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Induced seismicity in the Tbilisi region, East Georgia

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The paper gives an overview on the underground fluid and geodynamical response to oil production processes and discusses the possible oil pumping-induced seismicity in the Tbilisi region, Georgia. The intensive oil production in 80-s disturbs the regime of the central hydrothermal deposit and causes depletion and desalination of springs.
Analysis of data in the period of intensive increase in oil production rate at the Samgori-Ninotsminda oil field in 1975 and its drastic decrease in 1985 points to close connection of hydrological regime of thermal water in boreholes #1 Botanic-Garden (1 BG) with oil production level: fast increase of oil production leads to drastic decrease of debit in the central borehole to almost zero and 20-meters decrease of water level in the with some relatively long (month) time lags. Water debit in 1BG begin slow recovery after termination of pumping.
In Tbilisi region during 1970-1989 was produced more than 5.1010 to kg of oil so according to existing statistics the level of extraction is close to critical for appearance of induced seismicity. The stress change induced by hydrocarbon extraction is as a rule small, but the deviatory stress exceeding 0.01 MPa may trigger seismic activity. In order to distinguish the seismohydraulic effect we plotted the seismic activity (SA) versus time in the time interval, covering periods before (1960-1970), during (1970-1989) and after termination (1990-2004) of oil production interval. To exclude the effect of local seismic network changes during 1960-2004 only the catalog of the Tbilisi Seismic Observatory (TSO), where the registration conditions were not changed in this period has been used. In the analyzed catalog were included events occurred within circular area of radius 50 km around TSO. Three types of TSO catalog were analyzed: TSO1 included all events, recorded at the observatory, even smallest ones; TSO2 included only the events of magnitude M [U+F0B3] 2.5; TSO3 included the events of magnitude M < 2.5 and TSO4 is the catalog of explosions, compiled by the Seismic Monitoring Centre of Georgia. According to the catalog TSO1 the SA increase in the hydrocarbon production period is evident. The distributions reveal very interesting details of local seismicity. Around the same period the seismic activity increased significantly. The effect is present even after exclusion of possible artifacts connected with industrial explosions and it can be seen also in distribution of earthquakes of magnitude M [U+F0B3] 2.5, which can not be identified as explosions.
All this evidence lead us to the conclusion that the oil production and resulting pore pressure changes in some parts of the region lead to changes in the Coulomb stress, which are favorable for triggering induced seismicity. We presume that due to high stress-sensitivity of the region there is nonlinearity in seismicity response to weak external impact (here – recurrence of explosions). The induced seismic activity of significant amplitude is synchronized with the explosion regime, as even for earthquakes of magnitude M [U+F0B3] 2.5 there is a clear maximum at 12 h G.M.T, when the most of explosions lake place.