

The Cataclysmic 2004 Tsunami on NW Sumatra – Preliminary Evidence for a Splay Fault Secondary Source Along the Western Aceh Basin

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The tsunami generated by the great Sumatra earthquake of 12/26/2004 devastated 200 km of Sumatra coast from Kuede on the north end of the island to south of Meulaboh on the west coast. Of the roughly 223,000 lives lost during this event, 72% of the casualties were caused by the near-field tsunami that struck northern Sumatra; the remaining deaths were due to the far-field tsunami that impacted coasts around much of the Indian Ocean. Post-tsunami reconnaissance surveys of the northwest coast of Sumatra indicate tsunami flow depths of 5 to 12 m along the north coast and 7 to 20 m along the west coast; peak run up is as high as 39 m west of Banda Aceh near Lhoknga. Flow depths and run up heights are significantly larger than tectonically-generated tsunamis documented for earthquakes of comparable or greater magnitude. They suggest that alternate sources, such as secondary intraplate faults, may have contributed to the tsunami in addition to interplate slip on the Sumatra megathrust.

To investigate alternate sources of the tsunami, interviews were conducted with 110 eyewitnesses, who were situated both on land and offshore during the tsunami. We obtained information on wave arrival times, precursory sea withdrawal, the number of waves, wave train characteristics, wave heights, and wave periods. The majority of our interviews along the west coast indicate that arrival time of the tsunami from start of the earthquake ranged from ~22 minutes in the Lhoknga area to ~32 minutes at Meulaboh, where the continental shelf is widest. Back tracing these arrival times, using a simple linear wave model indicates a candidate source along the western edge of Aceh Basin, coincident with the eastern margin of the forearc high and the west Andaman fault. The Andaman fault is mapped as a west-side-up structure (Sieh & Natawidjaja, 2000) and our working hypothesis is that it is a west-dipping backthrust that splays off the Sumatra megathrust. Coseismic wedging of the Aceh Basin beneath the forearc high along a steeply-dipping splay fault could provide a tsunami source that would satisfy the requirements of: 1. Proximity to northern Sumatra; 2. A long source area parallel to the Sumatra coast; 3. Large amplitude vertical displacement of the sea surface; 4. A leading negative wave; and 5. Short wave periods.

Comparable examples of complex tsunami sources in subduction zones include 1964 Alaska (Mw 9.2), 1960 Chile (Mw 9.5), and probably great tsunamigenic paleoseismic events in Cascadia. Data from both Alaska and Chile showed that a major fraction of the total fault slip can be partitioned between the gently dipping megathrust and intraplate splay faults that break relatively steeply to the surface (Plafker, 1969; Plafker and Savage, 1970). Intraplate thrusting during some Cascadia paleoearthquakes also appears to be required by data on neotectonic deformation and paleotsunami deposits near the southern Cascadia margin (Plafker and Carver, 1999). For tsunami generation, this means that the initial wave at the source can be higher and closer to shore than it would be for slip entirely on the megathrust. Implications in the near field coastal zone are reduction of warning times for inhabitants and increased likelihood of devastation by inundation.