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Influence of induced seismicity on seismic hazard in the Urals, Russia

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Traditionally common methods of seismic hazard assessment for wide territories including countries or large regions take into account only natural earthquakes. As result the main efforts of scientists in problem of seismic zoning are aimed to zoning factors and conditions that raise the probability of strong tectonic earthquakes. Such approach is obviously correct if the natural seismicity is dominant. But in some regions the contribution of induced earthquakes as well as nontectonic seismic events may be comparable to tectonic one or even prevail over it. The main factors composing induced seismicity are exploration of deposits (oil and gas extraction, open-cast and underground mining), hydraulic structures (dams, reservoirs, power stations), underground storage of waste or gas etc. In fact, many kind of such human activity influence on seismicity. It is the reason of development of many preventing measures to minimize possible negative sequences. One of them is correct estimation of seismic hazard and possible risk due to appearance of induced seismic sources.
We have tried to estimate the contribution of induced earthquakes occurring in the Urals that is the region of moderate seismic activity, where hundreds of deposits of different mineral types are under exploration. To obtain reliable result we followed the idea of probabilistic-deterministic forecasting of dangerous seismic processes according to methodology offered by V.I. Ulomov that have become common in Russia and other countries since the end of XX century. To estimate an actual seismic hazard for some mining districts of the Urals, the data set of hundreds of natural and induced earthquakes happened during recent decades was used. Including macroseismic information it has become the base for development of two prognostic models. The first one is the model of zones generating induced seismic sources. It describes parameters of whole variety of induced and man-made seismic sources that may occur in the Urals, including mine fields, open pits, oil deposits and reservoirs on rivers. The second one is the model of the seismic effect generated by induced earthquakes. Both models differ sufficiently from ones elaborated earlier only for natural seismicity by other researchers.
As result we have obtained new maps of seismic hazard for the Middle Urals. They were calculated in terms of seismic intensity and peak ground acceleration and show the actual level of possible seismic effect due to induced seismicity. It is shown earthquakes only from three mine districts may generate the most significant seismic effect. They occur at the area of Severouralsk bauxite deposit, Nizhniy Tagil iron ore deposit and Verkhnekamskoye potash deposit. In the first two districts there are conditions for generating strong Mw 4.5 tectonic events, that caused by stress-strain changes due to deep mining. In potash mines main hazard is caused by roof falls. Other zones are not able to induce events that produce effect greater than background normal level (5 points of MSK-64 scale).