Geoscience Frontiers xxx (2017) 1–4

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Geoscience Frontiers

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

GEOSCIENCE FRONTIERS

Field report

Field report: Research along the Yarlung Suture Zone in Southern Tibet, a persistent geological frontier

ARTICLE INFO

Article history:
Received 14 September 2017
Received in revised form 29 September 2017
Accepted 3 November 2017
Available online xxx
Handling Editor: C.J. Spencer

Keywords:
Tibetan Plateau
Himalaya
Field work
Structural geology
Suture zone
HP metamorphism
UHP metamorphism
History of geology

ABSTRACT

The Yarlung Suture Zone in Southern Tibet marks the boundary between India and Asia—formerly separated by an ocean basin—and is a critical record of the tectonic processes that created the Tibetan Plateau. The Yarlung Suture Zone is also a frontier research area, as difficulty of access has limited research activity, providing ample opportunities for new discoveries. This paper documents field research conducted by the authors along the Yarlung suture zone in eastern Xigaze (Shigatse, Rikaze) County, ~250 km west of the city of Lhasa, in July 2017. The goal of this research was to map the Suture Zone structure in detail, and more specifically to understand the branching relationships between two major fault systems—the Great Counter Thrust and Gangdese Thrust. A summary of early geological exploration is included to provide context for this research.

1. Introduction

The Tibetan Plateau (Fig. 1) comprises a spectacular mountain belt of extreme elevation (average >4500 m) and aerial extent (2.5 million km^2; Fig. 1). The rugged beauty of this region and the potential it holds for scientific discovery motivated European expeditions beginning in the late 19th century. Today, the region continues to attract the attention of the international scientific community. The Tibetan Plateau is alluring to geologists studying continental tectonic processes, as it was produced by a series of inter-continental collisions that culminated in the ongoing India-Asia collision. Despite sustained interest, the challenge of accessing the Tibetan Plateau limits research activity, maintaining its status as a research frontier. In this paper, I document field structural geology research conducted in July 2017 along the geological boundary between India and Asia in southern Tibet—the Yarlung Suture Zone (Fig. 1). Major geological expeditions in Tibet and modern developments are summarized to provide historical context. My personal experiences with travel, permitting, and field work are highlighted to reveal the ways that the modern geological expedition has evolved from the time of the early explorers, presenting new challenges and opportunities.

2. Geological exploration of the Tibetan Plateau

Systematic exploration of the Tibetan Plateau by western scientists began with the expeditions of Swedish geographer Sven Hedin, who mapped southern Tibet and located the source of the Brahmaputra and Indus Rivers at the turn of the 20th century. Early geological exploration began about thirty years later, primarily focusing on the Himalaya in India, Nepal, and Pakistan due to the difficulty of accessing the Plateau's interior. Augusto Gansser, a Swiss geologist, discovered fault-bounded slivers of oceanic crust (ophiolites) along the Indus River in northwestern India (Heim and Gansser, 1939), providing evidence that would become critical during the development of Plate Tectonic Theory. In the early 1970's, John Dewey and Kevin Burke became the first to interpret the Tibetan Plateau as the result of collision between India and Asia (e.g. Dewey and Burke, 1973). Their paper revisited samples of volcanic rocks collected by Sven Hedin in 1916, arguing that they provided evidence for subduction of oceanic crust prior to India-Asia collision (Harris, 1992).

The first large geological expedition to Tibet took place between 1980 and 1983, involving cooperation between French and Chinese scientists to map and document more than 2000 km of the Indus-Yarlung Suture Zone (Tapponnier et al., 1981). Soon after, the 1985 Geotraverse expedition documented more than 1700 km of the Tibetan Plateau interior between the city of Lhasa in southern Tibet and the town of Golmud (Fig. 1). Their 22-person team identified several distinct terranes (Fig. 1) that accreted to the southern margin of Asia during Paleozoic and Mesozoic time, culminating with Cenozoic India-Asia collision (Chengfa et al., 1986). The number of geologists working on the Tibetan Plateau increased dramatically after 1990, likely resulting from a combination of less restrictive entry policies and the increasing ease of international travel.

Peer-review under responsibility of China University of Geosciences (Beijing).

Please cite this article in press as: Laskowski, A.K., et al., Field report: Research along the Yarlung Suture Zone in Southern Tibet, a persistent geological frontier, Geoscience Frontiers (2017), https://doi.org/10.1016/j.gsf.2017.11.002

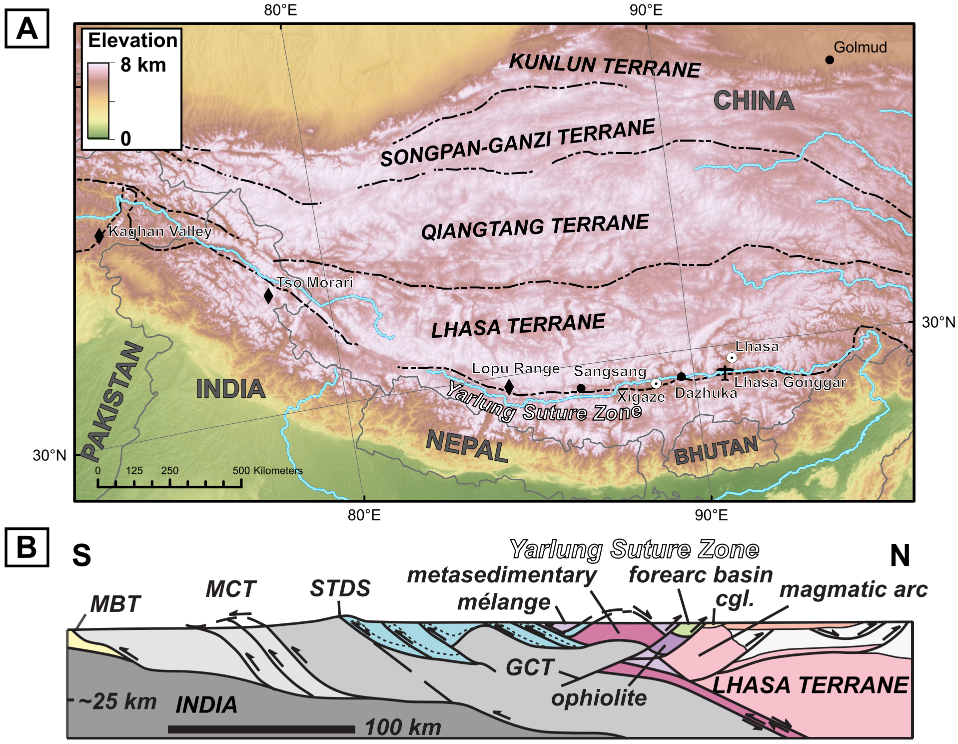

Figure 1. (A) Geographic and tectonic features of the Tibetan Plateau. Sutures are indicated by the dashed line. Locations discussed in the text are indicated by the white circles (major cities), black circles (minor cities), diamonds (high-pressure metamorphism localities), and airplane (airport) symbols. Digital elevation data from the Global Multi-Resolution Topography Database (gmrt.marine-geo.org). (B) Generalized geologic cross section from the southern Lhasa Terrane to the Indian foreland, through the Lopu Range, adapted from Laskowski et al. (2016). Cgl. – nonmarine conglomeratic strata, STDS – South Tibetan Detachment System, MCT – Main Central Thrust, MBT – Main Boundary Thrust, GCT – Great Counter Thrust. The Gangdese Thrust is not shown due to the uncertainty of its location.

Further breakthroughs in understanding the tectonics of the Tibetan Plateau arose from detailed investigation of high- and ultrahigh-pressure metamorphic rocks exposed along the Indus-Yarlung Suture Zone. These are well documented at the classic Kaghan Valley and Tso Morari localities in northwestern India, forming the basis for our understanding of continental subduction and high-pressure exhumation during inter-continental collision (e.g. Guillot et al., 2008; Beaumont et al., 2009). Until recently, high-pressure (HP) metamorphic rocks related to India-Asia collision had not been documented in Chinese Tibet (Xizang), possibly due to difficulty of access. Recent discovery of a blueschist block in the Yarlung Suture Zone mélange near Sangsang, Tibet (Ding et al., 2005) and high-pressure metasedimentary rocks in the Lopu Range (Laskowski et al., 2016) indicate that HP metamorphism is not limited to the western portion of the Indus-Yarlung Suture Zone (Fig. 1). With further field exploration and detailed metamorphic petrology analyses, more evidence for HP metamorphism is likely to be discovered in Chinese Tibet.

3. Research motivation

Field structural geology remains a critical tool along the Indus-Yarlung suture zone, where large areas have only been mapped at 1:500,000 scale. Detailed geologic mapping is critical to understand the mechanisms that drove uplift of the Suture Zone from below sea level to modern elevations of more than 3500 m. The north-dipping Gangdese Thrust (Yin et al., 1994), thought to carry magmatic arc rocks of the southern Asian margin over the Yarlung Suture Zone assemblages, has been interpreted as a crustal-scale structure that drove uplift of the Plateau interior (Harrison et al., 1992). However, other workers question the existence of this structure (e.g. Aitchison et al., 2003), creating a discrepancy in the literature that can possibly be resolved through field structural geology. Furthermore, the timing and possible branching relationships between the Gangdese Thrust and splays of the south-dipping Great Counter Thrust system (Fig. 1) are not known. This summer, I targeted an exposure of the Indus-Yarlung Suture Zone east of Tibet's second largest city, Xigaze (Shigatse, Rikaze; Fig. 1). This region provides a relatively deep exposure of the Suture Zone geology as a result of feedbacks between Yarlung River incision and uplift along a rift flank.

4. Modern conveniences and remaining logistical challenges

The process of conducting field work in Tibet began with the initiation of work permit applications in October, 2016, enabled by collaboration with Prof. Lin Ding and Prof. Fulong Cai at the Institute of Tibetan Plateau Research (ITPR) in Beijing, China. In June, 2017, I received word from Prof. Fulong Cai that the permits were likely to be approved in early July, setting the field season in motion. With formal invitation letter in hand, I drove to the Chinese Consulate in Los Angeles with my field supplies to obtain an entry visa. On July 2, having received final confirmation that the Tibet entry and work permits would arrive within days, I booked a flight to Beijing only 13 h before it was scheduled to depart.

Upon my arrival in Beijing, I met another colleague from ITPR, Dr. Houqi Wang, to travel back to Beijing Capital Airport. His assistance was critical, as Tibet permits are only allowed to be in the possession of Chinese nationals. Upon arrival at the airport, we noticed that many flights were delayed or canceled due to rain and fog. We spent most of the day waiting for an update on our flight, which was eventually canceled. The next few hours were a

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