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CHARACTERISTICS AND EVOLUTION OF MESOZOIC FORELAND FOLD AND THRUST BELT IN WESTERN KUNLUN SHAN, CHINA*

CHEN Han-lin(陈汉林)[1], ZENG Hua-sheng(曾华生)[1], SHEN Xiao-hua(沈晓华)[1], YANG Shu-feng(杨树锋)[1], ZHANG Guoc-cheng(张国成)[2], Xiao Wen-jiao(肖文交), LI Ji-liang (李继亮)[2] and ZHAO Dong-dong(赵冬冬)[1]

([1] *Department of Earth Sciences, Zhejiang University, Hangzhou 310027, China*)
([2] *Institute of Geology, Chinese Academy of Sciences, Beijing 100029, China*)

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Abstract: The authors' analysis of the chemical components and sedimentary characteristics of the well developed Triassic strata in the southeastern part of western Kunlun Shan led them to conclude that the sediments comprise a set of typical deep-water to semi-deep-water flysch that formed in the passive continental margin of the Qiangtang Block. This suit of strata had undergone strong deformation giving rise to a SW-thrusting duplex, imbricate fans, high-angle thrust fault, recumbent fold, SW-inverted fold, etc.. The deformational intensity weakens gradually southeastward. This is a foreland fold and thrust belt caused by the collision between the Qiangtang Block and the island arc on the southern margin of the the Tarim Plate at the end of late Triassic.

The sedimentary and deformational characteristics of the Triassic strata were used to reconstruct the evolution of this foreland fold and thrust belt as proposed below. Before the end of Triassic, this region was a passive continental margin in the north of the Qiangtang Block. The end of Triassic to Jurassic was a stage of thrusting, folding, uplifting and development of the foreland basin. The evolution of the fold and thrust was completed in Cretaceous.

Key words: Western Kunlun Shan, Triassic strata, sedimentary environment, deformation, passive continental margin, foreland fold and thrust belt
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INTRODUCTION

Kunlun Shan located at the juncture of Eurasia and Gondwana is a very important subject in geological research (Fig. 1). Many geologists conducted researches in Western Kunlun Shan (Pan et al., 1990, 1992, 1995, 1996; Yao and Hsu, 1994; Li et al., 1996; Ding et al., 1996; Matte et al., 1996). Triassic strata with special sedimentary and structural deformational characteristics are widely developed in southwestern Kunlun Shan. Study of sedimentary environment, deformational characteristics and tectonic evolution of this suit of strata is the key not only to resolving the late Paleozoic-Early Mesozoic evolution of the Kunlun Shan orogenic belt, but also for inferring the prototype of the Tarim Basin in late Paleozoic-Early Mesozoic.

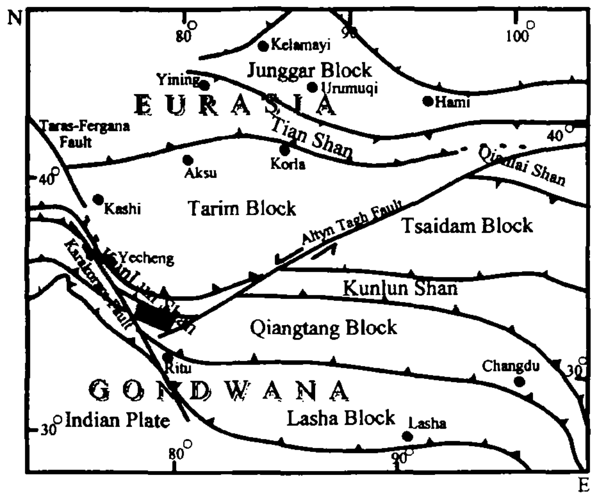

Fig.1 Tectonic sketch of Western China and adjacent region
■ Research region

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SEDIMENTARY CHARACTERISTIC AND ENVIRONMENT OF TRIASSIC STRATA

The Triassic stratum that develops widely in the south of the Kangxiwa fault divides it into three stratum systems (Xinjiang Geology and Mineral Bureau, 1993; Wen et al., 1996) (Fig. 2). Lower Triassic strata comprise the Xiaheweitai Group, middle Triassic strata comprise the Shangheweitai Group and upper Triassic strata comprise the Keleqinhe Group.

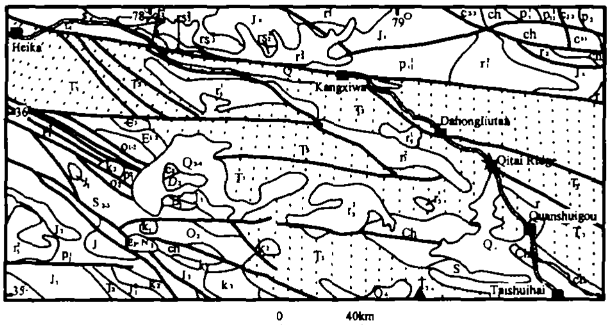

Fig. 2 Geological map of Kangxiwa-Tianshuihai region

Upper Triassic Keleqinhe Group distributes widely along the NWW direction in the region from the Kangxiwa fault to south of the Quanshuigou Fault (Fig. 2) as a set of 2500 – 4800 m thick marine facies flysch. There is fault contact between lower strata and the marine facies flysch (Xinjiang Geology and Mineral Bureau, 1993; Wen et al., 1996; Zhang et al., 1997; Zhang, 1997).

In the region from the Tianshuihai Fault to south of the Kongkashankou Fault, Middle Triassic Shangheweitai Group and lower Triassic Keleqinhe Group strata are exposed as a 800 – 1200 m thick sequence of siltstone, sandstone, thick-bedded limestone and gray carbonaceous siltstone (Xinjiang Geology and Mineral Bureau, 1993; Wen et. al., 1996) containing many fossils of *coral*, *Ammonitida and Lamellibranchia*. The Upper Triassic Keleqinhe Group strata exposed at the region of Jialewanhe, Kongkashankou as a suit of 4000 m thick flysch is in conformable contact with middle-lower Triassic strata and in unconformable contact with upper Jurassic Longshan Group strata (Xinjiang Geology and Mineral Bureau, 1993; Wang et al. 1995; Wen et al., 1996).

In the region 80 – 100 km west of Tianshuihai, lower Triassic Group facies distribute locally as fault sheets in unconformable contact with Permian Group facies as a flysch sequence consisting of schistose siltstone, gray fine sandstone, and interlayer of limestone and purplish-red siliceous radiolarian fossils (Zhang et al., 1997; Zhang, 1997).

The source of sediment and its Triassic environment can be deduced from the geochemical characters of the clastic rock. The flysch samples collected from under the Tongtian Bridge and those from the Konka Mountain Pass fall in the passive continental margin zone in the $Al_2O_3/SiO_2 - (Fe_2O_3 + MgO)$ (Fig. 3) diagram showing that they originated from the passive continental margin and also showing that the samples from Qitai Ridge originated from the active continental margin (Fig. 3).

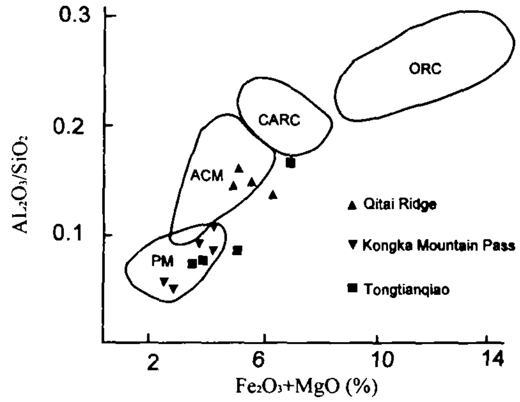

Fig. 3 Diagram of $Al_2O_3/SiO_2 - (Fe_2O_3 + MgO)$ (Zhang, 1997)
PM: Passive Continental Margin;
ACM: Active Contin-ental Margin;
CARC: Island Arc in Contin-ental Crust;
OARC: Island Arc in Ocean crust

Sedimentology analysis showed that the northward or northeastward dipping paleocontinental slope's middle-lower Triassic sediments are mature felsic minerals originated from the passive continental margin. In late Triassic were developed mainly limestone and debris depositing in the stable shelf region in the southern Konka Mountain Pass-Karakorum zone. The sediment was from the south stable continent. But in the region in the northern part of the Konka Mountain Pass-Karakorum zone, for example Qitai

Ridge, Dahongliutan, Kangxiwa, Heika, etc., the sediments were mainly influenced by active continental margin. These characteristics probably suggested the past existence of a remnant sea-basin between the Qiangtang Block and the island arc in the southern margin of the Tarim Plate (Chen, 1998).

DEFORMATION OF LATE TRIASSIC STRATA IN THE WESTERN KUNLUN SHAN REGION

The Triassic strata had undergone intense north to south deformation with gradually weakening intensity (Fig. 4)

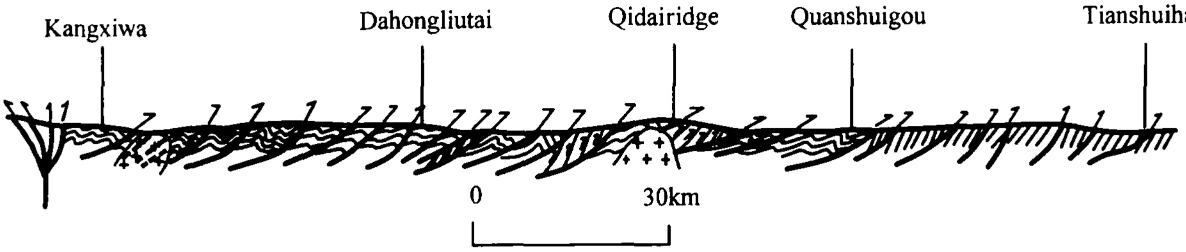

Fig.4 Sketch of deformation at the region of Kangxiwa-Tianshuihai

The well developed strong ductile deformation in the region between the Kangxiwa Fault zone and the Dahongliutan Fault is the most important characteristic of this region. For example, at the place of the Xinjiang-Tibet highway between the 351 km and 353 km road signs and the Hasheng highway between the 0 km and 10 km road signs, the mylonite is very developed. The profile shows that there are many granitic mylonite and dioritic mylonite with clear banded structure, mortar system and mylonitic structure (Fig. 5). It is easy to know from the developed feldspar mortar structural lineation that the mylonite was caused by N-S thrusting and right-lateral strike slipping. The N-S directional thrusting is earlier than the right-lateral strike slipping.

Fig.5 Ductile deformation near the 351km road sign area

Many duplexes, imbricate fans and oblique or inverted folds are developed in the region between the Dahongliutan and the 532 km road sign of the Xinjiang-Tibet highway. The sandstone-mudstone in the upper Triassic flysch sequence evolved into slates and schists.

The profile of the Xinjiang-Tibet highway 495 km road sign area shows typical imbricate thrusts resulting from the southward movement along N-dipping planes (Fig. 6).

Fig.6 Imbricate thrust in the 495km road sign area

The profile of the of Xinjiang-Tibet highway 531km road sign area, the deformation gave rise to a multilayer duplex. In the lower part of the profile section, imbricate thrusts are near one another and form a roof thrust (Fig. 7). In the profile there are a lot of tight folds that are oblique to or invert slightly to SW.

The strong deformation at the north side of the Qitai Ridge develops many duplexes, passive roof duplexes and tight folds. For example, the profile of the Xinjiang-Tibet highway 533 km road sign area is mainly characterized by passive roof duplex and tight fold. Faults in the lower part thrust southward and converge to a back thrust to make up a typical passive roof duplex. The horses of the duplex pop up into an antiformal stack. The thrusts above back thrust form back-thrusting imbrications (Fig. 8). The folds are tight and directions of axial planes are in disorder; all these indicate the complexity of the deformation.

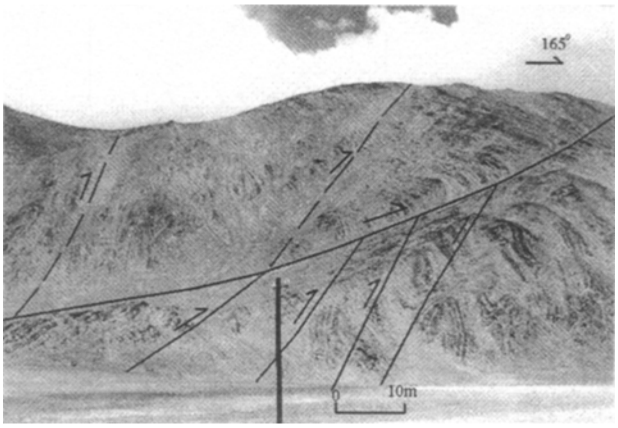

Fig.7 Duplex in the 531km road sign area

Near Quanshuigou, the deformations are weak and form imbricate fans and back-thrusts. In the left part of the profile section at Quanshuigou(Fig.8), there are a group of southward direction imbricate thrusts. In the right part is developed a southward dipping thrust with direction reverse to that of the others. Together, they make up a structural triangular belt (Fig.9).

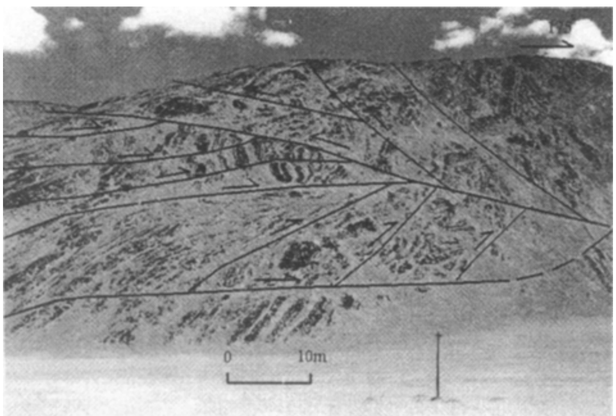

Fig.8 Passive roof duplex and tight fold in the 533km road sign area

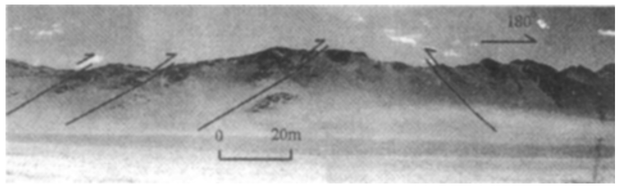

Fig.9 Imbricate thrust and backthrust near Quanshuigou

The weak deformation in the Quanshuigou-Tianshuihai region is characterized by board folds, monoclines and S-thrusting imbricate fault association (Fig. 10).

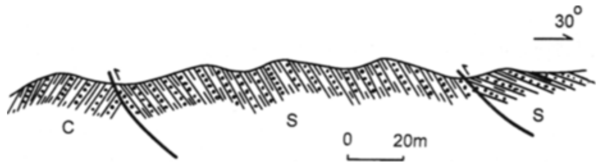

Fig.10 Thrust in Quanshuigou-Tianshuihai region

According to the deformation and sedimentary characteristics, it can be concluded that the Kangxiwa-Tianshuihai region belonged to a foreland fold and thrust belt in Early Mesozoic.

THE EVOLUTION OF FORELAND FOLD AND THRUST BELT IN WESTERN KUNLUN SHAN REGION

Before the end of Triassic, the Western Kunlun Shan region was a part of the passive continental margin of the Qiangtang Block, and developed very thick passive margin sedimentary strata. At the end of Triassic, the Qiangtang Block collided with the island arc on the southern margin of the Tarim Plate that was formed by the subduction of Kunlun Ocean (A branch of Paleo-tethys) during the time from Late Paleozoic to Middle Triassic (Chen, 1998). This collision led to the ceasing of passive continental margin sedimentation of the Qiangtang Block. Since then, the Kangxiwa-Tianshuihai region reached the stage of foreland thrusting, folding, uplifting, degradation and forming of foreland basin and evolution. Its evolution can be divided into five phases.

1. The Triassic phase

Early to Late Paleozoic was characterized by a passive continental margin depositional sequence consisting of clastic rock, limestone and flysch formation with interbedding of volcanic clastic rock. This sequence implies that the sedimentary environment was shallow to semi-deep seawater (Zhang et al., 1986; Yang et al., 1990; Guo et al., 1991; Yi et al., 1991, 1995; Xinjiang Geology and Mineral Bureau, 1993; Wang , 1995).

In Early to Middle Triassic, the sedimentary environment changed into deep water, and very thick deep-water flysch formation developed in the Kangxiwa-Tianshuihai region. The provenance of flysch formation was from the Qiangtang Block.

In Late Triassic, the sandstone in the flysch formation contained volcanic debris from the island arc in the southern margin of the the Tarim Plate. This suggests that the Kunlun Ocean (A branch of Paleo-tethys) was very narrow, and that the passive continental margin of the Qiangtang Block was close to the island arc on the southern margin of the The Tarim Plate that was active in Late Paleozoic and Early to Middle Triassic.

2. The Late Triassic to Early Jurassic phase

In Late Triassic-Early Jurassic, the Qiangtang Block collided with the island arc developed on the southern margin of the Tarim Plate. The strata in the Kangxiwa-Tianshuihai region were deformed strongly. Under the strong compressive stress from the northeast direction, the Paleozoic to Triassic sedimentary wedge that was developed in the passive continent margin underwent strong thrusting and folding, and developed a lot of reversal folds, recumbent folds, duplexs, imbricate thrusts, etc.. The propagational direction was southwestward i.e. from Kangxiwa to Tianshuihai. The structural polarity was NNE to SSW was deduced from the deformational pattern in this region. The latest marine facies stratum that deformed in the collision was Late Triassic Keleyuehe Group (Wang, 1995).

3. The Early Jurassic to the Middle Jurassic phase

Because of the strong thrusting deformation, the folded and thrusted sedimentary wedge uplifted constantly. In the south of Tianshiuhai that was at the front of this sedimentary wedge, the down-warping elastically of the lithosphere led to the development of the earliest foreland basin sedimentary strata. The molasse of Early to Middle Jurassic Bagongbulansha formation developed very well in the north of Karakorum Mountain (Fig.2) (Xinjiang Geology and Mineral Bureau, 1993; Wang et al., 1995).

4. The Middle Jurassic -Late Jurassic phase

In Middle Jurassic, owing to the sustained thrusting, the sedimentary wedge became thicker and shorter constantly and spread to the south continually, which caused the deformation to be stronger in the Quanshuigou region where its deformation was quite weak in Late Triassic and Early Jurassic, and formed tight fault-bend folds and thrusting imbricate fans. Because of the stronger thrust, the foreland basin in the south of Tianshihai expanded to the south and the water deepened (Wang et al., 1995; Yi, 1995). In the region south of Qiaoertianshan, the sediment was mainly made up of carbonatite in foreland basin (Guo et al., 1991; Wang et al., 1995; Yi, 1995). At the north of Qiaoertianshan, as the result of uplifting, the Early to Middle Jurassic sedimentary region (Molasses Formation) became denuded.

5. After the Cretaceous

The gradual weakening of the orogenics and the weakening of the compressive stress in this region after Cretaceous led to the cessation of the fold and thust belt's evolution.

CONCLUSIONS

Research on the sedimentary characteristics, sedimentary environment, and the structural pattern of the Triassic strata's deformation led to the conclusions below.

1. The Kangxiwa-Tianshuihai region Triassic sediment comprise a set of typical deep-water to semi-deep-water flysch formation developed in the passive continental margin environment.

2. The deformation in the Kangxiwa-Tianshuihai region gave rise to a SW-thrusting duplex, imbricate fans, high-angle thrust fault, recumbent fold, SW-inverted fold, etc. The deformation weakens gradually southwestward. In

Kangxiwa, the deformation is characterized mainly by high-angle thrust fault and lots of tight folds. In Dahonglutan, the deformation is characterized by duplexes, imbricate fans and reverse folds. In the north of Quanshuigou, the deformation is characterized by imbricate fans, passive roof duplexes and tight folds. South of Quanshuigou, the deformation is characterized by a few high-angle thrusts and some board folds. The deformation of Kangxiwa-Tianshuihai is characterized by foreland fold and thrust belt.

3. Based on sedimentary characteristics and deformational characteristics, we put forward the evolution of the foreland fold and thrust belt in the Kangxiwa-Tianshuihai region. Before the end of Triassic, the region was a passive continental margin in the north of the Qiangtang Block. At the end of Late Triassic, the Qiangtang Block collided with the island arc on the southern margin of the Tarim Plate. End of Late Triassic to Jurassic was a period of thrusting, folding, uplifting and forming of foreland basin. In Cretaceous, the evolution of fold and thrust ceased.

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References

Chen Hanlin, 1998. Characteristics and evolution of Taxkorgan-kangxiwa collision orogenic belt and coupling between orogenic belt and Tarim basin. Ph. D. Dissertation (In Chinese, with English Abstract).

Ding Daogui, Wang Daoxuan, Liu Weixin et al., 1996. The western Kunlun orogenic belt and basin. Geological Publishing House, Beijing, p. 1 – 120 (In Chinese).

Guo Tieying, Liang Dingyin, Zhang Yizhi et al., 1991. Geology of Ali in Tibet. China University of Geosciences Press, Beijing, p. 1 – 12 (In Chinese)

Li Yongan, Li Xiangdong, Sun Dongjiang et al., 1996. Tectonic evolution of the Qiangtang Block and Kangxiwar structure zone in Kara-Kunlun mountains southwest of Xinjiang, China. Xinjiang Science & Technology & Hygiene Publishing House (K), p.21 – 105 (In Chinese).

Matte, Ph., Tapponnier, N. et al., 1996. Tectonics of western Tibet, between the Triam and Indus. *Earth Planet. Sci. Letter.*, **142**: 311 – 330.

Pan Yusheng, 1990. Tectonic features and evolution of the western Kunlun Shan region. *Scientia Geological Sinica*, **3**: 224 – 232 (In Chinese, with English Abstract).

Pan Yusheng and Wang Yi, 1992. Geological characteristics and tectonic evolution of Kunlun and Karakorum ranges. *In*: Advances in Geoscience(2), Institute of Geology, Academica Sinica, Science and Techology Press, Beijing, p. 80 – 84 (In Chinese, with English Abstract).

Pan Yusheng, 1994. Discovery and evidences of the fifth suture zone of the Qinghai-Xizang Plateau, *Chinese Journal of Geophysics*, **37**(2):241 – 250 (In Chinese, with English Abstract).

Pan Yusheng, Wang Yi et al., 1995. Geology along the line from Yecheng to Shiquanhe and tectonic evolution of the region involved. *Acta Geologica Sinica*, **8**: 119 – 133 (In Chinese, with English Abstract).

Pan Yusheng, 1996. Geological evolution of the Karakorum. and Kunlun Mountains. Seismological Press, Beijing, p. 1 – 320.

Wang Dongan and Chen Ruijun, 1995. Sedimentary characteristic contrast of different Block in Western Kunlun-Karakorum, Proceedings of international conference on Qinghai-Xizang Plateau and Global change. Science Press, p. 291 – 301 (In Chinese).

Wang Dongan and Chen Ruijun, 1995. Characteristics and facies change in Karakorum region. *Scientia Geologica Sinica*, **30**(3): 291 – 301 (In Chinese, with English Abstract).

Wen Shixuan, Sun Dongli et al., 1996. Stratigraghy and Palaeontology. *In*: Pan Yusheng (eds.): Geological Evolution of the Karakorum and Kunlun Shan. Seismological Press, Beijing, p.1 – 21.

Xinjiang Geology & Mineral Bureau, 1993. Geological annals of Xinjiang, Geological Publishing House, Beijing, 1 – 514 (In Chinese).

Yao Yongyun and Hsu, K. I., 1994. Origin of the Kunlun Mountains by arc-arc and arc-continent collision, *The Island Arc*, **3**:75 – 89.

Yang Zhirong and Long Nengli, 1990. Research of Marine Triassic in Karakorum and Eastern Kunlun Shan, Xinjiang Province. *Xinjiang Geology*, **8**(4):321 – 331 (In Chinese, with English Abstract).

Yi Jiexiang, 1991. Discussion of property of carboniferous basin in Western Kunlun Shan, *In*: Tethyside evolution and mineralization process in Western China. Electronic Technological Publishing House, Beijing, p. 51 – 52 (In Chinese).

Yi Jiexiang and Bian Qiantao, 1995. Geological map of Karakorum, Western Kunlun Shan and adjacent region. Science Press, Beijing (In Chinese).

Zhang Guocheng, Li Jiliang, Chen Hanlin et al., 1997. Trassic flysch trace fossils and their geological significance from Karakorum ranges in Xinjiang, China. *Scientia Geologica Sinica*, **1**:83 – 96.

Zhang Guocheng, 1997. Mesozoic sediments and tectonic evolution of Western Kunlun-Karakorum foreland fold and thrust, Ph. D. Dissertation (In Chinese, with English Abstract).

Zhang Zhide, Zeng Yacan, Yang Depu et al., 1986, Division of Early Permian Strata in Kongkashankou and its significance. *Xinjiang Geology*, **4**(4): 58 – 66 (In Chinese, with English Abstract).