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RARE SEISMOGENIC EVENTS IN THE ILE ALATAU

Abstract. In the relatively recent geological history of the Ile Alatau region, large earthquakes have triggered significant disturbances to the earth's surface, including massive seismogenic landslides and debris flows. Through a retrospective analysis of these events and the application of modern research methods, the authors were able to estimate the age and scale of these phenomena. The findings underscore the necessity of considering such large-scale disasters in the planning and development of foothill territories. Given that the region is one of the most seismically active areas in Kazakhstan, the potential for giant landslides and mudflows induced by strong earthquakes represents a tangible and ongoing risk. The study also identified critical gaps in previous research, particularly concerning the timing of past events and methods for quantifying their characteristics. Using data from unmanned aerial vehicle (UAV) imagery, advanced software, and morphometric analysis of solid runoff and mudflow deposits, the authors refined the quantitative parameters of catastrophic natural events that occurred hundreds or even thousands of years ago. A review of previously published datings of rare geologic catastrophes was conducted. The results show that rare seismogenic phenomena have not been adequately considered in existing engineering protection schemes due to insufficient knowledge and gaps in regulatory design standards. Further studies are essential to address these shortcomings and ensure safer land-use planning in seismically active zones.

Keywords: earthquake, landslide, rockfall, mudflow, natural disasters.

Introduction. In this study, rare events are understood as discrete occurrences that are observed extremely infrequently due to the complex of natural processes, whose genetic interconnections are often not statistically confirmed. Seismogenic phenomena such as blocking landslides, secondary mudflows, and floods fall into this category. A regional analysis of large-scale slope deformations of seismogenic origin in the mountainous areas of Kazakhstan has been presented in the works [8, 9]. Modern studies indicate that the Northern Tien Shan region, and in particular its frontal ridge – the Ile Alatau – has repeatedly experienced destructive landslides and mudflows, whose occurrence was directly linked to strong earthquakes. Thus, the catastrophic natural events discussed in this paper represent a consistent pattern in the long sequence of geological processes that have recurred over thousands of years and will inevitably occur again in the future. The conditions for their formation remain unchanged, namely:

– The Ile Alatau region contains large active seismic faults, where heightened seismic activity is regularly observed.

– The foothill terraces of the Ile Alatau are composed of loess-like sediments with poor engineering-geological properties, which, under strong seismic impacts and prior soil moisture saturation, can lead to the large-scale formation of blocking landslides and mudflows.

– The high-mountain zone of the Ile Alatau retains extensive modern glaciation, a vast reserve of unconsolidated deposits from contemporary and Upper Quaternary moraine complexes, and a significant energy potential due to the altitude difference of 3.5–4.0 km from the headwaters to the foothills.

The focus of this study is the largest seismogenic events in the central part of the northern slope of the Ile Alatau (figure 1).

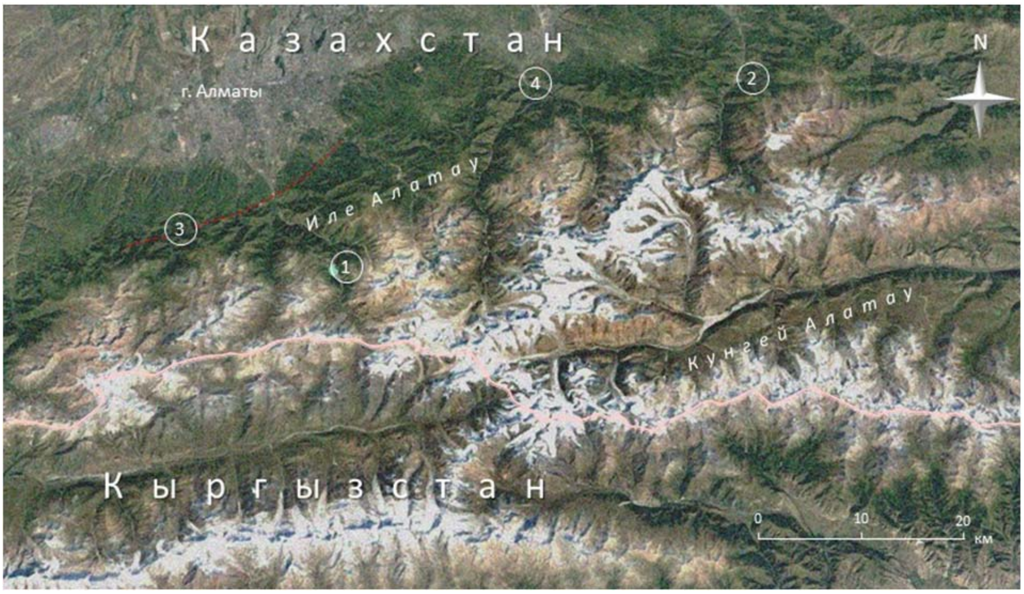

Figure 1 – The area and the objects of the study:
1 – Blocking landslide and the Big Almaty Lake; *2* – blocking landslide and the Yesik Lake;
3 – fault zone and the epicenter of the Verny earthquake of 1887; *4* – ancient giant mudflow in the valley of the Talgar River

Materials and Methods. An essential element of any scientific research is accounting for previous studies, with a list of key publications provided in the references. A retrospective analysis of accumulated data, incorporating modern research methods and a more detailed examination of study sites, enables the refinement of seismogenic event characteristics, their quantitative attributes, and chronological framework. In many cases, mountain landslides and rockfalls, in the absence of direct observations, have been assumed to be responsible for a series of mudflow catastrophes. However, further researches have shown that erosion and associated displacement processes in contemporary and Upper Quaternary frontal moraines were the primary drivers in specific cases [6, 8]. Conversely, numerous landslide dams that impound high-mountain lakes were mistakenly identified as ancient moraines, a misinterpretation that could only be corrected through additional modern investigations [9, 8]. The dating of damming landslides remains a particularly challenging issue. Frequently, event timing has been inferred by analogy with similar nearby formations and presumed seismic events. However, in the absence of precise data, this method significantly broadens the potential age range of such phenomena over several millennia [2, 3].

The authors argue that refining the timing of major seismic catastrophes is crucial for assessing current conditions and forecasting future developments. A promising approach to dating damming landslides is the discrete and integral evaluation of unconsolidated debris in landslide dams and mudflow deposits, which form extensive alluvial fans at the entrance to high-mountain basins. Even in the absence of direct data – an expected challenge – chronological constraints can be established using average denudation rates and sediment discharge volumes from mountain regions worldwide. These values are widely accepted, making this method a scientifically justified research tool [4].

A highly informative method for determining the age of large-scale seismic dislocations involves analyzing the volume of unconsolidated landslide or mudflow deposits embedded in the original valley relief. To reconstruct the pre-event topography, researchers compare the continuation of mountain slope and valley floor forms buried beneath landslide or mudflow deposits with the modern surface [8, 6, 4]. In some cases, geophysical methods can help restore buried relief, provided that the boundaries of the original relief and landslide bodies are reliably identified, which is complicated by the homogeneity of loose debris masses.

Remote sensing techniques, including multi-temporal satellite imagery, facilitate the study of seismogenic dislocations, landslides, and mudflows not only at local sites but also across vast, inaccessible regions. The research utilizes satellite imagery from Landsat, Sentinel, Google Earth, and the Shuttle Radar Topographic Mission (SRTM), which provides digital elevation model (DEM) data for Earth's surface.

Results and Discussion. The Ulken Almaty. Fifteen kilometers from Almaty, on the northern slope of the Ile Alatau at approximately 2500 m above sea level, lies the Ulken Almaty (Big Almaty) Lake. Currently, the lake functions as a multipurpose reservoir with a regulated water volume of 14 million m^3, serving energy and water supply needs.

According to specialized studies, the lake was formed due to a massive earthquake-induced blocking landslide-rockfall, with a volume of up to 380 million m^3, originating from the left slope of the Ozyornaya River valley, a tributary of the Ulken Almaty River [8]. To prevent a potential lake outburst caused by a mudflow entering the lake – similar to the 1963 Yesik event (see this article) – that was formed higher up the valley profile. In the 1980s the crest of the lake dam was increased by 10 m with the construction of an open spillway (figure 2) [5].

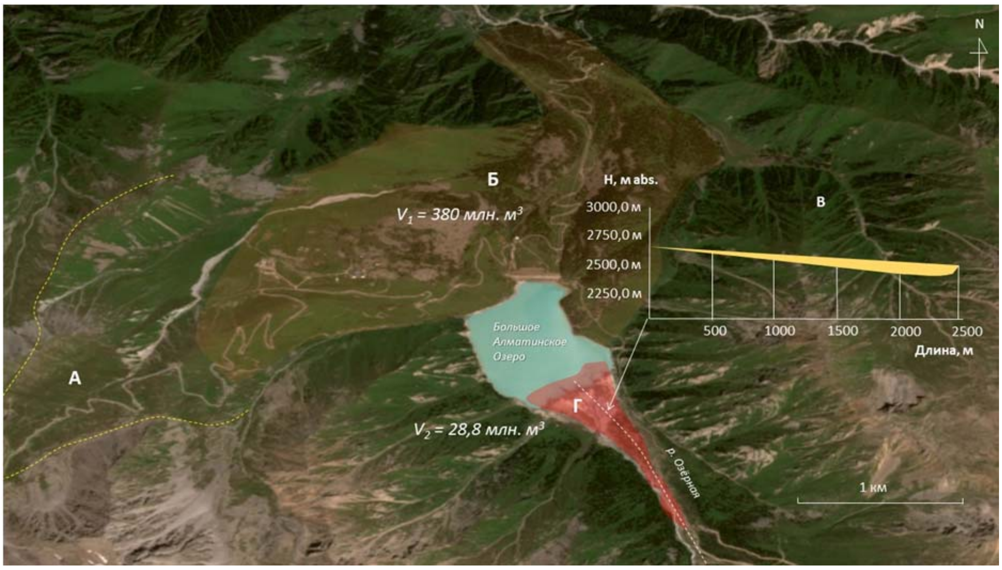

Figure 2 – The situation in the area of blocking of the Ozernaya River by a landslide:
A – escarpment and separation zone; *B* – landslide body [8]; *C* – profile along the alluvial fan; *D* – mudflow alluvial fan [4]

Although the origin and morphology of the lake's seismogenic dam are well studied, its age remains debated. Some researchers estimate the landslide-rockfall's age to be between 8,000 and 15,000–20,000 years [2, 3]. The only argument given in support of this assumption is the landslide in the Yesik River valley. However, no direct evidence supports this claim. The blockages of the Yesik and Ulken Almaty Rivers occurred at different altitudes (1750 and 2500 m respectively) and are associated with different seismic faults.

On the other hand, there is objective evidence suggesting a significantly younger age for the formation of the lake dam. During the deepening of the water intake in the lake dam, layers of silty lake sediments containing remains of Tien Shan spruce were uncovered. Samples of organic material were collected by A. P. Gorbunov from the Institute of Geography, which were later subjected to radiocarbon dating at a laboratory in Novosibirsk, determining their age to be 1500±200 years. Taking into account the accumulated silty deposits (2.2 m), the formation of the blocking landslide dam was preliminarily estimated at 2200±200 years [1].

To further substantiate the existence period of the lake, a morphological method was later applied, based on obtaining morphometric characteristics of the debris flow fan at the entrance to the lake basin and estimating its formation time.

The volume of unconsolidated deposits in the debris flow fan, determined through partial restoration of the relief profile and considering its glacial modification in the upper section of the lake basin (a characteristic trough), was 28.8 million m^3. The volume of sediments, calculated based on the average and maximum values of denudation in mountainous terrain over 2000 years, ranged from 13.0 to 47.7 million m^3, averaging 30.35 million m^3, which closely aligns with the previously obtained estimate [4]. If we assume that the denudation rate in the central part of the Ile Alatau, including the Ozyornaya River basin, corresponds to the mean value of loose material washout (denudation products) at 0.19 mm/year, then the volume of the debris flow fan near the lake – given a catchment area of 71.8 km^2 and a sediment accumulation period of 2000 years – would be 27.3 million m^3, which is also very close to the value obtained using the morphometric method.

The volume of deposits can also be estimated using the solid runoff modulus. According to recommendations [12], if we assume that the conditions in the Ozyornaya River basin are similar to the areas composed of ancient sedimentary or igneous rocks, with a maximum solid runoff modulus of 880 t/km^2/year, then over 2000 years, 47.7 million m^3 of material should have been transported to the blocking area. At an average long-term solid runoff modulus of 240 t/km^2/year, this value would be 13 million m^3, giving an overall average of 30.35 million m^3.

It should be noted that immediately after the seismogenic landslide, the blocking dam enabled the accumulation of a significant volume of water. The initial lake that was formed most likely breached within a few days, triggering a catastrophic outburst flood downstream and creating an erosional incision in the lower part of the natural dam.

The Yesik. The exceptional event of July 7, 1963, in the Yesik River valley stands out among the region's natural disasters. At that time, a large mountain lake, which had been formed due to a landslide dam blocking the river at an elevation of approximately 1750 m, burst as a result of the entry of a catastrophic mudflow into the lake. The mudflow had peak discharges of 7,000-12,000 m^3/s (figure 3).

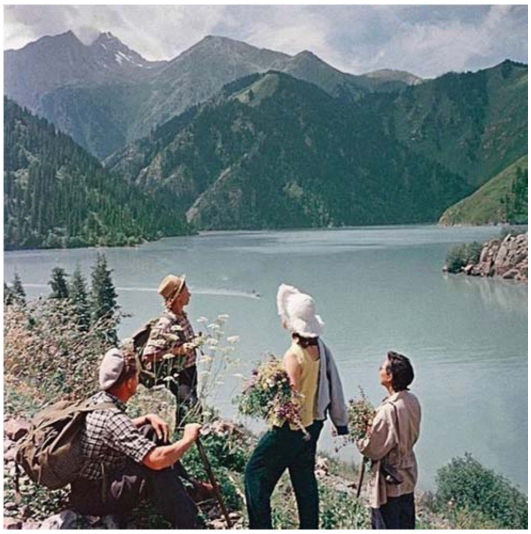

Figure 3 – The Yesik Lake before 1963 (postcard)

The glacial mudflow, with a volume of 5.8 million m^3, caused a sharp rise in the lake level (by at least 1.5 m) and generated destructive waves up to 5.5 m high. This led to an increase in outflow discharge, intense retrogressive erosion in the lower part of the dam, subsequent dam failure, and near-complete drainage of the lake basin [6] (figure 4).

A comparison of the 1963 mudflow volume with the total sediment accumulation in front of the blocking landslide throughout the lake's existence is particularly important. The age of the Yesik landslide dam, based on estimates of the maximum thickness of laminated silts deposited in the lake basin, has been assessed at 4,000 years [7]. Through repeated leveling surveys of the longitudinal profile of the alluvial fan, the total volume of mudflow and flood deposits at the lake entrance was determined to be 82 million m^3 [6].

By using an analogy-based approach with denudation intensity values from other mountainous regions, the approximate age of the lake – and consequently, the blocking landslide – can be estimated. Interpolating the data obtained for the mudflow fan at the Ulken Almaty Lake, the age of the Yesik River blockage is estimated at 5,700 years.

It is crucial to highlight that this was a highly unusual event: a lake that had existed for thousands of years was completely destroyed by a mudflow – even though the mudflow volume was an order of magnitude smaller than the total sediment volume accumulated in the lake basin throughout its history (figures 3, 4).

Figure 4 – The blocking landslide and the catastrophic mudflow on July 7, 1963 in the Yesik River valley:
A – scarp and landslide detachment zone; *B* – landslide body; *C* – mudflow alluvial fan.
Photo 1 was made by Qazaq TV, Photo 2 is a Sentinel-2 image for July 24, 2021

The powerful lake dam, composed of a landslide body with a volume of 20–25 million m^3, was completely breached by the water flow. The resulting catastrophic outburst flood, with a discharge of up to 1000 m^3/s, destroyed up to 200 houses, bridges, roads, and infrastructure in the downstream valley. Later, in the 1980s, a mudflow protection dam with a tunnel spillway was constructed at the breach site, partially restoring the Yesik Lake.

The Verny Earthquake of June 9, 1887 (M = 7.3, focal depth = 20 km, horizontal rupture length = = 35 km) caused numerous surface ruptures and landslides, with a total displaced volume estimated at 440 million m³, some individual landslides exceeding 50 million m³ [9, 11].

Among the most catastrophic consequences of the earthquake, as documented by I. V. Mushketov, were landslides in the Aksay, Kokcheka, and Prokhodnaya (Ulken Almaty) River basins, as well as in Koturbulak (figure 5).

The Akzhar rockfall, with a volume of 60 million m³, occurred in the Aksay River basin, forming two major rupture zones with an escarpment and destroying a lake that previously existed downstream in the valley. The collapsed masses, largely composed of biotite granites and diorites, moved into the main Aksay River valley, creating a temporary dam, which later breached, generating a powerful mudflow that traveled more than 20 km across the piedmont alluvial fan.

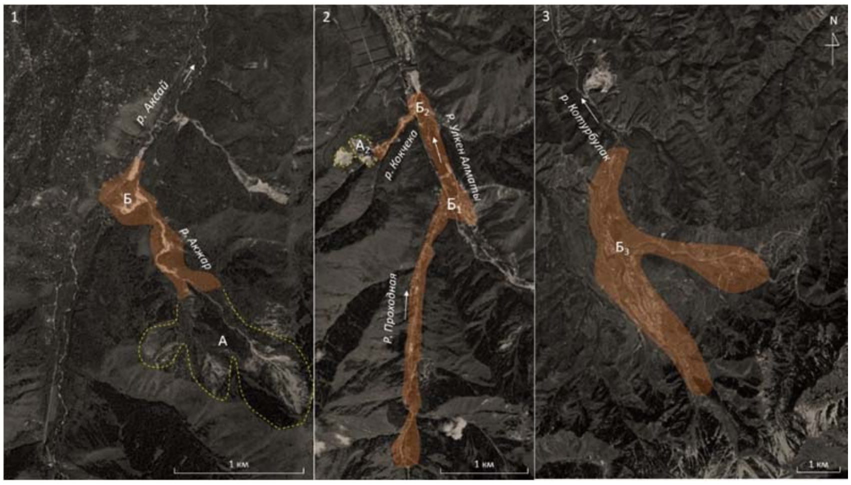

Figure 5 – Landslides triggered by the June 9, 1887 earthquake: *1* –Akzhar landslide (*A* – escarpment and rupture zone, *B* – landslide body, *C* – secondary debris flow zone) [8]; *2* – Landslides in the Ulken Almaty River basin (A^2 – Kokcheka tributary escarpment and rupture zone, B^2 – landslide body, B^1 – Prokhodnaya River landslide body); *3* – Landslide in the Koturbulak River basin (A^3 – rupture zone, B^3 – landslide body).
The landslide boundaries were delineated based on markers specified in [9]

Large landslides also occurred in the Ulken Almaty River valley, on its small left tributary, Kokcheka (24 million m^3), as well as in the Prokhodnaya River basin (54 million m^3). In the Koturbulak River basin, a landslide of 56 million m^3 was formed.

Today, the areas occupied by these ancient landslide bodies have been developed and are used for various economic and social purposes, which raises significant concerns. It is well known that strong earthquakes in this region may reactivate these old landslides, with all the associated negative consequences.

According to topographic and geodetic surveys conducted by F. Brusnitsyn one month after the earthquake, it was possible to reconstruct the conditions in the Aksay River valley as they were on June 9, 1887 [9]. Scheme 1 (figure 6) shows that on this date, a significant portion of the Aksay River valley was filled with liquefied landslide deposits.

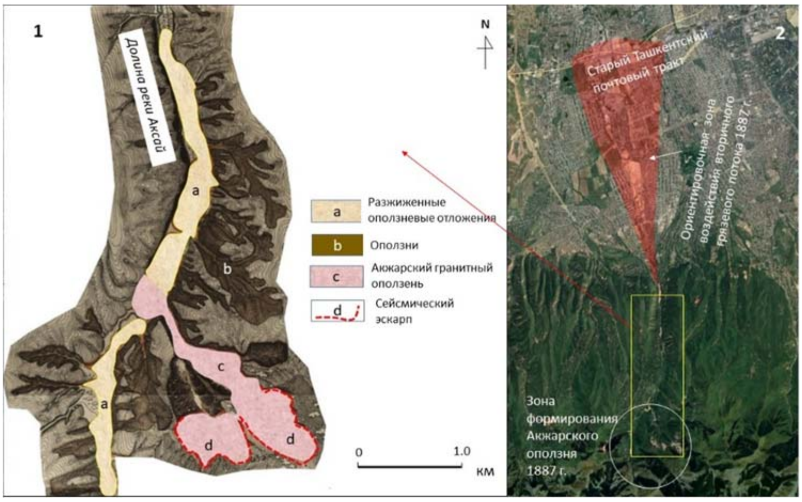

Figure 6 –
Conditions in the Aksay River valley
on June 9, 1887

Eyewitness accounts indicate that the river's flow was completely blocked and was only restored approximately 20-22 hours later, after the breach of the temporary dammed lake. A rough estimate suggests that during this period, the temporary reservoir could have accumulated 0.7–0.8 million m^3 of river water.

The sudden water release inevitably led to the movement of unstable liquefied masses, resulting in the formation of a large-scale mudflow, which traveled over 15 km across the gentle piedmont plain. The mudflow covered the old Tashkent postal road for approximately 8 km (scheme 2, figure 6). The mass of mud, spreading over a vast area, destroyed all bridges and rendered the Tashkent road impassable, severing communication between Verny (Almaty) and Kaskelen (Mushketov I., 1890).

Talgar. In the Talgar River valley, at its emergence onto the alluvial fan, traces of an ancient giant mudflow have been identified. These traces remain visible on the right slope of the valley in the form of a distinct boulder line, with some sections located 75 m above the riverbed (figure 7).

Figure 7 –
Traces of an ancient giant debris flow in the Talgar River valley:
A – maximum debris flow level on the right valley slope;
B, *C* – large boulders (diameter >5 m) marking the maximum level of the ancient mudflow

Using modern satellite imagery, it was possible to reconstruct the approximate valley cross-sections at maximum elevations and estimate the approximate cross-sectional area of the ancient mudflow. Based on these rough approximations, the cross-sectional area was determined to be approximately 30,000 m^2, which, given the previously mentioned flow depth, results in staggering peak discharges exceeding 500,000 m^3/s or more (figure 8, table).

Figure 8 – The section of the Talgar River valley where the giant ancient mudflow exited the valley. The marked features include the maximum flow level on the valley slopes, cross-sectional profiles, averaged cross-section, and an 8.5 million m^3 mudflow protection dam constructed in 2005 [10]

Drone survey data for cross-sections in the Talgar River valley

Points	Longitude	Latitude	Elevation (m a.s.l.)	Points	Longitude	Latitude	Elevation (m a.s.l.)
Profile 1							
1	77°12'33,330" E	43°15'37,405" N	1192.41	10	77°12'44,911" E	43°15'39,633" N	1120.75
2	77°12'34,735" E	43°15'37,680" N	1176.63	11	77°12'46,316" E	43°15'39,770" N	1119.83
3	77°12'35,866" E	43°15'37,817" N	1172.39	12	77°12'47,653" E	43°15'40,010" N	1119.07
4	77°12'36,996" E	43°15'38,091" N	1150.23	13	77°12'48,920" E	43°15'40,215" N	1120.14
5	77°12'38,333" E	43°15'38,296" N	1138.92	14	77°12'50,359" E	43°15'40,558" N	1130.40
6	77°12'39,463" E	43°15'38,502" N	1131.86	15	77°12'51,661" E	43°15'40,935" N	1156.82
7	77°12'40,800" E	43°15'38,845" N	1126.22	16	77°12'52,998" E	43°15'41,106" N	1162.59
8	77°12'42,102" E	43°15'39,084" N	1125.82	17	77°12'54,128" E	43°15'41,312" N	1177.16
9	77°12'43,369" E	43°15'39,324" N	1122.45	18	77°12'55,225" E	43°15'41,551" N	1192.66
Profile 2							
1	77°13'00,040" E	43°15'34,459" N	1209.99	10	77°12'47,054" E	43°15'32,026" N	1135.30
2	77°12'58,053" E	43°15'34,082" N	1191.94	11	77°12'45,889" E	43°15'31,820" N	1134.40
3	77°12'56,408" E	43°15'33,808" N	1177.03	12	77°12'44,484" E	43°15'31,512" N	1133.16
4	77°12'55,003" E	43°15'33,602" N	1158.55	13	77°12'43,148" E	43°15'31,272" N	1137.20
5	77°12'53,736" E	43°15'33,362" N	1155.11	14	77°12'41,812" E	43°15'31,067" N	1137.83
6	77°12'52,262" E	43°15'33,122" N	1144.55	15	77°12'40,612" E	43°15'30,792" N	1143.43
7	77°12'50,994" E	43°15'32,814" N	1139.30	16	77°12'39,276" E	43°15'30,518" N	1166.14
8	77°12'49,692" E	43°15'32,540" N	1135.74	17	77°12'37,974" E	43°15'30,347" N	1180.38
9	77°12'48,390" E	43°15'32,300" N	1133.13	18	77°12'36,535" E	43°15'29,999" N	1207.01
Profile 3							
1	77°12'39,499" E	43°15'19,755" N	1244.11	10	77°12'53,684" E	43°15'22,541" N	1156.01
2	77°12'41,107" E	43°15'20,074" N	1223.20	11	77°12'55,025" E	43°15'22,828" N	1155.33
3	77°12'42,994" E	43°15'20,439" N	1195.99	12	77°12'56,387" E	43°15'23,072" N	1159.39
4	77°12'44,715" E	43°15'20,773" N	1170.11	13	77°12'57,788" E	43°15'23,355" N	1176.20
5	77°12'46,509" E	43°15'21,122" N	1151.90	14	77°12'58,944" E	43°15'23,560" N	1185.08
6	77°12'48,180" E	43°15'21,456" N	1154.45	15	77°13'00,088" E	43°15'23,804" N	1201.11
7	77°12'49,686" E	43°15'21,749" N	1153.97	16	77°13'10,244" E	43°15'24,010" N	1217.13
8	77°12'51,186" E	43°15'22,047" N	1153.41	17	77°13'20,015" E	43°15'24,151" N	1228.01
9	77°12'52,512" E	43°15'22,304" N	1151.24	18	77°13'20,735" E	43°15'24,305" N	1238.29

A key distinguishing feature confirming this event as a mudflow rather than a landslide is the presence of boulder deposits along the upper edge of the flow. Given the relatively low channel gradients, a landslide would have completely filled the river valley with its mass, which is not observed in this case. There are no historical records of such a colossal mudflow catastrophe, suggesting that the event occurred thousands of years ago.

The aftermath of this prehistoric mudflow includes the formation of an enormous alluvial fan, now occupied by the city of Talgar and numerous other settlements across an area of at least 400 km^2.

The exact genesis of this event remains speculative, but the regional conditions, particularly its proximity to one of the largest glaciated high-altitude centers in the Ile Alatau (Talgar Peak, 4979 m), suggest the involvement of both seismic and glaciological factors. This region is characterized by active seismic faults and extensive glaciation, which could have triggered ice-rock avalanches that transformed into mudflows, similar to the 1970 Huascarán event in Peru [13, 14].

Importantly, arguments presented by the authors regarding this ancient mudflow were not considered during the design of the mudflow protection dam on the Talgar River, as no existing engineering regulations accounted for such extreme events.

Conclusion. Over the past several millennia, the geological history of the Ile Alatau has been shaped by massive landslides and mudflow disasters triggered by strong earthquakes.

There remains the possibility of a breaching of the dammed lakes in the event of the collapse of large seismogenic landslides into the water area and further negative developments with the displacement of water from the basins. This study has established that landslide deposits formed by major seismic events have been extensively developed, with dozens of major recreational, commercial, and infrastructure projects now operating in mountain valleys. Many of these structures are located in areas of heightened landslide and mudflow risk, often without proper consideration of the geological hazards.

A particularly critical finding from this research is the discovery of the ancient giant mudflow in the Talgar River valley, which occurred several thousand years ago. The scale of this event – in terms of cross-sectional area, average depth, and peak discharge – surpasses all known mudflows in the Ile Alatau. Irrefutable evidence of this ancient mudflow includes maximum flow level markers on the valley slopes, represented by large boulders deeply embedded in the ground. The mudflow formed a massive alluvial fan, which was later inhabited and developed by settlements, agricultural land, and infrastructure.

Currently developed engineering protection plans for the region do not account for seismogenic landslides and mudflows. This highlights an urgent need to develop methodologies for assessing and calculating the quantitative characteristics of seismogenic landslides and mudflows, making it one of the most pressing research priorities.

When conceptually formulating the authors' vision of the development pathways for a methodology to assess the quantitative characteristics of seismogenic landslides and debris flows, several important aspects should be noted. At present, predictive quantitative assessments of seismogenic landslides and debris flows are lacking due to the high uncertainty surrounding the occurrence of such events. However, by employing the method of analogs, it becomes possible to identify potential locations and scales of seismogenic phenomena in the event of a recurrence of large earthquakes.

For instance, the Verny earthquake of 1887 (M = 7.3) triggered widespread seismogenic landslides and debris flows, with a total volume amounting to 440 million cubic meters. The main seismotectonic dislocations occurred along active tectonic faults, the locations of which are well known and have been mapped. Therefore, in the case of large earthquakes comparable to or exceeding the Verny event in magnitude, the occurrence of widespread landslides and debris flows can be expected. This, in turn, enables the modeling of such phenomena and the formulation of long-term forecasts.

Large-scale landslides may occur as a result of seismotectonic dislocations on the slopes of mountain river valleys. Particularly hazardous situations may arise from river blockages and the collapse of large volumes of material into mountain lakes, potentially leading to lake outburst floods.

Strong earthquakes can also trigger glacier collapses or accelerate glacial surges. Empirical evidence demonstrates that such phenomena can be identified through the use of monitoring techniques and remote sensing methods.

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ІЛЕ АЛАТАУЫНДАҒЫ СЕЙСМОГЕНДІК ҚҰБЫЛЫСТАР

Аннотация. Іле Алатауының салыстырмалы түрде жаңа геологиялық тарихында ірі жер сілкіністері жер бетінің бұзылуына және орасан зор сейсмогендік көшкіндер мен селдерге әкелді. Авторлардың осы оқиғаларды ретроспективті талдауы және қолданылған заманауи зерттеу әдістері аймақтағы сейсмогендік көшкіндер мен сел тасқындарының жасын негізді түрде бағалауға және олардың ауқымын бағалауға мүмкіндік берді, бұл тау бөктерлерін одан әрі игеру кезінде осындай ауқымды апаттарды ескеру қажеттігін көрсетеді. Өңірдегі аумақтардың, объектілердің және тұрғындардың қауіпсіздігін зерттеу және бағалау кезінде облыстың Қазақстанның ең сейсмикалық белсенді аймағында орналасқанын және күшті жер сілкінісі салдарынан болатын алып көшкіндер мен сел тасқындарының қаупі объективті шындық екенін ескеру қажет. Алдыңғы зерттеулердің нәтижелерін талдау осы табиғи апаттардың уақытында және олардың сандық сипаттамаларын бағалау әдістерінде олқылықтарды анықтады. Сонымен қатар, ұшқышсыз ұшатын аппараттардың (ұшқышсыз ұшу аппараттарының) мәліметтерін, заманауи бағдарламалық кешендерді, сондай-ақ қатты ағынды және сел шөгінділерін бағалаудың морфометриялық әдісін пайдалана отырып, жүздеген және мыңдаған жылдар бұрын болған ежелгі табиғи апаттардың сандық сипаттамалары нақтыланды. Бұрын әртүрлі басылымдарда жарияланған сирек кездесетін апатты геологиялық құбылыстардың мерзімі бағаланды. Зерттелетін аумақты игеру кезінде ерекше сирек кездесетін сейсмогендік құбылыстар осы құбылыстар туралы жеткілікті білімнің жоқтығынан және жобалауға қойылатын нормативтік талаптарда олқылықтардың болуына байланысты кешенді инженерлік қорғау сызбаларында есепке алынбағаны анықталды. Анықталған олқылықтарды толтыру үшін сирек кездесетін сейсмогендік құбылыстарды одан әрі зерттеу қажет.

Түйін сөздер: жер сілкінісі, көшкін, құлау, сел, табиғи апаттар.

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РЕДКИЕ СЕЙСМОГЕННЫЕ ЯВЛЕНИЯ В ИЛЕ АЛАТАУ

Аннотация. В относительно недавней геологической истории Иле Алатау в результате крупных землетрясений произошли индуцированные ими нарушения земной поверхности и огромные по своим масштабам сейсмогенные оползни и сели. Выполненный авторами ретроспективный анализ указанных событий, применённые современные методы исследований позволили обоснованно оценить возраст сейсмогенных оползней и селей в регионе, а также оценить их масштаб, что предполагает необходимость учета подобных крупномасштабных катастроф при дальнейшем освоении предгорных территорий. При выполнении исследований и оценок безопасности территорий, объектов и населения в регионе необходимо принимать в расчет то, что район расположен в наиболее сейсмоактивной области Казахстана и риск образования гигантских оползней и селей, вызванных сильными землетрясениями, является объективной реальностью. Анализ результатов предыдущих исследований выявил пробелы, касающиеся времени возникновения указанных природных катастроф, а также методов оценки их количественных характеристик. Кроме того, с использованием данных съемки с беспилотных летательных аппаратов (БПЛА), современных программных комплексов, а также морфометрического метода оценки твердого стока и селевых отложений уточнены количественные характеристики древних природных катастроф, произошедших сотни и тысячи лет назад. Оценена датировка редких катастрофических геологических явлений, ранее опубликованных в различных изданиях. Установлено, что при освоении исследуемой территории в схемах комплексной инженерной защиты не учитывались выдающиеся редкие сейсмогенные явления из-за отсутствия достаточных знаний об этих явлениях и наличия пробелов в нормативных требованиях к проектированию. Для восполнения выявленных пробелов необходимы дальнейшие исследования редких сейсмогенных явлений.

Ключевые слова: землетрясение, оползень, обвал, селевой поток, природные катастрофы.