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ON PREDICTABILITY OF INDUCED SEISMICITY VARIATIONS

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Sergey TURUNTAEV[1,2,3] and Alesya KAMAY[2,3]

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The effect of human activity on the Earth's interior during the exploitation of mineral deposits, filling in water reservoirs, hydrocarbon production, utilization of geothermal energy, etc. often causes activation of seismic processes, i.e., generates induced seismicity. The induced seismicity is a subject of a great number of publications, for example, Simpson (1986), Adushkin and Turuntaev (2005), Nikolaev (1994).

The main problems to be solved when studying the induced seismicity are those related to forecasting and preventing catastrophic earthquakes. In contrast to natural earthquakes, in this case, there is no question concerning the place of a probable induced earthquake because such events are expected to hit the neighborhood of the action applied. Typically, the energy of the induced earthquake is defined by the scale of action; but in some cases, it may significantly exceed the inducing impact**s**.

Efficient methods for analyzing the behavior of complex dynamical systems (to which the geophysical systems pertain) were developed during the recent decades in the field of nonlinear dynamics. In particular, these methods allow one to distinguish between the systems characterized by different types of stability and to identify the changes in the state of the system, which are caused by external action. The latter statement is based on the assumption that if a system exposed to some impact has changed its state, the analyzed processes in this system will contain a deterministic component defined by the external factor. The appearance of the deterministic component should decrease the fractal dimension of the attractor in the phase space of the system states (if such attractor is distinguished) and decrease the dimension of the embedding space (the number of the key parameters required for describing the behavior of the system).

In the present paper, we use Grassberger and Procaccia (1983) method for analyzing the seismicity in several regions that suffered from technogeneous impacts. The study yielded two main results. The first is the fact that the induced seismicity exhibits higher degree of determinism and predictability of the seismic process. The second is the discovery of the changes in the seismic regime, which are caused by rather weak impacts compared to the energy of tectonic processes.

Four data sets were studied: (1) the seismicity and characteristics of the extraction and injection of a fluid in the region of the Romashkino oil field; (2) the seismic activity before and after the large-scale explosions on Burlykiya and Uch-Terek Rivers in Kyrgyzstan; (3) the seismicity in the region of the Geysers geothermal complex in California, United States; (4) the microseismic background recorded by active low-frequency seismic prospecting method (ANChAR).

To explain the obtained results, we consider the rate-and-state model with a two-parameter friction law (Hobbs, 1990) and assume that the technogeneous impact of any nature causes the critical shear stress to decrease (for example, due to the increased pore pressure when injecting liquid, or during the vibration action, etc.). It was found, that decrease of the critical shear stress due to some action results in diminishing of correlation dimension as well as dimension of embedding space, as it

[1] Dr.Sci., Institute of Geosphere Dynamics, Moscow Institute of Physics and Technology, All-Russia Institute of Automatics, Moscow, s.turuntaev@gmail.com
[2] PhD student, Moscow Institute of Physics and Technology, All-Russia Institute of Automatics, Moscow, Moscow, alesia.kamay@gmail.com

was seen in real cases. The presence of the stable states opens the possibility of forecasting the development of induced seismic activity.

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