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# Parameters of the Strong Paleoearthquakes Along the Talas-Fergana Fault, the Kyrgyz Tien Shan

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## 1. Introduction

### 1.1 Geological-tectonic structure and evolution of the Talas-Fergana Fault in the Cenozoic

The Talas-Fergana Fault (TFF) is the largest strike-slip structure in the central Asia. It forms an obliquely-oriented boundary between the north-eastern and south-western parts of the Tien Shan (Fig. 1). The last one includes the Fergana depression, Chatkal-Kurama mountain system and Alay valley. A wide belt of latitudinal oriented ranges, which are located between the Kazakh platform and Tarim basin, represents the north-eastern Tien Shan.

Many scientists were engaged and are still interested in studying the problem of recent movements along the Talas-Fergana Fault (K.E. Abdrakhmatov, T.P. Belousov, V.S. Burtman, O.K. Chediya, A. Khodzhaev, V.I. Knauf, A.M. Korjenkov, N.P. Kostenko, V.N. Krestnikov, I.N. Lemzin, V.I. Makarov, P. Molnar, V.A. Nikolaev, V.N. Ognev, A.V. Peive, V.I. Popov, G.N. Pshenin, E.Ya. Rantcman, S.V. Ruzhentsev, V.M. Sinitsyn, N.M. Sinitsyn, S.F. Skobelev, D.V. Shtange, A.L. Strom, L.D. Sulerzhitsky, A.I. Suvorov, V.G. Trifonov, N.N. Verzin, R.E. Wallace, and others. Most researchers interpret the TFF as a right-lateral strike-slip fault active since Palaeozoic time. Right-lateral movements rejuvenated in the late Cenozoic because of crustal shortening linked to the India-Eurasia collision. The tectonic movements along the intracontinental strike-slip faults contribute to absorb part of the regional crustal shortening, thus strike-slip motions along the TFF are necessary for the complete assessment of the active deformation of the Tien Shan orogen.

Our focus is to improve the understanding of the intracontinental deformation of the Tien Shan mountain belt as a whole and the occurrence of strong earthquakes along the whole length of the TFF. The aim of the work is an attempt to reveal features of relief occurred during strong paleoearthquakes along the Talas-Fergana Fault, TFF fault segmentation, length of the seismogenic ruptures, energy and age of ancient catastrophes. Mentioned data

are critical for complete seismic hazard assessment for a territory with absence of materials on historical seismicity.

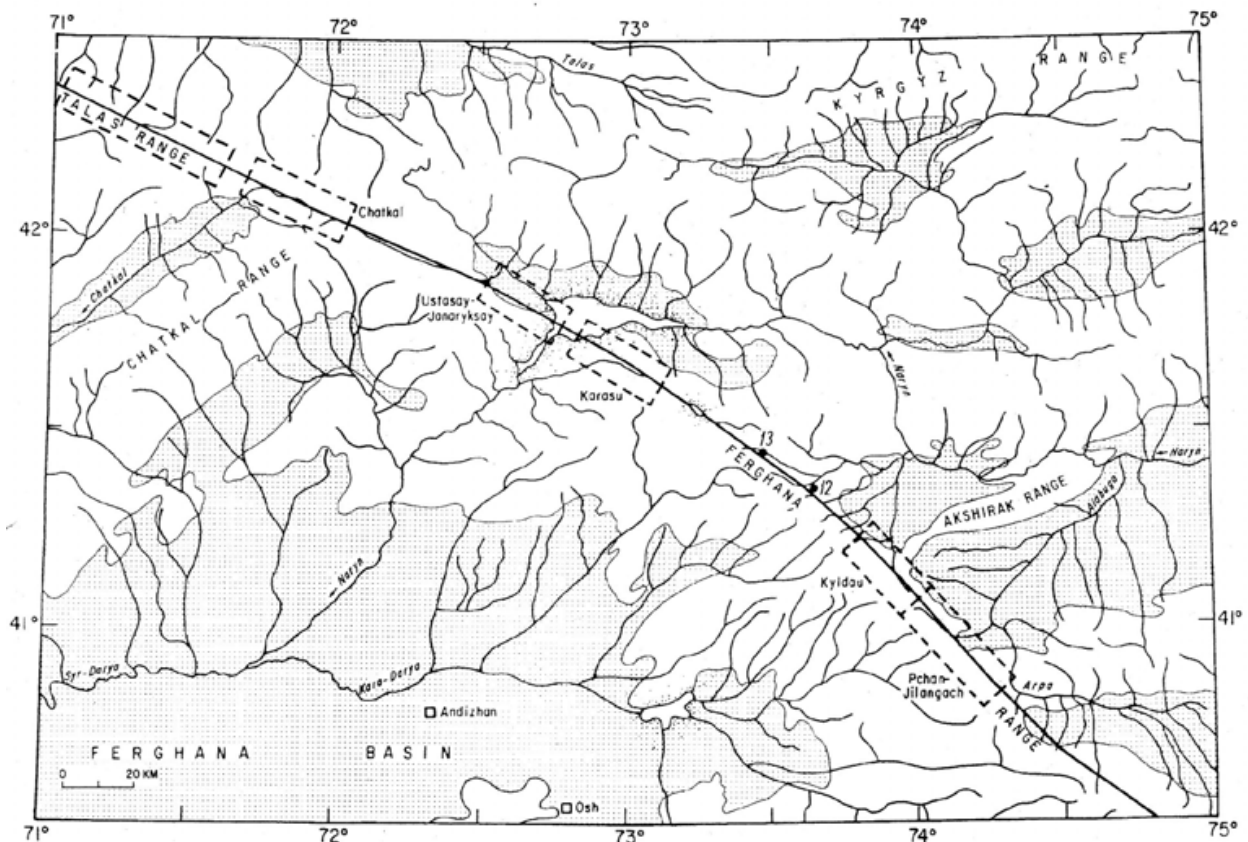


Fig. 1. The map of the Talas-Fergana Fault's line and adjacent territories (modified after Burtman et al., 1996). Dashed rectangular shows studied portions of the fault. Sedimentary basins are indicated by regular dotted filling. Irregular dotted area shows lakes and reservoirs. Numbers along the fault's line are observation points N12 and N13 from Burtman et al. (1996).

Many authors (Khodzhaev, 1985; Burtman et al., 1987, 1996; Trifonov et al., 1990, 1992; Abdrakhmatov and Lemzin, 1991; Korjenkov, 1993, 2006; Korjenkov et al., 2006, 2009, 2010 and others) were occupied also by a detailed paleoseismological study of the TFF zone. Some of them (Burtman et al., 1987, 1996; Trifonov et al., 1990, 1992; Rust et al., 2008; Korjenkov et al., 2009, 2010) collected samples for the radiocarbon dating. Because the organic material has deposited later than the formation of the upslope facing scarp, displacing channels of gullies and watersheds, the radiocarbon dates (Table 1) point on minimum ages of the events which led to relief forms' displacement along the fault zone.

All features pointing on seismic-rupturing character of the upslope facing scarp, developed along the fault zone, are testifying that the Talas-Fergana Fault is "alive" until present. As related to its morphologic-kinematic characteristics, most of scholars believe that the fault is right-lateral strike-slip fault's structure, they point on amplitude of displacement along it from hundreds meters to 12-14 kilometers during Cenozoic time (Ranzman and Pshenin, 1963; Trifonov et al., 1990 and others).

Last summary of materials of previous investigations along the Talas-Fergana fault is cited in papers by Korjenkov (2006), Korjenkov et al. (2006, 2007, 2009, 2010), Rust et al. (2008).

Field station	River valley or name of the fault segment	Value of the horizontal displacement, m	Radiocarbon age, years
1	Dzhilangach	19	3970 ±40
2	Dzhilangach	40 ±3 40 ±3 40 ±3	1940 ±50 2630 ±70 2740 ±70
3	Dzhilangach	45 ±3	1720 ±70
4	Chitty-Western	40 40	4590 ±100 15800 ±1300
5	Birguzy	35 ±5	3030 ±90
6	Birguzy	27	3740 ±600
7	Pchan	90 ±3	3150 ±40
8	Pchan	21–24 21–24 21–24	2180 ±120 2280 ±70 2540 ±70
9	Pchan	25 ±1	2640 ±600
10	Kyldau	23–24	2320 ±40
11	Kyldau	125 ±25 60 ±25	3670 ±80 3670 ±80
12	Urumbash	17–20	1510 ±60
13	Keklikbel	10–12	1240 ±60
14	Dzhanaryksay	14 ±2	1440 ±30
15	Chatkal	17–20	1450 ±40
16	Chatkal	20 40	1350 ±60 1350 ±60
17	Chatkal	20 20 40	1150 ±40 2020 ±50 2020 ±50
18	Chatkal	20 40	1220 ±50 1220 ±50

Table 1. Radiocarbon dates of the samples collected from the displaced gullies along the TFF (by Trifonov et al., 1990, 1992 и Burtman et al., 1996)

2. Methodology

Besides traditional route field investigations, forestalling by interpretation of air-photos and satellite images, study of existing archive and published literature, we have conducted a detailed mapping of selected key test sites:

- Kara-Bura one in a region of the pass with the same name across the Talas Range,
- Sary-Bulak test site in riverhead of the river with the same name – left tributary of the Uzun-Akhmat river and



- Kok-Bel test site in a region of a pass with the same name on the “Bishkek-Osh” highway (Fig. 2).



Fig. 2. Digital map of relief of the western Tian Shan. The locations of the investigated test sites are shown in the map.

On the prospected ranges the TFF line usually goes across the slope of one of river valleys or a ridge (range) slope. Along the line there is usually a fault scarp in the form of a swell. Height of this scarp is usually equal to several dozens centimeters - the first meters. On the investigated ranges the numerous broken forms of a modern relief were found: valleys of temporary waterways and watersheds between them, upper parts of which are shifted in a horizontal direction - to the right to a distance from several dozens to several hundreds meters. The identical width and morphology of the shifted parts of dry valleys above and below the fault line testifies that the shift occurred quickly. It allows linking such shifts with earthquakes (Burtman et al., 1987).

The majority of the shifted valleys of temporary waterways have remained below the fault line, where on the slope at earthquake a fault scarp was formed in the shape of a swell. This scarp has isolated the lower continuation of the broken valley, while seasonal waters found other drain, washing away the scarp in the lowest place. Further the isolated part of the valley could continue to be displaced along the fault.

For definition of time of movements along the TFF indirect method of V.G. Trifonov (1985) was used. At formation of a scarp on the slope along the fault line a depression was also formed. This scarp has impound the waters flowing down the slope and filtering along the fault plane, which created conditions for swamping of the depressions in the vicinity of the

fault. The beginning of formation of a peat swamp and a thick soil layer testifies to occurrence of a fault scarp which formed because of horizontal displacement along the fault. For definition of age of these formations samples of organic material for the radiocarbon analysis in bore pits, prospected in impounded parts of valleys, were taken. The received radiocarbon dates, based on the sum of the organic substance which was accumulated during some period of time, are always later dates as compared to the moment of beginning of accumulation. Determination of residual activity of carbon in our samples was carried out on a device QUANTULUS-1220 (Liquid Scintillation Counters) at the Institute of Geology and Mineralogy of the Siberian Branch of the Russian Academy of Science, Novosibirsk. For age calculation the half-life period of  $^{14}\text{C}$  was used equal to 5570 years. The age was calculated from 1950. Age determination was done based on fraction of humic acids.

### 3. Northwestern part of the Talas-Fergana fault

#### 3.1 Investigations in Ara-Beyik – Kara-Kasmak interfluve

In the most west of Kyrgyzstan (the Ara-Beyik river valley) the TFF trace is unclear. Probably, it is divided into several zones parallel to each other and differing in character of the Holocene slip. The fault zone can be identified in outcroppings of rocks along the right slope of the river valley where there is a wide zone of crushed basement rocks.

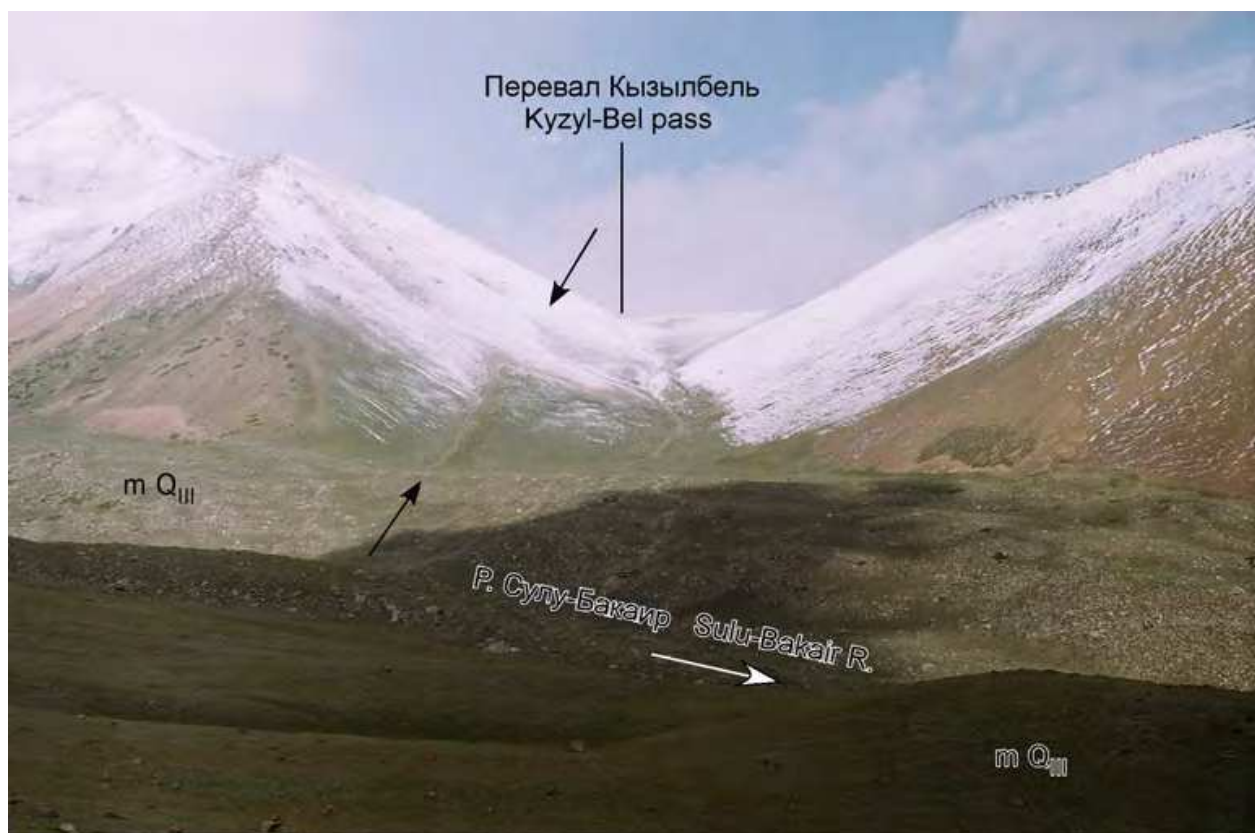


Fig. 3. The right-lateral deviation of dry channels (shown by black arrows) along the Talas-Fergana trace on the left slope of the Sulu-Bakair river valley.

In the Sulu-Bakair River valley the TFF zone cuts a moraine of Middle and Late Pleistocene age and is expressed as a deep and wide upslope facing scarp. Although the moraine is



several tens meter thick, the fault zone is marked by springs. Above the TFF line there is a stairs on the slope consisting of upslope facing scarps located one above another and formed in loose colluvial and moraine deposits. Slip displacements are not clearly seen here excluding some cases. Thus, for example, two neighboring scours on the left slope of the Sulu-Bakair river valley within the TFF zone have experienced a right-lateral bending (Fig. 3). On the right bank of the river a small stream channel was beheaded along the fault, and now its upper reaches are at a distance of 128 m from the lower ones (Fig. 4). A neighboring stream channel was shifted to the right on the distance of 57 m, but its valley is smaller than that of previous one.

In a place of crossing of the Korumtor Spring by the Talas-Fergana Fault (Shilbilisay River basin) the fault is expressed by a visible depression in relief. An upslope facing scarp is located along it. Its width – 30 m, depth – down to 3 m (Fig. 5). The upslope facing scarp is also visible in a body of Late Pleistocene ( $Q_{III}^2$ ) moraine.



Fig. 4. The right-lateral deviation of channels on the distance of 128 m in the Late Quaternary moraine on the right slope of the Sulu-Bakair river valley within the TFF zone.

The Talas-Fergana Fault zone is well exposed in the region of the Kara-Bura pass due to building an automobile route. Here the fault is represented by a zone of hundreds meter wide composed of completely crushed cataclasites and milonites and rocks with traces of initial structural-material features. There are also lenses not modified by tectonic processes. The TFF line is clearly identified by lows in the relief and saddles on watershed spurs.

Probably to the west of the Kara-Bura pass the right-lateral slip turned to a fault plane to the north of the TFF. Thus, in the upper reaches of the Kara-Bura river on the northern slope of

the Talas range we observed an upslope facing scarp causing beheading and right-lateral shifting of dry channels and scours (Fig. 6 and 7).

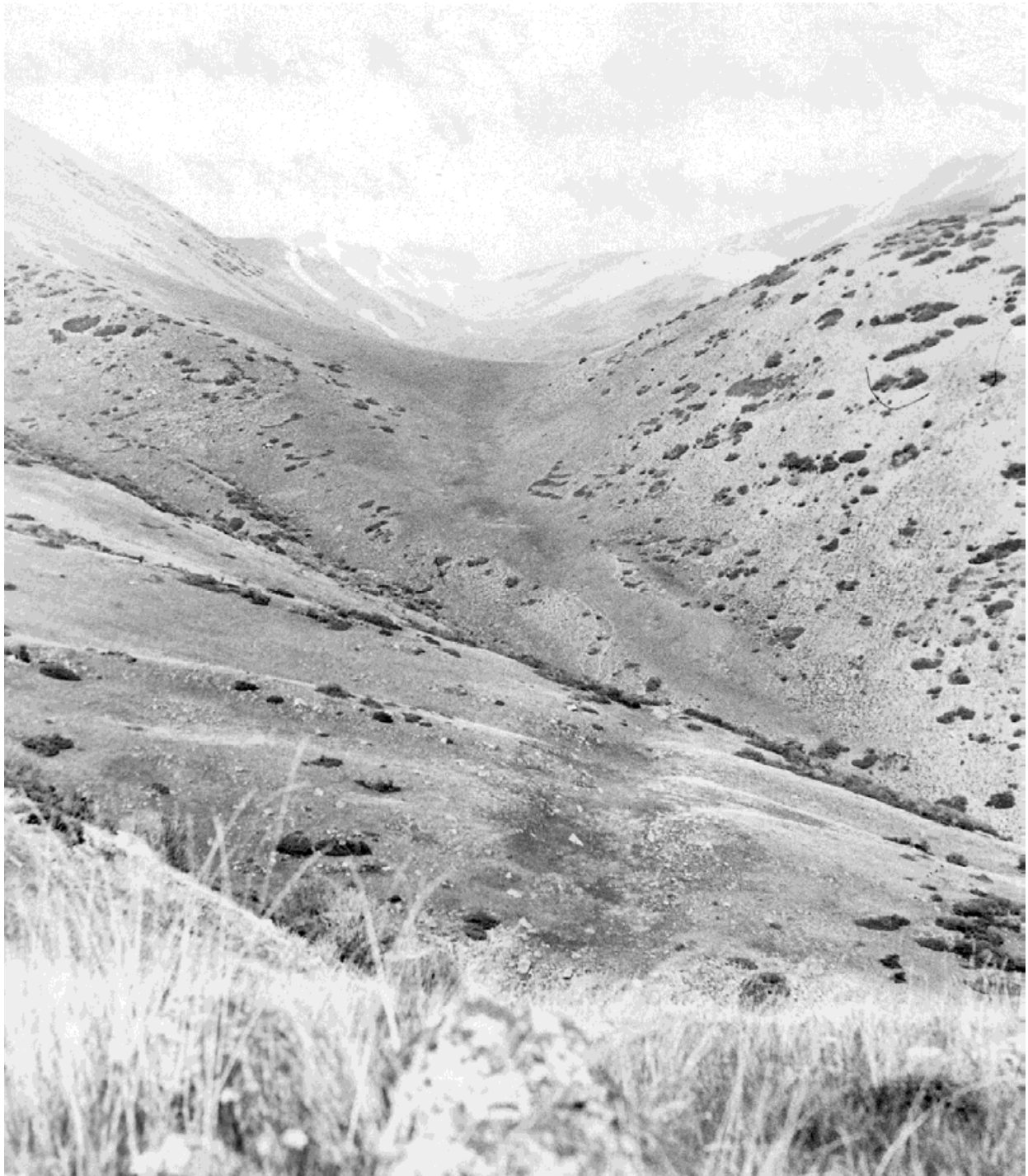


Fig. 5. A photograph of the Talas-Fergana Fault zone. A view NW-ward from Korumtor river basin.

To the south-east of the Kara-Bura pass the Talas-Fergana Fault is well pronounced in three recessional moraines filling the upper valley of the Karakasmak river. Here it is represented by a zone of sagging located at oblique angles to each other and cutting moraine and



fluvioglacial sediments. Along the southern line one can observe right-lateral deviation of dry channels (up to 34.7 m) and watersheds between them. We also observed a recessional moraine body deposited at the end of the Late Pleistocene and shifted on 28.3 m. Further to the south there is a stairs consisting of upslope facing scarps on a steep slope.

As we described above, along the whole its length the Talas-Fergana Fault is expressed in relief in a form of a deep depression – upslope facing scarp which cuts both basement rocks and Quaternary deposits (Fig. 8).



Р. Кара-Буря Kara-Bura R.

Fig. 6. Beheaded dry scours (shown by dashed lines) on the right slope of the upper Kara-Bura river valley. The rupture of upper and lower parts of the scours occurred along the slip fault (show by arrows) located in the north of the main trace of the Talas-Fergana Fault.

Mentioned above upslope facing scarp testifies on active seismic life of NW chain of the Talas-Fergana Fault. A number of features point on the fact that it is a real seismic-rupture form and not a depression of weathering developed along a zone of milonites and cataclazites.

1. Localization to the fault of a number of seismic-gravitation forms (rock- and landslides). For example, a limestone rockslide which locates in 500-600 m east of the Kara-Bura pass (Khodzhaev, 1985).
2. Linear upslope facing scarp is well traced, in spite of it crosses different relief forms, as well as different rock formations. It is particularly well expressed in moraine bodies.
3. The up slope facing scarp cuts channels of temporary springs where the tectonic dams are formed. An existence of the tectonic dams is the direct evidence of impulse

movements along the fault during a moment of its seismic refreshment (Khromovskikh and Nikonov, 1984).



Fig. 7. Upper reaches of the Kara-Bura river, right slope of the valley. Picture of one of beheaded scours (shown by dashed line) along a slip fault (shown by two arrows) in the north of the TFF. The upper portion of the scour is shifted to the right.

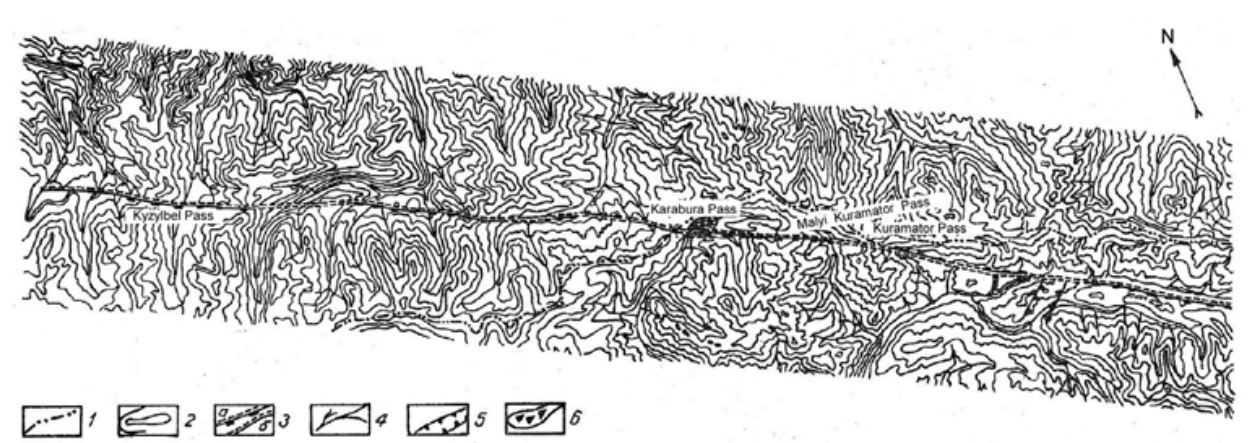


Fig. 8. A map of the Talas seismogenic structure (modified after A.K. Khodzhaev, 1985): 1 – watershed line of the Talas Range; 2 – contour lines in 200 m; 3 – seismogenic ruptures (a – normal faults, b – cracks); 4 – rivers and springs’ beds; 5 – river captures; 6 – seismically induced rockslide.



4. An intake of frontal parts of recent taluses by the upslope facing scarp testifies on youth and instantaneity of its formation. This phenomenon one can observe east of the Kara-Bura pass. If not, an ancient upslope facing scarp would be covered by the colluvial material, the talus would gush over the scarp and will continue its movement down the slope.

### 3.2 Kara-Bura test site

We have mentioned above about our investigations on special geodetic test sites. The first region is located to the south-east of the Kara-Bura pass in the upper reaches of the Kara-Kysmak river (Chatkal region, Djalal-Abad oblast). Here the Talas-Fergana Fault passes downward from the pass and cuts Late Pleistocene recessional moraines. The fault zone is clearly marked by elongated depressions, as well as by right-lateral shifts of stream beds and watersheds between them.

We constructed a digital elevation model of the site (Fig. 9). Using the model and taking into account characteristic elements of the relief we could measure the right-lateral slip along the fault. Thus, for example, a Late Pleistocene recessional moraine (Shubin et al., 1992) was shifted for 28-34 m (B1-B2, Fig. 10). This displacement began, apparently, 5910  $\pm$  130 years ago to what testifies the absolute age of the sample SOAN-6526 selected in detrital deposits which filled the crack, formed in the stretching zone along the fault (Fig. 11). Thus, the calculated rates of displacement in the second half of Holocene on this site of the fault were 4.70 - 4.90 mm/year.

In the body of the phased moraine of the middle of late Pleistocene (Shubin et al., 1992), the stream valley (Fig. 9 and 10) was cut. Its age, hence, is more young - apparently, the end of late Pleistocene. The thalweg of the valley was displaced to the right at 34.78m (A1-A2, Fig. 9). The watershed to the east from this stream was displaced practically on the same distance (31.07 m).

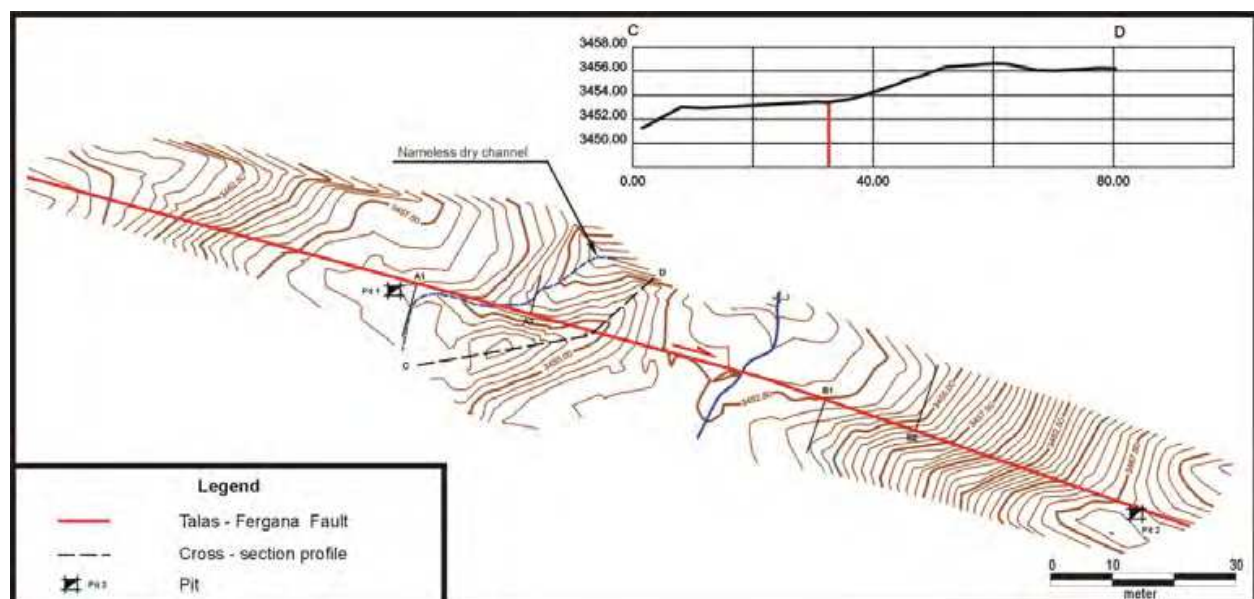


Fig. 9. Digital map of the Kara-Bura test site. Detailed mapping of the Talas-Fergana Fault zone with a use of an electronic tachometer. Pit1, Pit2- pits. Contour lines in 0.5m. Segment A1 - A2 along the fault line - displacement of the dry gully on 34,78 m. Eastern watershed of the dry gully (A - B profile) is displaced on 31,07 m. Segment B1 - B2 - right-lateral displacement of an age of Late Pleistocenemoraine on 28,34 m.



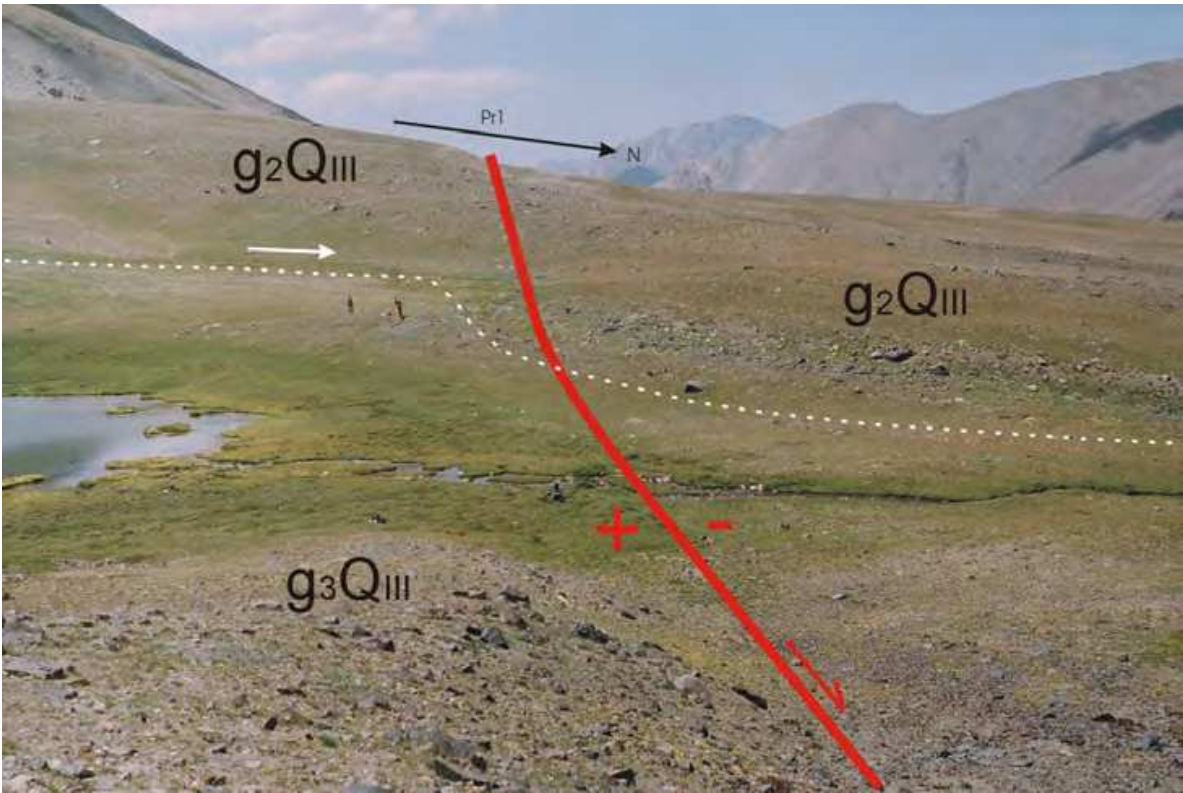


Fig. 10. Photo of the Kara-Bura polygon. View north-westward. The red line is the TFF, the white dashed line is the dry channel, the arrow Pr1 is the profile line in Fig. 9, g2QIII is a recessional moraine of the middle of Late Pleistocene. g3QIII is a recessional moraine of the end of Late Pleistocene.

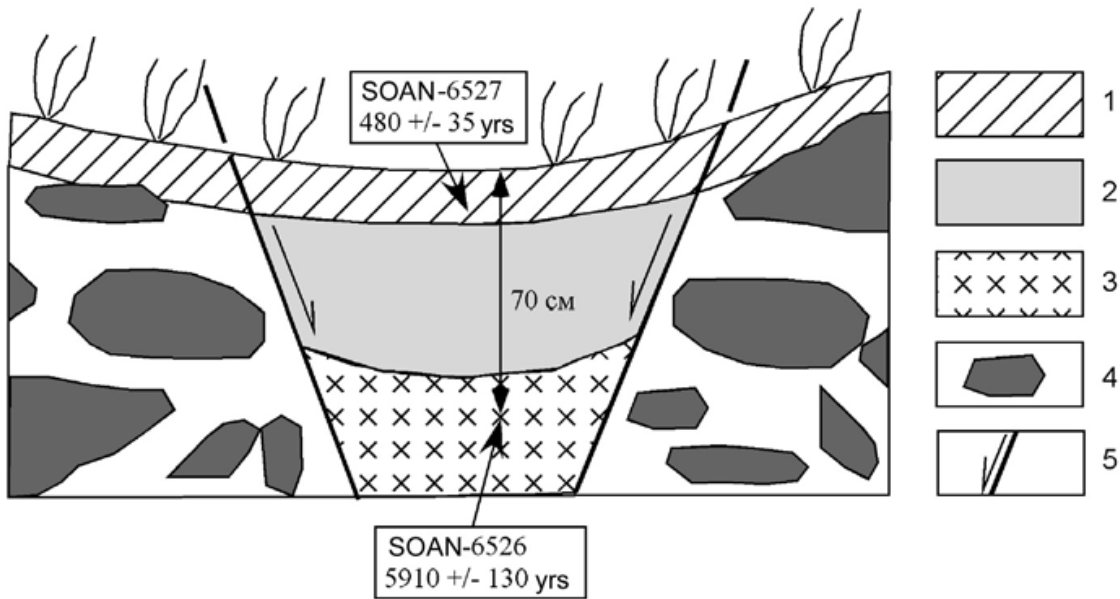


Fig. 11. A schematic sketch of a trench No. 2, which was prospected through graben in a transitive zone of the stretching in the zone of the Talas-Fergana fault. 1 – is characterized by poorly developed mountain soil, 2 – is characterized by loess-like loamy soil with gravel, 3 – sand and detritus deposit/sedimentation, which filled the graben, 4 – moraine deposits/sedimentations of the end late Pleistocene, 5 – fault planes which have formed the graben.

We examined the bore pit (Fig. 12) in the flood plain of the dry rivulet - in the SW wing of the TFF. Here the tectonic dam and impounded deposits, in connection with right-lateral displacements along the NE wing of the TFF, were formed. In the buried soil formed on a moraine of the middle of late Pleistocene (Shubin et al., 1992), we took a sample with absolute age of  $6100 \pm 200$  years (SOAN-6523). At this particular time, apparently, there was the first earthquake which has displaced for the first time the body of the moraine and fluvial deposits. Thus, the calculated rates of displacement for the last  $\sim 6$  thousand years comprised  $4.93 - 5.89$  mm/year.

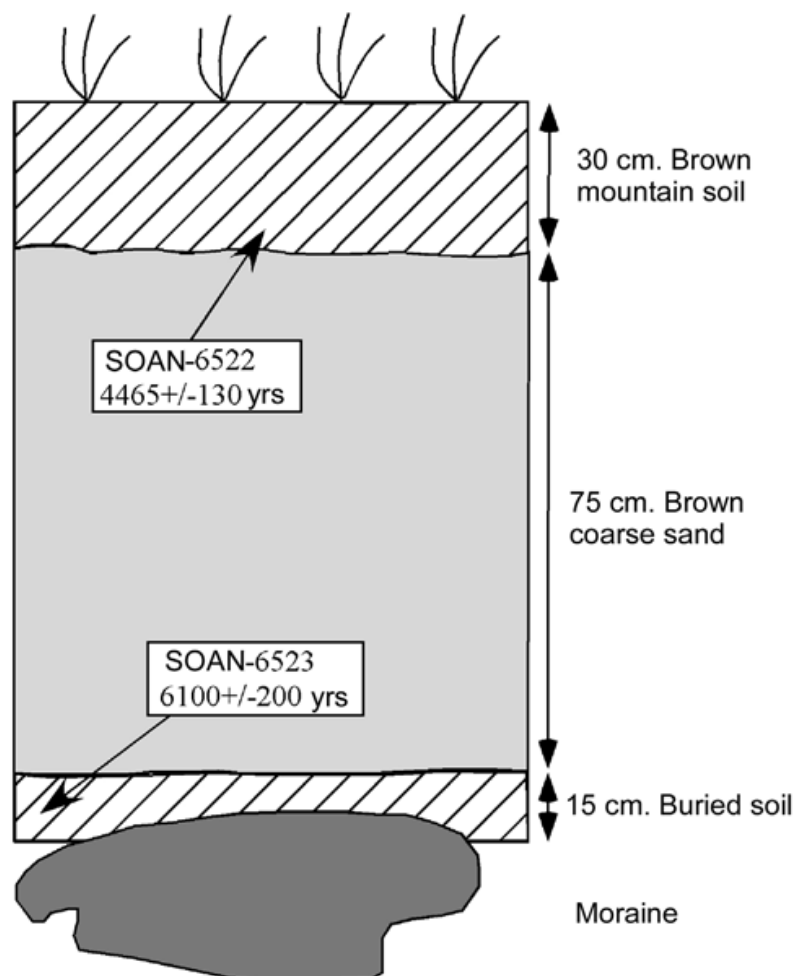


Fig. 12. Impounded deposits/sedimentations in bore pit 1, examined in SW wing of the TFF.

The absolute ages of the deposits formed in the bottom parts of both pits: in bore pit 1 and trench 2, give statistically the same age  $\sim 6$  thousand years which, apparently, is age of the first earthquake in Holocene which we managed to record. However in bore pit 1 (Fig.12) is available one more absolute age determination: in the bottom part of modern soil. Age of this sample by results of the radiocarbon analysis is  $4465 \pm 130$  years old (SOAN-6522). This is the minimum age of the second seismic event, recorded by us: in the middle Holocene. After the 1st earthquake on the examined site of the fault the tectonic dam was formed, which has led to accumulation of impounded deposits on which the soil cover, eventually, was formed.

However the earthquake, which took place 4.5 thousand years ago, was not the last earthquake on given site of the TFF. We have examined two pits in hanging (SW) and foot (NE) wings of the fault scarp formed along TFF (Fig. 9, 10 and 13). In them – samples were taken in the bottom part of the layer of turf, the absolute age was  $405 \pm 100$  years old (SOAN-6525) for a hanging wing of the scarp and  $460 \pm 40$  years old (SOAN-6524) for the foot wing. These two dates indicate in the occurrence of the seismic event 400-500 years ago. These data prove to be true also by the age determination SOAN-6527 ( $480 \pm 35$  years old) of the modern soil received from the bottom part in trench 2 (Fig. 11).



Fig. 13. The late Holocene seismoshoulder/seismoledge along the TFF (it is shown by a red faltering line), which is breaking the flood plan of the unnamed rivulet/say. The SW wing is raised. In both wings pits on depth of 15 cm were selected samples in the bottom part of the turf/peat layer for definition of their absolute age.

Summarizing data on the Kara-Bura test site, we received (calculated) the following rates of horizontal tectonic displacement since the middle Holocene: 4.70-5.90 mm/year. During this time in the named area along the Talas-Fergana fault minimum three strong earthquakes took place: about 6000 years, 4500 years and 400-500 years ago. The data of absolute age, determined on the Kara-Bura test site regarding the latter earthquake, coincide with the archeo-seismologic data on the destroyed caravansary located in the middle part of the Kara-Bura river valley (Korjenkov et al., 2009).

### 3.3 Investigations in the Kara-Kasmak – Sary-Bulak interfluve

In the interfluve of right inflows of the Karakuldzha-Chatkalskaya river (Dzhashilsai, Dzhosho and others) (Fig. 14A) there are no clear evidences of vertical differential



displacements of the TFF walls. However in the south of the region the vertical component can be observed. Thus, above the mouth of the Chiimtash river (right inflow of the Karakuldzha river) and a pass of the same name one can observe a typical upslope facing scarp up to 8 km long half-filled with clastic material that results in only 1.0-1.5 m height difference between the hanging and foot walls of the fault. Nevertheless, it is seen from walls of gullies cutting the seismogenic structure that the depth of the upslope facing scarp is about 4 m (Chediya, 1986). V.S. Burtman et al. (1987) reported a depth of the seismic depression (or the height of the seismic scarp in the shape of swell) up to 5 m (point 23 in Fig. 15). Besides, it is possible to observe a 10 m thick Middle Pleistocene moraine adjoining to the downslope vertically thrust wall of the fault (the left slope of the Karakuldzha river valley with elevation mark 3296 m), i.e. in this case there is a clearly marked 15-m thrusting of the north-eastern wall in the Late Pleistocene – Holocene. If to prolong mentally toward the fault the Early Pleistocene surface of the fault walls (Fig. 14 B) the stated above will be proved (Chediya, 1986).

V.S. Burtman et al. (1987) noted that the vertical fault plane is clearly marked due to the ragged relief. By the field station 20 (Fig. 15) in a section of a slope of the spring valley one can observe changing of a tilt of the fault plane upward. At the depth 20 m the nearly vertical (80°) fault plane becomes more gentle (up to 45°); near the surface it becomes steeper again (65°). Such phenomenon is probably conditioned by plastic flow of Quaternary alluvial sediments downward the valley slope. The flow was more intense at the depth 5-20 m that resulted in preservation of the steeper fault plane near the surface and tectonic swell near the fault line (Burtman et al., 1987).

At the Karakuldzha-Narynskaya river head (Fig.14 C) the amplitude of the north-eastern wall thrusting can be inferred from the shifted Early Pleistocene surface as 250-300 m (Chediya, 1986). As for horizontal movements along the TFF within the region, V.S. Burtman et al. (1987) found 26 ruptured forms of the modern relief within the site of 16-km long, showing horizontal displacement along the fault line (Table 2). The majority of the forms are small channels. At two points (18 and 24 in Table 2 and Fig. 15) one can observed shifted slopes of channels and at other two points (2 and 20) watersheds of mountain ridges are shifted. Statistically horizontal displacements up to 25-35 m are prevailing (histogram in Fig. 16), but in some cases (marked by a star in Table 2) displacements up to 35-45 m have been measured. In some places the main line of the fault is divided into some branches which either die out (point 11 in Fig. 15), or join the fault line again limiting the tectonic lens (point 23). Moreover, fault-satellites pass parallel to the main fault line at the distance of 70-100 m, along which horizontal displacement of the relief forms from 3 up to 10 m is observed (points 15 and 18). Displacement along the fault-satellites together with plastic deformation of the fault walls compensates changing amplitude of the slip along the main fault plane (Burtman et al., 1987).

For determination of the slip time Burtman et al. (1987) used organic material collected in pits. 5 samples were collected for radiocarbon age determination by Burtman et al. (1987) in pits dug in a drainless sagging (a, Fig. 15 and 16) and depressions (b-d, Fig. 15 and 16) with springs draining along the fault plane. The samples were collected from clays rich in organic material and overlaid by thick soil. Radiocarbon ages (determinations GIN-4300-4304) determined from the total of accumulated organic material is always younger than the time of the accumulation beginning. Therefore, the oldest age ( $2020 \pm 50$  years) is starting the

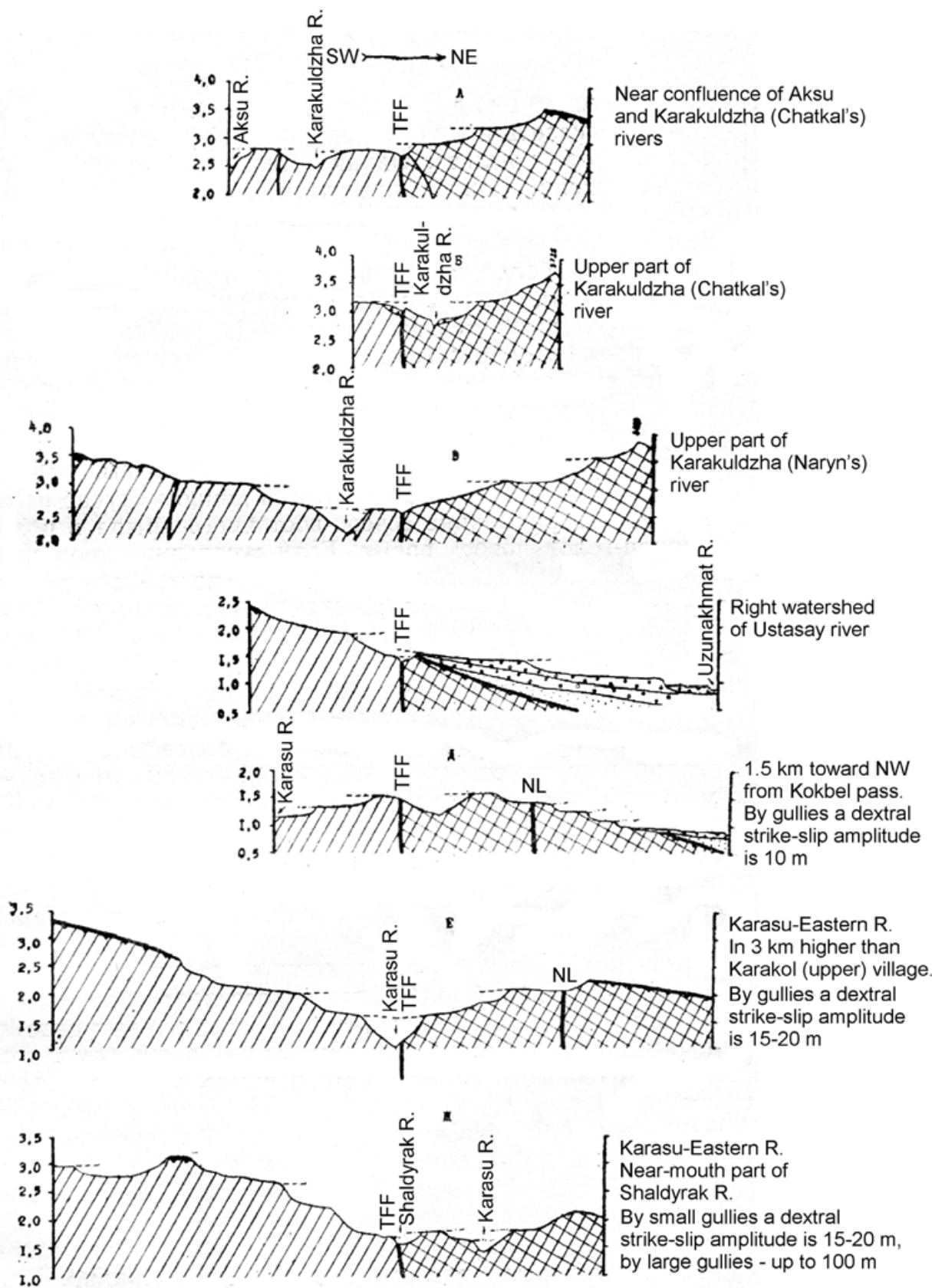


Fig. 14. Geological-geomorphological cross-sections of the Talas-Fergana Fault zone (modified from Chediya, 1986). T-F – Talas-Fergana Fault, L-N – the line of Nikolaev.

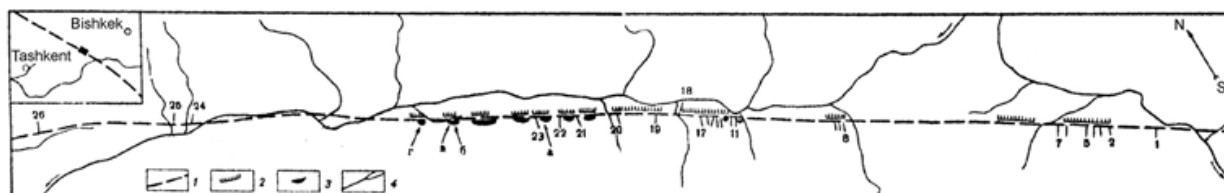


Fig. 15. Talas-Fergana Fault in the Karakuldzha-Narynskaya and Karakuldzha-Chatkalskaya river basins (modified from Burtman et.al., 1987). 1 – line of the modern fault, 2 – tectonic swell, 3 – near-fault valleys, 4 – streams.

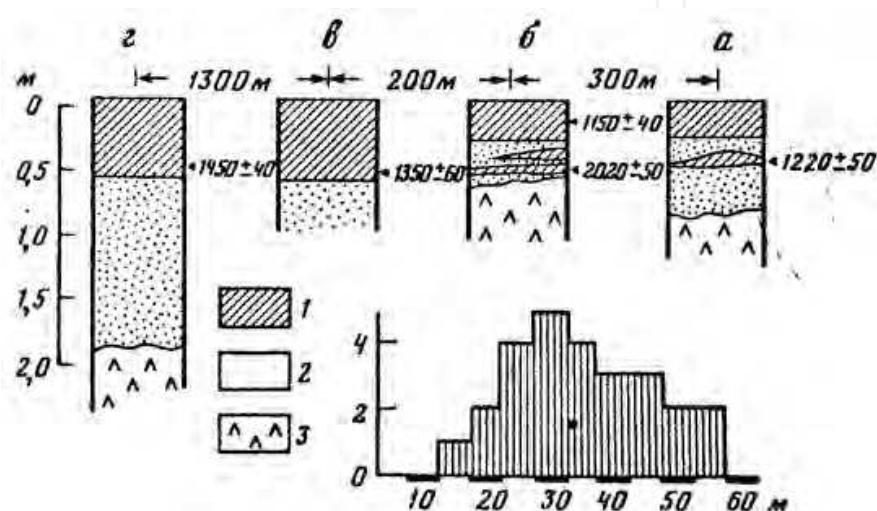


Fig. 16. Position of radiometric samples in sections of near-fault saggings and the histogram of recent movements along the fault (modified from Burtman et.al., 1987): 1 – soil and peat rich in organic material; 2 – clay, loam, clay sand; 3 – basement rocks.

swamping along the line of the Talas-Fergana Fault. V.S. Burtman et al. (1987) also examined a sample (GIN-4299) collected in the upper part of the peat bog at the point 11 (Fig.15). The age of the sample is  $250 \pm 50$  years that does not contradict to the age given above.

The investigation carried out by V.S. Burtman et al. (1987) allows conclusion that a displacement with a horizontal amplitude 30-40 m and small vertical component occurred along the Talas-Fergana Fault at historic time. This displacement took place after an earthquake occurred about 2000 years ago.

Passing downward along the Karakuldzha-Narynskaya river up to the place where the fault divides the Atoinock uplift and Ketmentyube depression one can observe turning of the hanging north-eastern wall of the fault into the foot wall (Fig. 14 D). On the right watershed of the Ustasai river the amplitude of vertical displacement is equal to previous one in the upper reaches of the Karakuldzha-Narynskaya river but with reverse orientation. Near the Naryn river valley the amplitude reaches more than 1000 m (Chediya, 1986).

V.G. Trifonov et al. (1990) found Holocene gullies and small watersheds on the right bank of the Dzhanyarsay river shifted for 6, 8-9 and 14-17 m, respectively. The upper reaches of the river with traces of trough structure and a lateral moraine aging to the end of the Middle Pleistocene are shifted for 1.5 km relatively nowadays cut off lower parts of the valley. In other words the shifting of the Dzhanyarsai river valley started in the beginning of the Late



Pleistocene, therefore the average slip rate is about 1.5 cm/year. On the right bank of the Dzhanaryksai river a terrace aging to the beginning of the Late Pleistocene as well as the river inflows, formed at the same time, are shifted to the right for 550-650 m. Terraces and valleys formed in the end of the Late Pleistocene are shifted for 150 m.

Points	Distance from a previous point	Displacement, m
1	-	35
2	600	35
3	175	25
4	50	30
5	50	30
6	250	24
7	100	45
8	3500	23
9	16	23
10	70	40
11	2200	50
12	10	50
13	120	30
14	33	30
15	30	30
16	100	40-45
17	20	40-45
18	600	50-60
19	110	35
20	600	35
21	700	20
22	300	17
23	400	20
24	3600	40
25	300	40
26	2100	50-60

Table 2. Horizontal displacement of the relief forms along the fault in the Karakuldzha-Narynskaya and Karakuldzha-Chatkalskaya river valleys (modified from Burtman et.al., 1987)

To the north-west the fault is divided into several branches. Thus, there are two parallel branches in the Ustasai river valley. The north-eastern one is younger. One can observed right-lateral displacement of Late Holocene channels along the branch for 10 m. As for the south-western branch one can observe galleys cutting the Late Pleistocene terrace and shifted for 150 m to the right. The last displacement probably characterizes the whole Holocene slip; in this case the slip rates is about 1.5 cm/year. Thus, average rate slips of Holocene and Holocene-Late Pleistocene displacements along the segment of the fault in the north-west of the Toktogul reservoir display the same tendency as those in the Late Holocene: they increase in 1.5-2 times comparing with slip rates on the south-eastern portions of the fault.

We pointed above, that many researchers reported about displacement of channels of the gullies on first tens meters. Thus V.S. Burtman et al. (1987) cited evidences of strike-slip movements in Karakuldzha-Chatkalskaya and Karakuldzha-Narynskaya river basins (Fig. 15, Table 2).

V.S. Burtman et al. (1987) point that the same width and morphology of displaced parts of the dry valley above and below the strike-slip fault testifies on a fact that the displacement occurred fast. This circumstance has allowed V.S. Burtman et al. to tie such displacements with earthquakes. Citing on a fact that every valley has its only one ancient continuation, they came to a conclusion that observed displacements are the result of one strong earthquake.

For us it's seemed impossible that one-act horizontal displacement along the strike-slip fault can reach a value of 60 m during one event. World experience of recent strong and catastrophic earthquakes gives us examples of 10 m, maximum 15 m displacements during one event (Strom and Nikonov, 1997). It is not clear also a value of possible creep displacements, their contribution into total value of observed displacement of valley's thalwegs. Most probably a number of the strong earthquakes, occurred along described segment of the fault, have led to formation of a shift of gullies on few tens meters.

The same authors (Burtman et al., 1987) cite data on radiocarbon dating of the samples collected by them in pits excavated in the fault zone (Fig. 15 and 16).

In Fig 16 one can observed that at investigated segment of the fault the dated soils give us at least 4 events led to accumulation of loose slope material in a near-fault depression where soil was formed later. Minimum ages of these events:

1. 2020±50 years,
2.  $(1450 \pm 40 + 1350 \pm 60) / 2 = 1400 \pm 50$  years,
3.  $(1150 \pm 40 + 1220 \pm 50) / 2 = 1185 \pm 45$  years,
4. 250±50 years.

Stations ## 22 and 23 are most close to places where samples were collected. There 17 m and 20 m displacements correspondently were measured. Most probably for these total (cumulative) values of displacement there were responsible 3 strong earthquakes, that is 6-7 m during one event in average. These values are in agreement with the world data analysed by A.L. Strom and A.A. Nikonov (1997).

### 3.4 Sary-Bulak test site

The second test site was located in the Sary-Bulak river basin of the Toktogul Region of the Jalal-Abad oblast (Fig. 1 and 2). The mapped area was in the left bank of the upper part of the Sary-Bulak river (the right tributary of the Uzun-Akhmat river). Here we observed the right-lateral displacement of many river beds of small water and dry gullies, as well as watersheds between them.

We performed mapping with electronic tachymeter of the area in the upper part of the valley of a large dry stream along the TFF zone (Fig. 17 and 18). Here systematic displacement to the east (to the right) took place at 65,40 m (section A-B in Fig. 17); 113,06 m (section A-B in Fig. 17) and 336,49 meters (section A-F in Fig. 17) of the bottom parts of the dry valley. Age of the displaced dry valley, apparently, is the beginning of late Pleistocene, since it cuts the mid-Quarterly alluvial surface.

Bore pits, dug on the left slope of the «legless» valleys (Fig. 19), give a similar picture of the near-surface deposits developed there. At the top there is the soil developed on the loess-like loam. This layer of loam with scattered detritus fragments, probably, is «a colluvial

wedge», which collapsed downwards from the nearby slope during the earthquake. Soil formation processes started on loamy deposits after that collapse about 5 thousand years ago (samples SOAN-6529 and SOAN-6531). The age of the above mentioned samples is the minimum age of the earthquake which had occurred there. The samples, which were taken in the top part of the layer, gave radiocarbon ages of  $1130 \pm 100$  years old (SOAN-6528) and

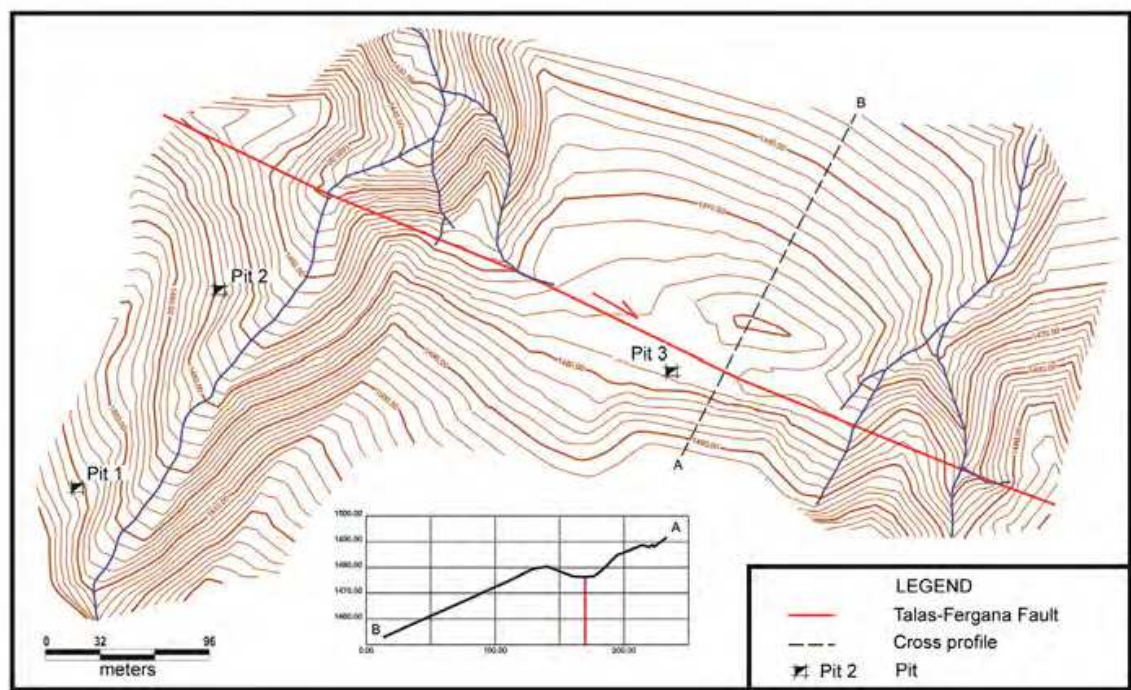


Fig. 17. Sary-Bulak test site and main elements of relief.

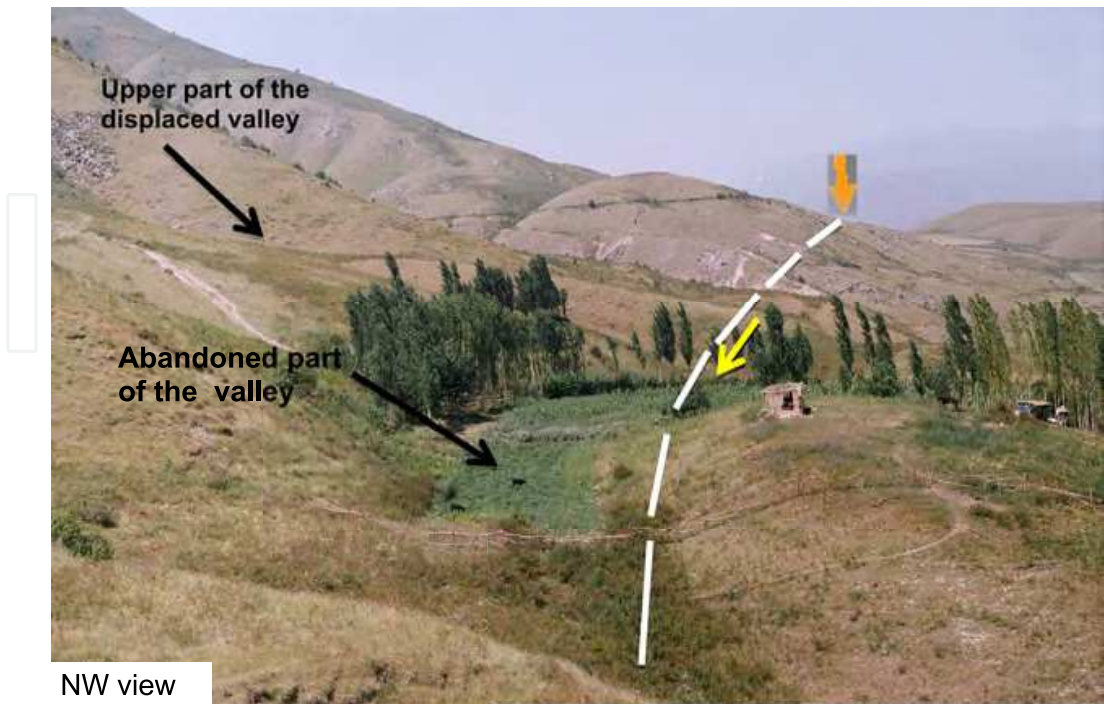


Fig. 18. A fragment of the upper part of the valley of the Sary-Bulak River.



440 ± 45 years old (SOAN-6530). These age determinations indicate the minimum time periods when there were later soil deformations in the investigated area, apparently, caused by the next seismic motions. These deformations have led to burial of soil fragments, where we have taken samples for determination of absolute age, - to switching on in these fragments of "the geological counter of time».

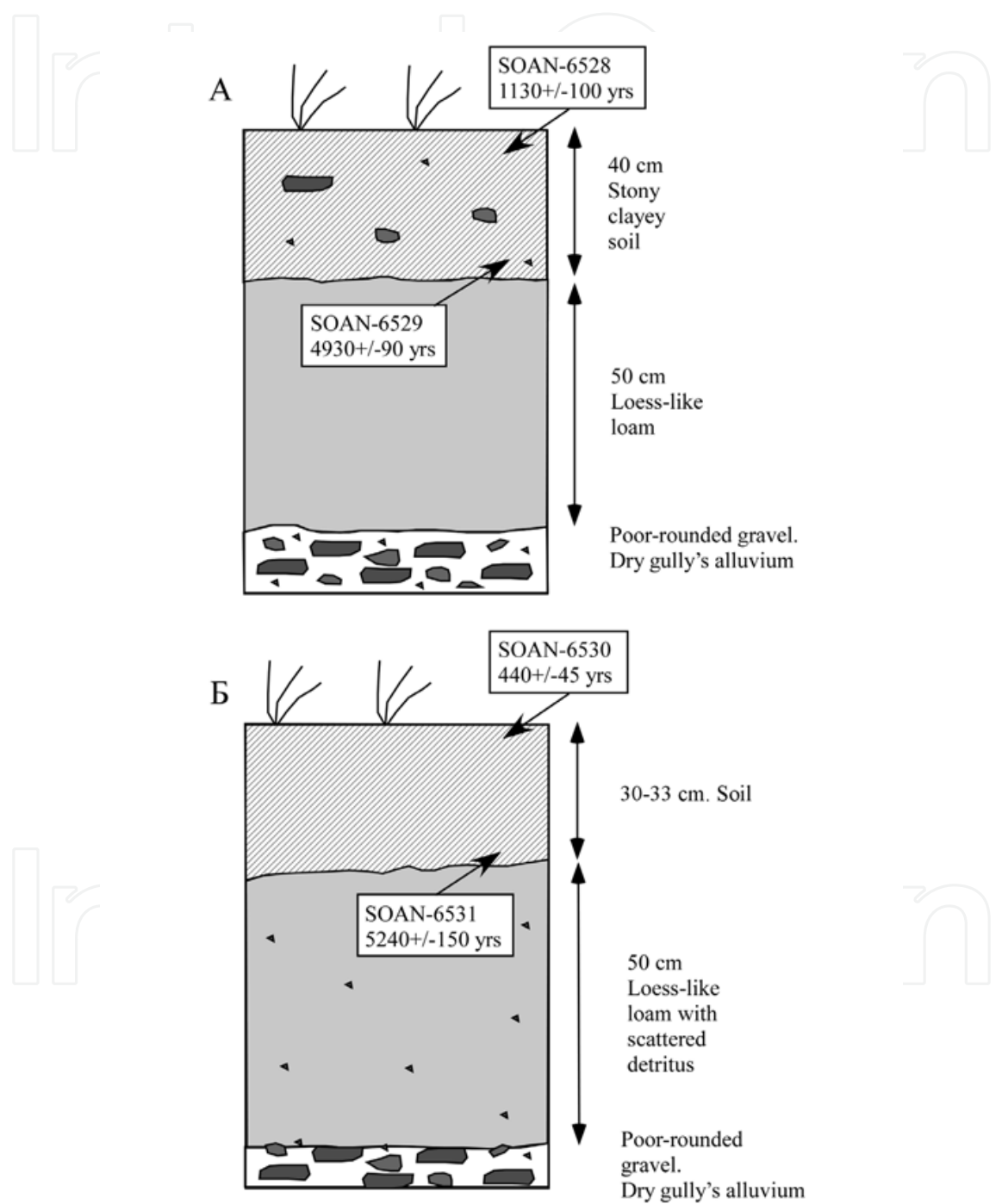


Fig. 19. Bore pits1 (A) and 2 (B) on Sary-Bulak test site.

Bore pit 3 (depth of 155 cm), which was dug directly in the fault zone in the abandoned part of the valley, has shown a more complicated picture (Fig. 20). Here from top we observed a

significant layer of reclaimed soil with underlying loess-like loam. Under the loam layer there is a layer of buried soil. Contact of the layer of loam and buried soil is very uneven (see Fig. 20).

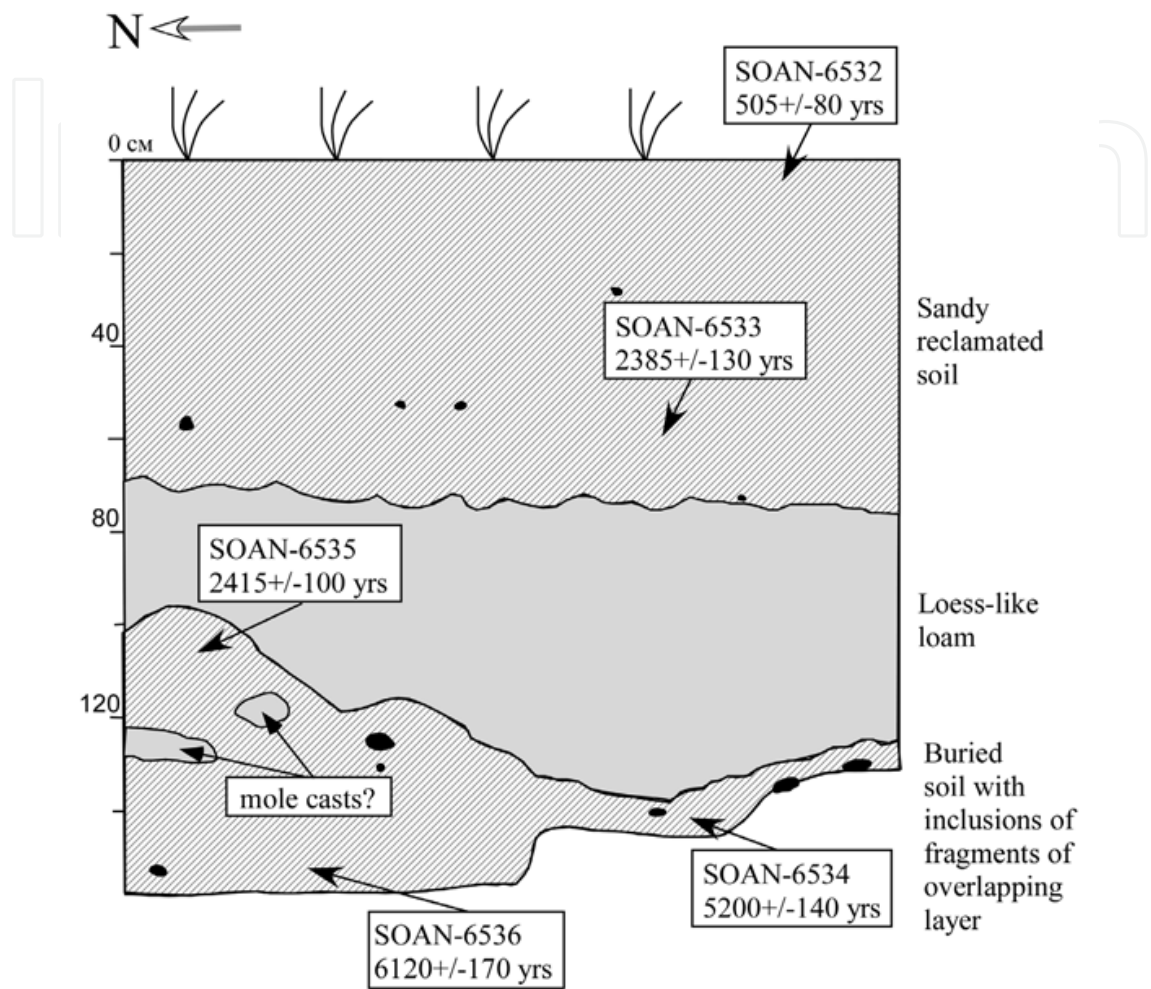


Fig. 20. Bore pit 3 at the Sary-Bulak test site. Recent reclaimed soil is separated from the buried soil by the «colluvial wedge». Black stains in the drawing are pebbles of average roundedness.

The available section gives us sufficient material for sedimentation history reconstruction and tectonic development of the site in mid-late Holocene. The buried soil started to be formed about 6 thousand years ago (sample SOAN-6536), apparently, after the material displaced during the earthquake from the nearby slope was stabilized in the riverbed of the abandoned valley.

The following sample - SOAN-6534 taken above is an evidence of one more earthquake which occurred about 5 thousand years ago, which traces have been found by us in the neighboring bore pits 1 and 2. The next seismic event took place approximately 2 400 years ago (samples SOAN-6533 and SOAN-6535). It has led to destroying of an ancient soil cover, its coverage by the «colluvial wedge» which is in turn covered by modern reclaimed soil. The latter seismic event known to us occurred about 400-500 years ago (SOAN-6532). Its traces are reflected also in bore pit 2, which was dug nearby.

It is hardly probable, that in past 6 thousand years there were occurred a displacement at 336.49 meters along the fault (Fig. 17, section A-I). However displacement at 65.40 m (section A-B) or 113.06 m (section A-B) is plausible, considering the data published in the world literature (see Strom's and Nikonov's executive summary published in 1997). It is necessary to note, that Burtman et al. (1996) informed on regular displacement of valleys of temporary waterways along the Talas-Fergana fault by  $110 \pm 10$  m in the (from the west to the east) Ustasay, Sary-Bulak, Dzhanyaryksay river basins.

Thus, average rate of displacement along the TFF at the Sary-Bulak test site, since middle of Holocene, can reach 10.7-18.5 mm/year. Our results are close to the data received by Burtman et al. (1996) on the site located in several kilometers SE from Sary-Bulak. In the Dzhanyaryksay river basin the mentioned authors calculated rate of displacement of 9-12 mm/year during last ~1.5 thousand years on 14-metre displacement of a dry gully.

Let's notice, that the closest age determinations of  $1150 \pm 40$  years old (GIN-4302) and  $1220 \pm 50$  (GIN-4304) were received by Burtman et al. (1987) in the bottom part of modern soil along the TFF line in upper area of the Chatkal river, approximately at the distance of 70 km to NW from Sary-Bulak test site. These data assume not shorter length of the seismogenic rupture.

Probably, one more age determination got by Trifonov et al. (1990) concerns this age group:  $1240 \pm 60$  year ago; it was received by them on the right bank of the Keklikbel river. The latter site is also located at a considerable distance of more than 100 km to SE from the Sary-Bulak test site. Then the plane of the seismogenic rupture begins with upper reach of the Chatkal river and stretches for the distance of almost 200 km to the valley of the Keklikbel river. Theoretically it is possible: we can recollect, that the length of the well studied rupture of the Kebin (Kemin) earthquake of 1911 ( $M=8.2$ ) in Northern Tian-Shan reached this value (Bogdanovich et al., 1914). However in the valley of Keklikbel river probably also that there was occurred an independent earlier event.

Thus, minimum number of the earthquakes which occurred at this site in Holocene is 5. Their minimum ages are ~ 6 thousand years ago, ~ 5 thousand years ago, ~ 2.4 thousand years ago, ~ 1.1 thousand years ago and 400-500 years ago.

The earliest (~ 6 thousand years) and latest age determinations (400-500 years ago) coincide with the absolute data received at the Kara-Bura test site, located at the distance of 90 km to NW from the Sary-Bulak test site. This fact assumes similar length of the seismogenic rupture formed twice in the middle and in the end of the Holocene.

Data of absolute age (400-500 years ago), received on the Kara-Bura and Sary-Bulak test sites coincide also with archeoseismologic data on the destroyed caravanserai located in an middle part of the Kara-Bura river valley (Korjenkov et al., 2009).

## **4. Middle part of the Talas-Fergana fault**

### **4.1 Investigations in Ustasay-Karasu interfluvium**

In a distance of 6 km south of the Naryn river the Talas-Fergana fault limits the Ketmentyube depression filled with the Toktogul reservoir. Features of vertical movements are analogous to previous ones. Further, up to the Kokbel pass, the fault plane passes on the left bank of a nameless channel which is drained to the Naryn river. The whole low left slope of the valley is cut with short (up to 500-700 m) small gullies which were probably formed in the Late Pleistocene-Holocene (Chediya, 1986). The whole slope with all gullies is cut by the Talas-Fergana fault. In a profile of the gullies' watersheds one can clearly observe

that a straight depression is located along the fault. Mainly it filled by the colluvium-alluvium material of few meters thickness, which is shelved from upper part of the slope, i.e. it is the amplitude of the Holocene thrusting of the Kochkortobe uplift. Comparison of the Early Pleistocene surface (E in Fig. 14) gives the value about 150 m (Chediya, 1986).

Although a trace of the fault in the Ustasay-Zhanaryksay region is less expressed, than in south-east or further north-west, sections of well expressed displacements are distribute along whole zone of the fault, and right-lateral displacement is evident (Fig. 21). Maximum values of displacements of watersheds and spring valleys near station # 14 reach  $110 \pm 10$  m (Burtman et al., 1996).

Burtman et al. (1996) have measured a displacement of a small gully -  $14 \pm 2$  m in the field station #14 (Fig. 21). A pit in upper part of the gully near the fault trace reaches hard rocks in a depth of 0.5 m under the soil of 0.45 m thickness. Organic part of the soil - 0.1 m from the whole layer (depth 0.35-0.45 m) gives the radiocarbon age of the seismic event equal  $1440 \pm 30$  years ago.

We have studied segments of the Talas-Fergana Fault zone in 2 km south-east from the Aktaybulak-Korumtokay interfluve - in a region of the Ustasay-Sarybulak pass. Everywhere we measured right-lateral displacement of spring beds and watersheds between them on a value of first ten meters (Fig. 22 a). Eastwards, a displacement of the spring valleys and watersheds between them reaches hundreds meters (as, for example, in the right bank of the Sarybulak River). It is necessary to mention also a vertical uplifting of southwestern limb of the fault on a value of 20 m. In tie with lateral movements along the fault, in some places the consequent spring valleys, flowing down the slope, are blocking by so-called barrier ridges (Fig. 22 b), in front of which there are forming a local depressions, where fine material is accumulated.

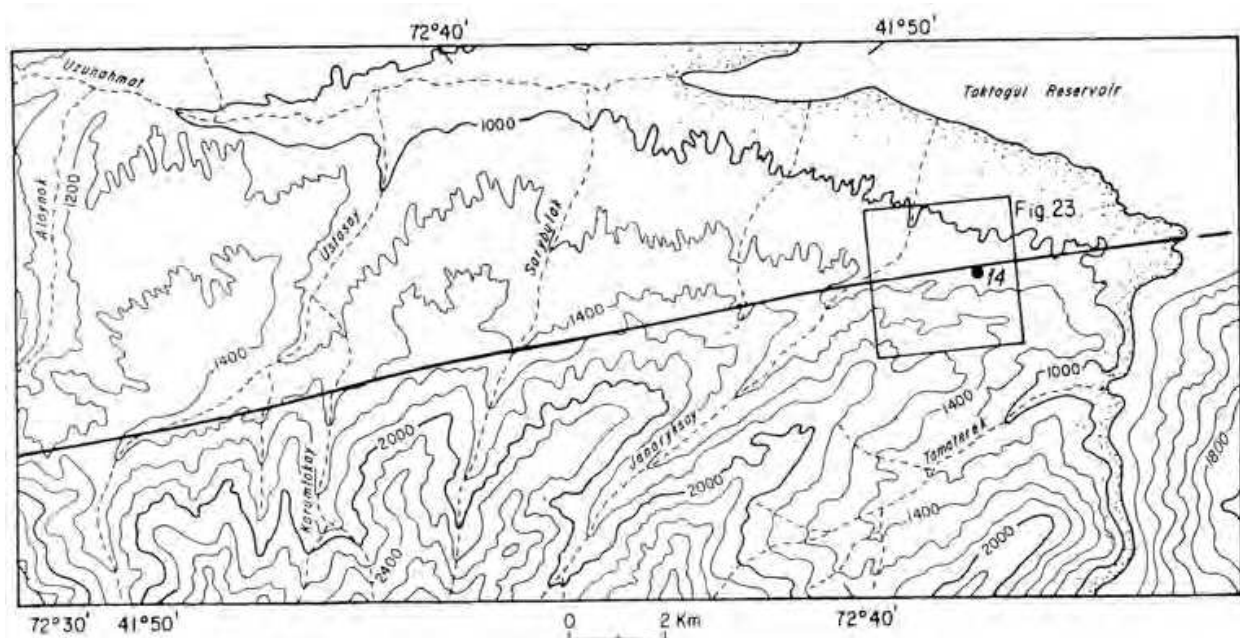


Fig. 21. Topographic map of a fragment of the Talas-Fergana Fault in the Ustasay-Dzhanaryksay interfluve (modified after Burtman et al., 1996). Black line marks a trace of the Talas-Fergana Fault. A location of the field station # 14 is shown. Contour interval in 200 m.





Fig. 22. a. Right-lateral displacement of a channel of a dry gully (white arrows) and watershed ridge along the line of the Talas-Fergana Fault (shown by the dotted line).



Fig. 22. b. Barrier ridge (a shepherd tent is by foot of it) in a zone of the Talas-Fergana Fault (shown by the dotted line) in the Aktaybulak-Korumtokay interfluves.



Fig. 22. c. A structure of the Talas-Fergana Fault zone in the Aktaybulak-Korumtokay interfluves. Fault gouge, filled the fault zone, is overlaid by folded alluvial deposits, in which fragments blue clays laying below are found.

In 500 m south-east of previous field station an irrigation canal exposes the fault zone. In south-western wall of the canal there are exposed (up-down):

- Greyish-black soil;
- Light-brown loess-like loam;
- Folded grey alluvial deposits with inclusions of torn fragments of the blue clays' horizons;
- Folded blue clays with inclusions of deformed loam horizons.

Last two horizons one can observe in Fig. 22 c. A layer, consisting of clays and loams, is representing itself fault gouge, filled the fault zone.

#### 4.2 Kok-Bel test site

The third test site, examined by us, is located approximately at the distance of 30 km to the southeast from Sary-Bulak test site (Fig. 1 and 2). Here during climbing up the pass with the same name from the Ketmen-Tyube depression a systematic right-lateral displacement of small dry gullies and watersheds between them is observed along the TFF zone (Fig. 23). Here we also produced a detailed digital map of the site of the TFF zone by an electronic tachymeter (Fig. 24).

Along one kilometre section of the fault we measured systematic displacement of forms of the modern relief, the upper parts of which are shifted to the right along the fault line in a horizontal direction (Table 3). All measured elements of the relief were small dry valleys of temporary waterways - "says", as well as watersheds between them.



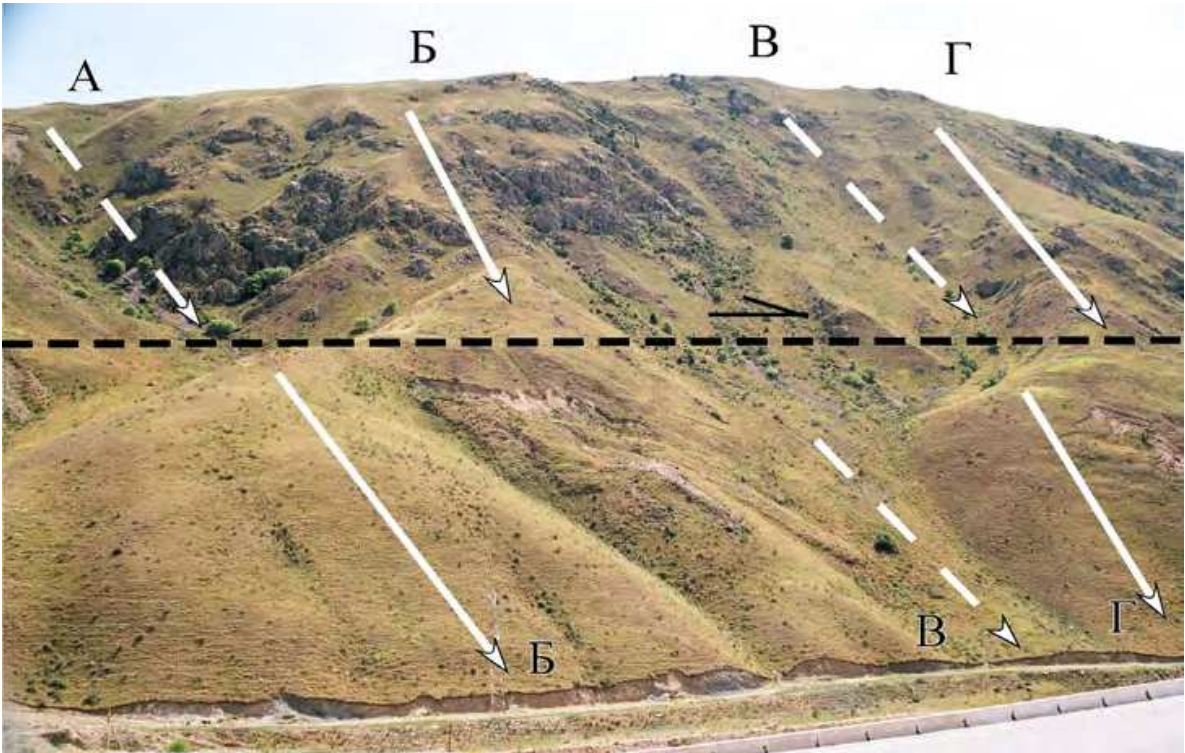


Fig. 23. Displacement to the right of dry rivulets (says) (white faltering lines) and watersheds between them (black faltering lines) along the Talaso-Fergana fault line (a sub horizontal faltering line) to NW from the Cook-Bel pass.

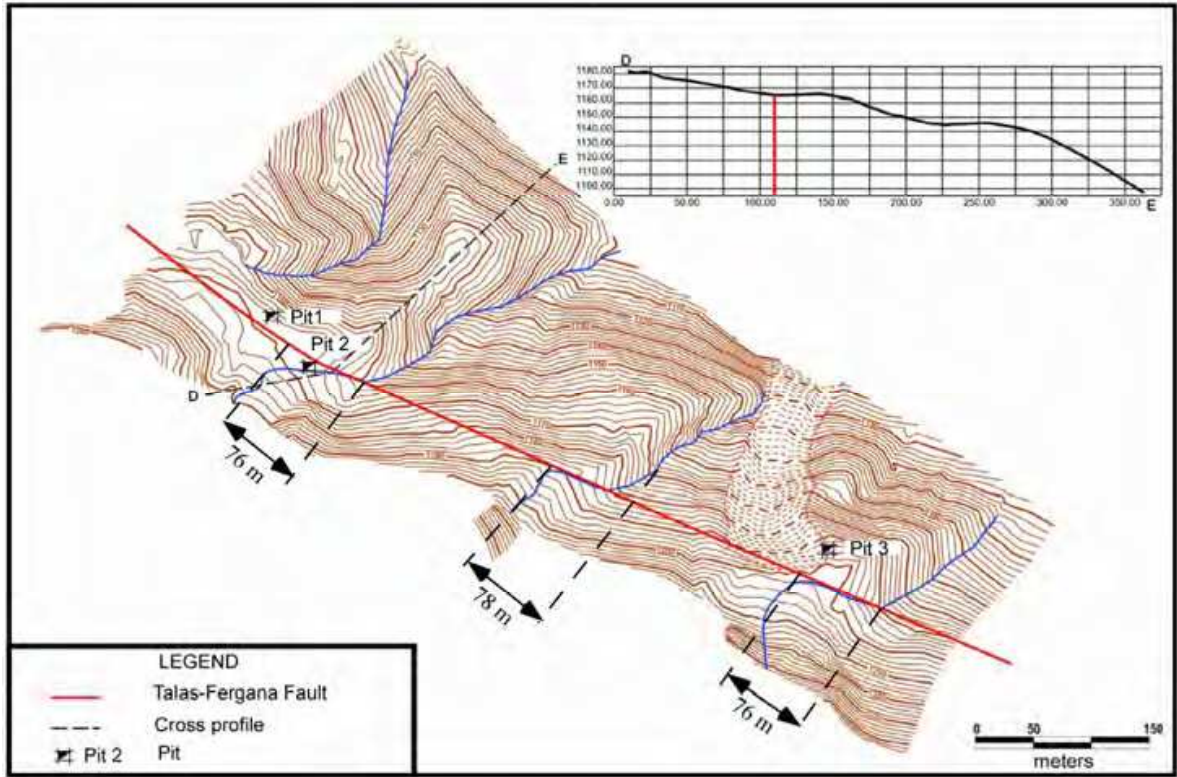


Fig. 24. The Topographic map the Kok-Bel test site, drawn according to shooting by electronic tachometer. Values of displacement of dry waterways beds are shown.



No of points/sites	The displaced element of the relief	Displacement size/ value, m
1	Watershed	110,54
2	Dry rivulet (say)	47,62
3	Watershed	97,17
4	Dry rivulet (say)	53,8
5	Watershed	39,62
6	Dry rivulet (say)	15,7
7	Watershed	41,58
8	Dry rivulet (say)	57,63
9	Watershed	76,23
10	Dry rivulet (say)	52,93
11	Watershed	50,14
12	Dry rivulet (say)	63,83
13	Watershed	51,36
14	Dry rivulet (say)	116,3
15	Watershed	68,71
16	Dry rivulet (say)	98,55
17	Watershed	99,03
18	Dry rivulet (say)	13,26
19	Watershed	16,94
20	Dry rivulet (say)	70,11
21	Watershed	77,70
22	Dry rivulet (say)	70,36
23	Watershed	61,96
24	Dry rivulet (say)	64,83
25	Watershed	50,92

Table 3. Horizontal displacement of forms of a relief along the Talas-Fergana fault to NW from the Kok-Bel pass, measured by electronic tachometer

To NW from the Kok-Bel pass we measured 25 valleys of dry gullies (says) and watersheds between them displaced to the right at the distance of up to 120 m. Pay attention at the various representativeness of displacement of different amplitude: some maxima are emphasized whereas intermediate values are absent (Fig. 25). Similar non-uniformity according to Trifonov et al. (1990) indicates the decisive contribution of impulse seismogenic motions into total movement.

To north-east from the the Kok-Bel pass along the Talas-Fergana fault we dug 2 bore pits and cleaned a natural exposure - a scar of a landslide, which was directly in the fault zone (Fig. 26 and 27). Value of horizontal displacement of the dry rivulet and the adjacent watershed, measured by electronic tachymeter, comprised 76 m. We correlated this value

with the most ancient date -  $4900 \pm 230$  years. Thus, we receive probable rates of horizontal tectonic movements since mid Holocene equal to 14.81-16.27 mm/year.

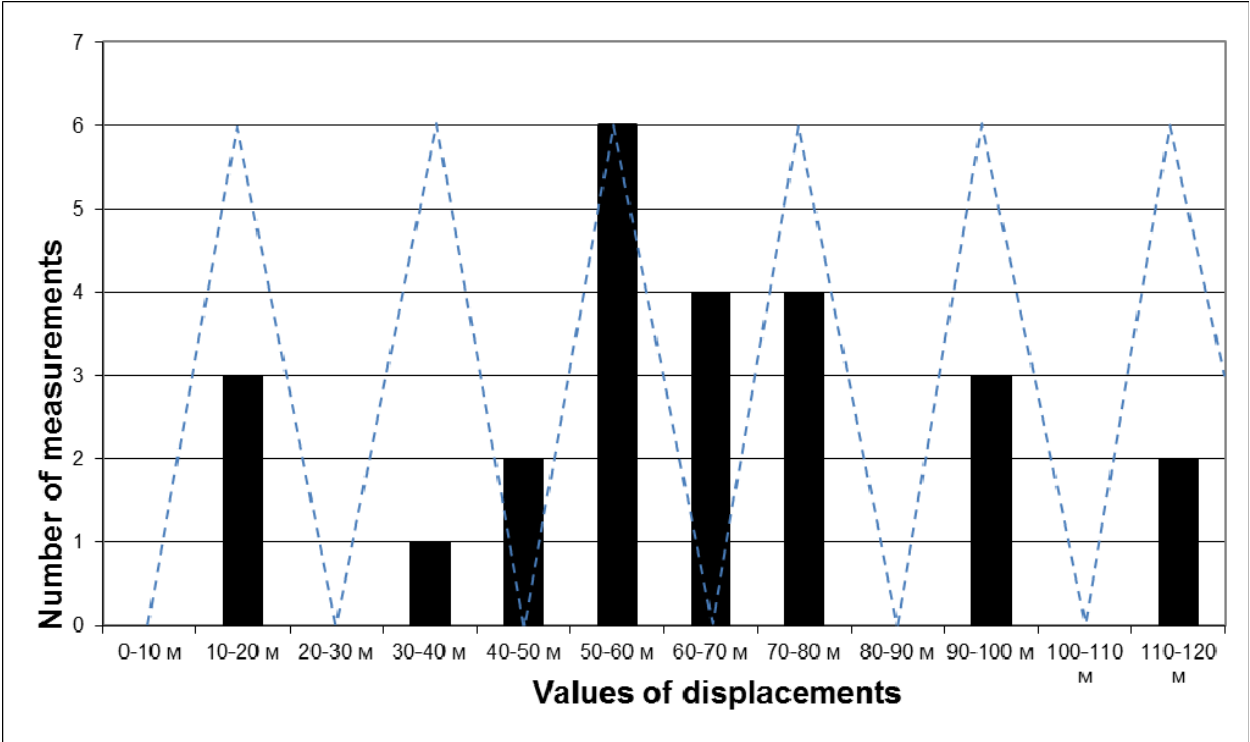


Fig. 25. The histogram of amplitudes distribution of Holocenic right-hand-side displacements of dry water currents and watersheds between them on the Talas-Fergana fault to NW from the Kok-Bel pass (only 25 measurements).

The last strong earthquake on the examined site occurred, apparently, about ~275 years ago. An evidence to that are absolute dates of samples SOAN-7021 ( $270 \pm 85$  years), SOAN-7024 ( $370 \pm 90$  years) and SOAN-7026 ( $240 \pm 50$  years), taken in bore pit No 1 and clearing No 3 in the lower parts of the modern soil developed on the underlying «colluvial wedge». Similar dates were received also by Burtman et al. (1987) along TFF line in upper reach of the Chatkal river -  $250 \pm 50$  years (GIN-4299). Though distance between the Kok-Bel test site and the Karakuldzha-Chatkalskaya river valley is about 100 km, but apparently this was the length of the plane of the seismogenic rupture of this age.

In the same bore pit at the depth of 30 cm we found a fragment of ceramic ware. The form is spherical, the fragment was produced on a potter's wheel from well mixed clay with addition of coarse-grained and fine-grained sand. Firing of the fragment was uniform. The fragment was blackened with smoke. The indicated signs are the most typical for Middle Ages epoch-VIII-XII centuries AD (K.S.Tabaldiev, a written communication). For narrowing down the date determination additional artifacts are necessary. On the other hand, manufacturing of similar thin-walled spherical ceramics in Fergana valley and in its foothills is an ancient tradition. Production of ceramic vessels made on a potter's wheel were introduced in I millennium BC. They are characterized by red angob and painted ceramics which we do not see in this fragment. The described fragment of ceramics had been buried during the collapse of the colluvial wedge which occurred during the last strong earthquake. Subsequently on sediments of this wedge the soil the age of which was determined as  $270 \pm 85$  years old (SOAN-7021) was formed.

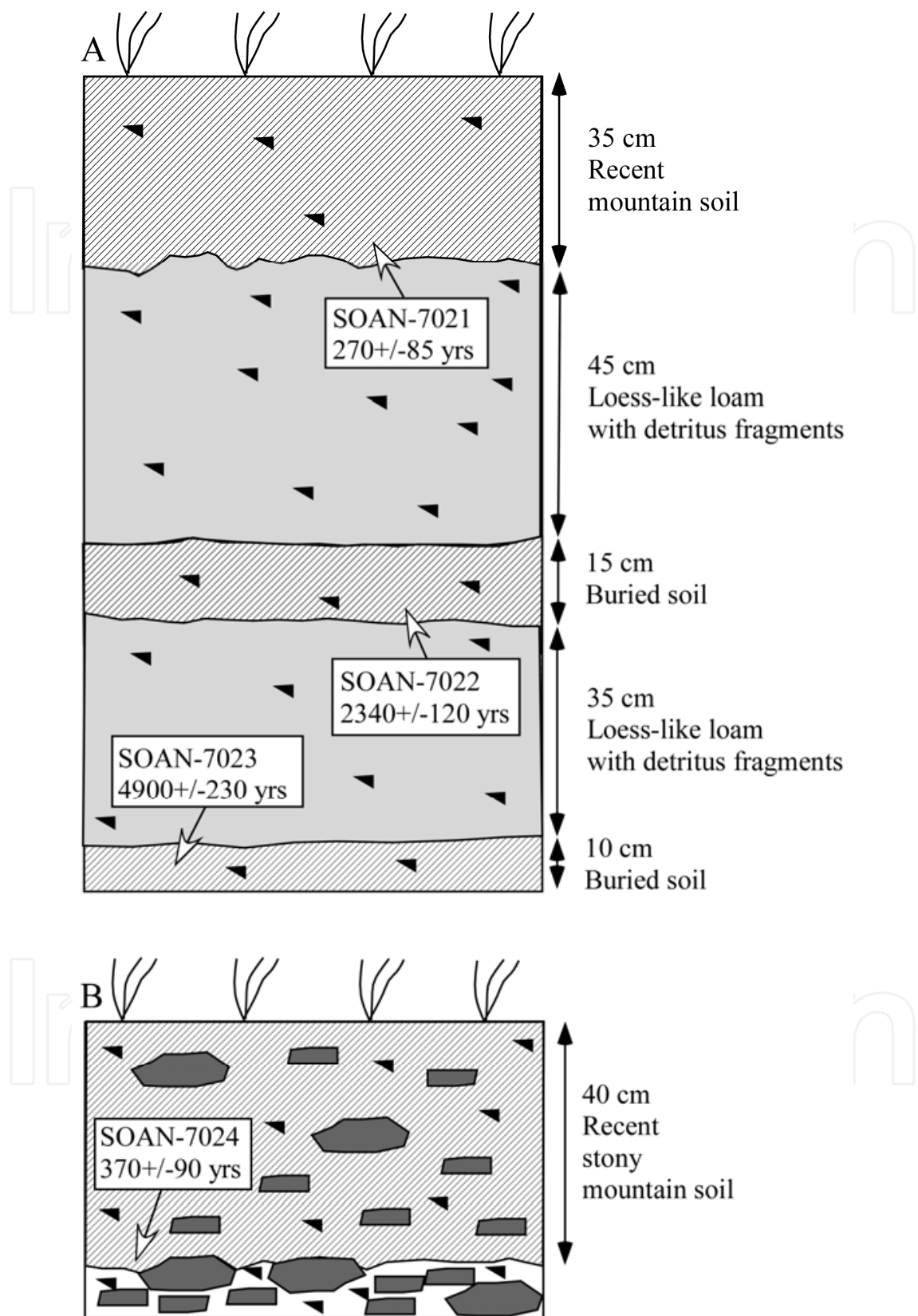


Fig. 26. Schematic drawing of bore pits No 1 (A) and No 2 (B), which were examined in the Talas-Fergana fault zone at the distance of 1 km to NE from the Kok-Bel pass.



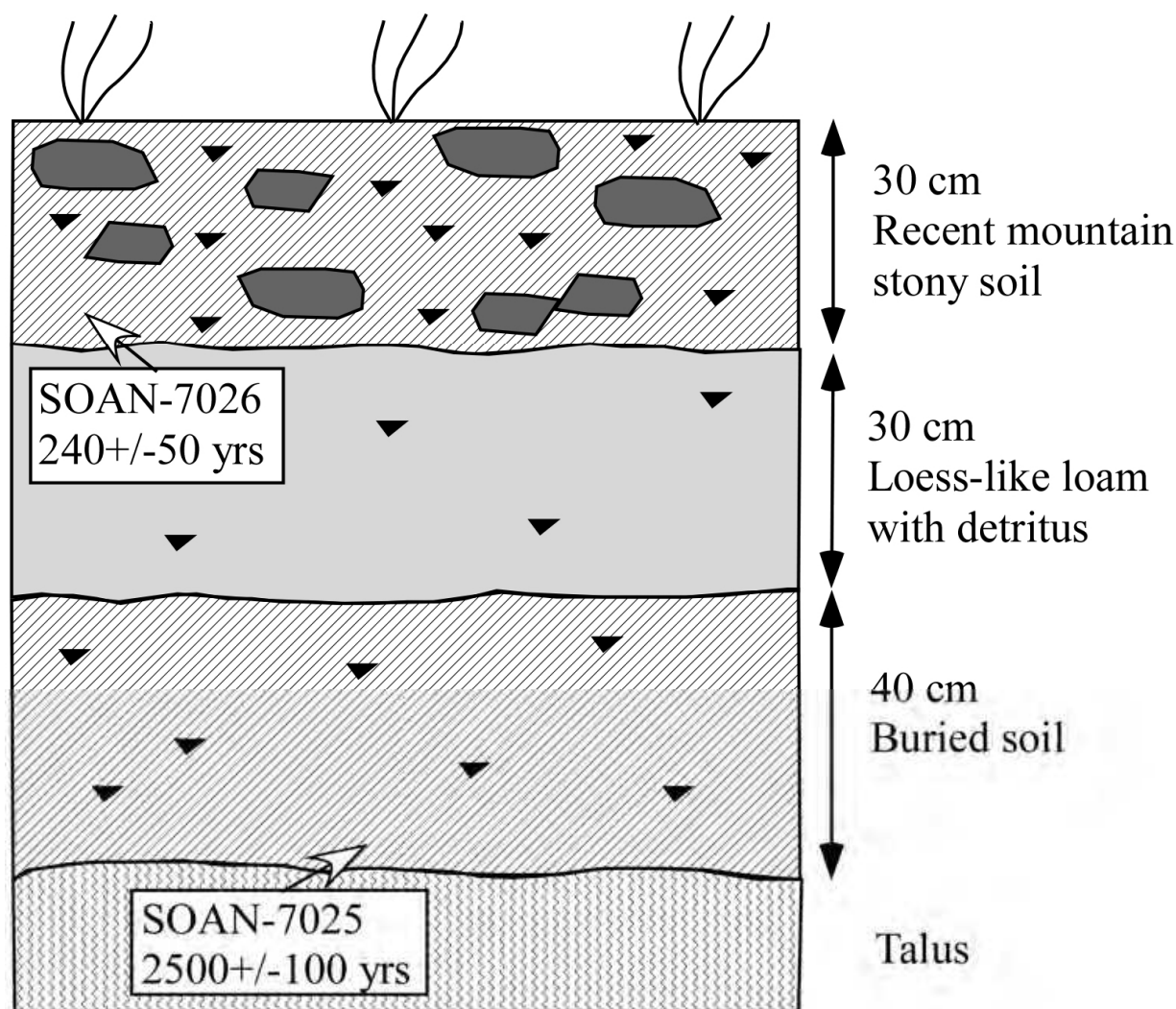


Fig. 27. A schematic drawing of clearing of the natural exposure – a scar, which was formed due to landslide collapse in the zone of the Talas-Fergana fault at the distance of 1 km to NW from the Kok-Bel pass.

The following strong earthquake occurred approximately ~2400 years ago. Absolute date determinations of two samples (SOAN-7022 -  $2340 \pm 120$  years and SOAN-7025 -  $2500 \pm 100$  years) testify to it, the samples were taken in bore pit No 1 and clearing No 3 in the lower part of buried soil. It is not excluded, that this earthquake has left its traces also in the river valleys: Kyldau (dated as  $2320 \pm 40$  years ago according to Trifonov et al. (1990)) and Pchan (dated as  $2180 \pm 120$  years – GIN -7052;  $2280 \pm 70$  years - Beta-47550;  $2540 \pm 70$  years - Beta-47549 according to Burtman et al. (1996)). If it so, the length of this seismogenic rupture reached 100-200 km.

The most ancient earthquake, the traces of which were found at the Kok-Bel test site, took place about 5 thousand years ago to what absolute dating of sample SOAN-7023 testifies.

#### 4.3 Investigations in the Karasu-Kyldau interfluvium

Further south-east the zone of the fault crosses the Toktogul water reservoir and stretches along the Karasu river valley (Fig. 1 and 28). However well-expressed displacements (up to

tens of meters) along the fault one can observe south-west and north-east from the valley. Watersheds and spring valleys were displaced from  $\approx 40$  to 225 m and  $>2$  km. Not far from the Kok-Bel pass, where main highway from the Fargana Valley crosses the Ketmen'-Tyube Depression which is occupied by the Toktogul water reservoir at present time, right-lateral displacements on  $\approx 300$  m are well expressed. It is especially well visible in south-western slope of a dry valley stretched parallel to the fault trace.

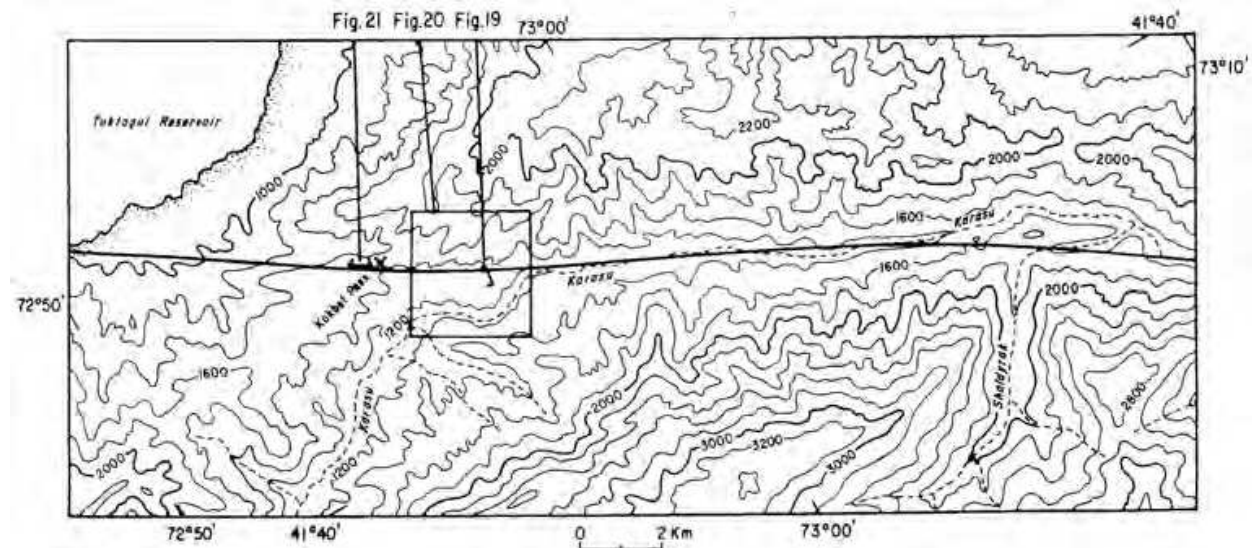


Fig. 28. A topographic map of the Talas-Fergana Fault Fragment along the Karasu River Valley (Burtman et al., 1996). A black line is a fault trace. Isoline intervals – 200 m.

In the south-east of the Kokbel pass the Talas-Fergana fault cuts the lower part of the right slope of the Karasu river valley for the distance of 6 km. The zone is characterized by strongly crushed Devonian deposits and numerous springs, that provokes to wide development of landslides. If to go upward on the Middle Pleistocene terraces of the left slope of the Karasu river one can observe a clearly expressed right-lateral slip along the fault. Here the length of galleys (therefore, time of their development) increases, and the slip amplitude is up to 15-20 m (Chediya, 1986). Analysis of geomorphologic levels does not allow determination of vertical displacement amount.

Further the fault passes on the left slope of the Karasu valley. In two kilometers of the place there is a seismic rockslide (considering its characteristic form) occurred along the fault and dammed the half of the valley. Here on the left slope of the Karasu river there are also gullies large in the length and time of development (since the Middle Pleistocene). One can clearly observe right-lateral displacement of lower parts of the gullies along the fault plane. If the displacement in small galleys reaches 15-20 m, the large ones are characterized by 100 m displacement (Chediya, 1986). If it is so, we can speak of long-term strike-slip fault which was active for the most part of the Quaternary. For example, E.Ya. Rantcman and G.N. Pshenin (1967) reported a 750 m displacement of a Middle Pleistocene moraine in the upper reaches of the Karasu-Eastern river.

A cross zone of the Shaldyrak river by the fault is very interesting. Meeting the fault, the river turns at the angle  $90^\circ$  and flows along the fault for the distance of 2 km, then it turns again and inflows into the Karasu river. The bending of river channel as well as a watershed between its lower parts and the Karasu valley agrees with the scheme of the right-lateral

displacement for 2 -2.5 km which could occur during the Pleistocene. However, it would be irresponsibly to infer that basing only on one river bending. Comparison of hypsometrical elevation of the terrace  $Q_{II}^1$  on both sides of the fault testifies to thrusting of north-eastern wall for 150 m (Chediya, 1986).

Above the Shaldyrak river mouth up to the Karasu lake the fault passes on the central part (near-bed) of the valley (Fig. 29); so we cannot speak of any evidences of displacement here. South-east of the “Karasu” fragment the Talas-Fergana Fault crosses a high-elevated area where a moraine was displaced on  $\approx 30$  m (Burtman, 1964).

Further to the south-east along the TFF zone (the Kuroves and Keklikbel rivers' basins) V.G. Trifonov et al. (1990) reported on 32 structures shifted to the right for 36 m (see Fig. 30 c). Displayed maximums of displacement are not so contrasting as those reported by V.G. Trifonov et al. (1990) in the south-east (Fig. 30 a, b), and not correlated to them. V.G. Trifonov et al. (1990) supposed that either other impulses of movements occurred here or creep processes were prevailing. The second supposition is more probable due to abundant elastic clay-shale rocks in the portion of the fault. Movements along the fault and damming caused formation of small depressions with peat bogs on the right slope of the Keklikbel river valley in the surface of a moraine deposited by a small Late Pleistocene glacier. The radiocarbon age of one of samples collected in the bottom of one of the depressions is  $1240 \pm 60$  years (9 in Fig. 31). In the immediate vicinity of the depression one can observe only general displacement of the late Pleistocene moraine occurred during much larger time interval. However, in the north-west there is a number of Late Holocene displacements evidences with prevailing amplitude 10-12 m. If the radiocarbon age of the depression is characterized the displacement, the average slip rate does not exceed 0.8-1 cm/year, i.e. close or a little higher than that on the site to the south-east of the described one (Trifonov et al., 1990).



Fig. 29. Straight-line segment of the Karasu-Eastern River from the Shyldyrak massif to Karasu rockslide. The photograph was made from the rockslide body toward north-west.



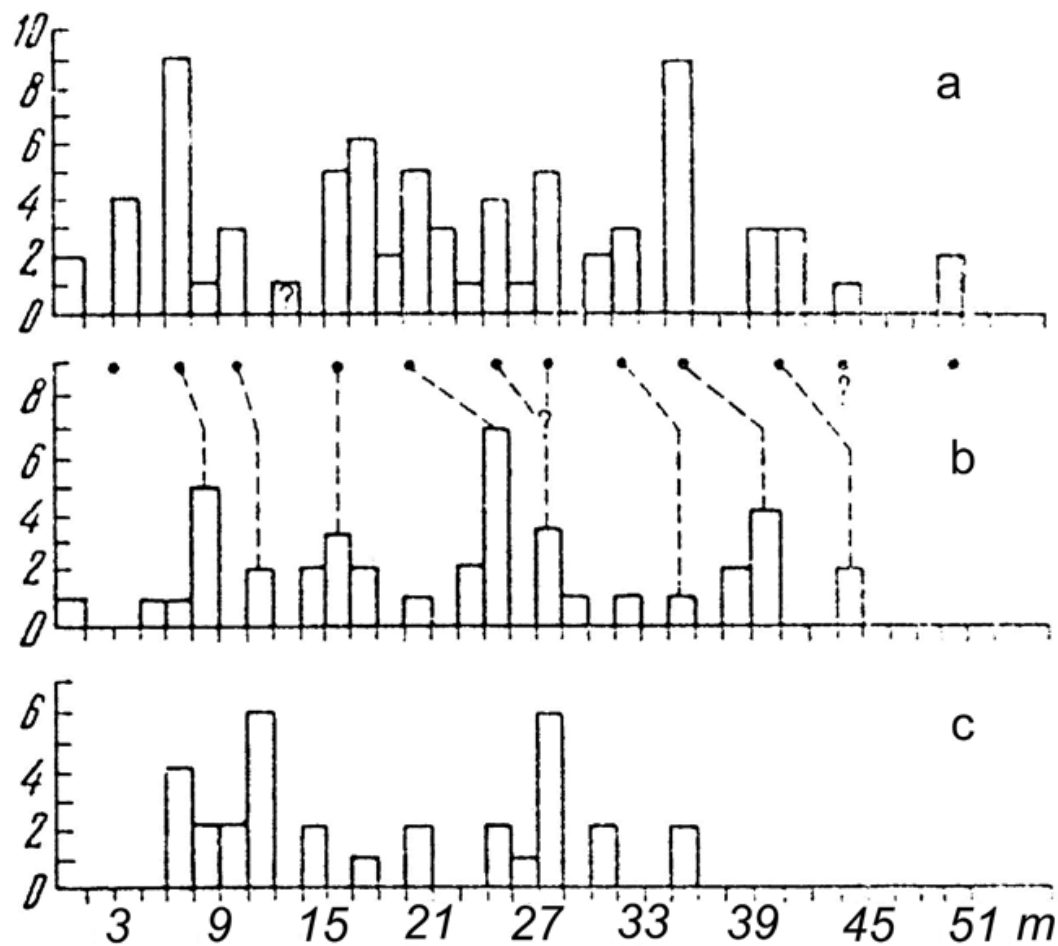


Fig. 30. Histograms of amplitude distribution for the Holocene right-lateral deviation of channels and other small forms of the relief along the Talas-Fergana Fault (modified from V.G.Trifonov et.al., 1990): a – from the Kok-Kiya pass to the Biruza river (points show probable strong earthquakes); б – in the Pchan and Kyldou river valleys; в – in the Kuroves and Keklikbel river valleys. The horizontal axis – amplitude of displacement; the vertical one – number of shifted forms of the relief.

On the right slope of the Keklikbel river valley V.G. Trifonov et al. (1990) found right-lateral displacement of channels for 60, 70-80, 135, 230, 300, 450-500 and 700-800 m. Shifted trough valleys and moraine deposits filling the troughs are of the greatest interest. The Late Pleistocene moraine is shifted for 135 m to the right. It is unclear if the time of its depositing is only the Holocene or the end of the Pleistocene too. More clear evidence is shifting of the Late Pleistocene moraine for 700-800 m relatively its trough valley. This moraine of about 10 m thick covers a depression cut in the surface of the beginning Middle Pleistocene (40-50 m), i.e. it was formed in the end of the Middle Pleistocene. Obviously, the moraine displacement can occur in the Late Pleistocene and Holocene, i.e. for the last 100 000 years, that gives the average slip rate 0.7-0.8 cm/year, which is close to the slip rate of the Late Holocene displacement between the Pchan and Kyldou river valleys. It is necessary to add that the mentioned amplitudes of displacements are accompanied by thrusting of the south-western wall of the fault. For displacement 135 m the thrusting is up to 5-6 m, for 300 m – 8-10 m, for 450-500 m and 700-800 m – several tens meter. Thus, the vertical component is 10-30 times less than the horizontal one (Trifonov et al., 1990).

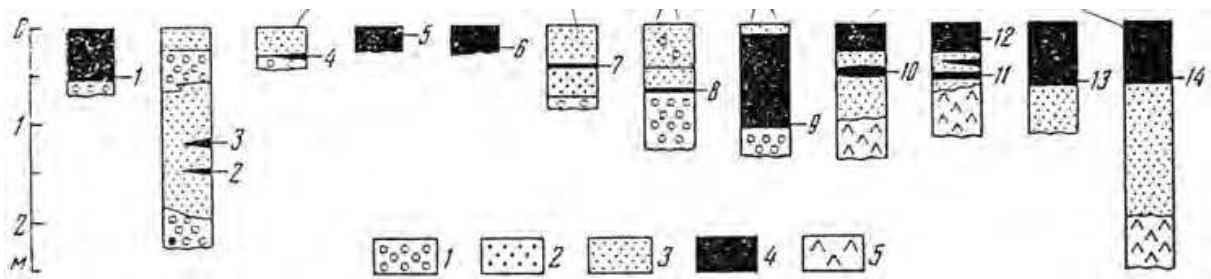


Fig. 31. Sections of near-fault depressions and their radiocarbon ages within the Talas-Fergana Fault (modified from V.G. Trifonov et al., 1990). 1-3 – the first portion of the fault: 1 - 3970±40 years, left bank of the Bolsun river in the north-west of the Kok-Kiya pass. 2 - 15800±1300 years, 3 - 4590±100 years, the both ages are from a section on the right bank of the Chitta-Severnaya river in the north-west of the Dzhilangach river; 4-7 – the second portion of the fault: 4 - 3740±600 years, interfluvium of the Biruza and Pchan rivers in the north-west of the pass between them. 5 - 3150±40 years, to the north-west of the previous point, 6 - 2640±600 years, upper reaches of the Pchan river in the south of the Chityndy pass, 7 - 2320±40 years, upper reaches of the Kyldou river valley; 8 – the third portion of the fault: 1510±60 years, interfluvium of the Urumbash and Kuroves rivers; 9 – the fourth portion of the fault: 1240±60 years, right bank of the Keklikbel river; 10-14 – the sixth portion of the fault (from V.S. Burtman et al., 1987): 10 - 1220±50 years, upper reaches of the Chatkal river, 11 - 2020±50 years, 12 - 1150±40 years and 13 - 1350±60 years, in 1 km to the north-west of the previous place, 14 - 1450±40 years, in 1.5 km to the north-west of the previous place. 1 – detritus, 2 – sand, 3 – clay, loam, sandy loam, 4 – the same rocks rich in organic material, and peat bogs; 5 – basement rocks.

Right bends of large river valleys (Kugart, Kaldama, Kyzylsu, Urumbash, Kuroves and oth.), described by V.G. Trifonov et al. (1990), allows inferring their right-lateral shifting for 3-4 km. These authors studied some of the bending channels and reconstructed their initial form. Minimal value of the right deviation is: for the Kongurtobe river – 2.8 km, the Kaldama river – 1.8 km, the Molasu river – 1.8 km, the Dzhindisu river – 2 km and the Urumbash river – 1.5 km. Since the mentioned river valleys were formed in the Early Pleistocene (Kostenko et al., 1972; Makarov, 1977), duration of slip processes is hundreds thousand years.

#### 4.4 Investigations in the Kuroves-Malasu interfluvium

In mentioned region the Talas-Fergana Fault goes along a foot of north-eastern slope of the Fergana Range. South-western limb of the fault, composed by Paleozoic rocks of the range, is trusted on many hundreds of meters, and north-eastern limb, covered by the Cenozoic deposits, is dropped on the same value. Here, in significant degree there are developed gravitation formations, the scars of which are in north-eastern slope of the Fergana Range, and landslide bodies descend into the Kazarman (Kugart) depression.

### 5. South-eastern part

#### 5.1 Investigations in the Kyldou-Dzhilangach interfluvium

There are a few evidences of Holocene slip along the TFF between the Pchan and Kyldou river valleys, since here the fault passes along river beds. V.G. Trifonov et al. (1990) found right-lateral displacement of small channels for 17-20, 34-37, 60-66 m. The radiocarbon age of a sample collected from loams composing a gully terrace shifted for 17-20 m (?) is 1510±60 years (section 8 in Fig. 31). This means that the average slip rate is less than 1.1-1.3 cm/year.

On the second section – in the Pchan and Kyldou river valleys (see Fig. 30 b) V.G. Trifonov et al. (1990) marked 41 structures shifted to the right up to 45 m. Measured maximums are comparable with maximum displacements on the first site (from the Kokkiya pass up to the Biruza river), but differ (with 2 exclusions) by 10-20% larger slip amplitudes. This fact reflects increasing intensity of movements from the first section to the second one at a similar regime of development, i.e. prevailing of seismogenic movements.

For calculation of slip rates on the both sites V.G. Trifonov et al. (1990) investigated sections of near-fault depressions formed in result of damming of the channels by shifted gully slopes and upslope facing scarps occurred simultaneously with the slip events. Sediments at the bottom of the depression correspond to the time of the movements (Fig. 31). They show slip rate about 0.5 cm/year for the first section (the sample age is  $3970 \pm 40$  years at total slip 19 m) and about 0.7 cm/year for the second one ( $3760 \pm 600$  years at total slip of the gully on  $27 \pm 1$  m). The values agree with other age determinations on the first and second section (see Fig. 31). Thus, in section 2 the age of a sample, collected at the bottom of a 1.5 m scarp synchronous to the 40 m slip along the northern branch of the fault, is  $15800 \pm 1300$  years, that gives the rate slip along the branch 0.25 cm/year. In sections 5-7 the age of samples from upper layers is  $3150 \pm 40$ ,  $2640 \pm 600$  and  $2320 \pm 40$  years at total slip  $90 \pm 3$ ,  $25 \pm 1$  and 23-24 m, respectively. Moreover, the first measurement was made in a gully characterizing by a right-lateral displacement of the channel for 7-8 m occurred after filling the near-fault depression with sediments. The displacement gives the probable limit of slip rate 0.24 cm/year (Trifonov et al., 1990).

Between the Kokkiya pass and the Biruza river valley (the right inflow of the Pchan river) V.G. Trifonov et al. (1990) found 75 water channels and other forms of the relief shifted up to 50 m to the right. Different distribution of various amplitudes should be noted: there are 11 or 12 maximums while the intermediate values either are absent or represented by single shifted forms (Fig. 30 a). The irregularity was noted for the first time by R.E. Wallace (1968) at studying of Late Holocene slip along the San Andreas Fault in California. V.G. Trifonov (1985) studied the same phenomenon by the example of the Hangai, Kobdin and Dolinoozersk active faults in Mongolia, where the morphological features of displacement and character of the revealed irregularity are similar to those found on the studied site of the Talas-Fergana Fault. Obviously, here the irregularity testifies to prevailing impulse seismogenic movements in the total slip. The amplitude difference of maximum values on neighboring sites, i.e. slip amount at a single impulse of movement, varies from 3 to 6 m; the average value is 4-4.5 m.

It is interesting that the TFF is not active at present time according to GPS data (Midi and Hutter, 2001), and the maximum right-lateral displacement along the fault is estimated as 2-3 mm/year for the north-western portion and almost zero for the south-eastern one. Apparently, the main slip along the fault was caused by strong movements (several meters) during earthquakes. During the intervals between the earthquakes the fault is blocked and is characterized by strain accumulation, which drops once upon several hundreds-thousands years.

A fragment of the Talas-Fergana Fault "Kyldau" (Burtman et al., 1996) demonstrates a series of right-lateral displacements from 12 m for small gullies to 125 ( $\pm 25$ ) m for watersheds (Figs. 32 and 33). In a pit section located in north-western slope of the watershed, displaced on 125 ( $\pm 25$ ) m, in a fault zone a black soil of 0.3 m thickness overlays a brown soil of 0.6 m thickness. The last one overlays a clay and sand strata (Fig. 34). Contact surface of a brown soil and clay-sand layer is tilted on about  $20^\circ$  toward north-east. Radiocarbon dating gives an age 3962–4132 years B.P. (point 11, table 1), which is most ancient from the investigated samples in



this part of the Talas-Fergana Fault. Seismotectonic deformations in the Talas-Fergana Fault zone are in association with gravitation formations, probably seismically-induced.

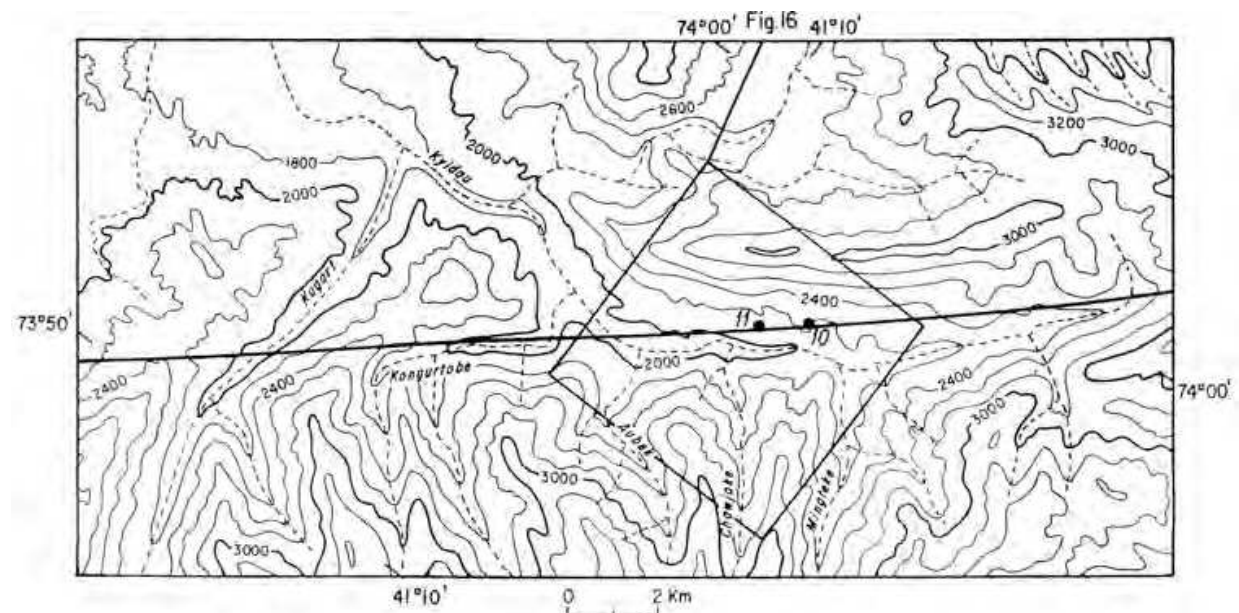


Fig. 32. Topographic map of the Talas-Fergana Fault along the Kyldau River Valley (Burtman et al., 1996). Black line is a fault trace. Figures point location of the field stations 10 and 11.

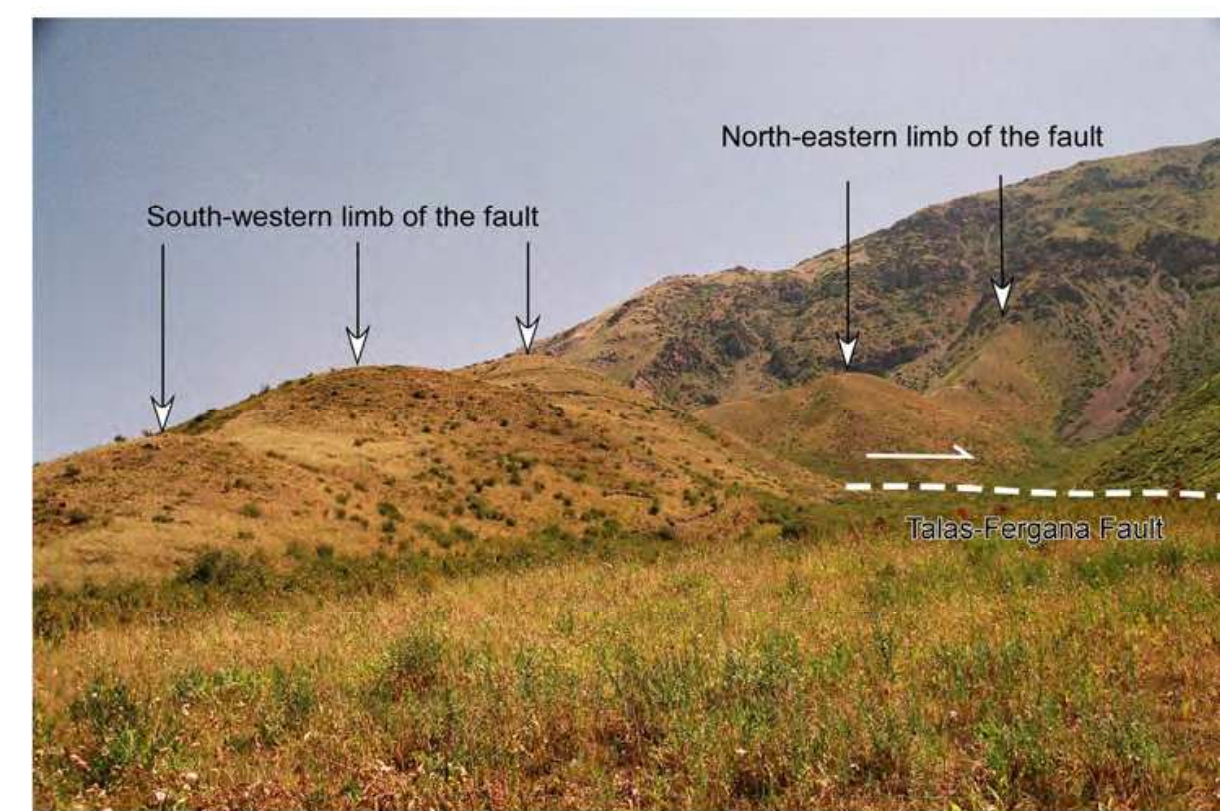


Fig. 33. The Talas-Fergana Fault goes along the right slope of the Kyldau river valley – south-western slope of the Yangyzkyr (“Lonely”) ridge and displaces the watershed right on tens of meters.

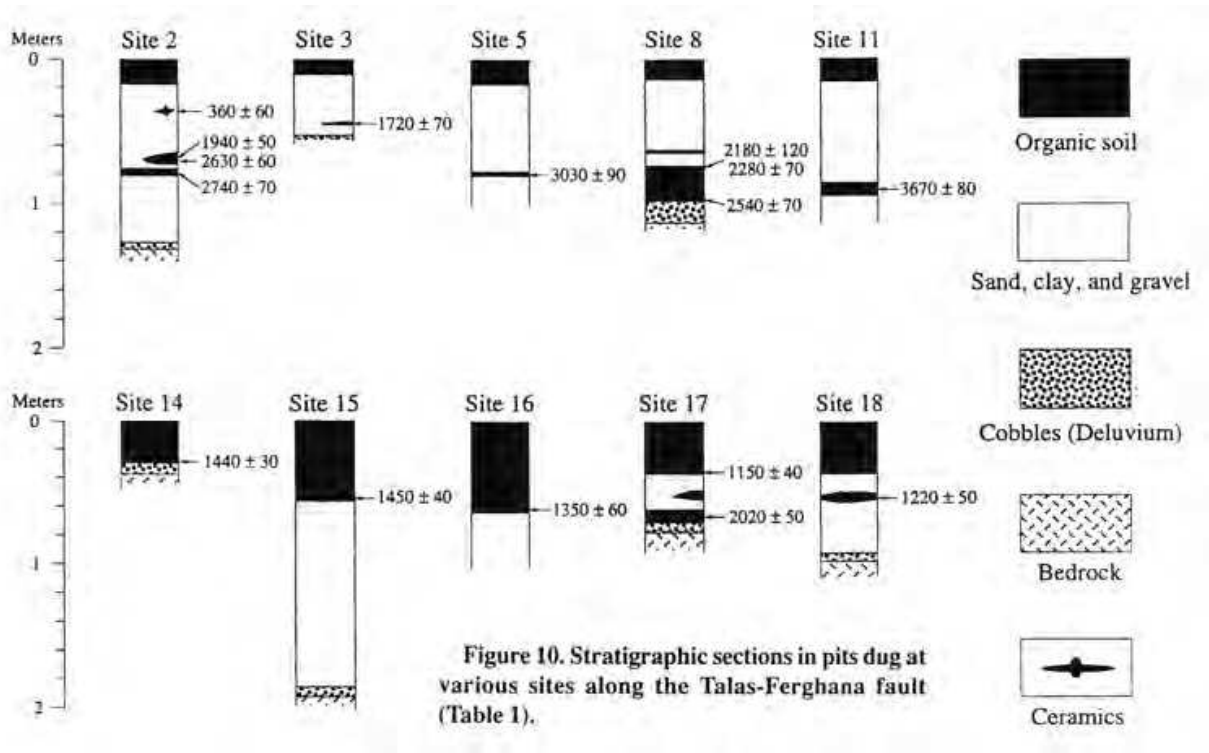


Fig. 34. Stratigraphic sections of pits excavated in different localities along the Talas-Fergana Fault by Burtman et al., 1996 (See also Table 2).

5.2 Investigations in the Dzhilangach-Pchan interfluve

Southern most part of the Talas-Fergana Fault, where there were collected samples for determination of the absolute age (Burtman et al., 1996), includes a segment of the fault located between Dzhilangach and Pchan river basins (Fig. 35). Both in the north and in its middle parts the Talas-Fergana Fault looks as a lengthy up-slope facing scarp of 10-30 m width and down to 5 m depth (Fig. 36). In given locality there are clear evidences of a horizontal component along the fault: displacement of gullies (Fig. 37 and 38) and watersheds (Fig. 39) among them on a value of few tens of meters. Thus along the

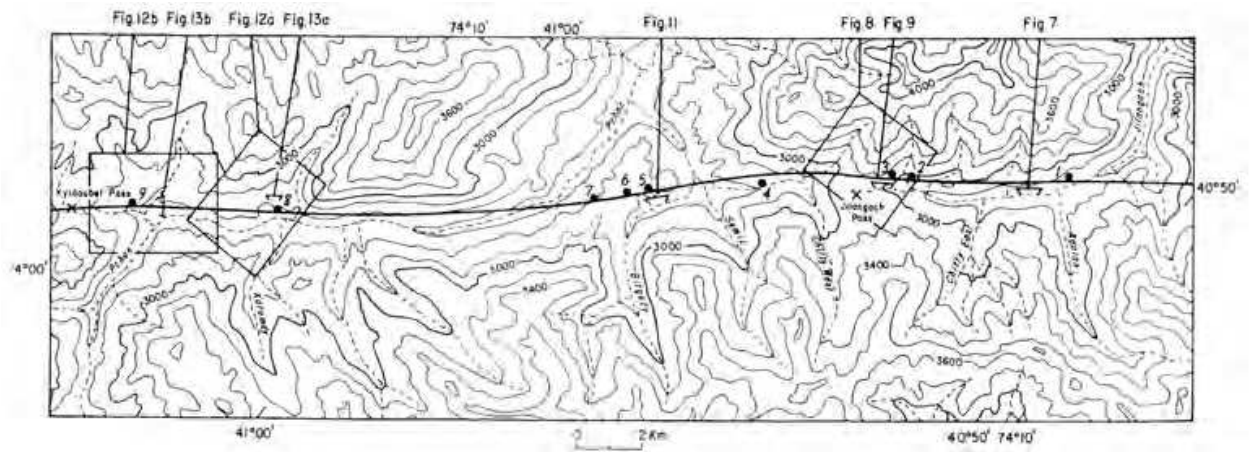


Fig. 35. Topographic map of a fragment of the Talas-Fergana Fault in the Pchan-Dzhilangach interfluvies (Burtman et al., 1996). Black line is a fault trace. Numbers are localities of pits where samples for absolute age were collected. Isoline interval – 200 m.



Fig. 36. On whole its length a line of the Talas-Fergana fault is expressed as lengthy up-slope facing scarp (shown by pointers) which cuts any forms of relief. A region of the Dzhilangach pass.



Fig. 37. A region of the Dzhilangach pass. One can observe right-lateral displacement of gullies on 40-50 meters. Arrows placed in left slopes of mentioned gullies.



Dzhilangach river valley a value of horizontal displacement according to geomorphologic data is from 19 to 45 m (See Table 1), in Chitty-Western river basin – 40 m, in the Birguzy river basin – 27-35 m, in the Pchan river basin – from 21 to 90 m.



Fig. 38. Close view on a zone of the Talas-Fergana Fault. Left slope of the Dzhilangach river valley. One can observe right-lateral displacement of gullies. For a scale pay attention for a group of people in the center of photograph.



Fig. 39. Displacement of gully channels (solid line) and watersheds along the Talas-Fergana Fault line (dashed line) in a region of the Dzhilangach pass. “B” marks a watershed located higher a slope; “H” point its continuation down the slope. As a scale look on two shepherd tents higher and right of “H” in the center of photograph.

It is clear that such values of displacements cannot be attributed to only one earthquake. Indeed absolute dates (table 1) testifies on minimum eight earthquakes occurred in 15800, 4590, about 3955, about 3095, about 2635, 2230, 1940, 1720 years ago.

In tie with mainly strike-slip movements along the fault, often in its zone there are formed specific deformation forms: so-called tectonic swells (Fig. 40), which are like a barrier ridges for consequent drainage and near-fault depressions – places of accumulations of fine material from adjacent slopes. In those depressions one has to conduct pit excavations for samples collection for absolute dating.



Fig. 40. A view toward north-west along the Talas-Fergana Fault. A region of the Semiz river mouth. Here the springs – tributaries o of the river flowing down toward south-west are dammed by the tectonic swells (shown by pointers) serving as barrier or “shatter” ridges for consequent drainage.

## 6. Discussion of the results - assessment of energy (maximum magnitude) of paleoearthquakes by the length of the seismogenic rupture

We have collected all absolute dates of paleoearthquakes occurred along the Talas-Fergana Fault obtained by us and combined them with the data obtained earlier by V.S. Burtman et al. (1987, 1996) and V.G. Trifonov et al. (1990, 1992) in table 4 and in Fig. 41. Totally there were collected 55 dates in 14 localities appurtenant to Late Pleistocene – Holocene.

An analysis of Fig. 41 has led us to a conclusion that the Talas-Fergana Fault zone can be generally divided onto three chains according to peculiarities of the lateral distribution of earthquakes. The first – north-western chain starts from the Kurkureusu river valley in the far west of Kyrgyzstan and stretches to about Sary-Bulak river valley in the Ketmen-Tyube depression. The second – central chain stretches toward south-east from the Sary-Bulak river valley to the Urumbash River (Kazarman depression) inclusively. Third – south-western

River valley or a name of the fault segment	Obtained radiocarbon ages, years	Average age of the earthquakes, years
Dzhilangach	1720 ±70 1940 ±50 2630 ±70 2740 ±70 3970 ±40	1720 ±70 1940 ±50 2685 ±70 3970 ±40
Chitty-Western	4590 ±100 15800 ±1300	4590 ±100 15800 ±1300
Birguzy	3030 ±90 3740 ±600	3030 ±90 3740 ±600
Pchan	2180 ±120 2280 ±70 2540 ±70 2640 ±600 3150 ±40	2230 ± 120 2590 ± 600 3150 ±40
Kyldau	2320 ±40 3670 ±80 3670 ±80	2320 ±40 3670 ±80
Urumbash	1510 ±60	1510 ±60
Keklikbel	1240 ±60	1240 ±60
Karasu	285 ± 35 975 ± 65 980 ± 55 1015 ± 75	285 ± 35 990 ± 75
Kok-Bel	240 ± 50 270 ± 85 370± 90 2340 ± 120 2500 ± 100 4900 ± 230	295 ± 90 2435 ± 120 4900 ± 230
Dzhanaryksay	1440 ±30	1440 ±30
Sary-Bulak	440 ± 45 505 ± 80 1130 ± 100 2385 ± 130 2415 ± 100 4930 ± 90 5200 ± 140 5240 ± 150 6120 ± 170	475 ± 80 1130 ± 100 2400 ± 130 4930 ± 90 5220 ± 150 6120 ± 170
Chatkal	250 ± 50 1150 ±40 1220 ±50 1220 ±50 1350 ±60	1385 ± 60 2020 ±50 1195 ± 50



	1350 ±60 1450 ±40 2020 ±50 2020 ±50	
Kara-Bura	405 ± 100 460 ± 40 480 ± 35 4465 ± 130 5910 ± 130 6100 ± 200	450 ± 100 4465 ± 130 5910 ± 130 6100 ± 200
Sulu-Bakair	5210 ± 155	5210 ± 155

Table 4. Radiocarbon dates of samples collected from displaced gullies along the Talas-Fergana Fault (by data of Korjenkov et al., 2009, 2010, as well as V.S. Burtman et al., 1987, 1996 and Trifonov et al., 1990, 1992)

chain starts from Kyldau river valley and ends in a region of southern state border of Kyrgyz Republic. We understand whole conventionality of our division, especially without materials on the Talas-Fergana Fault from Kazakhstan and China.

Because of uneven investigations and bareness of existed materials one has to talk very carefully on segmentation of the Talas-Fergana Fault zone. According to existing data we select 13 segments: 3 – in the northwestern chain of the fault, 5 or 6 in the central chain and 4 or 5 in southeastern chain (See Fig. 41).

An analysis and comparison of materials of Table 4 and Fig. 41 have allowed us to reveal 18 paleoseismic events, 17 of which occurred in the second half of Holocene (Table 5 and Fig. 42). We assessed also distances between localities, where there were determined absolute ages of the seismogenic displacements, occurred (supposedly) during one seismic event. We conditionally accepted these distances as minimum lengths of the seismogenic ruptures.

Some of the extreme values of rupture lengths, such as 270 km and 220 km for earthquakes occurred in 4530 and 1980 years ago, provoke a natural doubt. Although such length of the seismogenic ruptures is theoretically possible, however known strong historical earthquakes in the northern Tien Shan demonstrate maximum length of the rupture barely reaching 200 km: for example, Kebin (Kemin) earthquake of 1911 (Bogdanovich et al., 1914). It is possible that in such (and probably in some other) cases it took place an artificial unification of different earthquakes occurred in different parts of the fault, but in close time frames. Nevertheless one cannot exclude a possibility of propagation of many segments along almost whole plane of the Talas-Fergana Fault (during both discussed earthquakes there were united 11 segments in three chains of the disjunctive). An example of such propagation in the Tien Shan is mentioned Kebin earthquake during which there was a propagation of 6 fault segments of the fault zone close in time (Delvaux et al., 2001).

A distribution of paleoearthquakes along the Talas-Fergana Fault in time (for exclusion of individual “jumps”) has clear evidence (Fig. 42). In interval 6000-4500 years ago the strong earthquakes occurred in north-western chain of the fault. Then a seismic activity has spread over to the south-eastern chain: 4500-2500 years ago. In the interval 2500-1500 years ago the strong earthquakes occurred in the central and south-eastern chains of the fault. Then the seismic activity is concentrated in north-western and central chains: 1500-250 years ago.

How the fault will behave in future is not clear. Here apparently it can be two variants of events' development: 1) the seismic activity will continue in north-western and central chains of the fault or 2) most probably will spread over to its south-eastern chain, where now there is so-called "a seismic gap": last earthquake occurred here already 1720 year ago!

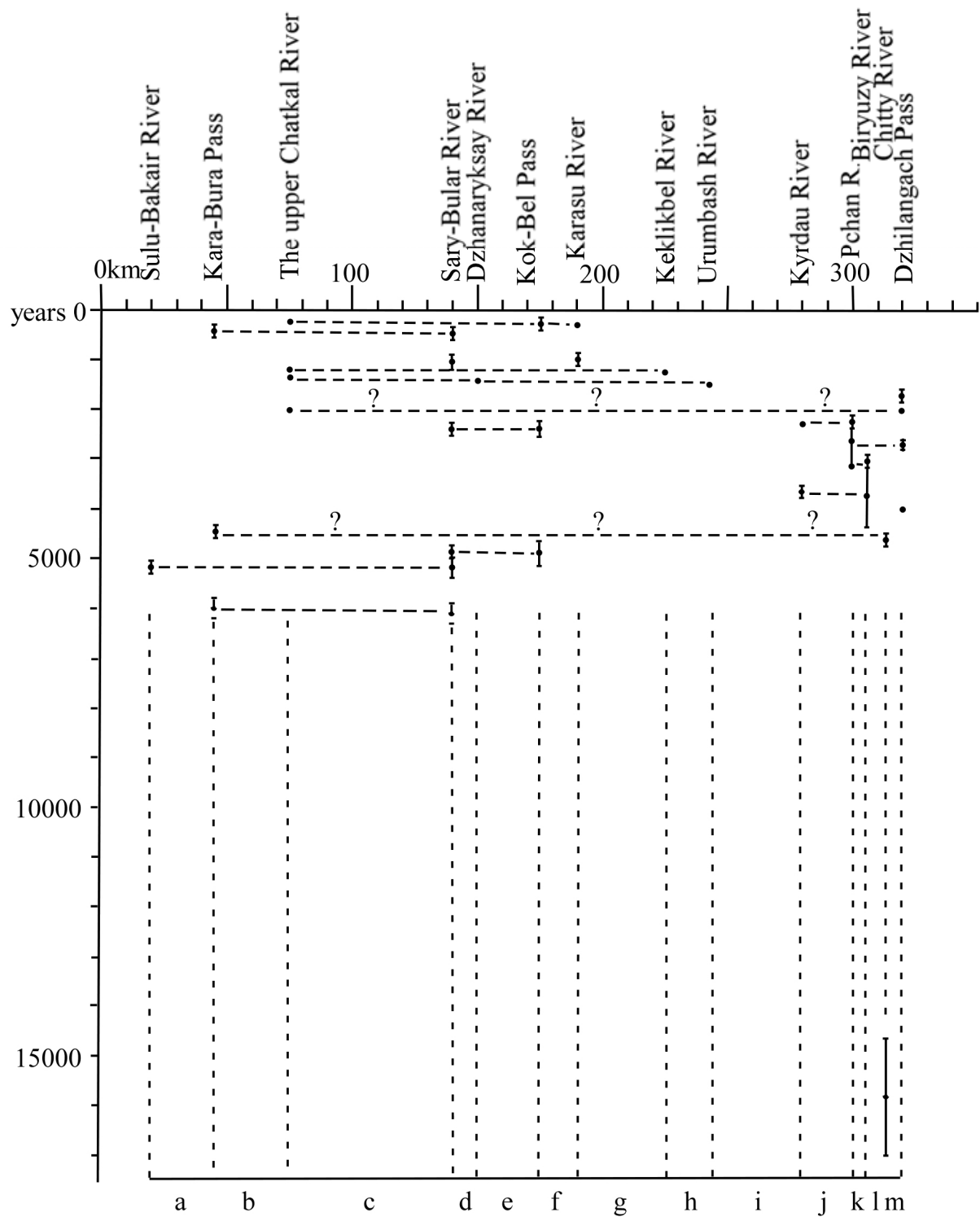


Fig. 41. Distribution of the earthquakes and segmentation along the zone of the Talas-Fergana fault in bounds of the Kyrgyz Republic

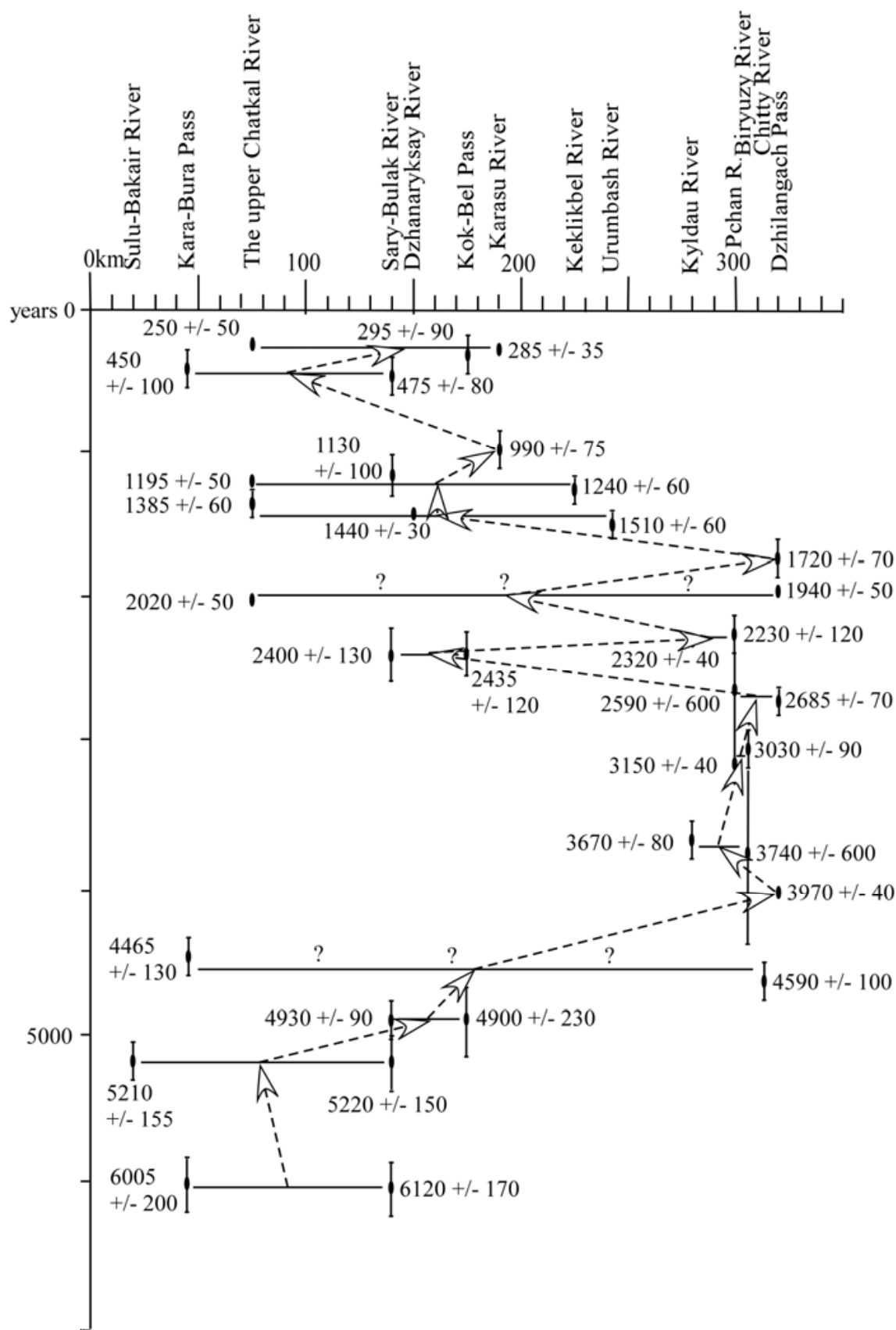


Fig. 42. Migration of the earthquakes along the Talas-Fergana Fault zone in Holocene



##	River valley or a name of the segment where an earthquake has occurred (from – to)	Minimum length of the rupture, km	Average (calculated) age of the earthquake, years ago	Interval between given and previous earthquakes
1	Region of the Kara-Bura Pass – the Sary-Bulak river valley	100	6065	
2	The Sulu-Bakair River valley – the Sary-Bulak river valley	120	5215	850
3	The Sary-Bulak River valley – the Kok-Bel Pass	40	4915	300
4	Region of the Kara-Bura Pass – the Chitty-Western River valley	270 ?	4530	385
5	A region of the Dzhilangach Pass	?	3970	560
6	The Kyldau River valley – the Burguzy River valley	30	3705	265
7	The Pchan River valley – the Birguzy river valley	10	3090	615
8	The Pchan River valley – the Dzhilangach Pass	20	2640	450
9	The Sary-Bulak River valley – the Kok-Bel Pass	40	2420	220
10	The Pchan River valley	?	2275	145
11	Head of the Chatkal River valley – a region of the Dzhilangach Pass	220 ?	1980	295
12	A region of the Dzhilangach Pass	?	1720	260
13	Head of the Chatkal River valley – the Urumbash River valley	170	1445	275
14	Head of the Chatkal River valley – the Keklikbel River valley	150	1190	255
15	The Karasu River valley	?	990	200
16	A region of the Kara-Bura Pass – the Sary-Bulak river valley	100	465	525
17	A head of the Chatkal River valley – the Karasu River Valley	120	275	190

Table 5. Average (calculated) ages of strong earthquakes occurred in the Talas-Fergana Fault zone in Holocene, interval between them and minimum length of the seismogenic rupture.

An important question in a concern of the long-term forecast of strong earthquakes is their reoccurrence. We have calculated intervals between strong earthquakes along the Talas-

Fergana Fault during the second half of Holocene (Table 5) where representation of the earthquakes is more complete. They rank from 145 to 850 years. Thus, an average calculated reoccurrence of the earthquakes along the whole zone of the Talas-Fergana Fault is 375 years. However, an arithmetic mean value is not the best characteristics of the natural phenomena. Comparison of number of the strong earthquakes along the fault with interval of their occurrence (Fig. 43) has allowed us to reveal three clear peaks of the earthquake occurrence in the second half of Holocene divided by intervals in 300 years.

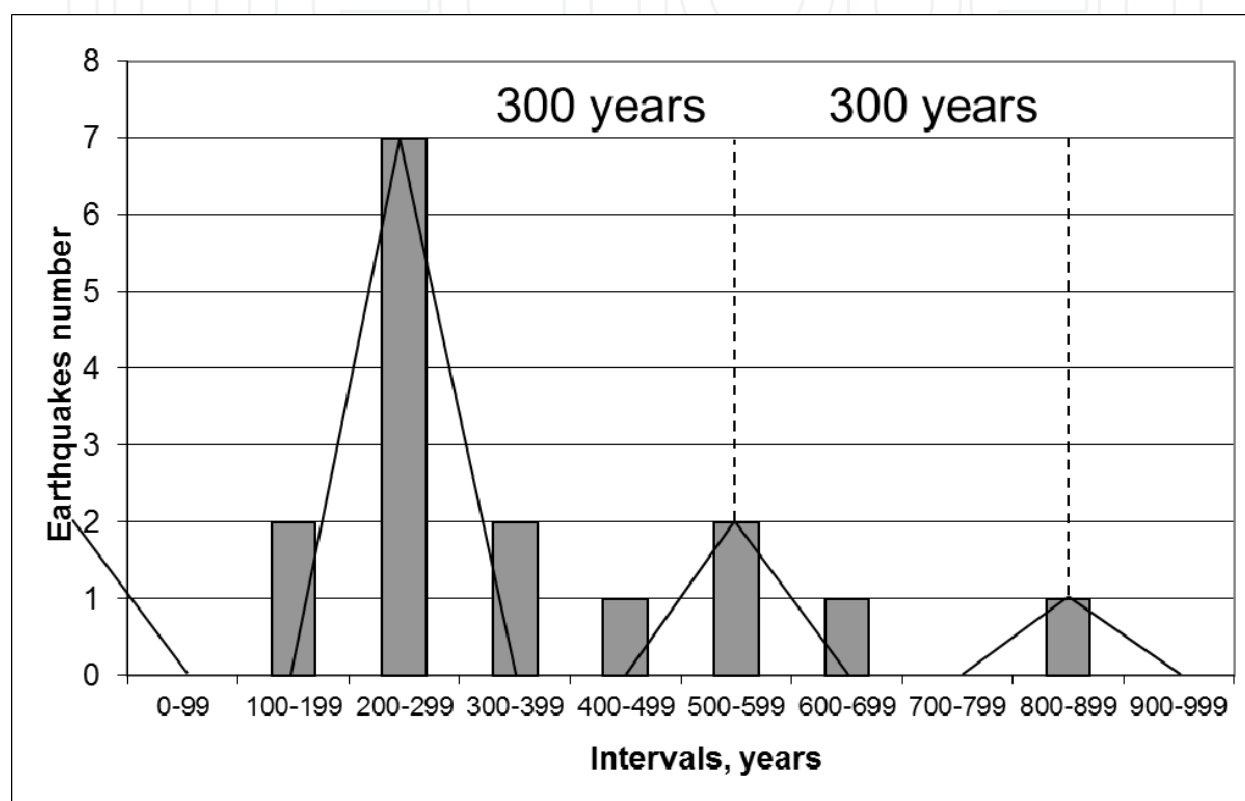


Fig. 43. Comparison of number of the strong earthquakes along the Talas-fergana Fault with intervals of their occurrence

Taking into account all said above, we can supposed that the next strong earthquake ( $M > 7$ ) most probably will occur in approximately 25 years: 300 years minus 275 years (an age of the last strong paleoearthquake) in south-eastern limb of the Talas-Fergana Fault.

We have discussed above that we have conducted a segmentation of the Talas-Fergana Fault zone by existed data (Fig. 41). In result there were revealed 13 segments: from "a" to "m". We wrote also that by previous studies (Delvaux et al., 2001) there was revealed that during strong Tien Shan earthquakes it takes place a unification of several segments of the fault zone. We pointed above that during Kemin earthquakes of 1911 ( $M=8.2$ ) it took place a unification of 6 segments of the Chilik-Kemin seismogenic zone of total length to 200 km (Delvaux et al., 2001). The same unification of the segments could take place also during strong earthquakes which occurred along the Talas-Fergana Fault zone (Table 6).

##	<i>A river valley or fault segment where the earthquake has occurred (from – to)</i>	<i>Minimum length of the rupture, km</i>	<i>Number of united/ propagated segments (see Fig. 41)</i>	<i>Possible maximum magnitudes of the paleoearthquakes</i>
1	A region of the Karabura Pass – the Sary-Bulak river valley	100	2 (b, c)	7,71
2	The Sulu-Barair River valley – the Sary-Bulak river valley	120	3 (a – c)	7,75
3	The Sary-Bulak River valley – the Kok-Bel Pass	40	2 (d, e)	7,49
4	A region of the Kara-Bura Pass – the Chitty-Western River valley	270	11 (b-l)	7,95
5	A region of the Dzhilangach pass	?	?	?
6	The Kyldau River valley – the Birguzy River valley	30	2 (j, k)	7,42
7	The Pchan River valley – the Birguzy River valley	10	1 (k)	7,16
8	The Pchan River valley – a region of the Dzhilangach pass	20	3 (k-m)	7,33
9	The Sary-Bulak River valley – a region of the Kok-Bel Pass	40	2 (j, k)	7,49
10	The Pchan River valley	?	?	?
11	Upper part of the Chatkal River valley – a region of the Dzhilangach pass	220	11 (c-m)	7,90
12	A region of the Dzhilangach pass	?	?	?
13	An upper part of the Chatkal river valley – the Urumbash River valley	170	6 (c-h)	7,84
14	An upper part of the Chatkal River valley – the Keklikbel River valley	150	5 (b-g)	7,81
15	Karasu River valley	?	?	?
16	A region of the Kara-Bura Pass – the Sary-Bulak River valley	100	2 (b, c)	7,71
17	An upper part of the Chatkal River valley – the Karasu River valley	120	4 (c – f)	7,75

Table 6. Lengths of the seismogenic ruptures along the Talas-Fergana Fault zone and possible magnitudes of earthquakes.



We have analyzed number of formulae for determination of paleoseismic catastrophes' magnitudes according to parameters of seismic rupture, published by different investigators: V.P. Solonenko and V.S. Khromovskikh (1978), A.A. Nikonov (1984) and D.L. Wells and K. J. Coppersmith (1994). Let's investigate their formulae for magnitude assessment by a length of the seismogenic rupture expressed in the surface and check these results on measured parameters of the fault scarps and an instrumental magnitude of the Tien Shan's Suusamyr earthquake of 1992 occurred in the depression with the same name (Bogachkin et al., 1997).

During the earthquake in the surface there were occurred only two short seismogenic ruptures with a total length of 4 km, a distance between them was 26 km (Bogachkin et al., 1997). A magnitude assessed instrumentally was  $M_s = 7.3$ . As it was discussed above at a description of the Suusamyr earthquake, in this case we have a deal with so-called "blind" seismogenic rupture, larger part of which did not reach the surface. Let's assume that the total length of the rupture (L) was  $4 + 26 \text{ km} = 30 \text{ km}$ .

- By formula of V.P. Solonenko and V.S. Khromovskikh (they used the earthquakes of the Baykal Lake and Caucasus regions):

$$M = 0.6 \lg L + 6, \text{ we got } M = 6.89.$$

- By A.A. Nikonov (he used data on Central Asian earthquakes):

$$M = 6.61 + 0.55 \lg L, \text{ we got } M = 7.42.$$

- By formula D.L. Wells and K.J. Coppersmith (they use world data):

$$M = 5.08 + 1.16 \lg L, \text{ we got } M = 6.79.$$

Cited above calculations show that the data by V.P. Solonenko and V.S. Khromovskikh (1978) on earthquakes parameters of the Baykal Lake and Caucasus regions, as well as world data by D.L. Wells and K.J. Coppersmith (1994) give underestimated magnitude of the earthquake if compare with the instrumental value. At the same time the formula by A.A. Nikonov (1984), calculated by him for earthquakes of the Central Asia gives a value which only on 0.1 higher than an instrumental value. This is a very good result especially if we are taking into an account that an accuracy of magnitudes determination by such method is in bounds of  $\pm 0.5$  of the magnitude unit. This is why in our magnitudes assessments we based on formula by A.A. Nikonov (1984), which he specially deduced for a territory of the central Asia.

Our calculation (Table 6) have shown that according to paleoseismological data along the Talas-Fergana Fault zone there are possible earthquakes with magnitude  $M > 7$ , and during unification of many segments (up to 11) a maximum magnitude can reach  $M = 8$ . One can not exclude however that along the fault zone there were occurred two or more independent earthquakes divided by short time intervals. This interval we can not reveal because of significant miscalculations of Radiocarbon method of dating. It is possible that there were a clustering of the earthquakes along the seismogenic zone. In a history of strong earthquakes of the Tien Shan such clustering took place in the end of XIX – beginning of XX centuries. Here along so-called Northern Tien Shan Seismic Zone during only 26 years there were occurred 4 strong earthquakes: Belovodsk one of 1885 with  $M_{LH} = 6.9$ ; Verny earthquake of 1887 with  $M_{LH} = 7.3$ ; Chilik one of 1889 with  $M_{LH} = 8.3$  and Kebin earthquake of 1911 with

$M_{LH} = 8,2$  (Dzhanuzakov et al., 2003). If paleoseismologists will study consequences of those earthquakes in 3011 using the Radiocarbon method, then because of miscalculations of the method, for them it will be that different segments of the Northern Tien Shan Seismogenic Zone activated simultaneously in 1900 AD plus-minus 50 years...

Thus we understand all conditionality and approximateness of cited above attempts to conduct of the segmentation of the Talas-Fergana Fault zone and calculations of magnitudes of paleoearthquakes with use of so scanty data along the fault zone of 350 km length only in Kyrgyzstan territory. However one has to start from something. The future materials on age of displaced of relief elements, full-fledged paleoseismological trenches, which will cross the whole fault zone, will help to define more precisely cited above numbers.

## 7. Conclusion

1. 1. The authors' study along the Talas-Fergana Fault zone, as well as analysis of published data have shown that during Neotectonic time the fault developed as a dextral strike-slip fault. It is possible that dextral displacements are spread also on secondary fault planes north and south from the main fault trace.
2. Based on data of absolute dating of authors as well as previous scholars there were determined rates of Holocene and Late Pleistocene dextral movements – 0.2-1.9 cm/ year.
3. The whole zone of the Talas-Fergana Fault is marked by well-developed paleoseismic deformations: up-slope facing scarps and fault scarps, as well as horizontal displacements of the relief forms. In association with them there are revealed numerous seismogravitation forms: rock- and landslides.
4. Collected data on the absolute age determination of mentioned above deformations by the Radiocarbon method point on more than 18 strong earthquake occurred along the fault zone during interval of 275 -15800 years.
5. Reoccurrence of the strong earthquakes along the Talas-Fergana Fault zone during second part of Holocene is about 300 years.
6. The zone of the Talas-Fergana Fault by peculiarities of lateral distribution of the earthquakes can be divided onto 3 chains and 13 segments. First – north-western chain starts from the Kurkureusu River valley in most west of Kyrgyzstan and stretches up to about Sary-Bulak River valley in the Ketmen'-Tyube depression. Second – central chain stretches toward south-east from the Sary-Bulak River valley up to Urumbash River valley (Kazarman depression) inclusively. Third – south-eastern chain starts from the Kылдау River valley and ends in a region of Kyrgyzstan State border.
7. Next strong earthquake along the fault most probably will occur in its south-eastern chain during nearest tens of years.
8. Parameters of the seismotectonic deformations point on  $M > 7$  of occurred earthquakes and intensity of the oscillations  $I > IX$ . These data have to be taking into account during compiling of a new Map of the Seismic Zoning of Kyrgyz Republic territory.

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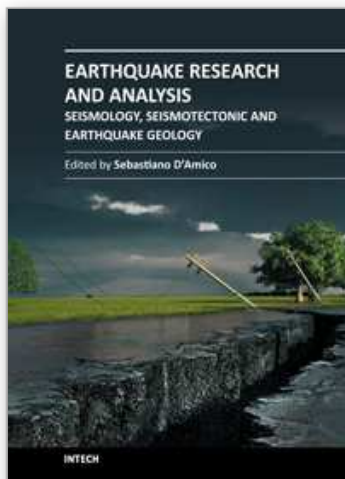


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