Stressing and breaking a single strong asperity: the Mw 8.2 2014 Northern Chile earthquake

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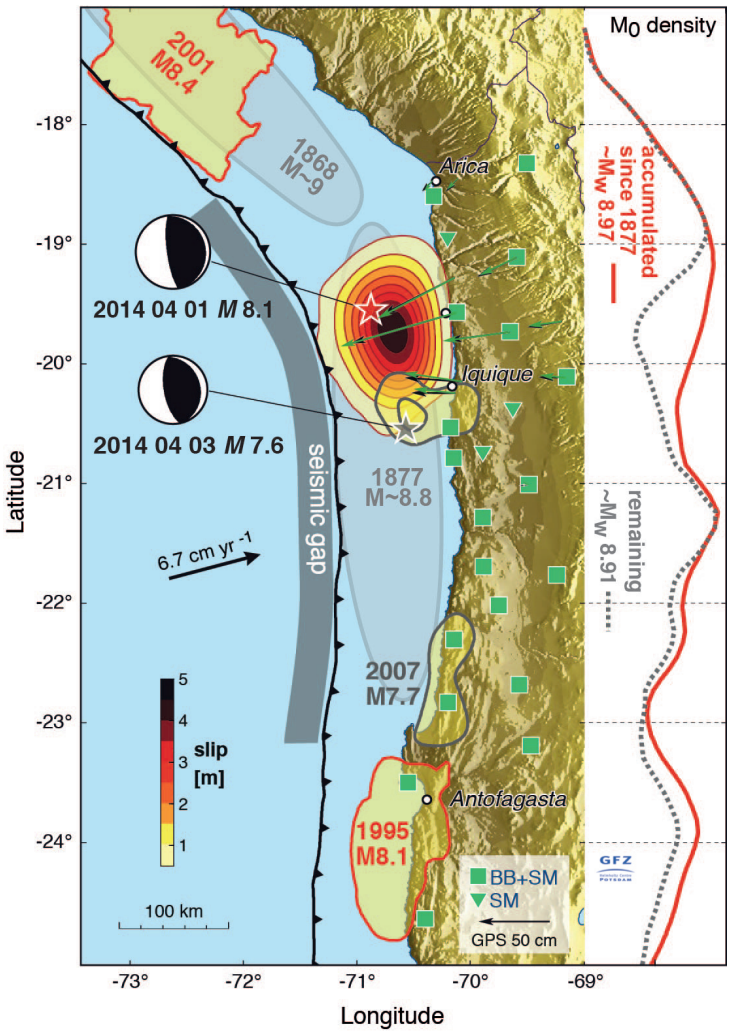

Figure 1: The northern Chile seismic gap with slip patches of recent instrumentally recorded earthquakes. Slip of the 2014 event is color coded. Green symbols are IPOC seismic stations.

On 1 April 2014, Northern Chile was struck by a Mw 8.2 earthquake following a protracted series of foreshocks. The Integrated Plate Boundary Observatory Chile (IPOC) monitored the entire sequence of events, providing unprecedented resolution of the build-up to the main event and its rupture evolution. The Iquique earthquake broke a central fraction of the so-called northern Chile seismic gap, the last major segment of the South American plate boundary that had not ruptured in the past century (Fig. 1). Modeling of long-term GPS measurements revealed that the part of the megathrust fault that broke during the earthquake was strongly locked before. Published slip models of the mainshock generally agree on a compact slip patch with up to 10 m of slip and a high stress drop. We analyze in detail seven years of seismicity and relocate thousands of earthquakes in the rupture region before and after the earthquake. Our results reveal that until two weeks before the earthquake seismicity occurred exclusively down-dip and to the sides of the mainshock asperity, whereas the asperity itself and the region updip remained quiet, probably due to its setting in the stress shadow cast by the strong asperity. The b-value of the background seismicity gradually decreased during the years before the earthquake indicating increased stressing. A foreshock series commenced two weeks before the mainshock with a Mw 6.7 event in the upper plate. After the upper plate yielded, foreshocks infringed quickly on the megathrust updip of the asperity. In the following two weeks the foreshocks spread such that a ring of seismicity around a quiet zone got closed. This is a well known pre-seismic pattern termed Mogi Doughnut, coined by the Japanese seismologist Kiyoo Mogi in the 1960s. The mainshock finally nucleated at the northern end of the foreshock area and ruptured mainly downdip towards higher locking. The main slip patch occupied the pre-seismically quiet zone, i.e. the Mogi Doughnut's hole. The early and largest aftershocks aggregated also updip of the rupture region. We show that this pre- and post-seismic pattern can be explained by a simple conceptional model of stressing and breaking a single strong asperity.