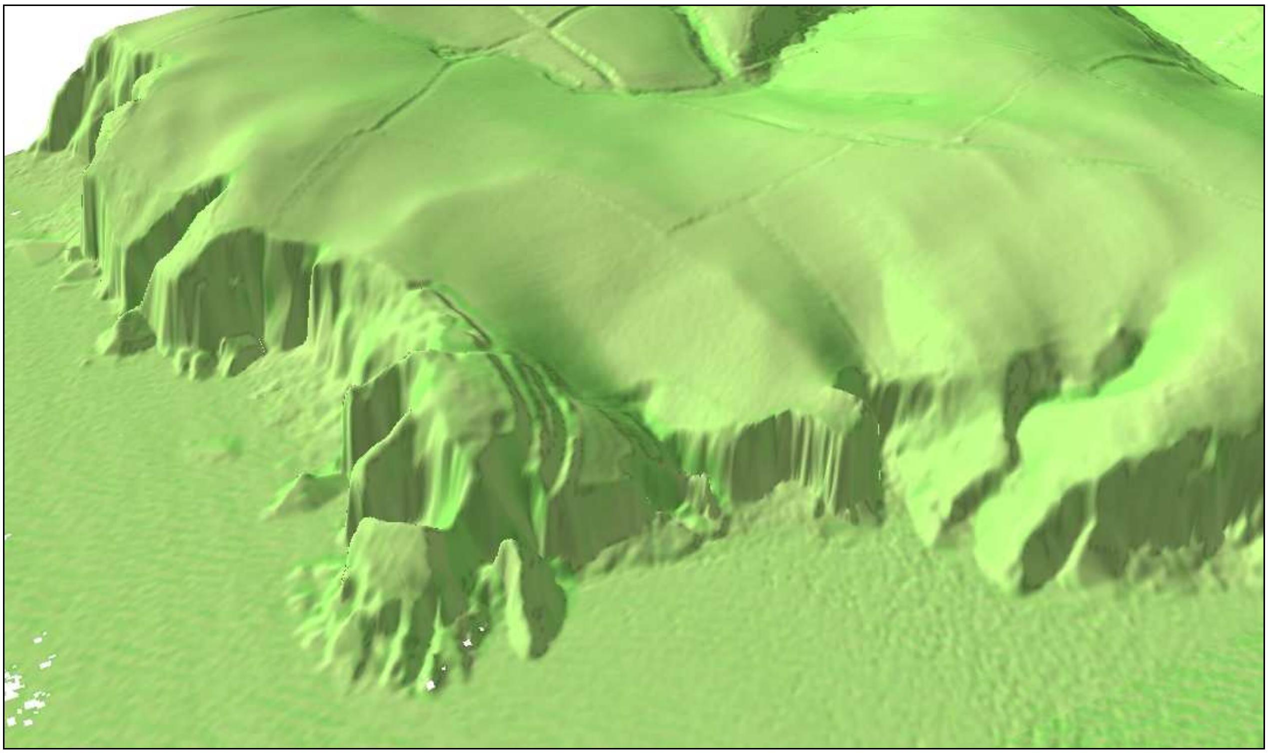
PREHISTORIC DEFENDED ENCLOSURES: REMOTE SENSING 2008-2009



Prepared by Dyfed Archaeological Trust
and Royal Commission on Ancient and
Historical Monuments (Wales)
For Cadw

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PREHISTORIC DEFENDED ENCLOSURES REMOTE SENSING

Gan / By

Marion Page, Toby Driver, Louise Barker, Ken Murphy and Pete Crane

With contributions from
Tom Pert and Salvatore Garfi

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Ymddiriedolaeth Archaeolegol Dyfed Cyf
Neuadd y Sir, Stryd Caerfyrddin, Llandeilo, Sir Gaerfyrddin SA19 6AF
Ffon: Ymholiadau Cyffredinol 01558 823121
Adran Rheoli Treftadaeth 01558 823131
Ffacs: 01558 823133
Ebost: info@dyfedarchaeology.org.uk
Gwefan: www.archaeolegdyfed.org.uk

Dyfed Archaeological Trust Limited
The Shire Hall, Carmarthen Street, Llandeilo, Carmarthenshire SA19 6AF
Tel: General Enquiries 01558 823121
Heritage Management Section 01558 823131
Fax: 01558 823133
Email: info@dyfedarchaeology.org.uk
Website: www.dyfedarchaeology.org.uk

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SUMMARY

Coastal promontory forts are among the largest prehistoric monuments in Britain. Those in southwest Wales form an important group, most of which are Scheduled Ancient Monuments. The coastal location of these forts exposes them to constant erosion, from both the elements and from walkers on the Pembrokeshire Coast Path. Coastal erosion is the main problem and is predicted to increase significantly as a result of climate change. The aim of the Defended Enclosures Remote Sensing project is to attempt to quantify the rate and location of coastal erosion for seven coastal promontory forts in Pembrokeshire through the gathering of baseline data. Dyfed Archaeological Trust, in partnership with Royal Commission on Ancient and Historic Monuments (Wales), undertook the project in 2008/2009. The project found that when used in isolation none of the remote sources give enough information to accurately interpret a site, but that used in combination a working plan can be produced in a day or so that can quickly be verified, and annotated where necessary, through ground truthing.

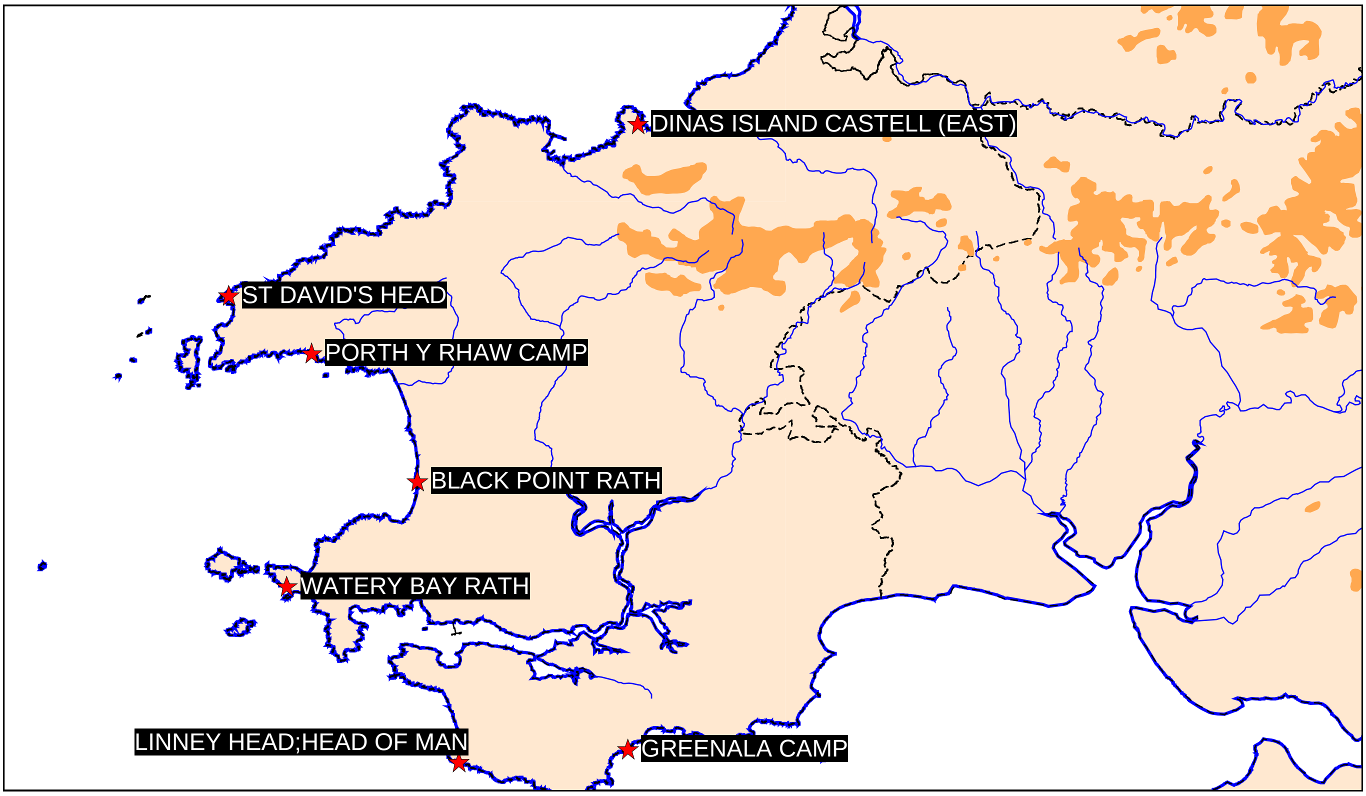


Fig.1. Map showing sites investigated by the project.

INTRODUCTION

Between 2005 and 2007 Cadw grant-aided the Dyfed Archaeological Trust to undertake threat related assessments of defended enclosures in the three counties of southwest Wales. These assessments identified a paucity of site plans and descriptions of the larger defended enclosures, most of which comprise substantial earthworks and consequently have been designated scheduled ancient monuments. Owing to this lack of baseline data these sites are not properly understood, it is not always possible to identify specific management issues, and monitoring change has not been possible.

Coastal promontory forts are recognised to have particular issues associated with them. They are highly visible monuments experiencing constant coastal erosion. In addition, many lie on or close to the Pembrokeshire Coast Path and suffer low-level visitor erosion. Coastal erosion is the main problem, and this is expected to worsen significantly with climate change. However, it has not so far been possible to quantify either the rate or location of coastal erosion other than in the most generalistic terms. This project aims to establish baseline date for five coastal promontory forts by means of remote sensing and ground truthing. Seven forts have been selected for this survey: Black Point Rath; Dinas Island (East); Greenala Camp; Linney Head; Port y Rhaw; St David's Head and Watery Bay.

The Trust has undertaken this project in partnership with the Royal Commission. The Commission's expertise in LIDAR and air photo interpretation has greatly assisted in the detailed recording of each monument and the assessment of rates of erosion over half a century of aerial photography. This has been supported 'ground-truthing' and geophysical survey undertaken by the Trust.

This report is one of several outputs from the project. Among others will be the publication of ground plans and descriptions of the forts through a variety of media, including Coflein; publication of the methodology with critical analyses; a report on the forts suitable for publication, possibly in *Archaeology in Wales* and talks and lectures to publicise the investigations and the sites.

ACKNOWLEDGEMENTS

I would like to thank RCAHMW for making office space available to me for a pleasant week spent analysing the LiDAR data for the forts. Thanks to Ken Murphy of DAT and to Toby Driver and Louise Barker of RCAHMW for their work on the project and input into this report and to Salvatore Garfi and Tom Pert, also of RCAHMW, for training and assistance with the GIS software used to analyse the raw LiDAR ascii files and create the map regressions.

DATA SOURCES

LiDAR
Light Detection and Ranging (LiDAR) data, captured at 2-metre resolution. This data was received under licence from the Environment Agency.

Modern Digital Vertical Aerial Photographs
National Assembly of Wales vertical colour aerial photographs of the relevant areas.

Oblique Archaeological Aerial Photographs
RCAHMW 2009 colour aerial photographs of Black Point Rath, Greenala Camp, St David's Head and Watery Bay.

Historic Ordnance Survey Maps
1st, 2nd and 4th edition digital Ordnance Survey maps of the relevant areas, supplied under licence from the Welsh Assembly Government.

Modern Ordnance Survey Maps
Modern Ordnance Survey 1:10,000 digital mapping supplied by Cadw under licence from the Welsh Assembly Government.

Geophysical Survey
Pete Crane of Dyfed Archaeological Trust undertook geophysical (magnetometer) surveys of Greenala Camp and Porth y Rhaw Camp early in 2009.

REMOTE SENSING METHODOLOGY

LiDAR

Two-metre resolution Light Detection and Ranging (LiDAR) data was obtained under license from the Environment Agency. Using a pulsed laser beam LiDAR measures the height of the ground surface and other features from an aircraft. At metre and sub-metre resolution LiDAR can provide highly detailed and accurate models of the land surface.

The raw LiDAR data was supplied in ASCII format. The files were processed using ArcScene software at the offices of RCAHMW to produce three-dimensional digital elevation models (DEMs) of the promontory forts. With the data thus processed the images were manipulated in order to view the landscape from a variety of different angles. The height and direction of the sun were altered relative to the landscape, to allow the resulting shadow effects to give the best DEM of the archaeological features. Additional raster images, in the form of historic black and white aerial photographs, were also 'draped' over the 3D landscape and the same effects created.

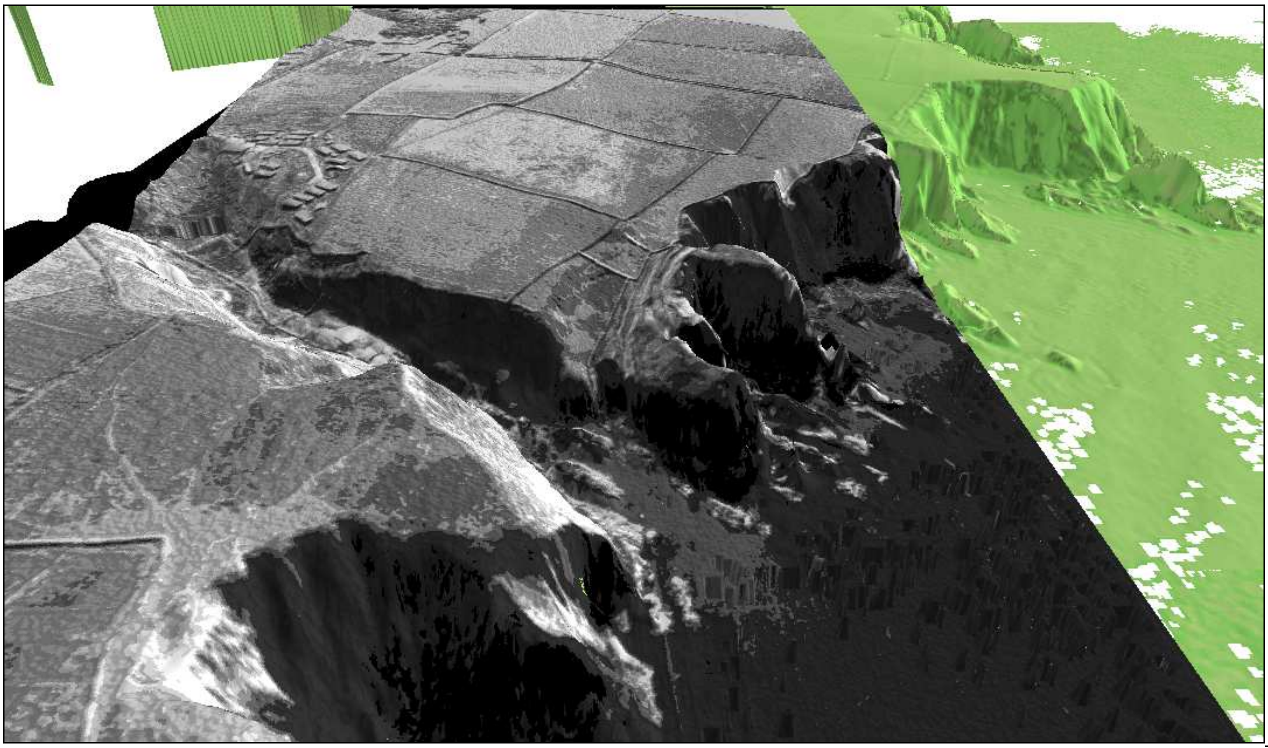


Fig. 2. Porth y Rhaw (PRN 2721) DEM with 1946 RAF aerial photograph overlay

The LiDAR data was also obtained as jpegs that had been registered for use in GIS. These were used along with other sources to create archaeological plans of Greenala Camp, Linney Head and Watery Bay Rath. Copies of the resulting plans were taken to these sites for ground truthing.

Old vertical aerial photographs

Black and white aerial photographs dating from the 1940s and 1950s were used in the creation of archaeological plans. The copies held at RCAHMW have been georeferenced for the project. These were 'draped' over the LiDAR DEMs and were also used in the creation of map regressions.

Modern digital vertical air photographs

National Assembly of Wales vertical aerial photographs were used in the creation of archaeological plans for ground truthing and for map regression.

Oblique archaeological aerial photographs
Modern colour RCAHMW aerial photographs were used for reference when compiling archaeological plans for ground truthing and for illustrative purposes in this report.

Historic Ordnance Survey maps
Digital historic Ordnance Survey mapping was used in the creation of the archaeological plans for ground truthing. This map data was also used to create map regressions; comparisons of the position of the cliff edge at the sites on a variety of data sources from the past hundred years or so. The results of this exercise are the establishment of baseline data and a record of cliff top retreat.

Modern Ordnance Survey maps
1:10,000 digital Ordnance Survey mapping was used in the creation of archaeological plans for ground truthing.

Archaeological survey
For comparative purposes and to create further baseline data the result of a topographic survey undertaken by Louise Barker of RCAHMW was viewed over the DEM for the fort at Linney Head. An archaeological plan derived from this survey is also included for comparison with that produced from remote sensing. A plan produced from the results of topographic survey of Greenala Camp is also included.

Geophysical survey
At Greenala Camp and Porth y Rhaw Camp a geophysical survey was undertaken on the interior of the fort.

APPRAISAL OF DATA SOURCES

LiDAR
The LiDAR data gives a good visual impression of the form of an archaeological site. It can be used to create 3D representations of the landscape that can be viewed from all angles. This gives LiDAR an advantage over other remote sensing data in that one can 'move around' a site without leaving one's desk. For the remote sensing project the disadvantages were that 2m resolution LiDAR data did not pick up all archaeological features at the sites, nor did it accurately show the position of cliff edges.

Old Vertical Aerial Photographs
These black and white images were often taken from a very high level. This makes them less useful for producing remote sensing plans. The height makes detailed observation of sites problematic and the lack of colour means that one cannot accurately differentiate between vegetation, topsoil and bare rock. Where they are available in pairs they can be viewed stereoscopically, allowing one to differentiate between cropmarks, soilmarks etc. and upstanding features.

Modern Digital Vertical Aerial Photographs
The National Assembly of Wales aerial photographs, being georeferenced, can be compared with other georeferenced data. They also have the advantage of colour, which allows one to differentiate vegetation from bare rock etc. but they cannot always be viewed stereoscopically. The fact that they are recent images however, means that they are useful baseline data, which can be compared with future images in order to monitor erosion.

Oblique Archaeological Aerial Photographs
These have the advantage of having been taken for archaeological purposes and in the best weather conditions to pick up detail. Since they cannot be georeferenced they cannot be compared with other such data for comparison of cliff edge etc. Modern colour oblique aerial photographs are excellent for differentiating between soil, vegetation and rock at these coastal sites to allow monitoring of erosion.

Historic Ordnance Survey Maps
Being georeferenced these can be compared with other georeferenced datasets. They proved to be a very good source of information for producing remote sensing plans of the forts. They are quite accurately mapped and the interest of the surveyors in the archaeology was such that they hachured in many of the archaeological features, such as banks and ditches, on the early editions. However, this detail is not reproduced on the later maps.

For map regression the old maps are less useful because between the land may not have been re-surveyed. Cliff loss is therefore not recordable between map editions.

Modern Ordnance Survey Maps
The modern digital Ordnance Survey mapping is not as useful as the historic editions. Archaeological features are not shown in as much detail any more. Digital mapping means that these can be compared with other georeferenced data but the usefulness of this for map regression is doubtful, as the cliff edge seems to have been copied from earlier editions rather than resurveyed.

Geophysical Survey
The springy tussock grass, the density of archaeological features and the presence of ferrous material from the 1990s excavations in the interior of Porth y Rhaw Camp meant that the survey results were not easy to interpret.

Summary of Appraisal of All Sources
The appraisal of data sources in this way reveals that used in isolation no remote source of information can accurately interpret archaeological sites of this nature. Used together the

remote data sources can give a good basic interpretation of a site to provide a ground plan that can be verified with a site visit.

The same is true for the examination of cliff edge retreat and vegetation/soil erosion. The remote data sources, including 2m LiDAR data, are only capable of capturing useful monitoring data when used as part of a suite of data sources including topographic survey.

RESULTS

The results are presented on a site-by-site basis in alphabetical order. For each site the existing Historic Environment Record (HER) description is followed by some, or all of the following: Digital Elevation Model; Digital Elevation Model with aerial photograph overlay; map regression based on historic and modern mapping; aerial photographs; archaeological plan based on remote sensing; archaeological plan based on field survey.

Black Point Rath: PRN 3128, NGR: SM85971527

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Black Point Rath is shown on the 1st Edition Ordnance Survey 1:2500 map of 1889 as a univallate promontory fort. The map shows the fort naturally defended by high sea cliffs to the west and south, and by a curving bank approximately 120m long with an external ditch to the north and east. An entrance lies between the bank terminal at the south end and the edge of the cliffs. The internal area is about 120m E - W and 35m N - S, although it is likely that by 1889 a considerable amount had been lost to the sea.

The fort is suffering severe coastal erosion. The whole of the promontory is slowly crumbling into the sea and resembles a blancmange sliding off a plate. The fort is probably 5m to 10m lower than it was 100 years ago, and great fissures have opened up all over its surface making a visit an extremely hazardous operation. However, some details of the fort are still visible. The bank stands to over 3m high internally and over 5m above the base of the ditch. Where it has cracked open the shattered stone composition of the bank is clearly visible. On a previous visit in 2001 a chevaux de frise was visible beneath the bank, but erosion has now removed it.

The Royal Commission in 1925 record that the Rev. J Phillips excavated two hut circles within the fort and found charcoal, two spindle whorls, ox bone, teeth, oyster and mussel shells, a piece of pottery and a burnt clay floor.

Results

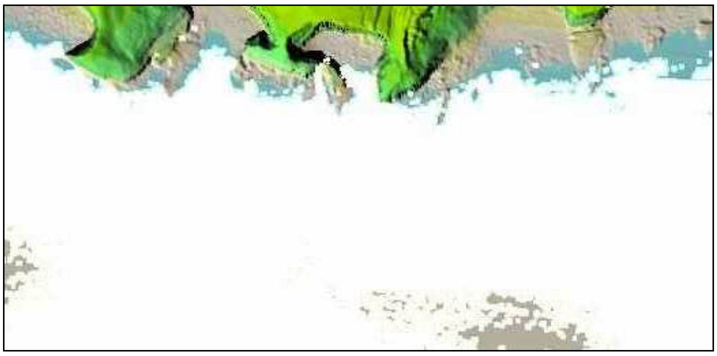


Fig.3. LiDAR jpeg

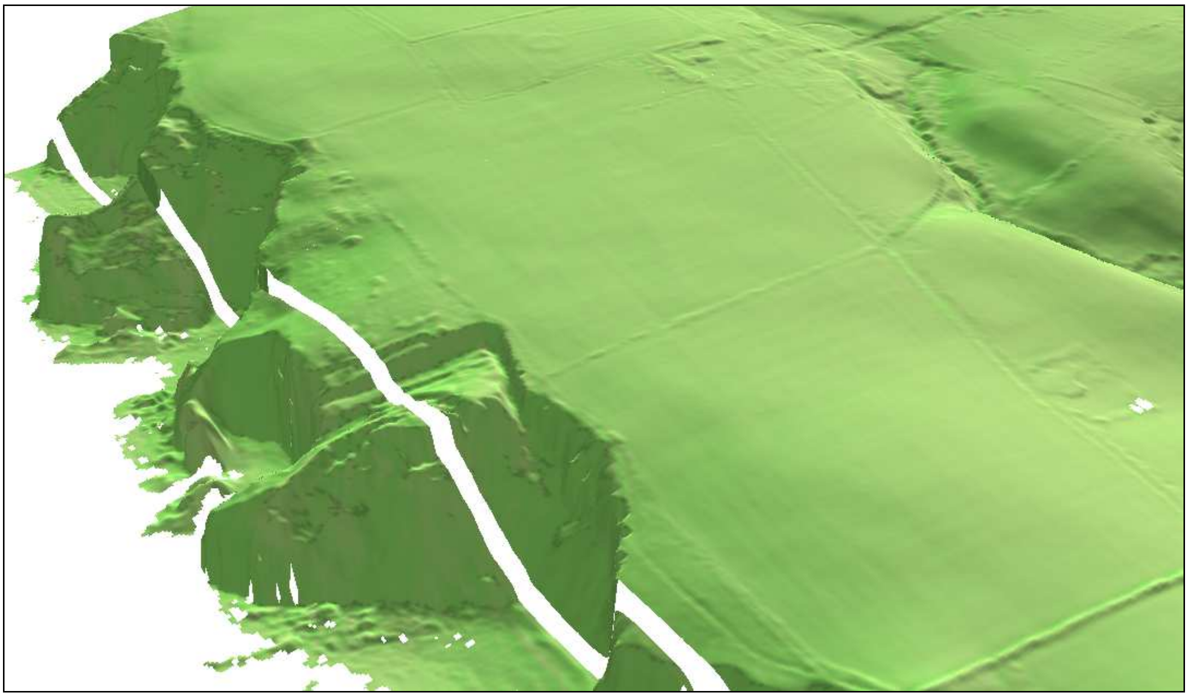


Fig.4. Digital Elevation Model

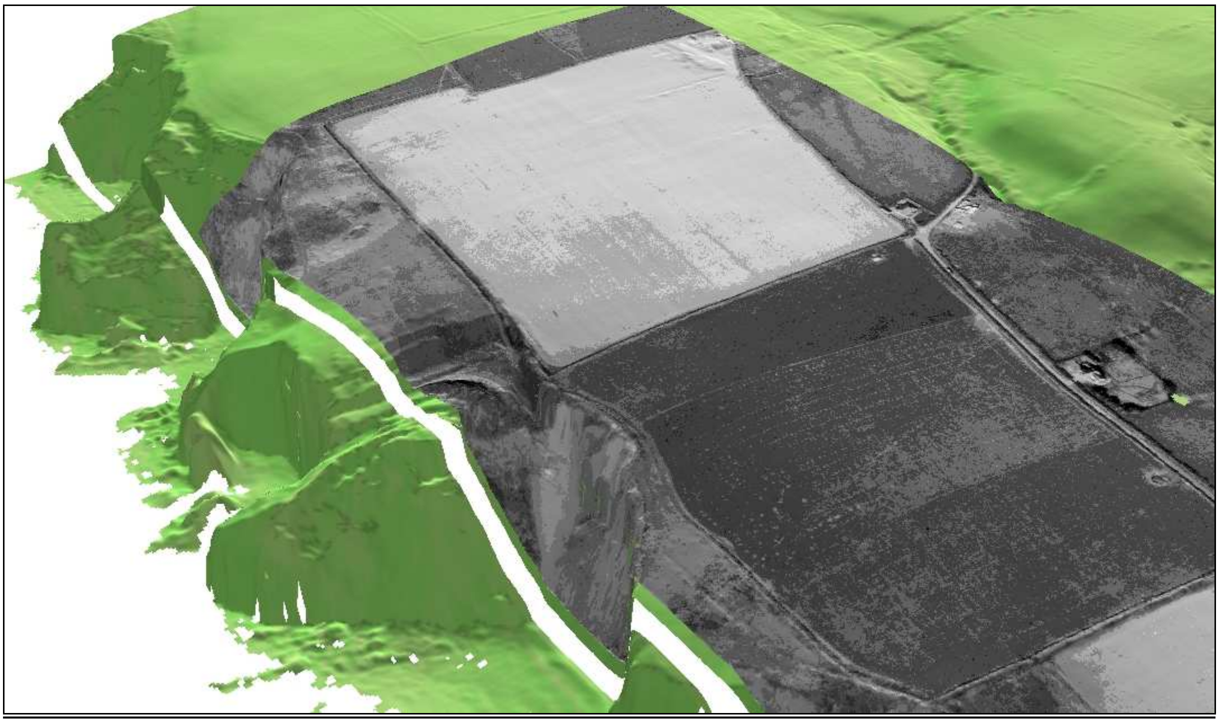


Fig.5. DEM with AP overlay

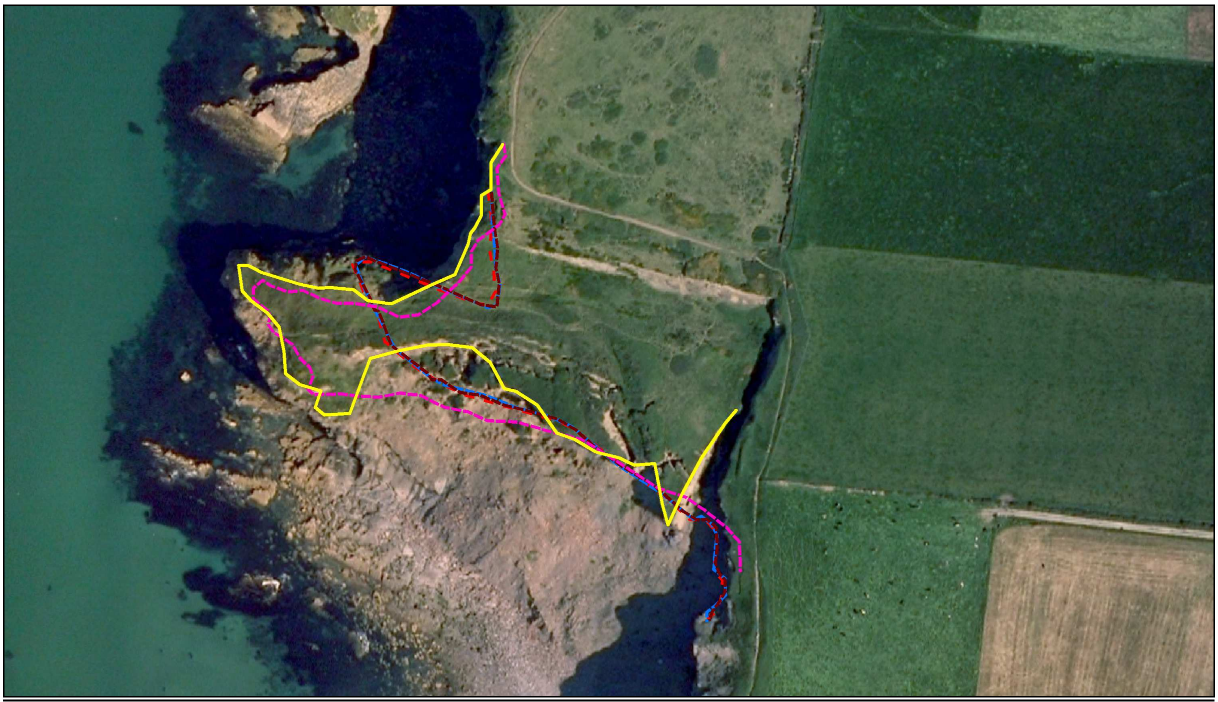


Fig.6. Map regression

- - - - = 1st edition OS map
- - - - = 2nd edition OS map
- - - - = 3rd edition OS map
- - - - = Black & white aerial photograph
- - - - = NAW colour aerial photograph

Fig.7. 1972 Aerial photograph

Fig.8. 2008 RCAHMW aerial photograph

Discussion
Of all the forts in the study, Black Point Rath appears to be at the greatest immediate risk from coastal erosion. In 1981 the Ancient Monument Inspector recorded that this was a fine promontory fort, but that in places several fractures had cut through the earthworks and that recording should take place before 'the whole site falls into the sea'. By time of a 2002 visit the site was in a perilous condition with much of the defences and interior already lost.

The HER entry records that between 2001 and the 2006 Defended Enclosures project visit a chevaux de frise has been lost to the sea and the bank has cracked open revealing its internal structure. Similarly, the 2009 map regression shows that on the south side of the monument a great deal of cliff loss has occurred since the 1972 aerial photograph was taken. The modern colour aerial photograph clearly shows a deep fissure running north to south on the eastern side of the monument that was not there at the time of the 1972 photo. The yellow line on the map regression was thought to record the extent of surviving vegetation as shown on the modern vertical colour AP and in comparison with that from the 1972 image it showed considerable vegetation loss. In fact the 2008 RCAHMW photograph reveals that this line is the edge of both vegetation and soil, with nothing but bare rock existing to the south.

Wainwright (1971) notes that the artefactual material recovered by Phillips is 'probably indicative of Iron Age occupation' but these finds could date from any period from the Iron Age to the Early Medieval. The Research Agenda for Wales records that we know little about the occupation of this type of site during Roman and Early Medieval periods and it would therefore be useful to securely date this occupation.

As well as the deep north-south fissure shown on the modern vertical aerial photograph others running east-west are visible on the LiDAR image and 2008 RCAHMW photograph. Of all the available data sources this image (Fig. .) shows most clearly the extent of coastal erosion at this site.

Recommendations
Black Point Rath should be subject to a field visit as soon as possible. If it is deemed safe to do so then recording of the remainder of the site should take place as a matter of priority and if possible should include excavation to obtain secure dating evidence for the occupation.

Dinas Island Castell (East): PRN 1587, NGR: SN01344019

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
This is a small, rectangular, earthwork defended enclosure occupying the flat top of an inland promontory at 40m above sea level, 170m from the coast at Cwm-yr-Eglwys. Immediately to the north, east and south of the enclosure the land falls steeply away to sea level. The enclosure does not make use of these steep slopes in its defensive circuit, but relies on a constructed bank and ditch set back from the break of slope. To the west land rises gently away from the site.

The defences are most pronounced on the north side, where they seem to incorporate a natural, low break of slope. Here a c.10m wide bank rises c.0.5m above the interior and 3m over a shallow (0.5m deep) ditch, which is 5m wide. A break in the bank and ditch in the centre of the north side indicates the position of a simple entrance. On the west side the defences run parallel and close to a hedge-bank. The defensive bank is here 1m high externally and internally, with traces of a ditch between the defensive bank and the hedge-bank. The south and east sides are defined by scarp slopes. In 2006, the site was under dense gorse scrub and brambles, which were impossible to penetrate. The interior could not be examined owing to the vegetation, and the west and south defences and exterior on these sides could only be glimpsed.

The Ordnance Survey in 1974 described the enclosure as 60m E-W and 50m N-S, with a level interior. Traces of a 2-cell rectangular building 24m x 8m were noted in the interior. The interior was then largely clear of vegetation.

The Ordnance Survey noted two small quarries close to the enclosure - these were not seen in 2006 owing to the vegetation. Many badger runs were noted over the earthworks in 2006, but there did not appear to be any setts in the enclosure itself. Slight surface weathering over the banks revealed their earth and shalely-stone construction.

Results

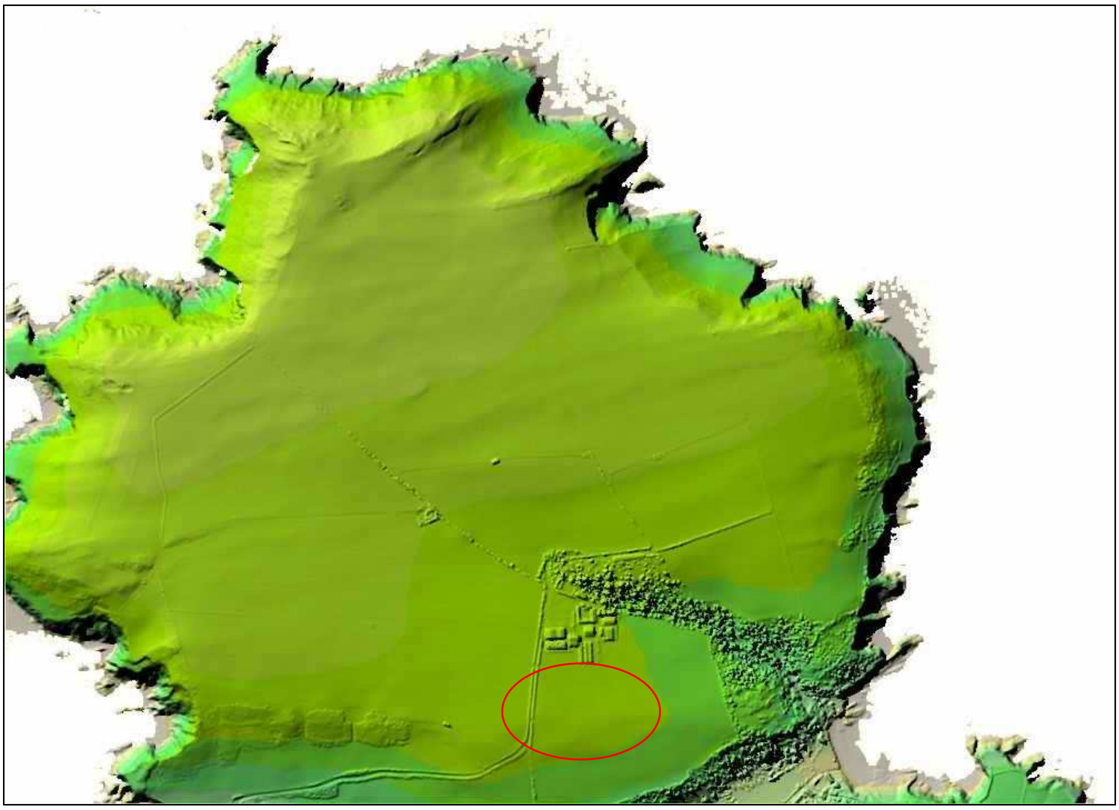


Fig.9. LiDAR jpeg; site location circled.

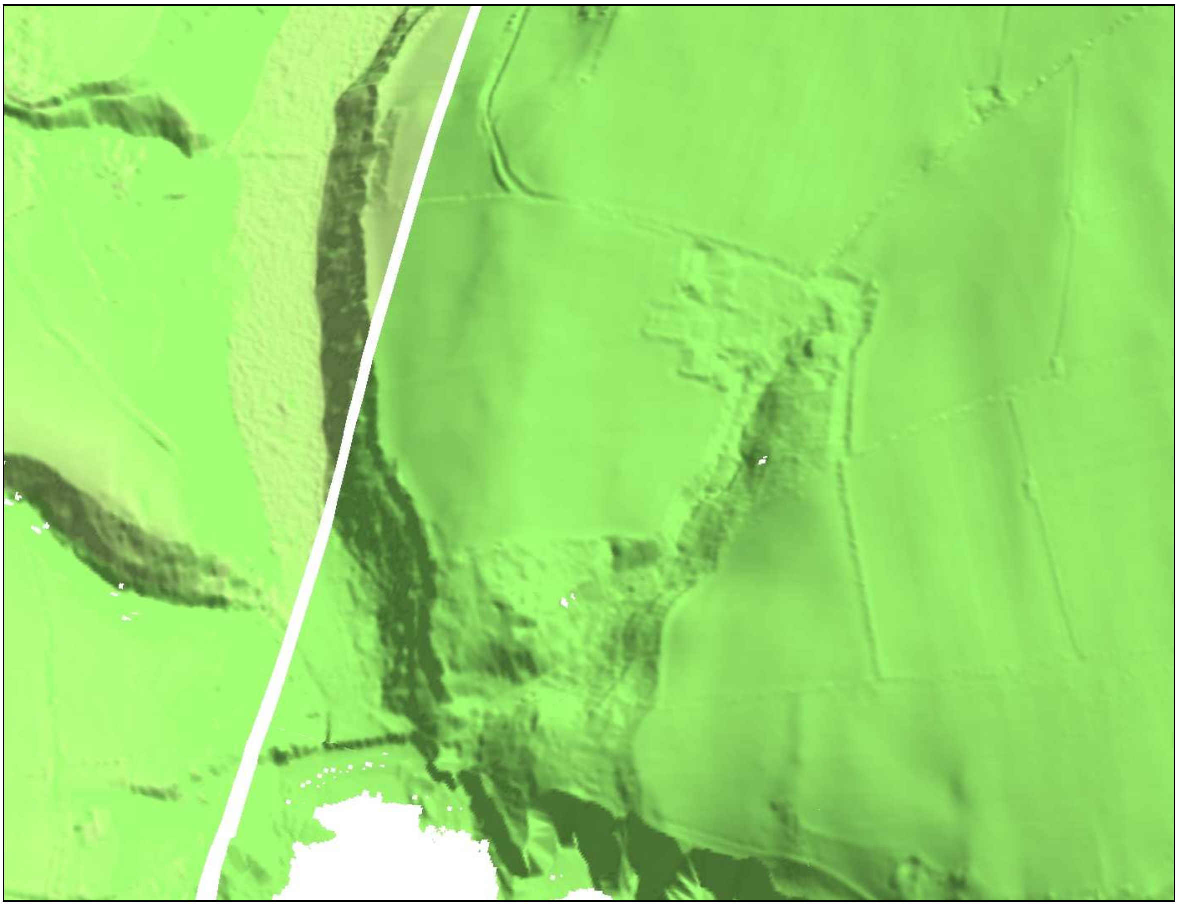


Fig.10. Digital Elevation Model

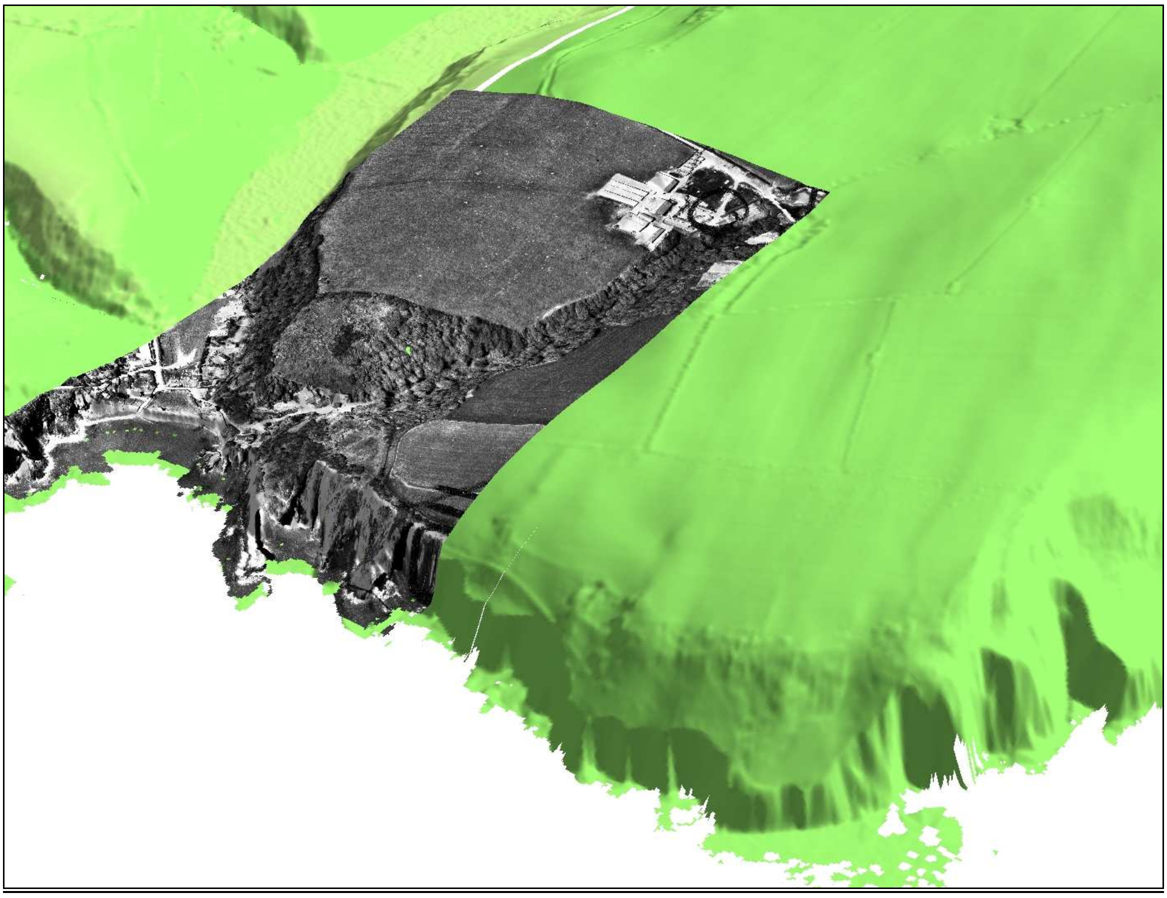


Fig.11. Digital Elevation Model with AP overlay

Discussion
The location of this site meant that map regression was not undertaken, as coastal erosion is not an issue. There is very little that can be said about the results. Nothing can be seen, on the jpeg, the Digital Elevation Model or the overlain aerial photograph, of the archaeological features recorded by the Ordnance Survey in 1974 and the Defended Enclosures project in 2006. One can only conclude that dense vegetation prevents this site being seen by any method other than field survey.

Recommendations
No specific recommendations.

Greenala Camp: PRN 4205, NGR: SS00659658

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Greenala Camp is a heavily defended, multivallate coastal promontory fort. It occupies a raised promontory at 40m above sea level, which is naturally protected to the south and east by high sea cliffs. The north, landward, side is defended by four massive banks and ditches. These are constructed on the north-facing slope of the promontory, greatly increasing their impressiveness when viewed from the land. A gap midway along the defences marks an entrance.
The western end of the defensive system is confused, with possibly additional banks and berms. Aerial photographs show a possible two further lines of defence c. 40m to the northwest (RCAHMW 2003/5056-54) as well as a very ploughed out annexe bank c. 150m from the main defensive circuit (RCAHMW 985056-06).
The sloping interior measures c. 120m E-W and c. 55m N-S, but it is likely that a considerable amount has been lost to coastal erosion. The RCAHMW in 1925 recorded numerous hut circles within the interior, but later authorities have not noted these. The site is under rough grass with some bracken and a little blackthorn scrub on the defences. The Pembrokeshire Coast Path crosses the site, but little visitor erosion results from this.

Results

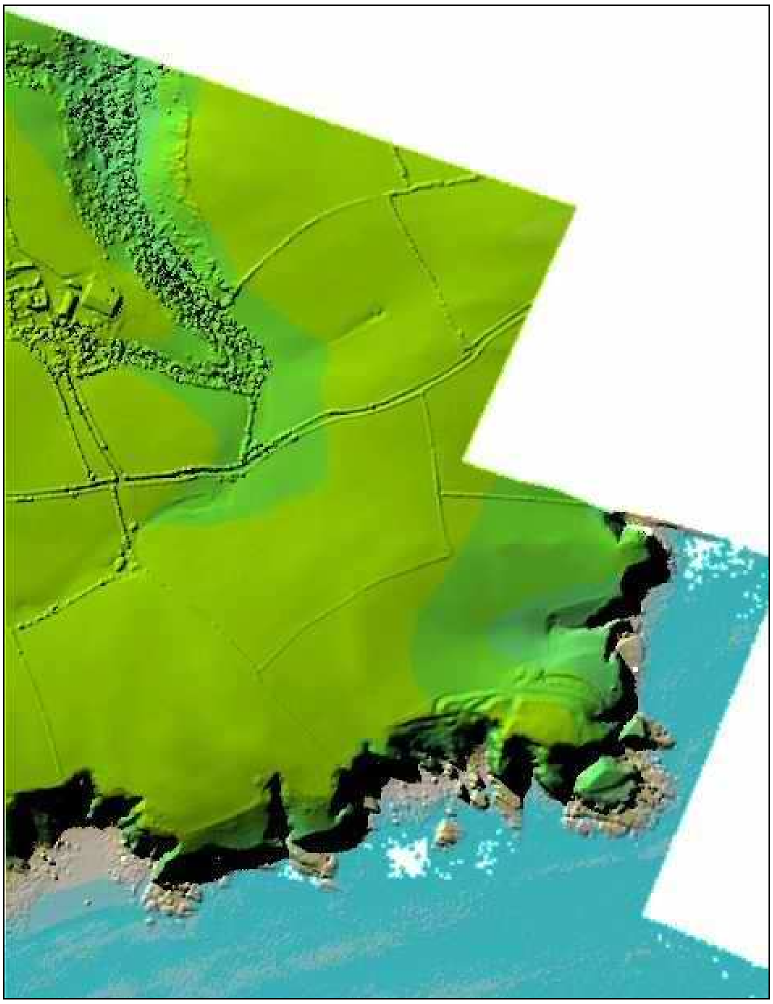


Fig.12. LiDAR jpeg

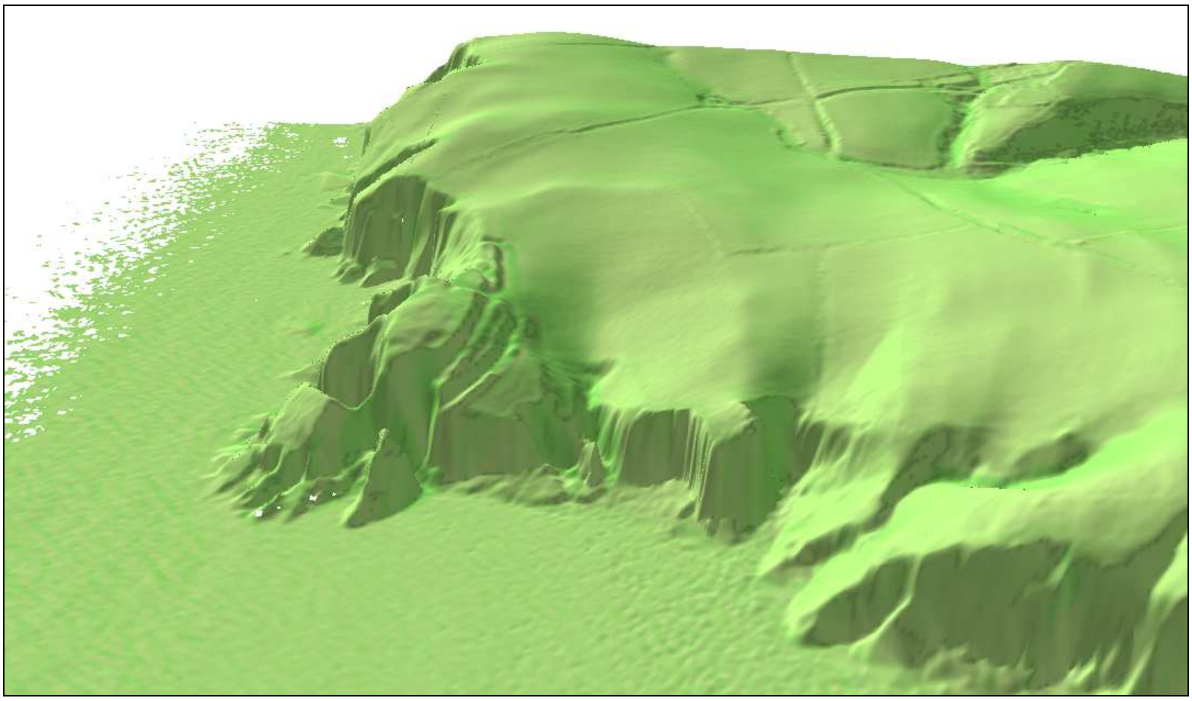


Fig.13. Digital Elevation Model

Fig.14. Digital Elevation Model with AP overlay. Note the continuation of the ditches at 'A'.


Fig.15. Digital Elevation Model with AP overlay seen from different angle.


Fig.16. Map regression. Yellow line in this image shows edge of apparently stable vegetation.

- - - - = 1st edition OS map
- - - - = 2nd edition OS map
- - - - = 3rd edition OS map
- - - - = 1968 aerial photograph
- - - - = NAW colour aerial photograph

Fig.17. 2009 RCAHMW aerial photograph

Fig.18. 2009 RCAHMW aerial photograph

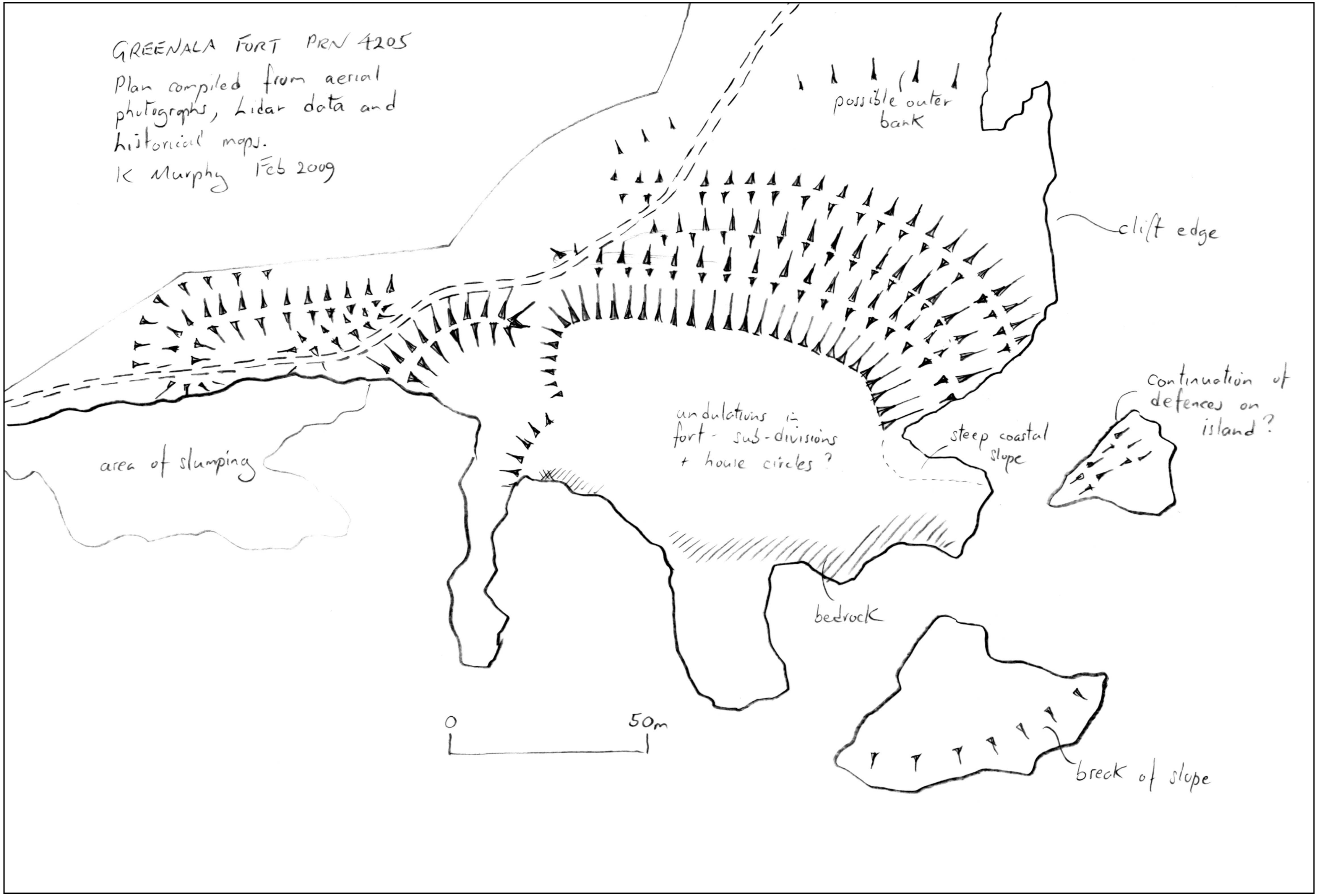


Fig.19. Plan based on remote sensing

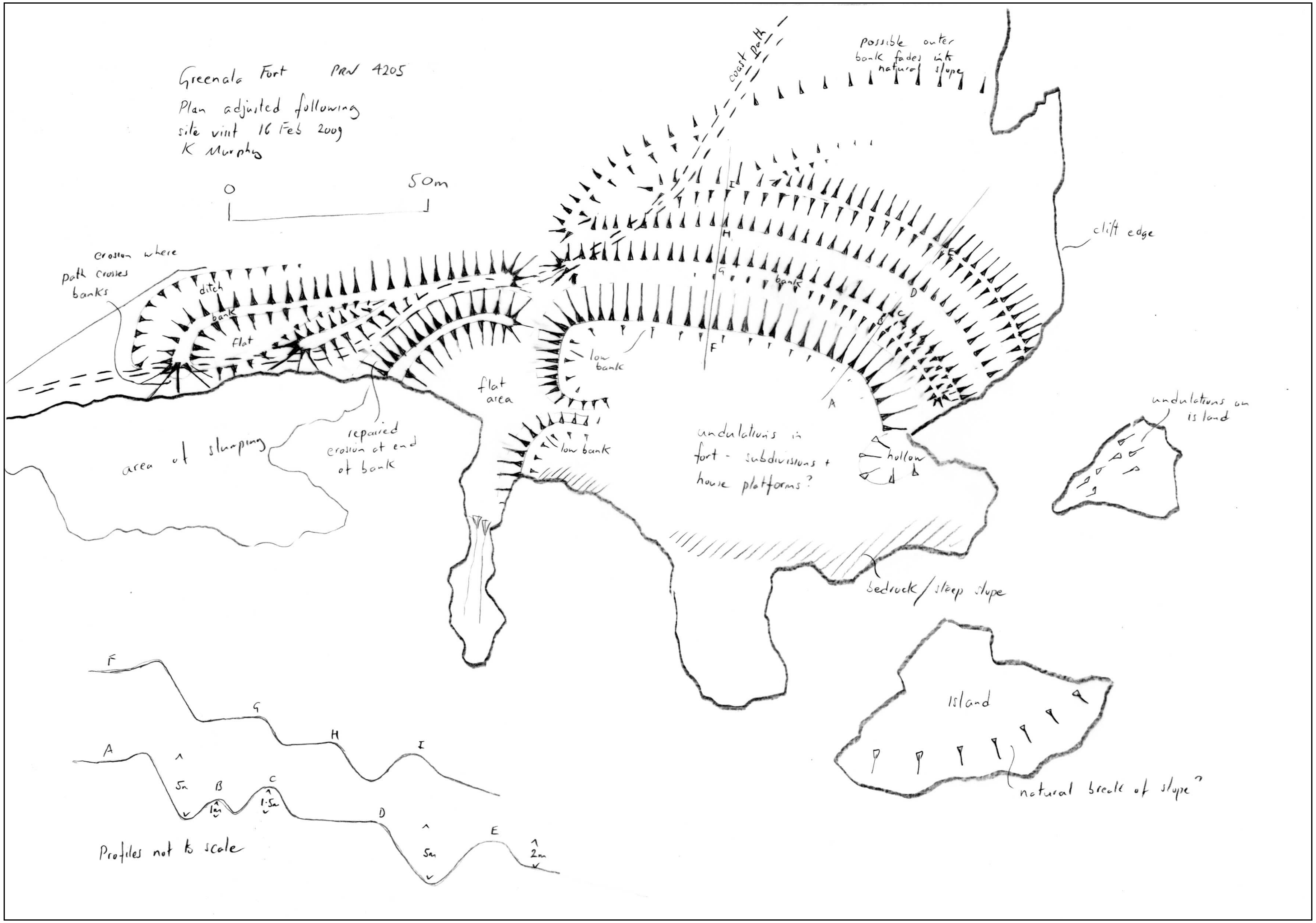


Fig.20. Amended plan following field visit

Discussion
Greenala Camp is one site where the LiDAR data has proved useful for detecting archaeological features. On the plan produced by remote sensing it was possible only to suggest that there might be a continuation of the fort's ditches on the offshore stack to the east, and a site visit was required to confirm this. With the 1968 Ordnance Survey aerial photo overlain on the DEM the remains of the ditches in this area are clearly visible.

However, the pre- and post- field visit plans, and Ken Murphy's report (Appendix II) reveal that ground truthing picked up much more detail than was visible on remote sensing, in particular detail of the defensive system and low earthworks in the fort's interior. The full topographic survey by RCAHMW picked up yet more detail.

Map regression based on historic aerial photographs proved to be particularly difficult for Greenala. It was hard to differentiate between cliff top and cliff face or between vegetation and rock on the black and white image, hence on the map regression there appear to be areas of 'gain' between 1968 and the modern colour vertical AP. Generally this site appears to have been stable since as long ago as the first edition Ordnance Survey map (1885). Ancient Monument Inspections over many years have recorded that the site is under long grass and bracken. The last such visit was in 2000, but the 2007 and 2009 RCAHMW photographs show that this is still the case today.

Recommendations
In the past it has been noted by Monument Inspectors that there is the potential for plough damage to this site and this, along with potential visitor and sheep damage, should be monitored. The site does not at present appear to be suffering from coastal erosion; thus the only recommendation is that the site is re-evaluated in five years time, for monitoring purposes.

Linney Head (Head of Man): PRN 539, NGR: SR8886195689

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Linney Head is a good example of a coastal promontory fort occupying a very exposed position on the far south west of Pembrokeshire. The site is naturally protected by vertical limestone cliffs to the west, south and east and by built defences to the north. It is of at least two phases. The earlier phase consists of faint traces of a bank and ditch defending a sub-promontory c. 65m by 40m within the main fort. The second phase comprises a bivallate defence running for approximately 135m across the neck of the promontory with an entrance mid-way along them, and defending an area c. 146m by 85m. Two lines of widely spaced bank and ditch lie to the west of the entrance, the outer line of which curves into towards the entrance. There is a possible bastion mound outside the east side of the entrance, with a short curving length of ditch and bank outside it. However, the defences to the east of the entrance are univallate only. The site is under short, coastal grass and is severely affected by coastal erosion - large patches of soil are eroding off the interior close to the cliff edge and parts of the cliff are also collapsing, particularly at the western end of the defences, revealing a section of the banks and ditches, including a buried soil beneath a bank. Quarrying has also taken place at the western end at some time. Since World War Two the fort has lain within the Castlemartin firing range, and has been pockmarked by shell holes. It has now been taken out the impact zone.

Results

Fig.21. LiDAR jpeg.

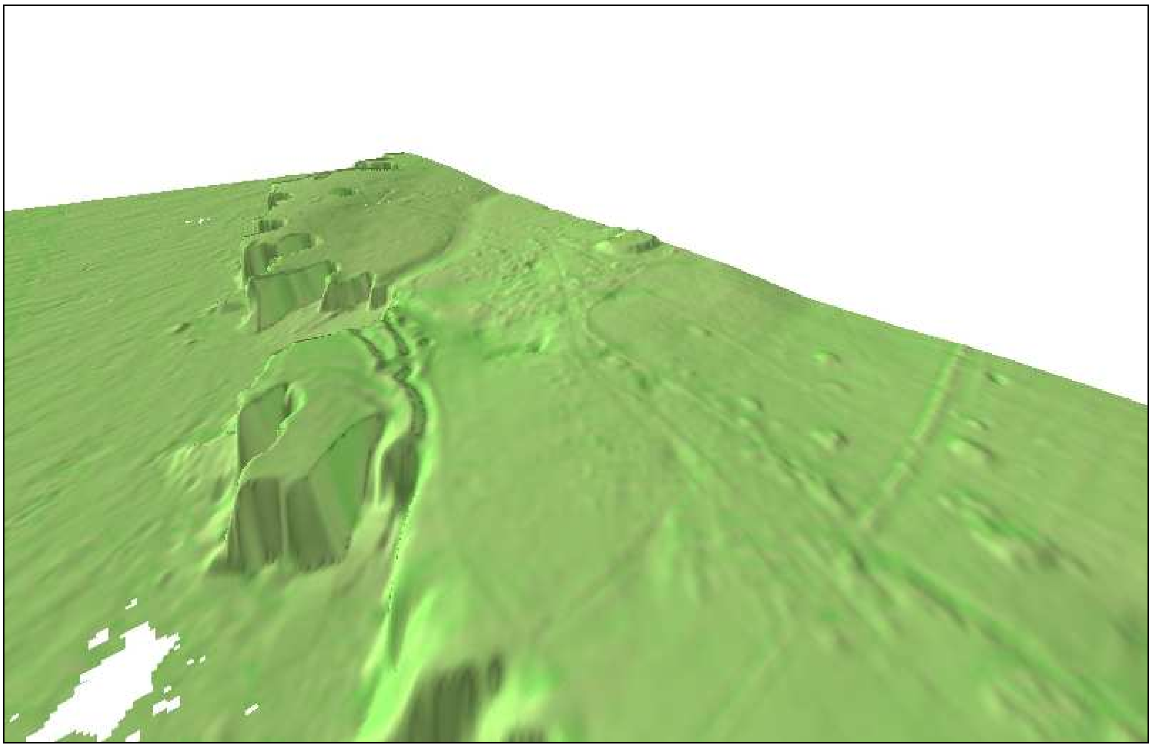


Fig.22. Digital Elevation Model

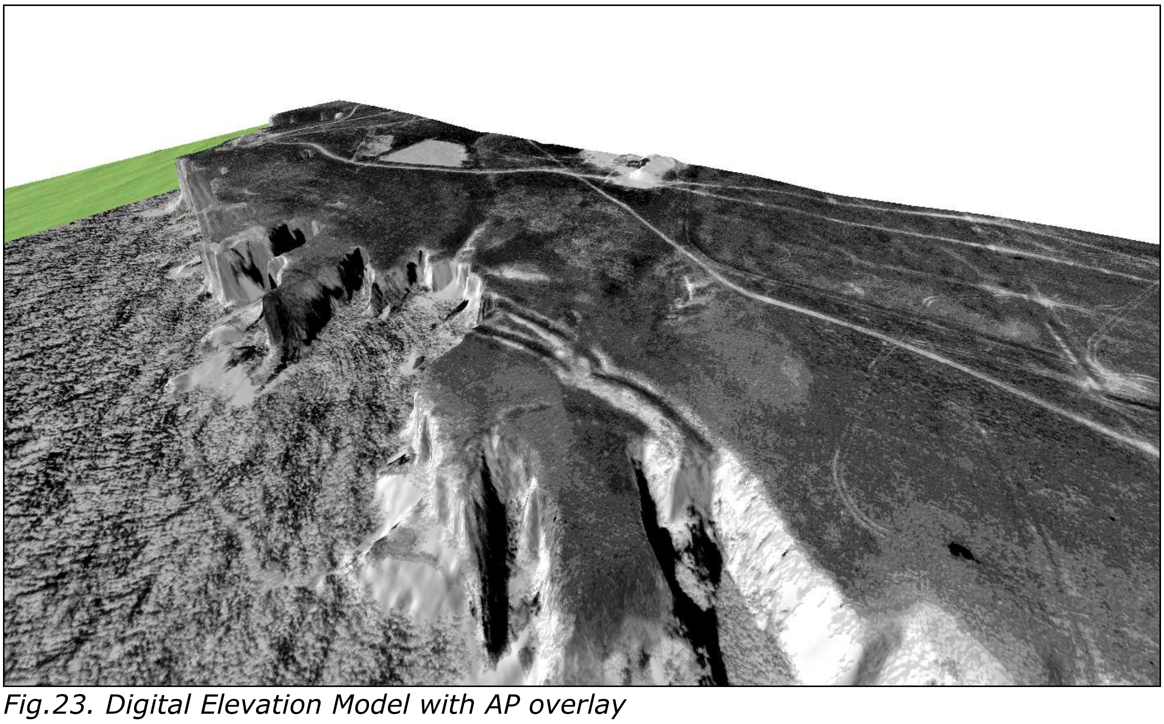


Fig.23. Digital Elevation Model with AP overlay

Fig.24. Map regression

- - - - = 1st edition OS map
- - - - = 2nd edition OS map
- - - - = 3rd edition OS map
- - - - = Black & white aerial photograph
- - - - = NAW colour aerial photograph

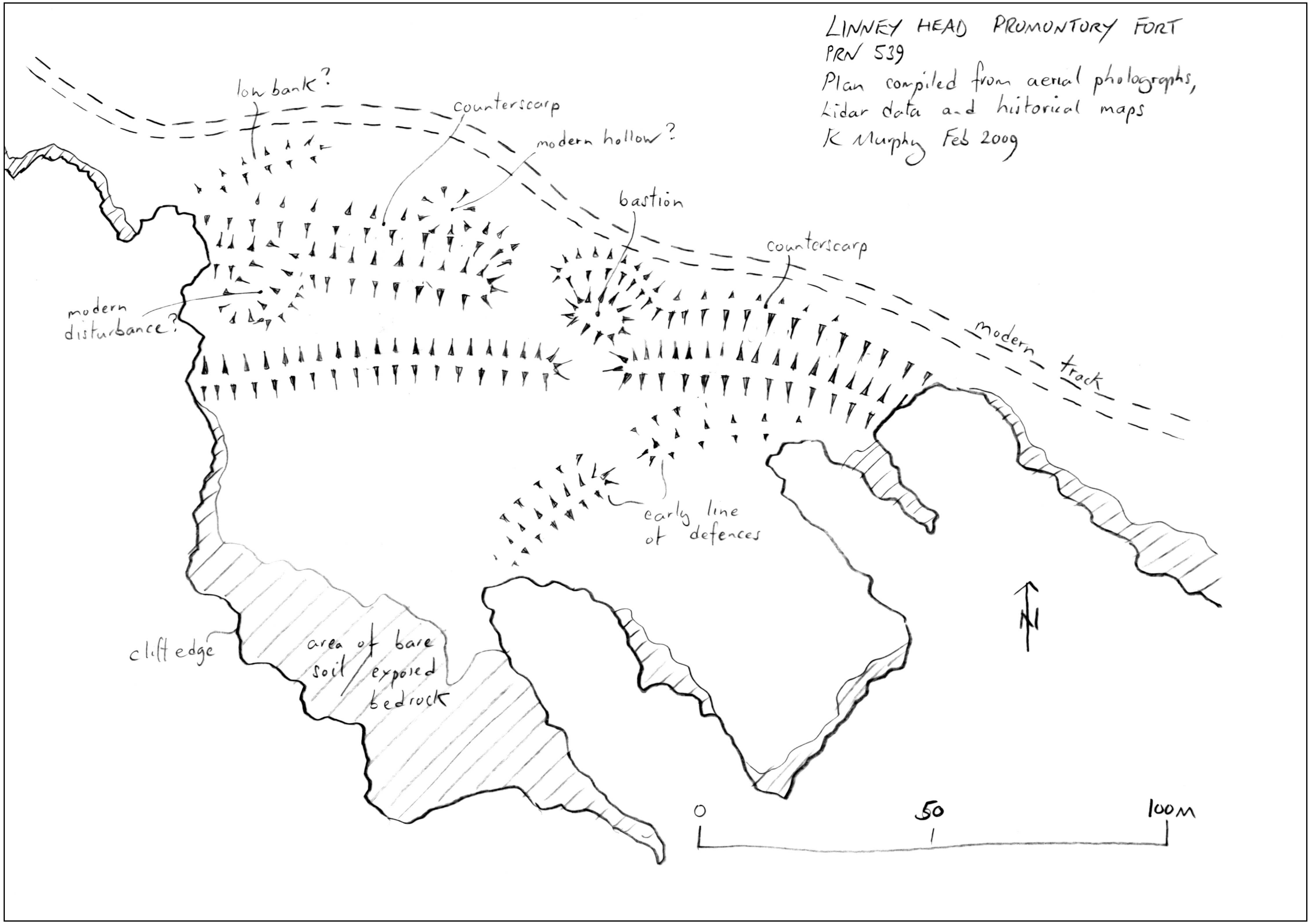


Fig.25. Plan based on remote sensing

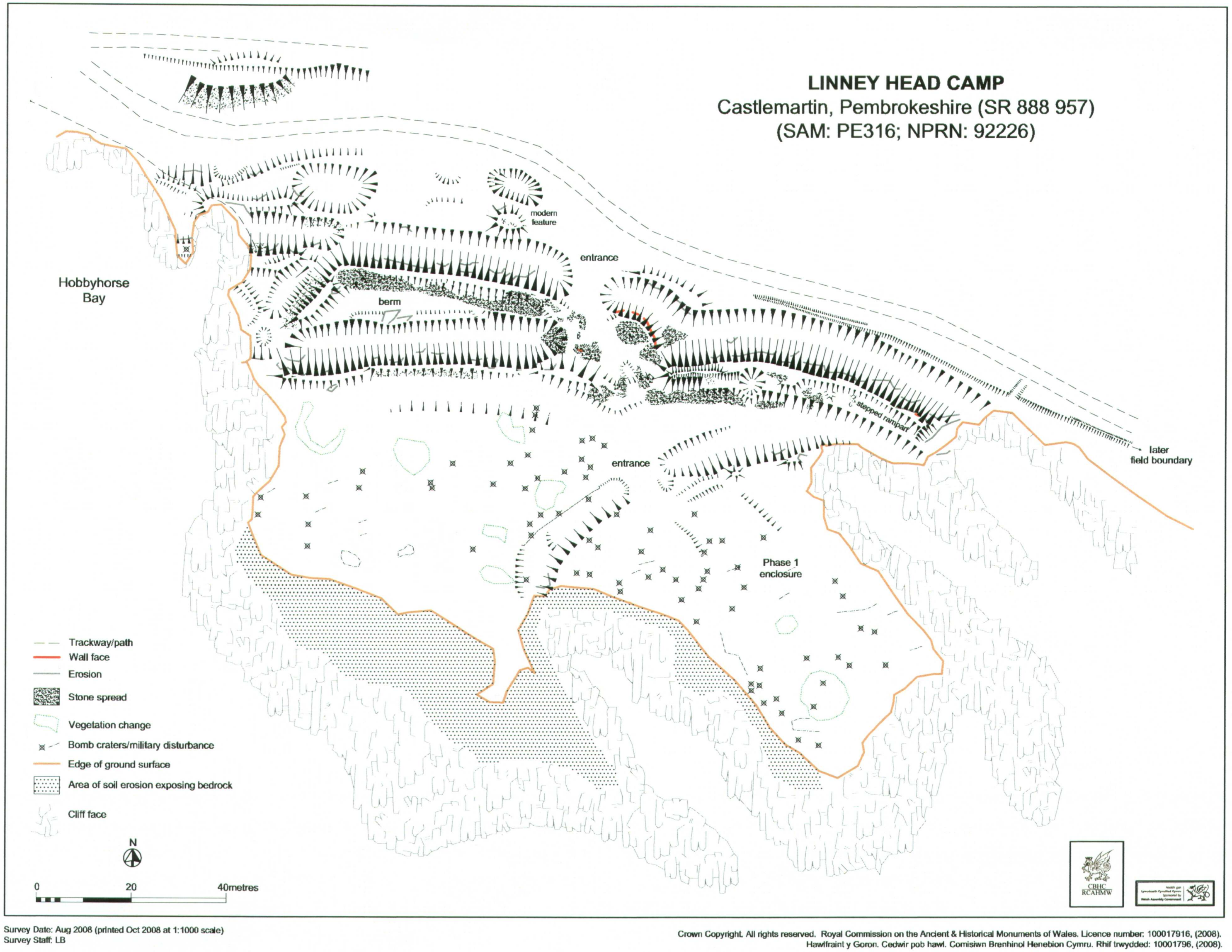


Fig.26. Results of RCAHMW field survey (see Appendix I)

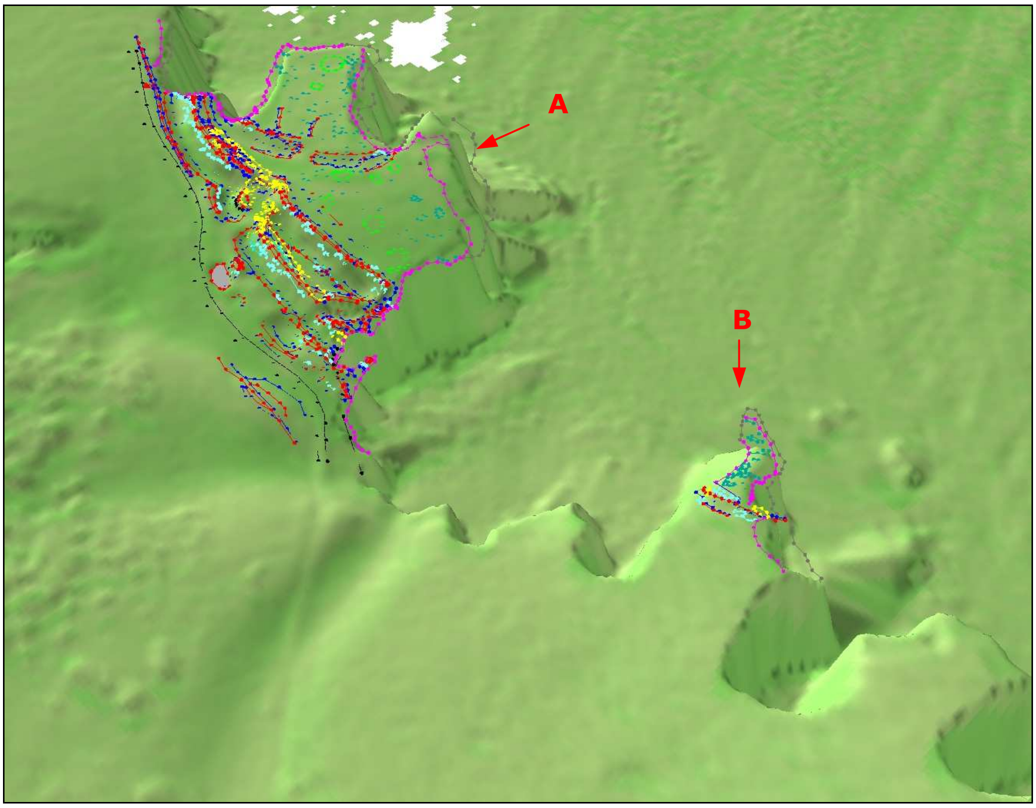


Fig.27. Digital Elevation Model overlain with GPS survey results: Note the discrepancies in recording of the cliff edge at points A & B.

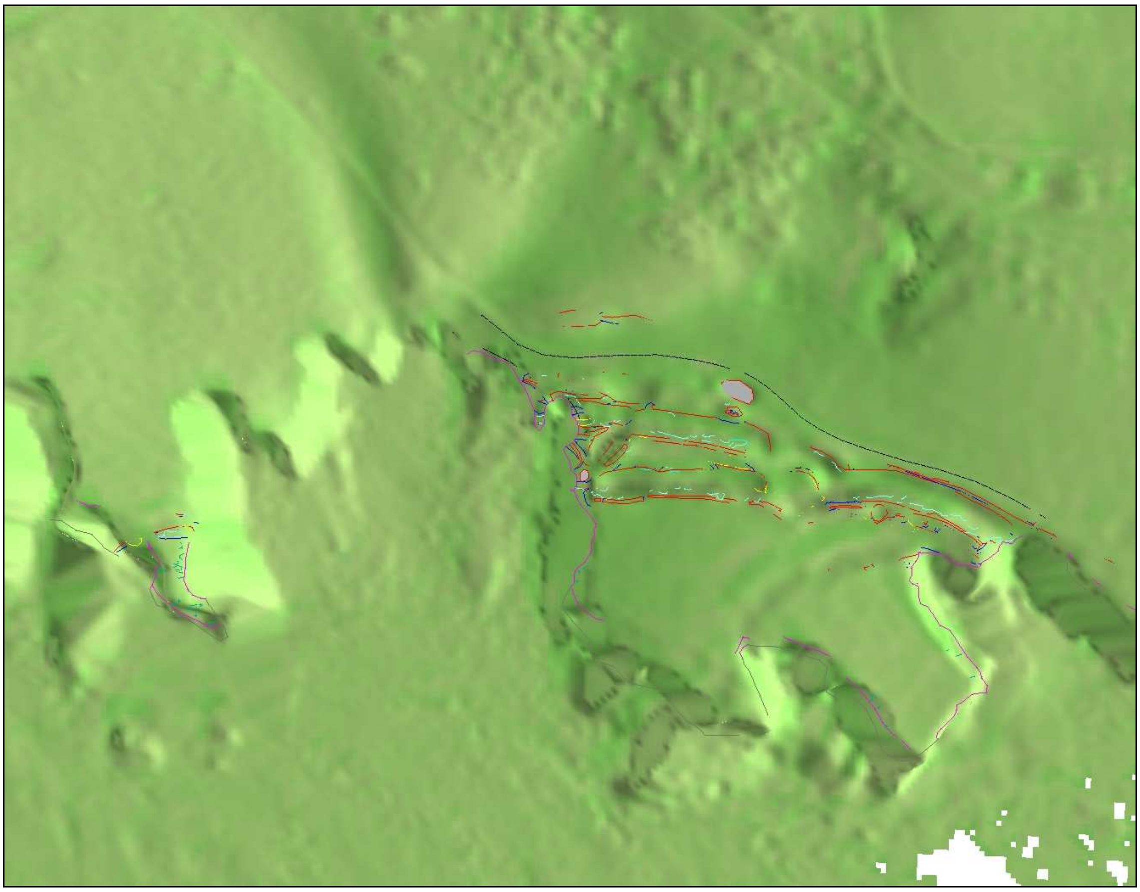


Fig.28. GPS survey in plan over DEM. Despite the discrepancies in recorded cliff edge between the two datasets there is little variation in the location of archaeological features.

Discussion
Archaeological features show up well on the DEM for the fort at Linney Head and there is a good correlation between their position on this and on the GPS survey. However, the two datasets differ wildly in their recording of the position of the cliff edge: areas where Louise Barker of RCAHMW was able to safely walk to carry out the survey (Figs. &) appear to have been in mid-air, hovering over the sea according to the DEM!

Ken Murphy finds (Appendix II) that generally there is a good correlation between a plan produced for this site from remote sensing and from the RCAHMW survey plan, although ditches to the defensive banks were not easy to delineate and some of the detail on the banks were mapped incorrectly in the former.

What the map regression clearly shows is the extent of vegetation loss on the south side of the site, as mentioned in the HER description, subsequent soil erosion poses a risk to this site and needs to be carefully monitored. The HER description also records that parts of the cliff are collapsing to the west: again this can be seen on the map regression and should be monitored for the threat it poses to the earthworks. This erosion was also mentioned by the most recent Monument Inspector's report (1999). This report also notes that the western and eastern terminals of the defences are undergoing considerable erosion, which at the western end has exposed a cross-section of the ditch and a buried soil.

Recommendations
Linney Head is vulnerable to coastal erosion and needs regular monitoring visits. Recording of the U-shaped ditch mentioned in the Monument Inspection report is recommended, as is sampling of the buried soil.

Porth y Rhaw Camp: PRN 2721, NGR: SM786242

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Porth y Rhaw is a multivallate coastal promontory fort much reduced by coastal erosion. The c. 30m high sea cliffs have suffered erosion, so much so that the interior of the fort is now reduced to two small promontories, the eastern one 70m N-S and 25m E-W and the western one 70m SW-NE and 30m NW-SE. These two reduced promontories were undoubtedly once much larger, and probably formed a single block of unknown dimensions. The remains of the interior are relatively level, but immediately to the north of the interior land falls away quite steeply into a shallow valley. The defences make use of this slope, with the inner bank occupying the crest of the valley side, lending a monumental aspect to the whole site. There are four lines of bank and ditch in total. The three inner curving inner ones are close-set and parallel, and c. 120m long. The inner bank rises 4m above the ditch, the second bank is less substantial and rises just 1m above the ditch and the third 1m-2m above the ditch. The outer, fourth, bank is straighter than the others and its course diverges from them at its west end, perhaps indicating a separate phase of construction. Because of the slope the outer bank is almost 20m lower that the inner bank. The entrance has suffered from erosion, but a gap through the inner bank towards its eastern end close to the cliff edge marks its position. Terminals of the second and third banks stop short of the cliff edge - any continuation of these banks, if there were any, has been lost to the sea.

Excavations in 1995-98 revealed the remains of at least eight timber roundhouses, some of which had been rebuilt several times, including one in stone. Radiocarbon dates indicate that occupation started in the early-to-mid Iron Age, and pottery indicates it continued into the 4th century AD.

The site is under rough grass. Apart from the landward side, the whole site is suffering from severe cliff erosion.

Results

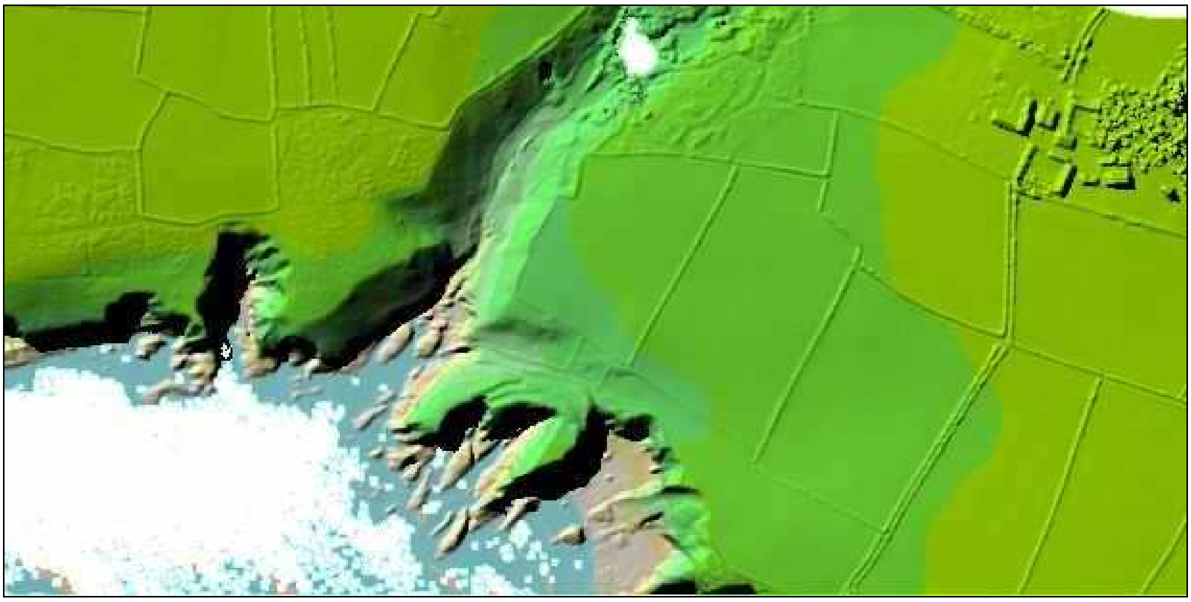


Fig.29. LiDAR jpeg

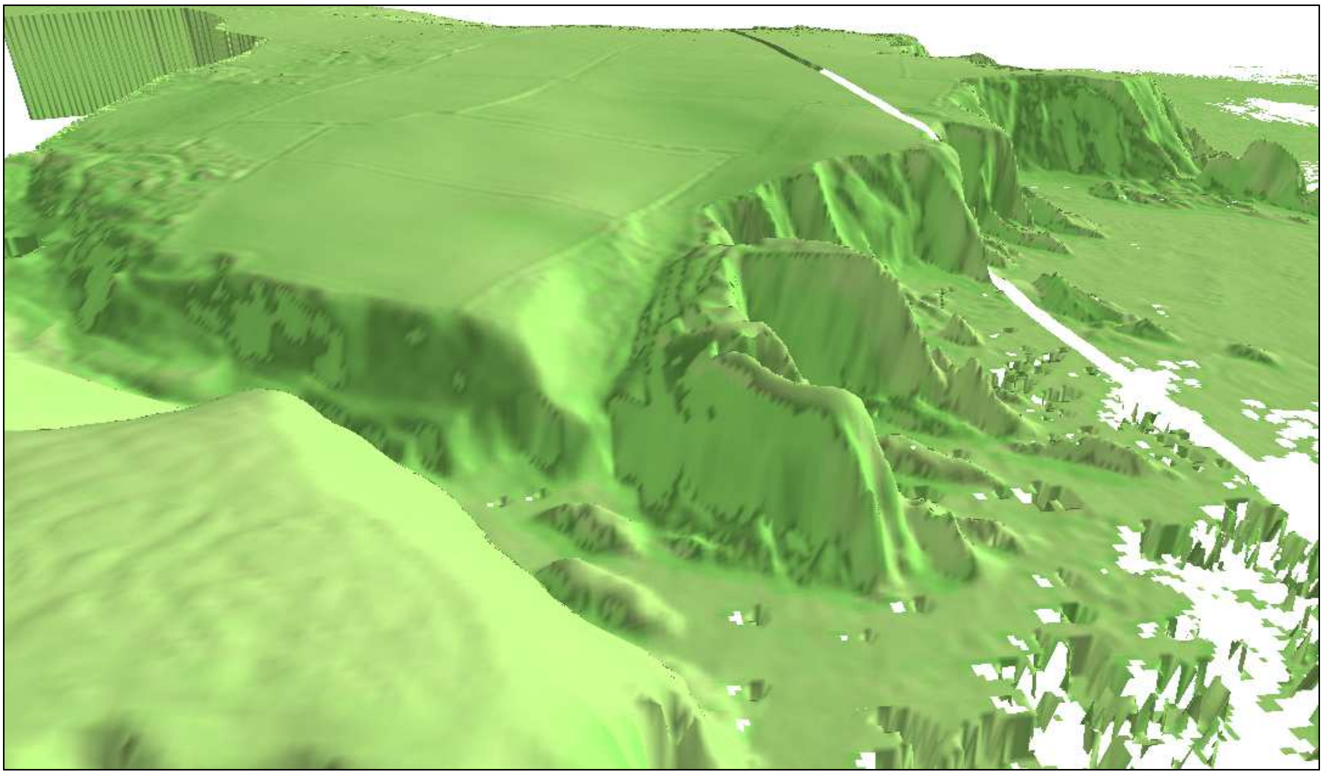


Fig.30. Digital Elevation Model

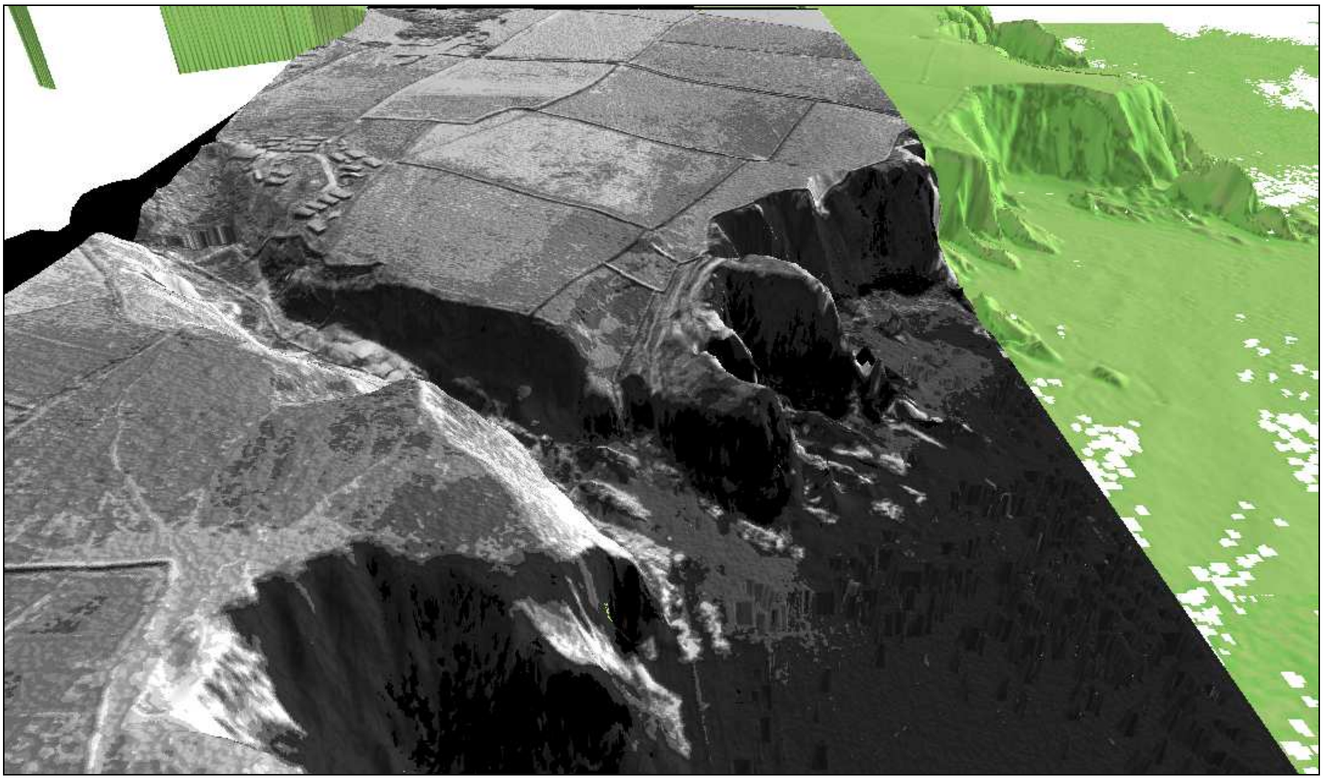


Fig.31. Digital Elevation Model with AP overlay

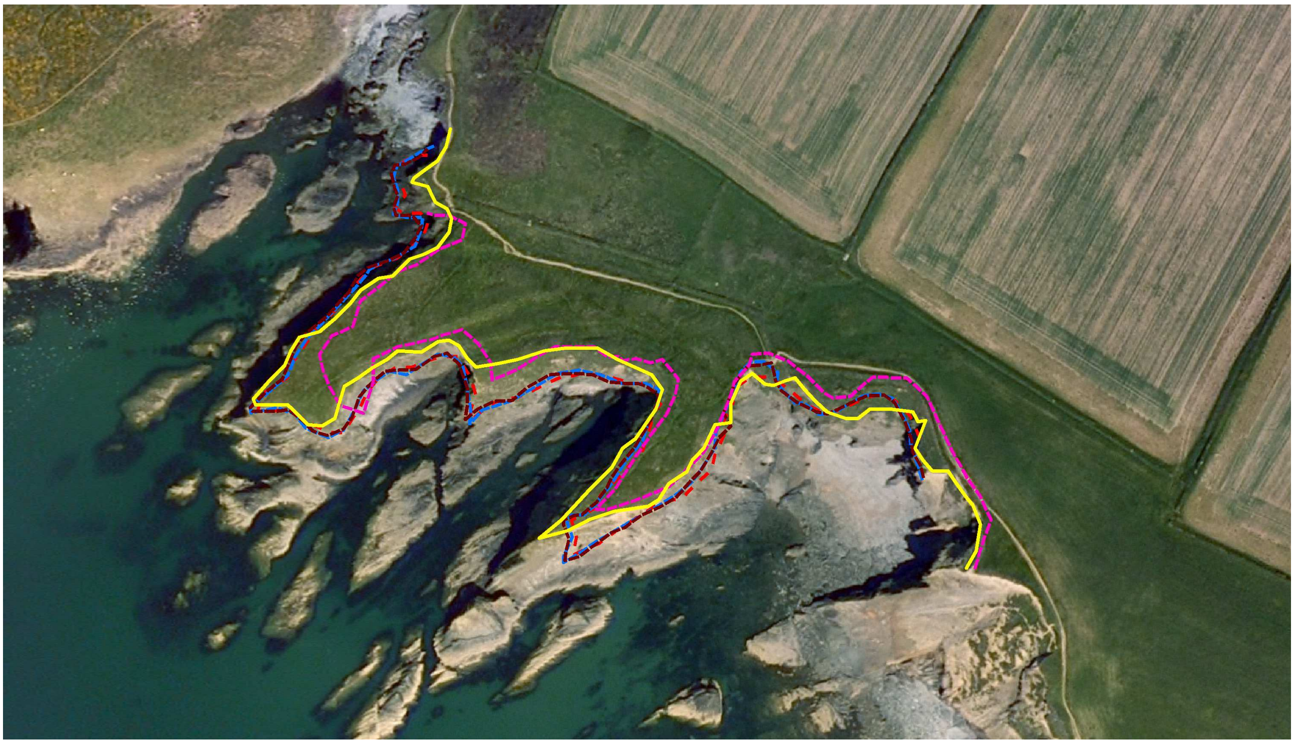


Fig.32. Map regression

- - - - = 1st edition OS map
- - - - = 2nd edition OS map
- - - - = 3rd edition OS map
- - - - = Black & white aerial photograph
- - - - = NAW colour aerial photograph

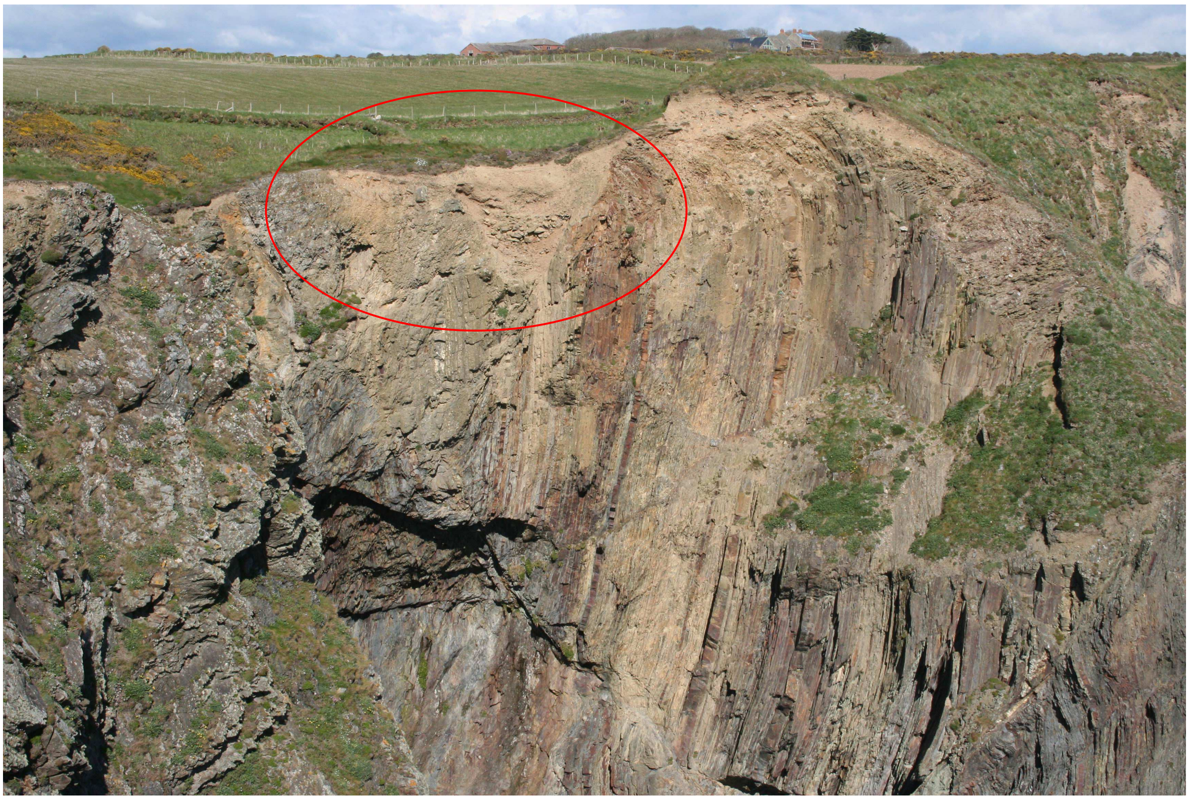


Fig. 33. 2009 DAT image taken from the south-western tip of the westernmost promontory and showing the ditches in section

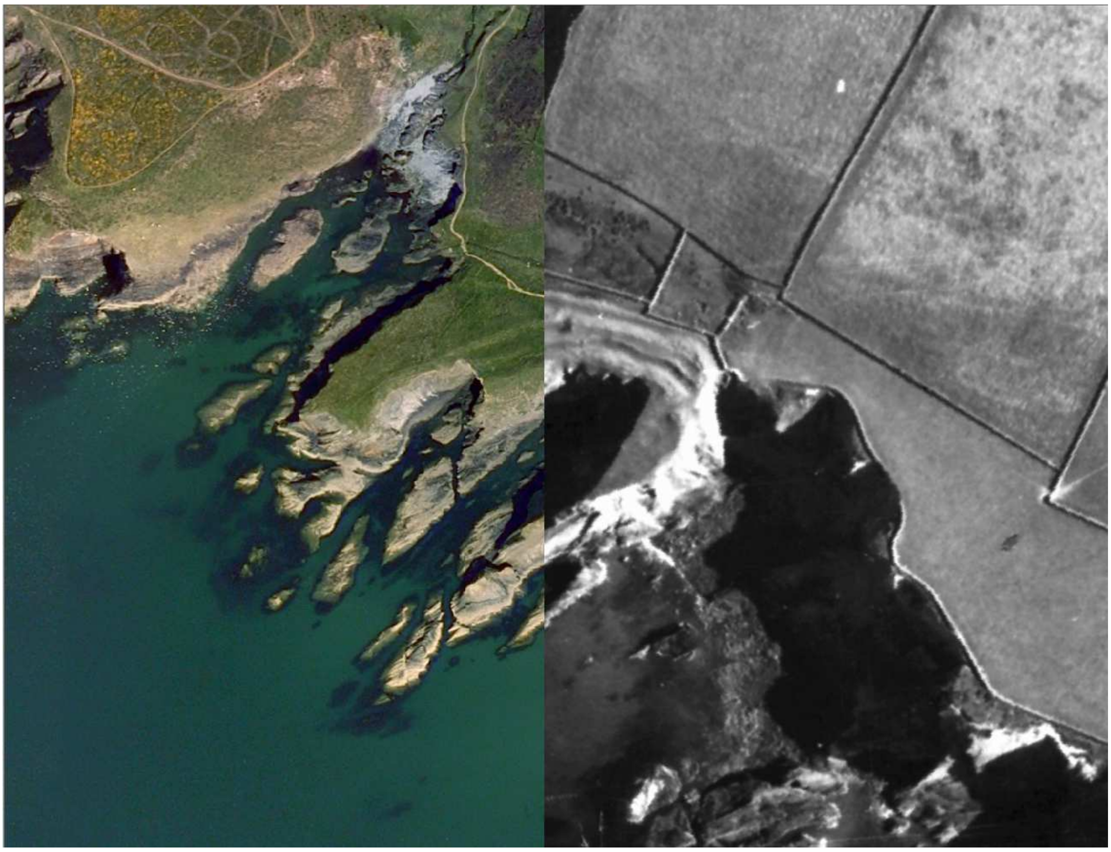


Fig.34. Side by side comparison of historic and modern AP mapping.

Discussion
Due to the nature of its location and northern defences this is the most dramatic in appearance of all the sites in the study. It is obvious that it was once a much larger site and that most of the interior has been lost to the sea. This must have occurred a considerable time ago, since the map regression shows little change to this site since the time of the first edition Ordnance Survey map (1891). Vegetation loss is occurring, however, and should be monitored. As with Greenala the nature of the black and white aerial photograph made it difficult to accurately map the cliff edge for this element of the map regression and a 'gain' is shown between the dates of this and the modern vertical colour photograph.

Recommendations
Porth y Rhaw appears not to be threatened by cliff-loss but the map regression does show loss of vegetation and this should be monitored. The site was carefully recorded by DAT in the 1990s and further recording is not recommended at present.

St David’s Head: PRN 2624, NGR: SM72202790

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Located at approximately 35m above sea level, Clawdd y Milwyr, on the tip of St David's Head is a classic promontory fort. It is defended by a multivallate defensive system, which lies on the western side of a shallow saddle, from which land to the north and south falls away steeply in narrow gullies to cliff-tops and the sea. Immediately within the defences on the west side is an extensive outcrop of bare rock, while to the east the land rises steadily and gently.

The main component of the defensive system is in inner rubble bank, now mostly covered with vegetation, but with bare stone exposed on the eastern flank and around the entrance. The bank survives to a maximum of 2.2m high and c. 10m wide. Wall-faces of three to four courses of dry-stone masonry can be seen towards the northern end of the bank exterior and in the entrance passageway, indicating a passageway width of 2.1m. There is not surface evidence to indicate anything other than a simple entrance. A ditch c. 0.5m deep and 4m wide lies outside the main bank, then a earth stone bank up to 1m high and 4m wide. It is uncertain whether this is a counterscarp, or some other component of the defences. It has no ditch outside it, but 4m -5m from it is a third bank. This has the appearance of a boulder-faced hedge-bank. However, it does seem to be a defensive component as at the entrance the boulders curve in to flank an entrance track-way. A spread of boulders 25m - 30m east of the defences may be a chevaux-de-frise, although none are placed upright and they seem to be a natural spread of stones left by the fort's builders.

The area enclosed by the defences is c. 3.4ha, but very little of this is suitable for occupation; most is bare rock and the western end is washed by the sea. A sloping grassy shelf 50m by 30m provides the only suitable location for dwellings. Seven, possibly eight, stone-built roundhouses lie here. Each house lies on a terrace cut into the slope and is defined by numerous earth-fast boulders. The houses are circular or sub-circular and measure from 8.0m to 9.8m diameter. Six houses were excavated by Baring Gould in 1898. He recognised floors and heaths in the houses and found pottery, blue glass beads, spindle whorls and stone artefacts - all consistent with a Romano-British date.

Results

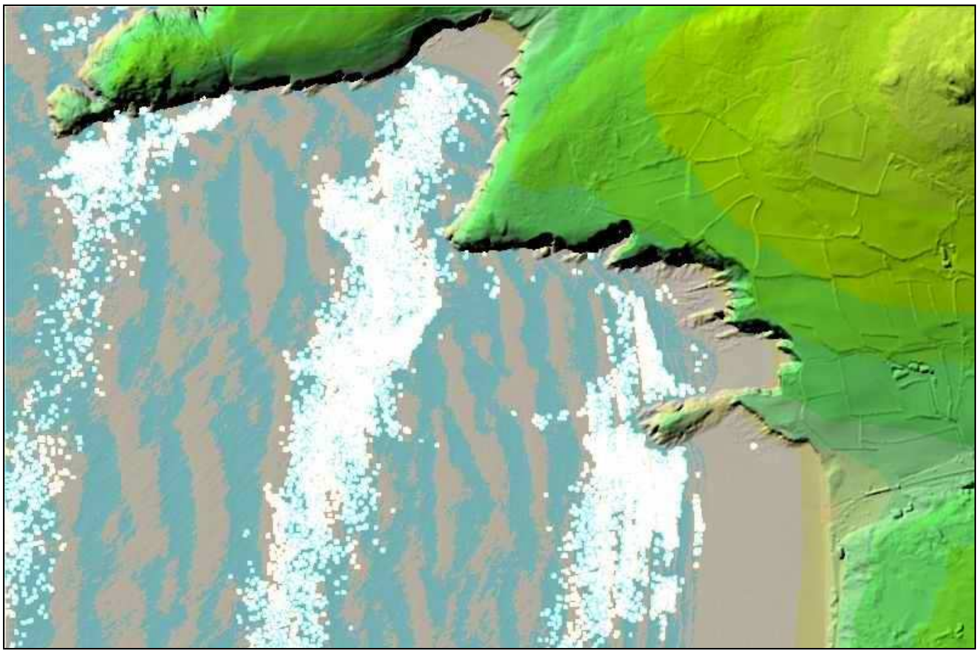


Fig.35. LiDAR jpeg

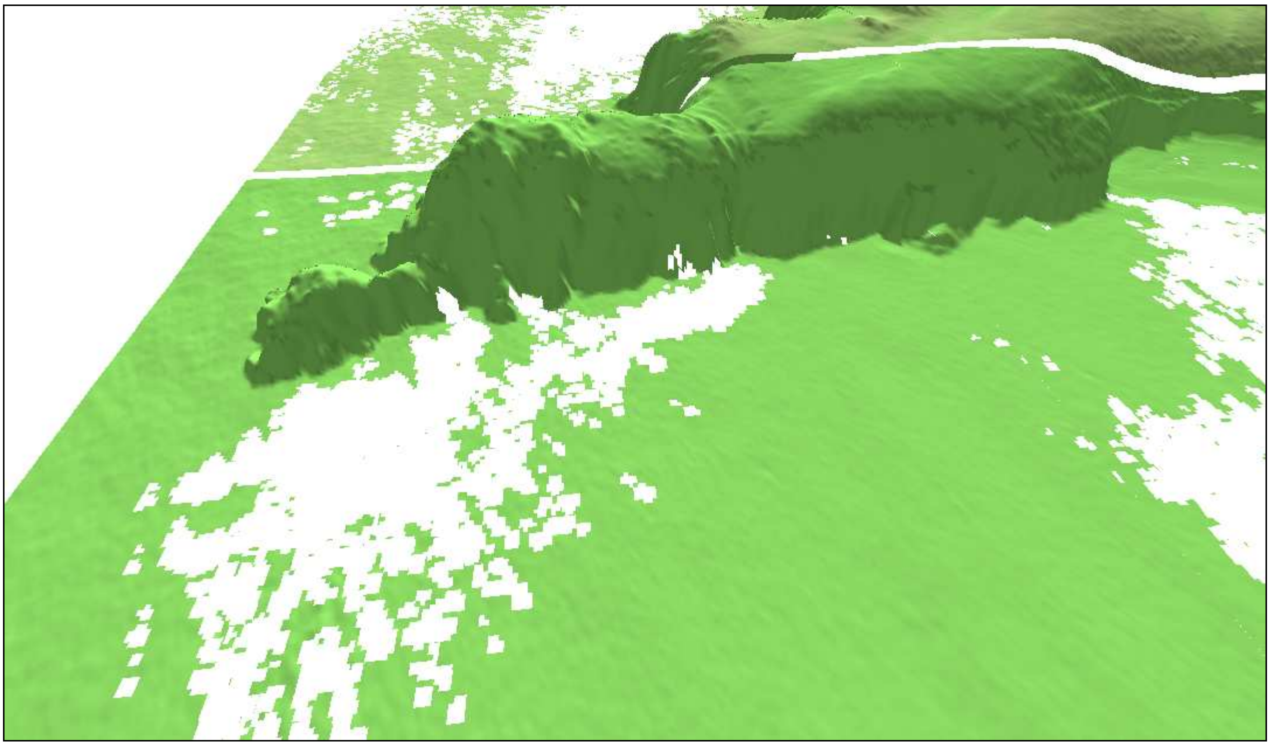
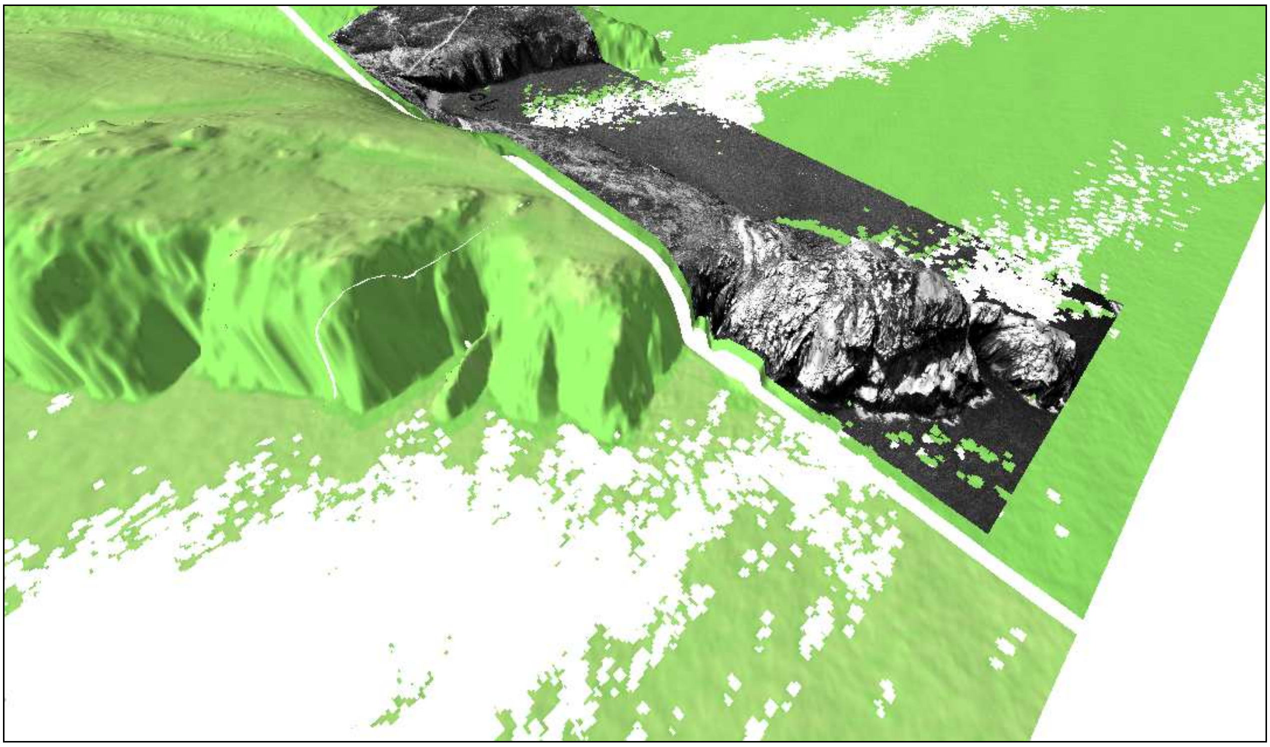
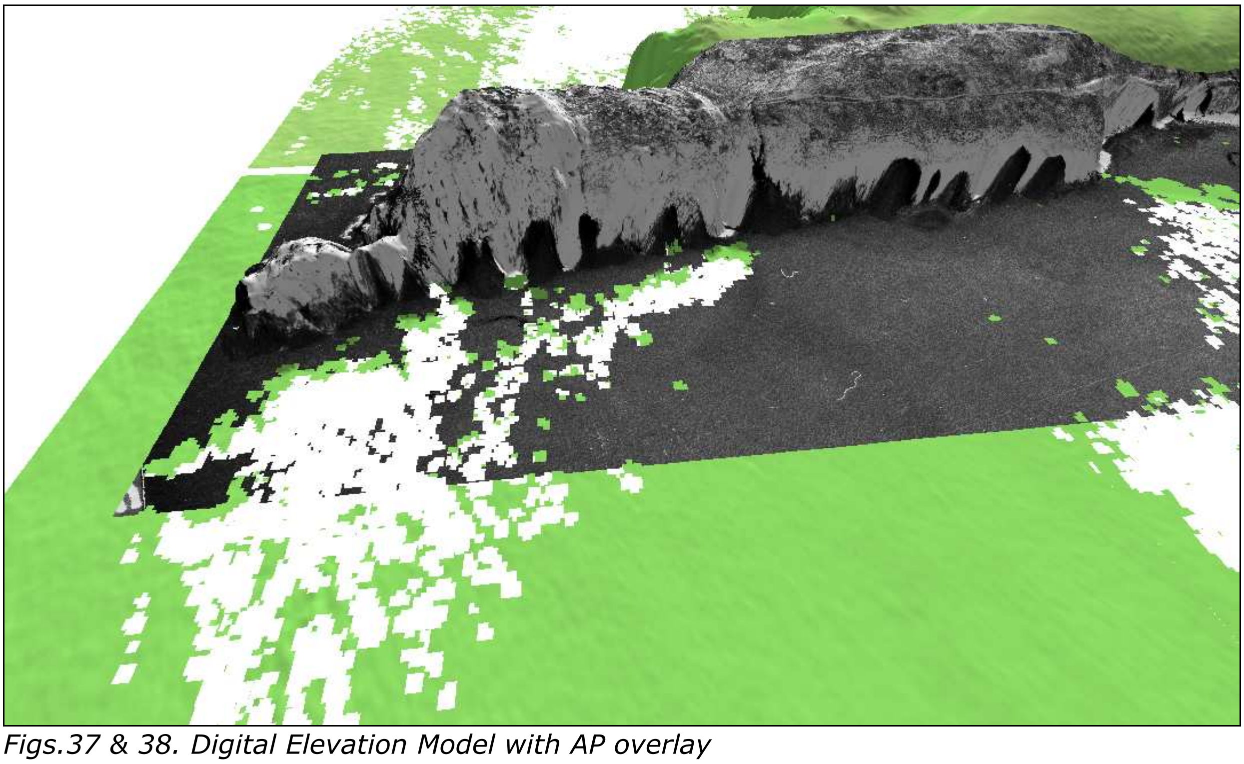


Fig.36. Digital Elevation Model





Figs.37 & 38. Digital Elevation Model with AP overlay

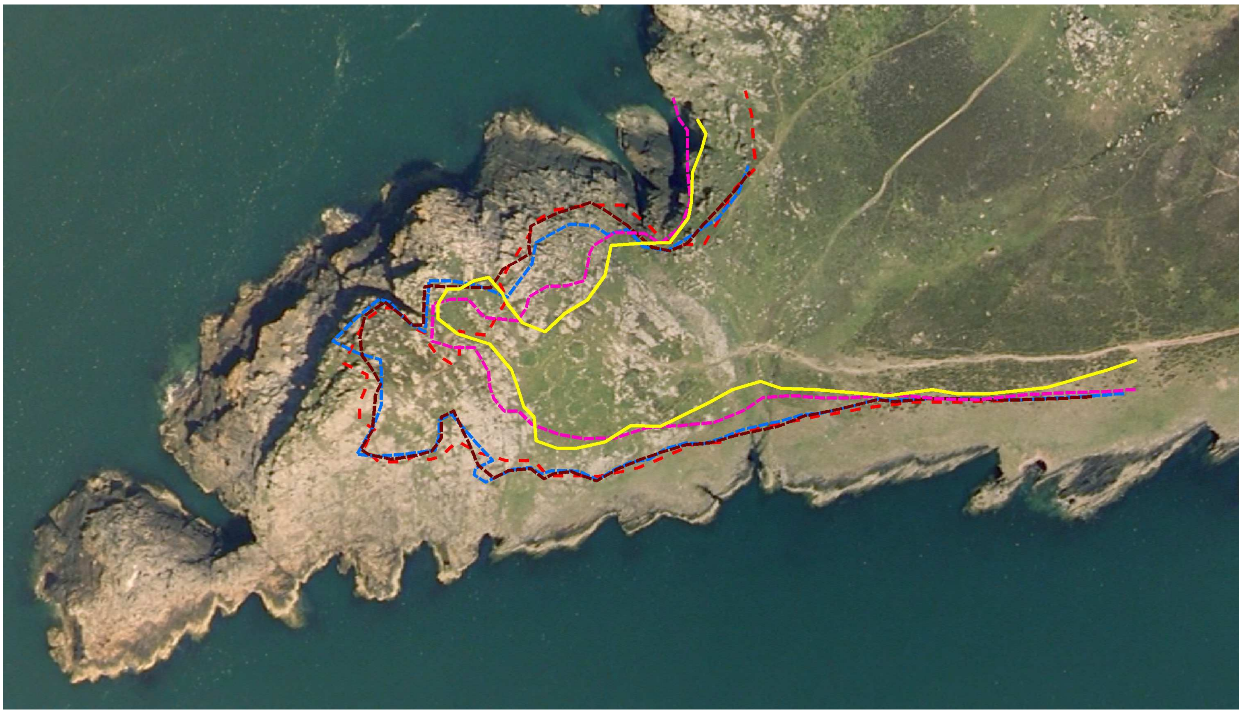


Fig.39. Map regression.

- - - - = 1st edition OS map
- - - - = 2nd edition OS map
- - - - = 3rd edition OS map
- - - - = 1972 aerial photograph
- - - - = NAW colour aerial photograph

Fig.40. 2009 RCAHMW aerial photograph

Discussion
The defences mentioned in the HER description are revealed quite clearly in the DEM for St David's Head. Map regression for this site is tricky due to the nature of its location, and is not felt to be particularly meaningful. For the 1972 aerial photograph and the modern colour photograph the map regression digitises the extent of vegetative cover, for monitoring purposes. Cliff loss appears to be minimal at this site and the greatest threat appears to be from vegetation loss followed by soil erosion. The Monument Inspector's report notes that the interior and the hut circles are well-preserved and in a stable condition.

Recommendations
The ramparts at this site are considered to be more vulnerable than the interior but the threat is from visitor, rather than coastal, erosion and it is this that should be monitored. Vegetation loss may be occurring and the site will need re-evaluating at some point in the future to check for this.

Watery Bay (South Castle Rath): PRN 2939, NGR: SM76870794

HER Information (derived from 2006 Cadw-funded Defended Enclosures Project)
Watery Bay is a multivallate coastal promontory fort. Its western and southern sides are protected by high sea cliffs, its northern and eastern sides are defended by three lines of curving bank and ditch. The inner bank is the most substantial and is flanked by an outer ditch, then a small central bank, a second ditch, a third bank and finally an outer ditch. The whole system is c. 115m long and 35m wide. A natural gully runs along the eastern side of the site; the defences stop short of this gully providing a simple entrance. A low bank curving along the cliff top on the east side of the interior seems to be part of the defensive circuit. The interior is level and measures 60m E-W and 45m N-S; it is assumed that some has been lost to the sea. The site is under rough grass with bramble and bracken over the banks.

Results

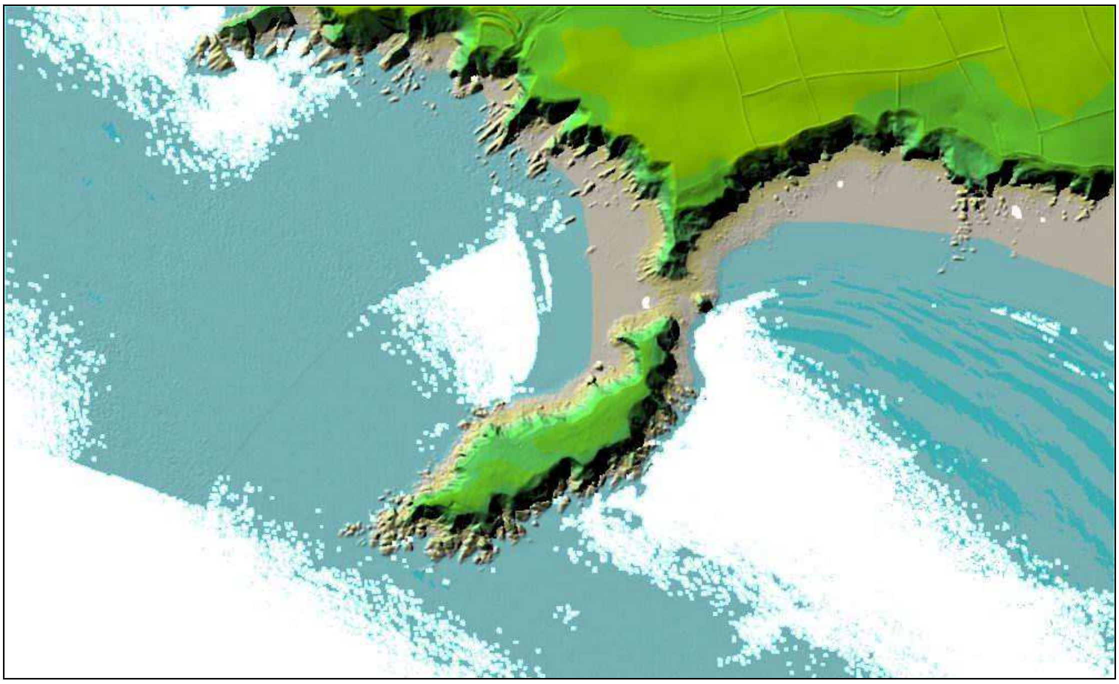


Fig.41. LiDAR jpeg. The fort is at the very top of this image, which also shows Gateholm Island.

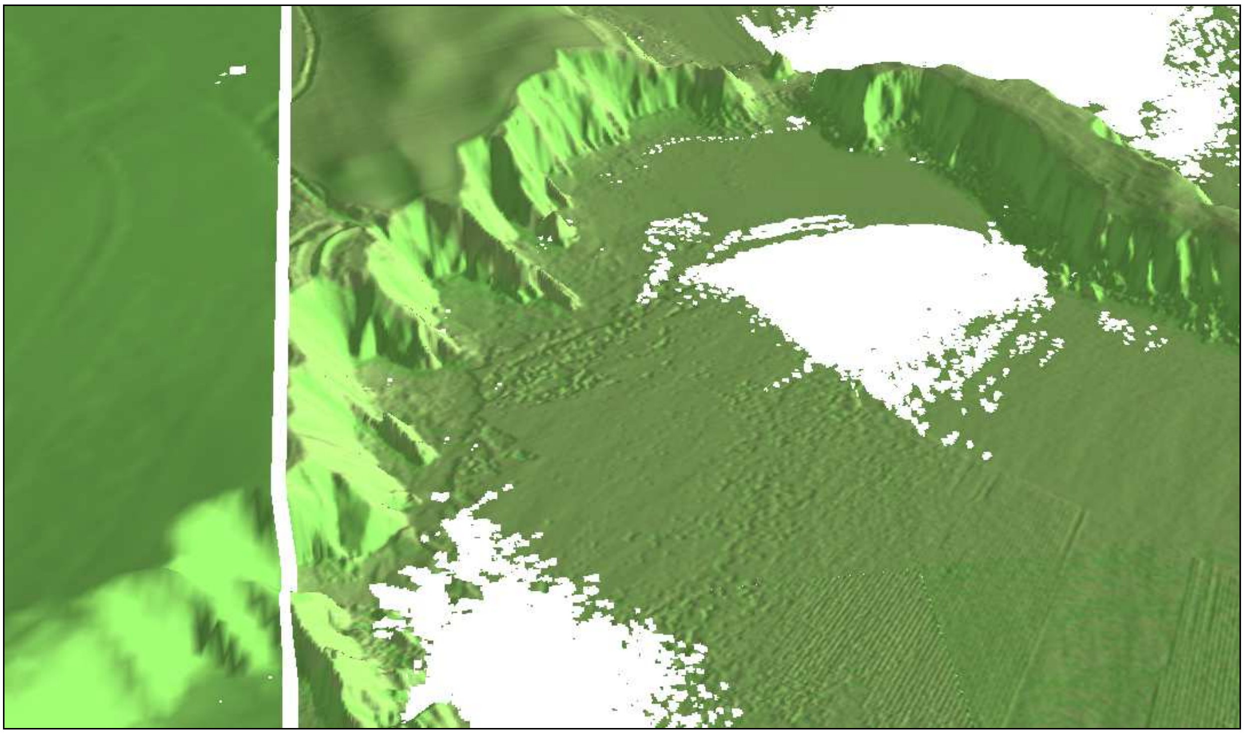


Fig.42. Digital Elevation Model


Fig.43. Digital Elevation Model with AP overlay

Fig.44. Map regression

- - - - = 1885 OS map
- - - - = 1908 OS map
- - - - = 1953 OS map
- - - - = 1946 aerial photograph
- - - - = NAW colour aerial photograph

Fig.45. 2009 RCAHMW aerial photograph

Fig.46. 2009 RCAHMW aerial photograph

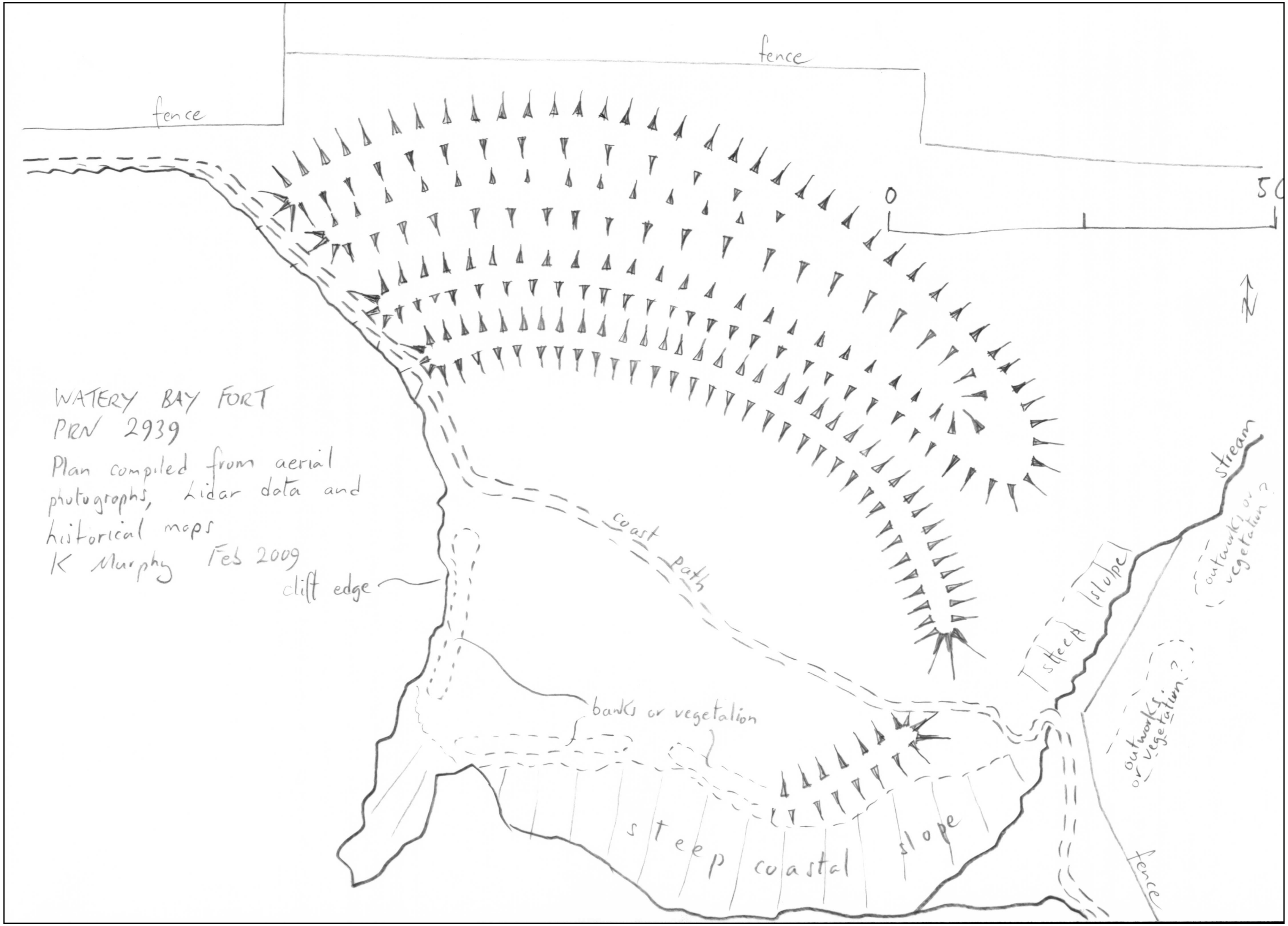


Fig.47. Plan based on remote sensing

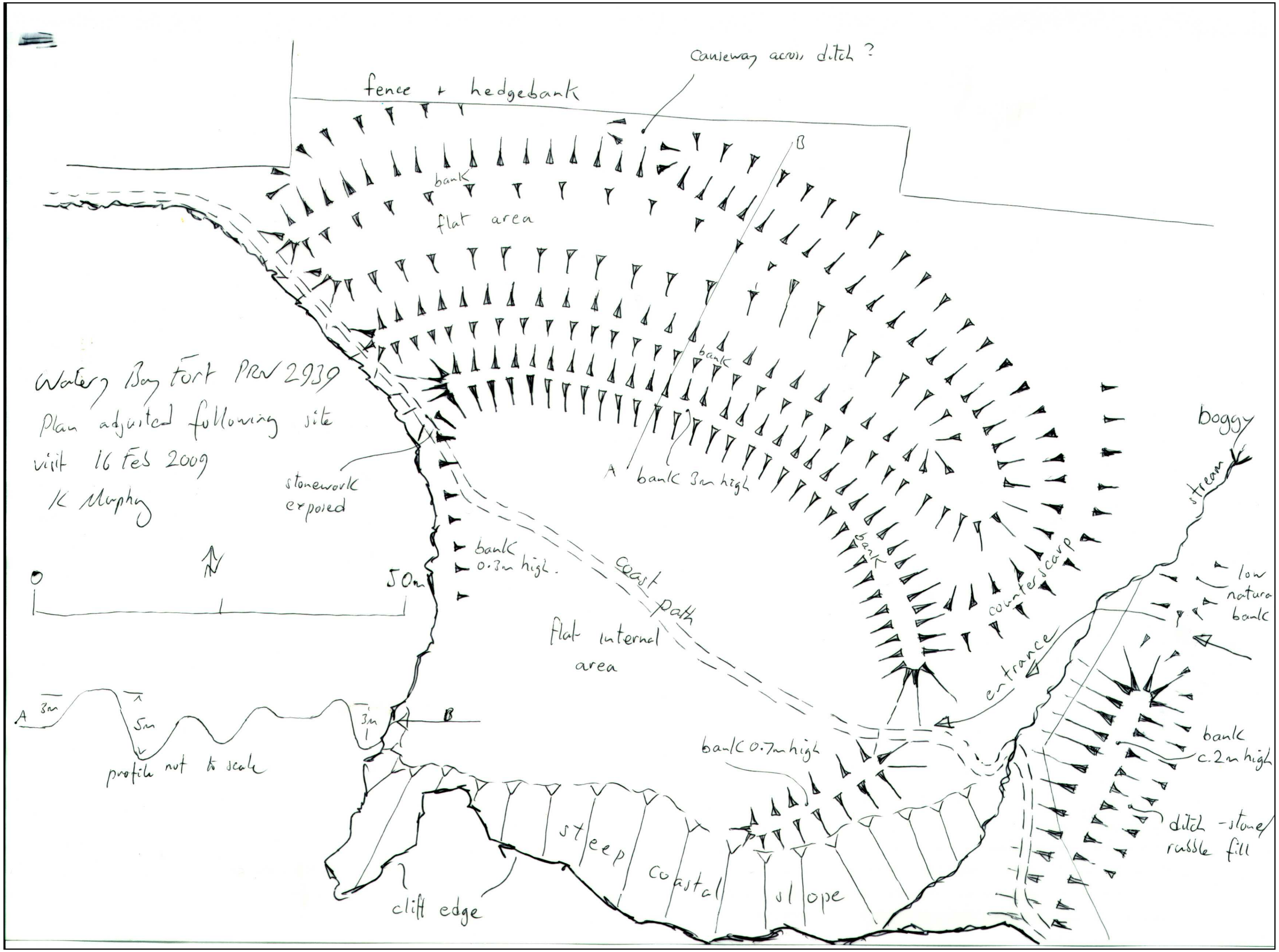


Fig.48. Plan based on field visit

Discussion
As with Greenala Camp, the fort at Watery Bay is best illustrated by the RCAHMW aerial photograph and the post-field visit archaeological plan. For reasons already mentioned in this report, cliff edge digitisation for map regression was tricky from the black and white aerial photograph. Generally, the site appears to be quite stable at present. It is perhaps worth monitoring on the eastern side where there is the possibility that a fissure similar to the one at Black Point Rath could open up along the line of the stream.

Monument Inspector's reports going back to the 1980s record that the greatest threat to this site is from visitor and animal erosion.

Comparison of the pre- and post-visit archaeological plans once again shows that remote sensing did not reveal all of the features, while others could only be securely interpreted by a field visit.

Recommendations
In addition to monitoring footpath and animal erosion monitoring of this site for potential coastal erosion on the eastern side is recommended.

CONCLUSION

This project has been a useful pilot to test the effectiveness of remote sensing data for capturing archaeological information. For the forts in the pilot study we now have a baseline dataset against which to monitor future coastal erosion.

The primary conclusion of the project is that no remote source of information used in isolation can accurately interpret archaeological sites of this nature. Used together the remote data sources can give a good basic interpretation of a site to provide a ground plan that can be verified with a site visit.

It has been shown that LiDAR data at 2m resolution is adequate for recording the general forms of upstanding earthworks, but not for recording detail. However, data at this resolution has proved to be inadequate for showing precise cliff-edge detail to a standard suitable for accurately measuring rates of cliff-loss and coastal erosion; the cliff-edge shown by LiDAR for Linney Head was only demonstrated to be inaccurate in places following comparison with metrical ground survey. Higher resolution (<1m) LiDAR data may not achieve this either: recent projects undertaken by the Discovery Programme in Ireland for the Hill of Tara and other archaeological complexes found that 1m and 15cm resolution data was still inadequate and specially commissioned 1cm resolution data was captured from a helicopter instead, albeit at a considerable cost (T. Driver, pers. comm.). New metrical ground survey of coastal promontory forts under study is still felt to be the only wholly reliable method of fixing baseline data on the form of the monument, the cliff edge and in particular on erosion edges (extent of topsoil cover and bare rock exposures etc.) which LiDAR data does not show. Collecting data with GPS also provides a wider, more useable dataset.

LiDAR is also not felt to be the best tool for seriously recording coastal erosion as new data is not available at short notice, for instance after storm events. Future aerial survey will be the best means of quickly recording these monuments at such times: the colour images shown in this report show how useful a format they are for gathering information on vegetation and soil erosion.

Although the earthworks appeared to be shown in detail on the LiDAR images, comparison of archaeological plans produced from remote sensing with their amended version following field visit reveals that there are subtleties in both survival and interpretation that cannot be established by remote sensing alone. A field visit to each site under study is still considered an essential pre-requisite for analysis and assessment of promontory forts through the use of LiDAR and GIS on-screen. Familiarity with a site is essential to assess the nature and terrain and for cliff-loss study.

Depending upon the accuracy required a detailed survey of a site will not always be necessary, but for important monuments and those under threat it is crucial. Archaeological survey is not simply about recording what's there; it is also the only way to develop a detailed understanding of an earthwork monument and an invaluable way to extract conclusions about chronology and development of the site to enable informed comparison with other regional and national sites.

LiDAR can provide data for rapid initial assessment of large areas but is a complementary method of survey, best used in conjunction with the traditional archaeological techniques of ground survey, aerial survey and map/documentary analysis.

Map regression involving comparison of a variety of historic map and aerial photo sources to assess the rate of cliff-loss to coastal erosion in the past has proved difficult; differences in approach to recording cliff edges were observed on each of the 1st, 2nd and 3rd edition OS maps – sometimes 'gains' were shown in the exact depiction of the cliff edge. Similarly, historic RAF and OS vertical air photographs from the 1940s, 1950s and 1960s proved an extremely useful source of comparative evidence; yet, it was difficult to compare historic winter shots taken in low light with strong shadows with present NAW vertical images on the GIS taken with few or no shadows, as the ability to identify an exact cliff or slope edge on the latter was problematic. Despite this the map regressions that were produced have been useful in some instances for showing cliff loss during the twentieth century.

As a pilot project this work has been a valuable way to develop expertise in the use of airborne laser scanning and comparative aerial, map and GIS datasets to begin to chart cliff-loss and coastal erosion at archaeological sites. It has shown a clear way forward for the future integration of LiDAR data in archaeological projects, but has also produced evidence to show that more traditional methodologies for field survey and site recording remain essential components of coastal archaeological monitoring at the present time.

REFERENCES USED

Black Point Rath
Environment Agency LiDAR tile D0063344
Environment Agency LiDAR jpeg D0063344
RAF vertical aerial photograph 106G/UK/1425 frame 4152, 15th April 1946
RCAHMW aerial photograph, Crown Copyright AP_2008_0278
RCAHMW Inventory of Ancient Monuments: Pembrokeshire (1925), no. 278, p.107.
Wainwright, G. (1971) *Excavations at Tower Point, St Brides, Pembrokeshire.* Archaeologia Cambrensis Vol.CXX, p.84-90.

1st edition (1891) Ordnance Survey 1:1050 map, sheet XXVISE.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet XXVISE.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet XXVISE

Dinas Island Castell (East)
Environment Agency LiDAR tile D0061197
Environment Agency LiDAR jpeg D0061197
Ordnance Survey aerial photograph, 72_137, frame 172. 1972

Greenala Camp
Environment Agency LiDAR tile D0055120; D0032821
Environment Agency LiDAR jpeg D0055120; D0032821
Ordnance Survey aerial photograph 68/034, frame 055. 1968
RCAHMW aerial photograph, Crown Copyright AP_2009_0286.jpg
RCAHMW aerial photograph, Crown Copyright AP_2007_1816.jpg

1st edition (1885) Ordnance Survey 1:1050 map, sheet XLIIINW.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet XLIIINW.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet XLIIINW

Linney Head
Environment Agency LiDAR tile D0055624
Environment Agency LiDAR jpeg D0055624
RAF vertical aerial photograph: 58/2985 frame 0331. 30th June 1959
1st edition (1885) Ordnance Survey 1:1050 map, sheet LIISW.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet LIISW.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet LIISW

Porth y Rhaw Camp
Environment Agency LiDAR tile D0063366
Environment Agency LiDAR jpeg D0063366
RAF vertical aerial photograph: 106G/UK/1625 frame 5018. 7th July 1946
1st edition (1891) Ordnance Survey 1:1050 map, sheet XXINW.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet XXINW.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet XXINW
DAT photograph DAT2009-17.1.jpg

St David's Head
Environment Agency LiDAR tile D0063381
Environment Agency LiDAR jpeg D0063381
Ordnance Survey aerial photograph 72/167, frame 012. 1972
1st edition (1891) Ordnance Survey 1:1050 map, sheet XIVSW.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet XIVSW.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet XIVSW
RCAHMW aerial photograph, Crown Copyright AP_2009_0378.jpg

Watery Bay (South Castle Rath)
Environment Agency LiDAR tile D0063381
Environment Agency LiDAR jpeg D0063381
RAF vertical aerial photograph: 106G/UK/1629, frame 5010. 8th July 1946
1st edition (1885) Ordnance Survey 1:1050 map, sheet XXXISE.
2nd edition (1908) Ordnance Survey 1:10560 map, sheet XXXISE.
3rd edition (1953) Ordnance Survey 1:10560 map, sheet XXXISE
RCAHMW aerial photograph, Crown Copyright AP_2009_0354.jpg
RCAHMW aerial photograph, Crown Copyright AP_2009_0357.jpg

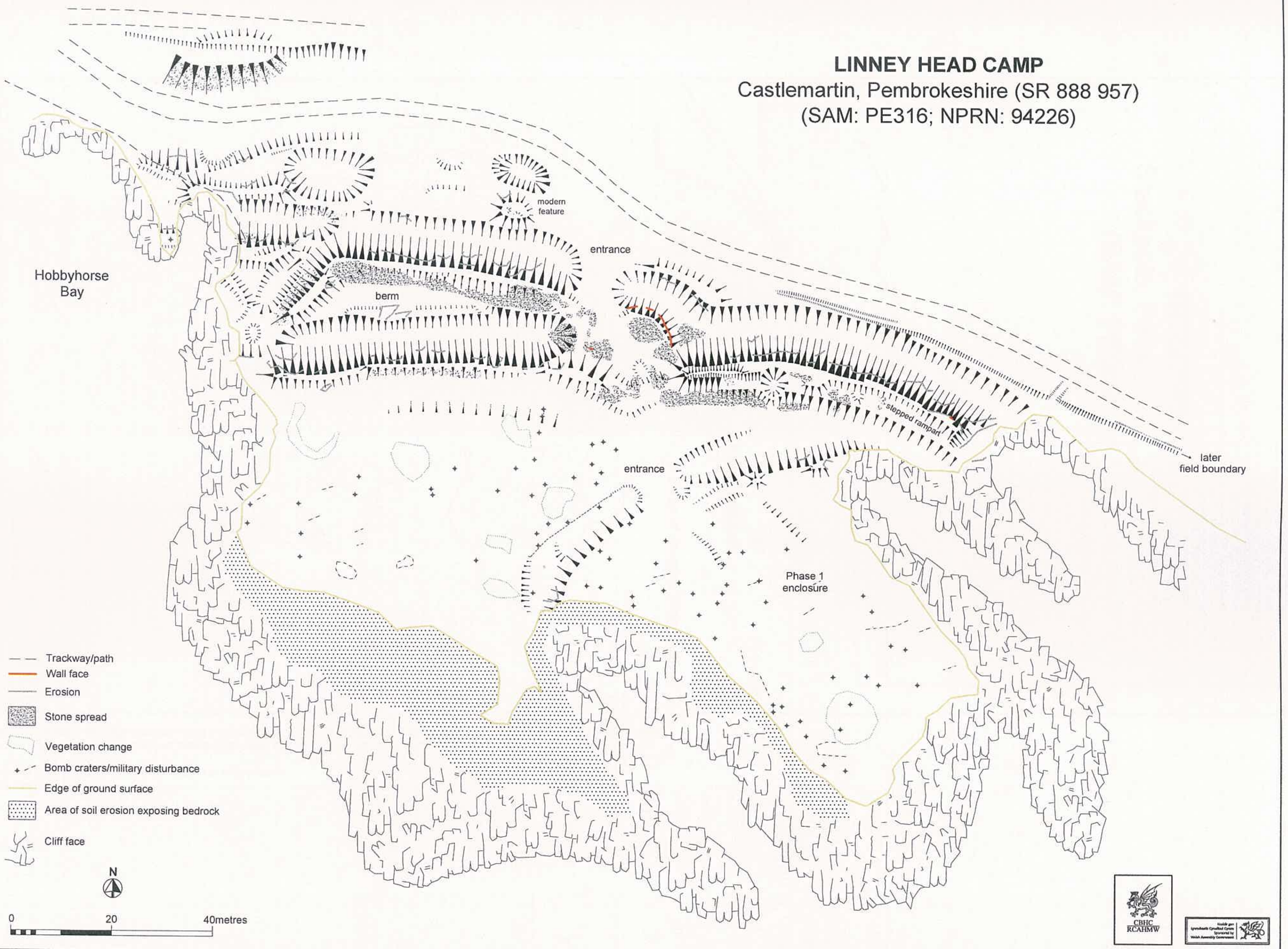
APPENDIX I

TOPOGRAPHIC SURVEY RESULTS: GREENALA CAMP AND LINNEY HEAD

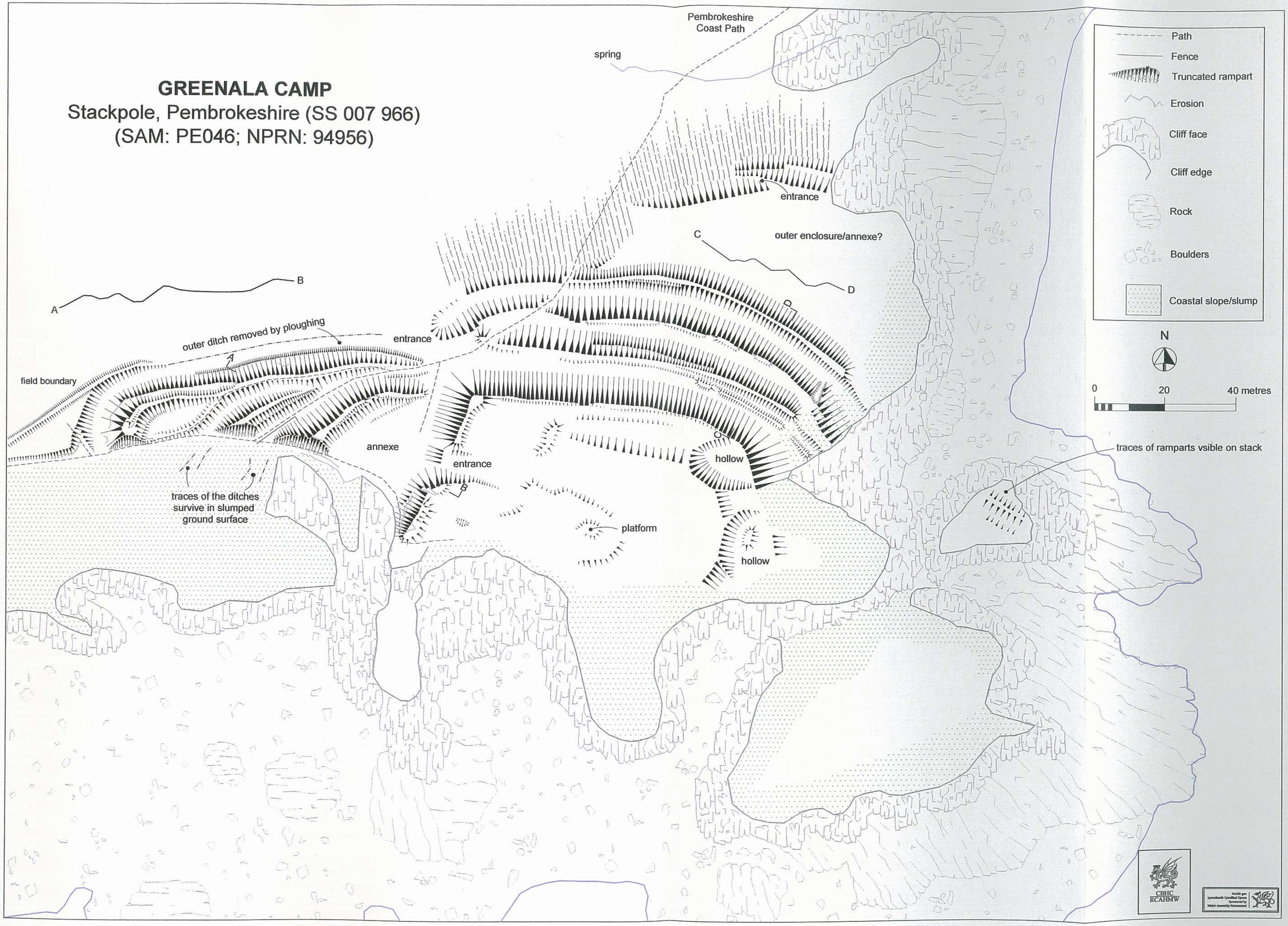
L. Barker

LINNEY HEAD CAMP

Castlemartin, Pembrokeshire (SR 888 957)
(SAM: PE316; NPRN: 94226)



Survey Date: Aug 2008 (printed March 2009 at 1:1000 scale)
Survey Staff: LB



Survey Date: Aug 2008 (printed March 2009 at 1:1000 scale)
Survey Staff: LB

APPENDIX II

DRAWING OF ARCHAEOLOGICAL PLANS FROM REMOTE SENSING DATA
K. Murphy

Three archaeological hachure plans were drawn from remote sensing data. The object was to assess the usefulness of the different sources of remote sensing data and whether accurate plans could be drawn using solely this type of data.

The three sites selected were: Linney Head Fort, Greenala Fort and Watery Bay Fort. These were selected as both Linney Head and Greenala were surveyed by the RCAHMW during the course of this project and so had comparable data, whilst Watery Bay had no modern survey data.

The remote sensing data used to compile the plans were: historic and modern Ordnance Survey maps, Lidar, vertical aerial photographs and archaeological oblique aerial photographs.

Large-scale Ordnance Survey maps (1:2500, 1:10,560 and 1:10,000) were used as base maps for the surveys. Historical maps (1:2500 late 19th century 1st Edition and early 20th century 2nd Edition) proved to be the most useful as they provide detail not shown on later versions. Modern OS are not particularly useful for two reasons: first, site detail is rarely shown; second, the position of the coast and cliff edges seems to be copied from earlier maps. Electronic versions of the maps were used which have the advantage of being geo-referenced for ease of comparison.

One a base map had been compiled it was possible to add detail from other sources:

> Older vertical aerial photographs (mostly dating to the 1940s) were often taken from high levels and are in black and white. They are available as stereo pairs. As they are taken from a high level it is difficult to identify detail on individual sites, and as they are monotone differentiating areas such as eroding topsoil from exposed bedrock is problematic. Stereoscopic viewing helps in identifying detail.
>
> Modern digital vertical photographs have the benefit of colour, but are not always available stereoscopically. They also have the advantage of being geo-referenced and so can be directly compared with similar geo-referenced data. Another advantage is that they are recent photographs and that it is possible to identify detail such as bedrock, soil erosion owing to the colour information.
>
> Oblique aerial photographs specifically taken for archaeological purposes have the great advantage of targeting archaeological detail and having been taken in optimum weather conditions to show such detail. However, they are not geo-referenced, making comparisons with other data more difficult.
>
> Lidar data available from the Environmental Agency were at 2m intervals. This is not of sufficient resolution to identify detail. In particular it is very poor at defining large earthworks and major changes of slope such as is found on coastal promontory forts. However, on more level ground, even slight earthworks are detectable at 2m resolution. It is geo-referenced making comparison with other data simple.

No one data source shows sufficient information to enable the drawing of a comprehensive archaeological plan, however a good plan can be made using all data sources. No one source is pre-eminent, although it would be very difficult to draw an accurate plan without the OS map data.

The Linney Head map compiled from remote sensing was shown to be accurate in its main components when compared with the RCAHMW survey. All the major elements of the site were identified from remote sensing data and accurately portrayed, and areas of erosion were shown. However, some detail was not evident from on the remote sensing data: ditches to the defensive banks were not easy to delineate and some of the detail on the banks were mapped incorrectly. The interpretation of features was also problematic, for instance what the RCAHMW consider to be a final defensive phase was thought to be modern disturbance on the remote data.

At Greenala a remote sensing map was taken out into the field for checking and the map redrawn. Both maps are reproduced in this report. It is clear than ground truthing picked up much more detail than was visible on remote sensing, in particular detail of the defensive system is not particularly well represented on the map produced solely from remote sensing. Low earthworks in the fort’s interior were also invisible on all remote sensing data, but were seen during the site visit. It was not possible to map these during the site visit owing to the limited amount of time available. A comparison with the map following the site visit and the RCAHMW survey map shows a remarkable match, although the lack of internal evidence on the remote sensing map is a striking feature. Detail (or lack of it) of the outer defensive bank is also noticeable.

The RCAHMW did not undertake a topographic survey of Watery Bay so the pre- and post-field visit remote sensing drawings are the only surveys. It is quite clear when comparing these two drawings that a lot of detail and clarity was gained from a site visit. As with Linney, ditches of the defensive system did not show well on the remote sensing data. It was also difficult, if not impossible, to distinguish between dense gorse/bramble vegetation and earthwork banks. In particular a massive bank on the east side of the entrance was not visible on remove sensing data.

Drawing plans from remote sensing data is a quick and efficient means of obtaining adequate site plans. Once the various sources have been compiled it takes about two hours to draw a plan such as the ones shown here. Site visits are rapid, about one hour per site, and compiling a revised drawing takes one to two hours.

APPENDIX III

PORTH Y RHAW, PEMBROKESHIRE 2008: GEOPHYSICAL SURVEY

P. Crane

SUMMARY

A geophysical survey was undertaken on the interior of Porth y Rhaw coastal promontory fort, as part of the Cadw 'Defended Enclosures Remote Sensing' project. The results confirmed the information from the partial excavations in 1995-98, that the interior is densely occupied. The plot of the geophysical survey is difficult to interpret, although a few possible roundhouses and a four- or six-post structure appear likely.

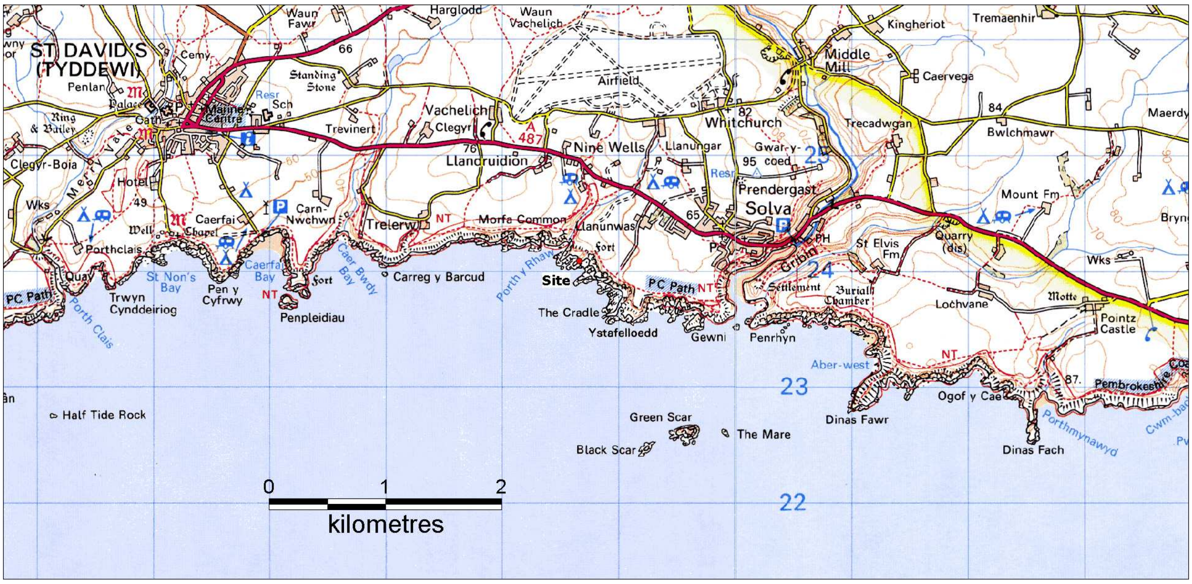


Fig. 1. Location map

INTRODUCTION

Project commission
Cadw grant-aided Dyfed Archaeological Trust to undertake a geophysical survey on the interior of Porth y Rhaw coastal promontory fort, Solva, Pembrokeshire (centred on SM 7865024090)(Fig 1), as part of a larger project on remote sensing on coastal defended sites.

Scope of the project
The project was designed to establish whether a geophysical survey, using a gradiometer, could detect archaeological features on this site.

Report outline
Because of the limited nature of this project, together with the considerable archaeological evidence in the area, this report is restricted solely to the results of the geophysical survey.

Abbreviations
Sites recorded on the Regional Historic Environment Record (HER) are identified by their Primary Record Number (PRN) and located by their National Grid Reference (NGR).

THE SITE

Location and Archaeological Potential

Porth y Rhaw (SM 7865024090) lies on the coast 3.5km east of St David's, 2km west of Solva, and 0.8km south of the A487 road at Nine Wells (Fig 1). The fort is situated adjacent to the coastal footpath. This site is a Scheduled Ancient Monument (SAM PEMB 273) and is also registered as a Site of Special Scientific Interest (SSSI).

The remains of the fort lie on the eastern side of a stream running south from Nine Wells. Two promontories occupied by the fort are undoubtedly the eroded remains of a single much larger area, projecting southwestward into St Bride's Bay. The surviving promontories are on high ground, somewhat separated from the hinterland by a minor stream, which issues just outside the fort's entrance, and a steeply sloping valley. The remains of the multiple banks and ditches are still very impressive, especially as the inner defences are on much higher ground than the outer bank.

The promontories comprise 35m high sandstone and mudstone cliffs. Both of the promontories are enclosed by a third ditch and fourth bank, and possibly also by an outer counterscarp bank, which has been utilised by a much later hedge bank, along part of which the Pembrokeshire Coast Path now runs.

On the western side the full depth of the defences survive. There are four banks with three ditches between them. The inner bank and ditch are very steep and massive. The second bank is far less pronounced.

Although the entrance through the outer defences appears to have been eroded away on its eastern side, the entrance still survives through the inner bank. There is an inturn to the western terminal of the inner bank. Indications of former excavation trenches survive around the entrance on the inner and third banks. These trenches possibly relate to the excavation durining the Second World War, or more likely "treasure hunting" in the 1960s reported by some locals.

On the eastern promontory, some 25m inside the entrance, there is a suggestion of a hut circle, noted both on the Ordnance Survey 1973 and Rees (1992); these indications were confirmed in the 1995 evaluation. Towards the southern end of the interior, at the highest point, there appears to be a low bank.

Excavations in 1995-98 revealed the remains of at least eight timber roundhouses, some of which had been rebuilt several times, including one in stone. A pebbled surface was found extending inwards from the entrance. There was also evidence of metalworking. Radiocarbon dates indicate that occupation started in the early-to-mid Iron Age, and pottery indicates it continued into the 4th century AD (Crane 1998 and forthcoming).

METHODOLOGY

Geophysical Survey Instrumentation

A fluxgate gradiometer survey provides a relatively swift and completely non-invasive method of surveying large areas.

The survey was carried out using a Bartington Grad601-2 dual Fluxgate Gradiometer, which uses a pair of Grad-01-100 sensors. These are high stability fluxgate gradient sensors with a 1.0m separation between the sensing elements, giving a strong response to deeper anomalies.

The instrument detects variations in the earth's magnetic field caused by the presence of iron in the soil. This is usually in the form of weakly magnetised iron oxides, which tend to be concentrated in the topsoil. Features cut into the subsoil and backfilled or silted with topsoil therefore contain greater amounts of iron and can therefore be detected with the gradiometer. There are, however, other processes and materials that can produce detectable anomalies. The most obvious is the presence of pieces of iron in the soil or immediate environs which usually produce very high readings and can mask the relatively weak readings produced by variations in the soil. Archaeological features such as hearths or kilns also produce strong readings because fired clay acquires a permanent thermo-remnant magnetic field upon cooling. This material can also get spread into the surrounding soil leading to a more generalised magnetic enhancement around settlement sites.

Not all surveys produce good results as anomalies can also be masked by large magnetic variations in the bedrock or soil or high levels of natural background "noise" (interference consisting of random signals produced by material within the soil). In some cases, there may be little variation between the topsoil and subsoil resulting in features being un-detectable. It must therefore be stressed that a lack of detectable anomalies cannot be taken to mean that that there are no below ground archaeological features.

The Bartington Grad601 is a hand-held instrument and readings can be taken automatically as the operator walks at a constant speed along a series of fixed length traverses. The sensor consists of two vertically aligned fluxgates set 1.0m apart. Their Mumetal cores are driven in and out of magnetic saturation by an alternating current passing through two opposing driver coils. As the cores come out of saturation, the external magnetic field can enter them producing an electrical pulse proportional to the field strength in a sensor coil. The high frequency of the detection cycle produces what is in effect a continuous output (Clark 1996).

The gradiometer can detect anomalies down to a depth of approximately one metre. The magnetic variations are measured in nanoTeslas (nT). The earth's magnetic field strength is about 48,000 nT; typical archaeological features produce readings of below 15nT although burnt features and iron objects can result in changes of several hundred nT. The instrument is capable of detecting changes as low as 0.1nT.

Geophysical Survey Data Collection
The gradiometer includes an on-board data-logger. Readings in the surveys were taken along parallel traverses of one axis of a grid made up of 20m x 20m squares. The traverse interval was 0.5m. Readings were logged at intervals of 0.25m along each traverse giving 3200 readings per grid square (medium resolution).

Geophysical Survey Data presentation
The data was transferred from the data-logger to a computer where it was compiled and processed using ArchaeoSurveyor 2 software. The data is presented as grey-scale plot (Fig 2) where data values are represented by modulation of the intensity of a grey scale within a rectangular area corresponding to the data collection point within the grid. This produces a plan view of the survey and allows subtle changes in the data to be displayed. A separate grey-scale plot with interpretation of the main features is also included (Fig 3).

Geophysical Survey Data Processing

The data is presented with a minimum of processing although corrections are made to compensate for instrument drift and other data collection inconsistencies. High readings caused by stray pieces of iron, fences, etc are usually modified on the grey scale plot as they have a tendency to compress the rest of the data. The data is however carefully examined before this procedure is carried out as kilns and other burnt features can produce similar readings. The data on some noisy or very complex sites can benefit from 'smoothing'. Grey-scale plots are always somewhat pixellated due to the resolution of the survey. This at times makes it difficult to see less obvious anomalies. The readings in the plots can therefore be interpolated thus producing more but smaller pixels and a small amount of low pass filtering can be applied. This reduces the perceived effects of background noise thus making anomalies easier to see. Any further processing is noted in relation to the individual plot.

Reliability

Geophysical survey is an immensely useful tool but it should be realised that while a survey will detect a wide range of features, it may not detect *all* buried features. A gradiometer survey detects changes in magnetic flux density and relies on there being a detectable difference between the archaeology and the substrate. This may not occur for many reasons (e.g. a cut feature being backfilled with subsoil). It must therefore be stressed that a lack of archaeological responses from a geophysical survey does not prove that there is no archaeology present.

Grid locations

The survey grids were located by measurements to fixed points such as cliff edges and metal survey markers located during the survey (Fig 4: A2, B and B2).

RESULTS

Limitations

The survey was undertaken on the 6th June 2008. The weather was fine. The interior of the fort has long and very springy grass, often in large tussocks. Part of the large bank on the eastern side of the inner entrance was also surveyed. This bank is very steep and this, together with the tussock grass, made survey conditions difficult, so the survey was undertaken very slowly. This was feasible as the survey area was very small, only about 1200 square metres, but very awkward. During the survey about twenty walkers came up to the site to ask what was going on. This was probably just less than 50% of the people passing the site during work.

The underlying geology is mudstone and sandstone, with light sandy topsoil (British Geological Survey 1994) with bedding layers in near-vertical formation. The 1990's excavations revealed varying depths of silt deposits on the bedrock, which may have produced anomalies in the survey. There is a large amount of anomalies; this is probably because of the amount of occupation over a considerable time, as shown by the excavation on the western side of the promontory. Because of the density of anomalies they are not of easily recognisable form.

There are a number of ferrous responses. Three of these are permanent grid pegs from the excavation (Figure 4 A2, B and B2). There were also other metal grid pegs and survey nails left in the excavation area. There are also a few other ferrous type anomalies within the backfilled excavation area which are likely to be other iron grid pegs or planning nails.

Geophysical interpretation
(Fig 4)

Only the major features are discussed. The metalled entrance (1) between the inner banks (2 and 3) can clearly be seen, although its southern extremity is uncertain. On the southern edge of the eastern inner bank (3) there are two apparent heat-affected areas with another a little further to the south (4): these are possibly hearths or ovens. Also just to the south of this bank (3) there is a possible four- or six-post structure (5). (A seventh anomaly there is probably a ferrous response.)

The only definite roundhouse that can be recognised is the one with stone footings found in the excavation (6). There is a possible entrance on the northern side of this roundhouse. The western side of this roundhouse does not show in the backfilled area of the excavation. However, this roundhouse is only really discernible because its location is already known.

There are two arcs (7 and 8) that may represent parts of roundhouses. On the eastern end of the southern arc there is probably some heat-affected material. Southwest of this there are a number of anomalies: the only probable recognisable feature is another arc (9) that may well be the eastern part of a roundhouse, the western side of which was found during the excavations.

As already mentioned under Limitations above, there are three permanent grid pegs from the excavation (A2, B and B2) and there were also other metal grid pegs and survey nails left in the excavation area, on the western side of the geosurvey area.

DISCUSSION AND SUGGESTIONS FOR FURTHER WORK

With such a lot of anomalies features are difficult to interpret, as geophysical survey itself does not indicate phasing. It is also noticeable that features are not identifiable in the backfilled area, but a lot of the excavated features were very shallow. The permanent iron grid pegs, put in for the excavations, each obscure an area of over three metres diameter. These, along with the survey nails and one other grid point at the north end of the excavation area, have caused some problems. With hindsight it would have been better to use smaller iron pegs.

There were a number of tourists walking the coast path, who came to look at what we were doing. In this instance there was plenty of time to explain to these visitors what we were doing and about this site and coastal forts in general. This aspect of facilitating visitor interest should be incorporated in any future work adjacent to the coast path: there would have been difficulties in the high season coping with higher numbers of people and still trying to undertake the survey.

A topographic survey was undertaken as part of the excavation strategy. Further topographic survey would not appear necessary. There may be slight surface features, but the problem of recognising these with such large tussocks of grass cover would be very slim. However, a quick survey of the eroding cliff edges at regular intervals or after any significant landslips would assess the amount of site loss and possible further erosion areas. The amount of erosion would appear to be slow, but the southeastern end of the promontory may need excavation and recording in the not too distant future.

There is always a possibility that the grass on this site could be burnt off in a dry summer by an accidental fire. This risk also exists on a number of other coastal fort sites, especially those adjacent to the coast path. If this does happen there could be very rapid loss of surface deposits. Therefore it is strongly recommended that an action plan is in place to undertake survey work, both topographical and geophysical, along with surface collection and any rescue excavation necessary should, or more likely when, this emergency arises.

CONCLUSION

This survey appears to confirm the results of the excavation, in that the interior of this promontory fort was densely occupied. However, individual features are difficult to recognise. The clearest result is probably from the metalled trackway leading into the fort and the stone-footed roundhouse, both of which were recorded in the earlier excavations.

ACKNOWLEDGEMENTS

I would like to thank Gwillam Bere for his help with this geophysical survey.

ARCHIVE DEPOSITION

The archive will initially be held by DAT, before being passed to the National Monument Record, Aberystwyth.

SOURCES

British Geological Survey. 1994. The Rocks of Wales 1:250,000

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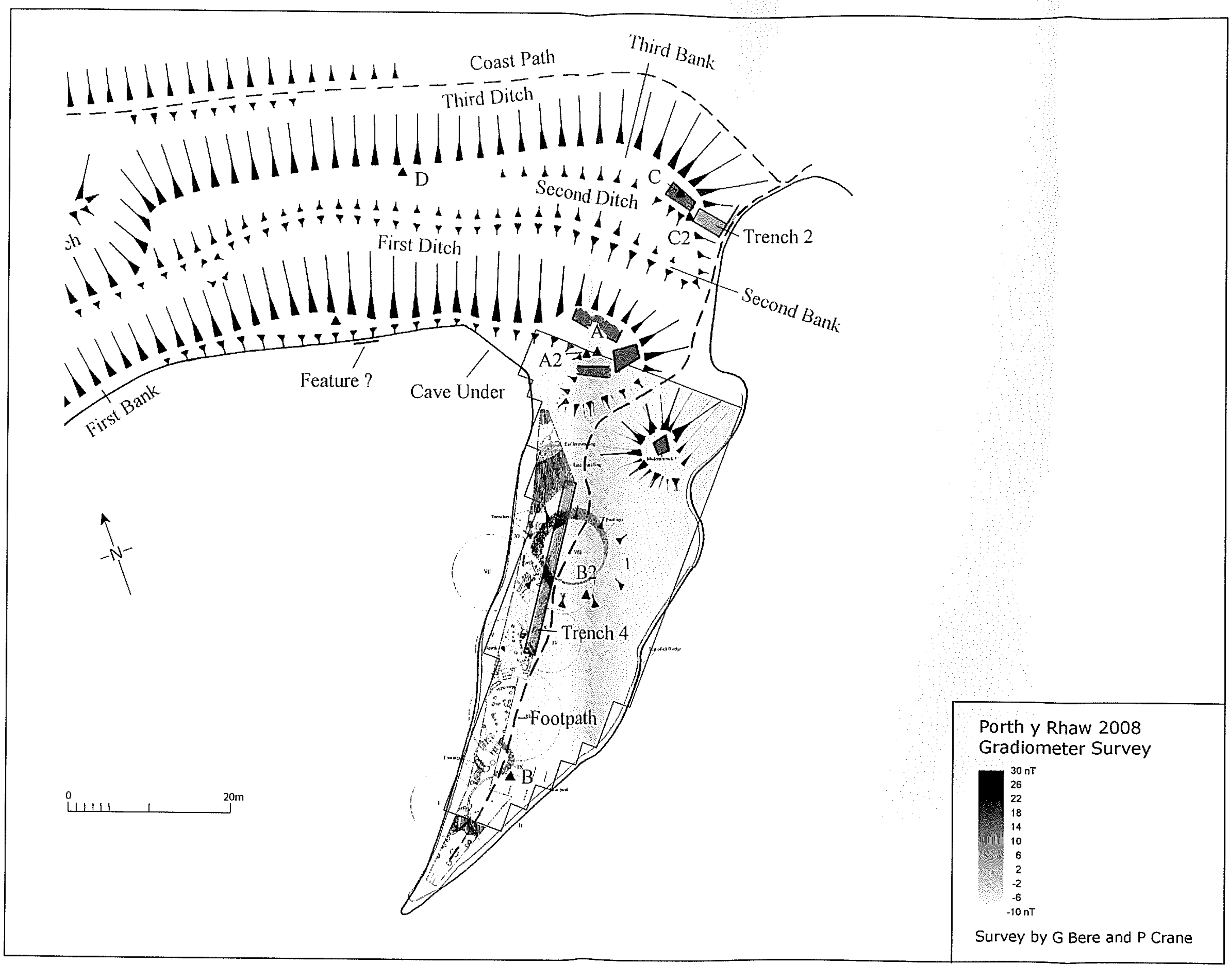

Figure 2: Plan of western promontory with area of geophysical survey. Scale 1:500 at A3

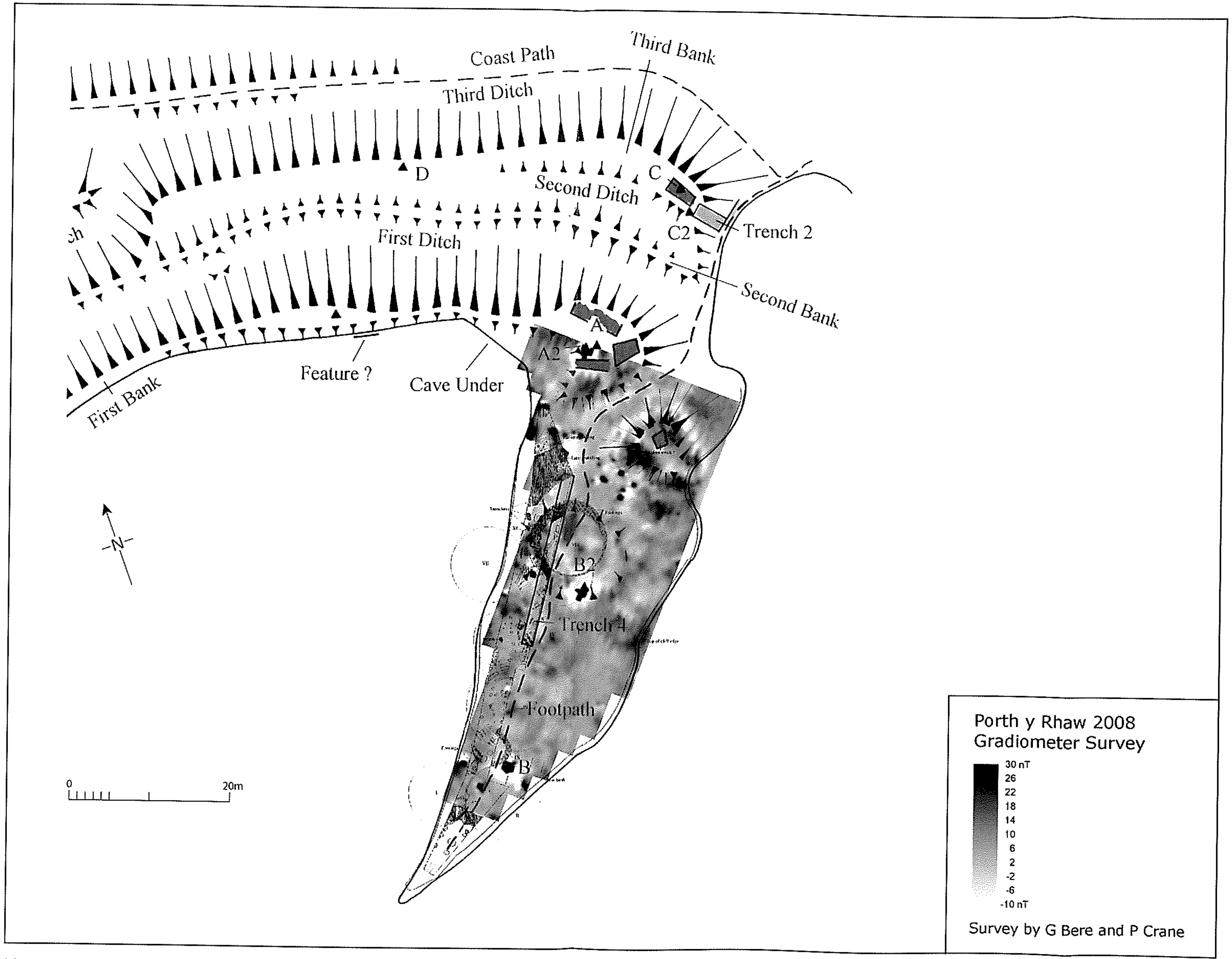

Figure 3: Plan with gradiometre survey, grey-scale. Scale 1:500 at A3

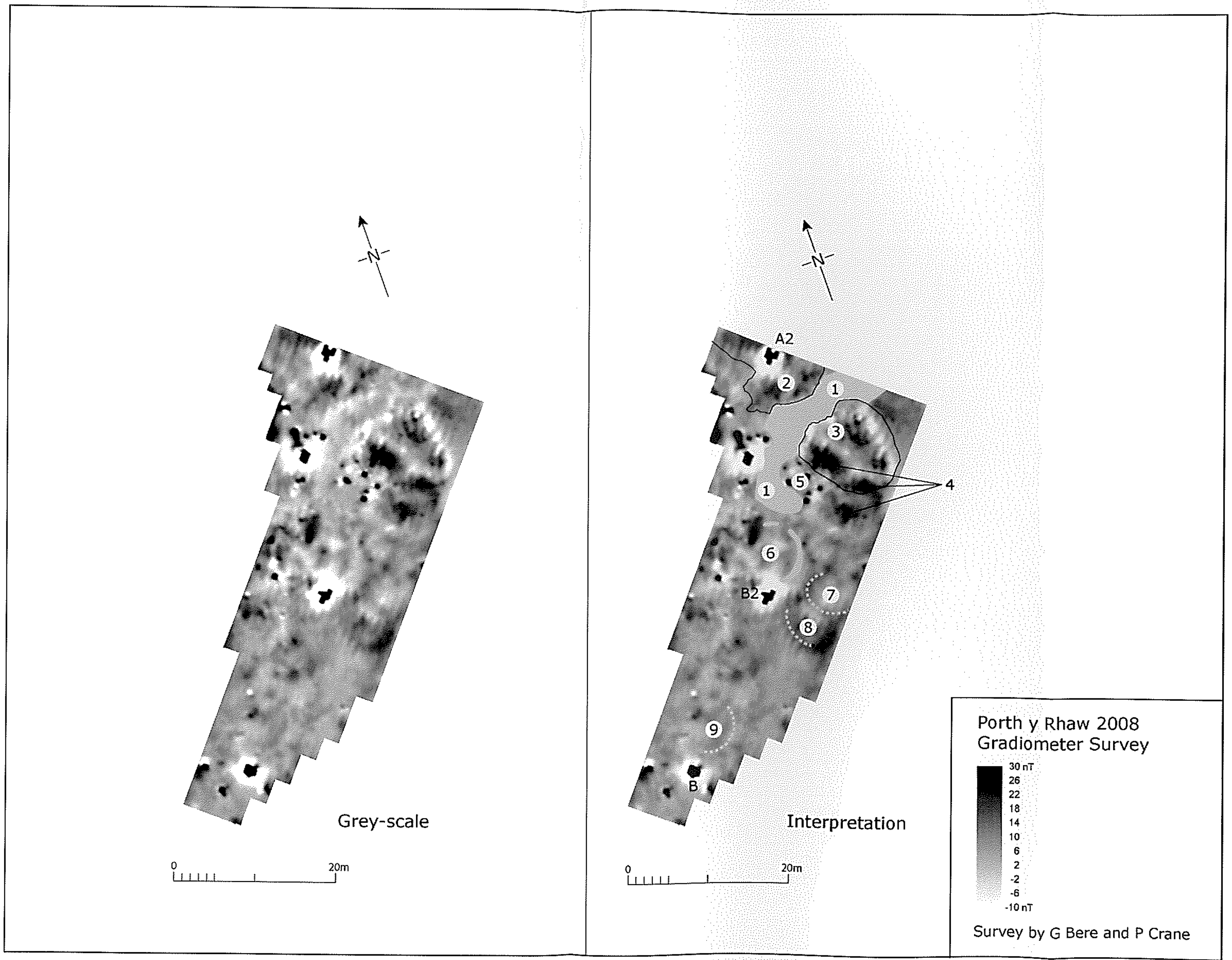

Figure 4: Gradiometre survey, grey-scale and interpretation. Scale 1:500 at A3

APPENDIX IV

GREENALA CAMP, PEMBROKESHIRE 2008: GEOPHYSICAL SURVEY

P. CRANE

SUMMARY

A geophysical survey was undertaken on most of the interior and inner defence of Greenala Camp coastal promontory fort, as part of the Cadw – Defended Enclosures Remote Sensing project. The results indicate at least three roundhouses and other features. However, much of the survey area was obscured because of high vegetation.

INTRODUCTION

Project commission

Cadw contracted Dyfed Archaeological Trust to undertake a geophysical survey on the interior of Greenala Camp, a coastal promontory fort, at Freshwater East, Pembrokeshire (centred on SS00759650)(Fig 1), as part of the Defended Enclosures Remote Sensing project.

Scope of the project

The project was designed to establish whether a geophysical survey using a gradiometer could detect archaeological features on this site.

Report outline

Because of the limited nature of this project, together with the considerable archaeological evidence in the area, this report is restricted solely to the results of the geophysical survey.

Abbreviations

Sites recorded on the Regional Historic Environment Record (HER) are identified by their Primary Record Number (PRN) and located by their National Grid Reference (NGR).

THE SITE

Location and Archaeological Potential

Greenala Camp (SS 00759650) lies on the coast 1.5km southwest of Freshwater East and 2km west of Stackpole (Fig 1). The Pembrokeshire Coast Path runs through the outer defences. This site is a Scheduled Ancient Monument (SAM PEMB 46). Most of the site, and all of the area of the geophysical survey is on National Trust land. Some of the outer defence is in private ownership.

This site is on a coastal promontory that is higher than the adjacent mainland. The cliffs fall very steeply to the sea some 40m below. On this naturally defensive location multiple banks and ditches were constructed and these are still notable today. The inner banks, especially around the entrance on the western side, are particularly impressive. Just outside of this there is a small annex with an outer entrance to the north, utilising the inner defensive bank as one side of the gateway. There are further high defensive banks to the west – these are now beside the cliff edge and it is probable that a considerable interior or further defences to the south have been lost.

No recent archaeological excavation has taken place on the site, but human bones were found in "in a midden in ditch" sometime in the past (HER PRN 4205). The RCAHMW in 1925 recorded numerous hut circles within the interior, but later authorities have not noted these, although two hut platforms are clearly defined at the eastern end of the interior.

METHODOLOGY

Geophysical Survey Instrumentation

A fluxgate gradiometer survey provides a relatively swift and completely non-invasive method of surveying large areas.

The survey was carried out using a Bartington Grad601-2 dual Fluxgate Gradiometer, which uses a pair of Grad-01-100 sensors. These are high stability fluxgate gradient sensors with a 1.0m separation between the sensing elements, giving a strong response to deeper anomalies.

The instrument detects variations in the earth's magnetic field caused by the presence of iron in the soil. This is usually in the form of weakly magnetised iron oxides, which tend to be concentrated in the topsoil. Features cut into the subsoil and backfilled or silted with topsoil therefore contain greater amounts of iron and can therefore be detected with the gradiometer. There are, however, other processes and materials that can produce detectable anomalies. The most obvious is the presence of pieces of iron in the soil or immediate environs which usually produce very high readings and can mask the relatively weak readings produced by variations in the soil. Archaeological features such as hearths or kilns also produce strong readings because fired clay acquires a permanent thermo-remnant magnetic field upon cooling. This material can also get spread into the surrounding soil leading to a more generalised magnetic enhancement around settlement sites.

Not all surveys produce good results as anomalies can also be masked by large magnetic variations in the bedrock or soil or high levels of natural background "noise" (interference consisting of random signals produced by material within the soil). In some cases, there may be little variation between the topsoil and subsoil resulting in features being un-detectable. It must therefore be stressed that a lack of detectable anomalies cannot be taken to mean that that there are no below ground archaeological features.

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The gradiometer can detect anomalies down to a depth of approximately one metre. The magnetic variations are measured in nanoTeslas (nT). The earth's magnetic field strength is about 48,000 nT; typical archaeological features produce readings of below 15nT although burnt features and iron objects can result in changes of several hundred nT. The instrument is capable of detecting changes as low as 0.1nT.

Geophysical Survey Data Collection

The gradiometer includes an on-board data-logger. Readings in the surveys were taken along parallel traverses of one axis of a grid made up of 20m x 20m squares. The traverse interval was 0.5m. Readings were logged at intervals of 0.25m along each traverse giving 3200 readings per grid square (medium resolution).

Geophysical Survey Data presentation

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Reliability

Geophysical survey is an immensely useful tool but it should be realised that while a survey will detect a wide range of features, it may not detect *all* buried features. A gradiometer survey detects changes in magnetic flux density and relies on there being a detectable difference between the archaeology and the substrate. This may not occur for many reasons (e.g. a cut feature being backfilled with subsoil). It must therefore be stressed that a lack of archaeological responses from a geophysical survey does not prove that there is no archaeology present.

Grid locations

The survey grids were located by RCAHMW GPS survey.

RESULTS

(Fig 2)

Limitations

The geophysical survey was undertaken on the 28th and 29th July 2008. On the first day the weather was very hot with the following day overcast. The southern half of the interior of the fort, on the coastal side, has long grass, often in large tussocks. This did not cause many survey problems. The annex just outside of the inner entrance and the inner banks either side of the entrance were likewise covered, but the steepness of the banks here made walking difficult (Photo 1). The northern half of the interior was covered with bracken, much up to 0.6m high and with some parts up to 0.8m high. Here there were considerable problems with the survey machine having to be raised well above its normal operating height (0.25m) and this has caused considerable deterioration of the results. Because of this tall vegetation the far north and the eastern end of the interior were not surveyed and neither was the bank of the inner annex.

On the northern edge of the north bank, north of the inner entrance, there is a large ferrous-type response which is probably modern. In the interior there are what look like old trenches, which have not been backfilled. These trenches may be the result of Home Guard activity during the Second World War.

The underlying geology is Old Red Sandstone, with light sandy topsoil (British Geological Survey 1994). This did not appear to cause any survey problems.

Geophysical interpretation

(Fig 3)

Only the major features are discussed.

The most obvious features are the entrance (1) through the inner banks (2 and 3). On the bank (3) immediately south of the inner entrance (1) there are at least four areas that are likely to be hearths or ovens.

In the interior there a number of circular features that are likely to represent the remains of roundhouses. Three of these are reasonably distinct (5, 6 and 7); the southwestern of these (7) appears to show features within it. There are five other possible roundhouses (8, 9, 10, 11 and 12), that again appear to have internal features. Additionally there are at least two arcs (13 and 14) that could be parts of ring ditches.

There is one particular area (15), in the south west of the interior, that indicates significant amounts of activity; included in this are two probable heat-affected areas (16 and 17). However, this area may well have been affected by the trench digging that still can be seen in the surface.

At an angle across the interior there are two vague parallel lines (18 and 19), which are considered to be natural features, but could turn out to be manmade.

The bank (20) of the annex, again like the inner bank (3) appears to have some heat-affected areas on it but also some near its interior base. These may be hearths but could also be pits with heat-affected material in their fills. Like much of the interior of the fort, the annex also indicates archaeological features within it but of no recognisable pattern.

DISCUSSION AND SUGGESTIONS FOR FURTHER WORK

Had the height of the vegetation been known beforehand no attempt would have been made to undertake this survey. The result was a compromised survey and injuries to staff of two twisted ankles probably by stepping into hidden rabbit holes.

The probable trenches seen in the surface of the interior are not though to be excavation trenches, as these would likely have been targeted on the defences as well, where there is no sign of modern activity, and Second World War works would appear to be more likely.

It is recommended that this geophysical survey is re-done and expanded to cover the entire interior, either when the vegetation is much lower or, for preference, when the site has been strimmed. This should also be done at a time when access can be gained into the field to the north where a better zero point to calibrate the equipment is likely to be found.

There were a number of tourists walking the coast path who came to look at what we were doing. In this instance there was plenty of time to explain to these visitors what and why we were doing thing this work and about this site and coastal forts in general. This aspect of facilitating visitor interest should be incorporated in any future work adjacent to the coast path: there would have been difficulties in the high season coping with greater numbers of people and still trying to undertake the survey.

CONCLUSION

This survey appears to confirm the results of the excavation suggesting that the interior of this promontory was densely occupied. However, individual features are difficult to recognise. The clearest result is probably from the metalled trackway leading into the fort and the stone-footed roundhouse, both of which were recorded in the earlier excavations.

ACKNOWLEDGEMENTS

I would like to thank the students who assisted with this geophysical survey and Louise Barker of RCAHMW for undertaking the topographical survey onto whose plan this survey has been placed.

ARCHIVE DEPOSITION

The archive will initially be held by DAT, before being passed to the National Monument Record, Aberystwyth.

SOURCES

British Geological Survey 1994 The Rocks of Wales 1:250,000

Clark A J 1996 *Seeing Beneath the Soil* (2^{nd} edition). Batsford, London

Photo 1: Steep bank south of inner entrance looking at entrance from inner annex. This caused problems with even data collection. View NW

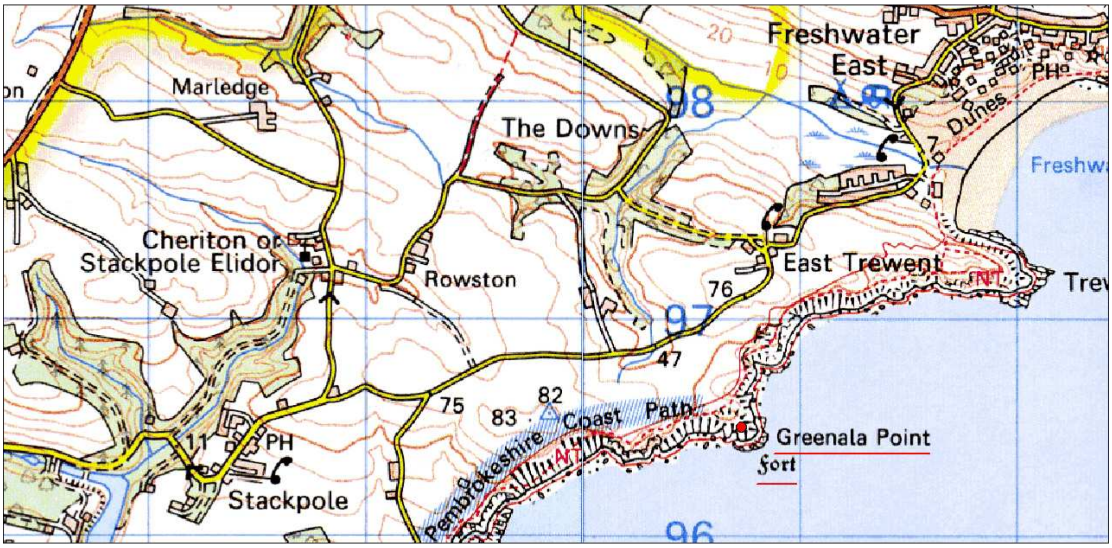

Figure 1: Location, SS 0073096480
Reproduced from the 1997 Ordnance Survey 1:50,000 scale Landranger Map with the permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright Cambria Archaeology, The Shire Hall, Carmarthen Street, Llandeilo, Carmarthenshire SA19 6AF. Licence No AL51842A.

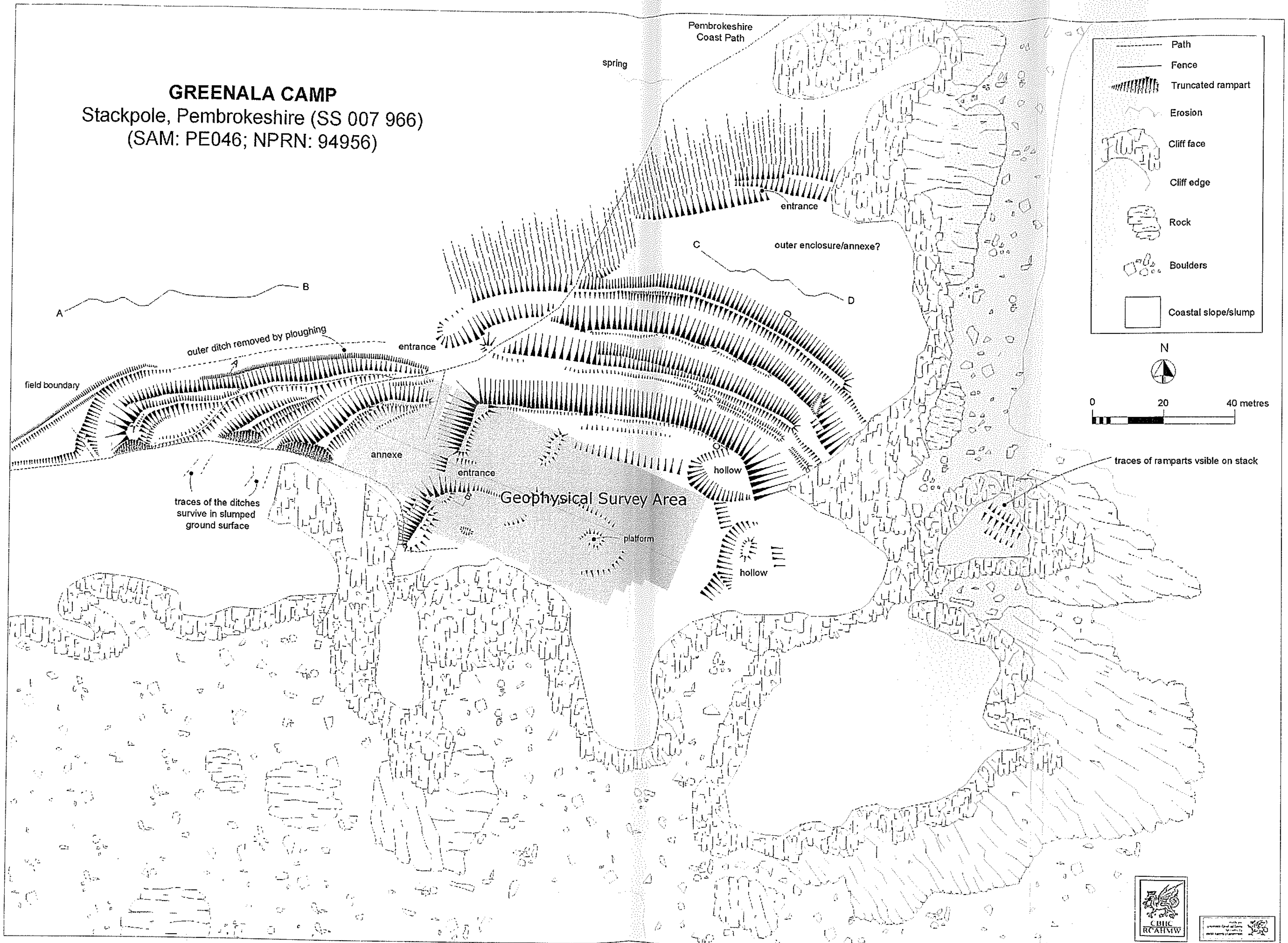

Figure 2: Geophysical Survey Area

Survey Date: Aug 2008
Survey Staff: LB

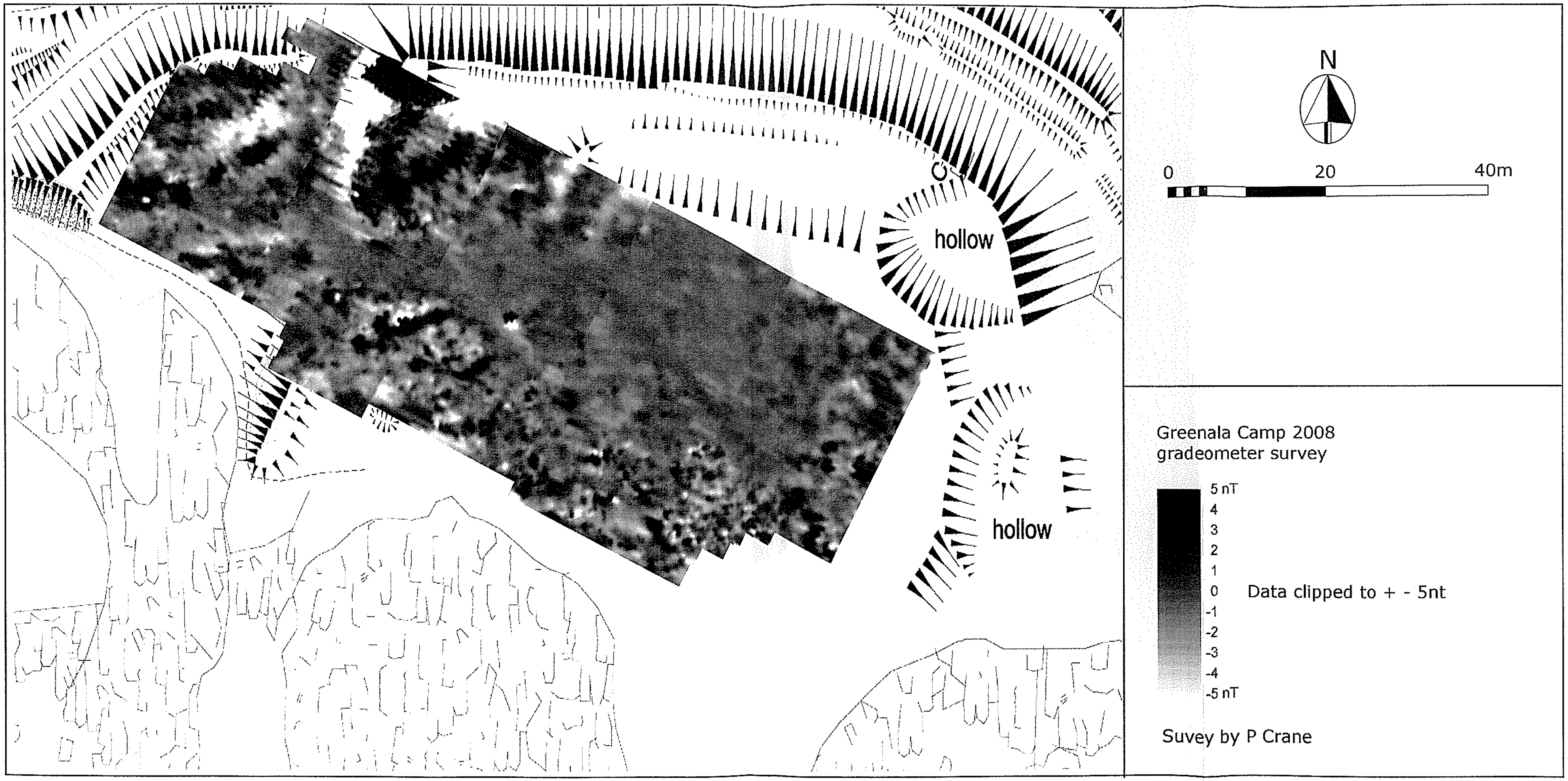

Figure 3: Gradiometer survey, grey-scale. Scale 1:500 at A3. Based on map from RCAHMW

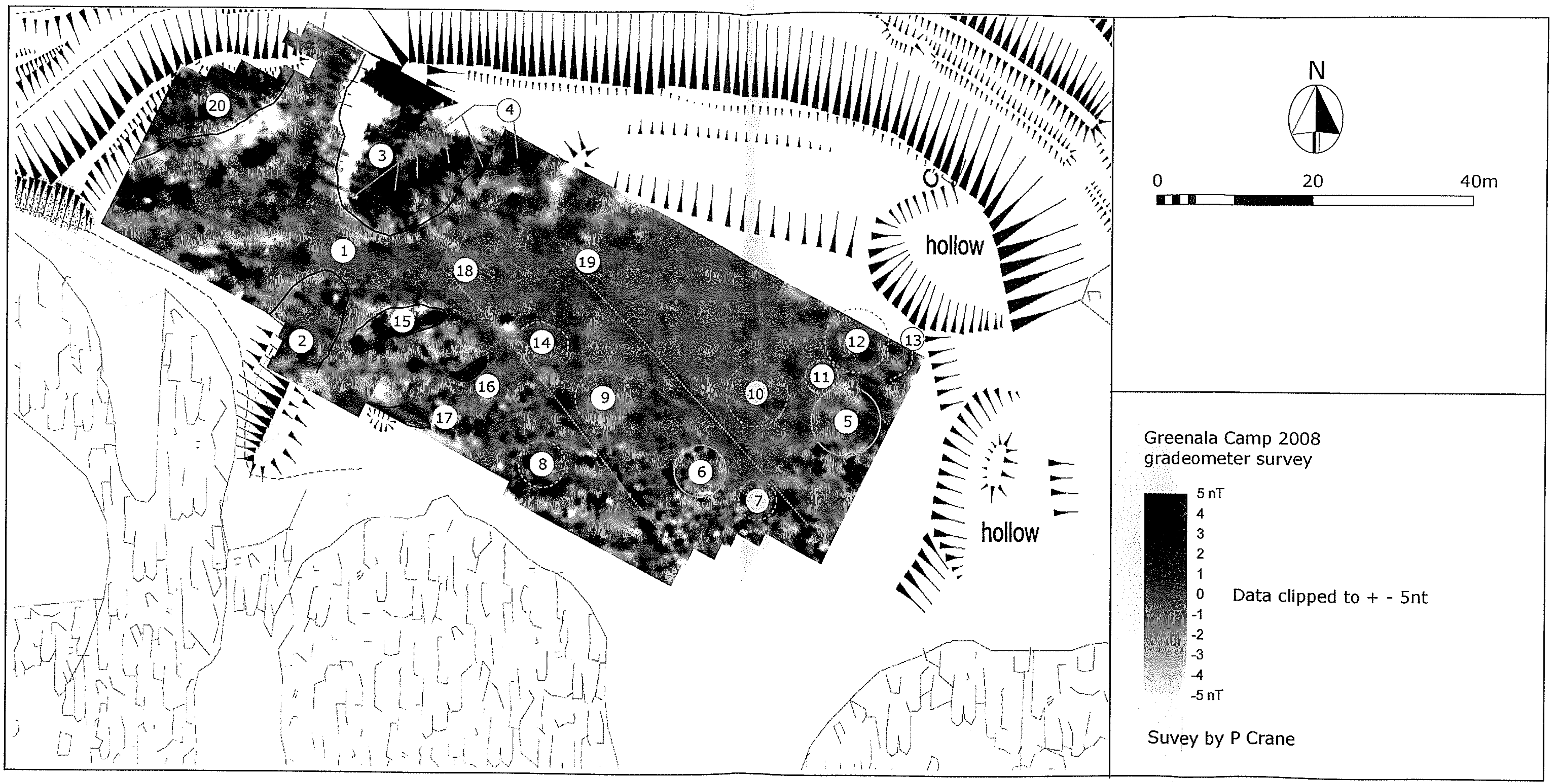

Figure 4: Gradiometer survey, grey-scale. Interpretation. Scale 1:500 at A3. Based on map from RCAHMW

PREHISTORIC DEFENDED ENCLOSURES: REMOTE SENSING

RHIF YR ADRODDIAD / REPORT NUMBER 2009/12

Mawrth 2009
March 2009

Paratowyd yr adroddiad hwn gan / This report has been prepared by Marion Page

Swydd / Position: Historic Environment Record Manager

Llofnod / Signature .... Dyddiad / Date

Mae'r adroddiad hwn wedi ei gael yn gywir a derbyn sêl bendith
This report has been checked and approved by Ken Murphy

ar ran Ymddiriedolaeth Archaeolegol Dyfed Cyf.
on behalf of Dyfed Archaeological Trust Ltd.

Swydd / Position: Director

Llofnod / Signature .... Dyddiad / Date

Yn unol â'n nôd i roddi gwasanaeth o ansawdd uchel, croesawn unrhyw sylwadau sydd gennych ar gynnwys neu strwythur yr adroddiad hwn

As part of our desire to provide a quality service we would welcome any comments you may have on the content or presentation of this report