Journal of Astronomical History and Heritage, 25(2), 277–289 (2022).

THE 1989 OPOTIKI BOLIDE: ACCUMULATED EVIDENCE FOR A NEW CARBONACEOUS CHONDRITE METEORITE FROM AOTEAROA / NEW ZEALAND

Wayne Orchiston and John Drummond
Centre for Astrophysics, University of Southern Queensland, Toowoomba, Queensland 4350, Australia.
E-mails: wayne.orchiston@gmail.com; kiwiastronomer@gmail.com

Abstract: On Monday 12 June 1989 a detonating fireball was widely observed from the East Coast–Bay of Plenty region of New Zealand, and subsequently a number of small meteoritic specimens were recovered near Opotiki. These were submitted to the Geological Survey of New Zealand in Wellington where they were identified as fragments of a carbonaceous chondrite. However, no detailed account of this meteorite was written up and published either at that time or subsequently.

This belated report summarises what we know about the Opotiki Bolide, and is based on contemporary newspaper reports, and fieldwork conducted in the impact area at the time by the two authors of this paper and by the Scottish-Australian astronomer, Robert McNaught.

Keywords: New Zealand; Opotiki Bolide; carbonaceous chondrite meteorite; Dr Alva Challis

1 INTRODUCTION

Aotearoa / New Zealand is a sparsely populated mountainous nation in the south-west Pacific, and can claim only a small number of meteorites. Those mentioned in Orchiston's (2016) book *Exploring the History of New Zealand Astronomy …*, are listed in Table 1 and plotted in Figure 1, but only the ones with yellow dots in the map have been formally described, listed in the Meteoritical Bulletin Datebase (https://www.lpi.usra.edu/meteor/) or MBD, and therefore are officially recognized.[1]

One of the 'missing meteorites' is the 'Opotiki Meteorite', and although no sizable masses of this carbonaceous chondrite were ever recovered and analysed it is hoped that this account will provide adequate documentation to justify the official listing of this meteorite in the MBD. As such, this paper is based on a variety of archival records (including contemporary newspaper reports) from Aotearoa / New Zealand, and a field study in the impact region carried out by the authors of this paper soon after the bolide was first reported in the nation's newspapers.[2]

2 NEWSPAPER REPORTS OF A BOLIDE AND METEORITE FRAGMENTS

Typical of public accounts of the bolide is the following, drawn from an article in the *Gisborne Herald* that was published on Tuesday 13 June 1989, the day after the impact (and for localities mentioned below see Figure 2):

> Three schoolboys in the tiny Waipiro Bay settlement had the science lesson of their life last night as they tracked what was believed to be a falling meteorite across the East Cape.
>
> Robert Colbert, 10, Justin Tibble, 9 and David Rasmussen, 12, were playing on the trampoline outside their school just after 3pm when they saw a 'lone line of blue' moving across the Urewera Ranges.
>
> "It turned into a yellow ball of fire," said David. "It carried on going and split into four pieces — they were sort of like diamonds, yellow," he said.

Table 1: Known Aotearoa / New Zealand meteorites, in order of discovery.[3]

Name	Discovery Year	Discovery Mode	Type	Weight
Manaia (= Wairarapa Valley)	1863	Farming	H6 Stony	6 kg
Makarewa	1879	Railway construction	L6 Stony	2.3 kg
Mokoia	26 Nov 1908 (fall)	Search	CV3 Stony	4.5 kg
Waingaromia	1915	Farming	IIIAB Iron	9.2 kg
Berhampore (Wellington)	Early 1920s (fall)	Search	Stony	Cricket ball size
Morven	1925	Farming	H4/5 Stony	7.1 kg
View Hill	1952	Farming	IIIAB Iron	33.6 kg
Dunganville	1976	Prospecting	IIIAB Iron	54 kg
Kimbolton	1976	Farming	H4 Stony	7.5 kg
'Otago' (= Dunedin)	1960	Laboratory analysis	LL3 Stony	5.1 g
Opotiki	12 June 1989 (fall)	Search	Stony	V. small fragments
Ellerslie (Auckland)	12 June 2004 (fall)	'Search'	L5 Stony	1.3 kg
Whakamarama	13 May 2013	Search	Iron	?

Figure 1: Distribution of New Zealand meteorites. Only those shown in yellow are officially recognized (map: Wayne Orchiston).

The three boys rushed over to alert their teacher Warren Field who just caught the tail end of the episode.

The four pieces were sending out what looked like "smoke signals", puffs of smoke which just seemed to hang in the sky, not moving.

Mr Field saw one piece coming down somewhere over the horizon in the direction of Whakatane.

About a minute later they heard the loud sonic boom. "It was sort of like thunder," said Robert.

"We measured it with a compass and map afterwards," said Mr Field. "I believe if there are any pieces to be found they are about midway between here and Whakatane according to the speed and height and distance of travel …

[The next day] On discovering it was a meteorite, the boys were inspired to study the subject further. They re-enacted the event this morning to get a precise timing of the incident.

Their estimations show the object travelled some 40 degrees across the sky in eight seconds. The explosion was heard one minute and 10 seconds later.[4] (Trio gets blast of science, 1989).

Later in the same newspaper article the (anonymous) *Gisborne Herald* reporter mentions that the explosion "… was heard as far

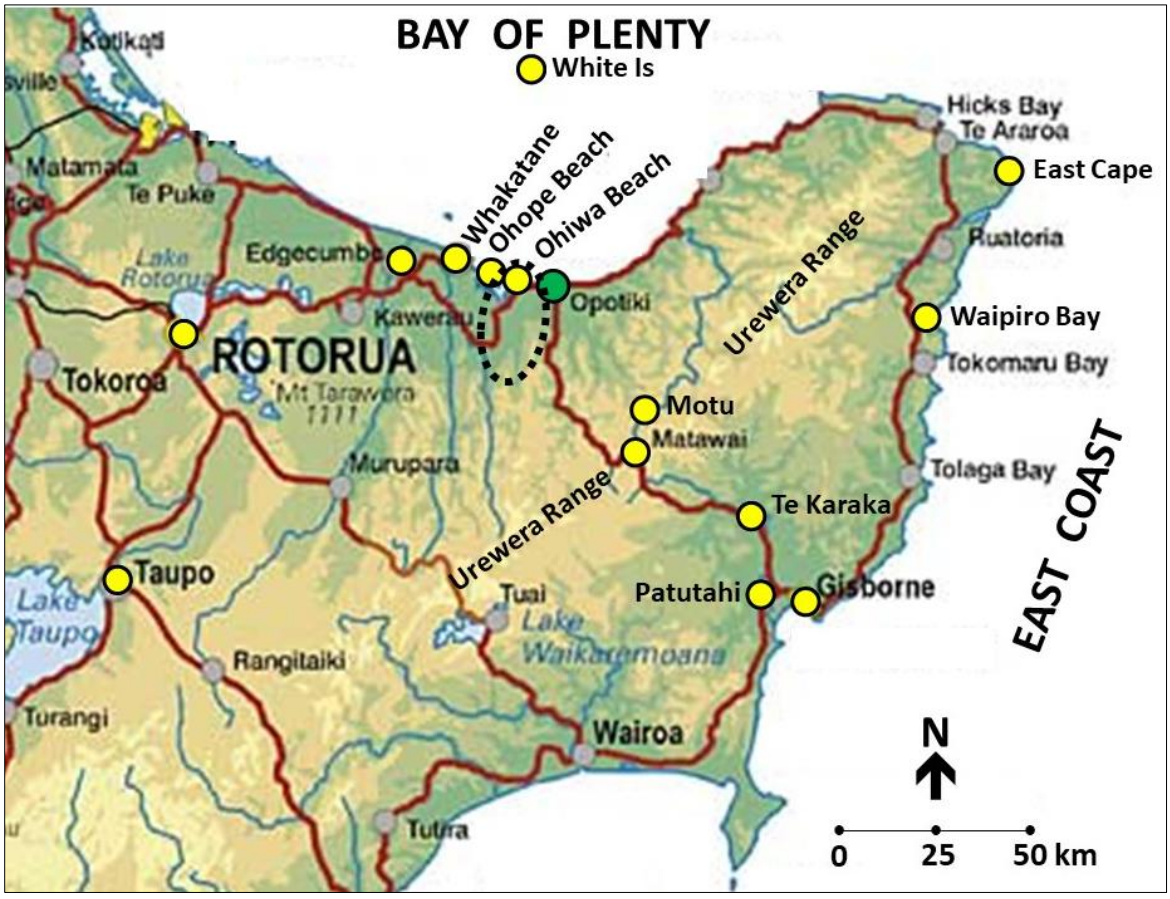

Figure 2: Bay of Plenty–East Coast localities mentioned in the text (map: Wayne Orchiston).

inland as Motu, Matawai and Te Karaka." (ibid.). Te Karaka farmer Graeme Newman "… described it as "subsonic". It was just an explosion to start with and then continued for 8 to 10 seconds." (ibid.). Mr Newman's first impression was that White Island had erupted.[5] At the time, the second author of this paper was at Patutahi, near Gisborne, and he also heard the explosion.

On 13 June the *New Zealand Herald* carried a story about the meteorite that provided a wider, Bay of Plenty, perspective. In the sensationally-titled report "Flaming whiz-bang from outer Space", Kevin Townsend and Max Avery reported that "Hundreds of people saw the meteorite as it sped across the sky leaving a smoky trail in its wake." They mentioned that the control tower at Rotorua Airport received calls from people in Rotorua, Taupo, Whakatane and Opotiki who saw the object. Mr Marr, a farm worker at Edgecumbe, west of Whakatane (see Figure 2), provided vital details. He

> … saw a bright [orange] ball of flame the size of a house streaking through the sky from the Bay of Plenty coast just after 3 pm.
>
> "It was so bright that I threw my arm up to shield my eyes.
>
> "I watched it for about three seconds. It seemed so close it was almost as though I could reach out and touch it. Then it exploded in front of me with no sound whatsoever.
>
> "About 10 seconds later there was a noise just like thunder which went on for about four seconds,[4] rather like the Edgecumbe earthquake." (Townsend and Avery, 1989).[6]

At the time there was cloud at about 16,000 feet, and visibility was quite good.

At nearby Gow Road in Edgecumbe, the former Mayor of Whakatane, Jack Gow, and his son David were working on a fence when they saw

> … a cluster of silver-white lights coming from the north-east at a 45 degree angle towards the ground with a trail of bluish smoke.
>
> The biggest piece of debris was the size of a small petrol can, although the cluster seemed to disintegrate before it hit the ground several hundred metres away in some farmland. (ibid.).

There is always a foreshortening effect with these sorts of observations, where impact sites appear to be very much closer than they are in reality, and this also proved to be the case on this occasion, for later that afternoon police searched the "… farmland where the object was thought to have landed [but] failed to find any debris." (ibid.).

One of the other interesting features of the Townsend and Avery (1989) story was information supplied by Frank Andrews, an astronomer at Carter Observatory in Wellington.[7] Whilst stressing that what people may expect to find would be regular meteorites, Andrews also stated that there was a remote possibility that the object seen in the sky might have been a man-made satellite returning to Earth and partially burning up in the atmosphere. He warned that if that were the case

> … some of the debris might be radioactive pieces of a nuclear reactor.
>
> As a safety precaution Mr Andrews advised anyone finding a piece of debris to mark it and call either the police or the Department of Scientific and Industrial Research, who would investigate the discovery. (ibid.).

As we shall see shortly, this sage advice was followed exactly.

One day later, on Wednesday 14 June 1989, the *New Zealand Herald* carried a story copied from Whakatane's *The Beacon*, which revealed that meteoritic samples had been recovered. On 12 June an Opotiki builder named John Petersen was overseeing the construction of a new cowshed for his neighbour Mrs Wairata Walker who also lived on Dunlop Road, Opotiki,

> … when he heard what he described as "a big thump" about 3pm.
>
> "It shook the whole shed. It was a frightful bang," he said.
>
> "Then there was a rumbling sound, and while that was going on there was a sound like shrapnel hitting the roof." (Bits follow fireball, 1989).

Petersen paid little attention to this disturbance, but after hearing about a possible meteorite impact on the national TV news that evening he examined the site on 13 June and

> Lying on the new concrete floor of the shed he found eight little chunks of material about the diameter of a 5c piece.
>
> "It looked just like black soot with white spots," he said.
>
> "It must have been the stuff that I heard falling." (ibid.).

Petersen then called the police, who sealed off the area and collected samples. Eventually Constable Ivan Parke from Edgecumbe arrived with a borrowed Geiger counter, "… and declared the objects free from radioactivity." (ibid.). The police then sent the samples to Dr

Alva Challis (1930–2010; Figure 3), who worked for the Geological Survey of New Zealand in the nation's capital, Wellington. Dr Challis was Aotearoa / New Zealand's leading authority on meteorites, and had previously researched and written up the Dunganville Meteorite which is listed in Table 1 (see Challis, 1984).[8]

Even before the samples reached her, Dr Challis was enthusiastic about this latest New Zealand meteorite, but she cautioned that

> … the meteorite could be spread over a large part of the countryside.

Figure 3: An undated photograph of Dr Challis at her microscope (after Nathan, 2020: 29).

> "The meteorite must have broken up, and probably material is distributed over a wide area of the Bay of Plenty, and perhaps even wider.
>
> "It is going to be hard to find the material unless there is a larger piece somewhere. People should be on the lookout for things that look like lumps of charcoal, but are heavier." (Bits follow fireball, 1989).

The following day (15 June) a report in the *Opotiki Times* indicated that by this time Dr Challis believed that the biggest pieces of the meteorite "… probably fell in the Bay [of Plenty] and Opotiki seems to have received the tail-end of the break-up." (Monday June 12 …, 1989).

Just one day later Dr Challis' suspicions were confirmed when she reported to the media that the meteorite was indeed a carbonaceous chondrite,

> Staff from the Department of Scientific and Industrial Research in Lower Hutt took just a few hours to confirm that the handful of small charcoal-type pieces found near a cowshed on Tuesday were part of an unusual carbonaceous chondrite. (Townsend, 1989).

Dr Challis said this was

> … an exciting find because … [the samples] contain organic matter such as water and an unusually high level of carbon.
>
> "They have got the ingredients of life there." (ibid.).

Dr Challis then impressed on readers the importance of sending her additional samples and, because it had rained since the impact, remaining fragments

> … would be very soft and friable and would not last very long.
>
> Every scrap of material is invaluable to us and we hope people in the district will be able to send us more pieces … as soon as possible before being washed away.
>
> "And of course we are very hopeful someone will send us a bigger piece than those found so far." (Meteorite was rare variety, 1989).

If adequate samples were received, "… detailed test would then be carried out, probably involving scientists and equipment from overseas." (Bits follow fireball, 1989).

Meanwhile, Dr Challis announced that the samples she had already received were enough to justify naming the new find the 'Opotiki Meteorite'. This followed the international convention of assigning a name relating to the find-locality, and she expected that "The name would eventually be entered into the official international record of meteorites held in Arizona." (Townsend, 1989). In fact, that never occurred, primarily because the larger samples of the meteorite that she was seeking never materialized. The primary reason for this will emerge in Section 3, below.

3 POST-IMPACT FIELDWORK BY THE AUTHORS OF THIS PAPER AND BY ROBERT McNAUGHT

The authors of this paper were both resident in Gisborne at the time of the meteorite impact, and three weeks later, early in the morning on 9 July we drove to Opotiki, and spent

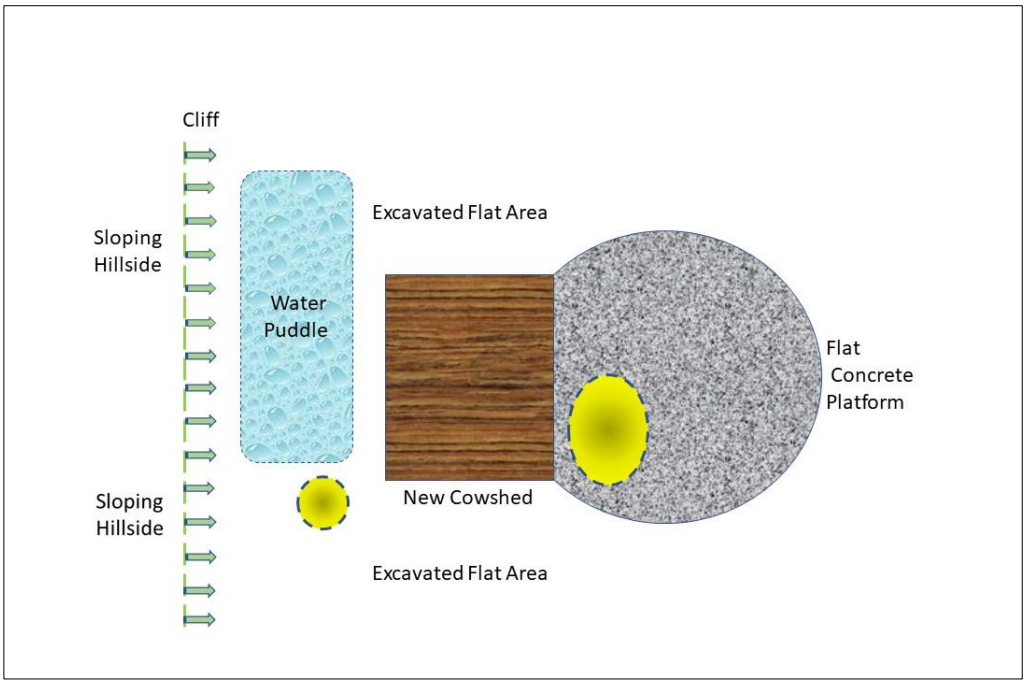

Figure 4: A schematic diagram (not to scale) showing the excavated hillside, new cowshed and water puddle. The gold-coloured circle and ellipse show the two locations where meteorite fragments were found (diagram: Wayne Orchiston).

a long day interviewing locals who lived in Dunlop Road, Opotiki, including John Petersen (1936–2011), photographing the new cowshed, and searching unsuccessfully for any remaining meteorite fragments.[9]

John Petersen (pers. comm., 9 July 1989) told us that on the day of the impact (Monday 12 June 1989) the sky was overcast, and when he was constructing the cowshed suddenly there was "… a terrific noise – like terrific gunfire – echoing round the hills." Then he heard something impacting on the roof of the cowshed.

Mrs F. Amoamo (pers. comm., 9 July 1989) also lived in Dunlop Road, and she reported that her husband, Frank, was at home at the time and he also heard "… an explosion, like dynamite, and there was a shock wave and the door rattled."

Meanwhile, after seeing the TV news that evening, early next morning Petersen (pers. comm., 9 July 1989) went to the cowshed straight after sunrise, and upon looking at the concrete platform in front of the cowshed he saw these small fragile fragments that looked like "… jet black soot, with little white dots." It had rained heavily overnight, and these fragments were only found in two places, on the concrete in front of the cowshed and on the ground at one location behind the cowshed, near a large puddle of water. In order to erect the cowshed, a section of the adjacent hillside had been removed, and a tract of flat land had been prepared. On the basis of John Petersen's description, and with his assistance, we drew a crude sketch (not to scale), which illustrates these features, and this is reproduced here in Figure 4.

John Petersen stressed that altogether there were only five or six fragments, the largest of which was the size of a thumb nail. Darryl Sturm (pers. comm., 9 July 1989), who also lived on Dunlop Road and was helping construct the cowshed, confirmed that samples were only collected from these two locations, while Petersen (pers. comm., 9 July 1989) stated that he, Sturm and the Police, were the only ones who saw and collected meteorite samples on the day after the impact.

Peterson (pers. comm., 9 July 1989) and Sturm (pers. comm., 9 July 1989) both told us that on Thursday 15 June, two DSIR scientists arrive by car and spent the day at the cowshed and surrounds and drained the puddle of water behind the cowshed. Apparently, they found more meteorite fragments at the cowshed under the flashing, and when they left they "Took quite a few bits and pieces away." (Peterson, pers. comm., 9 July 1989). But evidently these did not include enough meteorite fragments because Dr Challis was unable to conduct further studies or write a paper on the 'Opotiki Meteorite'. Perhaps this is not surprising given the fragile

nature of carbonaceous chondrite fragments after being exposed to rainfall. Both Petersen (pers. comm., 9 July 1989) and Sturm (pers. comm., 9 July 1989) referred to this, and Sturm stated that the fragments disintegrated when touched.

One of the authors (WO) had a private meteorite collection, so when we drove to Opotiki we took reference samples with us that we could show our informants. We had examples of complete stony meteorites with typical fusion crust, and etched and polished slices of different types of stony meteorites. Both Petersen (pers. comm., 9 July 1989) and Sturm (pers. comm., 9 July 1989) saw similarities between the chondrules visible in our reference specimens and the fragments they had collected near the cowshed.

Figure 5: Scottish-Australian astronomer Robert McNaught is famous for his comet and minor planet discoveries (https://earthsky.org/space/nova-reticuli-2020-southern-hemisphere/attachment/robert-mcnaught-sq/).

In 1989 the first author of this paper (WO) was between astronomy jobs, and serving as the Director of the Gisborne Museum and Arts Centre. Over the years he had built up an excellent working relationship with Roger Handford, the 'science reporter' at local radio station 2ZG, who also made a point of covering local astronomical 'news'. Naturally, he was keen to report on the 9 July Opotiki fieldtrip after we returned to Gisborne. This had an unexpected consequence, for on 20 July 1989 Handford (pers. comm., 1989) advised that he had samples of the 'Opotiki Meteorite' that an anonymous donor had left for him at the 2ZG front desk when he was out on an assignment. In a small sealed plastic bag were what looked like samples of meteorite fusion crust, and in the accompanying note the anonymous donor stated that they had been camping on the beach near Ohope at the time of the Opotiki event when there was a loud explosion, they looked up, and heard material falling on the awning of their caravan. They then proceeded to collect a plastic bag full of this material. Subsequently, these specimens were passed on to the first author of this paper, and in November 1989 they were on public display at the Museum (see Director compares slice of heavens, 1989). Unfortunately, the donor of these fragments did not include a name or contact telephone number on the note they left for Handford, so we have not been able to obtain additional information. Most pressing would be to determine the precise location of the caravan: whether at Ohope Beach itself, or Ohiwa Beach (which is between Ohope Beach and Opotiki). All we know is that they were "Camping near Ohope." (ibid.). Be that as it may, this does provide further confirmation that a meteorite impact was experienced in the Opotiki–Ohope region on 12 June 1989.

Robert McNaught (b. 1956; Figure 5) was based at Siding Spring Observatory in northern New South Wales, Australia, when he heard about the Opotiki Bolide, and in late June 1989 he flew to New Zealand to investigate the event. He spent his time interviewing people in and near Opotiki who witnessed the bolide and/or heard the explosion. After returning to Australia he analysed the accumulated data and then wrote a report which, unfortunately, was never published (McNaught, pers. comm., 30 April 2022).

Sadly, all of McNaught's records were destroyed in 2013 when he lost his house during the notorious New South Wales bushfires, but when contacted recently in regard to his Opotiki investigation he said (McNaught, pers. comm, 25 April 2022) that there were a few memories that were probably strong enough to be considered as 'data'. These were:

> … the path [of the fireball] was quite shallow and crossed the coast near Opotiki with an end height of perhaps 15km. The closest actual sighting was from a primary school in Opotiki where the sonic boom was very loud. Only one pupil (perhaps an 8 year old girl) had a clear view of the fireball before the sonics, and it rose in the north ending quite high up in the sky. Of the sonics, the loudest reports I came across were from houses along the coastal cliffs [between Opotiki and Ohiwa Beach]. The precise descriptions are lost but I do remember one lady (an artist with a studio I believe) describ-

> ing it as being like a truck colliding with the house. Several people thought White Island had exploded.
>
> Other than that, all I can think of is that I was satisfied any meteorites had fallen on Maori land to the south of Opotiki.

This is contrary to Dr Challis' initial impression—as reported in the newspapers—and means that the great bulk of the meteorite fragments fell in heavily forested mountainous country in the Urewera Range, an inhospitable and rarely visited region that makes the likelihood of meteorites recoveries almost zero (cf. Director compares slice of heavens, 1989). On the basis of other strewnfields (e.g. Wasson,1985: Figure 1.5) we can assume that the 'Opotiki Meteorite' strewnfield is elliptically shaped, and that the heavier individual meteorites fell towards the southern end of the strewnfield, with the smallest fragments and fusion crust impacting in the Opotiki–Ohiwa Beach area. We have plotted an *indicative* strewnfield in Figure 2 (the black dotted ellipse) but, in the absence of further recovered meteorite fragments, the precise orientation, size and shape of the *actual* strewnfield cannot be determined.

4 DISCUSSION

4.1 Dr Challis' Identification of the Opotiki Samples and Her Naming of the Meteorite

One of the things that initially mystified us when researching the Opotiki Bolide was the speed with which Dr Challis was able to positively identify the samples sent to her as not just from a stony meteorite but specifically from a carbonaceous chondrite. However, it is clear that even before the courier arrived in Wellington with the samples, she already had her suspicions, based not only on newspaper accounts, but also on telephone conversations where she was provided with specific information about the samples.

So what characteristics most readily distinguish carbonaceous chondrites from all other stony meteorites? There are two: their distinctive aroma, and their relatively more friable nature. Dr Duncan Steel (pers. comm., 26 May 2022) mentioned that he encountered this aroma when visiting one of the leading USA meteorite research centres:

> They are smelly! That is, they smell like sulphurous oil, generally. When I was once visiting the huge collection at Arizona State University, I saw that the CCs were all kept sealed in glass jars/vials. Pop the top off and take a sniff, and you smell it. Other meteorites are not treated that way.

Dr Challis also would have been aware of this olfactory feature, derived primarily from the organic compounds in carbonaceous chondrites (and especially CM meteorites), and after the arrival of the small friable samples from Opotiki it took her only a few hours to examine them, test their carbon content, and confirm her prior suspicions (Townsend, 1989). She was so convinced that these samples were from a carbonaceous chondrite meteorite that she not only publicly announced this to the newspapers of Aotearoa / New Zealand, but she went further and assigned a name to it: the Opotiki Meteorite. She certainly was familiar with the international protocols surrounding the formal naming of new meteorites, and she was so certain that Aotearoa / New Zealand had acquired a new meteorite that she was happy to name it, in anticipation that the name subsequently would be ratified by the Meteoritical Society (Townsend, 1989).

Sadly, that did not happen during her lifetime, because she did not take the obvious next step and write a research paper on the Opotiki Meteorite, or at very least pen a short report for the Geological Survey of New Zealand or a geological newsletter. The more substantial samples that she required for that paper were hidden in the heavily forested mountains of the Urewera Range. With the passage of the years and exposure to rainfall they gradually disappeared, just as the idea of writing that all-important paper also gradually disappeared from her consciousness as she responded to demands of other research projects.

In the course of this project we approached GNS Science, the successor to the Geological Survey of New Zealand, and asked about archival records relating to Dr Challis' investigation of the Opotiki Bolide. A search was made, but no relevant records were located (Dr Matt Sagar, pers. comm., 30 May 2022). We also asked after the samples sent to Dr Challis from the Opotiki cowshed, but they no longer existed. Admittedly, there was one 'Opotiki Meteorite' sample listed in the National Petrology Reference Collection, Collection Number P57619, but this was not from the cowshed. Instead, it is listed in the PETLAB Database as from "Ohope Beach Motor Camp, Opotiki", and it was registered on 13 July 1989, one month after the impact event. This association with the caravan park is interesting in light of the samples of fusion crust for a caravan awning obtained at or

near Ohope Beach and currently in the possession of the first author of this paper. But when we went to compare the two meteorite samples, the P57619 sample could no longer be located (Matt Sagar, pers. comm., 17 May 2022).

4.2 Māori Culture, Meteorites and Te Hapua o Rongomai

To the Māori, fireballs were known as *Rongomai*, and occasionally one of these would escape from the heavens and crash to Earth as a meteorite. This is reflected in a locality near Wellington named Te Hapua o Rongomai, where *Rongomai* is said to have descended to Earth (Best, 1955: 67). This place name was presumably inspired by a witnessed impact, which therefore must have occurred sometime between the initial Polynesian settlement of Aotearoa / New Zealand in CE 1230–1280 (Wilmshurst et al., 2011) and the arrival of Europeans in the nineteenth century.

Elsdon Best (1856–1931; Craig, 1964), the Ethnologist at the Dominion Museum in Wellington from 1910 until his death, was an authority on Māori culture and astronomy (e.g. see Best, 1955) and he believed that "Te Hapua-o-Rongomai is probably at the mouth of the Owhiro Stream." (Best, 1919). Owhiro Bay is a small isolated bay on the rugged coast south of Wellington and overlooking Cook Strait, and is fed by a small stream (see Figure 6). Although there is no indication of *Rongomai's* composition in Best's account, if this legend has a factual basis and *Rongomai* was an iron or a stony-iron type of meteorite then it could be a worthwhile exercise to conduct a geophysical survey of this locality for evidence of meteoritic material. This need not be a time-consuming exercise since Owhiro Bay is small, and the area in the vicinity of the stream mouth is even more restricted.

Meanwhile, Best is silent on whether meteorite impacts were viewed as good or bad omens by Māori—which is natural given the rarity of such events—but the Opotiki Bolide provides us with an interesting case study. When the owner of the new cowshed, Mrs Wairata Walker, learnt about the meteorite impact from her son, Waka, she wondered about the significance of this event and told the *Opotiki News* reporter "I don't know what the Maori people think, whether it's a good omen or a bad one." The newspaper decided

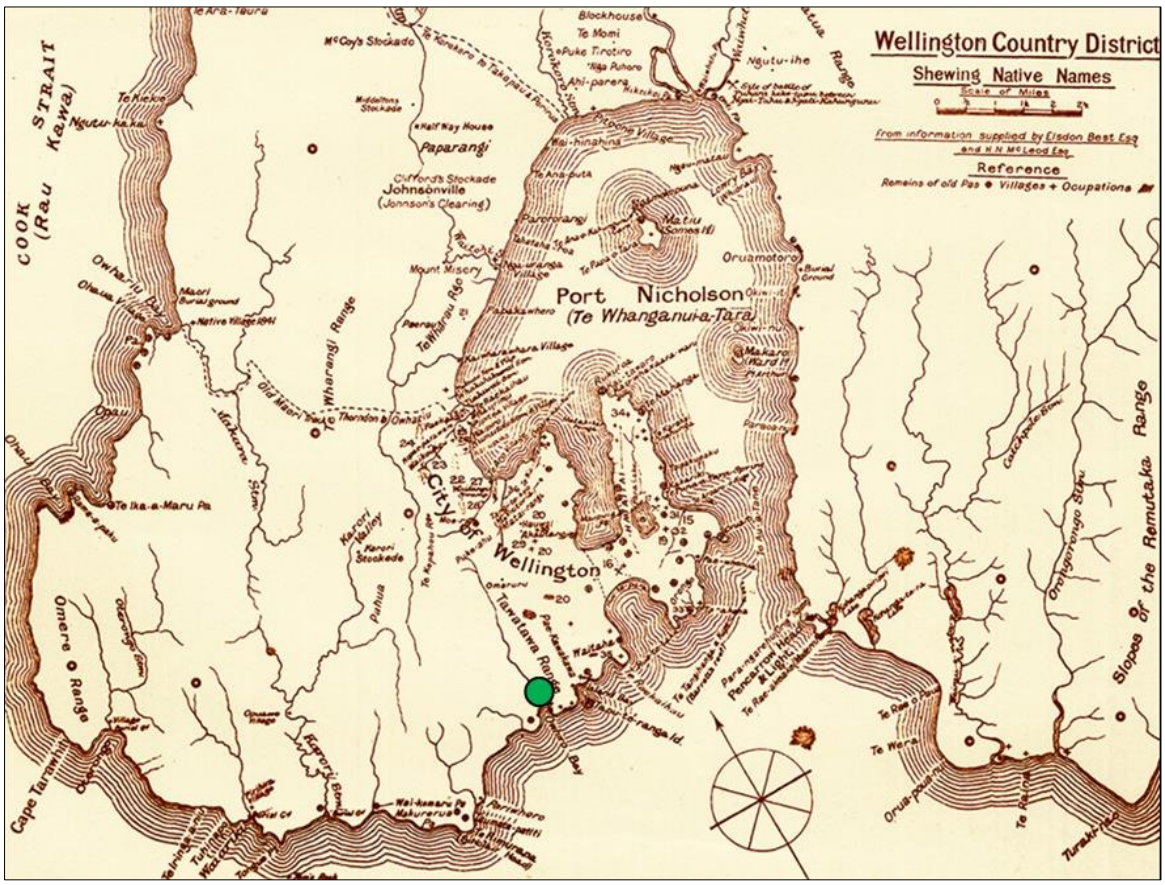

Figure 6: A map of the Wellington region showing Māori sites and settlements, based on data provided by Elsdon Best. Owhiro Bay is marked by the green circle (https://farm2.staticflickr.com/1893/44328673842_71603ae540_o.jpg).

to put her mind at rest and they contacted respected local elder Mr Tiwai Amoamo (1910–1991) and asked for his opinion. His reply indicates that he must have looked logically and philosophically at the situation:

> "To me it's a good omen. One of those things that happens just once in a lifetime …
>
> "From the pieces that have fallen on the property we can learn something from the scientists who have the knowledge of such things. We can always learn something from each other." (Monday June 12 …, 1989).

4.3 The National Meteorite Search

As has been pointed out elsewhere,

> … the frequency of meteorite finds in agricultural areas of the USA, Canada and Europe and the areal extent of comparable agricultural land in Aotearoa/New Zealand indicates that … [Table 1, here] in no way reflects the true meteorite population. Clearly, many more meteoritic impacts occurred between AD 1000[10] and 1768 than the mere handful reflected in this table. (Orchiston 2016: 63).

The most promising scenario for the discovery of new meteorite finds (as opposed to falls) is with farming, but the prevalence of mountainous heavily forested country in the East Coast–Bay of Plenty area makes success less likely in this region of Aotearoa / New Zealand than elsewhere.

Since some of the finds listed in Table 1 were made during farming activities, a carefully planned systematic National Meteorite Search is warranted, especially in regions that have been subjected to intensive farming over the past century or more (e.g. in Northland, the Waikato, around Mt Taranaki, and in the Manawatu and the Wairarapa Valley in the North Island, and on the Wairau Plains, the Canterbury Plains and coastal south Canterbury, certain isolated river valleys in Central Otago, and the Southland Plains inland from Invercargill) in the South Island.

In these areas—and, indeed, throughout Aotearoa / New Zealand generally—it is vitally important to create a greater public awareness of what different types of meteorites look like, and of their value as scientific laboratory specimens.

5 CONCLUDING REMARKS

In this paper we have used newspaper reports and our own fieldwork, supplemented by a contemporary field study by Australia's Robert McNaught, to document the existence of a carbonaceous chondrite meteorite that was seen to fall near the town of Opotiki in the North Island of Aotearoa / New Zealand on the afternoon of 12 June 1989. The bolide was witnessed by many people in the Bay of Plenty–East Coast region and its sonic performance was enjoyed by many more, but few meteorite fragments were recovered.

However, those that were proved enough for Dr Alva Challis from the Geological Survey of New Zealand to identify them as portions of a carbonaceous chondrite. Her request for further specimens went unanswered because the great majority of the strewnfield lay in heavily forested mountain country inland from coastal Opotiki. Consequently, Dr Challis never was able to write up the anticipated definitive report on what she termed the 'Opotiki Meteorite', and so it was not entered in the Meteoritical Bulletin Datebase. We are hoping that this paper will be accepted as a belated substitute that will now warrant the listing of the Opotiki Meteorite as the eleventh officially-recognised meteorite from Aotearoa / New Zealand.

The chances of now recovering fragments of this meteorite are near zero, but we suspect that there are many meteorites that have been recovered in the course of farming operations over the past century or more that await identification in private 'rock collections', and in farm garages and sheds throughout the nation. We therefore advocate the launch of a 'National Meteorite Search' that primarily focuses on those areas that have been most intensively-farmed. This ambitious project should aim to dramatically increase the level of public awareness *vis-à-vis* meteorites, both as important elements of the nation's heritage and as research tools that have the potential to throw new light on the early evolution of the Solar System and even on the origin of life here on Earth.

We also advocate that prior to the launch of the National Meteorite Search publicity is given to the fact that any meteorites discovered will be subject to the Protected Objects Act 1975, where Schedule 4 includes both meteorites and tektites as categories of 'Protected Objects' under the Act. Hopefully, this will help prevent the sale of any newly-discovered meteorites to overseas interests.

This last-mentioned point is important given the rapid growth in meteorite collecting worldwide, and the presence of many collectors with 'deep pockets' who will be only too eager to immediately rush to our shores,

illegally purchase newly-reported meteorites, and try to spirit them out of the country. Since these meteorites will be part of our national 'scientific heritage' it is essential that they remain in Aotearoa / New Zealand.

6 NOTES

1. For a somewhat dated overview of Aotearoa / New Zealand meteorites see Calder (1975), and the much more recent account by Schiff (2021), although for some unexplained reason this omits any mention of the Waingaromia Meteorite—which is described by Orchiston (1991; 1997).
2. This paper is a greatly expanded version of a conference poster (Orchiston and Drummond, 2022) that was on display from 4 to 6 June 2022 in Whangarei, New Zealand.
3. In this table, the basic listing is after Orchiston (2016: 62), but further details have been taken from the Meteoritical Bulletin Database (MBD) or based on data provided in this *JAHH* paper. The Manaia Meteorite was found near the town of Masterton, but is listed in the MBD as 'Wairarapa Valley'. The 'Berhampore Meteorite' was found at Berhampore, a suburb in the nation's capital, Wellington. The 'Otago' Meteorite cannot be accurately provenanced, other than to the large South Island Province of Otago, so the MBD listing of it as from 'Dunedin', the Provincial capital, is very misleading. It is interesting that after the 1989 impact of the Opotiki Bolide, the next meteorite known to fall on New Zealand was the Ellerslie Meteorite, which by a strange coincidence impacted on 12 June 2004, the very same day and month as the Opotiki Meteorite! Note that in the MBD the Ellerslie Meteorite is listed as 'Auckland', because 'Ellerslie' had already been assigned to a meteorite from Australia. Finally, the inclusion of the 'Whakamarama Meteorite' in Table 1 requires further research, because the persuasive information (including a photograph) that was in the public domain when the Orchiston (2016) book was being researched, is no longer available. However, if current (i.e. 2022) data are reliable it is clear that the impact of a small meteorite was witnessed, although at this stage there is no conclusive evidence that this was an iron meteorite.
4. This Waipiro Bay figure is clearly an underestimate, as it represents a distance of about 25 km, whereas disintegration of the meteoroid actually occurred near Opotiki, about 90 km from Waipiro Bay. Mr Marr's estimate is also a gross underestimate, given that the disintegration occurred about 30 km to the east of him.
5. White Island, now officially known as Whakaari / White Island, is an active andesite stratovolcano in the Bay of Plenty, 48 km due north of Ohiwa Beach, which is about half way between Opotiki and Whakatane (see Figure 2). It was well known to the Māori, and was noted, but not visited, by Captain Cook in 1769. From the mid-1880s until the 1930s it supported an intermittent sulphur-mining industry, but it was always a dangerous place and all 10 miners were killed in 1914 when part of the crater wall collapsed and they were engulfed by a lahar. Whakaari / White Island is New Zealand's most active volcano, with the latest major eruption on 9 December 2019 killing 22 tourists and tourism operators. In addition, 25 survivors were seriously injured at this time. By coincidence, the second author of this paper had visited the island on an eco-tourism excursion just five weeks before this catastrophic event.
6. The 6.5 Edgecumbe Earthquake occurred on 2 March 1987, and although there were no fatalities it was the most damaging earthquake in Aotearoa / New Zealand since 1968. Since then, the major Christchurch earthquakes of 2010 and 2011 have occurred, with extensive damage and major fatalities.
7. The first author of this paper (WO) has known Frank Andrews since the 1950s when he and I were schoolboys together in Christchurch, and later, Frank was responsible for the schools and public education programs at Carter Observatory when I was Executive Director of the Observatory in the 1990s (see Andrews et al., 1998; Andrews and Orchiston, 1994; Leather et al., 1997; 1998; Orchiston and Andrews, 1995; Orchiston et al., 1995). While primarily interested in stellar evolution and cosmology, Frank was a valued source of public information on many areas of astronomy, and he once mentioned to me (Andrews, pers. comm, 1997) that when he was still a boy he and his father (who also had a strong interest in astronomy) visited a North Canterbury farm where they were shown what was, without doubt, an iron meteorite. This had been discovered during farming operations, and subsequently was lost when it, and the old farm house, were bulldozed into a nearby river bed.

8. Dr Gwyneth Alva Challis (Watters, 2011) who preferred to be called Alva, was born in Port Talbot, south Wales, on 25 January 1930, and studied radiography before emigrating to Aotearoa / New Zealand with her parents in 1952. After completing an MA in Geology at Victoria University of Wellington (VUW), she studied for a PhD in Geology at Cambridge University where she met her future husband Ross Lauder (who formerly taught her geology at VUW). They married in Wellington in 1963, the year she graduated from Cambridge—she was the first woman from Aotearoa / New Zealand to complete a doctorate in the geosciences (Nathan, 2020). Until her retirement, Dr Challis worked for the New Zealand Geological Survey, where she researched a variety of petrological projects (Smale, 1995), including meteorites from Aotearoa / New Zealand. At the Geological Survey, "… she had a reputation for being happy to help others with their mineral identification and analysis work." (Donoghue, 2011). Six years after the impact of the Opotiki Meteorite Dr Challis retired to Motueka in the South Island, where she worked as a volunteer at the local museum. She died in Nelson on 21 November 2010 at the age of 80 (ibid.).
9. By the time we began researching this paper both Dr Challis and Mr Petersen had passed away, so we could not seek additional information from them. Furthermore, as a result of technological evolution (i.e. from SLR cameras to mobile phones) and with both authors shifting houses (and in the case of WO cities and even countries) we have not been able to locate any of the photographs that we took during our one-day visit to Opotiki in 1989.
10. Since this was written the acknowledged arrival date of the Māori in Aotearoa / New Zealand has been revised and is now believed to have occurred between AD 1230 and 1280 (see Wilmshurst et al., 2011).

7 ACKNOWLEDGEMENTS

We are grateful to the following people for their assistance: Mrs F. Amoamo, John Petersen and Darryl Sturm (all Dunlop Road, Opotiki) for first-hand information about the meteorite; Roger Handford (formerly *Gisborne Herald*) for providing fusion crust specimens of the meteorite; John Peterson (Opotiki) for providing copies of newspaper articles about the meteorite; Rob McNaught (Australia) for supplying information about his own investigation of the meteorite; and Dr Matthew Sagar (GNS Science), for arranging a search of Dr Challis' archival records and for checking the contents of the National Petrology Reference Collection. We also wish to thank Professor Matthew Colless (Mt Stromlo and Siding Spring Observatories) for helping put us in touch with Robert McNaught.

Finally, we wish to thank Professor Jack Baggaley (University of Canterbury, New Zealand), Dr Peter Jenniskens (SETI Institute and NASA Ames Research Center, USA), and Dr Duncan Steel (Xerra Earth Observation Institute, New Zealand) for reading and commenting on the manuscript.

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Wayne Orchiston was born in Auckland (New Zealand) in 1943, has a PhD from the University of Sydney, and is an Adjunct Professor of Astronomy in the Centre for Astrophysics at the University of Southern Queensland in Toowoomba, Australia. Formerly, he worked at the National Astronomical Research Institute of Thailand (Chiang Mai), James Cook University (Townsville, Australia), the Australia Telescope National Facility (Sydney) and Carter Observatory (Wellington, New Zealand).

He has wide-ranging research interests but has mainly published on historic transits of Venus; historic solar eclipses; historic telescopes and observatories; the emergence of astrophysics; the history of cometary, meteor and minor planet astronomy; the astronomy of James Cook's three voyages to the Pacific; amateur astronomy and the amateur–professional interface; the history of radio astronomy in Australia, France, India, Japan, New Zealand and the USA; and Indian, Southeast Asian and Māori ethnoastronomy. He has also written about the Waingaromia Meteorite from New Zealand.

Wayne's recent books include *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Skies Changed* (2015, Springer, co-authored by Stella Cottam), *Exploring the History of New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits* (2016, Springer); *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy* (2017, Springer), *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe* (2017, Springer, co-edited by Tsuko Nakamura), *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities* (2021, Springer, co-edited by Mayank Vahia) and *Golden Years of Australian Radio Astronomy: An Illustrated History* (2021, Springer, co-authored by Peter Robertson and Woody Sullivan). Wayne has also edited or co-edited a succession of conference proceedings.

Since 1985 Wayne has been a member of the IAU, and he is the current Immediate Past President of Commission C3 (History of Astronomy). He is the Founding Chair of the History & Heritage Working Group of the SE Asian Astronomy Network. In 1998 he co-founded the *Journal of Astronomical History and Heritage* and is the current Managing Editor. He and Dr Stella Cottam were co-recipients of the American Astronomical Society's 2019 Donald Osterbrock Book Prize, and in 2013 minor planet '48471 Orchiston' is named after him.

John Drummond became fixated with astronomy at the age of ten when his mother pointed out the Pot in Orion to him. From that moment on he was hooked on the Universe. Joining the Junior Section of the local Gisborne Astronomical Society not long after, John would regularly do group meteor watches, telescope viewing and listen to astronomy talks. He also developed an interest in photography, and it was not long before he combined these two interests and began astrophotography. John's photographs have been used in many overseas books and magazines—and were used on two New Zealand stamps. He was the Director of the Royal Astronomical Society of New Zealand's Astrophotography Section for thirteen years until 2018. He is currently the Director of the Society's Comet and Meteor Section.

John lives about 10km west of Gisborne, on the east coast of the North Island of New Zealand, and has a range of telescopes up to 0.5 metres in diameter. He regularly images with these telescopes and CCDs, and also carries out astrometry of comets, asteroids and NEOs, and sends his observations to the IAU Minor Planet Center. He has also confirmed several comets and co-discovered about 20 exoplanets in collaboration with the Ohio State University—including the unusual 2-Earth-mass planet orbiting a binary star, which forced astronomers to rethink planetary formation models. John is a co-author of more than 60 research papers, and he is also a contributing editor for the *Australian Sky and Telescope* magazine. He enjoys giving talks around New Zealand on historically famous astronomers.

John was the President of the Royal Astronomical Society of New Zealand from 2016 to 2018 and is currently the Society's Executive Secretary; in 2019 he was made a Fellow of the Royal Astronomical Society of New Zealand. In 2016 John was awarded an MSc (Astronomy) by Swinburne University in Melbourne (Australia), and currently he is researching the history of cometary astronomy in New Zealand as a part-time off-campus internet-based PhD student in the Centre for Astrophysics at the University of Southern Queensland (Australia), co-supervised by Dr Carolyn Brown and the first author of this paper.

When not doing astronomy, John is a secondary school science teacher. He also enjoys surfing the great waves of Gisborne and pottering around on his small farm tending to his sheep.