Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS01-14 Room:302 Time:May 19 15:45-16:00

Earthquakes recovering the strain energy lost at interseismic stage

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Earthquakes are generally believed to be a process of releasing elastic stress accumulated before the earthquake. Recurrence of great earthquakes along a plate boundary has been successfully explained with this concept. Here, we show that this is not always the case. There is another class of plate-boundary earthquakes whose slip recovers original stress that has been lost through the interseismic stage. Such earthquakes do not occur in the seismically active inner (landward) segment of a megathrust wedge. Their occurrence is limited to the seismically less active outer (oceanward) segment, characterized in topography by steep seafloor and gently dipping plate interface. We develop a two-dimensional, analytical elastic model of the wedge, subject to gravitational body force, with a sloping seafloor at the top and frictionally dragged at the base by a rigid plate. The intensity of drag force is measured by basal frictional coefficient mu_e. It can be shown that as mu_e is increased from 0, shear strain energy in the wedge initially decreases, reaches a minimum and then begins to increase. If mu_e reaches a threshold before it brings the wedge into the minimum shear energy state, the resultant slippage takes place towards increasing shear strain energy as well as horizontally tensile stresses. Such a seemingly strange process can be understood by considering the role of gravitational potential energy associated with the seafloor slope. Earthquakes in this category include most of tsunami earthquakes and the 2011 great Tohoku-Oki earthquake involving both the outer and inner segments with much larger slip in the outer segment.

Keywords: great earthquake, tsunami earthquake, megathrust wedge, fault frictional slip, absolute stress