Fluid–rock interaction across a greenschist- to granulite-facies transition, Reynolds Range, central Australia: implications for regional-scale fluid flow in LP/HT orogenic belts

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Introduction

The determination of the length-scale, timing and mechanisms of fluid infiltration is a major goal of metamorphic petrology. Fluid flow in metamorphic terrains may occur isothermally or along temperature gradients. Fluid flow along temperature gradients is likely to occur during contact metamorphism (Dipple & Ferry 1992) and also may occur during low-pressure/high-temperature (LP/HT) regional metamorphism. Here we present petrological and stable isotopic constraints on the fluid/rock interaction history of the Reynolds Range Group, a mid-Proterozoic LP/HT metamorphic belt from the Arunta Complex of central Australia.

Regional Setting

The Reynolds Range Group (RRG), a metamorphosed cover sequence from the polymetamorphosed Reynolds Range, consists of interlayered quartzites, pelites and carbonates that are continuous along strike for *c*.100 km. Metamorphism of the RRG commenced with $M2_1$ contact metamorphism around early granites. $M2_1$ assemblages were partially overprinted during regional $M2_2$-$D2_2$ metamorphism that ranged from greenschist- (*c.* 400°C) to granulite- (*c.* 700–750°C) facies conditions at 4 to 5 kbar. $M2_2$ isograds intersect the strike of the Reynolds Range, and map-scale $F2_2$ folds, at moderate to high angles (Fig.1). The mineral assemblages and

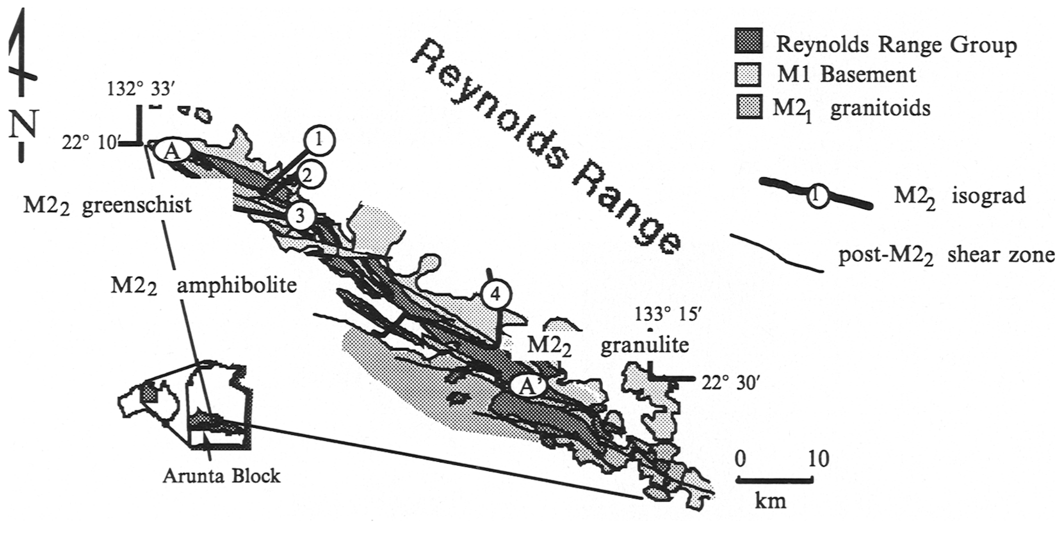

FIG. 1. Locality map, showing the Reynolds Range. $M2_2$ isograds are as follows: 1 = sphene-in isograd in calcite-rich marbles; 2 = k-feldspar + anorthite-in isograd in calcite-rich marbles; 3 = biotite-in isograd in metapelites; 4 = sillimanite-in isograd in metapelites.

fluid flow history described below are attributed to the M2-D2 tectonic cycle.

Petrology of and stable isotope geochemistry of marbles and metapelites

The marbles and metapelites crop out at $M2_2$ greenschist-, amphibolite- and granulite-facies grades, making it possible to examine the prograde history of $M2_2$ fluid/rock interaction. The fluid composition constrained by the low-variance mineral assemblages that occur in interlayered calcite- and dolomite-rich marbles and metamorphosed calcareous marls change from XCO_2 < 0.05 at greenschist-facies conditions, to $0.25 < XCO_2 < 0.75$ and, locally, $0.95 < XCO_2 < 1.0$ at granulite-facies grades. Over the same grade transition metapelitic rocks change from shales to migmatitic gneisses. At the highest grades the metapelites melted under low-a_{H_2O} vapour-absent conditions.

At greenschist-facies grades the marbles and metapelites have lower $\delta^{18}O$ values ($\delta^{18}O$(carb) = 15.8 to 19.7 V-SMOW, mean = 17.7±1.1‰ 1σ; $\delta^{18}O$(WR pelite) = 6.4 to 15.3‰, mean = 11.7±1.7‰ 1σ) than those of typical of low-grade metasediments elsewhere, but similar d13C values (d13C(carb) =-1.4 to 0.7 PDB, mean = 0.0±0.3‰ 1σ). The amount of $\delta^{18}O$-heterogeneity of these greenschist-facies rocks, alone, is comparable to the total heterogeneity in stable isotope composition that have been recorded in similar rocktypes from other contact- or regional-metamorphic terrains across large metamorphic grade changes. The lowest $\delta^{18}O$ values indicate that these rocks have experienced significant fluid/rock interaction. Marbles and metapelitic rocks at amphibolite- to granulite-facies grades have: a) similar average stable isotope values, and b) similar isotopic heterogeneity to greenschist-facies stratigraphic equivalents ($\delta^{18}O$(carb) = 13.1 to 20.5‰ mean = 17.1‰ 1σ, $\delta^{13}C$(carb) =−3.1 to 1.4‰, mean = −0.3±0.8 1σ; $\delta^{18}O$ (WR pelite) = 6.7 to 14.3‰, mean = 10.6±2.0 1σ). The variation of oxygen and carbon stable isotope values with increasing $M2_2$ grade define sub-horizontal bands (Fig. 2).

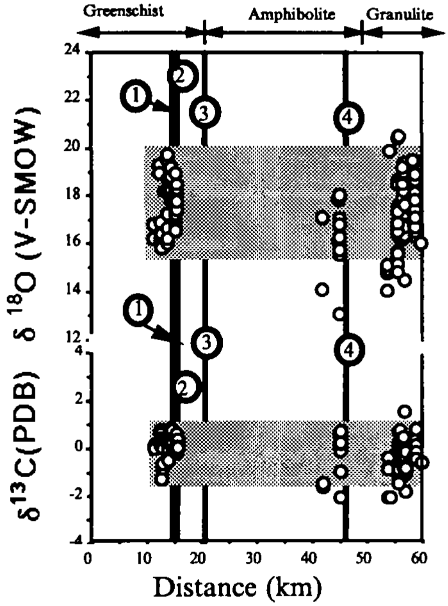

FIG. 2. Stable isotope traverse for marbles with increasing grade along the length of the Reynolds Range (traverse A-A' in Figure 1). Isograds are numbered as for Figure 1.

Discussion

The recognition of low-$\delta^{18}O$ metacarbonates and metapelites at regional greenschist- to granulite-facies grades has important implications for the fluid-rock interaction history of the Reynolds Range Group, and other LP/HT metamorphic belts. The distribution of low-variance high-XCO_2 mineral assemblages in the marbles at medium to high grades, and the lack of systematic lowering of $\delta^{18}O$ and $\delta^{13}C$ values for both marbles and metapelites with increasing regional grade implies that there was little fluid-rock interaction in the marbles or metapelites along the prograde $M2_2$ P–T path at grades higher than the greenschist facies. We attribute the lowering of $\delta^{18}O$ values throughout the Reynolds Range to channelled fluid flow that was associated with $M2_1$ contact metamorphism around early granites. These granites crop out from $M2_2$ greenschist- to upper amphibolite-facies grades, and are associated with high-temperature mineral assemblages that are partially preserved through the regional metamorphic overprint (Buick and Cartwright, 1994; Buick *et al.*, 1994). At the highest $M2_2$ grades a similar early history of contact metamorphic fluid/rock interaction is likely, even though $M2_1$ granites do not occur at present-day erosional levels.

References

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