The Eighth Wonder of the World in New Zealand– the third, Black Terrace

A. Rex Bunn, Independent Researcher

Email: rexbunn2015gmail.com

This paper is a non-peer reviewed preprint submitted to EarthArXiv

Abstract

The greatest tourism and geoscience attraction in the southern hemisphere, in the nineteenth century were the siliceous *Pink and White Terraces*, the lost *Eighth Wonder of the World* in New Zealand. In 1886, the Mount Tarawera eruption buried the terraces. In the absence of any government survey or evidence of their locations or destruction; debate over their survival continued until the 1940s.

There were three feature silica terraces at Lake Rotomahana, though prior to the author's research this third, Black Terrace was forgotten. In 2016, we noted the efforts by Hochstetter and Petermann to include a terrace on their left map borders named *Te Ngawha Atetuhi* (Hochstetter and Petermann, 1864).

In 2017, I marked this for later research. That year the Bunn−led *PAWTL2 Project* launched in response to global interest. Research focused on the Terrace and I published the seminal report on the Black Terrace (Bunn, 2018). This collated indigenous Māori and Western history with previous research. This report concluded that the colonists had confused a post-eruption feature Black Terrace Crater with the pre-eruption silecous Black Terrace.

One of my 2017-2018 PAWTL2 team returned to the Black Terrace Crater site in 2018 and conducted sub-surface imaging: locating the crater and conjecturing they had found the lost Black Terrace. This paper confirms their imaging is from the crater location and discloses the true location of the Black Terrace nearby, based upon new spatial, survey, trigonometric, cartographic and topographic evidence.

Keywords: Black Terrace, Black Terrace Crater, Ferdinand von Hochstetter, spatial, historical survey data, Tarawera eruption, Pink, Black and White Terraces, Lake Rotomahana, Rotomahana Basin.

Introduction

Ferdinand von Hochstetter (1829−1884) first documented and sketched three feature siliceous sinter terraces at Lake Rotomahana, though prior to the author's research the third terrace was forgotten. In 2016, the efforts by Hochstetter and Petermann to include a terrace on their left map borders named *Te Ngawha Atetuhi* [Te Tuhi's Spring] were noted in Figure 1 (Bunn & Nolden, 2016).

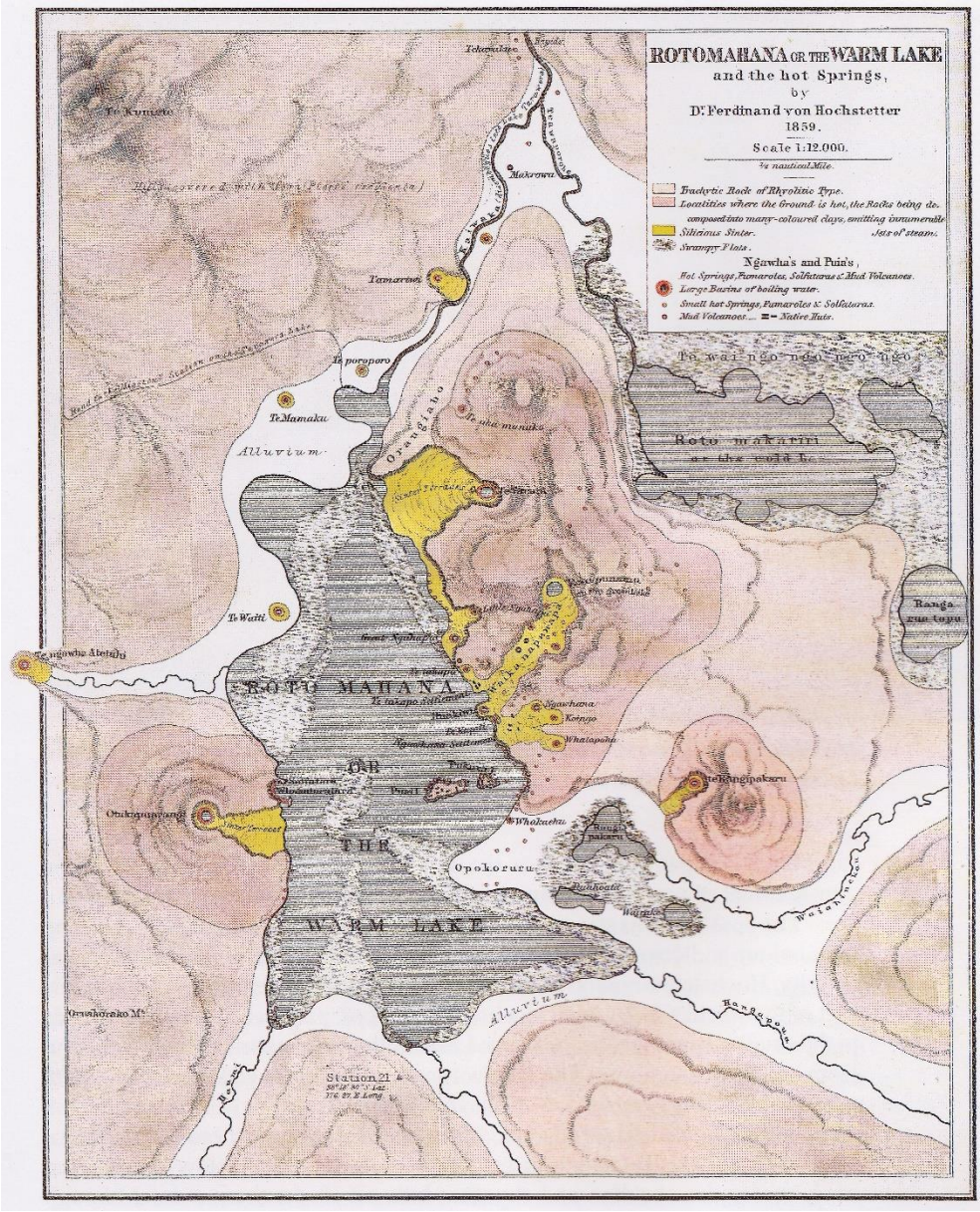

Fig. 1: Map of Lake Rotomahana from the English edition of Hochstetter & Petermann's *Geological and Topographical Atlas of New Zealand – Te Ngawha Atetuhi is outside the left border* (Hochstetter & Petermann, 1864).

Included in the 1870−1886 tourism literature, there was mention of a *Black Terrace*. While there was then uncertainty over whether the Pink and White Terraces lay on land or water, there is no doubt about the *Black Terrace*. It is located on land and was buried by eruption ejecta and erosion. Hochstetter described it thus: "A little beyond the lake, in a small side valley, lies the Atetuhi; …" (Hochstetter, 1867). In geomorphology, the term *side valley* has a precise meaning i.e. a valley close to mountains and with a low Strahler order. The Terrace formed from a spring and this formed a stream; a first-order Strahler stream (NSW Dept. of Industry, 2018). To be sure, Dr Sascha Nolden checked Hochstetter's nineteenth century German (S. Nolden, personal

communication 22 March 2022). He used the term *Seitental*, (also known as a *Nebental*). These have the same meaning in present-day English. I examined the first-generation photography of Hochstetter's manuscript maps of Lake Rotomahana and discerned the topographic detail around the Black Terrace. He drew a ridge above and around the Terrace, forming a short, side valley debouching into the south side of a larger valley which drained Kumete Ridge into the lake. This larger valley thus has a second or possibly third-order Strahler stream, we reference as *Black Terrace Stream*.

Given Hochstetter's pre-eruption cartography, finding this Terrace could enable triangulation of the Pink and White Terraces. In 2017, I marked this for later research. That year the Bunn−led *PAWTL2 Project* launched in response to global interest. Research focused on the Terrace and I published the seminal report on the Terrace and Crater (Bunn, 2017b). This collated Māori and Western history with previous research.

From this report, colonists had confused *Black Terrace Crater* with *Black Terrace*. The findings herein confirm this. Given eruption landform changes and the lack of a survey, no colonist could specify the Terrace locations. The Māori view was canvassed among tribal elders by Ngāti Rangitihi guide Alfred Warbrick (1860–1940). These elders, (with superior topographic mapping knowledge to the colonists); insisted the Pink and White Terraces survived the eruption and were buried in mud (Warbrick, 1934, 1936). This research paper verifies their judgement. In 2017, I published six recorded Crater locations. These were narrowed to four and the search field and transect in Figure 2 was set. In 2017 the Terrace was believed to lie north of this, but in 2019 it was seen to lie north-west of the Crater search field (Bunn, 2019b).

The published 2018−2019 iterations V−VI of Hochstetter's survey plotted the location of the Terrace spring ~300m from the Crater field in Figures 2−3 (Bunn, 2019b).

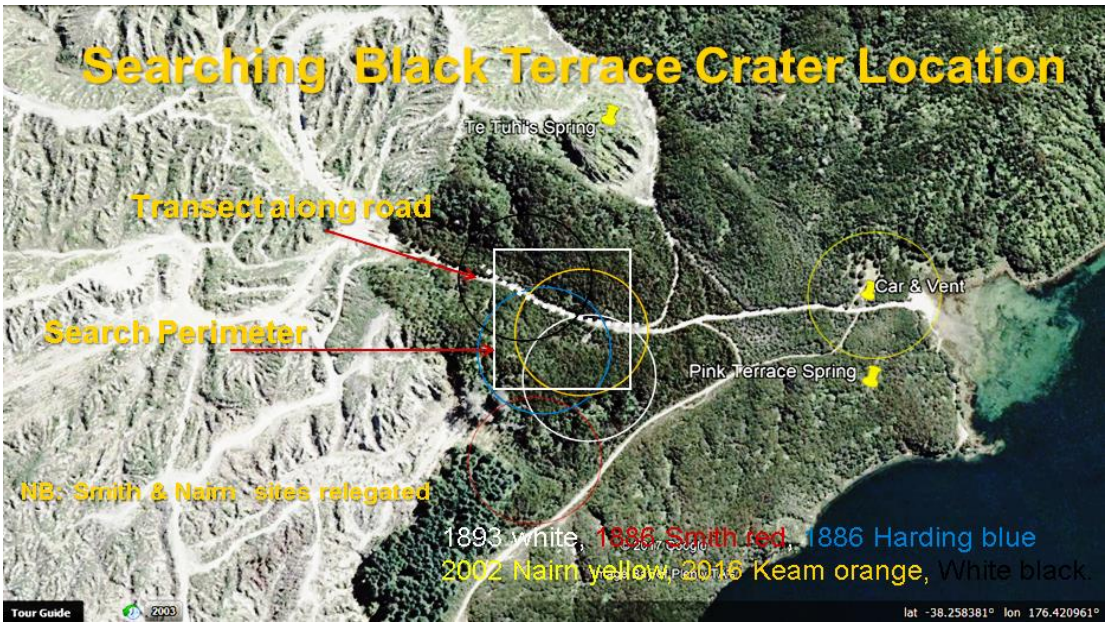

Fig. 2: Black Terrace Crater Locations in Google Earth™ (adapted from Bunn, 2017; Bunn, 2019b).

Iteration IV of Hochstetter's survey was developed in 2017. Following auditing by Nick Davies and David Stewart of Cheal Consultants, a landmark error on the Tarawera massif (i.e. composed of Wahanga, Ruawahia and Tarawera peaks); was recognised and reported (Bunn et al, 2018). That led to Iterations V−VI which *inter alia* corrected the Terrace location to the forest road adjacent to the Crater. In Figure 3 the Crater search field lays centre-to-centre ~300 m from the Terrace field. The search fields are ≤80 m apart. Ironically, the *PAWTL2 Project* team drove over both sites. I recall walking the Crater field, collecting black rocks for x-ray diffraction. Both search fields are shown and the Terrace from Hochstetter map georeferencing in Figure 3 (Bunn, 2019b).

Fig. 3: Black Terrace and Crater Search fields, in green boxes (Bunn, 2019b).

The PAWTL2 Project ended in 2018 and the ground penetrating radar (GPR) investigations were not immediately followed with more work over these fields. Later that year, former PAWTL2 honorary geologist Dr Phil White returned with GPR and passive seismic equipment. He now reports locating evidence of the Crater within the Figure 3 field: *Through a combination of geological and geophysical techniques, we believe that we have relocated the buried Black Terrace Crater*… (White, 2020).The White et al imaging suggests the crater is coterminous with the orange circle in Figure 2. This circle was Bunn's interpretation of a sketch by Ron Keam (1932−2019), (Keam & Lloyd, 2016).

The eyewitness record shows the Crater grew to ~180 m (~200 yds.) diameter with an area of ~2.5 ha. It lay north-west of the main 1886 eruption crater. The probable centre of White's site lies ~400 m from today's shore. This is consistent with reports the Crater was ~400 m from the Rotomahana crater. *Boat Launch Bay* had an eruption vent and chronic erosion since 1886. These obscure the 1859 shore, as with Kaiwaka Stream. The Terrace lies nearly 200 m further inland on Hochstetter's survey and mapping.

Triangulating the Black Terrace Location

The only records showing Black Terrace Crater and Black Terrace are Figures 6 and 7: (with the caveat the ponding over the predicted location cannot finally be proven to lie above the Terrace without excavation).

Hochstetter's and Petermann's mapping is compared with triangulation by Sine Rule in Figure 4.

The mapped distances are:

a) Black Terrace−Pink Terrace = ~714 m Hochstetter and ~713 m Petermann.

b) Crater−Pink Terrace = ~340 m Hochstetter and ~466 m Petermann.

c) Black Terrace−Crater = ~404 m Hochstetter and ~311 m Petermann.

d) Black Terrace−White Terrace = ~1,609 m Hochstetter and ~1,489 m Petermann.

By Sine Rule these distances are:

e) Black Terrace−Pink Terrace = ~748 m Hochstetter and ~728 m Petermann.

f) Crater−Pink Terrace = ~346 m Hochstetter and ~475 m Petermann.

g) Black Terrace−Crater = ~435 m Hochstetter and ~324 m Petermann.

h) Black Terrace−White Terrace = ~1,619 m Hochstetter and ~1,490 m Petermann.

There is reasonable precision with the mapping and trigonometry for the inter-Terrace distances (a, d, e and h). There is less agreement regarding the Crater−Terrace distances (b, c, f and g). There are gross errors in the inter-map distances (b and c) and with the calculated distances (f and g). These cannot be explained by earth curvature or slope. Unfortunately it is not possible to accurately triangulate the Black Terrace Crater location with either Rotomahana map. The pre/post eruption hiatus is too great. However, cartographic analysis herein answers the central question i.e. is the Black Terrace in Black Terrace Crater or not? The Crater remains a quasi-proximal survey datum, given it appeared as the final eruption phase. The proximal landmarks so far verified by us at Lake Rotomahana include Rangipakaru Hill (Patiti Island), Steaming Ranges (Tarata Peninsula), Te Kumete, the old and new lake inter-terrace shores, Station 21 and Puai Station. Quasi control points are now the Black Terrace Crater and Te Poroporo.

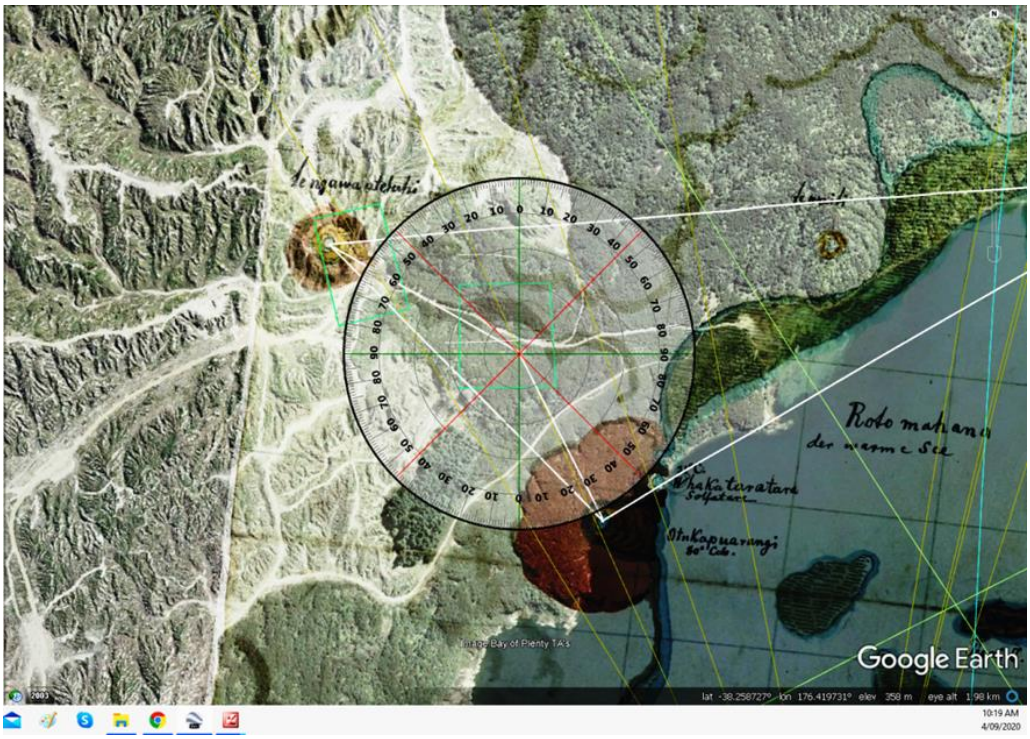

Fig. 4: Triangulating Black Terrace Crater with Hochstetter's 1859 map (Bunn).

Black Terrace cartography

There are multiple post-eruption records showing Black Terrace Crater with one quasi-proximal landmark i.e. Te Kumete. An example is S. P Smith's (1840-1922) 1886 map in Figure 5 (Smith, 1887). This major peak along Kumete Ridge was used by Hochstetter as a key landmark from both his stations. It is noteworthy for reportedly maintaining its elevation after the eruption at 1,830 ft (558 m). Te Kumete is also marked on Petermann's 1864 map. To test the positions of the Black Terrace and of Black Terrace Crater, relative to Te Kumete I georeferenced available cartography with Google Earth. The maps included Hochstetter's April 30, 1859 map, Petermann's 1864 map, Smith's unpublished 1886 sketch map, his 1886 and 1894 maps; and Harding's 1887 map. On Google Earth, the azimuth from Black Terrace Crater (estimated centre) to Te Kumete is 347° ± 1°. It is the same azimuth on Smith's and Harding's 1886 and 1887 maps as well as on Smith's 1894 map. Next, I georeferenced the Hochstetter and Petermann maps on Google Earth and measured the azimuth from Black Terrace Crater to Te Kumete. Both maps recorded 347° ± 1°, confirming sound mapping and georeferencing. On these maps I then checked the azimuth from Black Terrace to Te Kumete. It is 358° ± 1° on Petermann and 5° ± 1° on Hochstetter; (the difference being expected given the known Petermann flaws which narrow the lake shape). The significant variance between the Terrace and the Crater azimuths i.e. 11° with Petermann and 18° by Hochstetter, confirms the Black

Terrace and Black Terrace Crater lie on discrete, vicinal locations. For the avoidance of doubt, the Black Terrace does not lie in Black Terrace Crater, as White surmised (White, 2020).

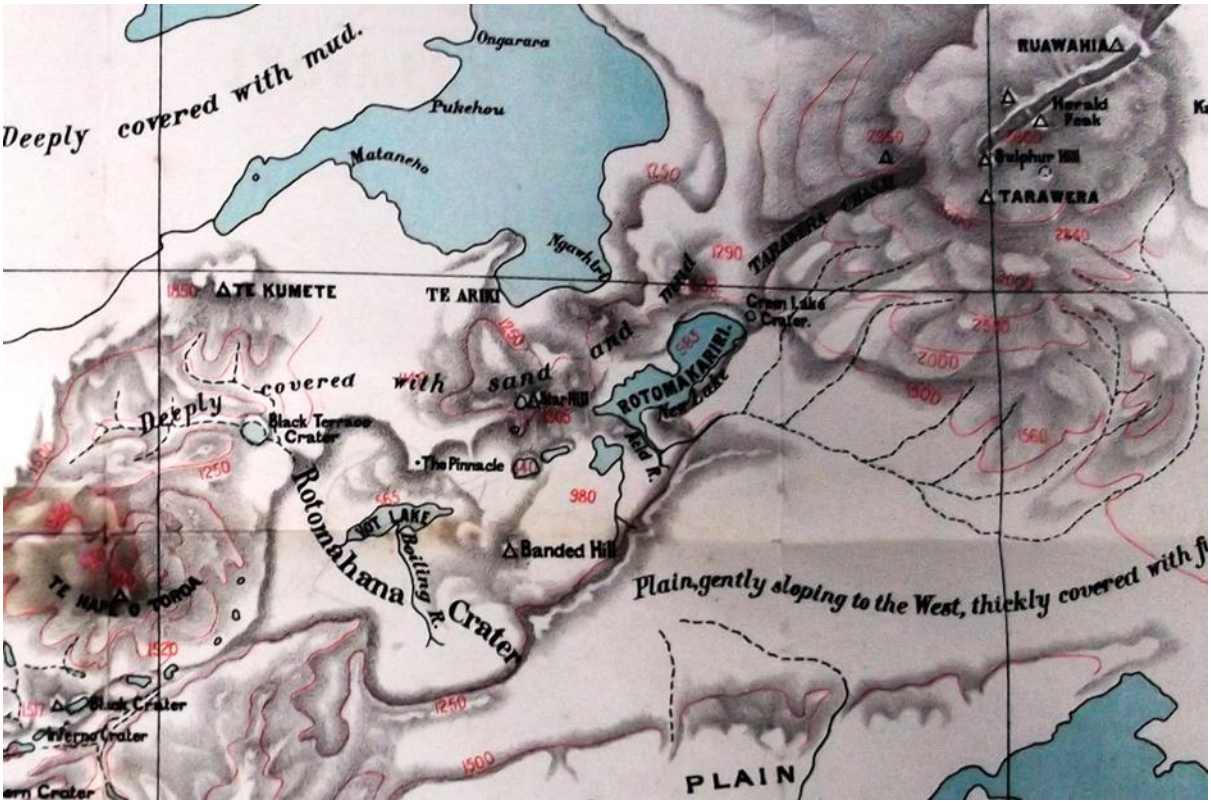

Fig. 5: Segment of S. P. Smith's 1886 map of the Tarawera area showing Te Kumete and Black Terrace Crater (Smith, 1886).

Black Terrace Stream

The Black Terrace spring drained to the lake, via a nameless stream which is here referenced as *Black Terrace Stream*. This led along a valley at an azimuth of 108º, entering the lake north of the Pink Terrace. The watercourse is now deep underground, beneath a forestry road on an alignment of ~110º from the Black Terrace to the Black Terrace Crater.

As the crow flies, the Black Terrace lies 585 m from the stream exit on Hochstetter's map (500 m on Petermann's map in Figure 1). The Black Terrace lies within the Figure 2 and 8 search box on both maps.

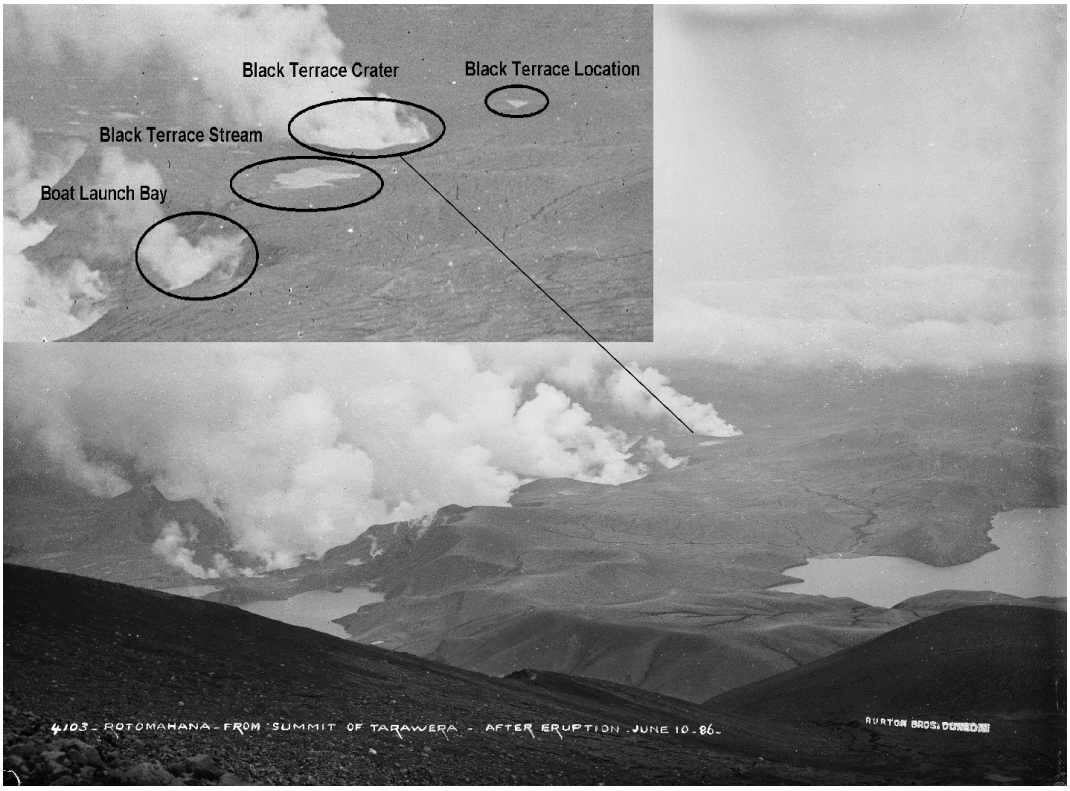

Fig. 6: Black Terrace, Black Terrace Crater and Stream with Boat Launch Bay. (Inset, MA_I269460 Te Papa National Museum of New Zealand).

Figure 6 is an August 1886 photograph of the north-west section of the eruption crater. The inset shows (from right to left) the Black Terrace location, the Black Terrace Crater, the post-eruption course of the Black Terrace Stream and its exit into what is now termed *Boat Launch Bay*. Note the steaming-fog plume from the main crater entry at Boat Launch Bay. This is one of seven eruption craters along the north shore (Nairn, 1979). This one erupted beneath the Black Terrace Stream near its exit into the old lake.

Note: this photograph shows there were two eruptions through the bed of Black Terrace Stream: one creating Boat Launch Bay and a second creating Black Terrace Crater. The eruption sequence proceeded upstream under Black Terrace Stream exit on 10 June, and under Black Terrace Crater on 31 July, 1886.

Figure 6 is attributed to Alfred Burton (1834−1914) but the photograph was probably taken by Charles Spencer (1854−1933). Ponding over the Black Terrace location is noted, with the Black Terrace Crater and surface water flowing between the locations into what became Boat Launch Bay. While in 2017 this water-flow connection had not yet been made, its significance was raised at the October PAWTL2 session: *From your Sunday talk, these may be … lateral flow from the bentonite-capped Te Tuhi's Spring, running down till they hit the hotspot under the BTC [Black Terrace Crater] location? There was a 51 day hiatus between eruptions i.e. Rotomahana*

and BTC and where else could the subsoil water fuel have come from...? (pers. comm. R Bunn: P White, 2 November 2017). Little rain had fallen in the interim.

Black Terrace photogrammetric optics

The original Figure 6 print is uncropped. The aspect ratio of 1.31 indicates it was taken on a whole-plate camera with the view angle of a standard lens of 216 mm focal length (Dallmeyer, 1874). Very rarely do Rotomahana prints qualify for photogrammetry (Bunn, 2019a). The camera position was found on Google Earth, by the photographer's *rule of thirds* composition i.e. composing the features on a photograph with a grid, which divides the image into thirds. Black Terrace Stream is centrally located for minimal lens distortion. There appears little or no lens shift. The Black Terrace Crater−Tarawera object distance is 6,730 m vs as photo-estimated at ~7,200 m, a 6.5% perspective error, partly from slight foreshortening. Applying photogrammetric optics (Ask, 1943; Langford, 2010); the key measures are:

a) Black Terrace−Black Terrace Crater (edges) ~200 m

b) Black Terrace Crater – main Crater ~460 m

c) Black Terrace Stream estimated length ~760 m

I compared the same measures from Hochstetter's April 30 map georeferencing at ~200 m, ~390 m, ~700 m. There is reasonable agreement between the methods; sufficient to confirm a horizontal gap existed between Black Terrace and Black Terrace Crater locations.

The Black Terrace Crater appears in the 1894 map in Figure 7 (Smith, 1894). The adjacent Black Terrace location appears, (though it may be an artifact on the position). It is the right location and would supply water fuel to Black Terrace Crater and via Black Terrace Stream into the old and new lakes. The present outlet vents continuous bubbles. Also shown is the new Trig station on Te Kumete.

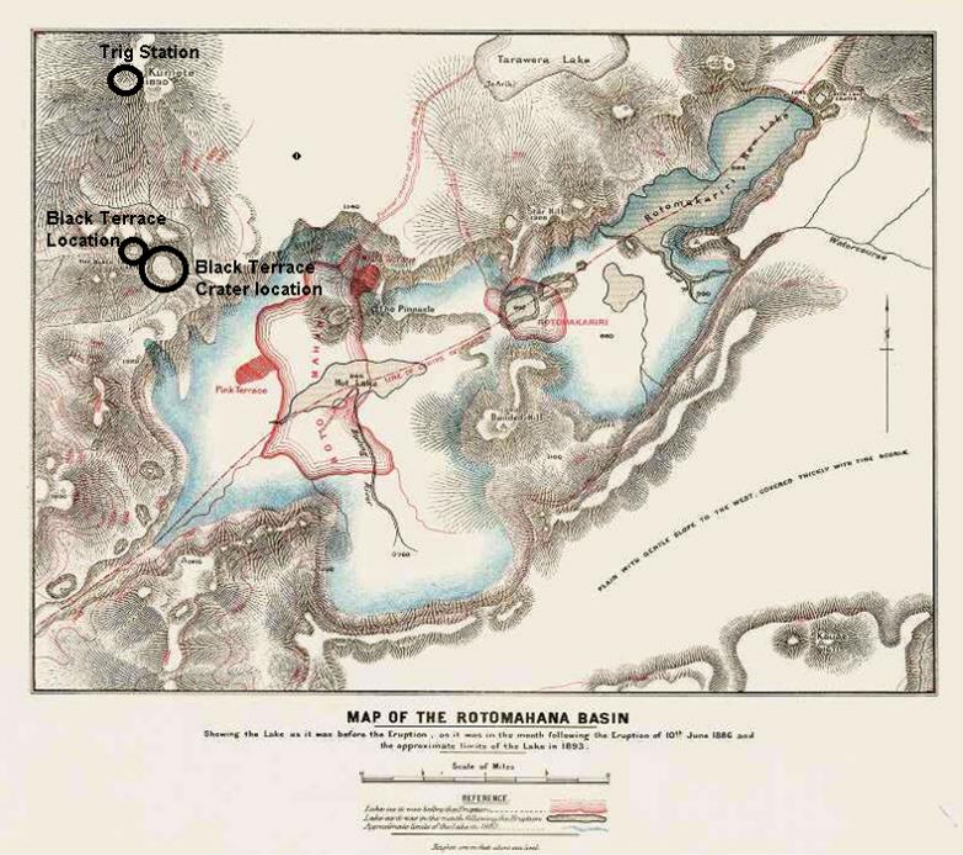

Fig. 7: Black Terrace Crater and Black Terrace (Smith, 1894).

Testing prior investigations

The rediscovery of Black Terrace Crater enables evaluation of earlier Pink and White Terraces studies. Chief of these are the 2011−2014 findings by a joint New Zealand-American project (de Ronde, 2018). Measurement was undertaken of their reported distance from Pink Terrace−Black Terrace Crater at ~900 m (de Ronde, 2018). This is a ~500 m error against the Hochstetter (340 m) and Petermann (464 m) maps. The New Zealand-American Pink Terrace−Black Terrace distance is ~1,150 m, an error of ~500 m against Hochstetter and Petermann cartography. Over a small lake of 1,600 m length, these are egregious errors.

Other institutional workers in 2018 related Black Terrace Crater to Pink Terrace, georeferencing with the Petermann map to posit a distance of ~900 m. Their distance Pink Terrace−Black Terrace is ~1,140 m. Their horizontal error is also a gross ~500 m (Lorrey & Woolley, 2018a, b).

That year Keir, de Ronde et al and Hook published Pink and White Terrace locations; each relying on pre-eruption photography (Keir, 2018; Hook, 2018; Bunn, 2019a; de Ronde, 2018). Keir's locations erred from Hochstetter's survey coordinates by ~ 465 m (Pink Terrace) and ~ 438 m (White Terrace). Both Keir's and de Ronde's locations were criticized by Hook, despite his similar errors of ~ 346 m and ~ 531 m respectively (Hook, 2018). All these researchers followed Alpha Harding (1856-1945), who mistakenly placed old Lake Rotomahana inside new Lake Rotomahana (Harding, 1887). The only researcher publishing a Pink Terrace location near

Hochstetter's coordinates is Herbert Fitzgerald in 2014 (Fitzgerald, 2014). It is more than coincidence Fitzgerald and the author lived near Rotomahana, each having the advantage of decades of immersion in the landscape, absorbing colonial and Māori oral and written history. Each of us developed a gestalt grasp of the Terrace landscape, something denied FIFO researchers (*fly in, fly out*). We self-funded researchers are also unbound by the deadlines of taxpayer funding grants.

All other present-day researchers also err altimetrically, by relying on Keam's guess i.e. that the pre-eruption Lake Rotomahana altitude was ≤292 MASL; rather than our published, evidence-based altimetry of 303 MASL (Keam, 2015; Bunn & Nolden, 2018; Bunn, 2022). Their trust is misplaced for White reports the base of Black Terrace Crater lies at 305-310 MASL (White, 2020). Were Keam's guess correct; White's Crater and Black Terrace elevation would lie in mid-air. This instances the priority I attach to altimetry at Lake Rotomahana (Bunn, 2022).

Surface artifacts

The PAWTL2 team in 2017 and later White, searched for surface evidence of Black Terrace Crater: *Proximity to the crater is indicated by boulders (up to 1.5m diameter) that overlie the Rotomahana mud near the site. Those boulders are mostly rhyolite, but include several fragments of silica sinter* (White et al, 2020).

Where White reports boulders and sinter, PAWTL2 members in 2017 recorded sinter, boulders and a rare fossil lying 100−200 m from Black Terrace Crater and a similar distance from the Black Terrace location. The 2017 PAWTL2 Project sample collection is held at Whakarewarewa, Rotorua and appears included (without acknowledgment), in White's Figure 2. We note that while surface rocks and sinter are found around the lake; *most large blocks were carried in by surge flows rather than emplaced as ballistic ejecta* (Nairn, 1979, 2002).

The PAWTL2 Project fossil is linked to Black Terrace Crater and Black Terrace Stream, for Scion analysis showed it is rare, geothermally fossilised wood: *"I can confirm it was wood but is actually completely fossilised/mineralized… I am guessing this type of mineralisation could occur in a geothermal environment … fossilized wood is very uncommon in NZ – I only know of one other incidence (a fossilised Kauri forest in Southland) ..."* (pers. comm. Lloyd Donaldson: Rex Bunn, 26 October, 2017).

This fossil evidences the nearby location of Black Terrace Crater but not necessarily of the Black Terrace─ for petrified wood was reported only around Black Terrace Crater in 1886: *Numerous boulders and stones of all colours and descriptions lie scattered about in all directions. We picked up some fine specimens here, amongst which were lumps of petrified wood and charcoal."* (New Zealand Herald, 1887). These site reports reveal that among the boulders, stones and petrified wood, there was no silica sinter seen in or around the crater. This surprised visitors and one described Black Terrace Crater as a misnomer. I have seen only one lay mention of possible sinter near the Crater, but every other report remarks on its absence. The sinter I and White found, likely came from the Black or Pink Terrace or another non-terrace site.

The PAWTL2 fossilised wood can be viewed at the *System for Earth Sample Registration* (SESAR).

The 2017 fossilised wood sample is IGSN:IEREX0002 at:
https://app.geosamples.org/uploads/files/IEREX/IEREX0002_DSCF4623zCut27.4.JPG

The PAWTL2 sinter samples can be viewed at:
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

Sinter and lava bomb samples from our 2016 scuba dives near the Pink and White Terrace sites (as then estimated); can be viewed at:

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

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

White on Black Terrace Crater

White at al accept the colonist's assumption that Black Terrace Crater erupted on/near the Black Terrace site, yet produce no more evidence for a Black Terrace than the colonists. They report: *None of the sinter boulders found to date near this site are black; most are typical white siliceous sinters* (White et al, 2020). The *burden of proof* requires black or dark coloured sinter and none has been found there. Yet their findings are otherwise consistent with Hochstetter's survey Folio and help confirm the Black Terrace location, thus:

a) White and our georeferencing agree that Black Terrace Crater lies under the forest road, which on its 110º azimuth overlies the Black Terrace Stream through much of its distal length. This Stream lies 40-50 m below the road in its buried alluvial valley, on a ~108º azimuth.

b) The reported diameter of the kidney-shaped Black Terrace Crater agrees with eyewitness accounts and is consistent with it being centered beneath the forest road.

c) The crater base lies at 305-310 MASL, consistent with it erupting midway along the Black Terrace Stream at this altitude.

d) White's crater altitude is consistent with our lake altimetry of 303 MASL. It invalidates Keam's guessed ≤292 MASL (Keam, 2015).

e) White's findings support our conclusion the new lake shore overlaps the old lake shore here.

f) As with the PAWTL2 Project in 2017, their GPR unit failed to penetrate the Rotomahana mud and thus essential altimetry cannot be reconstructed i.e. from the pre-eruption surface to the present surface; a distance of 40-50 m across sloping ground. White's seismic data however, enabled me to reconstruct the altimetry.

g) Recognising Black Terrace Stream lies beneath the road, suggest White's upstream GPR and seismic horizons may be post–eruption discordant stream beds connecting Black Terrace with the Crater.

h) White overlooks Hochstetter's eyewitness account of the Black Terrace lying in a Side Valley. As discussed, Black Terrace cartography shows it lay in a Side Valley with its waters joining the

Black Terrace Stream, to enter the old lake between Whakataratara and Waiti. White's GPR and seismic imagery (consistent with 1886 photography) show alluvial stratigraphy upstream and downstream from Black Terrace Crater. These confirm the Black Terrace Crater lies partway along the Black Terrace Stream and is not in the Side Valley where cartography and eyewitnesses place the Black Terrace spring. The stratigraphy of the Black Terrace site anyway, will not resemble that of Black Terrace Crater in White (White et al, 2020).

i) Black Terrace-Te Kumete forensic cartography verifies the Black Terrace lies some way west of the Black Terrace Crater.

Terrace Spring Locations from Folio Observation Station Coordinates (Bunn, 2021a)

Terrace	Latitude	Longitude	Spring Altitude
Pink Terrace	38.2613°-38.2623° S*	176.4216° E	~327 MASL
White Terrace	38.2557° S	176.4322°-176.4342° E*	~331 MASL
Black Terrace	38.2574° S	176.4165° E**	~320 MASL

* Approximate long axis of Terrace

** Terrace axis ~145° The midpoint coordinates are from meta-analysis of georeferenced Hochstetter and Petermann maps, where the Black Terrace spring lies within the 2019 search box on each map, as in Figure 8 (Bunn, 2019b, 2020c). Note: underlining its significance, Black Terrace lies outside the border on Petermann's map.

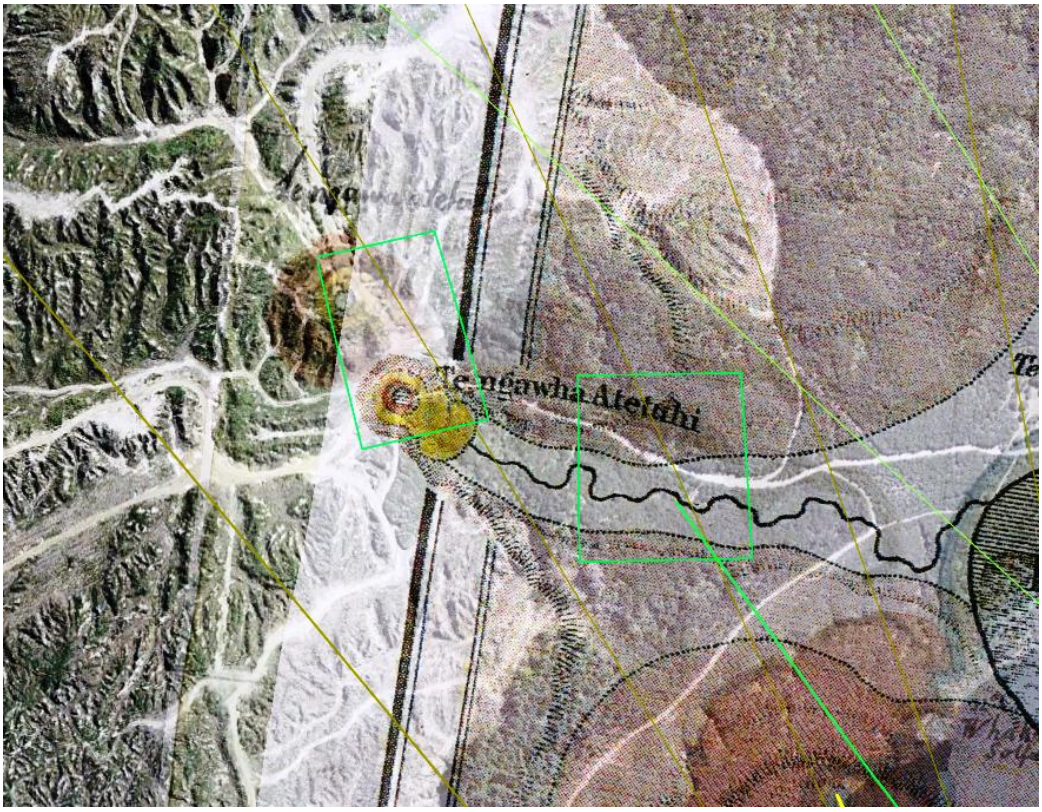

Fig. 8: Black Terrace Spring georeferenced via Hochstetter's observation stations as control points; from his April 30 map and Petermann's 1864 map. Both locations lie within our 2019 search box, shown in green.

Conclusions

The empirical evidence on the location of Black Terrace Crater is timely, for current research has enabled Hochstetter's survey Folio triangulation to be followed across the North Island to Lake Rotomahana. Black Terrace Crater lies within the search field established in 2017 (Bunn, 2017b).The Black Terrace location lies nearby. Accepting White's location, the Black Terrace Crater was georeferenced and triangulated with the Black, Pink and White Terraces via trigonometry, forensic cartography, photogrammetric optics and Google Earth. While Black Terrace Crater has not been excavated, its coordinates have been confirmed.

The Crater allows empirical testing of previous studies, which estimated the Black Terrace Crater−Pink Terrace distance at ~900 m (de Ronde, 2018; Lorrey, 2018a and b). Both the de Ronde et al and Lorrey et al studies have a ~500m hamartia. Keir and Hook have similar errors, despite Hook claiming to have resolved what he termed the *battle of the maps* (Hook, 2018). Following Harding's mistake, all these workers mistakenly place the Pink and White Terraces over the new crater lake. Further, all these workers applied incorrect altimetry (Bunn, 2022). A Black Terrace Crater−Pink Terrace distance of ~340 m debars Black Terrace Crater being coterminous with Black Terrace, as some colonists and White suggest. The devastation meant no colonist could say, where proximal landmarks lay. The only published maps i.e. Hochstetter and Petermann's agree the Black and Pink Terrace springs were ~700 m apart.

The surveyed location of Black Terrace lies close to Black Terrace Crater, along the same forest road: enabling access for excavation. The Crater provides a new survey reference for the Terraces, after Rangipakaru Hill was confirmed as the first surviving proximal landmark (Bunn, 2020c). The Folio dataset and Black Terrace Crater findings together enable sub-surface imaging, drilling and excavation at Lake Rotomahana; to verify the survival and possible recovery of the fabled Terraces (Bunn, 2021a).

Acknowledgments

I acknowledge the ongoing collaboration with Dr Sascha Nolden, without whom this research at the Rotomahana Basin would not have been possible.

Funding

This research was self-funded by the author, in the public interest.

References

Ask, R. E. (1943) Elements of Photogrammetric Optics, in American Society of Photogrammetry, *Manual of photogrammetry,* 1952.

Bunn, A. R. (2017b) Rediscovering Te Tuhi's Spring and Black Terrace Crater, The Forgotten Rotomahana Spring and Crater. *PAWTL2 Project*, DOI: 10.13140/RG.2.2.27742.66886

Bunn, Rex. (2019a) Photographic embellishment and fakery at the Pink and White Terraces. *New Zealand Legacy,* Vol 31.1, 5-10, June 2019).

Bunn, A. R. (2019b) Hochstetter's Survey of the Pink and White Terraces: The Final Iteration. *Surveying+Spatial*, 99, 30−35.

Bunn, A. R. (2020c) Reconciling New and Old Surveys of the Pink and White Terraces. *Surveying+Spatial*, 102, 29−36.

Bunn, A. R. (2021a) Submissions to the Māori Affairs Committee, New Zealand House of Representatives, on the Ngāti Rangitihi Claims Settlement Bill, 2021.

Bunn, R. (2022). "The first evidence-based altimetry for locating the lost Eighth Wonder of the World: the Pink, Black and White Terraces". Academia Letters, Article 5204.

Bunn, R. and Nolden, S. (2016) Te Tarata and Te Otukapuarangi: Reverse engineering Hochstetter's Lake Rotomahana Survey to map the Pink and White Terrace locations. *The Journal of New Zealand Studies*, [S.l.], n. 23, Dec. 2016. doi.org/10.26686/jnzs.v0i23.3988.

Bunn, A. R. and Nolden, S. (2018) Forensic cartography with Hochstetter's 1859 Pink and White Terraces survey: Te Otukapuarangi and Te Tarata. *Journal of the Royal Society of New Zealand*, 48, 39−56. Published online: 7 June 2017.

Bunn, A. R., Davies, N. and Stewart, D. (2018) Dr Hochstetter's Lost Survey, *Surveying+Spatial*, 94, 5−13.

Dallmeyer, J. H. (1874) *On the Choice and use of Photographic Lenses*, Anthony & Co, New York.

De Ronde, C. E. J., Tontini F. C. and Keam, R. F. (2018) Where are the Pink and White Terraces of Lake Rotomahana? *Journal of the Royal Society of New Zealand*, 49, 36-59.

Fitzgerald, H. F. (2014) *The Pink and White Terraces Revisited,* Rotorua, H. F. Fitzgerald, Levin, New Zealand.

Harding, A., in Thomas, A. P. W. (1887) *Report on the eruption of Tarawera and Rotomahana*, General Survey Office, Wellington, Map.

Hochstetter, F. (1867) *New Zealand: its physical geography, geology and natural history with special reference to the results of Government expeditions in the Provinces of Auckland and Nelson,* Stuttgart: Cotta.

Hook, G. and Carey, S.P. (2018) *Relocating the Pink and White Terraces of Lake Rotomahana, New Zealand: resolving the 'battle of the maps'. Tuhinga, 30, 178-208.*

Keam, R. F. (2015) The Tarawera eruption, Lake Rotomahana, and the origin of the Pink and White Terraces, *Journal of Volcanology and Geothermal Research,* 314, 10−38.

Keam R. F. and Lloyd, E. F. (2016) Post-1886-eruption Rotomahana hot springs, *GOSA Transactions: The Journal of the Geyser Observation and Study Association*, 13, 39.

Keir, W. (2018) "The location of the Pink and White Terraces of Lake Rotomahana" *Journal of the Royal Society of New Zealand*, 48, 1-20.

Langford, M. (2010), *Basic Photography,* Focal Press, Oxford, 397.

Lorrey, A. M., and Woolley, J.-M. (2018a). Location of the Pink, White and Black siliceous sinter Terraces at Lake Rotomahana, New Zealand: Re-evaluating Ferdinand von Hochstetter's legacy cartography and survey measurements with historic maps and LIDAR. Lecture and Manuscript to Tūhourangi Tribal Authority and PAWTL2 Project Team (Rotorua). doi: 10.3389/feart.2018.00205

Lorrey, A. M., and Woolley, J.-M. (2018b). Locating Relic Sinter Terrace Sites at Lake Rotomahana, New Zealand With Ferdinand von Hochstetter's Legacy Cartography, Historic Maps and LIDAR. *Frontiers in Earth Science* 6:205. doi: 10.3389/feart.2020.00068

Nairn, I. A. (1979) Rotomahana-Waimangu eruption, 1886: base surge and basalt magma, *N.Z. Journal of Geology and Geophysics*, 22, 3, 363−378.Smith, S. P. (1887) The Eruption of Tarawera, Government Printer, Wellington, Map, 57.

Nairn, I. A. (2002) *Geology of the Okataina Volcanic Centre*, IGNS, Wellington.

New Zealand Herald (1887), Volume XXIV, Issue 7840, 8 January 1887, 1.

NSW Department of Industry (2018), Determining stream order Fact sheet.

Smith, S. P. (1894) Notes on the Present State of the Country Immediately Round the site of the Eruption of Tarawera, General Survey Office, Wellington, 1894.

Warbrick, A. (1934) *Adventures in Geyserland*, Reed, Dunedin, 88

Warbrick, A. (1936) The Lost Terraces. New Zealand Herald, Volume LXXIII, Issue 22420, 16 May 1936, 3. https://paperspast.natlib.govt.nz/newspapers/NZH19360516.2.198.25 Accessed 16 June, 2022.

White, P., Lorrey, A., Woolley, J-M, Vidanovich, P. (2020) Black Terrace, Rotomahana. Proceedings 42nd New Zealand Geothermal Workshop.