# DETERMINING AREAL EXTENT OF AD 186 TAUPO ERUPTION AND POST ERUPTION SEDIMENT IN THE RANGITAIKI PLAINS, NEW ZEALAND

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## ABSTRACT

Sediment cores are ideal for examining past, present, and future changes to the landscape and environment of the observed area. The Rangitaiki Plains have an especially rich stratigraphy with depositional layers highlighting significant volcanic events in the region. Examining cores from two sites near the Rangitaiki River displayed ash and outwash not only from the AD 186 Taupo eruption but also from the AD 1305 Kaharoa eruption from the Tarawera Volcano. Analysis of the derived sediment cores contributes to a better understanding of the Rangitaiki Plains and measures can be put into place to reduce, divert, or control the damage in the event of another small or large-scale eruption.

*Keywords*: Rangitaiki Plains, Taupo Volcano, sediment cores, ash deposits, debris flow

## INTRODUCTION

Large-scale volcano eruptions are responsible for some of the world's greatest natural disasters and are associated with some of the most widespread and hazardous phenomena including, pyroclastic flows, thick ash deposits, lahars, and tsunamis. These hazards not only occur at the time of eruption, but also leave potential for further damage decades later, such as lake breakout floods, land instability, or increase in erosional processes (Manville et al, 2004). During the initial eruption, ash deposition and ignimbrite emplacement coat the landscape of the surrounding area and, over time, get buried. The extent of these hazards is well preserved in the geological record and has distinct characteristics that differentiate the stratigraphic layering.

Sediment stratigraphy analysis is extremely important in reviewing past volcanic events and the extent of damage that resulted. The thickness and composition of each layer reveals 1) the environment prior to the volcanic eruption; 2) the amount of ash and ignimbrite deposited; 3) later events that occurred in response to the eruption; and 4) how the landscape has rebounded from the impacts of the volcano. This study will assess sediment cores along the Rangitaiki Plains and more specifically, examine ash and outwash layers that have deposited within the Rangitaiki region as a result of the AD 186 Taupo eruption.

Previous studies by Simon Bloomberg (2009) have interpreted shallow cores derived from the Rangitaiki Plains and used them to investigate the depositional environment within the region. His findings concluded that one of the main sediment supplies into the plains was volcaniclastic material fluvial deposit washed down from surrounding rivers after explosive volcanic events. Ignimbrite layers within the derived core samples provided outwash evidence not only from the AD 186 Taupo eruption, but also remobilized ignimbrite from the AD 1305 Kaharoa eruption. Bloomberg (2009) further noted that the ignimbrite outwash in the Rangitaiki Plains likely did not reach out to the coastline. Core layers unrelated to volcanic activity include accumulation of organic material and flood plain deposits. This supports the changes seen in the depositional environment in the two cores taken from the Orini Farms, Rangitaiki Plains later reviewed in this paper.

## Background

The North Island of New Zealand is located at the eastern edge of the Australian Plate and overrides the oceanic lithosphere of the Pacific Plate (Fig. 1). Subduction of the Pacific Pate beneath New Zealand allows magma to rise up through the earth’s surface and form volcanic features throughout the region. Stress from the collision of the Pacific and Australian plates cause the overriding crust to extend and form a back arc basin in the Central North Island of New Zealand (Cole, 1990). This continental back arc rift is known as the Taupo Volcanic Zone (TVZ).

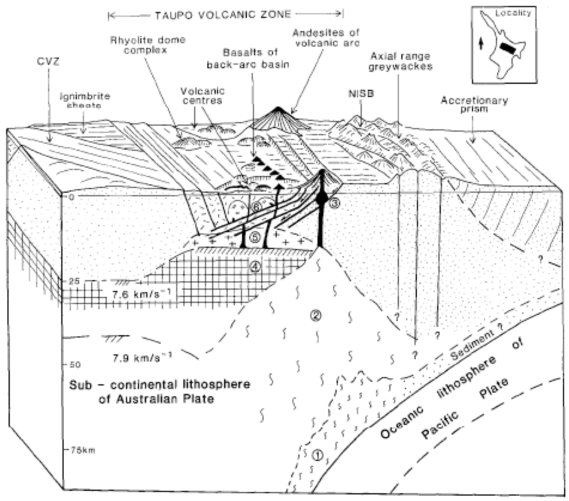


Fig. 1 – Cross-section of the Australian Plate-Pacific Plate collision on the northeast coast of TVZ in the Central North Island, New Zealand.

The TVZ extends from Ruapehu Volcano 300km northeast to White Island and has a maximum width at its center measuring 50km (Snelling, 2003). This area is known to be one of the most active geothermal settings in the world and accounts for the majority of New Zealand's current volcanic activity (Fig. 2). Numerous vents below the surface result in both small and large-scale eruptions throughout the region's history.

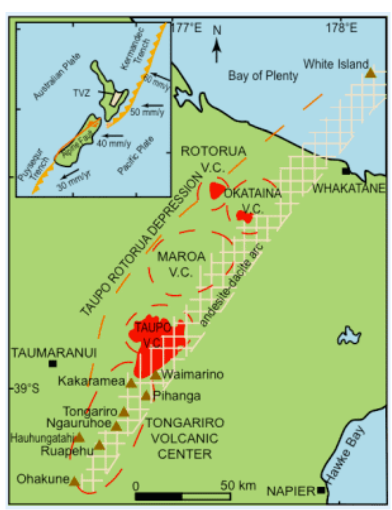


Fig. 2 – Areal view of the TVZ located in the Central North Island, New Zealand

The TVZ is named after the largest volcano in the zone, Taupo Volcano. The rhyolitic magma generated beneath the volcano has very high silica content and is very viscous resulting in extremely explosive eruptions. Approximately 1,800 years ago, this supervolcano erupted a plume of hot ash and debris; ultimately releasing devastating pyroclastic flows down the flanks of the volcano. The debris flow entered the banks of major rivers surrounding the volcano, directing ash and other material away from the eruption site and enabling it to flow long distances and spread out along the plains. As energy dissipates, the pyroclastic flow is deposited as an ignimbrite, a mixture of pumice and ash, and buries the existing topography beneath thick layers of volcanic material. In total, there were approximately 30,000km$^2$ of air fall deposits and 20,000km$^2$ of ignimbrite emplacement within the central North Island of New Zealand as a result of this eruption (Wilmshurst and McGlone, 1996).

Although it is difficult to recognize, Lake Taupo is actually a large, rhyolitic caldera, which formed when the ground collapse after the large-scale Taupo eruption. Water filled in the caldera and formed a crater lake atop the volcano (Fig. 3). These types of lakes can be especially dangerous because the channels feeding into rivers become blocked by the large amounts of ash and debris deposits. The walls of the lake that are made from pyroclastic debris are extremely unstable and, in time, the dam can fail releasing a surge of water from the lake down the adjoining rivers. This even is known as a lake breakout flood. The displacement of large amounts of water, sediment, and volcanic material results in violent floods and lahars and has enough energy to flow hundreds of kilometers downstream with unstoppable force. Decades after the Taupo eruption, Lake Taupo had a breach caused by the refilling of the intercaldera lake (Manville, 2002). This break in the ignimbrite dam discharged approximately 20km$^3$ of water into the Waikato River at the northern end of Taupo Lake (Manville et al., 1999).

Fig. 3 –Ariel view of Taupo Lake, a caldera formed by the Taupo eruption

This sudden outflow of water from the Waikato River extended into nearby rivers, such as the Rangitaiki River. Ash and debris were carried down and spread out into the Rangitaiki Plains, where the outflow collected in areas of lower elevation. Since the eruption of AD 186, the shape and path of the Rangitaiki River has been transformed in many ways, as has the topography the area. Examining the shape of the surrounding landscape is important in determining the rate of erosion, remobilization of sediment, and direction of transport, thus giving a better understanding of where and how much sediment will be deposited (Manville et al, 2004). It is also important to study the sedimentation along the river resulting from past eruptions in order to determine how far debris will flow into the Rangitaiki Plains if a similar sized eruption were to occur.

The geology of the area surrounding the volcano contains evidence of ash deposits and thick layers of ignimbrites that extend over 100km north into the Rangitaiki Plains. These ignimbrite deposits can be classified into two distinct layers as defined by Wilson (1985). The first layer consists mostly of pumice material from the flow head and coarsens upward into a thin lithic composition due strong fluidization resulting from high velocities in the debris flow. The second layer has similar composition and great lateral variation as a result from turbulent flows originating from the collapse of the eruption column (Wilson, 1985). In general, the deposition of the volcanic material varies in thickness throughout Taupo Volcanic Zone (TVZ) and consists mostly of pumice clasts, vitric ash, and lithic fragments (Manville et al, 2004).

The core samples that were collected for analysis were located within the Rangitaiki Plains approximately 100km north of Taupo Lake and 5km south of Thorton Beach within the Bay of Plenty (Fig. 4). Site 1 is approximately 300m east of the current channel of the Rangitaiki River and Site 2 is an additional 200m to the east of Site 1 parallel to the adjacent McLean Rd and located in the Orini farmlands (Fig. 5). The cores were sampled from the flat, low-lying flood plains of the Rangitaiki River. This area is the optimal location for volcano sediment analysis in predicting the extent of damage because it is a vast open area where the debris layer is deposited evenly and is uninterrupted.


Fig. 4 – Locality map of the Bay of Plenty, New Zealand. Site 1 and Site 2 have been identified approximately 120km from the center of Lake Taupo.


Fig. 5 – Locality map of Orini Farms adjacent to the Rangitaiki River where Site 1 and Site 2 cores were derived approximately 230m apart.

## METHODS

*Field Procedures:*

Site 1 and Site 2 sediment was retrieved on 16 February 2012 using a vibro-core machine to core the earth's surface approximately 6m deep. When the exact sites were chosen, a small hole was dug approximately 30cmx30cmx30cm to remove the topsoil and vegetation. Then, the bottom of the aluminum was angled using a handsaw so that the pipe can better penetrate the ground. The 6m long aluminum pipe was placed into the ground ensuring that it was vertically straight. The vibrating machine was clamped to the pipe approximately 2m high. Then, the vibrator was turned on and the pipe was guided into the ground. The intensity of vibrations may be increased to help the pipe penetrate the soil more efficiently. Once the clamp reached the ground, the machine was turned off and the clamp was moved about 2m further up the pipe. This process was repeated until the pipe was about 5m into the ground. Then, the distance from sediment inside the pipe to the top of the pipe was measured and the distance from the ground level to the top of the pipe was measured. These values are used to calculate the compaction of sediment. Water was poured into the remaining space at the top of the core and then sealed to create a vacuum and prevent the soil from falling out the bottom during the removal of the pipe. The tripod was set up directly above the pipe and the chain was attached. Finally, the pipe was cranked all the way out of the ground and lied down horizontally. The bottom of the core was cut for a flat surface and capped to preserve the sediment. The seal was removed and the water was emptied from the top of the core. The empty space at the top of the core can be sawed off at the start of the sediment. The top of the core was capped and clearly labeled with location, date, and direction of core top.

*Lab Procedures:*

Once the cores were transported back to the lab for analysis, there were a series of steps followed in order to open the aluminum pipe and expose the sediment layers. A machine is used to cut through the aluminum pipe on either side but is designed to leave the soil intact. Then, a metal wire is run along the center of the pipe dividing the sediment core in two halves. When separated, the layers are exposed and ready for analysis. One half of the core was photographed with a centimeter ruler for scale in order to document the original stratigraphy before any changes occur to the core. The other half of the core was wrapped in plastic wrap in order to keep the soil from drying and crumbling. It was labeled as ARCHIVE and stored in case it is needed for future use. Otherwise, only the photographed core half is used for analysis and wrapped in plastic when not in use.

*Research Plan:*

The change in stratigraphy is examined in order to construct a diary of sediment deposit unique to the Rangitaik Plains. Closer analysis of the thickness of the ash and pumice layers will reveal how much ash and ignimbrite can be expected in the Rangitaiki Plains if another large scale Taupo eruption were to occur.

## RESULTS

*Site #1 Core*

The topmost layer of the core is 18cm of topsoil. Soil forming processes result in a darker brown color as it intercalates with the medium brown color soil below. This second layer is 145cm thick and composed of well-compacted muds. There are small spots of rust colored sediment throughout the layer indicating oxidation has taken place. This type of deposition is characteristic of a flood bank deposit. Approximately 92cm into the core, within the second layer, there is a 5cm heterogeneous sand layer composed of moderately sorted sand and pumice. The bottom of the second layer has an abrupt change into a medium-dark brown colored mud. The 74cm thick layer 3 transitions from muddy to more organic composition with increasing amount and size of biogenetic material at the bottom of this third layer. Layer 4, 15cm thick, demonstrates a sudden change in environment. The sediment is a light brown silt composition unlike the organic material observed in the surrounding layers. Layer 5 is an extremely anoxic environment deposition consisting solely of black, organic material 10cm thick.

There is an abrupt change in layer 6 consisting of an 11cm thick deposit of ash. The pumice material is the size of course sand and is light gray in color. It is loosely packed and moderately sorted. Layer 7 is 45cm thick and identical to layer 5 in organic composition. In other words, the organic material is 66cm thick with an 11cm ash deposit interrupting the normal anoxic conditions. Layer 8 is an abrupt change to a sandy, medium gray deposit with pieces of pumice dispersed throughout. Similarly, layer 9 is a massive 103cm thick deposit consisting mostly of light to medium gray fine sands. There are laminations present throughout the layer and cobble size pumice concentrated at the bottom of the core but sporadically present throughout the layer. See Appendix Fig. A2 for summary of Site #1 Core results.

*Site #2 Core*

Layer 1 consists of 17cm of dark brown topsoil undergoing the same soil forming processes as Site #1. The top layer gradually transitions to a medium-dark brown mud 45cm thick; however, there are vertical lenses totaling a length of 39cm within the layer. These lenses are mostly composed of light gray ash mixed with some mud. The bottom of this layer intercalates with layer 3, 29cm of black organic matter. Then, there is an abrupt change to layer 4, a massive medium gray deposit. This 251cm thick layer consists of some laminated segments but mostly fine sands with sporadically placed cobble sized pumice. The very bottom of this layer contains a log measuring 11cm in diameter. Over time, it has been broken up into fibrous, organic material. Preceding this layer is a 5cm thick ash deposit. This layer is loosely packed containing very coarse sized grains. Lastly, layer 6 is a massive deposit of organic material containing small woody pieces dispersed throughout the layer. See Appendix Fig. A2 for summary of Site #2 Core results.

## Discussion

The core retrieved from Site #1 has a small layer of topsoil and then a massive layer of mud near the top of the core. Given the close proximity to the Rangitaiki River, this type of deposition is considered a flood bank deposit. The river is perched up due to the natural levees that are created by the sediment flowing downstream and it would be expected to find a thick layer of fluvial deposition right beneath the surface of the riverbank. The small heterogeneous sand layer interrupting normal deposition has coarser grains, thereby indicating a higher energy level during the time of deposition. This could be a large storm event or even a tsunami bringing sediment in from the coast due to its sandy texture. Progressing down the core there is an increasing amount of organic material before abruptly changing to a light brown silt layer. Due to the texture, it is likely that this layer was the result of sediment over washing the riverbanks and depositing as fine silts and clays in the flood plain. Underlying this layer is a large segment of organic material characteristic of a fluvial plain environment.

Within the organic matter lies a small ash layer consisting of pumice. Because this layer is not followed by outwash material, but instead returns to the original organic environment, there is reason to believe that it is not the result of the Taupo Volcano. As previously described, the Taupo eruption was so large that debris was washed from the Waikato River into the Rangitaiki River and deposited in the low lying plains of the basin. In the case of this ash layer, the lack of outwash suggests an entirely different eruption.

After examining the composition of the ash layer, there was an elevated amount of basaltic material observed, not typically found in ash deposits derived from the Taupo Volcano. The thickness and depth of the layer indicates that the eruption must have been significant and recent. This evidence, in combination with the composition, suggests the ash was a result of the Kaharoa eruption, the largest eruption to have occurred in the TVZ in the last 1,000 years (Leonard et al, 2002). Kaharoa erupted from the Tarawera Volcano in AD 1305 and discharged material from seven vents along an 8km long area (Leonard et al, 2002). The late breakout flood was confined to the catchment explaining why there was not evidence of outwash debris in the cores retrieved. Ash that has been previously examined in the area surrounding the eruption has been shown to contain “rare clasts of granodiorite, diorite, gabbro and olivine clinopyroxenite,” which would likely be found upon further examination of the ash layer observed in the core retrieved from Site #1 (Leonard et al, 2002).

Below the organic material, the Site #1 core exposes two similar massive layers, light gray in color and sporadically placed pumice; the first however, contains coarser sand and the second consists of multiple segments of fine-grained laminations. Change in grain size simply implies there was a fluctuation in energy. The presence of pumice suggests these layers may be the result of outwash material from a large-scale eruption. Laminations imply a lower energy environment; therefore, proving that it was not an outbreak flood but instead an outwash deposit occurring over a timescale of months to years. Based on the sizeable thickness of the layer, it could be hypothesized that the outwash came from a large-scale eruption such as Taupo; It is difficult to determine without being able to observe deeper sediment, which the core was not able to retrieve.

The second core shows the obvious topsoil layer but then gradually transitions into a mud layer containing vertical lenses of pumice material. Lack of outwash and similarities in composition confirm that the pumice presented in this layer was also derived from the Kaharoa eruption and corresponds to the ash layer found in the core from Site #1. The ash is presented as lenses because it was not deposited evenly farther away from the eruption. The pumice is evident at a much shallower depth than at Site #1 because it is at a further proximity to the Rangitaiki River. Below is a dark black layer consisting solely of organic material common to flood plain environments.

Then, there is an abrupt change to a massive, light gray layer nearly identical to the outwash layer observed at Site #1 with clasts of pumice material; therefore, it can be assumed that these two layers are correlated and were derived from the same eruption. This core, however, contains a layer of ash below the outwash that can be used to support the hypothesis that both the outwash and the ash were in fact deposited by the AD 186 Taupo eruption. The ash contains more of a rhyolitic composition commonly found in super volcanoes like Taupo Volcano.

The ash layer derived from the Taupo eruption has a surprisingly similar thickness to the ash layer derived from the Kaharoa eruption, even though the Taupo eruption was of much greater magnitude than the Karharoa. This can be explained by the proximity of the site of the cores to the sites of the eruptions. Although Taupo erupted more material, it was a much further distance from the Rangitaiki Plains so there was less ash fall in that particular area. Coincidently, the decrease in ash fall produced a similar sized deposit to the Kaharoa ash fall, hence why the two layers have approximately the same thickness.

The outwash of the Taupo eruption is widely known to have flowed from Taupo, down the banks of the Waikato River in a single, high-energy event. What then explains the long timescale of outwash deposition within the Rangitaiki Plains northeast of the Waikato River (Fig. 6)? This could be a consequence of the overwhelming amount of material in combination with the low-lying topography. As the debris flowed down the Waikato River, it overrode the banks and collected in the basin where the Rangitaiki River is located. By the time the volcanic material reached the Rangitaiki River, the energy dissipated and flowed with much less force. This scenario explains the low energy laminations observed in the core layers the months to years-long timescale.


Fig. 6 – Map of Waikato River (left) and Rangitaiki River (right)
in relation to Taupo Lake, the site of the Taupo eruption.

Future data collection within the Rangitaiki Plains should include deeper cores near the flood bank providing more layers of sediment. This would allow for better comparison between corresponding layers of distal cores. For example, if the core at Site #1 had been a few meters deeper, it would likely have provided an ash layer that could be analyzed and compared to Site #2 ash layer to further support the depositional history of Taupo eruption within the Rangitaiki Plains.

## CONCLUSION

The results collected by the retrieved cores provide indisputable evidence that ash and debris spewed from the AD 186 Taupo Volcano did in fact extend to the Rangitaiki Plains. The ash layer is comprised of pumice and orthopyrexene minerals that are characteristic of the large-scale Taupo eruption. Laminations are observed in the overlying pumice material presenting evidence of a slow, long-term ignimbrite deposition. This supports the theory that the energy of the outwash in the Waikato River dissipated by the time it spilled into the Rangitaiki River and deposited in the Rangitaiki Plains in a low energy environment.

Shallower ash layers that were examined have unique biotite minerals concluding that the ash was deposited by the AD 1305 Kaharoa eruption in the Tarawera region. Lack of outwash is expected because the debris remained in the catchment and did not flow into the Rangitaiki Plains. Both cores provided substantial evidence of the deposition that results from volcanic activity in the region. Future studies will further support the areal extent of the Taupo eruption within the Rangitaiki Plains.

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