



**University
of Victoria**

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

TIANHAOZHE SUN

BSc (Tongji University, 2011)

**“Crustal Deformation Association with Great Subduction
Earthquakes”**

School of Earth and Ocean Sciences

Thursday, July 20, 2017

2:00 P.M.

Bob Wright Centre

Room A319

Supervisory Committee:

Dr. Kelin Wang, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. George Spence, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Stan Dosso, School of Earth and Ocean Sciences, UVic (Member)
Dr. Michel Lefebvre, Department of Physics and Astronomy, Uvic (Outside Member)
Dr. Earl Davis, Pacific Geoscience Centre, Geological Survey of Canada (Additional Member)

External Examiner:

Dr. David Schmidt, Earth and Space Sciences, University of Washington

Chair of Oral Examination:

Dr. Janet Storch, School of Nursing, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The slip behaviour of subduction faults and the viscoelastic rheology of Earth's mantle govern crustal deformation throughout the subduction earthquake cycle. This Ph.D. dissertation presents research results on two topics: (1) coseismic and postseismic slip of the shallowest segment of subduction faults and (2) postseismic deformation following great subduction earthquakes controlled by mantle viscoelasticity.

Topic 1: Slip behaviour of the shallowest subduction faults. By modelling high-resolution cross-trench bathymetry surveys before and after the 2011 Mw 9.0 Tohoku-oki earthquake, we determine the magnitude and distribution of coseismic slip over the most near-trench 40 km of the Japan Trench megathrust. The inferred > 60 m average slip and a gentle increase by 5 m towards the trench over this distance indicate moderate degree of net coseismic weakening of the shallow fault. Using near-trench seafloor and sub-seafloor fluid pressure variations as strain indicators in conjunction with land-based geodetic measurements, we determine coseismic-slip and afterslip distributions of the 2012 Mw 7.6 Costa Rica earthquake. Here, trench-breaching slip similar to the Tohoku-oki rupture did not occur during the earthquake, but afterslip extended to the trench axis and reached ~ 0.7 m over 1.3 years after the earthquake, exhibiting a velocity-strengthening behaviour. These two contrasting examples bracket a possibly wide range of slip behaviour of the shallow megathrust. They help us understand why large tsunamis are generated by some but not all subduction earthquakes.

Topic 2: Postseismic deformation following great subduction earthquakes. Due to the asymmetry of megathrust rupture, with the upper plate undergoing greater coseismic tension than the incoming plate, viscoelastic stress relaxation causes the trench and land areas to move in opposite, opposing directions immediately after the earthquake. Seafloor geodetic measurements following the 2011 Tohoku-oki earthquake, modelled in this work, provided the first direct observational evidence for this effect. Systematic modelling studies in this work suggest that such viscoelastic opposing motion should be common to all $M_w \geq 8$ subduction earthquakes. As the effect of viscoelastic relaxation decays with time and the effect of fault relocking becomes increasingly dominant, the dividing boundary of the opposing motion continues to migrate away from the rupture area. Comparative studies of ten $8 \leq M_w \leq 9.5$ subduction earthquakes in this dissertation quantifies the primary role of earthquake size in controlling the "speed" of the evolution of this deformation. Larger earthquakes are followed by longer-lived opposing motion that affects a broader region of the upper plate.