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Oligocene-Miocene burial and exhumation of the southernmost Gangdese mountains from sedimentary and thermochronological evidence

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ABSTRACT

The Kailas conglomerates crop out ubiquitously along the southernmost boundary of the Gangdese batholith. They unconformably overlie the Gangdese batholith and are displaced by the Great Counter thrust (GCT) fault, forming a fault contact with the Xigaze forearc basin, the associated subduction complex and the Tethyan Himalayan sequence. These strata furnish a record of uplift and paleoenvironmental change in the Indus-Yarlung suture zone during the Oligocene-Miocene. Our new and previously published low-temperature thermochronometric data from the Gangdese batholith and the Kailas conglomerates indicate a period of rapid exhumation beginning approximately 17–15 Ma centered on the southern margin of the Gangdese batholith, whereas regional uplift commenced significantly earlier during the deposition of the Kailas conglomerates, based on the presence of an abrupt facies transition from deep-water lacustrine deposits to red alluvial fan or fluvial deposits. The period of rapid exhumation probably lagged behind the initiation of faster uplift, while the related changes in the depositional environment were most likely recorded immediately in the basin stratigraphy. Subsequently, the Kailas conglomerates were buried in association with the development of the north-directed Great Counter thrust, while rapid exhumation was facilitated by efficient incision by the paleo-Yarlung river at approximately 17–15 Ma.

1. Introduction

Along the entire length of the Indus-Yarlung suture zone, the several kilometer-thick middle Cenozoic age Kailas conglomerates rest unconformably upon the Gangdese batholith (Aitchison et al., 2009; Aitchison et al., 2002b; DeCelles et al., 2011; Leary et al., 2016b; Qian, 1985; Wang et al., 2013; Wu, 1979; Yin et al., 1988). These conglomerates provide a detailed record of the depositional environments and erosional processes during the uplift of the Gangdese and Himalayan mountains that helps illuminate the timing and geodynamic mechanism of this orogeny. The Kailas conglomerates were first recognized and named by Heim and Gansser (1939). Subsequently, this sequence has been known by other names, as the Gangdese conglomerates (Li et al., 2017b; Yin et al., 1988), the Gangrinboche conglomerates (Aitchison et al., 2002b; Wang et al., 2013), the Qiuwu Formation, the Dazhuqu Formation, the Luobusa Formation (Qian, 1985; Wu, 1979; Yin et al., 1988), or the Kailas Formation (DeCelles et al., 2011). For the sake of clarity, we use the original name chosen by Heim and Gansser (1939).

During the Oligocene-Miocene, there was dramatic denudation along the southern margin of the Gangdese batholith, most likely related to crustal thickening and uplift (Carrapa et al., 2014; Harrison et al., 1992; Pan et al., 1993). The Kailas conglomerates were deposited during the late Oligocene-early Miocene (26–18 Ma) (DeCelles et al., 2011; Li, 2004; Wang et al., 2013), so the evolution of the Kailas conglomerates presumably record the crucial stages of uplift and exhumation in southern Tibet. Yet, an abrupt facies transition from deep-water lacustrine deposits to red fluvial deposits in this stratum has received relatively little attention. This sharp facies transition extends > 1300 km along the length of the conglomerate belt which suggests to us that it reflects the broader trend in regional kinematics, rather than local uplift.

In this paper, we synthesize fieldwork, previously published stratigraphic sections, and thermochronometric data from this study and others to understand the timing, and the role of processes and mechanisms controlling subsidence, burial, and uplift along the southern margin of the Gangdese batholith.

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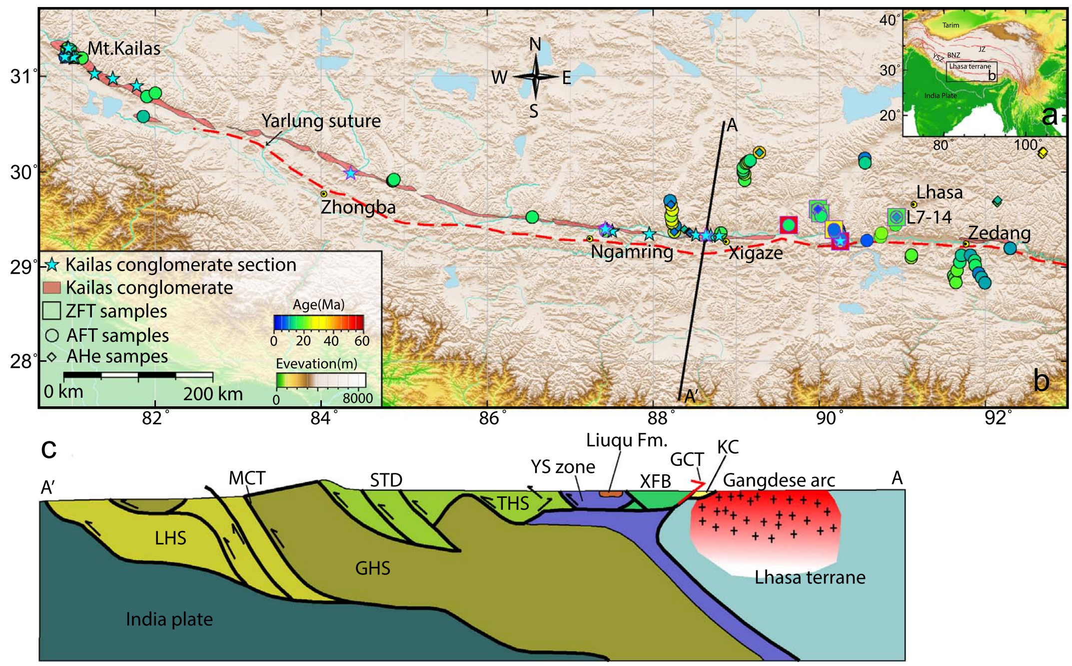

Fig. 1. (a) Digital elevation model of the India-Eurasian collision zone showing the location of major sutures in red, and the regional context of Lhasa terrane. (b) Digital elevation model of the Lhasa terrane showing the Yarlung suture zone (dashed red line), the Kailas conglomerates (the extent of the outcrops are shown in red), and the locations of new and previously published sections (stars) along with ZFT (squares), AFT (circles), and AHe (diamonds) samples. Our samples and sections are outlined in purple. The published AFT and (U-Th)/He are data from Carrapa et al. (2014); Copeland et al. (1995); Dai et al. (2013); Li et al. (2015b); Tremblay et al. (2015); Wang et al. (2007); Zhao et al. (2015); Ge et al. (2017). (c): Simplified north-south cross section of southern Tibet and Tethyan Himalaya, modified from Yin and Harrison (2000) and Carrapa et al. (2014). The cross sections show the Kailas conglomerates (KC), the South Tibetan detachment (STD), the Main Central Thrust (MCT), the Yarlung suture zone (YS zone), the Tethyan Himalaya Sequences (THS), the Great Counter Thrust (GCT) the lesser Himalayan Sequences (LHS), Xigaze Forearc Basin (XFB), the Great Himalayan Sequence (GHS), the Lhasa terrane, and the Indian plate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Geological setting

The area near the Yarlung suture zone (YSZ) is composed of four tectonic units. From north to south, these units are the Gangdese batholith, the Xigaze forearc basin, the Yarlung suture zone, and the Tethyan Himalayan sequence (Yin and Harrison, 2000) (Fig. 1b).

The Gangdese batholith is located in the southern part of the Lhasa Block (Fig. 1a) and extends almost 2000 km from Kailas in the west to Namche Barwa in the east. The origin of the Gangdese batholith is generally ascribed to subduction-zone volcanism related to the Neo-Tethys subduction and subsequent India-Asia collision during the late Mesozoic-Paleogene. Outcrops of volcanic and plutonic rocks of late Mesozoic to Cenozoic age that display a wide variety of compositions can be traced along the entire length of the Gangdese batholith. Typical lithology of the Gangdese batholith includes late Triassic-early Tertiary calc-alkaline granitoids (Chung et al., 2005; Ji et al., 2009; Ji et al., 2014; Scharer et al., 1984), the mostly volcanoclastic Linzizong Group (ca. 69 to 40 Ma), and post-collision magmatic rocks (Lee et al., 2009; Mo et al., 2007; Xia et al., 2011; Zhu et al., 2008). The initial India-Asia collision during the late Paleocene (Hu et al., 2015; Hu et al., 2016), was followed by post-collision magmatism that occurred throughout the Lhasa terrane, often closely associated with N-S trending normal faults or grabens that developed under post-orogenic extensional strain. This magmatic episode produced mostly small volume potassic, ultra-potassic or adakite plugs, dikes and sills that frequently intrude the Gangdese batholith and the linzizong group volcanic and sedimentary successions (Chen et al., 2012; Chung et al., 2005; Guo et al., 2013). The post-collision magmatism mainly range from 26 Ma to 8 Ma (Chung et al., 2005; Chung et al., 2003; Li et al., 2015b; Zhang et al., 2014; Zhao et al., 2009). The geodynamic for this post-collision magmatism is usually explained by one of three geodynamic models: intracontinental subduction of the Indian continental lithosphere (Ding et al., 2003; Guo et al., 2006; Guo et al., 2013), break-off of the India slab (Maheo et al., 2002; Miller et al., 1999; Tian et al., 2015; Williams et al., 2004), or convective removal of the lithospheric mantle (Chung et al., 2005; Huang et al., 2015; Liu et al., 2014; Zhao et al., 2009). The Xigaze forearc basin was formed along the active southern margin of the Eurasian plate during the Cretaceous and is dominated by deep-water turbidites with minor carbonates (An et al., 2014; Dürr, 1996; Einsele et al., 1994; Li et al., 2017a; Wang et al., 2012). The clastic detritus of the Xigaze forearc basin strata were derived from the Gangdese batholith and the central Lhasa terrane (An et al., 2014; Orme et al., 2015; Wang et al., 2012; Wu et al., 2010). The Yarlung-Zangbo

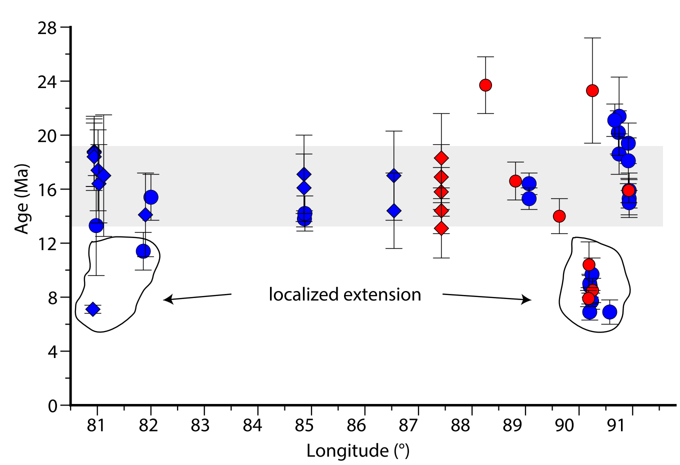

Fig. 2. Plot showing the age (Ma) results and longitude location of apatite fission track samples from the southernmost Gangdese batholith (diamonds) and Gangdese conglomerates (circles). Blue backfill samples are from previous work (Carrapa et al., 2014; Copeland et al., 1995; Yuan et al., 2009; Yuan et al., 2002); Red samples are from this study. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)