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Original paper

Study of the activity dynamics of the Otman-Bozdag mud volcano

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Abstract: Relevance. Otman-Bozdag is one of the most active and potentially hazardous mud volcanoes of the Absheron Peninsula, capable of producing large-scale emissions of breccia, gases, and thermal energy. Until recently, the absence of continuous seismic monitoring limited detailed analysis of subsurface processes and eruption dynamics. The installation of a modern digital seismic network in 2022 within an international project enabled real-time monitoring of mud volcanic activity. **Aim.** This study aims to investigate the seismic and geodynamic features of the Otman-Bozdag mud volcano, identify stages of its activity, and assess its connection with deep tectonic structures of the South Caspian Basin. **Methods.** The study is based on historical eruption data and continuous seismic records from 35 Kinemetrics and 12 Nanometrics stations. Seismic monitoring was conducted using SeisComP5 to detect local seismicity, identify P- and S-waves, estimate source depth, timing, and energy parameters. Stress regime variations were analyzed using the Lode–Nadai coefficient, complemented by satellite-based mapping of breccia redistribution. **Results.** The results indicate that the Otman-Bozdag mud volcano operates as a multi-level fluid discharge system controlled by deep-seated faults of the South Caspian Basin. Variations in the Lode–Nadai coefficient reflect transitions from stable to unstable stress states, coinciding with periods of volcanic activation. Seismic data allow precise determination of eruption onset, source depth, duration of individual stages, and total released energy.

Keywords: mud volcano, Otman-Bozdag, seismic monitoring, Nanometrics, breccia, fluid dynamics, Lode–Nadai coefficient.

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ГЕОГРАФИЯ

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Оригинальная статья

Исследование динамики активности грязевого вулкана Отман-Боздаг

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Резюме: Актуальность работы. Отман-Боздаг – один из наиболее активных и потенциально опасных грязевых вулканов Апшеронского полуострова, способный производить масштабные выбросы брекчии, газов и тепловой энергии. До недавнего времени отсутствие непрерывного сейсмического мониторинга ограничивало детальный анализ подземных процессов и динамики извержений. Установка современной цифровой сейсмической сети в 2022 году в рамках международного проекта позволила осуществлять мониторинг грязевой вулканической активности в режиме реального времени. **Целью** данного исследования является изучение сейсмических и геодинамических особенностей грязевого вулкана Отман-Боздаг, выявление стадий его активности и оценка его связи с глубинными тектоническими структурами Южно-Каспийского бассейна. **Методика исследования** основана на исторических данных об извержениях и непрерывных сейсмических записях с 35 станций Kinemetrics и 12 станций Nanometrics. Сейсмический мониторинг проводился с использованием SeisComP5 для обнаружения локальной сейсмичности, идентификации P- и S-волн, оценки глубины очага, времени возникновения и энергетических параметров. Вариации режима напряжений анализировались с использованием коэффициента Лоде-Надаи, дополненного спутниковым картированием перераспределения брекчии. **Результаты** показывают, что грязевой вулкан Отман-Боздаг функционирует как многоуровневая система разгрузки флюидов, контролируемая глубинными разломами Южно-Каспийского бассейна. Вариации коэффициента Лоде-Надаи отражают переходы от стабильных к нестабильным состояниям напряжений, совпадающие с периодами вулканической активности. Сейсмические данные позволяют точно определить начало извержения, глубину очага, продолжительность отдельных стадий и общую высвобожденную энергию.

Ключевые слова: грязевой вулкан, Отман-Боздаг, сейсмический мониторинг, Nanometrics, брекчия, флюидодинамика, коэффициент Лоде–Надаи.

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Introduction

Azerbaijan is one of the world's unique and exemplary regions for the development of mud volcanism. Of the approximately 2,500 mud volcanoes known on the planet, more than 350 are located on the land of Eastern Azerbaijan and in the adjacent Caspian Sea area (Fig. 1). All main types of mud-volcanic manifestations are represented here – active, extinct, buried, submarine, island, as well as sites with intense hydrocarbon seepage. The annual activity of mud volcanoes in the country ranges from 3–5 to 10 or more eruptions during years of heightened seismic activity, averaging 7–12 events per year. Over the past two centuries–since 1810–and during the last 25 years of monitoring on 94 volcanoes, a total of 443 eruptions have been recorded [Rahmanov, 1987; Aliyev et al., 2009; Ustyugov, Ershov, 2019]. Most of these episodes were synchronized with earthquakes which, considering their magnitude, hypocentral depth, and distance to the volcano, often acted as a "trigger mechanism" for the activation of mud-volcanic processes.

Studies of the geochemical and mineralogical characteristics of sedimentary rocks in Eastern Azerbaijan demonstrate the important role of geochemical indicators in reconstructing sedimentation conditions and identifying the sources of terrigenous material. The analysis of mud volcano breccias carried out in the study by [Baloglanov, 2023] revealed regular patterns in the distribution of chemical elements and their relationship with sedimentation processes and deep sources of material. Geological and geochemical investigations of mud volcano breccias in the eastern part of the region also show that their composition reflects the structural features of the sedimentary cover and the tectonic activity of oil- and gas-bearing structures [Baloglanov, Babayev, 2023]. Additional data on mineralogical and geochemical proxies of Miocene sediments indicate the complex origin of the sedimentary material and suggest a relationship between the sources and various lithological complexes, which is important for interpreting the formation conditions of hydrocarbon-bearing basins in Eastern Azerbaijan [Yolchuyeva et al., 2025].

However, an eruption occurs only when the volcano itself is in a state of energetic readiness to release [Aliyev, Bayramov, 2008; Ahmedbeyli, 1975]. Of particular interest is the high concentration of active volcanoes with regular eruptions. Among them are the widely known Lokbatan (29 eruptions) and Keyreki (19) on the Absheron Peninsula, Shikhzarly (26) in Gobustan, Gushchu (15) in the Shamakhi district, and Khare-Zirya (13) in the northern part of the Baku archipelago [Aliyev, Yetirmishli, 2021]. Each mud-volcano eruption provides new information, a "message" about the processes occurring in the subsurface. Unfortunately, due to the short duration of mud-volcanic eruptions, it is almost never possible to observe and follow the entire mechanism from start to finish. Usually, geologists learn about it with some delay, and in the case of remote volcanoes, observations occur after the eruption has ended. How the process unfolds is often recorded mainly from eyewitness accounts.

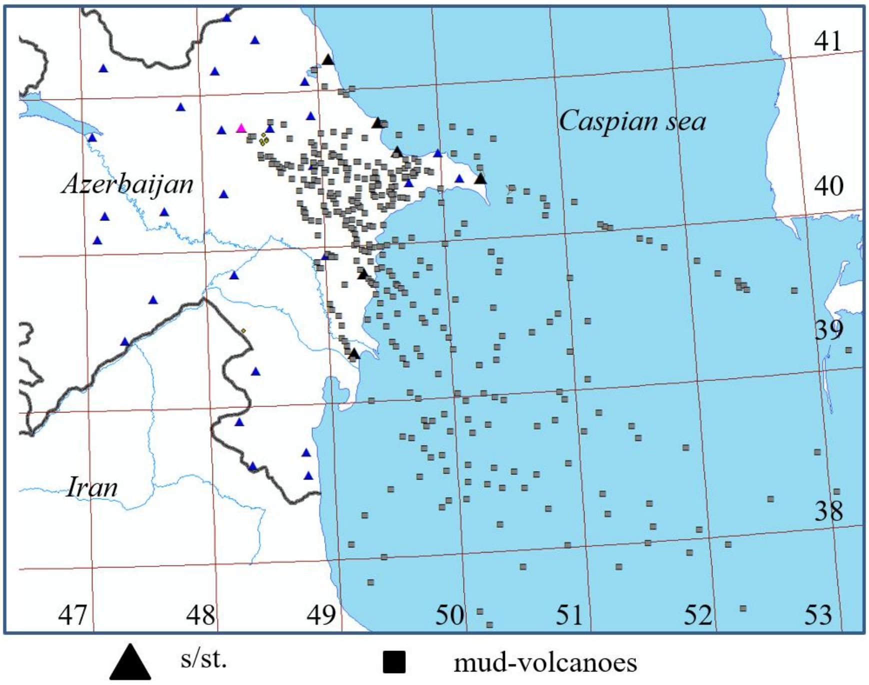

Fig. 1. Diagram of the distribution of mud volcanoes in Azerbaijan and the southern Caspian region

Thanks to the high-resolution capabilities of digital seismic equipment produced by Kinemetrics (USA), the Republican Center of the Seismic Service under ANAS has been able since 2003 to record and analyze mud-volcano eruptions, determining the time and duration, number of phases, hypocentral depth (vent), and eruption energy [Kazimova et al., 2016]. In 2022, within the framework of an international project, the Republican Center installed an additional 22 Nanometrics seismic stations (Canada) in Azerbaijan. For the first time in the world, 12 of these stations were deployed in the Absheron and Gobustan regions to study mud-volcano dynamics, and a dedicated monitoring group was established to track mud-volcanic activity.

The installation of high-sensitivity seismometers and GPS stations near mud volcanoes allows for monitoring microseismic activity and crustal deformations before and after eruptions. Such networks help identify correlations between volcanic eruptions and tectonic shocks. For example, analysis of digital records from volcanic stations several hours before the Lokbatan mud-volcano eruption on 11 August 2022 showed that the eruption did not occur instantaneously, but rather involved a preparatory phase [Yetirmishli, Kazimova, 2023]. Thus, the activation of the mud volcano started several hours prior to the eruption.

Given the high concentration and diversity of mud-volcanic manifestations, particular interest is focused on the Otman-Bozdag volcano, which is one of the most dynamic and well-studied mud-volcanic structures of Southern Absheron. Its activity, including major historical and recent eruptions, makes it a representative model for analyzing mud-volcanism mechanisms, highlighting the relevance of the present study.

Research Methodology

As noted above, in 2022, within the framework of an international project, the network of high-precision digital seismic stations in Azerbaijan was significantly expanded. The Republican Center of the Seismic Service installed an additional 22 Nanometrics stations (Canada), enhancing both the sensitivity of detection and the accuracy of localizing seismic events of various origins. A distinctive feature of the project was the first-ever deployment worldwide of a specialized system for studying mud-volcano dynamics: 12 stations were installed in the Absheron and Gobustan regions, where the highest concentration of active mud volcanoes is observed.

These stations formed a unified local network aimed at detailed monitoring of mud-volcanic activity. Data processing and analysis are performed using the SeisComP5 software package, adapted for real-time monitoring and automatic event classification. The system algorithms allow for the detection of anomalous signals characteristic of mud volcanoes, which differ from tectonic earthquakes in spectrum, amplitude-time structure, and duration.

The data-processing methodology consists of several sequential stages. At the first stage, events are automatically detected, and the first arrivals of P- and S-waves are identified. Then, hypocentral parameters are refined: the coordinates and approximate location of the mud-volcano vent are determined using data from nearby stations with minimal error. For each event, the exact eruption onset time and duration are recorded, which is particularly important for studying eruption dynamics and energy release.

The next stage involves analysis of seismic signal shapes, spectral content, and phase structure. The number of phases, signal energy, and temporal characteristics are used to classify eruption types and assess the magnitude of the process. Event energy is additionally calculated, allowing comparisons between eruptions and identification of temporal trends.

To understand the formation mechanism of mud eruptions and assess potential volcanic activity, we analyzed the evolution of the stress state around the volcano using the Lode–

Nadai parameter. In seismology, this parameter is applied when reconstructing the stress tensor from focal mechanism data. The Lode–Nadai parameter ($\mu\sigma$) characterizes the type of stress state, reflecting the relationship between the three principal deviatoric stresses at a fixed maximum shear stress [Babayev et al., 2019]. Since the calculations exclude the spherical component of the tensor, the parameter characterizes only the deviatoric state associated with material deformation. Its value is defined as $\mu\sigma = (2\sigma_2 - \sigma_1 - \sigma_3)/(\sigma_1 - \sigma_3)$, ranging from –1 to +1. $\mu\sigma = +1$ corresponds to a near-biaxial tension state ($\sigma_2 \approx \sigma_1$), $\mu\sigma = -1$ corresponds to biaxial compression ($\sigma_2 \approx \sigma_3$), and $\mu\sigma = 0$ corresponds to pure shear. In the international literature, the related parameter $\Phi = (\sigma_2 - \sigma_3)/(\sigma_1 - \sigma_3)$ is often used, which is connected to the Lode–Nadai parameter by $\mu\sigma = 1 - 2\Phi$.

Mud Volcano Otman-Bozdag

The Otman-Bozdag mud volcano is located 60 km from Baku, between the villages of Sangachal and Gobustan, and approximately 5 km west of the Karadag station of the Azerbaijan Railway. It represents one of the most characteristic and well-studied features of the Absheron mud-volcanic province. Morphologically, the volcano has the shape of a truncated cone, typical for ancient and repeatedly reactivated mud-volcanic edifices. The absolute height of the crater exceeds 400 m above sea level, emphasizing the substantial scale of the volcanic structure (Fig. 2). The steep slopes of the volcano are dissected by a system of radially diverging small erosion gullies, reflecting both the prolonged influence of surface runoff and the lithological composition of erupted materials [Golubyatnikov, 1913; Yakubov, 1976].

The crater shape of Otman-Bozdag is a representative example of a mud-volcanic caldera. It is characterized by steep and high inner walls formed due to repeated collapse phases and subsidence of the central part following degassing and fluid outflow. The central area of the crater is lowered, consistent with models of subsidence of mud-volcano chamber roofs. Seven concentric ledges are observed on the crater floor, reflecting the staged evolution of crater morphology and likely associated with alternating periods of activity and relative quiescence [Suleymanov, Pashaly, 1953].

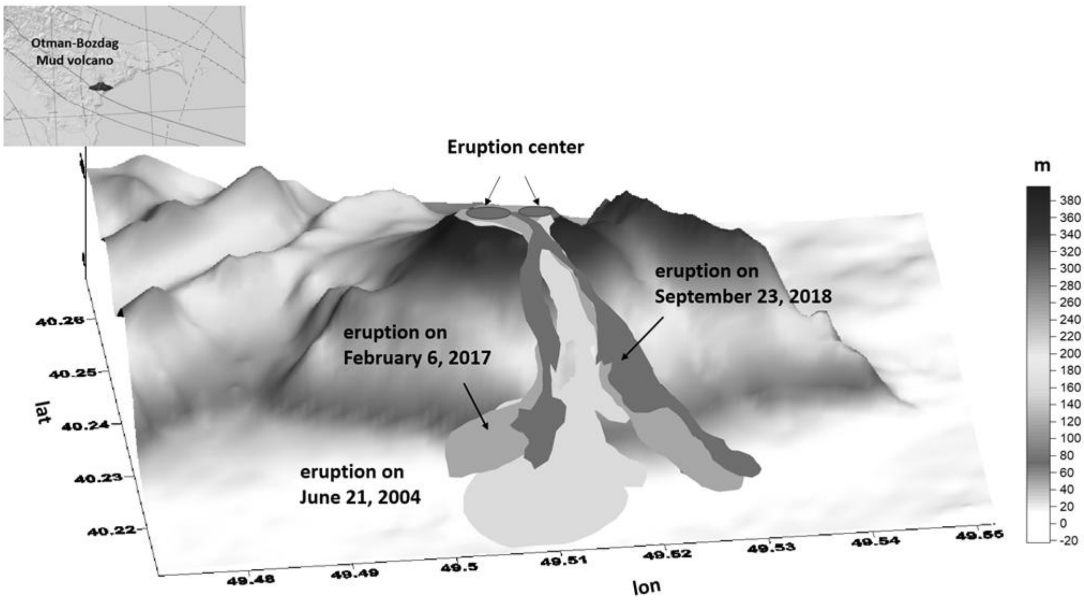

Fig. 2. Topographic model of the Otman-Bozdag mud volcano

The crater, measuring approximately 500 × 400 m, is partially filled with mud-volcanic breccias and clayey masses on the side of the stream channel, while its opposite part is overlain by hill deposits. On the crater surface, a cluster of closely spaced mud cones is localized-active point-like vents that periodically erupt liquid mud, formation waters, and gas. Although the gas volumes are small, their constancy indicates ongoing migration of deep fluids and confirms that the volcano remains active [Yakubov, 1976]. The area of the cone cluster reaches approximately 60 m, reflecting the compactness of the active central vent.

During intense mud-volcano eruptions, breccia ejections form powerful fan-shaped or tongue-shaped flows, which can extend hundreds of meters in width and more than a kilometer in length. The thickness of such flows typically reaches 10–12 m, and in some cases exceeds these values. These deposits often cover significant areas, as observed at the Inchabel and Dashmardan volcanoes, where breccia coverage reaches 37.7 and 31.9 km², respectively, with an average thickness of about 100 m. The figure shows tongue-shaped breccia flows of the Otman-Bozdag volcano in 2004, 2017, and 2018.

The eruption products consist of clayey mass containing fragments of rocks of various ages. Breccia from the cones includes materials from the productive layer, diatomite deposits, as well as older stratigraphic horizons, confirming the involvement of deep fluid-retentive complexes in eruption formation. The uplift of these rocks to the surface reflects the activity of vertical fault-fracture zones, along which degassing and pressure release occur.

To the west, north, and east, Otman-Bozdag is bordered by Absheron limestones, as well as inclined limestones containing mollusk shells. These formations dip toward the volcano, consistent with regional folding patterns and indicating the presence of favorable structural traps for fluid migration.

Some studies suggest that the volcano is formed within a synclinal structure, as similar forms are observed at other regional volcanoes. However, geological data from the surrounding area, including the orientation of sedimentary layers and main structural elements, indicate that Otman-Bozdag is associated with anticlinal uplifts. Its central vent aligns with the axis of the Karadag anticline and lies within its tectonically disrupted zone, reflecting a direct link between mud-volcanic activity and fault-controlled pathways for deep fluid release [Yusubov et al., 2019].

No surface oil manifestations are observed within the volcanic area. However, subsurface layers indicate continued directed migration of hydrocarbon fluids, suggesting ongoing deep fluid migration. The proximity of the Karadag oil field confirms the potential involvement of regional hydrocarbon-bearing horizons in the volcano's fluid supply.

Despite the absence of surface oil emissions, considering the significant hydrocarbon reserves in the lower parts of the productive layer in neighboring areas of the Gabristan zone and the favorable local geological conditions, the presence of oil-bearing horizons within the studied valley is likely. This underscores the need for further geological and geophysical studies aimed at clarifying fluid migration pathways, the depth of feeding channels, and the role of regional tectonics in sustaining volcanic activity.

Chronology of Eruptions of the Otman-Bozdag Mud Volcano

The Otman-Bozdag mud volcano has repeatedly demonstrated powerful activity over the past two centuries. The first documented eruption occurred on February 3, 1854, when the explosion ejected breccia up to 20 meters high, forming a deposit covering approximately 1,000 hectares with a thickness of up to 2 meters and a total volume of about

20 million cubic meters. In the evening of November 23, 1904, a strong explosive eruption was observed, accompanied by gas release and a flame reaching 100 meters. The eruption occurred in three phases; the crater was cut by cracks up to 1.2 km long and 0.7 m wide, while the breccia flow extended 3 km in length and 1.75 km in width, covering an area of 250 hectares [Golubyatnikov, 1913].

On January 31, 1922, at 18:25, an eruption lasting 25 minutes occurred, producing a flash and a cloud of black smoke. The flame reached over 500 meters, but the emission of new breccia was minimal: most of the mass movement resulted from cracking of old flows and their displacement from the crater center to the periphery. In the autumn of 1951, the breccia cover occupied an area of about 7 hectares, with thickness varying from 0.5–1 meter at the periphery to 4–5 meters in the center, giving a total volume of 182,000 cubic meters. Linear cracks with amplitudes of 1–2 meters were recorded in the crater zone, and scattered eruption products on the surface indicated local combustion [Kovalevsky, 1922].

On October 1, 1965, at 12:50, an eruption lasted 2.5 hours, accompanied by underground rumbling, explosions, and emission of gas and breccia [Kerimov et al., 1966; Buniat-Zade, Gorin, 1974]. Flames exceeded 100 meters, forming a mushroom-shaped cloud of white smoke. The breccia deposit, 220 meters in diameter, covered 4 hectares with a thickness of 1–2 meters and a total volume of 52,500 cubic meters. Concentric and radial cracks up to 600 meters long, 3 meters deep, and 0.4–0.5 meters in displacement amplitude were observed.

In the spring of 1985, gas ignition and a breccia eruption with a thickness of 1 meter over 2 hectares (diameter ~160 meters) were observed. Fracturing zones formed within the crater, and one of the cracks reached 400 meters in length in the near-latitudinal direction. On December 12, 1994, at 17:45, a 40-minute eruption occurred, accompanied by gas ignition and formation of a breccia cover measuring 240 × 210 meters (5 hectares) with a thickness of 0.5–2 meters and a volume of 63,000 cubic meters. Three major cracks were recorded, each 450 meters long, over 3 meters deep, and 2 meters wide.

On June 21, 2004, in the evening, underground rumbling, explosions, and breccia ejection to a height of 20–25 meters were observed. The volume of breccia ejected by the volcano was 52 m^3 with a thickness of 0.4–1.8 meters, covering an area of 4.3 hectares within a crater field measuring 240 × 195 meters.

On February 6, 2017, the Otman-Bozdag volcano erupted explosively in two stages. The first stage lasted 3 minutes 23 seconds with a source depth of 3 km, and the second stage lasted 5 minutes at the same depth. During the second stage, a fire column rose 270–300 meters above the crater. Deep cracks appeared near the crater. This was the 9th registered eruption of the Otman-Bozdag volcano, the previous one having occurred in 2004. During the survey, several deep cracks were discovered near the crater, some up to 6 meters wide and 4 km long. In addition to fire and smoke, the volcano emitted a large amount of mud, covering an area of 12 hectares. The eruption was recorded by 8 digital seismic stations: Gobu, Ali-Bayramly, Gobustan, Gala, Altyagach, Pirgulu, Siyazan, and Khinalyg.

On September 23, 2018, the volcano erupted again after a one-year pause. The first event occurred at approximately 08:53, and the second at 09:58. Flame heights reached 200–300 meters. Following the eruption, numerous cracks up to 40 meters deep formed in the surrounding area (Fig. 3).

On October 11, 2025, at 08:27 local time, another eruption of Otman-Bozdag occurred in the Karadag was district, was recorded in three phases. The first phase started at 08:27 and lasted 10 minutes, the second from 08:39 to 08:51 (12 minutes), and the third from 09:02 to 09:06 (4 minutes) (Fig. 4). The source depth reached 4 kilometers, and the total energy released was 2.19×10^7 J. The eruption was accompanied by a fire column.

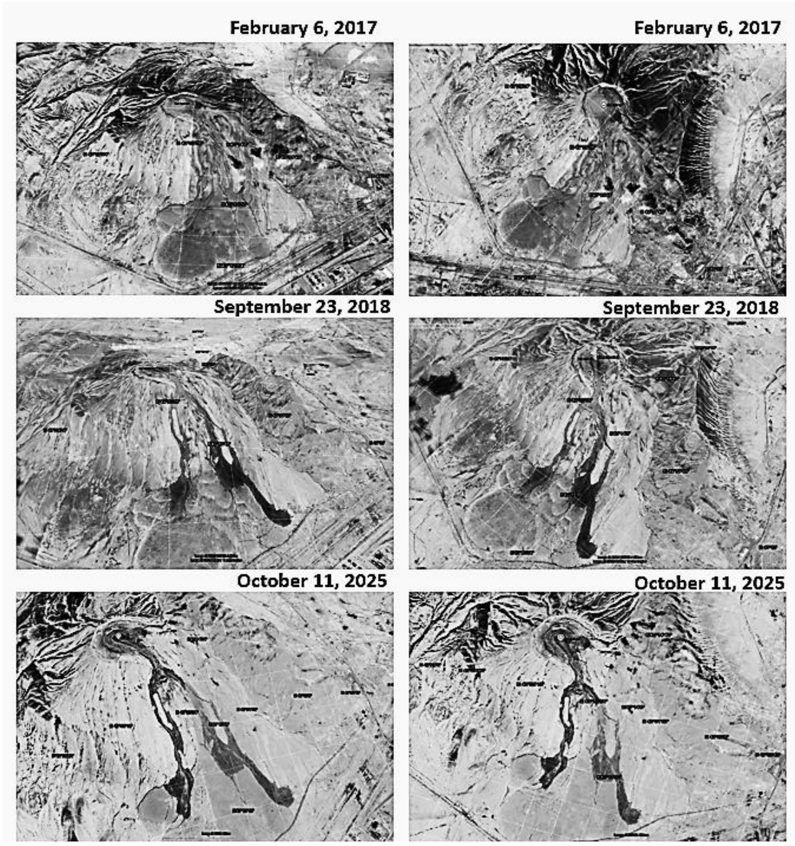

Fig. 3. Maps of mud-volcanic breccia flows of Otman-Bozdag in 2017, 2018, and 2025, constructed based on Google Earth Pro data

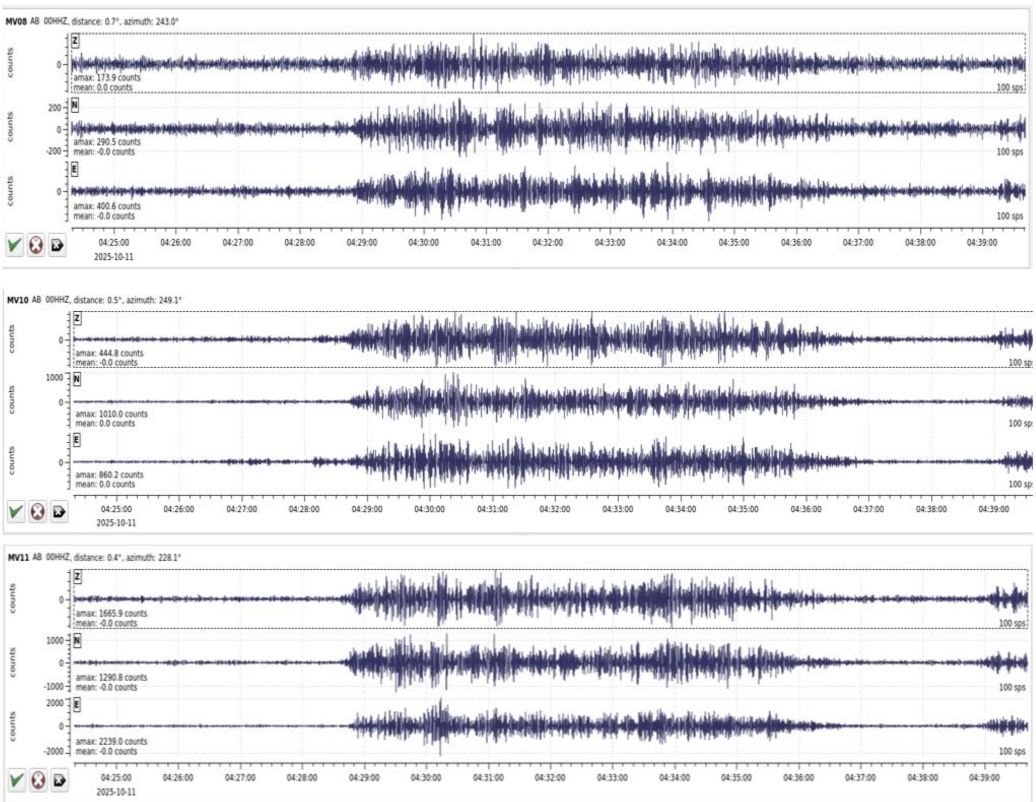

Fig. 4. Waveform record of the Otman-Bozdag mud volcano eruption in 2025

Throughout the 19th–20th centuries, similar volcanic activity was recorded on the nearby Gil Island, with eruptions observed in 1810, 1859, 1860, 1895, 1896, 1913, 1926, 1937, 1960, and 1962.

Analysis of Otman-Bozdag eruptions over the past 170 years shows pronounced irregular periodicity. Intervals between events range from 3–4 years to 30–40 years, indicating no regular cycle and a dependence on complex deep-fluid processes. The longest pause (33 years) occurred between the 1922 and 1951 eruptions, while the shortest–around 3 years–was recorded between 2017 and 2018, reflecting an overall increase in activity in the 21st century.

Comparison of normalized eruption intensity indicators–fountain height, deposit area, and breccia volume–highlights key events reflecting the volcano's evolving dynamics. The 1854 eruption stands out as an absolute extreme: its deposit, covering ~1000 ha with a breccia volume of ~20 million m^3, far exceeds all subsequent events. The coincidence of maxima in area and volume underscores the exceptional power of this event on a geological scale.

In terms of gas emission and visual effects, the 1922 eruption is notable, producing a flaming column over 500 m–the highest recorded. Despite a relatively small new breccia volume, this event represents a phase of extreme degassing of deep fluids.

The second half of the 20th century shows a trend of reduced eruption scales; however, the 1965, 1985, and 1994 events still exhibited marked fracturing, underground rumbling, and intense gas release. Although integrated parameters decreased, the volcano retained high structural mobility, indicating continued activity of the feeding system.

In the 21st century, a new phase of enhanced dynamics is observed. The 2004 eruption, though small (~52 m^3), exhibited significant seismoacoustic expression. The most intense modern events occurred in 2017, 2018, and 2025, reflecting a trend toward more frequent and stronger eruptions.

Spatial–temporal variations of the Lode–Nadai coefficient in the Otman-Bozdag mud volcano region (2004–2025)

The maps presented illustrate the spatial–temporal variations of the Lode–Nadai coefficient in the Otman-Bozdag mud volcano region for 2004, 2017, 2018, and 2025 (Fig. 5). The coefficient values reflect changes in the type of deviatoric stress state, ranging from dominant extension (negative values, cool tones) to predominant compression (positive values, warm tones).

In 2004, the area around the volcano was characterized by a pronounced dominance of extensional stresses, manifested as a large zone of negative μ_S values to the south and southwest of the volcano. By 2017, the stress field had redistributed: local compression zones formed to the north and northeast of Otman-Bozdag, possibly indicating a shift in the local tectonic regime or a response to recent seismodynamic processes.

In 2018, the stress field showed further strengthening of areas with positive coefficient values, especially in the northern part of the region, while the zone of negative values persisted in the south but had shifted. This reflects a transition from a predominantly extensional stress regime to a mixed or even compressional type in certain areas.

By 2025, negative coefficient values again dominated the central and southern parts of the region, yet new local compression zones appeared, demonstrating the high temporal variability of the deviatoric stress field in the area.

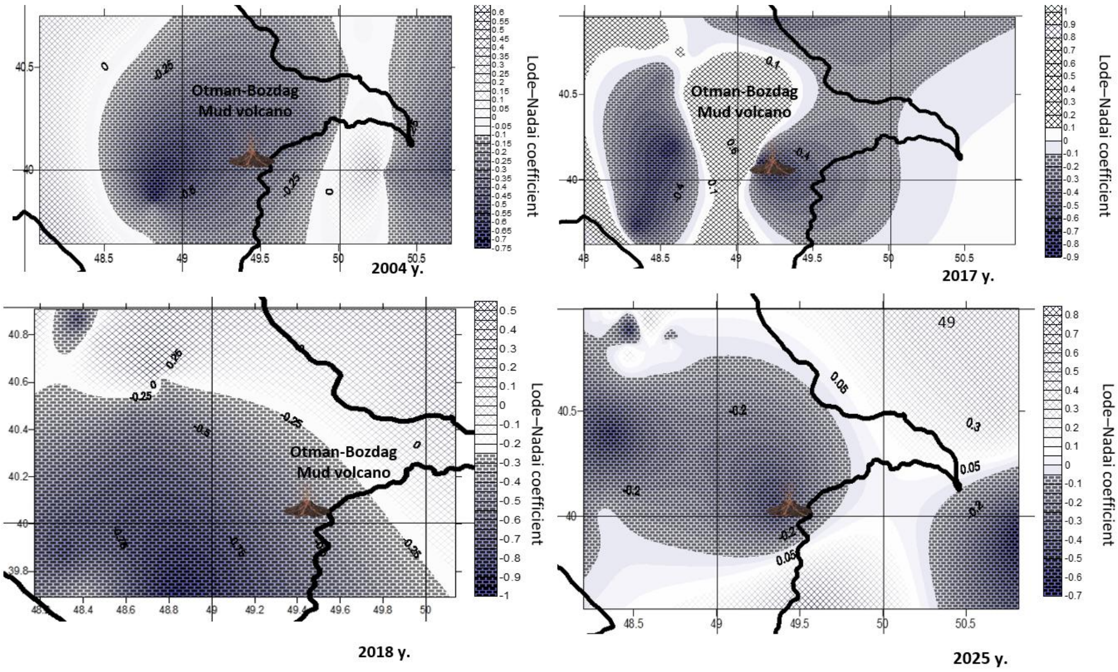

Fig. 5. Evolution of the Lode–Nadai coefficient field around the Otman-Bozdag mud volcano for 2004, 2017, 2018, and 2025

The observed variations of the Lode–Nadai coefficient indicate a highly dynamic local stress regime around the mud volcano. The redistribution of deviatoric stresses may be linked both to regional tectonic processes and to periods of volcanic activation, changes in pore pressure, or local responses of the sedimentary cover to deep geodynamic processes.

Discussion of Results

The Azerbaijani mud-volcanic province, with the world's largest concentration of active and diverse mud volcanoes, represents a unique natural laboratory for studying deep fluid-dynamic processes. The high frequency of eruptions, coupled with their close relationship to regional seismicity, provides exceptional observational opportunities [Yunuslu, 2024; Ivanov et al., 2019; Etiope, Milkov, 2004; Wright, Burgess, 1992; Svensen et al., 2009].

The deployment of high-sensitivity digital seismic stations (Kinemetrics and Nanometrics), along with the creation of the world's first specialized mud-volcano monitoring network, has enabled the detailed analysis of eruption preparation and development dynamics. The data confirm that mud-volcanic processes exhibit a pre-activation phase lasting from several minutes to a few hours.

Morphological features of the Otman-Bozdag mud volcano–including its well-developed caldera, concentric terraces, and radial fracture system–clearly indicate multiple phases of activity, accompanied by repeated cycles of degassing, collapse, and deep fluid discharge.

Geological and structural evidence shows that Otman-Bozdag formed not within a synclinal depression, as previously thought, but along an anticlinal uplift of the Karadag structure, intersected by deep faults. This confirms the direct link between mud-volcanism and tectonic channels of reservoir pressure release.

The chemical and lithological composition of breccias, containing fragments of stratigraphic complexes of various ages–from the productive layer to diatomite and older horizons–indicates the involvement of a multi-level system of impermeable layers and deep fluid reservoirs in eruption formation.

The chronology of Otman-Bozdag eruptions over the past 170 years demonstrates the cyclicity and periodicity of volcanic activity, including both major explosive and relatively minor events. Eruption energetics, ejecta volumes, and fracture parameters vary significantly, reflecting the dynamic pressure regime in the feeding system.

Analysis of the Lode–Nadai coefficient shows that an inhomogeneous deviatoric stress state develops around the volcano, changing over time and correlating with eruption periods. This parameter can therefore serve as an additional indicator of mud-volcanic pre-activation.

The spatial association of the volcano with hydrocarbon migration zones and the proximity of oil and gas-bearing horizons in the Karadag area suggest a possible role of hydrocarbon fluids in feeding the system, highlighting the need for further deep geophysical studies.

This study confirms that Otman-Bozdag serves as a representative natural model of the mud-volcanic process in Southern Absheron. Its comprehensive investigation–including seismic monitoring, morphometric analysis, geological mapping, and stress-field assessment–significantly advances the understanding of mud-volcano formation mechanisms and evolution in Azerbaijan.

Conclusion

The Azerbaijani mud-volcanic province represents a unique natural laboratory for studying deep fluid-dynamic processes. Its high eruption frequency and strong connection to regional seismicity make it an invaluable observational site. The use of digital seismic stations (Kinemetrics and Nanometrics) enabled, for the first time, detailed analysis of eruption preparation and development, revealing pre-activation phases lasting from several minutes to a few hours.

Eruptions of Otman-Bozdag depend on the stress–strain state of the crust and the volcano's energetic readiness, highlighting the nonlinear interaction between tectonics and the fluid system. The volcano's morphology and the composition of breccias indicate multiple cycles of degassing and the involvement of multi-level fluid reservoirs.

Geological and structural data confirm the volcano's connection to deep faults of the Karadag structure, while analysis of the Lode–Nadai coefficient shows a correlation between deviatoric stress and periods of volcanic activity. The spatial association with oil and gas-bearing zones suggests a possible role of hydrocarbon fluids in the feeding system.

Otman-Bozdag serves as a representative model of the mud-volcanic process in Southern Absheron, and its comprehensive study significantly enhances the understanding of the mechanisms governing the formation and evolution of mud volcanoes in Azerbaijan.

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