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Age constraints on the India–Asia collision derived from secondary remanences of Tethyan Himalayan sediments from the Tingri area

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ABSTRACT

We report paleomagnetic results from the Zhepure Shan Formation and the Youxia Formation of the Tingri section (28°42′N/86°43′E) and the Longjiang section (28°27′N/86°40′E) in southern Tibet. A lower coercive component demagnetized below 30 mT and a higher coercive component demagnetized between 30 mT and 100 mT were separated. Rockmagnetic analyses reveal magnetite as the remanence carrier. The differences in coercivity are probably due to a wider grain size spectrum and therefore different domain states. Remanence directions of the low-coercive component are highly scattered and were not considered for further analysis. Directions of the high coercive component of Members A–C of the Zhepure Shan Fm are fairly well grouped within sites ($k > 8$ for most sites) whereas those of Member D and the overlying Youxia Fm are highly dispersed. Applied fold tests indicate a postfolding remanence for Members A–C. The latest possible time for remanence acquisition of Members A–C is constrained to a mean of 48 Ma by comparing the determined paleolatitudes to the curve of expected paleolatitudes versus age, calculated from the APWP of India. Deformation of the rocks is likely related to India–Asia collision and therefore the remanence age yields a constraint on the latest possible age of the India–Asia collision. In consideration of an extended pre-collisional northern Indian margin (Greater India) the determined values of 48 Ma (mean) and 37 Ma (youngest possible age within 95% confidence limits) underestimate the age of the continental collision.

1. Introduction

Collision of the Indian and Eurasian continents is one of the most spectacular geological events in the Cenozoic. It resulted in the formation of the Himalayan mountain range and the Tibetan Plateau (e.g. Yin and Harrison, 2000; Yin, 2006), which had a major impact on the evolution of the Asian monsoon system (An et al., 2001; Harris, 2006) and the drying of the Asian interior (Rea et al., 1998; Fang et al., 2008). The timing of the initial collision of India and Eurasia is an important boundary condition for models of plateau formation and climate evolution. Despite of decades of research the collision age is still disputed. There are multiple indications for a collision around the Paleocene/Eocene boundary based on geological and paleomagnetic evidences (e.g. Patriat and Achache, 1984; Klootwijk et al., 1992; Critelli and Garzanti, 1994; Privnik and Wells, 1996; Rowley, 1996, 1998; Guillot et al., 2003; Leech et al., 2005, 2006; Najman et al., 2010; Zhang et al., 2012). However, an earlier collision age at around the Cretaceous/Paleocene boundary was proposed by several authors (Jaeger et al., 1989; Ding et al., 2003, 2005; Mo et al., 2008; Wan et al., 2002) and Aitchison et al. (2007) argued for a very late collision at about 34 Ma. Recently, van Hinsbergen et al. (2012) proposed a two-stage model, in which first a Himalayan microcontinent collided with the Eurasian plate at c. 50 Ma, followed by subduction of highly extended continental and oceanic lithosphere of Greater India, before finally a "hard" India–Asia collision with the thicker Indian continental lithosphere occurred at 25–20 Ma.

Knowledge about the pre-collisional paleolatitudinal positions of the continental margins of southern Eurasia and northern India is crucial for determining the age of the initial collision. Paleomagnetism is the only method which can directly determine paleolatitudes and thus is an important tool for this purpose. The "late collision" hypothesis of Aitchison et al. (2007) initiated several new paleomagnetic investigations on the Lhasa Block (Chen et al., 2010; Dupont-Nivet et al., 2010; Liebke et al., 2010; Sun et al., 2010, 2011; Tan et al., 2010), which substantially extended the previously available paleomagnetic data set from this unit (Achache et al., 1984; Westphal et al., 1983; Chen et al., 1993). A compilation of all the results from Paleocene to early Eocene volca-

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nic rocks of the Lhasa Block (Najman et al., 2010) indicates that the southern Eurasian margin was located at around 12°N during this time (for a reference longitude of 90°E).

On the Indian plate, primary remanences of lower tertiary age were reported from Tethyan Himalayan sediments of the Gamba and Duela area by Patzelt et al. (1996) and Yi et al. (2011), from which the northern extent of the pre-collisional Indian margin was determined. Besse et al. (1984), Appel et al. (1998), and Tong et al. (2008) investigated Paleocene sediments of the Tethyan Himalaya in the Tingri area and found a remagnetization residing in magnetite. Besse et al. (1984) assumed that this remagnetization is caused by the growth of secondary minerals due to a solid transfer in consequence of local tectonics. Tong et al. determined the remagnetization to about 54 Ma and argued that the secondary character is a consequence of thermal remagnetization related to the India–Asia collision. Besse et al. (1984) and Tong et al. (2008) also revealed a primary component in few sites from which a paleopole for the northern Indian margin may be concluded. However, for a reliable statistics more primary remanence directions are necessary. In this study we present results of our new paleomagnetic investigations on late Paleocene and Early Eocene Tethyan Himalayan sediments of the Tingri area which provide additional constraints on the collision age and the age of deformation of the sediments.

2. Geological setting and sampling

The Himalayan fold-thrust belt between the Indian shield in the south and the Indus-Yarlung suture zone in the north can be divided into four litho-tectonic units, which are separated by major fault systems (LeFort, 1975, 1996; Yin, 2006; Webb et al., 2011). From south to north these units are: the Siwaliks molasse belt forming the hanging wall of the Main Frontal Thrust (MFT), the Lesser Himalaya separated from the Siwaliks molasse by the Main Boundary Thrust (MBT), the Greater Himalayan Crystallines divided from the Lesser Himalaya by the Main Central Thust (MCT), and the Tethyan Himalaya separated by the South Tibetan Detachment (Fig. 1a). The Tethyan Himalaya comprises mostly low-grade Paleoproterozoic to Eocene metasediments, which probably were deposited along the passive northern margin of India (Brookfield, 1993; Liu and Einsele, 1994; Pan et al., 2004). Only in few locations (NW Zanskar, Tingri, Gamba) the Paleocene to Eocene sequence is preserved. At Tingri and Gamba these sediments are unmetamorphosed while in NW Zanskar low-grade metamorphism even altered the uppermost levels. Due to deformation of these sediments, the Indian foreland sequences are dissected into a north-dipping fold and thrust belt (e.g. Aikman et al., 2008; Godin, 2003; Murphy and Yin, 2003; Yin et al., 2010a, 2010b; Webb et al., 2011).

The Tethyan sequence of the Tingri area is dominated by a syncline striking approximately E–W, which forms the Zhepure mountain range. Tethyan Himalayan sediments ranging from the Danian Jidula Fm to the Early Eocene Youxia Fm and the overlying Shenkeza Fm are exposed in the study area (Fig. 1b). The Jidula Fm in the Tingri area is mainly composed of quartz sandstones (Willems et al., 1996). Due to the lack of age diagnostic fossils, it has only been dated indirectly by its stratigraphic position. The lower boundary is constrained by the occurrence of foraminifera from the Pseudobulloides zone in the Zhepure Shanpo Fm and is of Danian age. The top is probably also Danian (Willems et al., 1996). The Jidula Fm is overlain by the Zhepure Shan Fm, which can be divided into four members (Members A–D) (Figs. 2 and 3) (Zhang et al., submitted for publication). In the following the term "Members A–D" is referred to the members of the Zhepure Shan Fm which were classified and biostratigraphically dated by Zhang et al. (submitted for publication)

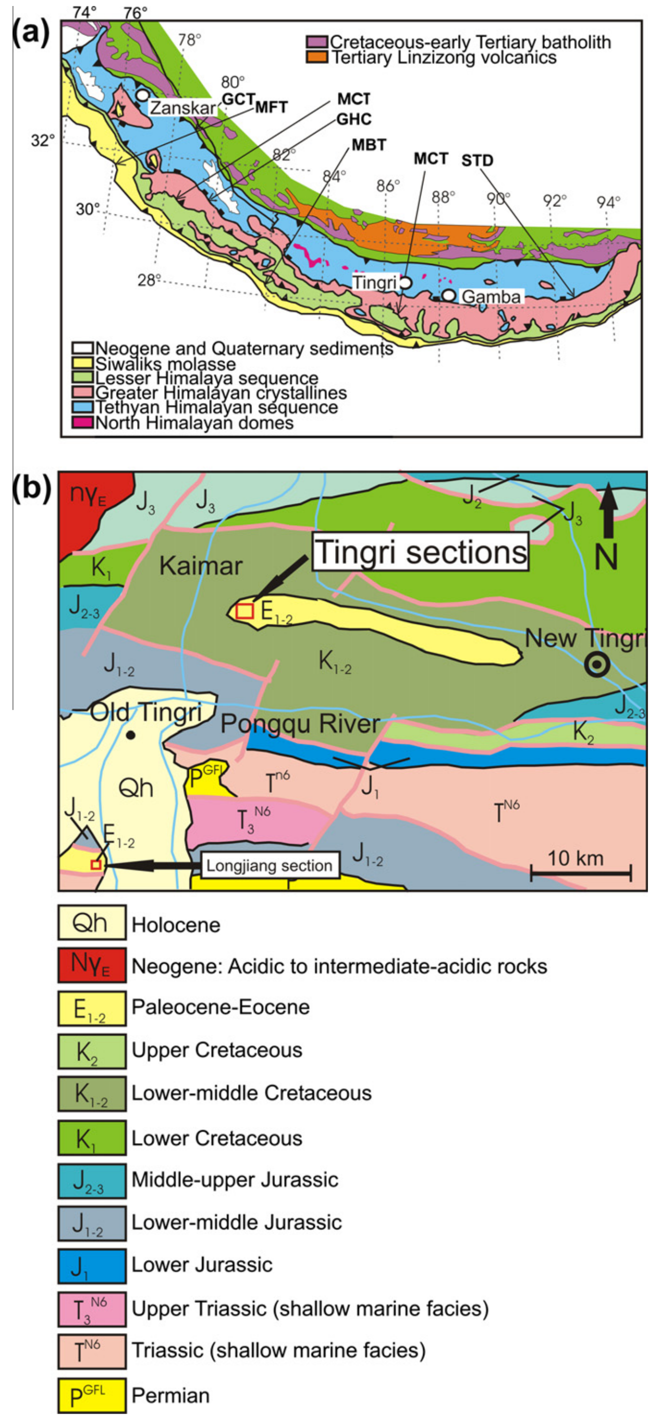

Fig. 1. (a) Sketch of the major tectonic units of the Himalayan mountain range and the Tibetan Plateau. GCT: Great Counter Thrust, MFT: Main Frontal Thrust, MCT: Main Central Thrust, SDT: South Tibetan Detachment, MBT: Main Boundary Thrust [modified after Yin, 2006]. (b) Geological map of the Tingri area. Red boxes: study areas [modified after the Geological Map of Qinghai-Xizang (Tibet) Plateau and Adjacent Areas, Chengdu Cartographic Publishing House].

(Fig. 3). The classification is based on the lithofacies of our sampling area and differs from the classification of Willems et al. (1996) whose profile was located elsewhere.

Member A is about 165 m thick and comprises seven lithologically distinct cycles. Each cycle is composed of an alternating sequence of marl/clay in the lower part and thin-bedded limestone in the upper part. Biostratigraphic dating based on planktic and larger foraminifers yielded an age of upper Danian to upper