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Tectonic evolution of the Qinghai-Tibet Plateau

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ABSTRACT

The Qinghai-Tibet Plateau, composed of several continental slivers within the eastern Tethyan domain, is one of the pivotal sites to examine to better understand the theory of plate tectonics and the orogenic evolution on Earth. This plateau is generally inferred to be a collage of several continental blocks that rifted from Gondwanaland and subsequently accreted to the Asian continent. However, recent recognition of over twenty ophiolite mélange zones and their associated island arcs indicates that the traditional model of tectonic evolution requires revision. Based on 177 recently finished 1:250,000 scale geological maps and related studies, we summarize the main tectonic context of the Qinghai-Tibet Plateau and propose a new integrated model to account for the new findings. The complex orogen of the immense Qinghai-Tibet Plateau, consisting of multiple island arc-basin systems that developed at different stages while surrounded by the North China, Yangtze, Tarim, and Indian plates, is emphasized. The entire orogen, surrounded by suture zones that mark the locations of oceanic closure, is investigated by examining (I) the first-order tectonic units and ophiolitic mélanges (including arc–arc/continent collision zones) and (II) their internally enclosed blocks as the second-order tectonic units. Therefore, the Qinghai-Tibet Plateau is divided into three major orogenic systems, namely, from northeast to southwest, the Early Paleozoic Qinling–Qilianshan–Kunlunshan (Qin–Qi–Kun), the Late Paleozoic–Triassic Qiangtang–Sanjiang, and the Late Paleozoic to Cenozoic Gangdese–Himalaya orogenic systems, which are separated by the Kangxiwa–Muzitagh–Maqin–Mianxian and the Bangong–Shuanghu–Changning–Menglian sutures, respectively. We propose that the formation and evolution of the Qinghai-Tibet Plateau to have been intrinsically related to those of the eastern Tethys, recorded by the Longmu Co-Shuanghu ophiolite mélange zone, the Southern Qiangtang Paleozoic accretionary arc-basin system, the Bangong–Nujiang suture zone, and their associated, composite island arc-basin systems. The present-day Bangong–Shuanghu–Changning–Menglian suture system marks the final closure of the Tethyan Ocean. The Yarlung Zangbo 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 a result of the India–Asia collision at the end of Cretaceous, followed by the northward indention of the Indian plate that resulted in significant intra-continental deformation and plateau uplift in the Cenozoic.

1. Introduction

It is very important to study the Qinghai-Tibet Plateau as a part of the eastern Tethyan domain to increase our understanding of global tectonics, continental accretion, and ocean–land transformation because of the unique tectonics and evolution of this plateau. Since the bloom of the plate tectonic theory in the 1960s, the Qinghai-Tibet Plateau has been regarded as an ideal site for study to understand the plate tectonic theory and the processes associated with the formation and evolution of continental orogens on earth. The Qinghai-Tibet plateau, which has traditionally been considered to be composed of five suture zones and their intercalated blocks for decades, is generally regarded as a collage of several continental fragments that rifted from Gondwanaland and then accreted to the Asian continent (Chang and Cheng, 1973; Allegre et al., 1984; Dewey et al., 1988; Yin and Harrison, 2000). Nevertheless, a recently completed 1:250,000 scale geological survey and associated studies indicate that this simple model needs to be revised because it does not provide a logical interpretation for

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the presence of over 20 recently discovered ophiolite mélange zones and island arc-basin systems (Li et al., 2004a; Pan et al., 2002a; Wang et al., 2004). This paper, based on the recently obtained data from this geological survey and studies, aims to (1) re-divide the tectonic units of the Qinghai-Tibet Plateau, (2) summarize their basic characteristics, and (3) present a new evolutional model for the formation of the plateau. This study not only provides a new tectonic framework of the Qinghai-Tibet Plateau and its adjacent areas but also an integrated geological setting for better understanding the regional mineralization in different geological and tectonic units. In addition, because of the recognition of the different tectonic boundaries reported in this paper, this study also enhances our capacity to prevent and handle geological disasters.

2. Tectonic framework of the Qinghai-Tibet Plateau

The tectonic evolution of the global lithosphere involves the shift between continental and oceanic lithosphere. The continental lithosphere can be transformed into oceanic lithosphere through rifting, while the latter can be converted into continental lithosphere through subduction. The subduction of oceanic lithosphere can form several kinds of continental arcs and back-arc basins, namely, composite island arc-basin systems (Pan et al., 2004a, 2009), the formation and evolution of which are a mark of the conversion of oceanic lithosphere into continental lithosphere. During this conversion, a series of tectonic units, connected in their geodynamics but possibly differing in their evolution, can be shaped. Some of these units can disappear due to the subduction of oceanic lithosphere, and the remaining units are preserved in orogenic belts that form the composite island arc-basin systems that can be recognized today. Hence, tracking and recognizing the origin of these tectonic units (including ophiolitic mélanges or subduction-accretionary complexes and their enclosed blocks or microcontinents) in orogenic belts formed in diverse periods is expected to provide important insights that help to better understand the evolution and transition between oceanic and continental lithosphere.

The Qinghai-Tibet Plateau is not only a natural site to examine active continent–continent collision, but also a key site to study the evolution and transition between oceanic and continental lithosphere over geological time. This plateau is an excellent place to study these processes because the first-order feature of the Qinghai-Tibet plateau is that it is composed of huge orogenic systems related to a series of composite island arc-basin systems formed in diverse periods, and the plateau is surrounded by the North China, Yangtze, Tarim, and Indian cratons. The formation of the huge orogenic system of the Qinghai-Tibet Plateau has involved a series of geological processes related to oceanic lithosphere subduction, arc–arc/continent collision, such as the formation of the oceanic lithosphere subduction-related island arcs, subduction accretionary complexes, continental arcs, microcontinents, and their enclosed back-arc basins, inter-arc basins, and marginal sea basins. Such complicated geological processes are expected to be unraveled based on the analysis of the components, temporal–spatial features and evolution of currently preserved geological records in the Qinghai-Tibet Plateau.

To date, many studies on the tectonic units and the evolution of the Qinghai-Tibet Plateau have been published over several decades (Huang, 1945; Şengör, 1984; Chang et al., 1986; Wang and Mo, 1995; Hsü et al., 1995; Pan et al., 1997, 2002b). This paper, based on 177 recently finished 1:250,000 scale geological maps and associated studies, presents new tectonic units of the Qinghai-Tibet Plateau delineated by performing a temporal–spatial structural analysis of the comparative tectonics and the tectonic facies to examine the temporal–spatial distribution, nature, and regional geophysics of key geological events. In this paper, the huge orogenic belts surrounded by convergent crustal consumption zones (here, referred to as suture systems) that mark the locations of oceanic closure (Wang, 1985) are considered as first-order (I) tectonic units and named after their geographic names plus their first-order (I) tectonic attributes (e.g., Qin–Qi–Kun orogenic system) (Fig. 1); the ophiolite mélange (including arc–arc/continent collision zone) and their internally enclosed blocks are considered as second-order (II) tectonic units and named after their geographic name plus their second-order (II) tectonic attributes (e.g., Eastern Kunlun arc-basin system); and the geological units bounded by regional faults that were formed during an oceanic–continental transition (e.g., subduction complex, continental arc, back-arc basin, forearc basin, intraoceanic arc or oceanic arc, foreland basin, retroarc foreland basin, pull-apart basin, epicontinental rift or rift basin) are regarded as third-order (III) tectonic units and named after their geographic name plus their third-order (III) tectonic attributes (e.g., Northern Kunlun magmatic arc).

3. Main features of huge orogenic system

The Qinghai-Tibet Plateau can be divided into three huge orogenic systems, from northeast to southwest: (1) the Qinling–Qilianshan–Kunlunshan, (2) the Qiangtang–Sanjiang, and (3) the Gangdese–Himalaya, which are bounded by the Kangxiwa–Muzitagh–Maqin–Mianxian and Bangong–Shuanghu–Changning–Menglian suture systems, respectively (Fig. 1). The plateau includes nine first-order, 37 s-order, and 81 third-order tectonic units (Fig. 1; Table 1).

3.1. Early Paleozoic Qinling–Qilianshan–Kunlunshan (Qin–Qi–Kun) orogenic system of the Pan-Cathaysian continental margin

This orogenic system is situated as a huge belt to the north of the Kangxiwa–Muzitagh–Maqin–Mianxian suture system and to the south of Tarim and North China cratons (Fig. 1). It is also referred to as the Central Orogenic Belt (Yin and Zhang, 1998) or Central Orogenic System (Zhang et al., 2003). This system includes the Zoulang back-arc basin, the Sunan–Tianzhu ophiolite mélange zone, the Zoulang Nanshan island-arc, the Yushigou–Yeniugou–Qingshuigou (Northern Qilian) ophiolite mélange zone, the Central Qilian–Huangyuan block, the Danghe Nanshan–Lajishan ophiolite mélange zone, the Southern Qilian magma arc, the Zongwulongshan rift, the Quanji massif, the Tanjianshan magma arc, the Saishitengshan–Xitieshan (northern margin of the Qaidam basin) ophiolite mélange zone, the Hongliugou–Laipeiquan ophiolite mélange zone, the Central Altyn–Milanhe–Jinyanshan block, the Apa-Mangnai ophiolite mélange zone, the Qaidam block, the Hezuo-Lixian epicontinental rift, the Xinghai–Zeku back-arc foreland basin, the Xiqingshan block, the Northern Qimantagh magma arc, the Qimantage ophiolite mélange zone, the Ayakeku Cenozoic fault basin, the Northern Kunlun magma arc, the Elashan continent arc, the Saishitang–Xinghai ophiolite mélange zone, the Qiaerlong–Kuerliang back-arc rift basin, the Oytog–Tamuqi island-arc, the Kudi–Qimanyute ophiolite mélange zone, and the Liushitagh–Shangqihan magmatic arc (Unit III and subunits; Fig. 2, Table 1). The Kunlun front arc developed in the western margin of the Pan-Cathaysia continent in the Early Paleozoic. To the north of the Kunlun front arc, the Tarim, Qaidam, Qimantage, Altyn Tagh, Qilianshan, and Lajishan regions underwent a series of geological events during the Early Paleozoic, including, for example, island-arc formation, back-arc spreading/subduction, arc–arc/continent collision. During the Devonian, most areas evolved into continental lithosphere as part of the southwestern margin of the North China craton.