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RESEARCH ARTICLE

Longmu Co–Shuanghu plate suture and evolution records of paleo-Tethyan oceanic in Qiangtang area, Qinghai–Tibet plateau

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Abstract Three Late Triassic plate sutures, namely, the Longmu Co–Shuanghu suture, Kunlun–Qinling suture and Xijinwulan–Jinshajiang suture, have been recognized on the Qinghai–Tibet plateau. Data show that the last two sutures have no essential elements of the northern boundary of Gondwana. This paper briefly introduces the facts of the existence of the paleo-Tethys Ocean in the Longmu Co–Shuanghu suture, i.e., the ages and natures of Early Paleozoic ophiolites, Permian ophiolites, Devonian–Permian radiolarian cherts, accretionary relics of different natures, two types of tectonic mélange zones and ophiolites. The starting time of paleo-Tethys Ocean in Qiangtang may be traced back to the Early Paleozoic and the records about the oceanic basin evolution lasted from the Late Devonian to Late Triassic. It is thought that the Longmu Co–Shuanghu suture was the site for the extinction of the paleo-Tethys Ocean on Qinghai–Tibet plateau and an important window for the reconstruction and inversion of the early-stage formation and evolution of the Qinghai–Tibet plateau, as well as the northern boundary of Gondwana wich the geoscience community has paid attention to in the past few decades.

Keywords Longmu Co–Shuanghu plate suture, paleo-Tethyan Ocean, north boundary of Gondwanaland, Qiangtang, Qinghai–Tibet plateau

1 Review and argument about Longmu Co–Shuanghu suture zone

The evolution of Tethys and the boundary between Gondwana and Eurasia have become one of the hottest problems of geoscience, since Plate Tectonic Theory was applied to the study of the Qinghai–Tibet plateau. Indus–Tsangpo suture zone (Gansser, 1964), Bangonghu–Nujiang suture zone (Li et al., 1982; Liu et al., 1983; Pan et al., 1983, 1997, 2002, 2004; Pan et al., 2004a; Xiao et al., 1986; Ren, 1997) and Xijinwulan–Jinshajiang suture had been considered as the boundary between Gondwana and Eurasia or the record of paleo-Tethys in different times, respectively (Huang et al., 1984; Huang and Chen, 1987; Qian, 1994).

Based on 1:1 000 000 regional geological investigation in 1987, Li (1987) considered the Longmu Co–Shuanghu–Lancangjiang plate suture zone to be the north boundary of Gondwana in Carboniferous–Permian. In the 1980s, some researchers had realized that the boundary between Gondwana and Eurasia should be in the Qiangtang area since the sedimentary rocks and cold water biology of Gondwana facies occurred in the southern slope of the Karakorum Mountain and southern Qiangtang area. Sengor et al. (1988, 1991) suggested that the Qiangtang suture or Chasang suture had divided Qiangtang into East and West Qiangtang (Sengor et al., 1988, 1991). Some scholars thought the central Qiangtang area was situated in the abortive rift (Wang et al., 1987; Deng, 1996; Deng et al., 1996; Yin, 1997). We carried out the field work in central Qiangtang area between 1991 and 1993, supported by the National Natural Science Foundation of China, and the results have been published recently (Li and Zheng, 1993; Hu et al., 1995; Li et al., 1995a, b; Li, 1997; Cheng et al., 1998). However, Deng et al. (1996) thought, after their exploratory research, that the "suture", "blueschist high pressure belt", "mélange" and "ophiolite" did not exist and the Longmu Co–Shuanghu suture was not the north boundary of Gondwana. From 1996 to 1998, we carried out comprehensive researches on the central Qiangtang uplift, supported by PetroChina Company Limited, and we thought

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there was enough evidence to prove Longmu Co–Shuanghu suture to be the north boundary of Gongdwana during the paleo-Tethys stage (Li, 2001, 2003). However, Kapp et al. (1999, 2003) suggested that the metamorphic rocks were an Early Mesozoic mélange that was underthrust from the Jinshiajang suture and then exhumed in the interior of the Qiangtang block, and the boundary between Gondwana and Eurasia was the Jinshajiang suture.

Deng et al. (2000, 2001, 2002) published their research work about the blueschist and the age and process of the high metamorphism in Gangma Co area. Lu et al. (2006) reported the blueschist and its age in Hongjishan area, west Qiangtang, and Wang et al. (2006b) reported the age data of the blueschist from Qiagelela, Shuanghu area and discussed its tectonic significance.

The geophysical work, such as Jilong–Sangehu geophysical profile carried by the Chinese Academy of Sciences, International deep profiling of Tibet and the Himalaya (INDEPH) and the geophysical work carried by PetroChina Company Limited, had come to an approximate conclusion that there was an important geophysical borderline along Lugu–Ejiumai–Shuanghu (that is the location of Longmu Co–Shuanghu suture) (Kong et al., 1996, 1999). Magnetotelluric (MT) research work carried out by Zhang et al. (1996) suggested that the electrical property and high-ohmic body in South Qiangtang and North Qiangtang were different. The high-ohmic body in South Qiangtang was thicker and asymmetric; on the contrary, that in North Qiangtang was thinner and the electrical resistivity was lower, which implied that the basement in South Qiangtang and North Qiangtang was different (Liang et al., 1983).

With the recent development of 1:250 000 regional geological investigation and research, many new progresses and discoveries have been made. For example, the Ordovician–Devonian from South Qiangtang area was found to accord with those from Nyalam and Shentza area; Yangtze type Devonian–Permian was discovered in North Qiangtang area; Late Devonian and Late Permian radiolarian silica rocks were discovered in Shuanghu area; eclogite and Early Paleozoic oceanic crust relic and Permian oceanic island ophiolite were identified in Qiangtang area, and so on (Zhai et al., 2004).

2 Tethys evolution and plate tectonics in Qinghai–Tibet plateau

Professor Chen (1994) came to a comprehensive conclusion for the 100-year study on Tethys. With the increase of data and the progress of research, the concept of Tethys has changed from one Mesozoic Tethys into many evolution stages since the Paleozoic, and lots of papers named the paleo-Tethys and new Tethys with different precept (Li et al., 1995b; Pan et al., 2004). Recently, some researchers considered it to be Paleozoic Tethys and Mesozoic Tethys (Chengdu Institute of Geology and Mineral Resources, China Geological Survey, 2005). In this paper, paleo-Tethys is the one that occurred between the Gondwana and Yangtze plates during Devonian–Triassic, and new Tethys is the one that occurred in the Indus–Tsangpo suture zone and Bangonghu–Nujiang suture zone during Permian–Oligocene.

Three Triassic sutures have been recognized (Fig. 1). The Kunlun–Qinling suture zone is the boundary of Tarim–North China plate and Yangtze plate (Eurasian plate is made up of Yangtze plate and Tarim–North China plate); Longmu Co–Shuanghu suture is the boundary of Gondwana plate and Yangtze plate. The opening age of Bangonghu–Nujiang ocean was Late Triassic. However, without the relics of Paleozoic ocean, the earliest ophiolite age was 193 Ma (Qiu et al., 2004); the oldest radiolarian was Late Triassic (Wang et al., 2002a, b), and the SHRIMP zircon age from gabbro dikes in Shemala, Gerze was 221 Ma (Zeng et al., 2006, 1:250 000 Gerze Regional Geological Investigation Report), and the closure age was Middle Jurassic–Early Cretaceous. He et al. (2000) obtained SHRIMP zircon age of ophiolite from Shiquanhe–Yongzhu–Jiali belt of 218 Ma. The opening age of the Indus–Tsangpo ocean was Permian or Triassic, but the closure age was later. All these give us important information that the opening of the Bangonghu–Nujiang ocean accelerated the closure of Qiangtang paleo-Tethys. Bangonghu–Nujiang suture is a new Tethys suture developed within Gondwana, which cannot constrain the accretion in the north margin of Paleozoic Gondwana and cannot make up the north boundary of Gondwana. Therefore, we consider the Longmu Co–Shuanghu–Changning–Menglian suture zone to be the north boundary of Gondwana in Qinghai–Tibet plateau (Li et al., 2006a) and Fig. 1 is the tectonic framework in the Late Triassic of the plateau.

3 Evolution of paleo-Tethys in Qiangtang area (Fig. 2)

3.1 Ophiolitic

Ophiolitic mélange or tectonic mélange is the key to rebuild a paleo-ocean. However, the information kept in ophiolite or mélange is limited, because the matter in the oceanic crust and mid-oceanic-ridge has mostly been subducted and recirculated, and the ophiolites preserved in the plate margin are almost oceanic island ophiolite, or MORB-like and island arc ophiolite, such as the ophiolite from Longmu Co–Shuanghu suture zone. However, the research on ophiolites from this suture has obtained some progress. The “ophiolites” were reported without intact ophiolitic assemblage (Li, 1987; Xiao et al., 1988) and controversy occurs on whether it is indeed ophiolite or not (Deng, 1996; Deng et al., 1996; Zhai et al., 2007).

3.1.1 Early Paleozoic oceanic crust relic

Early Paleozoic oceanic crust relic occurs at Guoganjianianshan only and extends from east to west for about 40 km in central Qiangtang area (Fig. 2), which consists of

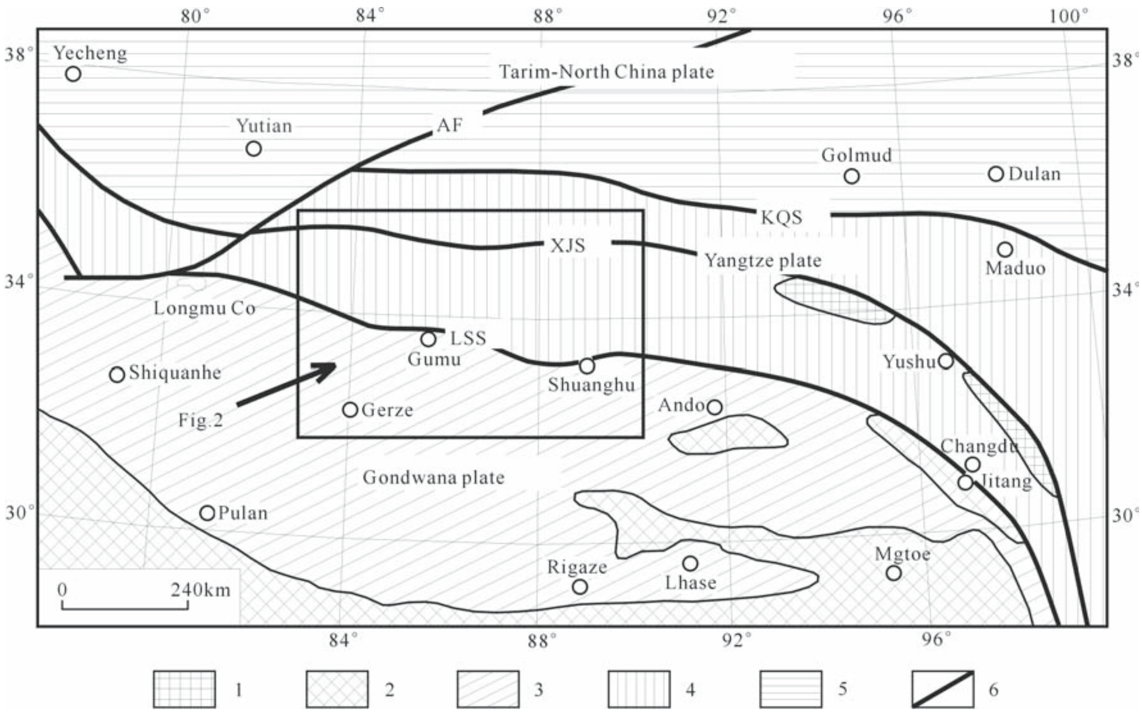

Fig. 1 Qinghai–Tibet plateau sketch map of plate suture of T_3 (after Li et al., 2006a)
1. Jinning basement of Yangtze plate; 2. Pan-African basement of Gondwana; 3. Paleozoic accretionary of northern Gondwana; 4. Yangtze plate; 5. Tarim–North China plate; 6. Late Triassic suture; LSS. Longmu Co–Shuanghu suture; XJS. Xijinwulan–Jinshajiang suture; KQS. Kunlun–Qinling suture; AF. Altyn Tagh strike slip fault

metamorphic cumulate, basalt and some actinolite greenschist. The contents of SiO_2 in metamorphic cumulate range from 43.03%–53.42%, TiO_2 1%–2.67%, Al_2O_3 16.75%–21.52%, CaO 7.03%–11.13%, K_2O 0.05%–0.38%; the rare earth element (REE) pattern is near smooth and trace element spidergram like that of middle ocean ridge basalt (MORB) (Chen, 1994).

The cathodeluminescence (CL) images of zircons from the metamorphic cumulate indicate that they are metamorphic zircons and SHRIMP dating results are Early Silurian. Ar/Ar age of actinolite from metabasalt (actinolite schist) is 220 Ma, consistent with Ar/Ar ages of glaucophane and phengite. These ages suggest that the protolith age of oceanic relic was earlier than Early Silurian and experienced two stages of metamorphism, Early Silurian and Late Triassic. Late Triassic metamorphism was the result of the close of paleo-Tethys in Qiangtang area.

3.1.2 Middle Permian ophiolite

Middle Permian ophiolite spreads along Hongjishan, Jiaomuri, Xueshuihe, Mayigangri, Naruo, Qiagelela and Caiduochaka in central Qiangtang area, extending over 500 km. The rocks consist of pyroxene peridotite, olivine pyroxenite, gabbro-diabase, basalt, pillow basalt, and radiolarian siliceous rock. According to fossils from interlayer, the pillow basalt age is Middle Permian, and turbidite with Bouma sequence occurs in Jiaomuri area. The ophiolites formed in a MORB-like setting just like the ophiolite in Sanjiang area based on their assemblage and geochemistry feature (Chen, 1994).

3.2 Radiolarian siliceous rock and turbidite from Qiangtang area

Radiolarian siliceous rock together with pillow basalt from ophiolite signifies ocean floor or deepwater sediment and can help identify tectonic setting and depth of the sedimentary basin. Many radiolarian siliceous rocks have been found in the Qiangtang area, such as, Triassic rocks to the south of Caimaercuo (Li et al., 1997) and Permian rocks in Jiaomuri and Heishishan (Li et al., 2006, 1:250 000 Mayigangri Regional Geological Investigation, Tibet). Zhu et al. (2006) obtained Late Devonian Famennian age and Late Permian Changxingian Stage radiolarians from black siliceous rocks in the Caiduochaka area in the east Shuanghu. Devonian Famennian age radiolarians are major *Entactinids*, such as, *Stigmosphaerostylus oumonhaoensis*, *Trilonehe echinata* and *Archocyrtium riedeli*, Permian Changxingian Stage radiolarians are major *Neoalbaillella*, such as, *N. ormithoformis* and *N. optima*. These radiolarians were first discovered in Tibet (Zhu et al., 2006), which can provide some important information on the formation and evolution of paleo-Tethys in the Qiangtang area. There is no evidence suggesting that other Devonian ocean had existed in the Qiangtang area. Radiolarian siliceous rocks, deep water flysch, oceanic island basalt, and sedimentary rocks indicate an ocean island

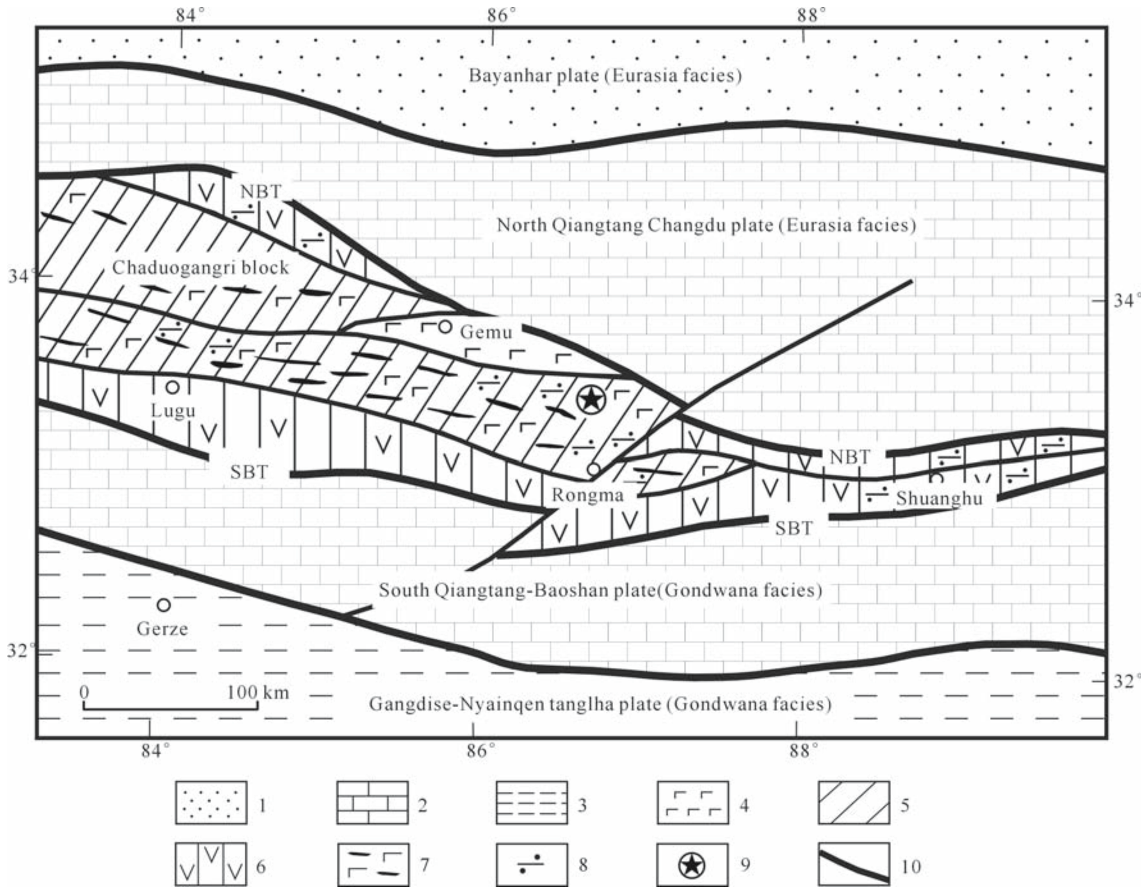

Fig. 2 Tectonic sketch map of paleo-Tethyan sutures of Qiangtang area, Tibet
1. Bayanhar flysch facies sedimentary rocks; 2. Mesozoic sedimentary rocks; 3. Mesozoic orogenic belt; 4. Early Paleozoic oceanic relic; 5. Late Carboniferous active accretionary wedge; 6. Early–Middle Permian accretionary rocks; 7. Basalt, basite dike swarms; 8. blueschist belt; 9. Eclogite; 10. Fault; NBT. main north boundary fault of Longmu Co–Shuanghu suture; SBT. main south boundary fault of Longmu Co–Shuanghu suture

occurred in this area in the Late Permian, and the earth's crust might have begun cracking in Late Devonian. Sun et al. (1996) took red radiolarian siliceous rocks from Jinghong in the south of Lancangjiang for oceanic sediment. Zhang et al. (2003) considered siliceous rocks from Gengma area of West Yunnan to be the ocean marginal sediment in the continental margin. Radiolarians and their occurrence position in Qiangtang area and West Yunnan area are similar (Wang et al., 2000; Zhang et al., 2003, 2005; Zhu et al., 2006), which suggests that there is one tectonic belt or ocean in Qiangtang and West Yunnan area, that is, Tethys in Qiangtang area linked with Tethys in West Yunnan area after Late Devonian.

Although turbidite is few, flysch formation with two ages has been identified in the central Qiangtang area. Early Permian flysch and Lower Permian Qudi Group of about 300 m thick locates in Heishishan and Jiaomuri areas in Rongma Town, Nima County. The flysch consists of alternating lamella fine sand and silty mud; calcareous concretion occurs at the east side of Heishishan, with scolite fossils. Late Triassic flysch that occurred in the south of the Caimaercuo area, Chabu Town, Gerze, is mainly of sand mudstone, kiesel siltstone, kiesel mudstone and siliceous rocks.

3.3 High pressure metamorphic rock in Qiangtang area

There are two-epoch blueschists in the Qiangtang area, and one is Early Permian blueschist with the glaucophane Ar-Ar age of 282 and 275 Ma (Deng et al., 2001); for example, Gangmacuo blueschist is mainly glaucophane and crossite and their formation temperature is about 400°C, pressure about 7 kPa (Deng et al., 2000, 2001, 2002); the other is the Late Triassic one. For example, Hongjishan, Pianshishan, Lanling in Rongma, Jiaomuchagari, Naruo Qiagelela and Caiduochaka blueschists are mainly crossite with metamorphic temperature 410–460°C, pressure 6.7–7.5 kPa (Hu et al., 1995; Bao et al., 1999). C type eclogite occurs as lens in muscovite blueschist and garnet muscovite schist in the Gemuri area, central Qiangtang (Li et al., 2006b). Phengites Ar-Ar age of 219–217 Ma from eclogite and its country rocks suggests eclogitic metamorphism age was Late Triassic. That is, two blueschists with a discrepancy of about 60 Ma occur in central Qiangtang area, which suggests that the evolution of paleo-Tethys in this area is very complicated.

Recently, phengite Ar-Ar age of (231 ± 1) Ma from Jiuxi Group was obtained from the south side of Taniantaweng

(Wang et al., 2006a), and Late Triassic age from metamorphic basalt in Changdu area. Therefore, high-pressure metamorphic belt in the Qiangtang area has reached the Taniantaweng and Jitang areas in Changdu, and connected with the Lancangjiang blueschist belt in West Yunnan area (Zhao et al., 1994).

The protolith of high pressure metamorphic rock is ophiolitic mélange or accretionary wedge, northern Gondwana, in central Qiangtang, without Yangtze type sediment involved in high pressure metamorphic rocks. Therefore, the Longmu Co–Shuanghu suture maybe a strike slide boundary and Gondwana subducted beneath Eurasia (Yangtze) along this suture.

4 Different times of accretion body from Longmu Co–Shuanghu suture

4.1 Early Paleozoic oceanic crust relic

Although Early Paleozoic oceanic crust from Guoganjianianshan is only 100 km^2 (Fig. 2), it is the oldest in the Longmu Co–Shuanghu suture zone and it even extends to Changning–Menglian suture zone in West Yunnan area. The relic distributes nearly from west to east, unconformably underlying Upper Triassic to the north and up thrust to the south on Carboniferous–Permian rift sedimentary rocks (experienced later Triassic high pressure metamorphism). It is very important for this relic to rebuild paleo-Tethys evolution in the Qinghai–Tibet plateau.

4.2 Late Carboniferous–Early Permian active margin accretionary wedge, south Qiangtang

Late Carboniferous–Early Permian active margin accretionary wedge in south Qiangtang area, named Carboniferous Chameng Formation and Zhanjin Formation in South Qiangtang area, Jiuxi Group in Jitang area, Dingjiazhai Formation and Woniusi Formation in West Yunnan area, Puji Group in south Thailand, extends from Karakorum south slope to Qiagelela west Shuanghu, about 800 km long and 100 km wide, bounded by huge west-east distributed faults, and reaches Jitang, Changning–Menglian area and Thailand peninsula. Late Carboniferous sedimentary rocks from Qiangtang area are composed of sandstone, argillaceous slate, ice-sea diamictite basalt, pillow basalt and so on, with few fossils except for some cold-water biota fossils (Liang et al., 1983; Guo et al., 1991). The rock assemblage indicates the existence of the sediment of continental marginal rift with the thickness of several kilometers in south Qiangtang area, and basalt proportion is more than 50% in some areas. Besides, Late Carboniferous within plate basalts and basite dyke swarm extend from east to west in the accretionary wedge (Li et al., 1995b; Wang et al., 2004). The protolith of high pressure metamorphic rocks are mainly basic volcanic rock and gabbro (or diabase) in Late Carboniferous rift sedimentary rocks (Li et al., 1995b; 2001).

4.3 Lugu–Jiaomuri–Qiagelela Early–Middle Permian oceanic island accretionary rocks

Lugu–Jiaomuri–Qiagelela Early–Middle Permian oceanic island accretionary rocks were first recognized and were named clastic-carbonate rock-MORB assemblage in active marginal sea, Gondwana in "the study of Longmu Co–Shuanghu paleo-Tethys suture zone, Tibet" (Li et al., 1995b).

The oceanic island accretionary rocks, the best one preserved in Longmu Co–Shuanghu suture zone, extend from Lugu to Shuanghu with more than 350 km in length and ca 40 km in width, consisting of limestone, biologic limestone, pillow basalt, brecciform basalt, basaltic conglomerate, fine conglomerate, and radiolarian siliceous rock. There are coral, polyzoa, etc. fossils in limestone interbedding with basalt, such as six layers of interlaid limestone and basalt in the Jiaomuchaka area. The thickness of pillow basalt in west Jiangaizangbu is over 600 m, and is mixed with some limestone block (Li et al., 1995b). The sedimentary rocks are mainly conglomerates and most gravels are basalt and limestone. Cements are kalk and basaltic clastics without continental clastics. All these characters of the accretionary body accord with those of ocean island or seamount, and are bounded by large fractures.

4.4 Tectonic mélange from Longmu Co–Shuanghu suture zone

The mélange from the Longmu Co–Shuanghu suture zone can be classified into two types: high pressure tectonic mélange and sedimentary structure mélange. The former, about 500 km, extends from Hongjishan, Pianshishan, Lanling, Naruo, Qiangelela to Caiduochaka in the Shuanghu area. The latter is shorter and located to the north of the former along the Longmu Co–Shuanghu suture with about tens of kilometers in length and about tens of kilometers in width, for example, Guoganjianianshan, Saie in Chasang area and Qiagelela (Li et al., 1995b; Cheng et al., 1998). The matrix of the mélange is Late Triassic sedimentary rocks and exotic block is mainly Devonian, Carboniferous and Permian limestones. It had been named "tectonic blend" and considered to be the result of the subduction of Longmu Co–Shuanghu suture (Li et al., 1995b).

4.5 Caprocks of ophiolitic mélange

The first caprock of ophiolitic mélange in Guoganjianianshan, central Qiangtang area, can indicate the transformation of tectonic properties in this area. A suite of sedimentary rocks overlay on the ophiolitic mélange and neopaleozoic metamorphic rocks in north Guoganjianianshan in angular unconformity. At the bottom of the sedimentary exists basal conglomerate that comes from ophiolitic mélange and Neopaleozoic metamorphic rocks. Above the basal conglomerate are sandstone, siltstone, siliceous sandstone, and some exotic blocks with fossils. Zircon SHRIMP age of interlayer rhyolitic from the bottom is Late Triassic, so we established the Wanghuling Formation (T_3), which represents the sedimentary rocks after the close of the suture. The angular unconformity overlying the ophiolite in Guoganjianianshan provides the latest time of the paleo-Tethys in the Qiangtang area.

5 Discussion

5.1 The evidence of paleo-Tethys in central Qiangtang area

The differences of Neopaleozoic–Triassic sedimentary formation, biogenic derivation, magmatic activity, metamorphism and tectonic movement between south and north Longmu Co–Shuanghu suture and oceanic relic confirm the existence of paleo-Tethys in this area (Li et al., 2006a). The marine sedimentary sequence since Ordovician in the south Qinghai–Tibet plateau developed in the north Gondwana margin and the similar basement, Paleozoic sedimentary sequence and biogenic derivation are premises of identifying Gondwana (Li et al., 2006a). The caprocks after Jinning basement and South China epoch and late Caledonian movement are ubiquitous in the Yangtze plate. Different constitution and evolutionary history are the key to subdividing different plates. There are divarications on the shape, width, and so on of paleo-Tethys. Late Carboniferous–Early Permian active marginal and Permian oceanic island accretionary wedge, Early Paleozoic oceanic relic, Permian oceanic ophiolite, Devonian–Triassic radiolarian siliceous rock, eclogite-blue schist, high pressure metamorphic belt and Late Triassic mélange in the central Qiangtang area provide basic data for rebuilding the evolution process of paleo-Tethys.

5.2 Evolutionary period of paleo-Tethys in Qiangtang area

It is difficult to ensure the evolutionary period of paleo-Tethys in the Qiangtang area based on current data. The metamorphic oceanic relic occurs in Guoganjianianshan and metamorphic age is Early Silurian by zircons SHRIMP dating; whether it is the mark of paleo-Tethys or not still needs further study. Permian oceanic island ophiolite in Jiaomuri area cannot represent host oceanic basin. However, Late Devonian radiolarian siliceous rocks from Shuanghu area and Permian and Triassic radiolarian siliceous rocks from other areas can indicate that the evolution of paleo-Tethys in the Qiangtang area is successive from Late Devonian to Triassic and could connect with Changning–Menglian ocean. The chronology of high pressure metamorphic minerals (Li, 1997; Kapp et al., 1999, 2000; Wang et al., 2006b) and the time of the sedimentary rocks overlying on ophiolite in Guoganjianianshan provide the latest age of paleo-Tethys in the Qiangtang area. Therefore, the evolutionary period of paleo-Tethys in the Longmu Co–Shuanghu suture zone begins from Late Devonian and ends at 220 Ma and may prolong to Early Paleozoic.

5.3 The north boundary of Gondwana: Longmu Co–Shuanghu suture

Every tectonic unit has its own time-spatial evolution domain. As Gondwana cracks and converges, the evolution of Tethys experienced this from Paleozoic to Mesozoic. Where then is the north boundary of Gondwana? Different scholars have drawn different conclusions, and their perception of the boundary between Gondwana and Eurasia is also different. In the past decades, several sutures had been considered to be the north boundary of Gondwana. As the data and research work developed, divarication focuses on Longmu Co–Shuanghu suture and Bangonghu–Nujiang suture (Li et al., 1982; Liu et al., 1983; Pan et al., 1997, 1983, 2002, 2004a, b; Ren, 1997). Some scholars suggested that the Bangonghu–Nujiang suture is the north boundary of Gondwana, which experienced ancient Tethys, paleo-Tethys and new Tethys (Pan et al., 1997, 2002; Pan et al., 2004a; Chengdu Institute of Geology and Mineral Resource, China Geological Survey, 2005). However, there is no relic of a Paleozoic ocean in the Bangonghu–Nujiang suture, and the ages of ophiolite and radiolarians are Late Triassic (Qiu et al., 2004; Wang et al., 2002a). Therefore, the suture cannot restrain the Gondwana Paleozoic accretion body and is not the boundary between Gondwana and Eurasia during the paleo-Tethys stage. The opening of the Bangonghu–Nujiang ocean accelerates the close of paleo-Tethys in the Qiangtang area, and paleo-Tethys and new Tethys have formed a geodynamic system.

According to the research on the basic tectonic unit in the Qinghai–Tibet plateau and Late Triassic plate sutures, the Longmu Co–Shuanghu suture zone preserves many data of the evolution of paleo-Tethys, with basic feature of north boundary of Gondwana. Although it is still questionable, the central Qiangtang area is the key to rebuilding the early evolution of the Qinghai–Tibet plateau. In the past 20 years, great improvements have been obtained in the study on the Longmu Co–Shuanghu suture, though some key problems are still needed lucubrating.

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