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The 2010 Maule Earthquake: Geophysical Investigations Three Years On

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On February 27, 2010, the Central Chilean margin ruptured over a length of ∼400 km in the Mw 8.8 Maule earthquake. The international seismological community responded quickly by organising the International Maule Aftershock Deployment (IMAD) consisting of more than 140 seismological stations from Chile, Germany, France, the USA and the UK. This land seismic network is complemented by 30 ocean bottom seismometers in the northern portion of the rupture, operating from September to December 2012. Similar efforts were carried out by the geodetic community, installing more than 65 cGPS stations and an even larger number of campaign sites. Last but not least surveys of coastal uplift and surface faulting provide constraints on the immediate coseismic response as well as on the longer term evolution of the margin.

In the MARISCOS project (MAule eaRthquake: Integration of Seismic Cycle Observations and Structural investigations) seismological, geodetic and geological approaches are combined in order to link coseismic slip, the postseismic response, and the longer term properties of the margin. We have created a bulletin of over 16000 events with low epicentral uncertainties. Seismic activity occurs in 4 main groups: (1) Normal faulting outer rise events at depths between the surface and 30 km depth. (2) a dipping 70-80 wide band along the whole rupture zone, thin in cross-section. Most of the events in this band are consistent with plate interface seismicity, but a kink in cross-section suggests the existence of a splay fault forming the shallowest part. This band is separated from the trench by a 50 km aseismic zone and is approximately terminated by the coastline on the landward side (at least to the north of the main shock epicentre), likely corresponding to the plate interface-continental Moho intersection at depth. (3) elongated clusters of seismicity at 40-50 km depth and with plate interface focal mechanisms, which occur below the continental Moho. (4) Pronounced crustal seismicity, most prominently normal faulting seismicity with strike oblique to the trench occur at the northern limit of the rupture zone. The northern part of the rupture zone is imaged with local earthquake tomography and shows elevated vp/vs values (∼1.85) in the western part of the intense crustal seismicity. Further seismicity occurs at intermediate depth range (80-120 km) and shallowly in the volcanic arc.

Improved models of coseismic and postseismic slip were computed based on the high density geodetic data and with a realistic plate geometry and elasticity structure. The postseismic response over the first 420 days is characterised by elongated patches of afterslip downdip of the coseismic slip in the rupture zone north of the hypocentre, which spatially largely coincides with the main plate interface seismicity (group 2). The equivalent moment of the afterslip is much larger than the cumulative seismic moment of the aftershocks, but although there is a close temporal correspondence in the decay of afterslip and seismicity, the slip of some aftershocks might be larger than the cumulative afterslip. A deeper patch of afterslip to the south of the coseismic slip is not associated with significant seismicity.

Based on the detailed aftershock locations, we have implemented dynamic station corrections for back-projection of the main shock using stations in the US, Antarctica, and Africa. Using this calibration we are able to image coherent energy at frequencies above 2-4 Hz. Similar to other investigators we find that higher frequency energy release is found downdip of the lower frequency release and geodetic slip, but contrary to some published work we locate the HF release for the northern part of this rupture near the downdip end of the main aftershock zone (group 2), updip of the deep band (group 3) for rupture times > 50 s. Before 50 s, we find rupture further downdip nearer group 3 seismicity at the deepest part of seismogenic plate interface.

Taken together, these results indicate that rather than being either velocity weakening (unstable, seismogenic) or velocity strengthening (stable, creeping), the plate interface over large areas can switch between both modes of frictional behaviour and is maybe over large areas in a conditionally stable regime, where fluid diffusion

can control the variable behaviour.