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# Paleogene carbonate microfacies and sandstone provenance (Gamba area, South Tibet): Stratigraphic response to initial India–Asia continental collision

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ABSTRACT

The Paleogene marine strata in the Gamba area of south Tibet comprise carbonates of the Zongpu Formation and siliciclastic rocks of the Enba and Zhaguo Formations, documenting the final stages of marine deposition in the Tethyan Himalaya. The ~350-m-thick Zongpu Formation was dated as late Danian to Ypresian based on larger benthic foraminifers. Thirteen distinct microfacies identify three sedimentary environments. Mudstone, wackestone with Udoteacean algae, bioclastic-peloidal packstone, packstone with Rotaliids and green algae, floatstone with *Alveolina* and *Orbitolites* were deposited in restricted lagoonal environments. Bioclastic packstone and grainstone with Rotaliids were deposited in high-energy shoal environments. Floatstones with Nummulitids or Alveolinids were deposited in shallow open-marine environments. The Zongpu Formation was accumulated on a carbonate ramp. It documents two deepening-upward sequences separated by an unconformity corresponding to the Palaeocene/Eocene boundary and marked by a conglomerate with limestone clasts. The overlying Enba Formation comprises greenish grey calcareous shales intercalated with litho-quartzose sandstones in the upper part and capped by subaerial litho-quartzose red beds of the Zhaguo Formation. Petrographic analysis, detrital zircon geochronology and Hf isotopic data indicate that detritus in the Enba and Zhaguo Formations, deposited on the Indian passive margin, was derived from the Asian active margin in the north. These clastic units were thus deposited after the onset of the India–Asia continental collision in the early Himalayan foreland basin. Major lithological and paleoenvironmental changes occurred at three stratigraphic levels: the Jidula/Zongpu boundary (~62 Ma), the Paleocene/Eocene boundary (~56 Ma) and the Zongpu/Enba boundary (~51 Ma). Our provenance study confirms that the India–Asia collision was already under way during the deposition of the Enba Member (i.e., by ~51 Ma) and, along with facies analysis and general palaeogeographic considerations, indicates that Neo-Tethys was still wide open during the Early–Middle Paleocene. It is thus argued, consistently with previous studies, that the Paleocene/Eocene disconformity documented in the Gamba area as in the northwestern Tethyan Himalaya is likely to record flexural uplift consequent to initial underthrusting of the Indian continental margin beneath Asia at, or just a little earlier than, 56 Ma.



## 1. Introduction

The timing of the initial India–Asia continental collision is critical to understand the Himalayan orogenic process and the subsequent crustal shortening and deformation. During the past decades, a variety of approaches and techniques have been used to constrain the timing of the initial India–Asia collision (e.g., Rowley, 1996; Najman et al., 2010; Yi et al., 2011). Nevertheless, a precise age of the collision remains disputed, with views ranging from ~70 to 34 Ma (Yin and Harrison, 2000; Aitchison et al., 2007). The Paleogene marine sediments of southern Tibet preserve crucial information that helps us to constrain the age of initial India–Asia continental collision and paleogeographic scenarios immediately before and after closure of the Neo-Tethys Ocean.

The Cretaceous–Paleogene strata in the Gamba area have been the subject of several palaeontological, stratigraphical and sedimentological studies (Hayden, 1907; Mu et al., 1973; Wen, 1974;

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Zhang and Geng, 1983; Wan, 1987; Xu and Mao, 1992; Willems and Zhang, 1993; Li and Wan, 2003; Wan et al., 2002, 2010; Wang et al., 2010a,b). However, detailed studies on carbonate microfacies and sandstone provenance are lacking. Here we present a new sedimentary study of the Paleogene succession, corroborated by detailed microfacies analysis, sandstone-petrography, and detrital-zircon U–Pb–Hf geochronology and geochemistry aimed at reconstructing the step-by-step evolution of the Zongpu carbonate ramp and successive Enba and Zhaguo siliciclastic sedimentation during the initial stages of the India–Asia collision.

## 2. Geological setting

### 2.1. Geological background of the Tibetan–Himalayan orogen

The Himalayan orogenic belt consists of a series of east–west (or northwest) oriented lithotectonic units (Fig. 1A). From north to south, these units include: (1) the Gangdese magmatic arc, composed of Upper Triassic to Paleogene calc-alkaline granitic batholiths (Chung et al., 2005; Chu et al., 2006; Wen et al., 2008; Ji et al., 2009), intruding Paleozoic and Mesozoic sedimentary strata and unconformably overlain by the Paleogene Linzizong volcanic succession (Mo et al., 2008; Lee et al., 2009); (2) the Xigaze forearc basin, filled mainly by Cretaceous deep-water turbidites and minor marly carbonates (Einsele et al., 1994; Dürr, 1996; Wan et al., 1998; An et al., 2014); (3) the Yarlung Zangbo suture zone, which marks the contact between the Indian and Asian continental margins and includes ophiolites and tectonic mélange (Hébert et al., 2003; Dubois-Côté et al., 2005; Dupuis et al., 2005; Bédard et al., 2009) overlain by post-early Eocene siliciclastic sediments (Wang et al., 2010a,b); (4) the Tethyan Himalayan sedimentary succession, deposited along the northern margin of the Indian subcontinent, and subdivided into a proximal southern zone and a distal northern zone (Ratschbacher et al., 1994). The southern Tethyan Himalaya is characterized by shelfal carbonates and terrigenous Palaeozoic to Eocene strata (Willems and Zhang, 1993; Jadoul et al., 1998; Garzanti, 1999), whereas the northern Tethyan Himalaya is dominated by Mesozoic to Paleogene outer shelf, continental slope and rise deposits (Liu and Einsele, 1994; Hu et al., 2008).

### 2.2. Paleogene stratigraphy of the Gamba area

The Gamba area is a classic locality for Paleogene stratigraphy in the southern Tethyan Himalaya, including the Jidula, Zongpu, Enba and Zhaguo Formations (Mu et al., 1973; Wan, 1985, 1987; Willems and Zhang, 1993; Zhou et al., 1997; Li and Wan, 2003; Wang et al., 2010a,b) (Figs. 1B, 2).

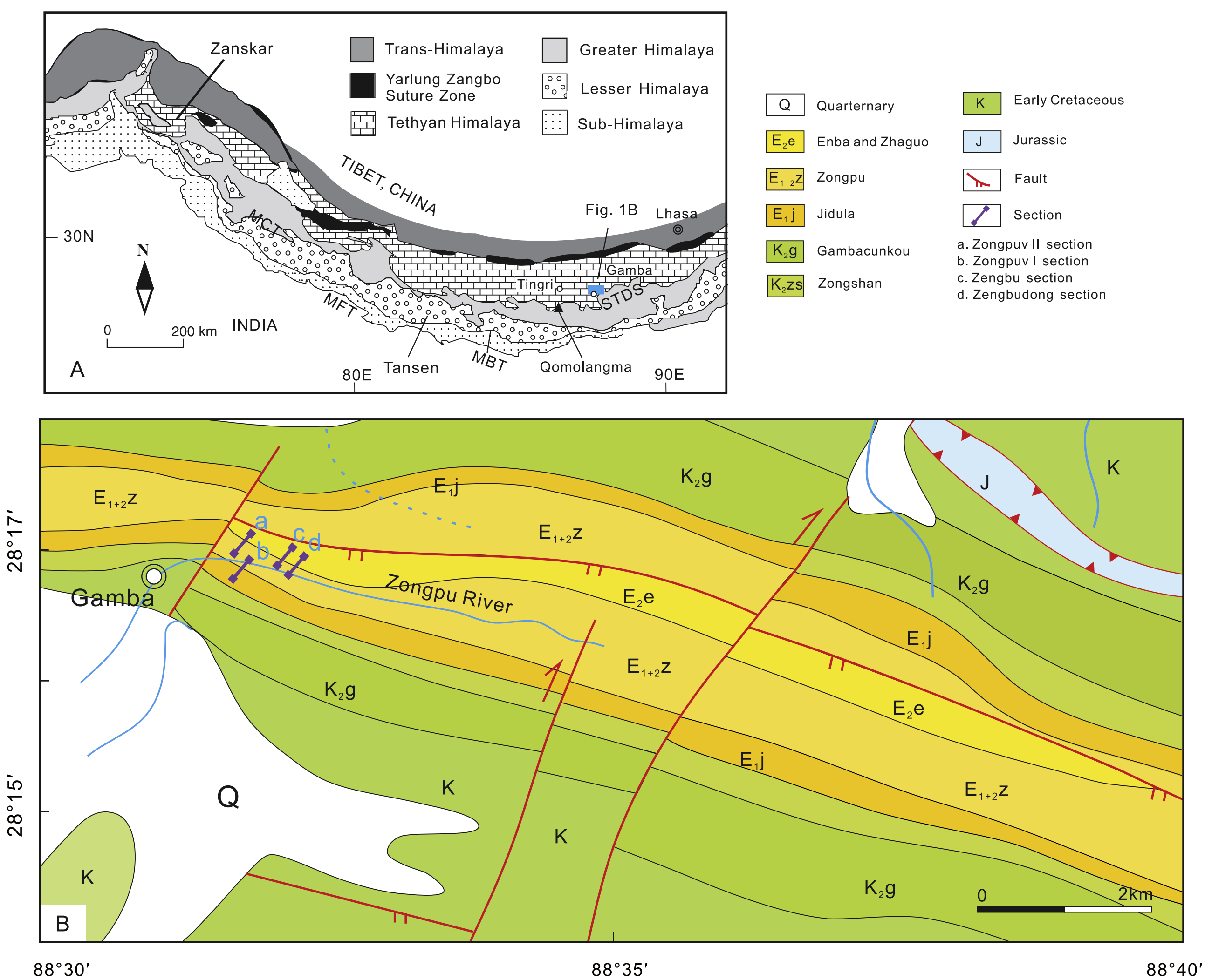


**Fig. 1.** (A) Geological sketch map of the Himalayan Range (modified after Gansser, 1964); (B) Geological map of the Gamba area showing the studied stratigraphic sections (modified after the 1:200,000 Gyangze sheet, Wan and Liu, 2005).