

## Traces of Strong Earthquakes at Ahsiket, the Ancient Capital of the Ferghana Valley

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Received June 15, 2020; revised July 12, 2020; accepted December 11, 2020

**Abstract**—Studies in archeoseismology were conducted in the Ferghana Valley revealing traces of strong earthquakes that occurred in ancient times. We pointed out in our previous publications that the ancient city of Eilatan perished in the 1st century BC when devastated by a strong earthquake. It was during that time that the capital Farghana (Akhsiket) was damaged. We also detected there a seismic rupture at the surface and other evident deformations in the previous structural elements. We determined the magnitude of the seismic disaster ( $M = 7.6$ ) based on the greatest displacement on the seismogenic rupture emerging at the surface right in the middle of the ancient city. The associated seismic motion completely destroyed or considerably deformed all structures and seriously damaged and destroyed the city walls. It was probably for that reason that the new kings of the Ferghana Valley built a new residence for themselves on Mugtepe after the 90s BC. The site is referred to in a Chinese source *Hanshu* as Guishuan. We have succeeded to determine from data to be found in archeological sources that the abovementioned fortifications in the capital were built in the time span 104–90 BC, while the intensity X earthquake itself seems to have occurred approximately in 91–90 BC. The earthquake involved all of the Ferghana Valley, hitting the towns and villages in the northern Ferghana especially heavily. A conspicuous example is furnished by the falling-apart of massive fortress walls in the citadel and the Shahrستان of the town of Farghana (Ahsiket). It is possible that the seismogenic rupturing that emerged at the surface in the ancient Ahsiket and Eilatan occurred at the same time. A similar strong earthquake occurred later on, during the 11th to the earlier half of the 12th century. We identified traces of this seismic event at several objects of the Karahanid age in the shakhristan and rabad. These materials must be incorporated for a new assessment of earthquake hazard for the Ferghana Basin.

**Keywords:** archeoseismology, seismic deformation, kinematic indicators, ruins, seismic rupture, Ferghana, Ahsiket, ancient cities, the Silk Road, strong earthquakes

**DOI:** 10.1134/S0742046321020044

### INTRODUCTION

Large earthquakes have large extents of their rupture zones, violent ground motion in their epicentral zones, and, very frequently, their ruptures emerge at the ground surface. In that last case, thrust or normal slip at earthquake rupture zones produce extensive seismic scarps at the ground surface. When strike slip movements occur, the result is to produce systematic flexures in all relief forms along the rupture plane, e.g., flexures in the beds of temporary water streams and of divides between these. Similar deformations also appear at human settlements, when a seismogenic rupture displaces all walls in the same sense throughout its length. As an example, a strike slip combined with a thrust movement displaced the walls of the medieval Kamenka fortress (*Karahanid* time) in the

northern Issyk Kul region at the beginning of the 12th century AD for nearly 4 m in a lateral direction and for 2 m vertically (Korzhenkov et al., 2006).

The emergence of a seismic rupture at the ground surface was a disaster for the local population. The intensity of seismic motion in the epicentral zone can then reach  $I0 = IX-X$  or greater on the MSK-64 scale. However, this is exceptionally important information for seismological geologists: the parameters of a surface rupture can be used to find the magnitude (energy) of the responsible earthquake based on existing empirical relations. As an example, the magnitude of the seismic event that has destroyed the Kamenka fortress was estimated as  $M_s = 7.4 (\pm 0.5)$  (Korzhenkov, 2006).

The Eski Ahsi settlement site was formerly the capital of an important state. At present its appearance is seen as spread-out ridges and hills whose surface does not provide any information for specialists of any discipline. However, the ever present erosion and the modern industrial activities of man occasionally expose the structure of the rocks underlying an archeological monument, as well as surviving parts of structures. Exposures such as these are mostly available along the southern margin of the city where its walls are being undermined by a great water stream of Central Asia, the Syr Darya River (formerly Yaksart). The automobile highway running along the western wall of the fortress also produces local collapses of the spread slopes and exposes artefacts that were hidden before. There are manmade pits as well, which are sites of archeological excavation where wall remains and the bedrock structure are deliberately set for view under the roof of a special booth. We have tried to study all exposures mentioned above in order to find possible traces of significant ancient earthquakes.

The archeological studies of residual deformations, traces, and impact of ancient strong earthquakes in archeological monuments of Uzbekistan were first conducted in 2019 in the Namangan Region. The region is in the northeastern Ferghana Basin in the middle of the western Tien Shan. The present paper reports archeoseismological studies in the ancient city of Ahsikent in the Turakurgan District, near the village of Shakhand, on the right bank of the Syr Darya River.

There are numerous ancient archeological monuments in the Turakurgan, Kasansai, Chust, Pap, and Naryn districts of the Namangan Region. The monuments have been destroyed by time and natural disasters. Residual deformations due to ancient earthquakes have been found in the ruins. We measured azimuths of the fissures, displacements at fractures, and the dip angles of the seismic deformations found in the ancient monuments. We tried to get a deeper understanding of the seismotectonic processes and the associated high level of earthquake hazard for the region by considering the geological and tectonic setting favoring seismic activity in the region.

Our archeological studies have revealed the fact that, since the end of the Bronze Age and in the beginning of the Early Iron Age, settlements began to arise in plains of the right bank of the Syr-Darya River (Fig. 1). Irrigated agriculture was intensively developing during the first millennium BC, as large canals appeared, hence the area of anthropogenic landscape became wider. In particular, a manmade canal appeared in the 10th to 9th century BC where an older dry tributary of the Kasansai had been; the canal ran north of the modern village of Buramatut and reached the village of Ahsi. It was owing to this canal that the agricultural workers managed to cultivate a few tens of hectares more. The result was a new micro-oasis which we

called the Ahsiket oasis. The evidence for the latter is a thick enough irrigation agricultural layer (0.75 m) and pottery dating back to the Late Bronze Age (Anarbaev, 2013) detected under the occupational layers of the Eski Ahsi settlement (Ahsikent).

In ancient times, the Ferghana residents applied the same name (Farghana) to both their state and to the main capital; the word had the sense of a terrain surrounded by mountains (walls) with a single entry. Chinese records translate the word Farghana as Yuan, while applying the combination Dai-Yuan (Greater Farghana) to the state of Farghana. Later on, since the second half of the 9th century, the town of Farghana was mentioned as Ahsiket in Arabic sources, while coin evidence shows that it had the double name of Farghana—Ahsiket. It was only since the second half of the 11th century that the sources spelt it as Ahsikat, while being mentioned as Ahsi during the Babur epoch. We have succeeded in finding that the capital Farghana (Yuan) was at the location of a modern archeological site, the Eski Ahsi settlement (Ahsikent).

The settlement is on the right bank of the Syrdarya River (Fig. 2), 25 km southwest of the town of Namangan near the village of Shakhand (Anarbaev, 2013). The town was built in the 3rd century BC and consisted of three parts: ark (fortress), shakhristan<sup>1</sup> (Ahsi IA, Ahsi IB), suburb<sup>2</sup> (Ahsi II, Ahsi III, and Ahsi IV). In ancient times, the town occupied over 50 ha, while being around 70 ha during the early Middle Ages. During the mature Middle Ages, its area reached over 400 ha; accordingly, the population was over 200 thousand people. As a result, Ahsiket became a “mega-city” of its time during the 9th to 12th centuries. One can trace the evolution of material culture from its earlier periods to the mature Middle Ages, when the Ahsiket residents reached such a high level as to enable them to produce high quality steel (Damask steel) and to use it to make various weapons like swords, daggers, and armor (Anarbaev, 2019).

## THE DATA

### *Historical Archeological Studies: the Capital of the Ancient Ferghana*

The antiquity was, for Ferghana and for the other regions in Central Asia, a time when all societal spheres were being gradually, stage by stage, involved in the world civilization. The most conspicuous manifestation of these changes was a rapid rise of urbanization, the development of previously existing cities, and the appearance of new ones. By that time, the migration processes that started in the east then advanced into nearly the entire steppe strip of Eurasia. Ferghana was involved in human migration during the 2nd and

<sup>1</sup> Shahrستان (the inner city).

<sup>2</sup> It was called *rabad* (the outer city) during the Middle Ages.

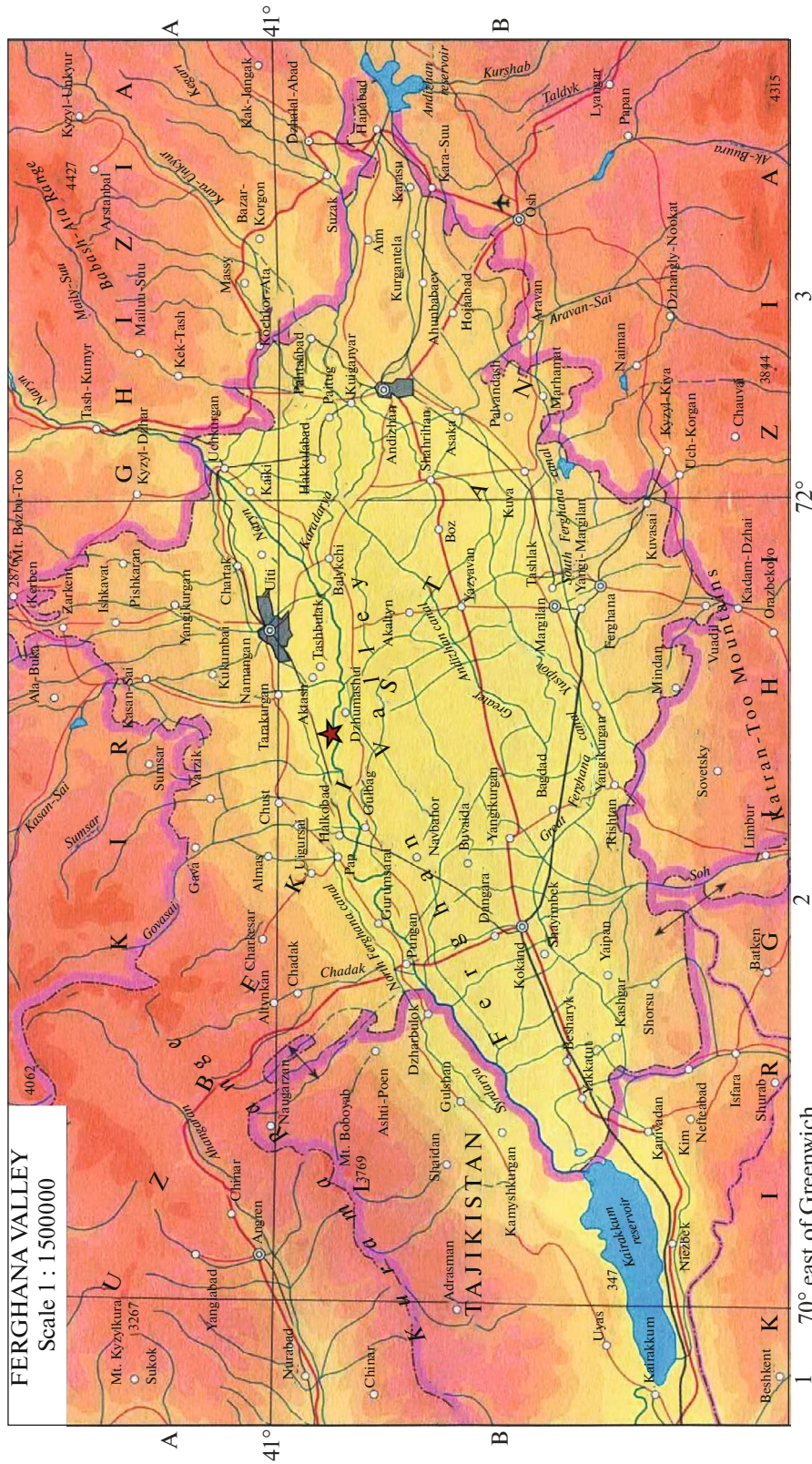


Fig. 1. A topographic map of the Ferghana Valley. The red star marks the location of the ancient city studied here (Ahsiket).



Fig. 2. A space image (GoogleEarth) of the Ahsikent site. The numerals are the numbers of figures in this paper.

1st centuries BC. In particular, the movement of nomadic yuezhi tribes from eastern Turkestan to Ferghana and farther into the west and south of Central Asia finds archeological confirmation. The movement involved numerous great and minor peoples in Eurasia. Some of these settled in Ferghana and gradually were assimilated by the local population, becoming rightful Ferghana residents later on. The migrants brought a new funeral rite into the valley, with corpses being buried in catacombs and shallow pits. Since that time, a powerful burst of population occurred related to settlement on new land, to the appearance of new cities, villages, and the development of mining industries (Anarbaev, 2017).

Sima Qian who wrote the historical work *Shiji* used a report of the Chinese diplomat Zhang Qian about the events of 138–90 BC to describe Ferghana as a country of 70 cities. This source mentions the names of only three of these, namely, Yuan, Ershi, and Yucheng. Of these, the town of Yuan (Farghana) was the capital of the confederation, while Yucheng (Eilatan) and Ershi (Marhamat) were the centers of small domains. The ancient Ferghana inhabitants called their country and its capital by a single word, Farghana, which meant a terrain surrounded by mountains (walls) with a single entry. The Chinese ambassador Zhang Qian had to solve the problem of distinguishing between the Ferghana city and the state of Farghana in his description of the voyage. He solved the problem by adding the word “dai” before “yuan”. The character “dai” means large, great, while “yuan” means a terrain surrounded by mountains or hills. In particular, the *Shiji* document contains several occur-

rences of the words Yuancheng (the town of Yuan) and “Yuanwang” (the governor of Yuan) (Khodzhaev, 2009; Anarbaev, 2019).

The Chinese ambassador Zhang Qian, who visited Ferghana (128–127 BC), was struck with the splendid quality of the local horses whose breed was much different from that in ancient China. Chinese sources say that “The inhabitants love wine as much as their horses love the mu-su grass”<sup>3</sup> (Bichurin, 1950). Zhang Qian called the Ferghana horses “celestial”. He gave a spectacular description of these celestial horses for the Emperor Wu-Doo. The Emperor sent a special embassy to Ferghana in 105 BC to buy purebred horses, but received a refusal; the result was to start a four-year war which the Chinese won. All of these events are described at length in the historical records *Shiji* and *Hanshu*. It is in these chronicles that we find the first written evidence for the political and socio-economic life in Ferghana during antiquity. According to these reports, the ancient state of Ferghana was governed by a governor with the help of two aides. The political life of the country was controlled by the “Council of the Elders”. They discussed important issues of state, including the declaration of war, the conduct of peaceful negotiations and, in case it was deemed necessary, the fate of the governor himself was decided (Bichurin, 1950).

Serious changes took place in the political life of Ferghana after 90 BC, namely, the power passed to the Great Yuezhi tribes. They built a small town at the Mugtepa site in the upper Kasansai. It was their polit-

<sup>3</sup> Alfalfa.

ical capital or, to be more exact, the headquarters of the new Ferghana kings. It is referred to in Chinese chronicles as “Guishuan”. The new kings seem to have been living in tents as evidenced by the Mugtepa topography: judging by the microrelief, the central empty space of the settlement had no monumental buildings, so tents were likely to have been there.

While remaining the economic and cultural center of the valley, the town of Farghana did not disappear from history, being recorded time and again in books written by Arab historians and geographers during the 8th to the earlier half of the 9th century (Tabari, 1987; Ibn Hordadbeh, 1986). Since the later half of the 9th century, the town of Farghana was referred to in Arabic sources as Ahsiket, while numismatic data show that it had continued to bear a double name until the mid-11th century, viz., Farghana-Ahsiket. The town was mentioned as Ahsi during the Babur epoch (1493–94) (Baburnama, 1993).

The caravan route that connected China and northern Central Asia, or the so-called Northern Route, went through Ferghana in the 2nd century BC and later; that is to say, it ran from Kashgar through the Terekdavan Pass into the Ferghana Valley, and thence into Maverannahr and farther through the Great Steppe to the northern Black Sea coast. Chinese silk and bronze artefacts were transported along this route into the lower Volga region, the Urals, the North Caucasus, and the northern Black Sea coast (Lubo-Lesnichenko, 1988). The returning caravans brought glassware, purebred horses, fruit, cotton, armor, etc. In particular, Ferghana supplied the Han Court with horses, armor, wine, and cotton.

The Great Silk Road served for communication between the East and the West extending from the Mediterranean coasts to China and Korea (Anarbaev, 2012). The road served as a route for diplomatic embassies, pilgrims and travelers, merchants carried various merchandise from east to west and from west to east, including gemstones, purebred horses, metal wares, china, quaint objects from many countries, medicaments, dyestuffs, etc. However, silk was the costliest merchandise. It gave its very name to this road. However, it should not be forgotten that there was another commodity that was as costly, namely, the Ferghana horses. The numerous contacts gave rise to an active exchange of material and other kinds of wealth.

Archeological studies showed that the city of Farghana (Ferghana) arose in the 3rd century BC at the location of the Eski Ahsi settlement (Ahsiket). The site consists of remains of the citadel (fortress), the shahristan (the inner city), and the rabad (the outer city) (see Fig. 2). Archeology revealed distinct phases in the variation of its historical topography. At first, the city consisted of two parts: the ark (fortress) and the shahristan (the inner city) with an area of over 40 ha, with the handicraft suburb (Ahsi II) whose area was about 10 ha being added later on, in the second century BC. The city then consisted of three parts and occupied an area of over 50 ha. In the earlier Middle

Ages the city expanded eastward (Ahsi III), and its area was about 70 ha.<sup>4</sup> In the 9th to 12th centuries, the area of the Ahsiket City (Farghana) reached more than 400 ha and its population was over 200 thousand people. The evolution of its material culture can be fairly clearly traced from the earliest period until the mature Middle Ages, when the Ahsiket residents reached such a high level as to enable them to produce high quality steel (Damask steel) and to make of it various types of weapons, including the so-called famous Damask blades.

The fortress walls of the city acquired an imposing appearance in the beginning of the 1st century BC, that is, a powerful fortification system had been erected during 10 years. In particular, two thick fortress walls were built in the second shahristan (Ahsi IB) with towers of sorts made of unbaked bricks and pasha<sup>5</sup>. The wall was wider than 20 m at the base, with the height also being at least 20 m. The towers were rectangular in the citadel and juttied out beyond the walls, while going along the wall perimeter in the second shahristan (Ahsi IB), standing above the citadel and being within its plane (Anarbaev, 2013). All of these fortification works were carried out at once after the inroad of the Chinese army in 104–99 BC. Excavations showed that the walls were preserved to heights of 15 m, and the towers up to 18 m; they are still rather sturdy.

The city was expanding east during the early Middle Ages. The older city walls were being repaired and new ones were built. The city's defense increased. The city extended north and northwest as the rabad during the 9th to 12th centuries. At that time the shahristan's residents were artisans who were mostly engaged in black metallurgy and metal processing. There were special stoves (crucibles) to produce pure (Damask) steel to make the so-called “Damask swords”. The city had an underground water-supply lines in the mid-10th century which had served for over 250 years. The lines were built of baked bricks in the shape of an arched gallery with a pipeline made of ceramic pipes inside (Anarbaev, 2013).

It was in the 9–12th centuries that Ahsiket (Farghana) had a level of wealth that was high for that time. The streets inside the shahristan were paved in baked bricks. The residential and artisan districts were furnished with underground water supply. The city hauzes<sup>6</sup> were surrounded by planted trees. The city gates of the rabad were in green vegetation (Betger, 1957). The ubiquitous use of sewers, tashnau<sup>7</sup> and badrabs in the shape of waste pits and latrines, was important for sanitation in the conditions of urban life (Anarbaev, 1981).

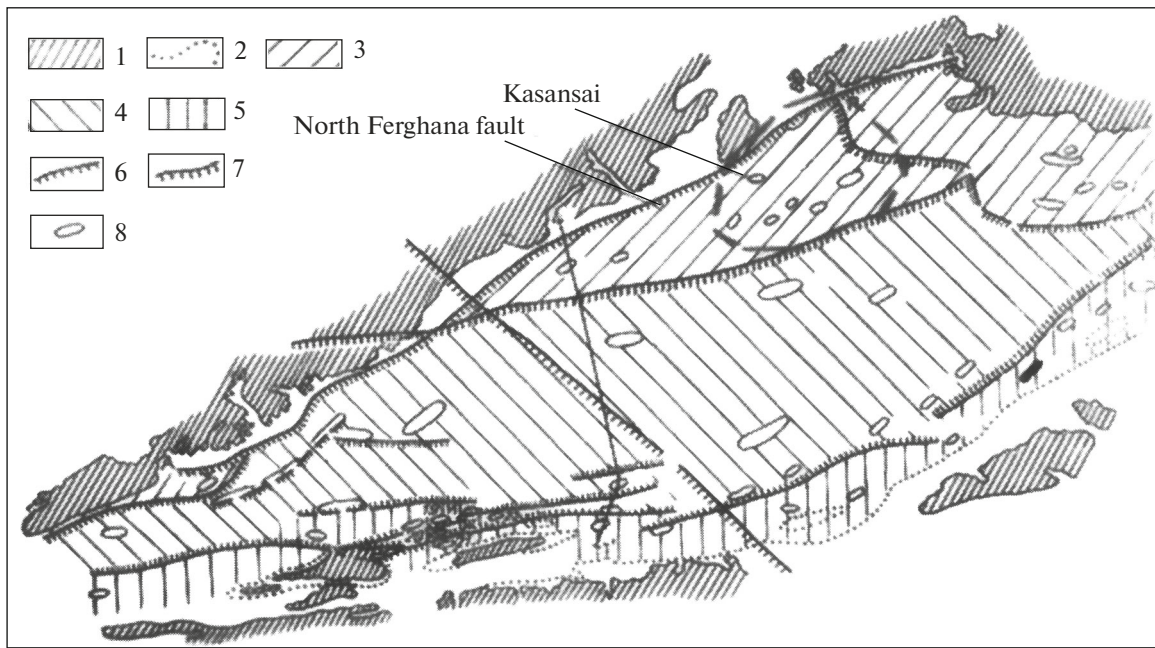
Now it is to be asked why have there been interruptions in the history of this important regional center,

<sup>4</sup> The bulk of the eastern suburb was destroyed by the Syr Darya River.

<sup>5</sup> Well-prepared clay.

<sup>6</sup> Hauz means pond.

<sup>7</sup> Tashnau is a sewage facility.



**Fig. 3.** A map showing the locations of major faults, flexures, and anticlinal folds in the Ferghana Basin (Zununnov et al. (1973) with modifications). (1) exposures of pre-Mesozoic formations; (2) lines of washout in the Paleogene Turkestan layers; (3) north side; (4) central graben; (5) south side; (6) faults; (7) flexures; (8) anticlinal folds studied by seismic prospecting and which are expressed in Paleogene deposits; the dashed line marks a zone of seismically active anticlinal folds.

and why has it been altogether abandoned? Was it only due to the devastation by enemies from the outside that Ahsiket fell and was abandoned by its residents? This study is devoted to these issues.

#### *Brief Information on the Geology, Tectonics, and Seismicity of the Region*

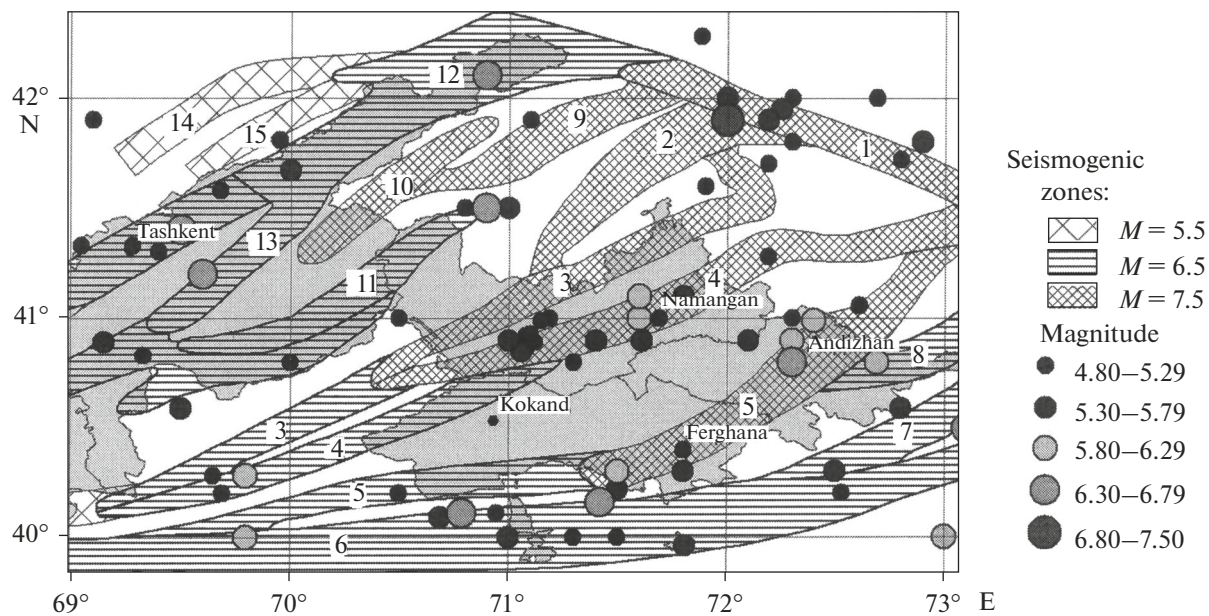
We know that the eastern and northern parts of the Ferghana depression are surrounded by the system of the following mountain ranges: Mogoltau, Chatkal-Kurama, Atoinak, and Baubashata. The basement of the Ferghana depression consists of the Kurama Upper Paleozoic complex, and the crust is 45–50 km thick there (Zununnov et al., 1973). The Mesozoic to Paleozoic formations (Jurassic, Cretaceous, Paleogene, Neogene, and Quaternary ones) reach a thickness of 11 km. Tectonically, the deep-seated North Ferghana fault and the South Ferghana flexure–fault zone are structural controlling features in the region.

It should also be pointed out that the ancient capital of Ferghana (Ahsiket) is situated between the North Ferghana fault and North Ferghana flexure–fault zone. The North Ferghana fault was first identified by V.I. Popov (1938). This discontinuity bounds the Ferghana depression to the north and extends along the foothills of the Kurama mountain range and the northern slopes of the Bayastan Ridge (Fig. 3).

The North Ferghana fault zone has a width of 20–25 km and extends for 240 km. The morphology of the fault is as follows: it is a reverse fault with a displacement amplitude of 3 km, with the discontinuity changing its morphology further southwest to become a reverse or thrust fault (Ibragimov, 1976; Yarmukhamedov et al., 1979). By its dynamics and evolution, the fault divides into a northeastern and a southwestern part (Table 1). It should be pointed out that the western part of the fault was evolving during the orogenic period of the Upper Paleozoic. A younger age is out of the question, since there are no manifes-

**Table 1.**  $M_{\max}$  for some seismogenic zones in eastern Uzbekistan (Ferghana Basin, see Ibragimov, 1976, 1978; Ibragimov et al., 1980, 1986, 2011)

No. of seismogenic zone	Names of seismogenic zones	Maximum possible magnitude $M_{\max}$	Notes
1	North Ferghana, eastern part	7.5	Single seismogenic zone
2	North Ferghana, eastern part	6.5	Single seismogenic zone
3	Namangan	7.5	—



**Fig. 4.** Seismogenic zones in eastern Uzbekistan (after Ibragimov (1976) with modifications). (1) Talas–Ferghana; (2) Chatkal–Atoinak; (3) North Ferghana; (4) Namangan; (5) Andizhan; (6) South Ferghana; (7) Kurshab; (8) Taldysai; (9) Chatkal; (10) Sandalash; (11) Angren; (12) Pskem–Tashkent; (13) Nurekata; (14) Lyangar; (15) Ugam–Karzhantau.

tations at the ground surface and at depth in the Mesozoic deposits (Yarmukhamedov et al., 1979). However, there are Neogene and Quaternary molasses on both sides of the fault, providing evidence of active movements during the time. The northeastern part of the fault originated during Mesozoic time, and active movements are recorded to have occurred along it during Paleogene to Neogene time.

The Chatkal–Kurama mountains are constantly pushing toward the Ferghana Basin along the North Ferghana fault, thus displacing the axes of newly formed folds by 200–500 m toward the anticlinal band: Chust–Pap, Kasansai, and Namangan anticlines (Fig. 4) (Popov, 1938; Ryzhkov, 1964; Yakubov et al., 1986). As previously hypothesized by V.I. Popov and O.A. Ryzhkov, the North Ferghana fault does run, as would be the usual occurrence, along the zone of contact between Paleozoic and Mesozoic–Cenozoic deposits, but is displaced west and southwest by 6–8 km (Popov, 1938; Ryzhkov, 1964). That fact was subsequently confirmed by the seismic prospecting operations as reported by Ibragimov et al. (1986).

The geological structure of the Ferghana Basin is known to contain Paleozoic, Mesozoic, and Cenozoic deposits. However, the goal of the present study consists in investigation of ancient strong earthquakes. Accordingly, we shall restrict ourselves to a brief summary of the geology of the region for Neogene to Quaternary time. It was during that time span that the deposits of the Bactrian, Tashkent, and Golodnaya Step Formations were accumulated.

The Bactrian deposits in the Ferghana Basin are grey conglomerates involving interbeds of light brown aleurolite–clayey rocks. The age of the Bactrian series was determined to be the Upper Pliocene to Lower Pleistocene (Gramm, 1962). The Lower Pleistocene deposits are the Sokh Formation of North Ferghana; they are composed of sands and loess-like loam. They are clays and sandstone in the Chust–Pap anticline zone. The Middle Pleistocene deposits (the Tashkent Formation) are grey conglomerates and a thick loess layer. The Upper Pleistocene deposits (the Golodnaya Step Formation) are loess deposits underlain by pebble; they occur in three terraces along the Syr Darya River, its tributaries, and young fan cones (Ibragimov, 1970). The Holocene deposits (the Syr Darya Formation) consist of sand and gravel, while pebble is less abundant.

Figure 3 highlights a zone of high rates of recent movements (red dashed line) (see Table 1) and seven seismically active folds: Namangan-6, Iskovat-7, Shorbulak-8, Kukumbai-9, Turakurgan-10, Kasansai-11, and Tergachi-12.

One important characteristic of a fault consists in the rates of recent crustal movements in the region. We tried to estimate the rates of young and recent crustal movements by measuring the heights of upland terraces based on the idea that the depth of an incision is in direct proportion to the uplift magnitude (Yarmukhamedov et al., 1979; Yakubov et al., 1986) (see Table 1).

It can be seen from Table 2, which shows an example from the Kasansai River, that the rates of uplift in

**Table 2.** The amplitudes of the rate of Holocene tectonic movements in a segment of the North Ferghana fault (Yar-mukhamedov et al., 1979; Yakubov et al., 1986)

Name of river	Moderate mountains		Low mountains	
	amplitude, m	rate, mm	amplitude, m	rate, mm
Kasansai	$\frac{42.4-98.6(3)}{59.8}$	$\frac{2.84-5.52}{4.0}$	$\frac{10.2-33.9(3)}{25.33}$	$\frac{0.67-2.30}{1.68}$

**Table 3.** A list of strong earthquakes for the Namangan Region, 1400–2019 (*Novyi katalog ...*, 1977; Abdrakhmatov et al., 2008; *Katalog silnykh zemletryasenii ...*, 2011; Korzhenkov et al., 2019)

Nos.	Name of earthquake	Date	Geographic coordinates		Depth, km	Magnitude, $M_{Lnew}/M_{Wnew}$
			$\varphi$ N	$\lambda$ E		
1	Namangan	1494	41.00	71.60	6	5.1–5.5
2	Ahsi*	1620	<b>40.90</b>	<b>71.40</b>	6	5.8–6.0
3	<b>Namangan*</b>	24 Mar 1908 22h 7m	<b>40.90</b>	<b>71.00</b>	26	5.4–5.7
4	Namangan	23 Jan 1912	41.00	71.70	12	5.2–5.6
5	<b>Namangan*</b>	8 Dec 1927 10/22/47.00/	<b>41.00</b>	<b>71.60</b>	14	6.0–6.1
6	<b>Namangan*</b>	13 Jan 1941 00/55/53.00/	<b>40.80</b>	<b>71.30</b>	20	5.1–5.5
7	Yartepa	18 Jan 1942 16/36/31.00/	41.10	71.60	21	5.9–6.0
8	Balykchi	30 Apr 1966 30 Apr 13/41/10.00/	41.15	71.97	18	5.0–5.4
9	Pap	17 Feb 1984 23/26/52.90/	40.85	71.06	20	5.5–5.6

The symbol \* marks those earthquakes which occurred near the ancient city of Ahsikent.

an upland of moderate height exceed the rates of recent movements observed in low mountains and plains by factors of 2 to 3. High rates of tectonic movements such as these for uplands of moderate height were also recorded in the valleys of the Namangansai, Chartaksai, Almasai, and Chadaksai rivers. It should also be added that the low-mountain type of relief is sharply and densely dissected by an extensive zone of *adyrs*.

The numerator in (3) shows the number of transects and the range of amplitude variation; the denominator contains average amplitude values; the Holocene duration is assumed to be 0.015 Ma.

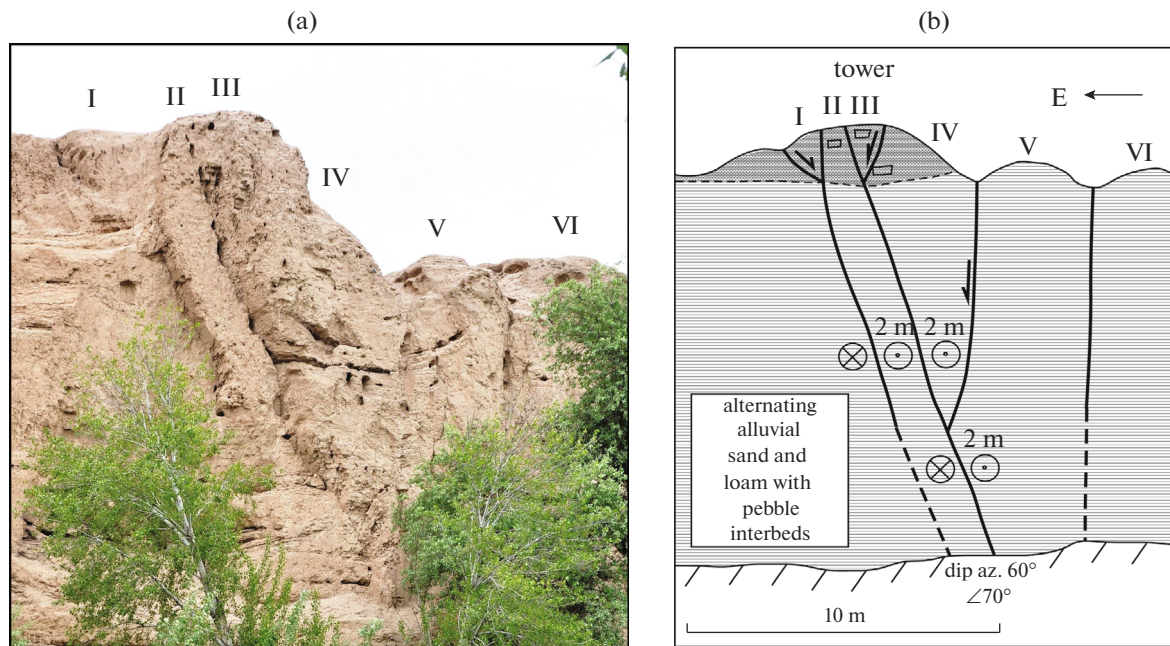
Among all geophysical techniques of surveying, the most reliable information on the presence of discontinuities, their amplitudes and morphology is furnished by seismic prospecting; its evidence clearly identifies the North Ferghana fault based on anomalous attenuation of reflected and refracted waves (Ibragimov et al., 1986). An analysis of the gravity field measured in the North Ferghana zone (the fault and the flexure–fault zone) enabled Sh.M. Kadyrov (Ibragimov et al., 1986) to come to the inference about the origin of

the Chust–Pap, Kasansai, and Namangan folds, namely, that these originated by deformation in the surface of the Paleozoic basement related to activity of block tectonics in the region accompanied by seismicity. Seismotectonic studies (Ibragimov, 1976, 1978; Ibragimov et al., 1980, 1986, 2011) identified seismogenic zones where large ( $M \geq 5.0$ ) earthquakes of the region occurred and assessed the maximum possible earthquakes ( $M_{max}$ ) in these zones (see Table 1, Fig. 4).

An analysis of the catalog of large ( $M \geq 5.0$ ) earthquakes showed that all earthquakes were confined to these zones of anticlinal folds in seismogenic zones (see Table 1) (*Novyi katalog ...*, 1977; Abdrakhmatov et al., 2008; *Katalog silnykh zemletryasenii ...*, 2011; Korzhenkov et al., 2019).

We note that the Ahsi earthquake of 1620 whose seismic intensity was  $I = 9$  on the MSK–64 scale, the 1908 Namangan earthquake with  $I = 7$ , the 1927 Namangan earthquake with  $I = 8$ , and the Namangan earthquake of 1941 with  $I = 6–7$  as listed in Table 3, were all confined to the Namangan seismogenic zone where there is the eponymous set of anticlinal folds





**Fig. 5.** An exposure of an older seismic rupture at the surface. The eastern wall of the fortress undermined by the Syr Darya River (the earlier half of the 1st century BC). (a) photograph, view to NNE, Roman numerals marking several different blocks of the brick masonry and the underlying rocks fractured by ruptures; (b) a schematic off-scale sketch, black subvertical solid lines mark fault planes, discontinuous lines mark hypothetical faults. Arrows indicate direction of slip, and so do circles: those with dots inside (arrowhead) give direction of displacement for the block toward the viewer, a circle with a cross inside (arrow fletching) indicates movement of the block away from viewer.

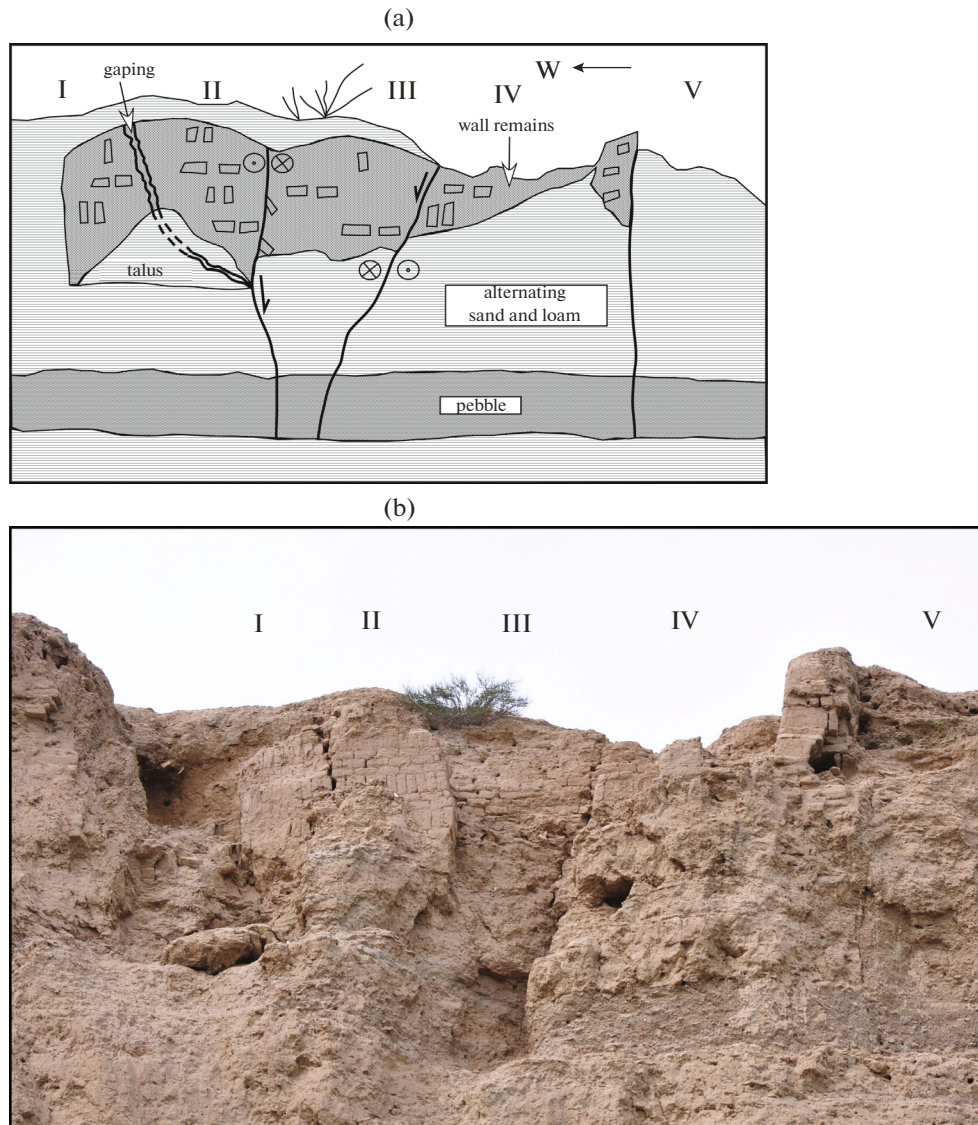
(see Fig. 4). An analysis of the large earthquakes showed that one earthquake had  $M = 5.5$ , and the other three had  $M = 6.0$ – $6.1$ , with these events occurring during different time spans in the 15th and 20th centuries. According to the above data on geology, tectonics, seismotectonics, and a map of seismic zoning for Uzbekistan, OSR-2011 (Artikov and Ibragimov, 2002), the Namangan Region is an intensity IX zone of seismic motion.

#### *Archeoseismic Materials*

The ancient inhabitants of Ahsiket were unlucky, but we, the archeoseismological team, have been lucky: we discovered the surface traces of an ancient seismic rupture among spread-out hills in the area itself of the ancient city (see Fig. 2). Inspection of an enormous exposure on the right (north) slope, which is a steep scarp of the Syr Darya R. valley with the remains of the southern Ahsiket fortress wall at the rim, resulted in detecting two parallel ruptures that have displaced the fortress wall (possibly the ruins of a tower, Fig. 5) and the underlying alluvial deposits. Both of the rupture planes show right lateral strike slip movement. The distance between the two is approximately 5 m, with the displacement on the main (eastern) being up to 4 m and that on the western up to 2 m. This duplex is accompanied on both sides by small normal-fault planes that are identified in brick

masonry only. Normal-slip planes of greater amplitude are also available east of the fault zone described above. It thus appears that we have to deal here with a large structural assemblage consisting of strike slip and normal ruptures whose formation seems to have occurred in the earlier half of the 1 century BC, judging from archeological evidence.

Normal-movement planes and small displacements (a few tens of centimeters) on these are typical for the Ahsiket eastern fortress wall. As an example, there are packets of brick masonry, in comparatively good condition, a few hundreds of meters east of the abovementioned fault zone; this masonry was formerly the outer, eastern, face of the fortification edifice (Fig. 6). The wall remains are here broken up by normal fractures, although one of the fractures (that between blocks II and III, see Fig. 6) was noticed to involve a left lateral component with an amplitude of up to 0.5 m. For a neighboring fracture (between blocks III and IV, see Fig. 6), the normal component is combined with a small right lateral component, up to 0.2 m. The fractures cut through the brick masonry both quite across it and across an underlying layer of alternating sandy loam and loam, but neither of the planes penetrates below the pebble layer that lies still deeper. Considering that circumstance, we came to the inference that these discontinuities originated from strong surface motion (the “skyscraper effect”) rather than being due to seismotectonic movements or



**Fig. 6.** Discontinuous, mostly normal, deformations in the southern part of the first shahristan (Ahsi IA) reaching the Syr-Darya River (10–11th century). The normal faults “decay” in the pebble mass. Roman numerals indicate different blocks of brick masonry and the underlying deposits broken by faults. (a) diagrammatic off-scale sketch, black subvertical solid lines mark fault planes, intermittent lines mark hypothetical faults. Arrows indicate direction of displacement, and so do the circles: those with dots inside (arrowhead) indicate direction of displacement for the block toward viewer, a circle with a cross inside (arrow fletching) denotes movement of the block away from viewer; (b) photograph, view northward.

subsidence. In the last case, the associated fractures must be open from below. In our case, however, one has an opposite situation: the maximum opening of the fissures (up to a few tens of centimeters) was noticed in its upper part, near the ground surface.

For the two preceding observation sites, we showed fractures striking nearly north–south perpendicular to the strike of the eastern fortress wall. However, this wall also contains fractures of another direction (Fig. 7), which are parallel to the strike of the fortification edifice. Strong seismic motion caused a falling-apart of the thick fortress wall as a whole, wrenching and tilting its inner, northern, part northward, which resulted in

a gap between the fallen-apart parts. It is important to note that the abovementioned fracture went straight through the brick masonry.

We also observed the generation of normal-movement planes, not only in the Ahsiket fortress walls, but also in the city wall that surrounded the rabad (the area populated by artisans). As an example, grabens were formed in the north wall of the western rabad on conjugate normal ruptures during a strong earthquake (Fig. 8). The normal-faulting planes decay down the wall that is brick masonry on top and consists of soil below, in situ or filled land. Occasionally, one notices pull-aparts along normal-faulting planes, providing

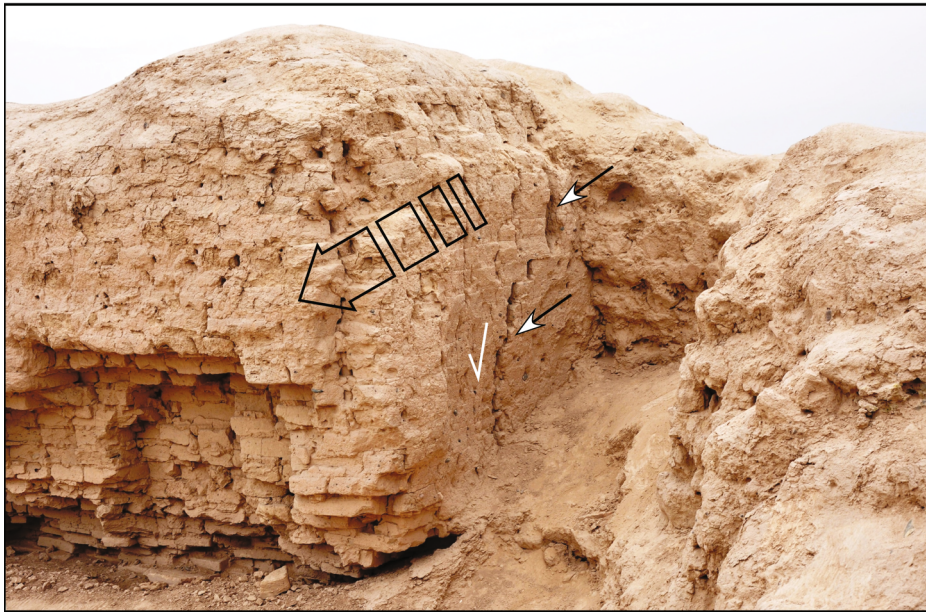
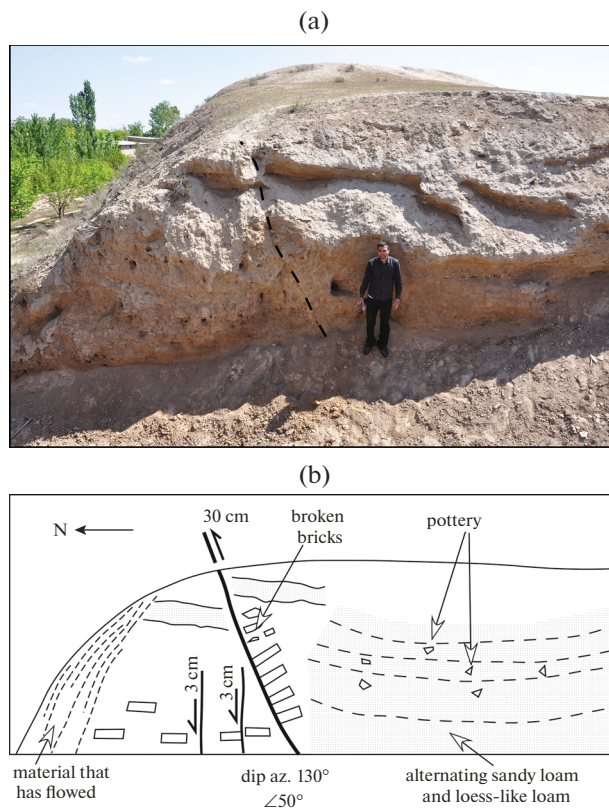


Fig. 7. Part of the southeastern fortress wall falling toward the inside of the fortress (Karahanide period). View to SE.



Fig. 8. Grabens in the north wall of the western rabad (Ahsi II). The formation of pull-aparts on faults signals instantaneous generation of grabens during strong earthquakes (Karahanides period). Heavy lines denote faults, black arrows indicate direction of displacement on these.



**Fig. 9.** Overthrust fault in the old archeological trench in the north wall of Ahsi IB (1st century BC). (a) photograph, view northward, intermittent line indicates the main fault plane; (b) diagrammatic off-scale sketch, heavy line marks overthrust plane, semi-heavy lines indicate secondary ruptures in overthrust front, black arrows indicate direction of displacement.

evidence of the fact that the ruptures were instantaneous. These facts confirm that the deformations were caused by earthquake motion.

Falling-apart of massive fortress walls due to strong earthquakes can be accompanied, not only by the formation of descended and/or tilted parts of structures, but also by the formation of local surface thrusts due to lateral pressure exerted by adjacent (large as to volume and mass) parts of the fortification edifice. We noticed such an overthrust in a collapsed archeological trench dug in the northern wall of the second shahristan (Ahsi IB) (Fig. 9). We cleaned somewhat the eastern wall of the trench and detected a rupture in the brick masonry of the outer armor which dates back to the first half of the 1st century BC. The rupture plane dips southeast (azimuth 130°) at an angle of 50°. The displacement is up to 30 cm. The overthrust resulted in a complex deformation, namely, the bricks tilting north in the lower part of the hanging wall of the fault and fragments accumulating in the upper part of the discontinuity. The footwall has two cuts, with the north limbs subsiding by 3 cm. Conditions for some extension seem to have formed back of the overthrust, leading to

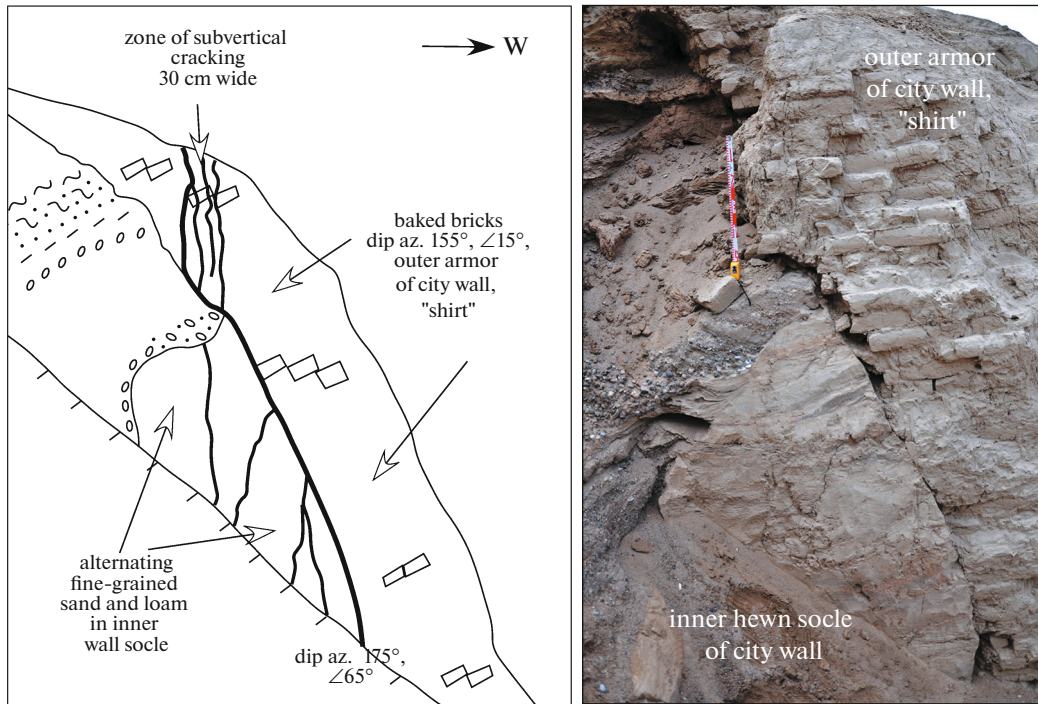
synclinal deformation of alternating layers of sandy loam and loam that compose the socle of the fortress wall. It is of interest to note that the socle is of secondary origin, it is made earth: fragments of pottery are encountered in the alternating layers.

If strong earthquake motion cuts through thick packets made of unbaked bricks that compose the fortress walls, both along and across, then one can expect deformation in those parts of the walls which consist of hewn bedrock socle and the “armor” (Fig. 10). We also noticed deformations such as these in the western wall of the second shahristan (Ahsi IB). We found the socle of a fortification edifice in the modern east–west consequent scour; the lower part of the base is composed of alternating fine-grained sandstone and loess-like loam and alternating alluvial pebble layers, medium-grained sandstone, loam and clays in the upper part (see Fig. 10a). This exposure of deformed bedrock deposits that were formerly deposited by the Syr Darya and hewn by the ancient builders, with a strong outer armor of unbaked bricks being added to its outer (western) part. The strong earthquake shook the connection between the socle and the “armor” that was once strong, leading to openings between different parts of the wall and deformation (generating a filamentary subvertical cracking) in adjacent parts of the wall.

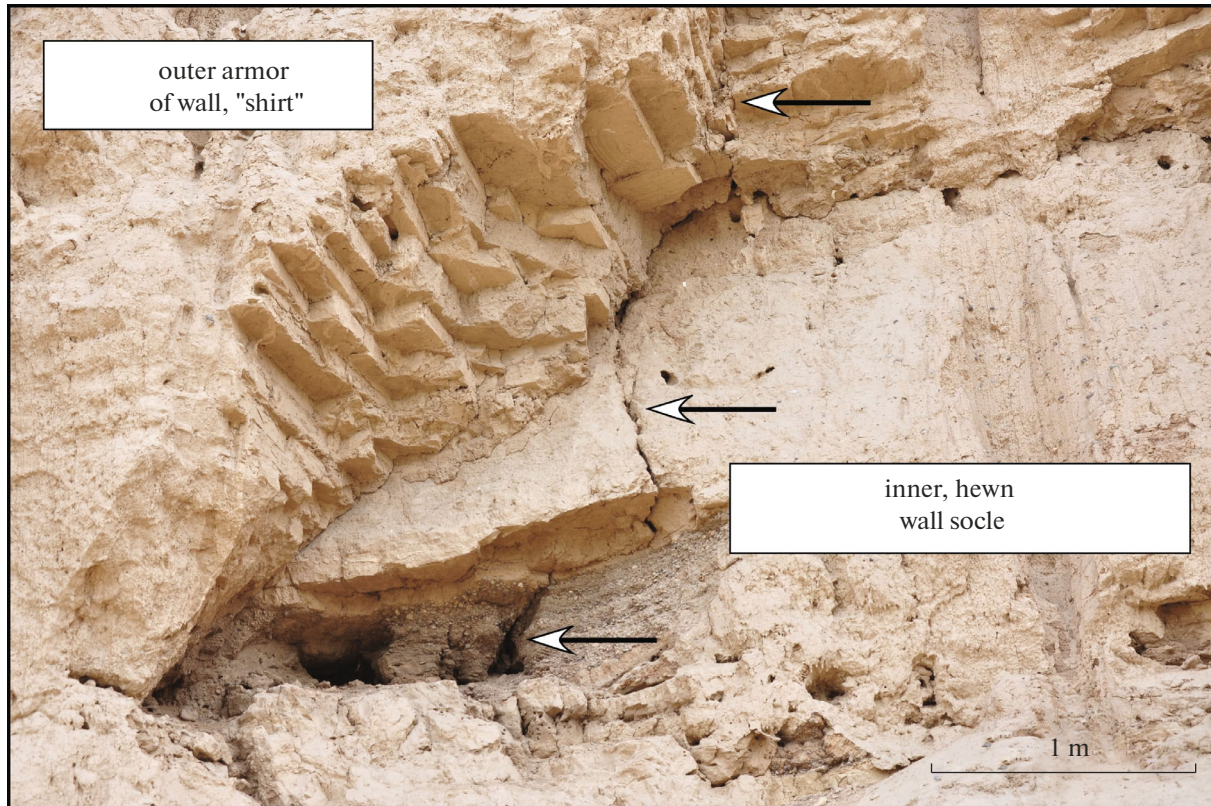
Strong seismic motion in the ancient Ahsiket produced, not only open fissures and cracks at the socle–armor boundary, but also real through ruptures that cut both component parts of the wall (Fig. 11). The western city wall, in a niche cleaned by the archeologists, shows one such rupture cutting through rocks of varying grain-size composition. The rupture went from dense massive clays at the base of the exposure upward into the pebble layer, while still further up, it occurred in dense massive clay again. One can see that the rupture plane passes into a packet of baked bricks that compose the armor of the fortification edifice. We have managed to measure the elements of fault strike in the upper clay layer: azimuth 105°, angle 40°. The rupture involved a small, 4-centimeter, left lateral component. One also notices the presence of subvertical cracks in the brick masonry that run parallel to the face of the fortification edifice.

Deformation in ancient paved slabs is deemed by some archeoseismologists to provide evidence of a seismogenic origin of the damage (Altunel, 1998; Silva et al., 2009; Rodríguez-Pascua et al., 2011). We have detected strong deformations such as these in Ahsiket, at the site of the extant archeological excavation (Fig. 12). They are most likely due to soil subsidence. However, this subsidence too was formed in filled land above the zone of the subvertical rupture.

It was only at the location of the archeological excavation temporarily in abeyance at present that we have managed to discover seismic inertial deformations. These are damage and destruction of structures



**Fig. 10.** Opening and formation of cracking zones at the socle—"armor" boundary. Western wall of Ahsi IB (1st century BC). (a) diagrammatic off-scale sketch, heavy line indicates boundary between media, semi-heavy lines indicate cracks in semi-bedrock ground and in brick masonry; (b) photograph, view to south.



**Fig. 11.** Throughgoing crack that penetrates both bedrock deposits of fortress wall socle (alluvial pebble and washed-out loess-like deposits) and the "armor", which is the outer armor of an unbaked brick masonry (1st century BC). The west fortress wall which reaches a regional highway. The view east.



**Fig. 12.** Deformation in pavement slabs that are possibly due to subsidence events in a fault zone (Karahanides period). View northwest. The pillars supporting the enclosure are 1 m high.

caused by strong directed seismic motion, with the base of the edifice being displaced along with the soil away from the epicentral area (in the case of an overthrust or reverse movement), while the upper part remains as it were in place because of inertia and tilt and/or collapse toward the seismogenic rupture (Korzhenkov and Mazor, 1999). It was in this manner that parts of a staircase and the adjacent north–south wall tilted and collapsed W–SW (Fig. 13) at the location of the archeological excavation now in abeyance at the Ahsikent site.

Systematic tilting of walls and their collapse in the same direction were also observed in our survey of rabad structures. As an example, the north–south walls of an edifice in the western rabad, which are preserved to heights of 1 m, demonstrated a systematic tilt and subsequent collapse of their tops eastward (Fig. 14). The walls strike at  $165^{\circ}$ – $170^{\circ}$ , while their angle of tilt is  $70^{\circ}$ – $75^{\circ}$ . The perpendicular walls have not survived.

Another example of inertial forces arising during strong earthquakes was noticed when surveying the western fortress wall of the Ahsikent site. Here, the archeological section of a wall socle made of earth showed an extant fragment of a ceramic water-supply pipe extending toward the western rabad (Fig. 15). The strong earthquake displaced the eastern part of the wall with an extant pipe southward, while the western

part broke, split, and remained in place—flew northward by a distance of 1 m.

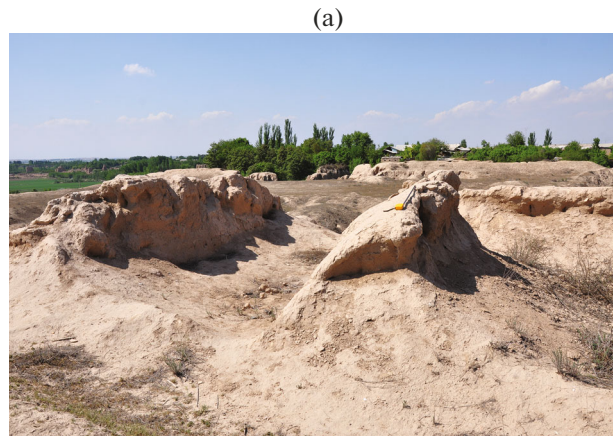
Strong ground motion can chip corners of buildings away (Fig. 16). If seismic motion acts at an angle to the strike of adjacent walls (see Fig. 16b), then both of the two walls will oscillate perpendicularly to the strike. The connection between the two can then be severed, making a gaping space between the split-off corner part and the adjacent walls. It is just such deformations which we observed in an edifice in the western rabad (9th to 11th centuries) (see Fig. 16a).

## DISCUSSION OF THE OBSERVATIONS AND CONCLUSIONS

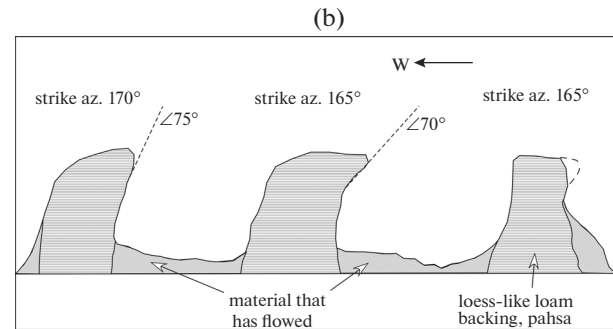
Our archeoseismological studies have revealed traces of strong earthquakes that occurred in antiquity. A comparative analysis of archeological and written sources made it possible to relate these earthquakes to definite historical periods. We remarked in some of our previous work that the ancient city of Eilatan perished owing to a strong earthquake in the 1st century BC (Korzhenkov et al., 2019a, b). It was during that time that the capital of Farghana (Ahsiket) received severe damage. We also discovered at that location the surface trace of a seismic rupture (see Fig. 5), as well as other large deformations in structures erected



**Fig. 13.** Tilts of structures and collapse of bricks that compose a staircase in the W–SW direction (Karahanides period).



(a)

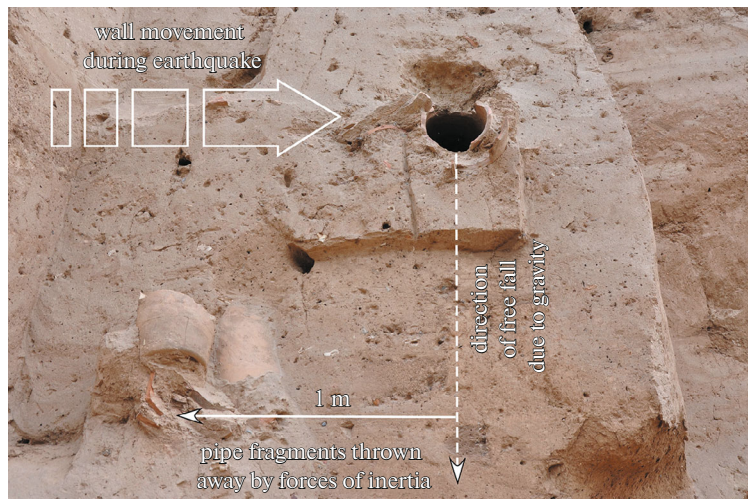


(b)

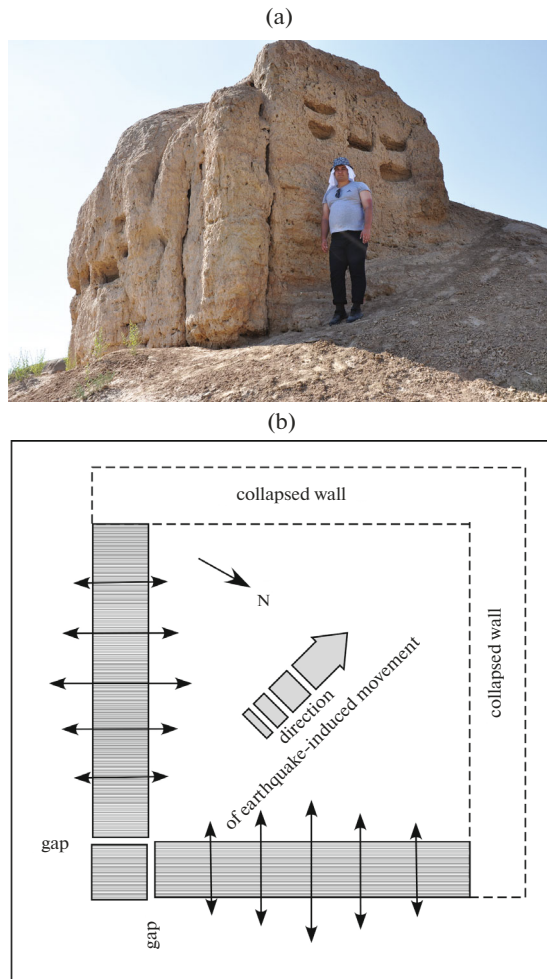
**Fig. 14.** Tilts in north–south walls in a room of a residential house in the western rabad, 9–11th century. (a) photograph of west and middle walls, view W–NW; (b) diagrammatic off-scale sketch showing a cross-section of the walls.

before that time (see Figs. 6, 9–11). We determined the magnitude of this seismic disaster from the maximum displacement as measured by us for the seismogenic rupture that emerged at the surface in the area of the ancient city itself.

The common procedure is to make use of the formulas from (Wells and Coppersmith, 1994), but we pointed out previously (Korzhenkov, 2006) that calculations based on these formulas systematically underestimated magnitudes for events in the Tien Shan or-



**Fig. 15.** Northward displacement of fragments of a ceramic pipe during an earthquake (Karahanides period). West fortress wall. View east.



**Fig. 16.** Cutting-off of a corner of an edifice in the western rabad (Ahsi II) due to difference in amplitudes of ground motion of perpendicular walls during an earthquake. (a) photograph taken in 2019; (b) diagrammatic off-scale sketch, plan view.

gen. The best formulas to use for Central Asia are those due to A.A. Nikonov (1988). We used one of the formulas:

$$M_w = 7.09 + 0.79 \log D,$$

where  $D$  is the maximum displacement on the seismogenic rupture. The calculations gave  $M = 7.6$ . That is to say, the intensity of the seismic motion that destroyed the ancient city of Ahsiket was  $I_0 = X$  on the MSK-64 scale. Large seismic oscillation such as these have completely destroyed or considerably deformed all buildings and seriously damaged and destroyed the city walls. It was probably for this reason that the new kings of the Ferghana Valley built a new residence on the Mugtepe after the 90s BC, which was mentioned in the Chinese source Hanshu as Guishuan.

We can now restrict the time span for the construction of fortress walls in the capital of Farghana and for the strong earthquake that we dated to originate during the 1st century BC (Korzhenkov et al., 2019b). We

used archeological data to find that these fortification structures in the capital were erected in 104–90s BC, while the intensity X earthquake itself must have occurred approximately in 91–90 BC. The shaking hit the entire Ferghana Valley, with especially severe damage visiting cities and villages in the North Ferghana. Spectacular examples are furnished by falling-apart of massive fortress walls in the citadel and shahristan of the city of Farghana (Ahsiket).

It may well be that the seismogenic rupturing that emerged at the ground surface in the ancient cities of Ahsiket and Eilatan took place at the same time. However, it was more likely a cluster burst of seismic activity in the region. Similar seismic “storms” are known to have occurred in Tien Shan. As an example we can cite global seismic disasters of the 19th and early 20th centuries: the 1889 Chilik ( $M_{LH} = 8.3$ ) event, the 1902 Kashgar ( $M_{LH} = 8.2$ ), and the 1911 Kebin ( $M_{LH} = 8.2$ ) earthquakes (Dzhanuzakov et al., 2003) with shaking intensities of  $I_0 = X$ –XI. Earthquakes with magnitudes between  $M = 6.5$  and  $M = 8.0$  producing changes in relief, unconsolidated deposits, and in bedrock occur much more frequently. The next earthquake to occur in the Ferghana Valley took place in the 4–5th centuries as inferred from archeological data<sup>8</sup>. The quake destroyed the ancient Kyul-Tepe. Its intensity of shaking was VIII–IX. Traces of that earthquake may also have survived at the Eski Ahsi site (Ahsiket). Additional archeoseismological studies are required to discover its traces. A similar strong earthquake occurred later, in the 11th century or the earlier half of the 12th century. We have found traces of this seismic event on several objects of the Eski Ahsi site (see Figs. 7, 8, 12–16).

The archeoseismological materials obtained by our team have been summarized in Table 4, which is still incomplete. Further studies in the Ferghana Valley will help supplement and expand the parameterized catalog of strong older earthquakes.

Have there been other strong earthquakes in the Ferghana Valley? (*Novyi katalog ...*, 1977) edited by N.V. Kondorskaya and N.V. Shebalin reports a Namangan earthquake for 1494,  $I_0 = 8$ –9. Information on the earthquake is scanty and discrepant among different historical events. However, the fact that a strong damaging earthquake occurred in the Namangan area in 1494 was confirmed by subsequent studies of seismicity (*Novyi katalog ...*, 1977; Ibragimov et al., 1986; Butovskaya et al., 1961).

The catalog has some information on the Ahsi earthquake of 1620 near the town of Namangan, which destroyed the town completely. According to descriptions of Muhammad-Tahiri ibn Abul Kasymi (as quoted in (*Novyi ...*, 1977)), the degree of damage in the buildings and structures of Ahsi and the morphologic changes in the ground surface (relief) corre-

<sup>8</sup> We dated it in previous work as belonging to the first few centuries AD (Korzhenkov et al., 2019a; 2019b).



**Table 4.** A list of strong historical earthquakes in the Namangan Region identified by Korzhenkov et al. (2019b, 2020) from archeoseismological data

Nos.	Name of earthquake	Approximate date	Geographic coordinates		Inferred magnitude, $M_s$	Intensity of seismic shaking	Notes
			$\varphi$ N	$\lambda$ E			
1	Swarm of great earthquakes in North Ferghana	90–91 BC	40°32' (Ahsikent)	71°16' (Ahsikent)	7.6 ± 0.5 (Ahsikent)	$I_0 = X$ (Ahsikent)	Cities Ahsiket and Eilatan destroyed
2		4–5th centuries	40°55' (Eilatan)	72°10' (Eilatan)	7.6 ± 0.5 (Eilatan)	$I_0 = X$ (Eilatan)	
3		In late AD 8th century				$I_L = VIII-IX$	Ancient Kuyultepa destroyed
4		In 11th or earlier half of 12th century				$I_L = IX$	Deformations in Mugkala Traces of this seismic event in several objects of Eski Ahsi site (Ahsiket)

spond to seismic intensity  $I_0 = 9$ , and the meizoseismal area was situated in the North Ferghana seismogenic zone.

The life in Ahsiket completely stopped after this seismic event. People did not settle down in its ruins, and it was only during Soviet time that collective farms began to invade the old town, ploughing and smoothing out areas in the ancient rabads, and having the areas involved in agricultural activities and construction. It should not be forgotten, however, that damaging earthquakes are not a rare occurrence in the Ferghana Valley, with the interseismic period being a few hundreds of years. For this reasons the materials we have obtained should be incorporated in a new assessment of earthquake hazard for the Ferghana Basin.

Instrumental seismological data for the last 100 years have proved insufficient for earthquake hazard assessment with the maximum possible earthquake  $M_{MAX}$ , keeping in mind the return period of strong earthquakes. Viewed in this light, information on older earthquakes that have occurred in the Namangan Region would clarify the issue of return periods for strong earthquakes ( $M \geq 7.5$ ).

The territory of eastern Uzbekistan (Ferghana Basin) is an area of high seismicity in the Republic generating intensity IX catastrophic earthquakes, as they occurred in the far past.

#### ACKNOWLEDGEMENTS

We wish to thank the anonymous reviewers of our manuscript for helpful and friendly remarks.

#### FUNDING

The field surveys in the Namangan Region, as well as in the laboratory in Moscow, Samarkand, and Tashkent were supported by the Russian Foundation for Basic Research, project nos. 18-55-41005 Uzb\_t, 19-55-53017 GFEN\_a, and according to the projects Uzbekistan–Russia MRU-FA-61/2017 and FA-F-8-006, G.A. Mavlyanov Institute of Seismology in the Republic of Uzbekistan, as well as the State Program of Research (Schmidt Institute of Physics of the Earth, Russian Academy of Sciences).

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*Translated by A. Petrosyan*