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Did differences in strength and frictional behaviour of subducted sediment constrain the rupture of the great 1960 Chile earthquake?

G. Roeser (1), J.H. Behrmann (2), A. Kopf (3)

(1) Geologisches Institut, Universität Freiburg, Freiburg, Germany, (georg.roeser@geologie.uni-freiburg.de / Phone: +49-761-2036503) (2) Marine Geodynamics, IFM-GEOMAR, Kiel, Germany, (3) RCOM, Universität Bremen, Bremen, Germany

The great 1960 Chile subduction thrust earthquake is the largest, ever instrumentally recorded earthquake on Earth. The 1000 km long coseismic rupture with a 20˚ eastward dip is located between the overriding South American and the downgoing Nazca plates between 37˚S and 46.5˚S. After a foreshock broke the segment between 37.03˚S and 38.74˚S, the rupture associated with the main shock one day later apparently propagated southward, and terminated near the Chile Triple Junction at 46.5˚S. The Southern Chile Trench is characterized by underthrusting and subduction of large amounts of terrigenic and hemipelagic sediments. Seismic reflection data show a thick layer of underthrust sediment, which is probably located between the overriding and downgoing plates at greater depth. Hence the mechanics of the seismogenic zone may be largely constrained by the strength and frictional behaviour of subducted sediment.

We have studied petrography and geotechnical behaviour of modern trench hemipelagics to document variations that might explain the nucleation and propagation pattern of the coseismic rupture. Samples between 36˚S and 46.5˚S are from gravity cores collected during R/V SONNE Cruises (SO181, SO156, SO102), as well as from ODP Leg 141 cores. Under the assumption that young sediments in the Southern Chile Trench with near-orthogonal subduction mirror material now located in the zone of coseismic rupture (requiring 1 Ma steady state of the system), we found the following. High-strain ring shear testing data show high shear strength (up to 8 MPa at 16 MPa effective normal stress) and high coefficients of friction (?g= 0.3-0.5) at the northern end of the studied trench segment. Both parameters decrease dramatically and system-

atically southward to values of 3 MPa at 16 MPa mean effective stress and ? as low as 0.15. At the southern termination of the rupture values abruptly increase to those seen at the northern end of the rupture. Quantitative X-ray diffraction petrography on the mostly fine-grained clayey silts shows that plagioclase content decreases southward (from over 50% to 35%) while quartz increases from 10% to 25%. Clay minerals and, more importantly, muscovite show a slight but systematic southward increase, which partly accounts for the observed decrease in μ and also favours enhanced pore pressures in the deeper subduction zone during mineral dehydration.

Whatever the exact cause for the observed variations in strength and frictional behaviour, we envisage a scenario where the great Chilean earthquake rupture of 1960 nucleated in an asperity zone caused by mechanically strong subducted sediment at 37˚S. Shearing then catastrophically propagated southward into a very wide weak zone almost 1000 km long, defining the extraordinarily large coseismic rupture. Rupture was apparently delimited by another zone of strong material at the latitude of the Chile Triple Junction.