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Large ancient earthquakes in the western Issyk-Kul basin (Kyrgyzstan, northern Tien Shan)

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ABSTRACT

New paleoseismological and archaeoseismological data from the western Issyk-Kul basin of Kyrgyzstan (northern Tien Shan) provide new insights on active fault in the actively-deforming, basement-involved thrust system of Central Asia. Newly discovered fault scarps follow south-and north-dipping thrust faults which delineate the Kyrgyz and Kungey ranges bordering the Issyk-Kul basin. Motion on these faults generated earthquakes with magnitudes 6.2–7.6 and MSK-64 shaking intensities VIII-XI. Deformation observed in the zone of the Toguz-Bulak fault results from two Holocene earthquakes and another event that occurred about 8000 yr BP. Two more events, at 13,000 and 3000 yr BP, deformed the northeastern periphery of the Kyzyl-Ompul Uplift. Archaeoseismological research in the Northern Sary-Bulun settlement in the western periphery of the Boz-Barmak Uplift, revealed traces of another earthquake of MSK-64 shaking intensity I ≥ VIII dating back to the 12th Century. The obtained data correlates well with results of previous paleoseismological and archeoseismological studies. They show that in the northern Tien Shan there were clusters of strong earthquakes with ages of 14–13, 8, 4–3 ka ago and in the 11–12th centuries AD divided by periods of 4–5 ka. We infer that coseismic slip on these faults may have formed a tectonic dam at the edge of the basin through growth of the Boz-Barmak Uplift, and this dam ultimately deflected the Chu River into its modern channel which bypasses the lake. Lacustrine sediments in the northeastern periclinal segment of the Boz-Barmak Uplift bear signatures of soft-sediment deformation structures (seismites) corresponding to seven M ≥ 5–5.5 (I ≥ VI-VII) earthquakes timed at about 20,000 yr BP.

1. Introduction

The Tien Shan of Central Asia represents one of the largest (∼2500 km long and 300–500 km wide) and most active intracontinental orogenic system on earth (Avouac et al., 1993; Abdrakhmatov et al., 1996; Molnar and Ghose, 2000). This orogenic system formed in direct response to the Indo-Eurasian collision in what had been the back-arc setting of the southern Asia margin prior to collision (e.g. Molnar and Tapponnier, 1975; Tapponnier and Molnar, 1979; Le Pichon et al., 1992; Yin, 2010). The orogenic style of this system is important because it converted what had been stable continental crust into a complex system of basement involved thrust ranges and adjacent basins (Schultz, 1948; Tapponnier and Molnar, 1979; Chediya, 1986; Burtman, 2012). The internal structure of these systems is complex and recent studies have demonstrated patterns of distributed deformation throughout the region with local interactions among thrust systems and between strike-slip and thrust systems (Chediya, 1986; Jolivet et al., 2010; Yin, 2010; Selander et al., 2012; Macaulay et al., 2014).

In this study we consider the active deformation of the Issyk-Kul basin in the northern Tien Shan (Fig. 1). The Issyk-Kul basin region is actively deforming but surrounded by the relatively stable Kazakh and Junggar blocks in the north and Tarim in the south (Fig. 1). Issyk-Kul is the largest intramontane basin in the northern Tien Shan with a length

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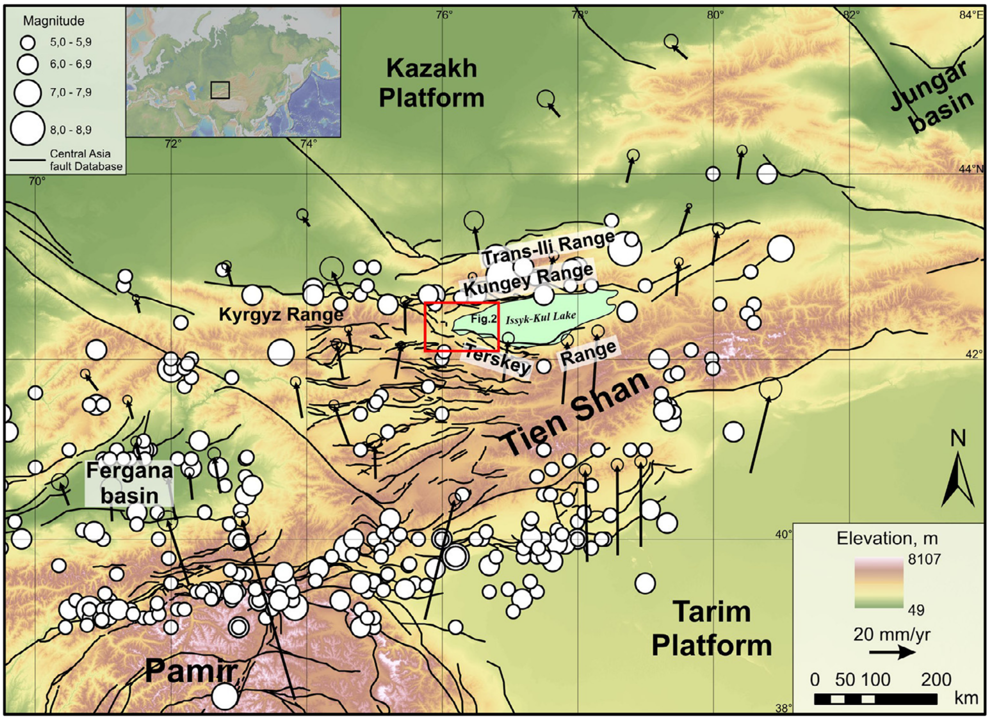

Fig. 1. Location map of study area in northern Tien Shan, Central Asia. The active faults from the Central Asia Fault Database of Mohadjer et al. (2016). The historical and instrumentally registered earthquakes are taken from Kal'metjeva et al. (2009). GPS-derived velocities with respect to Eurasia (Zubovich et al., 2010). The ellipses are 95% confidence. Digital elevation model (SRTM) was made from (http://srtm.csi.cgiar.org/).

of 250 km and a width of 80 km and a Cenozoic basin fill of almost 5000 m (Chediya, 1986; Fortuna, 1993). The basin is largely filled by an internally drained lake, Lake Issyk-Kul, with a maximum depth of 668 m (De Batist et al., 2002). The total Cenozoic structural relief in the Issyk-Kul area exceeds 10 km given the highest elevations of the Terskey (5281 m) and Kungey (4760 m) ranges plus the basin fill (Fig. 1).

An important scientific problem in the region is the analysis of its seismotectonics and paleoseismicity, because reliable seismological data are limited here to the period of the last 200–250 years (Kondorskaya and Shebalin, 1977; Kal'metjeva et al., 2009). The main source of information about the location of seismic foci zones, maximum possible magnitudes and repetition periods of large earthquakes is data of paleoseismological and archeoseismological studies. In this paper we describe the active deformation in the western end of the Issyk-Kul basin (Fig. 2). We begin with a brief review of the local geology and then describe results from active tectonic studies evaluating the paleoseismic history of the region. We report new data on prehistoric and historic seismicity from the western end of the Issyk-Kul basin. These findings have important implications for active tectonics in the area which is locally densely populated and hosts depositories of toxic and nuclear wastes. We use these observations to discuss the implications of the distribution of active structures to late Quaternary evolution of the region. We conclude with a hypothesis that this region carries a potential for better understanding of ancient intramontaine lacustrine systems through assessment of the role of hydrologic balances when tectonics deflects rivers into, or out of, the intramontaine system.

2. Geological setting

2.1. Tectonic setting

The modern Tien Shan trends E-W and has, contraction-related basin and range terrains, with more than 10 km of structural relief, based on the displacement of the Mesozoic pre-orogenic erosion surface. The ranges formed under transpression as typical flower structures, while the intermontane basins delineated by reverse (thrust) faults and related folds are ramps or half-ramps filled with several kilometers of sediment (Chediya, 1986; Tibaldi and Graziotto, 1997; Tibaldi et al., 1997, 2015; Thompson et al., 2002; Bullen et al., 2003; Buslov et al., 2007; Jolivet et al., 2010; Korjenkov et al., 2011; Selander et al., 2012; Delvaux et al., 2013; Goode et al., 2014; Macaulay et al., 2014). Total Cenozoic crustal shortening amounted to 100–250 km (Avouac et al., 1993; Abdrakhmatov et al., 1996; Burtman, 2012). Current shortening rates by GPS measurements reach 20 mm/y (Abdrakhmatov et al., 1996; Yang et al., 2008; Zubovich et al., 2010).

Many faults in the region are active seismogeneic structures responsible for large historic and instrumentally recorded earthquakes, including several great events that occurred in the northern Tien Shan within the past 100 years. These include: the Belovodsk (02.02.1885; M = 7.0; Io = IX-X), Verny (08.06.1887; M = 7.3; Io = IX-X), Chilik (11.07.1889; M = 8.3; Io = X), Kemin or Kebin (03.01.1911; Ms = 8.2; Io = X-XI), Djalanash-Tyup (24.03.1978; M = 7; Io = VIII-IX), Chon-Baisoorun (12.11.1990; M = 6.4; Io = VIII), and Suusamyr (18.08.1992; M = 7.3; Io = IX-X) earthquakes (Kondorskaya and Shebalin, 1977; Ghose et al., 1997; Mellors et al., 1997; Djanuzakov et al., 2003; Kal'metjeva et al., 2009). The directions and amounts of seismotectonic strain inferred from source parameters agree with GPS estimates (Molnar and Ghose, 2000; Tychkov et al., 2008).

The Tien Shan developed upon a pre-existing stable platform with a thin veneer of Mesozoic sedimentary rock underlain by a basement of Precambrian and Paleozoic metamorphic, volcanic, and sedimentary complexes intruded by intermediate, felsic, and mafic igneous rocks (Fig. 3). Deformation of the Late Paleozoic-Cretaceous erosion surface in the Issyk-Kul area began during the deposition of the 70 m thick Late Cretaceous-Paleogene Kokturpak Fm. (Sidorenko, 1972; Chediya, 1986; Trifonov et al., 2008; Burtman, 2012). The Kokturpak deposits crop out in small areas north and south of the Lake (Fig. 3) and consist of red, brown, and purple[1] clay and silt with minor salt and gypsum, intercalated with thin layers or lenses of whitish limestone and marl. In the basin periphery, the formation also includes red, pink, and grey alluvial siltstone, sandstone, conglomerate, and breccia. At the base of the

[1] For interpretation of color in Figs. 2 and 3, the reader is referred to the web version of this article.