New biostratigraphic evidence of Late Permian to Late Triassic deposits from Central Tibet and their paleogeographic implications

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ABSTRACT

Triassic deposits in the Bangong-Nujiang Suture Zone are important for understanding its tectonic nature and evolutionary history, but have not been systematically studied due to a lack of biostratigraphic data. For a long time, the Upper Triassic Quehala Group featuring clasolite has been regarded as the only rocky unit. In recent years, the silicite-dominated Gajia Formation that bears radiolarian fossils was suggested to represent Ladinian to Carnian deposits. The Upper Permian and Lower Triassic rocks have never been excavated and thus are considered to be absent. This research, however, reveals that fossils aged from the Late Permian to Anisian of the Middle Triassic and Norian of the Late Triassic have been preserved in the central Bangong-Nujiang Suture Zone, which provides evidence of Upper Permian to early Middle Triassic deposits and provides new insights on the Upper Triassic strata as well. A new Triassic strata succession is thus proposed for the Bangong-Nujiang Suture Zone, and it demonstrates great similarities with those from Lhasa to the south and Qiangtang to the north. Therefore, we deduce that the Bangong-Nujiang Suture Zone was under a similar depositional setting as its two adjacent terranes, and it was likely a carbonate platform background because limestones were predominant across the Triassic. The newly acquired biostratigraphic data indicate that Lhasa and Qiangtang could not have been located on two separate continents with disparate sedimentary settings; therefore, the Bangong-Nujiang Suture Zone likely did not represent a large ocean between them. This conclusion is supported by lithostratigraphic and paleomagnetic research, which revealed that Lhasa and Qiangtang were positioned at low to middle latitudes during the Early Triassic. Combining this conclusion with fossil evidence, we suggest that the three main Tibetan terranes were in the same palaeobiogeographic division with South China, at least during the Latest Permian to Early Triassic. The Early Triassic conodont species Pachycladina obliqua is probably a fossil sign of middle to low latitudes in palaeogeography.

INTRODUCTION

The Bangong-Nujiang Suture Zone (BNSZ), which is bounded by the Lhasa terrane to the south and the South Qiangtang terrane to the north, is an E–W trending tectonic unit in central Tibet (Pan et al., 2013; Zhu et al., 2016) (Fig. 1). In research into dispersion, amalgamation, and convergence between Eurasia and Gondwana, the tectonic background of Bangong-Nujiang during the Triassic has always been a tantalizing subject (Scotese and McKerrow, 1990; Pan et al., 2012; Metcalfe, 2013). At present, disagreements abound, as represented by two opposite opinions. The mainstream view is that it was one part of the Tethyan Ocean between Eurasia and Gondwana, and the Bangong-Nujiang terrane to have remained on the north margin of Gondwana since the Late Permian that began rupturing as a continental rift along the BNSZ at the end of the Late Triassic (Zhao et al., 2001) (Fig. 3). Others pointed out that Lhasa and Qiangtang were in a similar marine setting during the Triassic (Ji et al., 2018a), separated only by a wide seaway rather than a large ocean (Yang et al., 1984; Chen et al., 2001).

These disputes primarily resulted from rarely documented stratigraphic data. The ocean opinion was based on siliceous rock producing radiolarian fossils of the Late Triassic Carnian in the Dingqing area (Wang et al., 2002) or on the siliceous rock of radiolarian-bearing siliceous Gajia Formation in the Nagqu area of central Tibet (Pan et al., 2012; Zhu et al., 2013). The viewpoint placing Lhasa and Qiangtang to be closely connected, both having had a common migration history during the Permian to Triassic (e.g., Scotese and McKeorry, 1990; Wang et al., 2003). In this opinion, disputes still exist about their depositional setting. Some explained them as a land since the Late Permian that began rupturing as a continental rift along the BNSZ at the end of the Late Triassic (Zhao et al., 2001) (Fig. 3). Others pointed out that Lhasa and Qiangtang were in a similar marine setting during the Triassic (Ji et al., 2018a), separated only by a wide seaway rather than a large ocean (Yang et al., 1984; Chen et al., 2001).

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close marine Triassic deposits and faunas found in both Lhasa and Qiangtang (Yang et al., 1984; Chen et al., 2001; Ji et al., 2018a).

Stratigraphic evidence has invariably been a main contributor to interpretations of tectonic nature. However, Triassic sedimentary data remain rare at present, especially in the BNSZ, where a Lower Triassic deposit has never been reported and is thus believed to be missing, which contrasts greatly with adjacent areas where Triassic marine sediments were disclosed to be well developed. For example, in the Lhasa terrane to the south, Lower Triassic deposits are widespread in the western portion (Ji et al., 2006, 2007a, 2007b, 2007c; Wu et al., 2007, 2014, 2017, 2018; Zheng et al., 2007), and a complete Triassic succession has been established in accordance with the sections found in the Coqen and Wenbudangsang areas (Ji et al., 2007b; Wu et al., 2007, 2014), implying that the west Lhasa terrane was in a carbonate platform setting during the Triassic (Ji et al., 2018a; Wu et al., 2018). Similar deposits were found in South Qiangtang as well (Guizhou Institute of Geological Survey, 2005; Zhang et al., 2005; Li et al., 2018). The common sedimentary evidence discovered on both sides suggests that they should be affiliated with a similar carbonate platform setting. As a tectonic zone between these two terranes, biostratigraphic research in the BNSZ will be helpful in providing crucial evidence to support this hypothesis. Accordingly, we launched a comprehensive biostratigraphic investigation to the north of Ban’ge area in the central BNSZ. As a result, deposits for the Upper Permian to early Middle Triassic and the Norian of the Upper Triassic were first discovered in the study area. The details are given in the following sections.

GEOLOGICAL SETTING

The investigated area is located south and southwest of Daruco Lake (Fig. 1). Tectonically, it belongs to the Dongkaco stratigraphic division in central BNSZ. According to a 1:250000 Geological survey on the Ban’ge Sheet (Chen et al., 2015), the rocky units in this area consist primarily of the Lower Devonian Da’erdong

Figure 1. Sketch map showing (A and B) the main tectonic terranes of Tibet (simplified after Pan et al., 2013), and (C) the geological map for the study area (modified after Chen et al., 2015).
Early to Middle Triassic (T1-T2) that was rifted as a continental rift at the end of the Late Triassic (T3). This rifted segment included the same old land together with the Lhasa terrane (LS) and the Qiangtang terrane (QT) during the Tethys Ocean. Under this view, the Bangong-Nujiang Ocean (BNO), which belongs to a part of the Tethys Ocean. Under this stratigraphic background, the Palaeozoic rocks are commonly treated as broken blocks inserted within the Mesozoic strata, and the Upper Permian to the Triassic strata below the Quehala Group clasolite was thought to be absent (Fig. 1). Because previous studies have not provided reliable age information for the related strata, we sought to strengthen the biostratigraphic investigations of the originally described Jieniu Group near Shemari Village and the Da’erdong Formation in western Jiaqu County (Fig. 1). As a result, we acquired Late Permian corals and Early to Middle Triassic conodonts from the Jurassic Jieniu Group and Late Triassic Norian corals from the Devonian Da’erdong Formation. The new fossil data reveal that the prior stratigraphic assignment is incorrect. More importantly, these data allow for a revision of the ages for the related strata and their contacting relationship as well.

**NEWLY OBTAINED BIOSTRATIGRAPHIC DATA**

**Late Permian to Middle Triassic Biostratigraphy in the Shemari Section**

The Shemari section, located north of Shemari Village, starts at point A (N31°34'31.3", E90°39'33.8", H4875 m) and ends at point A' (N31°34'41.2", E90°39'24.8", H4889 m) (Fig. 1). The rocks are characterized by dolomite interbedded with limestone, occasionally filled with Cretaceous basalts in some beds (Fig. 4), and have been described as the Jurassic Jieniu Group but with no fossil record (Chen et al., 2015). Through our detailed biostratigraphic investigation, we obtained fossils ranging from the Late Permian to the Middle Triassic, indicating that the strata here have been erroneously correlated and need to be revised.

Altogether, there are 26 beds. According to the fossils and lithology, beds 10–13 are a repetition of beds 1–9, with a fault developed between beds 9 and 10. To clearly demonstrate the fossil distribution in the column figure, the beds below the fault are omitted, but some typical fossil species belonging to the genus *Waagengophyllum* are marked at an estimated position level (Fig. 4). The rock above bed 26 cropped out poorly, and sampling for this part is difficult. Nevertheless, we acquired a Late Permian coral fauna (Fig. 5), two early Triassic conodont faunas, and a Middle Triassic conodont fauna from this section (Fig. 6), which are described in detail below.

**Late Permian Coral Fauna**

Late Permian coral fauna was obtained from beds 1, 8, and 10 (Fig. 4). It primarily consists of species belonging to the genus *Waagengophyllum*.
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### Lithology

| Bed | Formation |
|-----|-----------|
| 1   |           |
| 2   |           |
| 3   |           |
| 4   | Mailonggang Fm. |
| 5   |           |
| 6   |           |
| 7   |           |
| 8   |           |
| 9   |           |
| 10  |           |

### Section AA’

| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

### Section BB’

| 1   | 2   | 3   | 4–5 | 6   |
|-----|-----|-----|-----|-----|
| 100m| 240m| 400m| 600m| 1000m|

### Corals

- Distichophyllia tenuis
- Procylolites sp.
- Pseudoretiophyllia nazhanacensis
- Retiophyllia sp.

### Conodonts

- Chiosella gondolellides
- Chiosella homeri
- Neospathodus brochus
- Neospathodus triangularis

### Distribution of Main Fossil Species

- *Waagenophyllum crassiseptatum*
- *Hibbardellides* sp.
- *Hindeodus* cf. *postparvus*
- *Pachycladina obliqua*
- *Paragondolella leibermani*
- *Neogondolella ex. gr. regale*
- *Neogondolella* sp.
- *Lonchodina* sp.
- *Chiosella gondolellides*
- *Chiosella timorensis*
- *Paragondolella constricta*
- *Paragondolella leibermani*
- *Paragondolella* sp.

**Note:** The prefix of the samplings is 091020 a mark of the float sampling.
The conodont specimens are grouped into Fauna of the Early Triassic Parafurnishius Hindeodus, Pachycladina, and Platyvillosus regularis. These specimens could not be used to accurately discriminate (Chen et al., 2016). The current research shows that the specimens of this genus could co-occur either with Hindeodus cf. postparvus in sample 091020-21 or with Pachycladina obliqua in samples 091020-23 and 091020-30 (Fig. 4). The latter species spread from Late Induan to Early Olenekian. Thus, we deduce that this taxon should range from the Late Induan to the Early Olenekian of the Early Triassic.

### Induan to Early Olenekian Conodont Fauna of the Early Triassic

Induan to Early Olenekian Conodont fauna of the Early Triassic was found in beds 9 and 13. The conodont specimens are grouped into Hindeodus, Pachycladina, and Parafurnishius, which are typical Early Triassic genera. Among them, specimens of Pachycladina and Parafurnishius dominate over those of Hindeodus in abundance.

Pachycladina, a shallow water facies index fossil of the Late Induan to the Early Olenekian, is frequently found in dolomitic rocks. Specimens of this genus have been widely reported in the western Tethyan area (Perri and Andraghetti, 1987; Aljinovic et al., 2006; Kolar-Jurkovsek et al., 2017), the USA (Solien, 1979), South China (Wang and Cao, 1981; Jiang et al., 2000), and Tibet (Xia and Zhang, 2005; Zheng et al., 2007).

In contrast, Parafurnishius has been rarely documented. It was found in Induan strata in Sichuan Province, South China, by Yang et al. (2014), who described Parafurnishius as a new genus, with Parafurnishius xuanhanensis being its type species. Similar specimens were discovered in the Idrija-Ziri area of Slovenia, although they were designated as another genus Platyvillosoa, with two species Platyvillosus corniger and Platyvillosus regularis discriminated (Chen et al., 2016). The specimens from South China and Slovenia share common characteristics with those of Platyvillosoa because of their broad platform, although they are obviously different from the latter because of the highly developed tall denticles on the oral side. Thus, we think it is more reasonable to assign them to the genus Parafurnishius. The present specimens from the BNSZ are obviously similar to this taxon. Here, we tentatively put them under the name Parafurnishius xuanhanensis. The detailed systematic classification needs to be scrutinized in the future. The age of this genus remains unclear due to the rarity of acquired materials. In South China, the genus was aged to the Early Induan due to its association with Hindeodus postparvus (Yang et al., 2014), whereas in Slovenian, it was aged to the Early Olenekian, although other accompanying species were not observed (Chen et al., 2016). The current research shows that the specimens of this genus could co-occur either with Hindeodus cf. postparvus in sample 091020-21 or with Pachycladina obliqua in samples 091020-23 and 091020-30 (Fig. 4). The latter species spread from Late Induan to Early Olenekian. Thus, we deduce that this taxon should range from the Early Induan to the Early Olenekian of the Early Triassic.

### Late Olenekian Conodont Fauna of the Early Triassic

The Late Olenekian conodont fauna of the Early Triassic were discovered in sample 091020-37 of bed 21 and float sample 091020-34 collected from bed 20. The specimens were abundant and well preserved, and they were assigned to Chiosella, Triasspathodus, and Magnigondolella.
Specimens of Triasspathodus and Magnigondolella dominate in terms of yield. For the genus Triasspathodus, its typical species of the Late Spathian, including Triasspathodus homeri and Triasspathodus triangularis, are recognized. Regarding the genus Magnigondolella, most specimens could be assigned to Magnigondolella ex. gr. regale because of their high denticles, which are arranged uniformly, a typical characteristic of the species Magnigondolella regale (Mosher, 1970). This species ranges from the latest Early Triassic to the earliest Anisian (Orchard, 2007).

In contrast, specimens of the genus Chiosella are rare in this fauna, although the key species Chiosella timorensis is identified. The first appearance datum (FAD) of Chiosella timorensis is believed to be the base of the Anisian (Xia and Zhang, 2005), although Goudemand et al. (2012) noted that the FAD of this species is more likely the Late Spathian because it was found to co-occur with the ammonoids Neopopanoceras haugi (Hyatt and Smith) and Keyserlingites inyoense (Smith), two diagnostic species of the Late Spathian Haugi zone (Goudemand et al. 2012). Based on this analysis, the assemblage of conodont fauna in bed 19 belongs to the Late Olenekian of the Early Triassic.

**Late Anisian Conodont Fauna of the Middle Triassic**

The Late Anisian conodont fauna of the Middle Triassic is acquired from sample 091020-39 in bed 24. It is noteworthy that the sample was collected as a float form but is characterized by limestone, which is in accordance with the rocks in bed 24. Therefore, we deduce that it should have been sourced from bed 24 or upward along the slope. This conjecture requires further investigation for validation. Nevertheless, the fauna and its age are important for providing reliable information on the deposits during the Middle Triassic.

The specimens in this fauna are abundant and well preserved, and most of them belong to gondolellid elements. They could be assigned as Magnigondolella bifurcata, Magnigondolella constricta, and Paragondolella leibermani, which are index fossils of the Late Anisian (Sweet et al., 1970; Kovács, 1994). Therefore, we believe that the present fauna represents the Late Anisian of the Middle Triassic.

**Late Triassic Norian Fossils from the Jiaqun Section**

Section BB′ is located west of Jiaqun Town, with a starting coordinate point B N31°39′01.8″, E90°34′07.2″, and H4803. The rocks here are characterized by limestone, with 7 beds subdivided (Fig. 4). Previous research correlated this set of limestone to the Lower Devonian Da’erdong Formation (D3), but there is no fossil evidence (Fig. 4). Through our biostratigraphic investigation, however, we acquired coral fossils (Fig. 5) from bed 3 (Fig. 4) that could be designated as Pseudoretiophyllia nazacunensis and Distichophyllia tenuis. Both of these are diagnostic species of a Late Triassic Norian age (Liao and Deng, 2013); thus, we revise the limestone as Late Triassic Norian strata from the Devonian Da’erdong Formation.
CONODONT CORRELATIONS

Studies investigating Triassic conodont biostratigraphy in Tibet were initially performed in the mid-1970s (Wang and Wang, 1976). To date, marine Triassic sections have been shown to cover the Lhasa terrane (Ji et al., 2006, 2007a, 2010; Wu et al., 2007, 2014, 2017, 2018; Zheng et al., 2007) and the Qiangtang terrane (Xia and Zhang, 2005; Guizhou Institute of Geological Survey, 2005; Zhang et al., 2005; Li et al., 2018). The recognized conodont biozones from different parts of Tibet could be well correlated with the international zones established by Swee et al. (1970) (Fig. 7). To determine the differences between conodont faunas from the study area and from the other areas in Tibet, we carried out a thorough comparison.

Correlation with Southern Tibet

Southern Tibet, also known as the Himalaya terrane, has attracted extensive interest from biostratigraphic researchers (Wang and Wang, 1976; Orchard et al., 1994; Shen et al., 2006; Yuan et al., 2018). To date, excluding the problematic Late Permian conodonts, a relatively complete Triassic conodont succession has been established (Fig. 7).

For the Induan to Early Olenekian faunas, both Southern Tibet and the Shemari section have specimens of Hindeodus, although Southern Tibet has a relatively high productivity and diversity of the specimen. Nonetheless, the difference between the two areas seems to be more conspicuous: the Shemari section is characterized by Pachycladina, Parafurnishia, whereas the southern Tibet section features specimens of Neospathodus. This difference is probably caused by a diverse depositional background, with the study area likely being in much shallower water than southern Tibet. The Late Olenekian faunas are similar in both areas. For example, both faunas have Triasspathodus, Magnigondolella, and Chiosella species. The Middle Triassic Anisian faunas, such as Neogondolella bifurcata and Neogondolella constricata, are also similar in the two areas.

Correlation with the Lhasa Terrane

Triassic conodont studies in the Lhasa terrane began in the 1980s, focusing on regions near Lhasa City, where only the Early Triassic Triasspathodus homeri zone and Norian Epigon­
dolella fauna of the Late Triassic were reported (Sun et al., 1981; Ji et al., 2003). Dramatic progress was achieved in the 21st century, with successive discoveries of more marine Triassic sections (Ji et al., 2006, 2007a, 2007b, 2007c, 2010; Zheng et al., 2007; Wu et al., 2007, 2014, 2017, 2018). A complete conodont succession ranging from the Late Permian to the Triassic has thus been established, based on the limestone-dominated Dibuco section (Ji et al., 2006; Wu et al., 2007) and the Wenbudangsan section (Wu et al., 2014). The dolomite-type succession has also been recognized in the Zoço section (Ji et al., 2007a; Zheng et al., 2007) and the Namutso section (Wu et al., 2017) (Fig. 7).

Late Permian conodonts are rare in terms of yield in the Shemari section, which is very similar to observations in the Wenbudangsan section (Wu et al., 2014) and the Zoço section (Ji et al., 2007a). The present Induan to Early Olenekian conodonts are characterized by elements of Pachycladina, which clearly differ from those in the limestone-dominated sections but are similar to those in the dolomite-developed sections in Lhasa. The Late Olenekian fauna in the present section is similar to that found in the limestone-type section, sharing common specimens of Chi­"osella, Magnigondolella, and Thiasspathodus. For the Middle Triassic, conodont fauna in the Shemari section are older than those found in the limestone-dominated sections of Lhasa. The Shemari section is characterized by Anisian species, including Neogondolella bifurcata, Neogdon­
dolella constricta, and Paragondolella lieber­
manii, whereas the limestone-dominated section of Lhasa bears specimens of Quadrulaella polyg­
nathiformis and Paragondolella inclinata ranging from Late Ladinian to Early Carnian (Fig. 7).

Correlation with the Qiangtang Terrane

To date, Triassic conodonts in Qiangtang have been sporadically documented. The conodont sequence there is assembled from a few sections. Nevertheless, Early Triassic and Late Triassic biozones have been recorded as covering nearly the whole area. For example, the Early Triassic Olenekian Triasspathodus homeri-Tria­s­
spathodus triangularis assemblage zone was found to have spread in both South Qiangtang (Guizhou Institute of Geological Survey, 2005; Zhang et al., 2005) and North Qiangtang (Xia and Zhang, 2005). In addition, the Late Triassic Norian Epigondolella zone and the Early Triassic Pachycladina-Hadrodontina-Parachirognathus were recognized from north Qiangtang (Xia and Zhang, 2005) (Fig. 7).

The Late Olenekian Triasspathodus homeri­Tri­asspathodus triangularis fauna occurs in both Qiangtang and the BNSZ. The Pachycladina-Hadrodontina-Parachirognathus fauna in North Qiangtang is also similar to the present Pachycladina fauna, both characterized by producing index species of shallow water facies. We disagree with Xia and Zhang (2005) that the Pachycladina fauna is younger than Triass­
spathodus triangularis. The available data regarding this fauna assemblage are generally from below the Triasspathodus triangularis zone (Orchard, 2007). Here, we insist that the Pachycladina fauna represents a Late Induan to Early Olenekian age, which is older than the Neospathodus triangularis zone.

The above mentioned correlations among faunas from different areas in Tibet suggest that the newly recognized Late Permian to Middle Triassic conodont faunas in the BNSZ are well correlated with those in southern Tibet, the Lhasa terrane, and the Qiangtang terrane.

DISCUSSION

Succession for Upper Permian to Triassic Strata in the BNSZ

Based on new biostratigraphic data and previously reported rocky units, we propose a stratigraphic scheme for Upper Permian to Triassic strata in the BNSZ that is obviously different from that of previous research (Fig. 8). The details are documented in the following subsections.

Mujiculo Formation for Upper Permian to Lower Triassic Strata

The Mujiculo Formation, defined in the Xainza area of the Lhasa terrane, is a set of dolomite ranging from the Late Permian to Early Triassic according to the coral fauna Waagenophyllum-Liangeshanophyllum-Lobatophyllum (Cheng et al., 2002) and conodont specimens of Pachycladina (Wu et al., 2017), which spreads extensively in the Lhasa terrane (Wu et al., 2018). The Upper Permian and Lower Triassic strata discovered in the Shemari section coincide well with the diagnosis of the Mujiculo Formation in both lithology and fossils. Meanwhile, Late Permian coral fossils and Early Triassic conodonts occurred simultaneously in this section, indicating that the Upper Permian and Lower Triassic were likely continuously deposited. In addition, the obtained Early Triassic conodont faunas include not only Late Induan to Early Olenekian Pachycladina fauna but also Late Olenekian species, such as Chiosella timoren­sis, Magnigondolella ex. gr. regale, and Thiass­pathodus homeri, ensuring that the Mujiculo Formation could extend up to the end of the Lower Triassic.

Gajia Formation for the Middle Triassic Ladinian to the Late Triassic Carnian Strata

The Gajia Formation, discovered in the Nagqu area and characterized by siliceous rocks bearing Ladinian radiolarian fossils (Nimaciren...
| Series | Stage | International conodont zones | Southern Tibet | Lhasa (or Gangdese) | Qiangtang | Bangong-Nujiang |
|--------|-------|-----------------------------|----------------|---------------------|----------|----------------|
|        |       |                             | Limestone-type | Dolomite-type       |          |                |
| Sweet et al., 1971 | Wang et al., 1976, Tian, 1982 | Ji et al., 2006, 2007, Wu et al., 2014 | Ji et al., 2007, Zheng et al., 2007, Wu et al., 2017 | Xia et al., 2005, Zhang et al., 2005 | This paper |
| Upper Triassic | Upper Ladinian | Carinian | Sweet et al., 1971 | Wang et al., 1976 | Ji et al., 2006, 2007 | Xia et al., 2005 |
| | | | Ep. hindentata | Ep. multidentata | Ep. sp. | Ep. postera- |
| | | | Ep. alnumis | Ep. alnumis | Qd.polygnathiformis | Qd.polygnathiformis |
| | | | Ns. newpassensis | Ns. newpassensis | Qd.polygnathiformis | Pg. inclinata |
| | | | Ep. mungosensis | Ep. diebeli | Ch. timorensis | Ch. timorensis |
| | | | Pg. excelsa | Mg. regale | Ng. jubata | Ng. jubata |
| | | | Ch. timorensis | T. triangularis | Ch. timorensis | Ch. timorensis |
| | | | Ns. gondolellides | Ns. gondolellides | Ts. homeri | Ts. homeri |
| | | | Ng. milleri | Ns. waagena | Ns. waagena | Ns. waagena |
| | | | Ns. dieneri | Ns. dieneri | Ns. cristagalli | Ns. cristagalli |
| | | | Sws. kummeli | Sws. kummeli | Ns. dieneri | Ns. dieneri |
| | | | Ng. carinata | Ns. carinata | Sws. kummeli | Sws. kummeli |
| | | | H. typicalis | H. typicalis | H. parvus | H. parvus |
| | | | Lielongou Fm. | Lielongou Fm. | Wenbuqiangou Fm. | Xiala Fm. |
| | | | Wenbuqiangou Fm. | Wenbuqiangou Fm. | Xiala Fm. | Xiala Fm. |
| | | | Ng. changxingensis | Ng. changxingensis | Ng. changxingensis | Ng. changxingensis |
| | | | gondolellides elements (pending detailed future study) | gondolellides elements (pending detailed future study) | gondolellides elements (pending detailed future study) | gondolellides elements (pending detailed future study) |
| | | | Pg. bifurcata | Pg. bifurcata | Pg. bifurcata | Pg. bifurcata |
| | | | Ts. triangularis | Ts. triangularis | Ts. triangularis | Ts. triangularis |
| | | | Ng. jubata | Ng. jubata | Ng. jubata | Ng. jubata |
| | | | Ns. cristagalli | Ns. cristagalli | Ns. cristagalli | Ns. cristagalli |
| | | | Ns. dieneri | Ns. dieneri | Ns. dieneri | Ns. dieneri |
| | | | Sws. kummeli | Sws. kummeli | Sws. kummeli | Sws. kummeli |
| | | | H. postparvus | H. postparvus | H. postparvus | H. postparvus |
| | | | I.sarcica | I.sarcica | I.sarcica | I.sarcica |
| | | | Ns. cristagalli | Ns. cristagalli | Ns. cristagalli | Ns. cristagalli |
| | | | Ns. dieneri | Ns. dieneri | Ns. dieneri | Ns. dieneri |
| | | | Sws. kummeli | Sws. kummeli | Sws. kummeli | Sws. kummeli |
| | | | H. postparvus | H. postparvus | H. postparvus | H. postparvus |
| | | | I. staeschei | I. staeschei | I. staeschei | I. staeschei |
| | | | H. parvus | H. parvus | H. parvus | H. parvus |

Figure 7. Conodont zones of late Permian to Triassic among the main divisions of Tibet.

Ep.-Epigondolella; Pg.-Paragondolella; Ng.-Neogondolella; Mg.-Magnigondolella; Qd.-Quadralella; Ch.-Chiosella; H.-Hindeodella; I.-Isarcicella; Ns.-Neospathodus; Ts.-Triasspathodus; Nvs.-Novispathodus; Sws.-Sweeospathodus; Pach.-Pachycladina; Parach.-Parachirognathus; Hid.-Hadrontina; Pf.-Parafurnishius; Gl.-Gladigondolella; Zh.-Zhulong; J.-Jiangrang; D.-Dibuco; Ml.-Mailonggang; Qh.-Quehala; ?-undetermined; Fm.-Formation
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| System | Series | Rao et al., 1987 | Chen et al., 2015 | Pan et al., 2004 | Nimaciren et al., 2005 | Zhu et al., 2013 | This paper |
|--------|--------|-----------------|-----------------|-----------------|---------------------|-----------------|------------|
|        |        | Bangongco-Nuijiang SR | Dongqiao-Jiangco SSR | Bangongco-Nuijiang SR | Northern Lhasa | Bangongco-Nuijiang SSR | Bangong-Nuijiang (central part) |
|        | Gangdese-Ningqianggula SR | Dongkaco | Dongkaco SSR |             |                     |                 |            |
|        | Nagur-Luolong SSR |             |             |     |                     |                 |            |

| Jurassic | Sandy Shale, Siltstone, Volcanic tuff | Jienu Group | Xihu Group | Muganggri Group | J1 | Qehala Formation | Mailonggang Formation | Gajia Formation | ? | Mujiuco Formation | ? | Xiala Formation |
|---------|--------------------------------------|-------------|------------|-----------------|----|-----------------|---------------------|-----------------|---|-----------------|---|-----------------|
| Triassic | Qehala Group | Qehala Group | ? |                |                |                |                        |                |   |                 |   |                 |
| Permian | lower middle upper | lower middle upper | lower middle upper | Xiala Formation | ? |                |                        |                |   |                 |   |                 |

Figure 8. Main schemes for the Permian to Jurassic strata division in the Bangong-Nujiang Suture Zone (BNSZ).

and Xie, 2005), has been treated as a Ladinian to Carnian rocky unit in the central BNSZ (Pan et al., 2012). The present investigation does not provide sufficient lithological information regarding the Middle Triassic strata. From typical Anisian conodont fauna, we learn that the Middle Triassic sediments were definitely deposited in this area and the Anisian strata feature limestone. It is noteworthy that the siliceous component in the rocks increased at the end of our measured section, making it plausible to consider the Gajia Formation as a Late Middle Triassic rocky unit. Knowledge of the Middle Triassic is obviously insufficient at present. It is a problem demanding further investigation in the future.

**Upper Triassic Strata**

The Upper Triassic rocky unit in the BNSZ has been observed to be a set of clasolite defined as the Qehala Group and contacting with the Palaeozoic limestones in unconformity (BGRMRX, 1993; Chen et al., 2015). This work, however, demonstrates that the limestone below the Upper Triassic clasolite was, in essence, Late Triassic Norian rather than Palaeozoic. An identical limestone and clasolite pattern for the Upper Triassic was also found in the Lhasa terrane, where the limestone known as the Mailonggang Formation has been proven to be Norian and the clasolite has been proven to be Rhatian to Early Jurassic through biostratigraphic investigations (Wang et al., 1983; Lin et al., 1989; Ji et al., 2007c). Thereby, we correlate the limestone in the BNSZ to the Mailonggang Formation. The overlying clasolite is assigned as the Qehala Formation, to refer to the clasolite above the Norian limestone.

The Tectonic Mélange Phenomenon in the BNSZ

Traditionally, the BNSZ was believed to be characterized by developing tectonic mélange. The main characteristic in the stratigraphy is that the Palaeozoic rocks usually thrust into the Mesozoic strata by fault block forms (Chen et al., 2014, 2015).

This tectonic mélange interpretation collides with the biostratigraphic research. For example, the Oma area in the western part of the BNSZ was thought to be a representative region with developed tectonic mélanges in which the Palaeozoic Permian limestones there thrust up into the Jurassic strata (Chen et al., 2014). However, our biostratigraphic studies revealed that the so-called Permian rocky unit is in fact of a Jurassic age because abundant Jurassic coral fossils were recognized within it (Ji et al., 2011). Thus, the mélangé phenomenon in the Oma area is incredible.

The study area is another typical site featuring a tectonic mélange phenomenon (Chen et al., 2015; Lai et al., 2017). Similarly, through biostratigraphic work, the “Jurassic blocks” that had been described as inserted by the Permian Xiala Formation (see Fig. 1, section AA′) are revised to Upper Permian to Middle Triassic strata, and the “Devonian rocks” contacting with the Triassic Qehala Group in unconformity (see Fig. 1, section BB′) are correlated with the Upper Triassic Mailonggang Formation.

The above two examples from the Oma area and the present Ban’ge area indicate that it is problematic to explain the BNSZ as a tectonic mélangé zone. At least, the biostratigraphic evidence at present does not support that. To verify this hypothesis, more investigative work needs to be done in the future.
Strata Correlations in Lhasa, the BNSZ, and Qiangtang

In Lhasa, the Upper Permian to the Triassic succession has been well established based on biostratigraphic research in the Coqen and Wenbudangsang areas (Ji et al., 2007b, 2007c, 2018b; Wu et al., 2014). In ascending order, it includes the Upper Permian Wenbudangsang Formation dominated by limestone bearing rich chert-nodules; the Lower to Middle Triassic Garenco Formation characterized by limestone; the Ladinian to the Carnian Zhulong Formation featuring abundant siliceous rocks interlayered with thin-layered limestone; the Norian Jianzhanong Formation made up of a set of clasolite rocks (Li et al., 2018). Meanwhile, Lower Triassic dolomite is dispersed in both Lhasa and Qiangtang (Fig. 9).

A comparison showed that the strata succession established in the BNSZ has many similarities to that in Lhasa and Qiangtang (Fig. 9). For example, the Lower Triassic was characterized by limestone; the Ladinian to Carnian had an increased silicite ingredient; the Norian strata were limestone again; and the Rhatian featured clasolite. Depositions better reflect the sedimentary setting. The Triassic succession commonly found in these three areas indicated that extensive marine transgression took place since the Early Triassic, which reached a climax during the Ladinian to Carnian and was then followed by recession beginning in the Norian. Regarding the lithology, the increasing silicite component, which was usually interbedded with limestone, indicates that the seawater deepened (Fig. 9).

From the column variation, the BNSZ and its two adjacent areas were assumed to be synchronized (Fig. 9), although biostratigraphic investigations should be strengthened in the future to provide reliable age information. In addition, the depositions through the Triassic are dominated by limestones, so we conjecture that the three areas were likely affiliated with a similar carbonate platform system from the Late Permian to the Late Triassic, albeit with a somewhat changed depositional setting. The extensively distributed Lower Triassic sections in Lhasa and Qiangtang (Fig. 10) could provide evidence for this deduction. According to biostratigraphic and lithostratigraphic analyses, the Lower Triassic deposits in Lhasa consisted of limestone-type and dolomite-type deposits (Ji et al., 2018b). Regarding the Early Triassic palaeolithofacial map, the dolomitic evaporation facies alternates with the carbonate platform depression facies (Wu et al., 2018). The same model should be applicable in Qiangtang, where the dolomite was also reported from the Qiangduo area crossing the BNSZ (Guo et al., 1991), whereas the dominated bioclastic limestone or oolitic limestone was documented from the eastern part (Fig. 10).

New lower Triassic evidence from the Ban’ge area showed that the central BNSZ was likewise dominated by carbonate (mainly dolomite) facies, affirming that Lhasa, Qiangtang, and the BNSZ belonged to the same depositional system during the Early Triassic (Fig. 10).

![Figure 9. Sketch column map showing the Upper Permian to Upper Triassic strata succession among the Bangong-Nujiang Suture Zone (BNSZ), Lhasa, and Qiangtang. The succession of Lhasa is based on research by Ji et al. (2007b, 2018b); the succession of Qiangtang is after work by Guo et al. (1991) and Li et al. (2018); and the succession of the BNSZ is from BGMRX (1993), Wang et al. (2002), Nimaciren et al. (2005), and this research. Fm—formation.](http://pubs.geoscienceworld.org/gsa/lithosphere/article-pdf/11/5/683/4830227/683.pdf)
Palaeogeographic Implications

In research on the palaeogeographic evolution of Tibetan terranes, the paleo positions of Lhasa and Qiangtang have been a debated topic, although the latest Permian to Early Triassic period is usually neglected (e.g., Metcalfe, 2013). Two apparently different views exist. One view asserted that the two terranes were located on two sides of the Tethyan Ocean. Under this view, Lhasa stayed in Gondwanaland, whereas Qiangtang drifted northward as a component of the Cimmerian Continent. The distance between them enlarged in the Late Triassic when Qiangtang rapidly moved to the north (Belov et al., 1986; Muttoni et al., 2009; Metcalfe, 2013; Wakita and Metcalfe, 2005; Zhu et al., 2013; Yan et al., 2016; Lucas, 2017). The other view posited that Lhasa and Qiangtang both departed from Gondwanaland as a part of the Cimmerian Continent. The distance between them enlarged in the Late Triassic when Qiangtang rapidly moved to the north (Belov et al., 1986; Muttoni et al., 2009; Metcalfe, 2013; Wakita and Metcalfe, 2005; Zhu et al., 2013; Yan et al., 2016; Lucas, 2017). This viewpoint tended to assert that the two terranes were in the same plate; however, the knowledge about their depositional setting was incongruous. Some researchers described them as a land with rare marine sediments primarily deposited during the Triassic (Zhou et al., 2016). Others considered them to be in a common sea background as suggested by sporadic biostratigraphic and lithostratigraphic data (Yang et al., 1984; Chen et al., 2001; Boucot et al., 2013; Ji et al., 2018a).

It is well known that in the palaeogeographical analysis, the determined factors mostly come from biostratigraphic, lithostratigraphic and paleomagnetic evidence. For example, the Permian biostratigraphic models for the major terranes in the Qinghai-Tibet Plateau proposed by Zhang et al. (2013) were dependent on biostratigraphic and lithostratigraphic data. For the same reason, the usual avoidance of the Latest Permian to the Early Triassic during palaeogeographical discussions is also caused by scarce biostratigraphic and lithostratigraphic data. Thus, our newly acquired biostratigraphic evidence from the BNSZ together with the collected information from Lhasa and Qiangtang is helpful for pushing this research forward.

Biostratigraphically, the Lower Triassic deposits in the three regions are common not only in developing carbonate rocks but also in producing the shallow water index conodont species Pachycladina obliqua. In addition, the Late Permian coral genus Waagengophyllum in this study was recognized in the other two regions (Wang et al., 2003). Similar depositions and fossils indicate that Lhasa, Qiangtang, and BNSZ were not far separated from each other. At least it was impossible that they existed in two continents with quite different depositional settings. This opinion is supported by lithostratigraphic and paleomagnetic research. First, the extensively distributed carbonate (especially dolomite) from the Neoproterozoic to the Middle Triassic was a sign of a warm, shallow water environment that developed only along the low to middle latitudes (Chen et al., 2001). Second, the magnetic data indicated that Qiangtang was approximately equatorial (Huang et al., 1992; Boucot et al., 2013), whereas Lhasa was in the southern hemisphere between 16.5° ± 3.9° S and 18.4° ± 10.7° S (Zhou et al., 2016). Thus, the paleomagnetic data together with the lithostratigraphic analysis both insist that Lhasa and Qiangtang were located at low to middle latitudes during the Early Triassic rather than distantly separated in two continents (Fig. 11). The conodont species Pachycladina obliqua may be a fossil sign marking a low to middle latitude. It is basically produced from shallow water facies such as dolomite (sometimes in oolitic limestone). And, according to the collected documents, this species spread only among middle to low latitudes, such as in North America, the western Tethys, and South China (Fig. 11). Nevertheless, the accuracy of the positions still depends on acquisition of more reliable biostratigraphic and paleomagnetic data in the future.

CONCLUSIONS

1) Biostratigraphic progress has been made in the central BNSZ. By performing a biostratigraphic study in the Ban’ge area of the central BNSZ, we discovered fossils of Late Permian to Late Triassic Norian for the first time. Four faunas are recognized altogether, including the Late Permian coral fauna Waagengophyllum crassiseptatum-Waagengophyllum cf. ganhaizien­se; the Early Triassic (the Induan to the early Olenekian) conodont fauna Pachycladina obliqua–Para­furnishius xuanhanensis–Hindeodus cf. postparvus; the Early Triassic (the late Olenekian) conodont fauna Chiosella
“Devonian rocks” contacting the Upper Triassic Paragondolella leibermani; which is that Palaeozoic sediments were thrust gondolella bifurcata–Paragondolella constricta–Upper Triassic Norian; and the Quehala Formation after Lucas, 2017).

the Early Triassic based on paleomagnetic, lithostratigraphic, and biostratigraphic data (modified Figure 11. Map showing the relative positions of Lhasa, Qiangtang, and Bangong-Nujiang during the Early Triassic based on paleomagnetic, lithostratigraphic, and biostratigraphic data (modified after Lucas, 2017).

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REFERENCES CITED

Alijnovic, D., Kolar-Jurkovsek, T., and Jurkovsek, B., 2006, The lower Triassic shallow marine succession in Gorski Kotar region (external Dinarides, Croatia): Lithofacies and Conodont dating: Rivista Italiana di Paleontologia e Stratigrafia, v. 112, no. 1, p. 25–53.

Belov, A.A., Gatinsky, Yu.G., and Mossakovsky, A.A., 1986, A precis on pre-Alpine tectonic history of Tethyan paleo-oceans: Tectonophysics, v. 127, p. 197–211, https://doi.org/10.1016/0040-1951(86)90061-2.

BGMRX (Bureau of Geology and Mineral Resources of Xizang Autonomous Region), 1993, Regional geology of Xizang (Tibet) Autonomous Region: Beijing, Geological Publishing House, 450 p. (in Chinese with English Abstract).

Bo, J.E., Wang, X.L., Gao, J.H., Yao, J.X., Wang, G.H., and Hou, E.G., 2017, Upper Triassic reef coral fauna in the Renacao area, northern Tibet, and its implications for palaeobiogeography: Journal of Asian Earth Sciences, v. 146, p. 114–133, https://doi.org/10.1016/j.jseaes.2017.05.006.

Boucot, A.J., Chen, X., and Sciotese, C.R., 2013, Phanerozoic paleoclimate: An atlas of lithologic indicators of climate: Society for Sedimentary Geology, SEPM Concepts in Sedimentology and Paleontology, v. 71, 478 p.

Chen, X., Yuan, Y.P., and Boucot, A.J., 2001, Paleozoic climage evolution of China: Beijing, Science Press, 325 p. (in Chinese).

Chen, Y.L., Zhang, K.Z., Guo, Y.D., and Wen, J.H., 2014, Chinese Regional Geological Survey Report (1:250000 Oma Sheet): Beijing, China University of Geosciences Press, 163 p. (in Chinese).

Chen, Y.L., Chen, G.R., and Zhang, K.Z., 2015, Chinese Regional Geological Survey Report (1:250000 Ban Ge Sheet): Beijing, China University of Geosciences Press, 253 p. (in Chinese).

Chen, Y.L., Kolar-Jurkovsek, T., Jurkovsek, B., Alijnovic, D., and Belov, A.A., 2016, Early Triassic conodonts and carbonate rock composition of the Upper Permian Mujiu Co Formation and ruffose coral assemblage in the Xainza area, northern Tibet: Geological Bulletin of China, v. 21, no. 3, p. 140–143 (in Chinese with English abstract).

Goudemand, N., Orchard, J.M., Bucher, H., and Jenks, J., 2012, The elusive origin of Chiosella timorensis (Conodont Triassic): Geobios, v. 45, p. 199–207, https://doi.org/10.1016/j.geobios.2011.06.001.

Guizhou Institute of Geological Survey, 2005, 1:250000 Dingopo and Gyamco Sheets in Xizang: Sedimentary Geology and Tethyan Geology, v. 25, no. 1–2, p. 45–50, (in Chinese with English abstract).

REFERENCES CITED

Alijnovic, D., Kolar-Jurkovsek, T., and Jurkovsek, B., 2006, The lower Triassic shallow marine succession in Gorski Kotar region (external Dinarides, Croatia): Lithofacies and Conodont dating: Rivista Italiana di Paleontologia e Stratigrafia, v. 112, no. 1, p. 25–53.

Belov, A.A., Gatinsky, Yu.G., and Mossakovsky, A.A., 1986, A precis on pre-Alpine tectonic history of Tethyan paleo-oceans: Tectonophysics, v. 127, p. 197–211, https://doi.org/10.1016/0040-1951(86)90061-2.

BGMRX (Bureau of Geology and Mineral Resources of Xizang Autonomous Region), 1993, Regional geology of Xizang (Tibet) Autonomous Region: Beijing, Geological Publishing House, 450 p. (in Chinese with English Abstract).

Bo, J.E., Wang, X.L., Gao, J.H., Yao, J.X., Wang, G.H., and Hou, E.G., 2017, Upper Triassic reef coral fauna in the Renacao area, northern Tibet, and its implications for palaeobiogeography: Journal of Asian Earth Sciences, v. 146, p. 114–133, https://doi.org/10.1016/j.jseaes.2017.05.006.

Boucot, A.J., Chen, X., and Sciotese, C.R., 2013, Phanerozoic paleoclimate: An atlas of lithologic indicators of climate: Society for Sedimentary Geology, SEPM Concepts in Sedimentology and Paleontology, v. 71, 478 p.

Chen, X., Yuan, Y.P., and Boucot, A.J., 2001, Paleozoic climateau evo lution of China: Beijing, Science Press, 325 p. (in Chinese).

Chen, Y.L., Zhang, K.Z., Guo, Y.D., and Wen, J.H., 2014, Chinese Regional Geological Survey Report (1:250000 Oma Sheet): Beijing, China University of Geosciences Press, 163 p. (in Chinese).

Chen, Y.L., Chen, G.R., and Zhang, K.Z., 2015, Chinese Regional Geological Survey Report (1:250000 Ban Ge Sheet): Beijing, China University of Geosciences Press, 253 p. (in Chinese).

Chen, Y.L., Kolar-Jurkovsek, T., Jurkovsek, B., Alijnovic, D., and Belov, A.A., 2016, Early Triassic conodonts and carbonate rock composition of the Upper Permian Mujiu Co Formation and ruffose coral assemblage in the Xainza area, northern Tibet: Geological Bulletin of China, v. 21, no. 3, p. 140–143 (in Chinese with English abstract).

Goudemand, N., Orchard, J.M., Bucher, H., and Jenks, J., 2012, The elusive origin of Chiosella timorensis (Conodont Triassic): Geobios, v. 45, p. 199–207, https://doi.org/10.1016/j.geobios.2011.06.001.

Guizhou Institute of Geological Survey, 2005, 1:250000 Dingopo and Gyamco Sheets in Xizang: Sedimentary Geology and Tethyan Geology, v. 25, no. 1–2, p. 45–50, (in Chinese with English abstract).
basin evolution: Beijing, Science Press, 439 p. (in Chinese with English abstract).
Zheng, Y.Y., Xu, R.K., Wang, C.Y., Ma, G.T., Lai, X.L., Ye, D.J., Cao, L., and Liang, J.W., 2007, Discovery of Early Triassic conodonts in western Gangdise and the establishment of the Tangnaike Formation: Science in China Series D: Earth Science, v. 50, no. 12, p. 1767–1772.
Zhou, Y.N., Cheng, X., Yu, L., Yang, X.F., Xu, H.L., Peng, X.M., Xue, Y.K., Li, Y.Y., Ye, Y.K., Zhang, J., Li, Y.Y., and Wu, H.M., 2016, Paleomagnetic study on the Triassic rocks from the Lhasa Terrane, Tibet, and its paleogeographic implications: Journal of Asian Earth Sciences, v. 121, p. 108–119, https://doi.org/10.1016/j.jseaes.2016.02.008.
Zhu, D.C., Li, S.M., Cawood, P.A., Wang, Q., Zhao, Z.D., Liu, S.A., and Wang, L.Q., 2016, Assembly of the Lhasa and Qiangtang terranes in central Tibet by divergent double subduction: Lithos, v. 245, p. 7–17, https://doi.org/10.1016/j.lithos.2015.06.023.
Zhu, T.X., Jiang, X.S., Feng, X.T., Zhang, Y.J., Mao, X.D., Zhu, L.D., Zhou, M.K., Wang, X.F., Xiong, G.Q., Wu, H., Liu, D.Z., and Lü, J., 2013, Qinghai-Tibet Plateau and its adjacent areas explanation book of 1:5000000 Mesozoic tectonic-lithofacial geological map: Beijing, Geological Publishing House, 309 p. (in Chinese).