1814

Landscape of Neolithic Axes

Final Report

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Project No. G2495 / C107

Report No. 1814

Event PRN 49154

Prepared for: Cadw

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CRYNODEB

Yn 2019, 2021, 2022 a 2023, ymgymerodd Ymddiriedolaeth Archeolegol Gwynedd mewn partneriaeth â Chynllun Partneriaeth Tirwedd y Carneddau ac Awdurdod Parc Cenedlaethol Eryri â gwaith maes i ymchwilio i ble a sut yr oedd bwyeill cerrig Neolithig yn cael eu cynhyrchu ar ac o amgylch ffynonellau cerrig Grŵp VII ger Llanfairfechan a Phenmaenmawr, Conwy. Defnyddiwyd cloddio prawf i nodi lleoliadau cudd o waith bwyell, ynghyd â ffosydd gwerthuso bach, gyda'r cyfan wedi'u cloddio a'u cofnodi gan wirfoddolwyr niferus. Roedd yr ardaloedd a gafodd eu harchwilio yn cynnwys gwaith ar neu ger ffynonellau cerrig wrth droed Dinas ar Fferm Ty'n y Llwyfan (SH 6978 7397), ar Garreg Fawr (SH 6887 7334) ac i'r de o Graig Lwyd (Cors y Carneddau) (SH 7143 7473), yn ogystal â safle anheddiad yn yr ucheldiroedd, o'r enw Maes y Bryn (SH 705 738). Mae'r prosiect hefyd wedi ystyried tystiolaeth a ddarganfuwyd mewn gwaith blaenorol i gael darlun cyflawnach o ddefnydd y dirwedd gyfan. Mae'r adroddiad hwn yn cyfuno canlyniadau pob tymor maes gyda dadansoddiad ôl-gloddiad a thrafodaeth ehangach ar y dirwedd.

Mae'r prosiect wedi datgelu maint y dirwedd a oedd yn gysylltiedig â chynhyrchu bwyeill cerrig. Defnyddiwyd y nifer fawr o ffynonellau cerrig wedi'u gwasgaru ar draws yr ardal hon lle bynnag yr oedd y garreg o ansawdd addas, gyda mannau gweithio helaeth iawn wedi'u dangos wrth y mwyafrif o'r ffynonellau cerrig. Mae presenoldeb fflint mewn sawl safle ac weithiau crochenwaith yn dynodi bod aneddiadau wedi bod yn y dirwedd hon hefyd. Mae'r berthynas agos rhwng yr aneddiadau a chynhyrchu bwyeill yn cael ei dangos gan y malurion bwyell a ddarganfuwyd ar y safleoedd hyn.

Adferwyd tua 1404kg o falurion bwyell gan y prosiect, ac mae hyn yn cael ei astudio fel rhan o PhD, gyda'r adroddiad terfynol i ddod. Mae darganfyddiadau eraill yn cynnwys crafwyr ac offer eraill wedi'u gwneud ar fflisiau Grŵp VII, a darnau bach iawn o grochenwaith cynhanesyddol; un o'r Neolithig ac un o'r Oes Efydd.

Ymhlith y nodweddion a'r darganfyddiadau diweddarach a ddarganfuwyd yn ddamweiniol yn ystod y gwaith roedd pwll gofannu canoloesol, llwyfan adeiladu o'r Oes Haearn, amgaead â phalisâd posibl a chasgliad bach o grochenwaith Rhufeinig.

SUMMARY

In 2019, 2021, 2022 and 2023 Gwynedd Archaeological Trust in partnership with the Carneddau Landscape Partnership Scheme and the Eryri National Park Authority undertook fieldwork to investigate where and how Neolithic stone axes were made on and around the Group VII stone sources near Llanfairfechan and Penmaenmawr, Conwy. Test pitting was used to identify buried axe-working locations, with some small evaluation trenches, all dug and recorded by numerous volunteers. Areas investigated included working on or close to stone sources at the foot of Dinas on Ty'n y Llwyfan Farm (SH 6978 7397), on Garreg Fawr (SH 6887 7334) and to the south of Graig Lwyd (Cors y Carneddau) (SH 7143 7473), and a settlement site on the uplands, known as Maes y Bryn (SH 705 738). The project has also considered evidence found in previous work to obtain a fuller view of the use of the

whole landscape. This report combines the results of all the field seasons with post-excavation analysis and broader discussion of the landscape.

The project has revealed the extent of the landscape involved in stone axe production. The numerous stone sources scattered over this area were all used wherever the stone was of suitable quality, with very extensive areas of working demonstrated at most of the stone sources. The presence of flint on several sites and very occasionally pottery indicates that this landscape was also occupied by settlements. The close relationship of the settlements to the axe production is demonstrated by the axe debris found on these sites.

About 1404kg of axe debris was recovered by the project, and this is being studied as part of a PhD, with the final report still to come. Other finds include scrapers and other tools made on Group VII flakes, and tiny pieces of prehistoric pottery; one Neolithic and one Bronze Age.

Later features and finds discovered incidentally during the work include a medieval smithing pit, an Iron Age building platform, a possibly palisaded enclosure and a small collection of Roman pottery.

Plate 1. Neolithic stone axehead with original haft from Ehenside Tarn, Cumbria (British Museum)

Plate 2. Stone axes and adzes would have been used in the construction of the Early Neolithic rectangular Neolithic buildings, of which this reconstruction of the building at Parc Cybi, Holyhead is an example (drawing by Helen Flook)

Plate 3. Pike O'Stickle in Great Langdale, one of the main sources of stone for axeheads was on the face of the crag and the scree below consists largely of axe debris (photo by Jane Kenney)

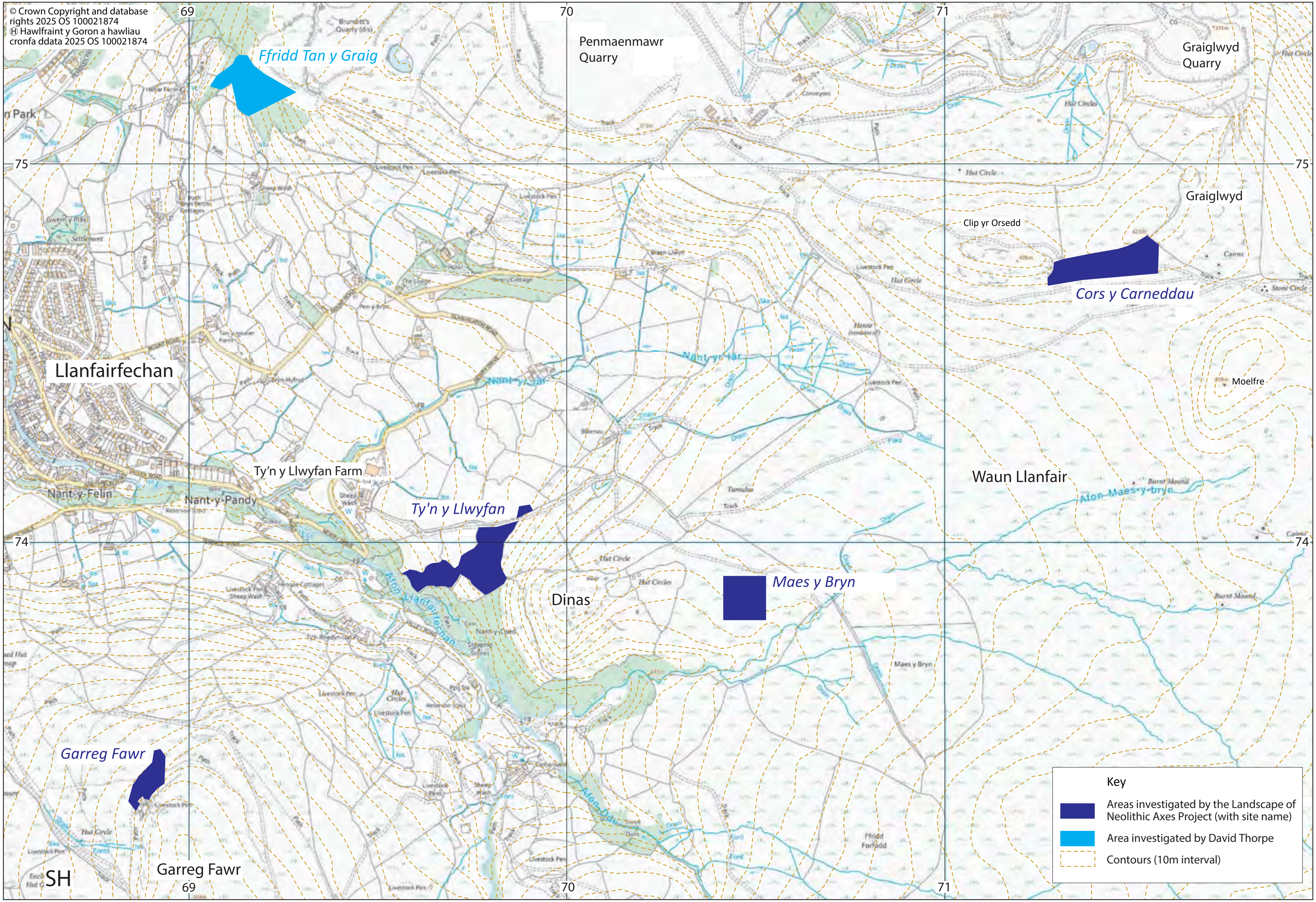


Figure 1. Areas investigated by the Landscape of Neolithic Axes Project

1. INTRODUCTION

1.1. Neolithic stone axeheads

The axe, with a polished stone axehead (Plate 1), was a tool of considerable significance, both practically and socially, in the Neolithic period. Not only did axes enable forest clearance and the construction of large timber buildings (Plate 2), but they were probably also symbols of status. Axeheads were selected as appropriate objects to be offered within ceremonial monuments indicating their cultural and possibly religious significance. Flint was often used for polished axeheads in south-eastern England but elsewhere axeheads were made from fine igneous rocks that could be knapped like flint. Petrological analysis has identified several sources of the stone for these axes in Britain. The stone types identified have been classed as belonging to several Groups. Some sources were preferred and material from these was dispersed widely. The preference for certain sources implies that there were qualities in the stone, or possibly in the location of the source, that made axeheads from these materials particularly desirable. The source that produced the most axeheads, which were most widely distributed, was in the central Lake District, focussed around Great Langdale (Group VI) (Claris and Quartermaine 1989) (Plate 3). Axes from this source have been found across Britain and considerable work has been done to study the area and identify quarry and axe-working sites. The second most widely distributed axes come from the Group VII stone source. Group VII axes are found over most of England and Wales, with occasional ones elsewhere (Clough 1988, Houlder 1988). This source can therefore be considered of second in importance in Britain to the Great Langdale source.

Group VII axes were demonstrated to come from a stone source near Penmaenmawr, Conwy, known as Graig Lwyd (Warren 1919, 1921, 1922). There has been some recognition that axe-working debris could be found over a much wider area, not just around the hill of Graig Lwyd. Axe debris was recorded as being found around the hills of Garreg Fawr and Dinas above Llanfairfechan (RCAHMW 1956, xliii, Houlder 1976, 58), but little professional archaeological work had been done to investigate the wider landscape and to study the stone sources beyond Graig Lwyd. However, the axe-working sites have been investigated by local historians, indicating that there was an extensive landscape around Penmaenmawr and Llanfairfechan across which evidence for Neolithic axe-working could be found. This is a landscape of national importance for British Neolithic studies, which has long deserved detailed study.

1.2. The project

The aim of the project was to investigate this nationally important Neolithic landscape, which has previously received remarkably little archaeological study. The landscape of the stone sources forms part of the northern end of the Carneddau mountain range. The Carneddau are the focus of the Carneddau Landscape Partnership Scheme (CLPS), a large-scale Heritage Lottery funded project involving a group of 23 agencies and organisations under the leadership of the Eryri National Park Authority (ENPA). The CLPS aims to help conserve the threatened heritage of the Carneddau by increasing understanding and enjoyment of the cultural and natural heritage of the area across a wide range of communities, individuals, and organisations. The current project, known as the Landscape of Neolithic Axes Project, was developed with the CLPS, and has been delivered in partnership with the CLPS and ENPA. The aim was to include the local community and other volunteers in all aspects of the study and to raise awareness and understanding of this important archaeological resource, as well as answering academic research questions.

A major challenge to identifying axe-working locations in this landscape is to recognise sites and deposits obscured under turf and vegetation either in the pasture fields or on the moorlands. To solve

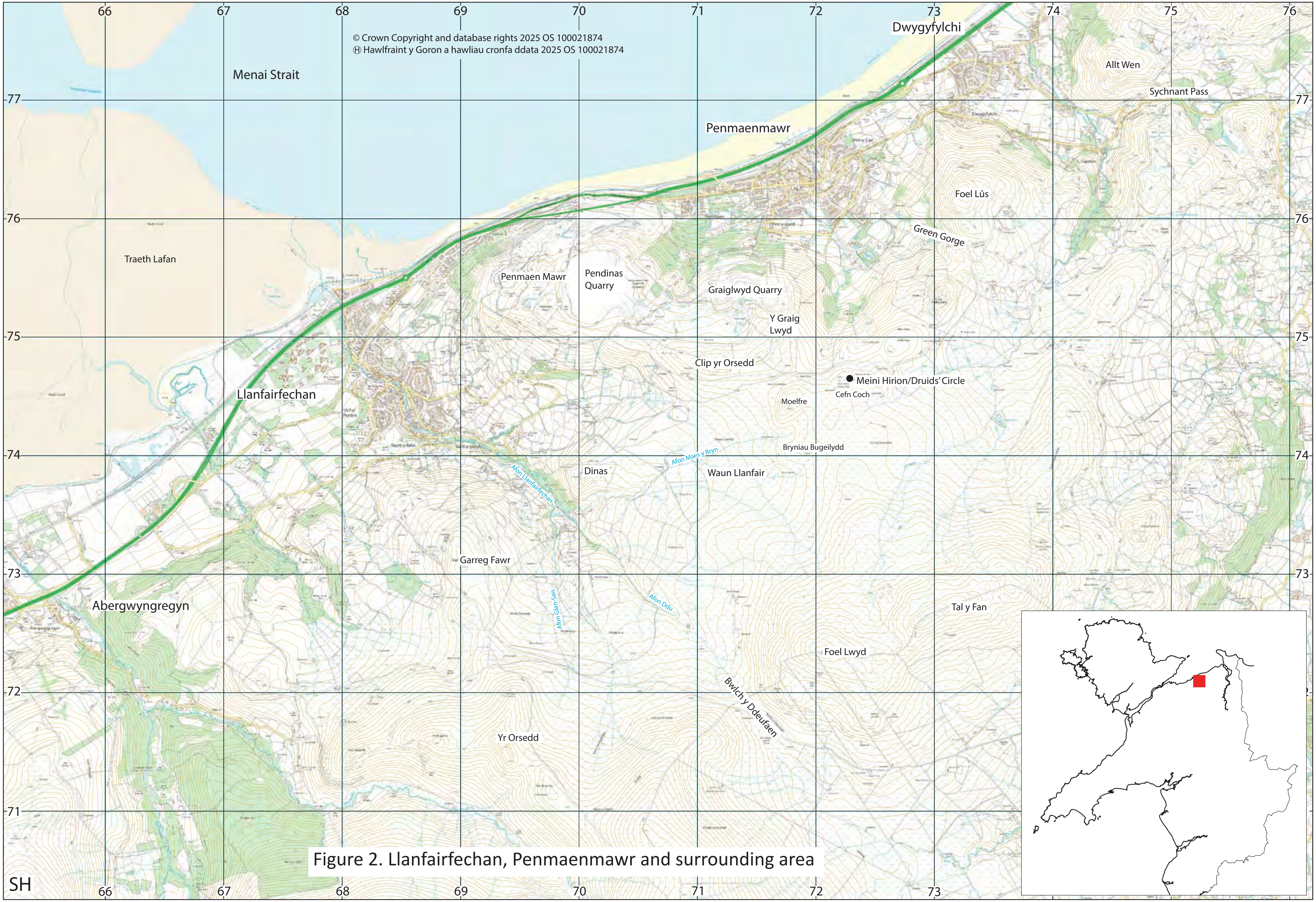


Figure 2. Llanfairfechan, Penmaenmawr and surrounding area

Plate 4. View over Llanfairfechan to Traeth Lafan and Anglesey beyond from Garreg Fawr

Plate 5. View of Dinas from Garreg Fawr

Plate 6. View of Garreg Fawr from Dinas

this problem the project concentrated on test pitting to allow deposits to be sampled and artefacts to be recovered. In places a few small excavation trenches were also used to identify and characterise sites associated with the axe working.

Fieldwork was undertaken in 2019, 2021, 2022 and 2023 in partnership with CLPS and the ENPA, with the involvement of numerous volunteers. Areas investigated included extensive work at the foot of a hill known as Dinas on Ty'n y Llwyfan Farm, Llanfairfechan, other stone sources on Garreg Fawr and to the south of Graig Lwyd (Cors y Carneddau), and a settlement site on the uplands, known as Maes y Bryn (Figure 1).

This report combines the results of all the field seasons with post-excavation analysis and broader discussion of the landscape. Although it is titled “final report” additional fieldwork is planned for summer 2025 and this will be reported separately.

1.3. Geology and Landscape

Llanfairfechan and Penmaenmawr lie on the north coast of Wales on the southern side of the Menai Strait with Anglesey to the north (Figure 2). At this point the Strait widens as it opens into Conwy Bay and the extensive Traeth Lafan (Lafan Sands) covers much of the Strait at low tide (plate 4). The village of Llanfairfechan has developed on an alluvial fan where the Afon Llanfairfechan crosses the coastal plain to the sea after its short journey from the uplands to the south-east. Penmaenmawr occupies a narrow coastal plain at the foot of a steep escarpment. It is enclosed from the outside world by the hills of Penmaen Mawr to the west and Alltwen and Penmaen Bach to the east. The village is dominated by quarries which have hollowed out Penmaen Mawr and also quarried much of the rocky outcrop of Graig Lwyd.

Llanfairfechan is also overlooked by Penmaen Mawr but has a more open aspect to the west. The upper part of the valley above Llanfairfechan is narrow and overlooked by two hills; Dinas and Garreg Fawr. Dinas is a distinctive hill with a flat summit at about 320m OD, on which was located an Iron Age hillfort (PRN 392). Its southern and western flanks are bare scree with the woodland of Nant y Coed covering its foot to the west (plate 5). Garreg Fawr is a less dramatic but a bulkier presence with an outcrop of rock at the top reaching 364m OD (plate 6). To the south are the higher mountains of the Carneddau range and to the east the long, isolated ridge of Foel Lwyd and Tal y Fan, the latter reaching 610m OD (Plate 7).

Penmaen Mawr used to be crowned by the Braich y Dinas hillfort (PRN 712). However, the hillfort and much of the top of the mountain have been quarried away and its slopes remodelled by screes of quarry waste (Plate 8). A length of the original crags and natural scree below them still survives on the western side of the mountain (Plate 9). Running east from Penmaen Mawr is a ridge called Clip yr Orsedd at the eastern end of which is a rock outcrop known as Y Graig Lwyd (the grey crag). The outcrop was formerly more extensive but has been partially quarried away by the Graiglwyd Quarry (Plate 10). This also had natural scree running down below it, some of which is buried under quarry waste, but some survives on its northern and eastern sides, largely overgrown with heath vegetation.

The streams of Afon Maes y Bryn and Afon Ddu, which meet with Afon Glan-Sais to form the Afon Llanfairfechan, drain an upland plateau, known as Waun Llanfair (Plate 11). This is now a wet, marshy, and rather desolate place but is covered with Bronze Age and Iron Age monuments indicative of more intensive use in the past (Caseldine *et al* 2017). The eastern side of Waun Llanfair is closed off by a shallow ridge running north from Tal y Fan. At the northern end of this ridge is a group of Bronze

Plate 7. View over Waun Llanfair with Tal y Fan and Foel Lwyd in the distance

Plate 8. View of Penmaenmawr Quarry from Clip yr Orsedd showing the large hole where there was once Braich y Dinas hillfort

Plate 9. View of the western end of Penmaen Mawr showing Ffridd Tan y Graig and the scree and crags above

Plate 10. Aerial photograph of Graig Lwyd (the crag in the foreground) partially cut away by Graig Lwyd Quarry (copyright Royal Commission on the Ancient and Historical Monuments of Wales)

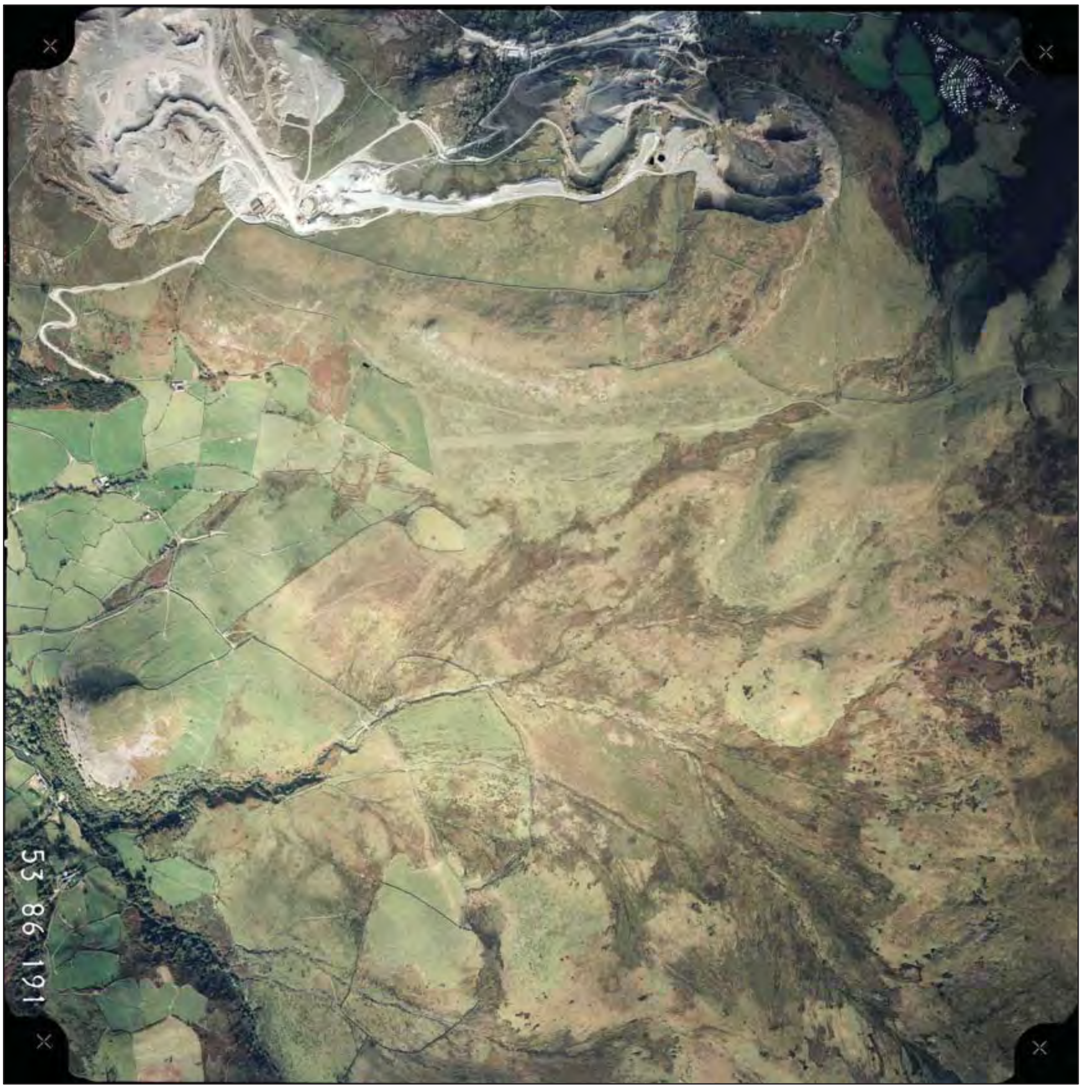


Plate 11. Aerial photograph of the uplands to the east of Llanfairfechan and south of Penmaenmawr showing the boggy area of Waun Llanfair in the middle and the Penmaenmawr Quarry at the top (Snowdonia National Park Authority, flight 5386, frame 191, date 1986)

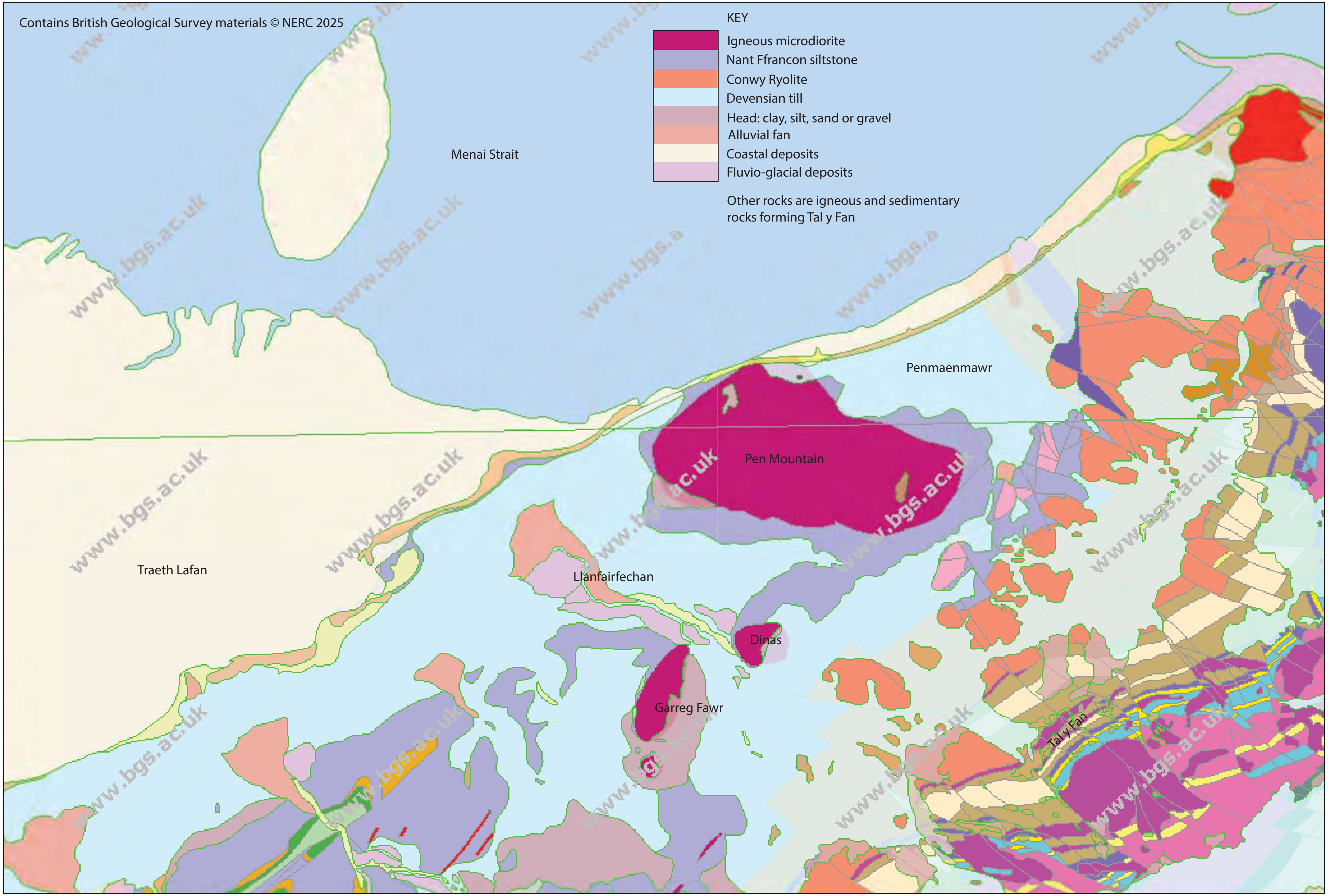


Figure 3. The geology of the Llanfairfechan and Penmaenmawr area

Age monuments including the Meini Hirion (Druids' Circle) stone circle (Plate 12), a ring cairn and other features with further cairns and a possible stone circle a little to the west and a standing stone and stone circle to the east.

This area was of interest to the Neolithic people, and therefore of interest to us today, because of its geology (Figure 3). The bedrock under most of the area is siltstone of the Nant Ffrancon Subgroup, an Ordovician sedimentary rock. Protruding through these deposits are intrusions of silica-poor magma, also of Ordovician date. These rocks are a Microdiorite (BGS Geology Viewer (BETA)).

The bedrock is partially overlain by a blanket of glacial till with some deposits of glacial sands and gravels. Alluvial deposits are restricted to the narrow base of the river valley until they open out to form an alluvial fan under the village of Llanfairfechan. Around the eastern and southern sides of Garreg Fawr are deposits of "head", clay, silt, sand, and gravel that have accumulated by down slope movements such as solifluction and soil creep during or after the glacial period (BGS Geology Viewer (BETA)).

On a petrological level the igneous rock, referred to locally as "Pen Granite", is defined as augite granophyre (Clough 1988, 7). The magma intrusions cooled more quickly around their margins resulting in the rock being coarser grained in the middle of the mass but very fine grained around the edges. Even the coarser grained stone can be roughly knapped, allowing it to be shaped into setts used in the nineteenth century to pave the streets of Liverpool and other cities. However, where it is very fine grained, around the chilled margins of the intrusions, the rock has a good conchoidal fracture and is particularly suitable for stone axe manufacture. The main area of this very fine rock is a zone 50m to 100m wide around the eastern and southern edges of the Graig Lwyd outcrop (Williams and Davidson 1998, 3-5), and this is usually thought of as the stone axe source, but there is similar rock on Dinas, Garreg Fawr and round the western margin of Penmaen Mawr.

1.4. Previous Archaeological Work

Stone axeheads were made by knapping a piece of natural scree or quarried stone into shape before finishing it by grinding and polishing. The roughly knapped pre-form for an axehead is known as a 'roughout' (Plate 13). During the manufacturing process faults in the stone often caused roughouts to break and they were then discarded on the working site. These broken roughouts and the flakes knapped from them are the indicative signs of an axe-working site and they can be present in very large numbers on an undisturbed site.

Although roughouts had been identified in the area previously Samuel Hazzledine Warren, a geologist and antiquarian from Essex, is credited with recognising, in 1919, that Y Graig Lwyd was an 'axe factory' (Williams 1998, 18). Warren undertook excavations in the early 1920s (Warren 1919, 1921, 1922), and found several tons of axes and roughouts, many of the best specimens of which were distributed to museums across Britain (Warren 1919, 1922; Glen 1935, 189). In 1926 HGO Kendall excavated Warren's site E at the top of Graig Lwyd before it was destroyed by quarrying (Kendall 1927).

The main axe working areas over Graig Lwyd were investigated in the 1990s by Gwynedd Archaeological Trust (GAT) and Bangor University Department of Continuing Education. This included detailed surveys of the surviving working areas and some small excavations. The surveys revealed the extent of the preserved working hollows in the natural screes on the northern slopes of Graig Lwyd. The scree being the main source of stone for making the axeheads. However, excavations

Plate 12. Volunteers visiting the Meini Hirion (Druids' Circle), PRN 541

Plate 13. Examples of roughouts from Graig Lwyd excavated by Samuel Hazzledine Warren (Warren 1922, Figs 7, 8 and 10)

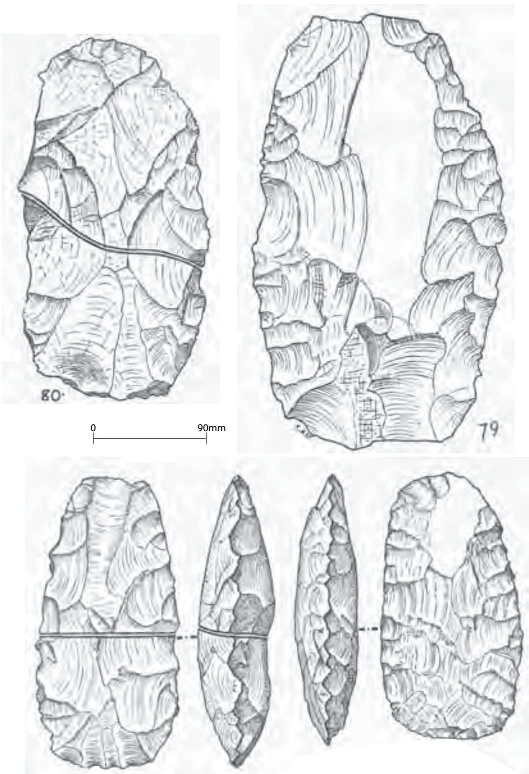


Plate 14. Samuel Hazzledine Warren excavating at Graig Lwyd in 1922 (from Williams 1998)

Plate 15. Excavation of trench E at site F on Graig Lwyd in 1993 (courtesy of John Llywelyn Williams)

Plate 16. Trench E at site F on Graig Lwyd excavated in 1993 showing axe roughout placed in the corner (courtesy of John Llywelyn Williams)

Plate 17. Excavation of Cairn 67 (PRN 67327) in 1993 (courtesy of John Llywelyn Williams)

and test pitting also demonstrated that the summit of the hill had been exploited for axe making, including quarrying of bedrock (Plates 15 and 16), as well as extensive use of the screes (Flook and Williams 1992, Davidson and Williams 1998, Williams and Davidson 1998, Williams and Davidson 2002).

The 1990s work also included the excavation of two cairns to the west of the main outcrop, which proved to have axe-working debris beneath them (PRNs 67326 and 67327 (Williams and Davidson 1998, 17-18)) (Plate 17). A project run by GAT to study the pollen evidence and prehistoric sites on the marshy plateau of Waun Llanfair, found axe-working flakes under two other cairns (PRN 470 and 485), as well as a narrow axe or pick of Graig Lwyd rock under one of the cairns (Caseldine *et al* 2017, 97-101, Caseldine *et al* 2007, 5-8). These finds were associated with flint tools and other evidence of more general occupation, suggesting that a range of activities took place at these sites, and they could be the remains of settlement sites. Our understanding of the vegetation history of the uplands in this area is also based on detailed pollen work carried out as part of this project (Caseldine and Griffiths 2017).

In 1961 there was a rare opportunity to fieldwalk one of the ffriddoedd just east of Dinas, when it was ploughed. Mr J. Davies found axe-working flakes scattered over a wide area, with roughouts, hammerstones and a small number of flint flakes (Davies 1961). This represented one of the most likely Neolithic settlement sites identified in the area (PRN 4720).

Ivor E Davies of Penmaenmawr collected evidence of axe-working, now in Storiel, Bangor, and informed the Royal Commission of the extent of the workings (RCAHMW 1956, xliii). Since the 1990s David T. Jones of Llanfairfechan collected axe roughouts and explored axe-working sites around Llanfairfechan. Mr Jones' collection and knowledge of axe-working sites was recorded in 2017 (Kenney 2017). Mr Jones identified three main axe-working sites: one the screes below the western end of Penmaen Mawr (PRN 67330), on Garreg Fawr (PRN 67328) and in the screes at the foot of Dinas (PRN 67329). Some of his finds were published with John Llywelyn Williams (Jones and Williams 2004, Williams and Jones 2003), and his collection is now in Penmaenmawr Museum. In 2017 GAT carried out a review of the environs of the stone sources, drawing on Mr Jones's work (Kenney 2017). A Management and Interpretation Plan for this landscape was produced in 2018-19 along with a survey of one of the identified axe-working sites (PRN 67329) (Kenney 2019). These studies provide the basis for the current project.

1.5. Palaeoenvironmental Evidence

Our understanding of the vegetation history of the uplands in this area has been enhanced by some detailed pollen work carried out as part of a project on Waun Llanfair. This work includes three pollen columns and samples taken from buried soils under excavated features (Caseldine and Griffiths 2017). This evidence suggests that in the later Mesolithic period Waun Llanfair was covered in hazel woodland with stands of pine on higher ground and alder in wetter areas. Some birch and probably oak was present, with oak woodland with a component of elm at lower levels.

Towards the start of the Neolithic the pine pollen declined, and alder increased. A fire event and drop in hazel pollen suggests an early Neolithic clearance event and there are also hints of pastoral use of the area. A decline in elm pollen occurred at the same time. In the middle Neolithic a decline in oak pollen suggests clearances in the oak woodlands. Although much of the area was wooded there are hints of open heath grassland nearby.

In the later Neolithic there was alder woodland in the wetter areas, oak woodland in the higher valleys and open hazel and birch woodland with some grass and heathland on the high, drier slopes. There was some small-scale clearance with the use of fire and some grazing activity. Barley type pollen was present in a buried soil with Graig Lwyd flakes and could indicate cereal cultivation. Some of the evidence from beneath two cairns that were excavated suggests a more open grass and heathland environment.

Woodland was still present in the area in the Bronze Age, so throughout the period of exploitation of the Group VII stone sources the area was largely wooded with some open areas on the higher slopes. The amount of alder pollen shows that parts of Waun Llanfair were wet during the Neolithic, as they are today, but the presence of trees would mean that more of the area would have been better drained than at present. The trees would also make it a more sheltered environment than at present.

It seems likely that the scree slopes from which the axe material was obtained were never heavily vegetated. The slopes of Dinas, where sheep have been kept off them, have stunted oaks growing on the scree but little undergrowth. The natural screes on the western side of Penmaen Mawr are also wooded but again many areas have little undergrowth, although sometimes considerable amounts of moss. Most of the scree slopes may have been similarly bare in the Neolithic period, making them accessible and suitable stones easy to locate.

1.6. Summary of Fieldwork on the Landscape of Neolithic Axes Project

See Figure 1

In 2019 GAT and the ENPA undertook test pitting in a field just west of site PRN 67329, at the foot of Dinas on Ty'n y Llwyfan Farm. Sixteen test pits were dug by volunteers. This demonstrated that the test pit methodology was efficient at locating evidence of axe-working in the pasture fields. It showed that axe debris was present well beyond the limits of the screes and working seemed to extend over a much wider area than previously assumed (Ryan Young, Smith and Kenney 2020).

Fieldwork was to continue in 2020 and despite the COVID-19 pandemic plans were made for work in October. However, a local lockdown imposed at the start of October made it inappropriate to have volunteers working on the project and the fieldwork was cancelled. The national lockdown over the winter and into March 2021 made it impossible to carry out fieldwork with volunteers later in the year.

Work recommenced in 2021, when a more extensive season of work was undertaken to investigate the Ty'n y Llwyfan site. This included test pitting to investigate the extent of the working and a small evaluation trench to establish the nature and preservation of working floors within the undisturbed natural screes. Test pitting was also carried out on the possible settlement site discovered in 1961 (PRN 4720). This site is referred to as Maes y Bryn and the test pitting provided evidence of axe making but also evidence to support the interpretation of this as a settlement site (Kenney and Smith 2022). Investigation of the Maes y Bryn site continued in 2022, so that a total of 30 test pits has been dug at this site. This confirmed the use of the site for domestic tasks with the discovery of more flint and scrapers made on the Group VII stone. The test pitting at the Ty'n y Llwyfan site was also extended in 2022 and small excavations carried out to further investigate features identified in earlier test pits (Kenney and Smith 2023). The work in 2023 extended the investigation of the wider landscape with test pitting at two other stone sources; Garreg Fawr and an area known as Cors y Carneddau to the south of Graig Lwyd. Further work was also carried out at Ty'n y Llwyfan, including the completion of excavation in the evaluation trench in the Dinas screes (Kenney and Smith 2024).

Plate 18. Volunteers excavating a test pit on Garreg Fawr

Plate 19. Volunteer sieving spoil to recover axe flakes

Plate 20. Volunteers recording a test pit at Ty'n y Llwyfan

2. METHODOLOGY

2.1. Aims and Objectives

The research objectives of the overall project were to contribute to the understanding of Neolithic axe production. Specific aims included identifying the extent of axe-working areas, both the limits of known working areas and identifying the distribution of these areas across the landscape. Other potential aims were to identify contemporary occupation and axe-finishing sites, to locate potential quarrying sites, and to obtain dates from the axe-working sites to contribute to dating the duration of the activity. Not all these aims could be fulfilled in the current work but remain for future projects to tackle. However, the current work succeeded in laying the groundwork for understanding the landscape.

While the project aimed to produce archaeological information to understand a nationally important but understudied landscape, of equal importance was the aim to enable volunteers to engage with this landscape and its prehistory and experience archaeological fieldwork.

The work focused around Dinas, above Llanfairfechan to define and quantify an extensive axe-working location, and to generate an important assemblage for studying how and where working took place. This included excavation on the source screes and test pitting beyond the screes to contrast activity and characterise the levels of preservation and disturbance of deposits. Other stone sources on Garreg Fawr and around the margins of Waun Llanfair were investigated to provide comparative assemblages and explore the extents of the axe-working areas. Investigation of the Ffridd Tan y Graig site on Penmaen Mawr by David Thorpe, who started as a volunteer on the project, has also contributed to this objective by providing roughouts from another source for comparison. A settlement site on which axe making took place was also investigated and some hints of settlement activity have been identified at the source sites, resulting in the beginnings of a landscape perspective.

2.2. Fieldwork

Test pitting

An extensive test pit survey was at the heart of the fieldwork programme. Test pits allow the investigation of deposits obscured beneath pasture and other vegetation in a rapid but controlled manner. Additionally, they provide the opportunity for volunteers of varying experience and ability to be involved in excavation and recording, generally without having to deal with complex features and layers. The test pits were used to identify the quantity and character of axe debris across the areas to be sampled. They enabled the layers with the highest concentrations of debris to be identified and foci of activity to be located.

The test pits measured 1m square (Plate 18) and were generally situated with the sides facing the points of the compass for consistency and easy recording with volunteers, although in some cases, where it was thought more useful, they were orientated down the slope. The turf from each pit was removed by hand and stacked nearby for reinstatement after the excavation was complete. The spoil from within the pit was removed stratigraphically by layer, sieved onto a tarpaulin, using a sieve with a 1cm mesh, and any artefacts found were retained (Plate 19). The test pits were generally excavated down to the natural subsoil, though occasionally this was not reached. The layers within the pit were then recorded on simplified context sheets, using a booklet produced specifically for this project (Plate 20). The numbering system on this project for both contexts and finds uses the pit number as a prefix e.g. (901)

is the first context within test pit 9. Where the section was of interest a section drawing was created at a scale of 1:10. If there were features of interest in the base of the test pit then a post-excavation plan was drawn, at scale of 1:10 or 1:20. All the test pits were photographed during and after excavation. Stony layers were photographed in plan before excavation and at least one representative section was photographed for each pit. The test pits were located using a survey quality Trimble Global Positioning System (GPS).

The excavation and recording of the test pits were carried out by volunteers under the supervision and guidance of GAT and ENPA archaeologists. In some cases, test pits were laid out on a grid or in transects, but often vegetation made this impossible. At the Ty'n y Llwyfan site test pits were laid out in relation to topographic features. Test pits 86, 87, 94, 97 and 98 were dug to allow the school children and YAC members to carry out excavations. They were positioned in locations already known to have a high density of artefacts and they were not dug to full depth.

See the appendices of the yearly reports for location, depth and context detail of each test pit. The fields at Ty'n y Llwyfan are identified using the traditional fieldnames; Roland and Gareth Wyn Jones kindly informed the author of the names.

Table 1. Summary of test pitting sites

Site name	Central NGR	Location	Date of fieldwork	Number of test pits
Ty'n y Llwyfan: Cae Graig	SH 698 739	Foot of Dinas	13th to 20th November 2019; 6th to 18th October 2021; 20th September to 4th October 2022	60
Ty'n y Llwyfan: Cae Dafydd	SH 696 739	Field below Cae Graig	20th September to 4th October 2022	8
Ty'n y Llwyfan: Cae Bach/ Cae Uchaf	SH 6980 7402	Foot of Dinas, north of Cae Graig	25th September to 6th October 2023	18
Garreg Fawr	SH 6888 7335	An area at the foot of the crags on Garreg Fawr	10th to 14th July 2023	14
Cors y Carneddau	SH 7143 7474	Part of the south facing slope between Graig Lwyd and Clip yr Orsedd	17th to 21st July 2023	16
Maes y Bryn	SH 705 738	On plateau east of Dinas	22nd to 28th September 2021; 4th to 8th July 2022	30

Evaluation trench and other small trenches

Roughouts and axe-working flakes had been recovered from the screes at the foot of Dinas on its western side. This area (PRN 67329) had been surveyed in 2018 to record surface features and locations where axe debris was visible on the ground surface (Kenney 2019). This showed that the natural screes in this area had been used as a source of stone for making axeheads and these had been worked in this area. However, the nature, depth, and preservation of archaeological deposits in this area could not be determined from surface inspection alone. An evaluation trench was therefore dug to investigate this in 2021 and was completed in 2023.

The evaluation trench (T31) was located towards the southern end of the previously surveyed area where small axe-flakes were visible on the surface, suggesting that the area may not be seriously

Plate 21. Volunteers excavating trench 31 (© ENPA)

Plate 22. Volunteers excavating trench TP73

Plate 23. Volunteer annotating the orthomosaic for trench 75 to record the location of axe debris

disturbed (Plate 21). The trench measured 4m by 2m and was laid out running directly down the slope across a slight terrace. At the end of the 2021 season, it was covered with plastic sheet and backfilled, and reopened in 2023. Excavation was carried out by volunteers under supervision and they also bagged and recorded finds, annotated the plans, and assisted with surveying.

The deposits were carefully excavated in thin spits, which coincided with layers where possible. Loose flakes recovered during cleaning were bagged and plotted with the Trimble GPS. When cleaning down to the top of a spit an attempt was made to keep flakes *in situ* as much as possible. When a spit was cleaned, as well as general photographs, numerous photographs were taken for photogrammetry. Targets were laid out and surveyed in with the Trimble GPS and were included in the photographs. The Agisoft Metashape Professional program was used to combine the photographs to create a 3D model of the site. This was georectified using the surveyed targets. From this data an orthomosaic could be produced. This is a combined, perfectly horizontal image exactly to scale and georectified. This image was traced onto drafting film and annotated in the field to show which items were flakes and which were roughly flaked blocks. Find numbers were also added as finds were lifted.

Planned finds were lifted before excavating the next spit. Flakes, roughouts and smaller or more complex flaked pieces were bagged for further study. Larger blocks, which had been only roughly worked with one or two flakes removed, were recorded on site. These were photographed, measured and weighed then discarded on the spoil heap and used to backfill the trench. They were marked on the annotated plans.

The quantity of material and care needed to excavate each spit meant that the scree deposit was not fully excavated across the whole trench. However, to investigate lower deposits a narrow sondage was dug down the north-east side of the trench. This demonstrated the depth of the scree and allowed a view of deposits over which the scree had built-up. The sondage reached a depth of 1.0m, beyond which it was not safe or practical to continue digging.

Soil from the trench was deposited on a plastic sheet alongside the trench, allowing for easy backfilling once the excavation was complete. On final backfilling no plastic or geotextile was placed in the trench, as it was considered unacceptable to leave plastic in the ground over the long term.

In Cae Graig, Ty’n y Llwyfan test pits indicated areas worth further investigation, and this was achieved by using small trenches, part-way between test pits and evaluation trenches. A 2m by 2m trench (TP39) was dug to recover more material from a shelf on a natural scarp, where TP15 had shown there was a concentration of material. This was dug in the same way as the standard test pits. Another 2m by 2m trench (TP 73) was positioned to investigate an area of charcoal found in TP16 (Plate 22). This trench was excavated in the same as the test pits, but excavation stopped when undisturbed natural scree was reached. This trench was recorded in plan by photogrammetry (as described above) to produce a geolocated and accurately scaled orthomosaic. The orthomosaic was printed out and annotated on site and used to draw up the final plan of the trench. Two sections of the trench were drawn at a scale of 1:10.

Trench 75 measured 3m by 2m and was positioned over test pit 37 to investigate a dense deposit of stone and axe debris located in that test pit. In this case the main aim was to expose the surface of this deposit to determine its extent. The surface of the stone layer was recorded using photogrammetry. Axe debris present in the surface of this deposit was collected and the location of each piece marked on the orthomosaic (Plate 23). Part of the deposit was removed along the western side of the trench to expose a line of larger stones, which were then also recorded in plan by photogrammetry. A sondage was dug against the northern side of the trench to obtain a section through the deposits and reveal more

Plate 24. Volunteers washing axe debris

Plate 25. Pupils from Ysgol Capel Ulo helping to dig test pits

information about how they had built up. This section was drawn at a scale of 1:10. As the limits of the stone deposit were not fully seen within trench 75, two trenches measuring 1m by 2m were dug to the north and south of trench 75. These trenches (TP 85 and 89) were excavated down to the surface of the stone deposit, which was recorded in plan by photogrammetry, but no finds were collected from this deposit in these trenches. In trenches 75, 85 and 89 axe debris was recovered from the topsoil and ploughsoil by sieving in the same way as the test pits, and all layers in the sondage dug through the stone deposit in trench 75 were sieved for axe debris and all material collected. In all these small trenches photography was used for recording the excavations and descriptions of the deposits were made.

As with the test pits excavation and recording was carried out by volunteers under the supervision and guidance of GAT and ENPA archaeologists

Table 2. Summary of small trenches

Trench	Central NGR	Location	Date of fieldwork
T31	SH 69845 73922	In screes immediately east of Cae Graig	6th and 14th October 2021 25th September to 5th October 2023
TP39	SH 69763 73968	Shelf on natural scarp, Cae Graig	6th and 18th October 2021
TP73	SH 69758 73888	On lower terrace, Cae Graig	20th September to 4th October 2022
TP75, 85, 89	SH 69779 73950	On upper terrace, Cae Graig	20th September to 4th October 2022

2.3. Post-excavation work

Volunteers undertook the cleaning and cataloguing all the finds (Plate 24). Finds were washed, dried, weighed and counted. Finds were catalogued on a spreadsheet. George Smith then inspected a sample of the collection and assessed the material (see the yearly reports for the assessment of the axe debris).

The fieldwork has produced an assemblage of national importance. To provide detailed and informed analysis and obtain the maximum information, funding from the 2023 Collaborative Doctoral Awards Competition of the White Rose College of Arts and Humanities (Universities of Leeds, Sheffield and York) was obtained by Bob Johnston of Sheffield University for a PhD student to study the Group VII axe sources. The studentship is designed as a partnership with the Carneddau Landscape Partnership Scheme / ENPA and one of the main aims is for the student to carry out a detailed study of the axe debris from this project. Rebecca Vickers was appointed as the PhD student and started work in October 2023.

Rebecca is using data from a reference assemblage to inform the analysis of the archaeological assemblage. The reference assemblage was produced specifically for the study by a skilled experimental archaeologist (James Dilley), who was recorded while making axe roughouts and explained his processes and decision making throughout. The analysis methodology involves sorting the debitage into size categories and recording four attributes (platform type, bulb of percussion type, flake profile and knapping errors). The completeness of flakes is also recorded and the presence of any intentional retouch (see Appendix I for detailed methodology). Rebecca will also analyse roughouts produced by the project and compare them to other Group VII roughouts recovered from previous excavations at Graig Lwyd and found from sites away from the sources.

Post-excavation work studying finds other than axe debris, obtaining radiocarbon dates and pulling together the descriptive and interpretative text on the fieldwork has been carried out by GAT and the results are included in this report. The prehistoric pottery has been studied by Frances Lynch, Roman pottery by Gill Dunn, and the flint and stone items by George Smith. Selected artefacts have been professionally illustrated. The assemblage of metal-working debris, mainly from TPs 16 and 73 was assessed and catalogued by Tim Young of GeoArch, who recommended further analysis of material from TP73. The further analysis included bulk elemental analyses of samples of the smithing slag and hearth ceramic, with two SEM mounts of coarse hammerscale considered in the assessment to be unusual.

Four bulk soil samples that were collected were considered worth processing. These have been processed using the standard GAT wet sieving and floatation methodology with flots recovered in a 250-micron sieve. The residues from the processing were sorted to recover any finds, which were included in the analysis by the relevant specialists. The flots were sent to AOC Archaeology for the analysis of the charred plant remains and suitable items were selected for radiocarbon dating. Six AMS dates were obtained from the Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Laboratory on material from the four soil samples; two dates each from pits [7307] and [11605] to obtain dates for activity represented in the pits, one date from hearth 12903 and one date from deposit 8804 at the base of the upper lynchet in Cae Graig. The material chosen for dating was generally short-lived material, though only oak was present in pit [7307] and deposit 8804, so oak charcoal had to be selected with the risk that these may be dates on old wood.

A summary of finds from each test pit are listed in Appendix II.

2.4. Outreach

A major aim of the project was to enable volunteers to engage with the landscape and its prehistory. The focus was therefore very much on providing an opportunity for volunteers of all ages, backgrounds and abilities.

Adult volunteers were recruited and managed through the CLPS, with onsite training, supervision and management by GAT and ENPA staff. CLPS also funded welfare facilities and the site vehicle. Some volunteers came for a day or two and some for the duration. As well as excavation the work provided an opportunity for volunteers to learn recording, photography, finds identification, section drawing and occasionally GPS survey. Volunteers undertook the daunting task of cleaning and cataloguing all the finds. This responsible task involved the use of an Excel spreadsheet and the sorting of finds into an organised system, giving them a good experience of the nature of post-excavation archaeological work.

Table 3. Volunteer involvement

Number of adult volunteers	Fieldwork phase
46	July 2023
28	September 2023
28	July 2022
54	September/October 2022
16	September 2021
51	October 2021
39	November 2019
7	Finds processing 2023-24
6	Finds processing 2022-23
5	Finds processing 2021-22

2	Finds processing 2019-20

Local primary schools have been involved throughout the project. Pupils have taken part in the test pitting but have also had in school sessions to introduce them to the Neolithic period and archaeology, and follow-on sessions involving learning to record axe flakes from the project (Plate 25). Test pitting, especially where there is a good chance of finding artefacts, is well-suited to younger audiences and the sessions produced a considerable number of axe flakes and some special finds.

The school programme was funded by the National Lottery Heritage Fund through the Carneddau Landscape Partnership Scheme and delivered by Dan Amor, Sian Evans and Bethan Jones of GAT, with the assistance on site of Rhys Mwyn and CLPS staff. There were also Young Archaeologists' Club sessions on site in 2021 and 2022.

Table 4. Local school involvement

School	Number of pupils involved	Year
Ysgol Pant y Rhedyn, Llanfairfechan	66	2023
Ysgol Pencae, Penmaenmawr and Ysgol Capel Ulo, Dwygyfylchi	63	2022
Ysgol Pant y Rhedyn, Llanfairfechan	70	2021

Public walks and talks have been carried out throughout the project to inform people about the work.

2.5. Archiving

Reports have been produced each year, and these have been submitted to the Gwynedd Historic Environment Record (HER). This submission has followed the HER submission procedure including a submission spreadsheet with sites to be added to the HER, including a summary of each site, which is translated into Welsh, as are the site names. Sites reported on in previous years are therefore already included on the HER.

The digital archive will be submitted to RCAHMW for long term curation, along with the paper archive. The finds will not be deposited in a museum until the completion of the analysis on the axe debris, so that the possibility of all finds being deposited in a single museum can be explored. Discussion with potential receiving museums will take place and a discard policy will be devised. The retained material will be deposited with the museum. It would be ideal for this museum to be Penmaenmawr Museum, but their storage space is limited, and discussions will be held with other museums, particularly the National Museum, to determine whether a larger proportion of the assemblage can be retained.

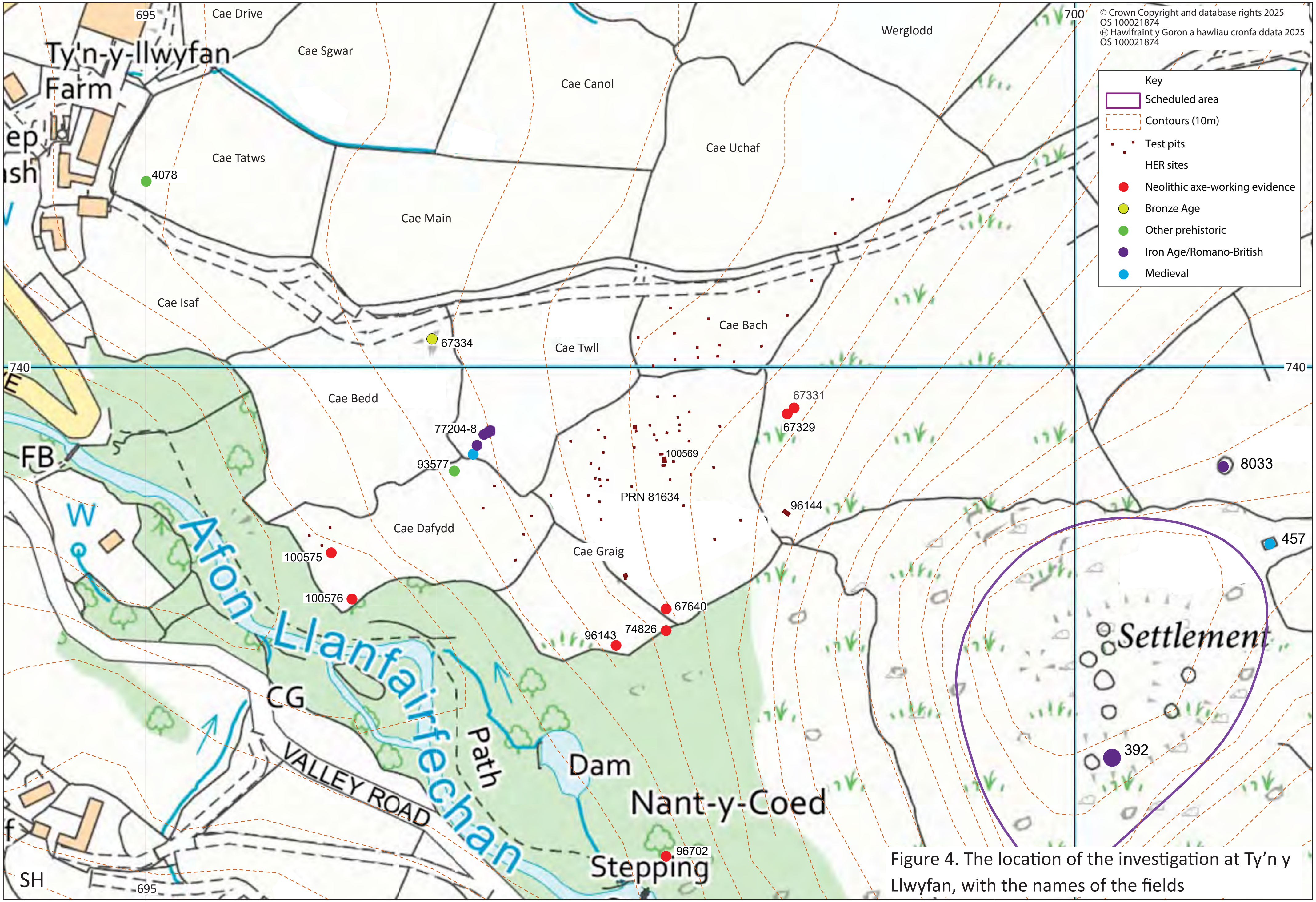


Figure 4. The location of the investigation at Ty'n y Llwyfan, with the names of the fields

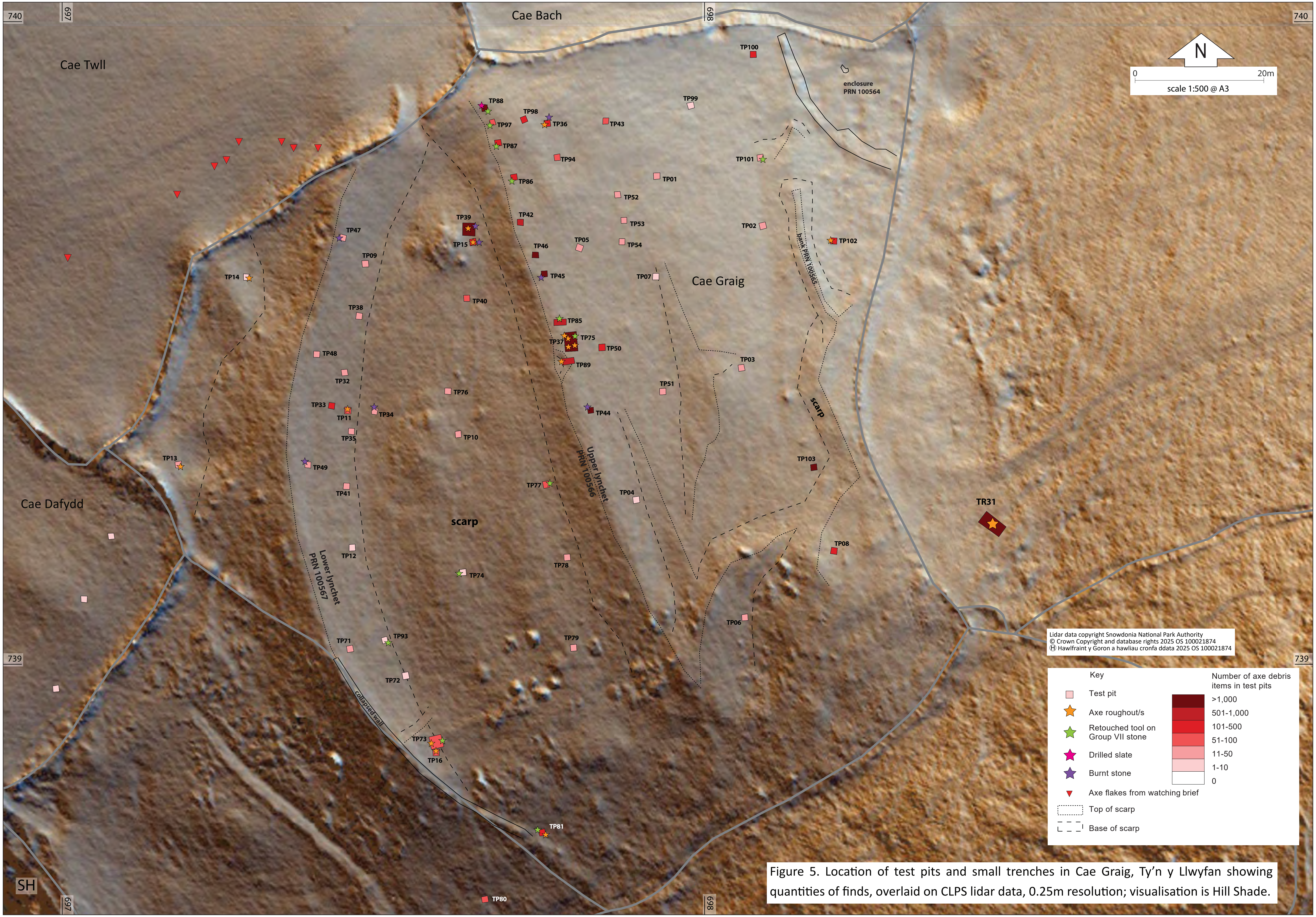


Figure 5. Location of test pits and small trenches in Cae Graig, Ty'n y Llwyfan showing quantities of finds, overlaid on CLPS lidar data, 0.25m resolution; visualisation is Hill Shade.

Plate 26. Dinas showing the bare screes (© ENPA)

Plate 27. Test pitting in Cae Dafydd (CLPS)

Plate 28. TP102 from the west, showing natural scree immediately below the turf

3. RESULTS

3.1. Ty'n y Llwyfan

Topography
Much of the southern, eastern, and western sides of Dinas are covered in natural screes that are bare and unvegetated (Plate 26). On the northern side, where the slopes are covered in grass, there is still scree under the vegetation in places. In the improved fields below the western side of the hill the continuation of scree under the turf is indicated by the uneven ground surface, with glacial till forming the substrate under the rest of the fields. However, it is not always possible to identify the presence of scree from the surface when ploughing has caused the formation of lynchets across the slope.

Much of the work in this area concentrated on a field (Cae Graig) that lies just on the boundary between scree and glacial till at the western foot of Dinas (Figure 4). In total 60 test pits and four small trenches were dug across Cae Graig (PRN 81634). Investigation continued into a field (Cae Dafydd) further west, down the slope, where 8 test pits were dug (PRN 100575), and to the north of Cae Graig (in Cae Bach and Cae Uchaf), where 18 test pits were dug.

The lower part of Cae Graig slopes steeply but running across it are two lynchets (terraces formed by ploughing on a slope), probably of Iron Age date (Figure 5). The upper lynchet (PRN 100566) runs nearly north-north-west to south-south-east but slopes up hill. The lower, northern part of this terrace is about 19m wide, but the southern part of the terrace is only about 7m wide. However, it ranges in height from about 1.5m at the northern end and 3.5m at the southern end, so the narrower part of the terrace is the higher. The lower lynchet (PRN 100567) curves around the hill slope. The terrace of this is fairly flat and level and up to about 11m wide. The height of the lower lynchet is harder to determine as it merges with the hill slope, but in places it appears to be about 6m high. These lynchets have been created by soil movement as a result of ploughing, but it is also probable that the faces of the lynchets were revetted with stone.

Along the eastern, upper side of the field is an irregular scarp formed by the underlying scree, though the scree does seem to extend a little west of this. Running almost north from the scarp, down the hill slope, is a low stony bank (PRN 100565), nearly parallel to the upper lynchet. This bank ends near a curving, heavily denuded stone wall that forms a small enclosure of uncertain date in the north-eastern corner of the field (PRN 100564).

These traces of ploughed lynchets and enclosures show that although this is a steep field it was fairly heavily used for agriculture in the past and this will have influenced the distribution of axe debris found. The latest ploughing of the field occurred in the 1970s and included the steep scarps (Gareth Wyn Jones, pers. com.). Along the south-eastern side of the field there is exposed scree or scree under a thin layer of soil, and it is covered with oak trees of considerable age.

To the north of Cae Graig the fields, Cae Bach and Cae Uchaf (Figure 6), are less steeply sloping, with a more gradual slope down from south-east to north-west. Cae Bach also slopes up towards the boundary with Cae Graig, with a slight platform just north of the wall.

The lower field, Cae Dafydd, slopes steeply down from east to west (Figure 7, Plate 27). It has no evidence of ancient fields running through it, though it has obviously been ploughed, more intensively so than Cae Graig. There are two natural shelves in the slope and the field becomes more level towards the lower, western end. This field runs along the northern side of the steep gorge formed by the Afon Llanfairfechan. Access to this gorge would have been very difficult from this field in most places but in

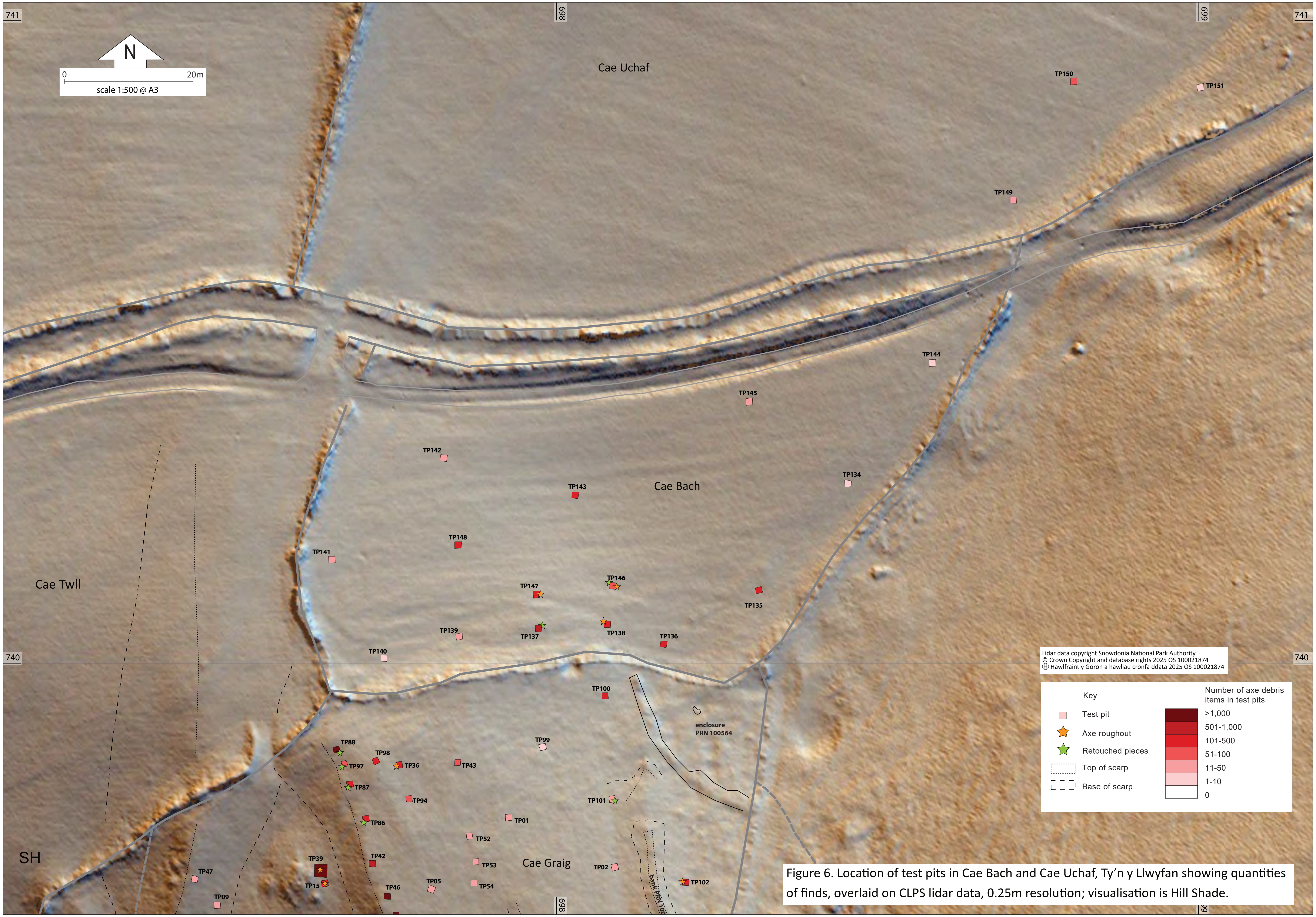


Figure 6. Location of test pits in Cae Bach and Cae Uchaf, Ty'n y Llwyfan showing quantities of finds, overlaid on CLPS lidar data, 0.25m resolution; visualisation is Hill Shade.

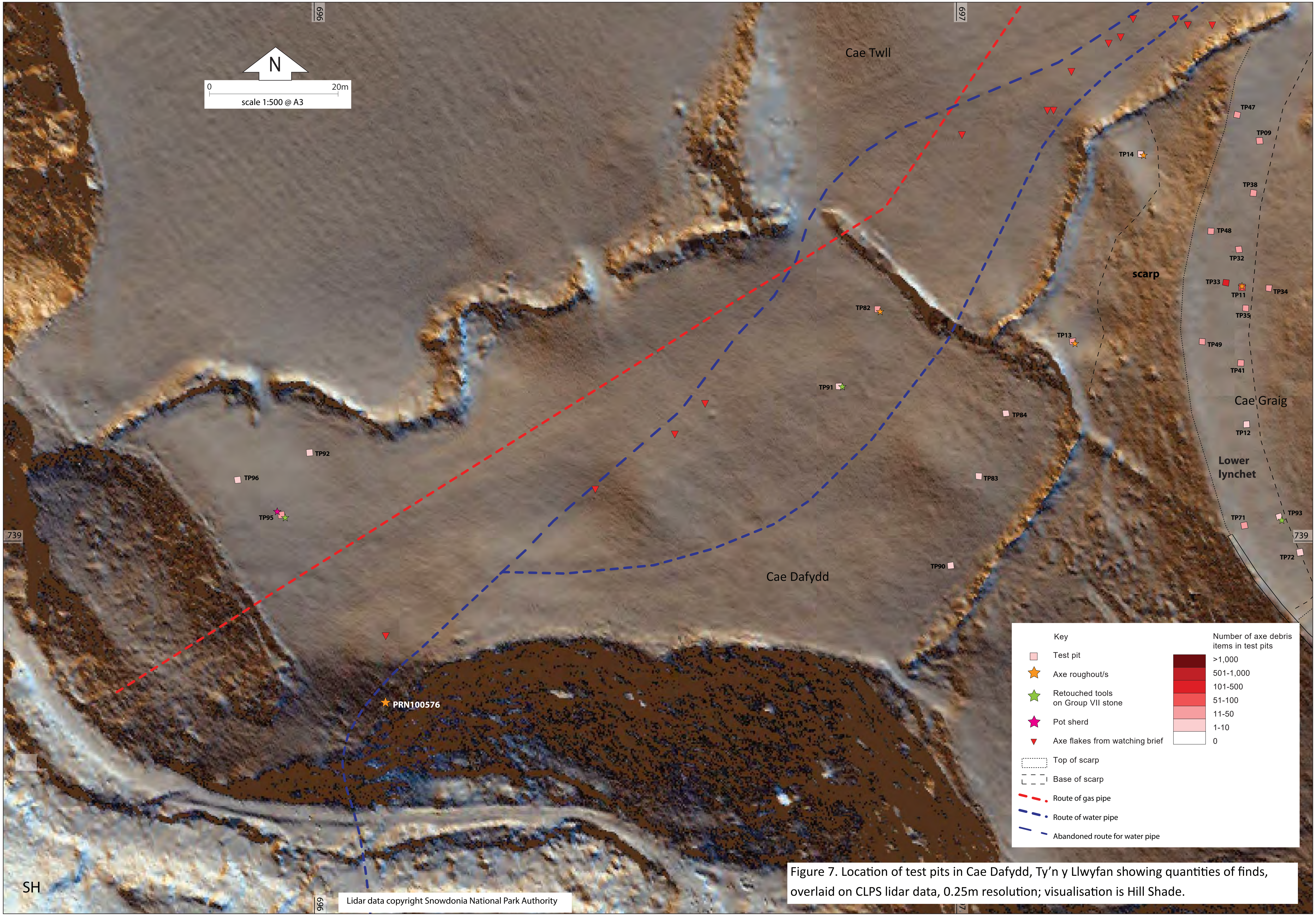


Figure 7. Location of test pits in Cae Dafydd, Ty'n y Llwyfan showing quantities of finds, overlaid on CLPS lidar data, 0.25m resolution; visualisation is Hill Shade.

Plate 29. South facing section of TP80, showing depth of scree

Plate 30. Roughout (SF8103) *in situ* in TP81, from the south

Plate 31. TP100 from the west showing scree under a depth of ploughsoil

its lower corner the slope is much less steep, providing a natural ramp down to the river. A high-pressure gas pipeline runs across the field. In 2018 a mains water pipe was replaced and laid along a new route. The route across this field was monitored by Aeon Archaeology (Dean and Cooke 2019) and some Roman period features were found near the gateway, so the route was abandoned and another route created running round the edge of the field, in which the pipe was laid. The test pitting in this field had to avoid these three service routes to avoid any possible damage to the pipes and to avoid digging through already disturbed ground. During the watching brief on the water pipe route some pieces of axe debris were found.

Cae Graig (PRN 81634, overall site centred on SH 6978 7397)

See Figure 5

The screes

Several test pits were dug to locate the edge of the screes and to investigate the nature of the scree and the type of working within it. Along the eastern side of the field TP08 and TP102 were dug into scree buried under about 0.15m of turf and topsoil (Plate 28). TP102 was dug to a depth of 0.35m then abandoned as further excavation was too difficult, but TP08 showed the scree to only be about 0.2m deep. Test Pits TP80 and 81 investigated the scree under the trees on the south-eastern side of the field. Here the ground slopes very steeply but there are slight terraces within the slope. Most of these could be natural but TP81 was on the edge of a shelf that had been used as a field boundary. Scree was reached in TP80 0.27m below the surface but it was directly under the turf in TP81. In TP80 the scree was 0.25m deep (Plate 29), and in TP81 it was about 0.3m deep, with a loose colluvial layer and glacial clay below. The scree layer, at least along the south-eastern side of the field, is therefore relatively thin. All these test pits produced considerable quantity of flakes, and roughouts from TP102 and TP81 (Plate 30). There were many large pieces from primary flaking, which must have been taking place directly on the scree. Numerous roughouts are visible in the open screes under the trees all down the south-eastern side of the field and around TP08.

On the eastern side of the field the edge of the scree was indicated by a slight scarp, but this was not visible at the northern end and scree was seen to be obscured under ploughsoil. No scree was seen in TP01, TP02, TP03, TP99 and TP103, but test pits TP100 and 101 had natural scree; TP100 had up to 0.4m of ploughsoil overlying the scree (Plate 31). The field slopes down towards its northern boundary and ploughsoil has moved downslope and built up against that northern boundary, completely burying the scree in this area, with TP 100 and 101 near the edge of the scree deposit. TP06 was located on a sloping shelf on the edge of the area of obvious scree. This had about 0.2m of loose scree and seemed to be on the edge of the main scree deposit. While there were very few pieces of axe debris in TP99, there was a scatter of finds from TP01, TP02, TP03 and TP101 (including a retouched flake), with a considerable number in TP100 and 103.

Lynchets

Test pits on the upper lynchet showed that deposits on the uphill side of the terrace are generally fairly shallow (TP07, 51, 52, 53 and 54 were no more than 0.3m deep down to the natural glacial clay) and that the downhill edge is very deep (TP 42, 44, 45 and 46 had depths between 0.72m and 1.05m, though TP04 was only 0.45m deep) (Figure 8). The difference in depth is due to a build-up of colluvial deposits moved downslope through the action of ploughing. At the lowest levels the soil movement was probably through natural processes. Large quantities of axe debris were recovered from the downhill test pits, throughout the full depth of the lynchet deposits, and very little from the uphill ones. While there was axe debris found throughout the lynchet deposits the quantity in the ploughsoil showed that some had moved relatively recently, as demonstrated by the find of a roughout in the ploughsoil in TP36 (Figure 9).

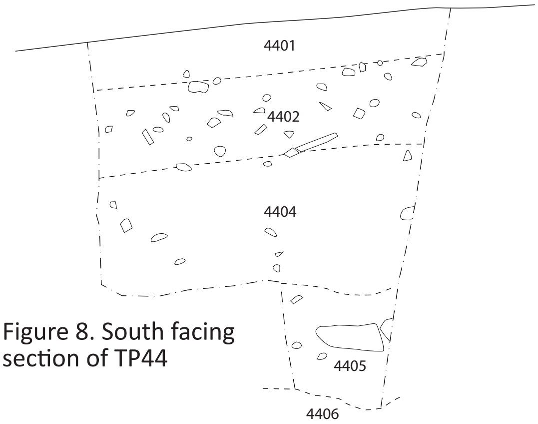


Figure 8. South facing section of TP44

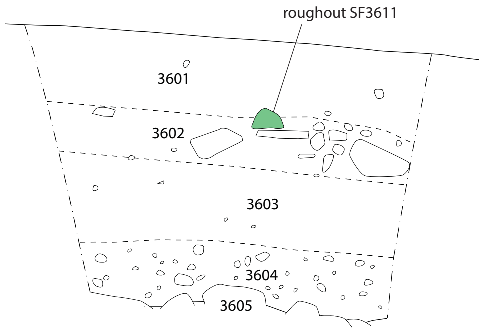


Figure 9. West facing section of TP36

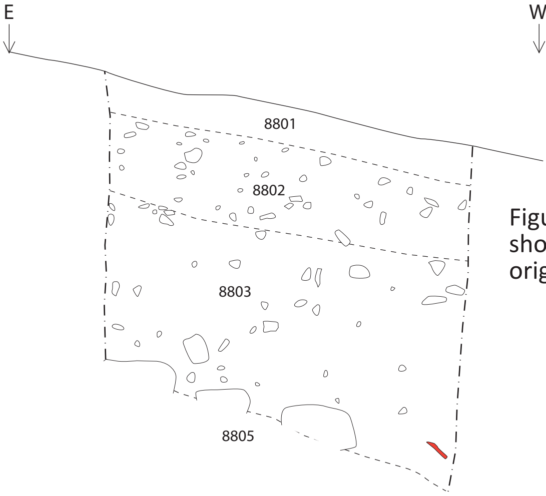


Figure 10. North facing section of TP88, showing colluvium (8803) and the original slope of the glacial clay (8805)

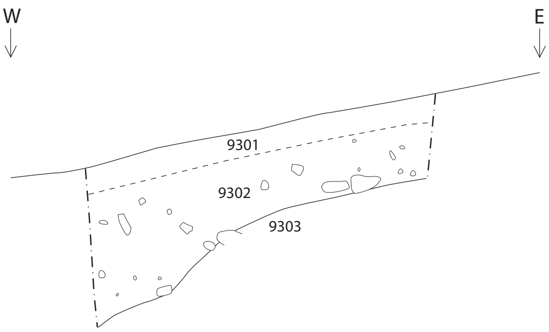


Figure 12. South facing section of TP93, showing shallow deposits on uphill side of lower lynchet

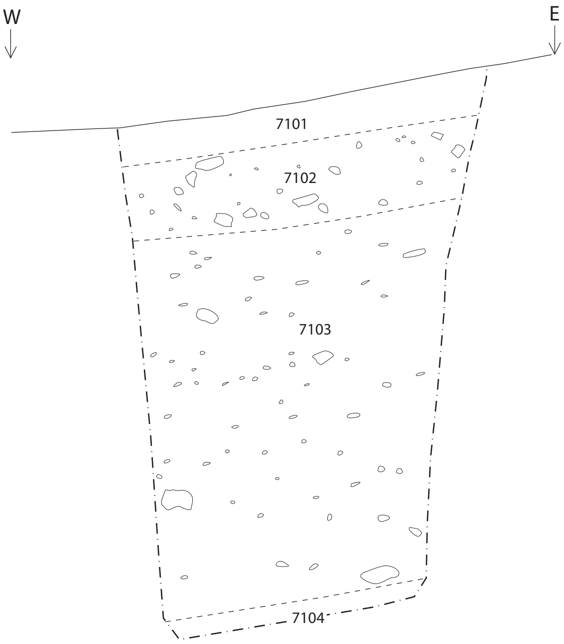
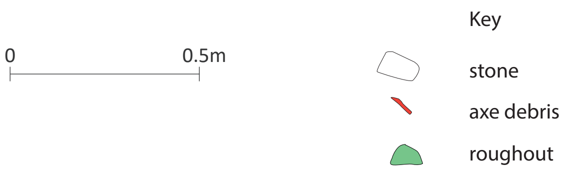


Figure 11. South facing section of TP71, showing depth of lower lynchet deposit



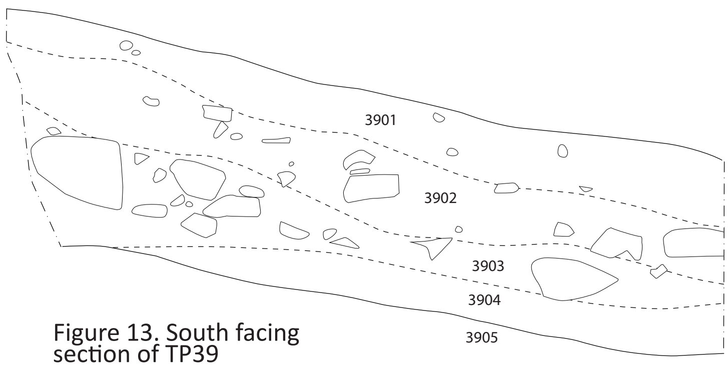


Figure 13. South facing section of TP39

Plate 32. TP88 showing its location on the edge of the upper lynchet

Plate 33. South facing section of TP71, showing depth of deposits

Test pits 86, 87, 94, 97 and 98 were dug to allow the school children and YAC members to carry out excavations and they were not dug to full depth. However, they confirm the density of axe debris at the northern end of the upper lynchet, and not just at the edge of the lynchet. TP88 was dug to a full depth of 0.9m and had a lower ploughsoil or colluvium layer 0.52m thick under the more recent ploughsoil (Plate 32, Figure 10). This layer (8803) was a mid-yellow-brown clayey silt with c.20% small stones and gravel and occasional flecks of charcoal. The interface between this and the natural clay was given context 8804 and some charcoal was also present at this level. The whole test pit was particularly rich in axe debris but layer 8803 had a high concentration of small flakes suggestive of fine working. This layer also produced a small piece of slate with three unfinished drill holes (SF8805). While this is very difficult to date its presence low down in the test pit in association with quantities of axe debris means that it could be of a Neolithic date (see Section 4.4 below).

The lower lynchet showed a similar profile. TP47, TP48, TP49 and TP71, located on the terrace edge, were between 0.71m and 1.35m deep, while test pits TP11, TP12, TP32, TP34, TP35, TP38 and TP72, located at the uphill side of the terrace, had depths between 0.30m and 0.36m, though TP09 was 0.53m deep. Colluvial deposits having built up to create the terrace, which is fairly level and clearly has been repeatedly ploughed. For example, test pit TP71 on the outer edge of the southern end of the terrace (Plate 33, Figure 11) had 0.12m of turf and topsoil, 0.30m of ploughsoil, described as dark brown silt with c.50% small stones, and 0.90m of colluvium, a mid-yellow-brown silt with c.50% small stones. In comparison, TP93 located on the uphill side of the terrace exactly opposite TP71, was 0.54m deep on the western side but its depth was largely due to including a steep part of the base of the hillslope (Figure 12).

The lynchet narrows at its southern end towards a pointed corner. Just before this corner is a scarp running perpendicularly across the terrace. This scarp is about 0.3m high and fairly well-defined (Figure 5). It seems to form a small headland where most ploughing along the terrace stopped. The remains of a collapsed field wall run along the edge of the terrace at this point and can just be seen continuing under the trees to the south-east. This wall is part of a boundary that ascends the slope from the north-west, but it is possible that where it runs along the edge of the terrace it incorporates some of the original terrace revetment. However, there are no stones visible along the rest of the terrace, so it is not confirmed that this was revetted.

While none of the test pits on the lower lynchet were as productive as those on the upper lynchet, the northern part of the lower lynchet did produce a general scatter of axe debris. There appeared to be a concentration of activity around TP33 and TP11, including a roughout from TP11. In contrast the test pits on the southern end of the lynchet produced little axe debris and there seems to have been no axe production activity over much of this part of the field.

Just below the scarp of the lower lynchet two test pits were dug (TP13 and TP14). These were 0.43m and 0.50m in depth. TP14 only produced 5 pieces of axe debris but TP13 produced 42, and both had roughouts. Axe flakes recovered from the watching brief on the water pipe trench also showed that axe debris extended further down the slope into Cae Twll. This may indicate working a considerable distance from the edge of the screes.

A soil sample was taken in TP88 on the upper lynchet from the interface (8804) between the ploughsoil/ colluvium of the lynchet make-up and the glacial clay. This was not a well-defined layer but was probably part of early colluvial movement underlying the lynchet and essentially part of the soil buried under the lynchet as it developed. The charred plant remains from this sample were few but there were three charred weed seeds, one of which was identifiable as dock (see Section 4.9 below).

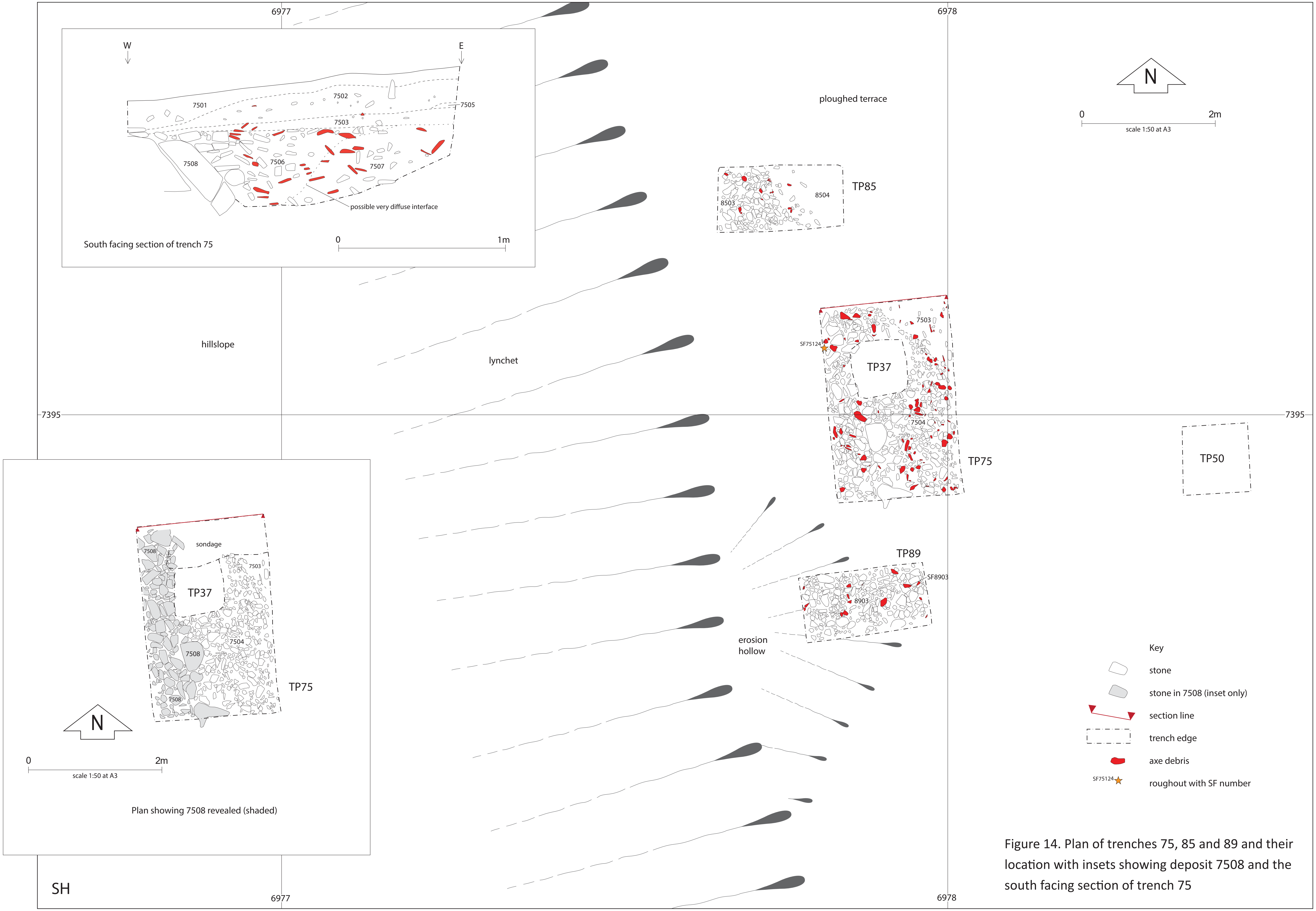


Figure 14. Plan of trenches 75, 85 and 89 and their location with insets showing deposit 7508 and the south facing section of trench 75

Plate 34. Trench 75 from the east, showing stone deposit 7504. The square hole is TP37 dug in 2021.

Plate 35. Trench 75 from the south, showing larger stones 7508 exposed in the western part of the trench

Plate 36. South facing section of trench 75

This could suggest disturbance and even agriculture prior to the build-up of the lynchet. There was also a small amount of oak charcoal, which was dated and produced a middle Bronze Age date (SUERC-130056, 1380-1120 cal BC) (see Section 5 below). As all the deposits in the lynchet have moved downslope and therefore been significantly mixed and the interface layer also appears to be a colluvial deposit the origin of the dated material is unclear, but it is suggestive of the soil below the lynchet being exposed and in use during the Bronze Age. This would be consistent with an Iron Age date for the lynchet and suggests that this is not a Neolithic lynchet despite the quantity of axe material mixed into it.

Trenches 75, 85 and 89 (PRN 100569, centred on SH 69779 73950)

Part of the upper lynchet was investigated in more detail because TP37 revealed layers of densely packed stone including natural scree and large quantities of axe debris under just 0.2m of topsoil and ploughsoil. The stone deposit was at least 0.77m deep but was not bottomed in the test pit. Small trenches were excavated to explore this stone deposit. Trench 75 was positioned over TP37 and measured 2m by 3m, and trenches 85 and 89 were positioned to the north and south of this to try to locate the limits of the deposit (Figure 14).

In trench 75, under 0.09m of turf and topsoil, was 0.16m of ploughsoil (7502). Under 7502, in the north-east corner of the trench, was a 0.10m thick patch of reddish-brown silty loam with numerous flecks of charcoal (7505), which extended up to 0.3m into the trench. This was probably the result of bioturbation, possibly under an area of scrub burning, though part of a ceramic tuyère (SF75131) was recovered from this layer. Beneath this was another 0.10m of ploughsoil (7503), similar to that above but more orange in colour and stonier. This lay directly on the dense layer of stone (Plate 34). This stone deposit (7504/7506) was composed of at least 80% stones and axe debris in a brown silty loam matrix. The stones were densely packed and up to 0.20m long. A high proportion of the deposit was composed of axe flakes and other axe debris, including a roughout (SF75124). This deposit was recorded in plan and axe debris on the surface of the deposit was lifted and individually numbered and marked on the plan. Most of the flakes on the surface of 7504/7506 lay horizontally, but many of those throughout the deposit also lay fairly level or slightly sloping. Flakes and other debris were distributed throughout the deposit with no obvious layers purely of flakes.

In the western part of the trench 7504 overlapped a rough line of larger stones. Some of 7504 had probably slumped downslope and a thin layer of it covered larger stones along this side of the trench. Deposit 7504 was removed in this area to expose deposit 7508, sub-rounded and sub-angular stones up to 0.45m long with a dark brown silty loam matrix (Plate 35). These stones were generally unworked, though there were some flakes between them. In a sondage dug along the northern side of the trench, 7508 could be seen more clearly. Some of the larger stones seemed to have been stacked against each other, sloping down from west to east, with medium sized stones packed around them (Figure 14, inset). It appeared that the larger stones had been dumped to form a linear deposit with the smaller stones (7504/7506) had built up against these. A very large stone just projected through the grass at the southern end of the trench formed part of this linear deposit.

In the north-eastern corner of the trench a limit could be seen to the stones 7504/7506 with a less stony deposit (7507) lying beyond. This was an orange-brown silty loam with occasional small stones and some flakes, but much fewer stones and flakes than 7504/7506. However, in section the difference between 7506 and 7507 was very difficult to determine (Plate 36). A very diffuse interface could be defined where the quantity of stone became less (Figure 14 (inset)), but it appears most likely that 7504/6 and 7507 were actually part of the same deposit that had become sorted as it moved down slope with more stones settling out in the western part and towards the top of the deposit.

Trench 85 showed that the stone deposit continued north, here recorded as 8503, but its north-eastern limit could also be seen with the less stony deposit (8504) beyond (Figure 14, Plate 37). Flakes and other worked pieces seen in the surface of 8503 and 8504 were recorded on plan but no finds were recovered. The stone deposit was seen in trench 89 about 0.3m below the ground surface (Plate 38). Here it was recorded as 8903 and again flakes visible in the surface were recorded but not lifted, except for a roughout (SF8903).

The stone deposit therefore seems to run roughly along the edge of the upper lynchet, but its north-east limit is not exactly parallel to the lynchet edge, and it could extend some distance from the edge of the lynchet to the south. However, no trace of this deposit was seen in TP50, so it cannot have extended that far. A hollow in the top edge of the lynchet was not related to the underlying deposits and seems to have been a superficial erosion hollow.

The stone deposit (7504, 8503 and 8903) appears to be integral to the structure of the upper lynchet. The top of this deposit defines the height of the lynchet and the larger stones along the western side seem to almost revet the lynchet and form the face of the lynchet. There is no evidence that this was a pre-existing heap of stone as the stone were incorporated as part of the deposits forming the lynchet and not underlying them. It is not yet clear how far the stone deposit extends, but most of the test pits along the edge of the lynchet contained only soil, so the stone deposit was not necessary for the creation of the lynchet.

It is possible that this material moved downslope from a location probably not far above and became sorted through the movement. The stones do appear to be roughly sorted by size, with the larger stones (7508) settling on the downhill, western side, and the smaller stones collecting behind them. Further uphill there are fewer and fewer stones, so that 7507 is largely stone-free soil. The way that the stone and flakes merge with the ploughsoil suggests that the stone deposit built-up as the lynchet was formed. The depth of the stone deposit as seen in TP37 shows that it is as deep as the lynchet is high and it must be an integral part of that feature. The stone deposit does not act as a general revetment to the lynchet as most of the lynchet edge does not have this stone. It is possible that Iron Age ploughing repeatedly crossed a deposit of stone and axe debris, successively disturbing it and sending stone moving downhill, until the original deposit was entirely eroded away, and all the material had collected on the edge of the lynchet. This interpretation implies that none of the material is *in situ* and that *in situ* Neolithic deposits are extremely unlikely in this field beyond the areas of scree. However, it is not clear that this process would have created such a dense concentration of stone throughout the whole depth of the lynchet, and understanding of how this deposit formed remains inconclusive.

Central scarp

The steep central scarp running across the field between the upper and lower lynchets is up to about 10m high and up to about 40m wide. Test pits TP10, 40, 74, 76, 77, 78 and 79 were dug on the scarp and these were between 0.20m and 0.52m deep. Within the general slope there are two rather rounded, sloping terraces, much less clearly defined than the lynchets, but most clearly seen towards the southern part of the field. These appear to be natural features rather than remains of fields, but might have been locations chosen for working axes, so test pits were located here to investigate whether these had been used or had collected material. They had between 0.15m and 0.32m of ploughsoil, generally a grey-brown clayey silt with a variable quantity of stones. Below this in TP77 was a soft yellow-brown silty clay with some stones, which appeared to be an erosion deposit filling irregularities in the glacial clay and probably of entirely natural origin. TP74 and TP76 had patches of darker material that were probably from root disturbance, and it is likely that gorse had grown on this slope at various periods, as it still does on the southern end of the slope. The evidence suggests that this slope and the slight terraces on it are natural, though there has been shallow ploughing over the scarp. A small number of

Plate 37. Trench 85 from the east showing stone deposit 8503 and largely stone-free deposit 8504

Plate 38. Trench 89 from the west, showing stone deposit 8903

Plate 39. South facing section of TP15

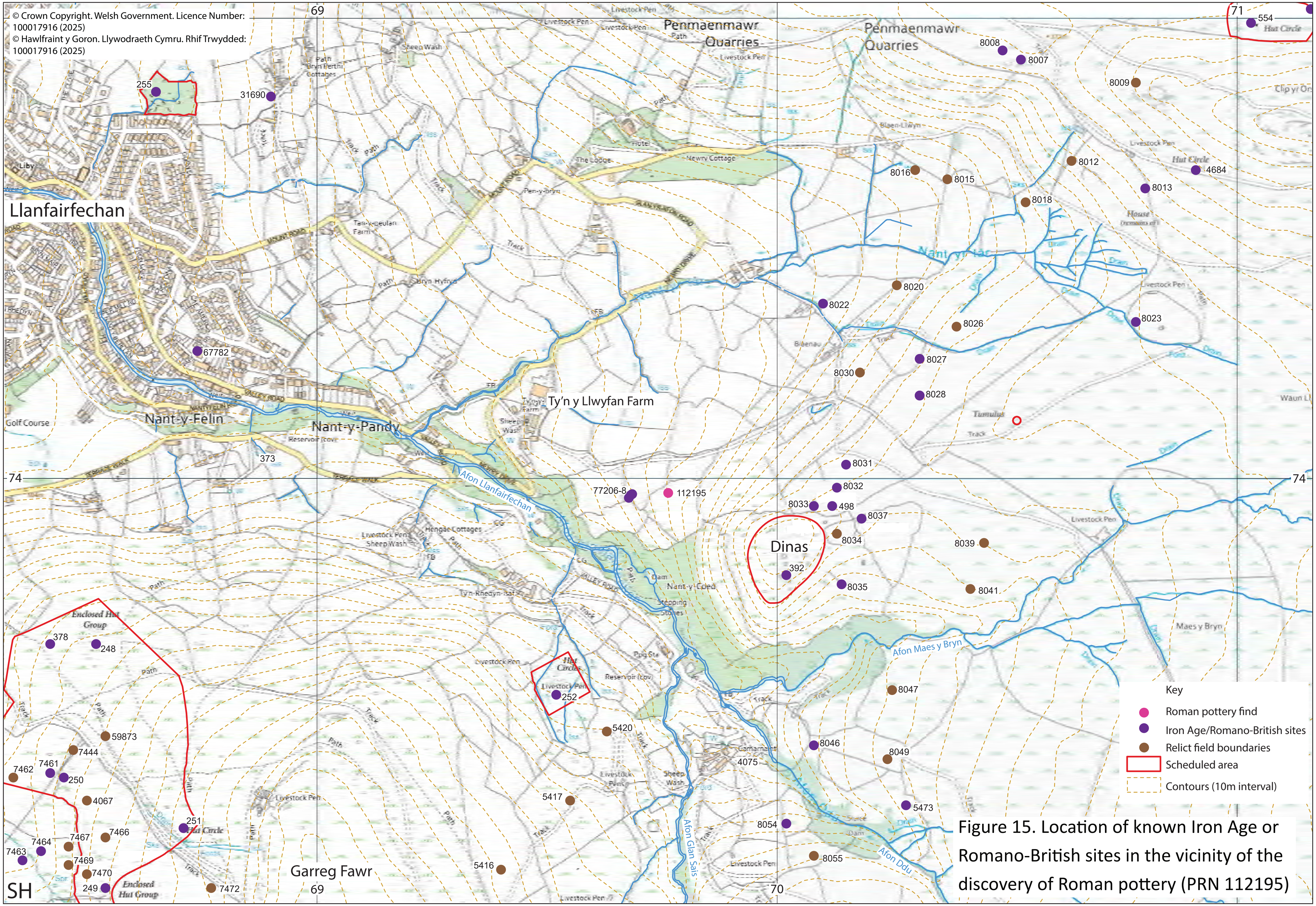


Figure 15. Location of known Iron Age or Romano-British sites in the vicinity of the discovery of Roman pottery (PRN 112195)

axe flakes were recovered from these test pits, but these had probably moved down the slope from higher up and there was no axe working taking place on this slope.

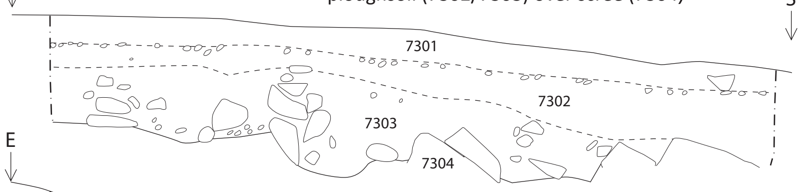
On the northern end of the central scarp is a small shelf, measuring about 10m by 6m, currently with some field clearance stones and a hawthorn tree on the edge. This was investigated by TP15, which was 0.52m deep (Plate 39). Below the topsoil this contained 0.3m of ploughsoil (1502) and 0.25m of colluvium (1503), a yellowish-brown sandy clay containing larger stones. The test pit produced large quantities of axe flakes, possible hammerstones and some burnt stones. This location was further investigated by a 2m by 2m trench (TP39), which was 0.58m deep, with the same layers; ploughsoil (3902) and stony colluvium (3903) (Figure 13). This lower layer is essentially scree with colluvial soil and may have moved downslope prior to the Neolithic. The hard, concreted natural (3904) contained stones up to 0.6m long that protruded into the layers above.

This trench produced a large amount of axe debris, including a broken roughout from layer 3902 and large roughly flaked blocks and a roughout from layer 3903. There was clearly some earlier colluvial movement down the slope potentially bringing axe debris with it, but later movement would have been trapped by the lynchet. This suggests that much of the axe debris on the shelf had been generated here. This is supported by the presence of large, flaked blocks and roughout, and these indicate primary working in this location. This material may therefore be largely *in situ*, though some disturbance is suggested by the discovery of Roman pottery. One piece of Roman pottery came from layer 3902 (SF3916) and two pieces from layer 3903 (SF3931 and 3932). The sherds have been allocated PRN 112195. The sherds are possibly of a second century AD date (see Section 4.6 below), and are not excessively eroded, suggesting they have not travelled far in the ploughsoil, but their presence within 3903 suggests disturbance of this layer. The sherds indicate Roman period occupation nearby, but there are no settlements are known in the vicinity. No evidence of a structure, floor layers or even a consolidated buried ground surface was seen in TP39, so there is no firm evidence for Roman occupation of this shelf.

Few Roman finds have been discovered in the immediate area; a copper alloy bracelet (PRN 2840), possibly Roman but possibly early medieval in date, was found somewhere on the slopes of Penmaen Mawr (Anonymous 1937). Roman artefacts were found within the hillfort of Braich y Dinas (PRN 712) that stood on the mountain before it was lost to quarrying. These finds included coins (Trajan, Hadrian and Nerva) and pottery including samian ware (Hughes 1923, 247-260). This shows that hillforts in the area might be used into the Roman period, as might some of the roundhouse settlements. There are a number of roundhouses and roundhouse settlements in the area (Figure 15), set within relict field systems most probably also of Iron Age date. Many of the irregular field boundaries above Llanfairfechan are also probably Iron Age in origin, suggesting an intensively cultivated landscape in the Iron Age, almost certainly continuing into the Roman period. The Roman road from Caerhun to Segontium ran just south of Garreg Fawr, so access to Roman pottery was probably not difficult, but very little may have been used in lower status roundhouses and settlements.

In Cae Twll, about 80m west of the findspot of the pottery (Figure 15) some features (PRN 77206-8) of possible Roman date were found during a watching brief on a water pipe trench (Dean and Cooke 2019, 28). Here a narrow curving gully was found in the base of what appeared to be a terracing cut, with a pit nearby. These features produced radiocarbon dates from the first to fourth centuries AD (86 - 242 cal AD (Beta – 519687), 74 - 226 cal AD (Beta – 519688), 242 - 386 cal AD (Beta – 519689), all at 95.4% probability). It was not possible in a narrow trench to determine fully the character of these features but a narrow wall slot in the base of a terracing cut is suggestive of a timber roundhouse. If this was in use in the second century AD, as seems possible from the dates this may have been the origin of the pottery.

Figure 17. West facing section of TP73, showing ploughsoil (7302/7303) over scree (7304)



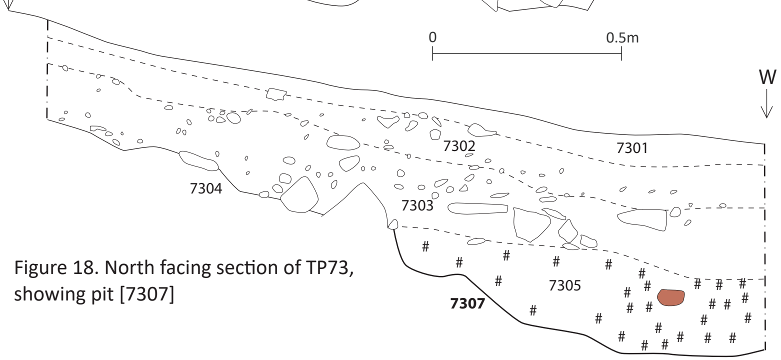


Figure 18. North facing section of TP73, showing pit [7307]

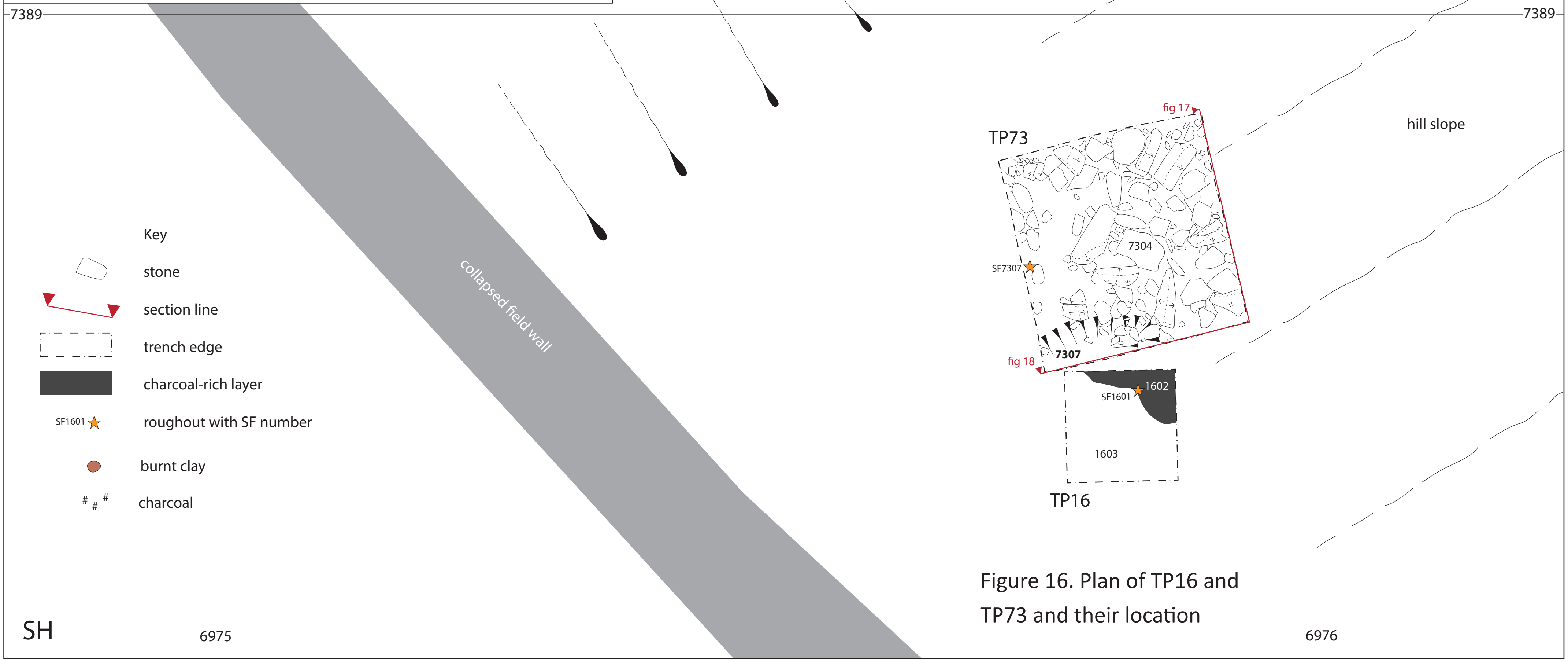


Figure 16. Plan of TP16 and TP73 and their location

Plate 40. TP73 showing natural scree (7304) and part of a pit [7307] in the top left corner

Plate 41. Pit 7307 in the corner of TP73, from the north

Plate 42. TP136 from the west

Trench 73 with smithing pit (PRN 100568, centred on SH 69758 73888)

In the pointed corner forming the southern end of the lower lynchet in Cae Graig (Figure 5) TP16 revealed a charcoal-rich deposit (1602), as well as producing a roughout. To investigate the significance of the charcoal-rich deposit a 2m by 2m trench (TP73) was excavated immediately adjacent to TP16 (Figure 16). This was excavated in the same way as the other test pits, but it was planned in detail by photogrammetry. TP73 was up to 0.57m deep and the natural scree was exposed in the base of the test pit (Plate 40, Figures 17 and 18). The scree (7304) was composed of large angular stones up to 0.6m long, large sub-rounded stones and smaller cobbles in a matrix of yellow-brown silty sand. The scree was not removed to discover its depth. Over this was 0.26m of ploughsoil or colluvial deposits described as orange-brown sandy silt. The upper part of this (7302) had fewer stones, while the lower part (7303) had about 50% stones, as it mixed with the upper part of the scree. The turf and topsoil were 0.10m deep. This shows that the screes extend at least this far into the field but there has been some ploughing or at least soil build-up over the screes. Unlike the test pits a little to the north there were some pieces of axe debris from this test pit, including a roughout, indicative of axe-working on the screes.

In the south-western corner of the test pit was a small pit [7307]. About a quarter of the pit was seen in the trench, and this appeared to be sub-oval in plan with fairly steep north side, more gradually sloping east side and rounded base. The visible part of the pit measured 1.15m by 0.40m and it was 0.30m deep (Plate 41, Figure 18). Pit 7307 cut through the scree, explaining some irregularity in its sides, and it was filled by a very dark brown crumbly silt with patches of charcoal and flecks of charcoal (7305). Deposit 7305 contained slag and burnt clay, and was sealed under the ploughsoil. The slag shows that this feature was not Neolithic.

1.6kg of smithing waste was recovered from TPs 16 and 73, including smithing hearth cake and smithing fines from a bulk soil sample (see Section 4.7 below). There were also fragments of ceramics from the lining of the pit or from an upstanding hearth wall. Several pieces of hearth ceramic showed evidence for the margin of a blowhole but were insufficient to determine whether the blowhole was located within a simple clay wall or within a preformed ceramic tuyère. The smithing hearth cakes are typical of those formed in a hearth using a ceramic tuyère or a blowhole in a ceramic wall, rather than an iron tuyère. The margin of a ceramic tuyère was found in TP75, though this was 67m away, uphill, so it is not certain that this came from the same smithing activity.

A sample of smithing hearth cake (SHC) and a piece of hearth ceramic were investigated through bulk analysis and there was microanalysis of the microresidues (see Section 4.8 below). The SHCs are suggestive of light or intermittent work, and the microresidues suggest high temperature forging, including welding employing the use of a quartz flux. The analysis suggested that the iron being worked was from a bog iron source.

A bulk soil sample was taken from pit [7307], which produced 12.5g of charcoal, all oak, most likely the fuel for the smithing. There was also a single fragment from barley found, which could suggest the use of barley straw to light the fire.

Two radiocarbon dates were obtained from fill (7305) (see Section 5 below). These dates (SUERC-130048: cal AD 890-1000 and SUERC-130049: cal AD 1150-1260) were very different with the latter probably providing the best date for the smithing. A 'fiddle-key' nail (SF7314) typical of the medieval period, was found amongst the slag, which would fit with this date, so it seems likely that the smithing activity dated to the 12th-13th century AD.

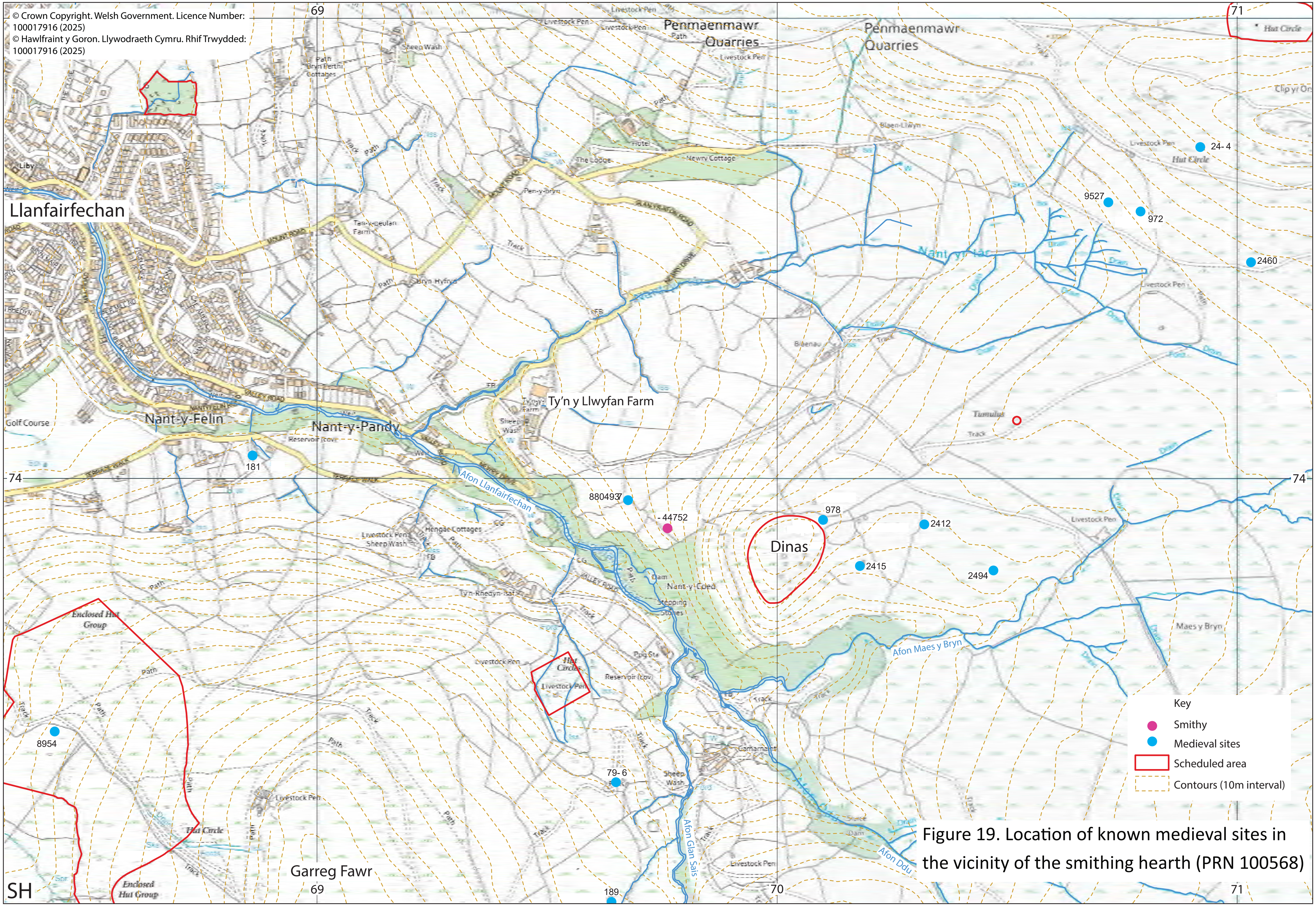


Figure 19. Location of known medieval sites in the vicinity of the smithing hearth (PRN 100568)

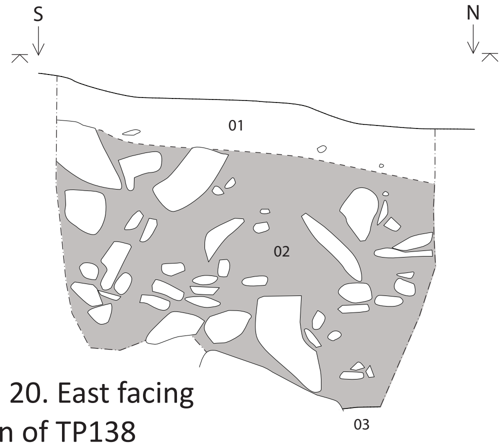


Figure 20. East facing section of TP138

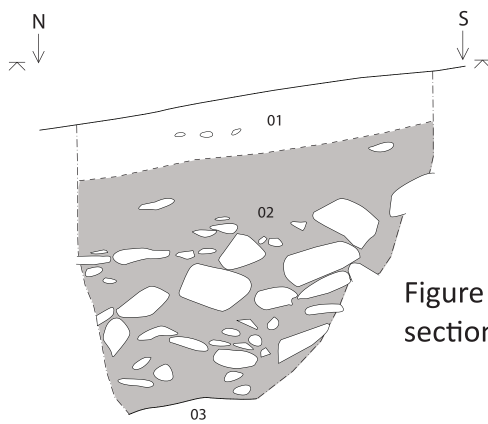
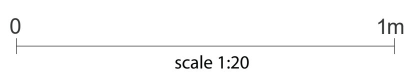
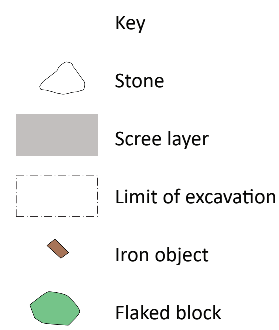


Figure 21. West facing section of TP147





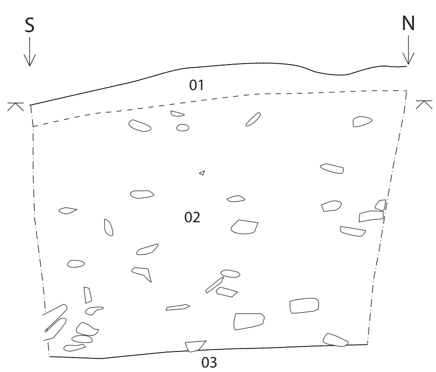


Figure 22. East facing section of TP137

Pit [7307] therefore appears to have been a medieval smithing hearth. The purpose of the smithing is unknown, but included forging and welding, so was more than just light farrier work. It is possible that it may have been associated with construction, implying a timber building nearby, which is difficult to imagine due to the slopes, unless it stood on the lower terrace.

The context of the smithing is uncertain. There are house platforms and long huts of probable medieval date to the east of Dinas within a field system dating originally from the Iron Age but clearly used in the medieval period (Figure 19). Across the valley, north-west of Camarnaint is a similar field system with medieval house platforms within in it, so there was considerable medieval activity in this upper part of the valley. None of these sites have been excavated so their dates are unknown. The only medieval sites know about close to the smithing site are two ditches (PRN 77204 and PRN 77205) found in the watching brief on the water pipe trench. Charcoal from these was dated to 776 - 971 cal AD (Beta – 519685) and 410 - 546 cal AD (Beta – 519685) (Dean and Cooke 2019, 28). Dating charcoal from ditches is problematic as it is not obvious what activity the charcoal is related to, but it does suggest some early medieval activity in the area. It is very likely that the terraces within Cae Graig and the other fields in this area were farmed throughout the medieval period, but no settlement evidence is known close to the smithing site.

If the smithing was related to the production of nails and tools for building it would presumably have been in close proximity to the site of a timber building. The steep slopes of the ground in this area mean that if there was a building here it must have been on the flat surface of the lower terrace. As the house platforms across the area are scattered within the field system it is possible that a building in the corner of the terrace was domestic, but it might alternatively have been a barn. All the known long huts in the area are stone-built but that is because only remains of stone buildings are visible on the ground surface. Where only a rectangular platform survives it is possible that it had a timber building rather than stone. There may have been numerous timber buildings within the fields in the upper part of the valley in the medieval period, but without excavation these cannot be found.

Cae Bach and Cae Uchaf (part of PRN 81634, centred on SH 6980 7402)

Figure 6

Test pitting in Cae Bach showed that the axe production continued to the north of Cae Graig, with another focus of activity separate from the one at the northern end of the upper lynchet in Cae Graig (Figure 6). TP100, on the edge of the screes in Cae Graig, seems to have been part of this focus and the ground sloped down towards the north from here. There were unexpectedly deep deposits of scree under the southern part of Cae Bach and axe-making had been active in this area. TP136 had scree embedded in the glacial clay (13603) (Plate 42), while TP138 had over 0.68m of scree in the form of densely packed sub-angular stones with large stones in the base (13802) (Figure 20). TP146 had 0.30m of similar scree above glacial clay with scree embedded in it (14603) (Plate 43), and TP147 had 0.70m of scree (14702) over glacial clay (14703) (Figure 21). However, while TP137 had 0.68m of mid orange-brown clayey silt (13702), this had no large pieces of scree within it (Figure 22). This layer appeared to be a build-up of colluvium, effectively a lynchet that formed against the scree deposits, forming a slight platform. Two large boulders within TP147 appeared to be possibly part of a revetment to this platform but are likely to be just a natural part of the scree (Plate 44). Across this area a considerable quantity of axe debris was found with TP137 having 818 pieces (26536g).

Further west the deposits are much shallower and contain much less scree, with TP139 and TP140 being no more than 0.25m deep, and there was much less axe debris in this area. To the north there was no scree. TPs 143 and 148 had a significant quantity of axe debris but there was very little further north and north-east. In TPs 134, 135, 141, 142, 144, 145, and 148 the ploughsoil was between 0.14m and 0.34m thick with little or no stones from the scree and few flakes. TP143 had a deeper deposit of

Plate 43. West facing section of TP146

Plate 44. Large stones in TP147, from the north

Plate 45. North facing section of TP150

ploughsoil (0.51m) and a significant number of axe flakes, but some of this deposit is probably ancient colluvium filling a hollow in the natural topography and this movement of soil has probably brought axe debris into this area from upslope to the south.

In Cae Uchaf TP151 showed that there was no scree on the foot of the steep slope running down from Dinas. This test pit showed a build-up of 0.60m of topsoil and colluvium over fractured mudstone. The mudstone is the bedrock here and there was no trace of scree over the top of this. However, TP149 and TP150 at the base of the slope did show a loose scree deposit (0.23m and 0.30m thick) below the ploughsoil (Plate 45). Within this were axe flakes, with TP 150 producing 96 flakes and TP 149 had 137 flakes. This suggests that wherever the scree was found it was used. This scree is probably a tail of material coming down from scree on the main slope to the south of the track.

Cae Dafydd (PRN 100575, centred on SH 696 739)

Figure 7

In 2018 an archaeological watching brief by Aeon Archaeology on the renewal of a water pipeline found axe flakes just below the bottom boundary of Cae Graig and a few scattered south-west towards the cliff above the Afon Llanfairfechan (Dean and Cooke 2019). Twenty-seven flakes (PRN 93577) were found along the route of the pipeline (Figure 7). Flakes were also found in the spoil from the pit dug to investigate a burst water pipe (PRN 96143, see Figure 4). These finds showed that axe debris could be found down to the edge of the wooded gorge in which the Afon Llanfairfechan flows and that the lower field was worth investigation.

Eight test pits were dug in Cae Dafydd (TP 82, 83, 84, 90, 91, 92, 95, and 96) (Figure 7). They were between 0.20m and 0.42m deep; the shallowest were TP90 and 91 and the deepest TP95. This suggests thinner soil deposits on the steeper slopes and soil deposition in the lower part of the field. However, TP92 and TP96 in the lower part of the field were only 0.31m and 0.29m deep respectively, so it seems that there was only soil build-up in undulations in the glacial clays, rather than generally deeper soils in the lower part of the field. All had about 0.10m to 0.15m of turf and topsoil over ploughsoil that was a dark grey-brown silty loam with varying amounts of stones. The glacial clay in this field was a pale yellow-brown sandy clay with medium and large stones.

The numbers of pieces of axe debris from these test pits was low but constant, suggesting that some working had been taking place in this field but that the precise location was not identified. This is supported not only by the flakes recovered in the water main watching brief but the discovery of two roughouts from this field. One roughout was found in TP82 and the other (SF10053, PRN 100576, see Figure 7) was found on the ground surface in the southern corner of the field. This must have been disturbed by the water pipe trench and left on the surface. It is notable that this roughout is at the start of the natural ramp leading into the river gorge, and it might be this area that needs to be searched for an activity focus.

Perhaps the most important find from this area came from TP95. This is a tiny sherd of Early Neolithic pottery (see Section 4.5 below). It was from the ploughsoil and is eroded and has obviously moved from its original position, but it does indicate Neolithic domestic activity somewhere in the area. This tiny artefact supports the suggestion that this sheltered field close to water may have been a settlement location, but much more work would be necessary to confirm where settlement occurred and how extensive it was.

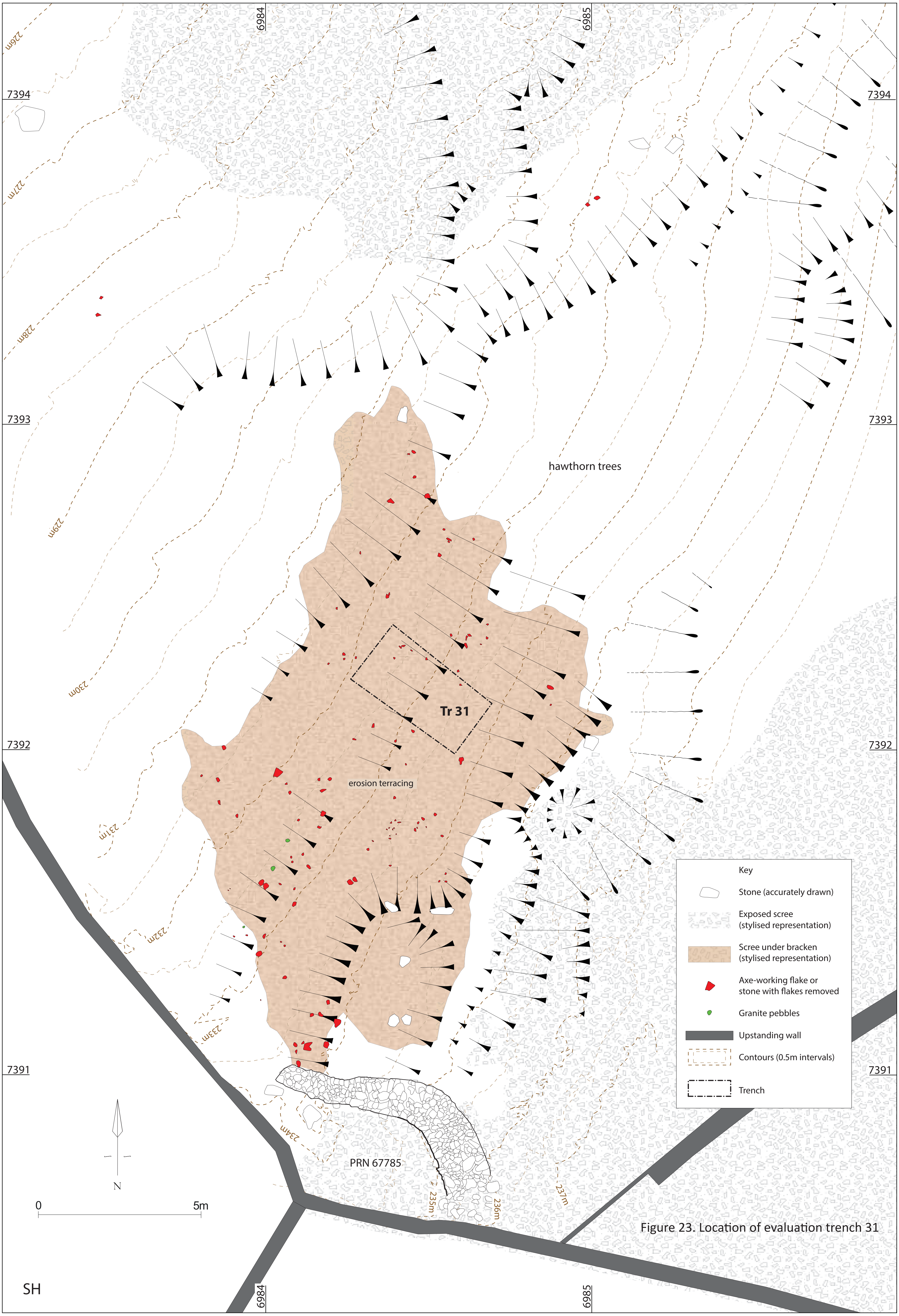


Figure 23. Location of evaluation trench 31

Figure 24. Orthomosaic of trench 31 at end of excavation showing sondage on north-east side

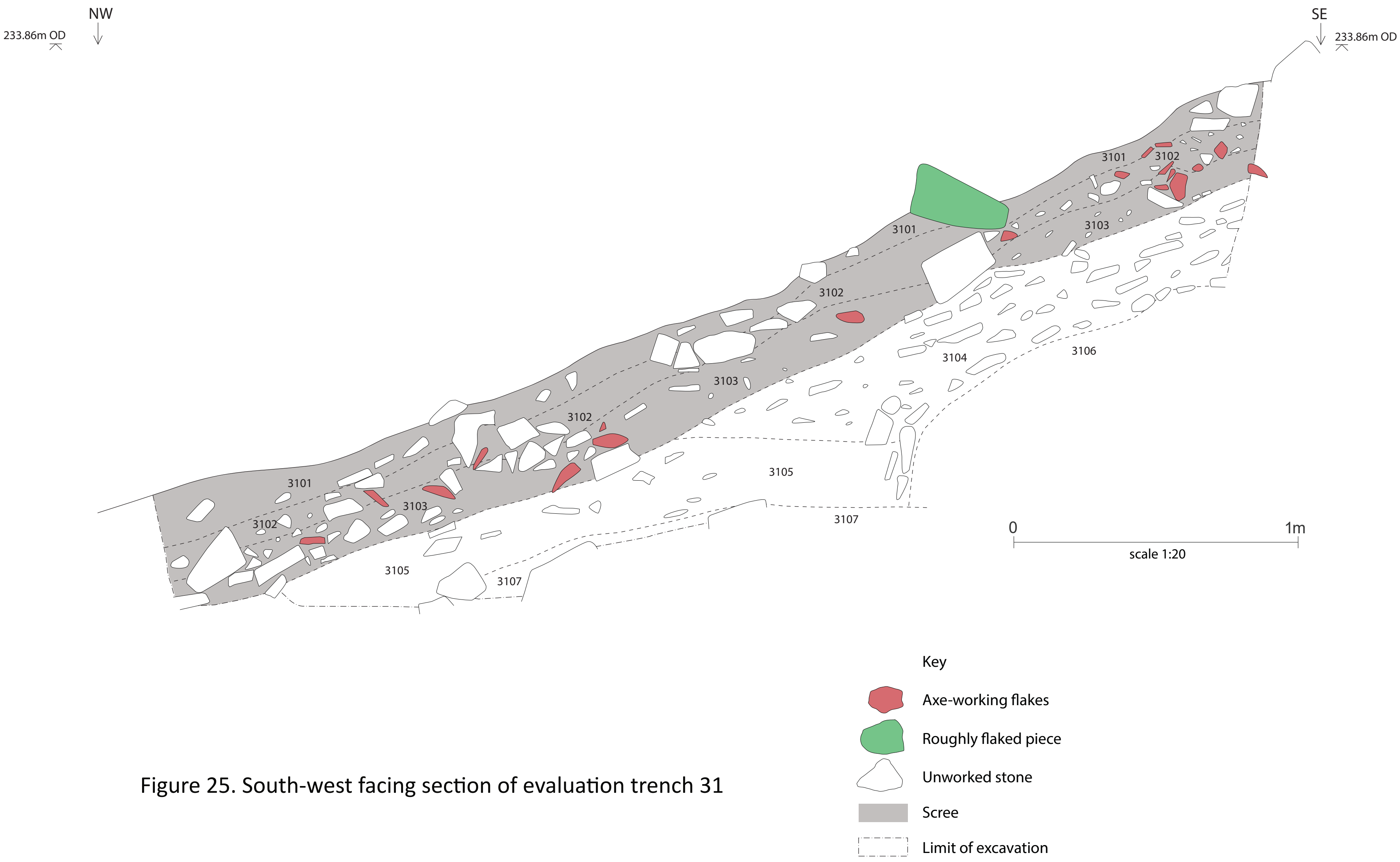


Figure 25. South-west facing section of evaluation trench 31

Figure 26. Axe debris and scree stones recorded from three spits through the scree in trench 31

Plate 46. Trench 31 at completion of excavation
showing sondage, from north-west

Plate 47. South-west facing section of trench 31 in sondage

Plate 48. Trench 31 from the south-east showing surface of scree fully exposed and showing the position of the trench just above the improved fields

Plate 50. Lower part of layer 3103, showing larger pieces towards lower part of trench, from north-west

Plate 49. Surface of layer 3103, from north-west

Dinas Screes

To investigate the undisturbed screes at the foot of Dinas but east of the ploughed fields an evaluation trench was dug in an area of the screes which had been consolidated by soil development and where axe flakes were visible on the soil surface. The evaluation trench provided a view through the scree beyond the area of agricultural disturbance (Figure 23). The evaluation trench measured 4m by 2m and most of the scree was removed, recovering the axe debris within it, but there was not sufficient time to fully excavate layer 3103. A sondage was dug against the north-east side of the trench to investigate lower deposits (Figure 24, Plates 46 and 47).

The scree was covered by only a thin layer of bracken debris (Plate 48) and proved to be a maximum of 0.40m deep, accounting for layers 3101, 3102 and 3103, which were arbitrary spits through the scree (Figure 25, Plate 49). The area investigated was on a fairly steep slope of about 30 degrees and there was evidence of scree movement down this slope as there was a tendency for larger items to collect lower down (Plate 50). However, this sorting was not entirely consistent as larger pieces were also found higher up the slope, and it is possible that much of the movement could be accounted for by people turning over the scree looking for good pieces rather than the whole body of scree moving down the slope causing general sorting. Localised disturbance of the screes during the Neolithic period was also suggested by the distribution of flakes. When the surface of the scree was exposed a concentration of small flakes was found in the south-eastern corner of the trench (Figure 26). This appeared to be largely intact knapping debris. Larger flakes were recorded from lower down the trench. This upper layer represents the last knapping activity on the site and appeared to be undisturbed. Lower down in the scree such patterning was not found, with flakes fairly evenly distributed. There remained a general tendency for larger flakes to concentrate at the lower end of the trench but otherwise there were no specific concentrations. It is suggested that this is due to the disturbance of the scree in the Neolithic period causing movement of scree and flakes. Many flakes slipped down between the scree to collect just below the main body of scree, in the lower part of layer 3103.

Below the scree were colluvial or solifluction deposits that had probably formed at the end of the last ice age. There were few flakes within these deposits. Layer 3105 did produce a few flakes, but this was a very loose deposit, and flakes had probably been introduced by root action or animal burrowing. Generally, the stones in these deposits were all orientated at the same angle of slope and the whole deposit appeared to have slipped downhill. Layers 3105 and 3107 had high proportions of shale pieces, with 3107 being largely composed of shale with little matrix. Deposit 3106 was firmer than the other deposits and sloped down much more steeply. It is possible that the steep slope was due to this slumping over a boulder but layer 3107 extended underneath 3106, and it may be that 3106 was a consolidated block of deposit slipping down slope together. The complex natural processes of slumping and probably freeze/thaw action make relationships between these deposits less easy to interpret than would be expected for anthropogenic deposits. The quantity of shale in 3107 suggests that the shale bedrock was not much further down, but the depth of the sondage made it unsafe to continue further excavation.

The trench therefore revealed solifluction deposits of late glacial or early post-glacial age over which the scree had slipped or fallen. This scree was extensively used as a source of stone for making axeheads, which were knapped directly where the source scree was collected. It appears likely that the search for suitable pieces of scree resulted in the screes being disturbed and turned over, so that only the latest knapping episodes might be expected to survive as intact knapping floors.

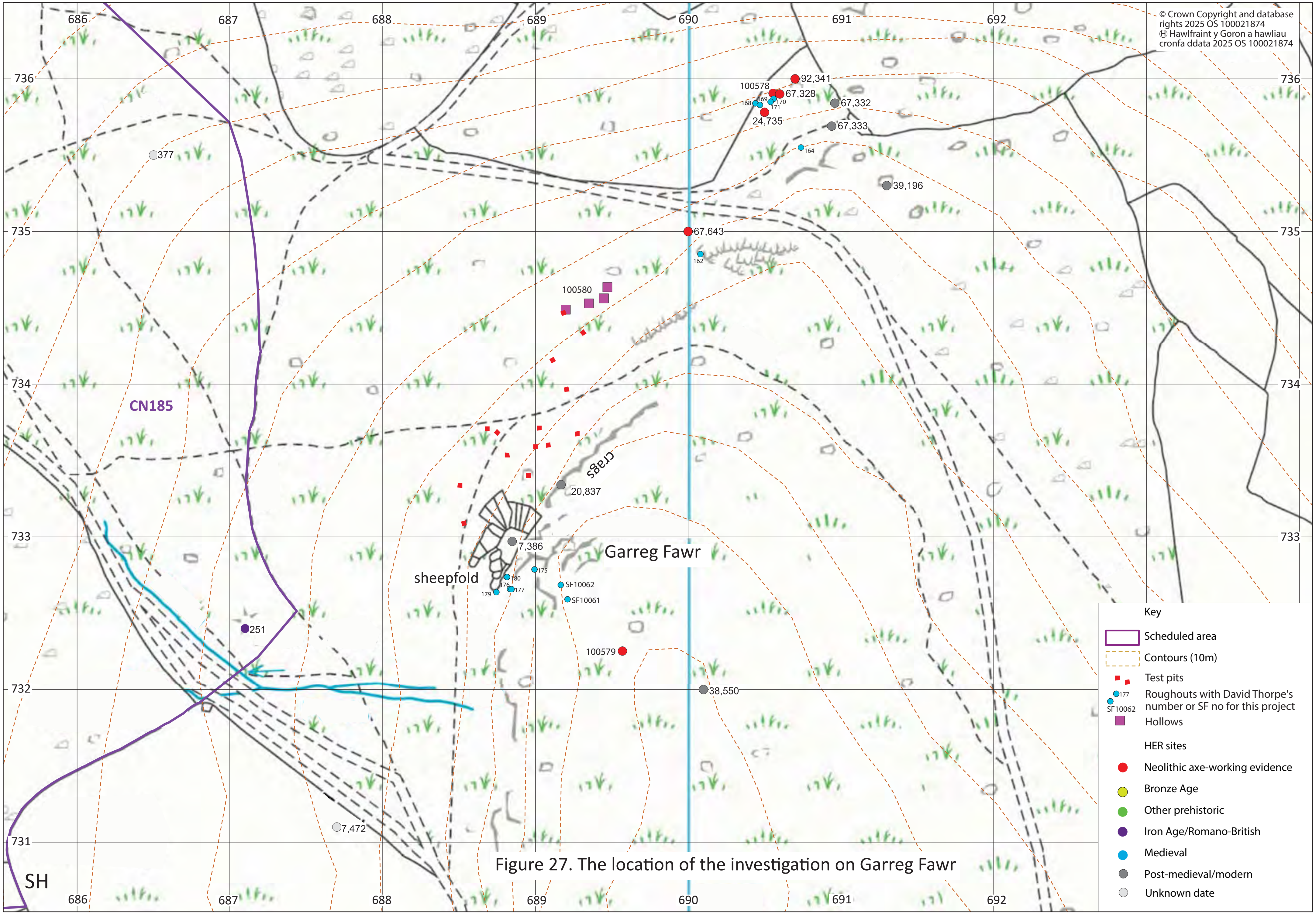


Figure 27. The location of the investigation on Garreg Fawr

Figure 28. The position of test pits on Garreg Fawr

Plate 51. The crags on Garreg Fawr with scree and quarry waste below and the crags and Ffridd Tan y Graig screes in the distance

Plate 52. The crags on Garreg Fawr with scree and quarry waste below, from the north

Plate 53. Quarry in Garreg Fawr crags with quarry waste below, from the north-west

3.2. Garreg Fawr (PRN 103600, centred on SH 6887 7334)

Topography and archaeology

The microdiorite outcrops near the summit of Garreg Fawr as cliffs about 20m high (Figure 27, Plates 51 and 52). Below these are screes, partly covered in turf but largely buried under waste from a small post-medieval quarry (PRN 20837) in the cliffs (Plate 53). There are also extensive scree deposits, some open but much under turf, around the northern side of the hill.

Field-walking by David T Jones on the north-western side of Garreg Fawr, above Ffridd Hengae, revealed substantial evidence of axe making at an altitude of approximately 280m OD (Figure 27). The area is an exposed scree slope in which some large, tumbled boulders and possibly bedrock protrude (PRN 67328). Two complete roughouts (PRN 24735) stacked on top of each other were found by David T Jones. Another roughout was found in 2021 (PRN 92341) and reported to the Portable Antiquities Scheme. David Thorpe has also investigated this area and found several roughouts and hammerstones (Thorpe 2023). The knapping debitage can be found scattered throughout the exposed scree, and smaller flakes can be found in erosion scars beyond the limit of the exposed scree. Some of the boulders within the scree have pieces broken from them (PRN 100578). David T Jones found another roughout on Garreg Fawr (PRN 67643). Its location was not accurately recorded but it probably came from a similar area. The exposed scree continues to the east around the northern side of Garreg Fawr, but no flakes have been found here, and the stone is generally not as fine and suitable for axe making.

There is a fine multi-cellular sheepfold (PRN 7386) built against the foot of the cliffs (Plate 54) and the author has heard casual references to roughouts being found in this, but no finds have been formally recorded from this area. However, inspection of the open screes to the south of the cliffs revealed some worked material and rounded clasts (possible hammerstones) (Figure 27, see Thorpe 2023 and Kenney and Smith 2023, 75-76). A rock outcrop near the top of Garreg Fawr has a possibly quarried face, which is heavily weathered and possibly suggestive of Neolithic quarrying (PRN 100579). The waste heap from the post-medieval quarry (PRN 20837) is composed of pieces of fine microdiorite, some of which have produced very well-formed flakes. This material is clearly of the high quality necessary for axe making. Working of the screes below the cliffs would therefore seem to be very likely, but the scree not covered by recent quarry waste is obscured under turf, making test pitting the best way to explore this area.

The area investigated is on a north-west facing slope that runs down from the crags near the summit of Garreg Fawr (Figure 27). There is a fine view over Traeth Lafan towards Anglesey and views towards the higher mountains of Foel Fras and Lwytmor and in the opposite direction to Penmaen Mawr. From the summit of Garreg Fawr, Dinas can also be clearly viewed.

The area is covered by closely grazed turf, making test pits relatively easy to dig, but also by numerous gorse bushes. Gorse in part of the area has been burnt off, but this is now growing back and provided an obstruction to test pit digging. More established gorse bushes also provided obstructions in some of the area investigated. Further down the slope and on the summit, there are extensive areas of heather and bilberry. Areas of erosion are few, so it is difficult to search for axe debris except in the open screes not covered by quarry waste.

Much of this slope is protected by a scheduled area (CN185) due to an enclosed Iron Age farmstead (PRN 248) and its surrounding field system and other features. However, there was plenty of room above the scheduled area for test pitting, so there was no risk of accidentally trespassing on this. There is no trace of field boundaries north-east (uphill) of the scheduled area and it appears that the upper part of the hill has never been ploughed, even in the prehistoric period. However, the sheepfold has been

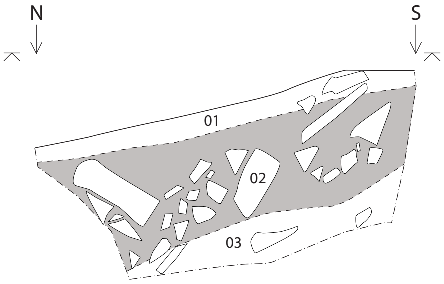


Figure 29. West facing section of TP104

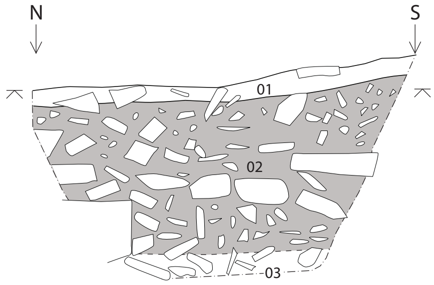
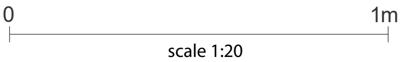
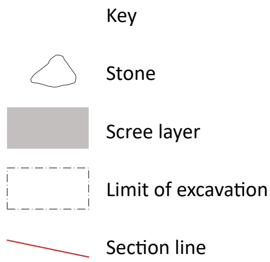


Figure 30. West facing section of TP109





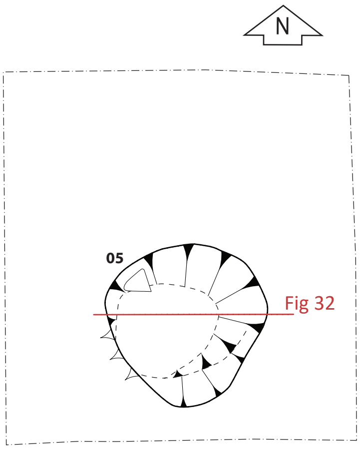


Figure 31. Plan of TP116 showing pit [11605]

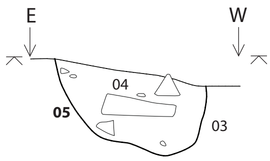


Figure 32. North facing section of pit [11605]

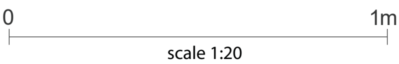


Plate 54. Multi-cellular sheepfold on Garreg Fawr, from the east with Traeth Lafan in background

Plate 55. East facing section of TP108

Plate 56. West facing section of TP104

built over an earlier monument (PRN 103602) (Figure 28). This is visible as a subtle stony scarp running around the north-west side of the sheepfold (further described and discussed below).

The lidar[1] (light detection and ranging) plot for this area shows the field systems in the scheduled area but does not indicate fields or other features within the test pitted area, except for several slight hollows (PRN 100580). These were seen on the lidar data and inspected on the ground (Kenney and Smith 2023, 75-74). These are slight platforms terraced into the slope with a little build-up of material on the southern side, and they are distributed in a shallow arc across the hill slope (Figure 27). A test pit (TP114) was dug into one of these to determine whether they were related to the axe working.

Test pits

The aim was to work along and down the slope out from where the quarry waste indicated good stone. Test pits were roughly 20m apart, but placed where the gorse allowed, with some pits in between (Figure 28). Fourteen test pits were excavated.

The glacial clay across the area was generally an orange-brown or yellow-brown stony clayey silt. Where this was investigated, as in TP108 and TP111, it could be seen that this contained a high proportion of shale fragments and it is a mixture of fragments from the underlying shale with glacial deposits, probably through freeze/thaw action (Plate 55). In TP108 this deposit (10803) was only 0.17m thick, while in TP111 the deposit (11103) was over 0.4m thick. In both cases, directly under this was the shattered upper surface of shale bedrock (10804 and 11104). This bedrock must underlie the whole slope from the foot of the microdiorite crags. It was assumed that the microdiorite scree continued for some distance down this slope, but it was proved to be much more restricted than assumed. In TPs 104 and 111 the scree (10402 and 11102) was of densely packed angular stones up to 0.3m long, and 0.30m and 0.25m thick respectively (Figure 29, Plate 56). A little further down the slope in TPs 105, 107 and 108 the scree was much less densely packed and was mixed with colluvial soil deposits. In TP107 the scree was 0.13m deep and in TP108 only 0.08m deep and it had largely tailed off. In TP105 the relevant layers were 0.34m thick but there were only occasional blocks that came from the scree. Further down the slope in TP115 there was still some scree in the subsoil, but by TP106, about 42m from the open screes, there was no scree, only hill wash present. Axe working debris was present in TP106, so the activity area may extend further down the slope, even though there is no scree here.

TP109 was positioned close to the base of the crag in a hollow between slopes of natural scree. This test pit had 0.43m of scree within in it, composed of densely packed sub-angular stones up to 0.2m long (Figure 30, Plate 57). However, the fact that the scree was sub-angular rather than angular and the texture and even sound of the stones suggested that this was not the right quality of stone for axe making. Some recent flakes were found but only 5 Neolithic flakes were recovered from the test pit. TP109 was at the foot of part of the crag noted for closely spaced fracture lines and it appears that the texture and properties of this stone are not suitable for axe making (Plate 58).

TPs 110, 112 and 113 were positioned further north of TP109 and further down the slope. TP110 contained a 0.17m deep layer of colluvium mixed with shale fragments but no scree, while in TP112 this colluvial layer did contain some scree (Plate 59) and in TP113 there was a 0.3m thick layer of scree. However, in TP112 and 113 it appears that the scree was of the wrong stone. Six axe flakes were recovered from TP110, three from TP113 and only one from TP112. These are probably part of a

[1] The casing of “lidar” follows Deering and Stoker 2014.

Plate 57. TP109 from the west

Plate 58. The crag adjacent to TP109, showing closely spaced fracture lines

Plate 59. Scree in TP112, from north-north-west

Plate 60. TP116 with pit [11605] half sectioned, from the west

Plate 61. North facing section of pit [11605]

Plate 62. Pit [11605] fully excavated

general spread of flakes moved by erosion and other processes across the hill, and do not represent axe-making in the immediate vicinity.

TP114 was positioned to investigate a hollow in the hill slope, one of at least 5 in this area. In this test pit, under 0.05m of topsoil, there was 0.17m of scree with angular stones up to 0.48m long, but again this scree seems not to have been the right stone as there were only 3 rather uncertain flakes. The hollow is a D-shaped scoop into the hill slope with a slight build-up of material on the downhill side. It is up to 0.75m deep and measures about 6.5m by 4.0m. The hollow may have been caused by erosion or disturbance of the scree, but the lack of axe debris suggests that this was not due to axe-making activity.

The hill slope has several large erratic boulders scattered over it but generally these are of local stone and are fairly angular. One stone is much more rounded and has weathered to a white surface. This appeared to be a distinctive landmark. It was postulated that Neolithic people might have gathered at this landmark and could have sheltered behind it while making axes. A test pit (TP115) was placed immediately north-east of the stone in its lee. This test pit did produce a significant quantity of axe debris but there was no indication that it was *in situ* and may well have moved down slope with the scree within which it was mixed. Some axe debris was found in TP106, a little further downhill, showing that axe working was taking place in the general area, and it cannot be proved that the boulder was specifically used by the axe makers.

As axe debris seemed to be increasing towards the south-east two test pits (TP116 and 117) were placed further in this direction and these proved to be the most productive. The tail end of the scree was visible in TP116 as a layer 0.18m thick, but this was not particularly dense. However, 150 pieces of axe debris (9233g) were recovered from this test pit, suggesting that some of this material may have been brought down from productive scree a little higher up rather than sourced directly from the scree in the test pit. This test pit was of particular interest because it had a small pit in the base (see below).

Early Bronze Age pit (PRN 103601, SH 68850 73334)

The pit [11605] exposed in the base of TP116 was sub-circular, 0.4m in diameter and 0.22m deep (Figures 31 and 32, Plates 60 to 62). It had fairly steep sides; the western side was undercut but not the start of a burrow. The sides curved gradually into a rounded base. The fill (11604) was a dark brown clayey loam with *c*.10% angular stones up to 0.2m long and occasional pieces of charcoal. The longest stone lay horizontally in the middle of the feature. The stones were not obviously packing stones but there are a couple of long thin ones that might have performed that function but had been disturbed. Two axe flakes (SF11603) were hand collected from the fill of the pit and 23 small flakes (SF11606) were recovered by wet sieving the pit fill.

All the fill of pit [11605] was taken as a bulk soil sample and this contained 33 fragments of hazelnut shell, and 16.2g of charcoal, a mix of oak and hazel (see Section 4.9 below). The charcoal suggests debris from a fire, with the hazelnut shells disposed of in the fire. While both fuelwood and nuts might be brought from some distance away, they do support the pollen evidence for woodland at this height in the Neolithic period and show that, in common with many Neolithic groups, hazelnuts were a common food source.

The soil sample also produced a tiny fragment of burnt mammal bone (SF11608), too small to be identified to species but suggestive of food waste. A sherd of pottery (SF11607) was also recovered. The fabric of this sherd is consistent with the Middle Neolithic Impressed Ware tradition, but it lacks any decoration, and Frances Lynch raised the possibility of it being Bronze Age in date (see Section 4.5

Plate 63. Bank of enclosure PRN 103602, from north-east

Plate 64. Bank of enclosure PRN 103602, from north-north-east

Plate 65. TP117 showing [11705] and [11707], from east

Plate 66. East facing section of TP117 showing section through circular cut in [11705]

Plate 67. North facing section of TP117 showing section showing linear slot part of [11705]

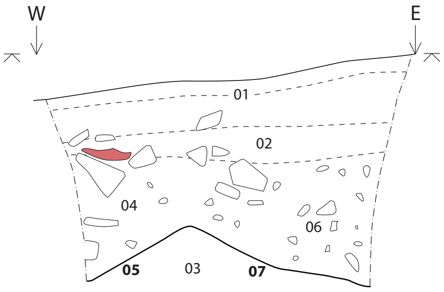


Figure 33. South facing section of TP117

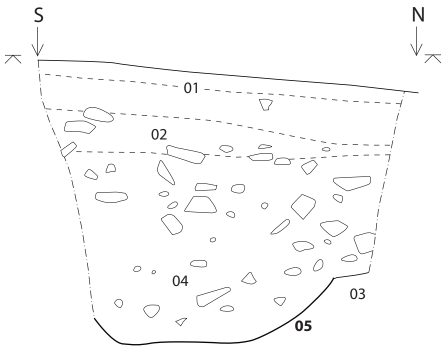


Figure 34. East facing section of TP117

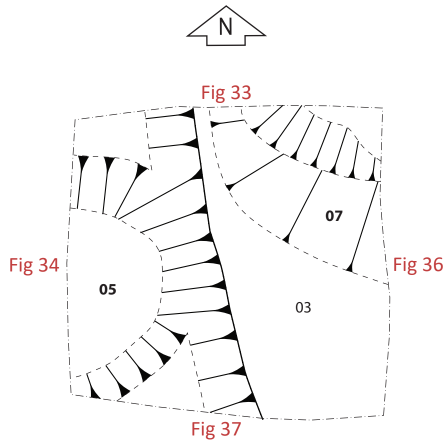


Figure 35. Plan of TP117 showing features [11705] and [11707]

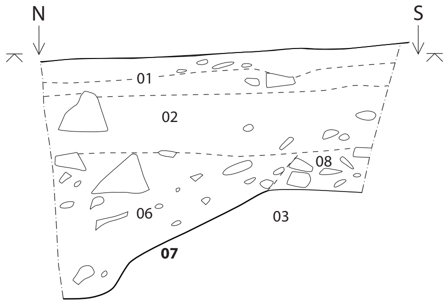


Figure 36. West facing section of TP117

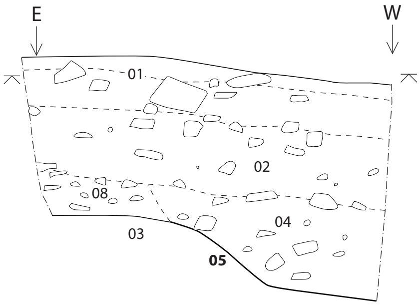
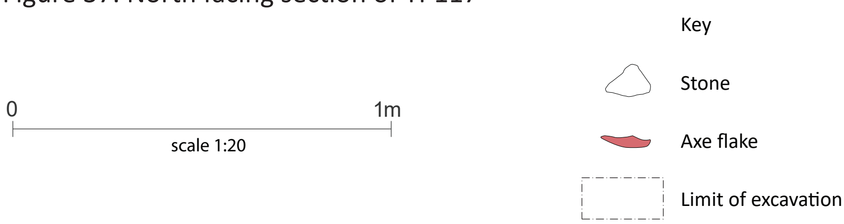


Figure 37. North facing section of TP117



below). The presence of hazelnuts shells, burnt bone, and a pot sherd is highly suggestive of domestic waste and hints at occupation of this site, even if just a temporary occupation.

Two radiocarbon dates were obtained from hazel roundwood and a hazelnut shell from fill (11604). These two indistinguishable dates (SUERC-130050: 1890-1740 cal BC and SUERC-130054: 1890-1700 cal BC) suggest that there has been no contamination or disturbance, and that the activity associated with the pit occurred in the Early Bronze Age. Despite the large inclusions in the pot sherd, which are typical of the Middle Neolithic period, it is likely that the pot sherd is Bronze Age and that the axe flakes are residual. Unfortunately, the pit cannot therefore be linked to the axe-making but might possibly be related to the nearby enclosure (PRN 103602).

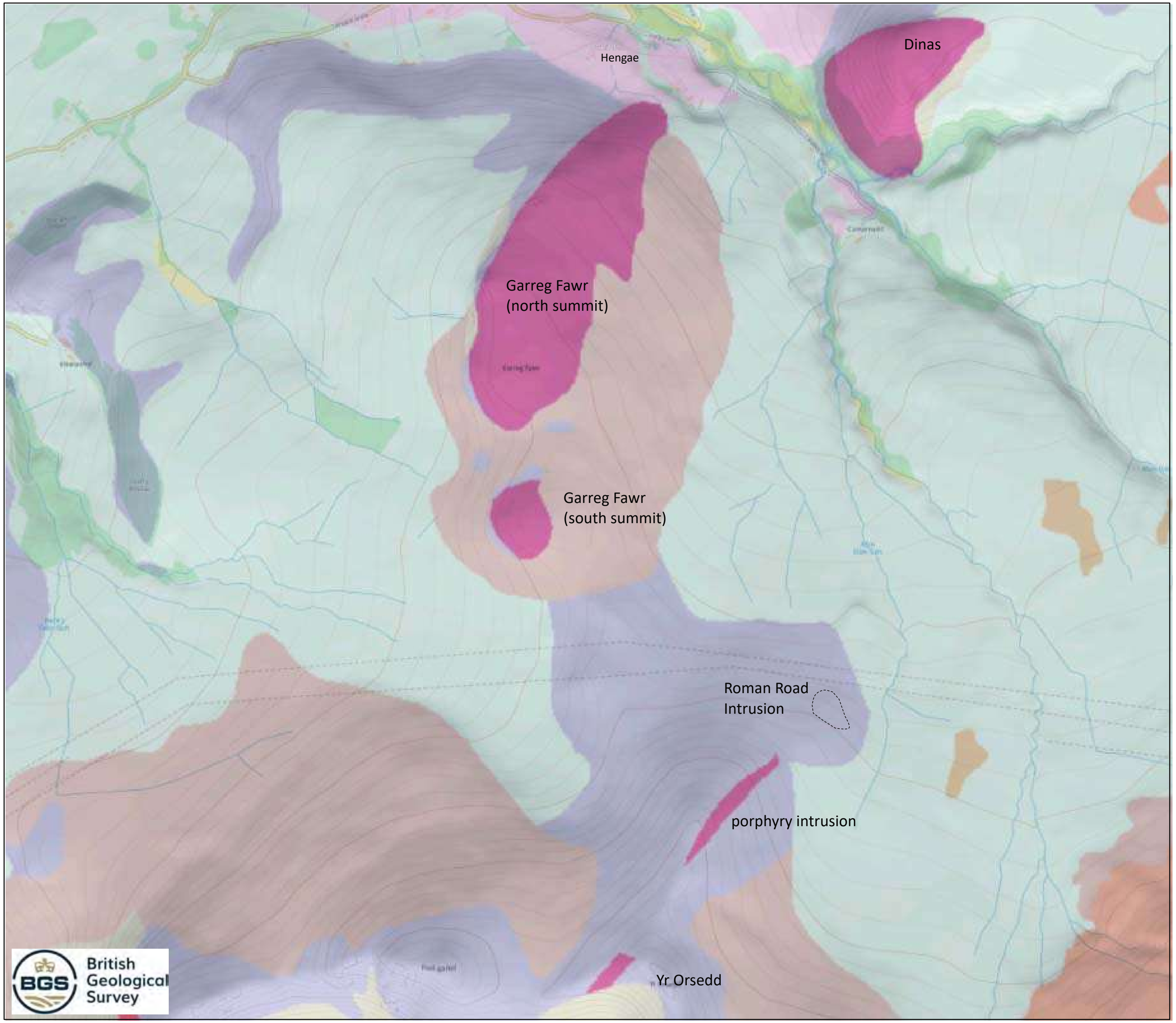
Probable Iron Age enclosure (PRN 103602, SH 68856 73316)

The chance of a test pit locating an archaeological feature is low but TP117 also revealed features in its base. A curving rocky scarp about 60m long and up to about 1.4m high defines probably part of a very eroded sub-circular enclosure (PRN 103602) underneath the sheepfold (Figure 28, Plates 63 and 64). Probably stone used to create a bank or wall for this enclosure has been robbed to build the sheepfold and the interior appears fairly level. An aerial photograph by RCAHMW (AP_2005_2847, Coflein NPRN 308677) shows this feature clearly and shows that there is a low stone bank on top of the scarp, which may be the remains of a stone wall. TP117 was positioned just inside the scarp on the level platform. In the base of the fully excavated test pit was a straight slot about 0.25m deep [11705]. This ran along the western side of the test pit, roughly parallel to the enclosure scarp (Figures 33 to 37). In the base of this slot was what was probably a circular cut, though only half could be seen in the test pit (Plates 65 to 67). This was 0.5m deep overall, 0.68m in diameter, and it had fairly steep sides and a flat base. Although there were no post-packing stones, it is likely that this circular cut was a posthole for a substantial post. This seems to have been set in the base a shallower trench. It is suggested that this may be part of a palisade trench, although a much large area would have to be excavated to confirm this. In the north-east corner of the test pit was another hollow with more gently sloping sides [11707] but still nearly 0.35m deep. Both these features were filled with a mid-brown silt with c.30% angular stones up to 0.2m long, which was loose and very soft in places. This layer and the sub-soil or possible cultivation soil above were full of axe debris (206 pieces, 10742g).

The enclosure is probably Iron Age, and the test pit suggests it may have had a wooden palisade, probably to keep cattle in. This enclosure was constructed over an area that had been intensively used for axe making and axe debris became incorporated into the fills of features relating to the enclosure. Centuries later the sheepfold was built over the top. The presence of pit [11605] about 12m away and dating to the Early Bronze Age hints that this site could have originated in the Bronze Age with perhaps casual occupation to be enclosed in the later Bronze Age or Iron Age. This area would repay further investigation, not only to determine the nature of the Neolithic activity but to investigate the form and function and date of the enclosure.

Full extent of microdiorite outcrops and potential for other sites

The current work has focused on the obvious screes and the crags near the summit of Garreg Fawr, but the geological map shows the microdiorite intrusion extending over a much wider area (Figure 38). The intrusion extends down the north-eastern side of the hill almost to Hengae. Most of the slope is covered in grass and bracken and has not been investigated except for the area of open scree at the top (PRN 67328). However, there is presumably scree all down this slope and the likelihood of axe-working there is high. The broad summit plateau of Garreg Fawr is mostly microdiorite. In 2023 a rapid visit was made to this area by members of the current project. This identified that the natural screes to the south of the crags had been used for axe-making with some axe flakes spotted and rounded clasts, possible



Key

	Microdiorite
	Glacial Silt, Clay and Gravels
	Siltstone
	Devensian till

Figure 38. Geological map of the Garreg Fawr area from British Geological Survey's Geology Viewer, showing both superficial and bedrock geology

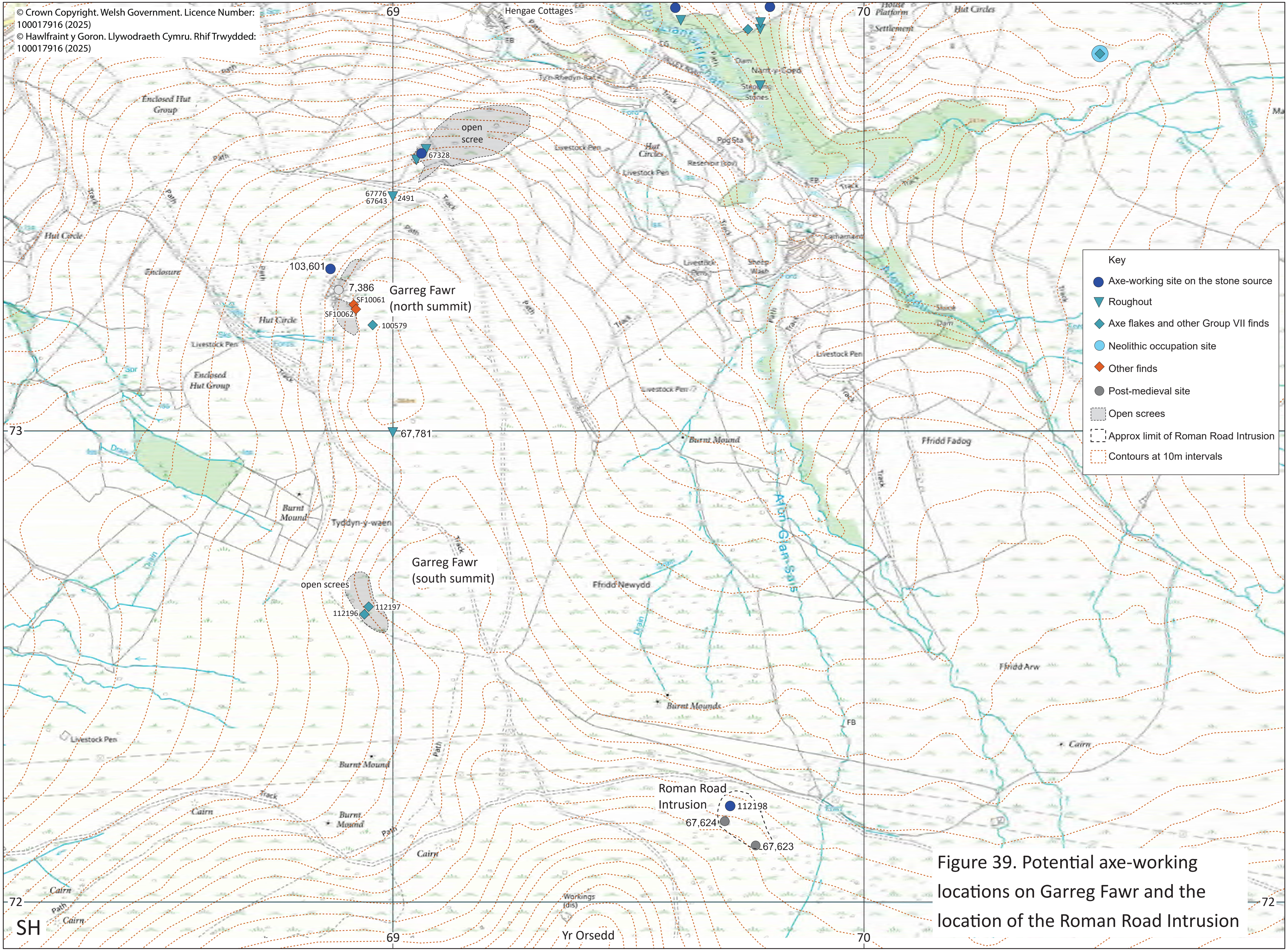


Figure 39. Potential axe-working locations on Garreg Fawr and the location of the Roman Road Intrusion

hammerstones, one of which was collected (SF 10062), as well as a possible quartz tool (SF 10061) (Figure 27 and Figure 39). Roughouts and flakes have been found on the screes here by David Thorpe.

Table 5. Finds from Garreg Fawr screes

Id. No.	Length (mm)	Breadth (mm)	Thickness (mm)	Weight (g)	Description	Easting	Northing
SF 10061	97	82	41	426	Plano-convex piece of white quartz with possible crushing around the edges. Seems to have been a piece of quartz deliberately broken in half to produce the flat base.	268921	373259
SF 10062	132	113	59	1348	Rounded clast found on Garreg Fawr	268916	373268
DT 175					Flakes and worked debris in old, oxidised scree. Sett working material above and below, but older material is well-weathered with percussion scars and big flakes up to 50cm x 20cm	268899	373278
DT 176					Large amount of lichen covered percussion scarred flakes below summit above sheep folds	268883	373265
DT 177					Rough roughouts with flakes and weathered scree and potential hammer stones	268884	373265
DT 179 PRN 100413					Large broken potential broken roughout next to sheepfold	268874	373263
DT 180 PRN 100418					Large possible roughout left as found. Well oxidised, well lichened with smaller potential roughout (broken). Good percussion scarred flakes in area	268881	373273

On the top of Garreg Fawr microdiorite outcrops can be seen and one appeared possibly quarried (Figure 39). This outcrop (PRN 100579, SH 68969 73207) has a low face that appears to have been broken and there is a flat area of ground below it as if very small-scale quarrying has taken place. The face is well-weathered. Other vertical faces on low outcrops nearby appear natural and are more regular than this one. This may be the result of ice plucking removing a block of fractured bedrock, but it is possible that the block was removed in the Neolithic period like the small quarry investigated on Graig Lwyd (Williams and Davidson 1998, 12-13). Patches of scree are visible in places across the northern end of the plateau and down the north-eastern side, some of which look to have potential for axe-working, but these have not been searched closely for axe-working debris. The southern end of the main intrusion outcrops on the western side of Garreg Fawr and though there are few open areas of scree here this area would also benefit from close inspection.

Garreg Fawr has a less prominent southern summit about 620m to the south and actually slightly higher than the northern summit at 377m OD (Figure 39). There is a separate microdiorite intrusion on the western side of this summit. Although a large part of this side of the hill is densely covered with gorse there is open scree here. This area was inspected on 03/01/2025 and while some of the scree does not look or sound to be of axe-making quality, there are areas with better quality stone (Plate 68). Two axe

Plate 68. Screes on western side of the southern summit of Garreg Fawr with Garreg Fawr northern summit and Ynys Seriol in the background

Plate 69. Springs below the microdiorite intrusion on the southern summit of Garreg Fawr

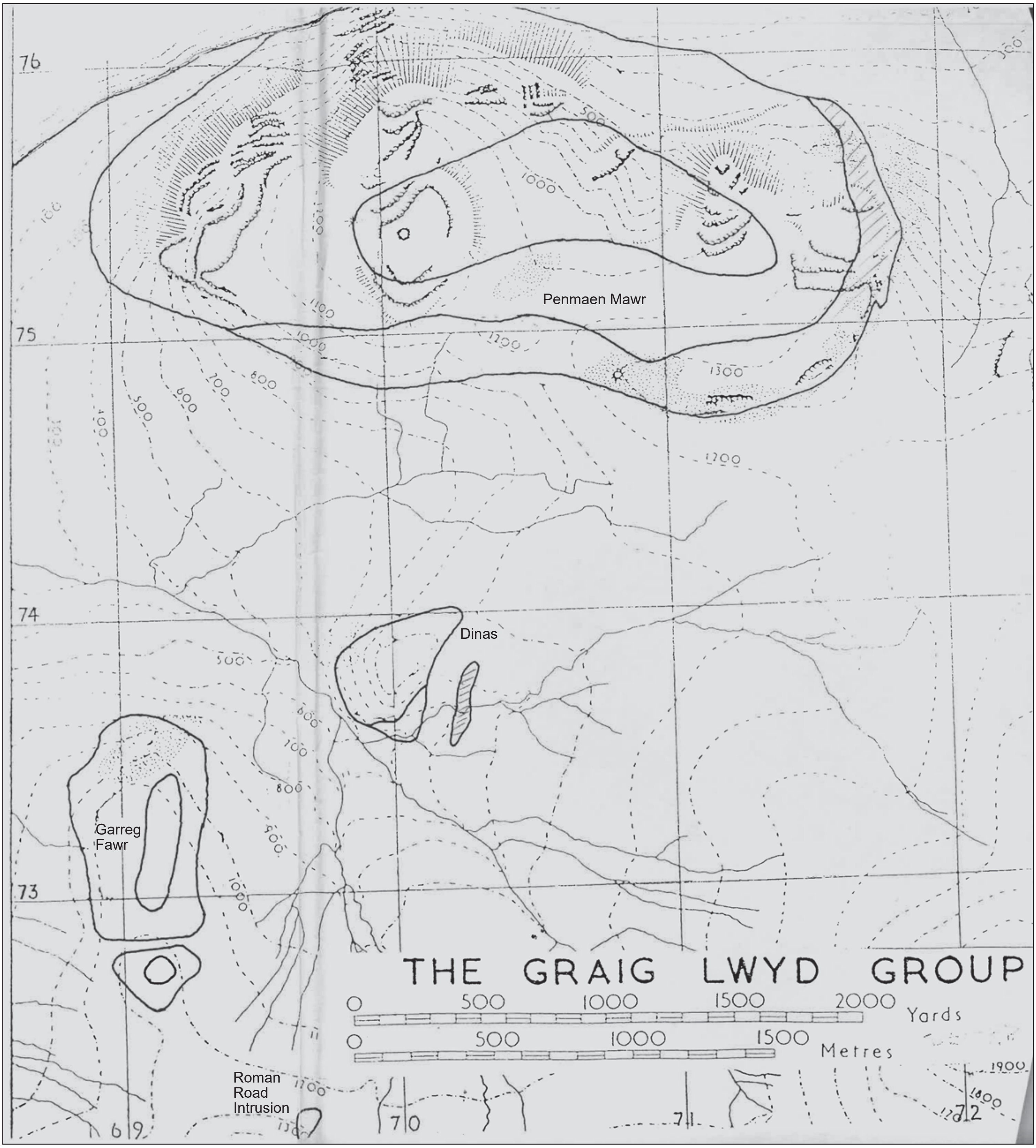


Figure 40. Plan of limits of microdiorite intrusions from Ritchie 1991

Plate 70. Boulders and bedrock outcrops at the Roman Road Intrusion

Plate 71. Boulder on the Roman Road Intrusion with a flake removed, probably by a geological hammer, showing that this is microdiorite

Plate 72. Shepherds' shelter (PRN 67623) including microdiorite scree

flakes (PRN 112197) (see Figure 59) were found in this area and a block at the base of the scree appeared to have been worked (PRN 112196). At the foot of the hill in this area are small springs, the streams from which have exposed scree and some pieces of microdiorite are visible in this (Plate 69).

All though little has been published about the microdiorite sources other than Graig Lwyd the Implement Petrology Group in the 1980s and 1990s was well aware of the other microdiorite intrusions and their potential for use as axe sources. Notes for an Implement Petrology Committee Workshop (Ritchie 1991) has recently been located in the Gwynedd HER. This includes information from a 1969 PhD by RA Davies. Davies mapped the limits of the intrusions, giving slightly different limits to the British Geological Survey, but most significantly he identified a new intrusion which he called the Roman Road Intrusion, as it was visible from the track to Bwlch y Ddeufaen close to the route of the Roman road (Figures 39 and 40). This area was also inspected on 03/01/2025 and small outcrops and boulders of microdiorite can be seen (Plate 70). One boulder has a fresh flake scar, probably produced by RA Davies geological hammer, which clearly shows the stone type (Plate 71). A sheepfold and shepherds' shelter in the area have microdiorite scree built into their walls, which can be securely identified where fresh breaks are present (Plate 72). One outcrop seems to have a block removed, like the possible quarry on Garreg Fawr, though this may also be due to glacial plucking rather than quarrying (Plate 73).

The British Geological Survey show a linear intrusion running down from Yr Orsedd to just above this location (Figure 38). They label that intrusion as porphyry, but the microdiorite seems to be an extension of this. The area is heavily covered with heather, bilberry and grass with no visible open screes, so identifying whether it has been worked would require test pitting. This is an area that would repay further investigation to confirm Neolithic working.

Table 6. Sites and features potentially relating to axe-working on Garreg Fawr South and the Roman Road Intrusion

Area	**Site**	**PRN**	**Easting**	**Northing**
Garreg Fawr South	Exposed scree		268940	372695
Garreg Fawr South	Springs		268894	372705
Garreg Fawr South	Exposed scree		268930	372636
Garreg Fawr South	Exposed scree		268944	372628
Garreg Fawr South	Knapped lump, not collected	112196	268940	372612
Garreg Fawr South	Two axe flakes collected	112197	268949	372628
Roman Road Intrusion	Roman Road Microdiorite Intrusion, central point	112198	269710	372200
Roman Road Intrusion	Shepherd's shelter with microdiorite in the walls	38396/67623	269767	372115
Roman Road Intrusion	Small outcrop of microdiorite		269785	372120
Roman Road Intrusion	Large sheepfold with microdiorite in the walls	38397/67624	269708	372173
Roman Road Intrusion	Microdiorite outcrop inside sheepfold		269714	372184
Roman Road Intrusion	Microdiorite boulders		269713	372215
Roman Road Intrusion	Microdiorite boulders forming rough wall foundations		269711	372202
Roman Road Intrusion	Microdiorite outcrop		269737	372216
Roman Road Intrusion	Microdiorite outcrop with glacial plucking or quarrying		269741	372220
Roman Road Intrusion	Microdiorite boulder with geological sample taken from it		269737	372223

Plate 73. Microdiorite outcrop with blocks removed by quarrying or ice plucking

Plate 74. View looking east from the upper part of Cors y Carneddau towards the Meini Hirion, with Moelfre and Tal y Fan. The burial cairn (PRN 464) is towards the foot of the slope.

Plate 75. South facing section of TP120

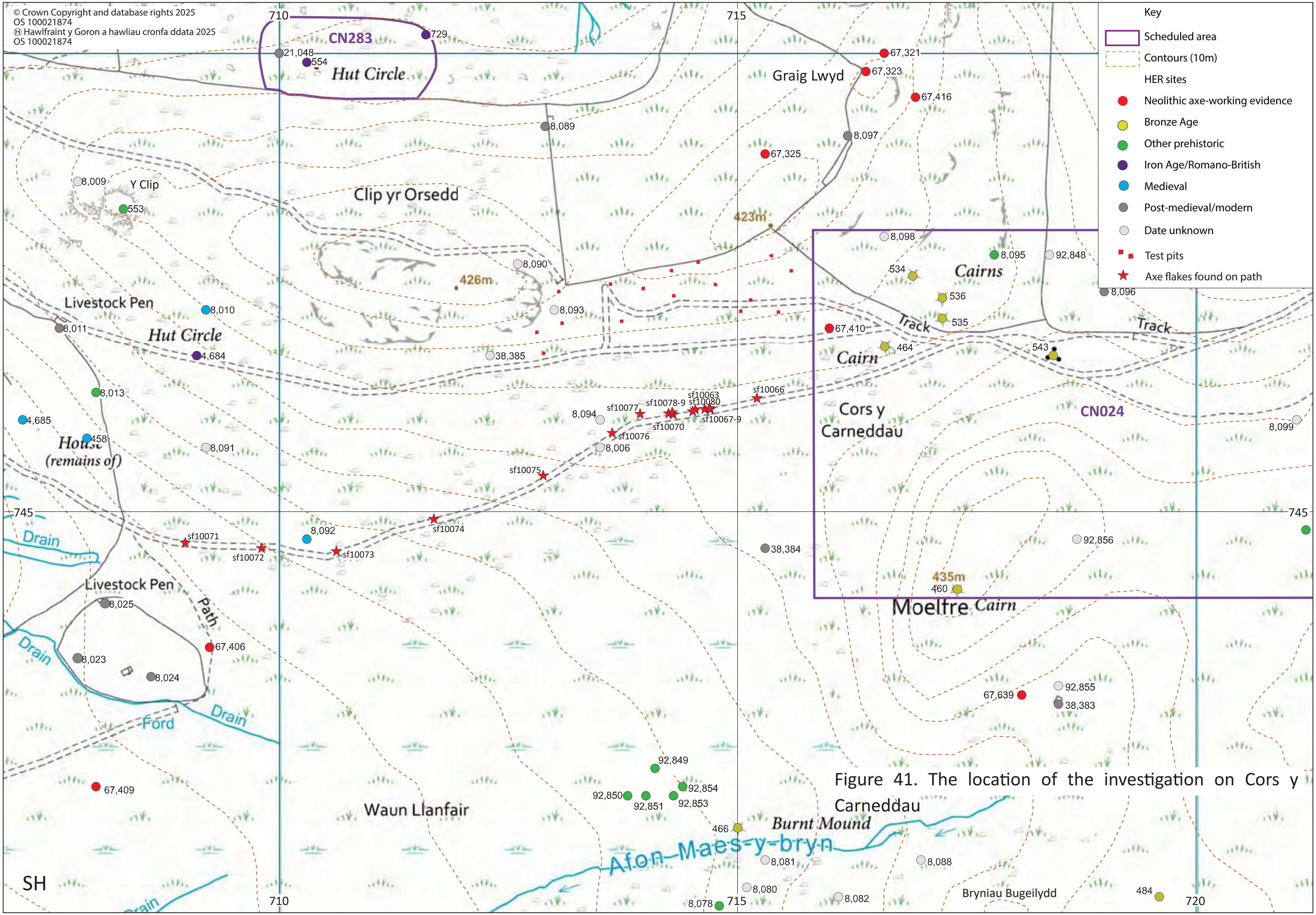


Figure 41. The location of the investigation on Cors y Carneddau

3.3. Cors y Carneddau (PRN 103604, centred on SH 7143 7473)

Topography and archaeology

The area investigated forms the south-western end of the Graig Lwyd outcrop and is on the chilled margins of the igneous plug. This is also on the northern margin of an extensive marshy, upland plateau of Waun Llanfair (Figure 41, Plate 7). The site is on a south facing slope, which generally slopes fairly gradually down from small rocky outcrops to the edges of the marsh. However, much of the lower part of that slope is covered with dense gorse, so the test pitting was concentrated on the higher parts, where there is closely grazed grass but also extensive bilberry coverage. The location has wide views to the south towards Foel Fras and the Foel Ganol ridge on the opposite side of Waun Llanfair. There are also views to the south-east, to Tal y Fan, and to the east towards the Meini Hirion (Druids' Circle) (PRN 541), a prominent Bronze Age monument (Plate 74), though this is not quite visible from the area investigated. There are numerous other Bronze Age monuments in this area. To the south-west both Dinas and Garreg Fawr can be seen.

A large Bronze Age burial cairn (PRN 464) lies on the eastern end of this slope, and it is likely that this and other monuments marked a Bronze Age routeway across the hills. PRN 464 is in the western end of a large scheduled area (CN024), also including the Meini Hirion. The limit of this was marked out with canes to prevent any test pits accidentally being dug within the scheduled area. The test pits were positioned in a very rough grid running west from outside the scheduled area. Scree is not visible on the surface in this area so it was difficult in advance to estimate where the most productive areas might be or indeed if any axe working would be found here.

Chance finds of flakes or roughouts and some archaeological excavation has indicated activity involving axe making around the edges of the Waun Llanfair (Figure 41). David T Jones has found axe flakes along the western edge of Waun Llanfair, including PRN 67406, and he found a complete and finely worked axe roughout (PRN 24725). Hazzledine Warren mentions an axe working site (PRN 67409) on Waun Llanfair, though this cannot be located with much precision (Warren 1919, 342) and found a roughout between Clip yr Orsedd and Dinas (Warren 1922, 2). Excavations at two cairns within Waun Llanfair (PRN 470 and PRN 485) revealed axe-working flakes in buried soil under the cairns, and narrow pick of Group VII rock was found under PRN 485 (Caseldine *et al* 2017, 97-102). There were also Neolithic flint tools at these sites suggesting these could be significant settlement sites. Hazzledine Warren found what appears to be an axe-working floor (PRN 67410) on Cors y Carneddau. This is described as "to the west of Carneddau [the large burial cairn PRN 464] nearly every molehill was seen to have several small flakes upon it, and when one dug through the turf evidence of a true chipping-floor was at once apparent" (Warren 1919, 342) and "a great quantity of flakes near the Carneddau Cairn" (Warren 1922, 2). Both reports suggest an extensive axe-working area and intact flaking floors beneath the turf. David T Jones also found numerous flakes in this area in molehills. Warren also found a large, knapped block of scree actually within the large cairn PRN 464 (Warren 1922, 17). The finds suggest widespread Neolithic activity around Waun Llanfair, both close to and at some distance from the rock sources, with a high possibility of extensive working on Cors y Carneddau.

Test pits

Sixteen test pits were dug across this area (Figure 42). Some aimed to investigate immediately below or on top of rock outcrops and other to test how far down the slope screes and working extended. TP120 found fractured bedrock (12003) under 0.48m of peaty soil (Plate 75). The soil appeared to be a largely undisturbed podsol with a dark, peaty upper layer (12001) and a leached lower horizon (12002). There was a considerable quantity of axe-working debris and scree in the peaty upper part of the soil (12001).

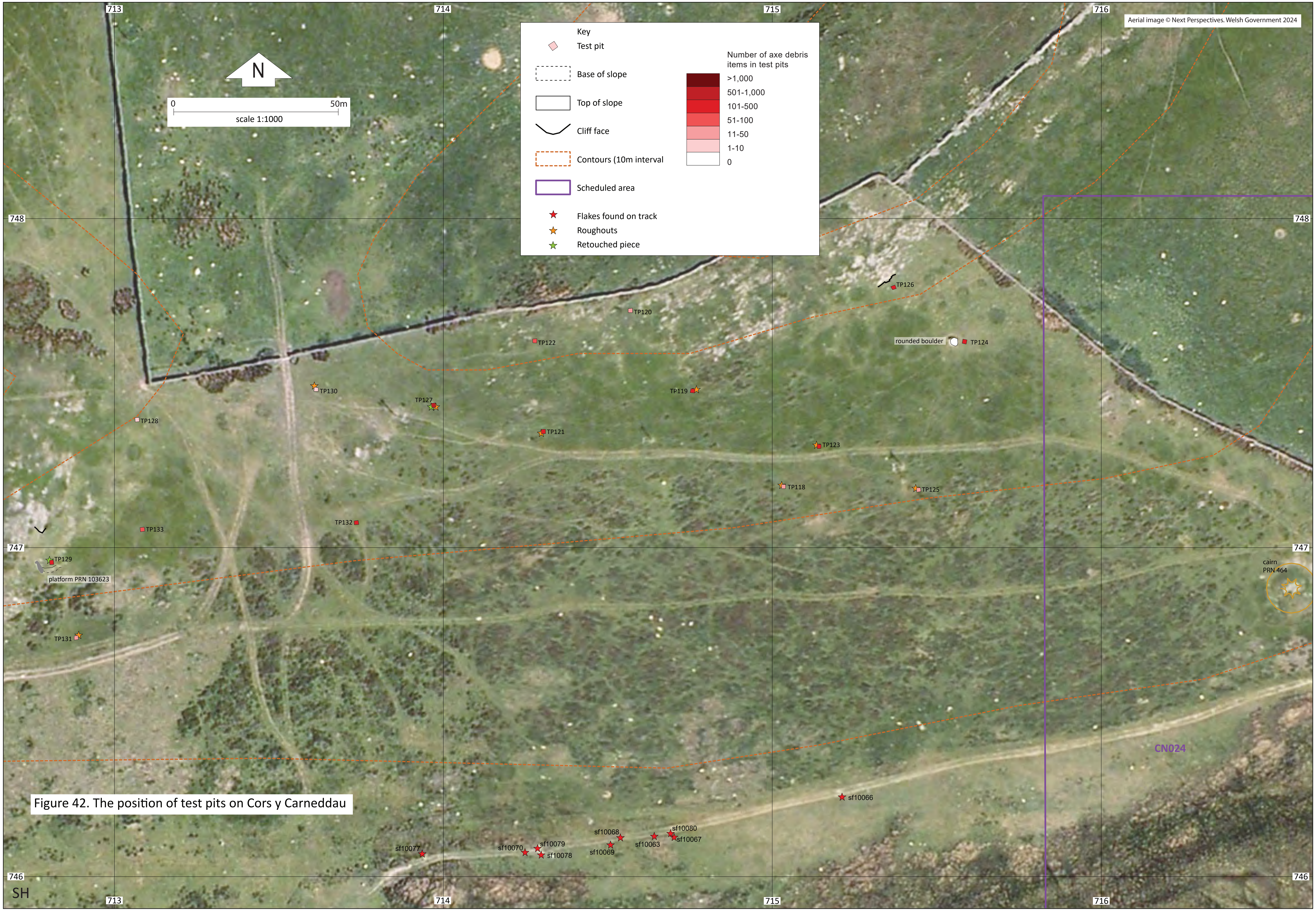


Figure 42. The position of test pits on Cors y Carneddau

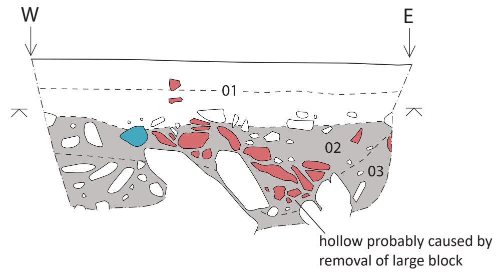
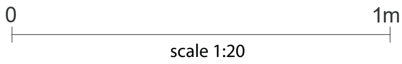
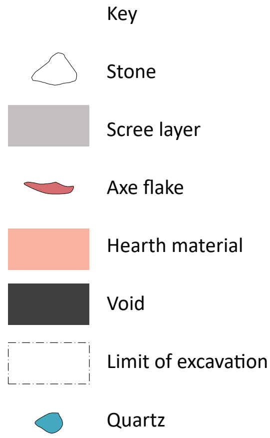


Figure 43. South facing section of TP123





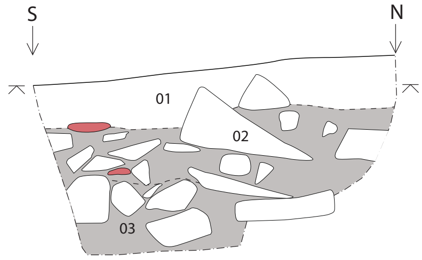


Figure 44. East facing section of TP127

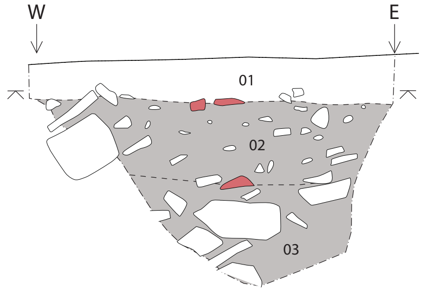


Figure 45. South facing section of TP127

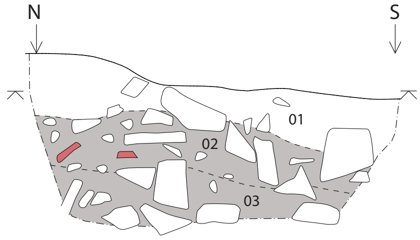


Figure 46. West facing section of TP127

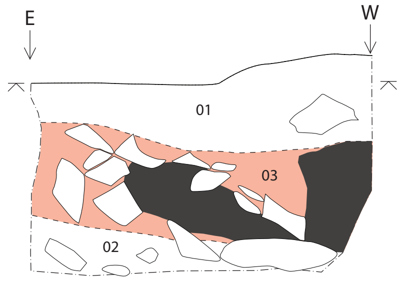


Figure 47. North facing section of TP129

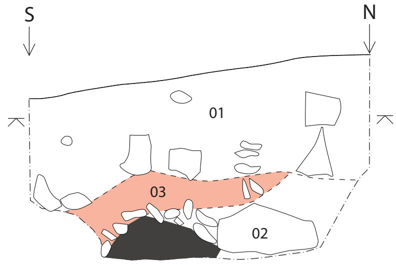


Figure 48. East facing section of TP129

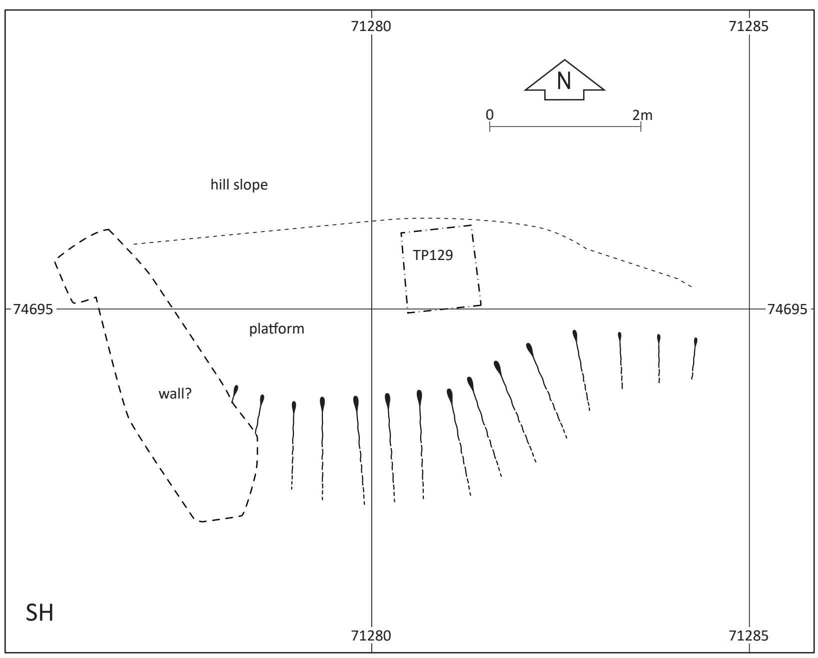


Figure 49. Plan of platform PRN 103623

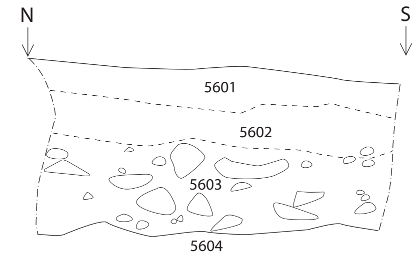
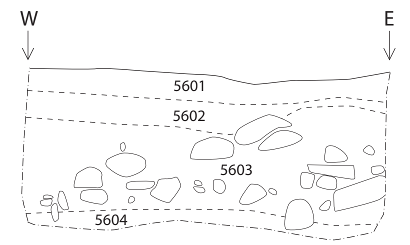


Figure 50. West and south facing sections of TP56 with grey silt layer 5603



There were stones up to 0.38m long within the soil layer, but it is possible that stone was being prised from the bedrock, though no unequivocal evidence of this was seen. The rest of the test pits showed that although there is no scree visible on the ground surface it could be found across the slope, though generally it was not deep. At the foot of small crags or bedrock outcrops TP126 revealed scree 0.20m deep, including a large block that had been struck (Plate 76). Under the scree was a shaly colluvial layer, overlying the yellow-brown glacial clay. TP119 and TP122, high up on the slope and close to the bedrock had a thin layer of scree (0.14m and 0.16m thick respectively) over the stony, orange-brown silty clay that formed the glacial deposits. Across much of the area investigated the glacial deposits were quite gravelly, as well as stony.

At the mid-level of the slope TP121 and TP123 had a thicker deposit of scree than the higher test pits. In TP121 the scree was about 0.25m deep and in TP123 an upper disturbed scree and a lower undisturbed scree were together over 0.35m deep. TP130, at a similar level, only had 0.1m of scree, but that did include a boulder, under which there was an axe flake, suggesting movement of the scree while axe-working was taking place. TP124 had up to 0.19m depth of scree but it was less dense, with scree pieces mixed into the sub-soil. Here the scree was also underlain by a shaly colluvial deposit over the glacial clay. TP124 was positioned in the lee of a distinctive rounded boulder but there was not enough axe debris from this location to prove that this had been used for shelter or as a landmark and attracted knapping rather than other locations (Plate 77). In TP123, where the scree was densely packed there was evidence of the scree having been disturbed. The way that some of the scree stones were piled up or sloping into a hollow, probably created by the removal of a larger block (Figure 43), suggested the scree had been sorted through in search for suitable pieces for axe-making.

Further down the slope in TPs 118 and 132 the scree was tailing off at a depth of 0.11m and 0.15m. In TP118 the glacial deposit had few stones but in TP132 it had a high proportion of shale fragments as seen elsewhere in the colluvium. TP125 showed that there was still a significant scree component to the sub-soil forming a layer 0.18m deep.

TP127 was different to other test pits in this area. It was located on a slight plateau at the same altitude as TP119 but not as close to the bedrock outcrops. This had 0.2m of scree with a brown silt matrix (12702) (Figures 44 to 46). This also had evidence of the scree having been disturbed with some pieces appearing to be stacked (Plate 78). However, under this was more densely packed scree, but with an orange-brown gritty silt matrix (12703). The colour of the matrix suggested that this had not been disturbed, but some axe flakes were recovered from within this deposit, possibly having slipped down from higher up. The total scree depth was therefore above 0.45m, and it was not possible to reach the base of the scree in the test pit. It is likely that the underlying topography caused scree to collect and build-up to a greater depth in places. This test pit produced 578 pieces of axe debris including particularly large flakes and some large struck pieces. It appeared that the scree here contained a greater proportion of large pieces of good quality stone and was probably particularly targeted as a source of large flakes as blanks for roughouts. Some of these large pieces may have been from quarried rock, naturally fractured pieces from the surface of the bedrock that had been prised out.

Further west, in the col between the Graig Lwyd ridge and the Clip yr Orsedd ridge, there was an area with little or no suitable stone. In TP133 scree was visible but this was noticeably less angular than elsewhere. It was densely packed, but the pieces were sub-angular or sub-rounded and the crystals in the stone were more prominent, seen to be shining in the sun. The stone in the scree therefore appeared to be less suitable for axe-making. However, 72 items of axe debris were recovered, suggesting that there was activity in this area. TP128, positioned in the col, had only 0.12m of scree mixed with colluvium, but much of this was small pieces and few convincing axe flakes were recovered from this

Plate 76. TP126 at foot of small crags with struck block, from the south

Plate 77. Location of TP124 on leeward side of rounded boulder, from north-east

Plate 78. East facing section of TP127

Plate 79. Small crags on the eastern end of Clip yr Orsedd, from the south

Plate 80. Built platform into which TP129 was dug, from the east

Plate 81. Hearth deposit (12903) over loose, voided stone deposit (12902), from the east

Plate 82. North facing section of TP129

test pit. Scree generated from outcrops on the eastern end of Clip yr Orsedd and moving downhill to the east and south-east therefore did not appear to be suitable for axe production.

On the southern face of the eastern end of Clip yr Orsedd there are small cliffs and outcrops that do appear to be of good stone (Plate 79). Some of these have fractures that may have been produced by people striking flakes directly from the bedrock. To investigate whether this stone had been used TP129 was positioned on a flat area under the crags. However, this proved to be flat because this was a deliberately created platform (PRN 103623), for a small building (see below). TP129 was dug to a depth of 0.6m, at which point it was too unstable to dig further but the glacial deposits had not been reached. Under 0.20m of turf and peaty topsoil was an unconsolidated dump of angular stones up to 0.25m long with a very dark grey-brown organic silt matrix or often voids between the stones (12902) (Figures 47 and 48). These stones were scree that had been moved downhill to create the platform, but the stone was good axe-making quality and included a high proportion of axe debris (110 pieces, 16115g). Over the top of the stone dump was a hearth deposit (12903) which had slipped down amongst the upper most stones (see below). The construction and use of this platform has caused the natural scree to be moved and disturbed but the quantity of axe debris within it shows that axe-making took place in this area, with the scree and debris probably originating only a short distance up the slope.

Downhill from TP129 was TP131. Here the scree deposit was only 0.15m deep with the lower part of that embedded in yellow-brown silty clay derived of the natural glacial clay. There were fewer axe flakes from this test pit, but it did produce one roughout, indicating working in the general area.

In addition to the test pits axe flakes were found over a wider area. As the volunteers walked up the path from Llanfairfechan they spotted axe flakes in the path or eroding out of its edges. These flakes have been collected and their locations recorded by GPS (Figure 41). While some of these may have been moved down the path during its use, they are likely to indicate axe working in the rough area in which they were found. This suggests that axe debris can be found all down the slope beneath the location of the test pits, but also that the area of working is much more extensive and is likely to extend, at least sporadically, west of the area investigated until the rocky outcrop (Y Clip) at the western end of Clip yr Orsedd.

Roughouts were fairly common from the test pits in this area, occurring in test pits with fewer flakes as well as those with many flakes. This supports the impression of extensive axe-making activity. Only the finds from test pits TP127 and TP129 were assessed, so the number of retouched pieces in this area is currently unclear. However, in the two assessed test pits there were retouched pieces, with TP127 producing four pieces. The presence of casually retouched pieces may, therefore, be widely expected. There was only one small piece of flint debitage present (in TP119), but this may indicate flint tools being manufactured on the site.

Building platform (PRN 103623, SH 71279 74695)

TP129 was dug into a small building platform (Figure 49, Plate 80). This was a deliberately created platform, measuring about 5.4m by 2.4m. The platform had a scarp up to 0.47m high on the southern side and the remains of a rough wall running down the slope on the western side. It appeared to have been created for a small rectangular structure. The test pit showed that the platform was formed from an unconsolidated dump of angular stones up to 0.25m long with a very dark grey-brown organic silt matrix or often voids between the stones (12902) (Figures 47 and 48). These stones were scree that had been moved downhill to create the platform. Over the top of the stone dump was a layer of strong orange-brown gritty silt (12903) which had slipped down amongst the upper most stones (Plates 81 and 82). This layer contained charcoal and pale speckles suggestive of ash deposits and appeared to be the remains of a hearth, probably just a fire on the ground surface rather than a built hearth.

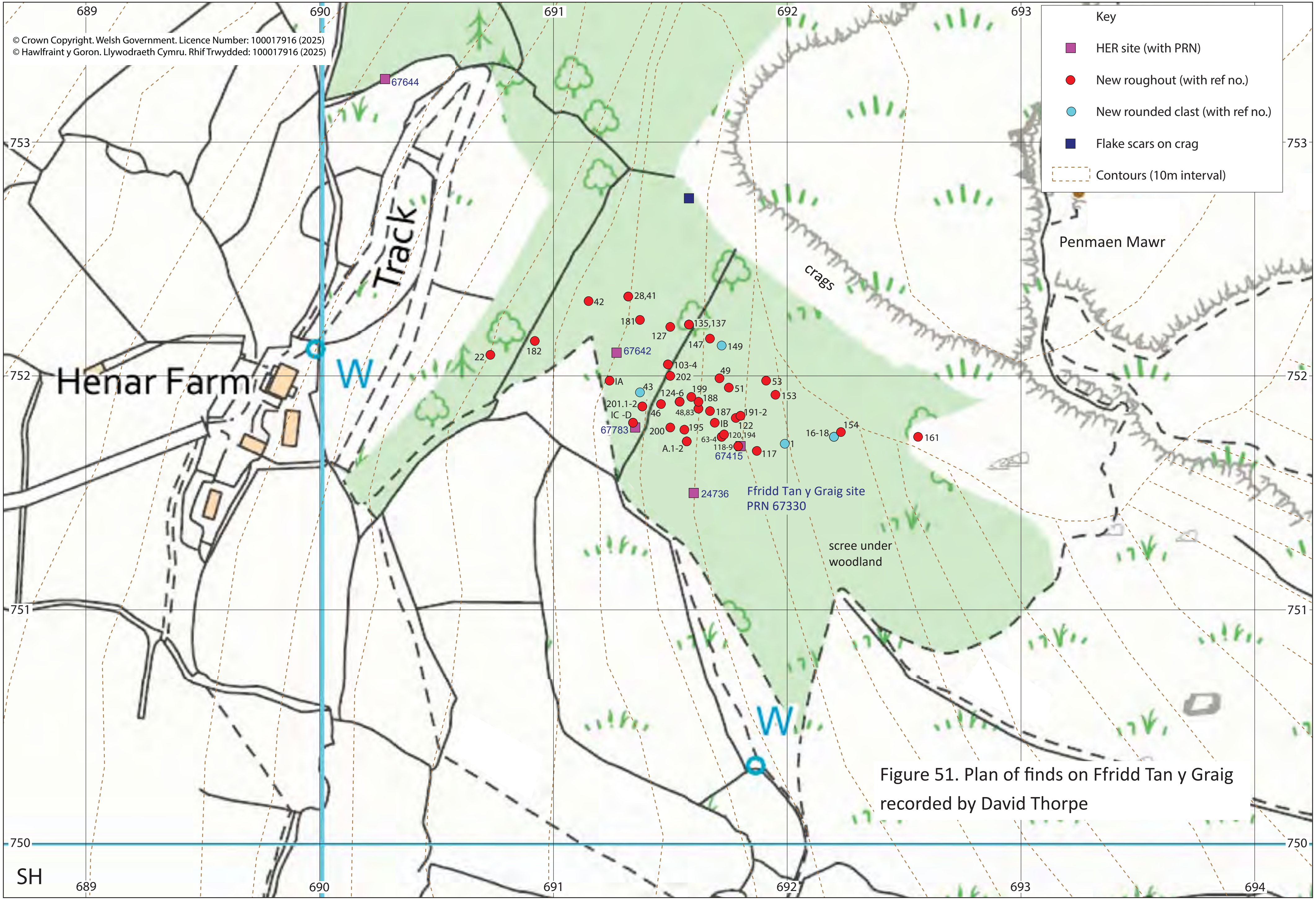


Figure 51. Plan of finds on Ffridd Tan y Graig recorded by David Thorpe

A bulk soil sample was taken from deposit 12903 and this contained fragments of burnt peat as well as two fragments of alder charcoal (see Section 4.9 below). This suggests that the fuel for the hearth inside this small structure came from the marsh of Waun Llanfair, with peat being cut for fuel and the alder that would have grown in this wet area also being collected. Fuel-ash slags from the hearth were not identifiable to any particular fuel (see Section 4.7 below). A fragment of an organic-tempered plaster or mortar could hint that the structure was of stone which was mortared or plastered inside. This seems unlikely for a small structure in this location, but rough internal plastering could have blocked holes in a drystone wall.

A fragment of alder charcoal, probably fuelwood, was radiocarbon dated, and this date (SUERC-130055, 770-480 cal BC) suggests the hearth was used in the middle Iron Age (see Section 5 below). The roughly rectangular shape of the platform had suggested that this may have been of medieval date. Only a very small circular structure could have fitted on the platform, so it would not have been the location of a domestic roundhouse. There may have been a small temporary shelter. The fact that the hearth was little more than a fire on top of the loose soily deposits covering the stone of the platform supports this as a casually occupied site. There is a dispersed roundhouse settlement about 300m away on the northern side of Clip yr Orsedd (SAM Cn283, PRN 554) and a small roundhut (PRN 4684) about 370m to the west (Figure 41). These have not been excavated so their dates are unknown, and they are as likely to date from the Roman period as the Iron Age. These sites may not have been related to the activity on the platform, which does suggest temporary use of the uplands in the middle Iron Age rather than settlement.

3.4. Ffridd Tan y Graig (PRN 67330, centred on SH 6915 7518)

Field-walking by David T Jones identified an axe flaking area on the western face of the main outcrop of Penmaen Mawr (Figure 51). Much of the scree is either covered by vegetation or by quarry waste but a few gaps are left where axe flaking debitage can be found. The discovery in this area of a broken axe roughout (PRN 24736) was published in 2004 (Jones and Williams 2004).

This area is under woodland and the natural scree is much confused by stone dumped from the quarry, some of which has fallen a long way and often smashed, with fresh flakes scars. However, it seems probable that this scree was also worked for setts in the early 19th century phase of quarrying before the large companies took over, explaining some of the more deliberate fresh flaking. Much of the scree is natural, especially further down the slope, and heavily patinated flakes and roughouts can be found in it.

David Thorpe has also investigated Ffridd Tan y Graig, starting in the winter of 2021/2022, identifying roughouts over a larger area than recorded by David T Jones (Figure 51). His collection provides a valuable sample of roughouts from this site, which was a stone source of comparable importance to Dinas (see Kenney and Smith 2023, Appendix IV for list of finds). He has recorded the location of axe roughouts, flakes, percussion scarred screes, potential core material and outcrops, and rounded cobbles that were probably used as hammerstones.

The roughouts are varied in form, but generally quite thick, resulting in their discard. Some of the roughouts found in this area are narrow and probably aiming at pick-like tools rather than axes, and some either really large or of odd shape, and may be aiming at tools other than axes. Some roughouts and potential cores were found on the open ffridd away from outcrops suggesting human transport.

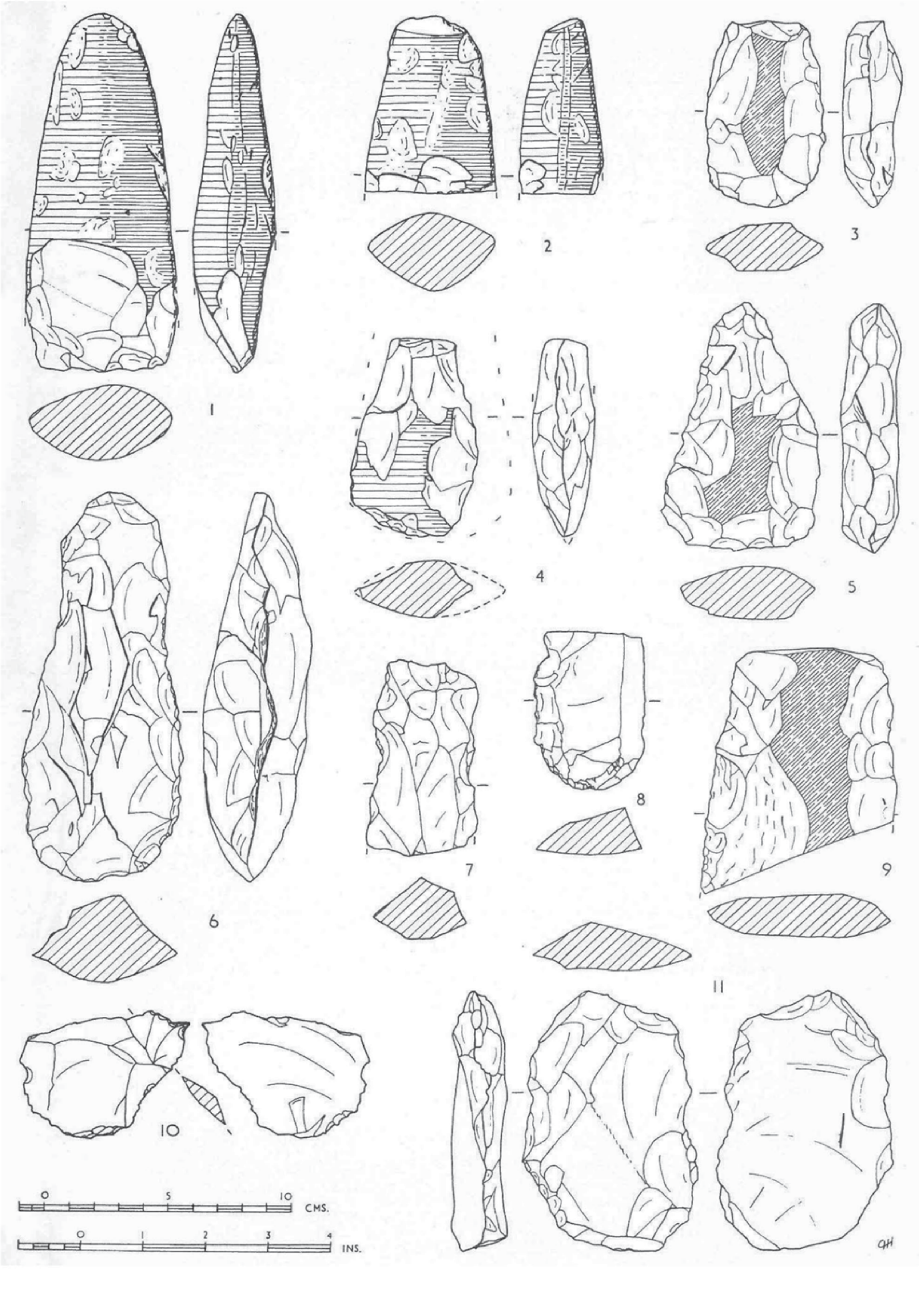


Figure 51. Finds from the Maes y Bryn site in 1961 (Davies 1961, Fig 1)

1-4: polished axes, 5-7, 9: roughouts, 8: scraper, 10: borer, 11: chopper (8, 10, 11 on Group VII flakes)

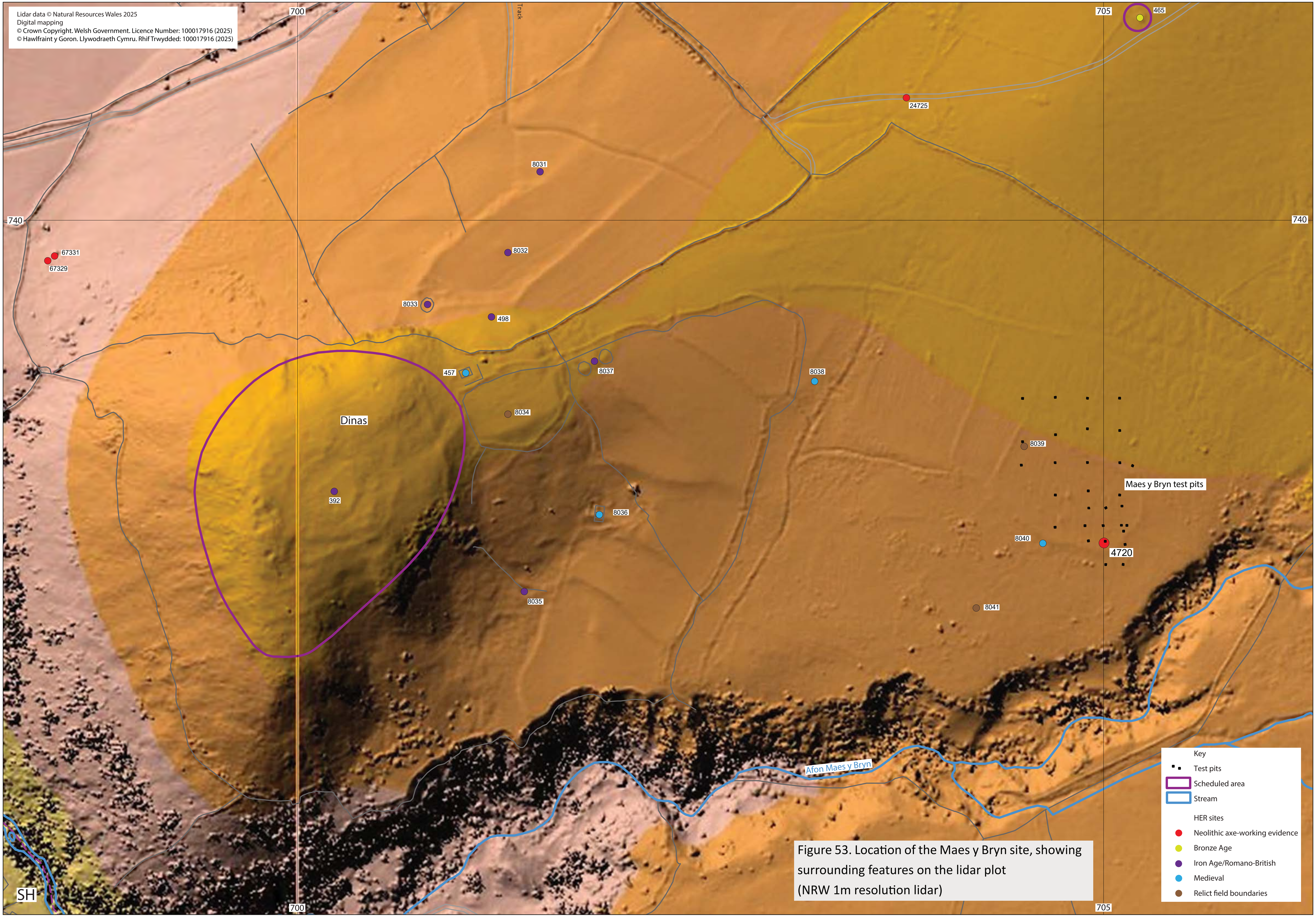


Figure 53. Location of the Maes y Bryn site, showing surrounding features on the lidar plot (NRW 1m resolution lidar)

Plate 83. Location of the Maes y Bryn site to the east of Dinas, arrow points to site (photograph by David Longley)

Plate 84. TP57 from the south, showing boulder

Plate 85. Stone in TP 20 showing several phases of plough marks

3.5. Maes y Bryn (PRN 4720, centred on SH 70500 73800)

Introduction

In the winter of 1960-61 the ffridd east of Dinas was ploughed for the “first time in living memory” according to Mr H. Jones of Ty’n y Llwyfan Farm (Davies 1961, 1). In May 1961 J. Davies walked the field and, despite it being partially obscured by the sprouting crop, found a quantity of axe debris. A second visit with Ivor Davies, a local historian from Penmaenmawr, produced more finds. This collection included 7 roughout axes or pieces of roughouts and 3 roughouts for smaller, parallel sided implements, possibly picks or chisels. Many axe-flakes were found, and three flakes worked into tools, including a scraper. Three pieces of flint were found, one retouched into a borer. Unusually for the area there were also four finished polished axes. One had a blade crudely resharpened by reflaking, one was a broken butt end and two were tools made from reworking larger polished axes, so they were a quite different shape to the original and only small areas of the original polish remained. Further finds not described in detail were found on a later visit, including two more flint flakes. The discovery was promptly published in the Transactions of the Caernarvonshire Historical Society, including some excellent finds drawings (Davies 1961) (Figure 52).

This site is about 330m from the screes of Dinas, so while close to the source rock it is quite separated from it (Figure 53). Davies concluded that “there can be little doubt that the spot represents at the least a temporary encampment of the axe-makers, if not a more permanent settlement” (Davies 1961, 4). He also considered that “the whole area would amply repay systematic excavation” (Davies 1961, 1). No further investigation of this site had taken place, until the current project. The field is now under rough pasture, and fieldwalking, except to recover finds from molehills, is no longer a possibility but test pitting presented a useful technique to rediscover this site.

Please note that while the name of Maes y Bryn has been used for this site, this is for convenience as the nearest named feature on the 1:25000 map is Maes y Bryn, and the site is close to the Afon Maes y Bryn. However, Maes y Bryn correctly refers to the ffridd on the south-eastern side of Afon Maes y Bryn (see Kenney and Smith 2022, 17).

Topography and archaeology

The site is on a south facing slope above the Afon Maes y Bryn, which here runs in a deep, steep-sided gorge (Figure 53, Plate 83). The field is a ffridd, an enclosure just below the mountain wall in which sheep can be kept enclosed and off the open mountain without grazing the improved grassland lower down. Davies does not say what the crop was that was planted in 1961, but it was presumably an improved grass seed mix, as the grass here is of good quality. Part of the field is overgrown with rushes, and it appears that this lower southern part was not ploughed in 1961. The field is clearly wet in winter. Although used for pasture in recent centuries the south facing slope could have made it suitable for arable agriculture in the past, when high crop yields were not expected, and animal drawn ploughs could cope with rougher ground and steeper slopes. Just to the west on the eastern slopes of Dinas a series of terraces or lynchets can be clearly seen. There are both roundhouses and a small medieval farmstead within these fields, and it is probable that they were first used in the Iron Age but must have still been used in the medieval period.

Closer to the site investigated, the traces of former fields are slighter but still quite visible on the ground and on the lidar plot (Figure 54). The lidar data used in this figure is part of a high-resolution survey commissioned by the Carneddau Landscape Partnership Scheme. This provides detail not previously available on other lower resolution lidar data sets. The lidar shows that there are some straight boundaries, visible as low banks, running down the slope and slight traces of narrow ridge and furrow on the same alignment. There are also occasional low mounds that appear to be field clearance

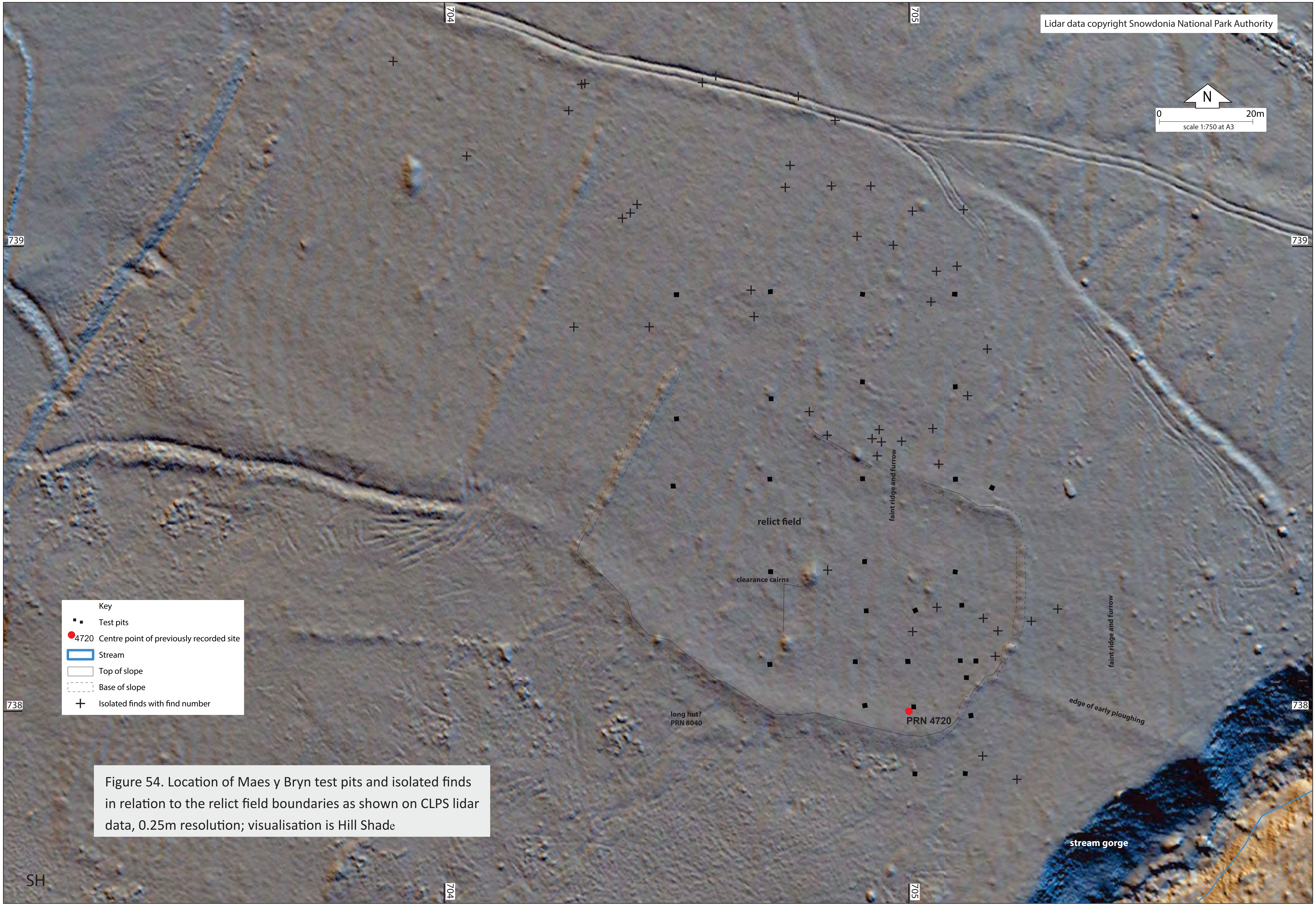


Figure 54. Location of Maes y Bryn test pits and isolated finds in relation to the relict field boundaries as shown on CLPS lidar data, 0.25m resolution; visualisation is Hill Shade

Figure 55. Detail of the Maes y Bryn test pits

cairns. Around the area investigated one of the straight boundaries forms the western side of a small field defined on the southern side by a gently curving scarp up to 0.9m high. Its eastern side is defined by a very slight curving bank. There are faint traces of a northern side to this field indicated by the remains of a bank at the eastern end and a largely ploughed out scarp further east. There are gaps in the eastern boundary that are presumably due to disturbance but may possibly be original. The faint ridge and furrow seems to have crossed the northern boundary of this field but respected the southern scarp edge.

The curving character of the southern and eastern boundaries of this field suggest that these are part of an original, probably Iron Age field, which has been reused in the medieval period, when the ridge and furrow was created and the straight field boundaries. The medieval ploughing seems not to have extended south of the relict field and this southern part of the field may never have been ploughed. That modern ploughing episode presumably extended over the relict field boundaries and other features within the ffridd but as this was a single episode it has not destroyed all evidence of the earlier fields. The nature of the ground surface and vegetation suggests that the modern ploughing extended no further south than the southern scarp.

The site is close to the open, marshy ground of Waun Llanfair, but is on a south facing slope, which would be warmer and drier than much of the surrounding area.

Test pits

Davies central grid reference for the site (SH 705738) proved to be in the south-east corner of the relict field and in 2021 test pits were located in a rough grid working north from this point, with three test pits positioned outside the field boundary to compare deposits there (Figure 55). In 2022 test pits were laid out in a grid 20m apart extending out from the area investigated in 2021, covering most of the relict field and extending further upslope to the north. The full area investigated measured about 85m by 65m and a total of 30 test pits were excavated.

The natural subsoil was generally a yellow-brown gritty clay representing a glacial till. Sometimes the subsoil had larger stones within it but did not seem particularly stony at this site. TP57 contained a boulder, which was just concealed under the turf (Plate 84), but in general test pits were positioned to avoid boulders. This natural subsoil was between 0.20m and 0.4m below the ground surface, with the soil deposits being slightly deeper closer to the southern boundary of the relict field and shallower both south of the field and further north within the field. This suggests some soil movement within the ploughed deposits. A stone embedded in the subsoil in TP20 had plough scars from several phases of ploughing in different directions demonstrating that the relict field had been ploughed several times (Plate 85). The only deeper test pit was TP56, in which the natural subsoil was 0.45m below the surface. This had a different depositional history to the other test pits and will be discussed separately below.

In all the test pits there was a dark brown slightly clayey silt, with a varying amount of stone that was well mixed and represented a ploughed soil layer under the topsoil. In some test pits this layer could be divided into two, with the lower part being slightly lighter in colour and often stonier, representing the mixed interface with the natural subsoil. There was no clear ploughsoil layer in TP 28 and TP29 south of the relict field where the surface suggests that no ploughing had occurred.

In most cases the axe debris was found in the topsoil and the ploughsoil and was therefore disturbed from its original context. Even the debris found towards the base of the test pits will have been disturbed by the earlier ploughing, this made it seem unlikely that *in situ* deposits of axe-working debris would be found within the area of the relict field. Beyond the limits of the relict field TP28

Plate 86. Section of TP28, outside the relict field

Plate 87. TP56 from the south showing layer 5603

Plate 88. Microdiorite scraper and retouched flake in situ as found in TP56

produced no axe debris, but a small amount came from TP29, including a roughout. In these test pits a layer 0.2m deep represented undifferentiated topsoil, with deposits below that appearing largely undisturbed. In TP28 the lowest layer was particularly stony (Plate 86), while in TP29 the equivalent layer was a less stony buried soil. This suggests that there may be undisturbed prehistoric deposits surviving south of the relict fields. However, in TP29 the axe debris came from the topsoil and so was in a disturbed context and the absence of axe debris from TP28 suggests that there may have been little activity in this area.

In the base of TP55 was an irregular linear hollow [5505] with some charcoal in its fill, probably the result of burrowing or root action. TP64 had a narrow straight linear cut [6405] across the test pit base, which was probably a plough scar.

In TP56, under a thin ploughsoil was a grey clayey silt (5603) with about 35% stones up to 0.3m long (Figure 50, Plate 87). The layer was 0.26m deep and was greyer in colour and less mixed in appearance than layers in the other test pits. The density of larger stones was also higher than elsewhere. This test pit was located just uphill from the remains of the northern bank defining the relict field. The stony bank had probably protected the area of the test pit from more than superficial ploughing and layer 5603 was probably undisturbed. The stone in this layer may have originated from the field bank, but the stone from the bank would be more likely to have fallen downhill and the stone in the test pit did not slope towards the bank. It is therefore possible that there was another origin for the stone. To investigate whether this layer continued behind the bank TP66 was dug about 7m east of TP56. However, TP66 was only 0.29m deep, did not contain the grey silty layer and was fairly stone-free. TP56 therefore appears to have detected a restricted area of undisturbed deposits, that do not continue all along the back of the bank. This grey silt deposit (5603) is probably of some significance because, as well as containing axe-flakes, it produced three scrapers made on flakes of microdiorite (Plate 88) (see Section 4.2 below).

No dug features were located in the test pits. The size of the test pits means that it is unlikely that features will be encountered unless there is a high density of them in an area. However, the complete lack of dug features, with the evidence of early ploughing, may indicate that pits and postholes could have been heavily truncated. It is unlikely that layers such as hearth deposits would have survived in this area. The most likely place to find undamaged cut features and undisturbed deposits would appear to be near TP56. However, a piece of burnt clay found in TP64 could have been part of an oven or hearth structure.

The axe debris was fairly evenly distributed but with little material in TPs 59, 60 and 67, suggesting a limit to the scatter to the south-west. There was a slightly higher number of flakes from TP22, 27 and 30, possibly indicating a concentration of working in this area, but flake numbers also increased to the north (Figure 55). A survey of molehills was carried within the area investigated by the test pits and further north and north-west up the hill slope. The molehills were inspected for axe flakes and 46 of these were found (Figure 54). These finds indicate that the artefact scatter continues to the north and north-west of the limit of test pitting. A more extensive molehill survey might clarify the full extent of the artefact scatter, though this does rely on an even spread of molehills, which is often not the case.

The axe flakes from both the test pits and the molehills were small flakes from secondary roughouts, with no primary flakes from initial shaping of scree. The roughouts worked must have been created elsewhere and brought to the site for finishing. The roughout (SF2902) from TP29 may represent the type of object taken to the site ready worked, though could have been a tool rather than a roughout. Other finds included 16 flint and chert flakes; unretouched flakes from small beach pebbles, as well as a flake of crystal quartz from TP65 (SF6504). The one retouched flint piece is a tiny thumbnail scraper made on a very small flint pebble (SF2702). This is a fairly dense collection of flint for an upland site in this area and it indicates that other tasks were undertaken on this site, not just axe manufacture. Finds from TP 27 support a focus of activity in the south-eastern corner of the area investigated, but flints from TP58, TP61, TP67 and especially TP64, suggest other foci of activity further up the hill slope (Figure 55).

TP64 produced a scraper on a flake of microdiorite, as well as the three scrapers from TP56, and other retouched tools on microdiorite flakes were found in TP56, TP64, TP68 and TP69. The three scrapers from TP56 suggest a focus of settlement activity near that test pit but the distribution of the other retouched pieces reinforcers the impression of an increase in activity in the north-western part of the area investigated. Scrapers are traditionally thought to have been used for processing hides into leather, though usewear analysis does indicate that they were used for other scraping tasks. Generally, their use is suggestive of a domestic site, however temporary. The quality and apparent lack of use could indicate that the microdiorite scrapers were being made on this site for use elsewhere, though the flint thumbnail scraper must have been made for use on the site.

In TP22 a flake of Group VII stone was found that had polish over the dorsal face (SF2205). This is a flake from a finished stone axehead. Davies found several finished axes that had been reworked or roughly resharpened. This flake is one that could have been produced by reshaping or breaking down a finished axe. It is evidence that finished axes were brought to the site, probably at the end of their useful life and reworked on the site.

Davies (1961) does not give an indication of the size of the artefact scatter that he identified but implies that finds were recovered over quite a wide area. It is likely that there are several foci of axe-working within the general area. The axe flakes from the molehills indicate that the edge of the artefact scatter has not been reached by the test pits on the north and north-west side sides. Further work is needed to identify the limits of the artefact scatter and to determine whether any features relating to settlement survive, but the range of artefacts found strongly support the idea that this was a Neolithic settlement site.

4. ARTEFACT AND ECOFACT ANALYSIS

4.1. Axe debris

By George Smith and Jane Kenney

About 1404kg of microdiorite axe debris was recovered by the project, including part-finished and rejected or broken axehead roughouts and a great quantity of waste flakes and fragments. This has been assessed by George Smith, but only a proportion of the material has been inspected. The assemblage is being studied in detail by Rebecca Vickers of Sheffield University as part of a PhD. This full analysis will study the distribution and nature of the assemblage, but the following preliminary observations can be made from the assessment.

The raw material across the sites investigated all derives from scree blocks rather than quarrying. The scree was easily available but would be surface-weathered and not very good material; quarrying would have produced unweathered and better-quality stone. The worked waste pieces were also nearly all considerably weathered subsequent to their manufacture. The use of scree has meant that even the largest flakes are small compared to those from excavated areas of the main Graig Lwyd quarry, where the raw material was massive flakes quarried from *in situ* outcrops (Williams and Davidson 1998 and 2002).

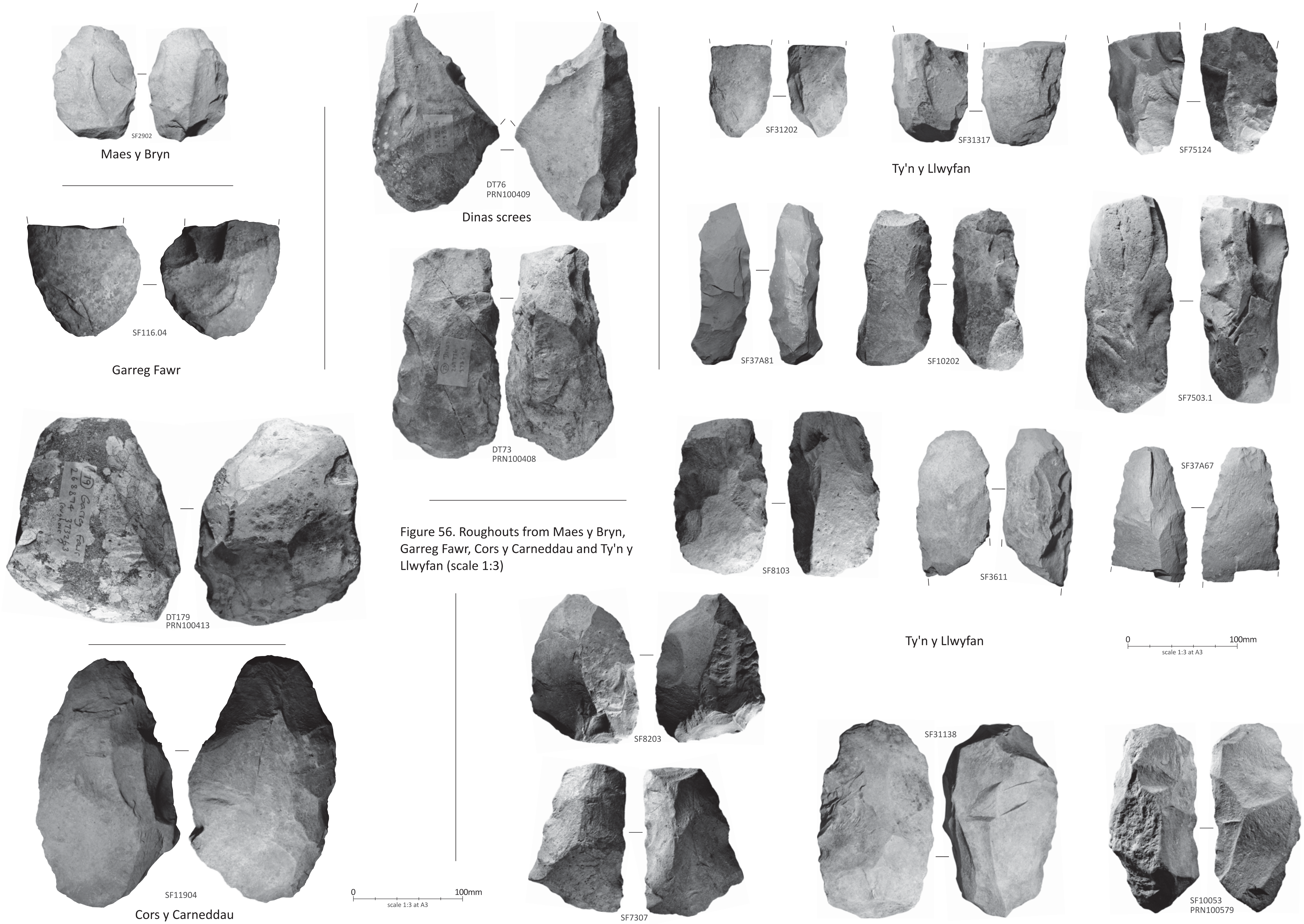


Figure 56. Roughouts from Maes y Bryn, Garreg Fawr, Cors y Carneddau and Ty'n y Llwyfan (scale 1:3)

Primary, secondary and tertiary flakes were all present, in the Ty'n y Llwyfan test pits, but there were fewer primary flakes, and the tertiary flakes were the most numerous. This is partly due to the latter being the thinnest and therefore easiest to break, so multiplying the count of number of items. The high rate of breakage suggests considerable trampling over the working areas, though disturbance by ploughing might also cause breakages. The number of tertiary flakes does indicate that final working was taking place in the area, especially on the upper lynchet, where the proportion of tertiary flakes was highest. Though the experimental work undertaken by Rebecca Vickers shows that small, thin flakes are produced at all stages of axe-making. The larger secondary flakes and the primary flakes were mainly found in test pits on the screes. It is notable that TP75 also contained a significant number of larger secondary flakes and the primary flakes, however, there were also a large number of tertiary flakes. There is perhaps a suggestion of more mixed working in this area than elsewhere with both primary and tertiary working occurring in the same location. It may be significant that the breakage rate of the flakes was lower than elsewhere suggesting less trampling or less disturbance by ploughing.

The number of flakes from Cae Dafydd was much less than from most of the higher test pits and generally these were only smaller flakes, but TP90 produced only larger flakes. The slightly higher number of flakes in TP95, in association with a retouched flake and a piece of Neolithic pottery suggests a focus of activity near this location.

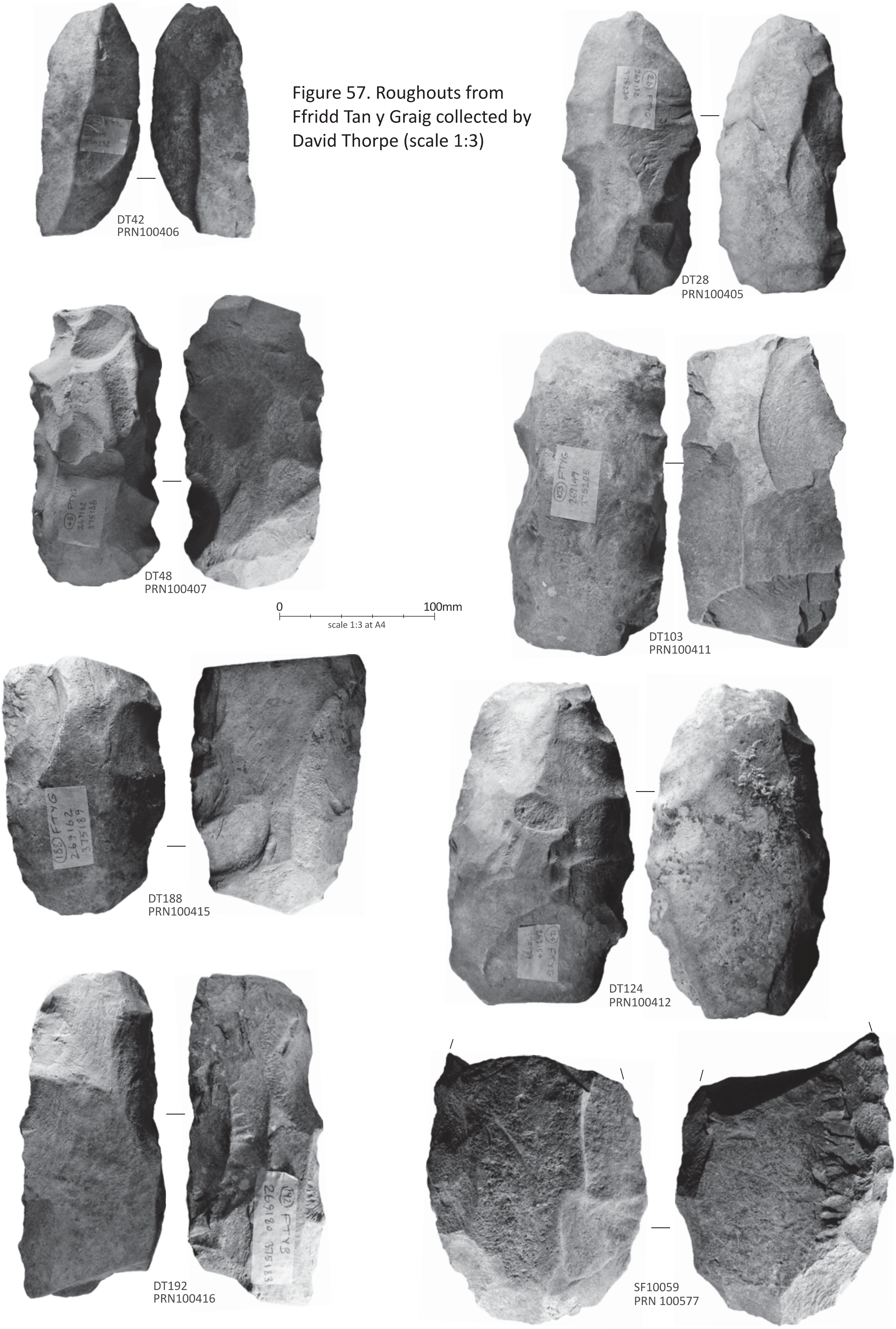
At Garreg Fawr the area of axe working is restricted, and this appears to be because the best quality raw material is restricted in area. The proportions of flakes of different sizes suggests that the complete sequence of working from blank to finished object was taking place, with about one third of the total devoted to preliminary work and the rest to final shaping. There was a high rate of breakage, especially of the smaller, thinner flakes, but there were variations in this with TP117 having a lower rate of breakage than TP116, possibly reflecting different degrees of trampling on different parts of the site.

At Maes y Bryn there was a high proportion of smaller flakes, which had probably been produced using a soft hammer and were indicative of thinning and shaping bifacial objects, such as axeheads. There were no large primary flakes and the roughouts must have been created elsewhere and brought to this site for finishing. There were few complete flakes, suggesting breakage due to trampling.

All the roughouts were made using scree blocks as raw material either primarily or on large flakes struck from scree blocks. The latter could be large, thick, flat flakes or very large, thick flakes similar to a core trimming flake with a dorsal ridge from two previous removals. That gave a central thicker area that could become the body of an axe. Nineteen pieces recorded as roughouts were found in the evaluation trench (Trench 31) in the undisturbed screes, showing that there is a fairly high density of roughouts in the screes. Roughouts were also found in test pits on the screes within Cae Graig. Several roughouts were found in TP75, but this may have been due to the stony deposit in this trench originating from a scree deposit further up the slope. Roughouts from TP15 and TP39 may also be related to an isolated deposit of scree in this location. Generally, roughouts were rare in test pits away from screes. This suggests that roughouts were generally created on the screes, and resulting in failed roughouts being discarded here, with successful roughouts were taken a little further away to be finished off. However, occasionally a roughout was discarded at some distance from the screes as shown by the two roughouts from Cae Dafydd.

The axe roughouts that have been found are fairly early stage rejects or practice pieces, rather than late stage broken rejects. The roughouts from Ty'n y Llwyfan were mostly shapes suitable for the creation of simple, elongated axe heads but a small number were for production of narrow, chisel type axe-heads, e.g. SF37A81 (Figure 56), which is thick with a pronounced triangular cross-section. Most were

Figure 57. Roughouts from Ffridd Tan y Graig collected by David Thorpe (scale 1:3)



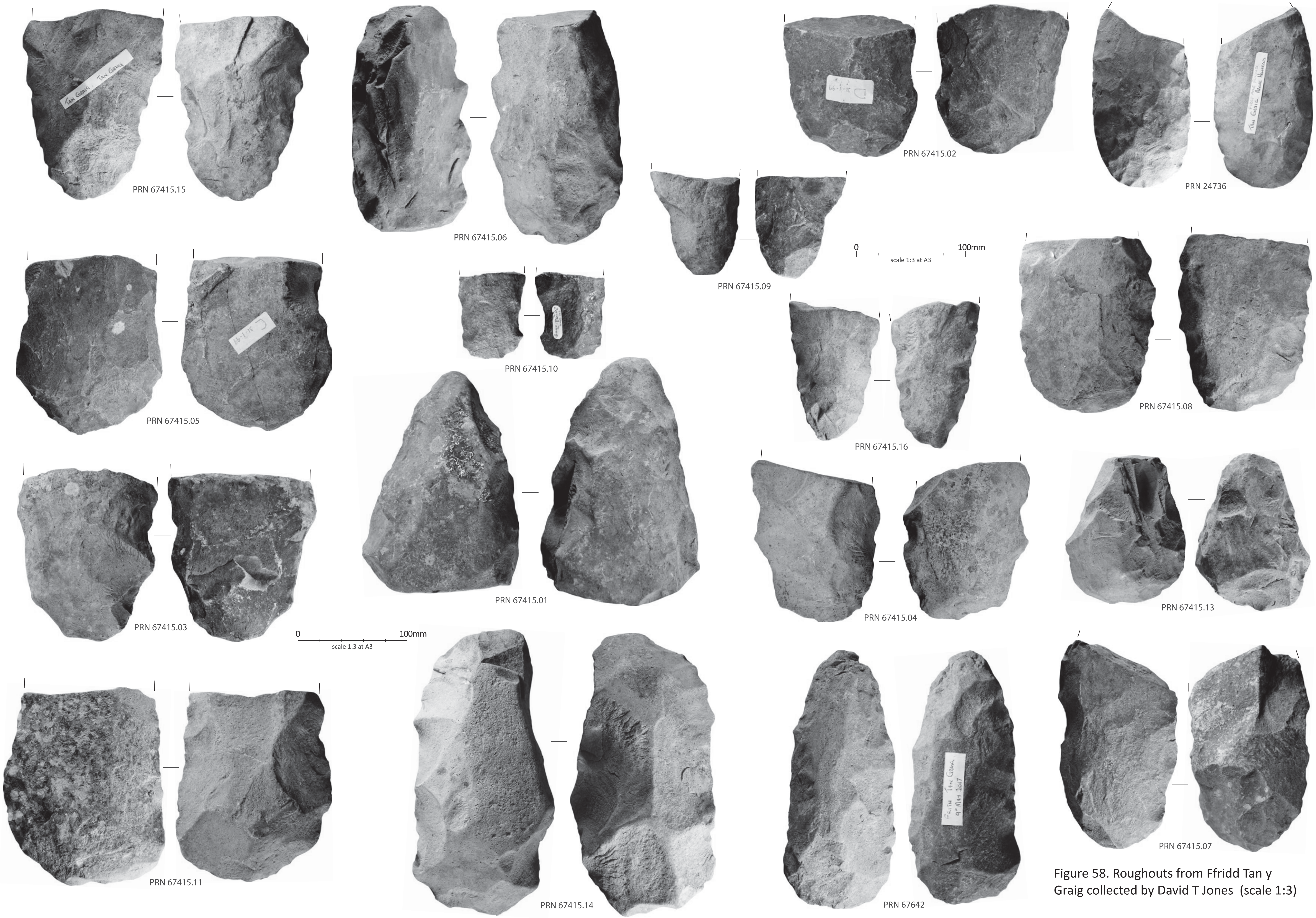


Figure 58. Roughouts from Ffridd Tan y Graig collected by David T Jones (scale 1:3)

Axe flakes from Garreg Fawr South

PRN112196

Knapped block on Garreg Fawr South

Figure 59. Axe debris from Garreg Fawr South (PRNs 112196 and 112197)

of asymmetric cross-section, with one flattish face and one steeper. This seems to have resulted from the use of blanks that were large thick flakes of which the dorsal surface retained a ridge from the previous block core preparation, seen in the case of SF37A67 (Figure 56). That ridge would then need thinning, with difficulty, and some roughouts have hinge fractures from attempts at such thinning (e.g. SF31317, Figure 56). In the case of the unusual large ovate roughout SF31318 (Figure 56), the asymmetric cross-section is very pronounced, producing a boat-shaped profile more suitable for production of an adze than axe.

Several of the roughouts are snapped across, most medially, e.g. SF31317, SF31202 and SF37A67 (Figure 56), while others snapped at an angle like SF3611 (Figure 56). The latter seems likely to have happened as an accident during manufacture, while the medial breaks could be deliberate, perhaps destruction of a failed product. The roughout from Garreg Fawr (SF11604) was the broken half of a nearly complete axe which must have been rejected because it had a twist that was impossible to correct (Figure 56). Some had been abandoned after reaching a point where a complete piece could no longer be achieved, e.g. SF37A81. Initial roughouts could have been taken away from the primary production site for further finishing at sites such as Maes y Bryn.

The roughouts collected from Ffridd Tan y Graig by David Thorpe have a similar range of forms to those from Ty'n y Llwyfan but are mostly much larger (Figure 57). This is partially confirmed by the finds collected by David T Jones from the same area, though his collection does include some small examples (Figure 58). This collection does include some almost finished examples; PRN 24736 was almost ready for grinding when it broke, and PRN 67642 was also not far from being finished but has a fault and an odd lump which was probably not worth the effort to remove. Many of these roughouts are broken almost in half.

Flakes from Garreg Fawr South (PRN 112197)

Figure 59

Two flakes were collected from the edge of an area of open scree on the western side of the southern summit of Garreg Fawr (SH 68949 72628). Both flakes are broader than they are long. The largest weighs 488g and measures 99mm by 132mm by 33mm. The smaller flake weighs 73g and measures 55mm by 82mm by 18mm. Both have well-defined platforms and bulbs of percussion, though the smaller flake has broken off rather irregularly due to faults in the stone. The largest is a primary flake with the exterior of the scree forming the dorsal face. The smaller flake has poorly defined flake scars on the dorsal surface and is heavily weathered.

4.2. Microdiorite Scrapers and other flake tools

By George Smith and Jane Kenney

Scrapers

Four scrapers made on microdiorite flakes were found at Maes y Bryn and one scraper on Garreg Fawr (Figure 60). Other retouched tools may be less well-formed scrapers (such as SF75133, Figure 60) and others are potentially still to be identified in the assemblage. The scrapers are neatly-made, specific types of tool, very different from casually worked flake tools found at Ty'n y Llwyfan and elsewhere. These are convex end scrapers but with additional working. SF5607 has scraper edges down both sides giving it a neat oval shape and SF6405 is also neatly shaped with the scraper edge extending down one side. SF5604 has retouch to form one edge as a knife and SF11707 has fine retouch down one side.

All the scrapers are made on fairly thick flakes that appear deliberately struck for the purpose, rather than being debris from axe making. There is no trace of polish or grinding on the flakes, so they are not

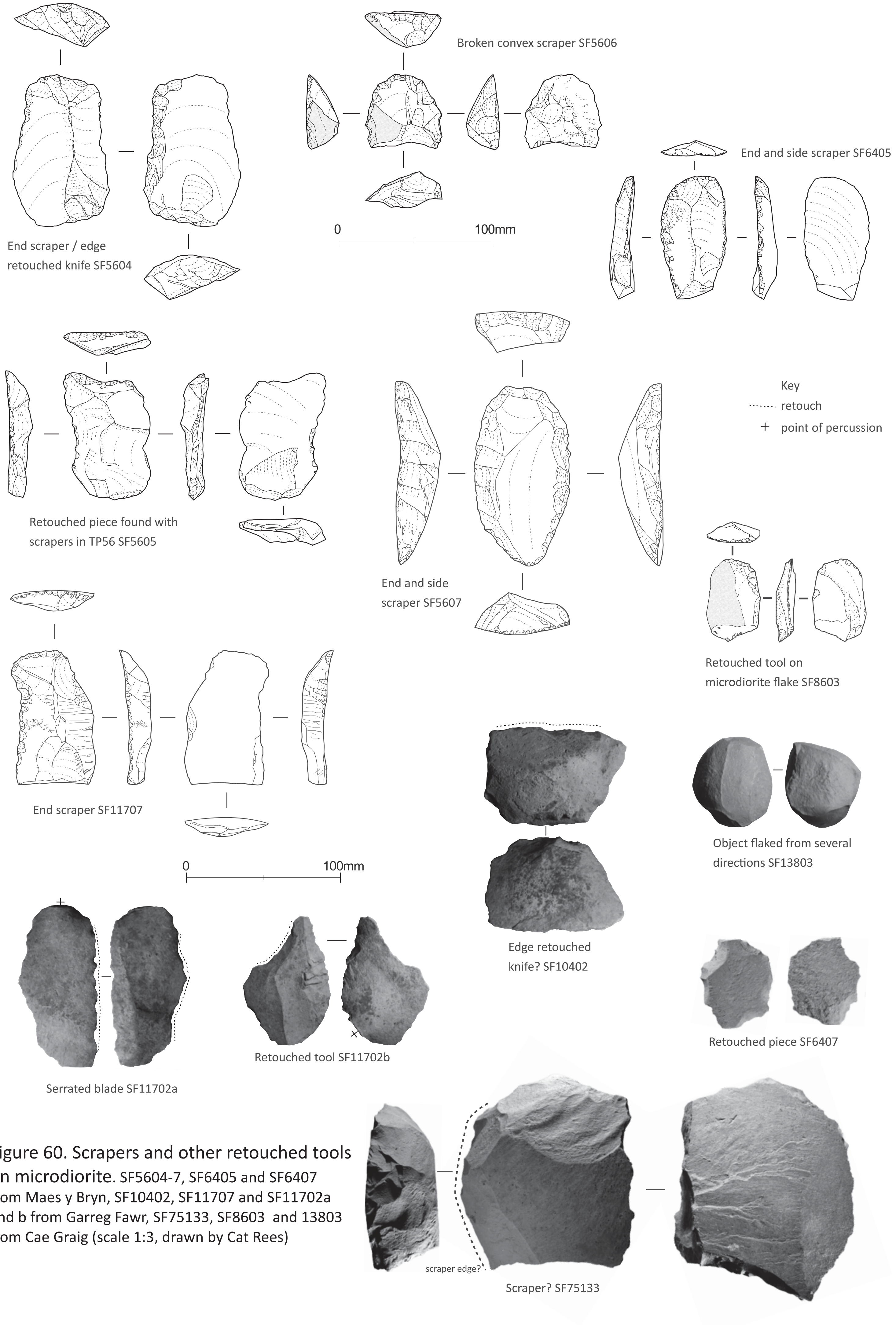


Figure 60. Scrapers and other retouched tools on microdiorite. SF5604-7, SF6405 and SF6407 from Maes y Bryn, SF10402, SF11707 and SF11702a and b from Garreg Fawr, SF75133, SF8603 and 13803 from Cae Graig (scale 1:3, drawn by Cat Rees)

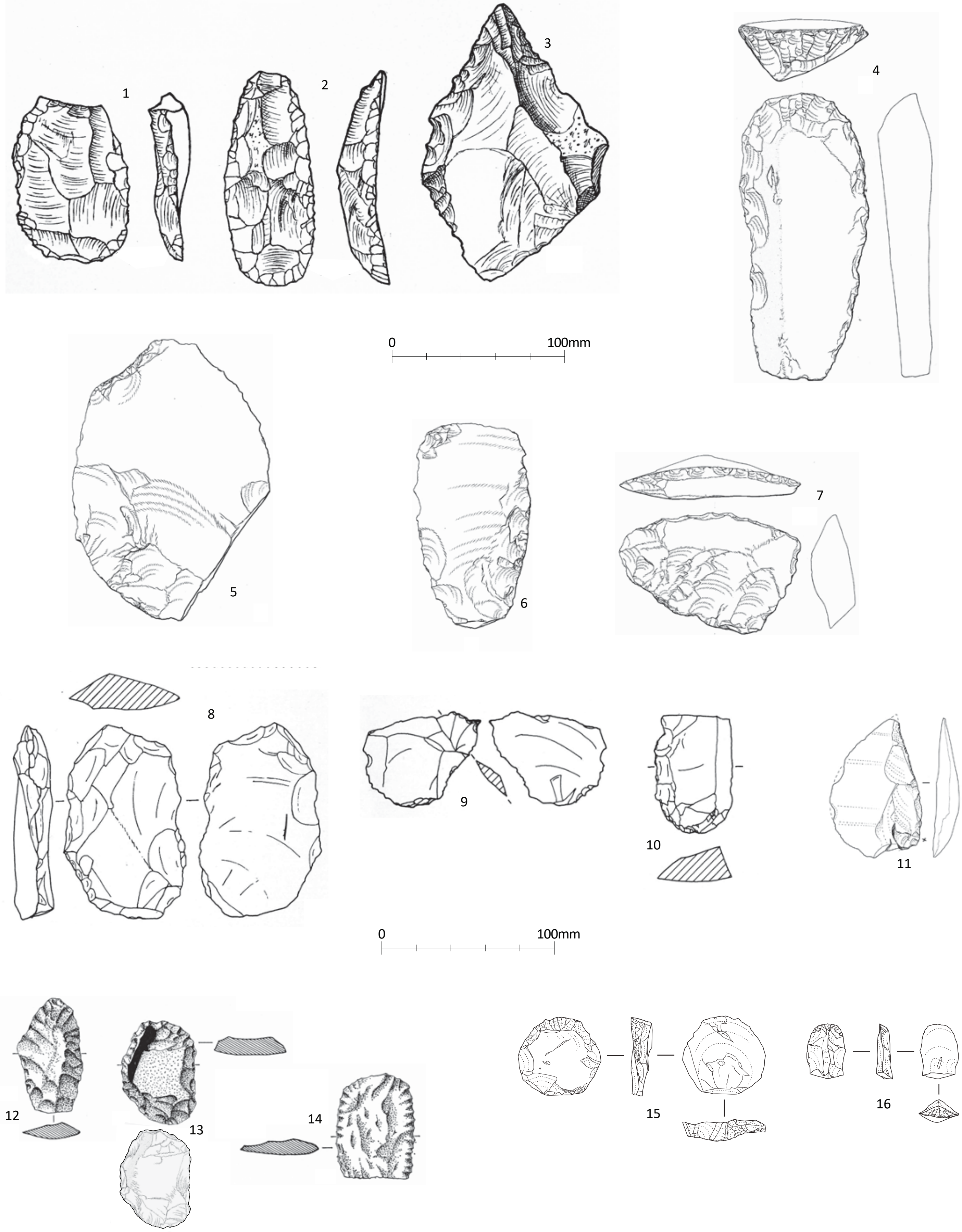


Figure 61. Scrapers and other tools made on Group VII stone (scale 1:3)

1-7: from Graig Lwyd, 1-2 - scrapers, 3 - trimmed point (borer) (Warren 1922, Fig. 14), 4 - scraper, 5-7 - knives (Burrow 2003, Fig. 14, p46). 8-10: finds from Maes y Bryn (Davies 1961, Fig. 1), 8 - chopper, 9 - borer, 10 - scraper. 11: from Nant Farm, Porth Neigwl, edge retouched knife Smith *et al* 2017, 14). 12-14: from Bryn yr Hen Bobl (Lynch 1969, Fig. 59), with improved illustration of No. 13 (Burrow (2003, 51), 13-14 - scrapers, 12 - scraper-like tool made on another fine igneous rock (Williams and Kenney 2009). 15 -16: scrapers on quartz arenite from Llanfaethlu (drawn by Cat Rees, courtesy of CR Archaeology).

from repurposed polished axes. It appears that prepared blocks were worked specifically to produce suitable flakes for making scrapers.

In 1961 Davies found one scraper made on a microdiorite flake on his first visit to the Maes y Bryn site (shown on Figure 61), and an unspecified number of scrapers on a subsequent visit (Davies 1961, 3, 5). The scraper that he had drawn is made on a thick flake, similar to SF5604. These tools are a particular feature of this site.

Scrapers are traditionally thought to have been used for processing hides into leather, though usewear analysis does indicate that they were used for other scraping tasks. Generally, their use is suggestive of a domestic site, however temporary. The quality and apparent lack of use could indicate that the microdiorite scrapers may have been made on the Maes y Bryn site for use elsewhere, though the presence of a flint thumbnail scraper shows that activities requiring scrapers were taking place on the site. The scraper from Garreg Fawr must have been made at this source site alongside the production of axes but may have been intended for use elsewhere.

While relatively little notice has been taken of scrapers made on the microdiorite, they were also found at Graig Lwyd. Samuel Hazzledine Warren (1922, 26) described finding "some scrapers" made on flakes of microdiorite in his excavations. Warren kept the best of the scrapers for his own collection (Williams 1998, 26), but the rest are presumably in one of the museums that he sent material to (Cardiff, Manchester, the British Museum and Oxford). Eight are in the collection of the National Museum Wales, Cardiff (accession numbers 21.79/131, 21.79/132, 21.79/156, 21.79/172, 21.79/173, 21.79/175, 21.79/176 and 21.79/277), along with four stone knives made on the same stone (accession numbers 21.79/E, 21.79/150, 21.79/278 and 21.79/279) (https://museum.wales/collections/online/). Although Burrow (2003, 138, Fig 14) only lists one scraper and 3 knives (4 are illustrated). Warren describes two of the scrapers and an unusual trimmed pointed flake (Warren 1922, 27, 28) (see Figure 61). On Figure 61 No. 2 is the "best scraper" that Warren retained for his own collection.

HGO Kendall found scrapers when excavating Warren's site E at the top of Graig Lwyd. He says that "A dozen or more distinct scrapers – more or less "horse-shoe" – and some flakes used as hide scrapers were found," but he provides no illustrations (Kendall 1927, 146). Warren also reported finding "a few scrapers", apparently on microdiorite, from the top of the Gwddwg Glas (Green Gorge) above Penmaenmawr (PRN 67408), a considerable distance from Graig Lwyd (Warren 1922, 2).

Away from the stone sources tools other than axes on Group VII stone are even rarer. In the list of Graig Lwyd finds from across Britain complied by Glen (1935, 202-203, 218) he includes a scraper made from a Graig Lwyd axe found on the Great Orme. There are two crude scrapers from under the tomb of Bryn yr Hen Bobl, Anglesey (Lynch 1991, fig 29, p108; Lynch 1969, fig 59, 166) (Figure 61). These were loosely associated with axe-working debris on Graig Lwyd stone indicating the production of axe roughouts, but six flakes were knapped from the same partly polished object, including the flakes used for the scrapers (Williams and Kenney 2009). There is also another scraper-like tool from this site made on another fine igneous rock. Two scrapers made on what was initially thought to be Group VII stone were found at Llanfaethlu, Anglesey in a late Neolithic pit group with the broken blade of a microdiorite adze and microdiorite flakes as well as a complete rhyolite axe. However, on analysis the scrapers proved to be of quartz arenite (Horák 2019) (Figure 61).

The use of microdiorite scrapers is clearly rare away from the source rock and seems to be related to reworking or breaking down polished axeheads. However, scrapers would seem to be a relatively common tool produced at or near the Group VII stone sources.

Table 7. Microdiorite scrapers

TP	Find No.	Context	Weight (g)	Length (mm)	Width (mm)	Thickness (mm)	Description
Maes y Bryn							
056	5604	5602	159	97	62	24	Convex end scraper/edge retouched knife on a thick, long flake and with inverse retouch along one side edge
056	5606	5602	53	46	49	24	Broken convex scraper on a thick flake
056	5607	5603	224	116	62	28	Ovate end and side scraper on a large thick flake, unifacially trimmed all round
064	6405	6402	50	75	42	15	End and side scraper on a thick medium long flake
Garreg Fawr							
117	11707	11706	84	88	52	13	End scraper on Group VII flake

Casually retouched tools

In addition to scrapers microdiorite flakes were also used to make other more casually retouched tools. A number of retouched tools or possible retouched tools made from flakes of microdiorite have been identified during the current work. Table 8 below lists possible tools. This is not a full list as not all the debris collected was inspected in detail and recognition of retouch as opposed to accidental damage improved during the project so more of these tools were recognised in later seasons. The detailed analysis being carried out by Rebecca Vickers of Sheffield University will identify more of these tools and look at their distribution.

Identification is much less secure than would be the case if the objects were made from flint or chert because the stone used is subject to surface dissolution. The majority of the pieces recovered are quite deeply weathered so although retouch is still visible any usewear that might be present on casually retouched pieces is no longer present. The weathering also makes finer identification of manufacture difficult. There is also the problem of damage from trampling, but causal retouch can be recognised by its regularity, which distinguishes it from trample damage. Where the secondary edge flaking is unifacial, regular and continuous as opposed to bifacial, irregular and discontinuous, it is likely to be deliberate.

Of the more definite tools there were two large edge-retouched knives (SF7588 and included in SF7303) and a denticulate scraper (included in SF7401). The largest retouched tool (SF6803), from TP68, was a thick, flat scree fragment of which one edge had been bifacially flaked to produce a strong sharp edge, probably as chopping tool. One piece (SF6902), from TP69 was a piercer, produced by edge retouching a flake to a narrow point and a piece from pit was probably a fragment of a broken piercer. These were not carefully produced like the scrapers found at Maes y Bryn, and were probably *ad hoc* tools, made for use on-site, but they do suggest that other tasks, possibly domestic ones, were being carried out as well as the axe-making. See Figure 60 for other examples.

The retouched tools were made on flakes of various different forms and rarely on blades. However, TP138 in Cae Bach contained a few blades (flakes at least twice as long as wide). It is unclear if these were being deliberately produced as blanks for tools. This test pit also produced an object made of

Group VII stone which appeared to have flakes taken off from various angles as if trying to create a roughly spherical shape (see Figure 60 (SF138.03)). The flaking was not done in a way suggestive of it being a core, so it may have been to deliberately shape the stone, rather than to produce blades.

In Cae Graig, Ty'n y Llwyfan the distribution of the retouched or possibly retouched pieces was as extensive as the general spread of material and occurred where the largest amounts of waste material occurred. The retouched pieces from TP15 were within a dense mass of axehead-working debitage that was probably *in situ*, which would mean good preservation of material. The more scattered pieces found in other pits were subject to scree slope movement and to a long period of cultivation disturbance in the plough lynchets there, resulting in a high degree of surface weathering.

At Garreg Fawr casually retouched pieces were also quite widespread with one even coming from TP110, beyond the main area of activity. Most of these were casually retouched but the more definite tools included an edge retouched knife and a serrated blade (Figure 60 (SF10402 and SF11702a). The likely implication is that at the axe-making sites these were disposable tools, for immediate use rather than carefully made to take or use elsewhere. They indicate that the axe working areas were not entirely specialised, with other activities taking place, such as preparing food for consumption during axe-making. At Maes y Bryn piercers made on microdiorite flakes and a retouched chopping tool support the evidence from the microdiorite scrapers, flint scraper and flint flakes that domestic activity was taking place on the site.

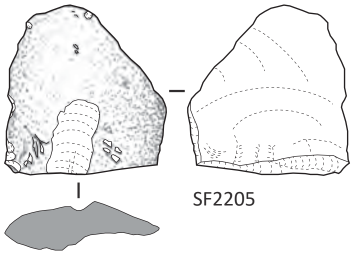
The predominance of objects from Ty'n y Llwyfan is largely because of the greater number of pits excavated there, however, it is also affected by the overall quantities of debris exposed. In terms of density, Maes y Bryn produced most pieces of worked microdiorite flakes, probably due to it being a settlement site.

Table 8. Retouched tools from the test pits

	Maes y Bryn
Pit no.	*Description*
064	Piercer? Small flake fragment with an elongated point (now broken) produced by steep unifacial edge retouch
068	Possible chopping tool. Small piece of scree bifacially flaked one end
069	Piercer: medium flake retouched to a narrow point.
	Garreg Fawr
Pit no.	*Description*
104	Scraper? Steep retouch on a convex edge (secondary use)
	Edge retouched knife
110	Possible reject edge retouched knife or axe-head making practice piece
111	Thick flake with small areas of abraded polish on centre of both faces
115	Casual trimming on distal end
116	Cutting tool
	Retouched piece, not specific
117	Piercer
	Serrated blade
	End scraper on a blade
	Cors y Carneddau
Pit no.	*Description*
127	Cutting tool. Retouched on a sharp, straight edge
	Possibly deliberate secondary edge flaking

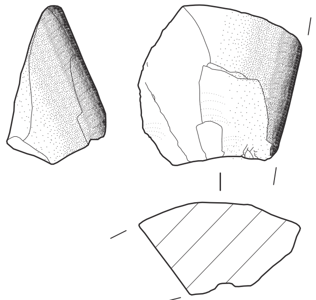
	Possibly deliberate secondary edge flaking
	Possibly deliberate secondary edge flaking
	Ty'n y Llwyfan
Pit no.	*Description*
015	Cutting tool. Some bifacial retouch
	Unclassified retouched piece
037	Unclassified. Thick flake with steep retouch along one straight edge
073	Large flake. Edge-retouched knife
074	Denticulate scraper
	Denticulate scraper?
075	Possible casually retouched piece, medium
	Edge retouched knife Large, flat, thin slab of ovate shape with unifacial invasive flaking.
077	Possible casually retouched piece, large
	Possible casually retouched piece, large
081	Possible edge-retouched knife
085	Possible casually retouched piece, small
	Possible casually retouched piece, medium
	Possible casually retouched piece, medium
086	Retouched piece. A thick medium flake fragment with a chance convex tip and one edge of which may have some deliberate retouch to produce a sharp slightly convex edge. Possibly just damage but too weathered to be certain
087	Denticulate scraper?
088	Possible casually retouched piece, medium
	Possible casually retouched piece small
091	Large flake with possible casual edge retouch. Edge-retouched knife?
093	Possible edge-retouched knife
095	Possible casually retouched piece, large
097	Possible casually retouched piece, medium
101	Possible casually retouched piece, small
102	Possible casually retouched piece, medium
	Possible casually retouched piece, medium
	Possible casually retouched piece, large
137	Cutting tool. Regular, continuous retouch on a chance sharp edge
	Cutting tool.
	Cutting tool.
	Casually retouched piece
	Casually retouched piece
	Casually retouched piece
146	Casually retouched piece

The presence of retouched tools on microdiorite flakes was recorded during excavations at Graig Lwyd by Warren (1922, 26-8). He mentions finding "a single example of the circular disc, flaked on both sides, a few side choppers, some scrapers and trimmed flakes (all made on the same Graig Lwyd rock) but not a single arrow-point, and no cores" (Warren 1922, 26). Retouched knives on microdiorite flakes from Warren's excavations at Graig Lwyd are in the National Museum of Wales (Burrow 2003, Fig 14, 46). Davies found a borer and a chopper as well as scrapers at Maes y Bryn (Davies 1961, 3). Along with three roughouts found in 1968 on Garreg Fawr (PRN 2491) was a "rectangular tool" made on

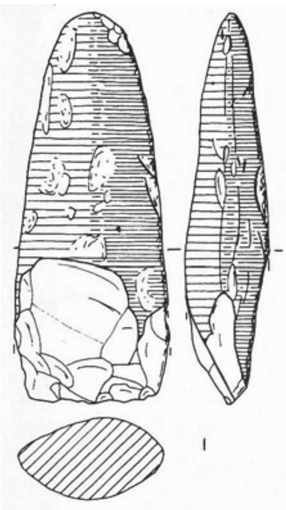


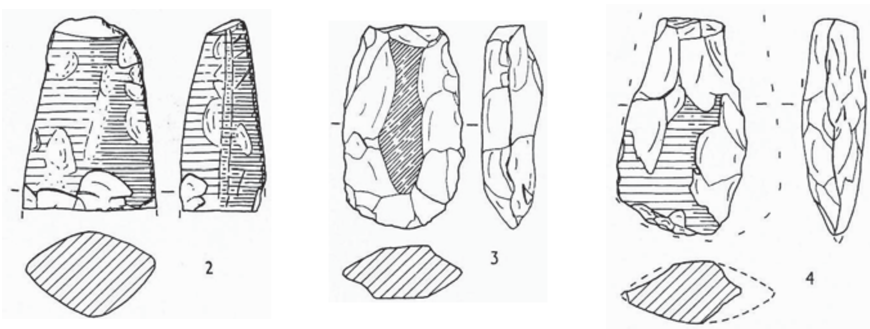
0 50mm
scale 1:2 at A4

Flake from Group VII polished axe from Maes y Bryn (drawn by Cat Rees)



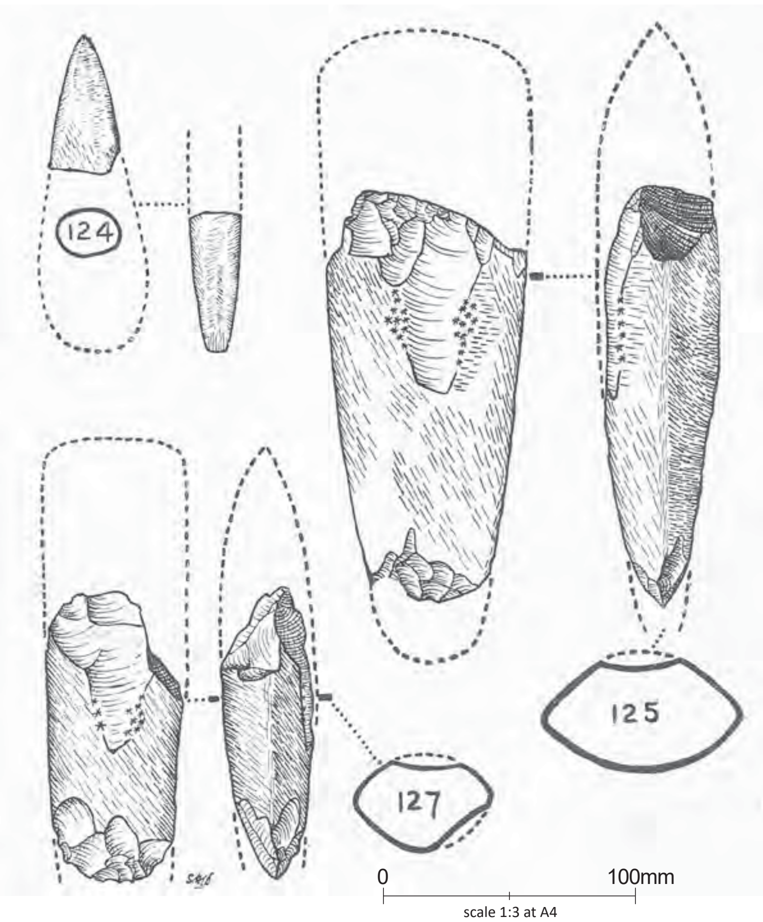
Medallion-shaped flake from a Group VII polished axe found in Pit Group VIII at Parc Bryn Cegin, Llandygai (SF113) (drawn by Tanya Williams)





Reworked polished axes from Maes y Bryn (Davies 1961, Fig 1)

0 100mm
scale 1:3 at A4



Reworked polished axes from Graig Lwyd (Warren 1922, Fig 13)

Figure 62. Reworked polished axes and flakes from polished axes

microdiorite. It had “concave edges which have been deliberately serrated” (Dunn 1968). See Figure 61 for some examples of these retouched tools.

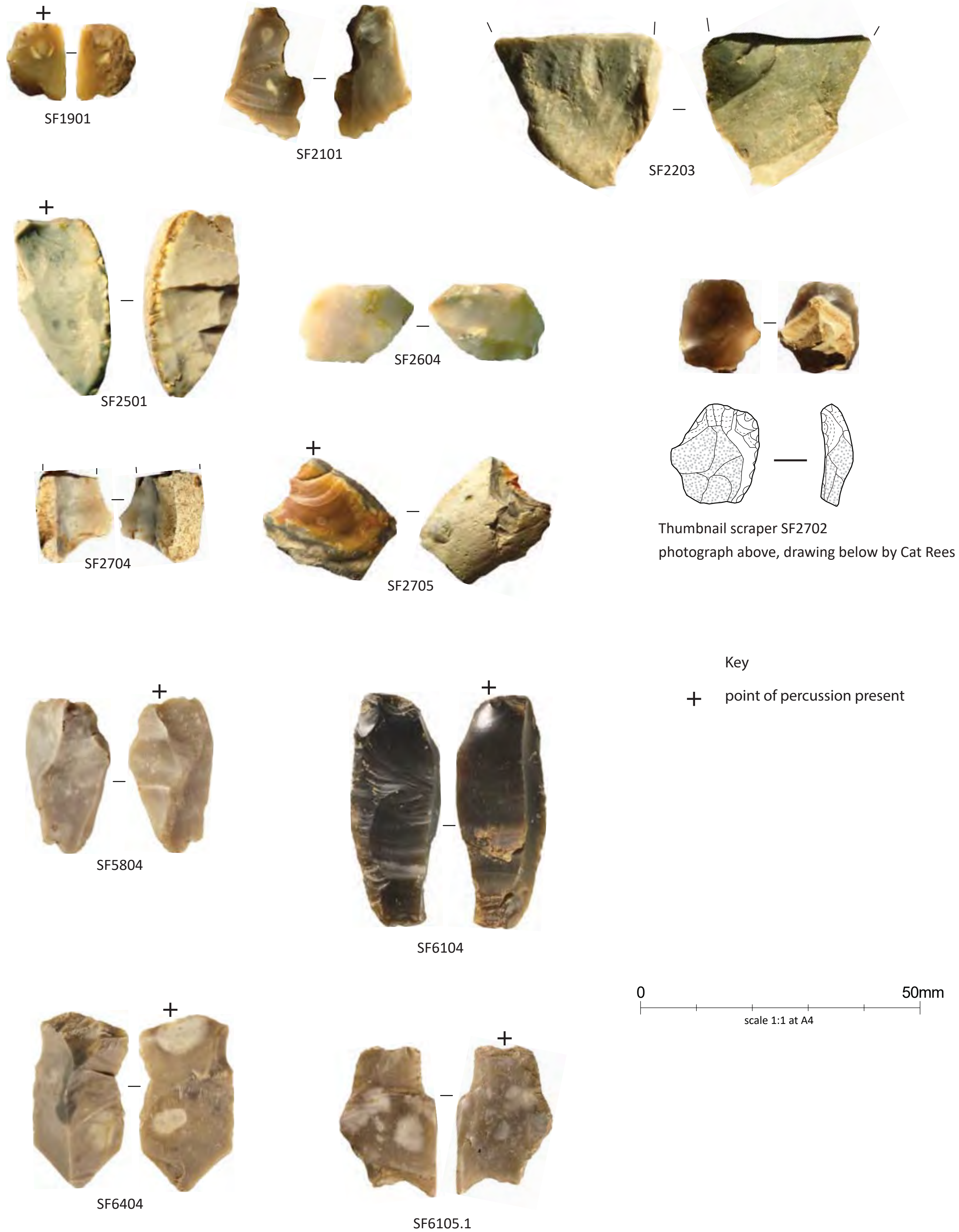
A possible comparison with the flake tools is a large, serrated flake tool of Mynydd Rhiw stone found in excavations at a quarry hollow at Mynydd Rhiw, Llŷn, associated with axe-working debris (Houlder 1961, 127, Fig. 13. 1). However, several retouched flake tools of Mynydd Rhiw stone, including scrapers, awls and knives, also came from a Bronze Age layer, post-dating axe production, so the serrated flake might not have been Neolithic (Houlder 1961, 119, Fig.7). Two large flakes of Group VII stone, one retouched as a knife, were found near a burnt mound of Early Bronze Age date at Porth Neigwl, Llŷn (Smith *et al* 2017, 14-16) (Figure 61, No. 11). These came from mixed material from a cliff collapse and probably originated from the buried soil rather than from the burnt mound. The flakes were not from a reworked polished axe and appeared to have come directly from the Group VII stone source, despite the Mynydd Rhiw source overlooking the site. It is therefore possible that retouched tools from the Group VII source travelled a considerable distance from the source area.

Reworked polished axes

In TP22 at the Maes y Bryn site a flake of Group VII stone was found that had polish over the dorsal face (Figure 62, SF2205). This is a flake from a polished stone axehead, produced by reshaping or breaking down a finished axe.

Davies (1961) found four finished polished axes at this site. One had a blade crudely resharpened by reflaking, one was a broken butt end and two were tools made from reworking larger polished axes (Figure 62). These all appeared to be axes that had been used until they were worn or broken and were then reworked or roughly resharpened to repurpose them for other uses. Warren also found several polished axes at Graig Lwyd, all broken and some reworked (Warren 1922, 24-26). The broken butt of a partially polished axe was found at the Gwddwg Glas (Green Gorge) near Foel Lûs (PRN 67408) (Warren 1919, 342; 1922, 2).

Finished microdiorite axes that have not been reworked are rare from the area. There was a nearly complete polished axe (PRN 67648) was found in Penmaenmawr town, illustrated in the Royal Commission Inventory (RCAHMW 1956, Fig 10 (no.5), liii (no. 19)), a ground stone axe (PRN 4704) from Bwlch y Ddeufaen, and a polished axe found at Sychnant Pass (PRN 67645). Apart from the Penmaenmawr axe these are on the edge of the stone source area and support the idea that the finished axes were mostly used outside the source area. Worn out axes therefore seem to have been brought back to the source area at the end of their useful life and reworked on or close to the stone sources. Warren speculates that broken axes were roughly knapped to produce make-shift substitutes until a new axe could be obtained from the source, when the broken axe blade was discarded (Warren 1922, 25), but why carry the reworked broken axe back to the source before discarding it? It is possible that there was some significance in returning an old axe back to the source. The flake from TP22 is similar to “medallion-shaped” flakes from polished axes found buried in pits at Parc Bryn Cegin, Llandygai, about 12km away (Figure 62). It has been argued that these were the result of “exfoliating” axes, removing the polished surface, as a ritual activity, with the resulting flakes being deposited in pits (Williams, Kenney and Edmonds 2011). This forms part of a tradition seen across Britain of axes being deposited, often after being broken or burnt, in significant locations. Bringing the wornout axes back to where they were made does suggest a ritual function, though it may just have been considered appropriate to deposit some old axes when acquiring new ones. Possibly residents of the area felt able to reuse deposited axes if it was expedient to do so. It is possible that some were deliberately buried in pits, in which case the Maes y Bryn site, with its shallow deposits and lack of confusing scree might be the best place to find such a deposition.



Rock crystal flake SF6504

Figure 63. Flint and chert flakes from Maes y Bryn, with rock crystal flake and thumbnail scraper

4.3. Flint and chert

By George Smith

Figure 63

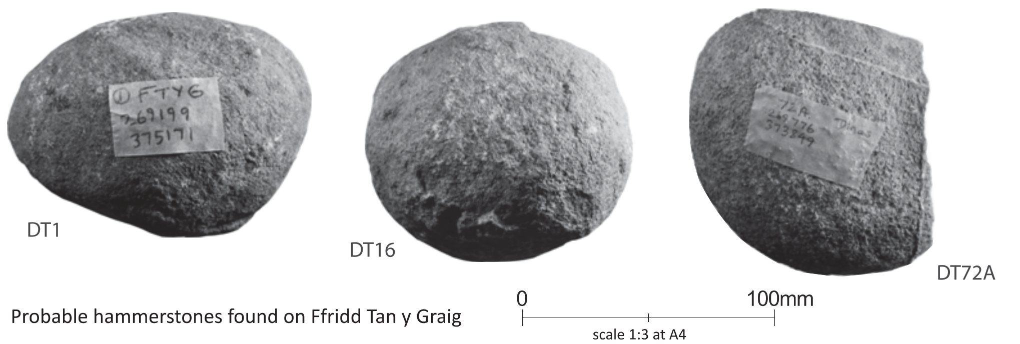
At Ty'n y Llwyfan only two pieces of flint came from all the 87 test pits. Both are small probable knapping waste fragments, but of no diagnostic value. They came from two widely separated pits. In comparison, Maes y Bryn, although a smaller area with only 30 pits excavated, produced a scatter of 13 pieces of worked flint. This was all made from locally sourced pebble material, lacking any imported material that might signify Later Neolithic activity. It was characterised by one retouched piece, a small 'thumbnail', pebble-backed scraper and other pieces with showing evidence of bipolar, anvil working of small pebbles, such as scalar shattered pieces. In contrast, there was one trimming flake from a small blade core, made from better quality flint. This piece could suggest a Later Mesolithic presence here, but it was found close other pieces of bipolar technology so it probably belongs with the rest of the activity.

In England, small 'thumbnail' scrapers have been seen as a Later Neolithic or Early Bronze Age attributes (Wainwright 1972) but have equally been found in Early Neolithic settlement contexts, for instance at Briar Hill, Northamptonshire (Bamford 1985). Around most of the Atlantic seaboard, including Wales they derive, along with bipolar working, from the need to make use of pebble flint raw material, with no specific period association (David 2017). However, on Anglesey, small scrapers and a bipolar technology were found in a large flint assemblage from an Early Neolithic settlement context beneath the chambered tomb of Trefignath (Healey 1987). A similar date seems probable for the flint pieces from Maes y Bryn, but that cannot be certain. It contrasts with the large, finely worked pieces of microdiorite, which are of a Middle or Later Neolithic style, a period when better quality imported flint was becoming available as shown at Parc Bryn Cegin, Bangor, where imported flint was found in association with some re-use of Graig Lwyd axehead stone found (Kenney 2009, 38-42). There may have been more than one period of activity represented at Maes y Bryn but that is uncertain.

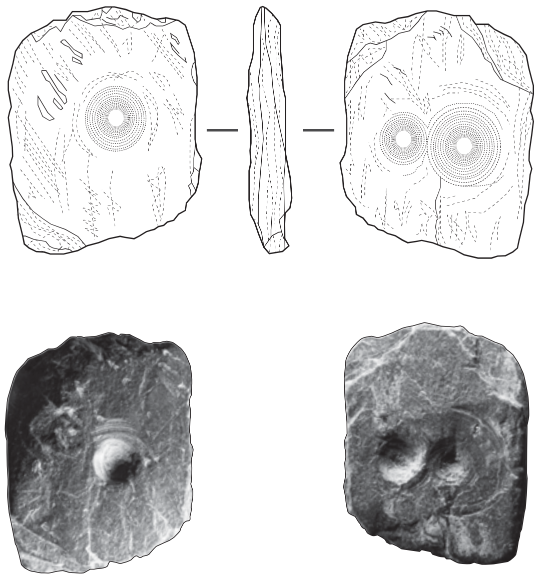
Black chert is found *in situ* in limestone areas of Anglesey and as pebbles and cobbles in drift deposits in Anglesey (Greenly 1919). Most is of poor quality, but occasional pieces are finer. A piece of such fine material was found at Maes y Bryn, from TP 67, It was the tip of a small thin flake, possibly deriving from a blade core. There were also four pieces of light grey chert, probably, like the flint, deriving from pebbles from the glacial drift. One was a flake fragment from TP 20 at Maes y Bryn.

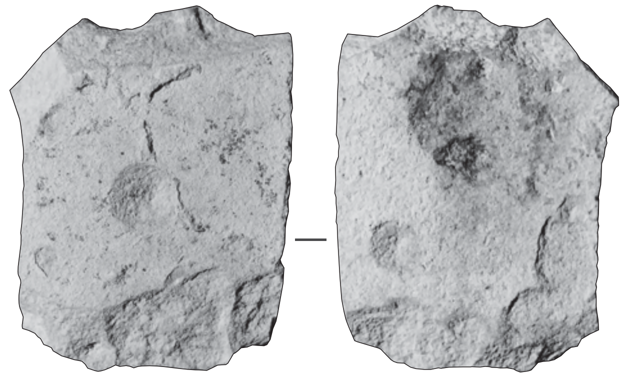
Table 9. Flint and chert

Test Pit	Find No	Context No	Description	Weight (g)	Number of items	Length (mm)	Breadth (mm)	Thickness (mm)	Notes
Cors y Carneddau									
119	11908	11901	Flint Flake	0.8	1	15.6	15.3	2.4	Small broken flake of grey flint.
Garreg Fawr									
106	10603	10601	Flint Flake	0.2	1	12.7	11	3.3	Tiny chip. Brown flint with cortex.
Maes y Bryn									
19	1901	1901	Flint Flake	0.3	1	13.6	10.3	5.3	Mid brown flint pebble frag. Probably anvil-struck
20	2003	2002	Chert Flake	5.4	1	30.9	28.6	7.4	Lt grey chert. Broken flake.
21	2101	2101	Flint Flake	0.5	1	22.6	14.3	6.2	Grey-brown flint. Frag, probably from an anvil-struck core
22	2203	2202	Flint Flake	4.5	1				
25	2501	2501	Flint Flake	5.8	1	31.8	17.5	11.3	Frag of split pebble. Pale grey flint.
26	2604	2602	Flint Flake	0.5	1	19.5	14.8	3.6	Pale brown flint. Flake fragment.
27	2702	2701	Scraper	1.2	1	16.5	14.5	5.2	Thumbnail scraper on a flake with pebble cortex. Dark grey-brown flint.
27	2704	2702	Flint Flake	0.4	1	15.8	14.9	6.2	Secondary flake with pebble cortex. Pale grey flint.
27	2705	2702	Flint Flake	1.8	1	20.6	17.6	4.9	Primary flake, probably from an anvil-struck core. Brown and dark grey flint.
58	5804	5802	Flint Flake	2.4	1	27.2	15.1	6.6	Poor quality mid-grey flint. Probably scalar and anvil-struck.
61	6104	6102	Flint Flake	5.7	1	40.6	15.7	7.4	Good quality, probably imported black flint. Small blade core, punch-struck
61	6105.1	6102	Flint Flake	2.5	1	26.8	16.6	4.3	Irregular scalar piece from an anvil-struck pebble of mottled mid-grey flint
61	6105.2	6102	Flint Flake	3.8	1	27.7	15.1	10.7	Small pebble frag. Light brown flint.
64	6404	6401	Flint Flake	2.8	1	30.5	16.2	6.1	Small, irregular scalar piece, probably anvil-struck. Grey flint.
67	6703	6702	Chert Flake	0.3	1	16	8.8	2.6	Tip of a small thin flake of fine black chert. Possibly from a blade core.
67	6702	6702	Flint Flake	0.4	1	14.4	11	3.5	Small. Thin, tertiary

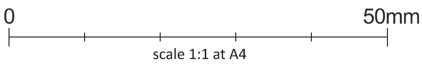


Probable hammerstones found on Ffridd Tan y Graig

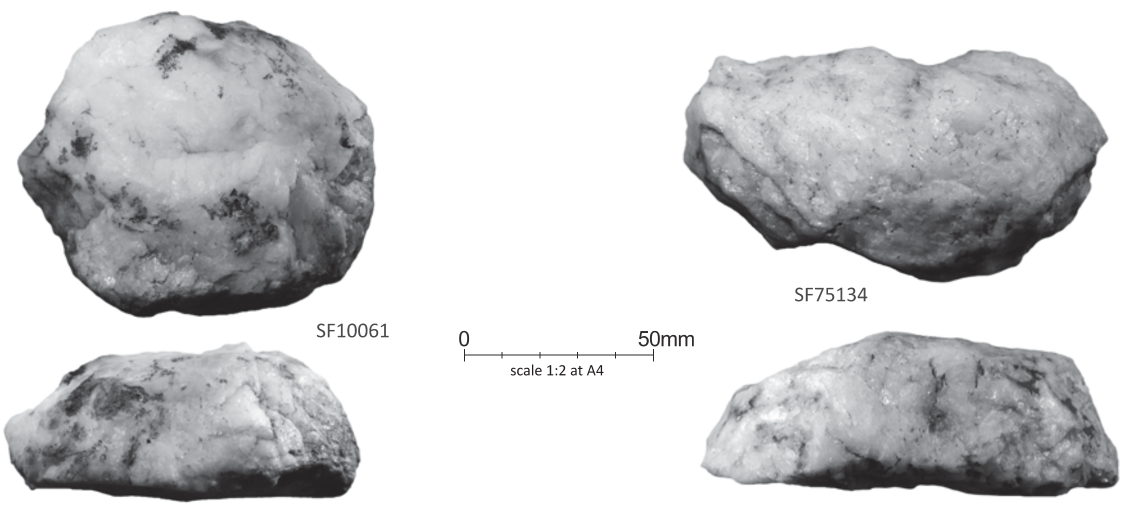




Mudstone plaque with circular hollows from Llanfaethlu (same scale)



Drilled slate SF8805
drawing above (by Cat Rees) , photographs below



Possible quartz tool from Garreg Fawr

Possible quartz tool from TP75, Cae Graig

Figure 64. Miscellaneous finds

Test Pit	Find No	Context No	Description	Weight (g)	Number of items	Length (mm)	Breadth (mm)	Thickness (mm)	Notes
									flake of pinkish grey flint. Punch struck.
Ty'n y Llwyfan									
42	4208	4201	Flint Flake	0.4	1	14.9	6.6	2.7	Small fragment of debitage in dark grey flint
45	4509	4501	Chert frag	5.3	1	31.6	21.1	7.6	Broken piece of a rather cherty pebble. Possibly worked. Grey chert.
148	14803	14802	Flint Flake	0.7	1	20.4	10.9	4.3	Flint chip, pale brown flint.

4.4. Other stone

By George Smith and Jane Kenney

Hammerstones

During the test pitting stones potentially suitable for use as hammerstones were collected; most lacked any signs of hammering in the form of battering or worn facets. One of the exceptions was a cobble over 150mm long of a coarse conglomerate from Pit 129 at Cors y Carneddau. This has one flat end facet, but this was not regular enough in nature to have convincingly shown that it had been created artificially. At Maes y Bryn two heavy cobbles of quartzite and one piece of sandstone were identified as possible hammer-stones; the sandstone piece having a possible working facet, although badly weathered. There was therefore no unequivocal evidence of use as hammerstones.

It was expected that hammerstones would be found as the splitting of larger rock fragments would have required heavy blows, even if all the subsequent shaping was carried out with antler hammers. Even if pebbles of a suitable hard rock for flaking were prized objects, curated along with the finished axes and not discarded on site, occasional fragments of broken ones should be present. Initial quarrying or breaking of large pieces of scree would also have required heavy impact by large hammerstones that would be more likely to have been left on site. Large, battered beach pebbles and boulders were reported to have been found at the early Graig Lwyd excavations (RCAHMW 1964, xlv). Similar material was found during a more recent re-excavation of some of Warren's trenches, but with no confirmation of features that would show if they were hammerstones or just chance pieces from the glacial drift (Williams and Davidson 1998, 13). Hammerstones have been found at the Langdale axe source in the Lake District and have been the subject of petrological study (Bradley and Suthern 1990), but their physical character was not studied, and no examples were illustrated. Modern replicated manufacture of axeheads from Graig Lwyd stone using stone pebbles as hammerstones produces distinctive worn facets on the pebbles (Dilley, pers. com.).

Within in the screes at Ffridd Tan y Graig, Dinas and Garreg Fawr rounded stones can be found. These are mostly cobble-sized (10-20 cm diameter) with a few small boulders (Figure 64). They are quite common and are often in association with axe-working debris. The rock-type of these cobbles has not yet been identified. David Thorpe considers that some cobbles appear to be sandstone but many look like a coarser diorite. They are generally a very hard stone and appear to be rounded due to onion-skin weathering rather than water erosion. There is some doubt about the origin of these cobbles. These stones were well known to David T Jones, who was informed that they could be found in the bedrock in the quarry, and that the quarrymen often threw them down over the cliffs. The question is whether they were naturally occurring in the screes or collected elsewhere and brought in by Neolithic people specifically as hammerstones. On the top of Garreg Fawr are large, rounded boulders apparently of the same stone. These are far too large to have been brought as hammerstones and must have either occurred in the bedrock or been brought in by glacial action.

The rounded cobbles often have dimples or facets and broken or damaged faces, though classic chattering damage from use as a hammerstone is rarely seen. This is probably partly due to the hardness of the stone and partly to the weathering of the cobbles. Mark Edmonds (emeritus professor at York University) was convinced that some of the facets on these clasts could have resulted from use as hammerstones. Whatever their origin the presence of these, often hand-sized stones, in locations where scree is being worked into roughouts strongly suggest that they would have been used as hammerstones.

Table 10. Number of stones collected as potential hammerstones

Test Pit	No. of items
Ty’n y Llwyfan	
001	4
009	2
010	3
011	3
013	2
015	8
016	4
037	3
039	1
043	1
075	1
137	1
138	2
142	1
143	2
146	1

Test Pit	No. of items
147	3
149	1
150	3
151	1
Cors y Carneddau	
125	1
127	3
132	1
133	1
Garreg Fawr	
112	1
113	1
117	2
Maes y Bryn	
056	1
064	1

Partially drilled slate
By George Smith and Jane Kenney

A partially drilled piece (SF8805) was found in TP88, from context 8803, the main body of the upper lynchet in Cae Graig. This is a small thin natural fragment of slate, measuring 32mm by 25mm and up to 6mm thick (Figure 64). It has been shallowly drilled, probably by a flint point, once on one side and twice on the other. The drill holes are about 7mm in diameter and up to 4mm deep. There are concentric scratches round two of the holes. Around one hole there is a broad semi-circle of scratches indicating that part of the tool used was much wider than the drill point that made the hole. These drill holes are not in line, and if the aim was to drill a hole through the piece, the attempt failed. The drilled piece was found at some depth in TP88, in association with axe-making flakes, but the deposit is mixed and has moved due to ploughing, so it cannot be proved that this item was Neolithic in date.

The function or intended function of the piece is unclear. As the drill holes are not opposed there seems to be no deliberate attempt to form a hole right through the stone, and it might be a practice piece. If it was a failed or practice attempt at making an object with a hole through, the size of the piece could have made a bead, as found on several Mesolithic sites. It could also have potentially made a spindle whorl, though it would have made a very small one. Both these options would have required considerable further working, and there is no evidence that either was actually the aim of the piece. Stone spindle whorls in North Wales tend to be of Iron Age or Roman date and no certainly Neolithic example is known, however, at Graig Lwyd on Warren's site E Kendall found "One spindle whorl – perhaps Neolithic, judging from its hour-glass shaped orifice," but he provides no illustrations (Kendall 1927, 146).

It is possible that there was no intention to actually drill through the stone. A small plaque of mudstone, only a little larger than this one was found on the extensive Neolithic settlement site at Llanfaethlu, Anglesey. This has a pecked or ground hollow in the centre of one side and off centre on the other (Figure 64). At 7.5mm diameter the hollows are of a similar size to the drill holes in SF8805 and also appear to have been made by a rotary action. It has been suggested that this was a top bearing for a bow drill, allowing downward pressure to be maintained on the drill while it was rotated (Ian Brooks in Rees and Jones forthcoming). The holes in SF8805 seem to have been formed by a sharp implement, possibly the point of a drill, perhaps while a bow drill was being used on another object held against the slate, though it is a very small piece of stone to be chosen for this function.

Quartz
Quartz was routinely collected from the test pits in 2019, but this proved to be unworked and provided no information other than quartz being naturally available in the area. In subsequent years quartz was only collected if there was any possibility that it might be worked. On close inspection most of the collected pieces proved not to be worked. A large piece of white quartz (SF75134) was found in TP75, weighing 304g, it measures 107mm by 56mm by 38mm. This appeared to be a large, roughly rounded pebble of quartz that had been broken in half deliberately, possibly to make a tool (Figure 64). The function and significance of this piece is uncertain but another, very similar, was found on Garreg Fawr (SF10061). This was a plano-convex piece of white quartz with possible crushing around the edges. It weighs 426g and measures 97mm by 82mm by 41mm. It seems to have been a piece of quartz deliberately broken in half to produce the flat base (Figure 64).

There was also one very small piece of transparent crystal quartz (SF6504) found on Maes y Bryn in TP65. This only measures 15.5mm by 8.3mm by 5.5mm, but appears deliberately flaked (Figure 63). The use of crystal quartz in North Wales appears generally to be restricted to the Early Neolithic (Kenney 2009, Kenney *et al* 2020, 263), though crystal quartz was also used on a Mesolithic site on Bardsey Island (Ynys Enlli) (Edmonds *et al* 2009).

Burnt stone

Stones thought to be heat-shattered or otherwise showing signs of burning were collected. Close inspection of these removed some as not being heat-affected, but possibly or definitely heat-fractured stones was found scattered across Cae Graig and two test pits in Cae Bach at Ty'n y Llwyfan, in four test pits at Maes y Bryn (TP057, 058, 060 and 064) and in two test pits at Garreg Fawr (TPs 116 and 117) (Figures 5, 6, 28 and 55). The burnt stones are of a range of lithologies, but the most convincing examples are on coarse-grained igneous rocks. At Ty'n y Llwyfan these are mostly an occasional one or two stones and they are likely to be the result of gorse burning, though higher numbers in TPs 047 and 049 suggest more intensive activity. TP39 had the most burnt stone (39 pieces) and the adjacent TP15 also had a number of burnt stones (5). The 10 burnt stones from TP47 could possibly have moved down slope from this area. While a concentration of burnt stones on the natural shelf on which TPs 15 and 39 were located could indicate activity here this location also has a hawthorn tree growing there today and may have been a focus for gorse in the past and have experienced more gorse burning than elsewhere in the field. However, the association of burnt stones with three sherds of Roman pottery does add to the possibility of activity here.

At Maes y Bryn only one or two burnt stones were found per test pit but the test pits with burnt stones (TP057, 058, 060 and 064) were fairly close together in the upper part of the field investigated. The stones were also typical of ones shattered by deliberate heating and in two cases were associated with finds other than axe debris (a flint flake from TP58 and a flint flake and a scraper and possible piercer on Group VII stone from TP64). While the burnt stones here may also be the result of gorse clearance it seems probable that they were the result of Neolithic occupation activity.

The burnt stones from Garreg Fawr are also likely to be the result of occupation activity. One was recovered from the fill of pit 11604, the fill of pit [11605], which also contained axe flakes and a small sherd of pottery. This pit was radiocarbon dated to the Bronze Age and seems to represent occupation activity in this period, to which the burnt stones were possibly related. The two burnt stones from TP117 were also from the fill of a feature (11704, fill of feature [11705]. This feature is suggested as being possibly a posthole on a palisade around an Iron Age enclosure, but the quantity of axe debris also from this fill shows earlier material has been mixed into the fill. However, it seems most likely that the burnt stone originated from Iron Age activity inside the enclosure.

Table 11. Table of test pits producing burnt stone

Area	Test Pit	Weight (g)	No. of items
Garreg Fawr	116	86	1
Garreg Fawr	117	495	2
Maes y Bryn	57	468	2
Maes y Bryn	58	57	1
Maes y Bryn	60	210	1
Maes y Bryn	64	57	1
Ty'n y Llwyfan	15	969	5
Ty'n y Llwyfan	34	87	2
Ty'n y Llwyfan	36	709	3
Ty'n y Llwyfan	39	2959	39
Ty'n y Llwyfan	44	354	1
Ty'n y Llwyfan	45	69	1
Ty'n y Llwyfan	47	562	10
Ty'n y Llwyfan	49	312	5
Ty'n y Llwyfan	88	144	2
Ty'n y Llwyfan	137	94	1
Ty'n y Llwyfan	138	40	1

SF9502

Neolithic pot sherd from TP95 in Cae Dafydd

0 20mm
scale 2:1

SF11607

Bronze Age pot sherd from TP116 on Garreg Fawr

sf3916

sf3932

sf3931

0 50mm
scale 1:1

Roman pot sherds from TP39 in Cae Graig

Figure 65. Prehistoric and Roman pot sherds

4.5. Prehistoric Pottery

By Frances Lynch

Figure 65

Two prehistoric pot sherds were found during the project. One came from TP95 in Cae Dafydd, Ty'n y Llwyfan and one from a pit in TP116 on Garreg Fawr.

SF 9502, Context 9502.

Size 17 x 14 x 5mm, weight 1g.

The outer surface is definitely burnished, and the inner surface is smoothed and matt. The dark brown clay contains occasional small angular stone grit. There are some very slight scratches, perhaps from small finger-nails on the outer surface, but they might be accidental. This is almost certainly Early Neolithic Irish Sea Ware because of the clear signs of burnishing.

SF 11607 from Context 11604

Only one small undecorated sherd was found, but the fabric is sufficiently distinctive, in the context of this location above Llanfairfechan, and reported association with pieces of Graig Llwyd stone, to suggest that it belongs to the Middle Neolithic Impressed Ware tradition.

The piece is 58 x 44mm and 9mm thick. The colour is an orange/red on the outside and mainly black on the inside. It is hard fired. The clay is quite heavily gritted with pale angular rock in pieces averaging 5mm across. No quartz is recognisable, but some of the pieces are white, others are a light brown. A geologist would be able to be more precise. The grits stand proud of both the inner and outer surfaces. There is no sign of decoration.
If the sherd had come a lower altitude, it might have been considered to belong to the Late Bronze Age, but the plain pottery of this period is normally thicker and smoother.

4.6. Roman Pottery

By Gill Dunn

Figure 65

Three sherds of Roman pottery were recovered from test pit 39 in Cae Graig, Ty'n y Llwyfan.

<u>Context 3902, Find no 3916</u>

1 sherd weighing 10g

Body sherd of a handmade, black-burnished ware jar. Fairly poor condition. Orange external surface. Given that the exact form of the vessel cannot be determined and there is a lack of any diagnostic decoration, only a broad date of 120+ can be given.

<u>Context 3903, Find no 3931</u>

1 sherd weighing 15g

Body and base of a greyware jar or flagon. Abraded. Some oxidation at the base and on the internal surface. Groove running around the wall at the base of the vessel. Almost vertical at the base before flaring outwards. Base diameter is indeterminate due to the small size of the sherd. Date of late first/second century.

<u>Context 3903, Find no 3932</u>

1 sherd weighing 3g

Hard greyware curved sherd with two parallel grooves 15mm apart on the external surface. The clay appears to have been 'pulled' or 'stretched' at the narrow end of the sherd, but it is difficult to determine whether it was originally open at this end, or enclosed, thus creating a hollow 'cylinder'. Possibly a spout.

4.7. Assessment of the archaeometallurgical materials

Dr T. P. Young, GeoArch

Summary

The submitted assemblage comprised a total of approximately 100 significant pieces, plus some fine debris (total 1.7kg). The majority of this material (1.6kg) derives from a deposit of smithing waste investigated in adjoining test pits 16 and 73 at Ty'n y Llwyfan. The waste was present in TP16 as a spread that contained several small smithing hearth cakes (SHCs). The SHCs are of a size typically formed during fairly 'light' blacksmithing that did not involve much welding. In TP73, some residues occurred in deposit (7303), but most were in context (7305), the fill of pit [7307]. This pit (PRN 100568) may be the smithing hearth itself. The fill of the pit contained a single 'fiddle-key' nail, suggesting that the feature may be medieval. The hearth ceramic assemblage from the pit contained several fragments from around the blowhole of the hearth. Context (7505) in TP 75 produced a single small ceramic fragment suggestive of derivation from a ceramic tuyère. Ceramic tuyères are known, if relatively uncommonly, from the Iron Age in Wales and adjacent areas, but the use of a ceramic tuyère in the medieval period would be an unusual occurrence in Wales (but is typical of medieval ironworking in Ireland.).

The microresidue assemblage from pit [7307] is also rather unusual, for it includes large flakes of particularly flat and shiny flake hammerscale (FHS) and very little, if any spheroidal hammerscale. Such an assemblage suggests prolonged heating of iron with flat surfaces, but at below welding temperature.

TP40 produced a single fragment of hearth lining, suggesting the smithing may have been undertaken at others points in the landscape.

TP129 also produced a small quantity of pyrotechnological residue from a hearth. This hearth may have been non-metallurgical. The sampled material contained burnt organic material (of ambiguous origin), some finely granular fuel ash slag, and two fragments of stone that probably derived from the Carboniferous coal measures. It is unclear whether they are purely coincidental (with an origin in the glacial drift), or whether the hearth had burned coal.

Methods

All materials were examined visually, using a low-powered binocular microscope where required. The identifications of materials in this report, as an assessment during which no instrumental analysis was undertaken, are necessarily limited and must be regarded as provisional.

Results

General

The submitted assemblage comprised a total of approximately 100 significant pieces, plus some fine debris (total 1.7kg). The majority of this material (1.6kg) derives from a deposit of smithing waste investigated in adjoining TPs16 and 73 at Ty'n y Llwyfan. TP40 produced a single fragment of hearth lining and TP129 a small quantity of pyrotechnological residue from a, probably non-metallurgical, hearth. The summary catalogue is presented as Appendix IV, Table 1.

Iron-working (blacksmithing) residues

Residues from ironworking (blacksmithing) were primarily associated with adjacent TPs 16 and 73. Two contrasting suites of residues were recovered from the charcoal-rich spread in TP16 and from the pit in TP73.

The spread in TP16 (context (1603)) produced a small, dense smithing hearth cake (SHC) weighing 128g, an apparently 'double' SHC, with an upper conventional small, dense SHC attached to an obliquely-descending cake, possibly an earlier, displaced SHC, but with the two sharing a finely-dimpled surface. There was also a small fragment probably derived from a similar SHC. The overlying context ((1602) yielded two small scraps of smithing slag.

In contrast, the fill of pit [7307] (context (7305)) produced several fragments of technical ceramic (total 192g) including fragments of a blowhole through the ceramic, as well as 16 fragments of slag (total 352g) comprising fragments from dense sheets, lobate flows and lower density blebby slags. Overlying contexts (7303) and (7302) produced small quantities of similar residues. The ceramic is insufficient to determine whether the blowhole was located within a simple clay wall or within a preformed ceramic tuyère.

Context (7305) also produced an assemblage of smithing fines, comprising flake hammerscale (FHS), slag spheroids and rounded blebs, many of maroon- surfaced FAS/lining slag; some fired clay; some probably oxidised iron debris in thin sheets and some rare blebby pieces of dense slag.

TP75 produced a fired clay fragment (from context (7505)) possibly from the margin of a ceramic tuyère.

Other materials

TP129 (context (12903)) produced a small assemblage from a hearth. This assemblage contained much concretionary material (including some probable natural Mn/Fe crusts). There are fragments of burnt organic material of uncertain origin, and also some of very fine clinker, formed by agglomerations of globules on millimetre scale. There are also some lithic grains including one piece of ferruginous sandstone and one probably of sphaerosiderite, both lithologies suggestive of derivation from the Carboniferous Coal Measures. The magnetic nature of the now-pinkish shale, that dominates, may suggest that it has been burnt. The co-occurrence of burnt shale, ferruginous sandstone, sphaerosiderite, and the unidentified burnt organic material might suggest that these materials are residues from the burning of coal, although the fuel ash slags are not conclusively the product of any particular fuel. One fragment within this sample appears to be of an organic-tempered plaster or mortar.

Interpretation

The SHCs in the assemblage are small, the isolated example weighs 128g and the example with two fused masses (suggestive of accumulation in two work periods) weighs 166g. The SHCs are dense and well-formed, typical of those formed in a hearth using a ceramic tuyère or a blowhole in a ceramic wall, rather than an iron tuyère. Other associated macro-residues include various low-density slags, including some slightly unusual highly clinker-like vesicular spheroidal particles.

If the presence of the fiddle-key nail is taken as evidence for a medieval age, then there are very few assemblages in the region for comparison (a medieval smithing hearth was recorded from site 3/14 of the Pwllheli to Blaenau pipeline (Young 2011a); medieval smithing was recorded from Parc Cybi (Young 2019); medieval smithing residues were found at Hen Gastell (Young 2016)). There are distinct similarities with the SHC assemblage from Hen Gastell, where besides one large and one medium SHC (c. 1000g, 306g), there was a range of small examples (72g, 80g, 84g, 104g and 168g) similar to those in the present assemblage. These included one attached to an inclined second mass of slag. The Hen Gastell assemblage was also noted to contain a ‘large proportion of nubs and fragments of gravelly slag’. Whilst far from conclusive, the observations suggest that the present assemblage and that from Hen Gastell may lie within the same technological milieu.

The purpose of the smithing at Llanfairfechan is not readily apparent. The microresidues (with large, shiny FHS but an absence of SHS) suggest iron being heated for a considerable period of time at a relatively low temperature (although this requires further investigation). The SHCs indicate some modest loss of iron from the workpiece. Taken together, this suggests forge work involving significant shape change of the iron but not welding.

The context of the smithing at Hen Gastell suggested that it may have been associated with construction. The same could be true here, even if a nearby medieval structure has not yet been recognised. Medieval smithing hearths in fields are commonly attributed to the need to repair implements like scythes close to the point of use during busy seasons, but the residues here point to a higher degree of forging than that simple use would require.

Further work

The evidence for the smithing is slightly unusual, particularly in the nature of the hammerscale present. A limited analytical investigation of the scale and the associated macroresidues is recommended to enable further clarification of the purpose of the activity. This is reported on below.

4.8. Ironworking Residues

Dr T. P. Young, GeoArch

Summary

The assemblage from the project comprised a total of approximately 100 significant pieces, plus some fine debris (total 1.7kg). The majority of this material (1.6kg) derives from a deposit of smithing waste, believed to be of 12^{th}- 13^{th} century age, (see Section 5 below) investigated in adjoining test pits 16 and 73 at Ty’n y Llwyfan. This smithing waste formed the focus of the analytical investigation.

The waste was investigated through bulk analysis of one sample of smithing hearth cake (SHC) and one piece of hearth ceramic and through microanalysis of microresidues. The SHCs are suggestive of light or intermittent work, although the assemblage was too small to make definite interpretation. The microresidues suggest high temperature forging, including welding employing the use of a quartz flux. The analysis suggested that the iron being worked was dominantly phosphoric and perhaps ultimately from a bog iron source. Flake hammerscale (FHS) was present as particularly large and shiny fragments, possibly because of their separation from the iron substrate through the development of a phosphorus-rich detachment zone. The use of the welding flux appears sparing, perhaps because the iron welded easily.

The purpose of the smithing is unknown, but included forging and welding, so was more than just light farrier work for instance, but equally it does not appear to have been intensive.

Methods

Project rationale and history

This assessment was conducted in August 2024 and was commissioned by Jane Kenney of Heneb. The materials derive from a programme of test-pitting undertaken by the former Gwynedd Archaeological Trust as part of the *Landscape of Neolithic Axes Project* (Project G2495).

The assessment (see Section 4.7 above) resulted in the statement: ‘The evidence for the smithing is slightly unusual, particularly in the nature of the hammerscale present. A limited analytical investigation of the scale and the associated macroresidues is recommended to enable further clarification of the purpose of the activity.’

The analysis phase of the work was designed around two components: firstly the bulk elemental analysis of an example of a smithing hearth cake from the assemblage (a 125g example from <1605>, context (1603)) and of a fragment of hearth ceramic (from <7309>/<7312> from context (7305), secondly analytical electron microscopy of micro-residues via separate strew mounts of tabular and spheroidal particles (flake and spheroidal hammerscale).

Analytical methods

Bulk chemical analysis was undertaken using two techniques. The major and minor elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P and S) were determined on a fused bead using wavelength-dispersive X-Ray fluorescence (WD-XRF). Whole-specimen chemical analysis for thirty-six trace elements (Be, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Th, and U) were undertaken using a sample in solution by Inductively-coupled Plasma Mass Spectrometry (ICP-MS). Both XRF and ICP-MS analyses were commissioned from ChemoStrat Ltd (Welshpool, UK).

For XRF analysis, samples were ground using a tungsten carbide shatter mill, dried at 105C overnight and then 0.5g was mixed with 6.5g of 50:50 LiT/LiM flux and fused to produce a glass disk using a Claisse M4 Fluxy automatic fused disk maker. The samples were analysed using a Bruker S4 WDXRF using the default wavelengths for the elements identified. Calibration was via a selection of iron slag reference materials and geological reference materials.

Samples for trace elemental analysis by ICP-MS were drawn from a second aliquot of the powdered material using the alkali fusion method (Jarvis and Jarvis 1992a and 1992b; Pearce *et al.* 1999). Once prepared, the samples were then all subjected to analysis using a Thermo Scientific XSERIES 2 ICP-MS. Data quality was strictly monitored in terms of precision and accuracy by five international rock standards of known concentration and varying compositions which are run after every 20 unknown samples. In addition, external monitoring of data quality is carried out four times a year via the GeoPt round robin proficiency testing program (*http://www.geoanalyst.org/ overview.html*).

The results of the elemental analyses are presented in Appendix IV Tables 2, 3 and 4.

Polished blocks for investigation on the SEM were prepared in the School of Earth and Ocean Sciences, Cardiff University. Electron microscopy was undertaken on the Zeiss Sigma HD Field Emission Gun Analytical Scanning Electron Microscope (aSEM) in the School of Earth and Ocean Sciences, Cardiff University. Images presented here include backscattered electron photomicrographs (BSEM) to illustrate microstructures and secondary electron images (SEI) for the recording of loci of microanalysis. Microanalysis was undertaken using the system's energy-dispersive x-ray analysis system (EDS) controlled by Aztec software. The Astimex olivine, pyrope and magnetite standards were employed calibration process. The assistance of Dr Duncan Muir is gratefully acknowledged.

The GeoArch site code used for the samples is LFF. The microanalytical data are presented in Appendix IV-A. SEM images of all areas are included in Appendix IV-B, including, where appropriate, details of the analysed points/areas on SEI images.

All EDS analyses were collected with all elements analysed (including oxygen, but not carbon; all samples were carbon-coated). Area analytical totals were frequently far from 100%, because the analytical system is designed to provide totals of 100% from spot analyses in the centre of the field. The area analyses required for this project are not standardised in the same way and will diverge from a total of 100% (either above or below, depending on the location of the area #with respect to the centre of the field). In order to make the microanalytical results simply comparable across materials (and also sites), no attempt has been made to adjust for the oxidation state of elements with variable valency. The figures employed in the report have therefore been constructed with elements expressed as oxides in weight% calculated stoichiometrically and normalised, except for mineral structure calculations, where the measured oxygen has been used.

Throughout this report standard mineral terminology is applied to both natural and anthropogenic materials – although artificial phases are no longer strictly considered to be minerals.

All dates quoted in this report (unless specifically attributed as quotes) have been recalibrated using OxCal 4.4 with the IntCal20 calibration curve, rounded out to 10 years, and quoted as 2s, unless specifically stated.

Results

General

The assemblage submitted for assessment comprised a total of approximately 100 significant pieces, plus some fine debris (total 1.7kg). The majority of this material (1.6kg) derives from a deposit of smithing waste investigated in adjoining TPs16 and 73 at Ty'n y Llwyfan. TPs 75 and 40 each produced a single fragment of hearth ceramic and TP129 a small quantity of pyrotechnological residue from a non-metallurgical hearth.

The summary catalogue is presented as Appendix IV Table 1.

Iron-working (blacksmithing) residues

Investigation of the residues from ironworking (blacksmithing) were focused on materials from adjacent TPs 16 and 73. Two contrasting suites of residues were recovered from the charcoal-rich spread in TP16 and from the pit in TP73.

The spread in TP16 (context (1603)) produced a small, dense smithing hearth cake (SHC) weighing 128g, an apparently 'double' SHC, with an upper conventional small, dense SHC attached to an obliquely-descending cake, possibly an earlier, displaced SHC, but with the two sharing a finely-dimpled surface. There was also a small fragment probably derived from a similar SHC. The overlying context ((1602) yielded two small scraps of smithing slag.

In contrast, the fill of pit [7307] (context (7305)) produced several fragments of technical ceramic (total 192g) including fragments of a blowhole through the ceramic, as well as 16 fragments of slag (total 352g) comprising fragments from dense sheets, lobate flows and lower density blebby slags. Overlying contexts (7303) and (7302) produced small quantities of similar residues.

Context (7305) also produced an assemblage of smithing fines, comprising flake hammerscale (FHS), slag spheroids and rounded blebs, many of maroon-surfaced FAS/lining slag, some fired clay, some probably oxidised iron debris in thin sheets and some rare blebby pieces of dense slag. This context also produced an example of a 'fiddle-key' horseshoe nail, a type usually dated to the 12th-13th centuries. Two radiocarbon dates were obtained on oak charcoal from (7305): SUERC-130048 (1101+/-23BP) and SUERC-130049 (858+/-23 BP), which calibrate to cal. AD 890-1000 and to cal. AD 1150-1260 respectively. A date between the mid-12th and mid-13th centuries therefore seems possible, taking account the artefact and scientific evidence.

TP75 produced a fired clay fragment (from context (7505) possibly from the margin of a ceramic tuyère.

<u>Description of the ironworking macroresidues from TPs 16 & 73</u>

The most significant elements of the macroscopic assemblage from TPs 16/73 were two smithing hearth cakes (SHCs), both from TP16 <1605> from (1603). SHCs are slag cakes that form just below the air input, from a mixture of iron (or iron oxide) lost from the workpiece and melted hearth lining, with lesser contributions from the fuel ash and, where appropriate, from any welding flux employed by the smith. SHCs are typically approximately plano-convex in shape, with a rounded base and a sub-triangular to sub-oval shape in plan.

Firstly from (1603) there was a 'double' SHC with an overall weight of 166g. This comprised an upper component, measuring 50x90x20mm, possibly slightly deformed by folding, attached to lower component, measuring 35x60x15mm; inclined in such a way that the two are continuous on one side. The base is finely prilly with fuel impressions and rust; the top is smoothish, dimpled with only a faint hint of lobes. This example was not examined in further detail. ‘Double’ SHCs are formed when the smith displaces the accumulated slag downwards to clear space in front of the blowhole, rather than removing it from the hearth.

Secondly, a straightforward, single, dense SHC, weighing 128g and measuring 60x70x30mm. It is crudely plano-convex. The top has fine fuel impressions on a poorly lobate surface, partly obscured by rust. The base is also crudely lobate, but rusty, with abundant adhering flake hammerscale. The SHC is internally vesicular, with simple subspherical vesicles up to approximately 4mm with more complex larger ones, some still containing charcoal remnants, up to 10mm.

The elemental composition of this piece was determined on a full-thickness sample (LFF4). The analysis (Appendix IV Tables 2-4) shows a high iron content (68.6% when expressed as FeO), a moderately high silica and alumina (18.7% and 4.7% respectively; with SiO_2/Al_2O_3 = 3.9). The alkalis and alkali earth elements are present in very low concentrations, with manganese and phosphorus both also low (with 0.15% MnO and 0.27% P_2O_5). The upper crust normalised rare earth element (REE) profile (Appendix IV Figure 1) is relatively flat, with a very similar shape to that of the analysis of a ceramic sample (LFF3), but slightly relatively depressed in the light REE (LREE). SHCs from blacksmithing typically have the largest non-iron input from the hearth lining, which thus supplies most of the REE.

The assemblage from TPs 16 and 73 includes several other pieces of dense iron slags, including a possible incipient SHC, fragments from SHCs and fragments from flows from the hearth floor. There were also many fragments of fired clay, indicative of a placed clay pit lining or, more likely an upstanding hearth wall. Several pieces of hearth ceramic showed evidence for the margin of a blowhole but were insufficient to determine whether the blowhole was located within a simple clay wall or within a preformed ceramic tuyère.

Description of the ironworking microresidues from TPs 16 & 73

The fill of pit [7307] (context (7305)) produced a rich assemblage of microresidues. The true microresidues include, dominantly, flake hammerscale (FHS; in this assemblage of unusually large size), with lesser quantities of spheroidal hammerscale (SHS). The coarser microresidues (passing up strictly into macroresidues) include slag spheroids, slag blisters and slag flats. Sub-sampling of the microresidues from <7311> (7305) was undertaken to provide separate strew mounts of SHS (LFF1) and FHS (LFF2).

Hammerscale is associated with the superficial oxidation of iron at high temperature (Young 2011b), with FHS mostly indicative of the solid (or semi-solid) oxide layer spalling from the workpiece, whereas SHS forms from the air chilling of spatter from the molten oxide layer (often melted under the influence of a smithing flux) expelled from the join during forge (or fire) welding.

Slag spheroids are droplets of smithing slag that cooled within the fuel bed of the hearth, without amalgamating into a large mass. Slag blisters are probably mostly formed as flake hammerscale but are lifted off the surface of the underlying metal by build-ups of gas (in some cases above underlying inclusions in the iron). Slag flats are thin skins of slag that form either on the surface of the workpiece or a tool.

Details: samples examined by ASEM

Sample LFF1

The sample of SHS particles is shown in Appendix IV Figure 2.

31 particles were investigated (Appendix IV Tables 5 and 6). For each particle (except S20) a bulk analysis by EDS was attempted, with a focus on areas devoid of voids, because some larger voids were observed on the SEM to contain small quantities of polishing medium (alumina powder). In a proportion of cases, it was not possible to analyse areas without any visible porosity, particularly for the more wustite-rich particles which contained little interstitial material. Those analyses for which careful inspection showed minor porosity have

been categorised as ‘slightly suspect’, those with slightly coarser porosity very likely to have formed a trap for the polishing medium were categorised as ‘very suspect’. Where possible, an estimate of the bulk composition of grains was determined by averaging the area analyses excluding the ‘suspect’ values, but in some cases, only ‘suspect’ regions were available for analysis, so this is noted in the table of compositions (Appendix IV Table 5)

The SiO_2 content of the SHS particles varies from less than 0.5% up to almost 22% (Appendix IV Figure 3). For SiO_2 contents of up to approximately 10%, the particles are dominated by stubby, complex, wustite dendrites and rounded, blebby ‘pseudo-dendrites’. At above 10% SiO_2, the wustite tends to be in finer, more delicate dendrites and is followed by either a glass or olivine, depending upon the rapidity of colling. Most particles show a very thin superficial crust, in which magnetite is the dominant phase. Some particles, from across the range of SiO_2 content show the development of magnetite dendrites across the width of the particle before wustite follows.

Some particles show inclusions of unmelted quartz flux. This was mainly very small (<100μm), but in a few cases larger grains were preserved (in one case of 400 μm). Seven particles showed fragments of unmelted oxide scale, lifted away from the iron substrate by the melted component (a process known as washing).

Small metallic prills were rare in the SHS. An example in S17 produced an analysis of approximately 95.2% Fe, 0.6% Co, 0.2% Ni, 3.2%As and 0.3% Sb and one from S32 of approximately 95.8% Fe, 1.4%Co, 2.0% Ni and 0.5% As (all in atomic%).

Sample LFF2

The sample of tabular particles is shown in Appendix IV Figure 4.

13 particles were investigated (Appendix IV Tables 7 and 8). For each particle either a bulk analysis extending across the whole thickness or a series of subareas spanning the thickness was attempted by EDS.

As with the SHS, analyses for which careful inspection showed minor porosity have been categorised as ‘slightly suspect’, those with slightly coarser porosity very likely to have formed a trap for the polishing medium were categorised as ‘very suspect (Appendix IV Table 7). Also for the SHS, ‘suspect’ particles may have slightly elevated $A_{l2}O_3$ at the expense of all other elements.

The tabular particles showed six varieties of microstructure (Appendix IV Figure 5):

1 (T3, T6). a neat, regular scale, with the magnetite and wustite zones developed evenly and with relatively constant thickness. There is little or no basal slag.

2 (T2, T4, T11, T12): a fairly neat scale, with a tendency to develop magnetite on both faces, in the absence of basal slag. Iscorite forms prominent ‘stitching’ between wustite grains in the lower part of the thickness.

3 (T9, T13): a neat regular scale, similar to (1), but developed over a thick layer of wustite-dominated basal slag.

4 (T1, T5, T8): scale retaining a thin outer magnetite zone, but the wustite zone has fragmented into slabs lying within a slag containing abundant new-formed wustite.

5 (T7): scale apparently showing the chaotic disaggregation of wustite, probably a new-formed wustite.

6 (T10): scale showing a siliceous composition with a quench texture including fine wustite dendrites. This has a very thin external crust.

Examples of scale of microstructural groups 1 to 3 all contain less than 4% SiO2, whereas those of groups 4 and 5 all contain 4% - 7% SiO_2. The single example of group 6 contains 19% SiO_2.

The compositional and microstructural difference between T10 and the remainder of the collection, means that it is probably best regarded as not flake hammerscale, but as a slag flat.

Small metallic prills were very rare in the tabular particles, but several examples were investigated within the fully melted tabular particle T10. These gave analysis of approximately 98.8% Fe, 0.6% Co, 0.1% Ni, of 98.8% Fe, 0.6% Co, and of 98.2% Fe, 0.6%Co, 0.2%Ni and 0.4% As.

Interpretation

The SHCs in the assemblage are small, the isolated example weighs 128g and the example with two fused masses (suggestive of accumulation in two work periods) weighs 166g. The SHCs are dense and well-formed, typical of those formed in a hearth using a ceramic tuyère or a blowhole in a ceramic wall, rather than an iron tuyère.

The elemental analysis of the individual SHC (LFF4) suggests it is equivalent to approximately 25% ceramic (of the composition of sample LFF3), plus 50% iron, 1.5% fuel ash and 6% silica (presumably from the flux). If the iron and phosphorus represent bulk loss of iron, then the iron contained 0.3%P, but such an estimate is speculative. The iron content of the ceramic is suspiciously high, and the chosen sample may itself have been contaminated by iron from the hearth, even if that was not apparent when the sample was chosen. If the FeO content of the ceramic had only been 7% than the added iron would contribute around 55% of the SHC.

The content of MnO in the scale is generally rather low (Appendix IV Figure 7c, Figure 8c). One single piece of FHS shows strongly elevated MnO (T11) and some particles of SHS show very slightly increased levels with respect to the others. The source for Mn in these samples is likely to be inclusions of Mn-rich iron smelting slag present in the iron being worked

Analysis of the microresidues demonstrates that phosphorus is abundant in some particles and is particularly abundant in the basal (inner) slags (Appendix IV Figure 7b, Figure 8b). The migration of phosphorus from the iron to the slag phase as the iron is oxidised during scale formation contributes to both slag formation and scale detachment. (Young 2019, 21)

The content of alkali and alkaline earth elements in the SHS shows a rapid increase in particles over approximately 15% SiO_2. In Figures 7a and 8a, this is demonstrated using the sum of CaO and K_2O. The SHS population has been divided into particles which do not show this enrichment (SHS (1)) and those that do (SHS (2)).

The SHS (1) group includes particles S2, S3, S4, S5, S6, S7, S8, S9, S11, S12, S13, S14, S15, S16, S17, S24, S25, S27, S28 and S30.

The SHS (2) group includes particles S1, S10, S18, S19, S21, S22, S23, S26, S29, S31 and S32.

The composition of the microresidues provides some insight into the process of SHS formation. The role of a quartz flux is significant. Its presence can be demonstrated not only by the relict quartz grains observed in 22% of the SHS grains examined, but also in the trend of increasing SiO_2/Al_2O_3 with SiO_2 content (Appendix IV Figures 7d and 8d) in the SHS grains in group SHS (1), reaching a peak value of approximately 10, very much higher than the value of 2.6 for the bulk analysis of the hearth ceramic (LFF3), or even the value of 3.9 for the bulk analysis of the analysed SHC (LFF4).

For SHS (2) particles, further increase in SiO_2 content is marked by a fall in SiO_2/Al_2O_3 and by elevated (K_2O + CaO). The fall in SiO_2/Al_2O_3 can be interpreted as an increased influence of the hearth ceramic, but the values for (K_2O + CaO) do not lie on such a trend – and these elements must be indicating, in addition, substantial incorporation of fuel ash.

The presence of a significant number of SHC particles in a compositional range with greater than 90% FeO and with FeO/(SiO_2+FeO) of greater than 95%, and with the wustite in those particles appearing to be new-formed with very little, if any, inherited solid phase, indicates that oxide scale was being melted under conditions with very low amounts of flux. That, in turn, indicates very high temperature conditions, probably in excess of 1300C. Such temperatures would be necessary for the welding of iron with a low carbon content.

Examination of the analyses of the residues on the Feo-SiO_2-Al_2O_3 ternary diagram (Appendix IV Figure 6, fields after Schairer & Yagi 1952) shows some of these same trends, with an array of analyses of group SHS (1) trending towards the SiO_2 pole, but that analyses of group SHS (2) become offset from this trend with slightly more aluminous compositions trending towards that of the hearth ceramic.

In summary, the microresidue assemblage suggests that much of the SHS (SHS (1)) was formed on the surface of phosphoric iron, enhanced by the use of a quartz smithing flux. The FHS (except particle T10) shows a similar influence, but an enhanced input from the fuel ash. A smaller proportion of the SHS (SHS (2) and particle (T10) formed under the additional influence of the hearth lining (as well as fuel ash). The scale with a low input of silica shows a variable, but commonly high content of phosphorus, indicating the iron was phosphoric.

On a broader scale, there are very few assemblages of similar medieval date in the region for comparison of the macroscopic residue assemblage (a medieval smithing hearth was recorded from site 3/14 of the Pwllheli to Blaenau pipeline (Young 2011a); medieval smithing was recorded from Parc Cybi (Young 2019); medieval smithing residues were found at Hen Gastell (Young 2016)). There are distinct similarities with the SHC assemblage from Hen Gastell where besides one large and one medium SHC (c. 1000g, 306g), there was a range of small examples (72g, 80g, 84g, 104g and 168g) similar to those in the present assemblage. These included one attached to an inclined second mass of slag. The Hen Gastell assemblage was also noted to contain a 'large proportion of nubs and fragments of gravelly slag'. Whilst far from conclusive, the observations suggest that the present assemblage and that from Hen Gastell may lie within the same technological milieu.

Two sites with the region have had hammerscale assemblages investigated previously: Parc Cybi ((Young 2019); with three assemblages, of Roman, medieval and post-medieval age) and Hen Gastell ((Young 2016) of medieval age).

The medieval phases of both these sites produce evidence for the use of iron with both elevated phosphorus (both in the iron and in the slag inclusions) and manganese (in the slag inclusions), suggesting the working of iron produced from a sedimentary ironstone source, probably a bog iron ore.

At Hen Gastell, the microresidues occurred in contexts from throughout the lifetime of the site during the 11th and 12th centuries. That assemblage may, therefore, be just slightly older than the present one.

The upper-crust normalised REE profiles for the macroresidues are similar to those recorded for the macroresidues from Hen Gastell (Young 2016 fig. 5a), suggesting that the clays employed for the hearths were similar.

If the macroscopic slags provide similarities with the assemblage from Hen Gastell, there are some significant differences in the details of the composition of the microresidues. At Hen Gastell there was a discrete population of SHS particles with around 20-25% SiO_2 that show elevated MnO (0.45-0.60%; Young 2016, fig 6). These were interpreted as having their origin in the expulsion of melted inclusions of smelting slag from the iron. Particles high in P_2O_5 occurred in the same compositional range (18-26% SiO2 for particles with over 0.8% P_2O_5), although in a wider range of individual particles. This pattern was interpreted as evidence for the working of phosphoric iron, bearing inclusions rich in manganese and phosphorus from the smelting of the iron from a bog iron ore.

The population of SHS from the medieval ironworking in Area E at Parc Cybi showed two even more extreme SHS particles with outlying compositions at 13.5% and 18.5% SiO_2, 4.9% and 6.3% MnO and 1.5% and 2.8% P_2O_5 respectively. This provides even stronger evidence for the nature of smelting slag inclusions in the metal there.

At Llanfairfechan the pattern of these elements is different. Manganese appears at elevated levels in just a few particles in this silica range (18-25%) but phosphorus is only shown in very elevated levels in particles with less than 10% silica. Similarly, the highest level of manganese (1.4%) was recorded in a FHS particle with very low (0.57%) silica.

At Hen Gastell, it was noted (Young 2016, 9) that one of the tabular particles showed an abnormally high content of magnesium (1.05-1.83% MgO), but that was not able to be explained. At Llanfairfechan it was also the case that some of the low-silica particles (5 of the 6 SHS particles and 1 of the two FHS with the lowest SiO_2) showed an abnormally high magnesium content relative to other particles. Two of these SHS particles were also those with the high P_2O_5 contents.

The datasets from all these sites are very small and thus any comparison must only be tentative, but it is possible that the smiths at Hen Gastell relied on a higher level of fluxing. It is also possible, but extremely speculative, that more of the phosphorus was contained in the slag inclusions in the iron used at Hen Gastell, rather than being present within the iron metal.

To return to the question that prompted the analytical phase of work – why is the flake hammerscale present at Llanfairfechan in such unusually large pieces; it is not possible to answer this conclusively, but a relatively sparse use of quartz smithing flux and detachment promoted instead by phosphorus in the inner slag, may be implicated.

Discussion

The analyses suggests that the iron being worked at Llanfairfechan was phosphoric and likely to have been smelted from a bog iron ore. As such, it resembles the evidence from Parc Cybi Area E and Hen Gastell.

The three sites differ, however, in the details of the composition of the hammerscale in ways which are likely to reflect the way in which the iron was being worked rather than the raw materials. At Llanfairfechan 25% of the analysed SHS particles show SiO_2 at less than 5%, as were 10 of the 11 pieces of FHS. In contrast, at Hen Gastell no SHS particles had less than 5% SiO_2, whereas 54% of SHS particles at Parc Cybi Area E had less than 5% SiO_2. The iron-rich SHS particles at Parc Cybi Area E commonly showed evidence for the transfer of incompletely melted wustite into the scale, whereas evidence for this was largely lacking at Llanfairfechan (although there was evidence for the transfer of unmelted fragments of unmelted scale).

The ironworking at Llanfairfechan thus appears to have been undertaken at higher temperature than at Parc Cybi, but with a relatively low use of flux. This may have been because the iron could be welded with little or no flux. The degree to which flux was employed may well have also been an individual trait of the smith involved.

Even if its use was more restricted at Llanfairfechan, a quartz flux was clearly used. This, together with the evidence for high temperature working, indicates that welding was a part of the work undertaken in the hearth.

The hearth, therefore, cannot simply have been for a farrier or for other very light work.

Attempting to estimate what the hearth might have been used for is difficult, because of the very small assemblage of SHCs preserved – which may not necessarily be at representative. If, however, the preserved single SHC at 128g is representative, then using the range of 50%-55% of that being iron lost to the hearth, then that equates to losing 65-70g of iron to the slag in a work period (this excludes iron lost to hammerscale).

Iron losses depend on many factors, but Soulignac and Serneels (2014) in an investigation into the fabrication of a simple hoe using traditional techniques, demonstrated losses of approximately 200g (+/-40g) for an SHC of this weight If the task involved welding, then losses of approximately 20-25% were incurred in an operation involving a single weld. To generalise their results very crudely only around half the iron loss appears to have been into the slag. On this basis, around 130-140g of iron lost in total (within extremely large margins of error). Thus, perhaps the 128g SHC represents the working of 500-700g of iron into an artefact(s) weighing 350-550g (or less if multiple welds were involved). Such a calculation is fraught with many potential sources of error and should only be used to give a most general idea of the amount of iron being processed.

4.9. Assessment of the macroplant fossils, charcoal and bone

By Jackaline Robertson, AOC Archaeology

Introduction and quantification

Four bulk samples from archaeological work undertaken as part of the landscape of Neolithic axes project in Llanfairfechan, Conwy, North Wales were submitted for environmental assessment in September 2024. The samples were collected from one possible Neolithic pit alongside three other features of unknown date. These were a pit with smithing waste, a hearth located on a platform, and a deposit described as the interface between the colluvium and natural. The ecofact assemblage was composed of carbonised macroplant, charcoal and bone. This assessment aimed to identify the ecofacts to species and assess their suitability for radiocarbon dating and potential for further analysis with reference to the Research Framework for the Archaeology of Wales (Accessed September 2024).

Methodology

This assessment was undertaken in line with published standards and guidelines (CIfA 2014). The bulk samples were processed by Heneb Gwynedd Archaeology Trust and the wash-overs were submitted to AOC Archaeology Group for environmental assessment. The wash-overs were assessed using a binocular stereo microscope at x10 – x40 magnification.

The macrofossils, charcoal, and bone were examined using a Leica stereo microscope at magnifications of x10 – x55. Species identifications of macroplants were confirmed using modern reference material and seed atlases (Cappers et al. 2006; Jacomet 2006). Charcoal identifications were confirmed by analysing the transverse, tangential, and radial sections of each fragment and using keys and texts (Schweingruber 1990; Hather 2000). Taxonomy and nomenclature for plants follows Stace (2010). The bone was too poorly preserved to be identifiable to species and instead was quantified by number, preservation, and weight. See Appendix V for full details of species identification and counts.

Results and observations

The macroplant

The carbonised macroplant totalled 37 finds which were recovered from pits [7307], [11605] and interface deposit (8804). The assemblage was composed of one cereal caryopsis, 33 nutshell fragments and three weeds. The species were hulled barley (*Hordeum vulgare* L.), hazelnut (*Corylus avellana* L.) and dock (*Rumex* sp.). In hearth (12903) there were small fragments of burnt peat which were semi-quantified. Preservation of the cereal and hazelnut was good, whereas the weeds and peat fragments were recorded as poor.

The charcoal

Charcoal (30.8g) was recovered from all four features and 52 fragments were identified to species. These species comprised alder (*Alnus glutinosa* (L.) Gaertn), hazel (*Corylus avellana* L.), and oak (*Quercus* sp.). Preservation of the fragments ranged from poor to adequate. Those described as poor were either vitrified or noticeably friable.

The Bone

One fragment of burnt bone (0.07g) was noted in pit [11605]. The bone fragment was poorly preserved and could not be identified to species or skeletal element. Instead, it was recorded as indeterminate mammal.

Other finds

Small pieces of industrial waste were recovered from pit [7307] and hearth (12903). These finds should be repatriated alongside any hand-retrieved material and assessed by the relevant specialist.

Modern contamination

Modern contamination in the form of roots, straw, seeds, leaves, moss, and insects was dispersed among the four samples. There is however no evidence that the archaeological integrity of any of these features has been noticeably compromised.

Summary of the contextual units

Context (7305) Pit [7307] Sample <5>

Macroplant: There was one hulled barley caryopsis.

Charcoal: The charcoal (12.5g) was formed entirely of oak.

Synthesis: This pit was described as containing smithing waste and the oak charcoal is likely fuel debris associated with this activity. The hulled barley is food waste reworked into the pit. The hulled barley and oak charcoal are suitable for dating.

Context (8804) Interface deposit Sample <6>

Macroplant: There were three weeds, of which one was identified as dock. The other two could not be identified due to poor preservation.

Charcoal: The charcoal (2g) was formed of oak.

Synthesis: The weeds probably grew in this area and were accidentally burnt, whereas the charcoal is fuel debris reworked into this deposit. The oak charcoal is suitable for radiocarbon dating.

Context (11604) Neolithic Pit [11605] Sample <7>

Macroplant: There were 33 fragments of hazelnut shell.

Charcoal: The charcoal (16.2g) was a mix of hazel (60%) and oak (40%). Hazel roundwood (10%) was noted within the assemblage.

Bone: There was one small fragment of burnt bone (0.07g) recorded as indeterminate mammal.

Synthesis: The hazelnut shell, bone, and charcoal are a mix of food and fuel debris disposed of within this pit. Both the hazelnut shell and hazel charcoal are recommended for dating. The animal bone fragment is not suitable for dating, as it is unlikely to contain sufficient carbon due to poor preservation.

Context (12903) Hearth Sample <8>
Macroplant: Fragments of burnt peat, all smaller than 4mm, were present within the hearth.
Charcoal: There were two fragments of alder (0.1g).
Synthesis: The ecofact evidence suggests that both peat and charcoal were used as fuel sources within the hearth. The alder charcoal is suitable for dating.

Discussion

The macroplant

The crops

The single hulled barley caryopsis recovered from the site represents a crop that has been cultivated in Britain from the prehistoric period onwards. The most information that can be gathered from this find is that food debris was reworked into a pit. Given the small size of the assemblage, it has no further information to offer concerning the dietary and economic role of cereals at this site.

The nuts

Hazelnuts are a common find at most archaeological sites, as they were regularly collected for food and the density of the shell means they were able to survive the charring process (Bishop 2019). It is also likely that the shells were deliberately exposed to fire during roasting, were burnt as a means of disposal, or were recycled for kindling within fire pits and hearths. The shells from this site demonstrate this resource was collected from the surrounding landscape when seasonally available during the Neolithic period. As the assemblage is relatively small, it is unclear how important this resource was to the diet of the site's inhabitants or if it continued to be exploited at later periods.

The fuel

Small fragments of peat were noted in context (12903), and it is possible this material was deliberately collected for fuel and burnt within the hearth alongside wood species.

The weeds

The only identifiable weed was dock, which typically grows in arable fields and waste ground. It probably grew on-site and was accidentally burnt. Dock has been collected as a wild food resource, but as only a single example was found, it is impossible to identify what role (if any) this species may have had at this site.

The charcoal

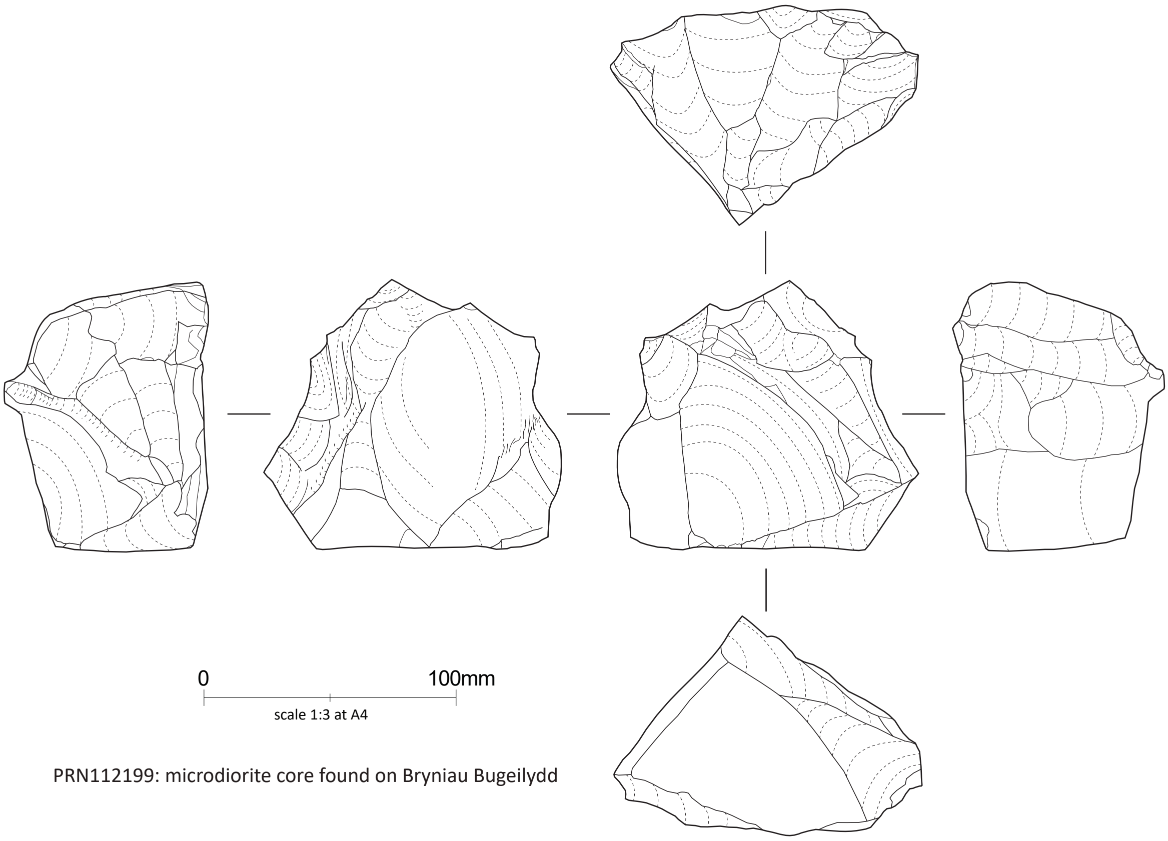
Alder, hazel, and oak are native to Wales and likely grew in the surrounding landscape. Alder favours more damp habitats, while hazel grows in hedgerows, scrub, or more open woods, and oak is adaptable to a variety of environmental conditions (Linford 2009; Stace 2010). The charcoal assemblage is representative of fuel debris and there is no evidence of the burning of small structural elements or wooden artefacts. The small size of the charcoal assemblage means that it is not possible to gather any further evidence regarding how woodland was used.

The bone

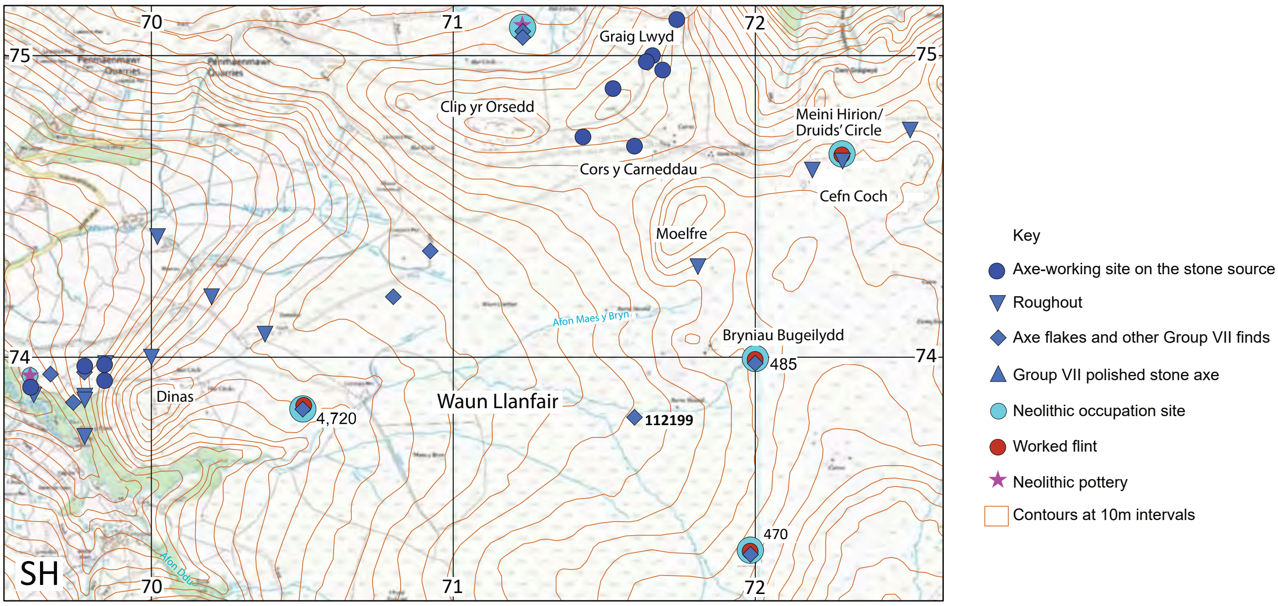
The presence of a single burnt bone fragment in Neolithic pit [11605] is of little interpretive value in understanding the dietary contribution and economic role of animals at this site.

Conclusions

The macroplant, charcoal, and bone have been fully assessed, and further species identifications are not required. While the ecofact assemblage is small, it is still possible to draw some conclusions about how plants and woodland were used at this site. During the Neolithic period, hazel in the form of both nuts and wood was exploited for food and fuel alongside oak. From the other three features of unknown date, it seems hulled barley



PRN112199: microdiorite core found on Bryniau Bugeilydd



Location of find spot of PRN112199

Figure 66. Microdiorite core and map of the find spot

may have been part of the diet, with alder, oak, and peat used for fuel. The small size of the assemblage means further analysis is not recommended, as it has no further information to provide in contributing to the research questions outlined in the Research Framework for the Archaeology of Wales (Accessed September 2024).
The hulled barley and hazelnut shell, along with the alder and hazel charcoal are suitable for radiocarbon dating. Oak is not normally recommended for dating as it is a slow-growing species and therefore not always dependable; however, as the ecofact assemblage is not extensive, it may have to be dated if there is no alternative material available. The ecofact assemblage is stored in a dry and stable condition and is suitable for long-term archiving.

4.10. Iron Objects

Table 12. List of iron objects collected

Find No	Sub-Area	Test Pit/Trench	Context No	Description	Weight (g)	Number of items
7314	Ty'n y Llwyfan	73	7305	Fiddle-key Nail	3.96	1
10604	Garreg Fawr	106	10602	Nail	1	1
13402	Ty'n y Llwyfan	134	13402	Square sided nail	4	1
14305	Ty'n y Llwyfan	143	14302	Iron object	17	1
14403	Ty'n y Llwyfan	144	14402	Iron objects	28	2

A small number of iron objects were found. Most of these were from the ploughsoil or lower topsoil and are most likely fairly recent items incidentally lost. However, there was one significant iron object, a fiddle-key nail (SF7314) from the fill of the smithing pit found in TP73. This type of nail is typical of the medieval period and may have been one of the items produced at the smithing hearth.

4.11. Bone/ Teeth

Very little bone was recovered from the test pitting. Unburnt bone is unlikely to survive for long in the acid soil, so chance finds are likely to be post-medieval or later in date. One fragment of burnt bone (SF11608, 0.07g) was recovered from in pit [11605] on Garreg Fawr. The bone fragment was poorly preserved and could not be identified to species or skeletal element and can only be identified as indeterminate mammal. This is likely to be Bronze Age in date considering the radiocarbon date from the pit, as burnt bone can survive for millennia in the soil.

The only other animal remains retained were a pig tooth (SF8605) from TP86 at Ty’n y Llwyfan. This came from the topsoil (8601) and is well-preserved and therefore most probably fairly recent, perhaps 19th century. It is a premolar that has been fairly heavily worn, so from an older animal.

4.12. Microdiorite Core from Bryniau Bugeilydd

A core on microdiorite (PRN 112199) was found near Bryniau Bugeilydd by David Thorpe at SH 716 738. This weighs 1003g, and measures 117mm by 97mm by 79mm (Figure 66). This has 5 flake scars where flakes have been removed, one not very successfully. These were struck from what appears to be a prepared platform as there are two flake scars on the platform, removed before the other flakes. Two of flakes removed would have been blades as the length of the scars are more than twice their width. A deeply concave scar shows where part of the base of the core has been removed. The core has clearly been on the ground surface for a long time as it has considerable lichen coverage and has been patinated to a very pale yellow-brown under that. The platform is dark in colour and is polished. The polish probably comes from sheep walking on, lying on or rubbing against this face.

Cores on Group VII stone appear to be rare, though some of the flakes recovered from the test pits were suggestive of deliberate production from a core. A small number of blades were identified in TP138 in Cae Bach and the flakes used for the scrapers appeared to be deliberately struck for the purpose, possibly from cores. Despite excavating tons of material at Graig Lwyd, Hazzledine Warren found nothing that he could call a core (Warren 1922, 26), though there are some objects from Graig Lwyd in the National Museum of Wales online catalogue that are described as such. Davies (1961, 3) mentions pieces of microdiorite, listed under hammerstones, but described as being more like cores. These appear not to have been roughouts but cores for the production of flakes, which were presumably either used for cutting as they were or were retouched into tools. There does therefore seem to have been a small element of use of core technology to produce flakes, possibly more commonly away from the stone sources than on them.

The find spot of the Bryniau Bugeilydd core is 1.4km from the Dinas screes, so it has been transported a considerable distance for use near this location. Finds of axe debris and flint under cairns PRN 470 and 485 suggest Neolithic occupation, perhaps of a temporary nature, on the eastern side of Waun Llanfair (Figure 66). The core is further evidence of occupation in this area, and the deliberate production of Group VII flakes presumably for flake tools.

5. RADIOCARBON DATES

Six samples were submitted for radiocarbon dating by accelerator mass spectrometry at the Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Laboratory (see Table 13 and Appendix VI for dating certificates). The material for dating was chosen after the charred plant remains had been studied and, where possible, short-lived species were selected. In some cases, only oak was available with the possibility that some of this could be from heartwood. Four features were dated: The smithing hearth (pit [7307]), from Cae Graig; pit [11605] on Garreg Fawr; hearth 12903 on building platform PRN 103623 at Cors y Carneddau, and an interface layer (8804) at the base of the upper lynchet in Cae Graig. Two samples were dated from the first two features to check for any disturbance, mixing or other issues. The hearth deposit produced little datable material with two small fragments of alder charcoal being the best items, but as these could have both been from the same branch only one piece was dated. There was also relatively little material from layer 8804 and only one date was obtained because the material could not be linked to a specific event and the date would be a general, range-finding date.

Smithing hearth pit [7307]

The two dates from this pit were very different; SUERC-130048 (cal AD 890-1000) dated to the early medieval period and SUERC-130049 (cal AD 1150-1260) is medieval. Only oak had been used as fuel for the smithy, so the dates were done on oak charcoal. It is suggested that the earliest date was the result of the sample being heartwood and much older than the smithing activity. The later date could be taken as the actual date of the smithing, though a third sample would have to be dated to confirm this. The discovery of a ‘fiddle-key’ nail, typical of the medieval period, does support this later date and it seems likely that the smithing activity dated to the 12th-13th century AD.

Pit [11605]

Two dates were obtained from pit [11605], and these were indistinguishable (SUERC-130050, 1890-1740 cal BC; SUERC-130054, 1890-1700 cal BC). It is not entirely impossible that the hazel roundwood and hazelnut came from the same branch, but more likely that these are independent items representing fuelwood and food debris from activity in close proximity to the pit. The two indistinguishable dates support each other and suggest the activity occurred in the Early Bronze Age. A small sherd of pottery and some axe flakes were recovered from this pit. Frances Lynch (see Section 4.5 above) considered the pot sherd to have a fabric consistent with Mid Neolithic Impressed Wares, especially with its large inclusions, but she also suggested that it was similar to Late Bronze Age pottery. The radiocarbon dates suggest that this sherd is of a Bronze Age date and that the axe flakes were residual in the pit fill.

Hearth 12903

The hearth deposit produced some fragments of peat that were not suitable for dating and two tiny fragments of alder charcoal. As these could have been from the same branch only one sample was dated, so there is only a single date from this deposit, with no corroboration. However, it is very likely that the alder was used as fuelwood. It would have grown in wetter areas and must have been deliberately brought on to the site, so the date is likely to represent the date of the hearth. This date (SUERC-130055, 770-480 cal BC) suggests the hearth was used in the early to middle Iron Age.

Interface layer/buried soil 8804

The soil sample from deposit 8804 produced some weed seeds, which were too small for dating and a small amount of oak charcoal. The latter was dated and produced a middle Bronze Age date (SUERC-130056, 1380-1120 cal BC). One of the seeds was identifiable as dock, suggesting arable or waste ground. The source of the oak charcoal is unknown; possibly the result of clearing the area by fire, possibly from fuelwood, perhaps spread on a field with manure. It does suggest that this deposit, which is probably the remains of a buried soil, was exposed in the Bronze Age allowing this charcoal to be mixed into it. This layer was probably the land surface before the development of the lynchet, and the date is consistent with an Iron Age date for the lynchet but rules out a Neolithic date.

Table 13. Table of Radiocarbon Dates (calibrated dates rounded outwards to nearest 10)

Lab No.	Context	Material	$\delta^{13}C$	Radiocarbon Age BP	Calibrated date (95.4% probability)
SUERC-130048	7305: fill of pit [7307]	Charcoal: Oak	-27.6 ‰	1101 ± 23	Cal AD 890-1000
SUERC-130049	7305: fill of pit [7307]	Charcoal: Oak	-26.2 ‰	858 ± 23	Cal AD 1150-1260
SUERC-130050	11604: fill of pit [11605]	Charcoal roundwood: Hazel	-26.5 ‰	3499 ± 23	1890-1740 cal BC
SUERC-130054	11604: fill of pit [11605]	Nutshell: Hazel	-25.8 ‰	3480 ± 23	1890-1700 cal BC
SUERC-130055	12903: hearth deposit	Charcoal: Alder	-28.6 ‰	2473 ± 23	770-480 cal BC
SUERC-130056	8804: Interface between lynchet and natural	Charcoal: Oak	-25.5 ‰	3006 ± 23	1380-1120 cal BC

6. DISCUSSION

6.1. Ty'n y Llwyfan

Figures 5-7

The test pitting showed axe debris widely spread over the fields investigated at Ty'n y Llwyfan but there were clear concentrations of debris. The main concentration is in the northern part of Cae Graig, which extends a short distance into Cae Bach. Much of the southern part of Cae Graig has little activity, until the screes along the southern and eastern edge are reached, and considerable activity is found wherever scree is present, whether currently open or now under grass. The lynchets show how much soil movement there has been since at least the Iron Age, and the main concentration of debris is not *in situ,* but material must have moved down slope from higher up the field, closer to the screes, and collected against the lynchet boundary. The generally small size of flakes from this area suggest that this material did not just erode off the scree, where initial working was taking place and flakes are generally larger. The presence of numerous very small flakes from this area, which were rare elsewhere, despite following the same methodology, suggests roughouts were finished off in this area prior to them being taken away for polishing. It is possible to suggest a focus of axe-production just below the edge of the screes in the northern part of Cae Graig.

The stone deposit in TP75, TP85 and TP89 (7504, 8503 and 8903) in the middle of the upper lynchet, appears to be integral to the structure of the lynchet but does not form a revetment. Previously it was considered whether this quantity of axe debris incorporated into the lynchet suggested that the lynchet was of Neolithic date, but that seems unlikely and the Bronze Age date from the base of the lynchet strongly argues against this. The stone must be from Neolithic activity that has become incorporated into an Iron Age lynchet. It presumably represents a deposit of scree with intense axe-making activity just uphill, i.e. east of the location of the test pits. There is a gradual scarp in the hill slope here which may be caused by a build-up of scree, though TP03, on top of this did not contain scree. The mechanism by which the stone and axe debris was incorporated into the lynchet from its base upwards, while remaining densely concentrated is not completely clear. OSL dating of the sediments in the lynchets would be useful to confirm the date of their build-up or construction.

The concentration of axe-making activity in the northern part of Cae Graig continues into the southern part of Cae Bach along with significant scree deposits. There has been movement of ploughsoil down into the southern part of Cae Bach, creating what is essentially the corner of a lynchet there, and this has probably brought axe debris down from working closer to the higher screes, with some working of the screes present under the ploughsoil in Cae Bach. Where scree deposits do not exist over the rest of the field there is much less evidence for axe working. The test pits in this area have found a clear limit to the area of working, though TP149 and 150 in Cae Uchaf do suggest that other small areas of working might be present where there were small pockets of scree.

The large quantity of axe material found in TP 15 and TP39 on a shelf within the scarp between the upper and lower lynchets suggests that this was a separate focus of activity, possibly using a lobe of scree that may have formed the shelf. Large, flaked blocks indicate that the scree here was being sorted through and tested for suitability for axe production, with roughouts and flakes showing that there was suitable stone. The ploughing causing the creation of the lynchets occurred above and below this location and even the occasional modern ploughing has probably avoided this location which would be very difficult to plough. The presence of field clearance stones on the edge of the shelf confirms that this shelf was avoided by ploughing and therefore a suitable place to deposit stones. The axe debris here is likely to be largely *in situ*, though the test pits showed the deposits were fairly well mixed and no undisturbed knapping floor was seen. The mixing of Roman pot sherds into the layers here does indicate some disturbance.

Axe flakes and a roughout from TP11 and TP33, along with a lower level of debris in other test pits on the northern end of the lower lynchet, indicate that this lynchet disturbed another, smaller focus of activity. With the upper lynchet trapping material moving downslope axe debris on the lower lynchet must have been generated close to that. This suggests small scale working taking place some distance from the screes, though the shelf (TP15 and TP39) could have been the scree source for this activity.

A lower level of axe debris was seen below the lower lynchet in TP13 and TP14 and in finds from the water pipe trench, but this still included roughouts. Similarly, Cae Dafydd produced lower concentrations of axe flakes but there were flakes scattered over the field and two roughouts were recovered. Twenty-seven flakes (PRN 93577) previously found along the route of a water pipeline across this field adds to the evidence (Dean and Cooke 2019). This suggests that axe-making also occurred much further from the screes but that the test pitting failed to locate the focus of activity. A small Neolithic pot sherd from a test pit in this field hints at Neolithic settlement somewhere nearby. The steep gorge formed by the Afon Llanfairfechan runs along the southern side of this field, with one of the few access routes into the gorge leading down from this field, making this fairly sheltered location ideal for settlement.

The evaluation trench (T31) showed that there was intensive working taking place in the open screes at the western foot of Dinas. The screes here are not deep, being about 0.4m deep. They appear to have been thoroughly sorted through by Neolithic people looking for suitable blocks, resulting in mixing of flakes through the scree and only the latest activity surviving as undisturbed knapping floors. However, such knapping floors do appear to have survived in places and there is a chance of some being associated with fires for warmth or cooking, which would provide valuable dating material. Where the screes are still exposed, they have been disturbed by later activity as can be seen by the remains of rough walling, hollows and platforms created in the scree. However, where the screes are consolidated by a thin layer of turf or bracken the evaluation trench has shown that the evidence of axe-making may be well preserved and largely undisturbed.

There has been no methodical search for roughouts on the southern and eastern sides Dinas. A preliminary inspection of the screes continuing up the western side of the hill suggested that not all the screes were of suitable stone for axe-making, but large areas were suitable. It is likely that most of the extensive screes that cover the sides of Dinas were used for sourcing stone for making axeheads. A roughout was found and reported to the Portable Antiquities Scheme in 2022 from the lower part of the Nant y Coed woodland (PRN 96702) and axe debris is likely throughout the woodland.

6.2. Garreg Fawr

On Garreg Fawr it appears that there were discrete, fairly small areas of axe working. The open screes on the north side of the hill were an area of working (PRN 67328) (Figure 39), though not all the exposed screes are of a suitable stone, so the working area is restricted. Axe flakes can be seen eroding out of the turf uphill of the open screes. The amount of gorse and the steepness of the slopes in this area meant that the extent of this area has not been investigated by test pitting. Between this area and the main crag, although some scree can be seen on the surface, it appears that there is no suitable stone and axe working did not take place. Even at the northern end of the crags the stone was not suitable, and axe working is only present southwards from the middle of the crags (Figure 28). This working was mainly concentrated close to the deeper screes at the foot of the crags. It did extend at least 43m down the slope from the edge of the scree visible on the ground surface, but the quantity of axe debris reduces with the distance down the slope. How much further down the slope axe debris can be found has not yet been tested but the lack of scree in the lower test pits suggests that the working probably does not continue much further. The main focus of the activity was probably under the sheepfold and further south. Some of the stone in this area seems to be very good quality and the roughout found was flat, possibly made on a large flake, possibly indicating the style of axehead that was made from this source.

The lack of ploughing in this area means that there is a better chance of dug features surviving here than in some of the other areas investigated and this was proved by finding a small pit in TP116, dated as Bronze Age rather than Neolithic. Disturbance of the Neolithic deposits has occurred in some part of this area such as where the enclosure under the sheepfold has mixed axe debris into soil that built-up inside the enclosure or was moved to level the area. Quarrying of the crag has also caused loss of the original crag face in the area of the best stone, so possibly removing some evidence for removal of stone from the crag. The quarry waste has also hidden probably worked screes. However, there are areas of scree to the south of the crags that have been worked and there is scree on the top of Garreg Fawr, which might also have been used. The preliminary evidence of axe-working on the southern summit of Garreg Fawr considerably extends the known area of working. This is also likely to be restricted as the intrusion here is not extensive, but it gives an indication of Neolithic people locating and using all suitable stone sources. While Dinas represents an extensive source with use very widely spread, Garreg Fawr presents a patchwork of small sources, that together may also have been very productive. Another of these small sources is probably the Roman Road Intrusion, south-east of Garreg Fawr, so there was a string of small sources along the southern boundary of the axe-production area, further emphasising the landscape scale of the stone sources.

6.3. Cors y Carneddau

Figure 41

Test pitting on Cors y Carneddau has demonstrated that stone from the southern slopes of the Graig Lwyd ridge was also used for axe-making. Even though no scree is visible on the surface today, a thin layer of scree exists below the turf across most of the upper part of this slope. In places the depth of scree was much greater, and this seems to have been particularly targeted, though axe-working had taken place everywhere that there was suitable scree. Although the hill slope has probably never been ploughed some of the axe debris may have moved down slope where the surface was exposed through tree throws or erosion. However, in many cases the axe debris is found amongst large scree pieces that have probably not moved significantly since they were produced at the end of the ice age. In some places however the scree did appear to be disturbed by Neolithic activity, with a suggestion of the removal of some large blocks in a search for suitable pieces for roughouts. It must be assumed that in the Neolithic period all this scree was exposed, allowing it to be used as a stone source, as there was no evidence of pits being dug to access it.

None of the test pits produced the density of flakes suggested by Hazzledine Warren's description of a knapping floor near the large cairn (PRN 464) (Warren 1919, 342). As this area is within the scheduled area it was avoided by the test pits, but the densest and least disturbed areas of working might be found here. The density of gorse on the lower slopes meant that much of the hillside at the same level as the cairn was not investigated and dense working might be spread more extensively on this lower slope. The finds of flakes from the path also suggests working down the slope.

It is possible that some stone may have been removed directly from the bedrock by prising small blocks out or striking flakes from protruding outcrops, though the test pits did not provide indisputable evidence of this. Scree was again the main source of stone, and it was extensively exploited. TPs 129 and 131 showed that there was axe-making from scree below Clip yr Orsedd, but the current work could not explore far along this area. Future test pitting might be used to determine how far working extends to the west. Axe flakes found on the path suggest that working did continue to the west.

6.4. Maes y Bryn

The test pitting at the Maes y Bryn site located axe debris in association with flints. Axe-working was clearly taking place on this site despite it being at least 330m from the source screes, but the flints, especially the thumbnail scraper, indicate that other activities took place here as well. It is therefore highly probable that there was Neolithic settlement in this area, though that may have been a temporary settlement. The discovery of flint flakes scattered widely suggests general activity over a wide area, though some have probably moved down slope due to ploughing, perhaps indicating the focus of settlement within the higher part of the area investigated. The microdiorite scrapers from TP56 suggest a focus of activity here and the presence of a scraper and a piercer with a flint flake in TP64 suggests that this is close to another focus of settlement.

Within the area of the relict field earlier archaeological deposits are unlikely to survive, though cut features might be possible. However, there is a possibility that south of the ploughed area there could be *in situ* Neolithic deposits and TP56 showed undisturbed deposits protected from ploughing by an ancient field bank. It therefore seems likely that archaeological features and deposits do survive within parts of the investigated area.

The finds from molehills indicate that the find scatter extends beyond the area investigated and it is possible that several foci of axe-working were present across the hillside. The work so far has been successful in confirming the location of this site and investigating the environment in which it survives but much more work is necessary to find its extents.

The Maes y Bryn site is in a favourable position for a settlement site, despite being at a height of 300m OD. It is on a south facing slope and close to a water source. It would have been close to fairly open scrubby woodland and marsh suitable for pasture for livestock with probably more open grazing on the mountains. The site would have made a suitable base for the summer upland grazing of livestock and may have been a site of repeated seasonal settlement. The suggestion of several activity foci over an extended area suggests repeated reoccupation by small groups, who were also making axes from preliminary roughouts brought from the Dinas screes. It is possible that this is where some of the axes were ground and polished, though the discovery of polishing stones would be needed to prove this, and these appear to be rarely found.

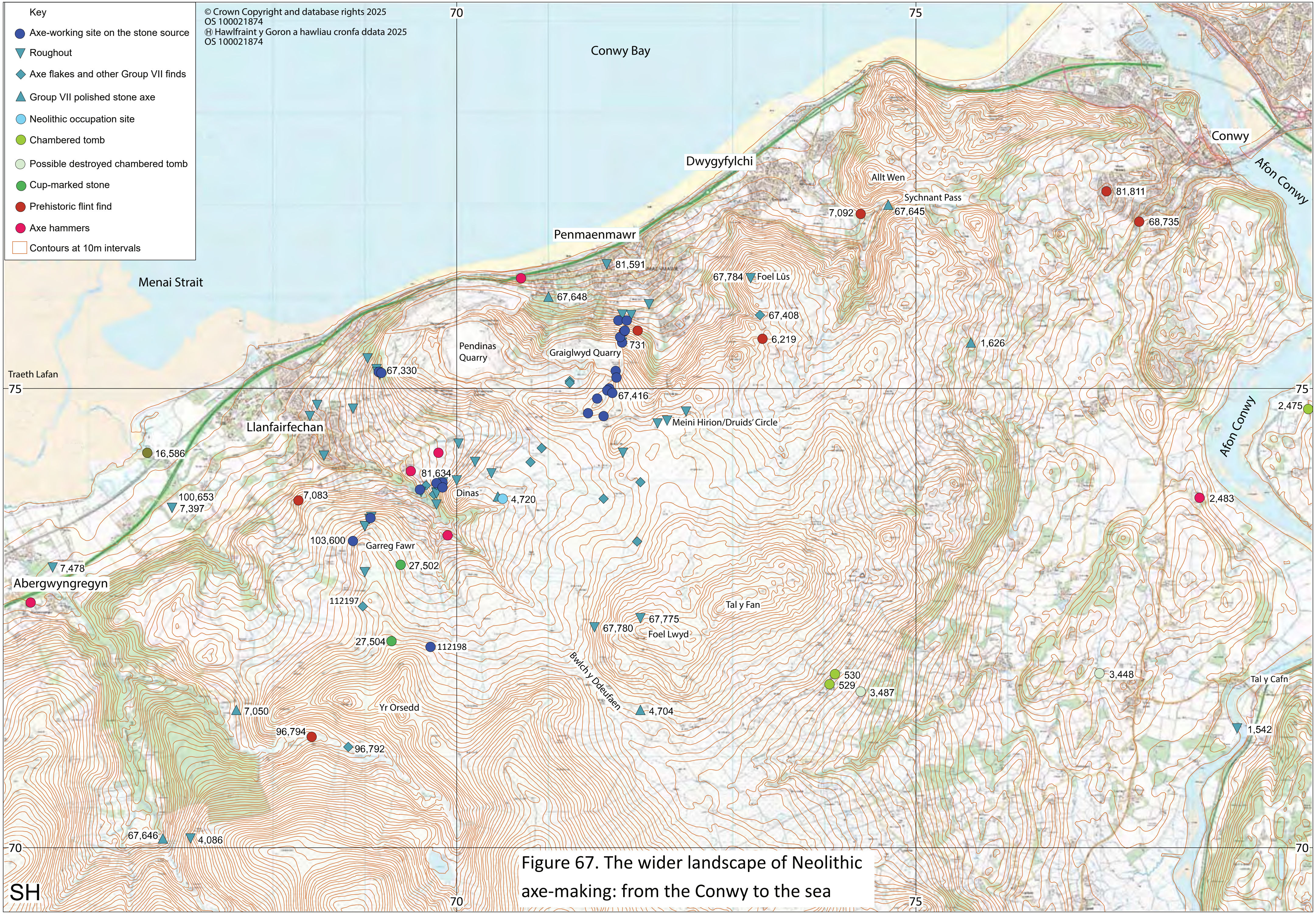


Figure 67. The wider landscape of Neolithic axe-making: from the Conwy to the sea

Plate 89. Maen y Bardd chambered tomb (PRN 529)

Plate 90. The other, less well known Maen y Bardd tomb (PRN 530)

Plate 91. View down the coast of Penmaen Mawr and other headlands from Bangor

7. THE LANDSCAPE OF NEOLITHIC AXES

Figures 67 and 68 (see Appendix VII for list of sites shown on these figures).

The wider context

This project has revealed the scale and extent of axe-production in the Llanfairfechan and Penmaenmawr area and allows the sourcing of stone for axes and the production of those axes to be seen in a full landscape context. Here the source area will be discussed as a whole after it has been placed in a wider landscape context.

The social and funerary landscape in which the axe-making took place is poorly understood, with surviving Neolithic funerary monuments being concentrated in the Conwy Valley, and none known north-west of the watershed (Figure 67). There are two Neolithic tombs located close together near Maen y Bardd above the Conwy Valley (PRN 529 and 530) (Plates 89 and 90). These lie within an extensive area of Iron Age fields, and it is not impossible that Neolithic fields pre-dated the Iron Age ones. Llanfairfechan is also surrounded by traces of Iron Age fields, which have probably removed any evidence of Neolithic agricultural activity, and obscured traces of Neolithic settlement. It is possible that there was a Neolithic tomb in this area in a similar position to the Maen y Bardd tombs; on the margin of the uplands. If there was a tomb it has long been removed by later agricultural activity. However, the presence of Bronze Age cairns and the Meini Hirion stone circle suggests that monuments have generally been preserved in this area and a chambered tomb, at least on the margins of the uplands, might be expected to have survived.

There is some evidence of a third tomb (PRN 3487) near Maen y Bardd, destroyed in the 19th century (Kelly 1975, 178-9; Lowe 1912). If this was indeed a Neolithic tomb it would represent an unusual concentration of tombs, presumably of different dates within the Neolithic period. These tombs are easily accessible from Bwlch y Ddeufaen, the pass through the hills from Llanfairfechan and it is possible that they served a wider area than just the lower Conwy Valley. However, the destruction of PRN 3487 does show that monuments might be removed when others in the vicinity survive.

The Allor Moloch burial chamber (PRN 2475) close to the banks of the Afon Conwy shows that Neolithic tombs might also be at a low level, and it is possible that there was a tomb on the coastal plain near Llanfairfechan or Penmaenmawr. The final breaching of the Menai Strait occurred between 5800 and 4600 BP (i.e. roughly 4600-3400 cal BC), near the start of or during the early Neolithic (Roberts *et al* 2011). Much of Traeth Lafan was probably not submerged until well after this date and would have been a coastal plain for much of the Neolithic period. There is some evidence that a chambered tomb once existed near the mouth of the Afon Ogwen on Traeth Lafan (Williams 1806). Williams (1806, 206) says that 'At the entrance to the first weir in the sands which belongs to the proprietors of Penrhyn, there was formerly a large cromlech'. This was still there, although collapsed in 1805. There may have been other tombs on the coastal plain, so a tomb near the mouth of the Afon Llanfairfechan is not impossible.

If a chambered tomb is interpreted as the focal point for a specific Neolithic group, the number of groups within the area and the possible extent of their territory cannot be estimated when the original number and location of tombs is not known. However, the location of potentially three tombs near Maen y Bardd suggests this was the focal point of a Neolithic group over a long period of time and that group may have covered all the land between the Conwy River and the sea. The stone sources would be within the middle of their territory with two possible routeways across the hills running close to major sources. In the north a Bronze Age routeway passing the Meini Hirion on Cefn Coch is indicated by cairns and stone circles, as well as a holloway adjacent to the Meini Hirion (Griffiths 1960, 313, 332-333). This route probably ran across Cors y Carneddau down to Llanfairfechan. If this route was used in the Neolithic period, it would have run past the stone sources on Graig Lwyd and Cors y Carneddau and may have passed close to Dinas. A series of Bronze Age standing stones also indicate that Bwlch y Ddeufaen was a major route at that period. Such an obvious pass through the hills must have been used in the

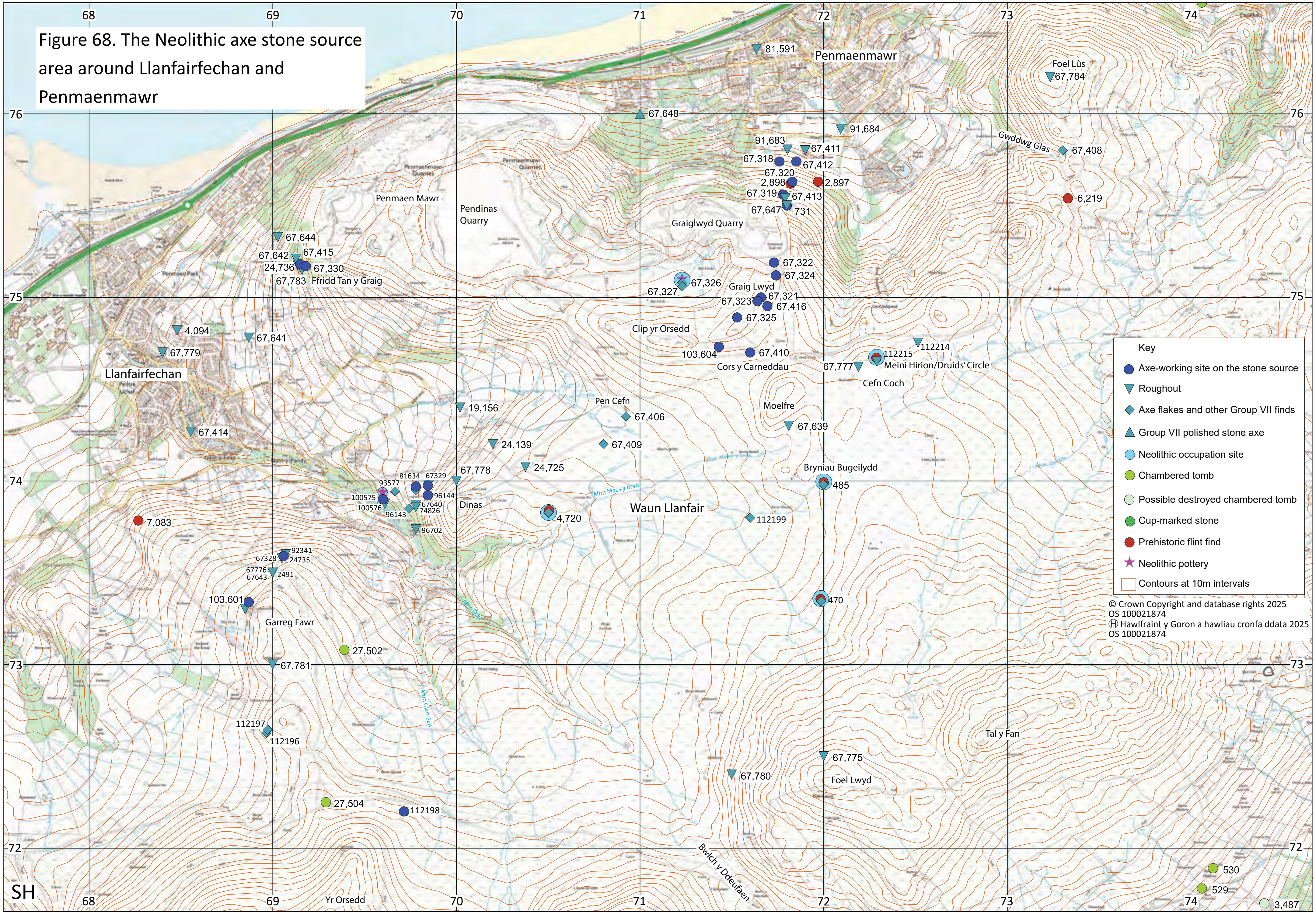


Figure 68. The Neolithic axe stone source area around Llanfairfechan and Penmaenmawr

Neolithic period, and routes from here could easily lead to Garreg Fawr, via the Roman Road Intrusion or to Dinas.

The discovery of a ground stone axe (PRN 4704) in Bwlch y Ddeufaen may support at the use of this pass in the Neolithic period. Generally, the only polished axes found within the stone source areas are very worn examples, repurposed for other uses, found at Graig Lwyd (Warren 1922, 24-26), at the Maes y Bryn site (Davies 1961) and at the Gwddwg Glas (Green Gorge) near Foel Lûs (PRN 67408) (Warren 1919, 342; 1922, 2). A nearly complete polished axe (PRN 67648) was found in Penmaenmawr town (RCAHMW 1956, Fig 10 (no.5), but the other polished axe from the area was found in Sychnant Pass (PRN 67645), again on a routeway. An axe (PRN 1626) was found in the Conwy Valley, and a roughout was found near Tal y Cafn (PRN 1542). It is tempting to see these as indicating an export route, but the Tal y Cafn roughout could have washed down river and cannot prove that this was a Neolithic crossing point. The scatter of axes in the Conwy Valley is far too sparce to actually indicate any specific route.

Settlement activity is particularly hard to detect without excavation. Occasional flint finds around the stone source area, such as a flint core from Dwygyfylchi (PRN 7092), a blade (PRN 81811) and flake (PRN 68735) from Conwy, and a flint awl (PRN 96794) from Cwm Anafon, give an indication of prehistoric activity, though not necessarily Neolithic. There are also a number of axe-hammers or mace heads from the area, with a concentration around Dinas. These objects date from the later Neolithic period, but they are not made from Group VII stone and their connection to the axe production is unclear. However, flints found with evidence of axe-working on several excavations across the source area are suggestive of settlement within that area and these will be discussed below.

Outside the source area the closest evidence of Neolithic occupation was a pit containing heat-fractured stones, probably an earth oven, which was radiocarbon dated to the Late Neolithic (PRN 71267) (Roberts 2018, 7, 9-10). This was found south-west of Abergwyngregyn at SH 64284 72247. Early Neolithic timber buildings found at Llandygai near Bangor, along with mid and late Neolithic pits indicate settlement on the coastal plain (Kenney 2009, Lynch and Musson 2004), and it is likely that settlement remains exist quite widely on the lowlands but have not yet been discovered by excavation. The connection between this settlement and the axe sources is demonstrated by the presence of flakes from Group VII stone axes found at both the Llandygai sites, Parc Bryn Cegin and Llandygai Industrial Estate.

The stone source area

The full use of the landscape in the production of stone axes is now much clearer than before this project (Figure 68). Although this has only been a preliminary investigation it has demonstrated that wherever suitable stone was present it was exploited by the Neolithic people. Microdiorite screes were extensively used as a source of stone for making axes, but previous work on Graig Lwyd shows that some quarrying of stone also took place and a small number of potential locations of this have been identified elsewhere, which deserve future investigation. Suitable stone is obviously present at Graig Lwyd, but this project has shown that this stone continues around the southern side of the Graig Lwyd hill and along the southern side of Clip yr Orsedd, and that this stone was used for making axes. Some isolated finds have indicated working at least in places further west along Clip yr Orsedd and the extent of this is still to be explored. There seems to be a gap in the suitable stone west of Clip yr Orsedd until the extensive screes on Ffridd Tan y Graig at the western end of Penmaen Mawr. These screes were heavily used and formed one of the major stone sources.

Test pitting on the western side of Dinas indicated the extent of the area of working. Where suitable stone is present in the open screes evidence of axe-working can be found but the working extended down the hill slope beyond the screes with dense debris present 41m down slope from the scree edge. There has been movement of material down the slope due to ploughing from at least the Iron Age onwards but the presence of axe debris up to 230m down slope from the edge of the screes including roughouts, indicates the presence of working areas away from the stone source. This probably involved transporting scree blocks or proto-roughouts to more suitable locations for working. The presence of a small sherd of Neolithic pottery in one of the lowest test pits investigated could indicate that this working took place in or near contemporary settlement, but this would need more investigation.

The investigation of the Maes y Bryn site to the east of Dinas demonstrated that some axe working did take place up to 300m from the stone source within settlement. In this case the size of the flakes recovered suggests that partially worked roughouts were taken to the site for further working. Investigation of molehills in this area suggested that the area of working was extensive. The discovery of surface finds and finds during excavation indicate that there was considerable axe-making activity around Waun Llanfair often at considerable distance for the stone sources. David T Jones found axe flakes around Pen Cefn, including two flakes in erosion on the path recorded as PRN 67406. He also found a complete and finely-worked axe roughout (PRN 24725) (Williams and Jones 2003) possibly lost on the way to be ground. In June 1919 Hazzledine Warren found what appears to be an axe working floor (PRN 67409) on Waun Llanfair. This cannot be located with much precision. Warren describes the find and location as "a small chipped axe, with numerous flakes in the same 'felsitic' material, not far from the Dinas behind Llanfairfechan" (Warren 1919, 342) and "a small chipped axe between Clip yr Orsedd and the Dinas" (Warren 1922, 2), probably on the path that runs along the western side of Waun Llanfair. The description of numerous flakes suggests that this was an axe working site, but a considerable distance from any source.

The current work has demonstrated that Cors y Carneddau was part of the stone source. Hazzledine Warren found extensive evidence of working (PRN 67410) to the west of the large cairn (PRN 464). This is described as "to the west of Carneddau (also on top of the moors) nearly every mole-hill was seen to have several small flakes upon it, and when one dug through the turf evidence of a true chipping-floor was at once apparent" (Warren 1919, 342) and "a great quantity of flakes near the Carneddau Cairn" (Warren 1922, 2). Both reports suggest an extensive axe-working area and intact flaking floors beneath the turf. Our test pitting has shown that there is scree under the turf in the higher part of this area and this was used for making axes, as well as possibly the removal of fractured bedrock for axes. This working probably extends along part of the southern side of Clip yr Orsedd.

The excavation of Bronze Age monuments on Cefn Coch in 1958 and 1959 produced evidence of axe-working about 650m east of this source. The excavation of the Meini Hirion (Druid’s Circle) (PRN 541) produced a roughout, the possible butt end of a broken roughout and 8 flakes (PRN 112215) (Griffiths 1960, 309). What is described as "a small hatchet-shaped implement of Graig Lwyd rock" (Griffiths 1960, 309), presumably a roughout (PRN 112214) was found in the boulder circle PRN 539 and a fine complete roughout (PRN 67777) was found while excavating the confused group of stones (PRN 544) (RCAHMW 1964, 111). It is possible that there is some link between axe-making activity here and the location of the later monuments. A hollow-way next to the stone circle has been suggested as part of a Bronze Age route, further supported by monuments along the route (Griffiths 1960, 313, 332-3). It is possible that a similar route was used in the Neolithic period from the Graig Lwyd area to the east, and that axe-making took place along this. However, it may be that axe-making took place so extensively in many locations that any excavation has a high chance of exposing some. Eighteen pieces of flint were also found at the Meini Hirion, including two cores and a scraper. Most were scattered around the site poorly stratified but two came from the buried soil beneath the bank (Griffiths 1960, 313, 326). These were not diagnostic to period but are perhaps more likely to be associated with the Neolithic axe-making than the Bronze Age stone circle, especially as most probably originally came from the original ground surface. The amount of flint, especially the scraper, is suggestive of settlement and like the Maes y Bryn site indicates axe-making or finishing at a settlement site.

Evidence for axe production even further from the stone sources is indicated by a site found by Hazzledine Warren at the top of the Gwddwg Glas (Green Gorge) near Foel Lûs (PRN 67408) (Warren 1919, 342; 1922, 2).

Warren describes the find as consisting of "a great number of flakes, a few scrapers, and a fragment of a partly polished axe" (Warren 1922, 2) and "an abundance of 'felsitic' flakes, a few scrapers, and one broken butt-end of a partially polished axe" (Warren 1919, 342). This is about 650m from the likely edge of the Graig Lwyd screes, but on an obvious route from the uplands down onto the coastal plain. Warren also mentions an axe found on the summit of Foel Lûs (PRN 67784) (Warren 1922, 2).

The extent of the spread of axe-making debris and the ease with which it can be found by excavation is shown by the fact that most of the few excavations that have taken place in this area have produced axe flakes, even when they have been targeting later monuments. Two of cairns were investigated just west of the Graig Lwyd source area. In a pit under cairn PRN 67326 (Cairn 65 in the survey records) were numerous axe-making flakes of Graig Lwyd stone, lumps of charcoal and several sherds of coarse pottery, with other flakes and pot fragments below the cairn. On the surface of the pit fill was a flat stone that might have been a capping stone and a possible anvil stone was standing upright towards the centre of the pit (Williams and Davidson 1998, 17-18). In a buried soil under cairn PRN 67327 (Cairn 67 in the survey records) were numerous axe-making flakes. A mixed sample of charcoal from this layer was radiocarbon dated to 4350-3990 cal BC at 95.4% confidence (5330+/-90 BP (SWAN-142)). An upright stone was found under the cairn with a concentration of flakes to the south of it. A rough-out axe was also found under the cairn (Williams and Davidson 1998, 18-19). The radiocarbon date has been suggested as indicating an early start to the use of Graig Lwyd stone (Williams *et al* 2011, 269; Williams and Kenney 2011), but it is a date with a large error on bulk charcoal with no direct relationship to the axe flakes, so it is not a reliable date to be used in this way. The pit and the pottery under Cairn 65 are strongly suggestive of settlement, though the date of the pottery is not known.

Two cairns on the edge of Waun Llanfair were investigated in 2007. Cairn PRN 470 partially sealed a buried soil containing a scatter of waste pieces of flint and Graig Lwyd stone. Under cairn PRN 485 was a scatter of artefacts, including three flint scrapers, a flint knife, a broken oblique arrowhead and a small and narrow axe or pick of Graig Lwyd rock (see figure app II.2.5) as well as several waste flakes of flint and Graig Lwyd rock, including axe-trimming flakes. The style of the flint tools and radiocarbon dates from the buried soils indicate a late Neolithic date (Caseldine *et al* 2017, 97-101). The presence of flint tools at these sites suggests more activities than just axe-working taking place and they could be significant settlement sites. In all these cases it seems that it was incidental that a cairn was built on the site of Neolithic settlement and axe-making, showing how widespread such sites probably were, but they are only found by excavation.

The axe flakes found under these cairns indicates the knapping of roughouts well away from the stone sources, at probable settlement sites. It is likely that there are many locations where axes were worked away from the stone sources in favourable locations. The discovery of roughouts from around the edges of Waun Llanfair also supports this, as does the discovery of a block of microdiorite used as a core (PRN 112199). This was found on the eastern side of Waun Llanfair and supports both the production of tools on microdiorite in this area and that not all of those tools were axes.

On Garreg Fawr the fact that not all the exposed and easily available microdiorite was suitable for axe-making was clearly demonstrated. Axe debris was limited in its spread even where crags and screes of microdiorite were present. Axe debris was only present in any quantity near screes that were demonstrably of a good quality. By chance the quality of the stone could be easily judged because much more recent quarrying presented numerous fresh flakes for inspection. The current work added to a known area of working in open screes on Garreg Fawr showing that there are at least two separate working sites on the hill. However, the microdiorite intrusion forms the whole hill and there is another intrusion at the southern end of Garreg Fawr. It appears likely that axe-working took place on the summit of Garreg Fawr and probably on its western side. A small number of finds of axe debris in open screes on the southern intrusion suggests working here and future investigation is likely to show extensive working across Garreg Fawr.

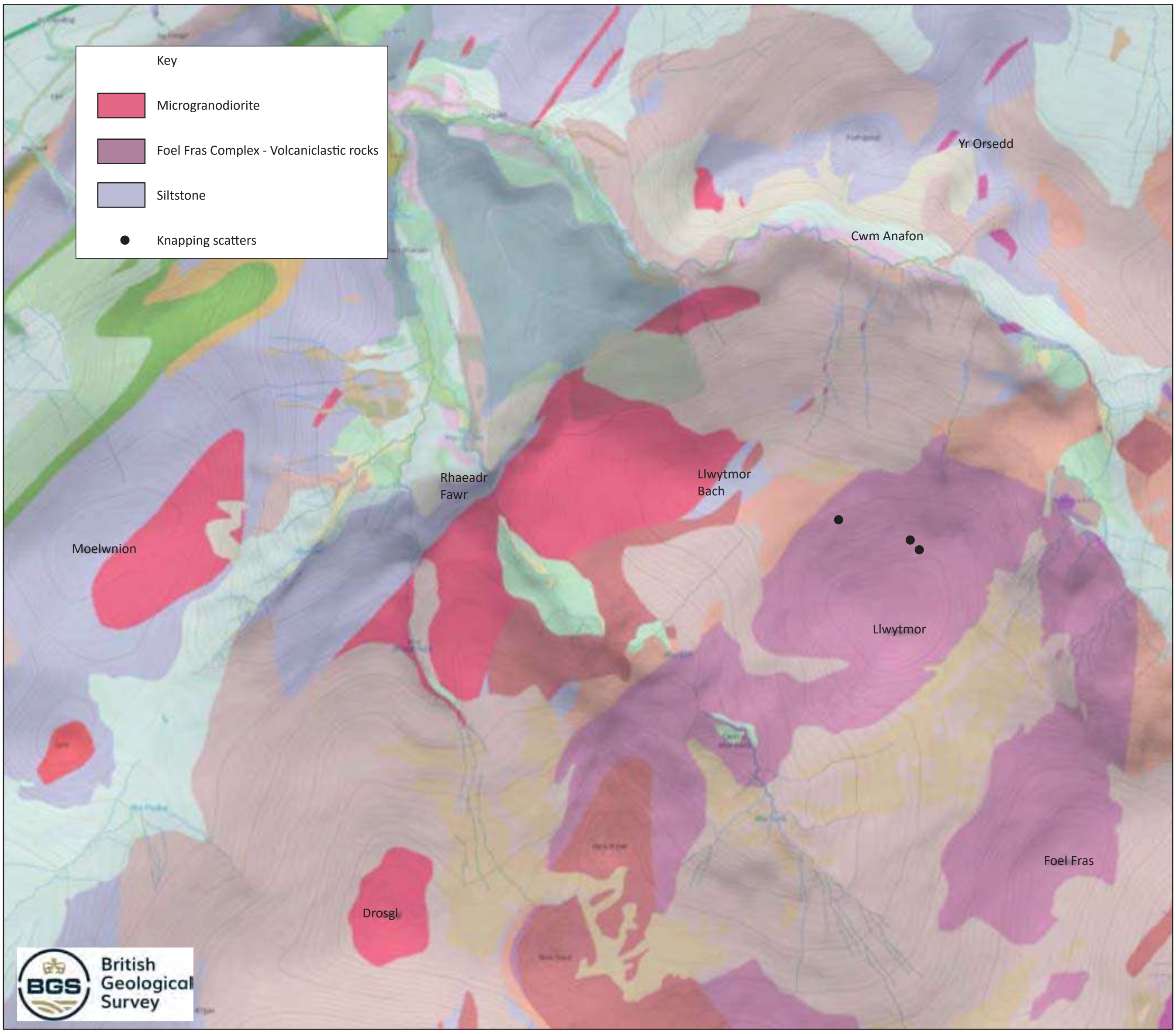


Figure 69. Geological map from BGS Geology Viewer showing areas of microgranodiorite and location of flake scatters on Llwytmor

Figure 70. Detail of flake scatter at SH 68977 69652 showing glacial erratic blocks (courtesy of Ian Brookes)

The rediscovery of another microdiorite intrusion (PRN 112198) previously recorded only in an unpublished PhD and other unpublished notes potentially extends the stone sources around the southern side of Waun Llanfair and emphasises the relevance of this whole landscape for axe production. Although no axe debris has yet been located at this stone source the evidence that Neolithic people knew about and exploited all suitable stone elsewhere in this area strongly suggest that this source was also used as it appears to be of good quality stone at least in parts.

The current evidence provides an image of axe production taking place over a wide area from Penmaen Mawr in the north to the foot of Yr Orsedd in the south, with most of the working taking place on the screes at the stone sources but with some working occurring away from the sources in various locations, probably in more sheltered locations and near settlement sites. It is not yet known whether all these sources were in use at the same time, but the quantity of material found at the main sources suggests their use throughout the Neolithic period, so it is likely that at least on a broad scale they were all contemporary.

While new stone sources might be found within the main source area there is the possibility of axe working elsewhere. The BGS Geology Viewer shows extensive areas of bedrock around Aber Falls, Abergwyngregyn, and further west, which is labelled as Micrograndiorite, a term which can be used for the Group VII stone (Horák 2019) (Figure 69). An initial inspection of the screes near Aber Falls and other areas suggested that the rock was not sufficiently fine grained to be suitable for making axes, but there could be finer rock elsewhere. To the south-east on Llwytmor flake scatters from what appears to be axe-making have been found (National Trust Heritage Record Online, Record Id 46791, Ian Brooks pers. com.). Llwytmor has bedrock of the Foel Fras Volcanic Complex of Volcaniclastic rocks, but the flakes seem to be from glacial erratic boulders (Figure 70). It seems unlikely that there are previously unidentified other large scale stone sources for axes that have been extensively worked, but it may be that no one has looked for axe working in this area.

The extent of axe production occurring at a lower level around Llanfairfechan and Penmaenmawr has not been thoroughly studied by this project but roughouts have been found in gardens within Llanfairfechan and Penmaenmawr suggesting material was taken to lower levels to be worked. The screes below Graig Lwyd come down to about 130m OD. Finds of roughouts right to the base of the screes shows that all this material was suitable for working and axe makers did not have to travel all the way to the summit to obtain suitable material, though clearly, they also felt it necessary to do so. While most of the sources are upland this direct link to the lowlands should not be neglected. Graig Lwyd stands above Penmaenmawr visible from most locations and probably more prominent when most of its scree was unvegetated as it must have been. There were presumably also more extensive screes that have now been removed by quarrying on this northern side. The extent of suitable stone on the northern side of Penmaen Mawr has not yet been investigated, but it is possible that there was axe production there that has been lost to quarrying. Penmaen Mawr is a very dominant presence over the town of Penmaenmawr, so the stone sources and people working on them would have been very prominent to those living or travelling through the area. The same applies to Llanfairfechan, where the town is surrounded on three sides by highly visible stone sources. While it is clearly anachronistic to compare the sites of Llanfairfechan and Penmaenmawr in the Neolithic with the quarrying towns of the 19^{th} and early 20^{th} centuries these locations must surely have had a specific character relating to the axe production. Even if production was the result of small scale working over a very long period of time it would have been impossible for people living here not to be aware of their land being the source of axes used over a very wide area. The sheer quantity of axe debris at all the source sites does suggest that working was probably on more than just a small casual scale and it would seem likely that local people were heavily involved in that production however it was organised.

While most of the stone sources are highly visible from Llanfairfechan and Penmaenmawr, the hill of Penmaen Mawr is visible from along the coast in both directions (Plate 91). It is easily recognisable from Anglesey and from the Great Orme, as well as from the sea. It would have been even more recognisable in the Neolithic period when its summit was considerably higher and more domed, before the quarry. Dinas is also a notable feature when viewed at a distance from the north, from Anglesey or the sea. The source of the stone axes would therefore be visible and prominent to many people living or travelling within north-west Wales. The people that lived in or used the rectangular timber building found at Parc Bryn Cegin, Llandygai could have looked across to Penmaen Mawr from very close to the building, if the land had been sufficiently cleared of trees. Those travelling past along the coastal plain or by boat would have been able to recognise the stone source from a considerable distance and perhaps used to Penmaen Mawr to navigate by.

Finds such as those at Llandygai and others on Anglesey show that Neolithic settlement occurred on the lowlands. There was no issue with the forests being too dense to clear and coastal locations may have had lighter forest cover or natural clearings due to the effect of the sea and exposure to winds. It is therefore perhaps safe to assume some Neolithic occupation in and around the areas of Llanfairfechan and Penmaenmawr and some clearance here for agriculture, though probably small and varying in location over the centuries. The lack of peat deposits to preserve a pollen record in the lowlands mean that the extent and natural of agriculture here will probably always remain speculative. The upper part of the Llanfairfechan valley also appears favourable for settlement. It is relatively sheltered and has the Afon Llanfairfechan and other streams as a water source. Ty'n y Llwyfan Farm stands on a fairly level shelf in the slope of the valley (*llwyfan* is a shelf or stage), which is formed of glacial gravels and is therefore well-draining. This would seem to be a good location for a Neolithic settlement with easy access to the Dinas stone source. The only evidence that the project produced of settlement here is the tiny pot sherd from TP95 in Cae Dafydd, but this is suggestive.

The Maes y Bryn site with its worked flint and scrapers represents a settlement site in the uplands on the edge of Waun Llanfair. The recovery of flints with axe debris from under cairns PRN 470 and 485 on the other side of Waun Llanfair and flint also with axe debris from under the Meini Hirion (PRN 541) suggest widespread occupation sites only found by excavation (Figure 68). A pit with pottery under a cairn (PRN 67326) near Graig Lwyd also probably indicates Neolithic settlement. A single flint flake (PRN 6219) found on the track to Ty'n y Ffridd Farm near Foel Lus, cannot add much to the evidence of Neolithic settlement but the fact that it was found not far from the Green Gorge axe-working site could be significant. A flint knife and a flint blade (PRNs 2897 and 2898) found on the screes below Graig Lwyd could indicate other activities taking place within the axe working area, but there are no drawings or detailed descriptions of these finds. A collection of eight flint items (PRN 7083), scrapers, flakes and nodules are recorded as being found in a molehill on Bryn-y-Goleu Farm at the foot of Garreg Fawr (Lynch 1986, 38). The exact location of these is not recorded, but they also hint at settlement activity that may be Neolithic in date not far from an axe stone source.

Settlement in the uplands may have been temporary seasonal settlement and although axes do seem to have been produced at these sites they were presumably occupied for other purposes as well. The uplands would have been good pasture for livestock. The pollen work in Waun Llanfair (Caseldine and Griffiths 2017) shows that the woodland here was scrubby and could have been opened more easily for more extensive areas of pasture. Evidence of clearance events in the pollen record show that this took place at various times in the Neolithic period. However, a few cereal pollen grains from a buried soil sealed under a cairn and dated to the late Neolithic suggest that there was at least some arable cultivation as high as 400m OD, so at least the later Neolithic people may have been living in the uplands to tend their crops as well as to herd livestock. Settlements or occupation sites where axes were partially roughed out or finished are likely to have been a common feature of the landscape.

The current project has not been able to address the question of where axeheads were ground and polished. As this process would have taken many hours it is probable that it took place in a settlement site or at least in a very sheltered location. It is possible that this activity could have taken place at the Maes y Bryn settlement, but the current work found no specific evidence to prove this. The only good evidence of polishing is to find a polishing stone (polissoir). One was found in Llandygai near Bangor about 12km from the source. The stone used was of a type used to make axes and it had been knapped into shape, but the stone is possibly Group VIII from

Pembrokeshire or Group XV from the Lake District (Burrow 2003, 78, 130; Lynch and Musson 2004, 45). The striations on the polishing surface make it very likely that it was used to polished stone axes; it was buried in a cremation burial (FA370). A sandstone slab from pit FB39 had linear wear marks on its surface and is also likely to have been an axe polisher (Lynch and Musson 2004, 69). A stone described as an axe polishing slab came from Bryn yr Hen Bobl (Burrow 2003, 77, 114). This site had flakes both from probably making axes from Group VII stone and from breaking down finished axes. It seems possible that Group VII roughouts were being imported for final finishing on this site (Lynch 1991, 106-8). Both are low level locations with evidence for occupation. However, even if many of the roughouts were transported down to the lowlands for finishing, it is possible that somewhere around or within Waun Llanfair grinding and polishing of axeheads was taking place and the identification of polissoirs is a possibility.

8. CONCLUSIONS

The current project has been a preliminary investigation of the extent and nature of the sites relating to the making of stone axes, but it has revealed the extent of the landscape involved in stone axe production in the Neolithic period. The numerous stone sources scattered over this area were all used wherever the stone was of suitable quality, with very extensive areas of working demonstrated at most of the stone sources. The presence of flint on several sites and very occasionally pottery indicates that this landscape was also occupied by settlements. The close relationship of the settlements to the axe production is demonstrated by the axe debris found on these sites.

There is still much to do to fully understand this important landscape. The use of the screes on the southern and eastern sides of Dinas have not been investigated but brief inspection indicates that the whole area was used. Similarly, the extent of the working on Garreg Fawr, Clip yr Orsedd and particularly the Roman Road Intrusion need to be more fully investigated. A priority is to test whether the stone sources can be chemically or petrologically distinguished, which could enable the specific products of each source area to be identified.

Waun Llanfair has a high potential for Neolithic settlement and axe-making sites away from the sources. Finding these will not be easy but explorative test pitting might reveal evidence. Areas that have already produced roughouts or flakes could be targeted. The drier land and sheltered hollows around Bryniau Bugeilydd might be a potential location for settlement.

The results of the study of the axe debris assemblages collected by this project will add further understanding of how and where production was undertaken, potentially identifying specific characteristics of individual sources. When the analysis is complete a final publication will be produced for publication in the Proceedings of the Prehistoric Society.

9. COPYRIGHT

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11. REFERENCES

Anonymous, 1937. 'Roman bracelet from Wales', *Antiquaries Journal* Vol XVII, No. 3, 318- 319

Bamford, H. M., 1985. *Briar Hill, Excavation 1974-1978*. Archaeol. Monog. No. 3, Northampton Development Corporation.

Bradley, R. and Suthern, R., 1990. Petrographic analysis of hammerstones from the Neolithic quarries at Great Langdale. *Proceedings of the Prehistoric Society* 56,117-122.

Burrow, S., 2003. *Catalogue of the Mesolithic and Neolithic Collections in the National Museums and Galleries of Wales*, National Museums and Galleries of Wales, Cardiff

Cappers, R. T. J., Bekker, R. M. & Jans, J. E. A. (2006). *Digital Seed Atlas of the Netherlands.* Groningen: Barkhuis Publishing and Groningen University Library.

Caseldine, A. E. and Griffiths, C. J., 2017. Palaeo-environmental Evidence from Waun Llanfair, In Caseldine *et al* 2017, 106-129

Caseldine, A. E., Griffiths, C. J., Roberts, J. G., Smith, G. and Williams, J. Ll, 2017. Land use and environmental history of Waun Llanfair, an upland landscape above Penmaenmawr, North Wales, *Archaeologia Cambrensis* vol. 166, 89-140

Caseldine, A., Roberts, J. G. and Smith, G., 2007. *Prehistoric Funerary and Ritual Monument Survey. Burial, Ceremony and Settlement Near the Graig Lwyd Stone Axe Factory, Palaeo-Environmental Study at Waun Llanfair*, unpublished GAT report no. 662

Chartered Institute for Archaeologists (CIfA) 2014. *Standard and guidance for the collection, documentation, conservation, and research of archaeological materials.*

Claris, P. and Quartermaine, J., 1989. 'The Neolithic quarries and axe-factory sites of Great Langdale and Scafell Pike: a new field survey,' *Proceedings of the Prehistoric Society* 55, 1-25

Clough, T. H. McK. and Cummins, W. A. (eds), 1988. *Stone Axe Studies Volume 2*, CBA Research Report No 67

Clough, T. H. McK., 1988. 'Introduction to the regional reports: prehistoric stone implements from the British Isles,' in Clough and Cummins (eds) 1988, 1-11

David, A. 2017. Between a rock and a hard place. Bipolar flint working in West Wales. *Archaeology in Wales* 56, 1-12.

Davidson, A. and Williams, J. Ll., 1998. *Survey and Excavation at the Graiglwyd*, unpublished GAT report no. 296

Davies, J., 1961. Stone axes from near Dinas, Llanfairfechan, *Transactions of the Caernarfonshire Historical Society*, Vol 22, 1-5

Dean, J. and Cooke, R., 2019. *DCWW, Newry Llanfairfechan, Conwy, Water Main Renewal, watching brief*, unpublished Aeon Archaeology Report 0192

Deering, C. A. and Stoker, J. M., 2014. 'Let's Agree on the Casing of Lidar,' *LiDAR News Magazine*, vol 5, no. 6 (https://lidarmag.com/wp-content/uploads/PDF/LiDARNewsMagazine_DeeringStoker-CasingOfLiDAR_Vol4No6.pdf)

Dunn, C. J., 1968. 'Garreg Fawr', *Archaeology in Wales* No. 6, 6

Edmonds, M., Johnston, R., La Trobe-Bateman, E., Roberts, J. G., Warren, G.M., 2009. 'Ynys Enlli: Shifting Horizons' In: McCartan, S., Woodman, P.C., Schulting, R., Warren, G.M., (eds). *Mesolithic Horizons: Papers presented at the Seventh International Conference on the Mesolithic in Europe, Belfast 2005*. Oxford: Oxbow.

Flook, R. M. and Williams, J., Ll., 1992. *Graiglwyd Archaeological Survey*, unpublished GAT report no. 50

Glen, T. A., 1935. 'Distribution of the Graig Lwyd Axe and its Associate Cultures,' *Archaeologia Cambrensis* vol. XC, part 2, 189-218

Greenly, E., 1919. *The geology of Anglesey*, Memoirs of the Geological Survey, England and Wales.

Griffiths, W. E., 1960. 'The Excavation of Stone Circles near Penmaenmawr, North Wales', *Proceedings of the Prehistoric Society*, vol 26, 303-339

Hather, J. G., 2000. *The Identification of the Northern European Woods: a guide for archaeologists and conservators*. London: Routledge.

Healey, E., 1987. 'Lithic Technology', In Smith, C.A. and Lynch, F. *Trefignath and Din Dryfol*, Cambrian Archaeological Monograph 3, 51-9.

Horák, J. M., 2019. A Petrological Examination of Axe Fragments from the Neolithic Settlement site Llanfaethlu Anglesey, unpublished report Amgueddfa Cymru - National Museum Wales for CR Archaeology (shared courtesy of CR Archaeology)

Houlder, C. H., 1961. The Excavation of a Neolithic Stone Implement Factory on Mynydd Rhiw in Caernarvonshire, *Proceedings of the Prehistoric Society* 27, 108-43

Houlder, C. H., 1976. 'Stone axes and henge-monuments,' In Boon, G. C. and Lewis, J. M. (eds), 1976, *Welsh Antiquity*, National Museum of Wales, Cardiff, 55-62

Houlder, C. H., 1988. 'The petrological identification of stone implements from Wales,' in Clough and Cummins (eds) 1988, 133-136

Hughes, H. H., 1923. 'Prehistoric remains on Penmaenmawr (known as Braich y Dinas)', *Archaeologia Cambrensis* vol LXXVIII, 243-268

Jacomet, S. (2006). *Identification of Cereal Remains from Archaeological Sites* (2nd ed.). Basel: Archaeobotany Lab IPAS, Basel University.

Jarvis, I. and Jarvis, K. E., 1992a. Inductively coupled plasma-atomic emission spectrometry in exploration geochemistry. In: Hall, G. E. M. & Vaughlin, B. (eds), *Analytical Methods in Geochemical Exploration*. Journal of Geochemical Exploration Special Issue.

Jarvis, I. and Jarvis, K. E., 1992b. Plasma spectrometry in earth sciences: techniques, applications and future trends. In: Jarvis, I. & Jarvis, K. E. (eds), Plasma Spectrometry in Earth Sciences. *Chemical Geology*. **95**, 1 - 33.

Jones, D. and Williams, J. Ll., 2004. Garreg Fawr, Llanfairfechan, *Archaeology in Wales*, Vol. 44 p. 145-6

Kelly, R. S., 1975. 'The probable sites of some disappeared chambered tombs in Caernarvonshire in the light of antiquarian references,' *Archaeologia Cambrensis* vol. CXXIII (1974), 175-179

Kendall, H. G. O., 1927. Further Excavations at the Graig Lwyd Neolithic Stone Axe Factory, Penmaenmawr, *Archaeologia Cambrensis*, vol LXXXII, part 1, 141-146

Kenney, J., 2009. 'Recent excavations at Parc Bryn Cegin, Llandygai, near Bangor, North Wales', *Archaeologia Cambrensis* 157 (2008), 9-142

Kenney, J., 2017. *Group VII Axe-working Sites and Stone Sources, Llanfairfechan, Conwy: report and gazetteer*, unpublished GAT report no. 1416

Kenney, J., 2019. *Group VII Axe-working Sites: Management and Interpretation Plan with a survey of an example site*, unpublished GAT report no. 1472

Kenney, J, McGuinness, N., Jones, B., & Ryan Young, C., 2020. *Parc Cybi, Holyhead: Final Report on Excavations*, unpublished GAT report no. 1512

Kenney, J. and Smith, G., 2022. *Landscape of Neolithic Axes: report on fieldwork in 2021 at Llanfairfechan*, unpublished GAT report no. 1623

Kenney, J. and Smith, G., 2023. *Landscape of Neolithic Axes: report on fieldwork in 2022 at Llanfairfechan*, unpublished GAT report no. 1698

Kenney, J. and Smith, G., 2024. *Landscape of Neolithic Axes: report on fieldwork in 2023 at Llanfairfechan and Penmaenmawr*, unpublished GAT report no. 1766

Linford, J. (2009). *A Concise Guide to Trees*. Bicester: Baker and Taylor (UK) Ltd.

Lowe, W. B., 1912. *The Heart of Northern Wales*, self-published, Llanfairfechan

Lynch, F., 1969. 'The Contents of Excavated Tombs in North Wales,' in Powell, T.G.E., Corcoran, J.X.W.P., Lynch, F. and Scott, J.G. (eds), 1969. *Megalithic Enquiries in the West of Britain*, Liverpool University Press, Liverpool, 149-174

Lynch, F.M., 1986. *Museum of Welsh Antiquities, Bangor, Catalogue of Archaeological Material*, University College of North Wales, Bangor

Lynch, F.M., 1991. *Prehistoric Anglesey*, Anglesey Antiquarian Society

Lynch, F. and Musson, C., 2004. 'A prehistoric and early medieval complex at Llandygai near Bangor, North Wales', *Archaeologia Cambrensis* vol 150 (2001), 17-142

Pearce, T. J., Besly B. M., Wray D., and Wright D. K. 1999. Chemostratigraphy: a method to improve interwell correlation in barren sequences - a case study using onshore Duckmantian/Stephanian sequences (West Midlands, UK*). Sedimentary Geology* 124, 197- 220.

RCAHMW (Royal Commission on the Ancient and Historical Monuments of Wales) 1956. *An Inventory of the Ancient Monuments of Caernarvonshire, Volume I: East*, HMSO, London

RCAHMW 1964. The Graig Lwyd group of axe factories, in - *An Inventory of the Ancient Monuments in Caernarvonshire Volume III: West*, xli-l. HMSO, London

Rees, C. and Jones, M., forthcoming. Excavations at Llanfaethlu, Anglesey

Research Framework for the Archaeology of Wales. Available at: (https://www.archaeoleg.org.uk). Accessed September 2024.

Ritchie, P. R., 1991. *Scottish Stone Research Project: Notes for Implement Petrology Committee Workshop (Groups VI, VII and IX)*, unpublished notes held in Gwynedd HER

Roberts, J. A., 2018. *A55 (T) Abergwyngregyn to Tai'r Meibion Improvement Advance Works: Mitigation Report*, unpublished GAT report No. 1432

Roberts, M. J., Scourse, J. D., Bennell, J. D., Huws, D. G., Jago, C. F., and Long B. T., 2011. 'Late Devensian and Holocene relative sea-level change in North Wales, UK', *Journal of Quaternary Science* (2011) 26(2) 141–155

Ryan Young, C., Smith, G. H., and Kenney, J., 2020. *Landscape of Neolithic Axes Project: Year 1 Test Pitting, Ty'n y Llwyfan, Llanfairfechan*, unpublished Gwynedd Archaeological Trust Report 1536

Schairer, J.F. and Yagi, K. 1952. The system $FeO-Al_2O_3-SiO_2$. *American Journal of Science (Bowen volume)*, 471-512.

Schweingruber, F. H., 1990. *Microscopic Wood Anatomy*. Birmensdorf: Eidgenössische Forschungsanstalt WSL.

Smith, G. H., Caseldine, A. E., Griffiths, C. J., Peck, I., Nayling, N., and Jenkins, D., 2017. 'An Early Bronze Age burnt mound trough and boat fragment with accompanying palaeobotanical and pollen analysis at Nant Farm, Porth Neigwl, Llŷn Peninsula, Gwynedd', *Studia Celtica*, 1-63

Soulignac, R and Serneels, V., 2014. The reconstruction of smithing activities through an ethnoarchaeological and archaeometric approach of metallic wastes, pp. 277-284 *in*: B. Cech and T Rehren (eds) *Early Iron in Europe*, Montagnac.

Stace, C., 2010. *New Flora of the British Isles* (3rd ed.). Cambridge: Cambridge University Press.

Taylor, S.R. and McLennan, S.M. 1981. The composition and evolution of the continental crust: rare earth element evidence from sedimentary rocks. *Philosophical Transactions of the Royal Society*, **A301**, 381-399.

Thorpe, D., 2023. Roughouts and finds in Llanfairfechan area, in Kenney and Smith 2023, 69-74

Wainwright, G. J., 1972. The excavation of a Neolithic settlement at Broome Heath, Ditchingham, Norfolk. *Proc. of the Prehistoric Society* 38, 1-97.

Warren, S. H., 1919. A Stone Axe-factory at Graiglwyd, Penmaenmawr, *Journal of the Royal Anthropological Institute of Great Britain and Ireland*, 49, 342-365

Warren, S.H., 1921. Excavations at the stone axe factory of Graig Lwyd, Penmaenmawr, *Proc. Royal Anthropological Institute of Great Britain and Ireland*, 51, 165-99

Warren, S. H., 1922. The Neolithic Stone Axes of Graig Lwyd, Penmaenmawr, *Archaeologia Cambrensis*, vol LXXVII, part 1, 1-32

Williams, J. Ll., 1998. 'A kind of Sheffield of the Stone Age' – Samuel Hazzledine Warren's excavations of a Neolithic Axe Factory on the Graiglwyd, Penmaenmawr, 1919-1921, *Transactions of the Caernarvonshire Historical Society*, vol 59, 7-34

Williams, J. Ll. and Davidson, A., 1998. 'Survey and Excavation at the Graiglwyd Neolithic Axe-factory, Penmaenmawr,' *Archaeology in Wales,* vol. 38, 3-21

Williams, J. Ll. and Davidson, A., 2002. 'Field Survey at Graiglwyd, Penmaenmawr,' *Archaeology in Wales,* vol. 42, 3-16

Williams, J. Ll. and Jones, D., 2003. 'Llanfairfechan, north-east of Dinas,' *Archaeology in Wales*, Vol. 43, 96-7

Williams, J. Ll. W. and Kenney, J., 2009. 'Graig Lwyd (Group VII) Lithic Assemblages from Excavations at Parc Bryn Cegin, Llandygai, Gwynedd, Wales – Analysis and Interpretation, *Internet Archaeology*, issue 26 (https://intarch.ac.uk/journal/issue26/30/toc.html) (accessed 06/03/2025)

Williams, J. Ll. W. and Kenney, J., 2011. 'A chronological framework for the Graig Lwyd Neolithic axe factory, an interim scheme', *Archaeology in Wales,* vol. 50, 13-20

Williams, J. Ll., Kenney., J. and Edmonds, M., 2011. 'Graig Lwyd (Group VII) assemblages from Parc Bryn Cegin, Llandygai, Gwynedd, Wales – analysis and interpretation,' in Davies, V. and Edmonds, M. (eds) *Stone Axe Studies III*, Oxbow Books, Oxford, 261-278

Williams, W., 1806. 'A survey of the ancient and present state of the county of Caernarvon'*, Trans. Caerns. Hist. Soc*. 36 (1975), 194-231

Young, T.P. 2011a. Assessment of the archaeometallurgical residues from the Pwllheli to Blaenau pipeline (G2148). *GeoArch Report 2011/38*. 3 pp.

Young, T.P. 2011b. Some preliminary observations on hammerscale and its implications for understanding welding. *Historical Metallurgy,* **45,** 1, 26-41.

Young, T.P. 2016. Archaeometallurgical residues from Hen Gastell, Llanwnda, Gwynedd. *GeoArch Report 2016/37*. 97pp.

Young, T.P. 2019. Archaeometallurgical residues from Parc Cybi, Holyhead, Ynys Môn. *GeoArch Report 2018/26*, 263pp.

Websites
BGS Geology Viewer (BETA), British Geological Survey: https://geologyviewer.bgs.ac.uk/
(accessed 05/01/2024)

Coflein: NPRN 308677 https://coflein.gov.uk/en/site/308677/images?term=308677 (accessed 20/03/2025)

National Trust Heritage Record Online: https://heritagerecords.nationaltrust.org.uk/map (accessed 20/03/2025)

National Museum Wales Online Catalogue: https://museum.wales/collections/ (accessed 20/03/2025)

APPENDIX I: Preliminary Methodology for the Technological Analysis of the Experimental Roughout Debitage and the Archaeological Assemblage from the Landscape of Neolithic Axes Project Excavations

Rebecca Vickers, Sheffield University

Introduction and justification

This document will summarise the method of technological analysis employed in the study of six experimental roughouts and associated debitage. The main aim was to understand and characterise debitage from different stages of the production process, through the identification and quantification of four technological attributes. The analysis also produced a qualitative description for each stage, to allow for the debitage to be characterised in a holistic manner. The combination of both qualitative and quantitative analysis provides several opportunities to discuss the results, and the significance of particular characteristics identified.

An aim of the thesis is to explore whether the results of the analysis of the experimental material, can shed light on the archaeological assemblage. To allow for parallels to be drawn, the production of the roughouts was designed to match as closely as possible the conditions of roughout production at Graiglwyd in the Neolithic period. As such, raw material was selected from the same three sources demonstrated to be exploited for roughout production in the Neolithic: Graiglwyd, Dinas and Garreg Fawr. Furthermore, an experienced experimental archaeologist with skills working with microdiorite was commissioned to produce the roughouts. Although we cannot say for sure that people in the Neolithic had the same level of skill, it seems likely that given the extensive evidence for roughout production found in the landscape, that experience of producing roughouts was common. It was therefore more appropriate for someone with knowledge of the material to produce the roughouts, as opposed to someone with no prior experience.

For comparisons to be drawn between the experimental and archaeological material, the same method of analysis will be used for both assemblages. With the exception of two additional attributes that will be explored in the archaeological assemblage, as detailed in section 3.6. The analysis is split into two processes, firstly a 'sorting' stage, followed by the quantification of attributes and a brief description of the debitage. These stages will now be detailed.

Sorting

In the sorting stage the debitage was sorted into five size categories. Although traditional technological analysis might involve taking individual measurements of each flake, due to the size of this assemblage and time constraints a rapid method of gaining size information was developed. This method allowed a broad understanding of the frequency of different sizes of debitage, rather than a detailed overview of exact dimensions. For the experimental material each stage (Stage 1-3) from each roughout was subject to this process (Figure 1). For the archaeological assemblage the debitage accompanying each finds number was sorted into the size categories (Figure 2). This approach was chosen for the archaeological material to retain the integrity of the finds numbers and archaeological recording process, despite some finds numbers coming from the same contexts. Once sorted, each size category was counted, weighed and bagged separately. For the archaeological assemblage each size category was given a new individual finds number, that merged the previous finds number and the size category. For example, SF102 became SF102.2, SF102.3, SF102.4 etc. This retains the information from the archaeological recording process, but allowed for each size category to be recorded separately with its corresponding number, weight and analysis on a Microsoft Access database (Figure 3).

Size category 1	<20mm
Size category 2	21-50mm
Size category 3	51-80mm
Size category 4	81-100mm
Size category 5	100mm+

Table 1: Size categories used for technological analysis.

Figure 1: Size sorting the experimental debitage.

Figure 2: Size sorting the archaeological assemblage.

Debitage

Find number	Size group	Context	Total count	Total weigh	Complete flake	Broken flake	Plain Platform	Facetted Platform	Trimmed Platform	Abraded Pl	Large bulb	Small bulb	Bulbar scar	Diffuse bult
102.1	1	102	1	1.64	1	0	0	0	0	1				1
102.2	2	102	8	111.82	5	3	4	0	0	1	3	1		1
102.3	3	102	7	225.08	4	3	5	0	0	0	1		1	3
102.4	4	102	0	0	0	0	0	0	0	0				
102.5	5	102	1	356.29	1	0	1	0	0	0				1

Figure 3: Screenshot of Microsoft Access Database used in the technological analysis.

Analysis of attributes

Four attributes were selected for analysis, to provide insight into technological processes and decisions made during knapping. Once the debitage was sorted, it was then analysed to count the presence and absence, and frequency for each attribute. A brief justification for each attribute will now be given:

Platform type

This refers to the striking platform found on the proximal portion of a flake. This is identified as a flat surface at one of the flake, that has been struck to remove flakes (Andrefsky, 1998). Variability in the form of striking platforms has been shown to provide insight into the stage of production, as well as provide insight into types of platform preparation undertaken to impact the size and shape of the detached flake. To capture a wide range of types, four platform types were identified and quantified for each size category. These were: plain (unmodified) platforms, facetted platforms, abraded platforms and trimmed platforms.

Bulb of percussion types

The bulb of percussion can be found on the ventral, proximal portion of a flake and refers to a raised hump that is produced when the wave of force from striking travels through the flake. Many researchers believe that the form of the bulb can provide insight into the type of hammer used when striking. Although much of this research has been undertaken on flint as the raw material, so it is unclear how this may translate to microdiorite. Four types of bulbs were identified and quantified for each size category. These were: discrete (large and small), diffuse and bulbar scars.

Flake profile

The thickness, thinness and curvature of flakes were identified and quantified to characterise the flake profiles. Although there are several precise methods for measuring flake profiles, this can be a very time intensive process. Therefore, three 'categories' of profiles were chosen and the number of these were quantified for each size category to undertake this in a rapid process. These were: thick (defined as a length to thickness ratio of less than 3:1), thin and straight, thin and curving. It is hypothesised that the thickness of flakes should reduce, and the curvature of flakes should increase as the production process develops.

Knapping errors

Flakes can terminate in a variety of ways, however the default termination for a successful flake is a feathered termination. If an issue is encountered or error made, the force that detaches the flake may be interrupted and the flake may terminate in a step, hinge or overshoot fracture. These are known as knapping errors. Some researchers have argued that the identification of these errors can provide insight into the technical skill of the knapper. However, flaws in the raw material also play a major role in flake terminations. The frequency of knapping errors was quantified as a total. Each error type was not quantified individually, but the presence of varied knapping errors was captured at the end in the general description.

General description

At the end of the quantification stage, each size categories is then described in a long text box on the Microsoft Access database. These descriptions aim to capture some of the features that are harder to quantify such as the shape of flakes, the texture of the raw material and the overall impression of the technology.

Additional archaeological attributes

Two additional attributes were identified in the archaeological assemblage. These were: completeness of flakes (complete vs broken) and secondary technology. In an archaeological assemblage we would expect that post depositional processes, such trampling or fluvial processes, would frequently break flakes. It is important to quantify this through the completeness of flakes, to understand the impact of these processes on the evidence. Secondary technology refers to intentional retouching of flake edges to create tools such as scrapers or borers. We know that the experimental assemblage has not been subject to either of these factors, and therefore it would be redundant to quantify.

ANDREFSKY, W. 1998. *Lithics: Macroscopic Approaches to Analysis,* Cambridge, Cambridge University Press.

APPENDIX II: Finds from Each Test Pit

Test Pit/Trench	Material/find type	Weight (g)	Number of items
001	Group VII Axe Debris	747	20
001	Possible hammerstone	2354	4
002	Group VII Axe Debris	765	18
003	Group VII Axe Debris	1340	27
004	Group VII Axe Debris	307	7
005	Group VII Axe Debris	846	28
006	Group VII Axe Debris	1761	57
007	Group VII Axe Debris	19	3
008	Group VII Axe Debris	2152	73
009	Group VII Axe Debris	422	34
009	Possible hammerstone	705	2
010	Group VII Axe Debris	1053	24
010	Possible hammerstone	1648	3
011	Group VII Axe Debris	2996	88
011	Possible hammerstone	1961	3
012	Group VII Axe Debris	289	5
013	Group VII Axe Debris	3025	42
013	Possible hammerstone	1828	2
014	Group VII Axe Debris	739	5
015	Group VII Axe Debris	26112	319
015	Other stones ???	18256	7
015	Burnt stone	969	5
015	Possible hammerstone	3652	4
015	Quartz	143	5
016	Group VII Axe Debris	2348	56
016	Stone with hole?	14	1
016	Possible hammerstone	1829	4
016	Slag/burnt clay	431	9
017	Group VII Axe Debris	767	41
017	Quartz	281.5	11
018	Group VII Axe Debris	389	48
018	Quartz	493	26
019	Flint flakes	0.8	2
019	Group VII Axe Debris	187	28
019	Quartz	274	31
020	Chert flake	5.4	1
020	Group VII Axe Debris	30.5	8
021	Flint flake	0.5	1
021	Group VII Axe Debris	84	12
021	Quartz	102	20

Test Pit/Trench	Material/find type	Weight (g)	Number of items
022	Flint flake	4.5	1
022	Group VII Axe Debris	610.5	40
022	Quartz	3	1
023	Group VII Axe Debris	67	7
023	Quartz	348	60
024	Group VII Axe Debris	184	15
024	Quartz	244	39
025	Flint flake	5.8	1
025	Group VII Axe Debris	27	6
025	Quartz	149	19
026	Flint flake	0.5	1
026	Group VII Axe Debris	304	35
026	Quartz	359	48
027	Flint **scraper** and 2 flint flakes	3.4	3
027	Group VII Axe Debris	647	31
028	Group VII Axe Debris	0	0
028	Quartz	358	16
029	Group VII Axe Debris (including roughout)	658	16
030	Group VII Axe Debris	708	82
030	Quartz	417	33
031	Group VII Axe Debris (including 16 roughouts)	507570.5	5393
031	Other stone	131	0
031	Quartz	170	1
032	Group VII Axe Debris	2027	19
032	Quartz	220	11
033	Group VII Axe Debris	726	70
033	Quartz	127	11
034	Group VII Axe Debris	157	7
034	Burnt stone	87	2
035	Group VII Axe Debris	551	18
035	Quartz	87	10
036	Group VII Axe Debris (including roughout)	7759	153
036	Burnt stone	709	3
036	Quartz	36	6
037	Group VII Axe Debris (including 6 roughouts)	88618	798
037	Possible hammerstone	153	1
037	Possible hammerstone	1332	2
037	Quartz	236	13

Test Pit/Trench	Material/find type	Weight (g)	Number of items
038	Group VII Axe Debris	1588	28
038	Quartz	15	2
039	Chert (unworked)	44	1
039	Group VII Axe Debris (including 9 roughouts)	73935	2243
039	Other stone	61	1
039	Burnt stone	2959	39
039	Possible hammerstone	1958	1
039	Pottery (Roman)	28	3
039	Quartz	3863	163
040	Group VII Axe Debris	1435	58
040	Quartz	242	21
040	Slag/burnt clay	11	1
041	Group VII Axe Debris	1340	18
041	Quartz	50	3
042	Flint flake	0.4	1
042	Group VII Axe Debris (including roughout)	17589	985
042	Quartz	255	37
043	Group VII Axe Debris	1567	62
043	Possible hammerstone	795	1
043	Quartz	686	5
044	Group VII Axe Debris	15184	1127
044	Burnt stone	354	1
044	Quartz	161	6
045	Chert fragment	5.3	1
045	Group VII Axe Debris	16788	1506
045	Burnt stone	69	1
045	Quartz	475	51
046	Group VII Axe Debris	12446	1006
046	Quartz	459	42
047	Group VII Axe Debris	1140	33
047	Burnt stone	562	10
047	Quartz	67	5
048	Group VII Axe Debris	689	40
048	Quartz	17	1
049	Group VII Axe Debris	1835	19
049	Burnt stone	312	5
049	Quartz	199	11
050	Group VII Axe Debris	2757	324
050	Quartz	561	19
051	Group VII Axe Debris	351	15

Test Pit/Trench	Material/find type	Weight (g)	Number of items
052	Group VII Axe Debris	628	18
053	Group VII Axe Debris	330	48
053	Quartz	39	7
054	Group VII Axe Debris	246	26
055	Group VII Axe Debris	208	25
056	Group VII Axe Debris	1728	56
056	Possible hammerstone	1010	1
057	Group VII Axe Debris	429	26
057	Burnt stone	468	2
057	Quartz	6	1
058	Flint flake	2.4	1
058	Group VII Axe Debris	316	37
058	Burnt stone	57	1
059	Group VII Axe Debris	542	8
059	Quartz	124	1
060	Group VII Axe Debris	27	3
060	Burnt stone	210	1
061	Flint flakes and pebble fragment	12	3
061	Group VII Axe Debris	350	32
062	Group VII Axe Debris	560	27
063	Group VII Axe Debris	180	37
064	Flint flake	2.8	1
064	Group VII Axe Debris	260	48
064	Group VII Axe Debris (other)	56	2
064	Burnt stone	57	1
064	Possible hammerstone	679	1
065	Group VII Axe Debris	436	38
065	Crystal quartz flake	0.7	1
066	Group VII Axe Debris	290	30
067	Chert flake	0.3	1
067	Flint flake	0.4	1
067	Group VII Axe Debris	20	9
068	Group VII Axe Debris	971	48
069	Group VII Axe Debris	296	63
070	Group VII Axe Debris	89	20
071	Group VII Axe Debris	266	22
072	Group VII Axe Debris	168	8
073	Group VII Axe Debris (including 2 roughouts)	2920	60
073	Other stone (possibly worked)??	2.8	1
073	Quartz	162	6
073	Slag/burnt clay	1174	numerous

Test Pit/Trench	Material/find type	Weight (g)	Number of items
074	Group VII Axe Debris	205	6
075	Group VII Axe Debris (including 4 roughouts)	97332	3404
075	Possible hammerstone	1114	1
075	Quartz	304	1
075	Slag/burnt clay	4	1
076	Group VII Axe Debris	715	11
077	Group VII Axe Debris	2460	61
078	Group VII Axe Debris	2648	11
079	Group VII Axe Debris	701	15
080	Group VII Axe Debris	6305	58
081	Group VII Axe Debris (including roughout)	7094	125
082	Group VII Axe Debris (including roughout)	854	19
083	Group VII Axe Debris	298	9
084	Group VII Axe Debris	74	4
085	Group VII Axe Debris	10451	1015
085	Quartz	39	3
086	Animal tooth	2	1
086	Group VII Axe Debris	1768	154
087	Group VII Axe Debris	3715	297
087	Quartz	25	3
088	Group VII Axe Debris	15797	1205
088	Stone with partially drilled holes	7	1
088	Burnt stone	144	2
088	Other stone (natural)	30	1
088	Quartz	92	2
089	Group VII Axe Debris (including roughout)	16407	724
090	Group VII Axe Debris	9	1
091	Group VII Axe Debris	86	2
092	Group VII Axe Debris	425	9
093	Group VII Axe Debris	218	3
094	Group VII Axe Debris	948	91
094	Quartz	9	1
095	Group VII Axe Debris	553	21
095	Pottery (prehistoric)	1	1
096	Group VII Axe Debris	11	2
097	Group VII Axe Debris	1731	91
098	Group VII Axe Debris	1901	210
099	Group VII Axe Debris	91	5

Test Pit/Trench	Material/find type	Weight (g)	Number of items
100	Group VII Axe Debris	4549	260
101	Group VII Axe Debris	834	43
102	Group VII Axe Debris (including 3 roughouts)	15786	186
103	Group VII Axe Debris	2708	77
104	Group VII Axe Debris	3535	76
105	Group VII Axe Debris	438	12
106	Flint flake	0.2	1
106	Group VII Axe Debris	1329	66
106	Iron nail	1	1
107	Group VII Axe Debris	2045	76
108	Group VII Axe Debris	1170	56
108	Other stone (geological sample)	422	16
109	Group VII Axe Debris	70	5
110	Group VII Axe Debris	197	6
111	Group VII Axe Debris	744	16
111	Other stone (geological sample)	827	9
112	Group VII Axe Debris	13	1
112	Possible hammerstone	194	1
113	Group VII Axe Debris	45	3
113	Possible hammerstone	378	1
114	Group VII Axe Debris	11	3
115	Group VII Axe Debris	1639	31
116	Group VII Axe Debris (including roughout)	9316	173
116	Burnt stone	86	1
116	Pottery (prehistoric)	4	1
116	Burnt bone	0.07	1
117	Group VII Axe Debris	10742	206
117	Burnt stone	495	2
117	Possible hammerstone	211	2
118	Group VII Axe Debris (including roughout)	4485	43
119	Flint flake	0.8	1
119	Group VII Axe Debris (including roughout)	35279	274
120	Group VII Axe Debris	3734	89
121	Group VII Axe Debris (including roughout)	16443	162
122	Group VII Axe Debris	4847	78
123	Group VII Axe Debris (including roughout)	20280	438
123	Quartz	11	1

Test Pit/Trench	Material/find type	Weight (g)	Number of items
124	Group VII Axe Debris	5490	153
125	Group VII Axe Debris (including 2 roughouts)	11484	86
125	Possible hammerstone	1092	1
125	Quartz	2470	45
126	Group VII Axe Debris	4550	134
127	Group VII Axe Debris (including 4 roughouts)	76257	575
127	Other stone (natural)	21	1
127	Possible hammerstone	1636	2
127	Possible hammerstone	335	1
128	Group VII Axe Debris	427	9
129	Group VII Axe Debris	16702	128
129	Quartz	871	1
129	Slag/burnt clay	88	
130	Group VII Axe Debris (including roughout)	7552	47
131	Group VII Axe Debris (including roughout)	1161	21
132	Group VII Axe Debris	5540	143
132	Possible hammerstone	786	1
133	Group VII Axe Debris	9002	72
133	Possible hammerstone	2089	1
134	Group VII Axe Debris	189	9
134	Iron nail	4	1
135	Group VII Axe Debris	3591	110
136	Group VII Axe Debris	4456	220
137	Chert (unworked)	15	1
137	Group VII Axe Debris	26364	817
137	Burnt stone	94	1
137	Possible hammerstone	172	1
138	Group VII Axe Debris (including roughout)	27709	456
138	Burnt stone	40	1
138	Possible hammerstone	1527	2
138	Quartz	12	1
139	Group VII Axe Debris	683	34
140	Group VII Axe Debris	156	9
141	Group VII Axe Debris	463	25
142	Group VII Axe Debris	1611	37
142	Possible hammerstone	626	1
143	Group VII Axe Debris	8792	287

Test Pit/Trench	Material/find type	Weight (g)	Number of items
143	Iron object	17	1
143	Possible hammerstone	511	2
144	Group VII Axe Debris	165	5
144	Iron objects	28	2
145	Group VII Axe Debris	556	19
146	Group VII Axe Debris (including roughout)	24304	447
146	Possible hammerstone	3362	1
147	Group VII Axe Debris (including roughout)	15219	230
147	Possible hammerstone	2820	3
148	Flint flake	0.7	1
148	Group VII Axe Debris	3350	268
149	Group VII Axe Debris	763	37
149	Possible hammerstone	406	1
150	Group VII Axe Debris	7256	96
150	Possible hammerstone	1438	3
151	Group VII Axe Debris	94	4
151	Possible hammerstone	1590	1
Molehills and trackway, Maes y Bryn	Group VII Axe Debris	951	55
Ffridd Tan y Graig, surface find	Group VII Roughout	1758	1
Ffridd Tan y Graig, surface find	Possible hammerstone	991	1
Garreg Fawr, surface find	Possible quartz tool	426	1
Garreg Fawr, surface find	Possible hammerstone	1348	1
Track to Waun Llanfair, surface finds	Group VII Axe Debris	1870	23
Ty’n y Llwyfan, surface finds	Group VII Axe Debris (including 2 roughouts)	1413	7
Ty’n y Llwyfan screes, surface finds	Group VII Roughouts	2739	5

APPENDIX III: Summary Catalogue of Archaeometallurgical Materials

weights in g, assm = assemblage of small pieces

Test Pit	Context	Find No.	Bag weight	Item weight	Item No.	Description
TP16	1602	1606		6.92	1	fragment of thin dense sheet, top smooth, but slightly lobed and hints of broad dimples, base finely fuel dimpled, dense slag
				2.6	1	apparently very viscous prill of highly vesicular lining slag; maroon surface to glass dark with sand grains
TP16	1603	1605		166	1	double SHC; upper. 50x90x20mm, SHC, possibly deformed by folding, attached to lower SHC, 35x60x15mm; inclined in such a way that the two are continuous on one side; base finely prilly with fuel impressions and rust; top smoothish, dimpled with faint hint of lobes only
				128	1	60x70x30mm, small dense SHC; crudely plano-convex; top with fine fuel impressions on a poorly lobate surface, partly obscured by rust; base also crudely lobate, but rusty, with abundant adhering flake hammerscale, internally vesicular, but fracture obscured partly by rust
				32	1	lobate piece of slag; low density; some gravel, but resembles the slags in the SHCs
				72	5	lower density slags - lining slags, coarsely sandy clinkery slags, maroon surface, in rounded and more sheet-like forms
				7	assm	bag with small fines sample - dust and charcoal
TP73	7302	7304		7.02	1	small fragment of rather sintery-appearing slag; finely granular and rich in very fine charcoal debris
TP73	7303	7305		8.27	1	vitrified and slagged oxidised-fired lining
				7.06	2	nubs of fuel ash slag
				12.8	1	small sheet of dense slag, smooth top, fuel dimpled base; must be a modified small flow
				68	2	highly altered iron-bearing slag?
TP73	7305	7309	584	132	9	fragments of fired clay, all oxidised-fired with dark glassy slag; of identical aspect to b/h piece
				36	1	tip of clay around protruding blow-hole; slagged and vitrified; blow-hole slightly deformed,

Test Pit	Context	Find No.	Bag weight	Item weight	Item No.	Description
						originally c25mm diameter? blow-hole partly occluded by slag descending across it
				24	1	slagged and vitrified oxidised-fired clay; one side shows a pale curved lateral face suggests a tuyère margin
				352	16	Iron slag; of the two largest pieces, each 64g, one shows lobate flow across hearth floor, the other may be a proto-SHC; other fragments very variable - the denser slags tend to be fragments of sheets, lower density ones tend to be more blebby and lobate
				8	assm	small bag labelled 'iron rich material from soil' which includes slag debris and hammerscale
TP73	7305	7311	360	360	assm	unusual assemblage with very large, very shiny FHS fragments; lots of spheroids and rounded blebs, many of maroon-surfaced FAS/lining slag; some fired clay; some probably oxidised iron debris in thin sheets and some blebby pieces of dense slag, but these are rarer
TP73	7305	7312	140	3.96	1	Fiddle- key nail
				61.6	27	blebby low-density slags
				15.61	8	oxidised-fired clay
				0.72	1	slagged oxidised-fired clay - possibly from blow-hole margin
				0.66	1	slagged oxidised-fired clay
				16.65	4	probable scraps of iron
				16.55	3	laminated iron cemented sand; has rounded cavities, but does not appear to be a slag
				8.74	4	rounded pebbles of natural rock
				6.92	4	dense slag, mostly finely prilly
				5.51	1	laminated sandy material with charcoal clast
TP75	7505	75131		4.67	1	small fragment of fired clay, oxidised in core, reduced on surface; front face is 14x24mm, then turns to side 12mm high, along a line with a radius of 30mm (but angular so this estimate is only approximate); could be from the margin of the face of a tuyère
TP40	4002	4004		11.27	1	lining slag with small amount of attached vitrified lining; slag surface shows some deep dimples and a slightly pendent lobe?
TP129	12903	12907	92	92	assm	assemblage with much concretionary material; one fragment appears to be plaster with moulds of organic temper; there are fragments of burnt organic material, and some of very fine clinker with globules on millimetre scale forming agglomerations, other concretionary

Test Pit	Context	Find No.	Bag weight	Item weight	Item No.	Description
						materials may be natural Fe/Mn crusts; one piece appears to be sandstone grain from inside coal seam and another is possibly a sphaerosiderite grain; the magnetic nature of the now-pinkish shale, that dominates, probably suggests this is partly burnt, however, the intergrowth of Mn oxides and what appears to be fired clay, may suggest that some of the colour is natural.

APPENDIX IV: Archaeometallurgical Materials Tables and Appendices

Appendix IV Tables

Table 1: Summary Catalogue of Archaeometallurgical Materials
weights in g, assm = assemblage of small pieces.

TP	context	find	bag label	bag wt.	item wt.	item no.	description
TP16	1602	1606			6.92	1	fragment of thin dense sheet, top smooth, but slightly lobed and hints of broad dimples, base finely fuel dimpled, dense slag
					2.6	1	apparently very viscous prill of highly vesicular lining slag; maroon surface to glass dark with sand grains
TP16	1603	1605	slag		166	1	double SHC; upper. 50x90x20mm, SHC, possibly deformed by folding, attached to lower SHC, 35x60x15mm; inclined in such a way that the two are continuous on one side; base finely prilly with fuel impressions and rust; top smoothish, dimpled with faint hint of lobes only
					128	1	60x70x30mm, small dense SHC; crudely plano-convex; top with fine fuel impressions on a poorly lobate surface, partly obscured by rust; base also crudely lobate, but rusty, with abundant adhering flake hammerscale, internally vesicular, but fracture obscured

TP	context	find	bag label	bag wt.	item wt.	item no.	description
							partly by rust
					32	1	lobate piece of slag; low density; some gravel, but resembles the slags in the SHCs
					72	5	lower density slags - lining slags, coarsely sandy clinkery slags, maroon surface, in rounded and more sheet-like forms
					7	assm	bag with small fines sample - dust and charcoal
TP73	7302	7304	slag		7.02	1	small fragment of rather sintery-appearing slag; finely granular and rich in very fine charcoal debris
TP73	7303	7305			8.27	1	vitrified and slagged oxidised-fired lining
					7.06	2	nubs of fuel ash slag
					12.8	1	small sheet of dense slag, smooth top, fuel dimpled base; must be a modified small flow
					68	2	highly altered iron-bearing slag?
TP73	7305	7309	burnt clay, slag, charcoal	584	132	9	fragments of fired clay, all oxidised-fired with dark glassy slag; of identical aspect to b/h piece
					36	1	tip of clay around protruding blow-hole; slagged and vitrified; blow-hole slightly deformed, originally c25mm diameter? blow-hole partly occluded by slag descending across it
					24	1	slagged and vitrified oxidised-fired clay; one side shows a pale curved lateral face suggests a tuyère margin
					352	16	Iron slag; of the two largest pieces, each 64g, one shows lobate flow across hearth floor, the other may be a proto-SHC; other fragments very variable - the denser slags tend to be fragments of sheets, lower density ones tend to be more blebby and lobate
					8	assm	small bag labelled 'iron rich material from soil' which includes slag debris and hammerscale

TP	context	find	bag label	bag wt.	item wt.	item no.	description
TP73	7305	7311	slag/hammerscale from <5>	360	360	assm	unusual assemblage with very large, very shiny FHS fragments; lots of spheroids and rounded blebs, many of maroon-surfaced FAS/lining slag; some fired clay; some probably oxidised iron debris in thin sheets and some blebby pieces of dense slag, but these are rarer
TP73	7305	7312	slag from coarse residue <5>	140	3.96	1	fiddle key nail
					61.6	27	blebby low-density slags
					15.61	8	oxidised-fired clay
					0.72	1	slagged oxidised-fired clay - possibly from blow-hole margin
					0.66	1	slagged oxidised-fired clay
					16.65	4	probable scraps of iron
					16.55	3	laminated iron cemented sand; has rounded cavities, but does not appear to be a slag
					8.74	4	rounded pebbles of natural rock
					6.92	4	dense slag, mostly finely prilly
					5.51	1	laminated sandy material with charcoal clast
TP75	7505	75131	furnace lining		4.67	1	small fragment of fired clay, oxidised in core, reduced on surface; front face is 14x24mm, then turns to side 12mm high, along a line with a radius of 30mm (but angular so this estimate is only approximate); could be from the margin of the face of a tuyère
TP40	4002	4004			11.27	1	lining slag with small amount of attached vitrified lining; slag surface shows some deep dimples and a slightly pendent lobe?

TP	context	find	bag label	bag wt.	item wt.	item no.	description
TP129	12903	12907	mag material from <8>	92	92	assm	assemblage with much concretionary material; one fragment appears to be plaster with moulds of organic temper; there are fragments of burnt organic material, and some of very fine clinker with globules on millimetre scale forming agglomerations, other concretionary materials may be natural Fe/Mn crusts; one piece appears to be sandstone grain from inside coal seam and another is possibly a sphaerosiderite grain; the magnetic nature of the now-pinkish shale, that dominates, probably suggests this is partly burnt, however, the intergrowth of Mn oxides and what appears to be fired clay, may suggest that some of the colour is natural.

Table 2: major element analyses by XRF expressed as wt% for macroscopic materials.

Raw measured values, except for calculated columns for FeO (as an alternative to Fe_2O_3). < = below detection.

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	LOI	total
LFF3	50.33	19.19	19.63	17.66	0.253	2.26	0.46	0.671	2.814	1.002	0.173	<0.15	4.36	96.78
LFF4	18.68	4.73	76.18	68.55	0.147	1.29	0.83	<0.1	0.807	0.384	0.271	0.251	-2.09	103.32

Table 3: trace element analyses by ICP-MS for macroscopic materials (part 1).

Raw numerical values in ppm. < = below detection.

Sample	Be	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Cs	Ba
LFF3	2.90	144.95	101.12	24.22	63.44	136.26	113.67	25.09	128.82	73.49	25.60	118.54	14.57	3.15	6.60	6.88	534.13
LFF4	0.71	38.24	27.56	19.94	42.69	108.78	<	7.99	21.87	76.25	9.96	79.92	4.53	9.23	14.52	0.47	200.16

Table 4: trace element analyses by ICP-MS for macroscopic materials (part 2).

Raw numerical values in ppm. < = below detection.

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Pb	Th	U
LFF3	32.40	70.15	7.68	28.29	5.19	1.07	4.53	0.73	4.77	0.96	2.87	0.43	2.86	0.43	3.35	1.11	1.55	28.20	12.58	2.36
LFF4	9.03	19.14	2.28	8.72	2.01	0.42	1.89	0.30	1.95	0.40	1.17	0.16	1.12	0.17	2.22	0.31	0.27	1.58	2.98	0.73

Table 5: estimated major element composition expressed as wt% for SHS particles (LFF1) ordered by SiO_2 content.

For details of how these were calculated see text. < = below detection.

Particle#	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CoO	NiO
Normal																
S14	<	<	1.24	4.71	0.33	<	<	<	0.16	<	<	<	0.15	92.93	0.48	<
S28	<	0.10	1.94	7.05	0.30	<	<	<	0.20	<	<	<	0.19	89.72	0.50	<
S2	<	0.20	2.67	7.18	0.21	<	<	<	0.15	<	<	<	0.06	89.10	0.43	<
S27	<	0.44	2.61	8.75	0.21	<	<	<	0.22	0.15	<	<	0.15	86.86	0.62	<
S6	0.15	0.39	2.39	10.28	0.30	<	<	0.20	0.21	0.21	<	<	<	85.43	0.46	<
S7	<	0.52	2.52	11.90	0.31	<	<	<	0.54	0.18	<	<	0.06	83.51	0.45	0.03
S3	0.11	0.68	3.34	13.26	0.08	<	<	0.25	0.26	0.30	<	<	0.13	81.17	0.41	<
S25	<	0.67	2.14	13.97	0.39	<	<	<	0.41	0.27	<	<	0.18	81.48	0.47	<
S13	<	0.18	1.42	13.97	<	<	<	0.20	0.18	<	<	<	<	83.58	0.47	<
S16	<	0.40	1.51	14.18	0.29	<	<	<	0.41	0.07	<	<	0.23	82.48	0.42	<
S26	0.33	0.35	2.45	14.70	0.43	<	<	0.70	0.99	0.09	<	<	0.19	79.35	0.42	<
S19	0.40	0.30	2.63	15.37	0.17	<	<	0.70	0.47	0.17	<	<	0.11	79.22	0.46	<
S32	<	0.67	2.52	15.94	0.48	<	<	<	0.99	0.16	<	<	0.68	78.14	0.41	<
S24	<	0.79	1.92	16.05	0.27	<	<	<	0.26	0.41	<	<	<	79.80	0.50	<

Particle#	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CoO	NiO
S29	0.87	0.71	4.43	16.38	0.27	<	<	1.32	1.55	0.24	<	<	0.14	73.61	0.42	<
S10	0.09	0.67	2.45	18.75	0.58	<	<	0.31	0.59	0.20	<	<	0.10	75.85	0.41	<
S31	<	0.90	2.67	19.92	0.37	<	<	0.21	0.63	0.37	<	<	<	74.45	0.46	<
S21	0.24	0.70	5.34	20.67	0.71	<	<	0.82	0.91	0.37	<	<	0.49	69.34	0.38	<
S22	0.51	0.62	4.55	20.87	0.62	<	<	1.19	1.51	0.32	<	<	0.16	69.30	0.34	<
S23	0.43	0.54	4.16	21.63	0.59	<	<	1.26	0.67	0.29	<	<	0.33	69.73	0.37	<
S18	0.78	1.03	5.32	21.64	0.39	<	<	1.22	1.71	0.37	<	<	0.22	66.92	0.39	<
S1	0.37	0.78	4.64	21.72	0.27	<	<	0.89	0.63	0.39	<	<	0.17	69.77	0.36	<
Slightly suspect																
S8	<	0.27	3.37	5.70	0.68	<	<	0.15	0.30	<	<	<	<	87.32	0.95	<
S15	0.13	0.46	4.20	8.29	0.32	<	<	0.24	0.33	0.15	<	<	<	85.42	0.47	<
Very suspect																
S9	<	0.08	3.89	0.41	0.07	<	<	<	0.15	<	<	<	<	94.86	0.49	0.05
S17	<	0.15	8.66	0.87	0.12	<	<	<	0.12	0.05	<	<	<	89.55	0.49	<
s4	<	0.48	6.97	1.40	1.80	0.17	<	<	0.19	0.18	<	<	0.14	88.20	0.47	<
S30	<	<	10.45	1.67	0.39	0.09	<	0.06	0.30	<	<	<	0.06	86.49	0.48	<
S11	<	0.82	7.05	2.21	1.26	0.67	<	<	0.24	0.60	<	<	0.18	86.52	0.47	<
S5	0.11	0.55	8.34	2.95	0.15	0.26	<	0.11	0.45	0.23	<	<	<	86.32	0.47	0.02
S12	<	0.21	3.82	3.01	0.16	<	<	0.04	0.09	<	<	<	0.23	91.97	0.49	<

Table 6: physical and mineralogical properties of spheroidal hammerscale particles (LFF1).
Ordered by SiO_2 content.

Particle#	SiO_2 wt%	main porosity	microstructure	quartz grains	metal prills	unmelted scale	group
							1
S9	0.41	dispersed	stout wustite dendrites and pseudo-dendrites				1
S17	0.87	central	stout wustite dendrites, but variable size		y		1
S4	1.40	dispersed	stout wustite dendrites, but variable size				1
S30	1.67	central	stout wustite dendrites, but variable size				1
S11	2.21	central	finely dendritic wustite in glass – nucleated on emulsion blebs?				1
S5	2.95	central	stout wustite dendrites, but variable size		?	y?	1
S12	3.01	central	initial magnetite dendrites followed by dense but fine and well-formed wustite				1
S14	4.71	central	stout wustite dendrites and pseudo-dendrites in fayalite				1
S8	5.70	marginal	initial magnetite dendrites followed by dense but fine and well-formed wustite				1
S28	7.05	dispersed	stout wustite dendrites, but variable size			y	1
S2	7.18	dispersed	stout wustite dendrites		?		1
S15	8.29	dispersed	stout wustite dendrites, but variable size, in glass				1
S27	8.75	central	medium wustite in glass				1
S6	10.28	central	stout wustite dendrites in glass				1
S7	11.90	dispersed	fine wustite dendrites in low proportion of glass	400μm grain		y	1
S3	13.26	dispersed	finely dendritic wustite in glass		?		1
S25	13.97	central	finely dendritic wustite in fayalite	50μm grain		y	1
S13	13.97	central	fine-medium wustite in fayalite				1
S16	14.18	dispersed	finely dendritic wustite in fayalite	80μm grain		y	1
S26	14.70	dispersed	fine-medium wustite in fayalite/glass	300μm grain			2
S19	15.37	dispersed	initial magnetite dendrites followed by dense but fine and well-formed wustite				2

Particle#	SiO_2 wt%	main porosity	microstructure	quartz grains	metal prills	unmelted scale	group
S32	15.94	dispersed	finely dendritic wustite in fayalite				2
S24	16.05	dispersed	finely dendritic wustite in fayalite/glass			y?	1
S29	16.38	dispersed	finely dendritic wustite in glass, with wustite clots				2
S10	18.75	dispersed	finely dendritic wustite in fayalite	80μm grain			2
S31	19.92	dispersed	finely dendritic wustite in fayalite				2
S21	20.67	dispersed	finely dendritic wustite in glass, with wustite clots	multiple <150μm			2
S22	20.87	dispersed	finely dendritic wustite in fayalite/glass	multiple <100μm			2
S23	21.63	central	finely dendritic wustite in fayalite/glass				2
S18	21.64	dispersed	finely dendritic wustite in fayalite/glass				2
S1	21.72	dispersed	finely dendritic wustite in glass				2
S20	n/a	central	stout wustite dendrites and pseudo-dendrites		y	y	n/a

Table 7: estimated major element analyses by EDS expressed as wt% for flake hammerscale particles (LFF2).
For details of how these were calculated see text. < = below detection.

Particle#	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CoO	NiO
Normal																
T9	0.36	<	0.85	3.21	1.06	<	<	0.39	0.49	<	<	<	<	92.87	0.54	0.23
T10	0.89	0.85	4.95	19.24	0.24	0.05	<	1.74	2.31	0.32	<	<	0.20	68.75	0.38	<
Slightly suspect																
T11	<	0.30	1.86	0.57	0.19	<	<	<	0.19	<	<	<	1.35	95.03	0.49	<
T8	0.23	0.23	3.29	4.26	0.18	<	<	0.18	0.16	<	<	<	<	90.92	0.54	<
T1	<	0.36	2.92	4.96	0.23	<	<	0.22	0.25	0.15	<	<	0.12	90.21	0.59	<
Very suspect																

Particle#	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CoO	NiO
T6	<	<	1.42	0.42	0.31	<	<	<	<	<	<	<	<	97.39	0.46	<
T12	<	<	2.71	1.58	<	<	<	<	<	<	<	<	0.28	95.02	0.41	<
T13	<	0.23	2.29	1.79	0.19	0.06	<	<	0.38	0.06	<	<	0.43	94.11	0.46	<
T2	<	0.16	4.33	1.81	0.49	<	<	0.11	0.40	<	<	<	<	92.04	0.50	<
T4	0.11	0.15	7.49	3.50	0.39	0.08	<	0.13	0.44	<	<	<	0.18	87.14	0.38	<
T3	<	0.27	2.30	3.09	1.64	0.14	<	0.23	0.88	<	<	<	0.40	90.43	0.47	0.15
T5	<	0.26	4.22	5.39	0.51	<	<	0.23	0.57	<	<	<	<	88.23	0.40	<
T7	<	0.56	5.97	6.92	0.49	<	<	<	0.49	0.14	<	<	0.27	84.75	0.42	<

Table 8: physical and mineralogical properties of flake hammerscale particles (LFF2).
Ordered SiO_2 content.

particle#	SiO_2 wt%	microstructure	iscorite?	quality
T6	0.42	1		normal
T11	0.57	2	yes	slightly suspect
T12	1.58	2	yes	very suspect
T13	1.79	3		very suspect
T2	1.81	2	yes	very suspect
T9	3.21	3		normal
T8	4.26	4		slightly suspect
T1	4.96	4		slightly suspect
T4	3.50	2		very suspect
T3	3.09	1		very suspect
T5	5.39	4		very suspect
T7	6.92	7		very suspect
T10	19.24	6		very suspect

Table 9: major element analyses by EDS expressed as wt% for the inner slag layer of flake hammerscale particles (LFF2).
< = below detection.

Particle#	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	FeO	CoO	NiO
Normal																
T9	<	0.57	4.83	9.63	0.97	0.21	<	<	0.74	0.26	<	<	0.34	82.06	0.42	<
Slightly suspect																
T10	<	0.11	3.50	5.33	1.71	<	<	<	0.33	0.14	<	<	0.10	88.32	0.46	<

Appendix IV.A: Archive of EDS analyses

Presented as wt% element, collected as 'all elements measured'.

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	2	885	16.93	0.21	0.23	3.46	4.27	0.1	0	0.3	0.19	0.2	0.11	0	0	0	27.29	0.17	0	0	0	0	0	0	0	0	53.47
LFF1	2	886	23.24	0	0.45	0.95	7.88	0.11	0	0.05	0.07	0.14	0.18	0	0	0.08	48.19	0.25	0	0	0	0	0	0	0	0	81.59
LFF1	2	887	28.54	0.32	0.44	2.57	10.07	0.12	0	0	0.8	0.47	0.2	0	0	0.12	49.66	0.23	0	0	0	0	0	0	0	0	93.53
LFF1	3	888	27.2	0.2	0.44	2.04	8.99	0.11	0	0	0.59	0.37	0.23	0	0	0.14	51.98	0.3	0	0	0	0	0	0	0	0	92.59
LFF1	3	889	27.43	0	0.75	0.82	0.66	0	0	0	0.08	0.42	0.07	0	0	0.2	65.26	0.31	0	0	0	0	0	0	0	0	96.01
LFF1	3	890	28.5	0	0.27	3.19	1.86	0	0	0	0.23	0.12	0.56	0	0	0	62.66	0.36	0	0	0	0	0	0	0	0	97.74
LFF1	3	891	28.71	0	0.31	3.07	1	0	0	0	0.12	0	0.58	0	0	0	63.66	0.27	0	0	0	0	0	0	0	0	97.73
LFF1	3	892	27.37	0	0.29	3.05	0.66	0	0	0	0	0	0.53	0	0	0	64.28	0.32	0	0	0	0	0	0	0	0	96.5
LFF1	3	893	33.01	0.78	0.52	3.82	15.51	0.17	0	0	1.69	0.93	0.15	0	0	0.18	40.04	0.22	0	0	0	0	0	0	0	0	97.01
LFF1	3	894	33.29	0.73	0.54	3.86	15.92	0.13	0	0	1.6	0.95	0.11	0	0	0.17	40.22	0.25	0	0	0	0	0	0	0	0	97.77
LFF1	3	895	24.81	0	0.65	0.63	11.16	0.21	0	0.09	0	0.17	0.13	0	0	0.18	41.52	0.26	0	0	0	0	0	0	0	0	79.82
LFF1	3	896	26.97	0	0.63	1.3	10.45	0.21	0	0.08	0	0.21	0.17	0	0	0.15	48.55	0	0	0	0	0	0	0	0	0	88.72
LFF1	3	897	34.6	0.9	0.73	3.61	16.88	0.16	0	0	1.65	0.88	0.09	0	0	0.16	39.07	0.22	0	0	0	0	0	0	0	0	98.94
LFF1	4	898	3.39	0	0	0	0	0	0	0.73	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	4.17
LFF1	4	899	23.54	0	0.13	1.72	3.37	0.08	0	0	0	0.11	0	0	0	0.09	65.89	0.3	0	0	0	0	0	0	0	0	95.24
LFF1	5	900	24.77	0	0	1.37	0.18	0.06	0.22	0.13	0	0.32	0	0	0	0	57.14	0.31	0.11	0	0	0.54	0	0	0	0	85.15
LFF1	5	901	23.32	0	0.11	1.02	3.13	0.09	0	0	0	0.09	0	0	0	0	67.93	0.35	0	0	0	0	0	0	0	0	96.04
LFF1	5	902	27.13	0	0	0.29	0.09	0.08	0.26	0.05	0	0	0	0	0	0	63.1	0.35	0.12	0	0	0.54	0	0	0	0	92
LFF1	5	903	26.33	0	0	0.18	0.1	0	0.23	0.06	0	0	0	0	0	0	64.59	0.28	0	0	0	0.47	0	0	0	0	92.25
LFF1	5	904	27.67	0	0	0.35	0.16	0	0.2	0.13	0	0.09	0	0	0	0	63.36	0.27	0	0	0	0.61	0	0	0	0	92.84
LFF1	5	905	26.82	0	0	0.29	0.18	0	0.23	0.12	0	0.09	0	0	0	0	63.3	0.26	0	0	0	0.6	0	0	0	0	91.88
LFF1	5	906	25.53	0	0	0.25	0.11	0	0.14	0.06	0	0.08	0	0	0	0	65.35	0.29	0	0	0	0	0	0	0	0	91.82
LFF1	5	907	21.56	0	0	0.39	0.09	0	0	0	0	0	0	0	0	0	72.98	0.45	0	0	0	0	0	0	0	0	95.47
LFF1	5	908	21.39	0	0	0.41	0	0	0	0	0	0	0	0	0	0	73.12	0.34	0	0	0	0	0	0	0	0	95.27
LFF1	5	909	20.54	0	0	0.48	0.09	0	0	0	0	0	0	0	0	0	72.87	0.37	0	0	0	0	0	0	0	0	94.35
LFF1	5	910	21.93	0	0.14	0.42	0	0	0	0	0	0	0	0	0	0	73.19	0.35	0	0	0	0	0	0	0	0	96.02
LFF1	5	911	30.18	0	0.24	0.54	12.98	0.32	0	0	0	0.22	0	0	0	0	52.94	0.25	0	0	0	0	0	0	0	0	97.67
LFF1	5	912	29.93	0	0.22	1.5	12.8	0.25	0	0	0	0.26	0	0	0	0.08	51.92	0.26	0	0	0	0	0	0	0	0	97.21
LFF1	5	913	30.78	0	0.23	0.53	13.18	0.28	0	0	0	0.27	0	0	0	0.08	52.64	0.33	0	0	0	0	0	0	0	0	98.32
LFF1	5	914	23.45	0	0	2.71	0.19	0.12	0.41	0.14	0.07	0.7	0	0	0	0	48.46	0.3	0	0	0	0.53	0	0	0	0	77.09
LFF1	5	915	11.61	0	0.14	2.06	0.1	0	0.31	0.12	0	0.8	0	0	0	0	47.27	0.31	0.13	0	0	0.35	0	0	0	0	63.19
LFF1	6	916	26.23	0.4	0.4	3.15	7.66	0	0	0	0.74	0.36	0.13	0	0	0.09	56.28	0.31	0	0	0	0	0	0	0	0	95.76

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	6	917	25.32	0.16	0.37	1.97	5.83	0.07	0	0	0.22	0.28	0.15	0	0	0.12	59.39	0.25	0	0	0	0	0	0	0	0	94.14
LFF1	6	918	22.81	0	0.33	1.4	4.99	0.07	0	0	0	0.08	0.16	0	0	0.08	57.43	0.31	0	0	0	0	0	0	0	0	87.67
LFF1	6	919	27.17	0.32	0.41	2.69	8.18	0	0	0	0.86	0.39	0.15	0	0	0.1	55.26	0.29	0	0	0	0	0	0	0	0	95.83
LFF1	7	920	22.73	0	0.38	1.1	5.19	0	0	0	0	0.1	0.18	0	0	0.08	58.22	0.31	0	0	0	0	0	0	0	0	88.29
LFF1	7	921	23.19	0	0.39	1.22	5.31	0	0	0.05	0.07	0.12	0.17	0	0	0.08	57.65	0.32	0	0	0	0	0	0	0	0	88.55
LFF1	7	922	23.76	0	0.39	1.48	4.87	0.06	0	0	0.07	0.09	0.17	0	0	0.13	58.91	0.29	0	0	0	0	0	0	0	0	90.22
LFF1	7	923	23.06	0	0.54	0.8	11.31	0.18	0	0.11	0	0.17	0.12	0	0	0.14	39.2	0.19	0	0	0	0	0	0	0	0	75.83
LFF1	7	924	25.21	0	0.54	1.36	8.59	0.19	0.05	0.08	0	0.29	0.12	0	0	0	55.54	0.33	0	0	0	0	0	0	0	0	92.3
LFF1	7	925	25.18	0	0.56	1.26	11.56	0.13	0	0.09	0	0.19	0	0	0	0.09	44.89	0.29	0	0	0	0	0	0	0	0	84.24
LFF1	7	926	26.36	0	0.48	1.19	10.7	0.28	0	0.09	0.07	0.18	0.09	0	0	0.07	43.11	0.3	0	0	0	0	0	0	0	0	82.91
LFF1	7	927	22.08	0	0.53	0.84	10.78	0.14	0.05	0.07	0	0.14	0.08	0	0	0.12	42.9	0.23	0	0	0	0	0	0	0	0	77.96
LFF1	8	928	23.08	0	0.22	3.21	0.56	0.81	0.09	0	0	0.1	0.11	0	0	0.1	55.21	0.31	0	0	0	0	0	0	0	0	83.79
LFF1	8	929	23.09	0	0.25	3.52	0.63	0.61	0.06	0.06	0	0.11	0.08	0	0	0.1	57.89	0.36	0	0	0	0	0	0	0	0	86.76
LFF1	8	930	23.48	0	0.28	3.21	0.69	0.69	0.08	0	0	0.12	0.11	0	0	0.1	60.03	0.31	0	0	0	0	0	0	0	0	89.1
LFF1	9	931	24.99	0	0	0.27	0.06	0	0	0	0	0	0	0	0	0	68.59	0.3	0	0	0	0	0	0	0	0	94.2
LFF1	9	932	25.05	0	0	0.28	0	0	0	0	0	0	0	0	0	0	68.08	0.34	0	0	0	0	0	0	0	0	93.75
LFF1	9	933	25.34	0	0	0.27	0.11	0	0	0	0	0	0	0	0	0	69.18	0.39	0	0	0	0	0	0	0	0	95.28
LFF1	9	934	22.09	0	0	0.33	0	0	0	0	0	0	0	0	0	0	72.75	0.4	0.11	0	0	0	0	0	0	0	95.68
LFF1	9	935	22.19	0	0	0.45	0	0	0	0	0	0	0	0	0	0.09	72.45	0.5	0	0	0	0	0	0	0	0	95.68
LFF1	9	936	23.93	0	0.17	0.75	0.06	0	0	0	0	0	0	0	0	0	71.74	0.38	0	0	0	0	0	0	0	0	97.03
LFF1	9	937	22.08	0	0.16	0.5	0	0	0	0	0	0	0	0	0	0	72.03	0.41	0	0	0	0	0	0	0	0	95.18
LFF1	9	938	21.93	0	0	0.35	0.07	0	0	0	0	0	0	0	0	0	72.59	0.45	0.12	0	0	0	0	0	0	0	95.51
LFF1	9	939	22.92	0	0	0.32	0.16	0	0	0	0	0	0	0	0	0	72.03	0.38	0.11	0	0	0	0	0	0	0	95.91
LFF1	9	940	25.28	0	0	0.24	0.15	0	0	0	0	0	0	0	0	0	69.32	0.4	0	0	0	0	0	0	0	0	95.38
LFF1	9	941	25.19	0	0	0.26	0.26	0	0	0	0	0	0	0	0	0	68.41	0.41	0	0	0	0	0	0	0	0	94.53
LFF1	9	942	26.08	0	0	0.27	0	0	0	0	0	0.1	0	0	0	0	66.83	0.29	0	0	0	0	0	0	0	0	93.56
LFF1	9	943	24.87	0	0	0.56	0.14	0	0	0	0	0	0	0	0	0	64.23	0.31	0	0	0	0	0	0	0	0	90.11
LFF1	9	944	21.96	0	0.47	0.5	0	0	0	0	0	0	0	0	0	0.14	71.89	0.33	0	0	0	0	0	0	0	0	95.29
LFF1	9	945	21.1	0	0.3	0.57	0	0	0	0	0	0	0	0	0	0.1	71.32	0.4	0	0	0	0	0	0	0	0	93.78
LFF1	9	946	24.57	0	0.18	0.53	0.1	0	0	0	0	0	0.13	0	0	0.11	70.27	0.27	0	0	0	0	0	0	0	0	96.16
LFF1	9	947	27.25	0	0.11	8.24	1.85	3.77	0.21	0.07	0	0.5	0.07	0	0	0	38.94	0.22	0	0	0	0	0	0	0	0	81.25
LFF1	9	948	21.58	0	0.11	4.5	2.1	3.61	0.35	0.07	0	0.58	0.13	0	0	0	32.08	0.16	0	0	0	0	0	0	0	0	65.27
LFF1	9	949	22.26	0	0.26	2.63	0.35	0.57	0	0	0	0.13	0.07	0	0	0.08	62.79	0.3	0	0	0	0	0	0	0	0	89.45
LFF1	10	950	24.7	0.2	0.33	2.49	3.59	0	0	0	0.24	0.68	0.1	0	0	0	62.32	0.31	0	0	0	0	0	0	0	0	94.96
LFF1	10	951	18.07	0	0.3	5.19	0.44	0.07	0.14	0.08	0.06	0.21	0.14	0	0	0	52.47	0.31	0.09	0	0	0	0	0	0	0	77.57

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	10	952	22.99	0	0.28	2.68	0.56	0.15	0.09	0	0	0.09	0.13	0	0	0	60.43	0.31	0	0	0	0	0	0	0	0	87.69
LFF1	10	953	21.81	0	0.23	3.57	1.74	0	0.06	0.08	0.11	0.33	0.1	0	0	0	59.37	0.35	0	0	0	0	0	0	0	0	87.74
LFF1	10	954	19.1	0.22	0.3	4.17	0.65	0	0.15	0.12	0.09	0.27	0.13	0	0	0	52.51	0.34	0	0	0	0	0	0	0	0	78.04
LFF1	10	955	22.64	0	0	3.44	3.38	0.12	0.55	0.09	0	0.48	0.15	0	0	0	38.6	0.16	0	0	0	0	0	0	0	0	69.61
LFF1	10	956	28.84	0	0	3.38	2.15	0.29	0.68	0.28	0	0.25	0.08	0	0	0	46.44	0.22	0	0	0	0	0	0	0	0	82.61
LFF1	11	957	26.77	0	0.46	0.66	0.22	0	0	0	0	0.46	0	0	0	0	66.24	0.28	0	0	0	0	0	0	0	0	95.1
LFF1	11	958	25.72	0	0.31	0.77	0.21	0	0	0	0	0	0.09	0	0	0	67.71	0.35	0	0	0	0	0	0	0	0	95.17
LFF1	11	959	25.1	0	0.33	0.74	0.13	0	0	0	0	0	0.14	0	0	0	68.6	0.31	0	0	0	0	0	0	0	0	95.35
LFF1	11	960	23.5	0	0.28	0.65	0.13	0	0	0	0	0	0.11	0	0	0	70.47	0.42	0	0	0	0	0	0	0	0	95.55
LFF1	11	961	23.19	0	0.23	0.67	0.07	0	0	0	0	0	0.08	0	0	0	71.57	0.39	0	0	0	0	0	0	0	0	96.2
LFF1	11	962	22.42	0	0.41	0.67	0.11	0	0	0	0	0	0.1	0	0	0	71.98	0.35	0	0	0	0	0	0	0	0	96.04
LFF1	11	963	22.32	0	0.49	0.67	0.09	0	0	0	0	0	0.13	0	0	0	72.16	0.43	0	0	0	0	0	0	0	0	96.29
LFF1	11	964	21.74	0	0.28	4.42	0.45	0.12	0.07	0	0	0.11	0.11	0	0	0	59.16	0.29	0	0.12	0	0	0	0	0	0	86.88
LFF1	11	965	14.2	0	0	22.2	0.61	0.09	0.07	0.32	0	0.28	0	0	0	0	13.16	0	0	0	0	0	0	0	0	0	50.95
LFF1	11	966	12.08	0	0	2.16	1.05	0.31	0.36	0.2	0	0.19	0.11	0	0	0	37.16	0.21	0	0	0	0	0	0	0	0	53.84
LFF1	12	967	26.16	0.27	0.23	1.89	5.6	0.12	0	0	0.39	0.21	0.09	0	0	0	61.35	0.35	0	0	0	0	0	0	0	0	96.65
LFF1	12	968	23.49	0	0.24	1.11	3.95	0.11	0	0	0	0.1	0.14	0	0	0	63.9	0.36	0	0	0	0	0	0	0	0	93.4
LFF1	12	969	23.31	0	0.2	0.95	4.07	0.1	0	0	0	0.1	0.12	0	0	0	64.17	0.39	0	0	0	0	0	0	0	0	93.43
LFF1	13	970	21.84	0	0.11	0.67	0.15	0	0	0	0	0	0.11	0	0	0	71.48	0.36	0	0	0	0	0	0	0	0	94.72
LFF1	13	971	22.28	0	0.15	0.72	0.13	0	0	0	0	0	0.1	0	0	0	71.43	0.39	0	0	0	0	0	0	0	0	95.2
LFF1	13	972	23.71	0	0.1	0.72	0.42	0	0	0	0	0	0.15	0	0	0	70.15	0.35	0	0	0	0	0	0	0	0	95.6
LFF1	13	973	22.36	0	0.12	0.75	0.11	0	0	0	0	0	0.1	0	0	0	71.16	0.42	0	0	0	0	0	0	0	0	95.02
LFF1	13	974	21.76	0	0.12	0.74	0.2	0	0	0	0	0	0.13	0	0	0	70.88	0.34	0	0	0	0	0	0	0	0	94.17
LFF1	13	975	22.45	0	0.15	0.76	0.51	0	0	0	0	0	0.13	0	0	0	70.37	0.28	0	0	0	0	0	0	0	0	94.66
LFF1	13	976	21.59	0	0.13	0.77	0.3	0	0	0	0	0	0.16	0	0	0	71.13	0.34	0	0	0	0	0	0	0	0	94.43
LFF1	13	977	21.65	0	0.12	0.72	0.35	0	0	0	0	0	0.08	0	0	0	70.94	0.33	0	0	0	0	0	0	0	0	94.19
LFF1	13	978	21.55	0	0.19	0.63	0.24	0	0	0	0	0	0	0	0	0	71.11	0.35	0	0	0	0	0	0	0	0	94.09
LFF1	13	979	24.15	0	0.13	1.23	0.16	0	0	0	0	0	0.2	0	0	0	67.78	0.31	0	0	0	0	0	0	0	0	93.96
LFF1	13	980	23.44	0	0.15	0.61	0.55	0	0	0	0	0	0	0	0	0	66.77	0.33	0	0	0	0	0	0	0	0	91.84
LFF1	13	981	23.87	0	0.14	1.03	0.5	0	0	0	0	0	0.07	0	0	0	66.67	0.25	0	0	0	0	0	0	0	0	92.54
LFF1	13	982	24.25	0	0.17	0.61	0.18	0	0	0	0	0.08	0	0	0	0.08	66.17	0.36	0	0	0	0	0	0	0	0	91.91
LFF1	13	983	31.01	0.53	0.48	1.97	16.19	0.52	0	0	1.3	0.67	0	0	0	0.15	40.32	0.2	0	0.12	0	0	0	0	0	0	93.44
LFF1	13	984	34	0.71	0.35	3.05	16.8	0.46	0	0	1.24	0.79	0	0	0	0.09	40.52	0.18	0	0	0	0	0	0	0	0	98.19
LFF1	13	985	31.56	0.77	0.41	2.88	13.61	0.35	0	0	0.94	0.41	0.08	0	0	0.09	51.12	0.28	0	0	0	0	0	0	0	0	102.5
LFF1	13	986	25.93	0.32	0.23	1.57	5.78	0.16	0	0	0.48	0.22	0.09	0	0	0	61.65	0.29	0	0	0	0	0	0	0	0	96.72

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	14	987	51.47	0	0	0	47.15	0	0	0	0	0.07	0	0	0	0	0.15	0	0	0	0	0	0	0.21	0	0	99.05
LFF1	14	988	24.09	0	0.31	1.03	5.36	0.15	0	0	0	0.38	0.12	0	0	0	60.66	0.27	0	0	0	0	0	0	0	0	92.37
LFF1	14	989	22.77	0	0.27	1.26	4.79	0.07	0	0	0	0.32	0.11	0	0	0	60.16	0.27	0.11	0	0	0	0	0	0	0	90.11
LFF1	14	990	22.69	0	0.31	1.07	5.13	0.1	0	0	0	0.32	0.13	0	0	0.09	59.26	0.35	0	0	0	0	0	0	0	0	89.45
LFF1	14	991	24.42	0	0.3	1.55	5.71	0.14	0	0	0	0.4	0.1	0	0	0	58.9	0.31	0	0	0	0	0	0	0	0	91.83
LFF1	14	992	23.86	0	0.29	1.22	5.02	0.15	0	0	0	0.36	0.14	0	0	0.09	60.38	0.37	0	0	0	0	0	0	0	0	91.87
LFF1	14	993	23.73	0	0.27	1.28	4.87	0.13	0	0	0	0.35	0	0	0	0.09	59.61	0.39	0	0	0	0	0	0	0	0	90.71
LFF1	14	994	22.24	0	0	2.1	1.7	0	0	0	0	0.12	0	0	0	0	65.52	0.35	0	0	0	0	0	0	0	0	92.04
LFF1	15	995	24.72	0	0	0.29	0.39	0	0	0	0	0	0	0	0	0	68.05	0.33	0	0	0	0	0	0	0	0	93.78
LFF1	15	996	25.66	0	0	0.26	0.29	0	0	0	0	0	0	0	0	0	68.93	0.4	0	0	0	0	0	0	0	0	95.53
LFF1	15	997	30.26	0	0.11	0.17	13.84	0.08	0	0	0	0.62	0	0	0	0	51.92	0.21	0	0	0	0	0	0	0	0	97.22
LFF1	15	998	21.86	0	0	0.26	0.32	0	0	0	0	0	0	0	0	0	72.38	0.42	0	0	0	0	0	0	0	0	95.23
LFF1	15	999	24.73	0	0	0.3	0	0	0	0	0	0	0	0	0	0	69.52	0.29	0	0	0	0	0	0	0	0	94.85
LFF1	15	1000	30.14	0	0	0.23	13.79	0.1	0	0	0	0.57	0	0	0	0	52.48	0.35	0	0	0	0	0	0	0	0	97.65
LFF1	15	1001	21.85	0	0	0.25	0.22	0	0	0	0	0	0	0	0	0	72.6	0.38	0	0	0	0	0	0	0	0	95.29
LFF1	15	1002	26.14	0	0.08	0.19	8.33	0	0	0	0	0.11	0	0	0	0	63.39	0.3	0	0	0	0	0	0	0	0	98.54
LFF1	15	1003	25.35	0	0	0.29	0.11	0	0	0	0	0	0	0	0	0	69.91	0.39	0.1	0	0	0	0	0	0	0	96.16
LFF1	15	1004	22.68	0	0	0.24	0.29	0	0	0	0	0	0	0	0	0	72.32	0.37	0	0	0	0	0	0	0	0	95.91
LFF1	15	1005	29.63	0	0	0.21	12.98	0.1	0	0	0	0.59	0	0	0	0	53.07	0.33	0	0	0	0	0	0	0	0	96.9
LFF1	15	1006	22.04	0	0	0.27	0.08	0	0	0	0	0	0	0	0	0	72.61	0.37	0.11	0	0	0	0	0	0	0	95.48
LFF1	15	1007	10.5	0	0	2.66	0.79	0	0	0.09	0	0.1	0	0	0	0	45.54	0.23	0.14	25.24	0	0	0.57	0	0	0	85.86
LFF1	15	1008	22.13	0	0	0.37	0.2	0	0	0	0	0	0	0	0	0	72.32	0.37	0	0	0	0	0	0	0	0	95.39
LFF1	15	1009	30.31	0	0.62	0.42	13.22	0.19	0	0	0	0.56	0	0	0	0.17	49.18	0.25	0	0	0	0	0	0	0	0	94.93
LFF1	15	1010	31.41	0	0.38	1.73	13.38	0.21	0	0	0	0.8	0.07	0	0	0.1	49.43	0.19	0	0	0	0	0	0	0	0	97.72
LFF1	15	1011	18.71	0	0.12	4.9	5.95	0.64	0.06	0	0	1.12	0.13	0	0	0.09	43.95	0.28	0	0	0	0	0	0	0	0	75.96
LFF1	15	1012	8.63	0	0.07	4	2.56	0.19	0.09	0.05	0.07	0.54	0.12	0	0	0	45.11	0.26	0	0	0	0	0	0	0	0	61.69
LFF1	15	1013	23.06	0	0	0.79	0.6	0	0	0	0	0	0.19	0	0	0	70.27	0.38	0	0	0	0	0	0	0	0	95.28
LFF1	15	1014	24.81	0	0.29	1.93	8.02	0.22	0	0.05	0	0.55	0.13	0	0	0.12	50.63	0.25	0	0	0	0	0	0	0	0	87
LFF1	15	1015	23.91	0	0	0.89	2.05	0	0	0	0.1	0.15	0	0	0	0	62.73	0.33	0	0	0	0	0	0	0	0	90.16
LFF1	15	1016	23.1	0	0	0.94	1.13	0	0	0	0	0	0	0	0	0	70.38	0.33	0	0	0	0	0	0	0	0	95.88
LFF1	15	1017	23.41	0	0	3.04	1.55	0	0	0	0	0.08	0	0	0	0	67.45	0.32	0	0.13	0	0	0	0	0	0	95.98
LFF1	15	1018	22.4	0	0	0.78	1.06	0	0	0	0	0	0	0	0	0	69.74	0.34	0	0	0	0	0	0	0	0	94.32
LFF1	15	1019	28.11	0	0.31	0.99	11.48	0.14	0	0.05	0	0.65	0	0	0	0	50.43	0.36	0	0	0	0	0	0	0	0	92.51
LFF1	15	1020	29.18	0	0.22	0.19	12.73	0.11	0	0	0	0.55	0	0	0	0.08	52.76	0.23	0	0	0	0	0	0	0	0	96.04
LFF1	15	1021	28.99	0	0.09	0.45	12.14	0.07	0	0	0	0.31	0	0	0	0	54.45	0.28	0.1	0	0	0	0	0	0	0	96.88

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	15	1022	24.01	0	0	0.19	6.38	0	0	0	0	0.21	0	0	0	0	64.17	0.33	0	0	0	0	0	0	0	0	95.29
LFF1	15	1023	29.88	0	0.1	0.22	12.32	0.09	0	0	0	0.42	0	0	0	0	56.44	0.33	0	0	0	0	0	0	0	0	99.81
LFF1	15	1024	27.12	0	0	0.2	11.32	0	0	0	0	0.21	0	0	0	0	55.67	0.29	0	0	0	0	0	0	0	0	94.81
LFF1	16	1025	12.57	0	0.08	0.94	1.41	0.16	0	0	0.07	0.11	0	0	0	0	35.75	0.39	0	0.53	0	0	0	0	0	0	52.01
LFF1	17	1026	22.7	0	0.12	1.23	0.07	0	0	0	0	0	0	0	0	0	60.48	0.35	0	0.3	0	0	0	0	0	0	85.26
LFF1	17	1027	21.74	0	0.15	1.28	0.08	0	0	0	0	0	0	0	0	0	59.46	0.3	0	0.23	0	0	0	0	0	0	83.24
LFF1	17	1028	21.58	0	0.11	1.21	0.1	0	0	0	0	0	0.1	0	0.05	0	58.44	0.36	0	0.34	0	0	0	0	0	0	82.28
LFF1	17	1029	21.74	0	0.1	1.34	0.12	0	0	0	0	0	0.07	0	0	0	57.96	0.29	0	0.26	0	0	0	0	0	0	81.88
LFF1	17	1030	19.78	0	0	0.82	0.19	0	0	0	0	0	0.07	0	0	0	56.5	0.3	0	0.24	0	0	0	0	0	0	77.9
LFF1	17	1031	19.89	0	0.1	1.27	0.08	0	0	0	0	0	0.08	0	0	0	54.83	0.27	0	0.29	0	0	0	0	0	0	76.81
LFF1	17	1032	19.75	0	0.13	1.31	0.11	0	0	0	0	0	0.08	0	0	0	53.25	0.4	0	0.34	0	0	0	0	0	0	75.38
LFF1	17	1033	19.02	0	0.12	1.31	0.17	0	0	0	0	0	0.06	0	0	0	51.5	0.29	0	0.26	0	0	0	0	0	0	72.72
LFF1	17	1034	17.79	0	0.12	1.24	0.1	0	0	0	0	0	0.06	0	0	0	48.49	0.37	0	0.39	0	0	0	0	0	0	68.57
LFF1	17	1035	19.49	0	0.11	0.49	0.28	0	0	0	0	0	0	0	0	0	61.32	0.31	0	0.39	0	0	0	0	0	0	82.39
LFF1	17	1036	20.65	0	0.09	0.51	0.51	0.12	0	0	0	0	0	0	0	0	62.38	0.31	0	0.34	0	0	0	0	0	0	84.91
LFF1	17	1037	27.89	0.17	0.24	0.32	11.01	1.48	0	0	0	0.54	0	0	0	0.12	41.9	0.22	0	0.24	0	0	0	0	0	0	84.13
LFF1	17	1038	26.66	0	0.23	0.33	10.41	1.68	0	0	0	0.56	0	0	0	0.14	39.29	0.17	0	0.24	0	0	0	0	0	0	79.71
LFF1	17	1039	25.86	0	0.25	0.43	10.01	1.67	0	0	0	0.47	0	0	0	0.14	37.44	0.16	0	0.23	0	0	0	0	0	0	76.65
LFF1	17	1040	21.1	0	0.12	1.41	2	0.26	0	0	0	0.07	0	0	0	0.07	55.04	0.36	0	0.34	0	0	0	0	0	0	80.77
LFF1	18	1041	22.71	0	0.12	1.88	0.18	0	0	0.05	0	0.1	0	0	0	0	68.07	0.39	0	0	0	0	0	0	0	0	93.5
LFF1	18	1042	21.73	0	0	1.89	0.17	0	0	0.07	0	0.1	0	0	0	0	61.9	0.27	0	0	0	0	0	0	0	0	86.13
LFF1	19	1043	24.92	0	0	0.25	0.06	0	0	0	0	0.1	0	0	0	0	67.92	0.4	0	0	0	0	0	0	0	0	93.65
LFF1	19	1044	24.78	0	0.09	0.25	0.17	0	0	0	0	0.14	0	0	0	0	68.69	0.35	0	0	0	0	0	0	0	0	94.47
LFF1	19	1045	24.23	0	0.1	0.23	0	0	0	0	0	0	0	0	0	0	69.02	0.35	0	0	0	0	0	0	0	0	93.92
LFF1	19	1046	22	0	0.13	0.3	0.06	0	0	0	0	0	0	0	0	0	72.52	0.38	0.11	0	0	0	0	0	0	0	95.51
LFF1	19	1047	24.37	0	0	0.32	0	0	0	0	0	0	0	0	0	0	69.8	0.36	0	0	0	0	0	0	0	0	94.84
LFF1	19	1048	22.02	0	0	0.27	0.07	0	0	0	0	0	0	0	0	0	72.56	0.4	0	0	0	0	0	0	0	0	95.33
LFF1	19	1049	24.14	0	0	0.29	0.06	0	0	0	0	0	0	0	0	0	69.44	0.37	0	0	0	0	0	0	0	0	94.3
LFF1	19	1050	22.32	0	0	0.27	0.06	0	0	0	0	0	0	0	0	0	72.82	0.43	0	0	0	0	0	0	0	0	95.91
LFF1	19	1051	22.64	0	0	0.27	0.06	0	0	0	0	0	0	0	0	0	72.83	0.31	0	0	0	0	0	0	0	0	96.11
LFF1	19	1052	25.6	0	0	0.24	0.08	0	0	0	0	0	0	0	0	0	70.67	0.38	0	0	0	0	0	0	0	0	96.97
LFF1	19	1053	22.27	0	0	0.27	0.08	0	0	0	0	0	0	0	0	0	72.61	0.35	0	0	0	0	0	0	0	0	95.59
LFF1	19	1054	24.81	0	0	0.28	0	0	0	0	0	0	0	0	0	0	69.48	0.37	0	0	0	0	0	0	0	0	94.95
LFF1	19	1055	21.89	0	0	0.22	0	0	0	0	0	0	0	0	0	0	72.69	0.37	0	0	0	0	0	0	0	0	95.18
LFF1	19	1056	25.82	0	0.09	0.2	0	0	0	0	0	0.23	0	0	0	0	67.93	0.34	0	0	0	0	0	0	0	0	94.63

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	19	1057	23.18	0	0	1.72	0.17	0.09	0	0	0	0.09	0	0	0	0	69.08	0.39	0.11	0	0	0	0	0	0	0	94.82
LFF1	20	1058	24.88	0	0.36	0.71	6.84	0.19	0	0	0	0.31	0.09	0	0	0.12	56.29	0.33	0	0	0	0	0	0	0	0	90.12
LFF1	20	1059	26.9	0	0.4	1.03	8.28	0.2	0	0	0.19	0.34	0.12	0	0	0.1	55.09	0.31	0	0	0	0	0	0	0	0	92.95
LFF1	20	1060	28.42	0.18	0.36	1.6	9.12	0.25	0	0	0.52	0.53	0.11	0	0	0.08	51.98	0.33	0	0	0	0	0	0	0	0	93.49
LFF1	20	1061	25.91	0	0.36	0.91	7.25	0.27	0	0	0	0.32	0.11	0	0	0.1	58.52	0.31	0	0	0	0	0	0	0	0	94.05
LFF1	20	1062	25.99	0	0.37	1.01	7.53	0.23	0	0	0	0.24	0.11	0	0	0	56.43	0.32	0	0	0	0	0	0	0	0	92.22
LFF1	21	1063	34.86	0.4	0.53	1.64	17.12	0.39	0	0	1.01	0.97	0	0	0	0.13	42.24	0.19	0	0	0	0	0	0	0	0	99.48
LFF1	21	1064	34.85	0.45	0.58	1.65	18.26	0.44	0	0	1.17	1.2	0	0	0	0.14	39.79	0.21	0	0	0	0	0	0	0	0	98.73
LFF1	21	1065	25.26	0	0.57	0.47	11.91	0.52	0	0.09	0.06	0.39	0	0	0	0.1	38.04	0.19	0	0	0	0	0	0	0	0	77.6
LFF1	21	1066	33.63	0.41	0.56	1.54	16.79	0.45	0	0	1.18	1.09	0	0	0	0.11	42.18	0.22	0	0	0	0	0	0	0	0	98.17
LFF1	21	1067	32.55	0.45	0.49	2.48	15.54	0.41	0	0	1.3	1.09	0	0	0	0.09	42.1	0.22	0	0	0	0	0	0	0	0	96.72
LFF1	21	1068	25.46	0	0.41	1.08	0.31	0	0	0	0	0.06	0.09	0	0	0.1	66.86	0.24	0	0	0	0	0	0	0	0	94.62
LFF1	21	1069	26.85	0	0.29	1.48	1.28	0	0	0	0.42	0.22	0.13	0	0	0.08	63.75	0.3	0	0	0	0	0	0	0	0	94.8
LFF1	21	1070	25.72	0	0.13	2.08	0.41	0	0	0	0	0	0.24	0	0	0	66.17	0.28	0	0	0	0	0	0	0	0	95.03
LFF1	21	1071	26.7	0	0.15	2.08	0.6	0	0	0	0	0	0.29	0	0	0	65.18	0.31	0	0	0	0	0	0	0	0	95.3
LFF1	21	1072	26.16	0	0.14	2.31	0.84	0	0	0	0	0.06	0.27	0	0	0	64.22	0.23	0	0	0	0	0	0	0	0	94.23
LFF1	21	1073	22.41	0	0.15	0.55	0.32	0	0	0	0	0	0.12	0	0	0	70.6	0.43	0	0	0	0	0	0	0	0	94.58
LFF1	21	1074	24.47	0	0.13	0.8	2.09	0	0	0	0.13	0.17	0.16	0	0	0	68.17	0.35	0	0	0	0	0	0	0	0	96.48
LFF1	21	1075	28.1	0.32	0.4	1.81	9.77	0.24	0	0	0.74	0.67	0.11	0	0	0.09	53.91	0.26	0	0	0	0	0	0	0	0	96.42
LFF1	21	1076	27.09	0	0.37	1.33	8.17	0.24	0	0	0.3	0.39	0.11	0	0	0.08	51.48	0.32	0	0	0	0	0	0	0	0	89.87
LFF1	21	1077	23.01	0	0.28	1.36	3.71	0.14	0	0.06	0.1	0.16	0.1	0	0	0.1	55.12	0.24	0	0	0	0	0	0	0	0	84.37
LFF1	22	1078	25.01	0	0.3	3.46	1.19	0.47	0.35	0.05	0	0.14	0.25	0	0	0.1	50.85	0.29	0	0	0	0	0	0	0	0	82.45
LFF1	22	1079	18.35	0	0.41	2.08	0.36	0.34	0.06	0.12	0	0.11	0.29	0	0	0.11	49.1	0.26	0	0	0	0	0	0	0	0	71.6
LFF1	22	1080	23.5	0	0.11	2.38	1.61	0.06	0	0	0.07	0.12	0	0	0	0.16	64	0.35	0	0	0	0	0	0	0	0	92.35
LFF1	22	1081	23.01	0	0.11	1.24	0.92	0.07	0	0	0	0	0	0	0	0.16	64.22	0.33	0	0	0	0	0	0	0	0	90.06
LFF1	22	1082	25.11	0	0.09	0.95	5.87	0	0	0	0.2	0.12	0	0	0	0	63.59	0.35	0	0	0	0	0	0	0	0	96.29
LFF1	22	1083	26.78	0	0.11	0.78	7.92	0	0	0	0.32	0.13	0	0	0	0	59.74	0.32	0	0	0	0	0	0	0	0	96.1
LFF1	23	1084	23.75	0	0.84	1.99	0.12	0	0	0.05	0	0.1	0.27	0	0	0.17	61.72	0.25	0	0	0	0	0	0	0	0	89.26
LFF1	23	1085	21.14	0	0	3.85	0.44	1.76	0.23	0.08	0	0.51	0.38	0	0	0	32.97	0.2	0	0	0	0	0	0	0	0	61.56
LFF1	23	1086	20.45	0	0	4.36	0.52	1.74	0.21	0.09	0.14	0.28	0.39	0	0	0	35.31	0.24	0	0	0	0	0	0	0	0	63.74
LFF1	23	1087	27.48	0	0	2.08	1.44	0.32	0.39	0.29	0	0.3	0	0	0	0	42.99	0.17	0.29	0	0	2.34	0	0	0	0	78.08
LFF1	23	1088	23.82	0	0	2.02	1.42	0.75	0.27	0.2	0	0.22	0.06	0	0	0	43.1	0.2	0.16	0	0	1.46	0	0	0	0	73.68
LFF1	23	1089	19.82	0	0.1	2.44	1.68	0.81	0.19	0.18	0	0.34	0.17	0	0	0	43.73	0.24	0.1	0	0	0.7	0	0	0	0	70.51
LFF1	25	1090	24.87	0	0.1	0.74	5.6	0	0	0	0.15	0.12	0	0	0	0	63.65	0.39	0	0	0	0	0	0	0	0	95.63
LFF1	26	1091	24.24	0	0.1	0.67	5.49	0	0	0	0	0.11	0	0	0	0	65.44	0.37	0	0	0	0	0	0	0	0	96.41

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	26	1092	29.95	0	0.15	0.29	12.98	0	0	0	0	0.11	0	0	0	0	54.29	0.32	0	0	0	0	0	0	0	0	98.07
LFF1	26	1093	29.45	0	0.25	0.29	12.55	0	0	0	0	0.13	0	0	0	0	55.36	0.34	0.11	0	0	0	0	0	0	0	98.49
LFF1	26	1094	29.01	0	0.22	0.29	12.78	0	0	0	0	0.11	0	0	0	0	55.31	0.32	0	0	0	0	0	0	0	0	98.04
LFF1	26	1095	29.52	0	0.17	0.32	12.32	0	0	0	0	0.11	0	0	0	0	57.33	0.26	0.1	0	0	0	0	0	0	0	100.1
LFF1	26	1096	30.34	0	0.18	0.29	13.36	0	0	0	0	0.14	0	0	0	0	53.16	0.3	0	0	0	0	0	0	0	0	97.76
LFF1	26	1097	21.4	0	0	0.33	0.11	0	0	0	0	0	0	0	0	0	73.47	0.38	0	0	0	0	0	0	0	0	95.7
LFF1	26	1098	21.25	0	0	0.32	0.1	0	0	0	0	0	0	0	0	0	73.24	0.3	0	0	0	0	0	0	0	0	95.21
LFF1	27	1099	22.02	0	0	0.71	1.79	0.18	0	0	0	0.09	0	0	0	0.1	65.58	0.38	0	0	0	0	0	0	0	0	90.86
LFF1	27	1100	22.1	0	0	0.75	1.78	0.18	0	0	0	0.11	0	0	0	0.09	66.07	0.37	0	0	0	0	0	0	0	0	91.44
LFF1	28	1101	23.01	0	0	0.48	2.19	0.11	0	0	0	0.11	0	0	0	0.12	67.92	0.29	0	0	0	0	0	0	0	0	94.23
LFF1	28	1102	23.64	0	0	0.48	2.37	0.06	0	0	0	0.12	0	0	0	0.12	67.53	0.34	0	0	0	0	0	0	0	0	94.67
LFF1	28	1103	29.1	0	0.19	0.35	12.33	0.52	0	0	0	0.47	0	0	0	0.23	52.12	0.28	0	0	0	0	0	0	0	0	95.58
LFF1	28	1104	21.47	0	0	0.43	0.16	0	0	0	0	0	0	0	0	0.08	72.13	0.33	0.11	0	0	0	0	0	0	0	94.71
LFF1	28	1105	21.73	0	0	0.41	0.23	0	0	0	0	0	0	0	0	0.08	72.07	0.39	0	0	0	0	0	0	0	0	94.91
LFF1	29	1106	24.41	0.18	0.26	1.87	4.49	0.11	0	0	0.32	0.33	0.08	0	0	0	61.66	0.31	0	0	0	0	0	0	0	0	94.03
LFF1	29	1107	23.5	0.17	0.28	2.34	4.49	0.13	0	0	0.28	0.31	0.08	0	0	0	56.58	0.3	0	0	0	0	0	0	0	0	88.45
LFF1	29	1108	22.07	0	0.25	2.24	2.93	0.12	0	0	0.12	0.16	0.08	0	0	0	60.29	0.34	0	0	0	0	0	0	0	0	88.6
LFF1	30	1109	21.76	0	0.26	0.59	0.15	0	0	0	0	0	0.12	0	0	0.09	72.3	0.34	0	0	0	0	0	0	0	0	95.61
LFF1	30	1110	21.52	0	0.19	0.6	0.11	0	0	0	0	0	0.1	0	0	0	73.09	0.36	0	0	0	0	0	0	0	0	95.97
LFF1	30	1111	21.75	0	0.19	0.59	0.09	0	0	0	0	0	0.09	0	0	0	73.16	0.37	0.1	0	0	0	0	0	0	0	96.35
LFF1	30	1112	21.02	0	0.19	0.58	0.08	0	0	0	0	0	0	0	0	0	73.01	0.38	0	0	0	0	0	0	0	0	95.26
LFF1	30	1113	21.33	0	0.23	0.57	0.08	0	0	0	0	0	0.1	0	0	0	73.24	0.39	0	0	0	0	0	0	0	0	95.94
LFF1	30	1114	21.09	0	0.24	0.55	0.09	0	0	0	0	0	0.08	0	0	0	72.87	0.42	0	0	0	0	0	0	0	0	95.33
LFF1	30	1115	33.21	0.59	0.45	3.2	16	0.33	0.05	0	1.23	1.29	0.07	0	0	0.1	41.16	0.25	0	0.12	0	0	0	0	0	0	98.06
LFF1	30	1116	31.08	0.7	0.47	3.12	15.32	0.33	0	0	1.37	0.99	0	0	0	0.13	43.76	0.2	0	0	0	0	0	0	0	0	97.48
LFF1	30	1117	32.13	0.64	0.4	3.18	15.09	0.32	0.06	0	1.35	1.26	0	0	0	0.11	42.38	0.19	0	0	0	0	0	0	0	0	97.09
LFF1	30	1118	23.84	0	0.41	3.74	8.97	0.49	0	0.07	0	0.24	0.1	0	0	0.08	39.07	0.2	0	0	0	0	0	0	0	0	77.19
LFF1	30	1119	21.68	0	0.32	1.76	7.11	0.47	0.06	0.06	0	0.17	0.15	0	0	0.09	47.92	0.27	0	0	0	0	0	0	0	0	80.05
LFF1	30	1120	24.08	0	0	3.12	3.73	0.48	0.29	0.1	0.16	0.11	0.1	0	0	0	47.75	0.25	0	0	0	0	0	0	0	0	80.18
LFF1	30	1121	21.58	0	0.22	1.6	2.2	0.14	0	0	0	0.07	0.1	0	0	0	61.72	0.37	0	0	0	0	0	0	0	0	87.99
LFF1	31	1122	24.05	0	0.24	0.75	6.15	0.12	0	0	0	0.3	0	0	0	0.13	59.66	0.33	0	0	0	0	0	0	0	0	91.73
LFF1	31	1123	24.73	0	0.23	0.85	6.58	0.12	0	0	0	0.28	0.07	0	0	0.19	58.35	0.32	0	0	0	0	0	0	0	0	91.74
LFF1	31	1124	24.85	0	0.24	0.94	5.85	0.18	0	0	0	0.31	0	0	0	0.13	61.23	0.32	0	0.13	0	0	0	0	0	0	94.18
LFF1	31	1125	24.44	0	0.21	0.82	6.62	0.11	0	0	0	0.29	0	0	0	0.2	57.51	0.28	0	0	0	0	0	0	0	0	90.48
LFF1	32	1126	24.78	0	0	0.3	0	0	0	0	0	0	0	0	0	0.22	67.13	0.37	0	0	0	0	0	0	0	0	92.8

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	32	1127	25.97	0	0	0.36	0.06	0	0	0	0	0	0	0	0	0.12	68.92	0.39	0	0	0	0	0	0	0	0	95.82
LFF1	32	1128	25.81	0	0	0.46	1.27	0.12	0	0	0	0	0	0	0	0.08	67.4	0.33	0	0	0	0	0	0	0	0	95.47
LFF1	32	1129	22.35	0	0	0.43	0.27	0	0	0	0	0	0	0	0	0.09	72.33	0.43	0	0	0	0	0	0	0	0	95.91
LFF1	32	1130	21.94	0	0	0.5	0.2	0	0	0	0	0	0	0	0	0.11	72.27	0.44	0.12	0	0	0	0	0	0	0	95.58
LFF1	32	1131	23.88	0	0	0.72	0.53	0	0	0	0	0	0	0	0	0	70.68	0.4	0	0	0	0	0	0	0	0	96.21
LFF1	32	1132	22.23	0	0	0.83	0.65	0	0	0	0	0	0.1	0	0	0	70.61	0.35	0	0	0	0	0	0	0	0	94.77
LFF1	32	1133	19.79	0	0	0.79	0.28	0	0	0	0	0	0.11	0	0	0.11	70.55	0.34	0	0	0	0	0	0	0	0	91.97
LFF1	32	1134	24.08	0	0	0.83	2.33	0	0	0	0	0.12	0	0	0	0.15	67.19	0.43	0	0	0	0	0	0	0	0	95.13
LFF1	32	1135	22.7	0	0	0.78	0.19	0	0	0	0	0	0.09	0	0	0.09	71.71	0.43	0	0	0	0	0	0	0	0	95.99
LFF1	32	1136	29.28	0	0.39	0.41	12.64	0.16	0	0	0	0.45	0	0	0	0.26	53.06	0.28	0	0	0	0	0	0	0	0	96.92
LFF1	32	1137	20.56	0	0.22	0.77	10.58	0.16	0	0.05	0	0.47	0	0	0	0.27	48.63	0.28	0	0	0	0	0	0	0	0	81.97
LFF1	32	1138	29.99	0	0.32	0.42	13.7	0.14	0	0	0	0.43	0	0	0	0.3	51.9	0.3	0	0	0	0	0	0	0	0	97.5
LFF1	32	1139	31.66	0	0.36	0.59	13.57	0.3	0	0	0	0.5	0	0	0	0.29	48.63	0.28	0	0	0	0	0	0	0	0	96.18
LFF1	32	1140	31.27	0	0.39	0.46	13.87	0.28	0	0.05	0	0.47	0	0	0	0.28	50.41	0.21	0	0	0	0	0	0	0	0	97.69
LFF1	32	1141	31.48	0	0.41	0.44	14	0.28	0	0	0.06	0.47	0	0	0	0.3	50.03	0.3	0	0	0	0	0	0	0	0	97.76
LFF1	32	1142	30.79	0	0.43	0.64	13.53	0.26	0	0	0.19	0.42	0	0	0	0.28	49.22	0.29	0	0	0	0	0	0	0	0	96.04
LFF1	32	1143	30.71	0	0.41	0.52	14.05	0.27	0	0	0.12	0.51	0	0	0	0.3	49.95	0.32	0	0	0	0	0	0	0	0	97.17
LFF1	32	1144	24.54	0	0.22	0.67	5.8	0.12	0	0	0	0.24	0.09	0	0	0.17	60.28	0.31	0	0	0	0	0	0	0	0	92.43
LFF1	32	1145	24.37	0	0.21	0.72	6.22	0.11	0	0	0	0.27	0	0	0	0.16	60.41	0.28	0	0	0	0	0	0	0	0	92.76
LFF1	32	1146	25.12	0	0.28	0.51	9.73	0.2	0	0.05	0	0.41	0	0	0	0.2	48.9	0.33	0	0	0	0	0	0	0	0	85.71
LFF1	33	1147	21.02	0	0.13	4.35	0.4	0.06	0	0.06	0	0.11	0	0	0	0	60.51	0.34	0	0	0	0	0	0	0	0	86.98
LFF1	33	1148	20.12	0	0.1	4.83	0.42	0.07	0	0.16	0	0.11	0	0	0	0	59.24	0.29	0	0	0	0	0	0	0	0	85.34
LFF1	33	1149	18.22	0	0	2.81	0.25	0	0	0.06	0	0	0.07	0	0	0	60.55	0.36	0	0	0	0	0	0	0	0	82.32
LFF1	33	1150	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	86.07	0.68	0.19	0	0	3.54	0	0.63	0	0	91.24
LFF1	34	1151	22.03	0	0.1	0.32	0.07	0	0	0	0	0	0.07	0	0	0	71.52	0.42	0	0	0	0	0	0	0	0	94.53
LFF1	34	1152	21.67	0	0.14	0.38	0.07	0	0	0	0	0	0.09	0	0	0	73.5	0.35	0	0	0	0	0	0	0	0	96.2
LFF1	34	1153	20.54	0	0.12	0.32	0.07	0	0	0	0	0	0.09	0	0	0	73.17	0.35	0	0	0	0	0	0	0	0	94.66
LFF1	34	1154	2.33	0	0	0.14	0	0	0.06	0.1	0	0	0	0	0	0	82.2	0.47	0.18	0	0	4.46	0	0.77	0	0	90.71
LFF1	34	1155	3.24	0	0	0.19	0	0	0	0.1	0	0	0	0	0	0	83.65	0.65	0.19	0	0	3.67	0	0.57	0	0	92.26
LFF1	34	1156	1.79	0	0	0.21	0	0	0	0	0	0	0	0	0	0	84	0.54	0	0	0	4.23	0	0.8	0	0	91.55
LFF1	34	1157	1.09	0	0	0.18	0	0	0	0	0	0	0	0	0	0	84.41	0.55	0.19	0	0	4.36	0	0.77	0	0	91.55
LFF1	34	1158	0	0	0	0.16	0	0	0	0	0	0	0	0	0	0	85.47	0.6	0.18	0	0	3.92	0	0.69	0	0	91.02
LFF1	34	1159	0	0	0	0.16	0.1	0	0	0	0	0	0	0	0	0	84.2	0.59	0.16	0	0	3.76	0	0.66	0	0	89.64
LFF1	35	1160	29.3	0.56	0.61	2.79	10.06	0.17	0	0	0.98	1.22	0.21	0	0	0.17	51.7	0.32	0	0	0	0	0	0	0	0	98.1
LFF1	35	1161	18.59	0	0.16	7.91	0.86	0.12	0	0.12	0	0.13	0.25	0	0	0	45.98	0.28	0	0	0	0	0	0	0	0	74.4

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	35	1162	26.48	0.43	0.49	3.78	7.76	0.15	0	0	0.73	0.91	0.22	0	0	0.13	50.06	0.25	0	0.13	0	0	0	0	0	0	91.53
LFF1	36	1163	29.81	0.6	0.63	2.83	10.11	0.16	0	0	1.04	1.2	0.23	0	0	0.18	51.82	0.29	0	0	0	0	0	0	0	0	98.9
LFF1	37	1164	26.51	0.27	0.17	1.36	6.97	0.06	0	0	0.55	0.32	0.1	0	0	0.08	59.61	0.37	0	0	0	0	0	0	0	0	96.38
LFF1	37	1165	26.56	0.31	0.18	1.34	6.97	0.08	0	0	0.57	0.33	0.1	0	0	0.08	59.74	0.33	0	0	0	0	0	0	0	0	96.6
LFF1	38	1166	25.6	0	0	0.22	0	0	0	0	0	0	0	0	0	0	67.02	0.38	0.11	0	0	0	0	0	0	0	93.33
LFF1	38	1167	25.4	0	0	0.17	0	0	0	0	0	0	0	0	0	0	69.05	0.37	0.11	0	0	0	0	0	0	0	95.09
LFF1	38	1168	24.92	0	0	0.17	0	0	0	0	0	0	0	0	0	0	69.21	0.36	0	0	0	0	0	0	0	0	94.66
LFF1	38	1169	25.26	0	0	1.21	0.32	0	0	0	0	0	0.09	0	0	0	67.57	0.31	0	0	0	0	0	0	0	0	94.75
LFF1	38	1170	25.32	0	0.13	1.21	0.19	0	0	0	0	0	0.11	0	0	0	67.82	0.29	0	0	0	0	0	0	0	0	95.07
LFF1	38	1171	25.57	0	0.1	1.57	0.19	0	0	0	0	0	0.14	0	0	0	67.65	0.32	0	0	0	0	0	0	0	0	95.53
LFF1	38	1172	25.72	0	0.1	1.71	0.24	0	0	0	0	0	0.12	0	0	0	67.3	0.33	0	0	0	0	0	0	0	0	95.52
LFF1	38	1173	26.03	0	0.12	1.74	0.32	0	0	0	0	0	0.15	0	0	0	67.02	0.4	0	0	0	0	0	0	0	0	95.77
LFF1	38	1174	25.24	0	0	1.74	0.26	0	0	0	0	0	0.18	0	0	0	67.12	0.36	0	0	0	0	0	0	0	0	94.9
LFF1	38	1175	26.27	0	0	1.7	0.5	0	0	0	0	0	0.18	0	0	0	66.46	0.25	0	0	0	0	0	0	0	0	95.37
LFF1	38	1176	25.27	0	0	1.51	0.28	0	0	0	0	0	0.13	0	0	0	67.14	0.3	0	0	0	0	0	0	0	0	94.64
LFF1	38	1177	25.58	0	0.16	1.46	0.29	0	0	0	0	0	0.11	0	0	0.08	67.53	0.29	0	0	0	0	0	0	0	0	95.5
LFF1	38	1178	24.94	0	0.11	1.44	0.25	0	0	0	0	0	0.13	0	0	0	67.02	0.33	0	0	0	0	0	0	0	0	94.22
LFF1	38	1179	25.05	0	0.09	0.77	0.98	0	0	0	0.09	0	0.09	0	0	0	69.55	0.37	0	0	0	0	0	0	0	0	96.98
LFF1	38	1180	32.91	0.51	0.32	1.63	15.74	0.16	0	0	1.18	0.77	0	0	0	0.13	45.49	0.26	0	0	0	0	0	0	0	0	99.1
LFF1	38	1181	30.81	0.5	0.3	1.48	14.1	0.13	0	0	0.99	0.59	0	0	0	0.12	51.24	0.32	0	0	0	0	0	0	0	0	100.6
LFF1	38	1182	23.28	0	0	0.47	1.09	0	0	0	0	0	0.07	0	0	0	71.15	0.38	0	0	0	0	0	0	0	0	96.44
LFF1	38	1183	27.7	0	0.1	1.63	3.22	0	0	0	0.4	0.21	0.13	0	0	0	61.8	0.34	0	0	0	0	0	0	0	0	95.54
LFF1	38	1184	23.92	0	0	0.8	0.92	0	0	0	0	0	0	0	0	0.09	70.25	0.38	0	0	0	0	0	0	0	0	96.36
LFF1	40	1185	27.34	0	0	0.61	0.37	0	0	0	0	0.13	0	0	0	0	66.01	0.37	0	0	0	0	0	0	0	0	94.84
LFF1	40	1186	25.65	0	0	0.18	0.17	0	0	0	0	0	0	0	0	0	69.1	0.41	0.11	0	0	0	0	0	0	0	95.62
LFF1	40	1187	25.27	0	0	0.28	3.19	0.18	0	0	0	0.07	0	0	0	0	65.92	0.36	0	0	0	0	0	0	0	0	95.26
LFF1	40	1188	22.33	0	0	0.16	0.23	0	0	0	0	0	0	0	0	0	71.8	0.34	0	0	0	0	0	0	0	0	94.86
LFF1	40	1189	23.06	0	0	0.22	0.08	0	0	0	0	0	0	0	0	0	70.78	0.29	0	0	0	0	0	0	0	0	94.42
LFF1	40	1190	21.35	0	0	0.23	0.18	0	0	0	0	0	0	0	0	0	71.75	0.44	0	0	0	0	0	0	0	0	93.95
LFF1	40	1191	22.5	0	0	0.39	0.19	0	0	0	0	0	0	0	0	0	71.86	0.41	0	0	0	0	0	0	0	0	95.35
LFF1	40	1192	34.64	1	0.2	2.2	17.05	0.38	0.1	0	1.65	1.98	0	0	0	0.09	38.79	0.25	0	0	0	0	0	0	0	0	98.33
LFF1	41	1193	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	85.58	1.3	1.83	0	0	0.62	0	0	0	0	89.48
LFF2	2	1194	25.17	0	0.1	0.37	0	0	0	0	0	0	0	0	0	0.12	69.03	0.38	0	0	0	0	0	0	0	0	95.16
LFF2	2	1195	25.38	0	0.13	0.44	0.06	0	0	0	0	0.17	0	0	0	0.11	68.85	0.35	0	0	0	0	0	0	0	0	95.49
LFF2	2	1196	26.29	0	0.14	1.04	0.26	0	0	0	0	0	0.11	0	0	0	68.57	0.28	0	0	0	0	0	0	0	0	96.69

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	2	1197	22.87	0	0.21	0.73	0.1	0	0	0	0	0	0.1	0	0	0.13	72.21	0.35	0	0	0	0	0	0	0	0	96.71
LFF2	2	1198	23.74	0	0.18	0.77	0.12	0	0	0	0	0	0.12	0	0	0	71.89	0.47	0	0	0	0	0	0	0	0	97.28
LFF2	2	1199	21.82	0	0.21	0.67	0	0	0	0	0	0	0	0	0	0.11	72.13	0.39	0	0	0	0	0	0	0	0	95.33
LFF2	2	1200	23.48	0	0.19	0.77	0.1	0	0	0	0	0	0.1	0	0	0	72.31	0.34	0	0	0	0	0	0	0	0	97.29
LFF2	2	1201	22.95	0	0.12	0.73	0.19	0	0	0	0	0	0.1	0	0	0	71.93	0.45	0.11	0	0	0	0	0	0	0	96.6
LFF2	2	1202	22.56	0	0.17	0.67	0.09	0	0	0	0	0	0.11	0	0	0	72.29	0.36	0	0	0	0	0	0	0	0	96.27
LFF2	2	1203	22.11	0	0.13	0.49	0	0	0	0	0	0	0	0	0	0.1	72.89	0.42	0.11	0	0	0	0	0	0	0	96.25
LFF2	2	1204	22.33	0	0	0.5	0.07	0	0	0	0	0	0	0	0	0.09	72.93	0.35	0	0	0	0	0	0	0	0	96.27
LFF2	2	1205	22.43	0	0.13	0.52	0.08	0	0	0	0	0	0	0	0	0.09	72.28	0.31	0.12	0	0	0	0	0	0	0	95.96
LFF2	2	1206	22.82	0	0.17	0.66	0.09	0	0	0	0	0	0.08	0	0	0	72.11	0.43	0	0	0	0	0	0	0	0	96.35
LFF2	2	1207	22.56	0	0.15	0.65	0.09	0	0	0	0	0	0	0	0	0	72.18	0.47	0	0	0	0	0	0	0	0	96.1
LFF2	2	1208	25.88	0	0.14	0.58	0.12	0	0	0	0	0	0.08	0	0	0	68.56	0.38	0	0	0	0	0	0	0	0	95.76
LFF2	2	1209	34.31	0.62	0.41	2.86	16.13	0.57	0.1	0	1.3	1.47	0	0	0	0.21	40.89	0.16	0	0	0	0	0	0	0	0	99.03
LFF2	2	1210	34.43	0.57	0.45	2.91	16.49	0.61	0.11	0	1.36	1.24	0	0	0	0.21	40.88	0.19	0	0	0	0	0	0	0	0	99.44
LFF2	2	1211	34.73	0.57	0.43	3.06	16.29	0.6	0.11	0	1.5	1.38	0	0	0	0.22	40.94	0.21	0	0	0	0	0	0	0	0	100
LFF2	2	1212	17.41	0	0.09	9.97	0.44	0	0	0	0	0.07	0	0	0	0.1	64.62	0.39	0	0.14	0	0	0	0	0	0	93.23
LFF2	2	1213	18.46	0	0.1	5.48	0.69	0.39	0.07	0	0	0.73	0	0	0	0.09	57.09	0.29	0	0	0	0	0	0	0	0	83.39
LFF2	2	1214	16.42	0	0.1	11.95	0.95	0.06	0.05	0.06	0	0.24	0	0	0	0	56.73	0.42	0	0.13	0	0	0	0	0	0	87.11
LFF2	2	1215	35.15	0.73	0.44	2.68	17.2	0.66	0.11	0	1.49	2.13	0	0	0	0.25	38.12	0.22	0	0	0	0	0	0	0	0	99.19
LFF2	2	1216	33.38	0.71	0.49	2.75	16.35	0.61	0.1	0	1.19	1.46	0	0	0	0.21	40.74	0.26	0	0	0	0	0	0	0	0	98.25
LFF2	2	1217	26.17	0	0.21	0.57	0	0	0	0	0	0.36	0	0	0	0.16	67.32	0.35	0	0	0	0	0	0	0	0	95.15
LFF2	2	1218	24.2	0	0.21	1.48	2.23	0.1	0	0	0.18	0.17	0.09	0	0	0.1	67.61	0.45	0	0	0	0	0	0	0	0	96.8
LFF2	3	1219	23.27	0	0.09	2.14	0.79	0.2	0	0	0.08	0.26	0	0	0	0	66.94	0.37	0	0.13	0	0	0	0	0	0	94.27
LFF2	3	1220	27.86	0.21	0	0.32	0	0	0	0	0.1	0.29	0	0	0	0	66.46	0.27	0	0	0	0	0	0	0	0	95.51
LFF2	3	1221	24.27	0	0	0.37	0.09	0	0	0	0	0	0	0	0	0	69.48	0.4	0	0	0	0	0	0	0	0	94.61
LFF2	3	1222	22.02	0	0	1.99	0.23	0	0	0	0	0.08	0	0	0	0	72.1	0.34	0	0	0	0	0	0	0	0	96.76
LFF2	3	1223	23.46	0	0	4.05	0.26	0	0	0	0	0.07	0	0	0	0.08	69.86	0.41	0	0	0	0	0	0	0	0	98.18
LFF2	3	1224	22.15	0	0	0.4	0.11	0	0	0	0	0	0	0	0	0.1	73	0.45	0	0	0	0	0	0	0	0	96.22
LFF2	3	1225	23.32	0	0	0.48	0.13	0	0	0	0	0	0	0	0	0.09	71.94	0.34	0	0	0	0	0	0	0	0	96.29
LFF2	3	1226	23.29	0	0	0.52	0.12	0	0	0	0	0	0	0	0	0.11	72.89	0.41	0	0	0	0	0	0	0	0	97.34
LFF2	3	1227	27.38	0.59	0.09	0.8	4.05	1.93	0.46	0	0.62	2.07	0	0	0	0.14	60.04	0.3	0	0	0	0	0	0	0	0	98.46
LFF2	3	1228	26.24	0.49	0	0.86	4.2	0.86	0.09	0	0.29	0.65	0	0	0	0.14	64.41	0.44	0	0	0	0	0	0	0	0	98.66
LFF2	3	1229	23.79	0	0	0.87	0.56	0.06	0.06	0	0	0.09	0	0	0	0.09	71.51	0.41	0	0	0	0	0	0	0	0	97.44
LFF2	3	1230	37.8	0.93	0	24.3	12.28	0.36	0.06	0.11	0.63	1.47	0.1	0	0	0.07	8	0	0.09	0.25	0	0	0	0	0.37	0	86.83
LFF2	3	1231	31.4	0	0	33.53	2.06	0.25	0.06	0.09	0.11	0.53	0	0	0	0	14.73	0	0	0.14	0	0	0	0	0	0	82.91

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	3	1232	30.27	0	0	35.52	1.53	0.15	0.08	0.12	0.09	0.4	0	0	0	0	11.84	0	0	0.13	0	0	0	0	0	0	80.14
LFF2	3	1233	25.87	0	0	0.38	0.38	0.42	0	0	0.07	0.35	0	0	0	0.12	66.84	0.33	0	0	0	0	0	0	0	0	94.74
LFF2	3	1234	25.8	0	0	0.58	0	0	0	0	0	0	0	0	0	0	69.41	0.39	0	0	0	0	0	0	0	0	96.19
LFF2	3	1235	23.5	0	0	0.65	0	0	0	0	0	0	0	0	0	0	71.18	0.37	0	0	0	0	0	0	0	0	95.7
LFF2	3	1236	22.17	0	0	0.52	0.13	0	0	0	0	0	0	0	0	0.08	73.04	0.39	0	0	0	0	0	0	0	0	96.34
LFF2	3	1237	25.74	0	0	0.81	3.37	0.31	0.06	0	0	0.21	0	0	0	0.11	66.13	0.38	0	0	0	0	0	0	0	0	97.12
LFF2	4	1238	26.25	0	0	0.85	4.48	0.39	0	0	0.12	0.35	0	0	0	0.14	64.02	0.28	0	0	0	0	0	0	0	0	96.88
LFF2	4	1239	26.07	0	0	0.9	4.38	0.4	0	0	0.13	0.31	0	0	0	0.1	64.16	0.33	0	0	0	0	0	0	0	0	96.78
LFF2	4	1240	28.59	0.24	0.09	0.95	5.47	0.68	0.07	0	0.32	0.41	0	0	0	0.14	63.36	0.31	0	0	0	0	0	0	0	0	100.7
LFF2	4	1241	27.23	0	0	0.9	4.68	0.67	0	0	0.21	0.72	0	0	0	0.1	62.92	0.39	0	0	0	0	0	0	0	0	97.82
LFF2	4	1242	24.66	0	0	0.8	3.72	0.3	0	0	0.18	0.22	0	0	0	0.12	64.82	0.33	0	0	0	0	0	0	0	0	95.16
LFF2	4	1243	26.31	0	0	0.9	4.13	0.17	0	0	0	0.09	0	0	0	0.1	65.33	0.3	0	0	0	0	0	0	0	0	97.34
LFF2	4	1244	28.13	0	0	1.03	4.57	0.8	0	0	0.24	0.67	0	0	0	0.1	63.29	0.35	0	0	0	0	0	0	0	0	99.2
LFF2	4	1245	22.89	0	0	0.49	0.38	0.17	0	0	0	0.24	0	0	0	0.1	70.98	0.41	0	0	0	0	0	0	0	0	95.66
LFF2	4	1246	25.09	0	0	1.26	0.18	0	0	0	0	0	0	0	0	0.08	69.01	0.29	0	0	0	0	0	0	0	0	95.91
LFF2	4	1247	25.05	0	0	1.22	0.35	0	0	0	0	0.09	0	0	0	0	68.99	0.37	0	0	0	0	0	0	0	0	96.07
LFF2	4	1248	22.21	0	0	0.5	0.13	0	0	0	0	0	0	0	0	0	72.41	0.4	0	0	0	0	0	0	0	0	95.63
LFF2	4	1249	25.32	0	0	0.84	3.29	0.34	0	0	0.07	0.24	0	0	0	0.13	66.85	0.36	0	0	0	0	0	0	0	0	97.43
LFF2	4	1250	25.19	0	0	0.83	3.82	0.34	0	0	0	0.24	0	0	0	0.13	65.21	0.35	0	0	0	0	0	0	0	0	96.11
LFF2	4	1251	26.6	0	0	0.92	3.99	0.43	0	0	0.08	0.24	0	0	0	0.1	64.54	0.31	0	0	0	0	0	0	0	0	97.22
LFF2	4	1252	25.65	0	0	0.56	1.6	0.79	0.19	0	0.4	1.1	0	0	0	0.11	66.87	0.32	0	0	0	0	0	0	0	0	97.59
LFF2	4	1253	26.01	0	0	1.91	1.18	0.24	0.28	0	0.11	0.16	0	0	0	0	68.99	0.39	0	0	0	0	0	0	0	0	99.27
LFF2	5	1254	23.45	0	0.15	1.13	1.34	0.67	0.05	0	0.17	0.59	0	0	0	0.29	65.55	0.34	0.11	0	0	0	0	0	0	0	93.85
LFF2	6	1255	23.92	0	0	6.72	0.39	0.22	0	0	0	0.47	0	0	0	0.29	63.06	0.27	0	0	0	0	0	0	0	0	95.34
LFF2	6	1256	14.98	0	0	9.01	0.75	0	0.13	0	0	0.35	0	0	0	0.34	58.87	0.36	0	0.18	0	0	0	0	0	0	84.97
LFF2	6	1257	20.29	0	0.07	12.16	0.42	0	0	0	0	0.2	0	0	0	0.27	59.21	0.41	0	0	0	0	0	0	0	0	93.03
LFF2	6	1258	16.84	0	0	8.74	0.6	0	0	0	0	0.28	0	0	0	0.31	60.47	0.33	0	0.19	0	0	0	0	0	0	87.76
LFF2	6	1259	17.36	0	0	7.76	0.38	0	0	0	0	0.23	0	0	0	0.35	63.04	0.34	0	0	0	0	0	0	0	0	89.47
LFF2	6	1260	18.56	0	0	12.25	0.39	0	0	0	0	0.16	0	0	0	0.24	57.51	0.29	0	0.16	0	0	0	0	0	0	89.56
LFF2	6	1261	21.37	0	0	15.34	0.26	0	0	0	0	0.13	0	0	0	0.23	57.02	0.32	0	0.14	0	0	0	0	0	0	94.81
LFF2	6	1262	22.03	0	0	17.63	0.48	0.08	0	0	0	0.19	0	0	0	0.21	48.31	0.33	0	0.15	0	0	0	0	0	0	89.41
LFF2	6	1263	11.8	0	0	2.62	0.08	0	0	0	0	0	0	0	0	0.24	69.86	0.39	0	0	0	0	0	0	0	0	84.99
LFF2	6	1264	19.68	0	0	11.29	0.46	0	0	0	0	0.16	0	0	0	0.27	59.08	0.32	0	0.11	0	0	0	0	0	0	91.36
LFF2	6	1265	22.23	0	0	6.66	0.22	0	0	0	0	0.15	0	0	0	0.28	69.43	0.29	0	0	0	0	0	0	0	0	99.25
LFF2	6	1266	20.32	0	0.08	5.32	0.31	0	0	0	0	0.17	0	0	0	0.3	68.57	0.36	0	0	0	0	0	0	0	0	95.43

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	6	1267	16.44	0	0	8.69	0.42	0	0	0	0	0.15	0	0	0	0.26	63.23	0.36	0	0.15	0	0	0	0	0	0	89.7
LFF2	6	1268	19.01	0	0	9.76	0.25	0	0	0	0	0.1	0	0	0	0.16	60.81	0.37	0	0.14	0	0	0	0	0	0	90.61
LFF2	6	1269	21.56	0	0	7.29	0.47	0.38	0	0	0.13	0.74	0	0	0	0.25	63.93	0.37	0	0	0	0	0	0	0	0	95.13
LFF2	6	1270	23.15	0.48	0.13	0.27	1.35	3.91	0	0	0.77	6.16	0	0	0	0.31	55.94	0.32	0	0	0	0	0	0.37	0	0	93.16
LFF2	6	1271	23.36	0.4	0.13	0.6	1.21	3.75	0	0	0.94	6.58	0	0	0	0.36	54.88	0.26	0	0	0	0	0	0.36	0	0	92.82
LFF2	6	1272	21.86	0.36	0.21	0.42	1.78	3.63	0	0	1	6.68	0	0	0	0.44	52.24	0.27	0	0	0	0	0.24	0.52	0	0	89.65
LFF2	6	1273	27.43	0.5	0.19	0.44	3.21	6.63	0	0	1.78	13.46	0	0	0	0.52	33.17	0.19	0	0	0	0	0.35	0.86	0	0	88.73
LFF2	6	1274	22.89	0.71	0.32	0.39	1.58	5.38	0	0	1.08	6.6	0	0	0	0.47	53.95	0.33	0	0	0	0	0.27	0.56	0	0	94.53
LFF2	6	1275	22.03	0.52	0.3	0.53	2.21	4.65	0	0	0.98	5.95	0	0	0	0.43	54.7	0.36	0	0	0	0	0	0.36	0	0	93.02
LFF2	6	1276	21.35	0.47	0.29	0.58	1.3	3.47	0	0	0.55	4.15	0	0	0	0.35	61.93	0.34	0	0	0	0	0	0.4	0	0	95.17
LFF2	7	1277	23.92	0.27	0.27	0.67	3.25	4	0.08	0	1.23	6.7	0	0	0	0.52	46.19	0.36	0	0	0	0	0	0.45	0	0	87.91
LFF2	7	1278	33.9	0.55	0.48	1.39	8.72	7.13	0.18	0	2.29	9.23	0	0	0	0.76	30.8	0.16	0	0	0	0	0	0.54	0.25	0	96.38
LFF2	7	1279	22.61	0.7	0.43	0.89	2.48	5.14	0	0	1.53	5.55	0	0	0	0.47	52.88	0.29	0	0	0	0	0	0.29	0	0	93.25
LFF2	7	1280	25.63	0.69	0.51	0.76	2.85	6.57	0.06	0	1.55	6.67	0	0	0	0.52	47.4	0.27	0	0	0	0	0	0.5	0	0	93.99
LFF2	7	1281	28.88	0.47	0.48	1.2	7	4.94	0.19	0	1.62	5.67	0	0	0	0.65	41.19	0.23	0	0	0	0	0	0.43	0.16	0	93.12
LFF2	7	1282	28.54	0.51	0.47	1.44	6.95	5.33	0.13	0	1.4	5.49	0	0	0	0.55	46.68	0.28	0	0	0	0	0	0.34	0	0	98.11
LFF2	7	1283	27.19	0.43	0.38	1.05	5.59	4.63	0.11	0	1.21	5.03	0	0	0	0.52	48.53	0.25	0	0	0	0	0	0.43	0	0	95.34
LFF2	7	1284	26.87	0.3	0.33	1.04	5.18	3.94	0.13	0	1.5	5.64	0	0	0	0.58	42.64	0.28	0	0	0	0	0	0.41	0	0	88.85
LFF2	7	1285	24.5	0.5	0.43	1.61	6.53	3.63	0.15	0	1.34	3.65	0	0	0	0.48	50.54	0.3	0	0	0	0	0	0.23	0	0	93.87
LFF2	7	1286	33.26	0.44	0.5	1.77	7.43	6.98	0.21	0	1.65	7.58	0	0	0	0.7	36.58	0.21	0	0	0	0	0	0.48	0	0	97.82
LFF2	7	1287	37.98	0.18	0.25	18.27	5.87	5.23	0.18	0	1.46	5.89	0	0	0	0.55	24.45	0.18	0	0.11	0	0	0	0.3	0	0	100.9
LFF2	7	1288	26.68	0.65	0.53	1.09	5.05	6.07	0.11	0	1.32	5.36	0	0	0	0.57	47.78	0.3	0	0	0	0	0	0.3	0	0	95.81
LFF2	7	1289	34.05	0.55	0.5	1.89	8.9	7.22	0.36	0	1.77	7.2	0	0	0	0.84	32.27	0.14	0	0	0	0	0	0.5	0	0	96.2
LFF2	7	1290	26.67	0.52	0.51	1.14	4.92	6.27	0.12	0	1.79	4.75	0	0	0	0.65	45.32	0.25	0	0	0	0	0	0	0	0	92.92
LFF2	7	1291	25.21	0.39	0.45	1.18	5.56	3.97	0.16	0	1.08	4.31	0	0	0	0.56	48.77	0.27	0	0	0	0	0	0.22	0	0	92.14
LFF2	7	1292	30.65	0.53	0.42	1.72	8.72	5.37	0.3	0	1.82	6.38	0	0	0	0.65	36.88	0.24	0	0	0	0	0	0.32	0	0	94
LFF2	7	1293	24.48	0.63	0.18	15.39	1.2	0.16	0.11	0.26	0.11	0.52	0	0	0	0.14	49.72	0.26	0	0.15	0	0	0	0	0	0	93.31
LFF2	7	1294	24.67	0.84	0.25	12.6	2.71	0.85	0.65	0.3	0.65	1.82	0	0	0	0.22	47.13	0.25	0	0.13	0	0	0	0	0	0	93.07
LFF2	7	1295	30.39	0.32	0.41	0.99	7.06	5.37	0.33	0	1.34	6.29	0	0	0	0.76	37.37	0.25	0	0.14	0	0	0	0.44	0	0	91.45
LFF2	7	1296	27.5	0.3	0.36	1.31	6.69	4.13	0.21	0	1.58	4.52	0	0	0	0.65	41.35	0.23	0	0	0	0	0	0.3	0	0	89.12
LFF2	7	1297	18.78	0.37	0.54	0.55	2.37	2.15	0.06	0	0	0.19	0	0	0	0.51	63.43	0.37	0	0	0	0	0	0	0	0	89.31
LFF2	7	1298	20.85	0.34	0.47	0.94	3.63	2.59	0.12	0	0.37	1.97	0	0	0	0.47	61.36	0.35	0	0	0	0	0	0	0	0	93.46
LFF2	8	1299	30	0.28	0.43	1.04	7.1	5.42	0.29	0	1.42	6.31	0	0	0	0.76	37.87	0.25	0	0	0	0	0	0.5	0	0	91.67
LFF2	8	1300	24.66	0.38	0.49	1.7	9.07	5.63	0.25	0	1.82	5.5	0	0	0	0.62	36.68	0.22	0	0	0	0	0	0.33	0	0	87.34
LFF2	8	1301	32.85	0.35	0.77	1.37	8.93	6.26	0.46	0	0.86	5.3	0	0	0	1.17	38.03	0.27	0	0	0	0	0	0.4	0	0	97.01

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	8	1302	23.26	0.15	0.64	0.57	4.68	3.42	0.05	0	0.06	0.34	0	0	0	0.7	57.39	0.35	0	0	0	0	0	0	0	0	91.62
LFF2	8	1303	31.92	0.14	0.57	1.11	7.78	5.74	0.07	0.05	0.13	0.83	0	0	0	0.87	43.65	0.17	0	0	0	0	0	0	0	0	93.02
LFF2	9	1304	23.38	0	0	1.99	1.43	0.18	0.05	0	0	0.17	0	0	0	0.11	64.84	0.38	0	0	0	0	0	0	0	0	92.52
LFF2	9	1305	22.97	0	0	1.27	0.77	0.09	0	0	0	0.12	0	0	0	0.11	70.64	0.31	0	0	0	0	0	0	0	0	96.29
LFF2	9	1306	23.02	0	0	1.27	1.17	0.14	0	0	0	0.16	0	0	0	0.1	69.98	0.41	0	0	0	0	0	0	0	0	96.25
LFF2	9	1307	23.76	0	0	1.24	1.4	0.23	0	0	0	0.2	0	0	0	0.1	68.14	0.36	0	0	0	0	0	0	0	0	95.43
LFF2	9	1308	24.98	0	0	2.38	1.67	0.31	0.06	0.07	0.08	0.18	0	0	0	0.08	62.83	0.3	0	0	0	0	0	0	0	0	92.95
LFF2	9	1309	15.87	0	0.1	2.91	0.78	0	0	1.02	0.07	0.23	0	0	0	0.1	36.85	0.15	0	0	0	0	0	0	0	0	58.09
LFF2	10	1310	32.42	0.29	0.16	1.03	14	1.71	0.42	0	0.88	1.99	0	0	0	0.26	45.28	0.21	0	0	0	0	0	0	0	0	98.66
LFF2	10	1311	31.99	0.31	0.13	1.09	14.14	1.86	0.51	0	0.99	2.9	0	0	0	0.29	43.51	0.25	0.1	0	0	0	0	0.23	0	0	98.29
LFF2	10	1312	32.07	0.29	0.14	1.15	13.71	1.81	0.71	0	0.89	2	0	0	0	0.27	45.31	0.21	0	0	0	0	0	0	0	0	98.57
LFF2	10	1313	32.31	0.31	0.11	1.12	13.51	1.79	0.77	0	0.83	2.02	0	0	0	0.24	45.56	0.24	0	0.11	0	0	0	0	0	0	98.92
LFF2	10	1314	33.04	0.24	0.08	0.99	13.77	1.94	0.78	0	0.73	1.95	0	0	0	0.25	44.88	0.17	0	0	0	0	0	0.23	0	0	99.06
LFF2	10	1315	33.89	0.26	0.15	1	13.59	1.98	0.72	0	0.71	2.01	0	0	0	0.26	44.78	0.22	0	0	0	0	0	0	0	0	99.57
LFF2	10	1316	32.72	0.34	0.13	1.07	13.69	1.74	0.5	0	0.96	2.21	0	0	0	0.2	45.14	0.29	0	0	0	0	0	0	0	0	98.99
LFF2	10	1317	35.06	0.37	0.13	1.03	14.8	2.36	0.74	0	0.88	2.77	0	0	0	0.27	42.24	0.25	0	0	0	0	0	0	0	0	100.9
LFF2	11	1318	23.91	0	0.14	2.09	2.36	0.21	0	0	0.18	0.39	0	0	0	0	64.44	0.3	0	0.14	0	0	0	0	0	0	94.18
LFF2	11	1319	34.01	0.57	0.2	2.33	14.84	1.14	0.08	0	1.56	2.45	0	0	0	0	41.98	0.17	0	0	0	0	0	0	0	0	99.32
LFF2	11	1320	33.29	0.5	0.18	2.26	14.73	1.14	0.06	0	1.48	2.4	0	0	0	0.1	42.07	0.23	0	0	0	0	0	0.25	0	0	98.69
LFF2	11	1321	31.25	0	0.27	2.89	11.67	1.22	0.18	0	0.22	2.7	0	0	0	0	45.24	0.19	0	0	0	0	0	0.24	0	0	96.08
LFF2	11	1322	34.95	0.67	0.19	2.43	15.6	1.33	0.09	0	1.93	2.63	0	0	0	0	39.45	0.21	0	0	0	0	0	0	0	0	99.48
LFF2	11	1323	34.72	0.65	0.26	2.49	15.34	1.31	0.1	0	1.82	2.47	0	0	0	0	40	0.23	0	0	0	0	0	0	0	0	99.39
LFF2	11	1324	35.03	0.51	0.31	2.59	15.8	1.29	0.11	0	1.9	2.41	0	0	0	0	39.44	0.27	0	0	0	0	0	0.29	0	0	99.93
LFF2	11	1325	22.22	0	0.11	0.55	0.1	0	0	0	0	0	0	0	0	0	72.69	0.42	0	0	0	0	0	0	0	0	96.09
LFF2	11	1326	22.61	0	0	0.5	0.15	0	0	0	0	0	0	0	0	0	72.41	0.41	0	0.12	0	0	0	0	0	0	96.19
LFF2	11	1327	22.43	0	0	0.52	0.16	0	0	0	0	0	0	0	0	0	72.13	0.4	0	0	0	0	0	0	0	0	95.65
LFF2	11	1328	33.07	0.13	0.31	0.57	11.85	1.71	0.09	0	0.09	1.78	0	0	0	0.1	45.52	0.25	0	0	0	0	0	0.17	0	0	95.64
LFF2	11	1329	32.7	0	0.25	0.63	11.04	1.72	0.08	0	0	1.89	0	0	0	0	46.09	0.2	0	0	0	0	0	0	0	0	94.59
LFF2	11	1330	32.08	0.23	0.3	0.8	11.67	1.78	0.12	0	0.28	2.25	0	0	0	0	43.72	0.25	0	0.11	0	0	0	0	0	0	93.59
LFF2	12	1331	21.87	0	0	0.69	0.18	0.13	0	0	0	0	0	0	0	0	69.93	0.33	0	0	0	0	0	0	0	0	93.13
LFF2	12	1332	33.91	1.38	0.19	1.02	17.2	0.48	0	0	1.03	5.48	0	0	0	0.17	34.48	0.14	0	0	0	0	0	0.31	0	0	95.79
LFF2	12	1333	34.3	1.36	0.14	0.93	17.42	0.44	0	0	0.9	5.47	0	0	0	0.13	35.98	0.21	0	0	0	0	0	0.38	0	0	97.68
LFF2	12	1334	34.26	1.42	0.14	0.9	17.7	0.47	0	0	0.97	5.58	0	0	0	0.15	35.05	0.2	0	0	0	0	0	0.4	0	0	97.24
LFF2	12	1335	29.27	1.44	0.29	0.99	13.12	0.32	0	0	0.57	3.38	0	0	0	0.12	49.71	0.21	0	0	0	0	0	0.28	0	0	99.7
LFF2	12	1336	25.71	1.3	0.41	1.19	11.3	0.43	0	0	1.13	4.68	0	0	0	0.12	48.67	0.27	0	0	0	0	0	0.32	0	0	95.53

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	12	1337	26.06	1.15	0.31	1.35	9.7	0.29	0	0	0.68	4.03	0	0	0	0.09	52.94	0.35	0	0	0	0	0	0.27	0	0	97.24
LFF2	12	1338	17.63	0	0.08	12.8	0.87	0.06	0.06	0.05	0	0.25	0	0	0	0	49.42	0.26	0	0.22	0	0	0	0	0	0	81.7
LFF2	12	1339	19.83	0	0	8.48	0.65	0	0	0	0	0.15	0	0	0	0	63.56	0.36	0	0	0	0	0	0	0	0	93.03
LFF2	12	1340	18.3	0	0	16.61	1.05	0.19	0.04	0.08	0.08	0.38	0	0	0	0	31.35	0.17	0	0	0	0	0	0	0	0	68.26
LFF2	12	1341	18.81	0	0	18.26	1.03	0.62	0.07	0.17	0.15	0.52	0.25	0	0	0	36.77	0.26	0	0.19	0	0	0	0	0	0	77.1
LFF2	12	1342	20.68	0	0.05	18.09	1.64	0.11	0	0.11	0.1	0.41	0	0	0	0	19.19	0.15	0	0	0	0	0	0	0	0	60.54
LFF2	12	1343	31.16	0.72	0	0.23	0.87	12.98	0.11	0	2.52	3.98	0	0	0	0.19	40.4	0.25	0	0	0	0	0	0	0	0	93.4
LFF2	12	1344	29.16	0.74	0.07	0.21	1.08	11.73	0.13	0	2.01	2.89	0	0	0	0.15	45.93	0.26	0	0	0	0	0	0.22	0	0	94.58
LFF2	12	1345	29.64	0.53	0	0.21	1.21	11.87	0.18	0	1.75	2	0	0	0	0.18	46.26	0.25	0	0	0	0	0	0	0	0	94.08
LFF2	12	1346	33.52	0.81	0	0.12	2.13	14.03	0.24	0	1.97	1.36	0	0	0	0.16	43.7	0.25	0	0	0	0	0	0	0	0	98.27
LFF2	12	1347	22.11	0	0	21.4	1.02	0.05	0.07	0.08	0	0.18	0	0	0	0	46.2	0.26	0	0.21	0	0	0	0	0	0	91.55
LFF2	12	1348	26.24	0	0	24.73	0.6	0.26	0	0.06	0	0.15	0	0	0	0	33	0.15	0	0.17	0	0	0	0	0	0	85.35
LFF2	12	1349	30.32	0.4	0	0.16	1.82	12.22	0.16	0	1.49	0.82	0	0	0	0.18	47.04	0.22	0	0	0	0	0	0	0	0	94.82
LFF2	12	1350	31.49	0.19	0	0.18	2.01	12.8	0.3	0	0.63	0.73	0	0	0	0.15	46.78	0.3	0	0	0	0	0	0	0	0	95.55
LFF2	12	1351	30.94	0.69	0	0.27	1.83	11.4	0.22	0	2.8	1.5	0	0	0	0.14	43.62	0.27	0	0	0	0	0	0	0	0	93.69
LFF2	12	1352	31.02	0.21	0	0.13	1.77	12.43	0	0	0.44	0.29	0	0	0	0.16	48.59	0.28	0	0	0	0	0	0	0	0	95.31
LFF2	12	1353	11.98	0	0.07	10.36	0.86	0.06	0.08	0.2	0	0.25	0	0	0	0	48.95	0.23	0	0	0	0	0	0	0	0	73.03
LFF2	12	1354	19.27	0	0	14.88	0.85	0	0.13	0.07	0.06	0.26	0	0	0	0	52.92	0.29	0	0.2	0	0	0	0	0	0	88.94
LFF2	13	1355	2.37	0	0	0	0	0	0	1.05	0	0	0	0	0	0	0.27	0	0	0	0	0	0	0	0	0	3.69
LFF2	13	1356	20.77	0	0.27	2.56	2.62	0.18	0	0.07	0	0.28	0.07	0	0	0.17	53.29	0.27	0	0	0	0	0	0	0	0	80.54
LFF2	13	1357	21.84	0	0.22	2.59	1.31	0.07	0	0.07	0	0.14	0	0	0	0.16	66.27	0.35	0	0	0	0	0	0	0	0	93.02
LFF2	13	1358	20.95	0	0.32	2.38	3.25	0.22	0	0.05	0	0.42	0.11	0	0	0.22	51.25	0.31	0	0	0	0	0	0	0	0	79.47
LFF2	14	1359	22.36	0.16	0.13	1.62	1.85	0.07	0	0	0.14	0.11	0	0	0	0	65.67	0.39	0	0	0	0	0	0	0	0	92.51
LFF2	14	1360	26.07	0	0	0.28	0	0	0	0	0	0.07	0	0	0	0.09	68.38	0.34	0	0	0	0	0	0	0	0	95.23
LFF2	14	1361	25.35	0	0.1	0.8	0.21	0	0	0	0	0	0	0	0	0	68.33	0.37	0	0	0	0	0	0	0	0	95.16
LFF2	14	1362	22.5	0	0.13	0.61	0.12	0	0	0	0	0	0	0	0	0	72	0.46	0	0	0	0	0	0	0	0	95.81
LFF2	14	1363	23.02	0	0.18	0.57	0	0	0	0	0	0	0	0	0	0	71.81	0.4	0	0	0	0	0	0	0	0	95.99
LFF2	14	1364	21.84	0	0.11	0.46	0.1	0	0	0	0	0	0	0	0	0	72.68	0.41	0.15	0	0	0	0	0	0	0	95.75
LFF2	14	1365	22.33	0	0	0.42	0.07	0	0	0	0	0	0	0	0	0	72.74	0.38	0.11	0	0	0	0	0	0	0	96.04
LFF2	14	1366	35.39	0.95	0.25	2.49	17.44	0.31	0	0	1.6	1.46	0	0	0	0.18	38.68	0.23	0	0	0	0	0	0	0	0	98.99
LFF2	14	1367	35.09	1.06	0.18	2.56	16.73	0.27	0	0	1.92	0.98	0	0	0	0.12	40.12	0.21	0.11	0	0	0	0	0	0	0	99.36
LFF2	14	1368	34.01	1.14	0.39	2.36	15.84	0.32	0	0	1.3	0.96	0	0	0	0.13	46.47	0.26	0	0	0	0	0	0	0	0	103.2
LFF2	14	1369	34.26	0.74	0.27	1.63	15.24	0.27	0	0	1.38	0.88	0	0	0	0.13	45.09	0.25	0	0	0	0	0	0	0	0	100.1
LFF2	14	1370	34.42	0.82	0.27	2.39	16.67	0.34	0	0	1.38	1.1	0	0	0	0.12	41.09	0.26	0	0	0	0	0	0	0	0	98.84
LFF2	14	1371	33.89	0.84	0.25	2.46	16.66	0.28	0	0	1.62	1.05	0	0	0	0.14	41.13	0.21	0	0.13	0	0	0	0	0	0	98.66

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	14	1372	30.42	0	0.31	1.05	11.74	0.53	0.05	0	0	0.71	0	0	0	0.14	43.64	0.21	0	0	0	0	0	0	0	0	88.81
LFF2	14	1373	33.63	0.71	0.18	2.46	16.47	0.34	0	0	1.49	1	0	0	0	0.12	41.62	0.16	0	0	0	0	0	0.18	0	0	98.36
LFF2	14	1374	33.33	0.81	0.25	2.52	16.74	0.3	0	0	1.57	0.98	0	0	0	0.12	40.82	0.24	0	0	0	0	0	0	0	0	97.68
LFF2	14	1375	33.9	0.75	0.22	2.52	16.61	0.32	0	0	1.54	0.98	0	0	0	0.12	41.2	0.21	0	0	0	0	0	0	0	0	98.39
LFF2	14	1376	33.64	0.87	0.18	2.57	15.93	0.28	0	0	1.57	0.95	0	0	0	0.1	42.3	0.23	0.11	0	0	0	0	0	0	0	98.72
LFF2	14	1377	35.54	0.78	0.2	2.76	16.77	0.33	0	0	1.57	0.91	0	0	0	0.11	41.19	0.19	0	0	0	0	0	0	0	0	100.4
LFF2	14	1378	34.33	0.89	0.21	2.81	17.17	0.31	0	0	1.85	0.96	0	0	0	0.09	40.01	0.28	0	0	0	0	0	0	0	0	98.9
LFF2	14	1379	33.47	0.82	0.21	2.77	16.13	0.27	0	0	1.68	0.82	0	0	0	0.09	42.19	0.18	0	0	0	0	0	0	0	0	98.64
LFF2	14	1380	34.23	0.9	0.2	2.78	16.69	0.29	0	0	1.76	0.93	0	0	0	0.11	40.34	0.16	0	0	0	0	0	0	0	0	98.38
LFF2	14	1381	27.55	0.32	0.1	1.54	7.02	0.12	0	0	0.76	0.38	0.08	0	0	0	58.76	0.35	0	0	0	0	0	0	0	0	96.99
LFF2	14	1382	33.07	0.7	0.16	2.6	15.82	0.29	0	0	1.38	0.82	0	0	0	0.11	42.86	0.28	0	0	0	0	0	0	0	0	98.1
LFF2	14	1383	33.33	0.76	0.18	2.77	16.36	0.3	0	0	1.66	0.83	0	0	0	0.11	41.39	0.21	0	0	0	0	0	0	0	0	97.91
LFF2	14	1384	33.89	0.76	0.19	2.65	16.43	0.34	0	0	1.56	0.83	0	0	0	0.08	41.76	0.21	0	0.13	0	0	0	0	0	0	98.85
LFF2	15	1385	25.25	0	0	2.52	0.21	0	0	0	0	0.33	0	0	0	0	64.86	0.33	0	0	0	0	0	0	0	0	93.5
LFF2	15	1386	22.81	0	0	0.58	0.14	0	0	0	0	0	0	0	0	0	72.64	0.31	0	0	0	0	0	0	0	0	96.48
LFF2	15	1387	23.23	0.26	0	0.44	1.45	0.44	0	0	0.31	0.33	0	0	0	0	69.65	0.41	0.17	0	0	0	0	0	0	0	96.7
LFF2	15	1388	22.53	0	0	1.12	0.56	0.21	0	0	0.11	0.08	0	0	0	0	71.21	0.41	0	0	0	0	0	0	0	0	96.22
LFF2	15	1389	22.28	0	0	1.13	0.24	0.26	0	0	0.11	0.13	0	0	0	0.09	71.41	0.45	0	0	0	0	0	0	0	0	96.1
LFF2	15	1390	21.41	0	0.12	1.5	0.18	0.12	0	0	0	0.08	0	0	0	0.11	70.47	0.41	0.11	0	0	0	0	0	0	0	94.5
LFF2	15	1391	24.25	0	0.09	2.05	2.33	0.76	0	0	0	0.23	0.08	0	0	0.11	63.15	0.36	0	0	0	0	0	0	0	0	93.41
LFF2	15	1392	24.28	0	0.11	1.96	2.39	0.74	0	0	0	0.24	0.07	0	0	0	63.23	0.26	0	0	0	0	0	0	0	0	93.29
LFF2	15	1393	24.64	0	0.09	1.14	2.2	0.58	0	0	0	0.2	0.07	0	0	0.11	64.83	0.38	0	0	0	0	0	0	0	0	94.23
LFF2	15	1394	27.38	1.89	0.09	0.75	9.98	3.43	0.07	0	2.49	3.21	0	0	0	0.16	45.31	0.29	0	0	0	0	0	0.28	0	0	95.34
LFF2	15	1395	32.98	2.28	0.11	0.69	12.35	4.76	0.08	0	3.2	3.94	0	0	0	0.19	38.75	0.22	0	0	0	0	0	0	0	0	99.55
LFF2	15	1396	30.44	1.92	0.08	0.55	10.51	4.66	0.08	0	3.22	4.16	0	0	0	0.18	35.92	0.19	0	0	0	0	0	0.24	0	0	92.15
LFF2	15	1397	33.13	2.02	0	0.74	12.6	4.61	0.08	0	3.38	4.44	0	0	0	0.18	34	0.22	0	0	0	0	0	0.38	0	0	95.77
LFF2	15	1398	29.27	1.79	0	0.75	10.62	3.69	0.07	0	2.66	3.01	0	0	0	0.15	44.08	0.24	0	0	0	0	0	0	0	0	96.33
LFF2	15	1399	26.63	1.67	0	0.7	6.74	2.11	0	0	1.3	1.28	0	0	0	0.1	60.6	0.32	0	0	0	0	0	0	0	0	101.4
LFF2	15	1400	33.24	2.06	0.09	0.69	12.89	4.8	0.09	0	3.37	3.52	0	0	0	0.17	36.45	0.25	0	0	0	0	0	0.26	0	0	97.88
LFF2	15	1401	31.24	2.15	0.12	0.75	12.11	4.18	0.09	0	2.96	3.1	0	0	0	0.15	40.51	0.2	0.1	0	0	0	0	0	0	0	97.65
LFF2	15	1402	28.46	1.56	0.08	0.79	9.64	3.46	0.1	0	2.69	2.58	0	0	0	0.15	40.91	0.24	0	0	0	0	0	0	0	0	90.68
LFF2	15	1403	27.86	1.81	0.16	0.57	6.7	6.63	0.06	0	1.79	2.67	0	0	0	0.22	43.66	0.31	0	0	0	0	0	0.24	0	0	92.68
LFF2	15	1404	27.77	2.21	0.18	0.74	5.54	7.11	0	0	3.14	2.24	0	0	0	0.14	45.62	0.2	0	0	0	0	0	0	0	0	94.9
LFF2	15	1405	23.74	0.77	0	0.6	0.97	1.53	0	0	0.57	0.24	0	0	0	0	69.27	0.28	0	0	0	0	0	0	0	0	97.97
LFF2	15	1406	28.4	2.16	0.18	0.76	3.45	8.32	0	0	3.5	3.12	0	0	0	0.21	42.02	0.24	0	0	0.14	0	0	0	0	0	92.5

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	15	1407	30.41	3.26	0.21	0.45	2.17	11.9	0.06	0	5.02	2.31	0	0	0	0.23	39.46	0.23	0	0	0	0	0	0	0	0	95.71
LFF2	15	1408	32.29	0	0.29	1.19	8.56	2.6	0	0	0.12	0.8	0	0	0	0.25	51.7	0.26	0	0	0	0	0	0	0	0	98.05
LFF2	15	1409	33.29	0	0.23	0.73	9.02	2.92	0.06	0	0.14	0.59	0	0	0	0.19	48.28	0.25	0	0	0	0	0	0	0	0	95.7
LFF2	15	1410	30.53	0	0.19	0.74	7.72	2.83	0.07	0	0.16	0.65	0	0	0	0.19	47.29	0.2	0	0	0	0	0	0	0	0	90.56
LFF2	15	1411	31.91	0.13	0.24	0.82	8.54	2.61	0	0	0.15	0.64	0	0	0	0.15	51.11	0.24	0	0	0	0	0	0	0	0	96.54
LFF2	15	1412	33.65	0	0.23	1.04	9.88	3	0	0	0.16	0.6	0	0	0	0.2	45.2	0.27	0	0	0	0	0	0	0	0	94.22
LFF2	15	1413	32.39	0	0.24	0.81	8.97	2.97	0	0	0.15	0.78	0.07	0	0	0.23	46	0.28	0	0	0	0	0	0	0	0	92.88
LFF2	15	1414	26.58	0	0.18	4.07	6.17	1.73	0.07	0	0	0.92	0.06	0	0	0.15	48.49	0.26	0	0	0	0	0	0	0	0	88.68
LFF2	15	1415	32.62	0	0.25	0.63	9.05	3.18	0	0	0	0.98	0	0	0	0.22	45.97	0.27	0	0	0	0	0	0	0	0	93.16
LFF2	15	1416	23.98	0	0.19	0.75	6.38	1.64	0	0	0	0.61	0	0	0	0.15	57.83	0.33	0	0	0	0	0	0	0	0	91.85
LFF2	15	1417	13.39	0.34	0.11	2.17	1.2	0.2	0.08	0.19	0.21	0.58	0.12	0	0	0	43.95	0.19	0	0	0	0	0	0	0	0	62.72
LFF2	15	1418	27.48	0	0	0.3	0	0	0	0	0.42	0.09	0	0	0	0	65.91	0.26	0	0	0	0	0	0	0	0	94.46
LFF2	15	1419	24.73	0.33	0	0.29	0	0	0	0	0	0.24	0	0	0	0	68.87	0.28	0	0	0	0	0	0	0	0	94.73
LFF2	15	1420	23.86	0	0	0.32	0.12	0	0	0	0	0	0	0	0	0	68.89	0.36	0	0	0	0	0	0	0	0	93.55
LFF2	15	1421	22.11	0	0	0.32	0.06	0	0	0	0	0	0	0	0	0	72.85	0.37	0	0	0	0	0	0	0	0	95.72
LFF2	16	1422	27.3	0.48	0.46	3.17	7.26	0.14	0.1	0	1.03	1.22	0.23	0	0	0.11	50.96	0.32	0	0	0	0	0	0	0	0	92.78
LFF2	16	1423	27.87	0.69	0.52	2.51	8.83	0.12	0.06	0	1.43	1.62	0.22	0	0	0.13	53.43	0.23	0	0	0	0	0.21	0	0	0	97.88
LFF2	16	1424	28.74	0.64	0.54	2.8	9.12	0.09	0	0	1.48	1.67	0.19	0	0	0.17	52.05	0.3	0	0	0	0	0	0	0	0	97.8
LFF2	16	1425	0	0	0	0.23	0.19	0	0	0	0	0	0	0	0	0	92.05	0.58	0	0	0	0	0	0	0	0	93.04
LFF2	16	1426	2.01	0	0	0.2	0.06	0	0.07	0	0	0	0	0	0	0	88.42	0.54	0.24	0	0	0.56	0	0	0	0	92.11
LFF2	16	1427	2.67	0	0	0.31	0.14	0	0	0	0	0	0	0	0	0	93.24	0.59	0	0	0	0	0	0	0	0	96.96
LFF2	16	1428	0	0	0	0.22	0	0	0	0	0	0.07	0	0	0	0	95.13	0.64	0	0	0	0	0	0	0	0	96.06
LFF2	16	1429	4.95	0	0.1	0.78	1.65	0	0	0	0.23	0.23	0.08	0	0	0	89.07	0.47	0	0	0	0	0	0	0	0	97.56
LFF2	17	1430	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	88.76	0.61	0.11	0	0	0	0	0	0	0	89.66
LFF2	17	1431	0	0	0	0.19	0	0	0	0	0	0	0	0	0	0	95.32	0.66	0.12	0	0	0	0	0	0	0	96.29
LFF2	17	1432	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	94.86	0.62	0.14	0	0	0	0	0	0	0	95.83
LFF2	17	1433	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	94.72	0.6	0.12	0	0	0	0	0	0	0	95.66
LFF2	17	1434	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	93.96	0.61	0	0	0	0	0	0	0	0	94.79
LFF2	17	1435	0	0	0	0.23	0	0	0	0	0	0	0	0	0	0	90.26	0.63	0.21	0	0	0.54	0	0	0	0	91.87
LFF2	17	1436	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	89.84	0.56	0.18	0	0	0.47	0	0	0	0	91.28
LFF2	17	1437	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	90.38	0.62	0.24	0	0	0.5	0	0	0	0	91.96
LFF2	17	1438	22.15	0	0.32	0.38	0.34	0	0	0	0.08	0.13	0.29	0	0	0.09	72.38	0.35	0	0	0	0	0	0	0	0	96.52
LFF2	17	1439	22.03	0	0.37	0.54	0.92	0	0	0	0.25	0.26	0.22	0	0	0.11	70.2	0.35	0	0	0	0	0	0	0	0	95.27
LFF2	17	1440	36.41	1.1	0.62	4.33	17.76	0.25	0	0	2.77	3.76	0.11	0	0	0.15	32.82	0.19	0	0	0	0	0	0	0	0	100.3
LFF2	17	1441	33.85	1.16	0.62	3.99	15.01	0.22	0	0	2.12	2.58	0.15	0	0	0.15	45.07	0.26	0	0	0	0	0	0	0	0	105.2

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF2	17	1442	36.36	0.97	0.58	4.27	17.38	0.27	0.05	0	2.35	4.8	0.09	0	0	0.15	31.57	0.14	0	0	0	0	0	0.4	0	0	99.38
LFF2	17	1443	35.61	0.92	0.64	4.21	17.55	0.24	0.06	0	2.72	3.56	0.11	0	0	0.17	32.89	0.23	0	0	0	0	0	0	0	0	98.9
LFF2	17	1444	35.16	0.92	0.61	3.87	17.48	0.29	0.06	0	2.61	3.71	0.16	0	0	0.23	33.28	0.18	0	0	0	0	0	0.25	0	0	98.8
LFF2	17	1445	35.82	1	0.59	4.25	17.7	0.23	0.07	0	2.68	4.07	0.12	0	0	0.2	31.65	0.21	0	0	0	0	0	0	0	0	98.59
LFF2	17	1446	28.25	0.64	0.46	2.52	8.93	0.1	0	0	1.41	1.63	0.18	0	0	0.15	53.87	0.35	0	0	0	0	0	0	0	0	98.5
LFF2	17	1447	28.5	0.78	0.5	2.77	9.78	0.1	0	0	1.63	1.87	0.19	0	0	0.13	51.33	0.37	0	0	0	0	0	0	0	0	97.96
LFF2	17	1448	34.69	0.93	0.63	3.89	16.84	0.25	0.06	0	2.61	3.77	0.14	0	0	0.17	34.95	0.21	0	0	0	0	0	0.29	0	0	99.43
LFF2	18	1449	23.22	0	0.17	0.91	0.25	0.08	0	0	0	0.13	0	0	0	0.98	69.16	0.37	0	0	0	0	0	0	0	0	95.27
LFF2	18	1450	23.82	0.21	0.17	1	1.23	0.49	0	0	0.19	0.38	0	0	0	0.76	67.34	0.3	0	0	0	0	0	0	0	0	95.89
LFF2	19	1451	22.55	0	0	1.29	0.67	0	0	0	0	0	0	0	0	0.19	66.89	0.29	0	0	0	0	0	0	0	0	91.88
LFF2	19	1452	15.64	0	0	24.21	1.38	0	0.11	0.24	0.13	0.3	0	0	0	0	6.92	0	0	1.2	0	0	0	0	0	0	50.13
LFF2	19	1453	27.95	0	0	32.4	1.38	0.05	0.15	0.2	0.11	0.45	0	0	0	0	4	0	0	0	0	0	0	0	0	0	66.68
LFF2	19	1454	28.79	0	0	31.31	0.7	0	0.07	0.05	0	0.48	0	0	0	0	4.9	0	0	0	0	0	0	0	0	0	66.31
LFF2	19	1455	24.34	0.11	0.06	24.7	1.88	0.13	0.14	0.14	0.15	0.67	0	0	0	0	6.27	0	0	0.08	0	0	0	0	0	0	58.66
LFF2	19	1456	12.16	0	0	12.59	0.42	0.08	0.12	0.11	0.1	0.72	0	0	0	0	8.15	0	0	0	0	0	0	0	0	0	34.46
LFF2	19	1457	19.31	0	0	21.79	1.08	0.16	0.03	0.07	0.1	0.28	0	0	0	0	5.2	0	0	0	0	0	0	0	0	0	48.03
LFF2	20	1458	24.07	0	0	0.17	0	0	0	0	0	0.19	0	0	0	0.27	67.02	0.28	0	0	0	0	0	0	0	0	91.99
LFF2	20	1459	24.65	0	0	0.18	0	0	0	0	0	0.22	0	0	0	0.34	69.29	0.29	0	0	0	0	0	0	0	0	94.97
LFF2	20	1460	21.47	0	0	0.19	0	0	0	0	0	0.27	0	0	0	0.48	72	0.32	0	0	0	0	0	0	0	0	94.74
LFF2	20	1461	22.13	0	0	0.23	0	0	0	0	0	0.07	0	0	0	0.34	72.83	0.35	0.13	0	0	0	0	0	0	0	96.08
LFF2	20	1462	21.84	0	0	0.27	0	0	0	0	0	0	0	0	0	0.31	72.34	0.42	0.13	0	0	0	0	0	0	0	95.31
LFF2	20	1463	21.93	0	0.21	0.37	0	0	0	0	0	0	0	0	0	0.31	72.57	0.39	0	0	0	0	0	0	0	0	95.78
LFF2	20	1464	22.11	0	0.39	0.59	0	0	0	0	0	0	0	0	0	0.2	72.45	0.37	0	0	0	0	0	0	0	0	96.11
LFF2	20	1465	22.26	0	0.24	0.53	0.15	0	0	0	0	0	0.14	0	0	0.2	72.51	0.36	0	0	0	0	0	0	0	0	96.38
LFF2	20	1466	22.87	0	0.24	0.56	0.06	0	0	0	0	0	0.08	0	0	0.18	72.12	0.33	0	0	0	0	0	0	0	0	96.45
LFF2	20	1467	24.28	0	0.29	2.17	3.83	0.36	0.07	0	0	0.45	0.13	0	0	0.22	54.56	0.28	0	0	0	0	0	0	0	0	86.66
LFF2	20	1468	22.2	0	0.36	2.03	0.33	0.08	0.05	0	0	0.12	0.07	0	0	0.25	68.57	0.37	0	0	0	0	0	0	0	0	94.43
LFF2	20	1469	22.25	0	0.09	0.53	0	0	0	0	0	0	0	0	0	0.35	72.7	0.31	0	0	0	0	0	0	0	0	96.25
LFF2	20	1470	22.32	0	0	0.42	0	0	0	0	0	0.19	0	0	0	0.45	71.92	0.38	0	0	0	0	0	0	0	0	95.68
LFF2	20	1471	24.79	0	0	0.17	0	0	0	0	0	0.25	0	0	0	0.3	69.21	0.33	0	0	0	0	0	0	0	0	95.05
LFF2	20	1472	21.91	0	0	1.18	0.14	0	0	0	0	0.42	0	0	0	0.24	64.15	0.32	0	0	0	0	0	0	0	0	88.38
LFF2	20	1473	34.82	0	0	40.18	1.07	0	0.07	0.05	0	0.27	0	0	0	0	5.71	0	0	0.12	0	0	0	0	0	0	82.3
LFF2	20	1474	42.21	0	0	46.3	1.18	0	0.07	0.06	0.07	0.29	0	0	0	0	5.4	0	0	0.1	0	0	0	0	0	0	95.68
LFF2	20	1475	32.91	0	0	39.41	0.75	0	0	0.04	0	0.16	0	0	0	0	14.34	0	0	0.1	0	0	0	0	0	0	87.72
LFF1	42	1476	22.85	0	0.21	2.72	1.74	0	0	0	0.12	0.16	0	0	0	0.17	65.98	0.3	0	0	0	0	0	0	0	0	94.25

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	42	1477	30.29	0.35	0.36	3.56	11.55	0.32	0	0	1.18	1.08	0.2	0	0	0.4	47.75	0.23	0	0	0	0	0	0	0	0	97.28
LFF1	42	1478	21.47	0	0.36	1.56	5.79	0.23	0	0.12	0.13	0.16	0.18	0	0	0.27	44.92	0.29	0	0	0	0	0	0	0	0	75.48
LFF1	43	1479	21.04	0	0.17	0.45	0	0	0	0	0	0	0	0	0	0.18	73.26	0.32	0	0	0	0	0	0	0	0	95.41
LFF1	43	1480	33.5	0.51	0.33	3.43	16.07	0.62	0.09	0	1.36	1.53	0	0	0	0.4	40.25	0.15	0	0	0	0	0	0	0	0	98.24
LFF1	43	1481	20.81	0	0.2	0.46	0.09	0	0	0	0	0	0.07	0	0	0.18	72.76	0.39	0	0	0	0	0	0	0	0	94.98
LFF1	43	1482	33.62	0.48	0.45	3.86	16.03	0.5	0	0	1.6	1.52	0	0	0	0.44	39.17	0.28	0	0	0	0	0	0	0	0	97.95
LFF1	43	1483	31.37	0	0.46	1.08	10.79	0.53	0.1	0	0	0.35	0.18	0	0	0.46	47.41	0.22	0	0	0	0	0	0	0	0	92.95
LFF1	43	1484	29.78	0	0.4	1.08	8.6	0.62	0.21	0	0	0.64	0.13	0	0	0.32	48.3	0.27	0	0	0	0	0	0	0	0	90.36
LFF1	43	1485	29.3	0	0.56	1.09	11.18	0.43	0.14	0	0	0.51	0.14	0	0	0.47	46.69	0.21	0	0	0	0	0	0	0	0	90.71
LFF1	44	1486	26.74	0.32	0.4	2.31	8.11	0.25	0	0	0.73	0.82	0.17	0	0	0.13	53.04	0.2	0	0	0	0	0	0	0	0	93.22
LFF1	44	1487	51.52	0	0	0	47.39	0	0	0	0	0.08	0	0	0	0	0.45	0	0	0	0	0	0	0.24	0	0	99.68
LFF1	44	1488	32.96	0.32	0.33	1.58	15.14	0.19	0	0	0.71	0.92	0.13	0	0	0.09	46.35	0.23	0	0	0	0	0	0	0	0	98.96
LFF1	44	1489	31.2	0	0.48	1.13	12.05	0.58	0.05	0	0.19	0.76	0.13	0	0	0.13	46.25	0.31	0	0	0	0	0	0	0	0	93.27
LFF1	45	1490	28.68	0.38	0.37	2.42	9.78	0.27	0	0	0.99	1.08	0.19	0	0	0.12	53.82	0.27	0	0	0	0	0	0	0	0	98.37
LFF1	45	1491	27	0.39	0.36	2.15	8.37	0.22	0	0	0.85	0.95	0.13	0	0	0.13	55.74	0.35	0	0	0	0	0	0	0	0	96.65
LFF1	45	1492	30.38	0.41	0.4	2.61	10.97	0.3	0	0	1.12	1.21	0.17	0	0	0.15	50.98	0.25	0.1	0.13	0	0	0	0	0	0	99.19
LFF1	45	1493	28.14	0.39	0.39	2.22	8.69	0.22	0	0	0.89	0.96	0.16	0	0	0.1	55.73	0.31	0	0	0	0	0	0	0	0	98.2
LFF1	45	1494	35.11	0.58	0.58	3.55	16.77	0.52	0.06	0	1.48	2.06	0.09	0	0	0.19	38.41	0.15	0	0	0	0	0	0	0	0	99.56
LFF1	45	1495	34.48	0.59	0.57	3.5	16.9	0.55	0.06	0	1.42	2.35	0.11	0	0	0.19	37.84	0.17	0	0	0	0	0	0.23	0	0	98.98
LFF1	45	1496	33.22	0.63	0.63	3.43	15.96	0.49	0	0	1.72	1.54	0.1	0	0	0.16	41.04	0.23	0	0	0	0	0	0	0	0	99.14
LFF1	45	1497	22.59	0	0.15	0.58	0.27	0	0	0	0	0	0.18	0	0	0.08	72.23	0.31	0	0	0	0	0	0	0	0	96.4
LFF1	45	1498	32.3	0.7	0.48	3.65	15.11	0.4	0	0	1.59	1.56	0.11	0	0	0.12	44.92	0.27	0	0	0	0	0	0	0	0	101.2
LFF1	45	1499	34.12	0.74	0.62	3.52	16.52	0.51	0.07	0	1.85	1.68	0	0	0	0.17	38.43	0.23	0	0	0	0	0	0	0	0	98.45
LFF1	45	1500	34.28	0.53	0.52	3.34	15.92	0.52	0.07	0	1.31	1.9	0.07	0	0	0.21	40.01	0.23	0	0	0	0	0	0	0	0	98.9
LFF1	45	1501	34.79	0.54	0.65	3.19	16.1	0.59	0.07	0	1.22	1.81	0.12	0	0	0.18	39.54	0.23	0	0	0	0	0	0	0	0	99.03
LFF1	46	1502	31.62	0.45	0.34	2.35	13.27	0.25	0	0	1.47	0.76	0.12	0	0	0.28	46.66	0.22	0	0	0	0	0	0	0	0	97.8
LFF1	46	1503	27.95	0.32	0.27	2.67	9.35	0.21	0	0.05	1	0.47	0.16	0	0	0.22	47.98	0.32	0	0	0	0	0	0	0	0	90.98
LFF1	46	1504	28.08	0.3	0.25	2.16	9.34	0.27	0	0	0.95	0.43	0.13	0	0	0.24	50.2	0.26	0	0	0	0	0	0	0	0	92.62
LFF1	46	1505	40.1	0.12	0	4.84	34.41	0	0	0.07	6.55	0	0	0	0	0	1.21	0	0	0	0	0	0	0	0	0	87.29
LFF1	46	1506	12.18	0	0	10.84	0.34	0.09	0	0.08	0	0.07	0	0	0	0	2.9	0	0	0	0	0	0	0	0	0	26.5
LFF1	46	1507	7.66	0	0	7.29	0.32	0.04	0	0.03	0	0.1	0	0	0	0	1.51	0	0	0	0	0	0	0	0	0	16.95
LFF1	47	1508	26.28	0.28	0.35	1.87	9.09	0.21	0	0	0.95	0.44	0.18	0	0	0.23	48.57	0.27	0	0	0	0	0	0	0	0	88.7
LFF1	47	1509	25.07	0	0.26	0.82	0.08	0	0	0	0	0.06	0.15	0	0	0.18	67.84	0.33	0	0	0	0	0	0	0	0	94.8
LFF1	47	1510	32.63	0.52	0.4	2.13	15.48	0.36	0	0	1.37	0.78	0.08	0	0	0.33	44.49	0.27	0	0	0	0	0	0	0	0	98.83
LFF1	47	1511	25.7	0	0.29	0.28	0.06	0	0	0	0	0.14	0	0	0	0.25	68.02	0.3	0	0	0	0	0	0	0	0	95.03

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	47	1512	26.7	0	0.12	2.4	0.35	0	0	0	0	0	0.37	0	0	0	66.04	0.34	0	0	0	0	0	0	0	0	96.32
LFF1	47	1513	31.24	0.64	0.41	2.64	14.49	0.3	0	0	1.43	0.71	0.15	0	0	0.3	47.64	0.22	0	0	0	0	0	0	0	0	100.2
LFF1	49	1514	25.59	0	0.58	0.77	12.25	0.18	0	0.09	0	0.24	0.14	0	0	0.13	45.96	0.25	0	0	0	0	0	0	0	0	86.19
LFF1	49	1515	24.55	0	0.55	0.77	10.56	0.13	0	0.1	0	0.17	0.18	0	0	0.13	45.38	0.25	0	0	0	0	0	0	0	0	82.77
LFF1	49	1516	25.61	0	0.68	0.79	11.82	0.21	0	0.1	0	0.2	0.16	0	0	0.16	45.43	0.26	0	0	0	0	0	0	0	0	85.42
LFF1	49	1517	25.12	0	0.45	0.95	7.01	0.11	0	0	0	0.17	0.23	0	0	0	57.76	0.37	0	0	0	0	0	0	0	0	92.15
LFF1	49	1518	20.27	0	0.1	0.47	0.8	0	0	0	0	0	0	0	0	0	63.18	0.29	0	0	0	0	0	0	0	0	85.11
LFF1	50	1519	24.87	0	0.34	1.66	6	0.23	0	0.11	0	0.32	0.16	0	0	0.1	58.06	0.33	0	0	0	0	0	0	0	0	92.17
LFF1	50	1520	23.98	0	0.36	0.89	6.12	0.16	0	0	0	0.28	0.14	0	0	0.1	58.34	0.36	0	0	0	0	0	0	0	0	90.73
LFF1	50	1521	24.62	0	0.4	1.19	6.08	0.18	0	0.08	0	0.28	0.15	0	0	0.09	57.37	0.34	0	0	0	0	0	0	0	0	90.77
LFF1	50	1522	23.97	0	0.4	1.41	5.97	0.15	0	0	0	0.27	0.14	0	0	0.15	58.14	0.36	0	0	0	0	0	0	0	0	90.96
LFF1	51	1523	23.41	0	0.36	0.85	6.01	0.16	0	0.05	0	0.27	0.15	0	0	0.15	58.22	0.31	0	0	0	0	0	0	0	0	89.94
LFF1	51	1524	22.4	0	0	0.49	0.5	0.07	0	0	0	0	0	0	0	0	69.86	0.33	0.14	0	0	0	0	0	0	0	93.78
LFF1	51	1525	27.18	0	0.66	0.62	11.98	0.3	0	0.06	0	0.48	0	0	0	0.27	45.78	0.27	0	0	0	0	0	0	0	0	87.58
LFF1	51	1526	26.18	0	0.69	0.52	12.38	0.32	0	0.05	0	0.44	0	0	0	0.19	46.45	0.19	0	0	0	0	0	0	0	0	87.42
LFF1	51	1527	28.39	0	0.72	0.58	12.51	0.35	0	0.06	0	0.49	0.09	0	0	0.28	46.29	0.3	0	0	0	0	0	0.16	0	0	90.22
LFF1	52	1528	50.57	0	0	0	47.11	0	0	0	0	0.09	0	0	0	0	0.24	0	0	0	0	0	0	0.2	0	0.26	98.46
LFF1	52	1529	25.65	0.22	0.2	1.24	6.46	0.17	0	0	0.56	0.67	0.08	0	0	0.13	60.34	0.34	0	0	0	0	0	0	0	0	96.05
LFF1	52	1530	25.17	0.3	0.18	1.19	6.47	0.19	0	0	0.56	0.67	0	0	0	0.14	59.87	0.28	0	0	0	0	0	0	0	0	95.02
LFF1	52	1531	25.37	0.2	0.24	1.35	7.07	0.18	0	0	0.56	0.71	0.08	0	0	0.16	58.73	0.33	0	0	0	0	0	0	0	0	95
LFF1	53	1532	24.41	0	0.22	0.72	10.19	0.53	0	0.07	0	0.41	0.1	0	0	0.17	35.84	0.21	0	0	0	0	0	0	0	0	72.87
LFF1	53	1533	24.31	0	0.1	1.7	0.38	0	0	0	0	0	0.13	0	0	0	64.08	0.34	0.12	0	0	0	0	0	0	0	91.16
LFF1	53	1534	18.7	0	0.15	0.58	0.45	0	0	0	0	0	0.07	0	0	0.11	64.79	0.34	0	0	0	0	0	0	0	0	85.18
LFF1	53	1535	22.3	0	0.19	0.79	2.66	0.07	0	0	0.18	0.21	0.08	0	0	0.12	65.03	0.24	0	0	0	0	0	0	0	0	91.86
LFF1	53	1536	22.32	0	0.11	0.55	0.74	0	0	0	0	0	0	0	0	0	67.81	0.34	0	0	0	0	0	0	0	0	91.87
LFF1	53	1537	25.46	0	0.13	1.45	0.73	0	0	0	0	0.06	0.09	0	0	0.08	64.03	0.28	0	0	0	0	0	0	0	0	92.31
LFF1	53	1538	32.57	0.45	0.36	2.14	15.95	0.46	0.07	0	1.17	1.83	0	0	0	0.26	41.9	0.18	0	0	0	0	0	0	0	0	97.35
LFF1	53	1539	32.56	0.44	0.36	1.35	16.5	0.45	0.07	0	1.29	1.51	0	0	0	0.28	41.88	0.18	0	0	0	0	0	0.18	0	0	97.04
LFF1	54	1540	21.18	0	0.23	1.2	3.55	0.08	0	0	0	0.14	0.08	0	0	0.1	58.44	0.43	0	0	0	0	0	0	0	0	85.42
LFF1	55	1541	24.1	0	0.12	0.93	4.07	0.17	0	0	0	0.17	0	0	0	0.15	66.15	0.38	0	0	0	0	0	0	0	0	96.24
LFF1	55	1542	23.1	0	0	1.04	2.3	0.08	0	0	0	0.11	0	0	0	0.12	68.06	0.38	0	0	0	0	0	0	0	0	95.2
LFF1	56	1543	26.84	0.62	0.43	2.26	7.72	0.13	0	0	1.12	1.13	0.15	0	0	0.08	56.93	0.33	0	0	0	0	0	0	0	0	97.75
LFF1	56	1544	26.27	0.67	0.42	2.42	7.54	0.1	0	0	1.06	1.06	0.14	0	0	0.13	56.61	0.33	0	0.11	0	0	0	0	0	0	96.85
LFF1	57	1545	19.59	0	0	3.84	0.91	0.19	0.06	0.17	0.08	0.24	0	0	0	0	55.81	0.27	0	0	0	0	0	0	0	0	81.15
LFF1	57	1546	17.19	0	0	4.67	0.34	0.08	0	0.17	0	0.1	0	0	0	0.07	48.14	0.3	0	0	0	0	0	0	0	0	71.08

sample	site	#	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Sb	Ba	Pb	Total
LFF1	58	1547	26.2	0	0.49	1.28	8.45	0.15	0	0	0.16	0.41	0.2	0	0	0	52.47	0.33	0	0	0	0	0	0	0	0	90.15
LFF1	59	1548	26.56	0.25	0.5	2.1	8.85	0.16	0	0	0.51	0.65	0.23	0	0	0.09	50.97	0.31	0	0	0	0	0	0	0	0	91.19
LFF1	59	1549	32.29	0.44	0.48	3.13	12.02	0.13	0	0	1.14	1.1	0.18	0	0	0.09	47.56	0.21	0	0	0	0	0	0	0	0	98.77
LFF1	59	1550	18.45	0	0.37	2.02	2.56	0.06	0	0.12	0.13	0.08	0.22	0	0	0	47.5	0.31	0.11	0	0	0	0	0	0	0	71.92
LFF1	59	1551	22.74	0.2	0.5	0.78	0.18	0	0	0.07	0	0.29	0	0	0	0.09	58.73	0.28	0	0	0	0	0	0	0	0	83.87
LFF1	60	1552	25.94	0	0.39	1.67	7.24	0.18	0	0	0	0.77	0.08	0	0	0.53	57.32	0.34	0	0	0	0	0	0	0	0	94.45
LFF1	60	1553	43.01	0	0	2.37	0.16	0.32	10.61	0.08	5.97	0.08	0	0	0	0	29.63	0.14	0	0	0	0	0	0	0.28	0	92.65
LFF1	61	1554	30.81	0	0.4	0.56	12.77	0.31	0	0.05	0	0.85	0.09	0	0	0.64	42.45	0.24	0	0	0	0	0	0	0	0	89.18
LFF1	61	1555	31.86	0	0.56	0.72	12.6	0.28	0	0.06	0	0.88	0	0	0	0.63	42.23	0.26	0	0	0	0	0	0	0	0	90.1
LFF1	61	1556	27.83	0	0	1.57	0.81	0.41	0.12	0.17	0	0.08	0.07	0	0	0.14	57.93	0.26	0	0	0	0	0	0	0	0	89.39
LFF1	61	1557	25.14	0	0	0.57	0.23	0	0	0	0	0	0	0	0	0.21	65.28	0.35	0	0	0	0	0	0	0	0	91.78
LFF1	61	1558	25.09	0	0.36	0.82	6.51	0.2	0	0	0	0.55	0.1	0	0	0.45	54.5	0.26	0	0	0	0	0	0	0	0	88.84

Appendix IV.B: Archive of BSEM images showing locations of analyses.

Figure 1. Upper crust-normalised rare earth element (REE) profiles (normalisation after Taylor & McLennan 1981) for a sample of hearth ceramic (LFF3) from context (7305) <7309>/<7312> and for a sample (LFF4) through the thickness of a 125g SHC from context (1603) <1605>.

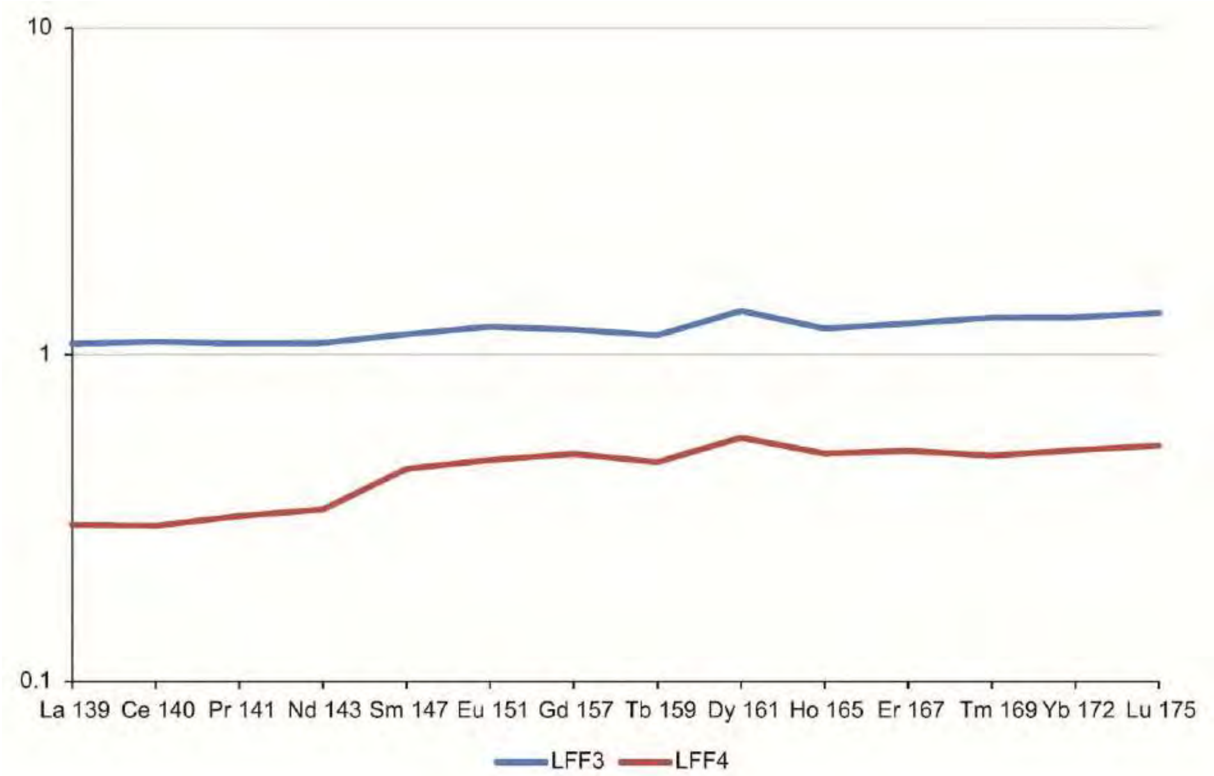


Figure 2. Backscattered electron image montage for sample LFF1 of spheroidal hammerscale (SHS) sub-sampled from <7311> (7305).

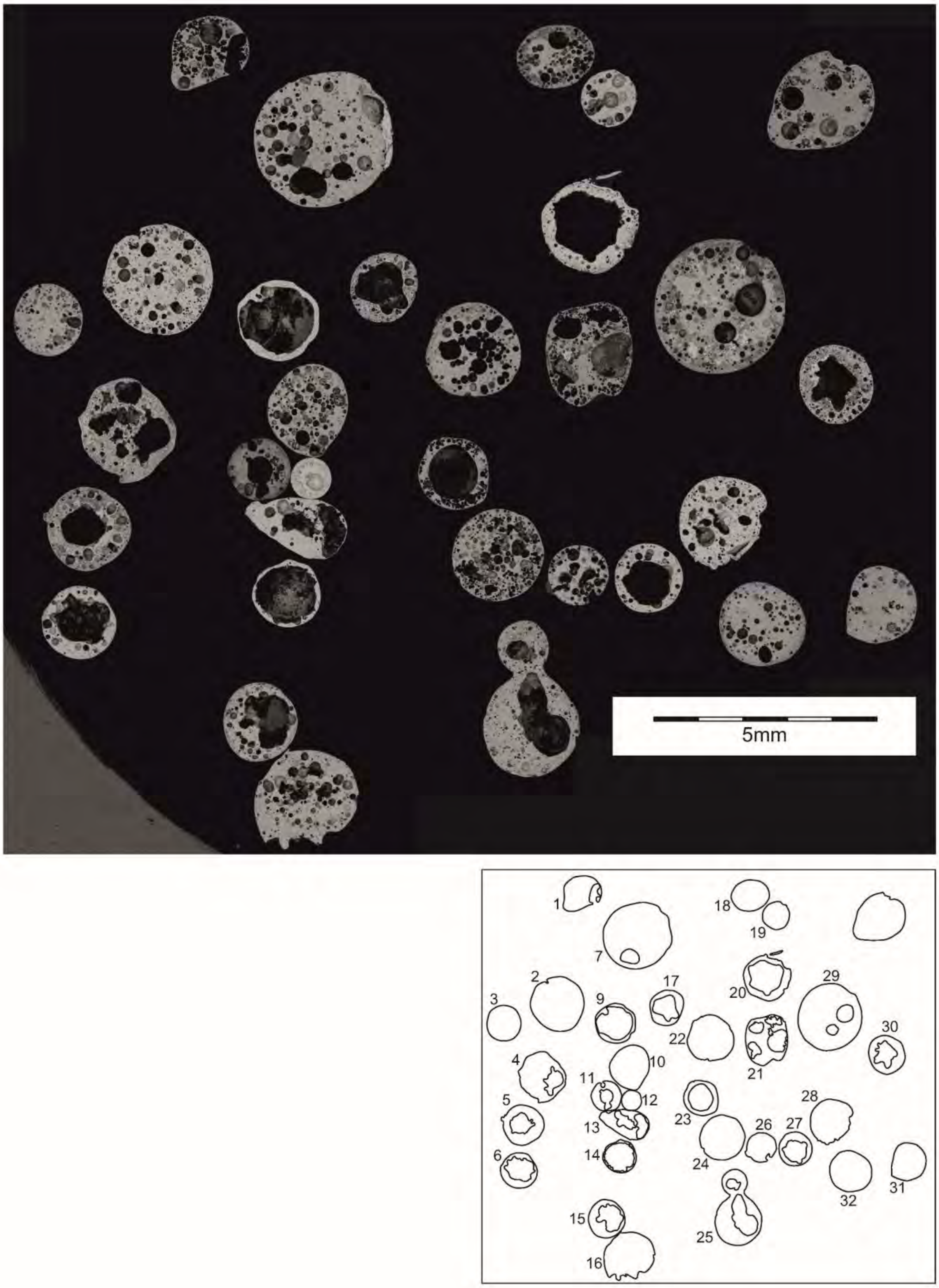


Figure 3. Backscattered electron images of selected grains of spheroidal hammerscale (SHS) illustrating textures across a range of iron contents. Scale bars 1mm for the whole grain images and 100μm for the microstructural detail.

S9: 0.4% SiO2, 94.9% FeO (Group SHS (1)

S15: 8.3% SiO2, 85.4% FeO (Group SHS (1)

S26: 14.1% SiO2, 79.4% FeO (Group SHS (2)

S1: 21.7% SiO2, 69.8% FeO (Group SHS (2))

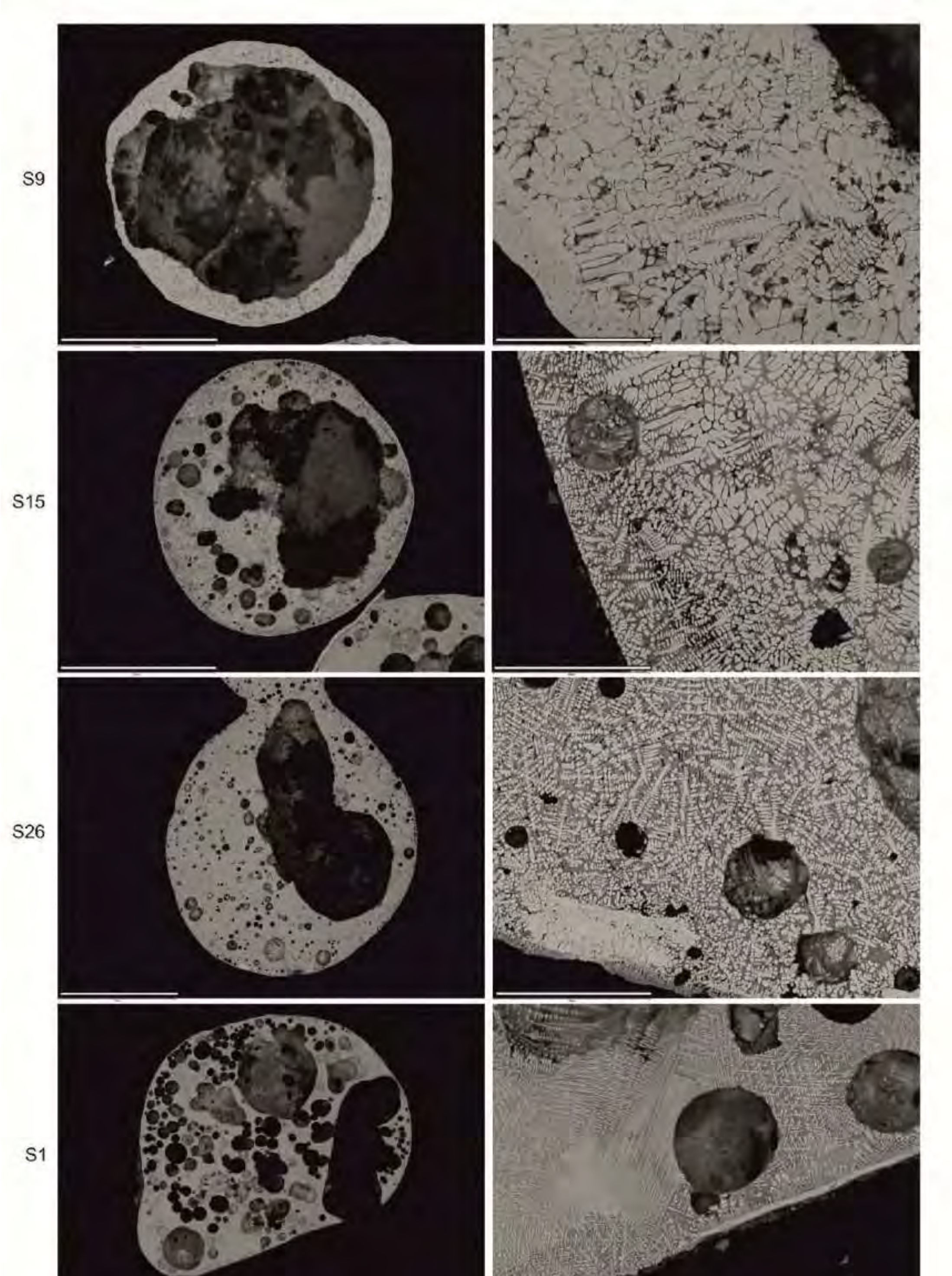


Figure 4. Backscattered electron image montage for sample LFF2 of tabular particles sub-sampled from <7311> (7305). The particles are of flake hammerscale (FHS) except for T10, which is of slag.

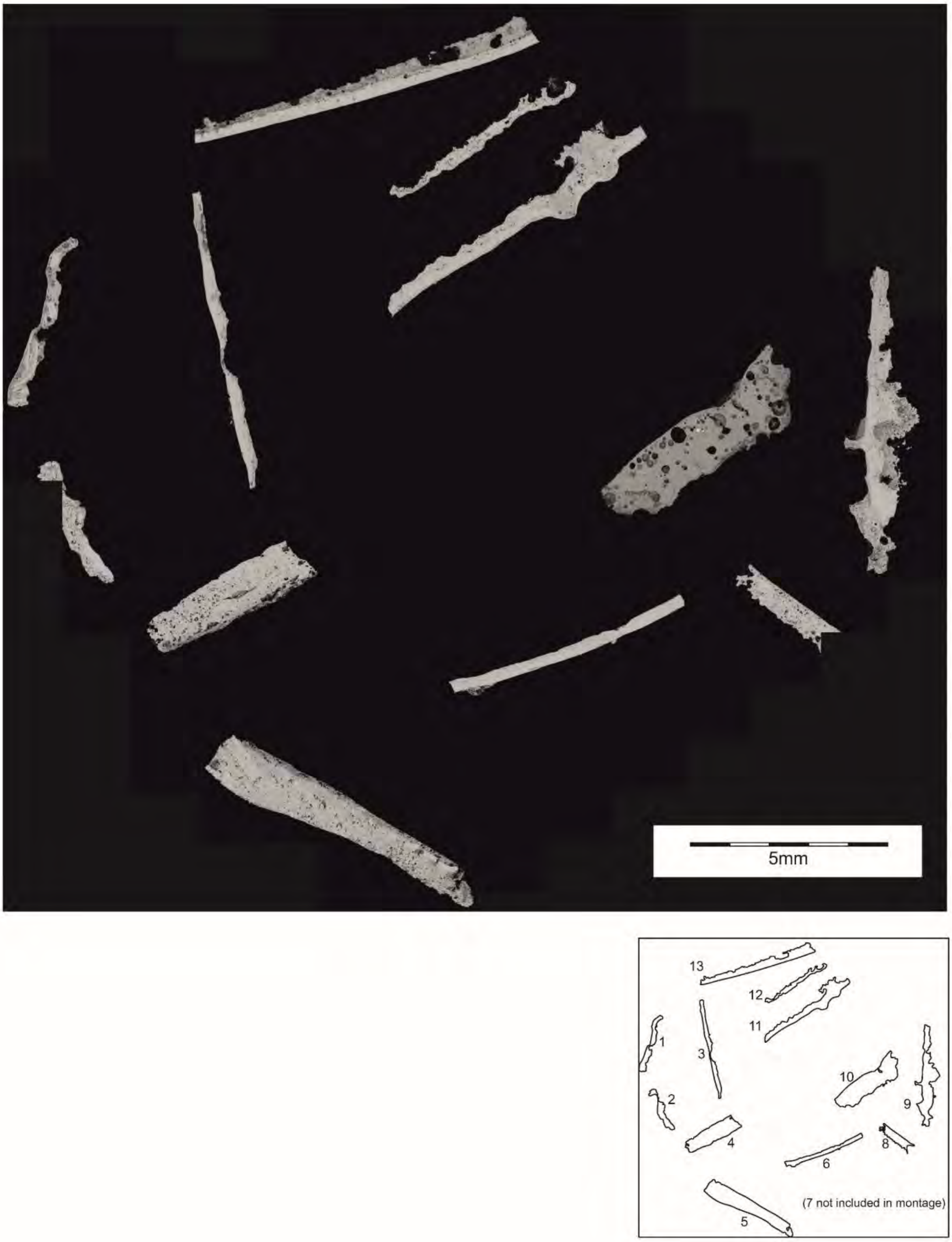


Figure 5. Backscattered electron images of selected tabular grains illustrating the six microstructural groups. Types 1-5 are flake hammerscale (FHS); Type 6 is a slag. Scale bars are 250μm.

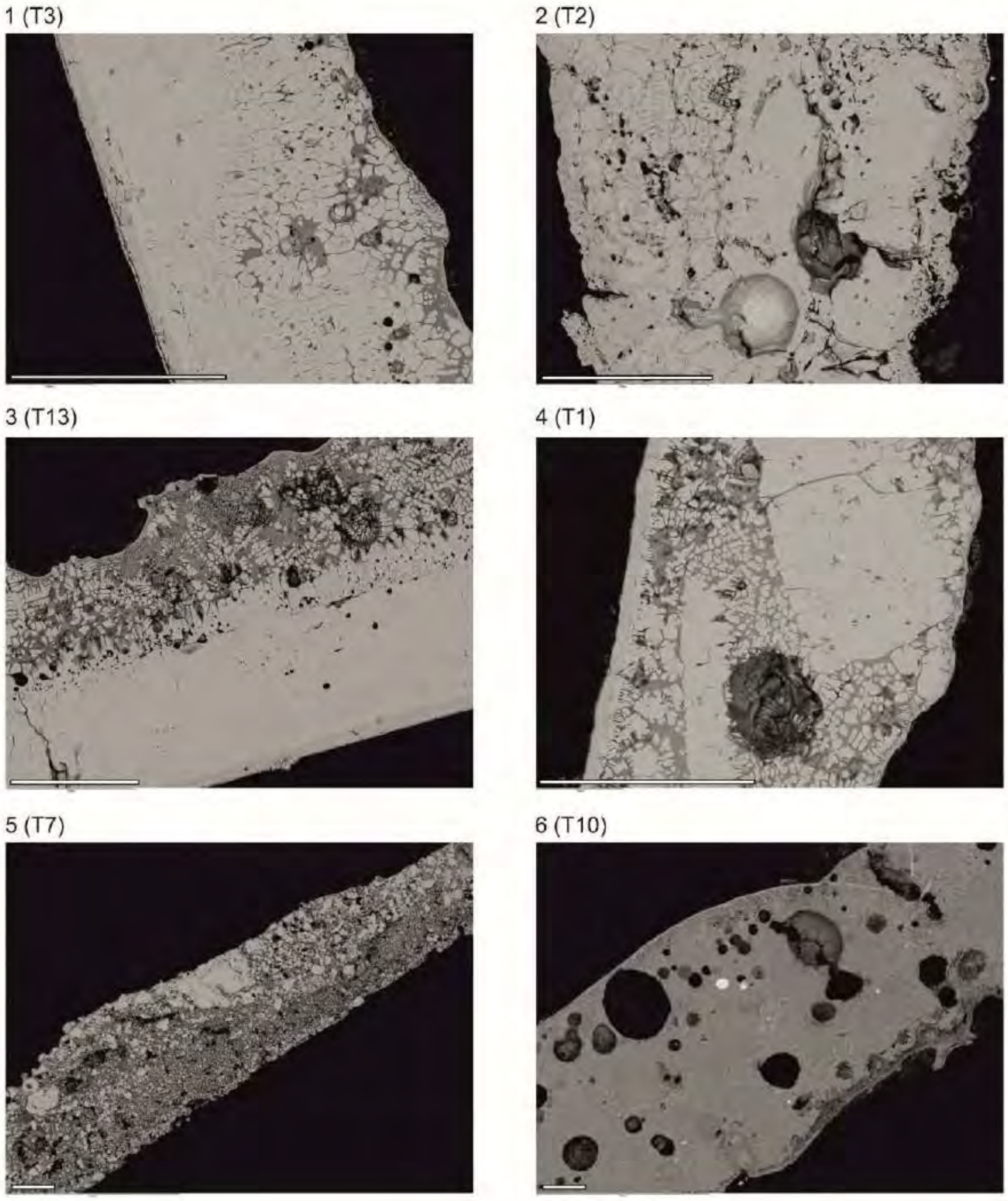


Figure 6. Analyses of materials from Llanfairfechan plotted within the ternary system SiO_2-Al_2O_3-FeO (fields after Schairer and Yagi 1952, fig 6).

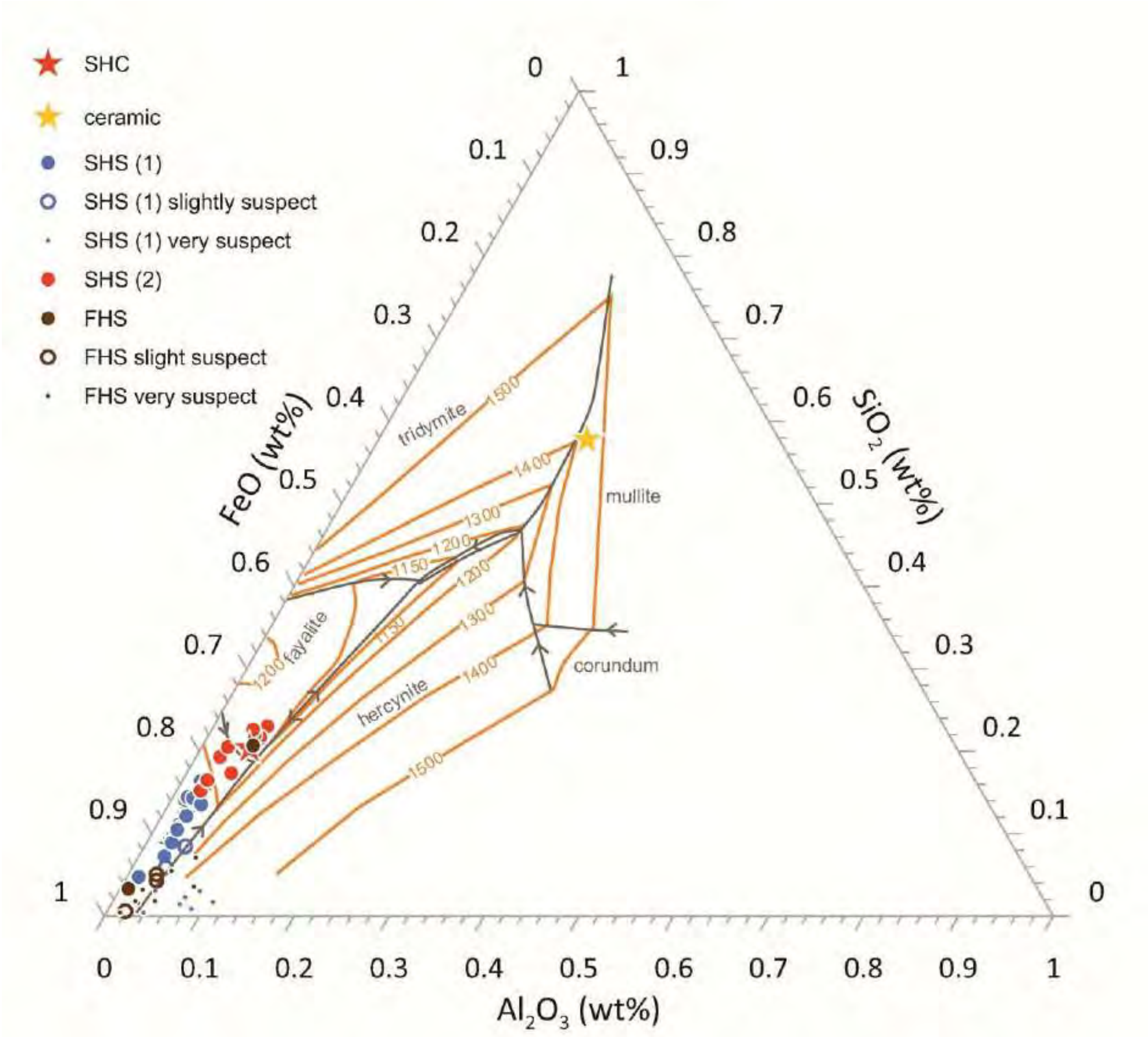


Figure 7. Analyses of materials from Llanfairfechan plotted as:

a. $CaO + K_2O$ (wt%) against SiO_2 wt%
b. P_2O_5 (wt%) against SiO_2 wt%
c. MnO (wt%) against SiO_2 wt%
d. SiO_2/A$_{l2}$O$_3$ (wt%) against SiO_2 wt%

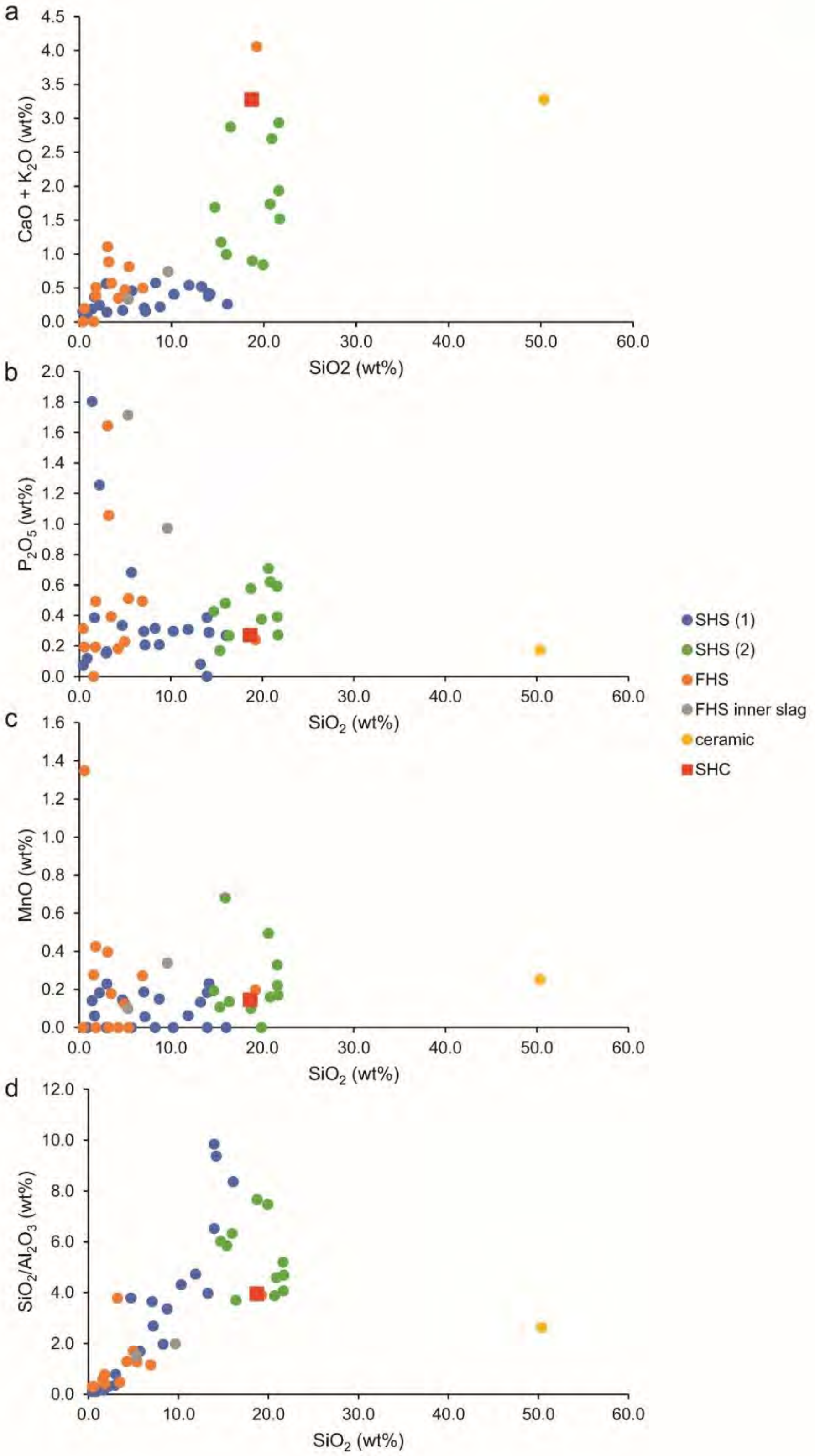
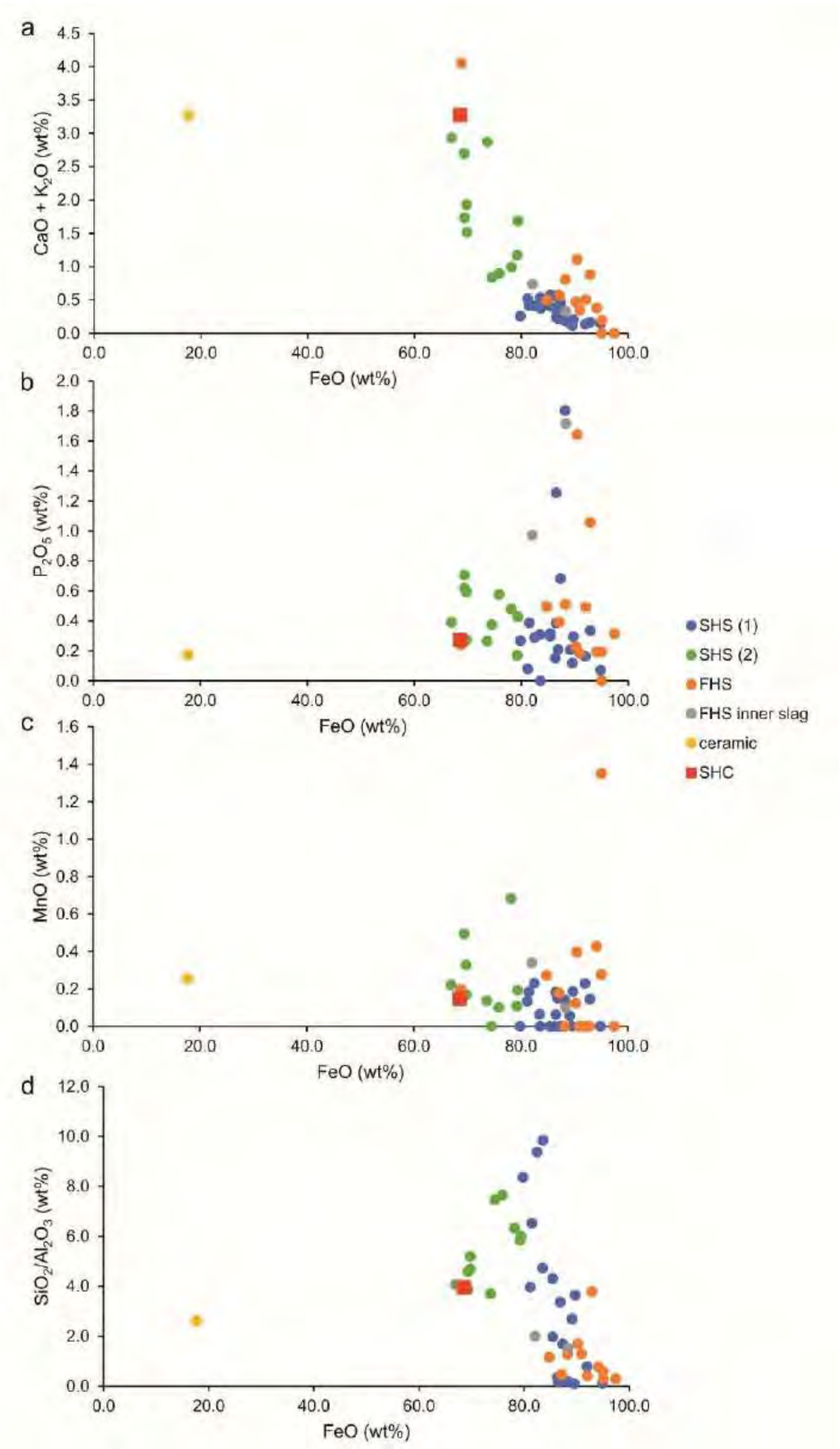


Figure 8. Analyses of materials from Llanfairfechan plotted as:

a. $CaO + K_2O$ (wt%) against FeO wt%
b. P_2O_5 (wt%) against FeO_2 wt%
c. MnO (wt%) against FeO wt%
d. $SiO_2/A_{l2}O_3$ (wt%) against FeO wt%



APPENDIX V: Tables for Assessment of the Macroplant Fossils, Charcoal and Bone

Table 1. Carbonised macroplant fossils

Sample			**5**	**6**	**7**	**8**
Feature			**Pit 7307**	**Interface**	**Pit 11605**	**Hearth**
Context			**7305**	**8804**	**11604**	**12903**
Sample Vol (l)			30	10	20	20
Flot weight (g)			258	27	66	132
% Analysed			100	100	100	100
Species	**Name**	**Part**				
Crops						
Hordeum vulgare L.	Hulled barley	Caryopsis/es	1			
Nuts						
Corylus avellana L.	Hazel	Nutshell frag(s)			33	
Fuel						
Peat	Peat	Frag(s)				***
Weeds						
Rumex sp.	Dock	Achene(s)		1		
Unknown	Indet	Achene/seed		2		

Key:*=<10, **=10-29, ***=30-99, ****=>100

Table 2. Charcoal Species

Sample	**Feature**	**Context**	**Species**	**Name**	**Frag**	**RW**	**Weight**
5	Pit 7307	7305	*Quercus* sp.	Oak	20		12.5
6	Interface	8804	*Quercus* sp.	Oak	10		2
7	Pit 11605	11604	*Corylus avellana* L.	Hazel	10	2	
7	Pit 11605	11604	*Quercus* sp.	Oak	8		16.2
8	Hearth	12903	*Alnus glutinosa* L. Gaertn	Alder	2		0.1

Key: Frag=fragment, RW=roundwood, total weight of sample recorded in gram in last row.

Table 3. Burnt Bone

Sample	**Feature**	**Context**	**Species**	**Element**	**Number**	**Pres**	**Size**	**Burnt**	**Weight**
7	Pit 11605	11604	I/M	Fragment	1	Poor	<10	Yes	0.07

Key: I/M=Indeterminate mammal, size recorded in mm and weight recorded in grams.

APPENDIX VI: Radiocarbon Dating Certificates

SUERC | RADIOCARBON LABORATORY

Rankine Avenue, Scottish Enterprise Technology Park, East Kilbride, Glasgow G75 0QF, Scotland, UK
Director: Prof. Darren F Mark Tel: +44 (0)1355 223332 www.glasgow.ac.uk/suerc

RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130048 (GU69628)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Ty'n y Llwyfan, Llanfairfechan
Context Reference	7305: fill of pit [7307]
Sample Reference	G2495-05A
Material	Charcoal : Oak
$\delta^{13}C$ relative to VPDB	-27.6 ‰
Radiocarbon Age BP	1101 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

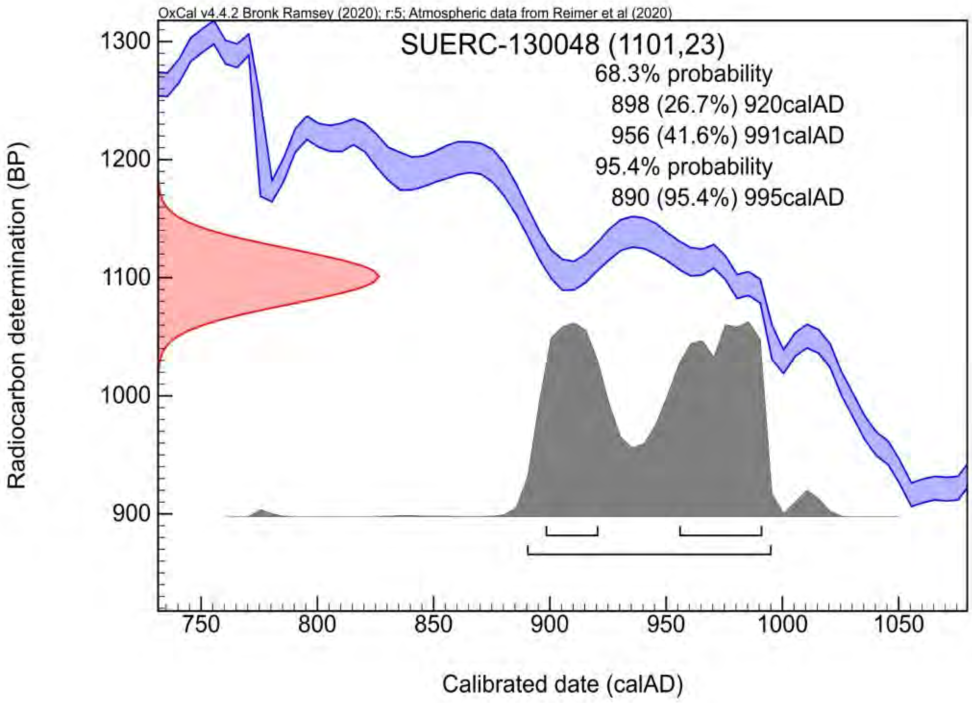
Conventional age and calibration age ranges calculated by : B Tagney

Checked and signed off by : Helen Rose Hill

University of Glasgow

The University of Glasgow, charity number SC004401

The University of Edinburgh is a charitable body, registered in Scotland, with registration number SC005336



The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

SUERC | RADIOCARBON LABORATORY

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RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130049 (GU69629)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Ty'n y Llwyfan, Llanfairfechan
Context Reference	7305: fill of pit [7307]
Sample Reference	G2495-05B
Material	Charcoal : Oak
$\delta^{13}C$ relative to VPDB	-26.2 ‰
Radiocarbon Age BP	858 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

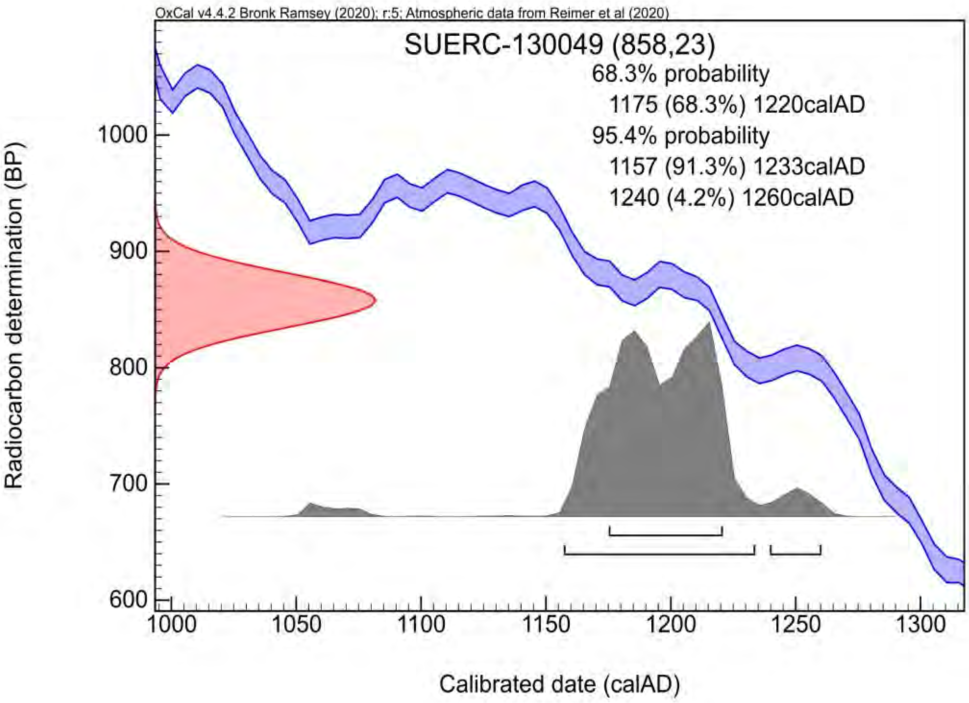
Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

Conventional age and calibration age ranges calculated by :

Checked and signed off by :



The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

SUERC | RADIOCARBON LABORATORY

Rankine Avenue, Scottish Enterprise Technology Park, East Kilbride, Glasgow G75 0QF, Scotland, UK
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RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130050 (GU69630)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Garreg Fawr, Llanfairfechan
Context Reference	11604: fill of pit [11605]
Sample Reference	G2495-07A
Material	Charcoal roundwood : Hazel
$\delta^{13}C$ relative to VPDB	-26.5 ‰
Radiocarbon Age BP	3499 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

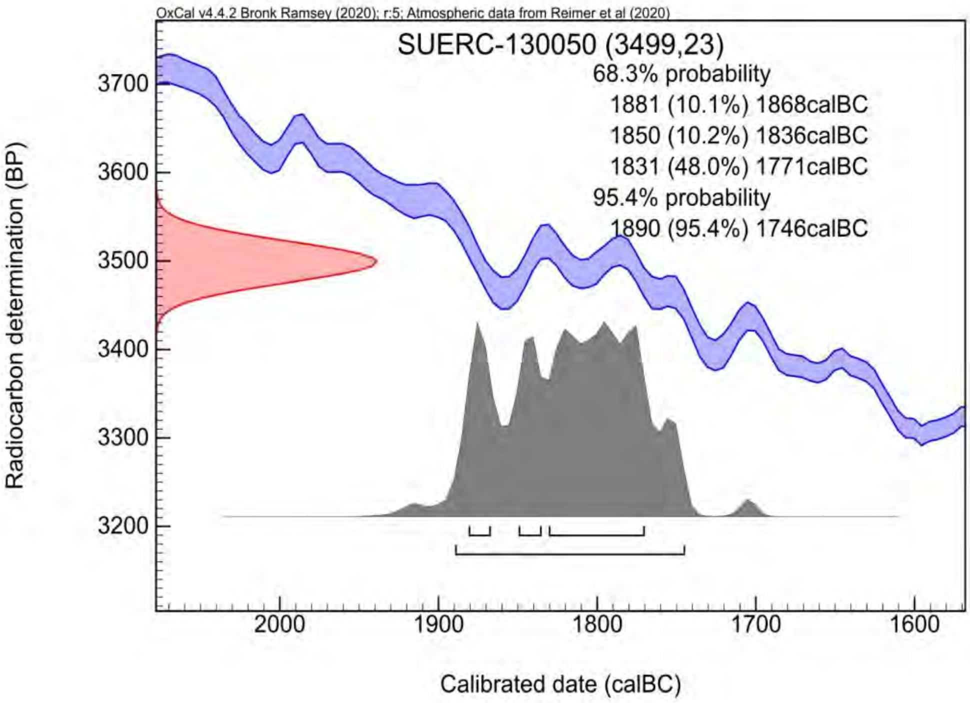
Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

Conventional age and calibration age ranges calculated by : B Tagney

Checked and signed off by : Helen Rose Hail



The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

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RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130054 (GU69631)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Garreg Fawr, Llanfairfechan
Context Reference	11604: fill of pit [11605]
Sample Reference	G2495-07B
Material	Nutshell : Hazel
$\delta^{13}C$ relative to VPDB	-25.8 ‰
Radiocarbon Age BP	3480 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

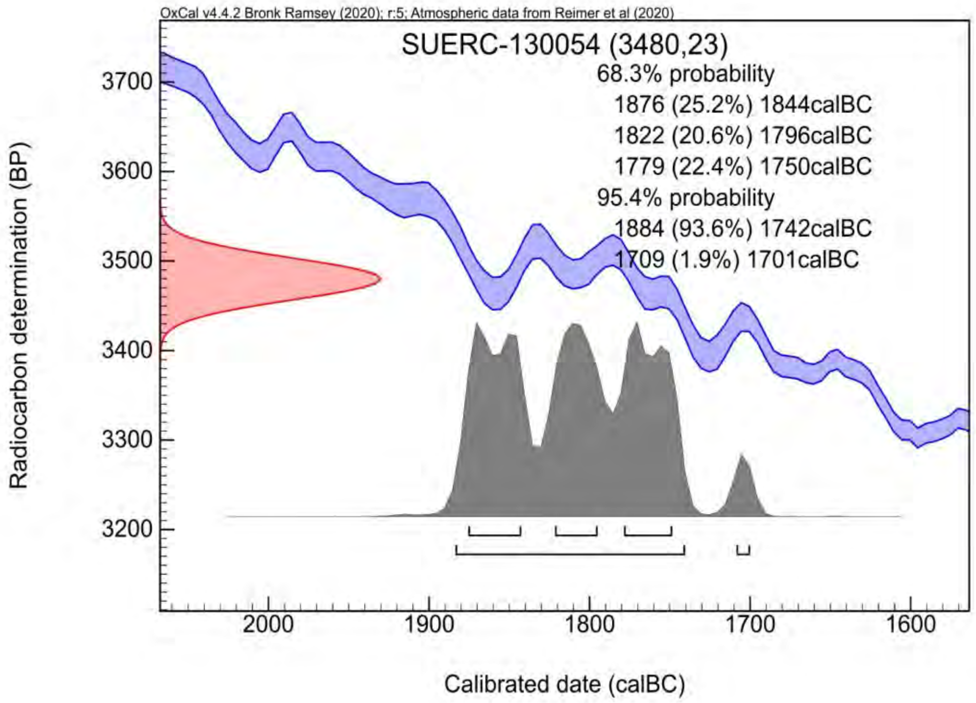
Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

Conventional age and calibration age ranges calculated by :

Checked and signed off by :

University of Glasgow



The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

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RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130055 (GU69632)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Cors y Carneddau, Penmaenmawr
Context Reference	12903: hearth deposit
Sample Reference	G2495-08A
Material	Charcoal : Alder
$\delta^{13}C$ relative to VPDB	-28.6 ‰
Radiocarbon Age BP	2473 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

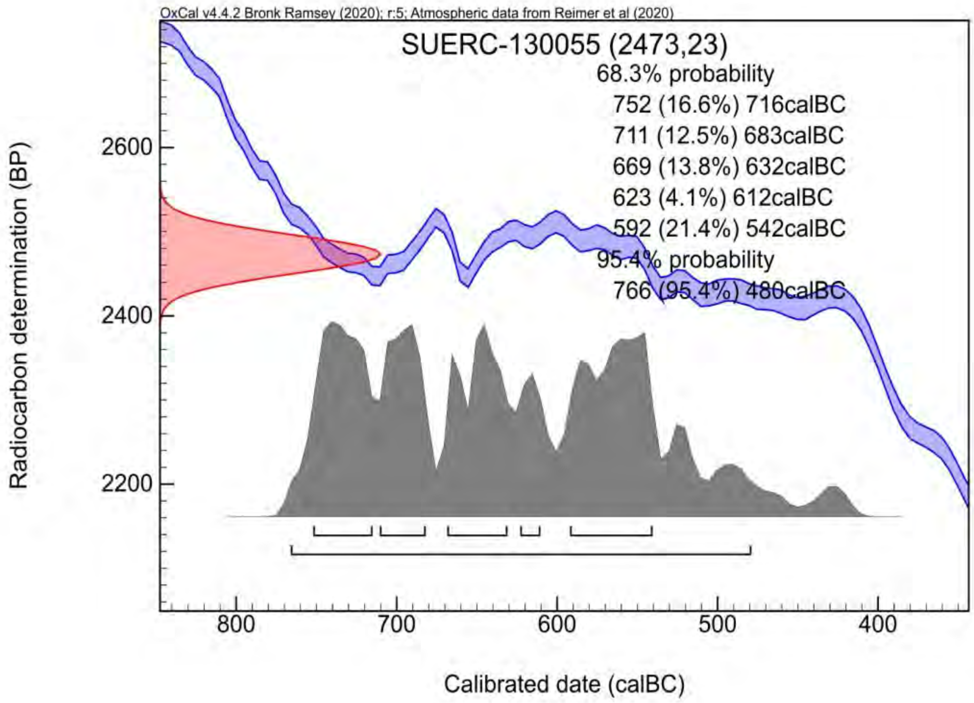
Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

Conventional age and calibration age ranges calculated by : B Tagney

Checked and signed off by : Helen Rose Hill



The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

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RADIOCARBON DATING CERTIFICATE
09 January 2025

Laboratory Code	SUERC-130056 (GU69633)
Submitter	Jane Kenney Heneb: The Trust for Welsh Archaeology The Corner House 6 Carmarthen Street Llandeilo, Dyfed SA19 6AE
Site Reference	Ty'n y Llwyfan, Llanfairfechan
Context Reference	8804: Interface between lynchet and natural
Sample Reference	G2495-06A
Material	Charcoal : Oak
$\delta^{13}C$ relative to VPDB	-25.5 ‰
Radiocarbon Age BP	3006 ± 23

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD) and requires calibration to the calendar timescale. The error, expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

Samples with a SUERC coding are measured at the SUERC AMS Laboratory and should be quoted as such in any reports within the scientific literature. The laboratory GU coding should also be given in parentheses after the SUERC code.

Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016) *Radiocarbon 58(1) pp.9-23.*

For any queries relating to this certificate, the laboratory can be contacted at suerc-c14lab@glasgow.ac.uk.

Conventional age and calibration age ranges calculated by :

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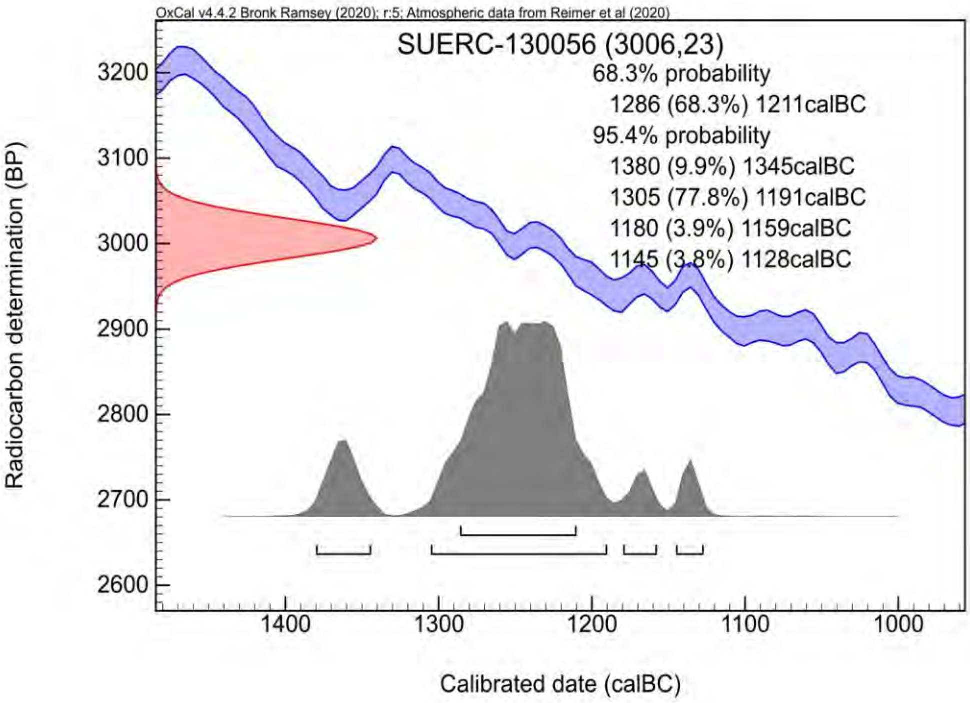

The radiocarbon age given overleaf is calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.*

The above date ranges have been calibrated using the IntCal20 atmospheric calibration curve.†

Please contact the laboratory if you wish to discuss this further.

* Bronk Ramsey (2009) *Radiocarbon 51(1) pp.337-60*
† Reimer et al. (2020) *Radiocarbon 62(4) pp.725-57*

APPENDIX VII: Neolithic sites on Figures 67 and 68

PRN	Site Name	Summary	NGR
485	Cairn, Bryniau Bugeilydd	Small cairn probably for burial. Excavation trench revealed Neolithic activity beneath.	SH72007398
529	Maen y Bardd Burial Chamber, Caerhun	A well-known and well visited burial chamber of portal dolmen type, located near the Roman road from Caerhun to Caernarfon. The stone chamber is still intact but the shape of the cairn which would once have covered it is confused by the remains of later field boundaries. Located within a rich multi-period archaeological landscape, the presence of a Bronze Age cist grave and two standing stones close by indicate that this was probably a well-travelled route way long before the construction of the Roman road.	SH74067178
530	Burial Chamber, Near Maen y Bardd		SH74127189
539	Stone Ring, Cefn Coch, Above Penmaenmawr		SH72507476
544	Stone Circle, Cefn Coch, Above Penmaenmawr		SH72197463
731	Axe Factory, N of Graig Lwyd	The hard igneous rock of Graig Lwyd was used for the production of stone axe heads in the Neolithic period. Various working sites were investigated in the 1920s and excavations in 1993 revealed more areas of Neolithic workings. Graig Lwyd was one of the largest 'axe factories' in Britain and its products are found all over the country, identified by petrological analysis. Working areas and the debris of axe making, waste flakes, rough-outs, broken axe heads etc can still be found.	SH718755
1542	Axe Roughout, Findspot, Tal y Cafn Uchaf		SH785713
1626	Polished Stone Axe, Findspot, Llechen Uchaf	Findspot of polished Neolithic stone axe	SH756755
2483	Stone Axe Hammer, Findspot, Conway Valley Nurseries		SH78097381
2491	Axe Heads, Findspot, Garreg Fawr	Findspot of three roughouts of Neolithic stone axes	SH690735
2880	Perforated Axe Hammer, Findspot, Penmaenan	Findspot of a late Neolithic or Bronze Age perforated stone axe-hammer.	SH707762
2897	Flint Implement, Findspot, North-East of Graig Lwyd		SH71977563
2898	Flint Implement, Findspot, Graig Lwyd		SH71827562
3448	Chambered Cairn (possible), Ty'n y Groes		SH770719
3487	Burial Chamber, Site of, Blaen-y-bardd		SH744717
3671	Axe Hammer, Findspot, Moel Wnion		SH6469
4071	Axe Hammer, Findspot, College Farm, Aber		SH65367267
4075	Perforated Stone Axe Hammer, Findspot	Findspot of three late Neolithic or Bronze Age perforated stone axe-hammers, one of which is in Bangor Museum and has been analysed.	SH699734

PRN	Site Name	Summary	NGR
4078	Perforated Stone Axe Hammer, Findspot, Ty'n y Llwyfan	Findspot of a late Neolithic or Bronze Age perforated stone axe-hammer.	SH695741
4086	Stone Axe, Findspot, Rhaeadr-fawr		SH671701
4091	Stone Tool (Mace), Findspot, N of Dinas Fort	Findspot of a late Neolithic or Bronze Age perforated stone axe-hammer.	SH698743
4094	Graig Lwyd Roughout, Findspot, The Close, Llanfairfechan	Findspot of three roughouts of Neolithic stone axes	SH68487482
4704	Graig Lwyd Axe, Findspot	Findspot of a Neolithic stone axe	SH720715
4720	Axe-working site, Maes y Bryn, near Dinas	Site with evidence for working Neolithic stone axes	SH705738
6219	Flint Flake, Findspot, Foel Lus		SH73337554
7050	Stone Axe, Findspot, Nr Hafod y Gelyn	Findspot of a Neolithic stone axe	SH676715
7083	Flint Implements, Findspot, Bryn Golau		SH6873
7092	Flint Core, Findspot, Dwygyfylchi		SH744769
7397	Graig Lwyd Axe Roughout, Findspot, Gorddinog	Findspot of a roughout Neolithic stone axe	SH669737
7478	Graig Lwyd Axe, Findspot, Henfaes, Aber	Findspot of a roughout Neolithic stone axe	SH65607305
16586	Submerged Peats, Glan y Mor		SH66637430
19156	Stone Axe Fragment, Findspot, Llanfairfechan	Findspot of a roughout Neolithic stone axe	SH70027440
24139	Graig Lwyd Roughouts, Findspot, Blaenau	Findspot of two roughout Neolithic stone axes	SH702742
24725	Graig Lwyd Axe, Findspot, Llanfairfechan	Findspot of a roughout Neolithic stone axe	SH7037774076
24735	Stone Axes, Findspot, Garreg Fawr	Findspot of two roughout Neolithic stone axes	SH6905073578
24736	Stone Axe, Findspot, Ffridd Tan y Graig	Findspot of a roughout Neolithic stone axe	SH69167515
27502	Cup Marked Stone, Camarnaint		SH69397308
27504	Cup-Marked Stone, Llanfairfechan		SH69297225
67318	Axe-working floor, site A, Graig Lwyd	Working floor where Neolithic stone axes were produced.	SH71767574
67319	Axe-working floor, site B, Graig Lwyd	Working floor where Neolithic stone axes were produced.	SH71787556
67320	Axe-working floor, site	Working floor where Neolithic stone axes were produced.	SH71837563

PRN	Site Name	Summary	NGR
	C, Graig Lwyd		
67321	Axe-working area, site D, Graig Lwyd	Working floor where Neolithic stone axes were produced.	SH71667500
67322	Axe-working floor, site E, Graig Lwyd	Working floor where Neolithic stone axes were produced.	SH71737519
67323	Stone axe quarry, site F, Graig Lwyd	Area of Neolithic quarrying for material to make stone axes	SH71647498
67324	Axe-working area, site G, Graig Lwyd	Working area where Neolithic stone axes were made	SH71747512
67325	Stone axe quarry, site I, Graig Lwyd	Area of Neolithic quarrying for material to make stone axes	SH71537489
67326	Cairn, W of Graig Lwyd	Small cairn with evidence of Neolithic activity underneath	SH71237508
67327	Cairn, W of Graig Lwyd	Small cairn with evidence of Neolithic activity underneath	SH71237506
67328	Stone Axe Working Area, Garreg Fawr, Llanfairfechan	Area where stone was obtained to make Neolithic stone axes and axes were produced	SH69067359
67329	Stone Axe Working Area, Ty'n y Llwyfan, Llanfairfechan	Area where stone was obtained to make Neolithic stone axes and axes were produced	SH6984573975
67330	Stone Axe Working Area, Ffridd Tan y Graig, Llanfairfechan	Area where stone was obtained to make Neolithic stone axes and axes were produced	SH69157518
67331	Stone axe found at foot of Dinas, Llanfairfechan	Findspot of roughout Neolithic stone axe	SH6984973978
67406	Axe-working flakes, Pen Cefn	Findspot of Neolithic stone axe working flakes	SH7092474352
67408	Axe working site, Green Gorge, Foel Lus	Area where Neolithic stone axes have been made	SH733758
67409	Axe working site, Waun Llanfair	Area where Neolithic stone axes have been made	SH708742
67410	Axe working site, Cors y Carneddau	Area where Neolithic stone axes have been made	SH716747
67411	Stone axe, Graig Lwyd Farm	Findspot of a Neolithic stone axe	SH719758
67412	Axe working site, Graig Lwyd Farm	Area where Neolithic stone axes have been made	SH7185275740
67413	Stone axe findspot, Graig Lwyd	Findspot of a roughout Neolithic stone axe	SH7179075540
67414	Stone axe findspot, Llanfairfechan	Findspot of a roughout Neolithic stone axe	SH6855474268
67415	Stone axe roughout findspot, Ffridd Tan y Graig	Area where many roughout Neolithic stone axes have been found	SH69187517
67416	Quarried face, Graig Lwyd	Area of probable Neolithic quarrying to obtain material for stone axes	SH7169474952
67639	Stone axe roughout, Bryniau Bugeilydd	Findspot of a roughout Neolithic stone axe	SH71817430
67640	Stone axe roughout, Ty'n y Llwyfan	Findspot of a roughout Neolithic stone axe	SH69787387
67641	Stone axe roughout, Tyddyn Drain	Findspot of a roughout Neolithic stone axe	SH68877478

PRN	Site Name	Summary	NGR
67642	Stone axe roughout, Ffridd Tan y Graig	Findspot of a roughout Neolithic stone axe	SH6912775210
67643	Stone axe roughout, Llanfairfechan	Findspot of a roughout Neolithic stone axe	SH690735
67644	Stone axe roughouts, N of Henar	Findspot of two roughout Neolithic stone axes	SH6902875327
67645	Stone axe, Sychnant Pass	Findspot of a Neolithic polished stone axe	SH747770
67646	Stone axe, Rhaeadr Fawr, Aber	Findspot of a Neolithic stone axe	SH668701
67647	Two stone axe roughouts, Graig Lwyd	Findspot of two roughout Neolithic stone axes	SH718755
67648	Stone axe, Penmaenmawr	Findspot of a Neolithic stone axe	SH7176
67775	Two stone axe roughouts, Foel Lwyd	Findspot of two roughout Neolithic stone axes	SH720725
67776	Stone axe roughout, Garreg Fawr	Findspot of a roughout Neolithic stone axe	SH690735
67777	Stone axe roughout, Dwygyfylchi	Findspot of a roughout Neolithic stone axe	SH72297465
67778	Stone axe roughout, Dinas	Findspot of a roughout Neolithic stone axe	SH7074
67779	Stone axe roughout, Llanfairfechan	Findspot of a roughout Neolithic stone axe	SH684747
67780	Stone axe roughout, Foel Lwyd	Findspot of a roughout Neolithic stone axe	SH715724
67781	Stone axe roughouts, Garreg Fawr	Findspot of two roughout Neolithic stone axes	SH6973
67783	Stone axe roughout, Ffridd Tan y Graig	Findspot of a roughout Neolithic stone axe	SH6913575178
67784	Stone axe, Foel Lûs	Findspot of a Neolithic stone axe	SH732762
68735	Small Flint Flake, Gyffin, Conwy	The findspot of a probable prehistoric flint flake.	SH7743276815
71267	Pit, Abergwyngregyn	A pit thought to be prehistoric in origin with evidence of in situ burning.	SH6428472247
74826	Stone Axe Roughout, Findspot, Dinas	A Neolithic stone axe roughout found on the screes of Dinas by David T Jones of Llanfairfechan (Summary provided by Gwynedd Archaeological Trust).	SH6978073858
81591	Axe, Findspot, Penmaenmawr	The findspot of a neolithic axe roughout.	SH7163476352
81634	Stone Axe Working Area, Ty'n y Llwyfan Farm	Area of stone axe working found during test pitting by GAT in November 2019 (Summary provided by Gwynedd Archaeological Trust).	SH69787397
81811	Flint Blade, Findspot, Conwy	The findspot of a prehistoric flint blade.	SH7707577146
91683	Roughout & Flake, Findspot, Graig Lwyd Farm	The findspot of an axe roughout and axe-working flake from Graig Lwyd Farm, Penmaenmawr.	SH7180375805
91684	Roughout, Findspot, Penmaenmawr	The findspot of an axe roughout in Penmaenmawr.	SH7209375917
92341	Axe Roughout, Findspot, Garreg Fawr	The findspot of an axehead roughout.	SH69077360
93577	Worked Stone Assemblage, Findspot, Llanfairfechan	Worked stone finds recovered during an archaeological watching brief.	SH6966673944

PRN	Site Name	Summary	NGR
96143	Axe-working flakes, Ty'n y Llwyfan Farm	A small collection of Neolithic axe-working flakes recovered from an investigation pit on a burst water main (Summary provided by Gwynedd Archaeological Trust).	SH7674873826
96144	Stone Axe Working Area, Ty'n y Llwyfan, Llanfairfechan	An area of scree at the foot of Dinas where evidence of axe-working can be seen on the surface. This area was investigated with an evaluation trench (Summary provided by Gwynedd Archaeological Trust).	SH6984573922
96702	Roughout, Findspot, Nant y Coed	The findspot of a neolithic axe roughout.	SH6978073737
96792	Flake, Findspot, Near, Afon Anafon	The findspot of a flake of uncertain date.	SH6881971097
96794	Awl, Findspot, Near, Afon Anafon	The findspot of a flint awl.	SH6841971208
100569	Feature composed of stone and axe debris, Ty'n y Llwyfan Farm	A deposit of stone and Neolithic axe-working debris forming part of lynchet PRN 100566 (Summary provided by Gwynedd Archaeological Trust).	SH6977973950
100575	Stone Axe Working Area, Ty'n y Llwyfan Farm	An area investigated by test pitting that produced evidence for Neolithic stone axehead production and possibly settlement (Summary provided by Gwynedd Archaeological Trust).	SH6960073900
100576	Axe roughout, Findspot, Ffridd Tan y Graig, Llanfairfechan	A Neolithic stone axehead roughout found on the ground surface (Summary provided by Gwynedd Archaeological Trust).	SH6961173875
100653	Graig Lwyd Axe, Findspot, Madryn, Abergwyngregyn	One of two neolithic axes found c 1m mile apart on farmland near the village of Abergwyngregyn. Discovered accidentally through mechanical disturbance and the circumstances of their original deposition are not therefore known. (Williams, 2000).	SH 669 737
103600	Axe-working site, Garreg Fawr	Area of Neolithic axe-making activity investigated by test pitting in 2023 (Summary provided by Gwynedd Archaeological Trust).	SH68877334
103601	Pit, Garreg Fawr	Small pit of possible Neolithic date found in base of a test pit in 2023 (Summary provided by Gwynedd Archaeological Trust).	SH6885073334
103604	Axe-working site, Cors y Carneddau	Area of Neolithic axe-making activity investigated by test pitting in 2023 (Summary provided by Gwynedd Archaeological Trust).	SH71437473
112196	Axe-working debris, Garreg Fawr	A knapped block of Group VII stone located close to a probable stone axe making site.	SH6894072612
112197	Axe flakes (findspot), Garreg Fawr	Flakes from making Neolithic stone axes found in an area of open scree on the western side of the southern end of Garreg Fawr.	SH6894972628
112198	Microdiorite intrusion, Yr Orsedd	An outcrop of microdiorite (Group VII stone), which may have been used for making Neolithic stone axes.	SH6971072200
112199	Microdiorite core (findspot), Bryniau Bugeilydd	A block of Group VII stone used as a core to produce flakes.	SH7160073800
112214	Axe roughout, Cefn Coch, Above Penmaenmawr	A probable axe roughout found during the excavation in 1958-9 of the boulder circle PRN 539.	SH72507476
112215	Axe roughouts and flakes, Cefn Coch, Above Penmaenmawr	Objects on Group VII stone found during the excavation of the Druid's Circle/Meini Hirion (PRN 541) in 1958-59, including a roughout, a broken roughout and 8 flakes.	SH72287464

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