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Shallow subduction zone earthquakes and their tsunamigenic potential

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SUMMARY

We have examined the source spectra of all shallow subduction zone earthquakes from 1992 to 1996 with moment magnitude 7.0 or greater, as well as some other interesting events, in the period range 1–20 s, by computing moment rate functions of teleseismic *P* waves. After comparing the source spectral characteristics of 'tsunami earthquakes' (earthquakes that are followed by tsunamis greater than would be expected from their moment magnitude) with regular events, we identified a subclass of this group: 'slow tsunami earthquakes'. This subclass consists of the 1992 Nicaragua, the 1994 Java and the February 1996 Peru earthquakes. We found that these events have an anomalously low energy release in the 1–20 s frequency band with respect to their moment magnitude, although their spectral drop-off is comparable to those of the other earthquakes. From an investigation of the centroid and body wave locations, it appears that most earthquakes in this study conformed to a simple model in which the earthquake nucleates in a zone of compacted and dehydrated sediments and ruptures up-dip until the stable sliding friction regime of unconsolidated sediments stops the propagation. Sediment-starved trenches, e.g. near Jalisco, can produce very shallow slip, because the fault material supports unstable sliding. The slow tsunami earthquakes also ruptured up-dip; however, their centroid is located unusually close to the trench axis. The subduction zones in which these events occurred all have a small accretionary prism and a thin layer of subducting sediment. Ocean surveys show that in these regions the ocean floor close to the trench is highly faulted. We suggest that the horst-and-graben structure of a rough subducting oceanic plate will cause contact zones with the overriding plate, making shallow earthquake nucleation and up-dip propagation to the ocean floor possible. The rupture partly propagates in sediments, making the earthquake source process slow. Two factors have to be considered in the high tsunami-generating potential of these events. First, the slip propagates to shallow depths in low-rigidity material, causing great deformation and displacement of a large volume of water. Second, the measured seismic moment may not represent the true earthquake displacement, because the elastic constants of the source region are not taken into account in the standard CMT determination.

Key words: earthquake, subduction, tsunami.

INTRODUCTION

In the last 10 years, several shallow subduction zone earthquakes have excited destructive tsunamis, causing more than 1500 casualties in the period 1992–1994 alone. In general, tsunamis are caused by large shallow earthquakes beneath the ocean floor. Thus, the size of the event is one of the most important parameters that determines its tsunamigenic potential. A great shallow earthquake beneath the ocean floor should always be expected to be followed by a substantial tsunami caused by the large displacement of water near the ocean floor. However, a subclass of shallow subduction zone earthquakes, 'tsunami earthquakes', poses a special problem.

A tsunami earthquake was originally defined as an earthquake that generates a tsunami larger than one would expect from its conventional magnitude (Kanamori 1972). Typical

