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Physics of Megathrust Earthquakes: Introduction

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Subduction zones represent a key element of plate tectonics, whereby oceanic plates are recycled in the mantle and volatiles are expelled to the atmosphere, contributing to many facets of the Earth system, including seafloor spreading, continental drift, landscape formation, and some important climate forcing factors. Because the subducting plate shaves the bottom of the continental crust at low angle, a large area is available to faulting. Hence, subduction zones create the largest earthquakes on our planet, often associated with devastating tsunamis. The earthquake phenomenon fascinates because of the sudden devastation that it brings and the hidden mysteries of the subsurface. The physics of earthquakes is complicated to the extreme, but a recent realization in the scientific community is the inter-connectedness of the physical processes that contribute to earthquake generation. For example, the long quiescent period between large earthquakes sets the stage for several thermo-mechanical processes that play important roles in controlling the recurrence times and the characteristics of subsequent ruptures. This Physics of Megathrust Earthquakes Topical Issue of Pure and Applied Geophysics presents contributions discussing several important aspects of the seismic cycle at subduction zones.

First, the review by Okal (2018) in this issue presents a recount on how the familiar earthquake magnitude scale has been designed, and the multiple challenges associated with assigning a magnitude to remote earthquakes, based solely on records of the seismic waves that they generate. Lin et al. (2019) discuss a numerical method to calculate the static stress drop, another important earthquake rupture source property.

The next studies in this Topical Issue document the complexity of fault slip during the mostly quiescent period of the seismic cycle. Michel et al. (2018) describe the emergence of slow slip and slow earthquakes at the Cascadia subduction zone using long time series of geodetic data. Li et al. (2019) combine various geodetic data to document the spatial complementarity of seismic coupling with the rupture area of the 2015 Mw = 7.9 Gorkha, Nepal earthquake. Peña et al. (2019) investigate the quasi-static deformation that accrued for many years following one of the five largest instrumented earthquakes, the 2010 Mw = 8.8 Maule, Chile earthquake. Liu et al. (2018) provide sophisticated tools to investigate this kind of slow, distributed deformation at subduction zones. Shibazaki et al. (2019) investigate another facet of post-seismic deformation, focusing on the slow afterslip that spreads around the coseismic rupture of the 2011 Mw = 9.1 Tohoku-Oki, Japan megathrust earthquake.

The three following papers in this issue focus on the physics of megathrust earthquake ruptures by investigating the role of frictional properties on rupture style (Senatorski 2019), the role of geometrical segment boundaries on the down-dip segmentation of the megathrust (Ong et al. 2019), and the coupling between rupture propagation and tsunami generation (Lotto et al. 2018).

Last but not least, van Dinther et al. (2019) in this issue present sophisticated models of subduction zone dynamics that link the short-term seismic cycle with the long-term tectonic processes to argue for the presence of a secondary zone of uplift that can help understand the rheological structure of subduction zones.

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