# Two cycles of granulite facies metamorphism detected by Sm-Nd dating of garnet: implications for the Sm-Nd closure temperature

**B.J. Hensen**
**B. Zhou**

*Department of Applied Geology, University of New South Wales, Sydney, 2052, Australia < body-fr >*

## Introduction

The application of the garnet Sm-Nd dating method to granulite facies metamorphic rocks has been brought into question by recent claims of a low closure temperature (*c.* 600°C) for the Sm-Nd isotopic system in garnet (Mezger *et al.*, 1992, Burton *et al.*, 1993). We present evidence for a more robust garnet memory under granulite facies conditions. Our work demonstrates the existence of both inherited and co-eval monazite inclusions in garnets from different rocks. Model calculations show that very low levels of contamination (0.01–0.001 weight %) by inherited inclusions of monazite and zircon may completely swamp the garnet isotopic signature. We draw attention to the momentous implications for both Sm-Nd and U-Pb garnet chronology.

## Memory of a 1000 Ma year event retained in a 500 Ma granulite metamorphism

The granulite facies gneisses along the Prydz Bay coastline in eastern Antarctica have long been regarded as part of an extensive Proterozoic (*c.* 1000 Ma) terrane. However, recent work, has shown that parts of the region have experienced polycyclic granulite metamorphism. Garnet fractions and whole rock or matrix have been used to obtain Sm-Nd isochrons for a variety of rock compositions. Initial difficulties with monazite inclusions in garnet were overcome by using an acid leaching technique which eliminates monazite. Our chronology shows that the widespread medium pressure ($6 \pm 1$ kbar) granulite event took place at Pan African time (6 ages: 488–517 Ma; Hensen and Zhou, in press).

On Søstrene Island in the western part of Prydz Bay petrographic and electron micro probe evidence for an earlier higher pressure event has been found. In mafic granulite garnets show two stage breakdown to a coarse-grained outer (early) Opx-Plg $\pm$ Hbl symplectite and a fine-grained inner (late) Opx-Plg-Spl symplectite. The latter symplectite also occurs on a fracture cleavage in the garnet, spaced at 0.2–1mm. Conditions of the early, garnet forming, metamorphic event are 9 $\pm$ 1 kbar and 850 $\pm$ 50°C, and the late, nearly isochemical, breakdown of the garnet occurred at 6 $\pm$ 1 kbar and 700 **50**°C (Thost *et al.*, 1991).

Sm-Nd garnet-whole rock isotope analyses on a garnet core from Sostrene indicates an age of 988 $\pm$ 12 Ma for the first granulite metamorphism. The second thermal event is dated at 498 $\pm$ 12 Ma from a nearby pelitic sample. This later granulite facies metamorphism is the same Pan-African event as found in other parts of Prydz Bay. These results demonstrate that the garnet cores record the earlier high P-T event and also retain an isotopic memory of the timing of this event. The subsequent reheating to *c.* 700–750°C at *c.* 500 Ma did not reset the Sm-Nd isotopic system within garnet cores. Therefore it is concluded that the closure temperature of Sm-Nd system for garnet, with an effective diameter of 1mm, in these rocks is in excess of 700°C.

## Inherited monazite in granulite facies garnet

Microscopic to submicroscopic inclusions (in particular, zircon and monazite) in garnets are common in our samples. Most often the monazite inclusions formed at the time of metamorphism or have completely re-equilibrated during garnet growth, and monazite-contaminated garnet analyses fall on the isochrons defined by clean garnet-whole rock/matrix. However, inherited compositions were recorded in one case where the monazite-contaminated analyses define various mixing lines with apparent older ages. Model calculations show that as little as 0.001 wt% monazite contamination would result in Sm-Nd contents of the garnet concentrates to be dominated by the monazite. A similar amount of zircon contamination would have little influence on the Sm-Nd system. However, it would have very significant influence on a U-Pb garnet age.

Recent EPMA mapping of zoning patterns in

garnet from granulite facies rocks shows gradual, smooth variations in Fe, Mg and Mn, but abrupt euhedral zoning patterns for *REE* and P (Hiroi and Ellis, 1994). The euhedral zoning is interpreted as growth zoning and the difference between the *REE* and most other major elements is interpreted to indicate lower diffusion rates for the former. In view of this new information and of the high closure temperature for Sm-Nd diffusion in garnet indicated by our study (700°C rather than 600°C, as suggested by others recently) it is worth considering that small degrees of contamination of garnet by inherited zircons could be responsible for reported apparent age differences, and inferred differences in diffusivity between the Sm-Nd and U-Pb systems (Mezger *et al.*, 1992).

## References

Burton, K. W., Cohen, A. S. and O'Nions (1993) *Terra Abstracts, EUG*, in press.

Hiroi, Y. and Ellis, D.J. (1994) *EOS*, **75**, April 1994.

Hensen, B.J. and Zhou, B. (1994) *Australian J. Earth Sci.*, in press.

Mezger, K., Essene, E. J. and Halliday, A. N. (1992) *Earth Planet. Sci. Lett.*, **113**, 397–409.

Thost, D. E., Motoyoshi, Y., and Hensen, B. J. (1991) *J. Metam. Geol.*, **9**, 245–56.