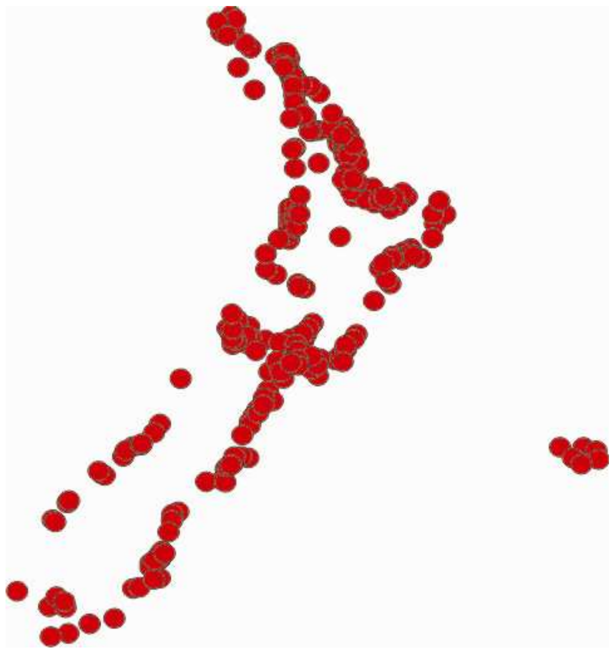
The New Zealand Palaeotsunami Database

James R. Goff



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Cover: Shape of the New Zealand coastline defined by the data point coverage of the palaeotsunami database

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Abstract

Goff, J.R. (2008). The New Zealand Palaeotsunami Database. ***NIWA Technical Report 131.*** **24p, database.**

A comprehensive New Zealand palaeotsunami database has been collated. It not only contains reference to palaeotsunamis - those with no written observations or prior to the historic record; but also hybrid tsunamis that are, to some degree, poorly-recorded historical events. To encompass the full range of data that could indicate past tsunami inundation, the database includes a range of information including:

- physical evidence from geological and archaeological sources
- geomorphological evidence
- cultural information from anthropological research and prehistoric Māori oral recordings.

Each line of data in the database summarises the evidence related to one site under a series of headings. The database contains over 330 line items and most likely describes between 30 and 35 events. The database is under ongoing development; this report represents the first major iteration of the process. Producing the database in report form creates a source of baseline data for the research community. It is hoped that the database will eventually be available on the internet so that additions and deletions can be made in an open, interactive environment.

Introduction

There has been a considerable amount of published palaeotsunami research over the past 20 years or so following the major work of Atwater (1987). This work has become increasingly relevant in the years following the devastating Indian Ocean Tsunami (IOT) of 26 December 2004 as scientists attempt to understand the magnitude and frequency of past events. It is only in the last few years however, that researchers have started to collate palaeotsunami data with an aim to creating regional or national databases. The main focus prior to this was the creation of more comprehensive historical tsunami databases (e.g., Australia: Dominey-Howes 2007, Global NOAA/WDC: Broko 2008).

In New Zealand, the original historical database documented at least 32 tsunamis dating back to A.D.1840 (de Lange & Healy 1986). This was subsequently enlarged by Fraser (1998). Further additions and improvements have been made by several organisations and the database now contains information on about 40 events over the past 190 years or so (Berryman 2005). Unfortunately for New Zealand, the historical database can only ever extend back as far as the written record, around the start of the 19th century. Geologically this is an extraordinarily short record and it offers little indication of the magnitude and frequency of past tsunamis, nor what could be expected in the future. To extend our knowledge of past tsunamis further back in time we must rely upon the unwritten record. Since A.D.1994, researchers have continued to report on the sedimentary evidence of past tsunamis in New Zealand (e.g., Chagué-Goff & Goff 1999, Nichol et al. 2003, Kennedy et al. 2007). Geological information however, is not the only source of palaeotsunami data. Geomorphological (Goff et al. in press), archaeological (McFadgen & Goff 2007), and anthropological (King et al. 2007) data are also pertinent to the New Zealand record. The database contained in this report considers all these lines of evidence to create what is the most comprehensive nationwide palaeotsunami database anywhere in the world.

Definitions

A palaeotsunami is a 'tsunami occurring prior to the historical record or for which there are no written observations' (Kaitoku 2007). In reality though, the line between historical and palaeotsunamis is not quite as clear cut as the definition suggests. 'Hybrid tsunamis' generally represent a disjunct between the longevities of national historical databases – in other words, a palaeotsunami in one country is an historical event in another. A good example of this disjunct is the A.D.1700 Cascadia tsunami which is a palaeotsunami in North America and an historical one in Japan (Atwater et al. 2005). Hybrid tsunamis also include historical events with no written records. They are recognised in the database as unwritten personal observations (an historical equivalent of prehistoric oral traditions), or some other form of 'palaeotsunami data' (geological, geomorphological, archaeological, and anthropological data sources).

A final category of hybrid tsunamis are those that have limited documentation or poorly constrained information about the nature and extent of an event. It is the related 'palaeotsunami data' that enhances our understanding of these hybrids. When a tsunami is sufficiently large, it will almost undoubtedly fall into this category simply because it will have affected areas with little or no human habitation. Perhaps the most well known of these hybrid types is the IOT of 26 December 2004. It left behind widespread geological and geomorphological evidence in areas where historically documented material either lacks clarity or is non-existent (e.g., Hawkes et al. 2007, Morton et al. in press, Jaffe et al. 2006, Liu et al. 2005), but is sometimes recorded in unwritten personal observations.

New Zealand tsunami research

The country has experienced at least four large historic tsunamis with run-ups of 10 m or more. Three were local (Wellington: A.D.1855, ~10m; Waikari River: A.D.1931, ~15m; Gisborne: A.D.1947, ~10m) and the fourth was a distant event (South America: A.D.1868, ~10m) (Berryman 2005, de Lange & Healy 1986). Until recently, the A.D.1868 event was the only one believed to have caused a tsunami-related death in New Zealand (Berryman 2005). This figure has now grown to at least six, with four deaths from a local event in A.D.1903 (Anon 1903), one in A.D.1905 (Anon 1905), and some confusion over the number of Māori killed by the A.D.1868 event in the Chatham Islands (Anon 1868a, 1868b). Reports of the numbers of dead are split evenly between one dead and 'many'. This highlights an important issue with the historical record; the validity of some of the earlier accounts. A more comprehensive study of available historic information now shows that at least six people have died. It is highly likely that more deaths will come to light. There is uncertainty about the number of people killed by the A.D.1868 tsunami, and yet officially New Zealand has suffered only one death in historic times.

It is evident that the written record becomes more inconsistent and fragmented in the early history of New Zealand. For example, Lawson (1893) states that during the A.D.1855 earthquake and tsunami in Wellington, people jumped on board the only ship in the harbour to escape. The tidal wave, however, washed the ship inland and wrecked it, the people had to stay and so it could be said that 'Wellington owed its origin to a tidal wave'. Fortunately this is not the only evidence referring to the A.D.1855 tsunami to survive, or else we would have a somewhat blinkered view of the event. Poorly documented events from the earlier history of New Zealand, such as the A.D.1826 'tsunami' near Orepuke, have led to unwarranted levels of scientific speculation, and over-interpretation of the limited data. As more evidence comes to light it seems increasingly unlikely that this was indeed a tsunami at all (e.g., Buddle 1912).

Palaeotsunami deposits were first reported in the late 1990s (Chagué-Goff & Goff 1999, Goff & Chagué-Goff 1999). Subsequent research has not only fine-tuned the chronology of events (McFadgen 2007), but also expanded the record to between A.D.2003 and 13 000–46 000 years BP (before present) (Hancox et al. 2003, Kennedy et al. 2007). Geological evidence of historical tsunamis is generally best preserved for the larger events such as the A.D.1855 tsunami. The most well researched hybrid is the A.D.1826 Fiordland tsunami (Goff et al. 2004a). Palaeotsunami data therefore span the historic-palaeotsunami timeframe in New Zealand.

The database framework

The New Zealand palaeotsunami database considers a wide range of records, geographical variability, and tsunami sources. To establish the database framework, a series of headings was developed with detailed descriptors to clarify the nature of the data contained within them. The key descriptors are discussed below.

Nature of evidence

Three distinctive lines of evidence are defined, primary, secondary, and cultural.

Primary evidence recognises that a sedimentary record, be it in a geological (Goff et al. 1998; Goff & McFadgen, 2002a) or an archaeological (McFadgen & Goff, 2007) context, provides the most useful verifiable physical data of past tsunamis. Secondary evidence refers to physical data in the form of a distinct tsunami geomorphology. This may be either as the immediate or a delayed geomorphic response of sandy coasts to tsunami inundation (Figure 1; Goff et al. in press). Secondary evidence acknowledges that our current understanding of tsunami geomorphology is rudimentary and in the absence of additional supporting data, interpretations are most likely equivocal (Goff & Lane in press).

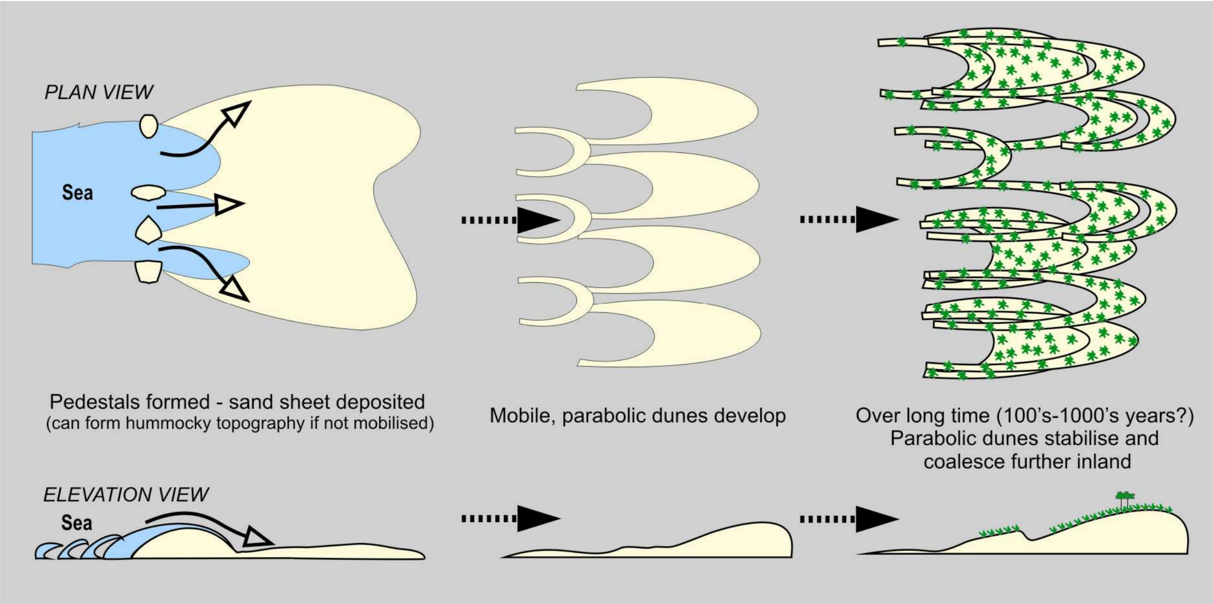

Figure 1: Conceptual diagram for the formation of a tsunami geomorphology in coastal dune systems.

Cultural data is only available for events that have occurred post-Māori arrival around A.D.1250 (McFadgen 2007). Prehistoric Māori had no written language, and as such much of the cultural data is in the form of oral recordings (King et al. 2007). Some anthropological interpretations of archaeological data however, have been included. McFadgen (2007) discusses the effects of tsunami inundation on settlement patterns and culture, and of particular relevance to the database is the relocation of settlements from low-lying coastal areas to hilltops around the same time as tsunami inundation. The database considers these anthropological interpretations in the context of the seismic driving of geological and geomorphological change. This combined physical process and human responses to seismically driven events was originally conceptualised by Goff & McFadgen (2002a). The incorporation of cultural information into the database adds significantly to our ability to identify past tsunamis. In particular, this is evident in the ability to better constrain the age of events through the use of well-dated archaeological sites, and in the number of data points identified for events post-Māori arrival.

Dating method

Establishing the chronology of past tsunamis is problematic in general and many techniques are used. Dating of events referred to solely in prehistoric Māori oral recordings is even more difficult, but has been successfully achieved when additional corroborative evidence is available (McFadgen 2007). It is not surprising therefore that the results of chronological analyses range from the annual dating of an event through to poorly constrained multi-century accuracy. Particular success has been achieved recently for events that have occurred since Māori arrival (McFadgen 2007). For example, cross-correlation between the physical evidence of past tsunamis, related seismic driving evidence (Goff & McFadgen 2002a), archaeological and anthropological data (McFadgen & Goff 2007) and a suite of different chronological techniques was used to determine a date of A.D.1480 for a particular event.

In recognition of the wide range of possible chronological tools, the database contains three broad categories of dating technique:

- geochronological – a 'catch-all' for numerous methods referred to at the end of the database
- historical – used for hybrid cases only
- currently undated – mainly for prehistoric Māori oral recordings.

Each site, however, has more specific details of techniques and results given under the 'Comments' heading at the end of the line, and in the references provided. For example, the dating technique for the historical A.D.1826 tsunami at Okarito was based upon dendrochronology, but full details from the references cited indicate that other supporting data such as radiocarbon dates were also used.

Source

On rare occasions, the probable tsunami source is known (e.g., Hauraki Plains), but in most cases it is not. The inferred source is usually linked to a possible location or locations. Inferences are based upon our current understanding of possible tsunamigenic sources capable of producing the reported evidence. Ongoing tsunami research is likely to improve our understanding of the sources for specific events but in the meantime the inferred sources should be seen as a general guide.

Palaeotsunami criteria

A list of possible palaeotsunami criteria is given at the end of the database. It is not implied that these are necessarily 'diagnostic' of tsunami inundation, but rather that these are the most common types of evidence reported from numerous tsunami studies (e.g., McFadgen & Goff 2007). The main focus is on the physical evidence for past tsunamis, but the importance of cultural data such as Māori oral recordings is acknowledged. In general, it is assumed that the greater the number of criteria listed for any one site, the more likely it is to relate to tsunami inundation and the higher the veracity or validity of the record. There are numerous sites with few criteria listed. In these instances it is recommended that additional data be sought to augment the database.

Discussion and conclusions

The New Zealand palaeotsunami database considers many disparate sources of information and as a result there are compromises in the nature and extent of the data presented. Māori oral recordings do not fit well within an overall structure focussed primarily on the physical evidence for past tsunami inundation. They do however, fit well within an overall strategy to incorporate any type of relevant data that could relate to possible tsunami inundation. Tsunamis require a source, and in many cases their generating events leave their own identifiable signals in the landscape that occur either immediately or soon after the event (e.g., uplifted beach, landslide) or as a delayed response (e.g., river aggradation, coastal village abandonment) (Goff & McFadgen 2002a). Inundation by a large tsunami can also completely change the coastal geomorphology (Goff et al. in press). The subsequent inland migration of destabilised coastal sands and formation of a parabolic dune system could therefore be a delayed geomorphic response to tsunami inundation. New Zealand is an isolated landmass and, as such, the only way that a generating event can leave an identifiable signal in the landscape and/or as a Māori oral recording is if it is associated with a local or regional source. Distantly sourced tsunamis have no local signals. In a broad-brush way therefore, the database has the potential to differentiate between local/regional and distance sources.

The initial search for evidence to incorporate into the palaeotsunami database has been wide-ranging. It has benefited from recent advances in the study of prehistoric Māori oral recordings (King & Goff 2006, King et al. 2007) and in the recent synthesis and interpretation of New Zealand's geoarchaeological data (McFadgen 2007) and geomorphic responses to catastrophic events (Goff et al. in press, Wells & Goff 2007). The database currently contains well over 300 items describing between 30 and 35 events. In some cases where there are numerous entries for an event, the dataset offers the ability to validate numerical models and determine source characteristics (Walters et al 2006, Goff & Lane in press). In other cases, a large number of contemporaneous primary lines of evidence adds value to secondary and cultural data of a similar age (Goff et al. in press), improving our overall understanding of a particular event, its effects, and source (Walters et al. 2006).

The New Zealand palaeotsunami database has been rigorously peer-reviewed with an aim of being all-inclusive when considering evidence of possible past tsunamis and their sources. This report is likely to represent the first iteration of many. It is hoped that future iterations will have proven erroneous material removed and additional data added. It is acknowledged that the database is not, and never will be, complete.

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