Relocation of seismicity of the Pannonian Basin using the Bayesloc multiple event location algorithm between 1996 and 2017

Barbara Czecze[1,2], István Bondár[1] , AlpArray Working Group

1 Eötvös Loránd University, Department of Geophysics and Space Science, Budapest, Hungary (barbara.czecze@ttk.elte.hu)
2 Research Centre for Astronomy and Earth Sciences, Geodetic and Geophysical Institute, Kövesligethy Radó Seismological Observatory

EGU2020-16663

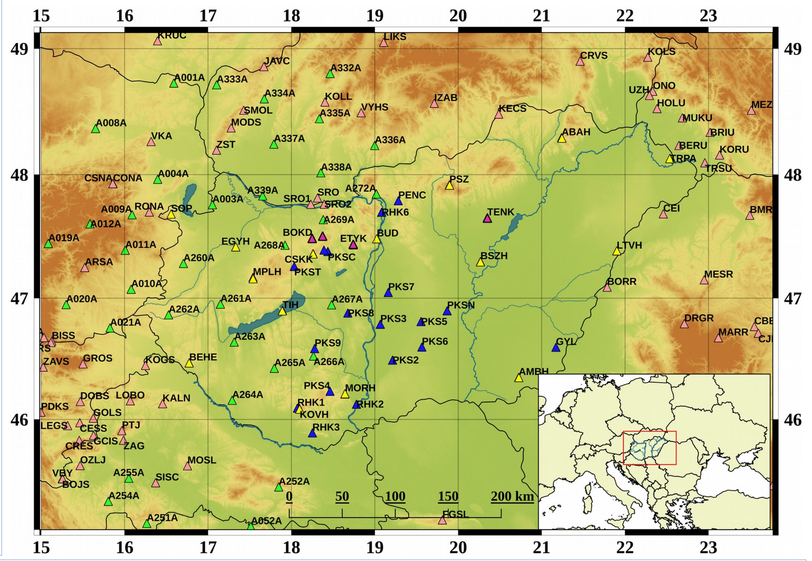
Introduction

The seismicity of the Pannonian Basin can be described as moderate. The recent seismic activity is caused by the Adriatic microplate's movement, which rotates counter- clockwise relative to Europe. Based on geophysical studies, the current stress field is typically characterized by compression. The main active tectonic structures are flower structures linked to reactivated faults and shear zones. Additional geological structural studies require the most accurate earthquake catalogue. We relocated all events in the Pannonian Basin with the iLoc location algorithm using travel-time predictions from RSTT, a global, three-dimensional velocity model of the crust and upper mantle to provide accurate single event locations. Then we applied the Bayesloc algorithm. We show that the results present an improved view of the seismicity of the region.

Data

In this work, we used Hungarian Earthquake Bulletin (HEB) data between 1996 and 2010 and Hungarian National Seismological Bulletin (HNSB) data between 2011 and 2017. **Fig 1** shows the area of this study and the main stations.

The Bayesloc method converges faster when absolute initial locations are input. The absolute locations of the earthquakes reported in the (HNSB) provided by the Kövesligethy Radó Seismological Observatory (KRSO) were relocated with the **iLoc** (Bondár et al., 2011) algorithm. iLoc relocations were performed with **RSTT** 3D global velocity model (Myers et al., 2010, Bondár et al., 2018).



Fg 1. Local and regional stations used in the locations. Yellow triangles represent Hungarian National Seismological Network permanent stations, magenta the temporary ones. Blue triangles represent the Paks Microseismic Monitoring Network (PMMN), green triangles represent the AlpArray Seismic Network (AASN), pink triangles represent other temporary stations from the neighboring countries.

Bayesloc algorithm

Bayesloc (Myers et al., 2007) is a **statistical model** of the multiple event system (developed at Lawrence Livermore National Laboratory) which includes event locations, travel-time corrections, assessments of arrival- time measurement precision, and phase labels. This algorithm does not linearize the seismic event location problem, and thus may produce better earthquake locations than standard linearized location techniques such as Geiger's method. Bayesloc uses the **Monte Carlo Markov Chain method** to sample the joint probability of the multiple-event system. Unlike most multiple event location algorithms, Bayesloc can handle not only event clusters but distributed seismicity of an entire region, thus perfectly posed for the task in hand. We used the **ak135 global velocity model** (Kennett et al., 1995) for all test runs. We performed data pre-processing before the Bayesloc run.

Prior constraints and Suspected explosions

Bayesloc also accepts **probabilistic prior constraints** on any of the input parameters, which can significantly tighten the distribution of all parameters. We had several hundred **confirmed quarry blasts** and mine explosions that qualify for ground truth help to anchor the seismicity pattern to known ground truth locations. Based on the day-time peak on the origin-hour distribution (**Fig 2**) of the bulletin earthquakes, we assume that there are anthropoghenic events labeled as earthquakes in the catalogue, therefore we created a **„Suspected explosions (SX)"** group. We have used the data of Mining and Geological Survey of Hungary (MFBSZ) which contained about 900 mine polygons.

Table 1 shows the prior constraints that we specified. The GT category consist of ground-truth events with known location accuracy. Known explosions are confirmed blasts, while earthquakes are all other events in the Bulletin with large distance standard deviation. Neither of the cases was time standard deviation specified.

	Distance SD (km)	Depth SD (km)
Earthquakes	20	5
Known explosions	10	0
Ground Truth events	2	0
Suspected explosions	15	3

Table 1. Prior constrains of different type of events

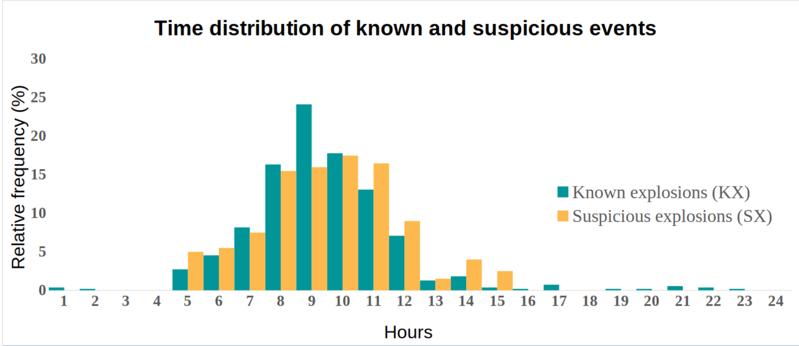


Fig 2. Origin-hour distribution of the SX, KX events

Phase statistics

An important element of the Bayesloc is the phases-review step. Bayesloc examines the probability of each input phase and can assign a more probable phase or mark it as an outlier. In this study, approximately **6%** of arrival-time measurements are found to be erroneous. Statistics of the re-labeled phases are shown in **Fig 3**. The number of outliers is noticeable for the phases Pn, Pg, Lg, Sg.

The distribution of posterior travel time residuals (ak135) changes compared to the prior distributions (RSTT). It can be clearly seen that the variance of the posterior residuals (**Fig 4 right**) decreases for each phase studied compared to the prior distributions (**Fig 4** left).

The joint posteriori distribution is determined using 4 Markov-Chains (**Fig 5**). Bayesloc examine the total probability of each configuration through MCMC testing, iteratively modifies each part of the model and proposes new components of the solution until the most probable convergent solution.

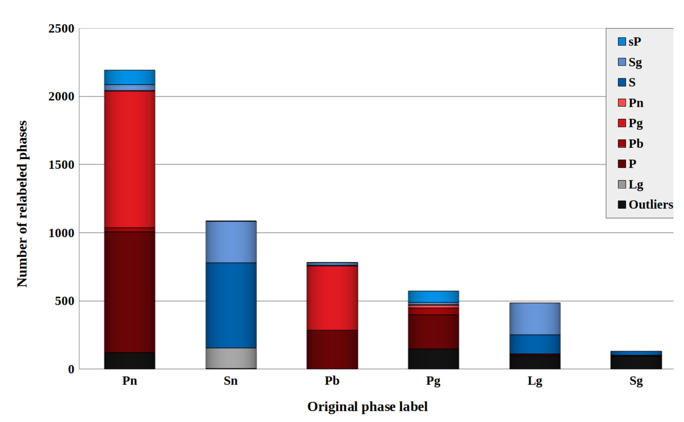


Fig 3. Relabeled phases. Each color indicate a new label

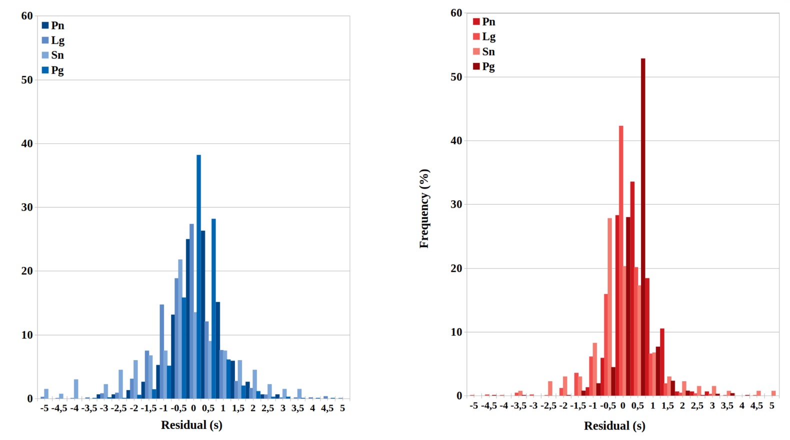


Fig 4. Posteriori TT residuals (left); Original RSTT TT residuals (right)

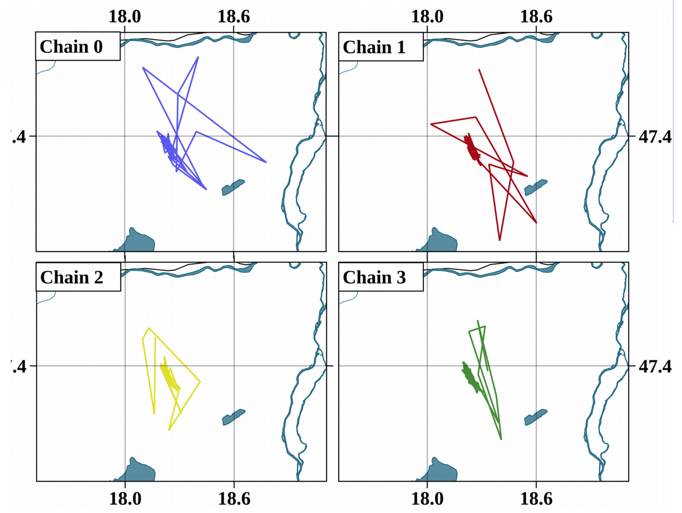


Fig 5. Example MCMC samples for one epicenter

Results

Fig 7 shows the cumulative distributions of **location coverage**, **mislocation** and **error ellipse area** (90% confidence) of ground-truth events in the case of iLoc initial coordinates (blue line) and Bayesloc locations (red line). The coverage parameter is smaller than 1 if the error ellipse contains the true location.

Fig 6 shows the depth distribution of the earthquakes in the case of the initial iLoc locations and the Bayesloc solutions. It can be seen that the peaks with depths of 5 and 10 km have disappeared, the depths are more balanced and realistic.

Fig 8 compares iLoc locations (A column) with Bayesloc locations (B column) in map view. The events around the mines are dramatically better clustered in Hungary and Croatia (**Fig 8B** 2,3,5) .

The final solution of Bayesloc using ak135 velocity model is considerably more accurate than the original locations. Reliable iLoc initial locations (with RSTT model) make a significant contribution to the final solutions. The prior constraints contributed remarkably to the outcome of the relocation.

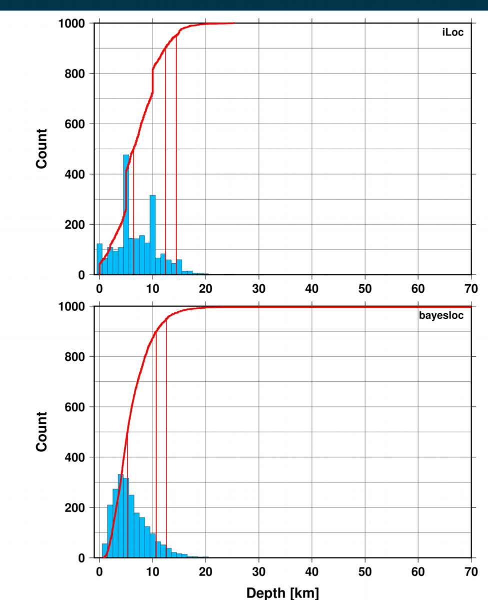


Fig 6. Depth distribution of the earthquakes in the case of the iLoc (top) and Bayesloc (bottom)

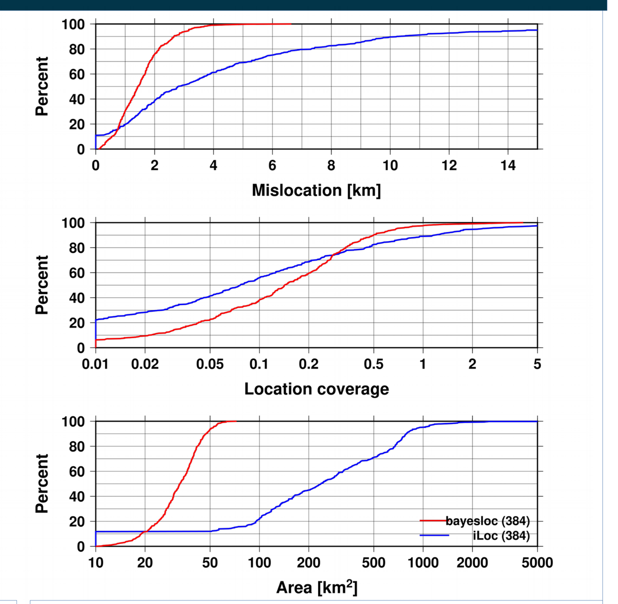


Fig 7. Mislocation, coverage parameter and error ellipse area (90 confidence) in the case of iLoc (blue) and Bayesloc (red)

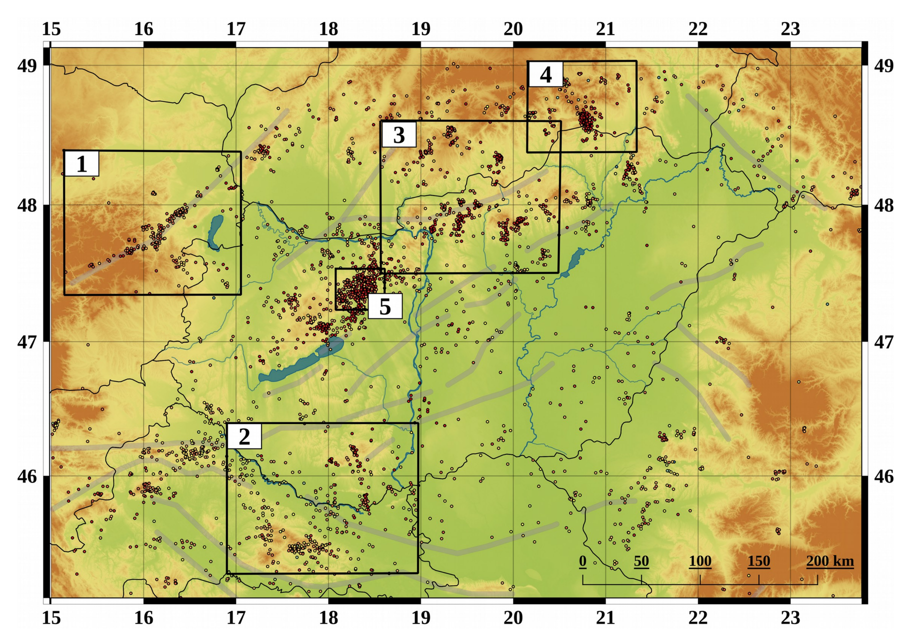


Fig 8A. Map view of the Bayesloc solutions. Framed areas are shown on Fig 8B. →

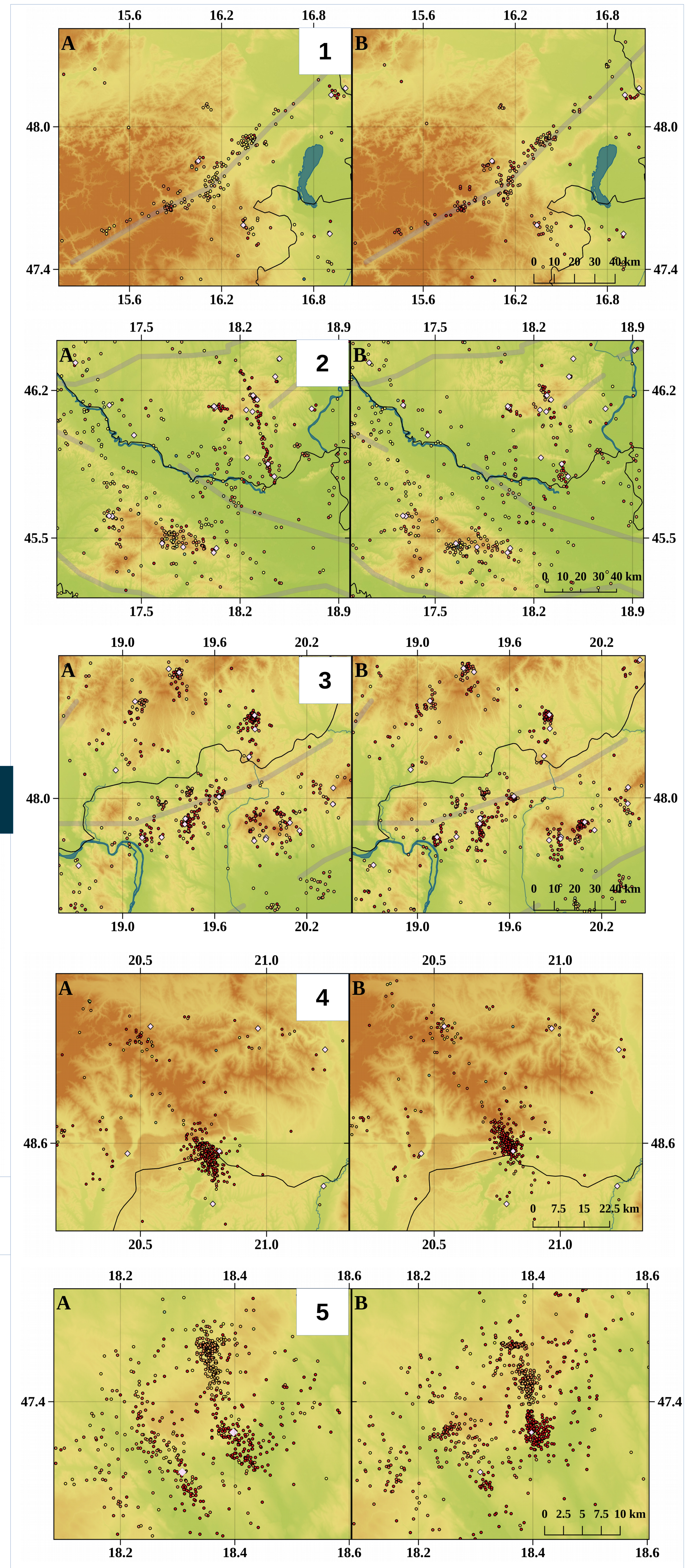


Fig 8B. Map view of the iLoc initial locations (A column) and Bayesloc solutions (B column). Mines are indicated with silver diamond. Events are colored depending on the depth (Red events are near the surface, while yellow-blue ones are deeper)

- Myers, S.C. M.L. Begnaud, S. Ballard, M.E. Pasyanos, W.S. Phillips, A.L. Ramirez, M.S. Antolik, K.D. Hutchenson, J.J. Dwyer, C.A. Rowe and G.S. Wagner (2010) A crust and upper-mantle model for Eurasia and North Africa for Pn travel-time calculation, Bull. Seism. Soc. Am., 100, 640-656.
- Myers, S.C., G. Johannesson, and W. Hanley, "A Bayesian hierarchical method for multiple-event seismic location," Geophys. J. Int., 171, 1049-1063, 2007.
-Myers, S.C., G. Johannesson, and W. Hanley, "Incorporation of probabilistic seismic phase labels into a Bayesian multiple-event seismic locator," Geophys. J. Int., 177, 193–204, 2009.
- Bondár I., P. Mónus, C. Czanik, M. Kiszely, Z. Gráczer, Z. Wéber and the AlpArrayWorking Group (2018). Relocation of Seismicity in the Pannonian Basin Using a Global 3D Velocity Model. Seismological Research Letters. https://doi.org/10.1785/0220180143
- Bondár, I., and Storchak, D., 2011, Improved location procedures at the International Seismological Centre: Geophysical Journal International, v. 186, no. 3, o. 1220-1244.
- Kennett, B.L.N., E.R. Engdahl and R. Buland. (1995). Constraints on seismic velocities in the Earth from travel times. Geophys. J. Int., 122, 108–124.

PROJECT FINANCED FROM THE NRDI FUND

This work was financially supported by the National Research, Development and Innovation Fund (Grant No. K128152), the ÚNKP-19-3 New National Excellence Program of the Ministry for Innovation and Technology.