Electronic Supplement to

Source Parameter Scaling and the Cascadia Paleoseismic Record

by Anne M. Tréhu

This electronic supplement contains figures and a table summarizing the total and asperity areas for the model of Lorito *et al.* (2012) for the 2010 Maule, Chile, earthquake.

Table S1 summarizes the source parameters for the different models presented in this article to enable the reader to reproduce the figures that summarize the data points used by Somerville *et al.* (2015) to derive scaling parameters for large subduction zone earthquakes.

Figure S1 summarizes the data used by Somerville *et al.* (2015) and illustrates the estimated total and asperity areas for the model of Lorito *et al.* (2012) for the 2010 Maule, Chile, earthquake. Results for four different published finite-fault solutions for the Maule event are also shown to illustrate the scatter due to the use of different algorithms. When several finite-slip models were available, Somerville *et al.* (2015) used their discretion to choose one model; the model chosen for the Maule earthquake is indicated.

Figure S2 shows area and slip solutions versus moment for a new database of plate-boundary thrust earthquake finite-slip solutions that became available while this article was in final review (Ye *et al.*, 2016). In this article, 114 events were reanalyzed using a consistent methodology, and a variety of interrelated source parameters were derived and discussed. The effective area estimates shown here were trimmed to satisfy the constraint that the static stress drop equal the stress drop derived from energy considerations. See Ye *et al.* (2016) for a comprehensive discussion of scaling parameters and their derivation, uncertainties, and trade-off among parameters. The implied scaling between effective area and moment is somewhat more scattered than that derived by Somerville *et al.* (2015). However, the data follow the same slope and fall between the lines defined by Somerville *et al.* (2015), based on total area or average slip and asperity area or average asperity slip.

Figure S2b also shows slip versus moment, based on an estimate of nondimensional turbidite mass (determined from the turbidite thickness and density) as a proxy for moment, as proposed by Goldfinger *et al.* (2012). This is an alternative method of estimating moment based exclusively on the turbidite data. This model for reconstructing the paleoearthquake history was not included in the original article because it does not provide an estimate of the slip area and includes only type A events (i.e., full margin ruptures). It is included in this supplement with the following assumptions to derive area and slip. Event age and nondimensional mass were digitized from figure 60 of Goldfinger *et al.* (2012). Seismic moment was determined from the nondimensional mass by assuming a linear relationship between turbidite mass and moment and setting M_w for the 1700 event to 8.75 (implying M_w 9.19 for the largest event on this scale, T16). If M_w for the 1700 earthquake is set to 9.0, all moments increase by a factor of 2.425, and T16 has M_w 9.45.

In Figure S2a, closed circles are areas for model CA12 and open circles are areas for the CL model. In Figure S2b, open circles represent slip calculated based on the time to the next event for events T18–T2, and black dots represent slip calculated based on the time since the previous event for events T17a–T1. A plate convergence rate of 36 mm/yr was assumed. If stress drop is controlled, at least in part, by local geology, this is unlikely. As noted by Goldfinger *et al.* (2012), calculating slip from the time to the following event yields a slight trend of increasing slip with increasing moment, whereas slips calculated based on the time since the previous event do not show a correlation between moment and slip, which was interpreted as supporting a time-predictable model for earthquake recurrence. The area versus moment relationship spans the entire range of stress drops indicated for modern earthquakes, and the slips are generally larger for a given moment than for modern earthquakes. If earthquake rupture dynamics are, at least in part, controlled by geologic factors, we might expect less variation in scaling relationships and stress drops for a particular region than is included in a global data set that includes all subduction zones.

Figure S3 compares the moments derived for all type A events for several models. Type A events are those with a whole-number ID in Table S1, plus event 17a. See the main article for a discussion of the constraints on and assumptions behind models CA12a, CA14, and CL. Event T17a (Table S1) is plotted as 18; event T18 is plotted as 19 in Figure S3. Model CL shows the least variation in derived moment. There are significant differences between models CA12a and the turbidite mass model, especially prior to event T10 (age 4.6 ka). Table S1 contains the source dimensions, slip, moment, and moment magnitude used to generate Figures 3–5 of the main article.

Figures

Figure S1. (a) Slip model of Lorito *et al.* (2011) for the M_w 8.8 Maule, Chile, earthquake of 2010 compared with the total area (black dashed line) and asperity area (white dashed line) derived from this model by Somerville *et al.* (2015). (b) Total area and asperity area derived by Somerville *et al.* (2015) from published slip models. To illustrate the scatter among models derived by different research groups, results are shown for four different models for the Maule earthquake; the model shown in (a) is circled. (c) Average slip and average slip on asperities from Somerville *et al.* (2015). The selected model for the 2012 Tohoku earthquake is highlighted by a dashed oval, showing the unusually large slip compared to rupture area for this event.

Figure S2. (a) Area versus moment for the subduction-zone earthquake database of Ye *et al.* (2016). The best-fit total area and asperity area lines derived by Somerville *et al.* (2015), and the area versus moment relationships implied by the turbidite mass approach of Goldfinger *et al.* (2012) to estimating the area of type A events are also shown (black dots, model CA12; circles, model CL). (b) Slip versus moment for Ye *et al.* (2016) database and for the turbidite mass model, assuming a linear relationship between turbidite mass and moment and M_w 8.75 for the earthquake of 1700. Circles show slip calculated from the time to the following event for events T18–T2; black dots show slip calculated from the time since the previous event for events T17a–T1. These represent time-predictable and slip-predictable models, respectively, as discussed by Goldfinger *et al.* (2012).

Figure S3. Seismic moment derived for the turbidite mass model assuming a linear relationship between turbidite mass and moment and calibrated assuming M_w 8.75 or 9.00 for the Cascadia earthquake of 1700 compared with several of the models discussed in the article.

Table

Table S1 [plain-text Comma-separated Values; ~7 KB]**.** Fault parameters for the six models discussed in this article. Event IDs in column 2 are from Goldfinger *et al.* (2012). Effective width and slip for model CA14 were calculated as described in the text. Area for model CLmod2 is the same as the area for model CL. A shear modulus of 40 GPa was assumed for the moment (M_0) calculation for models except for CA12a, for which 30 GPa was assumed. Moment magnitude $M_w = \log(M_0)/1.5 - 6.0667$, with M_0 in newton-meters.

References

Goldfinger, C., C. H. Nelson, A. Morey, J. E. Johnson, J. Gutierrez-Pastor, A. T. Eriksson, E. Karabanov, J. Patton, E. Gracia, R. Enkin, A. Dallimore, *et al.* (2012). Turbidite event history: Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone, *U.S. Geol. Surv. Profess. Pap. 1661-F*, U.S. Geological Survey, Reston, Virginia, 332 pp.

Lorito, S., F. Romano, S. Atzori, X. Tong, A. Avalone, J. McCloskey, M. Cocco, E. Boschi, and A. Piatanesi (2011). Limited overlap between the seismic gap and coseismic slip of the great 2010 Chile earthquake, *Nat. Geosci.* **4,** 173–177, doi: 10.1038/ngeo1073.

Somerville, P., A. Skarlatoudis, and H. K. Thio (2015). Source scaling relations of subduction earthquakes for strong ground motion and tsunami prediction, *Final Rept., U.S. Geol. Surv. Award G13AP00028*, 25 pp.

Ye, L., T. Lay, H. Kanamori, and L. Rivera (2016). Rupture characteristics of major and great ($M_w \geq 7.0$) megathrust earthquakes from 1990 to 2015: 1. Source parameter scaling relationships, *J. Geophys. Res.* **121,** no. 2, 826–844, doi: 10.1002/2015JB012426.

[**Back**]