

Flat Rock Unidentified site inspection and artefact analysis



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Cover image: Site discoverer and reporter Ben Milner investigating artefacts concreted into a rock hole at Flat Rock, south of Geraldton on 29 June 2015 (R. Anderson/ WA Museum).

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Acknowledgements

Thanks to Ben Milner for reporting the site, to Stan Gratte, Midwest historian for providing information on Flat Rock artefacts, to WA Museum-Geraldton staff for support and logistics for the site inspection, to Karly Ogden, University of Western Australia archaeology student for volunteering to assist with cataloguing and photography of Flat Rock material, and to Kalle Kasi and Dr Ian MacLeod from the WA Museum, Department of Materials Conservation for lending their combined expertise to analyse and interpret the ferrous and copper alloy metal samples.

Executive summary

In February 2015 Mr Ben Milner reported discovering, and recovering ferrous and copper alloy fastenings concreted into rock holes at Flat Rock, 30km south of Geraldton (WAM DMA Wreck Report 191), and handed over the items to the WA Museum. The materials appeared to be related to a shipwreck, and a site inspection was subsequently conducted with Mr Milner on 29 June 2015 to investigate the site further. The nature and type of the finds recovered support the identification that the remains are likely from a portion of the wreck of a vessel constructed in the 19th or early 20th century.

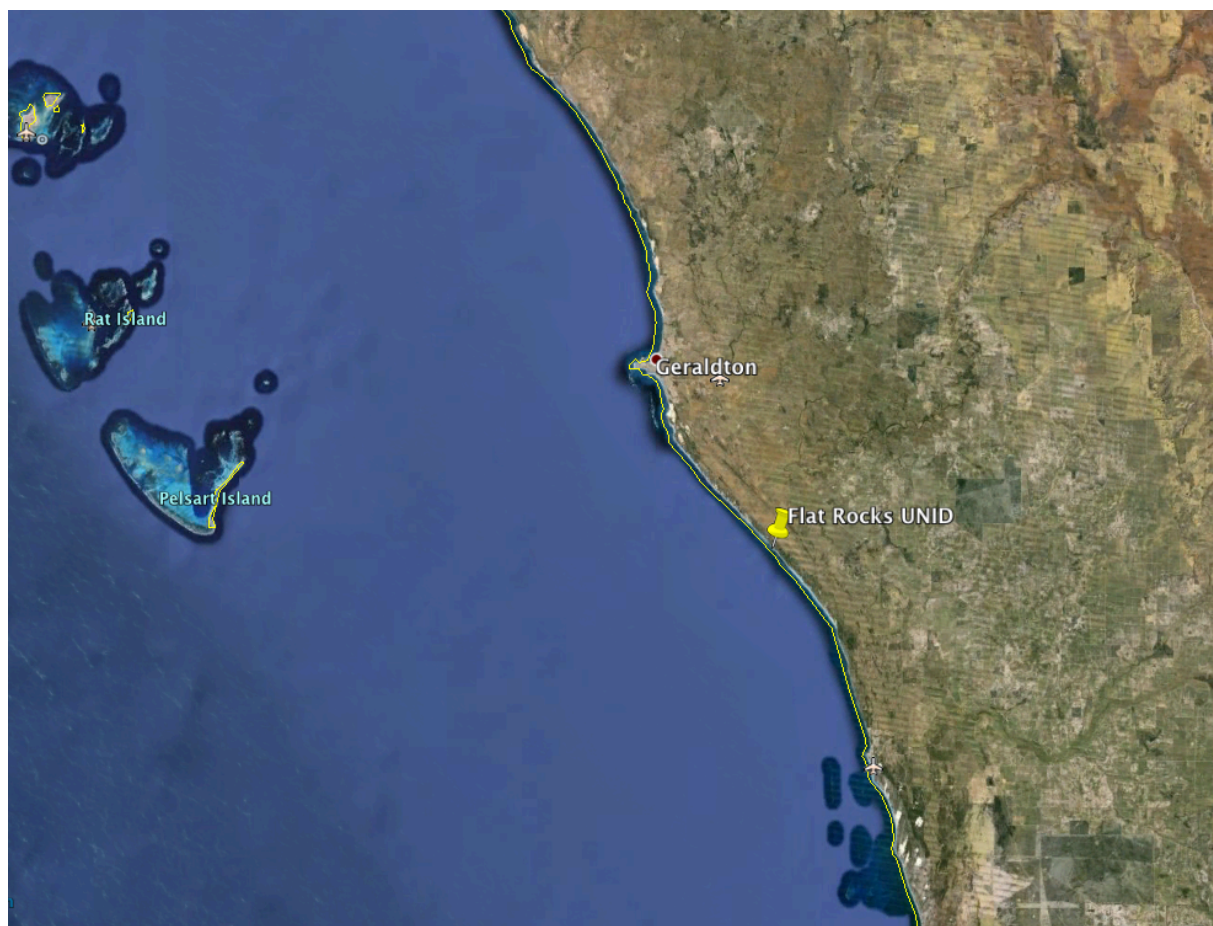


Figure 1 Location of Flat Rock Unidentified site 30km south of Geraldton, Western Australia (Google Earth)

Site environment

Flat Rock is a popular surfing spot, the name referring to a 50-100m wide intertidal calcarenite rock platform located directly in front of the car park, 2.5km off the Brand Highway, and 2 km south of the Greenough River mouth. The beach extending northwards and southwards from the carpark is described as extending 1.9km north of the car park as a 'narrow, crenulated steep reflective high tide beach partly fronted by beach rock and platforms' (Short 2006: 265). A gap in the outer reef and channel allow higher waves to reach the shore platform (Figure 2). It is a high-energy beach with consistent wave action breaking over the shallow rocky platform, and evidence of regular sand movement alternately burying and exposing limestone rock holes on the platform, both in the inter-tidal zone and higher up the beach during peak tides, large swells and storms.

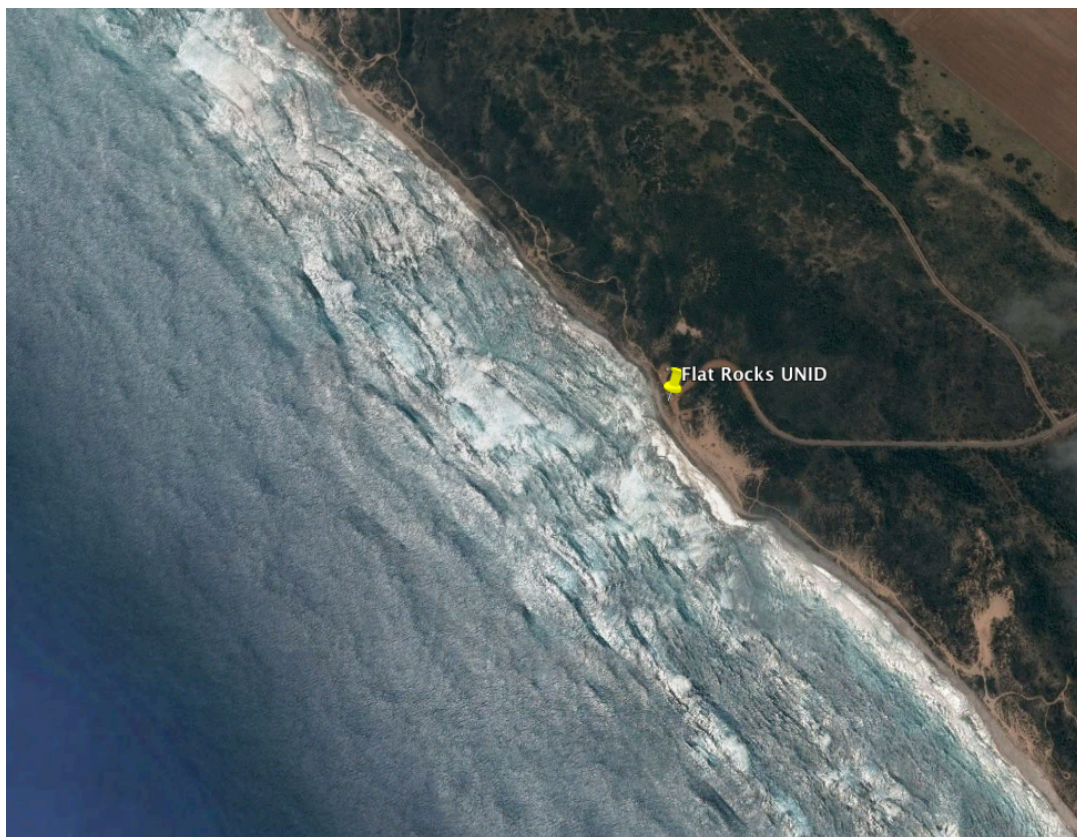


Figure 2 Location of Flat Rock Unidentified site on shoreline. Note gap in outer reef and channel. (Google Earth)



Figure 3 Limestone beach platform north of car park at Flat Rock showing rock holes, view south (R. Anderson/ WA Museum)



Figure 4 Mass of iron fastenings concreted together in a rock hole in the inter-tidal zone (R. Anderson/ WA Museum)

Historical research

Prior to Ben Milner's report the WA Museum had not previously received any reports of wreckage in this area, and no European survivor accounts of shipwrecks in the Greenough area. There was little European presence in the area prior to 1850-51, when land surveying and sales commenced at Champion Bay/ Geraldton and Greenough Flats leading to a greater presence of European agricultural settlers.

Some 19th and 20th century shipwrecks recorded to have been lost in or near this area include:

- *Mercury* (1806-1833)—255 tons, 14 guns, 3-masted barque disappeared with all crew and passengers *en route* from Madras to Swan River Colony (supposedly lost in vicinity of Greenough River based on European speculation/ interpretation of Indigenous accounts, but could also be Chapman River north of Geraldton due to early European confusion in naming of rivers);
- Indigenous accounts of an unidentified wreck reported at Greenough River mouth around September 1851 (Henderson 1988: 11; Worsley & Totty 2008: 129; *Perth Gazette and Independent Journal of Politics and News* 26/9/1851:2; *Perth Gazette and Independent Journal of Politics and News* 17/10/1851:3; *Inquirer* 15/10/1851:3);
- *Flying Foam* (1861-1872)—disappeared with all crew and passengers on voyage from Champion Bay (Geraldton) to Fremantle, last seen 11 km off coast of Champion Bay;
- *General Gordon* (1885-1889)—60 tons, 2-masted schooner abandoned at sea in a leaking condition south of Dongara;
- *Neptune* (1869(?)-1901)—a 22 ton cutter wrecked on rocks near Greenough River;
- Pearl luggers abandoned during retreat from Northwest Western Australia during World War II;
- Unidentified small fishing vessels.

Given the presence of the gap in the outer reef and channel, there is the possibility that the site could be flotsam that had drifted into the area, whether southwards from Greenough River mouth where at least on shipwrecks is recorded to have occurred, or elsewhere.

An 1851 newspaper account describes the loss of a wreck at the mouth of Greenough River described by Yamaji people as having occurred 'sixteen or seventeen years ago' before 1851. This was thought at the time to verify an earlier report in 1834 by Swan River Aborigines of a large wreck with survivors and money, and to perhaps to be a clue to the fate of the wreck of *Mercury* (1833) bound from Calcutta to the Swan River Colony (*Perth Gazette and Independent Journal of Politics and News* 26/9/1851: 2). The relevant newspaper references are transcribed below:

Champion Bay

The Bay natives have given a very clear description of the loss of a large vessel and all hands, at the mouth of the Greenough, about sixteen or seventeen years ago, which corresponds to the time the *Mercury* was lost; there is nothing of her to be seen there now, but the natives say a great quantity of things have been covered by the sand on the beach. This verifies the reports brought in by

the natives in 1834, and of which we extract the following account from the *Perth Gazette* of July 12th of that year.

ABOUT a week or ten days since, Tonguin and Weemat came to Parker's and gave him and his sons to understand, that they had recently learned from some of the northern tribes, that a ship was wrecked ("boat broke") on the coast to the northward, about 30 (native) day's walk from the Swan—that there was white money plenty lying on the beach for several yards, as thick as seed vessels under a red gum tree. On some article of brass being shewn, they said that was not like the money; but on a dollar being shewn, they recognised it immediately as the kind of money they meant; but laid the dollar on the ground and drawing a somewhat larger circle round it with the finger, said "the money was like that." They represented that the wreck had been seen six months ago, and that all the white men were dead, none, as it is supposed, having been seen by their-informants, the Weel men. They added that, at low water, the natives could reach the wreck, which had blankets (sails) flying about it: from which it is presumed that the supposed vessel. may not have entirely lost her masts on first striking, and they stuck up three sticks in a manner which led Parker's sons to understand that the wreck they were attempting to describe had three masts, but Parker himself did not infer the same meaning.

A day or two after Tonguin's visit, Moiley Dobbin called at Parker's with further information on the same subject, but derived from the same distant source: namely, the Weel men. Moiley had been informed by some of the latter that there were several white men, represented to be of very large stature, ladies and "plenty Piccaninni"—that they were living in houses made of canvas and wood—that there are five such houses, two large and three small—that they are not on a river but on the open sea—that the sea-coast, at the site of the wreck, takes a bend easterly into an apparent bay (as described by Moiley on the ground)—that the spot where the white money is strewed on the beach is some distance from the spot where the houses are and more within the bay; that the gabby (surf) breaks with very great noise where the money is, and as it runs back, the Weel men run forward and pick it up—that the white men gave the Weel men some gentlemen's (white) biscuit, and the latter gave in return spears, shields, &c.—that they, Moiley, Tonguin, and Weenat, had never seen the wreck or the white men, and were afraid to go through the territories of the Weel men, who are cannibals ; but that they intend to go as far as the Waylo country, and then coo-ee to the Weel men, who will come to meet them and give them some of the white money—and that the white men here could walk to the houses at the wreck in ten days,—but though the word walk be used, there can be little doubt that Moiley alludes to a "walk on horseback."

About four months previously the natives had tendered to the settlers on the Swan, several British coins which they reported to have obtained from the northern tribes. The government of the day sent the *Monkey* schooner in search of the supposed wreck, under charge of Mr Ommanney who was directed to proceed to Shark's Bay, the locality strangely believed to be indicated by the native description of its distance from the Swan, rather a blundering calculation of 30 days native walk or 10 days white man's ride—500 miles!

(*Perth Gazette and Independent Journal of Politics and News* 26/9/1851: 2)

Two later newspaper reports in October 1851 refer to more recent, unidentified burnt ship wreckage found south of the Greenough River mouth, with other wreckage found at Champion Bay for which there are no European survivor accounts, and which appears to have occurred just prior to October 1851:

Local and Domestic Intelligence

Returns of the wreck of some vessel, consisting of timber, planks, oars, rattans, &c., have been picked up at the Greenough. They were more or less scorched or burnt, and did not bear evidence of being long in the water. It is therefore conjectured that a vessel has been destroyed by fire at sea. Dr. Foley had started for the Greenough to search for other portions of the wreck, and had not returned when the '*Saucy Jack*' left.

(*Inquirer* 15/10/1851: 3)

The "*Saucy Jack*" from Shark's Bay

Portions of a burnt wreck have recently been found a few miles South of the Greenough, and the natives detail the affair with great minuteness. All hands were drowned in consequence of the rush of water out of the river preventing their swimming, and it has been conjectured the vessel was the *Mercury* from Calcutta some years since. Having completed all the arrangements we left on the 6th inst.. Numerous pieces of wreck have recently been picked up in the vicinity of Champion Bay, and a water butt apparently having been but a short time in the water.

(*Perth Gazette and Independent Journal of Politics and News* 17/10/1851: 3)

Site inspection

A site inspection was carried out by the author with Mr Ben Milner on Monday 29 June 2015. Mr Milner showed the locations of previous recovered finds, *in situ* material concreted in rockholes on the limestone platform, and locations of material presently buried under beach sand (Figure 5). The material visible in rock holes was concentrated directly in front of the Flat Rock car park, consisting of conglomerated ferrous fittings, and an occasional copper alloy sheathing tack. Some rock holes were marked with both ferrous and copper staining. Further south a ferrous bolt was seen lying in water in the inter-tidal zone, and a black bottle glass base (FLRK 6175) was recovered (Figure 10). GPS positions for these features and locations are listed in Appendix A.



Figure 5 GIS site plan of Flat Rock Unidentified site showing car park area, reef and location of artefacts and features marked (points marked in red) (see Appendix A)

Artefacts

Mr Milner handed in some small artefacts that he had recovered including a hook latch (possibly part of cabin furniture) (Figure 6), sailmaker's tool (Michael Gregg, WA Museum Department of Maritime History, pers. comm.) (Figure 7) and musket balls (Figure 8). There is also evidence of modern material mixed into the rock holes including eroded bricks and tiles (possibly related to toilet block construction), copper wire with plastic insulation, fishing gear and a pair of stainless steel nail scissors. Some material could not be verified as either historic or modern. Flat Rock is regularly visited by surfers, fishers, four wheel drivers and tourists, with some material and rubbish washing down from the car park onto the rock platform.



Figure 6 Copper alloy decorated hook latch, possibly related to ship's cabin furniture or fittings (R. Anderson/ WA Museum)

There is a range of fastenings including copper alloy sheathing tacks (both round and square section), copper alloy nails and ferrous bolts of differing dimensions. The variety of fastenings raises the possibility that the material may be related to more than one wreck (or parts of wrecks). Many of the ferrous bolts are corroded, broken and incomplete, making typological analysis difficult. There are some small fragments of copper alloy sheathing, while the presence of molten lead on the site (Figure 17) is some evidence for burning, a common practice in shipwreck salvaging to obtain metal fastenings, or indicating the wreckage had already burnt before drifting ashore.



Figure 7 Sailmaker's tool (R. Anderson/ WA Museum)

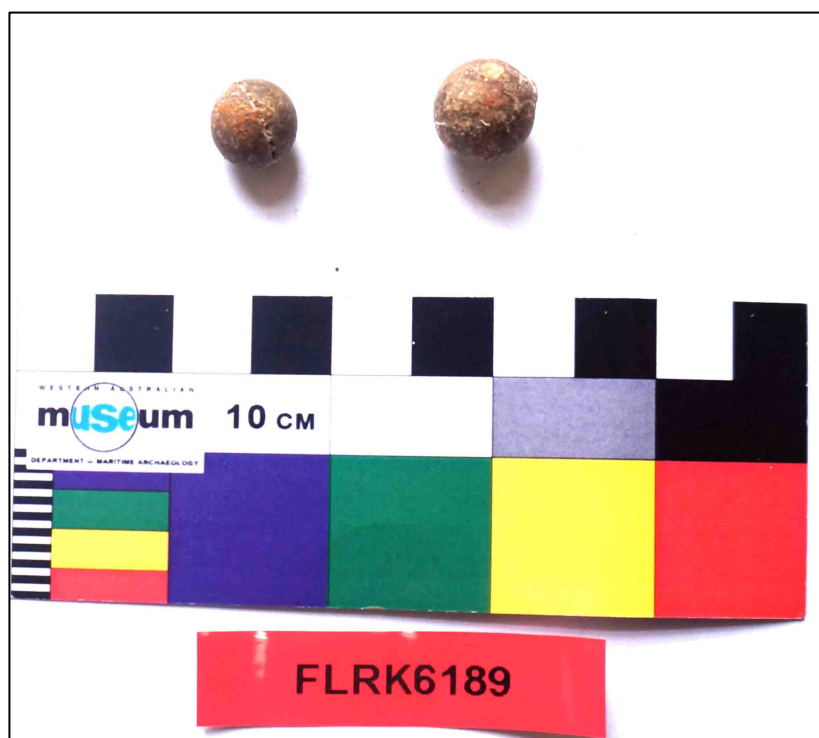


Figure 8 Musket balls (FLRK6189) (R. Anderson/ WA Museum)

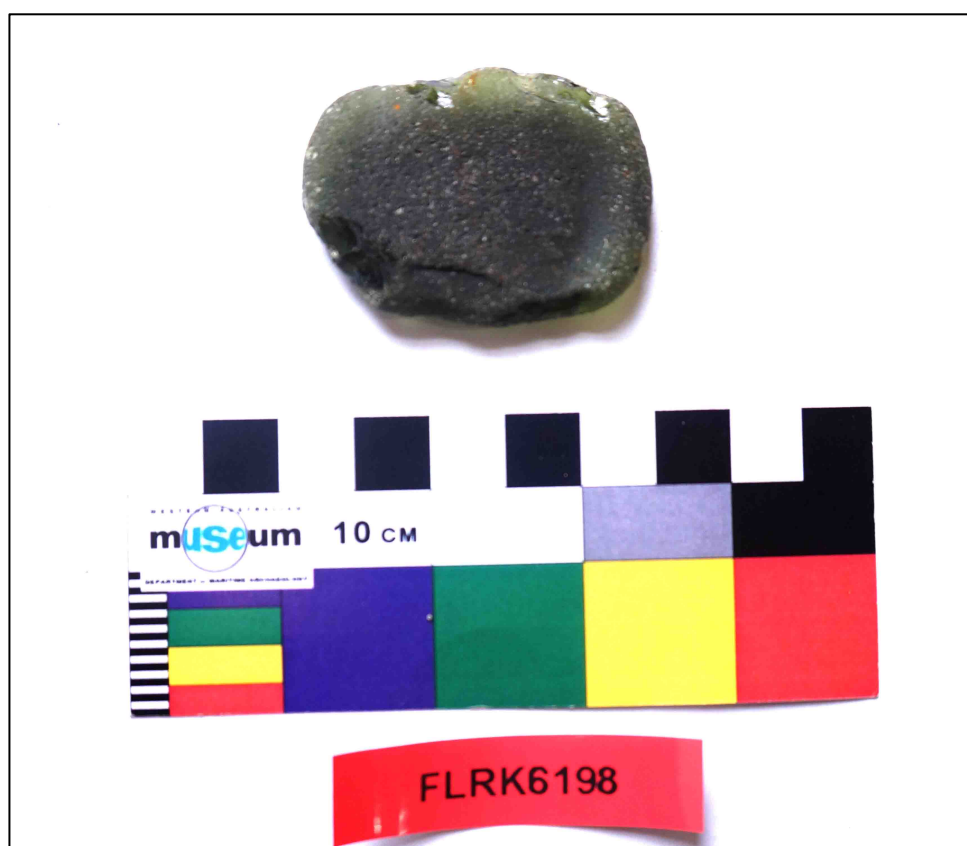


Figure 9 Fragment of green glass bottle base (R. Anderson/ WA Museum)



Figure 10 Green glass bottle base FLRK6175 recovered during site inspection south of Flat Rock car park (R. Anderson/ WA Museum)

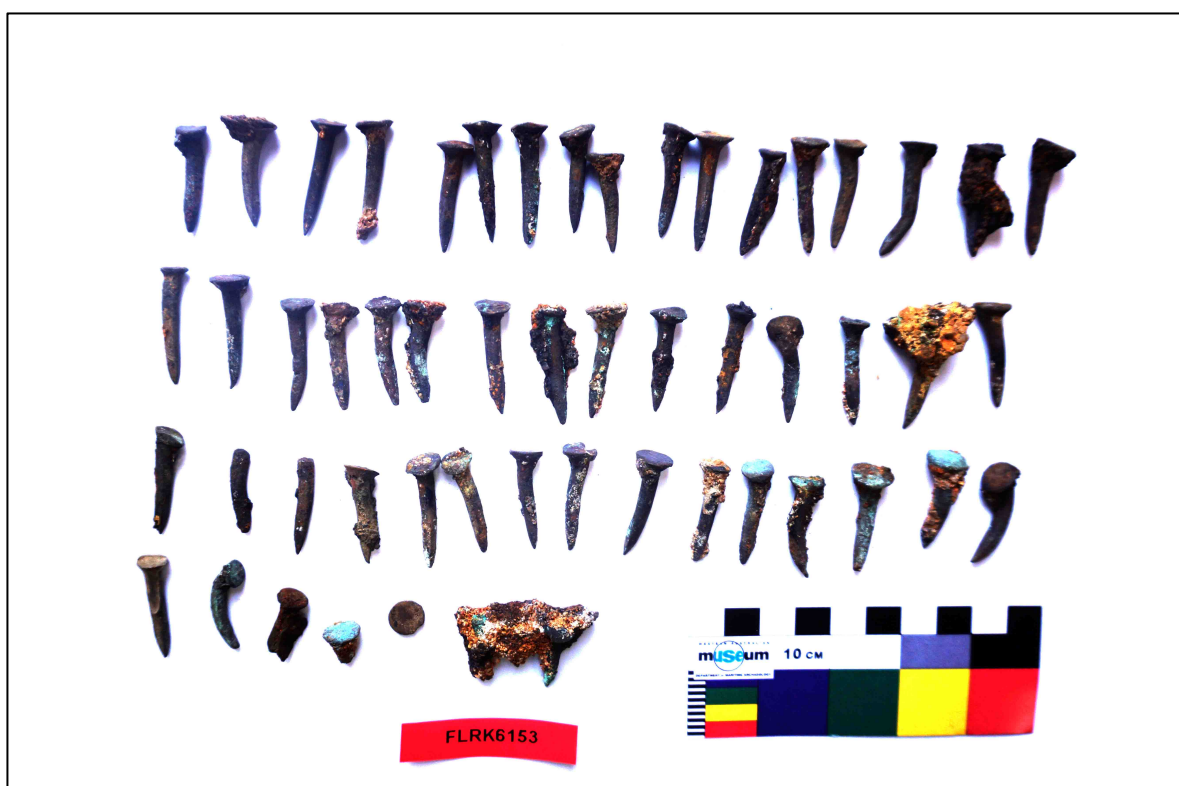


Figure 11 Copper alloy sheathing tacks (FLRK6153) (R. Anderson/ WA Museum)



Figure 12 Range of ferrous fastenings (FLRK6162) (R. Anderson/ WA Museum)



Figure 13 Large iron round headed, square section bolt (R. Anderson/ WA Museum)



Figure 14 Copper alloy square section clench nail with washer (R. Anderson/ WA Museum)



Figure 15 Four different types of small copper alloy nails, square section and cylindrical section with ragging (FLRK 6188) (R. Anderson/ WA Museum)



Figure 16 Corroded remains of a ferrous staple, possibly ship-related (R. Anderson/ WA Museum)



Figure 17 Fragments of molten lead (FLRK6145) (R. Anderson/ WA Museum)

Fastenings analysis

Conservator Kalle Kasi from the WA Museum's Department of Material Conservation undertook metal composition analysis using X-Ray Fluorescence (XRF) on selected samples of fastenings and sheathing fragments (Appendix B). The samples were cleaned to remove marine concretions and corrosion to obtain a bare metal surface in a number of places. The samples were:

FLRK 6153-1, FLRK 6153-2 – 2 x copper alloy sheathing tacks

FLRK 6193-1, FLRK 6193-2 – 2 x copper alloy nails, square shank

FLRK 6171-1, FLRK 6171-2 - 2 x ferrous fastenings

FLRK 6146 - 1 x fragment copper sheathing

FLRK 6209 - 1 x fragments ferrous metal



Figure 18 Cleaned sheathing tack samples FLRK6146-1 and FLRK6146-2 (R. Anderson/ WA Museum)

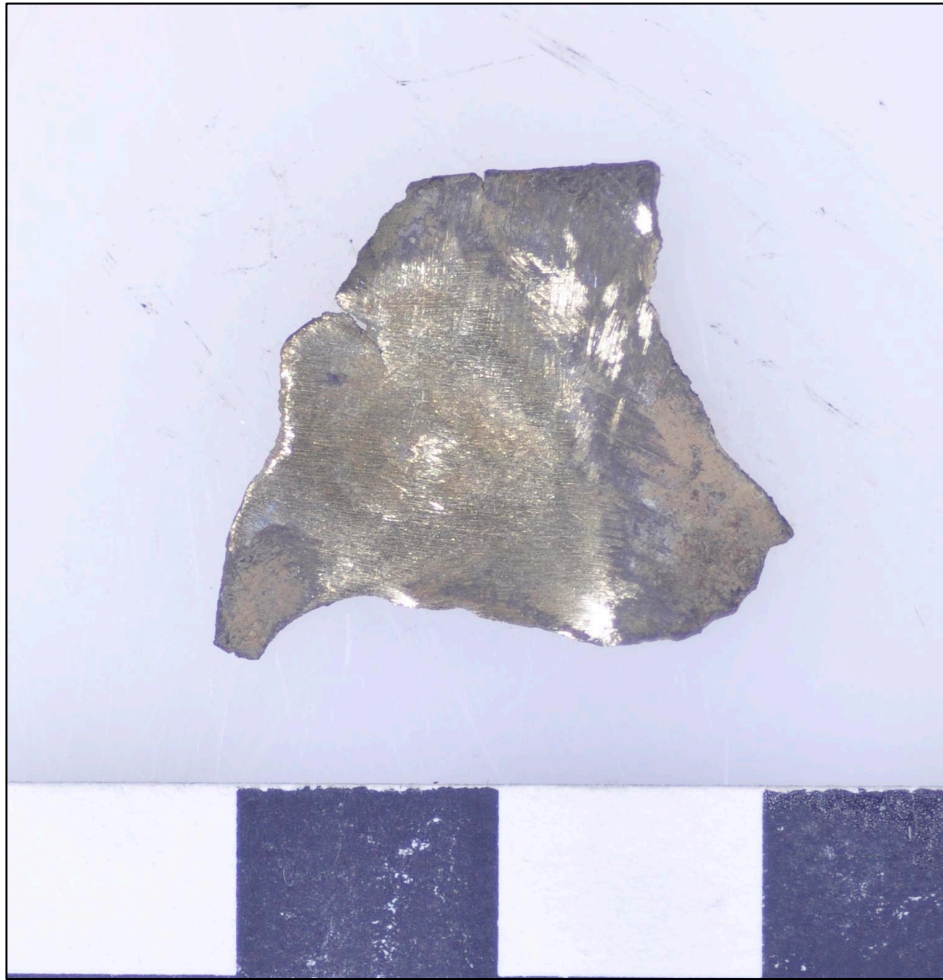


Figure 19 Cleaned sample of copper alloy sheathing FLRK 6146 (R. Anderson/ WA Museum)

Full results of analyses are provided in Appendix B with interpretation by Dr Ian MacLeod in Appendix C. Of note are the following interpretations of the materials:

- Sample FLRK6209 (cast iron fragment) is likely to be a partially decarburised cast iron, possibly indicative of the item having been heated to a temperature consistent with burning ships' timbers, and subsequently quenched;
- Samples of iron fastenings FLRK6171-1 and FLRK 6171-2 were from the same batch of wrought iron and displayed a highly ferritic structure with slag (silicate) inclusions, typical used in the construction of chain plate in 19th century ships;
- Sample FLRK6146 (copper alloy sheathing fragment) had greater than 32.5% zinc content, dating it to after Muntz metal patents taken out in 1832 for 60% copper/ 40% zinc when composition alloy sheathing for ships became widely used.

Discussion

The Flat Rock Unidentified site south of the Greenough River appears to be the remains of a portion of a wreck of 19th or 20th century origin that has not previously been reported, recorded or associated with any European survivor accounts of a known wrecking event.

European and Indigenous accounts from October 1851 describe wreckage from an unidentified vessel wrecked close to Greenough River mouth being scattered between an area south of the Greenough River mouth, and north to vicinity of Champion Bay indicating it occurred around late September to early October in 1851.

It is considered likely that the remains are related to an as yet unlocated, submerged main site further offshore, in the vicinity. Due to the limited amount of material, highly corroded and fragmented nature of the remains, and mixing with other modern materials it is difficult to draw any firm conclusions as to the identity and tonnage of the vessel(s).

The fragment of copper alloy sheathing FLRK6146 had a zinc content of 34.29%, which dates it to being constructed sometime after 1832 when Muntz lodged his patent for zinc-copper composition metal sheathing. Iron fastenings sampled are determined to be from the same batch of wrought iron, and consistent with use in 19th century sailing ships (Dr Ian MacLeod, Appendix C). Artefacts of molten lead and evidence of carburised iron as a result of burning and quenching (*ibid*) may be an indication that fastenings associated with timber wreckage remains on the beach were at one stage burnt. This material could have been burnt prior to the wreckage washing up, or as a post-depositional process such as the salvage practice of burning wreck timbers to recover metal fittings. Quenching could have occurred either at sea, or on the land with a high tide/ storm/ waves.

The presence of musket balls is some evidence for an earlier to mid 19th century date. Muskets were used until the widespread use of breech-loading rifles in the mid-19th century. 'Black glass' (in fact dark green glass made by adding iron slag to the glass) was used to manufacture British-made bottles until the 1870s (Jeanne Harris 2010: 12). None of the glass or metal artefacts has any makers' marks or other identifying features to enable more precise identification of place of manufacture to assist with origin or dating. The presence of small artefacts such as the hook latch and sailmaker's tool are an indication that a substantial enough portion of wreckage able to contain some artefacts such as furniture or cabin fittings and personal belongings was cast on the shore.

Statement of Significance

While the material remains of the site are scattered and fragmented, they are historically and archaeologically significant as the only available evidence for identifying the vessel, and offer clues to a wreck in the vicinity. Further artefacts may be discovered in the area that could assist in identifying the provenance of the vessel.

Legal Protection

As relics associated with a pre-1900 historic ship the remains of the Flat Rock Unidentified site are automatically protected under the *Maritime Archaeology Act 1973*, and it is an offence to disturb or remove any remains from the site without a permit from the Western Australian Museum.

However, as the material appears to be only a small portion of flotsam, in conjunction with the available historical evidence it is considered likely to be associated with an as yet unlocated main shipwreck site located offshore. In this case the Flat Rock Unidentified materials are considered to be relics associated with an historic shipwreck, and therefore protected by the Commonwealth *Historic Shipwrecks Act 1976*.

Summary

The Flat Rock Unidentified site consists of corroded and fragmented non-organic materials such as metals (iron, copper alloy, lead) and glass. It is interpreted as the remains of shipwreck structure or flotsam that has washed ashore, the timbers of which have subsequently degraded. The materials are considered likely to be related to a main site lying offshore, possibly in the vicinity.

The archaeological and historical evidence of the site's location south of Greenough River, the lack of any survivor accounts, indications of burning and a post-1832 construction date is tentatively considered to support the Flat Rock Unidentified site as possibly being associated with a Yamaji account of an unidentified wreck near, or at, Greenough River mouth where all hands lost their lives sometime around September 1851. Alternatively, it could be from other vessels recorded to have been, or possibly been, lost in the vicinity between 1833 and 1942.

Recommendations

1. That further searches for shipwreck material between Flat Rock and Greenough River mouth in the offshore, inter-tidal and beach zone be carried out as part of any future regional Midwest area survey work.
2. That a magnetometer search be undertaken in the vicinity of Greenough River mouth as part of any future regional Midwest area survey work.

References

Jeanne Harris, E., 2010, Glass Report, Darling Quarter (Walk), Darling Harbour, Sydney, Prepared for Casey & Lowe Pty Ltd. Available at: <http://www.caseyandlowe.com.au/wp-content/uploads/2009/04/Vol-3-Section-8.3-Glass-Report-Harris-FINAL.pdf>.

Short, A.D., 2006, *Beaches of the Western Australian coast: Eucla to Roebuck Bay: A guide to their nature, characteristics, surf and safety*, Coastal Studies Unit, University of Sydney and Surf Lifesaving Australia Ltd, Sydney University Press.

Worsley, P. & J. and Totty, D., 2008, *A windswept coast: Western Australia's maritime heritage between the Moore River and the Zuytdorp Cliffs*, Australian National Centre of Excellence for Maritime Archaeology, Special Publication No. 11.

Appendix A GPS positions

Description	Latitude (S)	Longitude (E)
Iron fastenings concreted in rock hole	-29.01372	114.77871
Iron fastenings concreted in rock hole	-29.01371	114.77869
Iron fastenings concreted in rock hole	-29.01371	114.77870
Iron staining in rock hole	-29.01352	114.77862
Iron conglomerate in rock hole with square fastening	-29.01040	114.77557
Approximate location of iron staple (recovered) and material in rock hole (sanded up this inspection)	-29.01057	114.77586
Iron fastenings	-29.01361	114.77866
Copper alloy staining, tacks	-29.01366	114.77866
Iron staining in rock hole	-29.01365	114.77870
Iron staining in rock hole	-29.01372	114.77871
Iron bolt in water in intertidal zone, iron staining nearby	-29.01532	114.78007
Small iron conglomerate, iron staining nearby	-29.01599	114.78068
Small rock hole with iron fragments	-29.01603	114.78071
Green glass bottle base (recovered)	-29.01456	114.77927
Rock holes with material, sanded up	-29.01371	114.77876

Appendix B Results of metallographic analyses

Kalle Kasi, Department of Materials Conservation, October 2015

CTRMS Job No 15/53:

Flat Rocks Unidentified (FLRK) XRF analyses of various Cu alloy and ferrous items

Items received for XRF analyses (measurements of metals):

FLRK 6153-1– copper alloy sheathing tack

FLRK6153-2 – copper alloy sheathing tack

FLRK 6193-1– copper alloy nail, square shank

FLRK6193-2 – copper alloy nail, square shank

FLRK 6171-1 – Ferrous fastening

FLRK6171-2 – Ferrous fastening

FLRK 6146 – copper alloy sheathing fragment

FLRK6209 – Ferrous fragment

X-ray Fluorescence (XRF) spectra were acquired with Bruker AXS Handheld Tracer III-SD (SNT3S2520) with channel resolution of 2048 and operating parameters: Rhodium tube X-ray source and 10 mm² XFlash[®] SDD peltier cooled detector with typical resolution of 145 eV at 100,000 counts per second (cps) over an area ~8mm². All analyses conducted at Tube Voltage of 40keV; Tube Current of 12µA with 0.025 mm (0.001") titanium/0.305 mm (0.012") aluminum (Yellow) filter in the X-ray path and a 120 second live-time count. For all of the copper alloys two surface areas (approx. 1cm²) were polished to bare metal using Dremel tool with a flap-wheel (80-grit). For the FLRK6209-Ferrous fragment only one area of the surface (approx. 1cm²) was polished to bare metal using dremel tool with a flap-wheel (80-grit). The ferrous fastenings FLRK 6171-1 and FLRK 6171-2 were hand cut with a hacksaw into two pieces as the surfaces were too extensively and unevenly corroded for the bare metal exposure using a Dremel tool and both exposed ends of the cut items were analysed.

For the ferrous items the elements analysed were: Fe, Mn, Cu and Ni by applying the low alloy Iron calibration coefficients (FE1.CFZ - issued with the equipment) and saving the quantitative chemistries in Weight Percent (Wt%) in MS Excel. For the artefacts where two areas per item were analysed the averages of the two measurements are reported.

	Iron	Manganese	Copper	Nickel
	Fe (Wt%)	Mn (Wt%)	Cu (Wt%)	Ni (Wt%)
FLRK6209 Ferrous fragment	98.75	0.44	0.04	0.01

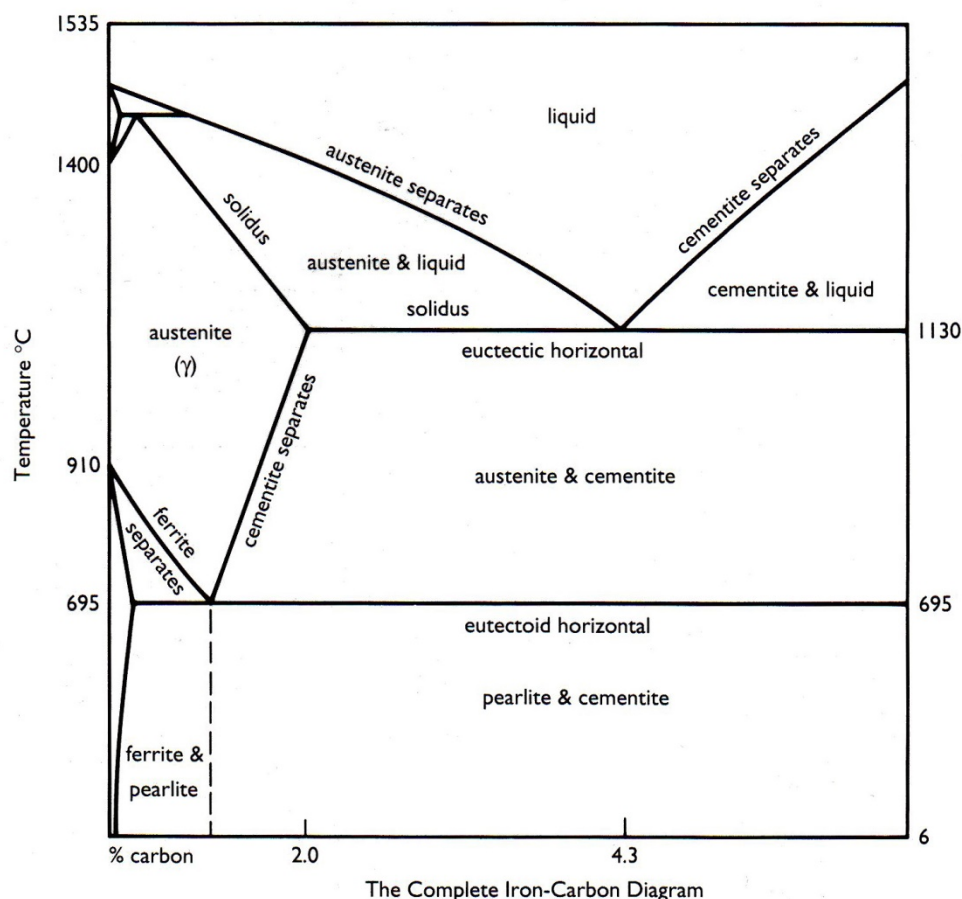
LRK6171-1 Ferrous fastening	99.12	0.05	0.14	0.03
LRK6171-2 Ferrous fastening	98.86	0.17	0.16	0.03

For the brass and unalloyed copper items the elements analysed were: Cu, Zn, Fe, Pb, Sn, As, Ag, Bi and Sb by applying copper alloy calibration coefficients (CU1.CFZ - issued with the equipment) and saving the quantitative chemistries in Weight Percent (Wt%) in MS Excel. For all the copper and copper alloy artefacts the averages of the two areas are reported.

	Copper	Zinc	Iron	Lead	Tin	Arsenic	Silver	Bismuth	Antimony
	Cu (Wt%)	Zn (Wt%)	Fe (Wt%)	Pb (Wt%)	Sn (Wt%)	As (Wt%)	Ag (Wt%)	Bi (Wt%)	Sb (Wt%)
FLRK6146_fragment-copper alloy sheathing	61.55	34.29	1.07	0.38	0.07	0.05	0.02	0.01	0.01
FLRK6153-1_copper alloy sheathing tack	78.62	16.12	0.25	0.80	1.26	0.19	0.03	0.05	0.06
FLRK6153-2_copper alloy sheathing tack	75.84	16.82	1.23	0.73	1.28	0.19	0.04	0.06	0.06
FLRK6193-1_copper alloy nail-square shank	99.70	0.05	0.00	0.04	0.07	0.00	0.02	0.02	0.02
FLRK6193-2_copper alloy nail-square shank	99.79	0.05	0.00	0.02	0.06	0.00	0.01	0.01	0.01

Appendix C Interpretation of metallographic analyses

Dr Ian MacLeod, Director, Fremantle Sites and Collections, October 2015



From the analysis totals for FLRK 6209 of 99.24% and the corrosion behaviour of the sample this material is likely to be a partially decarburized cast iron as the copper and nickel contents are low which indicates a relatively pure ore source. The high manganese content is typical of a cast iron and the low gap of possible carbon content in the analysis shows a maximum of 0.7% carbon which is hypo-eutectoid and as such the alloy would have significant amounts of the carbon tied up in residual pearlitic structures. This level of carbon is consistent with a cast iron fitting that may have been subject to being burnt (decarburized) at red heat associated with burning ships timbers and which was subsequently quenched. A full metallurgical analysis would confirm these observations but this is outside the resources of the conservation department to undertake at this point in time.

Sample FLRK 6171-1 gave a total analysis of 99.34% and the second sample had a total of 99.22% and the internal consistencies between the copper, nickel and manganese levels indicate that the samples came from the same batch of wrought iron. The high degree of corrosion observed in the samples is typical of the reactivity of a highly ferritic structure with slag (silicate) inclusions which are cathodic to the iron rich phases and so the latter are preferentially corroded in and along the lines of the inclusions. This material was typically used in the construction of chain plate in the 19th century sailing ships.

Sample FLRK 6146_fragment Cu alloy sheathing is typical of a duplex brass (greater than 32.5% zinc or zinc equivalence) which dates it to being after the Muntz patents were taken out following the realisation that additional zinc makes the alloy less prone to cracking on hot rolling which was used to achieve the desired gauge. However the problem for long-term materials performance on an historic shipwreck is that the zinc-rich beta phase is preferentially corroded and so such samples typically require twice as long to desalinate as single phase brasses.