ANSO-MAS 2026: THE 2ND CONFERENCE ON ENVIRONMENTAL HAZARDS IN ASIA - BUILDING RESILIENCE TO FUTURE HAZARDS

INTERSEISMIC AND COSEISMIC SEISMICITY PATTERNS AND FAULT NETWORKS IN THE CENTRAL PART BAIKAL RIFT

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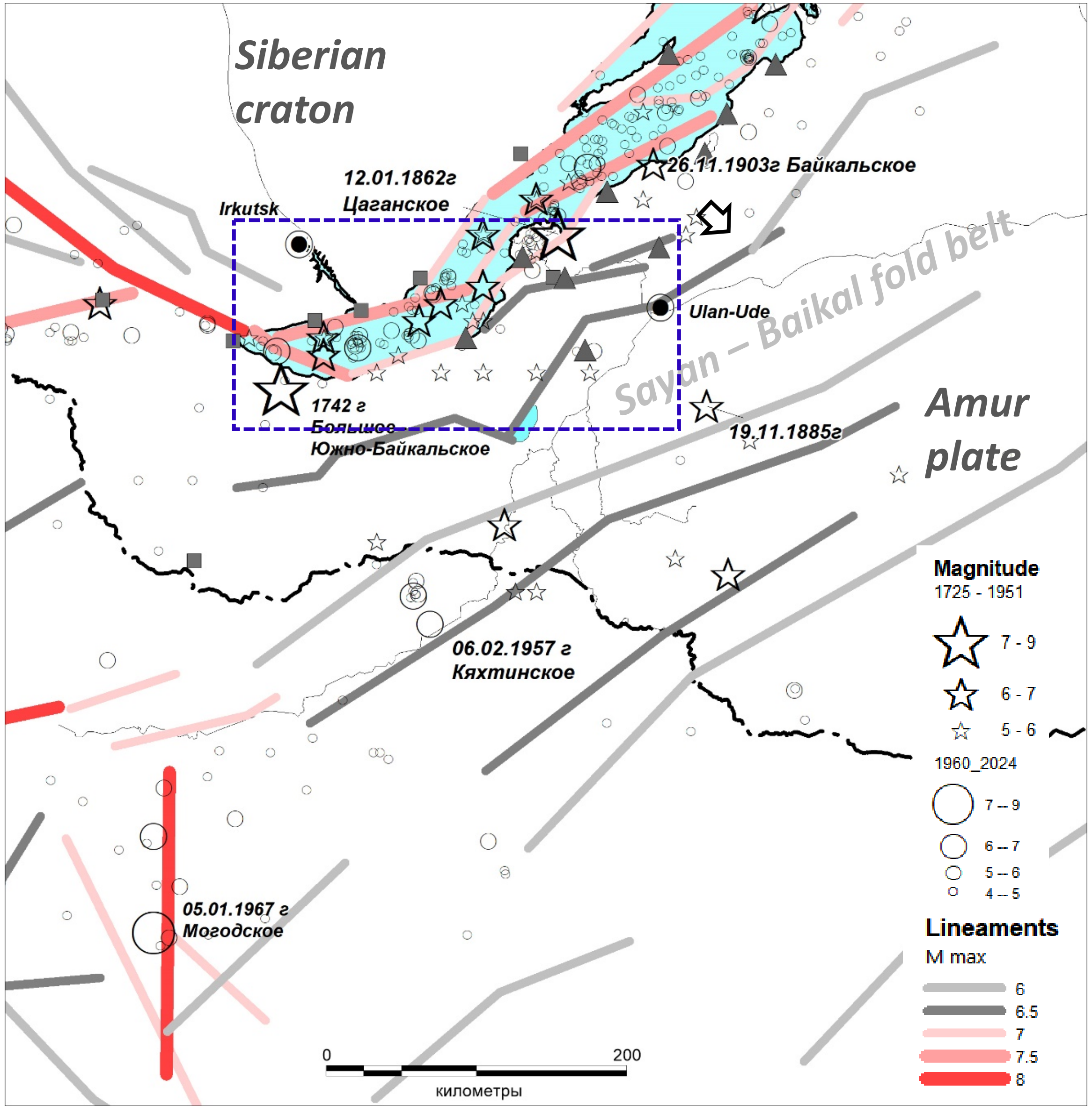
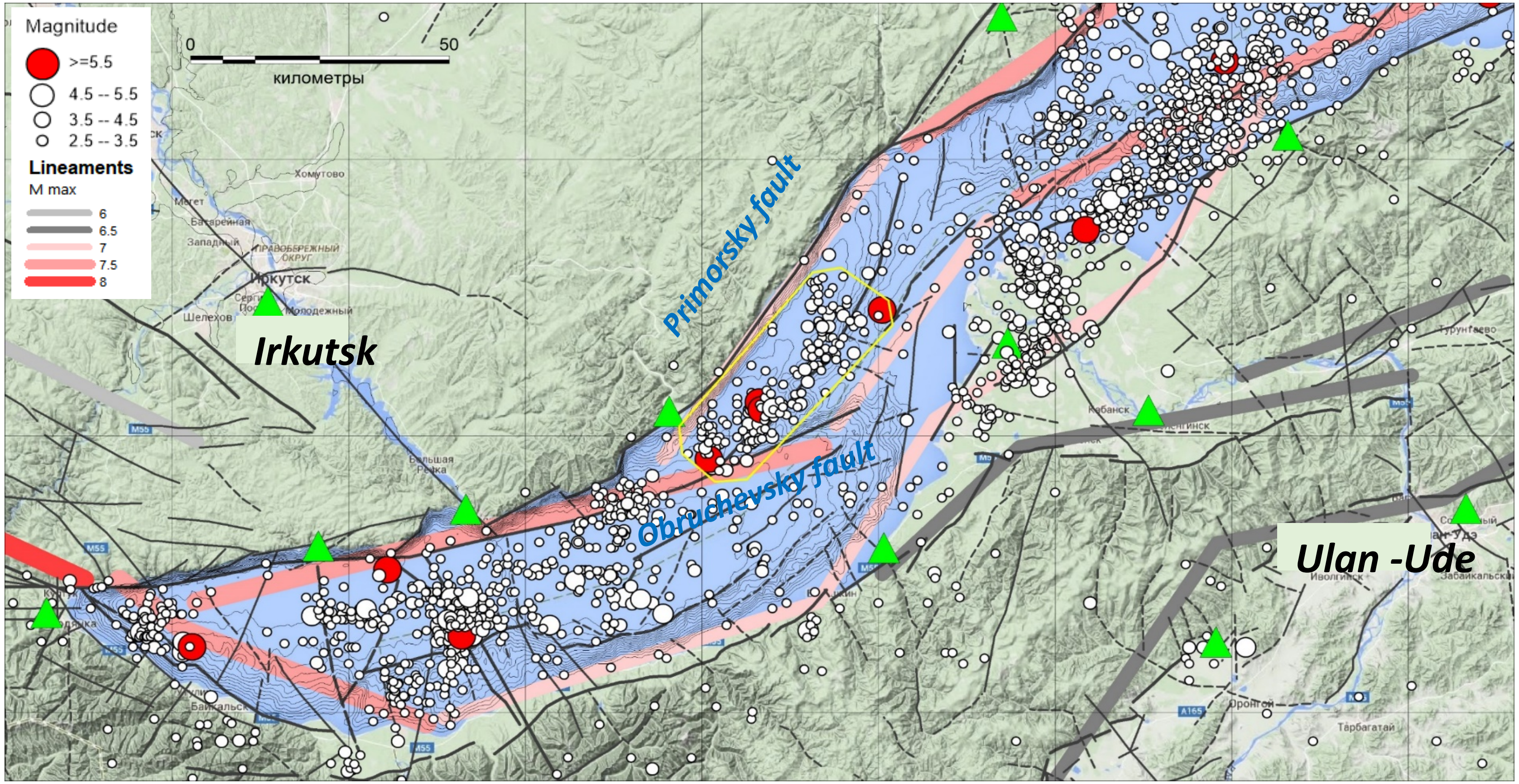
Seismotectonics and geodynamics of the Baikal Rift



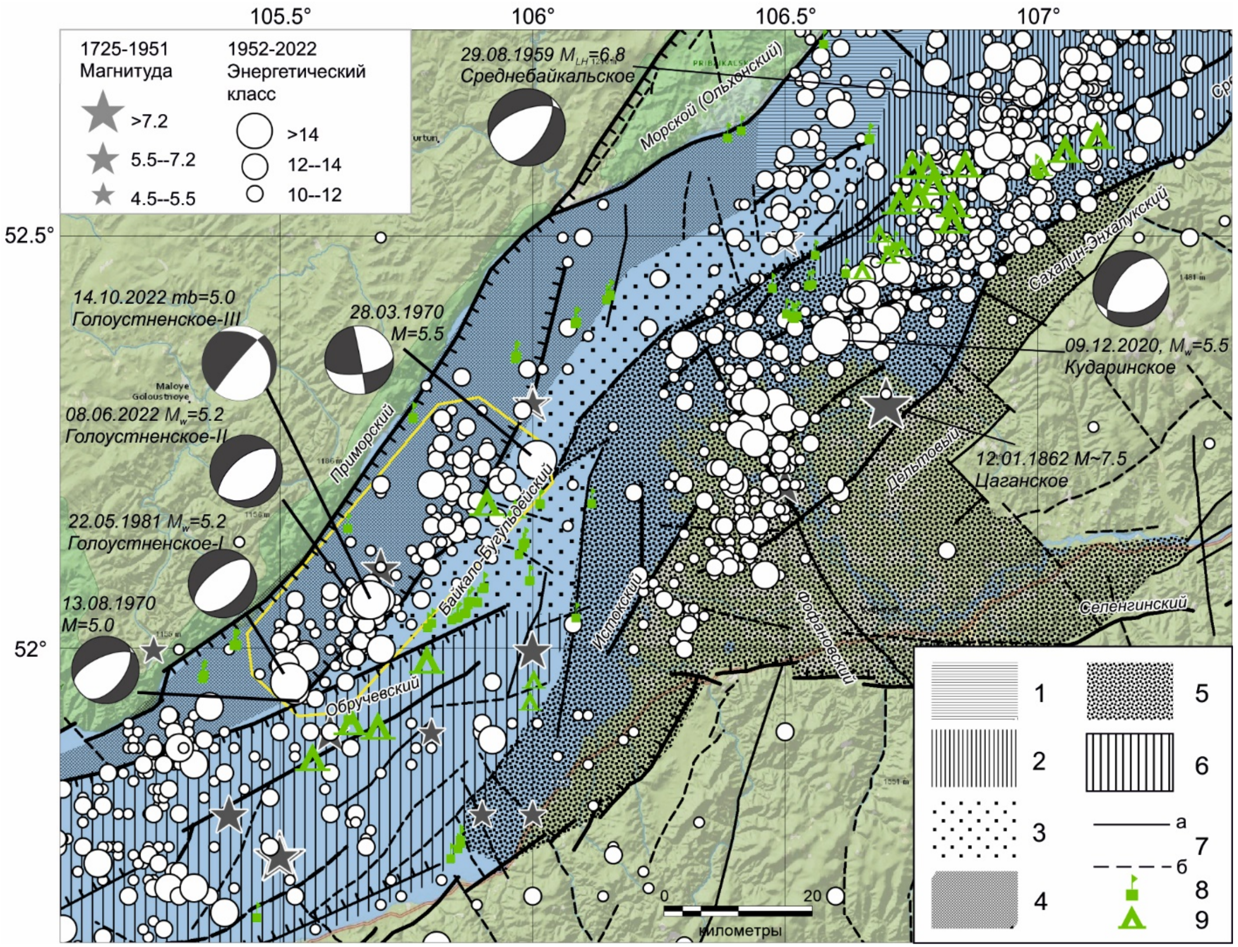
Motivation

- High seismic hazard in the Southern Baikal region
- Study of the relationship between faulting and seismicity, which has long been known for the strongest earthquakes

Seismotectonics and seismicity of the South Baikal Basin

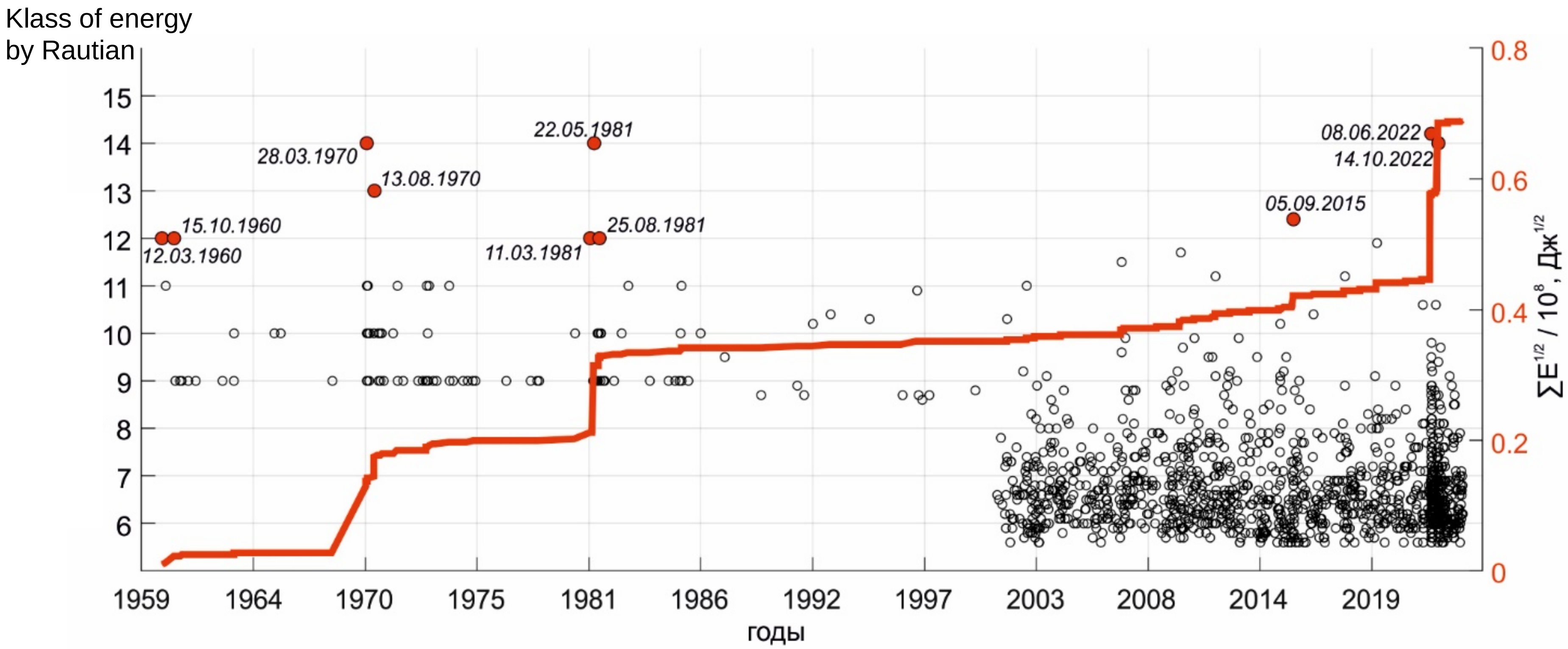


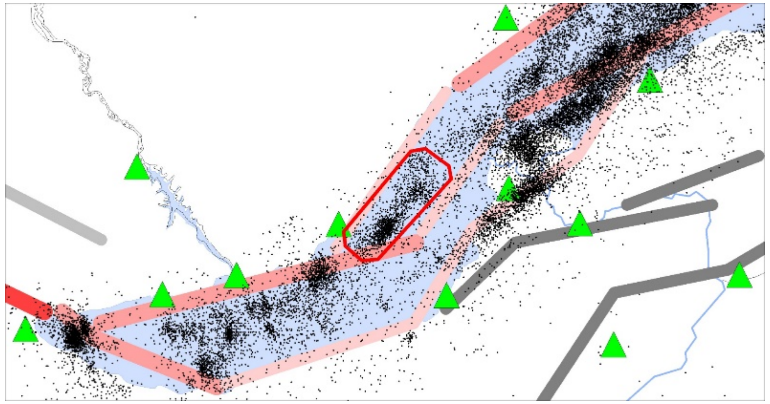
Seismotectonics and seismicity of Central Baikal



The Selenga Delta Accommodation Zone is characterised by a broad bathymetric saddle between the Central and South basins, and onshore is dominated by the delta of the Selenga River, perhaps the world's largest lacustrine delta. Multi-channel seismic data clearly demonstrate that the bathymetric saddle is not simply a thick accumulation of deltaic sediments, but instead is underlain by several elevated basement blocks that have undergone multiple episodes of deformation

Seismicity and cumulative energy of earthquakes of the Goloustnaya epicentral zone





Date	K	M
12 March 1960	*12*	*4.4*
15 October 1960	*12*	*4.4*
28 March 1970	*14*	*5.5*
13 August 1970	*13*	*5.0*
11 March 1981	*12*	*4.4*
22 May 1981	*14*	*5.2*
25 August 1981	*12*	*4.4*
8 June 2022	*14*	*5.2*
14 October 2022	*14*	*5.0*

Earthquake Clustering: Nearest-Neighbor Approach

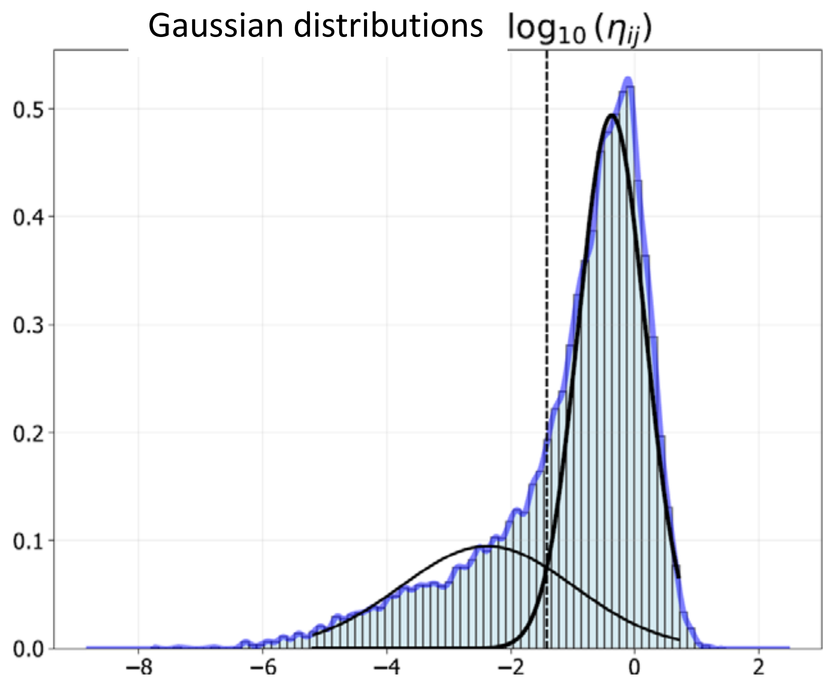
- For declustering, a method was used to estimate the inclusion of an earthquake in a cluster or unrelated group based on the nearest neighbor function (by Zalliapin, Ben-Zion, 2008, 2013):

$$\eta_{ij} = \begin{cases} t_{ij}\left(r_{ij}\right)^{d} 10^{-\gamma Klass_i}, & t_{ij} > 0 \\ +\infty, & t_{ij} \leq 0 \end{cases}$$

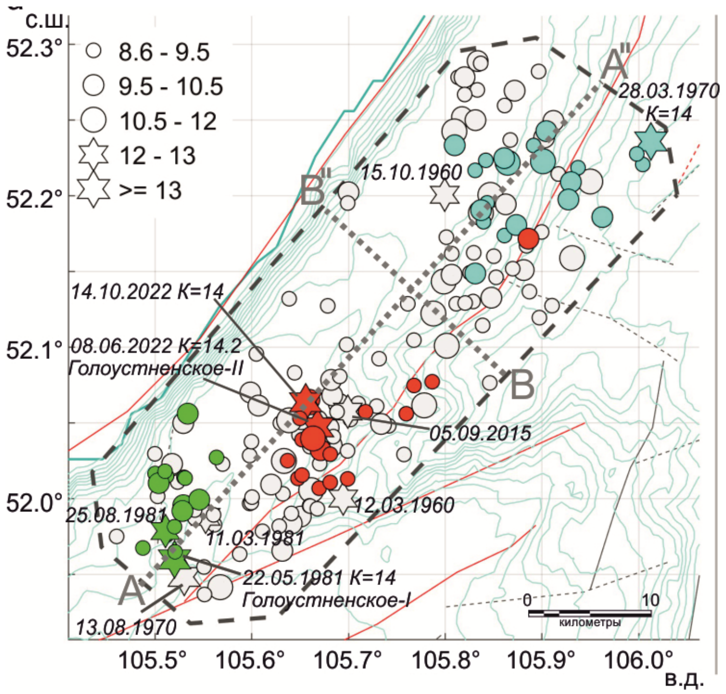
- Additionally, spatio-temporal restrictions on the energy of events were introduced [Tsuboi, 1956; Shebalin, Narteau, 2017]:

$$R_{crit} = 15\ (km) + 2 \cdot 10^{0.2Class_i - 2.3}$$
$$T_{crit} = 180\ (days) + 0.005 \cdot 10^{0.3Class_i}$$

- The algorithm for determining η0 was based on a linear combination of two Gaussian distributions [Zaliapin, Ben-Zion, 2013; 2016].



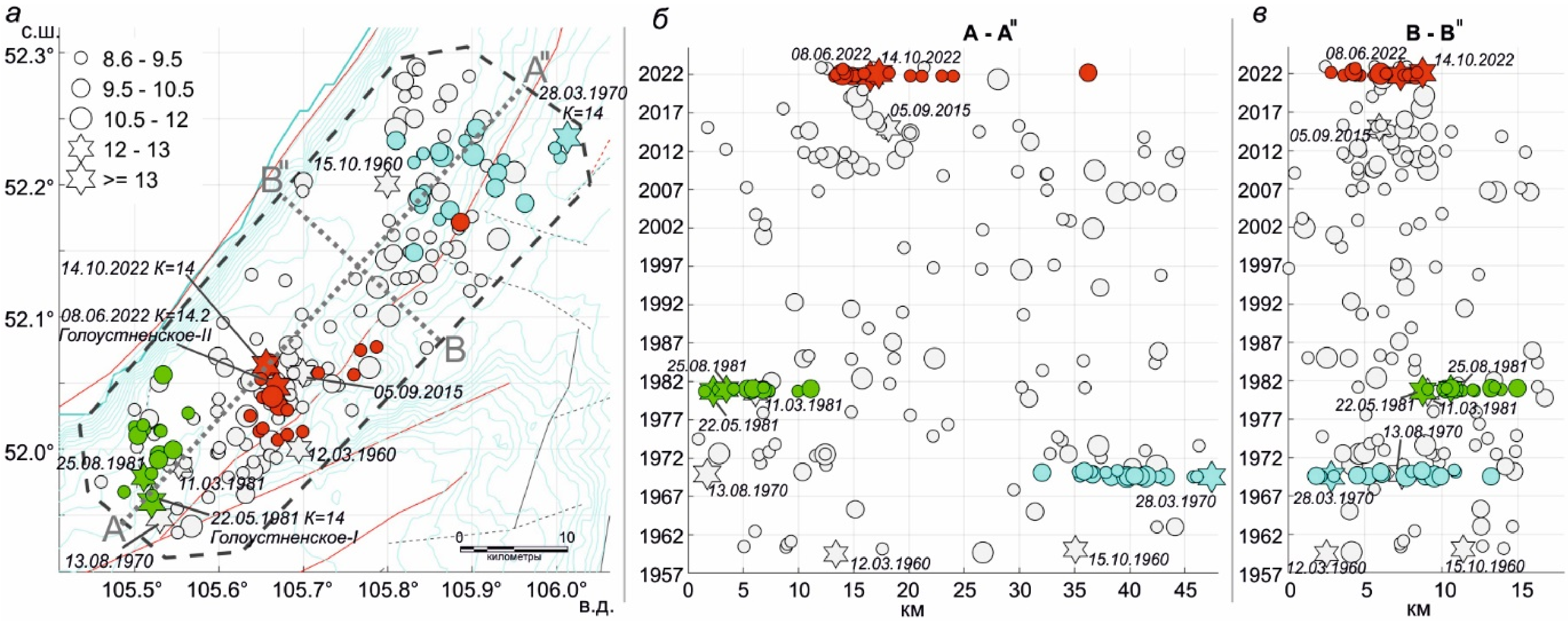
Characteristics of aftershock clusters of earthquakes of the GEZ with N ≥ 7



№	Date (main event)	Count, (N)	During, days	K_{min}	K_{max}	Diametr, km	Area, km^2
1	28-Mar-1970 09:44:56	21 (48*)	305.0	9.0	14	15.7	91
2	22-May-1981 09:51:20	17 (55*)	172.8	9.0	14	10.8	29
3	03-Apr-2007 14:28:26	7	67.1	7.5	11.5	8.4	16
4	25-Feb-2010 04:27:16	12	73.8	7.5	11.7	17.1	72
5	05-Sep-2015 05:00:30	25	151.0	6.5	12.4	24.1	94
6	10-Oct-2019 04:11:11	9	101.3	6.2	11.9	15.7	54
7	08-Jun-2022 12:24:19	298	361.3	6.2	14.2	36.9	486

- The epicentral region under study was delimited by a polygon (~ 50 x 20 km) based on the following assumptions: (1) the seismogenic fault zone is a flat structure, the boundaries of which are determined based on an analysis of the seismicity distribution; (2) the parameters of clustered seismicity characterize the macro dynamics of the rupture [Boatwright, Cocco 1996; Kocharyan, 2021].

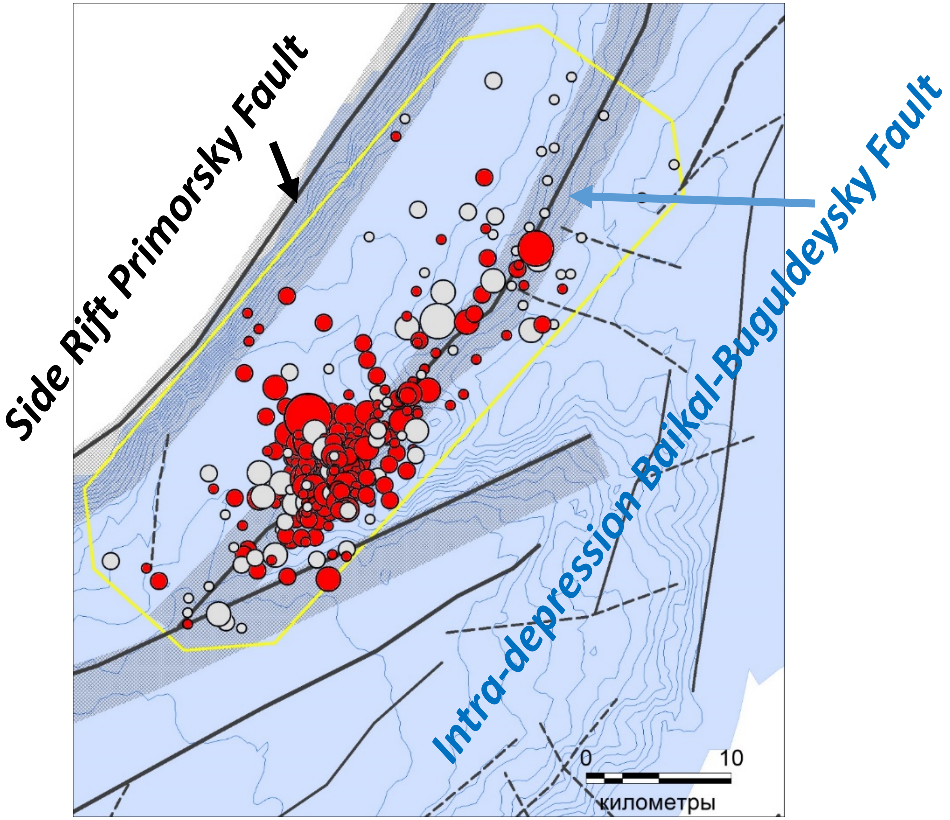
Evolution of seismicity within the Goloustnaya epicentral zone (GEZ) for 1960–2023



- Sequence ***blue*** (1970) occupies a relatively large area, and aftershocks propagate in a sublatitudinal direction toward the western side of the graben (the Primorsky Fault), while Sequence ***green*** (1981) is more densely packed and extends northward, also toward the Primorsky Fault. Aftershock cluster ***red*** (2022) occupies a larger area due to weaker events, and the sequence primarily develops toward the eastern side of the graben, where the Baikal-Buguldeysky Fault is located.

Main patterns aftershock sequences 08/06/2022 – 05/2023

Aftershock sequences 08/06/2022 – 05/2023 occupies a larger area due to weaker earthquakes, and the sequence primarily develops toward the eastern side of the graben, where the Baikal-Buguldeysky Fault is located.



Aftershock sequences follow clear patterns defined by temporal decay, spatial clustering, and crustal controls. Key features include the <u>Omori-Utsu law</u> for frequency decline, spatial correlation with mainshock stress changes, and regional variations related to heat flow.

- ***Space Patterns:***

Clustering near faults: *Aftershocks group closely along ruptured zones and areas with high Coulomb stress changes from the main event.*
Spatial extent: *Zones spread out over distances scaled to mainshock magnitude and fault geometry.*
Rock properties: *Events happen more often in regions with mid-range seismic velocities and heat flow, avoiding extremes that are too strong or too weak.*

Main patterns aftershock sequences 08/06/2022 – 05/2023

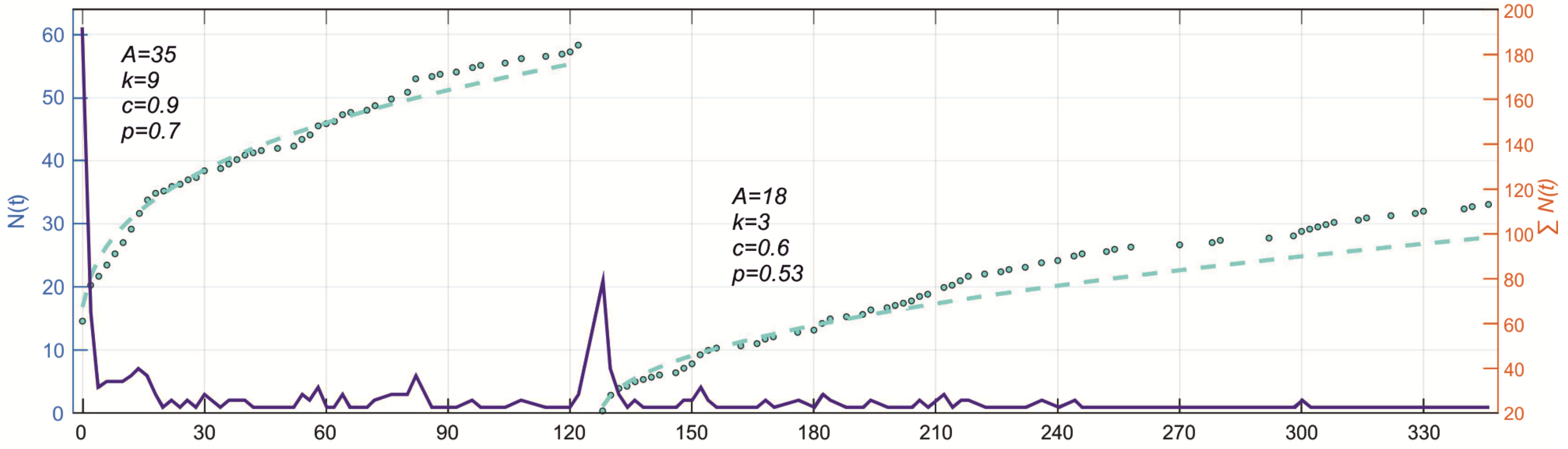
- ***Time Patterns:***

Power-law decay: *Event frequency drops quickly over time, matching the modified Omori's law.*

$N(t) = A + \frac{k}{1-p}(c+t)^{1-p}$ - *The cumulative number of aftershocks per day at time t after the main earthquake*

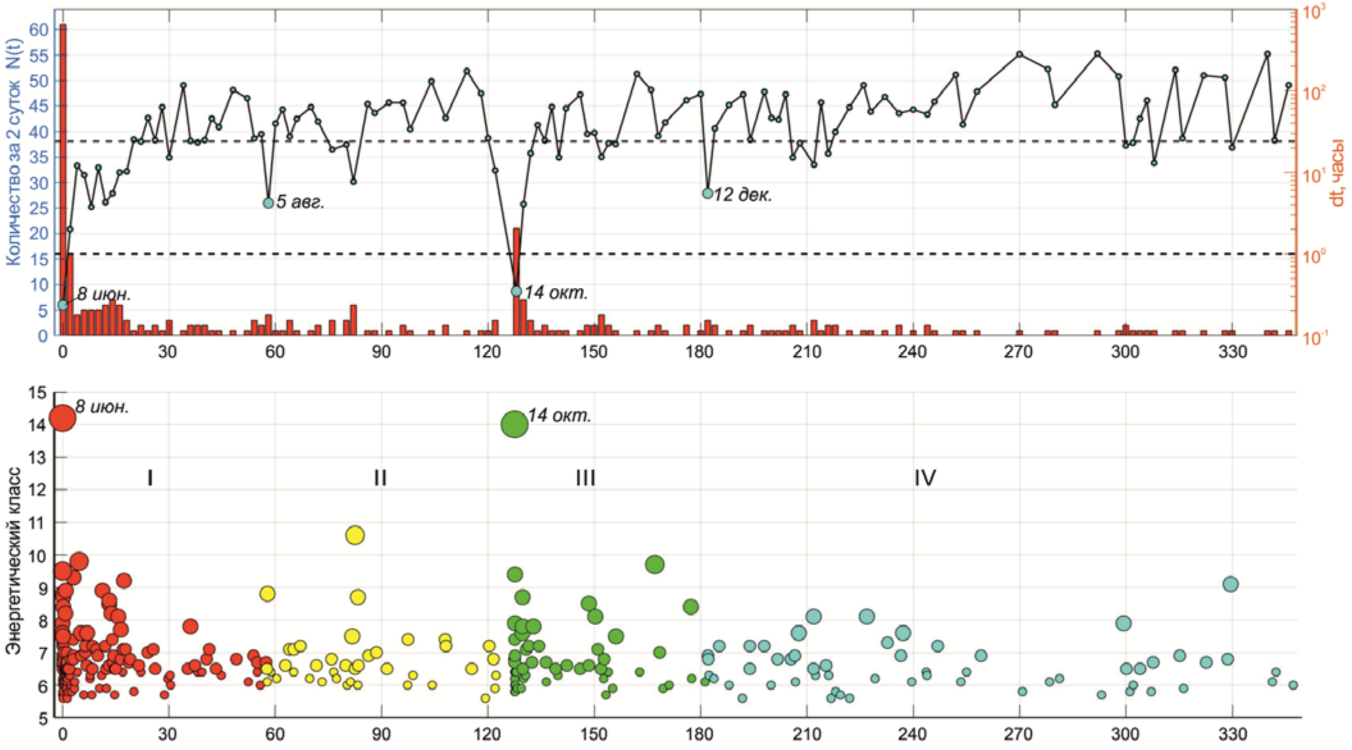
Decay rate (p-value): *Higher local crustal temperatures lead to faster sequence decay.*

Delay onset: *Time gaps before standard power-law decay start change depending on the seismic cycle and stress.*



standard (number of events per day) and cumulative forms of the modified Omori-Utsu law

Main patterns aftershock sequences 08/06/2022 – 05/2023

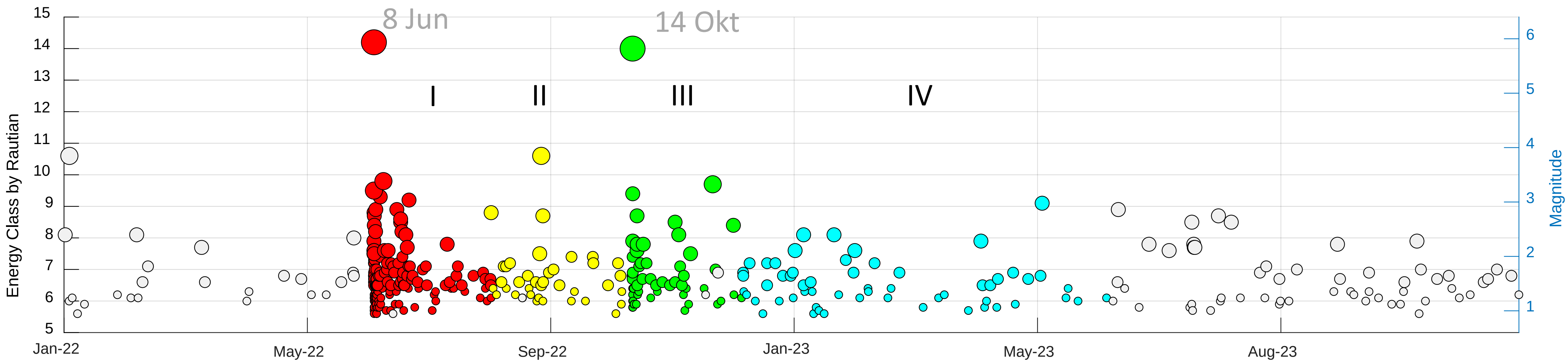


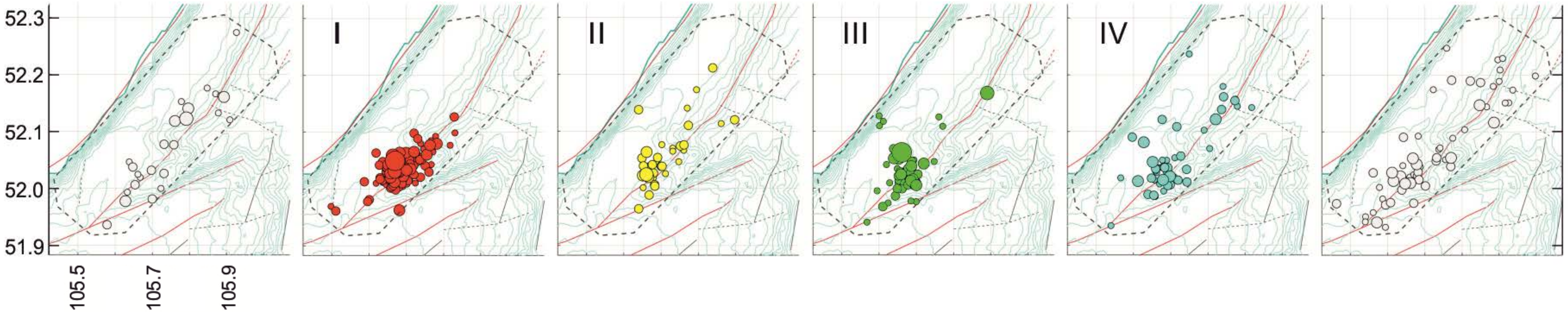
Variations in the average time interval Δt between successive events.
(The average Δt value over a 2-day window is used)

- Two critical Δt levels: 1 and 24 hours, below which clustering occurs in different modes.
- Four major minima (June 8, August 5, October 14, and December 12), which coincide with the onset of successive phases of the aftershock process, which initially follows Omori's law (phases I and III) and then clusters at the background energy level with the sporadic appearance of stronger tremors (phases II and IV).

These groups are highlighted in different colors.

Evolution of seismicity within the Goloustnaya epicentral zone for 2022–2023





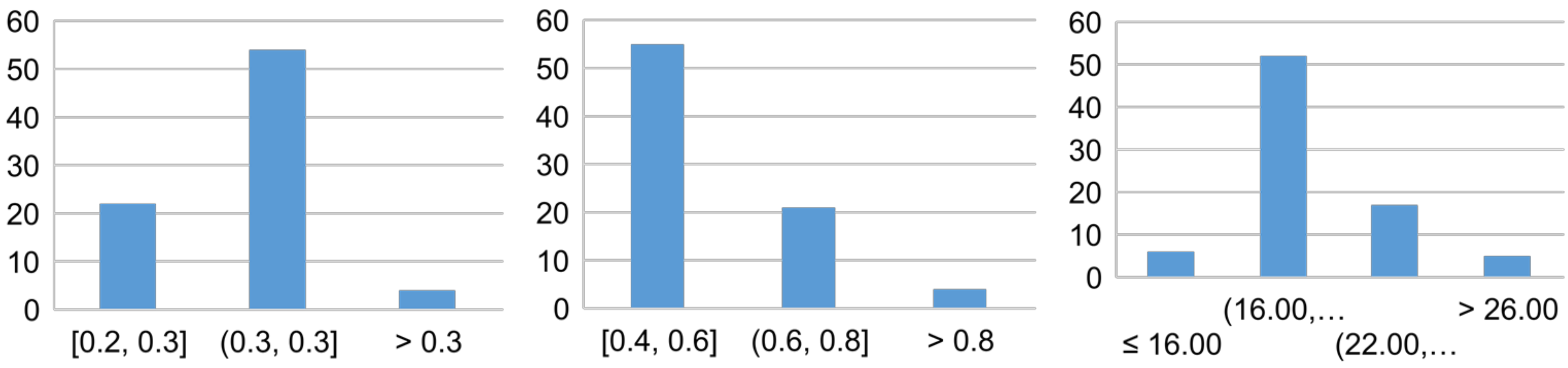
Earthquake relocation

- For earthquake relocation, events were selected according to the following criteria [Bondar et al., 2004; Diehl et al., 2021]: each event had to be recorded by at least six stations at epicentral distances of no more than 110 km, with the maximum possible azimuthal coverage. As a result, 80 events were selected.

- Hypoellipse software [Lahr, 2012] was used for relocation,

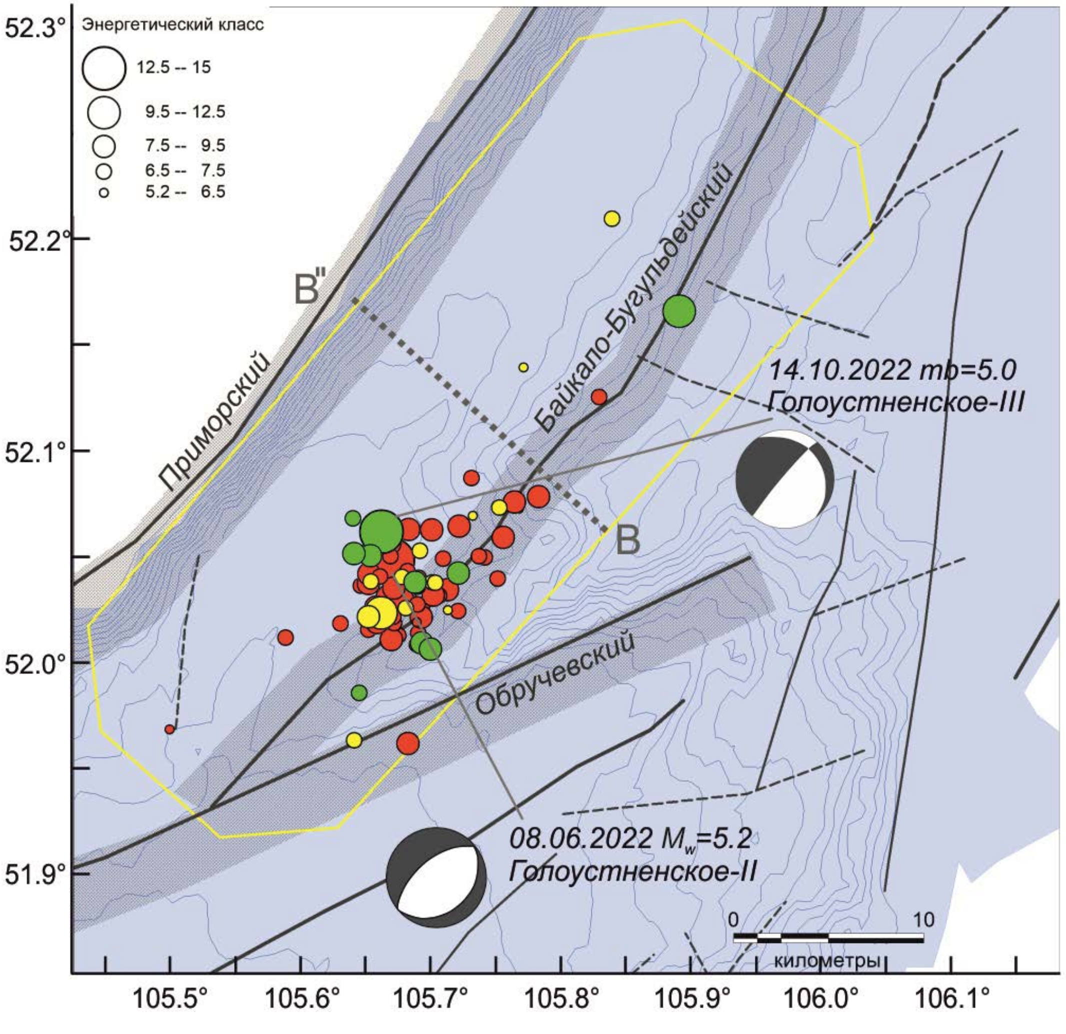
- Using the authors' methodological approaches [Belyashov, 2024]

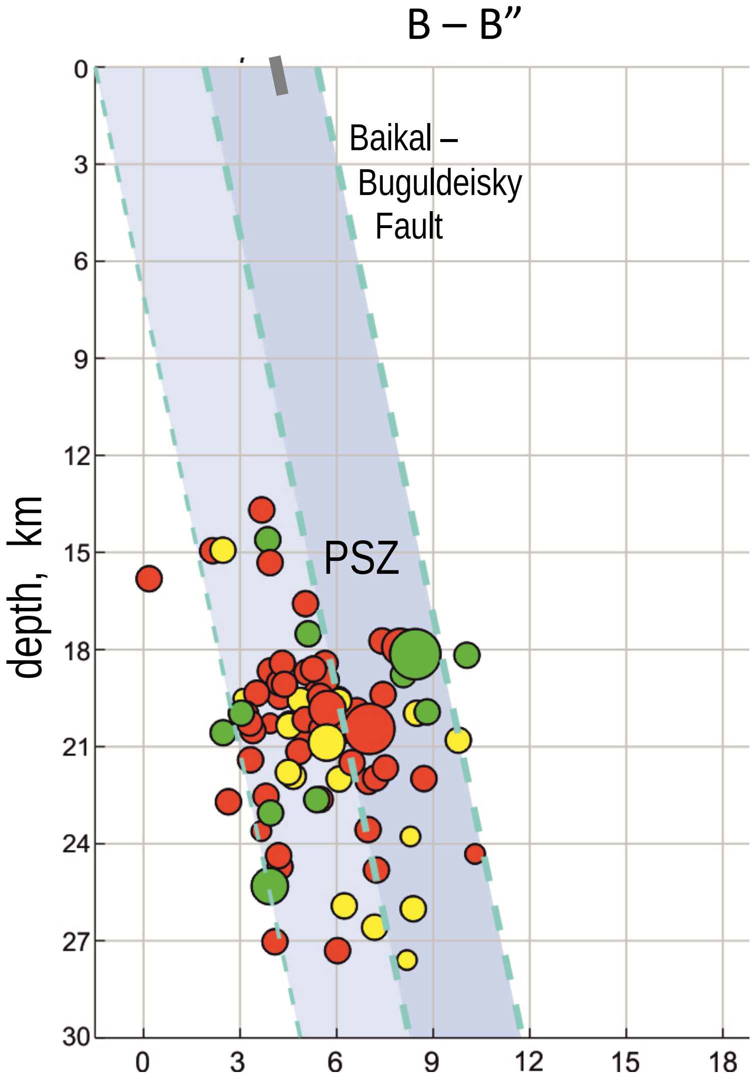
- The average horizontal (seh) and vertical (sez) errors were ~0.3 km for seh and ~0.6 km for sez.



SEH SEZ DEPTH, km

Earthquake depth 2022 within Goloustnaya zone





Principal Slip Zones (PSZ)

Seismic Damage Zones

Hauksson, E. Spatial Separation of Large Earthquakes, Aftershocks, and Background Seismicity: Analysis of Interseismic and Coseismic Seismicity Patterns in Southern California. *Pure Appl. Geophys.* **167**, 979–997 (2010). https://doi.org/10.1007/s00024-010-0083-3

Conclusion

- A study of earthquake clustering and relocation, using focal mechanism data, allowed us to identify the seismically controlled fault, determine its internal structure, and investigate the dynamics of rupture.

- This task is relevant for assessing the seismic hazard of the southern Baikal and Transbaikal regions, since although weak earthquakes are insignificant in terms of seismic hazard, their occurrences are an indicator of the state of the earth's crust at seismogenic depths, which otherwise cannot be explored or directly measured.

Thank you for your attention !