2012

Slip rate of the Aksay segment of Altyn Tagh Fault revealed by OSL dating of river terraces

Yiwei Chen
University of Hong Kong

Sheng-Hua Li
University of Hong Kong

Bo Li
University of Hong Kong, bli@uow.edu.au

Follow this and additional works at: <https://ro.uow.edu.au/scipapers>

Part of the [Life Sciences Commons](#), [Physical Sciences and Mathematics Commons](#), and the [Social and Behavioral Sciences Commons](#)

Recommended Citation

Chen, Yiwei; Li, Sheng-Hua; and Li, Bo: Slip rate of the Aksay segment of Altyn Tagh Fault revealed by OSL dating of river terraces 2012, 291-299.
<https://ro.uow.edu.au/scipapers/4607>

Slip rate of the Aksay segment of Altyn Tagh Fault revealed by OSL dating of river terraces

Abstract

The slip rate of Altyn Tagh Fault (ATF) was studied near the Aksay segment (39°24.572'N, 94°16.012'E), China, based on dating the terraces of a river passing through the ATF. Two river terrace risers were offset by the ATF and the fault displacements were recorded. Average slip rate of the Aksay segment of the ATF was estimated using the offset of terrace risers divided by the corresponding ages. The ages of the terraces were determined by optical dating of the loess deposited on the river terrace. Our results demonstrated that: (1) The optically stimulated luminescence (OSL) ages of loess can be used to constrain the terrace ages in the study area. (2) The average slip rate of the Aksay segment of the ATF in the last 6 ka is about 12 ± 1 mm/yr, given specific geomorphic assumptions discussed in the text. (3) In this situation, rather than the lower terrace age, the upper terrace age should be used in slip rate calculation as it is closer to the riser offset duration.

Keywords

rate, fault, revealed, osl, dating, river, terraces, aksay, segment, altyn, slip, tagh, CAS

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

Chen, Y., Li, S. & Li, B. (2012). Slip rate of the Aksay segment of Altyn Tagh Fault revealed by OSL dating of river terraces. *Quaternary Geochronology*, 10 291-299.

Slip rate of the Altyn Tagh Fault revealed by OSL dating of river terraces, the Aksay segment

Yiwei Chen ^a, Sheng-Hua Li ^{a,*}, Bo Li ^{a,b}

^a Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China

^b Present address: Centre for Archaeological Science, School of Earth and Environmental Sciences, The University of Wollongong, Wollongong, NSW 2522, Australia

* Corresponding author. E-mail: shli@hku.hk

Abstract:

The slip rate of Altyn Tagh Fault (ATF) was studied near the Aksay segment (39°24.572'N, 94°16.012'E), China, based on dating the terraces of a river passing through the ATF. Two river terrace risers were offset by the ATF and the fault displacements were recorded. Average slip rate of the Aksay segment of the ATF was estimated using the offset of terrace risers divided by the corresponding ages. The ages of the terraces were determined by optical dating of the loess deposited on the river terrace. Our results demonstrated that: (1) The optically stimulated luminescence (OSL) ages of loess can be used to constrain the terrace ages in the study area. (2) The average slip rate of the Aksay segment of the ATF in the last 6 ka is about 12 ± 1 mm/yr, given specific geomorphic assumptions discussed in the text. (3) In this situation, rather than the lower terrace age, the upper terrace age should be used in slip rate calculation as it is closer to the riser offset duration.

Keywords: OSL dating; Altyn Tagh Fault; slip rate; terrace; loess

1. Introduction

As one of the largest strike slip fault in Eurasia (~1600km), the active Altyn Tagh Fault (ATF) acts as the major boundary separating north Tibet and the Tarim Block (Tapponnier and Molnar, 1977; Ge et al., 1992). It defines the northern edge of the Tibet Plateau and forms a remarkable linear-structure on satellite images (Fig. 1). It

has been regarded as either a localized lithospheric boundary fault (Molnar and Tapponnier, 1975; Avouac and Tapponnier, 1993; Peltzer and Saucier, 1996) or a by-product of the thickening and deformation of strain in the viscous crust and lithospheric mantle that consequently leads to strike slip motion (Houseman and England, 1986; England and Molnar, 1997). To understand the general tectonics of India-Asia collision zone, the kinematics of this major boundary fault must be recognized. As one of the most important single structures accommodating India-Asia convergence, kinematic features of the ATF such as its total offset, history, and slip rate are of vital importance to the understanding of intra-continental geodynamics (Tapponnier et al., 2001; Yin et al., 2002). Estimating its shortening amount and slip rates are keys to understand kinematics within the India-Asia collision zone (Ge et al., 1992; Ding et al., 2004).

The slip rate of ATF has been heavily disputed for over two decades. Previous studies can be summarized into two groups with different slip rates: the fast group (Peltzer et al., 1996; Tapponnier et al., 2001) and the slow group (Houseman and England, 1986; England and Molnar, 2005; Zhang et al., 2007). Based on landform reconstructions, mainly from river terrace sites, the fast group suggested that long-term average slip rate is about 18-27 mm/yr (Meriaux et al., 2004, 2005; Xu et al., 2005). To the contrary, mainly based on GPS observations, the slow group suggested a slip rate of about 7-10 mm/yr (Bendick et al., 2000; Wallace et al., 2004; Zhang et al., 2007). Recent works also reported a similar slow rate from paleoseismic studies (e.g. Washburn et al., 2001a, 2001b) and river terrace studies (Cowgill et al., 2009). However, the major issue with the GPS record is that it only has decadal data and may have difficulties when extrapolating to a millennial scale. It was noticed that the neglect of transient deformation during the earthquake cycle in models of geodetic data can systematically underpredict or overpredict the slip rate (e.g. Hilley et al., 2009).

One of the difficulties in determining the ATF slip rate using the offset of a terrace riser is the selection of the terrace. Since there is only one scarp between two terraces, the choice of terrace ages (upper or lower) to represent the age of riser offset could be ambiguous. Because of this discrepancy the slip rate can vary by a factor of 1.2 to about 5 for the same site (Cowgill, 2007). This issue has been addressed in previous studies (e.g., Zhang et al., 2007) and it was suggested that different conclusions can be made for the same site even using the same chronological data. To avoid this problem, we studied streams deflected by the ATF and dated the loess deposited on stream banks instead of using river terraces, near old Aksay town (yellow rectangle in Fig. 1b). It was suggested that deposition of loess is related to the active fault. A slip rate of ~ 11 mm/yr in the Holocene is estimated for the ATF along this segment (Chen et al., submitted).

Previous chronology studies on river terraces related to the movement of the ATF were mainly from cosmogenic radioisotopes (e.g. ^{14}C , ^{10}Be , ^{26}Al) dating methods. It is assumed that the deposited boulder's surfaces have not been changed or been covered since they were exposed to air after the terrace formation. Any possible disturbance could lead to erroneous age estimation. An alternative dating method for sediments related to river terraces is OSL dating. This technique has undergone extensive developments for quartz OSL in recent years (Murray and Wintle, 2000; Wintle and Murray, 2006) and is particularly favorable for aeolian sediments (Li et al., 2002, 2007; Robert, 2008). The age obtained from OSL dating is the time elapsed since the sample's last exposure to sunlight. Recently some tectonic activity related materials were dated using OSL dating and their burial ages revealed paleoearthquake or active fault activities (e.g. Chen et al., 2003; Fattahi and Walker, 2007; Rizza et al., 2011).

In this study, we investigated a river site near old Aksay town, aiming to determine the slip rate of the ATF along this segment.

2. Geological setting and sampling strategy

2.1 Geological setting

The study area (red rectangles in Fig. 1) is located in the provincial border region of Gansu and Qinghai, near old Aksay town ($39^{\circ}24.572'N$, $94^{\circ}16.012'E$ and elevation 2700m), China. The ATF stretches east-northeast (ENE) and is almost parallel to the Altyn Mountains, which separates the Qaidam basin to the south from the Tarim basin to the north. A series of vast Quaternary alluvial fans are widely developed in this region, with elevations descending northwards from about 3000 m to about 1700 m on a 25 km-long slope. Late Quaternary surface ruptures like gouge zones, fault fracture materials and deflected/beheaded streams clearly indicate the fault trace.

The alluvial fans contain mainly gravels and boulders with little vegetation. Mostly originating within the Altyn Mountains, the northward flowing rivers drain the catchment and flow across the ATF. Loess is discontinuously distributed on terrace surfaces and overlies the alluvial gravels. These rivers are cut through and offset by the fault. They also incise deep into the alluvial gravels and the height difference between riverbed and alluvial fan surface ranges from several meters to a few tens of meters. About 6 km to the northeast from our study site, one profile cut by the Aksay Gou River (Fig. 1b) suggests that the alluvial fan's thickness is more than 80 meters (Ge et al., 1992). Groups of stream channels are deflected by the active fault and sharp deflections can be observed (arrowed in Fig. 1b).

Fig. 2 shows the studied river (notice view points of Fig. 3 and Fig. 4). It flows northward and is cut through by the ATF (dotted line). Three terraces, T0, T1 and T2, were identified (Fig. 2b and see photo in Fig. 3a). T2 is the highest and most well-developed terrace while T1 is the intermediate one. T0 is the modern river bed containing poorly sorted gravels. In the vicinity of the fault zone, elevation difference between T2 and T1, and T1 and T0 are 7 m and 5 m, respectively (Fig. 3a). Fault fracture materials (shown as white rectangle in Fig. 2a) can be observed on the east bank of the river at the intersection of the fault and the river (Fig. 3b, 3c). These highly-fractured materials help to locate the fault trace.

2.2 Sampling and offset measurement

The top of terrace T2 consists of two parts: loess deposits on the top and gravels beneath. The thickness of loess is about 1.2 m. The sharp contact between loess and the underlying gravels can be easily located (Fig. 5). According to our field observations, these loess deposits have the typical features of aeolian dust including massive structure, well sorting, common pores, no bedding, lack of coarse sand and gravels. We interpret these sediments as resulting from in situ aeolian deposition. Two loess samples (T2-A and T2-B, yellow triangles in Fig. 2b and Fig. 4a) were collected at the bottom of the loess layer on T2 (above the contact between loess and gravels). They were collected at the position immediately above the contact by inserting a stainless steel tube (5 cm in diameter, 25 cm in length) into the loess deposits. Since overlying loess was deposited after the formation of the T2, the ages of loess constrain the minimum age of T2. For T1, a thin loess layer interbedded within the gravels was found and we interpret it as lens of reworked loess. Two loess samples were collected from the loess lens (T1-A and T1-B, Fig. 6). In this case, the loess age is representative to the age of T1. Giving the long term slip motion of the ATF, it is assumed that these loess deposits were offset to the same degree of the terrace riser.

Two risers (T2/T1 and T1/T0) were offset by the left-lateral strike slip ATF. Fig. 4b, 4c shows the offset by viewing towards the upriver (notice the view points in Fig. 4a). The T2/T1 riser recorded a clear displacement and can be observed in Fig. 4c. By projecting the riser crests into the fault trace on satellite images, combined with measurements in the field-work, the total offset from the T2/T1 riser is about 78 ± 5 m. In the vicinity of the fault, T2/T1 riser is fairly straight and extends a few hundred meters linearly. The west bank of T1/T0 riser is not straight. This is probably due to river erosion and/or due to recent human activity in road constructions. To the contrary, the east bank of T1/T0 riser is straight and recorded a clear displacement of 20 ± 2 m (Fig. 2b and Fig. 4a).

3. Luminescence dating

All sample preparations were conducted in subdued red light condition. Each end of the samples was scraped away for water content and dose rate measurements. After 10% HCl and 20% H₂O₂ treatment to remove carbonates and organic materials, grains within the range of 90-125 µm were obtained by dry sieving for density separation. Quartz grains were then separated by sodium polytungstate heavy liquid with densities between 2.62-2.75 g/cm³. These grains were etched using 40% hydrofluoric acid (for 90 minutes) to remove feldspar grains. Then quartz grains were mounted on 10-mm-diameter aluminum discs with silicone oil as an adhesive for D_e measurement.

OSL signals were measured in the Luminescence Dating Laboratory of The University of Hong Kong using an automated Risø TL/OSL reader (model DA-15), with a ⁹⁰Sr/⁹⁰Y beta source (0.076 Gy/s on aluminium discs) as the irradiation source. Blue light (470±30 nm) from LEDs were used as the stimulating light source for quartz OSL measurements and infrared light (875±80 nm) from LEDs for feldspar contamination test. OSL signals were detected through two 3 mm thick Hoya U-340 filters.

The single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000; Wintle and Murray, 2006) was applied to determine the equivalent dose (D_e). Each disc underwent preheating (260°C, 10 seconds), OSL measurement (125°C, 100 s), test dose (4.0 Gy) OSL measurement and irradiation cycles with different regenerative doses. The test dose OSL used for sensitivity correction was measured after a cut-heat to 220°C. D_e values were obtained by comparing the sensitivity-corrected natural luminescence with the sensitivity-corrected regenerative luminescence from different regenerative doses. The recycling ratio and dose recovery test was used to test the reliability of SAR for our samples. Aliquots with a recycling ratio falling outside the range of 1.0±0.1 were discarded in D_e determination. In the dose recovery test, the samples were bleached for 200s using blue LEDs. They were then given an artificial irradiation of known dose. The SAR protocol was then conducted to check whether the determined D_e can recover the given dose. It was observed that the known dose

can be recovered within 10% to the delivered dose. Feldspar contamination was determined by measuring infrared stimulated luminescence signals (60°C for 300 s) and checking the shape of the 110°C TL peak (Li et al., 2002). Aliquots showing feldspar signals were abandoned.

The environmental dose rate contributed from Uranium and Thorium decay series was determined by thick source alpha counting technique. The alpha counting rates were converted into β and γ dose rates (Aitken, 1998). X-Ray Fluorescence (XRF) was used to determine the potassium content. Water content was measured from sample weights before and after drying at 105 °C in an oven. Cosmic ray contribution was calculated based on the burial depth and geomagnetic altitude (Prescott and Hutton, 1994).

4. Results and discussions

OSL dating results and riser offsets are summarized in Table 1. About 40 to 50 aliquots were measured for each sample to obtain the average D_e value. The distributions of D_e values from all samples are shown in radial plots in Fig. 7. It is shown that most of the D_e values are within $\pm 2\sigma$ of the central value (weighted mean). The results indicate that the quartz grains from our samples were fully zeroed at the time of deposition.

For the two samples from T1, the OSL ages for samples T1-A (1.86 ± 0.07 ka) and T1-B (1.71 ± 0.07 ka) agrees well with each other. The estimated age of T1 is 1.8 ± 0.1 ka. For T2, the OSL ages of samples T2-A and T2-B are 5.89 ± 0.22 ka and 5.73 ± 0.23 ka, respectively, which are consistent with each other within measurement errors. Hence, the age of T2 is about 5.8 ± 0.2 ka.

The slip rate of ATF can be calculated based on the ages of the offset risers, which can be constrained by the ages of the upper and the lower terraces. For a terrace riser between two terraces, the age of the riser must post-date the deposition of the upper terrace and predate the deposition of the lower. Before the formation of the lower

terrace, the balance between lateral erosion rate of river and riser displacement rate determines which terrace age is closer to the riser displacement duration (e.g., Cowgill, 2007). Three situations should be considered to constrain the age of the riser offset by fault. In the first case, if we assume that the left-lateral strike slip of the ATF occurs continuously and the lateral erosion rate of river is negligible when compared to the offset rate or slip rate of the ATF, the riser should be offset at the time of its formation and the riser age can be estimated using the upper terrace age. In the second situation, if the river lateral erosion is fast and the riser offset could be eroded very quickly, it is not until the lower terrace was formed that offset riser could be protected from erosion. In this case, the offset was recorded after the formation of lower terrace, and the lower terrace age is more suitable for estimating the riser age. The third situation lies between the first two situations. In this case, the true slip rate can only be constrained using the values based on the first two situations.

In this study, we have selected the upper terrace age to be the riser displacement duration, based on the assumption that situation 1 above represents an accurate description of the geomorphic evolution at this location. Given this assumption, the calculated minimum slip rate is 11.2 ± 1.2 mm/yr and 13.4 ± 0.9 mm/yr from T1/T0 (20 ± 2 m) and T2/T1 (78 ± 5 m), respectively. Therefore, the average slip rate of the Aksay segment of the ATF in the last 6 ka is about 12 ± 1 mm/yr (Fig. 8). This result is well concordant with our previous study which was based on deflected stream channels (Chen et al., submitted). From loess deposited on deflected stream banks, we obtained a slip rate of 11 ± 2 mm/year. From cosmogenic radioisotopes dating, Meriaux et al. (2005) and Xu et al. (2005) also studied the Aksay segment. Mainly using the lower terrace ages, they reported a slip rate of about 14~21 mm/yr along this segment. Zhang et al. (2007) argued that the age of offset terrace risers protected by topography upstream are more close to the age of the upper terrace, rather than the age of the lower terrace. By using the same data of Meriaux et al. (2005) and Xu et al. (2005), Zhang et al. (2007) obtained a slip rate of $\sim 10 \pm 2$ mm/yr. Cowgill et al. (2009)

studied Yuemake site of central ATF and by using both upper and lower terrace ages, they constrained the slip rate to be in the range of 9-14 mm/yr in the last 6 ka (Fig. 8). However, if the lower terrace was used to represent the riser offset duration time in our study, i.e. the age of T1 (1.8 ± 0.1 ka) was used for the offset of T2/T1 riser (78 ± 5 m), the slip rate is about 44 mm/yr. Such a high slip rate is significantly faster than previous results, even the fast group (18-27 mm/yr). It is thus suggested that using lower terrace to calculate fault slip rate can lead to an overestimation of slip rate in this region.

Since our results suggest that the upper terrace is closer to represent riser displacement duration, it indicates that the lateral erosion in this area was not significant comparing with the strike slip motion. This is supported by geomorphologic evidence. Firstly, the studied area locates at the front of the Altyn Tagh Mountain. The relatively high gradient in this area will lead to preferentially downwards incision other than lateral incision of rivers. Secondly, as pointed out by Zhang et al. (2007, 2008), if the lateral erosion was severe, the river channel would be continuously widen at both the upstream and downstream of the fault, but this is not supported from the satellite images and field observations (Fig. 2). Moreover, there would be no or little offset recorded at young terrace riser if there has been a strong lateral erosion. Hence, we suggest that upper terrace age is close to the riser age for our site. This can be further supported by the fact that the slip rate of 43 m/ka based on the lower terrace age is too fast to be realistic. Such a fast slip rate is much higher than previous results and it can even match to the moving speed between plates. Giving that this area is in an intra-continental deformation frame, this rate appears to be unlikely. In conclusion, we interpret that the upper terrace age is closer to the riser's displacement duration time compared with the lower terrace age. From this study, the Aksay segment of the ATF has a minimum slip rate of $\sim 12 \pm 1$ mm/yr in the last 6 ka.

5. Conclusion

OSL dating of the loess deposits on terrace surfaces constrains the terrace ages. The average slip rate of the ATF in this region in the last 6 ka was estimated to be 12 ± 1 mm/year, using the upper terrace age to represent riser displacement duration. Using lower terrace age may lead to overestimation of the slip rate in this area.

Acknowledgements

We thank the anonymous reviewer for providing many valuable comments. This study was financially supported by the grants to Sheng-Hua Li from the Research Grant Council of the Hong Kong Special Administrative Region, China (Project no. 7035/07P and 7028/08P).

References

- Aitken, M. J., 1998. An introduction to Optical Dating. Oxford University Press, Oxford.
- Avouac, J. P., Tapponnier, P., 1993. Kinematic model of active deformation in central Asia. *Geophysics Research Letters* 20, 895-898.
- Bendick, R., Bilham, R., Freymueller, J., Larson, K., Yin, G.H., 2000. Geodetic evidence for a low slip rate in the Altyn Tagh fault system. *Nature* 404, 69-72.
- Chen, Y.W., Chen, Y.G., Murray, A.S., Liu, T.K., Lai, T.C., 2003. Luminescence dating of neotectonic activity on the southwestern coastal plain, Taiwan. *Quaternary Science Review* 22, 1223-1229.
- Chen, Y.W., Li, S.H., Sun, J.M., Fu, B.H. Holocene slip rate of central Altyn Tagh Fault revealed by OSL dating. *Journal of Geophysical Research*, submitted for publication.
- Cowgill, E., 2007. Impact of riser reconstructions on estimation of secular variation in rates of strike-slip faulting: Revisiting the Cherchen River site along the Altyn Tagh Fault, NW China. *Earth and Planetary Science Letters* 254, 239-255.
- Cowgill, E., Gold, R. D., Chen X.H., Wang X.F., Arrowsmith, J.R., Southon, J., 2009. Low Quaternary slip rate reconciles geodetic and geologic rates along the Altyn Tagh fault, northwestern Tibet. *Geology* 37, 647-650.
- Ding, G.Y., Chen, J., Tian, Q.J., Shen, X.H., Xing, C.Q., Wei, K.B., 2004. Active faults and magnitudes of left-lateral displacement along the northern margin of the Tibetan Plateau. *Tectonophysics* 380, 243-260.
- England, P., Molnar, P., 1997. Active deformation of Asia: From kinematics to dynamics. *Science* 278, 647-650.
- England, P., Molnar, P., 2005. Late Quaternary to decadal velocity fields in Asia. *Journal of Geophysical Research* 110 (B12401).

- Fattahi, M., Walker, R.T., 2007. Luminescence dating of the last earthquake of Sabzevar thrust fault, NE Iran. *Quaternary Geochronology* 2, 284-289.
- Ge, S., Bai, M., Li, Y., Liu, G., Zhen, Q., Zheng, J., Zhu, D., 1992. Active Altyn Tagh Fault Zone. Seismological Press, Beijing (in Chinese with English abstract).
- Hilley, G.E., Johnson, K.M., Wang, M., Shen, Z.K., Bürgmann, R., 2009. Earthquake-cycle deformation and fault slip rates in northern Tibet. *Geology* 37, 31-34.
- Houseman, G.A., England, P., 1986. Finite strain calculations of continental deformation: 1. Methods and general results for convergent zones. *Journal of Geophysical Research* 91, 3651-3663.
- Li, S.H., Sun, J.M., Zhao, H., 2002. Optical dating of dune sands in the northeastern deserts of China. *Palaeogeography palaeoclimatology Palaeoecology* 181, 419-429.
- Li, S.H., Chen, Y.T., Li, B., Sun, J.M., Yang, L.R., 2007. OSL dating of sediments from deserts in northern China. *Quaternary Geochronology* 2, 23-28.
- Meriaux, A.S., Ryerson, F.J., Tapponnier, P., Van der Woerd, J., Finkel, R.C., Xu, X.W., Xu, Z.Q., Caffee, M.W., 2004. Rapid slip along the central Altyn Tagh Fault: Morphochronologic evidence from Cherchen He and Sulamu Tagh. *Journal of Geophysical Research* 109 (B06401).
- Meriaux, A.S., Tapponnier, P., Ryerson, F.J., Xu, X.W., King, G., Van der Woerd, J., Finkel, R.C., Li, H.B., Caffee, M.W., Xu, Z.Q., Chen, W.B., 2005. The Aksay segment of the northern Altyn Tagh Fault: Tectonic geomorphology, landscape evolution, and Holocene slip rate. *Journal of Geophysical Research* 110 (B04404).
- Molnar, P., Tapponnier, P., 1975. Cenozoic tectonics of Asia: Effects of a continental collision. *Science* 189, 419-426.
- Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32, 57-73.
- Peltzer, G., Saucier, F., 1996. Present-day kinematics of Asia derived from geologic fault rates. *Journal of Geophysical Research* 101, 27,943-27,956.
- Prescott, J.R., Hutton, J.T., 1994. Cosmic ray contribution to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurement* 23, 497-500.
- Rizza, M., Mahan, S., Ritz, J.F., Nazari, H., Hollingsworth, J., Salamati, R., 2011. Using luminescence dating of coarse matrix material to estimate the slip rate of the Astaneh fault, Iran. *Quaternary Geochronology* 6, 390-406.
- Robert, H. M., 2008. The development and application of luminescence dating to loess deposits: a perspective on the past, present and future. *Boreas* 37, 483-507.
- Tapponnier, P., Molnar, P., 1977. Active faulting and tectonics in China. *Journal of Geophysical Research* 82, 2905-2930.

- Tapponnier, P., Xu, Z.Q., Roger, F., Meyer, B., Arnaud, N., Wittlinger, G., Yang, J.S., 2001. Oblique stepwise rise and growth of the Tibet Plateau. *Science* 294, 1671-1677.
- Wallace, K., Yin, G.H., Bilham, R., 2004. Inescapable slow slip on the Altyn Tagh fault. *Geophysics Research Letters* 31, L09613.
- Washburn, Z., Arrowsmith, J.R., Forman, S.L., Cowgill, E., Wang, X.F., Zhang, Y.Q., Chen, Z.L., 2001. Late Holocene earthquake history of the central Altyn Tagh Fault, China. *Geology* 29, 1051-1054.
- Washburn, Z., Arrowsmith, J.R., Dupont-Nivet, G., Wang, X.F., Zhang, Y.Q., Chen, Z.L., 2003. Paleoseismology of the Xorxol segment of the central Altyn Tagh Fault, Xinjiang, China. *Annals of Geophysics* 46, 1015-1034.
- Wintle, A.G., Murray, A.S., 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurement* 41, 369-391.
- Xu, X.W., Tapponnier, P., Van der Woerd, J., Ryerson, F.J., Wang, F., Zheng, R.Z., Chen, W.B., Ma, W.T., Yu, G.H., Chen, G.H., Meriaux, A.S., 2005. Late Quaternary sinistral slip rate along the Altyn Tagh fault and its structural transformation model. *Science in China, D* 48, 384-397.
- Yin, A., Rumelhart, P.E., Butler, R., Cowgill, E., Harrison, T.M., Foster, D.A., Ingersoll, R.V., Zhang, Q., Zhou, X.Q., Wang, X.F., Hanson, A., Raza, A., 2002. Tectonic history of the Altyn Tagh fault system in northern Tibet inferred from Cenozoic sedimentation. *Geological Society of America Bulletin* 114, 1257-1295.
- Zhang, P.Z., Molnar, P., Xu, X.W., 2007. Late quaternary and present-day rates of slip along the Altyn Tagh Fault, northern margin of the Tibetan Plateau. *Tectonics* 26 (TC5010).
- Zhang, P.Z., Li, C.Y., Mao, F.Y., 2008. Strath terrace formation and strike-slip faulting. *Seismology and Geology* 30, 43-57 (in Chinese with English abstract).

Figure Captions

Fig. 1(a): Schematic map of major faults in India-Asia collision zone, modified after Tapponnier et al. (2001). Red rectangle shows the Aksay area. (b): Topographic map (90m Shuttle Radar Topography Mission data) of old Aksay displayed over satellite image. Red rectangle shows studying river while yellow rectangle shows our previous study site, i.e. deflected streams.

Fig. 2. Maps of study site. (a): Satellite image. Dark dotted line shows the active ATF. Yellow dotted line shows the riser between T2 and T1 and the white dotted line shows the riser of T1/T0. View point of Fig. 3a is also shown and white rectangle shows the fault fracture materials (see Fig. 3b, 3c). (b): Three terraces: T2(light yellow), T1(grey) and T0(dark grey). By projecting the riser crests into the fault trace on satellite images, combined with the field work, the total offset from T2/T1 riser is about 78 ± 5 m and is 20 ± 2 m from T1/T0 riser (also see Fig. 4). Triangle shows the location of four samples.

Fig. 3. Photos showing the terraces. (a): Southwest viewing of the site. Three terraces could be observed clearly. Height difference between T2/T1 (~ 7 m) and T1/T0 (~ 5 m) can be observed. (b) and (c): Photo of fault fracture materials (white rectangle in Fig. 2a).

Fig. 4. Fault offset measurement. (a): Satellite image showing the offset of terraces. All terms are same to Fig. 2a. By projecting the riser crests into the fault trace on satellite images, the total offset can be measured. (b): Southward viewing to the upper river. The offset of T1/T0 riser (20 ± 2 m) can be observed. White lines show the riser crest. (c): Offset recorded by the T2/T1 riser. The displacement of 78 ± 5 m can be observed clearly in this photo.

Fig. 5 Photos of sample T2-A (a) and T2-B (b). The top of the terrace is generally composed of two parts: thin loess deposit on the top and alluvial gravels beneath. Loess samples were collected just above the sharp contact (dotted lines) between loess and gravels.

Fig. 6 Photos of sample T1-A (a) and T1-B (b). Samples were collected from a thin loess layer interbedded within gravels.

Fig. 7 The D_e distributions shown in radial plots for all samples. D_e values within $\pm 2\sigma$ standard error band (shaded region) of the weighted mean are represented by filled points.

Fig. 8 Summary of slip rate of the ATF. From our study, it is suggested that upper terrace age is more suitable to represent riser displacement duration. Using lower terrace ages can lead to erroneous estimation.

1 Table 1

2 OSL dating result: D_e value, dose rate and ages

Sample		Alpha counting rate ^a	K content (%)	Water content ^b (%)	Cosmic ray ^c (Gy/ka)	Equivalent dose (Gy)	Dose rate (Gy/ka)	Offset (m)	Age (ka)
T1	T1-A	10.79±0.23	1.80	9.5	0.30	6.18±0.08	3.33±0.12	20±2	1.86±0.07
	T1-B	10.79±0.27	1.75	9.5	0.31	5.61±0.10	3.29±0.12		1.71±0.07
T2	T2-A	11.32±0.22	1.74	9.0	0.27	19.39±0.16	3.29±0.12	78±5	5.89±0.22
	T2-B	10.51±0.27	1.64	9.0	0.27	17.70±0.19	3.09±0.12		5.73±0.23

3 ^a The alpha counting rate is for a 42-mm-diameter ZnS screen and is given in units of counts per kilosecond.

4 ^b The error for the water content is estimated at ±20%.

5 ^c The error for the cosmic rays dose rate is estimated at ±0.02Gy/ka.

6 Fig. 1

7

8

9

10 Fig. 2

11

12

13

14 Fig. 3

15

16

17 Fig. 4

21 Fig. 5

22

23

24 Fig. 6

25

26

27

31 Fig. 8

32