Lithos 112 (2009) 149–162

Contents lists available at ScienceDirect

Lithos

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

Geochemistry and geochronology of the metamorphic sole underlying the Xigaze Ophiolite, Yarlung Zangbo Suture Zone, South Tibet

Carl Guilmette [a,*], Réjean Hébert [a], Chengshan Wang [b], Mike Villeneuve [c]

[a] *Département de géologie et de génie géologique, Université Laval, Québec, Canada G1K 7P4*
[b] *School of Earth Sciences and Mineral Resources, China University of Geosciences, Xueyuan Road #29, Beijing, PR China*
[c] *Geochronology Section, Geological Survey of Canada, 601 Booth St., Ottawa, ON, Canada K1A 0E8*

ARTICLE INFO

Article history:
Received 3 December 2007
Accepted 11 May 2009
Available online 18 june 2009

Keywords:
Amphibolite
$^{40}Ar/^{39}Ar$ dating
Geochemistry
Metamorphic sole
Tibet
Suprasubduction zone

ABSTRACT

Strongly foliated amphibolite clasts are found embedded within the ophiolitic mélange underlying the Xigaze Ophiolite near Bainang and Angren, Yarlung Zangbo Suture Zone, Southern Tibet. These high-grade amphibolites are interpreted as remnants of a dismembered subophiolitic metamorphic sole that would have formed during the inception of a subduction. They include garnet-clinopyroxene amphibolites, clinopyroxene amphibolites and common amphibolites. Petrographic descriptions, mineral chemistry and thermobarometry of these rocks can be found in a companion paper [Guilmette, C., Hébert, R., Dupuis, C., Wang, C.S., Li, Z. J., 2008. Metamorphic history and geodynamic significance of high-grade metabasites from the ophiolitic mélange beneath the Yarlung Zangbo Ophiolites, Xigaze area, Tibet. Journal of Asian Earth Sciences, 32, 423–437.]. The geochemistry of the amphibolites confirms that their protoliths were igneous mafic rocks of basaltic to pyroxenitic composition that were likely part of an upper oceanic crust. Rare Earth Elements contents are suggestive of an N-MORB origin. However, enriched LILEs and depleted Nb–Ta–Ti when compared to N-MORBs rather suggest a suprasubduction zone influence. A large proportion of the overlying ophiolitic mafic rocks share the same geochemical characteristics, suggesting the protoliths of the amphibolites might have crystallized in the same environment as the Xigaze ophiolitic crust, likely in a back-arc basin. $^{40}Ar/^{39}Ar$ step-heating dating of hornblende concentrates from three samples yielded ages of 123.6 ± 2.9 Ma, 127.7 ± 2.2 Ma and 127.4 ± 2.3 Ma. These cooling ages are slightly younger or overlapping magmatic and sedimentary ages obtained from the overlying ophiolite. All these new data support a model in which the ophiolitic crust and the protolith of the amphibolites were formed along the same spreading center above a subduction zone. The demise of the early subduction circa 130 Ma forced the inception of a new subduction zone at the SSZ spreading axis, burying SSZ mafic rocks underneath a SSZ ophiolitic mantle.

1. Introduction

Dynamothermal soles, or simply metamorphic soles, are strongly deformed and metamorphosed rocks found as welded sheets underlying the mantle section of many Tethyan-type ophiolites (Wakabayashi and Dilek, 2000, 2003 for reviews). Such rocks provide crucial information regarding the evolution of the overlying ophiolite, especially about its “emplacement” (Malpas, 1979; Spray, 1984; Jamieson, 1986; Hacker, 1990; Hacker et al., 1996; Wakabayashi and Dilek, 2000, 2003; Guilmette et al., 2008). Emplacement of an ophiolite, whether over an intraoceanic subduction zone or over a passive margin, is a critical event in understanding the early stages of a collision.

In the Tibetan–Himalayan orogen (Fig. 1), the Yarlung Zangbo Suture Zone (YZSZ), in South Tibet, contains the remnants of the ocean that separated India from Asia prior to the collision: the Tethys. The Yarlung Zangbo Ophiolites (YZO) are interpreted as relics of this oceanic basin. The genesis of the YZO and the mechanisms, timing and setting of their emplacement are critical regarding the setting and timing of the initial collision between the two continents. However, none of these are well constrained (Allègre et al., 1984; Girardeau et al., 1985, Zhou et al., 1996; Mahoney et al., 1998; Aitchison et al., 2000; Huot et al., 2002; Aitchison et al., 2003; Hébert et al., 2003; Malpas et al., 2003; Xia et al., 2003; Aitchison and Davis, 2004; Zyabrev et al., 2004; Xu and Castillo 2004; Abrajevitch et al., 2005; Dubois-Côté et al., 2005; Ding et al., 2005; Zhang et al., 2005; Dupuis et al., 2005a,b, 2006; Aitchison et al., 2007; Chen and Xia, 2008; Guilmette et al., 2008; Bédard et al., 2009).

The Xigaze Ophiolite (XO), in central Tibet, is the largest and best studied of all YZO, with continuous outcrops for over 250 km along-strike between Dazhuqu and Angren (Fig. 2), east and west of Xigaze in South Tibet. Based on field relationships, mineralogy, texture,

* Corresponding author. Tel.: +1 418 656 2131x12630; fax: +1 418 656 7339.
E-mail address: carl.guilmette.1@ulaval.ca (C. Guilmette).

0024-4937/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.lithos.2009.05.027

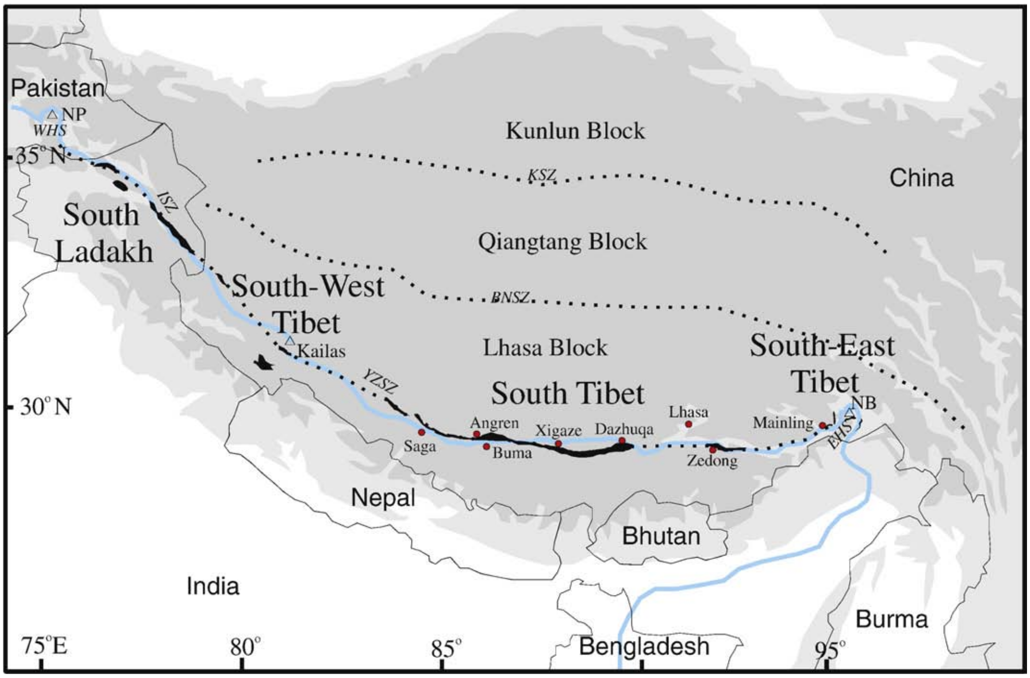

Fig. 1. Geological, physiographical and geographical context of the Tibetan Plateau and surrounding areas. Dotted lines represent the main suture zones. Black lenses represent the main ophiolitic complexes. Main cities or important villages are indicated next to dots. Plain black lines are international borders. White areas are below 1000 m, pale grey areas lie in between 1000 and 4000 m altitude whereas deep grey areas are higher than 4000 m. YZSZ = Yarlung Zangbo Suture Zone, ISZ = Indus Suture Zone, BNSZ = Bangong–Nujiang Suture Zone, KSZ = Kunlun Suture Zone, NP = Nanga Parbat, NB = Namche Barwa, WHS = Western Himalayan Syntaxis, EHS = Eastern Himalayan Syntaxis. Modified from Hodges (2000).

structure and metamorphic history, Guilmette et al. (2008) showed that strongly foliated amphibolite blocks found in the ophiolitic mélange underlying the XO could represent remnants of a metamorphic sole that would have formed during emplacement of the ophiolite as the hangingwall of a newborn subduction zone. Thus, geochemical and geochronological studies of these rocks might yield important clues regarding the pre-collisional setting within the Tethys. Here, we present major and trace element whole rock geochemistry altogether with new $^{40}Ar/^{39}Ar$ on hornblende ages for the rocks described by Guilmette et al. (2008). The geochemical and geochronological data are hereby presented in order to assess the nature of the protolith and the tectonic setting in which it was formed and also to locate in time the metamorphic history proposed by Guilmette et al. (2008). This information will then be used to better constrain the evolution of the XO and surrounding terranes in South Tibet.

1.1. Geological setting

The appellation YZO refers to all ophiolites outcropping along the Yarlung Zangbo River, within the YZSZ, including from west to east the Yungbwa, Saga, Sangsang, Xigaze, Zedong–Luobusa and the Eastern Himalayan Syntaxis ophiolites (Fig. 1). The XO, our study area, is situated in the central section of the YZSZ (Fig. 1). It comprises all the different ophiolitic massifs outcropping almost continuously from Angren to Dazhuqu along a 250 km long segment (Fig. 2).

In the study area (Fig. 2), the suture is oriented E–W. Late backthrusting overturned the sequences (Tapponier et al., 1981) so that they now dip steeply towards the south. However, stratigraphic relationships and shear senses indicate early thrusting of the ophiolitic nappes southward over Indian sedimentary rocks (Girardeau et al., 1985). The XO consists of a chain of eight distinct ophiolitic massifs that show lithological and geochemical similarities. These massifs were named after the nearest localities (Hébert et al., 2003) which are, from west to east: the Buma, Lhaze, Liuqu, Jiding, Beimarang, Qunrang, Bainang and Dazhuqu massifs (Fig. 2). In the XO, the ophiolitic sequence typically includes, from bottom to top, an ophiolitic mélange issued from the dismemberment of the base of the ophiolite during obduction (Huot et al., 2002; Dupuis et al., 2005a,b), a tectonized and serpentinized harzburgitic upper mantle section intruded by mafic magmas, a very thin or absent lower crust, an important sill complex and a volcano-sedimentary cover. However, most massifs show an incomplete Penrose-type section. Previous studies indicate that the crustal part of the XO formed within an Early Cretaceous (120 ± 10 Ma, Goepel et al., 1984; 126 ± 1.5 Ma, Malpas et al., 2003; Barremian–Aptian, Zyabrev et al., 1999; Aitchison et al., 2003; 132.0 ± 2.9 Ma, Chan et al., 2007) supra-subduction zone (SSZ) (Huot et al., 2002; Hébert et al., 2003; Xia et al., 2003; Xu and Castillo, 2004; Dubois-Côté et al., 2005; Dupuis et al., 2005a,b; Chen and Xia, 2008; Bédard et al., 2009) or mid ocean ridge (MOR) (Nicolas et al., 1981; Allègre et al., 1984; Girardeau et al., 1985; Mahoney et al., 1998; Zhang et al., 2005). However, even if Zhang et al. (2005) documented N-MORBs in the XO, they still agree that they most likely formed within a SSZ. Thus, given the strongly depleted and refertilized nature of the harzburgitic mantle, the large proportion of documented SSZ basalts (both BABBs and VABs) over N-MORBs, the absence or rarity of boninites, the presence of primary hornblende in gabbros and the presence of a volcaniclastic sequence conformably overlying the radiolarian chert cover, we will consider here, following the discussion provided in Metcalf and Shervais (2008), that the XO is of SSZ origin. The presence of subordinate N-MORBs documented by Mahoney et al. (1998) and Zhang et al. (2005) (no Ti or Ta analyses) supports the hypothesis that the XO represent the remnants of a mature back-arc basin (Dubois-Côté et al., 2005), where the subduction input is minor and sometimes nil, rather than a fore-arc (Aitchison et al., 2000). Paleomagnetic studies suggest that the site of genesis of the XO was located at equatorial latitudes during the Early Cretaceous (Abrajevitch et al., 2005).

The Barremian–Aptian ophiolitic volcano-sedimentary cover (Aitchison et al., 2003) shares its upper contact with Albian volcaniclastic shales and sandstones of the Xigaze group (Dürr, 1996; Wan et al., 1998). Early interpretations suggested that the contact was of depositional nature (Allègre et al., 1984; Burg et al.,