THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE: ADVANCES IN ASTRONOMY AND GEOPHYSICS

SEISMIC ACTIVITY IN THE GOBI-ALTAI PROVINCE

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INTRODUCTION

This study analyzed earthquakes that occurred in the Gobi-Altai provinve between 1964 and 2021 and estimated key parameters of the region's seismic regime using the Gutenberg–Richter law.

On March 20, 2020, an earthquake with a magnitude of 6.1 occurred at the junction of the active faults of the Mongol Altai and Gobi-Altai ranges, which located in Tonkhil soum of Gobi-Altai province. This earthquake took place along the same latitude and approximately one hundred kilometers north of the epicenter of the Takhin Shar earthquake. Observations indicate a correlation between the epicenters of the Tonkhil and Takhin Shar earthquakes. Additionally, it has been determined that another potential epicenter may exist about 18 kilometers south of the 2020 M6.1 epicenter, suggesting a broader seismic source area within this region.

The Gobi-Altay mountain range, located in the southern part of Mongolia, is a tectonically active and relatively young mountain system situated deep within the continental interior. It was uplifted around 5 million years ago as a result of compressional forces stemming from the distant Indo-Eurasian plate collision, located over 2,000 km away. The Gobi-Altai Range is part of the **Mongolian Altai mountain system**, characterized by **active reverse and strike-slip faulting**. The range itself stretches over **700 kilometers** and is composed of several subranges, such as **Ikh Bogd**, **Baga Bogd**, **Bayan Tsagaan Uul**, and **Gurvan Saikhan Uul**. These mountains were uplifted during the late Cenozoic (approximately the last 5 million years) in response to compressional forces.

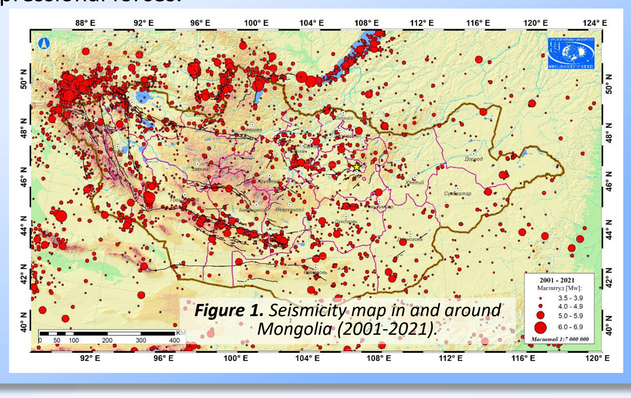

Figure 1. *Seismicity map in and around Mongolia (2001-2021).*

SEISMIC INTENSITY ESTIMATION OF TONKHIL EARTHQUAKE USING MACROSEISMIC QUESTIONNAIRES

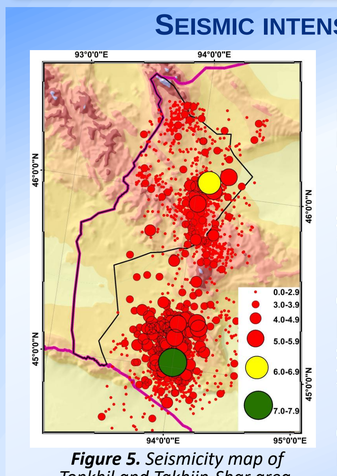

Figure 5. *Seismicity map of Tonkhil and Takhiin-Shar area.*

On March 20, 2020, an earthquake with a magnitude of 6.1 struck Tonkhil sum in Gobi-Altai Province, approximately 115 km north of the epicenter of the 1974 Takhiin Shar earthquake (fig.5).

The Tonkhil earthquake generated strong ground shaking, with theoretical estimates indicating an intensity of VI-VII at the epicenter area.

The event was felt widely across the western part of Mongolia, including most sums of Gobi-Altai province (notable the provincial center), as well as some areas in the neighboring provinces of Khovd, Zavkhan and Bayan-Olgii.

Immediately after the Tonkhil earthquake, we collected macroseismic questionnaires from residents who felt the event and analyzed the responses (fig.6).

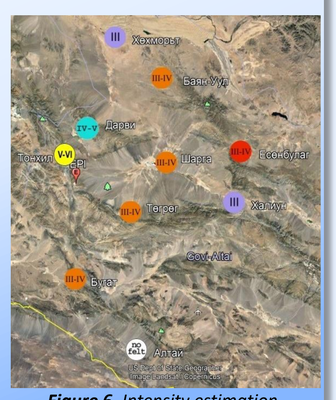

Figure 6. *Intensity estimation map using microseismic questionnaires.*

STUDY ON SEISMIC REGIME

Some of Mongolia's largest recorded earthquakes have occurred in the Gobi-Altai region:

- 1957 Gobi-Altai Earthquake: Magnitude 8.1, this event produced a surface rupture of approximately 270 km, one of the most significant intracontinental earthquakes in the 20th century.
- 1974 Takhiin Shar Earthquake: Magnitude 7.4, occurred in Bugat Soum, with an estimated intensity of IX at the epicenter and a rupture length of ~17 km.
- 2006 Biger Earthquake: Magnitude 6.3, located in the Gichgene Range, part of the same tectonic system.
- 2020 Tonkhil Earthquake: Magnitude 6.1, occurred in Tonkhil Soum, 115 km north of the 1974 event.

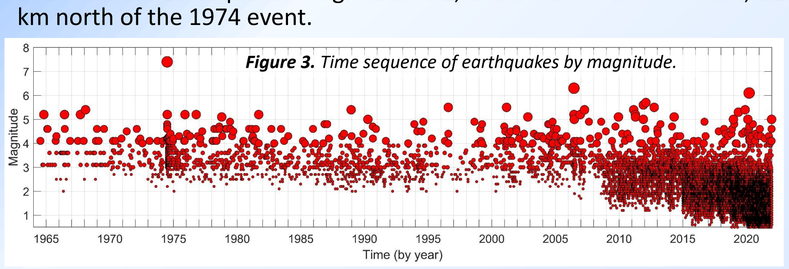

Figure 3. *Time sequence of earthquakes by magnitude.*

Earthquake data recorded between 1964 and 2021 within the territory of Gobi-Altai Province (lat: 41.7°–48.88°, long: 91.8°–99.8°) were obtained from the MNDC. A total of 62,879 earthquake events were registered in the region (fig.2). For the purposes of this study, only the 28,066 events that were detected by three or more seismic stations were selected and analyzed to ensure higher reliability and accuracy.

One of the key considerations in conducting a seismic regime study is determining the completeness magnitude (Mc). This refers to the minimum magnitude above which all earthquakes in the catalog are assumed to have been consistently and completely recorded over the entire study period.

Based on the seismic catalog used in this study, the recording capabilities have varied over time:

- From 1964 to 1973, only earthquakes with a magnitude of M3 or greater were reliably recorded;
- Between 1974 and 2008, events with M2 and above were consistently detected;
- From 2009 to 2014, earthquakes with M1 and above were included;
- Since 2015, even earthquakes below M1 have been recorded. Considering these variations, the completeness magnitude (Mc) for the study region is taken as M2.

This study utilizes a comprehensive catalog of 28,066 earthquakes that occurred in the study area from 1964 to 2021.

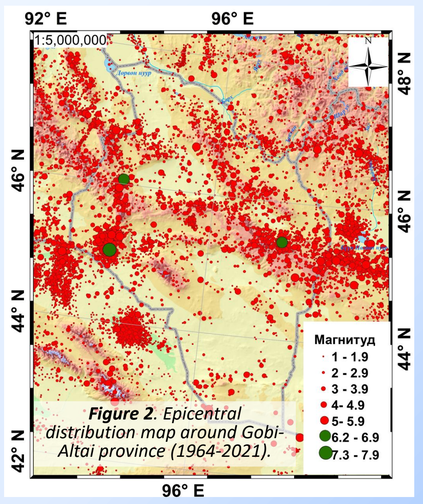

Figure 2*. Epicentral distribution map around Gobi-Altai province (1964-2021).*

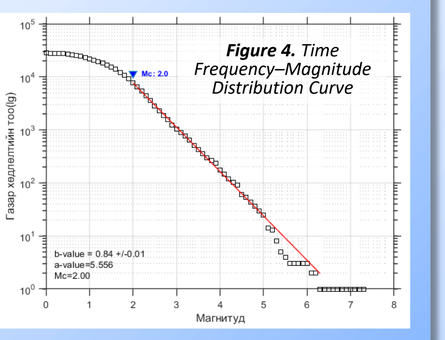

Figure 4. *Time Frequency–Magnitude Distribution Curve*

As part of this study, the magnitude–frequency relationship of earthquakes in the Gobi-Altai region was analyzed.

The b-value of the Gutenberg–Richter relationship was calculated to be 0.8, indicating a relatively low probability of large-magnitude earthquakes (fig.4).

However, the a-value was found to be 5.6, suggesting a high level of seismic activity in the region

THE TEMPORAL AND SPATIAL DISTRIBUTION OF EARTHQUAKES IN THE STUDY AREA

The temporal and spatial distribution of earthquake in the study area between 1967 and 2021 is illustrated in the following figures (fig.7 – fig.12).

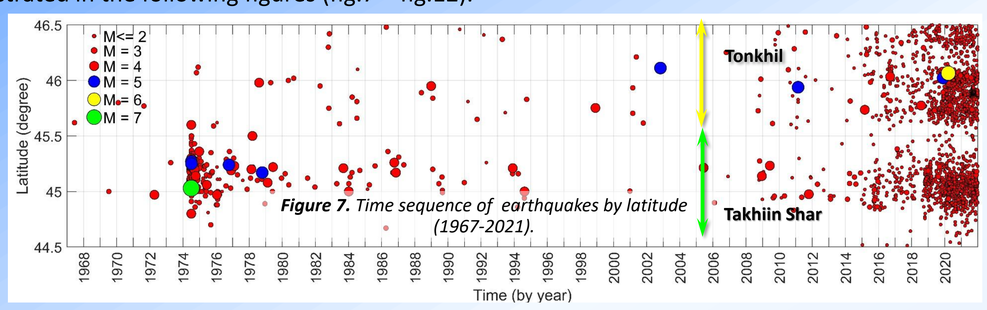

Figure 7. *Time sequence of earthquakes by latitude (1967-2021).*

The time-latitude distribution of seismic events indicates that many earthquakes occurred shortly after moderate-sized events in the region. The first notable case is the **Takhiin Shar** earthquake (green circle), which occurred in **1957**. However, due to limited seismic station coverage at the time, smaller events could not be detected (fig.7-8).

A second cluster of increased seismicity was observed following the **Tonkhil** earthquake (yellow circle) in **2020**, with a clear concentration of events around the latitude of this mainshock (fig.7-8).

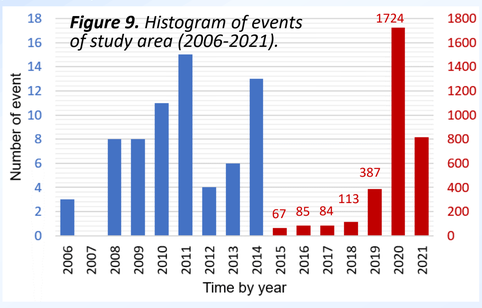

Figure 9. *Histogram of events of study area (2006-2021).*

- The number of detected seismic events began to increase at the end of **2018** (Fig. 9).
- The number of recorded earthquakes **tripled in 2019** compared to previous years.
- **Seismic activity was observed in the Takhiin Shar area** prior to the Tonkhil earthquake.
- A **series of light (M4) and moderate (M5) earthquakes** occurred in the same area during this period.

Between **2006 and mid-2008** (indicated by the green dashed line in Fig. 10), local analog seismic stations were gradually replaced with digital stations. This upgrade improved the ability to detect small earthquakes near the stations; however, weak seismic events within the broader study area still remained largely undetected (Fig.3)

In **September 2014** (green dashed line in Fig.10), the **"Altai" station** was relocated approximately **20 km southeast** of the provincial center. This relocation significantly improved the detection capability for **low-magnitude earthquakes** within the study area.

To ensure the consistency and reliability of the temporal and spatial analysis of earthquake distribution, it is essential to use data from a period in which there were **no changes** in station location or recording capacity (Fig. 10).

Therefore, for this study, we used data from the period **2015 to 2021**, when the station configuration remained stable in the area.

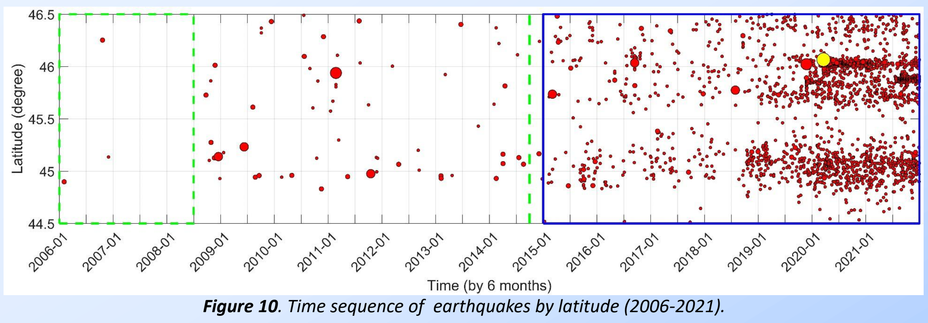

Figure 10*. Time sequence of earthquakes by latitude (2006-2021).*

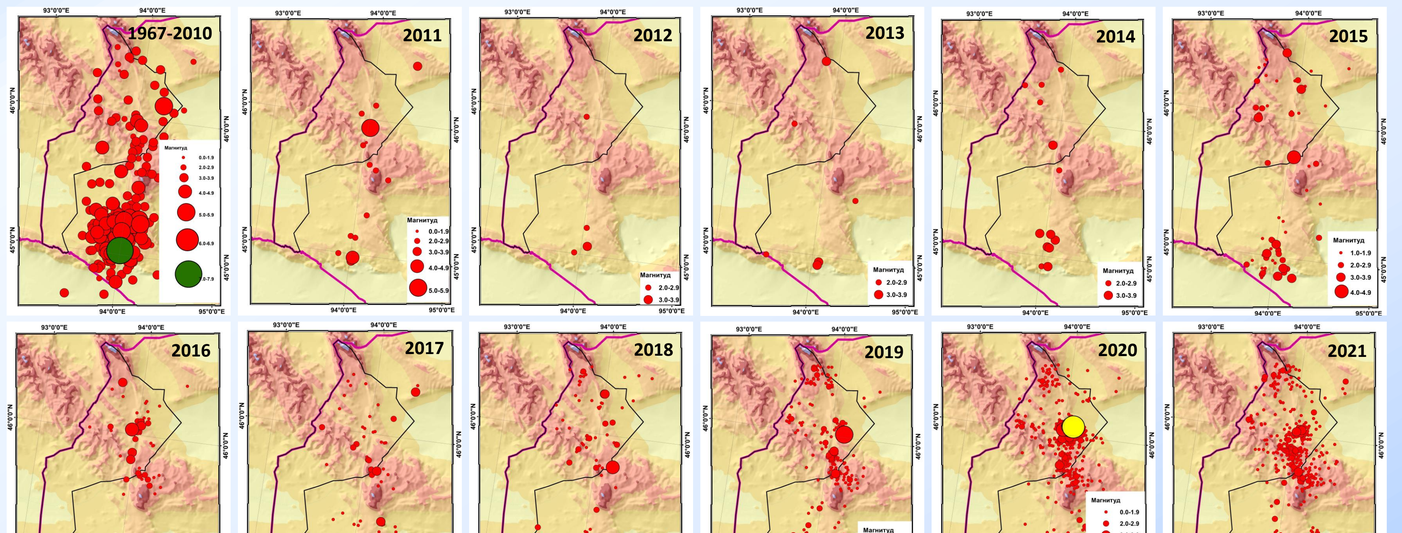

Figure 8. *Seismicity map of study area by year (1967-2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020 and 2021).*

The temporal and spatial distribution of earthquakes in the study area (Fig. 11) suggests a possible correlation between seismic activity in the **Tonkhil** and **Takhiin Shar** regions. A noticeable pattern emerges: numerous small earthquakes in the **Takhiin Shar area** (gray circles) tend to occur shortly **after moderate-sized earthquakes (M ≥ 4)** in the **Tonkhil area** (indicated by the blue arrow). Conversely, **moderate earthquakes** in the Tonkhil region are sometimes preceded by **minor earthquakes (M < 3)** in the Takhiin Shar area (indicated by the pink arrow).

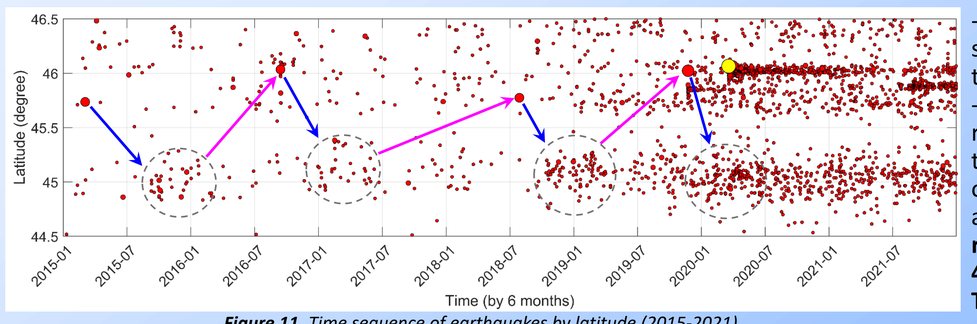

Figure 11. *Time sequence of earthquakes by latitude (2015-2021).*

- This observation indicates a potential seismic linkage or interaction between the **Tonkhil** and **Takhiin Shar** regions.
- Geographically, these two zones are roughly separated by **latitude 45.5°N**. For the purposes of this study, earthquakes occurring between **44.5°N and 45.5°N** are classified as part of the **Takhiin Shar region**, while those between **45.5°N and 46.5°N** are considered to belong to the **Tonkhil region**.

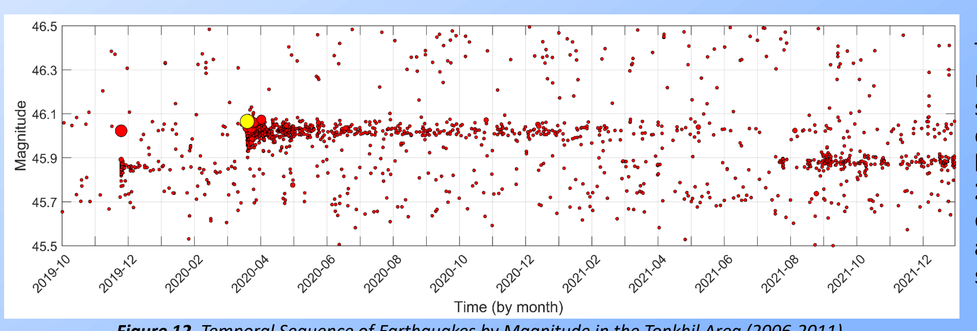

Figure 12*. Temporal Sequence of Earthquakes by Magnitude in the Tonkhil Area (2006-2011).*

The time sequence of earthquakes by magnitude in the Tonkhil area (Fig. 12) shows that a significant number of earthquakes occurred approximately **18 kilometers south** of the epicenter of the **2020 Tonkhil earthquake**. This region exhibited seismic activity both **before and after** the main Tonkhil earthquake sequence.

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RESULTS

The temporal and spatial analysis of earthquakes in the Tonkhil and Takhiin Shar areas yielded the following preliminary results:

- ❖ Earthquakes in the Tonkhil and Takhiin Shar regions appear to be related, suggesting that seismic activity in one area may trigger activity in the other.
- ❖ The seismicity distribution in these two regions is separated by the latitude 45.5N.
- ❖ A zone of increased small-magnitude seismicity was observed approximately 18 kilometers south of the epicenter of the Tonkhil earthquake.