RECONSTRUCTING TSUNAMIGENIC EARTHQUAKES ON THE NORTHERN KAMCHATKA SUBDUCTION ZONE: THE 1997 KRONOTSKY EARTHQUAKE AND TSUNAMI AND THEIR PREDECESSORS

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The northern Kamchatka segment of the Japan-Kuril-Kamchatka subduction zone has historically been characterized by more segmented behavior than southern Kamchatka (Fig. 1). Some details of these ruptures can be elucidated by examining tsunami runup records, including runup reconstructed from tsunami deposits (as in MacInnes et al., 2010). The most recent large earthquake in this region occurred on 5 December 1997, a Mw 7.8 offshore of Kronotsky Cape. The tsunami from this earthquake was recorded on tide gages at several stations in the Hawaiian Islands to be 0.15 to 0.30 m amplitude, but local tide gages at Ust-Kamchatsk and on Bering Island were not working. A limited post-tsunami survey found no more than about 2 m runup, south of Kronotsky Cape. However, this survey did not go north of Kronotsky Cape, where later-discovered tsunami-deposit evidence (and a corroborating eyewitness account) suggests that in 1997 there was local runup of 1.8 to 7.3 m at least 55 km along the coast (Fig. 2).

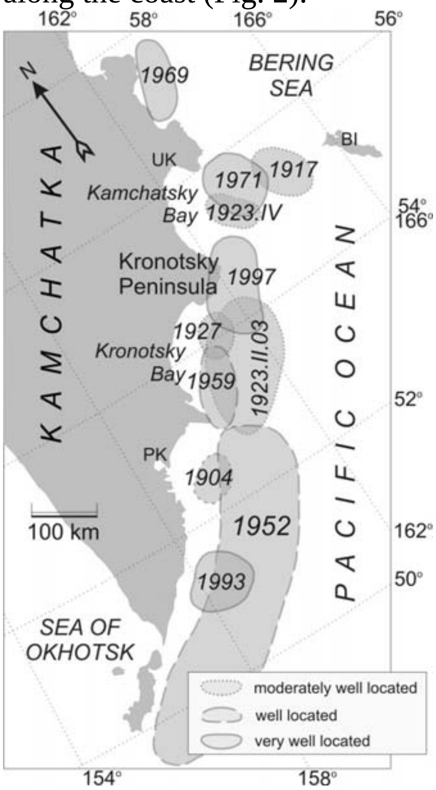

Figure 1. Interpreted rupture locations of largest 20th century earthquakes along the Kamchatka portion of the Kuril-Kamchatka subduction zone (after Gusev and Shumilina, 2004; their estimate of quality of location). PK = Petropavlovsk-Kamchatskiy; UK = Ust Kamchatsk; BI = Bering Island. This abstract suggests a revision of the source region for 1997.

Other historical earthquakes and tsunamis affecting Kamchatsky Bay (Fig. 1). The 1971 Kamchatsky earthquake and tsunami are discussed in LaSelle et al. JKASP abstract; 1917 is not well located or understood. Two local, large tsunamis hit this region in 1923. The deposit we identify as “1923” (above historical tephra Ksht$_3$, AD 1907) is larger than 1997 (Fig. 2), which in turn is larger locally than Kamchatka 1952 or Chile 1960. We tentatively interpret this deposit to be from the Mw 8.5, 4 Feb 1923 earthquake located in an overlapping region to the 5 Dec 1997 earthquake (Fig. 1), in sum farther south. The 14 April 1923 earthquake is reported to have generated high runup near Ust’ Kamchatsk; tide-gage amplitude in Hilo is 0.3 m, comparable to Kronotsky 1997. Based on this far-field record, we tentatively suggest a Mw of 7.8 for this event. The record of pre-20th century earthquakes and tsunamis is spotty. Earthquakes on 17 May 1841 and 17 October 1737 originated in the region of the 1952 south Kamchatka great earthquake. There is possibly a large (earthquake and) tsunami on Bering Island on 4 November 1737. Other possibilities in northeast Kamchatka are an 1849 earthquake in the vicinity of the Komandorsky Islands, and a 1791 event which has an intriguing account of having affected the mouth of the Kamchatka River (Ust’ Kamchatsk), reaching 7 km upstream.

Modeling 1997. Given the post-tsunami survey reported runup and given that the deposits surveyed in our field campaign of A.D. 2000 are from the 1997 tsunami any model must explain relatively low runup on Krontosky Peninsula and relatively high runup to the north (Fig. 2). The smooth runup distribution and the ratio of maximum runup to distance over which the tsunami had significant runup (order of 10^{-5}) indicate this tsunami was typical of a seismogenic source rather than a landslide source. The far-field tide-gage records are also indicative of a broad rather than a point source. Higher runup north of the cape can be explained by a distributed-slip tsunami source (earthquake) with concentrated slip in the northern part of the rupture; this northern part was a seismic gap between two events in 1923. In order to explain low runup to the south, we suggest the rupture there was partly located below the peninsula.

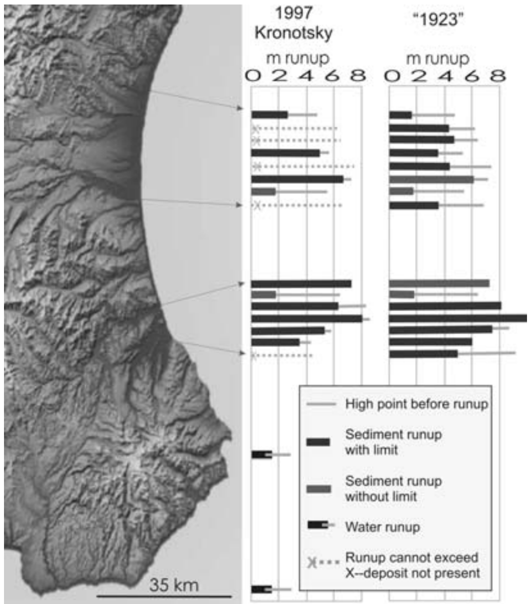

Fig. 2. Indicators of tsunami runup on and north of Kronotsky Peninsula generated by the 5 Dec 1997 and (4 Feb?) 1923 earthquakes; "water runup" indicates measurements of wrack lines in the post-tsunami survey.

Paleotsunamis between Ksht$_3$ (AD 1907) and KS$_1$ (c. AD 250). We base our analysis on the number of tsunami deposits between two distinctive marker tephra, separated by about 1700 calendar years. In any one profile, the number of deposits in this interval tends to decrease away from the coast and at higher elevations, although there is scatter in the data, likely due to preservation and identification differences. Including "1923" itself, all other pre-1997 deposits (typically 10-12) are more extensive than 1997. Most of these deposits are similar in extent and character to 1923, with 3-5 being more extensive than 1923. We do not have evidence of dramatically larger tsunamis than "1923," but the local terrain studied is not necessarily conducive to finding greater inundation, such as in Kiritappu marsh, Hokkaido. Still, the data suggest that this coast may experience a larger-than-1923 earthquake and attendant tsunami at least once every ~400 years, and tsunamis larger than 1997 at least every ~200 years. See Pinegina et al. (2003) for an analysis of Kronotsky Bay to the south.

Implications of this case study are several. The size of the tsunami based on its deposits and on a corroborating eyewitness account constrains the rupture characteristics of this earthquake. This recent historical tsunami also helps us interpret earlier historical and well as prehistorical earthquakes and tsunamis along the northern part of the Kamchatka subduction zone. Tsunamis originating from this region commonly have an impact not only locally but also on Hawaii, and in some cases even on the western coast of the Americas.

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We dedicate this work to the memory of Sasha Storcheus.