The fifth model for the unusual tsunami generation off northwest Sumatra during the 2004 Sumatra-Andaman earthquake

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A common character among fault models for the 26th December 2004 Mw 9.3 Sumatra-Andaman earthquake is large slip off northwest Sumatra [e.g., Hirata et al.,2006; Tanioka et al.,2006], which is considered to be responsible for huge tsunami heights of more than 20 m on average, as measured in field surveys along the west coast of Aceh [e.g., Borrero, 2005; Jaffe et al.,2006] . The generation mechanism of the huge tsunami remains unresolved, although four hypothetical models have been proposed. The first model is that coseismic slip along the Sumatran megathrust, or the plate interface, is responsible for generation of the huge tsunami [McNeil et al.,2005: Moran et al., 2005; Henstock et al., 2006]. In this case, however, an additional tsunami generation mechanism such as inelastic deformation of soft accretionary sediment near the trench is needed because only elastic deformation from slip along the megathrust cannot explain the transoceanic tsunami height expressed on the sea surface height (SSH), observed by satellite altimetry [Seno and Hirata, 2007]. The second model is that the most trenchward splay fault branching updip from the megathrust was displaced coseismically [Soh et al., 2005; Seeber et al., 2007]. Splay faults can generate larger tsunamis, primarily because of their steeper dip. The third model is that the most landward splay fault, located at the eastern margin of the Sumatran outer-arc high, was displaced coseismically [Sibuet et al., 2007]. The fourth model is that the huge tsunami was generated by the contribution of coseismic fault motion along the West Andaman Fault, just west of the Aceh (forearc) basin [Plafker et al., 2005, 2006], though ROV diving surveys could not found any signature of coseismic fault motion along this fault [NT05-02 scientific party, 2005; SEATOS scientific party, 2005].

Recent geophysical studies showing the detailed fault structure of the subduction zone help constrain possible tsunami sources off northwest Sumatra. Coseismic slip concentrated along only the deeper (landward) part of the megathrust cannot explain the observed SSH [Geist et al., 2007], indicating that earthquake coseismically ruptured the more trenchward portion of the fault. Calculated tsunami backward wave-fronts suggest that the trenchward boundary of the tsunami source off northwest Sumatra was located near the accretionary prism toe and that long-wave-approximated, maximum uplift area was located in the middle outer-arc high [e.g., Fine et al., 2005; Seno and Hirata, 2007]. Array analysis of short-period tsunami dispersed waves, observed with hydrophone arrays in the Indian Ocean, suggests that the source is located at 4.3N and 93.8E [Hanson et al., 2007]. This location coincides with along Middle Thrust, depicted by Sibuet et al. [2007], which is located in the middle outer arc-high. The estimate is considered precise because propagation velocity of short-period tsunami dispersed waves does not depend on water depth but it is possible that the source location may be a few tens of kilometers at most trenchward of this position. The source size was much smaller than 30 km in length[Hanson et al.,2007].

The timing and amplitude information provided by the satellite altimetry SSH data and the hydrophone array data, as well as tide gauge records, provide critical constraints on the location and mechanism of anomalous tsunami generation offshore northwest Sumatra. Taking these constraints into account, we can construct a new model to explain the unusual tsunami generation off northwest Sumatra, We thus propose the fifth model that the 2004 earthquake ruptured updip along the megathrust (plate interface) near the deformation front, but branched onto one of the outer-arc high splay faults: either the Middle Thrust or possibly the Lower Thrust of Sibuet et al.[2007].