STRUMBLE – PRESELI ANCIENT COMMUNITIES AND ENVIRONMENT STUDY (SPACES): SIXTH REPORT 2007–08

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INTRODUCTION

This report provides a brief interim account of fieldwork carried out in May 2007 when the focus was on walk-over surveys along the western slopes and north plateau of the Carn Meini outcrops in order to complete the mapping and recording of the upstanding field monuments in this area. Two geophysical surveys were also undertaken at cairns on Carn Meini and further samples of stone were taken for petrological study.

In Autumn 2007 and Spring 2008 attention turned to the investigation of the bluestones at Stonehenge, Wiltshire, culminating in an excavation within the circles carried out in April 2008 accompanied by much media interest. Some further limited fieldwork was undertaken along the Carn Meini ridge in September 2008, mainly cross-checking and updating earlier records of quarrying activity.

The background to the project is contained in previous interim reports (*AW* **42**, 17–28; *AW* **43**, 2–12; *AW* **44**, 104–9; *AW* **45**, 17–23; *AW* **46**, 100–107) while the thinking behind the project was published in 2002 (Darvill and Wainwright 2002). Detailed studies (Darvill and Wainwright 2003; 2003a) have been published elsewhere, together with a number of illustrated popular accounts (Darvill and Wainwright 2008; Alexander 2008; Jones 2008). SPACES is a multidisciplinary partnership between Bluestone, the School of Conservation Sciences at Bournemouth University, and the Royal Commission on the Ancient and Historical Monuments of Wales. It is undertaken in collaboration with specialists and experts from a range of other organisations and institutions.

CARN MEINI SURVEY

About 40 further individual features and structures were recorded and mapped in 2007–08, thus completing the survey of the Carn Meini outcrops and their immediate hinterland begun in 2006. The terminology adopted for reporting the 2006 survey (*AW* **46**, 100–107) is followed here.

Springs

The importance of the springs and rivulets on the south side of Carn Meini became apparent during the 2006 survey (*AW* **46**, 102–3). Two on the western end of Carn Meini flow into the Stone River, at the head of which stands the large Carn Menyn Cairn previously described (*AW* **46**, 103) and discussed further below. In 2007 five further springheads were recorded on the west and north side of Carn Meini. Most are of similar construction to those previously recorded with a crude wall screening off the springhead, thus creating a basin from which the streams run downslope.

Stone extraction

Rather less evidence of stone working was recorded on the upper plateau than on the southern slopes below. An incline was recorded on the north-west corner of Carn Meini below the western crag associated with two abandoned pillar stones and a pile of quarry debris. Stone-filled pits may represent extraction holes later filled with debris from dressing the stones. Towards the eastern end of the survey area four quarry-pits (numbered 2007 Sites 38 to 41) seemingly associated with the extraction of meta-mudstone were noted (Fig 1) to add to the nine examples recorded on the south side of Carn Meini in 2006 (*AW* **46**, 100–1). Site 41 (SN 14576 32694) was the largest of the four and comprised two conjoined

Fig 1. Quarry pit for the extraction of meta-mudstone at the eastern end of the Carn Meini ridge at c SN 14666 32730. [Photograph by Timothy Darvill]

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pits with spreads of upcast around about. A spherical stone maul about 0.2m across was noted near one of the quarries (Fig 2). Petrological descriptions of samples collected from Sites 39 and 40 on the north side of Carn Meini are provided by Rob Ixer below.

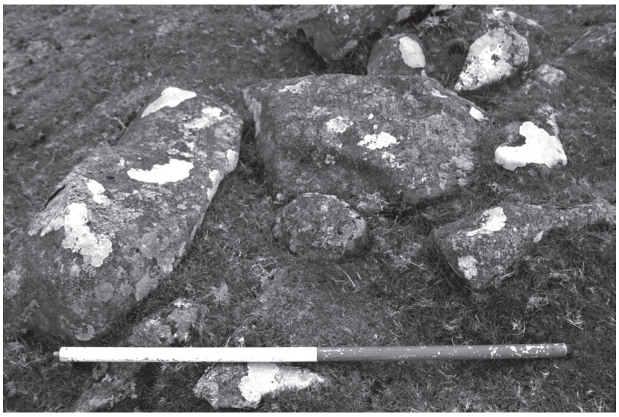

Fig 2. Stone maul in-situ adjacent to quarry pit at the eastern end of Carn Meini. [Photograph by Timothy Darvill]

Cairns

Six low cairns were recorded on the flat ground between the carns on the north side of the ridge. They are of regular form, 3–4m in diameter, frequently edged with stones, and typically possess a central cist or a hollow in an equivalent position (Fig 3). Slight traces of a ditch are sometimes visible.

Fig 3. Low stone-kerbed cairn on the north side of Carn Meini. [Photograph by Timothy Darvill]

META-MUDSTONE FROM QUARRIES ON THE NORTH SIDE OF CARN MEINI *by Rob Ixer*

Two meta-mudstones from Sites 39 (SN 14668 32736) and 40 (SN 14676 32736) were examined by transmitted and reflected light petrography to complement the earlier descriptions of samples collected in 2006. In addition three earlier samples (from Quarries 3, 5 and 7) were analysed by X-ray diffraction in order to confirm their major mineralogy. The three meta-mudstone samples from Quarries 3, 5 and 7 (petrographically described in *AW* **46**, 104–5) were investigated using whole rock X-ray diffraction in order to confirm and further specify their phyllosilicate minerals. All three rock samples were shown to comprise major amounts of muscovite together with quartz and with the iron-rich chlorite chamosite in samples from Quarries 3 and 7, but the magnesium-rich chlorite clinochlore in the sample from Quarry 5 (J. Kinnaird *pers comm*). These results are in agreement with those obtained petrographically.

New samples taken from Sites 39 and 40 were petrographically examined. The freshly broken meta-mudstones are a light blue grey (5B 6/1 on the G.S.A. rock-colour chart) and both samples show darker coloured, rounded to irregular spots 0.3–0.7mm in diameter. In hand specimen the mudstones show a variety of fabrics including original bedding (quarry 39) and more metamorphic, lensoidal textures (quarry 40).

Mineralogically the meta-mudstones are very similar to each other and to those previously described. In summary both comprise a fine-grained, white mica (muscovite) matrix intergrown with lesser amounts of fine-grained TiO_2 minerals and ?chlorite plus minor amounts of quartz, graphite, apatite, limonite and trace amounts of chalcopyrite and zircon. Zircon, some quartz, and some TiO_2 grains are detrital but most phases are authigenic. Locally, the meta-mudstones are cross-cut by thin quartz veinlets, some of which have been limonite-stained.

Their detailed petrography is sufficiently close to that already given (*AW* **46**, 104–5) that a reiteration is not necessary.

Lithologically, these samples are mudstones that have undergone very low-grade metamorphism with the development of chlorite porphyroblasts; they have not been silicified.

SPOTTED DOLERITE FROM CARN MENYN *by Rob Ixer*

Introduction

The spotted dolerites of the Preseli Hills, including Carn Menyn, have been of special interest since Thomas (1923) first recognised them as being the same lithology as the majority of the so-called 'bluestones' from Stonehenge. Despite this, and for almost the next seventy years, little systematic petrographical work was done on them until the transmitted light descriptions by Bevins *et al* (1989) later repeated and augmented by Thorpe *et al* (1991, 127). The opaque mineralogy (reflected light petrography) of the dolerites was first described by Ixer in Appendix A to Thorpe *et al* (1991, 150–2) and was later expanded and when it was also compared with a number of the

Stonehenge orthostats in Ixer (1996; 1997).

In all these studies only a restricted number of samples from Carn Menyn (s.s) were used and as the Preseli Hills' dolerites show petrographical variations between outcrops (Thorpe *et al* 1991; Ixer 1997) a re-examination of the petrography of the Carn Menyn outcrops is required before comparisons between rock from these sources and the Stonehenge bluestones can be properly re-evaluated.

The present transmitted and reflected light petrographies of a further nine dolerite samples, solely from Carn Menyn, confirm many of the earlier observations and suggest that within the main Carn Menyn outcrops, although there is some lithological variation, particularly in the degree of epidotisation, the majority of the dolerite can be regarded as 'uniform' in thin section.

Unlike earlier descriptions little, if any, carbonate or prehnite was recognised amongst the alteration minerals (in either transmitted or reflected light) and pumpellyite was seen to be very localised. However, as much of the alteration is very fine-grained and the relative amounts of the secondary minerals are very variable this variance is of little significance.

By contrast, the more extensive recent results suggest that the petrography of the opaque minerals, based on just two samples (Thorpe *et al* 1991 and further used in Ixer 1996 and 1997), is a true reflection of their mineralogy and textures, once again suggesting that opaque petrography is the better method.

The spots

One of the main aspects of the present study has been to look very closely at the iconic spots. These distinctive, pale spots originally described as feldspars (and often still called that in much of the archaeological literature) have been more recently interpreted as metamorphic porphyroblasts comprising plagioclase and alteration products and belonging to the low-grade metamorphism of the dolerites (Bevins *et al* 1989).

Petrographically the spots are seen to comprise ?relict chrome spinel together with relict feldspar; plus ?secondary feldspar; secondary, fine-grained clinozoisite; the two chlorite minerals chamosite and clinochlore; fine-grained muscovite and a coarse-grained epidote group mineral.

Whole rock X-ray diffraction of the pale spots has confirmed the presence of albite, (a secondary feldspar) epidote and chlorite (Richard Bevins *pers comm* 2007) and qualitative chemical analyses by SEM EDAX of a white spot about a chrome spinel has suggested the presence of clinozoisite, muscovite and clay minerals (Chris Blake *pers comm* 2007). The spots are or were undoubtedly feldspathic but now carry more alteration material than feldspar. It is significant that iron-rich chrome spinel (not a possible secondary mineral) only occurs within these spots (it is not found in the usual groundmass of the dolerites) suggesting that the original plagioclase 'knot' is not metamorphic but igneous.

The pale spots with iron-rich chrome spinel should be regarded as the key identification signature for Carn Menyn dolerites and the presence of this mineral within macroscopically 'unspotted' dolerites suggests that they are in truth crypto-spotted dolerites. This lessening of the importance of spotted and unspotted dolerites at Stonehenge is of significance.

The following detailed petrographical description is given and is offered as the basis for any future comparison between Carn Menyn dolerites and Stonehenge bluestones.

Sample descriptions

Twelve polished thin sections were prepared from nine samples collected from outcrops at Carn Menyn in autumn 2007 and spring 2008. Samples CM1-3 (two from each rock) and CM11 –15 (one from each) were collected from within the promontory enclosure at Carn Menyn (*c* SN 14370 32497) defined by the stone cross-wall excavated in 2005 (*AW* **45**, 17–19). CM16 (one thin section) was from immediately below Carn Menyn to the south, in the vicinity of a broken pillar stone previously reported (Darvill and Wainwright 2002a, 264 and fig 4).

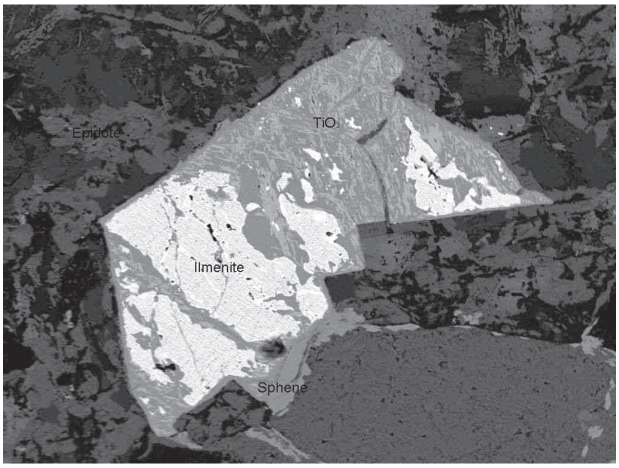

Fig 4. A euhedral crystal of ilmenite has altered to crystallographically orientated TiO_2 acicular crystals (light grey) within ?carbonate (dark grey). Locally a sphene mantle encloses the ilmenite. The silicate groundmass mainly comprises epidote and chlorite minerals. [SEM Photograph by Chris Blake]

Whole rock X-ray diffraction and semi-quantitative chemical analysis by SEM EDAX were performed on a typical spotted dolerite (CMQ2.2) these analyses concentrated on the mineralogy of the white spots and the dolerite groundmass.

In hand specimen the dolerite varies in the amount, size and density of its characteristic pale spotting. Samples CM12 and 15 are unspotted, other samples have rare, 4 –7mm diameter spots but the majority have pale spots 8 – 10 but up to 15mm in size. Locally the spotting is dense. The spots vary in colour from white (N9 on the Geological Society of America rock-color chart) or bluish white (5B 9/1) seen in freshly cut surfaces to light bluish grey (5B 6/1) or light greenish grey (5GY 8/1) but mainly pinkish grey (5YR 8/1) on weathered surfaces.

In thin section the Carn Menyn ophitic to sub-ophitic dolerites are highly altered with extensive epidotisation. The unaltered rocks comprise coarse-grained intergrowths between plagioclase-clinopyroxene-titanomagnetite-apatite.

Coarse-grained, zoned plagioclase laths are intensely and commonly altered to fine-grained clinozoisite (showing characteristic, low order interference colours) and white mica plus coarser grained epidote with high order interference colours. More locally plagioclase alters to clinochlore especially along its cleavage planes and rarely to quartz. Smaller plagioclase laths, those ophitically enclosed in clinopyroxene are more altered than larger crystals and in all cases feldspar cores are altered before rims. The original composition of the plagioclase is andesine-labradorite (Thorpe *et al* 1991) and an optical plagioclase determination of An44Ab56 using the albite twin law is consistent with that.

Smaller stubby, often zoned and simply twinned plagioclase (?albite) is far less altered than the main generation of plagioclase. It is associated with chlorite and epidote and more rarely with quartz. Some laths enclose apatite needles.

Clinopyroxene (augite) is locally twinned and/or zoned and is largely unaltered, some crystals have thin, acicular, pale green or brown fringes identified as amphibole. It carries small, rounded areas that now consist of clinochlore; these may be pseudomorphs, as it has been suggested that chlorite/serpentine pseudomorphs after olivine may be present (Bevins *et al* 1989), hence, these rounded patches may be ex-olivine. Acicular apatite is widespread and is 100–200µm in length.

Secondary minerals are abundant and include late-stage quartz or epidote mosaics and epidote-chlorite (clinochlore with brown interference colours) ± quartz ± pyrite intergrowths; some of these surround clinopyroxene and locally replace it, but mainly they infill void spaces between altered plagioclase-clinopyroxene-altered titanomagnetite. Within the epidote-chlorite intergrowths, euhedral, zoned, epidote, some with brown cores and clear margins, up to 180µm in diameter, is enclosed within chlorite or forms rims to chlorite infills.

Very locally chlorite with blue interference colours (chamosite) infills void spaces or occurs as veinlets cross-cutting clinochlore. Small, 5 - 40µm long, rhombic sphene is enclosed within chlorite. Elsewhere, minor amounts of wispy sphene mantle highly altered titanomagnetite and ilmenite.

Quartz is both cloudy and clear with strained extinction and serrated margins. Large, original crystals are replaced by later mosaics; elsewhere quartz forms spherulitic aggregates or thin veinlets.

Green to yellow-green fibrous fringes with moderate relief and showing high interference colours that may be amphibole radiate out from clinopyroxene or epidote and grow into quartz or chlorite. They are only present in very minor amounts.

Trace amounts of pumpellyite associated with quartz and brown ?biotite, if present, are rare.

SEM EDAX of the normal groundmass (Chris Blake *pers comm* 2007) confirms the presence of chlorite and clinozoisite.

The white spots appear to be very altered plagioclase and some even look tabular; they comprise abundant, fine-grained clinozoisite with very low order interference colours intergrown with lesser amounts of white mica, epidote with high order interference colours and chlorite (clinochlore); relict feldspar/secondary feldspar is also present, as is albite. Chlorite (both clinochlore and chamosite) lies along relict plagioclase cleavage within the spots. Very locally (CM12) cleavage traces carry chlorite surrounded by thin clinozoisite rims or vice versa. The spots carry a euhedral to rounded chrome-rich spinel. These carry small, 5µm diameter, silicate inclusions and are pitted and are altered to pale more ?iron-rich rims. Locally, fine-grained white mica or mica-chlorite intergrowths are the main component of the spots.

Brown-grey chrome-spinel with brown internal reflections is probably a primary relict phase and is characteristic of the pale spots as it is not found within the main body of the dolerite. It is present in small amounts even in the macroscopically unspotted dolerites as 10 –40 but up to 80µm in diameter, euhedral crystals or as 150–250µm diameter, 'pitted/speckled, rounded grains. In the latter case the grains may be shattered or enclosed in thin, up to 10µm wide, pale-coloured, ferrichromit/magnetite rims. The spinels are immediately surrounded by thin muscovite or rarely by 5µm wide, sphene rims themselves within fine-grained epidote. Semi-quantitative chemical analyses shows the spinel to be an iron-rich chrome spinel $(FeMgMn)(CrAlFe)2O_4$ (Chris Blake *pers comm* 2007).

Equant or skeletal crystals of titanomagnetite up to 400µm in diameter are extensively altered. Magnetite has altered totally to fine-grained sphene with white internal reflections, or has been lost, whilst crystallographically orientated, 2–5µm wide, ilmenite oxidation-exsolution lamellae have altered to fine-grained, acicular, colourless TiO_2 minerals or, if thicker, up to 15µm wide, to TiO_2 minerals with orange internal reflections. Titanomagnetite carries rare, 10–50µm diameter pyrite or limonite pseudomorphs after pyrite.

Many titanomagnetites are densely packed with altered ilmenite lamellae and carry lamellae of different thicknesses but others, up to 120μm in diameter, are devoid of fine-grained ilmenite oxidation exsolution lamellae. Very locally small, 20μm diameter, euhedral, magnetite crystals are collected into patches.

Ilmenite, up to 240 × 40μm in size, is intergrown with titanomagnetite as internal or external sandwiches but much forms discrete, lobate laths 40–400 × 200μm in size. Locally symplectite-like intergrowths between ilmenite and silicates occur. Most ilmenite is altered extensively but some is unaltered or has a speckled appearance or is just cut by thin 2–5μm wide, carbonate veins. Some ilmenite alters to orange TiO_2 minerals but most is replaced by fine-grained mixtures of 5–10μm diameter, bireflecting, colourless ?carbonate and small, 2–5 but up to 10 × 2μm long, pale-coloured to yellow TiO_2 minerals. The later are crystallographically controlled with respect to the original ilmenite grain. The standard alteration sequence is, ilmenite to ‘pitted’ ilmenite to carbonate to TiO_2 phases; relict ilmenite up to 100μm in size is commonly present. All generations of ilmenite in CM16 show a slightly different alteration sequence namely they are replaced by fine-grained mixtures of a very anisotropic ?secondary ilmenite and blue-grey TiO_2 minerals and then to carbonate or to fine-grained TiO_2 minerals that are crystallographically orientated (Fig 4).

Wispy sphene rims 5–100μm in thickness enclose ilmenite and thicker 60–80μm wide rims enclose very altered iron titanium oxide minerals. Locally, 20–200 × 100μm in size, wispy sphene is present in secondary minerals.

Sulphides are present in trace to minor amounts and are mainly associated with the alteration of the dolerite. Pyrite is the most abundant phase other than in CM13 where pyrrhotite is more common. Pyrite is present as 10–200μm diameter, euhedral crystals or as >200μm diameter aggregates of 10–15μm size crystals. Locally pyrite encloses 2–10μm diameter pyrrhotite or mixed chalcopyrite-pyrrhotite blebs. Much pyrite is oxidised to banded limonite, carrying 2–20μm diameter relict pyrite; commonly this limonite has very red internal reflections.

Trace amounts of 5–10μm diameter pyrrhotite or chalcopyrite are present in unaltered clinopyroxene or in ilmenite and titanomagnetite.

Epidote crystals up to 160μm in size, carry 5–40μm diameter hexagonal pyrrhotite, 2–60 (but up to 160μm) diameter chalcopyrite and 5–20μm diameter mixed chalcopyrite-pyrrhotite. More locally epidote carries 200μm diameter patches of fine-grained chalcopyrite.

Other secondary minerals carry discrete 10–30 pyrrhotite or chalcopyrite plus 40–200μm diameter patches of fine-grained chalcopyrite or very rare 5–20μm diameter, mixed chalcopyrite-mackinawite/valleriite or chalcopyrite-bornite or very, very rare mixed chalcopyrite-pyrrhotite-mackinawite/valleriite.

Chalcopyrite and pyrrhotite locally alter to limonite and chalcopyrite to covelline.

In CM13 pyrrhotite is the main sulphide, forming

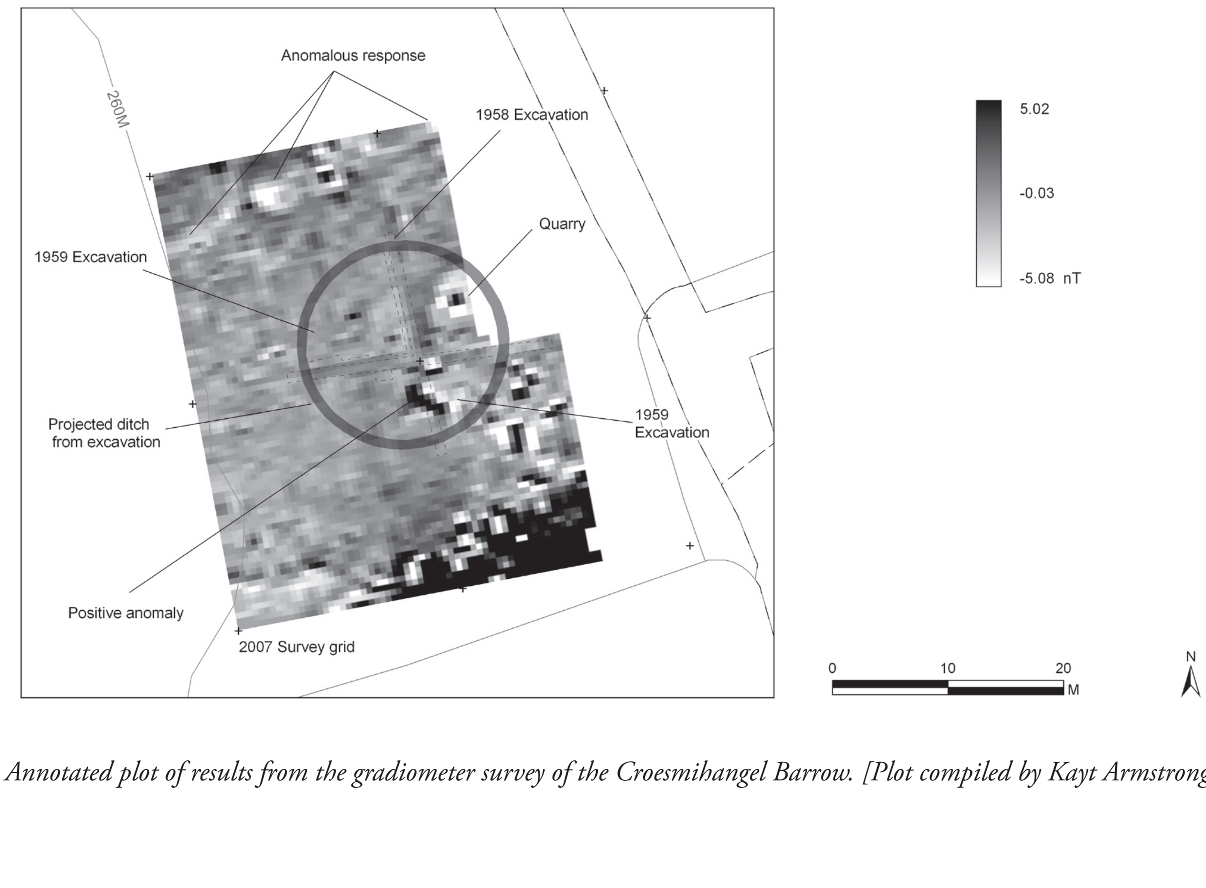

Fig 5. Annotated plot of results from the gradiometer survey of the Croesmihangel Barrow. [Plot compiled by Kayt Armstrong]

hexagonal crystals up to 200µm in diameter or aggregates up to 500µm in size within epidote; chalcopyrite rims this pyrrhotite. Here, pyrrhotite has altered to a fine-grained mixture of ?mackinawite and ?smythite (the so-called *zwischen produkt* of Ramdohr) or to fine-grained 2–5µm diameter pyrite/marcasite locally with characteristic bird's eye textures. Elsewhere 60 - 150µm diameter pyrrhotite alters to limonite along 0001 planes or in CM14 to fine-grained pyrite/marcasite.

CM14 is more altered than most of the other samples and where this is intense the rock has lost its original fabric both in hand specimen and in thin section and also becomes heavily limonitically stained.

In thin section both the magnetite and ilmenite components of titanomagnetite have altered to sphene that can be white, pale lemon-cream or orange-stained and pyrrhotite alters to fine-grained pyrite and marcasite.

With extreme alteration the rock comprises rounded, epidote aggregates with brown/dirty cores and clear, euhedral margins, or quartz-muscovite-epidote patches, or radiating ?muscovite (low relief and very high interference colours) rather like, but not the same as, the alterations seen in the pale spots.

GEOPHYSICAL SURVEYS *by Kayt Armstrong*

Two prehistoric cairns on Carn Meini were examined in May 2007. Croesmihangel Barrow on the eastern end of the ridge was surveyed with a fluxgate gradiometer (Geoscan FM36). This Bronze Age barrow was partially excavated in the 1950s (Nye *et al* 1983), and traces of the original excavation, executed in the quadrant method, remained visible as low-relief earthworks. In 2007 the barrow was surveyed in four 20m by 20m grids at 0.5m traverse intervals with four readings per metre at a resolution of 0.1nT. The results (Fig 5) clearly show the limits of the excavations as an area of disturbed signals. The excavations discovered four funerary urns with cremation deposits, one in a cist structure, and also showed stake holes and some evidence of structures within the cairn. The geophysical survey revealed a positive magnetic anomaly within the unexcavated area, near the centre of the cairn close to where some of the urns were found. This enhancement is unlikely to indicate a buried urn as such deposits rarely produce strong anomalies, rather it could indicate an area of burning in-situ or a concentration of heat-treated objects. The excavations found several deposits of charcoal interpreted as hearths. There was also a faint anomalous response at the north-east edge of the area surveyed that could be related to a supposed ditch around the cairn, though it is further out than the ditch located in the excavations.

The large cairn, Llach-y-Flaiddast, at the head of the 'stone river' on Carn Menyn was examined using four geophysical techniques for remote sensing: ground penetrating radar, electromagnetic, gradiometry, and resistivity. The cairn was quadranted into four 20m × 20m grids which provided a common geo-referencing system for all four surveys.

The radar survey was confined to the south-west quadrant, but does show some anomalies of interest. In a number of the profiles there are dipping horizons that are in the correct location to be a continuation of the ditch-like feature noted in earlier topographic surveys. The data has been timesliced to produce plan views of anomalous responses at a series of pseudo-depths. These do not show any clear archaeological anomalies and indicate the subsurface is very mixed with lots of stony inclusions. It is possible that there is a ditch that has been filled with stones falling from the side of the cairn.

The electromagnetic survey allowed mapping of the conductivity and magnetic susceptibility of the soils to about 0.5m. The conductivity measurements showed only small variations across the site. There is an area of low conductivity in the region of the stone river, possibly due to the thinner soils on that part of the site. To the east and south of the cairn there is a zone of higher conductivity responses that loosely relate to the ditch-like feature in the topography. The susceptibility measurements also show limited variation, but there are increases in the response that seem to be associated with structures noted around the east and north sides of the cairn; it is possible that human use of structures created from the fabric of the cairn has led to the topsoil becoming magnetically enhanced by fires or the disposal of waste (Fig 6).

The gradiometer survey was very noisy which is a reflection of the local geology; the stones are igneous intrusions that cooled rapidly and have strong remnant magnetism. This combined with the topography, which meant that at times there were rocks closer to the upper sensor than the topsoil was to the lower sensor, have led to a noisy and confused response. The noisier zone in the results largely corresponds to the cairn and the stone river, and there is a slight suggestion that the disturbance is stronger in the area of the previously mentioned structures. There are also some weak positive anomalies in the south-west corner of the area surveyed that are of archaeological interest as they occur in an area that seems to have been levelled.

The resistivity results were highly variable, indicating a thin topsoil over a more resistive parent, with many rocky outcroppings (Fig 7). Very strong high resistance anomalies correspond to the debris spread from the cairn that has been overgrown by peat soils. There is a low resistance area to the south-east of the cairn in the same area as the ditch like-feature. There are also some linear features that seem to be a reflection of the geology.

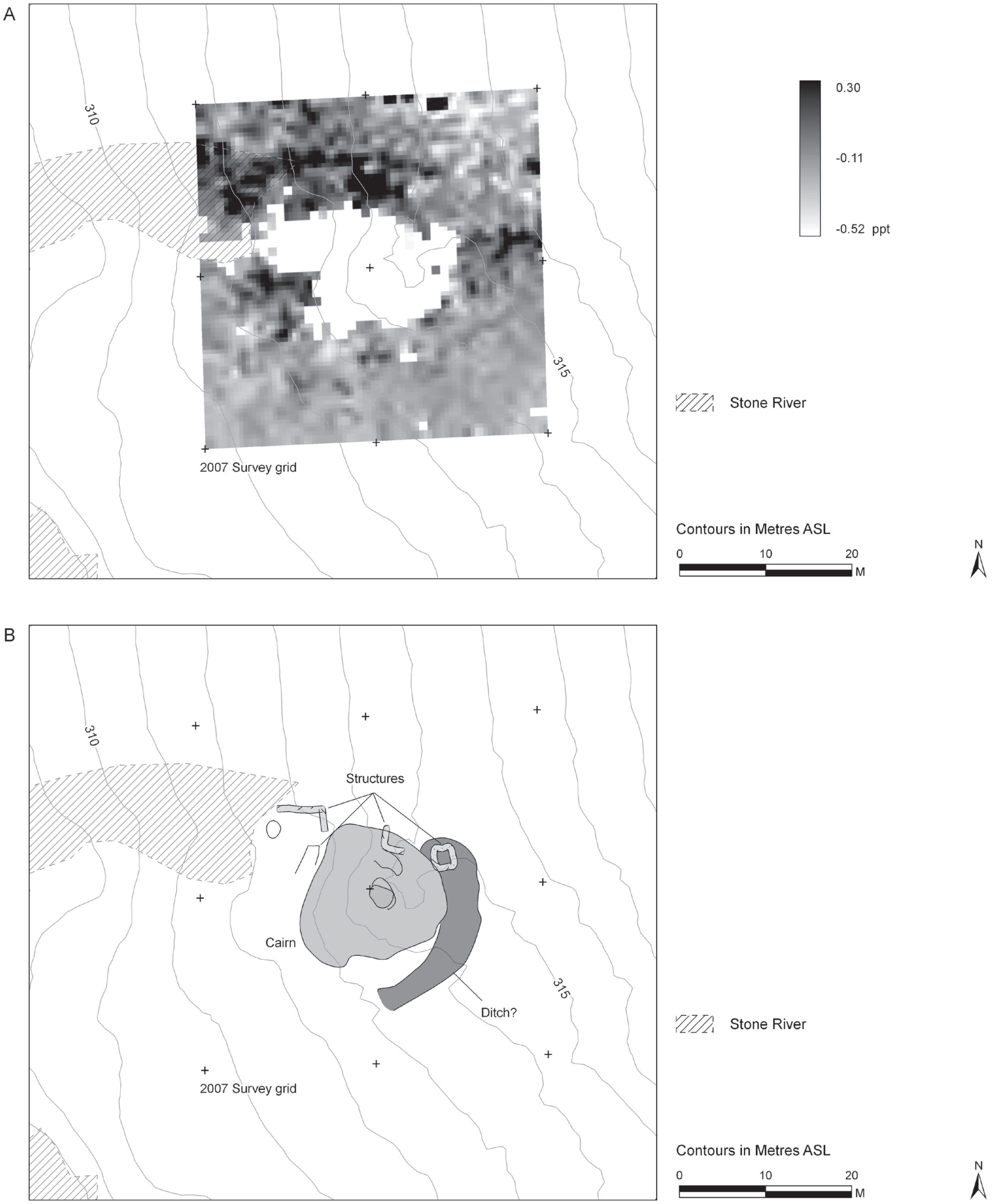

Fig 6. A. Plot of results from the magnetic susceptibility survey of the Carn Menyn Cairn / Llach-y-Flaiddast. [Plot compiled by Kayt Armstrong] B. Ground survey of same site.

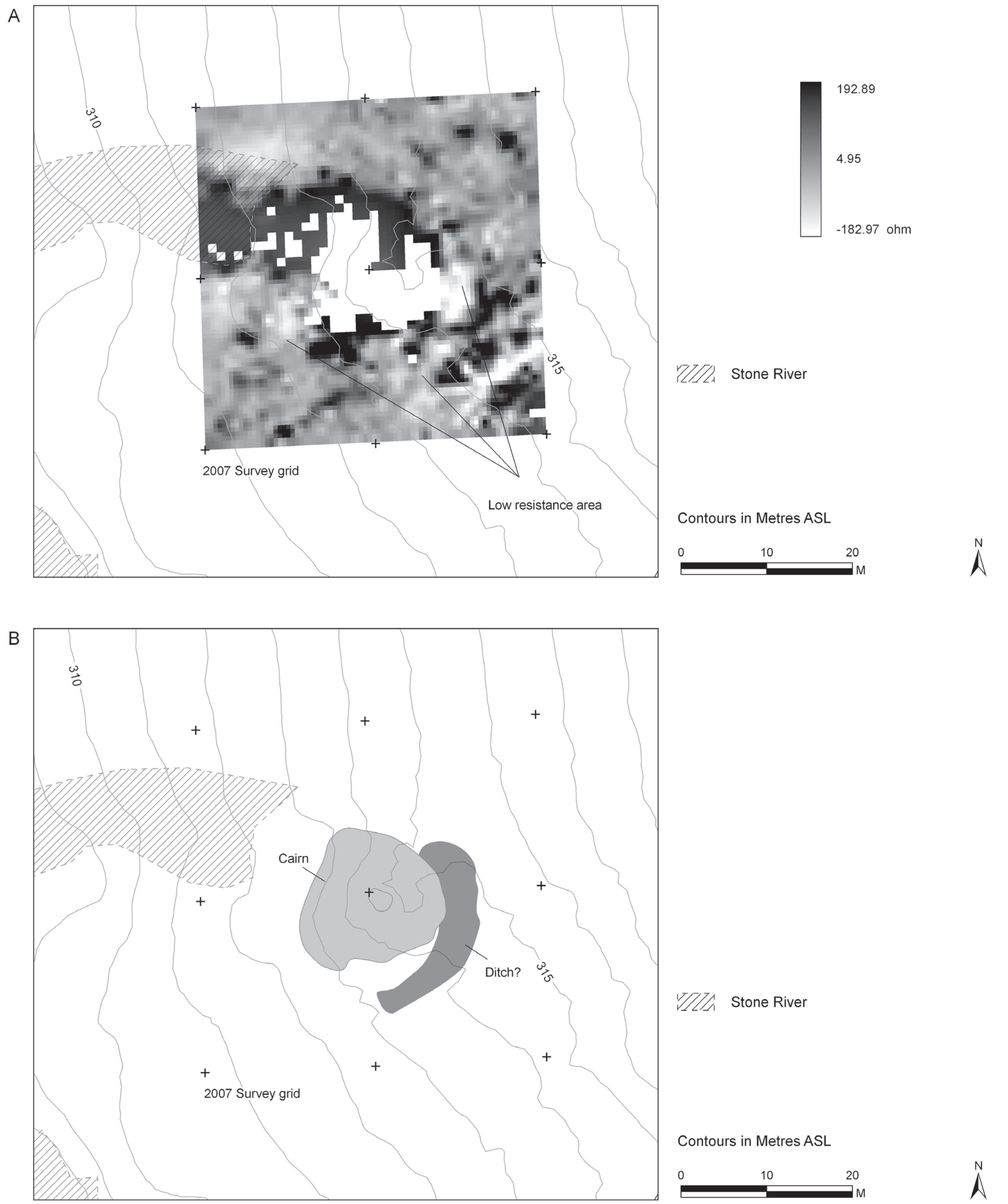

Fig 7. A. Plot of results from the resistivity survey of the Carn Menyn Cairn / Llach-y-Flaiddast. [Plot compiled by Kayt Armstrong] B. Simplified ground survey

SPACES AT STONEHENGE

In March and April 2008 attention shifted from the Strumble / Preseli study area of south-west Wales to the eastern end of the Bluestone Trail at Stonehenge in Wiltshire. Here, small-scale excavations were carried out in order to clarify the date of the first bluestone structure at the site (known as the Double Bluestone Circle; see Darvill 2006, 119–24) and to investigate the subsequent history of the bluestones through later phases of the monument, especially the incidence of broken bluestone in the so-called 'Stonehenge Layer' (Fig 8).

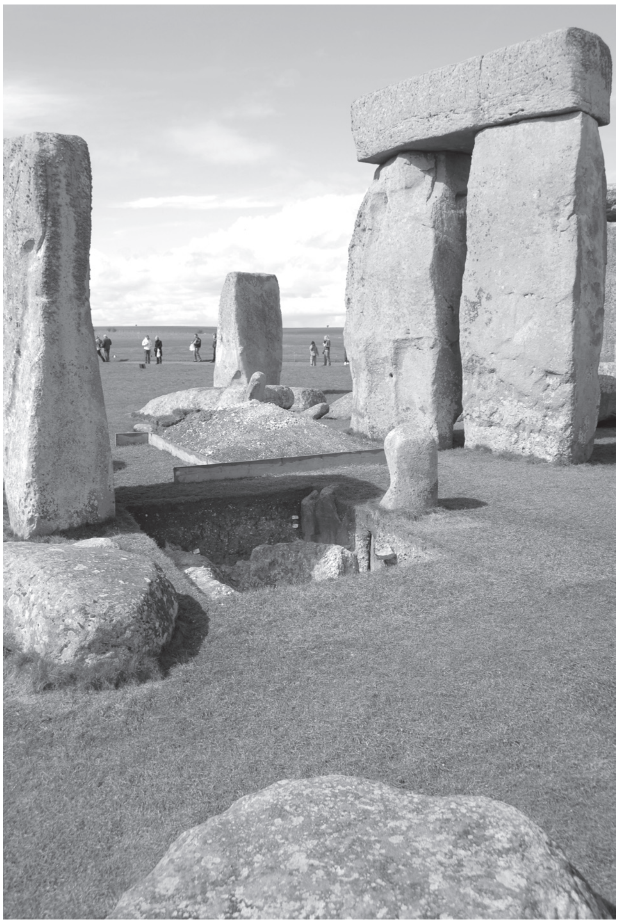

Fig 8. General view of the excavation at Stonehenge, Wiltshire, in April 2008. [Photograph by Timothy Darvill]

Acknowledgements

In 2007 the surveys were carried out by the authors with assistance in the field from Vanessa Constant, Paul Cheetham, Kayt Armstrong, Yvette Staelens, and Judith Wainwright. We would especially like to thank David Williams – the Lord of the Manor of Mynachlog Ddu – for access to Carn Meini, the Lady Marcher of Cemaes for permission to work at Croesmihangel Barrow, and the Countryside Council for Wales for their support. Permission for geophysical surveys at the Carn Menyn Cairn was provided by Cadw.

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