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Geochemical contamination and induced seismicity in shale hydrocarbon development

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The paper examines the environmental risks associated with the development of unconventional mega-reservoir hydrocarbon (*HC*) accumulations – shale formations. The risk of development of giant shale formations includes the danger of both geochemical contamination and the danger of induced seismicity. The shale formations are complex source both of HC and industrially significant, valuable, but also potentially toxic chemical elements such as *Co, As, Zn, Cs, Ag, Ni, Au, V, Se, Re, U, Pt, Mo, Hg, Cu*, and others [1,2]. Examples of industrial-scale extraction of *U, Ge, V, Mo*, and other metals from oil are known from international practice (USA, Canada, China).

Hydrocarbon production in shale formations involves horizontal drilling with hydraulic fracturing, proppant injection, and thermal stimulation. When extracting shale hydrocarbons using such methods, strong induced seismicity often occurs [3-5]. For example, the seismicity in Oklahoma, a region of intensive shale oil production, was evaluated to be systematically higher than in California, which is known for its strong earthquakes [3]. If weak or water-saturated soils prevailed in the region, then even not severe earthquakes could cause significant damage. In several cases, such as the case of the giant Groningen gas field, the danger of induced seismicity led to the termination of economically successful projects [4].

To reduce the risk of induced seismicity, some version of Semaphore method is used usually. According to the Semaphore methodology, if in a local area of the well a significant earthquake occur, the strong monitoring should begin, and if the repeated significant seismic effect occurs in the vicinity of an injection or production well, the operation of this facility is stopped. The inaccuracies of the use of this method, which may both underestimate or overestimate the danger, are discussed. Firstly, the induced earthquakes can occur at greater distances and with a longer time delay than assumed by the Semaphore method. On the other hand, a number of compelling examples show that a strong increase in induced seismicity is followed by a decline in earthquakes number [5]. Earlier, an example of such trend was noted for the reservoir and dam of the Enguri hydroelectric power station, Georgia [6]. The trend of an increase and subsequent decrease in induced seismicity under prolonged, strong anthropogenic impact is important from a practical perspective; physically, this effect can be explained by the relaxation of initial tectonic stresses [5].

The processes of geochemical contamination and development of induced seismicity significantly complicate industrial safety in shale play development and should be taken into account.

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