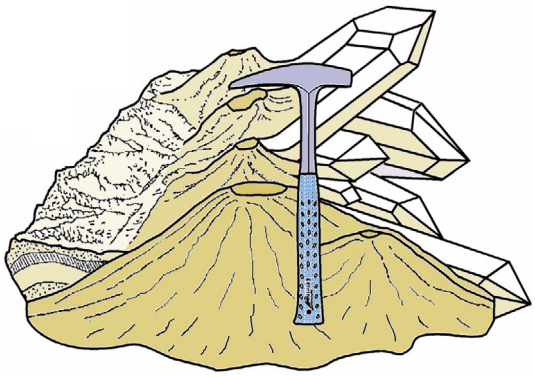


Geocene

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Contributions about the geology of New Zealand (particularly northern New Zealand) from members are welcome. Articles are lightly edited but not refereed.

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ORIGINAL FORM AND STRUCTURE OF TE PANE-O-MATAAHO/MĀNGERE VOLCANO

Bruce W. Hayward and Les O. Kermode *

Māngere Volcano (**Fig. 1**) is the largest volcano on the Manukau Lowlands in the southern suburbs of Auckland City (**Fig. 2**). It and its neighbour Māngere Lagoon have been dated as erupting 50,000 years ago (Hayward & Hopkins 2019). Māngere Volcano consists of a large, scoria cone complex surrounded by extensive basalt lava flows (**Fig. 2**). The scoria cone has been modified by a number of relatively small quarries and there has been some variation in our understanding of its structure and mode of eruption over the years. To best understand the scoria cone's original shape and structure, one needs to look at previous work undertaken before, during and after quarrying.



Fig. 1. View south over Māngere Mt, the largest volcano in the southern part of the Auckland Volcanic Field. The grassy slope and courts in the lower left are the site of the quarried away small breached crater.
Photo: Bruce Hayward, 2009.

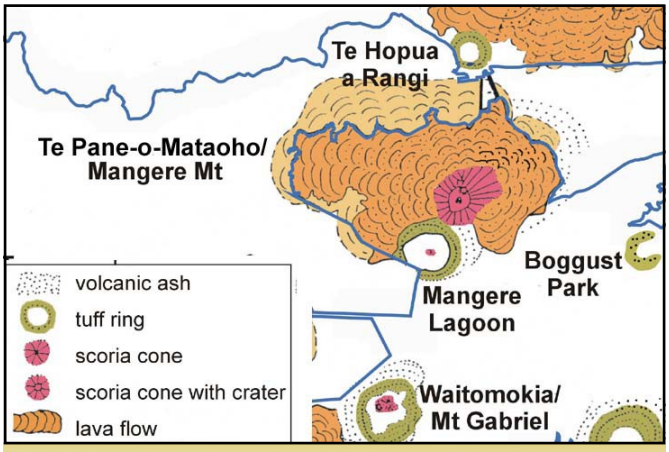


Fig. 2. Māngere Volcano consists of a central scoria cone complex (pink) surrounded by extensive lava flows (orange). Other nearby volcanoes are also shown. From Hayward (2019).

History of study of Māngere Mountain Volcano

The first published map to show any of the Māngere volcanoes was by Drury (1853) who identified "Mangeri Mt" with mounds of scoria over the lava flows to the northwest, but did not recognise nor name Māngere Lagoon Explosion Crater on the cone's southern margin as of volcanic origin.

In the middle 1850s, Charles Heaphy wandered around the Auckland Province as Provincial Surveyor and produced an unpublished map of the volcanoes of Auckland in 1857 (**Fig. 3**), which was published in Heaphy (1860) showing the "Mangarei" scoria cone and surrounding lava flows and the unlabelled Māngere Lagoon Explosion Crater (**Fig. 4**). Heaphy's mapping merely identified the location of Māngere Volcano and associated lagoon crater but provided no detail.



Fig. 3. Part of Heaphy's unpublished (1857) map showing "Mangarei" volcano and surrounding lava flows (brown).

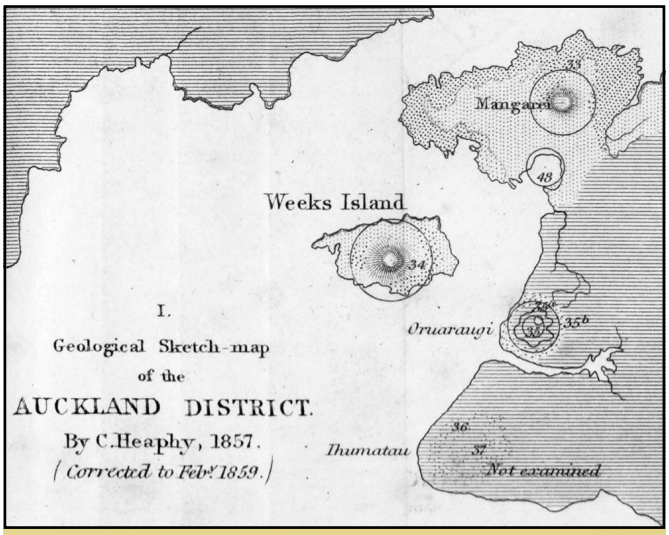


Fig. 4. Part of Heaphy's published (1860) map showing "Mangerei" volcano (top right) uncorrected from his 1857 map.

* Deceased

When Austrian geologist Ferdinand von Hochstetter arrived in Auckland on the frigate 'Novara' in December 1858, Heaphy let him copy onto tracing paper, his map of the Auckland Volcanic Field. Hochstetter used these tracings to locate and visit the various volcanoes as he travelled around, undertaking more detailed mapping of them. On 17 January 1859, Hochstetter was ferried across the Māngere arm of the Manukau Harbour from Onehunga to the Māngere shoreline. In his diary (Nolden & Hayward 2023) he wrote "*Mangere no 33 on the map, the mountain is a scoria cone about 500 feet high with 28–30° inclination, the crater of which is said to be almost completely preserved – I didn't take time to climb the summit. Lava flows are mainly in a northerly and westerly direction. An interesting tuff crater on the south side*". This latter refers to Māngere Lagoon explosion crater (**Fig. 5**).

On that day, Hochstetter walked south as far as Captain Haultain's farmhouse on the south side of Waitomokia tuff ring and then returned to Onehunga. Thus, he did not have a large amount of time to examine the geology of Māngere Mt volcano. Hochstetter must have realised that the volcanic landforms of Māngere Mt were complex and interesting as he later commissioned Auckland Survey Office draftsperson William Boulton to prepare a detailed field survey plan of the volcano (**Figs 6–7**). On Hochstetter's (1865) English version of his map of the Auckland volcanoes, he did not incorporate the survey results of Boulton and his representation of Māngere Mt is not easy to understand (**Fig. 8**). Hochstetter (1864) did take note of Boulton's survey in describing Māngere

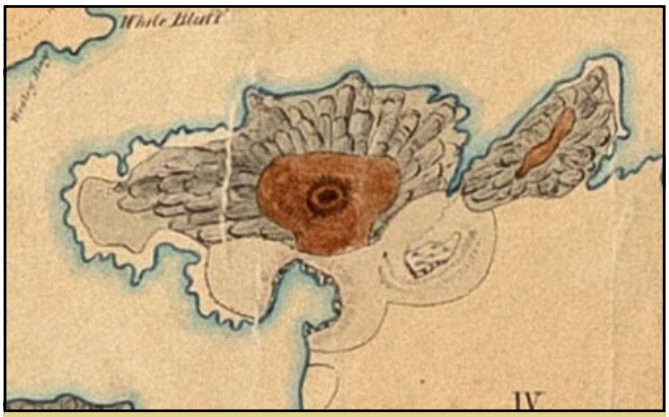


Fig. 5. Part of Hochstetter's unpublished 1859 map of Auckland volcanoes showing Māngere scoria cone with a single simple crater with lava flows "*mainly in a northerly and westerly direction. An interesting tuff crater on the south side*". Note he also shows an elongate scoria ridge surrounded by lava flows on the next peninsula to the east.



Fig. 6. William Boulton's unpublished survey plan of Māngere Mountain made in 1859 at the request of Hochstetter.

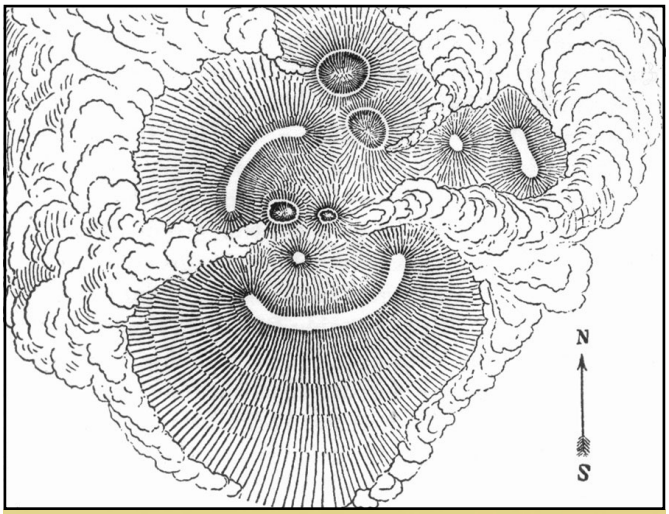


Fig. 7. Boulton's 1859 plan of Māngere Mt that was modified by Hochstetter and redrawn for lithography before being published in Hochstetter (1864). Note the addition of lava flows coming out of the craters and flowing out over the lowest saddles in the scoria cone ramparts around the main crater.

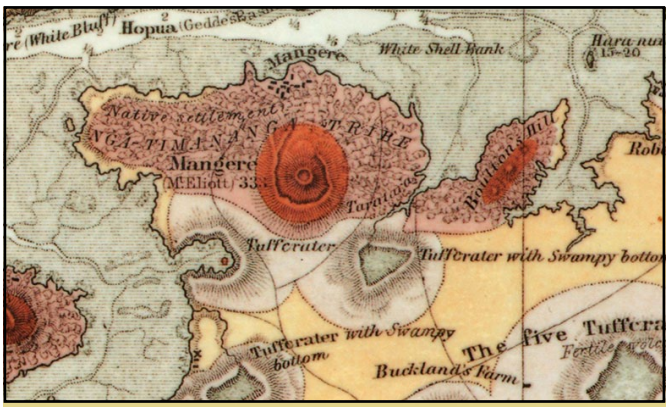


Fig. 8. Part of Hochstetter's published English version of his map of the volcanoes of Auckland (1865) redrafted by August Petermann from Hochstetter's unpublished 1859 map. Note that the spelling of Māngere has been corrected and Mt Eliott added in brackets. A swamp to the southeast of Mangere Mt has been labelled "Tuffcrater with Swampy bottom" but this is no longer recognised as a volcano (Hayward 2013). The peninsula to the east of Māngere, Hochstetter has named as "Boulton's Hill" and he now shows three small scoria cones on its crest. This is interesting as Hochstetter never actually visited the peninsula.

Mountain volcano in his account of the geology of New Zealand: "*Mangere or Mt Elliot … a scoria cone with steep slopes, with several small craters from which numerous lava flows have poured forth to form an extensive lava field at the foot of the hill.*" He also states that: "*The hill east of Mt Elliot that forms a peninsula projecting into Onehunga Bay seems to indicate an independent point of eruption, which I have named Boulton's Hill in memory of Mr Boulton, the surveyor who undertook measurements on my behalf in this district.*" Today this quarried ridge crest is not considered to have been the location of one of Auckland's volcanoes (Hayward 2013).

Firth (1930), as part of his study of the geology of all of Manukau County, was next to write something about Māngere Mt: "*This is the largest cone in the district; its eastern wall is extensively breached, but its western rim is intact and rises to a height of 350ft above sea level; a considerable portion of its centre is occupied by a large, splendidly preserved crater, from the floor of which rises a perfect small cone with two minor explosion pits.*" [In the accompanying figure caption, Firth refers to this small cone as "a small scoria-cone"] "*A smaller deep crater occupies a position at the northern margin of the breached eastern wall of the main cone, while a shallower one occurs nearby on its northern flanks. Stretching eastward from the breach there are a series of jumbled mounds of scoria and tumuli of scoriaceous basalt, beyond which is a small, localised flow of basalt, whilst at the base of the mountain, on its north-east side, there is a small cone of well-bedded scoria which also appears from the bedding to have been breached to the east. On its western side the main cone rises abruptly above a wide, low-lying, gently-sloping surface apparently underlain by highly scoriaceous basalt and occasional tuffs which represent the initial stages of activity.*"

Searle (1959) made more detailed observations of Māngere Mountain (**Fig. 9**) and nearby volcanoes and wrote that "*At Mangere, the volcanic landforms are far from simple and present a picture of superimposed cones and interfering craters that indicate frequent recrudescence of activity from fresh vents in the system. At best, the study of the external form of the final structure can give only a very incomplete history of the later events at such a centre. Mangere mountain is 350 ft high, stands on a broad base, and is truncated by a particularly large crater system. The south eastern and western parts of the rim are offset slightly in a saddle and the western rim is built to a much greater height. This relationship suggests that the centre of activity shifted to the north-west during the building of the main mass of the cone. The main crater is characterized by the presence of a tholoid-like cone surrounded by a number of crateral pits from which vigorous fire-fountaining hurled numerous large bombs that now litter the walls and floor of the very broad compound crater.*

"A particularly vigorous vent in the northwest of the crater was no doubt partly responsible for the upbuilding of the high part of the rim adjacent to it. A late event in the summit history was the opening of a major vent in the northern part of the rim of the main crater. A considerable portion of the rim was blown away and the cone built about the new vent was built out to encroach into the main crater. Activity at this vent produced a very deep, steep-walled crater.

"On the northnortheast side of the mountain there was formerly a low cone that has since been almost completely removed in quarrying. This, too, was an older feature than the main cone and seems to have been partly wrecked before the latter was built as its flank toward the mountain was scarred by an explosion crater, now filled in to some extent with scoria from the main eruptions. An irregular mass of agglutinate in the quarry floor marks the site of the throat of this lesser cone. The lower part of the mound is composed to a large measure by massive blocks blasted from the cover rock when the vent was opened. Some of these blocks are of dense chilled lava whilst others are of sedimentary origin, mostly baked to a pink brick; a few have been completely fused to slag. These fused and indurated sediments, apparently representative of the upper sediments that enclosed the rising magma before the vent was opened, would seem for the most part to have been post-Waitemata in age since they include many acid tuffaceous grits and occasional baked lumps of shell-bed material, derived from the Pliocene beds of the area. The indications are that few, if any, have come from depths greater than between 100 ft and 200 ft below the surface. At higher levels in the cone scoriaceous and slaggy basalt and bomb fragments predominate, indicating that the explosive phase gave place to some fire-fountaining, and the uppermost layers are composed almost wholly of small scoriae and lapilli ejected as activity waned.

"Lava has escaped at many points in the system. A major outflow, marked by a breached crater at a high level on the eastern flank of the main complex, produced a flow that covered a considerable area. Its surface is marked by a number of small mounds; some of these, near the breach, are composed of jumbled blocks and scoriaceous basalt and appear to be material from the edges of the rim of

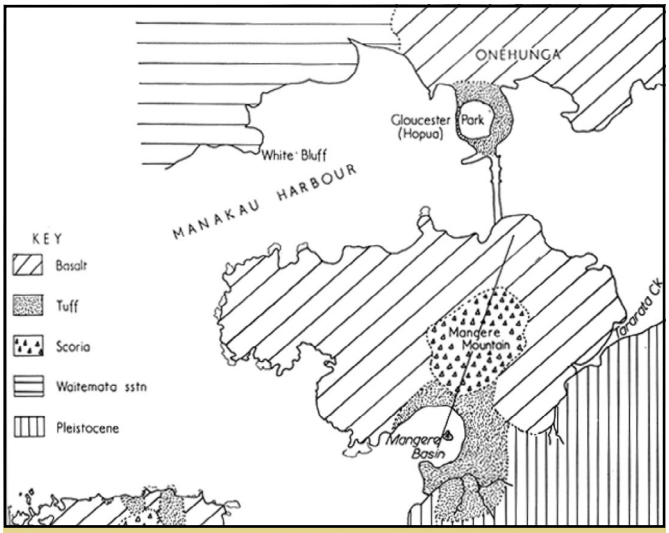


Fig. 9. Part of Searle's (1959, 1964) map of the volcanoes of the Māngere area which gives a simplified outcrop map of the distribution of tuff, scoria and basalt lava flows of Māngere Mt Volcano.

the cone that has been rafted away on the surface of the flow. Other mounds, farther from the mountain, are probably pressure ridges. The flow extends eastward as far as Tararata Creek, beyond which Hochstetter (1865) mapped a number of other volcanic mounds which he named Boulton's Hills. However, no volcanic materials other than a thin ash cover are to be found on the eastern side of the creek." Searle (1964) gave a similar but modified account.

The most recent geological map that portrays our current knowledge of the volcanoes of the area is Kermode's (1992) 1:50,000 map (**Fig. 10**). Kermode *et al.* (1992) summarised Les's interpretation of the volcano's geology: "*A large well-preserved scoria cone with a breached crater (the best example in the field). Within the crater the lava plug (surrounded by gas vents) is unique (in the Auckland field). There is a deep secondary explosion crater in the rim of the main scoria crater.*"

In the 1990s, one of us (LOK) prepared unpublished notes on various aspects of Māngere Mt. In his notes he wrote "*Hochstetter (1864) erroneously illustrated lava flow originating from scoria craters, and misinterpreted the several rafted scoria mounds and lava pressure ridges to the east to be a separate volcano that he named Boulton's Hill (this latter error was compounded on the published map by placing the name and symbol to the east of Tarata Creek*", which Searle (1959) noted there was never any volcanic rock as the lava flows stopped at the west side of the creek.

European modifications of Māngere Mt

Despite its present appearance, Māngere Mt scoria cone did not escape some quarrying in European times. Between 1900 and 1964, six separate scoria pits operated at different times around the lower northern and eastern slopes of the cone (**Fig. 11**). The largest quarry removed a prominent curved northeast ridge of scoria that extended

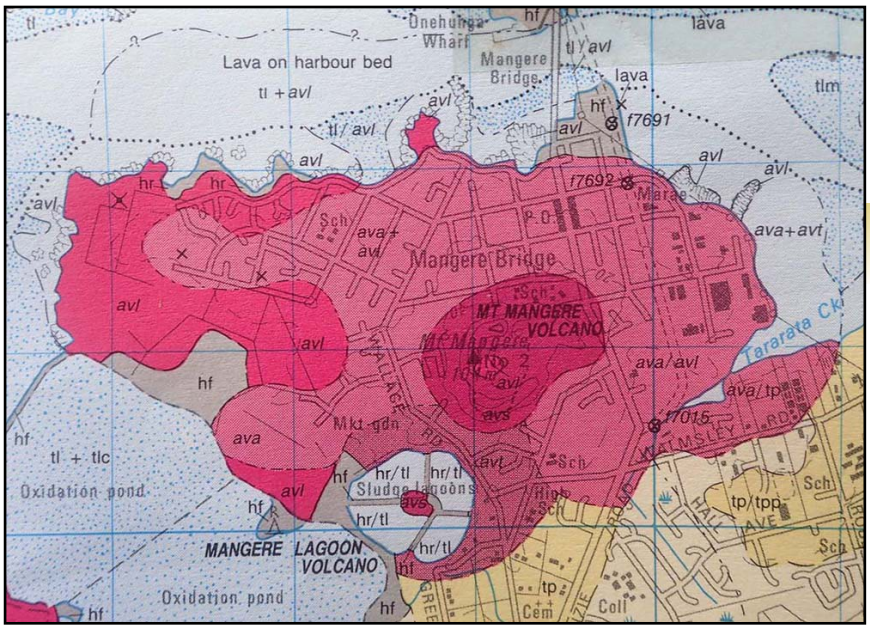


Fig. 10. Part of Kermode's (1992) geological map of Auckland showing his map of Māngere Mt and Māngere Lagoon volcanoes.

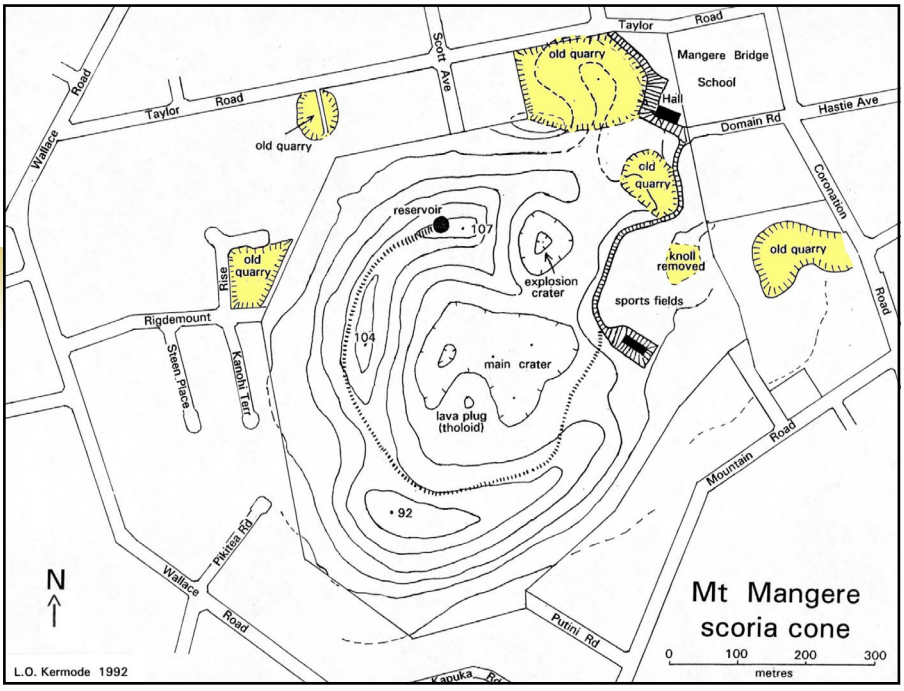


Fig. 11. Map of Māngere Mt scoria cones and quarrying extent. Unpublished by Les Kermode, 1992.

northwards from the main scoria cone and all signs of a former breached fire-fountaining crater (**Figs 12–15**) that had been mapped by Boulton (**Figs 6–7**). Photos of the profile of Māngere Mt from the north show that there was a high point (hill) on the crest of the spur that may have attracted quarrying (**Fig. 16**). Quarrying finished in about 1964 and the site is now used as the Bridge Park Bowling and Tennis clubs and open ground (**Fig. 17**).



Fig. 12. View north in 1899 from the high northern point on Māngere Mt looking down into the breached northeastern crater with the scoria ridge (with Māori earthworks) beyond. This has all been quarried away. Photo: Hugh Boscawen, Auckland Museum.



Fig. 13. View southwest in 1899 from the vicinity of present day Māngere Bridge shopping centre showing the original profile of Māngere Mt with the rounded ridge crest on right being the eastern scoria ramparts of the breached crater that was removed by quarrying. Photo: Hugh Boscawen, Auckland Museum.

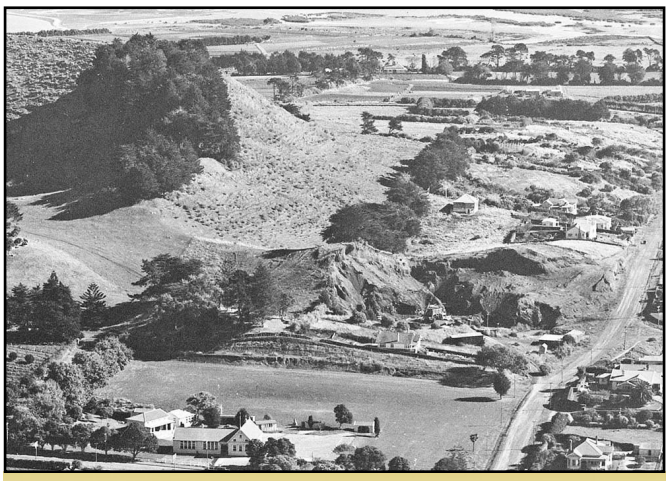


Fig. 14. Oblique aerial view looking west over Māngere Mt in 1949, showing the start of quarrying of the scoria ridge on the east side of the breached northeastern crater (lower right). Photo: Whites Aviation.



Fig. 15. Oblique aerial view looking southwest over Māngere Mt in 1957, showing active quarrying in the vicinity of the breached northeastern crater (lower right). Photo: Whites Aviation.

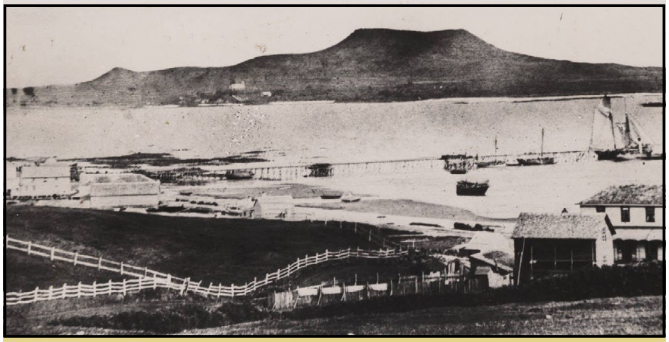


Fig. 16. View south from Onehunga in the 1860s showing the profile of Māngere Mt. Note the peaked hill at the far eastern end (left), which was on the crest of the curved spur around the small northeast breached crater that has been quarried away.
Photographer unknown, Onehunga Library.



Fig. 17. View from the northern slopes of Māngere Mt over the remediated site of the breached northeastern crater that was removed by quarrying in the 1950s–1960s. Photo: Bruce Hayward, 2015.

An earlier quarry behind the Manukau County Works Depot (now the Māngere Mountain Education Centre) was operational in the first half of the 20th century but appears to have been overgrown in a 1949 air photo (**Figs 18–19**). This quarry removed basalt and scoria mounds that were probably rafted there by flows that breached the eastern side of the main crater scoria ramparts (vicinity of soccer club rooms).

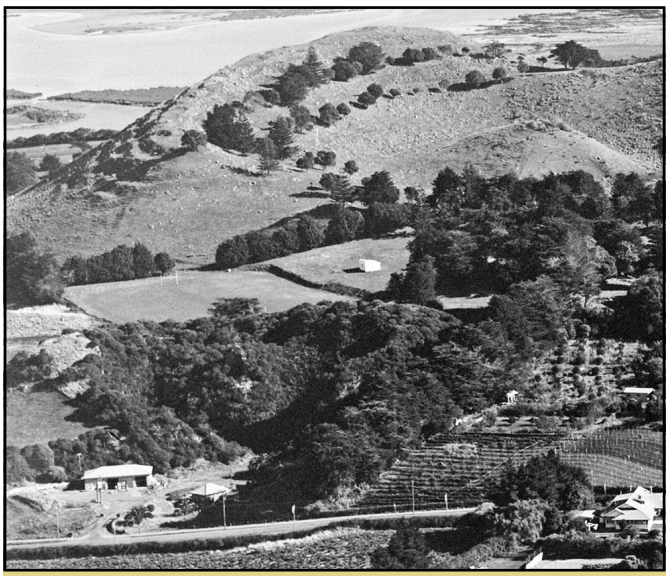


Fig. 18. Oblique aerial view looking west over overgrown quarry faces (foreground) in 1949 behind the Manukau County works depot (now Māngere Mt Education Centre) and pumphouse.
Photo: Whites Aviation.



Fig. 19. Partly overgrown faces of the County works depot quarry with brick disused water pumphouse in the foreground. The quarry was removing scoria and basalt that had been rafted away from the main cone on lava flows. Photo: Bruce Hayward, 2010.



Fig. 20. Oblique aerial view from the high northern point of Māngere Mt in 1960 down into the small, deep crater, showing active earthworks beyond in the vicinity of the modern playground and even down into the crater! Photo: Whites Aviation.

More quarrying and earthworks occurred mainly in rafted scoria mounds on either side of the entrance driveway to Māngere Domain in the 1950s–early 1960s (**Figs 15, 20**). These areas are now the soccer fields and the playground, skate park and basketball court area close to Māngere Memorial Hall. On the west side of the base of Māngere Mt scoria cone, at the end of what is now Ridgemount Rise, there was a small quarry in the 1950s–1960s that removed a small, rafted scoria mound (**Fig. 21**).

Probably the earliest quarrying on Māngere Mt (additional to the six shown on the map in **Fig. 12**) was a small pit on the crest of the scoria ramparts between the main crater and the deep northeast crater (**Fig. 22**). It was probably opened in the 19th century and operated only for a short time before being closed down.



Fig. 21. Oblique aerial view towards the east showing a small quarry at the base of Māngere Mt scoria cone (at the end of Ridgemount Rise) in 1960. Photo: Whites Aviation.



Fig. 22. Overgrown site of possibly the earliest quarrying on Māngere Mt on the scoria rampart between the main and deep craters. Photo: Bruce Hayward, 2010.

Outline geological structure of Māngere Mt Volcano
Māngere Mountain is the largest and best preserved volcano in the southern part of the Auckland Volcanic Field. It consists of a large, 106 m-high scoria cone produced by fire fountaining from its huge crater. The scoria cone rim has two distinct high areas (along the south and northwest sides). There were three identifiable craters/vents in a northnortheast oriented line (**Fig. 23**) – the large main crater, a second smaller but deep fire-fountaining crater situated in the middle of the scoria ramparts on the northeast corner of the main crater, and a third breached crater that was located out beyond the ramparts to the northeast. This breached northeast crater has been quarried away (see above) – it formerly had a high, curved, scoria spur on its eastern side capped with a peaked hill of scoria (**Fig. 16**). This small crater was breached to the northwest and the hill was presumably a result of wind-directed fountaining. Presumably lava flowed out from the vent and rafted away the scoria that had built up around this side of the vent. The modern google earth image (**Fig. 23**) shows that the breached northeast crater is at the northern end of the line of Māngere Mt vents, slightly offset to the west of the line as suggested by Boulton's map (**Figs 6–7**).

If the line of vents is extended south, it passes almost exactly through the scoria cone that was built around the vent of Māngere Lagoon explosion crater (**Fig. 21**). It seems highly likely that during eruption of Māngere Mt, magma rose as a dike intrusion up along a prominent fault or joint that oriented northnortheast and erupted from its upper edge in at least four places. Indeed, along this western side of the Manukau Lowlands there are three additional volcanoes aligned along the same lineament south of Māngere Lagoon – Pukeiti, Ōtuataua and Maungataketake (Hayward 2019, p. 23), with a fourth (Waitomokia) slightly offset to the east of the line.



Fig. 23. Google Earth image of Māngere Mt and Māngere Lagoon explosion crater with the four identified vents marked by yellow circles.

Māngere Mt is unique in Auckland in the presence of a small, 12 m-high, conical plug sitting over the vent in the centre of the main crater. After the finish of fire-fountaining eruptions, the magma in the vent had time to cool and solidify into a solid basalt plug with still-fluid magma in the plumbing beneath. Gas bubbles rising up through the column of viscous magma coalesced and gradually built up considerable pressure beneath the plug, sufficient to push the solid mass out of the volcano's throat, like a cork out of a bottle. As the plug was extruded, the pent-up gas escaped around its northern, eastern and southern sides, creating three small circular gas venting craters. The escaping gas also threw out many large globs of molten viscous lava that acquired aerodynamic spindle, spherical and corkscrew ribbon shapes as they cooled while hurtling through the air. Many of these bombs, broken or whole, still lie scattered around the gas vents and the inner walls of the main crater.

Firth (1930) believed this steep-sided mound in the centre of the main crater was a scoria cone. This was likely because on many parts of the sides of the mound there is scoriaceous spatter on the surface, but close examination shows it is a thin veneer or mantle over solid basalt beneath. In other places on the slopes of the mound there are 1–3 m faces of massive basalt visible beneath the grass (**Fig. 24**), which led Searle (1959) and Kermode *et al*. (1992) to recognise it as a solid plug (sometimes called a tholoid) that had been pushed out. The three gas venting craters blasted out not only bombs but scoriaceous spatter that has stuck to some of the sides of the still hot, and probably sticky, plug.

During the fire-fountaining eruptions from the main crater, the scoria rampart to the east was breached by lava flows, which rafted away the scoria in the vicinity of the present soccer club house and carpark and deposited



Fig. 24. The small plug (tholoid) in the centre of the main crater of Māngere Mt volcano. The vertical face (middle right) on the side of the tholoid is solid basalt. Photo: Bruce Hayward, 2015.

it as rubbly scoria mounds in the vicinity of the Māngere Mt Education Centre and further afield, as noted by many of the previous commentators. Large volumes of lava flowed from around the base of most of the cone, forming an extensive lava-flow field covering 5 sq. km. It spread out as a wide apron of overlapping lava flows on the gentle slopes of the forested Manukau River valley. These flows now form all the land beneath the suburb of Māngere Bridge, as far west as Ambury Park. East of Māngere Mt, the lava flows extend over 1 km beneath the route of the SW Motorway. To the south, flowing lava filled a depression between the base of Māngere Mt's scoria slopes and the crest of Māngere Lagoon's tuff ring with a smidgeon of lava flowing over the crest and down into the explosion crater itself (Hayward *et al*. 2016).

Pretty much all of Auckland's volcanoes began their eruption sequence with the rising molten magma interacting with cold ground water, producing explosive (phreatomagmatic) activity. This tended to throw out vast quantities of often-baked country rock and fragmented basalt to form a tuff ring. After most of the cold water was exhausted, the style of eruption switched to dry fountaining and lava flow effusion (Hayward 2019). At Māngere Mt, we have shown that Māngere Lagoon erupted shortly before the effusion of lava flows from the southern base of the scoria cone and thus the lagoon's explosion crater and tuff ring may have been produced by the earliest wet eruption in the 50,000 year old Māngere sequence.

Searle (1959) described baked blocks of soft country rock (Pleistocene rhyolitic sediment) in the walls of the active quarry forming the lower part of the cone surrounding the breached northeastern crater (see above) and these would have been thrown out of a phreatomagmatic vent. This location is too far away from Māngere Lagoon for the huge blocks to have come from that vent and therefore there must have been another early vent in the northeast, possibly the fore-runner of the breached crater that was quarried away. Searle (1959) also described basalt agglomerate inside the base of this quarry which we would join him in interpreting as vent-fill agglomerate from the fire-fountaining stage.

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THE AUCKLAND WAR MEMORIAL MUSEUM METEORITE COLLECTION

Hugh Grenfell

The Auckland War Memorial Museum (AWMM) has a small but interesting meteorite collection that was started in the late 19thC by Thomas Cheeseman (1845–1923) when the Museum was situated on the corner of Eden Crescent and Princes Street (Wolfe 2001; Grenfell 2023). When I started working on the Geology Collection in 2014, some of the wooden Geology cabinets (72 in total) were in a room next to the Marine Department at the rear of the Museum, but the majority had just been moved back from offsite and were in the Level 2 underground car park together with other oversized and miscellaneous specimens and collections such as the Brinkman Sand Collection (Grenfell 2017). All the meteorites were together in the same cabinet apart from two specimens on display (the Auckland and "Alice Springs" meteorites) in the Cheeseman Hall (Origins Gallery) and two misidentified specimens (the Ausson and Hedjaz meteorites). For some specimens we now have plenty of background information but others still have very little data. Adding as much new data as possible to each of these specimens and unraveling 1920's mix-ups was an interesting challenge. Museum Annual Reports, original registration records, historical archival correspondence, geological knowledge and literature all helped.

New Zealand

Wairarapa Meteorite (GE8514, Chondrite H6)*, **Plate 1, Figs 1a–d.** (See next page)
* Auckland War Memorial Museum Accession # and Meteoritical Bulletin Database (2026) classification.

The Wairarapa Meteorite was found in the early 1860s near the homestead of William Hodgson Donald (1815–1885). Donald (**Fig.1**) emigrated from near Wigton, Cumbria, to New Zealand, arriving in Wellington on the *George Fyfe* in October 1842 (Donald 2005). He managed a farm for William Barnard Rhodes (?1807–1878) at Pencarrow, Wellington, for a time. Then in partnership with Rhodes

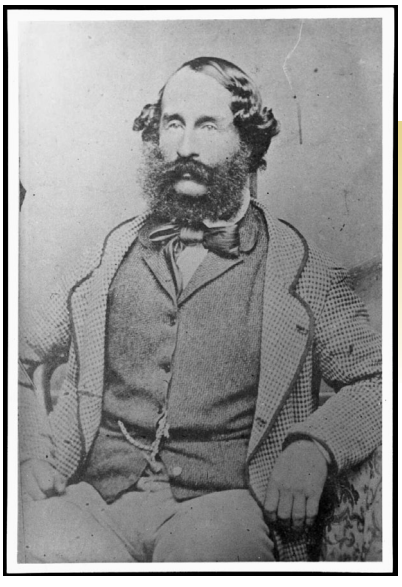


Fig. 1. Studio portrait of W.H. Donald in the 1870s by an unidentified photographer. Ref: AColl-7329-01. Alexander Turnbull Library, Wellington, New Zealand.

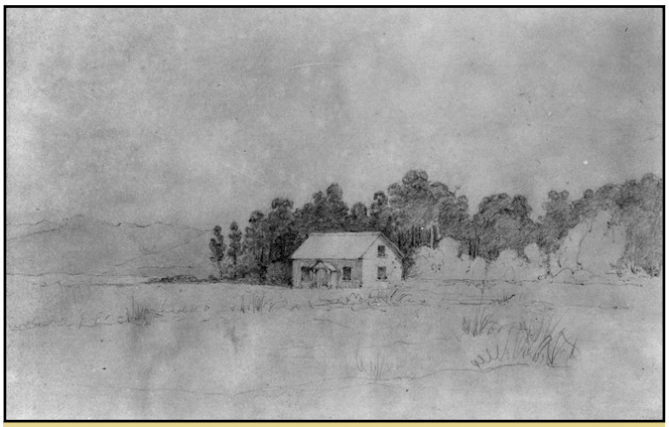


Fig. 2. Sketch the first Donald house at Kuripuni Bush by William Mein Smith in 1849. Ref: A-035-003. Alexander Turnbull Library, Wellington, New Zealand.

he acquired a large block of land, Manaia Station, near Masterton, in May 1848. The original two-storey Donald homestead with Kuripuni Bush behind (**Fig.2**) was illustrated in 1849 (Smith 1849), in two pencil drawings by William Mein Smith (1799–1869).

The Donald's next home, the large Solway House, was built nearby in 1877 adjacent to the present day Solway Showgrounds. The name Solway comes from the Donald's ancestral Cumbria home, Solway House (Donald 2005). In 1916 the homestead became Solway House College for Girls (later just Solway College at 49 Fleet Street).

Dates for when the meteorite was found have been variously stated as 1862, 1863 and 1864 (Battey 1962). In the first published reference about the meteorite (Crawford 1865, p.26), it was said to have been found "in front of Mr Donald's house" (i.e. the original Donald homestead – Fig. 2) "near the left bank of the Wai Ngawa (Waingawa) River". This dwelling is presumed here to have been near or in the same place as the subsequent 1877 Solway House, (i.e. -40.955182, 175.629066). The locality (and name) Tohirua given by some for the meteorite may be a corruption of Te Ore Ore (Battey 1962 and Richard Collins below) but nowhere named Tohirua has been found in New Zealand to date.

Subsequent owners

Richard Collins (??–1876)
Richard Collins, who farmed at Te Ore Ore from 1849, just east of Masterton and near the Ruamahanga River, is said to have been given the meteorite by W.H. Donald (Battey 1962, p.74). This must have been quite soon after it was found, since the meteorite turned up in the Colonial Museum, Wellington under Collin's name in 1866 (Colonial Museum 1866). Although Marriner (1909) stated Collins found it, it seems more likely that Donald was the finder as stated by Crawford (1865).



Plate 1. (Scale bar 1cm unless otherwise stated)
1a-b: Wairarapa Meteorite GE8514.3, **1c-d:** Wairarapa Meteorite GE8514.5;
2: Kimbolton Meteorite GE9618; **3a-c:** Auckland Meteorite GE15574, 3c current mutilated state;
4a-e: "Alice Springs" Meteorite GE9105 / GE10842, 4c close up of cut face showing the Widmanstätten pattern;
5: Australian tektites GE9390; **6:** Australian tektites GE8357; **7:** Toluca Meteorite GE681;
8: Brenham Meteorite GE157; **9:** Canyon Diablo Meteorite GE153; **10:** Odessa Meteorite GE9298;
11: Hedjaz Meteorite GE357.2 / GE15647; **12:** Ausson Meteorite GE375.1 / GE15648; **13:** Mekong tektite GE9389.

The Mantell Family
Before we discuss the next owners of the Wairarapa Meteorite, Walter B.D. Mantell, Walter G. Mantell and Katie Mantell, we need to sort out the Mantell family tree a little. They have some famous palaeontological connections.

Gideon Algernon Mantell (1790–1852) (Wikipedia 2025a) and his wife Mary Ann Mantell (neé Woodhouse, 1795–1869) (Wikipedia 2025b) are famous for discovering (and ultimately describing) the first known dinosaur, *Iguanodon*. This was at Cuckfield Quarry, Sussex in September 1820. Remarkably, the first *Iguanodon* fossil found by them (a tooth) is now held at the National Museum of New Zealand (Te Papa) (Registration # GH004839, see below also and Yaldwyn *et al*. (1997)). It was gifted to NMNZ by the Mantell family in 1930. That's right, the original fossil find of the first known dinosaur is held in New Zealand.

The Mantell's second child was Walter Baldrock Durrant Mantell (1820–95). A 19 year old W.B.D. Mantell emigrated to New Zealand in 1839 with the New Zealand Company and went on to have a career in the government service (Sorrenson 1990). He is now infamous for being appointed in 1848 to the office of "Commissioner for Extinguishing Native Titles", Middle Island (South Island) (Sorrenson 1990). He was in frequent contact with others in the "moa hunt", including William Colenso, Julius von Haast and James Hector. He sent important New Zealand fossil material (including moa) back to his father (Hodder & Hodder 2017). G.A Mantell passed moa fossils on to Richard Owen who first described them. When G.A. Mantell died in 1852, some of his fossil collections (including the *Iguanodon* tooth discussed above) were sent to W.B.D. Mantell in New Zealand.

Back to the Wairarapa Meteorite, it was "presented to" W.B.D. Mantell by Richard Collins in the late 1860's (Battey 1962, p.74). A catalogue of the Colonial Museum, Wellington for 1866 includes the meteorite and under "By whom sent" lists a Mr Collins (Colonial Museum, 1866). Mantell (who was closely associated with James Hector and the Museum) "deposited" the meteorite in the Colonial Museum in 1867 (Battey 1962, p.74). So the meteorite was never officially donated to the Museum by Mantell but remained as part of the collections for a time.

W.B.D. Mantell lived in Sydney Street, Wellington. Thomas Ward's map of central Wellington completed in 1891 shows Mantell's residence, next to Bolton Street Cemetery, at "Town Acre Number 502", Sheet No.15 (Cox 2025; Wellington Historic Map Viewer 2026). The property no longer exists after changes to Sydney Street and Bowen Street in the late 1920s. Mantell conveniently lived two "doors" up from the Colonial Museum and a few doors away from Government House and Parliament Buildings. He was easily able to keep his finger on the pulse of Wellington politics and institutions. As might be expected after 1891, "Town Acre Number 502" was subdivided.

W.B.D. Mantell's son Walter Godfrey Mantell (1864–1927) was a Wellington dentist. After his father died, W.G. Mantell lived in a corner of the original "Town Acre 502" property next to the Sydney Street access to the Bolton Cemetery (sometimes called the Sydney Street Cemetery) and had his dentistry practice there (Cox 2025, p.81). He was married to Catherine (Katie) Louise Marguerite Bucholz (1867–1950) in 1888 and inherited some of his father's collections.

W.G. & K. Mantell correspondence timeline (Auckland War Memorial Museum Library archives)
Correspondence in the AWMM Library archives between W.G. Mantell and others shortly before his death in 1927 and between Katie Mantell, and the Auckland Institute and Museum (AIM) after 1927, tracks the arrival of Wairarapa Meteorite (and likely two other meteorites – see below) to the AIM in 1928.

27 January 1926:
Paul Serra (French Consul, Auckland) on behalf of the Secretary of the Academy of Science, Paris, writes to W.G. Mantell requesting a piece of the Wairarapa Meteorite. The Academy Secretary at the time was Professor Alfred Lacroix (1863–1948), a prominent French mineralogist and geologist renowned for reorganising the Muséum National d'Histoire Naturelle (MNHN), Paris meteorite collection and rationalising stony meteorite taxonomy. Serra stated that it could be "*in exchange for a piece of a European meteorite*", which is significant regarding the source of the Hedjaz and Ausson meteorite fragments now in the AWWM collections (see below).

?February 1926 (handwritten):
Mantell replied "*Monsieur Paul Serra, French Consul, Auckland. Dear Sir, I have great pleasure in ?acceding to your request for Academy of Science, Paris for a portion of the Tohirua Meteorite which fell in the Wairarapa District. Also I ?have obtain(ed) from the Dominion Laboratory the analysis of the same. I am sorry of the delay as the meteorite was packed away preparatory to moving into another house also I have been ?? ??. Dear Sir, WGM*"

(The move Mantell talks about is probably from the Wellington Sydney Street address discussed above and was caused by large scale changes to Sydney and Bowen streets in the late 1920s).

18 February 1926:
The Consular Agent for France, Wellington wrote to Mantell regarding a request from Serra to call Mantell about obtaining a portion of the meteorite.

17 March 1926:
Paul Serra wrote to thank Mantell for the portion of the meteorite and the analysis. He sent it to Professor Lacroix, Muséum National d'Histoire Naturelle, Paris and he will ask Lacroix to send in exchange European meteorite material (see discussion below about the Ausson and Hedjaz Meteorites).

25 February 1928:
Letter from Johannes C. Andersen (1873–1962, Librarian,

Turnbull Library) to Gilbert Archey (1890–1974) (Director, Auckland Institute & Museum). Some of Mantell's collections were donated to the Turnbull in 1927 following W.G. Mantell's death. Andersen asked if Archey is interested in some pieces including "a bit of French meteorite" and two pieces of the "Masterton" meteorite and letters referring to it (presumably the above correspondence). The mention of "a bit of French Meteorite" is relevant later with regard to the Ausson and Hedjaz meteorite fragments.

27 Feburary 1928:
Archey writing to Andersen, thanked him for his letter and saying he would write to Mrs Mantell (Katie Mantell neé Bucholz).

27 February 1928:
Archey wrote to Mrs Mantell about the collection items including the meteorite pieces.

27 February 1928:
Archey to Stationmaster Wellington stated that freight is chargeable to the Dept of Internal Affairs.

6 March 1928:
Katie Mantell wrote to Archey about sending the meteorites to him and mentioned two pieces only plus original correspondence with them. Is she referring to the Wairarapa pieces or the two sent by the MNHM, Paris (see below)?

12 March 1928:
Archey wrote to Katie Mantell on receipt of the Māori objects and "two pieces of meteorite".

AIM Annual Report 1927-28, p.11:
"Mrs Mantell. Old Maori cloaks and meteorites". Meteorites plural is interesting and supports the probable source of the Ausson and Hedjaz meteorites (see below) ultimately being via Katie Mantell.

Timeline of pieces of the Wairarapa Meteorite held at AWMM (GE8514.1-6) 1928 – present
Much of this information comes from the handwritten paper Geology Collection Catalogue (Volume 2) and the back pages of this volume.

The original Mantell donation in 1928 consisted of two pieces (Original accession # 55/28). By 1954 there were three pieces recorded (GE8514.1–3) and reported to together weigh 13lbs 7oz (6095g).

In 1955 GE8514.2 was taken to England for analysis by the Curator of Geology, Hugh Battey. It doesn't seem to have come back.

In 1984 a piece was cut from GE8514.1 creating GE8514.4 (128g), which was sent to Paul Sipiera then affiliated with Otago University's Geology Department. It appears that in exchange Sipiera had already given the Museum a specimen of the Odessa Meteorite (GE9298 – see below) in November 1983.

In 1988 GE8514.1 was again cut to produce GE8514.5&6 (total weigh cut off 324.65g). GE8514.6 (54.75g) was sent to Prof. Brooks, Massey University, in exchange for a piece of the Kimbolton Meteorite (see GE9618 below).

Today the AWMM has three remaining pieces, the largest piece being GE8514.1 (currently on loan to Stardome Observatory & Planetarium, One Tree Hill Domain, Auckland since 1997), GE8514.3 and GE8514.5.

Other supposed pieces of the Wairarapa Meteorite
Reeds (1937) stated that a specimen is held at the American Museum of Natural History (Specimen #641, 7.5g), New York and that a 195g specimen is held by the Chicago Field Museum of Natural History (currently 62.03g seems to remain). Reeds speculated that they were fragments of the "Taranaki Meteorite" that fell in 1864 "*partly in the sea and partly on land at Turakina, after loud detonations, and appearance of fire-ball of which the smoke persisted for two hours.*" This event was reported in the Wanganui Chronicle (Wanganui Chronicle 1864). But this is unlikely since, as discussed above, Battey (1962) mentioned three dates for the meteorite being found: 1862 (New Zealand Court Catalogue of the Centennial International Exhibition, Melbourne, 1888, p.13), 1863 (Crawford 1865, p.26) and 1864 (Flight 1875, p.556). Additionally, the surface and fractures between pieces of the AWMM Wairarapa Meteorite specimen(s) are somewhat weathered, suggesting it was not a fresh fall.

We know from the Mantell correspondence above that in 1926 a piece was sent to the Muséum National d'Histoire Naturelle, Paris. Matthieu Gounelle (pers. comm.) at the MNHN, Paris confirms that there are currently 2 pieces in the collections (MNHN-GT-1512 (80.92g), MNHN-GT-1561 (3.76g)). Also see below regarding the Ausson (GE15648) and Hedjaz (GE15647) Meteorites as to how these pieces were probably sent to W.G. Mantell in exchange from the NMHN.

A thin section belonging to Prof. P. Marshall was in the Dominion Museum in 1962 (Battey 1962). It is possibly still in the collections of the NMNZ.

Whanganui Regional Museum has a specimen on display labeled "Wairarapa Meteorite" (WRM Collection: 1802.8667). But they have absolutely no data about its provenance, acquisition, etc.

Kimbolton Meteorite (GE9618, Chondrite H4),
Plate 1, Fig.2.
This c.7.5kg meteorite became wedged in the harrow of farmer Ray De Rose in 1976 while working his land near Kimbolton in the Manawatū District. It was described by Sipiera *et al*. (1986) and an audio description of finding the meteorite can be heard in the Radio New Zealand Archive (Radio New Zealand National 2022). AWMM's 68.9g piece was acquired from Prof R Brooks, Massey University in exchange for a piece of the Wairarapa Meteorite (GE8514.6, 54.75g) on the 10 Oct 1988.

Auckland Meteorite (GE15574, Chondrite L6), **Plate 1, Figs 3a–c**
Observed meteorite falls are extremely rare and for something to fall and be observed on the narrow strip of the Earth called New Zealand is even rarer. This spectacular event occurred at 9:30 a.m. on Saturday 12 June 2004 when a beautiful, 1.3kg, grapefruit sized meteorite punched through the roof and ceiling of the Archer family's home near the corner of Tecoma and Robert Streets, Ellerslie, Auckland, only 160 m from the Southern Motorway. The meteorite then bounced off a sofa, hit the ceiling again before coming to rest on the floor not far from where the Archer's grandson had been playing minutes earlier. Canterbury Museum apparently has that sofa now.

Traditionally (in the British Empire at least) meteorites were formally named after the nearest Post Office. The name Ellerslie Meteorite could not be used because there is already an Ellerslie Meteorite (1905) in outback Queensland. I formally named the Auckland Meteorite in 2020, 16 years after it fell (Meteoritical Bulletin Database 2026; also Gattacceca *et al*. 2021).

For a meteorite to be formally named it must have geochemical credentials. I started this process in 2016. The almost pristine specimen had a very small area of fall damage and some small fragments had been retained. In 2016, Dr Joel Baker (Geology Department, University of Auckland) offered to analyse some of this and also material from the "Alice Springs" Meteorite (GE9105 / GE10842). Nothing eventuated from this attempt because he "lost" both samples. A couple of years later a further very small amount of material was sent to Dr James Scott, Otago University in 2018. This was analysed and confirmed the Auckland Meteorite as a chondrite (Scott *et al*. 2019).

Sadly this once pristine specimen is no more since further analysis by Scott *et al*. (2023) saw this beautiful meteorite sliced up and unnecessarily butchered (3 slices, **Plate 1, Fig.3c**). Why was this done, given the modern analytical techniques available, is inconceivable. Plus it had already been confirmed what type of meteorite it was anyway in 2019.

Australia

"Alice Springs" Meteorite (GE9105 / GE10842, Iron octahedrite (maybe type IIIB)), **Plate 1, Figs 4a–e**
When I first examined it, this handsome iron octahedrite was on display in the Cheeseman Hall with a recent accession number (GE102842), presumably because it had "lost" its original number, but had no data associated with it. Eventually I was able to establish that it was mostly likely the 17lb (7.71 kg) iron meteorite from "Central Australia" mentioned in the Auckland Institute & Museum Annual Report (1950–51, p.20). This turned out to be GE9105. The 1950 weight given in the AIM Annual Report is very close to the weight measured accurately in 2016 (7.79 kg).

In the paper accession records, accession number 88/50 (#88, 17th April, 1950) names Mrs I.H. Badger (Adelaide) as the donor. As was common at the time it appears she used her husband's initials. She worked for T.S. Nettlefold & Sons (which later became K.G. Luke Pty Ltd) at 222 Pulteney Street, Adelaide. Her husband was a sales manager for T.S. Nettleford & Sons and his sales travels included Alice Springs in 1949 (Centralian Advocate, 1949).

This is the largest meteorite in the Geology Collections and because there are many possible "Central Australia" sites, its locality data currently just states it was probably from NW of Alice Springs, Northern Territories, Australia. At least three impact craters near Alice Springs could be a source; Henbury (southwest, -24.572094, 133.148175, found in 1931), Boxhole (northeast -22.612806, 135.195397, found in 1937) and Gosses Bluff (west -23.821272, 132.306773). The Henbury and Boxhole meteorites are irons (type IIIB) but no meteorites are recorded for Gosses Bluff. This is why, as mentioned above, an attempt was made in 2016 to geochemically "finger print" the specimen.

A cut and polished face displays the classic Widmanstätten pattern (Wikipedia 2026) of octahedrites (**Plate 1, Fig. 4c**). The lattice work of Kamacite / Taenite crystals (0.75–1.25 mm) is clearly visible on the polished face which was re-polished and etched by Liz Yuda (AWMM Collection Care) in November 2016. Note below that the number GE9105 was also used for the Toluca Meteorite (GE681) for some unknown reason.

Tektites (GE9390), **Plate 1, Fig.5.**
We have minimal data for these three Australian specimens donated by J.L. Neild on the 18th Feburary 1987.

Tektites (GE8357), **Plate 1, Fig.6.**
We have minimal data for these three specimens donated by Mrs H.W. Hemingway from the Nullabor Plains, Australia.

North America

Toluca Meteorite (GE681, Iron IAB-sLL), **Plate 1, Fig.7**.
This is a fragment of the Toluca Meteorite (an iron octahedrite) which were first found in 1776 near Jiquipilco, Toluca Valley, Mexico (19.566435 -99.566728).

The specimen was probably originally obtained by Thomas Cheeseman in the late 19thC from Horatio Nelson Rust (1828–1906), an American businessman, archaeologist and collector (Militello 2009). During the 1929 move of the Museum's Collections from the Princes Street site to the Domain site, the data (labels) for GE681 and GE157 (see below) were swapped. I found this had happened to a number of specimens in the Geology Collection that had become jumbled during the move and the specimens themselves were not numbered at the time nor linked to labels by a catalogue number. The important bound Geology Catalogues (Volumes 1–3) and the "new" Auckland Institute & Museum numbering appear after the move and opening of the Domain site in November 1929. Later

still, for some strange reason the Toluca Meteorite was again also wrongly numbered as GE9105 – a number also used for the "Alice Springs" Meteorite discussed above.

Brenham Meteorite (GE157, Pallasite, PMG-an), **Plate 1, Fig.8**.
The Brenham Meteorite is a pallasite from near Brenham, Kiowa County, Kansas (37.58250 -99.16361). Iron from the Brenham Meteorite strewn field was known to native Americans for at least 1500 years and the field was re-discovered by farmer Eliza Kimberly in 1882. There is little evidence of the Brenham community today, which was between Greensburg and Haviland. The farmland of this area is almost entirely devoid of rocks but farmers sometimes bent their plows on mysterious metallic objects. Eliza Kimberly, who had seen a large iron meteorite as a child, collected a large pile of these fragments. Despite being teased by husband Frank, Eliza wrote to various institutions for a number of years before someone finally came and her suspicions were confirmed. Husband Frank changed his tune when he found out how valuable the meteorites were. Brenham meteorites are still being found today and the largest piece yet (635 kg), an orientated pallasite, was found in 2005.

Pallasites are rare and this beautiful Brenham specimen, which is cut and polished on one side and natural on the other, has large gem quality olivine (peridot) crystals embedded in an iron-nickel alloy. Other Brenham meteorite fragments found lack the olivine crystals and are iron-nickel octahedrites which when cut, polished and acid etched display the classic Widmanstätten pattern.

When I was cataloguing this specimen, it was originally incorrectly numbered 681 (i.e. GE681, Toluca, Mexico in the Geology Catalogues V1). Specimens found from Toluca, Mexico are iron meteorites only and do not include pallasites. It also had clearly written on it "Kiowa Co." (Kiowa County), which is not in Mexico. This specimen is typical of the Brenham pallasite meteorites. I later also discovered the original late 19thC Ward display label with pin holes (Gill *et al.* 2019, p.33) stating "Meteoritic Iron, Kansas, United States" and numbered 25/2. So this meteorite was very likely on display in the Princes Street Museum when curated by Thomas Cheeseman. This label means acquisition of the specimen occurred in the late 19thC and not the early 20thC. Exchanges and purchases (e.g. the large casts in the Cheeseman Hall of Mesozoic marine reptiles) with the American natural history collector and dealer Henry Augustus Ward (1834–1906) were very important to the early Auckland Museum in Princes Street (Gill *et al*. 2019).

Canyon Diablo Meteorite (GE153, Iron IAB-MG), **Plate 1, Fig.9.**
The Canyon Diablo Meteorite refers to the many fragments of the asteroid impact that created Meteor Crater (also called Barringer Crater) in Arizona (35.02806 -111.02250). It is an octahedrite iron meteorite. Such fragments were well known to native Americans and were subsequently re-discovered by Europeans in 1891. Initially the small natural fragment AWMM had no labels or data with it, but research showed it to be part of an exchange between Horatio Nelson Rust and Thomas Cheeseman in 1898. Correspondence from Rust to Cheeseman on the 25th December, 1897 (AWMM Library archives) includes an outline sketch of the meteorite and says it weighed about 8 ounces. This was the definitive clue as to the identity of this meteorite.

Canterbury Museum has the fourth largest known Canyon Diablo fragment (485kg), and the largest outside the USA. It was part of many exchanges between Henry Ward and Julius von Haast in 1897 (P. Scofield pers. comm.). At the time, Canterbury Museum had a much more valuable exchange "currency" than the Auckland Museum in the form of moa bones and skeletons.

Odessa Meteorite (GE9298, Iron IAB-MG), **Plate 1, Fig.10.**
This Odessa meteorite fragment is an octahedrite iron meteorite and fragments were first discovered in 1922 associated with the Odessa Meteor Crater in Ector County, southwest of the city of Odessa, Texas (31.756227 -102.479076). AWMM has a small natural fragment of meteorite apparently exchanged by Paul Sipeira (then affiliated with the Geology Department, Otago Unversity) on the 16th March, 1983 for a piece of the Wairarapa Meteorite (i.e. GE8514.4).

Other
Both the Hedjaz and Ausson Meteorites below were not originally part of the meteorite collection and had been incorrectly labeled as the mineral Chondrodite (a relatively rare magnesium-iron nesosilicate) since the late 1920s.

Hedjaz Meteorite (syn. Et-Tlahi, El-Tlahi, Hejaz) (GE357.2 / GE15647, Chondrite L3.7-6 – apparently the only meteorite of this type known (Frederiksson *et al*. 1986)), **Plate 1, Fig.11.**
The fall is recorded in 1910 from the Tabuk Region, NW Saudi Arabia (27.60000,35.66667), near the northern part of the Red Sea. This 28g piece was apparently exchanged by the Muséum National d'Histoire Naturelle, Paris and Professor Alfred Lacroix with W.G. Mantell for a piece of the Wairarapa meteorite in 1926 (see archival correspondence above). The specimen still has its original MNHN, Paris label with it. It also has an original number 357.2 on it but was given a new number (GE15647) because GE357 was already in use for a carbonate rock specimen in the James R. Gregory Collection.

Ausson Meteorite (GE375.1 / GE15648, Chondrite L5), **Plate1, Fig.12.**
On December 9, 1858, in the early morning, inhabitants of the French Haute-Garonne Department, southern France (near the Spanish border) observed a bright meteor in the sky, then heard a loud detonation followed by a continuous rumble. The meteor moved from northeast to

southwest, according to witnesses. Two meteorites were found: one fell in a field located at the bottom of the hill that leads to Montréjeau, near the village of Ausson, weighing between 40–45 kg; the other stone, weighing 8–10 kg, fell on a barn belonging to Mrs. Capéran, next to the Clarac Church. The two meteorites recovered near Ausson and in Clarac were broken up by the inhabitants and shared. Fortunately, the members of a Commission set up by the Academy of Sciences of Toulouse managed to get beautiful pieces from the fall (Pelé 2026).

This 65g AWMM piece has its original Muséum National d'Histoire Naturelle, Paris label stating that it is part of the Montréjeau fragment. My research suggests it was apparently exchanged by the MNHN, Paris and Professor Alfred Lacroix with W.G. Mantell for a piece of the Wairarapa Meteorite in 1926 (see archival correspondence above). It also has an original number 357.1 on it but was given a new number (GE15647) because GE357 was already in use for a carbonate rock specimen in the James R. Gregory Collection (GE357 = Gregory #483).

Mekong Tektite (GE9389), **Plate 1, Fig.13.**
We have minimal data for this specimen from the Mekong Delta, Vietnam, donated by J.L. Neild on the 18th Feburary 1987.

So that is the AWMM Meteorite Collection. Very small by international standards but there are some interesting twists and turns in the acquisition history and curation of these specimens over time.

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RARE DEEP-SEA, RADIAL TRACE FOSSIL

Bruce W. Hayward and Geoff Evans

In July 2026, one of us (GE) was taking a walk along the local Narrow Neck Beach (**Fig. 1**) as he had done many times before. The sand level is currently low at the northern end and beds of Early Miocene (20 Myrs old) Waitematā Sandstone (Ballance 1964; Hayward 2017), which had not been seen for a long time, were exposed intertidally. As he passed a tilted bedding plane of sandstone (**Fig. 2**), Carol Bidwell, a near neighbour, pointed out something rather unusual, wondering what it was. He took a photograph (that included Coco the dog for scale) and sent it off to his geology-enthusiast mate, Ken Smith, for identification.

This "beach thingy" (**Figs 3, 4**), as Geoff's photograph was labelled, is a circular radial feature about 15 cm in diameter that is rust-coloured and slightly raised on the upper surface of a 20 cm thick sandstone bed. It consists of a number of 8 cm-long, sand-filled branches that radiate outwards from a central point, forming a complete circle. Each branch has an ellipsoidal cross-section that is 4–8 mm wide. Some of the branches have two rows of short, stumpy, close-spaced branchlets, one on either side (**Fig. 5**). Other branches have only one row or portion of a row of branchlets – maybe they originally had two rows but they may have eroded off?



Fig. 1. Location of Narrow Neck Beach, Devonport, Auckland.



Fig. 2. The "beach thingy" was found by one of us (GE) at the north end of Narrow Neck Beach in the intertidal sandstone beds (tiny black circle).

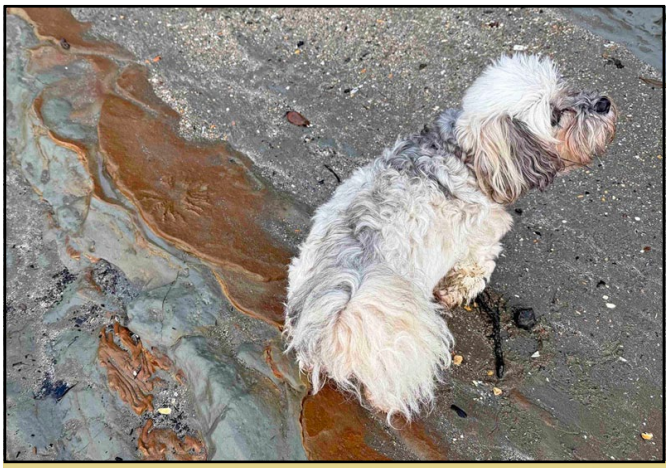


Fig. 3. Circular "beach thingy" on a rusty bedding plane to the left of Coco the dog. North end Narrow Neck Beach.



Fig. 4. The circular "beach thingy" trace fossil found by GE at Narrow Neck Beach. Width of fossil 15 cm.



Fig. 5. Six radiating branches of *Radionereites ballancei* from Narrow Neck -Takapuna cliff section of Waitematā Sandstones. Width of photo 15 cm.

A close examination of well-preserved branchlets (**Fig. 6**) shows that they are slightly curved back towards the centre of the circle and that they consist of a short U-shaped tube that extends outwards from the axis of the branch and then does a tight U-turn and returns to the axis. Another observation is that the branches and branchlets appear to be more iron-cemented (rusty or black-covered) than the host sediment (often grey or weakly iron-stained).

Nearly 80 years ago, Professor John Bartrum (1948), from Auckland University College, also discovered a weird "beach thingy" (**Fig. 7**) in the Waitematā Sandstones between Narrow Neck and Takapuna, just like Geoff had seen. He was not confident in identifying it and so took a photograph, wrote a short article and published it in the international journal 'Paleontology' asking for suggestions as to what fossil it might be. Unfortunately, Bart died soon afterwards and we do not know if he received any suggestions. Bart concluded in his article that "*the writer tentatively suggests that the organism represented may have been a sponge or a seaweed*."

In the 1960s, English-trained sedimentologist Peter Ballance joined the Auckland University staff and his first study was on the Waitematā Sandstones between Narrow Neck and Takapuna. He clearly showed that they were deposited in deep water by turbidity currents and contained a suite of different kinds of trace fossils, which included Bart's undetermined fossil "seaweed". In earlier times, many trace fossils overseas and in New Zealand had been thought to be fossil seaweed, because of the similarity of their shape and branching.

Ballance (1964) described this fossil and called it his trace fossil type F. In 1969, one of his graduate students, Murray Gregory, formally named Peter Ballance's specimen as *Radionereites ballancei* Gregory, 1969 (**Fig. 8**). He noted that each branch of this trace fossil with its branchlets was essentially the same as that in the globally-well-recognised trace fossil genus *Nereites*, which was described and named way back in 1839 in Scotland. *Nereites* usually has a single wavy or meandering back-filled burrow with "branchlets" on each side. *Radionereites* is distinctive in that it consists of a cluster of branches that radiate outwards from a single point and in extreme cases can produce a fully circular (or even overlapping) fan (**Figs 4, 9**).

Nowadays, the majority of marine trace fossils are widely recognised as the burrows of sediment-inhabiting animals. Trace fossils with shallow burrow systems like these, which appear to have systematically burrowed through a whole area of seafloor sediment, are inferred to have been made by deposit feeding animals that ingest sediment to extract living and dead organic matter (microalgae, bacteria, detritus) out of it. Once the food has been removed in the gut, the sediment is excreted and back fills the burrow. Prominent examples of such burrowing deposit feeders today are various kinds of worms and echinoderms.

Exactly what organism made our *Radionereites ballancei* ("beach thingy") is unknown but possibly the same as that



Fig. 6. Close-up of several branches with branchlets on either side of *Radionereites ballancei* specimen at similar stratigraphic level to the circular specimen, north end of Narrow Neck Beach. Photo width 6 cm.

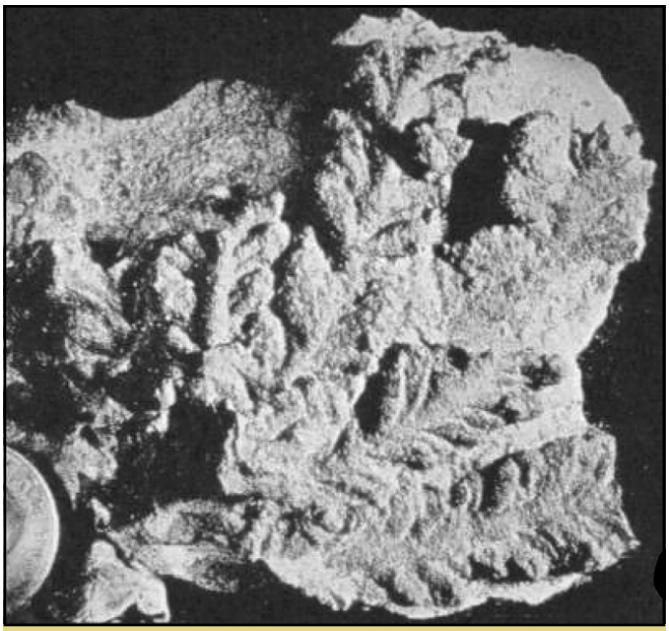


Fig. 7. Bartrum's (1948) "undetermined fossil" from near Narrow Neck. Width of photo about 10 cm.



Fig. 8. Ballance's (1964) trace fossil type F from Narrow Neck Beach to Takapuna cliffs. Also nominated by Murray Gregory (1969) as the type specimen of *Radionereites ballancei*. Width of photo 12 cm.

which produced *Nereites*. A kind of small worm seems most likely, because the branchlets appear to be loop-shaped burrows. The more cemented nature of the burrows compared with the host sediment of similar grain-size indicates that the sand filling the burrows is probably more permeable and not as tightly packed as the host sediment. This would allow oxygen-rich groundwater to pass through the burrows and oxidise iron minerals in the burrow sediment. This happens as the rocks get close to the surface because of uplift and erosion, and oxygen-rich groundwater can penetrate downwards to a few tens of metres depth.

More interesting is exactly why *Radionereites* does not appear to have been recorded from anywhere else in New Zealand or the Waitematā Sandstones away from the Narrow Neck–Takapuna section of cliffs. It is hard to believe that the animal that made these trace fossils only existed on the deep seafloor in this vicinity for a few thousand years before becoming extinct. Another possibility is that a population developed this unusual feeding trait that was passed on between generations for a few thousand years in this part of the Waitematā Basin before the practice died out again.



Fig. 9. Overlapping radial specimen of *Radionereites ballancei* from Takapuna–Narrow Neck cliffs. Specimen in National Paleontology collection, Lower Hutt. Photo width about 20 cm.

Whatever the answer, *Radionereites ballancei* is a rare trace fossil that can be found in a few beds on Auckland's North Shore. Get along there and have a look for yourself.

Acknowledgements

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