Sedimentary Record of the Planation Surface in the Hoh Xil Region of the Northern Tibet Plateau

YI Haisheng, WANG Chengshan, LIU Shun, LIU Zhifei and WANG Shifeng
Institute of Sedimentary Geology, Chengdu University of Technology, Chengdu 610059, Sichuan

Abstract Miocene marl is the most widespread Tertiary stratigraphic record in the northern Tibet Plateau, termed the Wudaoliang Group in the Hoh Xil region and the correlative Suonahu Formation in the Qiangtang region. The uniform marl overlies red beds of the Eocene-Oligocene Fenghuoshan Group. The Wudaoliang Group is generally 100–400 m thick, but the thickest strata are 700–1300 m, located in the Haidinghu (Haiding Lake) and Tuotuohe (Tuotuo River) regions respectively. Based on observations from eight measured sections and outcrops, the thin-bedded marl, which varies in colour from grey-white to light brown-grey, is explained as a large-scale or serial lacustrine deposit stretching throughout northern Tibet.

The Wudaoliang Group commonly crops out on geographic lowland at an average elevation of 4600 m above sea level within the mountain chains, showing concordant summit levels, e.g. the Fenghuoshan and Bairizhajia Mountains. These mountains with a flat ridge are considered to be remains of the palaeo-planation surface. However, the spatial distribution of the Wudaoliang Group is not confined by the current mountain-basin landform configuration. We have observed the Miocene Wudaoliang Group marl exposed on a 5233 m-high mountain peak. The largest difference in height between the current lake level and the mesa crest is 600 m; the maximum dip angle is 25°, but usually below 10°, which is obviously different from the Fenghuoshan Group red beds with moderate to strong structural deformation. The horizon of the Wudaoliang Group thin-bedded marl and its widespread occurrence throughout the northern Tibetan Plateau can only be reasonably inferred to a sedimentary record relevant to the palaeo-planation. Its deposition occurred on primary land floor by erosion at 20 Ma and its bed surface is a typical sign of geomorphic rise and collapse after the erosion.

Key words: Miocene, sedimentary record, planation surface, uplift, collapse, Hoh Xil, northern Tibet

1 Introduction

The Qinghai-Tibet Plateau is a special geomorphic and geographical unit in Asia. It is about 2000 km in length from east to west, 800 km in width from north to south and some 5000 m in height above sea level. The plateau is not a flat land surface. There are some over 7000 m-high mountains on it, such as the Gandise, Nyainqêntanglha and Kunlun Mountains, and some deep valleys which are dissected by rivers down to 3000 m. It has long been known that there was a widespread palaeo-planation surface. Most of the mountains have concordant summit levels, which are remnant traces of the palaeo-planation surface. Yang et al. (1983) proposed that there were two grades of planation surfaces. One was the plateau mountain surface, and the other was the basin plain surface. Shackleton and Chang (1990) held that there only existed a palaeo-planation about 10 Ma marked by the mountaintop surface within the plateau, and not a Pliocene planation corresponding to the low basin surface. Because of strong uplifting of the plateau since the Pliocene, the neogenic landforms overlapped on and deformed the palaeo-planation surface. Therefore, there are still different views on the shapes, grades, ages, and regional correlation of the palaeo-planation surfaces.

Erosion and deposition are two closely interdependent geological and geomorphic processes. Our research work in the northern Tibet Plateau shows that the deposits related to the planation were ever extensively distributed, which provide new evidence for determination of its grades and ages (Xu et al., 1997; Ma et al., 1998). On the other hand, the flat erosional peneplain surface can be regarded as a marker of the plateau uplifting (Li et al. 1981; Cui et al., 1996). Not only do the planation surface and its corresponding deposits provide references for the time, process and amplitude of the uplifting, but also its deformation can give a time constraint on the crustal shortening of the plateau since the Cenozoic (Li et al., 1999). Different from the Alpine-and-valley topography in the Himalayas, which has been eroded by both the Pacific Ocean drainage and the Indian Ocean drainage, and the ridge-and-valley in the eastern Hengduan Mountains, the northern Tibet Plateau is occupied by a widespread interior drainage system. Because the headwater erosion of rivers in the east including the Nujiang River, Lancang River and Jinsha River did not arrive at the northern Tibet Plateau, there has been preserved the most complete plateau mountain surface. The widely distributed Tertiary strata contain plentiful information of the eroding processes and successions. Based on the authors' field work in the area during 1997–1998 (Fig. 1), this paper discusses both landforms of palaeo-planation and markers of depositional processes.

2 Geomorphology and Distribution of the Planation Surface in the Northern Tibet Plateau

It is shown by field observations that there are two grades of topographic surfaces, which have their own distinctive shapes and distribution. One is the mountaintop surface, and the other is the basin surface. The

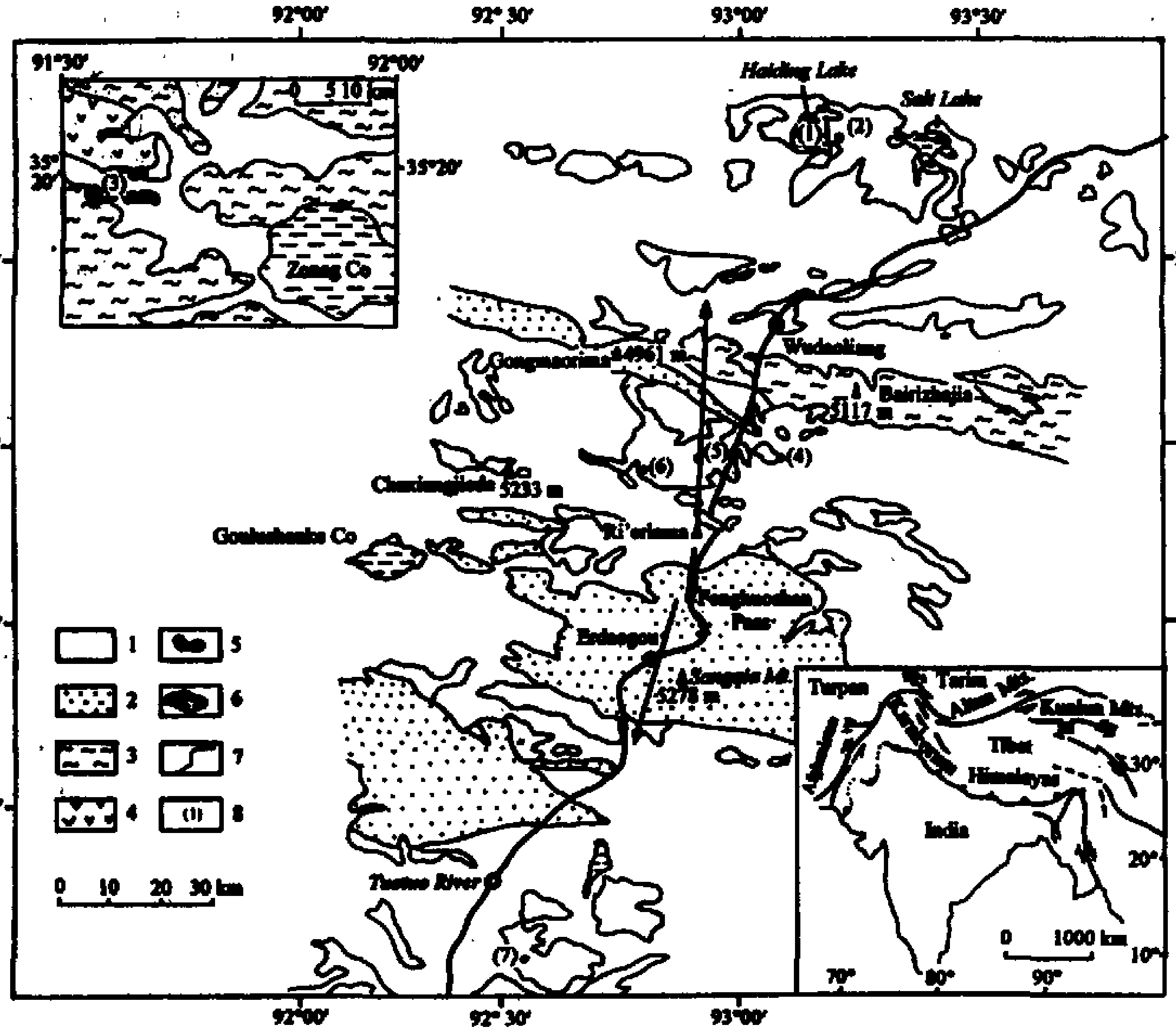

Fig. 1. Location map of the study area.

The lines with arrows show the topographic profile. 1. Wudaoliang Group (Miocene); 2. Fenghuoshan Group (Eocene); 3. Bayan Har Group (Triassic); 4. volcanic lava; 5. subvolcanic rock; 6. lake; 7. Qinghai-Tibet highway; 8. measured section and its number.

former, which represents a palaeo-planation surface, is characterized by concordant mountain summit levels culminating at about 5000 m. The latter, the lower basin surface, lies at about 4600 m on average.

The Hoh Xil region lies east of the northern Tibet Plateau. It is adjacent to the Kunlun Mountains to the north and the Tanggula Mountains to the south, respectively. It reaches the Qinghai-Tibet highway in the east and adjourns the Qiangtang area to the west. Except the 5600–6000 m high peaks in the Tanggula and the Kunlun Mountains, the Hoh Xil Mountains in the central part exhibit an interlacing landform pattern of relatively low lakes and plains with high peaks of 5200–5400 m above sea level. The plateau surface in this area dips towards the east at a 1/50 gradient.

Figure 2 is a topographical profile about 100 km long from north to south. It starts at the Ri'achiqu River (34°31′N, 92°44′E), about 20 km south to Erdaogou and ends at the Qumar River (35°15′N, 92°58′E). In the 45-km N-S extension of Fenghuoshan Mountain as shown in Fig. 1, the summits of nearly all the mountaintops are around 5000 m except several peaks such as 5332 m high Sangqia Mountain. These mountains show smooth tops and asymmetric slopes, steep in the south and gentle in the north. The length ratio of the southern slope to the northern slope is about 1:3, with the Fenghuoshan Pass as a dividing line. The flat mountaintop surfaces, a series of platform-like ridges, extend at least 80 km from east to west. The height of the mountaintop surface in Erdaogou decreases abruptly from 4900 m to 4600 m, forming linear cliffs on the south edge of Fenghuoshan Mountain.

The mountaintop surfaces are gently inclined towards the north from the Fenghuoshan Pass to Bairizhajia Mountain. The landform of this area is of a complicated pattern. It is often made up of low hills and wide-open valleys. It also includes linear Gongmaorima Mountain at 4800 m a.s.l. and island-shaped hills and isolated peaks such as Ri'erlama Mountain. Bairizhajia Mountain 10 km south of Wudaoliang, which is only 8 to 10 km wide, is another concordant summit level about 4850 m to 4950 m in height. These isolated peaks, which are disharmonious with the basin surface, should be a part of the same mountaintop surface.

On a larger geomorphic scale, from the Gandise Mountains to the Kunlun Mountains, there are both mountaintops and basin surfaces. All these mountaintop surfaces have smooth summits, which have been recognized as relics of the palaeo-planation by Yang et al. (1983) and Shackleton et al. (1990). Lakes and open-valleys occupy the basin surfaces which are separated by mountain chains. The mountain-basin series are approximately equal in length and width. The altitudes of the mountain summits show remarkable changes from north to south. They are higher (5200–5500 m) on both the north and south sides and lower (5000 m) in the middle Hoh Xil area. The mountaintop surface dissecting the Palaeogene red beds is the same one that spreads widely throughout the whole Qinghai-Tibet Plateau.

The basin surface in the northern Tibet Plateau, which was interpreted as another planation surface in the Pliocene by Yang et al. (1983), is mainly characterized by a wide and slightly waved topography with numerous lakes, low hills and shallow valleys. The basin surface is wide and shallow in the exorheic regions of the plateau. It occurs as a valley-form plain in the Nujiang River, the Yarlung Zangbo River, and the upstream of the Indus River. The altitude of the basin surface varies gently when viewed from a large area. That of the present lake surface in the northern Tibet reaches 5000 m, and declines to 4600 m near Fenghuoshan Mountain.

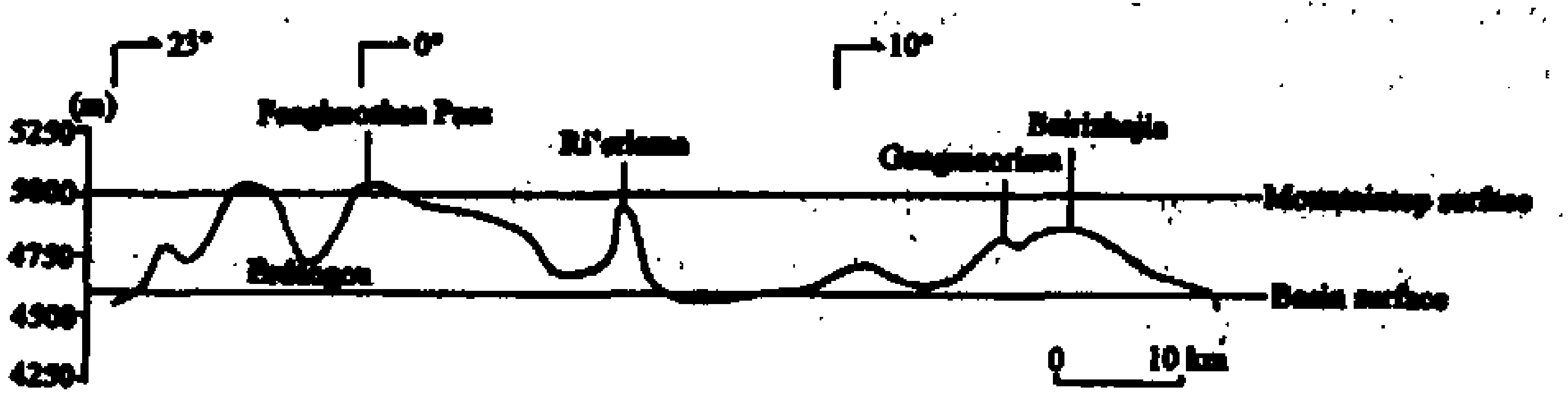

Fig. 2. N-S-trending topographic profile across Hoh Xil in the northern Tibetan Plateau. The average elevation of mountaintop surfaces is 5000 m, and the basin's landform surface is close to 4600 m above sea level. The location of the cross section is shown as lines with arrows in Fig. 1.

3 Depositional Record Corresponding to the Planation Surface

Yang (1983) and Shackleton (1990) already pointed out that the mountains having summit levels in the Hoh Xil area, as represented by Fenghuoshan Mountain and Bairizhajia Mountain, are the relics of the palaeo-planation aged from Eocene to Late Miocene. The strata dissected by the mountaintop surface include not only the Triassic and Jurassic but also the Eocene-Oligocene Fenghuoshan Group, which have been strongly folded and thrust (Yin et al., 1990). Similar geological phenomena are also observed in southern Tibet. The age of the palaeo-planation can be limited to the latest Late Eocene as supported by the fact that the planation surface truncated the 33–34 Ma isotopic-age Zangmaxikong syenite porphyry. However, the upper limit of the erosion surface is still uncertain because of lack of data. We have discovered in the field that the Miocene Wudaoliang Group is widely distributed in the basin between the Tanggula Mountains and the Kunlun Mountains. It is easily distinguished by its uniform marl and distinctive grey-white colour. In the neighbouring Qiangtang area, the Miocene Suonahu Formation is similar and comparable to the Wudaoliang Group. The top of the Wudaoliang Group comprises the present basin surface. It separated the uplands and mountain ridges, which are made up of Palaeogene red beds. The Wudaoliang Group basically keeps its original basin appearance except being gently deformed and eroded. We consider that the Wudaoliang Group is a depositional record corresponding to the palaeo-planation surface and can be used to determine its age. Its depositional age, facies succession and landform distribution are the keys to the interpretation of the palaeo-planation surface.

3.1 Stratigraphic sequence and depositional age

The Wudaoliang Group is a newly proposed stratigraphic unit. It overlaps unconformably the Eocene-Oligocene red beds. Similar phenomena can be found extensively in both Hoh Xil and Qiangtang. The typical section of the Wudaoliang Group is set up at Zaxiugari, 1 km west to the No. 76 station of the Qinghai-Tibet Highway (Gou and Deng, 1988; Gou, 1991; Guo, 1991). In this area, it is mainly composed of grey, yellow-grey marl. Its residual thickness ranges from 100 m to 400 m, is 760 m at the maximum. There are abundant fossils including ostracods such as *Eucypris, Cyprinotus, Youshashania* sp. and gasteropods such as *Radix* sp. and *Gyraulus* sp. We recently discovered gasteropods such as *Lymnaea* sp., *Galba* cf. *pervia* (Martin) and *Gyraulus* sp. in the Haidinghu and Zaxiugari sections. Sporopollen analysis shows that aciculignosa such as spruce (*Piceaepollenites*) and fir (*Abiespollinitts*) are dominant. There are minor ligneous laurisilvae such as *Betulaepolenites*./*Quercoidites*. *Chenopodipollis* of grass angiosperms is abundant and *compositae* is minor. In the Tuotuo River section, sporopollen mainly consists of gymnosperms, such as *Cedripites, Pinuspollenites, Abietineaepollenites* and *Podocarpidites*. There are some few angiosperm pollen including *Tricolpites* and *Quercoides*. Although the time intervals of these spores and pollen are long, we can conclude that the Wudaoliang Group was deposited approximately during the Tertiary. Ostracods such as *Eucypris, Limnocythere, Candoniella, Mandelstam, Cyclocypris* and *Daruinula* are standard and important Miocene fossils. Also, a few bivalve (*Sphaerium nitidium clessin*) and gasteropod fossils (*Galba subgiobosa, G. Elegans* (Ping) and *Valvata applabata* Yuoluo) in the vicinity of Goulu Co provide new evidence for the assumption that the Wudaoliang Group strata belong to the Miocene.

On the west bank of Zonag Co, it is clearly seen that the Wudaoliang Group overlaps on the black-grey trachyandesite lava with K-Ar ages of 15–19 Ma. The rhyolite porphyry, which wraps trachyandesite clasts, is dated at 22.31 Ma by using the Rb-Sr method (Zhang et al., 1994). However, field observations show that rhyolite porphyry is slightly younger than trachyandesite. So we take 22 Ma as the minimum age for the trachyandesite. It is inferred the Wudaoliang Group is no older than 20 Ma. Its upper limit is still not determined, because of lack of accurate age data and observations of its direct contact with the above strata. At the bottom of the Qiangtang Formation, a palaeomagnetic age of 5 Ma (Ge et al. 1994) in front of the Kunlun Mountains was found. The formation is composed of grey-green lacustrine clay and siltstone

500–700 m thick. Our primary work along the south front of the Kunlun Mountains shows that the Qiangtang Formation is younger than the Wudaoliang Group. Therefore, the age of the former is probably between 20 Ma and 5 Ma.

3.2 Lithofacies and relevant interpretation

Based on 9 measured sections (Fig. 3), the Wudaoliang Group can be divided into seven lithofacies types: (1) Grey-white, yellow-grey marl and limestone, which are the most common, forming up to 70% of the total thickness. The mud content varies from 20% to 40%. Clay minerals are dominated by illite and chlorite. (2) Dark-grey bioclastic limestones, bioclastics and skeleton including gastropods, ostracods and occasionally Chareae fragments. The total abundance reaches 10–40%, 85% at the maximum. (3) Grey-yellow, grey-white pellet-lump limestone and oncolite limestone. It is the typical lithofacies of the Wudaoliang Group. The pelletal grains are 0.1–0.5 mm in diameter, accounting for 30–40% of the total. Lumps are irregular shaped, 2–1 cm in diameter, amounting to 20–30%. Oncolite is 0–1.5 cm in diameter, occasionally up to 2–3 cm. This limestone also contains minor terrestrial silts and bioclasts. Lump and pelletoid limestones often undergo dolomitization, in which the dolomite content may reach 15%, 30% at the maximum. (4) Grey-green mudstone and silt-bearing mudstone. This lithofacies is minor and often interbedded with marls. (5) Grey and white gypsum, which is found in the upper part of the Tuotuohe section. The gypsum exists individually or as alternate beds with red or yellow mudstones. The cyclic beds are 2–5 m thick. (6) Dark-grey oil shale and carbonaceous shale. This type is only found in the Zonag Co section. The shale is interlayered with marl and mudstone. The individual layers are 10–15 cm thick. (7) Yellow sandstone and grey gravel, which occur at the

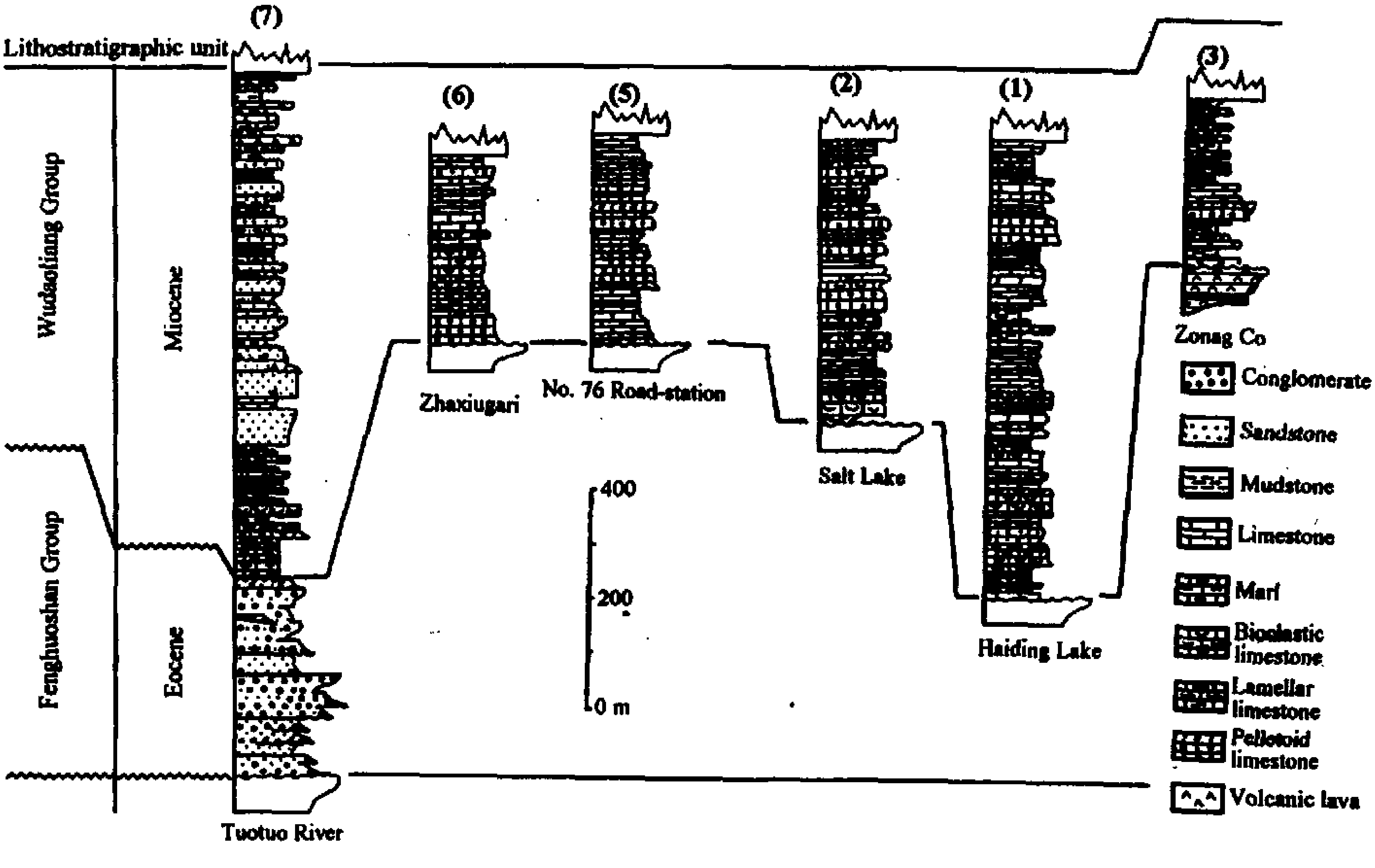

Fig. 3. Schematic stratigraphic columns of the Wudaoliang Group in the Hoh Xil region. (Location of the section is shown in Fig. 1.)

bottom of the Wudaoliang Group and sometimes contain clasts of plant fossils.

Based on the wide distribution of the Wudaoliang Group and analyses of its lithofacies and association, we think that it is deposited in a typical lacustrine environment. Similar deposits can be found in both modern and ancient lakes. Fossils of the Wudaoliang Group, including ostracods, gasteropods and Chareae, are species commonly living in terrestrial lakes filled with fresh or brackish water. Oil shale and carbonaceous shale are deposited in an anoxic environment above the lake floor. The appearance of lump limestone, pelletoid limestone, oncolite limestone and dolomitization implies saline or hypersaline water. The upper gypsum intervals indicate a dry and hot climate, which is comparable to the environment of present lakes in the northern Tibet Plateau.

According to the distribution and lithofacies of the Wudaoliang Group, we propose that it is deposited on a palaeo-planation surface. Its distribution can be traced over a large scale and strides over different geographic and topographic units, rather than only being limited to the Palaeogene basin region. Marl is inferred to have been deposited in large-and-shallow basins of flat topographic surface, which is produced by denudation and planation. Although the Wudaoliang Group and Suonahu Formation are located at presently different levels, we deduce there was once a uniform lake or a series of linked lakes on the whole northern Tibet Plateau.

It is clear that the Miocene marl is the remnant deposit over the palaeo-planation and may have covered the whole Northern Tibet planation. At the bottom of the Wudaoliang Group, there is an obvious depositional interruption. The approximately horizontal beds of the Wudaoliang Group unconformably overlap the Triassic Jieza Group, Bayan Har Group and Fenghuoshan Group. In the Gongmaorima area, weathering crust, palaeosol and gravel beds can be found at the bottom of the group (Fig. 4). In fact, gravel beds 1–3 m thick can be found over an extensive area from the Fenghuoshan to the Wudaoliang area. Our study reveals that the gravel comes mainly from the Triassic Bayan Har Group. The measured palaeo-currents confirm a flow in the southward direction. The grey gravel beds are interpreted as a fluvial or alluvium fan deposition. The palaeosol under the gravel beds is an important marker of the existence of erosion and planation. The associated brown-red clay layer, grey-white clay layer, and grey-green clay layer together make up a complete sequence of the weathering crust. Lensoid coarse sandstone-bearing gravel beds have a lateral extention of 10–20 m under the weathering crust. Other low mountains, such as Rierlama Mountain, which traverses the Wudaoliang Group and isolatedly stands out of the basin surface, probably represents the residual hills on the above peneplain surface.

4 Discussion

4.1 Origin of the topographic surface

Based on the geological mapping in combination with interpretation of topographic maps and remote sensing

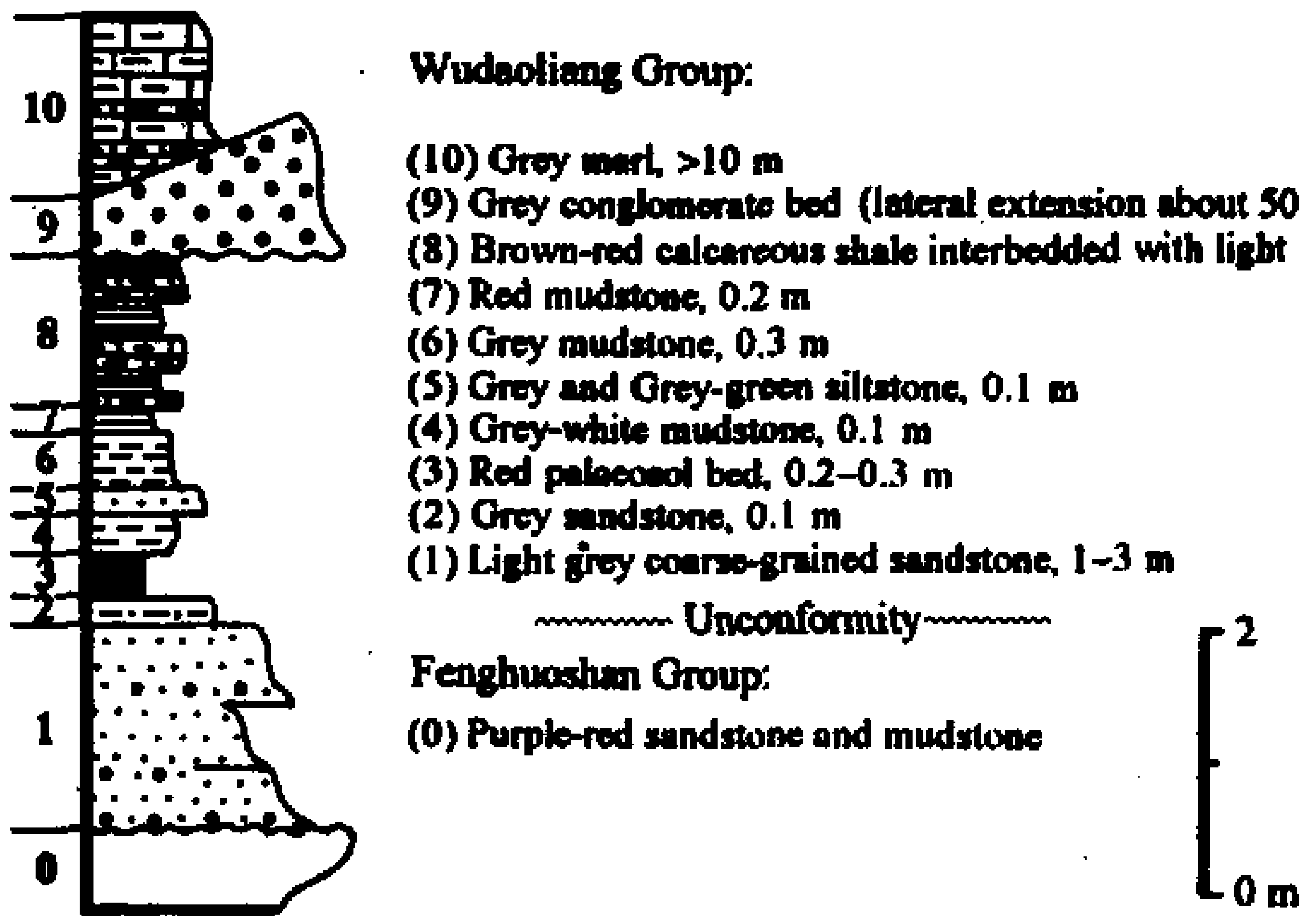

Fig. 4. The vertical section (Site 4 in Fig.1) showing the unconformable contact, palaeosol bed and weathering crust on the bottom of the Wudaoliang Group at the east fringe of the Gongmaorima Mountain, Hoh Xil.

images, there are two relationships between the mountaintop surface and the basin surface: (1) The two are separated by a steep slope (30–40°); (2) there is a transition between them with a very low slope (<10°). These two may occur individually or side by side in the same cordillera of the Hoh Xil area. The Fenghuoshan Mountain with a smooth ridge represents a uniform mountaintop planation, where the Eocene red beds have been peneplaned. At its south edge with an ascent of 30–40°, the mountaintop surface is separated from the basin surface by a linear fault, where the Fenghuoshan Group has been thrust southwards over the Wudaoliang Group. At the northern edge, the mountaintop surface lowers gradually to the basin surface. The linear low Gongmaorima Mountain made of monoclinic Fenghuoshan Group beds is a typical example of an asymmetrical mountain form. Its altitude ranges from 4961 m to 4665 m, 60–350 m higher than the basin surface. Its northern margin with an angle of 40–50° is separated from the basin surface by a fault. Its southern slope shows contrasted changes from 35° to 10° in an only 500 m distance. There are many hills with even summits in the Wudaoliang area, e.g., Bairizhajia Mountain with 4800–5100 m high summits composed mainly of the Triassic Bayan Har Group. Both sides of the mountain are gentle, with the dip angle being only 5–15°. The mountaintop surface gradually passed into the basin surface without a break.

Based on the above facts, we consider that there are no obvious boundaries between the mountaintop surface and the basin surface. It is the differential movement of fault blocks that has resulted in the two grades of topographic surface in Hoh Xil. The altitude of the Wudaoliang Group deposited in the inter-mountain and piedmont basins is changed progressively to the plateau surface. That is to say, the so-called Pliocene planation surface does not exist. We agree with Shackleton and Chang that the basin's landform resulted from the breakup and deformation of the palaeo-planation surface. Some present basin surfaces still remain the primary state of the palaeo-peneplain or pediplane, while the geomorphic patterns of palaeo-planation have been completely or partly disrupted by thrusts.

In fact, reliable Pliocene strata are limited to a minor area. Typical *Hipparion*-bearing Pliocene red clay beds are found only in southern Tibet and the Gangdise area. In northern Tibet, Pliocene deposits only occur in fault-controlled basins and valleys, such as the Kunlun Pass basin. There are scarce Miocene or Palaeogene strata underlying these deposits. So most of the Pliocene basins are recently formed. These Pliocene sediments filled in the lowland make the plateau landform more gentle. Consequently, the basin's topographical surface is not a unified planation surface.

4.2 Constraints on uplifting and shortening processes

In the Hoh Xil and Qiangtang areas, strata of the Miocene Wudaoliang Group and Suonahu Formation usually maintain a horizontal landform and occasionally occur as a wide platform. Their respective tops are concordant with the present basin surfaces. However, a series of isolated Wudaoliang Group platforms are found, which are 5–150 m higher than the present lake level (4500–4600 m). The altitude of platforms with smooth summits varies from place to place. Its top reaches 5300 m in the north front of Fenghuoshan Mountain, lowering northwards to 4700–4800 m in Gongmaorima and Wudaoliang, and even reaches the same level as the basin surface in the northernmost Zonag Co and Haidinghu regions.

The platforms are scattered on the present basin surface. Their landform pattern can be parallel or diagonal. They usually have an apparent origin of block-mountains, marked by a steep fault-cliff with straight mountain edges and asymmetric slopes. Among the microgeomorphologic units, the Miocene strata dip more steeply, locally at 30–40° and even 60°. The Wudaoliang Group in Chaxiangjiede still remains at the top of the mountain at 5252 m to 5336 m. It is the highest horizon where the group is distributed in this area, which is almost equal to the mountaintop surface. If we regard the group as a marker corresponding to the palaeo-planation, the relative height difference of the plateau uplift is 600 m compared to the present lake level.

It must be pointed out that the deformation that took place after the planation is minor. According to our unpublished strain measurement data, the compression percentage of the Fenghuoshan Group is 30%–40%, averaging 37%. But the calculation made on a balanced profile yields a compression percentage of only 9% for the Wudaoliang Group. If the crustal thickening and shortening are caused by stratigraphic deformation, the extensive deformation process should have been terminated at least before 20 Ma. Therefore, the age 20 Ma is a key time boundary in the evolution of the northern Tibet Plateau.

5 Conclusions

(1) In the northern Tibet Plateau, there are obviously two grades of topographic surfaces, i.e. the mountaintop surface and the basin surface, the average altitudes of which are 5000 m and 4600 m, respectively. The palaeo-planation surface represented by a flat and even summit level has strongly truncated the Eocene-Oligocene Fenghuoshan Group. It is a part of the palaeo-planation surface distributed throughout the Qinghai-Tibet Plateau.

(2) The widely distributed Wudaoliang Group and Suonahu Formation are deposits corresponding to the palaeo-planation. They bear similar lithofacies, lithology and filling sequences. At their base, there are unconformity surfaces, palaeosol and conglomerate beds. Based on fossils and isotope dating, the depositional age of the Wudaoliang Group is bracketed between 20–5 Ma.

(3) Based on relationships between the basin surface and the mountaintop surface, we suggest that there did not exist a Pliocene planation Stage. It is the differential movements of fault blocks that have resulted in the present low basin surface. The amplitude of the plateau uplift is 600 m compared to the present lake level.

Acknowledgements

This work was under the auspices of the National Key Project for Basic Researches on the Tibet Plateau (G1998040800). We would like to thank Liu Dengzhong, Huang Jijun, Zhu Lidong, Lin Jinhui, Wan Yongwen, Li Xianghui and Hu Xiumian for their assistance during the field work in 1997–1998. Prof. Li Yongzhao offered valuable comments when reviewing the manuscript, and Prof. Li Tingdong and Pan Guitang also gave their constructive comments on the paper. Thanks are due to them all.

Chinese manuscript received June 1999
accepted March 2000
handled by Hao Ziguo
English manuscript edited by Zhu Xiling

References

Cui Zhijiu, Gao Quanzhou, Liu Gennian, Pan Baotian and Chen Huailu, 1996. Planation surface, palaeokarst and the uplift of Qinghai-Tibetan plateau. *Science in China* (Series D, Earth Sciences) 26(4): 378–385 (in Chinese).

Cui Zhijiu, Li Deweng, Wu Yongqiu and Li Gengnian, 1998. On planation surface. *Chinese Science Bulletin*, 43(17): 1794–1804 (in Chinese with English abstract).

Ge Daokai, Cui Zhijiu, Wu Yongqiu, Liu Genghian, Wang Xiaohui and Yan Jingfu, 1994. Study on depositional and tectonic evolution of the Pass basin of Kunlun Mountains, Northern Qinghai-Xizang Plateau. In: China Society of the Qinghai-Tibetan Plateau Research (ed.), *Formation, Evolution, Environmental Change and Ecological System of Qinghai-Tibetan Plateau*. Beijing: Science Press, 126–135 (in Chinese with English abstract).

Gou Jin and Dun Guozhong, 1988. The review on age of the Fenghuoshan Group in Tanggula region. *Northwest Geology*, 45: 1–6 (in Chinese).

Gou Jin, 1991. The establishment of Miocene Wudaoliang Group and its ore prospecting significance. *Northwest Geology*, 12(53): 1–6 (in Chinese).

Guo Gengcheng 1991. Tertiary of Hoh Xil and Tanggula area. *Journal of Qinghai Geological Science*. 33: 6–11 (in Chinese with English abstract).

Li Jijun, Wen Shixuan, Zhang Qiangsong, Wang Fubao, Zheng Benxing and Li Bingyuan, 1979. A discussion on the period, amplitude and type of the Qianghai-Xizang Plateau. *Science in China*, (6): 608–616 (in Chinese with English abstract).

Li Tingdong, Gao Rui and Wu Gongjian, 1999. Lithospheric evolution and geodynamic process of the Qinghai-Tibet Plateau: An inspiration from the Yadong-Golmud-Ejin geoscience transect. *Acta Geologica Sinica* (*Eng. ed.*), 73(2): 173–180.

Ma Zongjin, Zhang Jiasheng and Wang Yipeng, 1998. The 3-d deformational movement episodes and neotectonic domains in the Qinghai-Tibet Plateau. *Acta Geologica Sinica*, 72(3): 211–227 (in Chinese with English abstract).

Shackleton R. M. and Chang C.F., 1990. Cenozoic uplift and deformation of the Tibet Plateau: the geomorphological evidence. In: Chang, C.F. (ed.), *The Geological Evolution of the Tibet Plateau*. Beijing: Science Press, 372–383 (in Chinese).

Xu Zhiqin, Jiang Mei and Yang Jingsui, 1997. Deep tectonophysical process of the uplift of the Northern Qinghai-Tibet Plateau. *Acta Geologica Sinica* (*Eng. ed.*), 71(1): 1–14.

Yang Yichou, Li Beingyuan, Yin Zheshang and Zhang Qingshang (eds.), 1983. *Geomorphology of Tibet*. Beijing: Science Press, 200–224 (in Chinese with English abstract).

Ying Jixiang, Xu Juntao, Liu Chengjie and Li Huan, 1990. The Tibetan Plateau: Regional stratigraphic context and previous work. In: Chang, C.F. (ed.), *Geological Evolution of Qinghai-Tibetan Plateau*. Beijing: Science Press, 39–41 (in Chinese).

Zhang Qingsong, Li Bingyuan, Yang Yichou and Yin Zesheng, 1980. Planation surfaces of the Qinghai-Xizang Plateau. In: Institute of Geography, Chinese Academy of Sciences (ed.), *Proceedings of Symposium on Qinghai-Xizang (Tibet) Plateau*. Beijing: Science Press, 259–260 (in Chinese with English abstract).

Zhang Yifu and Zheng Jiankang (eds.), 1994. Geological overview in Hoh Xil of Qinghai and adjacent areas. Beijing: Seismological Press, 40–44 (in Chinese with English abstract).

About the first author

Yi Haisheng Born in 1959; graduated from Chengdu University of Technology. He is now a professor of his alma mater, mainly engaged in teaching and research on sedimentology. Tel: 028-4079491; E-mail: yhs@cdit.edu.cn.