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Zircon U-Pb geochronological constraints on rapid exhumation of the mantle peridotite of the Xigaze ophiolite, southern Tibet

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ABSTRACT

The Xigaze ophiolite outcrops in the central segment of the Yarlung Zangbo suture zone, southern Tibet. It is characterized by large amounts of ultramafic units with minor mafic rocks. The mafic rocks consist of gabbros, diabases and basalts. The gabbroic rocks of the Xigaze ophiolite occur as layered bodies or isotropic dikes intruding into mantle sections. Hectometric-sized gabbroic bodies are well-preserved in Dazhuqu, Baigang and Jiding. However, their formation time and generation mechanism are not systematically proposed or well understood. In this study, nine samples of mafic rocks from the Xigaze ophiolite, including seven gabbros and two rodingites (altered from diabases), were selected for in situ zircon U-Pb and Hf isotopic analyses. The geochemical feature suggested that these rocks formed by the intrusion of melts of normal mid-ocean ridge (N-MORB) type. The U-Pb data yielded identical ages of 124–129 Ma within uncertainties. Positive zircon $\varepsilon_{Hf}(t)$ values indicated that these samples had an origin of depleted mantle source. Combined with previous studies on mafic dikes, amphibolite blocks and radiolarian cherts, it can be concluded that the Yarlung Zangbo ophiolites formed over a short period of time from 119 to 132 Ma. Hence, a rapid exhumation of the mantle peridotites and gabbroic rocks of the Xigaze ophiolite may have occurred to get intrusion of the diabase dikes and sills. It excludes the existence of a long-term ancient magma chamber or lens. It is more likely that the gabbroic rocks are a series of plutonic intrusions beneath a fossil slow-spreading ridge, rather than products of magma chambers. Therefore, the "Chapman detachment model" may be applied to the generation of the Yarlung Zangbo ophiolites.

1. Introduction

Ophiolites represent remnants of ancient oceanic lithosphere (e.g., Coleman, 1977; Dewey and Bird, 1971; Dilek, 2003; Dilek and Furnes, 2014). Though having been studied for about 200 years, the genesis of ophiolites is still intensely debated (Alabaster et al., 1982; Dilek and Furnes, 2011; Miyashiro, 1973; Pearce, 2003; Piccardo et al., 2004). The classical "Penrose model", established >40 years ago, implied a mature magmatic crust genetically linked to the mantle residue (Cann, 1974; Escartín and Canales, 2011; Pallister and Hopson, 1981; Smewing, 1981). This model has been further improved to be associated with an axial melt lens (AML) with a limited scale beneath a fast- or intermediate- spreading ridge (Canales et al., 2005; Collier and Sinha, 1990; Crawford et al., 1999; Detrick et al., 1987), although its role in the generation of the lower oceanic crust is still controversial (Boudier et al., 1996; Buck, 2000; Chenevez and Nicolas, 1997; Coogan et al., 2002; Garrido et al., 2001; Henstock et al., 1993; Kelemen et al., 1997; Korenaga and Kelemen, 1997, 1998; MacLeod and Yaouancq, 2000; Nicolas et al., 1988; Phipps-Morgan and Chen, 1993; Quick and Denlinger, 1993). However, for slow-spreading ridges (e.g., the Mid-Atlantic Ridge and the Southwest Indian Ridge), the AML is either absent or intermittent because of low melt supply and large heat loss (Kusznir, 1980; Lewis, 1983; Nicolas et al., 1988; Sinton and Detrick, 1992; Sleep, 1975). Recently, recognition of widespread large-offset detachment faults at slow- and ultraslow- spreading ridges has led to definition of a new "Chapman model" of seafloor spreading (Buck et al., 2005; Escartín et al., 2008; Escartín and Canales, 2011; Maffione et al., 2013). It was demonstrated in this model that detachment faults may play a central role in magmatic accretion along slow-spreading ridges (Escartín et al., 2008 and references therein). However, their effect on ophiolites forming in fossil slow-spreading ridges remains uncertain (Liu et al., 2014; Wu et al., 2014).

To further advance the understanding of this issue, the Yarlung Zangbo ophiolites in southern Tibet were studied in this paper. Recently,

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some evidence implied that the entire Yarlung Zangbo ophiolite belt, from west to east, may have formed in a short duration from 120 to 130 Ma (Dai et al., 2013; Wu et al., 2014; Zhang et al., 2016a; Zhang, 2014). However, this hypothesis still needs further discussion because of two unresolved doubts. One is the Jurassic ages obtained for the Zedang and Luobusa ophiolites in the eastern segment (Liu et al., 2013; Wei et al., 2006a; Zhong et al., 2006; Zhou et al., 2002). Another is the poor constraints on the formation time of the gabbros within the Yarlung Zangbo ophiolites, especially those with typical igneous foliation (Wu et al., 2014). Layered gabbros have only been found in the Xigaze ophiolite, which outcrops in the central segment of the suture (Girardeau et al., 1985a; Wu et al., 2014). They were interpreted to be generated in a series of small magma chambers or lens (Hopson, 2007; Wang et al., 1987). However, geological studies have suggested that the Yarlung Zangbo ophiolites may have formed in a slow-spreading ridge (Girardeau et al., 1985a, 1985b; Liu et al., 2014; Nicolas et al., 1981; Wu et al., 2014; Zhang et al., 2016a; Zhang, 2014), where magma chambers may be absent (Kusznir, 1980; Lewis, 1983; Sinton and Detrick, 1992). Hence, it needs further discussion whether or not the gabbros are products of ancient long-term magma chambers like those in Oman, which underwent repeated injections of melts and large-scale magmatic flow. A significant field occurrence in the Xigaze ophiolite is that the gabbros are intruded ubiquitously by diabase dikes and sills, which suggests that the gabbros have been exhumed to a shallower depth when the diabases generated. It is vital, therefore, to decipher the geochronological association of these two types of rocks. In other words, a long-term magma chamber may be absent or intermittent if the gabbros and diabases formed synchronously. We therefore carried out a combined U-Pb and Lu-Hf isotopic analyses of zircon separates from representative localities of the Xigaze ophiolite. Our results, combined with other geochronological studies focusing on this area, help us further constrain the tectonic evolution history of the Yarlung Zangbo ophiolites.

2. Geological setting

The Tibetan Plateau was amalgamated by numerous terranes including, from north to south, the Kunlun-Qilian, Songpan-Ganze, Qiangtang and Lhasa (Dewey et al., 1988; Metcalfe, 2013; Pan et al., 2012; Şengor and Natalin, 1996; Yin and Harrison, 2000) (Fig. 1a). These terranes are separated by suture zones forming by closure of the Paleo- and Neo-Tethys Oceans (Pan et al., 2012; Zhu et al., 2013). The Yarlung Zangbo suture zone is the southernmost and youngest suture. It records the northward subduction of the India plate beneath the Lhasa terrane and marks the site where the Neo-Tethys Ocean closed (Nicolas et al., 1981; Pan et al., 2012; Tapponnier et al., 1981; Yin and Harrison, 2000; Zhu et al., 2013).

Ophiolites in the Yarlung Zangbo suture zone make up the most famous ophiolite belt in China and have been studied for >30 years (Girardeau et al., 1985a, 1985b; Hébert et al., 2012; Nicolas et al., 1981; Wang et al., 1987; Wu et al., 2014). The ophiolite belt extends in a nearly E–W trending for >2000 km from Nanga Parbat in the west to Namche Barwa syntaxes in the east (Hébert et al., 2012). Overall, the Yarlung Zangbo ophiolites have a complete ophiolitic sequence, composed of predominant mantle peridotites, minor gabbros, sheeted sills and pillow lavas (Girardeau et al., 1985a, 1985b; Nicolas et al., 1981; Wang et al., 1987). They are geographically divided into three segments from west to east. Ophiolites in the western segment are distributed from Dongpo to Sangsang (Fig. 1b). Ophiolites outcropping in Dongpo, Purang (Yungbwa), Xiugugabu and Zhongba are characterized by the occurrence of large amounts of mantle peridotites but very rare mafic rocks (Bezard et al., 2011; Dai et al., 2011; Liu et al., 2014). The ultramafic massifs mainly consist of fresh refractory harzburgites with minor lherzolites and dunites (Liu et al., 2014; Xiong et al., 2011). They are crosscut by pyroxenite, gabbroic and diabase dikes (Dai et al., 2011; Liu et al., 2014; Wu et al., 2014; Xia et al., 2011; Xiong et al., 2011). The Saga and Sangsang ophiolites are composed of mantle

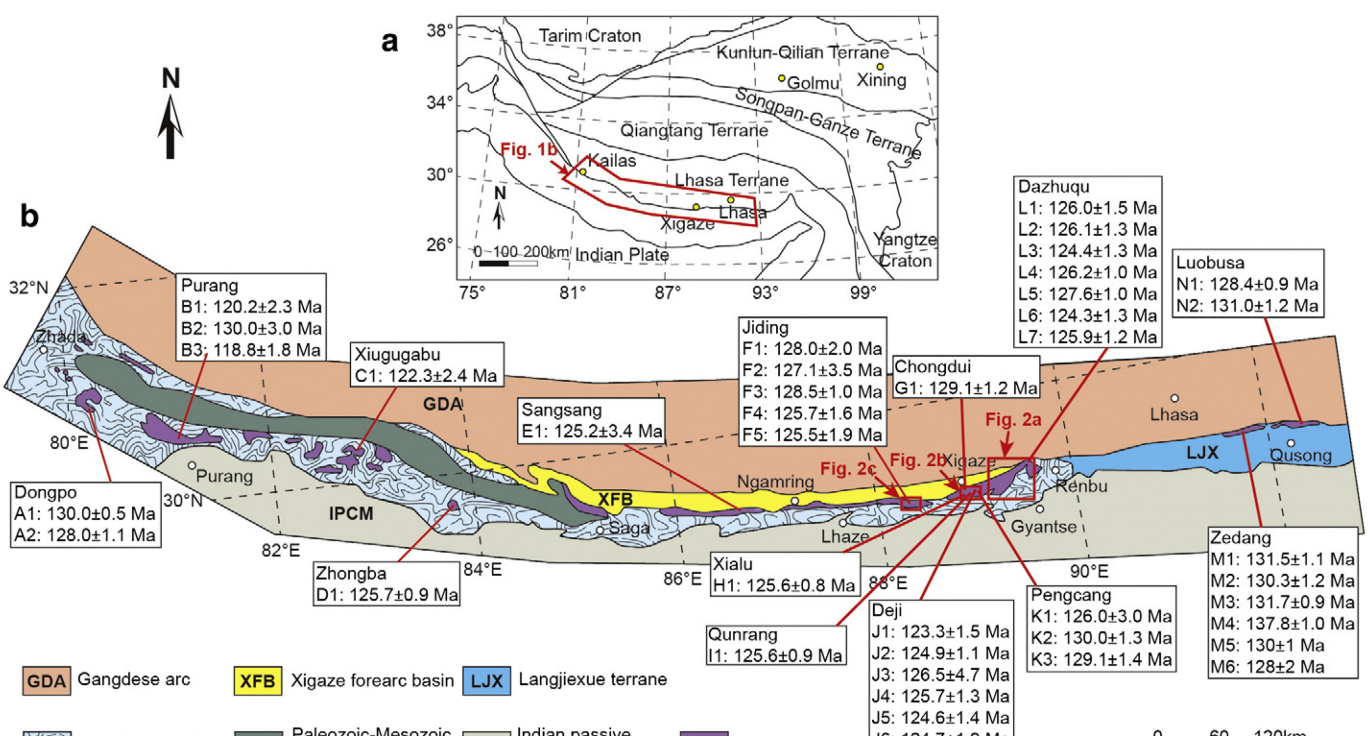

Fig. 1. (a) Simplified geological map of the Tibetan Plateau showing the major terranes and suture zones, modified after Wu et al. (2008). (b) Sketch geological map of southern Tibet illustrating the distribution and zircon U-Pb age data of the Yarlung Zangbo ophiolites, modified after Dai et al. (2011). Ages and numbers of ophiolites are listed in Table 1.