

Comparison of conventional and garnet-aluminosilicate-quartz O isotope thermometry: Insights for mineral equilibration in metamorphic rocks

DAVID P. MOECHER^{1,*} AND ZACHARY D. SHARP^{2,†}

¹Department of Geological Sciences, University of Kentucky, Lexington, Kentucky 40506, U.S.A.

²Institut de Minéralogie et Pétrographie, Université de Lausanne, CH-1015 Lausanne, Switzerland

ABSTRACT

Oxygen isotope thermometry based on fractionations among quartz, garnet, kyanite, sillimanite, and potassium feldspar in amphibolite to granulite facies schists and gneisses was compared to thermometry based on mineral equilibria (“conventional thermometry”). The former approach takes advantage of the exchange between quartz and more refractory minerals such as garnet and the aluminosilicates, and their potential for preserving peak oxygen isotopic fractionations. Although isotopic thermometry using these phases is potentially an approach for circumventing the problem in slowly cooled rocks of retrograde oxygen isotopic exchange with micas and feldspars, and of Fe and Mg exchange between garnet and biotite, the results are accurate or geologically meaningful in only certain settings. In most cases, the results of isotopic thermometry must be evaluated with the aid of quantitative forward models for calculating the amount of retrograde diffusive exchange among micas, feldspars, and quartz. Two models used here predict quartz isotopic compositions that differ by only 0.1 per mil and, in most cases, reproduce to within 0.2 per mil the measured isotopic composition of quartz. Excellent agreement between isotopic and conventional thermometry is obtained for mid-to-upper amphibolite facies rocks that have experienced one period of recrystallization and mineral growth, and if they are coarse-grained or cooled in the absence of a hydrous fluid phase. Isotopic temperatures of 850 °C are in excellent agreement with conventional thermometry in migmatitic granulite facies metapelites if cooling occurred under anhydrous conditions. In other cases, isotopic temperatures in granulite facies rocks are higher than conventional temperatures, a reasonable result in view of the tendency for retrograde cation exchange between garnet and biotite. In samples that have undergone multiple periods of recrystallization or metamorphism, isotopic temperatures from coexisting quartz, garnet, and aluminosilicates may be modified by diffusional exchange of quartz with micas and feldspars aided by recrystallization, by retrograde reactions involving the latter phases, or by open-system interaction with externally derived fluids. External fluid infiltration, combined with recrystallization of quartz and aluminosilicate, may result in isotopic reversals between garnet and matrix phases. Conventional thermobarometry in such complex rocks, based in large part on mineral equilibria involving garnet, may be erroneously assigned geological significance in the absence of insights provided by oxygen isotope analysis.