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Archaeoseismological Studies and Structural Position of the Medieval Earthquakes in the South of the Issyk-Kul Depression (Tien Shan)

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Abstract—We carried out archaeoseismological studies in the Southern Issyk-Kul region (Kyrgyz Tien Shan) and obtained radiocarbon datings of the collected samples. These data suggest that the sources of strong earthquakes have occurred in this territory in the 11th and (probably) 16th centuries. These earthquakes had magnitude $M \geq 7$ and seismic intensity of at least $I \geq 9$. The sources of these earthquakes were associated with the local adyr (piedmont) faults—components of the Pre-Terskei border fault. Our results demonstrate considerable underestimation of the seismic hazard for the South Issyk-Kul region in the latest *Seismic Zoning Map of Kyrgyz Republic* (2012), which should be taken into account in the construction of the new seismic zoning map for Kyrgyzstan.

Keywords: archaeoseismology, Issyk-Kul, Tien Shan, radiocarbon dating, seismic deformations, medieval earthquakes, medieval archaeological sites, tash-koro, the Turks, the Karakhanids

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INTRODUCTION

The Issyk-Kul region is located within the seismically active territory of Tien Shan and frequently experiences strong earthquakes (Dzhanuzakov et al., 2003). However, the epicenters of all the catastrophic earthquakes that occurred here are largely confined to the northern and eastern segments of the Issyk-Kul depression or, more exactly, to its mountain framing. Instrumental seismic network has not recorded strong ground shaking in the Southern Issyk-Kul region. Nevertheless, our studies conducted in 2009–2014 revealed the deformational structures of seismotectonic and seismogravitational nature, which were previously unknown. These structures were identified in the basins of the Kadzhi-Sai and Tossor rivers (Figs. 1 and 2). In combination with the deformations in the medieval archeological monuments, the newly revealed deformation structures mark the epicentral zones of the strong ancient earthquakes (Late Quaternary, Holocene, and historical) that occurred in the territory of the Southern Issyk-Kul region (Korzhenkov et al., 2014a; 2014b; 2014c; 2014d). The study of the revealed paleoseismic deformations enabled us to conclude about the underestimated seismic hazard in this region of the Issyk-Kul depression which is classi-

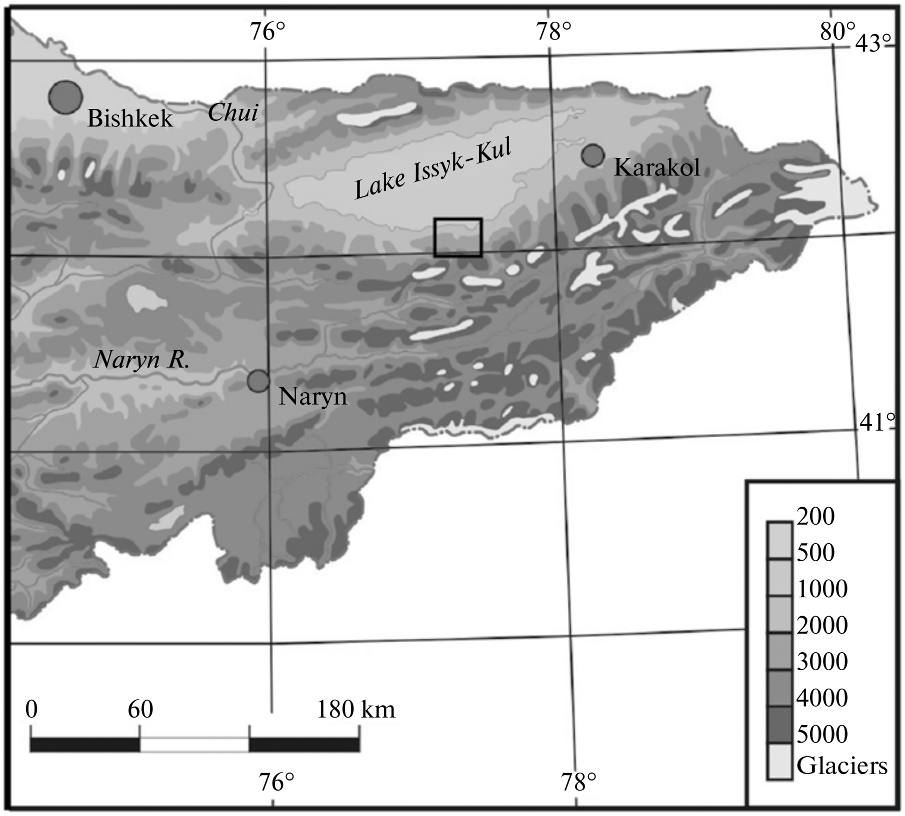

Fig. 1. The eastern part of the Kyrgyz Republic. The box in the Southern Issyk-Kul region shows the study region (see Fig. 2).

fied as a zone prone to the earthquakes with $M \leq 6.5$ in the last map of seismic zoning of the territory of Kyrgyz Republic (Abdrakhmatov et al., 2012). For surveying the territory, we used the standard set of the field observation methods which are used in archaeology and palaeoseismology.

ARCHEOLOGICAL STUDIES

We note that the study region is not only noted by the intricate rock exposures forming grotesque patterns (Korzhenkov and Yudakhin, 2011; Korjenkov et al., 2006; 2009) but also by the high ancient burial mounds (kurgans), petroglyphs, and remains of ancient settlements. For example, the remains of the ancient settlement as close as one km from the mouth of the Kadzhi-Sai River were explored. The archaeological studies supervised by D.F. Vinnik (Vinnik et al., 1978) established that these preserved remains are the caravansary built near the lake coast in the 10th to 13th centuries. The walls of the caravansary and other structures are composed of mudbrick of the same type. Excavations of this site yielded numerous fragments of pottery, grain mills, mill-stones, grindstones, human, and animal bones. In the upper reaches of the Kadzhi-Sai River (Kadzhi-Saz stow) and neighboring territory there are burial mounds of the sixth century B.C. to eighth century A.D. and two settlements from the 10th to 12th centuries A.D. North of the Tossor–Bokonbaevo road, traditional images of animals, mainly goats, are seen carved on the stones. The petroglyphs are dated to the first millennium B.C. During the field seasons of 2013–2014, we thoroughly surveyed the Kadzhi-Saz and Tossor archaeological sites and collected samples for the radiocarbon dating.

ARCHEOLOGICAL STUDY OF THE KADZHI-SAZ SITES

The Kadzhi-Saz sites are located in a small intermountain valley between the Tegerek and Kyzyl-Kungei ridges in the north and Terskey Ala-Too Range in the south. The archeological sites themselves are situated in the northern part of the region, in the Kadzi-Saz area, opposite to the junction of the Tegerek and Kyzyl-Kungei mountains. Here, a narrow antecedent gorge of the Kadzhi-Sai River cuts its way to the lake through the actively rising anticlinal uplift. The name of this site, saz, speaks of its bogginess due to the tectonic damming.

There are two sites. They are located within 200–300 m opposite each other on the eastern and western sides of the Kadzhi-Sai River (Fig. 3), which rises from the bogs somewhat upstream.

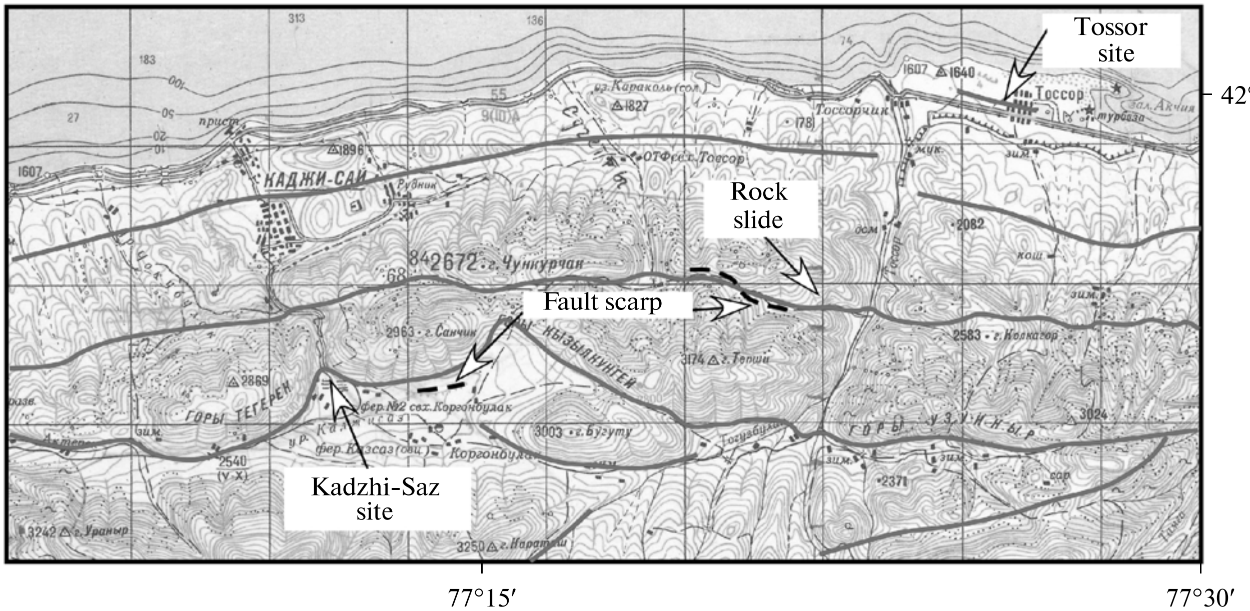

Fig. 2. The studied deformations in the basins of the Kadzhi-Sai and Tossor rivers. As a base map, the 1 : 200000 topographic chart is used. The grid spacing is 4 km. The solid lines on the map show the main faults.

The first record of the Kadzhi-Saz sites was made by A.M. Fetisov in 1878 (Fetisov, 1878). In 1978, they were surveyed by the archaeologist D.F. Vinnik (Vinnik et al., 1978; *Biosfernaya* ..., 2002), who determined the time of their functioning from the 10th to 12th centuries A.D. by analyzed the surface ceramic material. He describes these sites in the following way.

Kadzhi Saz archaeological site I. Four-cornered, 70 × 70 m, the walls with a height of 1–3 m. The entry gate is located in the center of the western wall. Remains of the ditch are fragmentarily present along the perimeter of the site. Cultural layer is insignificant.

Kadzhi Saz archaeological site II. Four-cornered, 60 × 60 m, the walls with a height of 1.5–3 m. The entry gate is located in the center of the eastern wall. The cultural layer has a small thickness.

Our survey generally supported this overall characteristic. However, both sites have a more complicated perimeter of the rampart, and the positions of the entry gates are not that clearly determined. At the time of our survey, both sites were completely (including the walls) covered by a dense bog vegetation, mainly cheegrass, which to a certain extent impeded the visual examination and determination of the topographic features.

The **Eastern Kadzhi Saz** archaeological site (site I in Vinnik's nomenclature) has been preserved better. Its walls are visually thicker and higher, presumably with a breach in the southwestern corner. The origin of this breach cannot be established without additional large-scale excavation works. The shear or downward displacement of the wall due to the earthquake is one of the probable scenarios.

The **Western Kadzhi Saz** archaeological site (site II according to Vinnik) is located somewhat lower in the present-day local topography. The walls appear to be lower and thinner. In the center of the site, a water-source well was drilled and the water pipes were installed during the Soviet time. For running the pipe outsides, the northern wall was cut near its western corner. At present, the edges of the cut are sloughed and partially covered in turf, and the floor is bogged due to the water inflow from the leaking well. Our survey revealed several ditches in the middle of the northern wall, near the southern corner on the western wall, and almost in the middle of the eastern wall. The latter most fully intersects the rampart and is the least covered in turf; and at its location we made a cut through the rampart (Fig. 4).

Following the contour of the previous cut, the section acquired a more complicated form. Segments 1, 3, and 5 intersect the wall; segment 3 is located somewhat more south, whereas segments 2 and 4 are parallel to the wall and connect segment 3 with segments 1 and 5, respectively. Two meters after passing the highest point, the cut was stopped without having reached the basement of the wall.

It was established that the body of the wall was constructed by "pakhsa" method—sequential laying of horizontal beds of soil with a thickness of 1 to 10 cm.

In the context of the objectives of our study (revealing signs of seismic activity in archaeological monuments), the central segment turned out to be the most important one. Here, on the southern wall of the section, a series of cracks and fractures were revealed. In some places, they cut through the entire thickness of

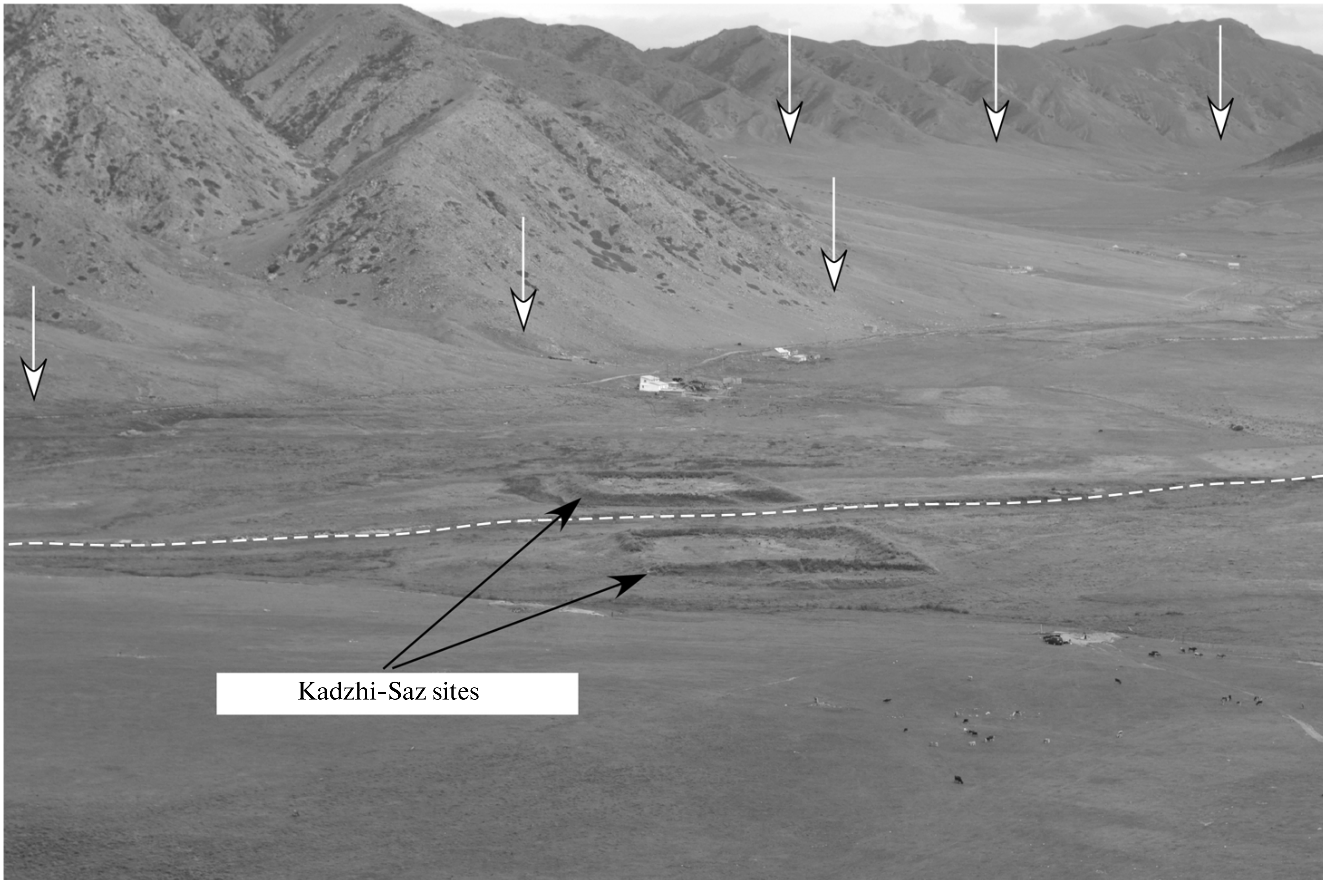

Fig. 3. The medieval fortresses (sites, caravansaries): Eastern and Western Kadzhi-Saz, which guarded the mountain gate through the gorge of the same name. Presently located on the bog formed by tectonic damming by the Tegerek-Sanchik Ridge (in the background). Southeast view. The white arrows show the Kadzhi-Saz fault along which tectonic thrusting of the ridge occurred. The dashed line shows the Kadzhi-Sai River.

the deposits; in other places, the cracks only capture the upper portion of the object and penetrate to a certain level. We interpret these fractures as the signs of two seismic events.

AN ARCHAEOLOGICAL STUDY ON THE TOSSOR MONUMENT

The Tossor archaeological site (Fig. 5) is located in the western margin of the settlement of the same name at a distance of 700–900 m from the present-day coastline of the lake, on the bank of one of the secondary delta branches of the Tossor River (as shown on the map compiled in 1956, updated in 1961 and 1970, and published in 1982) 3000 m from the main river mouth.

The first mention of this site appeared as early as 1885–1886 in two papers of botanist N.V. Sorokin (Sorokin, 1885) which summarized the results of his expedition to Tien Shan. V.V. Bartol'd (1966) in his *Report on the Trip of 1893–1894* (first published in 1897), referring to Mr. Dudin, presents the information that quite vaguely localizes the described object as a *small fortification* near *Tuzar*, somewhere between Ak-Terek and Ton, closer to the latter. In 1900, the information about the site was presented by V.K. Gern in *Drevnosti* (Antiquities)—the special treatise issued by the Moscow Archaeological Society, where he summarized the results of his voyage to Issyk-Kul in 1877. Together with the text, also the first plan of the site was published (Gern, 1900). The information about the site in Tossor was included in the best pre-Soviet bulletin on the antiquities of the *Kyrgyz steppes* ... compiled by I.A. Kastan'e (1910). In other words, even in the pre-Soviet period, the basic information about the Tossor site had been collected and published by a number of authors.

In the Soviet period, based on the results of his studies in the late 1920s, P.P. Ivanov placed this site on the first map of the archaeological monuments of the Issyk-Kul Lake region. Unfortunately, the map, just as Ivanov's report (1957), was published with a 30-year delay and without the description of the sites on the southern coast of the lake.

In the years before World War 2, this monument was surveyed by A.N. Bernshtam who somewhat later published the plan of the site (*Chuiskaya ...,* 1950).

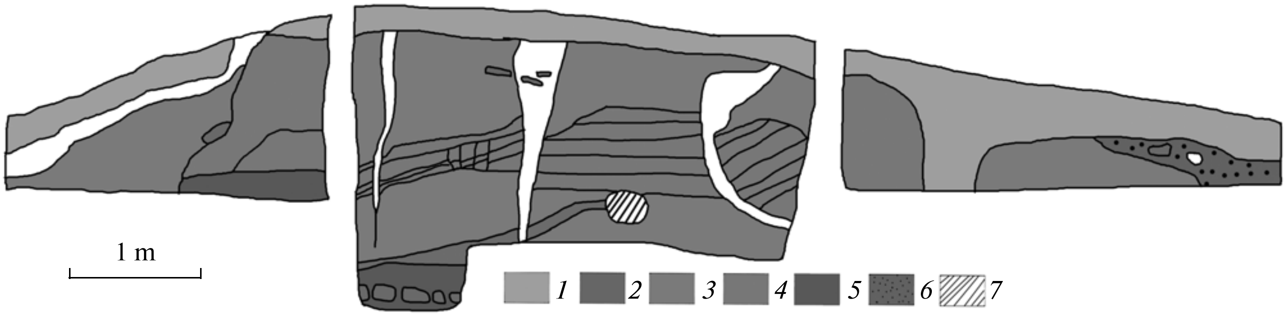

Fig. 4. The southern wall of the ditch dug out through the eastern wall of the Kadzhi-Saz site. Explanations are presented in the text. *1*, grassy turf; *2*, fragments of bricks; *3*, loose clayey layers; *4*, bands of clay and ground used for building the wall; *5*, filling; *6*, debris; *7*, burrows.

Since 1959, the archaeological sites of the Issyk-Kul Lake region have come into focus of Vinnik's studies. At the beginning of the 1960s, he described the Tossor site, compiled its new plan, and carried out the first documented archaeological excavations in the prospecting pit (Vinnik, 1967; 1985). According to his data, the site is a 100 × 100 m square oriented by the cardinal directions, with thick walls (14–18 m at the base), and at places sloughed. The walls are rather well preserved; their height reaches 2.5–3.5 m. At the corners and in the center of each wall, the monument is flanked by towers. The only gate was observed from the eastern side of the site in the center of the wall. According to Vinnik's description, the gate is Γ-shaped and reinforced by the additional tower. According to the pit dug in the southeastern segment of the site, the thickness of the cultural layer is 0.3–0.5 m. Based on the pottery collected in the site, Vinnik dated the site to the 10th to 12th centuries A.D.

The site had a predominant position in the Tossor valley. Its massive, heavy fortifications indicate that it was a significant post on the segment of the caravan path between the medieval towns of Ton and Barskhan.

Our selection of the Tossor site as an object for our study was determined by its location on the steep limb of the young rising anticline, which is cut along the fault and which follows along the southern wall of the site. In the north and east of the site there are buildings of the Tossor village; in the west, beyond the country road, there is a field.

On their external sides and on the top, all the walls of the site are occupied by the graves of the cemetery which was functioning up to the 2000s. The present-day cemetery is located south of the site. There are no graves in the internal surface of the rampart walls. The internal territory of the site is quite flat, without distinct undulations of previous constructions, and also without graves.

The northern segment of the eastern wall is cut by an old excavation. Information about this cut has not been published; however, it is mapped on the plan compiled by Bernshtam (*Chuiskaya* ..., 1950). Information about this cut is also not found in the archive data.

We decided to dig our trench at the place of the previous sloughed gap in the wall (Fig. 6) in order to minimize the damage to the integrity of the monument. The total length of our trench (the section) was 24 m and the maximal depth was 3.6 m, including the natural layers dug by 0.3 m. The wall is based on the undercut natural clay layer with a thickness of 0.5–1 m, which covers a layer of sand with gravel dug up to 0.15 to 0.2 m. The azimuth of the trench is 80°.

It was established that the wall was built by the "pakhsa" method—sequential laying of relatively horizontal beds of soil with a thickness of 10 to 20 cm, with the thickest bed (up to 40 cm) at the base. A total of 18 such bands have been preserved. The soil material for these purposes was excavated from outside the wall, which has fully depleted the clay layer up to its entire thickness. However, in contrast to the Kadzhi-Saz wall, the soil bands in Tossor do not stretch continuously across the full thickness of the walls forming a relatively flat continuous horizontal layer. Instead, the bands in Tossor form separate lenses that are one-third to half of the wall thickness, with one edge of the band being narrower than the other (the thicker edge is typically on the butt of the wall). The bands are slightly inclined from their higher position at the butt to the lower position in the body of the wall. It can be hypothesized that during the construction of the wall, the molding material was prepared (or brought to the place) by relatively small portions which were laid, as far as the material allowed, from a face of the wall to prevent the water of the molding mass from running across the vertical wall surface and, instead, to direct it to run inwards. This can explain the fact that one edge of the band is narrow and that the bands are slightly inclined. The bands were composed of the local clay loess soil with an admixture of sand from the near-top part of the Early Holocene Toup terrace of Lake Issyk-Kul, the place where the Tossor monument is located. The bands are separated by the sand–gravel interbeds with a thickness from 1 to 7–10 cm. The body of the wall contains a significant number of pebbles and

Fig. 5. The Tossor medieval site. Southwestern view from inside. Present-day burials on the walls of the monument. Seen on the background are the adyrs—piedmonts of the Terskei Ala-Too Ridge. The highest part of the Tegerek Ridge is the horizon.

boulders. The wall is preserved up to a height of 2.7 m and its original width was 4.8 m at the base.

The external face of the wall is inclined at an angle of 15°–20° to vertical. The slope of the internal face cannot be determined because the upper portion of the internal face has been eroded within this segment. A clear jigger-shaped destruction is observed in the bottom part of the internal face, which indicated the long persistence of the wall in open air.

The entire body of the wall is threaded by a system of nearly vertical parallel cracks, which testifies to their seismic origin. One of the widest cracks passed at a distance of 40 to 50 cm from the external face and caused the upper piece of the wall to fall to the outside (see below). The detachment occurred across the boundary between the bands.

In the western part, the excavation departs from the wall by 8 m. Beneath the bottom face of the jigger-shaped destruction of the wall, sloughed clay layers obliquely diverging from the wall are observed. The uppermost covering layer on this western segment of the trench, with a thickness of 40 cm, is composed of loose conglomerate (strongly oversanded ground, a small number of stones, and single pieces of the clay–soil band). Beneath it, a burnt layer with a thickness of up to 3 cm rests on the clayey natural ground. A clayey natural layer with a thickness of 20–30 cm covers the sandy layer excavated by 10–12 cm.

On the external side from the rampart, the trench stretches 10 m eastwards. The structure of the deposits accumulated in the eastern part of the excavation is of interest. Clay layers at an oblique angle of 10°–15° to the horizon immediately from the rampart are observed in its very bottom part. They are likely to have been formed as a result of the continuous erosion of the wall due to precipitation, which could occur both during the functioning of the site and soon after the end of human activity there.

Immediately on the oblique clayey layers, immediately adjacent to the wall, there is a fallen piece of the wall, which comprises a few bands with a total size of 35 × 70 cm. Another piece of the wall lies on the same layers 1.5 m from the fortress. The most distant discovered fragment of the wall is located at a distance of up to 4.5 m from the eastern face of the wall, where pieces measuring 32 × 62, 18 × 27, and 20 × 37 cm are found. The space between the crests of these pieces and the wall is filled with loose ground—the product of its sloughing. Importantly, such a distant dispersion of the wall fragments was not observed west of the wall.

Along the entire length of the trench, the natural ground is represented by a pale loess-like clay loam with a thickness of up to 50 cm. It is underlain by the lacustrine sands, which are observed in the quarry south of the site. The sands are coarse-grained with gravel and inclusions of small pebble.

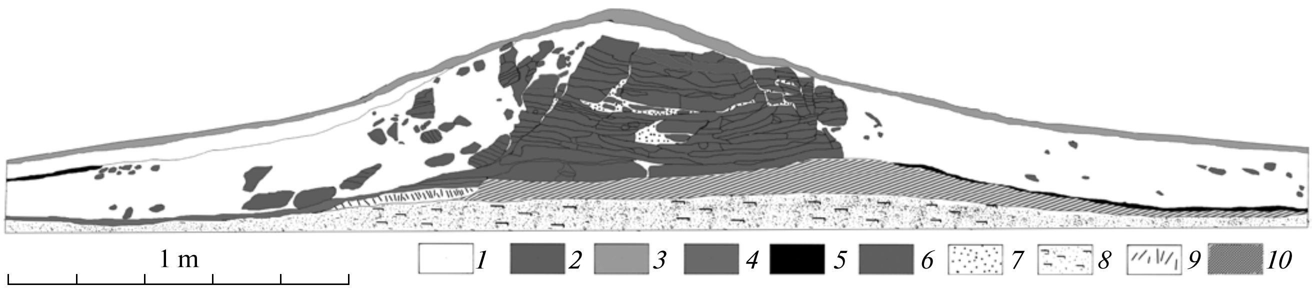

Fig. 6. The sketch of the southern wall of the ditch dug through the eastern wall of the Tossor site. *1*, Loose clayey layers; *2*, bands of clay with sand–gravel interbeds; *3*, grassy turf; *4*, clay layers of wall's erosion; *5*, burnt layer (coal and ash); *6*, stones; *7*, sandy gravel cavities; *8*, natural sand layer; *9*, primary slough of the wall; *10*, clayey natural layer.

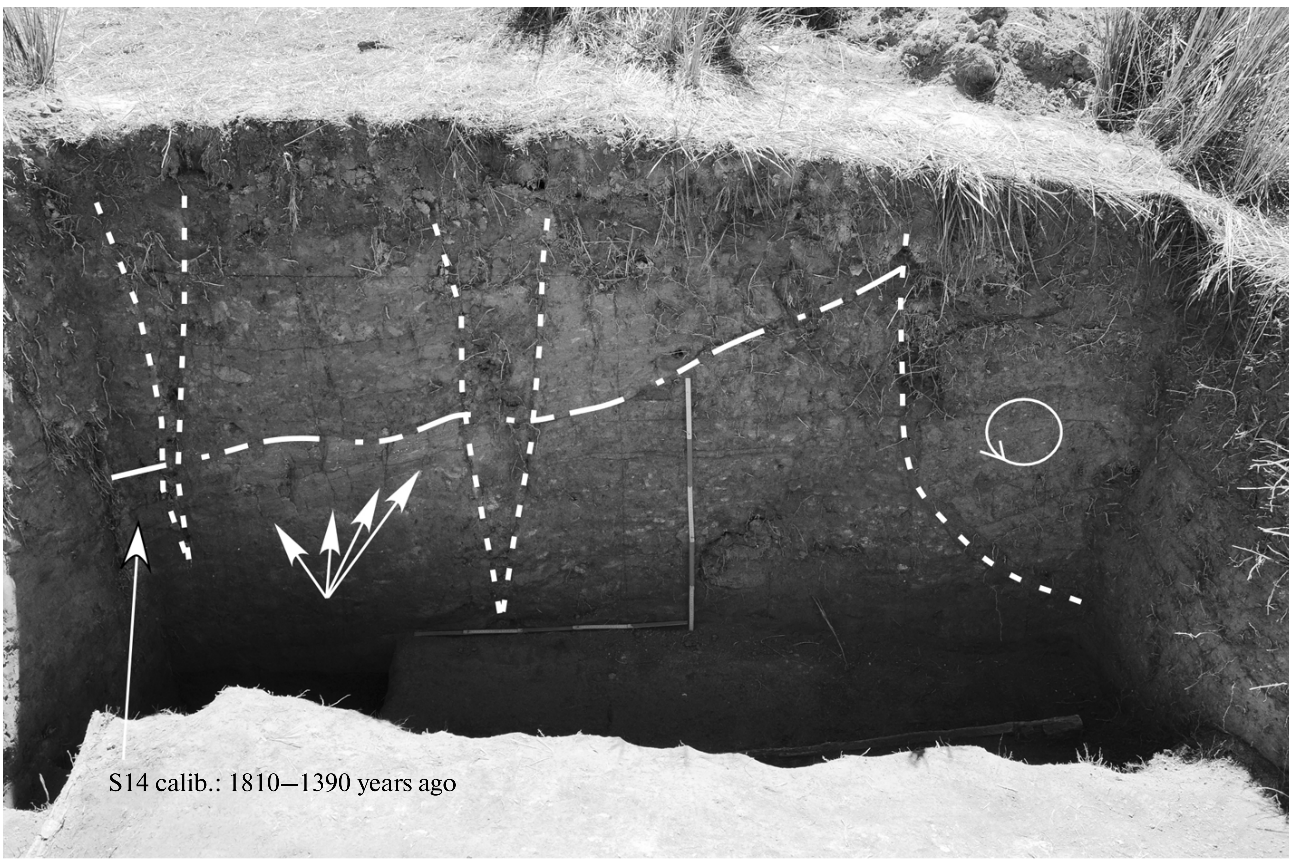

Fig. 7. The central part of the southern wall of the ditch dug through the eastern wall of the Western Kadzhi-Saz medieval site. The small arrows show the cracks that were formed during the first earthquake in the earlier (older) part of the wall. The white dashed-dotted line shows the boundary between the earlier and younger parts of the wall. The white shading marks the wedges that were formed during the second earthquake, as well as the rotation plane of the wall's block. The wedges obliquely cut the old and new parts of the wall.

ARCHAEOSEISMOLOGICAL STUDES OF THE MEDIEVAL SITES

Archaeoseismological Study of Medieval Sites in the Kadzhi-Saz Depression

Above, we have already mentioned the bogginess of the low parts of the Kadzhi–Saz depression. The present-day bog was formed at the place of a small lake which, according to the local people, had existed as early as at the end of the 19th century. The two sites are situated in the area where the Kadzhi-Sai River enters the rock masses of Mt. Tegerek and cuts it forming the antecedent segment of its valley. In their time, these medieval settlements guarded and maintained this mountain gate on one of the branches of the Silk Route (Fig. 3). The relative age of these sites was determined by Vinnik (Vinnik et al., 1978) from the surface ceramics as Karakhanids (10th to 12th centu-

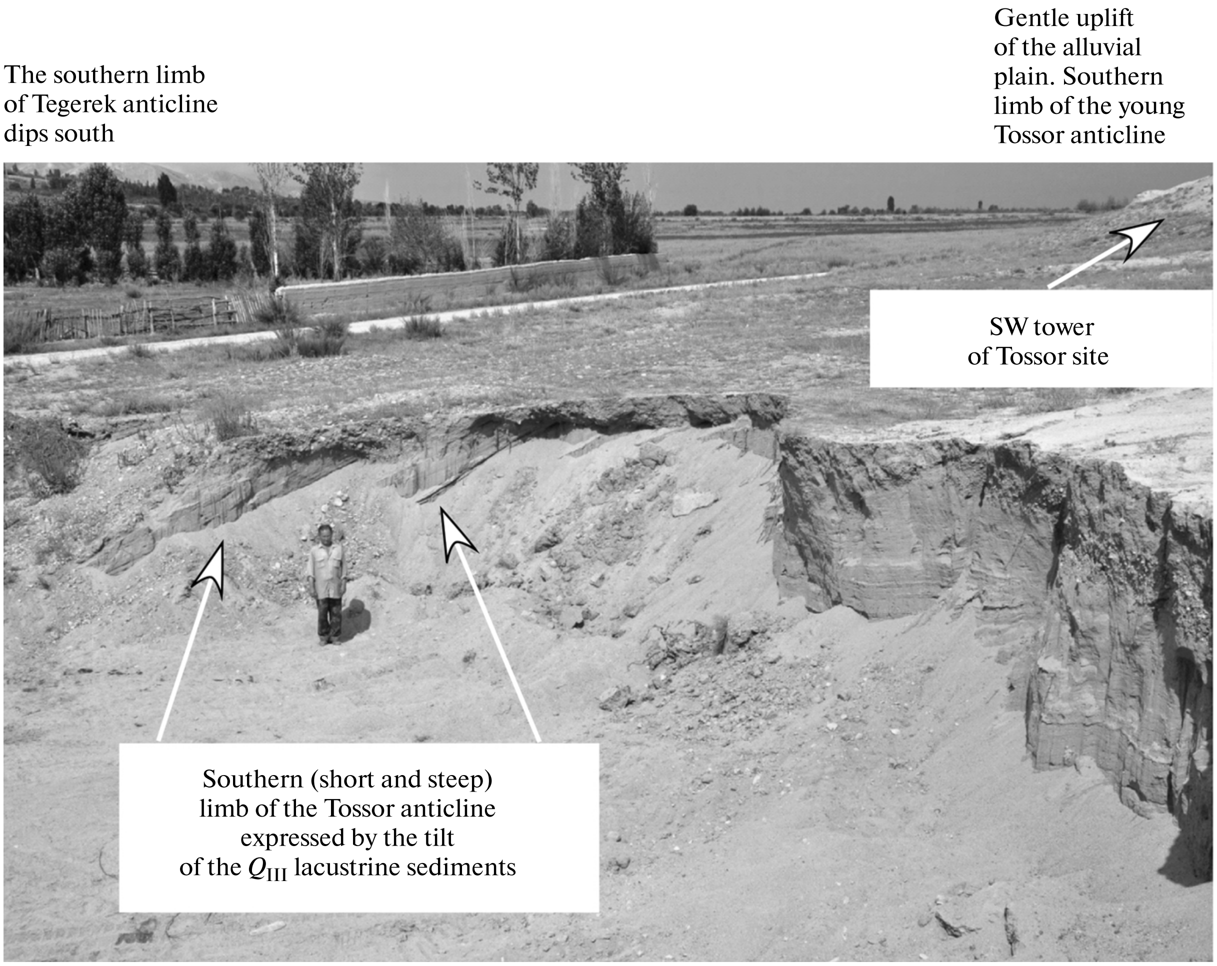

Fig. 8. The sand quarry south of the Tossor site. A significant (up to 20°) tilt of the coarse-grain sand layers marks the southern (short and steep, located above the fault) limb of the Tossor anticlinal structure.

ries A.C.). It is difficult to imagine that these fortresses were built in the middle of a lake or on a bog, since there are more suitable (higher elevated and drier) localities in this region. It is most likely that these objects were erected on dry land; however, the intense uplifting of the Tegerek Ridge caused the damming of the Kadzhi-Say River with the formation initially of a lake and then a bog in the Kadzhi-Saz depression. The seismic fault scarp along the zone of the Kadzhi-Saz fault testifies to the pulsed motions on the disjunctives (Korzhenkov et al., 2014a).

As has been described above, we cleaned the old groove which passes through the eastern wall of the western site (Figs. 4 and 7). In the southern wall of this trench, it can be seen that the wall consists of two parts: the primary part, which is presented in the bottom part, and a younger upper part. Clearly, the wall has been renovated. It is likely that during the first significant earthquake the upper portion of the initial wall was strongly damaged (cracked), due to which it was removed, and the new clayey layers were laid on the old part, which was more intact. The signs of this cracking are visible in the upper part of the old fragment of the wall. However, both the old and new parts have been pierced through by the wedges during the second strong earthquake. Besides, also separation with counterclockwise rotation of a significant western fragment of the wall around the horizontal axis took place.

In the trench dug by us, we collected a significant number of samples for determining their age by radiocarbon dating. However, it turned out that these samples contain too little organics to allow reliable dating. Only one sample (Vs-2551) gave the calibrated age of 204–625 years A.D. (third to seventh centuries A.D.). This sample was taken from the upper portion of the older (earlier) wall. The time interval of this sample covers the rather long historical period from the *Wusun* to the *Turks*. At the same time, the archaeological artifacts constrain the functioning of the site to the *Karakhanids* epoch (10th to 12th centuries A.D.). How can we interpret this inconsistency?

At some time in the past, the deep moat which surrounded and protected the Kadzhi-Saz sites, also served as a source of the material for building their

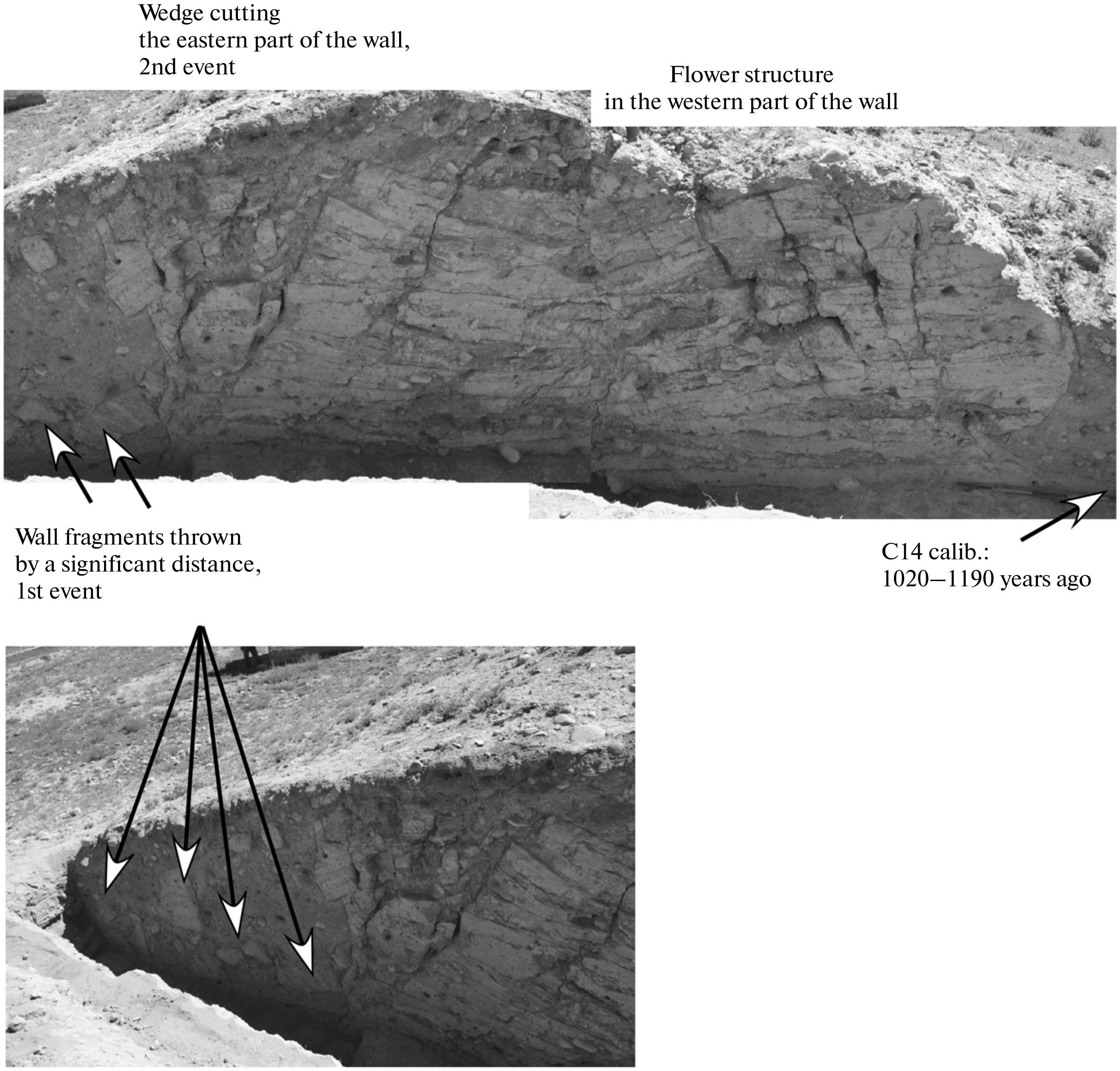

Fig. 9. The section of the southern wall of the ditch dug in the eastern wall of the Tossor medieval monument. Deformations from two seismic events are seen. During the first seismic event, the wall was damaged and the fragments were thrown quite far eastwards (bottom). During the second strong earthquake, the wall was broken by the cracks which form the flower structure in the western part of the wall, and by the wedge in the eastern part of the wall (top).

walls. Due to this, it is quite probable that, instead of reflecting the age of the wall's construction, the age of sample Vs-2551 corresponds to the deposition time of the silt—the loess-like clay loam which was accumulated in the lower part of the Kadzhi-Saz depression and used for building the sites. Thus, the age of this sample has paleogeographical value but not archaeological value.

The Archaeoseismological Study of the Medieval Site on the Tossor Village Edge

Twenty km east-northeast of the described Kadzhi-Saz sites, on the western edge of the Tossor village, there is another medieval site from the Karakhnids epoch (Fig. 5). Its Karakhnids age was also determined by Vinnik. The Tossor site was built above the core of the presently growing anticlinal structure (Fig. 8). Its southern steep limb located above the fault is traced in the sand quarry in the immediate proximity of the site south of it by the anomalous (up to 20°) southern dip of the Late Quaternary lacustrine deposits. The growth of the young structure is also reflected in the topography: the large oblique alluvial plain, which is gently dipping north towards Issyk-Kul, changes its dip direction to the opposite, inverse to the acting gravity forces, in front of the southern wall of the of the fortress. It is not by chance that the Tossor site was

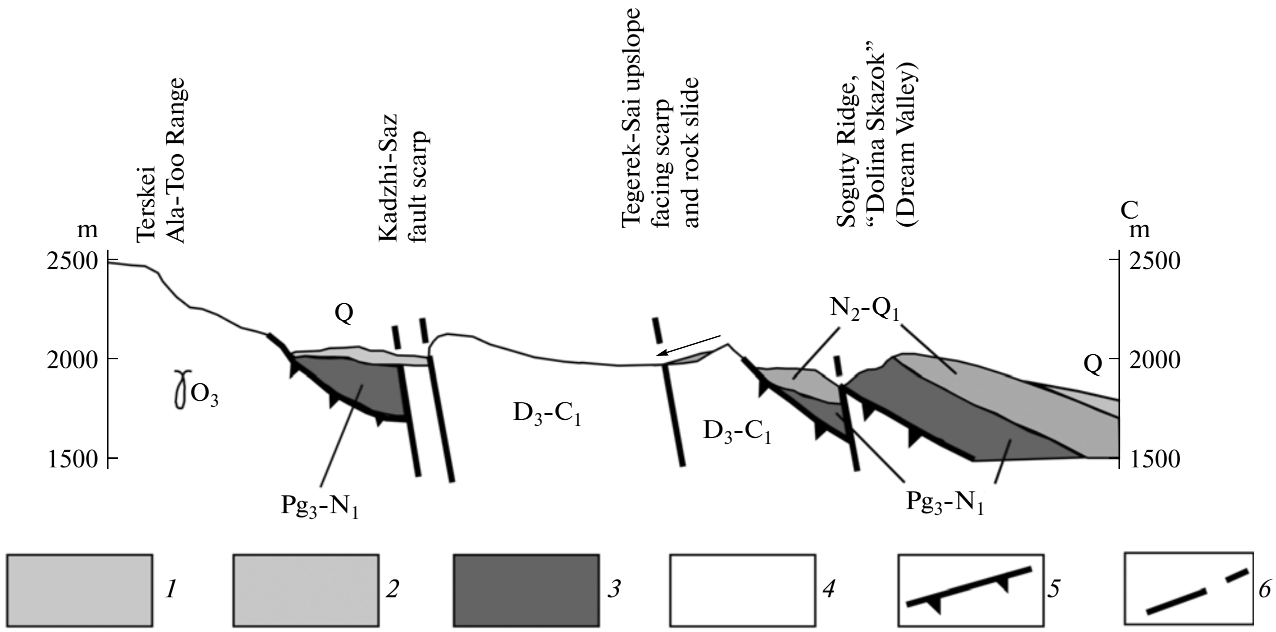

Fig. 10. The schematic longitudinal structural–geological profile along the Tossor River modified after (Chediya et al., 1988). The vertical and horizontal scales are identical. *1*, Quaternary; *2*, Pliocene–Early Pleistocene; *3*, Oligocene–Miocene; *4*, Pre-Cenozoic; *5*, pre-orogenic peneplain; *6*, Neotectoinic faults.

built here, at a certain elevation above the adjacent topography.

However, the strategically favorable location of the Tossor site played a negative role during the strong medieval earthquakes. In the southern wall of the trench that was dug in the eastern wall of the site, we revealed significant deformations (Figs. 6 and 9) related to two seismic events. During the first earthquake, the wall was strongly damaged; its fragments fell as far east as 4.5 m, which is more than the height of the wall itself. This points to strong seismic oscillations, since during the common static destruction which developed over a long time period, most of the detached pieces should have fallen within a radius of at most one-third of the height of the wall (Korjenkov and Mazor, 1999).

During the second seismic event, the wall was significantly cracked, which resulted in the formation of a flower structure in its western part. In the eastern part of the wall, a large wedge appeared where the fragments of the upper portion of the wall have fallen. Interestingly, neither the strongest cracking of the wall, nor its punching by a large wedge has caused complete destruction with the collapse of the wall eastwards and westwards. To all appearances, the wall that had been damaged by the first earthquake was surrounded by silt—the sloughed material that gradually accumulated during hundreds of years after the first seismic event.

It is important that in the western part of the section, inside the site, the slough of the western wall is underlain by an *extensive* layer of burnt material with a thickness of 3 cm, which rests almost on the natural ground. The calibrated radiocarbon age of this material is 1020–1090 A.C. (Vs-2535), which agrees with the age of the archaeological artifacts.

We note that the strongest damage and maximal death toll from the present-day strong earthquakes come from fire rather than from the collapsing of buildings due to the intense shaking of the ground. These facts should have been also observed during the similar ancient seismic events: the strong vibrations caused the ubiquitous damage and destruction of stoves and lamps—the sources of fire.

DISCUSSION

Our interpretation of the relationship between the signs of fire and a strong earthquake, which are likely to have occurred in the 11th century A.C., is supported by the paleoseismological studies in the dry valley of the Tegerek dry sai—the left tributary of the Tossor River (Fig. 10). In this region we have previously revealed the seismogenic fault which was a source area of a few earthquakes at least during the Holocene (Korzhenkov et al., 2014a; 2014d).

According to the data of R.J. Burgette (2008), the formation of adyrs (piedmonts) in the south of the Issyk-Kul Lake depression is most adequately described by the model of a gently dipping fault which flattens out in the northern direction. In the western part of the region of our study, this model is complicated by the presence of reverse thrusts (Fig. 11). Thus, despite the seeming dissimilarity of the recent

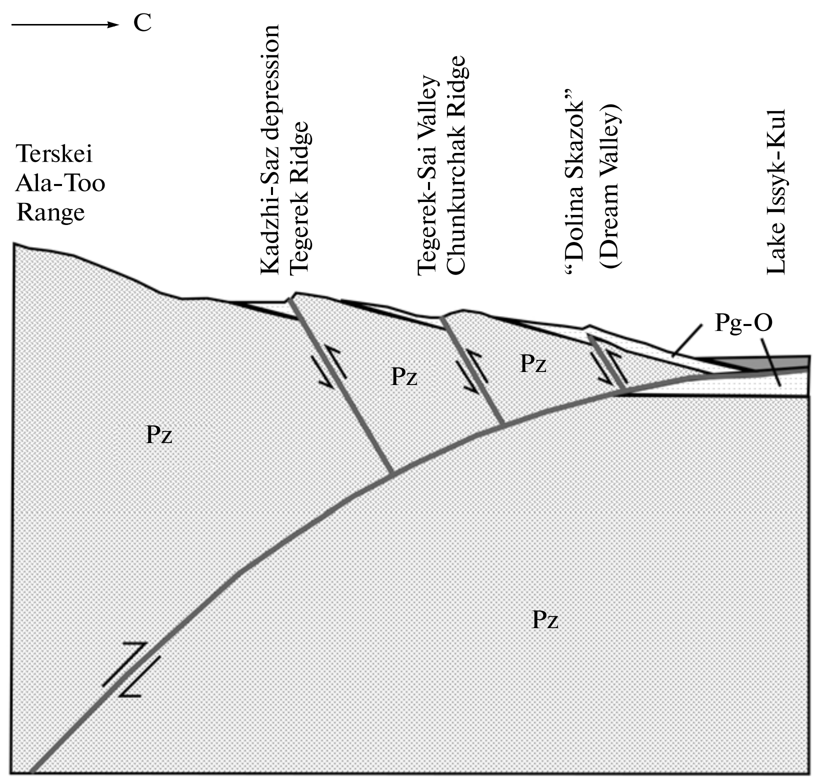

Fig. 11. The model of the northerly flattening main fault explaining the peculiar features of the recent structures of the South Issyk-Kul region modified after (Burgette, 2008).

structures in the different parts of the South Issyk-Kul region, all the peculiarities of these structures and the mechanism of their formation can be accounted for by a common model. Here, we should admit the existence of a single zone of a Pre-Terskei fault (Fig. 12), which is not a boundary fault in the classical sense of this term, but is a long-lived feature which separates structures with a different regime of motion during the Neotectonic time. Thus, the role of the sources of strong earthquakes is played by the local adyr (piedmont) second-order faults—the components of the main Pre-Terskei boundary fault.

Using the radiocarbon method, we managed to determine the age of the last slip on this fault and the time of the last mobilization of the large rockslide located in the immediate proximity of the seismogenic fault (table). The age of the fire in the Tossor site and the age of the last strong earthquake with the epicenter 15 km southwest of the site coincide within the error of radiocarbon dating and is about the 11th century A.D.

An additional argument in support of this conclusion is provided by the observed deformations of the Turkic funeral square-shaped fence (5th to 8th centuries A.D.) and the stone enclosure for holding livestock—tash-koro of the same age according to the archaeological data. Both deformed historical monuments are located in the immediate proximity of the seismic fault scarp along which the Tegerek adyr uplift was thrust southwards onto the adjacent Kadzhi-Saz intramontane depression. This scarp with a height of 4.5 m was formed by three earthquakes whose magnitudes were at least $M \geq 7$ and their seismic intensity, $I_0 \geq 9$ (Korzhenkov et al., 2014c; 2014d).

The Turkic funeral fence is located west of the seismic scarp on the traced continuation of the surface exposure of the seismic rupture (Fig. 13). There, the scarp which cuts the Late Pleistocene–Holocene alluvial fan of the Tegerek Ridge is covered/eroded by the young (Late Holocene?) alluvial flow. The bulk of the stones forming the fence are inclined down the hill, and a large boulder from its southern gate was knocked out and has also fallen down the slope. Importantly, the boulder that was thrown is seated deeply in the ground, which means that this event occurred quite long ago. All the deformed boulders are densely covered with lichen.

Near its western pediment, the seismic fault scarp is neighbored by the tash-koro (animal coral) discovered in our study (Fig. 14). By analogy with the similar monuments, the age of this object according to the archaeological data falls in the interval from the 10th (11th) to 12th centuries A.D. The tash-koro is also significantly deformed: many stones which composed it are thrown southwards by 50–70 cm. The thrown

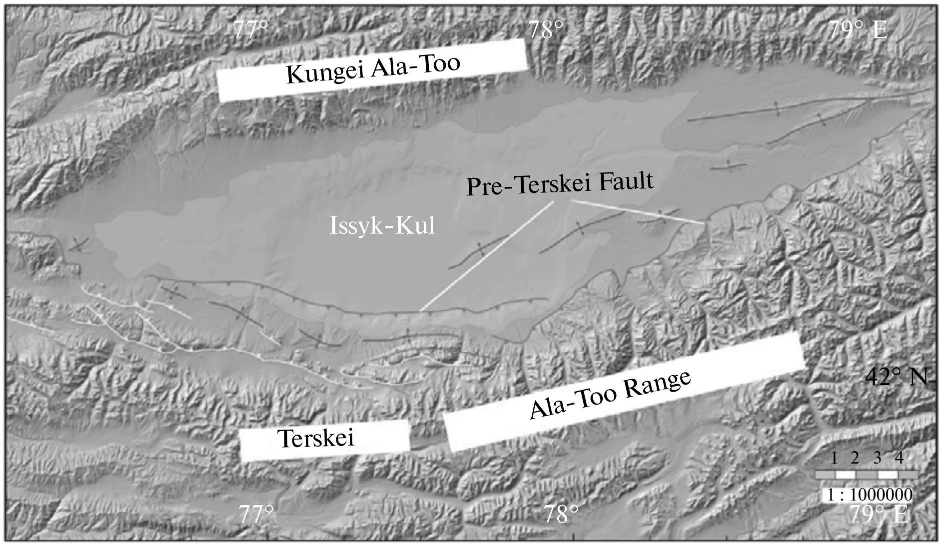

Fig. 12. The Pre-Terskei fault within the Issyk-Kul basin modified after (Burgette, 2008).

boulders do not lie on the surface but are located in the small hollows (moulds) surrounded by the silt which was accumulated around them over a thousand years. Both the displaced and in situ stones are significantly lichened.

The archaeological data for the time of the deformation of the Turkic funeral fence and tash-koro are consistent with the radiocarbon age of the ancient earthquake (11th century A.C.) established by us from the seismis deformations in the dry valley Tegerek sai (Korzhenkov et al., 2014a; 2014d) and from the deformations of the Kadzhi-Saz and Tossor sites (Korzhenkov et al., 2014b; 2014e).

In contrast to the first medieval earthquake whose age we may treat as established, the age of the second seismic event, whose signs are also perfectly manifest (the wedges in both sites, the flower structure in Tossor), is still uncertain.

It has been said above that the walls of the Kadzhi-Saz sites were renovated after the first earthquake; but how long was it inhabited after the first seismic catastrophe? In (Vinnik, 1978) it is noted that the cultural layer in these sites is thin (a few tens of cm). If the sites were built in the 10th century A.C. and hit by seismic events as shortly after it as the middle of the 11th century A.C., as suggested by our data, then the small thickness of the cultural layer becomes clear.

The existence of two sites at one locality (within a few tens of km apart from earth other) indicates the political, defensive, and administrative importance of

The radiocarbon datings of the paleoseismo- and historical deformations on the Southern Issyk-Kul region

Laboratory no. of sample	Description	^{14}C age, years ago	Instrumental error, years ($\pm 1\sigma$)	Calibrated age, years A.C.	Data source
Vs-2312	TSR-2, fragments of contemporary sandy-loam soil at the foot of seismic scarp (in the colluvial wedge)	1120 BP	70	924–1058 AD (10th–11th centuries A.C.)	Korzhenkov et al., 2014a
Vs-2313	TSR-1, bottom of the contemporary sandy-loam soil in the body of the rock slide	1140 BP	160	827–1085 AD (9th–11th centuries A.C.)	Korzhenkov et al., 2014a
Vs-2535	TOF-1; coal and ash. Medieval site on the edge of Tossor viillage, ditch through the eastern wall, western end of the ditch, depth 50 cm	925 AD	80	1020–1190 AD (11th–12th A.C.)	This work
Vs-2551	IKSW-3, sandy-loam with scarce organics, depth 80–100 cm (Kadzhi-Saz site)	1675 BP	180	204–624 AD (3rd–7th centuries A.C.)	This work

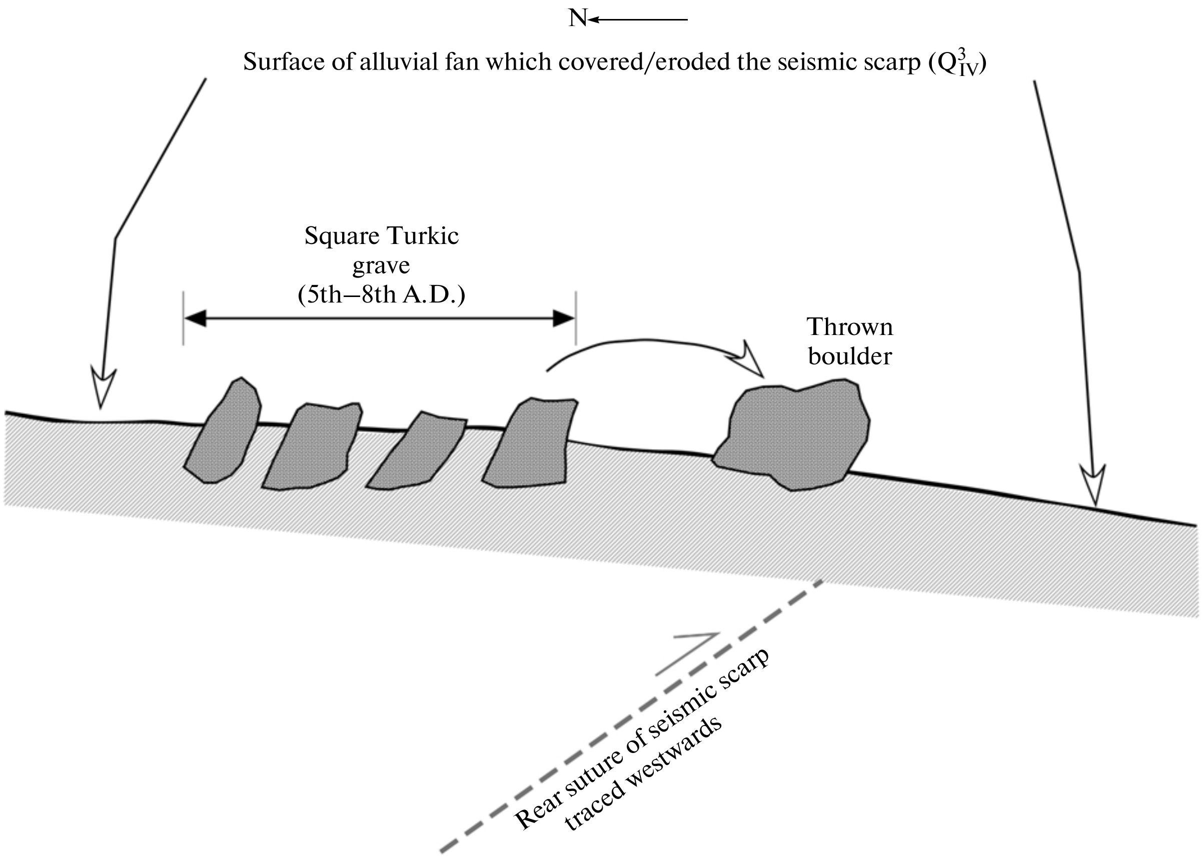

Fig. 13. The schematic of the deformations of the stonework of the Turkic grave on the surface of the alluvial fan covering/eroding the fault scarp at the foot of Tegerek Ridge. Eastern view. Explanations are presented in the text.

this area and that is why it was decided to repair the sites just after the first earthquakes. The works were started and probably finished soon; however, these settlements still had to be abandoned since they began to be bogged. During the earthquake that occurred in the 11th century A.C., the entire adyr Tegerek ridge was uplifted and thrust over the Kadzhi-Saz depression by a few meters (Korzhenkov et al., 2014b; 2014c; 2014e). A tectonic dam was formed across the Kadzhi-Saz River, and a lake appeared in the lower part of the depression which accommodates the archaeological monuments. The functioning of the sites had become impossible and they were abandoned by the inhabitants.

The abandoned walls composed of the mud bricks rapidly collapse: they slough like a pile of snow in the sun. The products of their destruction and washout from the upper portion of the walls are deposited close to the foot of the walls where they form gentle slopes. However, the lower part of the wall hidden by these slopes acting as the studs is well preserved in the section. Therefore, the second earthquake which left footprints in the form of deep wedges (fisheirs) has not led to the collapse of the remains of the medieval walls. The walls and wedges are perfectly well seen in the archaeological section (Fig. 8).

A similar situation took place in the Tossor site. According to Vinnik's data (Vinnik, 1967), this monument was also built in the 10th A.D. The cultural layer is thin (30–50 cm), as in the case described above. This fact also indicates that this settlement was inhabited during a relatively short time (probably, at most one century). During that time, its sloughing products were deposited on either side of the wall, and their thickness in the wall reached 60 cm. Inside the fortress, this slough is covered by a layer of burnt material with a thickness of up to 3 cm, which indicates a large fire with the simultaneous collapse of the wall fragments eastwards.

The considerable unidirectional eastward throwing-out of the pieces of the wall that was dug out by us suggests a strong seismic impact. However, in this case the site is unlikely to have been renovated; no signs of repair are observed. The walls of the abandoned construction, which are built of the loess-like clay loam, began sloughing, and the slopes were formed on either side of them, which protected the bottom parts of the walls from collapsing. The wall transformed into a gentle bank. Due to this, the internal structure of the wall was perfectly visible in the trench dug by us, notwithstanding the fact that the subsequent earthquake

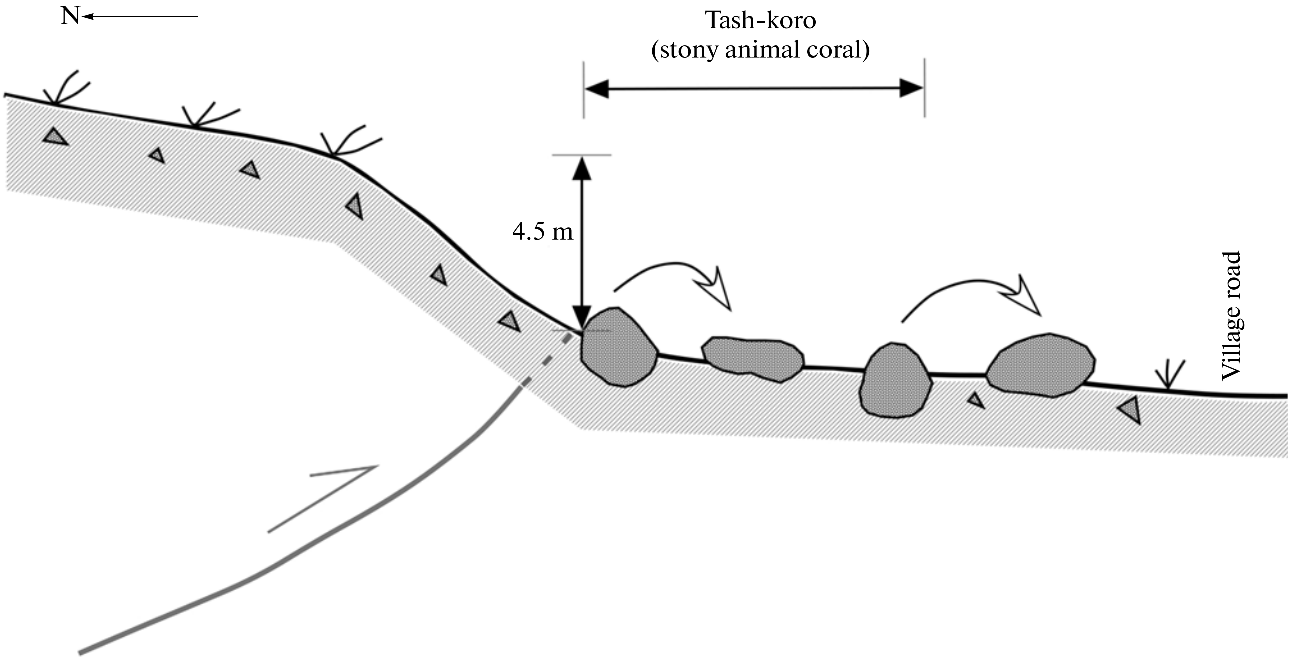

Fig. 14. The deformation of the stone enclosure for holding livestock—tash-koro in front of the fault scarp which cuts the alluvial fan of the Tegerek Ridge. The height of the fault scarp is 4.5 m. The schematic, eastern view. Many tash-koro boulders were pulled out and thrown southwards.

had strongly damaged the wall (with the formation of wedge and flower structures) (Fig. 10).

Thus, when did this earthquake occur? Judging by the fact that the thickness of the slough around the walls in the Kadzhi-Saz and Tosor sites reaches 1.6 m, their accumulation took many centuries. The existing data in the literature and archives on the archeology of the Issyk-Kul depression (Ivanov, 1957; *Biosfernaya* ..., 2002) suggest two periods of habitation of the towns in this region: the 10th to 12th centuries and 13th to 14th (rarely until 15th) centuries A.D. In the 17th century A.D., the region was populated by the *kalmyks*, and the 18th century marks the beginning of the present-day *kyrgyz* history of settlement of this territory. Only the 16th century A.D. remains blank. The *mogol* era has ended, while the *kalmyks* had not yet arrived. The scarce historical literature for the study region does not report strong earthquakes before or after that time. We may only conjecture that a strong earthquake or a series of such earthquakes in the 16th century A.D. put an end to the remains of the farming civilization in the Issyk-Kul Lake region and completely destroyed the political, administrative, and military structure of the region, which paved the way for the *kalmyk* tribes for passing through this region like a hot knife through butter, without any resistance from the local people.

CONCLUSIONS

The archaeoseismological studies carried out in the Southern Issyk-Kul region and the obtained radiocarbon datings suggest the formation of the sources of strong earthquakes in this region in the 11th and probably 16th centuries A.D.

The magnitude of these events was $M \geq 7$ and the seismic intensity was $I \geq 9$. The local adyr (piedmont) faults—components of the Pre-Terskei boundary fault—served as the sources of these earthquakes. The obtained data indicate a strong underestimation of the seismic hazard in the Southern Issyk-Kul region in the latest map of seismic zoning of the Kyrgyz Republic (Abdrakhmatov et al., 2012).

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