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Relict sapphirine+kyanite and spinel+kyanite associations in pyropic garnet from the eastern Sør Rondane Mountains, East Antarctica

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Abstract

Sapphirine, spinel, orthoamphibole±quartz and kyanite are included in porphyroblastic garnet in biotitic gneiss enclosed in a lens of metamorphosed ultramafic rocks in the Cambrian granulite-facies metamorphic complex of the eastern Sør Rondane Mountains, Queen Maud Land, East Antarctica. A bulk analysis of the biotitic gneiss reveals features characteristic both of ultramafic rocks, e.g., high contents of Cr and Ni, and of metasomatism associated with fluids having a crustal source, e.g., relatively elevated contents of Li, Rb, Mo, Cs, Ba, Tl, and Pb. This trace element signature is consistent with the biotitic gneiss being a slice of blackwall skarn that developed between harzburgite and the enclosing biotite–hornblende±garnet±orthopyroxene±clinopyroxene gneiss and was subsequently infolded or inserted by faulting. The matrix assemblage of the biotitic gneiss is garnet+corundum+hercynite+biotite+plagioclase+allanite+zircon. The included associations (all with biotite and rutile) are (1) sapphirine+kyanite, (2) spinel+kyanite, (3) sapphirine+spinel, (4) kyanite, and (5) orthoamphibole+plagioclase±quartz. The garnet porphyroblasts are compositionally zoned with broad pyropic cores (X_{Mg}(=Mg/(total Fe+Mg))=0.45–0.55) surrounded by Fe-richer rims ($X_{Mg}\approx 0.3$ at the outermost part). The garnet cores preserve compositions homogenized under peak conditions of the granulite-facies metamorphism (760–800 °C and 7–8 kb), whereas the Fe-enriched rims are attributed to an amphibolite-facies overprint at 500–600 °C. Theoretical calculations of garnet+corundum+spinel±sapphirine+kyanite equilibria in the FMAS system constrain possible P–T conditions for a sapphirine+spinel+kyanite+garnet ($X_{Mg}\approx 0.55$) assemblage to form near 450 °C and 4 kb on the prograde path. In contrast, a modified calibration of the Das et al. (Das, K., Fujino, K., Tomioka, N., Miura, H., 2006. Experimental data on Fe and Mg partitioning between coexisting sapphirine and spinel: an empirical geothermometer and its application. Eur. J. Mineral., 18, 49–58). sapphirine–spinel thermometer gives 860–895 °C for the included associations; pressures would have to be at least 12 kb to stabilize kyanite at these temperatures. Neither estimate is satisfactory and the stability range of kyanite+spinel–hercynite±sapphirine assemblages remains an unresolved question. The Sør Rondane Mountains constitute the third region for kyanite, sapphirine and spinel–hercynite inclusions in garnet in granulite-facies rocks of the Neoproterozoic–Cambrian orogen extending from the Sør Rondane Mountains to Lützow–Holm Bay and onward to Sri Lanka, southern India and southern Madagascar, and thus determining the stability range of kyanite+spinel–hercynite±sapphirine is critical for deducing the tectonic evolution of this orogen.

Keywords: Sapphirine+kyanite; Spinel+kyanite; P–T path; Sør Rondane Mountains; Antarctica

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1. Introduction

Sapphirine is found most typically in silica-undersaturated Al- and Mg-rich rocks metamorphosed under granulite-facies conditions (Deer et al., 1978); at the highest temperatures it also appears in silica-saturated rocks (Harley and Hensen, 1990; Harley, 1998). Sillimanite is the most common Al_2SiO_5 phase associated with sapphirine. Nonetheless, sapphirine is also found with kyanite as inclusions in garnet (Motoyoshi et al., 1989; Ogo et al., 1992; Hiroi et al., 1994), though not always in equilibrium (Simon and Chopin, 2001). Another sapphirine+kyanite paragenesis involves sapphirine formation as breakdown product of kyanite-bearing assemblages during decompression (e.g., Schreyer and Abraham, 1975; Grew, 1986; Johansson and Möller, 1986; Carswell et al., 1989; Möller, 1999; Baba, 1999; Straume and Austrheim, 1999; Baba, 2003), but these occurrences have a very different origin from the included assemblages of interest here. Spinel–hercynite solid solution is also most commonly found with sillimanite, but occurrences with kyanite±spinel–hercynite

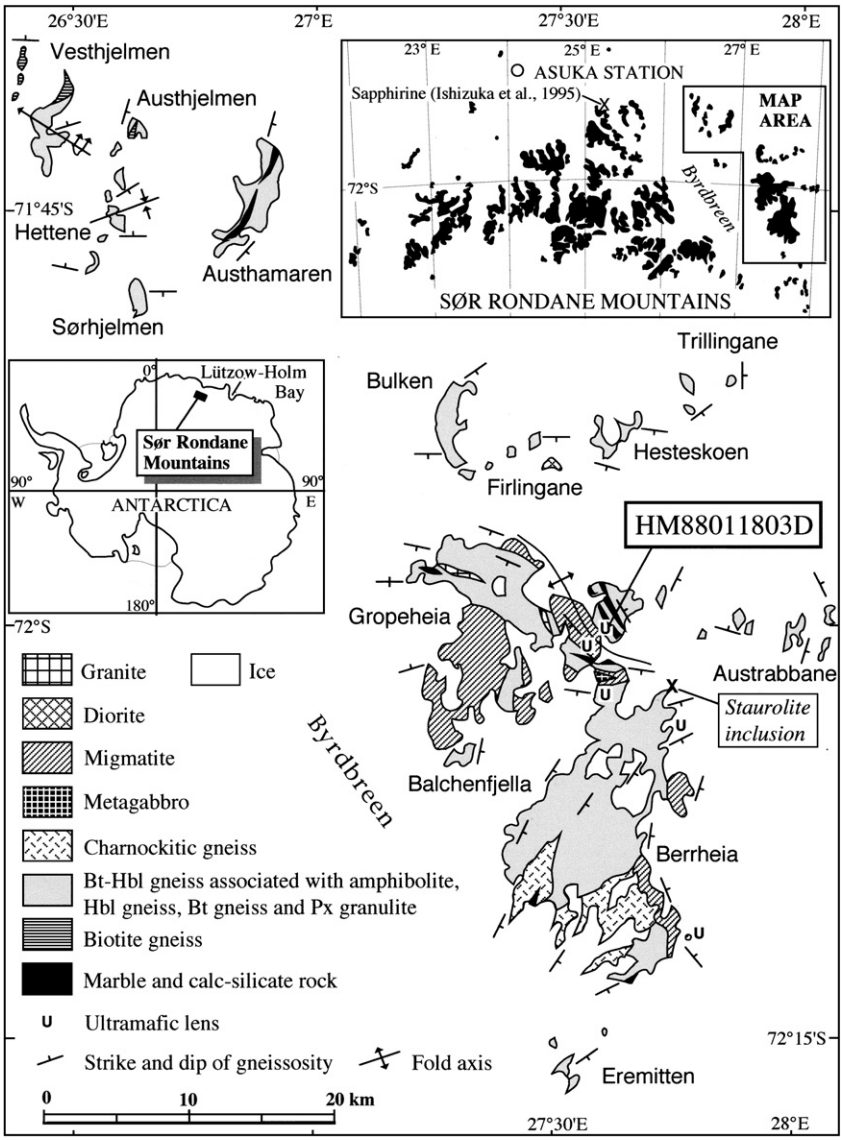

Fig. 1. Geologic map of the eastern Sør Rondane Mountains (modified from Asami et al., 1991, and Ishizuka et al., 1993) showing the localities for the sapphirine-bearing biotitic gneiss (sample HM88011803D, Makimoto et al., 1990; this paper), sapphirine-bearing meta-troctolite from Austkampane west of Byrdbreen (Ishizuka et al., 1995), and for a staurolite-bearing corundum–garnet gneiss (Asami et al., 1990).