Scaling relations of seismic moment and rupture area for outer-rise earthquake

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Outer-rise normal fault earthquakes are rare phenomena compared to subduction thrust earthquakes. Nonetheless, some of them have generated destructive tsunamis in the past, such as the 1933 Sanriku-oki earthquake, the 1977 Sumbawa earthquake, and the 2009 Samoa earthquake. Because outer-rise earthquakes tend to occur after a giant megathrust earthquake, large outer-rise earthquakes similar to the 1933 Sanriku-oki earthquake have been a concern after the 2011 Tohoku-oki earthquake. The scaling relationship plays a vital role in establishing a link between fault geometry and earthquake magnitude (e.g. Alvarez-Gomez et al 2012; Goda et al 2016). In previous studies, outer-rise earthquakes have been included in the data sets for regression (Blaser et al 2010; Alvarez-Gomez et al 2012 and Goda et al 2016). However, the scaling relation from those studies, which are shown in Figure, are failed to predict the fault rupture areas of outer rise earthquakes.

In this study, a new piece-wise scaling relation for rupture area (S) and seismic moment (M_0) was obtained for outer-rise earthquakes using data compiled from previous seismological studies. Twenty sets of S and M_0 pairs for ten earthquakes from independent studies were used for regression analysis. The compiled source parameters directly taken from previous literature were examined carefully based on the purpose of the studies to ensure that rupture area dimensions represent the "actual" rupture area. The rupture areas of the finite fault slip models were also examined carefully, and the dimensions of each model are estimated based on the definition of the autocorrelation width (Bracewell 1986).

Because the fault width, except for the 1933 Sanriku-oki earthquake, is perhaps not saturated, the entire dataset can be fit by a scaling relation with a slope of 2/3 (i.e. the rupture area is proportional to two-thirds the power of seismic moment). Due to the lack of data for large earthquakes whose fault width are saturated, the slope cannot be constrained for those earthquakes. The sparse data problem can be partially overcome by adopting a physically-based method using the circular crack model (Kanamori and Anderson 1975) and fault width saturated model, which sets the regression parameter b a priori.

To estimate rupture areas of outer-rise earthquakes whose fault down dip tips, respectively, do and do not reach the oceanic lithosphere base, regression parameter b in $S=(M_0/a)^{1/b}$ is 2 with the corresponding regression parameter $\log_{10}(a_2)$ being 1.402± 0.250, and b is 1.5 with the corresponding regression parameter $\log_{10}(a_1)$ being 6.401± 0.187. I Unlike the relation with a single slope, which is adopted by previous studies, the piece-wise scaling relation developed in this study can fit outer-rise earthquake data from Mw 7.2 to Mw 8.4 and also provides better estimation for the outer-rise earthquakes larger than the 1933 Sanriku-oki earthquake (Mw 8.4).

Reference

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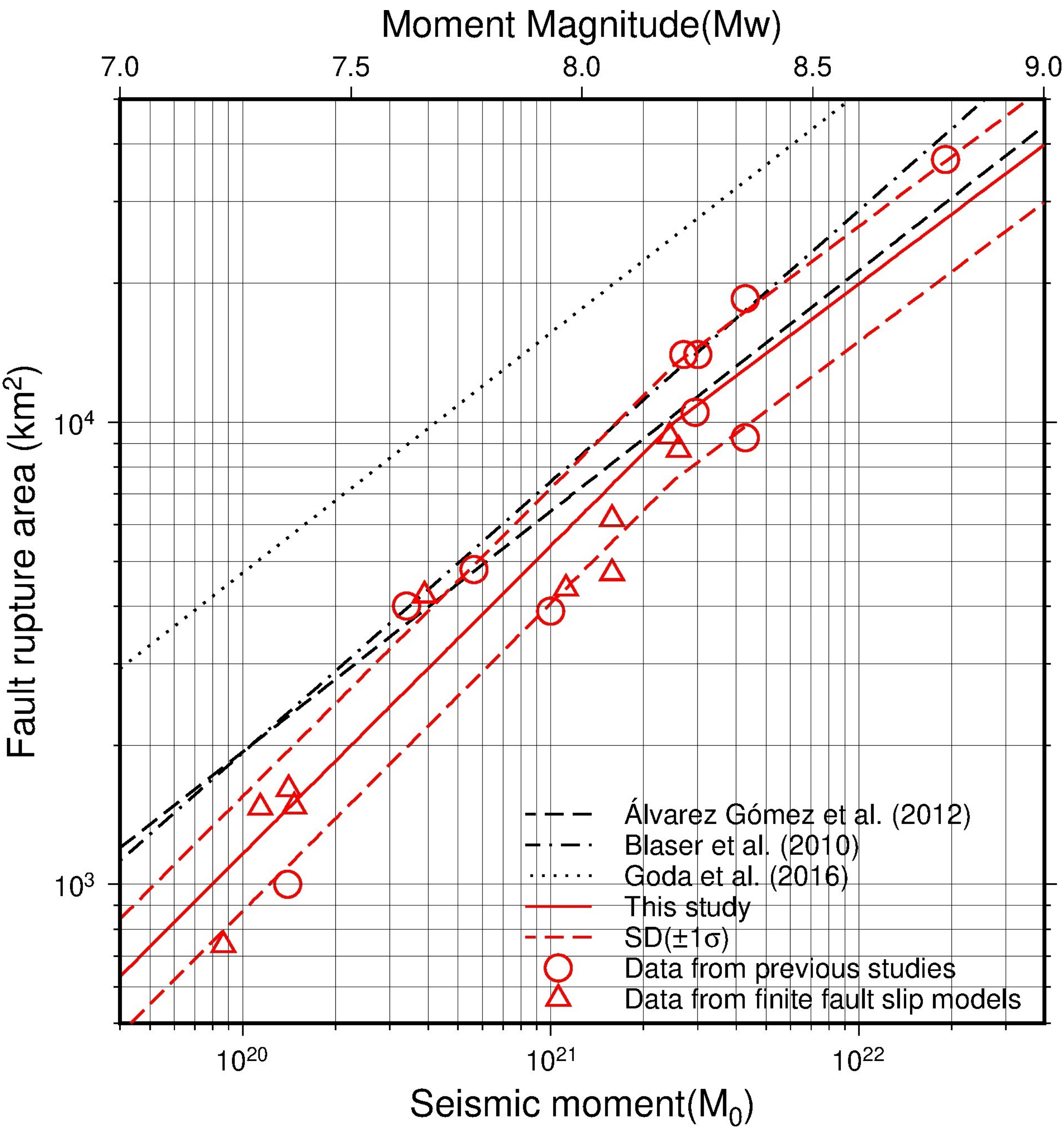
Moment Magnitude(Mw)
7.0
7.5
8.0
8.5
9.0
Fault rupture area (km2)
10^4
10^3
10^20
10^21
10^22
Seismic moment(M0)
Álvarez Gómez et al. (2012)
Blaser et al. (2010)
Goda et al. (2016)
This study
SD(±1σ)
Data from previous studies
Data from finite fault slip models