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Unusual event in the 17th century and seismic/aseismic slip along the Kuril Trench

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Paleoseismological data along the Pacific coast of eastern Hokkaido indicate that unusual earthquakes have repeated at about 500 year interval with the most recent event in the 17th century. We review paleoseismological data, examine coastal deformation and tsunami inundation from fault models, and propose a model of earthquake recurrence in the Kuril subduction zone.

Along the Pacific coast of eastern Hokkaido, historical tsunamis are typically from interplate earthquakes, with rupture length of 100 - 200 km. Such events, occurred in 1952 (Mw 8.1) and 1973 (Mw 7.8) as well as 1843 (M 8.0) and 1894 (M 7.9) have been considered characteristic of the southern Kuril trench.

Pleistocene marine terraces on the Pacific coast show slight net uplift, at an average of 0.1 - 0.4 mm/yr in the past several hundred thousand years, whereas tide-gauge data show gradual subsidence of 8 - 9 mm/yr since 1900. Infrequent unusual event (Armageddon) has been inferred (Ikeda, 1996) to resolve this conflict.

Holocene stratigraphic and microfossil studies have indicated sea-level changes in the last 3 ka (e.g., Sawai, 2001). Each event is marked by an abrupt upward change from brackish bay deposits to freshwater peat. The youngest change has been dated in the 17th century with an estimated uplift amount of 0.5 - 1m (Atwater et al., 2003). Such evidence has been found along the 100 km long coast and recurred up to seven times in the last 2.5 ka (Kelsey et al., 2002).

Extensive tsunami deposits indicate large prehistoric tsunamis (Nanayama et al., 2000; Hirawaka et al., 2000). At Kiritappu, for instance, sand sheets extend 3 km inland, much further than historic tsunamis. Ten sheets of tsunami deposits indicate recurrence of such unusual tsunami with an average recurrence interval of about 500 years. The most recent event occurred in the 17th century.

Historic documents in Honshu rules out unusual tsunamis that would cause damage along the Sanriku coast. Tsunami damage from the 1611 and 1677 earthquakes, both along the Japan trench, have been documented along the Sanriku coast.

We modeled and examined three types of earthquakes: Armageddon, interplate events, and tsunami earthquakes. The fault extends down to 85 km depth in the Armageddon model, and would cause the coastal uplift. Interplate earthquake fault, down to 50 km depth, would cause slight subsidence of coast. The ocean bottom deformation from the tsunami earthquakes is limited near the trench axis. We also varied fault length along the trench axis as 200 km (single segment) and 300 km (multi-segment).

Tsunami numerical modeling from these fault models calculates coastal tsunami heights for the Hokkaido and Honshu coasts and inundation for selected sites where the tsunami deposits were mapped (Satake et al., 2002). Only multi-segment fault can explain the tsunami deposits and lack of documented damage on Sanriku coast.

We model the recurrence of earthquakes along Kuril trench by incorporating two types of earthquakes; one is with 3 m slip at 90 year interval, and the other is 5 m slip at every 510 years. The two types of slip combined, the model yields 17 m slip of plate interface in 510 years. Both coseismic and interseismic slips produce continous coastal subsidence.

We assume deep postseismic slip linearly decreasing from 1.5 m to zero between 51 and 85 km depth. If such an event takes place during three years following the 3 m slip events, it roughly reproduces the observed coastal movements in the 20th century (Kasahara and Kato, 1980/81). Deep slip ranging 5 to 0 m during ten years after the 17th century event would cause ca 1 m coastal uplift and explains the paleoseismological observations (Atwater et al., 2003). However, the model still yields coastal subsidence after 510 years. In order to make the overall coastal movement stationary after the 500 year cycle, a larger deep slip (11m) following the 17th century event is needed.