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Where has all the Sinter gone?

From the Pink and White Terraces, the Greatest Tourist Attraction of the Southern Hemisphere

A. Rex Bunn

Independent researcher

Corresponding author, Rex Bunn, rexbunn2015@gmail.com

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‘If sulphurous light had shone from this vile well, One might have said it was a mouth of hell, So large the trap that by some sudden blow, A man might backward fall and sink below ...’

Hell's Partition, Victor Hugo.

Abstract:

Debate continues over the silica sinter Pink and White Terraces, the greatest tourist attraction of the southern hemisphere. The 1886 Tarawera eruption may or may not have destroyed them by burial or eruption. This research compiles surviving sinter. The volume is unexpectedly tiny, which bears on the debate. A database was developed including photography. A forensic approach was taken to atmospheric conditions which affected visibility. The eruption ejected ~ 0.5 km³ ash. Pink and White Terrace and other sinter occupied ~0.0003 km^3 –0.0004 km^3 of this. Finding sinter amongst the ejecta was unlikely. The probability of finding terrace sinter is ~0.03%–0.04%. This helps explain the small amount, presuming it existed. Many samples were unverified or lost. Surviving post-eruption samples are few. The scarcity is consistent with the terraces being buried and/or the vagaries of sample collection.

Keywords: Pink Terrace; White Terrace; Eighth Wonder; Silica; siliceous sinter; Tarawera eruption; Lake Rotomahana; volcanic eruptions; Te Tarata; Te Otukapuarangi**.**

1. Introduction

This research speaks to the enduring question of the Pink and White Terraces’ survival, New Zealand’s Eighth Wonder of the World. Unlike northern hemisphere calcium carbonate terraces, these were of siliceous sinter (silica). We examine the reports of Māori and colonist, reporters and tourists who travelled into the Tarawera eruption landscape and reported what they saw and guessed of the missing White Terrace in Figure 1.

Fig. 1. White Terraces, 1882, Auckland, by Charles Blomfield. Gift of Sir Guy Berry, South Africa, 1960. Te Papa Tongarewa (2 March 1960).

Figure 2 is an 1885 photograph exposed from a similar perspective.

Fig. 2. The White Terrace in 1885 (Te Papa Tongarewa MA_1103795).

In Figure 1, the White Terrace basins ‘glowed’ with turquoise, translucent water spilling in a preternatural audio-visual experience. The turquoise hue was from Rayleigh scattering by

colloidal silica particles clouding the water. In Figure 2 the figure is Guide Alfred Warbrick (1860–1940).

The research focusses on the contradictory reports from Māori and colonists, about the presence or absence of siliceous sinter on the ground about the Lake Rotomahana crater and whether it came from the Pink and White Terraces or other deposits. If the Terraces were buried under ejecta from the 1886 Mount Tarawera eruption, few Terrace fragments would be visible about the crater. If the Terraces were blown up as officially claimed— pieces should have been collected.

The Pink and White Terraces earned the Tūhourangi owners an annual income of NZD2–3,000,000 (in current terms). Given the tourist predilection for keepsakes e.g. bottles of St. Helens volcanic ash sold for USD20-30 (Magloff, 2006 31)— it would be surprising if the Māori owners failed to notice a fresh source of Terrace samples. They would sell them for 2/6 ea. (~NZD 220 today) to offset their lost tourism income from artifacts of silicified twigs and birds (Payton, 1888 124). Terrace samples fetched NZD 64,000 in 2012. The few samples auctioned in recent years with provenance are pre-eruption. The National Rock Collection in New Zealand has no samples, either pre- or post-eruption. The Otago Museum has a piece from George Valentine (1852–1890). Warbrick donated his collection to this museum. It had no sinter. The Buried Village had a sample. During the author's decades in Rotorua, no post-eruption silica terrace samples were encountered. Having searched for terrace samples, it is impossible to fossick at Lake Rotomahana, pick up a rock, identify it as siliceous sinter and affirm it came from a terrace before or after the eruption.

Germane is the alien environment at the Rotomahana Basin. Mount Tarawera was the first large volcanic eruption the Māori and colonists saw. Also germane was New Zealand society. In 1886, it was a British colony, with a history of governance by New South Wales. It was the most distant British colony and attracted folk comfortable with frontier living rather than intelligentsia.

While the first university was established in Otago in 1869, the country was sparsely populated with British emigres and first generation Caucasian New Zealanders. For example, the government science adviser Dr James Hector (1834–1907) possessed a medical degree but oversaw several departments including the New Zealand Geological Survey, Meteorological Service, Colonial Museum and Wellington Botanic Garden. Perhaps due to this managerial span, his report as first-responder to the eruption was unsatisfactory and

surveyors and academics were sent to report. There was enmity between the universities staffed with British expatriates and the locally-born in government departments (Keam, 1988 331). The Assistant Surveyor-General S. Percy Smith (1840–1922) who figures in the Terraces narrative entered a surveying cadetship at age 14.5 years, qualifying as an assistant-surveyor after two years. That comprised his formal education. In terms of geology, geomorphology or volcanism, he is better regarded as an amateur (as should this author). His later work in ethnology was challenged for falsification (Taonui, 2005 1). Smith and Warbrick from the Ngati Rangitihi sub-tribe in Rotorua became protagonists over the Pink and White Terraces— unto death.

2. Materials and methods

2.1. Literature review 1886–1940

The foremost historical review of the eruption was by Ron Keam (1931–2019) for his 1961–1978 souvenir booklets on the Tarawera eruption with The Buried Village and his 1988 opus *Tarawera* (Keam, 1978, 1988). On the 1986 eruption centenary, the Rotorua Museum & Rotorua Art Gallery published the *Tarawera Eruption Centennial Exhibition 1886-1986* in which Ian Nairn gives the finest lay description of the eruption (Rotorua Museum, 1986). Philip Andrews took on the booklet writing (Andrews, 1986).

Keam's research was restricted to print archives and microfiche. Digital scanning provides searchability. The National Library of New Zealand has media reports from the eruption online via their *Papers Past* resource. *Trove* is a similar digital archive by the National Library of Australia. The author of this paper is based in Australia. These archives contain more than 500 articles on the Tarawera eruption. Trove resources may not have been accessible to Keam— for this research, a quota sample database was formed of 300 Australasian newspaper articles stored by Papers Past and Trove from 10 June 1886, covering the eruption. Articles from the twentieth, fortieth and sixtieth eruption anniversaries were added. The author searched for reports of post-eruption terrace material. Few Terrace samples with provenance were found and the search expanded to include pre-eruption sinter.

2.2. First responder reports

The Tarawera eruption occurred on Wednesday night 9 June 1886, and pre-dawn on 10 June leaving an altered landscape. Over Thursday 10 June and Friday 11, no one ventured to the

crater. The first parties approached on 12 June, but were unable to reach the Rotomahana crater until 13–14 June.

2.3. Official period reports

The official reports include those by the government advisor Dr Hector, five reports by the Assistant-Surveyor General S. P. Smith (plus a supplementary report), (Smith 1886, 1887, 1894; Pond & Smith 1886; The Lost Terraces 1910, Keam 1988, 335), and later university reports from Sir Algernon Phillips Withiel Thomas (1857–1937), (Thomas 1887; Keam 1988, 332) and Prof. Frederick Wollaston Hutton (1836–1905), (Hutton 1887; Keam 1988, 332). There were contradictory reports from Te Arawa Māori and some colonists concerning the Pink and White Terraces. This became a public debate until World War II.

It seemed preferable to conduct the research from a three-sided perspective i.e. first the central government and General Survey Office, second the earth sciences academic sector and third the Māori. Tension within the colonial camp had expatriate British academics dismissively labelled as *the wise men* (Keam 1988, 331).

The Māori assessment of the eruption and the status of Pink and White Terraces was ignored by government and university rapporteurs. There were few academic Māori scholars. The relevant Māori source is Warbrick. The mātauranga Māori holistic knowledge contains the understanding, practices and beliefs of Māori people, rooted in their history, culture, and connection to the land. It emphasizes the relationship between people and the natural world, including flora, fauna, and ecosystems. The first modern application of mātauranga Māori to the location of the Pink and White Terraces was published in 2023 (Bunn, 2023a).

2.3.1. S. P. Smith, Assistant-Surveyor General

Smith first visited Rotomahana in 1858 and later as a surveyor. On 13 June 1886 Smith left Rotorua for Pareheru but could not reach he crater. He was ~5 km from the White Terrace and could not see detail. He was unable to approach the Pink Terrace. On 14 June he reached Hape-o-toroa Hill and again sketched the basin.

Smith made further trips to the area and published five official reports, the first preliminary report on 19 June (Smith, 1886). In July, he gave a lecture on the eruption (Pond & Smith, 1886). In March 1887, he was obliged to audit his survey of the Terraces after challenges to his reports (Keam, 1988 335). He published his main report in July 1887 (Smith, 1887). In 1894, he submitted a fifth report on the eruption (Smith, 1894). In 1910, after continuing

efforts by Warbrick and with Minister T. Mackenzie's support (Minister for Tourism Resorts) to obtain government backing to expose the terraces sites, he was asked for a sixth report (The Lost Terraces, 1910; Keam, 1988, 335). The six reports are reviewed, wherein Smith wrote an important official record questioned herein. After retiring, Smith studied Polynesian ethnography where his research is also challenged (Taonui, 2005).

2.4. Later reports

Public debate over the survival of the Pink and White Terraces continued until the eruption cohort passed in World War II. By 1936, only Warbrick and Harry Lundius (fl. 1886–1925) were alive (with Ina Haszard {1876–1954} and Willy Bennett {1874 –1959} as children at the eruption). In 1932, Warbrick retired as Chief Guide at Waimangu, aged 72 years, after 45 years at the Rotomahana Basin and nearly 2,000 ascents of Mount Tarawera. He continued his newspaper and radio media campaign on the fiftieth anniversary in 1936 after the publication of his book *Adventures in Geyserland* in 1934 (Warbrick, 1934, 1936). He died in 1940, believing the Terraces lay buried and could be recovered. After their nineteenth century starring role in international tourism, and passing interest by surveyors the Rotomahana Basin became a nursery for geoscience graduates.

With notable exceptions e.g. Prof. Patrick Marshall (1869–1950) chair of Otago University geology faculty, later geoscientists followed the General Survey Office claim the terraces were destroyed. Over 1979–2024 Nairn published seminal papers on the Tarawera eruption while Keam over 1961–1988 published the lay account (Nairn, 1979; 2002; Keam, 1988). From 1986, Rotorua historian Phillip Andrews published booklets listing six silica samples (Andrews, 1986). He mentioned informal bearings by James Healy (1910–1994) and Ted Lloyd. These remain unpublished as do bearings by Smith in 1873 (Hill & Paterson, 2011). Smith's notebooks are in the Turnbull Library but notebook Number 40 is not there. As the only reference to it is by Keam, it is regrettable it didn't appear in the 2019 auction of his collection. In 2011, a joint American-New Zealand project claimed in press releases to locate both terraces in Lake Rotomahana (De Ronde, 2011). No samples were produced. Their claim was submitted to peer review in 2016 and retracted (De Ronde et al, 2016). It was accepted until researchers pointed out errors in the claims (Keir, 2012; Bunn & Nolden, 2016, 2018, 2023; Bunn, 2023a, 2024).

Colin Simmons, of Rotorua Lapidary covered the Rotomahana Basin for 40 years and advised sinter samples '… are extremely rare and I have always come to the conclusion that

people had in fact picked up coloured sinter which was mistaken for parts of the terraces.' (pers. comm. Colin Simmons: Rex Bunn 21 October 2024).

The Tūhourangi Tribal Authority, owners of the Pink and White Terraces, advise their members possess no silica from Rotomahana (pers. comm. Rangitihi Pene: Rex Bunn 14 October 2024). This is significant for as Prof. Pou Temara points out " … despite the passage of time the 'tapu of Tarawera' still holds …" . This suggests that samples held by Te Arawa tribes would not be sold (Leaman, 2016).

2.5. Retention samples, pre- and post-eruption

The author anticipated samples would be held by public and private collections. This hope went unrealised. The samples (including sinter) collected by the author's PAWTL citizen-science projects over 2014–2018 probably outweigh other sinter samples with provenance from Lake Rotomahana.

2.6. Sinter area analysis

The difficulty in identifying siliceous samples from the basin as terrace or non-terrace is compounded by the area of sinter around the old lake— not associated with a terrace. The cartography and survey mapping by Ferdinand von Hochstetter (1829–1884) in 1859, later rendered and published by August Petermann (1822–1878) in 1861, includes non-terrace sinter in the geological colouring (Nolden & Nolden, 2013; Petermann, 1864; Bunn & Nolden, 2018, 2023). Using a geographic visualisation tool i.e. Google Earth Pro™, these non-terrace areas are measured. The maps were first georeferenced over the Rotomahana Basin in Google Earth to project the sinter areas at scale. Provision was made for sinter thickness and sub-surface plumbing.

2.7. Photointerpretation

The author expected that given Smith's reports, high-resolution photographs where he stood on Hape-o-toroa Hill on 14 June would show white terrace fragments.

2.8. Forensic visual effects on colour perception

Given the atmospheric changes in eruptions and reported by first responders, forensic practice requires an examination of the visibility conditions about the crater (Genge, 2004). The human eye contains two types of receptor cells i.e. rods and cones. These work together to perceive light and hue.

Rods are monochromatic and sensitive in low light, providing vision at dusk and night. They do not detect hue, and colour perception diminishes into grey scale in low light. Rods have low visual acuity making it harder to differentiate detail at dusk. Cones function in bright light and supply visual acuity and colour vision.

At dusk, the rods become more active and the cones ineffective. Our vision becomes monochrome making it hard to distinguish hues. At Lake Rotomahana on the author's 2016 scuba dives this switch to scotopic (rod-dominated) vision was noted. From one meter depth the pink sinter search was hampered by muted light, fading redness and poor visibility. On the rocky bottom, any white sinter was hard to detect (Bunn & Fisher, 2016).

3. Results

This paper examines what was encountered on the ground and recorded by colonists at the crater. The few reports of terrace sinter fragments are assessed. At that time, there were few volcanologists in New Zealand and no seismometers. Tarawera became one of the first major volcanic events to be studied there. No geologist witnessed it. Surveyors' reports were seized upon by geologists. This explains the official eruption reports being penned by a surveyor rather than a geologist, volcanologist, geomorphologist, engineer or geographer. The lay eyewitnesses' reports are evaluated. Their vision and perception were modified by ongoing eruptions, the distressing environment and air pollution.

3.1. Forensic analysis of post-eruption atmospheric disturbances

The 1886 eruption of Mount Tarawera and the Rotomahana-Rotomakariri cratering created atmospheric disturbances affecting vision, especially under changing light at dawn and dusk, and in cloudy weather. Photography was impacted. These disturbances included:

3.1.1. Ash clouds and volcanic dust: The eruption ejected volcanic ash into the atmosphere, creating clouds of dust. The particles scattered and absorbed light, reducing visibility and distorting colours. Ash fallout can give the air a grey or reddish tint, making it difficult to distinguish colours especially in low-light conditions (Raistrick, 1950).

3.1.2. Steaming-fog and hydrothermal eruptions: The hydrothermal explosions around Lake Rotomahana released steam and hot gases, forming steaming-fog. This fog mixed with ash, creating a dense, opaque haze that further obscured visibility. Condensation of steam in cooler air produced clouds of water vapour that diffused light, softening contrast and reducing the clarity of distant objects in Figures 3 and 5.

3.1.3. Sulphur dioxide and other volcanic gases: Gases e.g. sulphur dioxide (SO2) and hydrogen sulphide (H2S) would be released during the eruption from Wahanga, Ruawahia, Tarawera and the Chasm. These react with moisture to form sulphate aerosols, which scatter sunlight and cause a hazy, bluish tint. Airborne sulphur compounds can also affect hue perception, making colours less vivid or altering their hue.

3.1.4. Low Light and Twilight Effects: Given the eruption occurred in winter, the low solar angle created extended twilight which affected colour perception. Twilight scattering via volcanic aerosols and water droplets, could create unusual colour effects, such as reddish or purple hues, due to increased scattering of shorter wavelengths.

3.1.5. Bushfire smoke: There was forest on Mt. Tarawera and vegetation over the Steaming Ranges (Nicholls, 1959). The eruption would ignite bushfires leading to smoke mixing with the ash and steam. Fumaroles and hydrothermal vents generating H2S gas may have ignited (Bunn, 2023c). Smoke absorbs and scatters light, adding to the obscurity and darkening the atmosphere. Colour perception would be affected, as smoke gives air a brownish or yellowish tint, making it difficult to register hues (Mullins, 2021).

3.1.6. Optical phenomena: Volcanic eruptions can produce optical effects such as lightning due to the presence of particles, ice crystals, or charged ash. These effects might further distort vision during low light. Diffraction and scattering caused by the concentration of particulates could intensify twilight.

The ground colours around volcanic eruptions vary depending on the ejecta. The Rotomahana phase of the Tarawera eruption produced white, light grey, and cream-coloured surface deposits (Keam, 1988). The eruptions of tephra included coarse and fine materials, with colour variation. As magma interacted with groundwater, phreatomagmatic explosions gave fine ash. The steam generated from the superheated water created clouds of ash over the landscape.

3.2. Official and Published Reports

The first government reaction was to send their science trouble-shooter James Hector. There were no seismographs and it was suggested in parliament they be imported with an English volcanologist. Early reports suggested the Pink and White Terraces survived, but public relief turned to grief as later reports were published. From the outset, there was disagreement

among the stakeholders i.e. the Māori owners, government surveyors and academic earth scientists. This developed into a media debate for the next 50 years.

The debate divided government ministers and academics, while marginalising the Māori. The dubiety over the Pink and White Terraces' destruction can be gleaned by the number and types of official reports over 1886–1910. Ten official reports and some private reports are summarised in Table 1.

Table 1: Official and private reports on the Tarawera eruption.

	Reports on the 1886 Tarawera Eruption		
Date	**Ordered by**	**Report Type**	**Worker**
1886-06-14	Warbrick	1934 Book	Warbrick
1886-06-18	Ministry	Preliminary	Hector
1886-06-19	General Survey Office	Preliminary	S.P. Smith
1886-07-12	General Survey Office	Lecture	Smith & Pond
1887-03-09	Warbrick	Press	A. Warbrick
1887-03-11	General Survey Office	Audit	S.P. Smith
1887-05-31	Ministry	Final	Hutton
1887-07-16	Ministry	Resignation	Brown
1887-07-25	General Survey Office	Final	S.P. Smith
1888-08-24	Ministry	Final	Thomas
1894-07-26	General Survey Office	Follow-up	S.P. Smith
1910-03-26	General Survey Office	Follow-up	S.P. Smith
1922-01-12	Warbrick	Lobby	Warbrick
1931-09-26	Warbrick	Lobby	Warbrick
1934-06-10	Warbrick	Book	Warbrick
1936-05-16	NZ Herald	Lobby	Nikora
1936-06-08	Warbrick	1YA Broadcast	Warbrick
1936-06-11	NZ Herald	50th anniversary	J.D. Smith

3.2.1. J. Hector

The government representative James Hector made a hurried visit and his report was considered unsatisfactory by the government and later writers. It is not further discussed here.

3.2.2. S. P. Smith, Assistant-Surveyor General

Smith first visited Lake Rotomahana in 1858 as a teenage assistant-surveyor. His last pre-eruption visit was on 4 March 1886. It was recently noted “Smith was much more than a mere surveyor. He was interested in botany, conchology and geology, and had some scientific knowledge of all.” (Nolden, 2022).

On 13 June, Smith left Rotorua for Pareheru ~5 km from the White Terrace. Surprisingly, he took no photographer though Charles Spencer (1854–1933) photographed the eruption over 15–17 June. Smith took an artist who made sketches that were discarded but later published, comprising half his 1887 report. Smith approached Southern Crater ~3 km from the main crater on 13 June, noting the ground was ‘covered with fragments of stone, generally a whitish trachyte covered with flour, and on the brink of the crater was hard white mud’ (Keam, 1988 232). Smith made the sketch in Figure 3.

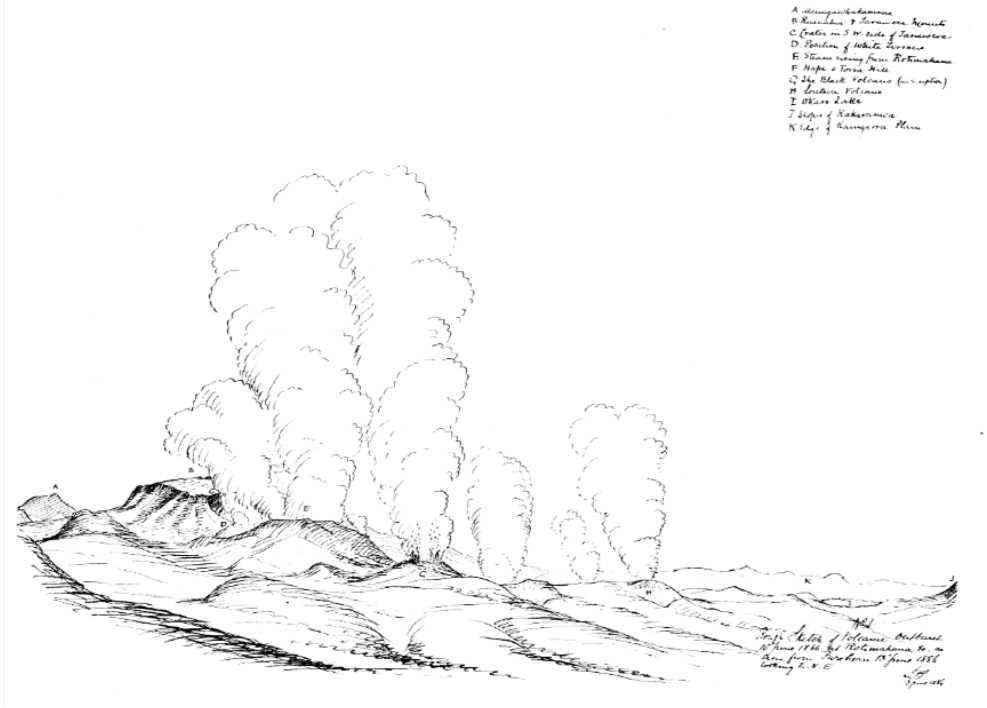

Fig. 3. Smith’s sketch from Pareheru, 13 June.

He was ~5 km from the White Terrace and could not see detail. He was unable to approach the Pink Terrace. Figure 4 is the current view from Pareheru highpoint to replicate Smith’s view. Navigation waypoints include the Chasm and three Tarawera peaks, Hape-o-toroa and the three foreground hills. The White Terrace area was not intervisible.

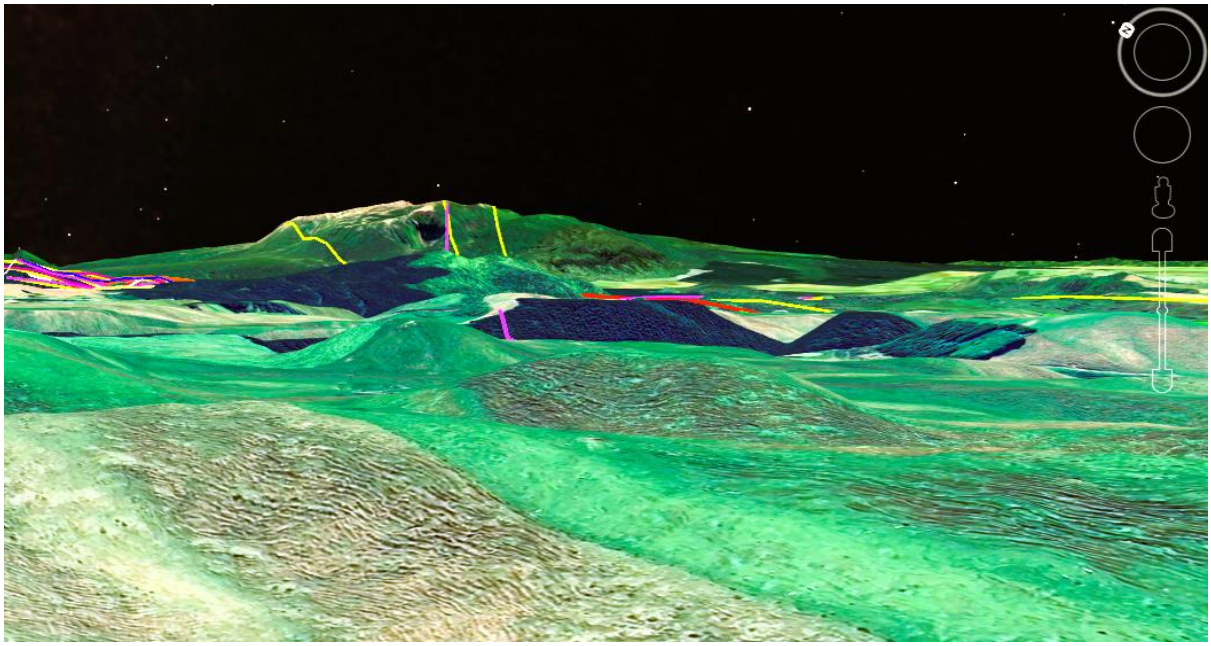

Fig. 4. Smith's 13 June sketch from Pareheru, replicated on Google Earth . Colour rays are survey bearings (Bunn).

On 14 June he reached Hape-o-toroa Hill and again sketched the cratering. See Figure 5.

Fig. 5. Smith's sketch from Hape-o-toroa, 14 June.

In Figure 5, Smith was ~3 km from the White Terrace. He was unable to inspect the ground. The steaming-fog and air pollution reduced visibility. In Figure 6, his view from Hape-o-toroa and Oruakorako Hill is replicated.

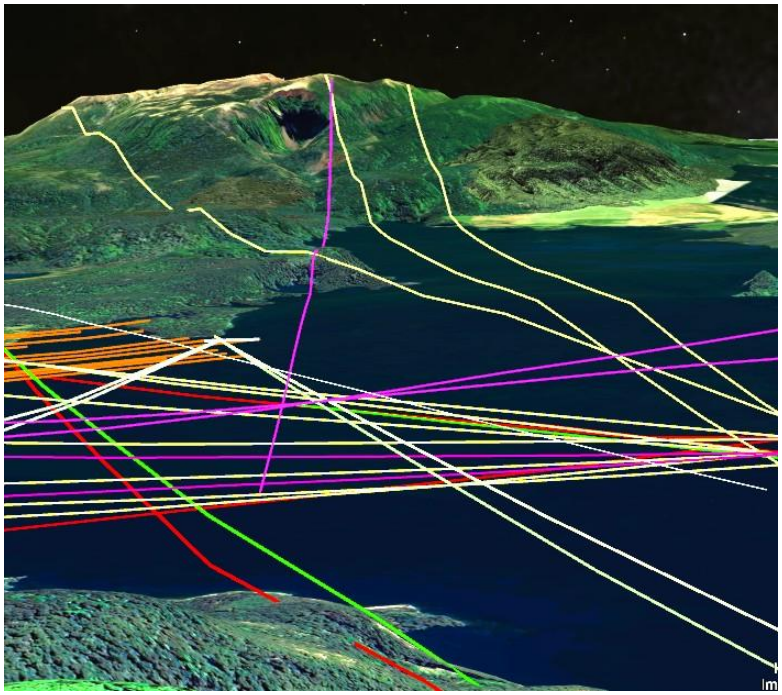

Fig. 6. Smith's 14 June sketch from Hape-o-toroa, replicated on Google Earth. Colour rays are survey bearings (Bunn).

Comparing Figures 5 and 6 with the Chasm and Ruawahia peak as waypoints, Smith's guesstimate of the White Terrace location is mistaken. He misidentified Star Hill, the highest point in the new landscape as the Steaming Ranges and placed the White Terrace ~1,100 m east. The consequences of his mistake were far-reaching. Smith persisted with it until c. 1910, when Warbrick reported Smith admitting the White Terrace may have been buried not erupted (Warbrick, 1934).

(a) Preliminary report; on 19 June, Smith made his preliminary report (Smith, 1886).

'Rotomahana and Terraces.— … The spot where once was situated the most beautiful object in the world, the White Terrace is now, I believe, occupied by a crater, forming a sort of horse-shoe bay in the side of the greater crater of Rotomahana, … the shape and contour of the ground is so altered by the mass of ejected matter that exact localities cannot at present be identified. Should this horse-shoe crater hereafter prove to be not exactly where the White Terrace stood, it is at any rate quite close to it, and its exact position does not affect the question as to whether the Terraces are in existence or not. If not there, then they are either buried deep under the stones and sand, or have sunk into the main crater. '(Smith, 1886).

On July 3, Smith publicly promoted Orakeikorako as alternative tourist terraces.

(b) Official lecture; on 12 July 1886 Smith and colleague James Alexander Pond (1846–1941) lectured at the Auckland Institute (Pond & Smith, 1886). Three extracts concern the terraces and landscape hues:

‘The whole country is clothed in a pale grey mantle. Hill and dale, level and steep, all is of the same hue’

‘At times, the bright sun … bring[s] vividly to the mind of the onlooker the semblance of a vast field of snow. … the ashen covering proves to be a fine, dry, powdered material, having throughout small fragments of scoria. Occasionally spherical or ovoid nodules are found, … Advancing through this material—which closely resembles in colour and appearance Portland cement—the deposit becomes deeper, so that walking was very fatiguing.’

‘The vast number of small fragments of siliceous sinter scattered over the country west and south-west of Rotomahana points to the destruction of the terraces, …’ (Pond & Smith, 1886). No sinter samples were mentioned.

(c) Survey audit; in March 1887, Warbrick’s claims of terrace survival, echoed by some in parliament, forced an audit. Today, an independent audit would be commissioned by a British or American volcanologist. Instead, Smith, his supervisor and the Commissioner of Roads were sent to Rotomahana. The outcome was predictable:

“Mr. Percy Smith will leave for Rotorua before the end of the week for the purpose of making the necessary survey. This action of the Government is consequent upon representations made to them by Alfred Warbrick, who has indicated a spot where he believes the White Terrace is buried. Should Mr. Smith's survey agree with Mr. Warbrick's calculation, work will be commenced with the object of digging the whole Terrace from underneath the deposit of mud.” (Keam, 1988 335).

Following the 1887 audit, Smith modified his claims on surface sinter. His report of sinter west and southwest of the crater is dropped and a new claim of sinter north of the crater is made.

(d) Main report; Smith published his main report in July 1887 after the academic contributions were excluded (Smith, 1887). He qualified his 1886 claims, describing the area:

‘The exact position of the terraces cannot be identified, as the ground around where they formerly stood has been blown away, but they evidently were close to and to the north-west

of the pinnacles [aka Cathedral Rock] … Fragments of the white marble-like siliceous sinter of which the terraces were formed have been found scattered around the northern side of the crater. …The site of the Pink Terraces cannot be identified with more certainty than the White Terraces … owing to the absence of any proper survey of Rotomahana, none of the features can be reproduced with exactitude … It is difficult to obtain a clear view of the crater, on account of the immense mass of steam arising from it. …' (Smith, 1887 57).

Note: Ferdinand Hochstetter's 1859 survey also places the White Terrace northwest of Cathedral Rock (Bunn & Nolden, 2023). See Figure 10 for ground conditions there.

(e) Follow-up report; In 1894, Smith was sent once more into the Rotomahana Basin for another report to parliament (Smith, 1894). Smith's conclusion on Terrace survival remained unaltered.

Smith was challenged in the media. There were many letters to the editor and a group developed that supported Warbrick in his claims one or both terraces survived. This media activity is sparsely summarised by Keam in his 1988 book. Keam did not support Warbrick's claim and insinuated he was senile. After studying Warbrick's writings and interviews over 50 years up to 1936, the author finds no evidence of intellectual impairment.

3.2.3. University reports

The government also commissioned three academics to report on the eruption— Sir Algernon Thomas, Prof. Frederick Hutton and Prof. Frederick Brown (1851–1922).

The tension between the General Survey Office and the three professors is captured in a letter by James McKerrow (1834–1919), the Surveyor-General who observed of Thomas and his colleague Brown:

'They are I fancy like some other learned men I have seen from Home, who have to unlearn a good deal after they come to the colony and get quit of a deal of self-complacency. A very common notion of new arrivals, is, that Colonials are a sort of unkempt inferior race which it is the privilege and duty of them – the learned men – to make stepping stones of.'(Keam, 1988 331).

The government intended a single report prepared by Smith. Thomas was to write up the craters, Brown the chemistry and Hutton the geology and eruption cause. Their reports were delayed— Brown resigned and Hutton and Thomas reported separately; Hutton on May 31,

1887, and Thomas, a year later. The terraces are barely mentioned in these academic reports, hence Smith's report on the terraces went unchallenged by any competent authority.

3.3. First Responder reports

Due to public grief and the newspaper editors and reporters in Rotorua after the eruption, early reports had verbatim reporting. Of the hundreds of press articles studied for this paper, representative examples are included from colonists citing the landscape colours and mention of terrace fragments.

3.3.1. William Berry (1834–1903)

Berry made the first eyewitness report on the landscape on 13 June, from above Pareheru Stream, ~3 km from the crater:

'For miles the whole country was covered with a deposit, which in the fading sunlight and strengthening moonlight, looked as white as snow. … It looked like an arctic scene … there were apparently hummocks of ice and mountains covered with snow. All this was a fine white deposit …' (Smith , 1988 213).

This white deposit was also reported by Warbrick's party on 10 June north of Tarawera. Berry reports it was 'just about dusk' when he walked to a vantage point. At the change of light, human vision becomes monochromatic. Noting small white terrace fragments on a white background seems unlikely at dusk with poor visibility as in Figure 10. The next morning, Thomson Wilson Leys (1850–1924) described the same area as an 'unbroken succession of grey hills and gullies' (Smith, 1988 214). His party walked on to Hape-o-toroa Hill, naming Black Crater en route. They reported:

'the whole mountain-side was strewn with fragments of terrace-formation, but as the surroundings of the old lake at many points were marked by areas of silicious deposit there was no clear evidence that these fragments came from either of the great Terraces.' (Smith, 1988 217). No silica samples were collected, though Leys showed Hector ejecta samples (Smith, 1988 221). Hector made no mention of samples.

3.3.2. Joshua Morgan (1858–1893) and Wairehene (Waea), (fl. 1886–1887).

Morgan and Wairehene on 13 June, were at Pareheru. On 14 June they walked around the crater to the Kaiwaka-Kokotaia area. They were the only ones close enough to each Terrace location to inspect the ground. They made no report of terrace fragments from Pareheru

towards Kokotaia. They encountered watercourses. One was possibly the Kaiwaka and another the overflow from springs. (Bunn, 2023e).

‘Passing along north of the Rotomahana crater … The travelling was dreadful … up one of these channels [that] the two men made their way, arriving at the top of the hill they could look down at a place where both the Pink and White Terraces had been. Not a vestige of either were to be seen.’ (The Volcanic Eruptions, 1886)

No other first responder reached the crater edge between Hape-o-toroa and Cathedral Rock. The next party to reach it was guided by Warbrick.

3.3.3. Alfred Warbrick

In his 1934 book, Warbrick recounts multiple rescue missions after the eruption. Neither then nor over the 45 years he worked at Rotomahana, did he report finding terrace fragments. He comments in his 1934 book on the 1887 disagreement with Smith that caused the government audit viz.

“He [Smith] thought that both had been blown up. I did not agree with him. I wanted to know why, if they had been destroyed, nothing of their remains had been found anywhere. This, he admitted, puzzled him too. I had been searching the country for weeks, and not an inch of the Terrace formation could I find. I had taken to Rotomahana several of the old Maoris who had spent most of their lifetime there, and they, too, were all of the opinion that the Terraces were still there, but buried in the mud; they declined to believe that they had been blown away. Mr. Smith ultimately conceded that they might have escaped the destruction and have been covered up.” (Warbrick, 1934 88).

Warbrick asserted the White Terrace and possibly the Pink Terrace survived the eruption and were buried along the shoreline (Bunn, 2023a). In 1936, on the fiftieth anniversary of the eruption, he gave his last interview (Nikora, 1936).

“I am certain they are there to be rescued I use the word 'rescued' deliberately. I admit that some men of my generation who were familiar with the Terraces and the general terrain of the region were as certain of their destruction as I am of their survival. It is an old controversy.”

“For the benefit of people of the younger generations, it is necessary to explain that prior to the eruption there had never been a survey of the lake which would have fixed points from

which the sites of the Terraces could have been accurately determined. I realise that in the absence of preexisting Survey maps theories as to the survival of the Terraces run the risk of being dismissed as personal opinion."

"Had they been shattered in that vast upheaval, a convulsion which threw debris thousands of feet into the air, is it not reasonable to assume that some fragments of the easily identified material which formed them, would have been found? Not a piece of it has ever been picked up over the area." (Warbrick, 1934).

"This fact was admitted to be reasonably significant … because the heavy rains that followed cut deep channels in the soft deposits … and the eroding of the slopes ... should have laid bare some traces of the silicious material … if they had been shattered and blown into the air." (Warbrick, 1934).

3.3.4. Edward Payton (1859–1944)

Members of the public shared Warbrick's scepticism with articles in the press into the twentieth century. Edward Payton was a prominent artist, photographer and author who was director of the Elam School of Art for 35 years and settled in Rotorua. He expressed the concern felt by many over the government handling of the Pink and White Terraces. He travelled to the Rotomahana Basin before and after the eruption, publishing his book *Round About New Zealand* in 1888 (Payton, 1888). Like most in New Zealand, Payton accepted Smith's claim but changed his opinion after standing over the White Terrace site with Thomas and Warbrick.

'For several weeks after examination had been made of these rifts, it was a point of doubt as to whether the celebrated Te Tarata, or White Terrace, had perished or not; but after a while people made up their minds that the worst had happened, … but there have always been some unbelievers, among others the Warbricks, who are very confident that the White Terrace is still in existence, though very much out of sight.' (Payton, 1888 354).

"I asked Warbrick where he believed it to be; but he said, 'I want you and Professor T [Thomas] who have both seen the Terraces, and knew them well, to see if you can find the place before I tell you my opinion; 'so, guided by my previous knowledge of the lake, I soon came to the place where I believed it to be, and found that there had been no explosion at all there, although the rift came very close. Of course, the whole hill is buried deeply and almost unrecognizably in mud and ashes; but from certain landmarks I satisfied myself that I was

right, so, calling Warbrick to it, said, ‘We are standing on Te Tarata now.’ He said, ‘That is just what I say, and had I £1,000 I would stake it on the Terrace being only buried below us.’ Professor T— [Thomas] declined to speak decisively, as he said he did not like to go against the opinions of the surveyors. Not only is the site sufficiently marked in my opinion, but the shape of the terrace is distinctly visible in the mud, and I am convinced that in the course of a few years, Te Tarata will be again visible …” (Payton, 1888 354).

3.4. Later reports

With notable exceptions generations of public sector geoscientists accepted the General Survey Office claim.

3.4.1. Patrick Marshall

In his 1912 book, Marshall claimed the White Terrace site was buried under ~30 m of scoria and dust along the northern lake shoreline where Payton, Warbrick, Te Arawa and Nolden and the author place it in Figure 7. (Marshall, 1912 109).

“the White and Pink Terraces—which constituted the most attractive sight of the hot-lakes district. The disastrous eruption of Tarawera in 1886 completely destroyed these terraces, and covered up their remnants with a hundred feet of scoria and dust.” (Marshall ,1912 111-112).

Fig. 7. Marshall's 1912 map. The red arrow shows Marshall's White Terrace location coincides with Warbrick, Hochstetter, Bunn and Nolden (Marshall, 1912).

3.4.2. Warbrick et al.

Warbrick lobbied the government through the press on eruption decennials. In 1910, he made such representations that Smith came out of retirement to continue his media rebuttal, and was, in turn, criticised as the debate continued in New Zealand and Australia. W. L. C. Williams asserted:

> Sir,— I do not wish to controvert any of Mr Percy Smith's statements, as his is expert evidence. But my impressions are certainly at variance with his. I went to the scene of the eruption on the (Tuesday, I think) ninth day after the eruption, accompanied by Captain Wey, and got quite a mile further than the party who went on the third day [Smith et al]. … My then impression was that whatever had happened to the white terrace, the pink terrace was safe, but covered up with eruption debris. (Williams, 1910 13).

3.4.3. 1936, debate continues

On the fiftieth anniversary, the subject remained newsworthy:

“Mr. Smith [J. D. Smith] is impressed with the fact that down the years during which great erosion has taken place no fragments of the silica which formed the Terraces— covering in the aggregate over 13 acres —have been found. He admits that some true specimens may have been picked up soon after the eruption but seeing that no more have been revealed suggests that the body of the Terrace probably remains intact.” (The Eruption, 1936 8).

C. A. Whitney observed:

“During the eruption there was a hill formed between the two lakes of 300ft above the surface level of Tarawera Lake and it is under this … the Terraces lie buried … But it is quite possible the toe of one or both of the Terraces, which ran out into the lake, may have been blown off ... It would not be a costly job to put down bores ...” (The Eruption, 1936 8).

3.4.4. Ian Nairn and Ron Keam

Over 1979–2024 Nairn published seminal technical papers on the eruption while Keam published mainly lay accounts including his finding a piece of silica channel at Rotomahana (Keam, 1961–1988, 2016). Nairn makes little reference to the Terraces (Nairn, 1979, 2002).

3.4.5. The Buried Village (Te Wairoa)

By the 1950s the Buried Village published a tourist guide (Smith c. 1950). From 1961, the booklet was co-authored by Keam (Keam, 1978). Over 1986–2005, the co-author is Philip Andrews (Andrews, 1986, 2005). Andrews lists six silica samples:

a) A New Zealand Herald artist allegedly retrieved a piece of ‘what he believed to be terrace sinter’. The claim is unverified.

b) Hotelier Joseph McRae (1849–1938) reportedly found ‘numerous pieces of terrace formation’ on his collapsed roof. This is not mentioned in any article or his dying declaration. Andrews says his claim was unverified (Andrews, 1986), (Bunn, 2023c).

c) In 1936 a piece of sinter was shown to the New Zealand Herald with the claim that it had been picked up in 1902 to the west of Lake Rotomahana. (Andrews, 2005 66). The claim is unverified.

d) Andrews reported an appeal for terrace specimens. One with provenance was a silica-encrusted twig from the Haszard family. This was likely pre-eruption.

e) The Buried Village has samples collected in 1979 ‘when the lake level was unusually low’ (Andrews, 2005 68). The 1979 hydrograph recorded 338.82 m.–339.45 m. The 100-year range is 333–342 m. so 1979 was unremarkable. In 2016–2017, the author dove the lake and found no samples. Invasive weeds will preclude finding samples in the shallows.

f) Te Amorangi Museum has a sinter sample. Andrews notes ‘it may be a relic of the White Terrace, but as there were many sinter deposits around the original Lake Rotomahana, there is no evidence for this.’(Andrews, 2005 68).

None of these samples appear to be post-eruption.

3.4.6. Terry Seward (1940–2022)

One verified terrace sample is a salmon-pink piece with provenance from 1987. This was examined by Prof. Terry Seward of Victoria University in Figure 8.

Fig. 8. Verified Pink Terrace sample, the pink hue was more pronounced in the sample (by permission T. Seward).

This sample confirms the nature of the pink hues on the Pink Terrace. Seward found it contained elevated arsenic and antimony concentrations. On the salmon-pink sample in Figure 8 he observed tiny aggregates of red to orange sulphides. One sample also contained gold, in an ore-grade concentration. Seward points out that arsenic and antimony sulphide colloids occur at several geothermal systems in the Taupo Volcanic Zone. At Waiotapu, he cites the spectacular *Champagne Pool* as being lined with this colloidal sulphide. He reports arsenic sulphide is bright canary yellow and antimony sulphide is brick red. Mixtures of these with the silica host give rise to colours ranging from yellow to orange, salmon pink, pink and brick red. These are the colours reported by eyewitnesses i.e. white at the bottom, pale pink as the terraces ascended, deepening to a salmon-pink nearer the upper basins and changing to yellow around the spring.

At the *Champagne Pool*, Seward advises the antimony and arsenic siliceous precipitates also contain gold, of up to ~three troy ounces per tonne and this is ore grade. The gold is adsorbed from the upwelling thermal water by the charged surface of the antimony and arsenic sulphide (pers. comm. Terry Seward: Rex Bunn, 2 May 2016). The Pink Terrace did contain gold but this did not contribute to its hues as gold and gold/silver amalgams are dull metallic and will be opaque and black (or dark grey) in appearance. (pers. comm. Terry Seward: Rex Bunn 1 May 2016).

3.4.7. Petlab, the National Rock Collection

Petlab is New Zealand's national rock, mineral and geoanalytical database. Of its 213,000 samples, there is no sinter sample from the nineteenth century Rotomahana Basin (pers. comm. Matthew Sagar: Rex Bunn 20 September 2024).

3.4.8. PAWTL samples

The PAWTL projects collected samples from the northern and western shores of Lake Rotomahana for X-ray diffraction testing. They were passed to the Tūhourangi Tribal Authority. Some were entered into the SESAR database at:

https://app.geosamples.org/uploads/files/IEREX/IEREX0002_DSCF4623zCut27.4.JPG

https://app.geosamples.org/uploads/files/IEREX/IEREX0001_DSCF4701Redux.JPG

https://app.geosamples.org/uploads/files/IEREX/IEREX0003_DSCF4604Z.JPG

https://app.geosamples.org/sample/igsn/IEREX0004

Samples from the 2016 scuba dives are at:

https://app.geosamples.org/sample/igsn/IEREX0005

https://app.geosamples.org/sample/igsn/IEREX0006

Samples 0001-0004 were surficial and likely post-eruption. Sample 0002 is rare wood fossilised in a geothermal spring.

The finest sample is the 3.5 kg pink piece in Figure 9. This was in the vicinity of the Pink and Black Terraces. Based on a 2012 auction, it might fetch ~$64,000 if auctioned.

Fig. 9. The 3.5kg piece of siliceous sinter found at ~38.257103, 176.419294 on 2017-10-12. This is the finest sinter PAWTL2 discovered. When lifted it was white and striated, with a pink hue when wet. When dry it takes on a tan hue. (Sample IEREX0001, SESAR, the System for Earth Sample Registration).

Sample IEREX0003 in Figure 10 may have come from the nearby Black Terrace site.

Fig. 10. PAWTL2 the squared dark sinter sample from near the Black Terrace site. Sample IEREX0003, (SESAR, the System for Earth Sample Registration).

3.4.9. Rotorua lapidary

Lapidarist Colin Simmons has seen few pieces from Lake Rotomahana in his lifetime: " … in the case of my specimen which was found in the early 1970's it was established that it had originated from a hot spring … Don Stafford the historian once showed me a piece of silica (feldspar type), that was more than likely to be part of the White Terrace – unfortunately, I have no knowledge as to where the specimen might be now." (pers. comm. Colin Simmons: Rex Bunn 21 October 2024).

3.4.10. Tūhourangi Tribal Authority

Neither the authority nor its members possess Terrace samples (pers. comm. Rangitihi Pene: Rex Bunn 14 October 2024).

3.4.11. Otago Museum

The museum received Warbrick's collection in 1887, including a bottle of volcanic flour. No sinter was included.

3.4.12 Hochstetter Collection Basel

The Hochstetter Collection Basel includes a manuscript inventory listing thirteen samples of Silica sinter (deposits from hot springs), which Hochstetter collected during his visit in 1859. These are shown in Figure 11 (under entry 5) and include pieces from the Pink and White Terraces, Ngahapu, Ngawhana and Whatapoho and artefacts. The samples include not yet hardened silica sinter from the spring of Te Tarata, and hardened sinter from the same (pers. comm. Sascha Nolden: Rex Bunn 1 December 2024). Hochstetter's collection represents the largest recorded group of Terrace samples with provenance. However, after his return to Vienna they became part of the Novara Expedition collections which were subsequently dispersed among various institutions in the Austrian Empire and their current location is unknown.

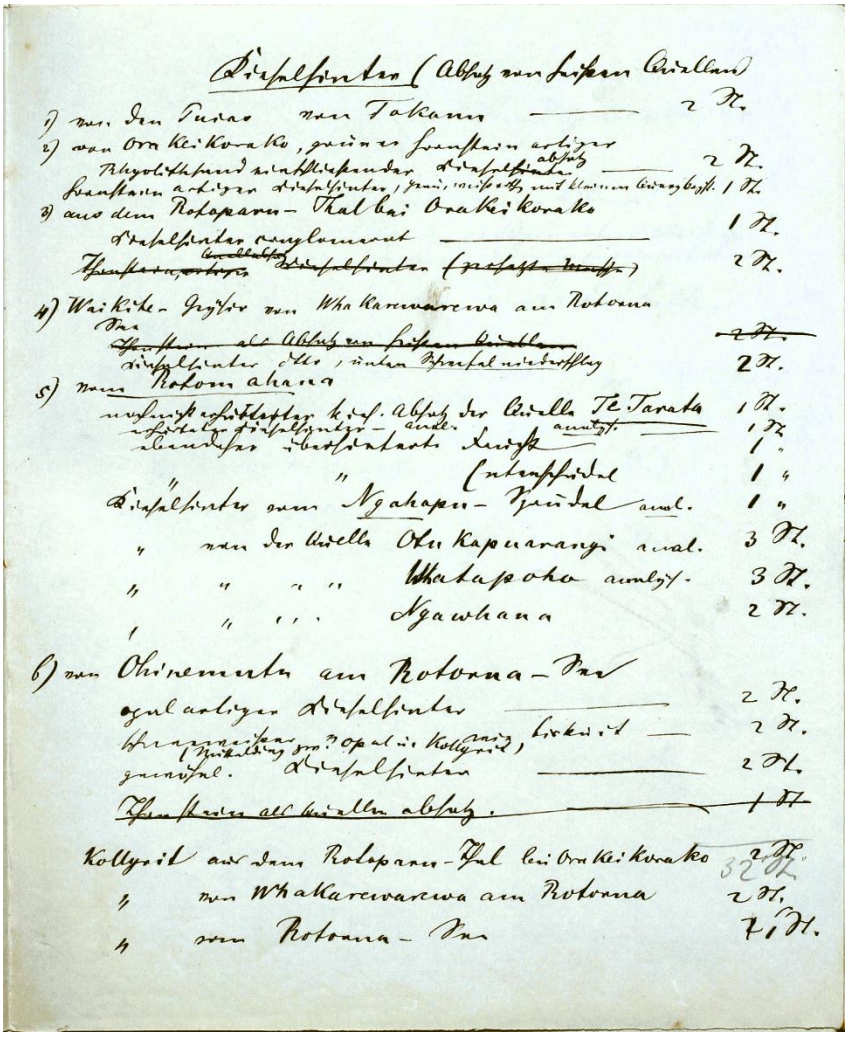

Fig. 11. The Hochstetter Collection Basel inventory listing thirteen samples of Silica sinter (deposits from hot springs), which Hochstetter collected during his visit in 1859.

3.5. Sinter area analysis

The difficulty in labelling surficial siliceous samples from the Rotomahana Basin is compounded by the area of non-terrace sinter around the old lake. Samples could also be from spring plumbing or pre-1886 eruption. In 2002, Nairn characterised the three Terrace areas as Rotomahana explosion breccia and/or redeposited ash and scoria and/or basalt scoria deposits from Tarawera (Nairn, 2002). He did not directly mention sinter.

Given multiple eruptions in the Taupo Volcanic Zone and the age of the terrace springs at ~7,000 BP, sinter must have been erupted and redeposited as Nairn described (Bunn, 2023d). Sinters are noted for longevity. Bridget Lynne reports New Zealand sinters reach ~3 million years old (Lynne, 2013). Thus, 1886 ejecta may include non-terrace paleo-sinters. Sample chemical and textural analysis is required to assess this. There is also the recent classification of pseudosinters (Hamilton et al, 2019).

Hochstetter's 1859 mapping includes non-terrace sinter areas around Lake Rotomahana. Using a geographic visualisation tool i.e. Google Earth Pro, these areas are measured using the polygon tool in Table 2.

Table 2. Sinter area of the Pink, Black & White Terraces and non-terrace sinter areas

	Sinter Areas around old Lake Rotomahana				
Map	**Formation**	**Area m^2**	**Map**	**Formation**	**Area m^2**
Hochstetter	White Terrace	46,213	Petermann	White Terrace	57,289
1859-04-30	Pink Terrace	12,189		Pink Terrace	24,752
	Black Terrace	9,481		Black Terrace	5,522
	Tamariwi	2,724		Tamariwi	5,830
	Aka Manuka	3,529		Aka Manuka	683
	Rangipakaru	4,987		Rangipakaru	5,512
	White-Ngawhana	77,131		White-Ngawhana	79,592
	Poroporo	332		Poroporo	883
	Mamaku	1,622		Mamaku	1,529
	Waiti	2,057		Waiti	2,433
	Total Terraces	67,883		Total Terraces	87,563
	Total Non-terrace	92,382		Total Non-terrace	91,620
	Grand Total	160,265		**Grand Total**	179,183
	Terraces %	42		Terraces %	49

In Table 2, the sinter areas shown on Hochstetter's 1859 map are compared with Petermann's 1861 map (Bunn & Nolden, 2023, Nolden & Nolden 2013, Petermann, 1864). Petermann has the total sinter larger than Hochstetter (18 ha versus 16 ha). Some sinter formations e.g. Poroporo are shown only on Petermann. Provision is made for these on the Hochstetter map. The Terrace: Non-terrace ratio is ~42–49% (excluding the terrace slopes containing more sinter than the lake shore). Any post-eruption sinter is more likely to come from a non-terrace origin, excluding any pattern to the eruptions and paleo-sinters.

The Rotomahana eruption ejected ~ 0.5 km³ rhyolite (Keam, 1988 345). Terrace and other sinter herein occupied ~0.0003 km³–0.0004 km³ of this and terrace sinter (if present) was ~0.0001 km³–0.0002 km³. Finding sinter amongst the ejecta was unlikely. To a statistician, the probability of finding small pieces of terrace sinter mixed with the ejected rhyolite, based on volume is 0.03–0.04%. This is a relative volume calculation assuming uniform distribution of sinter. The actual mixing conditions, similar colour, comminution, distribution and visibility were different, reducing the chances of finding sinter.

3.6. Photointerpretation

The first photographer to reach the Rotomahana Basin was Charles Spencer on 15–17 June. In Figure 12, is his high-resolution image of the crater taken from Hape-o-toroa Hill. The photograph is cropped and shows detail e.g. the facial expression. It gives a close-up view of the hillside reported by Smith as covered in terrace fragments. These are not apparent in this photograph. The image shows the persistent twilight in the basin. The steaming-fog and dust precluded observers from seeing the White Terrace from Hape-o-toroa.

Fig. 12. Hape-o-toroa Hill showing ejecta surface (Te Papa Tongarewa MA_1323009).

Figure 13 is an unenhanced cropped photograph of the crater near Cathedral Rock (aka the Pinnacle). The white surface is the ‘volcanic flour’. This illustrates the problem of locating small pieces of White Terrace immersed in a layer of white flour.

Fig. 13. Mount Tarawera Eruption, showing the white volcanic flour surface, G. Valentine (Te Papa Tongarewa MA_1254100).

3.8. Observer visual effects on colour perception

The atmospheric pollution discussed in section 3.1 caused difficulties for observers seeking terrace fragments.

Vision would be impaired with decreased contrast, colour shifts, and definition with perhaps temporary night blindness due to the unusual light. Ash, steam, smoke, dust and volcanic gases created a "twilight-like" effect during the day as observers noted— causing visual confusion, making it difficult to distinguish colours and impairing depth perception. This could lead to misinterpretations of the landscape, such as mistaking light-coloured ash, scoria or pumice deposits for sinter or seeing familiar features where none existed (and vice versa) in the chaotic environment.

To illustrate this, Figure 14 is taken on Mount Tarawera with Guide Roger Te Kiri and the author. The surface is covered in volcanic ejecta. The foreground scoria is black and white.

Fig. 14. Mt Tarawera surface showing surficial colours (Bunn).

Figure 15 is a cropped monochrome version of Figure 11. This reproduces the twilight encountered by early responders. When the ground surface is made up of black and white rock fragments, it is nigh impossible to identify the whitish pieces, even without low light and air pollution.

Fig. 15. Monochrome version of Figure 11 (cropped), (Bunn).

4. Discussion

The post-eruption surface of Hape-o-toroa Hill and the surrounding area was covered by ejecta. The Rotomahana ejecta comprised “a fluidised mass of fragments of rock, sand and dust together with steam and other gases … travelling across the ground at 150–200 C and

~200 kmh" (Keam, 1988 347). If the Terraces were involved, then their sinter was included in the fluidised mass. The base surge covered a circular area with a radius of ~6 km. First responders reported the ground was covered with dry, almost-white, volcanic flour (Smith, 1886). Overlaying this were other varicoloured ejecta; ballistic rocks, air-fall sand, mud, scoria, and water. An observer seeking white sinter faced difficulties. Detecting white sinter against a white background, with a black, grey and white admixture of rhyolitic material and darker basalt—in twilight with visibility impeded by clouds of steam, smoke and dust from ongoing eruptions; was for lay colonists in a state of high emotion and grief … who had never seen a volcanic eruption—practically impossible, even if sinter were present. Even then, it would be impossible for it to be identified without the chemical analysis Brown was to perform.

This analysis likely understates the volume of non-terrace sinter around the Steaming Ranges and old lake. Hochstetter marked over 50 geothermal sites around the lake in 1859. Only seven are included here, (albeit the White Terrace-to-Ngahapu section includes ten sites). Making provision for these unnamed sites and their plumbing suggests a ratio of Terrace-Non-terrace sinter closer to 30:70. Paleo-sinters would alter the ratio.

Having spent days with the PAWTL projects, turning over surface rocks around the lake shore and underwater near the terraces, it is impossible to identify sinter— unless one has a geologist or lapidarist at hand. Whitish, pinkish, creamish and blackish pieces of pumice, scoria or rhyolite are collected until the backpack fills. First responders faced additional difficulties of access and continuing eruptions. The white landscape and poor visibility were probably more of a hindrance than the vegetation and water-weed regrowth today.

The surveyors' reports are called into question by the politics involved and the changing sinter claims, as well as the conflict with university staff and Māori. The 1886–1936 media debate is hard to evaluate after a century. What is clear is that in New Zealand, there seem to be no post-eruption siliceous sinter terrace samples with provenance. Given the tourist samples repatriated to England and America, a search in these countries may assist, although most would be pre-eruption. The Basel collection is one example.

It is impossible to reconcile the debate between Smith and Warbrick. Smith had government support and prestige as a top public servant in a powerful department that was sequestering Māori land for settlers. Warbrick had the support of Te Arawa tribes and media which promoted his view for 50 years. He forced the government to commission follow-up reports

in 1887, 1910 and 1922. However, in 1887, 1894 and 1910, Smith was sent to re-investigate his findings. He was hardly likely to contradict these and the later investigations are questionable. If there were areas e.g., on Hape-o-toroa with plentiful silica sinter, why did they not figure in the official reports? A geologist's axiom is "nothing beats a piece of rock in the hand". No photographs or samples were included by Smith in any of five eruption reports despite public grief over the terraces from Smith's 19 June report announcing the loss. No post-eruption samples in public or private collections are attributable to Smith.

Apart from the Basel collection, Rotorua Museum and Otago Museum samples and some listed by Andrews, this research failed to locate siliceous sinter samples with provenance from the Pink, Black or White Terraces at Rotomahana. The only sinter verified as post-eruption is that collected around the crater between 1886–2024 i.e. by PAWTL, Rotorua Lapidary and possibly the Buried Village. The small volume makes it difficult to form conclusions. It is consistent with the statistical analysis and likely reduced by time and poor conservation. The scarcity is also consistent with the terraces being buried not erupted. It may also reflect the vagaries of sample collection and reporting.

5. Conclusions

There is a surprisingly small number of surviving sinter samples. Many were unverified or lost. Surviving post-eruption samples are even more rare. This rarity is predicted by the 2016–2024 survey evidence the terraces were buried, not erupted. It is also consistent with the vagaries of sample collection and conservation. In New Zealand, there seem to be no proven post-eruption siliceous sinter terrace samples. Warbricks' 1936 challenge that: "Not a piece of it has ever been picked up over the area" is supported by the evidence in this research.

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Conflict of interest

The author declares no commercial or financial conflict of interest. I certify that the submission is original work.

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