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Paleomagnetism of Eocene red-beds in the eastern part of the Qiangtang Terrane and its implications for uplift and southward crustal extrusion in the southeastern edge of the Tibetan Plateau

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ABSTRACT

A primary magnetic component with the acquisition time of 56.0–43.2 Ma was isolated between 580 °C and 685 °C from the Eocene Gonjo and Ranmugou Formations in the eastern part of the Qiangtang Terrane, Tibetan Plateau. The tilt corrected site-mean direction is $D_s = 35.5°$, $I_s = 29.3°$, $k = 45.9$, $\alpha_{95} = 3.2°$. The site-mean inclination increased from 29.3° to 41.6° after multiple inclination shallowing corrections, giving a paleopole of 57.9°N/192.1°E, $A_{95} = 2.9°$. Comparison of the Paleogene paleomagnetic data for the Qiangtang Terrane and Lhasa Terrane reveals that both terranes experienced latitudinal crustal shortening before 54–43 Ma, indicating the uplift of southern and central Tibet in the early Eocene. Subsequently, since 35.4 ± 2.4 Ma, the north of the Qiangtang Terrane experienced ~1300 ± 410 km of crustal shortening, indicating the uplift of the northern Tibetan Plateau. The Lhasa Terrane and Qiangtang Terrane have not experienced further crustal shortening since the late Eocene, and the southeastern part of Tibet cannot have provided abundant crustal material to accommodate the significant crustal southward extrusion in the southeastern edge of the Tibetan Plateau. The crust of the Tengchong Terrane and Shan–Thai Block did not experience significant southward extrusion since the late Oligocene–Early Miocene. The Indochina Block was situated in the north of the Qiangtang Terrane before the Oligocene, and since the early Oligocene, the Indochina Block began to experience southward extrusion from the north of the Qiangtang Terrane, which absorbed part of the crustal shortening in the north of the Qiangtang Terrane.

1. Introduction

The collision of the Indian Plate and Eurasia in the Paleocene, and the subsequent extrusion between them induced significant latitudinal crustal shortening across southern Eurasia during the Cenozoic (Tapponnier et al., 1982; Peltzer and Tapponnier, 1988; Jaeger et al., 1989; Beck et al., 1995; Yin and Harrison, 2000; Cande and Stegman, 2011; Van Hinsbergen et al., 2011). Part of the latitudinal crustal shortening (~900 km) was absorbed by the Cenozoic fold and thrust belts system across the Tibetan Plateau (Yin and Harrison, 2000; Spurlin et al., 2005; Yin et al., 2007; Van Hinsbergen et al., 2011). Examples are the Shiquanhe–Gaize–Amdo Thrust system in the southern part of the Qiangtang Terrane (QT), the Fenghuoshan–Nangqian fold belt in the northeastern part of the QT, the Qimen Tagh–North Kunlun thrust system, and the Nan Shan thrust system in the Qaidam Basin (Meyer et al., 1998; Yin and Harrison, 2000; DeCelles et al., 2002; Spurlin et al., 2005; Yin et al., 2007; van Hinsbergen et al., 2011). The other part is believed to have been accommodated since the Oligocene by large-scale southward extrusion of the Tengchong Terrane (TCT), the Shan–Thai Block (STB) and the Indochina Block (ICB), in the southeastern edge of the Tibetan Plateau, along several lithospheric-scale strike-slip fault systems (Tapponnier et al., 1990; Yang and Besse, 1993; Yang et al., 1995; Leloup et al., 1995; Wang et al., 1998a, 1998b; Wang and Burchfiel, 2000; Molnar and Dayem, 2010).

Recent GPS observations in the interior of Tibet and the surrounding areas show that the crust of the southeastern part of

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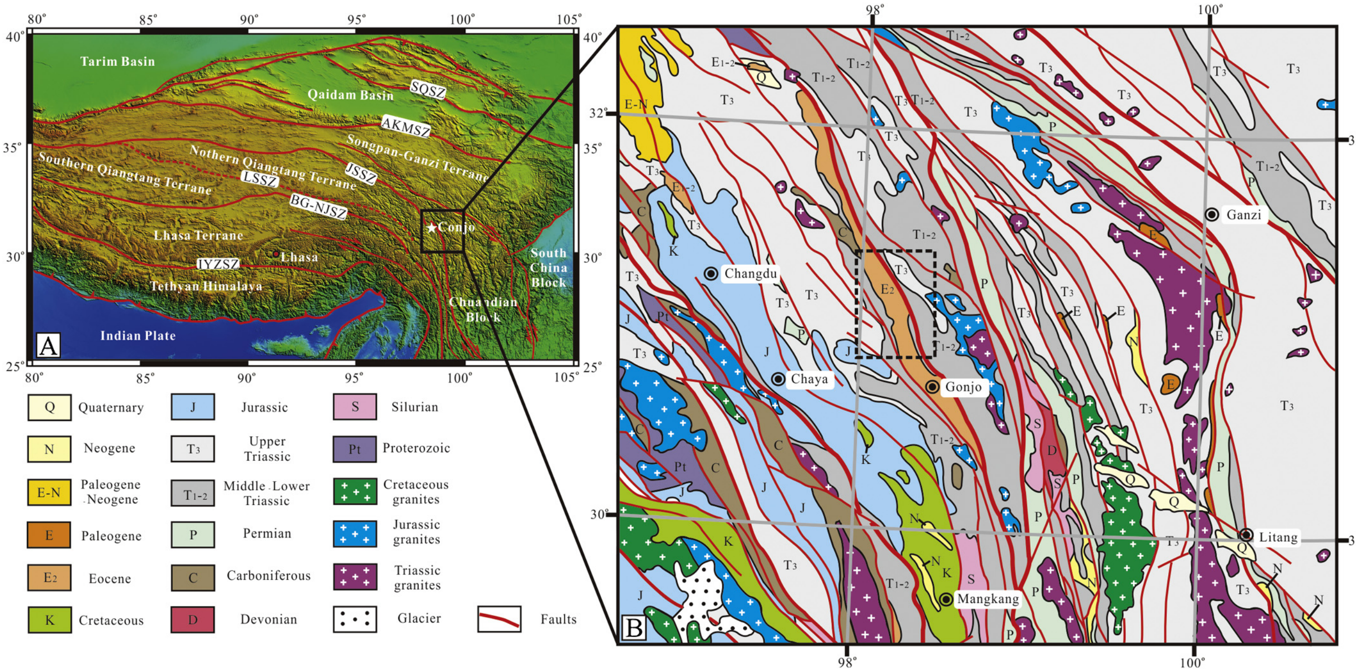

Fig. 1. (A): A schematic tectonic geological map of the Tibetan Plateau. (B): Tectonic map of the Gonjo area. IYZSZ, Indus-Yarlung Zangbo Suture Zone. BG-NJSZ, Bangong–Nujiang Suture Zone. LSSZ, Longmu Tso-Shuanghu Suture Zone. JSSZ, Jinshajiang Suture Zone. AKMSZ, Ayimaqing–Kunlun–Muztagh Suture Zone. SQSZ, South Qilian Suture Zone.

the Tibetan Plateau is currently experiencing clockwise rotational extrusion around the Eastern Himalayan Syntaxis (EHS) (Chen et al., 2000; Shen et al., 2005; Gan et al., 2007). Paleomagnetic studies of the Cretaceous and Paleogene red-beds of the ICB indicate that it experienced clockwise rotation accompanied by ∼700 ± 200 km southward extrusion since the Oligocene, which accommodated part of the post-collision crustal shortening across southern Eurasia (Yang et al., 1995; Otofuji et al., 1998; Sato et al., 2007; Zhang et al., 2012; Tong et al., 2013; Li et al., 2017a). However, the primary magnetic components of the Eocene volcanic rocks in the TCT, and the early Miocene secondary magnetic components in the northern edge of the STB, have suggested that the TCT and STB experienced only minor southward extrusion relative to East Asia, since the Oligocene (Kornfeld et al., 2014; Tong et al., 2016). Thus, the process of southward crustal extrusion in the southeastern edge of the Tibetan Plateau may be more complex than previously believed. In fact, the amount of latitudinal crustal shortening in southern Eurasia estimated from paleomagnetic studies is still highly controversial, ranging from 2400 km to less than 200 km (Sun et al., 2010; Tan et al., 2010; Ma et al., 2014; Li et al., 2017b). This may be the result of inclination shallowing of the Cretaceous and Paleogene red-beds (Tauxe and Kent, 2004; Huang et al., 2013) and possible remagnetization of the Cretaceous and Paleogene volcanic rocks of the Lhasa Terrane (LT) (Huang et al., 2015). In addition, the amount of post-collision latitudinal crustal shortening across southern Eurasia was mainly estimated from the Cretaceous and Paleogene paleomagnetic data from the central part of the LT. Therefore, it is unreasonable to evaluate the contribution of southward crustal extrusion in the southeastern part of the Tibetan Plateau to the post-collision crustal shortening across southern Eurasia, based solely on current paleomagnetic studies in the central part of the Tibetan Plateau.

The eastern end of the QT directly faces the northeastern frontend of the EHS (Fig. 1A). A series of Paleogene basins are distributed in the region, for example the Nangqian Basin, Dingqing Basin, Gonjo Basin and Basu Basin. These basins were filled by Paleogene red-beds occasionally interbedded with volcanic rocks. In this study, paleomagnetic analyses and multiple inclination shallowing tests were carried out on the Paleogene red-beds of the Gonjo Basin, at the eastern end of the QT, to reveal the process of southward crustal extrusion in the southeastern edge of the Tibetan Plateau, and its contribution to post-collision crustal shortening in southern Eurasia.

2. Regional geology and sampling

The QT is a narrow E–W extending block, which lies between the LT and the Songpan-Ganzi Terrane (SGT). The Bangong–Nujiang Suture Zone (BNSZ) and Jinshajiang Suture Zone (JSSZ) comprise the southern and northern boundaries of the QT, respectively (Fig. 1A). The Longmo Co-Shuanghu Suture further divides the QT into the Northern and Southern Qiangtang Sub-terranes (NQT and SQT) (Pan et al., 2004; Zhang et al., 2006; Liu et al., 2011; Zhu et al., 2013). The SQT began to assemble onto the NQT since the middle Triassic (244–237 Ma), finally comprising the integrated QT (Yan et al., 2016). Subsequently, since the late Triassic, the QT accreted onto the SGT along the JSSZ (Pullen et al., 2008; Zhu et al., 2013; Yan et al., 2016). In the eastern part of the QT, the tectonic lines composed of faults and fold-axis change gradually from E-W trending in the central Tibetan Plateau to SE-NW trending in the southeastern part of the Tibetan Plateau, and then extend into Yunnan Province with an approximate S-N trending (Fig. 1).

The Gonjo Basin is situated in the eastern part of the QT. It is elongated and extends in a SE-NW direction with a length of ∼258 km and a width of ∼1.5–18 km (Li et al., 2004) (Fig. 1A, B). The Eocene red-beds strata of the Gonjo Basin are designated the Gonjo Formation in the lower segment and the Ranmugou Formation in the upper segment; they have a total thickness of ∼2700 m and are mainly composed of purple-red fine-grained sandstone, siltstones, mudstone, and variegated sandy conglomerate (BGMRX, 1993; Zhou et al., 2003; Li et al., 2004; Studnicki-Gizbert et al., 2008). The Gonjo Formation unconformably overlies Lower and Middle Triassic limestone and volcanic rocks, and there is a conformable contact with overlying Ranmugou Formation. A serious of folds with SE-NW trending fold-axis is developed in the Gonjo