SOCAR Proceedings

Oil and gas fields exploration, geology and geophysics

journal home page: http://proceedings.socar.az

INSAR ANALYSIS OF THE AYAZAKHTARMA MUD VOLCANO AND ITS RESPONSE TO THE 2021 SHAMAKHI EARTHQUAKE: UNDERSTANDING SEISMO-VOLCANIC INTERACTIONS

B. G. Ahadov[1,2], F. A. Kadirov*[1,2]

[1]*Institute of Geology and Geophysics, Ministry of Science and Education Republic of Azerbaijan, Baku, Azerbaijan*

[2]*Institute of Oil and Gas, Ministry of Science and Education Republic of Azerbaijan, Baku, Azerbaijan*

ABSTRACT

In this study, the Interferometric Synthetic Aperture Radar (InSAR) method was employed for the first time to examine the correlation between moderate earthquakes and the dynamics of volcanoes in Azerbaijan.InSAR is a powerful technique for explaining the complexities of earthquakes in spatial times, providing more detailed insights into earthquake impacts than traditional methodologies. We analyzed pre-seismic, co-seismic, and post-seismic scenarios to determine potential possible relations between the 2021 Shamakhi earthquake (Mw5) and the Ayazakhtarma mud volcano. This research presents a comprehensive deformation time series data for the volcano derived from Sentinel 1A/B observations spanning 2017 to 2023. Concurrently, radar line-of-sight (LOS) displacement maps are prepared to represent the deformation associated with the earthquake in the pre-, co-, and post-seismic phases. Specifically, our analysis of the Ayazakhtarma mud volcano revealed significant LOS alterations in the pre-, co-, and post-seismic phases of ascending and descending orbits. Also, during a seven-year time series observation of the Ayazakhtarma mud volcano, two seismic events of magnitude Mw5 were recorded. These events demonstrated no significant influence on the mud volcano's activity, indicating that earthquakes of up to Mw ≤ 5 may not prompt significant eruptions in the Ayazakhtarma mud volcano. The study of the interferometric data has revealed fresh insights into the deformation behaviours of the Ayazakhtarma mud volcano and its interplay with seismic events.

Keywords: InSAR; deformation; earthquake; volcano; Ayazakhtarma; Azerbaijan.

© 2023 «OilGasScientificResearchProject» Institute. All rights reserved.

Introduction

Azerbaijan is located in an area known for significant seismic activity due to its unique geological characteristics, which contribute to the majority of earthquakes. It is surrounded by the Caspian Sea to the east, Russia to the north, Georgia to the northwest, Armenia and Turkey to the west, and Iran to the south. Moreover, Azerbaijan is characterised for hosting the largest number of mud volcanoes globally. Occurrences of mud volcanism or mud diapirs are dominant. With a count exceeding 250, these mud volcanoes are scattered both onshore and offshore, making Azerbaijan a prominent host of this fascinating natural phenomenon.

The collision between the Eurasian and Arabian plates generates significant stress in the region, leading to frequent seismic activities. This tectonic interplay results in subduction zones, thrust faults, and uplifted regions. The consequent stress, combined with the geothermal gradient affects fluid movements beneath the surface that may display through the activity of mud volcanoes. Several researches [1-7] provides insights into the geodynamics of the region and the potential linkages between tectonics, seismicity and delves deeper into the tectonic processes in the region. Historically, Azerbaijan has experienced several devastating earthquakes with magnitudes of M ≥ 6. Significant examples include the Goygol event (1139), Ganja (1235), Eastern Caucasian (1668), and Mashtaga (1842). Additionally, Shamakhi has been the epicentre for numerous significant seismic activities in the years 1192, 1667, 1669, 1828, 1859, 1868, 1872, and 1902. The Caspian Sea has also faced strong earthquakes in the years 1961, 1963, 1986, 1989, and 2000 [8]. These seismic events have not only reshaped the region's topography but also led to the destruction of structures and resulted in significant loss of life. Azerbaijan is host to over 250 terrestrial and marine mud volcanoes. Their activity and distribution could be influenced by regional crustal deformations and seismic events (fig. 1). Several studies [9-13] confirm the active status of many of these volcanoes.

We studied pre-, co-, and post-seismic phases to explore the potential effects of moderate earthquake on the Ayazakhtarma mud volcano. This volcano is located about 50 km away from the 2021 Shamakhi earthquake's epicentre. The Ayazakhtarma mud volcano is located 24 km west-northwest of Cheildagh village and exhibits a hill-like topography extending 3 km in length and 2 km in width. We used the InSAR technique to detect changes in the Earth's surface elevation both before and after earthquakes. This method helps understand what might trigger mud volcano

**E-mail:* kadirovf@gmail.com

http://dx.doi.org/10.5510/OGP20230400911

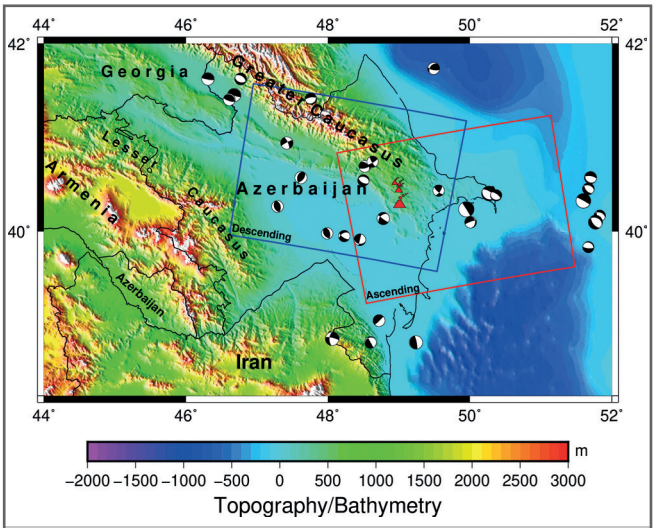

Fig. 1. Topographic and bathymetric map of the Caucasus region, focusing on our research area in Azerbaijan and highlighting seismic activity and locations of some active mud volcanoes

activity. InSAR is effective in mapping the spatial details of earthquakes and offers a more accurate characterisation of earthquake impacts compared to older methods. From our data, we found that moderate earthquakes (with a magnitude of Mw ≤ 5) do not seem to cause large eruptions in mud volcanoes. The absence of large eruptions in mud volcanoes, even in the wake of moderate earthquakes, suggests that there might be other predominant factors, perhaps internal to the volcanoes, that control their eruptive behaviours. This finding opens roads for further studies focused on the intrinsic dynamics of mud volcanoes and the thresholds that influence their activity.

Data and methods

For this study, we utilized the Sentinel-1 synthetic aperture radar (SAR) data, which is a part of the European Space Agency's (ESA) Copernicus Earth observation program. Sentinel-1 has become a vital tool in the field of remote sensing due to its capability to provide reliable, repeated, and high-resolution radar imagery. The dataset for our research spanned from 2017 to 2023, ensuring a comprehensive temporal coverage of the Ayazakhtarma mud volcano and the surrounding regions. Our primary aim was to investigate the potential relationship between intermediate earthquake and the activity at the Ayazakhtarma mud volcano. By analyzing pre-, co-, and post-seismic scenarios we aimed to determine any causal effects between seismic events and mud volcano behaviour.

Interferometric Synthetic Aperture Radar (InSAR) was our main analytical tool for this research. InSAR supports detecting and quantifying ground displacements, especially in geologically active regions like the area of the Ayazakhtarma mud volcano. For a comprehensive understanding of the seismic effects, we calculated the phase and LOS values for pre-, co-, and post-seismic events using both ascending and descending orbital tracks. LOS displacement maps offer valuable insights into how the ground surface moves in response to seismic events. These maps were crucial in our analysis of deformation patterns both within and surrounding the mud volcano during the seismic event. We derived a detailed deformation time series and velocities for the Ayazakhtarma mud volcano. These time series allowed us to observe and quantify the temporal evolution of deformations, providing a clearer picture of the volcano's behaviour and its potential relationship with nearby seismic activities.

Results and discussions

The interplay between significant earthquake events and nearby mud volcano eruptions has been studied in several studies [14-19]. Hayakawa et al., [19] examined a minor mud volcano in Murono using terrestrial laser scanning (TLS) in central Japan, uncovering detailed vertical displacements. They identified both uplifts and subsidence, highlighting the potential of these measurements in following seismic and inter-seismic ground changes. Their work suggested that the detected cracks might hint at subsurface fluid movements due to seismic activity and repeated the weakening of surface materials over time. Mellors et al., [15] observed that large earthquakes might trigger significant eruptions in mud volcanoes. Their study emphasized that this connection is stronger in areas where mud volcanoes experience seismic activities of around intensity 6, especially if the earthquake's epicentre is within 100 km of the mud volcano. Also, observed weak connection between major earthquakes and subsequent mud volcano activity that can manifest after a delay of up to a year. This was particularly evident in the sequence following the November 2000 Baku earthquakes, leading to increased mud volcano activity in 2001. Bonini [16] analysed the relationships between earthquakes and mud volcano eruptions in Northern Apennines and Sicily. Although certain mud volcanoes displayed increased activity linked to historical seismic events, aligning with known hydrological response thresholds, many eruptions occurred independently of seismic disturbances. This suggests that only mud volcanoes nearing a critical state of internal fluid pressure might be sensitive to seismic activation. Manga et al., [14] proposed that dynamic strains are more likely to trigger mud volcano eruptions due

Table

Sentinel-1 SAR Data Acquisition Dates and Orbit Details Categorized by Pre-seismic, Co-seismic, and Post-seismic Analysis Phases

Date	Orbit	Seismic phase	Radar data
2021.10.30-2021.11.11	Ascending	Pre-seismic	Sentinel1
2021.11.11-2021.11.23	Ascending	Co-seismic	Sentinel1
2021.11.23-2021.12.05	Ascending	Post-seismic	Sentinel1
2021.10.29-2021.11.10	Descending	Pre-seismic	Sentinel1
2021.11.10-2021.11.22	Descending	Co-seismic	Sentinel1
2021.11.22-2021.12.04	Descending	Post-seismic	Sentinel1

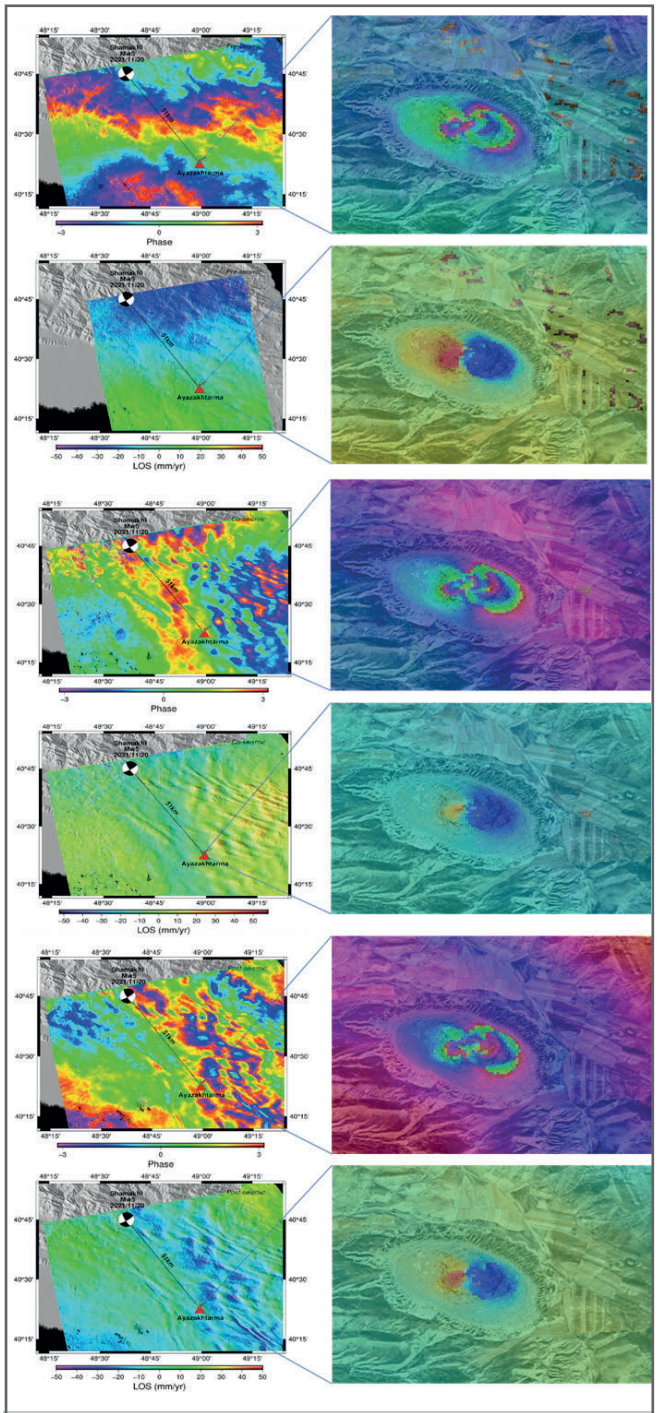

Fig. 2. InSAR analysis results, detailing phase and LOS for pre-, co-, and post-deformation scenes of the 2021 Shamakhi Mw5 earthquake and its direct impact on the Ayazakhtarma mud volcano, based on ascending track data

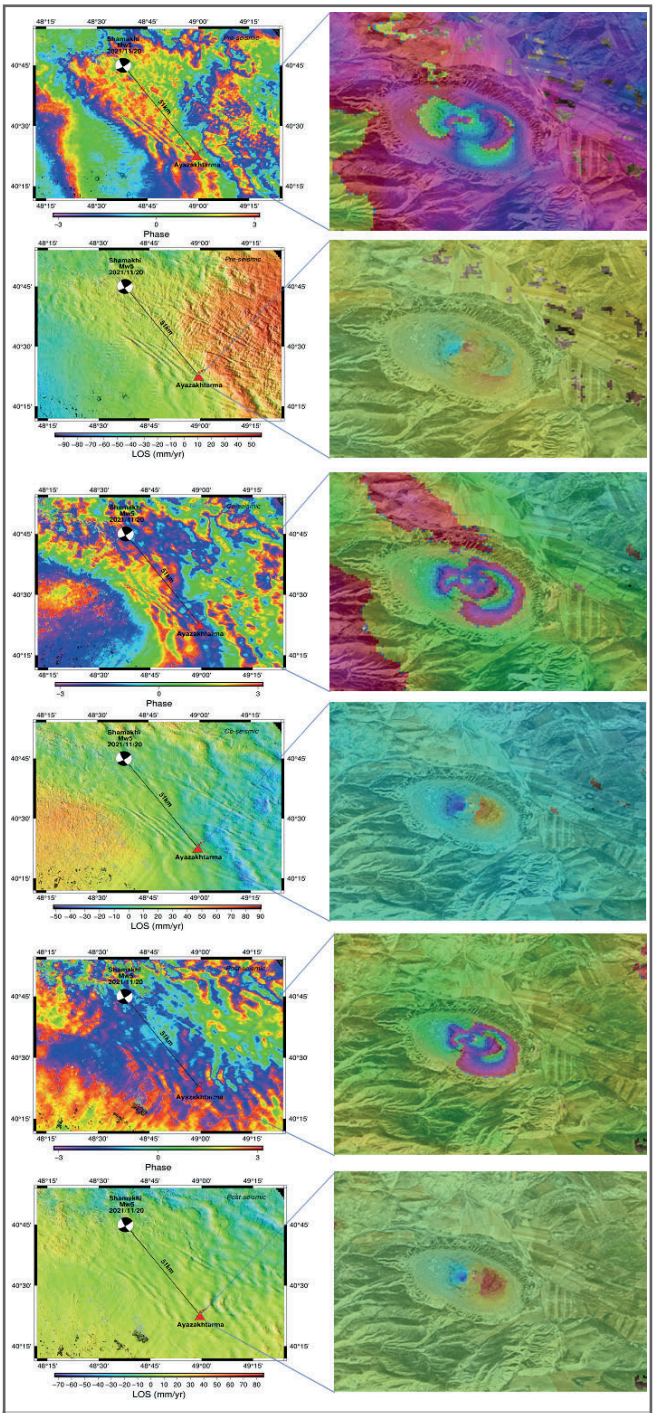

Fig. 3. InSAR analysis results, detailing phase and LOS for pre-, co-, and post-deformation scenes of the 2021 Shamakhi Mw5 earthquake and its direct impact on the Ayazakhtarma mud volcano, based on descending track data

to their larger magnitude as opposed to static strains. They also suggest a frequency dependency for triggering with longer seismic waves being more effective. Lastly, the study noted that the strain levels needed to initiate liquefaction or undrained consolidation are too high to explain the wide geographical range over which eruptions can be triggered.

The relationship between crustal deformations, as measured by GPS velocity, and mud volcano activity has been explored in several studies [20, 21]. Kadirov et al., [21] argue that the primary factor driving mud volcano eruptions is the intensity of gas generation processes within the Earth's interior, while crustal deformations serve as triggers. Their analysis indicates that vertical displacements are more predominant in mud volcanic activity, potentially originating from horizontal compression where horizontal strains function as triggering mechanisms. Previous studies [22,23] implemented InSAR techniques to monitor the Ayazakhtarma mud volcano. Lio and Furuya [23] utilized a distinct dataset to identify the surface displacements correlated with the activity at Ayazakhtarma.

Antonielli et al., [22] employed InSAR to monitor mud volcanoes in Azerbaijan between 2003-2005. They observed both uplift and subsidence in the ground, suggesting inflation and deflation zones within the volcanoes. Their study also

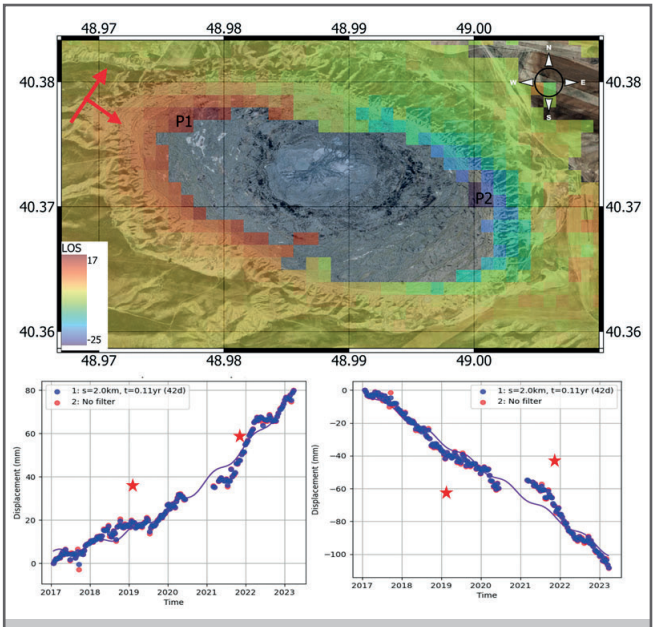

Fig. 4. The InSAR analysis-derived time series for Ayazakhtarma Mud Volcano. Sub-plots for points P1 and P2 display activity variations over time, red stars marking the Basqal and Shamakhi earthquakes

highlighted significant deformation events linked to main eruptions, marked by uplift and some minor subsidence. Moreover, the study observed short-lived deformation pulses not directly linked to major eruptive events. These pulses are thought to be related to subsurface fluid and mud redistribution. Their work was limited to a single orbital track and did not employ time-series analysis. Our study expands upon this by utilizing both ascending and descending orbital tracks, providing a more comprehensive view of ground deformation (fig. 2, 3). Additionally, our application of time-series analysis (fig. 4) allows for a more quiet understanding of the mud volcano's behaviour over time.

Unlike previous studies that have primarily relied on statistical methods to analyze the relationship between earthquakes and mud volcano eruptions, our research employs the InSAR technique. This approach allows for high-resolution observations obtained directly from radar data, making it a more accurate and valuable tool for this kind of analysis. By using the InSAR method, we have introduced a novel and more precise way to understand the dynamics of mud volcanoes concerning seismic activity, providing new perspectives that challenge previously held views based on statistical analyses. Our time-series observations before, during, and after seismic event reveal no considerable changes in the mud volcano during the seismic phases (fig.4). This finding contrasts with studies that have suggested a correlation between earthquakes and subsequent mud volcano activities. Instead, our data indicates that the mud volcano experiences periodic eruptions at specific intervals, unrelated to seismic activity. We observed no unusual upticks or downtrends in activity over the period analyzed. Specifically, our observations of the Ayazakhtarma mud volcano showed significant changes in Line-Of-Sight (LOS) values (fig. 2, 3). These LOS variations might be indicative of independent geophysical processes within the mud volcano. Analyzing these changes can help us better understand the internal dynamics and behaviors of mud volcanoes and guide further research on their activity patterns in the region.

Conclusion

Investigations into the relationship between earthquakes and mud volcano eruptions have found a varied connection. In some instances, mud volcanoes experienced elevated activity following seismic events that correlated with certain hydrological response thresholds. However, a significant number of eruptions seemed independent of any seismic activity. This suggests that only those mud volcanoes nearing an eruption due to strengthened internal fluid pressures might be susceptible to seismic influences. Seismogenic faults have been observed to influence the fluid reservoirs of mud volcanoes, suggesting that these volcanoes can potentially record disturbances related to tectonic activities. While past research predominantly depended on statistical methods to interpret these connections, our study adopts a novel approach, utilizing the InSAR technique to understand the potential relationship between moderate earthquakes and mud volcano activities in the region. This method represents a fresh perspective in this area of research. In our study of the Ayazakhtarma mud volcano, distinct zones of minor subsidence and uplift were identified, underlining the inherent deformation characteristics. Furthermore, the fault at Ayazakhtarma plays a key role in these deformation patterns, with the conspicuous fault or fracture system prominently positioned in regions that differentiate sectors of varying subsidence rates. The interferometric data analyzed revealed illuminating details on Ayazakhtarma's deformation patterns. Notably, we did not observe volcanic activity before or after the earthquake suggesting that the volcano's activity may be primarily governed by fluid dynamics and depth processes. In essence, while seismic events can offer valuable insights into our planet's geological processes, in this instance, the Ayazakhtarma mud volcano's behaviour appears to be more influenced by internal dynamics than external seismic triggers.

Overall, the use of InSAR data to study the relationship between mud volcanoes and earthquakes has provided valuable insights into the complex and dynamic nature of earth processes. Further research using InSAR and other geophysical techniques can help to improve our understanding of the interaction between earthquakes and other natural phenomena, ultimately contributing to better hazard mitigation and disaster management strategies.

We gratefully acknowledge the use of GMT [24] and QGIS for deriving all maps presented in this study. Our appreciation extends to the European Space Agency (ESA) for providing the Sentinel-1 data and to COMET for the LiCSAR data [25]. Furthermore, we would like to thank the developers of software packages [26, 27] as these tools were crucial in conducting the analyses for this research

References

1. Reilinger, R., McClusky, S., Vernant, P., et al. (2006). GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. *Journal of Geophysical Research: Solid Earth*, 111(B5), B05411.

2. Kadirov, F., Floyd, M., Alizadeh, A., et al. (2012). Kinematics of the eastern Caucasus near Baku, Azerbaijan. *Natural Hazards*, 63, 997-1006.

3. Kadirov, F. A., Floyd, M., Reilinger, R., et al. (2015). Active geodynamics of the Caucasus region: implications for earthquake hazards in Azerbaijan. *ANAS Transactions*, 3, 3-17.

4. Ahadov, B., Jin, S. (2017). Present-day kinematics in the Eastern Mediterranean and Caucasus from dense GPS observations. *Physics of the Earth and Planetary Interiors*, 268, 54-64.

5. Ahadov, B., Jin, S. (2021). Slip rates and seismic potential along main faults in the Eastern Mediterranean and Caucasus from dense GPS observations and seismic data. *Pure and Applied Geophysics*, 178, 39-54.

6. Ahadov, B., Ozturk, S. (2022). Spatial variations of fundamental seismotectonic parameters for the earthquake occurrences in the Eastern Mediterranean and Caucasus. *Natural Hazards*, 111(3), 2177-2192.

7. Telesca, L., Kadirov, F., Yetirmishli, G., et al. (2017). Statistical analysis of the 2003–2016 seismicity of Azerbaijan and surrounding areas. *Journal of Seismology*, 21, 1467-1485.

8. Kondorskaya, N. V., Shebalin, N. V. (eds.) (1982). New catalog of strong earthquakes in the USSR from ancient times through 1977. World Data Center a for Solid Earth Geophysics, Report SE-31, NOAA. *Boulder, Colorado, USA.*

9. Yakubov, A. A., Alizade, A. A., Zeinalov, M. M. (1971). Mud volcanoes of Azerbaijan SSR: Atlas. *Baku: Elm*.

10. Aliyev, A. A., Guliyev, I. S., Rakhmanov, R. R. (2009). Catalogue of mud volcanoes eruptions of Azerbaijan: 1810-2007. *Baku: Nafta-Press*.

11. Aliyev, A. A., Guliyev, I. S., Dadashov, F. H., Rakhmanov, R. R. (2015). Atlas of the world mud volcanoes. *Baku: Nafta-Press*.

12. Alizadeh, A. A., Guliyev, I. S., Kadirov, F. A., Eppelbaum, L. V. (2016). Geosciences of Azerbaijan. Vol. 1. *Heidelberg: Springer*.

13. Alizadeh, A. A., Guliyev, I. S., Kadirov, F. A., Eppelbaum, L. V. (2017). Economic minerals of Azerbaijan /in «Geosciences of Azerbaijan». Vol. II: Economic geology and applied geophysics. *Springer Cham*.

14. Manga, M., Brumm, M., Rudolph, M. L. (2009). Earthquake triggering of mud volcanoes. *Marine and Petroleum Geology*, 26(9), 1785-1798.

15. Mellors, R., Kilb, D., Aliyev, A., et al. (2007). Correlations between earthquakes and large mud volcano eruptions. *Journal of Geophysical Research: Solid Earth*, 112(B4), B04304.

16. Bonini, M. (2009). Mud volcano eruptions and earthquakes in the Northern Apennines and Sicily, Italy. *Tectonophysics*, 474(3-4), 723-735.

17. Rudolph, M. L., Manga, M. (2012). Frequency dependence of mud volcano response to earthquakes. *Geophysical Research Letters*, 39(14), L14303.

18. Babayev, G., Tibaldi, A., Bonali, F. L., Kadirov, F. (2014). Evaluation of earthquake-induced strain in promoting mud eruptions: the case of Shamakhi-Gobustan-Absheron areas, Azerbaijan. *Natural Hazards*, 72, 789-808.

19. Hayakawa, Y. S., Kusumoto, S., Matta, N. (2017). Seismic and inter-seismic ground surface deformations of the Murono mud volcano (central Japan): a laser scanning approach. *Progress in Earth and Planetary Science*, 4, 1-16.

20. Kadirov, F. A., Safarov, R. T. (2013). Deformation of the Earth's crust of Azerbaijan and adjacent territories based on GPS measurements. *ANAS Transactions*, 1, 47-55.

21. Kadirov, F. A., Guliyev, I. S., Feyzullayev, A. A., et al. (2014). GPS-based crustal deformations in Azerbaijan and their influence on seismicity and mud volcanism. *Izvestiya, Physics of the Solid Earth*, 50, 814-823.

22. Antonielli, B., Monserrat, O., Bonini, M., et al. (2014). Pre-eruptive ground deformation of Azerbaijan mud volcanoes detected through satellite radar interferometry (DInSAR). *Tectonophysics*, 637, 163-177.

23. Iio, K., Furuya, M. (2018). Surface deformation and source modeling of Ayaz-Akhtarma mud volcano, Azerbaijan, as detected by ALOS/ALOS-2 InSAR. *Progress in Earth and Planetary Science*, 5(1), 1-16.

24. Wessel, P., Luis, J. F., Uieda, L., et al. (2019). The generic mapping tools version 6. *Geochemistry, Geophysics, Geosystems*, 20(11), 5556-5564.

25. Lazecký, M., Spaans, K., González, P. J., et al. (2020). LiCSAR: an automatic InSAR tool for measuring and monitoring tectonic and volcanic activity. *Remote Sensing*, 12, 2430.

26. Sandwell, D., Mellors, R., Tong, X., et al. (2011). GMTSAR: An InSAR processing system based on generic mapping tools. *Scripps Institution of Oceanography Technical Report*.

27. Morishita, Y., Lazecky, M., Wright, T. J., et al. (2020). LiCSBAS: An open-source InSAR time series analysis package integrated with the LiCSAR automated Sentinel-1 InSAR processor. *Remote Sensing*, 12(3), 424.

InSAR-анализ грязевого вулкана Аязахтарма и его реакции на Шамахинское землетрясение 2021 года: понимание сейсмовулканических взаимодействий

Б. Г. Ахадов[1,2], Ф. А. Кадиров[1,2]
[1]Институт геологии и геофизики Министерства науки и образования Азербайджанской Республики, Баку, Азербайджан
[2]Институт нефти и газа Министерства науки и образования Азербайджанской Республики, Баку, Азербайджан

Реферат

В этом исследовании метод интерферометрического радара с синтезированной апертурой (InSAR) был впервые использован для изучения корреляции между умеренными землетрясениями и динамикой вулканов в Азербайджане. Этот метод позволяет более детально изучить последствия землетрясений, чем традиционные методологии. Мы проанализировали досейсмические, косейсмические и постсейсмические сценарии, чтобы определить потенциально возможные связи между Шамахинским землетрясением 2021 года (Mw=5) и грязевым вулканом Аязахтарма. В этом исследовании представлены комплексные данные временных рядов деформации вулкана, полученные на основе наблюдений Sentinel 1A/B за период с 2017 по 2023 год. Одновременно подготавливаются карты смещения радиолокационной прямой видимости (LOS), отражающие деформацию, связанную с землетрясением на до-, со- и постсейсмической фазах. В частности, наш анализ грязевого вулкана Аязахтарма выявил значительные изменения LOS на до-, со- и постсейсмической фазах восходящей и нисходящей орбитах. Также в ходе семилетних временных рядов наблюдений за грязевым вулканом Аязахтарма зафиксировано два сейсмических события магнитудой Mw=5. Эти события не оказали существенного влияния на активность грязевого вулкана, что указывает на то, что землетрясения силой до Mw≤5 не могут вызвать значительные извержения грязевого вулкана Аязахтарма. Изучение интерферометрических данных позволило по-новому взглянуть на деформационное поведение грязевого вулкана Аязахтарма и его взаимодействие с сейсмическими событиями.

Ключевые слова: InSAR; деформация; землетрясение; грязевый вулкан; Аязахтарма; Азербайджан.

Ayazaxtarma palçıq vulkanının InSAR təhlili və 2021 Şamaxı (Mw5) zəlzələsinə cavab: Seysmo-vulkanik qarşılıqlı təsirlərin anlaşılması

B. H. Əhədov[1,2], F. A. Qədirov[1,2]
[1]Geologiya və Geofizika İnstitutu, Azərbaycan Respublikası Elm və Təhsil Nazirliyi Bakı, Azərbaycan
[2]Neft və Qaz İnstitutu, Azərbaycan Respublikası Elm və Təhsil Nazirliyi, Bakı, Azərbaycan

Xülasə

Bu tədqiqatda Azərbaycanda orta güclü zəlzələlər və vulkanların dinamikası arasındakı əlaqəni araşdırmaq üçün ilk dəfə olaraq İnterferometrik Sintetik Diyafram Radar (InSAR) metodundan istifadə edilmişdir. InSAR zəlzələlərin xüsusiyyətlərini və təsirlərini öyrənmək üçün ənənəvi metodologiyalardan fərqli olaraq zəlzələlərin təsirləri haqqında daha ətraflı məlumat verən geniş istifadə edilən bir texnologiyadır. 2021-ci ildə Şamaxı zəlzələsi (Mw5) ilə Ayazaxtarma palçıq vulkanı arasında potensial mümkün əlaqələri müəyyən etmək üçün zəlzələdən oncə, zəlzələ anında və zəlzələdən sonrakı ssenariləri təhlil etdik. Tədqiqat işində 2017-2023-cü illərini əhatə edən Sentinel 1A/B datası istifadə edilərək vulkan deformasiyasının zaman seriyası məlumatları təqdim edilir. Eyni zamanda, zəlzələ ilə bağlı deformasiyanı pre-, co- və post-seysmik fazalarda əks etdirmək üçün radarların görmə xətti (LOS) üçün yerdəyişmə xəritələri hazırlanmışdır. Ayazaxtarma palçıq vulkanı ilə bağlı apardığımız təhlillər nəticəsində fərqli orbitlər boyunca pre-, co- və post-seysmik fazalarında əhəmiyyətli LOS dəyişiklikləri aşkar edilmişdir. Həmçinin, yeddi il ərzində Ayazaxtarma palçıq vulkanının müşahidəsi zamanı Mw5 maqnitudalı iki seysmik hadisə qeydə alınmışdır. Bu hadisələr palçıq vulkanının fəaliyyətinə əhəmiyyətli təsir göstərməmişdir, bu onu göstərir ki, Mw ≤ 5-ə qədər olan zəlzələlər Ayazaxtarma palçıq vulkanında əhəmiyyətli püskürmələrə səbəb ola bilməz. İnterferometrik məlumatların tədqiqi seysmik hadisələrlə Ayazaxtarma palçıq vulkanının deformasiyası və qarşılıqlı əlaqəsi haqqında yeni fikirlər irəli sürmüşdür.

Açar sözlər: InSAR; deformasiya; zəlzələ; volkan; Ayazaxtarma; Azərbaycan.