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Supporting Information for

**Mechanism for normal faulting in the subducting plate at the Mariana trench**

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**Introduction**

This supporting information includes description of the basic modeling method, supplementary illustrations of modeling results, and the data source of high-resolution multibeam bathymetry.

Text S1. Basics of models

At each point, the FLAC method solves a mass balance equation [*Cundall*, 1989],

and a stress balance equation

where *νi* is nodal velocity in the *xi* direction, *ρ* is density, *σij* is stress tensor, and *gi* is gravitational acceleration.

Yielding of the elasto-plastic material follows the Mohr-Coulomb failure criterion given by *Jaeger and Cook* [1979],

where *τ* is shear stress, *μ* is friction coefficient, *σn* is normal stress, and *C* is cohesion, which is dependent on plastic strain *εps*.

Following the approach of *Buck and Poliakov* [1998], *Poliakov and Buck* [1998], and *Lavier et al.* [2000], we assume the cohesion is reduced with increasing plastic strain:

where *C0* is initial cohesion for brittle material, *C1* is remaining cohesion when totally yielded, and *εc* is the characteristic plastic strain that controls the slope of cohesion reduction.

The rheological behavior of viscous material follows non-Newtonian power-law rheology given by *Chen and Morgan* [1990], which depends on temperature and strain rate,

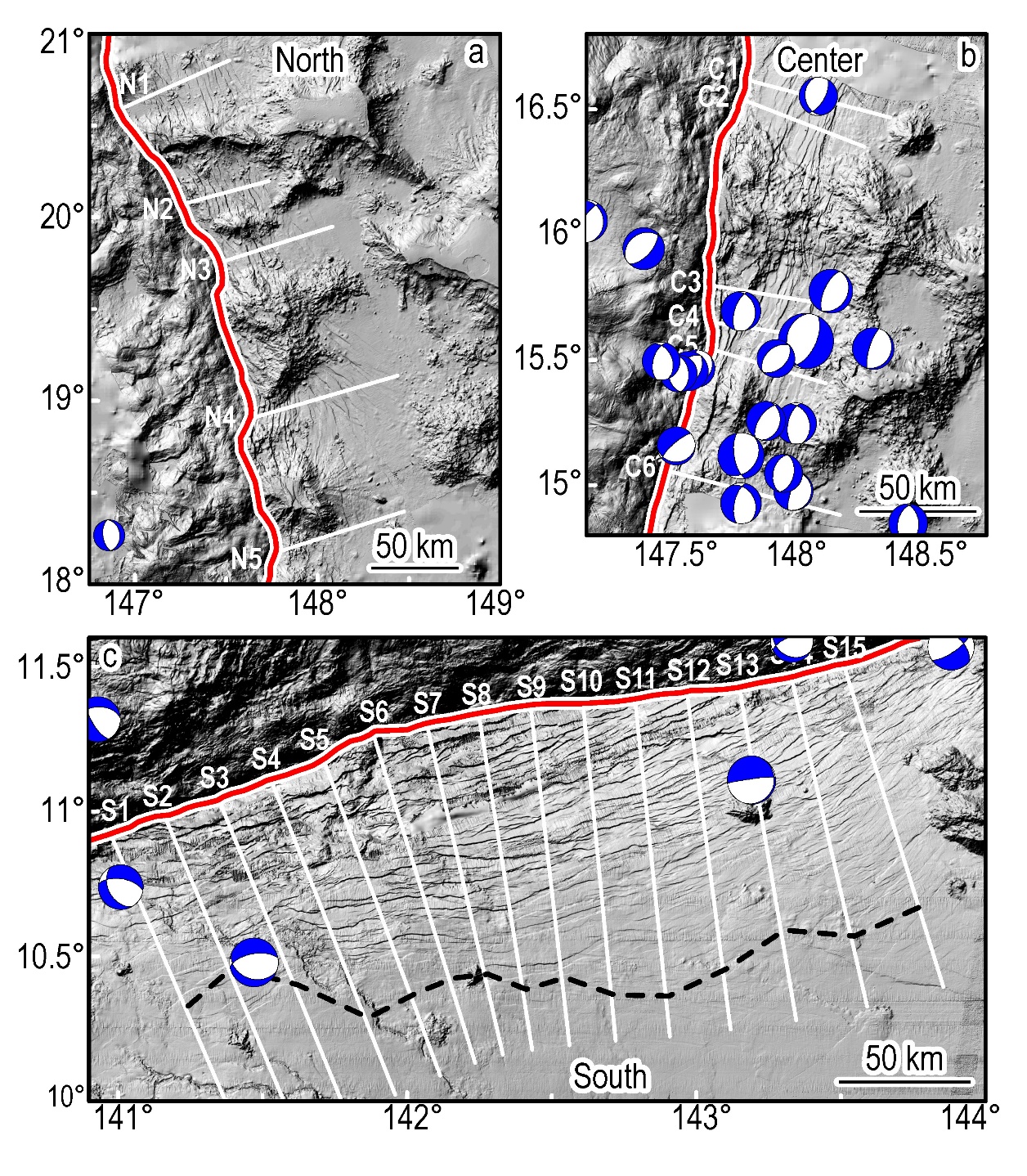
where , is the second invariant of the strain rate tensor, *A* is pre-exponential factor, *n* is creep exponent, *Q* is activation energy, *R* is gas constant, and *T* is temperature.

Text S2. Effect of horizontal tensional force on calculated normal faulting characteristics

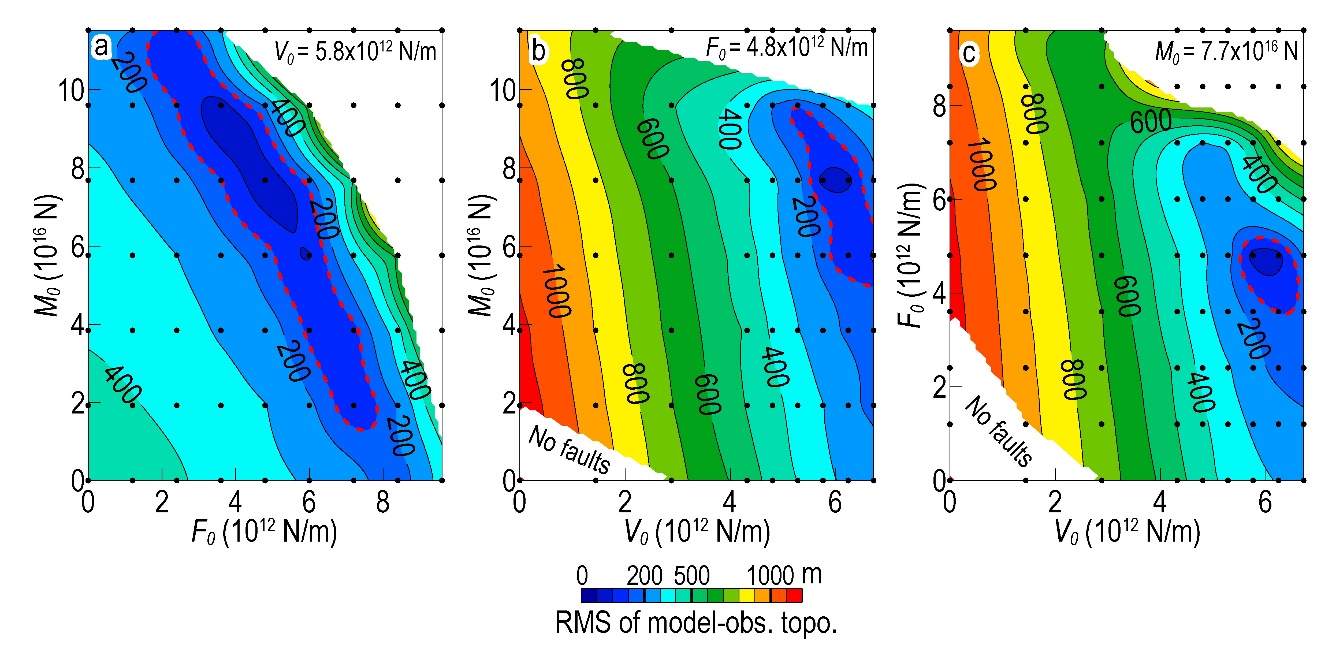
Model results suggest that when the horizontal tensional force *F0* increases, the distance of maximum fault throw is calculated to move towards the trench axis (Figure S3a). This implies that *F0* could help to concentrate normal faults towards the trench axis. The observed distance of maximum fault throw is 10-35 km from the trench axis for the southern Mariana trench (Figure S3b). Panel b shows that best-fitting models without *F0*, which can explain well the calculated non-isostatic topography, but can not explain the observed distance of maximum fault throw of the southern Mariana trench. In contrast, best-fitting models with *F0* can explain the calculated non-isostatic topography as well as the distance of maximum fault throw.

Text S3. Source of high-resolution multibeam bathymetry data

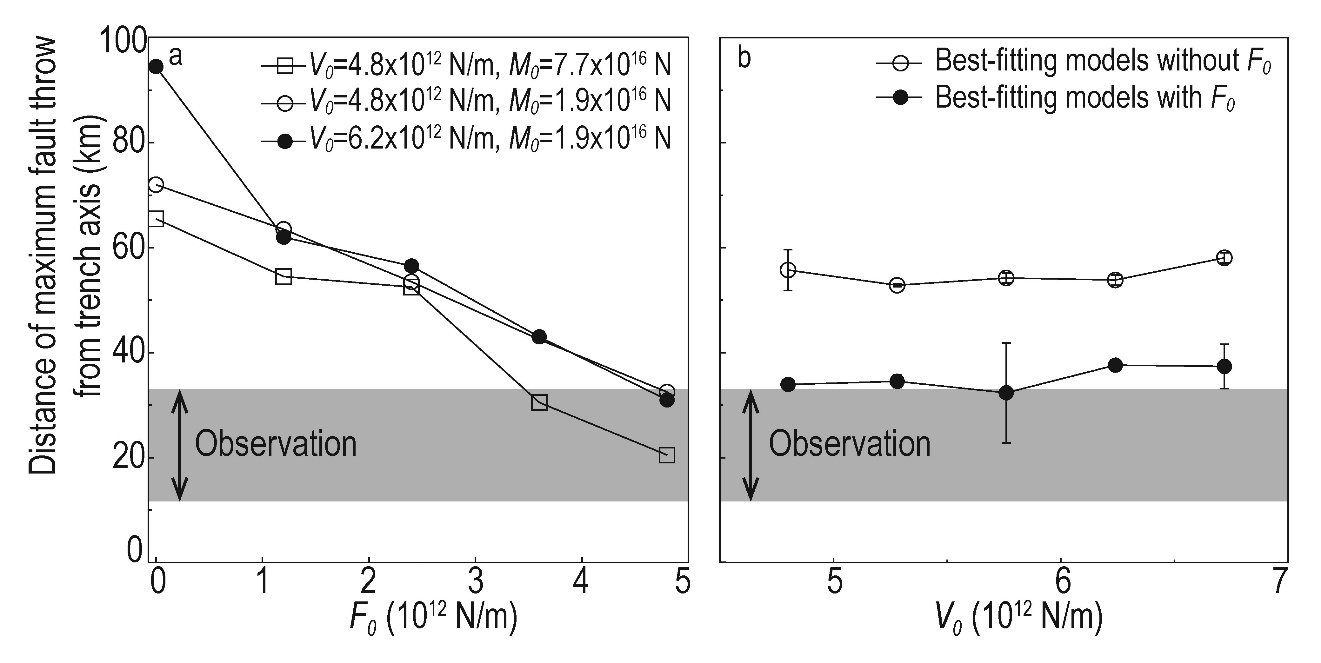
The high-resolution bathymetry data are downloaded from the National Geophysical Data Center (NGDC, *http://www.ngdc.noaa.gov*) and Global Multi-Resolution Topography Synthesis (GMRT) [*Ryan et al.*, 2009].

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**Figure S1.** Shade maps of topography illustrating normal faults at the northern, central, and southern Mariana trench. Locations of these three regions are marked by dashed boxes in Figure 1a. Red lines show trench axes. White lines show across-trench profiles for analysis. Black dashed lines in panel c show the approximate location of the central part of the outer-rise region, which was determined from the shallowest point on across-trench profiles of non-isostatic topography. Blue beach balls show normal faulting earthquake focal mechanisms from Global CMT (*http://www.globalcmt.org*)for events with magnitude greater than Mw 4.5.



**Figure S2.** RMS between the calculated non-isostatic topography and model topography as a function of applied tectonic forcing.



**Figure S3.** (a) Distance of maximum fault throw as a function of *F0* for fixed *V0* and *M0* values. (b) Distance of maximum fault throw as a function of *V0* for best-fitting models with and without *F0*. Grey columns indicate the observed distance of maximum fault throw from the trench axis at the southern Mariana trench.

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