Timing and mechanisms of carbon isotope exchange in granulite-facies calc-silicate boudins, Rauer Group, East Antarctica

IAN CARTWRIGHT,1 IAN S. BUICK,2 AND SIMON L. HARLEY3

1 Victorian Institute of Earth and Planetary Sciences, Department of Earth Sciences, Monash University, Clayton, Victoria 3168, Australia
2 Victorian Institute of Earth and Planetary Sciences, School of Earth Sciences, LaTrobe University, Bundoora, Victoria 3083, Australia
3 Department of Geology and Geophysics, Grant Institute of Geology, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW, U.K.

ABSTRACT

Mineralogically zoned, decimeter-diameter calc-silicate boudins enclosed within paragneisses from Little Italy Island, Rauer Group, east Antarctica underwent granulite-facies metamorphism ($P = 700–900$ MPa, $T = 840 ± 40$ °C) followed by near-isothermal decompression to 200–400 MPa. During decompression several mineral reactions occurred in the presence of a pore fluid ($\phi = 0.4$). The calc-silicate boudins show a general decrease in calcite $\delta^{13}C$ values from core (as low as $-17½$) to rim ($2$ to $10½$); by contrast, $\delta^{18}O$ values show little variation across the boudins. The $\delta^{13}C$ profiles are similar to those predicted to result from diffusion within a sphere that is surrounded by a homogeneous reservoir. Diffusion of carbon isotopes probably occurred synchronous with the post-peak metamorphic mineral reactions. At that time, centimeter-scale diffusion would have been facilitated by the presence of the fluid, while isotopic exchange between the minerals and the fluid would have been promoted by recrystallization. For metamorphic porosities of $10^{-2}$ to $10^{-3}$, the $\delta^{13}C$ profiles could have formed in a few thousand to hundreds of thousands of years. Small (millimeter to centimeter) scale variations in $\delta^{13}C$ values that may have been initially present within the boudins would have been homogenized on much shorter timescales than those required to form the profiles. The calculated timescales may reflect the time over which metamorphic recrystallization occurred and a reaction-enhanced porosity was present. Graphite formed locally in the paragneisses only at margins of the boudins probably reflects the local escape of CO$_2$-bearing fluids from the boudins into relatively low $f_{o_2}$ rocks.

INTRODUCTION

Fluids are important metamorphic and tectonic agents that control the stability of mineral assemblages, cause metasomatism and partial melting, and affect crustal rheologies; hence, documenting fluid-rock interaction is important in understanding crustal processes. The debate about the role of CO$_2$-rich fluids in producing low $a$H$_2$O granulite-facies assemblages (e.g., Newton et al. 1980; Newton 1986) has largely subsided. Many granulite-facies rocks contain mineral assemblages that are too reduced to have been in equilibrium with CO$_2$-rich fluids, or preserve discontinuities in stable isotope ratios or other geochemical parameters suggesting that they have not experienced significant pervasive fluid flow at any time (e.g., Lamb and Valley 1984; Valley et al. 1990; Cartwright and Valley 1991, 1992; Buick et al. 1993). However, while the peak of metamorphism in many granulite-facies terrains was probably fluid absent, many granulites underwent fluid-rock interaction either before or following the peak of metamorphism (e.g., Corbett and Phillips 1981; Cartwright 1988; Morrison and Valley 1991; Cartwright and Valley 1992; Buick et al. 1994; Cartwright et al. 1993; Buick and Cartwright 1995, 1996; Cartwright and Buick 1995). The timing and duration of these fluid flow episodes and the sources of fluids are often poorly known; hence, there is still a need to document and understand fluid-rock interaction in granulite-facies terrains.

Resetting of stable isotopes commonly occurs during fluid flow; however, it is less clear what the scale of isotopic resetting may be in the absence of fluids. Cartwright and Valley (1992) interpreted discontinuities in $\delta^{18}O$ values of 4–5‰ over $<10$ cm between anhydrous granulite-facies basic and tonalitic orthogneisses from the Lewisian complex (UK) as indicating that isotopic exchange was very limited in the absence of fluids. By contrast, Todd and Evans (1993) interpreted centimeter-to-decimeter-scale isotopic exchange between granulite-facies marbles and orthogneisses from the Seward Peninsula (USA) as occurring during granulite-facies metamorphism under fluid-absent conditions. The scale over which isotopic resetting occurs is probably controlled by the interplay of