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Three large tsunamis on the non-subduction, western side of New Zealand over the past 700 years

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ABSTRACT

The Tasman Sea between Australia and New Zealand is rarely considered as an important source for tsunamis. We review the past 1000 years of unusual events and find evidence for three (possibly four) large tsunamis, one historical and two during the period of Māori occupation prior to European arrival. Event 1 appears to have affected the town of Westport, New Zealand on the 12th August 1870 and Event 2 occurred in the South Taranaki Bight between 1470 and 1510 AD although it may extent farther south along New Zealand's West Coast. There are currently insufficient data to determine whether the West Coast sites represent a separate event or are associated with Event 2. Event 3 occurred between 1320 and 1450 AD along the West Waikato coast of the North Island, New Zealand.

In attempting to identify possible tsunamigenic sources for these large events we note the importance of considering a range of potential tsunamigenic options such as complex subduction zone earthquakes and a range of slope failure scenarios in order to better understand the threats posed not only by Tasman Sea sources but for similar geographical locations around the World.

1. Introduction

Recent events such as the 2011 Tohoku-oki tsunami have shown that we continue to under-estimate the magnitude of potential tsunamis. It is not simply the magnitude though, we are also under-estimating the significance of sources other than subduction zones such as submarine slope failures and volcanic-related events. Indeed, numerous types of mass failures off continental shelves or island edifices have the potential to be at least locally, if not regionally, catastrophic (Keating and McGuire, 2000; Williams et al., 2012; Terry and Goff, 2013).

The historical record is often cited to infer that (submarine) slope failures are relatively insignificant since they represent only about 10% of all known tsunamigenic sources (Gusiakov, 2009; Whitmore et al., 2009). However, these data fail to include slope failure-related tsunamis that have not been historically documented (e.g., Goff, 2011; Terry and Goff, 2013). While historical records are useful, there are considerable data gaps with many historically-documented tsunamis having no known source (e.g., Australia: 44% [64 out of 145], Goff and Chagué-Goff, 2014).

As a result of the recognised uncertainties associated with determining how large an event might be or what might have caused it, we should realistically not be surprised when unusual events are brought to our attention. While it is always appropriate to adopt a prudent approach when assessing high magnitude, low frequency events, we must be prepared to "expect the unexpected in natural hazards" (Davey, 2011). In this respect, based upon our current understanding of the hazard, researchers generally assume that some coastlines of the World are more exposed to tsunamis than others. Japan is more exposed than China, Chile more than Argentina and New Zealand more so than Australia. Invariably these assumptions are grounded in the proximity of these coastlines to subduction zones.

While this may indeed be true, it does not mean that those coastlines more distant from subduction zones are safe. Volcanic hot spots such as the Hawaiian Islands are indeed exposed to tsunamis generated by circum-Pacific subduction zones, but submarine slope failures off these islands' flanks provide a recognised source for not only large, local events (Goff et al., 2006a; Richmond et al., 2011) but probably on occasion for more distant shores as well. In the NE Atlantic, the Storegga slide off the coast of Norway caused a catastrophic region-wide tsunami that affected numerous countries (e.g., Smith, 2005). Acknowledging that such events have, in the past at least, been catastrophic, it is entirely plausible that many tsunamis generated by submarine slope failures in areas adjacent to subduction zones may have been incorrectly assigned to a fault rupture. There was indeed much debate surrounding the 1998 Papua New Guinea event when a larger than expected tsunami was initially assigned to a moderately large earthquake (McSaveney et al., 2000). Later work suggested a submarine slope failure source (Tappin

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et al., 2001), although it was most likely a combination of the two (Satake and Tanioka, 2003). A similar scenario has been shown to be the case for the 1771 AD Meiwa earthquake and tsunami at Ishigaki Island, Japan (Goto et al., 2010) and more recently this has been proposed for the 2011 Tohoku-oki event (Tappin et al., 2014). A combination of numerical modelling and historically-documented accounts indicated that a combined subduction zone-submarine slope failure scenario best describes the tsunami inundation and boulder movement associated with the 1771 AD Meiwa event (Goto et al., 2010).

It seems reasonable to suggest that submarine slope failures are most likely an under-represented tsunamigenic source and are possibly the cause of many "orphan" tsunamis in assorted historical and palaeotsunami databases. The high cost and logistical complexities of collecting detailed bathymetric and deep sea sediment data will doubtless ensure that such sources will remain a relatively unknown quantity for many years to come. However, as with the Storegga slide, it may be possible to make some progress in inferring submarine slope failure sources in regions where a fault rupture seems unlikely to have been responsible for causing either an historically or geologically-documented tsunami inundation.

This paper reports on three (possibly four) large tsunamis noted around the eastern periphery of the Tasman Sea, in areas that, based upon our current knowledge, do not appear to be exposed to large events generated along subduction zones.

2. Study region

The western coast of New Zealand forms the eastern boundary of the Tasman Sea and Australia the west, with only the minor remnant volcanic landmasses of Lord Howe Island (and Ball's Pyramid) and Norfolk Island (and Philip Island) found between them (Fig. 1). However, apart from these two large landmasses, defining the other boundaries of the Tasman Sea is more complicated. To the north and south the boundaries of the basin can be broadly defined by the northern end of the Norfolk Ridge and New Caledonia, and the South Tasman Rise and the Puysegur Subduction Zone (PSZ), respectively. Beyond these boundaries, but

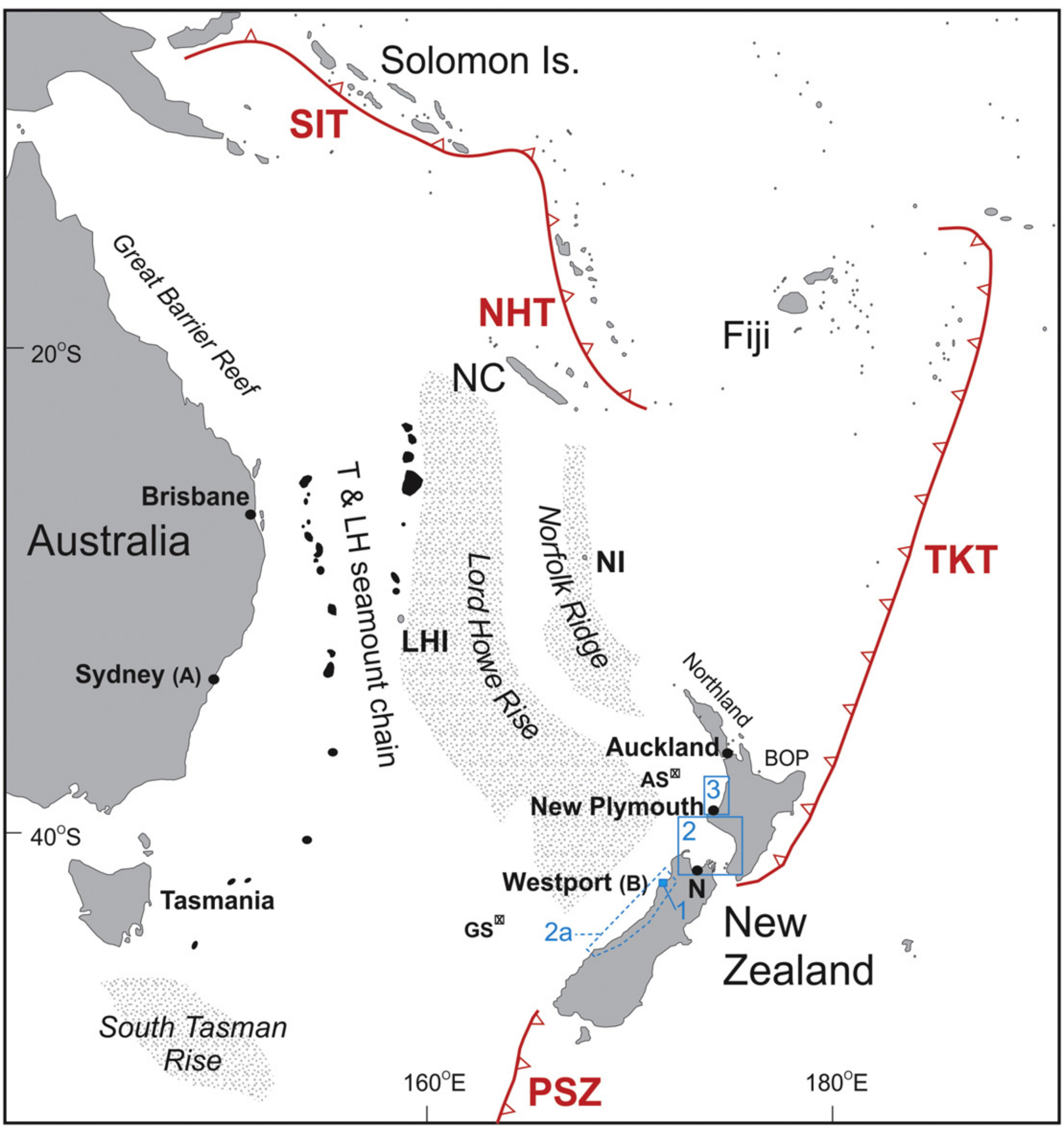

Fig. 1. The Tasman Sea region with associated subduction zones (approx. extent marked in red) and geomorphological features. Event areas discussed in the text are marked by blue boxes and are numbered 1, 2, 2a (dashed blue line) and 3. Subduction zones. NHT — New Hebrides Trench, PSZ — Puysegur Subduction Zone, SIT — Solomon Islands Trench, TKT — Tonga–Kermadec Trench. Other names: BOP — Bay of Plenty, LHI — Lord Howe Island (inc. Ball's Pyramid), N — Nelson, NC — New Caledonia, NI — Norfolk Island (inc. Philip Is.), T & LH — Tasmantid and Lord Howe, Sydney (A) and Westport (B) refer to Event 1 sites detailed in Table 2.