GEODETIC CONSTRAINTS ON THE EARTHQUAKE CYCLE IN THE SOUTH ICELAND SEISMIC ZONE

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Abstract

The South Iceland Seismic Zone (SISZ) is an E-W transform zone that accommodates the relative plate spreading of the North American and Eurasian plates across southwest Iceland. The left-lateral E-W shear at depth (below ~15 km) is accommodated in the brittle crust by many parallel N-S structures that rupture in moderate size (M_S 6-7) earthquakes. An ongoing earthquake sequence in the SISZ started with two Mw=6.5 earthquakes in the eastern and central part of the zone on June 17 and 21, 2000. Fault models based on geodetic (GPS and satellite radar interferograms (InSAR)) observations indicate that the main shocks ruptured two 10-15 km long N-S right-lateral strike slip faults, spaced about 17 km apart, with most of the slip occurring above 10 km depth (Pedersen *et al.*, 2003). The geodetic fault models were used to calculate the co-seismic Coulomb Failure stress changes, which indicated positive stress changes likely to promote failure on faults in the western and eastern parts of the SISZ (Árnadóttir *et al.*, 2003). This was indeed the case when the June 2000 earthquake sequence continued with two Mw6 earthquakes on May 29, 2008 in the western part of the SISZ. Again, the two main shocks ruptured near parallel N-S vertical right-lateral strike slip faults. This time, however, the sequence was intense as the events occurred within 3 s of each other with a fault spacing of less than 5 km (Hreinsdóttir *et al.*, 2009).

Several GPS surveys have been conducted in SW Iceland since the initial measurements in 1986. Prior to the June 2000 earthquakes a sparse network was observed in 1992 and two more extensive surveys were conducted in 1995 and 1999. Annual campaigns have been conducted in SW Iceland since 2000. Since 1999 a network of continuous GPS stations has been rapidly growing, with several stations located in the SISZ. This geodetic dataset therefore provides the most complete set of observations of co- and post-seismic deformation in Iceland, as well as a glimpse of the plate-spreading signal (Árnadóttir *et al.*, 2008, and references therein). The measurements also capture deformation due to the intense seismic activity and uplift observed in the Hengill area in 1994-1998.

The GPS velocities have been used to construct a kinematic model of the plate boundary in southwest Iceland. The model indicates left-lateral deep slip rates varying from 18 mm/yr on the Reykjanes Peninsula to 20 mm/yr along the SISZ, with the locking depth increasing from ~5 km in the western part of the Reykjanes Peninsula to ~15 km in the eastern SISZ.

The geodetic observations following the June 2000 earthquakes indicate post-seismic transient deformation occurring on at least two different time scales. A rapid transient observed by InSAR in the epicentral area during the first two months after the June 2000 main shocks has been explained by poro-elastic rebound. A slower transient signal is observed by GPS indicating afterslip (most pronounced in the first year) below the co-seismic rupture and/or visco-elastic relaxation of the lower crust and upper mantle in response to the co-seismic stress changes. The optimal visco-elastic models have a lower crustal viscosity of 0.5-1 x 10^{19} Pa s and upper mantle viscosity of about 3 x 10^{18} Pa s. The visco-elastic model, indicating a strong lower crust and a weaker upper mantle, better explains the vertical deformation obtained from time series analysis of InSAR data spanning 2000-2005 than an afterslip model.

The geodetic models for the 2000 and 2008 earthquakes indicate that these events have only released about half of the geometric moment accumulated by plate spreading across the SISZ since the last major earthquake in 1912. Assuming that all the strain induced by plate spreading is released seismically we therefore need to enhance our monitoring of the RP and the SISZ in preparation of continued earthquake activity in the near future.

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