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Tectonic Uplift of the Yili Basin during the Last Stage of the Late Pleistocene: Evidence from ESR and OSL Dating of Sediments in the Huocheng Area, Xinjiang

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Abstract: The Quaternary sediments in the Yili Basin can serve as archives for studying the Cenozoic basin–mountain relationship. In this study, based on typical natural sections and boreholes, the surficial sediments of the Huocheng area were studied, and their sedimentary ages were obtained using the optically stimulated luminescence (OSL) and electron spin resonance (ESR) dating methods. These dates, combined with changes in the sedimentary facies, provided details of the neotectonic movement in the Yili Basin and adjacent areas. By dating sediments from five sections and three boreholes, we determined that the surficial sediments of the Huocheng area were mainly formed in the Late Pleistocene, with scattered instances of Holocene sediments. The surficial sediments mainly consisted of alluvial fan facies, fluvial facies, lacustrine facies, and desert facies. Based on the activity on the Hongshanzui fault and the northern margin fault of the Wusun Mountains, the Huocheng area was uplifted synchronously with the Tianshan Mountains during the last stage of the Late Pleistocene, causing the desert facies sediments to be superimposed on the former paleo–lake sediments.

Key words: Yili basin, ESR, OSL, Late Pleistocene, neotectonic movement

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1 Introduction

The Yili Basin is a multi–stage superimposed basin located between the northern and southern Tianshan Mountains belts, occupied the western portion of the Yili–Central Tianshan Mountains block (Zhang et al., 1999). It is surrounded on three sides by mountains and opens to the west, just like a trumpet. The relief is higher in the east than in the west. The Yili Basin can be further divided into two sub–basins: the Yining sub–basin in the north and the Zhaosu sub–basin in the south, with the Wusun Mountains in the middle (Fig. 1). The remote effects of the India–Eurasia collision resulted in rejuvenation of the ancient Tianshan orogenic belt and multiple episodes of tectonic uplift since the Eocene (Molnar and Tapponnier, 1975; Tapponnier et al., 1986, 2001; Windley et al., 1990; Burchfiel et al., 1999; Shu et al., 2004; Yin, 2010; Sun et al., 2016). Therefore, it is a natural laboratory to investigate the Cenozoic tectonic evolution of the Tianshan Mountains and the adjacent area.

The basement of Yili Basin is composed of Meso–Neoproterozoic metamorphic rocks. Rifting occurred in the Carboniferous and subsidence has been occurring since the Permian. The Huocheng area has accumulated a large amount of sedimentary deposits since the Quaternary. These deposits recorded important information of the neotectonic movement in the Yili Basin. Therefore, analysis of the Quaternary sediments of the Huocheng area is important for the exploration of the evolution of the Yili Basin and its surrounding mountains. It will increase our understanding of the neotectonic movement in the basin. The local climate changes and neotectonic movements in the basin were investigated by studying the loess deposits (Song et al., 2010a, 2010b; Li et al., 2013; Zeng et al., 2014; Chen et al., 2010) and the active faults (Feng, 1986, 1997; Yin et al., 1993, 2003; Luo et al., 2003; Yuan et al., 2016, 2019a, 2019b) of the Yili Basin since the Pleistocene. However, the large–scale diversity of the Quaternary sediments have not been investigated in detail. In particular, geochronological studies of the sediments are lacking. In this study, we conducted optically stimulated luminescence (OSL) and electron spin resonance (ESR) dating of the Quaternary sediments of the Huocheng area, in the Yining sub–basin.

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2 Lithostratigraphy

The study area is in the northwestern part of the Yili Basin. The Quaternary sediments in this area include gravel, sandy gravel, sand, silt, clay, loess, and aeolian sand (Fig. 2). The Tianshan Mountains experience intense uplift since the Pliocene. From the Pliocene to the Early Pleistocene, only a few strongly cemented outcrops of typical molasses deposits, which form at the foot of the mountain (Xiyu Formation), are seen in northeastern Huocheng. The Middle Pleistocene contains a set of loose gravel and pebble deposits (Wusu Group), which are

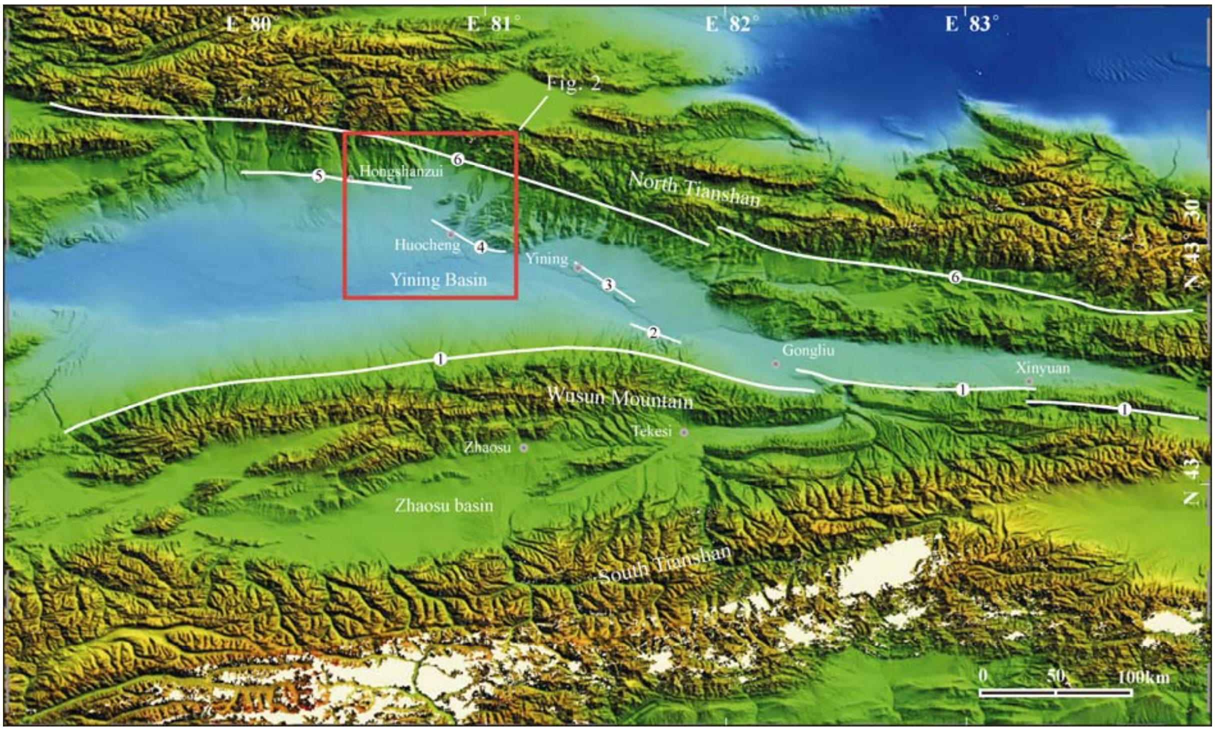

Fig. 1. Simplified tectonic geomorphology map of the Yili Basin.
① Northern Wusunshan fault; ② Yamadu fault; ③ Yining fault; ④ Huocheng fault; ⑤ Hongshanzui fault; ⑥ Kashi River fault.

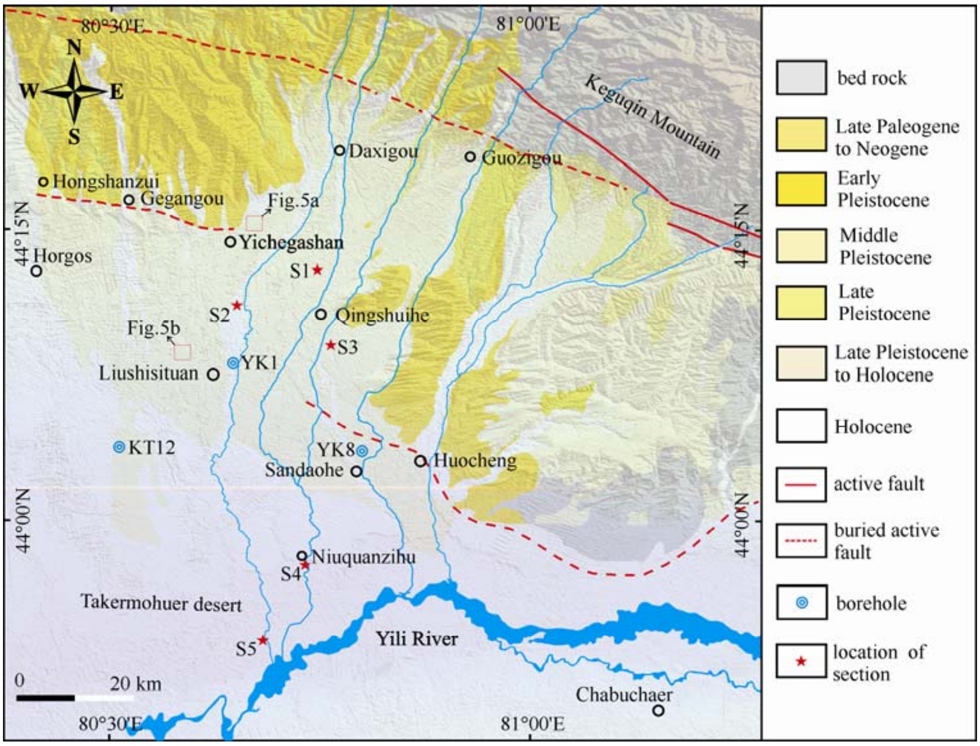

Fig. 2. Quaternary geological sketch of Huocheng area.

poorly rounded. These deposits are tongue–shaped in the eastern foothills of Daxigou and Guozigou area. The Late Pleistocene deposits consist of piedmont alluvial fan deposits (Xinjiang Group) and aeolian loess. The Xinjiang Group is mainly located in the piedmont plain, while the loess covers the hills and lowlands below Keguqin Mountain. The Holocene deposits contain modern river sediments and aeolian sands. The aeolian sands are mainly located in the Takemohuer desert.

3 Samples and Methods of Dating

In order to study the surficial sediments of the Huocheng area, a detailed field survey of the area was conducted. Five representative sections (S1–Qingshuihe section, S2–Jiaersu section, S3—Liushiwutuansanlian section, S4–Niuquanzihu section, and S5–Sandaohezi section) and three boreholes (KT12, YK1, and YK8) were thoroughly studied (Fig. 2). Qingshuihe section is an artificial pit, located in piedmont alluvial fan, about 3.2 km northern Qingshuihe. Jiaersu section and Liushiwutuansanlian section are located at low terraces of Sandaohezi river and Pakitai river, both are brickyard section. Niuquanzihu section is located at low terraces of Pakitai river's left bank, it is also a natural section along the western boundary of Takermohuer desert. Sandaohezi section is located on the first terrace of the estuary zone where Sandaohezi river joins Yili River. The sections and location photographs are shown in Figure 3. The borehole histograms shown in Figure 4. Various types of sediments in Huocheng area are included. The samples used for dating were collected based on their grain–size characteristics after a detailed analysis of the layering (Fig. 3).

Three samples for ESR dating and 11 samples for OSL dating were collected from five sections and two boreholes. One sample (S1–1) was collected from the Qingshuihe section (Fig. 3a), three samples (S2–1, S2–2, and S2–3) were collected from the Jiaersu section (Fig. 3b), two samples (S3–1 and S3–2) were collected from the Liushiwutuansanlian section (Fig. 3c), three samples (S4–1, S4–2, and S4–3) were collected from the Niuquanzihu section (Fig. 3d), three samples (S5–1, S5–2, and S5–3) were collected from the Sandaohezi section (Fig. 3e), and two samples (SL–2 and KT12–1) were collected from boreholes YK1 and KT12 (Table 1 and Table 2).

The ESR dating method is widely used to date fine particulate material such as silt, carbonate, glacier, and fault gouge (Zhang et al., 2002; Wu et al., 2003; Voinchet et al., 2007; Liu et al., 2009, 2011, 2013). To purify the target minerals (Quartz) for ESR measurement from samples by chemical pretreatment. Then 100–140μm fraction was separated by sieving. Each sample was spilt into ten aliquots. Nine of them were irradiated by a calibrated ^{60}Co γ–ray beam using exponentially increasing doses of 0, 200, 400, 800, 1400, 2000, 2800, 3600, 4600, 6000 Gy. ESR analyses was performed on a Bruker EMX1/6 spectroment set to following measurement conditions: room temperature, 0.2 mw E'center and/or 2.0 mw E'and Ge'center selected as the dating signal. The ESR analyses were conducted at the State Key Laboratory of Earthquake Dynamics (Beijing, China). The paleo–dose, annual dose, and the age of each sample are presented in Table 1.

The OSL samples were all processed and dated at the Neotectonic Chronology Laboratory of Institute of Disaster Prevention, following the simplified multiple aliquot regenerative–dose (MAR) protocol of Wang et al. (2005). These samples were first to dry–sieved to obtain 4–11μm fractions. The fractions were etched in 10% HCl and 10% H_2O_2 in order to remove carbonate phase and organic component. Then soaked in 35% HF to remove feldspar. OSL measurements were carried out on an automated Risø TL/OSL–DA–20 reader. The annual dose, equivalent dose, and the age of the samples are presented in Table 2.

Our dating results showed that the maximum age of the sediments is 65±16 ka and the minimum age is 4.5±0.5 ka. Only samples S2–3, S3–2, S4–3, and S5–3 are Holocene (Qh) sediments, remains are Late Pleistocene (Qp^3) sediments. These Holocene sediments are mainly fine calcareous clay, sand, silt, and aeolian sand. Therefore, the primary superficial sediments in the plain were mainly deposited in the Late Pleistocene (Qp^3).

Table 1 ESR dating results

Sample	Depth(m)	U(ppm)	Th(ppm)	K_2O(%)	W.c.(%)	Paleo–dose(Gy)	Annual dose(Gy/ka)	Age(ka)
KT12-1	9.5	1.63	10.6	2.22	5	214±54	3.28	65±16
SL-2	13.8	2.38	12.9	2.22	5	167±12	3.61	46±4.6
S1-1	8.7	2.48	9.8	2.18	5	94±24	3.39	28±6.9

Table 2 OSL dating results

Sample	Depth(m)	^{238}U(Bq/kg)	^{232}Th(Bq/kg)	^{40}K(Bq/kg)	W.c.(%)	Annual dose(Gy/ka)	Equivalent dose(Gy/ka)	Age(ka)
S2-1	8.1	30.6	48.9	719.5	5	3.9	59.6±2.9	15.2±0.7
S2-2	6.0	32.5	61.5	690.5	9	3.8	54.5±1.9	14.3±0.5
S2-3	3.3	33.5	51.8	688.7	5	3.8	31.4±0.9	8.2±0.2
S3-1	6.1	37.8	36.8	511.0	10	3.0	39.7±1.9	13.4±0.6
S3-2	1.7	33.6	50.8	644.7	10	3.3	31.8±2.1	9.6±0.6
S4-1	6.1	30.6	33.8	739.4	1	3.5	43.6±3.0	12.6±0.9
S4-2	5.4	26.1	39.0	676.8	1	3.6	45.0±2.7	12.5±0.7
S4-3	3.3	28.9	34.3	710.9	1	3.3	14.8±1.7	4.5±0.5
S5-1	8.8	48.9	49.9	625	5	3.4	68.2±4.2	20.3±1.2
S5-2	3.8	35.8	45.3	781.8	5	3.8	59.7±6.6	15.5±1.7
S5-3	0.5	46.8	35.7	653.8	5	3.3	27.3±2.1	8.4±0.7

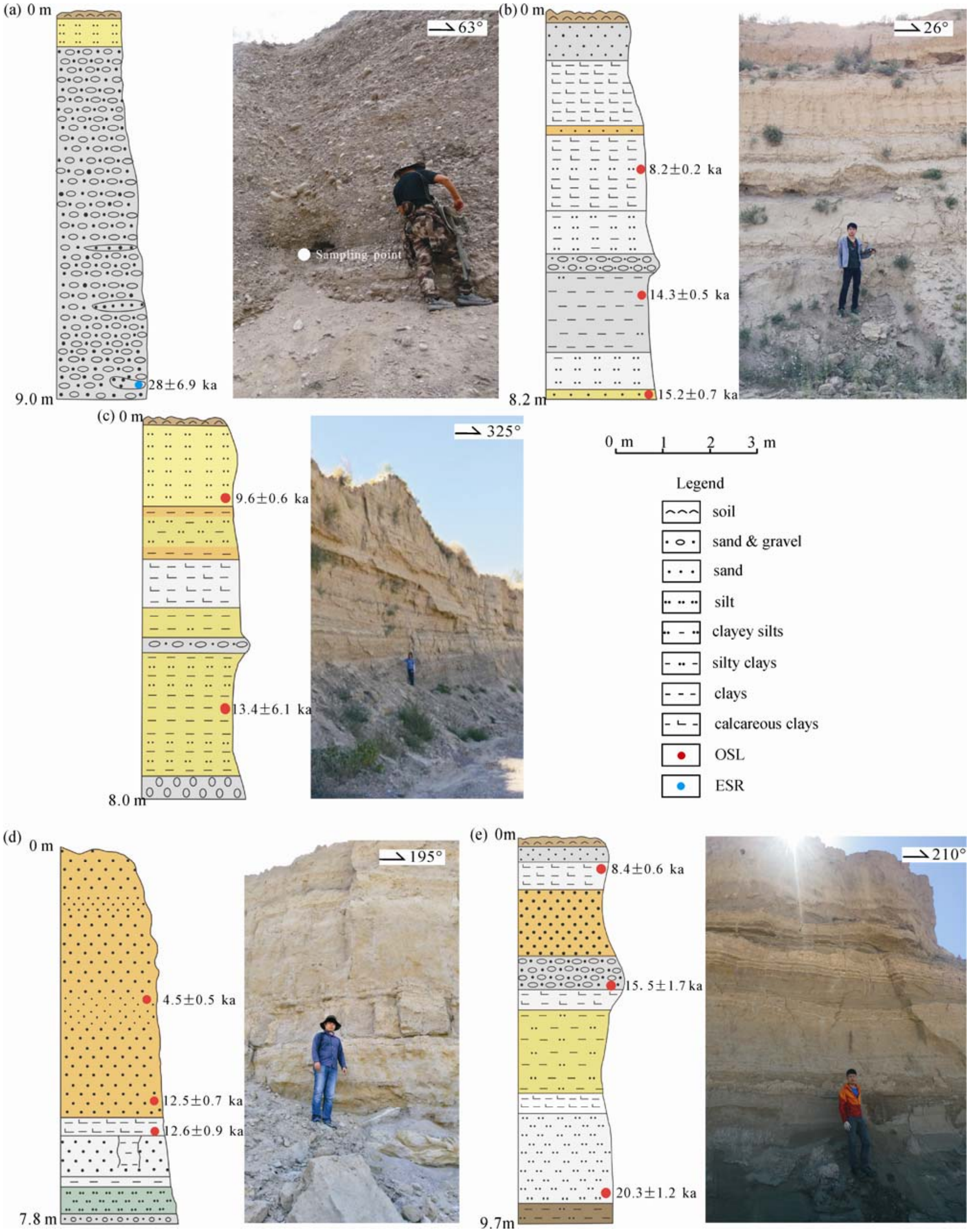

Fig. 3. The five representative sections.
(a) S1–Qingshuihe section; (b) S2–Jiaersu section;(c) S3–Liushiwutuansanlian section;(d) S4–Niuquanzihu section; (e) S5–Sandaohezi section.

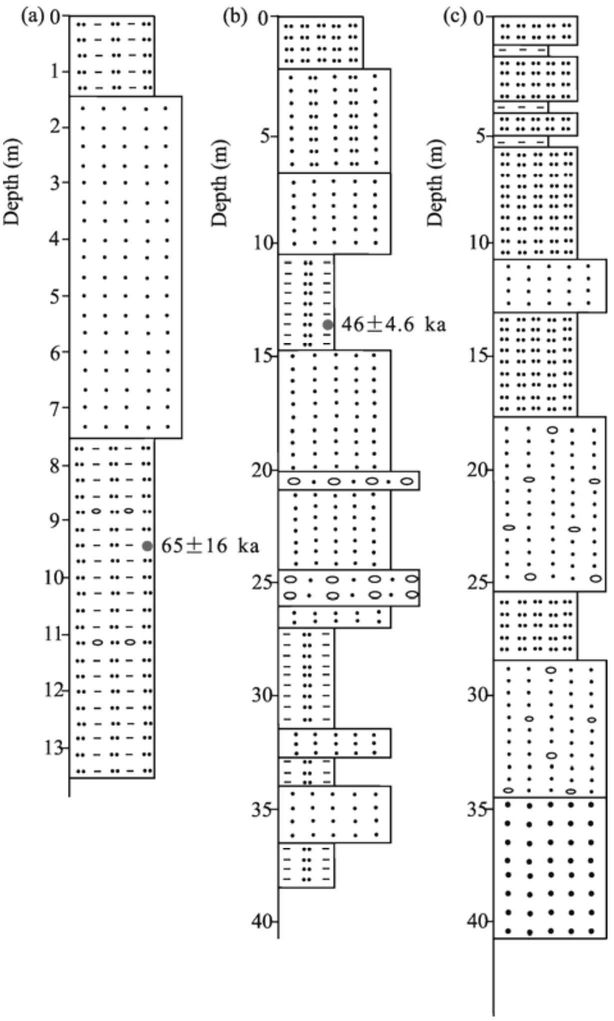

Fig. 4. Histograms of the three boreholes (legends are the same as in Fig. 3).
(a) KT12; (b) YK1; (c) YK8.

Table 3 Major lithofacies of the Huocheng area

Lithofacies	Code	Sedimentary structure	Explanation
Matrix-supported gravel	Gmm		Gravity-flow deposit
Massive gravel	Gcm	Massive	Gravity-flow deposit
Imbricate gravel	Gci	Imbricate	Channel deposit
Fine-cosrse sand,may contain gravle	Sh	Parallel bedding Rhythmic bedding	Channel deposit
Silty sand	Sr	Parallel bedding Rhythmic bedding	Channel deposit
Clay-silt	Fm	Horizontal bedding Massive	Still-water deposit
Aeolian and	Se	Aeolian cross bedding	Aeolian deposit

4 Discussion

4.1 Late Pleistocene sedimentary facies of the Huocheng area

The Huocheng area is a slightly tilted plain deposited in front of the Keguqin Mountains in the western Tianshan area. Based on the characteristics of the sediments and the sedimentary structure (Maill, 1984, 1996), the surficial strata of the Huocheng area can be divided into four sedimentary facies: the alluvial fan facies, the fluvial facies, the lacustrine facies, and the desert facies. The sediments can be grouped into four units: gravel, sand, silt, and clay. The seven major lithofacies of the Huocheng area and their genetic interpretation are shown in Table 3.

The alluvial fan in front of the mountain is wedge–shaped with an apron–like distribution. It is mainly composed of the Gmm, Gcm, Sh, Sr, and Fm units. Gmm is mainly found at the root of the fan, and outcrops in the Horgos, Gegangou, Yichegashan (Fig. 5a), Daxigou, and Guozigou areas. The gravels are mainly composed of clastic rock, volcanic rock, and granite, with a maximum diameter of ~1.5 m. Gcm is mainly found in the artificially mined pits in northern Qingshuihe. The gravels in this area become small, mostly 0.2–10 cm. The gravels exhibit a certain degree of roundness, sorting, and rhythmic bedding. The fan margin sediments, i.e., Sh, Sr, and Fm, are mainly distributed in the Jiaersu (Fig. 3b) and Liushiwutuansanlian (Fig. 3c) section. Sh mainly consists of gray–yellow medium–fine sand, some of which are present as lenses. Sr mainly consists of gray–yellow silt with parallel bedding. Fm mainly consists of gray–yellow clay and silt.

The fluvial facies are mainly distributed between Liushisituan and the Sandaohe. The sediments are mainly composed of Gci, Sh, Sr, and Fm, which are present in boreholes KT12, YK1, and YK8. Gci is mainly composed of imbricated gravel, which is present in a river retention deposit in northern Liushisituan (Fig. 5b). Sh is mainly composed of gray gravel, medium–coarse sand, and coarse gray brown sand. Sr is mainly composed of fine gray sand and fine gravel–bearing sand from a river bar deposit. Fm is mainly composed of thin clay or silt, which was deposited in a flood deposit in the flood season.

The lake sediments are mainly located under the present Takmohur desert. The sediments are mainly Gci, Sr, and Fm (Fig. 3d, 3e). Gci is mainly composed of gray gravel with sand lens, which was the result of seasonal flow enhancement. Sr is composed of gray green–yellow green silt formed in a reducing water environment; gray–white silt containing gray–white calcareous clay bands, reddish–brown iron bands, and reddish–brown rust spots. Fm is mainly composed of calcareous clay and calcareous silt (Fig. 6a). Both horizontal bedding and oblique bedding are well developed. There are thin sand beds between the clay beds, indicating the occurrence of multiple cycles. The lacustrine facies do not exhibit typical zonation. We speculate that the lake was related to the river, the lake shoreline was irregular, the lake area was small, and there may distribute several small lake basins.

The desert facies and lacustrine facies overlap vertically (Fig. 6a), indicating that a paleo–lake evolved into a desert in the last stage of the Late Pleistocene (Fig. 3d, 3e). Large –scale aeolian cross–bedding is observed in the Niuquanzihu section (Fig. 6b). From 1.4 m to 7.45 m, borehole KT12 contains grey–yellow desert sands with a

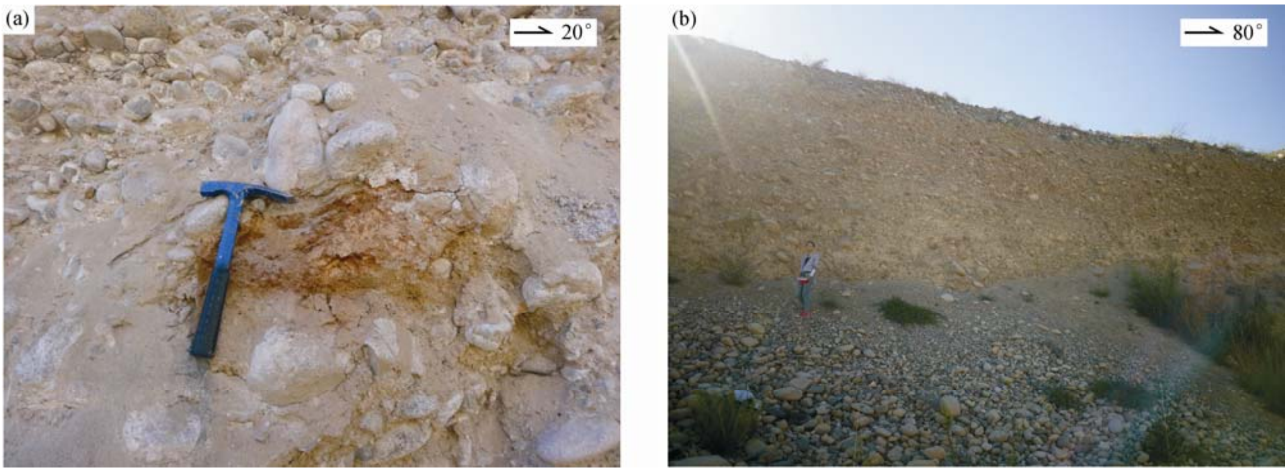

Fig. 5. Outcrop photos of the gravel lithofacies of the Huocheng area.
(a) Gmm in Yichegashan; (b) Gci in northern Liushisituan

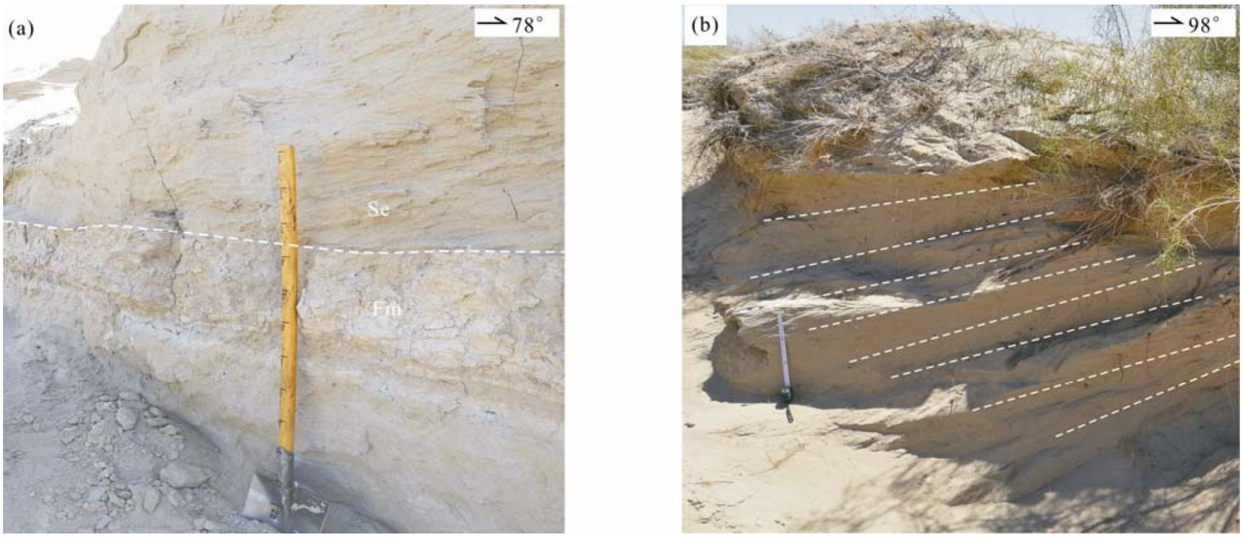

Fig. 6. Lacustrine facies overprinted by desert facies.
(a) Fm and Se in Niuquanzihu ; (b) Aeolian cross–bedding in Niuquanzihu.

uniform grain size. These sands are < 65 ka. At the end of the Late Pleistocene, the desert extended eastward to the Sandaohezi and Niuquanzihu area. There was a 15.5 ka sandy gravel layer above the sand deposits in the Sandaohezi section. The sediments in the Niuquanzihu section transitioned from calcareous clay to desert sands after 12.6 ka. The desert sands deposited quickly.

4.2 Late Pleistocene neotectonic uplift and evolution of the geomorphology of the Huocheng area

Mountain uplift and fault subsidence of the basin have occurred synchronously in western Tianshan Mountains since the Eocene (Chen et al., 2008). Uplift of the Tianshan Mountains resulted in the modern geomorphologic framework of the Yining sub-basin from the end of the Late Pliocene to the beginning of the Quaternary (Zhang et al., 1996; Deng et al., 2000; Wang et al., 2000; Yin et al., 2003; Han et al., 2004). Yili Basin is an intermountain basin in the western Tianshan Mountains. It recorded tectonic deformation information occurred in the Tianshan Mountains in Quaternary (Luo et al., 2003; Wang et al., 2006; Yuan et al., 2016, 2019a, 2019b). Neotectonic movement occurred at the latest Early Pleistocene, the latest Middle Pleistocene (Yuan et al., 2019a, 2019b), and latest Late Pleistocene (Yuan et al., 2016).

The sedimentary rates of four representative sections in the area are calculated according to the age of ESR and OSL measurement. We have determined that the sedimentary rates decreased significantly in the last stage of the Late Pleistocene in the area (Fig. 7). The rate of Jiaersu setion decreased from 233.4 cm/ka to 46.5 cm/ka at 14.3 ka, the rate of the Niuquanzihu section decreased from 700 cm/ka to 26.3 cm/ka at 12.5 ka, and the rate of the Sandaohezi section decreased from 104.2 cm/ka to 46.5 cm/ka at 15.5 ka. Therefore, during this time, the overall sedimentary rate in the area decreased, the lakes disappeared, and the lacustrine facies were overprinted by desert facies. There was little change in precipitation (30.4 –11 ka cold period; Li et al., 2011), which reflected the

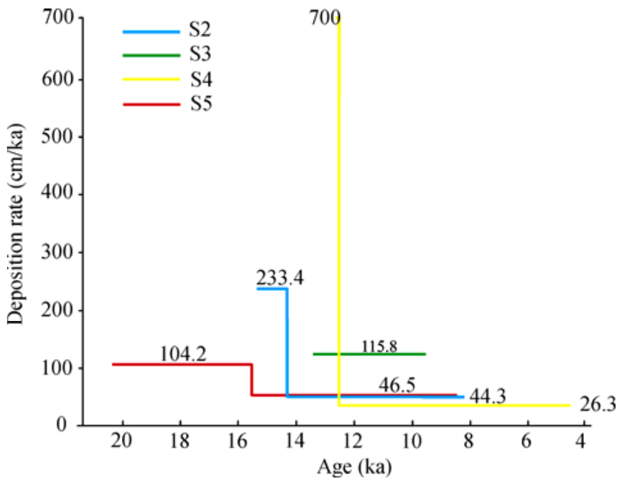

Fig. 7. The Late Pleistocene sedimentary rates of the representative sections in the Huocheng area.

tectonic uplift of the area.

The Hongshanzui fault is a basin–controlled fault in the northern part of the Yining sub-basin, which strongly thrusted southward at last stage of the Late Pleistocene (Yuan et al., 2016). This fault activity coincided with the uplift of the Huocheng area. In addition, the northern margin of the fault in the Wusun Mountains (the South Gongliu fault) also strongly thrust northward at this time (Luo et al., 2003). It indicates that the mountains on both sides of the Yining sub-basin have thrust towards the interior of the basin during this time. Even though the basin has been strongly uplifted, it's still subsiding relative to the mountains on both sides of the basin. The paleo–channel deposits in northern Liushisituan have been exposed on the surface (Fig. 5b). The transition from lacustrine facies to desert facies in Sandaohezi section and Niuquanzihu section at last stage of the Late Pleistocene is attributed to neotectonic uplift and the rapid expansion of the Takmohur desert.

Evolutionary model of the tectono-geomorphology of the Huocheng area in the Late Pleistocene was shown in Fig. 8. At the beginning of the Late Pleistocene (Fig. 8a), the Huocheng and northern Honshanzui area were flat, a series of alluvial fans with an apron-like distribution formed in the Hongshanzui, Horgos, and Daxigou areas. Yaomoshan, near Huocheng, is composed of the Xiyu Formation and the underlying eroded Neogene. A lake used to exist in the area that is now the Takmohur desert. The surficial strata of the Huocheng area can be divided

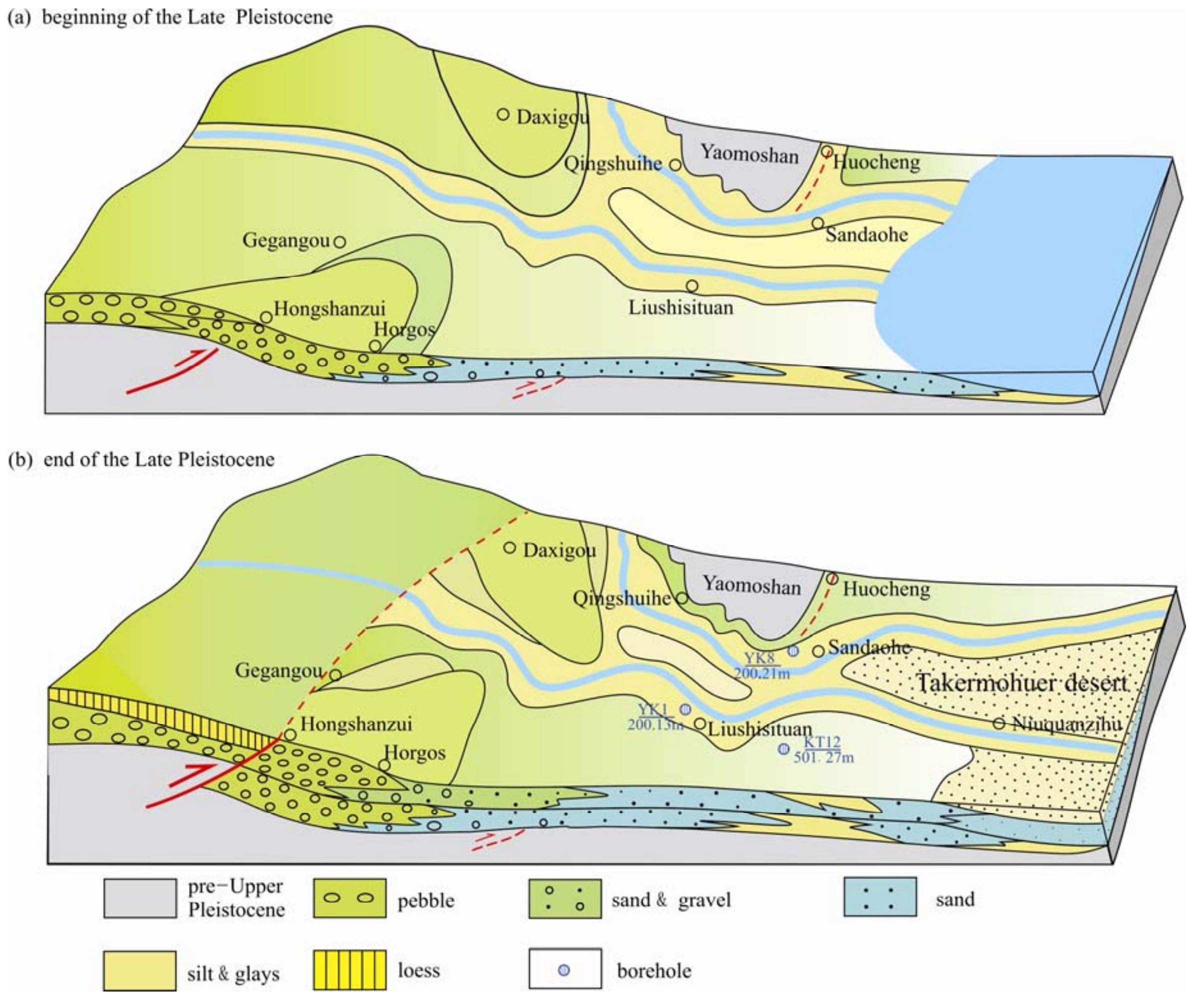

Fig. 8. Evolutionary model of the tectono–geomorphology of the Huocheng area in the Late Pleistocene.
(a) beginning of the Late Pleistocene; (b) end of the Late Pleistocene.

into three sedimentary facies: the alluvial fan facies, the fluvial facies, and the lacustrine facies. At the end of the Late Pleistocene (Fig. 8b), Tectonic uplift has occurred in the study area at the last stage of the Late Pleistocene. A blind fault strongly thrust southward from Hongshanzui, through Gegangou to Daxigou. Aeolian loess accumulated on the uplifted piedmont during this time, and the paleo-lake in the Takmohur desert area was replaced by desert. The surficial strata of the Huocheng area still can be divided into three sedimentary facies: the alluvial fan facies, the fluvial facies, and the desert facies.

In conclusion, the Huocheng area and the Tianshan Mountains were synchronously uplifted at last stage of the Late Pleistocene. Fault activity occurred along the margin of the basin at the same time. The desert extended eastward, the lake basins shrank, and the rivers cut down, resulting in the present geomorphologic framework of the Huocheng area (Fig. 8).

5 Conclusions

(1) ESR and OSL dating of the surficial sediments of the Huocheng area indicated that the sediments formed between 65±16 ka to 4.5±0.5 ka. Holocene sediments were only sporadically observed.

(2) The surficial sediments of the Huocheng area can be divided into alluvial fan facies, fluvial facies, lacustrine facies, and desert facies based on analysis of the sediment.

(3) Huocheng area experienced substantial amounts of uplift synchronously with the exhumation of the Tianshan Mountains at the last stage of the Late Pleistocene according to our dating results, the sedimentary facies distribution, and the activity on the Hongshanzui fault and the northern margin fault in the Wusun Mountains. The desert expanded eastward and desert sediments were superimposed on lake sediments in the Takmohur area at this time.

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References

Burchfiel, B.C., Brown, E.T., Deng, Q.D., Feng, X.Y., Li, J., Molnar, P., Shi, J.B., Wu, Z.M., and You, H.C., 1999. Crustal shortening on the margins of the Tien Shan, Xinjiang, China. International Geological Review, 41(8): 665–700.

Chen, Z.L., Li, L., Liu, J., Gong, H.L., Jiang, R.B., and Li, S.X., 2008. Preliminary study on the uplifting exhumation process of the western Tianshan range, northwestern China. Acta Petrologica Sinica, 24(4): 625–636 (in Chinese with English abstract).

Chen, X.L., Li, J.C., Fang, H., Zhu, T.Y., and Huang, Y.Z., 2010. Rare earth element characteristics and environmental changes recorded by loess deposition in the Ili Basin since the glaciation. Quaternary Sciences, 30(6): 35–42 (in Chinese with English abstract).

Deng, Q.D., Feng, X.Y., and Zhang, P.Z., 2000. Tianshan Active Tectonics. Beijing: Seismological Press, 1–419 (in Chinese).

Feng, X.Y., 1986. Active faults and earthquakes in Tianshan Mountains. Xinjiang Geology, (3): 103–109 (in Chinese with English abstract).

Feng, X.Y., 1997. Paleoearthquake of Xinjiang. Wulumuqi: Xinjiang science and Technology Press, 1–217 (in Chinese).

Han, X.Z., Li, S.X., Zheng, E.J., Li, X.G., Cai, Y.Q., and Chen, Z.L., 2004. Neotectonic activity characteristics of Yili basin and its relation to the formation of sandstone–type uranium deposits. Xinjiang Geology, 04: 378–381 (in Chinese with English abstract).

Li, C.X., Song, Y.G., Qian, L.B., and Wang, L.M., 2011. History of climate change recorded by grain size at the Zhaosu Loess Section in the Central Asia since the Last Glacial Period. Acta Sedimentologica Sinica, 29(6): 1170–1179 (in Chinese with English abstract).

Li, C.X., Song, Y.G., and Qiang, X.K., 2013. Effects of different components on magnetic susceptibility of the Yili eolian loess. Progress in Geophysics, 28(2): 747–753 (in Chinese with English abstract).

Liu, C.R., Yin, G.M., Gao, L., Li, J.P., and Lin, M., 2009. Reliability of quartz Ti–center in ESR dating of fluvial sediment. Nuclear Techniques, 32(2): 110–112 (in Chinese with English abstract).

Liu, C.R., Yin, G.M., Gao, L., Han, F., and Zhang, H.P., 2011. Research advances in ESR geochronology of Quaternary deposits. Seismology and Geology, 33(02): 490–498 (in Chinese with English abstract).

Liu, C.R., Yin, G.M., and Rainer, G., 2013. Research progress of the resetting features of quartz ESR signal. Advances in Earth Science ,28(1): 24–30 (in Chinese with English abstract).

Luo, F.Z., Bai, M.X., Chen J.B., 2003. Study on new activity characteristics of the active faults in Yili basin of Xinjiang. Inland Earthquake, 17(1): 4–10 (in Chinese with English abstract).

Miall, A.D., 1984. Principles of sedimentary basin analysis. New York: Spring–Verlag, 1–668.

Miall, A.D., 1996. The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis and Petroleum Geology. Berlin: Spring–Verlag, 1–582.

Molnar, P., and Tapponnier, P., 1975. Cenozoic tectonics of Asia: effects of a continental collision. Science, 189(4201): 419–426.

Shu, L.S., Guo, Z.J., Zhu, W.Y., Lu, H.F., and Wang, B., 2004. Post–collision tectonism and basin–range evolution in the Tianshan Belt. Geological Journal of China Universities, 03: 393–404 (in Chinese with English abstract).

Song, Y.G., Shi, Z.T., Fang, X.M., Nie, J.S., NAOTO, Ishikawa., Qiang, X.K., and Wang, X.L., 2010a. Loess magnetic properties in the Ili Basin and their correlation with the Chinese Loess Plateau. Science China Earth Sciences, 40(1): 61–72 (in Chinese with English abstract).

Song, Y.G., and Shi, Z.T., 2010b. Distribution and compositions of loess sediments in Yili Basin, Central Asia. Scientia Geographica Sinica, 30(2): 267–272 (in Chinese with English abstract).

Sun, Y., Chen, Z.L., Wang, Y., Han, F.B., Wu, Y., Meng, L.T., and Zhang, H., 2016. Mechanisms of Meso–Cenozoic differential uplift of Tianshan Mountains. Geotectonica et Metallogenia, 40(02): 335–343 (in Chinese with English abstract).

Tapponnier, P., 2001. Oblique Stepwise Rise and Growth of the Tibet Plateau. Science, 294(5547): 1671–1677.

Tapponnier, P., Peltzer, G., and Armijo R., 1986. On the mechanics of the collision between India and Asia. Geological Society of London Special Publications, 19(1): 113–157.

Voinchet, P., Falguères, C., Tissoux, H., Bahain, J.J., Despriéea,

J., and Pirouellea, F., 2007. ESR dating of fluvialquartz: Estimate of the minimal distance transport required for getting a maximum optical bleaching. Quaternary Geochronology, 2: 363–366.
Wang, X.L., Lu, Y.C., and Li, X.N., 2005. Luminescence dating of fine–grained quartz in Chinese loess–simplified multiple aliquot regenerative–dose (Mar) protocol. Seismology and Geology, 27(4): 615–623 (in Chinese with English abstract).
Wang, Y., Li, D.G., Wang, Y.B., and Li, J.C., 2000. Depositional characteristics of Late Cenozoic and their tectonic significance of foreland basins at both sides of Tianshan Mountains in China. Xinjiang Geology, 18(3): 245–251 (in Chinese with English abstract).
Windley, B.F., Allen, M.B., Zhang, M., Zhao, J.P., and Wang, J., 1990. Paleozoic accretion and Cenozoic redeformation of the Chinese Tien Shan range, Central Asia. Geology, 18: 128–131.
Wu, Z.H., Zhao, X.T., Jiang, W., Wu, Z.H., and Zhu, D.G., 2003. Dating Result of the Pleistocene Glacial Deposits on the Southeast Foot of Nyaiqentanglha Mountains. Journal of Glaciology and Geocryology, 25(3): 272–274 (in Chinese with English abstract).
Yin, A., 2010. Cenozoic tectonic evolution of Asia: A preliminary synthesis. Tectonophysics, 488: 293–325.
Yin, G.H., 1993. Neotectonic movement and earthquakes in Ili depression basin. Inland Earthquake, (2): 180–187 (in Chinese with English abstract).
Yin, G.H., Jiang, J.X., and Zang, Y., 2003. Research on Kashi river fault in Yili, Xinjiang and its activity. Inland Earthquake, 17(2): 109–116 (in Chinese with English abstract).
Yuan, S.H., Bai, X.D., Liang, W.T., Chi, B.M., Li, Y., Ma, H., and Han, P., 2016.Characteristics and latest activity of Hongshanzui fault in northwestern Yili basin, Xinjiang Province. Geological Bulletin of China, 35(1):117–122 (in Chinese with English abstract).
Yuan, S.H., Liu, X.Y., Bai, X.D., Li, J.G., Chi, B.M., Jiang, J.Y., Li, Y., and Zhao, Z.H., 2019a. New constraints on the Late Quaternary activity of the North Wusunshan Fault and its regional tectonic implications, Xinjiang. Journal of Earth Science, 1–13[2019–05–27].http://kns.cnki.net/kcms/detail/42.1874.p.20181220.2110.002.html (in Chinese with English abstract).
Yuan, S.H., and Franz, N., 2019b. Quaternary tectonic evolution of western Chinese Tianshan: A glance from Quaternary stratigraphy and active faults of the Yili Basin. Geophysical Research Abstracts, 21: EGU2019–7643.
Zeng, M.X., and Song, Y.G., 2014. Magnetic susceptibility characteristics of near–surface loess in the Ili basin, Xinjiang. Journal of Earth Environment, 5(2): 135–144 (in Chinese with English abstract).
Zhang, G.W., Li, S.Z., Liu, J.X., Teng, Z.H., Jin, H.L., Li, W., Huang, X.X., and Wu, Y.H., 1999. Structural feature and evolution of Yili basin, Xinjing. Earth Science Frontiers, 6(4): 203–214 (in Chinese with English abstract).
Zhang, P.Z., Deng, Q.D., Yang, X.P., Peng, S.Z., Xu, X.W., and Feng, X.Y., 1996. Late Cenozoic tectonic deformation and mechanism along the Tianshan Mountains, northwest China. Earthquake Research in China, 12(2): 127–140 (in Chinese with English abstract).
Zhang, Q., Zhu, C., and Fang, Y.S., 2002. Sedimentological Record of Environmental Evolution in the Mid–Pleistocene in Ningzheng Area. Acta Sedimentologica Sinica, 20(2): 307–313 (in Chinese with English abstract).

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