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Research Article

THE RESULTS OF ELECTROMETRIC STUDIES OF EARTHQUAKE PRECURSORS IN UZBEKISTAN

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ABSTRACT
In article "Electrometric precursors of the earthquakes" lit revealed changes to electromagnetic field by complex electromagnetic methods - an atmospheric electricity (AE), dipole electric flexing (DES), pulse of the electromagnetic radiation (EMP) on the territory Poltorack gas reservoir, Charvak water reservoir, South-Alamishik, Tamdybulak, Shirmanbulak polygons, epicentral zone Gazli earthquakes and on the other territory, connected with geodynamic processes, with mode of the usages technogenic objects, aftershock activity. The issues of using these results in earthquake forecasting are considered. It also contains the results of a study of variations in the complex of electromagnetic fields at the Yangibazar magnetic-ionospheric Observatory. Daily, seasonal, and short-term anomalous variations of the pulsed electromagnetic field associated with earthquakes and other processes in the earth's crust are identified.

***Keywords**: Telluric Currents, Natural Field, Atmospheric Electricity, Natural Impulses, Earthquake, Geodynamic Field*

INTRODUCTION
Electrometric methods for predicting earthquakes include methods for measuring anomalous variations in the electrical resistance of rocks in the earth's crust, telluric currents, natural electric field, atmospheric electricity, and natural pulses of The earth's electromagnetic field. These methods are used in many countries of the world to study various electromagnetic phenomena, man-made effects, as well as to predict earthquakes [Sadovsky M.A. 1982., Mavlyanov G.A., Ulomov V.I., Abdullabekov K.N., Khusamidinov S.S. 1979., Abdullabekov K.N. 1991., Fujinawa 1994., Barsukov O.M. 1973., Makhkamdzhanov I.M., Barsukov O.M., Nurmetov B.T. 1986].
Electrometric precursors of earthquakes in Uzbekistan were first observed by an employee of the Central Asian State University E. D. Chernyavsky up to 1.5-2 hours before the strong Jalalabad earthquake on August 1, 1924 in the form of anomalous changes in the atmospheric electric field [Chernyavsky E.A. 1925.]. Subsequently, anomalous changes in the atmospheric electric field were observed during the Chatkal (1946), Khait (1949), Brichmulla (1959), and other earthquakes [Chernyavsky E.A. 1955., Tserfas K.E. 1971].
After the devastating Tashkent earthquake of 1966. The Institute of seismology began large-scale studies of the complex of precursors, including electrometric ones. N. M. Mutaliev, I. M. Makhkamzhonov, M. T. Usmanova, M. Samokhvalov, S. S. Khusamiddinov and others. long-term electrometric studies were performed at the Tashkent, Ferghana, and Kyzylkum geodynamic polygons, Charvak reservoir, Poltorak underground gas storage, Tamdybulak, Shirmanbulak, southern Alamyshik, and the epicentral zone of the Gazli earthquakes. The following are the main important results of electrometric research in Uzbekistan.
The results of the study of abnormal changes in the electrical resistance of rocks by the method of an DES (dipole electrical sounding).
According to the results of studies at various polygons, anomalous changes in the electrical resistance of rocks before earthquakes were detected. In the DES method, a strong electric current is supplied to the earth's crust through grounding from special generators or other sources. Electric current passes through the layers of the earth's crust and is recorded on receiving lines, changes in the electrical resistance of rocks are observed, and on this basis, upcoming earthquakes are predicted [Golovkov V.P. 1983., Hayakawa., Y. Gokhberg M.B., Gufeld I.L., Dobrovolsky I.P. 1980.**]**.

MATERIALS AND METHODS

At The Institute of seismology of the Academy of Sciences of the Republic of Uzbekistan, the study of variations in electrical resistance of rocks by the DES method was first started in 1970-1973 By N. M. Mutaliev under the direction of O. M. Barsukov at the Poltoratsky underground gas storage facility located in the North of the Tashkent geodynamic polygon. The Poltoratskoye underground gas storage facility is located at a depth of 550-620 meters and consists of "Western"and "Eastern" anticline structures of sandy layers with a capacity of 20-25 meters with underground water. Natural gas with a pressure of 90-95 Pascal is pumped during the summer months using wells into anticline structures. During the winter months, gas is used for heating. Mode measurements of the electrical resistance of rocks by the DES method were carried out. According to the research results, the apparent electrical resistance ($\rho_к$) of rocks increases by 15-20% due to the replacement of reservoir water pores with gas under high pressure. In the winter months, on the contrary, after pumping gas, the pressure decreases, and water replaces the place of gas, there is a decrease in electrical resistance ($\rho_к$) by 15-20%. These results showed a strong response of the electrical resistance of rocks to changes in the environment and external influences, and the method is promising for modeling earthquake preparation processes in natural conditions – on the territories of man-made objects.

On April 8, 1976, the first Gazli earthquake occurred in the South-Western part of Central Kyzylkum, in the Gazli-Karatag seismogenic zone. Electrometric group of the laboratory of Geophysical methods and seismotectonics of the Institute of seismology of Uzbekistan Academy of Sciences at the direction of I. M. Mahkamdzhanov in April-may 1976. near the city of Gazli in may-July in the epicentral area of the earthquake (Karakyr) conducted studies using electrical station ERSU-71. With the help of a DC generator ERSU-71, a current of 30-40 amperes was passed into the ground. The length of the feeding dipole is 1000 meters [Sadovsky M.A. 1982.].

At a distance of 4 km in the city of Gazli (measuring line - 400m.) and 3 km in the epicenter (measuring line-300m.), the potential difference created by this current was determined. In both cases, the azimuth setting was used. $\rho_к$ measurements were performed for three to four days in hourly sessions lasting 3-5 minutes. Such studies of the stationary nature of studying $\rho_к$ variations over time were conducted for the first time in the epicentral zone of the Gazli earthquake in order to identify changes in $\rho_к$ variations associated with earthquakes.

On April 17-24, 1976, relatively high seismic activity was observed in the Gazli section, which corresponded to a decrease in electrical resistance, reaching K=12-13 8-10% for an earthquake, as well as a significant increase to 57%. These changes coincided with the moment of the earthquake on April 17, 1976 at 13: 49 GMT. On other seismically calm days, the daily course of the $\rho_к$ goes without noticeable changes. In the epicentral zone (Karakyr), changes in resistance are less frequent, and earthquakes with K=7-8 are clearly manifested in changes in $\rho_к$ that reach an amplitude of 15-20% (Fig. 1).

RESULTS AND DISCUSSION

Here, the measurements were carried out by hourly probing, containing 25-30 working pulses. This method of measurement was provided during the day to 500-600 independent of the values of $\rho_к$. In Fig. 1, the arrows show the moments and energy classes of the aftershocks of the Gazli earthquake. It should be noted that due to frequent aftershocks during the day, it is difficult to determine the beginning and end of anomalous changes for specific earthquakes.

Thus, as a result of hourly daily measurements, a decrease in electrical resistance was found 5-6 hours before the earthquake, and this phenomenon can be used as a precursor for predicting earthquakes.

Results of studies of variations in electrical resistivity ($\rho_к$) on the territory of the Charvak reservoir.

The study of variations in the time of electrical resistivity ($\rho_к$) of rocks during the filling of the Charvak reservoir was carried out using the method of dipole electric sensing (DES). Studies of $\rho_к$ variations were conducted in three stages. The first stage of research was carried out in 1975 near the village of Bogistan, located in the North-Eastern part of the reservoir (Fig. 2). the second stage was Carried out in June-October

1978 in the Northern part of the reservoir, and the third stage was carried out from mid-1981 in the North-Western part of the reservoir (Fig. 2).

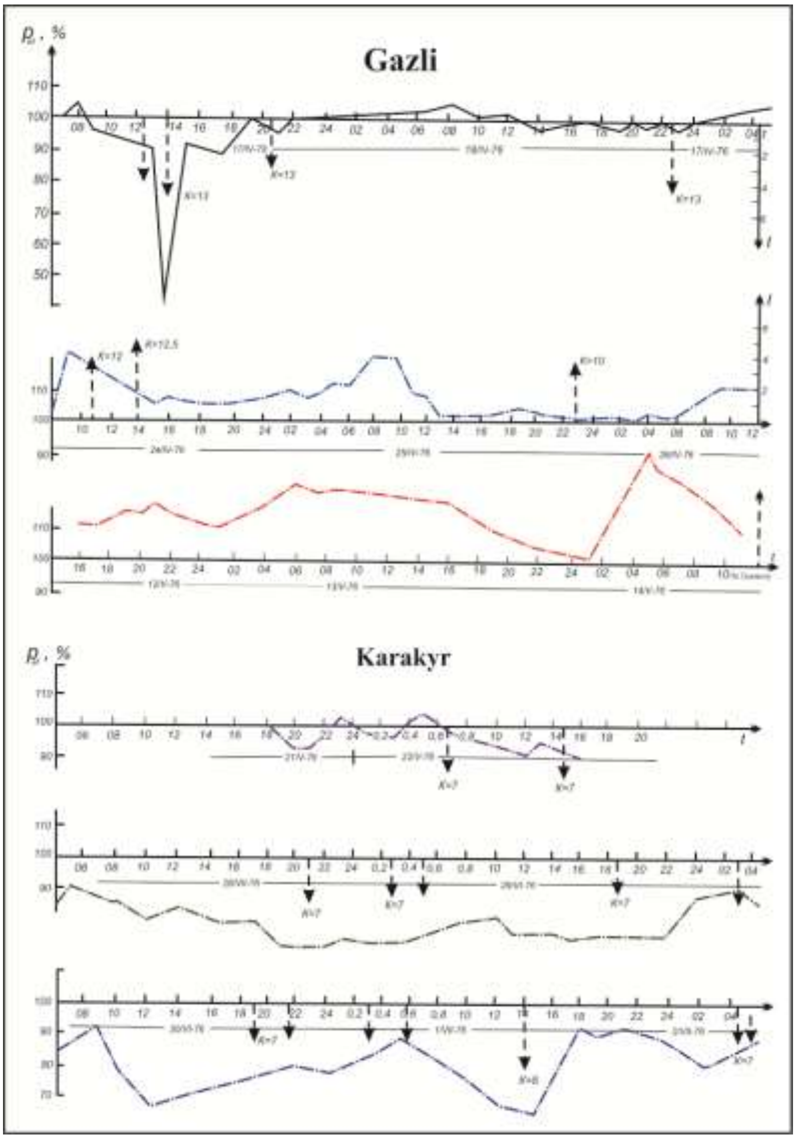

Figure 1: Graphs of daily changes in the ρ_K in the points of Gazli and Karakyr [Golovkov, 1983]

Electrical resistivity studies were carried out by passing a current of 29 kV through a 780-meter-long AB supply line. The current source was the generator of the electric exploration station ERSU-71. A current of 100 a was passed into the ground through the AB electrodes with a resistance of 8 Ohms. Potential differences were measured at humsan and Sijak stations located 4 and 10 km away from the AB line, respectively. Studies of electrical resistance variations were carried out using the method of O. M. Barsukov [Barsukov O.M. 1971].
Variations of electrical resistivity 1975, 1978 and 1981-1982 were mainly associated with changes in water volume in the reservoir, increasing water volume electrical resistivity was reduced by 4-6%, while reducing

the volume of water increased by 5-7%, i.e. the observed inverse correlation between water volume and electrical resistance [Makhkamdzhanov I.M. et al. 1986].

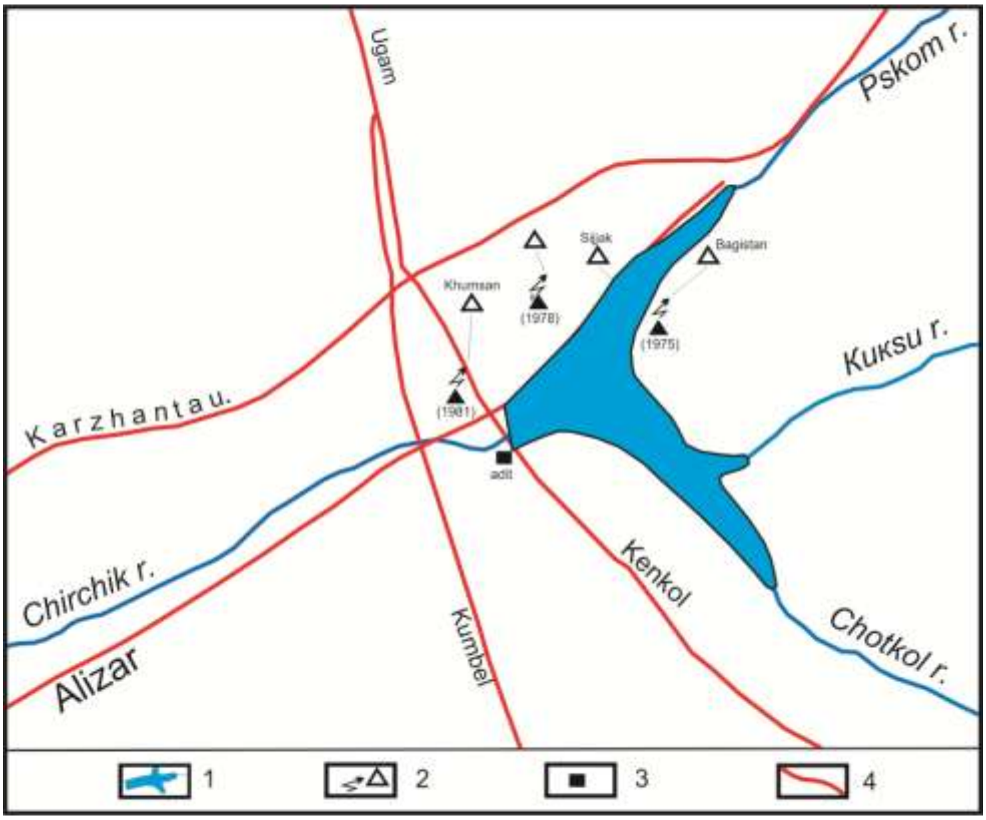

Fig. 2. layout of generator and receiving points of the DES method in the Charvak polygon: 1-contour of the Charvak reservoir, 2-generator and receiving station, 3-geophysical adit, 4-faults [Makhkamdzhanov *et al.*, 1986].

Figure 3 shows graphs of changes in electrical resistivity observed at the sijak and Khumsan receiving stations in 1982-1983, the volume of water in the reservoir, and shows the times of earthquakes near the Charvak test site. Based on the results of daily measurements of electrical resistance, its monthly average values were calculated. On the chart $\rho_к$ of the first group of companies, the minimum decrease in may-June by 5% coincided with a period of growth in water volume. Over the next 6 months, there was a gradual decrease in water volume with minor changes in electrical resistance. The second minimum – up to 7% - was observed at the humsan station in the period from December 1982 to February 1983. During this period, the power resistivity at Sidjak station decreased by only 1.5 %. The third minimum was observed in April-may 1983, at the Khumsan station by 2-7 %, at the Sidjak station by about 1%. The fourth minimum was observed in July-November 1983, at Khumsan station about 4.5-2%, at Sidjak station 3.5-0.5%. In the months of may and July, there was an increase in the volume of water, and since October it has decreased.
Thus, based on the results of research conducted in the Charvak reservoir landfill in 1975, 1978, and 1981-1983, significant effects of changes in water volume on changes in electrical resistance variations were revealed. Variations in electrical resistance associated with earthquakes near the landfill were also observed.

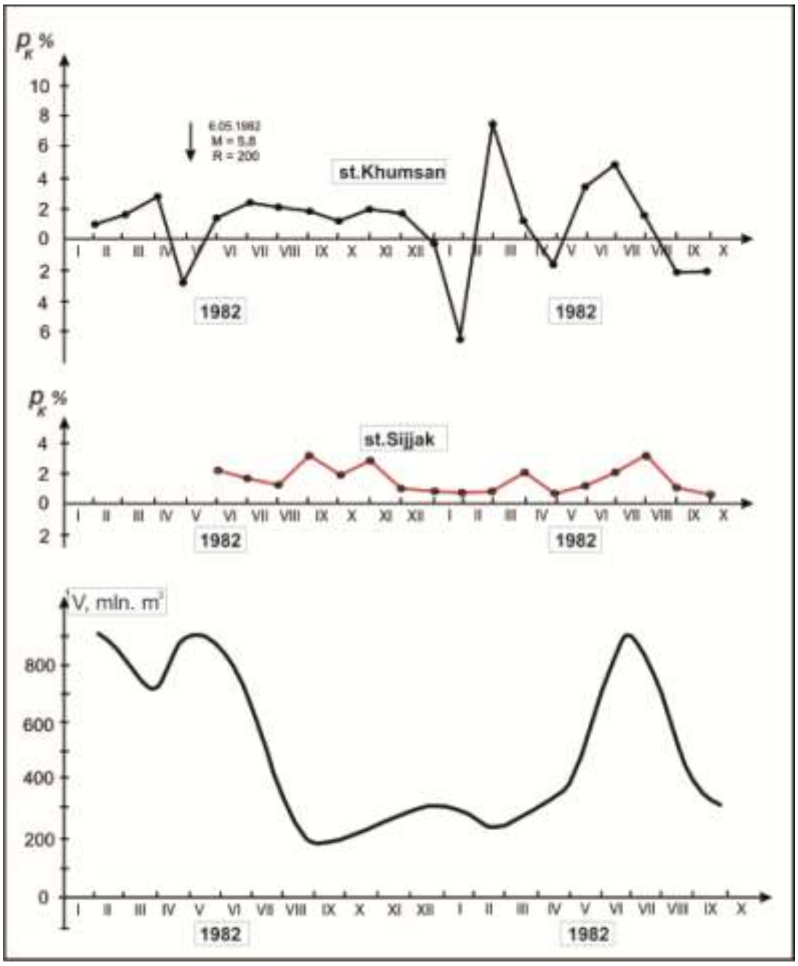

Figure 3: Changes in water volume (V) in the Charvak reservoir and electrical resistivity (ρк) at the Khumsan and Sidjak receiving stations in 1982-1983

Simultaneously with the DES method, observations of the natural electric field (ΔU) in the Geophysical tunnel were carried out at the Charvak polygon. The distance between points is 5m, the profile length is 40m. The measurements were carried out by the AE-72 autocompensator. During the observation period (1978-1983), anomalous changes in ΔU associated with changes in water volume and specific earthquakes were detected [Mavlyanov *et al.*, 1979; Makhkamdzhanov *et al.*, 1986].
One of the most promising methods for predicting earthquakes is the method of electromagnetic pulses (EMP), which is well developed in Uzbekistan. First, Professor A. A. Vorobyov of the Tomsk Polytechnic Institute [Vorobiev, 1970] theoretically justified the possibility of a strong electric field in the earth's crust. Since 1971. The Institute of seismology of the Academy of Sciences of the Republic of Uzbekistan in scientific cooperation with the Tomsk Polytechnic Institute started research on the study of EMPvariations in the geophysical adit located near the Charvak reservoir dam. According to the results of these studies, for the first time in the world, anomalous changes in EMP at a frequency of 12.5 kHz were identified, associated with the earthquake M=4.2 on January 10, 1972. In a short time, the number of stations was increased and dozens of predictive changes in EMP associated with earthquakes were registered. Within a few years, this method has spread to many countries around the world (USA, Japan, China, Greece, Russia, CIS countries, etc.). A few hours (days) before the earthquake, strong electromagnetic waves are released from the center of the preparing earthquake, which propagate in the layers of the atmosphere and ionosphere in the form of

pulses of electromagnetic waves up to hundreds, sometimes up to 1000 km. Since 1976, EMP and other methods have predicted more than 10 strong earthquakes.

So on the territory of the Yangibazar Magnetic and ionospheric Observatory, round-the-clock electrometric observations are organized with the help of a cluster center.

Figure 4 the average daily variations of EMP at the Yangibazar Observatory are shown calculated by averaging data from 365-day field intensity measurements. As can be seen from the Figure 4, the intensity of the field in the first half of the day is negative, and in the second - positive.

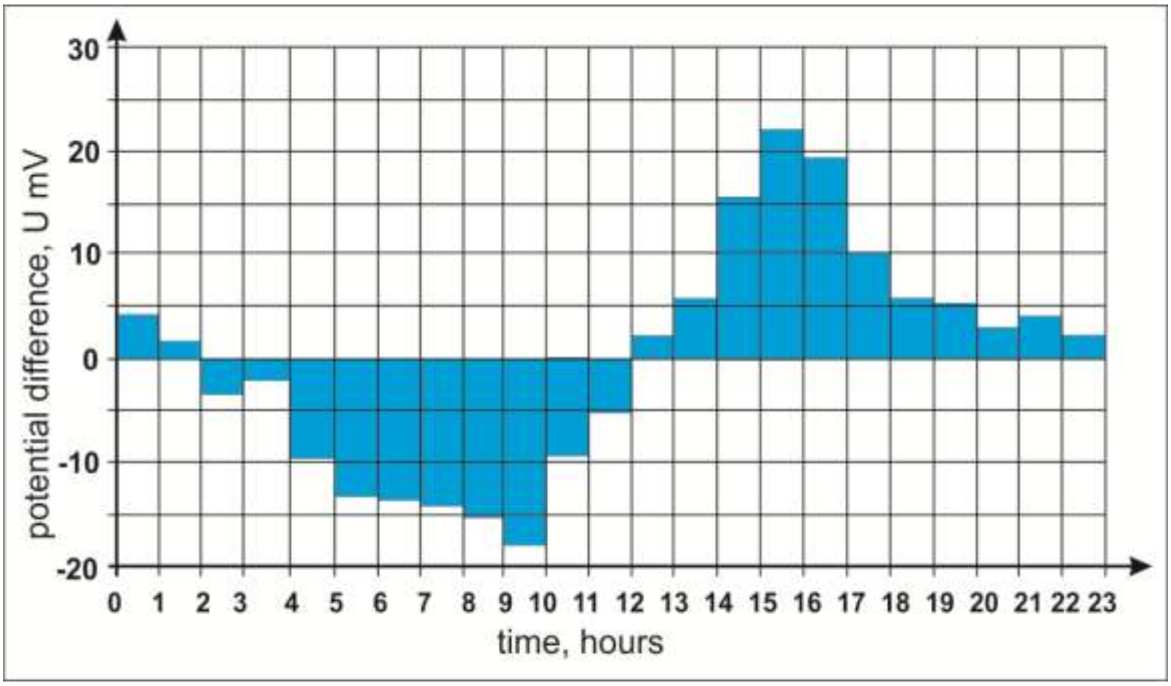

Figure 4: Average Daily variations of pulsed electromagnetic radiation at the Yangibazar Observatory (local time) (2013-2015)

As an example, see Figure 4 shows graphs of the daily course of EMP at the Yangibazar Observatory for 2013-2015. Analysis of the graph showed that diurnal variations in background intensity occur at all times of the year, but their shape and amplitude are subject to seasonal changes. The shape of the daily course in the winter months is more smoothed and does not have clearly defined patterns. The night maximum is planned after midnight, at least during daylight hours (6-14 hours). During the transition to the spring-summer season, the shape of the daily course changes and is characterized by the presence of two maxima-afternoon (16 hours) and at night. The minimum intensity of EMP occurs in the morning (9-10 hours). The amplitudes of diurnal variations are greatest in summer and smallest in the winter months. In the spring and autumn months, they are approximately the same and are the average between summer and winter values. Summer EMP intensity values reach 4000-5000 pulses per hour, and in winter they are much lower. This indicates that the causes that determine the forms of diurnal variations of EMP are interregional in nature. The highest EMP intensity values are observed in the summer months (June, July), and the lowest in the winter months (January, February). Absolute values of seasonal variations are in the order of minimum-20mV, and maximum-40mV. Thus, the main regularities of regular variations of EMP are as follows: - daily variations of EMP are characterized by a minimum signal level in the morning hours of local time and a maximum (in winter) - at night. - seasonal variations in EMI intensity are characterized by a maximum of EMI intensity in the summer months, and a minimum in the winter months. To analyze the relationship of variations in the background intensity of EMP with meteorological factors, we used data from the Kustovoy Center station.

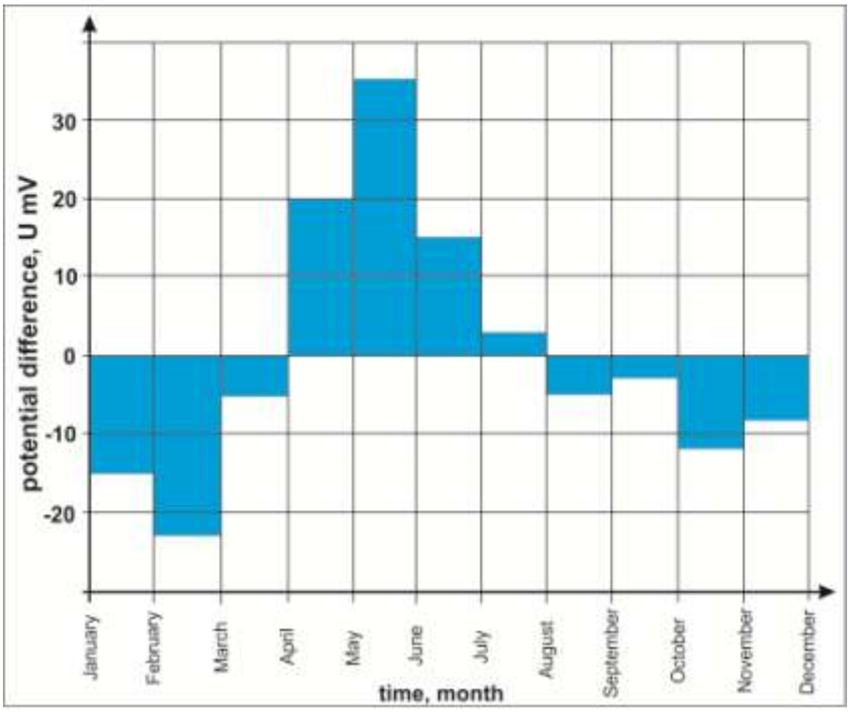

Figure 5: Seasonal variations of pulsed electromagnetic radiation at the Yangibazar Observatory. (2013-2015)

In Figure 5 annual variations of pulsed EMP at the Yangibazar Observatory are reflected. Thus, the intensity of EMP is high in the summer months, and low in the winter months.
Based on the results of statistical analysis of changes in the electromagnetic field pulses at the Yangibazar Observatory in 2013, it was found that strong changes are observed in the summer months relative to the winter months. But the average monthly schedule of changes differs from other months. These anomalous changes are compared with earthquakes in the region that occurred within a radius of LgR=0.204 M+1 km. The results of the analysis showed that the electromagnetic field from January to May 18 changed on average by 100-200 mV, and on May 20-25 it changed by 600-650 mV (Figure 6).

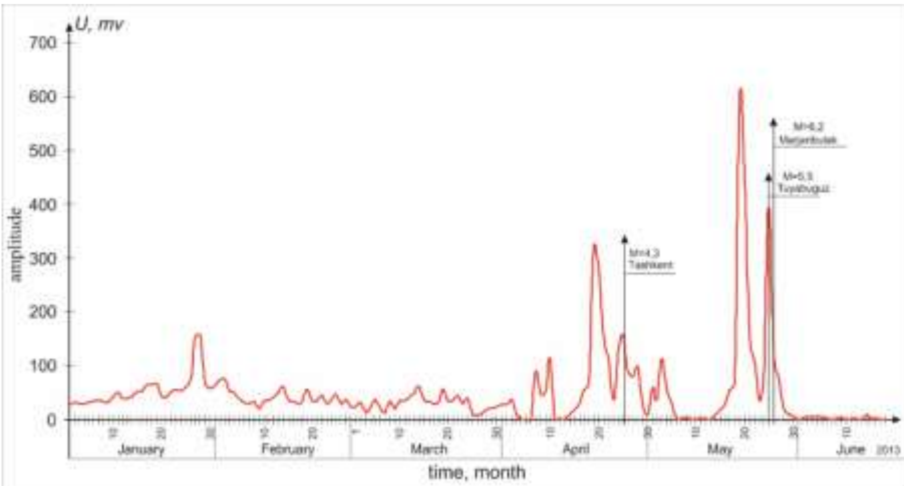

Figure. 6. Anomalous changes in the pulsed electromagnetic field at the Yangibazar Observatory associated with the Tuyabuguz and Marjanbulak earthquakes.

In Uzbekistan and other seismically active regions, numerous anomalous variations of EMP associated with earthquakes were identified in 1974-2017. The intensity of the amplitude of anomalies on normal weekdays increases from several tens to several hundreds, and even a thousand times. The results of continuous EMP observations at the Yangibazar magnetic ionospheric Observatory and variations in other regions are compared.
It was shown in [Gokhberg M. B. et al. 1980] that even when the entire energy of an earthquake source with E=10 j is transformed into electromagnetic energy, the EMP intensity on the daytime surface will be less than the background component. Therefore, the recorded anomalies are the result of the near-surface interaction of crustal blocks during their relative movement near the observation point and are determined by the physical properties of rocks, their material composition, and the nature of movement along the fault.

CONCLUSION

Thus, many years of scientific research have been carried out in Uzbekistan using complex electrometric methods – atmospheric electricity, dipole electric sensing, natural electric field, electromagnetic radiation pulses on the territories of the Poltorak gas storage facility, Charvak reservoir, South Alamyshik, Tamdybulak, Shirmanbulak, epicentral zones of the Gazli earthquakes and other places. As a result, anomalous changes in electric fields associated with geodynamic processes, modes of operation of man-made objects, earthquakes, aftershocks, and other processes are identified. The results showed that electrometric methods are one of the most effective methods.
Currently, in the territory of Uzbekistan, complex earthquake forecasting is continuously performed by using observations monitored by various methods, including geophysics, hydrogeoseismology, strainmeters, etc. The Tashkent region is characterized by 8 or 9 zones of seismic activity. In this region, we should expect some connection between seismic and electromagnetic phenomena, both in the atmosphere and in the accessible upper parts of the lithosphere. Hence, there is a possibility to establish natural relationships among these phenomena for the prediction of earthquakes.
The average daily, monthly and annual anomalous variations in the pulsed electromagnetic field associated with earthquakes were revealed. It was suggested that long-term, medium-term and short-term anomalous variations in the electromagnetic field associated with anthropogenic processes and earthquakes manifest according to models of earthquake processes.
On the basis of the scientific results regarding the identification of regularities in the electromagnetic anomalies of the indicators of seismically active zones in Uzbekistan, the average daily, monthly and annual variations in the pulsed electromagnetic field and anomalies related to earthquakes were utilized by the Ministry for Emergency Situations. The results allowed the forecasting of a number of strong short-term earthquakes (Tuyabuguz, Marjanbulak, and Tashkent) that occurred in the territory of Uzbekistan in 2013-2017.

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