Coandă and Venturi Effects at the Eighth Wonder of the World─ the White Terrace

Resolving the East Wind eruptions at the White Terraces

When the wind is in the east, 'tis neither good for man nor beast

─Italian proverb.

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Abstract

The grandest geotourism attractions in the southern hemisphere were the siliceous *Pink and White Terraces*, the *Eighth Wonder of the World*. In 1886, the Tarawera eruption buried them. In the absence of a survey to evidence their locations; public debate ensued until the 1940s. Recently, a survey was uncovered and led researchers to the Terrace locations.

Colonial visitors were told─ the White Terrace spring erupted in easterly winds. Having researched the Pink and White Terraces, these 1859 and 1882 reports were puzzling. Studies in *automotive crankcase ventilation* suggest a cause for these eruptions. After examining the topography of the White Terrace spring, embankment and apron: I suggest the puzzling eruptions were a product of three phenomenae: the Venturi and Coandă effects, with Bernoulli's principle. This paper presents the first evidence for the presence of Venturi and Coandă effects at the Lake Rotomahana Basin. It discusses how these effects contributed to postulated spring eruptions during the 1886 eruptions; which created so far unexplained water ponding around the Pink, Black and White Terrace locations. These surface waters contribute to the new paradigm for the Rotomahana Basin; where the topographic changes lead to the lost Terrace locations.

Introduction

In the nineteenth century, the greatest geotourism attractions below the equator were the *Pink and White Terraces*, the *Eighth Wonder of the World*. American and European tourists took the long sea voyage to New Zealand where the siliceous Terraces astonished a global audience. The Terraces were buried in the 1886 Rotomahana Basin eruption and assumed lost, until recent research rediscovered their locations (Bunn, 2022a, b, and c; Bunn & Nolden, 2022).

During the only survey of the Pink and White Terraces in 1859 by Ferdinand Hochstetter (1829−1884), his indigenous Māori guide Akutina Rangiheuea (?−1886), told him of strange eruptions at *Te Tarata*, the great White Terrace boiling spring. The "whole mass of water is suddenly thrown out with an immense force … such eruptions are said to occur only during violent easterly gales." To Hochstetter this could mean "the Tetarata spring is a geyser, playing at long intervals … the mass of water thrown out, therefore, must be immense" (Hochstetter; 1867, 411). In 1882, F. E. Talbot (1851-1923) was similarly advised by Guide Sophia Hinerangi (1832–1911): "The activity of the spring depends entirely upon the direction of the wind, we were told. Sophia says that Te Tarata is invariably dry when the wind is from the north-east, and the force and display depend almost entirely upon the direction of the wind." (Talbot, 1882). From Hochstetter's measurements, the great White spring erupted ≥3 ML of water compared with for example, Old Faithful geyser at Yellowstone, erupting 0.014-0.032 ML.

These reports by Tūhourangi guide Akutina Rangiheuea and much later by Guide Sophia fascinated me since reading them in 2014, for a conventional geological view is "strong winds cool the surface waters and delay geyser eruptions" (Witze, 2018). This view was proposed in 1951 by Marler and appears to have become accepted, although the mechanisms are unclear (Marler, 1951). Pool geysers, like Tarata are said to be the most sensitive "to surficial factors such as changes in wind speed and temperature" (Hurwitz & Manga, 2017). These American reports relate to Yellowstone geysers lacking the embankments of the Rotomahana pool geysers and thus would be unlikely to experience Venturi or Coanda effects.

The wind explanation appears simplistic for air like gases generally, is a poor conductor of thermal energy. There had to be more to these east-wind eruptions.

From my seminal study of *automotive crankcase ventilation*, I was struck by the similarity of the 1886 Rotomahana Basin phreatic eruption to the operation of an inverted *internal combustion engine* (Bunn, 2013). At Lake Rotomahana the process is also adiabatic. The lake floor serves as a piston, the lake as the crankcase, the geothermal system beneath the lake floor as the combustion chamber, with its water-steam fuel charge heated by magma and a magmatic or decompression event as the spark plug. The engine first fired on June 10, 1886 (Luketina, 2022). Venturi and Coandă effects are noted in automotive crankcase ventilation (Bunn, 2013).

As only one later, frank eruption from Tarata spring is recorded in 1885, it seems unlikely the White Terraces spring could be classed as a geyser and yet geophysicist

Ron Keam labelled it as one (Keam, 2015). The question remains unanswered, why should an easterly wind cause the Tarata spring to erupt? My automotive engineering research suggests the eruptions were caused by a combination of three phenomenae: the Venturi and Coandă effects, and Bernoulli's principle. These acting severally or in unison explain the phenomenon reported to Hochstetter. To my knowledge, this remains otherwise unexplained. More importantly for the study of the Pink, Black and White Terraces, these factors also explain apparent para-eruption water flows from White Terrace spring during the 1886 Rotomahana Basin eruption (Bunn, 2022b, and c).

Tarata Spring topography formed a Venturi

The architecture of the Tarata spring and its embankment created the topographic conditions for a Venturi to form. The spring was enclosed by a horseshoe-shaped, 20-25 m high embankment, opening to the west. Two peaks extended and elevated the embankment either side of the relatively narrow entrance, as in Figure 1. In easterly winds, a Venturi would form as airflow passed over the embankment and down and across the spring platform, exiting between the peaks. The airflow was constricted as it passed between the banks and entrance peaks. Its velocity would increase while air pressure fell, under Bernoulli's principle. This phenomenon is well known in urban geography and see:

http://thebritishgeographer.weebly.com/urban-climates.html#:~:text=The%20Venturi%2DEffect%20is%20a,network%20of%20high%2Drise%20buildings.

Fig. 1. Coandă effect and Venturi topography of Tarata Spring embankment (Bunn, 2017).

In a Venturi, fluid (or gas) flow accelerates and pressure falls: in this case across the spring and Terrace platform surface. The air pressure above the geothermal spring falls and this encourages the already boiling spring to erupt. The Tarata spring temperature was 84°C at the margin and boiling in the center (Hochstetter, 1867). Allowing for altitude, water there boils at ~98.9°C. For example, a 10% drop in air pressure over the spring brings this down to ~96°C, extending the spring area at boiling point (Wooten, 2011). The strength of the effects would depend on how the Venturi formed over the spring, platform and upper Terraces. At some point, the spring would erupt. *Lucy's Isle* in the platform between the peaks, may have divided the Venturi or formed a pair of Venturis: one forming in a southeast wind and a second in a northeast wind as Guide Sophia noted. It is significant that a southeast wind was recorded during the short Rotomahana Basin eruption (Nairn, 1979).

Coandă effect over the White Terraces

In easterly winds a synergistic effect, unknown in Hochstetter's' day would emerge over the White Terraces— the Coandă effect. The airflow passing over the embankment would be attracted to the convex banking surface under the Coandă effect, deflecting down and across the spring platform and upper Terraces. The easterly airflow striking the embankment would form low-pressure vortices inside the embankment. These would deviate the airflow down to adhere to the spring platform. *Lucy's Isle,* between the entrance peaks in the centre of the platform, may have contributed to the vortices and low pressure via transverse currents (Brookes, 2016). *Lucy's Isle* first appears in the literature in 1885 (Cowan, 1885). As Hochstetter documented the island in 1859 and omitted to name it, it may be presumed it was named between 1859-1885. Given tribal permissions for the landform naming and for the person's name ... must both have come from within Te Tūhourangi─ the name is likely to relate to a notable member of the tribe. The most likely individual is *Ruihi,* the wife of Te *Rangipūawhe* (1826-1905), the ariki (paramount chief) of Te Tūhourangi (personal communication: Rangitihi Pene, 26 September 2022)

The curving embankment and terrace surfaces would cause acceleration of the air stream under the Coandă effect and from Bernoulli's principle, a lower pressure between the air stream and the spring surface, causing more extensive boiling (Camuffo, 2019). American Frank Cowan's (1844–1905) evocative description of a *white rainbow* over the White Terrace spring, may reflect his unknowing view of the Coandă effect:

Above the sapphire cauldron; and above
The halo, overspreading half the pool,
A radiant arch of white─a rainbow blanched─ (Cowan, 1885. p. 23).

Surviving Evidence

I can find no surviving photographs witnessing this Coandă effect phenomenon, probably because the accompanying strong easterly winds would prevent canoe transport of the heavy cameras, (and prior to the mid-1880's), the bulky portable darkroom required on site at the Terraces. These items had to travel east by dugout canoes (with little freeboard) across Lake Tarawera, to the Kaiwaka Channel and up it to Lake Rotomahana. Also, the longer exposure times of wet-plate cameras in the earlier tourism period at the Terraces, would anyway preclude the effect being recorded (Bunn, 2019). In Figure 2, the effect of a north wind is shown across Tarata Spring, in a photograph taken on a later, dry-plate camera. The steaming-fog is blown from left to right across the embankment entrance and down over the southern Terraces. There is possible evidence of a Coandă effect over the upper Terraces, but this may instead be localised steaming-fog over a hot waterfall recorded there.

Fig. 2. White Terrace, under a strong north wind (cropped). Steaming-fog may be blowing across the southern Terraces. 1885, Burton, Te Papa (C.014925).

Years ago on the *Tongariro Crossing* (acknowledged as the best one-day walk in New Zealand), I witnessed a similar easterly Coandă effect. On the saddle between Mts Tongariro and Ngauruhoe at ~1,900 MASL, a strong east wind blew and low cloud descended around us. As the wind crossed the saddle the cloud acted as an *airflow witness*, like the steaming-fog in Figure 2. It curved down around us, adhering to the ridge and forming Coandă vortices. The line of vortices is seen above the observer, stretching from left to right as it impacts the ground in Figure 3. A complete vortex is captured on the right of the line, from memory spinning counterclockwise as expected. Shortly afterward, we were immersed in the cloud as it flowed across the plateau. While thus immobilised, a second phenomenon impacted. The impenetrable cloud began receding evenly from me. When I pivoted, the recession was occurring all around me, like a camera iris opening. In a minute, I was standing in the centre of a golden dome, doubtless caused by a clear-air vortex grounding on my position. At the time I was unaware of the Coandă effect and the mountain-top phenomenae were preternatural.

Fig. 3. Coandă Effect at the Tongariro Crossing, under a strong east wind. Note the line of Coandă vortices and a complete vortex forming to the right of the line (A. Bunn, 2008).

Base surge interaction

We should next consider the base surge effects during the 1886 eruption. From Ian Nairn's cross-bedding analyses, 20 of 23 base surges from the Rotomahana Basin eruptions were directed from the east i.e. from Great Crater Basin (Nairn, 1979). The hot surges were "steam-fluidised debris flows … in hurricane-velocity (>40 m/s), ground-hugging turbulent clouds" (Nairn, 1979). The Coandă effect and Bernoulli's principle would operate on the fluidised surges as they passed over the Pink and Black Terrace springs. Some probably passed over the White spring. One at least directed NNW over it (Nairn, 1979). Given the high surge temperatures, the three spring temperatures would spike, while pressures fell. The three phenomenae would rapidly lower air pressure over the three springs, to a greater extent than during easterly winds; causing the similar eruptions to those described by Rangiheuea described. No one survived to report these in 1886. Sadly, Rangiheuea and his family died in the 1886 eruption.

We now have a *chain of evidence* to explain how and why Tarata, the White Terrace spring erupted between 3.30 AM−5.30 AM on June 10, 1886 during the Rotomahana

Basin eruption. The spring water first percolated up through and then surfaced over the thick ejecta, (*inter alia* creating pooling around the Pink and Black Terraces) and a watercourse from ~300 m below the crater rim and carving out the great watercourse under Pukekiore Hill (Smith, 1887; Bunn, 2022b). This supports recent published findings on topographic changes to the Rotomahana Basin, during the 1886 eruptions (Bunn, 2022a, b, and c).

Conclusions

In summary, there is a logical engineering explanation for Rangiheuea's 1859 report to Hochstetter of easterly winds causing Tarata spring to erupt. The topography of the Tarata spring and its embankment enabled Venturi and Coandă effects to form during easterly winds. These wind conditions existed on the night of the 1886 Tarawera eruption. More importantly, similar effects are likely to have occurred during the 1886 Rotomahana basin eruption base surges; providing an explanation for otherwise unexplained, post-eruption surface water and watercourses around and below the three Terrace springs. Today, these effects contribute to the new topographic paradigm for the Rotomahana Basin: one which confirms the location of the White Terraces.

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Conflict of Interest

The author has no conflicts of interest to declare and there is no financial interest to report. I certify that the submission is original work.

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