

Diversity of outer-rise earthquakes: As an example of the Off-Fukushima earthquake on 26 October 2013

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Earthquakes occurring in the outer-rise of a subducting plate are associated with the ruptures of the subduing plate itself, that is, intra-plate earthquakes. Such outer-rise earthquakes have been considered to excite much larger high-frequency than earthquakes in the plate boundary of the subducting and overriding plates, because the outer-rise earthquakes should break a lithospheric part where no peculiar weak zones exist.

A M7.1 earthquake occurred off the coast of Fukushima on 26 October 2013, which was probably associated with the 2011 great Tohoku-oki earthquake. We analyzed broadband seismic waveform data of this event recorded by F-net and other seismic networks. Compared with other large outer-rise earthquakes, the high-frequency component ($>1\text{Hz}$) of all the stations along the Pacific coast of eastern Japan is not abundant although slightly larger than plate-boundary earthquakes of low-angle thrust faulting. In contrast, there was the excitation of several impulsive wave packets of several seconds in period. Since only high-frequency waves are abundant at common stations for aftershocks of this outer-rise earthquake, the above features should not be originated by either propagation path or site effect.

Unlike the other outer-rise earthquakes, the rupture process of this earthquake was unique, relatively smooth with several strong patches on a rather homogeneous fault. The breakout of these patches should have been connected without any complex unbroken areas on the fault in the end, in order to explain the observed waveforms. Although we do not deny the break of a virgin (without any peculiar weak planes) lithosphere in this case, several distinguished large strong patches are likely to characterize the heterogeneity in the fault region of this outer-rise earthquake.

Among recent large outer-rise earthquakes along subduction zones near Japan, we have found another example similar to the Fukushima-oki earthquake: for the M7.0 outer-rise event on 14 March 2012 at the junction between Kuril Trench and Japan Trench, several impulsive waveforms with minor high-frequency waves. The state stress of this subducting Pacific plate should be very complex, which might lead to its non-standard rupture process. We shall need to investigate broadband frequency excitation patterns carefully for large outer-rise earthquakes.

In summary, there should be a wide variety of heterogeneities and/or stress state within a subducting lithosphere, which may be important to consider not only the source process of outer-rise earthquakes but also their tsunami generations.

Keywords: outer-rise earthquake, intra-plate earthquake, high frequency seismic waves, fault rupture, heterogeneity of oceanic lithosphere