

Regularities of Seismicity of Western and Central Uzbekistan (Southwestern Part of Western Tien-Shan Region)

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Abstract

The paper discusses the spatial and temporal distribution of seismic activity in the southwestern part of the Western Tien Shan. The study identifies four groups of strong earthquakes that occurred in Western and Central Uzbekistan. The regularity of redistribution of the accumulated tectonic energy in the form of shuttle migration of seismicity with the recurrence rate of a group of strong earthquakes has been revealed. The synchronicity of periods of seismic activation of the Western Tien Shan (regional structure) and the Asian part of the Mediterranean-Asian seismic belt (structure of a large-regional scale) was found. At the same time, deviations from synchronicity are noted in the form of delays in the periods of seismic activation between the considered structures. The seismicity study revealed a deviation from the regularity of grouping of strong earthquakes in the seismic regime of the region. This was observed in the Gazli earthquakes. The strongest triple Gazli earthquakes of 1976 and 1984 with $M = 7.0 - 7.3$ were preceded by natural and technogenic triggers. Natural triggers included active fracturing (large fractures up to 100 km in length) in the north of Tamdybulak area, the absence any of tangible earthquakes in the epicentral area of Gazli for more than 40 years, and the appearance of small mud volcanoes—griffins before a strong earthquake. The technogenic triggers included a 40-year gas pumping at the Gazli fields and two underground nuclear explosions in 1966 (#273) and 1968 (#142) produced near the epicenter of the tectonic Gazli earthquakes of 1976 and 1984.

Keywords

Strong Earthquakes, Shuttle Migration of Seismicity, Cyclic Recurrence of Large Earthquakes, Natural and Technogenic Triggers

1. Introduction

The paper considers the development of regional seismicity in the Western Tien-Shan and the Turan platform [1]-[8]. Uzbekistan is located on the Turan platform and is conventionally divided by geologists into Western, Central, and Eastern Uzbekistan. The seismicity of Uzbekistan territory is also considered in the context of the geolocation of Western, Central and Eastern Uzbekistan.

In terms of seismicity, Eastern Uzbekistan is one of the highly dangerous seismic territories in Uzbekistan. In this part of Uzbekistan, earthquakes with seismic intensity $I_0 = 9 - 10$ balls (by MSK-64 Scale) can occur. The last strong Chatkal earthquake occurred on November 02, 1946, $M = 7.6$, $I_0 = 9 - 10$ balls, in the Talas-Fergana fault zone. At the southern end of this giant Talas-Fergana fault, in 1902 there was a Kashgar earthquake with $M = 8.1$, $I_0 = 10$ balls [9] [10].

Figure 1 shows distribution of the epicenters of earthquakes with $M \geq 3.5$ that occurred in Central Asia in the period from 2000 BC to 2017 AD [9] [11] [12] [13]. The important elements shown on **Figure 1** are two almost latitudinal bands of epicenters concentration (marked in black), clearly distinguished in the south. These bands indicate the location of the Pamir-Hindu-Kush deep-focus earthquakes, reaching depth of up to 300 km and indicate the place of intracontinental subduction of the Eurasian and Indian tectonic plates. Analysis of the Catalog of strong earthquakes showed that Eastern Uzbekistan acts as a single block of the earth's crust, where strong earthquakes with a magnitude of $M = 5.0$

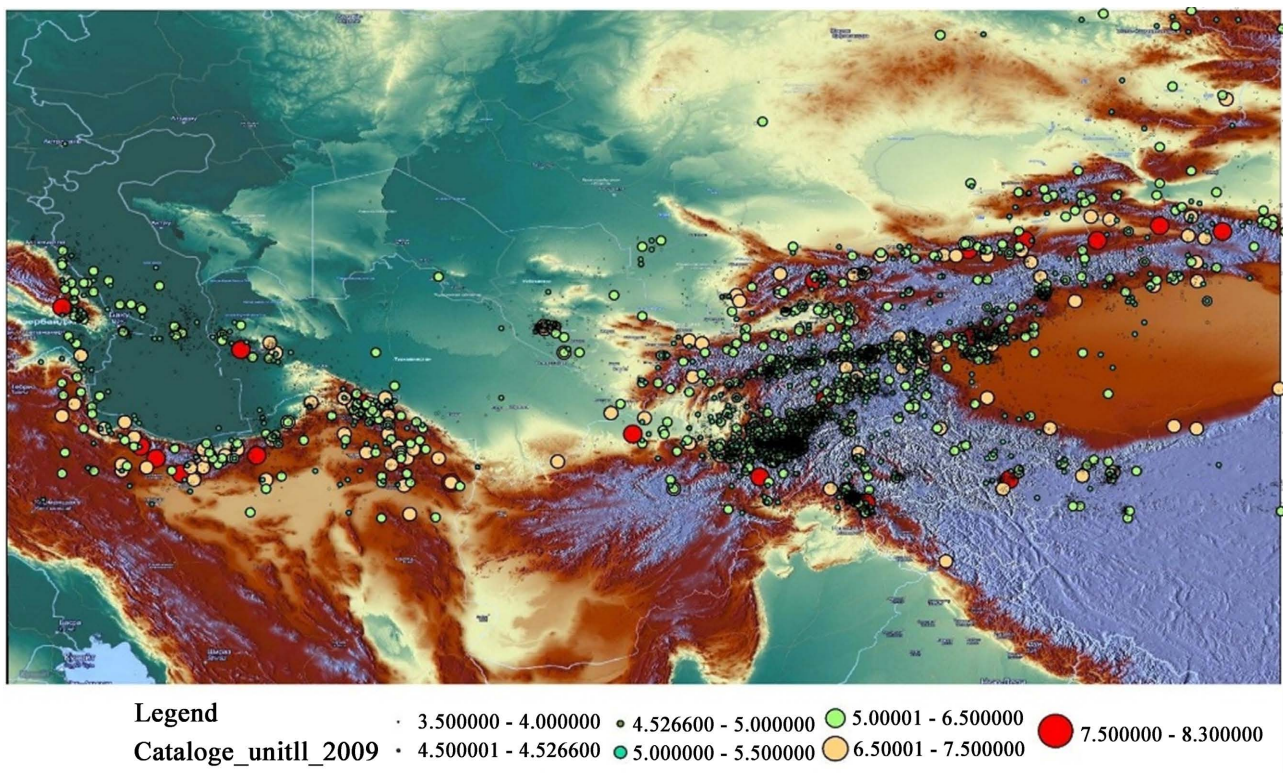


Figure 1. Map of epicenters of earthquakes with magnitude of $M \geq 3.5$ in Central Asia during 2000 BC - 2009 AD [Usmanova, M.T. and Shukurov, Z.F., 2016].

$\div 6.9$ are located in the area seismogenic zones, *i.e.* in zones of regional faults [14] [15] [16]. At the same time, earthquakes with a magnitude of $M = 7.0 \div 7.5$ are located at the intersections of large faults.

Regarding Western and Central Uzbekistan, the analysis of the Catalog of strong earthquakes and studies of the regional seismicity revealed that strong earthquakes with a magnitude of $M \geq 5.0$ are distributed unevenly. The epicenters of these strong earthquakes have signs of grouping in space and time and are distinguished into four groups of strong earthquakes (Table 1) [9] [10] [11] [12] [13]. According to the seismic activity signs, the study region also has divided into two parts, Western and Central Uzbekistan. Western and Central Uzbekistan, including the Central Kyzyl Kum desert, are classified as dangerous seismically active regions of Uzbekistan. In these territories, in the distant past, there were Bukhara earthquakes of 942, 1390, 1821 and 1822 with magnitude of $M \sim 7.0$ and nowadays, the well-known catastrophic Gazli earthquakes of 1976 and 1984 with magnitude of $M \geq 7.3$ ($I_0 = 9 - 10$ balls) [4] [5] [9] [15].

The study area is located in the southwestern part of the Western Tien-Shan and the Turan platform, where seismic activity has been controlled by the system of deep tectonic faults of Western Tien-Shan [1] [3] [14].

The first studies of the frequency of strong earthquake recurrence in the Western Tien-Shan were carried out by R.N. Ibragimov and K.N. Abdullabekov [15], who identified seven seismotectonic regions and analyzed their manifestation of seismic activity. The findings revealed that in all seismotectonic areas, strong earthquakes manifested cyclically, with a distinctive time of $T = 40_{\text{act.phase}} \pm 10 - 15$ years and $T = 40_{\text{pass.phase}} = 25 - 30$ years [15].

2. The Spatial-Temporal Distribution of Earthquakes in Western and Central Uzbekistan

2.1. The Main Regularities of Seismic Activation

As was discussed above, the analysis of the Catalog of strong earthquakes in the study area (Western and Central Uzbekistan) showed that strong earthquakes with a magnitude of $M \geq 5.0$ are unevenly distributed and the epicenters of these strong earthquakes have signs of spatial and temporal grouping [9] [10] [11] [12] [13].

The Bayesian method was used to calculate the probabilities of quiescence and activation in two neighboring regions, Western and Central Uzbekistan [17]. During the statistical analysis, the probability calculations were not carried out for the 1st group due to the lack of information. Data on historically strong earthquakes occurred within the period specified for 1st group have not been preserved for the following reasons:

- Possible skipping of strong earthquakes due to erosion/aeolian/denudation typical for the deserts and steppes of Western Uzbekistan (Kyzyl-Kum, partly the Karakum deserts);
- Climatic anomalies that erased the traces of past paleohistorical seismic shocks;

Table 1. Distribution of groups of strong earthquakes in time and over Western and Central Uzbekistan.

No.	Group	Seismic activity period	Western Uzbekistan (West)	Central Uzbekistan (East)	Probability onset of seismic activity with earthquake groups P(t)
1	I	900-1400	Strong Bukhara earthquakes of 942 and 1390 with $M \approx 7.0$	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	-
2		1400-1818 (1800-1818)	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Strong Samarkand earthquakes of 1490, 1799, 1817 and 1818 with $M = 5.0 - 6.1$	-
3	II	1821-1892	Strong Bukhara and Kyzyl-Kum earthquakes of 1821, 1822 and 1892 with $M = 6.4 - 7.0$	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Probability of occurrence of earthquakes in Western Uzbekistan: $P(t) = 2.941\%$
4		1897-1923	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Strong Uratyube earthquakes of 1897, 1897 and 1902; Matchin earthquake of 1923 with $M = 5.7 - 6.7$	Probability of occurrence of earthquakes in Central Uzbekistan: $P(t) = 2.855\%$ Probability of occurrence of earthquakes in Central Uzbekistan if there are no earthquakes in Western Uzbekistan: $P(t) = 2.941\%$
5	III	1928-1934	Earthquakes of 3 January 1928, 11 July 1928 and 1929 year; Tamdybulak earthquakes of 1932 and 1934 year with $M = 5.2 - 6.2$	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Probability of occurrence of earthquakes in Western Uzbekistan: $P(t) = 10.526\%$
6		1940-1966	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Earthquake of 1940, Bakhmal-(1) earthquake of 1955, Koshtepa earthquake of 1965 and Tashkent earthquake of 1966 with $M = 5.2 - 5.5$	Probability of occurrence of earthquakes in Central Uzbekistan: $P(t) = 9.418\%$ Probability of occurrence of earthquakes in Central Uzbekistan if there are no earthquakes in Western Uzbekistan: $P(t) = 10.526\%$
7	IV	1968-1984	Kyzyl-Kum earthquakes of 13 and 14 March 1968 y.; Gazly earthquakes of 8 April 1976, 17 May 1976 and 19 March 1984 with $M = 5.1 - 7.3$	Seismic quiescence; absence of strong earthquakes with $M \geq 5.0$	Probability of occurrence of earthquakes in Western Uzbekistan: $P(t) = 6.122\%$
8		2013-2017	Seismic quiescence, strong earthquakes with $M \geq 5.0$ absence	Marjanbulak earthquake of 2013, Kitab earthquake of 2016 and Bakhmal-(2) earthquake of 2017 with $M = 5.1 - 6.2$	Probability of occurrence of earthquakes in Central Uzbekistan: $P(t) = 5.748\%$ Probability of occurrence of earthquakes in Central Uzbekistan if there are no earthquakes in Western Uzbekistan: $P(t) = 6.122\%$

- Lack of settlements.

For the other three groups, the probabilities for the prohibition of seismicity

quiescence/activity at certain periods were calculated. Distribution of groups of strong earthquakes with magnitude $M \geq 5.0$ in time and over Western and Central Uzbekistan for the 1821-2017 is provided in **Table 1**.

The Bayesian methodology was used to calculate the probability of earthquake occurrence in time (years) [17]. Moreover, if there were two earthquakes in one year, then this year was calculated as one year with earthquakes, since onset of the time of seismic activity is considered. At the same time, the calculations included the impact of the seismic activities of two regions, Western Uzbekistan and Central Uzbekistan. In general, the calculations confirmed the periodic onset of seismic activity, leading alternately to the formation of strong earthquakes groups in Western and Central Uzbekistan.

According to the Gutenberg-Richter earthquake recurrence law, the recurrence periods of earthquakes with different magnitudes are determined by the logarithmic values of the seismic cycle duration. Using this methodology, the following estimates of the earthquake recurrence periods were calculated for the Western Tien-Shan (Tseis.cycle) [18] [19]:

- earthquakes with $M \geq 8.0$ - Tseis.cycle = 1000 ± 283 years;
- earthquakes with $M \geq 7.0 \leq 7.5$ - Tseis.cycle = 154.0 ± 51.3 years;
- earthquakes with $M \geq 5.5 \leq 6.1$ - Tseis.cycle = 49.0 ± 15.6 years;
- earthquakes with $M \geq 5.0$ - Tseis.cycle = 12.3 ± 2.7 years.

It is noted that the closer the study period is to the time of continuous operation of seismic stations in the region, the better the probabilistic estimates of earthquakes' onset.

Comparison of the seismic activity of Western and Eastern regions (**Table 1**) reveals the regularity of the alternate redistribution of the accumulated tectonic energy between these regions. As if some kind of "pendulum" operating on the "domino" principle creates a group of strong earthquakes around one strong earthquake with magnitude of $M = 5.1 \div 7.3$. Seismic activation at regular intervals migrates from west to east in the central part of Uzbekistan and back to the west. During the seismic activity of Western Uzbekistan, a seismic quiescence has observed in the east of Central Uzbekistan. Then seismic activity migrates to the east, and a seismic quiescence occurs in the west. Such cyclicity of seismic activity migration is shuttle. Provided that, the energy threshold, *i.e.* the magnitude of strong earthquakes, in Western Uzbekistan is one unit of magnitude higher than in the east of Central Uzbekistan [10]. The "shuttle" migration of seismicity with 18 - 22 km/year in Eastern Uzbekistan was identified and studied by scholars [5] [7] [20] [21].

2.2. Connection of Seismic Activity of Western and Central Uzbekistan with Large Regional and Planetary Seismotectonic Structures

It is important to consider how the identified "shuttle" migration of seismic activity in Western and Central Uzbekistan correlates with large regional and planetary seismotectonic structures.

The researchers [13] [15] [18] [22] [23] studied the seismicity of the Central Asia region considering the recurrence of seismic activity cycles in the Asian part of the Mediterranean-Asian seismic belt (**Figure 2**). They note that the Central Asian region has entered a seismically active phase since 2007, which may last until 2023. At this time, the probability of strong earthquakes in this region remains relatively high.

Strong earthquakes that occurred along the Mediterranean-Asian seismic belt seismically active phase with cycle T duration cycle of ~17 years, began in 2008 with an earthquake in the Aegean Sea (Greece) with magnitude of $M = 7.3$. Then, on August 24, 2016, the earthquake with $M = 6.2$ occurred in Accumoli (Italy). In 2017, the earthquake with $M = 6.5$ occurred on the islands of Greece (**Figure 2**). Recently, on October 30, 2020, a strong earthquake with $M = 6.7$ (USGS $M = 7.0$) occurred in the Aegean Sea, in the Izmir province (Turkey). This indicates the ongoing seismic activity of the seismic belt.

The next seismic activity of 2007-2023, experienced by the Central Asian region, is reflected in Uzbekistan through a series of strong earthquakes during 2011-2017, with a general increase in the seismic background. During this period, in the Western Tien-Shan where located Uzbekistan, several strong earthquakes occurred: Kansk earthquake of 20.07.2011 with magnitude of $M = 6.3$, $I = 8$ balls (by MSK-64 Scale); Tuyabuguz earthquake of 2013 with magnitude of $M = 5.6$, $I = 7$ balls; Marzhanbulak earthquake of 2013 with magnitude of $M = 6.3$, $I = 8$ balls; Kitab earthquake of 2016 with magnitude of $M = 5.1$, $I = 5$ balls; Bakhmal earthquake of 2017 with magnitude of $M = 5.1$, $I = 6 - 7$ balls [24] [25] [26].

A comparison of seismicity activity periods in the region regarding the Asian part of the Mediterranean-Asian seismic belt (**Figure 2**) is presented in **Table 2**.

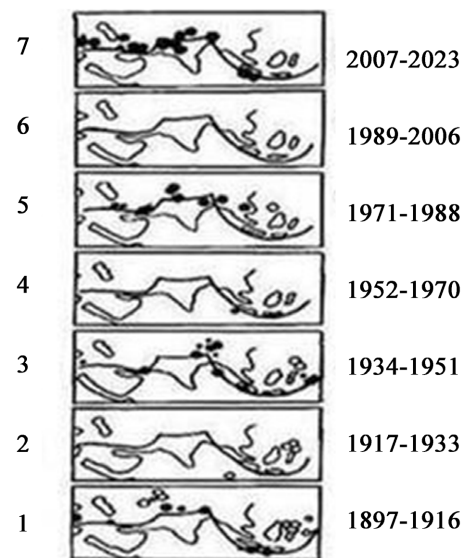


Figure 2. Peculiarities of manifestation of seismicity of Asian part of the Mediterranean—Asian seismic belt (up to 1970 according to [K. Mogi, 1974]; from 1971 to present days [K.N. Abdullabekov, M.T. Usmanova, 2003, 2008, 2016]).

Table 2. Comparative characteristics of periods of seismic activation in the Western Tien-Shan and the Asian part of the Mediterranean—Asian seismic belt.

No.	Periods of seismic activity in the Asian part of the seismic belt (Figure 2)	Periods of seismic activity in Western Tien-Shan region (Table 1)	Note
1	1897-1916(1)*	1897-1923	Relatively synchronous
2	1917-1933(2)*	1928-1934	Seismic periods activation is somewhat late
3	1952-1970(4)*	1940-1966	Seismic periods activation is somewhat late
4	1971-1988(5)*	1968-1984	Relatively synchronous
5	2007-2023(7)*	2013-2017	Relatively synchronous

Note: (1)*—numbers of stages of seismic cycles.

As shown in **Table 2**, there is a synchronicity of periods of seismic activation of two structures: Western Tien-Shan (regional) and Asian part of the seismic belt (large regional, planetary scale). Deviations from synchronicity in the form of a lag in the seismic activation period of 1952-1970/1940-1966 can be explained by the low magnitude level $M \sim 5.3$ of the main earthquake of the group, *i.e.* the fact that these earthquakes were ordinary in relation to events of a planetary scale.

2.3. Deviations from the Identified Regularities of Seismic Activity of the Study Area

During the data collation of the Catalog of Earthquakes of Uzbekistan, besides the four groups of strong earthquakes described above, the strong earthquakes with magnitude of $M \geq 5.0$, which did not fit into the established regularities of the seismic regime of the studied territory, were identified. These earthquakes include the well-known Gazli earthquakes. In this regard, the possible technogenic and natural causes of deviation from the regional seismicity were analyzed.

According to the Catalog of nuclear explosions, created at the Kazakhstan National Data Center [<https://www.kndc.kz/>], the dates of two nuclear test explosions carried out in Uzbekistan were identified: 1) 30 September 1966 with $M = 5.1$ (N 273) and 2) 21 May 1968 with $M = 5.1$ (N 142). Subsequently, seismic events that showed deviations from the regional seismic regime possibly were associated to these nuclear explosions.

A possible connection between the activity of strong earthquakes and nuclear explosions through the impact of nuclear explosions on the geodynamic regime of the region, as well as through the impact of other technogenic and natural events, cannot be ruled out. Therefore, the last three strong Gazli earthquakes of 1976 and 1984 with a magnitude of up to $M = 7.3$, which had a tectonic nature, should be also considered in the region. It should be noted that detailed work was carried out on the initiating effect of UNEs (underground nuclear explo-

sions) produced at the Semipalatinsk, Novaya Zemlya, and Nevada test sites on the earthquakes in Central Asia. The most pronounced manifestations of the Pamir-Hindu-Kush and Tien-Shan earthquakes were the response of seismicity to UNE in the Central Asia region [27].

The northern part of Western Uzbekistan in the 50s of the last century was considered to be weakly seismic, and the Gazli earthquakes that occurred were a kind of surprise [1] [3] [4] [5] [14]. However, a retrospective analysis of the geological, geophysical and seismological data of the region made it possible to assume that geodynamic processes and technogenic events that have taken place over the past 100 years in the Gazli region could create preconditions for the Gazli earthquakes [10].

Among these prerequisites the most significant are:

- 1) Activation of fracturing with giant cracks up to 100 km long, up to 1 m wide, and 1 - 2 m deep in the area of the Tamdybulak village in 1965 (*natural trigger*).
- 2) Absence of tangible earthquakes for more than 40 years in the epicentral region of Gazli earthquakes (*natural trigger*).
- 3) Appearance of linearly built small mud volcanoes—“griffins” in the epicentral area within 2 - 3 years (*natural trigger*).
- 4) Active and continuous 40-year gas pumping in the group of Gazli fields (*technogenic trigger*).
- 5) Underground nuclear explosions (*technogenic trigger*).

3. Conclusions

The following main regularities of the seismic regime of Western and Central Uzbekistan have been identified:

- 1) Four groups of strong earthquakes with $M \geq 5.0$ have been identified, which occurred in 1821-2017 and united around the “main” seismic shock with

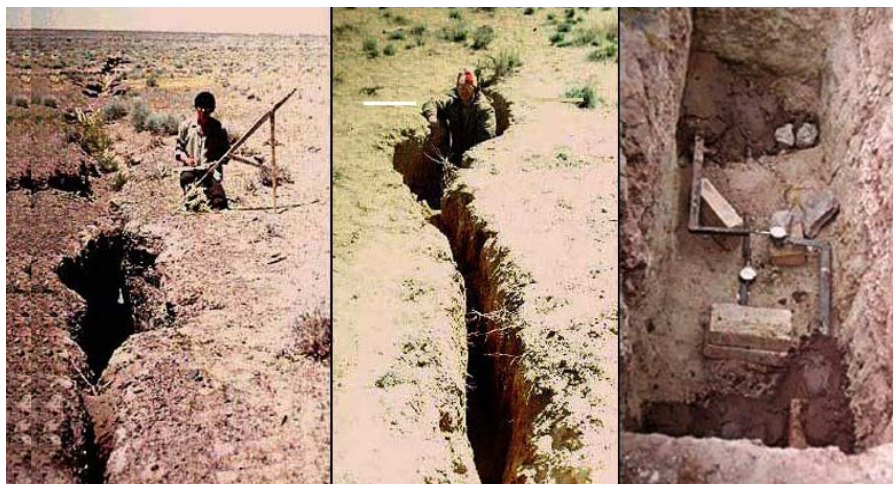


Figure 3. Kyzyl-Kum Desert, 1973. Monitoring of the deformation process of preparation the largest of Gazli earthquakes 1976, 1984, $M = 7.0 - 7.3$ on the Turan plate (from the archive of V.I. Ulomov).

$M = 5.1 - 7.3$. During the seismic activity of Western Uzbekistan, in the east of Central Uzbekistan there is a seismic quiescence and a return by shuttle migration of seismic activity to the east of Central Uzbekistan. In the same period, a seismic quiescence is observed in Western Uzbekistan. The shuttle migration of seismic activity in the region is periodically repeated by seismic cycles.

2) During the active seismic phase with cycle duration $T_{\text{length cycle}} \sim 17 - 18$ years, a group of strong earthquakes has formed and occurs. The duration of the passive phase cycle is also $T_{\text{length cycle}} \sim 17 - 18$ years. The energy threshold, the magnitude of strong earthquakes in Western Uzbekistan is one unit of magnitude higher than in the east of Central Uzbekistan.

3) Heterogeneous composition of shocks in groups complicates interpretation. There is a “main” strong shock with different magnitude values (from $M = 5.0$ to $M = 7.3$) and with varying return periods.

4) On the southwestern Western Tien-Shan (Western and Central Uzbekistan), there is a periodic recurrence of a group of strong earthquakes with the main shock of magnitude $M \geq 6.5$, which occur approximately synchronously with planetary seismicity processes.

5) Deviations from the general regularity of grouping Gazli strong earthquakes in the seismic regime of the region, associated with natural and technogenic events, were found. Forty years of constant gas pumping in the Gazli fields, underground nuclear explosions, crack formation processes, and absence of tangible earthquake in epicentral region of Gazli earthquakes for more than 40 years could become powerful triggers of three Gazli tectonic earthquakes of 1976 and 1984 with $M = 7.0, 7.2$ and 7.3 .

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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