual grains from the same sample was less than ±0.5 Ma from the mean for most samples, and may be explained by grain size variation between 600 and 1000 microns. The pattern of apparent age vs. proximity to the contact is smooth in the amphibolite with the "oldest" age (17.90 ±0.10 Ma) occurring about 34 cm from the contact, and the "youngest" age (15.04 ±0.04 Ma) occurring at the contact. Pelite ages cluster around 12.2 ±0.4 Ma, equal to the expected age (Mancktelow 1992), regardless of proximity to contact. The age differences across the contact are statistically enormous and cannot be explained by closure temperature variations due to grain size, biotite composition, or cooling rate differences. Rather, the smooth pattern of the age data in the amphibolite suggests that diffusive exchange of Ar across the contact is an important mechanism in the retention of differing amounts of excess Ar in biotites in the amphibolite. This implies that loss of radiogenic Ar from metamorphic rocks can be limited by Ar mobility within the rock matrix, and not solely by the retentivity of the minerals. The data are also suggestive of differing bulk diffusivities of Ar within the pelite matrix (faster) and amphibolite matrix (slower). The biotites furthest from the contact in the amphibolite, about 1.5 meters away, yield an age of 14.5 ±0.1Ma. At this location there is evidence for a zone of channelized layer -parallel fluid advection which appears to have provided a conduit for Ar loss. The maximum deviation of apparent age (ca. 18Ma) in the amphibolite from the true age (ca. 12 Ma), scales with L^2/D^*, where L is the thickness of the anomalous layer and D* is the bulk Ar diffusivity, and allows us to estimate the effective Ar diffusivity. The combined Sr and Ar isotopic data about this lithologic contact illustrate the importance and magnitude of cross-layer diffusional exchange during metamorphism, and raise a number of important questions about equilibrium and geochronology in metamorphic rocks. The ability of garnet and biotite to preserve evidence of syn-metamorphic disequilibrium in Sr and Ar isotopes respectively, provides opportunities to quantify the lengthscales of local chemical equilibration, mineral-fluid exchange rates, and Ar migration rates through rocks. Further systematic study of just those situations where the assumptions of equilibrium and standard geochronology break down may be critical for furthering understanding of the chemical and hydrological environment of metamorphism.

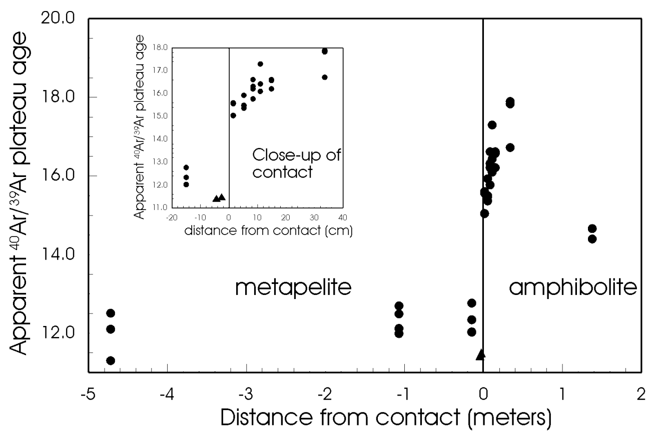

Figure 1: $^{40}Ar/^{39}Ar$ plateau ages from analyzed biotites vs. distance from the pelite/amphibolite contact. Circles are individual single crystal analyses, triangles are bulk furnace analyses on finer grained samples (250-425 micron diameter).

Baxter EF & DePaolo DJ, *Science*, **287**, **in press**, (2000).
Mancktelow NS, *Tectonophysics*, **215**, 295-317, (1992).