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# Coastal Subsidence Induced Several Tsunamis During the 2018 Sulawesi Earthquake

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**The height of the tsunami caused by the Sulawesi earthquake in 2018 was higher than that estimated from the magnitude of the earthquake, and its cause is not well understood. Although it is conceivable that tsunamis originated from landslides in several cases, it is not known whether landslides were occurring in the coastal area at the time. This report describes the results of a field survey conducted to investigate the traces of subsidence and the characteristics of the tsunami incidents in the bay far from the epicenter. Subsidence was observed at a minimum of seven points along the coast; in accord with the reports of eyewitnesses, this suggests that subsidence might have generated tsunamis.**

**Keywords:** earthquake, tsunami, Sulawesi, field survey, subsidence

## 1. Introduction

A field survey was conducted between October 12 and October 17, 2018. The purpose of the survey was to collect information on any geomorphological changes along the coast associated with the Sulawesi earthquake, more information on the tsunami characteristics and potential additional details from interviews with eyewitnesses. The following chapters discuss the findings obtained from the analysis of field survey data. They support the hypothesis that the tsunami waves generated by landslides were almost concurrent with the earthquake ground motions. **Fig. 1** shows an overview of this survey.

## 2. Subsidence Extent and Tsunami Behavior

We identified sites of potential subsidence along the coast during the field survey (orange filled circles, **Fig. 1**).

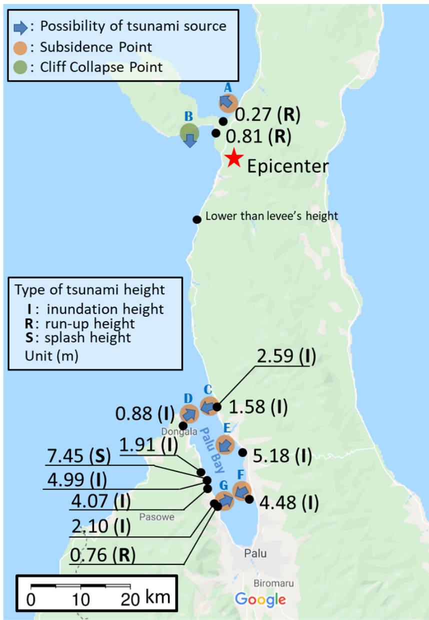


**Fig. 1.** Locations of the observed subsidence points, the points where the tsunami might have occurred, and observed tsunami height, which are corrected using the tide level in Palu at 18:02 on September 28, 2018.

More specifically, six areas show evidence of subsidence along the coast between the epicenter of the Sulawesi earthquake to the north, and the inner part of Palu Bay to the south.

At point A, the piles on the offshore side of the pier adjacent to the beach underwent subsidence. According to a resident, the beach slope gradient became steeper (around 17°); he also witnessed the arrival of the tsunami soon after the earthquake. Based on the same eyewitness, the sea started receding before the water splashed offshore at which point he realized the tsunami was arriving. We believe that the description of this eyewitness supports the hypothesis of a landslide occurring at this locality.

At point B, many instances of cliff collapse were identified. Tsunami waves approximately 2 m high inundated the village near point B soon after the seismic ground motion was felt. According to an eyewitness, this tsunami moved in a N-S direction.

At point C, many cracks were observed on the ground and many trees growing along the coast had fallen towards the sea. The tree fall could indicate that the lower offshore part of the ground had undergone subsidence. The recession of the sea following the earthquake was confirmed by another eyewitness, who observed the phenomenon from aboard a ship. We therefore believe that what appears as subsidence around point C is the result of land mass failure.

Near point D, there are many tilted houses and coastal structures. These structures indicate that subsidence took place at point D along the coast. According to an eyewitness, the tsunami struck the coast soon after the ground motion. This means that the subsidence at this point occurred due to a landslide.

At point E, according to the first survey [1], the piles of the peer disappeared in the village near Pantoloan Port. A vessel was transported by the tsunami toward the coast; reconstructing the dynamic of its motion, it appears that at first the sea receded, and then inundated the coast. Point F also presented some evidence of subsidence.

At point G, a large subsidence occurred in the presence of several eyewitnesses. They reported that the container yard disappeared about 100 m long from the coast. According to a UAV survey, it is estimated that one or more landslides occurred about 1 km along the coastline.


**Fig. 2.** Different view of the beach where elevation changes were measured nearshore. The red dashed line shows measured change in elevation at location G. The container yard disappeared about 100 m long from the coast.


**Fig. 3.** Inundation height and splash height measured between locations D and G. The splash height at this area is more than 8 m.

## 3. Tsunami Height Distribution

Inundation heights ranged from 2 to 6 m in Palu Bay, from 5 to 6 m in the middle and south part of the bay, and from 2 to 3 m in the north part of the bay.

The base of the peninsula near the hypocenter, 60 km north of the mouth of Palu Bay, also showed traces of the tsunami. The measured run-up heights reached about 2 m, and were lower than those in the bay. We believe that buildings were inundated by the tsunami after collapsing from the strong ground shaking.

**Figure 3** shows the inundation height and the splash height between points D and G. The splash height was greater than 8 m and the walls of the houses were destroyed by the tsunami splash. The cliff shown in **Fig. 3** seemed to have formed following the 1968 earthquake, said a resident. This area appears to be prone to landslides. Therefore, it is important to understand the ground characteristics and consider them during reconstruction plans.

## 4. Summary and Discussion

This article describes a second survey, whose aim was to obtain information on landslide traces that could not be found during the first survey, as well as evidence indicating that the tsunami was caused by those landslides.

The observation of tsunami heights from both the east and west sides of Palu Bay indicated that landslide-triggered tsunamis were generated on both sides of the bay. Additionally, since the height of the tsunami at the mouth of the bay was not very high, it is extremely likely that major tsunamis occurred primarily within the bay.

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