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Electromagnetic earthquake triggering phenomena: State-of-the-art research and future developments

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Developed in the 70s of the last century in Russia unique pulsed power systems based on solid propellant magneto-hydrodynamic (MHD) generators with an output of 10-500 MW and operation duration of 10 to 15 s were applied for an active electromagnetic monitoring of the Earth's crust to explore its deep structure, oil and gas electrical prospecting, and geophysical studies for earthquake prediction due to their high specific power parameters, portability, and a capability of operation under harsh climatic conditions. The most interesting and promising results were obtained during geophysical experiments at the test sites located at Pamir and Northern Tien Shan mountains, when after 1.5-2.5 kA electric current injection into the Earth crust through an 4 km-length emitting dipole the regional seismicity variations were observed (increase of number of weak earthquakes within a week). Laboratory experiments performed by different teams of the Institute of Physics of the Earth, Joint Institute for High Temperatures, and Research Station of Russian Academy of Sciences on observation of acoustic emission behavior of stressed rock samples during their processing by electric pulses demonstrated similar patterns - a burst of acoustic emission (formation of cracks) after application of current pulse to the sample. Based on the field and laboratory studies it was supposed that a new kind of earthquake triggering - electromagnetic initiation of weak seismic events has been observed, which may be used for the man-made electromagnetic safe release of accumulated tectonic stresses and, consequently, for earthquake hazard mitigation. For verification of this hypothesis some additional field experiments were carried out at the Bishkek geodynamic proving ground with application of pulsed ERGU-600 facility, which provides 600 A electric current in the emitting dipole. An analysis of spatio-temporal redistribution of weak regional seismicity after ERGU-600 pulses, as well as a response of geoacoustic emission recorded in the wells at a distance of 7-12 km from the emitting dipole to the ERGU-600 pulses confirmed the effects of an influence of electromagnetic field on the deformation processes in the Earth crust and the real existence of electromagnetic triggering phenomena. For verification of results of field observations laboratory studies of behavior of rock samples under critical stress-strain state and external electric actions were carried out at the spring and lever presses, as well as at the stick-slip models simulated the seismic cycle (stress accumulation and discharge) in the seismogenic geological fault. Various possible mechanisms of weak electrical stimulation (electric current density 10^{-7}-10^{-8} mA/cm^2 at a depth of earthquake epicenters of 5 to10 km) of deformation processes in the Earth crust, including increased fluid pore pressure, electrokinetic phenomena, magnetostriction, electrical stimulation of fluid migration into the fault area are considered. However, the mechanism of electromagnetic earthquake triggering phenomena is still open.

Based on the field observations of electromagnetic triggering of weak seismicity resulting in a partial safe release of stresses in the Earth crust a possibility of control of seismic process is considered for risk reduction of catastrophic earthquakes.

The results obtained from field and laboratory experiments on electromagnetic initiation of seismic events allow to consider a problem of lithosphere-ionosphere relations from another point of view. Keeping in mind that the current density generated in the Earth crust by artificial electric source is comparable with the density of telluric currents induced during severe ionospheric disturbances (e.g., magnetic storms) it may be possible under certain favorable conditions in lithosphere to initiate earthquakes by electromagnetic disturbances in ionosphere. A possibility of application of these triggering phenomena for short-term earthquake prediction is discussed.