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Methods

Finite-Element Model

To calculate the stress in the forearc, we use a plane-strain finite-element model of an elastic upper plate and a rigid lower plate in frictional contact following earlier studies (Dielforder & Hampel, 2021; Wang & He, 1999; Wang et al., 2019). The models are created and calculated using the commercial software ABAQUS (version 6.14). The basic model setup, boundary conditions, and material parameters are shown in Figure S1. All models are meshed using linear triangular elements with an average element edge length of ~2 km. ABAQUS computes the total stress in the elastic upper plate, which results from all applied boundary conditions, including gravity, isostasy, and friction along the plate interface. The gravitational force is calculated for a gravitational acceleration g = 9.81 m s-2 and densities of 2,800 and 3,300 kg m-3 for crustal and mantle parts, respectively. Seawater load is modeled using a pressure boundary condition, with values determined from seawater density (1,025 kg m-3) and depth. Friction is calculated for standard Coulomb friction by displacing the lower plate, such that the shear stress along the contact τ depends on friction coefficient μ' and normal stress σ_n ($\tau = \mu'\sigma_n$). Using the friction law allows us to describe the shear stress along the megathrust in a consistent manner.

The frictional contact comprises different parts of the plate interface. The upper section of the interface represents the seismogenic megathrust and comprises weakening and strengthening segments to allow for a coseismic decrease and increase in shear stress, respectively.

The models for the various transects analysed account for the site-specific forearc topography, seawater load, interface geometry, and crustal thickness. The forearc topography is approximated by the mean elevation, that we calculated along 100-km-wide swath profiles from the ETOPO1 global relief model using TopoToolbox for MATLAB. The interface geometry has been adopted from the Slab2 (Hayes et al. 2018) model by fitting an arc with constant curvature through the upper 100 km of the slab model.

Stress drop estimates

To calculate earthquake source parameters, we estimate the displacement spectral amplitude using Thomson's multitaper method (Thomson, 1982) from S-wave windows starting 0.2 sec before the arrival and containing 90%, 80%, and 70% of the energy at a specific station within a hypocentral distance of 25 km, 25 - 50km, and ≥ 50 km, respectively (Pacor et al., 2016). We ensure that each spectrum has a signal-to-noise ratio (SNR) ≥ 3 in a magnitude-dependent frequency band. We define the frequency band for a particular event by calculating corner frequencies corresponding to theoretical stress drop values of 0.01 and 1000 MPa, that we use as lower and upper-frequency limits, respectively. We then fit the spectra (i.e., single spectra fitting) using a trust-region-reflective minimization algorithm (Newville et al. 2014), with the following analytical expression:

$$\Omega_t(f) = \frac{\Omega_0 \, e^{-(\pi f t / Q)}}{\left[1 + \left(f / f_c\right)^{\gamma n}\right]^{1/\gamma}}$$

where Ω_0 is the long-period spectral amplitude, f is the spectral frequency, t is the travel time, Q is the quality factor, f_c is the corner frequency, and n is the high-frequency falloff rate (Brune 1970; Boatwright 1980). We use a spectral shape constant γ equal to 2 (Boatwright-model), which fits well most of the spectra. We then calculate the seismic moment (M_0) using the fitted Ω_0 values as follows:

$$M_0 = \frac{4\pi\rho c^3 R \Omega_0}{U_{\phi\theta}}$$

where ϱ is the density (kg m^{-3}), c is the S-wave velocity at the depth of the hypocentre (m s^{-1}), R is the station-event hypocentral distance, and $U_{\phi\theta}$ is the mean radiation pattern for S-waves (Madariaga 1976). We used S-wave velocities from existing local velocity models for Japan (VJMA2001, https://www.data.jma.go.jp/svd/eqev/data/bulletin/catalog/appendix/trtime/trt_e.html), Central Chile (Haberland et al., 2006) and Northern Chile (Graeber & Asch, 1999). We then calculate mean values and 95% confidence intervals for a particular event using a delete-one jackknife-mean (Prieto et al. 2006) when at least five station S-wave estimates are available.

Non-source related terms such site and path effects can bias the f_c estimate and the final stress drop estimates. To ensure as accurate as possible f_c estimates, we also use a spectral ratio approach. The ratio between two co-located event spectra at a specific station cancels possible site and path effects and allows high-quality f_c estimates from one or both events in the pair, depending on the frequency range of high SNR (Bakun & Bufe, 1975). To obtain event pairs, we cross-correlate 3-component full waveforms of events within 5 km hypocentral distance and retain event pairs with a cross-correlation coefficient ≥ 0.7 and a magnitude difference ≥ 0.5. An 0.5 magnitude difference ensures to select event pairs with f_c values differing enough to be resolved in the spectral ratio fitting. The displacement spectral ratio $\Omega_r(f)$ between the two event spectra can be written as:

$$\Omega_t(f) = \Omega_{0r}\left[\frac{1+\left(f/f_{c2}\right)^{\gamma n}}{1+\left(f/f_{c1}\right)^{\gamma n}}\right]^{1/\gamma}$$

where f_{c1} and f_{c2} are the corner frequencies of the larger magnitude target and the smaller magnitude empirical Green's function events (eGf), respectively. The spectral shape constant γ, as in the case of single spectra fits, is set to 2, as it results in better spectral ratio fits. We require at least five S-wave station ratios for individual event pairs, manually review the spectral ratio fits to ensure high quality, and check whether f_{c1} and f_{c2} or only f_{c1} could be resolved.

We use M_0 values from single spectra and f_c values either from single spectra or spectral ratio analysis to calculate stress drop values ($\Delta\sigma$) assuming a circular crack model with radius r (Eshelby 1957):

$$r = \frac{k\beta}{f_{c1}}$$

$$\Delta\sigma = \frac{7}{16}\frac{M_0}{r^3}$$

where β is the shear wave velocity at the hypocentral depth and k is a constant set to 0.26 assuming a symmetrical circular model with a rupture velocity of 0.8 β (Kaneko & Shearer, 2015).

We calculate moment magnitudes (M_w) using the M_0 values from S-wave single spectra and observe a good fitting with respect to the magnitude values reported in the initial catalogs. We do not consider events with $M_w \leq 3$ as we observe a systematic trend of lower stress drop values for these events. The trend of lower stress drops for lower magnitudes (*fc* ~> 10-15 Hz) is likely related to decreasing SNR values with magnitude and frequency and to bandwidth limitations of the 100 Hz seismometers. In case of events for which we obtain both the spectral estimates, we associate the spectral ratio stress drop value to event.

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