INTENSITY OF MUD VOLCANIC ACTIVITY – A HARBINGER OF EARTHQUAKE

Abstract: Information on paroxysms of mud volcanoes and earthquakes in Azerbaijan and published materials on both events were analyzed in the article to clarify the relationship between these geological phenomena. Based on the associative model related to the proposed effects, some estimates were made to determine the minimum distances from the epicenter to the volcanic eruption and the minimum values of earthquake magnitudes. It has been established that the most important method for predicting volcanic activation associated with natural factors is to periodically study (monitoring) the chemical composition of fluids emitted to the surface. The regime studies confirm that even before small magnitudes of seismic events, some anomalies were recorded in the chemical compositions of water-mud mixture and intensity of their flows.

Key words: mud volcano, earthquake, model, harbinger.

Language: English

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Introduction and a brief historical view

The issue of the influence of seismicity on mud volcanic activity in Azerbaijan has been considered in many scientific publications, beginning with the studies of G.V. Abikh on the mud volcanoes of the Southern Caspian, continued by a large team of scientists in the twentieth century and at the present time [Malinovskiy, 1938; Abikh, 1939; Akhmedbeyli, 1975; Mellors et al., 2007; Aliyev and Bayramov, 2008; Baloglanov et al., 2016; 2016; 2017]. The results of the performed studies unambiguously confirm about the genetic connection of mud volcanism with seismicity [Aliyev et al., 2001; Mellors et al., 2007; Venikova et al., 2014; Baloglanov et al., 2017; 2017; 2018; 2018].

What is the mechanism of impact? How can this be explained? In addition, what chemical changes are observed in the occurrence of two geological events, and do these changes make it possible to predict them? The proposed paper to clarify these issues on the example of the regions of Azerbaijan, which are well known with its active mud volcanoes, and the seismic zones are close enough to these volcanic areas.

The study area, and temporal-spatial characteristics

East Azerbaijan territory and the adjacent Caspian Sea belong to seismic active regions and here from time to time register strong tangible tremors, which significantly affect the activation, especially in the paroxysms of mud volcanoes. There were recorded 414 eruptions in 93 mud volcanoes over the past two centuries in Azerbaijan [Aliyev et al., 2009, 2015]. It should be noted that in a comparative analysis of data on earthquakes and recorded eruptions of mud volcanoes, it is necessary to take into account the magnitude of the earthquake, the depth of the source, the energy class, the distance between the epicenter and the volcano.

Depending on the tectonic properties of the volcanic zones, various geological factors, lithofacial and structural characteristics have different effects on the morphometric dimensions of the mud volcanoes as well as their activity forms. Tendencies in the activity of mud volcanoes and seismic intensity are associated with the possible interaction between these natural geological formations that occur as a result of geodynamic stresses on the Earth's crust. Their interaction is related to the location of adjacent
microplates, or tectonic blocks. Seismic layers are in analogous or similar geodynamic conditions in these tectonic blocks, and their waves that originated in one of them did not undergo damping before they were transferred to adjacent microblock [Aliyev et al., 2001; Abbasov and Aliyev, 2018].

Studies have shown that strong earthquakes with a magnitude of 4.5-5.0 or more points provoke eruptions of mud volcanoes. At the same time, the causal relationship is established confidently when the earthquake and mud volcano are within one fault structure and if the volcano has been at rest for a long time and has accumulated sufficient energy for the eruption paroxysm or the volcano is located in the zone of tectonic tension within a radius of 80-100 km from the epicenter of the earthquake [Aliyev, 2003; Melllors et al., 2007]. After the Caspian earthquakes of November 25 and December 6, 2000 and subsequent seismic events in the South Caspian to the south and southeast of Baku, in 2001 a record number of (16) eruptions of land and sea volcanoes was recorded in Azerbaijan.

A catalog of some registered eruptions of mud volcanoes and earthquakes in Azerbaijan

| Mud volcano         | Eruption date | Earthquake date | Coordinates | Magnitude | Depth (km) | Epicentral distance (km) |
|---------------------|--------------|-----------------|-------------|-----------|------------|--------------------------|
| Kalamaddin          | 28.01.1872   | 28.01.1872      | -           | 5.7       | -          | 24                       |
| Shikhzarli          | 28.01.1872   | 28.01.1872      | -           | 5.7       | -          | 40                       |
| Bozaakhtarma        | 13.02.1902   | 13.02.1902      | -           | 6.9       | -          | 51                       |
| Shikhzarli          | 13.02.1902   | 13.02.1902      | -           | 6.9       | -          | 45                       |
| Shekikhan           | 15.03.2008   | 17.02.2008      | 40.11 / 49.31 | 2.60     | 34         | 13                       |
|                    |              | 27.02.2008      | 40.39 / 50.32 | 3.00     | 37         | 96                       |
|                    |              | 06.03.2008      | 40.65 / 49.65 | 2.31     | 6          | 79                       |
| Bozdog-Guzdek       | 13.02.2009   | 08.02.2009      | 40.33 / 49.79 | 2.04     | 45         | 16                       |
|                    |              | 08.02.2009      | 40.15 / 49.99 | 2.12     | 60         | 41                       |
|                    |              | 10.02.2009      | 40.48 / 50.77 | 2.89     | 56         | 99                       |
| Lockbatan           | 04.02.2010   | 12.01.2010      | 40.13 / 49.95 | 2.53     | 56         | 28                       |
|                    |              | 14.01.2010      | 40.72 / 50.77 | 2.13     | 46         | 101                      |
|                    |              | 24.01.2010      | 40.47 / 48.71 | 2.37     | 15         | 86                       |
|                    |              | 30.01.2010      | 40.68 / 48.54 | 2.29     | 6          | 107                      |
| Dashmaradn          | 12.05.2011   | 23.04.2010      | 40.33 / 50.39 | 2.93     | 52         | 115                      |
|                    |              | 07.05.2011      | 40.28 / 49.12 | 1.88     | 6          | 10                       |
|                    |              | 08.05.2011      | 40.38 / 49.06 | 1.96     | 38         | 18                       |
| Lockbatan           | 20.09.2012   | 20.09.2012      | 40.32 / 49.76 | 1.40     | 5          | 5                        |
|                    |              | 20.09.2012      | 40.32 / 49.73 | 1.45     | 5          | 3                        |
|                    |              | 20.09.2012      | 40.34 / 49.78 | 1.90     | 12         | 7                        |
| Shikhzarli          | 20.12.2013   | 06.12.2013      | 40.65 / 48.53 | 2.03     | 9          | 46                       |
|                    |              | 13.12.2013      | 40.99 / 48.48 | 2.28     | 3          | 47                       |
|                    |              | 18.12.2013      | 39.95 / 49.09 | 2.04     | 39         | 60                       |
| Keireki             | 12.10.2014   | 21.09.2014      | 41.00 / 49.88 | 3.01     | 41         | 59                       |
|                    |              | 30.09.2014      | 40.14 / 48.99 | 2.01     | 43         | 77                       |
|                    |              | 12.10.2014      | 40.20 / 50.14 | 2.15     | 32         | 41                       |
| Akhtarmaardy        | 26.01.2016   | 01.01.2016      | 40.15 / 49.12 | 2.2      | 21         | 24                       |
Geochemical indicators for volcanic fluids and harbinger of earthquakes

The eruption of the mud volcano, first of all, depends on its own activity, but one of the additional external factor is also an earthquake. The activity of the volcano is caused by the outflow of gas from the mud volcanic reservoir through disjunctive disturbances in the earth's crust, which serve as a volcanic channel. The process of displacing the water-mud mixture overlapping the volcano channel with gas takes quite a certain time, which will depend on the geometry of the channel and the physical properties of the gas and water mud mixture.

In the world practice there are not yet sufficiently detailed results of studies in the field of forecasting eruptions of mud volcanoes. As a result of visually established changes in the crater field of the mud volcano, as well as observing the intervals of eruptions that occurred after the high-magnitude earthquakes recorded in the region, in some cases it is possible to forecast possible eruptions, but this method is not sufficient for more accurate prediction of eruptions of mud volcanoes. In our opinion, the most productive approach for investigating the relationship between mud volcanism and seismicity should be considered monitoring observations of gryphon-salse activity of mud volcanoes.

At the same time, the inverse relationship between the activation of mud volcanic activity and seismicity has also been established. Activation of the calm gryphon-salse stage of mud volcano activity occurs before seismic events, as in the preparation of weak earthquakes to 3.5-4.0 points on the Richter scale. In Azerbaijan for the first time this relationship was established in the 80s and early 90s of the last century, when monitoring was carried out on the mud volcanoes of the Shamakhi-Gobustan seismically
active area, from measurements of fluid flow rates, the study of gases, and water from 2-3 gryphons on the volcano. Daily and weekly observations of changes in the chemical composition of fluids were determined, and the obtained data were compared with the number of weak earthquakes. As a result, some gas hydrochemical indicators were found that cause the activation of mud volcanoes before these weak earthquakes [Aliyev et al., 1989; Aliyev, 1992].

At the last stage of earthquake preparation, some values in the chemical composition of gases and waters (CO\textsubscript{2}, He, B, Cl and SO\textsubscript{4}) increase due to the deep flow of liquids.

Similar study was carried out at the beginning of the new millennium. For clarity, we present some results of the studies performed. A strong activation was observed on the island volcano Garasu (Fig. 2a) on September 12, 2001. 10 days before the earthquake with a magnitude of 4.1 points in the north of the Baku archipelago. On the SW of Absheron Peninsula on the mud volcano of Pilpila Garadagh (Fig. 2b), an unusual mud flow was observed on October 16, 2002. An earthquake of 3.8 points occurred near the shore of the sea in the Baku archipelago on October 27. In the same month on October 29, on the volcano Agzybir (Fig. 2c) located in the east of the Lower Kura depression, close to the sea band, an outpouring of mud volcanic breccia was recorded, before the November 11th weak earthquake (3.2 points) also in the Baku archipelago. A powerful outpouring of copious dirt was recorded in Central Gobustan (Bayanata microblock) on the volcano Kichik Maraza (Fig. 2d) two days before the earthquake on July 19, 2007, which occurred near the place of activation of the volcano. Such proximity of the epicenter of the earthquake that took place on February 20, 2009 near the northern part of the Baku archipelago, in the Alat region, was noted after the noticeable intensification of the activity of the mud volcano Dashgil (Fig. 2e) in South Gobustan (Toragay microblock), etc. On May 13, 2018, a strong flow was recorded in the mud volcano Yandara (Figure 2f) located in the Lower Kura region. Three days after this event (on May 16, 2018), earthquake occurred at 55 km from the volcano with magnitude 3.2 in Saatli region. There are many such examples, which allow us to consider an increase in the flow rate of emitted water-mud mixture, anomalous changes in some components of the composition of fluids are harbingers of earthquakes.

Starting from the first months of 2017, along with the increase in seismic tensions in the territory of Azerbaijan, the eruption of mud volcanoes has also increased. Hydrochemical monitoring was carried out for 10 volcanoes (Dashgil, Shikhzarli, Durovdag, Uchtepe, etc.) on Shamakhi-Gobustan, Lower Kura and Absheron oil-gas bearing regions from April to July of this year. In the indicated period of time, periodically (once a week) samples of water-mud mixture were taken and temperature were measured. Evaluation of the activity of the investigated sopka was made visually relative to the flow rate of the water-mud mixture and gas. Determination of the chemical composition of waters from sopka and the concentration of basic anions and cations is performed by atomic spectroscopy, ion chromatography and titrimetry. During the monitoring period, the composition of some water
components (B, SO₄, Cl) increased abnormally, temperature of water from sopka changed sharply as well. As a result, it was established that after two successive earthquakes occurred on May 11, 2017, with magnitudes of M = 5.4 and M = 3.3, respectively, on May 31 of the same year was an eruption of the mud volcano Shikhzarli.

**Conclusion**

It is confirmed that a relatively better method for predicting of eruptions of mud volcanoes is periodic chemical studies on volcanic fluids. An increase in the flow rate of emitted water-mud mixture, anomalous changes in some components of the composition of fluids are harbingers of earthquakes.

In contrast to the results of the published works, it was found that seismicity can affect the eruption of mud volcanoes when its magnitude is M≥5.5, and the distance from the erupted mud volcanoes to the epicenter varies from 20 to 50 km.

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