The Berkovići (BIH) earthquake series – preliminary results of seismological research

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Mainshock: — 22 April 2022, 21:07, $M_L = 6.0$, $M_w = 5.7$ (Figs. 1, 5, 6)

Aftershocks: — 23 April 2022, 02:20, $M_w = 4.4$
— 24 April 2022, 04:27, $M_w = 4.7$ (Figs. 5, 6)

Epicentral area: — SE Bosnia and Herzegovina, wider Berkovići region (blue outline, Fig. 1)

Closest station: — DF01 (Ljubinje), 15 km to the south of the mainshock epicentre (Fig. 2)

Eq. catalogue: — 7327 aftershocks in the first 9 months, complete for M ≥ 1.3 (Fig. 4)
— Unexpectedly large focal depths, but within the zone of midcrustal events – grey dashed outline in Fig. 1 (also Figs. 5, 6)

Locations: — With source-specific station corrections (SSSC, 7 iterations)
— Means of solutions for 54 combinations of velocity models and program control parameters

Uncertainties: — Aleatory variation (mean of individual 90%-confidence ellipse major semiaxes)
— Epistemic uncertainty (radius of 90%-confidence region of 54 sets of solutions)
— Very dependent on the station coverage, especially for depth (Fig. 3)

Focal mechanisms: — Pure reverse on a gently dipping fault (mainshock), normal (!) for some aftershocks (Figs. 5, 6)
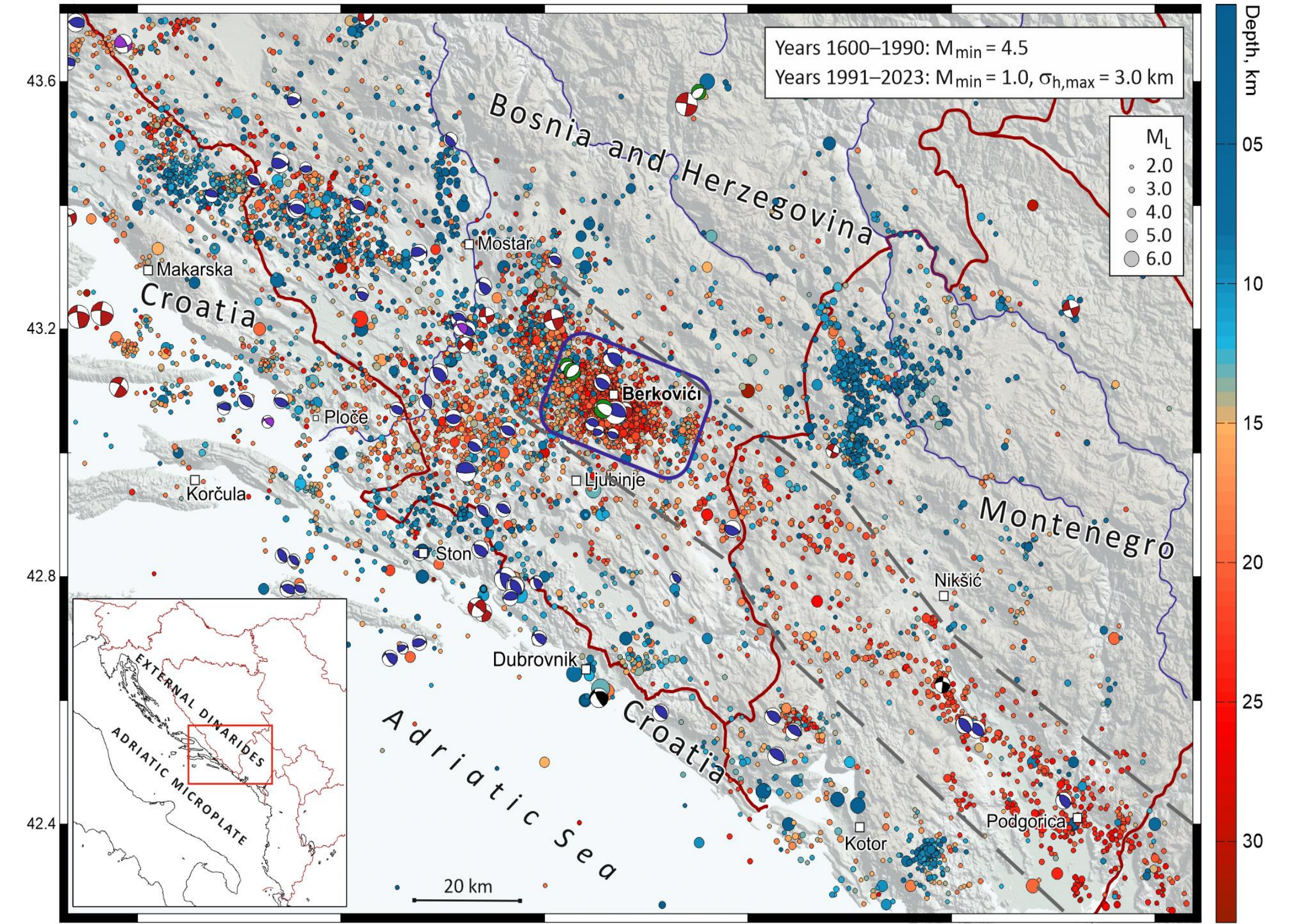

Fig. 1. Seismicity in the greater area of the Berkovići earthquake series (blue outline). Epicentres of all earthquakes in the Croatian Earthquake Catalogue are shown satisfying criteria shown in the top right corner (M_{min} – minimum local magnitude; $\sigma_{h,max}$ – maximum allowed standard error for the epicentre). Focal depth is indicated by the colourscale, and the symbol size scales with magnitude. Focal mechanism solutions (FMS) are from the Croatian FMS-database (M. Herak, personal communication; Herak et al., 2016). The style of faulting is colour-coded by the colour of the compressional quadrant (blue – reverse, red – strike-slip, green – normal, violet – transpression, black – unknown). Thick grey dashed lines delineate a zone of mid-crustal events. The red rectangle in the inset map shows the geographical position of the region presented in this figure.
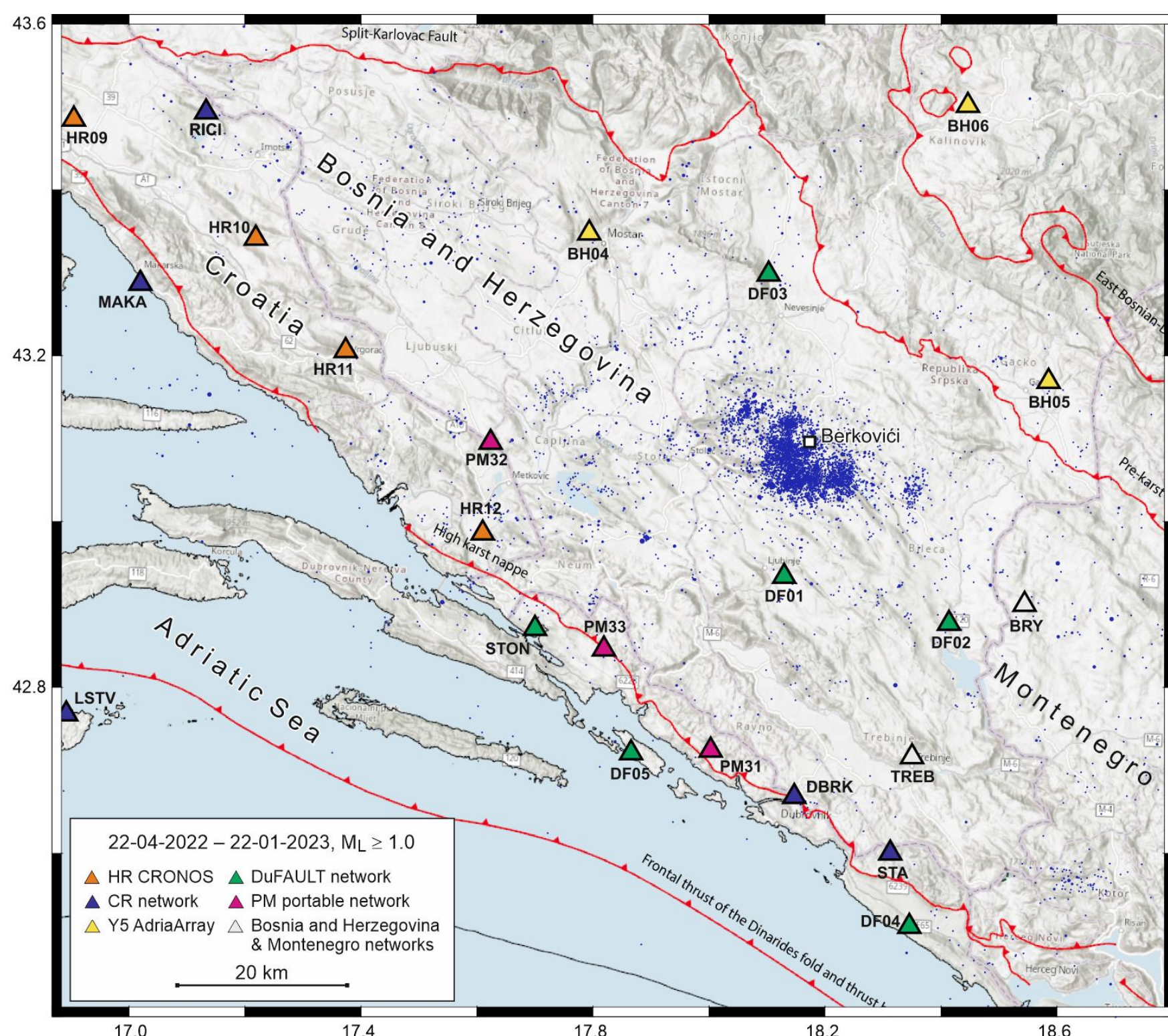

Fig. 2. Blue dots: Epicentres of the earthquakes, 22 Apr. 2022 – 22 Jan. 2023 (M ≥ 1.0); Seismic stations used are shown as coloured triangles (see the legend). Major faults separating tectonic units are after Shmid et al. (2020).
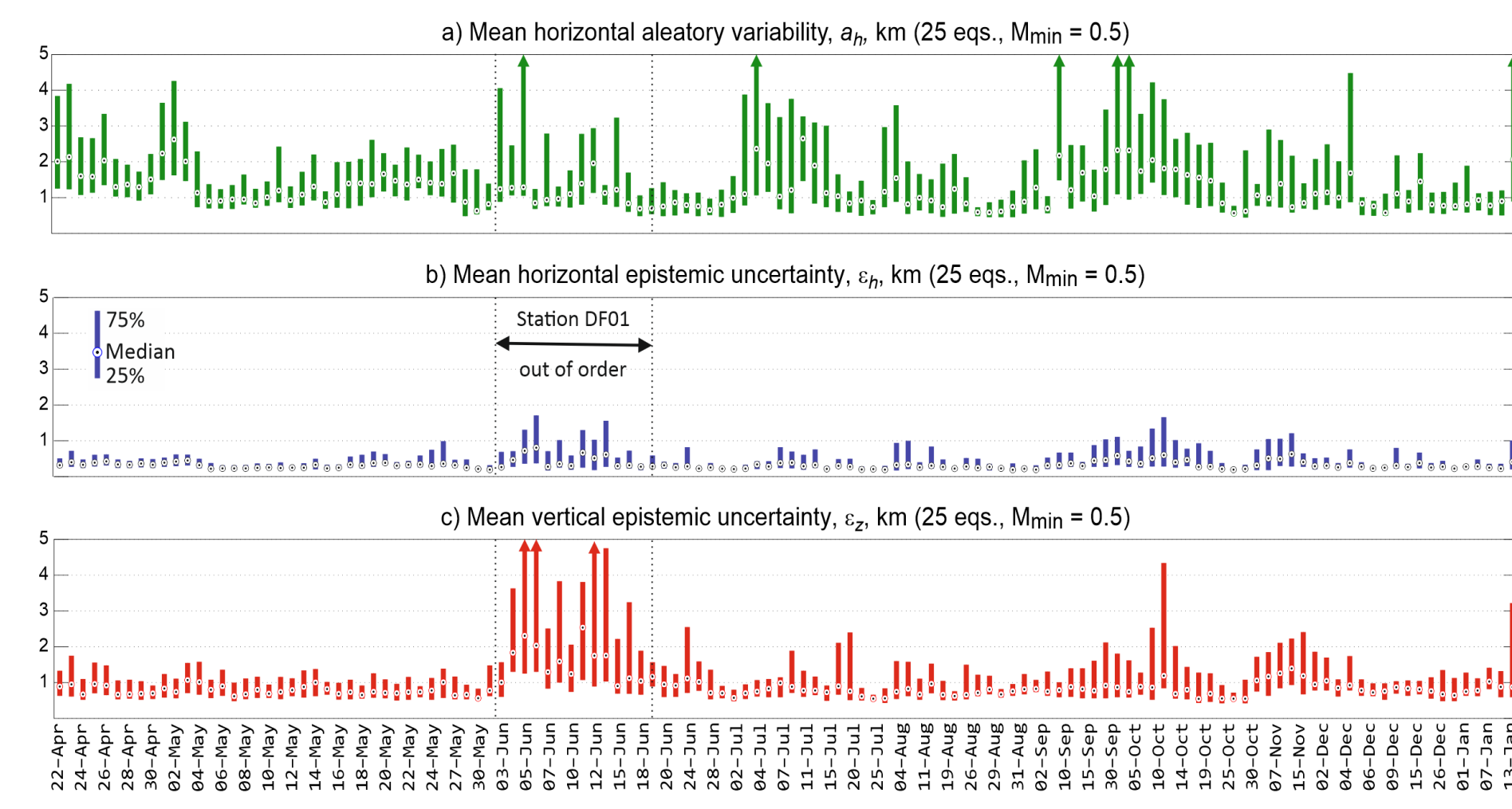

Fig. 3. Temporal variation of the location uncertainty measures estimated as a mean value of the corresponding measure in a sliding window containing 25 consecutive events with $M_L ≥ 0.5$. a) Mean aleatory variability (major half-axis of the 90% confidence ellipse); b) Mean epistemic uncertainty (90-percentile radius) of the horizontal coordinate; c) Mean epistemic uncertainty of the hypocentral depth (90-percentile radius). Bars topped with arrows indicate value larger than 5 km. Periods of increased uncertainty correlate well with the times when the closest stations were out of order.
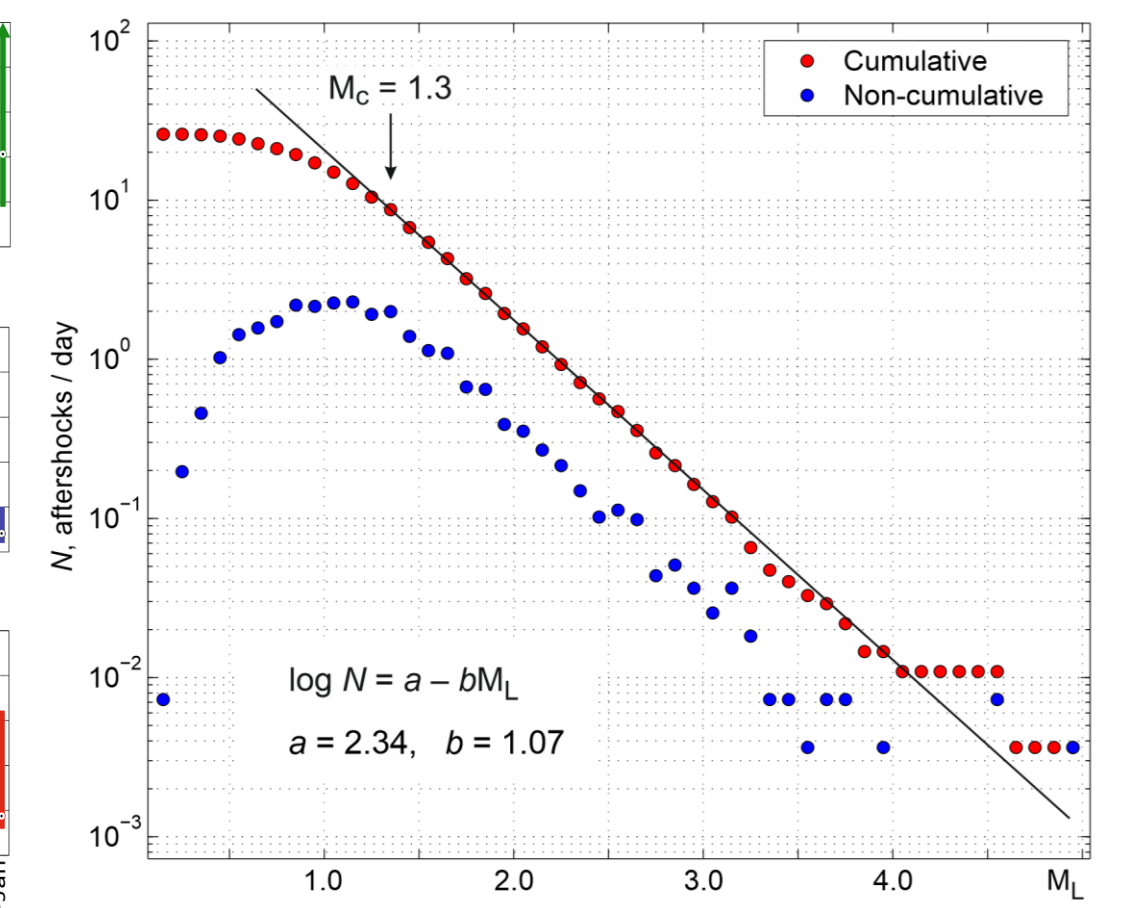

Fig. 4. Frequency-magnitude distribution for the first nine months of the Berkovići earthquake sequence (mainshock excluded). The aftershock catalogue is considered complete for $M_L ≥ 1.3$.
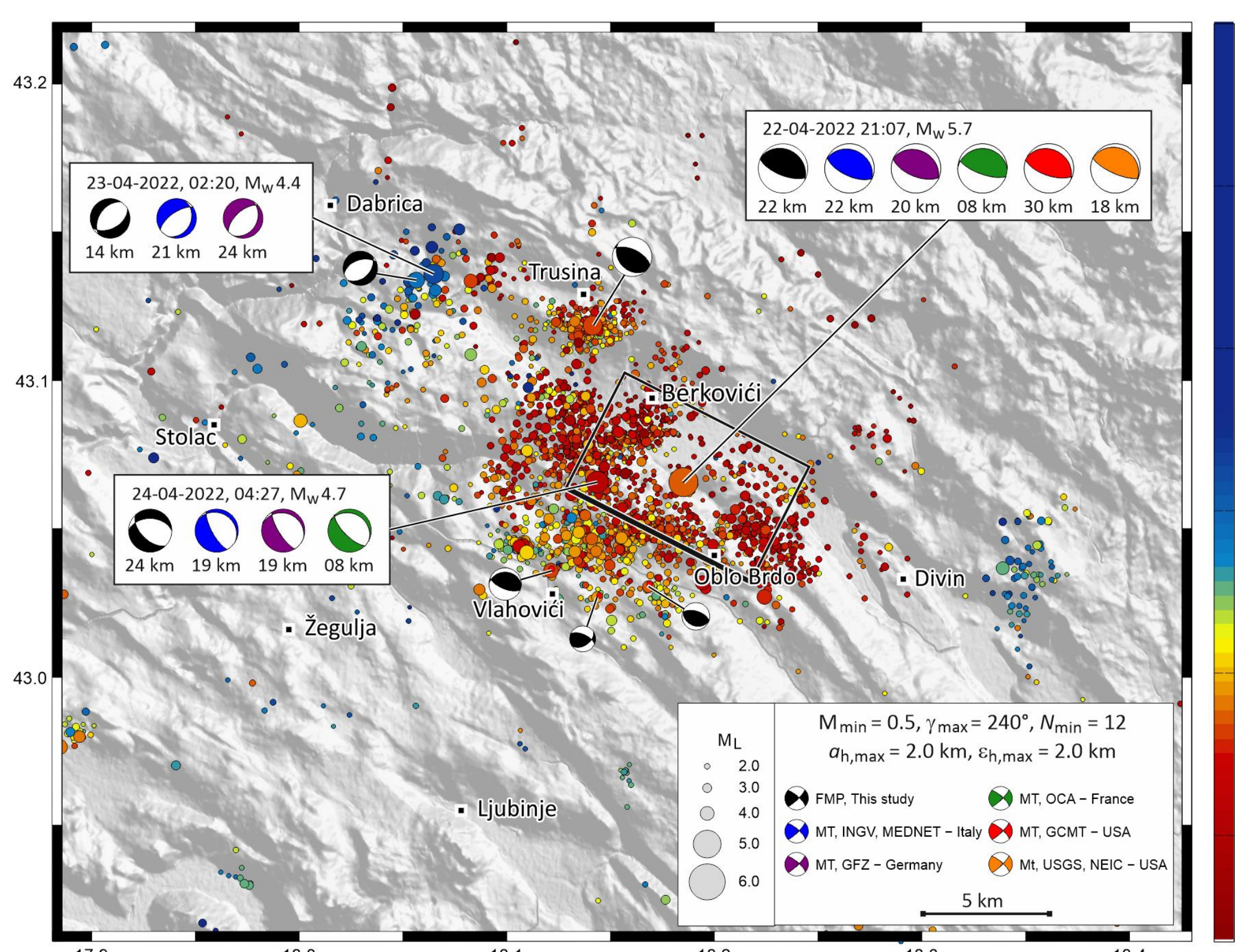

Fig. 5. Epicentres of the best located earthquakes, satisfying criteria shown in the bottom right corner (M_{min} – minimum local magnitude; γ_{max} – maximum allowed station azimuthal gap; N_{min} – minimum number of phases used; $a_{h,max}$ – maximum allowed aleatory variability for the epicentre; $\varepsilon_{h,max}$ – maximum allowed epistemic horizontal uncertainty). The focal depth is shown by colourscale. Best double couple solutions for the focal mechanism are shown as lower hemisphere beachballs. The compressional quadrant colour indicates the data source: Black – First motion polarity (this study), Other colours – Moment tensor inversion (see the legend). The surface projection of the assumed fault plane is shown as black rectangle. The thick black line shows the shallowest fault edge.
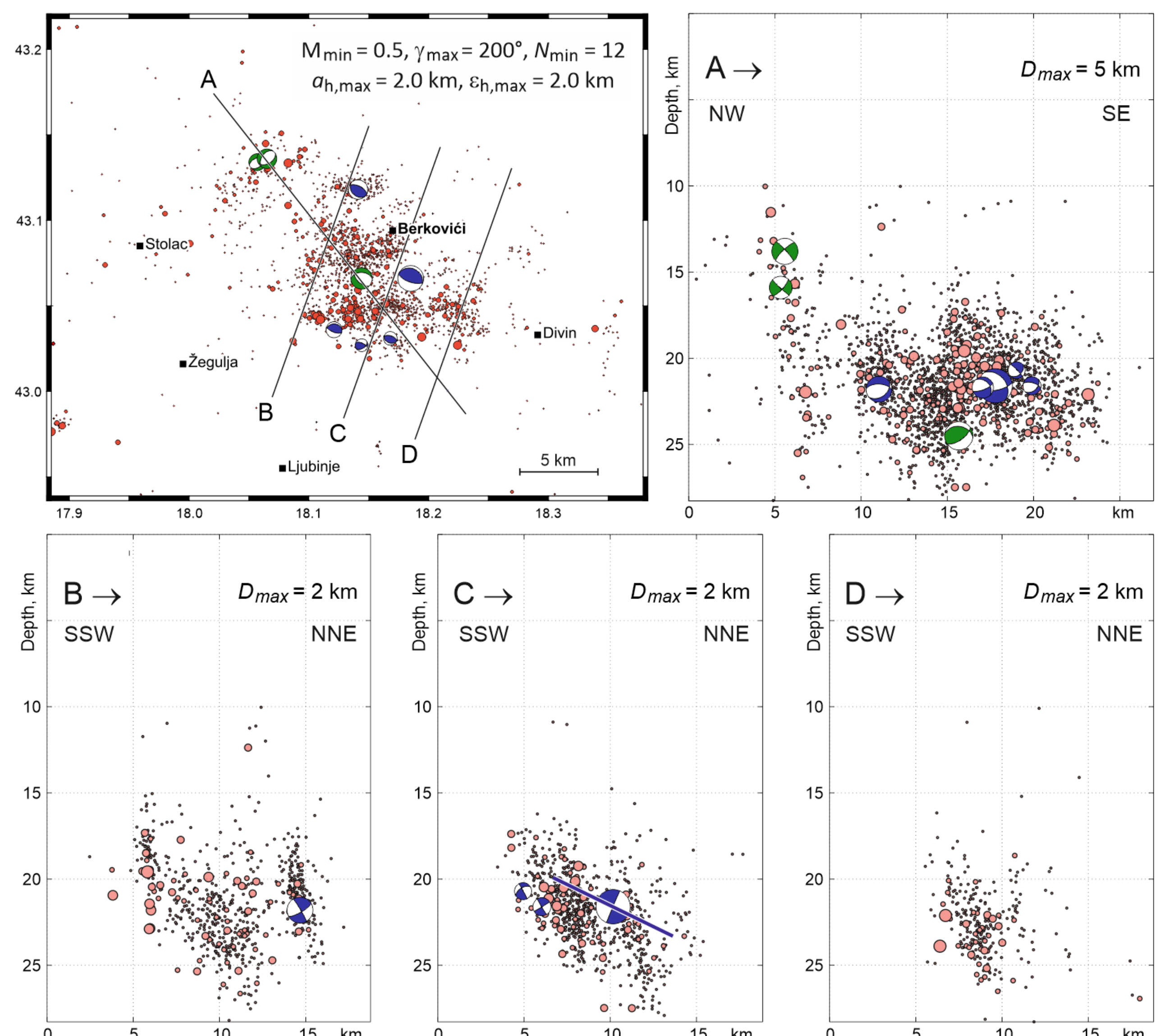

Fig. 6. *Top left:* Epicentres of earthquakes from the first nine months of the Berkovići sequence satisfying criteria shown in the top right corner (M_{min} – minimum magnitude; $a_{h,max}$ – maximum allowed aleatory variability for the epicentral coordinates; $\varepsilon_{h,max}$ – maximum allowed epistemic uncertainty for the epicentral coordinates; N_{min} – minimal number of phase onset times used for location; γ_{max} – maximal allowed station azimuthal gap). Beach-balls are lower hemisphere stereographic projection of the best solution. Blue and green compressional quadrants denote reverse and normal styles of faulting, respectively, and the size scales with magnitude. A–D: Vertical cross-sections along the lines shown in the map (top left). The FMS in the profiles are shown as farther hemisphere projections in the profile plane. Blue line in C) is cross-section with the assumed fault plane shown in Fig. 5.

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