

One Plate to find Them

How a unique surviving photograph confirmed the Hochstetter Paradigm and located the White Terrace—Eighth Wonder of the World

A Rex Bunn*

Independent Researcher

*Corresponding Author

A Rex Bunn, Independent Researcher.

Submitted: 2024, May 20; Accepted: 2024, Jul 16; Published: 2024, Sep 19

“All photographs are accurate. None of them is the truth.”
Richard Avedon

Citation: Bunn, A. R., (2024). One Plate to find Them. *J Huma Soci Scie*, 7(9), 01-23.

Abstract

This empirical research analyses a unique vintage photographic plate that confirms the location of a lost Wonder of the World, the Pink and White Terraces. Their location has been debated since 1886 when they were buried in a volcanic eruption. The paper is a meta-analysis that develops a Parallax Effect methodology with a Skyline Gauge to consolidate and test all 1886–2024 claims to the White Terrace location. Methods include photo-interpretation, photogrammetric optics, topography and forensic cartography. The results show many claims have significant errors. The Gauge location is consistent with the coordinates provided by the 1859 Hochstetter Survey, the Hochstetter Paradigm and early private sector claimants.

Keywords: William Fitzgerald Crawford, Parallax Effect, Pink and White Terraces, Te Tarata, Lake Rotomahana, Tarawera Eruption, Meta-Analysis Hochstetter

1. Introduction

The search for the White Terrace—the lost *Eighth Wonder of the World* in New Zealand was hampered by the landscape transformed during the 1886 Tarawera Eruption. Colonial rescue teams were unable to state quite where the White Terrace lay. The Rotomahana Basin lakes were now a series of craters from the June 10, 1886, geothermal eruptions. These slowly filled, forming a new Lake Rotomahana, some ten times the surface area and 34–39 m above the old lake.

Ferdinand Hochstetter’s (1829–1884) 1859 terrestrial survey, the only one completed in the Rotomahana Basin provided compass bearings from two observation stations (Bunn & Nolden, 2023) [1]. These stations now lie in the water column of the main eruption crater lake. His Station 21 is at times close to the current lake surface. His second Puai Island station is submerged 32–35 m in the new lake making it impossible to complete a usual survey resection from the stations. The only effective method of reconstructing Hochstetter’s survey bearings was to reverse engineer the stations’

locations by resecting the bearings’ reciprocals and establishing loci for each station together with error ellipses (Bunn & Nolden, 2016, 2018, 2023) [2,3]. Elevation Profiling could then extend the bearings underwater and assure intervisibility. Hochstetter had taken bearings on the Tarawera Massif and Kumete Ridge. These gave right-angled intersections for the most accurate loci (Bunn & Nolden, 2023) [1].

This is the process Dr Sascha Nolden and I followed from 2016–2023 and it was hampered by the landform changes, initial uncertainty over some of the Tarawera Massif landmarks and bearings and in the absence of any pre-eruption photography of Kumete Ridge—possible imprecision with the five bearings taken on Kumete Ridge. This was accentuated by the eruption surges which travelled to the northwest and deposited layers of volcanic ejecta over the anterior face of this ridge. The altered profile of the ridge and rainfall caused erosion in the decades after the eruption. Today, this and forestry operations slowly re-expose parts of the ridge. The highest landmark, Te Kumete Peak was thought to

have survived largely intact and maintained its elevation after the eruption, but given the primitive state of altimetry in the nineteenth century and the absence of before-and-after photographs, this could not be vouchsafed. Kumete in a modern translation refers to a food bowl and the Rotomahana Basin provided avian protein food to the Tūhourangi sub-tribe of Te Arawa over the winter from Lake Rotomahana (it was otherwise a bird sanctuary). The Kumete Ridge was covered in Bracken ferns (*Pteridium esculentum*) whose rhizomes and fronds were staple Māori foods.

Attempts to resect the Hochstetter bearings along the ridge contributed to the multiple survey iterations made by Nolden and I. Issues with the ridge topography helped disqualify the only other attempts to reconstruct the Hochstetter survey (Lorrey & Woolley, 2018a, b) [4,5]. It was impossible to field-truth these Kumete bearings that were important in setting the survey stations' coordinates so that surviving large-scale cartography could be oriented to complete the pre-eruption Rotomahana Basin topography and validate the survey loci and the proximal bearings on the Pink, Black and White Terraces. Given the new lake is 34–39 m above the old, intervisibility with the ridge landmarks can never be reproduced i.e., without draining the lake as the author attempted in 2014 (Bunn, 2014) [6]. Attempts by others at forming sight lines on distant landmarks using period photography failed to provide reliable data that matched Hochstetter's bearings (De Ronde et al IGNS, 2018; Keam, 2016; Keir, 2017; Lorrey & Woolley, 2018a, b; Hook & Carey, 2019) [7-10].

In 2020, Hochstetter's near-complete 1860 survey Folio was contributed to our research and this provided a replication dataset that we employed to validate our earlier survey iterations which drew on Hochstetter's surviving diary and survey notebooks

(Bunn & Nolden, 2023) [1]. This later Folio-based replication was published in 2023 and pleasingly agreed with our earlier Diary resections, ratifying the Sixth Iteration of Hochstetter's survey.

Improvements by 2024 for the LINZ (Land Information New Zealand) trig locations along Kumete Ridge and improving accuracy in their topographic mapping for the Rotomahana Basin assist our pre-eruption landmark navigation in this research. Coverage of the ridge by Google Earth™ is also improving with historical imagery. These developments and the unique photograph of Kumete Ridge enable the most accurate analysis of the White Terrace location and orientation since Nolden and I began in 2016.

2. Methods

The methodologies in the meta-analysis are applied to a single photograph exposed by a photographer from the author's hometown—the Gisborne, New Zealand photographer William Fitzgerald Crawford (1844–1915). The photograph in Figure 1 is the missing key to georeferencing Hochstetter's large-scale 1859 cartography and his 1859 compass survey data in the Rotomahana Basin. It enables a fresh approach to geolocating the White Terrace using the proximal landmarks along Kumete Ridge. These were with Te Rangipakaru and the Steaming Ranges, the most proximal surviving features of the pre-eruption Basin. The ridge landmarks are expected to be superior due to the partial loss of Te Rangipakaru and the Ranges in the 1886 eruption. Te Kumete Peak survived more or less intact, albeit covered with ash. Kumete Ridge has multiple Hochstetter bearings, permitting validation by included angle checks. The Crawford dry-plate photograph (as a digitally scanned and inverted negative image) enables us to compare the pre- and post-eruption landmarks along Kumete Ridge using a geospatial visualisation tool i.e., Google Earth Pro™.



Figure 1. Crawford's 1886 photograph of the White Terrace and Kumete Ridge (Tairāwhiti Museum).

This paper consolidates all 1886–2024 claims and blends four research methods: photointerpretation of the Crawford image, photogrammetric optics applied to the image, topography i.e., the pre-and post-eruption topography of Kumete Ridge with horizontal parallax scrolling and forensic cartography to validate the methods with large-scale maps of the Rotomahana Basin. Aiding these methods are Hochstetter's survey data and bearings.

2.1 Photointerpretation

There is a surprising volume of information in Crawford's photograph. It is more surprising as Kumete Ridge forms the backdrop for his major interest in the shot i.e., an exposure looking down the White Terrace from a southwest point.

2.1.1 Composition of Crawford's Photograph



Figure 2. Crawford and the Golden Ratio (Tairāwhiti Museum).

The Rule of Thirds is evident in previous Pink and White Terraces photographs but is not obvious here. In Figure 2 Crawford may apply the Golden Ratio. The key navigation shrubbery lies in the foreground spiral. Te Mamaku spring lies on the vertical. The figure gazes at the first spiral and the Hot Waterfall.

Nearly all surviving prints of the White Terrace are taken either from its base, across the Kaiwaka Channel or from over the lake. Crawford departed from this to shoot down the terrace and across the Kaiwaka into Kumete Ridge. This is the only such in-focus view I have seen in a decade. Another Crawford photograph of the White Terrace is in the Tairāwhiti Museum i.e., an orthodox up-terrace view of the Giant Buttress.

This Crawford composition resembles Daniel Mundy's (1826–1881) White Terrace 1870 exposure, taken further north on a lower terrace with a wet-plate (Mundy, 1875) [11]. With Crawford's

excellent depth of focus and two Alfred Burton (1834–1914) photographs taken that 1886 summer, we triangulate his camera position onto the upper, southwestern section of the terrace, as shown in Figures 4, 5 and 6. We navigate by the terrace basins and terrace vegetation i.e., mānuka (*Leptospermum scoparium*), using the shrubbery in Figure 1 as waypoints (geographic reference points). These mānuka bushes were growing in 1859 and were first photographed by Bruno Lancel Hamel (1837–?) in Figure 5. Mānuka is long-lived and in Figure 12 are bushes photographed in the 1890's which are visible on Google Earth.

For a reconnaissance over Kumete Ridge (where I trekked on PAWTL Projects) and to ensure the Crawford photograph is a fair view of Kumete Ridge today, I draped Crawford's print over an aerial oblique view of the Ridge. This is Figure 3 and there was sufficient spatial agreement between the images, with peaks marked for investigation.

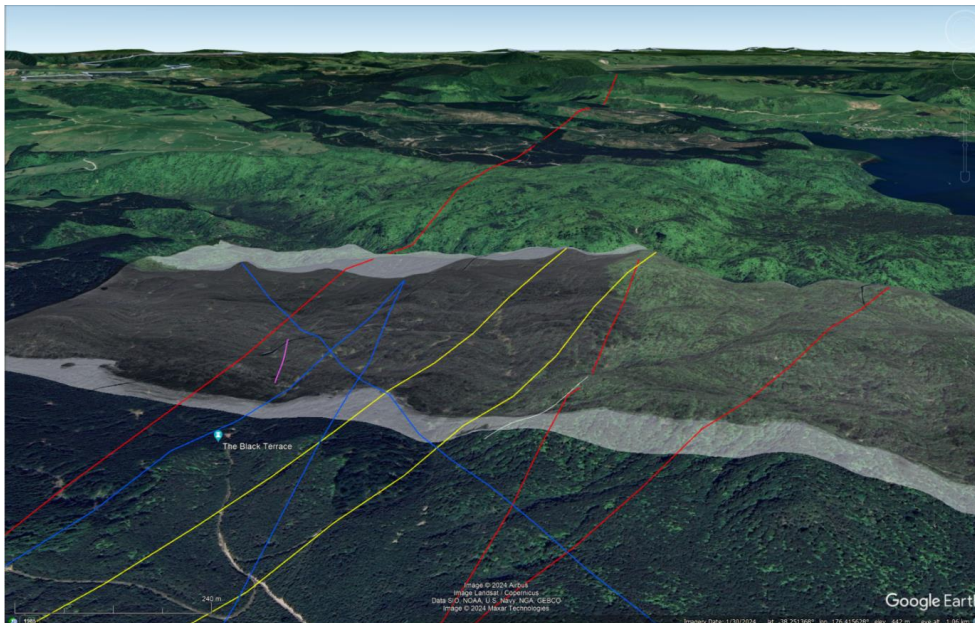


Figure 3. A reconnaissance with Crawford's positive image draped over Kumete Ridge on Google Earth.

On his 1886 shoot, Crawford would arrive by dugout canoe up the Kaiwaka Channel, providing sufficient water depth existed. By 1886, the lake was at a low level of 301–302 metres above sea level (m a.s.l.). In Figure 1 a pathway runs across from three o'clock (G in Figure 7). In Figure 1 this terminates at the terrace base, where a campsite is seen. This was likely cleared in 1885 by painter Charles Blomfield (1848–1926), (Williams, 1979) [12]. The nearby campsite may be that cleared by photographer George Valentine (1852–1890) and his party in 1885 (Hall, 2004) [13]. In Figure 14 Burton's tent is pitched in the clearing at three o'clock. Between it and the terrace is a bivouac, thatched with mānuka in Figure 14 but with bare poles (F) in Figures 1 and 7. In Figure 1, footprints start at the path junction with the clearing and terrace

edge and run across the terrace near the shrubbery in Figures 1, 4, 5, 6 and 7. I suggest these are visible as scoria would be on the boots and be trudged into the sinter where it is quickly laminated. In Figure 7 (below point G) there are two small black features on the first tier. In Figure 4, one is seen to be mānuka. However, the other does not appear and so cannot be vegetation. It may be Crawford's baggage, left while reconnoitring the terrace.

There was no well-reported path up the White Terrace save for one halfway up the northern side. As Hochstetter reported, it was easy to ascend this terrace as the water was mostly ankle-deep. Unlike the Pink Terrace, the White Terrace sinter required Tūhourangi-supplied footwear to protect visitors' feet from the abrasive surface.

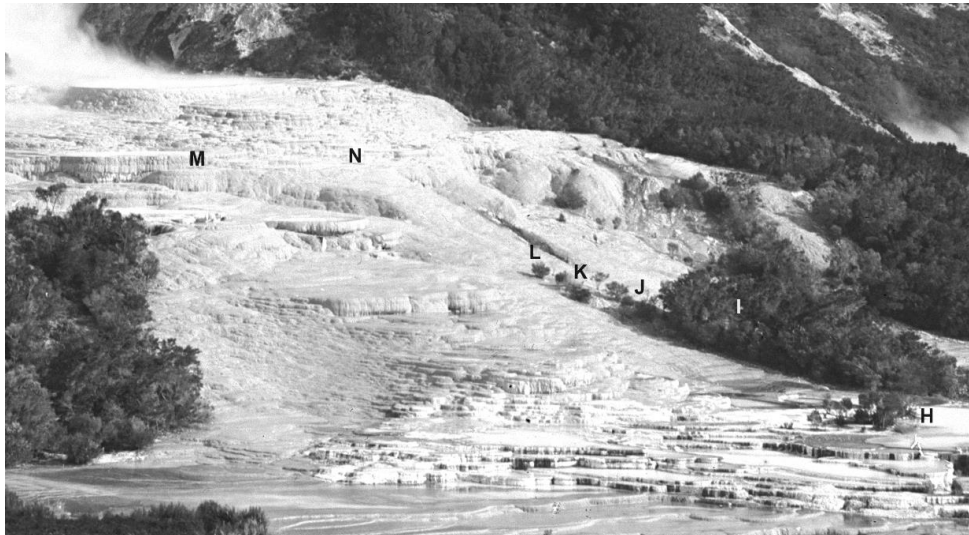


Figure 4. An inset photograph with navigation points on the White Terrace marked and cropped from an 1886 Burton photograph (MA1062706 Te Papa).

In Figure 4, we navigate to the camera position, ascending via the mānuka scrub marked as H-I-J-K-L. Keeping these bushes on our right as we climb, in Figures 1 and 7 we arrive at three large basins—shallow pools or wide steps. These lay below the main spring platform and were north of the Hot Waterfall above point J. From the architecture of the basins, Crawford’s seated guide and the buttress M in Figure 4, I conclude the camera position lay in

the topmost of the three pools, above the scrub-line I-J-K-L and below the main platform to avoid condensation.

These bushes are evident in Figures 1, 4, 5 and 6. Figure 5 is a lithograph by Arno Meermann (1829–1908) prepared from a photograph on Hochstetter’s survey (Hochstetter, 1867) [14].



Figure 5. *Te Tarata on the Rotomahana Lake*. Chromolithograph by Arno Meermann after an 1859 photograph by Bruno Hamel in Hochstetter *New Zealand* (1867).

Mānuka can live for decades, thus the larger pools on the lower terrace can also be used as waypoints. There is one reason why photographers would not set up on the main platform. The Tarata spring was constantly boiling:

“At the margin of the basin I found a temperature of 183 deg. F., but in the middle, where the water is in a constant state of ebullition to the height of several feet, it probably reaches the boiling-point. Immense clouds of steam, reflecting the beautiful blue of the basin, curl up, generally obstructing the view of the whole surface of

water;” (Hochstetter, 1867, p. 411) [14].

In 1886 there was significant set-up time for photography. Setting up on the main platform invited clouds of steaming-fog to form condensation on the ground-glass camera screen, lens and plates as in Figures 4 and 6. Photographs from the main platform were taken after the Tarata spring emptied during easterly winds or in low-flow periods. (Bunn, 2023a; Williams, 1979) [12,15].



Figure 6. An inset photograph with navigation points marked on the White Terrace and cropped from an 1886 Burton photograph (MA1062771 Te Papa).



Figure 7. Crawford’s photograph with navigation points marked (Tairāwhiti Museum).

Crawford elected to backlight his composition i.e., with the camera aiming into the sun, giving clear shadowing and a dramatic silhouette to the foreground figure.

2.1.2 Flora, Fauna and the Kaiwaka Channel

Hochstetter remarked on the monoculture of the fern-covered hills (*Pteris esculenta*). This is depicted in Crawford's image. The highest point on Kumete Ridge was/is Te Kumete Peak—point B in Figure 7. The other skyline features A, C, Z and Y are discussed in a later section. No fauna are visible in Crawford's photograph, despite the avian population at the lake. It was a Tūhourangi bird sanctuary and remains so. Exposure times were too long to arrest the movement of the flocks of pūkeko, ducks, teal and tōrea.

The Kaiwaka Channel was the only stream draining the lake and its entry lay beside the White Terrace. Point E in Figure 7 marks the Kaiwaka flowing left to right through a loop. Navigating by Hochstetter's large-scale map in Figure 13, this section is the first stream loop as it leaves the lake and we discuss it under Cartography. There was a second, larger embayment above it at the lake exit. The geothermal spring Te Mamaku in Figure 7 i.e., D, lay between the two loops. In Figures 13 and 21, a spring lies on either side of the loop i.e., Te Poroporo downstream and Te Mamaku upstream. Te Poroporo is too far downstream to appear in Figure 7. Also, the tourist path at G traverses from right to left and campsite F. This path is the termination of Hochstetter's *Road to the Mission Station on the Tarawera Lake*.

2.1.3 Te Mamaku and Steaming Fog Shows wind Direction and Force

Te Mamaku, a geothermal spring in the basin was catalogued by Hochstetter with its neighbour Te Poroporo. The steaming-fog plume indicates the meteorological conditions were close to the dewpoint, hence Te Mamaku was steaming as would be Tarata Spring. These conditions would cause condensation on camera glass surfaces and influence Crawford in his camera location. Te Mamaku evidences the wind direction in Crawford's photograph. The deflection of the Mamaku plume indicates a south-to-south-west wind blowing. This is common for the Rotorua wind rose in summer and at Rotomahana where the wind sweeps over the lake fetch. This would lead Crawford to position himself on the southern, windward side of the terrace and drop down a tier, out of the steaming-fog cloud and wind to minimise condensation risk and obtain camera stability.

2.1.4 The Seated Figure

The individual seated bathing on the terrace in Figure 1 is rendered with sufficient resolution to identify him against e.g., family records. He is an adult Māori male with symmetric features, well-groomed hair, a full moustache and a trimmed beard. He appears athletic and is wearing a wide ring on his left little finger. He joins Crawford on the Terrace and would be his guide.

Except for Alfred Warbrick (1860–1940) from the Ngāti Rangitihī Arawa sub-tribe, other Rotomahana guides by 1886 were generally female and from the Tūhourangi sub-tribe of Te Arawa.

Photographers who visited the Terraces during this period e.g., Alfred Henry Burton and George Valentine were guided by the most famous—Guide Sophia Hinerangi (c.1834–1911). Her colleagues included e.g., Guide Keita Rangitukia (Kate) Middlemass (1824–?) and Guide Kate Waroa (?–?). Male guides are recorded early in the 1870s tourist boom and Akutina Rangiheuea accompanied Ferdinand Hochstetter on the Pink and White Terraces. Today, despite efforts by the Tūhourangi Tribal Authority Crawford's guide remains unidentified. He may be Akutina Rangiheuea from the leading Tūhourangi family, who guided Hochstetter. Guide Rangiheuea and his family perished in the 1886 Tarawera eruption.

2.1.5 Meteorological Conditions

February temperatures around Rotorua lie between 20–30 C. At Lake Rotomahana they can be less with a chill factor. After triangulating Crawford's camera position, the optical axis of the camera aligns with the campsite and Te Kumete peak at an azimuth of ~305°. We can calculate the solar bearing from this location. While we are unsure of the day Crawford exposed the negative, we know it was early in 1886 as the Terraces were buried on 9–10 June. Crawford likely travelled from Gisborne that summer and I adopted February 1 for calculation. From his position, the solar azimuth of ~123° (or 303°) almost matched his camera's central axis i.e., the sun was tracking over Kumete Ridge. On February 1, 1886, this occurred at ~1.57 PM at an altitude of ~57°. A 1 m high shrub at that time cast a shadow of ~0.6 m. The shadows cast by the scrub are consistent with the shadow azimuth and length i.e., 0.6–1.2 m. Also, the figure's shadow is ~55% of his height. The shadow cast by the shrubbery marked 'I' in Figure 7 appears elongated. This may indicate lens distortion from the shift movement Crawford likely used. He may also have applied tilt or the Scheimpflug principle to gain depth of field. Yet, Dallmeyer argued against tilt with his lenses (Dallmeyer, 1874) [16]. The effect could be a result of the terrace gradient. Magnification suggests it could also be double-shadowing i.e., reflection from terrace buttresses casting shadows. This was reported at the Pink Terrace (Bunn, 2019) [17].

Crawford would be led first to the White Terrace, arriving around 11 AM. This was to maximise sunlight penetrating the basins and refracting through the translucent basin walls. Similarly, the Pink Terrace was visited in the afternoon when sunlight angled into its basins which glowed. The White Terrace wasn't white. Eyewitness accounts, such as that by Willy Bennett (1874–1959), report it had a cream hue (Bennett, 1954) [18]. With optimal meteorological conditions, solar elevation ensured the White Terrace basins 'glowed'. The turquoise, translucent water spilling over the basins gave tourists an animated, preternatural audio-visual experience. The turquoise hue was from Rayleigh scattering of sunlight by colloidal silica particles which helps account for the water opacity (Bunn, 2023b) [19].

Another likely misnomer is the common translation of Te Tarata as the Tattooed Rock. Tarata also has a botanical meaning derived from the leaves of the Lemonwood tree (*Pittosporum eugenoides*)

or the Karo tree (*Pittosporum crassifolium*), (Bunn, 2023b) [19]. This question is prompted by the adjacent geothermal features. On the left is Te Aka Mānuka and on the right is Ngāhutu. In front lie Te Poroporo (*Solanum aviculare* or *Artocarpus altalis* i.e., Breadfruit) and Te Mamaku (*Cyathea medullari*)—all translate as the names of shrubs or trees. The five features were likely given botanical names at the same time by immigrants in the 1,300s. Breadfruit does not grow in New Zealand but was a staple food in Polynesia, implying a Polynesian immigrant may have named Te Poroporo and adjacent features.

The Pink Terrace may also be a misnomer. It was multi-hued i.e., white around the base, pink intensifying as one travelled up the tiers and with a yellow hue about the top. The blue water in the Pink basins was a different hue from the White—azure. The water in the White Terrace was translucent (rather than transparent as in the Pink Terrace) and was so rendered by colonial artists.

2.2 Photogrammetric Optics

2.2.1 Crawford's Camera Rig at Rotomahana

The Crawford image in Figure 1 is produced from the original negative. It is a positive image digitally scanned, inverted and enhanced (within FADGI standards) from the original 1886 Crawford dry-plate i.e., a glass 10" x 8" negative plate. There is no cropping, enhancement or other embellishment to the negative. The plate is fractured into five pieces and reassembled and conserved by Dudley Meadows, Curator of Photography at the Tairāwhiti Museum, New Zealand.

The large-format negative has an excellent depth of field with minimal blurring on the distant skyline. The sky is washed out as was usual for the slow period emulsions. Photographers painted the sky or used a double exposure when printing.

The camera, lens and exposure factors for this photograph are unrecorded. We can estimate some factors by cross-referencing and others by photogrammetric optics. The history of New Zealand photography is poorly documented. The first development history was written in 1971 by Hardwick Knight after period photographers all died (Knight, 1971) [20]. Few cameras survive. Photogrammetric-optics analysis is thus challenging.

In the absence of records for this image, we may interpolate the likely camera, lens and focal length. Perhaps due to Gisborne's isolation, his long professional activity and conservation work by his family and the Tairāwhiti Museum, we know more about Crawford than many other New Zealand photographers.

Crawford's equipment started in the wet-plate era and his first dry-plate camera was a half-plate, followed in 1884 by a 10" X 8" dry-plate camera he used until 1896 (Robinson, 2024) [21]. In 1897 he purchased a quarter-plate camera and on 1897-07-17 was photographed shooting with a 12" X 10" camera on board a ship. The 12" X 10" format can be deduced as his forearm is photographed alongside the camera. An adult male measured ~12" from the olecranon process to the ulnar styloid process and both

can be estimated from his surface anatomy in the negative. From the design, nameplate and brass fixings, the camera is a Meagher. This make was used by New Zealand photographers. John Richard Morris (1854–1919) owned a 12" X 10" Meagher camera and used Dallmeyer lenses as did Alfred Burton. Crawford probably purchased Dallmeyer lenses as they were the British market leader.

Crawford's Rotomahana camera at the lake mounted a 10" X 8" dry-plate negative. This does not prove a 10" X 8" camera was used. Knight noted the use of 12" X 10" cameras mounting 10" X 8" plates. However, he likely used the 10" X 8" camera he owned from 1884–1896.

Cameras were bundled with lenses, cases and tripods. The Dallmeyer Rapid-Rectilinear landscape lens was the preferred lens in the UK and from Dallmeyer's sales records, sold to New Zealand photographers. Given Crawford is photographed operating a Meagher 12" X 10" camera, we may presume his older camera was also a Meagher. The make and model of the camera are less important than the lens and we do not know this. It was probably part of a bundle with the 10" X 8" camera and a standard 10" X 8" lens.

2.2.3 Optical Analysis

One way to estimate the approximate lens central axis and central point is to draw in the diagonals. Here, this lies in a cleared area between the terrace and Kaiwaka, close to the campsite. This is in the foreground and our interest lies in the background. The aim is to calculate the distance between the camera and Te Kumete. Dallmeyer supplied his standard Rapid-Rectilinear lenses with a focal length equal to the long side of the plate i.e., a 10" focal length lens for a 10" X 8" camera (Dallmeyer, 1874) [16]. Today, the film diagonal is used and his standard 10" X 8" lens would be said to have a focal length of 12"–13". He designed his standard lenses so the angle of view was 53°.

As we reverse engineer the Crawford negative, we use the angle of view to estimate whether a standard lens was used. We geolocate peripheral landmarks in the image and estimate their included angle—the camera angle of view. The closest peripheral datums i.e., the ridge beside point A and that north of Te Kumete along Kumete Ridge subtend an angle on Google Earth of ~58° (273°–331°) close to Dallmeyer's specification. Crawford thus might have used a standard lens, whether or not it was by Dallmeyer. We can check with optics whether Crawford used a standard lens.

The normal equations for photogrammetric optics, (Ask, 1943 and Langford, 2010) are [22,23]:

$$M=V/U \quad M=I/O \quad M=(V/F)-1 \quad I=O*M \quad O=I/M \quad U=F((1/M)+1)$$

where V= focal length of lens

M= Magnification

I= Image height [The 1 allows for lens assembly increment]

O= Object size (allowing for plate fractures)

V= Focal length (lens to film)

U= Actual object distance to e.g., the White Terrace

I tried combinations of datums with trigonometry and geometry and none gave a realistic output for either the lens focal length or the distance from the camera to Te Kumete. I suspect Crawford used shift and tilt movements and these upset the calculation. Also, the plate's central plane was probably a long way from the skyline. The equations suggest a lens of 100–170 mm focal length versus the ~250 mm expected focal length for a standard 10" X 8" lens. No conclusions can be drawn on the lens, save that it gave a fine depth of field.

To estimate the distance from Te Kumete I turned to cartography. In Table 3, the Petermann map measures 1,445 m from Tarata to Te Kumete and this is short. On Hochstetter's georeferenced April 30 map, the distance is closer to 1,700 m, which is consistent with other methods. The Petermann map has known errors and on it, Te Kumete is tucked into a corner.

2.3 Topography- Pre- and Post-Eruption Navigation with the Parallax Effect

All previous efforts to locate the Pink and White Terraces were handicapped by the lack of pre-eruption imaging of proximal landmarks surviving the 1886 eruption. Kumete Ridge which flanked the western shore of the old Lake Rotomahana contained four (in fact five) peaks that were used in the only survey of the

Pink and White Terraces. They were chosen by surveyor Ferdinand Hochstetter to provide right-angled intersections with bearings on the Tarawera Massif. These offered maximum survey accuracy for his survey stations' loci and the Pink and White Terraces bearings. Without high-resolution pre-eruption photography, there is no guarantee that landmark peaks on today's Kumete Ridge and its trig stations (which post-date the eruption); give reliable data for the 1859 survey bearings. This affects the six iterations by Bunn and Nolden of Hochstetter's survey and the attempts by Lorrey and Woolley to replicate their findings (Bunn & Nolden, 2023; Lorrey & Woolley, 2018a, b) [1,4,5]. The landforms in the Rotomahana Basin were transformed by the 1886 eruption and surveyors and geologists were unable to position Lake Rotomahana or the Terraces.

2.3.1 Kumete Ridge

After 138 years of weathering, erosion and forestry operations it is more difficult to locate the Terraces from Kumete Ridge than in 1886—unless we have before-and-after knowledge of today's landmark conformation. Up to now, we lacked that knowledge. That is why this Crawford photograph in Figure 1 is so important for researchers reconstructing the landscape to resolve the question that bedevilled generations of researchers—did the Pink, Black and White Terraces survive the 1886 Tarawera eruption?



Figure 8. A digital elevation model of Kumete Ridge illustrates the ridges' distinctive “Z” shape in Crawford’s photograph (New Zealand River Pilot).

It will help interpret the Crawford photograph to describe the ridge now and in 1886. In Figure 8, the top bar of the ‘Z’ covers Te Kumete and three Hochstetter landmarks. The diagonal encloses the major reentrant on Kumete with watercourse 1102173. This remains between point X and Te Kumete in Figure 10. The diagonal traces the ridge with its 460 m contour ending at point X. This is visible on the New Zealand Topo50 map, Google Earth and Crawford, triangulating X as a useful datum. The bottom Z bar returns northeast ending in another reentrant with watercourse 1755276. These watercourses showed no recent water flow in 2017. The midground topography in Crawford’s photograph is altered by

the eruption. Te Kumete remained visible after the eruption as in Figure 12 and other features are returning to view by erosion. The diagonal ridge today is more level than in 1886. This seems due to ash build-up in the plateau behind it. Heavy ash depths also persist around the shore. This causes an intervisibility issue as we approach Crawford’s altitude at 344 m a.s.l.

In this first Kumete Ridge topography, we are aided by Hochstetter’s 1860 survey Folio (Bunn & Nolden, 2023) [1]. This has an unpublished map of Kumete Ridge. The map is in Figure 9. It records four peak bearings. Peaks a)–d) are the focus herein.

The point a) conformation is revised. Hochstetter deletes the small knoll from his diary version.

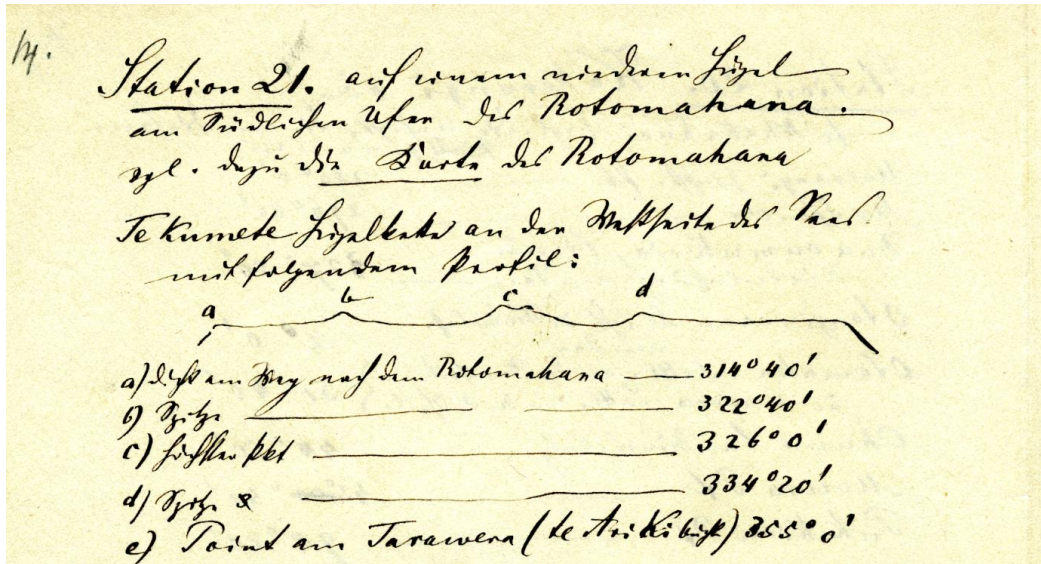


Figure 9. Hochstetter's Folio map of the peaks a)–d) along Kumete Ridge (Bunn & Nolden, 2023).



Figure 10. Crawford photograph with intervisible peaks from Hochstetter's survey on Kumete Ridge. The Skyline Gauge scale A to Te Kumete is in yellow and peak X the indicator is marked on the green scale (Tairāwhiti Museum).

In Figure 10, the only peak visible from Hochstetter's survey station 21 is Te Kumete, with its right extension seen in Figure 9. Peak A on Crawford has a parabolic shape with a summit to attract Hochstetter. It was not intervisible with Station 21 due to the foothills. Peaks a, b, and d had no intervisibility from Crawford's

position on the Terrace. This is unsurprising in the small basin with surrounding high country. This is one reason for Hochstetter's shift from Puai Island to Station 21— he had to overcome poor intervisibility from Puai Station at ~1 m above the lake.

On mapping and Google Earth, Point A is a landmark providing the western end of the distance Skyline Gauge developed herein to test all published White Terrace locations against the Crawford evidence. It anchors Crawford's angle of view on the left. The eastern end of the Skyline Gauge is Te Kumete Peak. The distance A–Te Kumete is 1,153 m on Google Earth. The perpendicular from point X to the gauge is 580 m. There is a sufficient gap for the gauge to measure distance via the Parallax Effect. The Kumete Ridge landmarks lie along a 55° azimuth and the White Terrace

location claims cluster along a range of ~600 m and aligned around an azimuth of ~50° for minimal distortion.

By serendipity, on Google Earth, the triangle formed by A–Te Kumete–Point X is a right triangle with angles of $26^\circ \pm 1^\circ$, $90^\circ \pm 1^\circ$ and $64^\circ \pm 1^\circ$. As the vertices are peaks, we set aside earth curvature. The gauge indicator Point X moves along the gauge scale with minimal distortion. A Google Earth image of Point X and its ridge is in Figure 11. This is 2011 imagery.

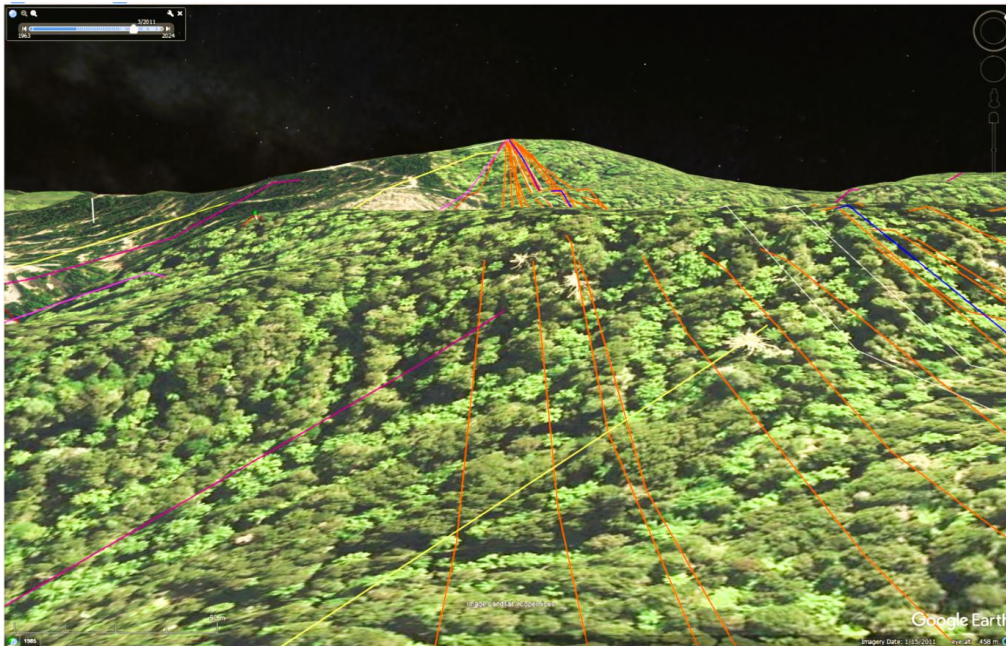


Figure 11. A view of point X with its green marker at 10 o'clock and its levelled ridge on Google Earth from 2011 when forestry operations gave a LIDAR-like view.

We inflate the Crawford photograph scale on Google Earth so the distance A–Te Kumete match at 14 cm. We match the azimuth, orientation and elevation. We adopt point X as the gauge pointer. Point X is now $9.2 \text{ cm} \pm 0.1\text{--}0.2 \text{ cm}$ (with plate fracture) along the gauge from A on the Figure 10 scale. As we move Crawford along the claimed White Terrace locations, point X scrolls across the gauge. With X on Google Earth as in the photograph, we have Crawford's camera azimuth. Terrace locations away from this will be inaccurate.

We scroll horizontally to the White Terrace locations claimed first by Alpha Harding (1856– 1945) and more recently by Keir, Hook & Carey, Lorrey & Woolley, Keam, de Ronde & Tontini and Fitzgerald et al. All these locations bar Fitzgerald and some of de Ronde's later claims are summated in Lorrey & Woolley (2018b) [5]. Latitude, longitude and elevation coordinates for the White Terrace are rarely mentioned by these authors. Lorrey and Woolley's conclusions rely on sketching sites for the old Lake Rotomahana over the new lake, using the Petermann map which is unsuited due to errors (Bunn, 2020a, b) [24,25]. Other authors' claims are added in Table 1.

In Table 1 and Figure 17, the published claims fall into two clusters,

a northern and a southern cluster. The White Terrace locations for authors in the southern cluster—IGNS, Lorrey & Woolley II, Keam, Bell et al, Hook & Carey et al lie between azimuths $308^\circ\text{--}315^\circ$ and 50–250 m southwest of Tarata Peninsula. The estimated IGNS iterations lie closer at 50–100 m off the peninsula. Other researchers locating the White Terrace spring further north and/or on land include Warbrick and Edward Payton (1859–1944), Lorrey & Woolley I (with PAWTL2), Winner, Fitzgerald and Bunn & Nolden. Coincidentally, of the researchers only Warbrick, Fitzgerald and I were Rotorua-based.

Apart from Hook & Carey, all parties failed to provide datums on the White Terrace. This is a prerequisite for any claim to survey accuracy. The footprint of this terrace, in its later years probably reached 4–5 hectares with the lowering lake. The only natural datum is its spring centre, which we innovated years ago. Only Hook & Carey follow our example. The remaining authors have little claim to accuracy due to their two-dimensional approach lacking evidence-based altimetry (Bunn, 2022) [26].

Table 1 summarises the investigators publishing post-eruption claims of locating the White Terrace.

138 Years of Claimed White Terrace Locations					
Investigators	Year	Methods & Iterations	White Terrace Datum	Coordinates	Error to Survey
	Published				m. Hochstetter
Warbrick & Te Arawa	1886–1888	Mātauranga Māori	None	No	<100
Edward Payton	1886–1888	Mātauranga Māori & site visits	None	No	<100
Smith, Harding & Thomas	1886–1894	Sketched guess	None	No	~350
Bell & later geologists	1906–Now	Copy of Harding guess	None	No	~450
Warbrick	1934	Mātauranga Māori	None	No	<100
Warbrick	1936	Mātauranga Māori	None	Indicative	<100
Keam	1961	Sketched guess (1st ed.).	None	No	~400*
Keam	1978	Sketched guess (4th ed.).	None	No	~400*
Winner WHOI	2012	Georeferencing maps	None	No	~150–200
Bunn	2014	Georeferencing/Maps	None	No	~300–400
Fitzgerald	2014	Photo-interpretation/Sight-lines	None	No	~200–300°
IGNS/WHOI/NOAA et al	2011–2016	Photo & Sonar interpretation ltns.	None	No	~300–400
Bunn	2016	SCUBA survey reconnaissance	None	No	~300–400
Bunn & Nolden I	2016	Hochstetter survey Diary ltn. III	None	Yes	~150
De Ronde & Keam et al	2016–2018	Draft map/Sight-lines/Photo ltns.	None	No	~400–500°
Bunn & Nolden II	2017	Hochstetter survey Diary ltn. IV	Spring	Yes	~100
Keir	2017	Photo-interpretation/Sight-lines	None	No	~400°
Lorrey & Woolley I	Mar-18	Survey replication attempt I	None	Yes	~300
Bunn, Davies & Stewart	2018	Hochstetter survey Diary ltn. V	Spring	Yes	≤ 50*
Lorrey & Woolley II	Nov-18	Survey replication attempt II	None	No	~400°
Bunn	2019	Hochstetter survey Diary ltn. VI	Spring	No	≤ 50*
Hook & Carey	2019	Photo-interpretation/Sight-lines	Spring	Yes	~550*
Bunn	2020	Survey reconciliation	Spring	Yes	≤ 50*
Bunn	2022	Altimetry/Boreholes/ Survey	Spring	Yes	n/a
Bunn & Nolden III	2023	Hochstetter survey Folio ltn.	Spring	Yes	≤ 50*
Bunn	2023	Topography, Geomorphology	Spring	Yes	≤ 50*
Bunn	2023	Seismic survey	Spring	Yes	≤ 50*
Bunn	2024	Parallax Effect	Camera on Terrace	Yes	n/a

* These authors' distances are measured to the Tarata spring centre, rather than to Crawford's location.
° These authors' distances are estimated to Crawford's location— from Lorrey & Woolley II, 2018.

Table 1. Investigators published claims for the White Terrace. Errors are against the Sixth, Folio Iteration of Hochstetter’s survey and Crawford’s camera location.

2.3.2 Parallax Effect

The method used in this section applies the Parallax Effect. This is a technique used in e.g., cartography, photography, medical imaging, architecture and astronomy to create depth and motion. Here we employ it to visualise the geographic locations of two (or more) points on a map, by varying the perspective e.g., using motion and overlays. Google Earth Pro is used to provide a dynamic view of Kumete Ridge topography. We adjust the viewpoint and viewing angle to equate with various claims of White Terrace positions. We adjust the claims to place their viewpoint relative to Crawford on the southwest terrace and a tier below the platform. Given the new lake is 34–39 m above the old, and the White Terrace platform was 25–30 m above the old lake, we adjust the observer eye line to 344 m a.s.l., i.e., close to the present lake at 339.8 m a.s.l. We overlay the survey location of Tarata Spring from Hochstetter’s survey bearings and map and establish Crawford’s location. I estimate his camera lay at 322–329 m a.s.l.

We then compose Crawford’s photograph over Google Earth, so the principal axis is close to Te Kumete azimuth. This proved to be 305°. From Crawford’s location; we scroll north and south to

other claims while holding altitude at 344 m a.s.l. and with the axis on Te Kumete. This dynamic short-range comparison better measures spatial relationships between the Terrace locations than a map, and offers a better understanding of Kumete topography. All the points and bearings lie within 2,000–2,800 m offering more accuracy than other workers relying on sightlines to distant peaks where e.g., refraction over the warm lake, atmospheric conditions, earth curvature, erosion and intervisibility hamper their efforts.

We find Crawford on the Terrace in 1886 looking at two Kumete peaks i.e. A and Te Kumete 1,153 m apart on Google Earth and the *Topo50* map. Next, we locate point X in Figure 10. The Parallax Effect occurs as X is 580 m in front of the ray connecting A and Te Kumete.

2.3.3 Kumete Ridge—Pre- and Post-Eruption Perspective

Figure 1 is not the only photograph Crawford exposed of Kumete Ridge. A second conserved by Dudley Meadows was identified during this paper. Between 1890–1900, Crawford returned to Rotorua and Tuminui where he observed Mt Tarawera in Figure 12.



Figure 12. Crawford's post-eruption view (cropped) of the Kumete Ridge posterior (Tairāwhiti Museum).

This photograph shows Te Kumete survived the eruption and remained the highest peak as observers reported. Time, gravity and rainfall have advanced erosion. The saddle survives where the Tūhourangi path from Te Wairoa climbed above the Wairua Stream.

2.4 Forensic Cartography

There was no large or small-scale topographic mapping of

the Rotomahana Basin before 1859. Hochstetter's large-scale watercolour maps were drawn on 1859-04-29 (1:16,000) and 1859-04-30 (1:8,000). His best map is Figure 13. His maps show Kumete Ridge and its peaks. In Figure 13, we can cross-reference landmarks in Crawford's negative to understand the Rotomahana Basin topography and White Terrace location before the 1886 eruption.

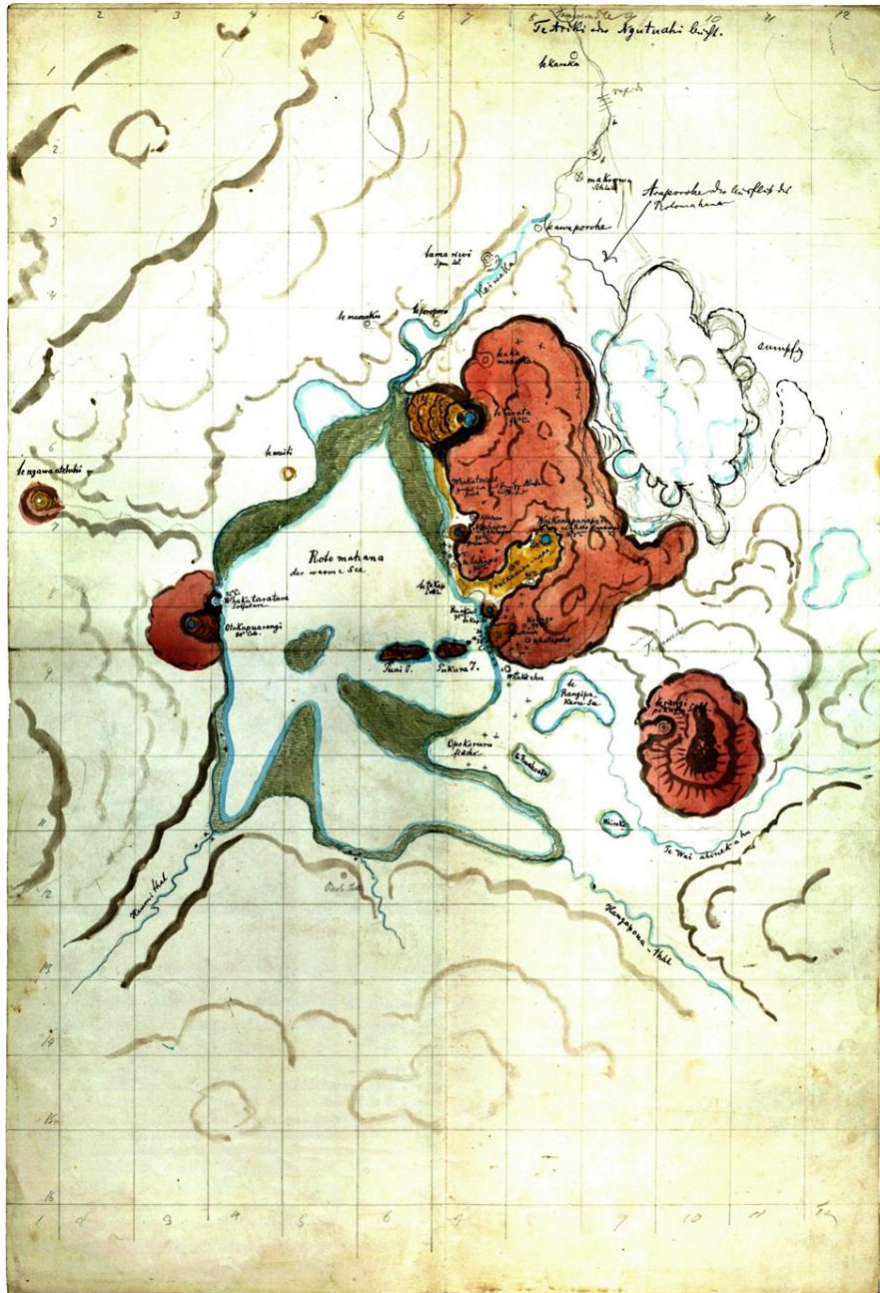


Figure 13. Large-scale map drawn by Hochstetter on 1859-04-30. (Hochstetter Collection Basel).

2.4.1 Kaiwaka Channel

Crawford above the true right bank shows the Kaiwaka Channel, the watercourse draining old Lake Rotomahana. This feature is poorly documented in surviving photographs. In Crawford's negative we see the second large loop in the channel as marked on Hochstetter's maps adjacent to the White Terrace. Given the 27 years between, stream vegetation has developed and the terrace extends beyond its 1859 footprint.

2.4.2 Te Mamaku

The geothermal spring Te Mamaku features in Hochstetter's writings, maps and artwork. It lay at the foot of the ridge and

between the first two loops of the Kaiwaka. Hochstetter drew it near a reentrant and this may survive under stream 1755276.

2.4.3 Paths

As discussed under Photointerpretation, the Tūhourangi formed many paths across the Rotomahana Basin. Crawford records paths across the landscape, which are confirmed by period mapping. In Figure 7, the tourist path enters the shot below point A and traverses the foothills below point C. On Petermann's map, this is the Road to the Mission Station on the Tarawera Lake. On the 1859-04-29 map, it meets the Kaiwaka below Te Poroporo for the crossing by canoe to Tarata.

Kumete Ridge slopes down to peak A and beside it lay the saddle where the mission path crossed the ridge. Between here and the Wairua Stream (1102174) the ridge was too steep to climb, hence a diagonal track. The frontal Tūhourangi Track today is a forestry road, following the foothill ridges down to Boat Launch Bay. Another Tūhourangi Track is visible on Crawford at point G in Figure 7. This track connects the Kaiwaka crossing with the campsite in Figure 14.

2.4.4 Constructions

The campsite at the terrace base is in Figure 7. Figure 14 shows it that year with Alfred Burton's camp. The bivouac in this view is unthatched and lying between a tent fly and the terrace. It is possibly a makeshift darkroom, although the non-potable lake water was not used for film processing (Williams, 1979) [12].



Figure 14. 1886 view of White Terrace campsite (Inset from Burton, Te Papa MA1062706).

2.4.5 Problems with Intervisibility

The central north island is hilly country as Hochstetter found when seeking landmarks during his survey. He often left the line of march to climb peaks for bearings. The Rotomahana Basin has surrounding high country hampering intervisibility. The new crater lake reaches nearly 40 m above the old. Other researchers ignored basin altimetry and their two-dimensional findings often fail altimetry checking (Keam, 2016) [8]. Some investigators associated trig stations with Hochstetter's landmarks, ignoring these post-dated Hochstetter's visit and the 1886 eruption. Error compounded with the adoption by recent workers of an altimetry guessed by Ron Keam. An example is Te Kumete which on Topo50 mapping is marked with Trig 3058 and is taken by some to mark Te Kumete as Hochstetter saw it (Lorrey & Woolley 2018b) [5].

Our bearings are tested with Elevation Profiling to ensure intervisibility across the altered landscape. Ignored by other researchers, there is a second trig station on Te Kumete. These are shown in Figure 15 i.e., 3058 and ALQC. Trig 3058 is on the Topo50 map while Trig ALQC (Te Kumete) is older, unbeaconed and overgrown. Trig 3058 is on the north side of Te Kumete, beacons and more visible from the north. ALQC is on the south side of the 540 m contour and shows south to Hochstetter's stations. Elevation Profiling shows trig 3058 was likely not intervisible to Hochstetter or Crawford. Every sightline and bearing around the Rotomahana Basin requires intervisibility checks due to foothills and eruption landforms. Crawford's plate is a reminder those working in the Rotomahana Basin must think in four dimensions i.e., Latitude, Longitude, Altitude and pre- and post-1886 Time.



Figure 15. Trig Stations 3058 and ALQC on Kumete Ridge (Simonsen, LINZ).

3. Results

The findings are reported here in the sequence presented in the Methods section.

3.1 Photointerpretation

3.1.1 Composition

The Crawford dry-plate negative, despite its fractures offers unique insight into the Kumete Ridge—the Tūhourangi food bowl with land access to tribal lands. Their paths from Te Wairoa, Piripai and Kokotaia crisscrossed the ridge when weather conditions prevented water access or for transport of bulky items unsuited for dugout canoes. The ridge tracks facilitated their proprietorship of the Pink and White Terraces and the tourist boom from 1870–1886.

The Crawford photograph was exposed in early 1886 when Alfred Burton also visited. Comparing two of his photographs with Crawford's we can use terrace foliage to triangulate from their campsite, across the terrace to Crawford's camera on the southern Terrace. Establishing this location enables us to reconcile landmarks in the photograph with period mapping and today's Topo50 map, as well as Google Earth. Key features in the foreground include Te Mamaku, foliage, specific basins and the Kaiwaka and Tūhourangi paths. Higher up on the ridge we see more paths and the skyline peaks as they appeared to Hochstetter.

3.1.2 Flora and Fauna

Crawford illustrates the monoculture of *Pteridium esculentum* fern along the ridge. His relatively short exposure time was still too long

to capture the abundant avian life moving across the landscape.

3.1.3 Te Mamaku

Te Mamaku correlates with the Kaiwaka section identified. It also provides information on meteorological conditions at the time of exposure. Crawford shot at a time when the lake was low. This is seen in the photograph where the lowest portion of the terrace apron is exposed as the Kaiwaka depth and width receded. Maps earlier when the lake was at a higher level, show this vegetation in midstream, before being engulfed by the extending terrace. The increase in exposed terraces indicates the growth of Tarata over the tourist period. In future, this may allow estimates of the terrace growth to be calculated.

3.1.4 Seated Figure

Despite enquiries to the Tūhourangi Tribal Authority and the Rangiheuea family, we are unable to identify Crawford's companion as Akutina Rangiheuea. A male Guide was unusual in 1886.

3.1.5 Meteorological Conditions

The inclusion of Te Mamaku enabled estimates of the wind force and direction and the dew-point. By examining the shadows, we can gauge the time of day for the exposure and estimate the camera position and distances to the ridge and peaks.

3.2 Photogrammetric Optics

This research is based on a dry-plate glass negative. Most terrace

negatives have not survived. This negative was digitally converted to a positive image by curator Dudley Meadows, without embellishment under the FADGI code. I expected to deduce the lens focal length and optics as we started from the negative but standard equations have not yielded answers. The angle of view indicates a standard 254 mm lens may have been used but I could not resolve the photogrammetric optics except to suggest a wider-than-standard lens may have been used. Crawford produced an outstanding photograph that was never bettered.

3.3 Topography and Parallax

3.3.1 Kumete Ridge

This first in-focus anterior view of the pre-eruption Kumete ridge topography completes our understanding of this important ridge. We now relate today's topographic mapping and the Google Earth digital elevation model (DEM) three-dimensional view of the terrain, to the pre-eruption conformation of the ridge. We can examine each ridge, spur and reentrant where Hochstetter trod and on which he took bearings, and correlate these with the pre-eruption shape and elevation of the landform. This gives an optimal view of the terrain, elevation, slope, and vegetation.

3.3.2 Parallax Effect

In Figures 1 and 10, Crawford's camera position is opposite Te Kumete, to the southeast. It is about 125 m from the centre of Tarata Spring. A Skyline Gauge is constructed along Kumete Ridge with the scale connecting Peaks A and Te Kumete. Crawford's scale and indicator are shown in Figure 10. With the 8" axis of the digital image (including the plate-holder border) scaled at 8", the inter-peak gauge distance is 9.4 cm. Point X is at 6.2 cm. The scale on Google Earth is better visualised with a gauge distance of ~14 cm i.e., to visualise peaks, valleys and spurs. As our interest lies with the skyline, the plate gauge is translated to Google Earth at 14 cm with an inflation factor of 1.489 i.e., to equilibrate the scales. Point X on Crawford is now located on Google Earth at 9.2 cm on the gauge (versus 9.23 cm as calculated).

Peak X is the ridge termination along the diagonal in Figures 10, 11 and 16 and forms the gauge indicator. Next, the White Terrace location estimates by the 1886–2024 generations of researchers are plotted on Google Earth. The published claims include guesses, sketches and large markers on small graphics. Rarely are coordinates or altitudes given as in Table 1. This collection of sites is then connected to Te Kumete by the orange rays in

Figure 17. The green rays mark the angle of view. Crawford's estimated camera position calculated from cartography, optics and photointerpretation is marked with a blue error ellipse in Figure 16 and a blue arrow in Figure 17.

While colonial surveyors claimed the terrace locations lay in the lake and were destroyed ... an inter-university panel comprising three professors i.e., Sir Algernon Phillips Withiel Thomas (1857–1937), Frederick Douglas Brown (1851–1922) and Frederick Wollaston Hutton (1836–1905) was recruited by the government to report on the Tarawera Eruption. They gave disorganised, untimely reports. The panellists publicly demurred on the Pink and White Terraces but the ex officio head privately expressed his opinion. Payton quotes Thomas as Warbrick, Thomas and he stood on the White Terrace location soon after the eruption: Payton said, "We are standing on Te Tarata now." Warbrick said: "That is just what I say, and had I GBP1,000 I would stake it on the Terrace being only buried beneath us." "Professor T---- [Thomas ARB] declined to speak decisively, as he said he did not like to go against the opinions of the surveyors" (Payton, 1888) [27]. Other investigators publicly disagreed with the government surveyors, instead placing the Tarata spring on land or the shoreline. These include the first claimants Alfred Warbrick (with Arawa kaumātua) in 1886, 1934 and 1936; Edward Payton in 1888, Cheryl Winner at WHOI in 2012, Herby Fitzgerald in 2014, Bunn & Nolden in 2016, 2018 and 2023, and Lorrey & Woolley (2018a) in 2018 [2,3, 34]. This latter paper shows Lorrey & Woolley's first attempt (while at the PAWTL2 Project) was better than their second which stands refuted (Bunn, 2020a) [24]. The northern cluster of sites about our sixth Hochstetter survey iteration includes all our iterations of Hochstetter's survey over 2016–2023. Other rays in Figure 17 are survey bearings.

To begin the parallax analysis, we centre Crawford's calculated position on Google Earth in Figure 16, at the intersection of the two green rays. The eyeline is at 344 m a.s.l. close to the water surface at ~340 m and Crawford's camera altitude at ~327 m. Given the eruption ejecta lying over the lake shores, peak A is obscured and is marked by a black bar. The scale is calibrated at 14 cm and the indicator is at 9.2 cm. In Figure 17, the two clusters of claimed terrace locations are marked by yellow ellipses—a northern and a southern cluster. Also, the right triangle of peaks has green markers.

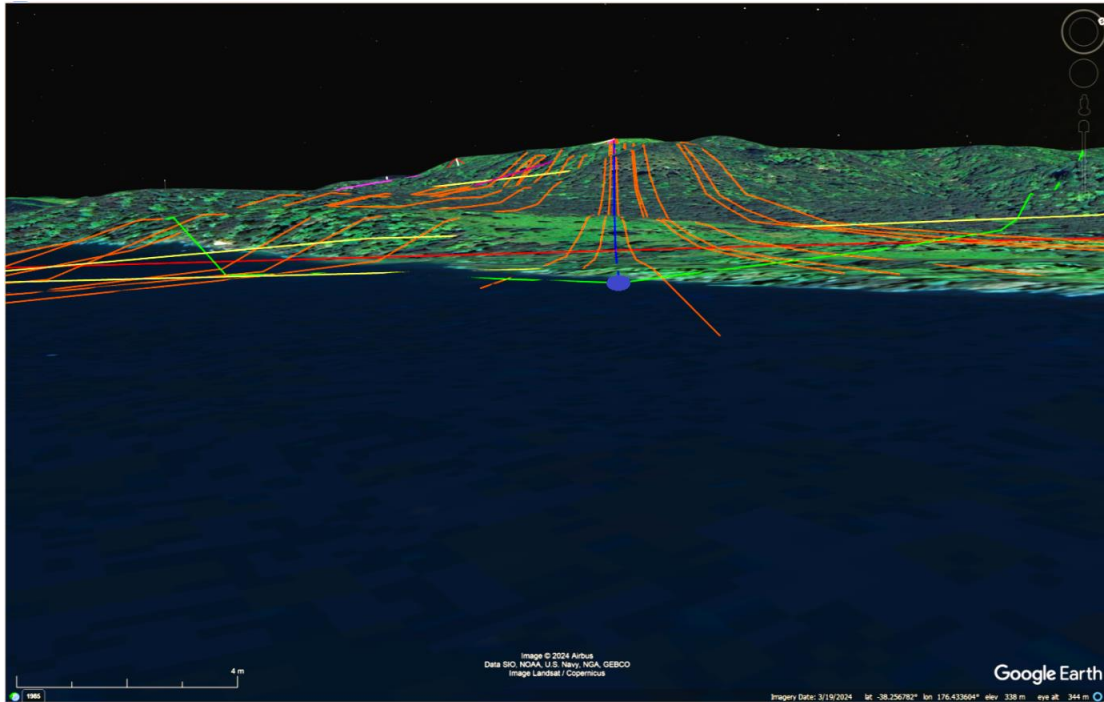


Figure 16. Reproducing Crawford’s field of view of Kumete Ridge. Colour rays are survey bearings.

We scroll the perspective to examine each location in the clusters, holding altitude and orientation on Te Kumete and checking calibration. In the northern cluster, the outlier is Lorrey & Woolley

(2018a) in 2018 [4]. Their indicator rests on 7.1 cm. The northern and southern clusters are enumerated in Table 2.

Gauging the Claimed White Terrace Locations 1886-2024					
(All readings at 344 m a.s.l. altitude)					
<u>Researchers</u>	<u>Year</u>	<u>Gauge Scale</u>	<u>A-Point X</u>	<u>Approx. error to</u>	
		<u>A-Te Kumete cm.</u>	<u>on Scale cm.</u>	<u>Crawford m.</u>	<u>Datum</u>
Crawford plate	1886	9.4	6.2	0	South Terrace
Crawford (inflated)	1886	14	9.23	0	South Terrace
Crawford (GE)	1886	14	9.2	0	South Terrace
Lorrey & Woolley I	2018	14	7.1	417	Not stated
Lorrey & Woolley II	2018	14	11.4	331	Not stated
Winner WHOI	2012	14	7.5	250	Not stated
Warbrick & Payton	1886–1940	14	9.0	44	Not stated
Bunn & Nolden I	2016	14	9.3	18	Tarata Spring
Bunn & Nolden II	2017	14	9.2	42	Tarata Spring
Bunn	2019	14	8.4	124*	Tarata Spring
Bunn & Nolden III	2023	14	8.4	124*	Tarata Spring
Fitzgerald	2014	14	8.7	289	Not stated
Smith, Harding & Thomas	1894	14	10.0	317	Not stated
IGNS/WHOI/NOAA/Waikato	2011–2023	14	10.6	343–439	Not stated
Bell & geologists	1906	14	11.2	387	Not stated
Keir	2014	14	11.3	330	Not stated
Keam	2016-2018	14	11.5	416	Not stated
Hook & Carey	2019	14	12.0	461	Tarata Spring

* Crawford used a different datum, hence the variance measures the inter-datum distance.

Table 2. White Terrace locations gauged by parallax.

In the northern cluster, the closest positions to Crawford's blue arrow and ellipse are Warbrick, Payton, Bunn & Nolden 2016 and Fitzgerald. Now we move to examine the southern group of locations marked by the cluster of orange rays in Figure 17. Two

rays are joined with a short white line. This contains the locations claimed by IGNS et al for the White Terrace over 2011–2023. No coordinates were given by this group and these are estimated from sketched markers.

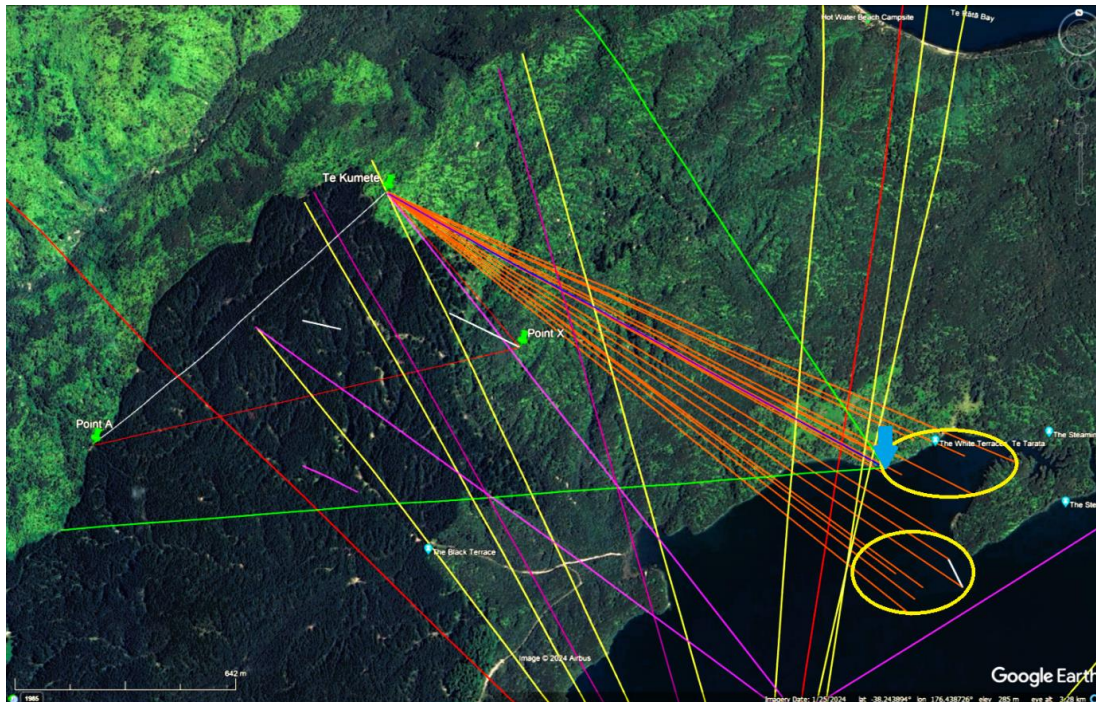


Figure 17. The 1886–2024 White Terrace locations claimed by generations of researchers (Bunn).

In Figure 18 the IGNS series is centred. The indicator X shifts to 10.6 cm on the scale. This series and all other locations in the southern cluster are distant from Crawford's position.

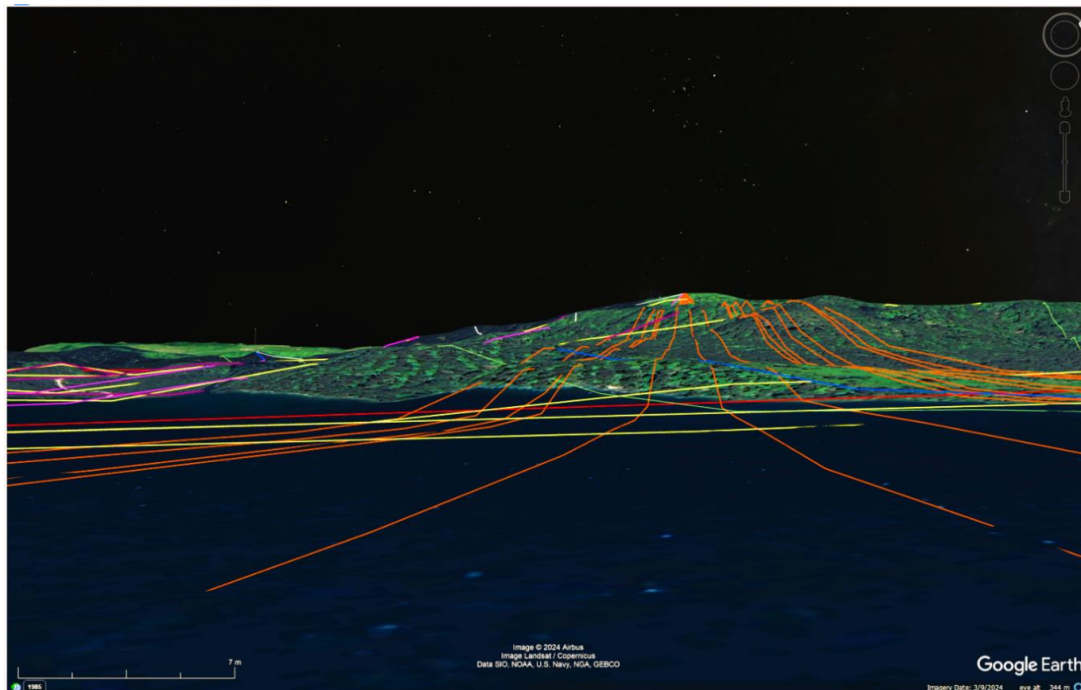


Figure 18. Viewing the Skyline Gauge from between IGNS positions (Bunn).

Further south, we arrive at the group of locations chosen by Lorrey & Woolley (2018b), Keir and Keam in Figure 19 [5]. The scale indicator rests on 11.5 cm versus the target point at 9.2 cm. This group of locations have worse errors.

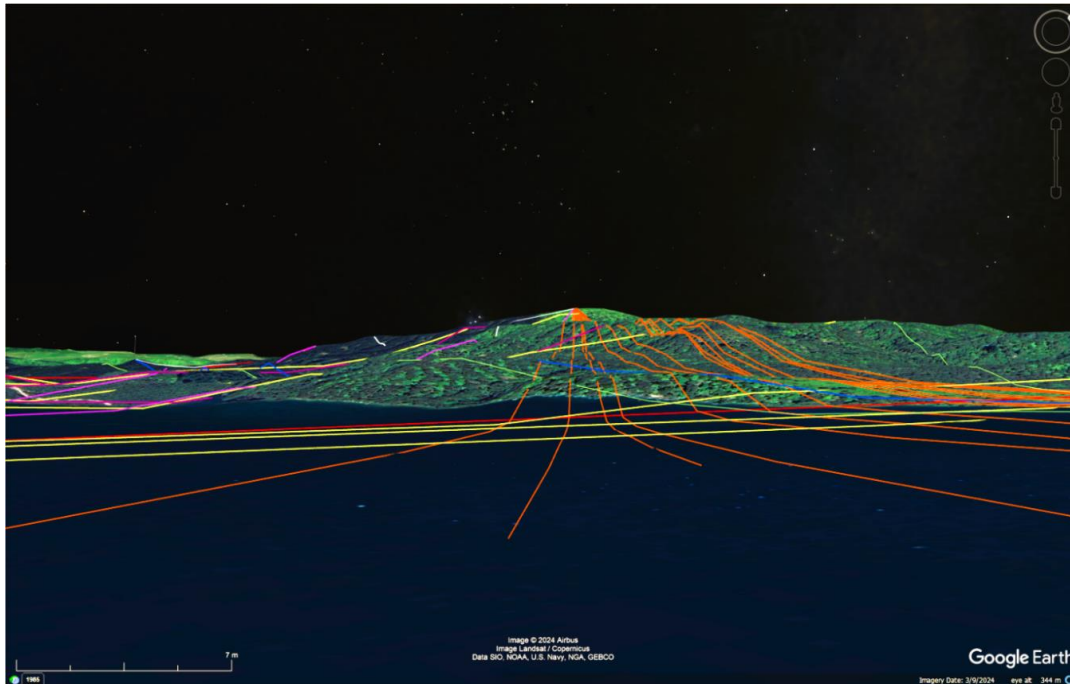


Figure 19. Viewing the gauge from the NIWA, Keir and Keam positions (Bunn).

The southern outlier is Hook & Carey in Figure 20. Their location measures 12.0 cm on the scale and has the worst error.

The researchers close to Crawford are Warbrick, Payton, Bunn & Nolden and Fitzgerald. Given the Hochstetter survey's Sixth

Iteration location is also consistent with Crawford, we conclude the northern site cluster is more accurate than the south and that the White Terrace spring lies along the shoreline, consistent with recent topographic research (Bunn, 2023c, d) [28,29].

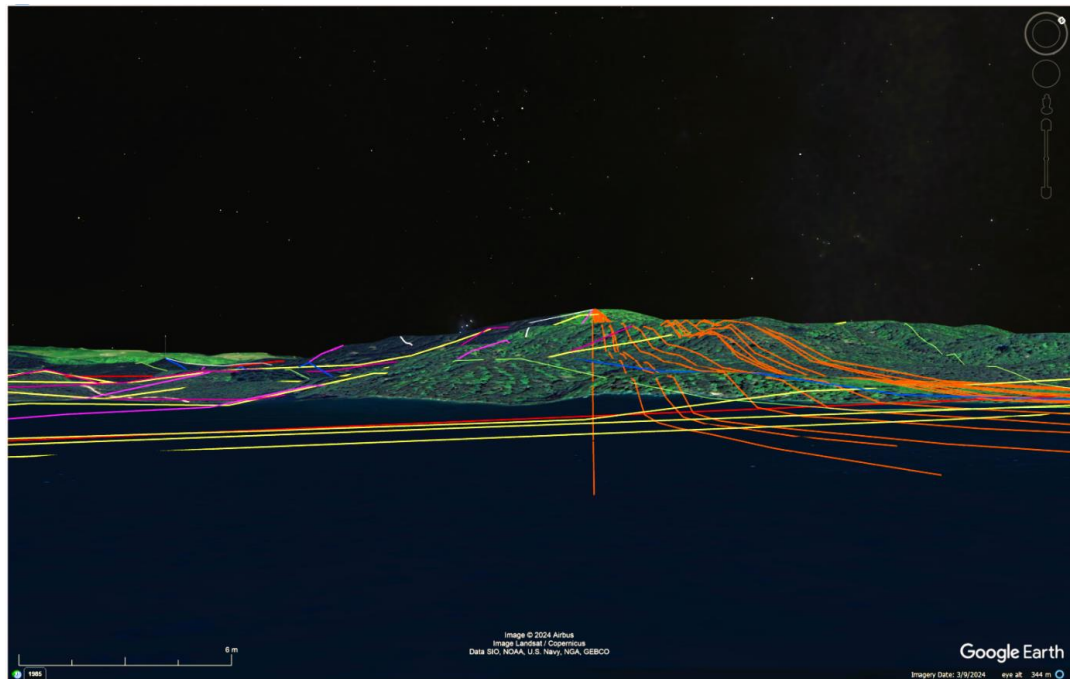


Figure 20. Viewing the gauge from the Hook & Carey position.

3.3.3 Kumete Ridge—Pre- and Post-Eruption Perspective

The evidence herein supports the finding that key pre-eruption features along the Kumete Ridge survived the 1886 eruption more or less intact, albeit with diminishing ash cover as weathering reveals the landform. While some of Hochstetter’s peaks are not intervisible from the White Terrace, Te Kumete is intervisible with Crawford’s location as well as Hochstetter’s stations. There is sufficient pre- and post-eruption agreement to judge the parallax analysis as reliable.

3.4 Forensic Cartography

The significant landmarks from Hochstetter’s survey and mapping tally with those in Crawford’s two photographs i.e., Te Kumete, Kaiwaka Channel, Terrace basins, foliage, Te Mamaku and the Tūhourangi paths. Digital elevation mapping and period mapping from Hochstetter and Petermann are consistent with the empirical findings. The estimated distances Te Kumete–camera from large-scale pre-eruption maps are shown in Table 3.

Forensic cartography and Crawford's Camera Location			
Map	Date	Te Kumete Azimuth	Distance to Camera
Hochstetter II	29/4/1859	307°	~1,850 m
Hochstetter III	30/4/1859	305°	1,675 m
Hochstetter III georeferenced	30/4/1859	305°	1,700 m
Petermann	1864	~310°	1,445 m
Crawford (via angle of view)	1886	305°	1,701 m

Table 3. Estimated distances from Te Kumete to Crawford’s Camera Position.

Of these data, the most reliable map is Hochstetter’s April 30 version. The actual distance appears at 1,700 m ± 25 m. Hochstetter initially transposed Mamaku and Poroporo and corrected this on

his April 29 map. In Figure 21 the relative positions of Crawford, Te Mamaku, Poroporo and the Kaiwaka loop are shown.

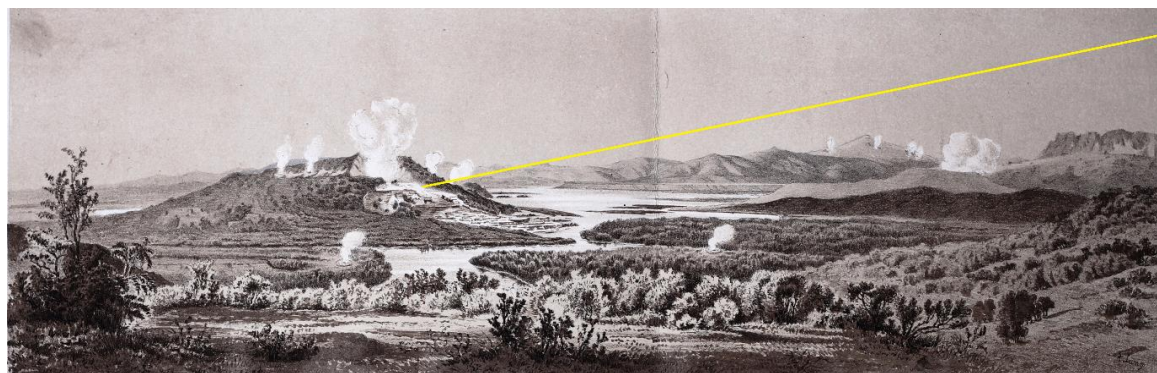


Figure 21. Poroporo (left) and Mamaku (right). Plate 9 no. 5 from Hochstetter (1867).

In Figure 21, the yellow ray shows the approximate axis of Crawford’s camera on Te Kumete relative to Te Mamaku and the Kaiwaka Channel loop.

4. Discussion

The Crawford photograph is significant as it is the first to detail the most proximal surviving landform to the White Terrace. Kumete Ridge survived the 1886 Tarawera eruption and remains virtually intact. While it is covered in ejecta from the Rotomahana Basin lakebeds much of this has eroded back into the crater Lake Rotomahana and the Wairua Stream gully. While we have identified other proximal landmarks e.g., Te Rangipakaru, this was located at ~2,000 m from the Tarata spring and was degraded by the eruption. Also, Kumete at 1,200–1,700 m provided multiple survey bearings for the first terrestrial survey in the region and its surviving peaks are important today when reconstructing the

survey and navigating the Basin.

These empirical findings support the Hochstetter Paradigm for the location of the White Terrace. They provide a further layer of evidence that the conventional New Zealand history of the Rotomahana Basin was incorrect in 1886 and remains so today.

The empirical Skyline Gauge developed for this paper has no connection with the Hochstetter survey yet agrees with Hochstetter survey findings and is consistent with the Hochstetter Paradigm. It is derived from Crawford’s image and translated to Google Earth Pro. The empirical findings derive from the architecture of Kumete Ridge. That is why Crawford’s photograph is so important.

In Figure 17, the clusters in this meta-analysis reveal the nature of the debate over the White Terrace. The northern cluster claims are all from the private sector. The southern sector claimants (with

one possible exception) are all from the public sector. Student's t-testing records significant differences between the clusters, suggesting they are from different populations ($p < 0.0001$).

This clustering schism illustrates the post-1886 debate over the Terraces is not so much scientific as ideological. This is echoed by Prof. Thomas herein where he defers to the General Survey Office. Integrity became compromised in New Zealand science. In 1886, the science advisor Sir James Hector KCMG (1834–1907) was sent to report on the eruption. His report was unacceptable and the task was passed to the General Survey Office and later to an inter-university Earth Sciences panel. Surveyors may have little remit for volcanism and their power derived from the sequestration of Māori land for immigration. The Survey Office report by Stephenson Percy Smith (1840–1922) was heavily pictorial.

Given this public versus private sector debate, the resolution may rest with the Māori as they reclaim the Rotomahana Basin. The Hochstetter Paradigm provides the topography and the bridge to 1886 as they resume ownership, reidentify the landscape and restore toponyms.

Acknowledgements

This final eighteenth research paper on the Rotomahana Basin and Te Tarata (The White Terrace) owes much to my colleague Dr Sascha Nolden, the downunder authority on the life and times of Ferdinand von Hochstetter, who reviewed the manuscript. Dudley Meadows kindly supplied the Crawford digital positives and gave technical and optics advice on the fractured Crawford plate negative. Rangitihi Pene has advised on the Tūhourangi history in the Rotomahana Basin, from the first day.

Conflict of interest

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

Funding

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

References

1. Bunn, R., & Nolden, S. (2016). Te Tarata and Te Otukapuarangi: Reverse engineering Hochstetter's lake rotomahana survey to map the Pink and white terrace locations. *Journal of New Zealand Studies*, (23), 37-53.
2. Bunn, R., & 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(1), 39-56.
3. Lorrey, A. M., & Woolley, J. M. (2018). 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 Tuhourangi Tribal Authority and PAWTL2 Project Team* (Rotorua). doi, 10.
4. Lorrey, A. M., & Woolley, J. M. (2018). Locating Relict 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.
5. Bunn, A. R. (2014, May). Raising the tattooed rock-A tourism proposal of national significance. In *Conference: Plenary Meetings of the TTA and PAWTL Project, Rotorua, NZ*.
6. de Ronde, C. E., Caratori Tontini, F., & Keam, R. F. (2019). Where are the pink and white terraces of Lake Rotomahana?. *Journal of the Royal Society of New Zealand*, 49(1), 36-59.
7. Keam, R. F. (2016). The Tarawera eruption, Lake Rotomahana, and the origin of the Pink and White Terraces. *Journal of Volcanology and Geothermal Research*, 314, 10-38.
8. Keir, B. (2019). The location of the Pink and White Terraces of Lake Rotomahana, New Zealand. *Journal of the Royal Society of New Zealand*, 49(1), 16-35.
9. Hook, G., & Carey, S. (2019). Relocating the Pink and White Terraces of Lake Rotomahana, New Zealand: resolving the 'battle of the maps'.
10. Mundy, D. L. (1875). Rotomahana and the boiling springs of New Zealand: a photographic series of sixteen views by DL Mundy; with descriptive notes by Ferdinand von Hochstetter, professor of the Polytechnic Institution of Vienna.
11. Williams, M. (1979). *Charles Blomfield*. A.H. & A.W. Reed.
12. Hall, K. (2004). *George D. Valentine: A 19th Century Photographer in New Zealand*. Craig Potton Publishing.
13. Hochstetter, F. V., (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.
14. Bunn, R. (2023a). Coanda and Venturi Effects at the Eighth Wonder of the World the White Terrace— Resolving the East Wind eruptions at the White Terraces. *J Environ Sci Curr Res*, 6, 044.
15. Dallmeyer, J.H. (1874). *On the choice and use of photographic lenses*. E. & HT Anthony & Company.
16. Bunn, R. (2019). Photographic embellishment and fakery at the Pink and White Terraces. *New Zealand Legacy*, 31(1), 5-10.
17. Bennett, W. (1954). The Eruption of Mount Tarawera, New Zealand Broadcasting Service.
18. Bunn, A. R., (2023). Identifying and Dating the White Terraces: New Zealand's Eighth Wonder of the World and the 1886 Rotomahana Basin Hydrology. *Authorea Preprints*.
19. Knight, H. (1971). *Photography in New Zealand: a social and technical history*. J. McIndoe.
20. Robinson, S. (2024). 'Crawford, William Fitzgerald', *Dictionary of New Zealand Biography*, first published in 1993. Te Ara - the Encyclopedia of New Zealand, accessed.
21. Ask, R. E. (1943). *Elements of Photogrammetric Optics, Manual of photogrammetry*, American Society of Photogrammetry, 2nd ed. 1952.
22. Langford, M. (2010). *Basic Photography*, Focal Press, Oxford, 397.
23. Bunn, R. (2020b). Commentary: Locating Relict Sinter

-
- Terrace Sites at Lake Rotomahana, New Zealand, With Ferdinand von Hochstetter's Legacy Cartography, Historic Maps, and LIDAR. *Frontiers in Earth Science*, 8, 68.
24. Bunn, A. R. (2020). Reconciling new and old surveys of the Pink and White terraces. *Surveying+ Spatial*, 102, 29-36.
 25. 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*, 5204.
 26. Payton, E. W. (1888). *Round About New Zealand*, Chapman & Hall, London.
 27. Bunn, A. R. (2023c). Resolving the 1886 White Terraces riddle in the Taupō Volcanic Zone. *Frontiers in Earth Science*, 11, 1007148.
 28. Bunn, A. R. (2023). The Eighth Wonder of the World in New Zealand: Seismic studies confirm the new Hochstetter paradigm. *Smart Tourism*, 4(1).
 29. Fitzgerald, H. F. (2014). *The pink and white terraces revisited: an account of ten years of research on Mount Tarawera Lake Tarawera and Lake Rotomahana: answers to how the pink and white terraces disappeared and the long lasting mysteries surrounding the volcanic eruption of 10th. June 1886*, H. F. Fitzgerald, Levin.
 30. Keam, R. F. (1961) *Tarawera Eruption*, (1st and 4th edns.). Keam, Auckland.
 31. Warbrick, A. (1934). *Adventures in Geyserland*. Dunedin: Reed, 88–89.
 32. Bunn, A. R., and Nolden, S. (2023). Ferdinand von Hochstetter's November 1860 Folio of New Zealand survey data and the location of the Pink and White Terraces. *Journal of Humanities and Social Sciences*, 6(8), 248-268.
 33. Bunn, A. R., and Nolden, S. (2023). Ferdinand von Hochstetter's November 1860 Folio of New Zealand survey data and the location of the Pink and White Terraces. *Journal of Humanities and Social Sciences*, 6(8), 248-268.

Copyright: ©2024 A Rex Bunn. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.