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U–Pb zircon ages and Hf isotopic compositions of metasedimentary rocks from the Grove Subglacial Highlands, East Antarctica: Constraints on the provenance of protoliths and timing of sedimentation and metamorphism

Wei Wang[a,b,*], Xiaochun Liu[a,*], Yue Zhao[a], Guanggao Zheng[a,b], Longyao Chen[a,b]

[a] Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China
[b] School of Earth and Space Sciences, Peking University, Beijing 100871, China

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ABSTRACT

To explore the geological evolution of the Grove Subglacial Highlands and their relationship with other terranes in the Prince Charles Mountains-Prydz Bay region of East Antarctica, 10 samples of metasedimentary rock were collected from glacial moraines in the Grove Mountains for zircon U–Pb dating and Hf isotopic analysis. Detrital zircon grains from all rocks have oscillatory zoned magmatic cores and diffusely zoned metamorphic rims. U–Pb ages from the cores are mainly concentrated in six populations: 3.4–3.2, 2.8, 2.6–2.3, 2.2–1.8, 1.8–1.5 and 1.5–0.95 Ga. Their initial ε_{Hf} values are −4.1 to +5.5, −12.5 to +4.9, −12.6 to +3.3, −13.0 to +4.7, −14.2 to +11.0, and −20.5 to +10.0, and their corresponding Hf model ages are 3.7–3.2, 3.4–3.1, 3.2–2.6, 2.9–2.1, 2.7–1.7, and 2.4–1.2 Ga, respectively. The maximum depositional ages of ca. 1090–940 Ma were calculated from the youngest detrital zircon cores of each sample. All age populations and Hf isotopic compositions can be found their provenances in the Prince Charles Mountains–Prydz Bay–Eastern Ghats region, indicating a genetic relationship between the two regions. However, we cannot rule out the possibility that the precursor materials of metasedimentary rocks from the Grove Subglacial Highlands were derived from the southern interior of the East Antarctic Shield (e.g., the Gamburtsev Subglacial Mountains and Vostok Subglacial Highlands). The late Mesoproterozoic/early Neoproterozoic (ca. 990–900 Ma) metamorphic event was not identified in our detrital zircon grains, and all metamorphic zircon rims were dated at ca. 560–540 Ma. This suggests that the collision suture of the late Neoproterozoic/Cambrian Prydz Belt should lie to the south of the Grove Subglacial Highlands.

1. Introduction

The Rayner Complex, which extends for more than 1000 km from Enderby Land in the west to Princess Elizabeth Land in the east, provides important clues about the role East Antarctica played in the formation of Gondwana. Geochronological data suggest that the major igneous activity recorded in the basement of the Rayner Complex, concentrated in the northern Prince Charles Mountains–Prydz Bay region, occurred during the period 1380–1020 Ma (Kinny et al., 1997; Liu et al., 2007b, 2009a, 2014a; Wang et al., 2008; Grew et al., 2012). However, the cover sequences that overlie the basement were deposited during the late Mesoproterozoic (Dirks and Wilson, 1995; Wang et al., 2008; Grew et al., 2012) or Neoproterozoic (Hensen and Zhou, 1995; Zhao et al., 1995; Kelsey et al., 2008). Most rocks in the complex record two periods of regional granulite-facies metamorphism, accompanied by widespread charnockitic and granitic magmatism at ca. 990–900 Ma and ca. 500 Ma, respectively (Young and Black, 1991; Manton et al., 1992; Kinny et al., 1997; Boger et al., 2000; Carson et al., 2000; Corvino et al., 2005; Liu et al., 2009a).

Unlike the late Mesoproterozoic basement in the Rayner Complex, the Grove Mountains south of Prydz Bay may represent a distinct Neoproterozoic basement (ca. 920–910 Ma) that was metamorphosed during a single late Neoproterozoic/Cambrian tectonic cycle (ca. 550–500 Ma) (Liu et al., 2007a). However, most of the basement in the Grove Mountains is hidden beneath the ice sheet, and the sparse exposures of bedrock are insufficient to fully characterize the geology of the entire area. Thus, the relationship between

* Corresponding authors at: Institute of Geomechanics, Chinese Academy of Geological Sciences, 11 Minzudaxue Nanlu, Beijing 100081, PR China. Tel.: +86 10 88815038; fax: +86 10 68422326.
E-mail address: liuxchqw@cags.ac.cn (X. Liu).

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the Grove Subglacial Highlands and the Rayner Complex remains poorly understood. In fact, a number of moraine belts are exposed on the glaciers of the Grove Mountains. Previous studies have concluded that the moraine erratics likely came from the southeastern subglacial bedrock of the Grove Mountains (Liu et al., 2009b; Hu et al., 2015), and may therefore provide important information about the geologic evolution of the Grove Subglacial Highlands.

In this contribution, we present U–Pb and Lu–Hf isotope data of detrital zircon grains from metasedimentary rocks collected from glacial moraines in the Grove Mountains. The aim is to constrain the possible protolith provenances and depositional ages of these metasedimentary rocks, and the timing of metamorphism. These data are then used to refine the geological history of the Grove Subglacial Highlands and its relationship with other nearby terranes, in the context of the evolution of East Gondwana.

2. Geological setting

The Prince Charles Mountains–Prydz Bay region is dominated by four Archean/Paleoproterozoic cratonic blocks, the late Mesoproterozoic Fisher Terrane, the early Neoproterozoic Rayner Complex and the late Neoproterozoic/Cambrian Prydz Belt (i.e., the reworked Rayner Complex). From north to south, the Archean/Paleoproterozoic blocks are the Vestfold Hills Block, the Rauer Group, the Lambert Terrane, and the Ruker Terrane (Fig. 1). The Vestfold Hills Block is characterized by magmatism and metamorphism at ca. 2.5 Ga (Black et al., 1991; Snape et al., 1997), and has an Archean/Palaeoproterozoic history that differs from that of the adjacent Rauer Group. The Rauer Group comprises Archaean tonalitic orthogneisses that yield emplacement ages of ca. 3.3 and 2.8 Ga (Kinny et al., 1993; Harley et al., 2013), interlayered with subordinate supracrustal paragneisses. The Lambert Terrane contains granitic–granodioritic orthogneisses with major protolith ages of ca. 2.4 and 2.1 Ga (Mikhalsky et al., 2006a, 2010; Corvino et al., 2008), and metasedimentary rocks that were deposited in the late Archean to early Palaeoproterozoic (Phillips et al., 2006). The Ruker Terrane consists of the Archean Ruker Complex, which records major igneous events at ca. 3.2 and 2.8 Ga (Boger et al., 2006; Phillips et al., 2006; Mikhalsky et al., 2006a, 2010), and overlying greenschist- to amphibolite-facies supracrustal sequences of various ages groups.

The Fisher Terrane, exposed north of the Lambert Terrane, is characterized by an abundance of 1300–1020 Ma mafic–felsic volcanism and intrusions, with subsequent amphibolite-facies metamorphism at 1020–940 Ma (Beliatsky et al., 1994; Kinny et al., 1997; Mikhalsky et al., 1999). To the immediate north, the Rayner Complex is dominated by granulite-facies gneisses that were formed mainly at ca. 990 Ma (Boger et al., 2000). Subsequent magmatism, metamorphism, and deformation occurred between 990 Ma and 900 Ma (Manton et al., 1992; Kinny et al., 1997; Boger et al., 2000; Carson et al., 2000). The Prydz Belt crops out along the Prydz Bay coastline and extends southward east of Amery Ice Shelf and cross into the Lambert Terrane and the Grove Mountains (Fitzsimons, 2003; Zhao et al., 2003; Liu et al., 2009b). The rocks in Prydz Bay consist mainly of mafic–felsic composite orthogneisses and migmatitic paragneisses, which are considered to be basement and cover sequences, respectively (Fitzsimons and Harley, 1991; Carson et al., 1995; Fitzsimons, 1997; Grew et al., 2012). Recently, most investigators have concluded that two major high-grade metamorphic events affected the eastern Amery Ice Shelf–Prydz Bay area: one at ca. 990–900 Ma and another at ca. 530 Ma (e.g., Hensen and Zhou, 1995; Wang et al., 2008; Liu et al., 2009a; Tong et al., 2014). The Archean basement rocks and exposed metasedimentary rocks of the Rauer Group may have also experienced two phases of high-grade metamorphism in the late Proterozoic and early Paleozoic (Tong and Wilson, 2006; Wang et al., 2007). However, some geologists argued that these rocks only subjected to high-grade metamorphism during the late Neoproterozoic/Cambrian (Kinny et al., 1993; Harley et al., 1998; Kelsey et al., 2003, 2007, 2008).

The Grove Mountains, located east of the southern Prince Charles Mountains, is considered an important part of the Prydz Belt in East Antarctica (Zhao et al., 2000, 2003; Mikhalsky et al., 2001a; Liu et al., 2006, 2007a, 2009b). This area consists mainly of high-grade metamorphic rocks and abundant charnockites and granites (Liu et al., 2006). The metamorphic rocks are dominated by orthopyroxene-bearing orthogneisses and mafic granulites, with minor garnet-bearing paragneisses and calc-silicate rocks (Liu et al., 2002, 2003). The protoliths of the orthogneisses and mafic granulites formed at ca. 920–910 Ma, then experienced late Neoproterozoic/Cambrian metamorphism at ca. 550–535 Ma (Liu et al., 2007a). The charnockites and granites were emplaced at 547–501 Ma (Liu et al., 2006). The moraine belts occur mainly on glaciers in the area near Mason Peaks, Wilson Ridge, Mount Harding, and Gale Escarpment (Fig. 2). Liu et al. (2009b) identified a number of late Neoproterozoic/Cambrian high-pressure (HP) mafic granulites from glacial moraines in the west of the Gale Escarpment. The *P*–*T* path calculated for the HP mafic granulites involved peak metamorphic conditions of 11.8–14.0 kbar and 770–840 °C, and a subsequent near-isothermal decompression of 6 kbar. These data provide evidence for a collisional tectonic setting for the late Neoproterozoic/Cambrian event near the Grove Mountains.

3. Sample description and analytical methods

3.1. Sample description

Ten samples of metasedimentary rocks were collected from glacial moraines in the Grove Mountains (Figs. 2 and 3). Sample localities, mineral assemblages, and dating results are listed in Table 1. These metasedimentary rocks are mainly paragneisses with a mineral assemblage of quartz, plagioclase, K-feldspar, biotite, garnet ± sillimanite in variable proportions. Garnet crystals are mostly allotriomorphic to hypidiomorphic and are in textural equilibrium with the other phases. Garnet contains inclusions of quartz, plagioclase, K-feldspar, biotite, and ilmenite. Sillimanite was observed in samples GR14-3-5, GR14-6-7, WR6-8, and GR14-15-1 as fibrolite and/or prismatic crystals around or within garnet. Sillimanite is also present in the metaquartzite sample (GR14-17-3) as fibrolite among the quartz grains, always found together with muscovite or biotite. Most of the biotite occurs around garnet or together with sillimanite. Rutile was only found in samples GR14-4-5, GR14-7-10, and GR14-11-1, and occurs as inclusions in garnet. Apatite, ilmenite, and zircon are minor (<2% by volume) components of most samples.

3.2. Analytical methods

Zircon grains were separated using conventional crushing and separation techniques, and then handpicked under a binocular microscope. Samples were mounted in epoxy resin, and then polished to expose grain centers in preparation for taking photomicrographs and for cathodoluminescence (CL) and LA–ICP–MS U–Pb isotopic analyses. LA–ICP–MS U–Pb dating and trace element analyses of zircon were conducted synchronously by LA–ICP–MS at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan, China, following the procedure described by Hu et al. (2008) and Liu et al. (2010). During the analyses, the output energy was set to 60 mJ, with a pulse repetition rate of 8 Hz and a 32 μm diameter