

**Supporting Information for**  
**Complex evolution of the 2016 Kaikoura earthquake revealed by teleseismic**  
**body waves**

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**Table S1.** 1-D velocity structure near the epicenter derived from CRUST2.0 (Bassin *et al.* 2000).

| Vp (km/s) | Vs (km/s) | Density ( $10^3\text{kg/m}^3$ ) | Thickness (km) |
|-----------|-----------|---------------------------------|----------------|
| 6.00      | 3.50      | 2.70                            | 15.00          |
| 6.60      | 3.70      | 2.90                            | 9.00           |
| 7.20      | 4.00      | 3.05                            | 11.00          |
| 8.00      | 4.60      | 3.30                            | 0.00           |

**Table S2.** 1-D velocity structure near the epicenter derived from CRUST1.0 (Laske *et al.* 2013).

| Vp (km/s) | Vs (km/s) | Density ( $10^3\text{kg/m}^3$ ) | Thickness (km) |
|-----------|-----------|---------------------------------|----------------|
| 5.80      | 3.40      | 2.63                            | 11.85          |
| 6.30      | 3.62      | 2.74                            | 9.90           |
| 6.90      | 3.94      | 2.92                            | 9.28           |
| 8.14      | 4.52      | 3.35                            | 0.00           |

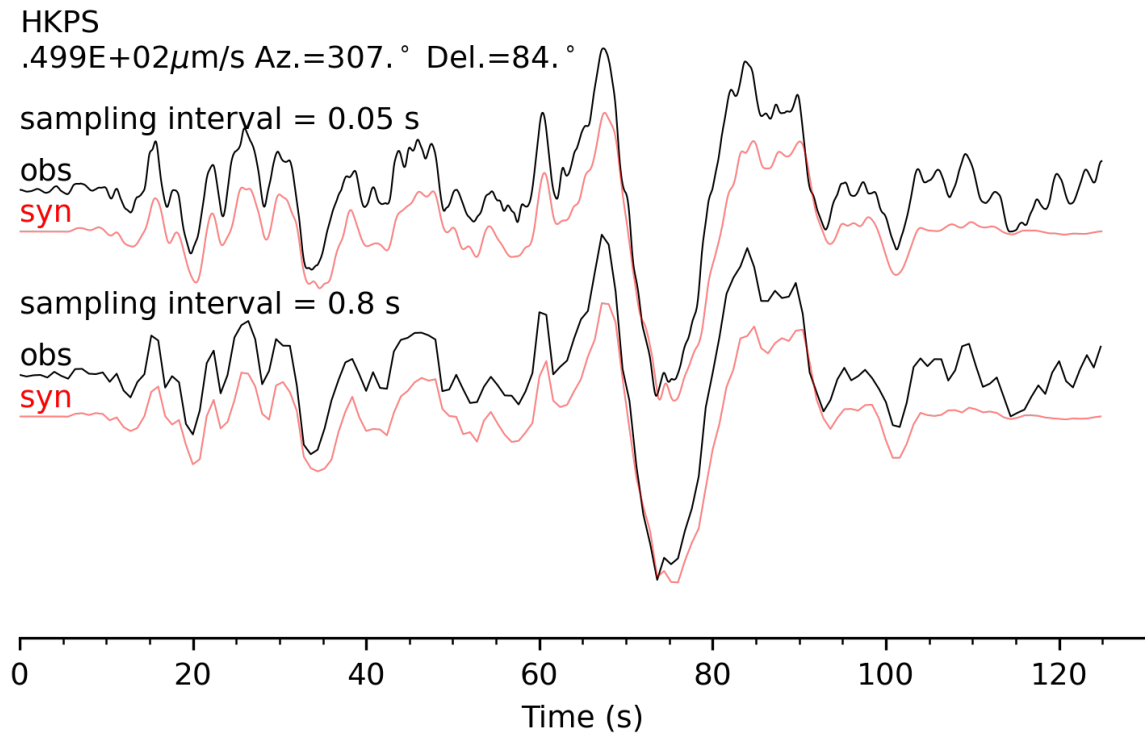


**Figure S1.** Comparison of observed (black) and synthetic (red) waveforms at HKPS plotted at sampling intervals of 0.05 s (upper) and 0.8 s (lower). 0.8 s is the calculation interval of the potency-rate density function of the inversion. The text above the waveform indicates station name, maximum amplitude of the observed waveform, station azimuth (Az.), and epicentral distance (Del.) from the mainshock.

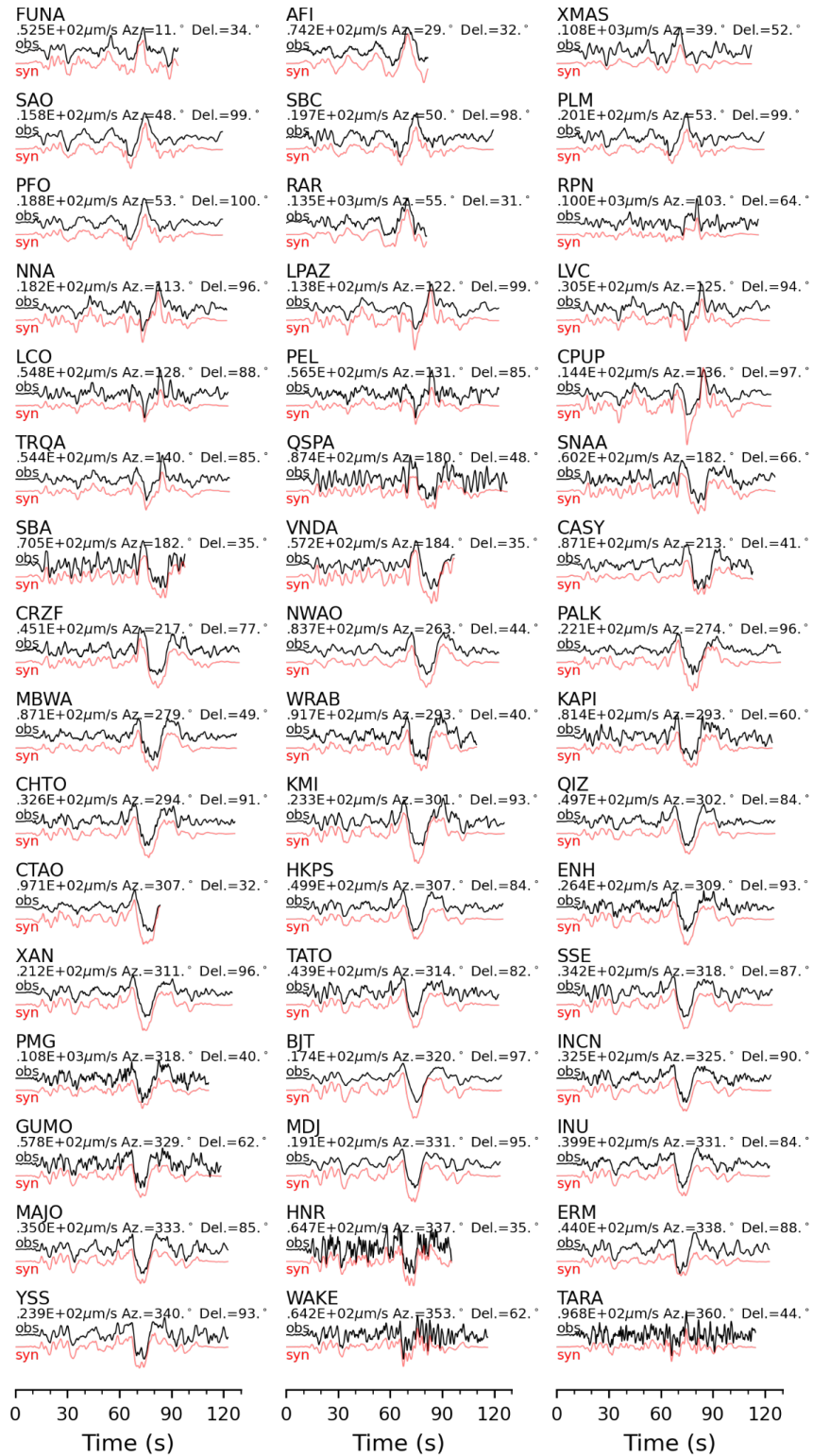


**Figure S2.** Observed waveforms (black line) and synthetic waveforms obtained from the preferred source model (red line) at each station. The text above the waveform indicates station name, maximum amplitude of the observed waveform, station azimuth (Az.), and epicentral distance (Del.) from the mainshock.

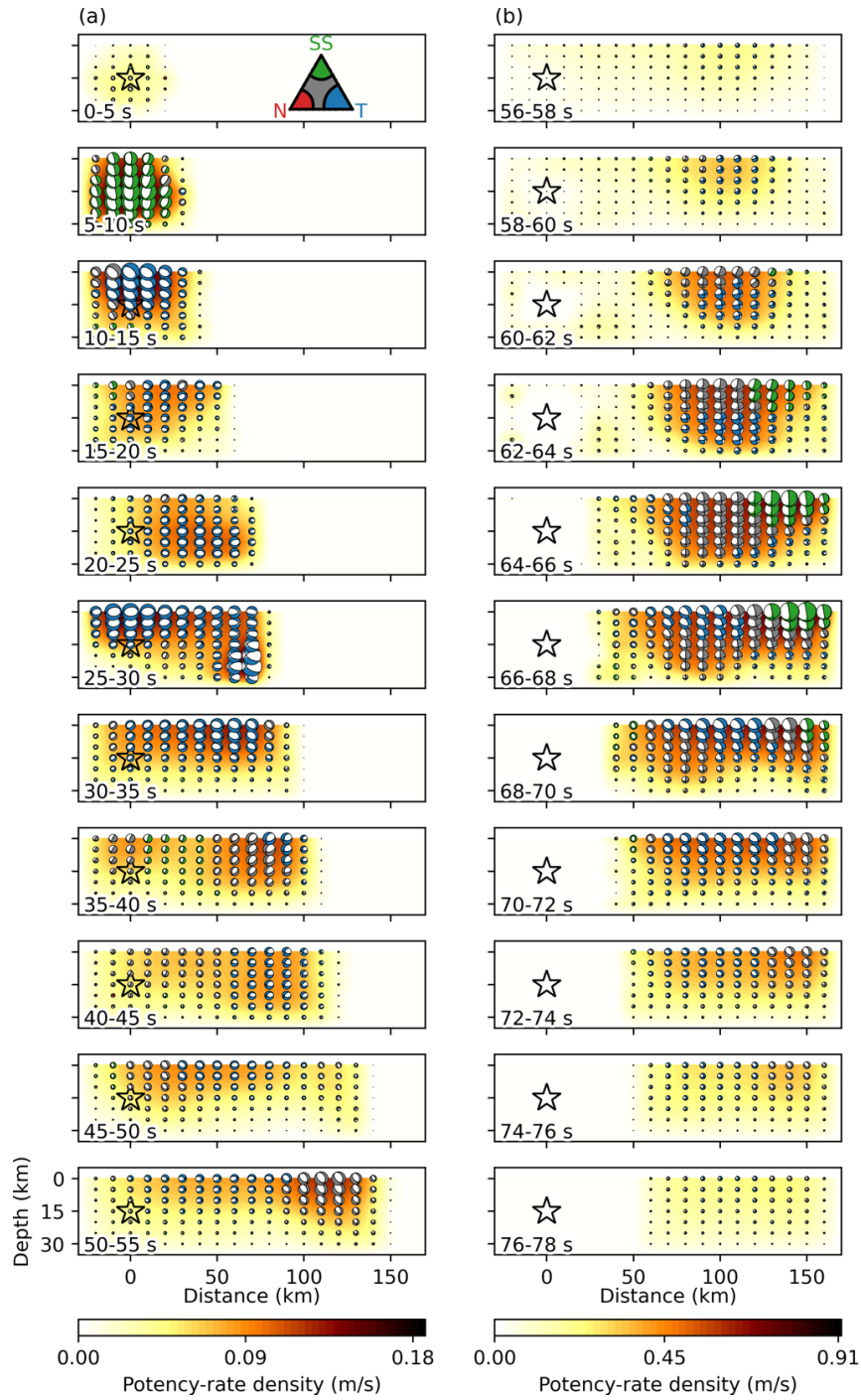


**Figure S3.** Full snapshots of potency-rate density tensors **a** before 55 s and **b** after 56 s. Beachballs are shown in cross-section view from the southeast side of the assumed model plane. Beachballs in the bottom panel are colored based on a Frohlich diagram (Frohlich 2001), in which blue is reverse faulting (T), green is strike-slip faulting (SS), red is normal faulting (N), and grey is other. The background color is scaled with the maximum potency-rate density during 0–55 s for **a** and 56–78 s for **b**; note that the scales differ for the two plots. The black star denotes the hypocenter (Lanza *et al.* 2019).

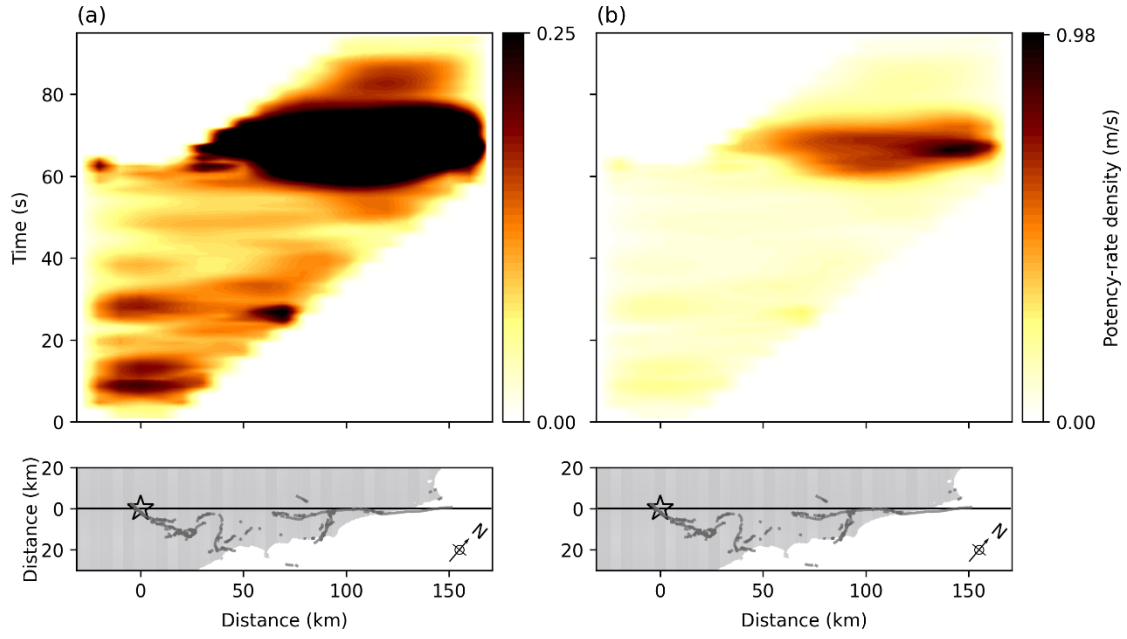


**Figure S4.** Potency-rate density evolution along the strike direction of the model plane. The background color is scaled with 0.25 m/s for **a** and maximum potency-rate density until 95 s for **b**. Note that we denote potency-rate density of more than 0.25 m/s as the color denoting 0.25 m/s in **a**.

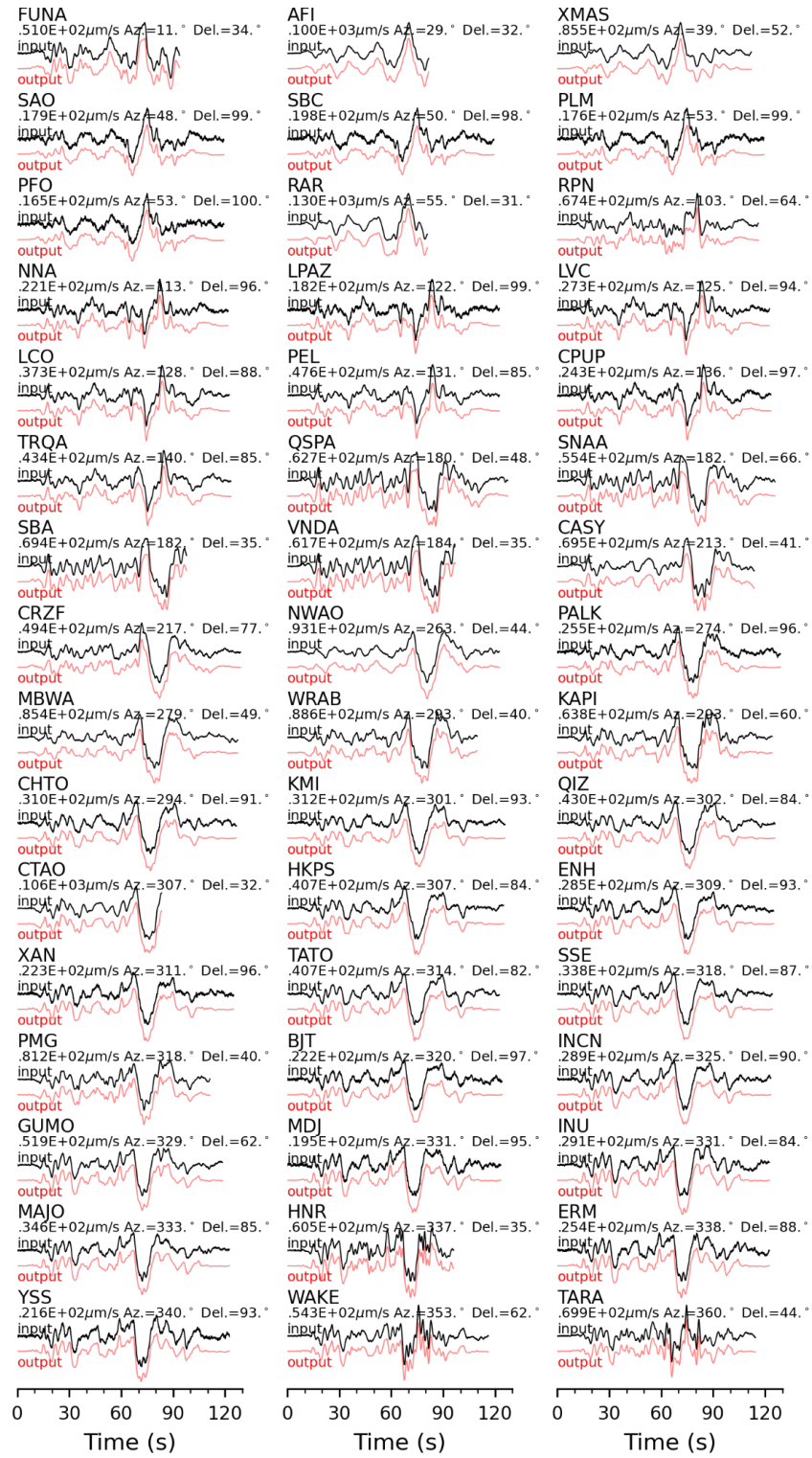


**Figure S5.** Input synthetic waveforms (black line) and output waveforms (red line) obtained in the reproducibility test using the analysis result for real waveforms as input. The letters above the waveform mean station name, maximum amplitude of the input waveform, station azimuth (Az.), and epicentral distance (Del.) from the mainshock.

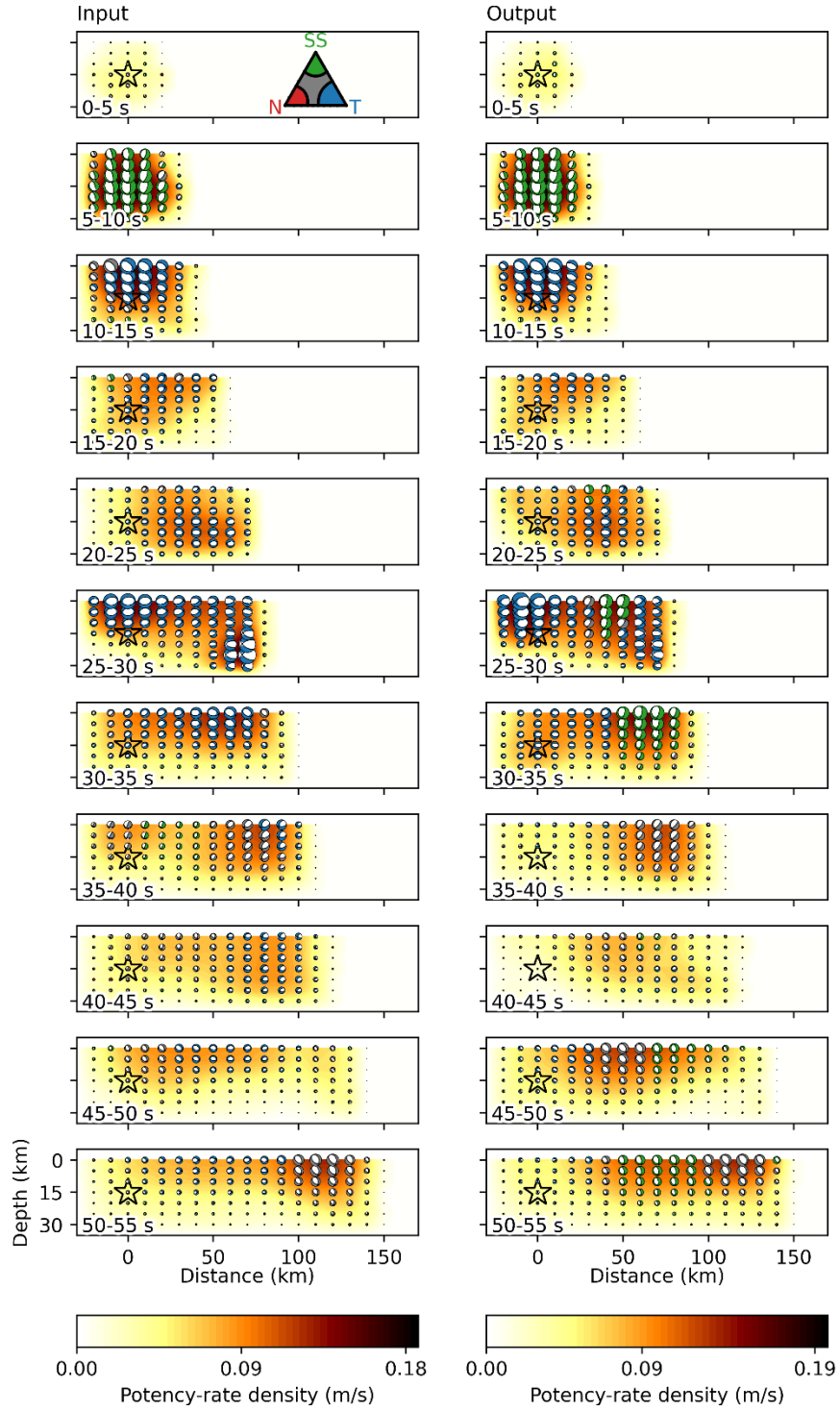


**Figure S6.** Snapshots of potency-rate density tensors before 55 s for the reproducibility test using the analysis result for real waveforms (Fig. 3 of the main text) as input. The left panels show input, and the right panels show output. Beachballs are shown in cross-section view from the southeast side of the assumed model plane. The background color is scaled with the maximum potency-rate density for input and output; note that the scales differ for the two plots. The black star denotes the hypocenter (Lanza *et al.* 2019).

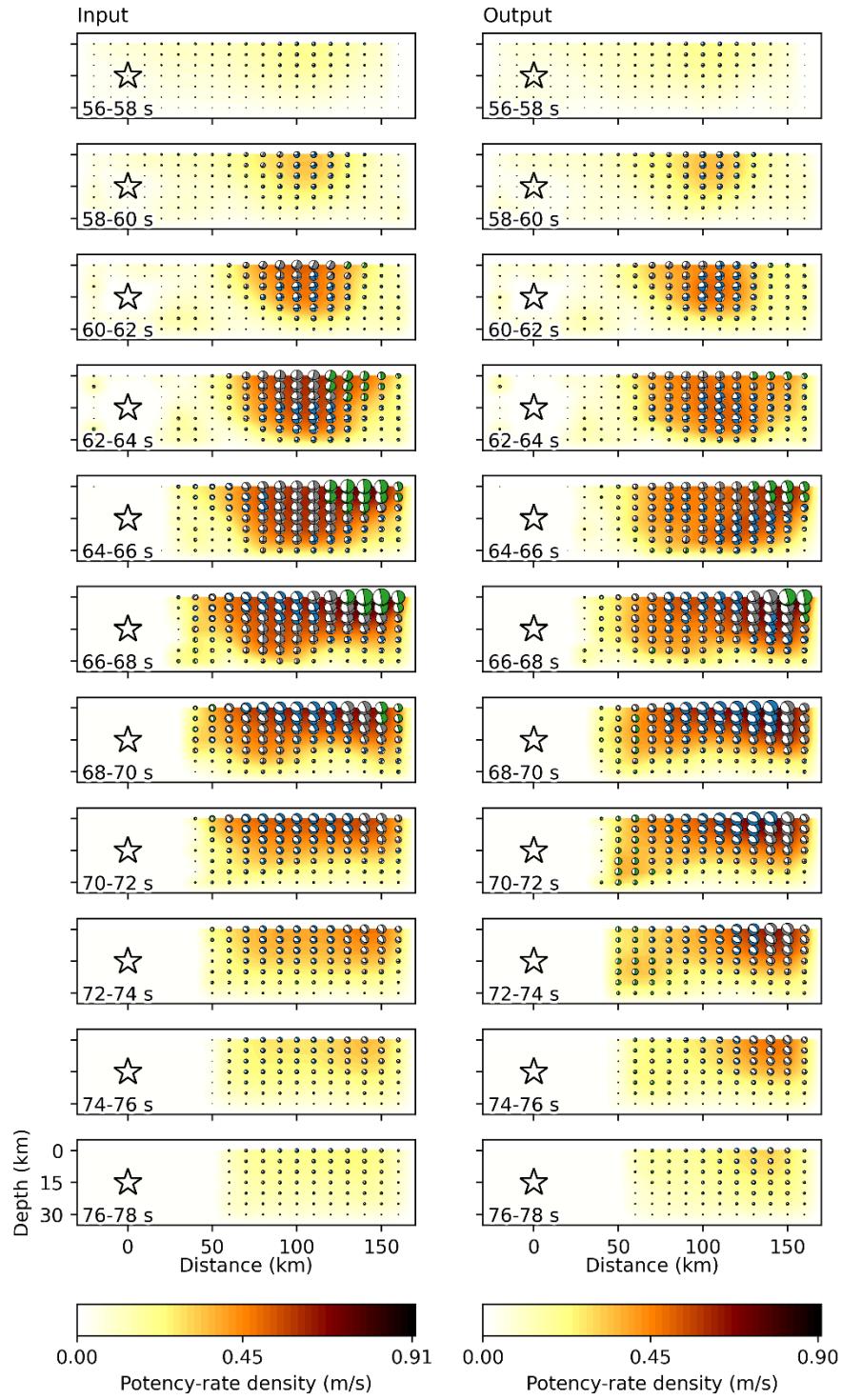


**Figure S7.** The same as in Fig. S6, but for time after 56 s.

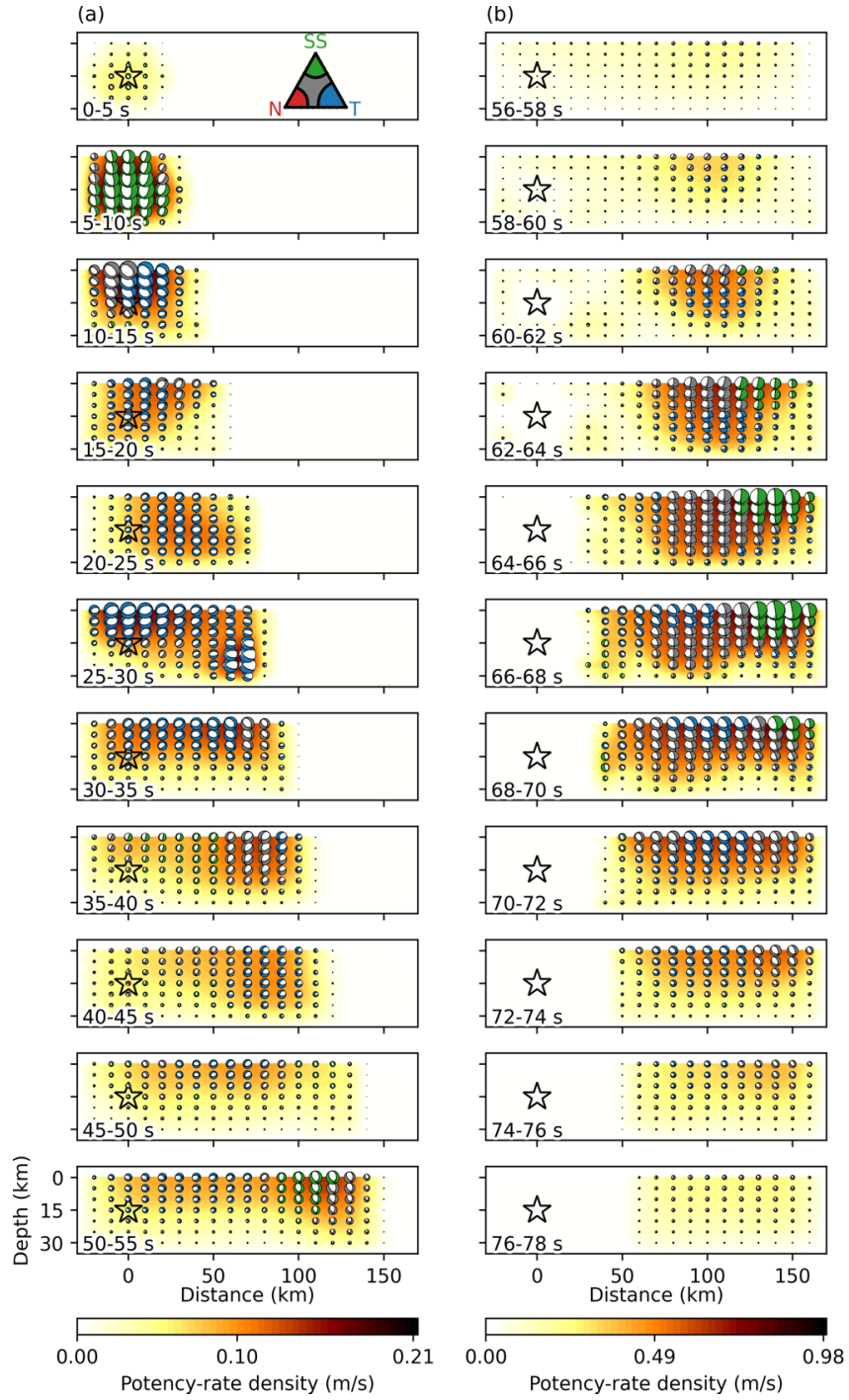


**Figure S8.** Full snapshots of potency-rate density tensors **a** before 55 s and **b** after 56 s for the sensitivity test using 1-D velocity structure near the epicenter determined based on CRUST1.0 (Laske *et al.* 2013). Beachballs are shown in cross-section view from the southeast side of the assumed model plane. The background color is scaled with the maximum potency-rate density during 0–55 s for **a** and 56–78 s for **b**; note that the scales differ for the two plots. The black star denotes the hypocenter (Lanza *et al.* 2019).

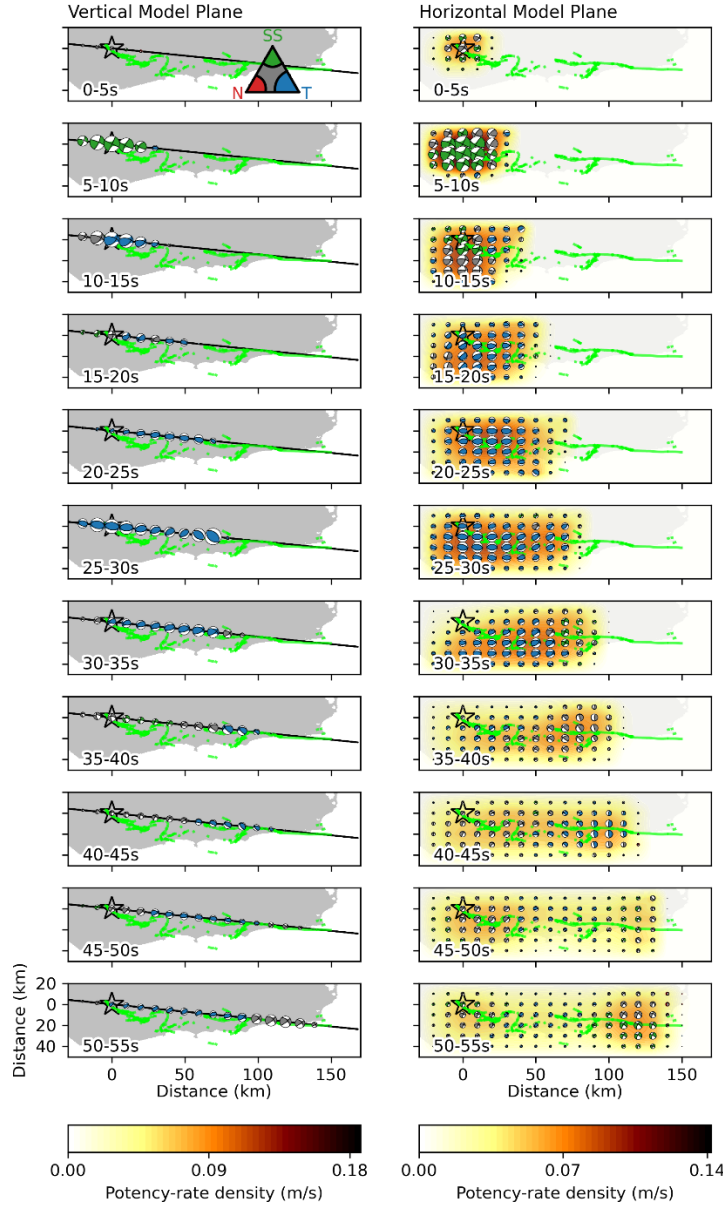


**Figure S9.** Snapshots of potency-rate density tensors before 55 s for the preferred source model using the vertical model plane (Fig. 3 in the main text) and the sensitivity test under the assumption of the horizontal model plane. In the left panels, we plotted only potency-rate density tensors with the greatest potency-rate density among potency-rate density tensors at the same location on the map. The black lines in the left panel denotes vertical model plane. Beachballs are shown in lower-hemisphere projection in the map. The background color is scaled with the maximum potency-rate density for results using vertical and horizontal model planes; note that the scales differ for the two plots. The green lines indicate surface ruptures (Langridge *et al.* 2016). The black star denotes the hypocenter (Lanza *et al.* 2019).

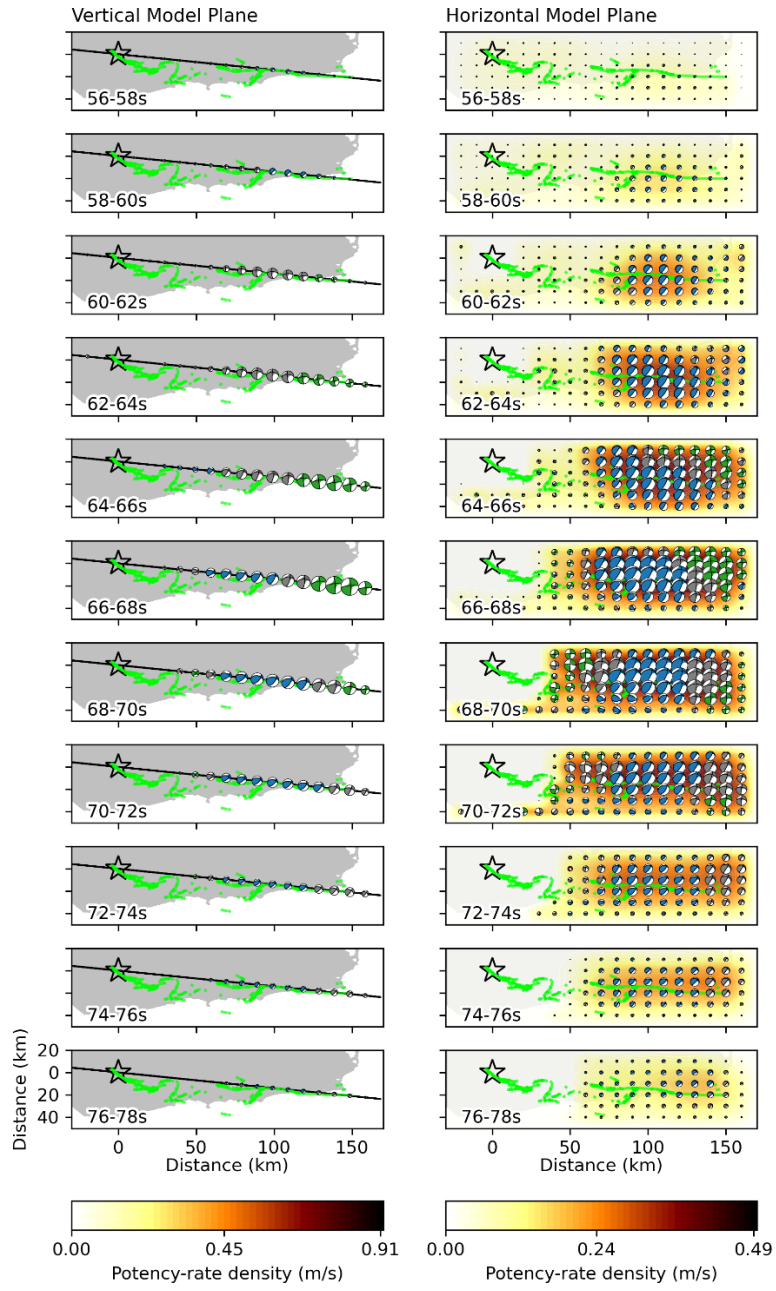


**Figure S10.** The same as in Fig. S9, but for time after 56 s.

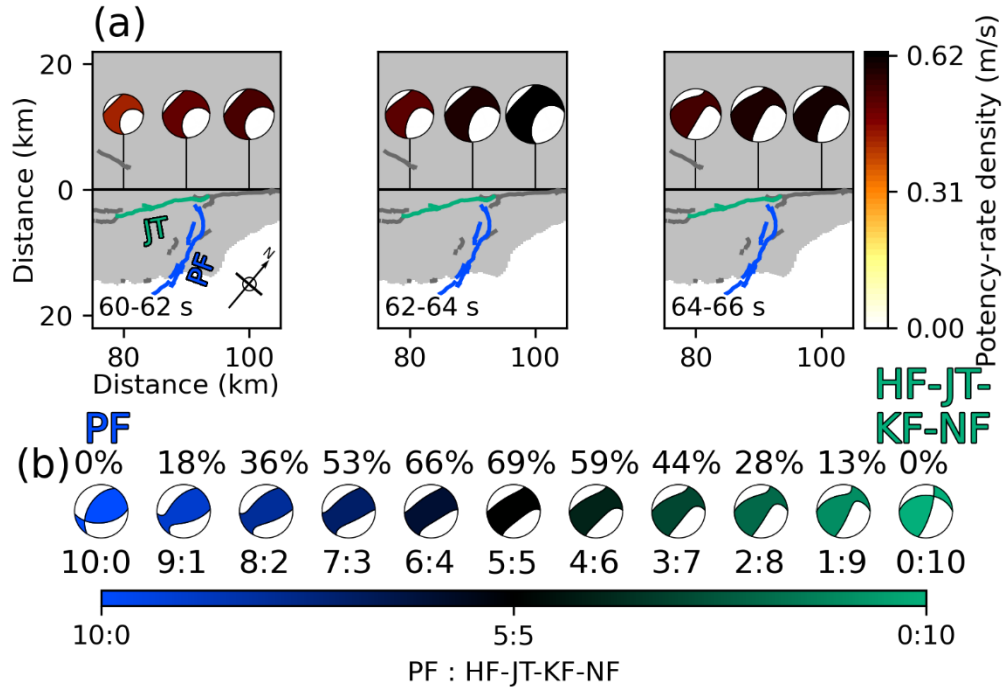


**Figure S11** Comparison of **a** the obtained potency-rate density tensors during 60–66 s in the top row of the model plane 80–100 km northeast of the epicenter and **b** visual summary of moment tensor transition between two endmembers: PF and HP-JT-KF-NF, where HP represents the Hope fault. Beachballs are shown as a lower-hemisphere projection in the map. **a** The color of the beachball symbols represents the potency-rate density. Grey, blue, and green lines indicate surface ruptures (Langridge *et al.* 2016). **b** The leftmost and rightmost moment tensors are focal mechanisms of the PF and HP-JT-KF-NF, respectively, estimated using geodetic data (Xu *et al.* 2018). Note that the largest slip of HP-JT-KF-NF was reported around the intersection between PF and JT-KF (Xu *et al.* 2018). The color of the beachballs and texts x:x represent the moment tensor ratio. Above each beachball is shown the ratio of the non-double-couple component. i.e. ratios of scalar moments of the end-member focal mechanisms.

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