Supporting information for:

Surficial sediment remobilization by shear between sediment and water above tsunamigenic megathrust ruptures: experimental study

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Text S1: Physical experiments set up

The physical experiments were carried out at St Anthony Falls Laboratory (University of Minnesota, Minneapolis). The element that mimics the seafloor subjected to earthquake motions consists of a rigid transparent rectangular duct (1 m-long, 0.2 m-high and 0.1 m-wide) closed at the top (Fig. 2a). This duct is mounted on a rigid frame connected to an offset shaft and motor that can shake it with periodic vertical motion at frequencies of 1-10 Hz and peak accelerations up to 1.5 g. The peak-to-peak amplitude (d) of the shaking can be 20.65 or 31.75 mm and is fixed in each run. Thus, the acceleration (a) is set by adjusting the shaking frequency (f), calculated from:

$$a = d * (2\pi f)^2$$

The duct is filled with water above a 0.07 m-thick sediment layer at the bottom. Above the top of the sediment, the ends of the duct are open and connected by flexible pipes to a water reservoir (Fig. 2b) that delivers a steady flow with a velocity up to 1 m/s above the sediment while both sediment and water in the duct are subjected to vertical shaking. The flow is set electronically and measured by a flowmeter sensor. Based on more than fifty calibration tests the flow error is mostly < 5 %. The main observational data are high-resolution video images obtained from two cameras fixed on the side and top of the shaking frame downstream from inlet distortions of the flow (Fig. 2c). Bed topography is scanned with a laser tool before and after each run.

We started with well-sorted sands, to study the impact of vertical shaking on sediment whose entrainment is well understood. Then, we used more complex mixtures of fine sand, silt and clay-size bentonite sediment. We used: 1) fine sand (13% >250µm; 250> 77% >125µm; 125µm> 10%); 2) industrial silt from Zeeospheres LLC (called Grey Silt N800), which mainly consists of coarse/medium silt (although 10% of this sediment has a grain size > 63 µm); and 3) clay-size bentonite sediment. The bentonite belongs to the smectite clay group and is characterized by high water absorption. The sediment was placed in the duct without compaction but with a flattened surface up to the lower level of the pipes delivering the water.

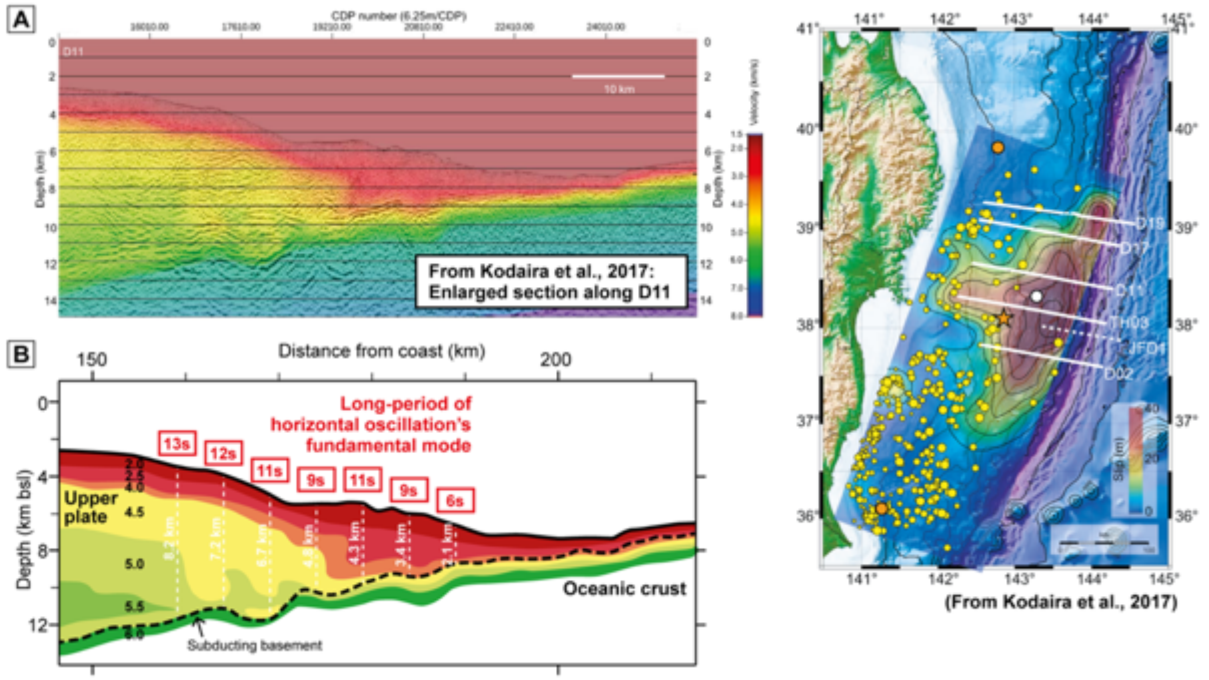

Figure S1: The horizontal oscillation's fundamental mode is modeled as a horizontally polarized ¼ wavelength S-wave with a node at the top of the subducting oceanic basement and a maximum amplitude at the top of the forearc wedge. The periods are calculated from the weighted average of S-wave velocities, Vs, obtained from the pre-stack depth migration interval P-wave velocities (Vp) in profile D11 (Kodaira et al., 2017) and the standard Vs = Vp/1.74. Given high fluid content and overpressure in the upper plate from the subducted sediment this value of Vs is likely an overestimate, leading to an underestimate of the periods.

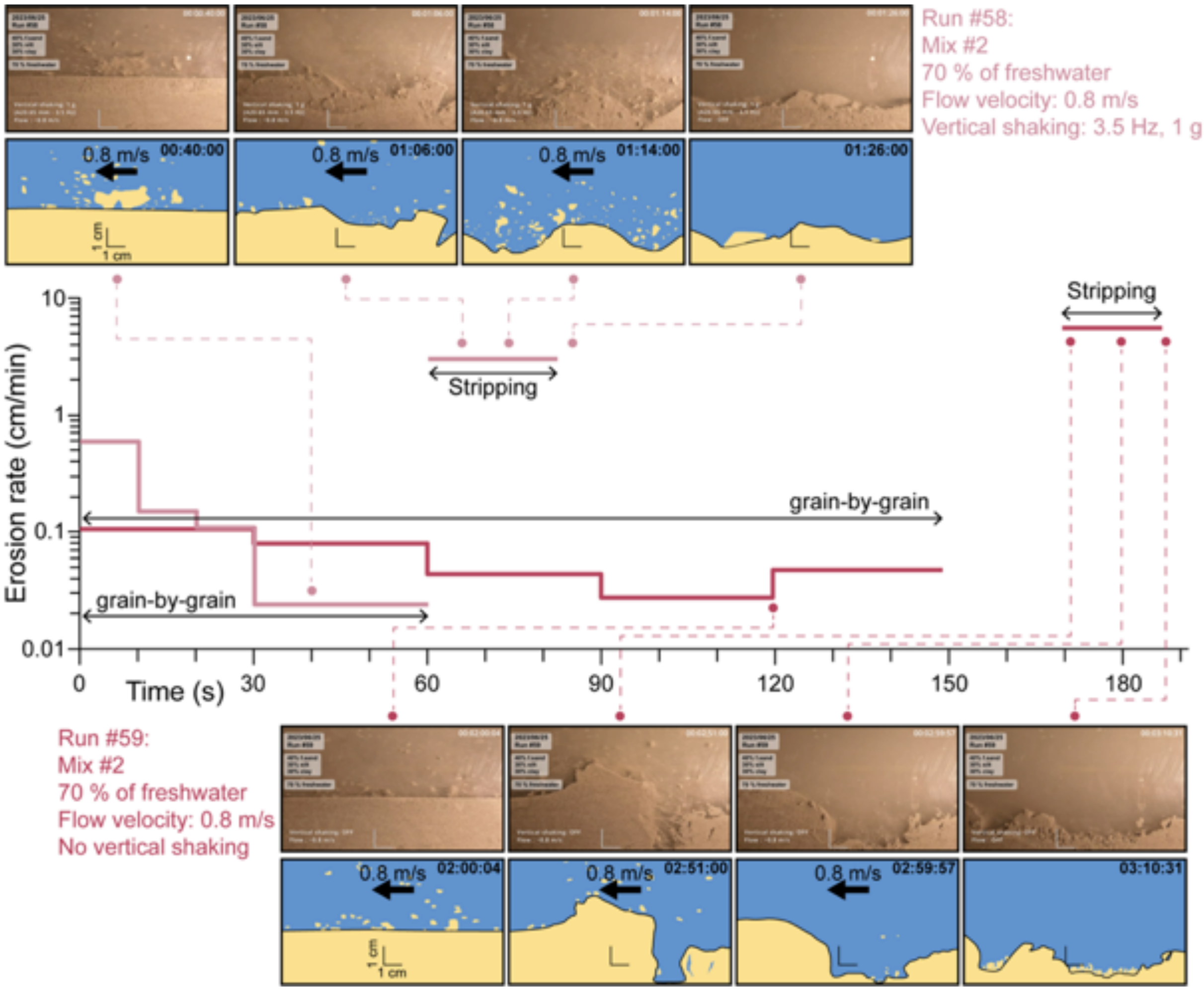

Figure S2: Evolution of the erosion rate of Mix #2 sediment with 70 % of fresh water under a flow velocity of 0.8 m/s without vertical shaking (Run #59, dark pink) and with a vertical shaking at 1 g (Run #58, light pink). The photos and their interpretative cartoons highlight different steps of runs; the black arrow gives flow direction.

Table S1: Composition of the sediment mixtures (the % are for the dry fraction) and water (freshwater or sea water).

	Fine Sand (%)	Silt (%)	Clay (%)	Water
Mix #1	10	40	40	Freshwater
Mix #2	40	35	35	Freshwater
Mix #3	40	35	35	Sea water

Table S2: Information for the Figure 3.

Mixture	Run #	Water content (%)	Flow velocity (m/s)	Shaking acceleration (g)	Run timing (min)	Erosion rate (cm/min)			Entrainement
						Topography profiles	From video records		
							Grain-by-grain	Stripping	
Mix #1	2	50	1	0	10	-	0.036		Suspension, Bedload
	5	50	1	1	10	0.02	0.045		Suspension, Bedload, clumps' entrainments
	10	60	1	0	10	0.01	0.036		Suspension, Bedload
	24	70	1	1	10	0.02	0.03		Suspension, Bedload
Mix #2	46	50	1	0	10	0.01	0.008		Suspension, Bedload
	50	50	1	1	10	0.015	0.029		Suspension, Bedload
	52	60	1	0	10	0.02	0.023		Suspension, Bedload, clumps' entrainments
	54	60	1	1	10	0.015	0.013		Suspension, Bedload, clumps' entrainments
	59	70	0.8	0	3.12	0.66	0.08	0.54	Suspension, Bedload, clumps' entrainments
	58	70	0.8	1	1.4	1.34	0.18	1.30	Suspension, Bedload, clumps' entrainments
	60	70	1	1	1.5	-		4.60	Suspension, Bedload, clumps' entrainments
	64	80	0.5	0	2	0.95	0.84		Suspension, Bedload, clumps' entrainments, sediment waves (?)
	65	80	0.5	1	2	1.15	0.95		Suspension, Bedload, clumps' entrainments, waves (?)
Mix #3	67	70	0.5	0	3	0.88		0.77	Suspension, Bedload, clumps' entrainments
	69	70	0.5	1	1.5	-		3	Suspension, Bedload, clumps' entrainments

Kodaira, S., Nakamura, Y., Yamamoto, Y., Obana, K., Fujie, G., No, T., ... & Miura, S. (2017). Depth-varying structural characters in the rupture zone of the 2011 Tohoku-oki earthquake. *Geosphere*, *13*(5), 1408-1424.