Chemical Geology 328 (2012) 259–277

Contents lists available at SciVerse ScienceDirect

Chemical Geology

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

Tholeiite–Boninite terrane in the North Qilian suture zone: Implications for subduction initiation and back-arc basin development

Xiaohong Xia [a], Shuguang Song [a,*], Yaoling Niu [b,c]

[a] MOE Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, China
[b] School of Earth Sciences, Lanzhou University, Lanzhou 730000, China
[c] Department of Earth Sciences, Durham University, Durham DH1 3LE, UK

A R T I C L E I N F O

Article history:
Accepted 1 December 2011
Available online 8 December 2011

Keywords:
Tholeiite
High-Ca boninite
Infant arc magmatism
Back-arc basin
North Qilian suture zone

A B S T R A C T

A tholeiite–boninite terrane occurs as a ~4.5-km-thick massif with lavas and intrusions in the Dachadaban (DCDB) area, the middle part of the North Qilian oceanic-type suture zone. It comprises two distinct lithological groups: the lower tholeiite unit and the upper boninite unit. The lower tholeiite unit consists of massive lava flows and subordinate gabbro intrusions with MORB-like characteristics that could represent 5–6% melting of an enriched MORB mantle. In contrast, the overlying boninite unit consists of pillow lavas, dolerite dykes and gabbro intrusions and shows high-Ca boninite features that may be formed by continuous melting of the extremely refractory mantle with the aid of a combination of the elevated mantle potential temperature of 1380–1460 °C at depths of 42–66 km and involvement of slab-derived hydrous fluids/melts. Zircon U–Pb SHRIMP dating shows that lower tholeiite magmatism lasted for at least 12 M.y. from 517 Ma to 505 Ma and upper boninite volcanism occurred between 505 and 487 Ma, which is consistent with the earliest age (486 ± 7 Ma) of the SSZ-type ophiolite belt immediately north of the Dachaidaban (DCDB) tholeiite–boninite terrane. The lower tholeiites are considered to represent the products of earliest infant arc magmatism by decompression-induced partial melting of the relatively "dry" and fertile upwelling mantle in response to the onset of subduction. The upper boninite unit with younger age of 487 ± 9 Ma is interpreted as earliest products of infant arc splitting and subsequent back-arc basin development. Therefore, the long-lived DCDB tholeiite–boninite sequence presents a key lithological record of early stages of supra-subduction zone magmatic activity evolved from subduction initiation at ~517 Ma to back-arc extension at ~487 Ma.

1. Introduction

A boninite is a relatively rare, but important primitive magma that currently erupts at modern arc—back-arc systems (e.g., Hawkins, 1976; Meijer, 1980; Crawford et al., 1981; Hickey and Frey, 1982; Reagan and Meijer, 1984; Falloon et al., 1987; Crawford et al., 1989; Boespflug et al., 1990; Pearce et al., 1992; Monzier et al., 1993; Hawkins and Castillo, 1998; Falloon et al., 2008; Niedermeier et al., 2008; Rubin et al., 2009). It has also been identified in a number of ophiolites and ophiolite-like terranes such as the Troodos ophiolite (e.g., Cameron, 1985; Flower and Levine, 1987), the Koh ophiolite (Sameshima et al., 1983; Meffre et al., 1996) and the Betts Cove ophiolite (Bédard et al., 1998; Bédard, 1999). Experimental studies and trace element modeling have shown that, in addition to the effect of water, elevated mantle potential temperature and mantle decompression are required to produce boninite magmas (Mysen and Kushiro, 1977; Flower and Levine, 1987; Sobolev and Danyushevsky, 1994; Bédard, 1999; Falloon and Danyushevsky, 2000; Sugawara, 2000). Boninites and boninite-like terranes are thus considered to be products of lithospheric extension and asthenospheric upwelling in response to the initiation of a subduction zone or back-arc opening (Crawford et al., 1981; Hickey and Frey, 1982; Tatsumi et al., 1983; Hawkins et al., 1984; Flower and Levine, 1987; Crawford et al., 1989; Falloon et al., 1992; Stern and Bloomer, 1992; Monzier et al., 1993; Meffre et al., 1996; Bédard et al., 1998; Bédard, 1999; Macpherson and Hall, 2001; Ishikawa et al., 2002; Hall et al., 2003; Ishizuka et al., 2006; Dilek and Thy, 2009; Pearce and Robinson, 2010).

Systematic stratigraphy, geochemistry and geochronology studies of boninite terranes from Izu-Bonin-Mariana (IBM) subduction system (Meijer, 1980; Arculus et al., 1992; Ishizuka et al., 2006; Dilek and Thy, 2009) have confirmed the view that boninites are generated through processes associated with subduction initiation and fore-arc extension (e.g., Stern and Bloomer, 1992; Bloomer et al., 1995; Hall et al., 2003; Stern, 2004). The subduction initiation model account for most geological and geophysical characteristics of the western Pacific Eocene boninite (Hall et al., 2003; Ishizuka et al., 2006) and has also been applied to the Central Asian SSZ ophiolite belt over thousands of kilometers (Dilek and Thy, 2009; Pearce and Robinson, 2010), the

* Corresponding author. Tel.: +86 10 62767729.
E-mail address: sgsong@pku.edu.cn (S. Song).

0009-2541/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.chemgeo.2011.12.001

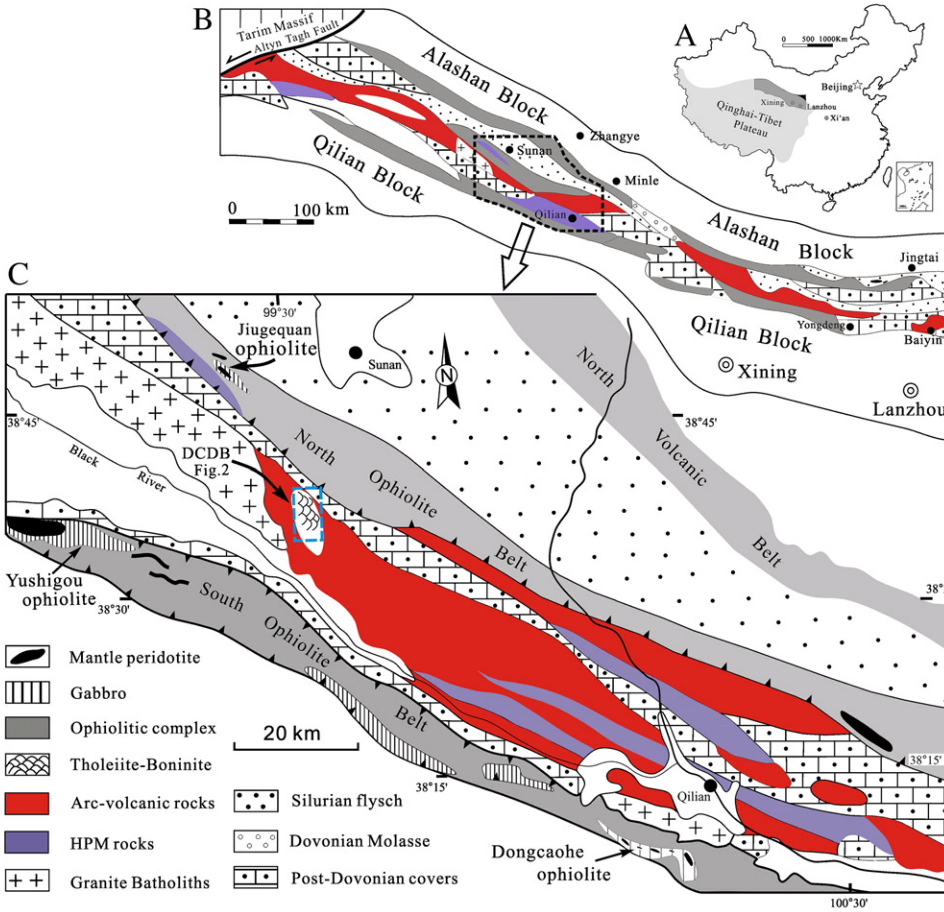

Fig. 1. (A) Schematic location for the North Qilian orogenic belt in Qinghai-Tibet plateau. (B) Geological map of the North Qilian Orogenic belt (simplified after Feng and He, 1995). (C) Enlarged area showing the locations of Dachadaban (DCDB) tholeiite–boninite terrane.
Modified after Song et al. (2007).

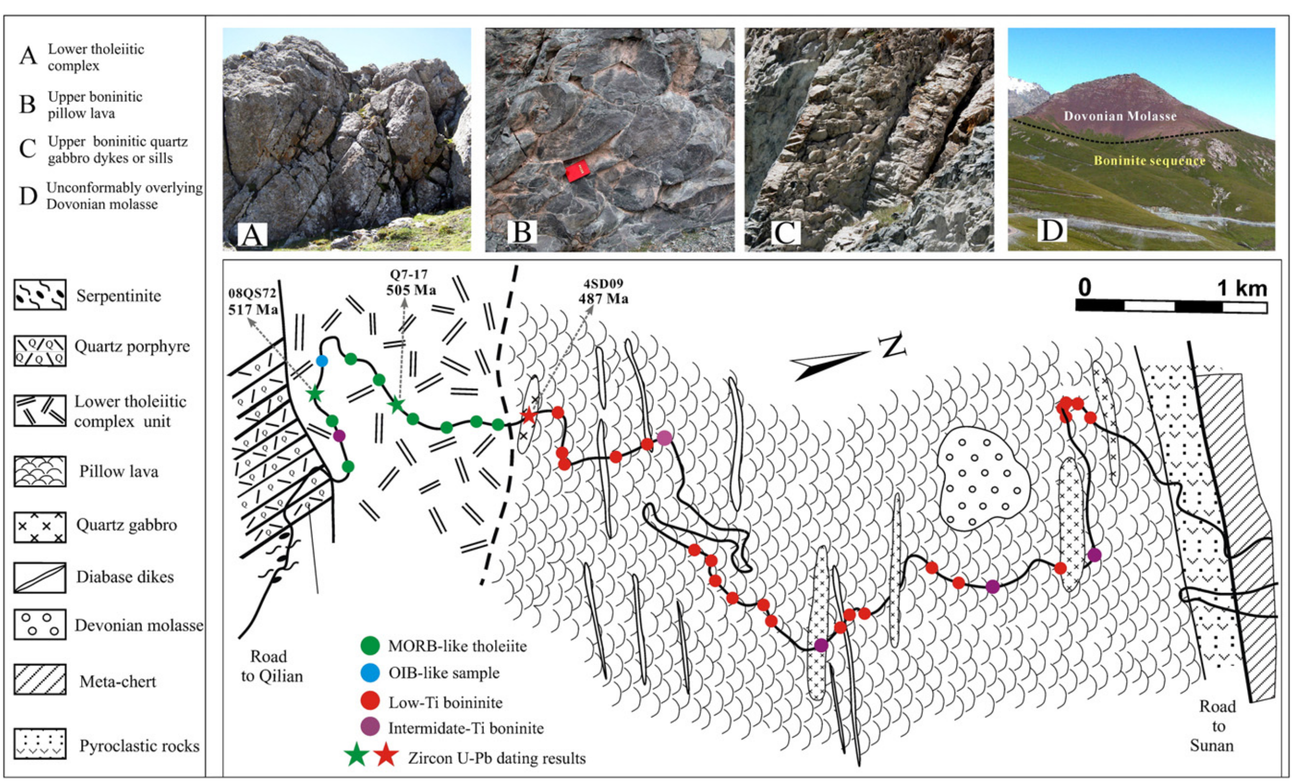

Fig. 2. Detailed geological map with field photos showing main lithological–geochemical units, stratigraphical relationships and sample types through DCDB tholeiite–boninite terrane.