Monitoring of high-mountain glaciers in the territory of Tien-Shan by stations of the International Monitoring System

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INTRODUCTION AND MAIN RESULTS

At KNDC, data from Makanchi's PS23 array revealed a large number of similar events with sources in the area of large glaciers in Tien-Shan. All events are in the 185-190 back-azimuth range at a distance of 550 km south of the station. The size of the epicentre area were about 90x90 km. Daily and seasonal variations in the number of events recorded were revealed, and their energy and magnitude was estimated.

At the end of 2023, three seismic and one infrasound stations were installed near glaciers on the Kazakh side to study the impact of climate change on the cryosphere. Seismo-acoustic recording will be carried out during 2023-2028. All seismic stations record well the events associated with processes in the glaciers. Data processing has been carried out and a seismic event bulletin has been compiled. Event magnitudes are mb≤3.5, energy classes K≤8.4. The possibility of studying glaciers remotely using permanent seismic and infrasound stations is shown. The data of seismic arrays for 20 years of observations are processed by the PMCC to search for regularities of seismic processes in glaciers related to climate change and to compare them with the results of studying the state of glaciation of Tien-Shan glaciers by different technologies.

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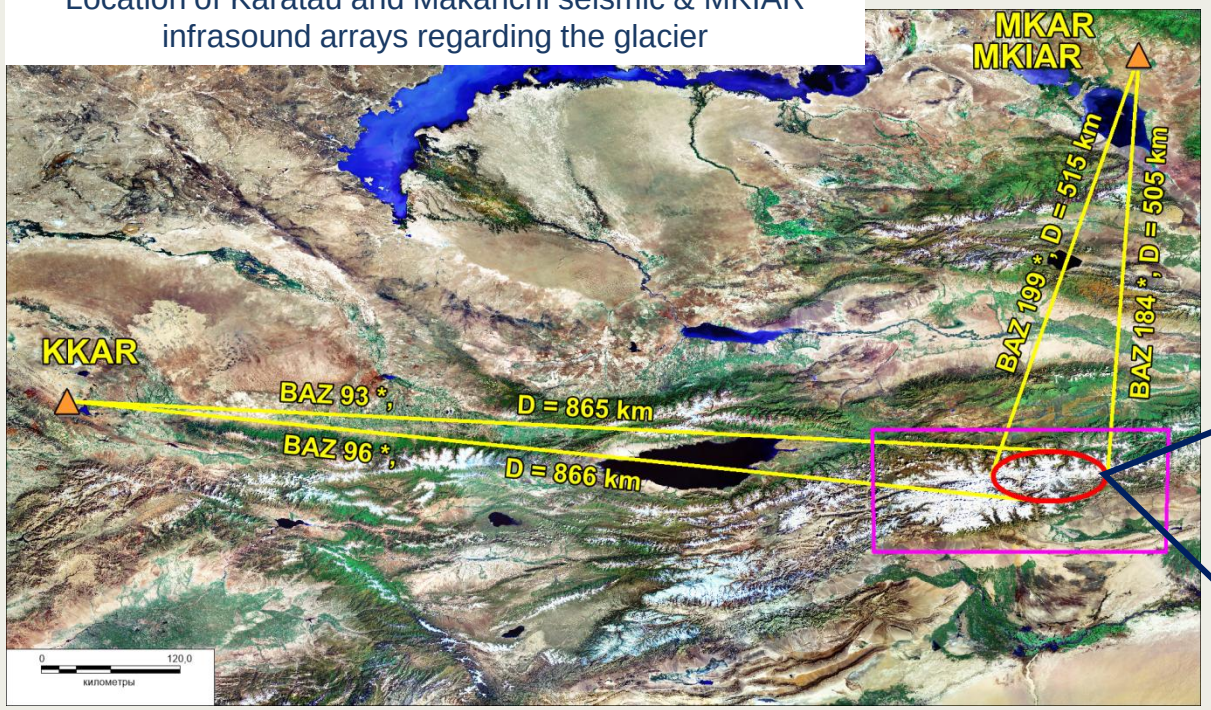
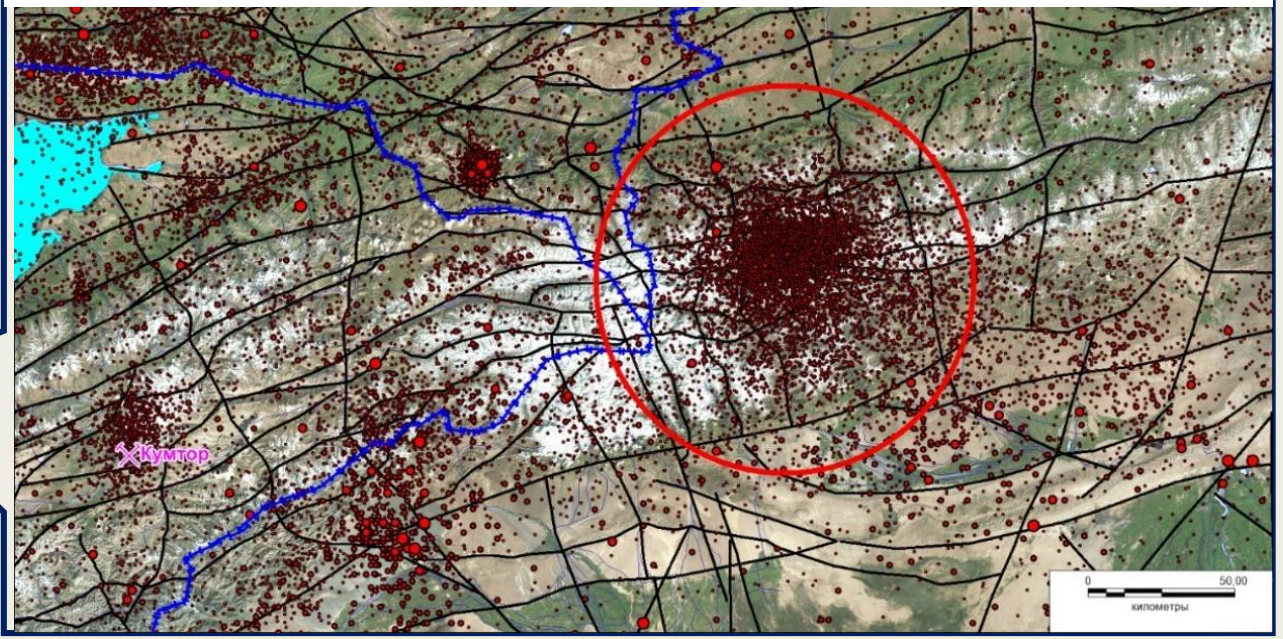
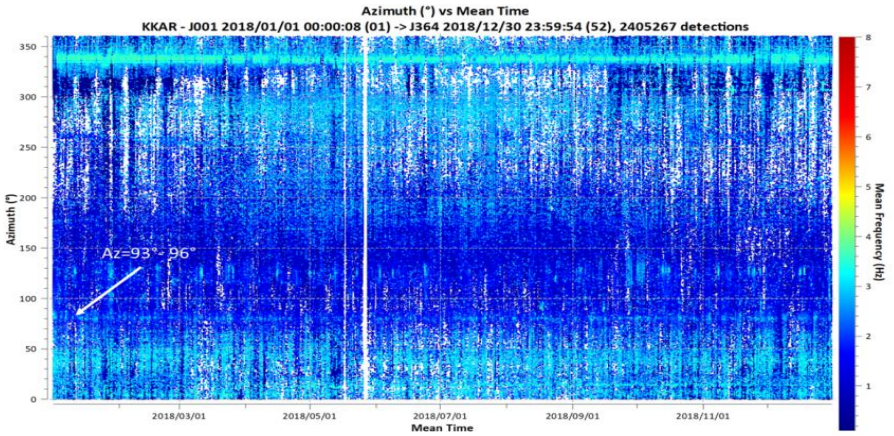
Location of Karatau and Makanchi seismic & MKIAR infrasound arrays regarding the glacier

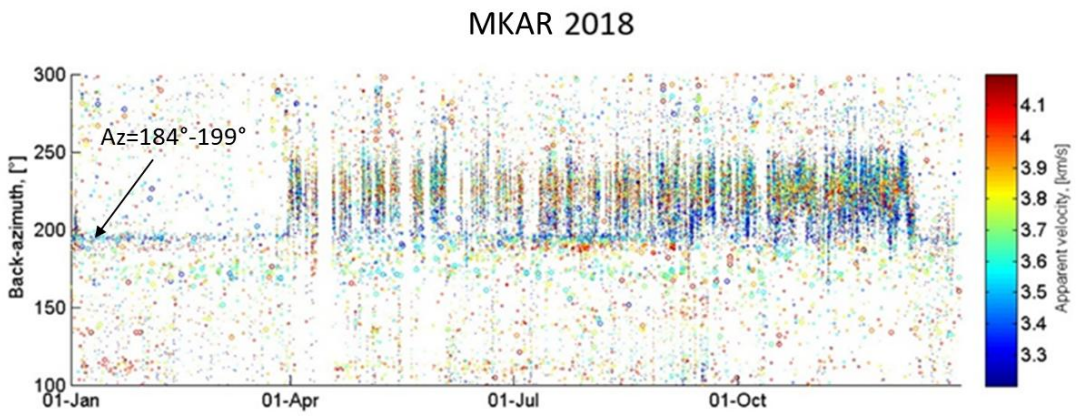


Tectonic map of the inner Tien Shan high mountain glacier study area (in red circle) with seismicity data (KNDC bulletin)



Detection at MKAR & KKAR using PMCC





A distinct phase (~3.5 km/s, back-azimuth ~195°) is observed, while another with higher velocity and smaller back-azimuth is less clear. These signals are undoubtedly related to glacial events (Lg and Sn phases).

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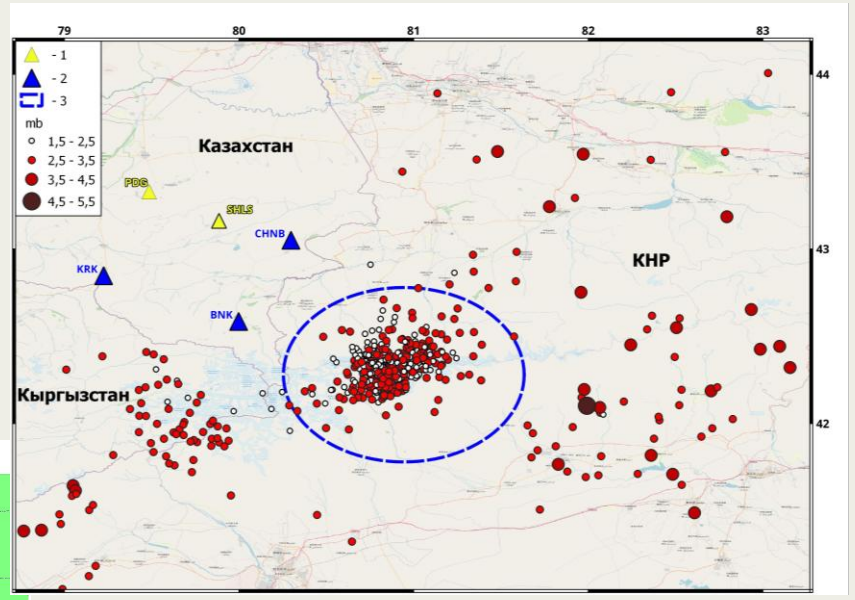
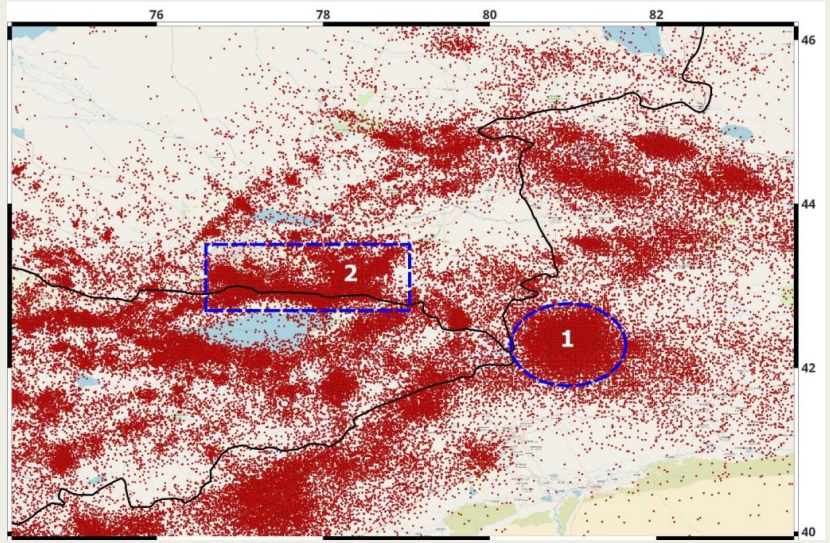
Deployment and Recording by Near-Field Stations

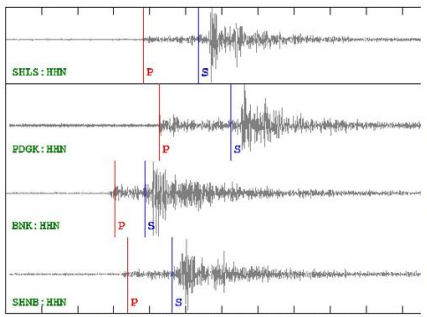
Glacial vs. Tectonic EQ's: A comparative analysis

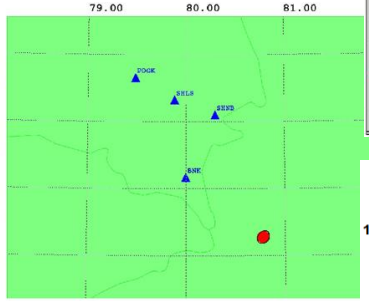




Map of EQ epicenters in the Tien Shan based on the CASHA-BU catalogue (1951-2017).

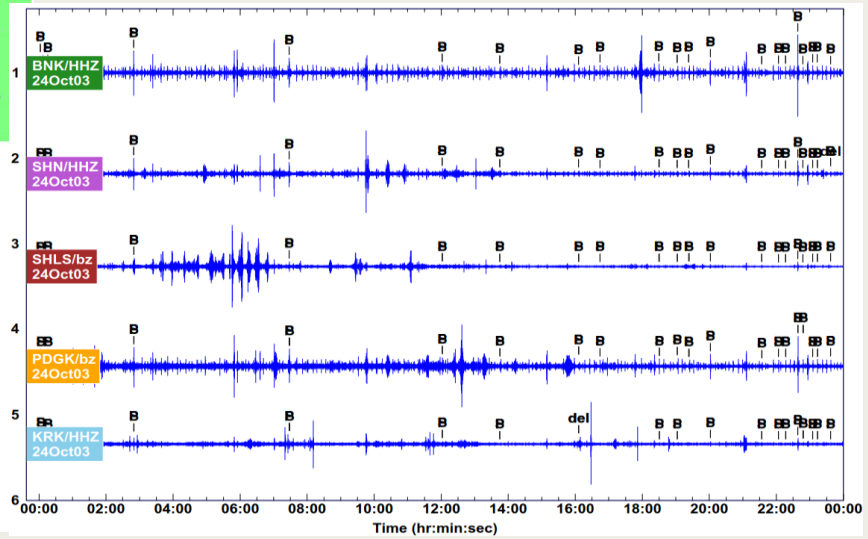
Data Processing (Manual & Automatic)



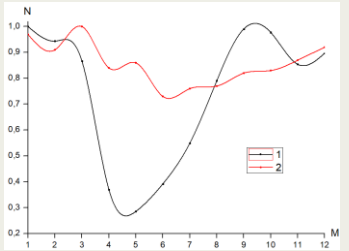


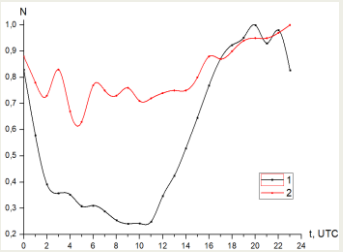

```
FI=42.13715 LD=80.78017 R=2.75352 ML=4.4 PROB=0.9919
T=          1718149838.3793 (11.06.2024  23.50:38.4)
NSTAT=4
NPHASES=8
NCOUPLES=4
NORIGINS=5
EXTRA: NP=4 NPT=4 NS=4 NST=4 NC=4 NCT=4
DETECTED BY:BNK;SHLS;PDGK;SHNB;KRK
LOC SCENARIO=camd
ERRLOC=0.354
DIFFLOC=8.4559
ELLIPSE: AzMajor=40 Rminor=4.5313 Rmajor=5.6641
DEPTH=7 DEPTHMIN=7 DEPTHMAX=16

Stat  Phase       Date         Time      Weight  Emph  Dist (km)   Amplit   Noise   ML  Probability
-------------------------------------------------------------------------------------------------
SHNB    P       11.06.2024  23.50:56.000  0.2593  1.00     100.5    103.1    15.6  4.42  0.7394
SHNB    S       11.06.2024  23.51:08.300  0.4049  1.00     100.5    502.6    15.6  4.80  0.8165
BNK     P       11.06.2024  23.50:52.400  0.1686  1.00      74.0    249.0    17.0  4.64  0.7785
BNK     S       11.06.2024  23.51:00.700  0.5649  1.00      74.0    749.0    17.0  4.82  0.8312
PDGK    P       11.06.2024  23.51:04.700  0.4738  1.00     161.3     23.8     4.0  4.03  0.8226
PDGK    S       11.06.2024  23.51:24.500  0.3893  1.00     161.3     42.6     4.0  3.98  0.8471
SHLS    P       11.06.2024  23.51:00.300  0.3226  1.00     127.1     46.5     4.7  4.19  0.8283
SHLS    S       11.06.2024  23.51:15.600  0.1701  1.00     127.1    117.5     4.7  4.29  0.8488
END EVENT
```

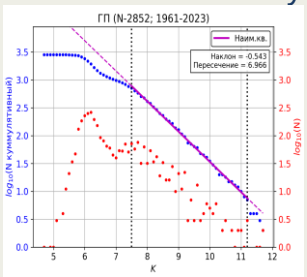


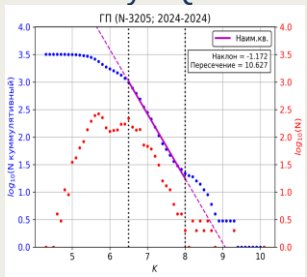
Waveforms from Near-Field Stations (2.0-4.0 hz)





Distribution of hourly and monthly EQ counts





GR curve based on the CASHABU-ISC catalogue (left) & local network catalogue (right)

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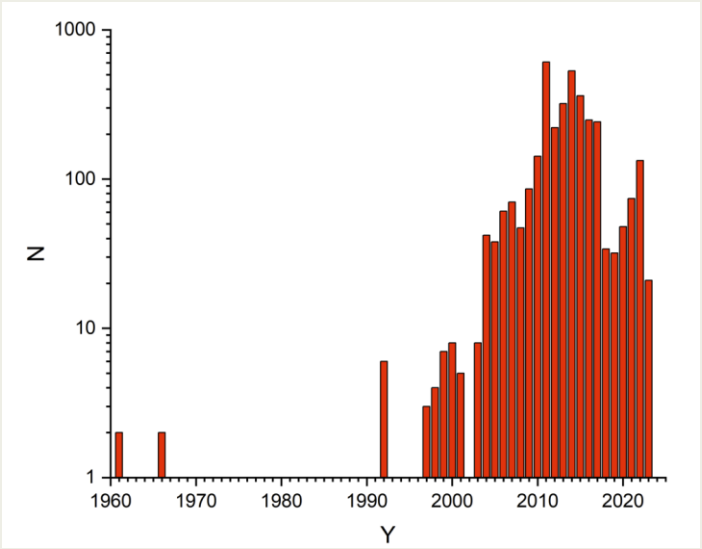
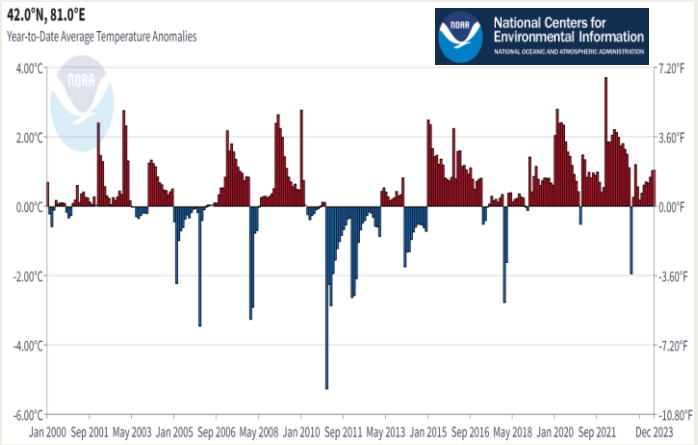
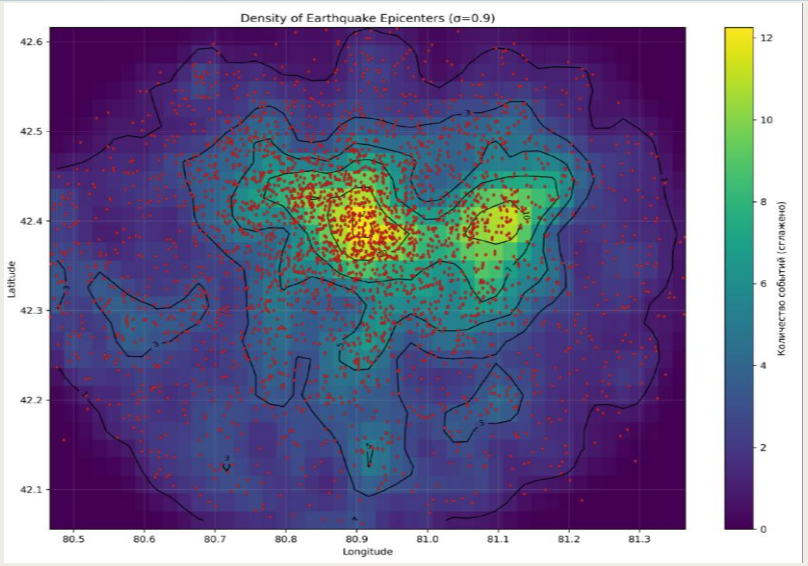
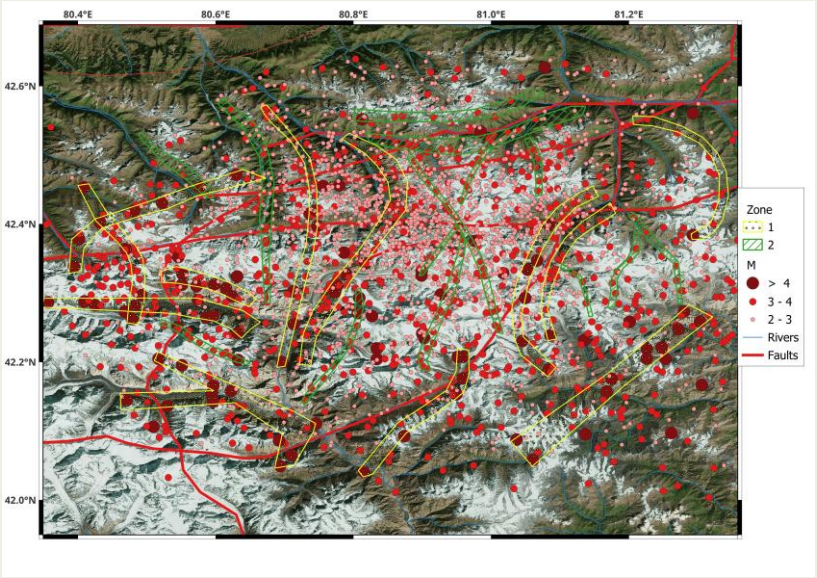


Annual Number of Recorded Seismic Events from the Glacier Area based on the CASHA-BU+ISC catalogue (1961-2023)





Seismicity density map within the study area



Epicenter map based on the CASHA-BU + ISC catalogue, classified by magnitude, with conditional zones.

CONCLUSION

- Glacier-related events can be effectively recorded and localized at large distances.
- The revealed patterns (growth of events, high proportion of small shocks, strong daily/seasonal cycles) confirm strong dependence of processes on climate factors.
- High b values indicate a swarm-like seismicity, important for assessing glacier instability.
- Further studies are needed to establish the exact link between b (ɣ) parameters and the mechanisms of ice fracturing and rupture formation.

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