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

Pujun Wang[1], Frank Mattern[2], Werner Schneider[3],
Wanzhu Liu[1], Shikai Li[1], Cai Li[1]

1. College of Earth Sciences, Jilin University, Chanchun, 130026 China
2. College of Geology, Berlin Free University, Berlin , D–12249 Germany
3. College of Geology, Braunschweig University, Braunschweig, D–38106 Germany

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 Chuanba Formation (K_{1c}), Duoba Formation (K_{1d}), Langshan Formation (K_{1l}) and Jiangba Formation (K_{2j}). The K_{1c} is composed of black shale, sandy pelite, siltstone, sandstone, coal beds and volcanic rocks, of shallow marine facies. The K_1d consists of terrestrial siliciclastics intercalated with some calcareous sandstone beds bearing *Orbitolina* sp. indicating marine influence. The K_{1j} is carbonate platform deposits of shallow marine and lagoon. The K_{2j} 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 marie 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, pertataining transport processes, the characterization of depositional systems and related tectonic implication.

2 The Cretaceous of the Bangong–Nujiang Suture Zone

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Corresponding author: Frank Mattern

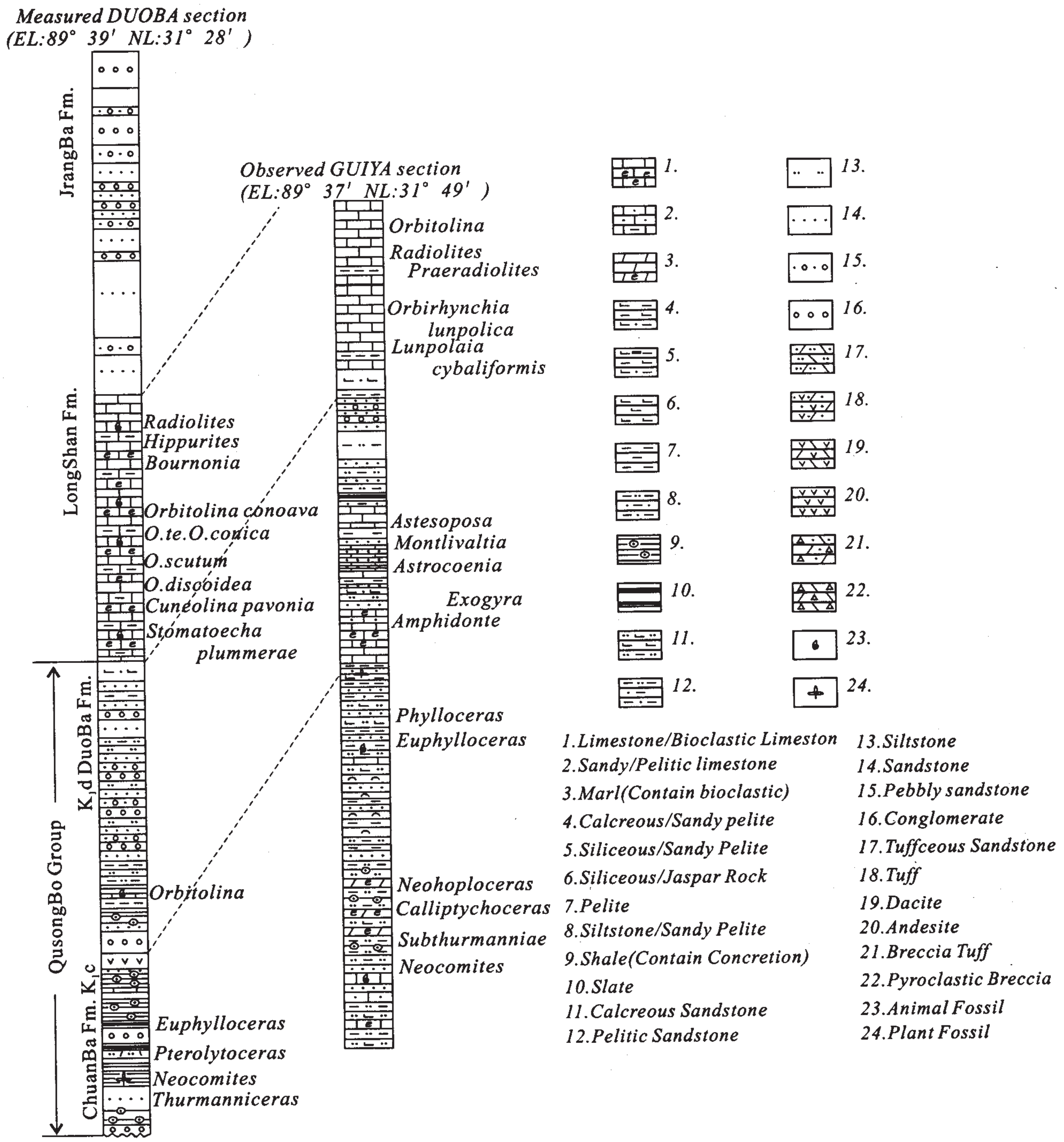

Fig. 1 Lithostratigraphic column and fossil assemblage of the Cretaceous sequence of the eastern Bangong–Nujiang suture zone (Northern Tibet)

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_3-K_{1c}), Lower

Cretaceous Duoba Formation (K_{1d}), Lower Cretaceous Langshan Formation (K_{1l}), Upper Cretaceous Jingzhushan or Jiangba Formation (K_{2j}).

The Upper Jurassic–Lower Cretaceous Chuanba Formation

Chuanba 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: *Euphylloceras, Lterolytoceras, 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 more than 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 coarser 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 Aptian-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 fluviodistributary 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 Aptian-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 Aptian-Albian age is also known for the marine, orbitolinid

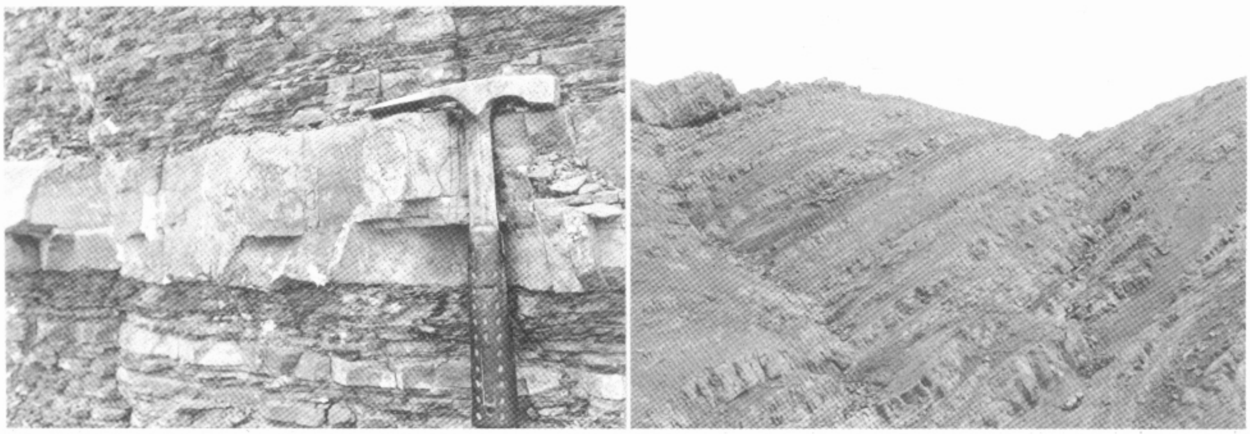

Fig. 2 Cretaceous sedimentary rocks of the Duoba Formation.
left: interbedded sandstone-siltstone-mudstone of the upper Duoba Formation; right: part of the typical section of Duoba Formation (pictures were taken by Pujun Wang, 1995)

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 4 127 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 1 300 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, lamenated 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 regradationgal 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 Lunpola 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-

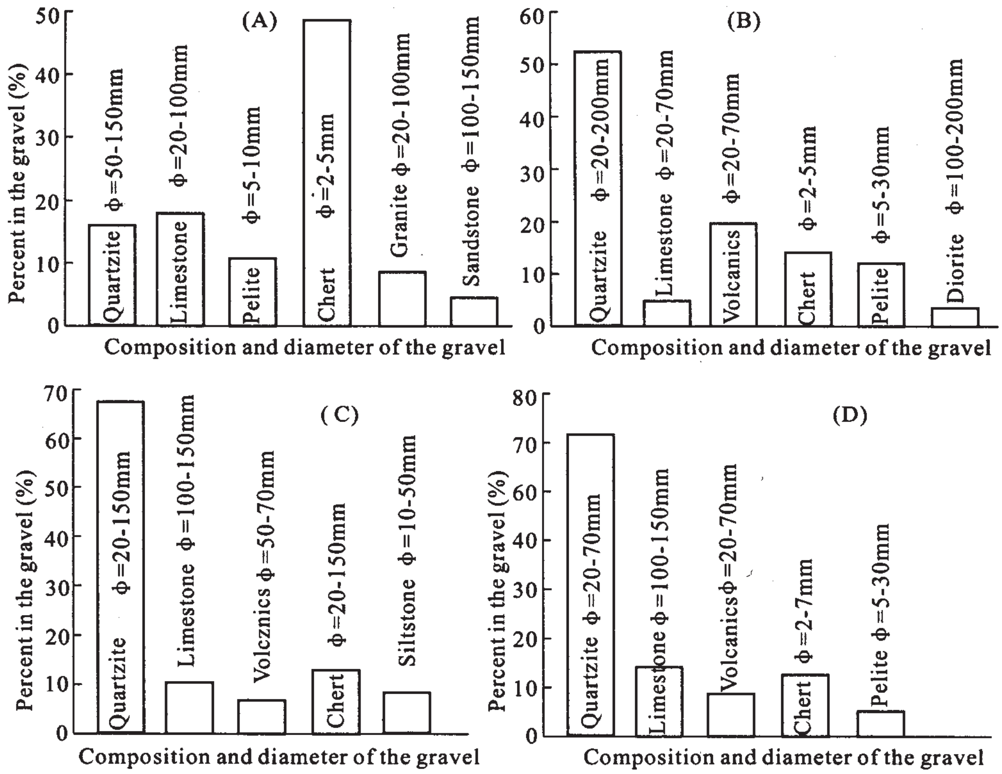

Fig. 3 Distribution diagram of the gravels from the conglomerate of the lower, middle and upper Duoba Formation

A, B, C and D are upward trending in composition and diameter change of the gravel

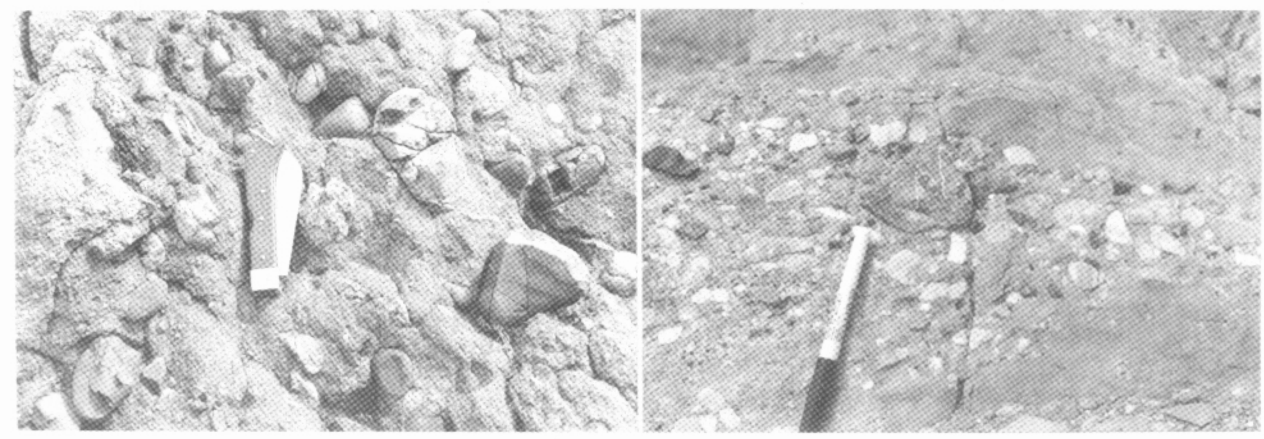

Fig. 4 Cretaceous sedimentary rocks of the Jingzhushan Formation
left: conglomerate of the lower Jingzhushan Formation; right: conglomerate of the upper Jingzhushan Formation
(pictures were taken by Pujun Wang, 1995)

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-beded sandstone layers of possible floodplain origin. The marine limestone bearing *Oysters* and Aptian/Albian *Orbitolinid* foraminiferans 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 biocalcarenites (1) and rudist-bioherms as irregularly shaped patch reefs extending laterally for a few tens of meters (2). Foraminefers and Gastropodas 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 fluviodistributary 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 occurred leading to transtensional rifting of the carbonate 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 continental blocks of Duoba area were surrounded by oceanic 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 mechanism than pure pull-apart which was important during rifting.

References

Coulon C, Maluski H, Bolliger C, Wang S, 1986. Mesozoic and Cenozoic volcanic rocks from central and southern Tibet: ^{39}Ar-^{40}Ar dating, petrological characteristics and geodynamical significance. *Earth Planet Sci*., **79**: 281-302

Dewey J F, Shackleton R M, Chang C, Sun Y, 1988. The tectonic evolution of the Tibetan Plateau. *Phil. Trans. Roy. Soc. London* A, **327**: 379-413

Dürr S B. 1996. Provenance of Xigaze fore-arc basin clastic rocks (Cretaceous, south Tibet). *Geol. Soc. Amer. Bull.* **108**: 669-684

Harris N B W, Holland T J B, Tindle A G, 1988. Metamorphic rocks of the 1985. Tibet Geotraverse, Lhasa to Golmud. *Phil. Trans. Royal Soc. London A*, **327**: 203-213

Jaeger J J *et al*., 1982. The contribution of Fossils to paleogeography of the Lhasa block (Tibet). **63**: 1093

Kidd W S F, Molnar P, 1988. Quaternary and active faulting observed on the 1985 Academia Sinica-Royal Society Geotraverse of Tibet. *Phil. Trans. Roy. Soc. London* A, **327**: 337-363

Leeder M R, Smith A B, Yin J, 1988. Sedimentology, palaeoecology and palaeoenvironmental evolution of the 1985 Lhasa to Golmud Geotraverse. *Phil. Trans. Roy. Soc. London* A, **327**: 107-143

Mattern F, Schneider W, Wang P, Li C, 1998. Continental strike-slip rifts and their stratigraphic signature: application to the Bangong/Nujiang zone (Tibet) and the South Penninic zone (Alps). *Geol. Rundsch*., **87**: 206-224

Mattern F, Schneider W, 2000. Suturing of the Proto- and Paleo-Tethys oceans in the western Kunlun (Xinjiang, China). *J. Asian Earth Sci*., **18**: 637-650

Miall A D, 1985. Architectural element analysis: a new method of facies analysis applied to fluvial deposits. *Earth Sci. Rev*., **22**: 261-308

Pearce J A, Deng W, 1988. The ophiolites of the Tibet Geotraverse, Lhasa to Golmud (1985) and Lhasa to Kathmandu (1986). *Phil. Trans. Roy. Soc. London* A, **327**: 215-238

Scharer U, Xu R H, Allègre C J, 1984. U-Pb geochronology of the Gangdese (Transhimalaya) plutonism in the Lhasa-Xigaze region, Tibet. *Earth Planet Sci. Letters*, **68**: 311-320

Smith A B, Xu J, 1988. Palaeontology of the 1985 Tibet Geotraverse, Lhasa to Golmud. *Phil. Trans. Roy. Soc. London* A, **327**: 53-105

Tibet Geological Bureau, 1993. Regional geology of Tibet. Beijing: Geological Press

Wang P J, Schneider W, Mattern F, Liu W Z, Li C, 1998. Sedimentation of the Bangong/Nujiang Suture Zone (BNSZ), Northern Tibet, SW China. *J. Changchun Univ. Earth Sci*., **27**: 21-32.

Woodcock N H, 1986. The role of strike-slip fault systems at plate boundaries. *Phil. Trans. Roy. Soc. London* A, **317**: 13-29

Yin A, Harrrison T M, 2000. Geological evolution of the Himalayan-Tibetan orogen. *Ann. Rev. Earth Planet Sci*., **28**: 211-280

Yin J, Xu J, Liu C, Li H, 1988. The Tibetan plateau: regional stratigraphic context and previous work. *Phil. Trans. Roy. Soc. London* A, **327**: 5-52

Yu G, Wang C, Zhang S, 1991. The characteristic of Jurassic sedimentary basin of Bangong Co-Dengqen fault belt in Xizang. *Bull. Chengdu Inst. Geol. Min. Res.*, **13**: 33-44 (in Chinese)