

RESEARCH ARTICLE

A case study of an earthquake swarm in Uzbekistan

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ABSTRACT

The article presents the results of a study of a swarm of weak earthquakes that occurred in one of the regions of Uzbekistan. The earthquake swarm occurred in the western part of the Fergana intermontane basin. This area is located between the seismically active North Fergana and South Fergana zones of regional faults. In 1990, only two earthquakes with a magnitude of 4.3 occurred in this area. Of particular interest is the fact that the area containing the epicenters of the weak earthquakes occupies the northeastern part of the Kokand Magnetic Anomaly, which has a maximum intensity of 500 nT. According to geophysical investigations, this anomaly is caused by a granitoid intrusion. The top of the intrusion is located at a depth of approximately 6–8 km; however, no reliable data are available on its horizontal dimensions. The hypocenters of the earthquake swarm are located at depths of 5–26 km. The only regional fault in the vicinity, the Kumbel–Kokand–Haydarkhan Fault, which has a north–northwestern strike, is located to the east of the area where the swarm of weak earthquakes occurred. This combination of geological, geophysical, and seismic characteristics represents a rare and poorly studied phenomenon. The few available publications on this subject are reviewed, in which various mechanisms have been proposed to explain the occurrence of this type of earthquake swarm. Considering the geological and tectonic conditions, as well as the specific geophysical characteristics of the area where this seismic event occurred, it is difficult for us to attribute the observed phenomenon to any of the proposed mechanisms with confidence. A geomagnetic storm was observed before and during the occurrence of these weak earthquakes. Therefore, other mechanisms may also be involved. Further cases of weak-earthquake swarms need to be

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documented and accumulated to allow a more reliable assessment of the mechanisms responsible for their occurrence.

Keywords: earthquake; magnitude; epicenter; fault; magnetic field

1. Introduction

The occurrence of strong earthquakes ($M \geq 5$) has traditionally been considered to be associated with active tectonic fault zones or areas located in close proximity to such zones. This view is based on the established understanding that tectonic fault zones act as concentrators of elastic stresses, whose release occurs through the generation of earthquakes.

During 2024–2026, a swarm of weak earthquakes was observed in Uzbekistan, representing a relatively poorly studied natural phenomenon. Some of these earthquake swarms occurred in areas where no seismically active faults have been identified. This is a rare and insufficiently studied phenomenon. Only a limited number of publications are available in which various possible mechanisms responsible for the occurrence of such earthquakes have been proposed.

The aim of this study is to investigate the occurrence of a swarm of weak earthquakes in the western part of the Fergana Basin.

The objectives are:

- to compare the timing of this seismic event with the occurrence of a geomagnetic storm;
- to examine and analyze data on the geological and tectonic structure, as well as the geophysical characteristics, of the area where the swarm of weak earthquakes occurred;
- to analyze published literature on the possible mechanisms responsible for the occurrence of weak-earthquake swarms.

2. Data and Methods

The original regional magnetic anomaly map was imported into the ArcGIS environment and georeferenced using identifiable geographic reference points and coordinate information available on the source map. Following georeferencing, the boundaries of the magnetic anomaly zones were digitized to create a GIS-based spatial representation of the original map. The earthquake catalogue was subsequently imported into ArcGIS using the geographic coordinates of the earthquake epicentres. The earthquake epicentres were then overlaid on the georeferenced magnetic anomaly map to examine their spatial distribution and possible association with the regional magnetic anomaly zones.

The magnetic anomaly boundaries shown in Figure 1 represent digitized interpretations of the source map and therefore should be considered as regional-scale spatial information rather than precise geological boundaries. Accordingly, the observed spatial correspondence between earthquake epicentres and magnetic anomaly zones is interpreted as a spatial association and not as definitive evidence of a causal tectonic or geological relationship.

3. Results

Thus, a swarm of weak earthquakes occurred in the western part of the Fergana Basin during March 6–27, 2025. Data on these weak earthquakes are presented in Table ^[1]. A total of 86 earthquakes were recorded during this period. As shown by the data, the majority of the earthquakes (65 events) occurred on March 7 and 8. The spatial distribution of the earthquake epicenters is shown in Figure 1. The Kokand Magnetic Anomaly was superimposed on the base map ^[2]. The numbers shown next to the epicenters indicate the

chronological sequence of their occurrence. The epicenters within the study area tend to be distributed in meridional and southwestern directions relative to the epicenter of the first earthquake (marked with an asterisk). The epicentral zone extends for more than 25 km to the north and approximately 12 km to the southwest. The sequence of earthquake occurrence in terms of both spatial distribution and hypocentral depth is characterized by a chaotic pattern.

Table 1. Catalog of the swarm of weak earthquakes for the period 6–27 March 2025 ^[1].

№	Date	Time	Latitude	Longitude	Depth	Mb
1	06.03.2025	19:21:33	40.47	70.83	15	1.6
2		23:10:23	40.51	70.9	10	2.5
3	07.03.2025	01:50:04	40.69	70.92	4	1.7
4		07:47:27	40.58	70.92	15	2.4
5		14:42:17	40.53	70.93	14	2.6
6		14:56:17	40.67	70.89	5	1.6
7		15:22:51	40.63	70.86	5	1.8
8		15:53:35	40.54	70.97	5	1.4
9		16:30:37	40.68	70.89	5	1.5
10		16:35:28	40.58	70.93	6	1.8
11		16:52:17	40.47	70.9	12	2.7
12		17:09:23	40.53	70.96	15	1.7
13		17:22:18	40.58	70.89	20	1.7
14		18:31:26	40.56	70.9	25	2
15		18:53:30	40.61	70.98	13	1.7
16		19:25:03	40.52	70.94	15	2.3
17		19:37:15	40.52	70.94	15	1.8
18		20:00:08	40.7	70.92	5	1.5
19		20:52:58	40.53	70.93	14	1.5
20		20:59:13	40.53	70.94	16	1.5
21		21:09:50	40.53	70.95	15	2
22		21:10:04	40.54	70.97	15	1.8
23		21:37:06	40.52	70.92	14	2.1
24		22:18:44	40.53	70.94	12	1.4
25		22:28:09	40.48	70.81	26	1.4
26		22:43:34	40.63	70.91	14	1.4
27		23:24:09	40.69	70.98	13	1.2
28		23:29:46	40.69	70.9	11	1.6
29		23:44:51	40.54	70.94	14	2.3
30	08.03.2025	00:09:17	40.58	70.93	10	2
31		00:43:21	40.59	70.91	5	2.2
32		01:29:03	40.65	70.86	11	1.3
33		02:43:03	40.71	70.9	3	1.3
34		02:44:51	40.52	70.95	15	2.4
35		02:58:51	40.68	70.95	12	1.2
36		03:13:21	40.64	70.92	13	1.1
37		03:32:40	40.63	70.93	14	1.3

38		03:46:37	40.5	70.89	10	2.4
39		04:05:40	40.53	70.92	14	2.4
40		04:32:34	40.69	70.91	5	1.6
41		05:09:52	40.47	70.9	8	2.4
42		05:53:57	40.7	70.94	4	1.3
43		06:39:58	40.49	70.81	21	2.2
44		06:42:15	40.7	70.86	5	2
45		07:39:25	40.6	70.94	9	2
46		08:02:07	40.56	70.92	10	1.8
47		08:28:23	40.65	70.88	11	1.4
48		08:30:08	40.7	70.9	5	1.4
49		08:32:38	40.56	70.92	11	2.2
50		10:26:58	40.42	70.65	4	1
51		11:14:42	40.63	70.95	15	2
52		12:17:21	40.66	70.91	13	1.2
53		12:27:00	40.59	70.94	8	2.2
54		12:51:06	40.52	70.88	5	1.2
55		12:51:51	40.62	70.9	14	1.3
56		14:18:23	40.53	70.94	13	2.1
57		14:47:42	40.69	70.9	10	1.4
58		15:00:51	40.63	70.9	14	1.2
59		15:05:46	40.47	70.76	24	1.9
60		15:52:32	40.62	70.89	15	1.2
61		16:24:14	40.59	70.93	5	1.7
62		17:00:02	40.71	70.88	5	1.1
63		17:21:53	40.73	70.9	4	1.2
64		20:21:21	40.65	70.92	13	1.3
65		21:41:02	40.38	63.36	8	1.6
66		21:47:59	40.16	71.02	12	1.6
67		23:14:14	40.5	70.94	15	1.4
68	09.03.2025	01:27:32	40.66	70.88	12	1.3
69		01:29:00	40.64	70.92	14	1.4
70		01:29:55	40.72	70.9	5	1.4
71		02:29:03	40.66	70.92	13	1.6
72		08:10:58	40.52	70.92	15	1.6
73	10.03.2025	00:33:28	40.56	70.98	15	1.4
74		08:32:19	40.7	70.92	5	1.7
75		11:19:13	40.55	70.94	14	2.5
76	11.03.2025	08:47:10	40.35	70.7	18	1.8
77	13.03.2025	08:27:04	40.54	72.11	6	2
78	17.03.2025	00:45:39	40.44	72.08	25	1.7
79		12:54:39	40.52	70.93	15	1.3
80		13:19:39	40.48	70.9	14	1.5
81		16:01:53	40.49	70.91	15	1.6
82	18.03.2025	09:13:11	40.48	70.9	14	2

83	23.03.2025	16:36:57	40.43	70.81	11	2.6
84		21:26:36	40.58	71.89	24	2.8
85	24.03.2025	03:01:04	40.43	70.8	5	1.8
86	27.03.2025	11:24:43	40.72	71.03	10	2

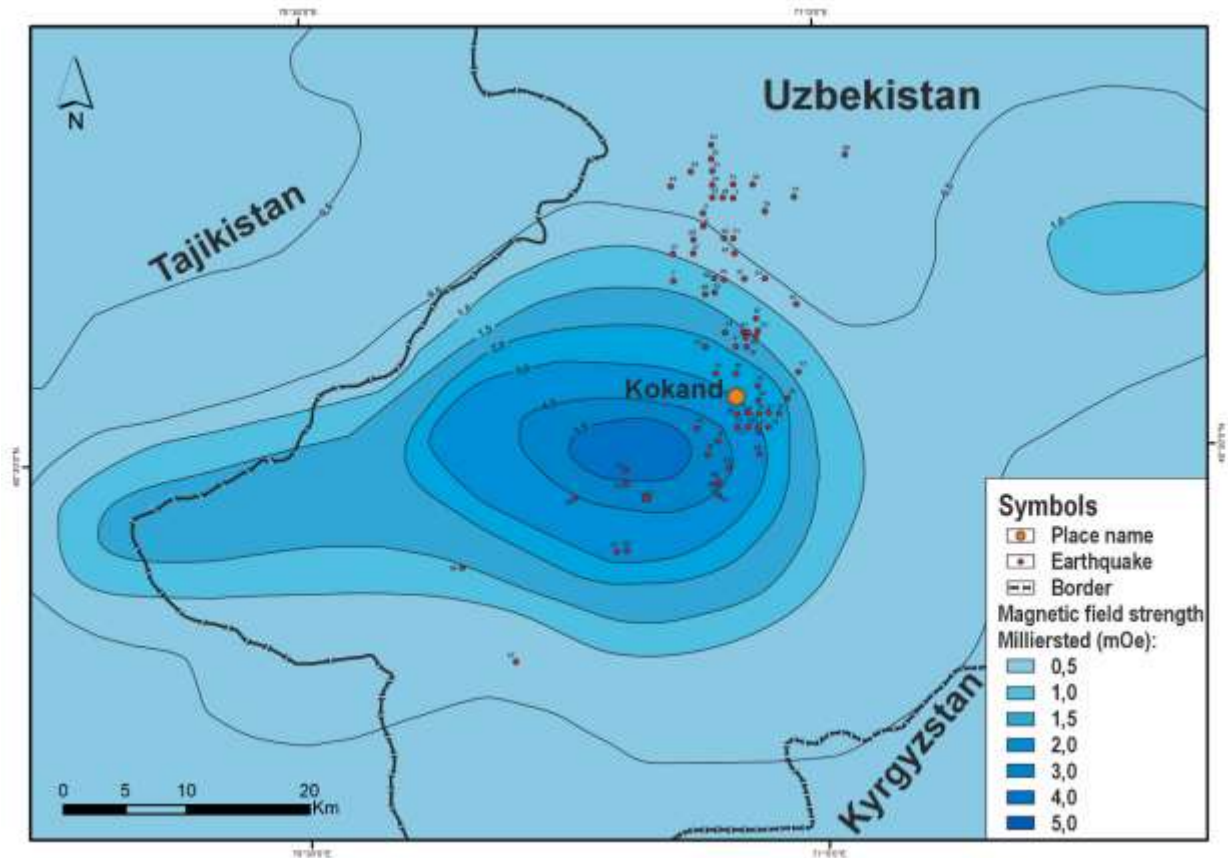


Figure 1. Spatial distribution of the epicenters of the swarm of weak earthquakes in the vicinity of Kokand ^[1], superimposed on the Kokand Magnetic Anomaly ^[2].

Figure 2 shows the variations in earthquake magnitude (a) and hypocentral depth (b) for the earthquakes that occurred during March 6–27, 2025. The geomagnetic field activity K-index data (c) for the same period are presented in the lower panel ^[3]. The K-index values ranged from 1 to 5. During March 6–27, the mean K-index value was approximately 2.5, with a maximum possible value of 8.

4. Discussion

No geomagnetic storm occurred either before or during the occurrence of the swarm of weak earthquakes that could have triggered the observed seismic activity. Possible relationships between these phenomena have been discussed in the publications cited below. Until the occurrence of this earthquake swarm, the area had not been characterized by any significant seismic activity.

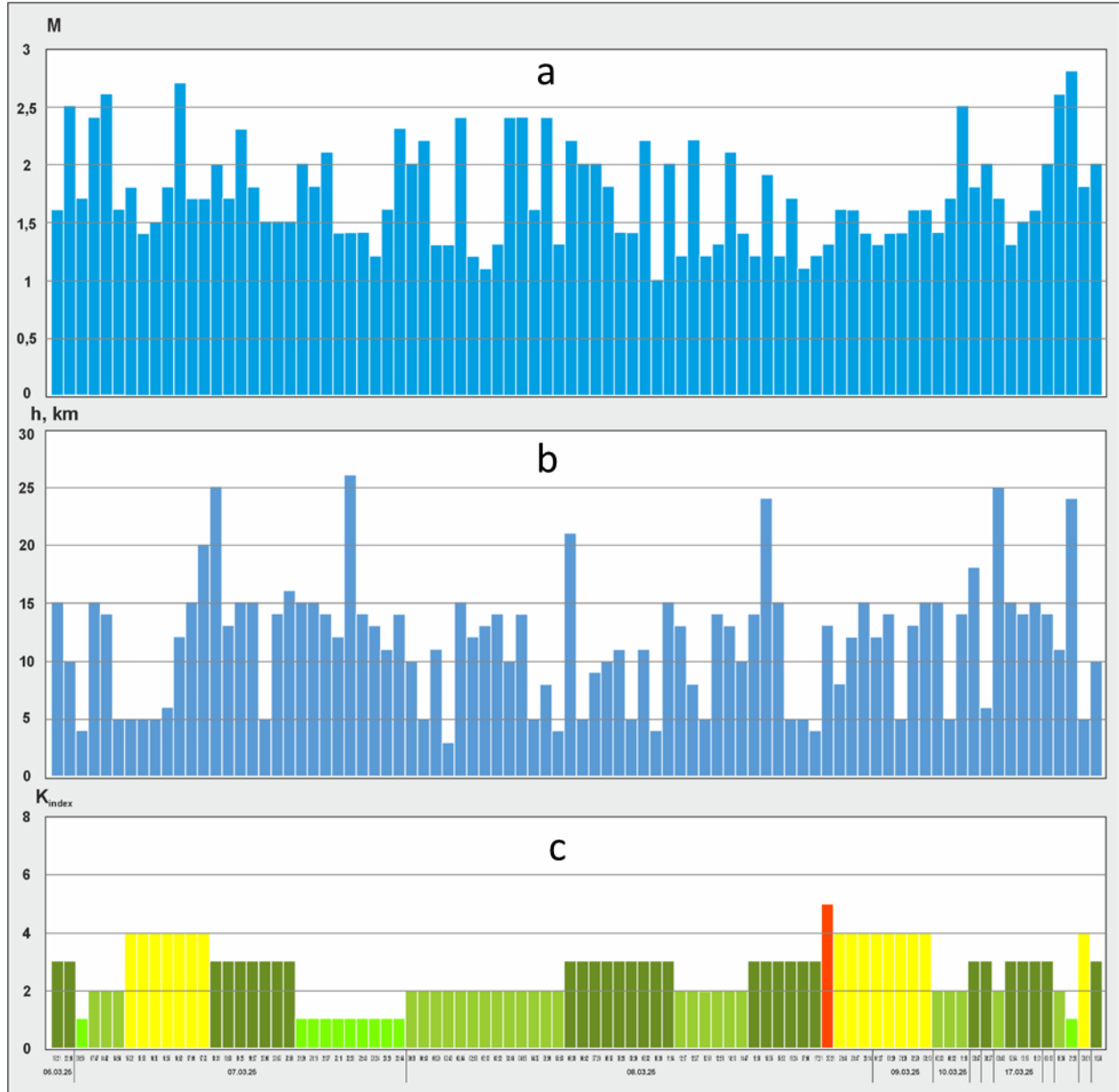


Figure 2. Variations in earthquake magnitude (a) and hypocentral depth (b) of the swarm of weak earthquakes ^[1], and K-index data representing geomagnetic field activity (c) ^[3] during March 6–27, 2025.

It is located between the seismically active North Fergana and South Fergana zones of regional faults. A map showing the locations of these faults, together with the epicenters of the recorded earthquakes, is presented in Fig. 3 ^[4]. As shown in the figure, the hypocenters of the strong earthquakes are predominantly distributed along these fault zones. The map includes earthquakes with magnitudes ranging from $M = 3.4$ to 6.8 that occurred since 1620. In the vicinity of Kokand, more precisely to the west and southwest of the city, two earthquakes with magnitudes of approximately 4.3 occurred in 1990.

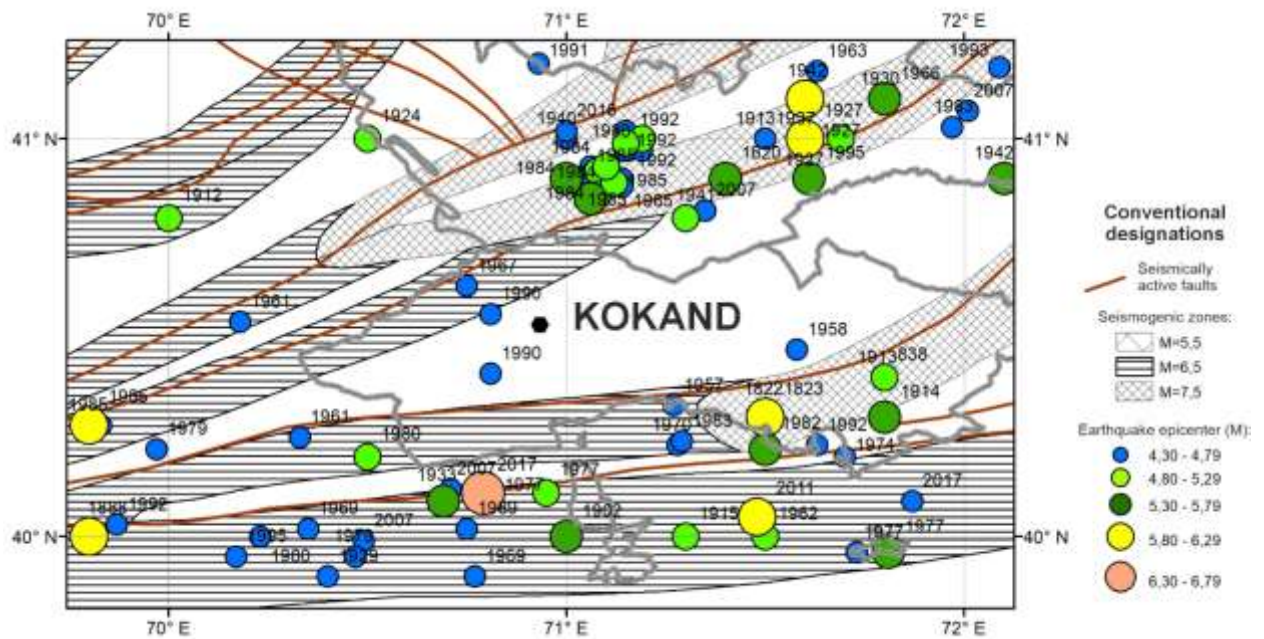


Figure 3. Fragment of the map of the North Fergana and South Fergana zones of regional faults, showing the epicenters of strong earthquakes [4].

From a geological and tectonic perspective, the Kokand area represents the western part of the Fergana intermontane basin. An intrusive body is located directly beneath the Kokand area at a depth of 6–8 km [5,6]. Its plan-view dimensions correspond to an area of approximately 900 km². At the surface, the intrusion is expressed as a high-gradient positive magnetic anomaly (**Fig. 1**). The maximum value reaches 500 nT. It should be noted that the Fergana Basin has been studied for more than 150 years in terms of its geological, tectonic, and structural characteristics. Extensive oil and gas fields are developed in the northern, southern, and eastern parts of the basin. However, no mineral deposits have been identified in the area of the Kokand Magnetic Anomaly. Consequently, this area remains relatively poorly studied from a geological and tectonic perspective. This anomaly is tentatively attributed to a granitoid intrusion. The anomaly has a pear-shaped configuration, with its long axis extending in the east–west direction. The majority of the weak-earthquake swarm occurred in the northeastern part of the magnetic anomaly. The earthquake epicenters are spatially distributed predominantly along a meridional direction. No reliable data are currently available on the spatial dimensions of the granitoid intrusion.

We applied an inverse modeling approach to magnetic exploration data to estimate the approximate parameters of the granitoid intrusion. For the interpretation, variations in the anomalous magnetic field were considered along two profiles oriented along the long (east–west) and short (meridional) axes of the anomaly. The results indicate that the depth to the top of the intrusion is approximately 6.8 and 7.0 km, while its horizontal extent is approximately 25 and 17 km, respectively. Accordingly, the estimated plan-view area of the granitoid intrusion is approximately 425 km². We then selected the earthquakes whose epicenters fell within this area. A total of 14 earthquakes were identified. These earthquakes occurred on March 6, 7, 8, 17, and 18, with focal depths ranging from 5 to 26 km. The 14 earthquakes account for approximately 16% of the total 86 earthquakes recorded during the swarm. Since no data are available on the lower boundary of the granitoid intrusion, it is difficult to determine whether the selected hypocenters of these 14 earthquakes are spatially associated with the granitoid intrusion. In our view, the occurrence of a swarm of weak earthquakes in the Kokand area represents a relatively rare phenomenon. The only known regional fault in the vicinity, the Kumbel–Kokand–Haydarkhan Fault, which has a north–northwestern strike, is located to the east of the

area where the swarm of weak earthquakes occurred. Within the Fergana Basin, this fault is represented by a dashed line on some tectonic maps and is not shown at all on others, indicating that its presence in this area remains uncertain. We also analyzed archival materials of the Ministry of Mining and Geology of the Republic of Uzbekistan concerning the Fergana Basin from the past 2–3 years. The results of 2D and 3D seismic tomography confirm the absence of tectonic faults within the study area. To date, no published scientific articles based on these archival materials are available.

The studies by N. A. Zakrzhevskaya and G. A. Sobolev examine the possible influence of geomagnetic storms on seismicity ^[7–9], as well as the effects of geomagnetic storms with sudden commencements on seismicity in different regions ^[10–12]. In particular, study ^[8] investigates variations in seismicity in the seismically active Caucasus region during periods following geomagnetic storms with sudden commencements. An earthquake catalogue covering the period from 1963 to 1990 was used. The results revealed an increase in the total number of earthquakes with an energy class of 7 and higher following geomagnetic storms observed in the region during 1963–1979. However, no such relationship was identified in the same area during 1980–1990. Geomagnetic impulses with sudden commencements preceded an increase in seismic activity by several days ^[8,9]. Similar studies were published by Adushkin et al. ^[10] and Sobisevich et al. ^[11]. In the study by Zotov et al. ^[12], high-latitude observations of so-called Big Magnetic Pulses (BMPs) were used to investigate a possible relationship between BMPs and earthquakes. The highest level of earthquake activity was observed during the first few hours following the occurrence of BMPs.

It has been reported that seismic activity increases following the occurrence of BMPs. In this case, the maximum number of weak earthquakes is observed with a delay of several hours relative to the onset of the BMP. It should be noted that there have been no published studies on this topic over the past 10 years or more.

5. Conclusion

During 2024–2026, a number of swarms of weak earthquakes occurred in Uzbekistan. These earthquake swarms were observed both within zones of seismically active regional faults and in areas where no active faults have been identified. This study presents the results of an analysis of a swarm of weak earthquakes that occurred in an area located between the seismically active North Fergana and South Fergana fault zones. The earthquake swarm occurred within an area characterized by the Kokand Magnetic Anomaly, which is associated with a granitoid intrusive body. The anomaly has a maximum amplitude of 500 nT. The top of the intrusive body is located beneath the sedimentary cover at a depth of approximately 6–8 km. The epicentral area is situated in the northeastern part of the magnetic anomaly, with the epicenters predominantly distributed in a meridional direction. The hypocentral depths of some earthquakes may indicate a possible spatial association with the granitoid intrusive body. A joint analysis of the geomagnetic field K-index data and the timing of the weak-earthquake swarm revealed no apparent relationship between geomagnetic activity and the occurrence of the earthquakes. A limited number of previously published studies concerning possible mechanisms responsible for the occurrence of weak-earthquake swarms are also reviewed. The entire Fergana Basin has been extensively investigated using geological and geophysical methods for approximately 150 years. However, the area of the Kokand Magnetic Anomaly remains relatively poorly studied due to the absence of significant mineral deposits and active regional faults in this area. Consequently, the spatial dimensions of the granitoid intrusion have not yet been determined.

The absence of geomagnetic storms before and during the occurrence of the swarm of weak earthquakes suggests the possible involvement of other mechanisms in the development of this seismic phenomenon.

We are unable to propose a specific mechanism responsible for the occurrence of the swarm of weak earthquakes in the area of the Kokand Magnetic Anomaly.

An anomalous swarm of weak earthquakes has also been reported by Zakrzhevskaya et al. [8]. However, that study likewise does not provide a definitive explanation for the possible mechanism responsible for this phenomenon.

Further research and the accumulation of new data in this field may provide important insights into the nature and mechanisms underlying the occurrence of swarms of weak earthquakes.

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