from Three Kings Islands and one northeast of North Cape - have by far the largest wave heights (but local to NRC) as recorded in the palaeotsunami data. Whilst further work is needed to help determine the characteristics, nature and extent of local sources for the entire combined region, the numerical modelling suggests that the most likely event that can explain the large runups responsible for the palaeotsunami data is potentially a submarine landslide northeast of North Cape, or a combination of events.

In Auckland region, tsunamis from the Tonga-Kermadec source have the largest elevations on the east coast but are not significant on the western shoreline. Both the Solomon Sea and New Hebrides sources create moderately large surface elevations around Kaipara Harbour and Great Barrier Island.

For the Waikato and Bay of Plenty regions, tsunamis from the Tonga-Kermadec source again have the largest elevations of all those considered here. Otherwise, there are similar, less significant, water elevations for the remaining sources, although slightly smaller for tsunamis from the Solomon Sea and New Hebrides areas.

Palaeotsunami data have proven useful for this project. When considered in conjunction with source models they provide a clear indication that the Tonga-Kermadec region is the most significant source for the combined regions. An additional lesson learned from this exercise is that some of the palaeotsunami sites could not have been inundated by credible scenarios from any of the distant and regional sources modelled. These deposits must have been laid down by local tsunamis, or an exceptional event that we have no knowledge of. The local modelling experiments attempt to address this issue.

This study points out that marine geophysics and the description of the subduction zones present major limitations in the knowledge base of potential tsunami sources. Further continental shelf research is required to investigate landslides and submarine faults. This leads to the question of how large could such subduction zone events be? The palaeotsunami data and inverse modelling would suggest that Mw 8.5 to 9.0 is not unreasonable although this is larger than current geophysical consensus. Moreover, the larger runup events recorded in palaeotsunami deposits in the Northland region are still lacking a definitive geophysical explanation. There are also rare palaeotsunami deposits in the other regions where the tsunami source has not yet been identified.

6. References

Not all the references are cited in the text; however, they provide a useful database of references for interested parties.


Bloomer, S.H.; Ewart, A.; Hergt, J.M.; Bryan, W.B. 1994. Geochemistry and origin of igneous rocks from the outer Tonga forearc (Site 841). *J. Hawkins, L.M. Parson, J. Allan et al. (Eds), Proceedings of the ODP, Scientific Results, 135, College Station, TX, USA (Ocean Drilling Programme)*: pp, 625-646.


Wright, I.C. 1993b. Southern Havre Trough - Bay of Plenty (New Zealand): structure and seismic stratigraphy of an active back-arc basin complex, South Pacific sedimentary basins, pp. 195-211.


Appendix 1: Some general tsunami information

The word tsunami is used internationally, and is a Japanese word meaning "harbour wave or waves". Tsunamis are generated by a variety of geological disturbances, particularly large seafloor earthquakes, submarine landslides (which may be triggered by an earthquake), volcanic eruptions (e.g., under-water explosions or caldera (crater) collapse, pyroclastic flows and atmospheric pressure waves), large coastal-cliff or lakeside landslides, and very occasionally a meteorite (bolide) impact.

In each case, a large volume of water is disturbed suddenly, generally affecting the whole water column from the floor of the ocean to its surface, creating a train of waves radiating outwards (similar to the wave train produced by a pebble thrown into a lake) until the waves either dissipate or they inundate a shoreline. Very large sources are required to cause tsunamis that are damaging at great distances from the source. The most common sources of these tsunamis are very large earthquakes along the subduction zones that ring the Pacific. However, meteorite impact and very large volcanic events are also possible sources. On the other hand, a tsunami that is generated locally (i.e., near the combined region’s shores) does not need such a large disturbance to be damaging and life threatening, but it would only affect a limited area of the region’s coast.

Tsunamis can be classified into categories either by the distance from their source to the area impacted, or more relevant for emergency management purposes, the travel time to the impacted area and the length scale of impact. For this report, three categories are defined:

- Local source/local impact event (within say 30 to 60 minutes travel time and affecting several 10’s of km of coast);

- Regional source/regional impact event (within 3 hours travel time and likely to affect the entire exposed coastal margin);

- Distant (remote) source/national impact event (longer than 3 hour travel time and likely to affect several regions).

Tsunami waves differ from the usual waves we see breaking on the beach or in the deep ocean, particularly in their length between wave crests. In a tsunami wave train, the distance between successive wave crests (or wavelength) can vary from several kilometres to over 400 km, rather than around 100 metres for waves at the beach. The time between successive tsunami wave crests can vary from several minutes to a few hours, rather than a few seconds. As tsunami waves reach shallow coastal waters, they slow down and steepen rapidly, sometimes...
reaching heights of 10 m or more. Shallow bays and harbours tend to focus the waves and cause them to bounce around and amplify (or resonate). Tsunami waves that overtop or breach natural coastal beach ridges and barriers can surge considerable distances inland in low-lying areas (order of 100’s of metres to a kilometre or more depending upon the wave runup height and the "roughness" of the land cover and built environment).

Key definitions to quantify tsunami are:

- **Tsunami period** (minutes)—the time between successive wave peaks. This can fluctuate during any particular event and vary between different locations within the same region. Periods are usually in the range of a few minutes (e.g., “local source/local impact” tsunami) to an hour or more for a “distant source/national impact” tsunami.

- **Tsunami height** (m)—taken as the vertical crest-to-trough height of waves, but it is far from constant, and increases substantially as the wave approaches the shoreline. Usually only used in conjunction with measurements from a sea-level gauge to express the maximum tsunami height near shore.

- **Tsunami runup** (m)—a more useful measure of the tsunami hazard is the maximum runup height, expressed as the vertical height the seawater reaches above the sea level at the time. This measure still has the drawback that it depends markedly on the type of wave (rapidly rising and falling, a bore, or a breaking wave) and on the local slopes of the beach and foreshore areas, so it is highly site-specific.

- **Inland penetration** (m)—the maximum horizontal distance inland from the shoreline or mean-high-water mark inundated by the tsunami. It depends on the tsunami runup and local topography, barriers and slopes within the coastal margin.
Figure 1 App.: Runup and coastal geomorphology a): Yala, Sri Lanka, 26 December 2004 - Dunes in the middle distance were removed when a hotel complex was built, the hotel was completely destroyed. 153 died. Runup onto the intact dune in the foreground was only sufficient to deposit a boat on the dune crest. Live vegetation is visible to the right of the photo.

http://www.maine.gov/doc/nrime/mgs/explore/hazards/tsunami/jan05.htm
Figure 2 App.: Runup and coastal geomorphology b): Yala, Sri Lanka, 26 December 2004 – Where dunes had been removed on the coast, the next dune system 500m inland slowed the flow so that only about 0.5-1.0 of water overtopped the 12m high dunes. It still had enough energy however to uproot trees while it overtopped the dune.

The behaviour of any given tsunami wave-field that arrives at any particular coastal locality can vary substantially, depending on several factors, including the generating mechanism, the location, size, and orientation of the initial source, source-to-locality distance, and local seabed and coastal margin topography. Conversely, all tsunamis from the same source area with similar generating mechanisms will propagate to a coastal locality in a similar manner, in which case scenario modelling can be very useful in determining local vulnerability to tsunami hazards.

The arrival of a tsunami wave-train (i.e., it isn’t just one wave) is often manifest by an initial draw-down of the level of the sea (much faster than the tide), but for other events, the first sign may be an initial rise in sea level. The waves that propagate towards the coast seldom break before reaching the nearshore area, and the larger waves will appear to have the whole ocean behind them. Thus the larger waves will move relentlessly forward inundating the coastal margin, until they reach maximum runup height before receding temporarily. Other tsunamis occur as an advancing breaking wave front or bore, which is the type of wave most people associate with a tsunami.