Mantle derived CO_2 and granulite genesis: evidence from noble gases

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Introduction

Noble gases, particularly He, are extremely sensitive indicators of mantle-crust interactions. This sensitivity arises from the more than two orders of magnitude difference between the $^3He/^4He$- ratios found in mantle and typical crustal rocks. One important aspect of mantle-crust interaction is the possible involvement of mantle-derived carbonic fluids in the dehydration of lower crust and thus in the genesis of granulites (e.g. Farquhar and Chacko, 1991 and refs. therein). However, this viewpoint is still a matter of controversy as the CO_2 may be generated internally (e.g. Raith and Srikantappa, 1993 and refs. therein). A recent noble gas study of a granulite sample from the Nilgiri Hills, Southern India (Dunai and Touret, 1993) provides unequivocal evidence for a mantle origin of most if not all of the samples volatiles. Because this finding impinges directly on the above controversy, my aim in the present study was to validate this finding utilizing an extensive suite of lower crustal rocks from the same area. I report noble gas data of enderbites, charnockites and meta-sediments from the Nilgiri Hills and for a meta-gabbro from the adjacent Bahvani Shear Zone. The samples come from localities scattered over an area of 650 km^2.

Samples and Experimental Procedures

I analyzed coarse-grained (1–3mm) garnet separates as the primary carbonic fluid inclusions are present only in the garnets or the quartz inclusions in the garnets (Srikantappa *et al.*, 1992). The garnets had inclusion free rims but the cores were distinctive and contained abundant mineral- and primary fluid-inclusions. Only garnet from a meta-gabbro from the Bahvani Shear Zone contained abundant secondary fluid inclusions. The noble gases were released by crushing of the samples. The analytical procedure for noble gas analysis is described in Dunai and Touret (1993).

Noble Gas Results and Discussion

The fluid inclusions of most garnets contain helium with $^3He/^4He$-ratios between 0.8 and 1.7 times the atmospheric ratio (R_a). Only garnets from localities in the immediate vicinity of the Moyar Shear Zone and from the Bahvani Shear Zone did I find more radiogenic $^3He/^4He$-ratios, with values of 0.2 and 0.6 R_a, respectively. Although lower, these ratios are still substantially higher than those typical for crustal rocks (< 0.1 R_a). The persistently high $^3He/^4He$-ratios found throughout the Nilgiri Hills are preserved in meta-intrusives as well as in meta-sediments. Thus mantle-derived fluids were ubiquitous during granulite formation.

Most of the ^4He in the fluid inclusions was in-situ produced by decay U- and Th-series isotopes hosted in the surrounding garnet. This finding is supported by: (i) the presence of nucleogenic ^{21}Ne in the fluid inclusions of some garnets ($^{21}Ne/^{22}Ne$ up to $0.16 \pm .02$); and (ii) by $^{21}Ne_{nuc}/^4He$-ratios as high as 4.8×10^{-8}, this ratio being in the range expected for nucleogenic production ($3.8 \pm .4 \times 10^{-8}$ to 6.8×10^{-8}, calculated for CO_2 after: Eikenberg *et al.* 1993 and refs. therein). Therefore, the volatiles that were originally trapped in the garnets contained He with a much higher $^3He/^4He$-ratio than measured. Thus, essentially pure mantle volatiles had to be present at the time of peak metamorphism.

Conclusions and outlook

The results of this study confirm the mantle provenance of the carbonic fluids associated with regional granulite formation in the Nilgiri Hills, southern India as was previously inferred by Dunai and Touret (1993). The mantle-derived fluids are ubiquitous in the lower crustal segment now exposed in the Nilgiri Hills. It may be that the Nilgiri Hills rocks are only unusual in that they still contain primary fluid inclusions and whereas other granulites lost their CO_2 (together with co-trapped He) during uplift. As discussed by Touret (1992), massive granulites as found in the Nilgiri

Hills may release their CO_2 during uplift, if P-T-conditions grossly deviate from the isochore of the CO_2-inclusions or if the rocks are strained. Such a release of CO_2 may be responsible for the generation of incipient charnockites as found to the north of the Nilgiri Hills and in southern Kerala. The He-signature found in secondary carbonic fluid inclusions of the meta-gabbro in the Bahvani Shear Zone may be an indication that such a release has occurred and the CO_2 has been retrapped.

References

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