IRSTI 37.31.19 https://doi.org/10.26577/JPEOS20261285

I. Litovchenko*, V. Lyutikova

NSCSOR of the Ministry of Emergency Situations
of the Republic of Kazakhstan, Almaty, Kazakhstan
*e-mail: litovira@rambler.ru

EARTHQUAKE SWARMS ACTIVITY AND THEIR THERMODYNAMIC AND RHEOLOGICAL PARAMETERS

This study examined the swarm activity of earthquakes within the research region covering the territory between 70–85°E and 39–46°N, as well as methods for the identification of swarm seismicity. New data on the thermodynamic and rheological parameters of swarm seismicity within the study area were obtained. During the observation period under consideration, swarm clusters of seismic events in the seismotectonics of the Northern Tien Shan region for 2017–early 2026 were identified and shown. As a result of the conducted investigations, quantitative values of thermodynamic and rheological parameters in the focal zones of earthquake swarm clusters were obtained. For the first time, quantitative results of calculations of thermodynamic and rheological parameters in earthquake swarm sources are presented. These calculations were performed using a universal computational methodology specifically adapted for seismic events. The study also demonstrates the temporal variation of parameters within earthquake swarm sources and presents the behavior of thermodynamic and rheological parameters over time, which is consistent with the computational model of the universal methodology. The obtained results offer scientific and practical potential for understanding the physics of seismic processes occurring in active environments. This allows for a more detailed and in-depth study of seismic processes and swarms.

Keywords: seismicity, swarms of earthquakes, thermodynamic and rheological parameters of swarms.

И.Н. Литовченко*, В.С. Лютикова

ҚР ТЖМ Сейсмологиялық байқаулар мен зерттеулердің
ұлттық ғылыми орталығы, Алматы, Қазақстан
*e-mail: litovira@rambler.ru

Жер сілкінісі үйінділерінің белсенділігі және олардың термодинамикалық және реологиялық параметрлері

Бұл жұмыс зерттелген аймақтағы (70-85° шығыс, 39-46° солтүстік) жер сілкінісі тобының белсенділігін және үйірлердің сейсмикалық қасиетін тану әдісін қарастырады. Зерттелетін аумақтағы үйінді сейсмикасының термодинамикалық және реологиялық параметрлері туралы жаңа мәліметтер алынды. Қарастырылып отырған бақылау кезеңінде Солтүстік Тянь-Шань аймағының сейсмотектоникасындағы сейсмикалық құбылыстардың шоғырлы шоғырлары анықталды және 2017 жылдан 2026 жылдың басына дейінгі кезеңге көрсетілді. Жүргізілген зерттеулер жер сілкінісіндегі термодинамикалық және реологиялық параметрлердің сандық мәндерін берді. Алғаш рет жер сілкінісіндегі термодинамикалық және реологиялық параметрлерді есептеудің сандық нәтижелері алынды және ұсынылды. Бұл есептеулер сейсмикалық оқиғаларға арнайы бейімделген әмбебап есептеу әдісін қолдану арқылы орындалды. Зерттеу сонымен қатар үйір ошақтарындағы параметрлердің уақытша өзгерістерін көрсетеді және әмбебап әдістің есептеу үлгісіне сәйкес уақыт бойынша термодинамикалық және реологиялық параметрлердің әрекетін нақты көрсетеді. Алынған нәтижелер белсенді орталарда жүретін сейсмикалық процестердің физикасын түсіну үшін ғылыми және практикалық әлеуетті ұсынады, сейсмикалық процестер мен үйірлерді неғұрлым егжей-тегжейлі және тереңірек зерттеуге мүмкіндік береді.

Түйін сөздер: жер сілкінісі, Солтүстік Тянь-Шань аймағының сейсмикасы, үйінділердің термодинамикалық және реологиялық параметрлері.

И.Н. Литовченко*, В.С. Лютикова
Национальный научный центр сейсмологических наблюдений
и исследований (ННЦСНИ) МЧС РК, Алматы, Казахстан
*e-mail: litovira@rambler.ru

Активность роев землетрясений и их термодинамические и реологические параметры

В работе рассматривалась роевая активность землетрясений в регионе исследования для территории 70-85°ВД, 39-46°СШ и метод распознавания роевой сейсмичности. Получены новые данные о термодинамических и реологических параметрах роевой сейсмичности на территории исследования. В рассматриваемый период наблюдений идентифицированы и показаны роевые скопления сейсмических событий в сейсмотектонике региона Северного Тянь-Шаня за 2017- начало 2026. гг. В результате проведенных исследований были вычислены и проанализированы базы данных слабой сейсмической активности и получены значения физических и механических параметров в очагах скоплений слабой сейсмичности. Приводимые результаты расчета физических и механических условий в очагах роевых землетрясений. Такие вычисления выполнены по универсальной вычислительной методике, специально адаптированной для сейсмических событий. Показано временное изменение параметров в очагах роев, наглядно представлено поведение термодинамических и реологических параметров во времени, что соответствует расчетной модели универсальной методики. Полученные результаты несут в себе научно-практический потенциал в понимании физики возникновения сейсмических процессов, протекающих в активной среде, позволяет более подробно и углубленно изучать сейсмические процессы и роевые скопления.

Ключевые слова: сейсмичность региона, рои землетрясений, термодинамические и реологические параметры роев.

Introduction

The current seismic situation is currently escalating daily, both globally and regionally. Powerful and catastrophic events (earthquakes) occur regularly across the Earth and are particularly recorded in high-seismic hazard zones. These zones include Turkey, Syria, Afghanistan, China, Taiwan, Japan, Indonesia, and parts of Russia and Kazakhstan. A striking example of such events is the January 2024 earthquake in Aksu, China, with a magnitude of M = 7.1. The main seismic shock was followed by a series of aftershocks with magnitudes greater than 4.0 (Catalog…, 2025). The recent magnitude 4.7 earthquake that occurred on April 3, 2024, in Almaty, Kazakhstan, once again highlighted the importance of predicting and mitigating the consequences of strong seismic events. Historical catastrophic events can also be considered in this context: the Verny earthquake of June 8, 1887 (M≈7.3-7.8; 43.2°N, 76.9°E; depth ≈20 km), the Kemin earthquake of January 3, 1911. (M≈8.0-8.1; 42.9°N, 77.3°E; depth ≈20 km) and the Chilik earthquake of July 11, 1989 (M≈7.8-8.0; 43.5°N, 78.8°E; depth ≈20 km) (Kurskeyev, 2004), which confirms the need for further scientific research in this area and its priority importance.

In addition to the main topic of consideration, this study includes an analysis of the dynamics of swarm seismicity in the NTS region for the period from 2017 to May 2026. In our opinion, the study of such phenomena is especially important in the context of the current phase of increased tectonic activity in this region.

In this context, a “swarm” refers to a group of weak seismic events (tremors) that appear and disappear in pulses within specific, limited zones. Such swarming clusters sometimes precede larger, more destructive events (earthquakes). The term “swarm” clearly reflects the visual similarity of epicenter clusters to a “swarm” of bees, which significantly facilitates understanding and representing the spatial distribution of seismicity in a region. A graphical clustering method is used to select and automatically recognize such cluster groups.

This tool is an applied method of pattern recognition in seismology. It allows for the identification and distribution of the monitored evolution of swarm activity. At earlier stages, this algorithm was successfully applied to the study of other seismically hazardous regions. The combination of artificial intelligence (AI) and pattern recognition methods provides a statistically valid assessment of earthquake swarm activity parameters.

Current research on earthquake swarms and volcano-tectonic seismicity in regions prone to this activity has made a significant contribution to the development of methods for detecting, localizing, and representing short-duration seismic events.

Literature review

This section provides a literature review and discusses key studies that highlight gaps and address overlooked areas in the current study.

In the work of (Barajas et al., 2023), seismic signals are analyzed and swarms are identified. The authors propose a method based on the Network Covariance Matrix (NCM) for comparing continuous seismic wavefields in tectonic and volcanic settings. This approach significantly improves the accuracy of identifying coherent signals in swarms and allows for the differentiation of tectonic and magmatic processes in the subsurface. Furthermore, in the work of (Barajas et al., 2024), a differential phase analysis method for detecting volcanic tremors was developed and presented, improving the accuracy of localizing the sources of such signals. Despite the volcanic orientation of these systems, this method can be adapted to analyze tectonic swarms and small-scale spatiotemporal structures. (Caudron et al., 2022) examined fluid-driven seismicity and stress transport, revealing that "an increase in fluid pressure preceded the 2014 phreatic eruption of Mount Ontake." The authors used NCM and interferometry techniques. These results highlight the role of fluid migration in "initiating swarming activity," which may be related to tectonic processes in fault zones. In (Farge et al., 2021), the authors modeled low-frequency earthquakes "as rapid transients of fluid pressure changes at subduction margins." This suggests that "swarm processes can reflect episodic fluid injection even in non-volcanic settings." (Fountoulakis and Evangelides, 2025) analyzed volcano-tectonic interactions and monitoring of the Santorini-Amorgos seismic sequence (2024–2025), linking high-resolution data to volcano-tectonic processes. This study highlights the importance of dense observation networks for analyzing swarm dynamics. In this study, (Druitt et al., 2019) reconstructed the Santorini magmatic system, demonstrating the interaction of magmatic intrusions with regional faults. This interaction reflects the behavior of tectonic swarms, in which stress redistribution can initiate microseismic clusters. (Contreras-Arratia et al., 2024) addressed the problem of a lack of seismic monitoring data in a context of limited funding, using the example of La Soufrière Volcano (Saint Vincent). The authors emphasized the critical need to develop accessible and robust algorithms for detecting swarm activity. This was partially achieved in this study using artificial intelligence (AI) methods. (Berezhnev et al., 2025) conducted regional studies and identified methodological limitations in the sources of tremors at Gorely Volcano, linking degassing processes to seismic activity. Despite its volcanic nature, the proposed approach can be adapted and applied to tectonic systems with increased fluid content, such as the Northern Tien Shan region. In their work, (Hindele et al., 2024) demonstrated that wind microseisms at Taupo Volcano can mimic tectonic signals. This underscores the urgent need to separate extraneous environmental noise from actual swarm activity. This study achieves this using multiparameter criteria–magnitude, distance, and time.

Despite significant progress in ongoing research, key gaps remain. Most studies focus on volcanic systems to understand the differences between tectonic and volcanic swarms, while the tectonic clusters of NTS swarms remain poorly understood. Currently, physical and mechanical parameterization is either lacking, or the available research is significantly limited in data availability. Some quantitative values describing physical and mechanical parameters are simply unavailable.

In this understanding, the integration of AI and existing clustering algorithms significantly increases the chances of identifying the physical nature of swarming clusters, but they are not sufficiently adapted to existing tectonic regimes.

This study analyzes seismic swarms in the Central Asian region, specifically considering regional specifics. It also develops an applied scientific approach to accounting for the relationship between thermodynamic and rheological parameters and tectonic stresses, further improving methods for automatically identifying and recognizing swarms in data-poor settings.

Methodology

The methodology in this study refers to the application of "graphical clustering to seismic events to recognize earthquake swarms." This pattern recognition algorithm is implemented in seismological research and big data analysis. This allows for tracking the evolutionary dynamics of swarm seismicity in a region prone to seismic processes. A similar method has previously been used to analyze seismically active zones in various regions subject to increasing seismicity using graphical clustering algorithms. Within the narrow confines of an intelligent approach to earthquake swarm recognition methods, this approach provides a sufficiently clear statistical basis for specifying numerical parameters for swarm clusters. Thus, the steps involved in "recognition" are as follows: Events are identified as "swarms" in the following cases:

- number of events $N\_sw \geq 3$ in a group of earthquakes;
- distance $L\_sw \leq 10$^' between event epicenters in a group;
- time interval $0<T\_sw \leq 15$"-" 26 days between consecutive events in a given group.

Only if the above conditions are met can an event be classified as a "SWARM." All events falling into this group are considered earthquake swarm activity. Thus, research has revealed that earthquake swarms predominantly form near tectonic faults. After swarm groups form in such zones, strong events with magnitudes greater than 6-7 are possible within 10-15 years A similar method for representing swarms of weak seismicity was applied to the seismotectonically active region of the TSS. The evolution of swarms of weak seismicity showed an increase in the number of swarms. It should be noted that a swarm illustrates a specific type of seismotectonic activity. It can be described as a process occurring within a limited area with a relatively short lifetime (max 26 days), but this process records a large number of weak events, which is typical of "background" seismicity. In this regard, the main difference from aftershock sequences is that swarms are not always associated with a primary high-magnitude event and, as a rule, do not exhibit a pronounced attenuation of activity over time.

The temporal dynamics of swarms for the period 2017–2026.05 is presented in Figure 1. In the seismically active region of the TSS under consideration, a strong earthquake with a magnitude of M = 7.1 and a focal depth of 65 km was recorded on January 23, 2024, in Aksu County, China, as well as an event with a magnitude of 5.0 in the Almaty region (see Figs. 2–4). The considered period of continuous swarming activity from 2017 to 2026.05 was approximately 9 years. The analysis of the recognition results obtained to date allows us to qualitatively characterize the recognition process itself, although the physical nature of swarms remains poorly understood. Swarms are observed both in continental seismic zones (e.g., the Caucasus) and in thrust subduction zones (e.g., the Kuril-Kamchatka zone).

Results and discussion

An analysis of physical and mechanical data in zones of weak seismicity ($M > 1.6$) demonstrates a deeper understanding of the nature of the swarm phenomenon. In this study, swarm-type events meeting the above criteria were identified using specialized algorithms and recognition methods based on the current earthquake database. After successfully sampling events, their key parameters were calculated and discussed below. All calculations in this study were performed using a universal approach, yielding numerical values for the thermodynamic and rheological characteristics of earthquake swarms for the period from 2017 to 2026. All events, processes, and phenomena occurring in the deep layers of the Earth confirm the importance and necessity of studying sources of information on the analysis of the physical and mechanical properties of the earth's crust and its layered structure. The magnitude and energy class of an event serve as the basic parameters for determining thermodynamic characteristics. Selected numerical values for the studied swarms are presented in Table 1, given in the publication (Litovchenko and Lyutikova, 2025).

Illustrations

The analyzed characteristics include parameters such as energy, temperature, stress, strain, energy density, potential energy, tensile strength, and others (see Table 1. Lyutikova and Litovchenko, 2025). Interpreting the physical and mechanical conditions of swarm formation is an important scientific and practical result. The calculated characteristics demonstrate a direct dependence of the following parameters: E, V, U, Ek G, αv, τcr, and lgη on magnitude. In this case, for each event (earthquake) with a magnitude greater than 1.6, all the above parameters were calculated using the corresponding formulas from the works of Tuliani L. The obtained parameters for all characteristics in the source of the "swarm" event were analyzed, and it was noted that such earthquakes obey the following hypothesis: firstly, it is based on changes in thermodynamic stresses and elastic deformations in the upper layers of the Earth (Somsikov, 2021, 2025). Secondly, it shows how the number of identified swarm events in the TSS changed from 2017 to early 2026. Thirdly, the diagram shows the size of each swarm event as directly proportional to its magnitude (see Figure 1).

Figures 2-4 analyze the spatial and temporal distribution of identified swarm events in the region. This allowed us to more accurately determine their clustering and concentration, as well as their geographic location.

Figure 1
Timeline of seismic events recorded in the seismic activity zone of the territory 70–85°E and 39–46°N from 2017 to May 2026

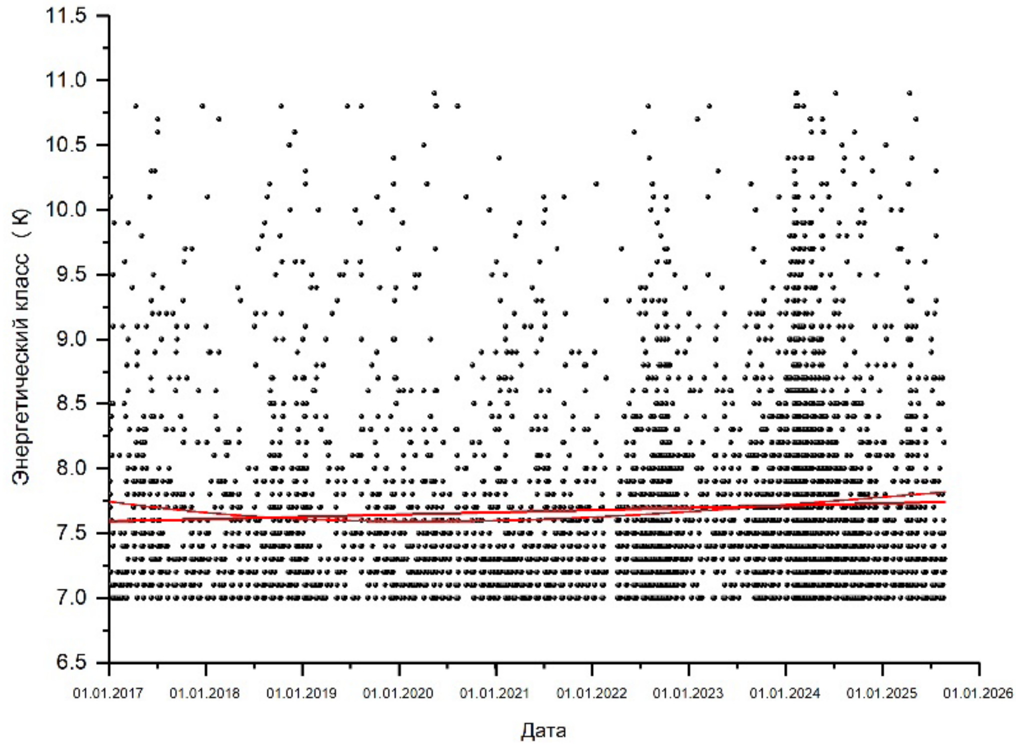


Figure 2
Distribution of seismicity in the area 70–85°E and 39–46°N and for the period 2017–2026

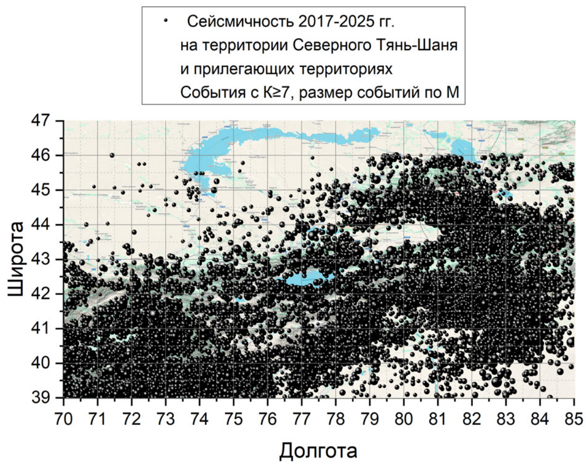


Figure 3
Distribution of earthquakes (black), swarms (green), and strong events (red) in the area 70–85°E and 39–46°N for 2017–2026

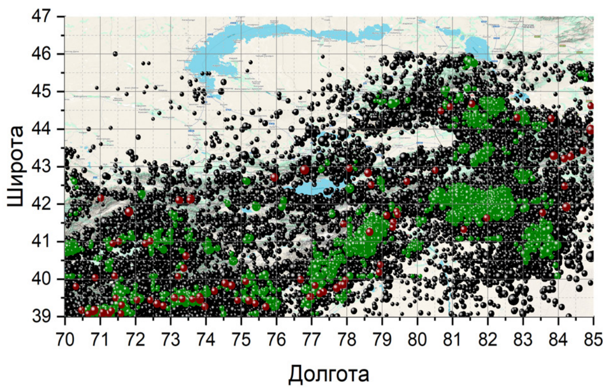
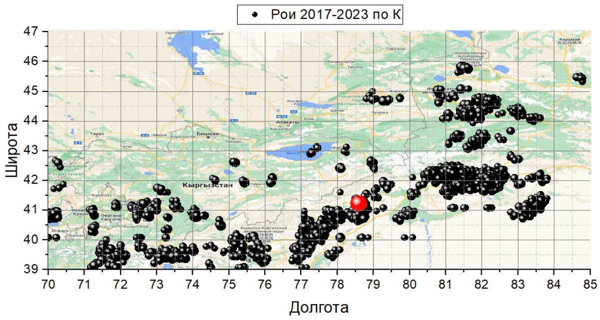


Figure 4

Distribution of earthquake swarms in the seismic zone between 70–85°E and 39–46°N from 2017 to May 2026 (the swarm radius is shown as a function of magnitude; the strong earthquake of April 3, 2024, with a magnitude of M=7.1 is shown in red)



Based on the obtained results, several important conclusions can be formulated. According to the authors, the accumulation of tectonic stresses is related to the heterogeneous distribution of temperature and variations in the physical properties of the geological medium. The release of these accumulated stresses is expressed through seismic activity, particularly earthquakes. The relationship between earthquake energy and source temperature at the moment of elastic stress release within seismic swarms (Tuliani, 1999) is described by the following equation:

$$T(K) = 196.8\,(\lg E_{max} - \lg E)$$

where 196.8 K represents a constant corresponding to a one-order variation in seismic energy (erg), and lgE denotes the logarithm of seismic-wave energy.

Subsequent analysis of the thermodynamic characteristics of swarm sources revealed a pronounced inverse relationship between seismic-wave energy and source temperature, as well as between earthquake magnitude and temperature. In other words, increasing temperature within the swarm source is accompanied by decreasing earthquake magnitudes and lower seismic-wave energy values.

Comparison of the calculated thermoelastic coefficient αv with experimental observations also demonstrates that αv increases with rising temperature. Changes in temperature and pressure within the medium are partially compensated, resulting in αv characterizing the average thermoelastic change in volume. The deformation parameter ε and the shear modulus G, along with the normal stress σ for the swarm, were estimated according to (Tuliani 1999). Then, the values of the listed parameters ε and σ increase with increasing T. The shear modulus G decreases. In this case, the relationships between magnitude M, energy E, and shear modulus with temperature T and effective stress are inverse. This, in turn, suggests that high temperatures and effective stresses correspond to lower event magnitudes, which corresponds to a decrease in the rigidity of the geological environment.

The established correlations between thermodynamic and rheological parameters within seismically active orogenic regions reflect specific geodynamic conditions associated with neotectonic deformation processes and localized partial melting of crustal material. In addition, the spatial distribution of earthquake swarms across the study region is distinctly nonuniform.

As a result, it can be concluded that the analysis of physical and mechanical parameters in the foci of swarm-type events allowed us to determine not only quantitatively the thermodynamic and rheological characteristics for a series of weak swarm-type seismic events, but also to construct schematic maps of the distribution of these clusters in the Northern Tien Shan and adjacent territories during the observation period.

Conclusion

Based on the obtained results, swarm-type events were identified, their characteristics were described, and numerical values of the physical and mechanical parameters at the source of each event were calculated. These parameters characterize the physical conditions under which swarm earthquakes occur. This allowed for a more accurate interpretation of the nature of swarm seismicity in the region. The obtained results demonstrate the existence of stable patterns between the energy, thermodynamic, and rheological characteristics of earthquake swarm foci. Ultimately, the analysis confirms that swarm seismicity is an important element of geodynamic processes in seismically active regions and can be used to further study the mechanisms of seismic activity preparation and development in tectonic fault zones.

Acknowledgments

The authors express their sincere gratitude to their supervisor, Academician of the National Academy of Sciences of the Republic of Kazakhstan A.K. Kurskeyev.

The study was conducted at the Laboratory of Physics of Geodynamic and Seismic Processes of the National Scientific Center for Seismological Observations and Research under the Ministry of Emergency Situations of Kazakhstan as part of ongoing fundamental research.

Additional work was conducted at the Laboratory of Geodynamic and Seismic Processes under project BR24992763, "Seismic Hazard Assessment of Regions and Cities of Kazakhstan Based on a Modern Scientific and Methodological Framework." Funding was provided by the Ministry of Education and Science of the Republic of Kazakhstan.

Author Contributions

Conceptualization, investigation and original draft preparation – I. Litovchenko; Data curation, visualization, editing – V. Lyutikova.

References

1. Barajas, A., Journeau, C., Obara, K., & Shapiro, N. M. (2023). Comparison of continuously recorded seismic wavefields in tectonic and volcanic environments based on the network covariance matrix. Journal of Geophysical Research: Solid Earth, 128 (12), e2023JB026784.

2. Barajas, A., Shapiro, N. M., & Prieto, G. (2024). Differential phase analysis for vol canic tremor detection and source location. Journal of Geophysical Research: Solid Earth, 129 (10), e2024JB029010.

3. Berezhnev, Y., Belovezhets, N., Shapiro, N. M., Abramenkov, S., & Koulakov, I. (2025). Tracking changes in the tremor sources associated with a gorely volcano degassing episode in 2013. Available at SSRN 5280535.

4. Caudron, C., Aoki, Y., Lecocq, T., De Plaen, R., Soubestre, J., Mordret, A.,Terakawa, T. (2022). Hidden pressurized fluids prior to the 2014 phreatic eruption at mtontake. Nature Communications, 13 (1), 6145.

5. Caudron, C., Soubestre, J., Lecocq, T., White, R. S., Brandsd´ottir, B., & Krischer, L. (2022). Insights into the dynamics of the 2010 eyjafjallaj¨okull eruption using seismic interferometry and network covariance matrix analyses. Earth and Planetary Science Letters, 585, 117502.

6. Contreras-Arratia, R., Chouet, B., Caudron, C., Nath, N., Balchan, A., Madoo, F., & Ramsingh-Reddock, H. (2024). Tracking seismicity in an underfunded institution: The case of la soufri`ere st vincent volcanic eruption 2020–2021. Journal of Volcanology and Geothermal Research, 446, 107990.

7. Druitt, T. H., Pyle, D. M., & Mather, T. A. (2019). Santorini volcano and its plumbing system. Elements: An International Magazine of Mineralogy, Geochemistry, and Petrology, 15 (3), 177–184.

8. Farge, G., Jaupart, C., & Shapiro, N. M. (2021). Episodicity and migration of low frequency earthquakes modeled with fast fluid pressure transients in the permeable subduction interface. Journal of Geophysical Research: Solid Earth, 126 (9), e2021JB021894.

9. Fountoulakis, I., & Evangelidis, C. P. (2025). The 2024–2025 seismic sequence in the santorini-amorgos region: Insights into volcano-tectonic activity through high-resolution seismic monitoring. Seismica, 4 (1).

10. Hindeleh, H. B., Savage, M., Illsley-Kemp, F., & Mestel, E. R. (2024). How a nonharmonic-like tremor at a volcanic lake could be caused by sustained wind: A case of study of taup¯o volcano. Volcanica, 7 (2), 749–764.

11. Somsikov V.M. (2025) Physics of Evolution in Physics. – 2025//mce.su/archive/doc488837/rus.pdf

12. Somsikov V. M. (2021) Fundamentals of the Physics of Evolution. – KazNU, 2021, 335 p.

13. Regional Earthquake Catalog http://some.kz/

14. Kurskeyev A.K. (2004) Earthquakes and Seismic Safety of Kazakhstan. Almaty, 2004. – 504 p.

15. Lyutikova V.S., Litovchenko I.N. (2023) Physical and mathematical criteria for recognizing earthquake swarms in the seismicity of the Northern Tien Shan and adjacent territories. Proceedings of the collection "Modern methods of processing and interpreting seismological data" of the XVII International Seismological School (Tashkent, September 11-15, 2023), Obninsk, 2023. p. 67.

16. Litovchenko I.N., Lyutikova V.S. (2025) The current stage of swarms activation Earthquakes in the Northern Tien Shan region and adjacent territories, and thermodynamic parameters of earthquake swarms. Tectonophysics and current issues in Earth Sciences. – Sixth Tectonophysical Conference at the IPE RAS. – Materials, report, to the 300th anniversary of the Russian Academy of Sciences. (07-12. 10.2024), Moscow, 2025. – SS.204-207.

17. Lyutikova V.S., Litovchenko I.N. (2025) Modern methods of swarm research scientific work". – 2025. No. 1. – International scientific and practical journal "Endless Light in Science", Astana, 2025.- CC .226-229. https://doi.org/10.24412/3007-8946-2025-31-226-229

18. Tuliani L.I. Seismicity and seismic hazard: based on thermodynamic and rheological parameters of the tectonosphere. M.: Scientific World , 1999. – 216 s

19. Litovchenko I.N., Lyutikova V.S. (2025) Thermodynamic parameters of earthquake swarms. – 2025.pp. 81-90. Science News of Kazakhstan No. 3 (166) Natural Sciences, Engineering and Technology. https://doi.org/10.53939/1560-5655_2025_3_81

Information about the authors:

Irina Litovchenko, (corresponding author) – Laboratory of Geodynamic and Seismic Processes, Lead Researcher, National Scientific Center for Seismological Observations and Research (NSCSOR), Ministry of Emergency Situations of the Republic of Kazakhstan, (Almaty, Kazakhstan, e-mail: litovira@rambler.ru).

Veronika Lyutikova – Master of Engineering and Technology, Laboratory of Geodynamic and Seismic Processes, Lead Researcher, National Scientific Center for Seismological Observations and Research (NSCSOR), Ministry of Emergency Situations of the Republic of Kazakhstan, (Almaty, Kazakhstan, e-mail: nikki.valo16@gmail.com).

Авторлар туралы мәлімет:

Ирина Литовченко, (корреспонденттік автор) – Қазақстан Республикасы Төтенше жағдайлар министрлігінің Сейсмологиялық бақылаулар мен зерттеулердің ұлттық ғылыми орталығының (NSCSOR) геодинамикалық және сейсмикалық процестер зертханасы, Жетекші ғылыми қызметкер (Алматы, Қазақстан, e-mail: litovira@rambler.ru).

Вероника Лютикова – инженерия және технология магистрі, геодинамикалық және сейсмикалық процестер зертханасы, Қазақстан Республикасы Төтенше жағдайлар министрлігінің Сейсмологиялық бақылаулар мен зерттеулердің ұлттық ғылыми орталығының (NSCSOR) геодинамикалық және сейсмикалық процестер зертханасы, Жетекші ғылыми қызметкер (Алматы, Қазақстан, e-mail: nikki.valo16@gmail.com).

Сведения об авторах:

Ирина Литовченко (автор для корреспонденции) – Лаборатория геодинамических и сейсмических процессов, Ведущий научный сотрудник, Национальный научный центр сейсмологических наблюдений и исследований (ННЦСНИ), Министерство чрезвычайных ситуаций Республики Казахстан (Алматы, Казахстан, e-mail: litovira@rambler.ru).

Вероника Лютикова – магистр техники и технологий, Лаборатория геодинамических и сейсмических процессов, Ведущий научный сотрудник, Национальный научный центр сейсмологических наблюдений и исследований (ННЦСНИ), Министерство чрезвычайных ситуаций Республики Казахстан (Алматы, Казахстан, e-mail: nikki.valo16@gmail.com).