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The Manifestation of Local Anomalous Variations of the Geomagnetic Field in Uzbekistan in Connection With the Problem of Earthquake Forecasting

S. Kh. Maksudov, V. R. Yusupov*, E. N. Khakimov, K. A. Sagdullaeva, B. B. Shakhriyev, and S. X. Nazarov

Institute of Seismology, Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan
* **Correspondence to:** V. R. Yusupov valijon.yusupov@mail.ru

Abstract: The problem of strong earthquake forecasting is a pressing issue. This issue has attracted special attention from scientists around the world working in this area. Interesting and encouraging results have been obtained over the past 50 years. Geophysical (geomagnetic, geoelectric, ionospheric), geodetic, hydrogeochemical and other methods are particularly widely used. Despite the use of modern equipment, methods of collecting, processing and analyzing the data obtained, there is no clear idea of the spatio-temporal features of the manifestation of precursor anomalies. The results obtained show the most diverse nature of the manifestation of precursors, differing in form, intensity and duration in time. In such a complex situation, anomalous changes in many geological and geophysical parameters have been identified that are not associated with the processes of preparing strong earthquakes or changing the weak seismicity of the region under study. These anomalous changes have a duration of 10–15 days to 10 years or more. They can have different forms and intensities. They are comparable in the noted parameters with anomalies caused by the processes of preparation of strong earthquakes. A distinctive feature of these anomalies is their more frequent manifestation in geological and geophysical parameters. The article examines the features of the manifestation of local anomalous variations of the geomagnetic field of the type under consideration on the territory of Uzbekistan. Determining the nature of the manifestation of these anomalies has scientific and practical significance in solving the problem of forecasting strong earthquakes.

Keywords: geomagnetic field, anomalous magnetic variation, earthquake precursor, shape, intensity, period.

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Research Article

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1. Introduction

The problem of forecasting strong earthquakes is one of the most urgent in the seismically active regions of the globe. Strong and destructive earthquakes that have occurred in the last 10–15 years on the globe (in Sumatra 2009, Italy 2009 and 2014, Haiti 2011, Russia 2013 (Kamchatka), Nepal in 2015, Turkey in 2023, and Morocco in 2023) confirm the need to expand geological and geophysical research on their forecasting. Today, comprehensive studies are being conducted in the USA, China, Japan, Russia, Uzbekistan and other countries of the world to solve the problem of forecasting strong earthquakes. According to the data of the last 5–10 years of research, the results have been obtained showing:

- the manifestation of earthquake precursors is not for all earthquakes;
- the occurrence of strong earthquakes without any abnormal changes in geological and geophysical parameters;

- the manifestation of abnormal changes in geological and geophysical parameters that are not accompanied by strong ($M \geq 5$) earthquakes, activation of weak seismicity of the studied area. Anomalous changes of the latter, "non-precursor" type, have been recorded in geophysical (geomagnetic, geoelectric, pulsed electromagnetic) fields and hydrogeochemical parameters.

2. Materials and Methods

This article presents the results of geomagnetic research in Uzbekistan for the period 2021–2024. During this period, the Yangibazar magnetic Observatory (operating since 1923) and 14 magnetic stations were in operation (Figure 1). Some of them have been in operation for more than 30 years. Absolute proton magnetometers Geometrics – 856 (USA), GSM-19T (Canada) and MV-01 (Russia) are used. The sensitivity of these magnetometers is 0.1 nT. The total error in identifying local anomalies is no more than 0.4–0.6 nT.

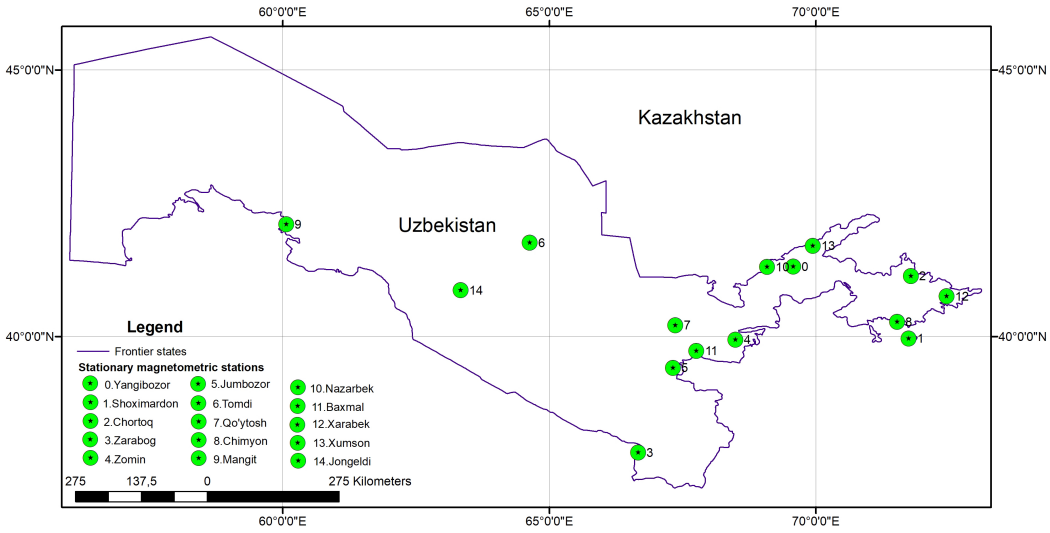

Figure 1. Location of magnetometric stations on the territory of Uzbekistan.

The modulus of the total geomagnetic field vector (**T**) is measured. The measurement frequency at all magnetic stations is after 10 minutes, and 144 magnetic field values are obtained in 24 hours. The absolute or relative daily and monthly average values of the geomagnetic field were used for data analysis. Changes in the relative values of the geomagnetic field at the stations are considered relative to the Yangibazar Observatory. The distance from the observatory to the nearest magnetic station is 40 km (station Nazarbek, No. 10), the longest distance is 1375 km (Mangit station).

3. Discussion of the Results Obtained

Figure 2 shows the change in the absolute values of the geomagnetic field for the period from June 10 to July 5, 2023. The change occurs at 10 out of 15 stations (the numbers near the curves in all figures correspond to the station numbers shown in Figure 1). Here, during the slow growth of the geomagnetic field, a decrease occurs, reaching a minimum value on June 15. Then there is a slow increase in the field value until June 30th. And then there is an increase in the rate of growth of the magnetic field, reaching a maximum on July 5. As you can see, the beginning and end of this anomaly occurs at about the same time in all stations. This anomaly did not appear at the other 5 stations.

An example is a change in the magnetic field at the Bakhmal station (11), where the anomaly did not appear. The table shows the values of the correlation coefficient of the anomalous change at the stations relative to the Yangibazar Observatory data. As can be seen from the table, the correlation is very high and amounts to 0.84–0.99. The exception, as noted, is the change at the Bakhmal station, where the correlation coefficient is 0.17. In this case, it is difficult to determine the location of the "focus" of this anomaly by the values

of the correlation coefficient or by the change in the intensity of the anomaly. The anomaly is the largest in terms of the area of manifestation identified in Uzbekistan. According to the size of the manifestation on the territory of Uzbekistan and its slight attenuation with distance, the anomaly may have manifested itself outside the territory of Uzbekistan.

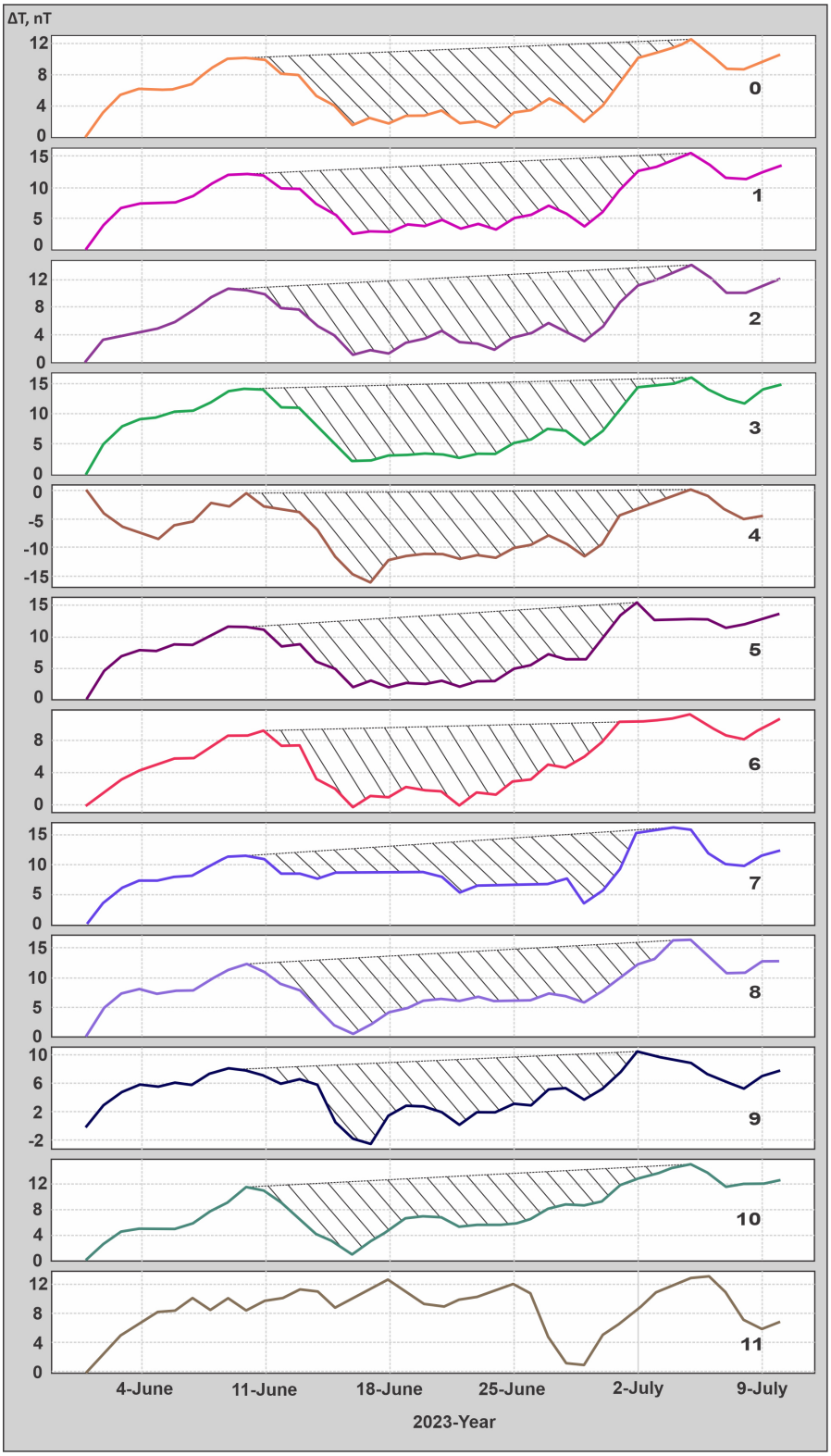

Figure 2. Changes in the average daily values of the geomagnetic field at 11 magnetic stations in Uzbekistan.

Table 1. Correlation coefficients of changes in the geomagnetic field at stations relative to the Yangibazar magnetic Observatory

No.	Station names	Yangibazar Observatory (Q)
1	Shakhimardan	0.99
2	Chartak	0.99
3	Zarabag	0.98
4	Zomin	0.95
5	Jumabazar	0.91
6	Tamdi	0.91
7	Koytash	0.89
8	Chimion	0.89
9	Mangit	0.88
10	Nazarbek	0.84
11	Bakhmal	0.17

The manifestation of a local anomalous variation at the magnetic stations of Nazarbek (10), Chartak (2), Kharabek (12) and Shakhimardan (1) is considered below (Figure 3). The bay-shaped anomaly of a positive sign began to manifest itself from the beginning of June 2022 and lasted until the beginning of October 2023. Figure 3 shows the change in the monthly average values of the geomagnetic field at the marked stations relative to the Yangibazar Observatory (0). The geomagnetic field change at Chimion (8) station, where this anomalous variation did not occur, is also shown here. The nature of the field change at this station differs significantly from the changes observed at the four stations mentioned above. Note that the Chimion (8) magnetic Station is located 50 km away. northeast of Shakhimardan station. The amplitude of the anomaly is 2–2.7 nT, the minimum value is 2 nT at Chartak (2) and Shakhimardan(1) stations and – 2.7 nT at Nazarbek (10) and Kharabek (12) stations. The duration of this bay-like anomaly increases in a southerly direction. The duration at the Nazarbek station (10) is about 9 months, at the Chartak station (3) – 13 months, at the Kharabek (12) station – 15 months and at the Shakhimardan(1) station – 16 months. By the nature of the decrease in the southern direction, it can be assumed that the "focus" of this anomaly is located south of Shakhimardan station.

A similar anomaly was observed at Zarabag (3), Zhumabazar (5), Bakhmal (11), Koytash (7) and Jangeldi (14) stations. The anomaly begins on May 12 and ends on August 13, 2024 (Figure 4). The duration of the anomaly is three months. The highest intensity is observed at the Zarabag – 16 nT station. Further north, it decreases, amounting to 7; 5; 4; 2.5 nT at the stations of Jumabazar, Bakhmal, Koytash and Jangeldi, respectively. As can be seen, the intensity of the anomaly decreases in the north direction. This anomaly does not appear at the more remote Tamdy (6) station (curve 6).

More detailed information about anomalies of this type from the previous research period was provided in our publications [*Maksudov*, 2024; *Maksudov et al.*, 2021], which showed a wide spatiotemporal manifestation of these anomalies. Each case of anomaly differs in form, sign, intensity, and duration. They do not correlate in time with strong earthquakes that occurred within the region or with the activation of weak seismicity in the area. The first cases of this type of anomaly were reported back in the 1960s [*Gryaznovskaya et al.*, 1970; *Pudovkin and Tanichev*, 1970a,b]. The large amount of measurement errors at that time raised doubts about the reliability of the identified anomalies. Nevertheless, the detected anomaly values exceeded 2–3 times the RMS error of the measurement of the components or the modulus of the total vector of the geomagnetic field.

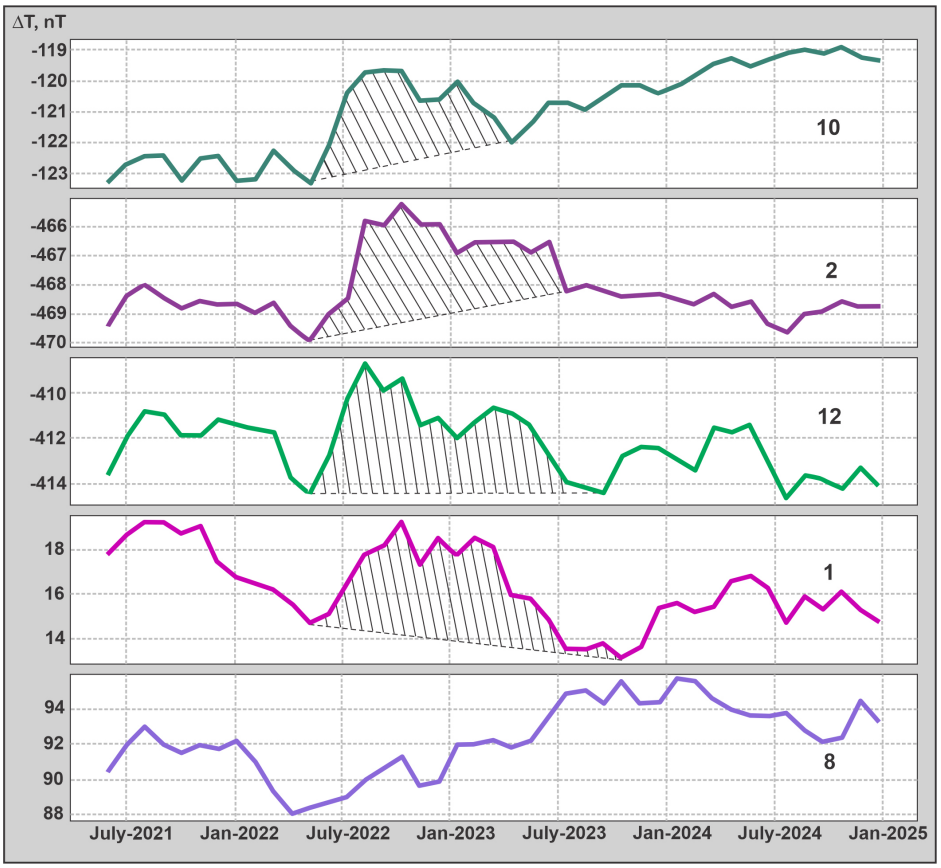

Figure 3. Changes in the relative monthly average values of the geomagnetic field at the Nazarbek, Chartak, Kharabek, Shakhimardan and Chimion stations for the period June 2022 – October 2023.

Long-term, high-precision and frequent geomagnetic measurements in the territories of geodynamic polygons of Uzbekistan allowed us to register numerous anomalous variations of this type [*Maksudov*, 2024; *Maksudov et al.*, 2021].

Interest in anomalous variations of this type is of particular importance due to the fact that in some cases anomalous changes in the geomagnetic field associated with the preparation of strong earthquakes have been identified [*Abdullabekov*, 1989; *Abdullabekov and Maksudov*, 2002; *Abdullabekov et al.*, 1994]. The parameters of the anomalous variations associated with earthquakes and those discussed in this article are comparable. The fact is that on the territory of Uzbekistan, which belongs to the seismically active territories of Central Asia, comprehensive geological and geophysical studies on the problem of earthquake forecasting are being conducted. Among the methods used is geomagnetic, which provides operational and informative results [*Abdullabekov*, 1989].

Research on the search for geomagnetic precursors of strong earthquakes in Uzbekistan began in 1968. The research was carried out using the methods of repeated profile, area and stationary regime measurements. Repeated changes were carried out with a frequency from once every 15 days to once every 3 months or less. The measurements were carried out at 1100 points with varying durations in terms of both area (profiles) and time intervals. The total length of the profile and area surveys was about 7750 km. The total number of stationary stations in the early 1980s in the entire territory of Uzbekistan was 36.

Long-term, high-precision and frequent geomagnetic measurements in the territories of geodynamic polygons of Uzbekistan allowed us to register numerous anomalous variations of this type [*Maksudov*, 2024; *Maksudov et al.*, 2021].

The research was organized in the territories of active regional faults, natural underground gas storage facilities, large reservoirs, exploited oil and gas fields, etc.

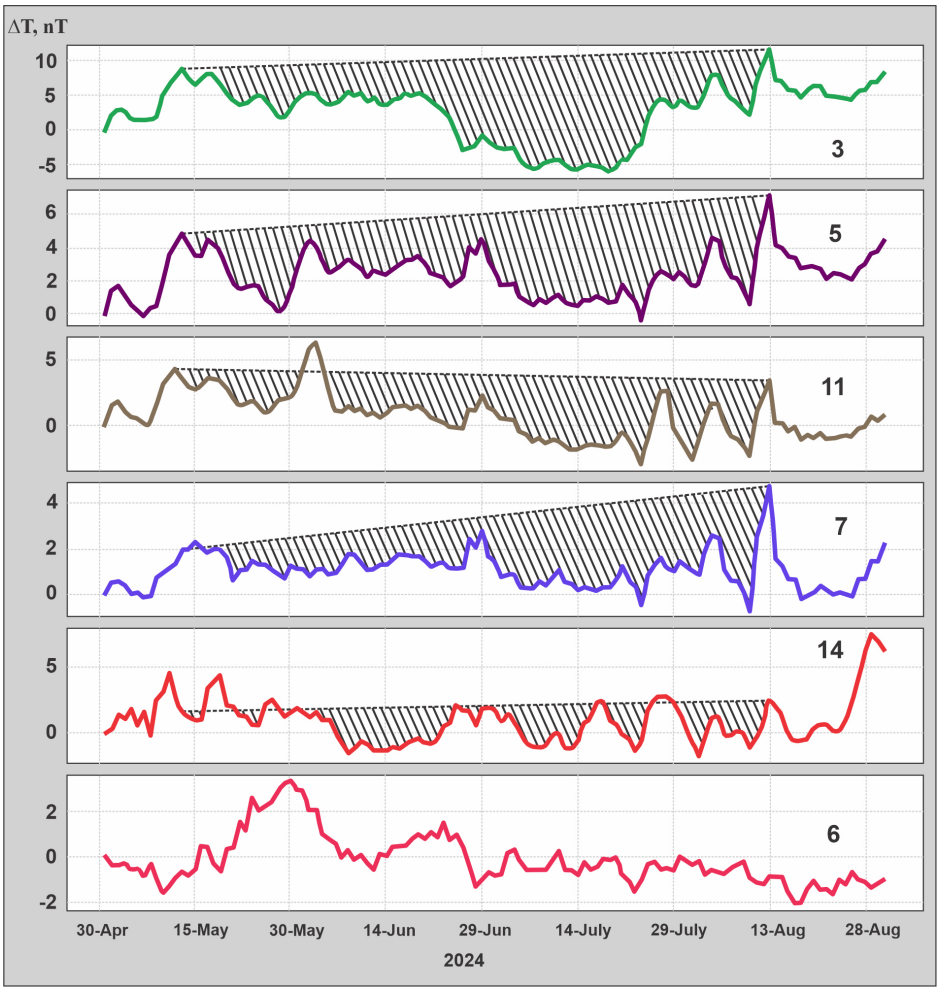

Figure 4. The change in the average daily values of the geomagnetic field at 5 stations in Uzbekistan.

As a result of more than 55 years of research, local anomalous variations of the geomagnetic field have been recorded due to:

- processes of preparation of strong earthquakes;
- activities of an underground natural gas storage facility;
- activities of a large reservoir;
- exploitation of oil and gas fields;
- processes occurring at various depths in the Earth's crust, upper mantle, and possibly deeper.

The local anomalous variations of the geomagnetic field given in the last paragraph were recorded as a result of long-term stationary measurements and frequent repeated measurements at the points of profile, area surveys.

The currently established features of the manifestation of these anomalous variations are as follows:

- they manifest themselves in various forms, intensity, duration and sign;
- they are not confined to any specific geological, tectonic, geomorphological structures, regional faults, seismically active zones, or geophysical fields;
- long-period anomalous variations of this type can be overlaid with the same shorter-period anomalous variations of various shapes, intensities and linear sizes;
- they have a different configuration of manifestation on the square;
- the configuration, magnitude, and area of these anomalies may change over time;
- in most cases, the changes are reversible.

From this point of view, local anomalous variations of a nature that is not yet known, which were previously recorded [*Maksudov*, 2024; *Maksudov et al.*, 2021] and those discussed in this article are the object of careful research. Determining their nature is a problem, the solution of which will increase the accuracy and reliability of identifying local anomalous variations caused by the processes of preparing strong earthquakes. As the research results show, a wide spatiotemporal spectrum of these local anomalous variations has been revealed. We are not aware of studies in the territories of seismically active regions where geomagnetic studies are conducted on the problem of predicting earthquakes with such a duration and a dense network of magnetic stations as in Uzbekistan. Consequently, there are also no statements about the nature of the manifestation of these local anomalous variations.

The analysis of all identified local anomalous variations shows a wide spatiotemporal spectrum of their manifestation. The linear dimensions range from the first kilometers to the first thousands of kilometers. The intensity of the anomalies ranges from 2.5 nT to 8–10 nT. The duration of the anomalies ranges from 15 days to seven years or more. The shapes of the identified anomalies are bay–shaped, sinusoidal, and trending. A bay-shaped anomaly has a positive or negative sign. Common to all identified cove-like anomalies is the reversible nature of their changes.

The reversible and short-lived nature of the changes in the identified local anomalous variations in the geomagnetic field suggests that these variations are not related to chemical, seismotectonic, or thermal processes in the lithosphere. These processes seem to occur very slowly and should have an irreversible part of the change in the considered variations of the geomagnetic field. If long-term (months, years) local anomalous variations can somehow be explained by the proposed mechanism [*Zeynalov*, 1966], then short-period (tens of days, the first months), apparently, cannot be explained by these mechanisms. The migration rate of these anomalous variations through various layers of the Earth (from the core to the crust) is also unknown today.

Therefore, it is difficult for us now to express even a tentative opinion about the nature of these variations. It can be noted that data from the geomagnetic field alone is probably insufficient to determine the nature. Given the urgency of solving the nature of these anomalous variations, it is proposed to conduct special long-term high-precision geomagnetic studies. Research, apparently, should be organized both in seismically active and weakly seismic areas at the same time. The duration of the observations will depend on the results obtained in the course of comprehensive research. To reliably determine the nature of the detected anomalous variations, special studies on electrodynamics and other geophysical methods should be conducted, as well as data on seismicity should be used.

Determining the nature of these local anomalous variations is of fundamental and applied importance. The applied aspect is primarily related to the relevance of solving the problem of forecasting strong earthquakes.

4. Conclusions

Based on the analysis of the obtained results of geomagnetic studies in Uzbekistan and the available data for other regions, it is very difficult to draw certain conclusions about the nature of the identified local anomalous variations. In our work [*Maksudov et al.*, 2021], we cited the available statements of various researchers regarding the nature of this kind of local anomalous variations [*Bullard*, 1948; *Elsasser*, 1941; *Lowes and Runcorn*, 1951; *Vestine et al.*, 1947]. The different spatial and temporal characteristics, linear dimensions, and intensity of these anomalous variations make it difficult to make certain assumptions about their nature. The complex geological and tectonic structure, the thermodynamic situation of the lithosphere, and the highly gradient manifestation of static geophysical fields in Uzbekistan determine the possibility of such a diverse manifestation of the revealed anomalous variations of the geomagnetic field. Local anomalies of small linear sizes and short duration in time may characterize processes within the Earth's crust. Longer-lasting and with larger linear dimensions anomalous variations may be related to processes within the mantle and deeper.

Given the urgency of solving the nature of these anomalous variations, it is proposed to conduct special high-precision geomagnetic studies. They should be organized by stationary and repeated area measurements in both seismically active and aseismic (weakly seismic) regions simultaneously. To reliably determine the nature of the detected anomalous variations, special studies on electrodynamics and other geophysical methods should be conducted, as well as data on seismicity should be used.

Determining the nature of these local anomalous variations is of fundamental and applied importance. The applied aspect is primarily related to the relevance of solving the problem of forecasting strong earthquakes.

Currently, geomagnetic research on earthquake forecasting is being expanded at the Institute of Seismology of the Academy of Sciences of Uzbekistan. New magnetic stations are being installed, and new profiles for repeated magnetic measurements have been laid. The total length is about 3500 km with 330 measuring points of the geomagnetic field. Since 2025, repeated measurements on profiles have been carried out once a month.

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