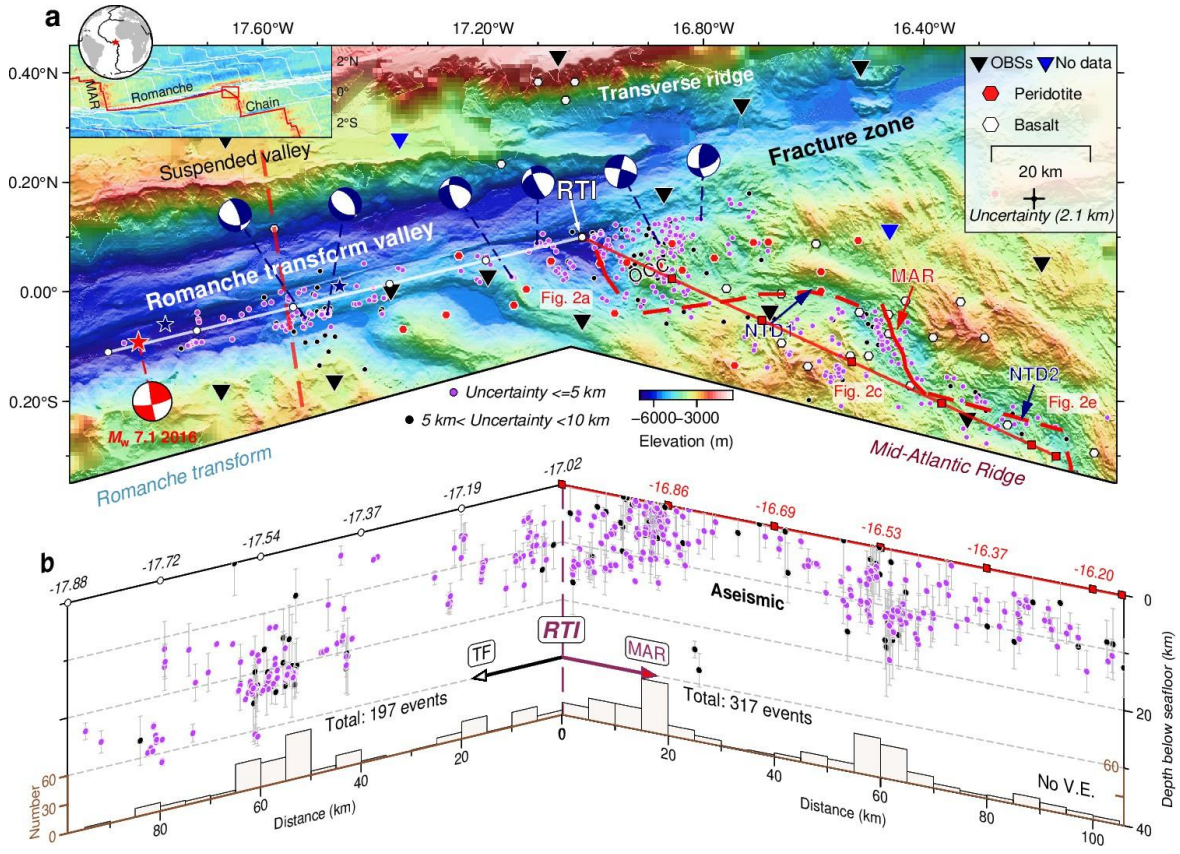
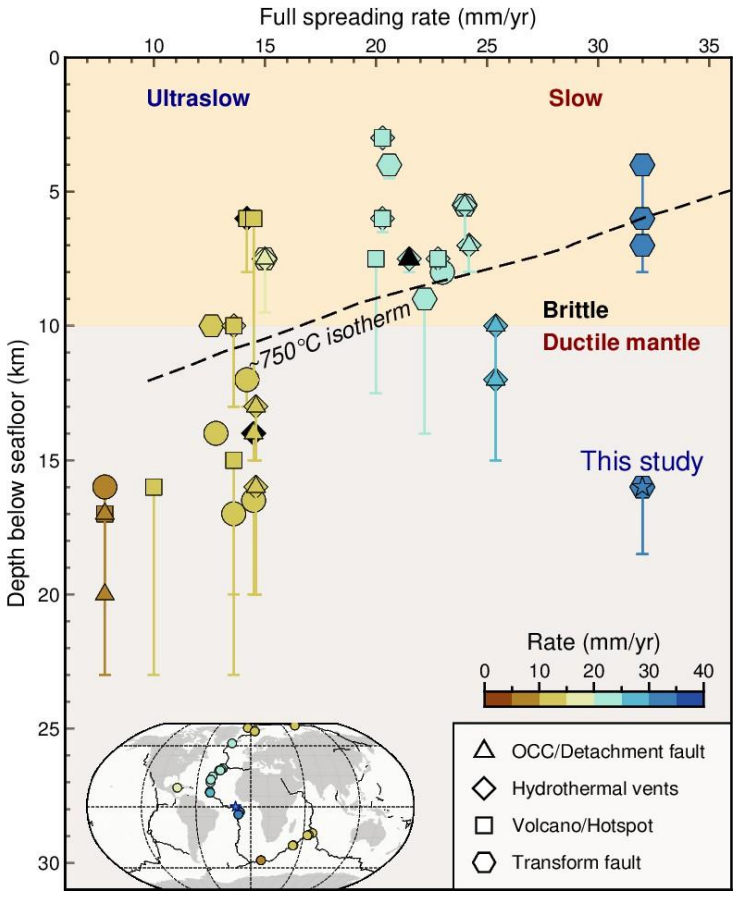
Extended Data Figs. 1-10



Extended Data Fig. 1

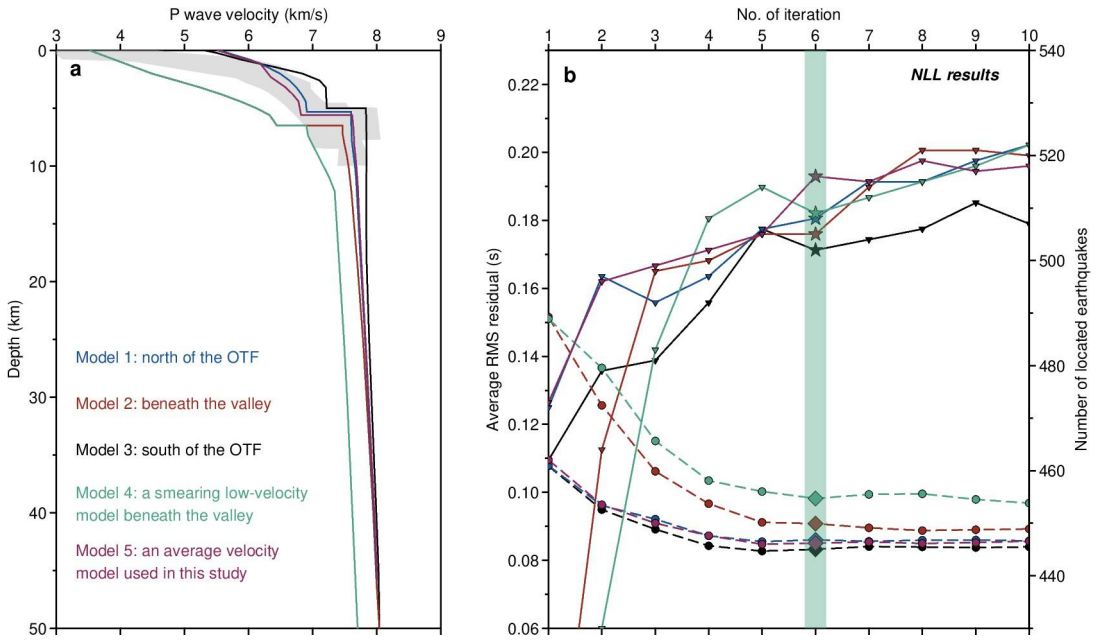
Seismicity. (**a**) Bathymetric map with seismicity in the study region, whose location is shown in the inset map on the upper left corner, in which white lines indicate the lithospheric ages[22] every 10 Ma. Solid and dashed red lines indicate the Mid-Atlantic Ridge (MAR) axes and non-transform discontinuities (NTD) shown in Fig. 2, respectively. Focal mechanisms (Supplementary Table 4) are shown in blue and white beach balls. Rock samples are shown in colored hexagons[16–18], and the average horizontal uncertainty (~2.1 km) after the relocation is marked by a black plus sign (see legend for symbols). The red star with a beach ball and two blue stars indicate the 2016 M_w 7.1 Romanche earthquake and two subevents, respectively[58]. The dashed red line shows the seismic refraction profile[45]. (**b**) Earthquake depths along the Romanche transform fault (TF) (white line in **a**) and along the MAR (red line in **a**) within ±10 km width of the profile. The bottom histograms show the numbers of earthquakes

along the profile. Zero position is the ridge-transform intersection (RTI) location. The white circle and red squares on the top mark the 20 km intervals and longitudes for reference. Depth uncertainties are plotted in gray lines. The other labeling is the same as that in Fig. 1.



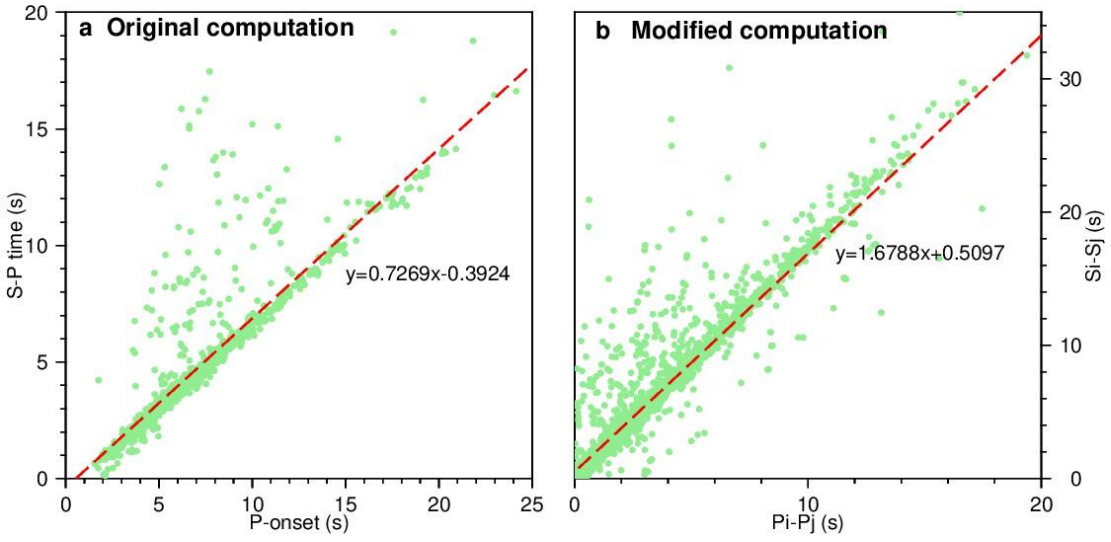
Extended Data Fig. 2

Statistics for the maximum depth distribution of seismicity and full spreading rates. Depths of earthquakes for slow- and ultraslow-spreading ridges are shown in blue and brown circles, respectively, whose locations are shown on the inset map. The color scale gives full spreading rates. The dashed black line indicates the 750°C isotherm [6]. The maximum depths are affected by several processes, e.g., detachments faults (triangles), hydrothermal vents (diamonds, a black one is inactive), volcanoes/hotspots (squares), and TFs (hexagons) (see legend for symbols). A compilation of all the depth data and references used in this figure can be found in Supplementary Table 1.



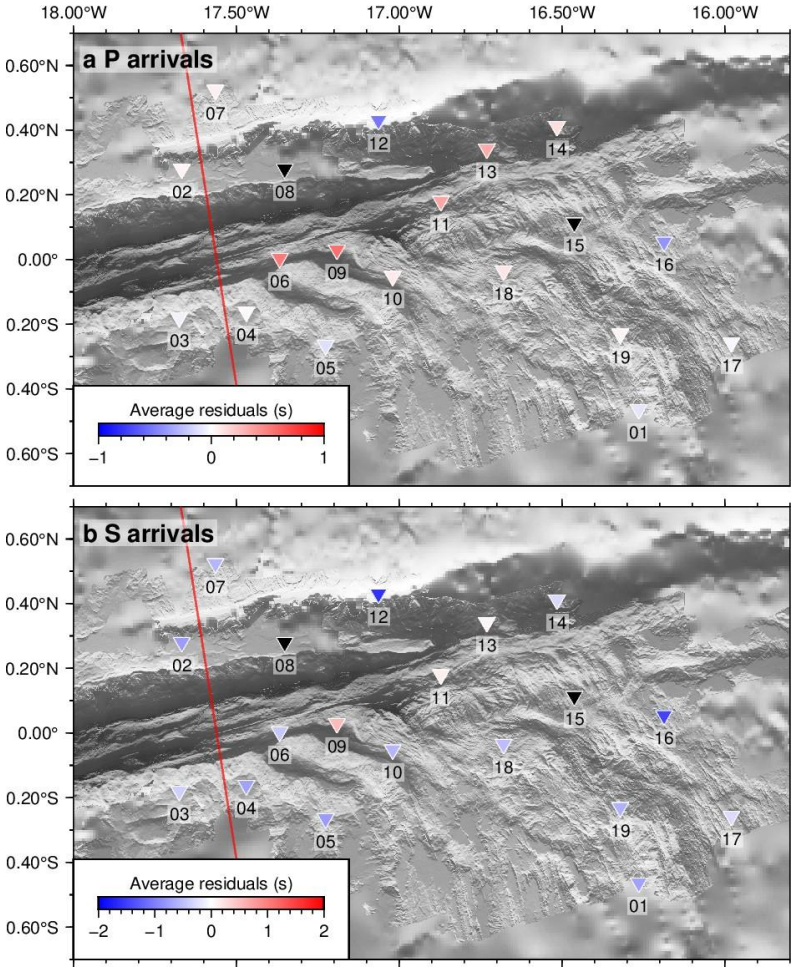
Extended Data Fig. 3

1-D P-wave velocity models. (**a**) Five 1-D models are derived from an active-source wide-angle seismic refraction profile[45]. The gray shade represents the velocity of the crust with age <7.5 Ma[48]. (**b**) Average RMS residuals (dashed lines with circles) and the number of located earthquakes (solid lines with inverted triangles) as a function of iterations using the five 1-D models shown in (**a**). The vertical green bar indicates the selected results for each 1-D velocity model. Model 5 (magenta) is the selected model for the earthquake location (see Supplementary Table 2).



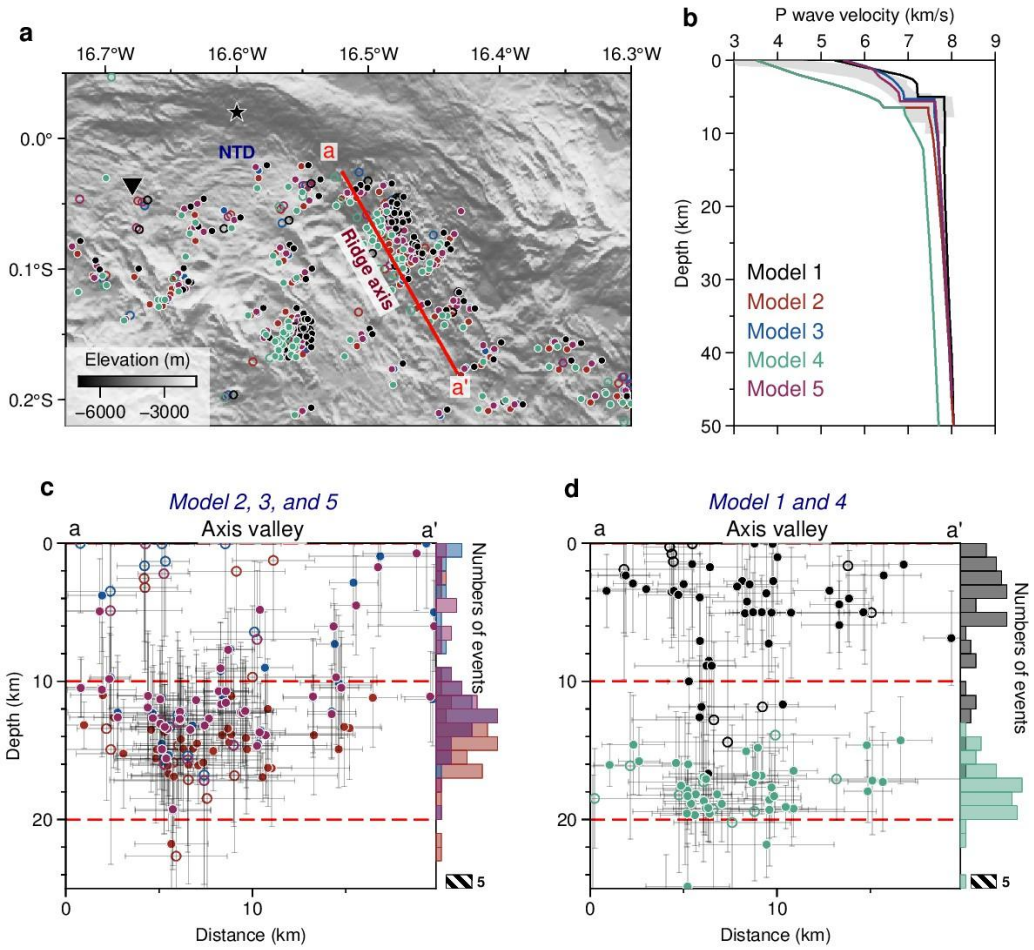
Extended Data Fig. 4

Wadati diagrams. (**a**) Original computation showing P-onset versus S-P time. (**b**) A modified computation showing time differences between P-arrivals (Pi-Pj) versus those between S-arrivals (Si-Sj) for each station pair (i, j) of each event[59]. In this study, the Vp/Vs ratio is ~1.73, which is used to estimate the S-wave velocity for the earthquake location.



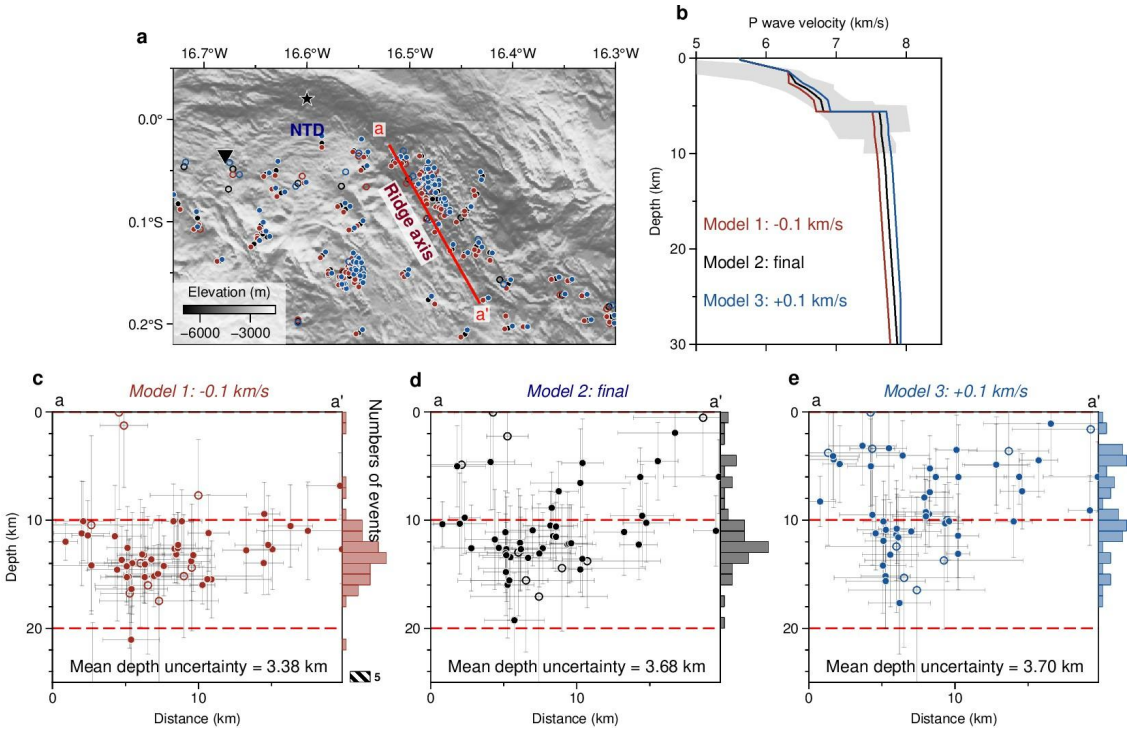
Extended Data Fig. 5

Cumulative travel time residuals. Average residuals for P- (**a**) and S-arrivals (**b**) on each station using the NonLinLoc location program[46]. Triangles indicate the locations of ocean bottom seismometers used in this study. The red line shows the location of the seismic refraction profile[45].



Extended Data Fig. 6

Earthquake depths along the MAR with five different 1-D velocity models. (**a**) Bathymetric map and located events. Solid and open dots indicate earthquakes with depth uncertainty of ≤5 km and 5-10 km, respectively. The color gives the results using different velocity models in (**b**). One transect along the ridge axis is shown in (**c, d**). The black star indicates an inactive hydrothermal mound suggested by the dive observations[16]. (**b**) Five tested 1-D velocity models. (**c-d**) The focal depth distribution of earthquakes along the profile (aa′) in (**a**). Gray lines mark the depth uncertainties. The histograms on the right show the depth distributions for the different 1-D velocity models in (**b**). A short column with a number is plotted for reference. Velocity Model 1 is too fast and not reasonable (see Methods). The other labeling is the same as that in Extended Data Fig. 1.



Extended Data Fig. 7

Depth resolution test along the MAR with three different 1-D velocity models. (**a**) Bathymetric map and located events. (**b**) A reduced velocity model by -0.1 km/s (red), an increased velocity model by +0.1 km/s (blue), and the final velocity model (black) are constructed. (**c-d**) The focal depth distribution of earthquakes along the profile (aa′) in (**a**). The other labeling is the same as that in Extended Data Fig. 6.

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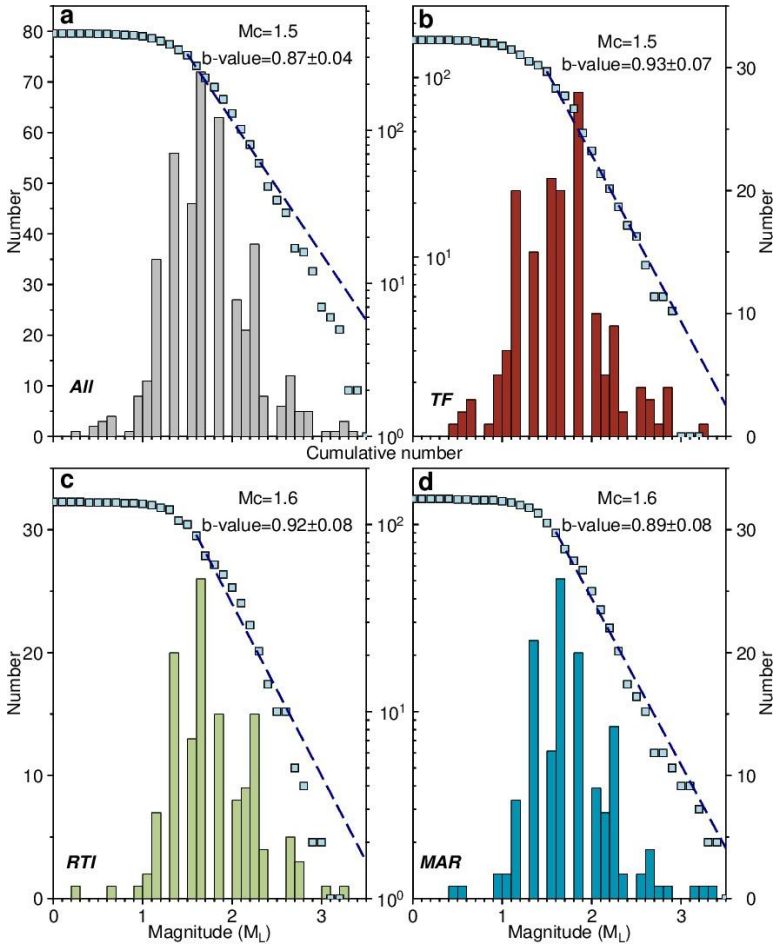

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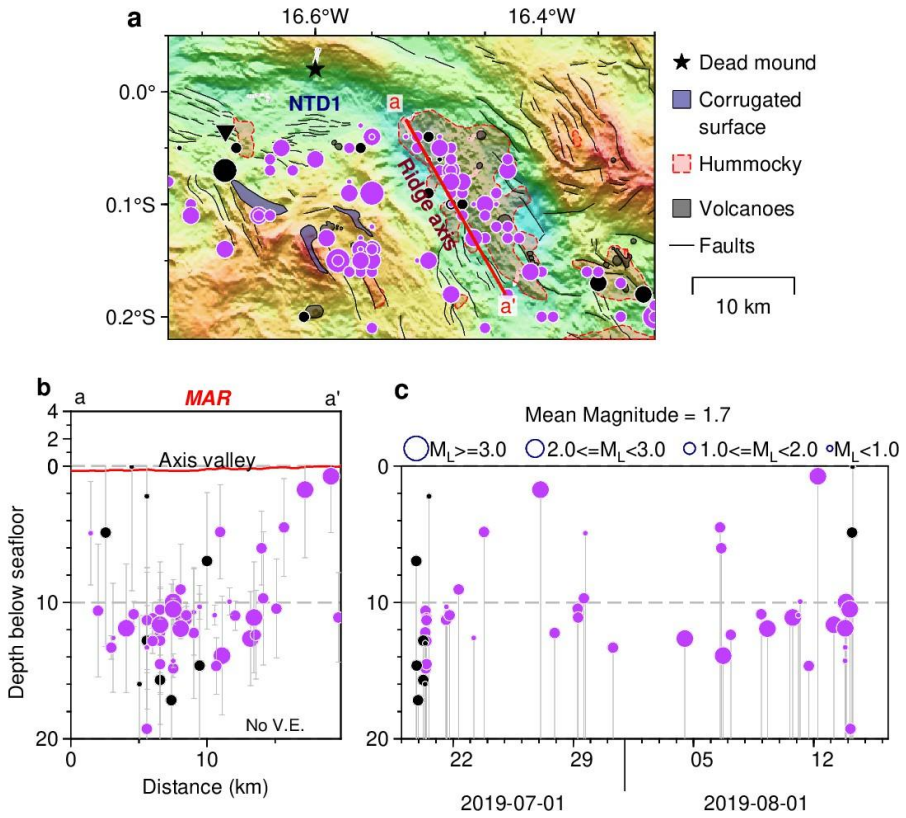
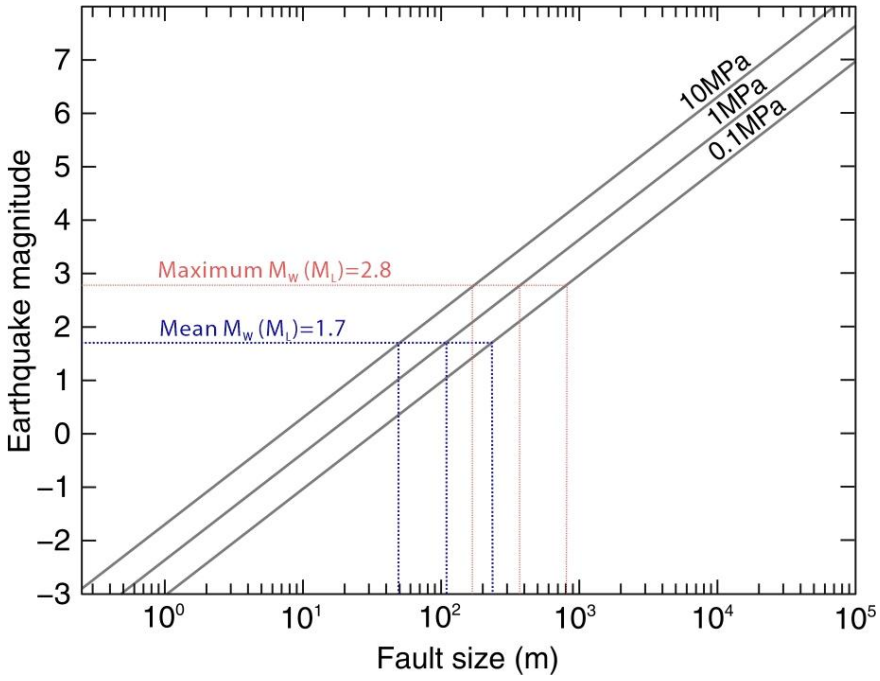
79 **Extended Data Fig. 8**

80 **Histograms of local magnitudes (M_L).** Earthquakes in the full catalog (**a**), along the
81 Romanche TF (**b**), in the RTI (**c**), and along the MAR (**d**) are shown in gray, red,
82 green, and blue columns, respectively. The cumulative number of events is marked by
83 blue squares on each map. Catalogs are analyzed using the ZMAP software[50] to obtain
84 the magnitude completeness (M_C) and B-values.



Extended Data Fig. 9

Seismicity, tectonic information, earthquake temporal distribution along the MAR. (**a**) Bathymetric map, events, and geological information. Hummocky seafloor and volcanic cones are shown in red and gray shades, respectively. One transect along the ridge axis is shown in (**b**). Triangles mark the deployed OBSs. (**b**) The cross-section of earthquakes. (**c**) The focal depth distribution of earthquakes as a function of dates from 19 July to 16 August 2019. Magnitude scales are shown on the top.



Extended Data Fig. 10

Scale relationships between fault length and magnitude were modified from Ref.[55,56]. Three thick lines indicate stress drops ranging from 0.1 MPa to 10 MPa. In this study, the averaged magnitude (M_L ~1.7) of the axial mantle earthquakes (Extended Data Fig. 9) is shown in dashed blue lines, assuming moment magnitude M_w=M_L for small events[54], leading to the fault size ranging between 50 m and 200 m. The dashed red lines indicate the fault sizes for the maximum M_w of 2.8.