Precambrian Research 262 (2015) 1–19

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Charnockites and UHT metamorphism in the Bakhuis Granulite Belt, western Suriname: Evidence for two separate UHT events

Martijn Klaver[a,*], Emond W.F. de Roever[a], Josefine A.M. Nanne[a,b], Paul R.D. Mason[c], Gareth R. Davies[a]

[a] Department of Geology and Geochemistry, VU University Amsterdam, The Netherlands
[b] Department of Earth Sciences, Durham University, United Kingdom
[c] Faculty of Geosciences, Utrecht University, The Netherlands

ARTICLE INFO

Article history:
Received 3 November 2014
Received in revised form 31 January 2015
Accepted 5 February 2015
Available online 17 February 2015

Keywords:
Charnockite
Ultrahigh-temperature metamorphism
Bakhuis Granulite Belt
Guiana Shield
Zircon geochronology

ABSTRACT

The Bakhuis Granulite Belt in western Suriname is an ultrahigh-temperature (UHT) metamorphic terrain in the centre of the Paleoproterozoic (Transamazonian) Guiana Shield. Next to the UHT granulites, the belt contains a 30 by 30 km body of orthopyroxene-bearing granitoids: the Kabalebo charnockites. This setting offers an excellent opportunity to investigate the source and origin of charnockite magmatism and the common association of charnockites with (ultra)high-temperature metamorphic terrains. We present a detailed geochemical dataset and LA-ICPMS zircon U/Pb ages with the aim to investigate the geochemical and geochronological relationship between charnockite magmatism and UHT metamorphism in the Bakhuis Granulite Belt. The Kabalebo charnockites have a characteristic trace element signature with elevated K_2O, P_2O_5, Zr, REE and Ba coupled with mobile element depletion, which is a consequence of high-temperature melting of anhydrous but fertile granulitic crust. Field and geochemical evidence suggests that the intermediate granulites in the Bakhuis Granulite Belt are the source of the Kabalebo charnockites. The new U/Pb zircon ages indicate that charnockite magmatism (1993–1984 Ma) postdates UHT metamorphism (2.07–2.05 Ga) by at least 60 Myr. We argue that it is not possible to maintain a thermal anomaly >200 °C in excess of a normal geothermal gradient for such a prolonged period and hence conclude that the Bakhuis Granulite Belt has experienced two distinct periods in which temperatures >950 °C were reached in the lower crust.

The presence of comagmatic metadolerite enclaves in the charnockites establishes that mafic magmatism occurred contemporaneously with, and was the likely heat source for, charnockite magmatism at 1.99–1.98 Ga. In contrast, the 2.07–2.05 Ga UHT metamorphic event is not associated with felsic or mafic magmatism in the Bakhuis Granulite Belt or nearby Guiana Shield and postdates the suturing of the juvenile North Guiana TTG-greenstone belt with the West African Shield by at least 10 Myr. We postulate that the UHT metamorphism at 2.07–2.05 Ga is the result of mantle upwelling in a slab tear in the subducted West African slab that formed as the result of crustal scale shearing and boudinage. Prior to the final stabilisation of the Amazonian–West African Shield at 1.90 Ga, northward subduction at 1.99–1.98 Ga caused the emplacement of voluminous hot, mafic magma, resulting in partial melting of the Bakhuis granulite suite to form the Kabalebo charnockites. Charnockite magmatism was roughly contemporaneous with the emplacement of a large belt of shallow granites and felsic volcanic rocks in the SW Guiana Shield. Despite their similar age, the inherited zircon populations suggest that the charnockites are derived from a distinct, juvenile source while the felsic volcanic rocks include an Archaean protolith.

1. Introduction

Charnockites are orthopyroxene-bearing granitoid rocks that occur in a wide variety of tectonic settings with a diversity of field relationships that suggests multiple modes of formation (Bhattacharya, 2010; Frost and Frost, 2008; Rajesh and Santosh, 2012). Magnesian, calc-alkalic charnockites form a common rock type in high-grade metamorphic terrains and are regularly

* Corresponding author at: De Boelelaan 1085, 1081HV Amsterdam, The Netherlands. Tel.: +31 020 59 83725.
E-mail address: martijn.klaver@vu.nl (M. Klaver).

http://dx.doi.org/10.1016/j.precamres.2015.02.014
0301-9268/

associated with ultrahigh-temperature (UHT) metamorphic rocks (Bhattacharya, 2010; Frost and Frost, 2008; Newton, 1992). These charnockites are often contemporaneous with peak metamorphic conditions (e.g. Korhonen et al., 2013; Peng et al., 2010), but can also be generated during subduction preceding the collisional event and UHT metamorphism (e.g. Rajesh et al., 2014) or due to post-collisional decompression (Newton, 1992; Zhao et al., 1997). The post-collisional charnockites often have a characteristic trace element signature of high K_2O, TiO_2, P_2O_5 and Zr combined with low fluid-mobile element (Cs–Rb–U–Th) concentrations, which is obtained through melting of dehydrated but fertile lower crust at elevated crustal temperatures (e.g. Kilpatrick and Ellis, 1992; Young et al., 1997; Zhao et al., 1997). Regardless whether charnockites are pre-, syn- or post-collisional, crustal melting at temperatures >900 °C and UHT metamorphism generally require an external heat source (Brown and Korhonen, 2009; Clark et al., 2011; Collins, 2002). Primitive mantle melts play a potentially important role in facilitating UHT conditions, even though voluminous (ultra)mafic rocks are scarce in many UHT occurrences (Kelsey and Hand, 2014). Nevertheless, mafic underplating has been proposed as the heat source (e.g. Liu et al., 2006), but recently ridge subduction has been inferred as the dominant process responsible for charnockite magmatism and ultrahigh-temperature (UHT) metamorphism in several locations (e.g. Peng et al., 2012; Santosh et al., 2012; Zhang et al., 2010).

A 30 by 30 km body of igneous charnockite, the Kabalebo charnockites, has been recognised in the southwest of the Bakhuis Granulite Belt (BGB) in western Suriname. The BGB is located in the centre of the Paleoproterozoic Guiana Shield and experienced UHT metamorphism (max. 1000–1050 °C at 0.85 GPa) at the end of the main phase of the Transamazonian Orogeny at 2.07–2.05 Ga (De Roever et al., 2003; Delor et al., 2003a). Emplacement of the Kabalebo charnockites was believed to be contemporaneous with the UHT event (De Roever et al., 2003; Kroonenberg and de Roever, 2010), similar to the charnockite magmatism and UHT metamorphism documented in the North China Craton by Peng et al. (2010) or Limpopo Mobile Belt by Rajesh et al. (2014). Geochronological confirmation, however, is lacking. Here we report a detailed petrogenetic study of the Kabalebo charnockites and granulites, including LA-ICPMS zircon U–Pb dating, to investigate the association of charnockite magmatism and UHT metamorphism in the BGB. To aid the interpretation of the new geochronological data, a major-, trace elements and Sr–Nd isotope study of the Kabalebo charnockites complemented with trace element and Hf isotope analysis on the dated zircons was performed. The new data are used to refine the current models for the evolution of the Guiana Shield during the Transamazonian Orogeny.

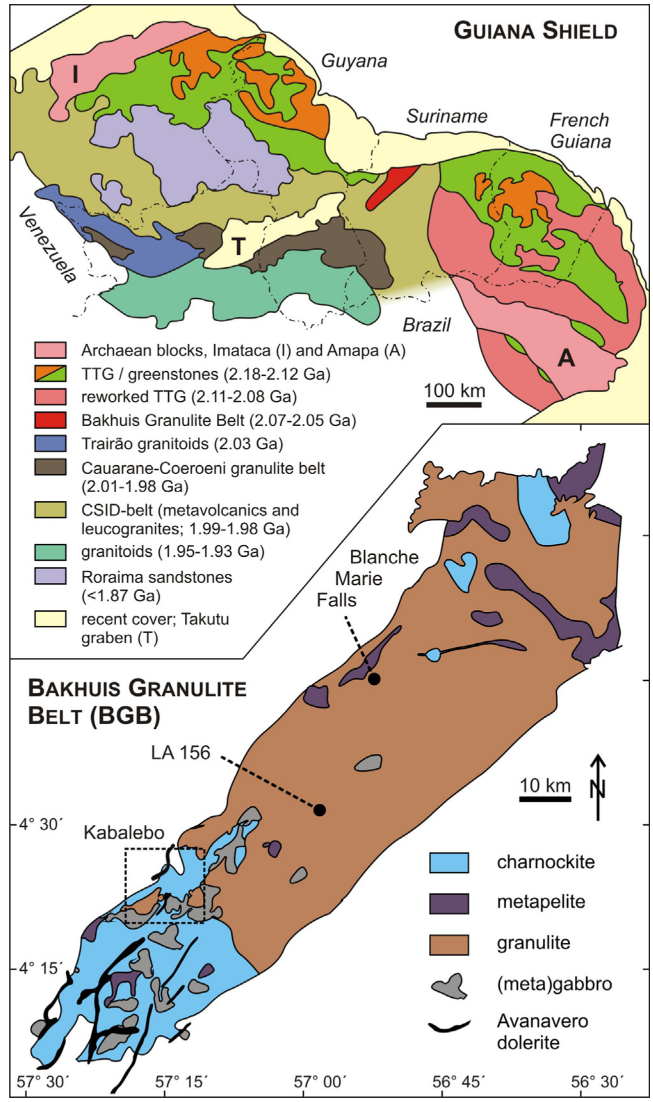

Fig. 1. Geological map of the Transamazonian Guiana Shield and Bakhuis Granulite Belt, modified after Delor et al. (2003a), Fraga et al. (2009) and De Roever et al. (2003). The lower map of the BGB is a detailed map of the red region in the upper Guiana Shield map. The dashed box labelled "Kabalebo" in the BGB map indicates the sampling area of the Kabalebo charnockites. See text for further discussion.

2. Geological setting

The Bakhuis Mountains in western Suriname are the topographical expression of a high-grade metamorphic belt: the Bakhuis Granulite Belt (BGB; Fig. 1). The NE–SW oriented belt, approximately 30–40 km wide and 100 km long, is incorporated in a horst-like structure bounded on both sides by steeply dipping shear zones. Rubidium–strontium and K–Ar ages determined on micas indicate formation of these shear zones during the Nickerie metamorphic event at 1.2 Ga (Cordani et al., 2010; Priem et al., 1971). Metapelitic lenses, banding and foliation in the belt reflect an elongated dome structure, which is cut off by the SE shear zone. Doming and exhumation might have initiated at the end of the main phase of the Transamazonian Orogeny (~2.06 Ga) and subsequent reactivation during the Tertiary gave the belt its present-day shape (Delor et al., 2003a).

The granulite suite of the BGB consists of mafic (30–35%) and intermediate (55%) granulites. Metapelites and quartzitic lithologies constitute the remaining 10–15% of the suite. Conspicuous and common compositional banding at the centimeter to meter scale and the presence of intercalated metapelitic, spessartine quartzite and calc-silicate bands suggest a predominantly sedimentary and/or volcanic protolith of the granulites. Orthopyroxene is invariably present in the granulite suite and its occurrence as a primary phase in leucosomes indicates migmatisation under granulite facies conditions. Peak metamorphic conditions reached 950–1050 °C at 0.85–0.90 GPa and hence the BGB is classified as an ultrahigh-temperature metamorphic terrain (De Roever et al., 2003). In the southwest of the belt, the granulites show an abrupt transition to orthopyroxene-bearing granitoids: the Kabalebo charnockites. Gabbroic and metagabbroic intrusions are scattered throughout the belt but occur more frequently in the southwest. Narrow metadolerite dikes are a common feature in the BGB. A variable degree of metamorphic overprint of the mafic bodies and dikes suggests that multiple generations of