The Cretaceous of the Eastern Bangong–Nujiang Suture Zone (Tibet): Tectono–Sedimentation*

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Abstract The ophiolite-bearing Bangong-Nujiang zone (BNZ) traversing central Tibet from east to west separates the Qiangtang block in the north from the Lhasa block in the south. The Cretaceous of the area includes Chuamba Formation (K₄c), Duoba Formation (K₄d), Langshan Formation (K₄d) and Jiangba Formation (K₄j). The K₄c is composed of black shale, sandy pelite, siltstone, sandstone, coal beds and volcanic rocks, of shallow marine facies. The K₄d consists of terrestrial siliciclastic intercalated with some calcareous sandstone beds bearing Orbitolina sp. indicating marine influence. The K₄j is carbonate platform deposits of shallow marine and lagoon. The K₄j is characterized by terrestrial thick massive red conglomerate. An active margin related to B-subduction zone is considered to be the geological setting of the Cretaceous sedimentation.

Key words Bangong-Nujiang suture zone, Cretaceous, sedimentology, tectonics, Tibet

1 Introduction

The Tibet plateau consists of terranes which were accreted in a southward-younging succession from Late Permian to Mid-Eocene (Dewey et al., 1988; Mattern et al., 1998; Mattern and Schneider, 2000). The Songpan-Ganzi terrane was accreted to the Kunlun during Late Permian along Kunlun-Qinling suture. The Qiangtang block was added onto the Songpan-Ganzi terrane at the Jinsha suture during Late Triassic-Early Jurassic. The Lhasa block became attached to the Qiangtang terrane along the Bangong-Nujiang suture zone (BNSZ) during the Mid-Late Jurassic in east part and during the Mid-Cretaceous in west Tibet (Yin and Harrison, 2000). Finally, India was added onto the Lhasa block along the Yalong-Zangbo suture during the Eocene.

The BNSZ runs at an approximate trend of 100° and is generally 15 to 20 km wide through central Tibet. In eastern Tibet, however, the trend changes to the SSE direction. The BNSZ separates the Qiangtang block in the north from the Lhasa block in the south. It is characterized by the occurrence of seemingly Late Triassic to Mid-Jurassic ophiolite bodies. Lower to Upper Jurassic are mainly of marine facies. The Cretaceous are terrestrial and marine deposits. The Cenozoic deposits are terrestrial predominantly.

The aims of our study are briefly the lithofacial characterization of Cretaceous sedimentary rocks as well as their depositional environments, pertaining transport processes, the characterization of depositional systems and related tectonic implication.

2 The Cretaceous of the Bangong–Nujiang Suture Zone

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Cretaceous strata are widely distributed in Tibet (Tibet Geological Bureau, 1993; Wang et al., 1998). Types of the Cretaceous sediments are complex including both marine and terrestrial facies. The study area is in the Bange-Biru-Luolong subdivision of the Gongdisi-Nianqing-Tanggula division. The whole sequence (Fig.1) is composed of Lower Cretaceous to Upper Jurassic Chuanba Formation (J_1-K_u), Lower
Cretaceous Duoba Formation (Kd). Lower Cretaceous Langshan Formation (Kb), Upper Cretaceous Jingzhushan or Jiangba Formation (Kc).

The Upper Jurassic–Lower Cretaceous Chu-anka Formation

Chuanka Formation is composed of black shale, sandy pelite, siltstone and sandstone intercalated in the middle part with several coal beds. Altered basalt and andesite are contained in the section. Their marine environment is characterized by the assemblage of fossils: *Euphyllloceras, Lierolytoceras, Neocomites and Thurmanniceras; Montlivaltia caryophyllata, Placotrochus cf. texanus*. The coal beds are swamp deposits of transitional facies.

The Lower Cretaceous Duoba Formation

The Duoba Formation is 1.3 km in thickness, mainly comprises terrestrial siliciclastics intercalated with some calcareous sandstone beds bearing *Orbitolina* sp. indicating marine influence (Yin et al., 1988). Previously the fine-grained terrestrial clastics are interpreted as flood plain deposits, the coarse ones are of sheet flood and channel origins (Leeder et al., 1988). Our study shows that the lower unit of formation of the conglomerate dominant section (Fig.3) is mainly alluvial fan and braided/meandering river deposits. Its middle section is fluvial and flood plain deposits (Fig.2). Their gravel grains are poorly sorted and most of them are angular to sub-angular in shape. The compositional maturity is low with complex fragments of quartzite, chert, limestone, volcanic rocks, pelite, sandstone and siltstone (Fig.3). The upper unit of the formation is lacustrine pelite and tuffite. Inter-tidal and tidal flat deposits are recognized in the upper most of the Duoba Formation in the study area of 89°39'E and 31°28' N, because the sand grains are well sorted with skolithos and the interbedded pelite contains *Orbitolina* sp., *Columnorbitolina tibetica*.

The Lower Cretaceous Langshan Formation

The Duoba Formation is overlain by the 700~900 m thick marine Langshan Formation in the Baingoin-Nam Co Lake area (Kidd et al., 1988; Leeder et al., 1988; Yin et al., 1988). Between the Langshan Mts. in the south and the Lunpola area, beds of the Duoba Formation interfinger with their lateral equivalents of the northern Xiaqiong Formation (Yin et al., 1988).

At the type locality in the Langshan Mts. (Duoba region) the ca. 1 009 m thick Langshan Formation exhibits massive rudist limestone (patch reefs) alternating with orbitolinid-bearing mudrocks which are overlain by fine-grained clastics passing into a limestone/mudrock sequence (Tibet Geological Bureau, 1993). The formation's rich fauna of corals, foraminifers, brachiopods, gastropods and bivalves provide a reliable biostratigraphy within the Aiptan-Albian, possibly also Cenomanian (Smith and Xu, 1988; Yin et al., 1988). The formation was deposited in very shallow marine environments with rudist patch reefs and back reef lagoons (Leeder et al., 1988).

The Xiaqiong Formation from South of Lunpola (>300 m thick) overlies Kimmeridgian strata of bioherms followed by dolomitic siltstones which may extend to the Jurassic/Cretaceous boundary (Leeder et al., 1988). According to Leeder et al. (1988), the lower part of the formation consists of thickening-up cross-bedded sandstones with common erosional surfaces alternating with mudstone representing fluviodeltaic channel sediments. The following strata are characterized by siltstone and fine-grained sandstone with periodic cross-bedded sandstone beds of possible floodplain origin (Leeder et al., 1988). Yin et al. (1988) also mentioned intercalated amygdaloidal basalt. Towards the top, marine limestones bearing oysters and Aiptan-Albian orbitolinids follow an exposure gap (Leeder et al., 1988). These beds have formally been included in the Xiaqiong Formation which passes upward into the Langshan Formation (Yin et al., 1988). Since an Aiptan-Albian age is also known for the marine, orbitolinid...
limestones of the Langshan Formation (Jaeger et al., 1982; Yin et al., 1988), it is practical to assign them to the Langshan Formation. Foraminifers and Gastropods definitely indicate Aptian and Albian age (Smith and Xu, 1988). It is unclear whether the Langshan Formation includes Maastrichtian deposits; the latest marine fauna appear to be Albian (Cenomanian?) orbitoline foraminifers (Smith and Xu, 1988).

**Upper Cretaceous Jingzhushan Formation (alternatively called Jiangba Formation)**

The Jingzhushan Formation was named after the name of the mountain and originally established by the fourth geological team of Tibet Bureau in 1973. And then it was revised and renamed as Jiangba Formation in 1978 by the geological survey of Tibet. Stratigraphic charts show a lack of post-Cenomanian or post-Turonian Upper Cretaceous rocks (Smith and Xu, 1988; Yin et al., 1988) although Campanian volcanic rocks (Coulon et al., 1986) occur in the region and are associated with red beds (Pearce, 1988).

The formation is characterized by red, thick, massive conglomerate up to 4127 m in thickness (Fig. 4). Crossbedding is very common in the sequence. Palaeo-current is generally to the west. Different from those of the Duoba Formation, the composition of the Jingzhushan Formation is composed of predominantly limestone (>50%~70%), then red sandstone (ca. 20%~40%), chert and quartzite (ca. 10%~30%). Volcanic fragments and granite debris can also be seen but not more than 10%.

### 4 Sedimentary facies, palaeogeography and provenance

On the northern side of the Langshan Mountain of the Duoba region, about 1300 m of the Duoba Formation’s immature siliciclastic deposits are exposed. Towards the top, this section displays the overall trend of a fining-upward sequence.

The lower part of Duoba Formation (ca./150 m thick) mainly consists of reddish, yellowish and greenish sandstone and conglomeratic/fanglomeratic beds all intercalated with red, violet and green pelites. The sandstone/pelite ratio is about 4:1 to 3:1. The medium to thick-bedded, plant-bearing sandstone units are lenticular and with thickness of 15 to 50 cm and length of several tens centimeters to several meters. They generally reveal textural and compositional immaturity although some of the pebbles are well rounded. While the coarser clastics represent alluvial fan and fan delta, the pelites are sediments of adjacent back swamp and or lagoons.
In the middle part of the Duoba Formation (ca. 450 m thick), the rock color changes from reddish to violet, green and gray. The number and thickness of the medium to thick-bedded coarse-grained clastic beds decreases towards the top of the section, showing an increasing predominance of green pelite. Up to more than one meter thick conglomerate and fanglomerate beds play a volumetrically minor role.

According to Miall (1985) nomenclature, laminated sand sheets (LS) as well as disorganized conglomerates, fanglomerates and sandstone (SG) predominate compared to channels (CH) as architectural elements in the lower and middle part of the formation. The polymict conglomerates contain components of shale, limestone, quartzite, chert, granite as well as mafic and acidic to intermediate volcanic fragments of different degrees of roundness (Fig.3). Occasionally, there are fining-upward sequences (Gms to Sm to St to Sh to F) within shallow (1-2) channels which occur in relatively thick (up to 35 m) shale intervals. There are also 25 m thick sandflats.

The uppermost part of the Duoba Formation (ca. 250 m) is represented by dark pelite and black shales intercalated with a few thin sandstone beds. This facies indicates the beginning stage of transgression of the wide-spread Aptian sea. The overall nature of the sequence is that of a fan delta exhibiting a regressive trend. A few palaeocurrent measurements on St units provide evidence for a W or SW-directed transport.

Between the Langshan Mts. in the south and the Lumpola area, the beds of the Duoba Formation laterally interfinger with the Xiaqiong Formation to the north. The latter overlies Kimmeridgian strata displaying bioherms followed by dolomitic siltstones which may extend to the Jurassic/Cretaceous boundary. The lower part of the Xiaqiong Formation con-

Fig. 3 Distribution diagram of the gravels from the conglomerate of the lower, middle and upper Duoba Formation
A, B, C and D are upward trending in composition and diameter change of the gravel
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Fig. 4 Cretaceous sedimentary rocks of the Jingzhushan Formation
left: conglomerate of the lower Jingzhushan Formation; right: conglomerate of the upper Jingzhushan Formation
(pictures were taken by Pujun Wang, 1995)

sists of cross-bedded sandstone layers displaying increasing thickness towards the top. The sandstone units which are alternating with mudstone often exhibit an erosional lower surface. The following strata are characterized mainly by siltstone and fine-grained sandstone beds with periodic cross-bedded sandstone layers of possible floodplain origin. The marine limestone bearing Oysters and Aptian/Albian Orbitolinid foraminifers which are following a major exposure gap have formally been considered to be a part of the Xiaqiong Formation which passes upward into the Langshan Formation (Yin et al., 1988). Since an Aptian/Albian age is also known for the marine Langshan Formation, it appears to be practical to associate these marine strata formally with the Langshan Formation.

The dark shales of the upper Duoba Formation are overlain by limestone, marlstone and shales of the Langshan Formation which measures ca. 1 000 m. At the type locality of the Langshan Mts. south of Duoba, the limestone of the Langshan Formation can be subdivided into two lithofacies: medium to thick-bedded bioclastic limestones (1) and rudist-bioherms as irregularly shaped patch reefs extending laterally for a few tens of meters (2). Foraminifers and Gastropods definitely indicate Aptian and Albian age.

5 Tectonic implication

Leeder et al. (1988) interpreted the Early Cretaceous fluvial red beds as molasse derived from the north including the Qiangtang block’s Jurassic molasse. The southward progradation of the Cretaceous clastics was associated with floodplain and fluviodeltaic channel systems but was halted by the Aptian-Albian transgression (Leeder et al., 1988). Following the marine interval, similar conditions existed as before (Dürr 1996). The immature red beds represent intramontane alluvial fans and terrestrial fan deltas whose composition is of local origin. During the Mid-Cretaceous, the Lhasa block was partly eroded and the detritus was shed southward into the Xigaze fore-arc basin which formed in response to north-directed B-subduction during India’s approach (Dürr, 1996). At the same time southern and central Tibet were affected by magmatism (Scharer et al., 1984; Coulon et al., 1986; Harris et al., 1988). The intramontane Cenozoic sediments preferably occur in E-W-trending subbasins displaying angular unconformities.

At active margins there is a higher probability of oblique than head-on convergence. The former commonly causes trench-linked strike-slip faults in the
upper plate (Woodcock, 1986). Thus, due to the
presence of two B-subduction zones, strike-slip in
the upper plate appears especially likely to have oc-
curred leading to transtensional rifting of the car-
bonate platform and formation of the Duoba area.
According to Yu et al. (1991), the northern margin
of the BNSZ displays an s-shape in map view which
implies a sinistral shear sense.

Spreading created a relatively wide oceanic back-
arc basin. This is implied by the fact that the contin-
ental blocks of Duoba area were surrounded by oce-
nic crust and by the existence of fore-arc and back-
arc lithosphere in the region. We thus consider oblique spreading as a more likely spreading mecha-
nism than pure pull-apart which was important dur-
ing rifting.

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