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Cosmogenic mega-tsunami in the Australia region: are they supported by Aboriginal and Maori legends?

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Keywords
tsunami, legends, Australia, comet, geological evidence

Disciplines
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Cosmogenic mega-tsunami in the Australia region: are they supported by Aboriginal and Maori legends?

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Abstract: Mega-tsunami have affected much of the coastline of Australia over the past millennium. Such catastrophic waves have left an imprint consisting predominently of bedrock sculpturing of the rocky coastline and deposition of marine sediments to elevations reaching 130 m above sea level. One of the largest of these events occurred in eastern Australia in the fifteenth century. This event may be related to the Mahuika impact crater found at 48.3° S, 166.4° E on the continental shelf 250 km south of New Zealand. A comet at least 500 m in diameter formed the crater. Maori and Aboriginal legends allude to significant cosmogenic events in the region, while Aboriginal legends about tsunami are common along the eastern Australian coast. Evidence for legends that could describe the impact of a cosmogenic tsunami also exists in NW Australia. Here geological evidence of a single mega-tsunami as recent as in the seventeenth century covers 1500 km of coastline. We term this event Wandjina after the artwork related to the legends. More attention should be given to oral traditions in searching globally for other sites of significant mega-tsunami.

> Then the sky moved . . . heaved and billowed and tumbled and tottered. The moon rocked. The stars tumbled and clattered and fell one against the other . . . The great star groups were scattered, and many of them, loosened from their holds, came flashing to the earth. They were heralded by a huge mass, red and glowing, that added to the number of falling stars by bursting with a deafening roar and scattering in a million pieces which were molten . . . Burragorang/Illawarra legend (Peck 1938, p. 202–203)
>
> He had never before seen the sea, and he did not know what it was. He believed it to be a great sky . . . and that the sky had fallen down . . . . It was that a great ancestor had left the earth and had gone up into the sky . . . . He tried to return but the hole that he had made was closed up. Yet he did not give up hope, and by beating upon it he loosened it and it fell. *What Makes the Waves* (Peck 1938, p. 119)
>
> The Moa disappeared after the coming of Tamaatea who set fire to the land. The fire was not the same as our fire but embers sent by Rongi [the sky] (Hill 1913, p. 331)

These legends—the first two Aboriginal from the coast of New South Wales south of Sydney and the third Maori from New Zealand (Fig. 1)—describe natural events or processes with a cosmic origin not usually invoked as being significant in the modern geological literature. If the large object in the Burragorang legend had struck the ocean, it would have had the potential to generate a regionally devastating tsunami. The impact would also have injected billions of tonnes of water into the atmosphere as superheated vapour that would have fallen subsequently as torrential rain that would have exceeded historical levels and produced catastrophic flooding. Research along the east coast of Australia since 1989 (Bryant 2001; Bryant & Nott 2001) indicates that a mega-tsunami struck and eroded the shores of Lord Howe Island and the rocky coastline of New South Wales over a distance of 600 km around AD 1500 (Fig. 1a). A comet impact in the region is the most likely cause of such a large and widespread event. The location of a possible impact has recently been discovered (Fig. 1b, c), lying in 300 m depth of water on the continental shelf 250 km south of New Zealand at 48.3° S, 166.4° E (Abbott *et al.* 2003). The crater is 20 km in diameter and could have been produced by a comet 0.5–1.05 km in size travelling at a speed of 51 km s^{-1} (calculations based on Marcus *et al.* 2005). When it struck, it would have generated an earthquake with a magnitude of 8.2 on the Richter scale. The lack of sediment that normally settles over time from the ocean suggests that the crater is less than 1000 years old. The comet has been named Mahuika after the Maori God of fire. Tektites found in sediments to the SE indicate a trajectory for

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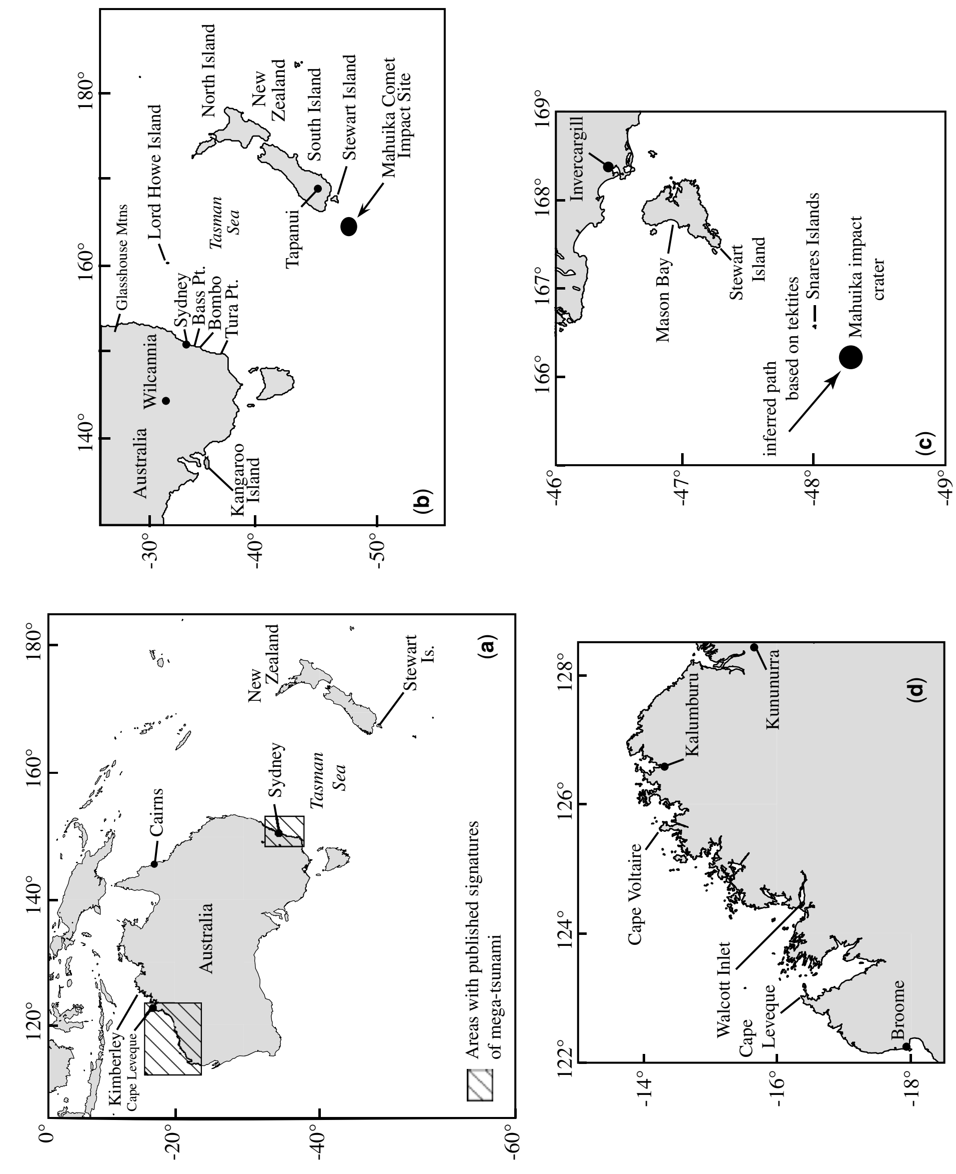

Fig. 1. Location maps (**a**) Australia and New Zealand; (**b**) Tasman Sea coastline; (**c**) Mahuika Impact area; and (**d**) the Kimberley.

this comet from the NW, across the east coast of Australia (Matzen *et al*. 2003). If the recent age of the event—which is yet to be confirmed by radiocarbon dating—were correct, Aborigines in Australia and Maori in New Zealand would have observed this comet's dying moments.

The purpose of this paper is twofold: to elaborate on the rich, indigenous oral history of the region to show that a recent cosmogenic mega-tsunami possibly occurred and to use similar types of oral history in the Kimberley region of NW Australia to identify other mega-tsunami in the Australian region.

Legends associated with comets and tsunami

Aboriginal legends

Aboriginal legends about comets and tsunami are ubiquitous throughout Australia (Peck 1938; Parker 1978; Johnson 1998). In the interior of New South Wales, the Paakantji tribe, near Wilcannia on the Darling River (Fig. 1b), tell a story about the sky falling (Jones & Donaldson 1989). A great thunderous ball of fire descended from the sky scattering molten rock of many colours. Unprecedented floods that forced people to flee to the tops of hills to escape drowning followed within a couple of days. Even though flooding fits within a scenario for a nearby comet impact into the ocean, such a story probably is modern and has incorporated elements of an older Aboriginal Dreamtime legend of the Flood. In South Australia, another legend tells of stars falling to Earth to make the circular lagoons fringing the coast.

Perhaps the most intriguing legend along the SE Coast of Australia is the story of the eastern sky falling quoted above (Peck 1938). It has several variants (Peck 1938; Massola 1968; Willey 1979; Johnson 1998). Aborigines in eastern Australia believed that the sky was held up on supports at the edges of the earth, and that the eastern prop either collapsed or was rotting. Tribes far into the interior of the continent were requested to send tribute to the east to be given to the spirit people in charge of holding up the sky so that it could be repaired. Possum rugs and stone axes were sent eastwards in response. Historians interpret the story as referring to the beginning of European colonization from the east; however, one version, quoted above (Peck 1938), is particular to the South Coast of New South Wales and may be describing the way tsunami affected the coast. The legend implies that the ocean fell from the sky. Substantial evidence exists for Aboriginal occupation of the open rocky headlands along this coast (Hughes & Sullivan 1974). At Bombo Headland, 70 km south of Sydney, tsunami overwashed a 40 m high headland. The wave separated from the headland and plunged back to the ocean surface 100–200 m into a bay on the lee side. Profuse amounts of coarse sediment dropped from the airborne flow into the bay under gravity (Fig. 2). Evidence of disturbed Aboriginal occupation 'silcrete hand axes and shaped blades' has been found on the lee side of headlands along this coast (Bryant 2001). Aborigines at these locations initially would have heard, but not seen, the tsunami approaching. Their first indication of disaster would have been when they looked up and saw the ocean dropping on them from the sky as the tsunami wave surged over headlands.

Additional physical and legendary evidence of major comet and tsunami impacts exists in SE Australia. In South Australia, the legend of Ngurunderi clearly alludes to tsunami (Flood 1995, p. 140–141). Ngurunderi was a great Ancestral figure of the southern tribes in South Australia, who established Tribal Laws.

> Long ago, Ngurunderi's two wives ran away from him, and he was forced to follow them. He pursued them... and went along the beach to Cape Jervis. When he arrived there, he saw his wives wading half-way across the shallow channel which divided Nar-oong-owie from the mainland. He was determined to punish his wives, and angrily ordered the water to rise up and drown them. With a terrific rush, the waters roared and the women were carried back towards the mainland. Although they tried frantically to swim against the tidal wave, they were powerless to do so and were drowned. Their bodies turned to stone and are seen as two rocks off the coast of Cape Jervis, called the Pages or the Two Sisters.

Nar-oong-owie refers to Kangaroo Island, South Australia (Fig. 1b). The history of Aboriginal occupation of Kangaroo Island remains enigmatic. The island shows extensive evidence of Aboriginal occupancy; but, when the first European, Matthew Flinders, landed on the island in 1802, it was unoccupied. Mainland Aborigines call Kangaroo Island, Kanga—the Island of the Dead. The coastline also evinces signatures of cosmogenic tsunami. Most significant are enormous whirlpools (features that have been linked to catastrophic flow under tsunami (Bryant 2001)) on the northern coast of the island, where the Aboriginal legend is set. In addition, there are vortex-carved caves and massive piles of imbricated boulders, some over four metres in diameter, near promontories.

Other tsunami and comet legends that could relate to the Mahuika Comet occur along the eastern coast of Australia. On the north coast of New South Wales, Aborigines speak of 'the moon setting in the east' and of flooding of rivers such as the Namoi from the ocean on a clear day. A spear from the sky fell into the sea followed by a great flood that changed the coastline (Cahir 2002).

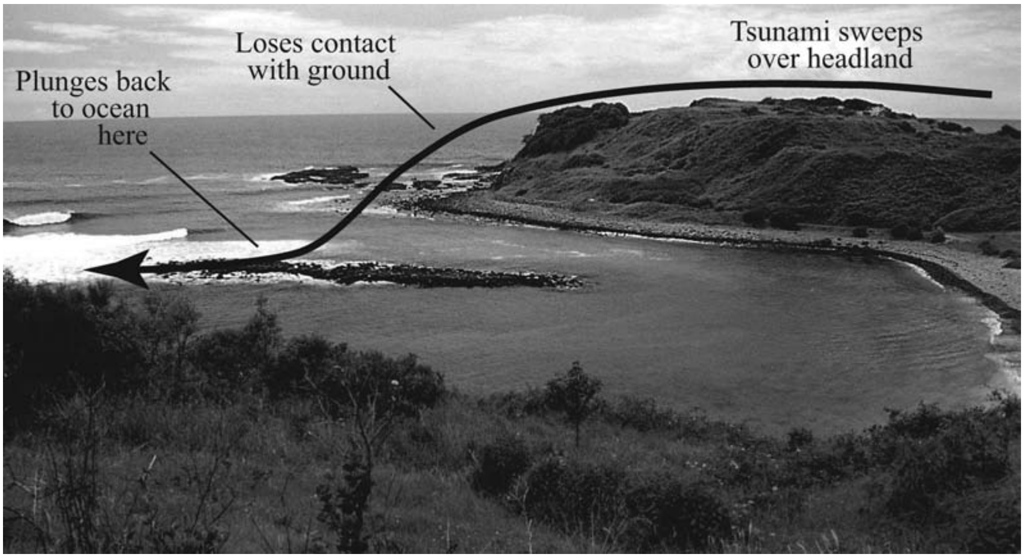

Fig. 2. Theorized flow of tsunami over Bombo Headland, NSW. The headland is 40 m above sea level on a tectonically stable coastline. The tsunami came in from the SE (the right), overrode and then detached from the headland. The boulder pile in the small bay is where the wave reattached to the ocean. Similar embayments in the region were occupied by Aborigines. The scenario shown here is responsible for Aboriginal legends about the ocean falling from the sky.

Individual large boulders on rock platforms are also identified as representing particular Aborigines struck down by a large wave. In SE Queensland, the Glasshouse Mountains, which lie at the western side of the coastal plain 20 km from the ocean, represent ancestral forms of Tibrogargan and his family. Tibrogargan one day was alarmed to see a great rising of the ocean and fled inland with this family. Individual peaks in the Glasshouse Mountains represent his family still gazing seaward at the threat. The family is estranged because Tibrogargan's son, Coonowrin, abandoned his mother, Beerwah, in the flight. Tibrogargan has turned his back on him and has vowed never to look on him again.

Maori legends

On the South Island of New Zealand, the Mahuika Comet impact would have been a dramatic event. Within 50 km of the southern coastline, it would have appeared as a fireball ten times larger than the sun, blown over 90% of the tree cover, and ignited grass and trees (Marcus *et al*. 2005). However, these effects would have ceased within 100 km of the coast. Steel & Snow (1992) believe that local Maori legends and place names refer to a comet event such as this one. They base their hypothesis on the legend of the *Fires of Tamaatea* (or *Tamatea*). Local ethnographic evidence is best chronicled in the Southland and Otago regions, centred on the town of Tapanui (Fig. 1b). Here there appears to be evidence for an airburst that flattened trees in a manner similar to the Tunguska event. The remains of fallen trees are aligned radially away from the point of explosion out to a distance of 40–80 km. Local Maori legends in the area tell about the falling of the skies, raging winds, and mysterious and massive firestorms from space. Tapanui, itself, translates as 'the big explosion,' while *Waipahi* means 'the place of the exploding fire'. Place names such as *Waitepeka*, *Kaka* Point, and *Oweka* contain the southern Maori word *ka*, which means fire. The local Maori also attribute the demise of the Moas, as well as their culture, to an extraterrestrial event. The extinction of the Moa is remembered as Manu Whakatau, 'the bird felled by strange fire'.

These interpretations have been criticized by Goff *et al*. (2003). Specifically, they state that the local place names referring to a cosmogenic fire event requires 'an in-depth knowledge of the culture and traditions of the Maori people' and interpretation requires the use of 'many references with cross-referencing between them . . . as opposed to citing an individual reference' (Goff *et al*. 2003). We have since gone back to an original source, *The Maori-Polynesian Comparative*

Dictionary compiled by Tregear (1891). The dictionary is based on over 160 references and traces Maori terms back to their Polynesian sources. It supports some of the interpretations made by Steel and Snow (1992). The dictionary refers to *Tamatea* as a very ancient person. He was the fifth in descent from Rangi, the Sky. The *Fire of Tamatea* refers to an older legend related to some volcanic catastrophe or conflagration before the Maori came to New Zealand. Tapanui, which is at the centre of Steel and Snow's (1992) cosmic firestorm, lies at the edge of the destructive effects of the Mahuika impact. Masse & Masse (2006) describes legends in South America referring to wildfires caused by cosmic airburst events. He also notes that although the fires had a cosmogenic source, few legends mention this fact. Masse (1995) also points out that some Polynesian place names and the names for legendary heroes or supernatural beings can be broken down into their literal components. In this sense, the place name Tapanui (great or large tapa) may relate to the meaning of tapa, which in the 1891 *Maori-Polynesian Comparative Dictionary* translates as 'to split' or 'to pulverize soil' (Tregear 1891). Similarly, the word *ka* appears in this dictionary as meaning 'to burn, to be lighted, to take fire', while *kaka* means 'red-hot' (Tregear 1891). Nowhere in Maori or Polynesian sources does it mean 'fever' as stated by Goff *et al*. (2003).

Possible age of the recent cosmogenic tsunami event

It is possible to constrain the age of a regional cosmogenic mega-tsunami event and with it many associated Aboriginal and Maori legends using four separate lines of evidence. First, it is possible to surmise the most likely time of meteorite and comet impacts over the last two thousand years using a combination of Chinese, Japanese, and European records of meteor, comet, and fireball sightings. Figure 3 plots the accumulated record, up to the beginning of the nineteenth century, when scientific observations began in earnest. The meteorite records for China and Japan are based upon Hasegawa (1992), while meteorite records for Europe come from Rasmussen (1991). The Asian meteorite records are the most complete with European sightings accounting for less than ten percent of the record over the last one thousand years. The comet record from Asia is based upon Hasegawa (1992). A quasi-cyclic pattern is evident in the comet sighting records that can be linked to the dominance of the Taurid complex in the inner solar system. This complex formed from the breakdown of a giant comet that entered the inner solar system about 15 000 years ago (Asher & Clube 1993; Asher *et al*. 1994). Recent times when the Earth crossed the trail of this comet debris occurred during 401–500, 801–900, 1041–1100, 1401–1480, 1641–1680 and 1761–1800. These intervals are shaded in Figure 3. By far the most active period of the past two thousand years happened between AD 1401 and 1480.

Second, twenty-nine radiocarbon dates have been obtained from marine shell found in disturbed Aboriginal middens, deposited in tsunami dump deposits and sand layers, and attached to boulders transported by tsunami along the New South Wales coast (Bryant 2001). Some of these dates were obtained from the Tura Point area where mega-tsunami was first identified as an important coastal process in Australia (Young & Bryant 1992). The radiocarbon ages were converted to calendar ages using the INTCAL98 calibration table for marine samples (Stuiver *et al*. 1998). The dates centre on the year AD 1500 ± 85. These dates can only be stated as the most probable time for the deposition of marine shell by tsunami because the flux of atmospheric radiocarbon production around this time was highly variable leading to age reversals in the marine radiocarbon chronology. Based upon the Australian east coast deposits, it is 95% probable that a cosmogenically induced mega-tsunami event occurred between AD 1200 and 1730. This span also incorporates the age of major New Zealand tsunami deposits (Goff & McFadgen 2002; Nichol *et al*. 2003). Unfortunately, age reversals and the absence of any cross-correlation with a genealogical record make it impossible to identify up to five regional events in New Zealand in the fifteenth century as hypothesized by Goff & McFadgen (2002) and Goff *et al*. (2003). A cosmogenic source must be considered given the magnitude of the event on both the east coasts of Australia and New Zealand and the widespread distribution of that evidence throughout the region.

The preference for a major impact during this period is also supported by a radiocarbon date from Stewart Island, New Zealand—the closest large landmass to the Mahuika impact site (Fig. 1c). The southern coast of this island shows massive erosion characteristic of mega-tsunami in the form of ramps, knife-like sluices and flutes cut into granite and orientated towards the impact site (Fig. 4). All of these types of landforms have been linked to mega-tsunami (Bryant & Young 1996; Bryant 2001). An age obtained from pipi (*Paphies australis*) located about 500 m inland and 30 m above sea level at Mason Bay on the west coast of Stewart Island yielded a corrected age of AD 1301 ± 36.

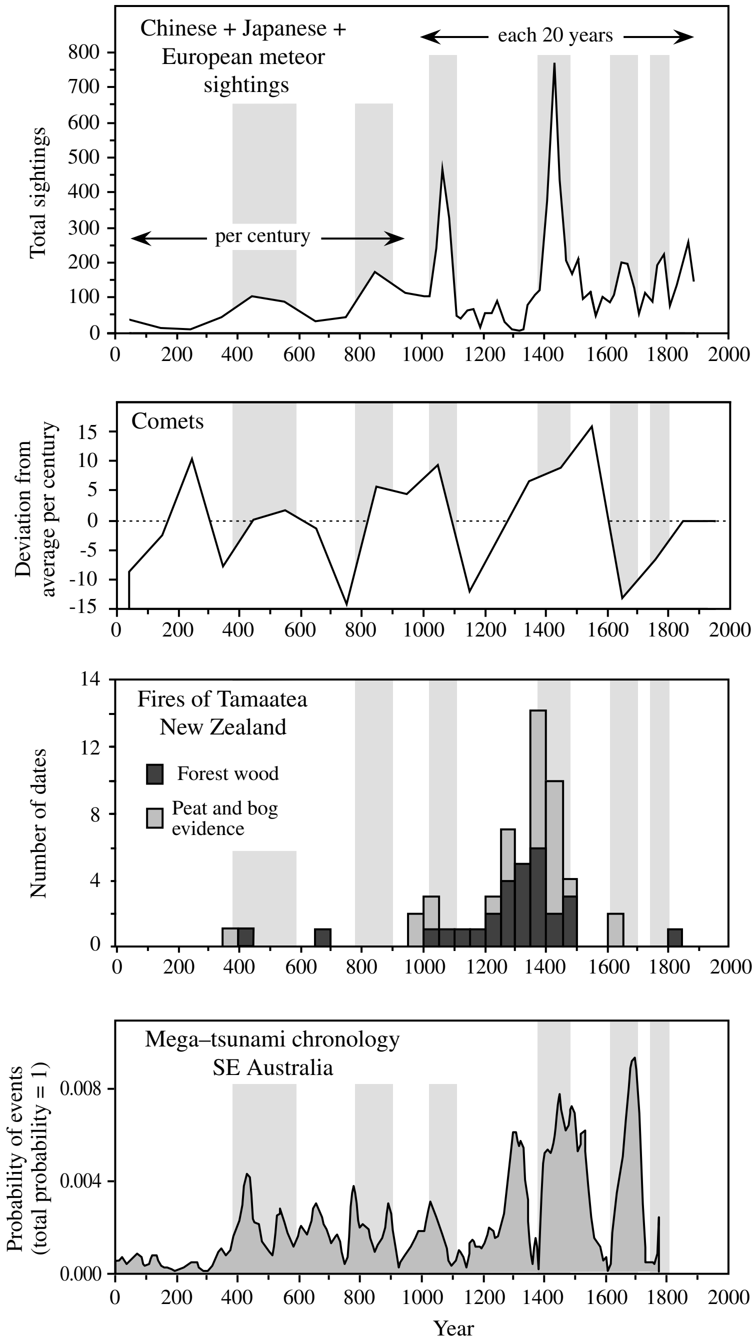

Fig. 3. Incidence of comets and meteorites, and related phenomena, between AD 0–1800. The meteorite records for China and Japan are based upon Hasegawa (1992), while meteorite records for Europe come from Rasmussen (1991). Peak occurrences are shaded. The Asian comet record is based upon Hasegawa (1992). The calibrated radiocarbon dates under the *Mystic Fires of Tamaatea* are from Molley *et al.* (1963) for forest wood and from McGlone & Wilmshurst (1999) for peats and bogs. The chronology of mega-tsunami is based upon twenty-nine radiocarbon dates of marine shell (Bryant 2001) with five additional acceleration mass spectrometry (AMS) dates from the Tura region of New South Wales. The panel was constructed by summing the calendar age distributions derived from the twenty-nine dates. The dips over the last millennium are an artefact of age reversals in radiocarbon chronology.

Fig. 4. Giant flutes cut into granite on the southern headland of Mason Bay, Stewart Island, New Zealand. The flutes point back to the Mahuika Comet Impact site. The flutes are over 40 m high and were cut by vortices in flow as the tsunami went over the headland from left to right.

Third, circumstantial evidence exists for a major environmental event that disturbed coastal Aboriginal culture within this period. For example, a disturbed midden has been found 30 m above sea level within Sydney Harbour (Attenbrow 1992). This is beyond the run-up of modern storm waves in the harbour. The date of this deposit is 1448 AD. There is also clear evidence that Aborigines switched from collecting large molluscs to fishing about 500–700 years ago (Sullivan 1987). We attribute this response to the fact that any large tsunami would have wiped out shellfish populations along the rocky coast. Aborigines thus switched to fishing to survive. At Bass Point, which is dominated by mega-tsunami erosion and which is a headland conducive to the legend of the ocean falling from the sky, the change occurred around AD 1380 (Bowdler 1976). Finally, middens at various sites along the South Coast of New South Wales indicate that edible mussels originating from more protected tidal inlets began to replace gastropods originating from rock platforms concomitantly with the switch to shell fishhooks (Sullivan 1987).

Fourth, it is possible to pin down the approximate age of the *Fires of Tamaatea.* The cosmic fires reported in Steel & Snow (1992) burnt vegetation across the South Island. There are two sources of organic material for radiocarbon dating this event: buried charcoal (Molley *et al*. 1963) and carbon derived from peats in swamps and bogs that have been burnt (McGlone & Wilmshurst 1999). This material traditionally has been interpreted as reflecting the time of deforestation due to Maori occupation in New Zealand. However, much of the burnt material comes from uninhabitable high country that was burnt on a vast scale. Figure 3 plots the distribution of dates, that span at least two centuries and terminate at the end of the fifteenth century. This wide range in dates is logical knowing that mature trees, already hundreds of years old, burnt. Goff *et al*. (2003) criticize this dating, pointing out that it is inaccurate, that there are ambiguous regions in the distribution of the dates, and that they peak before one in the observation of comets and meteorites. Even so, Bryant (2001) never tried to interpret the dates beyond the crucial point 'that few ages occur after the fifteenth century' concomitant with the peak in meteorite and comet observations. Even the replotting by Goff *et al.* (2003) of their corrected dates supports this assertion. The *Fires of Tamaatea* legend may well have a cosmogenic origin. More importantly, the timing of the fires is also coherent with the dating of mega-tsunami deposits along the adjacent coastline of Australia and New Zealand. These four lines of evidence all indicate that a regional mega-tsunami event that was probably due to a comet impact in the fifteenth century.

Cosmogenic tsunami in the Kimberley

Legends and geomorphic evidence

Some of the more intriguing legends about comets and tsunami come from the Kimberley (Fig. 1a, d). The NW coast of Australia shows some of the largest evidence collected to date of cosmogenic mega-tsunami (Bryant & Nott 2001; Nott & Bryant 2003). The direction of approach of this wave to the coast lies between 235° and 270°. However, evidence of this event has never been undertaken in the Kimberley, north of Cape Leveque, which is characterized by a rugged and indented coastline. There are five lines of evidence for cosmogenic tsunami in this region. First is the Aboriginal naming of landforms, the most significant of which is Comet Rock at Kalumburu (Fig. 5). Not only does the rock look like the head of a comet with an extending trail, but there is also an Aboriginal rock drawing on the lower face of the rock that mimics the form of the rock and that is orientated parallel to the rock feature. This rock is orientated 310° to the NW.

Second are specific legends about tsunami, the most notable of which occurs around Walcott Inlet (Fig. 1d). Here legends recount a very fast flooding from the ocean that filled this inland tidal body for up to 12 hours (Mowaljarlai & Malnic 1993). Other myths imply that water flooded to the top of 500 m high mesas surrounding this inlet. The flooding was extensive from Walcott Inlet in the south, to Kalumburu in the north, and to Kununurra in the east (Fig. 1d).

Third are the Wandjina rock art paintings and their associated interpretation. Wandjina paintings are very stylistic across the Kimberley. None is more than four centuries old. The paintings typically show a clown-like face painted white surrounding by an outer, barbed red halo that represents lightning (Fig. 6). They are without a mouth, their nose indicates where the power flows down (Mowaljarlai & Malnic 1993), and is a feature that looks remarkably like the comet symbol painted on the rock at Kalumburu. The Wandjina are the rain spirits of the Wunambul, Wororra, and Ngarinyin language people (Layton 1992). The Wandjina have great power and are associated mystically with creation and flooding rain. Their origin may be much older and traceable to the flood myths in the Dreamtime.

Fig. 5. Comet Rock, Kalumburu, Western Australia. The tail of the rock is orientated 310° to the NW. The painting of the comet is Wandjinan in age. This rock lies about 5 km from the ocean on a plain covered in a layer of beach sand.

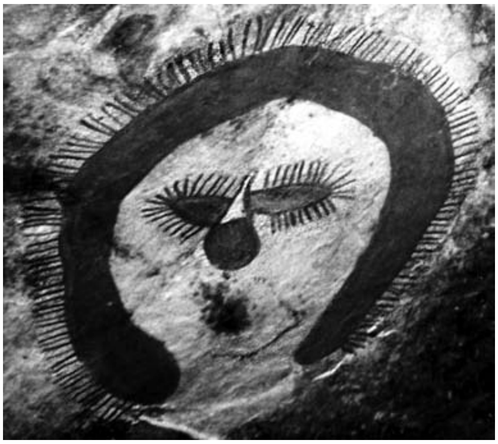

Fig. 6. A typical Wandjina face painted on rock shelters throughout the Kimberley. The barbed hood represents lightning. Wandjina do not have a nose or mouth. The comet-like symbol in place of the nose represents power. Wandjina do not need a mouth because their knowledge is greater than what can be spoken.

Although linked to the annual monsoon, the Wandjina depict something much more intense. One legend tells about a flood that was brought on by the 'star with trails' (Mowaljarlai & Malnic 1993). The Wandjina caused a great flood that started in the north of Australia and flooded the whole country. Just as quickly as the land was flooded, it drained. The Wandjina spirits came out of the sky or the sea and fought a battle with the Aborigines that the Wandjina won (Crawford 1973). The fights were repetitive. As well, the Wandjina fought amongst themselves (Crawford 1968). They came after the flood recreating and restoring the old culture. Wandjina do not have a mouth because their knowledge is beyond speaking. Were they to have a mouth, floods would be generated that would drown the whole Earth. The Wandjina were also associated with life after the widespread Walcott Inlet flood event referred to above (Mowaljarlai & Malnic 1993). Today they control the monsoon with its heavy rain, thunder, lightning, and floods.

Fourth is the subtle disturbance of sandstone rocks sitting on flat landscape surfaces on interfluves. Except for one characteristic, these rocks could be interpreted as weathering features resulting from long-term erosion during the Holocene. This characteristic is the tendency for isolated boulders to form trains on flat surfaces that in some cases contain blocks leaning against each other like fallen dominoes. The Kimberley craton is remarkably stable and presently unaffected by large earthquakes. Something has not only shaken the landscape recently but also cast boulders against each other in an ordered fashion. The orientation of these 'castaway' boulders is 350° to the NW. We propose that the alignment of shaken boulders reflects the direction of the blast wave from a cosmic airburst.

Fifth is the evidence for catastrophic erosion of relatively small streams, similar to that observed elsewhere across the northern Australian monsoon region (Nott *et al.* 1996). In one of the steams feeding into the King Edward River, where the modern channel is less than 70 m wide and 2 m deep, the flood channel is more than 500 m wide. It has evidence of boulders being transported in suspension by flows more than 4 m deep with sufficient intensity to sculpt out erosional features characteristic of vortices eroded under catastrophic flow (Dahl 1965; Kor *et al.* 1991). These channels appear to be recent and beyond the capacity of maximum probable rainfalls, which are the upper design criteria for modern floods. Rainfall induced by a comet impact with the ocean is a possible phenomenon that could have carved these channels.

Field evidence

The challenge was to pursue the sources of this evidence to the ocean and detect the signatures of catastrophic tsunami in the coastal landscape. This

(a)

(b)

Fig. 7. The basalt headland at Cape Voltaire. (**a**) The northern side of the headland. Tsunami flow has cut a smooth, undular ramped surface into columnar basalt. Note the scarcity of debris evacuated from this quarry. (**b**) The debris eroded from the north side of the headland has been transported by the tsunami to the lee of the headland sheltered from cyclone waves. The columnar basalt blocks are aligned with the direction of flow 350° NW.

landscape is also one subject to some of the most intense tropical storms in the world (Nott 2004) associated with winds in excess of 300 km hr^{-1} and storm surges of 3.6 m (Bureau of Meteorology 2000). Two sites stand out as showing evidence of tsunami. The first is located at Cape Voltaire directly west of Kalumburu. Here, waves beyond the capacity of cyclones have truncated the ends of headlands. This erosion was not controlled by bedrock lithology or structure as exemplified by the erosion into columnar basalt on the headland. Tsunami erosion on the exposed side of the headland created a ramp that cuts across the dominant structural control that normally would have influenced coastal landforms (Fig. 7a). This ramp terminates about 20 m above sea level. It would be tempting to attribute the excavation of the ramp to storm waves but for one additional factor. Little debris evacuated from the ramp is present either on the ramp surface or offshore. Instead, the columnar basalt has been broken into 5 m lengths, tossed over the 40 m high headland and deposited on the sheltered lee slope above the influence of storm waves such that individual blocks reflect the direction of flow, 350° to the NW (Fig. 7b). The second site is further south at Walcott Inlet where the best Aboriginal legend for a tsunami exists. Here, at Collier Bay, a tsunami has infilled an embayment with a mixture of sand, gravel and shell that rises at least 6 m above the swash or storm surge limit of tropical cyclones. Everywhere in the Kimberley, the coastline evinces either the erosional effect of a catastrophic wave or its depositional residue in sheltered embayments.

Chronology

It is possible to date the timing of this mega-tsunami in the Kimberley using radiocarbon dating of shell. Again, the same methodology as was used in the Tasman Sea region was used to calibrate the ages. Thirteen dates have already been reported for the comet-induced mega-tsunami detected south of the Kimberley (Bryant & Nott 2001; Nott & Bryant 2003). These are presented in the top panel

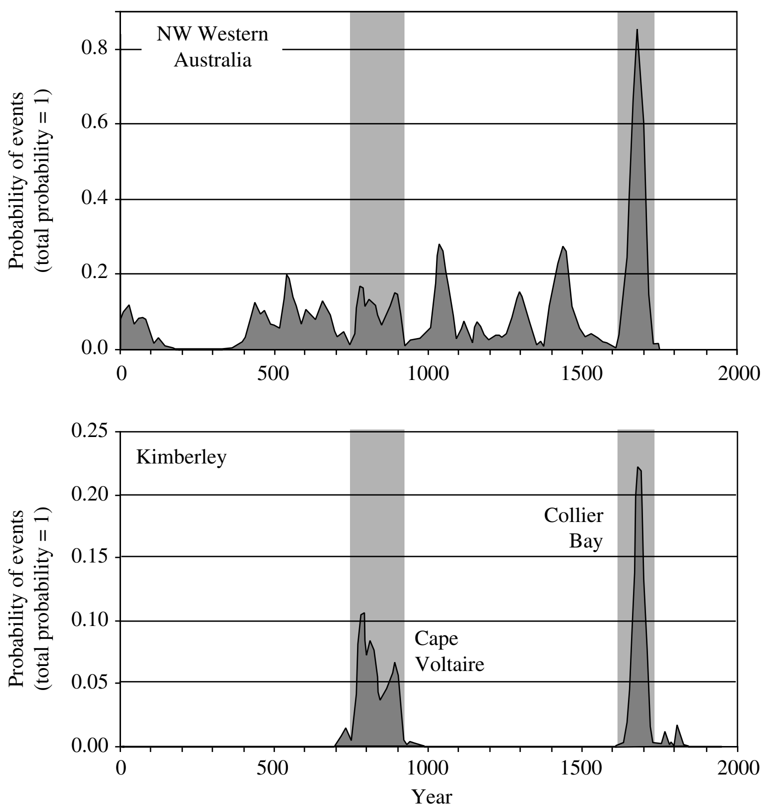

Fig. 8. The chronology for mega-tsunami in NW Australia. The upper panel has been constructed from thirteen radiocarbon dates using the same method as used in Figure 3 (Bryant & Nott 2001; Nott & Bryant 2003). The Kimberley dates are derived from a giant clam at Cape Voltaire (Wk14247) and molluscs at Collier Bay (Wk1448).

of Figure 8. The most recurrent age centres between AD 1620 and 1730 with a defined peak at AD 1690. The date from Cape Voltaire (bottom of Fig. 8) peaks earlier at 800 AD and may either be a separate tsunami event or the result of dating old shell. The date from Collier Bay corresponds with the prominent peak in NW Australia indicating that the effects of a mega-tsunami that occurred around the seventeenth century can now be traced along 1500 km of coastline. This age agrees with the age of the Wandjina paintings. Attempts are being made to retrieve more datable material from the Kimberley coastline to refine the chronology. Based on the evidence presented here, and because Aboriginal legends concentrate on the three main elements of a comet impact in the ocean: the comet itself, tsunami and flooding rains, this seventeenth century tsunami has been labelled the Wandjina event. No impact crater has yet been found, although attempts are being made to find it, if it exists. However, this is not a limitation to our research because both Aboriginal and Maori legends favour the explosion of meteoritic debris in the atmosphere, rather than an actual impact with the earth's surface. Bolides can also generate significant tsunami (Chyba *et al.* 1993; Verschuur 1996). The Wandjina event generated the biggest and most widespread mega-tsunami yet found in the Australian region. The wave reached a maximum of 35 km inland in the Great Sandy Desert, deposited sands up to 40 m deep on the lee side of headlands and laid down bedded gravels on the landward side of 40 m hills situated over 5 km inland (Bryant & Nott 2001; Nott & Bryant 2003). These aspects are an order of magnitude greater than that produced by any historic volcanic or earthquake generated tsunami originating from Indonesia (Nott & Bryant 2003). The spectacular nature of this cosmic phenomenon has dominated Aboriginal mythology for the past four centuries. Only by interpreting the proper significance of this rich oral history and artwork, especially in the Kimberley, can the true origin of this tsunami be recognized.

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