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Holocene turbidite and onshore paleoseismic record of great earthquakes on the Cascadia Subduction Zone: relevance for the Sumatra 2004 Great Earthquake

Details

Meeting	2005 Joint Assembly
Section	Union
Session	The Great Sumatra-Andaman Islands Earthquake and Tsunami of 26 December 2004 III
Identifier	U51A-03
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Index Terms	Paleoseismology [7221] Seismicity and tectonics [7230]

Abstract

Marine turbidite stratigraphy, onshore paleoseismic records of tsunami sand beds and co-seismic subsidence (Atwater and Hemphill-Haley, 1997; Kelsey et al., 2002; Witter et al., 2003) and tsunami sands of Japan (Satake et al., 1996) all show evidence for great earthquakes (M ~ 9) on the Cascadia Subduction Zone. When a great earthquake shakes 1000 kilometers of the Cascadia margin, sediment failures occur in all tributary canyons and resulting turbidity currents travel down the canyon systems and deposit synchronous turbidites in abyssal seafloor channels. These turbidite records provide a deepwater paleoseismic record of great earthquakes. An onshore paleoseismic record develops from rapid coseismic subsidence resulting in buried marshes and drowned forests, and subsequent tsunami sand layer deposition. The Cascadia Basin provides the longest paleoseismic record of great earthquakes that is presently available for a subduction zone. A total of 17 synchronous turbidites have deposited along ~700 km of the Cascadia margin during the Holocene time of ~10,000 cal yr. Because the youngest paleoseismic event in all turbidite and onshore records is 300 AD, the average recurrence interval of Great Earthquakes is ~ 600 yr. At least 6 smaller events have also ruptured shorter margin segments. Linkage of the rupture length of these events comes from relative dating tools such as the "confluence test" of Adams (1990), radiocarbon ages of onshore and offshore events and physical property correlation of individual event "signatures". We use both 14C ages and analysis of hemipelagic sediment thickness between turbidites (H), where H/sedimentation rate = time between turbidite events to develop two recurrence histories. Utilizing the most reliable 14C and hemipelagic data sets from turbidites for the past ~ 5000 yr, the minimum recurrence time is ~ 300 yr and maximum time is ~ 1300 yr. There also is a recurrence pattern through the entire Holocene that consists of a long time interval followed by 2 to 5 short intervals that is apparent as well in the land records. This pattern has repeated five times in the Holocene. Both onshore paleoseismic records and turbidite synchroneity for hundreds of kilometers, suggest that the Holocene turbidite record of the Cascadia Subduction Zone is caused dominantly by triggering of great earthquakes similar in rupture length to the Sumatra 2004 earthquake. The recent Sumatra subduction zone great earthquake of 2004 and the 1700 AD Cascadia tsunami sand of 3m height preserved in Japan (Satake et al., 1996) show that ocean-basin wide tsunami deposits result from these great earthquakes, which rupture the seafloor for hundreds of kilometers. Cascadia and Sumatra share many geological and physiographic similarities that favor the deposition of turbidites from great earthquakes, and tend to filter non earthquake turbidites from the record. Thus the paleoseismic methods developed in Cascadia could be applied to the Sumatran Subduction Zone and we expect that the turbidite record would yield a similar record ~10,000 yr in length. In Sumatra, the dearth of such records led to the lack of widespread recognition of the hazard, particularly from the northern Sumatra and Andaman-Nicobar region where geodetic data suggested weak plate locking. Evidence of a tsunami similar to the 2004 event from satellite imagery suggests the previous event was in the recent past.

Cite as: Author(s) (2005), Title, *Eos Trans. AGU*, *86*(18), Jt. Assem. Suppl., Abstract U51A-03