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Abstract 1-06

The geomagnetic field variations and earthquake activity

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The presentation focuses on the induced telluric currents in the Earth's lithosphere and their geodynamic impact. The currents in the lithosphere are induced by the geomagnetic variations (magnetic storms with sudden commencement (SSC), polar sub-storms and Sq variations), which originate externally from the ionospheric current system (mainly controlled by solar radiation), as well as by man-made/artificial electromagnetic impact. We analyzed whether external influences under certain conditions might accelerate earthquake occurrences than they normally would have under regular tectonic processes. Specifically, we investigated whether it is possible to find a direct pattern of natural or man-made activity which precedes seismic events and may be useful as a tool of short-term earthquake prediction. In recent years there were a few papers on a possible seismic triggering effect of pulsed electromagnetic signals of technological origin [e.g., 1, 5], where the variations of earthquakes in Tajikistan and Kyrgyzstan as a result of electric current injection into the Earth crust with application of pulsed MHD power system were analyzed. The authors concluded that the number of earthquakes tends to increase 3-5 days after the passage of electric pulse signal. If such an effect occurs, it is possible that a similar effect on the seismicity may be provided by electromagnetic sources of natural origin. First of all, it may be expected from exposure by magnetic storms and the accompanying geomagnetic disturbances.

Suggestion about triggering influence of geomagnetic disturbances (SSC) on seismicity in Kyrgyzstan, Kazakhstan and Caucasus (with maximum effect on 2-7 day after the storm commencement) is declared in [2]. It was noted that at searching for a relationship of seismicity with magnetic storms (SSC) were found the brightly denominated effects and their full absence (regional or local effects) that is explained the miscellaneous by geological construction of regions.

A recently discovered coupling of daily probability of earthquake occurrence with a local quiet solar-diurnal variation of geomagnetic field (Sq-variation) for the most areas of the globe (China, Italy, Greece, California, Austria, etc.) was investigated in detail in [3]. These results served as the first impulsion to the idea of universal coupling of daily seismic activity and regional Sq-variations of horizontal component H of geomagnetic field. A physical mechanism of Sq-variation (telluric currents) coupling with the daily occurrence of earthquakes was proposed and justified. It was shown that the induced telluric currents in the conductive lithosphere play an important role in the geodynamic process. Large-scale currents covered an area of about 10^6 km^2 and nearly uniform penetrate the lithosphere to a depth of 100 km. In the presence of the main geomagnetic field telluric currents produce the Lorentz force acting on the lithosphere. Numerical results showed that the mechanical moments of these forces suddenly provide a lot of energy comparable to the energy increment of tectonic deformation. As a result, the proposed model highlighted that the energy involved in this effect (called seismo-magnetic) is very high and comparable to the energy of tectonic deformation, for example, it is equivalent to the earthquake magnitude (Richter scale) of M = 4.0 on an area of 200 by 200 km.

An analysis carried out for Caucasus region shows the opposite effect (Fig.1). There are more earthquakes during a day-time than at night. Nevertheless, the correlation with the magnetic field variations is obvious. The features observed in the Caucasus region indicate that additional stresses introduced by perturbation of telluric currents in the crust induced by geomagnetic variations may contribute to decrease of the triggering threshold, or, under certain conditions, this perturbation has not a significant impact at all. Thus, we observe a significant difference for Caucasus region: for the circle area of diameter 300 km near Nalchik diurnal variation of seismicity obviously correlates with the regular Sq-variation of the geomagnetic field (according to Baksan observatory data), while for the Chechnya region (at the distance of 150-200 km), it is practically absent.

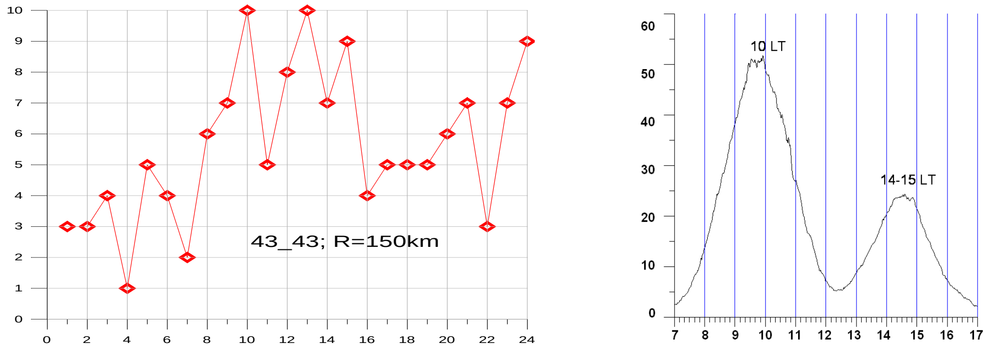

Fig.1. Left panel shows a number of earthquakes per hour for 1973 - 2005 in the vicinity of Nalchik (diameter 300 km) at local time (45º E). Right panel shows an absolute value of horizontal component Sq variations (7-17 LT) that corresponds to the daily maximum of seismic activity.

Vrancha area (Romania) is considered as one of the classic examples of concentrated seismicity. The seismic area here is a narrow band of 90 km length and 25 km width. For the Vrancha area it was revealed

[4] how the stressed rocks react on disturbances of geomagnetic field. It was showed that release of seismic energy in Vrancha area is connected with sharp increase of H-component of geomagnetic field. Such “gradients” before earthquakes are midnight polar substorms or more exactly - their midlatitude manifestation.

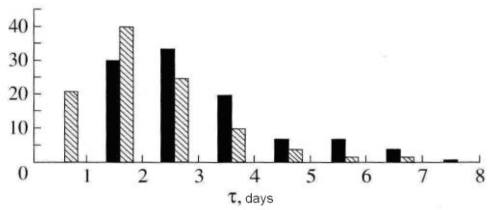

Fig.2. The time domain in days before earthquake occurrence in terrestrial crust after substorm maximum

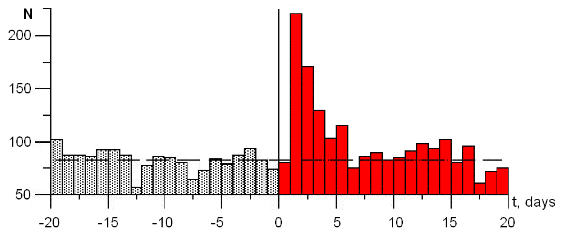

Fig.3. Daily number of earthquakes for upper 5 km layer of the crust at Bishkek test site for $M_b > 3.4$. 0 – Firing run of MHD generator

The time domain from maximum of substorm development before the earthquake is straight connected with epicenter depth. It was marked the difference in duration polar substorm before crust and upper mantle (deep focuses) pushes that determined by morphological peculiarities in spectrum of magnetic field variations. The time delay between substorm maximum and earthquakes realization corresponds to 2-3 days (200 events).

The same effect on the seismicity of the electric current pulses is provided by MHD generator and electric batteries. In [1, 5] the long-term observations of the influence of powerful current pulses on seismicity were analyzed, and it was concluded that the sharp increase of seismic activity correlates with a probability of 99% with firing runs of MHD generator, the increase of daily earthquake number appears in 1-6 days after the electric pulse (Fig. 3), and potentially affected area is hundreds of kilometers. Since the energy injected into the Earth by artificial electric pulses is several orders less than the released seismic energy, it was concluded about the triggering nature of electric impact and release of energy accumulated in the crust during tectonic processes in the form of increased number of relatively weak earthquakes.

It should be noted that the mechanism of electromagnetic triggering phenomenon is not clear yet, though various models and mechanisms were proposed. It is supposed that the "triggers" can cause earthquakes by changing the stress state of the crust. First of all, it requests an assumption of ponderomotive effects induced in the ground by electric currents. The magnitude of this effect df excited by MHD pulsed current dI easily estimated as $f = [dI \times B_0]$, where I – electric current, B_0 - constant geomagnetic field around the test site. An analysis shows the stress distribution (in N/m^2) in the horizontal direction in the upper 2 km layer. As a result, a low voltage pulses are within $1m^2$ area, however, their cumulative value across the entire test site may be significant. The greatest value of the voltage may reach the most conductive zones – geological faults filled by crushed or fluid-saturated rocks.

In [5] a model is discussed, in which a factor determined a possibility of generation of additional elastic field in rocks under electromagnetic action are electrical characteristics of the rocks, as well as a degree of energy saturation. The latter may be primarily due to a high level of free electric charges and electro-kinetic potential, as well as fluid saturation capability of the crashed rocks in geological faults. Since, as was shown in [1, 5], an efficiency of the triggering effects of electric current is observed at a depth of 0-5 km, which coincides with the hydrostatic zone of the crust characterized by the presence of free and bound water that fills cracks, pores, and cavities, we may assume an important role of fluids in the mechanism of generation of additional elastic stresses by electromagnetic pulses or weakening the seismogenic fault due to fluid migration under electromagnetic impact resulted in the fault lubrication and decrease of the fault effective strength.

Moreover, it was shown that the energy of magnetic storms released in the form of heat is comparable with the energy released by earthquakes. A distribution of the total heat flux along the profile at the surface due to quiet solar-diurnal variations produced by the five current rings with a current of 20 kA each was estimated. The flux is several times lower than the estimates obtained in [6] for SSC ($5 \cdot 10^{-7}$ W m^{-2}), but due to the nature of the regular solar-diurnal variations and their intensity increase during geomagnetic disturbances it may be assumed that the total absorbed energy may be comparable and even exceed the energy of magnetic storms. Estimates of average flows for the solar-diurnal variations, in general, are comparable with the estimates for the impact of magnetic storms and MHD generator, but there is a fundamental difference - the main part of the heat absorbed by the Sq variations occurs at greater depths.

As a conclusion we note that numerous observational results acquired during a few past years indicate an intense interaction between diurnal Sq variations of geomagnetic field and seismic activity. The discovered effect appears in many seismic-prone areas of the world. In particular, by providing a geophysical model, which fits the variety of observations qualitatively and includes a surprisingly high amount of energy transferred to the lithosphere, the thesis of a significant and general triggering mechanism due to the induced magnetic moment and the resulting torque gains much credibility. It is obviously that the described mechanism also applies to strong earthquake activity, thus being of importance for seismic risk considerations. The same effect on the seismicity is provided by artificial pulsed power systems. On the one hand, a fundamental aspect of the research is evident due to new knowledge on earthquake source behavior under external triggering impacts. On the other hand, there are applied geophysical aspects of these results, namely, the new opportunities for studying the state and properties of heterogeneous media and, consequently, as well as a possibility of control of the seismic regime.

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