https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

The physical and cultural traces of a 19th century volcano-collapse tsunami: New constraints on the magnitude and impacts of the 1888 Ritter Island tsunami, Papua New Guinea

Manuel C. David[1], Sebastian F.L. Watt[2], Harrison Gedikile[1], Simon J. Day[3], Hugh L. Davies[1,4,*]

[1] Earth Sciences, University of Papua New Guinea, Port Moresby, Papua New Guinea
[2] School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, U.K.
[3] Institute for Risk and Disaster Reduction, University College London, London, U.K.
[4] Research School of Earth Sciences, Australian National University, Canberra 2600, Australia
*Deceased

Correspondence to: Sebastian F.L. Watt (s.watt@bham.ac.uk)

Abstract. The lateral collapse of Ritter Island volcano, Papua New Guinea, on 13th March 1888, generated a devastating tsunami with observed effects at distances of up to 500 km. As the largest recorded volcano lateral collapse, the event is significant in improving our general understanding of volcano instability and associated hazards. Proximal records of the tsunami are limited to post-event reports of extensive coastal damage of nearby islands. Here, we present new field observations of tsunami deposits on these coastlines, supplemented by and interpreted alongside oral accounts from coastal communities (from 2004) and a reanalysis of contemporary reports. Our data reveal the widespread presence of massive and chaotic conglomerates deposited by the tsunami at sites up to 30 km from Ritter, with thicknesses of up to 2.0 m and extending up to 400 m from the shoreline. Such deposits may be indicative of large-magnitude landslide-generated tsunamis, and are generally structureless, coarsest and thickest near the coast, and contain mixed terrigenous and marine clasts, including corals, shells and benthic foraminifera. Isolated large coral blocks are also widespread tsunami inundation markers, reaching >200 m from the shore. The deposits extend to approximately half the maximum inundation distance indicated by oral accounts; the latter preserve precise detail consistent with the timing, spatial characteristics and impacts of the Ritter tsunami interpreted from prior geological surveys, distal accounts and simulations. Collectively, this study indicates that the impacts of the 1888 tsunami on proximal shorelines were larger than has been previously inferred from post-event reports. The maximum run-up height was likely many tens of metres on Sakar and Umboi and extensively exceeded 20 m on western New Britain. From the collated descriptions, we also estimate that ~2000–3000 deaths were caused directly by the tsunami. These new observations add to previous submarine surveys of the event, allowing the coupled process of landslide motion and tsunami generation at Ritter Island to be investigated more comprehensively.

Keywords. Ritter Island volcano; Papua New Guinea; Volcanic tsunami; tsunami deposit; oral history; coral reef blocks

1 Introduction

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Tsunamis generated by volcanic processes represent only a small proportion of all tsunamis (Latter, 1981) but may have extreme magnitudes, as exemplified by the 1883 (Verbeek, 1885) and 2018 (Grilli et al., 2019) tsunamis at Krakatau volcano, Indonesia and the 2022 Hunga-Tonga Hunga-Ha'apai tsunami (Lynett et al., 2022). Among volcanic hazards, volcanogenic tsunamis stand out for the severity of their impacts (Auker et al., 2013), reflecting their potential to cause damage at distances of tens or even hundreds of kilometres, their complex range of causal mechanisms, and the absence of clear precursory signals of tsunami generation (e.g., Paris et al., 2014; Day et al., 2015; Paris 2015; Watt et al., 2020). Tsunamis generated by volcanic landslides present a particular challenge, due to the difficulties in determining the potential size, timing and direction of slope failures.

Globally, tsunami-generating volcanic landslides with a volume of 0.5-5 km^3 occur around once every one-hundred years (Day et al., 2015; Watt et al., 2020). Few such events have been observed directly, and each thus provides an important opportunity to improve our understanding of the factors that lead to slope failure, landslide mechanisms, and the characteristics of associated tsunamis. Among all historical events, the 1888 collapse of Ritter Island is an exemplar, being the largest recorded volcano lateral collapse (Johnson, 1987; Day et al., 2015; Watt et al., 2019; Karstens et al., 2019) and one of only two such events (alongside the much smaller 2018 collapse of Anak Krakatau, Indonesia) with timed, eyewitness accounts of the associated tsunami (Cooke, 1981) that contain sufficiently accurate information to quantitatively constrain the kinematics of tsunami generation (Ward and Day, 2003; Karstens et al., 2020).

The impacts of the Anak Krakatau 2018 tsunami on the coastlines of Java and Sumatra highlight the damage caused by lateral-collapse tsunamis and the challenges of forecasting them (Walter et al., 2019; Grilli et al., 2019; Perttu et al., 2020; Cutler et al., 2022). Although the 1888 Ritter Island tsunami was far less well observed, the collapse volume (Day et al., 2015; Karstens et al., 2019) was around ten times larger than that of Anak Krakatau (Hunt et al., 2021), and it remains an important event for improving our understanding of volcanic-island geohazards.

In this paper, we seek to better constrain the characteristics of the Ritter Island tsunami in the near-source region (at straight-line distances of up to 67 km, spanning the nearby islands of Sakar, Umboi and Tolokiwa, and the western coast of New Britain), by using field observations of tsunami deposits supplemented by oral histories of the event from nearby communities and a reanalysis of contemporary reports. This advances our understanding of the tsunami magnitude and impacts, information which can ultimately be used in combination with distal written records (cf. Day et al., 2015), direct observations of the collapse scar and deposit (e.g., Karstens et al., 2019; Watt et al., 2019), and numerical landslide-tsunami modelling (e.g., Ward and Day, 2003; Karstens et al., 2020) to better constrain the event. We also provide new insights on the characteristics of volcano-tsunami deposits, which are little documented in the geological record but are important indicators of the occurrence and scale of pre-historical tsunamis (e.g., Ramalho et al., 2015; Paris et al., 2018; Madeira et al., 2020).

1.1 The 1888 lateral collapse of Ritter Island

Ritter Island is a basaltic to andesitic volcano in the Dampier Strait, west of New Britain island in Papua New Guinea. It lies between the larger volcanic islands of Umboi and Sakar, aligned with their eastern coasts (Fig. 1). In the early 19th century, Ritter's steep cone stood ~780 m above sea level, with contemporary reports implying frequent eruptive activity, typical of subaerial basaltic volcanism (Cooke, 1981; Johnson, 1987). In March 1888,

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

the volcano collapsed westward and was reduced to a north-trending, arcuate rocky ridge. This ridge is the subaerial headwall of an amphitheatre-shaped landslide scar that cuts deeply into the submarine edifice, with a base at approximately 800 m below sea level and a width between the submerged sidewalls of approximately three kilometres (Day et al., 2015; Karstens et al., 2019; Watt et al., 2019).

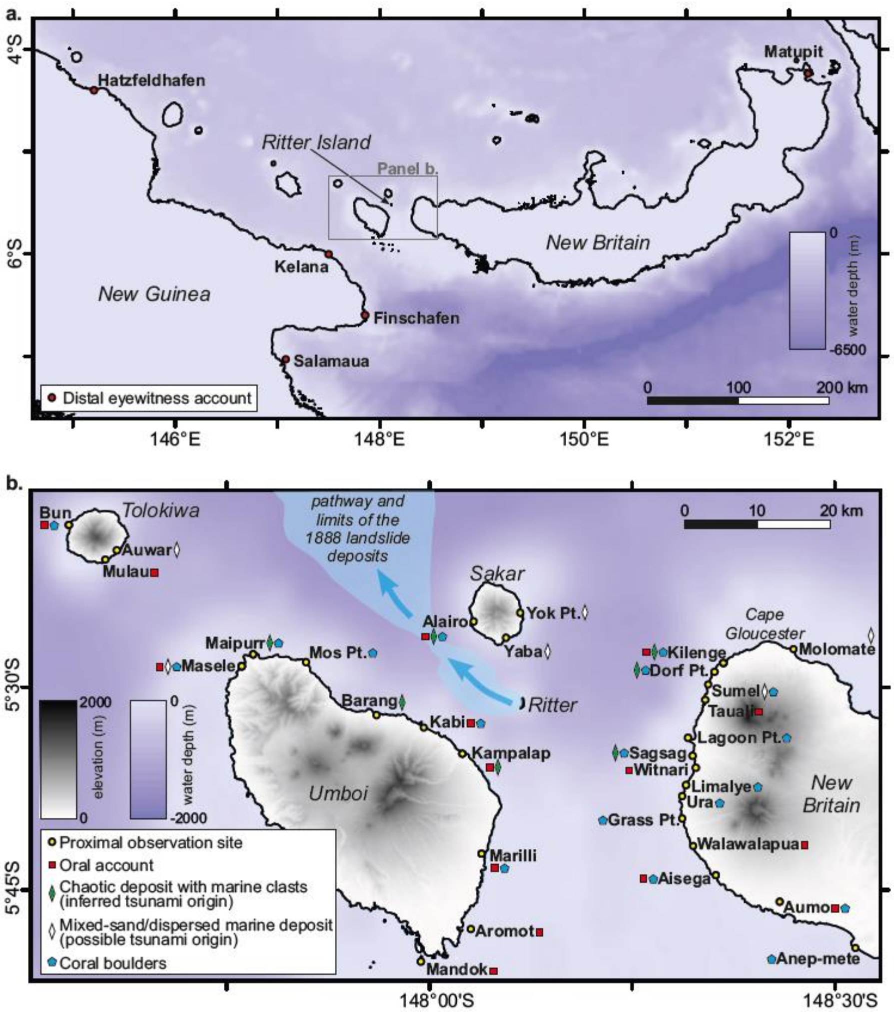

Figure 1: a: Regional map of the Bismarck archipelago and NE New Guinea. Sites of distal tsunami observations referred to in the text are labelled. b: Map of the study region, labelling all observation sites described in this study, including deposit details and locations of oral accounts. The extent of the Ritter Island 1888 submarine landslide deposits is from Watt et al. (2019).

Previous studies have identified the processes involved in the 1888 collapse through a combination of historical written accounts, marine geophysical methods and seafloor sampling (Day et al., 2015; Watt et al., 2019), showing that catastrophic structural failure of the edifice mobilised 2.4–4.2 km^3 of rock (Day et al., 2015; Karstens et al., 2019). This was associated with extensive deformation of seafloor sediments to the west (Karstens et al., 2019) and led to seabed erosion and secondary sediment failures, generating a complex set of

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

mass-flow deposits that extends at least 80 km to the north-west (Watt et al., 2019). In total, approximately 13 km^3 of material was mobilised as part of the event. A pumiceous component in the upper part of the submarine mass-flow deposits has been interpreted as the product of an accompanying explosive submarine eruption (Watt et al., 2019). The subsequent growth of a submerged volcanic cone in the collapse scar and reports of episodic submarine volcanic activity indicates ongoing explosive volcanism at the site (Cooke, 1981; Saunders and Kuduon, 2009; Day et al., 2015; Karstens et al., 2019).

On the eastern side of the Dampier Strait, the coast of New Britain forms a mountainous area with a cluster of large volcanoes that includes the persistently active Langila (Palfreyman et al., 1981) and the larger, extinct cone of Talawe to the west. Discontinuous fringing coral reefs are present along most of the coast between Cape Gloucester and Anep-mete (Fig. 1). On the western side of the Dampier strait, the large island of Umboi, to the south, encompasses three extinct volcanic cones, Barik, Saol and Talo, and various satellite scoria cones, within a discontinuous remnant of a caldera (Johnson et al., 1972). Most parts of Umboi, including the volcanic mountains, are heavily forested. The northern coast, particularly in the central part of the island, forms a narrow strip with a relatively gentle gradient at the foot of the volcanic cones, and is today settled by several villages. Discontinuous fringing and barrier coral reefs are present, particularly on the southeastern and extreme northwestern coasts, and an extensive drowned coral reef platform occurs at depths of up to 180 m off the northern coast (Day et al., 2015). To the north, Sakar comprises a single main volcanic cone, with densely forested slopes and deeply incised valleys that rise steeply from the coastline. A discontinuous narrow coastal plain is present in places between the cone and fringing coral reefs, which are least developed on the south-western side. Further west, beyond the tip of Umboi, is the island of Tolokiwa, which is very similar in both morphology and dimensions to Sakar, with fringing reefs around most of the island.

1.1.1 Contemporary written observations

There are no records of direct eyewitness accounts of the Ritter Island collapse (as opposed to the tsunami). Ritter, being a small, very steep-sided and highly active volcanic island, is not likely to have been inhabited in 1888, in contrast to the coasts of adjacent islands. The tsunami in 1888 destroyed or damaged several coastal villages on northern Umboi (Eric Kwa, pers. comm. 2003), as well as on Sakar and the western coast of New Britain (Sackley, 1974; Johnson, 1987). Previously reported, contemporaneously written eyewitness accounts of the tsunami are from more distal coastlines, at mission and trading sites on northern New Guinea and the east end of New Britain (Cooke, 1981; Ward and Day, 2003). These accounts, written by European traders and colonial officials, document run-up heights of several metres and refer to multiple strong wave arrivals with a period of a few minutes (consistent with a landslide-tsunami source), forming a single wave train. The nearest of these sites, at Kelana (Fig. 1), is approximately 100 km from Ritter, but because of the positioning of Umboi, the actual pathway of the tsunami would have been longer. There are no other documented eyewitness reports, and the descriptions provided here thus fill a significant gap in observations.

Observations of deposits from the 1888 tsunami are described from a post-event search for the two leaders (von Below and Hunstein) of a German exploration party on the western coast of New Britain. The search, four days after the tsunami, found that the land surface had been stripped of vegetation for a distance of about 1 km inland and was covered by tsunami sediment deposits more than 1 m thick (Anon., 1888a, 1888b, 1890, 1891; Steinhäuser, 1892). Ships' accounts, summarised in these contemporary reports and later sources (Sieberg,

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

1910; Everingham, 1977; Cooke, 1981; Ward and Day, 2003; Karstens et al., 2020), providing some approximate observations of tsunami damage on the west coast of New Britain, Umboi and Sakar. A further important insight is the absence of strong evidence for an accompanying large explosive eruption (Johnson, 1987; Ward and Day, 2003), such as those associated with the 1883 Krakatau tsunami (Verbeek, 1885) or the 2022 Hunga Tonga-Hunga Ha'apai tsunami (Lynett et al., 2022). Nevertheless, reports of a "fine, hardly noticeable ashfall" at Finschafen (Cooke, 1981), a thunder- or shot-like noise (Everingham, 1977; Cooke, 1981), and of possibly associated pumice clasts on the shore of western New Britain (cf. Karstens et al., 2020) and at Kelana (Everingham, 1977) (see Fig. 1 for locations), are potential indicators of associated eruptive activity. This is consistent with observations of a pumiceous component in the submarine landslide deposits (Watt et al., 2019), even if any accompanying volcanism is not considered to have been an important driver of tsunami generation (Ward and Day, 2003; Karstens et al., 2020).

1.2 The depositional record of tsunamis

Beyond direct observations and instrumental measurements of tsunami wave characteristics, the best constraints on tsunami parameters (wave height; run-up height; inundation distance) are provided by evidence of damage – such as that to buildings or vegetation – or by the deposits and other geomorphological imprints left behind (Costa and Andrade, 2020). Damage indicators may become rapidly obscured by cleanup and repair operations in urban areas, and recovery of vegetation elsewhere. In contrast, tsunami deposits provide an important longer-term record (Scheffers and Kelletat, 2003; Dawson and Stewart, 2007). For historical events, documenting these deposits has helped constrain the relationship between their characteristics, such as clast size, internal structure and thickness, and tsunami parameters (Gelfenbaum and Jaffe, 2003; Hori et al., 2007; Abe et al., 2012). For prehistoric events, such deposits can add to our understanding of tsunami magnitude and frequency (Goff et al., 2001; Paris et al., 2018). Nevertheless, the preservation of tsunami deposits is often sparse and their characteristics can be spatially variable and sometimes difficult to discriminate from other clastic coastal deposits (Shanmugam, 2012; Costa and Andrade, 2020). The grain size distributions and lithological characteristics of tsunami sediments vary with the sediment sources that are scoured by incoming tsunami waves. Documenting the nature of deposits left by a variety of historical events, with different sources and impacting different sedimentary environments, is thus valuable in adding to our general capacity to recognise and reconstruct ancient tsunamis. A further motivation for studying historical tsunamis generated by non-earthquake sources is that whereas there is a clear distinction between the wave parameters of large earthquake generated tsunamis, which are dominated by a few waves with periods of many hundreds of seconds, versus storm-generated wave trains, containing many hundreds of waves with periods of a few tens of seconds, the spectral complexity, intermediate wave periods and frequency-dispersive characteristics of landslide-generated tsunami wave trains (Ward, 2000; Ward & Day, 2003) means that the resulting deposits may show intermediate characteristics between those of earthquake-generated tsunamis and those produced by storm waves.

There are few historical examples of large-scale landslide generated tsunamis. The best documented analogue to the Ritter Island tsunami is that generated by the lateral collapse of Anak Krakatau in 2018 (Grilli et al., 2019). Islands within a few kilometres of Anak Krakatau are dominated by steep topography, with limited prospects for tsunami deposit preservation. At one sheltered site, a tsunami deposit of coarse beach clasts has been described (Cutler et al., 2021). More distally (60-90 km from source), continuous sandy deposits were documented widely on low-gradient coastal plains, generally fining upwards and in several cases containing rip-up clasts, with

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

multiple layers observed in a transect with more irregular topography (Putra et al., 2020). These deposits were relatively thin (<10 cm) and did not display a landward thinning trend. In addition, boulders of various lithologies, including coral blocks, were transported up to 100 m inland by the Anak Krakatau tsunami, reaching close to half the total inundation distance (Putra et al., 2020). These characteristics are comparable to historical earthquake-generated tsunami deposits, such as those in Thailand from the 2004 Indian Ocean tsunami (Hori et al., 2007). In that instance, sandy deposits extend for 1 km inland on coastal plains and again display no landward thinning trend. They generally fine upwards, in some cases displaying multiple layers, and are thickest (>30 cm in places) in coastal depressions. The basal layer of the 2004 Thailand deposits becomes finer landwards, consistent with the waning energy of initial tsunami inundation, while subsequent layers do not show this pattern and were potentially deposited by backflow (Hori et al., 2007). Coastal-plain sand deposits from the 2011 Tohoku earthquake-generated tsunami reached 60-90% of the tsunami inundation distance, thinning landward to form cm-scale layers or transitioning to muds at their depositional limit (Abe et al., 2012; Chagué-Goff et al., 2012). Although the above examples show that landward thinning is not a universal feature of tsunami deposits, it is widely cited as typical (cf. Dawson and Stewart, 2007; Costa and Andrade, 2020). These examples of tsunami deposits are also all from similar coastal-plain environments and are sand-dominated, reflecting the local beach and dune sediment source (cf. Abe et al., 2012).

The presence of marine clasts in tsunami deposits is a general feature: both historical and ancient tsunamis have been shown to deposit structureless or graded sands containing marine bioclasts, in some cases with rip-up clasts, forming distinctive beds in low-energy coastal environments (e.g., Sato et al., 1995; Bondevik et al., 1997; Gelfenbaum and Jaffe, 2003). However, depending on both the coastal topography and local sediment sources, deposits left by tsunamis may be much coarser grained, ranging from chaotic conglomerates to isolated large boulders. Coral boulders have been identified from the Indian Ocean tsunami (e.g., Dawson and Stewart, 2007) and are widespread features of historical events (Etienne et al., 2011), including those rafted inland by the Krakatau, 1883 volcanic tsunami (Verbeek, 1885). More continuous boulder deposits and conglomerates have in many cases been used to infer the occurrence of ancient, extremely large-scale tsunamis (Ramalho et al., 2015; Paris et al., 2018; Madeira et al., 2020), but there are few descriptions of comparable deposits from historical events (cf. Etienne et al., 2011). One recent example is the extreme landslide-generated tsunami at Taan fjord, Alaska in 2015 (Higman et al., 2018), which deposited extensive massive and very poorly sorted conglomerates that the authors note are dissimilar to literature-documented historical tsunami deposits, typified by normally graded sands (predominantly from earthquake sources).

There is no uniquely reliable indicator of tsunami deposition (Shanmugam, 2012). Tsunami deposits represent highly variable processes influenced by local geomorphology, sediment sources and transport processes, and share many features with storm-surge generated deposits (Costa and Andrade, 2020). Both tsunami and storm surge processes can produce anomalous coarse sandy deposits, containing beach material and shallow-marine faunal debris, which range from massive units to those displaying a variety of sedimentary structures. The landward limit of deposits is reflective of, but underestimates, total inundation (e.g., Abe et al., 2012; Chagué-Goff et al., 2012; Soria et al., 2018; Costa and Andrade, 2020). Both storm and tsunami processes can result in inland transport of boulders (Noormets et al., 2004) whose origin is not straightforward to discriminate. Although Goto et al. (2012) suggest that tsunamis can lead to boulder deposition substantially further from the reef edge, others suggest this may not be a universal relationship (Kennedy et al., 2017; Cox et al., 2018).

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Although tsunami deposits have received much attention as indicators of past tsunamis, the net impact of tsunamis on some shorelines may be erosional, rather than depositional. Several historical tsunamis, from both earthquake and non-earthquake sources, have produced extensive erosion (e.g., Lituya Bay, 1958 (Miller, 1960); Krakatau, 1883 (Verbeek, 1886)), particularly near to the shoreline (e.g., Gelfenbaum and Jaffe, 2003; Richmond et al., 2012). This may reflect both the nature of a coastline, such as steep or rocky shores without mobile sediment, where tsunami impacts may leave prominent erosional trimlines (Miller, 1960; Scheffers et al., 2012), and the characteristics of the wave. Waves with very large run-ups can be strongly erosive, and there may thus be a transition from erosion to deposition both as a wave moves inland, or as a wave train impacts a single site. Because of this, deposits may originate from later, smaller waves, emplaced on an erosive base, and are not necessarily related to the largest wave arrival.

2 Methods

In 2004, following information that there were still prominent exposures of tsunami sediment in the Ritter Island area (Eric Kwa, Matthias Sapuri, pers. comm. 2002), including blocks of reef limestone and lenses of exotic clastic sediment, a two-month programme of mapping and sampling was undertaken to sample and characterise the sediments that were deposited by the 1888 tsunami, from western New Britain to Tolokiwa, accompanied by recording of accounts of the tsunami that have been preserved as oral traditions by the descendants of eyewitnesses to the event (David, 2007). Information shared by local communities was recorded using an interview form modified from the approach outlined in Davies et al. (2003) to document impacts of the 1998 Aitape tsunami. These oral records provide important independent context for interpreting the deposits, enabling the characteristics of the deposits and the tsunami to be related directly, and establishing if additional historical tsunamis are a potential source of ambiguity when interpreting the 1888 event.

Evidence for tsunami deposits was assessed along transects perpendicular to the coastline at several sites in New Britain, Umboi, Sakar and Tolokiwa. Much of the New Britain coast was inaccessible for this purpose (between Sagsag and Anepmete; Fig. 1) because of swampy environments or steep coastal cliffs up to 20 m in height; similarly, widespread swamp areas and mangroves on SW Umboi prevented access. At each location, lines were measured perpendicular to the shoreline and between observation sites using a 50 m tape and a compass. Two Abney levels were used to take elevation readings along the traverse. Vertical samples to ~1.2 m depths were taken using a soil auger, and in places pits were also dug to a similar depth. At some sites, use was made of natural exposures in wave- or river-cut sections (Fig. 2). Descriptions were made in the field, with samples from distinct sedimentary layers (particularly any coarse clastic deposits containing marine clasts) also taken for subsequent grain-size and component analysis. Samples were dry-sieved in the range 65 to 0.025 mm, and >125 and >250 µm fractions examined for the presence of foraminifera and other marine microfossils (Fig. 2).

The interpretation of a tsunami derived deposit was based on the following criteria. First, we expected such a deposit to form a discrete near-surface layer that was coarser grained and more poorly sorted than its bounding sediment, and with distinct clast types, particularly the presence of marine clasts such as coral or shell material. Furthermore, we expect the sediment above and below to be of similar type, with the potential tsunami deposit thus forming a single anomalous layer. For example, if an exposure contained multiple coarse-grained beds, interbedded with finer sediment and without any evident marine material, as might be derived from fluvial processes, then further description or sampling was not undertaken.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

In addition to documenting continuous tsunami deposits in the near-surface coastal stratigraphy, large boulders of reef limestone were identified in the coastal and intertidal zones at many sites. The perpendicular distance from the shoreline (high-water mark), elevation and dimensions of these were measured and samples collected.

3 Results

3.1 Oral historical records

3.1.1 Constraints on tsunami parameters and associated volcanic activity

Oral accounts were shared principally by older villagers at fifteen sites in New Britain, Sakar, Tolokiwa and Umboi (including offshore islands), who were ancestors of those alive in 1888 (in most cases likely two generations removed, although one woman at Walawalapua, New Britain, stated that her parents were teenagers when they witnessed the event) (David, 2007). A summary of information recorded from these accounts is provided in Table 1, with a narrative summary in the Supplementary Data. In general, the oral historical descriptions are consistent with the expected nature of proximal tsunami impacts and thus support an inference of these being eyewitness accounts, as opposed to observations made more distally and then relayed by people that have subsequently settled the region. This therefore suggests continuous settlement in the area by survivors of the event, with the exception of Masele, Umboi (Table 1).

Accounts from twelve locations provide information on the timing of the event. Of these, seven state that the wave arrived in the early morning hours, which is consistent with the arrival time from distal eyewitnesses (Ward and Day, 2003). Two of the additional records (one from New Britain and one from Umboi) state that the event occurred in the evening, but both of these note that it was coincident with a traditional celebration (singsing). These celebrations can continue until dawn, and these accounts are thus still potentially consistent with an early morning tsunami arrival. The remaining accounts refer to an arrival time around midday (two accounts) or sunset (one further account). These accounts may reflect elements of recollections from separate tsunamis that have affected the region, such as the Ninigo Islands earthquake-generated tsunami of 1930, which was generated mid-morning (Everingham, 1977; Mercer et al., 2016). Although this introduces some uncertainty into accounts that have been passed through one or two generations, the early-morning timing of most descriptions is consistent with the Ritter tsunami and inconsistent with the 1930 event. Furthermore, many of the accounts summarised in Table 1 also include direct descriptions of Ritter Island. Other elements of the descriptions are consistent across multiple sites and islands and are in line with the expected magnitude of a large landslide-generated tsunami. Most accounts only recollect one tsunami and connect this event to Ritter. Two accounts referred to other historical tsunamis, inflicting smaller levels of damage, and in both cases we have inferred that the larger, earlier event is that from Ritter.

Accounts from three sites in New Britain refer to the sea receding before the tsunami arrival, but it is notable that such reports are absent from the other islands (two of these other reports explicitly refer to the sea not receding). This is consistent with a leading wave crest propagating to the west, in the direction of landslide failure, but a leading trough propagating towards New Britain in the east. This distinction in the waveform is in line with numerical models of the event (Ward and Day, 2003). Descriptions from several locations also refer to tremors, loud sounds, explosions or glows. These are stated as having occurred before the tsunami arrived and

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Table 1: Information from oral accounts of the Ritter Island 1888 tsunami shared by communities around the Dampier Strait (Fig. 1) in 2004 (David, 2007). (♠ indicates timing information that does not correlate with historical observations of the tsunami summarised in Ward and Day, 2003). A narrative summary is provided as Supplementary Data.

Location (Fig. 1); person(s) providing account	**Phenomena observed before tsunami**	**Arrival time of tsunami; duration; arrival type**	**Number of waves; tsunami height or runups /inundations; other phenomena**	**Damage and impacts**
Kilenge, New Britain; several elderly men	Sort of explosion on Ritter a few minutes before tsunami arrival.	In the afternoon (about sunset) ♠ Sea receded beyond normal low tide some minutes after the explosion. After a while, three large waves approached.	3 waves, the first small, second and third much bigger, at tree top heights (>15 m). Damage extensive to >300 m inland; inundation extending even further; fire-like glow on approaching waves. A separate account from Kilenge, reported in Sackley (1974) refers to the sea covering the area of the present airstrip (1050 m inland, 28 m elevation) and is broadly consistent with the above.	A big village, Akoni, NE of Kilenge was completely devastated (this village was celebrating a singsing at the time [*see also account from Kampalap*****]). Waves carried marine organisms, coral boulders and uprooted trees inland. Kilenge encountered less damage. The damage description is corroborated by an account referred to in Sackley (1974) from Kilenge, which refers to the large village of Akoni and three nearby smaller villages being destroyed.
Tauali, New Britain; one man (aged in 70s)	Sort of explosion or fire soon before tsunami. No earthquake felt or unusual noises heard.	About sunset ♠ Sea receded beyond low tide zone and built up at a distance.	Waves at tree-top heights (15-20 m); waves splashed over the top of local bluff (53 m height); fire-like glow on approaching waves.	Destroyed houses and uprooted trees; no casualties because people ran inland on initial wave retreat; coral boulders carried into intertidal zone.
Witnari, New Britain; one elderly man			2 huge waves.	Coastline destroyed; mentioned two white men at Lagoon Point who were washed away.
Walawalapua, New Britain; one woman (aged late 70s, recalled information from parents, stated to be teenagers at the time)	Small tremors woke villagers.	Early morning hours (estimate at 4 – 6 am).	3 huge waves estimated at tree top heights (15 – 20m). 1st and 2nd waves were bigger than 3rd with associated smaller waves.	Uprooting of trees 20 m inland; marine organisms dumped on the coastline. Village undamaged, since slightly inland.
Aisega, New Britain; one elderly man, detail passed on from ancestors		Around midday (12-2 pm) ♠; sea receded beyond tidal zone ahead of wave arrival.	2 huge waves surged, and inundation to *ca* 500 m inland. Height could have been 15 m.	Coastline destroyed. Villagers ran inland. Village was on higher ground inland, and not damaged. Mention two white men, killed between Witnari and Ura, and past Ura. A few days later, an outbreak of sores inflicted villagers and nearly wiped out a settlement. *
Aumo, New Britain; one elderly woman, detail passed on from parents			2 waves, the first smaller, the second larger.	Numerous fish & marine organisms dumped onshore. Timing unknown, because Aumo village was 5 km inland.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Alairo, Sakar; several people recalling detail passed on from ancestors	Before the tsunami, earthquakes felt and rumbling noise. The main shock occurred early in the morning (4-6 am), shaking everything. There were unusual phenomena accompanying this, including water squirting from the ground, a continuous popping sound like gunshots, and a smell of fire. After the main shock, they saw Ritter explode and the western half of the island sink into the sea.	Early morning hours, shortly after the main shock (which was estimated at 4 – 6 am) the island collapsed. The tsunami arrived a few minutes later.	2 huge waves not much distance apart, est. at height of coconut palm (> 20 m high); fire-like glows on the waves, with a noise like a low flying helicopter; damage extending 500 m inland, inundation must have gone further.	Coral, shells and marine organisms deposited on land. Uprooting of trees and complete destruction of houses. An epidemic of sores inflicted survivors a few days after the event.
Mulau, Tolokiwa; an elderly man (aged late 70s)	Tsunami arrived after a few small earth tremors were felt.	In the morning (estimate at 6 –8 am)	3 waves; first was small, passing under stilt house height (<1.5 m); second larger and the third sufficient to destroy the houses.	Villagers moved inland after first wave; no casualties; large extent. of coastline facing Ritter destroyed.
Bun, Tolokiwa; an elderly man	No receding sea, and no earthquakes	Around morning hours; no receding	One huge wave, height estimated at 5 m**	Swept everything back into the sea on the backwash. No-one killed or injured.
Masele, Umboi; several villagers				No details of the event: the villagers had settled here from inland sites and from Tolokiwa, after the tsunami***
Kabi, Umboi; one man (aged late 60s)	A woman saw smoke and fire from Ritter early in the morning (4-6 am), and told villagers to move inland because of strange happenings.	Early morning hours (estimate at 4 –6 am)		Not many people lost their lives, because villagers had moved inland. A few days later, sores/boils brought on by dust or another agent. A large village, Salegong (NW of Kabi), with an estimated population of 2000, was completely destroyed and almost everyone perished.
Kampalap, Umboi; one elderly man, recounts detail from ancestors	Felt tremors and saw water spouting from the vent at Ritter, accompanied by explosions, a moment or two before tsunami	Event happened in the evening, because Salegong (*see account from Kabi*) was having a singsing (*usually held in the evening but can continue until dawn*) when the tsunami hit them****	Huge tsunami waves	Swept away everything on the coast, dumped corals and marine organisms, scoured and changed land profiles on the coast. Kampalap was a little inland, so no description of wave available, and no one injured or killed.
Marille, Umboi; one man*****		Sometime in the morning		Considerable damage with ripped-up coral boulders, fish, shells and other debris dumped onshore. No-one was killed; villagers had moved to higher ground.
Aromot island, offshore Umboi; group of elderly men	No warning signs of tsunami, such as receding sea, earthquakes or other phenomena observed or heard.	Early in the morning, as villagers were preparing to go out fishing and gardening; no receding	2 huge waves with several smaller waves. The whole island was inundated.	The island was almost completely obliterated; the land area decreased; only two small trees were left standing (*and were pointed out during the interview*). The 2 waves swept over the island & change the island landform (decreased to smaller size). One pregnant woman was killed; all others survived, most escaping on canoes.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Mandok island, offshore Umboi; one elderly man	A main shock occurred before the tsunami	Around midday ♠	Waves reached stilt post house height (1-2 m). Smaller waves came over the island.	People gathered on elevated ground; a small girl was swept away.

*This account also mentions three days of darkness from a volcanic eruption, before the Ritter tsunami, although the exact dates are not known.
**This account makes reference to three tsunamis implied to have occurred since the Ritter event, the first two causing slight damage but not to the degree of the Ritter event, and the third occurring recently, around 1997, with no major damage.
***The villagers refer to a Catholic bishop resident at Masele in the 1840s or before. We infer that if the current villagers settled in the area after 1888, that the village was destroyed by the tsunami.
****Although stated to have occurred in the evening, the timing being coincident with a singsing is also potentially compatible with an early morning arrival. The same inference could be made for the account from Kilenge, given the reference to a singsing at nearby Akoni.
*****The same person also recounts a long period of darkness (an earlier event), leaving fine dust everywhere. This may refer to the Long Island eruption (Blong et al., 2018).

suggest that the lateral collapse was accompanied by or preceded by volcanic activity (potentially including felt earthquakes and/or explosions). Accounts from Alairo, Kampalap and Kabi, the three villages nearest to Ritter on Sakar and Umboi, which would have had direct views of Ritter, describe a range of phenomena that are consistent with volcanic explosions (shot-like sounds; smells of fire). Direct observations of smoke and fire at Kabi caused villagers to move inland. These suggest magmatic or phreatic explosive activity, which would not be surprising given that Ritter was a frequently active volcano (Johnson, 1987). Such activity may have occurred ahead of the collapse or as a consequence of the collapse, given that the failure plane cut the central conduit of the volcano and would have exposed it to seawater. The descriptions of tremors and explosions are potentially consistent with precursory volcanic activity, ahead of the lateral collapse, and there is a comparable observation referred to in Johnson et al. (1972).

There are no descriptions that provide constraints on wave period, but several accounts refer to two or three waves (mostly three), consistent with distal observations of the wave train (Ward and Day, 2003). At Aromot and Mandok, small and low-lying islands SW of Umboi, it is reported that waves inundated the entire island, but a specific height reference implies a run-up of 1.5 m, and nearly all people on these islands are reported to have survived the event. This height estimate, along with those from Tolokiwa of 1.5 m and 5 m, is unexpectedly low relative to eyewitness accounts from more distal sites on New Guinea (Ward and Day, 2003). Accounts that estimate wave parameters in western New Britain (15-20 m height; inundation to >500 m) and Sakar (heights >20 m), inferred from reports of waves reaching "tree-top" heights, are more in line with distal contemporary records. At Tauali, on western New Britain, it was reported that waves had splashed over the top of a bluff measured at ~50 m above sea level. From the four sites on northern and eastern Umboi, it is notable that there are no specific wave-height references, potentially indicating the more wholesale destruction of coastal settlements and that no direct eyewitnesses survived the event. Indeed, both on New Britain and Umboi there are large coastal villages that are reported to have been devastated. At Masele, Umboi, it was also noted that the village had been resettled since the time of the event (see Fig. 1 for locations and Table 1 for further details).

Some reference is made to erosion and deposition associated with the event. Erosional modifications or a powerful backwash are implied by reports from Umboi, Tolokiwa and New Britain. Other reports from Umboi, New Britain and Sakar refer to ripped-up coral boulders, fish, shells and other debris being deposited onshore (consistent with the contemporary reports of damage; Everingham, 1977; Cooke, 1981).

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Finally, it is notable that there are similarities between accounts from several areas that may not simply reflect common observations, but that also imply sharing of oral accounts between villages and islands after the event. These similarities include reference to two white men riding on or being swept away by the waves, noted in several accounts on New Britain and from Sakar. This appears to be a reference to the von Below and Hunstein expedition that disappeared in the event, and for whom a search party was sent out in subsequent days (cf. Anon., 1888b, 1891; Steinhäuser, 1892; Ward and Day, 2003). At Kilenge and Tauali (New Britain) fire-like glows, in both instances likened to a head-dress, are described on the crest of the waves, while fire-like glows on the waves are also referenced at Alairo (Sakar). The account from Aumo (New Britain) refers to two men with a head-dress as riding on the waves. The common elements to these accounts may reflect sharing of descriptions across the region. Despite this, we note that distinctive details (such as the receding of the sea from several sites in New Britain, in contrast to opposing details from other sites) suggest that the specific information in accounts is reflective of local impacts and observations. One further common detail is a reference to an epidemic of sores or boils that followed within days of the tsunami and was linked to those who had had contact with the event (noted in accounts from New Britain, Sakar and Umboi).

3.1.2 Casualties from the 1888 tsunami

Reports on casualties suggest that in villages on Tolokiwa and at several sites on New Britain and Umboi there were no deaths from the event, in several cases because villagers had already moved inland due to indications of unusual volcanic activity or behaviour of the sea. Nevertheless, entire villages are reported to have been destroyed on Sakar, Umboi and New Britain, including large settlements with many lives lost. The total number of fatalities from the 1888 tsunami is very poorly constrained but was previously estimated at 3000 by Johnson (1987). The basis for this is unclear, but it may have been estimated based on assumptions of relatively large average village populations in line with those of the later 20^{th} Century. Specific references in the oral accounts refer to the destruction of a large village on New Britain (Akoni) and (in two accounts) the large village of Salegong on Umboi (one estimating a population of 2000). Sackley (1974) refers to a separate account of Akoni being a very large village and the tsunami also destroying three smaller villages in the same area (between Kilenge and Cape Gloucester; Fig. 1). Other accounts suggest that at least two villages (possibly more; pers. comm. E.Kwa, 2003) were destroyed on Umboi, one and perhaps more (Table 1; cf. Steinhäuser, 1892; Sackley, 1974; Johnson, 1987) on New Britain, and one on Sakar, with small numbers of casualties in villages elsewhere. Post-event reports imply the destruction of additional villages, referring to the once-heavily settled coasts of Umboi (Anon., 1891) and that no settlements could later be found along its entire eastern coast (Anon., 1890), with formerly busy harbours on both the southeast and northwest tips (near Masele, consistent with the oral accounts recorded here) now close to deserted, where a local leader estimated hundreds of deaths (Anon., 1890, 1891).

The population of settlements destroyed in the event is unknown but can be estimated from the village sizes in Dunbar (1993), which indicates a global average from comparable communities of 150 ± 40 inhabitants, close to the average of 129 from a combined New Guinea dataset (including both settled hunter-gatherer and horticulturalist societies (cf. Dunbar, 1993)). The reports collectively imply that several villages were destroyed on Umboi, including the large settlement of Salegong, with depopulation of coastal villages along the entire eastern and northern coasts. Nevertheless, details in the oral accounts imply that at least in some of these

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

villages most people survived, but several of these were located slightly inland. An estimate of 1000-2000 deaths on Umboi is plausible, based on the details above and the destruction of multiple settlements. Additional destruction of several villages on New Britain (including reference to a larger village) and coastal settlements on Sakar would have added to this. On this basis, the estimate of 3000 in Johnson (1987) may be considered a maximum, with the number of deaths likely to be in the range of 2000-3000, but we note that this is subject to several uncertainties.

3.2 Field observations of tsunami deposits

3.2.1 Stratigraphy and sedimentology

The strongest evidence for tsunami deposits from the 1888 tsunami was obtained from three sites on Umboi (Maipurr, Barang and Kampalap) and one on Sakar (Alairo) (Fig. 1) that preserved deposits with similar characteristics, forming discrete beds of chaotic clastic sediment, tapering inland and containing marine clastic material (Fig. 3).

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Figure 2: Photographs of tsunami deposits at a: Maipurr, Umboi (pit dug 134 m inland), with red lines indicating internal stratification; b: Barang, Umboi (wave-cut face near shoreline), exposing chaotic conglomerate with detailed inset on right; c: Kampalap, Umboi (coastal cliff exposure), showing layered deposit rich in marine carbonate fragments, with detailed inset on right. See Fig. 1 for locations and Fig. 3 for logged sections. d: Typical examples of foraminifera sampled within the matrix of the studied deposits (top to bottom: Amphistegina sp., Calcarina sp., Ammonia beccarii, Anomalinella rostrata, Bolivina sp.; 50× magnification).

Alairo was the only site on Sakar where a deposit was found that strongly conforms to our expected tsunami deposit characteristics. The site lies on the west coast, 13 km NW of the centre of the Ritter collapse scar, on a coastline parallel to the landslide travel direction. The coastal slope in the area was measured to rise at 2.5° for 500 m, before rising steeply towards the island summit (consistent with coastal slope angles measured from the 30-m shuttle radar topography mission (SRTM) digital elevation model (DEM)). A pit dug at 250 m from the shore encountered, beneath 5 cm of organic soil, >70 cm of chaotic, very poorly sorted sediment, containing cobbles dispersed within a matrix of silt to pebbles, fining slightly upwards. The base could not be exposed due to the size of the clasts. Within this sediment were dispersed coral and shell fragments. No imbrication of clasts was observed. A very similar sequence was observed at a pit 400 m inland, to a depth of 195 cm; again, sub-rounded and chaotic mixtures of terrigenous and marine clasts were encountered, with the finer fraction containing benthic foraminifera and gastropod shells. A nearby river channel exposes the base of this layer, showing that this deposit is 1.5–2 m thick at 400 m from the shoreline (~17.5 m elevation, assuming a 2.5° slope), with an erosive base, and tapering slightly inland. A pit dug at 500 m did not encounter any coarse-grained layer, just comprising silt deposits to a depth of 1.2 m (Fig. 3). Two further sites were studied on the eastern coast of Sakar, at Yaba and Yok Point (Fig. 1; see Supplementary Data). Several pits were dug at Yaba for 600 m inland; a peated silt to sand, with pebble sized coral fragments, was found beneath 75 cm of soil at 100 m inland; and at 200 m inland, a silt containing infrequent pebbles at a depth of 120 cm. However, there was not the presence of a distinct chaotic layer, as observed at Alairo. At Yok Point, a beach outcrop exposes a waterlogged peat with coral and shell fragments, including benthic foraminifera. Both sites thus preserve deposits potentially derived from the 1888 tsunami, but without such distinctive characteristics as the deposits at Alairo.

On Umboi, the closest site to Ritter with strong evidence of a tsunami deposit was at Kampalap, 10.5 km SW of the centre of the Ritter collapse scar. Here, a 4.6 m high wave-cut cliff face exposes a 72-cm thick layer of chaotic marine (coral and shell fragments) and terrigenous sediment (Fig. 2), beneath 5 cm of organic soil (Fig. 3). Clasts are up to cobble size and include rip-up fragments of an underlying volcanic ash deposit that forms the remainder of the cliff exposure. No imbrication was observed. The base of the deposit is ~4 m above the high water mark. A pit dug 30 m further inland revealed a very similar sequence, with a 40-cm thick chaotic layer (up to pebble size, containing coral and shell fragments) overlying a grey silt at the top of the ash deposits (Fig. 3). The layer is 15-cm thick at a site dug 7 m further inland. Nearby, no evidence of a tsunami deposit was found 100 m inland, and we estimate that the deposit disappears approximately 40 m inland from the cliff edge. Based on measured slope angles, this puts the maximum height of the tsunami deposit at 7.5 m above the high water mark.

Further west, a site at Barang (20 km W of Ritter) again exposes a chaotic sediment layer, very similar in appearance to that at Alairo, in a wave-cut coastal cliff. The layer overlies a thin volcanic ash and has an erosional base; it is ~1 m in thickness, with a base 3.5 m above the high-water mark (Fig. 2). The layer is

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

slightly normally graded, with clasts ranging from fine sand to subangular cobbles, and contains corals, shell fragments and benthic foraminifera (Fig. 3). It could not be examined further inland. A transect at Maipurr, on NW Umboi (37 km WNW of Ritter) reveals a similar sequence, but unlike the previously described deposits, there is clear internal structure in the deposit. A pit excavated at 134 m inland revealed, beneath 23 cm of loamy topsoil, a >35-cm thick layered unit of poorly-sorted carbonate sand with pebbles, including coral and shell fragments and benthic foraminifera, with some finer grained intervals (Fig. 2). A similar deposit was observed 100 m further inland, 15-cm thick but without any clearly developed layering, 10-25 cm beneath the ground surface and overlying a brown loamy silt. We estimate that the layer tapers out ~300 m from the shoreline on this low-lying coastal platform, with an elevation close to sea level.

Two other sites were examined on Umboi. At Masele, just west of Maipurr, a 7-cm thick layer of fine mixed sand (containing black and white clasts), bounded by loamy silt, was found around 100 m inland (see Supplementary Data). At Kabi, east of Barang, a stream bank section exposed multiple coarse-grained clastic layers, but these contained no marine material and were interpreted as fluvial deposits.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

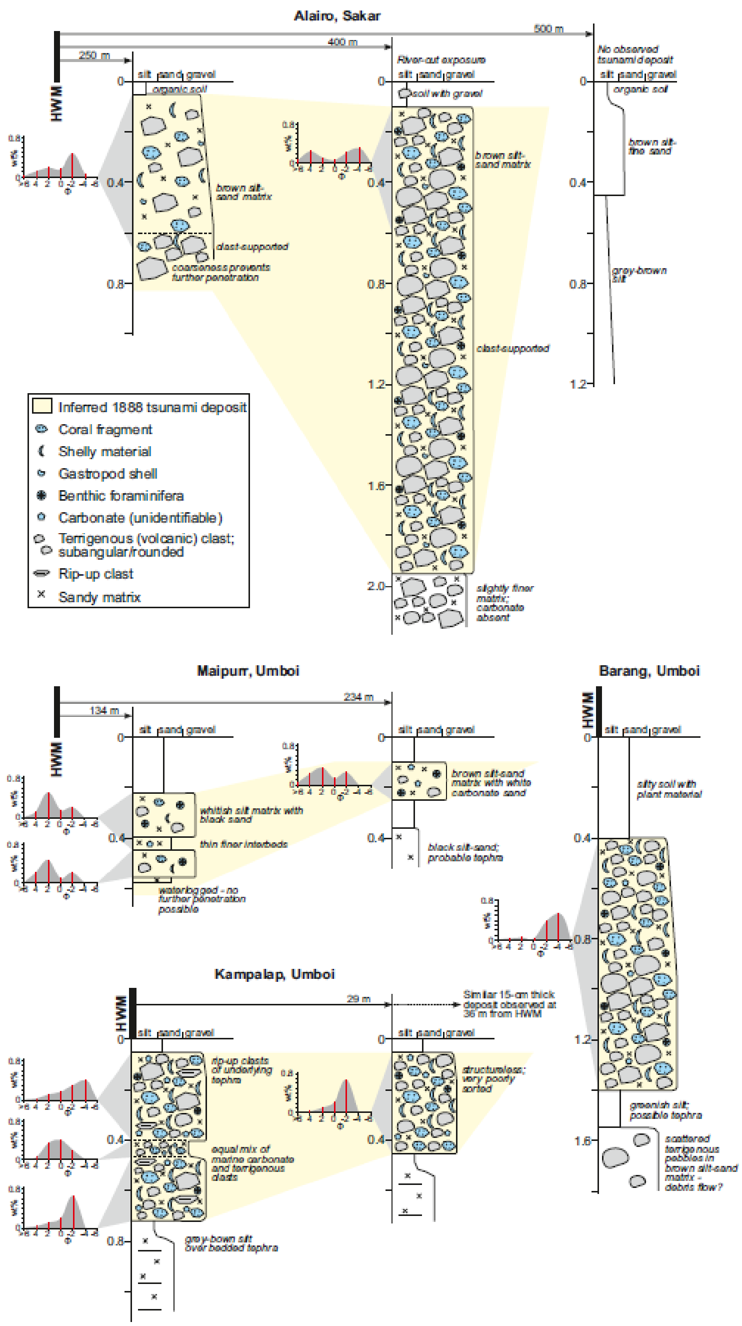

Figure 3: Fence diagram for key transects across tsunami deposits on Umboi and Sakar (site locations in Fig. 1). Distances from the high-water mark are indicated, and the sedimentological characteristics of each unit shown. Grain-size distributions for bulk samples taken from the indicated depth range are also shown.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

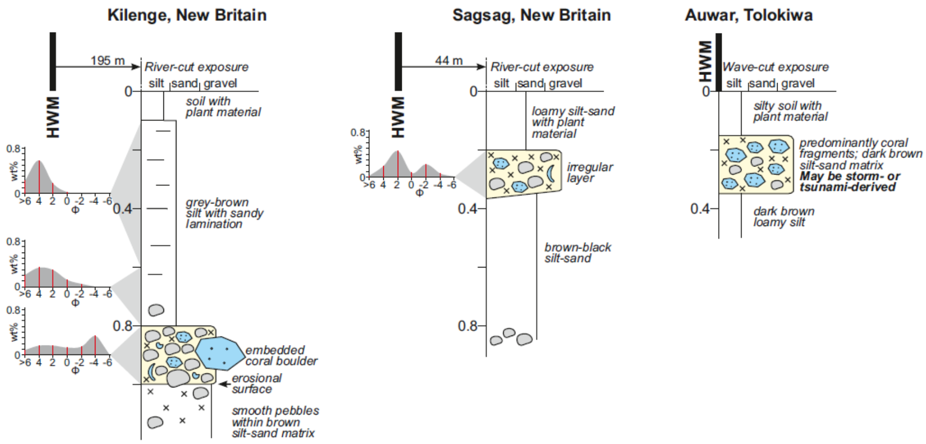

Figure 4: Logs of tsunami deposits observed on New Britain and Tolokiwa (site locations in Fig. 1). Distances from the high-water mark are indicated, and the sedimentological characteristics of each unit shown. Grain-size distributions for bulk samples taken from the indicated depth range are also shown.

On New Britain, in a flat area a few metres above sea level at Kilenge, 28 km E of Ritter, four pits 88 m to 383 m from the shore exposed pebbles and cobbles in a sandy matrix, but no material of marine origin. However, a river-cut exposure 195 m from the shore exposed a discrete 20-cm thick chaotic bed with an embedded coral boulder (1.5 m across and 30 cm high), containing subrounded cobbles and pebbles and a peaty silt/sand matrix with coral fragments and gastropod shells (Fig. 4). The bed lay beneath 80 cm of sand (topped by organic soil) and above a brown silt containing dispersed cobbles and pebbles. At Molomate (Fig. 1), an excavation 207 m from the coast preserved 10 cm of mixed sand (black and white grains, with fragmented carbonate) beneath 110 cm of fine to medium black sand (see Supplementary data). The deposit is similar to that found at Masele, on Umboi. Two other transects in the Cape Gloucester area found mixed sand deposits, in one case containing pebbles, beneath an uppermost homogeneous fine sand. However, in the absence of clear marine clasts, these cannot be identified as tsunami deposits. Comparable deposits were found south of Kilenge at two sites. At one of these, Dorf Point (67 m inland and close to sea level), coral and shell fragments up to pebble size were found in a >70-cm thick layer, scattered within a mixed black and white (marine carbonate) sand (Supplementary Data), beneath 20 cm of topsoil.

A final river-cut exposure at Sagsag, 24 km ESE of Ritter, at a site 44 m from the shoreline and 1 m above sea level, comprises a 15-cm thick chaotic deposit beneath 20 cm of topsoil, containing minor shell fragments and pebbles within a coarse sand matrix (Fig. 4). A further transect nearby found a peated silt with woody fragments (but no marine material) beneath 115 cm of silt, but no unambiguous signatures of a tsunami deposit.

On Tolokiwa, west of Ritter and beyond Umboi, three sites were examined, with the only potential tsunami deposit found at Auwar, 59 km WNW of Ritter. This wave-cut exposure, near the shoreline, preserved a 20-cm thick very poorly sorted deposit, comprising pebbles and cobbles (including coral fragments) in a sandy matrix. This lay beneath 15 cm of loamy soil and above a dark brown loamy silt (Fig. 4).

3.2.2 Grain-size and component observations

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Samples were collected from several of the deposits described above. In general, these layers form extremely poorly sorted and structureless deposits with erosive bases, in several cases thinning landwards, and occasionally showing slight normal grading. Only at Maipurr were clear internal parallel-bedded structures observed, and only at Kampalap were rip-up clasts of the underlying material seen. Clear clast imbrication was not observed. The coarser clasts (frequently up to pebble or cobble size) were mixed terrigenous lithologies, and generally rounded to sub-angular, while the beds also contained marine-carbonate (coral) fragments and broken shelly material. The sandy matrix of the chaotic beds in all the localities shown in Fig. 3 and 4 contained marine microfossils. These were absent from the two sandy deposits at Molomate (New Britain) and Masele (Umboi) described above, although these sands did contain fragmented carbonate. In all the chaotic deposits, benthic foraminifera were identified (*Bolivina sp., Anominella sp., Amphigestina sp., Calcarina sp., Ammonia sp., Eliphidium sp., Operculina sp*, and *Asterorotalia sp.*; Fig. 2). These species are consistent with a shallow neritic to slightly deeper (beyond the outer neritic zone at the continental slope) pre-transport habitat and are similar to those identified in deposits from the 2004 Indian Ocean tsunami on the Tamil Nadu coast of India (Nagendra et al., 2005). The matrix also contained algal fragments, ostracoda, small gastropod shells, echinoid spines, soft coral spicules and other unidentifiable bioclasts.

Bulk sediment samples were collected from all the coarse, poorly sorted deposits shown in Figs. 3 and 4 (see grain-size frequency curves) except for Auwar, Tolokiwa, as well as from the mixed sands at Molomate (New Britain) and Masele (Umboi) (Supplementary Data). Outlying cobble-sized clasts were excluded from the analyses. At Alairo, Sakar, samples at 250 m and 400 m from the shoreline are both bimodal, with larger coarse peaks. The peaks are more widely separated in the distal sample, showing both coarser and finer modes. At Maipurr, Umboi, all samples from 134 m and 234 m show extremely similar grain-size curves, the main difference being a slightly longer fine-tail in the more distal sample. The two coastal (cliff/wave-cut) exposures on Umboi, at Barang and Kampalap, are dominated by coarse clasts. A small, secondary fine mode is evident at Barang, while at Kampalap the unimodal distributions are skewed, with a fine tail. A sample 29 m inland at Kampalap is not discernably different from the cliff samples (where three samples show variable modes). On New Britain, single samples at Kilenge and Sagsag both have bimodal distributions, comparable to those observed on Sakar and Umboi (although the fine peak is dominant at Sagsag). Finally, the mixed sands at Masele and Molomate (Supplementary Data) show unimodal and near-symmetrical distributions, with poor sorting.

3.2.3 Coral boulders

Boulders of reefal limestone were found inland of the shoreline and in the inter-tidal zone throughout the study region (Fig. 1 and 5). These were most numerous on the west coast of New Britain, but also present on the N and E coasts of Umboi, the SW coast of Sakar, and on the W coast of Tolokiwa. Onshore boulders from New Britain (31 boulders; 11 sites) and Umboi (6 boulders; 4 sites) were measured; many more were present in the intertidal zone. On Sakar, the only observed boulders were in the intertidal zone at Alairo; those on Tolokiwa, at Bun, were partially buried. In addition, one large, rounded andesite boulder 200 m from the shore at Kabi, Umboi, was said by local people to have been transported inland by the tsunami but is not included in the measurements here.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

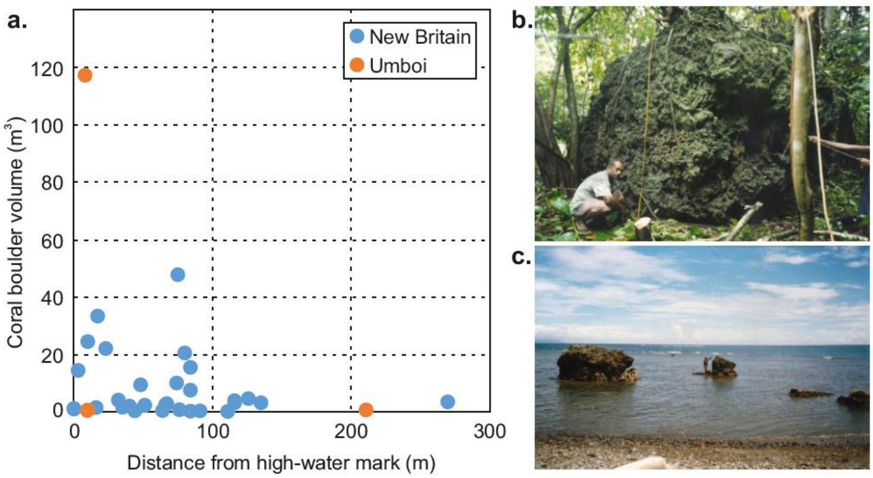

Figure 5: a: Coral boulder volume (assuming elliptical shape) versus distance from the high-water mark for boulders measured on New Britain and Umboi. b: A large coral block in the coastal forest (post-tsunami growth) at Dorf Point, New Britain (Fig. 1), ~80 m from the high-water mark and measuring 2.7 m high by 6 m across. c: Scattered coral blocks in the intertidal zone at Kilenge, New Britain (Fig. 1) (person for scale).

The maximum measured boulder width was 8.0 m and the maximum height 3.5 m. While many were relatively close to the shore, boulders were found up to 270 m from the high-water mark and at elevations of up to 3.9 m (Fig. 5). Most boulders were found on flat sandy berms and in low-lying coastal areas, and in most cases lay on the present-day ground surface, without substantial burial (except at Marilli, Umboi, and on Tolokiwa). All were irregular in shape and are inferred to have been transported directly from offshore fringing reefs.

4 Discussion

4.1 Tsunami details from oral accounts

Information obtained from oral accounts corroborates what was previously known about the 1888 Ritter tsunami. The timing information, consistent in most cases with the early morning occurrence known from distal records, implies that there is a continuous oral record of the event and lends strength to other insights obtained from the interviews. Although these insights are often qualitative, they align with contemporary post-event observations, including those inferring wave heights from coastal damage. They also confirm the presence of a widespread tsunami deposit, containing marine material. As noted above, multiple observations of initial wave drawdown in New Britain (Fig. 6), which contrast with descriptions from the other islands, are also consistent with the expected nature of the first wave arrival following the event. While most height references are relatively imprecise (e.g. tree-top heights), given that distance from the shoreline is unknown, one reference to water splashing over the top of a ~50 m high bluff at Tauali, New Britain, provides a more specific constraint. One comparable account was previously known from the Cape Gloucester area (Kilenge; Fig. 1), where oral descriptions note that the wave reached as far inland as the current airstrip (Sackley, 1974), which is 1050 m from the shore and 28 m above sea level (Fig. 6).

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

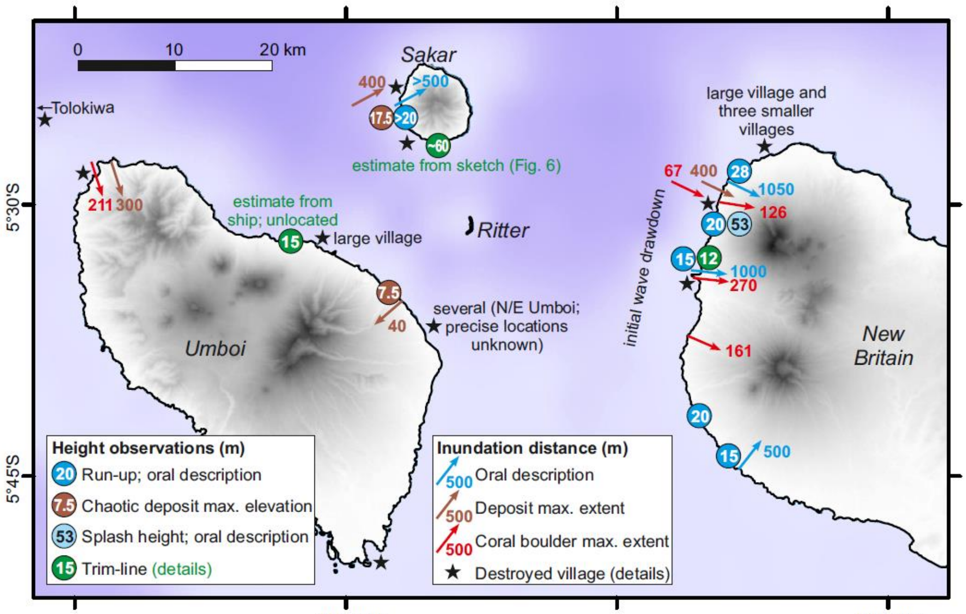

Figure 6: Summary of new constraints on the Ritter Island 1888 tsunami run-up, inundation and impacts, derived from the various indicated observation types.

Oral records also consistently refer to two or three wave arrivals. This is a smaller number of waves than described from more distal eyewitness accounts (Ward and Day, 2003), which in some cases refer to disturbed seas lasting several hours, implying a much longer wave train. These differences between the near- and far-field are consistent with a strongly frequency dispersive tsunami, with a short wave period, which is in line with expectations from a landslide source and is distinct from earthquake-generated tsunamis.

4.2 Insights from chaotic deposits

In all the exposures containing chaotic deposits with marine material, these form a single discrete layer (Figs. 2 and 3), generally buried beneath 5–25 cm of soil. It is thus reasonable to attribute the formation of this deposit, occurring at coastal sites throughout the study region, to a single event. The deposit's near-surface position and marine clastic constituents are consistent with deposition from a large-magnitude tsunami and with contemporary descriptions of onshore sediment deposition following the 1888 event. Nevertheless, some oral accounts refer to subsequent tsunamis, but these are noted as having been smaller and less damaging, and we know of no tsunami of comparable magnitude that has affected the region in the past few centuries (potentially since the Long Island eruption; cf. Blong et al., 2018). The oral accounts also imply that the Ritter event was so severe in its impacts that it has persisted in subsequent oral histories, and that it therefore stands out relative to other tsunamis that have impacted the region in recent generations.

The distinctive elements of the chaotic deposits, which may be used to recognise comparable tsunami deposits elsewhere, include the occurrence of marine microfossils in the finer matrix, coarser marine clastic material (e.g. coral fragments), extremely poor sorting, and a general lack of structure. Slight normal grading was present in some cases, but only at Maipurr and Kampalap (Fig. 2) was internal stratification observed, and only at

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Kampalap was this manifested in terms of sharp vertical changes in grain-size distribution. At three sites, deposits tapered inland (Alairo, Maipurr, Kampalap), but this was not associated with strong grain-size changes, the only observable effect being a slight increase in the finest grain-size fractions. Erosional bases were evident in several cases, but only in one instance were rip-up clasts found; it may be that these are not widely preserved unless the substrate is sufficiently consolidated.

Deposits of the type observed here could also conceivably have been produced by storm surges, but this is unlikely given the equatorial site of the region, where cyclonic storms are rare, and because storm surges are limited around small islands in deep-water settings (Heidarzedeh et al., 2018). The deposits are highly mixed in terms of lithologies, clast size, density and rounding, implying very limited hydraulic sorting. This is consistent with turbulent flow and a short-lived and highly energetic event – characteristics in line with a tsunami and with short-period waves, leading to very rapid deposition, rather than a longer-lived storm event with numerous similar wave arrivals, ultimately producing better sorted and more structured deposits.

Where we have been able to confidently identify deposits as being tsunami derived, they are coarse and very poorly sorted relative to many other historical tsunami deposits (see Sect. 1.2), being conglomeratic rather than sandy, with similar characteristics to the 2015 Taan Fjord deposits (Higman et al., 2018). This may reflect the extreme height of the wave in these proximal shorelines, as well as the short period of this landslide-generated tsunami. Tsunami conglomerates have been extensively recognised as evidence of prehistorical extreme landslide-derived tsunamis in ocean-island settings (Paris et al., 2018; Madeira et al., 2020). Our observations demonstrate that relatively nearshore conglomeratic layers may be an indicator of smaller landslide-derived tsunamis. These conglomerates can form discrete layers that share some characteristics with sandy tsunami deposits identified elsewhere, including structureless deposition, in some cases with normal grading and landward tapering. The structured deposits at Kampalap also suggest that, in suitable environments, backwash deposition and multiple wave arrivals can produce layered conglomeratic deposits.

The tsunami deposits described here were only preserved sporadically (Fig. 6). Coastal sections with steep topography could not be examined but are likely to offer limited potential for deposit preservation. In low lying coastal swamps or mangroves, access was also difficult, and any pits dug in these areas preserved only organic deposits. Thus, the formation of a distinctive tsunami-sediment deposit is dependent on both coastal environment and the local sediment source; sites with observed chaotic deposits were relatively low-lying coastal areas where gentle gradients continued for hundreds of metres inland. We interpret the pebble and cobble sized material to have been sourced from the shoreline, reflecting local lithologies. Their rounding is thus inherited, and contrasts with the angular nature of coral blocks and broken shell fragments that we interpret to have been directly sourced by the tsunami from the offshore fringing reef.

At Kilenge, New Britain, the chaotic deposit is buried beneath 80 cm of soil and silt and is thus substantially deeper than in the other studied exposures. This is potentially attributable to locally high sedimentation. Burial depth in general is not necessarily a good indicator of deposit age. The mixed sand deposits at other sites (e.g., at Molomate and Masele) were also relatively deeply buried. Because we did not find marine microfossils in these sands, it is more difficult to confidently ascribe their origin to the 1888 tsunami.

At several sites, particularly Kampalap and Barang on Umboi, there is clear evidence of erosion at the base of the chaotic deposits. These are sites close to Ritter where, along with Alairo on Sakar, we would expect the

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

largest wave heights. It is possible that the preserved deposits do not, therefore, reflect the initial or largest wave that impacted the site, but may represent smaller waves at the tail of the wave train. This may account for the relatively limited upslope extent of the deposits identified at these proximal sites on Umboi (Fig. 6), when compared with more distal sites, as well as the absence of any clear deposits at the most proximal field sites on Sakar. As summarised in Fig. 6, indications of height and inundation from chaotic deposits are systematically lower than those determined from oral accounts. The chaotic deposits do not, therefore, provide precise constraints on tsunami magnitude, except that to form such deposits at all requires large tsunamis with high flow velocities (cf. Etienne et al., 2011). We have identified chaotic conglomerates to distances of 30 km (or 60 km if the Tolokiwa deposit (Fig. 3) is from the 1888 event) and for several hundred metres inland (e.g., over 400 m on Sakar), but they are generally preserved in areas of very low elevation. On Umboi and Sakar, the closest sites to Ritter, the deposits extend several metres above sea level, but only on Sakar (estimated at 17.5 m) is this elevation comparable to the inundation height implied by oral reports (e.g., exceeding 20 m in Alairo; Fig. 6, Table 1). It is not surprising that the extent of the chaotic deposits would generally be substantially less than the maximum inundation, given the energy required to transport such sediment. Thus, while we consider that chaotic and very coarse-grained deposits hold strong potential as indicators of large magnitude tsunamis, their extent also likely substantially underestimates maximum inundation and run-up (Fig. 6). This is a valuable observation for the inference of wave run-up from deposits, and highlights the value of evidence from oral accounts or erosional indicators, such as trimlines, in obtaining more precise estimates of maximum run-up.

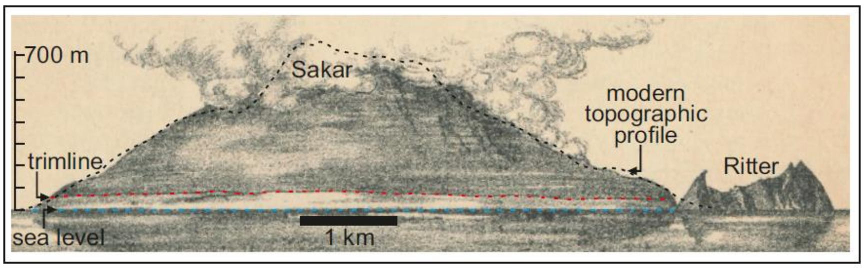

Figure 7: A sketch of Sakar from Anon. (1891) showing the post-tsunami trimline (cf. Cooke, 1981), fitted against an E-W topographic profile across Sakar. The scale is based on the topographic profile and indicates that the sketch clearly has some vertical exaggeration. The sketch is inferred to have been drawn from a position ~10 km off the Sakar shoreline, at a position due south of Ritter on the route of the ship *Ysabel* (Anon., 1890).

4.3 Tsunami magnitude

The impact of the 1888 tsunami at Alairo, Sakar, on an oblique coastline, was likely far lower than that on the more proximal coasts of Sakar and Umboi, where extensive observational gaps remain, potentially due to the wholesale destruction of coastal settlements. Insights from western New Britain may therefore offer the most robust indication of the magnitude of the Ritter tsunami, with run-ups extensively reported to have exceeded 20 m and one report noting waves splashing to over 50 m. Reports of inundation reaching 1 km in places are corroborated by chaotic deposits and coral blocks (see below) reaching hundreds of metres (Fig. 6). These observations are in line with previous simulations of the tsunami, with Karstens et al. (2020) modelling shoreline wave heights (before run-up) of ~10 m on the shore of New Britain. It is notable that the same models indicate maximum heights of 60–100 m on Umboi and Sakar, highlighting the remaining gaps in our knowledge of impacts at these most proximal sites.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Contemporary reports of the coastal vegetation trimline, which provided the clearest visual evidence of tsunami impacts in the aftermath of the Ritter tsunami, help partially fill this gap. Contemporary reports from the post-tsunami German expedition to the west coast of New Britain (Anon., 1888a, 1888b; Wharton, 1889; Sieberg, 1910) cite coastal damage to an elevation of 15 m, a trimline at 12 m, and inundation to a distance of 1 km in the vicinity of a destroyed village, implied to be at the location of von Below and Hunstein's camp (Anon., 1891; Steinhäuser, 1892). Steinhäuser (1892) provides a map showing tsunami inundation and the location of destroyed villages, with the coastal shape suggesting this is just north of Lagoon Point (Fig. 1), a conclusion supported by Anon. (1890) who refers to the site as near the village of Sagsag and to two separate oral accounts (Supplementary Data) that refer to the men being at Lagoon Point. On Umboi and Sakar, a 40 to 50 foot trimline was stated in Cooke (1981), based on Anon. (1891) and restated as ~15 m in Ward and Day (2003), which has been later repeated (e.g. Silver et al., 2009; Paris, 2015). The observation is based on a report from the ship *Ysabel*, taken two years after the event (Anon., 1891), which implies this is an estimate made from offshore (the relevant text translating as "a sharply marked strip along the entire coast, perhaps 40 to 50 feet"). It is unclear if this text refers to Umboi alone, or both Umboi and Sakar (the statement when repeated in Sieberg (1910) and Everingham (1977) infers that it refers to Umboi). Regardless, it is implausible that the trimline would have a consistent height all around Umboi, where contemporary sources highlight variability in the extent of damage (Anon., 1890). The height should thus be considered an approximation that is geographically non-specific. Its repetition in later studies has likely given an erroneously small impression of the scale of tsunami impacts on Umboi and Sakar. An independent estimate of the trimline height on Sakar can be made from a contemporary sketch in Anon. (1891; cf. Cooke, 1981), made from the *Ysabel* (Fig. 7). It is not precisely located, and both its stated distance (12 nautical miles) and bearing (WNW) cannot be correct, because island positions show that it was drawn approximately due south of Ritter, where the distance would place it on the coast of Umboi, well away from the path taken by the *Ysabel* (the route is mapped in Anon., 1890 and Steinhäuser, 1892). We therefore estimate that the sketch was taken south of Ritter, close to the mapped ship track and consistent with the location of Ritter in the foreground, at a distance ~10 km from Sakar. The variation in trimline height on the sketch can partly be attributed to the curvature of Sakar's coastline. By scaling the image to a present-day E-W topographic profile of Sakar, based on breaks in slope, and accounting for perspective using a 3.6 km radius for Sakar, the trimline height in the centre of the profile is 59–63 m (an apparent elevation of 80-85 m), assuming an observer at sea level 10 km from the shore. If the observer was at 10 m elevation, this estimate becomes 62–65 m, and is also 62–65 m for an observer at sea level but 12 km from the shore. The greater source of uncertainty is the precision of the sketch, but the profile is realistic and care has been taken by the observer to show subtle changes in the pattern of the trimline and the form of Ritter, suggesting a broadly accurate depiction. Regardless, the implication is of a trimline far higher than 15 m. This is much more consistent with the contemporary accounts collated in this paper (including the scale and extent of impacts in New Britain), with prior tsunami modelling (Ward and Day, 2003; Karstens et al., 2020), and with expectations based on comparable events (e.g., the much smaller collapse of Anak Krakatau left a sharp trimline on Rakata, 5 km away, reaching a height of 85 m; Grilli et al., 2021).

4.4 Coral boulders

Large coral blocks, rafted onshore, provide strong evidence for tsunami impacts (cf. Etienne et al., 2011) but, similarly to the chaotic deposits, limited constraints on maximum inundation. The majority of the measured boulders are relatively small (a few cubic metres) and only in a few cases did they extend more than 100 m from the shoreline. Larger blocks were limited to the near-shore area, and there thus appears to be a crude relationship between maximum boulder size and transport distance (Fig. 5). Blocks were far more prevalent on New Britain than on the other islands. This may reflect local topographic conditions and the extent of the fringing reef, but also potentially results from a difference in initial wave behaviour on New Britain. An initial negative wave arrival, resulting in drawdown and potentially exposing the fringing reef, may have led to draining of water from reef fractures and trapped air that then potentially facilitated fracturing and transport of reef blocks during subsequent wave inundation. An initial crest on Umboi, Sakar and Tolokiwa may have been less efficient at this process, although this is speculative given that in all cases there were still multiple wave arrivals, with recession between these.

The largest coral blocks carried on New Britain are >3 m on their longest axis. This is larger, for example, than any coral blocks in the Sumatra 2004 dataset in Etienne et al. (2011), but much smaller than some of the blocks documented after the 1883 Krakatau tsunami (Verbeek, 1885). The onshore transport distance is in line with other tsunamis, with blocks not reaching as far inland as those recorded in the Sumatra dataset. The size and distance patterns observed here support the inference of Etienne et al. (2011) that boulder size cannot be easily used to infer tsunami flow characteristics. Nevertheless, Putra et al. (2020) noted that coral blocks transported in the 2018 Anak Krakatau tsunami reached up to half the tsunami inundation distance. Our observations are broadly consistent with this (Fig. 7). Most blocks remain nearshore or in the intertidal zone, with the largest transport distances still being far less than the inundation indicated by sandy deposits (e.g., Maipurr) or oral accounts (e.g., Kilenge).

4.5 Evidence of accompanying eruptive activity

A continuing uncertainty about the Ritter Island collapse is whether eruptive activity played a significant role in the event. The oral reports and field observations summarised here provide further constraints on this. Several of the oral records note noises, tremors or other unusual phenomena in association with the event. In some instances it is unclear if these accompanied the tsunami arrival or occurred separately, and it is thus difficult to determine whether the phenomena were linked to the tsunami itself or to eruptive activity. Nevertheless, multiple reports from Sakar, Umboi and New Britain refer to explosions, fire, or fire-like smells at Ritter, in some cases stating that these occurred in the hours before the tsunami. Observations that suggest eruptive activity are not unexpected, since Ritter is known to have been a highly active volcano at the time (Johnson, 1987), but they provide important evidence that the failure may not have occurred independently of an eruption. Even if a magmatic eruption had not occurred, some accompanying phreatic explosions would also be expected as the edifice collapsed and the core of the volcano was exposed to seawater. One further report that implies precursory eruptive activity comes from Sackley (1974), where an eyewitness account from Kilenge, New Britain, refers to two to three days of eruptive activity that preceded the collapse.

Although the oral reports suggest that eruptive activity accompanied the collapse, the evidence that this was a large magnitude eruption is weaker. Distal accounts note a very fine ashfall (in Finschhafen; Cooke, 1981) and there are accounts of washed up pumice at Kelana and on New Britain (cf. Karstens et al., 2020). It is notable, however, that no pumice clasts were observed in the chaotic deposits described here. If pumice was numerous enough to be noted by damage observers in New Britain, then we would have expected it to be preserved among

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

the chaotic clastic deposits studied here. It is possible that pale-coloured, porous and angular coral fragments were confused with pumice in these contemporary reports. Regardless, we have found no onshore evidence of a large pumice-forming explosive eruption that accompanied the Ritter collapse, despite submarine evidence of post-collapse eruptive activity that generated pumiceous clasts (cf. Watt et al., 2019).

5 Conclusions

Newly compiled evidence of the Ritter Island 1888 tsunami, from oral accounts and tsunami deposits, corroborate existing distal observations and numerical tsunami models of the event. Oral descriptions of two to three wave arrivals, contrasting with longer distal wave trains, are consistent with a strongly frequency dispersive, landslide generated tsunami. A landslide source also aligns with accounts of a leading trough propagating east, towards New Britain, and a leading crest to the west. Specific timing and magnitude information, consistent with geographic location, suggest a fidelity in the oral records that has been preserved over at least two generations.

Massive conglomerates deposited by the 1888 tsunami are preserved in low-gradient narrow coastal plains throughout the proximal region, at distances exceeding 30 km. Poorly sorted and structureless conglomeratic deposits, suggesting a high turbulent velocity and rapid deposition, may be an under-recognised indicator of large magnitude landslide-generated tsunamis (cf. Higman et al., 2018). The deposits typically comprise conglomeratic beach-derived clasts mixed with angular coral blocks, within a sand matrix. The grain-size characteristics of this matrix is determined by the materials locally available for redistribution by the tsunami. The conglomerates are slightly coarser and thicker closer to Ritter, consistent with higher energy conditions, and show slight fining landwards, with tapering in some instances. They extend to approximately half the maximum inundation distance indicated by oral accounts. Similarly, boulders of reef limestone, likely to have been torn from fringing reefs by the tsunami, were widely observed but are generally restricted to the shoreline and intertidal zone. A small number of blocks extend further inland but are well inside the limits of inundation inferred from oral accounts. The envelope of maximum boulder dimensions defines an overall landward fining trend, but their transport distance does not show a clear relationship with distance from Ritter Island.

The collective observations reported here, alongside a reanalysis of post-event reports, imply much larger maximum run-up heights than have previously been documented, likely reaching many tens of metres on Umboi and Sakar. Observational gaps remain in oral accounts from these sites, likely because of the event's extreme destruction and the absence of surviving coastal communities. Multiple reports and observations from western New Britain indicate run-up heights exceeding 20 m, consistent with much larger values on Umboi and Sakar. The reports can also be used to re-evaluate fatalities from the event, which are inferred to be ~2000–3000.

This study highlights the value of oral histories in providing detailed and accurate insights into past disasters, at least for events that were so severe or unusual in their consequences that their record has been preserved across multiple generations. These oral accounts contain much more precise detail, constraining the impacts and magnitude of the Ritter tsunami, than can be ascertained from its deposits.

Data availability

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

All new data described in this study are provided as supplements to this manuscript.

Author contribution

MD and HD led the field survey, data collection and initial drafting, with input from HG. SW added further interpretation and led the final writing and presentation. All authors had input to the final manuscript.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

Generous assistance was provided during the 2004 field survey by Fr Ben Kaleh and field assistants Bonny and Leo at Kilenge Mission, Mark Mandrok and family at Kimbe, Earth Sciences technical staff (Mackenzie Baloiloi), and Centre for Disaster Reduction (Yayamel Aisi) and academic (Joseph Espi) staff, consultants Lloyd Werry, Agnes Keenan, academic colleagues Catherine Chague and Jody Webster, and the people of the Dampier Strait villages. Eric Kwa and Mathias Sapuri provided additional information for the field survey.

References

Abe, T., Goto, K. and Sugawara, D.: Relationship between the maximum extent of tsunami sand and the inundation limit of the 2011 Tohoku-oki tsunami on the Sendai Plain, Japan, Sediment. Geol., 282, 142-150, 2012.

Anon.: Nachrichten über Kaiser Wilhelms-Land und den Bismarck-Achipel, Neu Guinea Compagnie zu Berlin, Berlin, pp. 76-79, 1888a.

Anon.: Die Fluthwelle vom 13. März 1888, in: Nachrichten über Kaiser Wilhelms-Land und den Bismarck-Achipel, Neu Guinea Compagnie zu Berlin, Berlin, pp. 147-149, 1888b.

Anon.: Arbeiter-Anwerbung im Schutzgebiet, in: Nachrichten über Kaiser Wilhelms-Land und den Bismarck-Achipel, Neu Guinea Compagnie zu Berlin, Berlin, pp. 81-85, 1890.

Anon.: Die Ritterinsel und die Fluthkatastrophe in der Dampierstrasse am 13. März 1888, Aus dem Schutzgebiete der Neu Guinea Kompagnie, Mittheilungen von Forschungsreisenden und Gelehrten aus den Deutschen Schutzgebieten, 4, Ernst Siegfried Mittler und Sohn, Berlin, pp. 59-61, 1891.

Auker, M.R., Sparks, R.S.J., Siebert, L., Crosweller, H.S. and Ewert, J.: A statistical analysis of the global historical volcanic fatalities record, J. Appl. Volcanol., 2, 2, 2013.

Blong, R., Fallon, S., Wood, R., McKee, C., Chen, K., Magill, C. and Barter, P.: Significance and timing of the mid-17th-century eruption of Long Island, Papua New Guinea, Holocene, 28, 529-544, 2018.

Bondevik, S., Svendsen, J.I. and Mangerud, J.A.N.: Tsunami sedimentary facies deposited by the Storegga tsunami in shallow marine basins and coastal lakes, western Norway, Sedimentology, 44, 1115-1131, 1997.

Chagué-Goff, C., Andrew, A., Szczuciński, W., Goff, J. and Nishimura, Y.: Geochemical signatures up to the maximum inundation of the 2011 Tohoku-oki tsunami—Implications for the 869 AD Jogan and other palaeotsunamis, Sediment. Geol., 282, 65-77, 2012.

Cooke, R.J.: Eruptive history of the volcano at Ritter Island, Geol. Surv. Papua New Guinea Memoir, 10, 115-123, 1981.

Costa, P.J. and Andrade, C.: Tsunami deposits: present knowledge and future challenges, Sedimentology, 67, 1189-1206, 2020.

Cox, R., Jahn, K.L., Watkins, O.G. and Cox, P.: Extraordinary boulder transport by storm waves (west of Ireland, winter 2013–2014), and criteria for analysing coastal boulder deposits, Earth-Sci. Rev., 177, 623-636, 2018.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Cutler, K.S., Watt, S.F., Cassidy, M., Madden-Nadeau, A.L., Engwell, S.L., Abdurrachman, M., Nurshal, M.E., Tappin, D.R., Carey, S.N., Novellino, A. and Hayer, C.: Downward-propagating eruption following vent unloading implies no direct magmatic trigger for the 2018 lateral collapse of Anak Krakatau, Earth Planet. Sci. Lett., 578, 117332, 2022.

David, M.C.: The 1888 Ritter Island collapse tsunami: new data from sediments and oral histories. BSc. (Geology) Thesis, School of Natural and Physical Sciences and UPNG Centre for Disaster Reduction, University of Papua New Guinea, 174 pp., 2007.

Davies, H.L., Davies, J.M., Perembo, R.C.B. and Lus, W.Y.: The Aitape 1998 tsunami: Reconstructing the event from interviews and field mapping, Pure Appl. Geophys., 160, 1895-1922, 2003.

Dawson, A.G. and Stewart, I.: Tsunami deposits in the geological record, Sediment. Geol., 200, 166-183, 2007.

Day, S., Llanes, P., Silver, E., Hoffmann, G., Ward, S. and Driscoll, N.: Submarine landslide deposits of the historical lateral collapse of Ritter Island, Papua New Guinea, Mar. Petr. Geol., 67, 419-438, 2015.

Dunbar, R.I.: Coevolution of neocortical size, group size and language in humans. Behav. Brain Sci., 16, 681-694, 1993.

Etienne, S., Buckley, M., Paris, R., Nandasena, A.K., Clark, K., Strotz, L., Chagué-Goff, C., Goff, J. and Richmond, B.: The use of boulders for characterising past tsunamis: lessons from the 2004 Indian Ocean and 2009 South Pacific tsunamis. Earth-Sci. Rev., 107, 76-90, 2011.

Everingham, I.B.: Preliminary catalogue of tsunamis for the New Guinea/Solomon Islands, Bureau of Mineral Resources, Australian Government Publishing Service, Report 180, 1768-1972, 1977.

Fritz, H.M., Mohammed, F. and Yoo, J.: Lituya Bay landslide impact generated mega-tsunami 50th anniversary, in: Tsunami science four years after the 2004 Indian Ocean tsunami: Part II: Observation and data analysis, Birkhäuser, Basel, 153-175, 2009.

Gelfenbaum, G. and Jaffe, B.: Erosion and sedimentation from the 17 July, 1998 Papua New Guinea tsunami, Pure Appl. Geophys., 160, 1969-1999, 2003.

Goff, J., Chagué-Goff, C. and Nichol, S.: Palaeotsunami deposits: a New Zealand perspective, Sediment. Geol., 143, 1-6, 2001.

Goto, K., Sugawara, D., Ikema, S. and Miyagi, T.: Sedimentary processes associated with sand and boulder deposits formed by the 2011 Tohoku-oki tsunami at Sabusawa Island, Japan, Sediment. Geol., 282, 188-198, 2012.

Grilli, S.T., Tappin, D.R., Carey, S., Watt, S.F., Ward, S.N., Grilli, A.R., Engwell, S.L., Zhang, C., Kirby, J.T., Schambach, L. and Muin, M.: Modelling of the tsunami from the December 22, 2018 lateral collapse of Anak Krakatau volcano in the Sunda Straits, Indonesia, Sci. Rep., 9, 11946, 2019.

Grilli, S.T., Zhang, C., Kirby, J.T., Grilli, A.R., Tappin, D.R., Watt, S.F.L., Hunt, J.E., Novellino, A., Engwell, S., Nurshal, M.E.M. and Abdurrachman, M.: Modeling of the Dec. 22nd 2018 Anak Krakatau volcano lateral collapse and tsunami based on recent field surveys: Comparison with observed tsunami impact, Mar. Geol., 440, 106566, 2021.

Heidarzadeh, M., Teeuw, R., Day, S. and Solana, C.: Storm wave runups and sea level variations for the September 2017 Hurricane Maria along the coast of Dominica, eastern Caribbean sea: Evidence from field surveys and sea-level data analysis, Coast. Eng. J., 60, 371-384, 2018.

Higman, B., Shugar, D.H., Stark, C.P., Ekström, G., Koppes, M.N., Lynett, P., Dufresne, A., Haeussler, P.J., Geertsema, M., Gulick, S., Mattox, A. et al., The 2015 landslide and tsunami in Taan Fiord, Alaska, Sci. Rep., 8, 12993, 2018.

Hori, K., Kuzumoto, R., Hirouchi, D., Umitsu, M., Janjirawuttikul, N. and Patanakanog, B.: Horizontal and vertical variation of 2004 Indian tsunami deposits: an example of two transects along the western coast of Thailand, Marine Geol., 239, 163-172, 2007.

Hunt, J.E., Tappin, D.R., Watt, S.F.L., Susilohadi, S., Novellino, A., Ebmeier, S.K., Cassidy, M., Engwell, S.L., Grilli, S.T., Hanif, M. and Priyanto, W.S.: Submarine landslide megablocks show half of Anak Krakatau island failed on December 22nd, 2018, Nat. Commun., 12, 2827, 2021.

Johnson, R.W.: Large-scale volcanic cone collapse: the 1888 slope failure of Ritter volcano, and other examples from Papua New Guinea, Bull. Volcanol., 49, 669-679, 1987.

Johnson R.W., Taylor G.A.M. and Davies R.A.: Geology and petrology of Quaternary volcanic islands off the north coast of New Guinea. Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, Commonwealth of Australia, Record 1972/21, 1-127, 1972.

Karstens, J., Berndt, C., Urlaub, M., Watt, S.F., Micallef, A., Ray, M., Klaucke, I., Muff, S., Klaeschen, D., Kühn, M. and Roth, T.: From gradual spreading to catastrophic collapse–Reconstruction of the 1888 Ritter Island volcanic sector collapse from high-resolution 3D seismic data, Earth Planet. Sci. Lett., 517, 1-13, 2019.

Karstens, J., Kelfoun, K., Watt, S.F. and Berndt, C.: Combining 3D seismics, eyewitness accounts and numerical simulations to reconstruct the 1888 Ritter Island sector collapse and tsunami, Int. J. Earth. Sci., 109, 2659-2677, 2020.

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

Kennedy, A.B., Mori, N., Yasuda, T., Shimozono, T., Tomiczek, T., Donahue, A., Shimura, T. and Imai, Y.: Extreme block and boulder transport along a cliffed coastline (Calicoan Island, Philippines) during Super Typhoon Haiyan, Mar. Geol., 383, 65-77, 2017.

Latter, J.H.: Tsunamis of volcanic origin: summary of causes, with particular reference to Krakatoa, 1883, Bull. Volcanol., 44, 467-490, 1981.

Lynett, P., McCann, M., Zhou, Z., Renteria, W., Borrero, J., Greer, D., Fa'anunu, O., Bosserelle, C., Jaffe, B., La Selle, S. and Ritchie, A.: Diverse tsunamigenesis triggered by the Hunga Tonga-Hunga Ha'apai eruption, Nature, 609, 728-733, 2022.

Madeira, J., Ramalho, R.S., Hoffmann, D.L., Mata, J. and Moreira, M.: A geological record of multiple Pleistocene tsunami inundations in an oceanic island: The case of Maio, Cape Verde, Sedimentology, 67, 1529-1552, 2020.

Mercer, J., Gaillard, J.C., Crowley, K., Shannon, R., Alexander, B., Day, S. and Becker, J.: Culture and disaster risk reduction: Lessons and opportunities, in: Natural Hazards and Disaster Risk Reduction, edited by: Fearnley, C., Wilkinson, E., Tillyard, C.J., and Edwards, S.J., Routledge, London, 4-25, 2016.

Miller, D. J.: Giant waves in Lituya Bay, Alaska, US Geol. Surv. Prof. Pap, 354, 51-86, 1960.

Nagendra, R., Kannan, B.K., Sajith, C., Sen, G., Reddy, A.N. and Srinivasalu, S.: A record of foraminiferal assemblage in tsunami sediments along Nagappattinam coast, Tamil Nadu, Current Sci., 1947-1952, 2005.

Noormets, R., Crook, K.A. and Felton, E.A.: Sedimentology of rocky shorelines: 3.: Hydrodynamics of megaclast emplacement and transport on a shore platform, Oahu, Hawaii, Sed. Geol., 172, 41-65, 2004.

Paris, R.: Source mechanisms of volcanic tsunamis, Phil. Trans. Roy. Soc. A, 373, 20140380, 2015.

Paris, R., Switzer, A.D., Belousova, M., Belousov, A., Ontowirjo, B., Whelley, P.L. and Ulvrova, M.: Volcanic tsunami: a review of source mechanisms, past events and hazards in Southeast Asia (Indonesia, Philippines, Papua New Guinea), Nat. Haz., 70, 447-470, 2014.

Paris, R., Ramalho, R.S., Madeira, J., Ávila, S., May, S.M., Rixhon, G., Engel, M., Brückner, H., Herzog, M., Schukraft, G. and Perez-Torrado, F.J.: Mega-tsunami conglomerates and flank collapses of ocean island volcanoes, Mar. Geol., 395, 168-187, 2018.

Palfreyman, W.D., Wallace, D.A. and Cooke, R.J.: Langila volcano: Summary of reported eruptive history, and eruption periodicity from 1961 to 1972, Geol. Surv. Papua New Guinea Memoir, 10, 125-133, 1981.

Perttu, A., Caudron, C., Assink, J.D., Metz, D., Tailpied, D., Perttu, B., Hibert, C., Nurfiani, D., Pilger, C., Muzli, M. and Fee, D.: Reconstruction of the 2018 tsunamigenic flank collapse and eruptive activity at Anak Krakatau based on eyewitness reports, seismo-acoustic and satellite observations, Earth Planet. Sci. Lett., 541, 116268, 2020.

Putra, P.S., Aswan, A., Maryunani, K.A., Yulianto, E., Nugroho, S.H. and Setiawan, V.: Post-event field survey of the 22 December 2018 Anak Krakatau tsunami, Pure Appl. Geophys., 177, 2477-2492, 2020.

Ramalho, R.S., Winckler, G., Madeira, J., Helffrich, G.R., Hipólito, A., Quartau, R., Adena, K. and Schaefer, J.M.: Hazard potential of volcanic flank collapses raised by new megatsunami evidence, Sci. Adv., 1, p.e1500456, 2015.

Richmond, B., Szczuciński, W., Chagué-Goff, C., Goto, K., Sugawara, D., Witter, R., Tappin, D.R., Jaffe, B., Fujino, S., Nishimura, Y. and Goff, J.: Erosion, deposition and landscape change on the Sendai coastal plain, Japan, resulting from the March 11, 2011 Tohoku-oki tsunami, Sed. Geol., 282, 27-39, 2012.

Sackley, M.: Ritter's awake – after its 86-year sleep, Post-Courier, Thursday November 7, 1974, Port Moresby, Papua New Guinea, 1974.

Saunders, S., and Kuduon, J.: The June 2009 investigation of Ritter volcano, with a brief discussion of its current nature, Papua New Guinea Department of Mineral Policy and Geohazards Management Volcano Observatory, Open-File Report OFR 003/2009, 2009.

Sato, H., Shimamoto, T., Tsutsumi, A. and Kawamoto, E.: Onshore tsunami deposits caused by the 1993 Southwest Hokkaido and 1983 Japan Sea earthquakes, Pure Appl. Geophys., 144, 693-717, 1995.

Scheffers, A. and Kelletat, D.: Sedimentologic and geomorphologic tsunami imprints worldwide—a review, Earth-Sci. Rev., 63, 83-92, 2003.

Scheffers, A., Scheffers, S. and Squire, P.: Trimlines as evidence for palaeo-tsunamis, Nat. Haz., 63, 165-179, 2012.

Shanmugam, G.: Process-sedimentological challenges in distinguishing paleo-tsunami deposits, Nat. Haz., 63, 5-30, 2012.

Sieberg, A.: Die Erdbebentätigkeit in Deutsch-Neuguinea (Kaiser-Wilhelms-Land u. Bismarckarchipel), Dr. A Petermanns Mitteilungen aus Justus Perthes; Geographischer Anstalt, 56, pp., 116-122, 1910.

Silver, E., Day, S., Ward, S., Hoffmann, G., Llanes, P., Driscoll, N., Appelgate, B. and Saunders, S.: Volcano collapse and tsunami generation in the Bismarck volcanic arc, Papua New Guinea, J. Volcanol. Geotherm. Res., 186, 210–222, 2009.

Soria, J.L.A., Switzer, A.D., Pilarczyk, J.E., Tang, H., Weiss, R., Siringan, F., Manglicmot, M., Gallentes, A., Lau, A.A., Cheong, A.Y.L. and Koh, T.W.L.: Surf beat-induced overwash during Typhoon Haiyan

https://doi.org/10.5194/egusphere-2026-2101
Preprint. Discussion started: 16 June 2026

deposited two distinct sediment assemblages on the carbonate coast of Hernani, Samar, central Philippines, Mar. Geol., 396, 215–230, 2018.

Steinhäuser, R.: Die Flutwelle und die Hilfsexpedition von Finschhafen nach der Südwestküste von Neupommern, Westermanns Monatshefte, 71, 265–275, 1892.

Verbeek, R.D.M.: Krakatau, Imprimerie de l'Etat, Batavia, 1886.

Walter, T.R., Haghshenas Haghighi, M., Schneider, F.M., Coppola, D., Motagh, M., Saul, J., Babeyko, A., Dahm, T., Troll, V.R., Tilmann, F. and Heimann, S.; Complex hazard cascade culminating in the Anak Krakatau sector collapse, Nat. Commun., 10, 4339, 2019.

Ward, S.N. and Day, S.: Ritter Island volcano—lateral collapse and the tsunami of 1888, Geophys. J. Int., 154, 891-902, 2003.

Watt, S.F.L., Karstens, J., Micallef, A., Berndt, C., Urlaub, M., Ray, M., Desai, A., Sammartini, M., Klaucke, I., Böttner, C. and Day, S.: From catastrophic collapse to multi-phase deposition: flow transformation, seafloor interaction and triggered eruption following a volcanic-island landslide, Earth Planet. Sci. Lett., 517, 135-147, 2019.

Watt, S.F.L., Karstens, J. and Berndt, C.: Volcanic-island lateral collapses and their submarine deposits, in: Volcanic Debris Avalanches: From Collapse to Hazard, edited by: Roverato, M., Dufresne, A., and Procter, J., Springer Cham, 255–279, 2020.

Wharton, W.J.L.: Volcanic sea wave, Nature, 39, 303–304, 1889.

Supplementary Files

SF1. Summary of oral accounts regarding the 1888 Ritter Island tsunami (from 2004; based on David, 2007)

A narrative summary of oral accounts from villages around the Dampier Strait in 2004 (specific details are summarised in Table 1).

File provided as MS Word document.

SF2. Site details and additional descriptions for potential tsunami deposits not detailed in Figures 3 and 4

File provided as MS Word document.

SF3. Dimensions of large coral blocks measured at onshore coastal sites around the Dampier Strait

File provided as MS Excel table.