Large Interplate Thrust and In-slab Normal Faulting Earthquakes in the Mexican Subduction Zone, and Their Possible Stress Diffusion and Interactions

Takeshi Mikumo, Instituto de Geofisica, UNAM, Mexico

In the Pacific coast of southern Mexico, a number of large and great earthquakes have taken place frequently due to the subduction of the Cocos and Rivera plates beneath the North America plate, along the Middle America trench extending over 1000 km. The rate of plate convergence along the subduction zone ranges from 2 cm/yr (R.P.) to 5.0~6.5 cm/yr (C.P.). In addition, large normal-faulting earthquakes also take place in the subducting Cocos plate. In this work, we deal with interplate earthquakes with Ms>6.9 that occurred since 1900 to the present and two large in-slab earthquakes in this zone.

The 46 shallow interplate earthquakes that occurred in the subduction zone during the period appear to cluster in space and time. We first test the hypothesis that this clustering might come from coseismic stress interactions between these events. To do this, we estimate the spatial extent of the Coulomb failure stress (ΔCFS) change on the plate interface due to these earthquakes, and tentatively assume the distance of effective influence on adjacent events as 1 bar-contours. In this case, the rupture areas of the events are taken from their aftershock areas if available, and otherwise assumed from their surface-wave magnitudes, where an elliptical shape of slip distribution is assumed over the fault. Then, we perform a statistical test by using the χ^2 - goodness fit for many sets of inter-event time intervals between subsequent earthquakes whose spatial extent of stress influence overlaps each other. The tests show the existence of at least two groups of time intervals, 0–4 yrs and 30-50 yrs, where the observed frequencies well exceed those expected from a Poisson model. This implies that the probability of occurrence of another large event in the neighboring region after a given earthquake is about 30 %, about twice that expected from a random process. These results suggest that the spatio-time clustering of large earthquakes in the Mexican subduction zone may be more or less affected by the coseismic stress increase, if a change of 1 bar could be an appropriate value.

As a next step, we investigate the extent of possible stress transfer among a sequence of 5 large interplate earthquakes that occurred over an extensive segment of the northern subduction zone during 12 years from 1973 to 1985; These are the 1973 Colima (Ms7.5), 1979 Petatlan (Mw7.6), 1981 Playa Azul (Mw7.3), 1985 Michoacan (Mw8.1), and 1985 Zihuatanejo (Mw7.7) earthquakes. We again calculate the coseismic changes of ΔCFS inside the fault area and its extended plane on the plate interface, based on the slip distribution actually estimated from kinematic waveform inversion for each of the five events, and sum up their stress changes as a function of time. In this case, we include the effects from viscoelastic relaxation of the coseismic change, but found that these effects are less than 15 % during the 12 years. It is interesting to note that the rupture starting point of the largest 1985 earthquake was in the zone of total stress increase of about 0.5 bars due to the previous three events. It is not clear, however, if this order of small stress increase could actually trigger this large earthquake. Also, the 1973 earthquake that occurred more than 200 km northwest of the 1979 event probably may not have direct effects on the second

event. For these reasons, we tentatively consider here stress diffusion propagating laterally along the trench direction from each of these earthquakes, assuming a lithospheric subducting plate overriding an asthenosphere with a low viscosity of $10^{18} \sim 10^{19}$ P. This effect would enhance the coseismic stress change several to 10 years after the large event, and could be a possible candidate for stress interactions between somewhat remote earthquakes.

We also discuss the possiblity of stress interactions between large interplate thrust and subsequent in-slab normal-faulting earthquakes. These are the cases for the 1997 nearly-vertical, normal-faulting event (Mw7.1) that took place just beneath the ruptured zone of the 1985 Michoacan thrust earthquake (Mw8.1), and for the 1999 normal-faulting event (Mw7.5) that occurred below the downdip edge of the fault zone of the 1978 Oaxaca thrust earthquake (Mw7.8). For this purpose, we estimate the temporal change of the stress state in the subducting Cocos plate. This includes the coseismic change of the Coulomb failure stress due to the interplate earthquakes, their postseismic stress change due to plate convergence and the viscoelastic stress relaxation process of the coseismic change. It is found that both of the two in-slab events took place in the zone of maximum coseismic stress increase up to 4 to 10 bars. The postseismic effects change the coseismic stress patterns to some extent, but are not large enough to overcome the coseismic effects. These estimates suggest that the large interplate earthquake may have enhanced the chance of the in-slab normal-faulting events.

For long-term prediction of future large earthquakes at subduction zones due to stress transfer from previous large events, it would be necessary to estimate not only coseismic Coulomb stress changes but also their postseismic effects, taking into consideration the physical mechanism of time delay, such as stress difusion, stress corrosion, viscoelastic relaxation and plate convergence etc..