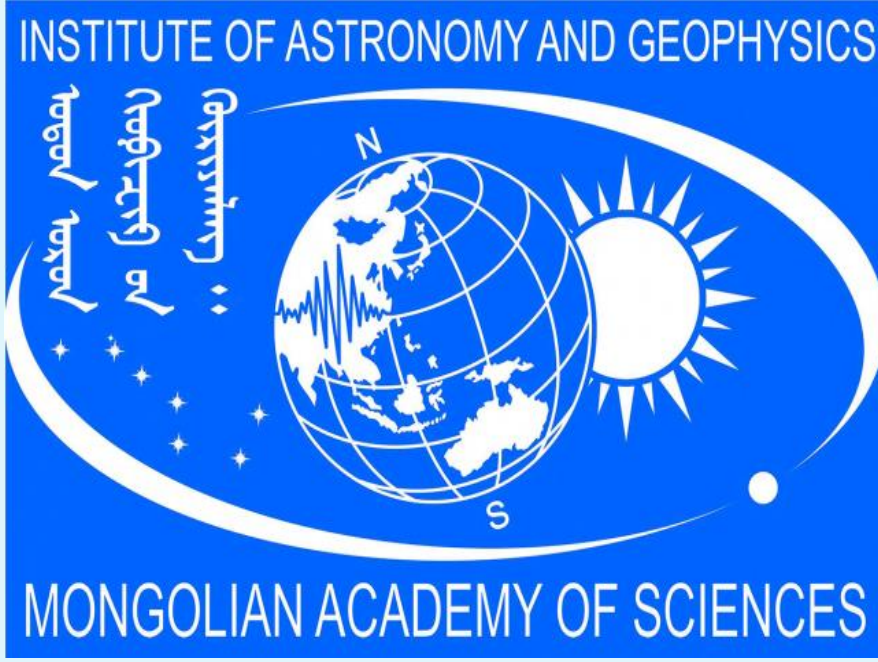




MACROSEISMIC ANALYSIS OF THE STRONG EARTHQUAKE THAT OCCURRED ON DECEMBER 24.2025.IN BULGAN SOUM, BULGAN PROVINCE, MONGOLIA

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Abstract

On December 24, 2025, at 18:38:02 Ulaanbaatar time, an earthquake with a magnitude of ML 4.1 occurred approximately 3 km east of the center of Bulgan Soum, Bulgan Province, Mongolia. The earthquake was strongly felt by residents of Bulgan Soum, the administrative center of Bulgan Province, with a population of approximately 15,000 people, as well as by residents of Orkhon Soum located to the south. This study aims to evaluate the distribution of seismic intensity and the effects of ground shaking associated with this earthquake. A macroseismic survey was conducted to investigate the spatial variation of earthquake effects. Primary macroseismic information was collected from 165 residents through questionnaires, and the collected data were analyzed using the MSK-64 intensity scale. The analysis shows that the strongest shaking effects were concentrated in the epicentral area, with decreasing intensity away from the source region. Based on the estimated intensity values, areas with similar seismic effects were identified and an isoseismal map was developed. The results provide important information on local site effects and the spatial characteristics of ground shaking caused by the earthquake.

Keywords: Macroseismic investigation, earthquake intensity, MSK-64 intensity scale

Methodology

Earthquake intensity can be evaluated using two approaches: instrumental and macroseismic methods. The macroseismic method assesses earthquake intensity based on the observed effects of ground shaking on the Earth's surface, buildings and structures, and the people exposed to the event. Earthquake intensity is expressed on a numerical scale rangimacroseismic indicators, including:

- Human perception and the effects on surrounding objects;
- Damage to buildings and engineering structures;
- Earthquake-induced natural phenomena.

These indicators can be assessed at numerous observation sites across the affected area (Munkhuu, D.). The primary basis of macroseismic investigation is the analysis of eyewitness accounts collected through standardized questionnaires designed to evaluate these indicators. In Mongolia, earthquake intensity is determined using the MSK-64 intensity scale, based on interviews with local residents and the assessment of their observations ng from **I to XII**, representing the severity of the observed effects (Munkhuu, D.).

Following a significant earthquake, the intensity of ground shaking is evaluated using several according to a standardized macroseismic questionnaire.

Macroseismic Investigation

Within a 300 km radius of Bulgan Province, a total of 4,475 earthquakes with magnitudes greater than or equal to 0.1 were recorded between 2025 and March 2026. The largest event in this sequence occurred at 18:38:02 (Ulaanbaatar time) on December 24, 2025, approximately 3 km east of Bulgan soum, the administrative center of Bulgan Province, with a moment magnitude (Mw) of 4.1.

To determine the macroseismic intensity of this earthquake, eyewitness surveys were conducted immediately after the event. Residents were contacted without delay, and their observations were collected and analyzed to establish a macroseismic database. For each soum where the earthquake was felt, intensity assessments were based on responses from at least 20 residents, whenever possible.

A total of 145 questionnaires were collected from residents of Bulgan soum, 20 from Orkhon soum (Bulgan Province), 2 from Bugat soum, 2 from Bayan-Öndör (Orkhon Province), and 15 additional responses from other soums. These eyewitness reports formed the basis for evaluating the spatial distribution of macroseismic intensity associated with the earthquake.

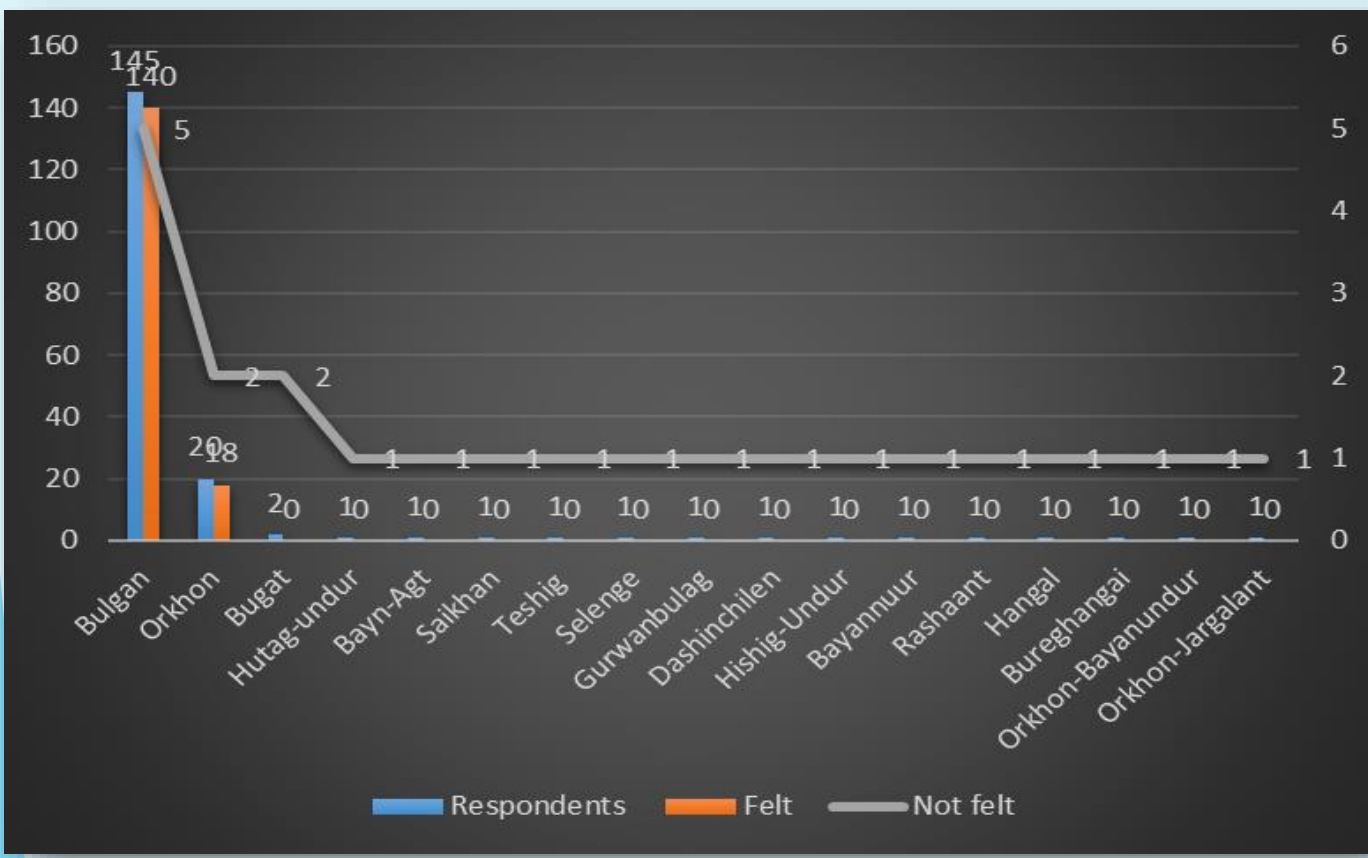


Figure 1. Number of respondents who reported feeling the ground shaking from the 24 December 2025 Bulgan earthquake by soum.

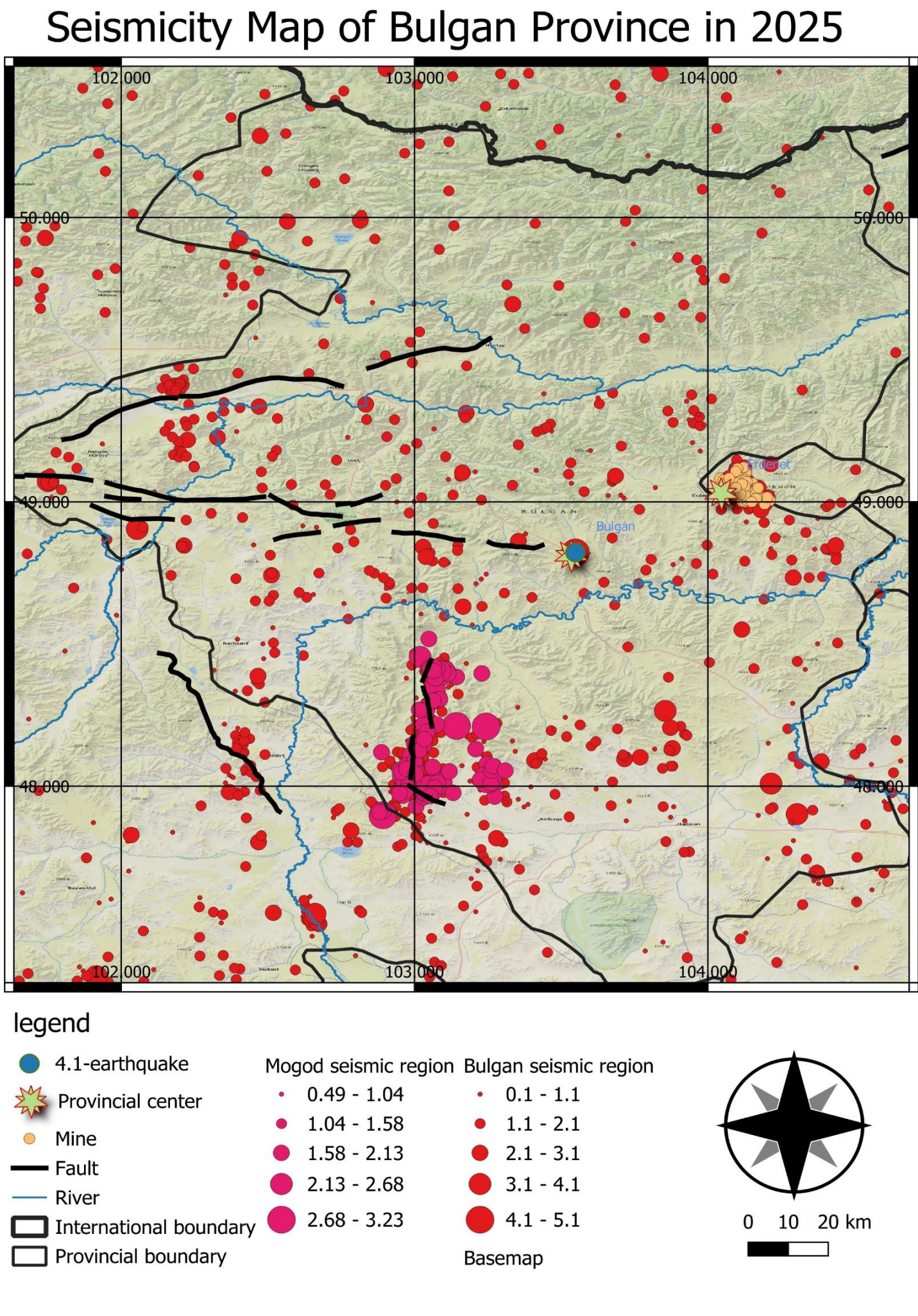


Figure 2. Epicenter Distribution Map of Bulgan Province-2025

Although the questionnaire survey included a relatively small number of respondents, most residents of **Bulgan soum** reported experiencing the earthquake shaking. The provincial center is situated within the epicentral region, and the macroseismic observations are consistent with the strong-motion accelerometer records. This agreement between eyewitness reports and instrumental measurements supports the reliability of the estimated macroseismic intensity.

Introduction

Bulgan Province is located in one of the seismically active regions of Mongolia. It lies close to several major historical earthquakes, including the destructive Mogod earthquake, which occurred more than 150 km south of Bulgan soum, and the Saikhan earthquake to the southwest. Strong earthquakes are among the most destructive natural hazards, capable of causing severe damage to buildings and infrastructure, as well as posing significant risks to human life. One of the fundamental measures for mitigating earthquake risk is the development of national seismic hazard and microzonation maps based on long-term seismological investigations (Adyaa, M.). According to the 2020 Seismic Hazard Zonation Map of Mongolia, Bulgan Province is situated within the MSK-64 intensity VIII–IX (9–10) seismic hazard zone, indicating a high level of earthquake risk. At 18:38:02 (Ulaanbaatar time) on December 24, 2025, an earthquake with a moment magnitude (Mw) of 4.1 occurred approximately 3 km east of Bulgan soum, the administrative center of Bulgan Province. Although moderate in magnitude, the earthquake was strongly felt by residents throughout the provincial center. The event caused considerable public concern and panic, while minor structural damage, including cracks in several buildings, was also reported. These observations highlight the necessity of conducting detailed macroseismic investigations to evaluate the earthquake's intensity distribution and its impacts on the built environment and local communities.

Discussion of Macroseismic Results

Settlements where earthquake shaking was felt:
Residents of Bulgan soum and Orkhon soum in Bulgan aimag reported feeling the earthquake shaking.

Settlements where earthquake shaking was not felt:
Residents of the other 14 soums of Bulgan aimag, as well as Bayan-Öndör and Jargalant soums of Orkhon aimag, did not report feeling the earthquake. Based on the questionnaire survey responses collected from residents who experienced the earthquake shaking, an isoseismal map showing areas of similar intensity was prepared.

Intensity assessment:
The earthquake generated shaking with an intensity of **V–VI** on the MSK-64 intensity scale at the epicentral area. In Bulgan soum, located approximately 3 km from the epicenter, the shaking was assessed as **V–VI** intensity. Most residents reported strong ground shaking. In addition, cracks were observed on the corridor walls of Building No. 104 and Building No. 109 in the 5th bagh of Bulgan soum, as well as on the supporting beam of Building No. 208. These observations support the assigned intensity assessment.

In Orkhon soum, located approximately 17 km south of the epicenter, the earthquake shaking was evaluated as **IV–V** intensity. Most residents reported experiencing shaking similar to windows and doors rattling or vibrations caused by a heavy vehicle passing nearby. Some residents also reported that hanging objects moved during the earthquake.

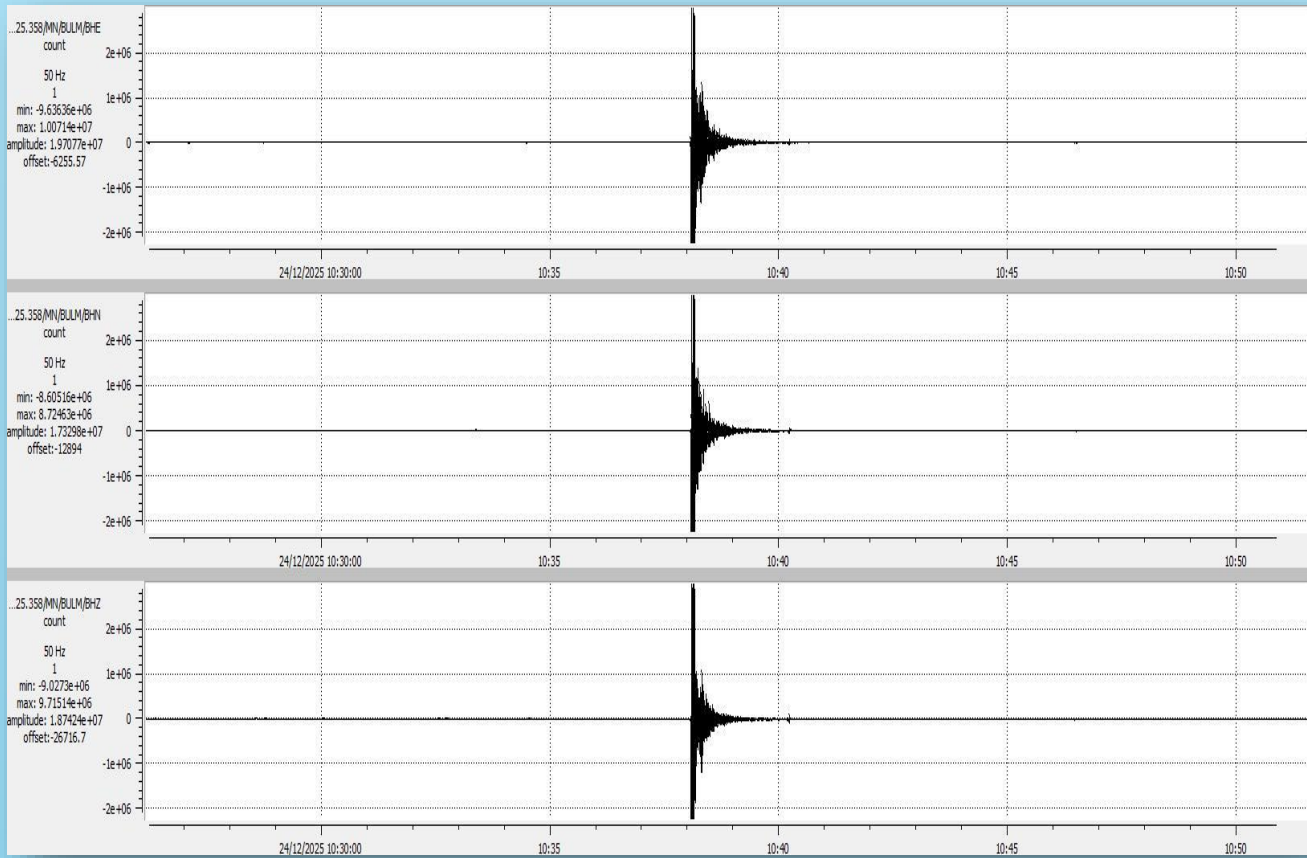


Figure 3. Waveform of the main earthquake recorded at Bulgan seismic station.

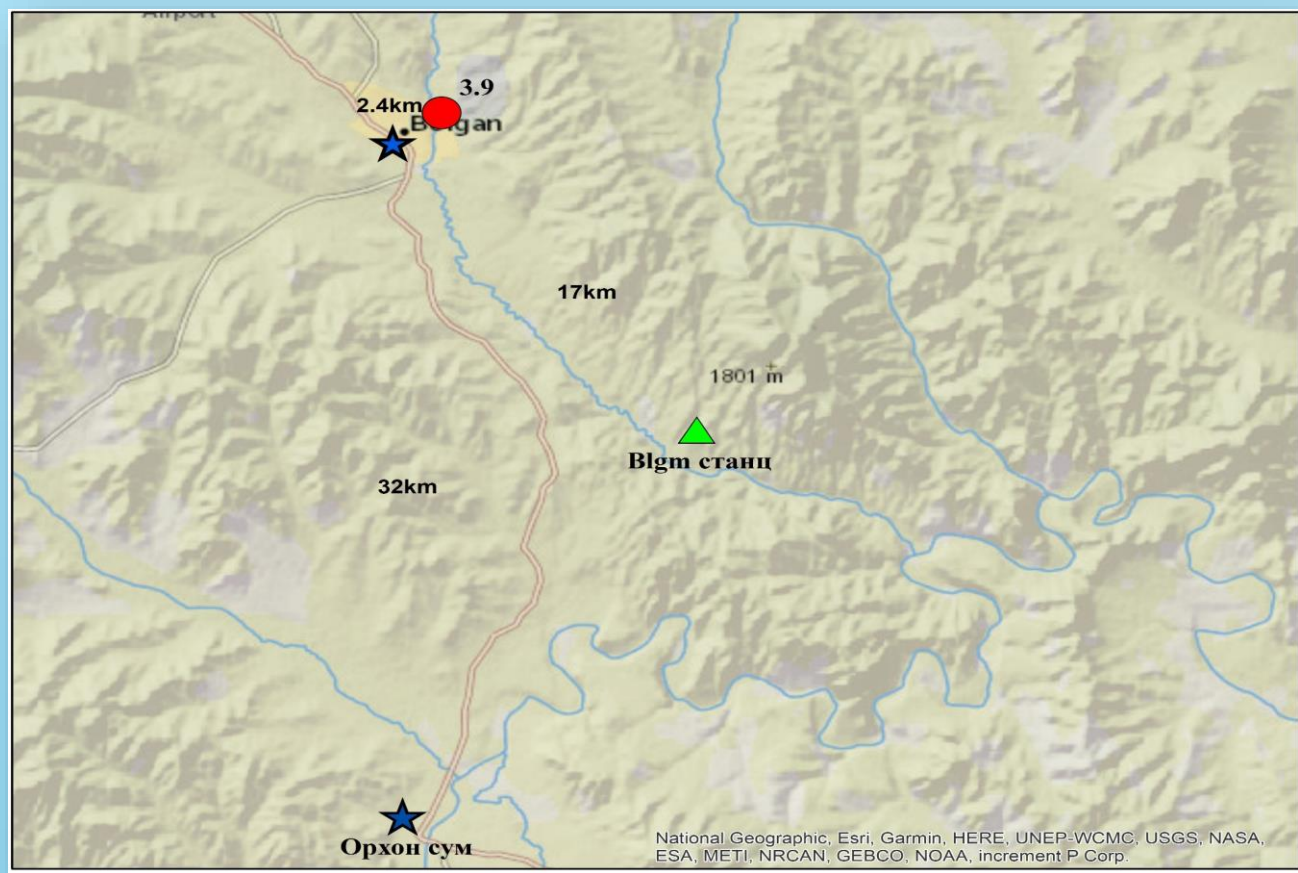


Figure 4. Location of the main earthquake in Bulgan Province.



Figure 5. Cracks in Building No. 208 caused by the earthquake.



Figure 6. Cracks in Building No. 104 caused by the earthquake.

References

- Adyaa, M. (2020). Earthquake. Ulaanbaatar.
- Adyaa, M. (2010). Seismic Regime of Mongolian Territory. Ulaanbaatar.
- Baljinnyam, I., Munkhoo, D., Tsembal, B., Dugarmaa, T., Adyaa, M., & Bayar, G. (1975). Earthquakes of Mongolia. Ulaanbaatar.
- Bulgan Station. (2025). Bulgan Station Annual Report–2025. Bulgan.
- Munkhuu, D., et al. General Concepts of Earthquakes.
- David.M.B, William.B.J, and Thomas.E.F. 1997. "Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes." A Summary of recent Work, Seismological Research Letters, Vol. 68, No. 1 12.
- Institute of Astronomy and Geophysics. (2025). Annual Report–2025. Ulaanbaatar.