JOURNAL OF
Pacific
Archaeology

– ARTICLE –

Locating the Pā Sites from Hartley Ferrar's Geological Maps

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Abstract

This paper explores the history of Hartley Ferrar's early 20th-century geological maps to identify the location of Māori pā sites in Te Tai Tokerau Northland, Aotearoa New Zealand. Although in regular use, Ferrar's maps represent an underexplored resource, revealing over 530 potential pā sites, including many not recorded in the national ArchSite database. The research leverages modern techniques such as georeferencing, manual digitisation, machine learning, and LiDAR analysis to locate sites and suggest possible locations for future surveys to identify unrecorded sites. It highlights the significance of combining historical cartographic data with advanced spatial technologies. The findings underscore the value of Ferrar and his team's meticulous mapping and use of local informant knowledge for understanding the region's cultural landscape, while also addressing challenges posed by landscape change, data quality, and evolving definitions of pā. The ongoing work contributes to heritage management, offering robust tools for site preservation and emphasising the need for continued field validation and collaboration with iwi and hapū. Ferrar's legacy persists through the enduring relevance of his maps for archaeological and cultural research in Aotearoa New Zealand.

***Keywords*:** Geological maps; New Zealand Archaeology; Māori pā sites; Hartley Ferrar; Cultural heritage management

To cite this article:
Bickler, S.H. and B.D. Jones. 2025. Locating the Pā Sites from Hartley Ferrar's Geological Maps. Journal of Pacific Archaeology, 15(1): Article 14:1-18. DOI: https://doi.org/10.70460/jpa.v15i1.388

Submitted: 15/10/2025, Accepted 10/12/2025, First online 18/12/2025

The Journal of Pacific Archaeology is a peer-reviewed open access journal published by the New Zealand Archaeological Association

1. Introduction

Despite decades of archaeological site surveying using various techniques and technologies, new major archaeological sites continue to be discovered in Aotearoa New Zealand (Aotearoa hereafter). The management of these treasures is crucial and identifying them is an essential part of archaeology's role in Aotearoa (Bickler 2018:55). While historical plans, aerial and satellite photography and maps have long been relied upon in archaeological and historical research (e.g., Jones 1994), their availability and accessibility online have sparked renewed interest in their use. This renewed interest goes beyond traditional georeferencing and manual digitization techniques (see McCoy 2017, 2021), with new methods utilizing machine learning and other techniques to extract various types of historical data from these sources (e.g., Uhl *et al.* 2018, Gobbi *et al.* 2019). The systematic use of these sources is essential, "[l]eaving out chances to add to the map is bad archaeology." (McCoy 2020:54).

This paper presents ongoing research into the location of pā, Māori fortified sites, that were recorded in the 1920s and 1930s during geological surveys conducted in the Te Tai Tokerau Northland (Te Tai Tokerau hereafter) region of Aotearoa. While many of these sites are well-known and have been documented through oral histories, local knowledge, and the national database of archaeological sites maintained by the New Zealand Archaeological Association (NZAA) ArchSite, the maps created by the geologists have not been systematically examined, and many of the sites they recorded have yet to be formally identified. The identification and preservation of these sites can help to enhance our understanding of Māori history and the ways in which Māori communities have interacted with their environment over time.

The Te Tai Tokerau region is a vast area that includes dense forests and remote locations that are difficult and costly to access. Despite the long history of archaeological research in the area, an examination of the site records (e.g., Bickler 2021) reveals that many sites were recorded through oral history, local informants, or archival records. Sites that were previously visited or located by archaeologists have often not been revisited or found subsequently, and their precise locations or full characteristics have not been accurately recorded. Compounding the issue, the ongoing effects of natural and human activities have obscured or destroyed some of these sites or parts of them, making them inaccessible or damaged. These factors have contributed to a significant gap in our understanding of the archaeological sites and cultural heritage of the Te Tai Tokerau region.

To address this knowledge gap, ongoing research is being conducted to systematically examine the geological survey maps and identify pā sites that have not yet been formally identified. This research involves a range of techniques, including ground-truthing, LiDAR (light detection and ranging) analysis, and geospatial analysis, to help identify potential pā locations and confirm their presence on the landscape. The use of LiDAR data in combination with Geographic Information Systems (GIS) can greatly aid in the identification of archaeological sites and features in Aotearoa (Jones and Bickler 2017, 2019, Hagan and Brown 2019, Bickler and Jones 2021) as it has worldwide (e.g., Chase *et al.* 2014, Evans 2016, Quintus *et al.* 2017, Rostain *et al.* 2024). However, the quality of the underlying LiDAR data is crucial to the success of

this approach. When the quality of the data is good, the identification of archaeological sites and features using LiDAR with GIS can be relatively easy (Bickler and Jones 2021, Jones and Bickler 2017, 2019). The use of the historical plans provides a useful starting point for that research.

2. Hartley Ferrar's Geological Plans

Hartley Ferrar was a young Irishman who grew up in South Africa and later went on to become a distinguished geologist. After graduating from the University of Cambridge, Ferrar joined Captain Robert Scott's first expedition to Antarctica in 1901, where he conducted geological surveys (Brook and Ferrar 2019:48-49) and which included a brief stay in New Zealand. Following his time in Antarctica, Ferrar journeyed to Egypt where he would spend nearly a decade conducting research before returning to New Zealand in 1914. During World War I, he served with the New Zealand Expeditionary Force between 1917-1919 in the Middle East. After returning to New Zealand, he joined the Geological Survey and began his extensive work on the geology of the country (Brook and Ferrar 2019). Although the contributions of Hartley Ferrar to geology in New Zealand have been recently discussed by Brook and Ferrar (2019), the historical value of his maps has received less attention. Two sets of geological maps produced by Ferrar for the New Zealand Geological Survey in 1925 and 1934 (Figure 1) have become invaluable resources for archaeological work in the north Auckland and Te Tai Tokerau region.

Covering thirty-six "survey districts" that span from the Kaipara Harbour and Hauraki Gulf to the Bay of Islands, these maps offer not only an introduction to the underlying geology of the region but also provide detailed information on other features such as roads, homesteads, rifle pits, whare (houses), and pā (fortified Māori settlements). Ferrar and his colleagues' meticulous work has resulted in maps offering a snapshot of local settlement, documenting the historical development of the landscape through the names of places and other details. However, we know little about the sources of information regarding the archaeological sites they identified. The Geological Survey's campsite locations are often shown on the draft geological plans and tracing the paths taken may provide more context to both the geological and heritage recording that resulted.

These maps have proven to be an essential tool for archaeologists working in the region. By examining Ferrar's maps, archaeologists have been able to identify and locate previously unknown sites, as well as gain a better understanding of the historical context of known sites. For example, in their study of Māori fortified sites in Te Tai Tokerau, Bickler and Jones (2021) leveraged Ferrar's maps to identify potential sites and confirm the state of known sites using newly available LiDAR data.

Ferrar's maps offer a unique window into the past, providing important insights into the historical development of the region and the settlement patterns of its inhabitants. They are a testament to Ferrar's skills as a geologist and cartographer and continue to be a valuable resource for researchers today.

3. Georeferencing and digitising the Pā

In previous research on the Ferrar maps, Bickler and Jones (2022) had utilized Machine Learning (ML) to aid in identifying the pā symbols and names. However, the recent availability of geo-rectified versions of the maps, along with the original field sheets used to create the published versions, has made it easier to locate the pā symbols manually. This has allowed for a more detailed exploration of the differences in the recording of heritage places between the field sheets and the final published versions. While not all the published versions of the maps were available online, the researchers were able to manually geo-rectify them to match the field sheets.

Bell and Clarke's geological maps from 1909, which covered three survey districts adjacent to those surveyed by Ferrar and his team, were also included in the analysis to allow for comparison of archaeological recordings (Figure 1). The Ferrar maps were used to identify the location of more than 530 possible pā sites, with over 170 sites not being obviously associated with records in the NZAA ArchSite database (Figure 2, Table 1). However, the accuracy of the location data for both ArchSite and the Ferrar maps is not always certain, as previously noted by Bickler (2018:60) and Bickler and Jones (2022). See Table 1 and more detailed view of the results for the Kai Iwi and Kaihu Survey Districts in figure 3. Additionally, while some peaks were named and identified as pā sites on the maps, other named locations were not labelled as pā although they are recorded in ArchSite now and likely to have been known locally as such when the Geological Survey went through.

In Aotearoa, pā sites typically refer to settlements usually but not always fortified that were built by Māori in pre-European times although they evolved significantly with the arrival of Europeans and access to muskets (Anderson 2016, Davidson 1987, Prickett 2016). These sites were constructed on prominent hilltops or other strategic locations to provide natural defensive advantages, such as clear visibility and difficult access. Pā sites were often surrounded by palisades made of timber and/or earthworks, and they served as places of refuge during times of conflict or warfare. Many pā sites are still visible today as archaeological features, and they are significant cultural and historical landmarks in New Zealand.

Approximately two-thirds of the over 530 possible pā site locations identified on the Ferrar maps could be correlated to sites in ArchSite, although not all were recorded as pā (Bickler and Jones 2022). This discrepancy may be due to the absence of defensive features when recorded in the field or in aerial photographs, or to differences in definitions of pā between archaeological and mana whenua perspectives (Walton 1999:47). Ferrar may have been recording named places as pā, which does not necessarily require defensive elements, while archaeological definitions typically include ditch and banks and/or palisading. Moreover, the functional nature of a place may have changed over time. Nevertheless, the presence of pā symbols on the maps, likely provided by local Māori informants, is valuable for understanding the cultural and historical landscape (Bickler and Jones 2022).

Figure 1: Index of geological survey districts covering Northland and Auckland, showing areas covered by Bell and Clarke (1909) in volume 8, Ferrar (1925) in volume 27 and Ferrar (1934) volume 34 (Image from Ferrar 1934 Index sheet).

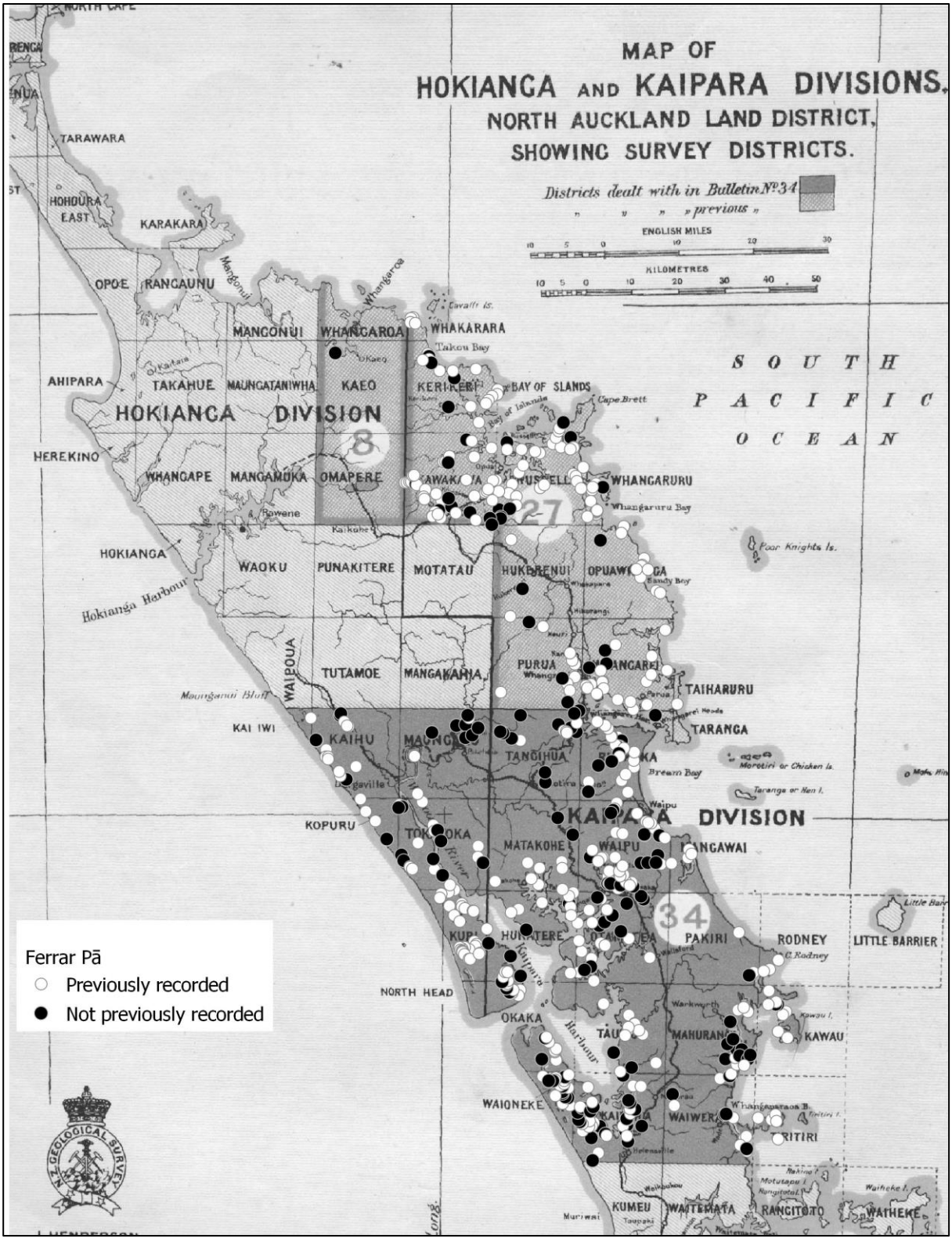

Figure 2: Location of pā that have been previously recorded (white dots) and pā that have not yet been previously recorded (black dots). Areas corresponding to the Bell and Clarke (1909) and Ferrar (1927 and 1934) surveys.

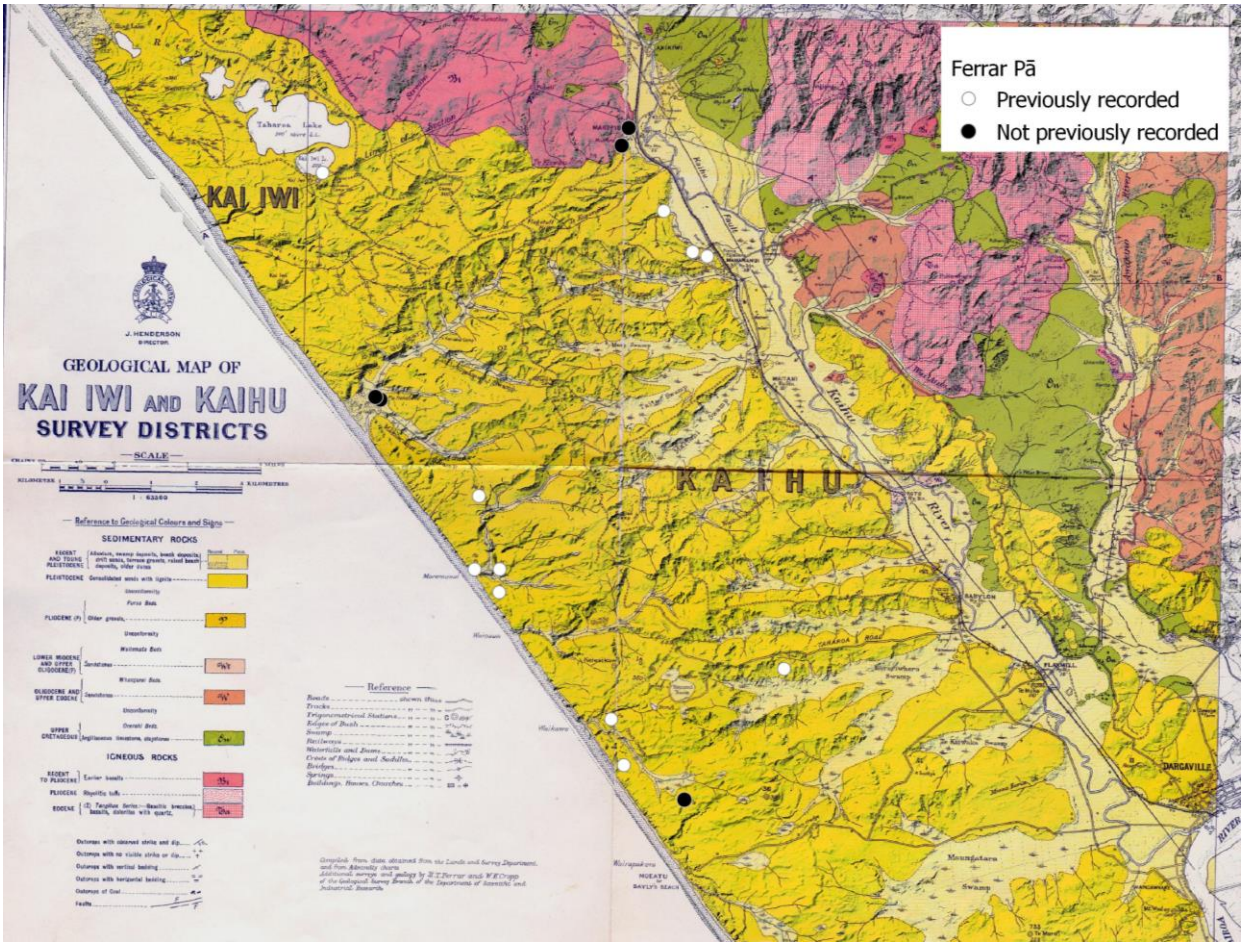

Figure 3: Geological map overlay of Kai Iwi and Kaihu Survey Districts, as originally published by Ferrar (1934), has been layered with the LiDAR hillshade to provide topographic relief. The locations of pā sites have been included on the map.

Table 1: Geological survey districts and number of pā sites not recorded and probably previously recorded in NZAA's ArchSite Database.

Survey District	Bulletin No.	Pā not in Archsite	Pā in ArchSite	Total
Bay of Islands	27	1	4	5
Hukatere	34	5	13	18
Hukerenui	27	1	2	3
Kai iwi	34		1	1
Kaihu	34	5	10	15
Kaipara	34	20	21	41
Kawakawa	27	9	32	41
Kawau	34	2	7	9
Kerikeri	27	4	14	18
Kopuru	34	1	3	4
Mahurangi	34	9	7	16
Mangawai	34		4	4
Matakohe	34	2	8	10
Maungaru	34	7	3	10
North Head	34			
Okaka	34	6	12	18
Opuawhanga	27	1	10	11
Otamatea	34	11	15	26
Pakiri	34	1	2	3
Purua	27	3	8	11
Rodney	34		3	3
Ruakaka	34	7	21	28
Russell	27	7	27	34
Taiharuru	27		1	1
Tangihua	34	11	6	17
Taranga	27			
Tauroa	34	4	12	16
Te Kuri	34		28	28
Tiritiri	34		6	6
Tokatoka	34	9	12	21
Waioneke	34	9	12	21
Waipu	34	14	27	41
Waiwera	34	5	7	12
Whakarara	27		4	4
Whangarei	27	3	19	22
Whangaruru	27	2	11	13
Kaeo - Bell and Clarke	8	1	1	2
Omapere - Bell and Clarke	8			
Whangaroa* - Bell and Clarke Index sheet	8			
Total		**160**	**373**	**533**

***Pah Island labelled on map but pā not specifically named (although recorded pā in ArchSite)**

4. LiDAR

Approximately one-third of the Ferrar sites were not previously identified in ArchSite, with the potential for further exploration and documentation if additional information confirming their presence could be obtained (Bickler and Jones 2022). To accomplish this, a desktop assessment was undertaken using LiDAR data in conjunction with satellite imagery.

The LiDAR dataset for Te Tai Tokerau was utilized to assess the likelihood of the Ferrar pā sites still being extant and to locate them more accurately. This was achieved by generating Digital Elevation Models (DEM) based on LiDAR data from the Te Tai Tokerau 2016-2018, using the ground classified points and Empirical Bayesian Kriging to interpolate the points (Bickler and Jones 2021). Empirical Bayesian Kriging (EBK) is a spatial interpolation technique used in geostatistics to estimate the value of an unknown variable at a location based on values observed at nearby locations. It is a modification of ordinary kriging that incorporates a prior distribution of the variable being estimated, which is estimated from the data itself (Hengel *et al.* 2007).

To highlight local relief and emphasize features such as pits, ditches, and terraces that are relatively small on the landscape, a composite image was created using Multidirectional hillshade (MH), slope, and skyview factor (SF) of the DEM. Multidirectional hillshading is a method that uses simulated lighting from various angles and directions to produce a 3D representation of the terrain surface. Skyview factor is a measure of the visible sky proportion from a given point on the terrain surface. The methodology used in this study was based on the approach developed by Guyot *et al.* (2018, 2021), which proved effective in identifying features that were previously invisible using conventional aerial imagery. In Aotearoa, this method was utilized to great effect in a previous study conducted by Bickler and Jones (2021) and duplicated here by layering LiDAR data with MH, slope, and SF layers, to highlight subtle topographic changes that indicated the presence of features such as defensive ditches, storage pits, and terraced gardens, associated with pā sites. The ML approach though, while useful for the more general search for archaeological sites across large landscapes, was overly laborious where identification of the locations that the geological survey plans had highlighted pā sites.

A simpler comparative approach between the georeferenced locations, satellite imagery and LiDAR (with hillshade) was adopted and manual investigation to determine whether archaeological features were present around the georeferenced pā locations. Typically, multiple sites were identified as potential candidates for archaeological examination based on similar proximity on the different images (Figure 4). This was a qualitative exercise to determine whether features such as earth-worked ditches could be observed alongside likely storage pits (rua) and constructed terracing, typically located on high points. These are the typically diagnostic features of pā and potentially distinguishable from both other natural features and more modern elements including farm tracks. The best of these candidates compared with the ArchSite data for further analysis (see Table 1, Figure 4), while other parts of the region and maps were also used to expand the search for additional sites.

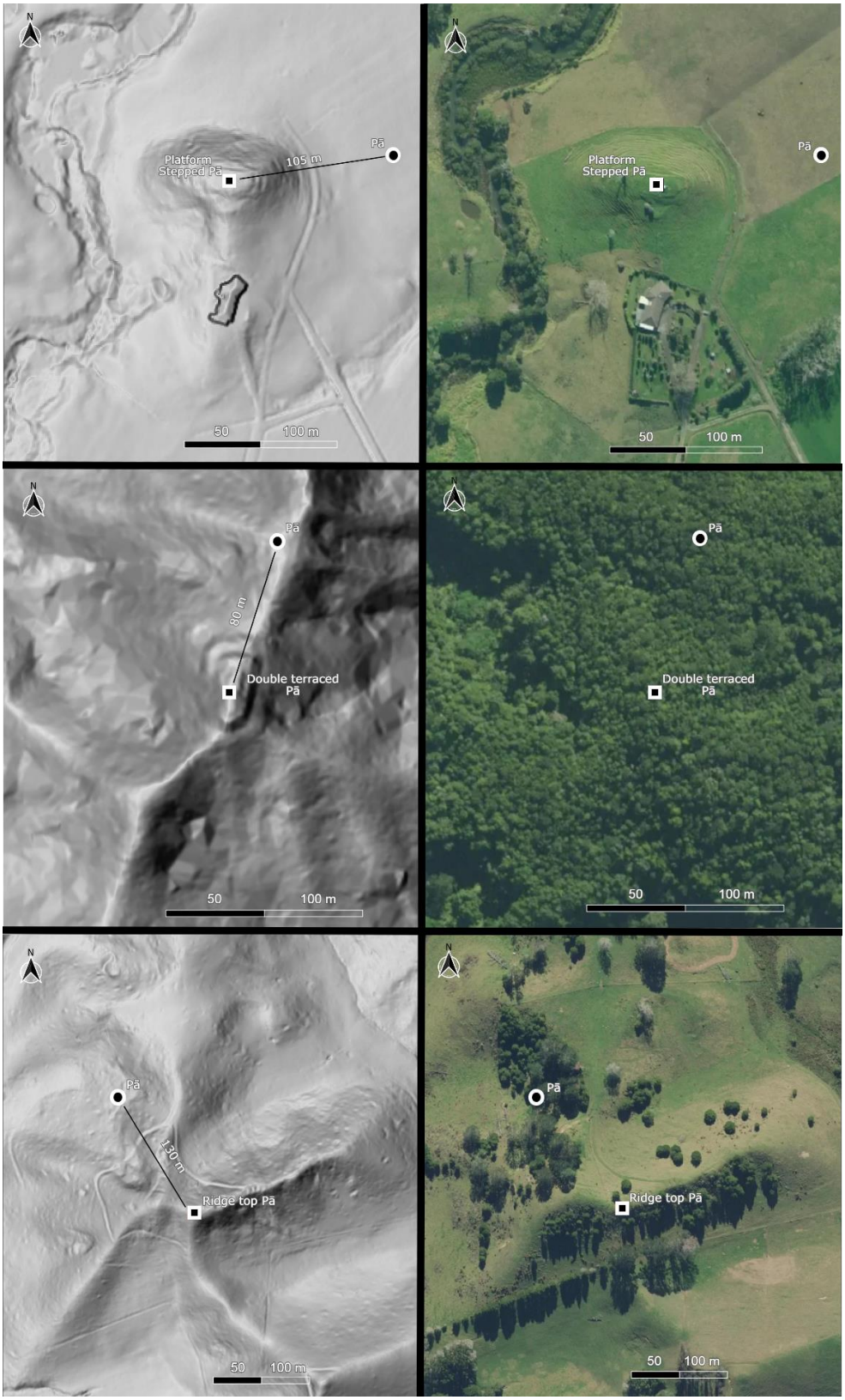

Figure 4: Pā sites originally identified on the Ferrar (circle) re-located with LiDAR and satellite imagery data (square). Examples from the NZ Topo AX30 mapsheet. and 2022 satellite imagery.

Despite these limitations of some of the map data, the use of LIDAR data in conjunction with other data sources, such as aerial imagery and ArchSite, has proven to be a valuable tool for identifying potential archaeological sites in the region. Combining information from the LiDAR data with vegetation reconstruction, archival imagery and archaeological research can result in reconstructions of the pā (e.g., Figure 5) from the Waiwera Survey District and described in Bickler *et al.* 2020). With continued exploration and refinement of these approaches, it is likely that even more sites will be discovered and described, shedding new light on the history and culture of the area.

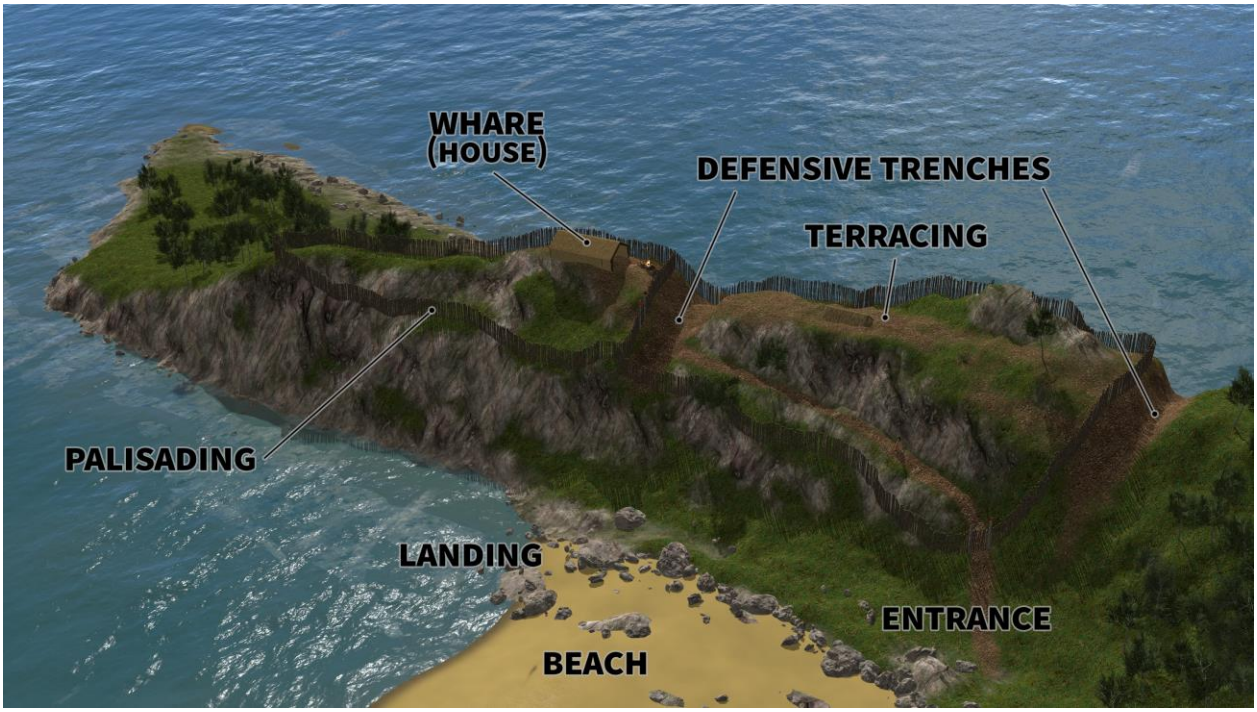

Figure 5: Reconstruction of pā site R10/291 based on LiDAR and field survey (adapted from Bickler *et al.* 2020).

5. Ferrar's Legacy

Results show how effective the blending of LiDAR and historical maps can be in enhancing site identification, especially in areas that have not been subject to comprehensive field survey. Brook and Ferrar (2019:54) state "Ferrar's geological legacy is ongoing" and that this legacy extends to archaeological survey especially in the north Auckland and Te Tai Tokerau regions relating to both Māori and European family history. The importance of that legacy of systematic geological survey across early 20th century New Zealand continues with the use and management of the data embedded in the geological plans. The colonialist origins of science including geology and archaeology in Aotearoa New Zealand are part of that legacy and require the reassessment that has been occurring (see e.g., Nathan and Priestley 2017, Jones *et al.* 2023).

The maps capture part of the complex history of land ownership, kaitiakitanga (guardianship) and mātauranga Māori (Māori knowledge systems) (see e.g., Allen and Phillips 2010, Bickler 2018: 293,

Solomon and Forbes 2010). The public accessibility of the data in the maps does not mitigate the issues relating to how the maps expose cultural information (Bickler and Jones 2021, Davis *et al.* 2021) and how the information can be used for management by iwi and hapū (e.g., Allen and Phillips 2010, Kaiser and Saunders 2021). On-going development and climate change driven processes have had an increasing impact on heritage places in Aotearoa (Bickler 2018: 319, Jones *et al.* 2023), and these impacts may be overlooked (Macinnis-Ng *et al.* 2023).

Examination of the published maps and field sheets highlighted the wealth of information about the cultural landscape, particularly in the form of place names, including those of battlefields, pā, peaks, rivers, and streams (Figure 6). It is likely that this information was collected during the field survey, a practice that was common among land surveyors in the 19th century, who often added extensive detail to their maps (see Byrnes 2014). The importance of these names cannot be overstated, as they link these places to local whakapapa and historical events (Bickler 2021). Whakapapa is a Māori concept that refers to genealogy, ancestry, and the interconnectedness of all things and can be represented as a family tree or a complex web of connections between people, places, and things (Royal 2016). Geological surveys from other areas may not always have included the presence of pā sites, but they contain a wealth of names captured from contemporary local informants, worth further research.

Ferrar's team noted a few other features of interest including a source of pipe clay, rifle pits and middens in dune areas. Interestingly, a crossed pair of swords usually indicative of a battlefield was found on a field sheet in the SW Kaihu District Plan at Moeatu Bayly's Beach, west of Dargaville. It probably marks the location of Te Kai-a-te-karoro or the Battle of Moremonui, perhaps the first battle using muskets around 1807 (Smith 1910:32-49). Obviously, it was still well known when the geological survey went through the area, but the battlefield was not included on the published plan.

6. Locating the Past

Why Ferrar and his team included heritage sites on the geological maps remains unknown; most other of the geological survey plans did not. However, Ferrar recognized the importance of acknowledging the changing cultural landscapes in which he was conducting his work. His interest in history was evident even before his involvement in creating the maps. For instance, he had previously shown an interest in the 3,000-year-old Turin Papyrus Mine Plan, as noted in Ferrar's 1913 publication cited in Brook and Ferrar's 2019 work (p. 48). A photograph taken by ethnographer Elsdon Best in 1930 and held at the Alexander Turnbull Library shows Hartley Ferrar observing the Te Miringa Te Kakara Meeting House in Tiroa shortly before he passed away (Figure 7). This photograph suggests that Ferrar's interest in history was lifelong and not solely related to his work on the geological maps.

Bell and Clarke, along with their team, had created some earlier maps which included a few pā sites. According to Moore (2012), Bell and Clarke (1909) had identified obsidian sources used for pre-colonial Māori tools near Kaeo. However, Ferrar's group seemed to have taken a more systematic approach towards identifying these sites. Geological plans from neighboring districts contained only a few markers, such as

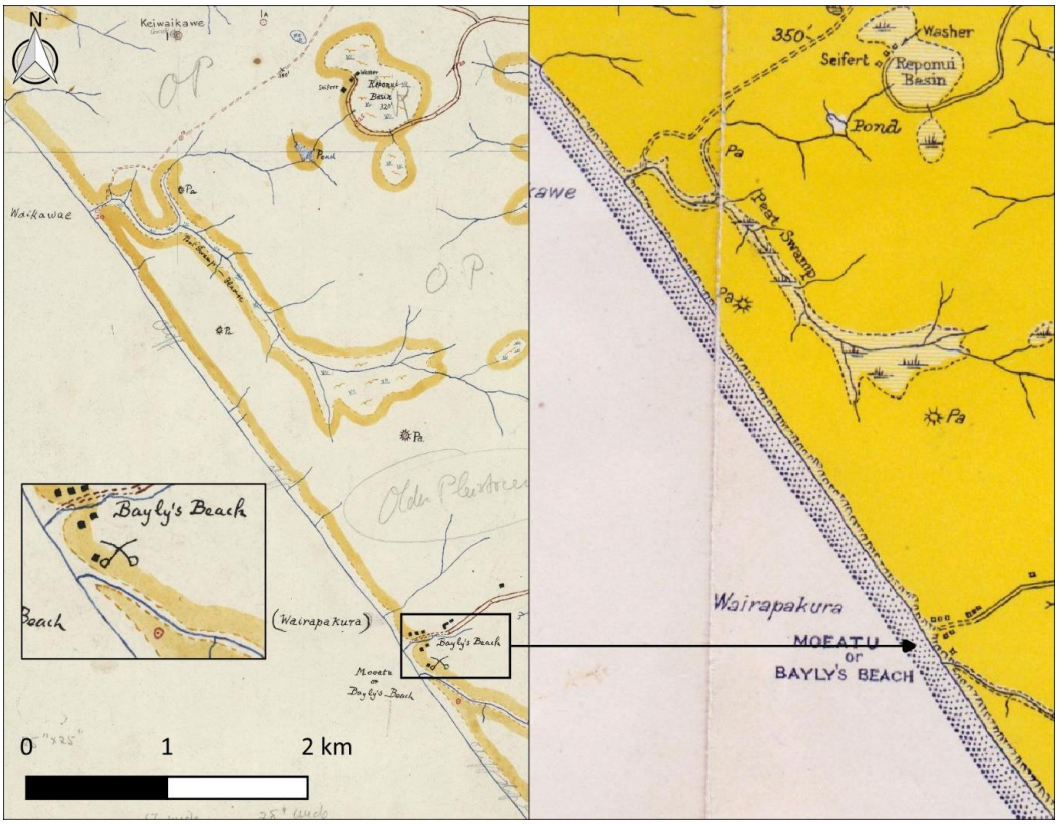

Figure 6: Section of the Kaihu Survey District Plan that displays the area of Moeatu Bayly's Beach. The left-hand side shows the field sheet; the right-hand side shows the published version. Inset highlighting battleground symbol not on published plan.

huts and houses, except for some Coromandel plans that had more extensive records of mines and mine-related infrastructure which had been tied to the earlier focus of the NZ Geological Survey's 19th century purpose. Ferrar's use and reliance on local informants is not well understood and presents a potential avenue of investigation for future research.

The maps illustrates Ferrar's group's attention to detail, particularly regarding heritage sites. Their systematic approach to mapping these sites likely contributed to a more accurate representation of the area's cultural and geological history. However, as mentioned earlier, the extent to which local informants influenced their identification of these sites requires further investigation.

Ongoing efforts are being made to confirm the remaining pā sites recorded on Ferrar's maps, but it is evident that there is still much to identify in Te Tai Tokerau (Bickler and Jones 2021, Jones and Bickler 2019) and mostly this is being done digitally although fieldwork is required. Te Tai Tokerau is a large region with a relatively low-density modern population. It has undergone significant landscape change in modern times and archaeological sites are threatened by the impacts of ongoing forestry, industrial and residential development and natural processes exacerbated by climate change (Jones *et al.* 2024). Where intensive

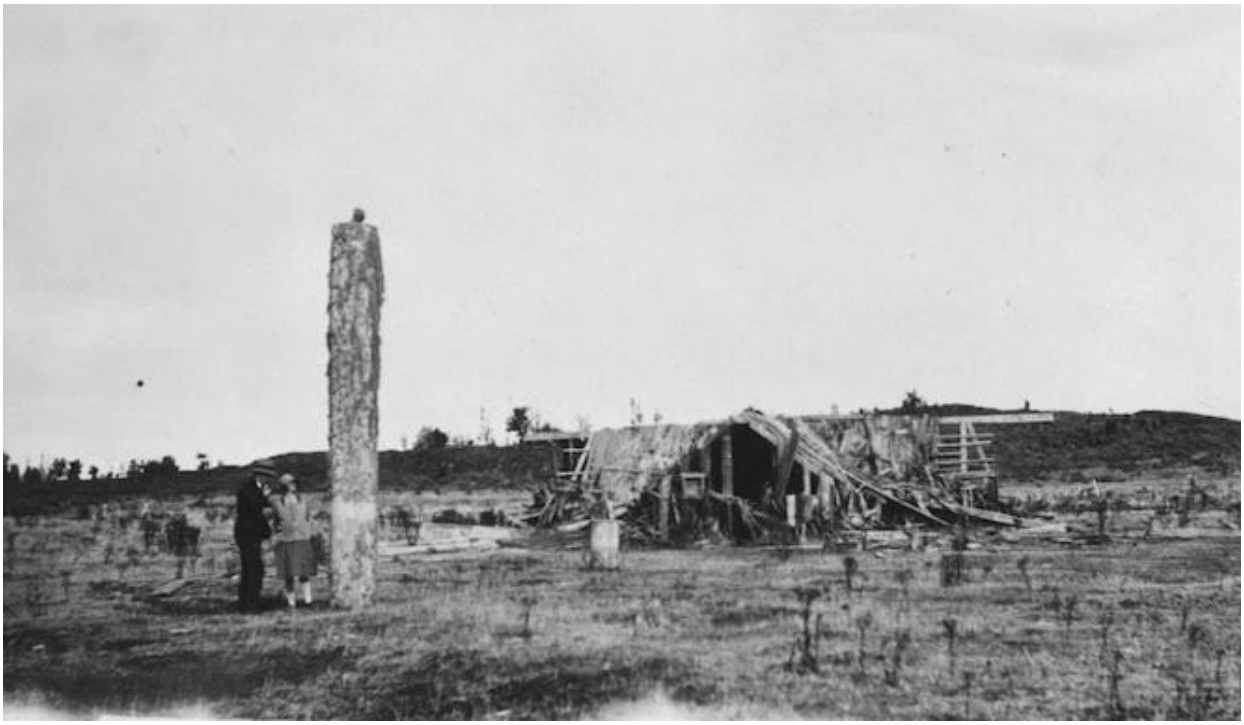

Figure 7: Hartley Traver visiting Niu pole and Te Miringa Te Kakara meeting house, Tiroa. Ferrar, Hartley Travers, d 1932: Niu pole and Te Miringa Te Kakara meeting house, Tiroa. Best, Elsdon, 1856-1931: Photographs. Ref: PAColl-4249-03. Alexander Turnbull Library, Wellington, New Zealand. https://natlib.govt.nz/records/22657719

archaeological field surveys have been undertaken in some of the Northland valley systems, the density of archaeological sites can be significantly higher than currently captured in ArchSite.

The combination of LiDAR and historical maps has proven to be a useful tool in re-investigating the cultural landscapes of Aotearoa, providing new insights into the cartographic and archaeological past. The techniques provide a robust toolkit in locating significant historical sites and preserving them for future generations. However, it is essential to conduct field surveys to validate the results of the identifications. Research conducted elsewhere in Aotearoa has demonstrated the productivity and necessity of such fieldwork for understanding landscapes (e.g., Hagan and Brown 2019). This approach offers the only practical, cost-effective solution to interrogating these cultural landscapes and providing a framework for their future management. Funding for such large-scale work remains difficult to obtain given the small pool of archaeologists and most of the archaeology undertaken in piecemeal fashion driven by land development (see Bickler 2018:315).

Ferrar's maps continue to be a valuable resource for heritage professionals, offering a snapshot of the social geography of these places. Advances in GIS and related disciplines have further increased the value

of these and other historic plans, enabling archaeologists to continue exploring and documenting the natural and cultural heritage landscapes of Aotearoa, as Hartley Ferrar had done.

Funding

This research received no external funding.

Data Availability Statement

GIS results available from authors on request.

GNS Science Dataset Catalogue. GNS Science, https://data.gns.cri.nz.

New Zealand Archaeological Association ArchSite Database, https://www.archsite.org.nz.

Partnerships

This research did not use any primary data from Indigenous contexts.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualisation, writing and analysis undertaken by Simon Bickler and Benjamin Jones.

Acknowledgements

This article, based on our previous work on machine learning (detailed in Bickler and Jones 2022), originated as a conference paper presented at GeoCart 2022. We are grateful to Matthew Jolly from the Northern Regional Council for providing us with LiDAR data for Te Tai Tokerau Northland. GNS Science NZ made their georeferenced scanned maps freely available, which helped us complete our map search efficiently. Mark Rattenbury directed us to this resource, and the GNS Science team made it accessible. Field sheets provided valuable insights into plan creation. Thomas MacDiarmid developed a 3D model of pā site R10/291 with the authors. Dianne Harlow introduced Bickler to the Ferrar maps many years ago. Peter Petchey suggested the potential influence of UK Ordinance Survey Plans. We would like to thank Dorothy Brown for her editing efforts. We would also like to thank Mark McCoy and the anonymous reviewers from the GeoCart '22 conference proceedings and JPA for their valuable comments. Lastly, we dedicate this paper to the late Kevin Jones, a pioneer in archaeological site surveying in Aotearoa.

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