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Strong Mediaeval Earthquake in the Chuy Basin, Kyrgyzstan

A. M. Korjenkov[a, b], V. A. Kol'chenko[c], Ph. G. Rott[d], and S. V. Abdieva[a]

[a] *Institute of Seismology, National Academy of Sciences of Kyrgyz Republic, Asanbay microraion 52/1, Bishkek, 720060 Kyrgyzstan*
e-mail: amkor61@yandex.ru

[b] *Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, ul. Bol'shaya Gruzinskaya 10, Moscow, 123995 Russia*

[c] *Institute of History and Cultural Herritage, National Academy of Sciences of Kyrgyz Republic,*
pr. Chuy 265a, Bishkek, 720071 Kyrgyzstan

[d] *Philosophische Facultaet, Universitaet Bonn, Am Hof 1, Bonn, D-53113 Germany*

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Abstract—The data presented in this paper show that in historical time the Chuy Basin in Kyrgyzstan was repeatedly subjected to strong earthquakes, which affected the inhabitants and the economic and political situation at that time. The deformed buildings in the Novopokrovka site of ancient settlements situated in the central part of the basin unequivocally indicate seismic damage and subsequent abandonment of the settlement. The earthquake happened at the end of the Karakhanid epoch (the end of the 12th century A.D.). The intensity of seismic oscillations (I = VIII–IX) at the site was reinforced by unfavorable engineering geology conditions. The source of the earthquake was probably related to displacements along the piedmont Ysyk-Ata Fault located to the south of the site.

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INTRODUCTION

The onset of Tien Shan mountain building was related to the late Oligocene [23]. The mountain belt arose and continued to develop as a result of ongoing collision of the Indian and Eurasian lithospheric plates [38]. Mountain building can be slow and gradual (millimeters per year and slower) and be described as creep; however, in the Tien Shan, instantaneous seismic events make the main contribution to mountain building [9]. Such movements are recorded by a network of seismic stations. Unfortunately, instrumental seismic records have been available only during the last 100 years, beginning from the Kemin earthquake in 1911 ($M > 8$), the seismogram of which was recorded by the seismograph installed at Potsdam.

To predict the date of the next strong earthquake, even approximately, the reoccurrence of strong seismic events, which took place along a certain active seismic fault over the last millennia, must be estimated. Such information can be obtained by historical seismology, archeoseismology, and paleoseismology.

The Novopokrovka site of ancient settlements is situated in the central part of the Chuy Basin at the eastern outskirts of the Bishkek urban area (Fig. 1). Its coordinates are 42°52′17.7″ N, 74°43′21.5″ E; its height is 783 masl.

The archeological study of this site was performed by P.N. Kozhemyako in 1952–1955. Among monuments of urban culture, he described and mapped five mediaeval settlements [6]: the core settlement with long walls (Novopokrovka I) and peripheral settlements (Novopokrovka II–V) (Fig. 2).

Recent archeological investigations were carried out in 2004 by the Novopokrovka detachment of the Institute of History and Cultural Inheritance, National Academy of Sciences of the Kyrgyz Republic with assistance of the Society of Exploration of Eurasia, Basel, Switzerland under the guidance of V.A. Kol'chenko and Ph.G. Rott [7]. The ancient settlements arose in the 7th to 8th centuries. The archeological site is multilayered, consisting of at least three practically unrelated construction levels. As is indicated by numismatic finds, the upper level (see below) is not older than the thirties of the 11th century A.D.

The performed special archeoseismological study revealed the unusual character of the destruction of walls in the trench located in the southeastern corner of the site. This paper is concerned with the seismic hazard of the nearest seismic active adyr (piedmont) Ysyk-Ata Fault and archeoseismological study of the deformed buildings.

SEISMOGEOLOGY OF THE CHUY VALLEY

The northern boundary of the region of recent mountain building in the Tien Shan extends, in particular, along the Chuy Valley, which is tectonic in origin. Numerous earthquakes have been recorded here (Fig. 3). Although most of the earthquakes are weak and can be recorded only using sensitive seismic

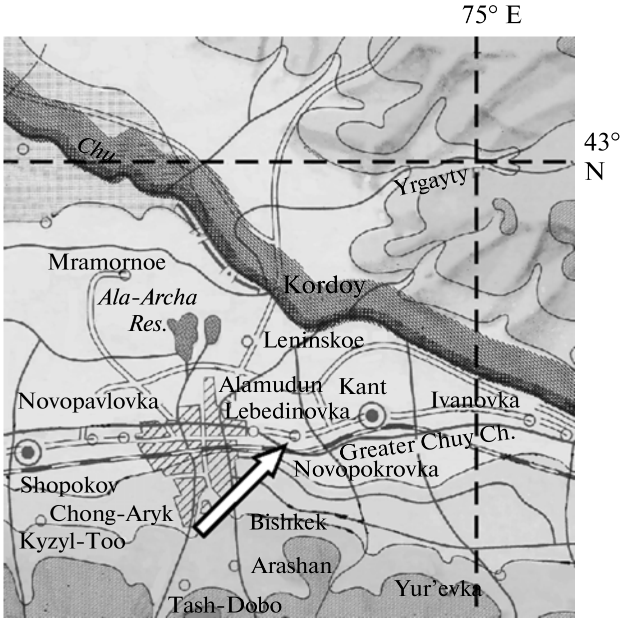

Fig. 1. Location of Novopokrovka Settlement in the central part of the Chuy region, Kyrgyzstan, after [11].

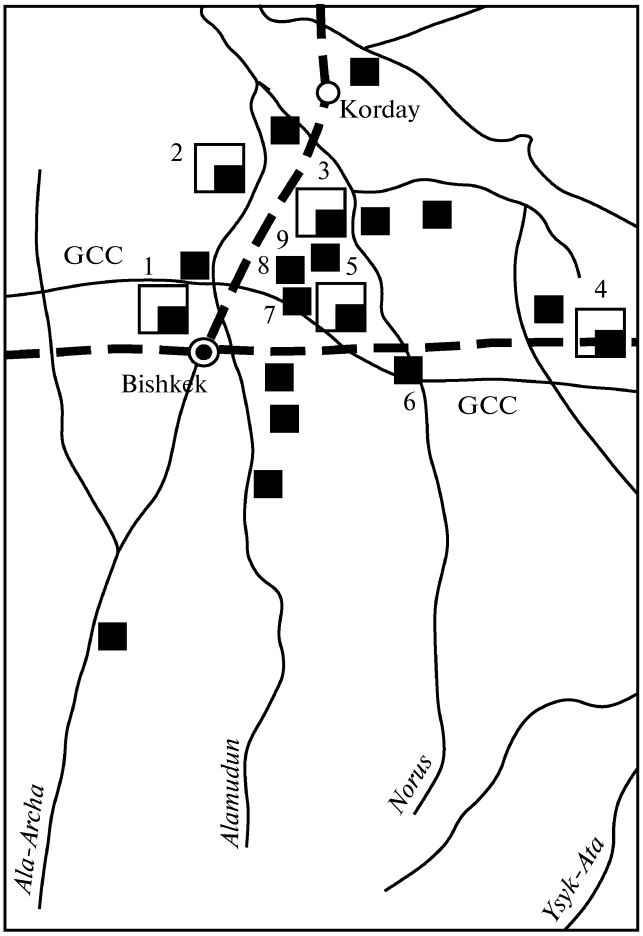

Fig. 2. Archeological sites of mediaeval settlements in the Chuy Valley, after Kozhemyako [6]: 1, Klyuchevsky; 2, Grozd; 3, Chumysh I; 4, Krasnaya Rechka; 5, Novopokrovka I; 6, Novopokrovka II; 7, Novopokrovka III; 8, Novopokrovka IV; 9, Novopokrovka V. GCC, Great Chuy Channel.

devices, rather strong shocks, perceptible to inhabitants of the area, are known. Rare earthquakes gave rise to significant destruction and even casualties. Historical records show that such earthquakes have recurred many times.

Information on strong earthquakes in the more remote past has been obtained from historical chronicles and from the results of paleoseismological studies. The so-called VIII–IX M 1475 Balasagun earthquake (1475, I = VIII–IX) destroyed the capital of the Karakhanid state—the Balasagun-city and its vicinity (the Burana archeological site eight kilometers south from the present-day town of Tokmok in the eastern Chuy Valley). According to [27], its epicenter was located on the northern slope of the Kyrgyz Range in the basin of the Shamshy River.

Fragmentary information on the 1770 earthquake near the present-day Belovodskoe Settlement (a large lake has been filled here) shows that its epicenter approximately coincided with the 1885 earthquake. A catastrophic earthquake took place at Merke Settlement (1865), at Tokmok (1867), and in the Chuy Valley (1873). Information on the catastrophic earthquake at the Belovodskoe Settlement was received on August 3, 1885. The scientific study of strong earthquakes in the Chuy Basin and its mountain framework began at this time.

Besides historical earthquakes, the trails of ancient seismic catastrophes are recorded in seismic deformations. Such trails are mostly localized in the southern part of the basin and on the northern slope of the Kyrgyz Range. The seismic dislocations in the southern framework of the Chuy Basin are subdivided into zones [1, 2, 20–22, 27], which in turn consist of several deformations clusters related to faults or tectonic blocks bounded by faults.

The long-standing investigations of the neotectonics of Central Asia, and the Tien Shan in particular, and the correlation of their results with instrumental data on seismicity has lain the basis for the concept of local and regional seismogenic boundary fault zones and lineaments crosscutting the main structural elements. As a rule, the main outburst of seismic activity is accounted for by splitting and en echelon arranged faults. The Shamshy segment of the South Chuy seismogenerating zone in the Northern Tien Shan is an example.

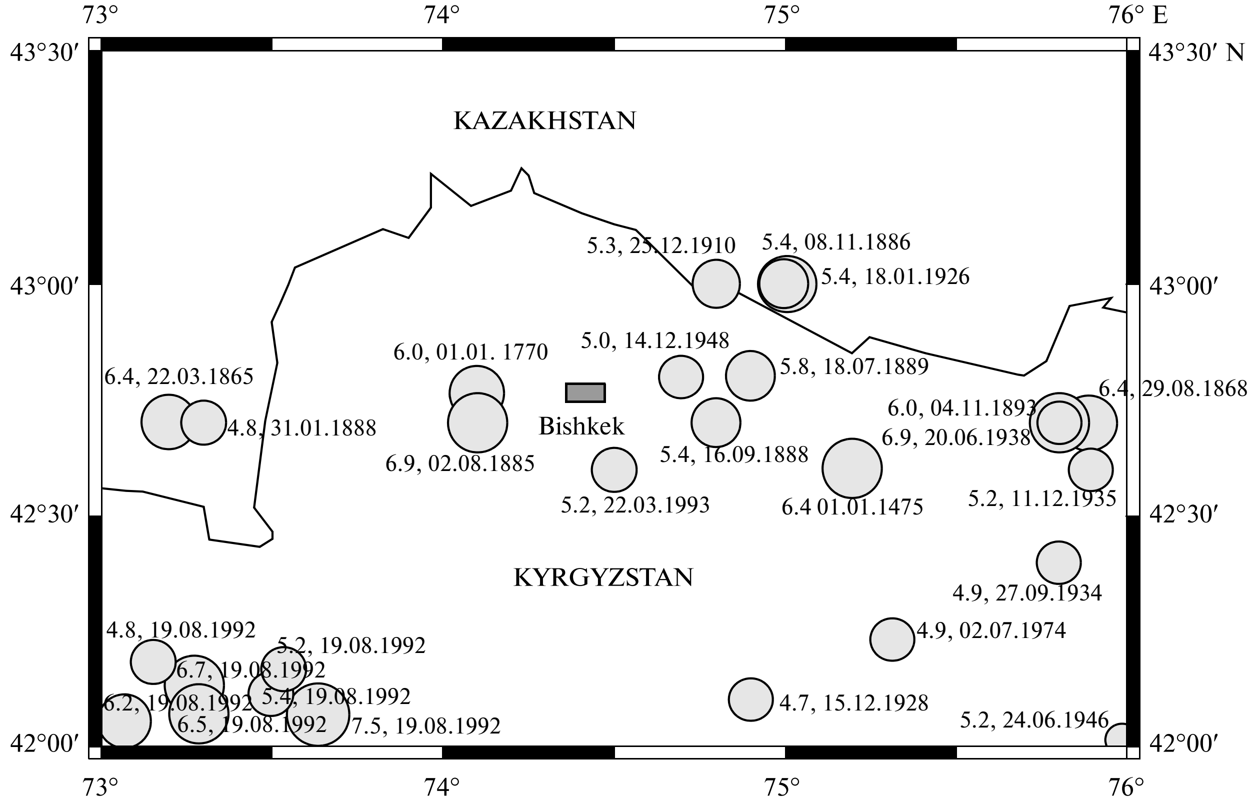

Fig. 3. Strong earthquakes in the Chuy Basin, after the data of Institute of Seismology, National Academy of Sciences, Kyrgyz Republic. Earthquakes differing in intensity are noted by circles differing in size. The larger the circle size, the greater the amount of seismic energy released. Numerals in circles: the first value is the magnitude; numerals following the commas represent the day, month, and year of the seismic event. The figure was kindly placed at our disposal by A.V. Berezina.

The South Chuy seismogenic zone is recognized within the North Tien Shan seismic belt [4, 15] at the boundary between the Chuy Basin and the Kyrgyz Range. This zone combines the three most important seismogenic boundary faults (Fig. 4). In the west, this is the Chonkurchak Fault, which controlled the epicenters of the Belovodsky catastrophic earthquakes 1865 and 1885 (ML = 6.4 and 6.9, respectively). To the east of Boom segment of the Chuy Valley, these are the Chilik-Kemin faults. Several very strong earthquakes, including the 1911 Kemin earthquake (ML = 8.2; I = X–XI) [14] are related to these faults. The eastern segment of the South Chuy seismogenerating zone located to the east of the Jylamysh River is related to the seismogenerating Ysyk-Ata Faults extending along the northern boundary of the foothills and the Shamshy–Tyundyuk Fault trending between the foothills consisting of the Cenozoic molasse and the Kyrgyz Range composed of pre-Mesozoic consolidated rocks.

Ch.U. Utirov traced the Kegety–Serafimovka zone of residual deformations along the Ysyk-Ata Fault, the Shamshy–Merken Zone along the Shamshy–Tyundyuk Fault, and the Kemin Zone along the Kemin faults [5]. The aforementioned major seismogenic faults and the second-order faults are responsible for strong historical and ancient earthquakes; their trails are marked by seismic deformations.

SEISMIC DEFORMATIONS ALONG THE YSYK-ATA ADYR (FOOTHILL) FAULT

The clay, sandstone, and conglomerate of the Chuy (Saryagach) Formation is thrust over the upper Quaternary fluvial pebblestone along the Ysyk-Ata Fault dipping at an angle of 17° at the surface (Fig. 5). The structure of the fault zone is complex. In the Ysyk-Ata Valley, it consists of three fault planes localized close to one another and separated by tectonic wedges untouched by friction. The maximum displacement is related to the northernmost plane (hundreds of meters over the entire Neotectonic period). The displacement along two faults located to the south is not so significant. The slip of the upper Quaternary alluvial embedding reaches 1–2 m [8]. The reverse fault displacement of the upper Quaternary alluvial fans for 20–25 m along

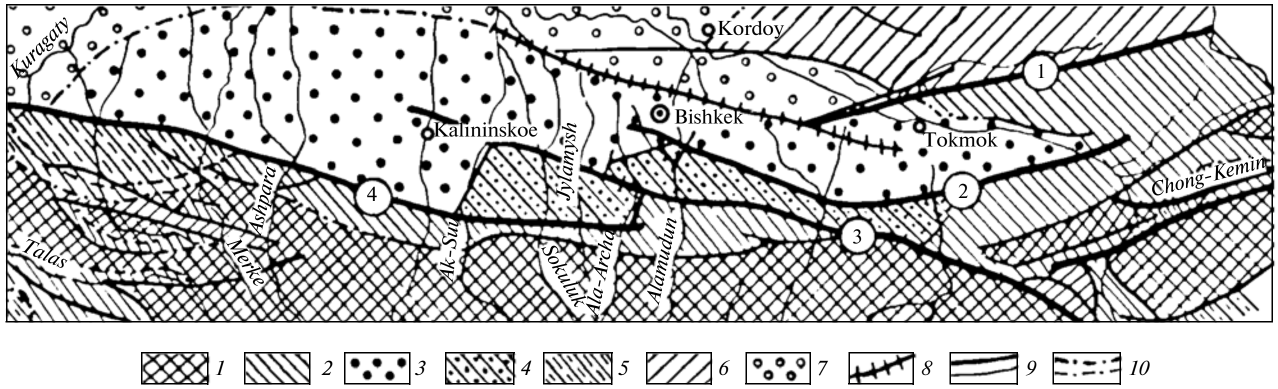

Fig. 4. Structure of junction zone of the Chuy Basin and the Kyrgyz Range, after [28]. (*1, 2*) Area of steady Cenozoic uplifting up to 4–5 km beginning from (*1*) Oligocene and (*2*) Pliocene; (*3*) area of steady Cenozoic subsiding (Kyrgyz Trough); (*4*) area of newly formed uplifts in the territory of the former Kyrgyz Trough; (*5*) area of intermontane basins with low-amplitude sagging and subsequent rising; (*6*) Quaternary uplifts with moderate amplitude in the Shu–Ili Mountains; (*7*) area of predominant Cenozoic sagging down to 0.5–1.0 km (Chuy Monocline); (*8*) flexure–fault zone; (*9*) boundary (above) and other (below) faults; (*10*) geological boundary (without faults). Numerals in circles: 1, Karakunuz Fault; 2, Ysyk-Ata Fault; 3, Shamshi–Tyundyuk Fault; 4, Chong-Kurchak Fault.

the Ysyk-Ata Fault is established along the line of the foothills.

In addition to the deformed terrace levels, four levels of accumulative terraces 0.5–1.5 m high are traced in the Ysyk-Ata Valley, where it crosses the fault of the same name. The accumulative terraces are enclosed into older terraces and do not reveal any signs of deformation [28]. Young terraces overlap older ones downstream the valley.

A fault gauge within the northern fault zone, separating Quaternary and Neogene sediments, indicates that recurrent displacements occurred along this particular fault plane. The repeated slip along this fault led to the re-orientation of pebbles and boulders along the fault plane (Fig. 5b).

Seismic (?) and gravity dislocations are observed in the Ysyk-Ata Fault Zone. For example, the head of the Kenkoktu Ravine is filled with a sagged material, which is distinguished by a special wavy surface and unusual vegetation with bush, whereas only grassy cover occurs down the ravine [8].

The structure of the Yur'evka section (Fig. 5a) gives evidence that the movements along the master fault took place at the end of the late Pleistocene or early Holocene. As a result, alluvium of Q^{2}_{III} terrace is thrown up along the line of the thrust fault for ~20 m, whereas the upper Holocene alluvium overlaps the fault zone without disturbances. It should be noted that Holocene displacements are not documented only at this locality. The data on the Sokuluk and Alamüdün valleys indicate that the late Holocene movements took place along the fault to the west of the Ysyk-Ata River.

Near the boundary of Bishkek, the Ysyk-Ata Fault extends along the outer limit of the foothills. On the right (eastern) slope of the Alamüdün Valley, this fault is clearly expressed as a scarp a few meters high (Fig. 6).

Trench no. 2 [28] has been dug in the meridional direction across the Ysyk-Ata fault plane to the west of the Kok-Jar Settlement (Fig. 7). The hanging wall of the fault is composed of Pliocene conglomerate with carbonate cement, which belongs to the Noruz Formation correlative to the Sharpyldak Formation and the upper part of the Chuy Formation [16]. The footwall of the fault consists of Pleistocene loose sediments.

The complete section of the hanging wall comprises the following units (from top to bottom) [28]: (1) recent soil underlain by alluvial pebbles and boulders with sandy filler pertaining to the Alamüdün terrace (Q^{1}_{III}); the alluvial cover does not exceed a few decimeters in thickness and overlies compact Pliocene conglomerate with signs of azimuthal and angular unconformity; (2) Pliocene conglomerate with strong carbonate cement and lenses of gravelstone and sandstone; (3) gravelstone, which forms a fold almost overturned to the north in the direction of displacement of the hanging wall; (4) boulder conglomerate resembling a bed (2) is also involved in deformation.

The section described above is thrust over the soil and the colluvium formed as a product of destruction of the escarpment of the Q^{1}_{III} terrace (layer 5 in Fig. 7) along the main plane of the Ysyk-Ata Fault (the dip azimuth is 190° SSW and dip angle is 19°) [28]. The colluvial layer consisting of siltstone with sporadic pebbles and boulders increases in thickness beneath

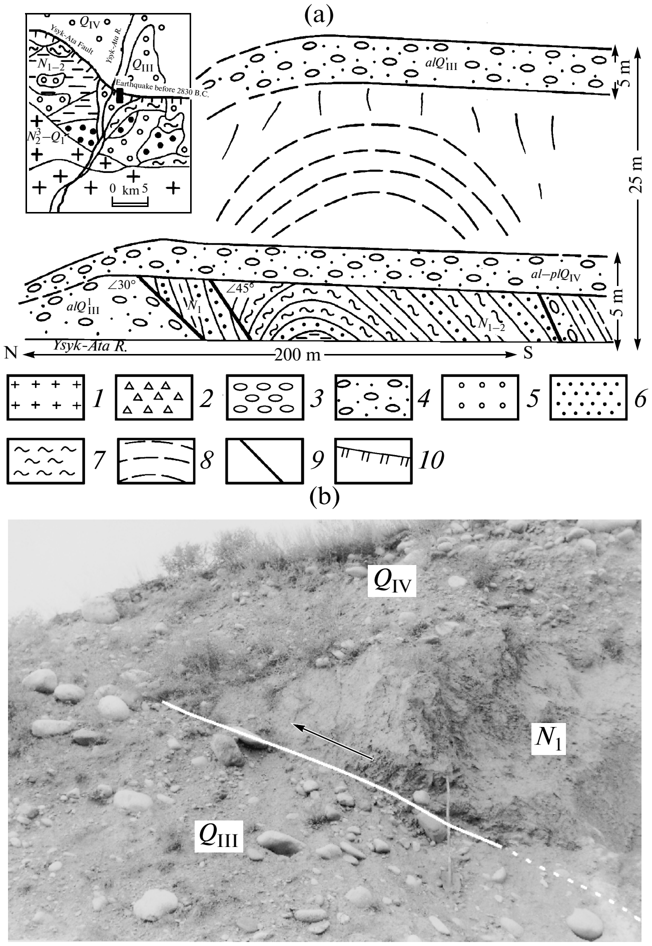

Fig. 5. The Ysyk-Ata Fault Zone on the right slope of the Ysyk-Ata Vallley, outcrop near Yur'evka Settlement: (a) sketch modified after [28] and (b) photo by A.M. Korjenkov, 1998. (*1*) Precambrian and Paleozoic rocks, mainly granitoids; (*2*) recent colluvial sediments (pattums); (*3*) Pliocene conglomerate with gravelstone and sandstone lenses; (*4*) alluvial pebbles with sand–silt filler of various ages; (*5*) middle Quaternary boulders and pebbles; (*6*) gravelstones of various ages; (*7*) clays of various ages; (*8*) loess-like loams of various ages; (*9*) plane of seismic fault; (*10*) recent soil.

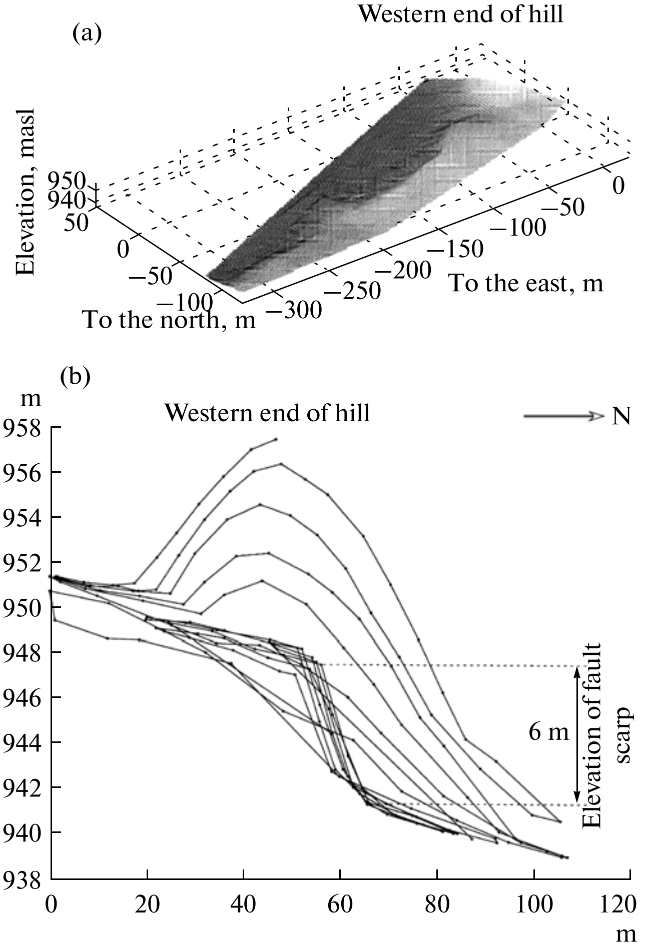

Fig. 6. A fault scarp along the Ysyk-Ata Fault: (a) 3D model of a scarp fragment at the eastern margin of Kok-Jar Settlement and (b) profiles nos. 41–55 across the scarp.

the fault plane and conformably dips under this plane, where gravel, pebbles, and boulders become predominant. Below the Ysyk-Ata Fault, the next parallel fault displaces this layer northward over the terrace sediments of the late Alamüdün Complex (Q_{III}^2). The cover of straw-colored loam 10–15 cm in thickness (layer *9* in Fig. 7) pertaining to this complex is underlain by loose alluvial pebbles with silty psammitic filler (layer *10* in Fig. 7), which plunges to an unknown depth. By analogy with other localities, this depth can reach a few tens of meters.

In the Ysyk-Ata Fault Zone, the alluvial section is disturbed by three or four thrust faults drawn after the photograph of the eastern wall in trench no. 2 [28]. In general, these faults are conformable to the main fault plane (Fig. 8).

Three lenses of Holocene colluvial material are wedged between the thrust planes localized in the thraw-colored loess-like loam belonging to Q_{III}^2 [28]. As judged from its composition, the frontal portion (nose) of the hanging wall (Pliocene conglomerate) collapsed due to the fast movement and vibration caused by strong earthquakes. After that, the collapsed sediments were squeezed and transformed into a lens during subsequent movement of the hanging wall.

The age of seismic events has been determined by dating of under- and overlying rocks with dark interbeds rich in humus, which were sampled by Chedia et al. [28] for determination of their radiocarbon age. The location of samples and their ages are shown in Fig. 8.

The oldest soil predated the lower fault plane, having radiocarbon ages of 5130 ± 50 and 5250 ± 60 years. The age of the soil in the lower colluvial lens is 2830 ±

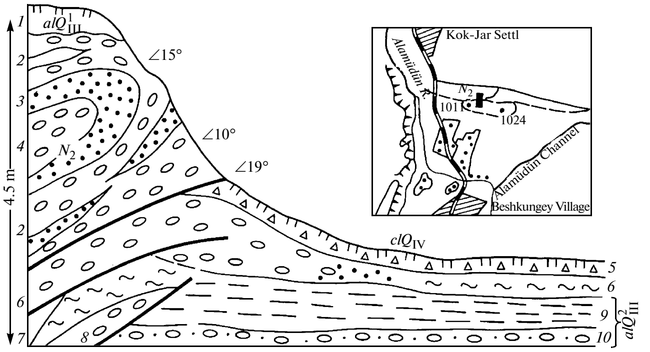

Fig. 7. Sketch of the Ysyk-Ata Fault Zone: the western wall of trench no. 2 near Kok-Jar Settlement, modified after [28]. See text for explanation and Fig. 5a for legend.

50 years. Thus, the first earthquake occurred in the time span between the above-mentioned dates [28].

The upper colluvial lens includes the soil dated at 1859 ± 40 years. The formation of the middle colluvial lens and thrusting along its boundary, as well as the formation of the roof and bottom of the upper lens took place as long ago as the third and the second millennia B.C. (2830 and 1850 years, respectively) [28].

In the Kok-Jar section (Fig. 8), the frontal portion of the hanging wall collapsed with the formation of colluvial lenses at least four times between 2830 and 1850 years ago and once later, between 1850 and 103 years ago. Thus, four earthquakes occurred here over a thousand years, i.e., one event per 250 years [28].

The date 103 ± 50 years is the age of the colluvial sequence collapsed (formed) on the slope of the fault scarp during the last earthquake related to displacement along the Ysyk-Atas Fault in 1885 A.D. Could it be that no earthquakes happened over 1750 years (from the 2nd to the 19th centuries A.D.) along this fault? This appears strange, because four strong earthquakes took place from the 8th century B.C. to the 2nd century A.D.

A possible explanation is that the seismic ruptures, which provoked some strong earthquakes in the Tien Shan, do not reach surface. For example, during the 1992 Suusamyr earthquake (M= 7.3; I = IX–X) two fault scarps were formed: one along the Suusamyr Boundary Fault and another along the Aramsu Foothill Fault [3, 29] 26 km apart from the first fault. As follows from the distribution of aftershocks, the fault zone of the Suusamyr earthquake extends for ~50 km [37], whereas the length of the two faults formed at the surface was only ~4 km. Such a phenomenon could take place if the displacements along the master faults were distributed by secondary splitting faults reaching the surface. The mechanism of this phenomenon is schematically shown in Fig. 9.

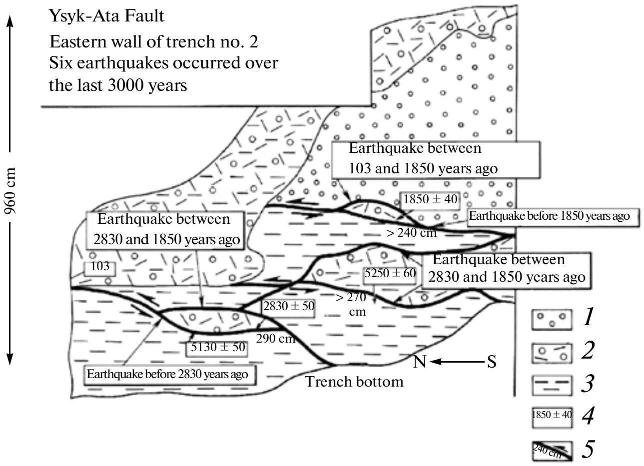

Fig. 8. Detailed documentation of the eastern wall of trench no. 2, modified after [28]. See text for explanation. (*1*) Pliocene conglomerate; (*2*) Holocene colluvial sediments; (*3*) Upper Quaternary loess-like loam; (*4*) radiocarbon age of paleosoil in colluvial wedges; (*5*) plane of seismic ruptures and offset along it; the arrow indicates the direction of thrusting of the hanging wall.

As concerns the Suusamyr earthquake, it is clear that the scarps along the Suusamyr and Aramsu faults imply widening of the fault zone near the surface. Finally, Mellors et al. [37] noted that aftershocks, which distinctly mark a fault plane at a depth, disperse near the surface. Much more significant dispersion established for shallow aftershocks is partly a consequence of poorly detected hypocenters at a shallow depth but also may be caused by widening of the fault zone toward the surface. The archeoseismological method is a reliable tool for identification of seismic disasters which do not leave behind significant seismic deformations.

Fig. 9. A scheme illustrating near-surface widening of the fault zone with distribution of total displacement along several splitting secondary faults reaching the surface along planes of border and foothill faults, after [9, 10]. Heavy lines are faults and thin lines are sedimentary beds.

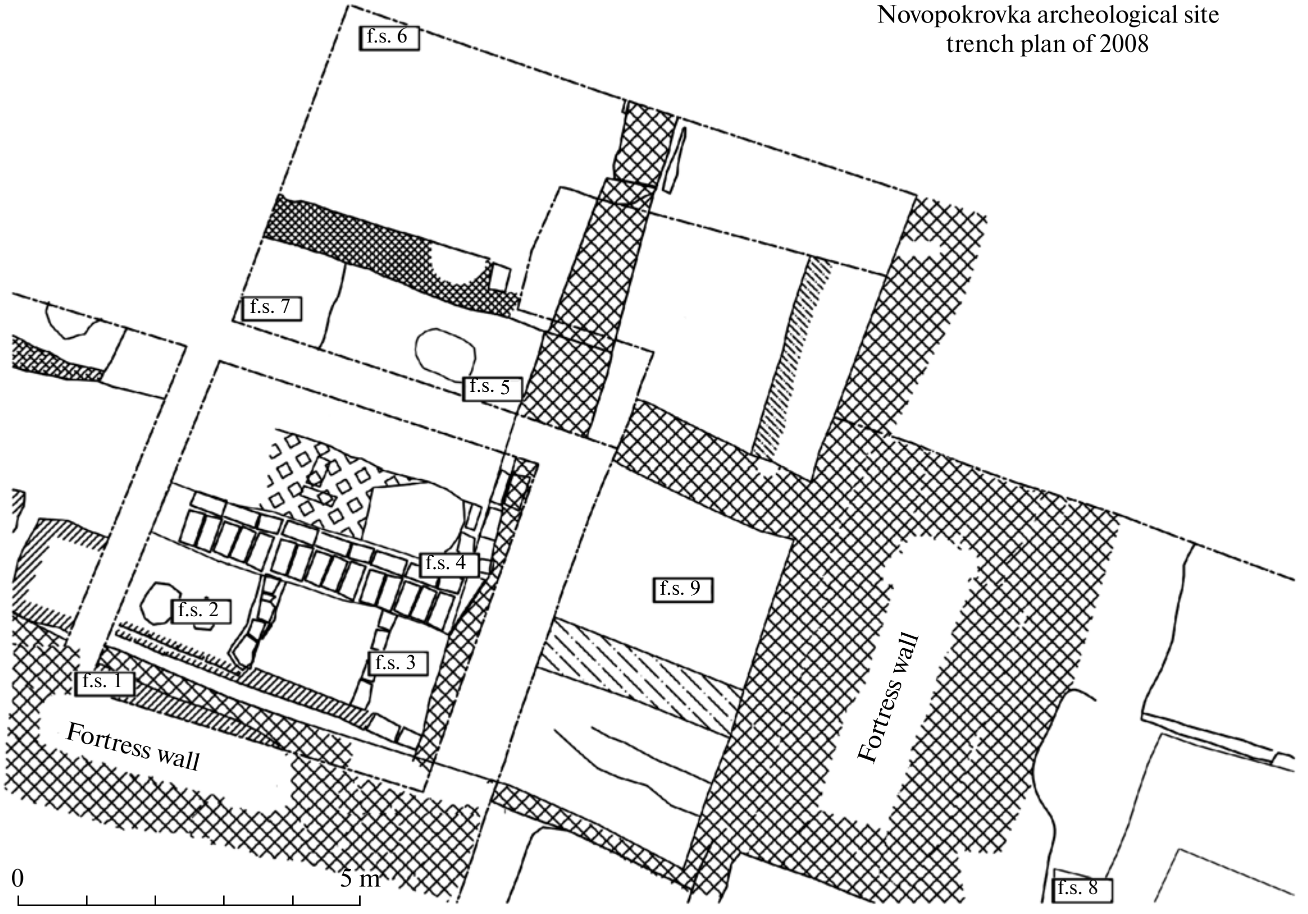

Fig. 10. Plan of a trench of the Novopokrovka ancient settlement as of 2008. Observation and measurement points (f.s.—field stations), used in the paper, are plotted.

ARCHEOSEISMOLOGICAL INVESTIGATIONS OF THE SECOND NOVOPOKROVKA ARCHEOLOGICAL SITE

We carried out a special archeoseismological study in a trench at the southeastern part of the second Novopokrovka archeological site (Fig. 10). Our study revealed numerous tilted and bent walls differing in age, shifts of the upper parts of the retained walls relative to their lower parts, cracking of walls near the corners, and other deformations. This technique has been successfully applied by many specialists [13, 17–19, 24, 26, 30–36, 39–42 and others] in different countries, thus there is no need to describe it specially here.

Shifted Walls

Shifted walls are important evidence for destruction that is seismic in nature. Indeed, it is difficult to imagine that the upper part of a wall composed of adobe bricks could be shifted over its entire extent without the application of external forces. The mechanism of this phenomenon is described in [32, 36]: the lower part of a building is displaced along with the ground in the horizontal direction under the effect of seismic movements. At the same time, the upper part

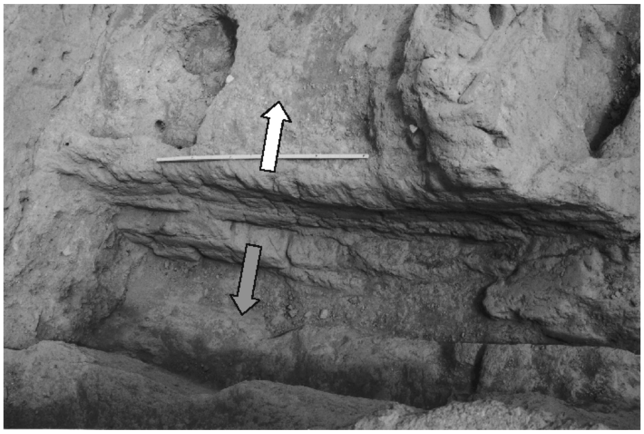

Fig. 11. The lower part of the southern wall has been moved-out to the south. The white arrow indicates relative (inertial) motion of the upper part of this wall to the north. Room 14.

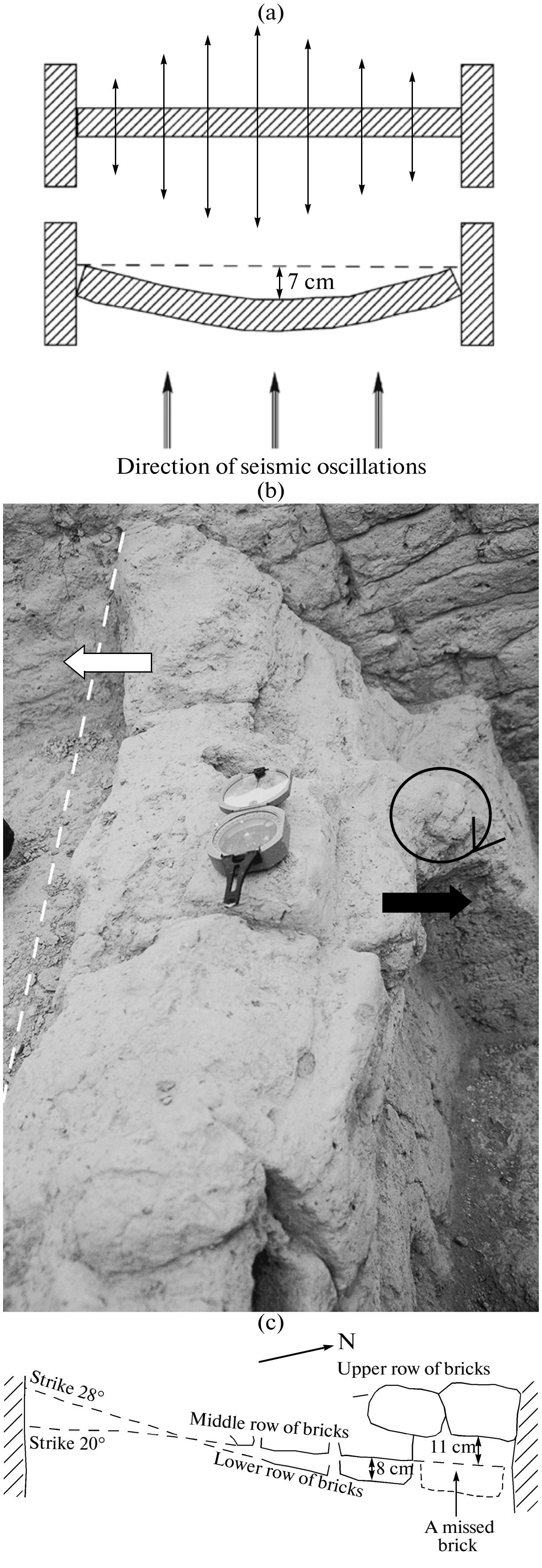

Fig. 12. Arcuate horizontal deformation of the upper part of the eastern wall in observation point 2 (f.s. 2): (a) deformation model (plan); (b) photograph, view to the north. The lower row of bricks has been moved-out to the east and turned clockwise. The upper row has been shifted to the west as shown in Fig. 12c (plan).

of the wall lags behind due to inertia. Such a phenomenon was noted for the southern wall of observation point 2 (f.s. 2). The lower part of the wall oriented at an azimuth of 112° ESE was shifted southward at an azimuth 202° SSW for a distance of 11 cm (Fig. 11) and both walls tilted to the north at an angle of 75°.

Lateral Bends of Walls

In addition to shifts and tilts, lateral arcuate bends of walls are found during archeological excavations in seismically hazardous regions [36]. Such an effect arises in the central parts of walls, owing to the highest freedom of oscillations (Fig. 12). At the Novopokrovka archeological site, the eastern wall of observation point 2 (f.s. 2) was deformed in such a manner. The wall is oriented at an azimuth of 20° NNE and curved on 7 cm.

Fracturing

Fracturing is a spectacular example of seismic damage of constructions. Indeed, walls constructed of adobe bricks or merely of clay begin gradually to sag with time like a lump of ice in the sun. Thus, the occurrence of numerous fractures at digging sites, along with other types of damage, can serve as additional evidence for the seismic nature of deformation [32, 36]. Nevertheless, such fracture can also arise by shrinkage of a building due to its aging or subsidence of the underlying ground.

Curious deformations in the Novopokrovka site are the fractures formed above the so-called refuse pits (Fig. 13). These pits are abundant at the studied excavation site. Although these pits were filled with building waste, bones of animals, broken ceramic vessels, ash, and feces, the density of the fill is much lower than the density of loess or fragments of destroyed walls, where these pits were dug. During seismic oscillations at the boundary between two media, the near-vertical fractures grew in denser and thus more brittle loams. Similar fractures above window frames, door apertures, and cave passages are abundant in zones of current and ancient strong earthquakes [10, 33–35].

Deformations in Corners of Buildings

Deformations in the corners of buildings are frequent damages induced by earthquakes. The cause of their abundance is clear: seismic waves exert an effect on per-

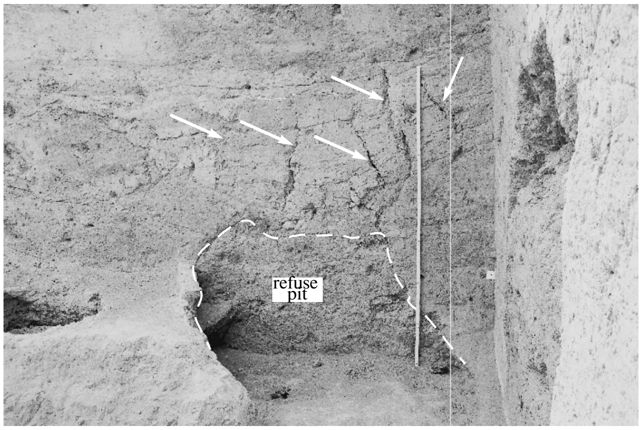

Fig. 13. Fractures above a refuse pit (f.s. 7 in Fig. 10).

pendicular walls at different angles. Thus, the amplitude and character of oscillations in variously oriented walls are different, and this leads to deformation and destruction of the corners in buildings (Fig. 14).

Such deformations have been observed, for example, at the northern wall of observation point 3 (f.s. 3) (Fig. 15), where a number of through-going cracks cut into five bricks (65 cm), as well as the cement between them. A wall of raw brick can incline with time without seismic impact; however, the occurrence of completely broken corners is not accidental and indicates that deformation was induced by an earthquake.

Deformations of Building Constructed on Subsided Grounds

The constructions situated in the epicentral zones of strong earthquakes are subject to significant damage. If the constructions have been erected on subsided ground, the degree of damage increases up to additional unit of the macroseismic MSK-64 scale. The seismic waves passing through a mass of unconsolidated materials compact them at one site and decompact with loss of cohesion between the grains at other sites. Such difference in engineering geological conditions under a basement of a building can induce subsidence of its fragments, damage, or destruction.

The ancient settlements of the Novopokrovka archeological site rest upon alluvial, proluvial, and eolian loose sediments (alternating sand, clay, and loam). Precisely these grounds, being subject to intense decompaction under seismic impacts, induce subsidence. For example, the main wall in square 1 to the north of observation point 3 (f.s. 3) reveals signs of dragging. The clay wall has been sagged; the bricks in this wall became curved at the junction with the perpendicular pakhsa wall (Fig. 16). Another example of sagging is observed in the southeastern corner of

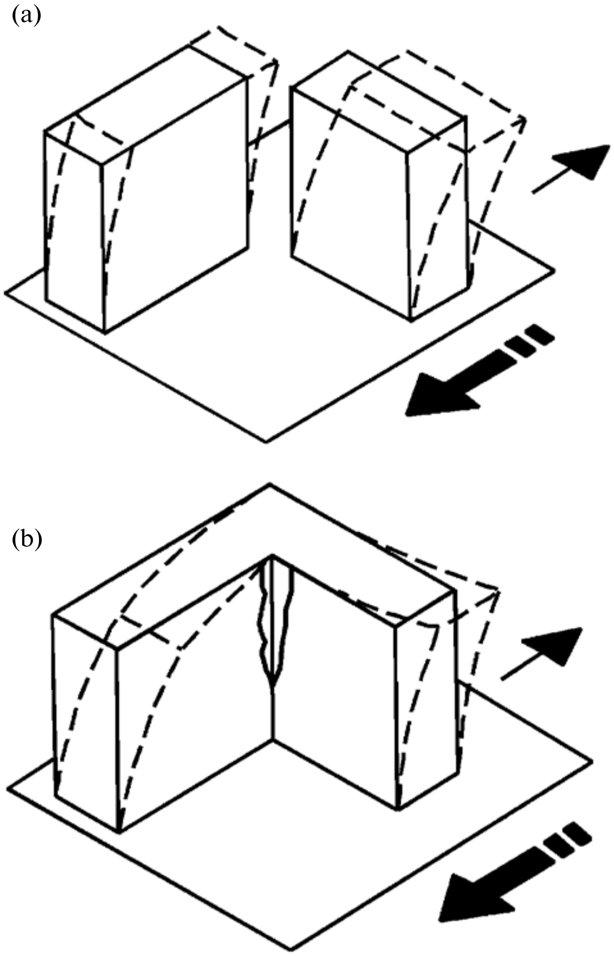

Fig. 14. Deformation of walls in buildings during strong earthquake: models, modified after [25]: (a) detached walls can oscillate without failure; (b) corners of buildings are destroyed first because of different directions and amplitude of oscillations.

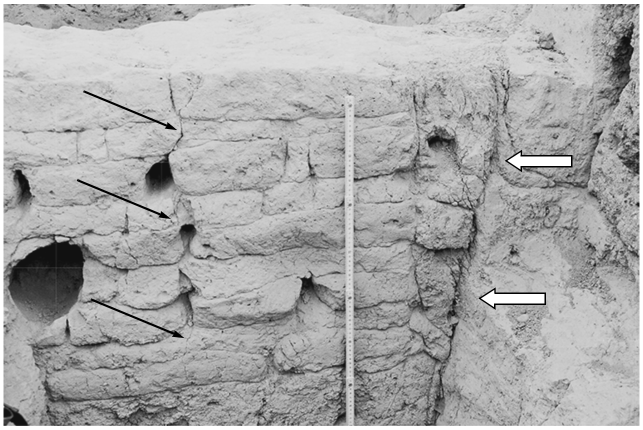

Fig. 15. Deformed corner portion of the northern wall in room 15 (white arrows). Through-going joint is indicated by black arrows.

Fig. 16. Subsidence of the main wall at f.s. 4 (Fig. 10) is indicated by white arrow. Due to the subsidence, the clay bricks at the junction with the opposite wall are curved downward. Cracking of both walls at their junction is noted.

Fig. 17. Sagging of the central fragment of wall at f.s. 5 (Fig. 10) along the extended fracture is documented by displacement of the yellow loess-like loam bed. The direction of displacement is shown by black arrows.

square 2. The central part of the meridional pakhsa wall has subsided along the extended fracture (Fig. 17). This displacement is clearly seen by sinking a lamina of yellow loess-like loam for 11 cm.

CONCLUSIONS

The data presented in the paper show that in historical time the Chuy Basin was repeatedly subject to strong earthquakes, which affected the inhabitants and the economic and political situation at that time.

The deformed buildings in the Novopokrovka site of ancient settlements unequivocally indicate damage of a seismic nature. It cannot be ruled out that the settlements were abandoned following a strong earthquake.

Walls of the Karakhanid period were subject to deformation. Thus, the age of earthquake corresponds to the end of the epoch of Karakhanids; most probably, it was the end of the 12th century A.D. The radiocarbon age of the significant landslide, which occurred in the Ysyk-Ata Valley to the south of the site (800 ± 40 years, sample LU-949 [12]), is indirect evidence for the synchronous destruction of the settlement.

The intensity of seismic oscillations at the site corresponded to I = VIII–IX on the MSK-64 macroseismic scale. The intensity of seismic vibrations was markedly strengthened by the unfavorable engineering geology of the Novopokrovka site, adding up to an additional point on this scale.

The source of the earthquake was probably related to displacements along the piedmont Ysyk-Ata Fault extending to the south of the site. The study of the boundary Shamshy–Tyundyuk Fault located further to the south did not reveal geomorphic indications of its seismic activity in the Holocene.

Additional archeoseismological, paleoseismological, and historical seismological investigations of the Novopokrovka site and other ancient settlements within the Chuy Basin and its mountain framework are required to specify the parameters of the ancient earthquakes.

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