

## Relations of Great Kurile Earthquakes Estimated from Tsunami Waveforms

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The Pacific plate subducts about 8cm per year under the Kurile Islands, so many great earthquakes occurred in the Kurile subduction zone. On 13 October 1963, great Kurile earthquake ( $M_w$  8.5,  $M_t$  8.4) occurred off the Etorofu Island. This event was an underthrust earthquake. The epicenter of the 1963 earthquake is located at  $44.8^\circ\text{N}$ ,  $149.5^\circ\text{E}$ , depth = 60 km. Also the largest aftershock ( $M_s$  7.2,  $M_t$  7.9) occurred on 20 October 1963. This aftershock generated an unusually large tsunami relative to the size of the seismic waves. The epicenter of the 1963 aftershock is located at  $44.7^\circ\text{N}$ ,  $150.7^\circ\text{E}$ , depth = 10 km. The 2006 Kurile earthquake occurred northeast of the 1963 Kurile earthquake. The epicenter of the 2006 earthquake is located at  $46.6^\circ\text{N}$ ,  $153.2^\circ\text{E}$ , depth = 30 km. To examine whether seismic gap exist between 1963 and 2006 earthquakes and to understand source processes of the main shock and the largest aftershock, slip distributions of the 1963 great earthquake and the largest aftershock were estimated using tsunami waveforms recorded at tide gauges along Pacific Ocean and Okhotsk Sea coast. In the case of the main shock, using 24 subfaults of  $50\text{ km}\times 50\text{ km}$ , slip amounts on each subfault were determined by the tsunami waveform inversion. The result shows that large slip amounts were found at the intermediate depth and the shallow part of the rupture area. The total seismic moment was estimated to be  $2.4\times 10^{21}\text{ Nm}$  ( $M_w$  8.2) by assuming that the rigidity is  $4.0\times 10^{10}\text{ N/m}^2$ . The 2006 earthquake occurred just next to the 1963 earthquake and no seismic gap exists between source areas of the 1963 and 2006 earthquakes. In the case of the largest aftershock, using 14 subfaults of  $50\text{ km}\times 50\text{ km}$ , slip amounts were estimated. Large slip amounts were found at the shallow plate interface near the trench. This largest aftershock is a tsunami earthquake. The seismic moment was estimated to be  $1.1\times 10^{21}\text{ Nm}$  ( $M_w$  8.0) by assuming that the rigidity is  $4.0\times 10^{10}\text{ N/m}^2$ . On 6 November 1958, the great Etorofu earthquake ( $M_w$  8.3) occurred southwest of the 1963 Kurile earthquake. The epicenter of the 1958 earthquake is located at  $44.4^\circ\text{N}$ ,  $148.6^\circ\text{E}$ , depth = 80 km. This earthquake was originally defined as an interplate earthquake although the depth was slightly deep. However, the earthquake was characterized by a high stress drop, a low aftershock activity at shallow depth, large high-frequency seismic waves, a large felt area, and a relatively small aftershock area. Therefore, the 1958 great earthquake was recently defined as a slab event. In this study, dip, depth, slip amount of the earthquake were estimated using tsunami waveforms recorded at tide gauge stations along the Pacific Ocean. Strike and rake of the fault model were fixed to be 225 and 90 degrees, respectively. First step, a rupture area previously estimated from aftershocks within 3 days,  $150\text{ km}\times 80\text{ km}$ , was used. The tsunami was numerically computed using interplate earthquake model (dip = 20 degree, depth = 16 km) and slab earthquake model (dip = from 20 to 60 degree every 10 degree, depth = from 27.5 km to 47.5 km every 10 km). We found that a slab earthquake model of dip = 40 degree, depth = 37.5 km best fit observed and computed tsunami waveforms. Second step, tsunami waveforms were calculated using various source models which have different rupture area at the same other parameters. However, the computed tsunami waveforms from the original rupture area,  $150\text{ km}\times 80\text{ km}$ , best explained the observed tsunami waveforms. Third step, using 48 subfaults of  $25\text{ km}\times 20\text{ km}$ , slip amounts were estimated by tsunami waveform inversion with the fault model decided parameters. Subfaults of large slip amounts were almost same as the rupture area of aftershock within 3 days. The seismic moment was estimated to be  $1.7\times 10^{21}\text{ Nm}$  ( $M_w$  8.1) by assuming that the rigidity is  $6.5\times 10^{10}\text{ N/m}^2$ .

About the 1969 earthquake, the earthquake (Mw 8.2) occurred southwest of the 1958 earthquake. The epicenter of the 1969 earthquake is located at  $43.2^{\circ}\text{N}$ ,  $147.5^{\circ}\text{E}$ , depth = 33 km. The 1969 and 1963 events were interplate earthquakes, but the 1958 event was a slab earthquake. Slip distribution of the 1969 earthquake will be estimated from tsunami waveform inversion to investigate source process of the earthquake and relations of locations of the 1969 and 1963 earthquake.

