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Timing, Displacement and Growth Pattern of the Altyn Tagh Fault: A Review

DAI Shuang[1,*], DAI Wei[2], ZHAO Zhenbin[1], LUO Junhua[1], QIANG Lei[1], MA Xin[1], ZHANG Xianwen[1] and XU Jianjun[1]

1 *Key Laboratory of Western China's Environmental Systems（Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, China*

2 *Gansu Bureau of Seismology, Lanzhou 730000, China*

Abstract: The Altyn Tagh Fault (ATF) is the longest, lithospheric scale and strike-slip fault in East Asia. In the last three decades, multidisciplinary studies focusing on the timing, displacement of strike-slip and growth mechanics of the ATF have made great progresses. Most studies revealed that the ATF is a sinistral strike-slip and thrust fault, which underwent multiple episodes of activation. The fault is oriented NEE with a length of 1600 km, but the direction, timing of activity and magnitude of its extension eastward are still unclear. The AFT was predominately active during the Mesozoic and Cenozoic, in relation to the Mesozoic collision of the Cimmerian continent (Qiangtang and Lhasa block) and Cenozoic collision of India with Asia. The AFT strike-slipped with a left-lateral displacement of ca. 400 km during the Cenozoic and the displacement were bigger in the western segment and stronger in the early stage of fault activation. The slip-rates in the Quaternary were bigger in the middle segment than in the western and eastern segment. We roughly estimated the Mesozoic displacement as ca. 150-300 km. The latest paleomagnetic data showed that the clockwise vertical-axis rotation did not take place in the huge basins (the Tarim and Qaidam) at both side of ATF during the Cenozoic, but the rotation happened in the small basins along the ATF. This rotation may play an important role on accommodating the tectonic deformation and displacement of the ATF. Even if we have achieved consensus for many issues related to the ATF, some issues still need to be study deeply; such as: (a) the temporal and spatial coupling relationship between the collision of Cimmerian continent with Asia and the history of AFT in the Mesozoic and (b) the tectonic deformation history which records by the sediments of the basins within and at both side of AFT and was constrained by a high-resolution and accurate chronology such as magnetostratigraphy and paleomagnetic data.

Key words：timing, displacement of strike-slip, growth, paleomagnetism, Altyn Tagh fault, Proto-Tethys

1 Introduction

The Altyn Tagh fault (ATF) is the longest lithospheric-scale fault in the eastern Asian continent. It is oriented NEE with a length over 1600 km. Natural earthquake records and geodetic data indicate that the ATF is still an active tectonic zone (IGSSB, 1992; Bendick et al., 2000; Wang et al., 2002). Together with the northern Qilian fault, the AFT defines the northern boundary of the Tibetan Plateau (Molnar and Tapponnier, 1975; Wittlinger et al., 1998). It contributed to the tectonic deformation (e.g. Burchfiel et al., 1989; Tapponnier et al., 1990, 2001; Zheng,1991a; Cui Junwen et al., 1999; Xu Zhiqin et al., 1999; Yin and Harrison, 2000; Ma Zongjin et al.,2001; Shen et al., 2001; Yin et al., 2002; Cowgill et al., 2003; Zhu et al., 2006; Liu Yongjiang et al., 2007; Clark et al., 2010; Xu Zhiqin et al., 2011; Sun Zhiming et al., 2012; Ran Bo et al., 2013; Xiao Ancheng et al., 2013; Yuan et al., 2013; Zheng et al., 2013; Pan Jiawei et al., 2015;Cheng et al., 2015; 2016）and mountains uplifting of the northern Tibetan Plateau and neighboring areas (e.g. Geoge et al., 2001; Jolivet et al., 2001; Sobel et al, 2001; Ritts et al., 2004; Wang Chengshan et al., 2004; Dai et al., 2005; Fang et al., 2005; Sun et al., 2005; Li Haibing et al., 2006; Fang et al., 2007; Xu Zhiqin et al., 2007; Wang et al., 2014; Chang et al., 2015; Cheng et al., 2016; Li et al., 2016; Wang et al., 2016a, 2016b). Therefore, the study on

* Corresponding author. E-mail: daisher@lzu.edu.cn

the ATF history is of crucial importance to decipher the evolution of tectonic-geomorphic patterns of the Asian continent, and to understand how the deformation of the Indian-Asian collision zone propagated to the northern Tibetan Plateau.

During the last three decades, the ATF has attracted more and more geologists' attention. By multidisciplinary approach, they have obtained abundant data over the timing, strike-slip displacement and growth mechanics of ATF. However, a lot of debates remain open. In this contribution, we summarized consensus and debates related to the ATF, and proposed some suggestions for future research.

2 The Geometry and Eastward Extension of the ATF

2.1 Altyn Tagh fault

The Altyn Tagh fault (ATF), also known as the southern marginal fault of the Altyn Tagh (Tagh means Mountain), is a fault passing through south of the Altyn Tagh Mountains, with a length of about 1600 km. The fault extends from the Lazhuglung Tibetan Autonomous Region at its southwestern end, to the Kuyake, Aqiang and Xorkol of Xinjiang Uygur Autonomous Region, then to Aksai, Subei and Kuantan Mountain (Yumen) of Gansu Province in its northeastern end (Fig. 1 and Fig. 2). The fault separates the Tibetan Plateau at the southeast and the Tarim Basin at the northwest. Its southwestern segment cuts the Kunlun Mountains, the middle segment bounds the Tarim and Qaidam Basins, while the northeastern segment cuts off the Qilian Mountains. The majority of the fault is well exposed and its structural features are obvious and characteristic. The main fault plane extends straightly along the NE 60°–70° direction, only with a slight bending in the northeastern and southwestern segments. The southwestern (west of 84°E) and northeastern (east of 94°E) segments are dipping with an inclination of 50°–70° towards the SE, and the central segment (84°E to 94°E) is steeply dipping to the NW (IGSSB, 1992). The fault is inclination reaches ca. 60^{o} towards the Moho and actually cut the Moho (Xu Zhiqin et al., 1999; Gao et al, 2001). In the most northeast segment, between Changma and Kuantan area, the fault trends in NE75° and fault planes are steep, being the west boundary of the Hexi corridor, and the fault separated the strata of the Paleozoic strata in the southeast from the Quaternary fluvial and alluvial sediments, and the Archean Dunhuang Group. In the satellite images, the fault is linear and straight, with a distinct color. The coloration disappears in the East, at the Badain Jaran Desert. Along the fault the topography is sharp and deep on both sides, with several hundred-of-kilometers long and narrow valley.

The ATF is discontinuously linear and tied to a group of arc-shaped faults (Cui Junwen et al., 1999). These arc-shaped faults, such as the Sulenanshan, Danghenanshan fault, etc. are located in the southeast of ATF, protruded northward near the ATF. The conjunction position of the linear and arc-shaped structure (Fig. 2), is called the branching-point (Cui Junwen et al., 1999). There are 13

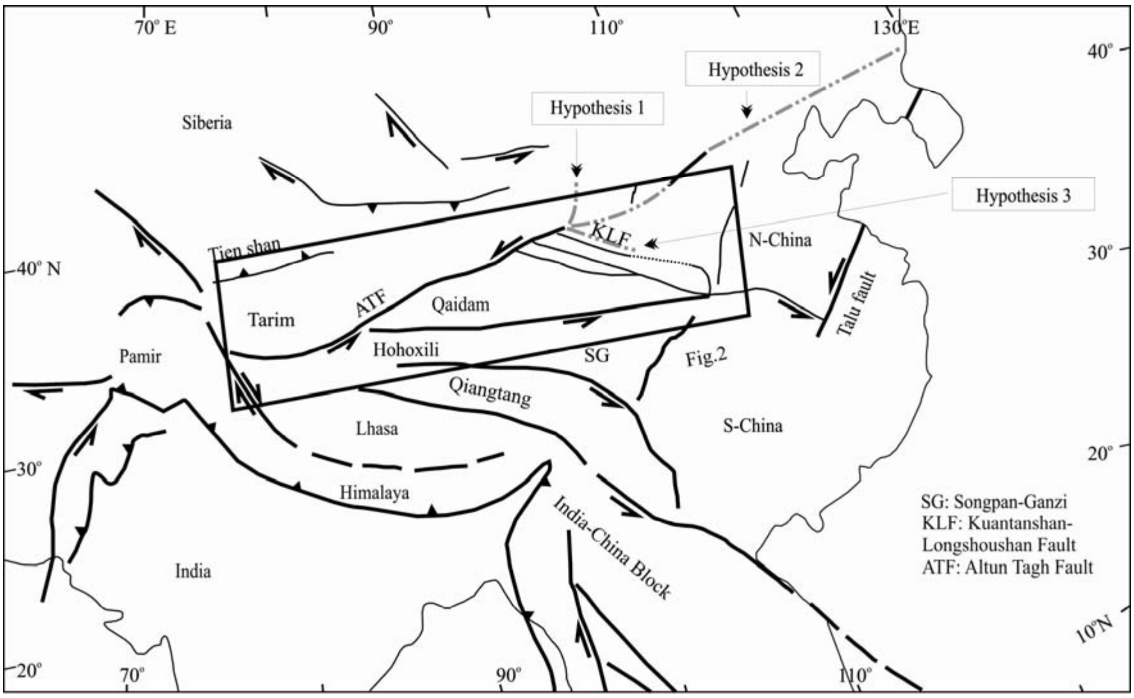


Fig. 1. The tectonic settings of ATF and hypotheses for eastward extension of ATF.

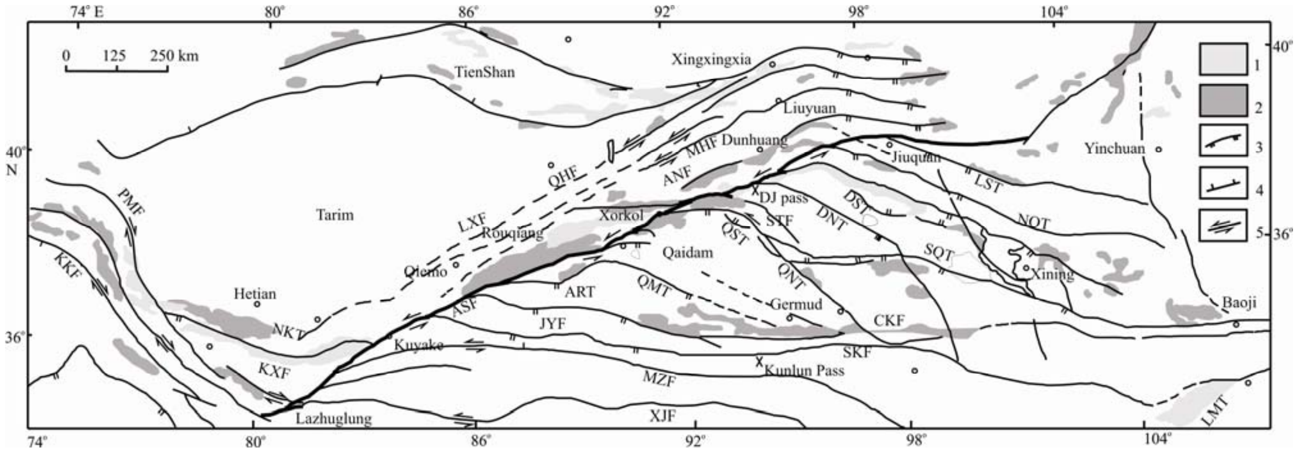


Fig. 2. the simplified geologic map of the Altyn Tagh fault belt and neighboring regions (modified from Cui et al., 1999).
1-Upper and Middle Proterozoic 2-Upper Archean and Lower Proterozoic 3-thrust fault or ductile shear zone 4-normal fault 5-sinistral fault. ASF, south marginal fault of Altyn Tagh; ANF, north marginal fault of Altyn Tagh; MHF, Milam-Hongliuyuan fault; QHF, Qiemo-Heijianshan fault; LXF, Luobuzhuang-Xingxingxia fault; KXF, Kangxiwa fault; NQT, north marginal thrust fault of Qilian; CQT, central Qianlian thrust fault; DST, Daxueshan-Shulenanshan thrust fault; SQT, south Qilian thrust fault; DNT, Danghenanshan thrust fault; QNT, north marginal thrust fault of Qaidam; STF, Saishiteng fault; QMT, Qimantag thrust fault; ART, Aerka thrust fault; JYF, Jinyu fault; CKF, central Kunlun fault; SKF, south marginal fault of Kunlun; MZF, Muztagh fault; XJF, Xijinwulan-Jinshajiang fault; PMF, east marginal fault of Pamir; KKF, east marginal fault of Karakrum; NXT, north marginal thrust fault of western Kunlun; LST, Kuantanshan-Longshoushan fault.

branching-points along the ATF.

At both sides of ATF the stratigraphy and structural geology are significantly distinct. The Archean, Early-Middle Proterozoic metamorphic rocks and Cenozoic terrestrial clastic sedimentary rocks are exposed in the northwest, while Phanerozoic volcanic and sedimentary rocks, and a few Proterozoic metamorphic rocks are exposed in the southeast. The Paleozoic mafic and felsic intrusions emplaced along the ATF belt. The present-day structural framework and landscape pattern probably formed mostly during the Neogene (IGSSB, 1992). The ATF also shows a NEE linear gradient zone on the Bouguer gravity anomaly field map, where the Bouguer gravity are higher in northwest side (Tarim) and lower in the southeast (e.g. Qaidam). Furthermore, it exhibits a regional scale of linear or chain positive or/and negative magnetic anomalies on the aeromagnetic map (IGSSB, 1992; Cui Junwen et al., 1999).

2.2 Altyn Tagh fault belt

The Altyn Tagh fault belt refers to a corridor area which is composed of several faults and relevant structures along the ATF. The fault(s) are parallel to the ATF, and cut the corridor zone into several structural belts (Fig. 2). Traditionally, this belt is defined as the structure zone which bound with two faults, the northern and southern margin fault of the Altyn Tagh which arrays as a sinistral echelon feather structure (Fig. 2). The southern margin fault is 1200 km long, from Lazhuglung at the southwest and passing through the Dangjinshankou Pass, and finally merging into the Qilian Mountain in the northeast (IGSSB, 1992). The northern margin fault (more than 600 km) bound the Altyn Tagh at the north, from Lapeiquan at the southwest to the Kuantan Mountain at the northeast. These two faults are overlapping between Lapeiquan and Subei areas over 5–20 km (IGSSB, 1992). Considering the link between the ATF and the regional faults, Zheng Jiandong (1991) and IGSSB (1992) expanded this definition, and suggested that the Altyn Tagh fault belt should include also the northern and southern margin fault of Altyn Tagh, Cherchen River fault, Sanwei Mountain fault, Lazhuglung -kuyake fault, Hongliugou-Lapeiquan fault, Jianggasayi fault, etc. After analyzing the regional geophysical characteristics, Cui Junwen et al. (1999) and Yin et al. (2002) further ascertained that the Altyn Tagh fault belt (also called as the Altyn Tagh fault system) consisted of five faults from south to north: southern margin of Altyn Tagh fault (the Altyn Tagh fault), northern margin of Altyn Tagh fault, Milan-Hongliuyuan fault, Cherchen-Heijianshan fault and Robzhuang-Xingxingxia fault (Fig. 2). For this definition, the belt is wide of ca. 90 km in the southwest and ca. 220 km in the northeast. From south to north, the faults strike changes from NEE into NE direction, and the faults spread eastward as a brush structure in the northeast (Fig. 2). Within the belt, each fault zone reaches tens of kilometers wide, consisting of several second-order faults (mostly with a feather-style organization). The assemblage of faults into a belt is complex, with either a strike-slip fault or/and thrust fault, or ductile shear zone organization. The faults have developed during a relatively long time, during which they involved strata from the metamorphic basement and Paleozoic intrusive rocks. The fault also played a role on the formation and evolution of the Mesozoic and Cenozoic sedimentary basins (Fig. 3).

2.3 Eastward Extension of Altyn Tagh fault

The southwestern end of the ATF is cut by the Karakoram fault (Molnar and Tapponnier, 1975; Yin et al., 2002), thus the westward extension of the ATF is agreeable. But its eastward extension is still debated. A few researchers proposed that the ATF extended in the west Jiuquan basin-Kuantan Mountain area, and arrayed as dendritic structure, finally ending in the Huahai basin (e.g. Gong Jianye et al., 2007). Three main hypotheses were proposed over the eastern extension of the fault. It developed either to the northeast, east or southeast (see Fig. 1). The extension towards the East occurred in the Cretaceous, or Oligocene-Miocene, Pleistocene.

The first hypothesis of an extension to the NE of the ATF corresponds to the development of a fault belt with a width of 100–250 km (Ren Jishun, 1980) and a length of ca. 400 km. The ATF fault is connected with the Ruoshui fault in the eastern part of Beishan (Wang and Mo, 1995), then it passes into the Mongolia around E101° (hypothesis 1 in Fig.1). In addition, Guo Zhaojie et al. (2008) studied the Sanwei-Shuangta, Daquan and Xingxingxia faults in the Beishan area, and concluded that these faults are closely linked to the ATF belt and probably formed in a similar dynamic settings. These faults began their activation during the Pliocene, and are younger from the south to the north, and their subordinate faults initiated 400 ka ago (Guo Zhaojie et al., 2008).

The second hypothesis of an extension of the ATF eastward is among other put forward by Zheng Jiandong (1991b), through the study of satellite and aerial images which after him show that the ATF passed through the Jinta basin, was then exposed in the western margin of the Badain Jaran Desert, with the extension direction gradually turning to ~EW direction, and finally closed at the eastern boundary of China (Ren Shoumai, 2002). Ge Xiaohong et al. (2001) proposed that the fault cut the Alxa block and the northern margin of the North China block, and finally was cut off by the Tanlu fault in East China. While others argued that the ATF turned eastward to NE direction at 104 °E, reaching the East Mongolian fault, the ATF in this scenario would reach the Okhotsk region and would have an extension of more than 2000 km (Yue and Liou, 1999, hypothesis 2 in Fig 1). In this views, the ATF already started sinistral strike-slipping in the Alxa and North China during the Oligocene (Yue and Liou, 1999; Yue et al, 2001, 2003, 2005; Darby et al., 2005; Webb et al., 2006) or the Cretaceous (Vincent and Allen, 1999; Lamb et al., 1999; Darby et al., 2005; Zhong et al., 2011), and stopped being active during the late Miocene (15-12 Ma) (Yue and Liou, 1999; Yue et al, 2003, 2005).

The third hypothesis of the ATF fault turning to the SEE towards the East also includes two different scenarios. The first scenario is that the fault passed through the west Hexi Corridor and extended to the SE in the north of Hexi Corridor. This view considered the northern margin of the Kuantan Mountain fault (west) and the southern margin of the Longshou Mountain fault (east) as the eastward extension part of the ATF (Hypothesis 3 in Fig. 1). Through the Kuantan Mountain, the fault involved various stratigraphic units into the strike-slip and thrusting belts in the Jinta Nanshan Mountain (Wang Jinrong et al., 2002). The Paleozoic succession from the Jinta Nanshan area got assembled together with the Altyn Tagh region in the southwest and with the Longshou Mountain area in the east during the Neoproterozoic. The sinistral slip and thrusting fault system may have formed in this time

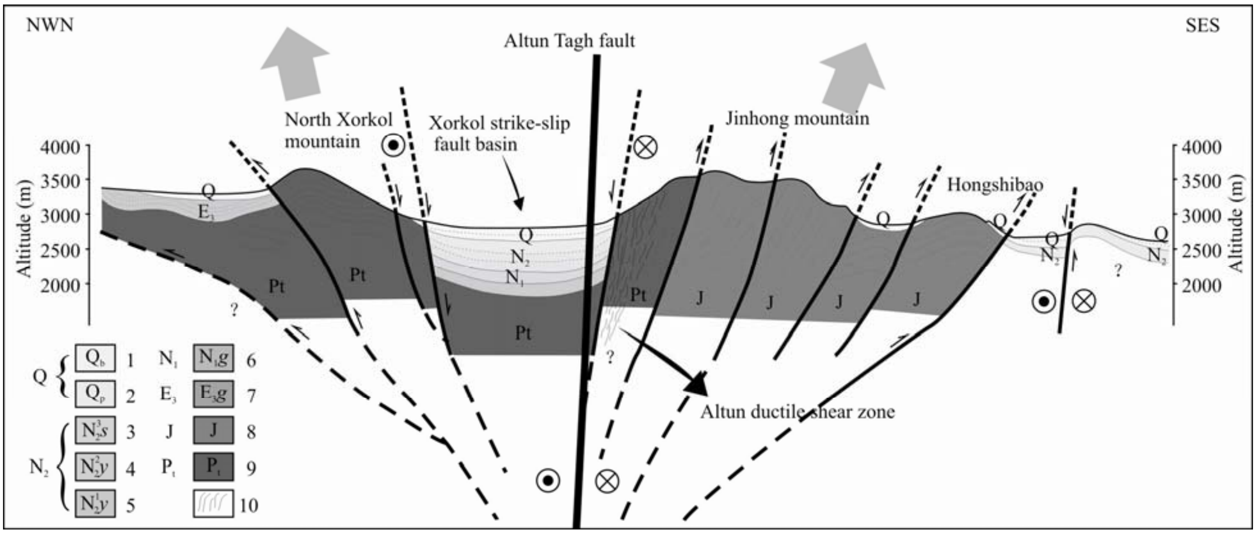


Fig. 3. the stuctural geology of the Xorkol section in the central segment of ATF (followed by Li et al., 2006).
1, Holocene; 2, Pleistocene; 3, Shizigou Fm.; 4, Upper Youshashan Fm.; 5, Lower Youshashan Fm., 6, Upper Ganchaigou Fm., 7, Lower Ganchaigou Fm., 8, Jurassic; 9, Lower Permian; 10, Ductile shear zone.

intervals (Cui Junwen et al., 1999; Wang Jinrong et al., 2002). The deep seismic reflection profiles indicate that the northern margin fault of the Kuantan Mountain (NFK) cut the crust and then go down to the mantle (Wu Xuanzhi et al., 1995). This fault indicated the position where the North China southward subducted beneath the Tibetan Plateau (Gao et al., 2001). The dip of NFK inversed to north near the surface from south in the deep. According to the paleomagnetic and sedimentologic data of the oldest Cenozoic Strata in the Hexi Corridor basin (Dai et al., 2005), the NFK has initiated the left-slipping at 40.2 Ma (the Middle Eocene), and it governed the Hexi Corridor basin developed, and caused the Hexi Corridor basin clockwise vertical-axis rotated by 14.7° from the Middle Eocene to the Miocene. This fault was also interpreted as being reactivated and turned into a strike-slip and into a dextral fault during the Miocene and Pliocene, and to form a "X" type structure, is association with the Altyn Tagh fault (Zhang Jin et al., 2007). The Kuantanshan-Longshoushan fault was active since ca. 1 Ma (IGSSB,1992; Meyer et al., 1998; Tapponnier et al., 2001; Zheng et al., 2013), indicating the periodic growth in most northern boundary of the Tibetan Plateau (Meyer et al., 1998; Tapponnier et al., 2001). Since the Pleistocene, the fault extended eastward to the Jinchang of Gansu Province and branched into 5 sinistral strike-slip faults, arrayed as a broom structure in the south of Alxa (Chen Wenbin and Xu Xiwei, 2006).

The second scenario of the SEE direction proposes that the ATF did not pass through the Hexi Corridor, but directly merged into the north Qilian fault. In this scenario, the deformation along the north segment of the ATF was largely accommodated by the uplift of the Qilian Mountain (Molnar and Tapponnier, 1975; Burchfiel et al., 1989; Yin et al., 2002; Luo et al., 2015; Shi et al., 2015). This phenomenon would have been significant in accordance with the GPS geodetic measurement (Bendick et al., 2000; Wang Genhou et al., 2001; Wang et al., 2002; Jiang et al., 2014; Cheng et al., 2015).

3 Timing of Activation of ATF

The initiation age and the duration are the most critical issues related to the ATF and its tectonic deformation. They are three hypotheses in relation to the initiation of the ATF fault, which are either the Paleozoic, Mesozoic or Cenozoic.

3.1 During the Cenozoic

This dominant working hypothesis but it includes three different views. The first is that the ATF strike-slip had its onset during the Miocene (Tapponnier et al., 1990, 2001; Wang, 1997; Metiver et al., 1998; Meyer et al., 1998; Wan Jinlin et al. 2001; Chen et al., 2002a; Chen Zhengle et al., 2002; Fang et al., 2007). This view was obtained the further support by the recent studies through comprehensive analysis of the tectonic deformation, mountain denudation and basin deposition in the Northern Tibetan Plateau (Chen et al., 2001; Yuan Sihua et al., 2008; Wang et al., 2010; Wu et al., 2012a; 2012b; Xiao Ancheng et al., 2013; Wu Lei et al., 2013; Chang et al., 2015). The second hypothesis argues that the AFT occurred during the Oligocene (or Eocene-Oligocene transition). For example, Meng et al. (2001) correlated the stratigraphy in both side of AFT, Qaidam-Qilian area and Tarim Basin, and speculated that the ATF separated Tarim and Qaidam-Qilian area before the Oligocene, with a left-lateral displacement of 400 km. The chronology of the Cenozoic sedimentary strata and tectonic deformation of the basins within and aside the ATF (Chen et al., 2004; Sun et al., 2005; Wang et al., 2006; Pei et al., 2009; Bovet et al., 2009; Lu et al., 2009; Zhuang et al., 2011; Pan Jiawei et al., 2015), sedimentary provenance (Ritts et al., 2004; Mao Liguang et al., 2013; Wang et al., 2016b), and the thermal chronology $^{40}Ar/^{39}Ar$ age of the rocks in the ductile shear zone (36.4 Ma and 26.3 Ma, Liu Yongjiang et al., 2003) and apatite fission-track age of the gneiss and granite in the ATF belt (35.6–13.6 Ma, Chen Zhengle et al., 2001) also support this view. The third view proposes that the ATF formed during the Early-Middle Eocene (e.g. Ge Xiaohong et al., 1998; Jolivet et al., 2001; Yin et al., 2002; Cowgill et al.,2003; Dai et al., 2005; Zhuang et al., 2011; Jia Dan et al., 2013; Mao Liguang et al., 2013; Ran Bo et al., 2013). For instance, Ge Xiaohong et al. (1998) inferred that the ATF occurred in the Eocene, in accordance with the formation of the reverse-S type synsedimentary structures in the Qaidam Basin. Yin et al. (2002) integrated data of sedimentary, Magnetostratigraphy and detrital apatite track dating of west Kunlun, Tarim, Qaidam and Hexi Corridor basins, and estimated an initiation age of ATF of 49 Ma. Cowgill et al. (2003) even demonstrated that the ATF started in West Kunlun area during the Eocene, and the left-lateral strike-slipping in this region was accommodated by the thrusting belts in the West Kunlun. The magnetostratigraphy data of the oldest Cenozoic sediments in the Hexi Corridor basin show that the first activation of ATF and the Northern Qilian fault happened about 40 Ma ago, followed by the second activation at about 33 Ma. These activations resulted in the uplift of the Qilian Mountains and adjacent regions, and in the clockwise vertical-axis rotation of the Hexi Corridor basin by 14.7° (Dai et al., 2005).

3.2 During the Mesozoic

This is another prevailing hypothesis for the history of ATF. Li Haibing et al. (2002), Li et al. (2002) and Xu

Zhiqin et al. (2001) proposed that the ATF strike-slip had its onset in the Early Triassic (about 245 Ma), Wang et al. (2005) thought it started earlier at 250 Ma. Jolivet et al. (2001) speculated that the early ATF and Kunlun faults initiated during the Late Triassic (Apatite fission-track age ranging from 221±22 Ma to 96±4 Ma), in relation to the collision between the Qiangtang and KunLun blocks, and following the the India-Asia collision (40±10 Ma). Ritts and Biffi (2000) argued that the ATF started left-lateral strike-slip in the Middle Jurassic, but Delville et al. (2001) proposes a younger age of Jurassic-Cretaceous (150 Ma±10 Ma), or earlier at 165-160 Ma (Wang et al., 2005). Liu Yongjiang et al. (2000) and Ge Xiaohong et al. (2001) gave an even younger estimation of Late Cretaceous (97 Ma–89 Ma), with a displacement of about 350 km–400 km, approximately synchronous to the formation of West Himalaya tectonic at 102 Ma–85 Ma. However, a later study by Liu Yongjiang et al. (2003, 2007) put this time back to the Late Jurassic-Early Cretaceous in relation with ^{40}Ar-^{39}Ar age of 178.4 Ma–135.4 Ma, obtained from the deformed granitic gneiss in the northern fault. Furthermore, the tectonic-stratigraphic features and volcanic activity observed as well as paleomagnetic data in the basins all point to a strongly active period of ATF during the Cretaceous (Vincent and Allen, 1999; Yang Jingsui et al., 2001; Chen et al., 2002a; Zhu Lidong et al., 2005; Li Haibing et al., 2006; Tang Yuhu et al., 2008; Wang Xiaofeng et al., 2008; Peng Nan et al., 2011; Zhong Fuping et al., 2011; Sun Zhiming et al., 2012; Tang Wenhao et al., 2012; Qin Suhua et al., 2013). Li Haibing et al. (2006) integrated the published data and concluded that the ATF had undergone 8 phases of strike-slip, i.e. during 245–220 Ma, 180–140 Ma, 120–100 Ma, 90–80 Ma, 60–45 Ma, Oligocene-Miocene, Pliocene-Pleistocene and Holocene.

3.3 During and prior to the Paleozoic

Zhang Zhitao (1985) firstly proposed that the ATF activity started during the early Paleozoic. Che et al. (1995) refined this time to the late Ordovician due to the lack of the Late Ordovician sediments in the Tazhong upheave. Some studies ascertained the early ATF as a Paleozoic plate suture (Che et al., 1995; Lai Shaocong et al., 1996; Liu et al., 1998; Liu Liang et al., 2015; Liu et al., 1999). Sobel and Arnaud (1999) further speculated that the ATF was a residual suture (Lapeiquan suture) which formed in the Early Silurian to Middle Devonian, equivalent to the Kudi suture. Liu Yongjiang et al. (2003) obtained the ^{40}Ar/^{39}Ar plateau age of 461Ma–445.2 Ma and 414.9 Ma-342.8 Ma and further confirmed that some thermal events took place during the Paleozoic. Recently, Chen Bolin et al. (2016), Zhang Ruoyu et al. (2016) and Wu Cailai et al. (2014, 2016) concluded that the Altyn Tagh area underwent three stages of tectonic evolution: Neoproterozoic-Cambrian oceanic crust expansion, Early to Middle Ordovician oceanic crust subduction and collision and Late Ordovician-Silurian extension post collision.

Zheng Jiandong et al. (1991a) considered that the Altyn Tagh region developed as an extension fault during the Variscian period until the Mesozoic, and was then transformed into a compressional and strike-slipping fault in the Cenozoic. Cui Junwen et al. (1999) determined that the sinistral strike-slip ATF started in the late Carboniferous, with expansion rate of only 1/2–1/13 as the Cenozoic. The fault grew fast during the Oligocene, especially after the Pliocene. Other researchers debated that the ATF occurred even earlier. For example, Zhou Yong and Pan Yusheng (1999) studied the Proterozoic arc structures, rheological fold morphology and rock microstructure, and proposed that the early left lateral strike-slip was at least 870 Ma old. Moreover, it also strike-slipped right-laterally from the Late Ordovician and Devonian (Zhou Yong and Pan Yusheng, 1998) or the Neoproterozoic (Yu Haifeng et ai., 1998).

4 Left-slip Displacement of the Altyn Tagh Fault

4.1 Strike-slip magnitude and spatial variation

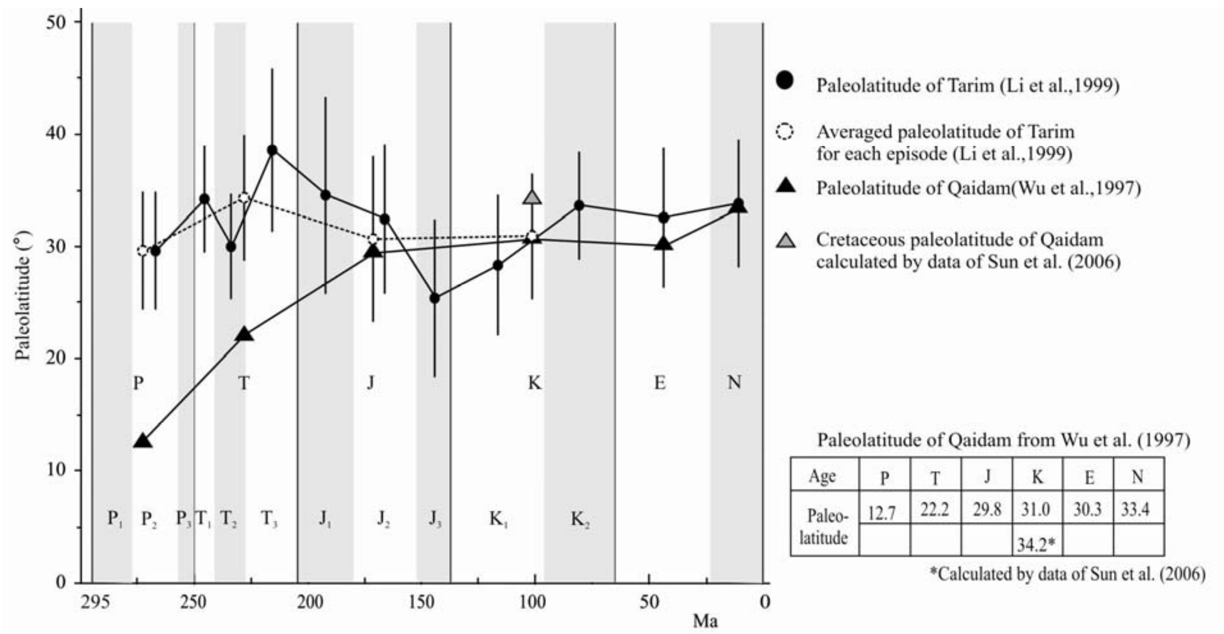
The strike-slip displacement and its variation is another essential issue for the ATF. There are three different viewpoints for the estimate of the amount of strike-slip displacement of the ATF: small, medium and large. Most researchers consider a relatively small displacement of the ATF of ca. 300–500 km. For example, Molnar and Tapponnier (1975) firstly speculated the overall slipping magnitude of 400 km since the Cretaceous. Other researchers reached similar conclusions by comparing the stratigraphy and magmatic rocks on both sides of the fault (total displacement of 350–400 km during the Mesozoic-Cenozoic; Xu Zhiqin et al.,1999; Ritts and Biffi, 2000; Meng et al., 2001; Ge Xiaohong et al., 1998; Gehrels et al., 2003; Cowgill et al., 2003). Huang Ligong et al. (2004) argued that the left-lateral strike-slip only took place in the Paleocene-Miocene with a maximum displacement of 400–500 km. Yin et al. (2002) determined the displacement of ATF at 470±70 km since the Early Eocene (49 Ma) and Chen et al. (2002a) estimated the displacement of 500±130 km between 24 Ma and 10 Ma using paleomagnetic data.

A larger displacement is also considered, between 550 km and 750 km. For example, Peltzer and Tapponnier (1988) and Cai Xuelin et al. (1992) proposed a maximum displacement reaching ~550 km since Mesozoic-Cenozoic, close to the estimate of ~580 km by Guo Shunmin and Xiang Hongfa (1998). Tapponnier et al. (1981) and Ding et al. (2004) propose a displacement of ~700km, while Ge Xiaohong et ai. (1998) propose a displacement in the range between 600–750 km, occuring during the Mesozoic.

The largest displacement considered by different research would reach a maximum of 900-1200 km. For example, Zhang Zhitao (1985) proposed a displacement starting in the Late Carboniferous, of ~1,200 km and Cui Junwen (1999) confirmed it with a distance of 1100 km or 1450 km. Li Haibing et al. (2007) reached a similar estimate of the displacement (900-1000km), but starting in the Middle Triassic. From the statements above, the estimate of the strike-slipped displacement during the Cenozoic is relatively close to about 400 km, but the estimate of displacement for the Mesozoic is still debated.

The spatial distribution of the sinistral strike-slip displacement of the ATF, varied along different segment. The displacement gradually reduced from the southwest to the northeast (Guo Shunmin and Xiang Hongfa, 1998; Meyer et al., 1996; Royden et al., 1997; Ding et al., 2004; Zhang et al., 2007;Luo et al., 2015). Along the western and central segment of the ATF the displacement was ~400 km since 40 Ma–37 Ma, to northeast, in the South Qilian segment (Shulenan Shan), it was ~150 km since 25 Ma–17 Ma (Ding et al., 2004), and in the Xorkol area it was 80-100 km at least since the Pliocene (Zhang Yue qiao et al., 2001; Chen et al., 2004). Furthermore, the eastern segment in the middle Qilian Shan and Hexi Corridor also has a displacement of ~150 km since the late Oligocene to the early Miocene (Ding et al., 2004), including 60–90 km since the Middle Miocene (Wang, 1997). Finally, toward to the Liupanshan area, the displacement was only ~60 km along Liupanshan fault since late Miocene, and 25 km along the Zhongwei-Tongxin fault (east of Liupanshan fault) during 5.3–3.4 Ma (Ding et al., 2004), and ~14 km along the Haiyuan fault since the Pliocene (Burchfiel et al., 1991).

The paleolatitude data (Fig. 4) indicate that since the Late Permian, the Qaidam Basin was located at the south of the Tarim Basin. This suggests that two basins underwent some episodes horizontal movement in the north-south direction. These movements were essentially linked to the plate tectonic events in the east Asia since the Late Permian, i.e. the Paleo-Asian Ocean closure at the Permian -Triassic transition, Cimmerian continent collision with Asia druing the Mesozoic and India collision with Asia during the Cenozoic (e.g. Liu, 1998; Yin et al., 2002; Dai et al., 2014). From the Late Permian to the Jurassic, the paleolatitude difference between these two basins decreased from 17 to 1. Taking into account the Tarim Basin in a relatively constant paleolatitude position (30-35°), this paleolatitude difference would be interpretated as the Qaidam Basin northward moving with a distance of ca.



Paleolatitude of Qaidam from Wu et al. (1997)

Age	P	T	J	K	E	N
Paleo-latitude	12.7	22.2	29.8	31.0	30.3	33.4
				34.2*		

*Calculated by data of Sun et al. (2006)

Paleolatitude of Tarim from Li et al. (1999)

Age	P_2	T_1	T_2	T_3	J_1	J_2	J_3	K_1	K_2	E	N
Paleo-latitude	29.7±10.6	34.1±9.4	30.0±9.3	38.7±14.6	34.7±17.6	32.4±13.2	25.2±14	28.2±12.6	33.8±9.6	32.6±12.8	33.7±11.3
Averaged Paleolatitude		34.26±11.1			30.76±14.93			31±11.1			

Fig. 4. the paleolatitude variations of the Tarim and Qaidam Basins.

1600 km between the Late Permian and Jurassic. Actually, the paleolatitude of the Tarim Basin varied during the Triassic and Jurassic. This may indicate that the Tarim basin also moved northward with regard to the Qaidam Basin, suggesting the ATF also strike-slipped in dextral within this time intervals. During the Cretaceous two basins were at the same paleolatitude (31°). This situation may indicate that there were no north-south direction movement between Tarim and Qaidam Basin. If the ATF were active during the Cretaceous, the strike-slipping of ATF would cause the basins being vertical-axis rotation rather than north- or southward movement. During the Cenozoic, the ATF reactivated left-lateral slipping, with an offset of about 1.3 latitudes (equivalent to distance of ca. 140 km). In the Neogene, two basins almost were located at the same paleolatitude, indicative of a very weak of the strike-slipping, but this was not in accordance with the geologic evidence (e.g. Yin et al., 2002; Ding et al., 2004).

4.2 Strike-slip rate

Due to the controversy on the timing and displacement magnitude of the ATF, it is also difficult to obtain a consensual conclusion for the strike-slip rate and its variation. For example, Yin et al. (2002) estimated an average slip-rate of 9±2 mm along the ATF since about 49 Ma. This estimate is very close to the geodetic data (9±5 mm) in the northern Tibetan Plateau (Bendick et al., 2000; Wang Genhou et al., 2001), and implies that the ATF has maintained a relatively steady deformation process since 49 Ma. But this estimate is more than twice the rate of 4±2 mm estimated for eastern segment of the ATF (east of 96 °E) since the Quaternary (Meyer et al., 1996). Li Hainbing et al. (2006) compiled the published slip-rates and obtained a variation of slip-rates along the ATF (Fig. 5). The compilation shows that the slip-rates are different along different parts of the ATF. Although the slip-rates obtained by different methods are quite different, in general, they can be divided into three segments, i.e. the west, central and east segment, with a slip-rate of 5–22 mm/a, 9–33 mm/a and 2–23 mm/a, respectively. The slip-rate of the central segment (between Kuyake and Annan dam) is higher than that of east segment (Annan dam eastward) and west segment (Kuyake westward). The slip-rate of the eastern segment gradually decreases eastward, especially with a sharp decrease at the branching-point. Totally, the ATF exhibited a low strike-slip rate after the collision of India with Asia. The rates varied in different segments and activity stages, and gradually decreased during the Quaternary Period (Meyer et al., 1996; Ding et al., 2004; Zhang et al., 2007; Luo et al., 2015).

5 Structural Properties and Growth Pattern of ATF

5.1 Structural property

The structural property of the ATF has also been in

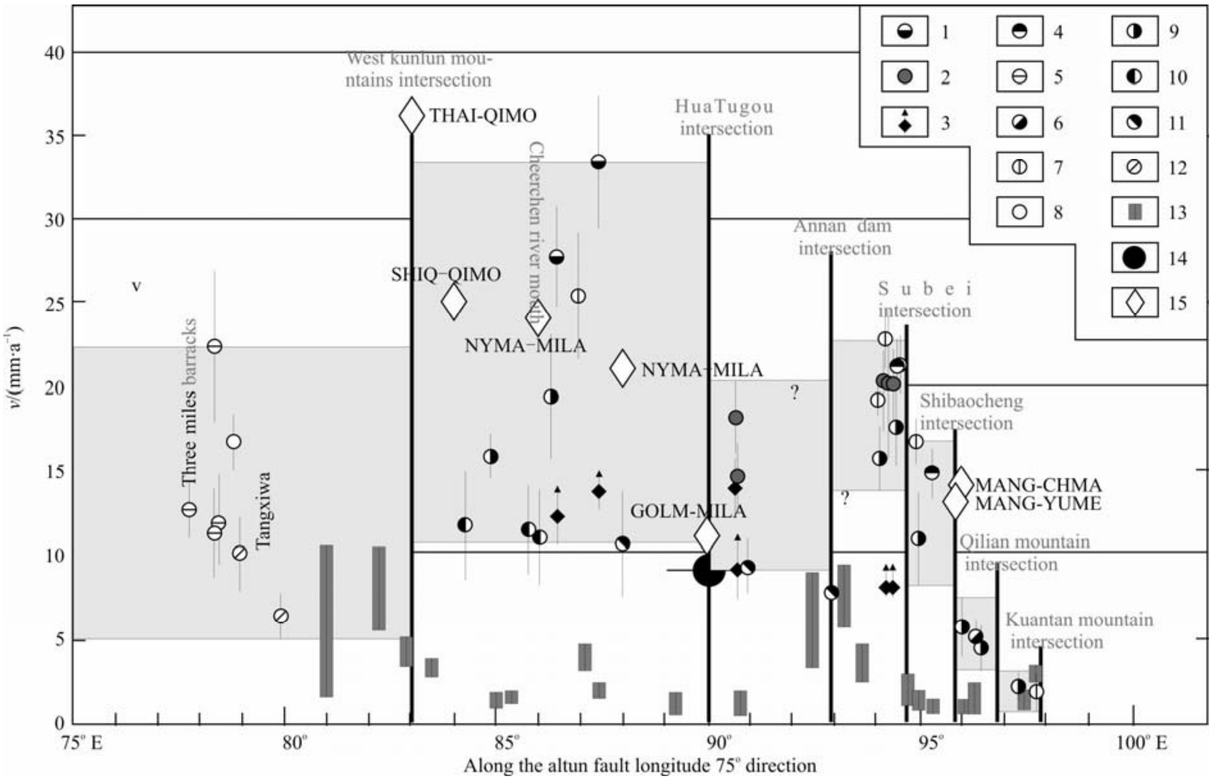


Fig. 5. Spatial variation of the slip-rate along the ATF (after Li et al., 2006 and the legend therein).

debated. For instance, some researchers thought it as a giant fault belt with a left-lateral slip and thrust and ductile shear properties (Zheng Jiandong, 1991a; Cai Xuelin et al., 1992). The fault activity onset during the Variscian and expanded during the Mesozoic, then transformed into a strike-slip fault due to the India-Asia collision. The fault started its activity as a compression and strike-slipping fault in the early stage of the collision, then the slipping style dominated during the Early Pleistocene or later (Zheng Jiandong, 1991b). Cui Junwen et al. (1999) argued that the early fault is a thrust but is then transformed into a thrust and strike slip fault, and superimposed to the normal slip since the Miocene. Xu Zhiqin et al. (1999) considered it as a strike-slip and transform fault. Wang Genhou et al. (2001) further demonstrated it as a sinistral and compressional transform fault since the Cenozoic. Liu Yongjiang et al. (2001) suggested that the ATF developed ductile shear and strike-slipping accompanied with a low-grade metamorphism in the deep part during the Late Cretaceous, and then extended upward to the surface and formed a strike-slip zone in the Middle Eocene. Xiao Ancheng et al. (2013) also demonstrated that the fault was dominated by basal shear during Late Eocene-Middle Miocene but by large-scale left-slip movement since then. The ductile shear would reach down to the mantle (Wittlinger et al., 1998; Xu Zhiqin et al., 1999), thus the ATF should be a lithospheric fault, with a brittle upper-crustal fault overlying a mantle shear zone (Wittlinger et al., 1998). Meanwhile, although most researchers considered the ATF as a sinistral strike-slip fault, the others debated it as a dextral slip during some time intervals. For example, Yu Huilong et al., (2002) obtained a small amount of paleomagnetic data and concluded that the ATF strike-slipped in sinistral during the Mesozoic, following in dextral during the Paleogene, and finally to sinistral again during the Neogene. Huang Ligong et al. (2004) compared the sedimentary characteristics and oil gas reservoir types among the Tarim, Qaidam and Dunhuang basins, and further described the ATF as a right-lateral strike-slip fault in the Paleocene-Miocene.

5.2 Growth pattern

With regard to the growth process of the ATF, there are two prevailing views related to its growth direction during the Cenozoic post the India-Asia collision. The first one thought that the direction is from the southwest to the northeast (e.g. Meyer et al.,1998; Tapponnier et al., 2001; Yin et al., 2002; Cowgill et al., 2003; Xu Xiwei et al.,2005). The growth process started by rupturing (cracking) in the central and south parts, then extending eastward. In the southwest the fault growth caused the formation of the Kunlun thrust system in the Early Eocene, and then of the Tianshuihai-Qimantag thrust faults during the Late Eocene and the Oligocene. To the northeast, this growth process simultaneously happened in the early Eocene and then expanded with the thrust history of the Qilian belt and the uplift of the Tibetan Plateau. The southern part of the ATF (south of the Qimantag) activated during the Eocene and the Oligocene (Yin et al., 2002). Then the Qimantag-Jinta segments activated during the Miocene (Yin et al., 2002; Cowgill et al., 2003). Some researchers argued that these segments initiated 10 Ma ago, and made the northern Tibetan Plateau eastward excursion with a distance of about 1000 km (Meyer et al., 1998; Tapponnier et al., 2001). The Altyn Tagh fault merged with the northern fault of Qilian during the Late Pleistocene and the earlies Quaternary, resulting in the Qilian Mountains clockwise rotated at 20–30° (Hou et al., 1999; IGCSA, 1992).

The second view proposed that the ATF developed from the northeast to the southwest (Cui Junwen et al., 1999). The strike-slip ATF was transformed from a thrust fault system in the northern Tibetan Plateau. The mechanism for the transformation was attributed to the lithospheric rigidity difference between the southeast (Kunlun-Qilian block) and the northwest (Tarim block) when thrusting northward. This difference caused the different thrusting velocity or the crustal thickness involved in the thrusting. The thrust and subsequent transformation along present-day the ATF and neighboring southeastern area (Kunlun-Qilian area) developed from the north to the south. The ATF can be regarded as a transforming and compressional deformation zone. It is decomposed into two components of deformation domain, one is left-lateral strike-slip and another is horizontal shortening and vertical stretching (uplifting). The former resulted in lateral movement along ATF and areas parallel to ATF, whereas the latter caused the shortening, crustal thickening and mountain uplift along the Altyn Tagh tectonic belt (Zhang Jianxin et al., 1998).

6 Discussion and Perspectives

Although existing studies concerning the Altyn Tagh Fault (ATF) have reached already large consensus over its history, some issues are still debated and need further research.

6.1 The history of the ATF

The ATF is a long-term active tectonic belt during the Mesozoic and Cenozoic, with multiple activity episodes. Along the whole fault, the activity history may encompass nine phases which can be well constrained by the multidisciplinary chronologic data, i.e. during ca. 250–220 Ma, 180–160 Ma, 150–100 Ma, 100–80 Ma, 60–45 Ma, 40–16 Ma, 14–6 Ma, 4–1 Ma and 0.1-present (Liu Yongjiang et al., 2000, 2003, 2007; Delville et al., 2001; Jolivet et al., 2001; Zhao et al., 2001; Yin et al., 2002; Chen et al., 2004; Dai et al., 2005; Fang et al., 2005; Wang et al., 2005; Li Haibing et al., 2006; Meyer et al., 1996; Zhuang et al., 2011; Ran Bo et al., 2013; Zheng et al., 2013; Wang et al., 2016a). The activity durations are clearly much longer than that of faulting quiescent. The kinematics (initiation, growth) varies during the different activity stages and along the different segments (e.g. Ritts and Biffi, 2000; Jolivet et al., 2001; Sobel and Arnaud, 2001; Yin et al.,2002; Liu Yongjiang et al., 2003; Cowgill et al., 2003; Ding et al., 2004; Li Haibing et al., 2006; Zhuang et al., 2011; Wu et al., 2012b; Chang et al., 2015). We can conclude that the current ATF formed first in the dynamic settings of the closure of Paleo-Tethys and collision of the Cimmerian continent, corresponding to the Qiangtang and Lhasa blocks with Asia in the Mesozoic (Yin and Harrison., 2000; Jolivet et al., 2001; Liu Yongjiang et al., 2003; Li Haibing and Yang Jingshui, 2004; Zhang Zhicheng et al., 2008; Dai et al., 2014). The Cenozoic fault activity is interpreted as related to the reactivation of the previous fault (i.e. the Mesozoic ATF) by the India-Asia collision. The first timing of fault starting activity during Cenozoic may indicate the age of distant deformation approaching the regions along ATF. The present studies suggest that deformation, along ATF, reached the Qaidam and Middle Qilian (inside the Tibetan Plateau) in the early Eocene (Zhuang et al., 2011), or later of 10±5Ma after the initial collision of India with Asia at 65–55 Ma (Yin et al., 2002; Dai Shuang,2003; Dai et al., 2009), and reached Hexi Corridor (outside the Tibetan Plateau) at 40.2Ma (late Eocene) after the entire India collision with Asia at 40 Ma or so (Dai Shuang, 2003; Dai et al., 2005).

Most researches showed indeed that the ATF activated in the Early Triassic to Jurassic (Ritts and Biffi, 2000; Yin and Harrison, 2000; Delville et al., 2001; Ge Xiaohong et al., 2001; Jolivet et al., 2001; Xu Zhiqin et al., 2001; Li Haibing et al., 2002, 2006; Liu Yongjiang et al., 2001, 2003, 2007). The Early Cretaceous is the most activity period of the fault (Delville et al., 2001; Liu Yongjiang et al., 2003, 2007; Li Haibing et al., 2006; Tang Yuhu et al., 2008). These activities may be related to the distant deformation effect of the collision of Qiangtang and Lhasa blocks with Asia in the Mesozoic (Yin and Harrison, 2000; Dai et al., 2014). However, these speculations were largely based on the thermal chronological data, such as Ar-Ar (e.g. Liu Yongjiang et al., 2003) or apatite/zircon fission track (e.g. Jolivet et al., 2001), i.e. the thermal or tectonic events. This still need more other evidences such as the detailed tecto-stratigraphy succession. Some issues should be addressed in the future studies for the Mesozoic history of ATF:1) was the Mesozoic ATF the distant deformation boundary of the collision zone of the Qiangtang and Lasa with Asia? 2) When and how the deformation propagated to the ATF area? what is the tectonic deformation and sedimentological respond along the ATF? 3) what is the coupling relationship between the Mesozoic history of ATF and the distant deformation propagation from the collision zones? 4) How long the displacement happened in the Mesozoic?

During the Paleozoic and Neoproterozoic, three episodes of tectonic movement, magmatism and metamorphism took place in the region of the Altyn Tagh (Chen Bolin et al., 2016; Zhang Ruoyu et al., 2016; Wu Cailai et al., 2014, 2016), indicating this region has undergone a long-term oceanic plate tectonic evolution. Some studies demonstrated that the regions along present ATF was a suture (e.g. Che et al.,1995; Lai Shaocong et al., 1996; Che Zicheng et al., 1998; Liu et al., 1998; Liu Liang et al., 1999, 2015; Sobel and Arnaud, 1999). Furthermore, some researchers proposed that the sinistral ATF had onset in this time intervel (e.g. Zhang Zhitao, 1985; Yu Haifeng et al., 1998; Cui Junwen et al., 1999; Zhou Yong and Pan Yusheng, 1999), with a sinistral displacement of 900-1500km (Zhang Zhitao, 1985; Cui Junwen et al., 1999). Actually, we think that these geologic records only account for the tectonics, magmatic and metamorphic events in the Altyn Tagh area in the early Paleozoic. Those events are unlikely to be interpreted as the activities of the fault, at least, not the present-day definition of ATF. Therefore, we do not think that the ATF had onset as early as the Paleozoic.

6.2 Displacement along ATF

The displacement along the ATF is another important controversial issue, mostly concerning its timing (starting and end time and duration) and magnitude of displacement along the ATF. The main reason of the controversial results is probably related to the fact that the different research studies employed different methodology, or that each individual study was would concern a restricted time interval or segment of fault. For example, study using sedimentology (Chen Zhengle et al., 2001; Chen et al., 2004; Ritts et al., 2004; Yue et al., 2001, 2004; Yin et al., 2002; Yuan Sihua et al., 2008; Wang et al., 2010; Wu et al., 2012a; 2012b; Mao Liguang et al., 2013; Ran Bo et al., 2013; Wang et al., 2016b), tectonic deformation analysis (Cai Xuelin et al., 1992; Zheng Jiandong, 1991b; Wang, 1997; Metiver et al., 1998;Meyer et al., 1998; Tapponnier et al., 1990, 2001; Li Haibing et al., 2006; Zhu et al., 2006; Zhuang et al., 2011; Wu Lei et al., 2013; Xu Bo et al., 2013; Xiao Ancheng et al., 2013), thermal chronology (Geoge et al., 2001; Jolivet et al., 2001; Wan Jinlin et al.,2001; Chen Zhengle et al., 2002; Cowgill et al., 2003;

Liu Yongjiang et al., 2003, 2007; Wang et al., 2006; Clark et al.,2010; Zheng et al., 2010) or Paleomagnetism (Chen et al., 1992, 1993, 2002a, 2002b; Gilder et al., 2001; Dupont-Nevit et al., 2002a, 2002b, 2003; Dai et al., 2005; Chang et al., 2015; Wang et al., 2016a) have reached very different conclusions.

The majority of estimates for left-lateral displacement of ATF concentrated in ca. 400 km during the Cenozoic (Xu Zhiqin et al., 1999; Ge Xiaohong et al., 1998; Meng et al., 2001; Yin et al., 2002; Gehrels et al., 2003; Cowgill et al., 2003). The displacement of ATF is generally longer in the west segment and in the early stage of fault (Guo Shunmin and Xiang Hongfa, 1998; Meyer et al., 1996; Royden et al., 1997; Ding et al., 2004; Zhang et al., 2007; Luo et al., 2015). During the Quaternary, the slipping rate are bigger in the middle segment of AFT (IGSSB, 1992; Bendick et al., 2000; Van der Woerd et al., 2001; Ding et al., 2004; Mériaux et al., 2004, 2005; Gold et al., 2009, 2011; Chen et al., 2013; He Wengui et al., 2015). Among these estimates, some are clearly constrained by the chronological data. For instance, Huang Ligong et al. (2004) proposed that the longest offset is 400–500 km which happened in the Paleocene to Miocene. Yin et al. (2002) argued that 470±70 km since 49Ma. But Cowgill et al. (2003) emphasized that only south segment (Minfeng-Qiemo) displaced at 475±70 km since Eocene. These estimates give a low slip rate of 9±2 mm/yr, similar to the rates determined by GPS (Bendick et al., 2000; Wang et al., 2002). However, Zhuang et al. (2011) speculated that this displacement took place between Early Oligocene and Miocene. This gave a bigger slip rate than the previous estimation. Chen et al. (2002) calculated the offset as 500±130 km between 24–10 Ma, using a paleomagnetic data, yielding a much higher rate than others. Even though, the strike-slipping rate along the fault are basically lower since it started activation (Meyer et al., 1996; Bendick et al., 2000; Yin et al., 2002; Ding et al., 2004; Wallace et al., 2004; Li Haibing et al., 2006; Zhang et al., 2007; Cowgill et al., 2009; Luo et al., 2015).

For the displacement during the Mesozoic, the estimates are roughly and mingled with the Cenozoic. For example, some studies proposed that total displacement at 350–400 km (e.g. Molnar and Tapponnier, 1975; Xu Zhiqin et al., 1999; Ritts and Biffi, 2000; Meng et al., 2001; Gehrels et al., 2003). Others gave a bigger estimate as 550–700 km since the Mesozoic (e.g. Peltzer and Tapponnier, 1988; Cai Xuelin et al., 1992; Guo Shunmin and Xiang Hongfa, 1998). Based on these estimates, here we have an estimate of ca. 150–300 km of ATF displacement during the Mesozoic.

6.3 Tectonic effect of the strike-slip

Most researchers evidenced that the Tarim and Qaidam, the two blocks aside of the ATF, rotated at vertical axis, and that this block-scale rotation resulted from the left-lateral strike-slipping of the ATF (e.g. Zheng Jiandong, 1991b; Li Yongan et al., 1992; Yang Huixin et al., 1992; Huang Huafang et al., 1993; Rumelhart et al., 1999, 2000; Yu Huilong et al., 2002; Fang Dajun et al., 2001; Li Pengwu et al., 2001, Yang et al., 2001; Gilder et al., 2001; Chen et al., 2002a, Fang et al., 2003; Yan et al., 2006, Bosboom et al., 2014). However, the latest paleomagnetic data do not support this hypothesis. For example, Dupont-Nivet et al. (2002a, 2002b) argued that these two block did not take place obvious vertical-axis rotation since the Miocene. The studies from Tianshan (7°±2.5° during the Miocene, Avouac et al., 1993; Sobel and Dumitru, 1997; Yin et al., 1998) and the latest paleomagnetic and anisotropy of magnetic susceptibility data for the Eocene to the Miocene strata of the Qaidam basin (Yu et al., 2014a, 2014b) also support this argument. Sun et al. (2006), Sun Zhiming et al. (2012) speculated that the Qaidam block or the whole northeastern Tibetan plateau has not moved northward and did not rotate on a vertical axis since the Cretaceous. Sun Zhiming et al. (2012) disputed the previous hypothesis that the Qaidam (probably together with Tarim) northward moved in the distance of 740±500 km to 1000 km, and clockwise rotated about 30° with regard to the North China block (Frost et al., 1995; Halim et al.,1998; Chen et al., 1993, 2002b). Therefore, no obvious vertical-axis block-scale rotation took place at both side of ATF. This indicates that the Altyn Tagh Fault as a pure shear fault (Cai Xuelin et al., 1992; Delville et al., 2001).

However, the paleomagnetic data indicated that a vertical-axis rotation took place in the basins within Altyn Tagh fault belt (Chen et al., 2002a; Dai et al., 2005; Li Haibing et al., 2006; Yan et al., 2013). Therefore, in the northern of Tibet Plateau and neighboring areas, probably there were no obvious vertical-axis block-scale rotation in the huge block such as whole Tarim and Qaidam Basin, but there existed apparent basin-scale vertical-axis rotation in the small basin within ATF belt (e.g. Xorkol, Hexi Corridor, Changma basin). This basin-scale rotation may be an important way to accommodate the tectonic deformation along the ATF.

6.4 Perspectives

In order to obtain accurate strike-slip history, displacement magnitude and the tectonic effect of ATF, both high-resolution chronology data and geologic evidence are required. Therefore, future studies should to be pluri-disciplinary and quantitative. We suggest that high-resolution magnetostratigraphic dating be conducted, together with collection of large geomagnetic data (declination and inclination) for the Mesozoic and Cenozoic sedimentary strata within and aside of the ATF. However, paleomagnetic techniques should be carefully applied. For example, Wu Huaichun et al. (2002) estimated a displacement magnitude of dextral strike-slip of 333 km post the Pliocene through paleomagnetism, even if these conclusions are obviously in disagreement with the geological evidence (Meng et al., 2001; Yin et al., 2002; Ding et al., 2004) and the 3D modelling (Cheng et al., 2015). In a small scale, i.e. in a basin or along a section, we suggest, that the paleomagnetic declinations and inclinations are averaged for a time window (age intervals or stratigraphic unit, thickness, etc.), then these averaged data can be used to discuss the horizontal moving or vertical-axis rotation of the basin or regions which they located. All these paleomagnetic data should be confronted with local other geologic data.

7 Conclusions

In the last three decades, the study on the timing, strike-slip displacement and growth mechanics of the Altyn Tagh fault (ATF) has made great progress and reached some consensus even if some questions are still open.

(1) The NEE-trending 1600-km-long ATF is a strike-slip and thrust fault which underwent multiple episodes of activation. The direction, time and magnitude of its extension eastward is still unclear. The ATF was predominately active over the Mesozoic and Cenozoic era. The activation during the Cenozoic was related to the collision of India with Asia, but the relationship between the AFT activation during the Mesozoic and the collision of the Cimmerian continent (Qiangtang and Lasa blocks) with Asia still need to be understood.

(2) The ATF strike-slipped with a left-lateral displacement of ~400 km in the Cenozoic, and the magnitude of displacement was longer in the western segment and in the early stage of the fault activation than that in the east segment and in the later stage. The ATF left-lateral slipping magnitude may be between 150–300 kilometers over the Mesozoic.

(3) The latest paleomagnetic data show that the vertical-axis rotation did not take place in the Tarim and Qaidam basins during the Cenozoic, but took place in the small basins with ATF belt. The rotation within the ATF belt may play an important role in absorbing the tectonic deformation and the displacement of the ATF.

(4) To fully and accurately understand the ATF activity history and mechanism, more studies are requested, such as the temporal and spatial coupling relationship between the collision of Cimmerian continent with Asia and the formation and activation of the AFT during the Mesozoic. Meanwhile, the study of the tectonic deformation history constrained by a high-resolution and accurate chronology (e.g. magnetostratigraphic dating and the paleomagnetic parameters) of the sedimentary basins within and in both side of AFT should also be addressed.

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About the first author

DAI Shuang, male, born in Xihe county of Gansu Province, China, in December, 1967.He received his Ph.D. Degree at Lanzhou University in 2003. Now he is a professor at Lanzhou University and his current research interests are tectonics and climatic change. He has published over 60 papers in peer-reviewed journals such as Nature and Journal of Geophysical Research. Add: 222 South Tianshui Road, Lanzhou, Gansu, China. 730000