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What happened at the northern Japan Trench (around 39.5 N) during the 2011 Tohoku earthquake ?

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For the 2011 Tohoku earthquake, many models of slip distribution based on seismic waves, GPS and tsunami data have been proposed. The maximum slip is located at around 38 N off Miyagi prefecture, although the amount and the down-dip location (depth) are different among the models. The coastal tsunami height was largest around Miyako city at 39.5 N, which is roughly 100 km north of the maximum slip. Satake et al. (2013, BSSA) made inversion of tsunami waveforms recorded on bottom pressure, GPS and costal wave and tide gauges to estimate spatial and temporal distribution of coseismic slips. Their result indicates that very large slips (maximum 69 m) occurred near the trench axis about 3 minutes after the earthquake origin time (rupture initiation), and it propagated toward north along the trench. They concluded that the delayed slip near the trench axis was the main cause of the largest tsunami in Iwate prefecture.

Because seismic wave analyses indicate that the rupture processes were at most 3 minutes, the delayed slip may not be seismic (faulting) origin. A recent paper by Tappin et al. (2014, Marine Geology) claimed that the cause of the large tsunami along the Iwate coast is a submarine landslide. Their analysis indicates that the submarine landslide occurred at 135 seconds after the origin time at around 39.5 N along Japan Trench, with a length of 40 km, a width of 20 km, a slope thickness of 2 km, a vertical offset (rotation) of 100 m. The total landslide volume was estimated as 500 km^3.

Along the Japan Trench off Iwate, a large slip occurred during the 1896 Sanriku earthquake. The estimated slip amount is 10 to 20 m, and the slip extended further north of the 2011 delayed slip. If coseismic slip occurred in 1896 and 2011, the total slip amount would be 20 to 30 m. Although this is smaller than the largest slip of the 2011 Tohoku earthquake, it is enigmatic that a slip larger than the plate convergence (~8 m/century) occurred within 100 years.

In order to identify the cause of the 2011 tsunami source off Iwate, whether it was a fault slip or a submarine landslide, submarine surveys such as detailed bathymetry or subsurface structure are expected.

Keywords: Tohoku earthquake, Japan Trench, tsunami, submarine landslide