Journal of Asian Earth Sciences 56 (2012) 147–159

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

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

# New interpretation of tectonic model in south Tibet

Liu Xiaohan [a,*], Kenneth Jinghua Hsu [b], Yitai Ju [c], Guangwei Li [d], Xiaobing Liu [a,e], Lijie Wei [b], Xuejun Zhou [a], Xingang Zhang [f]

[a] Key Laboratory of Continental Collision and Plateau Uplift, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China
[b] Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[c] China Metallurgical Geology Bureau, Beijing 100025, China
[d] Institute of Geology, Chinese Academy of Geosciences, Beijing 100037, China
[e] Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[f] College of Earth Science, Graduate University of Chinese Academy of Science, Beijing 100049, China

ARTICLE INFO

*Article history:*
Received 23 August 2011
Received in revised form 6 May 2012
Accepted 8 May 2012
Available online 18 May 2012

*Keywords:*
Yarlung Zangpo ophiolite zone
Tectonic plate boundary
Tectonic facies
Continental frontal arc
Back-arc basin
High Himalayan shear system

ABSTRACT

We present a new interpretation of tectonic evolution in southern Tibet that is drastically different from the existing models. A detailed tectono-sedimentary study crossing the Yarlung Zangpo ophiolite zone shows that many geological features are different from those commonly described in large subduction collision models. For example, no N–S oriented shear zones are found between the ophiolitic sequence and country flysch strata, whereas a conformable contact relationship is recognized between them. A tectonic window exists inside the ophiolite body in the Bailang region. Some intrusion-like mafic–ultramafic bodies occurred in the Renbu region, where the country strata are in sub-concordant contact with these bodies and show contact metamorphic aureole. Toward the west, the ophiolite zone was separated by flysch sequences into sub-parallel branches. In the Lhasa region, the sedimentary facies are similar on both sides of the Zangpo Valley, and have preserved an intact Mesozoic basin system. Instead of ophiolite rocks, volcaniclastic deposits occurred in the corresponding location of the ophiolite in the Zangpo Valley. Consequently, we conclude that the Zangpo ophiolite zone has a tectonic affinity of back-arc basin with its spasmodic growth of juvenile oceanic crust. The real tectonic suture, or the closure zone of the Neotethys, should be represented by the High Himalaya Central Gneiss Unit, which shows a large scale strong shearing in same orientation, high metamorphism and protracted re-mobilization. The oceanic crust subducted northward and split off the Himalaya continental front arc, created the Zangpo back-arc basin since Late Triassic. The collapse of the Zangpo back-arc basin by supra-subduction occurred since the Eocene. The final collision between India and the Himalayan arc took place since Late Eocene with a re-mobilized large shear system. The major mylonitic zones migrated progressively southward with bulk of shear slip absorbing the crust of north India and south Tibet.



## 1. Introduction

Characterized by a narrow belt of sporadic oceanic rocks, the Yarlung Zangpo ophiolite zone extends more than 2000 km east–west to the southern Tibetan Plateau. The zone lies between the Gangdese igneous arc to the north, and the north Himalaya volcano-sedimentary sequence formations (e.g. Tethyan Himalaya) to the south. A mélange zone cropped out intermittently along this zone. Gansser (1964) considered that the Zangpo ophiolite zone to mark a continental boundary between the Indian and Eurasian lithologic units. Then others accepted this to be the plate tectonic boundary in which the Zangpo zone represents the remnants of a large ocean, called Neotethys. This oceanic crust formed since the Late Triassic, and subsequently underwent northward subduction, followed by the continental collision at the beginning of the Cenozoic. The milestone contribution made by French Chinese cooperation at beginning 1980s, indicated that the Zangpo ophiolite represented a remnant of oceanic crust with extra-slow rate of spreading, formed south of the Gangdese Arc, in a fore-arc position. The ophiolite has preserved its cover of Albian radiolarites grading into the synchronous "Xigaze Group", leading to the conclusion that the Zangpo ophiolite is a remnant of the Asian oceanic crust on which the Gangdse Arc was built (e.g., Nicolas et al., 1981; Shackleton, 1981; Tapponnier et al., 1981; Xiao, 1984; Burg and Chen, 1984; Allègre et al., 1984; Li and Mercier, 1984; Mercier, 1984; LePichon et al., 1992; Einsele, 1994; Dürr, 1996; Wang et al., 1999; Miller et al., 2003; Yin, 2006). The investigations ranging from the petrology to geochemistry of the ophiolite themselves within the Zangpo belt have provided evidences for a multi-stage

* Corresponding author. Tel.: +86 10 82998383; fax: +86 10 62375165.
*E-mail address:* xhliu@mail.iggcas.ac.cn (X. Liu).

1367-9120/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2012.05.005

origin of these ophiolites which has even Indian Ocean's "isotopic signatures" (Dupuis et al., 2005; Zhou et al., 2002, 2005). But some researchers question this tectonic model because the evidence may not be complete or solid enough to support this model. Xiao et al. (1988) found evidence that the Zangpo ophiolite zone might represent the floor of a small ocean, or back-arc origin. Others are inclined to the similar opinions based on their petrology and geochemical studies, including the boninitic melts (Zheng et al., 2003; Pan and Ding, 2004; Geng et al., 2004), but it was puzzled that the Neotethys separating India and Eursia should have been so narrow. New synthesis of geochemistry studies made by Canadian group shows that ophiolites were all generated in supra-subduction zone and more specifically in arc (few fore-arc) and back-arc settings. In addition, most ophiolites were created in short lived (30 Ma) basins and generated close to the Eurasiatic continental margin. They proposed that Ladakh–Tibet ophiolites were generated in a supra-subduction context similar to Mariana arc, inter-arc and back-arc or Tonga–Lau system (Guilmette et al., 2008, 2009, 2011; Bédard et al., 2009; Hébert et al., 2011). Based on Dalziel's invention (1981), and Hsü et al. (1995, 1998, 1999) has proposed an archipelago model of orogenesis. They postulated that the High Himalayan Paleozoic sedimentary and basement rocks had an affinity to those of south Tibet. In this model, they propose that the Himalaya rocks provided the foundation of a south facing island arc separating the Eurasian and India continent. The ophiolites of Zangpo valley represent the Mesozoic back-arc ocean floor north of the Himalaya Arc. This back-arc basin collapsed due to the arc–arc collision when the Himalaya collided with the Gangdese Arc.

The new geological surveys over past 10 years have identified 21 ophiolite zones and 16 high pressure metamorphic belts within the Tibetan Plateau (Pan and Ding, 2004). Obviously, not each of them could represent a tectonic plate boundary, if any does. Zhu et al. (2011) suggested recently that the Mesozoic magmatism in the Lhasa Terrane may be associated with the southward Bangong–Nujiang Tethyan seafloor subduction beneath the Lhasa Terrane, which began in the Middle Permian (or earlier) and ceased in the late Early Cretaceous, and that the significant changes of zircon $\varepsilon Hf(t)$ at ~113 and ~52 Ma record tectonomagmatic activities as a result of slab break-off and related mantle melting events following the Qiangtang–Lhasa amalgamation and India–Lhasa amalgamation. Pan et al. argued also that the Zangpo Ocean opened as a back-arc basin in response to the southward subduction of the Tethyan Ocean lithosphere in the Middle Triassic and closed as result of the India–Asia collision at the end of Cretaceous (Pan et al., 2012).

Ding et al. (2005) have provided new evidence of initial southward obduction of oceanic rocks onto the North Himalaya strata during latest Cretaceous–earliest Tertiary, and input of Gangdese-affinity zircon detritus. An extensive field observations led Xu et al., 2006 to come up with new tectonic hypotheses. Li et al. (2010) reported that the north portion of North Himalayan (Tethyan sequence) exposed in south of the Zangpo ophiolite zone yield U–Pb detrital zircon age probability spectra and $\varepsilon Hf$ values that are in stark contrast with Tethyan sequence strata of known Indian affinity. They proposed that such strata represent a Late Triassic independent terrane resulted from a bathymetric barrier within the "Neotethys Ocean", such as a spreading center or an inter-Tethys arc system. Aitchison and others have noted that the model of the Zangpo Ophiolite as a single long-lived Neotethys must be over-simplified. They postulated "intra-oceanic subduction system", virtually similar to the Dalziel's model of back-arc basin collapse (Aitchison et al., 2000, 2002; Aitchison and Davis, 2004). Aitchison et al., 2007 argued for a 35 Ma event to the India–Asia collision, but the 55 Ma event to the India-Arc collision. Such difference of ages can be resolved if we recognize, on the basis of our model, that the 65 Ma age could represent the beginning of back-arc basin collapse and 35 Ma marks the age of the tectonic plate-collision. Benefited of all of new data collected from recent geological survey, we present in this paper the main results of our extensive field tectono-sedimentary investigations, coupled with the re-examination of mass of previous works published, we conclude that the Yarlung Zangpo ophiolite zone has a tectonic affinity of back-arc basin with its spasmodic growth of juvenile oceanic crust. The real tectonic suture, the Neotethys should be represented by the High Himalaya Central Gneiss Unit.

## 2. Description of the tectonic facies units

Based on different lithologic mechanisms, many tectonic models have been proposed over the decades. In this study, we use the tectonic facies theory to understand the basic orogenic features in southern Tibet. Tectonic facies units are the tectono-stratigraphic bodies underling fault bounded area which share a common history of geological evolution. In a collisional orogenic belt, the tectonic facies units include generally three sorts, e.g. overriding, overridden and escaped units, corresponding to the Austroalpine, Penninic and Helvetic units in the Alpine Orogeny (Hsü et al., 1999). We classified the studied area into eight tectonic facies units, and described their tectono-sedimentary feature as follow (Fig. 1):

### *2.1. Siwalik molasse unit*

The Tertiary Siwalik strata (A in Fig. 1) appear mainly in the footwall of Main Boundary Thrust (MBT) (e.g., Gansser, 1964; Decelles et al., 2001; Yin, 2006), as a narrow band, with the north face inclined and underthrust beneath the Lesser Himalayan sediments and granitoid rocks. The Paleocene–Eocene strata were marine while the Miocene–Pliocene were continental molasse. A general unconformity exists between Oligocene strata below and lower Miocene strata above, implying a tectonic event at the southern Himalaya Mountains. On the south margin of the Siwalik molasse sequence, Quaternary alluvial deposits widely covered the Himalayan foothill region as the Ganges Plain (an active Himalayan foreland basin). The Main Frontal Thrust (MFT) forms the boundary between them, which is regarded as the thrust contact between the Neogene Siwalik strata above and Quaternary deposits of the Indo-Genetic depression below. This fault is commonly expressed as a zone of folds and blind thrusts (e.g., Gansser, 1964, 1983; Lave and Avouac, 2000; Yin, 2006). During the Cenozoic Himalayan orogeny, this unit played a role of tectonic escaped deformation and metamorphism.

### *2.2. Lesser Himalaya Unit*

The Lesser Himalayan Unit (LH) (B in Fig. 1) includes the Proterozoic–Cambrian non-fossiliferous low-grade metamorphosed sequence in lower portion (metasedimentary rocks, metavolcanic rocks, and augen gneiss). In contrast to the North Himalayan (Tethyan Himalaya Sequence), no Ordovician to Carboniferous strata are found along the whole Himalayan orogen east of the Nanga Parbat, with a total stratigraphic thickness of about 10 km (e.g., Heim and Gansser, 1939; Lefort, 1975; Yin, 2006; Kohn et al., 2010). The Permian to Cretaceous unmetamorphosed strata, often referred to as the Gondwana cover, includes the Triassic sequence as a thick formation of plant fossil bearing sandstone and shale. Those sequences may have been sheared off from the Indian passive continental margin, and mixed with arc-basement rocks in a subduction zone. The Eocene to Early Miocene sediments cropped out in upper portion. The MBT, which was active in Middle to Late Miocene (De-