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Provenance of Late Triassic sediments in central Lhasa terrane, Tibet and its implication

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ABSTRACT

In southern Tibet, Late Triassic sequences are especially important to understanding the assembly of the Lhasa terrane prior to Indo-Asian collision. We report new data relevant to the provenance of a Late Triassic clastic sequence from the Mailonggang Formation in the central Lhasa terrane, Tibet. Petrographic studies and detrital heavy mineral assemblages indicate a proximal orogenic provenance, including volcanic, sedimentary and some ultramafic and metamorphic rocks. In situ detrital zircon Hf and U–Pb isotope data are consistent with derivation of these rocks from nearby Triassic magmatic rocks and basement that comprise part of the newly recognized Late Permian–Triassic Sumdo–Cuoqen orogenic belt. The new data suggests correlation with the Upper Triassic Langjiexue Group which lies on the opposing (southern) side of Indus–Yarlung ophiolite. Sediments from both the Mailonggang Formation and Langjiexue Group are interpreted to represent formerly contiguous parts of a sequence deposited on the southern flanks of the Sumdo–Cuoqen belt.

1. Introduction

The geology of Tibetan Plateau has received considerable geologic attention with much of this work being focused on the processes attendant to the ongoing collision of India and Asia (e.g. Molnar and Tapponnier, 1975; England and Searle, 1986; Tapponnier et al., 2001; Ding et al., 2005; Aitchison et al., 2007). In contrast, the pre-collisional and early collisional history of southern Tibet is relatively poorly understood. However, some recent important discoveries have begun to shed new light on this hitherto enigmatic phase. Firstly, the discovery of the Paleozoic eclogite, igneous rocks and metamorphic events at Sumdo to the northeast of Lhasa city suggest the existence of a previously unrecognized Permo-Triassic orogenic zone within the central Lhasa terrane, termed the Sumdo–Cuoqen belt (Chen et al., 2009; Yang et al., 2009; Zhu et al., 2009; C.Y. Dong et al., 2011; Li et al., 2011; X. Dong et al., 2011). Secondly, our recent investigations have suggested that the boundary between India and Asia may extend to the south of the Indus–Yarlung suture zone (IYSZ, Liu et al., 2010, 2012). In addition, new paleomagnetic data have been used to suggest a more complex, multi-phase collisional history than have been traditionally envisaged (Aitchison et al., 2007; Cai et al., 2012; van Hinsbergen et al., 2012). Finally, Zhu et al. (2011, 2013) have proposed that the Lhasa terrane derives from a continental fragment rifted from the Australian Gondwanan margin.

These discoveries and interpretations call into question some traditional view concerning the pre-and early collisional history of southern Tibet, and raise a raft of new questions. The Paleozoic–Mesozoic sedimentary sequences in Lhasa terrane provide a key to clarify these questions. In this study, we focus on the Late Triassic sedimentary sequences in the central Lhasa terrane. We use petrographic and detrital zircon isotopic data to constrain the provenance of the sediments. We also compare our data with that from the Late Triassic sequences on the south side of the Indus–Yarlung Zangbo ophiolite and in combination with the magmatic, tectonic and metamorphic constraints, and explore the implications of these Late Triassic sequences for the evolution of Lhasa terrane.

2. Geological setting of Lhasa terrane

Tibet is underlain by four E–W trending geologic terranes. From north to south, these are the Songpan–Ganzi, Qiangtang, Lhasa and the Himalaya terranes. Each is separated from the other by inferred sutures that from north to south are (1) Jinshajiang suture (JSS), (2) Bangong–Nujiang suture (BNS), and (3) Indus–Yarlung suture (IYS). These represent the multi-phase Tethyan Ocean relics, respectively (Yin and Harrison, 2000; Yin, 2006; Fig. 1).

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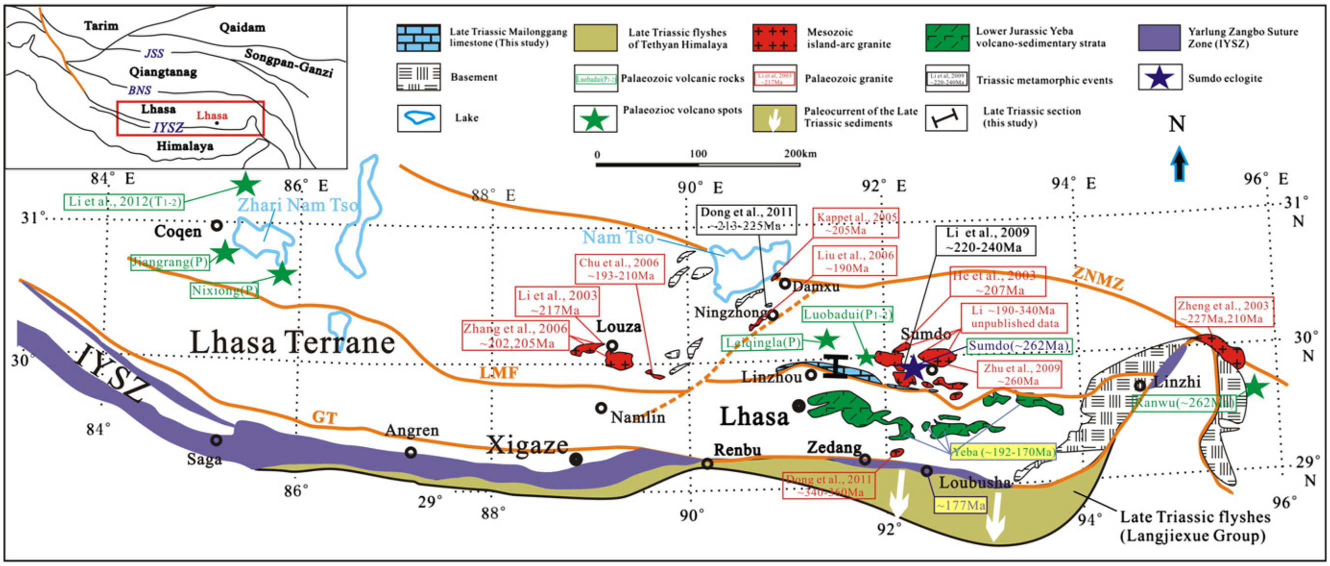

Fig. 1. The distributions of the basement rocks, Paleozic–Early Mesozoic magmatic rocks in Lhasa block, south Tibet. LMF, Luobadui–Milashan Fault; ZNMZ, Shiquan River–Nam Tsomelange zone.
Modified from Zhu et al. (2008), X. Dong et al. (2011), Zhu et al. (2013).

The Lhasa terrane extends more than 2000 km east to west and 200–300 km north–south. In the west it is truncated by the Karakoram strike-slip fault, and in the east it bends southward around the eastern Himalaya syntaxis (Dewey et al., 1988; Yin, 2006). It can be subdivided into the southern, central and northern Lhasa terranes, which are separated by the Shiquan River–Nam Tso mélange zone (SNMZ) to the north and Luobadui–Milashan Fault (LMF) to the south, respectively (Zhu et al., 2013, Fig. 1). The southern Lhasa terrane is characterized predominantly by Mesozoic–Cenozoic intrusive and volcanic rocks of the Gangdese arc. This includes the Early Jurassic Yeba and Tertiary Linzicong volcano–sedimentary rocks (Chu et al., 2006; Mo et al., 2007; Zhu et al., 2008; Ji et al., 2009; Zhu et al., 2010, 2013), as well as minor Mesozoic–Cenozoic sedimentary strata (Leier et al., 2007). Meanwhile, Precambrian crystalline basements occur locally in the Linzhi and Chayu areas (C.Y. Dong et al., 2011; X. Dong et al., 2011; Zhu et al., 2013). The northern Lhasa terrane comprises mainly Late Jurassic–Early Cretaceous sedimentary sequences (Yin et al., 1988; Leier et al., 2007), with some Mesozoic (mainly Cretaceous) volcano–sedimentary rocks and plutonic rocks (Zhu et al., 2011, 2013). The northern Lhasa thrust belt was tectonically active from the Cretaceous through to the Eocene (Kapp et al., 2007), prior to and during the early stages of India–Asia collision.

In the central Lhasa terrane, it exposes the Proterozoic to Early Cambrian metamorphic basement in the Nyainqentanglha area, and is covered with widespread Permo-Carboniferous metasedimentary rocks and small amounts of well-exposed Ordovician, Silurian, and Devonian strata, and Triassic limestone as well (Pan et al., 2006; Zhu et al., 2013). Paleozoic coesite-bearing eclogites have been documented in an E–W trending belt at least hundred km long the central Lhasa terrane, also named the Sumdo–Cuoqen belt (Chen et al., 2009; Li et al., 2009; Yang et al., 2009; Li et al., 2011; Fig. 1). The P-T for these eclogite conditions is estimated to be higher than 2.7 GPa and 730 °C, with coesite pseudomorphs implying high to ultra-high pressure conditions (Chen et al., 2009; L.S. Zeng et al., 2009; Q.G. Zeng et al., 2009; Yang et al., 2009). The geochemistry and Sr–Nd isotope analysis suggest a typical MORB affinity for the protolith rocks of the eclogites (Chen et al., 2009). Eclogites in fault contact with the garnet-bearing, muscovite–quartz schist in the Sumdo region have U–Pb zircon ages of 262 ± 5 Ma (Chen et al., 2008), while metamorphic zircon ages of ~225–212 Ma are reported from the Nyainqentagnlha area (X. Dong et al., 2011). Muscovite and amphibole from the adjacent muscovite–quartz schists and from the eclogites have Mid–Late Triassic ^{40}Ar–^{39}Ar ages in the range of 220–240 Ma (Li et al., 2009, 2011). Magmatism associated with this orogenic event include: (1) the Early and Middle Permian volcanic rocks that are exposed locally from Coqen in the west to Ranwu in the east (Geng et al., 2007; Zhu et al., 2010; Fig. 1); (2) the Late-Permian peraluminous granite at Pikang (Zhu et al., 2009); and (3) the Early–Middle Triassic volcanics (Li et al., 2012), and Late Triassic granites found in several areas (Li et al., 2003; Zheng et al., 2003; Kapp et al., 2005; Chu et al., 2006; He et al., 2006; K. Liu et al., 2006; Q.X. Liu et al., 2006; Zhang et al., 2007; Zhu et al., 2011, 2013). The latter may be attributed to the extension after the Late Permian–Triassic compression (Zhu et al., 2013) or the rifting of Lhasa terrane from Gondwana (Fig. 1).

3. Stratigraphy

Our study region is located in the central portion of the Lhasa terrane, in the Damxung-Linzhou area (Fig. 1), in a zone comprising mostly Ordovician to Tertiary strata. The Paleozoic sedimentary strata consist primarily of Carboniferous sandstone, metasandstone, shale and phyllite, with subordinate Ordovician, Silurian and Permian limestone together with interbedded mafic and felsic volcanic rocks. Triassic rocks are defined mainly by the Late Triassic Mailonggang Formation, with rare exposures of Early Triassic strata of the Chaqupu Formation. The Mailonggang Formation includes a large suite of limestone interbedded with sandstone and mudstone, which occur in thrusts contact above Cenozoic clastic sandstone of the K_2 Shexing Formation. The Early Jurassic Jialapu Group is composed of conglomerates, mudstone, and partly volcanoclastic sandstones, locally intruded by the Cenozoic granites. The Upper Jurassic Duodigou Group is made up of littoral facies carbonate. Cretaceous and Tertiary strata consist of clastic mudstone, sandstone and local conglomerate units and arkosic fluvial sandstone and mudstone successions (Li, 1990; Leier et al., 2007; Pullen et al., 2008). In central Lhasa, a northward -propagating retroarc thrust belt (Lhasa–Damxung thrust) developed between the Luobadui–Milashan fault and the Shiquan River–Nam Tso mélange zone (Fig. 1) has emplaced Paleozoic and Mesozoic strata over Cenozoic sequences, and was active between 105 and 53 Ma (Kapp et al., 2007). Tertiary Linzizong volcanic rocks unconformably over the Late Cretaceous clastic rocks (Mo et al., 2007).

In the study region, the Upper Triassic Mailonggang Formation consists of thick-bedded micritic limestones, interbedded with shale and siltstone in the upper parts of the succession, and clastic/lithic sandstone