Journal of Asian Earth Sciences 121 (2016) 108–119

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

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

Paleomagnetic study on the Triassic rocks from the Lhasa Terrane, Tibet, and its paleogeographic implications

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ARTICLE INFO

Article history:
Received 2 September 2015
Received in revised form 29 January 2016
Accepted 16 February 2016
Available online 16 February 2016

Keywords:
Paleomagnetism
Tibetan Plateau
Lhasa Terrane
Tethys
Triassic
Paleolatitude

ABSTRACT

We present paleomagnetic results from the newly discovered Early-Middle and Late Triassic marine sediments of the Lhasa Terrane. Orientated samples were collected from 32 sites (330 samples) on the north side of the Dibu Co Lake (84.7°E, 30.9°N), Coqên County, in the western region of the Lhasa terrane. Rock magnetic data revealed that most of the samples were dominated by magnetite and/or pyrrhotite. The stepwise demagnetization curves illustrated three-components: a low temperature component (Component A) near the present-day field (PDF), a secondary remanent magnetization (Component B) that may be from the Cretaceous Period, and a high-temperature component (Component C). The Component C were isolated from the Early-Middle Triassic rocks in 8 sites (47 specimens) and from the Late Triassic rocks in 6 sites (37 specimens). The Component C of the Early-Middle Triassic rocks passed a reversal test (B class, 95% confidence level) and a fold test (99% confidence level), that of the Late Triassic rocks passed a fold test (95% confidence level). The corresponding paleopoles for the Early-Middle and Late Triassic periods of the Lhasa Terrane were at 18.9°N, 208.4°E with A_{95} = 3.9° and 19.6°N, 211.8°E with A_{95} = 10.7°, respectively. We suggest that the Lhasa Terrane maintained a relative stable latitude (16.5 ± 3.9°S and 18.4 ± 10.7°S) in the southern hemisphere during the Triassic Period before moving northwards and amalgamating with the main body of Eurasia. The Qiangtang and Lhasa terranes, which were located at the mid-low latitudes of the southern hemisphere, might have been isolated between Eurasia and Gondwanaland since the Early Triassic Period. The Meso-Tethys, potentially represented by the Bangong–Nujiang suture zone (BNS) between the Lhasa and Qiangtang terranes, opened up in the Early-Middle Triassic Period and expanded during the entire course of the Triassic Period.

1. Introduction

The Tibetan Plateau is generally acknowledged to belong to the eastern Tethyan domain, its formation and evolution have long been a research focus for geologists (such as Chang and Zheng, 1973; Huang and Chen, 1987; Pan et al., 1997, 2012; Huang et al., 2000; Ren and Xiao, 2004; Li, 2008; Li et al., 2009; Wang et al., 2010; Zhu et al., 2011a,b; and Xu et al., 2011, 2013). It is generally accepted that the formation and evolution of the Tibetan Plateau were closely related to the rifted and northward-drift of a series of Gondwana-original terranes towards the southern margin of the Eurasia plate from the Late Paleozoic Period onwards, accompanied by the gradual contraction and/or opening of Paleo-, Meso-, and Neo-Tethys (Metcalfe, 1996, 2013; Wang et al., 2007; Ding et al., 2014).

The Lhasa Terrane is located between the Himalayan Terrane to the south and the Qiangtang Terrane to the north (Fig. 1). Recent investigations have suggested that the Qiangtang and Lhasa terranes preserve a large number of geologic records for the Tethys, the Bangong–Nujiang suture zone (BNS) between the two terranes most likely representing the disappeared relics of the Meso-Tethys (Fig. 1) (e.g. Xiao et al., 1986; Ren, 1997; Pan et al., 2004; Shi, 2007; Wang et al., 2008; Fan et al., in press; Liu et al., in press; and so on). This suture becomes a key region for addressing the process of amalgamation not only between the Qiangtang and Lhasa terranes but also between Gondwana and Eurasia. However, despite decades of mapping and data collection from this complex and long-lived convergence zone, the paleogrographic evolution of the Bangong–Nujiang ocean is still little understood, a factor which in turn places limitations on scientists' ability to produce an

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http://dx.doi.org/10.1016/j.jseaes.2016.02.006
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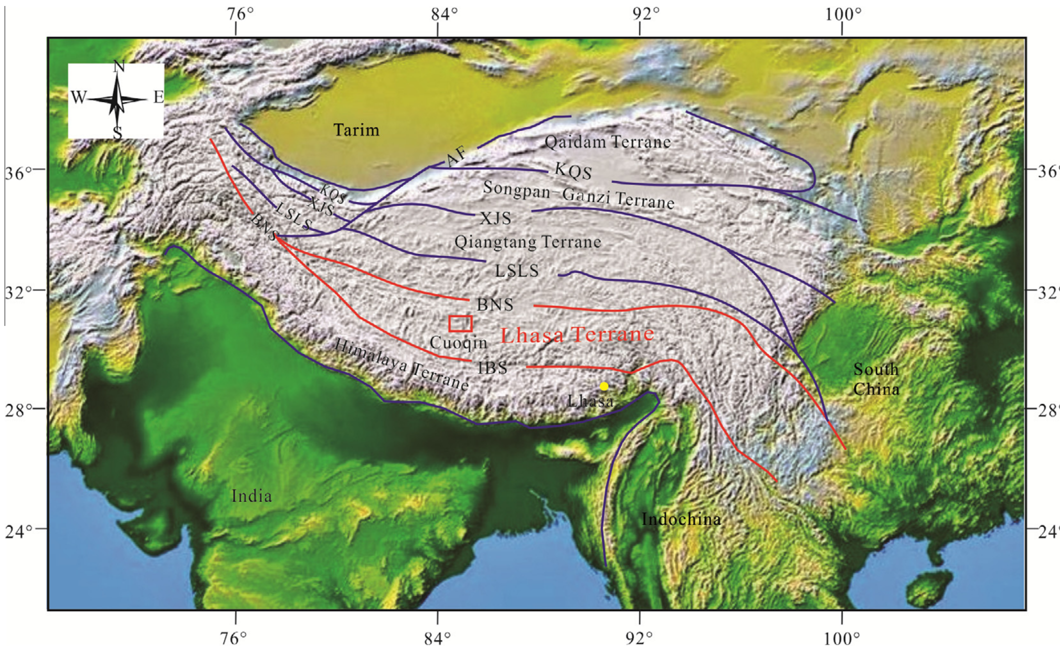

Fig. 1. Sketch of the major tectonic units of the Tibetan Plateau. IBS: Indus-YarlungZangbo suture zone, BNS: Bangong-Nujiang suture zone, LSLS: Lungmu Co-Shuanghu suture zone, XJS: Xijir Ulan-Jinshajiang suture zone, KQS: Kunlun-Qinlin suture zone, AF: Altyn Tagh Fault. Red box: study area. (modified after the Geological Map of Qinghai-Xizang (Tibet) Plateau and Adjacent Areas, Chengdu Cartographic Publishing House). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

accurate paleogeographic reconstruction of the Tibetan Plateau (Besse and Courtillot, 2003; Stampfli and Borel, 2002; Collins, 2003; Scotese, 2004; Golonka, 2007; Torsvik et al., 2008; Metcalfe, 2009; Choulet et al., 2011).

Paleomagnetism is an effective approach to the past tracks of plates and terranes. Paleomagnetic results can determine the paleolatitude of a terrane and, relevant changes thus can be applied to the paleogeographic reconstruction of the plate. In recent years, a series of paleomagnetic studies have been conducted on the Lhasa Terrane of the Tibetan Plateau and some important achievements have been accomplished (e.g. Pozzi et al., 1982; Achache et al., 1984; Zhu et al., 1984; Ye and Li, 1987; Lin and Watts, 1988; Dong et al., 1991; Torsvik et al., 2009; Tan et al., 2010; Yi et al., 2011; Sun et al., 2012; Liebke et al., 2013; Chen et al., 2014; Yang et al., in press; Zhao et al., 2015; and so on). Owing to different concerns (these studies mainly focus on the India–Asia collision), the available paleomagnetic data is mainly distributed in the Tertiary and the Cretaceous periods of Lhasa Terrane. There is little available data from the Paleozoic Period and none from the Early Mesozoic Period (Dong et al., 1991; Guo, 2009; Cheng, 2012; Ran et al., 2012a). In short, the present published paleomagnetic data are insufficient for us to clearly determine the movement of the Lhasa Terrane before its amalgamation with the main body of Eurasia, and insufficient for us to constrain the successive closure and opening of the Tethyan basins in Tibetan Plateau.

In this paper, we describe two Triassic paleomagnetic results from the newly discovered Triassic limestone on the Coqên area of the Lhasa Terrane to address the limitations in previous data sets. By investigating the positional changes (including the absolute position and the relative positions between terranes) and the kinematic characteristics of the Lhasa and Qiangtang terranes during the Triassic Period, this study provides critical paleomagnetic evidence for studying the Tethyan evolution and the reconstruction of the Tibetan Plateau.

2. Geology setting and sampling

Previously, it was believed that Triassic strata were missing in large areas of the western Lhasa region or no one could tell with certainty whether Triassic strata had developed in the Lhasa Terrane (Li et al., 1982; Rao et al., 1987; Liu et al., 1990; Xia and Liu, 1997; Zhao et al., 2001; Zhou et al., 2002). Since 2004, Ji et al. have successively discovered Early Triassic conodonts (*Pachycladina*, *Neohindeodella, Cornudina, Hadrodontina* and *Hibbardella* sp., etc.) in the Shiquanhe area of the Lhasa Terrane (Ji et al., 2006, 2007a; Zheng et al., 2007). Later, not only the Late Triassic Norian *Epigondolella* (Ji et al., 2006) but also Early and Middle Triassic conodonts *(Paragondolella polyg-Nathiformis*, *Xaniognathus* cf. *newpassensis* and *Iranognathus* sp., etc.) were observed (Wu et al., 2007) on the northern margin of the Dibu Co Lake in the Coqên area of Lhasa Terrane (Fig. 2a and b). The biostratigraphic studies of conodonts have successfully distinguished the Early to Late Triassic marine carbonate formations from the strata which was initially acknowledged to be the Permian in age. A lithostratigraphic unit division of Triassic strata in the Coqên area has been preliminarily proposed. According to the lithological features, the strata are divided (from bottom to top) into the Dibu Co, Gyangrang, Zhuglung, and Garing Co Formations (Table 1) (Ji et al., 2007b). Each formation is mainly composed of marine carbonates, and the content of these siliceous deposits is the primary marker for distinguishing between various formations. Siliceous deposits are developed locally in certain horizons of the Lower Garing Co Formation, which are mostly well developed in the Middle Zhuglung Formation and undeveloped in the Upper Gyangrang Formation. The Garing Co Formation is most likely in conformity with the Late Permian strata. The top boundary of the Gyangrang Formation contains dolomitic limestone and is in unconformity with the clastic rocks of the overlying Dibu Co Formation (Fig. 2d), which palynological studies have confirmed is composed of Late Triassic – Early and Middle Jurassic strata (Zhou et al., 2002; Ji et al., 2007b).