SEISMOTECTONICS OF OIL AND GAS AREAS IN LOWER KURA DEPRESSION OF AZERBAIJAN

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ABSTRACT. On the basis of data about the earthquakes that occurred on the territory of Azerbaijan in the Lower Kura depression and in adjacent areas, the possible impact of seismotectonic processes in the areas of active tectonic faults on hydrocarbon deposits is studied. Using isoseist maps of seismic fields of strong earthquakes and data of weak seismic shocks recorded by digital stations network, were determined potential source zones in the study area and was estimated their seismic potential. The results show that in the Lower Kura depression and in the border areas, there are potential source zones where there is a possibility of earthquakes with an intensity of Iₒ = IX ÷ X points (M = 6.6 ÷ 7.4). The cracks formed in the sources of these earthquakes cause destruction of the structures of oil and gas deposits that can eventually lead to migration of the oil and gas.

Some researchers argue that in the generation and migration of hydrocarbons, as well as in their accumulation on the lively parts of the earth's crust, the important role is played by natural seismic and tectonic processes [1,2].

Data on many weak seismic shocks in the oil and gas regions reveals great opportunities to research the spreading feature of seismicity, to investigate possible links of the oil and gas deposits with fault areas generating earthquakes and seismotectonic processes. The observation network of 35 digital seismic stations operating in the territory of Azerbaijan, allows to register the weakest earthquakes (M≥1) throughout the territory of the republic, including the Lower Kura depression, where there are numerous oil and gas fields.

The main purpose of the article is to study the effects of seismotectonic processes on the active tectonic faults to hydrocarbon deposits in the Lower Kura depression on the basis of earthquakes data.

The works of many researchers on the study of seismicity of different areas show that strong earthquakes occur in deep crust fault zones [3]. In addition, studies based on accurate and reliable seismic and geophysical data of strong earthquakes such as Ashgabat (Turkmenistan, 1948), Friuli (Italy, 1976-1977), Al Asnam (Algeria, 1980), Montenegro (1980), Gumdag (Turkmenistan, 1983), Caspian (Azerbaijan, 1986) show that all strong earthquakes occur in deep crust faults. [4]

On the territory of Azerbaijan, by a variety of geological and geophysical methods a number of faults have been identified [6,7,8,9,10,11,12,13,14,15]. However, maps of deep faults of republic created by different researchers on the basis of material obtained by geological and geophysical methods or as a result of their complex use, are different enough from each other. As it was noted by F.S.Akhmedbeyli and A.H.Gasanov comparing the currently used tectonic maps, in many cases, the spatial position and the amount of deep faults do not match [5].

If we take as a basis the regional faults on each of these maps, it is possible to compose the following generalized map of deep faults for the territory of the republic. (Figure 1)
Macroseismic data was collected and maps of isoseist macroseismic fields of many strong and medium-strength earthquakes that occurred until now in the territory of Azerbaijan were composed.

On isoseist maps can be seen that in the study area earthquakes with an intensity of more than VII points on MSK 64 scale were not observed. Basing on a comparison of isoseist and deep faults maps in Azerbaijan we can observe the connection of strong earthquakes with contrasting tectonic shifts in the fault zones (fig. 2 and 3). The figures clearly show the connection between earthquakes in the Lower Kura depression and Palmir-Absheron faults.
As was noted above, data on numerous weak seismic shocks creates an opportunity to identify the fault zones, generating earthquakes and to study possible links of seismotectonic processes taking place in these fault zones with oil and gas deposits. To this end, a map of the epicenters of the earthquakes registered in the territory of Azerbaijan in the period of 2004-2014 was compiled. Mapping of this period of time is associated with the establishment on the territory of the republic in 2004 of a wide digital seismic observation network. After the establishment of this observation network, the coordinates of earthquakes with low intensity (magnitude), including their depth, started to determine with high accuracy.

Seismic studies show that the seismic activity in the territory of Azerbaijan is distributed unevenly. While in some areas there is a high seismic activity, other areas are characterized by low seismic activity (Figure 4). As can be seen from the figure, the density of seismic shocks is mainly observed in areas of the Greater Caucasus, the Caspian Sea and the south-eastern regions. It should be noted that a large number of earthquakes is gathered in the western part of Azerbaijan. On the territory of the Lower Kura depression is registered a relatively small number of seismic shocks.
As can be seen from the research, strong earthquakes do not occur everywhere, but in areas of intense concentration of weak earthquakes. This refutes the idea of an equal distribution of the seismic potential in the regions with the same tectonic structures and fault zones. [16].

Taking this factor as a basis, T.Mammadli developed a method for determining the source zones of strong earthquakes on the basis of high concentration of weak earthquakes [17]. This method, unlike previous ones, allows to determine potential seismically dangerous areas without taking into account maps of deep faults and seismic statistics data of strong earthquakes. Application of this method revealed the presence of a variety of different active fault zones (i.e. potential focal areas) in the territory of Azerbaijan (Figure 5). The spatial positions of these fault zones show how mosaic is the structure of seismically active regions in the country.
In order to determine area features for earthquakes distribution in depth in the study was drawn up seismological section along profile I-I in the direction of SW-NE (Fig.6 and 7).

As can be seen from the section I-I, hypocenters of earthquakes, since the Earth’s surface extend to a depth of 60 km. But if closer to the central part of section on the distance of 40-80 to 20-25 km there is a dense concentration of seismic shocks, then in the extreme south-western and north-eastern parts the number of earthquake hypocenters, especially strong earthquakes with shallow depths, decreases. Over the past 10 years, was registered only one major earthquake that occurred in 2014 in Hajigabul region with \( M = 5.8 \) and a depth of \( H = 56 \) km. Compare of isoseist maps of strong and medium-strength earthquakes with fault zones confirmed their comparability (Figure 8 and 9).
Figure 8. Schematic map comparing active fault zones with pleistoseiz zones of known earthquakes with intensity in VI (on a XII-MSK-64 scale) points in the territory of Azerbaijan.

Figure 9. Schematic map comparing active fault zones with pleistoseiz zones of known earthquakes with an intensity of IX and more (XII-point scale MSK-64) in the territory of Azerbaijan.

In the scheme of allocation of active fault zones (or potential source zones) near the study area (regions of oil and gas deposits of the Lower Kura depression) potential source zones are clearly visible. They are active fault zones identified by the definition of strong earthquake zones on the basis of high concentration of weak earthquakes, corresponding to different segments of Vandam, Adzhichay-Alat, Kura, Absheron-Palmir and West Caspian deep faults.

The maximum magnitude (Mmax) of expected earthquakes in these focal areas was supposedly set between \( M_{\text{max}} = 5.8 \div 7.4 \), [17].

According to N.V. Shebalin, macroseismic effect of the strong earthquakes can be valued by the following equation for the macroseismic field:

\[
I = bM - v\log \sqrt{\Delta^2 + h^2} + c
\]

Where \( I \) - macroseismic effect at a given point (on scale MSK-64),

\( M \) - earthquake magnitude,

\( h \) - source depth,

\( \Delta \) - epicentral distance to the point I,

\( b, v, \) and \( c \) - coefficients

Generally \( b = 1.5 \); \( v = 3.5 \); \( c = 3 \).
Based on macroseismic data of large earthquakes that occurred in the territory of Azerbaijan, by F.T. Guliyev were redetermined equation coefficients of the macroseismic field [19] for the mountainous regions of the republic, where $b = 1.4$; $\nu = 3.6$; $c = 4$; and for depression regions $b = 1.5$; $\nu = 3.3$; $c = 2.7$;

Taking into consideration that the potential source zones are located in the mountainous and depression areas adjoined to the study area (Lower Kura depression) and using the macroseismic field equation, defined for the territory of Azerbaijan, it is possible to identify the level of seismic hazard for the said territory. (Figure 10).

![Figure 10. Estimated seismically dangerous areas with the expected intensity of X and XI points in the oil and gas regions of the Lower Kura depression.](image)

**Symbols:**
- The border areas with the intensity in X points (on MSK-64 scale)
- The border areas with the intensity in IX points (on MSK-64 scale)

![Figure 11. Deposits of oil and gas regions of the Lower Kura depression located of estimated seismically hazardous areas with possible intensity in X and IX points](image)

Comparing location of oil and gas deposits in the studied regions with an estimated seismical intensity in X and IX points, showed that a number of deposits is located in the areas covered by these seismically dangerous zones (the location of deposits was taken from the map "Places of oil and gas deposits of Azerbaijan and prospective structures", $M 1: 500 000$).

The results of the analysis of manifestations of numerous strong earthquakes on the earth’s surface, it becomes clear that in pleistoseist areas of high magnitudes and relatively low depths, breaks may appear on the surface of the earth. Usually such cases are observed during earthquakes with a magnitude of $M \geq 6.5$ and at a depth of $H = 10 \div 15\text{km}$. But such a situation can be observed in case of earthquakes at a depth ($H = 25 \div 35\text{km}$) and with a higher magnitude ($M \geq 7.5$).

The maximum magnitudes of expected earthquakes in the potential source zones occurring in the Lower Kura depression and adjacent to it territories, are estimated as $M = 6.6 \div 7.4$, depth $H = 15-$
30, and their seismic effect on the earth's surface, depending from the focal depth is estimated $I = VIII \div X$ points. Considering the above facts about the formation of discontinuities on the earth’s surface at a relatively strong earthquakes with shallow depths, we can come to the conclusion that the seismic hazard in IX-X points within the study areas, there may be cases of cracks formation, reaching the earth's surface. Such cracks, destroying the structure of oil and gas deposits, located at a depth of several thousand meters, can lead to migration of oil and gas. It should be noted, that after the strong earthquakes ($I = IX \div X$ points) there are cases of drying or vice versa saturation of spring waters in pleistoseist areas. These cases are associated with the aquifer overlapping, which is the source of these springs and water migration along the cracks formed after strong earthquakes. (Fig.11)

**Conclusion**

- Lower Kura depression is characterized by relatively low seismic activity. Earthquakes that occur here are related to geodynamic processes in active fault zones and mainly in respective segments of Kura and Absheron-Palmir deep faults.
- In the area of research earthquake hypocenters are distributed to 60 km in depth from the earth’s surface. But the most dense concentration of seismic shocks is observed at a depth range of 20-25 km.
- In this area have not been registered earthquakes with a magnitude more than VII points (on XII point MSK 64 scale). Nevertheless, in the study area and in the border areas there are potential focal zones of earthquakes with an estimated intensity $I = IX \div X$ points and magnitude ($M = 6,6 \div 7,4$). Cracks formed in cases of strong earthquakes, destructing the structure of oil and gas deposits, can cause migration of the accumulated here oil and gas.

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