briefing note
376
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The 28 September Mw 7.5 Sulawesi Earthquake

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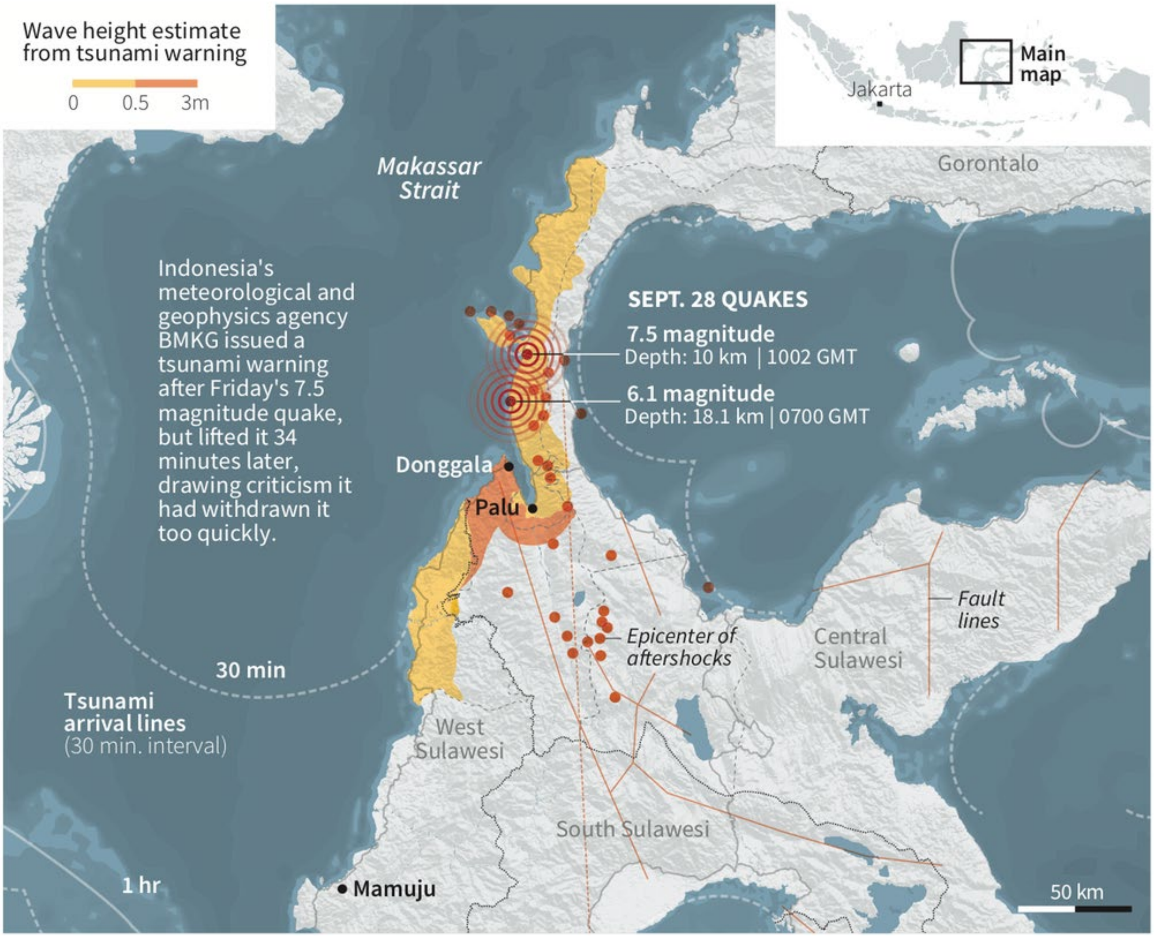
The 28 September Mw 7.5 Sulawesi Earthquake occurred on the Palu-Koro fault, which ruptured southward from the epicenter to a location south of Palu. The Palu-Koro fault is a strike-slip fault on which the two sides slide horizontally past each other (east side north and west side south on a fault aligned north-south in this case), and usually do not cause much vertical movement of the ground. In contrast, thrust faults (including subduction earthquake faults) are caused when one side is thrust under the other. Consequently they are much more likely to trigger a tsunami because the vertical movement of the ground raises a column of seawater, setting a tsunami in motion. Although most media attention has been focused on the tsunami, it is clear that strong near-fault ground motions from the earthquake caused massive structural damage and large scale soil liquefaction (which also caused major structural damage) before the arrival of the tsunami in Palu.



Map of the region surrounding the 28 September Mw 7.5 Sulawesi earthquake showing forecast tsunami inundation and arrival time contours. The north-south alignment of aftershocks (red dots) approximately outlines the location of the Palu-Koru fault rupture zone. Sources: USGS/Indonesia Tsunami Early Warning System/Reuters

Fifteen earthquakes with magnitudes larger than 6.5 have occurred near Palu in the past 100 years. The largest was a magnitude 7.9 event on January 1996, about 100km north of the September 2018 earthquake. Several of these large earthquakes have also generated tsunamis. In 1927, an earthquake and tsunami caused about 50 deaths and damaged buildings in Palu, and in 1968 a magnitude 7.8 earthquake near Donggala generated a tsunami that killed more than 200 people.

Despite this local history and the 2004 Boxing Day Sumatra earthquake and tsunami, many people in Palu were apparently unaware of the risk of a tsunami following the earthquake. The tsunami occurred in an area where there are no tide gauges that could give information about the height of the wave. The Indonesian Tsunami Warning System issued a warning only minutes after the earthquake, but officials were unable to contact officers in the Palu area. The warning was cancelled 34 minutes later, just after the third tsunami wave arrived in Palu. It is likely that the bay's narrow V-shape intensified the effect of the wave as it funneled through the narrow opening of the bay, inundating Palu at the end of the bay.

While it is possible that a more advanced tsunami warning system could have saved lives if it had been fully implemented, a system currently in the prototype stage may not have helped the people of Palu, as the tsunami arrived at the shore within 20 minutes of the earthquake. Such early warning systems are most useful for areas several hundred kilometres from the tsunami source. In regions like Palu where the earthquake and tsunami source are very close, education is the most effective warning system. If people feel more than 20 seconds of ground shaking, that should form the warning to immediately move to higher ground.

It is not yet clear whether the tsunami was caused by fault movement or by submarine landslides within Palu Bay triggered by shaking from the earthquake. It is possible that the fault cut through a submarine slope, with the horizontal displacement of the sloping sea floor pushing the water aside horizontally, causing it to pile up in a wave. Alternatively, as seems more likely, the tsunami may have been generated by a submarine landslide within the bay. The sides of the bay are steep and unstable, and maps of the sea floor suggest that submarine landslides have occurred there in the past. In that case, even if there had been tsunami sensors or tide gauges at the mouth of the bay, they would not have sensed the tsunami before it struck the shore in Palu.

It is clear from images of building damage that there was strong ground shaking in Palu and surrounding regions, as would be expected in the near-fault region of an earthquake of this magnitude. This shaking damage would have made structures even more vulnerable to the ensuing tsunami in low lying areas.

Another major cause of damage was the soil liquefaction in large areas within Palu and surrounding regions. Palu is situated on a plain composed of water saturated soft sandy soils. Images from the disaster area show large scale lateral spreading, in which buildings on chunks of thin brittle crust slide across the underlying liquefied sands as if they are flowing in the water. This has resulted in the total destruction of buildings in large areas, leaving a churned landscape composed of debris and buildings that have sunk into the liquefied soil.

Australian Tsunami Risk and Warning

Australia is sufficiently remote from major subduction earthquake source zones that there is enough time (a few hours) for tsunami warning for such events, and in any case the hazard from such tsunamis is quite low. The main source of tsunami hazard may come from the occurrence of local earthquakes offshore that trigger submarine landslides on the continental slope. Such earthquakes are thought to be infrequent, and so the hazard from them is thought to be low. Marine surveys have been undertaken to identify potential locations of past underwater landslides and estimate their recency and frequency of occurrence. Such landslides would generate local tsunamis that would give little time for effective tsunami warning.

The Australian east coast has experienced at-least 47 tsunami events in historical time. The largest occurred in 1960 as a result of the 22 May 1960 Mw 9.6 earthquake in Chile, the largest earthquake in recorded history. The recorded wave height at Fort Denison in Sydney Harbour was 1 metre, strong flow velocities caused damage to boats in Sydney Harbour and the Hunter River, and there was some minor inundation at Batemans Bay.

The Australian Government operates the Australian Tsunami Warning System, and states and territories maintain disaster plans and education programs. In the rare event of a large tsunami generated by a local source, emergency services would likely be overwhelmed and faced with significant challenges in achieving access to impacted areas due to damage to infrastructure.