LETTER

Feldspar thermometry in ultrahigh-temperature metamorphic rocks: Evidence of crustal metamorphism attaining ~1100 °C in the Archean Napier Complex, East Antarctica

TOMOKAZU HOKADA*

National Institute of Polar Research, 1-9-10 Kaga, Itabashi-ku, Tokyo 173-8515, Japan

ABSTRACT

Ultrahigh metamorphic temperatures attained in the mid- to lower-crust have been assessed by examining the mineral chemistry of ternary feldspars with relatively coarse exsolution lamellae from the Archean Napier Complex, East Antarctica. Chemical compositions of re-integrated perthitic, mesoperthitic and antiperthitic feldspars are calculated from the modal proportions and the chemical analyses of host and lamellar domains formed through exsolution. Based on ternary feldspar solvus models, re-integrated compositions of feldspars from a variety of rock types yield the minimum equilibrium temperatures ranging from 1000 to 1110 °C (0.8 GPa). These data confirm the suggestion that the regional thermal conditions of the Napier Complex reached or exceeded 1100 °C. As feldspar is one of the common constituents of the crustal rocks, this approach could be applicable to a wide variety of rocks in which feldspar represents exsolution textures.

INTRODUCTION

Peak conditions of high-temperature metamorphism are commonly estimated by using geothermobarometers or by examining mineral parageneses. Ultrahigh-temperature (UHT) metamorphism, which is defined as crustal metamorphism that occurred at peak conditions in excess of 900 °C at mid-to deep-crustal levels (Harley 1998), of the Archean Napier Complex in East Antarctica is indicated by the mineral parageneses sapphirine+quartz and/or osumilite (Dallwitz 1968; Ellis et al. 1980; Grew 1980, 1982; Motoyoshi and Hensen 1989) in Mg-rich rocks and inverted metamorphic pigeonite (Grew 1982; Harley 1987; Sandiford and Powell 1986, 1988; Harley 1998) in Fe-rich rocks. However, these diagnostic mineral parageneses are not common and, in addition, they do not give the actual temperatures attained, but only indicate that temperatures exceeded the lower temperature stability limits of the parageneses. Fe-Mg cation exchange geothermometers also have been applied to UHT metamorphic rocks (Harley 1983, 1985, 1998), but they give only closure temperatures (<1000 °C) of intracrystalline diffusion. Harley and Motoyoshi (2000) estimated the peak temperatures of a distinctive sapphirine quartzite from the Napier Complex as evidence for >1120 °C based on orthopyroxene containing up to 12 wt% Al₂O₃. None-theless, they noted that it remains to be demonstrated that these extremely high metamorphic temperatures were achieved over a regional scale in the Napier Complex.

Given the relative scarcity of critical assemblages, information constraining the maximum temperatures attained during the UHT metamorphism from a wide variety of common rock types is needed. Feldspars are ubiquitous in UHT metamorphic rocks, not only orthogneisses but also paragneisses of the Napier Complex and they commonly show perthitic, antiperthitic, or mesoperthitic exsolution textures (e.g., Harley 1985; Sheraton et al. 1987). Moreover, some of mesoperthitic feldspars are characterized by high anorthite contents (up to 17 mol%; Sandiford 1985) suggesting extremely high equilibrium temperatures. Similar compositions of mesoperthitic feldspars representing >1000 °C also have been reported from high-temperature granulite xenoliths in central Mexico (Hayob et al. 1989). The present study evaluates feldspar geothermometers that are applicable to UHT conditions and calculates equilibrium temperatures recorded in the hypersolvus ternary feldspars of the Napier Complex.

GEOLOGICAL SETTING

The Napier Complex occupies an area of 400 km × 200 km in Enderby Land, East Antarctica (Fig. 1). It consists of granulite-facies metamorphic rocks formed by multiple thermal events, including Late-Archean UHT metamorphism (Harley and Black 1997), and was subsequently intruded by unmetamorphosed diabase dikes at 1.2 Ga (Sheraton and Black 1981).

Analyzed samples were collected from Mt. Riiser-Larsen and Tonagh Island, both located in the highest-grade region characterized by the occurrence of sapphirine+quartz paragenesis in Mg-rich rocks (Fig. 1). Orthopyroxene-bearing felsic gneiss, garnet-bearing felsic gneiss, and two-pyroxene-bearing mafic granulite are dominant at both localities, whereas metapelitic and ultramafic gneisses are minor (Ishizuka et al. 1998; Osanai et al. 1999).

* Present address: Department of Geology, National Science Museum, 3-23-1 Hyakunin-cho, Shinjuku-ku, Tokyo 169-0073, Japan. E-mail: hokada@kahaku.go.jp