Notice of the Final Oral Examination
for the Degree of Master of Science

of

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BSc (University of Alberta, 2011)

“Strength of Megathrust Faults: Insights from the 2011 M=9
Tohoku-oki Earthquake”

School of Earth and Ocean Sciences

Tuesday, August 18, 2015
1:30 P.M.
Bob Wright Centre
Room A319

Supervisory Committee:
Dr. Kelin Wang, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Prof. George Spence, School of Earth and Ocean Sciences, UVic (Co-Supervisor)
Dr. Stan Dosso, School of Earth and Ocean Sciences, UVic (Member)

External Examiner:
Dr. Yan Jiang, Pacific Geoscience Centre

Chair of Oral Examination:
Dr. Randy Scharien, Department of Geography, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

The state of stress in forearc regions depends on the balance of two competing factors: the plate coupling force which generates margin-normal compression, and the gravitational force, which generates margin-normal tension. Widespread reversal of the focal mechanisms of small earthquakes after the 2011 Tohoku-oki earthquake indicate a reversal in the dominant state of stress of the forearc; from compressive before the earthquake, to tensional afterwards. This implies that the plate coupling force dominated before the earthquake, and that the coseismic weakening of the fault lowered the amount of stress exerted on the forearc, such that the gravitational force became dominant in the post-seismic period. This change requires that the average stress drop along the fault represents a significant portion of the fault strength. Two cases are possible: (1) The fault was strong and the stress drop was large or nearly-complete (e.g. from 50 MPa to 10 MPa, or (2) that the fault was weak and the stress drop was small (e.g. from 15 MPa to 10 MPa. The first option appears to be consistent with the dramatic weakening associated to high-rate rock friction experiments, while the second option is consistent with seismological observations that large earthquakes are characterized by low average stress drops. In this work, we demonstrate that the second option is correct. A very weak fault, represented by an apparent co-efficient of friction of 0.032 is sufficient to put the Japan Trench forearc into margin-normal compression. Lowering this value by ~0.01 causes the reversal of the state of stress as observed after the earthquake. A slightly stronger fault, with a strength of 0.045, does not agree well with the observed spatial extent of normal faulting for the same coseismic reduction in strength. We also calculate distributions of stress change on the fault and average stress drop values for the Tohoku-oki earthquake, as predicted from 20 published rupture models which were constrained by seismic, tsunami, and geodetic data. Our results reconcile seismic observations that average stress drops for large megathrust events are low with laboratory work on high-rate weakening which predicts very high or complete stress drop. We find that, in all rupture models, regions of high stress drop (20 – 55 MPa) probably indicative of dynamic weakening during seismic slip, but that the heterogeneous nature of fault slip does not allow these regions to become widespread. Also, coseismic stress increase on the fault occurs in many part of the fault, including parts of the area that experienced high slip (> 30 m). These two factors ensure that the average stress drop remains low (< 5 MPa). The low average stress drop during the Tohoku earthquake, consistent with values reported for other large earthquakes, makes it unambiguous that the Japan Trench megathrust is very weak.