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Possibility for the occurrence of tsunami-generated turbidity currents: Insights from the 2011 Tohoku-Oki Earthquake

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In this study, characteristics of the turbidites and turbidity currents associated with the 2011 Tohoku-Oki Earthquake and Tsunami were investigated. As a result, this study proposes a hypothesis suggesting that the large-scale tsunami can generate turbidity currents in deep sea. This hypothesis was verified by the numerical experiments of tsunamis and turbidity currents. The result of this research indicates that understanding of the initiation mechanism and behavior of the tsunami-generated turbidity currents are important to reconstruct paleo-events and paleo-environment change such as surface disturbance associated with earthquakes and tsunamis events.

The 2011 Tohoku-Oki Earthquake and Tsunami occurred at 5:46 (UTC) on March 11, 2011 off Tohoku region, Japan. At about 3 hours after the main shock of the Tohoku-Oki Earthquake, the sensors on the seafloor recorded that the anomalous event occurred (Arai et al., 2013). Subsurface sediment cores were collected at 16 sites over range of water depth 170-2000 m, and event deposits (newly emplaced sediment layers) were observed identified obviously at the top of 14 core samples. Sedimentological analysis of these layers implies that the event deposits can be interpreted as turbidites, and it is suggested that this anomalous event was affected by the turbidity current run from shallower regions.

Because of the absence of related submarine landslides in the shallow marine area, it is reasonable to consider that the turbidity current was developed from the tsunami itself (Arai et al., 2013). It is hypothesized that the suspension cloud was stirred up by the tsunami at shallower depths and it grew into the turbidity current via the self-accelerating process. Both the condition (flow velocity and distribution of event deposits) of turbidity currents and turbidites estimated from the observation and results of numerical simulations of the unsteady turbidity current were quite conformable to this hypothesis. The numerical experiments of turbidity currents suggested that the tsunami-generated turbidity currents can occur when seafloor sediment in shallow marine is eroded at least 1.4 cm in thickness (in case of the porosity 50%) by the tsunami. The numerical experiments of tsunamis (using iRIC-ELIMO) indicates that the Tohoku-Oki Tsunami can eroded substrate 1-2 cm in thickness off Miyagi Prefecture, suggesting that the tsunami erosion may exceed the requirement to develop the tsunami-generated turbidity currents. Thus, it is concluded that tsunamis that have a similar scale to the Tohoku-Oki Tsunami potentially produce turbidity currents.

Keywords: Tohoku-Oki earthquake, tsunami-generated turbidity current, event deposit