Sediment Pathways Across Trench Slopes: Results from Numerical Modeling

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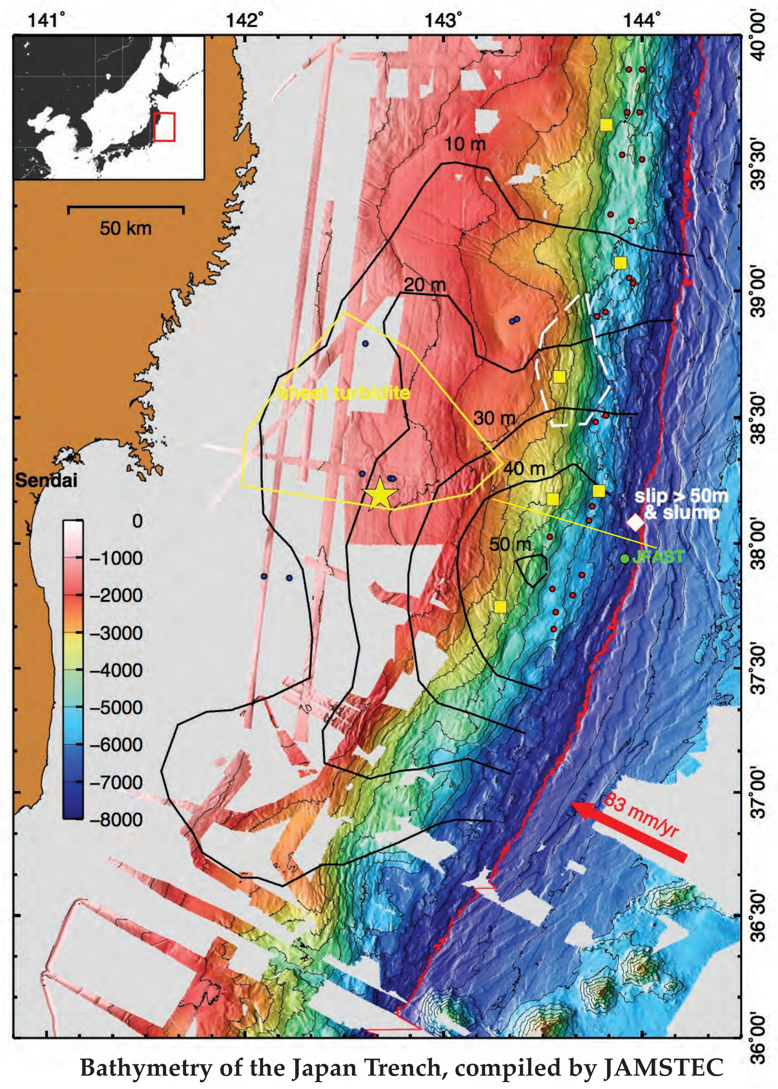
MOTIVATION

Until the 2011 Mw9.0 Tohoku earthquake, the role of giant tsunamis and earthquakes as agents of sediment dispersal and accumulation across erosional trench slopes was under-appreciated. Decades of seismic reflection surveys and sediment coring did document a general sedimentation pattern: Terrigenous sediments accumulate across the trench slope as a slope apron less than 1km-thick, whereas sediments at the trench axis are either accreted to the small frontal wedge, or subducted (2). A series of cruises carried out after the 2011 earthquake and tsunami revealed a variety of unsuspected sediment dispersal mechanisms, such as tsunami-triggered sheet turbidites (1). Furthermore, new piston cores collected across the trench slope indicate significant along-trench and across-trench variability in the way that sediments were mobilized by the 2011 event. Hence, the combined dataset suggests that giant earthquakes and tsunamis may be important agents for dispersing sediments across the trench slope.

To complement these new observational data, we modeled the pathways of sediments across various trench slopes (4, 5, 6, 7). The resulting maps provide snapshots of possible sediment sources and depocenters. They can be used to optimally position sediment cores and sample deposits from reccurring megathrust earthquakes.

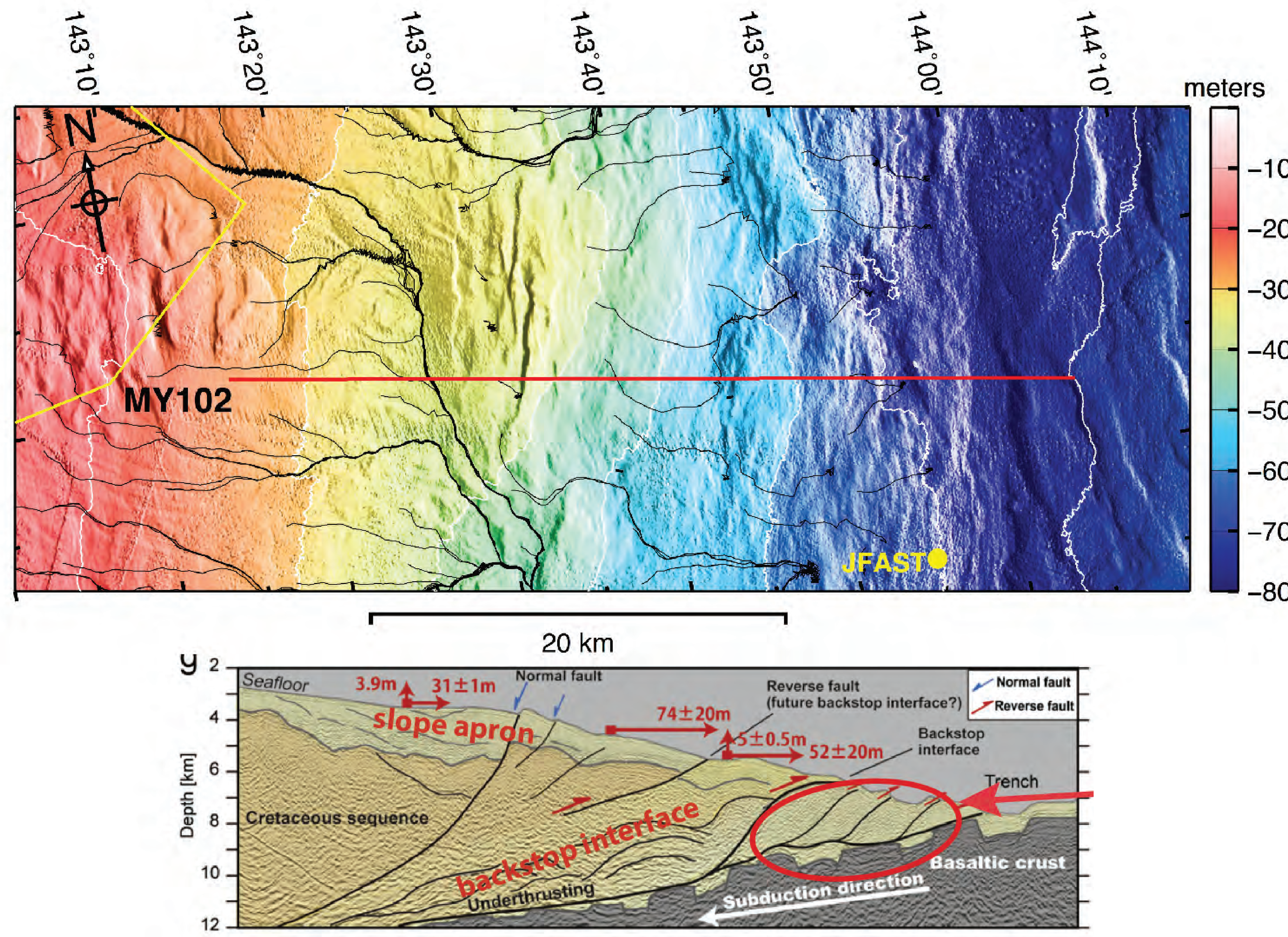
1



Bathymetry of the Japan Trench, compiled by JAMSTEC

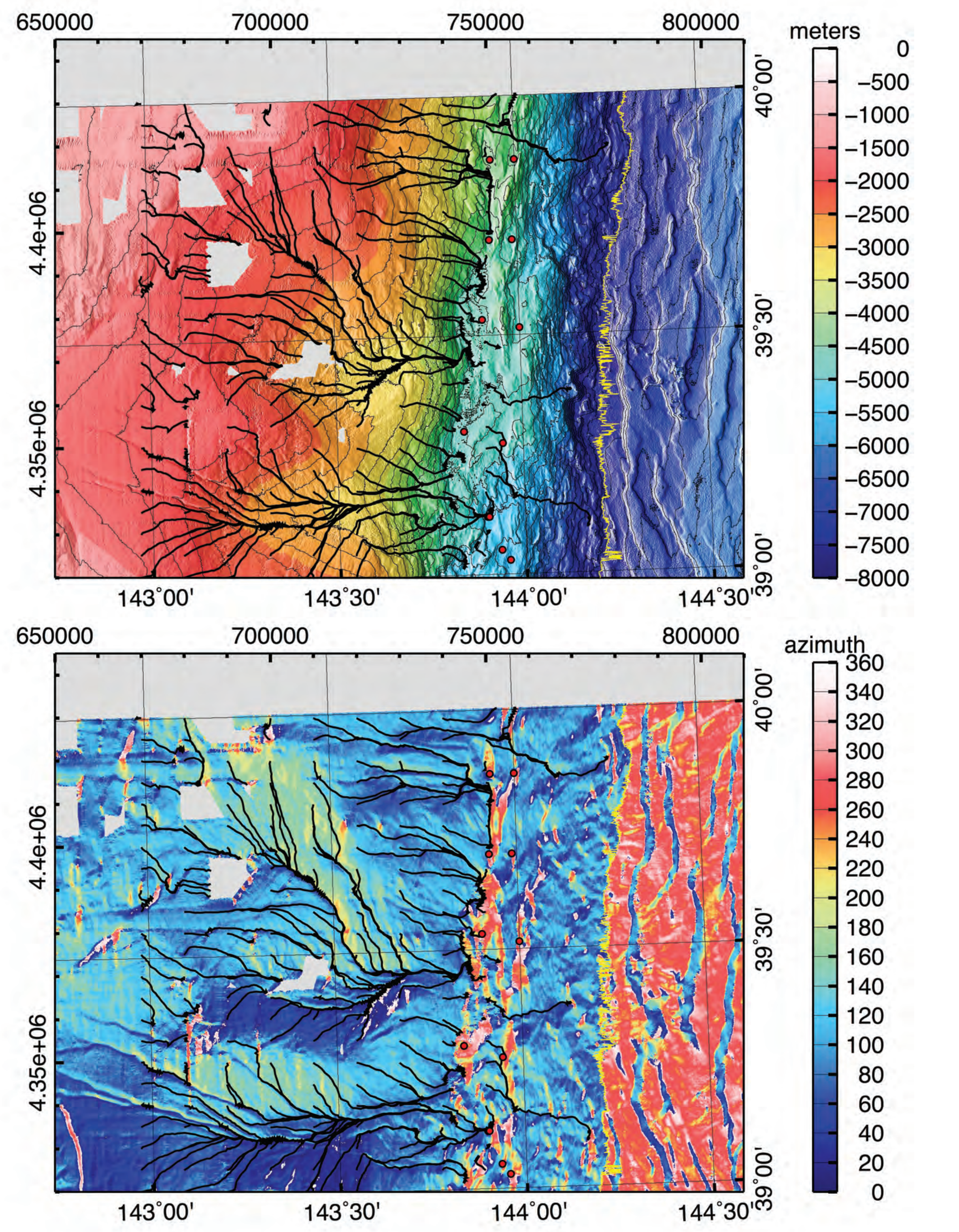
Yellow star: Epicenter of the 2011 Mw9.0 earthquake.
Thick black contours: Slip distribution [*Yagi & Fukahata, GRL 2011*].
White diamond: Documented fault slip at trench axis > 50 m [*Fujiwara et al., Science, 2011*].
Yellow squares: 2011 changes documented by submersible & cameras [*Tsuji et al., EPSL 2013*].
Yellow polygon: Documented tsunami-triggered sheet turbidite [*Arai et al., Geology 2014*].
Yellow line: location of seismic profile displayed at right.
Dashed white polygon: Possible tsunamigenic marine slide [*Kawamura et al., GRL 2012*].
Blue & red dots: Piston cores, 2013 *R/V NATSUSHIMA* expeditions.
Green dot: IODP site, cored after the 2011 earthquake.

2



Top. Bathymetry of the Japan Trench in the area of maximum fault slip on March 11. 2011
Red line: location of seismic profile displayed below. Black lines: Modeled downslope pathways.
Bottom: Seismic profile across the trench slope, interpreted by *Tsuji et al. [EPSL, 2013]*.
(red arrows: Coseismic displacements from seafloor observatory)

3



METHOD (3)

Pathways are modeled based on the assumption that transport direction is simply controlled by the slope azimuth.

The algorithm we developed comprises the following steps:
- Median filter (width: 1000m) is applied to bathymetric grid;
- Slope azimuth is derived from the bathymetric grid (3);
- Modeled pathways initiate at arbitray positions arranged on a regular grid pattern (red dots in 5, 6; yellow dots in 7)
- Successive downslope positions are extrapolated in the direction of slope azimuth at distance increment of 600 m - 1,000 m.

The optimal distance increments were determined by trial-and-error. However, they are compatible with the known behavior of turibiditic flows, which may step over 1 km-scale obstacles.

←

Bottom. Modeled pathways (black lines) overlaid on slope azimuths, as derived from the multibeam bathymetric grid.

Top: Modeled pathways (black lines) overlaid on bathymetry
Red dots: Location of piston cores collected in 2013 with the *R/V NATSUSHIMA*

RESULTS (4, 5, 6, 7)

4. JAPAN TRENCH

Most pathways issued from the shelf and upper slope terminate near the top of the small frontal wedge, and thus do not reach the trench axis. In turn, sediments transported to the trench axis are mostly derived from the small frontal wedge or from the subducting Pacific plate. There exists very few direct pathways from the shelf area to the trench. These results are consistent with existing seismic profiles across the trench slope (2), which reveal that the slope apron does not extend as far as the frontal wedge, and that the sediment fill in the trench is surprisingly thin (= similar to the sediment cover on the incoming plate).

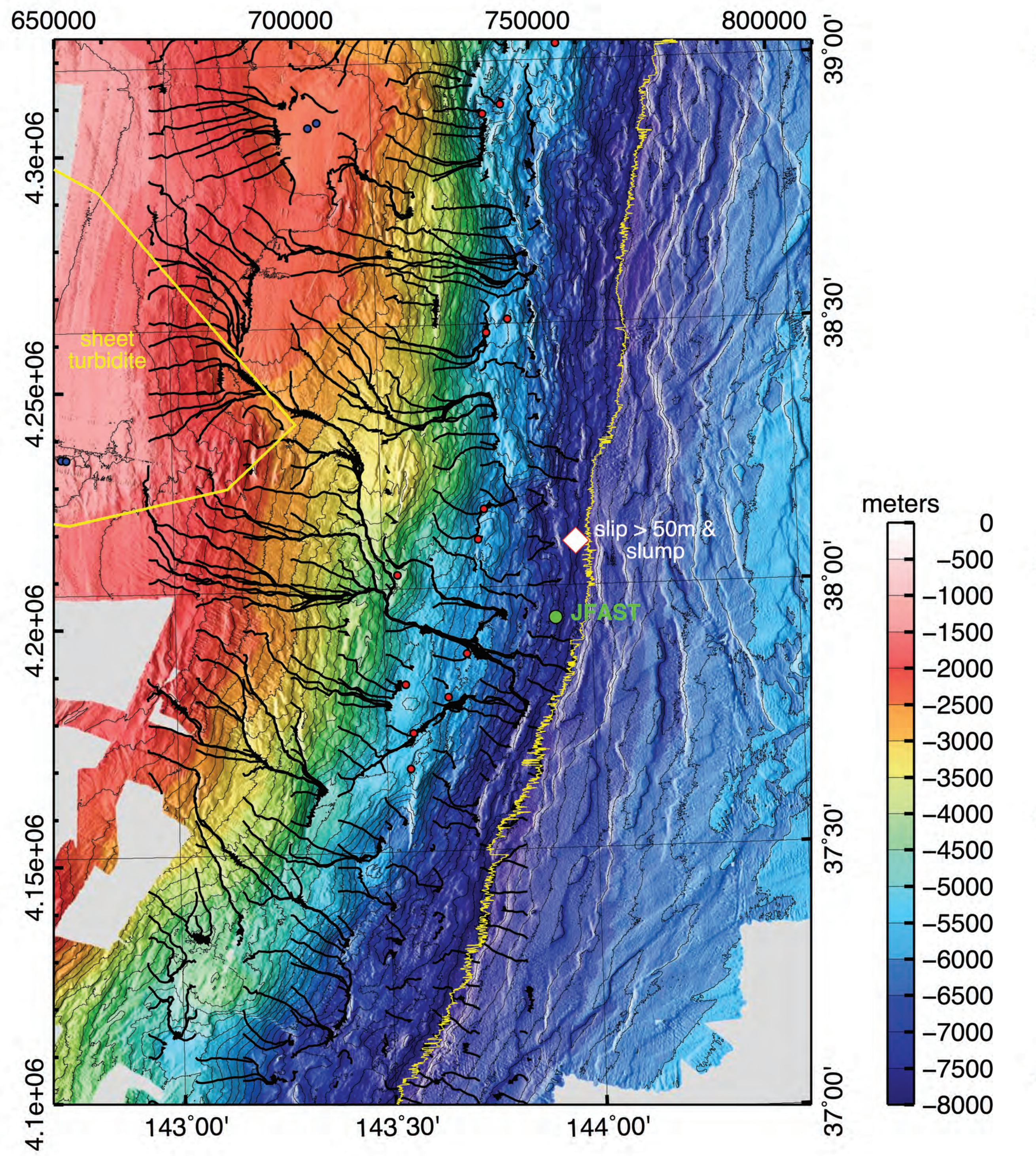
OTHER TRENCHES (5, 6, 7)

The same method has been applied to Cascadia Trench (5), Middle-America Trench (6), and Sunda Trench (7), three other trenches with adequate multibeam bathymetric coverage. Although local minima may artificially terminate modeled pathways, the overall patterns appear to be realistic.

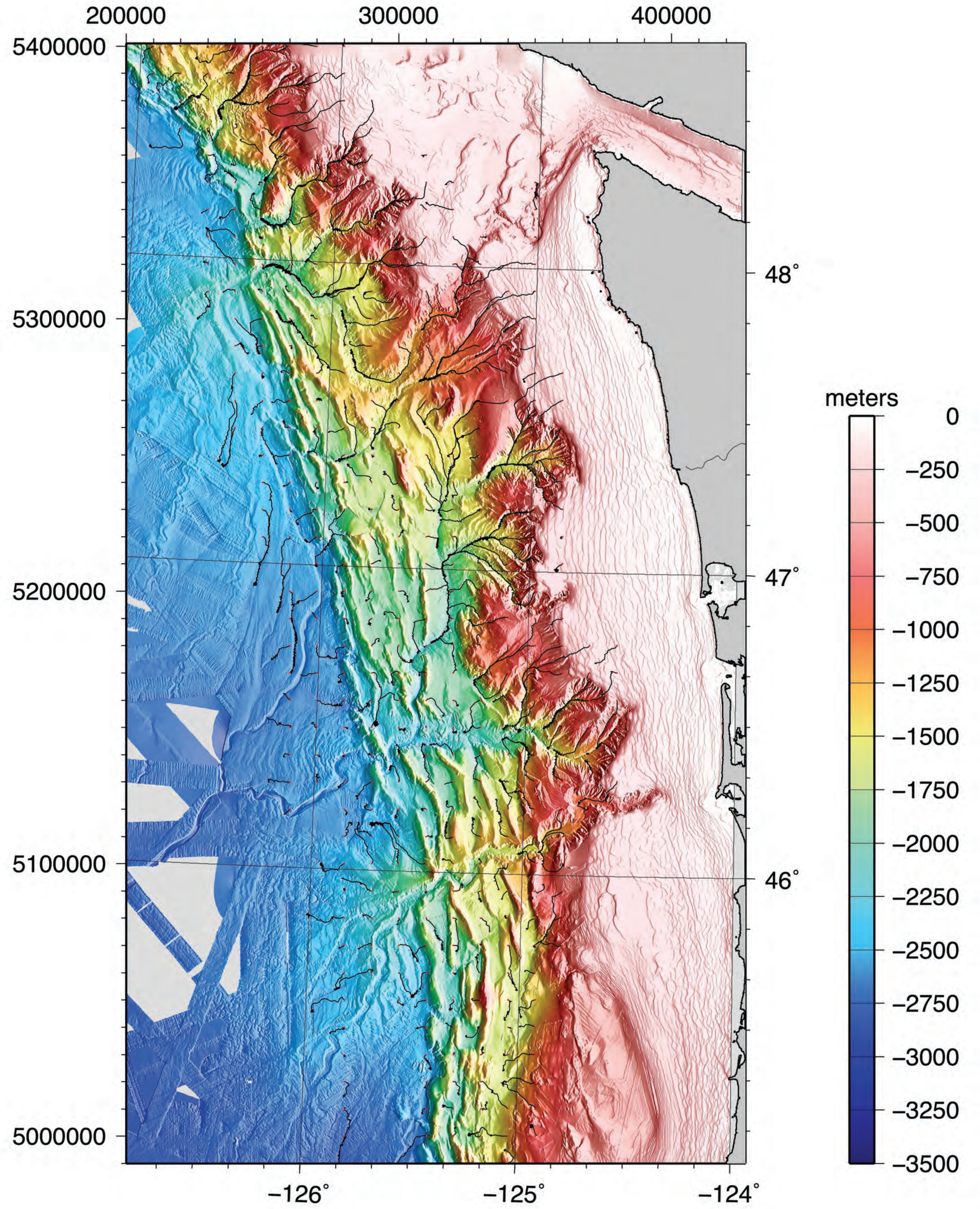
For the Cascadia and Middle-America trenches (5 and 6), sediments from the upper slope can readily find pathways to the trench through the numerous canyons. Some slope basins on the accretionary prism (Cascadia) or narrow frontal wedge (Costa Rica) are isolated from this canyon drainage systems. Their sediment infill is thus likely to be locally-derived. **Turbidites in these isolated basins may record seismic activity only - exclusive of storm and flood activity. This would make them ideal targets for paleoseimological studies.**

For the Sunda Trench (7), only a few canyons provide pathways to the trench axis and slope basins must be fed by locally-derived sediments.

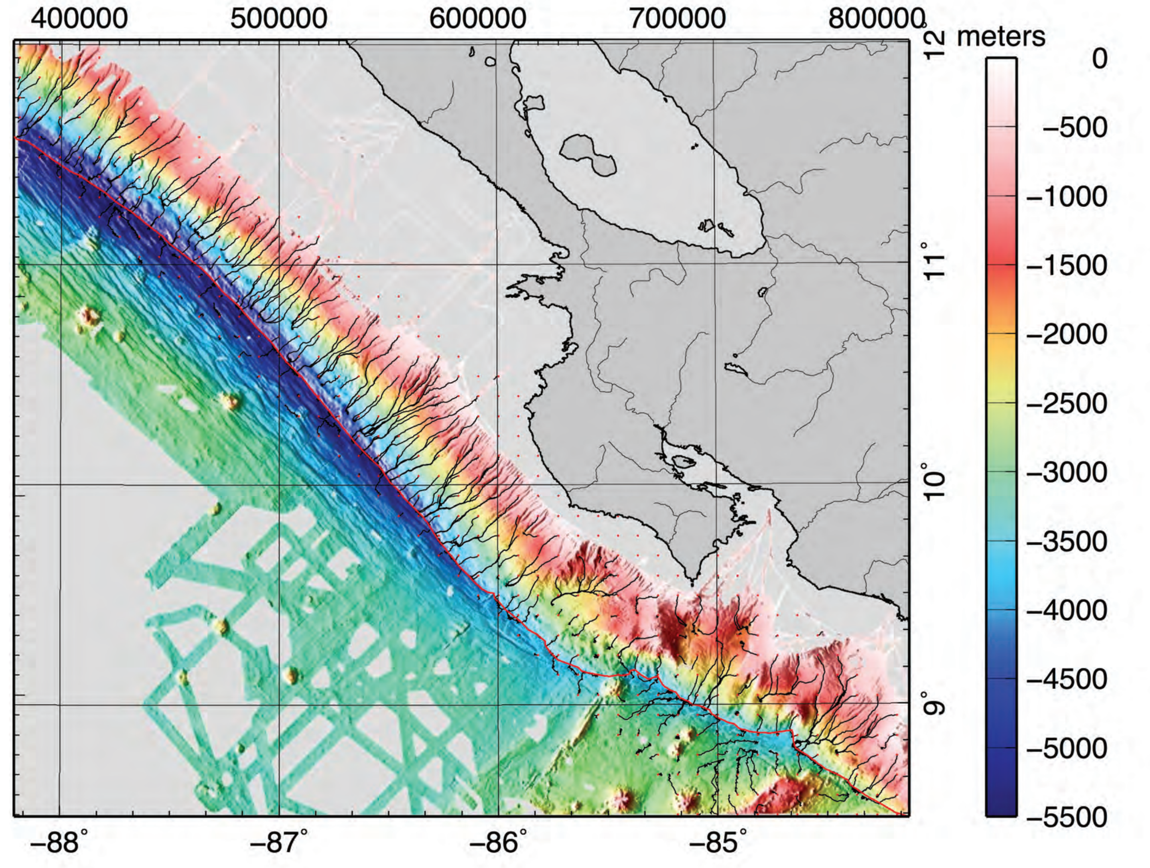
4 JAPAN TRENCH



5 CASCADIA



6 COSTA RICA



7 SUMATRA