

Tectonic geomorphological characteristics for evolution of the Manas Lake

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Abstract: Owing to global climatic changes and human activities, the lakes have changed dramatically in the Junggar Basin of Xinjiang in recent 50 years. Based on the remote sensing images from Beijing Satellite No.1 in 2006 together with the measured topographical data in 1999 and other data since the 1950s, this paper analyzes mainly the features of landforms around the Manas Lake and the changes of feeding sources of the lake. The results are as follows: (1) Tectonic movement brought about the fundamental geomorphological basis for lacustrine evolution, and the Manas Lake is one of small lakes broken up from the Old Manas Lake due to tectonic movement and drought climate; the Manas Lake had existed before the Manas River flowed into it in 1915. The geomorphologic evidences for evolution of the Manas Lake include: (a) Diluvial fans and old channels at the north of the lake indicate that the rivers originating from the north mountains of the Junggar Basin had fed the Old Manas Lake and now still feed the lake as seasonal rivers; (b) The Old Manas Lake was fed by many rivers originating from the mountains, except for the Manas River, from the evidence of small lakes around the Manas Lake, old channels, alluvial fans, etc.; (c) The elevations of the alluvial and diluvial fans are near to the 280 m a.s.l. and all of the small lakes and lacustrine plains are within the range of the 280 m a.s.l., which may prove that the elevation of the Old Manas Lake was about 280 m a.s.l.; (d) Core analysis of the Manas Lake area also indicates that the Manas Lake has existed since Late Pleistocene epoch. (2) Analysis on the feeding relations between the lakes and the lacustrine evolution shows that human activities are one of main driving forces of the lacustrine evolution in recent 50 years, and it is the precondition of restoring and maintaining the lacustrine wetlands in the study area to satisfy the feeding of the Baiyang and Manas rivers to the Manas Lake.

Keywords: the Manas Lake; the Junggar Basin; wandering lake; lacustrine evolution; lake inflow; Xinjiang

1 Introduction

In recent half a century, most of lakes in arid zone are shrinking or already dried up because impoundment water, industrial and agricultural water use and unreasonable land development at the upper and middle reaches of the feeding rivers in western China. For example, the Lop Nur, the Manas Lake and the West Juyan dried up in 1960s (Yang, 2004; Qiao *et al.*, 2007; Yao, 2007), and the Ebi Nur and the Bosten Lake had shrunken between 1950s and 1980s (Shi *et al.*, 2003). The loss or shrinking of these lakes in the arid zone has resulted in the devastating destroy on local ecology and environment, at the same time, the dry sand lakebeds become the sources of the sand- and dust-storm (Yang, 1998; Yue *et al.*, 2004). In recent 20

years, the global warming and man-made regulation make some shrinking or dry lakes recover, such as the Manas Lake (Yao, 2007), the Taitema Lake (Shi *et al.*, 2003) and the West Juyan (Qiao *et al.*, 2007). As the importance wetlands in arid zone, the evolutions of these lakes have become research hotspots, and more and more researches focused on the changes of the lakes (Mu *et al.*, 2001; Wu *et al.*, 2001; Liu *et al.*, 2004; Shao *et al.*, 2009), of which, the Manas Lake, an important tectonic subsidence in the Junggar Basin at the north of Tianshan Mountains (Mts.), undoubtedly becomes a research focus.

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The Manas Lake (formerly named as the Yihehake lake) is an inland lake fed by surface runoff sourcing from the north of the Tianshan Mts. (Mu *et al.*, 2001), it is located at 45°40′–45°57′N and 85°40′–86°15′E. Several small lakes such as the Large Alike Lake, the Small Alike Lake and the Alan Nur lake are distributed at the northwest side of the Manas Lake (Fig. 1). With a temperate continental climate, the mean annual temperature around the Manas Lake is about 8.8°C, and the mean annual precipitation is about 63.7 mm, and the mean annual evaporation is about 3,110.5 mm. In recent 50 years, with the rapid expansion of oases in the north Tianshan Mts., the water resources originating from the north of Tianshan Mts. have been over-exploited; the lakes in the Junggar Basin began to lose their water supplies. Therefore, the Manas Lake has endured the evolution process of shrinking–dried up–recovery–intermittent lake in recent half a century (Yao *et al.*, 2007). Many researches have focused on the evolution process of the Manas Lake and gradually get to a common view about it (Cheng *et al.*, 2001; Mu *et al.*, 2001; Yao *et al.*, 2007; Shi *et al.*, 2008), while there is a dispute that whether it is a wandering lake (Cheng *et al.*, 2001; Yao *et al.*, 2007; Shi *et al.*, 2008). Therefore, by studying the geomorphological characteristics and the changes of feeding sources of the lakes, this paper mainly discusses the nature of lacustrine evolution of the Manas Lake.

2 Methods

Based on the remote sensing images from Beijing Satellite No.1 in 2006 together with the measured topographical data in 1999 and other data since the 1950s, this paper maps the regional topography map and analyzes the main features of landforms around the Manas Lake by GIS software. Using the measured topographical data in 1999 in fieldwork, the study area's DEM is generated by ArcGIS. According to the DEM, topographic profiles from the Alike Lake to the Alan Nur lake/the Manas Lake and the Alan Nur lake to the Manas Lake are graphed respectively. Together with the topography maps, this paper analyzes the changes of feeding sources of the lake and discusses the nature of lacustrine evolution.

3 Results and discussion

3.1 Regional tectonic units

The Manas Lake is located in the Manas Lake–central depression belt of the Junggar Basin, a major tectonic subsidence center of the Basin; while the Large and Small Alike Lakes and the Alan Nur lake are located in the west-northern thrust belt of the Junggar Basin. The west-northern thrust belt is the regions full of oil and gas, for example, the famous Karamay oilfield. The wells of the oilfields can be recognized clearly from Beijing satellite No.1 images. There is the Zayer-Harat mountain uplift belt at the west of the thrust belt, and the Daerbute fault belt is located in this region. The Three-Springs uplift belt is located at the east of the Manas Lake-central depression belt and the Central uplift belt is located at the south of the depression belt. These two uplift belts with strong wind erosion are covered by tall ridge-like sand dunes. There is the Changji depression belt at the south of the Central uplift belt, where is the major oasis distribution region of the north flank of Tianshan Mts. because many large-scale alluvial fans and plains formed by the rivers originating from the north of Tianshan Mts. are developed there. There is the north flank depression belt of Tianshan Mts. at the south of the Changji depression belt, and large alluvial fans of rivers were formed here.

Faults in this region extend mainly along the northeast-southwest direction and the northwest-southeast direction. The faults along northeast-southwest direction are the Daerbute fault belt, the Karamay–Urho fault belt and the Kewu fault, which controls the tectonic pattern of the north-west side of the region. Faults along northwest-southeast direction are mainly located in the north flank depression belt, which are called by the fault belts of the southern Junggar Basin and control the landform pattern of the southern Junggar Basin (Fig. 1).

3.2 Regional tectonic movements and the evolution of the Old Manas Lake

Zhou (1963) indicated that the Manas Lake was a part of the Old Manas Lake which was formed in the early Pleistocene and it was a very large lake in Early Quaternary. In the Middle Quaternary, three regional tectonic movements happened in Xinjiang. The Ulungur

River and the Ertix River formed their own water systems and did not feed the Old Manas Lake again due to the uplift of faults; the Maqiao River at the south of the Old Manas Lake left it because of the development of the north flank depression belt. Owing to the decrease of feeding water and dry climate, the lake level of the Old Manas Lake dropped quickly and in Late Quaternary it broken up several small lakes including the Alan Nur lake, the Alike Lake and the Yihehake lake (now named as the Manas Lake) (Zhou, 1963; Xinjiang Integrated Survey Group of CAS, 1978, 1994; Guo and Tang, 1996; Mu *et al.*, 2001; Yang and Shi, 2003). According to the atlas of 1906–1910, the Alan Nur lake was a very large lake and fed by the Manas River (Zhou and Sun, 1906; Material Department, Survey Institute of North Manzhou Railway Affair Bureau, 1909; Shanghai Comercial Press, 1910). The

new tectonic movement, particularly the west plate of the Kewu fault uplifting, made the Alan Nur lake ascending and the south part of the Manas River's estuary descending; at the same time, the feeding water carried a lot of sediment into the Alan Nur lake, which made the lakebed and the riverbed of the river's estuary ascending gradually (Xinjiang Integrated Survey Group of CAS, 1978, 1994). At last, the Manas River was blocked and had to change its way to the north-east side in 1915 and poured into the Manas Lake (Mu *et al.*, 2001), but it still feeds the Alan Nur lake by a small branch. The water surface of the Alan Nur lake was 238 km² in 1950s, then it dropped quickly after the Manas River changing its way (Hu *et al.*, 2007), at last the Alan Nur lake dried up in the late 1960s (Xinjiang Integrated Survey Group of CAS, 1978, 1994).

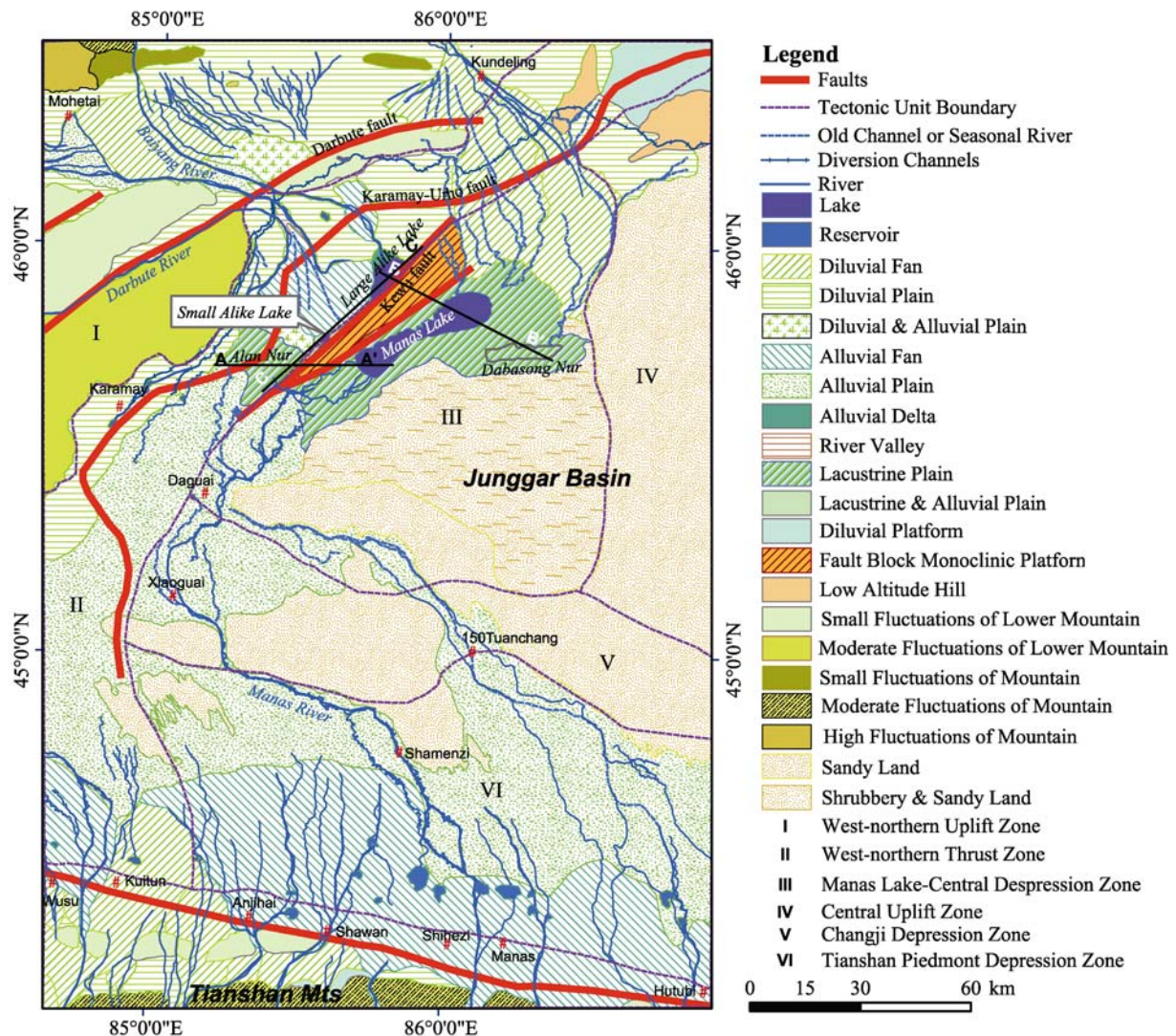


Fig. 1 Tectonic units and geomorphological map around the Manas Lake

The evolution of the Old Manas Lake shows that the Manas Lake and other small lakes have existed before 1915, at that time the Manas River changed its way and poured into the Manas Lake. The results of drilling core research in the Manas Lake (45°45'N, 86°00'E) shows that the region has been the lacustrine environment since the late Pleistocene (Thodes *et al.*, 1996). This study not only proves the existence of the Old Manas Lake, but also states that it has existed for a long time before the Manas River fed it in 1915.

3.3 The geomorphic evidences for the changes of the feeding sources of the lakes

According to the geomorphic features around the Manas Lake (Fig. 1), the old alluvial plains are located at the north of the Lake, and at present there is no perennial river flowing through it except for seasonal water flows. The old alluvial fans present that the rivers sourcing from the mountains at the north of the Junggar Basin had fed the Manas Lake before the Quaternary. There is a fault block monoclinic platform at the west of the Manas Lake, which separates the Manas

Lake from the Large and Small Alike Lakes. The east of the Manas Lake has a lacustrine plain; the Dabasong Nur Salt Lake and the Xiazijie Salt Lake are located in the plain. The south-eastern area of the lacustrine plain is distributed by tall shrub-sand dunes, and further the east is a large area of ridge-like sand dunes in nearly north-south direction. There is the modern alluvial plain of the Manas River at the south-west of the Manas Lake, and the Manas River feeds the lake from its southwest side. The north of the Large Alike Lake is the Urho alluvial plain and the alluvial fan plain of the Baiyang River, the Baiyang River feeds the Large Alike Lake from its north side and forms a small delta plain at the north of the Lake. An alluvial fan of the Daerbute River is located between the Alike Lake and the Alan Nur lake, which suggests the Daerbute River had fed the Lakes. The west of the Alan Nur lake is small fluctuations mountains with elevations of 650–850 m a.s.l. The south and the south-east of the Alan Nur lake are separately distributed the older delta plain and the modern alluvial plain of the Manas River.

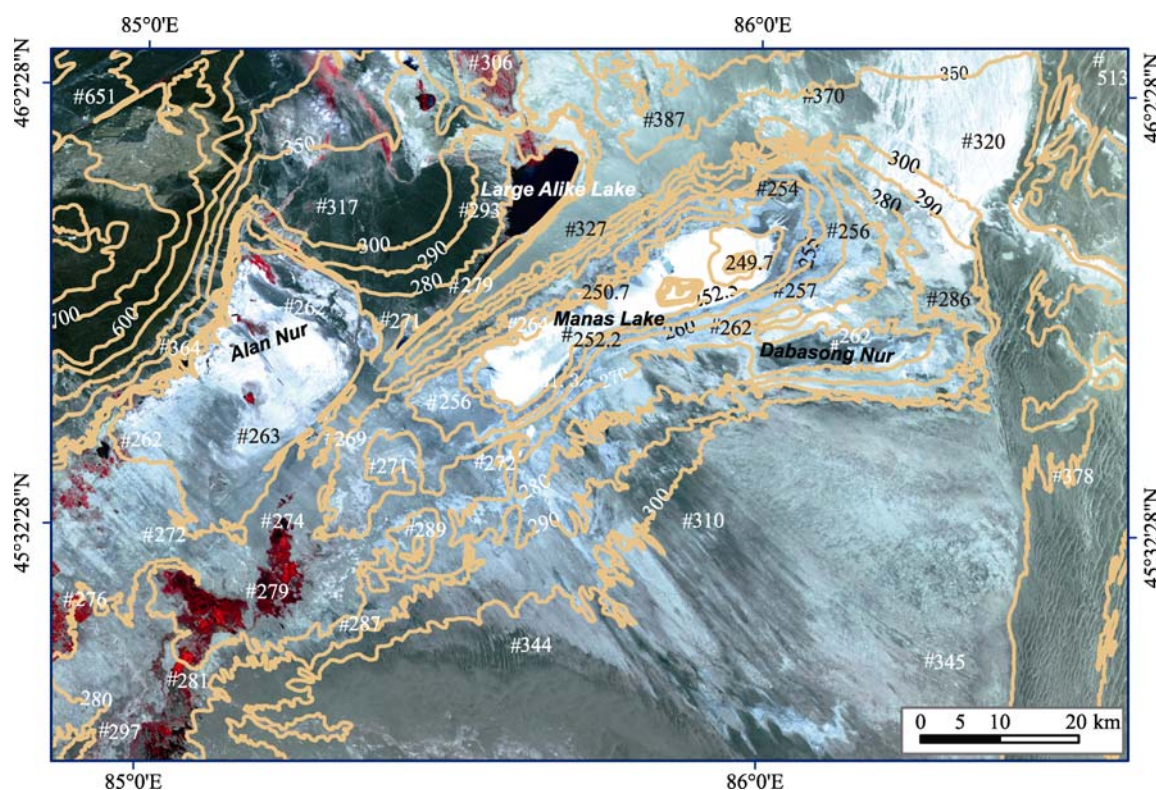


Fig. 2 Contour map and the extent of 280 m a.s.l. in the Manas Lake area (Background image is Beijing Satellite No.1 image on 22 June, 2006)

In addition, the lakes and lacustrine plains are all within the extent of 280 m a.s.l., and the fronts of the old alluvial fans around the lakes are near to 280 m a.s.l. (Fig. 2). Because the alluvial fans were formed at the estuary by the source of the rivers, it may prove that the elevation of the Old Manas Lake was about 280 m a.s.l. Moreover, the field investigation found that there were two old terraces at both the north sides of the Manas Lake and the Alike Lake (Zhou, 1963). The elevations of the two old terraces are 280 m and 270 m a.s.l. respectively, which suggests that elevation of the Old Manas Lake was about 280 m a.s.l. Therefore, the Old Manas Lake including the Manas Lake and three other lakes had existed for a long time and its elevation was about 280 m a.s.l. according to the geomorphologic evidences. Further analysis is still required to confirm the speculation.

Currently, the Alan Nur lake is a bare saline-soil plain, the elevation of its lakebed is about 261–263 m a.s.l., while the lakebed elevation and the water surface elevation of the Manas Lake are about 247 m and 253–255 m a.s.l. respectively. The Manas Lake is apparently lower than the Alan Nur lake. The elevation of the estuary of the Manas River is about 269 m a.s.l., and the Manas River mainly feeds the Manas Lake, still feeds the Alan Nur lake by a small branch at the estuary. Except for being fed by the Manas River, the Manas Lake is also fed by the seasonal rivers sourcing from the northern mountains and ground water of the fronts of the alluvial fans. The Alan Nur lake is fed by the Daerbute River and seasonal streams coming from the western mountains. The Large Alike Lake is fed by the Baiyang River and the Small Alike Lake is fed by the fracture water coming from the Large Alike Lake and the ground water of the front of the western alluvial fans.

3.4 Terrain characteristics and relationships between the lakes

Based on the topographical data (the accuracy is 1 m) in 1999, the elevation of the lakebed of the Manas Lake is about 247 m a.s.l. and the water surface elevation of the lake is about 255 m a.s.l.; the elevation of the lakebed of the Alan Nur lake is about 261–263 m a.s.l.; the water surface elevation of the Large Alike Lake is about 273–276 m a.s.l., and that of the Small Alike Lake is about 270 m a.s.l. In order to investigate

the relationships between the lakes, three topographic profiles along AA', BB' and CC' are graphed as Figs. 3, 4 and 5.

Although the Manas Lake is lower 9–10 m than the Alan Nur lake, due to the barriers of the fault block monoclinic platform and the modern alluvial plain of the Manas River, the two lakes can not feed each other except that the lake water level is higher than 269 m a.s.l. (Fig. 3). This implies that when the lake water of the two lakes is higher than the elevation of the estuary of the Manas River, they can adjust the water volume each other. There are the mountains at the north and west sides of the Large Alike Lake, and the fault block monoclinic platform with elevation of about 327 m a.s.l. barriers between the Large Alike Lake and the Manas Lake. Thus the Large Alike Lake can not feed the Manas Lake (Fig. 4). The Large and the Small Alike Lakes and the Alan Nur lake are located at the west of the fault block monoclinic platform formed by the Kewu fault and their topographies descend in turn. Due to the Kewu fault, the lake water of the Large Alike Lake can seasonally feed the Small Alike Lake from the fracture valley of the fault; therefore, water from the Large and the Small Alike Lakes can seasonally feed the Alan Nur lake (Fig. 5).

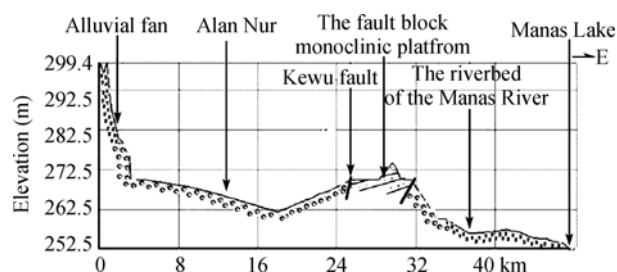


Fig. 3 Topographic profile from the Alan Nur lake to the Manas Lake (AA' profile)

The Large Alike Lake is an important wetland in the Karamay region. Since the irrigation of the Urho plain consumes in large amounts water of the Baiyang River, the lake once had been dried up. After the implementation of the Ertix Water Diversion Project, the pressure of water-using is to some extent alleviated in the Urho plain, the Karamay City and other oasis, and the inflow of the Large Alike Lake is stabilized. Therefore, the Alike Lake has been restored and the water area is growing. According to above analysis,

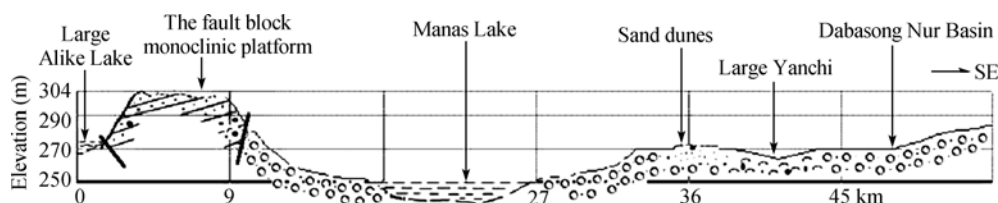


Fig. 4 Topographic profile from the Large Alike Lake to the Dabasong Nur (BB' profile)

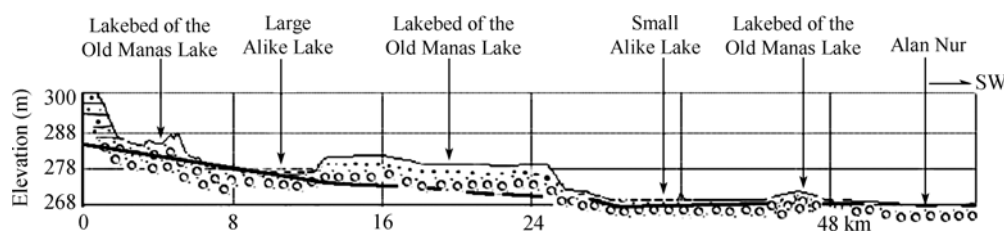


Fig. 5 Topographic profile from the Large Alike Lake to the Alan Nur lake (CC' profile)

the key of restoring and maintaining the wetland of the four lakes around the Manas Lake is to ensure that the Baiyang River and the Manas River have enough water to feed into the lakes.

3.5 Influence of human activities on the evolution of the Manas Lake

The Manas Lake was a large lake in 1950s. However, a large-scale cultivation of artificial oases began in Xinjiang after 1950. The Manas River Irrigation District, located in the upper and middle reaches of the river, was cultivated completely in 1962 and its designed irrigation water volume was $13.6 \times 10^8 \text{ m}^3$ (Xinjiang Local Records Compilation Committee, 1998), almost all water of the Manas River was drained and few of water could reaches the Manas Lake (Xinjiang Integrated Survey Group of CAS, 1994). The lake which is known as the lung of the Junggar Basin completely lost the water supplies function. It dried up in the late 1960s according to data of the topographic maps of 1:50,000 scale in 1970, however, the Large and Small Alike Lakes had wide water surface and connected each other by the marsh. Recent researches concluded the evolution processes of the Manas Lake and surrounding lakes in recent 50 years as two stages: the first stage was from the late 1950s to 1999 (for the Manas Lake, the Alan Nur lake) or 2001 (for the Large and Small Alike Lakes), which was the stage of lake shrinking or drying up; the second stage was from 1999 (or 2001) to now, which was the stage of lake

recovering or with intermittent water (Yao *et al.*, 2007).

4 Conclusion

In summary, the tectonic movements brought about the fundamental geomorphological basis for the lacustrine evolution, and the Manas Lake is one of small lakes broken up from the Old Manas Lake due to tectonic movement and dry climate; the Manas Lake had existed before the Manas River flowed into it in 1915. The geomorphologic evidences for the evolution of the Manas Lake include: (a) The rivers originating from the mountains north of the Junggar Basin had fed the Old Manas Lake and now still feed the lake as seasonal rivers; (b) The Old Manas Lake was fed by many rivers originating from the mountains except for the Manas River; (c) The elevations of the alluvial and diluvial fans are near to the 280 m a.s.l and all of the small lakes and lacustrine plains' elevations are within the range; (d) Core analysis result of the Manas Lake area indicates that the Manas Lake has existed since Late Pleistocene epoch. Moreover, the analysis on the feeding relations between the lakes and the lacustrine evolution indicates that human activities are one of main driving forces of the lacustrine evolution in recent 50 years. The precondition of restoring and maintaining the lacustrine wetlands in the study area is to satisfy the feeding of the Baiyang and Manas rivers and the inflow of the Manas Lake. Many methods,

such as tectonic, stratigraphic, palaeo-environmental reconstruction and geomorphologic comprehensive analyses should be used in future study on evolution processes.

References

- Cheng W M, Zhou C H, Tang Q C, *et al.* Landscape evolution of Manas Lake and its ecological environment effects, Xinjiang. *Quaternary Sciences*, 2001, 21 (6): 560–565.
- Guo J H, Tang Q C. *Xinjiang Hydrological Geography*. Beijing: Science Press, 1966. 28–81.
- Liu C Y, Huang C. Xinjiang geological traveling resources and environment protection. *Xinjiang Geology*, 2004, 22(4): 455–456.
- Material Department, Survey Institute of North Manzhou Railway Affair Bureau. *Xinjiang Chorographic Map*. Dongfang Academy, 1909. 1–2.
- Mu G J, Bao A M, Hao J. Geotectonic environment of the tail-end-lakes evolution, Xinjiang, China. *Arid Land Geography*, 2001, 24(3): 193–200.
- Qiao X X, Jiang X H, Chen J N, *et al.* Effect of transferring water on ecological environment in East and West Juyanhai Lake at the lower reaches of Heihe River. *Journal of Northwest A&F University (Natural Science Edition)*, 2007. 35(6): 190–194.
- Rhodes T E, Gasse F, Lin R F, *et al.* A late pleistocene-holocene lacustrine record from lake Manas, Zunggar (Northern Xinjiang, Western China). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 1996. 120: 105–121.
- Shanghai Commercial Press. *National Map of Qing Dynasty*. Shanghai: Shanghai Commercial Press, 1910. 35–36.
- Shao M C, Shao N, Shen Q, *et al.* Dynamic change and analysis of the lakes and in Bayingolin Mongolian Autonomous Prefecture, Xinjiang. *Arid Zone Research*, 2009, 26(3): 318–325.
- Shi X M, Li Y L, Yang J C. Climatic and tectonic analysis of Manas Lake changes. *Scientia Geographica Sinica*, 2008, 28(2): 266–271.
- Shi Y F, Shen Y P, Li D L, *et al.* Discussion on the present climate change from warm-dry to warm-wet in Northwest China. *Quaternary Sciences*, 2003. 23(2): 152–164.
- Wu S F, He W Q, Hu R J, *et al.* Analysis on the changing causes of the lakes in the basins and the plains in Xinjiang since recent years. *Arid Land Geography*, 2001, 24(2): 123–129.
- Xinjiang Integrated Survey Group of Chinese Academy of Sciences. *Xinjiang Integrated Survey Reports*. Beijing: Science Press, 1957. 28–63.
- Xinjiang Integrated Survey Group of Chinese Academy of Sciences. *Xinjiang Geomorphology*. Beijing: Science Press, 1978. 217–219.
- Xinjiang Integrated Survey Group of Chinese Academy of Sciences. *Xinjiang Quaternary Geology and Environment*. Beijing: China Agricultural Press, 1994. 239–256.
- Xinjiang Local Records Compilation Committee. *Annals of Xinjiang (Water Resources)*. Urumqi: Xinjiang People Press, 1998. 225–228.
- Yang B, Shi Y F. Warm-humid climate in Northwest China during the period of 40–30 ka B. P.: geological records and origin. *Quaternary Sciences*, 2003, 23(1): 60–68.
- Yang Q. The Lop Nor is not a wandering lake: views from the evolution of the Lop Nur. *Journal of Lake Sciences*, 2004. 16(1): 1–9.
- Yang X P. Desertification and land use in the arid area of central Asia. *Quaternary Sciences*, 1998, 2: 119–127.
- Yao Y H, Wang X Q, Zhou C H, *et al.* Changes of Manas Lake in the past 50 years in Xinjiang. *Advances in Water Science*, 2007, 18(1): 17–23.
- Yue L P, Yang L R, Li Z P, *et al.* Grain-size distribution of the sediments of dry lake-bed in the Northwest of China and sand-dust weather in East Asia. *Acta Sedimentologica Sinica*, 2004, 22(2): 325–331.
- Zhou S T, Sun H H. *Maps of the World in Twenty Century*. Shanghai: New Study Academy, 1906. 17.
- Zhou Y Y. Relationship between Quaternary terrestrial deposit types and the development of geomorphology and climates in Xinjiang. *Acta Geographica Sinica*, 1963, 29(2): 109–125.

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