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Traces of Ancient Earthquakes in Medieval Cities Along the Silk Road, Northern Tien Shan and Dzhungaria

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Abstract: The evidence for earthquake destruction at medieval cities along the Silk Road from 800 A.D. to 1500 A.D. was examined using techniques of archaeoseismological mapping of architectural components at three currently excavated sites in southern Kazakhstan: Koylyk (Antonovka), Talgar (Talkhir) and Akyrtash, located on the northern branch of the Silk Road, Kazakhstan. This study revealed the following features of seismic activity at all three sites: (a) fractures cutting through a few adjacent bricks; (b) wall-tilts and collapses; (c) horizontal shift of bricks and stones; (d) rotation of stones and bricks. These types of destruction occurred at or very near the epicentres of ancient earthquakes. In some cases it was possible to determine the degree (seismic intensity), the direction of seismic-wave generation, and also the repetition of major seismic events. Since this portion of the Silk Route is along the northern edge of the Tien Shan mountain chain, one of the most active seismic areas of the Eurasian Continent, it is possible that abandonment of these cities was due to natural disasters and not just to the repeated Mongol invasions of the 13–14th centuries. These data may be used for more precise estimation of earthquake hazards in this region of southern Kazakhstan.

Key Words: archaeoseismology, earthquake damage, medieval cities, Silk Road, Tien Shan, Dzhungaria, Kazakhstan

İpek Yolu Üzerindeki Ortaçağ Kentlerinde Eski Depremlerin İzleri, Kuzey Tien Shan ve Dzhungaria

Özet: Güney Kazakistan'daki İpek Yolu üzerinde yer alan Ortaçağ kentlerinde 800–1500 yılları arasında meydana gelen depremlerin yol açtığı tahribatlara ait veriler araştırılmıştır. Üç bölgede yapılan kazı çalışmalarında mimari unsurların arkeosismolojik haritalanması tekniğiyle eski depremler incelenmiştir: İpek Yolu'nun kuzey kolunda yeralan Koylyk (Antonovka), Talgar (Talkhir) ve Akyrtash civarında gerçekleştirilen bu çalışma aşağıdaki sismik deformasyon özelliklerini meydana çıkartmıştır: (a) birkaç komşu tuğlayı kesen çatlaklar; (b) duvarlarda çökme ve düşeyden sapma; (c) tuğlalarda ve taşlarda yatay oynama; (d) tuğlalarda ve taşlarda dönme. Bu tip tahribat eski depremlerin merkezüstü ve yakın çevresinde gelişir. Bazı durumlarda deprem şiddetini, sismik dalga hareketinin yönünü ve aynı zamanda kuvvetli deprem olaylarının tekrarlanmasını belirlemek mümkündür. İpek Yolu'nun bu kesimi Avrasya Kıtası'nın en aktif deprem bölgelerinden olan Tien Shan dağ sırasının kuzey ucu boyunca uzanır. Bu nedenle bölgedeki kentlerin terkedilme nedeni sadece 13–14 yy daki Moğol istilaları değil aynı zamanda doğal afetler nedeniyle de olmalıdır. Burada sunulan veriler aynı zamanda Güney Kazakistan bölgesindeki deprem tehlikesi ve deprem riskinin daha doğru tahmin edilmesinde de kullanılabilir.

Anahtar Sözcükler: arkeosismoloji, deprem hasarı, ortaçağ kentleri, İpek Yolu, Tien Shan, Dzhungaria, Kazakistan

Introduction

The objective of this work is to test the hypothesis that the periodic "catastrophic" burning and other types of architectural destruction at medieval centres along the Silk Road in southern Kazakhstan, in the 13th through 15th centuries A.D., could have been due to earthquake activity and not only to Mongol invasions.

In Kazakhstan, the Silk Road (Figure 1) followed the northern foothills of the great mountain systems of Central Asia – the Dzhungar and Tien Shan mountains (Figure 2). These young mountains formed during the last 30 million years (the neotectonic period) via the collision of the Indian and Eurasian plates. This fault line has been the location of much intense tectonic movement over many millions of years. It is known from historical

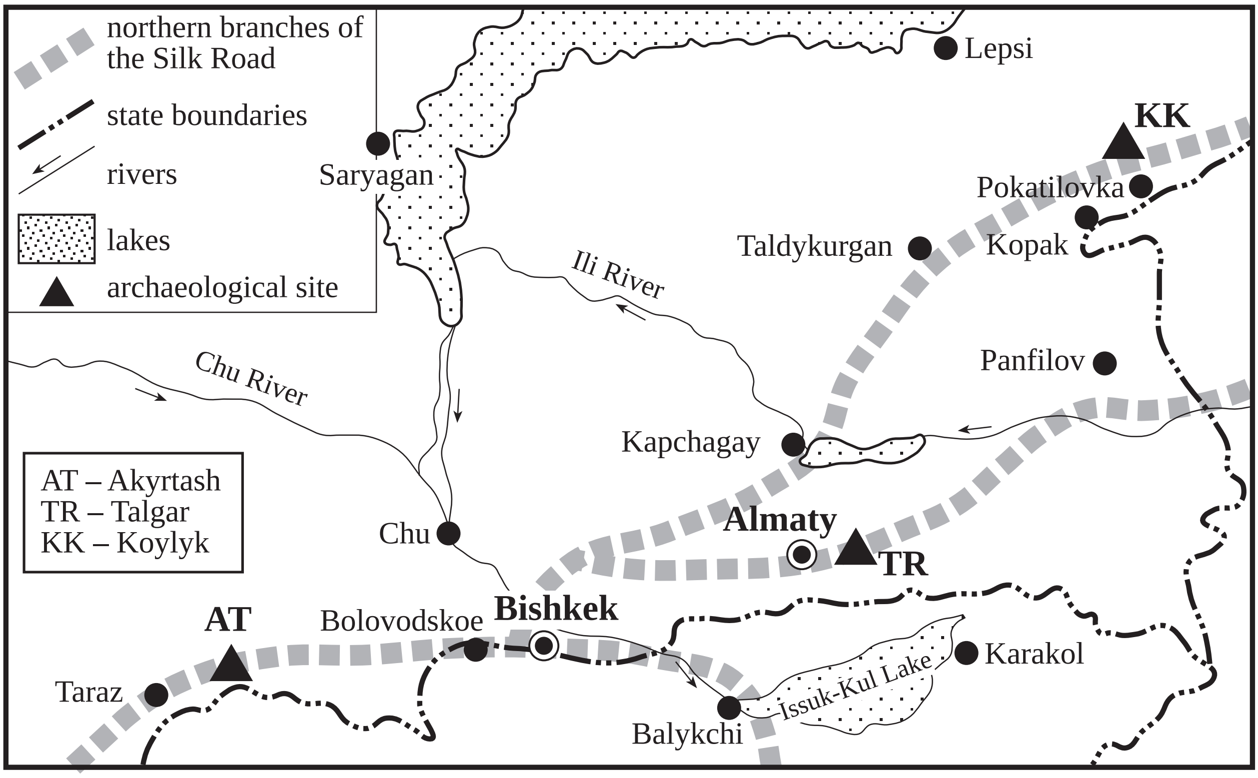

Figure 1. Administrative map of southern Kazakhstan and surrounding area.

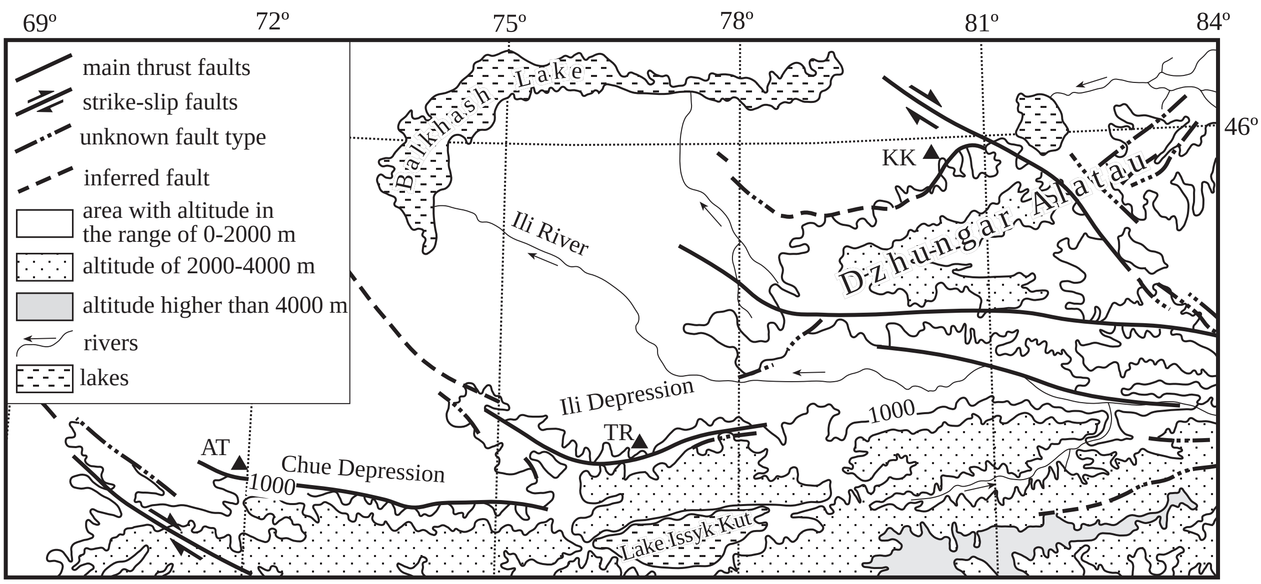

Figure 2. Active tectonics and topography of southern Kazakhstan and surrounding area (after Avouac *et al.* 1993, with additions and modifications).

accounts from the last hundred years that destructive earthquakes caused major damage (Figure 3).

Reliable earthquake data has been collected as far back as the second half of the 19th century, during the period when Russian military fortresses were constructed in this region. Scientific data recording the earthquakes of southern Kazakhstan were collected during the late 19th and early 20th century. Mushketov (1888, 1890a, b), Bogdanovich (1911), Bogdanovich *et al.* (1914) studied the strong Verny earthquake of 1887 and Kebin earthquake of 1911. In the succeeding years, a number of seismic stations were built along the edge of the northern Tien Shan and Dzhungaria ranges.

Before the 19th century, there are only sparse references to earthquakes: there was an I_0=IX destructive earthquake in 1475 in the vicinity of Burana village – near the modern town of Tokmak (Figures 1–3); and an I_0=VIII earthquake in 1770 at Belovodskoe village (Mushketov 1891, 1899; Chedia *et al.* 1998). In 1807, on the Almaty river, "a terrible catastrophe" took place; in 1865, there was an earthquake at Merke village; in 1867, an earthquake at Tokmak; in 1873, an earthquake in the Chu River valley; and in 1880, one at the Verny (Almaty) (Mushketov & Orlov 1893). On August 2, 1885, the Belovodskoe earthquake occurred in the Chu depression (M=6.9, I_0=IX–X) (Ignatiev 1886). Towns that were completely destroyed along the Kyrgyz side of the Tian Shan range include Belovodskoe, Sokuluk, and Pishpek (Bishkek). Two years later, on June 8, 1887, the Verny earthquake (M=7.3, I_0=IX-X) occurred; its epicentre was located near modern Almaty (Mushketov 1888; Vershinin 1889). In July 11, 1889, the catastrophic Chilik earthquake (M=8.4; I_0=X) occurred; its epicentre was located 120 km east of modern Almaty, at the eastern end of Trans-Ili Alatau range. This epicentre was located in the fault zone separating the Kungey and Trans-Ili ranges (Figures 2 & 3). In Verny (Almaty), the seismic intensity was I_0=VII–VIII of the MSK-64 scale. The epicentre of the Kebin earthquake of January 3, 1911, was located south of modern Almaty. It had a seismic intensity of I_0=X–XI within the first ten kilometres (Bogdanovich 1911; Velitzky 1911; Bogdanovich *et al.* 1914). Gutenberg & Richter (1954) estimated that the earthquake was one of the strongest catastrophes of the world with a magnitude of M>8 on the Richter scale. The area of maximum tremors was about 10,000 km^2 in size in the vicinity of the Kungey and Trans-Ili Alatau ranges. The earthquake left ruptures, some as long as 200 km. The tremors were recorded throughout an area of 4,000,000 km^2. The Kemin-Chu earthquake took place on June 20, 1938, and its epicentre was located at the junction of the Kyrgyz and Kungey Alatoo ranges (Vilgelmzon 1947). The last strong seismic event in the northern Tien Shan was the Suusamyr earthquake of August 18, 1992 (M=7.3, I_0=IX–X) (Korjenkov & Omuraliev 1993; Bogachkin *et al.* 1997; Ghose *et al.* 1997).

The locations of the epicentres of the major earthquakes of this region were all situated in the central part of the Trans-Ili and Kungey Alatao ranges. This is an area along the Silk Road. Thus, we can postulate that this trading route would have experienced considerable effects of major earthquakes during the medieval period. The acceleration rate of the tremors (more than g during some seismic events) led to severe or complete destruction of ancient cities that were typically built of mud brick (saman).

The earliest accounts of earthquakes in Dzhungaria (Figures 1–3) have been described by Mushketov & Orlov (1893). The oldest recorded earthquake occurred in 1716. However, systematic data are only available as far back as the second half of the 19th century. Thus, one can note the earthquakes of 1866 at the Kopal settlement and of 1874 at Lepsinsk town. Significant destruction of all types of buildings in the Dzhungaria region was caused by the transference of seismic waves that originated from earthquakes in China during the years 1906, 1958, 1962 and 1973 (Massarsky & Gorbunova 1964; Urazaev *et al.* 1974).

A number of major tremors are listed in the "Earthquakes of USSR," a catalogue by Gorshkov *et al.* (1941). This includes, for example, an earthquake of May 2, 1915 felt in the Lepsinsk region, that had a seismic intensity of I_0=VI. The epicentre of the August 20, 1967 earthquake was located on the northern slope of Dzhungar Alatau. In Pokatilovka village, nearest the epicentre, the earthquake was felt with a seismic intensity of I_0=VII (*in*: 'Earthquakes in USSR in 1967' (1970)).

Thus, we have at our disposal, a series of historical observations of earthquake activity that date back only as far as the last 100–200 years. However, to trace trends in seismic activity, we would need data for centuries and even millennia that could be used to: (a) estimate the

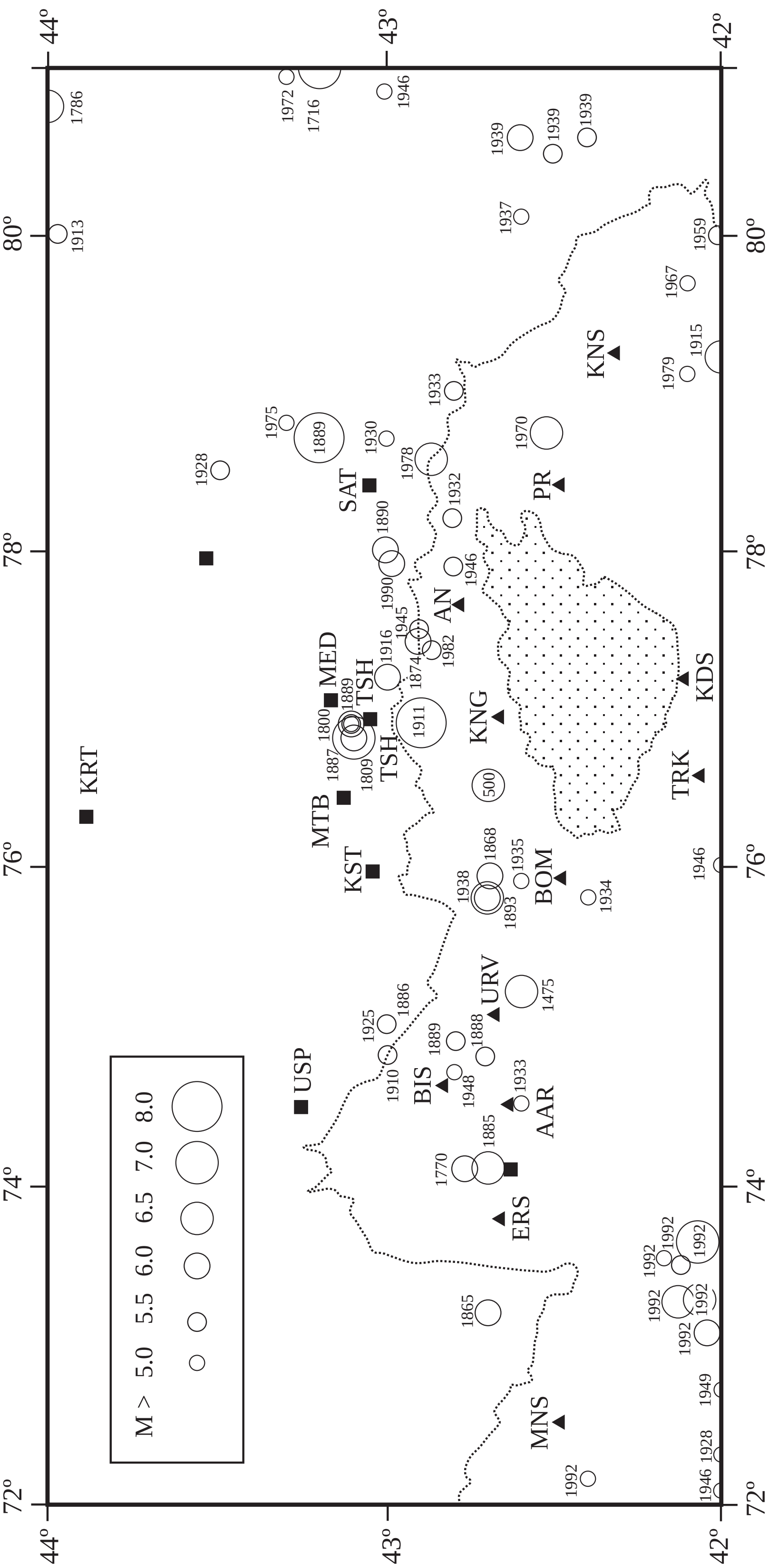

Figure 3. Epicentres map of southern Kazakhstan and surrounding area. Data was kindly provided by Mrs. Sadira Moldobekova (Institute of Seismology NAS, Kyrghyzstan). Black triangles are Kyrghyz seismic stations, squares – Kazakh seismic stations.

recurrence of earthquakes over time; (b) locate the ancient epicentres of these earthquakes; and (c) measure the intensity of these tremors and earthquakes. Methods of archaeoseismology (Hancock & Altunel 1997; Altunel 1998; Korjenkov & Mazor 1999a, c; Akyüz & Altunel 2001; Mazor & Korjenkov 2001 and many others) and seismogeology (e.g., McCalpin 1996) may be used to elucidate the occurrence of seismic events in the past.

We have conducted preliminary studies on three archaeological sites located on the northern branch of the Silk Road (Figure 1): (a) Koylyk, on the eastern outskirts of Koylyk (Antonovka) village in Dzhungaria, in the steppe region near the Dzhungar Alatau range, about 460 km northeast of Almaty; (b) medieval Talgar (Talkhir), on the southern outskirts of the modern regional centre of Talgar, at the base of the steppe zone below the foothills of the Trans-Ili Alatau, about 25 km east of Almaty; (c) Akyrtash, in southern Kazakhstan near the modern city of Taraz (Dzhambul), in the steppe region north of the Kirghiz range, about 480 km west of Almaty.

Each site is near active fault zones of the Tien Shan and Dzhungaria mountain ranges (Figure 2), but these differ in their construction types. Historical records of earthquakes in the Almaty area have registered M>8 on the Richter scale. Hence, seismic activity probably took place during the 400 to 600 year occupations of these medieval cities.

Description of Peculiarities of the Seismic Destruction at Archaeological Sites

Koylyk Site

The Koylyk (Antonovka) settlement is located 420 km northeast of the city of Almaty, in the Dzhungaria region in the eastern outskirts of the village of Antonovka, on the bank of the Ashchibulak River. In 1998, extensive excavations under the sponsorship of INTAS (EU- funded projects) were conducted at Koylyk (Antonovka). At Antonovka, the largest medieval period site along the Ili Valley, the city consists of a large fortress wall constructed of mud bricks, irregular in form but generally rectangular in shape. The archaeological evidence of mud brick buildings at Antonovka appears as a series of mounds or tells; the most concentrated area is in the eastern section of the site. The northeast city wall is about 1200 m long, while the southwest wall is approximately 750 m long. The city wall ranges from 3.5 to 4.5 metres in height. There is no south wall, since the ancient town is protected by the mountains. Every 30–45 m along the wall there are round towers. The height of some towers is 6–8 m. Not far from the western corner there is a rectangular mound, 120x150 m and 5.5 m high. Entrances to the settlement are located on the NW and SE sides of the mound (Baipakov & Korjenkov 2000).

This site has three occupation levels. Archaeological materials from the excavations, such as ceramics, glasses, or belt buckles, date the occupation of the settlement to between the 8^{th} century and 14^{th} centuries A.D. (Baipakov *et al.* 1999; Baipakov & Korjenkov 2000).

The first block excavations were placed on a square 30x30 m mound, about 4 m in height, found in the eastern part of the settlement. A wealthy farmstead was discovered in this mound, and dates to the $12–13^{th}$ centuries A.D. Remnants of the dwellings and farm buildings, Chinese and Iranian ceramics, and bronze wares were also found (Baipakov & Korjenkov 2000).

Other excavations were conducted 200 metres from the north entrance of the fortress wall. The 1998 excavation covered an area of 25 by 25 metres. This excavation uncovered a central room (12 m by 12 m) and an attached corridor. The central room may be a part of a temple, perhaps even one identified in historical records as a Buddhist temple. The walls of this central room are about 1.5 metres high and are built of mud bricks (Baipakov *et al.* 1999).

There were two periods of occupation at the temple, apparently from two different construction sequences. The second construction period is characterised by wall remodelling and filling-in of the NE and NW galleries with gravel and pebble fill – some as thick as 1.5 m. This construction fill probably was used to stabilize the northern part of the temple which was partially destroyed by an earthquake. The temple functioned from the 12^{th} century A.D. to the middle of the 13^{th} century A.D. There is also evidence of destruction by fire in this excavation unit (Baipakov *et al.* 1999; Baipakov & Korjenkov 2000).

The present study was conducted at both excavations: wealthy farmstead and Buddhist temple.

Wealthy Farmstead (Figure 4)

Wall collapse is the most common evidence found in buildings destroyed by earthquakes. Walls situated

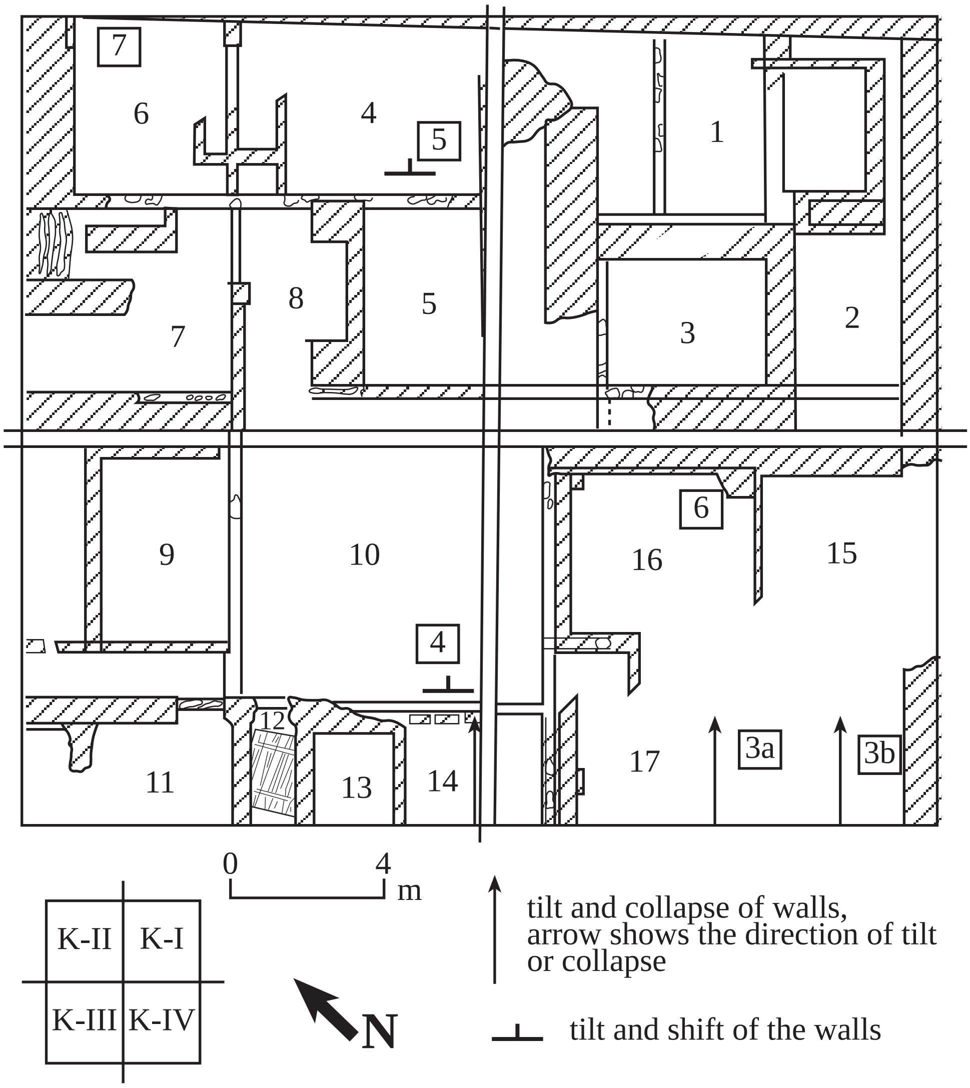

Figure 4. A scheme of an excavation of wealthy farmstead at the Koylyk site (modified from Baipakov & Korjenkov 2000). Numbers in squares correspond to the numbers of figures in given paper.

perpendicularly to the direction of the seismic wave usually have a single direction of collapse. At the same time, walls oriented parallel to the place where seismic waves are generated fall in a random manner (Korjenkov & Mazor 1999a–c).

The SE external *saman* (unfired brick) wall with a strike of 155º (IV Quadrat) collapsed inside the building in a NE direction along the compass bearing of 65º. Wall fragments were thrown a distance of up to 2 m (Figure 5a). This type of wall-fall is evidence for the seismic origin of collapse. The entire wall collapsed. The floor plaster was not damaged (Figure 5b), and fragments of the disintegrated wall lie on the floor. This suggests that the wall fell during a single event. The wall lacks indications of gradual disintegration of the *saman* due to the weathering effects of rain and snow after the abandonment of the building.

The systematic tilts of the walls are observable when the direction of seismic wave generation is perpendicular to wall trend (Korjenkov & Mazor 1999a–c). At room No. 10 (III Quadrat) a heating box-like pipe (*khan*) composed of fired bricks was tilted to the NE (dip azimuth 230º, dip

Figure 5. Collapse of *saman* walls in the wealthy farmstead at the Koylyk site. (a) SW external wall of the farmstead collapsed in NW direction. Bricks were thrown a distance of up to 2 m. (b) Preserved piece of a plaster from the inside wall.

Figure 6. Tilt of the heating box pipe (*kan*) in a NW direction (room No. 10). A wall built above the pipe collapsed in the same direction. Bricks were thrown a distance of up to 3.2 m (shown by the arrow).

angle 68º), as is seen in Figure 6. A *saman* wall situated above the heating pipe also collapsed in a NE direction. In this case, the bricks were thrown a distance of 3.2 m (Figure 6).

The foundation stones supporting the heating pipe in room No. 4 (II Quadrat) showed a similar pattern of collapse. The bearing of the pipe is 145º. The stones are tilted in a northeasterly direction, at angles 54°–75° (Figure 7a). The present-day position of the foundation stones is 20 cm higher than the fragments of preserved pipe in the southern corner of the room (Figure 7b). Thus, it appears that these stones were thrown up and fell in a tilted position relative to their original placement.

Shifts in the location of building components may also be indicative of seismic activity at a settlement, in much the same way that tilting and wall collapse can be used to document earthquake damage. The shift of part of a wall indicates that the seismic waves were generated perpendicular to the wall (Korjenkov & Mazor 1999a–c).

Such phenomena were discovered at the excavation of the farmstead at the Koylyk site. Mud brick or *saman* masonry of the NE wall of room No. 16 (Quadrat IV) shifted so as to fall towards each other in a NE direction at a distance of 10 cm (Figure 8). The bearing of the wall is 146°, while the bricks shifted along an angle of 56°. The wall fragment is slightly tilted in the same direction.

The data, given above, indicate the systematic destruction of the farmstead buildings. This systematic destruction and consequent evidence of wall collapse are due to earthquake damage. All observed types of destruction – tilts, collapses, and shifts in building components – show that the generation of seismic waves took place along a NE–SW axis. The systematic character of the destruction also indicates that there was a predominantly horizontal aspect to the seismic movements (Korjenkov & Mazor 1999a–c). Such horizontal movements are more typical of earthquakes that may have occurred some distance (30 km or more) from the original epicentre of the earthquake. The complete destruction of the *saman* buildings (observed in the farmstead) indicates an intensity of seismic oscillations of I_0=VII–VIII.

The ancient people may have recognized the problem of wall collapse due to seismic activity and tried to prevent wall damage; there is a method of construction in which a so-called “seismic buffer” is placed between the masonry walls of the farmstead. This “buffer” can be a

Figure 7. (a) Tilt of foundation stones (dip angle is 54°–75°) in NE direction in room No. 4; (b) uplifted modern position of stone surfaces (dashed line 1), as compared with their original position (dashed line 0).

wooden log (Figure 9a) or reed layer (Figure 9b). We are of the opinion that the ancient builders used this construction technique to buttress their buildings against the frequent earthquake activity in this region of the northern Dzhungarian range.

Buddhist Temple

In the temple building, there are two construction sequences: the lowest 10 rows of clay bricks are attributed to the first building period, and two rows of burned bricks above belong to the foundation of the second building period.

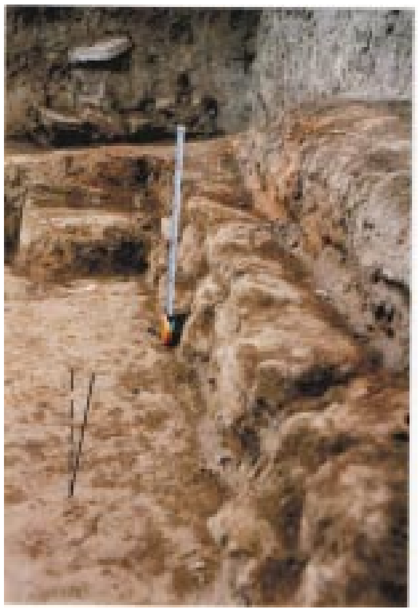

Figure 8. Shift and tilt in a northeast direction of lower course of masonry of *saman* bricks in room No. 16. Angle of declination of deformed wall is between the solid line (modern wall inclination) and the dashed line (originally vertical wall).

Figure 9. "Anti-seismic buffer" in the walls of the wealthy farmstead: (a) wooden log, (b) reed layer.

Why did the ancient inhabitants remodel the temple? And why at a later period was the upper part of the wall dismantled?

The temple is located near the seismic zone, and was consequently subject to seismic activity. Indeed, these two construction sequences might testify to the occurrence of seismic activity during the time the prehistoric inhabitants used this temple. That is, the collapsed walls of the temple may document two separate episodes of collapse due to seismic activity. However, it is difficult to document the exact direction of wall collapse and seismic wave generation since the wall collapses from the two events are jumbled together.

The nature of the wall collapse episodes for the temple walls are examined below (Figure 10) in order to reveal the causes of the destruction sequences at the temple.

The fracture lines or cracks found in the walls of ancient buildings are a common feature of ancient buildings. However, there can be several causes for the occurrence of such cracks or fractures, such as: (1) the natural processes of weathering, that is, alternating heating during the day and cooling at night; or (2) tectonic (seismic) movements. However, if the fractures cut through two or more adjacent bricks or stones, then they were the result of major stressors placed upon the wall. These disjunctures or cracks are formed when a high amount of energy is applied to exposed surfaces of adjacent bricks or stones (Fisher *et al.* 1995; Engelder & Fisher 1996; Becker & Gross 1996). Thus, the existence of cracks or fissures through two or more blocks cannot be attributed to weathering processes.

At the NW corner of the eastern entrance into the temple (see Figure 10), part of the upright support of the doorway was destroyed and partly collapsed. A collapsed piece ruptured the central part of the upright support piercing the heating pipe in the structure and creating an air hole or pocket in the central part of the upright post. Here there are a series of cracks and fissures that run through 10 bricks (Figure 11a). The same deformation is observable also at the NE corner of the western section of the doorway – a significant part of the corner collapsed. It exposed the heating duct and internal structure of the wall. We can observe numerous fissures that cut through two or more bricks as well as open cracks splitting the standing wall into different fragments (Figure 11b). The most remarkable cracks or fissures separate the vertical rows of the bricks in the entryway, causing them to collapse onto the floor.

Another example of a fissure that cuts through several bricks can be observed at the entrance to the temple in the NW corner of the eastern wall (Figure 10) in a low section of the wall (Figure 11c). Here a fissure, 50 cm in length, cut through six bricks.

These three examples were probably caused by earthquake tremors.

The eastern pier of the entrance to the main premises of the temple (see Figure 10) is tilted (Figure 12) at an angle of 80° (dip azimuth is 43°). The height of the preserved part of the upright support is 2.5 m.

A step at the entrance to the main premises of the temple is constructed of four *saman* bricks in height. The lower courses of the bricks have shifted toward the SW (221°), forming a crack 11 cm (maximum) in length, when compared to the upper brick courses (Figure 13). The height of the step above the bottom of the excavated surface is 32 cm, and the azimuth for the horizontal placement of the original step is 131°. Since this step did not bear any load from above, the shift of the lower courses of bricks away from the upper courses must be due to seismic tremors of the ground below the building.

There are other examples of seismic destruction; for example, the warping of the upper part of the wall of the central premises of the temple (directional azimuth is 132°) toward the NE (see Figure 10).

The three described patterns of seismic destruction of the walls (tilting, shifting, and warping) can be explained by seismic waves generated along a SW–NE axis.

There is serious damage found on the NE wall of central section of the temple: practically all the external layers of the wall (1 brick thick) have collapsed (see Figure 10). The same wall, along the buttressed inside corridor, is also seriously damaged (the directional azimuth of the wall is 41°). Significant parts of its internal wall (about 1 brick thick) have fallen toward the SE. In addition, the upper part of the wall appears to be warped towards the southeast.

The "podium" in the centre of the main premises of the temple shows evidence of destruction: its edges are not straight (Figure 14a) and individual bricks from lower courses have fallen inwards (Figure 14b). Since the

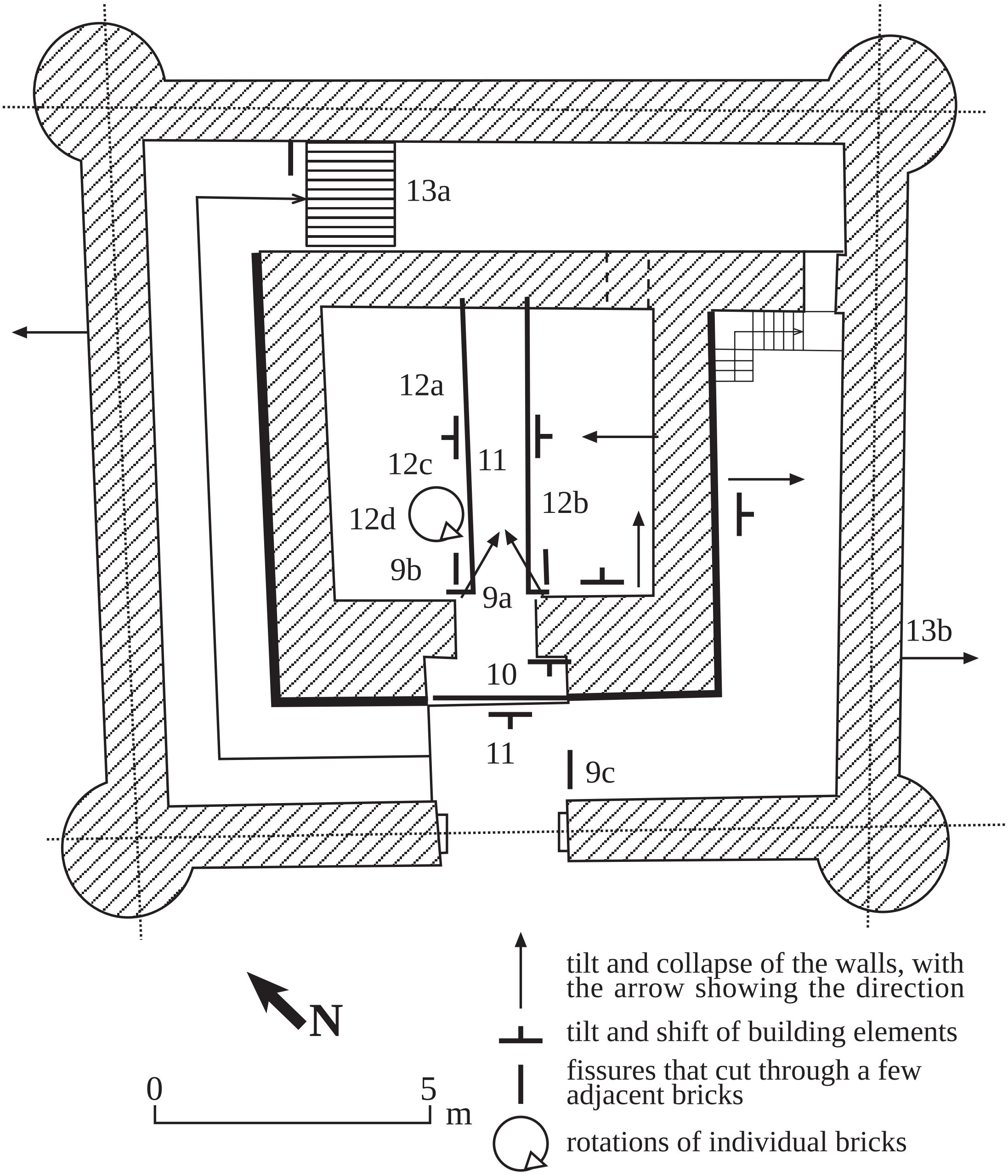

Figure 10. The scheme of an excavation of the Buddhist temple at the Koylyk site (modified from Baipakov & Korjenkov 2000). Numbers in the figure correspond to the numbers of the figures of given paper.

podium itself probably did not bear any significant weight and load, the most probable reason for its collapse is the seismic acceleration of the ground. The foundation of the podium is constructed of a layer of pebbles covered with reeds (Figure 14c). This layer could have served as an "anti-seismic buffer", similar to the reed layers and wooden logs found at the farmstead described earlier. Why was this gravel and reed layer part of the podium's foundation, especially if the podium did not bear heavy loads? Along with the shift of the lower course of bricks of the podium (7 cm in displacement) (see Figure 14b), there is evidence of displacement of the bricks up to a 10°

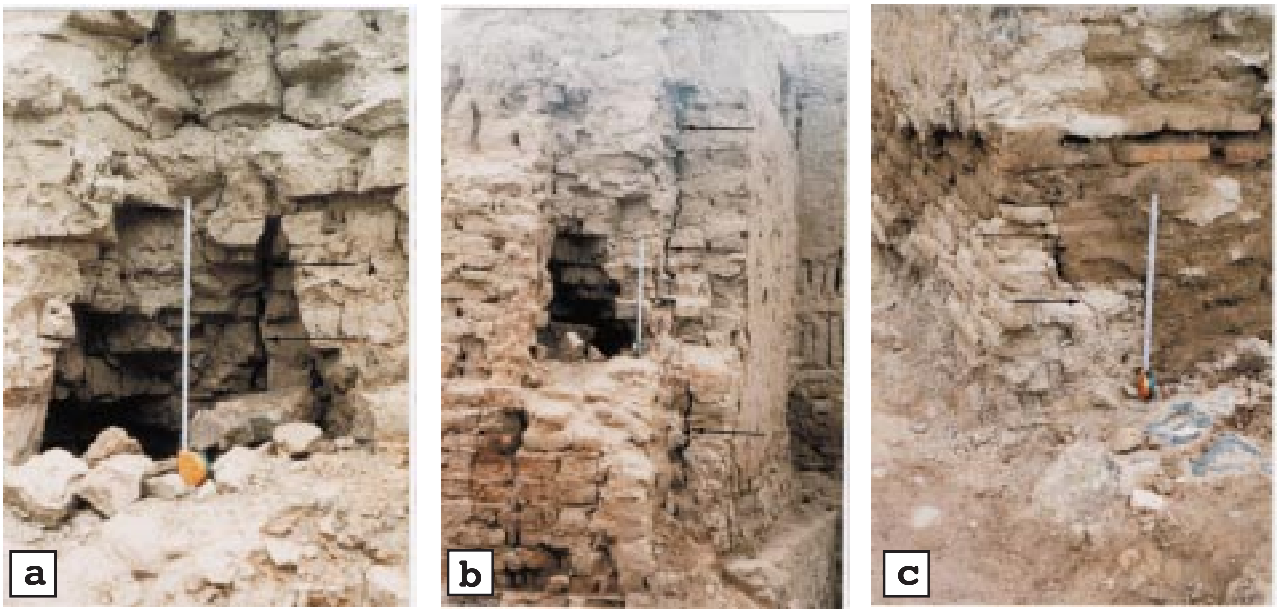

Figure 11. Intersecting fissures cutting through adjacent bricks. **(a)** NW corner of eastern upright support of the entrance into the central temple; **(b)** NE corner of the western upright support; **(c)** NW corner of the temple entrance.

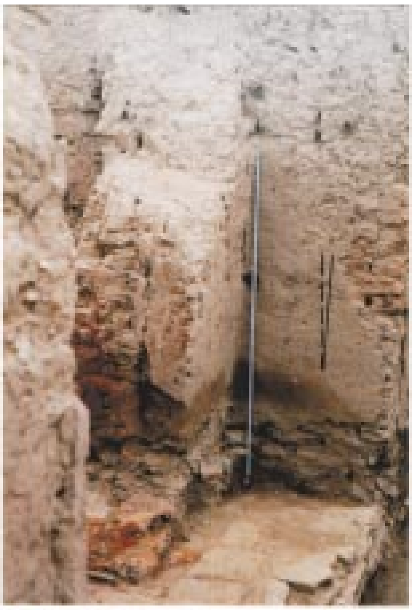

Figure 12. A SW-tilting column support of the entrance into the central chamber of the Buddhist temple.

Figure 13. Shift of a lower course of bricks in a step at the temple entrance.

rotation (Figure 14d). The directional azimuth of the podium is 41°, and the directional azimuth of the rotated brick is 51°, thus indicating a clockwise rotation.

Two stages of the temple building were previously mentioned: the lower courses of brick masonry that belong to the first stage of construction, and the upper

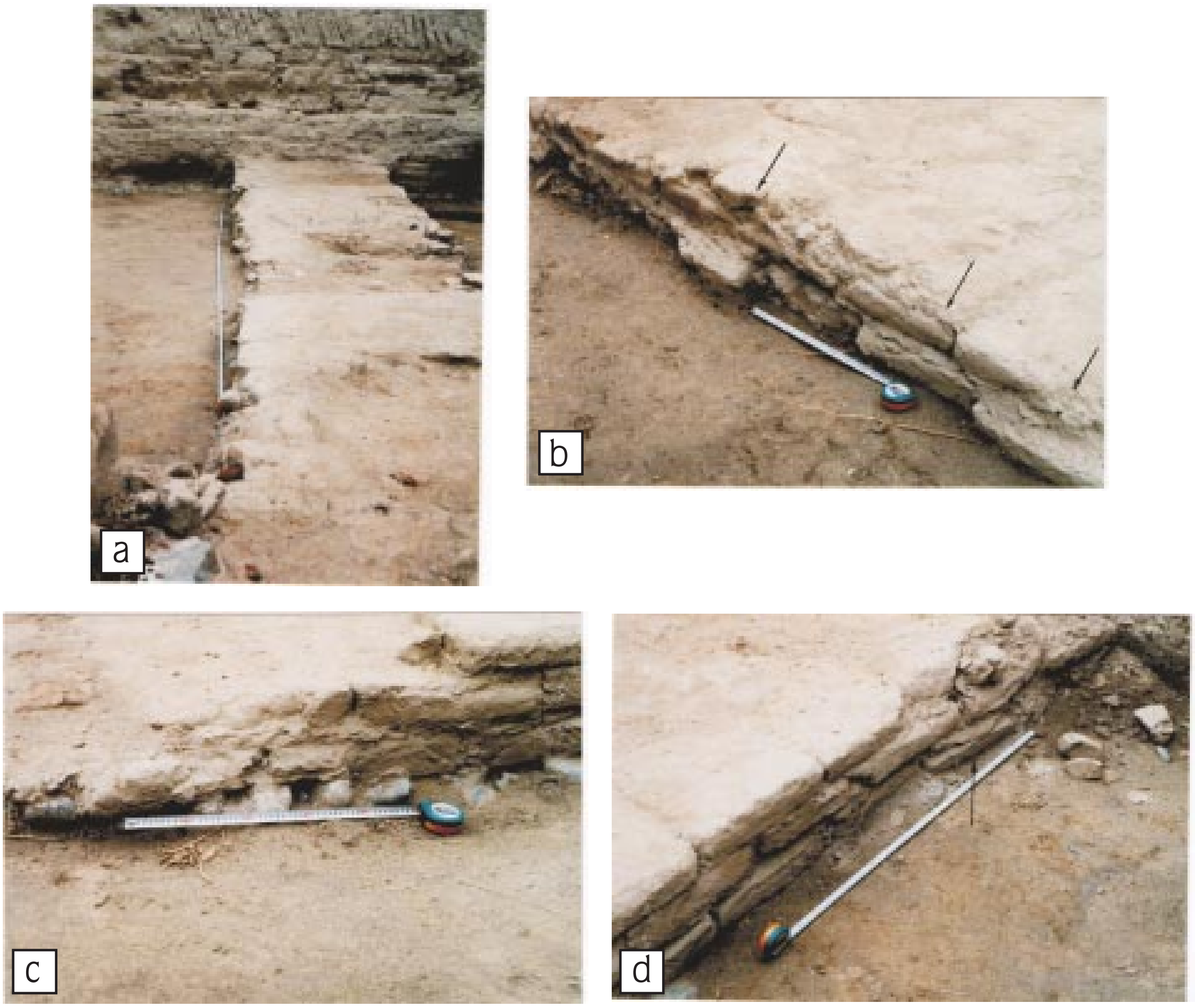

Figure 14. Deformation of the "podium" in the central room of the Buddhist temple: (a) uneven edges of the podium; (b) shifting of individual bricks; (c) "seismic buffer" of the podium, consisting of pebbles and reeds; (d) the shift and clockwise rotation of one of the bricks of the podium.

courses that belong to remodelling of the temple. The second stage of temple remodelling can be documented by the filling-in ("zabutovka") of the external corridor (see Figure 10) with layers of clay and pebbles (Figure 15a). At the bottom there is a 1.2-m-thick clay layer, then a pebble layer of 1.1 m, and above another clay layer of 1.6 m. Apparently the complete filling-in of the external corridor at the maximum height of the temple indicates that a new episode of seismic destruction occurred after the first remodelling of the temple. The filled-in corridor became a means of strengthening and stabilizing the upper courses of the temple walls, already in place during the first remodelling sequence of the temple.

This same method of filling-in the support walls (although less thick) also exists along the external wall of the temple (Figure 15b). The outward collapse of the external wall took place after the first remodelling, and suggests that there was possibly a third episode of seismic destruction at the temple. For example, the SE external wall of the temple collapsed toward the

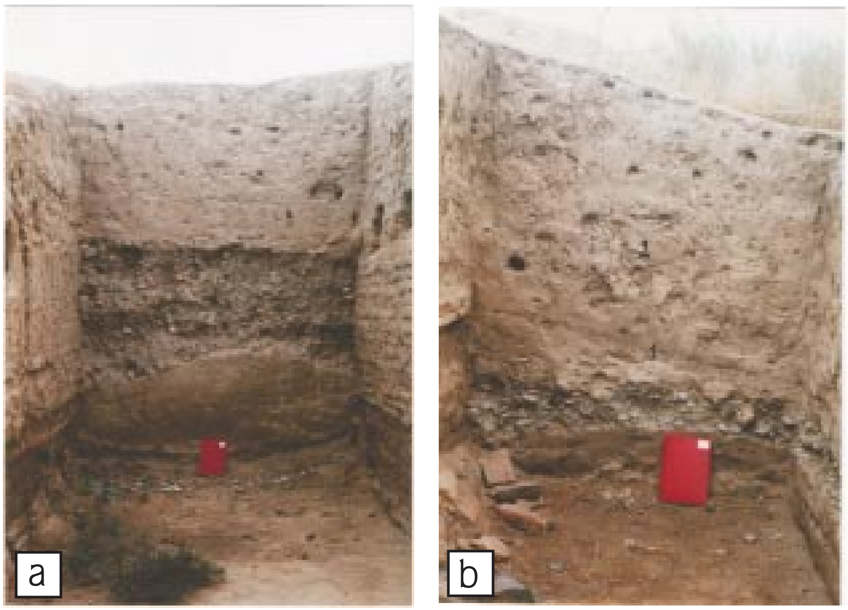

Figure 15. In-fill ("zabutovka") strengthening of the walls for protection against possible collapse. (a) Filling-in of external temple corridor; (b) "Zabutovka" along the external wall of the Buddhist temple. Here its thickness is 1 m maximum (near the wall). The top of the artificial embankment is marked by a horizon of organic material 1–3 cm in thickness (1). Above is a layer 1.0–1.2 m in thickness, a product of the destruction of the SW external wall of the temple: *saman* bricks and their fragments (2).

southeast and the *saman* bricks of the wall collapsed on top of the 1-m-thick fill layer (see Figure 15b). The directional azimuth of the wall is 44°; the bricks collapsed along the azimuth of 134°.

In summary, the study of seismic activity at the Buddhist temple has led to the following conclusions:

1. The temple was rebuilt twice during its existence.

2. The major reason for remodelling was destruction of the walls due to strong tremors from earthquakes whose epicentres were located within a known seismic zone of northwest Dzhungaria.

3. The seismic intensity of the earthquakes that led to the multiple episodes of destruction was about I_0=VII–VIII on the MSK-64 Scale.

Because of the superimposition of different types of wall collapse, produced by earthquakes of different periods, each with epicentres located at different locales, it was impossible to determine the direction of the seismic waves.

Medieval Talgar Site

Medieval Talgar (Talkhir) is a walled town at the mouth of the Talgar River that runs north of the slopes of the Trans-Ili Alatau Range of the Tien Shan mountains. Talkhir is an extensive site (Figure 16) with fortress walls that enclose an area of 9 hectares (Savelieva 1994). The fortress wall is made of courses of mud brick and rammed earth. Outside the large fortress wall is a settlement of outlying buildings consisting of residential areas to the south and the east. Cemeteries of the Mongol and Turkic periods are located south of the town. The town, which has been excavated since the 1940s by Soviet archaeologists, has been divided into three major chronological periods:

Period 1: the 8th to 9th and 10th centuries A.D., when the town belonged to the larger Turkic state of the Karluks of northeastern Semirechye;

Period 2: the 11th to 13th centuries when the town came under the influence of the Turkic khanate of the Karakhanids;

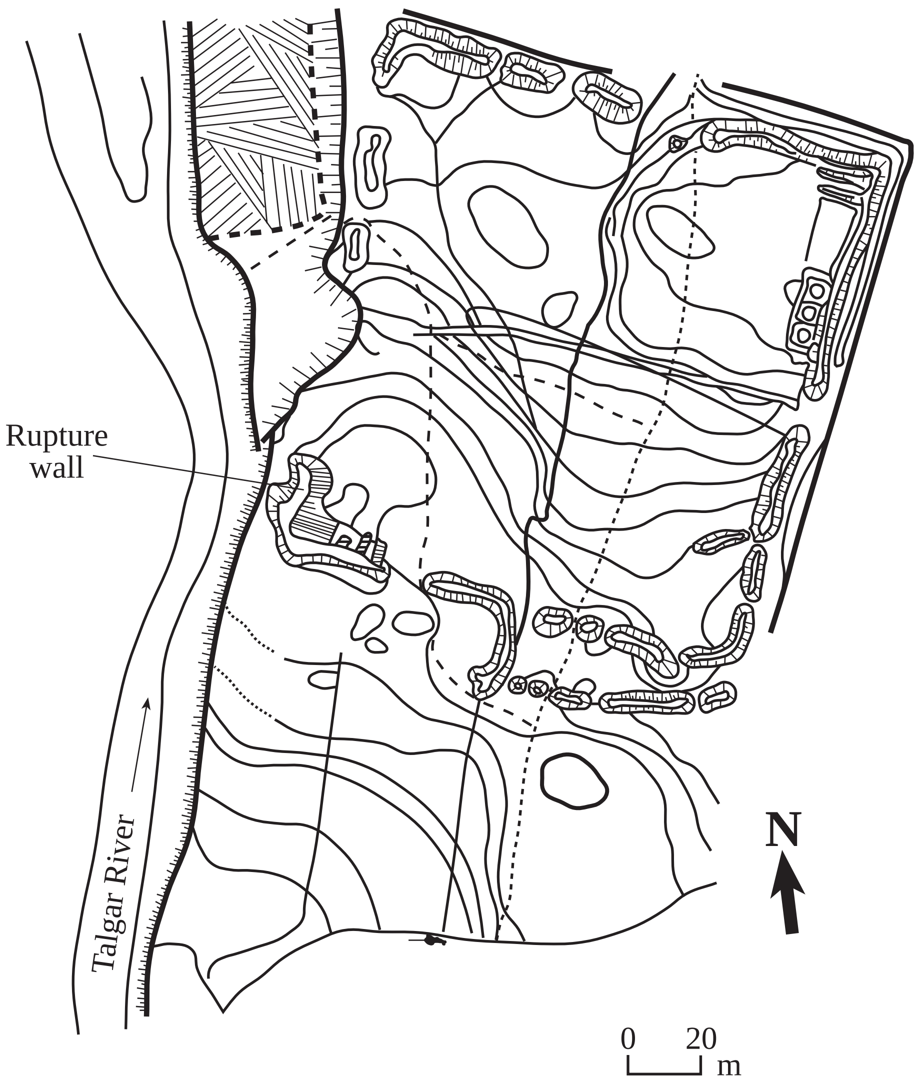

Figure 16. A plan of Talgar settlement (modified from Korjenkov *et al.* 2000).

Period 3: the second half of the 13th and beginning of the 14th century to the 15th century, when Talgar declined in size and regional importance. The town was conquered by the Mongols and, although settlement continued through the 15th century, it was no longer a magnet for caravan trade (Savelieva 1994).

The city has four main gates and two main cobbled routes: one running east-west and the other north–south (Kopielov 1984). On the west side of the Talgar River is a twin settlement known as Tunk. Tunk is only 6 ha in area (Kopielov & Kerekesha 1993). The main settlement of Talgar includes large buildings, craft-production areas (kilns, pottery-making areas, metal-working areas), and residential areas. Some of the residential areas to the southwest outside the walled enclosure appear to be large enclosed yards surrounding round yurt-like structures and animal corrals.

Talgar is along an important caravan route representing a northern branch of the Silk Road that connected the Ili River Basin to the Tarim Basin (currently part of western China). This route would have been less preferred than the main branch that connected the Fergana Valley of Uzbekistan and Kyrgyzstan to Kashgar in the Tarim Basin. Overland travel between Talgar and the Ili River or to points to the west probably took place when rivers such as the Talgar could have easily been crossed (before the snow melts in the early summer and after the August rains in the late summer).

Historical and archaeological records show that the primary trading sphere was southern and western in focus (Central Asian and Indian). Although Chinese imports did occur in the second and third time periods, the majority of trade items were Sogdian and Indian in origin. Major religions such as Buddhism, Nestorian Christianity, and Islam also were spread along these trade routes. In the latter two periods, material items representing peoples such as the Uigari, Kidani, Kereita, Merkita, and the Mongols have been found at Talgar.

Earlier local archaeologists believed that Talkhir, located right against the foothills of the Trans-Ili Alatau, was subject to heavy rains and snows that would have destroyed mud brick architecture. However, in Savelieva's 1998 excavations, the long buildings – major trade houses or caravansaries along the east–west wall inside the fortress, had stone and wood-beam sill foundations (Baipakov *et al.* 1999). Thus, the stone and wood-beam sill foundations could have been a kind of architectural strategy used by inhabitants who already understood the possible threat of earthquake activity.

Archaeoseismological study of the site can be implemented in order to discover the possible causes of the destruction of these ancient buildings. Medieval Talgar is located in one of the most seismically dangerous zones of Kazakhstan: at the crossing of the Alma-Ata thrust and the Talgar strike-slip fault. Here, strong earthquakes with magnitudes of M=7–8 (according to Richter Scale) and with seismic intensities of I_0=IX (Urazaev 1979) have been reported during historic periods.

We carried out preliminary work in the separate areas of the Talgar region of Kazakhstan with the purpose of revealing seismic deformation of the relief and the archaeological sites (Korjenkov *et al.* 2000). A pilot survey was made at an ancient settlement – Talgar – one of the largest towns of Middle Centuries along this fault line (Savelieva 1994).

Seismic activity was revealed at the western wall of the fort (Figure 17). The wall, built from clay bricks (*saman*), has a trend of 340°. The nature of the fissure found on the wall is complex: it consists of two cracks, the space between which is filled by a brown, clayey material a few centimetres thick. The zone of break extends downward. The wall consists of grey-yellow loess-like loam. The crack shows the displacement of a 11-cm-thick layer of dark-brown clay. The offset area of the fissure is 2.5–3.0 cm, and the southern block of saman below the fissure is thrust upward with a dip azimuth of 167°and a dip angle of 76°.

It is very important to note that the Talgar settlement is in a zone of dynamic earthquake activity, which is located just 0.5 km south of the archaeological site. The *adyr* fault belongs to a highly active seismic zone with a history of recurrent earthquakes (M=7–8 on the Richter scale, I_0=IX–X) – one event every few hundred of years; for example, one strong earthquake every 250 years for the Issyk-Ata (*adyr*) fault in Kyrghyzstan (Chedia *et al.* 1997). The described fissure at medieval Talgar follows in the same direction as one of the branches of the main fault of the Alma-Ata fault-line.

The excavations of the Talgar archaeological site were made in the 1970s and 1980s. Currently, the *saman* walls of the site, preserved after the excavations, are covered by a layer of loamy material. The cleaning of the fortress walls will probably reveal additional evidence of seismic activity and wall collapse at medieval Talgar.

Akyrtash Site

The Akyrtash (Kasribas) site is located at the foot of the northern slopes of the Kyrgyz range, 40 km east of the town of Taraz (Dzhambul). It has a unique medieval construction type for the Semirechye region: its walls are composed of huge blocks of bedrock – red Palaeozoic sandstone. The uniqueness of the site is also due to the fact that the building activity was not completed. Its construction was in its initial stage. Currently, it is possible to document only coursed stone walls composed of massive stone blocks up to 1–1.5 m high (Baipakov & Northedge 1997).

In 1998, extensive excavations under the sponsorship of INTAS were conducted at Akyrtash. At Akyrtash, an approximately 180 x 120 m site in the Talas River valley, the excavations reveal the use of large bedrock blocks for building construction. An extensive mapping project currently conducted by a Kazakh-French team under the direction of Dr. Baipakov, has revealed sandstone-block architecture of dwelling areas, a palace complex, and extensive courtyards. However, this mapping team did not study in great detail the causes of wall-fall, block

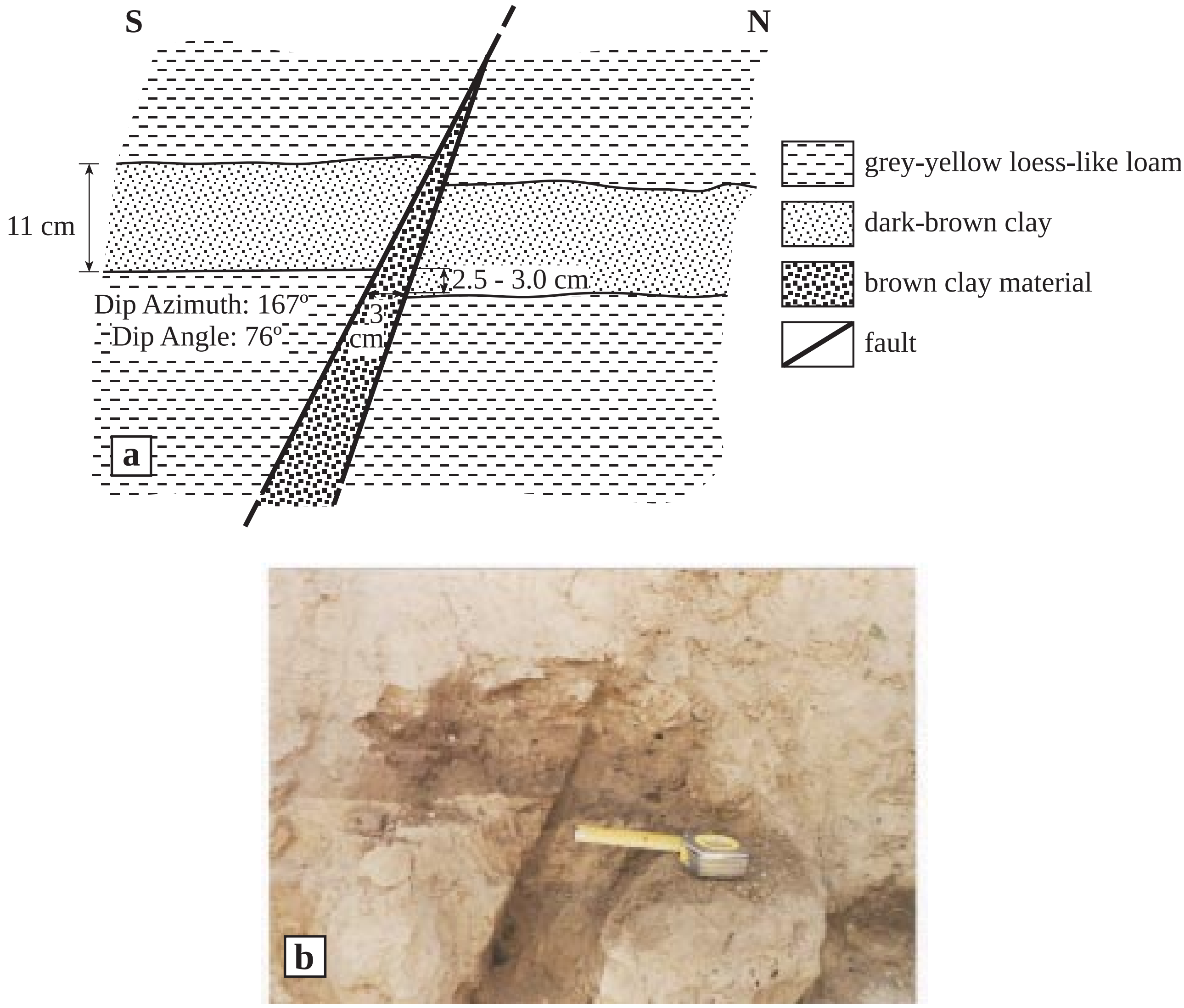

Figure 17. Field sketch (a) and photograph (b) of a seismic fracture in the western wall of the Talgar fortress.

rotation, and other evidence for architectural destruction or displacement (Figure 18). There is one construction period in the second half of the 8th century. It is interpreted as an unfinished palace complex built by Arabian architects by order of the Karluk Khaganate. However, the building was not completed and the walls are only one to three blocks high. The archaeologists believe that the site was abandoned due to political or economic factors (Baipakov *et al.* 1999). The observed wall deformation could be due to natural wall-fall, post-abandonment factors, or earthquake damage.

The preliminary study of the site has shown the existence of seismic destruction, for example, in the northern wall of corridor No. 103 (Figure 19a) there is evidence for the tilt and shift of the upper (second) block of the wall. The height of the preserved fragment of the wall is 115 cm. The size of displaced block is 85x70x50 cm. The block shifted and tilted northward (dip azimuth is 156°, dip angle is 60°) along an edge that is 12 cm in length. A bit eastward along the same wall another block

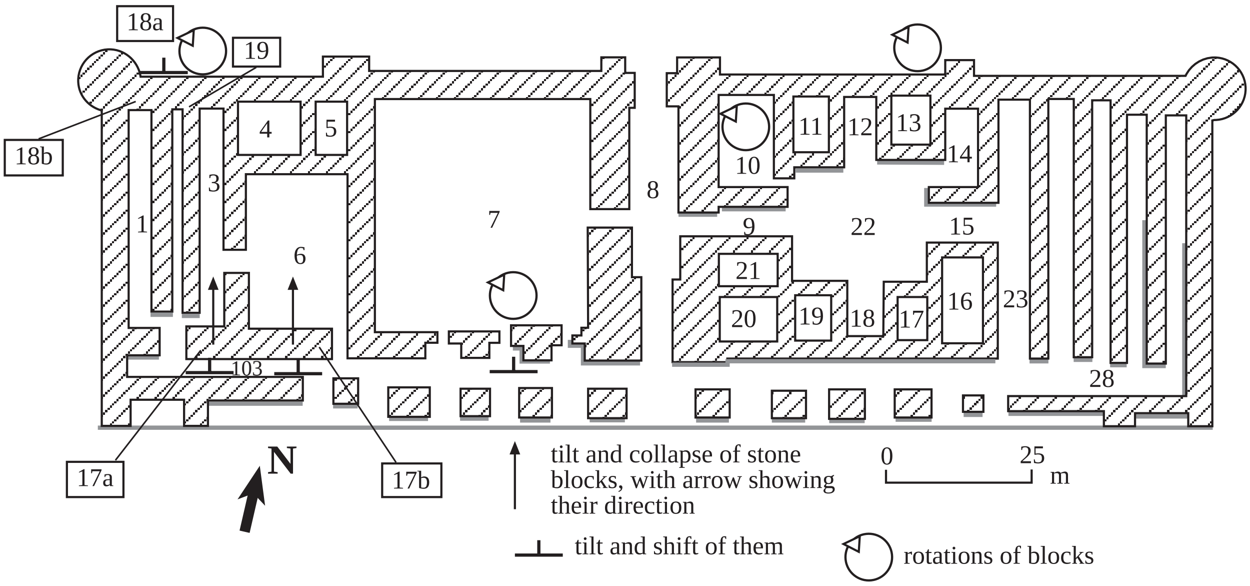

Figure 18. Seismogenic deformation in the northern part of the Akyrtash site (modified from Baipakov & Northedge 1997). Numbers in rectangles correspond to the numbers of the figures in the article.

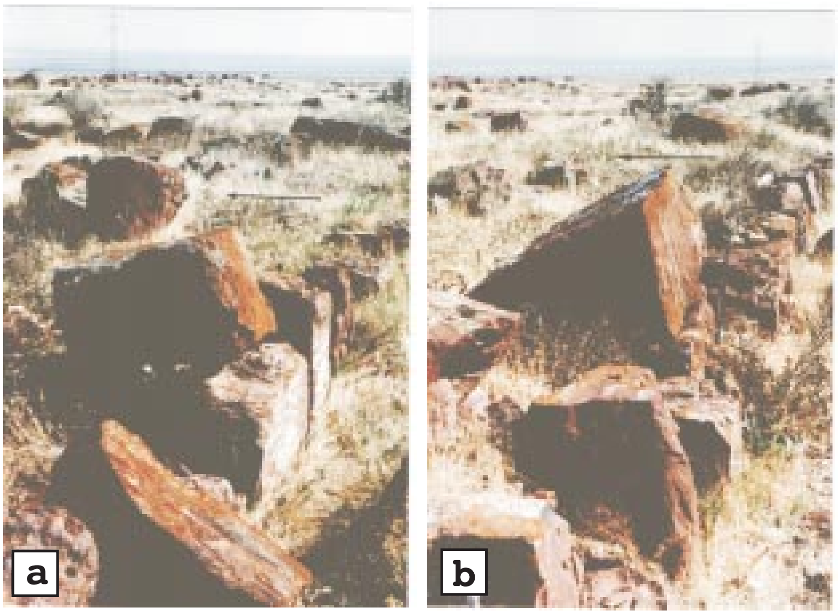

Figure 19. Tilt and shift of upper blocks in the walls, with arrows showing their directions. (a) northern wall of corridor No. 103 to the north; (b) southern wall of courtyard No. 6.

tilts in the same direction.

The block from this wall collapsed toward the NNW. The directional azimuth of the wall is 66°. At the foot of the southern side of the wall there are few blocks, but their quantity is six times less than those blocks on the northern side of the wall (2/12). These blocks were thrown a distance of 4 m northward from the base of the wall. Such a distance for wall tumble suggests that seismic activity was responsible for their location.

The same type of destruction can be observed in the external southern wall of courtyard No. 6 (Figure 18). Here, the upper block (100x70x50 cm) shifted toward the NNW along an edge 26 cm long, and at a tilt of 70° (dip azimuth is 165°) (Figure 19b). Here, fallen blocks were thrown northward a distance of 3.2 m, and the remaining height of the wall is 118 cm.

The external side of northern city wall underwent intense episodes of seismic activity. North of the long buildings, No. 2 and 3 (see Figure 18), the stone blocks shifted and were 3 m to the north (Figure 20a). At least six blocks were thrown 30 to 115 cm in distance.

The northward shifting of the wall-fall can also be observed at the inside of the city wall in room No. 1 (see Figure 17). Three blocks were shifted along the azimuth 340° (NNW), with a distance of 50–60 cm (Figure 20b). The directional azimuth of the wall is 70°.

All the described examples of seismic activity leading to wall collapse, tilting, and shifting indicate that seismic waves were generated along a NNW–SSE axis. Systematic tilt, collapse and shift of building blocks – with a weight of more than one ton each – must have been caused by seismic acceleration of the ground. Together with the shifting of blocks and their displacement due to being thrown from the city wall, it is possible to observe inside the city walls a block (75x50x40 cm) that has been rotated (Figure 21). The directional azimuth of the wall is 72°, the strike azimuth of the rotated block is 51°, and consequently the block was rotated counter-clockwise along an angle of 21°.

Along this wall to the east in room No. 10 (see Figure 18), there are two adjacent blocks (113x73x68 cm and 111x60x60 cm in size) that have rotated along a directional azimuth 47° and a strike azimuth of 21°, respectively. The directional azimuth of the wall in this place is 72°. However, in the same wall, farther to the east and inside of room No. 13 (see Figure 18), four adjacent blocks were rotated clockwise. The directional azimuth of the wall is 70°, and the blocks were rotated at angles of 15°–45°.

The rotations of building blocks weighing more than one ton each indicate that they have been moved by seismic tremors. The differences in the types of rotations of the blocks of one wall show either the nearness of an epicentre (domination of the vertical component of seismic movements: Korjenkov & Mazor 1999a–c), or the seismic movement of the underlying deposits (local effect).

Examples of the deformation described above are numerous, but even the cited data are enough for the following conclusions:

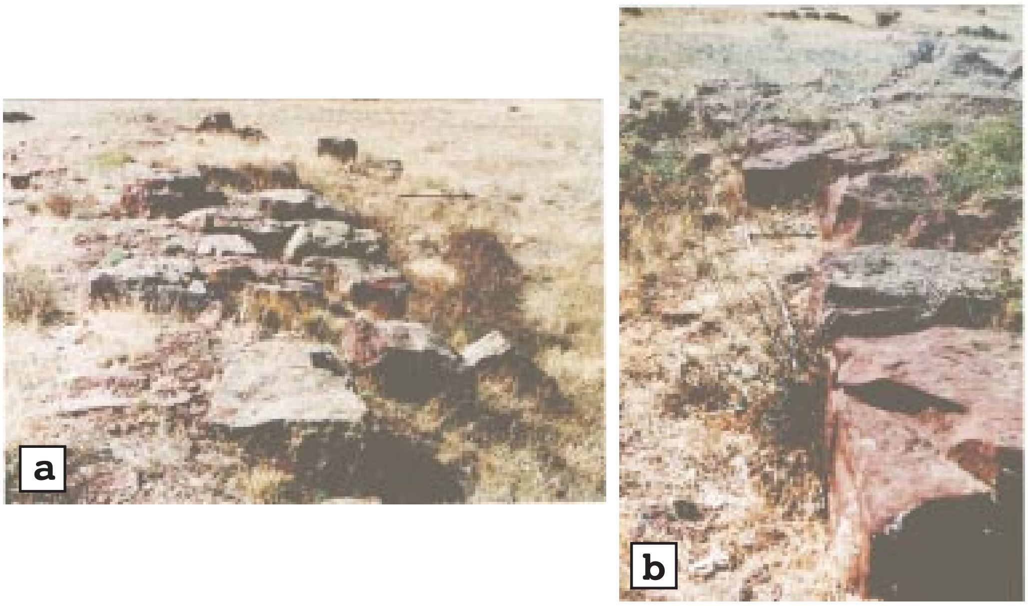

Figure 20. Northward shift of stone blocks (shown by arrows) of northern city wall: (a) to the north from rooms No. 2 and 3, dashed line shows original position of the stones; (b) southern wall of room No. 1.

Figure 21. Counter-clockwise rotation of a stone block measuring 75x50x40 cm. Blocks 1–3 were preserved in their original positions. Block 4 was rotated.

1. The building activity at the Akyrtash archaeological site was stopped due to an earthquake.

2. The seismic intensity characterizing the observed deformation is estimated as I_0=IX–X.

3. The direction of seismic-wave propagation is estimated to follow a NNW–SSE direction.

4. The significant seismic intensity and the absence of a systematic picture in the rotations of the building blocks appear to suggest that the epicentre of the earthquake was near the site.

Conclusions

1. This archaeoseismological study was conducted at three medieval sites along the northern branch of the Silk Road: Koylyk, Talgar and Akyrtash, located along a 700 km stretch of mountain ranges. The evidence of seismic destruction (deformation) was discovered at all three sites: systematic collapse, tilting, shifting of wall fragments, and also brick and stone rotations and fissures that intersect several courses of brick.
2. The intensity of the seismic destruction has been estimated as I_0 = (VII) – VIII for the Koylyk site, I_0=(VIII)–IX for medieval Talgar, and I_0=IX–X for the Akyrtash archaeological site.
3. At the ruins of the Buddhist temple, there is evidence for multiple instances of earthquake activity, which led to remodelling and eventual abandonment of the temple.
4. It has been possible to determine the directions of seismic-wave propagation for these sites: NE–SW for Koylyk site (for the earthquake that affected the wealthy farmstead); the epicentre of the earthquake that destroyed medieval Talgar was located in the immediate vicinity of the town; seismic waves that led to destruction at the Akyrtash site propagated along a NNW–SSE axis and the seismic epicentre was near the site.
5. For more exact locations of the ancient epicentres, it will be necessary to study other medieval sites using the “azimuthal method”.
6. The archaeoseismological study described above also has modern application with regard to developing a more precise set of causes for the destruction of medieval towns in the Semirechye region of Kazakhstan. This should be considered for modern-day construction along the foothills of the northern Tien Shan and northern Dzhungaria ranges.
7. Finally, the described archaeoseismological work calls for regional and international cooperation in compiling an archive of past seismic activity over the millennia.

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