

**Bangor University**

## **MASTER OF PHILOSOPHY**

### **Investigations into the mineralogy and petrology of the artefacts and sediments from the Lower Palaeolithic site of Pontnewydd Cave, North Wales**

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*Award date:*  
2002

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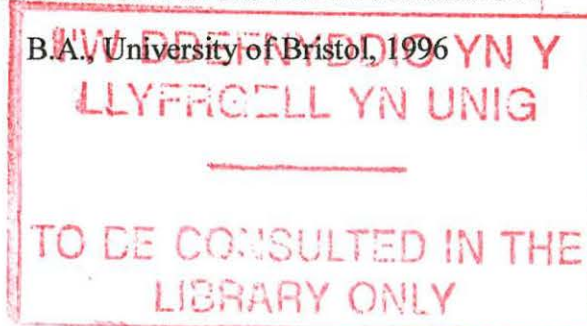
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INVESTIGATIONS INTO THE MINERALOGY AND PETROLOGY OF  
THE ARTEFACTS AND SEDIMENTS FROM THE LOWER  
PALAEOLITHIC SITE OF PONTNEWYDD CAVE, NORTH WALES.

BY

HEATHER JANE ESTHER JACKSON

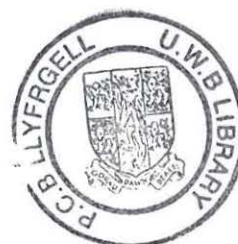
B.A. University of Bristol, 1996



THESIS

Submitted to the University of Wales, Bangor in candidature for the degree of  
Master of Philosophy

Bangor, Wales,  
June 2002





## ABSTRACT

Pontnewydd Cave is a remarkable site, providing the earliest evidence of hominid activity in Wales. The 1,284 artefacts are 225,000 years old, and lie within a derived context in the debris flows that form the sedimentary sequence in Pontnewydd Cave. It is almost unique among British Palaeolithic sites in possessing a lithic assemblage made on predominantly silicic igneous rocks.

The artefacts were studied in hand specimen and with a petrological microscope, and were classified into petrological groups. The mineral assemblages observed in the thin sections were compared with published descriptions and some examples of Ordovician igneous rocks. Where possible, the provenance of the rock was deduced. The majority of exotics that could be traced back to their original source derived from North Wales, and principally the Snowdonia area, but a smaller number also derived from the English Lake District. These results are consistent with those of previous studies (Bevins 1984).

A database of the tool types used at Pontnewydd, their dimensions, and the corresponding rock types from which they are manufactured was compiled. This database was then used to discuss whether some raw materials have been selected over others for artefact manufacture, and if so, whether different suites of raw materials have been used for certain tools. The results indicate that an overall preference has been exhibited for more silicic rocks, and that tools that required less refinement such as handaxes and cores were made on the denser lavas, whilst items that required retouch such as retouched flakes and scrapers were made on the more homogenous flint, chert and fine silicic tuff

Through optical microscopic studies of the heavy minerals from many of the layers within Pontnewydd Cave, it was possible to ascertain the approximate geological source of the sediments. Observation of the heavy minerals and the particle size distribution of the sediment also provided some information about the degree of weathering that the sediments were subjected to prior to their emplacement in the cave. This information supported the approximate chronology provided by Embleton and Livingston (1989) and provided new evidence for the source and environment of some of the layers from the New Entrance.

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## ACKNOWLEDGEMENTS

I wish to acknowledge with gratitude the advice, enthusiasm and kindness of Dr. D.A. Jenkins, particularly during my stay in Bangor, who supervised the sedimentary component of this project. I would like to thank Dr. S. Aldhouse-Green for recommending me for this project and for his continued co-operation and encouragement with the progress of the work. I would also like to express my gratitude to Dr. Richard Bevins for his practical advice and assistance with the petrological component of this project.

I wish to express my thanks to several members of staff of the Geology Department of the National Museums and Galleries of Wales; Dr. M. G. Bassett for the use of resources within the department, Alan Channing for help with computer software, Mike Lambert for sectioning the artefacts, and Jana Horák for her guidance. I would also like to thank Sally Pointer of the Education Department, NMGW for understanding the constraints of writing an M.Phil whilst in full-time employment, and Elizabeth Walker of the Archaeology and Numismatics Department, NMGW for access to the Pontnewydd Artefacts and use of her artefact measurements.

I am extremely grateful to the Friends of the National Museums and Galleries of Wales for awarding me funding for this Studentship. Finally, I would like to thank my family, particularly my parents Richard and Kirsten Jackson, and my friends David Trevarthen and Clive Trueman for their continued support and encouragement.



**Investigations into the Mineralogy and Petrology of the Sediments and  
Artefacts from the Lower Palaeolithic site of Pontnewydd Cave.**

**Chapter 1**

**INTRODUCTION, AIMS AND HISTORY OF  
PREVIOUS RESEARCH**

## **1. INTRODUCTION**

Pontnewydd Cave is situated in the Carboniferous limestone of the Elwy Valley, about 6km northwest of Denbigh and 10 km south of Rhyl, in North Wales (Figure 1.1). The site lies at the point of contact of two great ice sheets, now represented by the Welsh drift and the Irish Sea drift. Pontnewydd Cave is the northernmost Lower Palaeolithic site in Europe. It has survived successive glaciations, and yielded an impressive 1284 lithic artefacts, as well as associated faunal remains and environmental evidence. Excavations of the cave, conducted between 1978 and 1995 by Dr. Stephen Aldhouse Green (University of Newport) also produced hominid bones and teeth with possible Neanderthal characteristics (Stringer, 1984). The archaeological material found in the cave is not in a primary context, but is contained within debris flows, which have transported the artefacts from their original location around the cave mouths. The stone tool industry consists of hand-axes, Levallois cores and flakes, a cleaver, a Mousterian point, scrapers, chopping tools and knapping debitage, all made by hard hammer technique mostly on volcanic pebbles. A large number, and possibly all, of the raw materials that were used for the manufacture of the lithic artefacts have been interpreted as glacially transported cobbles.

### **1.1. Aims of the Investigation**

This project aims to undertake a petrological study of the artefacts and sediments from the Lower Palaeolithic site at Pontnewydd Cave. The objectives of this study are:

- To compile a database of the tool types used at Pontnewydd and the corresponding rock types from which they are manufactured. By studying the artefacts in hand specimen and under a binocular microscope, it will be possible to divide the material into rough petrological groupings. These initial rough identifications will be clarified by thin sectioning of selected samples and further study using polarizing microscopy. This database will then be used to establish whether some raw materials have been selected over others for artefact manufacture, and if so, whether different suites of raw materials have been used for certain tools.
- Where possible, to provide an indication of the original provenance of the raw materials used for artefact manufacture. The characteristic mineral assemblages observed in the thin sections will be compared with those in the literature, and previously prepared thin sections from known localities. Preliminary studies (Bevins

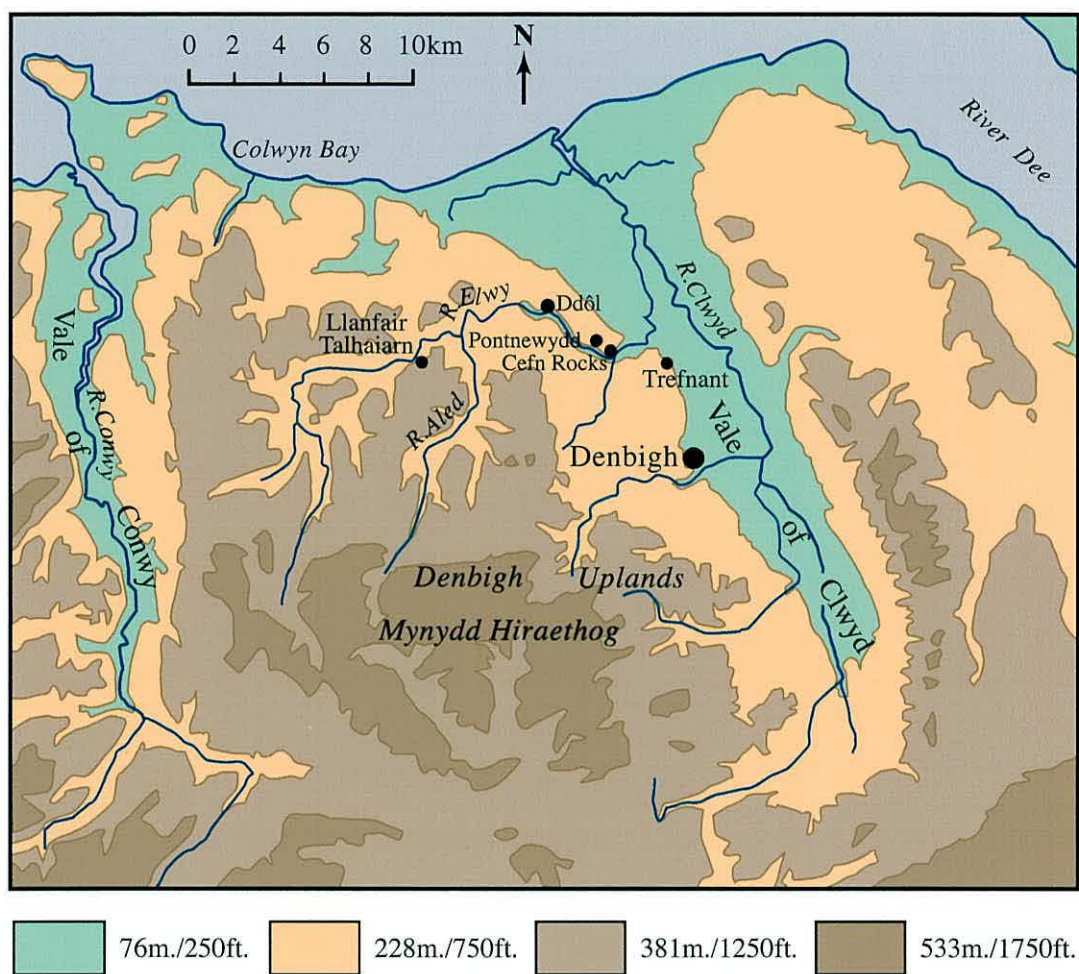


Figure 1.1. Map showing location of Pontnewydd and Cefn Caves and the Elwy Valley drainage.



1984), including petrological study of material excavated from 1979 - 1981, noted artefacts showing the effects of low grade metamorphism consistent with Ordovician volcanic rocks from Snowdonia and Cumbria. This study will therefore focus on these areas as likely candidates for the original provenance.

- To attempt to ascertain the geological source of the sediments collected from Pontnewydd Cave during successive excavations using optical microscopic studies of the heavy minerals within the sediment (to be undertaken in the School of Agriculture and Forestry Sciences, University of Wales, Bangor). Optical microscopy may also help indicate the degree of weathering to which the sediments were subjected prior to their emplacement in the cave.

## **1.2. Rationale**

Pontnewydd Cave is a remarkable Lower Palaeolithic site, being the earliest hominid occupation site in Wales. It is one of the few sites to have produced Middle Pleistocene hominid remains. It is therefore of great importance to archaeology that as much information as possible may be gleaned about the artefacts found there. The assemblage is 225,000 years old, lying within a derived context in the debris flows stratified within Pontnewydd Cave. In previous work, the sample size has been limited and it is therefore possible that enhancement of the numbers will cause earlier conclusions to be modified.

The Pontnewydd site presented unusual challenges for the toolmaker in the Palaeolithic and continues to do so for the archaeologist today. The artefact types may have been strongly influenced by the raw materials available; indeed a 'degree of raw material selection' by the Neanderthals has been suggested (Green, 1988). An understanding of the constraints of the rock types is therefore important.

These constraints are presumed to be primarily petrological, so a further petrological study of the artefacts should do much to elucidate the problems of tool manufacture at Pontnewydd. Accurate provenancing may also enable experimental work on the typology to be performed by professional knappers, such as Newcomer (in Green *et al.* 1984).

Questions still remain about the origin of the cave sediments and their weathering history prior to emplacement in the cave. Only further sedimentological analysis can

answer these questions. In the last seasons of excavation, an undisturbed entrance, containing a series of debris flows, was discovered at Pontnewydd. This study will attempt to correlate this recently excavated sequence with that present in the main cave.

There is little archaeological evidence in Wales for this period, but this does not necessarily mean that habitation was limited. Successive glaciations must have destroyed much of the evidence for human activity. Pontnewydd Cave offers a valuable insight into the glacial history of North Wales. For millennia the cave has acted as a sediment trap, enabling the glacial record of the area to be extended back to events pre-dating the tills and gravels which survive in the Elwy valley. Further work on the glacially derived boulders from which the artefacts were made will therefore contribute to the understanding of the earlier glacial history of the area.

### **1.3. General plan of the thesis**

Following a statement of the history of research on Pontnewydd Cave to date, the basic geology and geomorphology of the area are introduced (Chapter 2.1-2.4) and the sedimentology of the cave is described (Chapter 2.5). These sections provide a context for the analysis of the cave sediments described later in the thesis, in Chapter 4. The principal part of the thesis concerns the petrological study of the artefacts and the resulting trends in the use of raw materials within the lithic assemblage and this is given in Chapter 3. Finally, the general conclusions, based on the results of both studies of the artefacts and the sediments, are given in Chapter 5. Each individual chapter is prefaced by a short introduction followed by the analytical methods employed, then the results and discussion, and finally the conclusions are given. The details of the analyses are reported in full in the appendices.

### **1.4. History of Research**

#### **1.4.1. Pontnewydd Cave.**

Interest has been shown in the Carboniferous limestone caves in the north east escarpment of the Elwy valley for over 160 years. A series of excavations at Cefn Cave, Cae Gronw and Pontnewydd Cave have yielded much palaeontological and archaeological material, and generated further research in several disciplines. The Pontnewydd site has been in the ownership of the Williams-Wynn family for several generations, and is currently closed to the public.



The Reverend E. Stanley (1832) first examined the Cefn caves. During his excavation of the Cefn caves he also surveyed Pontnewydd Cave, which he found to be "entirely blocked up with soil". It would appear that no further investigations were undertaken there until 1870, when Boyd Dawkins (1874, 1880), the Rev. Edward Thomas and the landowner, Mrs. Williams Wynn, conducted an excavation. At the time of his visit in 1832 Stanley referred to the caves as "never yet opened" but it is possible that small scale unrecorded digging took place between Stanley's survey and Boyd Dawkins' excavations (see Currant 1984). Dawkins' excavations yielded only faunal remains, and no plans or sections were published. Although Boyd Dawkins claimed not to have found any artefacts, many have been recovered subsequently in the spoil that remained from what may have been his excavations, in addition to Pleistocene fauna (Green 1984). Bearing in mind the nature of the artefacts (see Chapter 3) it is perhaps not surprising that some were overlooked during these early investigations.

The next period of activity at Pontnewydd, during the 1870s and 1880s appears to have been confined to the recovery of animal remains and implements from the spoil tips at the front of the cave. McKenny Hughes (1874), who conducted an excavation at the site with Rev. Edward Thomas, reported that the site had been examined by the owners "some years ago" and indicated that the upper deposits had been almost entirely removed "for some 25 yards into the cave". Hughes' description of the cave deposits approximates quite closely to the position in which they were found at the start of the 1978 excavations (see Currant 1984) and Hughes' faunal list (1874, 1887) has been verified from surviving specimens in the Sedgewick Museum of Geology collections. By contrast, Dawkins' faunal list (1871, 1874, 1880) is found to be different in each publication and difficult to relate to any particular extant collection.

The excavations of Hughes and Thomas also succeeded in recovering a hominid tooth, since lost, from the cave, and in identifying the three units which still form the basis of the stratigraphy at Pontnewydd. These are the Yellow Cave Earth, the Breccia, and the Gravel, (which now correspond respectively to the Upper Clays and Sands, the Upper and Lower Breccia, and the Upper Sands and Gravels). McKenny Hughes (1887) also recognised the importance of the cave deposits in establishing the source of the raw materials used for artefact manufacture:

*"It would appear that here we have the toughest stone of a country where suitable flint could not be procured...the instruments are formed of felstone such as is abundant in the drift of the neighbourhood and cave deposits". He added: "even in a highly-finished implement this rock does not show the care bestowed on it in the same way that flint does".*

During the war the cave was used as a munitions store, and despite its status as a Scheduled Ancient Monument, awarded in July 1933, a small illegal excavation was carried out by cavers in the 1960s, which was published as a letter to "The Spelaeologist" (Kelly 1967). Interest was expressed in the site by Wilfred Jackson, whose photographs taken in the 1920s (Green 1984), still survive, and Molleson (1976) who summarised the known finds and excavations from the cave.

The first comprehensive excavations commenced in 1978 under the direction of Dr. S. Aldhouse-Green (then Dr. H.S. Green), as part of a National Museum of Wales Research Programme into the Palaeolithic settlement of Wales. The initial scope of the project embraced study of Cefn, Pontnewydd and Cae Gronw caves in the Elwy valley.

The preliminary findings of the Pontnewydd Cave work were presented shortly afterwards (Green *et al.* 1981b). This paper summarised the early discoveries relating to the stratigraphy (S.N. Colcutt and P.A. Bull), the chronology (H.P. Schwartz, J. Huxtable, N.C. Debenham, and T.I. Molleson), hominid and faunal remains (C. Stringer and A.P. Currant), and the archaeological material (H.S. Green and R.E. Bevins). A first monograph, which covered the excavations during the period 1978-1983, was published in 1984 by the National Museum of Wales (Green 1984). This was a multi-disciplinary publication in which several physical aspects of the site were discussed, including the location, geology and geomorphology (Embleton), the sediment stratigraphy (Colcutt and Bull), and the mineralogy and petrology (Jenkins, Bevins, Clayton). Also published within the monograph were the archaeological discoveries, such as the Palaeolithic artefacts (Green) and developments on the dating of the site (Schwarcz, Huxtable, Debenham, and Molleson). Later, Green (1986) provided an overview of the continuing excavations at Pontnewydd and also reported the results of work carried out at Cefn, Cae Gronw, Coygan and Little Hoyle caves. In his next paper, Green (1988) drew on the work that had been conducted on the natural damage and solutional rounding of the



artefacts (Bull 1984, Shackley 1974), and the relationship between typology and the raw materials used (Bevins 1984). Subsequently, a publication in *L'Anthropologie* (Green *et al.* 1989) described the advances that had taken place in the understanding of the Quaternary evolution (Embleton and Livingston), the sediment stratigraphy (Bull), and the geochronology of the cave (Schwarcz, Rae, Debenham, and Ivanovich). The implications of the erratic and artefact petrology were discussed and lithological descriptions of the main raw material types were presented by Bevins, while the distribution within the deposits and typology of the artefacts were considered by Green. The most recent synthesis (Aldhouse-Green 1995) provides fully up to date information on many aspects of the site, including discoveries from the New Entrance.

Since the start of the 1978 excavations, it has been felt that the deposits at Pontnewydd were of great importance as chronological markers that could help place the Quaternary sequence of the area (Embleton in Green 1981b). It is now known that only the very latest of the cave deposits can be correlated with the deposits and landforms of the present geomorphological system (Embleton and Livingston 1989). Thus the cave cannot be used as a stratigraphic marker for the Middle Pleistocene, but can be employed to make inferences about that part of the Quaternary not clearly represented by the geomorphological record. Moreover, early investigations recognised that the cave was located near to the estimated maximum limit of Irish Sea Ice, and it was hoped that the excavations would provide dating evidence for the glaciation of the area (Embleton 1984). The geomorphology will be considered in greater detail elsewhere (see Section 2.4), but central to any discussion on this topic is the fortuitous situation of Pontnewydd at the meeting point of the pre-Devensian Northern and Welsh glacial drifts (Embleton and Livingston 1989). Although the level of the river would have been higher, the broad outlines of topography during the interglacial occupation would have been similar to those of today (Green 1984). Excavation at the New Entrance in 1988 (Green and Livingston 1991) provided evidence that the rock face had receded considerably since the emplacement of the deposits, so the original form of the cave entrance can only be a matter of inference. It is likely however that the phreatic tube which currently forms the main cave once extended in a similar fashion beyond the present rock face, providing a relatively small area for habitation.



Sedimentological studies originally aimed to correlate the sequence of the three separate areas of the cave, which had been excavated. During these first seasons of excavation the stratigraphy was a matter for concern, in particular the difficulty of intra-site correlation within the cave (Green 1981b). The stratigraphy is described in detail elsewhere in this thesis (Section 2.5). In summary, however, the archaeological material found at Pontnewydd is not in a primary context, but is contained within sediments, which have moved bodily into the cave from around the original cave mouth (Colcutt 1984). These debris flows are of at least two different periods, but the earlier ones, which contain most of the artefactual, human and faunal remains, are considered to have been emplaced only a few thousand years after the occupation (Bull 1984, Colcutt 1984). The nature and process of debris flows has been investigated (Colcutt 1986), and further examples occur in Britain such as at Kent's Cavern, Dorset and GB Cave, Mendip.

The nature of the sedimentation in the debris flow units in which the artefacts, hominids and fauna were found was further considered in *L'Anthropologie* (Green *et al.* 1989). In particular, a revised and extended description of the Lower Sands and Gravels was given. This unit contains neither artefacts nor fauna but is rich in cobbles of volcanic rocks from North Wales (Bevins 1984), transported to the cave by glacial activity. Their presence is important because it demonstrates the local availability of these rocks, which were later used for tool manufacture by the early hominids (Bull *in* Aldhouse-Green 1995). Perhaps the most important inference to be drawn from the 1989 study was the relative rapidity of the sediment input debris flows. Over much of the 300,000 years that the sedimentary sequence represents, the cave and its sedimentary mechanisms are considered to have been quiescent. Whether post-depositional weathering did occur during these 'static' periods and the products of weathering were later themselves eroded, or whether the cave was sealed by a sediment plug, must remain conjecture (Bull 1989). The results of quantitative heavy mineral and clay mineral analyses, followed up by morphological studies involving examination by SEM, show that different sources and contexts were involved for the different debris flows (Aldhouse-Green 1995, Jenkins 1997).

An extensive programme based on Uranium-Series (U-Series) dating, Uranium relative dating and Thermoluminescence (TL) dating methods has been used to construct a

chronology of the Pontnewydd Cave deposits. The results of these techniques suggest that occupation took place within the range of Oxygen Isotope Stage 7 and earlier Stage 6 (Green 1981b). Further absolute and relative dating has been provided by U-Series and TL dating on stalagmite and flowstone (Schwartz 1984, Ivanovich 1984, Debenham 1984), and by TL dating on a burnt flint core (Huxtable 1984). Later, radiocarbon dating by accelerator mass spectrometry was added to the range of techniques, allowing fossil bone as well as speleothem to be analysed.

Hominid remains have also been found at Pontnewydd Cave. Stringer (in Green 1981b) reported that the molar from Pontnewydd closely resembled the molars among the early Neanderthal remains from the late Pleistocene site at Krapina in Croatia (Smith 1976), thought to date from the end of the last interglacial, around 100,000 years younger than the site at Pontnewydd. A further two hominid fragments - a piece of an immature jawbone and a vertebra - were found in unstratified deposits, and subsequently dated (Stringer 1984). The hominid fragments represent at least three individuals, an adult, an adolescent and a child (Stringer 1986, Green 1995). Faunal remains occur in three successive lithological units, the Intermediate Complex and the Lower and Upper Breccias (Currant 1984). The Intermediate Complex displays an interglacial fauna, with roe deer and beaver, whereas the Lower Breccia fauna indicates a climatic deterioration evidenced by the presence of Norway lemming and Northern vole (which would be consistent with an open steppe environment). When linked with the results from other areas of this multi-disciplinary project, the mammalian fauna can guide us towards a fuller understanding of the palaeoecological context of the human occupation.

The principal artefactual components discovered after the first phase of excavation were handaxes of Acheulian types, other implements (principally scrapers) and Levallois debitage (Green 1981b). Around 300 artefacts had been excavated, 40 of which were flint or chert, which were discussed in a parallel paper in *Antiquity* (Green 1981a). The nature of the artefacts and small size of the potential living area in the cave entrance suggested that the cave was used as a temporary butchery site.

Currently, the total number of Pontnewydd artefacts exceeds 1300, of which 90% were manufactured from the various siliceous and pyroclastic rocks derived from the low-grade metamorphosed volcanic terranes of north-west Wales and possibly the English



Lake District. There is little doubt that erratics from locally abundant glacial deposits provided the source of raw materials (Green *et al.* 1981, 1988, Bevins 1984). Their presence on the site, whether as artefacts in the Breccias or as unmodified pebbles in the Basal Sands and Gravels, suggests transport to the Elwy Valley before O.I.S. 6 (Green *et al.* 1981b).

Many of the artefacts from Pontnewydd display rounding of the flake ridges, which has been interpreted as a sign of "rolling". In his 1988 paper, Green drew on the work that had been conducted on the possible solutional rounding of the artefacts (Bull 1984, Shackley 1974). These studies indicated that the rounding was not a result of abrasion in the debris flows, but had occurred before emplacement, outside the cave. This was reinforced by the work of Swanson (1996). Natural damage resulting from exposure to a period of severe climatic conditions involving cryoturbation was also observed (Aldhouse-Green 1995). Green (1988) tabulated the updated identifications and properties of the raw materials, and in addition the suitability for knapping of each material and its availability in the local till were discussed.

The distribution within the deposits, and the frequency and the typology of the artefacts was considered (Green *et al.* 1989, Aldhouse-Green 1995). The Pontnewydd industry finds little close comparison with other sites either in Britain or adjacent continental areas (Green *et al.* 1981b). Newcomer (1984) conducted flaking experiments on the Pontnewydd raw materials and pointed out that the silicic igneous rock used may account for many of the unusual and 'archaic' features of the technology. He was also able to show the difficulties inherent in accurate identification of unmodified flakes and blades when such rocks are used.

The work at Pontnewydd has considerably increased the number of Middle Pleistocene hominid finds in Britain (Stringer 1986), and has considerably extended the area known to be inhabited by this period, being the most northwesterly Lower Palaeolithic site in Europe. The peoples of this time were therefore capable of inhabiting areas further north than had been previously recognised, and the intervening gaps in distribution may be as much an artefact of glacial erosion as due to the scarcity of caves (Wymer 1977). The recognition of an Acheulian site in the Highland zone has caused reflection on the

model of Palaeolithic settlement as having been confined to the lowland southeastern areas of England.

#### 1.4.2 Other Caves in the Elwy Valley

Green (1986) placed the Pontnewydd Cave site within its wider context in the Elwy valley, incorporating data from the excavation of both Cefn and Cae Gronw caves. Cefn Cave lies close to Pontnewydd in the Elwy Valley (Figure 1.1.), but the bulk of its sediments were removed during path construction by the owner (Stanley 1832) and unscientific excavations in the 19th Century. The fauna reported from the 19th Century excavations included hippopotamus, straight-tusked elephant, giant deer, red deer, bison, mammoth and woolly rhinoceros, lion, hyaena, cave bear, brown bear, wolf, red fox and badger (Campbell and Bowen 1989). This description clearly combines both an Ipswichian and Devensian fauna.

Recent excavations at Cefn have yielded a stratigraphic sequence, which was similar to that at Pontnewydd, consisting of several debris flows (Green and Walker 1991). Two stalagmite floors have been dated, one of which was emplaced during O.I. Stage 7 (a or c) and another during O.I. Stage 5 (128-70ka). The Green and Orange Silts below this thick stalagmite floor yielded a bear den fauna, which is too restricted in its range of species to be a useful chronological indicator. An Ipswichian hippopotamus fauna has also been discovered, but this could only be located in nineteenth century backfill (Green 1986). The basal debris flow, the Grey Silt, has been dated by U-Series on derived stalagmite to  $284 \pm 38/-28$  ka, and is therefore of a similar age to the artefact-bearing deposits from Pontnewydd. Excavation of this area has so far been limited, and as yet the only archaeological artefacts from Cefn are four flints, one of which is an Upper Palaeolithic Cresswellian point, which derive from a disturbed context near the west entrance (Green and Walker 1991).

At Cae Gronw (Figure 2.2.) two Pleistocene levels were identified: a complex basal debris flow containing blocks of derived stalagmite, and above this a soliflucted scree visually similar to the Pontnewydd Upper Breccia, which contained a Late Glacial fauna including collared lemming and bear. An overview of the finds, chronology and geomorphology of Pontnewydd, Cefn, Ffynnon Beuno, Cae Gwyn and Lynx caves was presented by Green and Livingston in 1991.

The work undertaken in this thesis forms part of the continuing post-excavation analysis of the artefacts and sediments from Pontnewydd Cave. These have already been discussed to some extent in several publications; specifically articles by Jenkins (1984, 1997) on the sand and clay mineralogy of the sediments, a discussion of the flints by Clayton (1984), and petrological investigations by Bevins (in Green 1981b, 1984, Green et al.1989).

**Investigations into the Mineralogy and Petrology of the Sediments and  
Artefacts from the Lower Palaeolithic site of Pontnewydd Cave.**

**Chapter 2**

**LOCATION, GEOLOGY, GEOMORPHOLOGY  
AND SEDIMENTOLOGY**



## **2. INTRODUCTION**

This section aims to locate Pontnewydd Cave both geographically, and within the geology of north Wales. It also gives an overview of the geomorphological context in which the cave was formed, and subsequently filled.

### **2.1. Location of the site**

Pontnewydd Cave (SJ 015710) lies 10 km due south of Rhyl, north Wales, several kilometres upstream of the point where the River Elwy enters the Vale of Clwyd (Fig. 1.1). Pontnewydd is one of several caves that occur in the Carboniferous limestone of the Elwy Valley; but along with the neighbouring Cefn Cave, it is of particular interest having yielded material of archaeological importance (see Chapter 3).

The Elwy Valley Caves are situated in the Dyserth Limestone Group of the Carboniferous Limestone, which forms a discontinuous outcrop along the northern and eastern margins of north Wales. At Pontnewydd the limestone outcrop is about 2 km wide. It dips to the northeast with its base resting on thin Carboniferous basement beds, which overlie the Silurian shales of the Denbigh Moors. The Dyserth Limestone is a uniform grey, bioclastic wacke, which contains few macrofossils of brachiopods, solitary corals (*Syringopora* sp.) and crinoid ossicles (Strahan 1890). The entire limestone outcrop exposed in this area is equivalent to only a small part of a more complete Carboniferous succession illustrated elsewhere in Britain.

### **2.2. Basic geology of north Wales**

Precambrian rocks in north Wales outcrop on Llŷn (the Lleyn peninsula), on Anglesey, and in the immediately adjacent mainland. Greenly (1919) distinguished two divisions in the Precambrian of Anglesey – the Mona complex and the Arvonian volcanic series. The former consists of gneisses, and the Bedded Succession, comprising meta-sedimentary and predominantly basic meta-volcanic rocks of greenschist to amphibolite facies. Both the Mona complex and the Arvonian volcanics were intruded by late Precambrian to early Cambrian granites.

Outcrops of Cambrian age in north Wales occur on Anglesey, in the 'Caernarvonshire slate belt', in the Harlech region, and in a small area of St. Tudwal's peninsula, on Llŷn. The slate belt lies between the Ordovician rocks of the mountains of Snowdonia and the Precambrian massif of Anglesey. The Cambrian rocks are strongly fractured, cleaved and metamorphosed. The most impressive outcrops of Cambrian rocks are in the Harlech Dome region, where massive coarse-grained sandstones are interbedded with more shaley formations in submarine fan complexes.

Ordovician sedimentary rocks are best represented on Anglesey, Llŷn, and between Bangor and Caernarfon., to the west of the Conwy Valley. Sedimentation throughout the region was mainly marine; black muds accumulated in deep seas, interrupted periodically by incursions of coarser sediment transported by gravity flows. The seas were shallower towards the margins of the Welsh Basin. Sedimentation was also strongly influenced by relatively short-lived volcanic episodes, which produced large volumes of coarser material, which was then reworked in the marine environment (Kokelaar *et al.* 1984). The wide variety of Ordovician volcanic rocks will be considered in more detail in Chapter 3.

The geology of the area fringing the coast on the mainland and enclosed by a line joining St. Asaph in the north east with Aber in the north west (map 2.1) is made up of Silurian greywackes, slumped mudstones and graptolite-bearing rocks. These form the greater part of the Denbighshire moors and the Clwyddian range.

To the north of the Silurian, lies a band of Carboniferous Limestone, in which Pontnewydd Cave is situated, running more or less south eastwards and southwards from the Great Orme along the western flank of the Vale of Clwyd. The only Devonian rocks in north Wales are on Anglesey, where outcrops occur on the north east coast of the island.

The Vale of Clwyd contains Lower Permian red aeolian sandstones, which are the only Permian rocks in North Wales. Triassic rocks are also represented in the Vale of Clwyd, but are not well exposed owing to the cover of glacial and other superficial deposits. The rock sequences are better known from the offshore deposits within the Irish Sea Basin which have contributed greatly to the heavy mineralogy of the glacial sediments in the



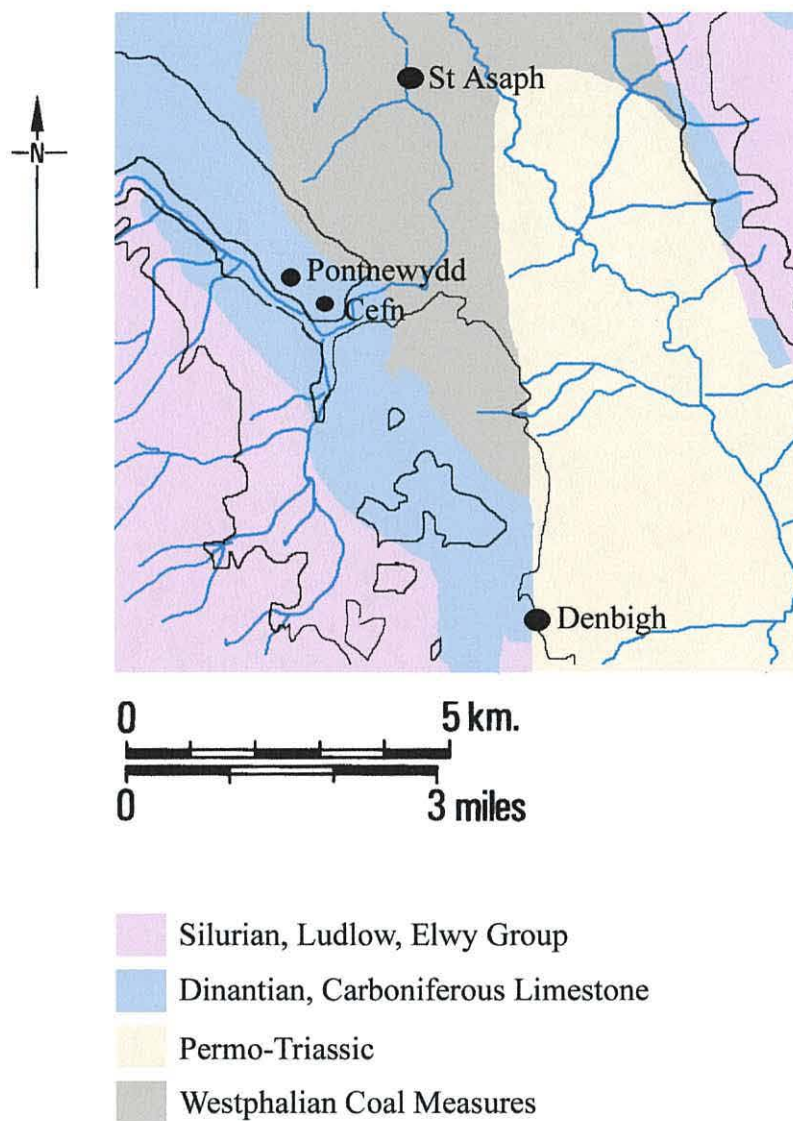


Fig. 2.1 Geological Map of the Pontnewydd area  
from BGS sheet 107 Denbigh (solid)

Pontnewydd area (Jenkins 1964, see Chapter 4). Jurassic strata are poorly represented in north Wales, but west of the main outcrops in England, Liassic outliers occur on the Shropshire and Cheshire borders and on the margin of Cardigan Bay.

Tertiary deposits are limited to a fault-bounded outlier at Llanbedr, where an exploratory borehole revealed Tertiary sediments ranging from clays to conglomerates. There are however, rare igneous intrusions of Palaeogene age on Anglesey (Greenly 1919).

Quaternary deposits are widespread across north Wales, although glacial erosion has ensured that few of the earlier glacial sediments have survived (see Chapter 2.4). Most of the Quaternary record therefore represents Late Devensian deglaciation. Many lowland areas are draped with thick sequences of glaciogenic sediments and display glacial landforms. In upland areas, evidence of small end-Devensian glaciers remain in corries and valleys. The Flandrian stage has left evidence in the form of fluvatile, lacustrine, and shallow marine sediments.

### **2.3. Origin of the Caves**

Major cave systems are known in the limestone of north Wales (Appleton 1989). Their size ranges from the largest, Ogof Llyn Parc; with over 4km of passages, to smaller caves such as Pontnewydd, which is 30m long. Although small, the dimensions of Pontnewydd are similar to other caves in the Elwy Valley, such as Cefn and Nant-y-Graig.

Pontnewydd Cave has a crudely rounded cross section suggesting that it was originally formed under phreatic conditions (Trudgill 1985) although other factors discussed below suggest a vadose origin. The water that formed the cave must have had a continuous underground path to its spring. This leads to the assumption that the cave probably continues eastwards, with much the same dimensions, beyond the limit of current excavation.

Vadose cave formation occurs as a result of dissolution of limestone by meteoric water, which may only occur when limestone is exposed at the ground surface. The Dyserth limestone of the Pontnewydd area would have been vulnerable to cave formation only before its burial by Mesozoic sediments and after their removal by the erosion during the

late Tertiary and Quaternary. If the caves were pre-Mesozoic, they would have been filled with younger sediments of Permian or Triassic age, and no such deposits have been found.

Pockets of Tertiary sediments observed on the limestone surface (Walsh and Brown 1971), however, can demonstrate erosion during the Tertiary. Limestone tends to be vulnerable to solution along joints. At Pontnewydd and Cefn Caves, one of the joint directions is parallel to the cliff face (Jones 1995); the caves therefore tend to grow parallel to the Elwy Valley, in a pattern governed primarily by jointing in the limestone.

The caves in the Elwy Valley are not restricted to one elevation and seem to occur 'stacked' one above another. Indeed, Cefn, Pontnewydd and Cae Gronw caves are all found on the north east escarpment, within a kilometre of each other, at heights of 75 m, 90 m and 110 m above sea level respectively. This indicates a vadose origin and could be interpreted as providing a record of an episodic fall in the water table (Jones 1995). Each time the water level drops, the older cave is abandoned and a new one is formed. The lowest cave is therefore the youngest.

By combination of this theory of rejuvenation with evidence for the glacial diversion of the Elwy (Embleton 1984) and an estimation of the chronology of valley incision (Green 1986, Jones 1995) it is possible to recreate the approximate position of the Pontnewydd Cave entrance 250,000 years ago. It is likely that the Palaeolithic entrance was a similar shape to that of the present-day cave, governed as it is by jointing, and that it lay further out into the now-eroded Elwy valley.

#### **2.4. Geomorphology of the Elwy Valley**

The Vale of Clwyd is floored by Permo-Triassic sandstones and Westphalian shales and lies between two outcrops of Silurian sandstones and shales, namely the Denbigh Moors and the Clwyddian Range. Four phases of glaciation during Quaternary times with ice from two different sources have shaped the current profile of the Elwy Valley (Embleton 1984; Green and Livingston 1991). Firstly, Welsh Ice moved north-eastwards from Arenig and Snowdonia, and secondly Irish Sea Ice moved southwards from Scotland and the Lake District. Critically, the tills left by these ice sheets are lithologically distinguishable.



Welsh Ice deposits and landforms are variable and reflect the bedrock over which the ice has travelled (Smithson 1953, Jenkins 1964, Younis 1983)., consisting mainly of crushed and fragmented Silurian mudstones and greywackes, along with frequent igneous clasts from Snowdonia or Arenig. Drumlins indicate that movement was from N to NE.

Irish Sea Ice deposits and landforms have two characteristic facies, one underlying the till plain in the north of the Vale of Clwyd, the other, a deposit of sand and gravel, which underlies the morainic region to the south of the till plain. Ice movement was oriented NNW-SSE in the Vale of Clwyd and trended NE-SW in the Elwy Valley (Green and Livingston 1991). Irish Sea drift is often composed of a pale reddish matrix derived from Triassic sandstones which make up the sea floor of the East Irish Sea Basin to the north of Wales (Jenkins 1964, Jackson et al 1995). It also characteristically contains microgranite and other igneous clasts from the Lake District and southern Scotland, including the distinctive Ailsa Craig intrusion (Bevins 1984). These two tills also carry distinctive heavy mineral suites (Jenkins 1964, Younis 1983), which are used in this thesis to deduce the origin of the sediment layers within Pontnewydd cave.

#### **2.4.1.Elwy drainage**

The local landscape is one of repeated glaciation. The River Elwy drains some 200 km of the Denbigh Moors which rise to a height of nearly 500 m on Mynydd Hiraethog (Figure 1.1). The evolution of the Elwy drainage system has been examined by Embleton (1960, 1984) who has shown that up to late Tertiary times, the drainage was to the north, following a pattern inherited from the northward dipping Mesozoic cover. These rivers headed for the coast between Colwyn Bay and Abergele, which was at least 200 m higher than present sea level.

Subsequently, the water table fell and the rivers were progressively captured, resulting in the present easterly flow direction of the Elwy. This was possibly due to gradual exploitation of structural weaknesses in the Silurian rocks. The Elwy now enters the Vale of Clwyd about 2 km downstream from Pontnewydd Cave, turning suddenly and breaking through the narrow ridge of limestone. There is evidence that pre-glacially the Elwy used to

enter the Vale of Clwyd further north, due east from Ddol (SH998 731), at a height of 160 m above sea level. The abandonment of this course has been attributed (Boswell 1949; Embleton 1960) to glacial diversion. A broad lobe of ice spreading up the Vale of Clwyd could have impeded the former path of the Elwy, turning it south-east and extending its course by around 4 km. This diversion must have taken place during a pre-Devensian glaciation, firstly because the Elwy valley is partly infilled by Devensian till (Embleton 1984), and secondly because valley depth indicates that valley incision started at around 725 ka (Green in Colcutt 1986, Jones 1995). It has been estimated that a level corresponding to that of Pontnewydd Cave was reached by 450 ka. This is consistent with the minimum age of the cave deposits, estimated at 300 ka (Green 1984). The erosional history as described above is only the final phase of the story, during the latest part of the Tertiary and the Pleistocene.

#### **2.4.2. Glacial History**

The majority of the evidence for the glaciations in this area comes from Pontnewydd, Cefn and Cae Gronw Caves, and the rather restricted glacial deposits to be found elsewhere in the region (Figure 2.2).

The Irish Sea Ice extended into the region and its deposits were noted on Moel Wnion (Gwynedd), and on Halkyn Mountain (Clwyd) in the last century, but are no longer visible. It penetrated the Vale of Clwyd for 20 km leaving erratics 1.6 km south of Denbigh (Embleton 1984), and around the entrance to Pontnewydd Cave (Jones 1995), although there is no evidence to suggest that these two events were contemporaneous. Irish Sea Ice probably covered all ground below 600 m on the north coast of Gwynedd, but was unable to penetrate far inland due to the presence of Welsh Ice, which covered the whole of Clwyd (Embleton 1984). There is also evidence for a temporary halt in the movement of Irish Sea ice, indicated by the presence of small moraines in the Vale of Clwyd near Trefnant (Embleton 1984, Figure 2.2).

Around 250-300 ka, Welsh Ice brought material from Snowdonia and the Arenig mountains (Green and Livingston 1991). A very weathered Welsh till containing Arenig volcanic clasts occurs on the summits of the Clwyddian Range at heights of 350 m,





and on the summit of Cyn-y-Brain at 560 m. It therefore seems likely that the highest point, Mynydd Hiraethog (497 m), was also covered with ice (Green and Livingston 1991). This illustrates that Welsh ice must have crossed the Vale of Clwyd (Embleton 1984). Cutting of this stretch of the Elwy Valley opened up Pontnewydd Cave, and on deglaciation tills slumped into the cave as debris flows. Stage 8 deposits, with erratic and heavy mineral evidence pertaining to Welsh Ice (Jenkins 1984), have been recovered from the cave excavation.

Two glacial advances have been recognised during the Late Devensian, involving both Irish Sea Ice and Welsh Ice. Evidence for the first advance, around 30ka, includes "Higher Level" Irish Sea tills found on the hills of the Clwydian Range (Green and Livingston 1991). These are shelly tills deposited by the Irish Sea Ice as it headed towards the English Midlands, during a period when an extensive Welsh Ice sheet stopped the Irish Sea Ice getting far inland. A radiocarbon date of  $33,740 \pm 2100$  BP was obtained on shells at 400 m OD on Moel Tryfan (Foster 1968).

Irish Sea Ice and Welsh Ice re-advanced in Late Devensian times, dated by radiocarbon evidence from Cae Gwynn Cave (SJ 085724) (Embleton 1984) and Ffynnon Beuno Cave, where a mammoth bone produced a date of  $18,000 \pm 1400$  BP (Rowlands 1971). Most of the present glacial landforms and deposits date from this most recent phase, which followed roughly the same flow patterns as previously. During the Late Devensian local ice masses in Snowdonia and Arenig were subordinate to a main dispersal centre - the Merioneth Ice cap (Greenly 1919, Foster 1968). This contributed to both westerly and easterly flows from the region. Irish Sea Ice deposits from this period occur at Colwyn Bay and near Denbigh (Campbell and Bowen 1989).

Periglacial conditions followed wastage of the Late Devensian ice sheet and some features, such as patterned ground at Waun-y-Garnedd, a broad saddle connecting Foel Grach and Carnedd Llewellyn (SH 688 653), are still active (Pearsall 1950, Scoates 1973). The Flandrian transgression is marked by the "Bryn Carrog" coastline (Rowlands 1955) which runs from Gronant (SJ 092 832) to Penmaen (SH 881 788) and the presence of marine and estuarine alluvium in the Vale of Clwyd. Finally there were landslides in fluvio-glacial

deposits caused by the failure of unstable slopes, and the lowering of water levels and subsequent entrenchment of the Elwy caused further removal of glacial deposits along the Elwy Valley.

The deposits in the Elwy Valley Caves consist of debris flows with some fluvial deposits. The only in situ formations are stalagmite floors, which have been dated using Uranium-Series to  $224 \pm 41/-31$  ka (Ivanovich et al. 1984). The three main caves all have similar depositional histories, with five debris flows at Pontnewydd, three at Cefn and two at Cae Gronw. Embleton (1984) has suggested that the Elwy re-excavated its drift-choked valley after each glacial stage, therefore fluidising the cave entrance deposits to create each set of debris flows. In support of this, Livingston (1986) has demonstrated that a local solifluction terrace (at 90m OD) is composed of re-deposited till from the Cefn Meiriadog ridge above the caves, and is truncated by landslides caused by the Elwy undercutting the unstable solifluction deposits.

The dynamic interplay between the Welsh and Irish Ice sheets has not yet been fully deciphered. Welsh Ice could presumably have spread further across Clwyd in the initial stages of a glaciation, yet Irish Sea Ice apparently managed to extend unimpeded 20 km up the Vale of Clwyd.



### 2.4.3. Summarised Chronology

| Period                      | Irish Sea Ice  | Welsh Ice  |
|-----------------------------|--|--|
| Before Oxygen Isotope St. 8 | Caused diversion of the Elwy and its flow marginal to the ice. Covered all ground below 600 m on the N coast of Gwynedd.   | Covered the whole of Clwyd.  |
| Oxygen Isotope Stage 8      | Present. On de-glaciation both Irish Sea and Welsh tills slumped into the cave as debris flows.  | Crossed the Vale of Clwyd, reached the Elwy Valley, and exposed Pontnewydd Cave. Cave sediments contain heavy minerals indicating Welsh Ice.   |
| Late Devensian (post 30 ka) | "Higher Level" tills found on the hills of the Clwydian Range. These were shelly tills with a C14 date of 33,740 $\pm$ 2100/-1800 BP (Foster 1968).                  | An extensive Welsh Ice sheet stopped the Irish Sea Ice getting far inland.   |
| Late Devensian (post 18 ka) | Most of the present glacial landforms and deposits date from this phase. Deposits occur at Colwyn Bay and near Denbigh.  | Ice masses in Snowdonia and Arenig were subordinate to the Merioneth Ice cap. This contributed to westerly and easterly flows from the region. |
| Flandrian                   | Periglacial conditions followed wastage of the Late Devensian ice. Landslides and lowering of water levels caused removal of glacial deposits along the Elwy Valley. | Flandrian transgression is marked by the presence of marine and estuarine alluvium in the Vale of Clwyd.                                       |

## **2.5. Sedimentology and Stratigraphy**

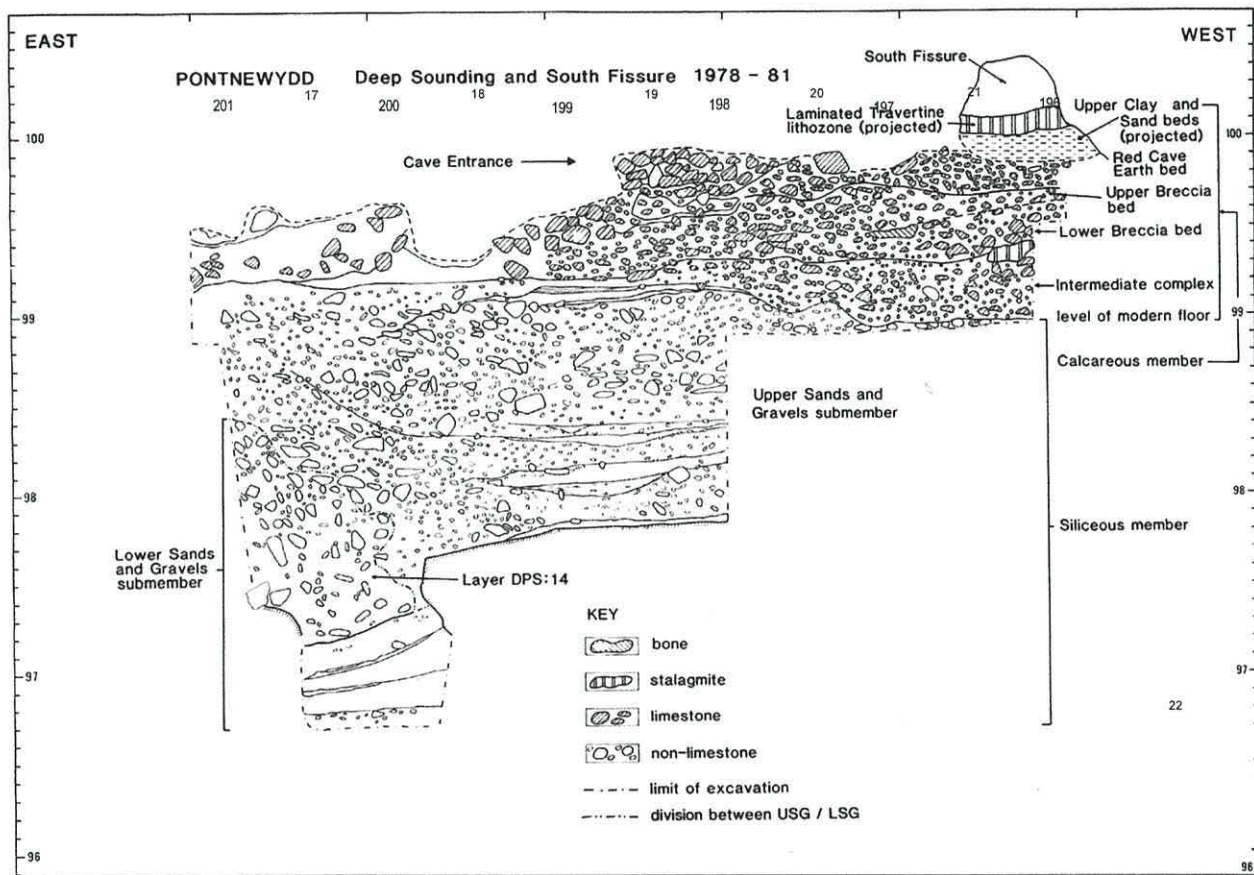
The sediments contained within Pontnewydd and Cefn caves once formed part of the Elwy Valley glacial fill (Green and Livingston 1991). However, their transport into the caves has not been a simple process, and the sediment sequence at Pontnewydd Cave represents a rather fragmentary record of the depositional and erosional events that took place during the 300,000 years of the cave's history. The reconstruction of events which occurred in the cave is complicated by stream erosion, weathering, biogenic and anthropogenic disturbance. The debris flows in which the sediments were emplaced were periodic events, perhaps incorporating sediment that had accumulated outside the cave over a considerable period of time. Each sedimentary unit (see description below) may therefore have been exposed to weathering processes of differing intensity prior to their deposition. Indeed the debris flows themselves are complex depositional events, with differing styles dependent on content and local geomorphology (Savage 1969, Pierson 1981, and Colcutt 1984). Furthermore, although the sequence of basal layers is well represented in the 'Deep Sounding' (Fig. 2.3) and the rest of the sequence is visible in the East Passage, the complete stratigraphy is not visible in any single section. The result of the many emplacement events and transport mechanisms that took place in the cave may therefore only be viewed in composite section.

Pontnewydd Cave displays a sequence of deposits (Fig. 2.3) which comprise three major units, which were first recognised by McKenny Hughes (1874): The Gravels, the Breccias and the Yellow Cave Earth (now recognised as the Upper Clays and Sands). These, together with *in situ* deposits such as speleothem, comprise the sedimentary sequence. The following summarised description of deposits relies primarily on evidence from Bull (1984) and Colcutt (1984).

### **2.5.1 Siliceous Member (Sm.)\***

This member contains a dominant siliceous component and includes the Lower and Upper Sands and Gravels. Although both these basal layers contain neither artefacts nor fauna, they are important, for they provide indirect evidence of earlier glacial activity. They contain abundant pebbles of siliceous rocks, mostly derived from glacial action from North Wales (Bevins 1984), and these provide the raw materials from which 90% of the archaeological implements are made.

\*Unit names and abbreviations from Colcutt (1984).





#### **2.5.1.1. Lower Sands and Gravels (LSGs)**

Site Datum: 96.65 to 98.40m.

This unit occurs only in the Deep Sounding (DPS: 22-14 see Colcutt 1984, p.37) and comprises a series of usually well-stratified sands and coarse to fine siliceous gravels. Some lithozones are heavily cemented by carbonates.

A series of gravelly deposits was brought in through the cave entrance by repeated rapid debris flows, which incorporated several pre-existing stream-laid deposits. It would appear from Scanning Electron Microscopy (SEM) studies (Bull 1984) that the deposit originated from glacial debris on the surface around the cave entrance. The fine-grained material comprises a mixture of sediment from varied lithologies and provenances (fluvatile, glacial, igneous rocks, sandstones etc.), which are so varied as to suggest that the mixing can only have taken place outside the cave, and most probably by glacial transportation and deposition (Bull in Green 1989). This unit also contains some fluvial episodes (Bull in Green 1995, Livingston 1989) but these are likely to be of only localised importance (Bull 1989). Particle size analysis indicates a glaciofluvial source for this deposit, and demonstrates some similarity to the terraces of the Elwy Valley (Livingston 1989). Texturally, the majority of the larger particles are siltstones and mudstones, but crystalline rocks, which are foreign to the solid geology of the Pontnewydd area, also occur (Colcutt 1984). Rocks of this type are common in the modern Elwy valley and probably derive from glacial sources (Bevins 1984, Bull 1984, Embleton 1984). Sedimentation in the LSGs was interrupted by at least two periods of quiescence, during which carbonates and 'sesquioxides' were precipitated (Colcutt 1984). In addition, towards the top of this unit, deposition became sufficiently intermittent for calcite cementation to take place.

#### **2.5.1.2. Upper Sands and Gravels (USGs)**

Site Datum 97.80 to 99.20m

This unit is again best exposed in the Deep Sounding (DPS:13-1, see Colcutt 1984, p.38) although it has been suggested that some of the other areas may contain a small basal component of USGs. The deposits are fairly well to poorly stratified siliceous gravels with rare beds of finer material. They are partially cemented near the cave walls. Debris flows brought further material, similar to that contained within the LSGs, into the cave. The USGs represent a continuous and probably more rapid accumulation of

sediment than the LSGs (Bull 1989). The low organic content of the Siliceous member as a whole suggests that a dense vegetation cover was not present at any time during the deposition of these beds. Furthermore, this member contains very little limestone, either in the form of fallen blocks or scree, yet there is a major rockface above the cave. The sediments cannot have derived from any surface deposit that lay exposed for long in the vicinity of the cave. The most likely solution (Colcutt 1984) is that the sediments were derived from a thick exotic sediment body, which choked the valley to well above the level of the cave.

### **2.5.2. Calcareous Member (Cm)**

This member contains the Intermediate complex, the Lower Breccia bed and the Fine Sand submember and is characterised by common matrix carbonate, speleothems, limestone clasts and the presence of bone.

#### **2.5.2.1 Intermediate complex (Ic)**

Site Datum 99.00 to 99.40m

Overlying the Upper Sands and Gravels is another debris flow unit termed the Intermediate Complex. This unit has characteristics in common with both the units above and below it. Its component lithozones are often present only as lenses or pockets, and it is best exposed at Site D (for example D:8-7, see Colcutt 1984, p.40). Its notable characteristics are coarse sand and fine siliceous gravel, high organic and 'sesquioxide' components, small amounts of corroded limestone, and traces of bone. The sediments of the Ic may generally be distinguished on the basis of colour, as they tend to carry a red-brown or orange-brown hue. This colour is now known to be partly due to orange-brown cutans of Ca-Fe-phosphate (Jenkins 1997).

The sediments of the Ic are heterogeneous and fragmented but contain the first traces of sediment from a strictly local source. The complex can be differentiated in stratigraphic and provenance terms from the underlying beds, but the principle difference is the increased chemical activity which has caused dissolution of some clasts and less stable minerals (Bull in Green 1989, Jenkins 1984). From this activity, it may be inferred that these deposits were laid down when the local conditions were warmer and wetter than those experienced during the emplacement of the Lower Sands and Gravels.



These patchy sediments contain the first occurrence of clastic limestone debris and animal bones, together with the remains and tools of man. Indeed, the most interesting archaeological deposits are the Intermediate complex and Lower Breccia.

Thermoluminescence dating on a burnt flint core from the Intermediate complex has provided a date of 200+/-25 ka (Green 1984). The sediments have been violently dissected and disrupted, perhaps by a subsequent debris flow, and it has been suggested (Bull in Green 1989) that specifically the uppermost layer of the complex, the Buff Intermediate, may be an Intermediate deposit reworked by the Lower Breccia debris flow.

The period between the deposition of the USGs and disruption of Ic sediments appears to have included a temperate stage, when significant growth of stalagmite occurred. This palaeoenvironmental model is borne out by pedological studies (Bull 1989) and by reference to the enclosed fauna (Currant 1984). The Intermediate complex displays evidence of warm climate weathering prior to deposition, and has an interglacial type fauna, illustrated by beaver and roe deer (Currant 1984). The presence of high levels of organic matter, carbonate precipitation, chemical alteration and faunal remains therefore indicate the influence of an interglacial, or at least a major interstadial, period. Jenkins (1984) also found many weathered heavy minerals in the Intermediate complex, and this pattern was repeated in the clay fraction with the depletion of relatively unstable chlorite and derived vermiculite (Jenkins 1997). However, Bull (1984) did not recognise any pedogenic features on the quartz grains. If soil formation did occur during this phase it could have affected the emplacement of deposits, as soil formation may not only reduce the frequency of debris flows, but ensure that they are more catastrophic when they do occur (Colcutt 1984). A climate change may further influence deposition, as initiation of flows is always linked with the sudden availability of large quantities of water.

#### **2.5.2.2. The Breccias**

Overlying the Intermediate Complex is a major deposit of breccias, emplaced by two or more rapid debris flow events. These comprise the Lower Breccia and Upper Breccia separated in some places in the cave by localised stalagmite growth and by a laminated silty pond-like deposit which itself contains several calcareous lenses. Although these Breccia units are quite distinct and fall within different submembers, they arose from



similar processes. Each unit contains matrix-supported melanges of coarse- and fine-grained materials but each shows evidence of shear zones which make interpretation of the sequence of events very difficult (Bull 1989). The breccias were high-energy deposition events with considerable erosive qualities, which relocated existing materials about the cave. Evidence of this erosive nature is seen in the scoured silt deposit separating the two Breccia units (Colcutt 1984). This silty deposit is a low energy fluvial deposit. It contains sediments indicative of cold climate conditions, which may be different from the climate that existed during the emplacement of the enclosing breccias.

#### ***2.5.2.2.1 Coarse Sand Submember (CSs)***

##### **Lower Breccia bed (LBb)**

Site Datum 99.20 to 99.60m in area D.

This unit is best represented in the cave at Site D (for example D:6-5, see Colcutt 1984, p.40) and comprises coarse siliceous sand, common fractured pebbles and a small percentage of corroded limestone clasts. The deposits are usually cemented, and bone and organic matter are common.

This has been interpreted as a major debris flow, which entered the cave, caused disruption of existing deposits and incorporated this older material into its own mass. This debris flow differs from the Intermediate complex most notably in the colour of the sediment and the dominance of local limestone debris at the expense of glacially derived material from further afield. The fauna of the Lower Breccia is similar to that of the Intermediate complex, but contains two new species: Norway lemming and Northern vole, which suggest a climatic deterioration towards an open steppe environment (Currant 1984). Bones from the Intermediate complex and those from the LBb display different types of preservation, which enables reworked material to be accurately differentiated. The drop in the organic content of this layer, relative to the Ic, may also imply conditions cooler than full interglacial. In terms of particle size and shape, this deposit most closely resembles the Irish Sea till deposits at Plas Chambres in the Vale of Clwyd (Livingston 1989).

In situ stalagmite illustrates that emplacement of the Lower Breccia must have ceased by 225 ka (Debenham et al. 1984). This, together with the date from the Intermediate

complex, suggests human occupation prior to 225 ka. This is supported by the morphological data on the hominid remains (Stringer 1984) which suggests an occupation by early Neanderthals.

#### ***2.5.2.2.2. Fine Sand Submember (FSs)***

This submember contains predominantly fine, non-carbonate sand, with common speleothem and limestone clasts. It consists of the Stalagmite lithozone, Silt beds, Upper Breccia bed, Red Cave Earth bed, Upper Clays and Sands, the Laminated Travertine lithozone and the Earthy lithozone.

##### Stalagmite lithozone (Sl)

Site Datum 99.40 to 99.50m, but patchy.

This unit (for example C:4 and D:4, see Colcutt 1984, p.40) contains several isolated stalagmites together with thin spreads of speleothem, associated with the Silt beds. As sediment input ceased, stalagmites were able to grow. This in situ stalagmite exhibits patterned growth from 220 ka to 90 ka. The cave mouth must therefore have been sealed during this period, and little sedimentation could occur until the emplacement of the Upper Breccia.

##### Silt beds (Sb)

Site Datum 99.50 to 99.65m in area D.

This unit (D:3 and D(E):7, see Colcutt 1984, p.41) comprises laminated silts with very little coarse material. A pool formed towards the back of the cave in which poorly-sorted sands and silts collected, interstratified with gradually decreasing amounts of stalagmite. This deposit contains a different fauna to the LBb (Currant 1984), a new quartz grain suite (Bull 1984), a low organic content (Colcutt 1984) and a different heavy mineral suite (Jenkins 1984), all of which may indicate colder conditions.

##### Upper Breccia bed (UBb)

Site Datum 99.65 to 100.00m in area D.

This unit (B:5, C:3, D:2 and D(E):6, see Colcutt 1984, p.39-41) includes abundant, slightly altered limestone clasts with a few fractured pebbles. The matrix contains a high proportion of silt and fine carbonate sand, and is cemented, particularly near the cave walls. Bone is common but organic matter is rare.



These sediments were the result of another massive debris flow, which channelled into and incorporated older sediments. This is the best preserved debris flow visible within the cave sequence. Local limestone debris was the dominant clastic material. Such a large number of limestone clasts in a matrix of fine material indicate a typical cold climate deposit. Particle size and shape indicate a source in soliflucted Irish Sea till deposits (Livingston 1989)

#### Red Cave Earth bed (RCEb)

Site Datum 99.70 to 99.85m in area B.

This unit (B:4, see Colcutt 1984, p.36) is almost exclusively composed of uncemented angular limestone clasts, set in a carbonate-rich silt. These traces of one final debris flow, significantly younger than UBb (Colcutt 1984), may represent a post-depositional flow and mass movement of the surface Upper Breccia units. Alternatively the high proportion of silt may indicate a local aeolian source, such as surface loess.

#### Upper Clays and Sands (UCS)

Site Datum 100.00 to 100.30m in area D.

The deposits (D:1, D(E):4-2, see Colcutt 1984, p.41) comprise laminated silty clays, and well-bedded clayey sands. Much small bone and organic material are present. These deposits form a sequence that is extremely common in British caves (Ford 1975).

During a late glaciation, permafrost, or ice-sheets carrying basement till, sealed off the entrances to the cave. For a time, water flowed overland, with only fine material being deposited underground. When the permafrost began to break down, the majority of the cave passages were choked with sediments so that a stream flowed, at a high level, westwards out of the cave depositing clays and sands (Colcutt 1984). This deposit therefore contains winnowed material from surface glacial debris together with reworked cave deposits.

#### Laminated Travertine lithozone (LTI)

Site Datum 100.00 to 100.15m in site B.

This unit (B:1 and D(E):1, see Colcutt 1984, p.41) forms thick, horizontally-bedded shelves of speleothem fragments, which were once probably part of a continuous floor. It indicates that water found its way deeper allowing stalagmite to grow. The whole



sequence is capped by stalagmite layers of Holocene age indicating the cessation of sedimentation.

#### Earthy lithozone (El)

Isolated pockets of this deposit adhere to the walls and roof of the cave. It is a dark deposit, rich in organic material and small bone and is interpreted as an input of Holocene organic-rich sediment.

### **2.5.3. New Entrance Stratigraphy**

A detailed summary of the stratigraphy of the New Entrance is in the process of completion (Aldhouse-Green in press). This description of the sedimentology will therefore be rather brief. The layers are not generally considered to link up with the sequence in the main cave, the only exception is layer 20, which is a facies of the Upper Breccia bed.

The sequence described here is that observed in the Eastern Section of the New Entrance, although only those sediments within the Cave Sequence are described here in any detail. Several of the deposits in the Cave Sequence were sampled by Aldhouse-Green during excavation and these were included in the heavy mineral and clay analysis of sediments undertaken as part of this thesis (see Chapter 4).

Topsoil and Colluvium: Unit containing layers 1-4, consisting of dark humic soil and angular to sub-angular limestone scree, generally clast-supported. This unit is about 60 cm thick.

Solifluction: A red soliflucted deposit containing layers 6 and 8.

Scree: Includes layers 16, 25, 17, 18, 19. This unit contains ill sorted angular to sub-angular limestone clasts, in a red-brown or buff-grey clay matrix. The deposit is mainly clast-supported, but locally matrix supported. Total thickness of scree unit: 3.4 m.

Cave Sequence: Total thickness of cave sequence: 3.6 m.

This unit contains layers 20, 22, 23, 24, 26, 28, 29, 33, 34, 38, 41, 42 and 44. The deposits are locally concreted and contain sub-angular limestone, exotic clasts, some artefacts and bones and occasional stalagmite. The matrix varies in colour from red-brown to buff-grey and may be clayey, silty or gravelly in texture. The deposits are both matrix- and clast- supported.

#### **2.5.4. Overview**

Perhaps the most important inference to be drawn from the study of the sediment stratigraphy at Pontnewydd is the punctuated nature of sediment input. The sediment sequence necessarily only provides evidence of those events in the cave's history whose deposits have survived. These events were probably not the only processes to affect the cave, and they represent very short phases over at least 300,000 years. During much of this time the cave and its sedimentary mechanisms would have been quiescent, although post-depositional weathering may have occurred during these static periods.

**Investigations into the Mineralogy and Petrology of the Sediments and  
Artefacts from the Lower Palaeolithic site of Pontnewydd Cave.**

**Chapter 3**

**INVESTIGATION OF THE ARTEFACTS**



### 3. INTRODUCTION

The principle characteristics of the industry at Pontnewydd are the importance of Levallois technique, the importance of handaxes, the scraper component, and a low component of artefacts that are characteristic of the Upper Palaeolithic. Typological study is rendered difficult by the fact that the non-flint rocks used often do not show the clean conchoidal fracture characteristic of flint, but may fracture along natural cleavage planes in the rock. The tools and debitage types which make up the assemblage may be detailed as follows: handaxes, a flake cleaver, a chopper, chopping tools, Levallois cores and debitage, one Mousterian point, discoidal and other cores, naturally backed knives, transverse, side and end scrapers, notches, picks, denticulates and truncated blades (Fig.3.1). Overall the industry has been described as: "*Upper Acheulian with important handaxe, Levallois and scraper components*" (Aldhouse-Green 1995). The Acheulian is defined by its characteristic artefacts, which are a wide variety of different shaped handaxes. The many forms they take have been described in several studies (Bordes 1968, 1968). The tool kit itself is suggestive of hunting (Binford & Binford 1966, Foley 1981a, Pradel 1972/3) and hide-processing. Unfortunately the bones were too damaged by depositional and post-depositional processes for any possible butchery marks to be preserved.

It is likely that all the artefacts at Pontnewydd constitute a single assemblage, in that they represent the activities of one cultural group inhabiting the site over a relatively short period of time (Green 1984). The artefacts initially seemed to represent a genuine single phase industry, but with the possibility of a brief earlier phase of activity represented by artefacts found within the Buff Intermediate layer (Green 1984, 1986). It was thought this could only be demonstrated conclusively by the discovery of cut-marks on bone relating to both of these phases (Green *et al.* 1989), but further excavation of the Intermediate layer has deemed discrete occupations improbable (Aldhouse-Green 1995). The artefacts in the Upper Breccia are part of this same assemblage (found in the Lower Breccia and Intermediate deposits) which were derived from the reworking of earlier deposits. It is not thought possible to draw distinctions between the industry found at the New Entrance and that of the main cave.

This chapter first outlines the methodology used in the study of the artefacts (Section 3.1.). Attention is then paid to the characterization of the rock types and likely

provenance of the artefacts (Section 3.2), including a brief consideration of the Ordovician rocks of Snowdonia and the Lake District which are the suggested sources of the raw material used at Pontnewydd. The method and results of an informal knapping experiment, conducted on raw materials collected from the Snowdonia area, are then outlined (Section 3.3), followed by an analysis of the trends of raw material use shown by the artefacts (Section 3.4). In this section, the statistical relationships between the raw materials available and the tool types for which they are used are also discussed. Lastly, this information is synthesised in an interpretation of the results gleaned from these studies (Section 3.5), along with the conclusions (Section 3.6).

### **3.1. Methodology**

#### **3.1.1. Sample collection**

The artefacts were collected as clasts during excavations at Pontnewydd Cave from 1978-1995. Although they have been used to discuss the source of the sediments in the Pontnewydd area, they are not a random selection of clasts, even those which are natural pebbles have been collected by the excavators due to their similarity to the material from which the artefacts were made.

#### **3.1.2. Artefact Identification**

Some 1300 artefacts were examined in order to compile a database, which would provide typological and lithological information for each artefact. Artefacts previously identified (Bevins 1984, Green 1988) were first examined in hand specimen to ensure familiarity with the rock types under study. The unidentified artefacts were then examined in hand specimen and given an approximate identification. Many artefacts were further examined under the binocular microscope, particularly if there was any doubt over their initial identification, or if the artefact was small and therefore displayed only a small surface area for examination. All artefacts under 3 cm in length were examined under the binocular microscope. The artefacts were then classified into the categories shown in Appendix 3.1, which are pragmatic categories that fall broadly in accordance with IUGS rock classifications (LeMaitre 1989).

#### **3.1.3. Measurements**

All artefacts excavated prior to 1984 were measured by Stephen Aldhouse-Green, and all artefacts excavated between 1984 and 1995 were measured by either Elizabeth

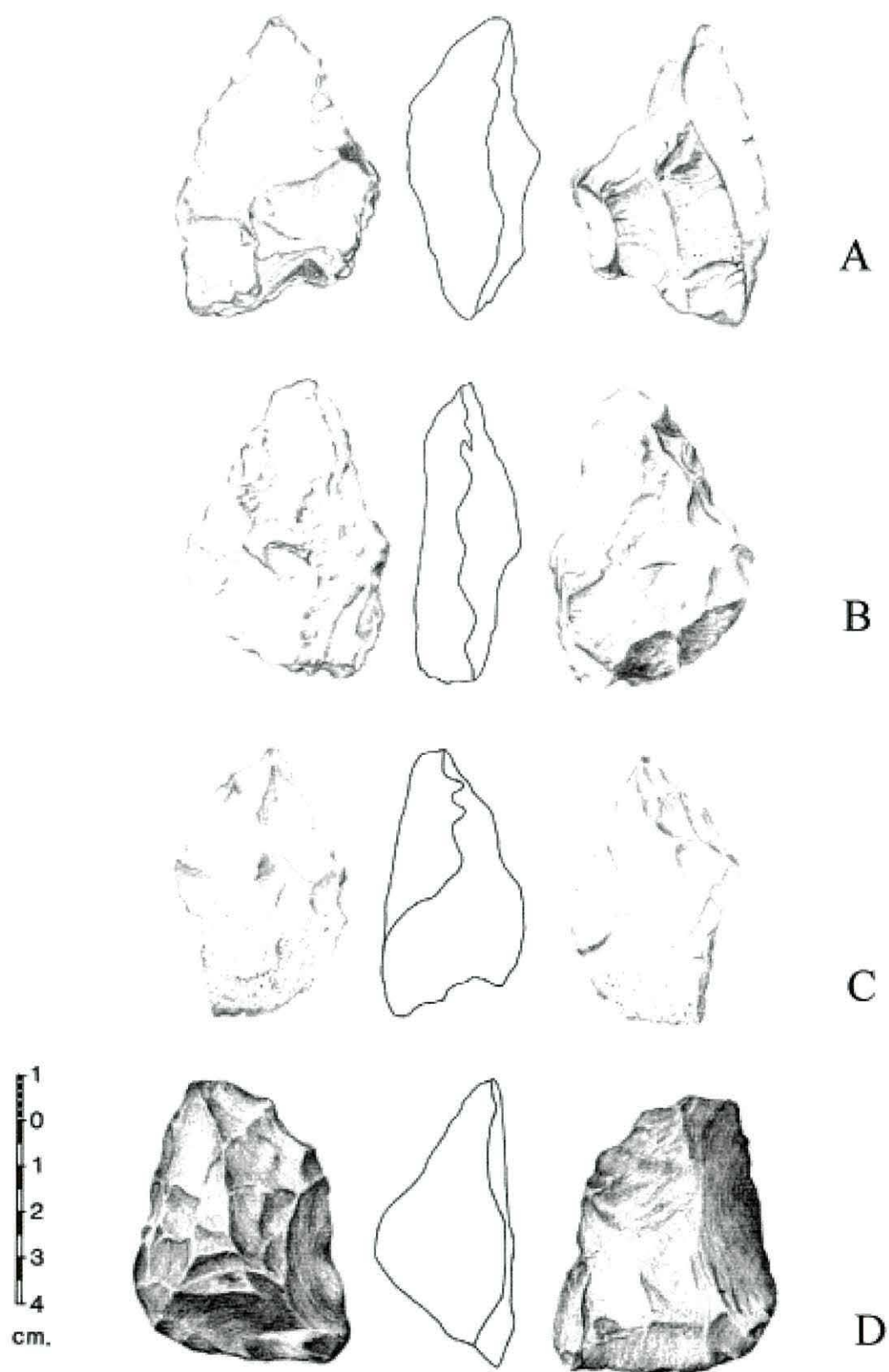


Figure 3.1. Pontnewydd handaxes. A: A66/9 fine silicic tuff, B: B18 crystal tuff, C: A49 carboniferous chert, D: A51 Feldspar Phyric lava.



Walker of the Archaeology Department NMGW, or in the course of this study. Length measurements were taken along the mid-axis perpendicular to the bulb of percussion and width measurements at the maximum width perpendicular to the length measurement. Thickness measurements were taken at the thickest point of the flake. These were recorded in the database referred to later in this chapter (Appendix 3.1).

#### 3.1.4. Sampling Programme

In order to clarify the hand specimen identifications and provide sufficient information for provenance studies permission was sought from the Advisory Council of the Department of Archaeology and Numismatics to sample selected artefacts, collected since the last major report (Green 1984). The total number of artefacts in the NMGW Pontnewydd collection is around 1300, and permission was sought and obtained to prepare thin sections from 93 artefacts. In selection of the material for thin section an attempt was made to limit the quantity as far as is possible while maintaining a representative sample, and to use artefacts which were damaged, or difficult to distinguish typologically, in order to limit the damage to the collection. Two artefacts were selected which characterised each group, and further artefacts were included which provided the 'end members' for each group. In cases where classification was uncertain, a thin section was proposed.

The assemblage from Pontnewydd required petrological examination to provide an accurate identification of the material and its provenance. The raw materials used are silicic volcanic rocks that were over-printed by low-grade metamorphism and deformation during the Caledonian Orogeny. As a consequence they have developed a variable fabric, which has had a greater impact on some original rock types than others. The rocks were therefore classified in a manner that, whilst broadly in line with standard IUGS nomenclature, took into account the impact of this alteration. This classification scheme should enable the maximum information to be derived from the artefacts. In addition, after the material had been discarded by the hominids, it was subjected to transport -- and, so, potentially to damage -- within debris flows and to post-emplacement solutional rounding. In consequence, most of the artefacts have acquired weathered surfaces additional to the cortical surfaces already present, further complicating identification from hand specimens alone. The use of a petrological microscope is necessary for any provenance study. Provenance studies are performed on

the basis of characteristic mineral assemblages, which cannot be seen in hand specimen.

#### 3.1.5. Polished thin section preparation

The proposed material was examined by Dr. S. Aldhouse-Green and any artefacts deemed to be of particular archaeological importance were not sectioned. The material was marked with chalk to indicate where a sample would cause the least damage to the artefact.

Thin section preparation was undertaken in the Rock Preparation Laboratory in the Department of Geology, National Museums and Galleries of Wales. A thin slice (5 mm) was removed from the artefact edge using a microtome saw, leaving a cut which can be back-filled with paste if necessary. One surface was polished and bonded onto a microscope slide with Epoxy resin, then ground and polished until the slice was 30  $\mu\text{m}$  thick. At this thickness most minerals are transparent and can therefore be viewed by transmitted light in a microscope. Using polarised light, minerals could then be identified by such properties as relief, cleavage, pleochroism, extinction, interference colours etc. and their inter-relationships and orientation studied.

The thin section was finished by polishing, rather than by addition of a cover slip. This leaves the section undamaged for future potential analyses and allows electron microprobe work, XRDA and x-ray fluorescence (XRF) to be carried out on the rock slices after mounting. The reliability of these techniques on polished thin sections is dependent on the grain size of the rock, as illustrated by Jenkins (1997). Reflected as well as transmitted light microscopy may also be used on polished thin sections, which permits the identification of opaque minerals.

#### 3.1.6. Potential Errors

Luedtke (1979) has distinguished three types of error that occur in source identification studies: i) Identification of an artefact as coming from one known source whereas it actually came from another known source;

ii) Identification of an artefact as coming from an unknown source when it actually came from a known source. Chemical changes such as weathering often result in this type of error.

iii) Identification of an artefact as coming from a known source when it actually came



from an unknown source. As many sources are undiscovered or uncharacterised, this too is likely to occur.

### 3.1.7. Statistical Analysis conducted for each rock type

#### 1. Chi<sup>2</sup> test

- a) Conducted on unfragmented non-debitage tools, to establish whether some tool types exhibited a significant deviation from the distribution expected by chance (at the 5% level).
- b) Conducted on the totals observed for each lithological category with the raw material distribution shown within each typological category (at the 5% level)
- c) Conducted on the raw materials used in each typological category compared with all other typological categories (at the 5% level).
- d) Conducted on the lithological distribution shown by handaxes compared with the raw material use of each other typological category (at the 5% level).
- e) Conducted on the lithological distribution of flakes compared with the raw material use of each other typological category (at the 5% level).
- f) Conducted on the raw material use for each typological category in the Main Cave compared to each typological category at the New Entrance (at the 5% level).
- g) All the above analyses were also conducted excluding artefacts made from flint.

#### 2. F-test

F-tests were carried out on pairs of logged data on each possible combination of rock types for each of the following categories: length (mm), width (mm), and thickness (mm), weight (g), length/width and thickness/length. The purpose of this analysis was to establish whether the data set was normally distributed and which rock types could be considered in the t-test.

#### 3. T-test

Two sample equal variance t-tests were carried out on pairs of logged data of several rock types for each of the following categories: length (mm), width (mm), and thickness (mm), weight (g), length/width and thickness/length, where possible. The purpose of this analysis was to establish whether the mean dimensions differed significantly for different rock types. The results of the f-test determined the categories on which the t-test could be implemented.



### **3.2. The results of characterisation of the rock types**

In total 1248 artefacts were placed within geological categories as described in Section 3.1. In order to aid clarification of these categories, 167 thin sections were examined. Eighty of these had been examined previously by Bevins (1984), to provide the original classification scheme for the Pontnewydd artefacts, although no record exists of any petrographic descriptions to accompany his classifications. The categories used in this study correspond to the categories of Bevins, although some groups have been added, in order to classify the wider variety of non-silicic rocks found in the 1984-1995 excavations.

| <b>Rock type</b>           | <b>Total no. of artefacts</b> | <b>ID in Hand Specimen</b> | <b>Identified in Thin Section</b> | <b>% ID in Thin Section</b> |
|----------------------------|-------------------------------|----------------------------|-----------------------------------|-----------------------------|
| Flint                      | 278                           | 278                        | 0                                 | 0                           |
| Rhyolite lava              | 128                           | 103                        | 25                                | 19.5                        |
| Rhyolitic tuff             | 96                            | 94                         | 2                                 | 2.1                         |
| FP lava                    | 132                           | 123                        | 9                                 | 6.8                         |
| Fine silicic tuff          | 170                           | 155                        | 15                                | 8.8                         |
| Crystal tuff               | 78                            | 55                         | 23                                | 29.5                        |
| Silicic tuff               | 34                            | 27                         | 7                                 | 20.5                        |
| Ignimbrite                 | 135                           | 111                        | 24                                | 17.7                        |
| Limestone                  | 4                             | 4                          | 0                                 | 0                           |
| Sandstone                  | 45                            | 41                         | 4                                 | 8.8                         |
| Siltstone                  | 21                            | 18                         | 3                                 | 14.2                        |
| Chert                      | 25                            | 24                         | 1                                 | 4                           |
| Baked shale                | 9                             | 6                          | 3                                 | 33.3                        |
| Crystal vitric tuff        | 6                             | 0                          | 6                                 | 100                         |
| Crystal lithic tuff        | 40                            | 24                         | 16                                | 40.0                        |
| Vitric tuff                | 6                             | 0                          | 6                                 | 100                         |
| Crystal pumice tuff        | 12                            | 5                          | 7                                 | 58.3                        |
| Crystal pumice lithic tuff | 7                             | 0                          | 7                                 | 100                         |
| Quartzite                  | 19                            | 18                         | 1                                 | 5.3                         |
| Andesite                   | 12                            | 11                         | 1                                 | 8.3                         |
| Dacite                     | 3                             | 1                          | 2                                 | 66.7                        |
| Microdiorite               | 17                            | 14                         | 3                                 | 17.7                        |
| Basalt                     | 7                             | 1                          | 6                                 | 85.7                        |

**Figure 3.1.1. Geological identifications made in hand specimen and thin section**

As can be seen from Figure 3.1.1., some rock types are more difficult to distinguish in hand specimen than others. In order not to bias the rock type distribution, the following groups were made, which were used to discuss the use of different raw materials. These broader categories were used for the graphical representation of the results and for the statistical analysis discussed later in the chapter. An outline of these rock types and their hand specimen descriptions is given in Appendix 2. Photomicrographs of selected thin sections, chosen to represent examples of the rock types examined, are provided in Figs. 3.2.1-3.2.10.

| <b>Petrological Grouping</b> | <b>Hand specimen Identification</b> |
|------------------------------|-------------------------------------|
| Flint                        | Flint                               |
| Rhyolite lava                | Rhyolite lava                       |
| Rhyolitic tuff               | Rhyolitic tuff                      |
| Silicic tuff                 |                                     |
| FP lava                      | FP lava                             |
| Fine silicic tuff            | Fine silicic tuff                   |
| Crystal tuff                 | Crystal tuff                        |
| Crystal vitric tuff          |                                     |
| Vitric tuff                  |                                     |
| Ignimbrite                   | Ignimbrite                          |
| Limestone                    | Sedimentary                         |
| Sandstone                    |                                     |
| Siltstone                    |                                     |
| Chert                        | Cherts                              |
| Silicified baked shale       |                                     |
| Crystal lithic tuff          | Crystal lithic tuff                 |
| Crystal pumice tuff          |                                     |
| Crystal pumice lithic tuff   |                                     |
| Quartzite                    | Quartzite                           |
| Andesite                     | Intermediate lavas                  |
| Dacite                       |                                     |
| Microdiorite                 | Microdiorite                        |
| Basalt                       | Basalt                              |

Figure 3.1.2. Rock type groupings used throughout the results chapter

### 3.2.1. Results of the thin section analysis

It was not possible to supply a provenance for all the artefacts examined in thin section. However, when certain characteristic features or minerals were present, an accurate provenance could be ascribed. Of the thin sections examined (see Appendix 1), only two could be conclusively tied to the Ordovician volcanic rocks of the Lake District. However, many of the rocks examined were too fine-grained for the details of their constituent minerals to be determined by petrological analysis alone, and x-ray fluorescence or microprobe work would need to be performed in order to attempt to ascribe a provenance. If literary references suggested a Welsh provenance, the sample was compared with extant thin sections in the collections of the National Museums and Galleries of Wales. If, after this comparison, a suitable match for the rock type was found within the volcanic rocks of North Wales, alternatives were not sought from further afield. The following description of Ordovician volcanic areas, which is mainly centered on the Snowdonian region, provides an overview of the context from which most of the samples appear to derive.

#### 3.2.1.1. Ordovician Volcanic areas in Wales (Figure 3.2.11)

##### *Tremadoc*

The earliest expression of Caledonian igneous activity in north Wales is the Rhobell Volcanic Complex, exposed in southern Snowdonia (Kokelaar 1979, 1986). Here, basic lavas and related basic, intermediate and silicic intrusions represent the eroded remnants of a volcano linked to subduction of the Iapetus oceanic crust.

##### *Arenig- Llandeilo*

Arenig to Llanvirn times saw widespread volcanism across Wales. A major volcanic centre was located in southern Snowdonia, to the SW of Dolgellau. The igneous episode recorded here, the Aran Volcanic Group (Pratt *et al.* 1995), was bimodal in character, with rhyolitic ash-flow tuffs as well as an eruption of basaltic pillow lavas.

##### *Caradoc*

During Caradoc times the majority of the igneous activity took place in north Wales, with centres located in Snowdonia and on Llyn. Snowdonia was the focus of the most important activity in the region. Two eruptive cycles have been determined in northern and central Snowdonia, separated by a period of quiescence and deposition of sediments.



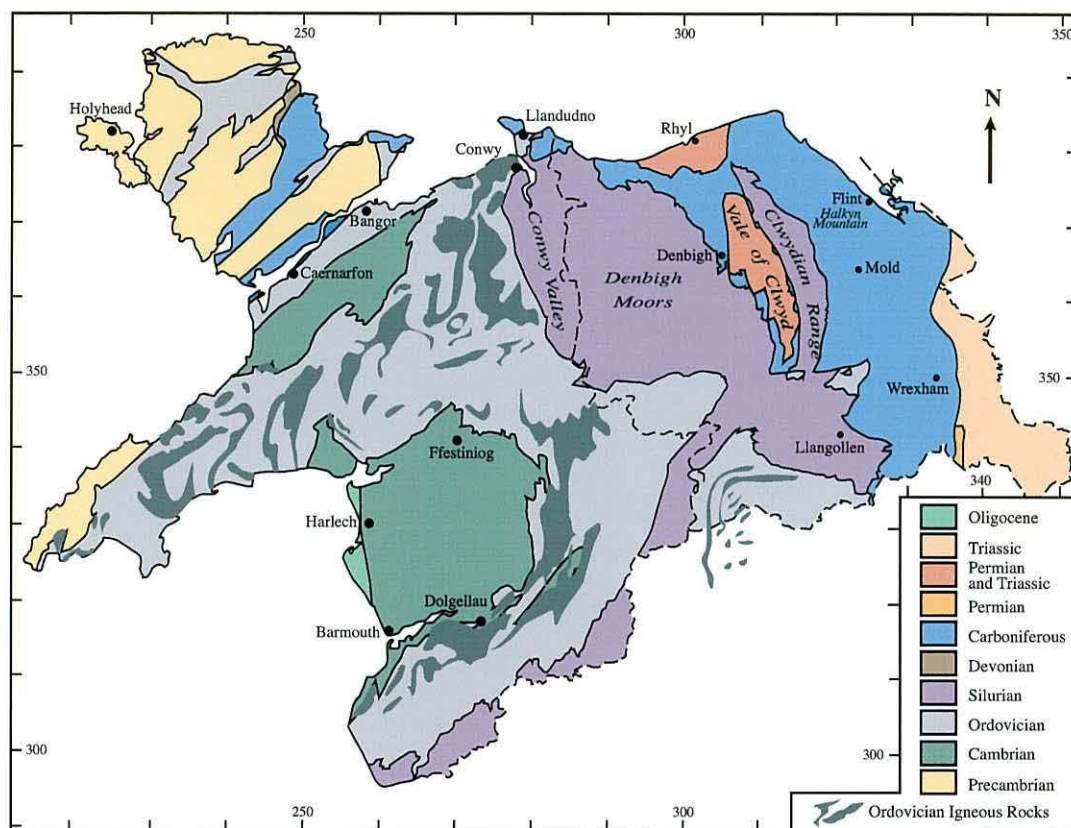


Figure 3.2.11 Geology of North Wales showing possible igneous sources for the Pontnewydd artefacts.

The earliest cycle comprises the Llewelyn Volcanic Group and the later the Snowdon Volcanic Group.

#### *The Llewelyn Volcanic Group*

The Llewelyn Volcanic Group comprises five formations, which are exposed mainly across northern Snowdonia. These eruptions occurred from four different centres, with deposition strongly controlled by contemporaneous faults, leading to deposits of variable thickness.

1. The most northerly formation, the Conwy Rhyolite Formation, comprises flow-banded rhyolitic lavas and ash-flow tuffs (Howells *et al.* 1991).
2. The Foel Fras Volcanic Complex is composed chiefly of trachy-andesitic lavas and ash-flow tuffs, with related high level intrusions including a caldera structure (Howells *et al.* 1983; Ball and Merriman 1989).
3. The Foel Grach Basalt Formation is exposed further to the southwest and is characterised by pillow basalts and hyaloclastic breccias.
4. The most southerly formation of the first eruptive cycle is the Braich-tu-du Formation, composed mainly of rhyolitic lavas and tuffs.
5. The final volcanic episode of this group is represented by the Capel Curig Volcanic Formation, exposed across northern and eastern Snowdonia (Howell *et al.* 1979; Howells and Leveridge 1980). This formation comprises welded and non-welded ash-flow tuffs, which were erupted from three volcanic centres.

#### *The Snowdon Volcanic Group*

The Snowdon Volcanic Group comprises a complex sequence of silicic ash flow tuffs, rhyolitic and basaltic lava flows and hyaloclastites. This group outcrops across Snowdonia, over a distance of 45 km. Three centres of activity have been defined (Howells *et al.* 1991), the Llwyd Mawr centre in the southwest, the Snowdon centre, and the Crafnant centre in the northeast.

1. The Llwyd Mawr Centre comprises silicic ash-flow tuffs of the Pitts Head Tuff Formation, which can be traced to the east into the Moel Hebog syncline. This formation contains welded ash-flow tuffs.
2. Activity at the Snowdon Centre was dominated by the eruption of voluminous acidic ash-flow tuffs with major caldera collapse. The earliest activity comprised welded ash-flow tuffs, the Yr Arddu tuffs, after which the caldera formed and a huge volume of acidic ash-flow tuffs were erupted. These formed the Lower

Rhyolitic Tuff Formation, which also contains intrusive rhyolites, particularly in the caldera area. This was followed by an episode of predominantly basic volcanic activity, which formed the Bedded Pyroclastic Formation. The final activity of the Snowdon Centre was the eruption of further silicic ash-flow deposits of the Upper Rhyolitic Tuff Formation.

3. The focus of activity then shifted to the Crafnant Centre. The eruption and emplacement of three primary, silicic, non-welded tuffs occurred, which now form the Lower Crafnant Volcanic Formation.

Volcanism in Caradoc times was not solely restricted to Snowdonia. To the east, in the Berwyn Hills, explosive silicic volcanism occurred and to the west, on Llŷn, products of volcanism can also be seen (Croudace 1982, Young and Gibbons in press).

#### English Lake District

As mentioned previously, another possible source for the Ordovician igneous, pyroclastic and volcanoclastic rocks is the Borrowdale Volcanic and Eyott Volcanic Formations (Millward *et al.* 1978) of the English Lake District. These rocks are similar in many respects to those examined in this study. However, rocks from Snowdonia are either of greenschist-grade, containing needles of actinolitic amphibole (Bevins and Rowbotham 1983) or fall within the prehnite-pumpellyite facies, whilst rocks from the Lake District may be hydrothermally altered (Mellor 1997). Where these minerals are present, it is possible to distinguish their sources on this basis. A possible source for some of the granitic rocks is the Ennerdale granophyre in the English Lake District (Bevins 1984).

#### 3.2.1.2. Areas and Formations from which the Pontnewydd artefacts derive

Despite the large number of thin sections that were studied in order to complete the artefact identification database, it was only possible to ascribe a provenance to these few samples.

#### Rhobell Volcanic Complex

Sample D165 is a tholeiitic basalt, identified by its orthopyroxenes. It contains skeletal oxides, which resemble oxides observed in sections from the Rhobell Volcanic complex, although basalts of this nature also occur in the Lake District.



### The Llewelyn Volcanic Group

The primary ash flow tuffs of the Capel Curig volcanic Formation are generally shard-rich with scattered crystals of feldspar and quartz set in a matrix of finely aggregated quartz, feldspar, sericite and chlorite. Shard fabrics vary from non-welded and vitroclastic to welded with eutaxitic and parataxitic textures. Variations in the proportions of these constituents may allow correlation at a more detailed level (Howells and Leveridge 1980). Sample A66/36 contains cusate forms recrystallised by a quartz-feldspar mosaic, the peripheries of which are highlighted by shreds of chlorite, a characteristic feature of the shards of the Capel Curig area. Sample D807 displays a parataxitic texture that although well developed is irregular, indicating rheomorphism. This feature has been observed in tuffs at Gallt yr Ogof and Tryfan, in the Capel Curig Volcanic Formation. Sample A689 contains both epidote and garnet crystals and resembles a Snowdonian ignimbrite. Garnet occurs in the Capel Curig Volcanic Formation in particular in the area near Tryfan and Gallt yr Ogof where it is associated with the intensely welded parts of the flows (Howells and Leveridge 1980), but is also present in the Lake District. Sample D384 contains ilmenite could therefore derive from the Conwy Rhyolite Formation. Sample B310 is an altered andesitic lava containing actinolite, which could derive from either the Foel Fras Volcanic Formation, Rhobell Volcanic Complex or western Lake District.

### The Snowdon Volcanic Group

The tuffs of the Lower Rhyolitic Tuff Formation are predominantly massive, poorly cleaved rocks, grey in colour with bleached weathered surfaces on which clasts and crystals are visible in places. Towards the top of some units the rock has a uniform flinty character and this is the case for sample D5311. Sample A102/1 exhibits a parallel arrangement of mica-replaced shards, a texture which occurs in parts of the Lower Rhyolitic Tuff Formation (Howells et al. 1973). Sample A490 is a basaltic tuff, which contains aggregates of chlorite and muscovite pseudomorphing plagioclase phenocrysts. It resembles material from the Bedded Pyroclastic Formation, in the Snowdon Volcanic Group. Sample F4534 contains coarsely recrystallised cusate and tabulate shards, accentuated by iron oxides gathering on the edges of the shards, this shard replacement is characteristic of the Lower Crafnant Volcanic Formation in the

Capel Curig district. Sample A549 is also likely to derive from the Lower Crafnant Volcanic Formation.

#### Snowdonia area

Epidote is widely developed in Snowdonia in the groundmass of fine-grained Palaeozoic volcanic rocks (Bevins 1994) but is also widespread in the western Lake District. Rutile has been described as an important component of the Bedded Pyroclastic Formation (Williams 1927). The presence of both epidote and rutile in samples B259 and A605, and their similarity to other Snowdonian material, would suggest a Snowdonian origin. Biotite is poorly represented in the English Lake District, so those samples which contain biotite, such as B415, A124/1, F959, are likely to be Snowdonian in origin. The flow-banded rhyolite in sample D4902 contains stilpnomelane needles, an indication of a possible origin from the Cadair Idris area (Bevins and Rowbotham 1983). Sample F5699 contains both epidote and piemontite, which has been reported in altered rhyolitic rocks from the Llanberis Pass (Williams 1927). Sample A625 is a cordierite hornfels from an acid intrusion, which closely resembles material from the Mynydd Mawr intrusion and the Tan-y-Grisiau granitic intrusions (Bevins *in press*), but does not resemble material from acid intrusions linked to activity in central Snowdonia.

#### North Wales

Samples F1314 and F1530 are microdiorites containing clinopyroxene, and are similar to samples from Llŷn (Croudace 1982), but may alternatively derive from similar outcrops at Garnfor, Garn Bodaun and Garn Ddu or possibly the Lake District. Sample A74/1 is a pyroxene-bearing microdiorite containing a pumpellyite-rich vein, which may have its origin on Llŷn or at Penmaenmawr (Bevins *pers. comm.*). Sample H9 is a fresh dolerite containing augite, rutile and magnetite. It is clearly a product of Tertiary volcanism and is likely to derive from Tertiary volcanic dykes in N. Wales or N. Ireland.

#### English Lake District

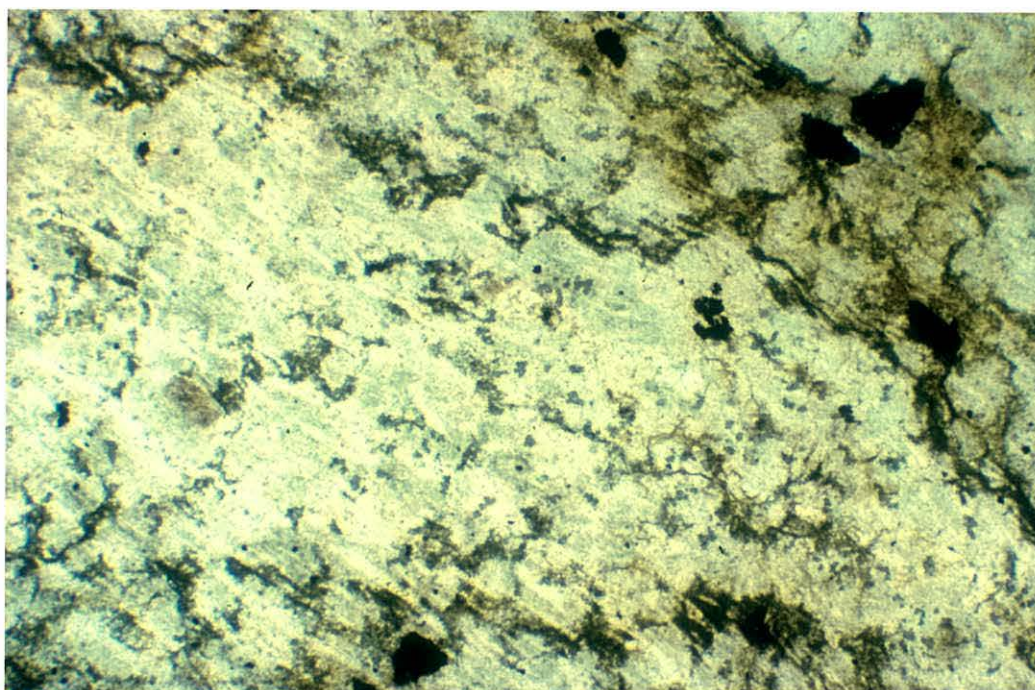
Sample A68/5 is an example of Ordovician basalt from Cumbria. It was distinguished on the basis of its cleaner-looking chlorite, the presence of magnetite and the heavily altered pyroxene. A further sample from this area was C1023, a calc-alkaline crystal

lithic tuff, which contained many large phenocrysts, mainly of altered pyroxene, in a quartz-feldspar matrix. Also present were many partially infilled vesicles and lithic fragments. Sample B72 is an ignimbrite containing both prehnite and brown amphibole (see Chapter 4) and may possibly derive from the Lake District as well.

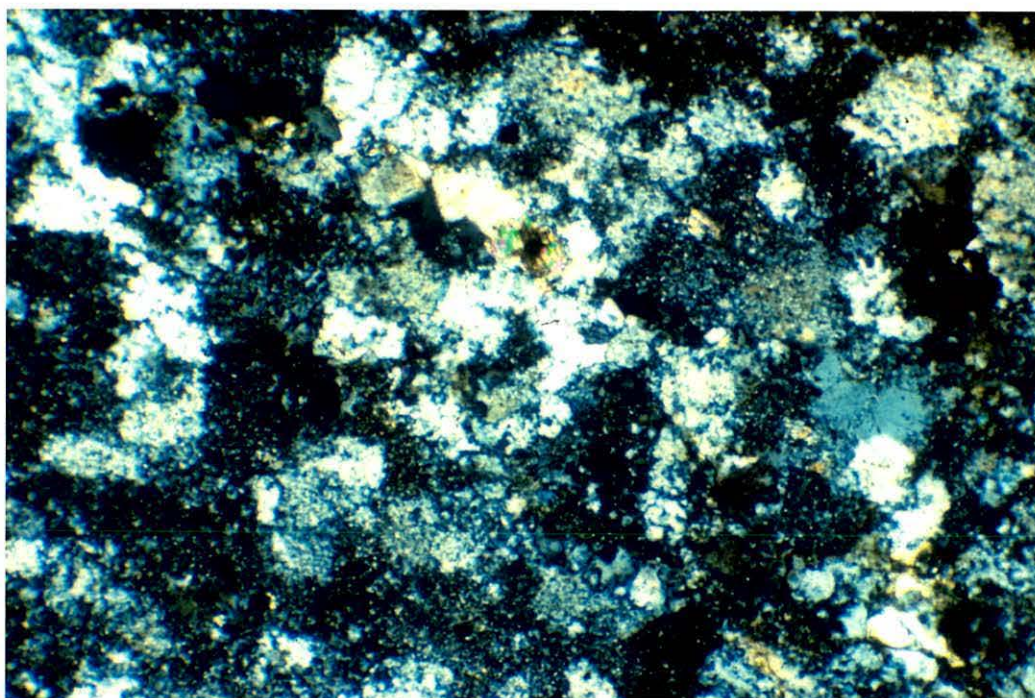
### **3.2.2. Overall characterisation of the rock types**

As can be seen in Appendix 3.1, the majority of the rock types found at Pontnewydd Cave are ignimbrites, rhyolitic tuffs, rhyolitic lavas and FP lavas. However, the sample of material collected from Pontnewydd is not necessarily a random selection of materials that were available in the local drift, as will be discussed in the next section. It would therefore be unwise to use the Pontnewydd assemblage to give any more than general indications as to the contribution of both Irish Sea and Welsh drift to the deposits of the local area. With this in mind, both the hand specimen identifications and the thin section analyses seem to show a greater contribution to the Pontnewydd assemblage from material derived from Welsh sources than from the English Lake District.





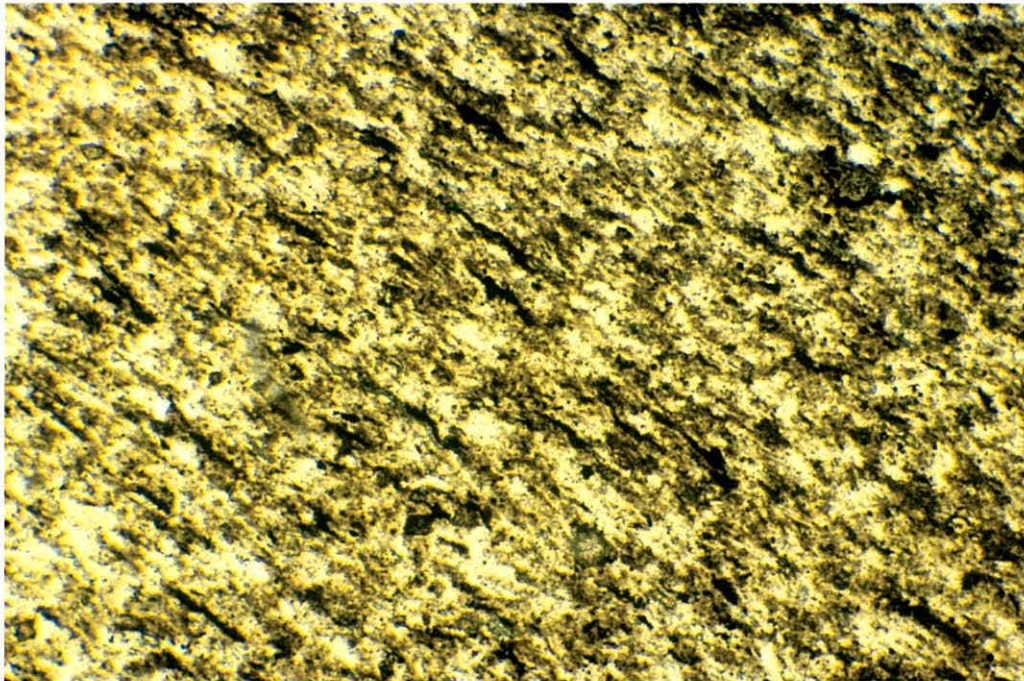
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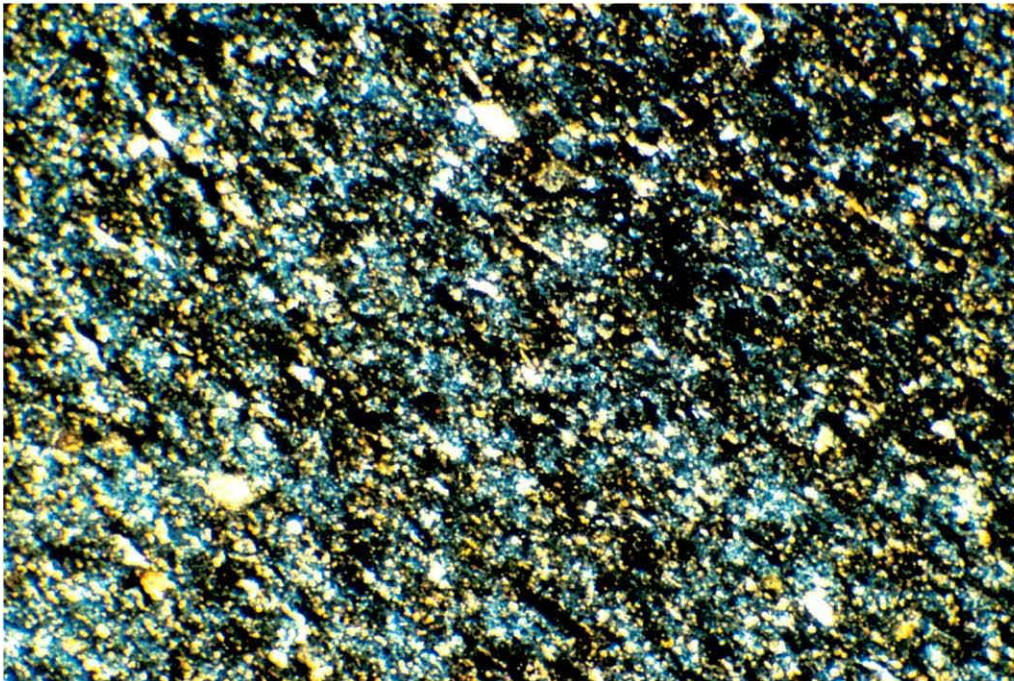
b.

Figure 3.2.1. TS252 (A689), ignimbrite, a. ppl, b. xpl. Field of view 4.4 mm. The rock contains primary garnet and plagioclase and secondary epidote. The primary eutaxitic texture is overprinted by 'snowflake' crystallization texture. Provenance Snowdonia.





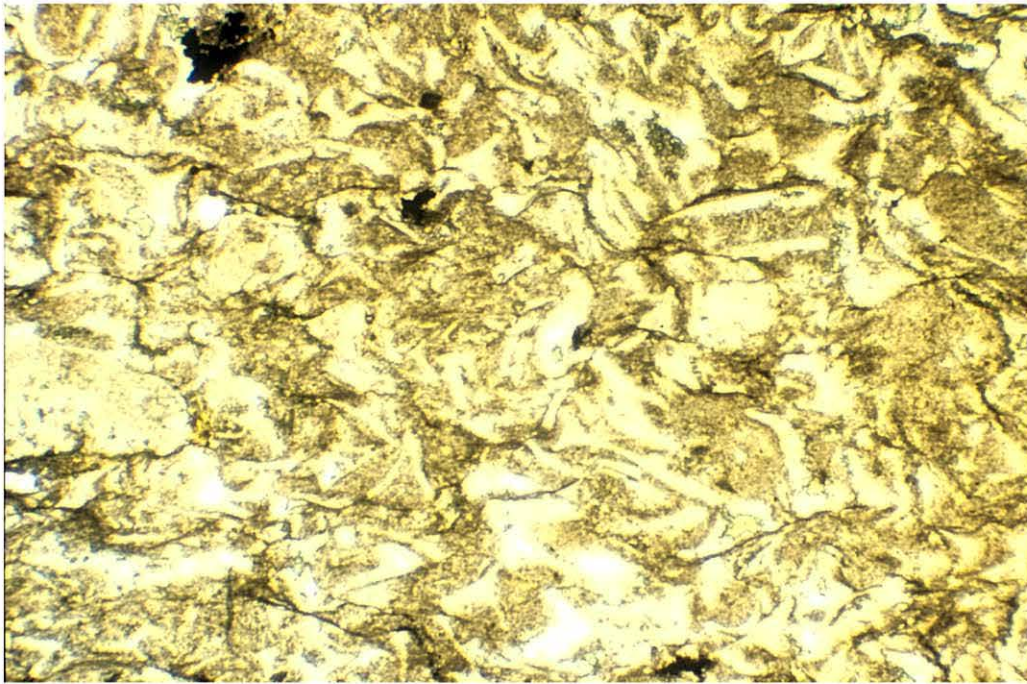
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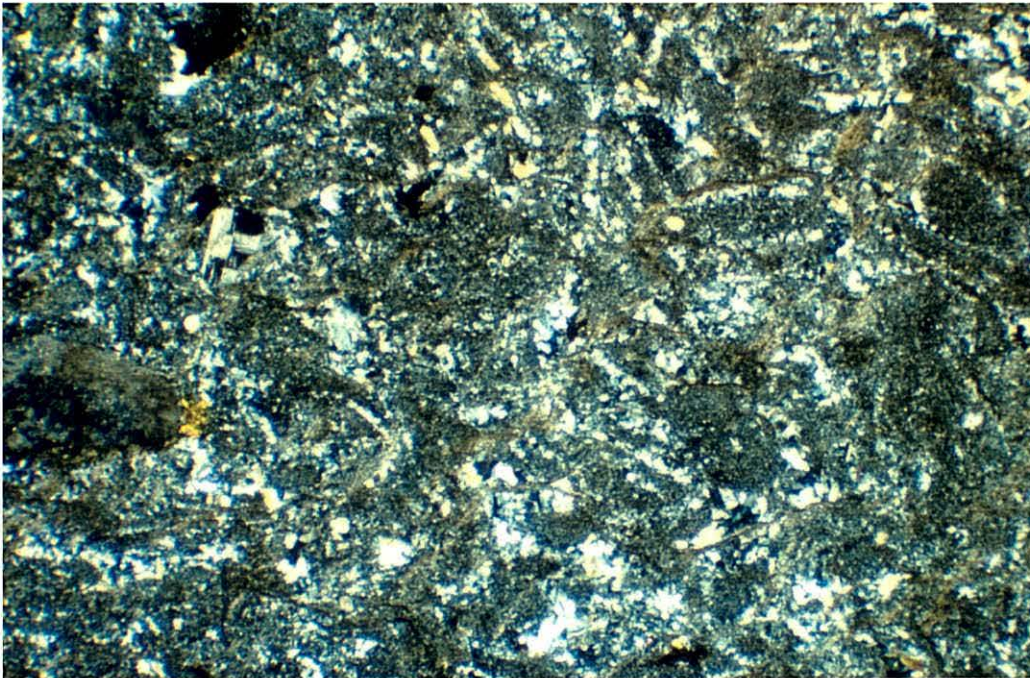
b.

Figure 3.2.2. TS270 (H1926), a. ppl, b. xpl. Field of view 4.4 mm.  
 Fine-grained, silicic tuff showing depositional layering accentuated by trails  
 of fine-grained iron oxide.





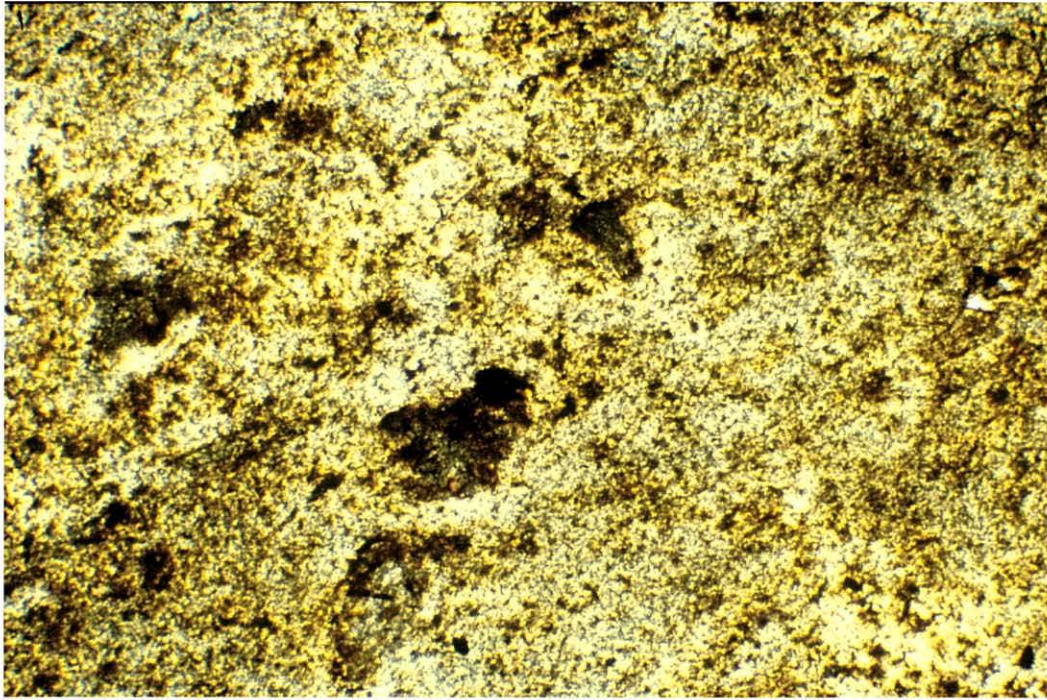
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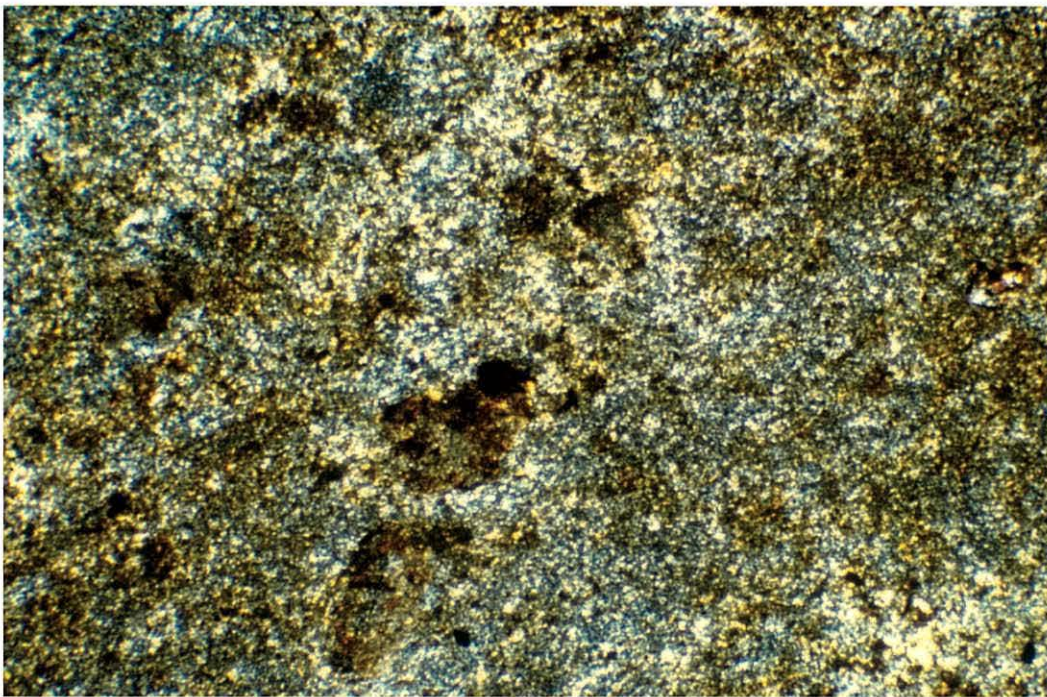
b.

Figure 3.2.3. TS274 (A549), a. ppl, b. xpl. Field of view 4.4 mm.  
 Crystal vitric tuff showing parataxitic texture and well developed, extensively  
 chloritised, cusped shards. Provenance Crafnant Volcanic Formation.





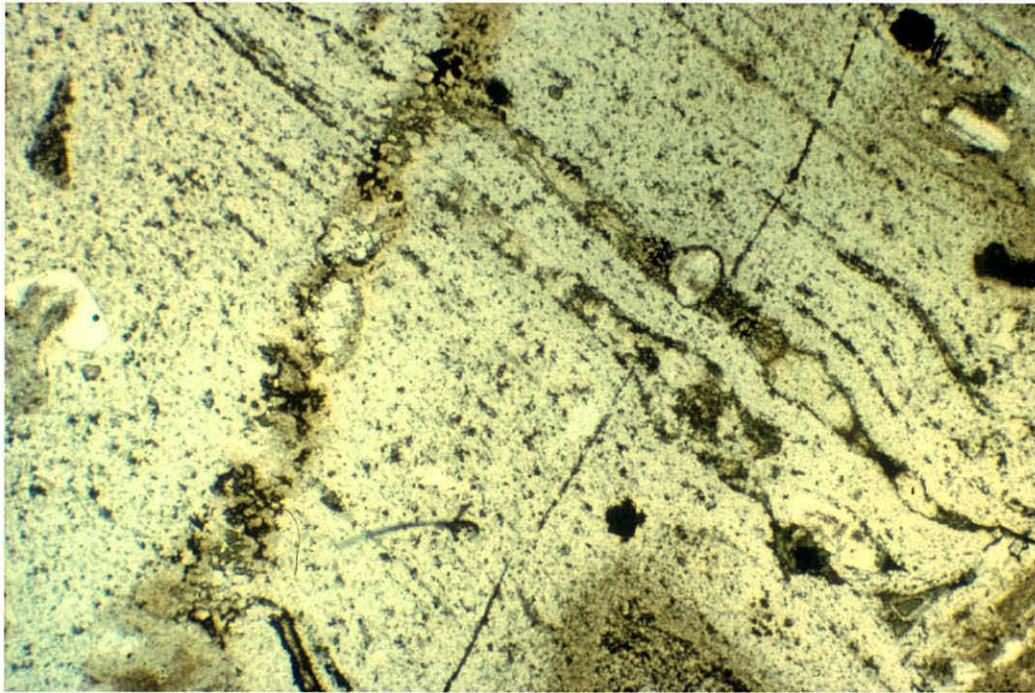
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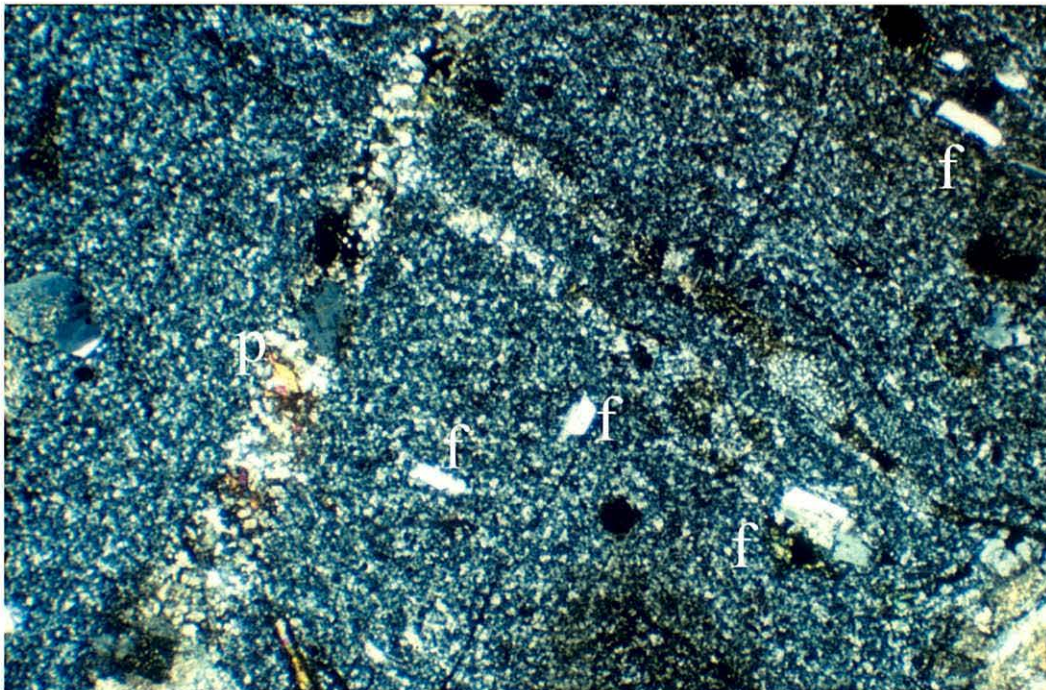
b.

Figure 3.2.4. TS 218 (D4902), flow banded rhyolite, a. ppl, b. xpl. Field of view 4.4 mm. The sample is intensely iron-stained and shows a non-directional flow-fabric. The presence of stilpnomelane needles is indicative of a Snowdonia provenance.





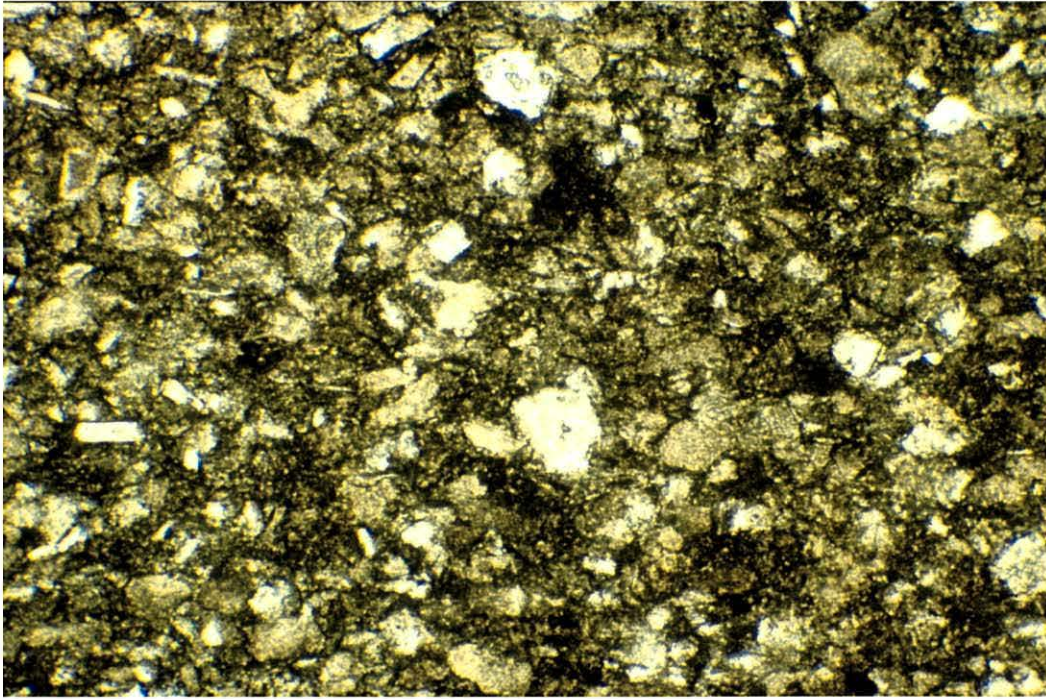
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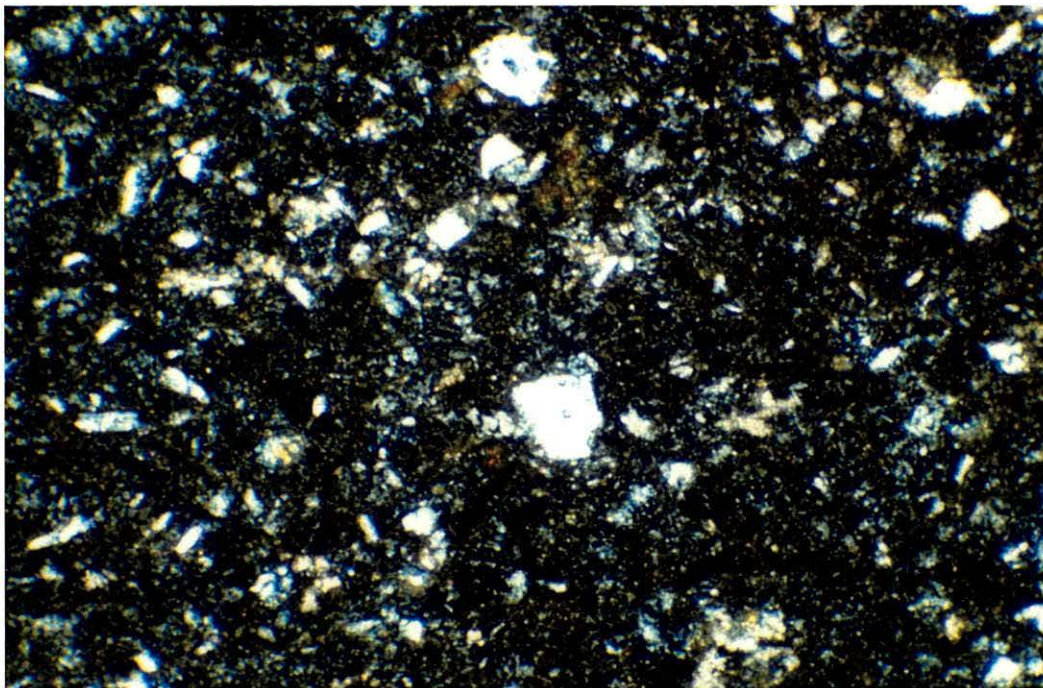
b.

Figure 3.2.5. TS233 (F5699), a. ppl, b. xpl. Field of view 4.4 mm. Flow banded rhyolite containing relatively unaltered feldspar phenocrysts (f). The vein, cutting the left side of slide, contains piedmontite (p) indicative of a Llanberis Pass provenance.





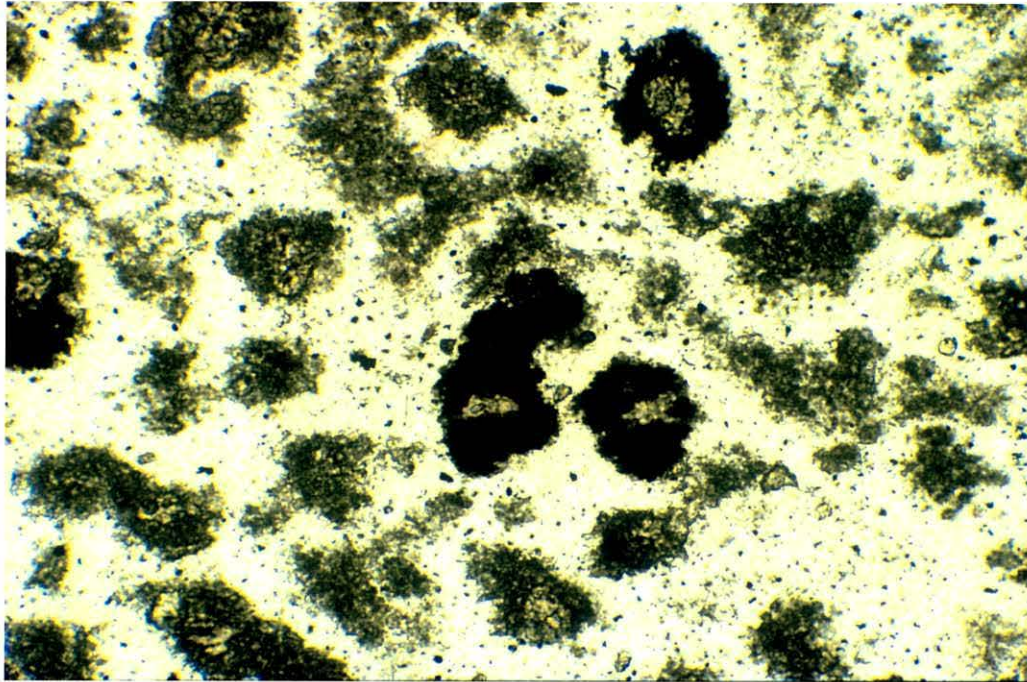
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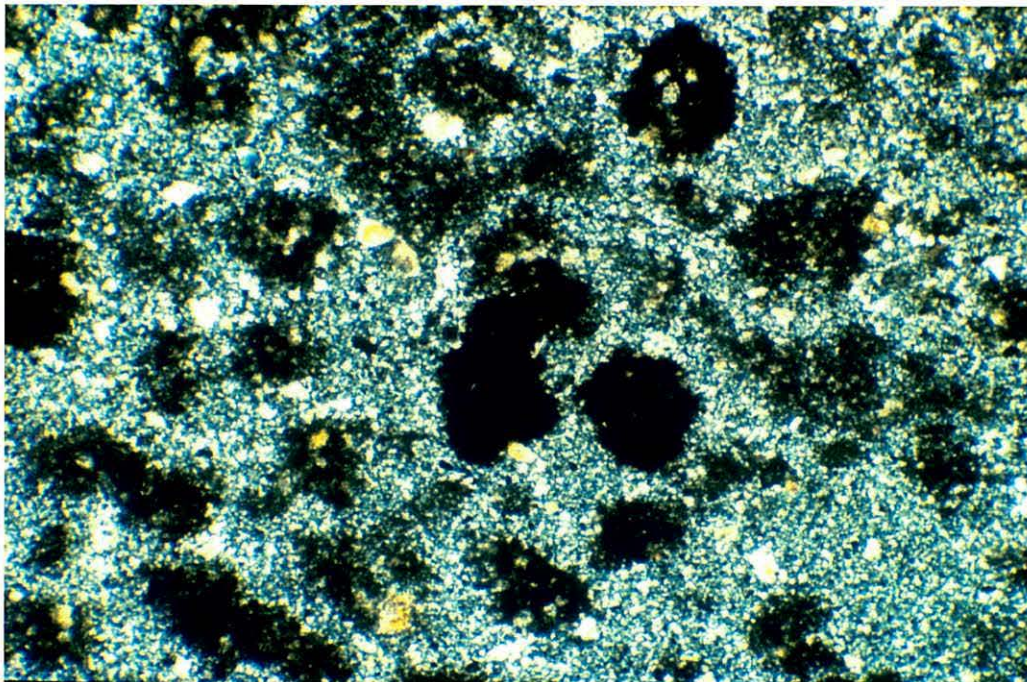
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Figure 3.2.6. TS236 (F4949), altered volcaniclastic sandstone, a. ppl, b. xpl. Field of view 4.4 mm.





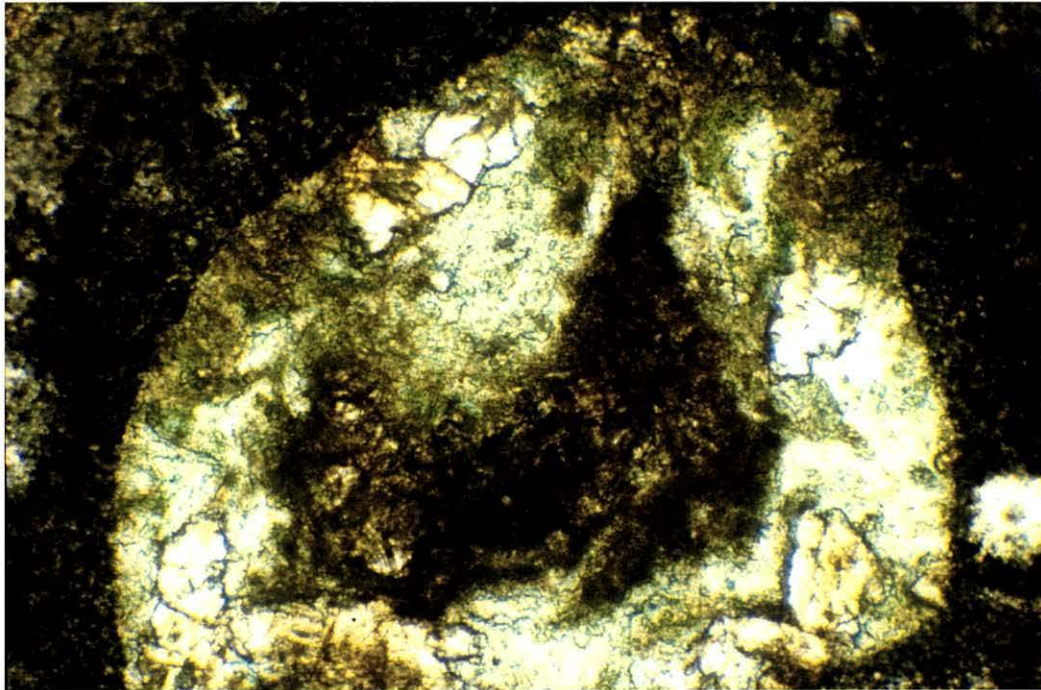
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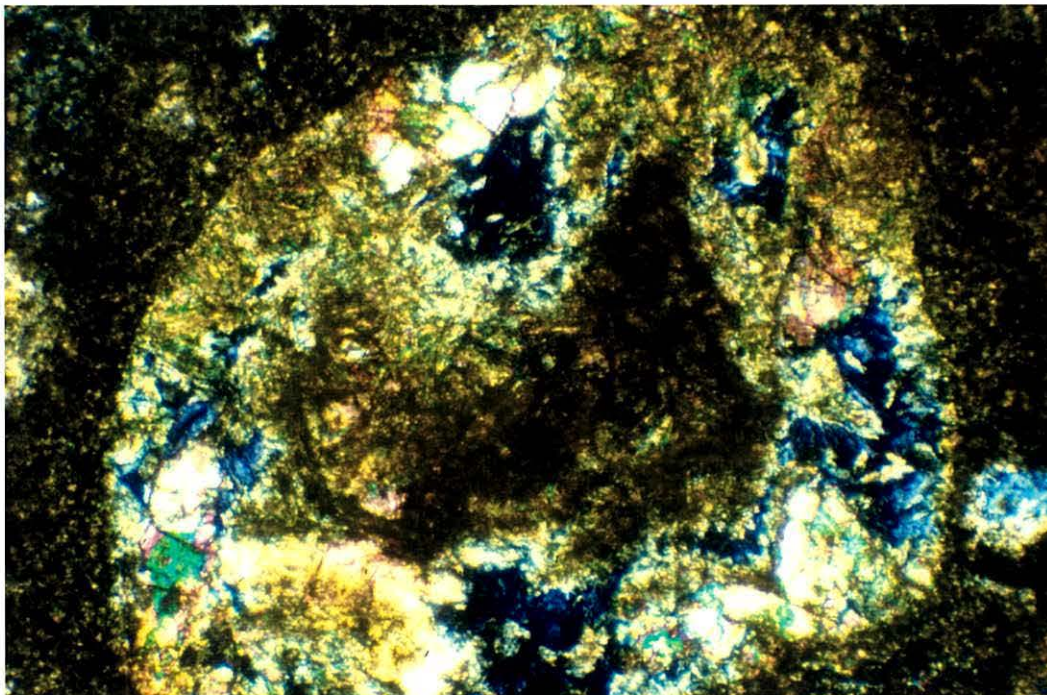
b.

Figure 3.2.7. TS251(A625), cordierite hornfels, a. ppl, b. xpl. Field of view 4.4 mm. Spots of cordierite resulting from contact metamorphism, in an aligned quartz matrix. Provenance from North Wales, either from Mynydd Mawr or Tan-y-Grisiau.





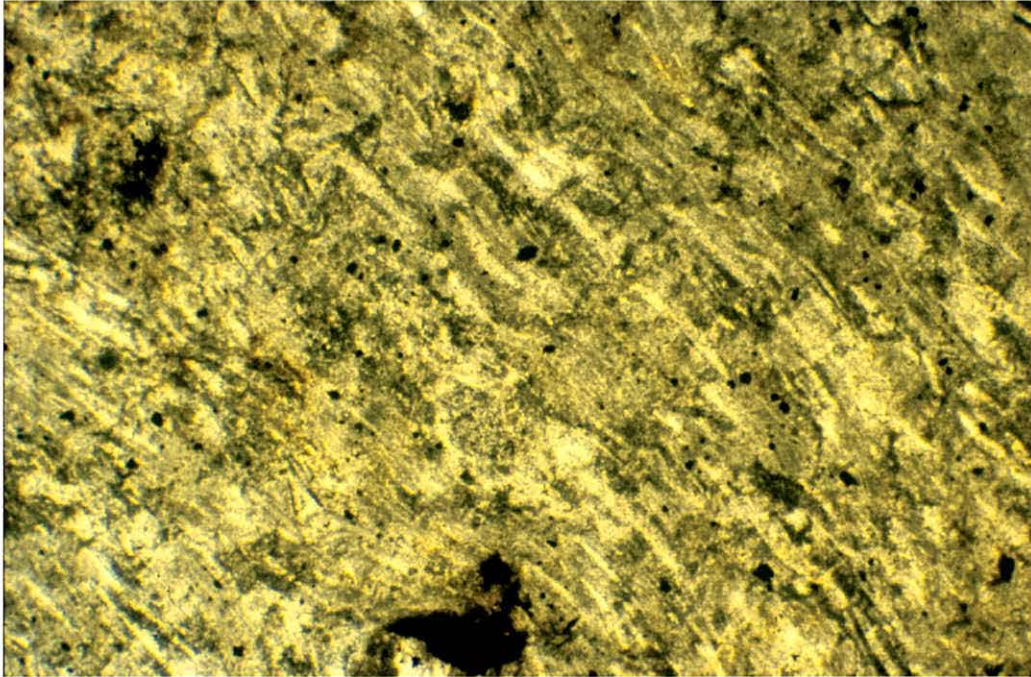
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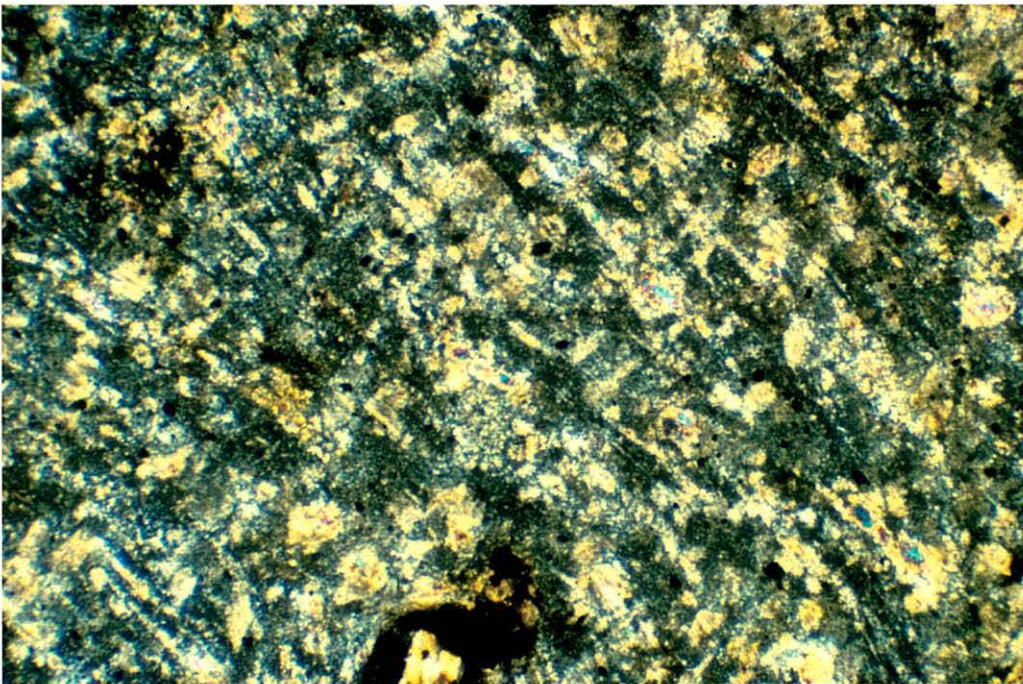
b.

Figure 3.2.8. TS273 (C1023), crystal lithic tuff, a. ppl, b. xpl. Field of view 4.4 mm. The tuff is highly vesiculated. The illustration shows a vesicle infilled by calcite, chlorite and epidote. Lake District provenance.





a.



b.

Figure 3.2.9. TS240 (F4700), ignimbrite, a. ppl, b. xpl. Field of view 4.4 mm. The eutaxitic texture, shown in these illustrations, encloses large crystals of pyroxene and plagioclase and is overprinted by 'snowflake' recrystallisation texture.



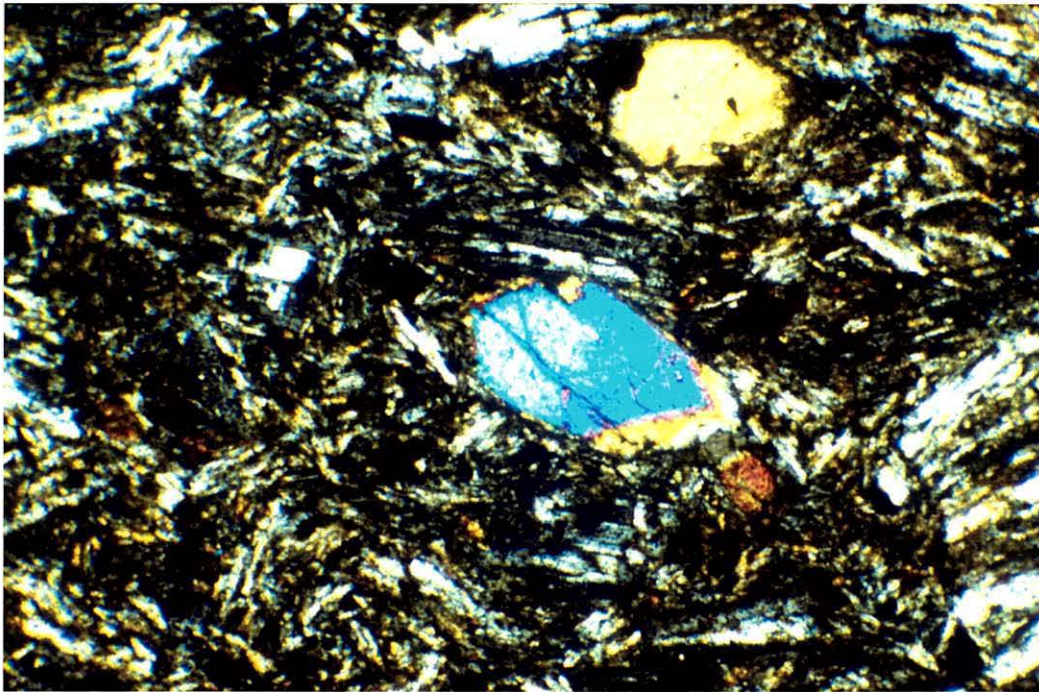


Figure 3.2.10. TS209 (H9), dolerite, xpl, field of view 4.4 mm. Phenocrysts of clinopyroxene and plagioclase in a groundmass of fine-grained plagioclase. The low level of alteration in the dolerite indicates a Tertiary (Palaeocene) age and therefore a provenance in either North Wales or Northern Ireland.



### **3.3. Informal Knapping Experiment**

The aim of this experiment was to indicate how rock type influenced technology and typology, and explore the ease of working of a variety of raw materials found at Pontnewydd. From experiments done by Newcomer (1984) it was anticipated that none of the material would be easy to flake due to unpredictable cleavage planes, weathering, and the frequency of accidents such as 'Siret's burin'.

#### 3.3.1.Method

A selection of igneous cobbles with sources in Snowdonia were collected from several areas of drift deposits in north Wales. In total 12 were collected. These were then offered to a knapper with around three years experience of working flint and limited experience of non-flint material. He was asked to produce any tools, preferably bifaces from any of the cobbles that he thought suitable for the task. He was not timed, but was asked for his comments throughout the experiment. He was offered hard hammers of ignimbrite and bunter quartzite and soft hammers of antler and boxwood. Knapping took place over a sheet and the cobbles were weighed before and after knapping and all debitage over 1cm was collected and weighed. Debitage under 1cm was not weighed due to the constraints of the environment under which the experiment was undertaken. The outlines of the cobbles were drawn before and after knapping (Figure 3.3).

#### 3.3.2.Results

In contrast to the opinion of Newcomer (1984) that the material could not be worked with a soft hammer, it was found to produce more controlled flakes than a hard hammer on this material. Very hard follow-through blows were necessary to detach flakes, and the best results were achieved using a combination of a large boxwood hammer and an ignimbrite hammerstone. This experiment reiterated Newcomer's view that the edges of coarser flakes could not be refined, they tend to crumble rather than flake neatly. Therefore, although it was possible to produce a functionally efficient tool, that could be defined within the same typological groups as a similar tool made on flint, it was difficult to produce a refined product, particularly with respect to retouch. Further points to result from the experiment were:

- Manufacture time was much faster for flint than on most of the materials knapped.

- Shape of the blank was critical to the success or failure of the finished piece.
- Water rounded cobbles contained fewer internal fractures than angular glacial cobbles, freshly collected from Welsh drift deposits. Therefore, the difficulty in producing an initial flake on a rounded cobble was more than compensated for by the relatively predictable nature of the material inside.
- The quartzite hard-hammer was less effective than an ignimbrite hard-hammer on this material.
- Although the tools produced were useable, the edges of the flakes were not as sharp as those made on flint. Due to the ease with which the edges crumble, these tools may need replacing more often than those of flint.
- It was sometimes difficult to control the direction of the flake, although this may be a result of unfamiliarity with the raw material. Internal flaws in the material, which were not immediately noticeable, continually hampered flaking.

In order of preference, easiest first, the rocks chosen were: crystal tuff, rhyolitic tuff, rhyolite lava, feldspar-phyric lava, silicified mudstone, ignimbrite. It was not possible to obtain a large enough piece of fine silicic tuff from the drift deposits investigated to produce an artefact. The pieces found were chosen by the knapper but were later disregarded due to their small size. Some of the artefactual material produced was measured and is recorded in Appendix 3.2.

### 3.3.3. Discussion

Heavy crude stone tools like those at Pontnewydd are clearly not indicators of lower intelligence or deficient craftsmanship. In this experiment, although the material was much harder than flint to work, the igneous raw materials used have not heavily constrained the tools that can be produced, but rather the level of refinement on these tools. As anticipated, the different rock types did have different flaking properties and this may have influenced the lithic assemblage at Pontnewydd.

The artefacts from Pontnewydd do not reflect anything like the quantity of material knapped because so much of the debitage is unrecognisable as artefacts and therefore discarded during excavation. Newcomer suggests that 98% of East Anglia flint debitage is



recognisable compared to 14.3% of that at Pontnewydd. The author also produced approximately this figure in an informal experiment at a meeting of the NMGW Archaeology department, where members watched an artefact being knapped in Graig Lwyd augite granophyre and attempted to identify debitage flakes. Out of the 14 flakes (all of over 2cm) most members, using traditional indicators such as a bulb of percussion or a visible striking platform identified three flakes, but said that in the field the number was likely to be less.

Prehistoric knappers paid as much attention to choosing and testing blanks as they did to making a tool, particularly on unfamiliar material. Perhaps they were testing the materials as they were found in the way that modern geologists do. Many geologists observe that different rocks have a characteristic ring when struck, in addition to the visible qualities of the rock, this may have played an important part.

Differences in flaking properties have been posited to cause variability in lithic assemblages and to influence the type of tool produced (Close 1980, Strauss 1980, Clark 1980). In experiments carried out by Maloney (1988) out of a selection of raw materials rhyolitic tuff proved the easiest to flake and there was some degree of correlation between the silica content of the material and its ability to produce good bifaces.

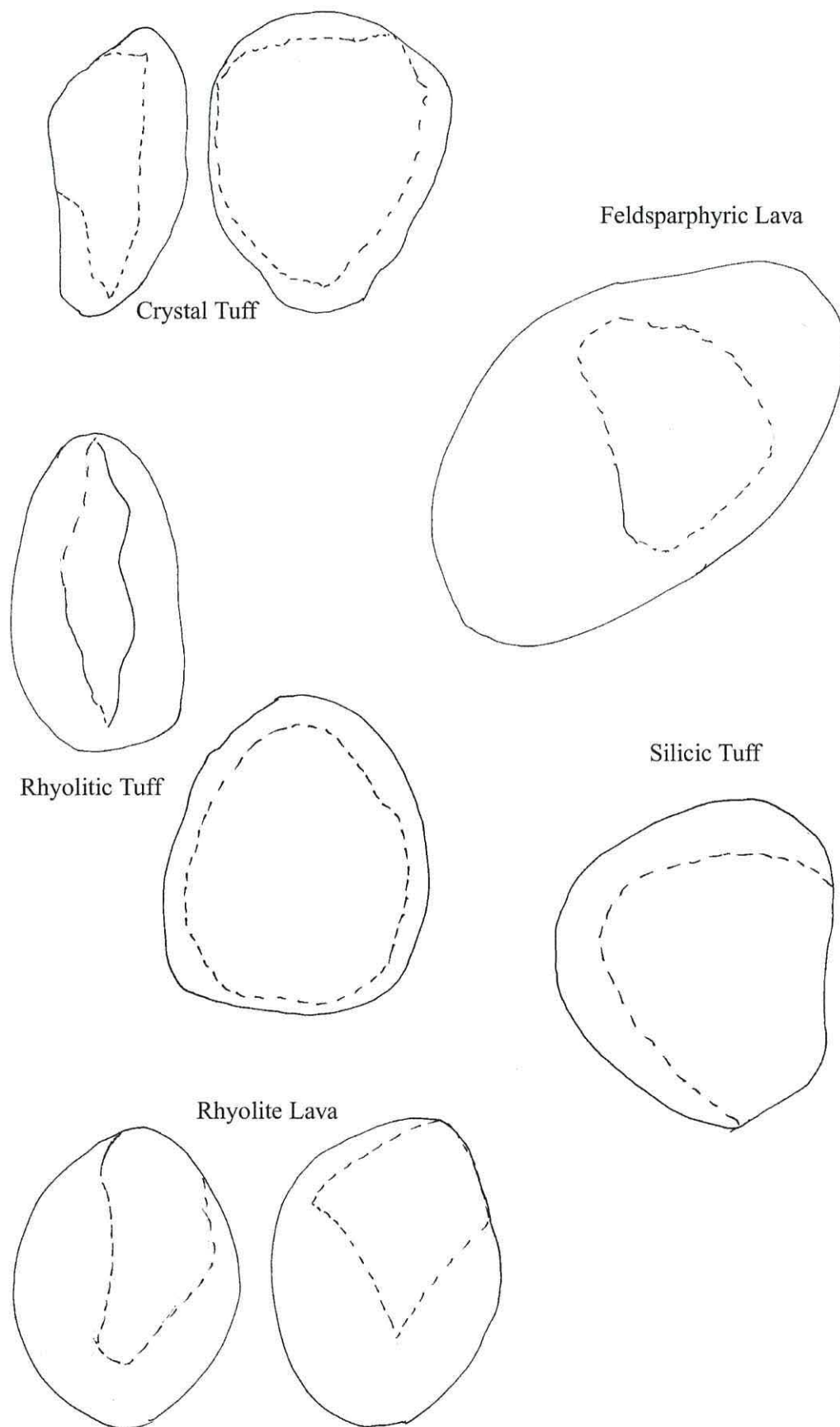


fig. 3.3 Outlines of cobbles before and after knapping



### 3.4. Trends shown by the Artefacts

Analysis of the artefact data (Appendix 3.1) is presented in Figures 3.4.1-3.4.19.

Figure 3.4.1. shows the numbers of each typological group that have been made on each rock type, and is the core data set for graphs relating to typology. Figure 3.4.2. displays the percentages of each lithological group which are used for each artefact type, and is the core data set for graphs relating to rock type.

#### 3.4.1. Macroscopic trends

The following are trends observed in percentage plots of the total data set of the Pontnewydd artefacts:

1. The rock types that are used in the greatest quantities are rhyolitic tuff, rhyolite lava and ignimbrite (Figure 3.4.6, graph 3). It is not known whether this is a reflection of their availability in the local landscape, as no comparative deposits have been studied. An analysis of exotic pebbles from the Upper and Lower Sands and Gravels would provide a suitable comparison.
2. The dominant components of the industry are handaxes, levallois flakes and cores, retouched artefacts and scrapers (Figure 3.4.6, graph 1). This seems to be a late Acheulian assemblage with a strong Mousterian component, characterised by the large number of Levallois tools.
3. Handaxes (Figure 3.4.7, graph 1) are mainly made from rhyolite (18.1%), FP lava (19.4%) and rhyolitic tuff (15.2%), with additional use of crystal lithic tuff (12.5%). Interestingly, 'handaxe' trimmer flakes show a slightly different pattern, being made from fine silicic tuff (28.5%), rhyolitic tuff (23.8%) and ignimbrite (14.3%).
4. Levallois products (Figure 3.4.7, graph 2) are mainly made from rhyolite (15.3%), FP lava (14.3%), and fine silicic tuff (14.3%) with further use of crystal tuff (13.2%) and microdiorite (9.9%).
5. Scrapers (Figure 3.4.7. graph 2) are made of FP lava (17.4%) and fine silicic tuff (13%) with other rock types, such as flint (10.9%) and crystal tuff (10.9%) also used.
6. However, retouched artefacts (Figure 3.4.7. graph 2) are mainly made from fine silicic tuff (24.5%) and flint (20.8%), with some use of ignimbrite (15.9%). Tool reuse exhibits a similar pattern to scrapers, as mainly fine silicic tuff (22.8%), FP lava (20.0%) and flint (14.3%) are used.

7. There are also many discoidal cores and other cores (Figure 3.4.7, graph 1).  
Discoidal cores are mainly made from ignimbrite (20%), FP lava (13.3%) and fine silicic tuff (13.3%). Cores are mainly of ignimbrite (23.1%), flint (18.0%), and quartzite (20.5%).
8. The majority of debitage is of flint (chunk/chip/spalls are 89% flint), with high percentages of fine silicic tuff (FST), ignimbrite, rhyolite and FP lava as well (Figure 3.4.7, graph 3).
9. When raw materials are studied by area there is a distinction between area in the main cave and those in the New Entrance (Figure 3.4.9). In area A, the dominant rock types are FST, rhyolite and ignimbrite. In area B/C they are FST, flint and FP lava, in area D dominant rocks are rhyolitic tuff, rhyolite and FP lava, in area F they are ignimbrite, FP lava and rhyolite, and in area H they are flint, rhyolitic tuff and ignimbrite.
10. The different rock types exhibit characteristic data as well. Crystal lithic tuff (Figure 3.4.5, graph 3) is used mainly for handaxes (25%).
11. Sandstone, siltstone and limestone (Figure 3.4.5, graph 2) are mainly used for discoidal cores (18.5%), retouched flakes (11.1%) and handaxes (11.1%).
12. Rhyolite lava (Figure 3.4.3, graph 2) is predominantly used for handaxes (22.8%) and levallois flakes (19.3%). Rhyolitic tuff (Figure 3.4.3, graph 3) follows a similar trend, being mainly used for handaxes (19%), and levallois flakes (12.1%).
13. Flint (Figure 3.4.3, graph 1) is mainly used for retouched flakes (17%), core fragments (17%) and artefact fragments (11.3%).
14. FP lava (Figure 3.4.4, graph 1) is mainly used for handaxes (19%), tool reuse (11.1%) and levallois flakes (11.1%).
15. Fine silicic tuff (Figure 3.4.4, graph 2) is mainly used for retouched flakes (18.1%), Levallois flakes (15.3%), and tool reuse (11.1%).
16. Crystal tuff (Figure 3.4.4, graph 3) is mainly used for levallois flakes (25%), retouched flakes (11.4%) and handaxes (11.4%).
17. Ignimbrite (Figure 3.4.5, graph 1) is mainly used for disc cores (14.1%), crude cores (14.1%) and retouched flakes (12.5%).



|                             | Flint      | Rhyolite<br>lava | Rhyolitic<br>tuff | FP<br>Lava | Fine<br>silicic<br>tuff | Crystal<br>tuff | Silicic<br>tuff | Ignim-<br>brite | Silt-<br>stone | Sand-<br>stone | Carb.<br>chert |
|-----------------------------|------------|------------------|-------------------|------------|-------------------------|-----------------|-----------------|-----------------|----------------|----------------|----------------|
| Artefact frag               | 6          | 2                | 0                 | 1          | 0                       | 0               | 1               | 0               | 0              | 0              | 1              |
| Blade fragment              | 0          | 0                | 1                 | 0          | 0                       | 2               | 0               | 0               | 0              | 0              | 0              |
| Chip                        | 66         | 1                | 2                 | 2          | 3                       | 1               | 1               | 1               | 0              | 3              | 1              |
| Chopping tool               | 0          | 1                | 1                 | 2          | 0                       | 1               | 1               | 1               | 0              | 0              | 0              |
| Chunk                       | 27         | 4                | 3                 | 3          | 15                      | 2               | 2               | 2               | 1              | 1              | 1              |
| Cleaver                     | 1          | 1                | 0                 | 0          | 0                       | 0               | 0               | 0               | 0              | 0              | 0              |
| Cobble frag                 | 0          | 0                | 0                 | 0          | 0                       | 1               | 1               | 4               | 0              | 2              | 0              |
| Core                        | 4          | 4                | 0                 | 1          | 1                       | 0               | 0               | 0               | 0              | 0              | 1              |
| Core fragment               | 9          | 3                | 1                 | 2          | 0                       | 0               | 0               | 2               | 0              | 0              | 1              |
| Crude core                  | 0          | 1                | 2                 | 2          | 0                       | 1               | 0               | 9               | 0              | 1              | 2              |
| Denticulate                 | 2          | 1                | 0                 | 0          | 1                       | 0               | 0               | 1               | 1              | 0              | 0              |
| Disc core                   | 3          | 3                | 4                 | 6          | 6                       | 2               | 1               | 9               | 1              | 4              | 1              |
| Discoidal core<br>fragment  | 1          | 0                | 0                 | 1          | 1                       | 0               | 0               | 1               | 0              | 1              | 0              |
| Flake                       | 27         | 32               | 23                | 35         | 31                      | 18              | 3               | 38              | 9              | 11             | 3              |
| Flake fragment              | 65         | 34               | 24                | 29         | 48                      | 18              | 11              | 29              | 4              | 10             | 9              |
| Hammerstone                 | 0          | 0                | 0                 | 0          | 0                       | 0               | 0               | 2               | 0              | 0              | 0              |
| Handaxe                     | 0          | 13               | 5                 | 12         | 3                       | 5               | 6               | 7               | 1              | 2              | 2              |
| Handaxe<br>fragment         | 0          | 1                | 1                 | 1          | 2                       | 0               | 0               | 0               | 0              | 1              | 0              |
| Handaxe<br>roughout         | 0          | 0                | 0                 | 2          | 2                       | 0               | 0               | 0               | 0              | 0              | 0              |
| Handaxe trimmer<br>flake    | 1          | 2                | 5                 | 2          | 6                       | 1               | 0               | 3               | 0              | 0              | 0              |
| Levallois core              | 2          | 3                | 1                 | 2          | 1                       | 0               | 1               | 3               | 1              | 0              | 0              |
| Levallois flake             | 3          | 11               | 5                 | 7          | 11                      | 11              | 2               | 4               | 1              | 0              | 0              |
| Levallois flake<br>fragment | 1          | 0                | 2                 | 0          | 2                       | 1               | 0               | 0               | 1              | 0              | 0              |
| Levallois point             | 0          | 0                | 0                 | 4          | 1                       | 1               | 0               | 0               | 0              | 0              | 0              |
| Naturally backed<br>knife   | 0          | 2                | 1                 | 1          | 2                       | 1               | 1               | 2               | 0              | 2              | 0              |
| Notch                       | 0          | 1                | 1                 | 0          | 3                       | 0               | 1               | 0               | 0              | 0              | 0              |
| Scraper fragment            | 1          | 0                | 0                 | 0          | 1                       | 0               | 0               | 0               | 0              | 0              | 0              |
| Retouched flake             | 9          | 3                | 4                 | 2          | 13                      | 5               | 1               | 8               | 0              | 3              | 2              |
| Scraper                     | 3          | 3                | 0                 | 4          | 0                       | 1               | 0               | 0               | 1              | 1              | 0              |
| Side scraper                | 1          | 2                | 4                 | 4          | 6                       | 4               | 0               | 4               | 0              | 1              | 1              |
| Spall                       | 40         | 0                | 3                 | 0          | 1                       | 1               | 0               | 1               | 0              | 0              | 0              |
| Truncated blade             | 0          | 0                | 0                 | 0          | 2                       | 1               | 0               | 0               | 0              | 0              | 0              |
| Abrupt alt.<br>retouch      | 1          | 0                | 0                 | 0          | 0                       | 2               | 1               | 1               | 0              | 0              | 0              |
| Tool re-use                 | 5          | 0                | 3                 | 7          | 8                       | 4               | 0               | 3               | 0              | 2              | 0              |
| <b>Totals</b>               | <b>278</b> | <b>128</b>       | <b>96</b>         | <b>132</b> | <b>170</b>              | <b>84</b>       | <b>34</b>       | <b>135</b>      | <b>21</b>      | <b>45</b>      | <b>25</b>      |

Figure 3.4.1. Summarised data from Appendix 3.1.

|                             | Vitric<br>tuff | Crystal<br>lithic tuff | Crystal<br>pumice<br>tuff | Quartz-<br>ite | Lime-<br>stone | Andesite<br>& Dacite | Micro-<br>diorite | Basalt   | Baked<br>shale | Totals      |
|-----------------------------|----------------|------------------------|---------------------------|----------------|----------------|----------------------|-------------------|----------|----------------|-------------|
| Artefact frag               | 0              | 1                      | 0                         | 1              | 0              | 0                    | 0                 | 0        | 0              | 13          |
| Blade fragment              | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 3           |
| Chip                        | 0              | 0                      | 0                         | 0              | 1              | 0                    | 0                 | 0        | 0              | 82          |
| Chopping tool               | 0              | 1                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 8           |
| Chunk                       | 0              | 1                      | 1                         | 2              | 0              | 0                    | 0                 | 0        | 0              | 65          |
| Cleaver                     | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 2           |
| Cobble frag                 | 0              | 1                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 9           |
| Core                        | 0              | 0                      | 0                         | 5              | 0              | 1                    | 0                 | 0        | 0              | 17          |
| Core fragment               | 1              | 0                      | 1                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 20          |
| Crude core                  | 0              | 0                      | 1                         | 3              | 0              | 0                    | 0                 | 0        | 0              | 22          |
| Denticulate                 | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 6           |
| Disc core                   | 0              | 0                      | 0                         | 0              | 0              | 3                    | 1                 | 1        | 0              | 45          |
| Discoidal core<br>fragment  | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 5           |
| Flake                       | 2              | 15                     | 6                         | 3              | 2              | 3                    | 2                 | 2        | 0              | 265         |
| Flake fragment              | 1              | 7                      | 4                         | 2              | 1              | 1                    | 3                 | 2        | 7              | 309         |
| Hammerstone                 | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 2           |
| Handaxe                     | 1              | 5                      | 1                         | 1              | 0              | 2                    | 0                 | 0        | 0              | 66          |
| Handaxe<br>fragment         | 0              | 1                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 7           |
| Handaxe<br>roughout         | 1              | 1                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 6           |
| Handaxe trimmer<br>flake    | 0              | 1                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 21          |
| Levallois core              | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 14          |
| Levallois flake             | 0              | 1                      | 1                         | 1              | 0              | 1                    | 9                 | 1        | 0              | 69          |
| Levallois flake<br>fragment | 0              | 1                      | 0                         | 1              | 0              | 0                    | 0                 | 0        | 0              | 9           |
| Levallois point             | 0              | 2                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 8           |
| Naturally backed<br>knife   | 0              | 0                      | 1                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 13          |
| Notch                       | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 1        | 0              | 7           |
| Scraper fragment            | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 2           |
| Retouched flake             | 0              | 1                      | 1                         | 0              | 0              | 1                    | 0                 | 0        | 0              | 53          |
| Scraper                     | 0              | 0                      | 0                         | 0              | 0              | 1                    | 0                 | 0        | 0              | 14          |
| Side scraper                | 0              | 1                      | 1                         | 0              | 0              | 1                    | 1                 | 0        | 2              | 33          |
| Spall                       | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 46          |
| Truncated blade             | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 3           |
| Abrupt alt.<br>retouch      | 0              | 0                      | 0                         | 0              | 0              | 0                    | 0                 | 0        | 0              | 5           |
| Tool re-use                 | 0              | 0                      | 1                         | 0              | 0              | 1                    | 1                 | 0        | 0              | 35          |
| <b>Totals</b>               | <b>6</b>       | <b>40</b>              | <b>19</b>                 | <b>19</b>      | <b>4</b>       | <b>15</b>            | <b>17</b>         | <b>7</b> | <b>9</b>       | <b>1284</b> |

Figure 3.4.1. Summarised data from Appendix 3.1.  
3-31b



|                        | Flint     | % Flint      | Rhy.      | % Rhy.       | Rhy. tuff | % Rhy.       | FP Lava   | % FP         | F-S tuff  | % Fine<br>silicic<br>tuff | xtal Tuff | %<br>Crystal<br>Tuff | Ignimbri<br>te | %<br>Ignimbri<br>te | Sedimen<br>tary | %<br>Sedimen<br>tary | Cherts    | % Cherts     | xtal<br>lithic<br>Tuff | %<br>Crystal<br>Lithic<br>Tuff |
|------------------------|-----------|--------------|-----------|--------------|-----------|--------------|-----------|--------------|-----------|---------------------------|-----------|----------------------|----------------|---------------------|-----------------|----------------------|-----------|--------------|------------------------|--------------------------------|
| Artefact frag          | 6         | 11.3         | 2         | 3.5          | 2         | 3.4          | 1         | 1.6          | 0         | 0.0                       | 1         | 2.3                  | 4              | 6.3                 | 2               | 7.4                  | 1         | 7.7          | 2                      | 7.1                            |
| Blade                  | 0         | 0.0          | 0         | 0.0          | 1         | 1.7          | 0         | 0.0          | 2         | 2.8                       | 3         | 6.8                  | 0              | 0.0                 | 0               | 0.0                  | 0         | 0.0          | 0                      | 0.0                            |
| Chopping tool          | 0         | 0.0          | 1         | 1.8          | 2         | 3.4          | 2         | 3.2          | 0         | 0.0                       | 1         | 2.3                  | 1              | 1.6                 | 0               | 0.0                  | 0         | 0.0          | 1                      | 3.6                            |
| Cleaver                | 1         | 1.9          | 1         | 1.8          | 0         | 0.0          | 0         | 0.0          | 0         | 0.0                       | 0         | 0.0                  | 0              | 0.0                 | 0               | 0.0                  | 0         | 0.0          | 0                      | 0.0                            |
| Core                   | 4         | 7.5          | 4         | 7.0          | 0         | 0.0          | 1         | 1.6          | 1         | 1.4                       | 0         | 0.0                  | 0              | 0.0                 | 0               | 0.0                  | 1         | 7.7          | 0                      | 0.0                            |
| Core fragment          | 9         | 17.0         | 3         | 5.3          | 1         | 1.7          | 2         | 3.2          | 0         | 0.0                       | 0         | 0.0                  | 2              | 3.1                 | 0               | 0.0                  | 1         | 7.7          | 2                      | 7.1                            |
| Crude core             | 0         | 0.0          | 1         | 1.8          | 2         | 3.4          | 2         | 3.2          | 0         | 0.0                       | 1         | 2.3                  | 9              | 14.1                | 1               | 3.7                  | 2         | 15.4         | 1                      | 3.6                            |
| Disc core              | 3         | 5.7          | 3         | 5.3          | 5         | 8.6          | 6         | 9.5          | 6         | 8.3                       | 2         | 4.5                  | 9              | 14.1                | 5               | 18.5                 | 1         | 7.7          | 0                      | 0.0                            |
| Discoidal core frag.   | 1         | 1.9          | 0         | 0.0          | 0         | 0.0          | 1         | 1.6          | 1         | 1.4                       | 0         | 0.0                  | 1              | 1.6                 | 1               | 3.7                  | 0         | 0.0          | 0                      | 0.0                            |
| Hammerstone            | 0         | 0.0          | 0         | 0.0          | 0         | 0.0          | 0         | 0.0          | 0         | 0.0                       | 0         | 0.0                  | 2              | 3.1                 | 0               | 0.0                  | 0         | 0.0          | 0                      | 0.0                            |
| Handaxe                | 0         | 0.0          | 13        | 22.8         | 11        | 19.0         | 12        | 19.0         | 3         | 4.2                       | 5         | 11.4                 | 7              | 10.9                | 3               | 11.1                 | 2         | 15.4         | 7                      | 25.0                           |
| Handaxe fragment       | 0         | 0.0          | 1         | 1.8          | 1         | 1.7          | 1         | 1.6          | 2         | 2.8                       | 0         | 0.0                  | 0              | 0.0                 | 1               | 3.7                  | 0         | 0.0          | 1                      | 3.6                            |
| Handaxe roughout       | 0         | 0.0          | 0         | 0.0          | 0         | 0.0          | 2         | 3.2          | 2         | 2.8                       | 0         | 0.0                  | 0              | 0.0                 | 0               | 0.0                  | 0         | 0.0          | 2                      | 7.1                            |
| Handaxe trimmer flake  | 1         | 1.9          | 2         | 3.5          | 5         | 8.6          | 2         | 3.2          | 6         | 8.3                       | 1         | 2.3                  | 3              | 4.7                 | 0               | 0.0                  | 0         | 0.0          | 1                      | 3.6                            |
| Levallois core         | 2         | 3.8          | 3         | 5.3          | 2         | 3.4          | 2         | 3.2          | 1         | 1.4                       | 0         | 0.0                  | 3              | 4.7                 | 1               | 3.7                  | 0         | 0.0          | 0                      | 0.0                            |
| Levallois flake        | 3         | 5.7          | 11        | 19.3         | 7         | 12.1         | 7         | 11.1         | 11        | 15.3                      | 11        | 25.0                 | 4              | 6.3                 | 1               | 3.7                  | 0         | 0.0          | 2                      | 7.1                            |
| Lev. flake fragment    | 1         | 1.9          | 0         | 0.0          | 2         | 3.4          | 0         | 0.0          | 2         | 2.8                       | 1         | 2.3                  | 0              | 0.0                 | 1               | 3.7                  | 0         | 0.0          | 1                      | 3.6                            |
| Levallois point        | 0         | 0.0          | 0         | 0.0          | 0         | 0.0          | 4         | 6.3          | 1         | 1.4                       | 1         | 2.3                  | 0              | 0.0                 | 0               | 0.0                  | 0         | 0.0          | 2                      | 7.1                            |
| Naturally backed knife | 0         | 0.0          | 2         | 3.5          | 2         | 3.4          | 1         | 1.6          | 2         | 2.8                       | 1         | 2.3                  | 2              | 3.1                 | 2               | 7.4                  | 0         | 0.0          | 1                      | 3.6                            |
| Dent. & Notch          | 2         | 0.0          | 2         | 3.5          | 2         | 3.4          | 0         | 0.0          | 4         | 5.6                       | 0         | 0.0                  | 1              | 1.6                 | 1               | 3.7                  | 0         | 0.0          | 0                      | 0.0                            |
| Scraper fragment       | 1         | 1.9          | 0         | 0.0          | 0         | 0.0          | 0         | 0.0          | 1         | 1.4                       | 0         | 0.0                  | 0              | 0.0                 | 0               | 0.0                  | 0         | 0.0          | 0                      | 0.0                            |
| Retouched flake        | 9         | 17.0         | 3         | 5.3          | 5         | 8.6          | 2         | 3.2          | 13        | 18.1                      | 5         | 11.4                 | 8              | 12.5                | 3               | 11.1                 | 2         | 15.4         | 2                      | 7.1                            |
| Scraper                | 3         | 5.7          | 3         | 5.3          | 0         | 0.0          | 4         | 6.3          | 0         | 0.0                       | 1         | 2.3                  | 0              | 0.0                 | 2               | 7.4                  | 0         | 0.0          | 0                      | 0.0                            |
| Side scraper           | 1         | 1.9          | 2         | 3.5          | 4         | 6.9          | 4         | 6.3          | 6         | 8.3                       | 4         | 9.1                  | 4              | 6.3                 | 1               | 3.7                  | 3         | 23.1         | 2                      | 7.1                            |
| Abrupt alt. retouch    | 1         | 1.9          | 0         | 0.0          | 1         | 1.7          | 0         | 0.0          | 0         | 0.0                       | 2         | 4.5                  | 1              | 1.6                 | 0               | 0.0                  | 0         | 0.0          | 0                      | 0.0                            |
| Tool re-use            | 5         | 9.4          | 0         | 0.0          | 3         | 5.2          | 7         | 11.1         | 8         | 11.1                      | 4         | 9.1                  | 3              | 4.7                 | 2               | 7.4                  | 0         | 0.0          | 1                      | 3.6                            |
| <b>Totals</b>          | <b>53</b> | <b>100.0</b> | <b>57</b> | <b>100.0</b> | <b>58</b> | <b>100.0</b> | <b>63</b> | <b>100.0</b> | <b>72</b> | <b>100.0</b>              | <b>44</b> | <b>100.0</b>         | <b>64</b>      | <b>100.0</b>        | <b>27</b>       | <b>100.0</b>         | <b>13</b> | <b>100.0</b> | <b>28</b>              | <b>100.0</b>                   |

Figure 3.4.2. Percentage of total artefacts of each rock type used for each tool type

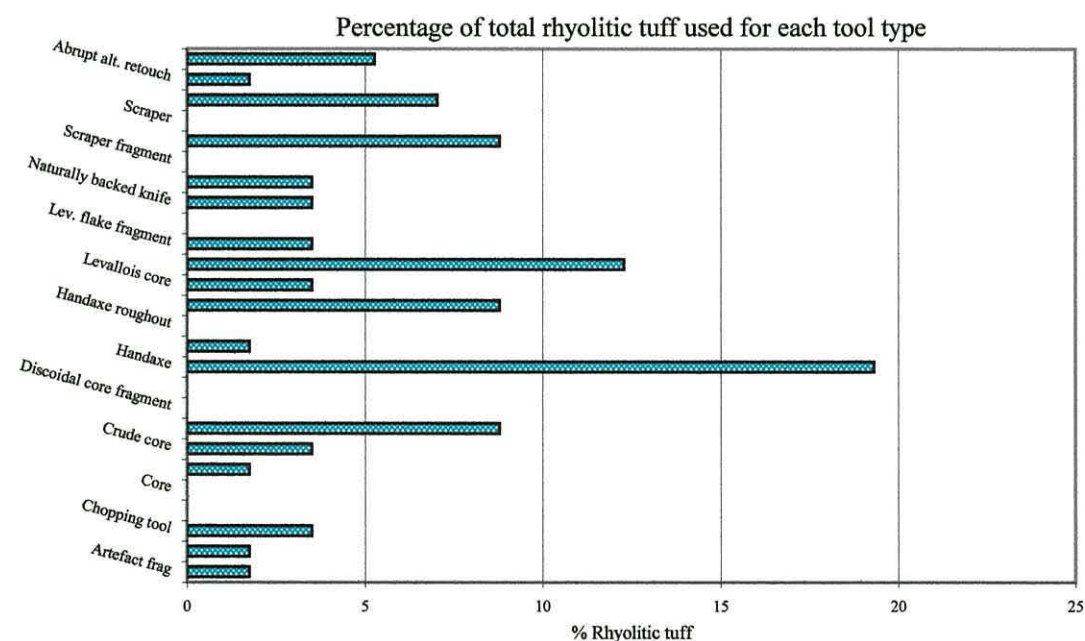
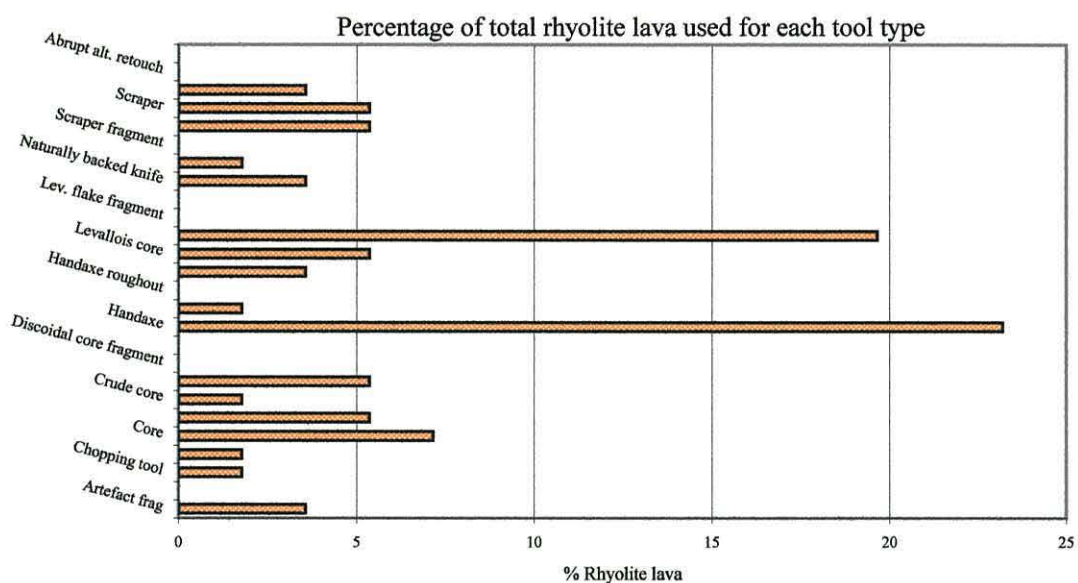
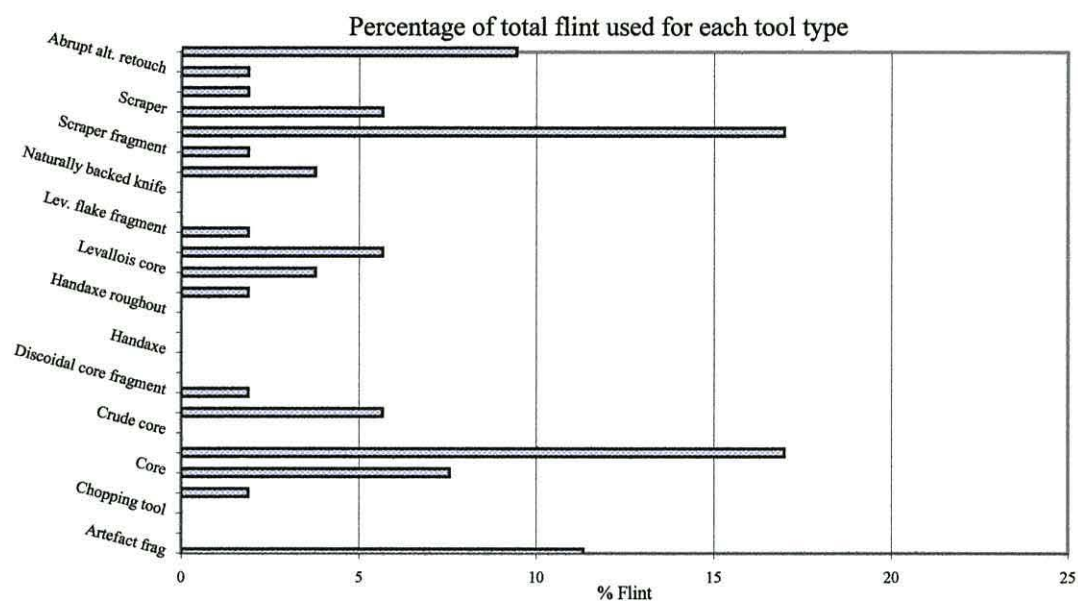


Figure 3.4.3. Percentages of total flint, rhyolite lava and rhyolitic tuff used for each tool type.



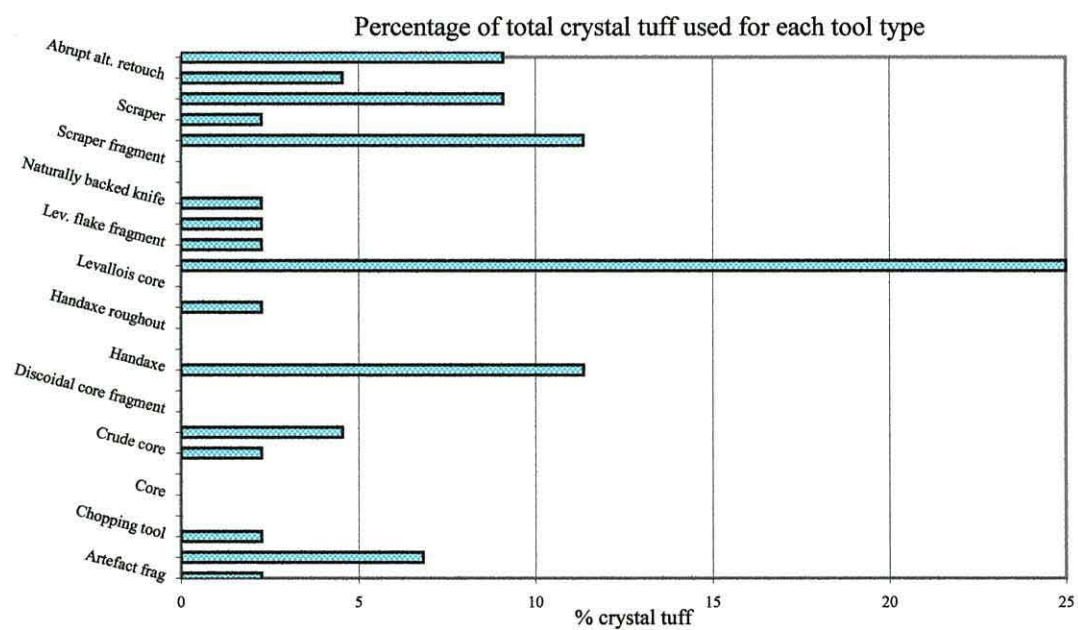
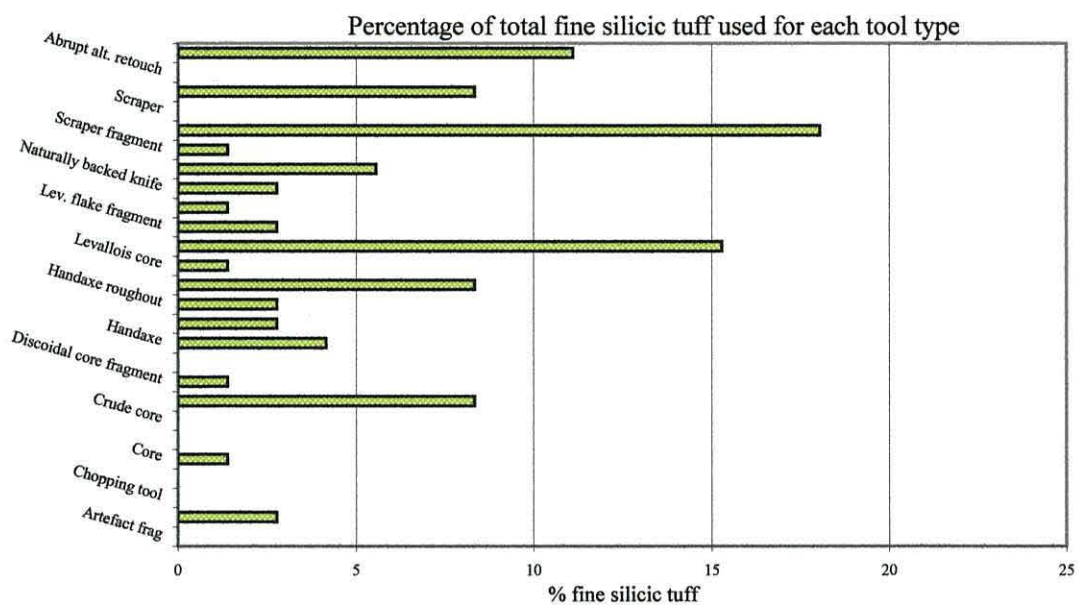
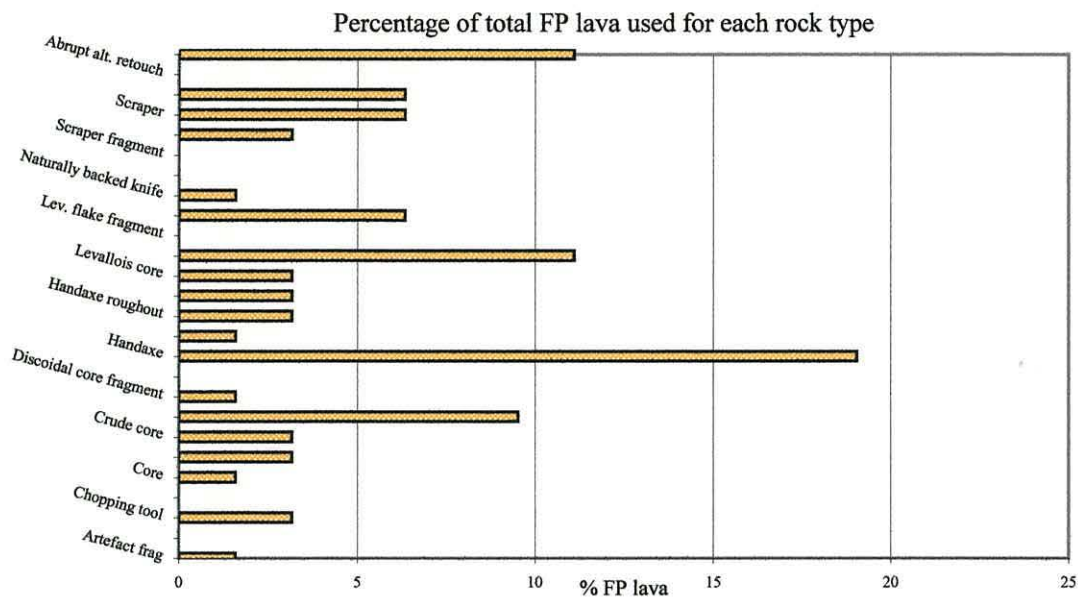


Figure 3.4.4. Percentages of total FP lava, fine silicic tuff and crystal tuff used for each tool type.

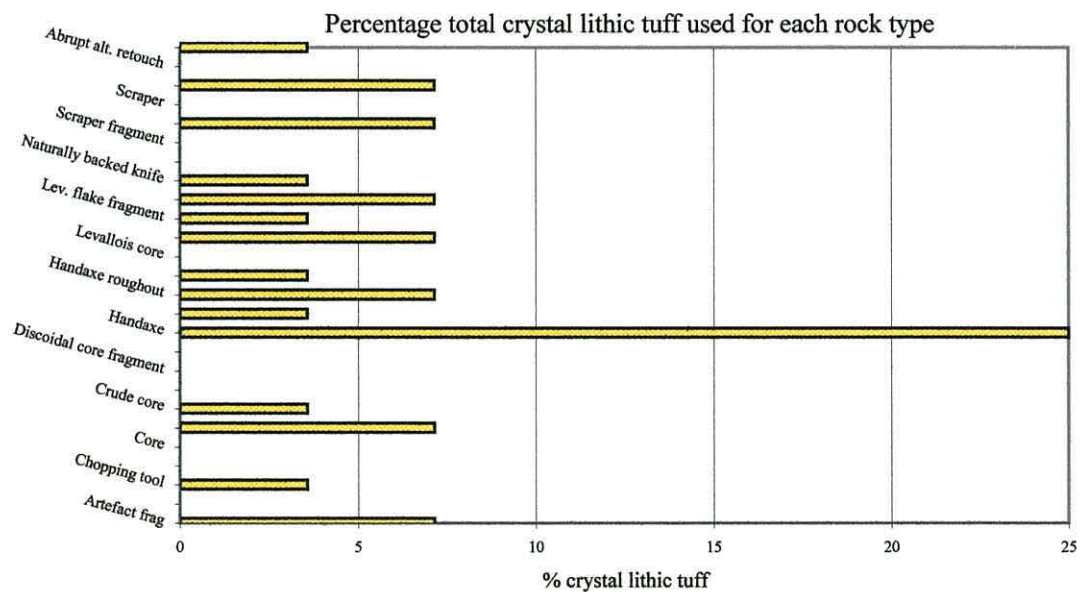
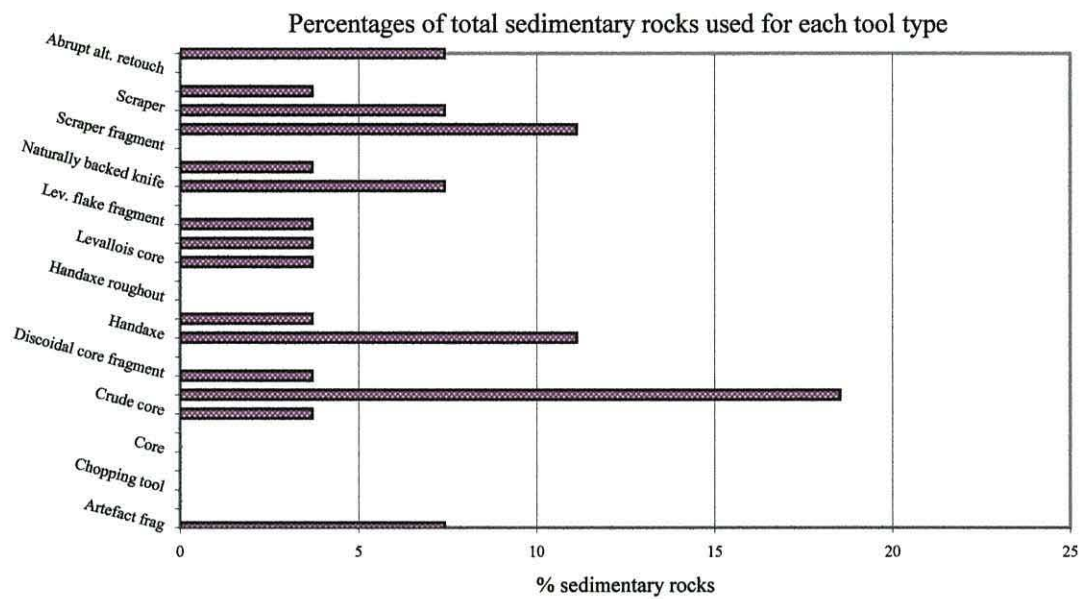
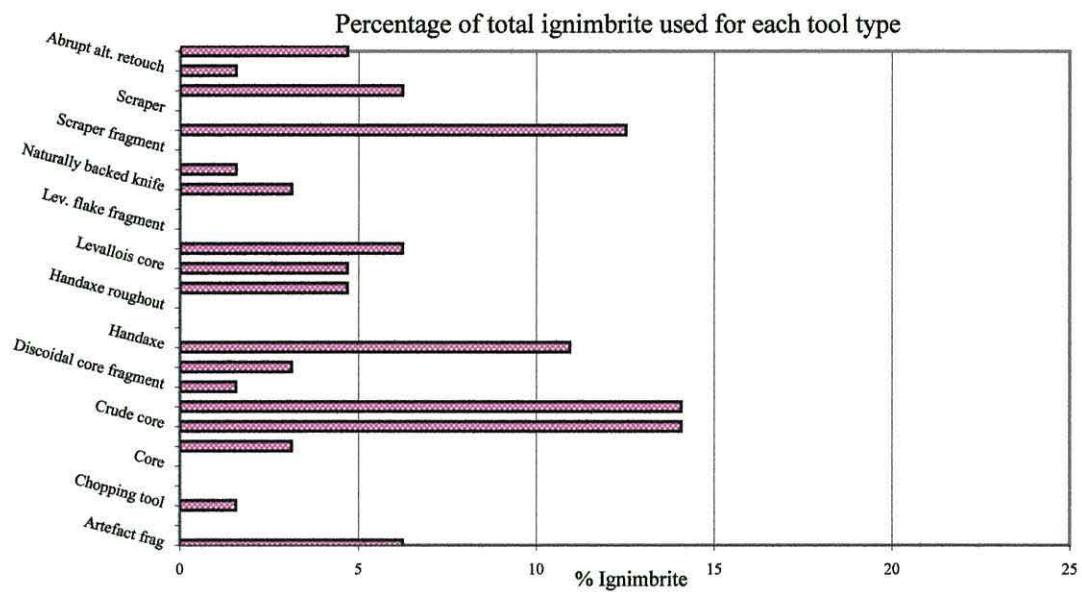
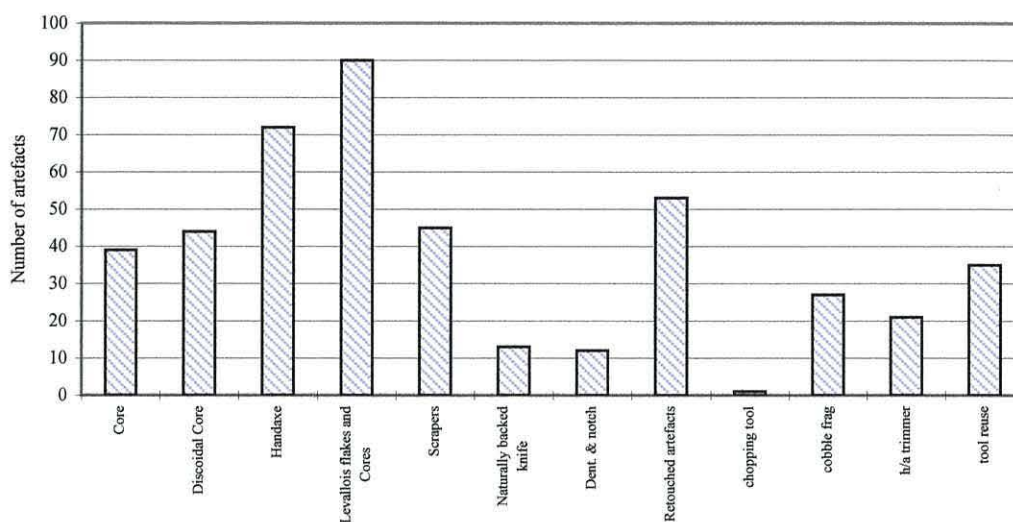


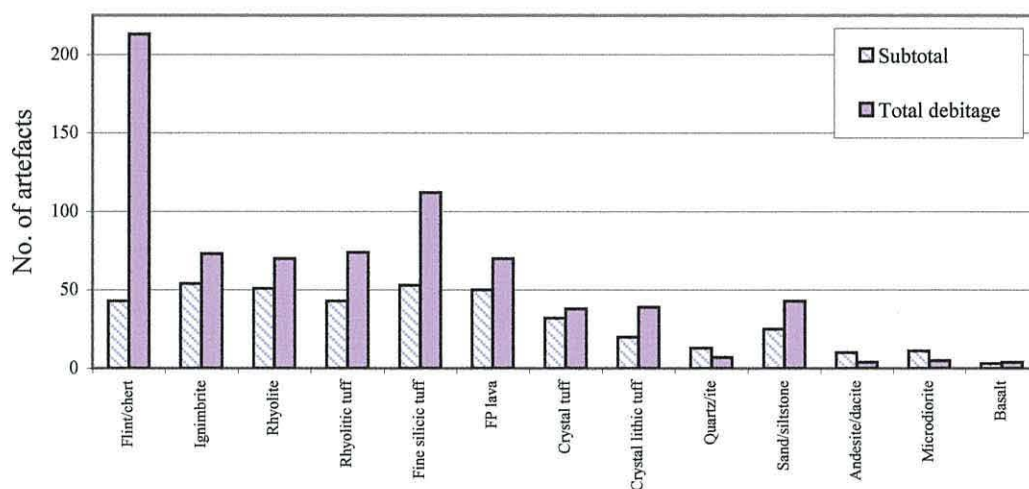
Figure 3.4.5. Percentages of total ignimbrite, sedimentary rock and crystal lithic tuff used for each tool type.



Numerical breakdown of the dominant components of the Pontnewydd assemblage, disregarding debitage



Relationship between quantity of artefacts and debitage for each rock type



Graph to show total weight (g) of artefacts for each rock type

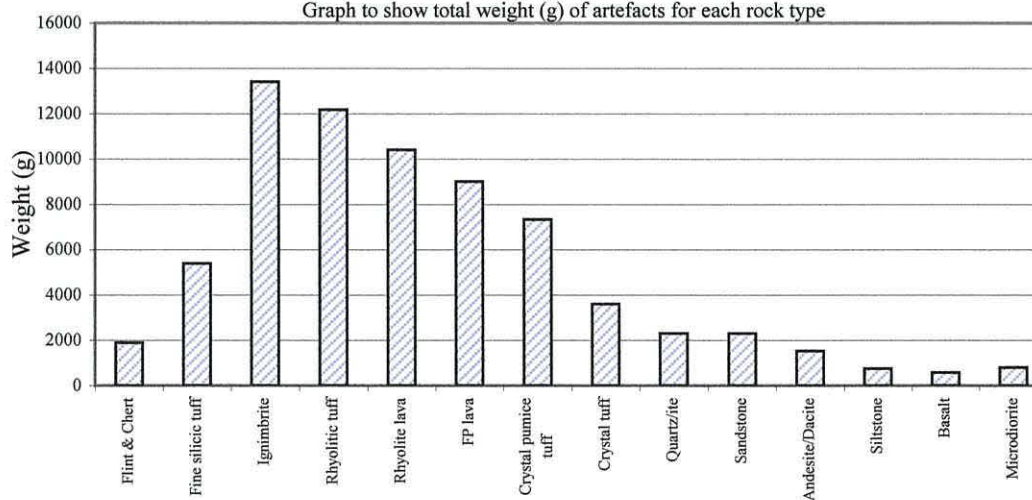
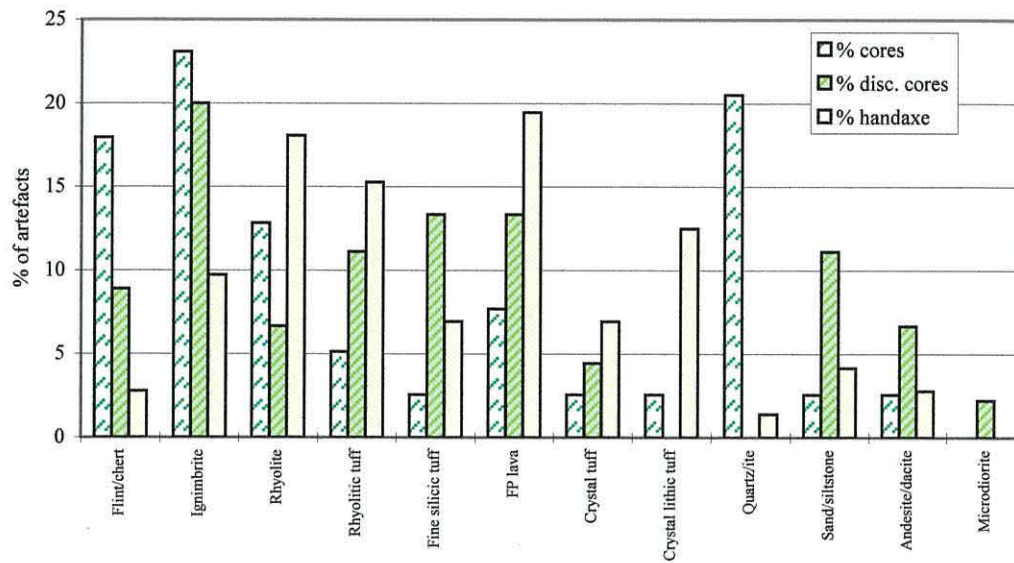
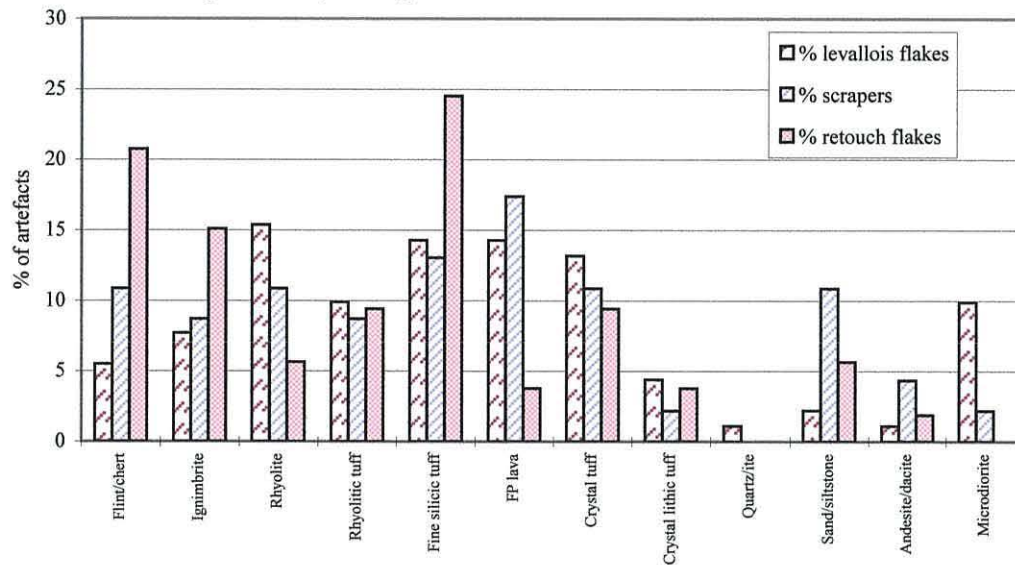


Figure 3.4.6 Overview of the composition of the Pontnewydd assemblage.

Graph to show percentage of cores and handaxes made from each raw material



Graph to show percentage of artefacts made from each raw material



Graph to show percentage of debitage from each rock type

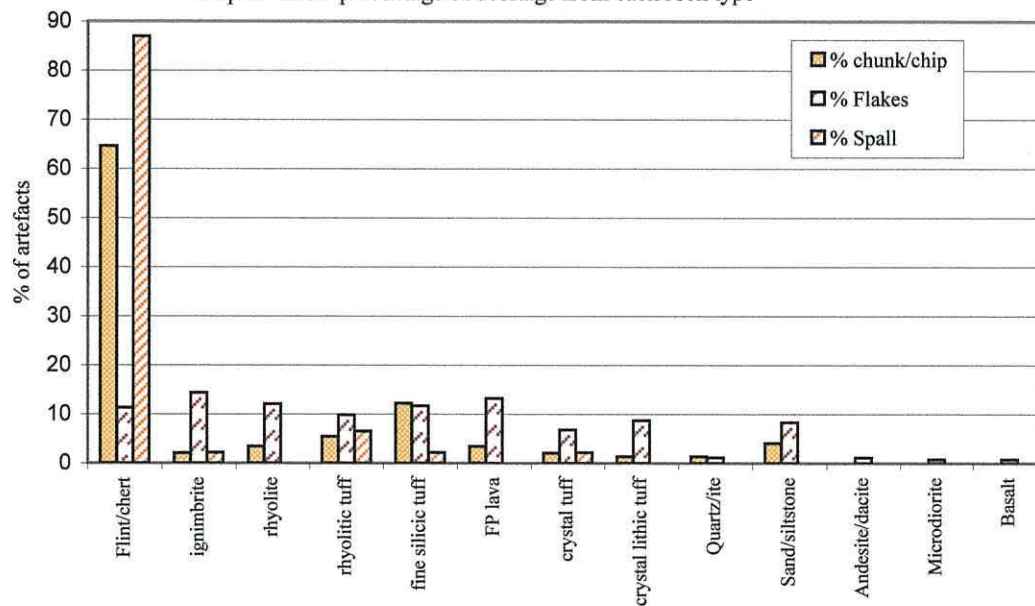


Figure 3.4.7. Percentages of the dominant artefact types produced from each raw material.



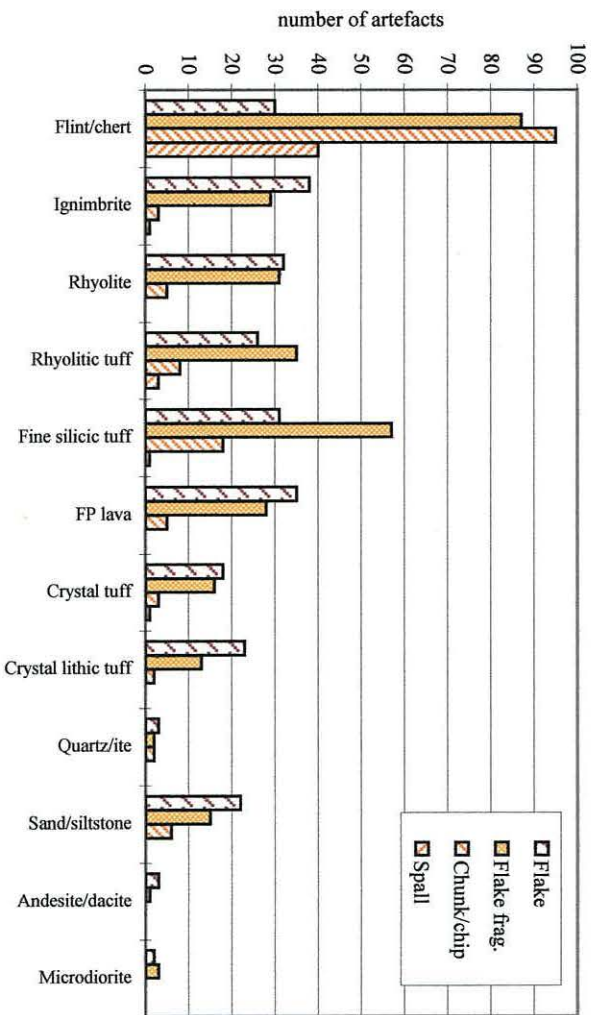
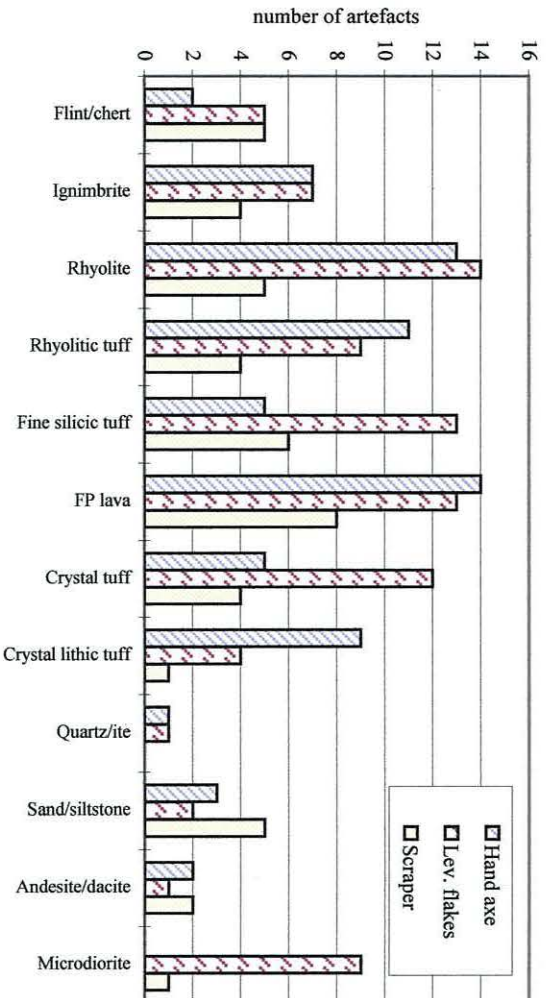
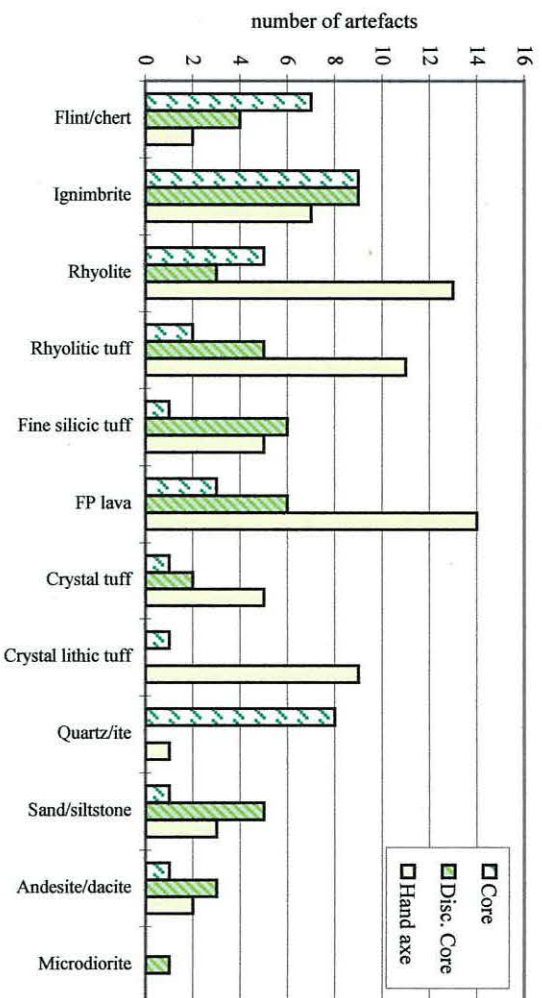
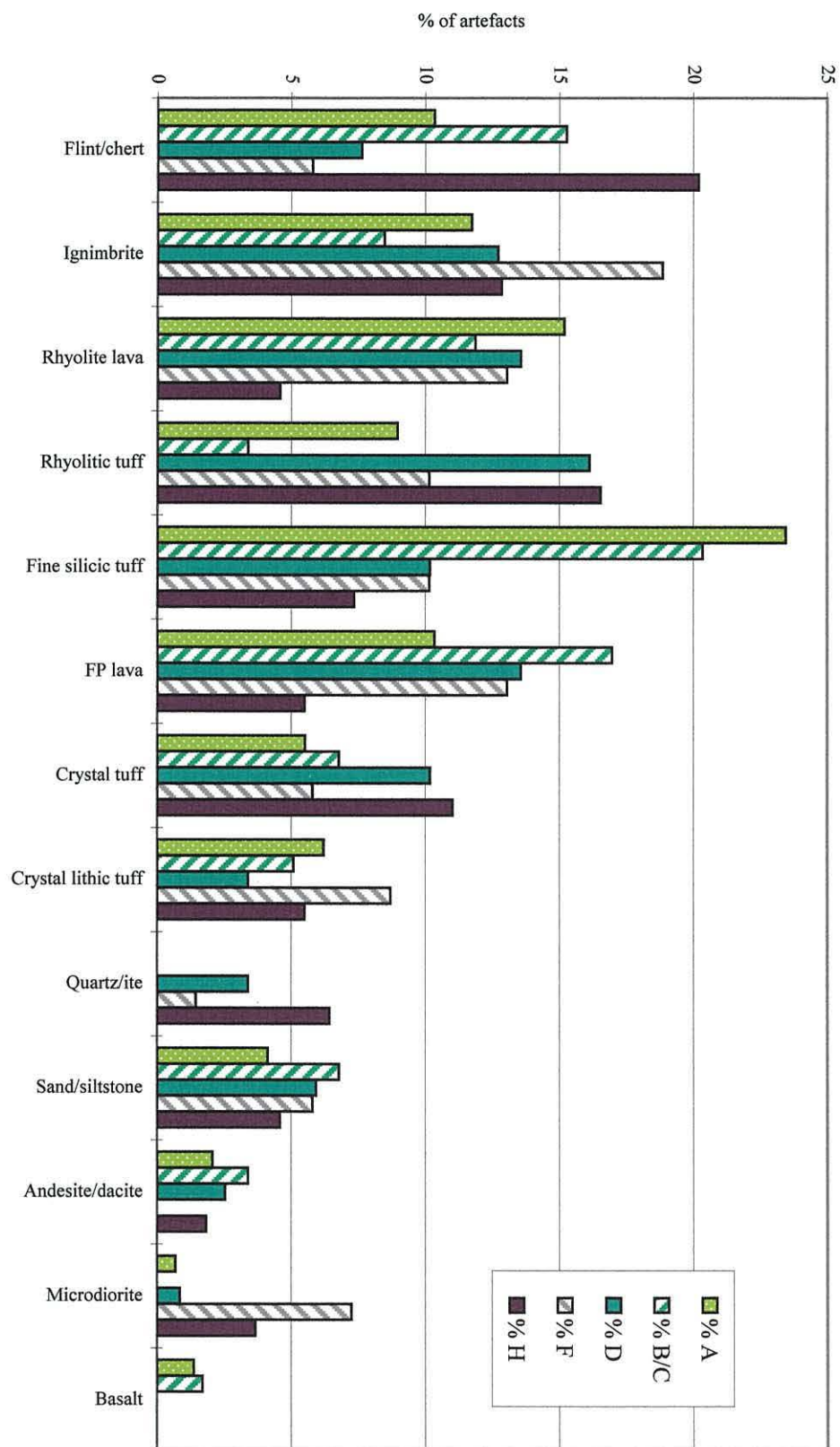


Figure 3.4.8 Numerical profiles of raw materials used for artefacts in the Pontnewydd assemblage.

Figure 3.4.9. Graph showing the distribution of artefact lithologies in Areas A-H, Pontnewydd Cave.





### 3.4.2. Trends exhibited by Artefact Dimension data

The following are trends shown in quantitative plots of length against breadth, length/breadth against thickness, length against thickness, thickness against weight and length/breadth against weight for each rock type.

1. Graphs of Length/breadth against thickness (Figure 3.4.10) show a difference in the thickness of flint, which is generally less than 20. The range of thicknesses did not differ greatly between the other rock types, with the exception of fine silicic tuff, whose artefacts were generally less than 30mm thick. Sandstone, rhyolitic and crystal tuff also produced some very thin flakes. Broadly speaking, artefacts of crystal lithic tuff and rhyolite appeared to be of similar thickness.
2. A graph illustrating the range of thickness of artefacts in the whole assemblage (Figure 3.4.12, graph 1), showed that artefacts of ignimbrite, FP lava, and sandstone were slightly thicker than the others. Flint had a greater range of L/Br/Th ratios for flakes than any other rock type (Figure 3.4.12, graph 2) and a smaller range of L/Br ratios for handaxes than any other lithology (Figure 3.4.12, graph 3).
3. There is a logarithmic correlation between weight and thickness, for artefacts and debitage made of all raw materials (Figure 3.4.11). The smallest artefacts in terms of weight are of flint, with fine silicic tuff, and rhyolite lava also having artefacts under 10g in weight.

### **3.4.3 Statistical data analysis**

#### 3.4.3.1. Chi2 Analysis

The following observations result from chi2 analysis of the initial data as detailed in Appendix 3.1, results of the analysis are shown in Figures 3.4.13-3.4.18.

Comparison of observed data for rock type and tool type with the results expected if there is equal rock use illustrate that there is a significant difference between an assemblage where all rock types are used equally and that found at Pontnewydd (Figure 3.4.13). The expected groupings were based on the assumption that all rock types were equally available and unbiased by the action of natural processes or man. This result may indicate that not all rock types are equally available in the area, and does not necessarily imply any selectivity on the part of the inhabitants of Pontnewydd. A more appropriate analysis would be to compare the Pontnewydd assemblage with a representative cross section of the rock types available in the drift deposits of the area. However, these are highly variable in character, and

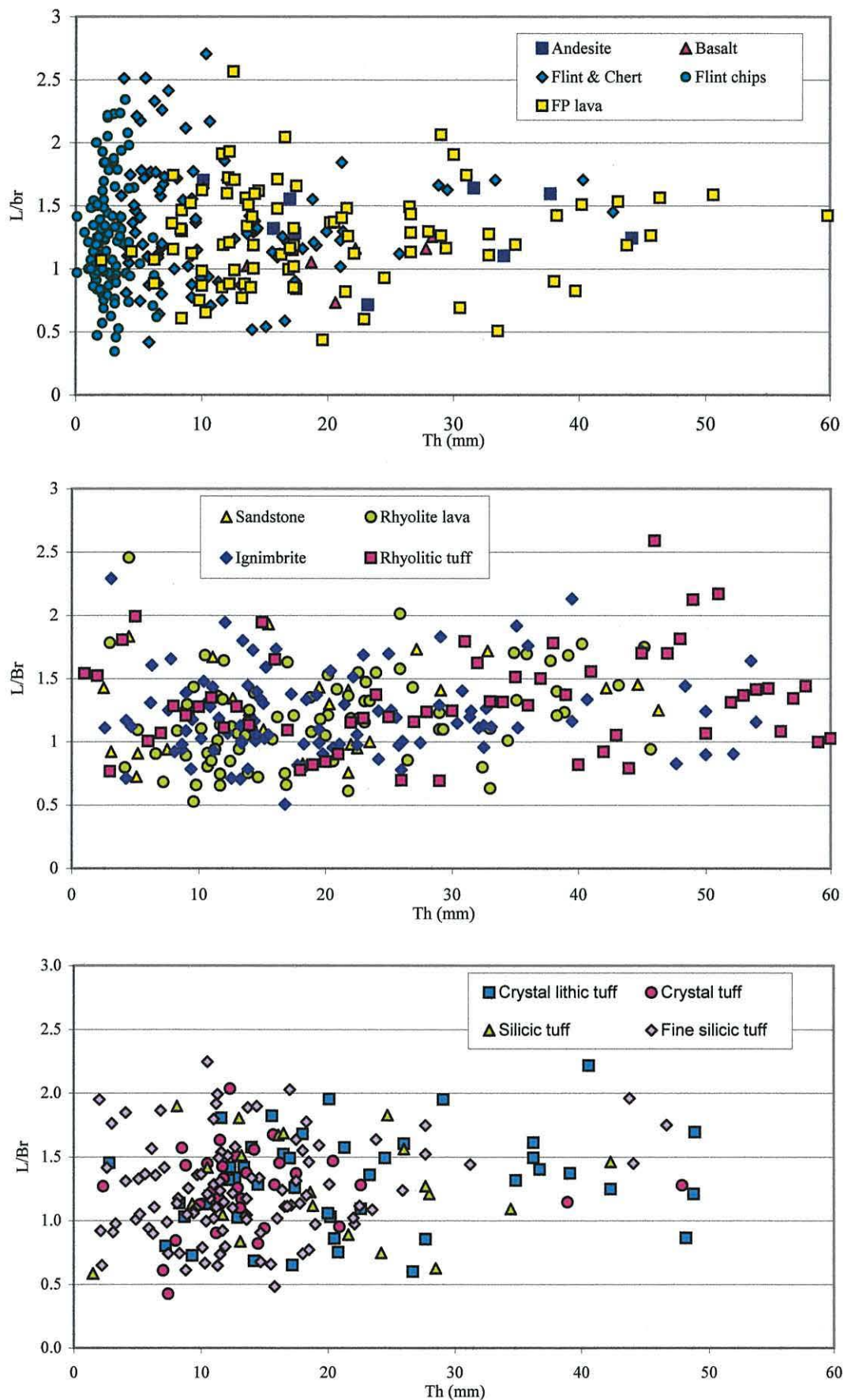


Figure 3.4.10. Artefact dimension data (length/breadth ratio [L/Br] vs. thickness [Th]) for the various lithologies described. Full data presented in Appendix 3.1.



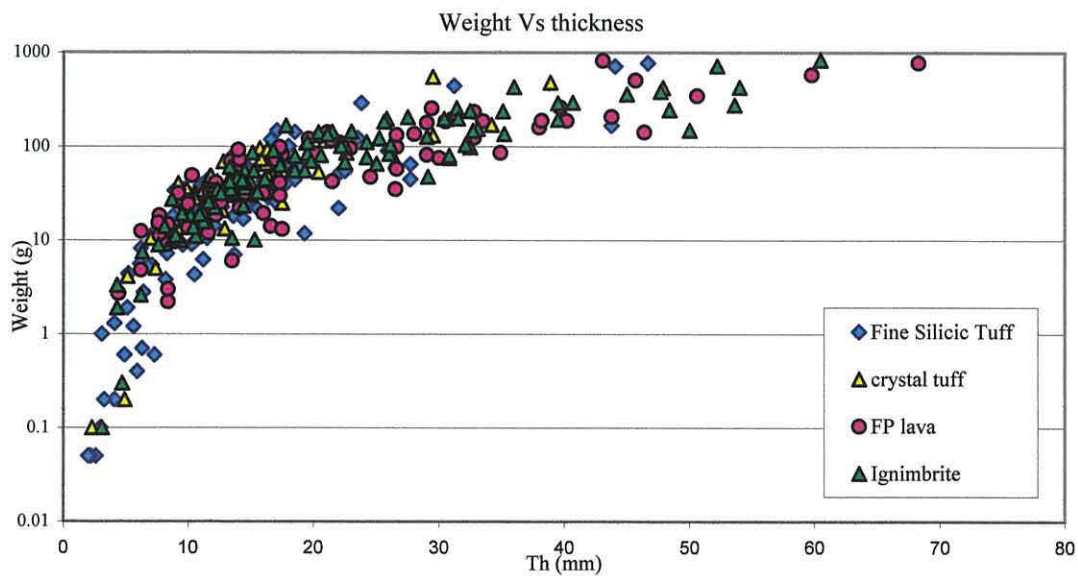
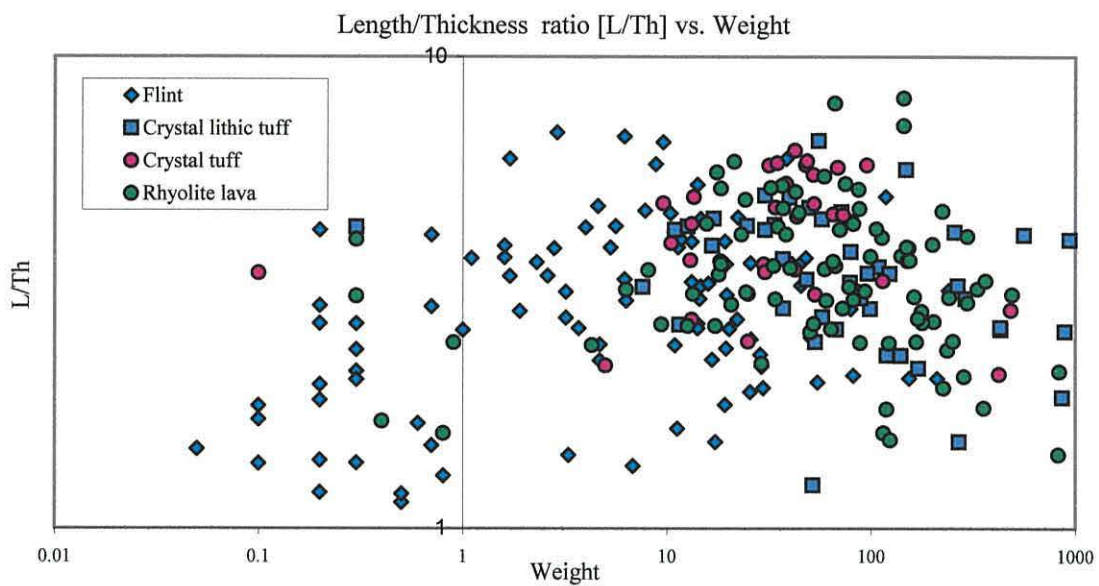
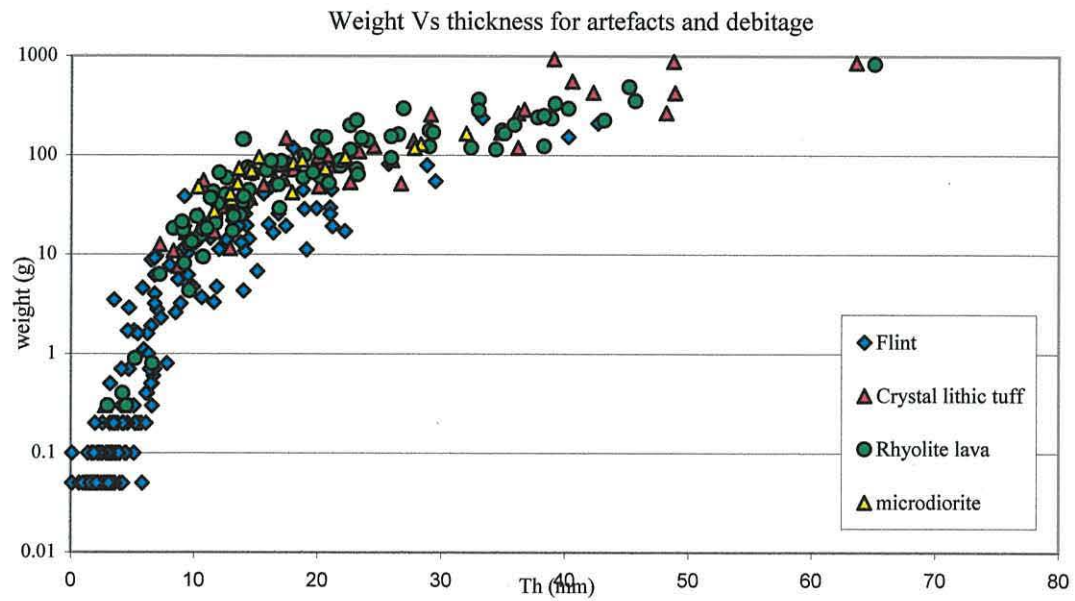


Figure 3.4.11. Graphs summarising weight and thickness data for various artefact lithologies.  
Full data presented in Appendix 3.1.

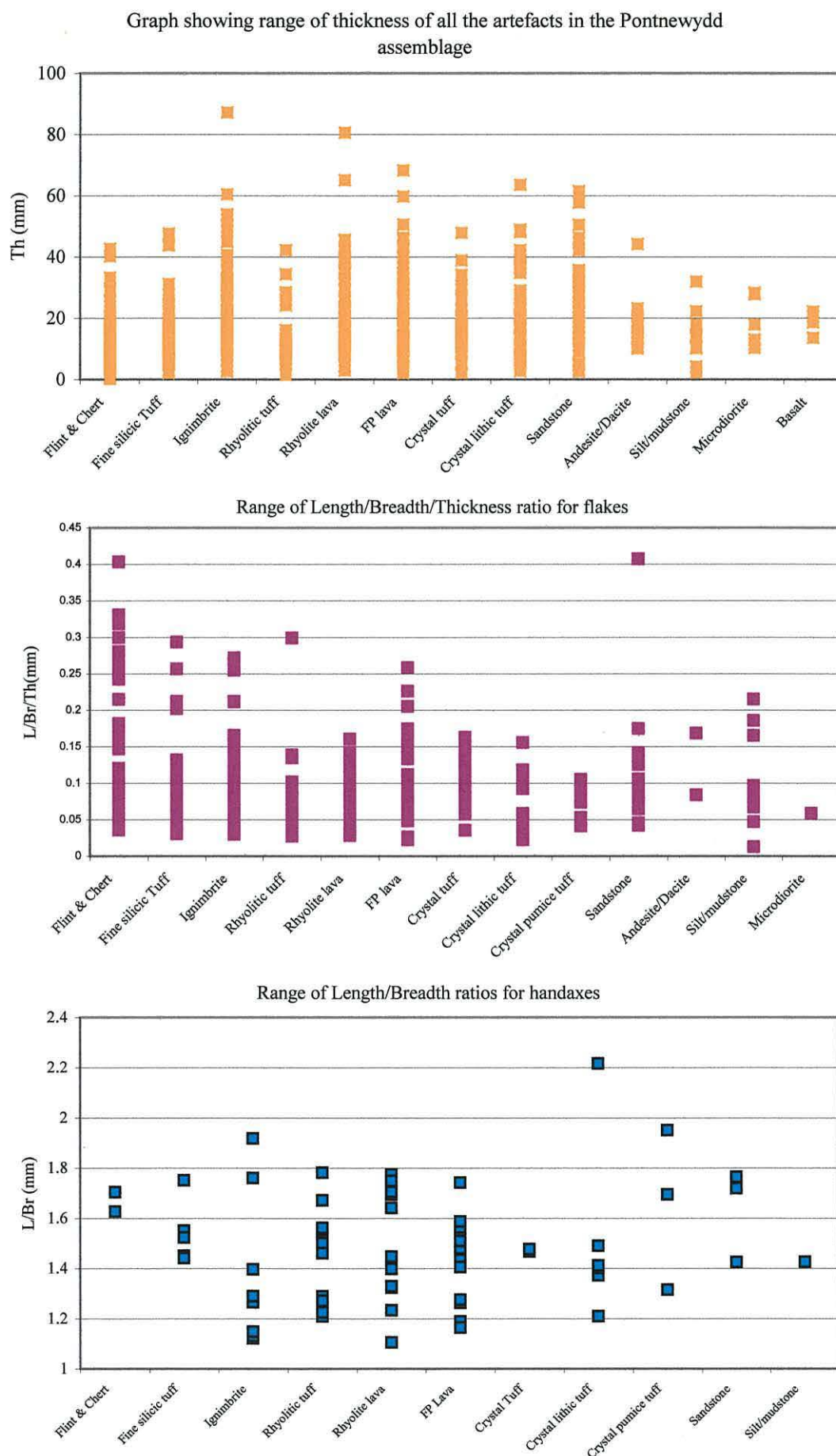


Fig. 3.4.12. Graphs showing data on artefact dimensions for each lithological group.  
Full data presented in Appendix 3.1.



attempts to characterise the deposits have been largely unsuccessful (Livingstone 1986).

2. Comparison of rock type data for each category (e.g. chunk/chip) with the total numbers of artefacts made on each rock type showed a significant difference, in the categories that contained the largest number of individuals (Figure 3.4.14). This may indicate that all tool types are significantly different from the totals, but only the larger groups contain sufficient numbers of individuals with which to make this difference clear.
3. Comparison of rock type data for each category with the distribution of rock types used for handaxes illustrated some interesting differences (Figure 3.4.15). In all the categories that could be accurately tested, handaxes had a significantly different profile of rock use. This difference extended to 'chunky' tools such as cores and crude cores, and interestingly also handaxe trimmer flakes, in addition to the anticipated differences between handaxes and 'finer' tools such as retouched flakes and scrapers.
4. Comparison of rock type data for each tool type category with flakes indicated that flakes are not representative of the assemblage as a whole (Figure 3.4.16). Each artefact produces flakes, so this difference is perhaps surprising. However, this may be partly due to the large number of flakes produced in the manufacture of some tools. It may also be due to the fact that flakes on some materials are more likely to be observed than others. Furthermore, details such as retouch are very obscure on some of the raw materials. It is therefore possible that whereas retouched flakes will easily be noticed in flint, they may have been overlooked in other raw materials. However, although cores, crude cores, levallois flakes and handaxes are made on significantly different raw materials to flakes, other tools of flake shape such as handaxe trimming flakes and naturally backed knives exhibit the same rock types as flakes.
5. Comparisons of rock types for each tool type category for the Main Cave and Site H illustrated some significant differences (Figure 3.4.17). The distribution of rock types used for scrapers, side scrapers and tool reuse was similar at both sites, but all

other tool types showed differences. Overall there are some basic differences in the assemblages at both sites. There are significantly more retouched flakes, levallois cores, handaxes and flakes in the main cave, and significantly less disc cores and chunk/chips. The relative proportions of scrapers and levallois flakes are the same in both sites. Therefore the main cave is enriched relative to site H in retouched flakes, levallois cores, handaxes and flakes.

6. Early in the analysis of the material from the whole site, it was observed that many of the differences between categories were due to the dominance of flint in some categories and its almost complete absence in others. Having established that flint was primarily used for more detailed tools, with a high incidence of tool reuse and retouched material, it was considered worthwhile to examine the total assemblage without flint to establish if other rock types were being used selectively for different tool types. The results of these analyses are shown in figure 3.4.18.
7. Comparison of rock type data (without flint) for each category with the distribution of rock types used for handaxes illustrated some interesting differences. Chunk/chips used less FP lava, less rhyolite, less crystal lithic tuff than handaxes, cores/crude cores and disc cores used more ignimbrite; and flakes, handaxe trimmer flakes, levallois flakes, retouched flakes, side scrapers and tool reuse all used more Fine Silicic tuff. It would seem that handaxes are therefore preferentially made on FP lava, rhyolite, crystal lithic tuff, with equal use of rhyolite lava to all other groups.
8. Comparison of rock type data (without flint) for each category (e.g. chunk/chip) with the total numbers of artefacts made on each rock type shows a significant difference for two tool types. The cores/crude cores are enriched in quartzite and ignimbrite, and microdiorite and crystal tuff dominate the levallois flakes.
9. Comparison of observed data for rock type (without flint) and tool type with expected data for equal rock use illustrate a significant difference in all tool types between an assemblage in which rock types are used equally and the Pontnewydd assemblage. The major deviations from an equal distribution are caused by the proportions of fine silicic tuff on chunk/chips, handaxe-trimming flakes, levallois



flakes, retouched flakes, side scrapers and tool reuse. Further differences are due to the use of ignimbrite for cores/crude cores, disc cores and flakes, FP lava for flakes, handaxes and scrapers, and crystal tuff for levallois flakes.

10. Comparison of rock type data (without flint) for each tool type category with flakes indicates that flakes are not fully representative of the assemblage. Compared to flakes, chunk/chips are relatively enriched in FST, cores in quartzite, disc cores in andesite, handaxes in silicic tuff and levallois flakes in microdiorite.

Taken as a whole the above information indicates that there is a degree of selectivity in the rock types that are used for tool manufacture at Pontnewydd. The major differences appear to lie in cores, handaxes levallois flakes and side scrapers. The notable difference in chips may be due to the greater production of small debitage during the manufacture of some tools, or may result from the greater visibility of both worked flint and fine silicic tuff compared to the coarser materials at the site.

#### 3.4.3.2. The f-test

F-tests were carried out on pairs of logged data on each possible combination of rock types for each of the following categories: length (mm), width (mm), and thickness (mm), weight (g), length/width and thickness/length. The results produced are displayed in Figure 3.4.19.

1. The variance about the mean for flint, compared with that of every other rock type, was significantly different in all categories. This meant that it was not possible to compare the mean dimensions of artefacts belonging to any rock type with artefacts of flint using a homoscedastic t-test. This difference in variance was caused by the cumulative frequency curves for flint being positively skewed as a result of the large numbers of flint implements with very small dimensions.
2. The variances of all tuffs (except rhyolitic tuff) and ignimbrite were not significantly different to each other, for all categories.
3. The variances of FP lava were significantly different to each of the other rock types, for at least one of the categories studied.
4. Fine silicic tuff had a distribution about the mean that was not significantly different to the tuffs, ignimbrite, rhyolitic tuff and rhyolite lava.

#### 3.4.3.3. The t-test

Two sample equal variance t-tests were carried out on pairs of logged data of several rock types for each of the following categories: length (mm), width (mm), and thickness (mm), weight (g), length/width and thickness/length, where possible. The results of the f-test determined on which categories the t-test could be implemented, for each pair of rock types. The results of the t-test are displayed in figure 3.4.20.

1. The greatest number of significant differences in the mean occur when comparing fine silicic tuff to any other rock type. These differences occur in almost all categories: length, width, thickness, weight and thickness/length. Fine silicic tuff therefore carries significantly different mean dimensions to all other rock types.
2. The mean length/width ratio is not significantly different for any rock types (except when comparing rhyolitic tuff and rhyolite lava).
3. The mean dimensions of silicic tuff are not significantly different in most categories to almost all other rock types. This pattern may be due to the small sample size for silicic tuff (21 artefacts).
4. If we consider the length category separately, we find that the rock types fall into the following groups based on a lack of significant differences between their means. Crystal lithic tuff, FP lava and ignimbrite form one group; rhyolitic tuff and rhyolite lava another; and crystal tuff and ignimbrite another.
5. If we consider the width category separately the rocks group, according to the lack of significant differences in their means, in this manner: FP lava and crystal lithic tuff; silicic tuff and ignimbrite; rhyolitic tuff and rhyolite lava. A further group of crystal lithic tuff, crystal tuff, ignimbrite and silicic tuff may exist, but this is complicated by the significant differences in the mean widths of crystal tuff and crystal lithic tuff. No t-test could be carried out on the width measurements for rhyolite.
6. If we consider the thickness category, we find that the rock types group together based on their means as follows: fine silicic tuff and crystal tuff; crystal lithic tuff, rhyolite lava, and FP lava; rhyolitic tuff and rhyolite lava; ignimbrite and crystal lithic tuff.
7. Lastly, if we consider the category of weight, rock types group within this category in a slightly different way: crystal lithic tuff and FP lava, FP lava and rhyolite lava, rhyolitic tuff and ignimbrite and crystal lithic tuff. Crystal tuff constitutes its own group in this category.



8. The two categories that I think will most influence the size of the flake and therefore the ease of knapping of each material are length and thickness. I therefore would expect raw material groupings based on a combination of these two features. The actual grouping of the dimension based data can be seen in Figures 3.4.10-12.

|                          | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>tuff | FP Lava | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltstone &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt | Totals   |         |
|--------------------------|------------------|------------------|-------------------|---------|----------------------|-----------------|--------------|-----------------|------------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|--------|----------|---------|
| Chunk/Chip               | 95               | 5                | 5                 | 5       | 18                   | 3               | 3            | 3               | 2                      | 4              | 1                         | 1                                  | 2          | 0                    | 0                 | 0      | 147      |         |
| EXPECTED                 | 8.647            | 8.647            | 8.647             | 8.647   | 8.647                | 8.647           | 8.647        | 8.647           | 8.647                  | 8.647          | 8.647                     | 8.647                              | 8.647      | 8.647                | 8.647             | 8.647  | 138.3529 |         |
| (o-e) <sup>2</sup> /e    | 862.355          | 1.538            | 1.538             | 1.538   | 10.116               | 3.688           | 3.688        | 3.688           | 5.110                  | 2.497          | 6.763                     | 6.763                              | 5.110      | 8.647                | 8.647             | 8.647  | 940.333  | sig. 5% |
| Core                     | 5                | 4                | 0                 | 1       | 1                    | 0               | 0            | 0               | 0                      | 0              | 0                         | 0                                  | 5          | 1                    | 0                 | 0      | 17       |         |
| EXPECTED                 | 1.000            | 1.000            | 1.000             | 1.000   | 1.000                | 1.000           | 1.000        | 1.000           | 1.000                  | 1.000          | 1.000                     | 1.000                              | 1.000      | 1.000                | 1.000             | 1.000  | 16       |         |
| (o-e) <sup>2</sup> /e    | 16.000           | 9.000            | 1.000             | 0.000   | 0.000                | 1.000           | 1.000        | 1.000           | 1.000                  | 1.000          | 1.000                     | 1.000                              | 16.000     | 0.000                | 1.000             | 1.000  | 51.000   | sig. 5% |
| Crude core               | 2                | 1                | 2                 | 2       | 0                    | 1               | 0            | 9               | 0                      | 1              | 0                         | 1                                  | 3          | 0                    | 0                 | 0      | 22       |         |
| EXPECTED                 | 1.294            | 1.294            | 1.294             | 1.294   | 1.294                | 1.294           | 1.294        | 1.294           | 1.294                  | 1.294          | 1.294                     | 1.294                              | 1.294      | 1.294                | 1.294             | 1.294  | 20.70588 |         |
| (o-e) <sup>2</sup> /e    | 0.385            | 0.067            | 0.385             | 0.385   | 1.294                | 0.067           | 1.294        | 45.885          | 1.294                  | 0.067          | 1.294                     | 0.067                              | 2.249      | 1.294                | 1.294             | 1.294  | 58.615   | sig. 5% |
| Dent. & Notch            | 2                | 2                | 1                 | 0       | 4                    | 0               | 1            | 1               | 1                      | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 1      | 13       |         |
| EXPECTED                 | 0.765            | 0.765            | 0.765             | 0.765   | 0.765                | 0.765           | 0.765        | 0.765           | 0.765                  | 0.765          | 0.765                     | 0.765                              | 0.765      | 0.765                | 0.765             | 0.765  | 12.23529 |         |
| (o-e) <sup>2</sup> /e    | 1.995            | 1.995            | 0.072             | 0.765   | 13.688               | 0.765           | 0.072        | 0.072           | 0.072                  | 0.765          | 0.765                     | 0.765                              | 0.765      | 0.765                | 0.765             | 0.072  | 24.158   | n/sig.  |
| Disc core                | 4                | 3                | 4                 | 6       | 6                    | 2               | 1            | 9               | 1                      | 4              | 0                         | 0                                  | 0          | 3                    | 1                 | 1      | 45       |         |
| EXPECTED                 | 2.647            | 2.647            | 2.647             | 2.647   | 2.647                | 2.647           | 2.647        | 2.647           | 2.647                  | 2.647          | 2.647                     | 2.647                              | 2.647      | 2.647                | 2.647             | 2.647  | 42.35294 |         |
| (o-e) <sup>2</sup> /e    | 0.692            | 0.047            | 0.692             | 4.247   | 4.247                | 0.158           | 1.025        | 15.247          | 1.025                  | 0.692          | 2.647                     | 2.647                              | 2.647      | 0.047                | 1.025             | 1.025  | 38.108   | sig. 5% |
| Flake                    | 30               | 32               | 23                | 35      | 31                   | 18              | 3            | 38              | 11                     | 11             | 15                        | 8                                  | 3          | 3                    | 2                 | 2      | 265      |         |
| EXPECTED                 | 15.588           | 15.588           | 15.588            | 15.588  | 15.588               | 15.588          | 15.588       | 15.588          | 15.588                 | 15.588         | 15.588                    | 15.588                             | 15.588     | 15.588               | 15.588            | 15.588 | 249.4118 |         |
| (o-e) <sup>2</sup> /e    | 13.324           | 17.279           | 3.524             | 24.173  | 15.237               | 0.373           | 10.166       | 32.222          | 1.350                  | 1.350          | 0.022                     | 3.694                              | 10.166     | 10.166               | 11.845            | 11.845 | 166.736  | sig. 5% |
| Handaxe                  | 2                | 13               | 5                 | 14      | 5                    | 5               | 6            | 7               | 1                      | 2              | 6                         | 3                                  | 1          | 2                    | 0                 | 0      | 72       |         |
| EXPECTED                 | 4.235            | 4.235            | 4.235             | 4.235   | 4.235                | 4.235           | 4.235        | 4.235           | 4.235                  | 4.235          | 4.235                     | 4.235                              | 4.235      | 4.235                | 4.235             | 4.235  | 67.76471 |         |
| (o-e) <sup>2</sup> /e    | 1.180            | 18.138           | 0.138             | 22.513  | 0.138                | 0.138           | 0.735        | 1.805           | 2.471                  | 1.180          | 0.735                     | 0.360                              | 2.471      | 1.180                | 4.235             | 4.235  | 61.654   | sig. 5% |
| Handaxe trimmer<br>flake | 1                | 2                | 5                 | 2       | 6                    | 1               | 0            | 3               | 0                      | 0              | 1                         | 0                                  | 0          | 0                    | 0                 | 0      | 21       |         |
| EXPECTED                 | 1.235            | 1.235            | 1.235             | 1.235   | 1.235                | 1.235           | 1.235        | 1.235           | 1.235                  | 1.235          | 1.235                     | 1.235                              | 1.235      | 1.235                | 1.235             | 1.235  | 19.76471 |         |
| (o-e) <sup>2</sup> /e    | 0.045            | 0.473            | 11.473            | 0.473   | 18.378               | 0.045           | 1.235        | 2.521           | 1.235                  | 1.235          | 0.045                     | 1.235                              | 1.235      | 1.235                | 1.235             | 1.235  | 43.336   | sig. 5% |
| Levallois core           | 2                | 3                | 1                 | 2       | 1                    | 0               | 1            | 3               | 1                      | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0      | 14       |         |
| EXPECTED                 | 0.824            | 0.824            | 0.824             | 0.824   | 0.824                | 0.824           | 0.824        | 0.824           | 0.824                  | 0.824          | 0.824                     | 0.824                              | 0.824      | 0.824                | 0.824             | 0.824  | 13.17647 |         |
| (o-e) <sup>2</sup> /e    | 1.681            | 5.752            | 0.038             | 1.681   | 0.038                | 0.824           | 0.038        | 5.752           | 0.038                  | 0.824          | 0.824                     | 0.824                              | 0.824      | 0.824                | 0.824             | 0.824  | 21.605   | n/sig.  |

Fig. 3.4.13. Chi<sup>2</sup> analysis: comparison of observed data with the results expected if raw materials are used equally for all typologies.



|                              | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>tuff | FP Lava | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltstone &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt | Totals  |         |
|------------------------------|------------------|------------------|-------------------|---------|----------------------|-----------------|--------------|-----------------|------------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|--------|---------|---------|
| Levallois flakes &<br>points | 3                | 11               | 5                 | 11      | 12                   | 12              | 2            | 4               | 1                      | 0              | 3                         | 1                                  | 1          | 1                    | 9                 | 1      | 77      |         |
| EXPECTED                     | 4.529            | 4.529            | 4.529             | 4.529   | 4.529                | 4.529           | 4.529        | 4.529           | 4.529                  | 4.529          | 4.529                     | 4.529                              | 4.529      | 4.529                | 4.529             | 4.529  | 72.471  |         |
| (o-e) <sup>2</sup> /e        | 0.516            | 9.244            | 0.049             | 9.244   | 12.322               | 12.322          | 1.413        | 0.062           | 2.750                  | 4.529          | 0.516                     | 2.750                              | 2.750      | 2.750                | 4.413             | 2.750  | 68.380  | sig. 5% |
| Naturally backed<br>knife    | 0                | 2                | 1                 | 1       | 2                    | 1               | 1            | 2               | 0                      | 2              | 0                         | 1                                  | 0          | 0                    | 0                 | 0      | 13      |         |
| EXPECTED                     | 0.765            | 0.765            | 0.765             | 0.765   | 0.765                | 0.765           | 0.765        | 0.765           | 0.765                  | 0.765          | 0.765                     | 0.765                              | 0.765      | 0.765                | 0.765             | 0.765  | 12.235  |         |
| (o-e) <sup>2</sup> /e        | 0.765            | 1.995            | 0.072             | 0.072   | 1.995                | 0.072           | 0.072        | 1.995           | 0.765                  | 1.995          | 0.765                     | 0.072                              | 0.765      | 0.765                | 0.765             | 0.765  | 13.697  | n/sig.  |
| Retouched flake              | 11               | 3                | 4                 | 2       | 13                   | 5               | 1            | 8               | 0                      | 3              | 1                         | 1                                  | 0          | 1                    | 0                 | 0      | 53      |         |
| EXPECTED                     | 3.118            | 3.118            | 3.118             | 3.118   | 3.118                | 3.118           | 3.118        | 3.118           | 3.118                  | 3.118          | 3.118                     | 3.118                              | 3.118      | 3.118                | 3.118             | 3.118  | 49.882  |         |
| (o-e) <sup>2</sup> /e        | 19.929           | 0.004            | 0.250             | 0.401   | 31.325               | 1.137           | 1.438        | 7.646           | 3.118                  | 0.004          | 1.438                     | 1.438                              | 3.118      | 1.438                | 3.118             | 3.118  | 78.920  | sig. 5% |
| Scraper                      | 3                | 3                | 0                 | 4       | 0                    | 1               | 0            | 0               | 1                      | 1              | 0                         | 0                                  | 0          | 1                    | 0                 | 0      | 14      |         |
| EXPECTED                     | 0.824            | 0.824            | 0.824             | 0.824   | 0.824                | 0.824           | 0.824        | 0.824           | 0.824                  | 0.824          | 0.824                     | 0.824                              | 0.824      | 0.824                | 0.824             | 0.824  | 13.176  |         |
| (o-e) <sup>2</sup> /e        | 5.752            | 5.752            | 0.824             | 12.252  | 0.824                | 0.038           | 0.824        | 0.824           | 0.038                  | 0.038          | 0.824                     | 0.824                              | 0.824      | 0.038                | 0.824             | 0.824  | 31.319  | sig. 5% |
| Side scraper                 | 2                | 2                | 4                 | 4       | 6                    | 4               | 0            | 4               | 2                      | 1              | 1                         | 1                                  | 0          | 1                    | 1                 | 0      | 33      |         |
| EXPECTED                     | 1.941            | 1.941            | 1.941             | 1.941   | 1.941                | 1.941           | 1.941        | 1.941           | 1.941                  | 1.941          | 1.941                     | 1.941                              | 1.941      | 1.941                | 1.941             | 1.941  | 31.059  |         |
| (o-e) <sup>2</sup> /e        | 0.002            | 0.002            | 2.184             | 2.184   | 8.487                | 2.184           | 1.941        | 2.184           | 0.002                  | 0.456          | 0.456                     | 0.456                              | 1.941      | 0.456                | 0.456             | 1.941  | 25.332  | sig. 5% |
| Spall                        | 40               | 0                | 3                 | 0       | 1                    | 1               | 0            | 1               | 0                      | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0      | 46      |         |
| EXPECTED                     | 2.706            | 2.706            | 2.706             | 2.706   | 2.706                | 2.706           | 2.706        | 2.706           | 2.706                  | 2.706          | 2.706                     | 2.706                              | 2.706      | 2.706                | 2.706             | 2.706  | 43.294  |         |
| (o-e) <sup>2</sup> /e        | 514.010          | 2.706            | 0.032             | 2.706   | 1.075                | 1.075           | 2.706        | 1.075           | 2.706                  | 2.706          | 2.706                     | 2.706                              | 2.706      | 2.706                | 2.706             | 2.706  | 547.033 | sig. 5% |
| Tool re-use                  | 5                | 0                | 3                 | 7       | 8                    | 4               | 0            | 3               | 0                      | 2              | 0                         | 1                                  | 0          | 1                    | 1                 | 0      | 35      |         |
| EXPECTED                     | 2.059            | 2.059            | 2.059             | 2.059   | 2.059                | 2.059           | 2.059        | 2.059           | 2.059                  | 2.059          | 2.059                     | 2.059                              | 2.059      | 2.059                | 2.059             | 2.059  | 32.941  |         |
| (o-e) <sup>2</sup> /e        | 4.202            | 2.059            | 0.430             | 11.859  | 17.145               | 1.830           | 2.059        | 0.430           | 2.059                  | 0.002          | 2.059                     | 0.545                              | 2.059      | 0.545                | 0.545             | 2.059  | 49.884  | sig. 5% |

Fig. 3.4.13. Chi<sup>2</sup> analysis: comparison of observed data with the results expected if raw materials are used equally for all typologies.

|                           | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava  | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltstone<br>& limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt   | Totals   |         |
|---------------------------|------------------|------------------|-------------------|----------|----------------------|-----------------|--------------|-----------------|------------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|----------|---------|
| Naturally backed<br>knife | 0                | 2                | 1                 | 1        | 2                    | 1               | 1            | 2               | 0                      | 2              | 0                         | 1                                  | 0          | 0                    | 0                 | 0        | 13       |         |
| EXPECTED                  | 3.068            | 1.296            | 0.972             | 1.336    | 1.721                | 0.850           | 0.344        | 1.367           | 0.344                  | 0.456          | 0.405                     | 0.253                              | 0.192      | 0.152                | 0.172             | 0.071    | 166.920  |         |
| (o-e) <sup>2</sup> /e     | 3.068            | 0.382            | 0.001             | 0.085    | 0.045                | 0.026           | 1.249        | 0.293           | 0.344                  | 5.235          | 0.405                     | 2.204                              | 0.192      | 0.152                | 0.172             | 0.071    | 13.925   | n/sig.  |
| Retouched flake           | 11               | 3                | 4                 | 2        | 13                   | 5               | 1            | 8               | 0                      | 3              | 1                         | 1                                  | 0          | 1                    | 0                 | 0        | 53       |         |
| EXPECTED                  | 12.507           | 5.283            | 3.963             | 5.449    | 7.017                | 3.467           | 1.403        | 5.572           | 1.403                  | 1.857          | 1.651                     | 1.032                              | 0.784      | 0.619                | 0.702             | 0.289    | 680.520  |         |
| (o-e) <sup>2</sup> /e     | 0.182            | 0.987            | 0.000             | 2.183    | 5.101                | 0.678           | 0.116        | 1.058           | 1.403                  | 0.703          | 0.257                     | 0.001                              | 0.784      | 0.234                | 0.702             | 0.289    | 14.677   | n/sig.  |
| Scraper                   | 3                | 3                | 0                 | 4        | 0                    | 1               | 0            | 0               | 1                      | 1              | 0                         | 0                                  | 0          | 1                    | 0                 | 0        | 14       |         |
| EXPECTED                  | 3.304            | 1.396            | 1.047             | 1.439    | 1.854                | 0.916           | 0.371        | 1.472           | 0.371                  | 0.491          | 0.436                     | 0.273                              | 0.207      | 0.164                | 0.185             | 0.076    | 14.000   |         |
| (o-e) <sup>2</sup> /e     | 0.028            | 1.844            | 1.047             | 4.556    | 1.854                | 0.008           | 0.371        | 1.472           | 1.068                  | 0.529          | 0.436                     | 0.273                              | 0.207      | 4.278                | 0.185             | 0.076    | 18.231   | n/sig.  |
| Side scraper              | 2                | 2                | 4                 | 4        | 6                    | 4               | 0            | 4               | 2                      | 1              | 1                         | 1                                  | 0          | 1                    | 1                 | 0        | 33       |         |
| EXPECTED                  | 7.787            | 3.290            | 2.467             | 3.393    | 4.369                | 2.159           | 0.874        | 3.470           | 0.874                  | 1.157          | 1.028                     | 0.643                              | 0.488      | 0.386                | 0.437             | 0.180    | 33.000   |         |
| (o-e) <sup>2</sup> /e     | 4.301            | 0.506            | 0.952             | 0.109    | 0.609                | 1.570           | 0.874        | 0.081           | 1.451                  | 0.021          | 0.001                     | 0.199                              | 0.488      | 0.979                | 0.726             | 0.180    | 13.047   | n/sig.  |
| spall chunk chip          | 135              | 5                | 8                 | 5        | 19                   | 4               | 3            | 4               | 2                      | 4              | 1                         | 1                                  | 2          | 0                    | 0                 | 0        | 193      |         |
| EXPECTED                  | 45.544           | 19.240           | 14.430            | 19.841   | 25.553               | 12.626          | 5.111        | 20.292          | 5.111                  | 6.764          | 6.012                     | 3.758                              | 2.856      | 2.255                | 2.555             | 1.052    | 193.000  |         |
| (o-e) <sup>2</sup> /e     | 175.703          | 10.539           | 2.865             | 11.101   | 1.680                | 5.893           | 0.872        | 13.081          | 1.893                  | 1.129          | 4.179                     | 2.024                              | 0.257      | 2.255                |                   | 0.000    | 233.472  | sig. 5% |
| Tool re-use               | 5                | 0                | 3                 | 7        | 8                    | 4               | 0            | 3               | 0                      | 2              | 0                         | 1                                  | 0          | 1                    | 1                 | 0        | 35       |         |
| EXPECTED                  | 8.259            | 3.489            | 2.617             | 3.598    | 4.634                | 2.290           | 0.927        | 3.680           | 0.927                  | 1.227          | 1.090                     | 0.681                              | 0.518      | 0.409                | 0.463             | 0.191    | 35.000   |         |
| (o-e) <sup>2</sup> /e     | 1.286            | 3.489            | 0.056             | 3.216    | 2.445                | 1.277           | 0.927        | 0.126           | 0.927                  | 0.488          | 1.090                     | 0.149                              | 0.518      | 0.855                | 0.621             | 0.191    | 17.661   | n/sig.  |
| Handaxe                   | 2                | 13               | 5                 | 14       | 5                    | 5               | 6            | 7               | 1                      | 2              | 6                         | 3                                  | 1          | 2                    | 0                 | 0        | 72       |         |
| EXPECTED                  | 16.99065         | 7.17757          | 5.383178          | 7.401869 | 9.53271              | 4.71028         | 1.906542     | 7.570093        | 1.906542               | 2.523364       | 2.242991                  | 1.401869                           | 1.065421   | 0.841121             | 0.953271          | 0.392523 | 72       |         |
| (o-e) <sup>2</sup> /e     | 13.22608         | 4.723143         | 0.027275          | 5.881667 | 2.155259             | 0.01782         | 8.788895     | 0.042933        | 0.431052               | 0.10855        | 6.292991                  | 1.821869                           | 0.004017   | 1.596677             | 0.953271          | 0.392523 | 46.46402 | sig. 5% |

Fig. 3.4.14. Chi<sup>2</sup> analysis: comparison of typological breakdown of raw material use with totals for each raw material.



|                              | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava  | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltstone<br>& limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt   | Totals  |          |
|------------------------------|------------------|------------------|-------------------|----------|----------------------|-----------------|--------------|-----------------|------------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|---------|----------|
| Totals                       | 303              | 128              | 96                | 132      | 170                  | 84              | 34           | 135             | 34                     | 45             | 40                        | 25                                 | 19         | 15                   | 17                | 7        | 1284    |          |
| % Totals                     | 23.59813         | 9.968847         | 7.476636          | 10.28037 | 13.23988             | 6.542056        | 2.647975     | 10.51402        | 2.647975               | 3.504673       | 3.115265                  | 1.94704                            | 1.479751   | 1.168224             | 1.323988          | 0.545171 | 100     |          |
| EXPECTED                     | 303              | 128              | 96                | 132      | 170                  | 84              | 34           | 135             | 34                     | 45             | 40                        | 25                                 | 19         | 15                   | 17                | 7        | 1284    |          |
| (o-e) <sup>2</sup> /e        | 0.000            | 0.000            | 0.000             | 0.000    | 0.000                | 0.000           | 0.000        | 0.000           | 0.000                  | 0.000          | 0.000                     | 0.000                              | 0.000      | 0.000                | 0.000             | 0.000    | 0.000   |          |
| Core                         | 5                | 4                | 0                 | 1        | 1                    | 0               | 0            | 0               | 0                      | 0              | 0                         | 0                                  | 5          | 1                    | 0                 | 0        | 17      |          |
| EXPECTED                     | 4.011682         | 1.694704         | 1.271028          | 1.747664 | 2.250779             | 1.11215         | 0.450156     | 1.787383        | 0.450156               | 0.595794       | 0.529595                  | 0.330997                           | 0.251558   | 0.198598             | 0.225078          | 0.092679 | 17      |          |
| (o-e) <sup>2</sup> /e        | 0.243            | 3.136            | 1.271             | 0.320    | 0.695                | 1.112           | 0.450        | 1.787           | 0.450                  | 0.596          | 0.530                     | 0.331                              | 89.632     | 3.234                | 0.000             | 0.000    | 103.788 | sig. 5%  |
| Crude core                   | 2                | 1                | 2                 | 2        | 0                    | 1               | 0            | 9               | 0                      | 1              | 0                         | 1                                  | 3          | 0                    | 0                 | 0        | 22      |          |
| EXPECTED                     | 5.192            | 2.193            | 1.645             | 2.262    | 2.913                | 1.439           | 0.583        | 2.313           | 0.583                  | 0.771          | 0.685                     | 0.428                              | 0.326      | 0.257                | 0.291             | 0.120    | 22.000  |          |
| (o-e) <sup>2</sup> /e        | 1.962            | 0.649            | 0.077             | 0.030    | 2.913                | 0.134           | 0.583        | 19.331          | 0.583                  | 0.068          | 0.685                     | 0.763                              | 21.971     | 0.257                | 0.000             |          | 50.006  | sig. 5%  |
| Dent. & Notch                | 2                | 2                | 1                 | 0        | 4                    | 0               | 1            | 1               | 1                      | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 1        | 13      |          |
| EXPECTED                     | 3.068            | 1.296            | 0.972             | 1.336    | 1.721                | 0.850           | 0.344        | 1.367           | 0.344                  | 0.456          | 0.405                     | 0.253                              | 0.192      | 0.152                | 0.172             | 0.071    | 13      |          |
| (o-e) <sup>2</sup> /e        | 0.372            | 0.382            | 0.001             | 1.336    | 3.017                | 0.850           | 1.249        | 0.098           | 1.249                  | 0.456          | 0.405                     | 0.253                              | 0.192      | 0.152                | 0.172             | 12.181   | 22.367  | sig. 10% |
| Disc core                    | 4                | 3                | 4                 | 6        | 6                    | 2               | 1            | 9               | 1                      | 4              | 0                         | 0                                  | 0          | 3                    | 1                 | 1        | 45      |          |
| EXPECTED                     | 10.619           | 4.486            | 3.364             | 4.626    | 5.958                | 2.944           | 1.192        | 4.731           | 1.192                  | 1.577          | 1.402                     | 0.876                              | 0.666      | 0.526                | 0.596             | 0.245    | 45      |          |
| (o-e) <sup>2</sup> /e        | 4.126            | 0.492            | 0.120             | 0.408    | 0.000                | 0.303           | 0.031        | 3.851           | 0.031                  | 3.722          | 1.402                     | 0.876                              | 0.666      | 11.646               | 0.274             | 2.322    | 30.270  | sig. 5%  |
| Flake                        | 30               | 32               | 23                | 35       | 31                   | 18              | 3            | 38              | 11                     | 11             | 15                        | 8                                  | 3          | 3                    | 2                 | 2        | 265     |          |
| EXPECTED                     | 62.535           | 26.417           | 19.813            | 27.243   | 35.086               | 17.336          | 7.017        | 27.862          | 7.017                  | 9.287          | 8.255                     | 5.160                              | 3.921      | 3.096                | 3.509             | 1.445    | 265     |          |
| (o-e) <sup>2</sup> /e        | 16.927           | 1.180            | 0.513             | 2.209    | 0.476                | 0.025           | 2.300        | 3.689           | 2.261                  | 0.316          | 5.510                     | 1.564                              | 0.216      | 0.003                | 0.649             | 0.213    | 38.049  | sig. 5%  |
| Handaxe trimmer<br>flake     | 1                | 2                | 5                 | 2        | 6                    | 1               | 0            | 3               | 0                      | 0              | 1                         | 0                                  | 0          | 0                    | 0                 | 0        | 21      |          |
| EXPECTED                     | 4.956            | 2.093            | 1.570             | 2.159    | 2.780                | 1.374           | 0.556        | 2.208           | 0.556                  | 0.736          | 0.654                     | 0.409                              | 0.311      | 0.245                | 0.278             | 0.114    | 269.640 |          |
| (o-e) <sup>2</sup> /e        | 3.157            | 0.004            | 7.493             | 0.012    | 3.728                | 0.102           | 0.556        | 0.284           | 0.556                  | 0.736          | 0.183                     | 0.409                              | 0.311      | 0.245                | 0.278             | 0.114    | 18.168  | n/sig.   |
| Levallois core               | 2                | 3                | 1                 | 2        | 1                    | 0               | 1            | 3               | 1                      | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0        | 14      |          |
| EXPECTED                     | 3.304            | 1.396            | 1.047             | 1.439    | 1.854                | 0.916           | 0.371        | 1.472           | 0.371                  | 0.491          | 0.436                     | 0.273                              | 0.207      | 0.164                | 0.185             | 0.076    | 179.760 |          |
| (o-e) <sup>2</sup> /e        | 0.514            | 1.844            | 0.002             | 0.218    | 0.393                | 0.916           | 1.068        | 1.586           | 1.068                  | 0.491          | 0.436                     | 0.273                              | 0.207      | 0.164                | 0.185             | 0.076    | 9.443   | n/sig.   |
| Levallois flakes &<br>points | 3                | 11               | 5                 | 11       | 12                   | 12              | 2            | 4               | 1                      | 0              | 3                         | 1                                  | 1          | 1                    | 9                 | 1        | 77      |          |
| EXPECTED                     | 18.171           | 7.676            | 5.757             | 7.916    | 10.195               | 5.037           | 2.039        | 8.096           | 2.039                  | 2.699          | 2.399                     | 1.499                              | 1.139      | 0.900                | 1.019             | 0.420    | 77.000  |          |
| (o-e) <sup>2</sup> /e        | 12.666           | 1.439            | 0.100             | 1.202    | 0.320                | 9.624           | 0.001        | 2.072           | 0.529                  | 2.699          | 0.151                     | 0.166                              | 0.017      | 0.011                | 62.472            | 0.802    | 94.270  | sig. 5%  |

Fig. 3.4.14. Chi<sup>2</sup> analysis: comparison of typological breakdown of raw material use with totals for each raw material.

|                           | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltst. &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt | Totals  |         |
|---------------------------|------------------|------------------|-------------------|---------|----------------------|-----------------|--------------|-----------------|----------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|--------|---------|---------|
| Naturally backed<br>knife | 0                | 2                | 1                 | 1       | 2                    | 1               | 1            | 2               | 0                    | 2              | 0                         | 1                                  | 0          | 0                    | 0                 | 0      | 13      |         |
| EXPECTED                  | 0.361            | 2.347            | 0.903             | 2.528   | 0.903                | 0.903           | 1.083        | 1.264           | 0.181                | 0.361          | 1.083                     | 0.542                              | 0.181      | 0.361                | 0.000             | 0.000  | 13.000  |         |
| (o-e) <sup>2</sup> /e     | 0.361            | 0.051            | 0.010             | 0.923   | 1.334                | 0.010           | 0.006        | 0.429           | 0.181                | 7.438          | 1.083                     | 0.388                              | 0.181      | 0.361                | 0.000             | 0.000  | 12.757  | n/sig.  |
| Retouched flake           | 11               | 3                | 4                 | 2       | 13                   | 5               | 1            | 8               | 0                    | 3              | 1                         | 1                                  | 0          | 1                    | 0                 | 0      | 53      |         |
| EXPECTED                  | 1.472            | 9.569            | 3.681             | 10.306  | 3.681                | 3.681           | 4.417        | 5.153           | 0.736                | 1.472          | 4.417                     | 2.208                              | 0.736      | 1.472                | 0.000             | 0.000  | 53.000  |         |
| (o-e) <sup>2</sup> /e     | 61.661           | 4.510            | 0.028             | 6.694   | 23.598               | 0.473           | 2.643        | 1.573           | 0.736                | 1.585          | 2.643                     | 0.661                              | 0.736      | 0.151                | 0.000             | 0.000  | 107.693 | sig. 5% |
| Scraper                   | 3                | 3                | 0                 | 4       | 0                    | 1               | 0            | 0               | 1                    | 1              | 0                         | 0                                  | 0          | 1                    | 0                 | 0      | 14      |         |
| EXPECTED                  | 0.389            | 2.528            | 0.972             | 2.722   | 0.972                | 0.972           | 1.167        | 1.361           | 0.194                | 0.389          | 1.167                     | 0.583                              | 0.194      | 0.389                | 0.000             | 0.000  | 14.000  |         |
| (o-e) <sup>2</sup> /e     | 17.532           | 0.088            | 0.972             | 0.600   | 0.972                | 0.001           | 1.167        | 1.361           | 3.337                | 0.960          | 1.167                     | 0.583                              | 0.194      | 0.960                |                   |        | 29.895  | sig. 5% |
| Side scraper              | 2                | 2                | 4                 | 4       | 6                    | 4               | 0            | 4               | 2                    | 1              | 1                         | 1                                  | 0          | 1                    | 1                 | 0      | 33      |         |
| EXPECTED                  | 1.941            | 1.941            | 1.941             | 1.941   | 1.941                | 1.941           | 1.941        | 1.941           | 1.941                | 1.941          | 1.941                     | 1.941                              | 1.941      | 1.941                | 1.941             | 1.941  | 31.059  |         |
| (o-e) <sup>2</sup> /e     | 0.002            | 0.002            | 2.184             | 2.184   | 8.487                | 2.184           | 1.941        | 2.184           | 0.002                | 0.456          | 0.456                     | 0.456                              | 1.941      | 0.456                | 0.456             | 1.941  | 25.332  | sig. 5% |
| spall chunk chip          | 135              | 5                | 8                 | 5       | 19                   | 4               | 3            | 4               | 2                    | 4              | 1                         | 1                                  | 2          | 0                    | 0                 | 0      | 193     |         |
| EXPECTED                  | 5.361            | 34.847           | 13.403            | 37.528  | 13.403               | 13.403          | 16.083       | 18.764          | 2.681                | 5.361          | 16.083                    | 8.042                              | 2.681      | 5.361                | 0.000             | 0.000  | 193.000 |         |
| (o-e) <sup>2</sup> /e     | 3134.84          | 25.565           | 2.178             | 28.194  | 2.337                | 6.597           | 10.643       | 11.617          | 0.173                | 0.346          | 14.146                    | 6.166                              | 0.173      | 5.361                | 0.000             | 0.000  | 3248.34 | sig. 5% |
| Tool re-use               | 5                | 0                | 3                 | 7       | 8                    | 4               | 0            | 3               | 0                    | 2              | 0                         | 1                                  | 0          | 1                    | 1                 | 0      | 35      |         |
| EXPECTED                  | 2.059            | 2.059            | 2.059             | 2.059   | 2.059                | 2.059           | 2.059        | 2.059           | 2.059                | 2.059          | 2.059                     | 2.059                              | 2.059      | 2.059                | 2.059             | 2.059  | 32.941  |         |
| (o-e) <sup>2</sup> /e     | 4.202            | 2.059            | 0.430             | 11.859  | 17.145               | 1.830           | 2.059        | 0.430           | 2.059                | 0.002          | 2.059                     | 0.545                              | 2.059      | 0.545                | 0.545             | 2.059  | 49.884  | sig. 5% |

Fig. 3.4.15. Chi<sup>2</sup> analysis: comparison of observed data with the distribution of raw materials as used for handaxes.



|                              | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava  | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltst. &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt | Totals   |         |
|------------------------------|------------------|------------------|-------------------|----------|----------------------|-----------------|--------------|-----------------|----------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|--------|----------|---------|
| Handaxe                      | 2                | 13               | 5                 | 14       | 5                    | 5               | 6            | 7               | 1                    | 2              | 6                         | 3                                  | 1          | 2                    | 0                 | 0      | 72       |         |
| %handaxe                     | 2.777778         | 18.05556         | 6.944444          | 19.44444 | 6.944444             | 6.944444        | 8.333333     | 9.722222        | 1.388889             | 2.777778       | 8.333333                  | 4.166667                           | 1.388889   | 2.777778             | 0                 | 0      | 100      |         |
| EXPECTED                     | 2                | 13               | 5                 | 14       | 5                    | 5               | 6            | 7               | 1                    | 2              | 6                         | 3                                  | 1          | 2                    | 0                 | 0      | 72       |         |
| (o-e) <sup>2</sup> /e        | 0.000            | 0.000            | 0.000             | 0.000    | 0.000                | 0.000           | 0.000        | 0.000           | 0.000                | 0.000          | 0.000                     | 0.000                              | 0.000      | 0.000                | 0.000             | 0.000  | 0.000    |         |
| Core                         | 5                | 4                | 0                 | 1        | 1                    | 0               | 0            | 0               | 0                    | 0              | 0                         | 0                                  | 5          | 1                    | 0                 | 0      | 17       |         |
| EXPECTED                     | 0                | 3                | 1                 | 3        | 1                    | 1               | 1            | 2               | 0                    | 0              | 1                         | 1                                  | 0          | 0                    | 0                 | 0      | 17       |         |
| (o-e) <sup>2</sup> /e        | 43.413           | 0.282            | 1.181             | 1.608    | 0.028                | 1.181           | 1.417        | 1.653           | 0.236                | 0.472          | 1.417                     | 0.708                              | 96.118     | 0.590                | 0.000             | 0.000  | 150.303  | sig. 5% |
| Crude core                   | 2                | 1                | 2                 | 2        | 0                    | 1               | 0            | 9               | 0                    | 1              | 0                         | 1                                  | 3          | 0                    | 0                 | 0      | 22       |         |
| EXPECTED                     | 0.611            | 3.972            | 1.528             | 4.278    | 1.528                | 1.528           | 1.833        | 2.139           | 0.306                | 0.611          | 1.833                     | 0.917                              | 0.306      | 0.611                | 0.000             | 0.000  | 22.000   |         |
| (o-e) <sup>2</sup> /e        | 3.157            | 2.224            | 0.146             | 1.213    | 1.528                | 0.182           | 1.833        | 22.009          | 0.306                | 0.247          | 1.833                     | 0.008                              | 23.760     | 0.611                | 0.000             | 0.000  | 59.057   | sig. 5% |
| Dent. & Notch                | 2                | 2                | 1                 | 0        | 4                    | 0               | 1            | 1               | 1                    | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0      | 13       |         |
| EXPECTED                     | 0.765            | 0.765            | 0.765             | 0.765    | 0.765                | 0.765           | 0.765        | 0.765           | 0.765                | 0.765          | 0.765                     | 0.765                              | 0.765      | 0.765                | 0.765             | 0.765  | 12.23529 |         |
| (o-e) <sup>2</sup> /e        | 1.995            | 1.995            | 0.072             | 0.765    | 13.688               | 0.765           | 0.072        | 0.072           | 0.072                | 0.765          | 0.765                     | 0.765                              | 0.765      | 0.765                | 0.765             | 0.765  | 24.158   | n/sig.  |
| Disc core                    | 4                | 3                | 4                 | 6        | 6                    | 2               | 1            | 9               | 1                    | 4              | 0                         | 0                                  | 0          | 3                    | 1                 | 1      | 45       |         |
| EXPECTED                     | 2.647            | 2.647            | 2.647             | 2.647    | 2.647                | 2.647           | 2.647        | 2.647           | 2.647                | 2.647          | 2.647                     | 2.647                              | 2.647      | 2.647                | 2.647             | 2.647  | 42.35294 |         |
| (o-e) <sup>2</sup> /e        | 0.692            | 0.047            | 0.692             | 4.247    | 4.247                | 0.158           | 1.025        | 15.247          | 1.025                | 0.692          | 2.647                     | 2.647                              | 2.647      | 0.047                | 1.025             | 1.025  | 38.108   | sig. 5% |
| Flake                        | 30               | 32               | 23                | 35       | 31                   | 18              | 3            | 38              | 11                   | 11             | 15                        | 8                                  | 3          | 3                    | 2                 | 2      | 265      |         |
| EXPECTED                     | 15.588           | 15.588           | 15.588            | 15.588   | 15.588               | 15.588          | 15.588       | 15.588          | 15.588               | 15.588         | 15.588                    | 15.588                             | 15.588     | 15.588               | 15.588            | 15.588 | 249.4118 |         |
| (o-e) <sup>2</sup> /e        | 13.324           | 17.279           | 3.524             | 24.173   | 15.237               | 0.373           | 10.166       | 32.222          | 1.350                | 1.350          | 0.022                     | 3.694                              | 10.166     | 10.166               | 11.845            | 11.845 | 166.736  | sig. 5% |
| Handaxe trimmer<br>flake     | 1                | 2                | 5                 | 2        | 6                    | 1               | 0            | 3               | 0                    | 0              | 1                         | 0                                  | 0          | 0                    | 0                 | 0      | 21       |         |
| EXPECTED                     | 0.583            | 3.792            | 1.458             | 4.083    | 1.458                | 1.458           | 1.750        | 2.042           | 0.292                | 0.583          | 1.750                     | 0.875                              | 0.292      | 0.583                | 0.000             | 0.000  | 21.000   |         |
| (o-e) <sup>2</sup> /e        | 0.298            | 0.847            | 8.601             | 1.063    | 14.144               | 0.144           | 1.750        | 0.450           | 0.292                | 0.583          | 0.321                     | 0.875                              | 0.292      | 0.583                | 0.000             | 0.000  | 30.243   | sig. 5% |
| Levallois core               | 2                | 3                | 1                 | 2        | 1                    | 0               | 1            | 3               | 1                    | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0      | 14       |         |
| EXPECTED                     | 0.389            | 2.528            | 0.972             | 2.722    | 0.972                | 0.972           | 1.167        | 1.361           | 0.194                | 0.389          | 1.167                     | 0.583                              | 0.194      | 0.389                | 0.000             | 0.000  | 14.000   |         |
| (o-e) <sup>2</sup> /e        | 6.675            | 0.088            | 0.001             | 0.192    | 0.001                | 0.972           | 0.024        | 1.973           | 3.337                | 0.389          | 1.167                     | 0.583                              | 0.194      | 0.389                | 0.000             | 0.000  | 15.985   | n/sig.  |
| Levallois flakes &<br>points | 3                | 11               | 5                 | 11       | 12                   | 12              | 2            | 4               | 1                    | 0              | 3                         | 1                                  | 1          | 1                    | 9                 | 1      | 77       |         |
| EXPECTED                     | 4.529            | 4.529            | 4.529             | 4.529    | 4.529                | 4.529           | 4.529        | 4.529           | 4.529                | 4.529          | 4.529                     | 4.529                              | 4.529      | 4.529                | 4.529             | 4.529  | 72.471   |         |
| (o-e) <sup>2</sup> /e        | 0.516            | 9.244            | 0.049             | 9.244    | 12.322               | 12.322          | 1.413        | 0.062           | 2.750                | 4.529          | 0.516                     | 2.750                              | 2.750      | 2.750                | 4.413             | 2.750  | 68.380   | sig. 5% |

Fig. 3.4.15. Chi<sup>2</sup> analysis: comparison of observed data with the distribution of raw materials as used for handaxes.

|                           | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava  | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltst. &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt   | Totals   |         |
|---------------------------|------------------|------------------|-------------------|----------|----------------------|-----------------|--------------|-----------------|----------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|----------|---------|
| Naturally backed<br>knife | 0                | 2                | 1                 | 1        | 2                    | 1               | 1            | 2               | 0                    | 2              | 0                         | 1                                  | 0          | 0                    | 0                 | 0        | 13       |         |
| EXPECTED                  | 1.472            | 1.570            | 1.128             | 1.717    | 1.521                | 0.883           | 0.147        | 1.864           | 0.540                | 0.540          | 0.736                     | 0.392                              | 0.147      | 0.147                | 0.098             | 0.098    | 34.450   |         |
| (o-e) <sup>2</sup> /e     | 1.472            | 0.118            | 0.015             | 0.299    | 0.151                | 0.015           | 4.942        | 0.010           | 0.540                | 3.952          | 0.736                     | 0.941                              | 0.147      | 0.147                | 0.098             | 0.098    | 13.681   | n/sig.  |
| Retouched flake           | 11               | 3                | 4                 | 2        | 13                   | 5               | 1            | 8               | 0                    | 3              | 1                         | 1                                  | 0          | 1                    | 0                 | 0        | 53       |         |
| EXPECTED                  | 6.000            | 6.400            | 4.600             | 7.000    | 6.200                | 3.600           | 0.600        | 7.600           | 2.200                | 2.200          | 3.000                     | 1.600                              | 0.600      | 0.600                | 0.400             | 0.400    | 140.450  |         |
| (o-e) <sup>2</sup> /e     | 4.167            | 1.806            | 0.078             | 3.571    | 7.458                | 0.544           | 0.267        | 0.021           | 2.200                | 0.291          | 1.333                     | 0.225                              | 0.600      | 0.267                | 0.400             | 0.400    | 23.629   | n/sig.  |
| Scraper                   | 3                | 3                | 0                 | 4        | 0                    | 1               | 0            | 0               | 1                    | 1              | 0                         | 0                                  | 0          | 1                    | 0                 | 0        | 14       |         |
| EXPECTED                  | 1.585            | 1.691            | 1.215             | 1.849    | 1.638                | 0.951           | 0.158        | 2.008           | 0.581                | 0.581          | 0.792                     | 0.423                              | 0.158      | 0.158                | 0.106             | 0.106    | 14.000   |         |
| (o-e) <sup>2</sup> /e     | 1.263            | 1.014            | 1.215             | 2.502    | 1.638                | 0.003           | 0.158        | 2.008           | 0.302                | 0.302          | 0.792                     | 0.423                              | 0.158      | 4.468                | 0.106             | 0.106    | 16.458   | n/sig.  |
| Side scraper              | 2                | 2                | 4                 | 4        | 6                    | 4               | 0            | 4               | 2                    | 1              | 1                         | 1                                  | 0          | 1                    | 1                 | 0        | 33       |         |
| EXPECTED                  | 3.736            | 3.985            | 2.864             | 4.358    | 3.860                | 2.242           | 0.374        | 4.732           | 1.370                | 1.370          | 1.868                     | 0.996                              | 0.374      | 0.374                | 0.249             | 0.249    | 33.000   |         |
| (o-e) <sup>2</sup> /e     | 0.807            | 0.989            | 0.450             | 0.029    | 1.186                | 1.380           | 0.374        | 0.113           | 0.290                | 0.100          | 0.403                     | 0.000                              | 0.374      | 1.050                | 2.264             | 0.249    | 10.058   | n/sig.  |
| spall chunk chip          | 135              | 5                | 8                 | 5        | 19                   | 4               | 3            | 4               | 2                    | 4              | 1                         | 1                                  | 2          | 0                    | 0                 | 0        | 193      |         |
| EXPECTED                  | 21.849           | 23.306           | 16.751            | 25.491   | 22.577               | 13.109          | 2.185        | 27.675          | 8.011                | 8.011          | 10.925                    | 5.826                              | 2.185      | 2.185                | 1.457             | 1.457    | 193.000  |         |
| (o-e) <sup>2</sup> /e     | 585.981          | 14.378           | 4.572             | 16.471   | 0.567                | 6.330           | 0.304        | 20.254          | 4.511                | 2.008          | 9.016                     | 3.998                              | 0.016      | 2.185                |                   | 0.000    | 670.591  | sig. 5% |
| Tool re-use               | 5                | 0                | 3                 | 7        | 8                    | 4               | 0            | 3               | 0                    | 2              | 0                         | 1                                  | 0          | 1                    | 1                 | 0        | 35       |         |
| EXPECTED                  | 3.962            | 4.226            | 3.038             | 4.623    | 4.094                | 2.377           | 0.396        | 5.019           | 1.453                | 1.453          | 1.981                     | 1.057                              | 0.396      | 0.396                | 0.264             | 0.264    | 35.000   |         |
| (o-e) <sup>2</sup> /e     | 0.272            | 4.226            | 0.000             | 1.223    | 3.726                | 1.108           | 0.396        | 0.812           | 1.453                | 0.206          | 1.981                     | 0.003                              | 0.396      | 0.920                | 2.050             | 0.264    | 19.036   | n/sig.  |
| Handaxe                   | 2                | 13               | 5                 | 14       | 5                    | 5               | 6            | 7               | 1                    | 2              | 6                         | 3                                  | 1          | 2                    | 0                 | 0        | 72       |         |
| EXPECTED                  | 8.150943         | 8.69434          | 6.249057          | 9.509434 | 8.422642             | 4.890566        | 0.815094     | 10.32453        | 2.988679             | 2.988679       | 4.075472                  | 2.173585                           | 0.815094   | 0.815094             | 0.543396          | 0.543396 | 72       |         |
| (o-e) <sup>2</sup> /e     | 4.641684         | 2.132274         | 0.24966           | 2.120545 | 1.390831             | 0.002449        | 32.98176     | 1.070508        | 1.323275             | 0.327063       | 0.908805                  | 0.31421                            | 0.041946   | 1.722502             | 0.543396          | 0.543396 | 50.31431 | sig. 5% |

Fig. 3.4.16. Chi<sup>2</sup> analysis: comparison of observed data with raw material distribution shown by flakes.



|                              | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava  | Fine<br>silicic tuff | Crystal<br>Tuff | Silicic tuff | Ignim-<br>brite | Siltst. &<br>limest. | Sand-<br>stone | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Basalt   | Totals  |          |
|------------------------------|------------------|------------------|-------------------|----------|----------------------|-----------------|--------------|-----------------|----------------------|----------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|---------|----------|
| Flake                        | 30               | 32               | 23                | 35       | 31                   | 18              | 3            | 38              | 11                   | 11             | 15                        | 8                                  | 3          | 3                    | 2                 | 2        | 265     |          |
| % flakes                     | 11.32075         | 12.07547         | 8.679245          | 13.20755 | 11.69811             | 6.792453        | 1.132075     | 14.33962        | 4.150943             | 4.150943       | 5.660377                  | 3.018868                           | 1.132075   | 1.132075             | 0.754717          | 0.754717 | 100     |          |
| EXPECTED                     | 30               | 32               | 23                | 35       | 31                   | 18              | 3            | 38              | 11                   | 11             | 15                        | 8                                  | 3          | 3                    | 2                 | 2        | 265     |          |
| (o-e) <sup>2</sup> /e        | 0.000            | 0.000            | 0.000             | 0.000    | 0.000                | 0.000           | 0.000        | 0.000           | 0.000                | 0.000          | 0.000                     | 0.000                              | 0.000      | 0.000                | 0.000             | 0.000    | 0.000   |          |
| Core                         | 5                | 4                | 0                 | 1        | 1                    | 0               | 0            | 0               | 0                    | 0              | 0                         | 0                                  | 5          | 1                    | 0                 | 0        | 17      |          |
| EXPECTED                     | 1.925            | 2.053            | 1.475             | 2.245    | 1.989                | 1.155           | 0.192        | 2.438           | 0.706                | 0.706          | 0.962                     | 0.513                              | 0.192      | 0.192                | 0.128             | 0.128    | 17.000  |          |
| (o-e) <sup>2</sup> /e        | 4.915            | 1.847            | 1.475             | 0.691    | 0.492                | 1.155           | 0.192        | 2.438           | 0.706                | 0.706          | 0.962                     | 0.513                              | 120.094    | 3.389                | 0.000             | 0.000    | 139.574 | sig. 5%  |
| Crude core                   | 2                | 1                | 2                 | 2        | 0                    | 1               | 0            | 9               | 0                    | 1              | 0                         | 1                                  | 3          | 0                    | 0                 | 0        | 22      |          |
| EXPECTED                     | 2.491            | 2.657            | 1.909             | 2.906    | 2.574                | 1.494           | 0.249        | 3.155           | 0.913                | 0.913          | 1.245                     | 0.664                              | 0.249      | 0.249                | 0.166             | 0.166    | 58.300  |          |
| (o-e) <sup>2</sup> /e        | 0.097            | 1.033            | 0.004             | 0.282    | 2.574                | 0.164           | 0.249        | 10.831          | 0.913                | 0.008          | 1.245                     | 0.170                              | 30.385     | 0.249                | 0.000             |          | 48.204  | sig. 5%  |
| Denticulates &<br>Notches    | 2                | 2                | 1                 | 0        | 4                    | 0               | 1            | 1               | 1                    | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 1        | 13      |          |
| EXPECTED                     | 1.472            | 1.570            | 1.128             | 1.717    | 1.521                | 0.883           | 0.147        | 1.864           | 0.540                | 0.540          | 0.736                     | 0.392                              | 0.147      | 0.147                | 0.098             | 0.098    | 13      |          |
| (o-e) <sup>2</sup> /e        | 0.190            | 0.118            | 0.015             | 1.717    | 4.042                | 0.883           | 4.942        | 0.401           | 0.393                | 0.540          | 0.736                     | 0.392                              | 0.147      | 0.147                | 0.098             | 8.290    | 23.050  | n/sig.   |
| Disc core                    | 4                | 3                | 4                 | 6        | 6                    | 2               | 1            | 9               | 1                    | 4              | 0                         | 0                                  | 0          | 3                    | 1                 | 1        | 45      |          |
| EXPECTED                     | 5.094            | 5.434            | 3.906             | 5.943    | 5.264                | 3.057           | 0.509        | 6.453           | 1.868                | 1.868          | 2.547                     | 1.358                              | 0.509      | 0.509                | 0.340             | 0.340    | 45      |          |
| (o-e) <sup>2</sup> /e        | 0.235            | 1.090            | 0.002             | 0.001    | 0.103                | 0.365           | 0.472        | 1.005           | 0.403                | 2.434          | 2.547                     | 1.358                              | 0.509      | 12.176               | 1.284             | 1.284    | 25.270  | sig. 10% |
| Handaxe trimmer<br>flake     | 1                | 2                | 5                 | 2        | 6                    | 1               | 0            | 3               | 0                    | 0              | 1                         | 0                                  | 0          | 0                    | 0                 | 0        | 21      |          |
| EXPECTED                     | 2.377            | 2.536            | 1.823             | 2.774    | 2.457                | 1.426           | 0.238        | 3.011           | 0.872                | 0.872          | 1.189                     | 0.634                              | 0.238      | 0.238                | 0.158             | 0.158    | 55.650  |          |
| (o-e) <sup>2</sup> /e        | 0.798            | 0.113            | 5.539             | 0.216    | 5.111                | 0.127           | 0.238        | 0.000           | 0.872                | 0.872          | 0.030                     | 0.634                              | 0.238      | 0.238                | 0.158             | 0.158    | 15.342  | n/sig.   |
| Levallois core               | 2                | 3                | 1                 | 2        | 1                    | 0               | 1            | 3               | 1                    | 0              | 0                         | 0                                  | 0          | 0                    | 0                 | 0        | 14      |          |
| EXPECTED                     | 1.585            | 1.691            | 1.215             | 1.849    | 1.638                | 0.951           | 0.158        | 2.008           | 0.581                | 0.581          | 0.792                     | 0.423                              | 0.158      | 0.158                | 0.106             | 0.106    | 37.100  |          |
| (o-e) <sup>2</sup> /e        | 0.109            | 1.014            | 0.038             | 0.012    | 0.248                | 0.951           | 4.468        | 0.491           | 0.302                | 0.581          | 0.792                     | 0.423                              | 0.158      | 0.158                | 0.106             | 0.106    | 9.958   | n/sig.   |
| Levallois flakes &<br>points | 3                | 11               | 5                 | 11       | 12                   | 12              | 2            | 4               | 1                    | 0              | 3                         | 1                                  | 1          | 1                    | 9                 | 1        | 77      |          |
| EXPECTED                     | 8.717            | 9.298            | 6.683             | 10.170   | 9.008                | 5.230           | 0.872        | 11.042          | 3.196                | 3.196          | 4.358                     | 2.325                              | 0.872      | 0.872                | 0.581             | 0.581    | 77.000  |          |
| (o-e) <sup>2</sup> /e        | 3.749            | 0.312            | 0.424             | 0.068    | 0.994                | 8.763           | 1.460        | 4.491           | 1.509                | 3.196          | 0.423                     | 0.755                              | 0.019      | 0.019                | 121.964           | 0.302    | 148.448 | sig. 5%  |

Fig. 3.4.16. Chi<sup>2</sup> analysis: comparison of observed data with raw material distribution shown by flakes.

|                              | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava | Fine<br>silicic tuff | Crystal<br>Tuff | Ignim-<br>brite | Sandst. &<br>siltst. | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Totals   |                       |  |
|------------------------------|------------------|------------------|-------------------|---------|----------------------|-----------------|-----------------|----------------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|-----------------------|--|
| Levallois flakes &<br>points | 1                | 9                | 5                 | 9       | 11                   | 8               | 2               | 1                    | 2                         | 1                                  | 0          | 1                    | 7                 | 57       |                       |  |
| Site H                       | 2                | 2                | 3                 | 1       | 1                    | 4               | 3               | 1                    | 1                         | 0                                  | 1          | 0                    | 4                 | 23       |                       |  |
| % Site H                     | 8.70             | 8.70             | 13.04             | 4.35    | 4.35                 | 17.39           | 13.04           | 4.35                 | 4.35                      | 0.00                               | 4.35       | 0.00                 | 17.39             | 100      |                       |  |
| EXPECTED                     | 4.96             | 4.96             | 7.43              | 2.48    | 2.48                 | 9.91            | 7.43            | 2.48                 | 2.48                      | 0.00                               | 2.48       | 0.00                 | 9.91              | 57       | K=11                  |  |
| (o-e) <sup>2</sup> /e        | 3.16             | 3.30             | 0.80              | 17.16   | 29.30                | 0.37            | 3.97            | 0.88                 | 0.09                      |                                    | 2.48       |                      | 0.86              | 62.36988 | Sig. 5%               |  |
| Retouched flake              | 10               | 3                | 5                 | 2       | 13                   | 3               | 8               | 3                    | 1                         | 1                                  | 0          | 1                    | 0                 | 50       |                       |  |
| Site H                       | 1                | 0                | 1                 | 0       | 0                    | 4               | 3               | 0                    | 0                         | 0                                  | 0          | 0                    | 0                 | 9        |                       |  |
| % Site H                     | 11.11            | 0.00             | 11.11             | 0.00    | 0.00                 | 44.44           | 33.33           | 0.00                 | 0.00                      | 0.00                               | 0.00       | 0.00                 | 0.00              | 100      |                       |  |
| EXPECTED                     | 5.56             | 0.00             | 5.56              | 0.00    | 0.00                 | 22.22           | 16.67           | 0.00                 | 0.00                      | 0.00                               | 0.00       | 0.00                 | 0.00              | 50       | K=4                   |  |
| (o-e) <sup>2</sup> /e        | 3.56             |                  | 3.36              |         |                      | 16.63           | 4.51            |                      |                           |                                    |            |                      |                   | 28       | Sig. 5%               |  |
| Scraper                      | 4                | 4                | 4                 | 5       | 6                    | 3               | 3               | 3                    | 1                         | 1                                  | 0          | 2                    | 0                 | 36       |                       |  |
| Site H                       | 3                | 1                | 0                 | 3       | 1                    | 2               | 1               | 2                    | 0                         | 1                                  | 0          | 0                    | 1                 | 15       |                       |  |
| % Site H                     | 20.00            | 6.67             | 0.00              | 20.00   | 6.67                 | 13.33           | 6.67            | 13.33                | 0.00                      | 6.67                               | 0.00       | 0.00                 | 6.67              | 100      |                       |  |
| EXPECTED                     | 7.20             | 2.40             | 0.00              | 7.20    | 2.40                 | 4.80            | 2.40            | 4.80                 | 0.00                      | 2.40                               | 0.00       | 0.00                 | 2.40              | 36       | K=9                   |  |
| (o-e) <sup>2</sup> /e        | 1.42             | 1.07             |                   | 0.67    | 5.40                 | 0.68            | 0.15            | 0.68                 |                           | 0.82                               |            |                      | 2.40              | 13       | n/sig.                |  |
| Tool re-use                  | 2                | 0                | 3                 | 3       | 4                    | 2               | 3               | 1                    | 0                         | 0                                  | 0          | 1                    | 0                 | 19       |                       |  |
| Site H                       | 1                | 0                | 0                 | 0       | 0                    | 2               | 0               | 0                    | 0                         | 1                                  | 0          | 0                    | 1                 | 5        |                       |  |
| % Site H                     | 20.00            | 0.00             | 0.00              | 0.00    | 0.00                 | 40.00           | 0.00            | 0.00                 | 0.00                      | 20.00                              | 0.00       | 0.00                 | 20.00             | 100      |                       |  |
| EXPECTED                     | 3.80             | 0.00             | 0.00              | 0.00    | 0.00                 | 7.60            | 0.00            | 0.00                 | 0.00                      | 3.80                               | 0.00       | 0.00                 | 3.80              | 19       | K=4                   |  |
| (o-e) <sup>2</sup> /e        | 0.85             |                  |                   |         |                      | 4.13            |                 |                      |                           | 3.80                               |            |                      | 3.80              | 13       | Sig. 5%               |  |
|                              |                  |                  |                   |         |                      |                 |                 |                      |                           |                                    |            |                      |                   |          | (but v.small numbers) |  |
| Totals                       | 109              | 79               | 58                | 79      | 92                   | 43              | 74              | 34                   | 21                        | 16                                 | 7          | 13                   | 14                | 639      |                       |  |
| Site H                       | 104              | 7                | 26                | 12      | 15                   | 17              | 28              | 13                   | 8                         | 3                                  | 8          | 1                    | 6                 | 248      |                       |  |
| % Site H                     | 41.60            | 2.80             | 10.40             | 4.80    | 6.00                 | 6.80            | 11.20           | 5.20                 | 3.20                      | 1.20                               | 3.20       | 0.40                 | 2.40              | 99.2     |                       |  |
| EXPECTED                     | 271.65           | 18.28            | 67.91             | 31.34   | 39.18                | 44.40           | 73.14           | 33.96                | 20.90                     | 7.84                               | 20.90      | 2.61                 | 15.67             | 647.776  | K=14                  |  |
| (o-e) <sup>2</sup> /e        | 97.38            | 201.62           | 1.45              | 72.46   | 71.21                | 0.04            | 0.01            | 0.00                 | 0.00                      | 8.51                               | 9.24       | 41.31                | 0.18              | 503.4114 | Sig. 5%               |  |

Fig. 3.4.17. Chi<sup>2</sup> analysis: comparisons of raw materials used in the Main Cave and the New Entrance.



|                       | Flint &<br>Chert | Rhyolite<br>lava | Rhyolitic<br>Tuff | FP Lava | Fine<br>silicic tuff | Crystal<br>Tuff | Ignim-<br>brite | Sandst. &<br>siltst. | Crystal<br>Lithic<br>Tuff | Crystal<br>pumice &<br>vitric tuff | Quartz-ite | Andesite<br>& Dacite | Micro-<br>diorite | Totals   |                       |  |
|-----------------------|------------------|------------------|-------------------|---------|----------------------|-----------------|-----------------|----------------------|---------------------------|------------------------------------|------------|----------------------|-------------------|----------|-----------------------|--|
| Chunk/Chip            | 55               | 4                | 2                 | 2       | 10                   | 2               | 2               | 4                    | 1                         | 0                                  | 1          | 0                    | 0                 | 83       |                       |  |
| Site H                | 84               | 1                | 9                 | 3       | 9                    | 2               | 4               | 2                    | 0                         | 1                                  | 1          | 0                    | 0                 | 116      |                       |  |
| %Site H               | 72.41            | 0.86             | 7.76              | 2.59    | 7.76                 | 1.72            | 3.45            | 1.72                 | 0.00                      | 0.86                               | 0.86       | 0                    | 0                 | 100      |                       |  |
| EXPECTED              | 60.10            | 0.72             | 6.44              | 2.15    | 6.44                 | 1.43            | 2.86            | 1.43                 | 0.00                      | 0.72                               | 0.72       | 0                    | 0                 | 83       | K=10                  |  |
| (o-e) <sup>2</sup> /e | 0.43             | 15.08            | 3.06              | 0.01    | 1.97                 | 0.23            | 0.26            | 4.61                 |                           | 0.72                               | 0.11       |                      |                   | 26.47581 | Sig. 5%               |  |
| Core                  | 3                | 4                | 1                 | 3       | 1                    | 1               | 7               | 1                    | 0                         | 1                                  | 4          | 1                    | 0                 | 27       |                       |  |
| Site H                | 6                | 1                | 1                 | 0       | 0                    | 1               | 2               | 0                    | 0                         | 0                                  | 4          | 0                    | 0                 | 15       |                       |  |
| % Site H              | 40.00            | 6.67             | 6.67              | 0       | 0                    | 6.67            | 13.33           | 0                    | 0                         | 0                                  | 26.67      | 0                    | 0                 | 100      |                       |  |
| EXPECTED              | 10.80            | 1.80             | 1.80              | 0       | 0                    | 1.80            | 3.60            | 0                    | 0                         | 0                                  | 7.20       | 0                    | 0                 | 27       | K=6                   |  |
| (o-e) <sup>2</sup> /e | 5.63             | 2.69             | 0.36              |         |                      | 0.36            | 3.21            |                      |                           |                                    | 1.42       |                      |                   | 13.66667 | Sig. 5%               |  |
| Disc core             | 4                | 3                | 3                 | 5       | 6                    | 2               | 7               | 4                    | 0                         | 0                                  | 0          | 3                    | 3                 | 40       |                       |  |
| Site H                | 0                | 0                | 2                 | 1       | 0                    | 0               | 2               | 0                    | 0                         | 0                                  | 0          | 0                    | 0                 | 5        |                       |  |
| % Site H              | 0                | 0                | 40                | 20      | 0                    | 0               | 40              | 0                    | 0                         | 0                                  | 0          | 0                    | 0                 | 100      |                       |  |
| EXPECTED              | 0                | 0                | 16                | 8       | 0                    | 0               | 16              | 0                    | 0                         | 0                                  | 0          | 0                    | 0                 | 40       | K=3                   |  |
| (o-e) <sup>2</sup> /e |                  |                  | 10.56             | 1.13    |                      |                 | 5.06            |                      |                           |                                    |            |                      |                   | 16.75    | Sig. 5%               |  |
|                       |                  |                  |                   |         |                      |                 |                 |                      |                           |                                    |            |                      |                   |          | (but v.small numbers) |  |
| Flake                 | 26               | 32               | 20                | 31      | 27                   | 17              | 28              | 13                   | 10                        | 8                                  | 2          | 3                    | 4                 | 221      |                       |  |
| Site H                | 7                | 2                | 6                 | 4       | 4                    | 1               | 10              | 6                    | 5                         | 0                                  | 1          | 0                    | 0                 | 46       |                       |  |
| % Site H              | 15.22            | 4.35             | 13.04             | 8.70    | 8.70                 | 2.17            | 21.74           | 13.04                | 10.87                     | 0.00                               | 2.17       | 0                    | 0                 | 100      |                       |  |
| EXPECTED              | 33.63            | 9.61             | 28.83             | 19.22   | 19.22                | 4.80            | 48.04           | 28.83                | 24.02                     | 0.00                               | 4.80       | 0                    | 0                 | 221      | K=11                  |  |
| (o-e) <sup>2</sup> /e | 7.64             | 175.87           | 3.71              | 57.21   | 38.53                | 101.11          | 1.80            | 0.00                 | 0.07                      |                                    | 0.01       |                      |                   | 385.9602 | Sig. 5%               |  |
| Handaxe               | 3                | 15               | 12                | 16      | 11                   | 5               | 9               | 2                    | 6                         | 3                                  | 0          | 1                    | 0                 | 83       |                       |  |
| Site H                | 0                | 0                | 4                 | 0       | 0                    | 0               | 1               | 1                    | 2                         | 0                                  | 1          | 1                    | 0                 | 10       |                       |  |
| % Site H              | 0                | 0                | 40                | 0       | 0                    | 0               | 10              | 10                   | 20                        | 0                                  | 10         | 10                   | 0                 | 100      |                       |  |
| EXPECTED              | 0                | 0                | 33.20             | 0.00    | 0.00                 | 0.00            | 8.30            | 8.30                 | 16.60                     | 0.00                               | 8.30       | 8.30                 | 0                 | 83       | K=6                   |  |
| (o-e) <sup>2</sup> /e |                  |                  | 19.60             |         |                      |                 | 0.06            | 4.78                 | 6.77                      |                                    | 8.30       | 6.42                 |                   | 45.93012 | Sig. 5%               |  |
|                       |                  |                  |                   |         |                      |                 |                 |                      |                           |                                    |            |                      |                   |          | (but v.small numbers) |  |

Fig. 3.4.17. Chi<sup>2</sup> analysis: comparisons of raw materials used in the Main Cave and the New Entrance.

|                           | Cf. Equal rock use    | Cf. Handaxes         | Cf. Total rock use   | Cf. Flakes           |
|---------------------------|-----------------------|----------------------|----------------------|----------------------|
| Chunk/Chip                | 58                    |                      |                      |                      |
| EXPECTED                  | 54.375                | 58                   | 58                   | 58                   |
| (o-e) <sup>2</sup> /e     | 87.8922414 sig. 5%    | 77.4071618 sig. 5%   | 20.6128219 n/sig     | 41.7390042 Sig. 5%   |
| Core                      | 12                    |                      |                      |                      |
| EXPECTED                  | 11.25                 | 12                   | 12                   | 12                   |
| (o-e) <sup>2</sup> /e     | 45.9166667 sig. 5%    | 145.512821 K-1>total | 113.01599 K-1>total  | 171.022967 K-1>total |
| Crude core                | 20                    |                      |                      |                      |
| EXPECTED                  | 18.75                 | 20                   | 20                   | 20                   |
| (o-e) <sup>2</sup> /e     | 60.35 sig. 5%         | 59.6858974 sig. 5%   | 40.4433777 sig. 5%   | 47.3829672 Sig. 5%   |
| Denticulates & Notches    | 11                    |                      |                      |                      |
| EXPECTED                  | 10.3125               | 11                   | 11                   | 11                   |
| (o-e) <sup>2</sup> /e     | 24.6761364 K-1> total | 22.9277389 K-1>total | 12.4041555 K-1>total | 19.6371327 K-1>total |
| Disc core                 | 41                    |                      |                      |                      |
| EXPECTED                  | 38.4375               | 41                   | 41                   | 41                   |
| (o-e) <sup>2</sup> /e     | 38.7789634 sig. 5%    | 30.7836148 sig. 5%   | 21.0260805 n/sig     | 24.9685542 Sig. 5%   |
| Flake                     | 235                   |                      |                      |                      |
| EXPECTED                  | 220.3125              | 235                  | 235                  | 100                  |
| (o-e) <sup>2</sup> /e     | 163.793351 sig. 5%    | 68.0986361 sig. 5%   | 14.3613051 n/sig     | 1.5258E-30 n/sig.    |
| Handaxe                   | 70                    |                      |                      |                      |
| EXPECTED                  | 65.625                | 100                  | 70                   | 70                   |
| (o-e) <sup>2</sup> /e     | 58.1964286 sig. 5%    | 0 n/sig              | 23.5009096 n/sig     | 43.9696877 Sig. 5%   |
| Handaxe trimmer flake     | 20                    |                      |                      |                      |
| EXPECTED                  | 18.75                 | 20                   | 20                   | 20                   |
| (o-e) <sup>2</sup> /e     | 42.75 sig. 5%         | 30.5602564 sig. 5%   | 11.3620385 n/sig     | 13.7951885 n/sig.    |
| Levallois core            | 12                    |                      |                      |                      |
| EXPECTED                  | 11.25                 | 12                   | 12                   | 12                   |
| (o-e) <sup>2</sup> /e     | 21.9166667 K-1> total | 10.3440171 K-1>total | 7.85916611 K-1>total | 10.2492267 n/sig.    |
| Levallois flakes & points | 74                    |                      |                      |                      |
| EXPECTED                  | 69.375                | 74                   | 74                   | 74                   |
| (o-e) <sup>2</sup> /e     | 66.2398649 sig. 5%    | 29.0883576 sig. 5%   | 55.5954486 sig. 5%   | 89.757905 Sig. 5%    |
| Naturally backed knife    | 13                    |                      |                      |                      |
| EXPECTED                  | 12.1875               | 13                   | 13                   | 13                   |
| (o-e) <sup>2</sup> /e     | 12.0336538 K-1> total | 12.0414201 n/sig     | 8.98623849 n/sig     | 11.5445461 K-1>total |
| Retouched flake           | 42                    |                      |                      |                      |
| EXPECTED                  | 39.375                | 42                   | 42                   | 42                   |
| (o-e) <sup>2</sup> /e     | 69.6607143 sig. 5%    | 54.3125763 sig. 5%   | 13.9331685 n/sig     | 21.2048699 n/sig.    |
| Scraper                   | 11                    |                      |                      |                      |
| EXPECTED                  | 10.3125               | 11                   | 11                   | 11                   |
| (o-e) <sup>2</sup> /e     | 30.4943182 K-1> total | 14.6783217 K-1>total | 19.968464 n/sig      | 21.3824153 K-1>total |
| Side scraper              | 31                    |                      |                      |                      |
| EXPECTED                  | 29.0625               | 31                   | 31                   | 31                   |
| (o-e) <sup>2</sup> /e     | 25.3850806 sig. 5%    | 22.5657568 sig. 5%   | 5.55567231 n/sig     | 6.96509676 n/sig.    |
| Tool re-use               | 30                    |                      |                      |                      |
| EXPECTED                  | 28.125                | 30                   | 30                   | 30                   |
| (o-e) <sup>2</sup> /e     | 50.2583333 sig. 5%    | 31.3111111 sig. 5%   | 13.6805877 n/sig     | 17.4192491 n/sig.    |

Figure 3.4.18. Chi<sup>2</sup> analysis: comparison of observed data with equal rock use, raw material use for handaxes, total rock use and raw material use for flakes



| Variances                 | L(mm)  | W(mm) | Th(mm) | Weight(g) | L/W(mm) | Th/L(mm) | n               |
|---------------------------|--|-------|--------|-----------|---------|----------|-----------------|
| crystal lithic tuff       | 0.050  | 0.042 | 0.071  | 0.437     | 0.017   | 0.022    | 40              |
| crystal tuff              | 0.071  | 0.064 | 0.067  | 0.573     | 0.018   | 0.025    | 52              |
| silicic tuff              | 0.079  | 0.057 | 0.094  | 0.619     | 0.023   | 0.026    | 21              |
| vitric tuff               | 0.044  | 0.008 | 0.069  | 0.211     | 0.034   | 0.018    | 6               |
| rhyolitic tuff            | 0.101  | 0.111 | 0.121  | 0.884     | 0.016   | 0.023    | 59              |
| rhy. lava                 | 0.064  | 0.058 | 0.071  | 0.484     | 0.017   | 0.025    | 87              |
| fine silicic tuff         | 0.098  | 0.097 | 0.074  | 0.758     | 0.018   | 0.026    | 102             |
| flint                     | 0.173  | 0.163 | 0.165  | 1.182     | 0.027   | 0.054    | 207             |
| FP lava                   | 0.039  | 0.037 | 0.070  | 0.374     | 0.022   | 0.036    | 90              |
| Ignimbrite                | 0.052  | 0.057 | 0.084  | 0.540     | 0.013   | 0.023    | 99              |
|                           |  |       |        |           |         |          |                 |
| <b>f-test</b>             | this tests the <b>variances</b> to see if they are significantly different from each other |       |        |           |         |          |                 |
| fst/flint                 | 1.770  | 1.683 | 2.236  | 1.560     | 1.509   | 2.117    | all significant |
| fst/cry lithic            | 1.974  | 2.316 | 1.030  | 1.735     | 1.087   | 1.159    | not significant |
| fst/xtal tuff             | 1.370  | 1.519 | 1.106  | 1.323     | 1.004   | 1.037    | not significant |
| fst/rhyolitic tuff        | 1.026  | 1.144 | 1.644  | 1.166     | 1.121   | 1.131    | not significant |
| fst/rhy. lava             | 1.524  | 1.679 | 1.042  | 1.565     | 1.056   | 1.034    | sig/not         |
| fst/FP lava               | 2.516  | 2.591 | 1.047  | 2.026     | 1.207   | 1.403    | sig/not         |
| fst/igni                  | 1.867  | 1.695 | 1.139  | 1.403     | 1.347   | 1.104    | sig/not         |
| cry.lithic/xtal tuff      | 1.441  | 1.525 | 1.073  | 1.312     | 1.083   | 1.117    | not significant |
| cry.lithic/silicic tuff   | 1.600  | 1.353 | 1.315  | 1.418     | 1.358   | 1.184    | not significant |
| cry.lithic/vitric tuff    | 1.132  | 4.966 | 1.028  | 2.067     | 2.050   | 1.223    | not significant |
| cry.lithic/rhyolitic tuff | 2.026  | 2.648 | 1.693  | 2.023     | 1.031   | 1.025    | sig/not         |
| cry.lithic/rhy. lava      | 1.296  | 1.379 | 1.012  | 1.109     | 1.029   | 1.120    | not significant |
| cry.lithic/flint          | 3.495  | 3.896 | 2.304  | 2.706     | 1.640   | 2.452    | all significant |
| cry.lithic/FP lava        | 1.274  | 1.119 | 1.016  | 1.168     | 1.312   | 1.626    | sig/not         |
| cry.lithic/ignimbrite     | 1.057  | 1.366 | 1.174  | 1.236     | 1.239   | 1.050    | not significant |
| xtal tuff/silicic         | 1.110  | 1.127 | 1.411  | 1.081     | 1.254   | 1.060    | not significant |
| xtal tuff/vitric          | 1.630  | 7.572 | 1.043  | 2.710     | 1.893   | 1.366    | sig/not         |
| xtal tuff/rhyolitic       | 1.406  | 1.737 | 1.817  | 1.543     | 1.117   | 1.090    | sig/not         |
| xtal tuff/rhy lava        | 1.112  | 1.105 | 1.061  | 1.183     | 1.052   | 1.003    | not significant |
| xtal tuff/FP lava         | 1.836  | 1.706 | 1.056  | 1.532     | 1.211   | 1.455    | sig/not         |
| xtal tuff/igni            | 1.362  | 1.116 | 1.259  | 1.061     | 1.342   | 1.064    | not significant |
| silicic/fst               | 1.234  | 1.712 | 1.276  | 1.224     | 1.249   | 1.022    | not significant |
| silicic/rhyolitic         | 1.266  | 1.958 | 1.288  | 1.427     | 1.400   | 1.155    | sig/not         |
| silicic/rhy. lava         | 1.235  | 1.020 | 1.330  | 1.279     | 1.319   | 1.057    | not significant |
| silicic/FP lava           | 2.039  | 1.514 | 1.336  | 1.656     | 1.035   | 1.373    | sig/not         |
| silicic/ignimbrite        | 1.513  | 1.010 | 1.120  | 1.147     | 1.682   | 1.128    | not significant |
| rhyolitic/rhy. Lava       | 1.563  | 1.920 | 1.713  | 1.825     | 1.062   | 1.093    | sig/not         |
| rhyolitic/FP lava         | 2.582  | 2.963 | 1.721  | 2.363     | 1.353   | 1.586    | mainly sig.     |
| Rhyolitic/igni            | 1.916  | 1.938 | 1.443  | 1.637     | 1.201   | 1.024    | sig/not         |
| rhy.lava/FP lava          | 1.651  | 1.543 | 1.004  | 1.295     | 1.275   | 1.451    | mainly sig.     |
| rhy.lava/ignim            | 1.225  | 1.009 | 1.188  | 1.115     | 1.276   | 1.067    | sig/not         |
| FP lava/igni              | 1.348  | 1.529 | 1.192  | 1.444     | 1.626   | 1.548    | sig/not         |
| Ignimbrite/flint          | 3.305  | 2.852 | 1.963  | 2.189     | 2.032   | 2.336    | all significant |

Figure 3.4.19. Results of F-test conducted on dimensions of the Pontnewydd artefacts

| t-test                     | Probability | v   | test done | sig. Value       | t-test                      | Probability | v   | test done | sig. Value       |
|----------------------------|-------------|-----|-----------|------------------|-----------------------------|-------------|-----|-----------|------------------|
| <b>Crystal tuff</b>        |             |     |           |                  | silicic/ignim (1 tail)      | 0.386       | 118 | Length    | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.294       | 71  | Length    | 0.05 not sig.    | silicic/ignim (1 tail)      | 0.331       | 118 | Width     | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.219       | 71  | Width     | 0.05 not sig.    | silicic/ignim (1 tail)      | 0.259       | 118 | Thickness | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.036       | 71  | Thickness | 0.05 significant | silicic/ignim (1 tail)      | 0.284       | 118 | Weight    | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.201       | 71  | Weight    | 0.05 not sig.    | silicic/ignim (1 tail)      | 0.386       | 118 | L/W       | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.371       | 71  | L/W       | 0.05 not sig.    | silicic/ignim (1 tail)      | 0.218       | 118 | Th/L      | 0.05 not sig.    |
| xtal tuff/silicic (1 tail) | 0.067       | 71  | Th/L      | 0.05 not sig.    | <b>Rhyolitic tuff</b>       |             |     |           |                  |
| xtal tuff/igni (1 tail)    | 0.095       | 149 | Length    | 0.05 not sig.    | rhyolitic/rhy.Lava (1 tail) | 0.091       | 90  | Length    | 0.05 not sig.    |
| xtal tuff/igni (1 tail)    | 0.037       | 149 | Width     | 0.05 significant | rhyolitic/rhy.Lava (1 tail) | 0.482       | 90  | Width     | 0.05 not sig.    |
| xtal tuff/igni (2 tail)    | 0.003       | 149 | Thickness | 0.05 significant | rhyolitic/rhy.Lava (1 tail) | 0.038       | 90  | Thickness | 0.05 not sig.    |
| xtal tuff/igni (2 tail)    | 0.036       | 149 | Weight    | 0.05 significant | rhyolitic/rhy.Lava (1 tail) | 0.032       | 90  | Weight    | 0.05 not sig.    |
| xtal tuff/igni (1 tail)    | 0.166       | 149 | L/W       | 0.05 not sig.    | rhyolitic/rhy.Lava (1 tail) | 0.019       | 90  | L/W       | 0.05 significant |
| xtal tuff/igni (2 tail)    | 0.001       | 149 | Th/L      | 0.05 significant | rhyolitic/rhy.Lava (1 tail) | 0.145       | 90  | Th/L      | 0.05 not sig.    |
| <b>Silicic tuff</b>        |             |     |           |                  | silicic/rhyolitic (1 tail)  | 0.311       | 73  | Length    | 0.05 not sig.    |
| silicic/fst (2 tail)       | 0.048       | 121 | Length    | 0.05 significant | silicic/rhyolitic           | 0.256       | 73  | Thickness | 0.05 not sig.    |
| silicic/fst (1 tail)       | 0.027       | 121 | Width     | 0.05 significant | silicic/rhyolitic           | 0.273       | 73  | Weight    | 0.05 not sig.    |
| silicic/fst (2 tail)       | 0.015       | 121 | Thickness | 0.05 significant | silicic/rhyolitic           | 0.255       | 73  | L/W       | 0.05 not sig.    |
| silicic/fst (2 tail)       | 0.031       | 121 | Weight    | 0.05 significant | silicic/rhyolitic           | 0.325       | 78  | Th/L      | 0.05 not sig.    |
| silicic/fst (1 tail)       | 0.418       | 121 | L/W       | 0.05 not sig.    | rhy.lava/FP lava (1 tail)   | 0.348       | 121 | Thickness | 0.05 not sig.    |
| silicic/fst (1 tail)       | 0.338       | 121 | Th/L      | 0.05 not sig.    | rhy.lava/FP lava            | 0.085       | 121 | L/W       | 0.05 not sig.    |
| silicic/rhy. Lava (1 tail) | 0.350       | 52  | Length    | 0.05 not sig.    | rhy.lava/FP lava            | 0.465       | 121 | Th/L      | 0.05 not sig.    |
| silicic/rhy. lava          | 0.305       | 52  | Thickness | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/rhy. lava          | 0.259       | 52  | Weight    | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/rhy. lava          | 0.245       | 52  | L/W       | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/rhy. lava          | 0.400       | 52  | Th/L      | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/FP lava (1 tail)   | 0.462       | 109 | Width     | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/FP lava            | 0.391       | 109 | Thickness | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/FP lava            | 0.368       | 109 | Weight    | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/FP lava            | 0.431       | 109 | L/W       | 0.05 not sig.    |                             |             |     |           |                  |
| silicic/FP lava            | 0.434       | 109 | Th/L      | 0.05 not sig.    |                             |             |     |           |                  |

Figure 3.4.20. Results of T-test conducted on Pontnewydd artefacts



| t-test                   | Probability | v   | test done | sig. Value       | t-test                        | Probability | v   | test done | sig. Value       |
|--------------------------|-------------|-----|-----------|------------------|-------------------------------|-------------|-----|-----------|------------------|
| <b>Fine silicic tuff</b> |             |     |           |                  | <b>Crystal lithic tuff</b>    |             |     |           |                  |
| fst/cry.lithic (1 tail)  | 0.177       | 139 | L/W       | 0.05 not sig.    | cry.lithic/xtal tuff (2 tail) | 0.042       | 90  | Length    | 0.05 significant |
| fst/cry lithic (2 tail)  | 0.645       | 139 | Th/L      | 0.05 not sig.    | cry.lithic/xtal tuff (2 tail) | 0.037       | 90  | Width     | 0.05 significant |
| fst/cry lithic (1 tail)  | 0.323       | 139 | Th/L      | 0.05 not sig.    | cry.lithic/xtal tuff (2 tail) | 0.003       | 90  | Thickness | 0.05 significant |
| fst/cry lithic (2 tail)  | 0.645       | 139 | L/Th      | 0.05 not sig.    | cry.lithic/xtal tuff (2 tail) | 0.013       | 90  | Weight    | 0.05 significant |
| fst/cry lithic (1 tail)  | 0.323       | 139 | L/Th      | 0.05 not sig.    | cry.lithic/xtal tuff (1 tail) | 0.439       | 90  | L/W       | 0.05 not sig.    |
| fst/cry lithic (2 tail)  | 0.000       | 139 | Thickness | 0.05 significant | cry.lithic/xtal tuff (2 tail) | 0.069       | 90  | Th/L      | 0.05 not sig.    |
| fst/cry tuff (2 Tail)    | 0.414       | 151 | L/W       | 0.05 not sig.    | cry.lithic/xtal tuff (1 tail) | 0.034       | 90  | Th/L      | 0.05 significant |
| fst/cry tuff (1 tail)    | 0.207       | 151 | L/W       | 0.05 not sig.    | cry.lithic/silicic (1 tail)   | 0.147       | 59  | Length    | 0.05 not sig.    |
| fst/cry tuff (2 Tail)    | 0.092       | 151 | Th/L      | 0.05 not sig.    | cry.lithic/silicic (1 tail)   | 0.181       | 59  | Width     | 0.05 not sig.    |
| fst/cry tuff (1 tail)    | 0.046       | 151 | Th/L      | 0.05 significant | cry.lithic/silicic (1 tail)   | 0.190       | 59  | Thickness | 0.05 not sig.    |
| fst/cry tuff (2 Tail)    | 0.033       | 151 | Length    | 0.05 significant | cry.lithic/silicic (1 tail)   | 0.128       | 59  | Weight    | 0.05 not sig.    |
| fst/cry tuff (1 tail)    | 0.036       | 151 | Width     | 0.05 significant | cry.lithic/silicic (1 tail)   | 0.331       | 59  | L/W       | 0.05 not sig.    |
| fst/cry tuff (1 tail)    | 0.083       | 151 | Thickness | 0.05 not sig.    | cry.lithic/silicic (1 tail)   | 0.475       | 59  | Th/L      | 0.05 not sig.    |
| fst/cry tuff (2 Tail)    | 0.050       | 151 | Weight    | 0.05 significant | cry.lithic/rhyolitic (1 tail) | 0.376       | 97  | L/W       | 0.05 not sig.    |
| fst/rhyolitic (2 tail)   | 0.035       | 159 | Length    | 0.05 significant | cry.lithic/rhyolitic (1 tail) | 0.337       | 97  | Th/L      | 0.05 not sig.    |
| fst/rhyolitic (1 tail)   | 0.069       | 159 | Width     | 0.05 not sig.    | cry.lithic/rhy. lava (1 tail) | 0.166       | 92  | Length    | 0.05 not sig.    |
| fst/rhyolitic (2 tail)   | 0.036       | 159 | Weight    | 0.05 significant | cry.lithic/rhy. lava (1 tail) | 0.258       | 92  | Thickness | 0.05 not sig.    |
| fst/rhyolitic (1 tail)   | 0.073       | 159 | L/W       | 0.05 not sig.    | cry.lithic/rhy. lava (1 tail) | 0.060       | 92  | L/W       | 0.05 not sig.    |
| fst/rhyolitic (1 tail)   | 0.491       | 159 | Th/L      | 0.05 not sig.    | cry.lithic/rhy. lava (1 tail) | 0.338       | 92  | Th/L      | 0.05 not sig.    |
| fst/rhy.lava (2 tail)    | 0.000       | 133 | Length    | 0.05 significant | cry.lithic/FP lava (1 tail)   | 0.067       | 128 | Length    | 0.05 not sig.    |
| fst/rhy.lava (2 tail)    | 0.000       | 133 | Width     | 0.05 significant | cry.lithic/FP lava (1 tail)   | 0.097       | 128 | Width     | 0.05 not sig.    |
| fst/rhy.lava (2 tail)    | 0.000       | 133 | Thickness | 0.05 significant | cry.lithic/FP lava (1 tail)   | 0.168       | 128 | Thickness | 0.05 not sig.    |
| fst/rhy.lava (2 tail)    | 0.000       | 133 | Weight    | 0.05 significant | cry.lithic/FP lava (1 tail)   | 0.084       | 128 | Weight    | 0.05 not sig.    |
| fst/rhy.lava (1 tail)    | 0.207       | 133 | L/W       | 0.05 not sig.    | cry.lithic/FP lava (1 tail)   | 0.357       | 128 | L/W       | 0.05 not sig.    |
| fst/rhy.lava (1 tail)    | 0.133       | 133 | Th/L      | 0.05 not sig.    | cry.lithic/igni (1 tail)      | 0.108       | 137 | Length    | 0.05 not sig.    |
| fst/FP lava (2 tail)     | 0.000       | 190 | Thickness | 0.05 significant | cry.lithic/igni (1 tail)      | 0.256       | 137 | Width     | 0.05 not sig.    |
| fst/FP lava (1 tail)     | 0.260       | 190 | L/W       | 0.05 not sig.    | cry.lithic/igni (1 tail)      | 0.342       | 137 | Thickness | 0.05 not sig.    |
| fst/igni (2 tail)        | 0.000       | 199 | Thickness | 0.05 significant | cry.lithic/igni (1 tail)      | 0.195       | 137 | Weight    | 0.05 not sig.    |
| fst/igni (1 tail)        | 0.462       | 199 | L/W       | 0.05 not sig.    | cry.lithic/igni (1 tail)      | 0.136       | 137 | L/W       | 0.05 not sig.    |
| fst/igni (2 tail)        | 0.043       | 199 | Th/L      | 0.05 significant | cry.lithic/igni (1 tail)      | 0.134       | 137 | Th/L      | 0.05 not sig.    |

Figure 3.4.20. Results of T-test conducted on Pontnewydd artefacts

### 3.5. Discussion of the results of the raw material studies

The raw materials used at the site (Bevins 1984, Clayton 1984) are all allochthonous and have probably reached the cave or its vicinity through the processes of glacial, periglacial and fluvial transport. The lithologies are very similar to unworked specimens in the cave deposits, and these in turn closely match the Ordovician rocks in Snowdonia, the Arenig Mountains of Gwynedd and those exposed in some areas of the Lake District (see Appendix 1: Petrological descriptions).

The raw material was obtained in the form of cobbles not normally greater than 25-30 cm in diameter (Green 1984). The size of the raw material and its quality has influenced the dimensions and refinement of the implements that could be produced. Fracture cleavages, that is microfaults resulting from compression and low-grade metamorphism of the rock strata, take the form of parallel planes of weakness, which may be discontinuous throughout the rock and occur in different planes in a single pebble. A further characteristic of the working of these volcanic rocks is the large number of *accidents de Siret* (Tixier *et al* 1980) among the artefacts and occurring experimentally (Newcomer 1984), in which flakes have split in two pieces more or less following the axis of percussion.

#### Flint

Flint is the classic rock type for British Palaeolithic tools and there is a close correlation, with the exception of Pontnewydd, between the distribution of Palaeolithic sites and the occurrence of flint bearing gravel deposits (Roe 1968, Fig 3.5.1.), although this distribution may also be influenced by climate. At Pontnewydd, however, only 10% of the worked material is flint. Flint that appears at the site is small (average length 19.0mm, width 15.2mm and thickness 6.8mm), and my work shows that the majority (89%) of small debitage (chunks, chips and spalls) is made of flint, which supports the suggestion (Green 1984) that knapping took place at the cave. The majority of the flint found at the site has been used to make retouched flakes (17%). The other two artefact types which dominate the flint distribution are core fragments (17%) and tool fragments (11.3%). These numbers show that flint at Pontnewydd was a valuable resource and was therefore exploited until it reached a state in which it was too fragmentary to be of further use. This value was probably due to its scarcity and the relative difficulty of finding flint of suitable size in the Devensian Irish Sea till deposits (something which neither this author or Livingston (1986) succeeded in doing). Unlike



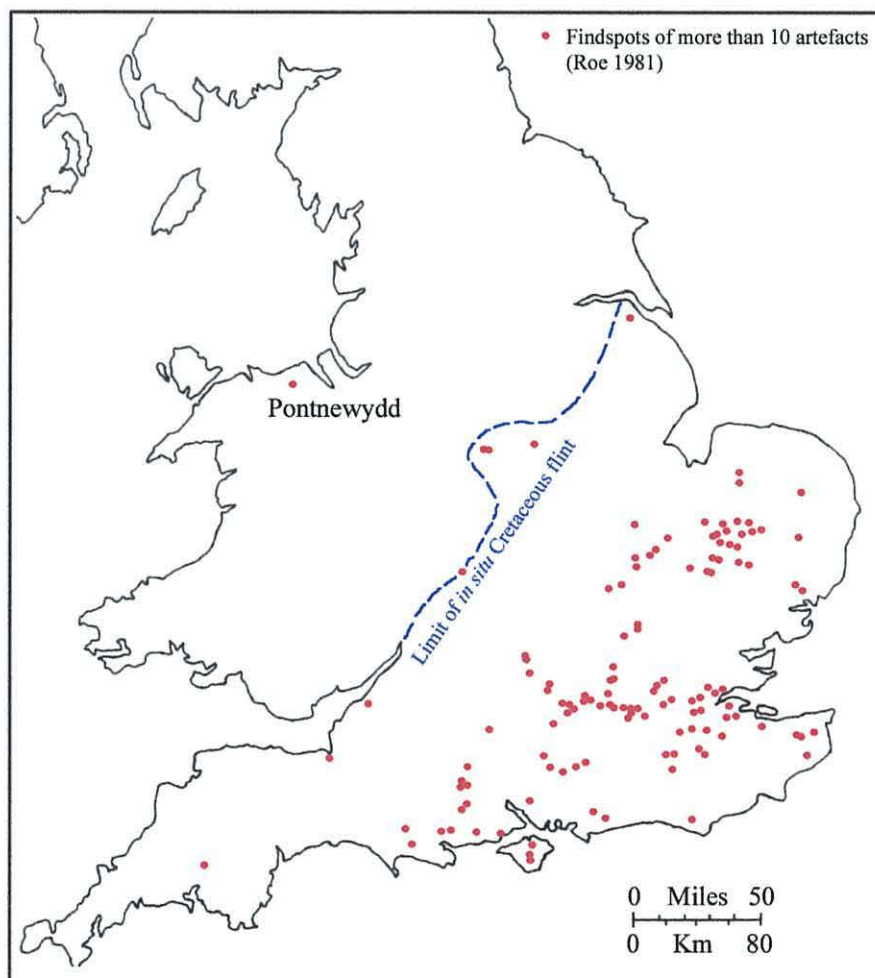


Fig.3.5.1 Pontnewydd Cave in relation to other Middle and Lower Palaeolithic sites in Britain. After Green 1984, based on work by Roe.

most of the raw materials used for artefact manufacture, flint is absent in the basal units of the cave deposits, but it may have been available nearby in the Irish Sea drift (Clayton 1984) or the local river gravels, as many pieces show evidence of water transport. The west coast of Scotland (300 miles to the north) is a likely source of the 'coalesced lephospheric' and 'skeletal rich' flints (Clayton 1984). Flint is also present in the green silt layer in Cefn caves (Green in Colcutt 1986) in a pre-Ipswichian context.

### Quartzite

Quartzite is the most common alternative to flint forming a major part of most African industries and those of the Lower Palaeolithic in the Midlands (Wymer 1986). African research (Leakey *et al.* 1972) has shown that quartzite tools, when used for skinning and cutting meat, retain a sharp edge for longer than tools manufactured from volcanic rocks. Experimental knapping work (Maloney *et al.* 1988) has shown that 59% of quartzite flakes are recognisable as artefacts, compared to 98% of flint flakes and only 14% of some volcanic debitage (Newcomer 1984). However, both quartz and quartzite are poorly represented at Pontnewydd. They are mainly used for cores, and constitute 20% of the miscellaneous core assemblage. Quartzite (100% silica) is theoretically superior to the silicic volcanic rocks (75-85% silica) that are used for the majority of the artefacts, but is less abundant in the local drift deposits.

### Other Sedimentary rocks

Sandstone and siltstone at Pontnewydd are mainly used for discoidal cores (18.5%), retouched flakes (11.1%) and handaxe trimming flakes (11.1%). Limestone is well represented at some sites (Terra Amata and Lazaret in France), but despite its abundance as a resource at Pontnewydd, it has been used for very little of the assemblage. This is probably due to its lack of durability.

### Volcanic Materials

90% of the worked material at Pontnewydd is volcanic material; altered igneous, pyroclastic or volcanoclastic material. This material is highly silicic therefore tough and suitable for knapping but has an inherent weakness: its pervasive spaced cleavage (Green 1984).

Volcanic rocks are frequently represented on Palaeolithic sites, although they are usually found on sites outside Europe (figure 3.5.4). Probably the largest assemblages



are from East Africa, where the use of basalt, andesite, trachyte, phonolite and nephelinite in the Olduvai gorge is well known (Leakey *et al.* 1972, Noll 1997). In Chile, Pleistocene man (Lanning 1971) used basalt, felsite and ignimbrite. Raw material types other than flint and chert were used preferentially at Ubeidiya in the Jordan Valley (Goren 1981), Terra Amata (Villa 1983), La Cotte de St. Brelade in Jersey (Callow and Cornford 1986) and Campas in the Tarn Valley (Tasovo 1976). At Terra Amata and Ubeidiya the rock types were used for specific tool types.

The volcanic lithologies found at Pontnewydd are, greatest weight first: ignimbrite, rhyolite tuff, rhyolite lava, feldspar-phyric lava, crystal lithic tuffs, fine silicic tuff, crystal tuff, andesite and dacite, microdiorite, and basalt (see figure 3.4.6, graph 3).

#### Rhyolite and Feldspar-phyric lava

Rhyolite and feldspar-phyric lava crystallise from a liquid state and are therefore less likely than the other rocks present to develop multiple fracture cleavages. This may explain their similar artefact range and implement frequency (Green in MacRae and Maloney 1988). They are mainly used for heavy-duty tools such as handaxes, choppers and cleavers as well as Levallois products. Rhyolite lava is mainly used for handaxes (22.8%), and Levallois flakes (19.3%). Indeed 17% of all handaxes found at Pontnewydd are made from rhyolite.

Rhyolitic tuff has a similar chemical composition to rhyolite but is more finely bedded and tends to contain smaller crystals, having formed from ash. It is mainly used for handaxes (19%) and levallois flakes, and a number of handaxe trimming flakes on this material have also been found (9%). Feldspar-phyric lava (FP lava) is mainly used for handaxes (19.0%) and Levallois flakes (11.1%), but is also substantially utilised for tool reuse (11.1%). This may be due to its relatively homogenous nature and hence its ability to retain an edge without shattering. Although used in the largest quantity for handaxes, FP lava still constitutes 17 % of the scraper population, and 20% of the number of reused tools are made from FP lava, a percentage second only to fine silicic tuff (FST).

#### Tuffs

Tuffs are deposited in beds and cleavages are more likely to develop. Crystal lithic tuff is the least homogenous of all the tuffs and the least suitable for the production of fine

artefacts. The Neanderthals at Pontnewydd appear to have been aware of these characteristics, as crystal lithic tuff is not used in large quantities and then mainly for the production of handaxes (25%). Crystal tuff is a relatively homogenous material, which is used for Levallois flakes (25%) and retouched flakes (11.4%), and some handaxes (11.4%). The crystal tuffs have a frequency of Levallois products similar to rhyolite (13% of artefacts). This would not necessarily be expected on geological grounds, but is probably due to their alteration under greenschist facies metamorphism, which has changed many of their constituent minerals and possibly homogenized them to some extent.

Although similar to tuffs in composition, ignimbrites are welded rather than bedded and are therefore more similar to rhyolites than tuffs in terms of their thermal history. This may explain why ignimbrites were rarely used for Levallois products, but primarily for disc cores (14.1%), crude cores (14.1%) and producing retouched flakes (12.5%). Ignimbrite dominates the discoidal core assemblage, providing 20% of these artefacts. Ignimbrites are highly durable material but also have a high degree of internal stability making them extremely difficult to flake unless they have suffered some degree of weathering. This was borne out by the author's experiments with some of the Pontnewydd raw material and also by Newcomer's (1984) experiments.

Fine silicic tuff is deposited in thin beds and therefore large cobbles are less likely to survive. FST is mainly used for retouched flakes (18.1%), levallois flakes (15.3%) and tool reuse (11.1%). FST provides a high percentage of Levallois artefacts (14%), scrapers (13%) and tool reuse (23%); the low mean size of these artefacts reflecting the raw material size. There is a scarcity of cores of fine silicic tuff. This may reflect a removal from the site of cores, or the bringing to the site of already roughed out artefacts; this may also be demonstrated by the lack of cortex on these artefacts (Green in MacRae & Maloney 1988).

The artefacts of both fine silicic tuff and flint have a high breakage frequency. This may be because these materials, even when broken, are more easily recognisable as artefacts, or because they occur in small pebbles, which are more likely to become flawed during transport. This is another demonstration of the similarity between these two materials when fractured.



### **3.5.1. Choice of rock type**

The choice of rock type is dependent upon three main factors: its suitability for the purpose, the ease with which it can be worked and its availability.

The physical properties of the rock determine how well a sharp cutting edge will be retained, or how long a hammerstone may stand up to repeated impacts. Stones that fracture conchoidally are the most desirable for flaking, and fracture is influenced by the percentage of silica within a raw material; for example flint (100% silica) fractures conchoidally. The second desirable feature in a raw material is its homogeneity. A homogenous rock lacks differences in texture, cracks, planes, flaws and other obstacles to the force of impact that passes through the material. The best rocks for knapping are therefore usually cryptocrystalline in nature, as in theory larger crystals will divert the impact force from its path. Rocks must also contain a degree of elasticity in order to carry the force through the body of material and produce a flake. The Lithic Grade Scale (Callahan 1979) gives some indication as to how easily certain rocks may be worked, although all the materials worked at Pontnewydd fall into his 'tough' category. Even within geological categories, the suitability of rocks for knapping may be highly variable, depending on their homogeneity, any metamorphism that they may have suffered and the extent to which they have been weathered. The final choice of material is often a compromise as the most durable rock may also be the hardest to work.

#### Choice of raw material in the Elwy Valley

Not all the erratics that occur in drift in the Elwy Valley area are used for artefact manufacture. Those avoided include local limestones and shales, weak weathered granites and some basic rocks, which would have been unsuitable for knapping, an element of choice has therefore been exhibited. Chi2 analysis has shown that raw materials were not used equally for all artefact types, and that the proportion of raw material used for each typology does not parallel the total use of that raw material throughout the assemblage. Both handaxes and flakes had significantly different profiles of rock use to the majority of other artefacts and in general, handaxes were preferentially made on FP lava, rhyolite lava and crystal lithic tuff, the rock types that on the basis of geological considerations should allow for the least refinement. Chi2 analysis also showed that cores and Levallois flakes showed significant differences in their profiles of rock use to the rest of the assemblage. Cores have been made on greater quantities of ignimbrite, the most highly silicic of the non-flint materials in the

assemblage, but also the hardest to work. Were these cores abandoned attempts at producing artefacts, or the result of a functional need to produce durable utilizable flakes from a difficult raw material? Levallois flakes appear significantly different because of the use of two less common rock types, crystal tuff and microdiorite. These rocks are less silicic than many of the other materials but are extremely homogenous, and seem to have suffered less internal weathering than some of the others. Indeed, in an informal knapping experiment (Section 3.3), crystal tuff proved the most desirable of the available materials. Overall, discussion of the macroscopic trends in the assemblage and the chi2 analysis (Section 3.4) leads to the conclusion that there is a degree of selectivity in the rock types that are used for tool manufacture at Pontnewydd. Profiles of rock type use are confused by the dominance of rhyolite and ignimbrite in the assemblage, and the lack of appropriate data to facilitate the comparison of the whole assemblage with the rock types available in the local area at the time of the habitation of Pontnewydd Cave.

The physical properties of these raw materials, including silica content and homogeneity can be used to account for the profiles of rock use for different typologies as seen in this assemblage (see Fig 3.5.2). Whilst this interpretation necessitates a lumping together of the geological categories into larger groupings, it must be remembered that the Neanderthals did not have the benefit of a petrological microscope and that the visual appearance of both FP lava and rhyolite lava, and ignimbrite and rhyolitic tuff is almost identical.

#### Lithological influence on flake dimensions

Having established a degree of selectivity in the raw materials, analysis of the measurements was undertaken in order to provide further clarification. It was hoped that the rock types would be clearly divisible on the basis of their mechanical attributes, for example the thickness, length and breadth of the artefacts produced. The variance about the mean of flint artefacts (as shown by the f-test), for all dimension measurements, was significantly different to all other raw materials. This was largely due to the very small size of many of the flint artefacts. The mean dimensions of artefacts of fine silicic tuff were significantly different to those of all other rock types (as shown by the t-test). Generally speaking this was also related to the relatively small size of artefacts of fine silicic tuff. The fact that artefacts of such small size were made out of these materials implies either that a small cutting edge produced on flint or fine



silicic tuff was as effective as a larger cutting edge on a different raw material, or that these small artefacts were being used for different purposes.

The feature that appears to divide the artefacts into the clearest groupings is that of thickness. It is also the category that provides groupings that are mirrored by the data obtained from examination of macroscopic trends as shown above. The rock types group together based on their mean thickness as shown in Fig.3.5.3.

It is possible that a rock mechanics experiment performed under controlled conditions, would indeed produce results that could place the raw materials into definite categories based on their flaking properties. Such an experiment could involve the knapping of flakes from a variety of raw materials using a hard hammer attached to a pendulum dropped from a set height, to produce an identical force of impact and angle of impact for each material. However, the assemblage at Pontnewydd is a varied selection of material, produced by a number of different individuals and cannot supply such objective measurements on the raw materials.

#### Choice of blanks in the Elwy Valley

Many of the artefacts at Pontnewydd show evidence of manufacture by striking flakes off pebbles, rather than angular blocks, and the shape of the blanks available must have played a part when deciding which materials to work. At La Riera in Spain pebble size seems to have affected the choice of raw material (Strauss 1980). White (1995) demonstrated that the shape of handaxes in southern Britain is largely dependent on the dimensions of the primary form of the raw materials i.e. the shape of the handaxe is determined by the shape and size of the blank. Ashton and McNabb (1994) were able to reconstruct the size and shape of large cutting tool blanks and therefore indicate to what extent this shape had affected the finished artefact. This is concurrent with the work of Fish (1979) who illustrated that the main constraint on tool manufacture is blank sizes available, rather than raw materials present.

At Pontnewydd, fine silicic tuff occurs in tabular fragments, which provide the perfect blanks, whereas the majority of rhyolite available would have been in the form of glacially rounded boulders. The size of the cobbles available may have limited the possibilities for thinning and refining, resulting in thicker pieces (Maloney *et al.* 1988). When experimentally flaking both glacially weathered pebbles and river washed

cobbles from the Pontnewydd area, I found the rounded cobbles more homogeneous and lacking in flaws than those directly from the glacial drift. Perhaps the action of water has broken cobbles along lines of weakness highlighted during glacial transport, leaving relatively predictable cobbles. Certainly it is likely that rather than extracting materials directly from the glacial drift, cobbles would have been collected from talus slopes at the base of the limestone cliffs or stream-bed deposits. It is also worth remembering that the effects of solifluction processes, vegetation and snow cover would have made different areas within the Elwy valley suitable for collecting materials at different times of year.

Whether the raw materials at Pontnewydd derived directly from the glacial till or were collected from the banks of the river Elwy, it is clear that they would have been readily available within the local 'foraging radius' (Mellars 1996). This is consistent with the raw material procurement patterns on Middle Palaeolithic sites in southwestern France (Geneste 1988, Turq 1988) which reveal a strong predominance of material derived from very local sources. In addition, all stages of the lithic reduction sequence at Pontnewydd are represented, from the initial importation of cobbles to the production of finished tools. This indicates that knapping took place at the cave and is consistent with the use of raw materials derived from the most local foraging zone of 4-5km from the site (Geneste 1988). It is likely that cobbles were subjected to trial flaking before transportation back to the cave, because as with many glacially weathered rocks, it would be difficult to tell the texture from the outward appearance of a pebble.

Many experiments, both formal and informal have been conducted on the viability of non-flint materials for knapping (Newcomer 1984, Jones 1979, Maloney *et al.* 1988) and the influence of raw material on morphology in the Acheulian (Ashton and McNabb 1994, Clark 1980, Toth 1982, White 1995). Jones (1979) replicated handaxes and cleavers from the Olduvai Gorge and suggested that raw material fracture properties and least-effort flaking strategies influenced aspects of biface morphology. By making and then using, bifaces of basalt and phonolite, he indicated that hominids had responded to the raw material mechanical properties by varying the intensity of retouch performed on the raw materials. This had the result of making some of the artefacts appear 'cruder' than others, a point which is paralleled in the assemblage at Pontnewydd. Experiments by Newcomer (1984) seem to demonstrate that the raw materials at Pontnewydd did not limit the tool types present, rather they may have



limited the possible levels of refinement.

Jones also demonstrated that a greater variety of raw materials in an assemblage resulted in increased morphological variability. His retouch approach has important considerations for the curation of certain materials over others. Clearly, coarse retouch of an artefact will reduce its size more rapidly than fine retouch. Although the igneous tools from Pontnewydd would have been functionally efficient for a short time, perhaps these raw materials would have required replacing more often than flint. This functional approach implies that stone knappers were primarily concerned with cutting edge characteristics and less concerned with maintaining or manufacturing plan forms. This may be indicated at Pontnewydd by the constant re-use of the flint tools indicated by the large amount of small flint debitage, and also the profiles of tool re-use within the assemblage.

Villa (1983) suggested that the physical properties of the raw material at Terra Amata influenced technology thereby causing assemblage variability. Experimental knapping work performed on quartzite (Maloney *et al.* 1988) has demonstrated some interesting points, which may be equally applicable to other highly silicic coarsely crystalline materials such as rhyolite. This work suggests that the nature of the raw material means that the strongest and sharpest edge is formed by the removal of the first few flakes, and the unpredictability of the material may limit continued flaking and therefore result in the production of a less complicated tool. Some of the observations made during these experiments apply particularly to the Pontnewydd assemblage (see Section 3.3: Informal knapping experiment).

### **3.5.2. Pontnewydd within its regional context**

Pontnewydd falls within the northern Province of Lower Palaeolithic sites (Figure 3.5.1) and a timescale which may be referred to as Period 1 (Gamble 1986).

Comparison of Pontnewydd with other sites of similar age is rendered difficult by the use of hard rocks, which may have affected both the technology and typology which remain in the archaeological record. However, the industry can be said to be Acheulian, rich in handaxes and the use of Levallois technique and with a low proportion of end-scrapers and truncated blades. Green (in Green *et al.* 1984) compares the industry with several north-western French industries described by Tuffreau (1976a, 1976b, 1978),

such as Bapaume, Biache-Saint-Vast (Tuffreau 1988) and Mesvin IV (Cahen 1981).

Within a more local context, there are no fully comparable sites to Pontnewydd. In Britain, there is a lack of sites of comparable age to Pontnewydd. Green (1984) draws parallels in terms of both age and industry with Caddington (Roe 1981) which is, unfortunately, in an area of widespread glacial flint. He also suggests Shide on the Isle of Wight (Jacobi *in press*), and the Mousterian assemblage at Robin Hoods Cave, Cresswell Crag (Dawkins 1876, 1877). However, he concludes that none of these assemblages are sufficiently similar to that at Pontnewydd to be worthy of comparison.

Most authors have assumed that variability between Palaeolithic assemblages reflects different cultural traditions between hominid groups (Bordes 1961, Collins 1969). Differences in duration and range of activities may also provide differences in an assemblage (Clark 1959). However, the wide ranging differences which prevent the Pontnewydd assemblage from being compared with any other within Europe may be a result of the physical properties of the raw material (Ashton & McNabb 1994, Callow 1994, Clark 1980).

It is suggested that any typological differences observed at Pontnewydd are the result of a functional but not refined artefact being produced at a relatively early stage in the knapping process. Dibble (1984) argued that Mousterian stone tools could assume a succession of forms depending on the amount and degree of retouch. The Pontnewydd artefacts are most likely the first stage in a graded succession of forms. Partly as a result of the constraints of the raw material, and partly as a result of choice, the inhabitants of Pontnewydd did not fully refine their tools.



| Rock type           | Silica content | Homogeneity | Grain size | Availability | % of artefact numbers |
|---------------------|----------------|-------------|------------|--------------|-----------------------|
| Flint               | 95%            | 10          | 1          | Low          | 24.4                  |
| Fine silicic tuff   | 90%            | 10          | 1          | Low          | 14.0                  |
| Ignimbrite          | 80-85%         | 5           | 3          | High         | 10.6                  |
| Rhyolite lava       | 75%            | 7           | 3          | High         | 9.7                   |
| Rhyolitic tuff      | 80-85%         | 8           | 2          | High         | 9.8                   |
| FP lava             | 75%            | 7           | 3          | High         | 10.1                  |
| Crystal tuff        | 60%            | 8           | 2          | High         | 6.1                   |
| Crystal lithic tuff | 55%            | 4           | 4          | High         | 4.8                   |
| Quartzite           | 90%            | 8           | 2          | Low          | 1.6                   |
| Sandstone           | 40-80%         | 7           | 4          | High         | 5.7                   |
| Andesite            | 55%            | 6           | 3          | Medium       | 1.2                   |
| Microdiorite        | 52%            | 6           | 3          | Medium       | 1.4                   |
| Basalt              | 48%            | 7           | 2          | Medium       | 0.6                   |

Figure 3.5.2. Table showing physical characteristics of the main lithologies found at Pontnewydd. Homogeneity is expressed on an ascending scale from 1-10, and grain size on an ascending scale from 1-5.

| <b>Raw Material</b> | <b>Av. L (mm)</b> | <b>Av. Br (mm)</b> | <b>Av. Th (mm)</b> | <b>Av. Wt (g)</b> | <b>Total Wt (g)</b> |
|---------------------|-------------------|--------------------|--------------------|-------------------|---------------------|
| Flint & Chert       | 19.0              | 15.2               | 6.8                | 9.2               | 1889.8              |
| Fine silicic tuff   | 48.9              | 40.8               | 13.4               | 52.9              | 5394.7              |
| Ignimbrite          | 65.2              | 55.5               | 22.3               | 136.8             | 13409.6             |
| Rhyolitic tuff      | 65.4              | 54.9               | 20.2               | 101.2             | 12175.3             |
| Rhyolite lava       | 67.4              | 57.8               | 21.0               | 118.3             | 10407.0             |
| FP lava             | 62.6              | 51.2               | 20.4               | 100.1             | 9012.3              |
| Crystal pumice tuff | 73.9              | 57.6               | 22.9               | 159.4             | 7333.5              |
| Crystal tuff        | 57.3              | 45.6               | 15.0               | 68.6              | 3604.0              |
| Quartzite           | 58.5              | 46.9               | 28.4               | 165.2             | 2312.7              |
| Sandstone           | 54.4              | 45.0               | 17.9               | 74.5              | 2309.7              |
| Andesite & Dacite   | 79.8              | 61.9               | 25.7               | 170.1             | 1531.3              |
| Siltstone           | 58.8              | 40.4               | 18.9               | 46.8              | 748.2               |
| Basalt              | 67.0              | 63.6               | 21.9               | 96.9              | 581.2               |
| Microdiorite        | 66.3              | 54.9               | 15.7               | 66.7              | 800.6               |

Figure 3.5.3. Average dimension measurements for artefacts made on each raw material.



| Rock Type  | Site  | Reference   |
|--|---|---|
| Limestone  | Terra Amata, France.<br>Lazaret, France.<br>Ambrona, Spain. | Villa 1983  |
| Quartzite  | Berinsfield (15%) & Stanton Harcourt (29%),<br>Oxfordshire  | MacRae 1988                                       |
|  | Wolvercote, England   | Tydesley 1986                                     |
|  | Ambrona, Spain  | Villa 1983  |
|  | Tarn & Agout Valleys, France                                | Tasovo 1976                                       |
|  | Pinedo & Aculadero, Spain                                   | Querol & Santonja 1979, 1983.                     |
|  | North Warwickshire (42.5%)                                  | Saville 1988                                      |
|  | Rodao & Milharos, Portugal                                  | Raposo, Carriera & Salvador<br>1985, Raposo 1987. |
| Ignimbrite, Rhyolite,<br>Various tuffs, Microdiorite,<br>Andesite, Dacite, Basalt,<br>Sandstones | Pontnewydd, North Wales (90%)                               | Green 1984, 1988, 1989, 1991,<br>1995             |
| Andesite   | Brandon, Warwickshire                                       | Fennel & Shotton 1977                             |
|  | Beckford, Worcestershire                                    | MacRae 1988                                       |
|  | Hilton, Derbyshire  | Posnansky 1963                                    |
|  | Abingdon, Oxfordshire                                       | MacRae 1988                                       |
|  | Berinsfield, Oxfordshire                                    | MacRae 1988                                       |
| Ignimbrite   | Carrant Valley, Warwickshire                                | Whitehead 1980                                    |
| Basalt, Nephelinite,<br>Phonolite, Trachyte,<br>Pyroxene-porphry,<br>Obsidian                    | Olorgesaille, Kenya   | Noll 1997   |

Figure 3.5.4. Use of Non-flint Raw Materials in some other sites of Lower Palaeolithic age

### 3.6. Conclusions

Several conclusions emerge from this section. Firstly, petrological analysis of a selection of the artefacts from the assemblage enables the classification of the artefacts into the appropriate geological categories. It also provides provenances for some of the raw materials, mainly located in the Llewelyn and Snowdon Volcanic Groups, but occasionally in the Borrowdale Volcanic Group of the English Lake District. This enables glacial cobbles that had derived from similar sources in Snowdonia to be collected for an informal knapping experiment, which served to highlight some of the physical properties of these raw materials.

Second, certain raw material types dominate the Pontnewydd lithic assemblage. These raw materials are those which contain a greater percentage of silica to the other materials. The correlation shown in the chi2 tests imply that Pontnewydd hominids selected those materials with superior properties relating to tool manufacture and use. Although the original distribution of rock types available in the local area is not known, the dominance of these materials suggests that the Pontnewydd hominids were aware of the physical and mechanical properties of these raw materials.

Third, metrical data obtained from all the artefacts in the assemblage except fragments indicated that artefacts made on flint were considerably thinner than those made on any other material, regardless of their shape. Artefacts made of fine silicic tuff were considerably smaller and thinner than other non-flint artefacts. It would be interesting to investigate physical properties such as the edge angle and stepped flake scar counts on each of the raw materials to see if morphological differences could be determined throughout the assemblage. This would imply that different raw materials had a measurable effect on the morphology of an artefact, a feature that it was not possible to prove during this study.

Finally, the distribution of artefact types within the areas of the new entrance and the main cave exhibits some differences. A greater percentage of artefacts at the new entrance are chips, flake fragments, cores, levallois flakes and scrapers, and a lesser percentage are disc cores, handaxes, and retouched artefacts. There is a greater percentage of flint and chert,



crystal tuff, rhyolitic tuff and quartzite at the new entrance and a significantly lower percentage of rhyolite lava and FP lava. Chi2 analysis was conducted on the material to ensure these differences were significant. It demonstrated a significant difference in the raw materials used for chips, cores, flakes, levallois flakes, and total use of raw materials used in the Main Cave and the New Entrance. There was no significant difference in the use of raw materials for scrapers and the numbers were too small for the results of the other categories to be valid. Overall the assemblage at the New Entrance seems to contain a greater proportion of small debitage, which may imply a less reworked deposit or a gentler mode of emplacement for the material. If the assemblages in the Main cave and at the new entrance are non-contemporaneous, the greater proportions of flint, crystal tuff and rhyolitic tuff at the New Entrance, could indicate that a different source within the glacial drift was being used.

In addition, the incorporation of the archaeological material into a debris flow includes dilution factors and a complex relationship between debris discharge rate and the uptake of archaeological material. We assume that the assemblage found at Pontnewydd is representative of the original material, but in a secondary context like this we cannot be sure how much of this material was incorporated into the debris flows.

**Investigations into the Mineralogy and Petrology of the Sediments and  
Artefacts from the Lower Palaeolithic site of Pontnewydd Cave.**

**Chapter 4**

**HEAVY MINERAL ANALYSIS OF THE  
SEDIMENTS**



## **4. INTRODUCTION**

The sediments at Pontnewydd are debris flows, thought to have derived from fluidisation of the mainly glacial deposits located around the cave mouth during periods of glacial regression. The influence of parent material on the properties of sediments is well recognised, and the earliest theories of sediment formation were based on the sediment being solely a function of rock weathering. Although sedimentary studies have expanded well beyond this limited interpretation, the geological component of a sediment is still a major factor. This chapter outlines the methodology used for the study of the sediments (section 4.1) and then provides an overview of the sources of the various minerals observed (section 4.2). It then provides a mineralogical survey of the sediments from Pontnewydd Cave, by heavy minerals analysis, the results of which are outlined in section 4.3. The trends exhibited by the heavy minerals are then discussed, with the application of cluster analysis, in section 4.4. The results obtained from particle size analysis of the sediments is discussed in section 4.5. The interpretation of the combined results and their general conclusions are outlined in section 4.6.

### **4.1. Methodology for study of the Sediments**

#### **4.1.1. Sampling Strategy**

As part of the post-excavation analysis in this thesis, examination of the cave sediments was undertaken, to supply information on their provenance, the mechanism of cave infill, and implications for the artefacts and fauna. A set of samples was taken from a single complete section in the cave (site F), thus minimising lateral variation so that depositional processes and post-depositional environmental conditions would be consistent throughout the samples. A further set of samples, particularly from the Intermediate Complex, were taken during excavation.

The samples examined as part of this thesis are mainly from Area D, Area F, and the New Entrance, see Figures 4.1.1, 4.1.2, and 4.1.3. Some samples are from the Deep Sounding, which is illustrated in the composite section (Figure 2.3). Although the chronostratigraphic succession is approximately the same throughout the cave, corresponding to the sequence presented in Section 2.5, there is considerable variation as to which units are represented within different areas.

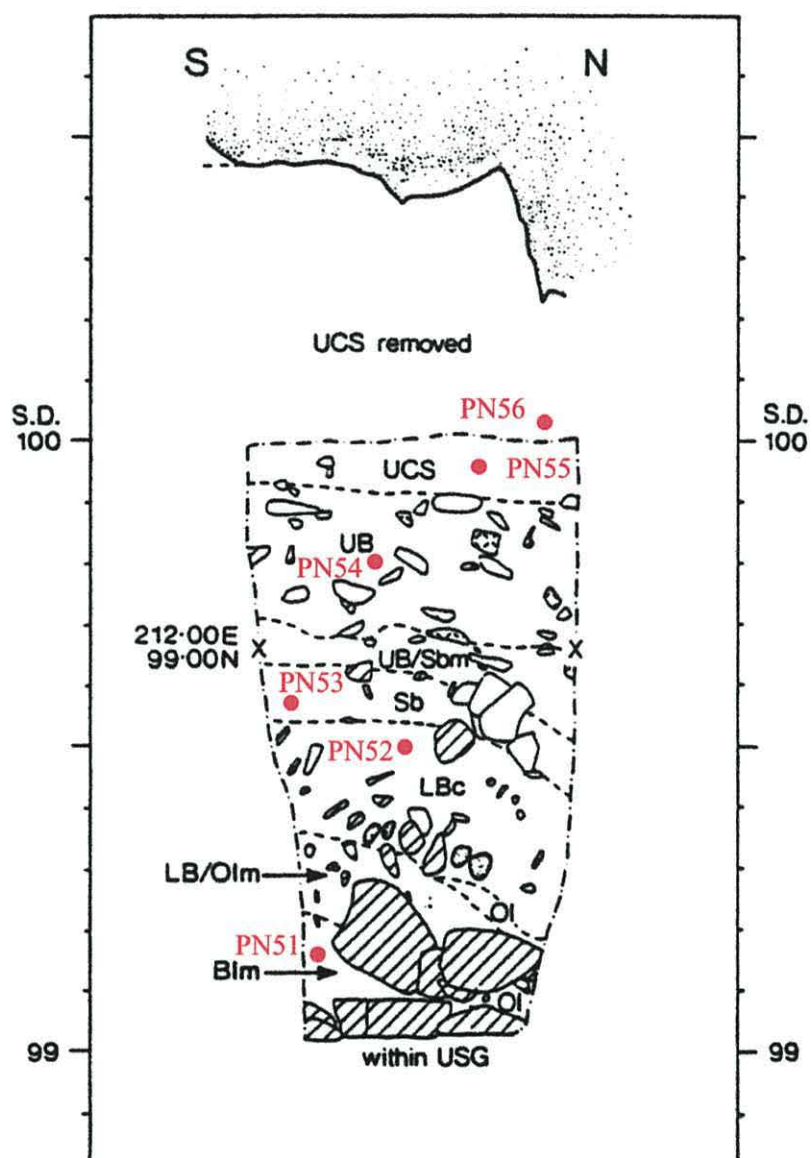


Figure 4.1.1 Location of samples used in this study, square G5 (east facing section) Pontnewydd Cave. (Section from National Museums & Galleries of Wales unpublished data).



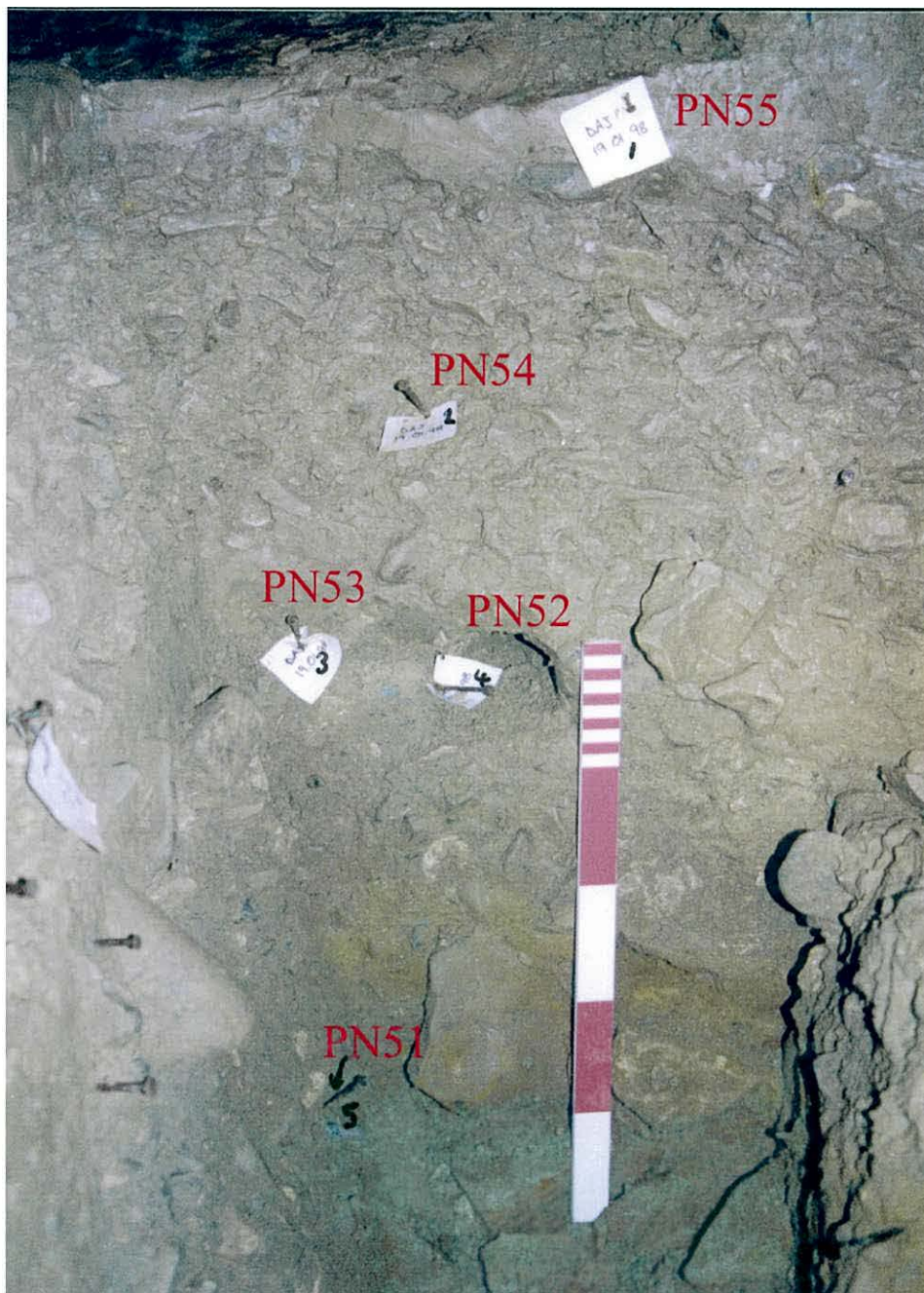


Figure 4.1.2 Photograph, corresponding to section illustrated in figure 4.1.1, showing the location of samples used in this study. Large bars 10 cm.

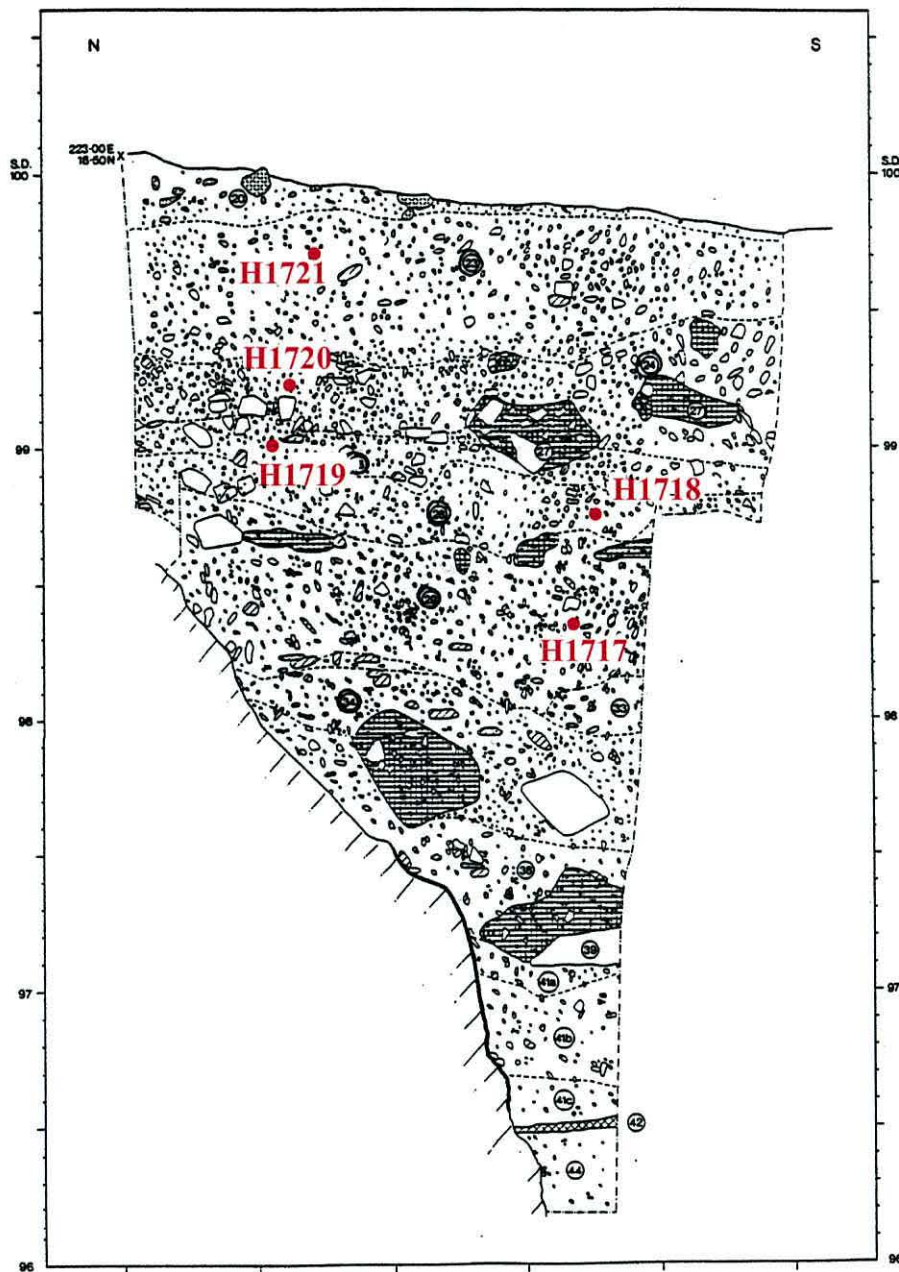


Figure 4.1.3. Site H, Pontnewydd Cave. West facing section showing the location of samples used in this study. *Units = metres.*



#### 4.1.2. Sample Collection

The sediment samples were collected from Pontnewydd Cave from the northwest face of Site F (Fig. 4.1.1) with a trowel and care was taken not to cause cross-contamination. Samples were taken from each of the major visible layers in the section and labelled as indicated in Fig 4.1.4. The preparative techniques and analyses outlined below were also applied to a number of samples which had been collected during excavation, by D.A. Jenkins, in 1984 from the north facing section at Site D, and by S. Aldhouse-Green, collected in 1989 from the section at the New Entrance.

| Location                             | No.   | Description               | % H <sub>2</sub> O | %sg>2.95 |
|--------------------------------------|-------|---------------------------|--------------------|----------|
| Pontnewydd Cave.<br>Site F. NW face. | PN51* | Buff Intermediate         | 22.30              | 4.5      |
| Pontnewydd Cave.<br>Site F. NW face. | PN52  | Lower Breccia bed (c)     | 6.80               | 0.87     |
| Pontnewydd Cave.<br>Site F. NW face. | PN53  | Silt deposit              | 14.80              | 0.85     |
| Pontnewydd Cave.<br>Site F. NW face. | PN54  | Base of Upper Breccia bed | 14.20              | 0.64     |
| Pontnewydd Cave.<br>Site F. NW face. | PN55* | Top of Upper Breccia bed  | 13.80              | 0.50     |
| Pontnewydd Cave.<br>Site F. NW face. | PN56  | Upper Clays and Sands     | 19.80              | 0.54     |

Figure 4.1.4: Samples from Pontnewydd Cave, collected 19/1/98.

*\* denotes samples which required treatment with sodium dithionite*

#### 4.1.3. Preparative techniques

The samples were weighed and placed in an oven at 100°C for 24 hours to dry. The water loss for each sample was then calculated. For each sample, the analysis focussed on two major areas: the identification and quantification of the heavy minerals; and measurement of the particle size distribution. Preparations were also made for identification of the clay minerals.

#### 4.1.3.1. Dispersion

For subsequent analysis it was necessary to separate the clay and sand fractions. This was undertaken as follows. The oven dried sample was passed through a 2 mm sieve and approximately 50g of the <2 mm fraction was placed in a 1 litre measuring cylinder, to which 1 litre of water and 10 ml of Calgon solution (to aid dispersion) were added. This mixture was agitated with a plunger and left to settle for 8 hrs, in accordance with Stokes' Law for sedimentation rates of clay, shown in Equation 1.

#### **Stokes Law:**

$$V = \frac{2 (d_1 - d_2) g r^2}{9f}$$

Where: V = settling velocity of particles

$d_1$  = specific gravity of particles

$d_2$  = specific gravity of liquid

$g^2$  = gravitational acceleration

r = radius of particles

f = viscosity of liquid at 20°C

#### Equation 1: Stokes Law of Settling

After 8 hrs, the top 10 cm containing the <2  $\mu$ m fraction were siphoned from the measuring cylinder into a glass beaker.

#### 4.1.3.2. Saturation of the clay fraction

For subsequent analysis it was desirable to have the clay fraction saturated with  $K^+$  and  $Mg^{2+}$ . To achieve this, the clay suspension obtained by siphoning off, above, was divided between two 300 ml glass beakers and one 100 ml polythene centrifuge tube. To one of the beakers, sufficient solid KCl (mol.wt. 74.5) was added to make a 1M solution, and to the other beaker sufficient solid  $MgAc_2$  (mol.wt. 214) was added to make a 0.5M solution. The 100 ml portion was left untreated for comparative purposes. The treated suspensions were left to stand overnight, the supernatant was decanted and they were poured into polythene centrifuge tubes to be re-dispersed with distilled water. All portions, both treated and untreated, were then centrifuged at 2500 rpm for 45 min. After centrifuging the supernatant was discarded and c.1ml of the remaining dispersed sediment was pipetted onto a clean glass slide (2.4 x 3.6 mm). These clay portions were left to dry and then analysed using XRDA. Although chlorite, vermiculite, dominant hydrous mica and kaolinite were identified, there was little difference in the mineralogy between samples so they will not be discussed further here.



#### 4.1.3.3. Removal of free iron oxides

This initial procedure was necessary for the samples indicated (Table 4.1.4) to remove amorphous Fe/Al hydrous oxides which would confuse the XRD traces. 20 g of dithionite was added to a beaker containing the sample and approximately 800 ml of citrate buffer (containing 0.15M sodium citrate and 0.05M citric acid). This was covered and placed in an oven at 80°C for an hour and stirred frequently. After cooling, the supernatant was carefully discarded, avoiding any loss of fine material, and the precipitate washed in distilled water and centrifuged twice, the supernatant from each centrifugation being discarded. This procedure was carried out before proceeding with K/Mg saturation as above.

#### 4.1.3.4. Separation of the fine sand fraction

For optical mineralogical analysis the 200  $\mu$ m-63  $\mu$ m fraction was required. This was obtained by washing the pre-treated sample, from which the clay fraction had been removed, through meshed sieves (630  $\mu$ m, 200  $\mu$ m and 63  $\mu$ m) with a fine jet of water. In each case, the material retained was flushed into an evaporating basin, surplus water was decanted off, and the sample was dried in an oven at 100°C. The >630  $\mu$ m and >200  $\mu$ m samples were stored for subsequent study, and the 200-63  $\mu$ m fraction was separated into its light and heavy mineral fractions.

#### **4.1.4. Heavy Mineralogy**

The small percentages (0.5-5.0%) of 'heavy minerals' ( $sg > 2.95$ ) in the fine sand fractions (63-200  $\mu$ m) of soils and sediments can often yield valuable information about parentage since different rock types produce different characteristic heavy mineral assemblages. This enables the provenance of sediments to be diagnosed. Such heavy mineral fractions are separated by floating off the main bulk of the light minerals - quartz and feldspar - in a liquid of appropriate density (e.g. tetrabromoethane  $sg = 2.95$ ). The densities of most mineral species vary over the range 2.5-5.0 according to composition and structure. The fine sand fraction was studied because in this size range grains are mainly composed of individual minerals (grains >200  $\mu$ m tend to be polymineralic) but are relatively easy to identify under the microscope.

##### 4.1.4.1. Separation of light and heavy mineral fractions

Tetrabromoethane was filtered through a 9 cm Whatman 541 filter paper into a clean,

dry, glass centrifuge tube and an accurately weighed amount of the 200-63  $\mu\text{m}$  fraction (around 4 g) was added. The mixture was stirred thoroughly with a glass rod and then centrifuged at 1500 rpm for five minutes. The two portions within the tube were then stirred separately without mixing, and the mixture centrifuged again. This process was repeated twice.

Once the light and heavy fractions had separated within the tetrabromoethane, a modified stopper was carefully inserted into the tube. This stopper was designed to securely fit the tapered tube, about 1 cm from its base, so the lighter minerals could be poured off without disturbing the heavier minerals beneath. The tetrabromoethane suspension containing the lighter minerals was suction-filtered through a Whatman 541 filter into a conical flask. The tetrabromoethane was retained for future use. The light fraction remained as a residue and was washed with acetone and placed in a 100°C oven to dry.

Any adhering light mineral particles were flushed out with a jet of water and then rinsed out with acetone. The stopper was released and the heavy mineral contents were washed, first with acetone, then with water, and poured out onto a watch glass. Care was taken to ensure all the heavy minerals were washed onto the watch glass. The watch glass was swirled to remove excess liquid. The heavy fraction was then labelled and placed in a 100°C oven to dry.

#### 4.1.4.2. Preparation of slides

For the detailed microscopic examination and identification it was necessary to concentrate on the small fraction of heavy minerals which could give greater information about the parentage of the sediment. Samples are normally mounted permanently in Epoxy resin ( $\text{RI}=1.54$ ), but may also be examined under liquids of different Refractive Indexes such as methyl salicate, in which individual grains may be manipulated and their RI's measured. The epoxy resin was prepared and placed in a 50 mg sample jar in an ultrasound bath to remove any bubbles. A small amount was then pipetted onto a clean dry slide and c. 0.01g of the heavy mineral sample were scattered over the resin. The grains were dispersed using a mounted needle to ensure they all lay in the same plane. A coverslip was gently applied and the resin left to dry. A few unmounted samples were also examined using reflected light.



#### 4.1.4.3. Identification of Heavy minerals

The samples were investigated using a Swift polarizing microscope with x10 and x40 objectives, predominantly using transmitted light. The characteristic properties of the individual non-opaque mineral species were noted and identified on the basis of their shape, relief, cleavage, inclusions, colour, pleochroism, extinction, length-fast or slow optic orientation, and interference colours. Detailed descriptions of the mineral species observed are presented in section 4.3.

Samples were analysed initially by a visual estimation on a scale of abundance running from 0-8 on an approximately logarithmic scale. Further analysis of many of the samples was conducted by point –counting, and recording the percentage of all non-opaque minerals present.

#### **4.1.5. Particle Size Classification**

After dispersion, the distribution of grains between selected size classes was measured. Particle size grading of soils is normally carried out on the fine earth fraction (<2 mm) and is standardised in terms of three classes - sand, silt and clay - based on the Wentworth scale.

The larger sand fractions were separated directly using sieves of suitable aperture (2 mm, 630  $\mu\text{m}$ , 200  $\mu\text{m}$  and 63  $\mu\text{m}$ ) and a strong jet of water. The smaller size fractions were analysed using a Sedigraph, which uses Stokes' Law (Equation 4.1) to calculate the concentration of grains of a particular settling velocity within a suspension whose density is known.

## **4.2. Heavy Mineral habits observed and their sources**

Pontnewydd Cave is sited close to the junction of Lower Palaeozoic mudstones and sandstones to the southwest and Carboniferous and Triassic limestones and sandstones to the north and east. It is also in an area where there has been a succession of complex glacial events including invasion by the Irish Sea ice from the north (Embleton 1970, 1984) leading to various superficial deposits of diverse origins. It was anticipated that this diversity might be reflected in the mineralogical composition of the derived cave sediments. Mineralogical analyses were therefore made of the heavy (sg. >2.95) fine sand (200-63µm) fraction (see Section 4.1: Methodology). The results are presented in Figures 4.1-4.6, and further details of the analyses can be found in Appendix 4.1.

The heavy mineral content of a sediment is a function of four variables: lithology of the source area, chemical stability of minerals, physical durability of the mineral and post depositional or diagenetic changes. These changes may include weathering at the site of deposition, replacement, destruction or etching (Folk 1974, Marshal 1977).

One of the aims of this study is to divide the sediments into two possible groups, those derived from Irish Sea till and those derived from the Welsh till. According to Younis (1983) the minerals showing the most significant variations between the Irish Sea and Welsh till are zircon, tourmaline, garnet, orthopyroxenes, clinopyroxenes, epidote and clinozoisite. The Irish Sea till is further characterised by its minor mineral component including staurolite, kyanite, and andalusite (Smithson 1953). It is likely that this contribution derives from the metamorphic rocks outcropping on the Irish Sea floor, and the Triassic rocks that form a major component of the geology of the basin.

The heavy mineral suites of each till represent the contribution of different lithologies to the till. Metamorphic rocks are represented by kyanite, andalusite, staurolite and glaucophane, silicic igneous rocks are represented by the presence of euhedral zircon and magnetite, garnet and green amphibole and yellow-orange rutile (Jenkins 1964) and mafic igneous rocks are represented by augite, enstatite and leucoxene.

### **4.2.1. Zircon ( $\text{ZrSiO}_4$ )**

Zircon occurs in all the samples analysed, in varying habits. Most of the zircons observed in the Pontnewydd samples are euhedral or subhedral and are therefore likely



to derive directly from igneous rocks. It is possible that the different euhedral habits observed derive from different volcanic sources, and it would be rewarding to research this further (see Jenkins 1964). Rounded zircons in the Pontnewydd samples probably derive from slightly water-worn tuff. Many of the zircons contain small, rounded opaque inclusions. Colourless (PN1, PN55), pale yellow (PN53) and pink (H1719, H1720) varieties were detected in the Pontnewydd samples.

Zircon is a characteristic heavy mineral of the rhyolitic lavas and tuffs of north Wales (Jenkins 1964), and an accessory mineral in granites, granodiorites and pegmatites (Bevins 1994). In Snowdonia zircon has been recorded in microgranites and granophyres, as well as in some extrusive rhyolitic rocks of the area (Bromley 1969; Howells *et al.* 1991). Zircon has also been observed in microtonalitic and granitoid rocks of Lower Palaeozoic age exposed across the Llyn peninsula (Croudace 1982). It is also found as a detrital mineral in the sedimentary arenaceous rocks of north Wales (Boswell 1927). Jenkins (1964) observed yellow and pink zircons as detrital grains and noted pink zircons in Cwm Idwal soils, and yellow zircons in soils from Drum, northeast of Bethesda (SH 708 696).

Zircon could also be derived from the Irish Sea drift (Section 2.4) as it is a common and widespread accessory mineral in the granitic rocks of the English Lake District, for example the Borrowdale Volcanic Group (Young 1987). Zircon has also been recorded from the heavy mineral suites of many sedimentary rocks in this area, for example the Coniston and Harlock grits of Silurian age, and in Carboniferous sandstones from the Langhorn and Overend Quarries (Lewis 1931). The true source of the zircons could be determined by trace metal or isotopic evidence.

Enhancement of the relative percentage of zircon in a sample, as compared to a typical north Wales soil, may indicate prolonged weathering causing the depletion of less resistant minerals.

#### 4.2.2. Rutile (TiO<sub>2</sub>)

In the Pontnewydd samples, subhedral to anhedral grains of rutile are ubiquitous, if only in small proportions (0.1-3.0%). It has been suggested that most rutile from igneous sources is yellow-orange, and that large rounded red-brown grains are derived from a

secondary detrital source (Jenkins 1964). The type of rutile present has been determined in the Pontnewydd samples where possible.

Despite its relative rarity, rutile may be derived from many basic igneous rocks in north Wales. Williams (1927) noted its presence in dolerites and acid intrusives, where it occurs as an alteration product of ilmenite. Pointon and Ixer (1980) observed this alteration at Parys Mountain, Anglesey, where they also recorded rutile occurring in association with pyrite and chalcopyrite. Elsewhere in north Wales, rutile has been described as an important component of the altered basic tuffs of the Bedded Pyroclastic Formation (Williams 1927). It is also present as a detrital mineral in sedimentary rocks. Bevins (1994) noted some other occurrences of rutile in the north Wales region, but these were of types not observed in the samples from Pontnewydd.

Rutile is also present in the English Lake District occurring in the Borrowdale Volcanic Group as an accessory mineral (Strens 1962), as an alteration product of ilmenite in gabbros at Carrock Fell mine, Grainsgill (Young 1987) and in the Coniston grits as a detrital mineral (Furness 1965). Rutile could therefore have been incorporated into Pontnewydd sediments from the Irish Sea drift.

#### 4.2.3. Anatase (TiO<sub>2</sub>)

Although anatase only occurs in small proportions in the Pontnewydd sediments, usually <1%, it was present in most of the sediments analysed. It occurs either as angular yellow grains (PN25, PN26), deep steely blue grains (H1716), or colourless rectangular basal plates (PN56). In some samples 'murky' anatase with dark first-order birefringence colours was observed.

Anatase is most abundant in acid intrusives in central Snowdonia although it has also been detected in the rhyolites and rhyolitic tuffs of the area, for example on Crib-goch Ridge, Snowdon (SH 609 544) and at Cwm Meillionen, near Beddgelert, often as an apparent alteration product of ilmenite (Jenkins 1964). It has also been recorded (Williams 1927) in dolerites and basic tuffs, again associated with ilmenite.

Macroscopic crystals occur in the Prenteg area and at Hendre Quarry, near Glyn Ceiriog, in quartz veins which cut through altered dolerites (Bevins 1994). Where anatase occurs in these low temperature Alpine-type veins it is often associated with



other minerals such as quartz, albite, chlorite and brookite. Anatase also occurs in altered volcanic rocks on Parys Mountain, Anglesey (Pointon and Ixer 1980). Both anatase and brookite may derive from the Lower Carboniferous shales from the St. Asaph area. A murky anatase, similar to that observed in some of the Pontnewydd samples, was noted by Jenkins (1964) who found it only in soils from the slopes of Snowdon.

Anatase is also present, although rare, in the mineral suite of the Lake District and therefore could have been incorporated into the sediments at Pontnewydd by the Irish Sea Ice. It is sometimes present within the Borrowdale Volcanic Group in rhyolites and as inclusions in porphyritic rocks, where it again occurs as an alteration product of ilmenite. However, I consider anatase to be indicative of Welsh influence.

#### 4.2.4. Brookite (TiO<sub>2</sub>)

Brookite is often associated with anatase, and this was found to be the case in samples from Pontnewydd. It occurs in small amounts (<1%) in a few of the samples. It is recognised by its high relief, tabular shape and extraordinary birefringence colours or “crossed axial dispersion” (PN14).

Brookite occurs in numerous parts of Wales, in particular in altered igneous intrusions such as dolerites and microgranites, or in quartz veins cutting such rocks, for example at Prenteg and Bwlch-y-Cywion, Gwynedd, and Hendre Quarry, Clwyd (Bevins 1994). Brookite is also commonly found as a detrital mineral for example in the Devonian beds of Anglesey (Greenly 1919) and occurs widely in the Silurian strata of the Denbighshire moors region (Jenkins in Warren *et al.* 1984).

Brookite is of restricted occurrence in the English Lake District, occurring as an accessory mineral in the Skiddaw granite (Young 1987) and in the Shap Granite Quarry with anatase, fluorite, and pyrite. It is also present as a heavy mineral in the Triassic sandstones of the St. Bees area (Versey 1939). However, due to its relative rarity in the Lake District, and the close proximity to the Elwy Valley of at least two possible sources (the Denbighshire shales and the various altered igneous rocks and veins of Snowdonia), it seems likely that the majority of brookite observed in the Pontnewydd sediments is of Welsh origin.

#### 4.2.5 Titanite (CaTiSiO<sub>5</sub>)

Brownish sub-rounded anhedral grains of titanite were found in small numbers in the Pontnewydd samples (PN16). It shows high birefringence and poor extinction.

Occasional grains were pleochroic (PN14). This form is that found in the low-grade metamorphosed basalts and dolerites of the Snowdonia area (Jenkins *pers. comm.*).

Titanite is present in various rhyolitic rocks in Snowdonia (Howells *et al.* 1991). It is also widely developed as a low grade metamorphic mineral in rocks of basaltic composition (Bevins 1994), as well as being recorded along with brookite in Alpine-type veins at Fron Oleu, near Prenteg, Gwynedd (Starkey & Robinson 1992). Titanite of the type found in the Pontnewydd samples (described above) has been found in soils on Snowdon (Williams 1927) and Cwm Idwal (Jenkins 1964).

Titanite has also been recorded in the Borrowdale Volcanic Group (Young 1987) from a variety of rock types including andesites and tuffs, often occurring as an alteration product of ilmenite. It occurs in the Shap granite and within its aureole, as an accessory mineral (Harker & Marr 1891), and is also recorded as a heavy mineral in Triassic sandstones from the St. Bees area (Versey 1939). It is therefore possible that titanite grains may have entered the Pontnewydd sediments from the Northern drift.

#### 4.2.6. Tourmaline (Na (Mg, Fe, Al, Mn)<sub>3</sub> Al<sub>6</sub>(BO<sub>3</sub>)<sub>3</sub> Si<sub>6</sub>O<sub>18</sub> (OH,F)<sub>4</sub>)

Tourmaline is ubiquitous in soils from Pontnewydd and is present in several varieties.

The most common are: a) rounded grains of straw to brown colour,

b) pale to dark green, euhedral pink to dark green, and anhedral colourless to blue.

It has been suggested (D.A.Jenkins *pers. comm.*) that the rounded brown tourmalines may derive from offshore Triassic material. Pink to dark green varieties are most common in samples from central Snowdonia (Jenkins 1964), while a bright blue variety (PN56) has been recorded in altered sandstones at Cwm Dwythwch, near Snowdon (Williams 1927). Well formed, zoned blue to brown tourmalines were found (Williams 1927) in sandstones of Arenig age, which were traced from Bwlch Gwyn to Brithdir. Subsequently Bromley (1969) located similar tourmalinized rocks in the contact aureole of the Tan-y-Grisiau microgranite. In all these cases the tourmaline is zoned from blue-



green to brown. On Anglesey, tourmaline has been identified in the Mona Complex (Greenly 1919). Although it is also present in the Harlech Dome, it occurs there as yellowish-green to greenish brown crystals, a type that has not been observed within the Pontnewydd sediments.

Equally, although tourmaline occurs at several localities in the Lake District, only the habits found in the Borrowdale Volcanic Group, and a blue tourmaline from the Shap area (Harker & Marr 1891) were similar to those found at Pontnewydd. There are also several detrital sources of tourmaline in the Lake District which could have contributed to the Pontnewydd sediments, for example in Triassic sandstones at St. Bees, in rocks at Langhorn Quarry and at Loweswater Flags (Young 1987).

#### 4.2.7. Apatite ( $\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})$ )

Apatite was present in nearly all of the samples from Pontnewydd, and in some cases it was very difficult to distinguish from the weathered bone fragments that dominated many of the samples. The distinction was made on the basis of complete extinction, rather than the 'wavy' extinction exhibited by bone. In the majority of samples studied, apatite was present as well rounded dusty-grey grains, striated parallel to the  $c$  axis, and this type is found in rhyolitic rocks (Jenkins 1964).

Apatite is widely developed in Wales, chiefly in igneous rocks of basic, intermediate and acidic composition (Jenkins 1964, Warren *et al.* 1984). It occurs in microtonalites of northern Llyn (Croudace 1982) and some sedimentary rocks. It occurs in mineral veins at Hendre Quarry and at Prenteg, Gwynedd (Starkey & Robinson 1992). In dolerites it occurs as euhedral hexagonal prisms (Williams and Jenkins 1999). Apatite is common in the Lake District, and its hardness of 5 would allow it to survive glacial transport to become incorporated into the Pontnewydd sediments.

#### 4.2.8. Garnet ( $\text{Ca}, \text{Mn}, \text{Mg}, \text{Fe}^{2+})_3(\text{Al}, \text{Cr}, \text{Fe}^{3+})_2\text{Si}_3\text{O}_{12}$ )

The garnets observed in the Pontnewydd samples are generally subhedral and colourless (PN52) although occasional euhedral grains (PN18) and pink garnets occur (PN53). The garnets are occasionally etched, usually in samples which exhibit other factors indicative of a high degree of weathering. Large murky spessartines also occur in some samples. The garnets observed in the Pontnewydd samples were identified as belonging

to the pyrope- almandine- spessartine series on the basis of their pink, dark red or brown colouration.

Garnet has been recorded as a primary mineral in rhyolitic rocks and as a detrital mineral in north Wales. Small pink almandine garnets are plentiful in rhyolites from Capel Curig and the Sychant Pass, Conway (Williams 1922, 1927). Rounded detrital grains of pink brown garnet have also been found in north Wales, but angular fragmentary grains and small euhedral grains are restricted to soils from Cwm Idwal, Moel Eilio (SH 557 577) and Drum (Jenkins 1964). Brown spessartine is well-developed in altered schistose sandstones intercalated between Talgau lavas in the Llanberis Pass (Williams 1927), and is widely developed in the Harlech Dome. Spessartine has also developed within sandstones in the metamorphic aureole of some dolerites and of the Bwlch-y-Cywion granite in the Nant Ffrancon Pass, and has been recognised in metamorphosed pelitic rocks (Gibbons & Horak 1990) and the derived soils (Younis 1983) from southeast Anglesey.

Garnet is a durable mineral and therefore may have been transported into the area in the Irish Sea drift. In the Lake District garnets are best known within the rocks of the Borrowdale Volcanic Group, although they are also an important component of a suite of hydrothermal veins within the aureole of the Shap Granite (Young 1987). Detrital garnet is also present in some Triassic sandstones such as the St. Bees Sandstone (Versey 1939).

#### 4.2.9. Staurolite $((\text{Fe}, \text{Mg})_2 (\text{Al}, \text{Fe})_9 \text{Si}_4 \text{O}_{20} (\text{O}, \text{OH})_2)$

Kyanite  $(\text{Al}_2 \text{SiO}_5)$ , Andalusite  $(\text{Al}_2 \text{SiO}_5)$

Grains of staurolite were found in a few samples (PN3, PN4, PN5a, PN5b, PN9, PN14), and several typical pink cleavage fragments of kyanite were also observed (PN5a, PN14). Andalusite was rarely found to be present in the sediments, usually associated with one of the other two minerals.

No *in situ* occurrence of these minerals is known in Wales. Both these minerals are characteristic of the Irish Sea drift of Anglesey, and Newborough Warren, Anglesey, from which staurolite has been reported (Greenly 1919), but not subsequently confirmed. They are also found on the coast of north Wales (Smithson 1953) and the



Lleyn peninsula. It is possible that some of the rounded brown tourmalines, dark green amphiboles and pink garnets have the same origin, together with other minerals that would be difficult to distinguish from their Snowdonian counterparts (Jenkins 1964).

The original sources of these minerals are likely to be in the Lake District, in contact-altered slates of the Skiddaw Granite (Young 1987). Detrital staurolite occurs in Permian deposits in the southern part of the Vale of Eden (Versey 1939). Kyanite occurs in altered tuffs in the Borrowdale Volcanic Group (Harker & Marr 1891), and andalusite is found abundantly in contact altered rocks of the Lake District, notably those around the Skiddaw Granite in the Glenderterra Valley, near Keswick (Rastall 1910; Young 1984). Previous workers have used these minerals as indicators of Irish Sea Drift (Smithson 1953, Younis 1983).

#### 4.2.10. Orthopyroxene (Mg SiO<sub>3</sub>)

In the Pontnewydd sediments orthopyroxene present is identified as hypersthene, or as colourless enstatite, with characteristic pink to yellow to pale green pleochroism and two cleavages. It also has parallel extinction. Interestingly, unlike the clinopyroxene, it did not appear to suffer extensive etching.

Enstatite occurs in the Penmaenmawr Intrusion (Bevins 1994) and in microtonalites on Lleyn (Croudace 1982). However, in most of the samples studied, orthopyroxene occurred only in association with minerals from the Irish Sea drift (PN14, PN9), so it seems most likely that this is the source. Enstatite is a common constituent of basalts and andesites within the Borrowdale Volcanic Group, although it is often replaced by chlorite. It also occurs in the Carrock Fell Intrusion (Young 1987). It is present as clastic grains in Triassic sandstones of the Vale of Eden (Versey 1939). Further geochemical work would need to be done to confirm whether orthopyroxenes found in Pontnewydd sediments do derive solely from the Irish Sea drift as no difference between enstatite from Wales and enstatite from the Lake District can be distinguished optically. However, the composition of enstatite from the two sources is very similar (see Croudace 1982 and Mellor 1997 respectively), so even Electron microprobe analyses may not be conclusive.

#### 4.2.11. Clinopyroxenes ((Ca, Mg, Fe, Ti, Al) (Al, Si)<sub>2</sub>O<sub>6</sub>)

The grains observed from Pontnewydd sediments are angular, anhedral and fresh in appearance, and are either colourless (non-pleochroic), colourless to purplish brown (titanaugite) or colourless to pale green (possibly aegerine augite); if pleochroic this is usually slight. Grains normally show bright birefringence colours up to those of the second order.

The most remarkable feature of many of the augites observed in Pontnewydd sediments was the degree of 'etching' which they have undergone. This seemed to occur mainly in colourless grains (PN19, PN20). Jenkins (*pers. comm.*) has suggested that this is a product of chemical weathering, to which certain augites are susceptible, depending on their origin. Jenkins (*op.cit.*) observed etched augites in relatively fresh soils in Snowdonia and non-etched augites in soils that have undergone a greater degree of weathering suggesting perhaps inherited preglacial weathering. Bevins (*pers. comm.*), however, has suggested that this etching is in fact a result of fracturing of the crystals rather than a chemical process. I support the solutional etching hypothesis on the basis that many of the crystals observed are so intensively 'etched' that they would not have survived such fracturing.

The clinopyroxene augite is a common and characteristic major component of the basic igneous rocks of north Wales, although in highly sheared dolerites it is commonly replaced by amphiboles and chlorites. In the Tal-y-Fan Intrusion, Gwynedd (Merriman *et al.* 1986) augite forms large ophitic plates. Detailed electron microprobe analyses of many of the augites in Wales have been carried out by Bevins (1982). Jenkins (1964) observed that soil augites in north Wales have a bimodal character, being either reasonably abundant or not present at all, and could be used to indicate whether dolerites contributed to the soil or not.

Some of the augites present at Pontnewydd may have been derived from the Irish Sea till, as augites are common in the Lake District, being a major component of basic igneous rocks (Young 1987); however it would be difficult to distinguish them either optically or chemically. I suggest that large pale green augites, often containing *en echelon* inclusions, seem to be associated with minerals from the Northern drift and therefore share that source.



#### 4.2.12. Amphiboles ((Cations) Si<sub>8</sub>O<sub>22</sub> (OH))<sub>2</sub>

Within the Pontnewydd samples, amphiboles were fairly common and sometimes accounted for as much as 10% of the sample (PN5a, PN26). Different varieties have been recognised according to their pleochroic scheme and habit. The most common type occurs in bladed prismatic sections (and are probably of the tremolite-actinolite series (Read 1970; Deer, Howie & Zussman 1997, Leake 1978)). They have the following pleochroic scheme: colourless/pale green/green. The next common type is colourless, and occurs in less rectangular fragments (PN20). Brown/colourless or brown/green amphiboles (PN4) with well-developed cleavages are also found, which could be hornblende. Grains of dark blue-green/green amphibole were also observed (PN19). Comparison with the study by Jenkins (1964) suggests these may derive from Moel Eilio.

Amphiboles have frequently been reported from dolerites in the north Wales area, and rare grains have been recorded in the basic tuffs from Snowdonia (Jenkins 1964). In Wales actinolite is widely developed in altered basic igneous rocks, and actinolite and tremolite have been reported from Anglesey (Greenly 1919), while Williams (1922) and Bevins and Rowbotham (1983) reported both minerals from Cadair Idris, and central and southern Snowdonia. Hornblende is common in the Lake District (Young 1987) but less so in north Wales and may therefore derive from Irish Sea till deposits.

##### 4.2.12.1. Glaucophane (Na<sub>2</sub>(Mg, Fe, Al)<sub>5</sub> Si<sub>8</sub>O<sub>22</sub> (OH))<sub>2</sub>

Grains of glaucophane (blue amphibole) were rarely observed in the Pontnewydd sediments, where they exhibited characteristic blue/violet/yellow-green pleochroism and were well rounded.

Glaucophane occurs in metamorphic rocks and is indicative of high pressures and low temperatures of metamorphism. It occurs in the rocks of the Mona complex on Anglesey where it was first reported by Greenly (1919). Horak and Gibbons (1986) have presented electron microprobe data on glaucophane from Anglesey. The rounded nature of the grains found in the Pontnewydd samples is consistent with their being wind-blown grains from deposits on Anglesey.

Glaucophane is not recorded from the rocks of the Lake District, and its only possible source in the Irish Sea till is from southern Scotland. Therefore if this mineral is found within a sample, it indicates that the deposit contains a component of Welsh loess.

#### 4.2.13. Clinozoisite ( $\text{Ca}_2 \text{Al}_3 (\text{SiO}_4)_3 \text{OH}$ ), Epidote ( $\text{Ca}_2 (\text{Al,Fe}^{3+}) \text{Si}_3\text{O}_{12}(\text{OH})$ )

It is difficult to distinguish between clinozoisite and epidote, so these will be considered together. The abundance of epidote in the Pontnewydd samples seems to correlate with the abundance of clinozoisite, although in smaller quantities. I defined epidote as having PPL colours which range from pale yellow/brown to apple green, with interference colours of third order greens and pinks. The grains were generally anhedral and often well rounded. The clinozoisite grains were usually colourless and characterised by their birefringence colours of anomalous blue-greys and pale yellows ranging up to oranges.

Both have been recorded as secondary minerals replacing feldspar in dolerites, with epidote usually forming where Fe is available. Epidote has also been found as detrital grains in the sedimentary rocks of north Wales. Many early descriptions of altered basic igneous rocks from Wales referred to the presence of epidote; however, Roberts (1981) has determined that these rocks, in Snowdonia and parts of Llyn actually contain clinozoisite, which has been supported by geochemical analysis (Bevins 1994). The minerals observed at Pontnewydd support this hypothesis, as clinozoisite was found to be much more abundant than epidote in the samples. Epidote is widely developed in Wales, particularly in altered volcanic rocks of basaltic composition of Precambrian and Lower Palaeozoic age, and good crystalline examples are found at Dinorwic Quarry, Gwynedd (Bevins 1994). Jenkins (1964) observed that, in soils, these minerals show similar distribution patterns to those of augite. I would regard epidote as one of the minerals characteristic of Snowdonian soils.

However, it is possible that clinozoisite and epidote could be derived from the Irish Sea drift, as samples have been found in the volcanic rocks of the Lake District. Clinozoisite is widely distributed within the Borrowdale Volcanic Group and the Eskdale Granodiorite (Young 1987). Epidote is an extremely common mineral occurring as an alteration product, particularly in the Borrowdale Volcanic Group (Strens 1962).

Allanite (a rare earth element rich epidote) was not observed in the Pontnewydd



samples, although it has previously been recorded in very small quantities (<1%) in soils from North Wales (Williams 1927, Jenkins 1964). It was located in around 50% of the samples investigated by Jenkins (1964), and it is possible that its presence was overlooked in this study.

Zoisite is rare, and was only found in one of the Pontnewydd samples, but may also be mistaken for clinozoisite. Only one sample of zoisite has been recorded from the Lake District, so it may be considered a Welsh indicator mineral.

#### 4.2.14. Chlorite and chlorite-like minerals $(\text{Mg, Fe, Al})_6 (\text{Si, Al})_4 \text{O}_{10}(\text{OH})_8$

Chlorite is found in all the sediments from Pontnewydd, and in some cases it dominates the heavy mineral fraction (e.g. PN56: 81.7% chlorite). A brown oxidised margin is present to many grains. The abundant chlorite in the sediments studied may be derived from either a Welsh or a foreign source, although in any interpretation its hardness of 2-3 must be considered. It is clear that several different types are represented in the Pontnewydd sediments, but these were difficult to distinguish.

A wide range of minerals of the chlorite group occur in different rock types in Snowdonia, although few species have been identified. Chlorite is common in Wales being particularly abundant in altered basic igneous rocks (Bevins and Rowbotham 1983). It pseudomorphs primary mafic minerals such as olivine or pyroxene, infills veins or vesicles or replaces groundmass as a devitrification product. Rounded pale green basal flakes of chlorite are an abundant constituent of Ordovician and Silurian shales (forming 40% of the rock, and 90% of its heavy minerals), and characterise the suite of minerals in the Powys soil group (Smithson 1953). Within sheared dolerites another pale green variety occurs (Jenkins 1964). Colourless and pale yellow varieties have also been recorded. In the Cwm Idwal and Snowdon areas, veins usually carrying quartz and calcite, but occasionally with pale green/straw chlorite, occur (Jenkins 1964). The types of chlorite described above could not usually be differentiated in the samples from Pontnewydd. A sample dominated by pale chlorite was assumed to be of predominantly Welsh origin.

Minerals of the chlorite group are common and widespread throughout the Lake District, especially as alteration products of primary ferro-magnesian minerals in many of the igneous rocks of the Borrowdale Volcanic Group (Strens 1962); and are also

present in many of the altered rocks in the aureoles of intrusions. Chlorite group minerals are an important constituent in many of the sedimentary rocks, such as shales of Ashgill age and sandstones of Silurian age (Rose and Dunham 1977) throughout the area; metalliferous veins also commonly contain small amounts of chlorite.

#### 4.2.15. Biotite $(K (Mg,Fe)_3 AlSi_3O_{10} (OH,F)_2$

Biotite was only rarely recorded by the author in the soils from Pontnewydd, possibly due to its potential for mis-identification as chlorite. It has a hardness of 2-3 and is therefore unlikely to survive transport in the Irish sea drift.

Biotite has been recorded from most of the rock types of north Wales (Williams 1927), and is particularly common as small green and brown flakes in some of the acid intrusions and as yellow to dark red-brown flakes in certain altered dolerites (Jenkins 1964). Biotite is an important component of doleritic intrusions in central Snowdonia, including those near Llyn Llydaw. Williams (1930) noted biotite in the Bwlch y Cywion granite showing grass-green to pale greenish yellow pleochroism. It is widely developed on Anglesey (Greenly 1919) being present in granites, amphibolites and gneisses of Precambrian age (Horak 1993). It is a component of the Penmaenmawr Intrusion (Sargent 1924) and occurs in the Rhiw Intrusion on Llyn, where it is partially altered to chlorite. Where present, it indicates a Welsh origin for the sediment.

#### 4.2.16. Other Non-Opaque Minerals

Prehnite and pumpellyite were both observed by Jenkins (1964) in a few isolated soils from north Wales, but were not observed in the Pontnewydd samples. These minerals are striking in appearance, so it is unlikely but possible that they were overlooked during this study.

Chloritoid occurs widely in Snowdonia in Ordovician rhyolitic lavas (Harker 1889), contact metamorphosed Ordovician slates and metamorphosed mudstones of the Cwm Pennant area (Bevins 1994). It was found only rarely in the Pontnewydd sediments, associated with other minerals of Welsh origin. No occurrence of chloritoid has been reported from the Lake District (Young 1984), but large basal plates appear to be associated with Irish Sea Drift assemblages.



Monazite occurs rarely in the Pontnewydd sediments as rounded grains (PN18, PN19) and is recognised by its pale yellow colour, high birefringence colours and high Refractive Index. It is found in the Harlech dome and in Ordovician rhyolites at Carneddau-y-Cribau, Gwynedd (Howells *et al.* 1991). Monazite is found in only one location in the Lake District, as an accessory mineral in the Shap Granite (Young 1987). It is therefore likely to be of Welsh origin in the sediments under study.

Glauconite was observed occasionally in the Pontnewydd sediments as small rounded yellow-green grains (PN5b, PN14). It is not present in north Wales. It is present in the Lake District at Shap Blue quarry (Young 1987) and in chalk exposures in northern Ireland, from where it is likely to have been transported by the Irish Sea drift to the Elwy Valley.

#### 4.2.17. Iron ore and opaque minerals

In most samples, the opaques were not studied in detail under reflected light, however, in a few samples where there was a large proportion of opaques (e.g. PN51) this was done. Magnetite and ilmenite ( $\text{FeTiO}_3$ ) have been reported in most of the rocks of north Wales. Both occur as anhedral grains, although euhedra of magnetite have been found in rhyolitic tuffs (Jenkins 1964).

Indeterminate minerals of the leucoxene group are often present in the Pontnewydd samples as alteration products of ilmenite from rhyolitic and basic tuffs, and are particularly common from dolerites. Grains are usually angular, white and opaque, with a fine granular texture. Leucoxene has been recorded previously from the soils of north Wales (Jenkins 1964).

Pyrite is present in many basic and rhyolitic rocks (Williams 1927). Jenkins noted that in north Wales, pyrite was most common in soils derived from basic tuffs. Within the samples studied, pyrite was rare.

Indeterminate grains of ferric oxide were common in the Pontnewydd samples although it is difficult to trace their origin to any rock type. They are mostly irregular, earthy orange-brown and pitted or dark brown and rounded. Jenkins (*pers.comm.*) reports a form found in rhyolitic rocks consisting of angular orange-red plates, generally isotropic but occasionally showing a mosaic of low birefringence. It has been suggested (Jenkins *op.cit.*) these may have originated as coatings on crystals of pyrite or magnetite. Some seem to be casts of bone or show a cellular structure suggesting they were casts of other

organic debris. Although haematite was observed, goethite was not.

#### **4.2.18. Summary**

Various assemblages may be recognised and attributed to particular sources. Almost all samples contain an abundance of pale green-grey chlorite, ranging from 92.1% in sample PN2, Upper Sands and Gravels, to 5.6% in sample PN22, Dark red silt, within the Intermediate complex. Most samples also contain minor zircon and tourmaline and this assemblage is characteristic of the Lower Palaeozoic mudstones (Jenkins 1984). Clinopyroxene, clinozoisite, amphiboles and apatite represent subordinate volcanic material, which could lie to the west in Snowdonia or to the southwest in the Arenig or Berwyn Mountains. Resistate minerals, possibly derived from a sandstone source such as the Triassic or Upper Carboniferous rocks to the north and east, include rutile, garnet, tourmaline, anatase and brookite. Additional minerals such as staurolite, kyanite, andalusite, chloritoid, orthopyroxene and glauconite suggest a more heterogeneous geological source. These additional minerals are usually associated in north Wales with the Devensian Irish Sea Drift (Smithson 1953).



### **4.3. Results of the Heavy Mineral analysis**

The results of the heavy mineral analysis are presented in Appendix 4.1 and a summarised table of data is displayed in Figure 4.4.1. Wherever possible, proportions were assessed as percentages of non-opaque minerals, and where bone formed a high percentage of the sample, this value was noted but not included in the calculation. At least 1000 grains were point-counted to produce the percentage results for each slide. Where no sample was available for analysis during this study, samples that had been previously examined by D.A. Jenkins have been included for comparative purposes. These samples were assessed by D.A. Jenkins on a logarithmic scale of abundance, rather than a point-counted percentage. These values may be converted to approximate percentages using the calibration curve or table shown in Figure 4.4.4. Minerals were only included in Figure 4.4.1 and the accompanying graphs if they constituted more than 0.1% of the assemblage.

#### **4.3.1. Notes on the Interpretation of each sample**

##### 4.3.1.1. Lower Sands and Gravels: PN1, PN10

The distribution of heavy minerals is shown in Figure 4.4.3, graph 1. Samples PN1 and PN10 follow approximately the same trend and consequently have the same source. The channel within the Lower Sands and Gravels, shows a different trend and is considered below. Anatase and Brookite are locally derived minerals, from the Silurian shales of the Denbighshire moors region. Further evidence for a Welsh origin is the dominant pale chlorite, which may be derived from Lower Palaeozoic volcanics or shales. Much of the garnet observed was brown spessartine, which could come from either a Welsh or an Irish Sea till source. Clinozoisite, pink/dark green tourmaline and epidote were present, which is consistent with a Welsh origin for this deposit. Orange brown rutile indicates a detrital source. The euhedral zircon observed here might come from Snowdonian rhyolites.

##### Channel Fill, Lower Sands and Gravels: PN9

The presence of staurolite, enstatite and andalusite indicate an origin in the Irish Sea till. However, the domination of the assemblage by chlorite and the presence of clinozoisite, pink/dark green tourmaline, epidote, euhedral green amphibole, aggregates and euhedral quartz indicate a more local origin. I therefore suggest a mixed origin for this sample.

##### 4.3.1.2. Upper Sands and Gravels: PN2

Distribution of the heavy minerals in this layer is shown in Figure 4.4.5, graph 1. This sample differs from those from the LSG, having a greater proportion of chlorite. The presence of

glaucophane suggests a Welsh origin for this deposit. This is likely to be derived from the blue amphibole bearing schists, of the Mona complex, on Anglesey. The presence of epidote which is widely developed in Welsh rocks of Lower Palaeozoic and Precambrian age, the pink/green tourmaline, blue-green amphibole and the high percentage of chlorite, support this hypothesis.

#### 4.3.1.3. Intermediate Complex (Ic): PN3

No *in situ* occurrence of staurolite is known in Wales. It is therefore likely to be from the Irish Sea Till. The domination of the sample by clinozoisite (common in Snowdonia) may indicate a mixed origin. The presence of anatase, pink zircon, almandine garnet and epidote suggest a Welsh influence. I would suggest, due to the high relative proportion of zircon, the etched clinopyroxene and the low proportion of ragged chlorite that this layer has undergone weathering.

#### Ic, Dark Red Silt: PN11, PN22

The heavy mineral distribution of this unit is shown in Figure 4.4.2, graph 2. The two samples are very similar, the only difference being the greater proportion of clinopyroxene in PN22. The extremely high proportion of clinozoisite and low value for chlorite suggests this is a weathered soil of Welsh origin. The high relative values for zircon, rutile and tourmaline, and the fact that both clinozoisite and amphibole were slightly etched, support this. Welsh varieties of tourmaline (straw/brown, colourless/green, and pink/blue black) were present. The presence of garnet (both colourless and pink varieties) anatase (both yellow and blue), and epidote supports a Welsh volcanic source. Sample PN22 was poorly separated, so included a large number of aggregates, some of which can be identified as fragmentary rhyolitic tuffs. There was a high proportion of opaques (68.8%) and ferric oxides. This, the presence of pink garnet and zircon, and the extreme red colour, necessitate comparison with PN51. Amphibole was dark green/pale green and green/brown, and curiously, the chlorite remaining was in good condition. The presence of kyanite (PN25) and brown amphibole (PN25) indicates an influence from the Irish Sea till.

#### Ic, Buff Intermediate: PN19, PN20, and PN24

The heavy mineral distribution of these samples is shown in Figure 4.4.2, graph 1. The samples are broadly similar to one another and their main differences lie in the proportion of epidote. PN51 is a sample from the top of the Buff Intermediate, but was taken from a different area of the cave, so will be considered separately. The major component of this layer derives from weathered Welsh drift, illustrated by depleted chlorite with fretted edges, clinozoisite, blue-green amphibole, etched almandine garnet, anatase and epidote. The presence of staurolite (PN24) and kyanite (PN19) indicates an origin in the Irish Sea till. Monazite (PN20) is present in, but not restricted to Wales. PN22 contained many aggregates, some of which could be identified as crushed pieces of tuff. Brown amphibole (PN24) has rarely been observed in the



Welsh sediments from Pontnewydd, so it is possible that this may derive from a northern source. This sediment has a mixed origin.

#### Ic, Orange Intermediate: PN26, PN27

The proportions of heavy minerals observed is displayed in Figure 4.4.6, graph 3. The greatest difference in this unit is the greater proportion of clinopyroxene and Irish Sea indicator minerals to the other Intermediate samples. The major contribution to this layer appears to have been from a weathered Welsh deposit. This is illustrated by the presence of chlorite, clinozoisite, blue-green amphibole, epidote and garnet. Many of both the chlorites and clinopyroxene had fretted edges. In Sample PN27, 8% of the chlorites had brown oxidised margins. In sample PN26, 5% of the clinopyroxene was pale green and etched, 90% pale brown and highly etched and 5% colourless with some etching. The degree of etching ranged from slight to skeletal. Of the tourmalines, 25% were pink/green and 75% were pale/brown. Many zircons were euhedral, having their origin in Snowdonian rhyolites. The presence of staurolite and kyanite indicates that a component of the sample comes from the Irish Sea till. The sample is therefore of a mixed origin.

#### Ic, Buff/Orange Intermediate: PN51

The distribution of heavy minerals observed in this sample is shown in Figure 4.4.6, graph 3. This sample derives from near the boundary between the Buff and Orange Intermediates and seems to show a closer affinity with samples from the Orange Intermediate. Due to the extremely high percentage of opaques (78.1%), the sample of non-opaque minerals was necessarily smaller than was taken for all other samples. This is most noticeable in the slightly exaggerated values for dark chlorite, apatite and titanite. Both bone and apatite were Fe stained. The aggregates were mainly fine-grained quartz-rich material, either rhyolites or tuffs. The high proportion of clinozoisite, zircon, pink/dark green tourmaline, epidote and titanite, which is present in many rhyolitic rocks in Snowdonia, suggests a weathered sample of Welsh origin.

#### 4.3.1.4. Lower Breccia a: PN15

The heavy minerals observed in this sample are shown in Figure 4.4.2, graph 3. The main difference between this and the other Lower Breccia samples is the proportion of chlorite and the low incidence of either Welsh or Irish Sea till indicator minerals. The presence of staurolite indicates an origin in the Northern drift. However, the rest of the assemblage appears Welsh, comprising clinozoisite, epidote and a high percentage of chlorite, so it is likely that the staurolite could be a wind blown grain, rather than direct from the Irish Sea till. Magnetite, observed here, is widely developed in Wales, in igneous rocks, Ordovician iron ores, occasional mudstones and mineral veins. Rutile was subhedral and yellow, typical of that observed in Snowdonian volcanic rocks, amphiboles were zoned.

#### Lower Breccia b: PN16

The proportions of heavy minerals observed in this unit are displayed in Figure 4.4.2, graph 3 and Figure 4.4.6, graph 2. The main distinction between this sample and samples in Lower Breccia c is the high proportion of chlorite, the presence of kyanite and the greater variety in the clinopyroxenes. The presence of staurolite and kyanite indicates an origin in the Irish Sea till. Etched augite, and etched garnet suggests this material has travelled some distance. However, the presence of clinozoisite, pink/green tourmaline, blue-green amphibole and epidote suggests that this sample is of Welsh origin. Titanite and anatase are present in Snowdonia and the euhedral zircon suggests a local input. I suggest a mixed origin for this sample.

#### Lower Breccia c: PN17, PN18, and PN52

The proportions of heavy minerals observed are displayed in Figure 4.4.2, graph 3 and Figure 4.4.6, graph 2. The high percentage of clinozoisite, together with depleted chlorite, blue tourmaline, epidote and a high proportion of colourless, yellow and pink varieties of zircon, suggest that this is a weathered layer of Welsh origin. The presence of anatase and titanite and etched titanaugite support this. Euhedral zircons, euhedral garnets and euhedral quartz (PN18) indicate a strong local influence. Zoisite (PN17) has been recorded in mica schists and diorites on Anglesey, and in veins at Penmaenmawr, N.Wales. Monazite (PN18) is present in, but not restricted to Wales. The presence of staurolite indicates an origin in the Irish Sea till, but this could be contamination from an aeolian source. The major component of this layer is from a Welsh source.

#### 4.3.1.5.Silt Deposit: PN4, PN14

The proportions of heavy minerals observed may be viewed in Figure 4.4.3, graph 3 and Figure 4.4.6, graph 1. The most notable feature of this deposit is the wide variety of minerals present from both Welsh and Irish Sea sources, and the high percentage of chlorite. The presence of staurolite, kyanite, glauconite (which occurs in the Cretaceous beds in Northern Ireland) and possibly that of etched enstatite, indicate an origin in the Irish Sea till. Both brown, blue and pink tourmaline (rubellite-PN53) are present, and this latter has not been observed in Welsh sediments from Pontnewydd. However, the minerals discussed below, suggest that this layer has a Welsh component. Yellow zircon, observed here, is present as detrital grains in the soils of Drum. Rutile is yellow and euhedral, suggesting a local volcanic source. Anatase and brookite are present in the local shales. Titanite occurs in Snowdonian volcanics as the small, lozenge-shaped, brownish-pink variety observed here. Green/black tourmaline and euhedral brown tourmaline were observed, and the latter is most common in the soils of Drum. Presence of chloritoid suggests a Welsh origin, as it occurs in Snowdonia in low and medium-grade metamorphosed mudstones. Epidote is widely developed in Wales, particularly in



hydrothermally altered Precambrian and Lower Palaeozoic volcanic rocks of basic composition. Zoisite and garnet (PN53) are present in the rocks of north Wales, anatase and brookite occur in the local Silurian shales and Glaucophane occurs on Anglesey. The clear presence of both Welsh till and Irish Sea till suggest a mixed origin for this layer.

#### 4.3.1.6. Upper Breccia: PN54

The heavy mineral species from this sample are shown in Figure 4.4.5, graph 2. The presence of chlorite, clinozoisite, anatase, titanite, garnet and epidote suggest that this sample is of Welsh origin. However, the presence of staurolite indicates a contribution from the Irish Sea till. There are two further peculiarities about this sample that may derive from a non-Welsh source. The first is the presence of brown amphibole (0.4%), the second that of aegerine-augite (0.2%) and titanite (0.4%), both highly etched. This sample is of mixed origin.

#### 4.3.1.7. Upper Clays and Sands: PN5a, PN5b, PN56

The percentages of heavy minerals observed in this unit are displayed in Figure 4.4.3, graph 2 and Figure 4.4.5, graph 2. Sample PN56 is from the very top of this deposit, and I suggest it has been contaminated by Holocene deposition. The presence of staurolite, rounded kyanite, and andalusite can be taken to indicate an Irish Sea origin for the material in this layer.

Orthopyroxene, is present in small amounts in north Wales, but has been observed in all Pontnewydd samples to be associated with other indicators of Northern drift. I would suggest a non-Welsh origin for this enstatite. Glauconite is also extremely rare in Wales, and orange-red rutile tends to derive from the Northern drift, which support the above. However, the presence of glaucophane, anatase, brookite, garnet, epidote (PN56), zoisite (PN56), yellow-orange rutile, and the high proportion of chlorite, indicates a fresh Welsh influence. The variety exhibited in the zircon, tourmaline, garnet and amphiboles, together with the above, suggest a mixed origin for this sediment.

#### Upper Clays and Sands: PN55

The heavy mineral distribution in this sample is shown in Figure 4.4.3, graph 2 and Figure 4.4.5, graph 2. The sample contains a dominantly relict assemblage. It has clearly been highly weathered and both the clinopyroxene and amphibole are etched. This may account for the high % of zircon, which was colourless and occurred as euhedral and rounded crystals. This sample contains constituents of both Welsh (anatase, titanite, garnet, clinozoisite, epidote) and Irish Sea till (staurolite, kyanite, enstatite, perhaps dark chlorite). Interesting features are the prevalence of garnet, both colourless and pink, and the presence of blue anatase and brown amphibole. Much of the clinopyroxene carried a colour tint. This sample contains 62.9% opaque minerals and is similar to PN5a.

#### 4.3.1.8. New Entrance Samples

The heavy mineral content of these samples is displayed in Figure 4.4.5, graph 3.

##### Layer 35: H1716

The presence of anatase, garnet, biotite, epidote, and pink/dark green tourmaline indicates a Welsh source for this layer. Zircon was subhedral, amphibole was green/blue green, garnets were pink, and clinopyroxene was occasionally etched. This sample is from a weathered Welsh source.

##### Layer 29: H1717

This layer is distinct from the other samples from the New Entrance. It contains minerals indicative of an Irish Sea influence, less chlorite and more clinozoisite than the other samples. The presence of staurolite, andalusite, brown amphibole and enstatite suggests an origin in the Irish Sea till. Rutile was golden yellow suggesting a volcanic rather than a detrital source. The presence of anatase, titanite, garnet, zoisite, blue-green and pale green amphiboles, dark green/pink and blue to brown zoned tourmalines suggest a contribution from the Welsh till. As with the previous samples from the new entrance, there were many unknowns due to the 'murky' nature of the minerals. This sample is of mixed origin, and it is likely that the Welsh component had suffered considerable weathering.

##### Layer 28: H1718

The presence of anatase, titanite, garnet, pink/dark green tourmaline and epidote suggest an input from a Welsh source. The subhedral, colourless zircon and red-orange rutile, suggest that some of the material has derived from sandstones. Further evidence of this is provided by zoned blue to brown tourmalines which were noted (Williams 1927) in Arenig sandstones from Bwlch Gwyn to Brithdir. The hornblende observed may derive from the English Lake District. Some clinopyroxene was etched, the unetched material being larger. I suggest this is a Welsh deposit with considerable input from an iron-rich source.

##### Layer 26: H1719

The presence of a high proportion of pink zircon, chlorite, anatase, titanite, garnet, clinozoisite, pink/dark green and blue tourmaline, suggest a predominantly Welsh source for this layer. Rutile was orange-yellow and many crystalline silicic aggregates were observed, indicating an igneous rather than a detrital origin. All chlorites were oxidised round the edges.

##### Layer 24: H1720

The percentage abundance of anatase, brookite, garnet, blue and pink/dark green tourmaline, epidote and chlorite indicate a soil of Welsh origin. Many of the zircons, which were euhedral and colourless, rounded and pink or large and murky, contained inclusions.



| Layer                                    | Sample | Likely source  | Mineral indicators  |  |
|--|--------|--|---|--|
| LSGs                                     | PN1    | Locally derived material from Silurian shales. Some Welsh till material.   | Anatase<br>Brookite<br>Dominant pale chlorite<br>Brown spessartine garnet<br>Clinzoisite                            |  |
| USGs                                     | PN2    | Welsh till deposits.   | Glaucophane<br>Epidote<br>Euhedral zircon<br>Dominant pale chlorite   |  |
| LSGs<br>Channel fill.                    | PN9    | Irish Sea till deposits, with an unweathered more local contribution. A deposit mixed prior to deposition in the cave. | Staurolite<br>Andalusite<br>Enstatite<br>Volcanic aggregates  | Dominant pale<br>Chlorite<br>Clinzoisite<br>Epidote<br>Euhedral Quartz |
| LSGs<br>Channel edge.                    | PN10   | Welsh till material.   | Dominant pale chlorite<br>Clinzoisite<br>Epidote<br>Weathered opaques?  |  |
| Intermediate<br>Complex                  | PN3    | Mixed origin.<br>Weathered local, Welsh and Irish sea material.  | Anatase      Staurolite<br>Epidote<br>Depleted chlorite<br>Clinzoisite<br>Etched clinopyroxene<br>Weathered garnets |  |
| Intermediate<br>Complex<br>Dark red silt | PN11   | Weathered material from a Welsh till source, incorporating volcanic material.  | Pink Garnet<br>Epidote<br>Volcanic aggregates<br>Rounded zircons<br>Clinzoisite                                     |  |
| Intermediate<br>Complex<br>Buff (a)      | PN19   | Weathered Welsh drift, with some contribution from the Irish Sea till.   | Kyanite<br>Monazite   | Depleted chlorite<br>Clinzoisite<br>Epidote<br>Volcanic aggregates     |
| Intermediate<br>Complex<br>Buff (b)      | PN20   | Local and Welsh till material, slight weathering evident on chlorite and garnet.                                       | Anatase<br>Epidote<br>Dominant chlorite<br>Clinzoisite  |  |
| Intermediate<br>Complex<br>Dark Red silt | PN22   | Weathered Welsh till material.   | Clinzoisite<br>Chlorite<br>Dominant Opaques<br>Enhanced zircon & rutile   |  |
| Intermediate<br>Complex<br>Buff          | PN24   | Mixed origin.<br>Weathered welsh till material, with some Irish sea till minerals.                                     | Staurolite<br>Kyanite   | Chlorite<br>Clinzoisite<br>Epidote<br>Garnet                           |
| Intermediate<br>Complex<br>Dark Red Silt | PN25   | Mixed deposit. Weathered Welsh drift, and local material with a small component from the Irish Sea till.               | Kyanite<br>Etched<br>Clinopyroxene  | Clinzoisite<br>Depleted chlorite<br>Anatase<br>Epidote                 |
| Intermediate<br>complex<br>Orange        | PN26   | Weathered Welsh till, with some local material and an Irish Sea till component. Also with a high % of opaque minerals. | Staurolite<br>Kyanite   | Clinopyroxenes<br>Garnet<br>Chlorite                                   |
| Intermediate<br>complex<br>Orange        | PN27   | Weathered Welsh till, with some Irish Sea till material.   | Etched<br>clinopyroxenes<br>Staurolite<br>Kyanite   | Chlorite<br>Garnet   |
| Intermediate<br>complex                  | PN51   | Weathered Welsh till with some local material.   | Titanite<br>Clinzoisite<br>Zircon   |  |
| Lower Breccia<br>(c)                     | PN18   | Weathered Welsh till origin, with some local material.   | Monazite<br>Euhedral quartz<br>Rounded zircon   | Clinzoisite<br>Depleted chlorite<br>Anatase<br>Titanite                |

Figure 4.3. Provenances of the Pontnewydd Samples and their mineral indicators

| Layer                 | Sample | Likely source  | Mineral indicators  |   |
|-----------------------|--------|--|---|---|
| Lower Breccia (c)     | PN17   | Weathered Welsh source, with some minor Irish sea till component.  | Staurolite  | Etched clinopyroxene<br>Clinozoisite<br>Zoisite<br>Dominant chlorite                      |
| Lower Breccia (a)     | PN15   | Slightly weathered Welsh source, with some minor Irish sea till component.   | Staurolite  | Clinozoisite<br>Epidote<br>Magnetite<br>Dominant chlorite                                 |
| Lower Breccia (b)     | PN16   | Mixed origin.<br>Some local material, a Welsh glacial component and material from the Irish Sea drift deposits. Some weathered material.   | Staurolite<br>Kyanite<br>Etched garnet<br>Etched clinopyroxene                  | Titanite<br>Anatase<br>Epidote<br>Clinozoisite  |
| Lower Breccia         | PN52   | Slightly weathered Welsh till  | Epidote<br>Garnet<br>Clinozoisite   |   |
| Silt Beds             | PN14   | Mixed origin.<br>Contains local Silurian minerals, Welsh volcanic minerals and Irish sea till minerals. Water that supplied the pond passed through several layers of deposit, collecting a varied mineral assemblage. | Staurolite<br>Kyanite<br>Glauconite<br>Chloritoid                               | Yellow zircon<br>Glauconite<br>Anatase<br>Titanite<br>Epidote<br>Magnetite<br>Pink garnet |
| Silt Beds             | PN4    | Mixed fresh assemblage.<br>Local, Welsh and Irish sea till material.   | Staurolite<br>Chloritoid<br>Yellow-orange rutile                                | Brookite<br>Dominant pale chlorite  |
| Silt beds             | PN53   | Mixed origin.<br>Fresh Welsh and local material with an Irish sea till component.  | Staurolite<br>Kyanite<br><br>Etched enstatite                                   | Brookite<br>Zoisite   |
| Upper Breccia         | PN54   | Mixed origin.<br>Slightly weathered Welsh and local material, with a component from the Irish sea till.  | staurolite  | anatase<br>Titanite<br>Garnet   |
| Upper clays and Sands | PN55   | Highly weathered Welsh, local and Irish sea till material.   | staurolite<br>kyanite<br>enstatite  | anatase<br>Titanite<br>garnet   |
| Top Layer             | PN56   | Fresh Welsh and local material with an Irish Sea till component.   | Staurolite<br>Kyanite   | Anatase<br>Brookite<br>Epidote  |
| Upper clays and Sands | PN5b   | Mixed origin.<br>Weathered Irish sea till material with fresh Welsh deposits.  | Staurolite<br>Andalusite<br>Enstatite   | Glauconite<br>Dominant pale chlorite<br>Glauconite<br>Euhedral zircon & garnet            |
| Upper clays and Sands | PN5a   | Mixed origin.<br>Fresh Welsh material with some Irish sea till component. Water-transported grains.  | Staurolite<br>Kyanite<br>Andalusite<br>Enstatite<br>Rounded zircon & tourmaline | Brookite<br>Anatase<br>Chloritoid<br>Epidote  |

Figure 4.3. Provenances of the Pontnewydd Samples and their mineral indicators



| Date | Site  | Layer             | Sample | Zircon | Rutile | Anatase | Brookite | Titanite | Tourmaline | Apatite | Garnet | Clinopyx | Clinozoisite |
|------|-------|-------------------|--------|--------|--------|---------|----------|----------|------------|---------|--------|----------|--------------|
| 1982 | DS    | LSG               | PN1*   | 3      | 2      | 1       | 1        | nil      | 4          | 2       | 2      | 4        | 4            |
|      |       | calibrated sample | PN1*   | 4      | 1      | 0.1     | 0.1      | nil      | 8          | 1       | 1      | 8        | 8            |
| 1982 | DS    | USG               | PN2    | 0.2    | 0.1    | nil     | nil      | nil      | 0.8        | 0.05    | 0.1    | 1.7      | 2.6          |
| 1982 | D     | LBr/Ubr           | PN3*   | 3      | 2      | 1       | nil      | nil      | 4          | 3       | 2      | 4        | 5            |
|      |       | calibrated sample | PN3*   | 4      | 1      | 0.1     | nil      | nil      | 8          | 4       | 1      | 8        | 16           |
| 1982 | D     | Silt bed          | PN4    | 1.2    | 1.1    | nil     | 0.1      | nil      | 2.3        | 1.2     | nil    | 2.7      | 4            |
| 1983 | D     | Silt bed          | PN14   | 0.2    | 0.3    | 0.1     | 0.1      | 0.4      | 1.9        | 3.4     | 1      | 4.2      | 2.9          |
| 1998 | F(N)  | Silt bed          | PN53   | 0.9    | 1.1    | 0.1     | 0.1      | nil      | 1.5        | 1.3     | 0.9    | 1.5      | 4.2          |
| 1982 | D     | UCS               | PN5a   | 6.3    | 2.3    | 0.9     | nil      | nil      | 7.1        | 7.3     | 2.6    | 10.3     | 4.2          |
| 1982 | D     | UCS               | PN5b*  | 5      | 3      | 1       | nil      | nil      | 4          | 2       | 3      | 3        | 1            |
|      |       | calibrated sample | PN5b*  | 16     | 4      | 0.1     | nil      | nil      | 8          | 1       | 4      | 4        | 0.1          |
| 1983 | DS, B | LSG               | PN9    | 1      | 1.4    | nil     | nil      | nil      | 2.4        | 3       | 0.2    | 3.2      | 5.9          |
| 1983 | DS, B | LSG               | PN10   | 1.3    | 0.1    | nil     | nil      | nil      | 2.4        | 0.4     | 0.6    | 1.8      | 7.2          |
| 1984 | D(N)  | LB(a)             | PN15*  | 4      | 2      | nil     | nil      | nil      | 3          | 3       | 2      | 4        | 4            |
|      |       | calibrated sample | PN15*  | 8      | 1      | nil     | nil      | nil      | 4          | 4       | 1      | 8        | 8            |
| 1984 | D(N)  | LB(b)             | PN16   | 2.2    | 0.5    | 0.2     | nil      | 0.05     | 3.9        | 1       | 1.4    | 3.7      | 11.4         |
| 1984 | D(N)  | LB(c)             | PN17   | 4.9    | 0.7    | 0.6     | nil      | nil      | 5.1        | 3       | 0.6    | 5.3      | 23.4         |
| 1984 | D(N)  | LB(c)             | PN18   | 9.2    | 1.4    | 0.5     | nil      | 0.1      | 6          | 2.3     | 2.7    | 3        | 21.2         |
| 1998 | F(N)  | LB                | PN52   | 1.2    | 1.2    | nil     | nil      | nil      | 2.5        | 4.3     | 0.6    | 0.6      | 8.1          |
| 1983 | D     | Ic (DRS)          | PN11   | 4      | 1.4    | nil     | nil      | nil      | 10.8       | 1.8     | 3.6    | 0.05     | 39.2         |
| 1984 | D(N)  | Ic(B)             | PN19   | 3.1    | 1.1    | nil     | nil      | nil      | 4.1        | 1.7     | 2.1    | 3.4      | 26           |
| 1984 | D(N)  | Ic(B)             | PN20*  | 5      | 3      | 1       | nil      | nil      | 4          | 2       | 3      | 4        | 4            |
|      |       | calibrated sample | PN20*  | 16     | 4      | 0.1     | nil      | nil      | 8          | 1       | 4      | 8        | 8            |
| 1984 | D(N)  | Ic(DRS)           | PN22   | 8.7    | 2.5    | 1.2     | nil      | nil      | 7.5        | 2.5     | 1.8    | 0.6      | 40           |
| 1984 | D(N)  | Ic(B)             | PN24*  | 4      | 2      | nil     | nil      | nil      | 3          | 3       | 2      | 5        | 5            |
|      |       | calibrated sample | PN24*  | 8      | 1      | nil     | nil      | nil      | 4          | 4       | 1      | 16       | 16           |
| 1984 | D(N)  | Ic(DRS)           | PN25*  | 4      | 1      | 1       | nil      | nil      | 4          | 3       | 1      | 4        | 5            |
|      |       | calibrated sample | PN25*  | 8      | 0.1    | 0.1     | nil      | nil      | 8          | 4       | 0.1    | 8        | 16           |
| 1984 | D(N)  | Ic(O)             | PN26   | 4.9    | 0.6    | 0.1     | nil      | nil      | 8          | 2.9     | 1.3    | 6        | 34           |
| 1985 | D(N)  | Ic(O)             | PN27   | 9.4    | 1      | nil     | nil      | nil      | 4.8        | 1.3     | 1.3    | 13.3     | 31.1         |
| 1998 | F(N)  | Ic                | PN51   | 7.8    | 2.2    | nil     | nil      | 1.1      | 7.8        | 1.1     | 2.2    | 5.5      | 31.2         |
| 1998 | F(N)  | UB                | PN54   | 1.8    | 1.6    | 0.8     | nil      | 0.1      | 2.1        | 3.1     | 1.5    | 4.2      | 8.1          |
| 1998 | F(N)  | UCS               | PN55   | 12.5   | 1.7    | 0.9     | nil      | 0.1      | 4.5        | 3       | 8.2    | 11       | 14.5         |
| 1998 | F(N)  | UCS               | PN56   | 2.4    | 0.7    | 0.6     | 0.1      | nil      | 2.8        | 1.3     | 1      | 2        | 1.8          |
| 1989 | H     | Layer 35          | H1716  | 5.3    | 0.8    | 1.3     | nil      | nil      | 2.2        | 0.8     | 1.8    | 6.6      | 9.8          |
| 1989 | H     | Layer 29          | H1717  | 9.1    | 1.8    | 2.5     | nil      | 0.3      | 4.7        | 2.5     | 2.2    | 8.8      | 14.7         |
| 1989 | H     | Layer 28          | H1718  | 2.2    | 1.4    | 0.3     | nil      | 0.3      | 4.9        | 2.6     | 1.9    | 7.5      | 14.2         |
| 1989 | H     | Layer 26          | H1719  | 6.1    | 1.7    | 0.5     | nil      | 0.2      | 2.6        | 3.1     | 2.6    | 5.7      | 10.1         |
| 1989 | H     | Layer 24          | H1720  | 7.1    | 1.4    | 1.7     | 0.1      | nil      | 2.1        | 5.6     | 5.3    | 4.2      | 10.9         |
| 1989 | H     | Layer 23          | H1721* | 4      | 1      | 1       | nil      | nil      | 4          | 3       | 1      | 4        | 5            |
|      |       | calibrated sample | H1721* | 8      | 0.1    | 0.1     | nil      | nil      | 8          | 4       | 0.1    | 8        | 16           |

\* Denotes samples assessed visually on an approximately logarithmic scale of 0-8 abundance.

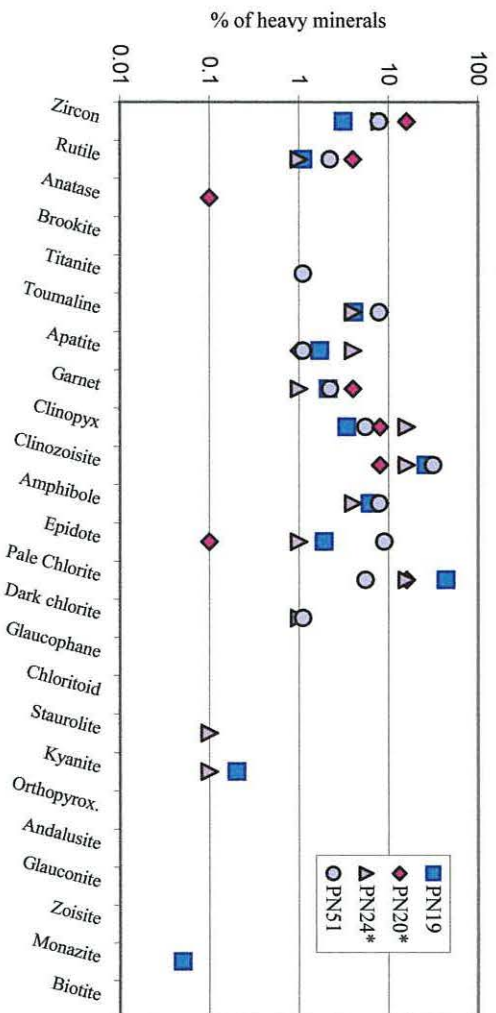
Table 4.4.1 Abundance of non-opaque, heavy mineral samples in sediments from Ponynwydd Cave (1982-1998).

| Amphibole | Epidote | Pale Chlorite | Dark chlorite | Glaucophane | Chloritoid | Staurolite | Kyanite | Orthopyrox. | Andalusite | Glaucinite | Zoisite | Monazite | Biotite | Aggregates | Totals |
|-----------|---------|---------------|---------------|-------------|------------|------------|---------|-------------|------------|------------|---------|----------|---------|------------|--------|
| 3         | 1       | 6             | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 33     |
| 4         | 0.1     | 64            | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 99.3   |
| 1.7       | 0.1     | 92.1          | nil           | 0.04        | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 99.49  |
| 3         | 2       | 4             | 2             | nil         | nil        | 1          | nil     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 36     |
| 4         | 1       | 8             | 1             | nil         | nil        | 0.1        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 56.2   |
| 4.9       | 0.6     | 75.2          | 1.3           | nil         | 0.05       | 0.3        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 5.3        | 100.25 |
| 5.6       | 0.7     | 77.2          | 0.9           | 0.05        | 0.05       | 0.1        | 0.05    | 0.1         | nil        | 0.1        | nil     | nil      | nil     | 0.1        | 99.45  |
| 3.1       | 0.5     | 81.3          | 1.2           | nil         | 0.05       | 0.4        | 0.05    | 0.1         | nil        | nil        | 0.2     | nil      | nil     | 1          | 99.5   |
| 9.9       | 0.7     | 40.9          | 0.7           | nil         | nil        | 0.5        | 0.2     | 0.4         | 0.9        | nil        | nil     | nil      | nil     | 4          | 99.2   |
| 3         | 1       | 6             | nil           | 1           | nil        | 2          | nil     | 1           | 1          | 1          | nil     | nil      | nil     | nil        | 38     |
| 4         | 0.1     | 36            | nil           | 0.1         | nil        | 1          | nil     | 0.1         | 0.1        | 0.1        | nil     | nil      | nil     | nil        | 78.7   |
| 2.4       | 2       | 68.3          | 0.6           | nil         | nil        | 0.2        | nil     | 0.2         | 0.2        | nil        | nil     | nil      | nil     | 3          | 94     |
| 2.2       | 0.6     | 79            | 0.05          | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 3          | 98.65  |
| 4         | 2       | 5             | 2             | nil         | nil        | 1          | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 4          | 40     |
| 8         | 1       | 16            | 1             | nil         | nil        | 0.1        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 8          | 68.1   |
| 5         | 1.6     | 66.4          | nil           | nil         | nil        | 0.05       | 0.05    | nil         | nil        | nil        | nil     | nil      | nil     | 1          | 98.45  |
| 7.7       | 2.1     | 42.7          | 0.2           | nil         | nil        | 0.1        | nil     | nil         | nil        | nil        | 0.7     | nil      | nil     | 1          | 98.1   |
| 6.6       | 1.2     | 43.6          | 0.2           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | 0.05     | nil     | 1.3        | 99.35  |
| 4.3       | 5.6     | 45.3          | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 19.2       | 92.9   |
| 4.7       | 11.2    | 4.3           | 0.05          | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 13         | 94.1   |
| 6.2       | 1.9     | 43.4          | nil           | nil         | nil        | nil        | 0.2     | nil         | nil        | nil        | nil     | 0.05     | nil     | 5.1        | 98.35  |
| 4         | 1       | 5             | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 2          | 38     |
| 8         | 0.1     | 16            | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 1          | 74.2   |
| 7.5       | 9.4     | 5.6           | nil           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 8          | 95.3   |
| 3         | 2       | 5             | 2             | nil         | nil        | 1          | 1       | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 38     |
| 4         | 1       | 16            | 1             | nil         | nil        | 0.1        | 0.1     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 72.2   |
| 3         | 3       | 2             | 1             | nil         | nil        | nil        | 1       | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 33     |
| 4         | 4       | 1             | 0.1           | nil         | nil        | nil        | 0.1     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 53.5   |
| 9.5       | 3.2     | 15.2          | nil           | nil         | nil        | 0.1        | 0.1     | nil         | nil        | nil        | nil     | nil      | nil     | 11.4       | 97.3   |
| 7.3       | 3.4     | 19.2          | 0.6           | nil         | nil        | 0.2        | 0.2     | nil         | nil        | nil        | nil     | nil      | nil     | 5          | 98.1   |
| 7.8       | 8.9     | 5.5           | 1.1           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 9          | 91.2   |
| 6.5       | 1.6     | 64.3          | 1.5           | nil         | nil        | 0.4        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 1          | 98.6   |
| 10.1      | 3.1     | 21.5          | 0.7           | nil         | nil        | 0.4        | 0.1     | 0.9         | nil        | nil        | nil     | nil      | nil     | 2          | 95.2   |
| 2.6       | 0.9     | 81.7          | 0.6           | nil         | nil        | 0.1        | 0.1     | 0.05        | nil        | nil        | 0.05    | nil      | nil     | nil        | 98.8   |
| 5.3       | 2.7     | 48.2          | 0.05          | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | 0.4     | 14.3       | 99.55  |
| 6.9       | 2.9     | 13.9          | 0.05          | nil         | nil        | 0.1        | 0.05    | 1.4         | 0.1        | nil        | 0.7     | nil      | nil     | 16.4       | 89.1   |
| 4.4       | 2.9     | 42.2          | 0.05          | nil         | 0.1        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 13.4       | 98.35  |
| 4.8       | 0.5     | 57.2          | 0.2           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 8          | 103.3  |
| 5.6       | 1.4     | 45.4          | 0.3           | nil         | nil        | nil        | nil     | nil         | nil        | nil        | nil     | nil      | nil     | 8.5        | 99.6   |
| 2         | 3       | 2             | 1             | nil         | nil        | nil        | 1       | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 32     |
| 1         | 4       | 1             | 0.1           | nil         | nil        | nil        | 0.1     | nil         | nil        | nil        | nil     | nil      | nil     | nil        | 50.5   |

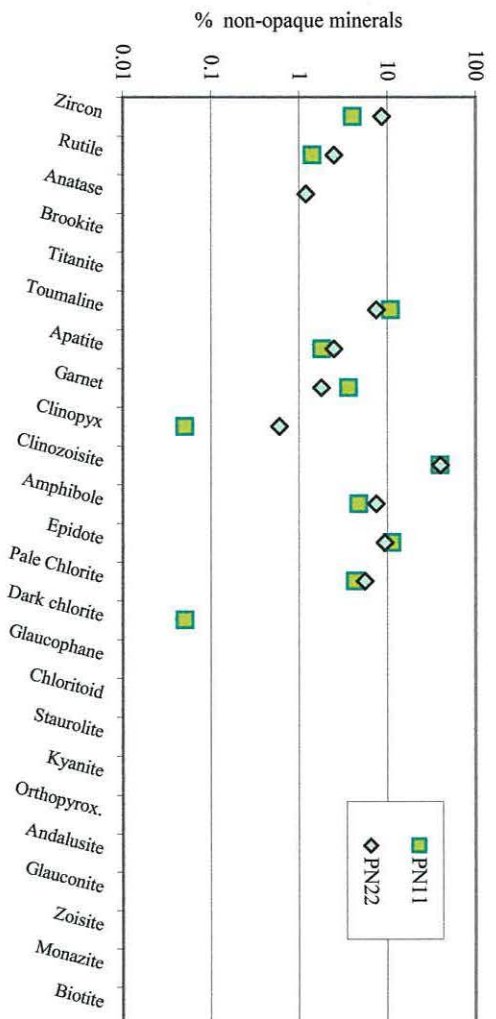
Table 4.4.1 (continued). Abundance of non-opaque, heavy mineral samples in sediments from Ponynwydd Cave (1982-1998).



# Intermediate Complex, Unit B



# Intermediate Complex, Unit DRS



# Lower Breccia, Units a, b, c

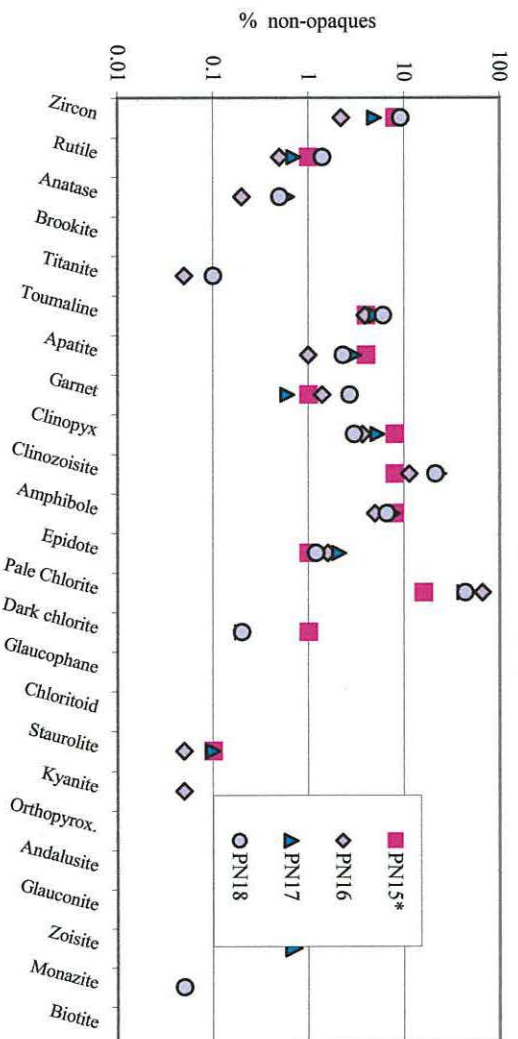
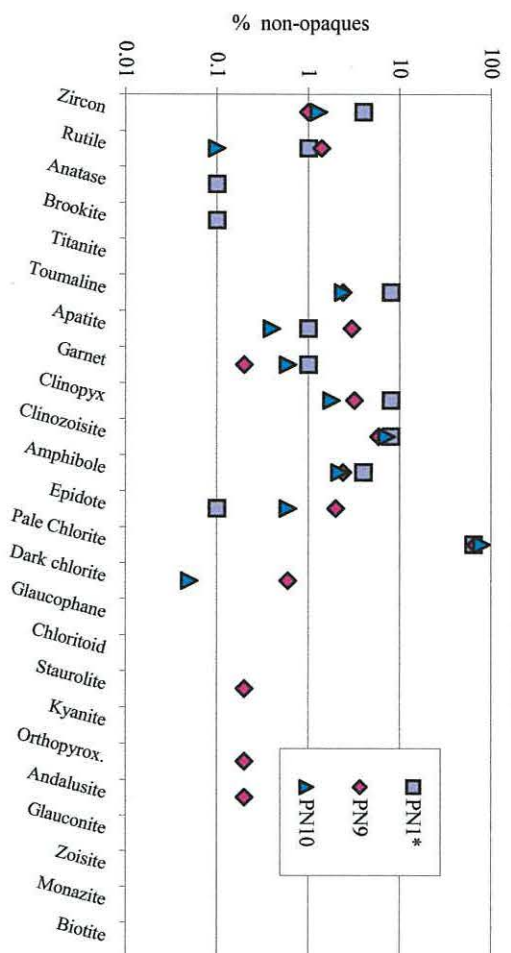
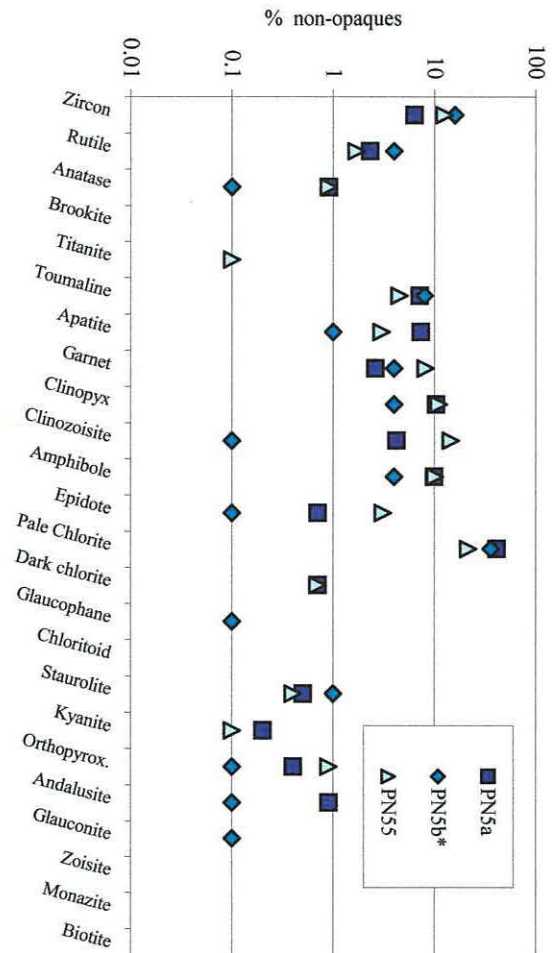


Figure 4.4.2. Non-opaque, heavy mineral content of samples from the Intermediate Complex and Lower Breccia beds. \* denotes calibrated samples.

# Sediments from Lower Sands & Gravels



# Sediments from Upper Clays and Sands



# Silt deposit

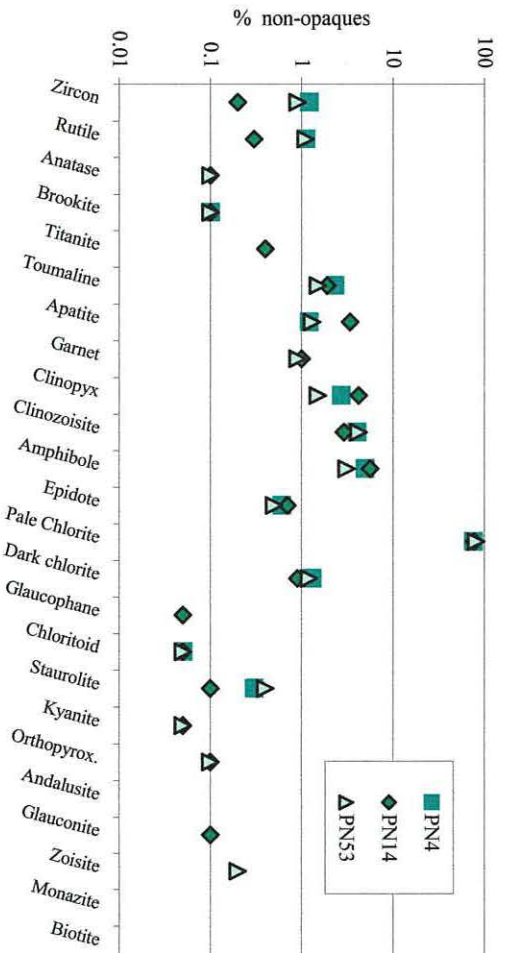
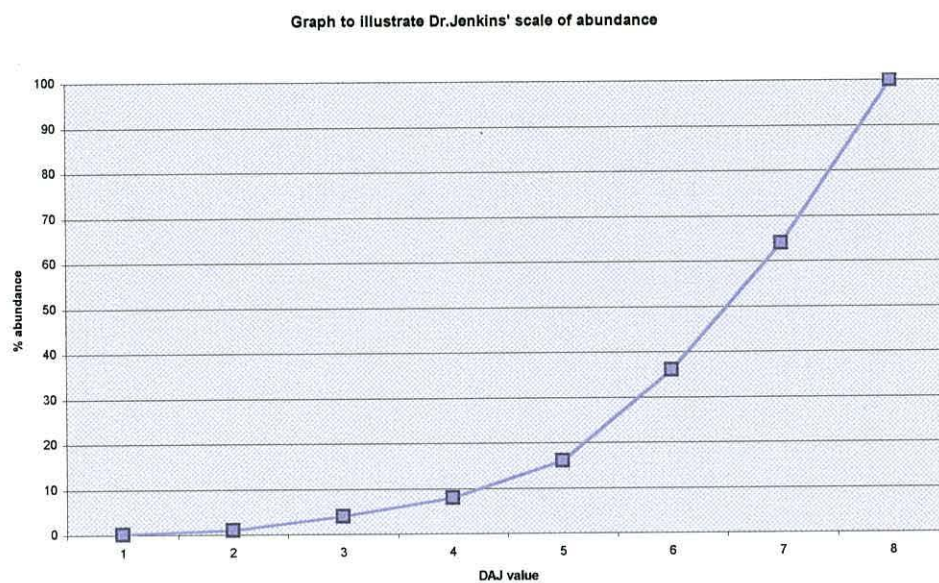


Figure 4.4.3. Non-opaque, heavy mineral content of sediments from the ~~Upper~~ Lower Sands Gravels, Uppers Clays Sands and Silt Deposit. \* denotes calibrated samples.





| DAJ scale | % abundance |
|-----------|-------------|
| 1         | 0.1         |
| 2         | 1           |
| 3         | 4           |
| 4         | 8           |
| 5         | 16          |
| 6         | 36          |
| 7         | 64          |
| 8         | 100         |

Fig. 4.4.4. Calibration ratio used to convert between D.A. Jenkins' scale of abundance and percentage, shown in graphical and tabular form.

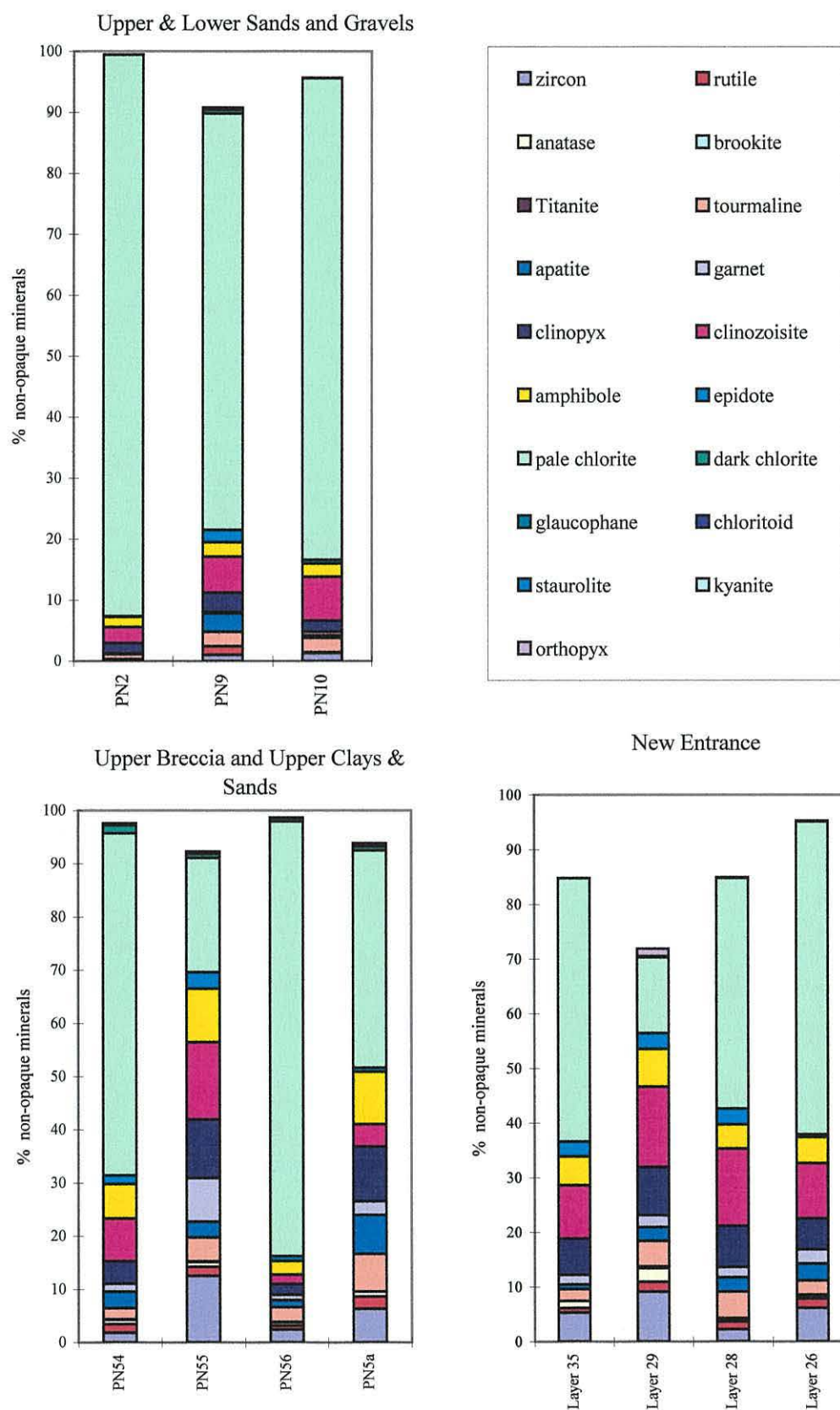


Figure 4.4.5. Graphical representation of the non-opaque, heavy mineral content of sediments from the Upper Lower Sands and Gravels, Upper Breccias Upper Clays Sands and New Entrance.



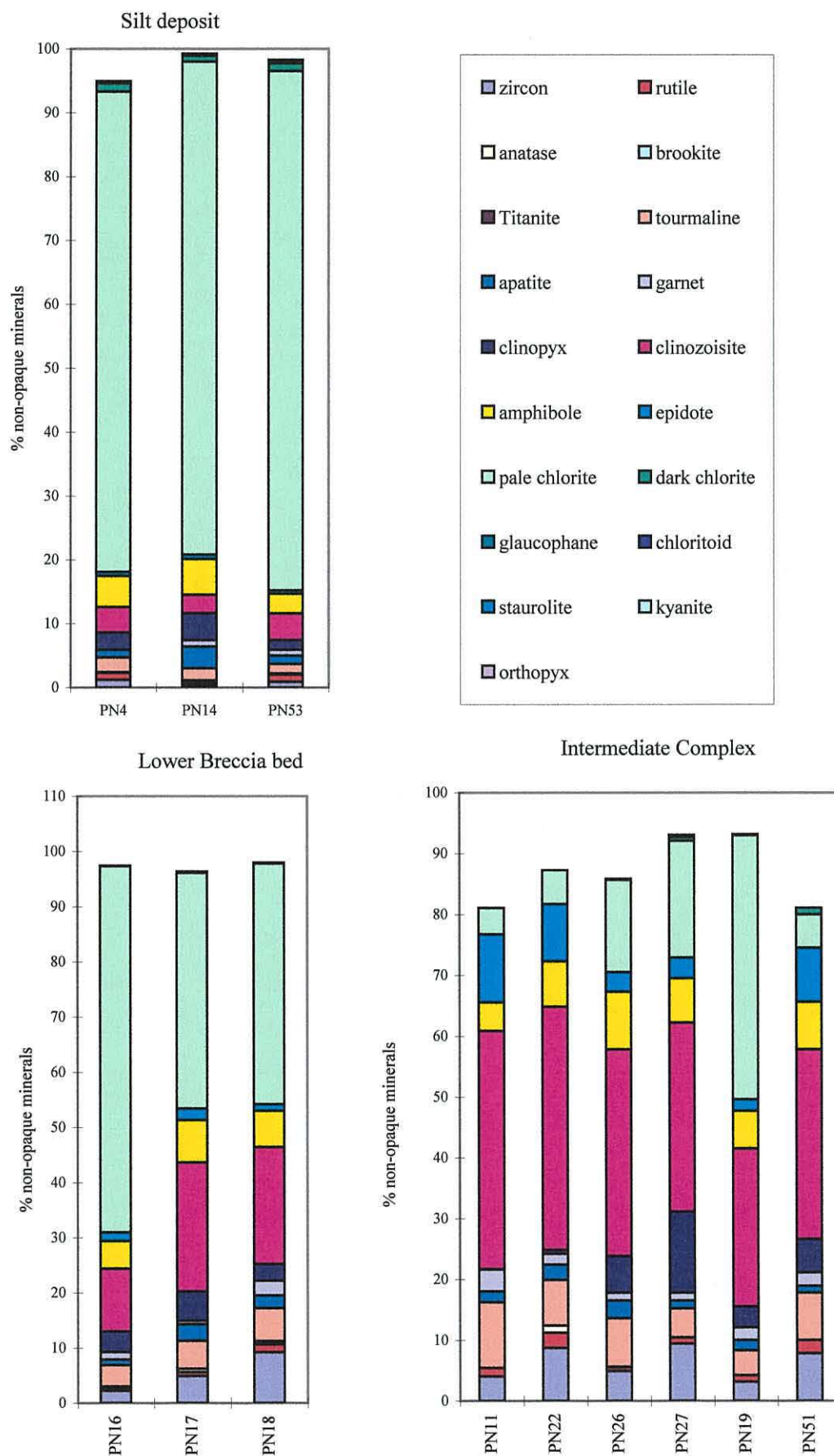


Figure 4.4.6. Graphical representation of the non-opaque, heavy mineral content of sediments from the Silt Deposits, Lower Breccia bed and Intermediate Complex.

# Irish Sea till

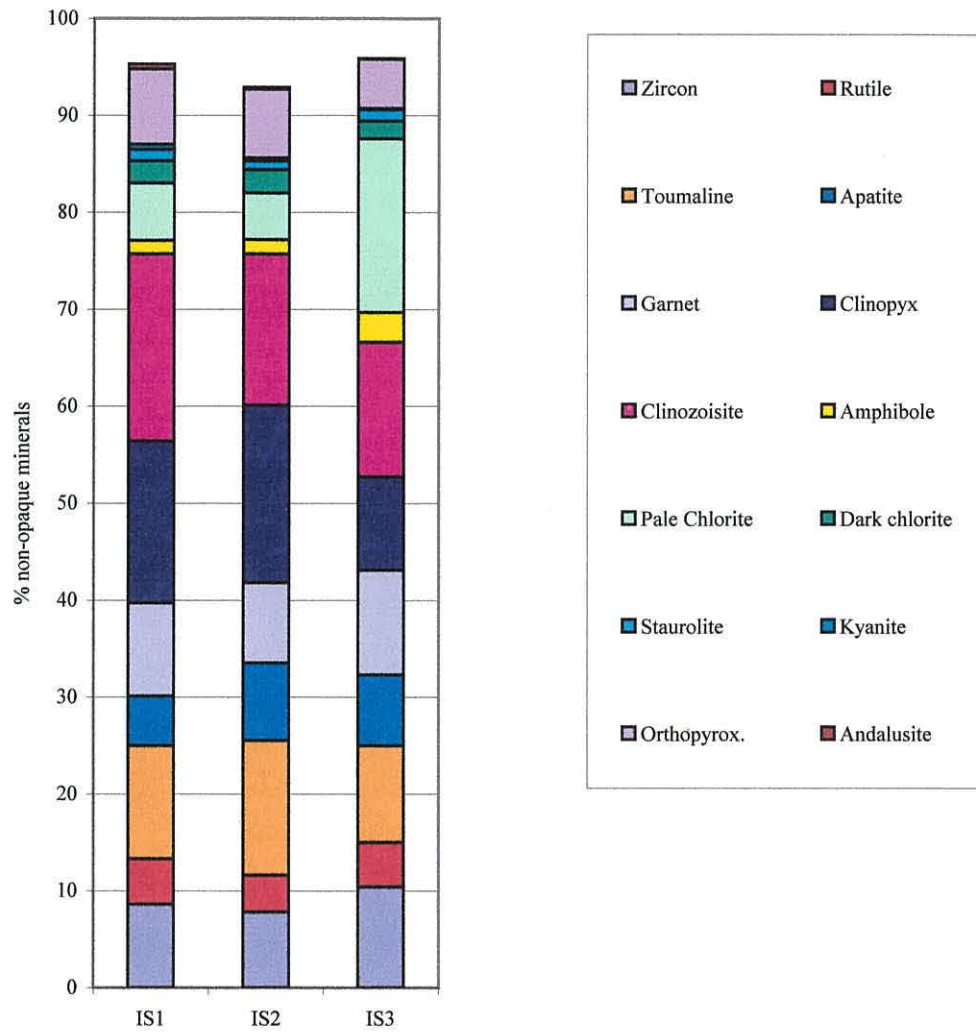


Figure 4.4.7. Non-opaque, heavy mineral content of sediments from the Irish Sea Till, data from Younis (1983).



#### 4.4. Trends exhibited by heavy mineral analysis of the sediments

##### 4.4.1. Macroscopic trends

1. Most of the samples were dominated by chlorite, together with minor zircon and tourmaline, which is characteristic of the local Lower Palaeozoic mudstones and Carboniferous basement beds (Livsey 1966). The number of other accessory minerals in these rocks is small, but rutile, brookite, sphene and garnet have been found in the Silurian rocks of Denbighshire (Jenkins *pers. comm*).
2. Samples PN2, PN56, PN53, PN14, and PN4, from the Upper Clays and Sands (UCS) and Silt deposit (Sb) respectively, all had a percentage abundance of chlorite in excess of 75%.
3. Clinopyroxenes, clinozoisite, amphiboles and apatite are found in all samples and represent addition of some material from mafic sources, such as dolerites.
4. Samples PN3, PN5a, PN27 and PN55, from the UCS and Intermediate Complex (Ic), all had a percentage abundance of clinopyroxene in excess of 10%.
5. Samples PN51, PN27, PN26, PN25, PN22, PN19, PN18, PN17, and PN11, all samples from the Intermediate Complex, contained between 20% and 40% clinozoisite.
6. Samples from the Intermediate Complex had a characteristic reddish hue, which indicates a source in the Irish Sea till. Samples from the Upper Clays and Sands were often also reddish.
7. The opaque minerals were not examined as part of this work, although in some samples over 50% of the total mineral assemblage was opaque. A high proportion of opaque minerals may indicate an origin in the iron-rich Irish Sea till.
8. The most diverse mineralogical assemblage derives from the UCS, the most recent sample. Presumably successive phases of glacial, fluvial and aeolian transport has provided an increasingly mixed deposit.
9. The highest percentage abundance of zircon was found in samples PN55 from the UCS, PN18 from the Lower Breccia, PN27 from the Intermediate Complex, and H1717 from the New Entrance.
10. The highest percentage abundance of tourmaline was found in samples PN22, PN26 and PN51, from the Intermediate Complex.
11. High levels of detrital tourmaline and zircon were also found in some samples from the Lower Sands and Gravels (LSG) and the Lower Breccia (LB). These were not

compared directly with the above percentages due to my concerns about the accuracy of converting measurements from D.A. Jenkins' scale of abundance to a percentage (see Figure 4.4.4).

12. Etching viewed on samples in the Intermediate complex and UCS indicate a degree of weathering. An increased resistate assemblage and depletion of less resistant minerals may also indicate weathering. However it is not possible to say whether this weathering took place during transport on the way to the cave, or outside the cave prior to the emplacement of the debris flows. In other words, a weathered sediment does not necessarily imply a long period between the deposition of the sediment outside the cave and its inclusion into the Pontnewydd stratigraphy.
13. Traces of rutile, garnet, anatase and brookite in samples from the Lower Sands and Gravels, the Silt deposits and the UCS indicate a contribution from Welsh sedimentary rock.

#### 4.4.2. Trends shown by cluster analysis of heavy minerals

In this study a Single Linkage Cluster Analysis method on SYSTAT was used. This choice was influenced by the limited range of multi-variant statistical analysis programmes licensed for use by the National Museums and Galleries of Wales. As the purpose of this analysis was to separate the sediments according to their provenance in either the Welsh or the Irish Sea till, for the first two analyses I have used the minerals suggested by Younis (1983) as useful indicators.

The phenogram for predominantly Welsh till minerals and mixed source minerals shown in Figure 4.4.10 shows a division into 6 broad groups, each containing at least two samples.

1. The greatest difference in similarity level is between groups 1, 2 and 3 and groups 4, 5 and 6. These groups are separated on the basis of generally higher zircon, tourmaline and clinozoisite values for groups 4, 5 and 6. This division clearly separates the Intermediate Complex from all other units in the cave, excepting the lower facies of the Lower Breccia (LBc).
2. The next greatest difference between two groups is between groups 4 and 5, and 6. This separation is on the basis of the high percentage of epidote in group 6, and separates the Dark Red Silt layer of the Intermediate Complex from the rest of the Intermediate and the LBc.



3. Samples in groups 1 and groups 2 and 3 exhibit the third greatest separation. This divides group 1, the Upper Clays and Sands and Layer 29 of the New Entrance, from the rest of the assemblage.
4. The next greatest separation, which results in a group no less than two, is between groups 4 and 5. This separates the Orange Intermediate from the Buff Intermediate and the LBc.
5. The final separation is between groups 2 and 3. This results in one group containing the silt deposit, UCS, Upper and Lower Sands and Gravels; and another group containing the Lower Breccia (b), and remaining samples from the New Entrance.

The phenogram for Irish Sea till and Welsh indicator minerals shown in Figure 4.4.9. divides the sediments into six groups.

1. The greatest difference in similarity level is between groups 1, 2 and 3 and groups 4, 5 and 6. This division clearly separates the Intermediate Complex from all other units in the cave, excepting the lower facies of the Lower Breccia (LBc). The samples in groups 4 and 5 contain the highest percentages of clinozoisite in the whole assemblage and so are probably separated on the abundance of this mineral.
2. The second division is between groups 4 and 5, and group 6. This separates the Dark Red Silt unit of the Intermediate complex (Ic) from the other units of the Intermediate and the Lower Breccia.
3. The next greatest difference in similarity level is between groups 4 and 5. This separates the Orange unit of the Ic from the Buff intermediate and LBc.
4. The following division is between groups 1 and groups 2 and 3, and separates only one sample, PN5a, from the rest of the assemblage.
5. The final difference in similarity level is between groups 2 and 3 and separates the Upper and Lower Sands and Gravels, Silt beds, Upper Breccia and PN56 from the LB (b), New Entrance samples and sample PN55 of the Upper Clays and Sands. This broadly separates samples with their origins in the Irish Sea till, from samples with a predominantly local influence.

Cluster analysis of all minerals observed in the Pontnewydd sediments shown in Figure 4.4.8. resulted in division into seven groups.

1. The greatest difference in similarity level was between groups 1,2,3 and 4 and groups 5, 6 and 7. This division separated the Orange Intermediate, Dark Red Silt, PN55 of the UCS and Layer 29 of the New Entrance from the rest of the assemblage.
2. The second greatest difference was between groups 1 and 2 and groups 3 and 4. This separated the LBc, Buff Intermediate, Layers 28 and 35 from the New Entrance and PN5a UCS from the Upper and Lower Sands and Gravels, Sb, the Upper Breccia, LBb and Layer 26 of the New Entrance.
3. The subsequent division separated group 7, the Ic Dark Red Silt from groups 5 and 6, the Orange Intermediate, PN55 UCS and Layer 29.
4. The next greatest distance was between groups 5 and 6. This separated the Orange Intermediate from a group consisting of PN55 UCS and Layer 29 of the New Entrance.
5. The following separation was between PN5a UCS, forming group 3 and LBc, the Buff Intermediate, and Layers 28 and 35 from the New Entrance, forming group 4. PN5a is one of two 'misfit points' in this phenogram, the other being PN2 USG.
6. The final large difference was between groups 1 and 2. Group 1 contained samples from the Sb and Upper and Lower Sands and Gravels and PN56 UCS. These are the samples that contain the highest percentage of chlorite in the assemblage. Group 2 contained PN9 LSG, the Upper Breccia, LBb and Layer 26 of the New Entrance.

In all three analyses, PN5a UCS formed an isolated group and PN55 UCS and Layer 29 of the New Entrance grouped together. This suggests that this layer of the New Entrance has a similar, highly mixed source to PN55. Furthermore, samples from the Dark Red Silt, and from the Orange Intermediate, consistently grouped together, and the difference between these samples and the whole of the rest of the assemblage was consistently high. It is clear that the Intermediate complex is a heterogeneous unit containing distinct layers that differ widely from each other. The Lower Breccia (c) consistently grouped with the Buff Intermediate and it is possible that scouring of the Intermediate surface by the emplacement of the Lower Breccia has provided some mixing of these layers. Alternatively, the two debris flows that make up these units are derived from the same external till deposits. Samples from Layers 26, 28 and 35 of the New Entrance tend to group together, rather than being intermixed among the other samples. This indicates a greater similarity with each other than with the other samples from the main cave,



suggesting that rather than being an extension of deposits found within the main cave, these layers are the result of emplacement from an alternative source. The Silt beds tend to group with samples from the Upper and Lower Sands and Gravels which may be a result of the high chlorite and low zircon content of these layers, indicating a lack of weathering and low input from a weathered source.

# **All minerals observed**

Distance metric is Euclidean distance

Average linkage method

Cluster Tree

Distances

20.000

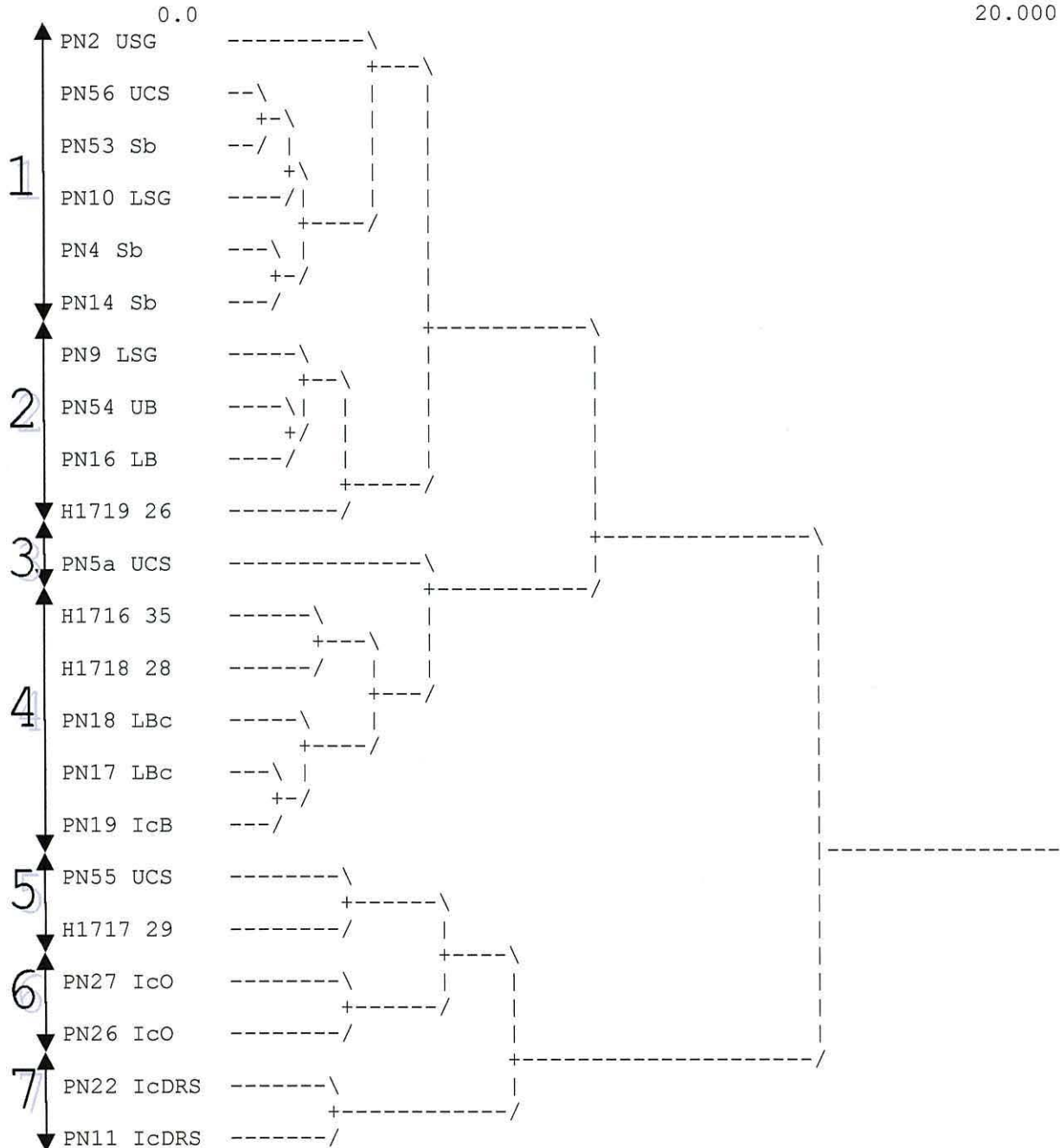


Figure 4.4.8. Single linkage cluster analysis of all heavy mineral species observed in the Pontnewydd sediments.



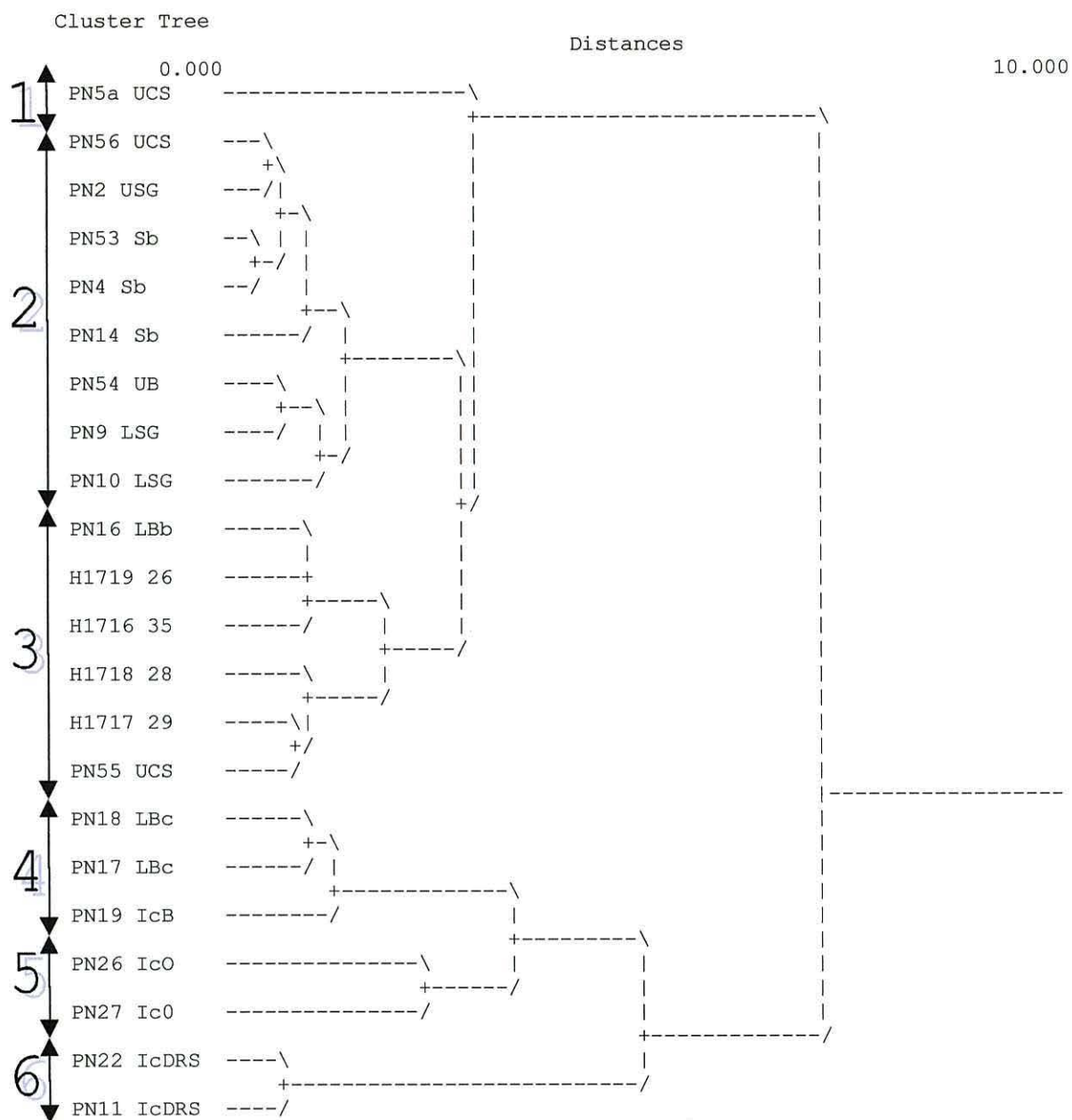


Figure 4.4.9. Cluster analysis of all Irish Sea till and Welsh till indicator minerals as suggested by the work of Jenkins (1964) and Younis (1983). Euclidean distance average, single linkage method: clinozoisite, glaucophane, anatase, brookite, titanite, chloritoid, clinopyroxenes, apatite, epidote, kyanite, staurolite, orthopyroxenes.

Welsh till minerals with mixed source minerals (based on Younis 1983).

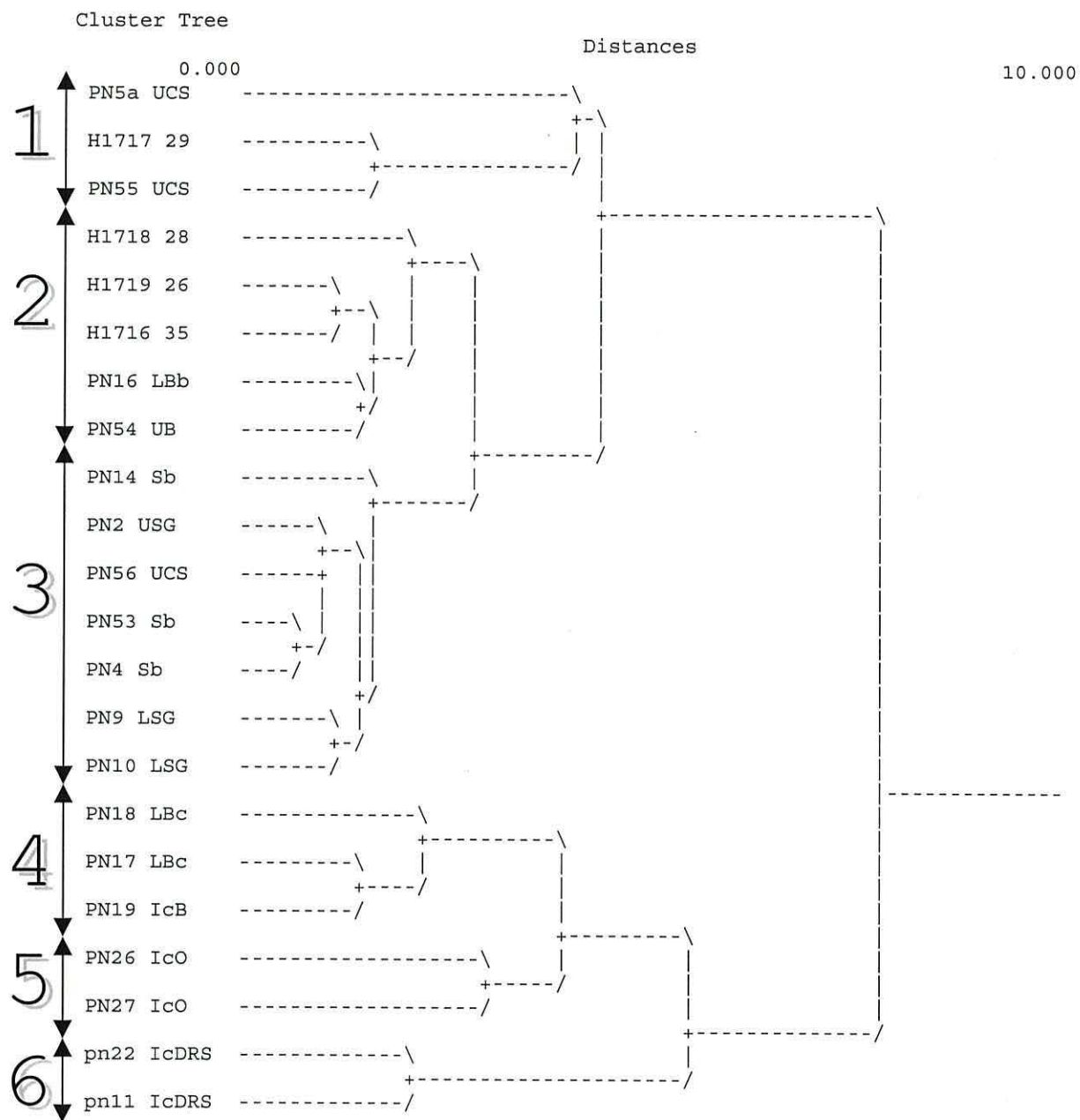


Figure. 4.4.10. Single link cluster analysis using zircon, tourmaline, anatase, brookite, titanite, garnet, epidote, apatite, clinopyroxene, amphiboles, clinozoisite, and glaucophane.



#### **4.5. Particle Size Analysis**

The particle size distribution of a sediment shows the proportions of the various sizes of particles which it contains. Particle size distribution in differing depositional environments has been studied by several authors (Folk and Ward 1957, Buller and McManus 1974). The texture (i.e. proportion of different particle size classes) of a sediment depends on several factors, the most important of which are lithological composition, sorting of rock and mineral fragments during transport, and the process of deposition.

This section aims to investigate the particle sizes of several samples from Pontnewydd and relate this to the parentage of the sediments under investigation. The particle size analysis is performed here on only a few samples, in an attempt to establish whether the mineral assemblages observed in Sections 4.3-4 are derived directly from relatively fresh till, or indirectly from the till as a result of fluvial processes. The results of the heavy mineral analysis (Section 4.3) indicate that a large number of the sediments are derived from mixed sources, containing components of both Welsh and Irish Sea till. Particle size analysis was therefore performed in order to indicate the possible processes that have resulted in such a mixed assemblage.

Fresh till usually contains a variety of lithologies and it is therefore likely that till samples will have approximately equal frequencies in each of their particle size categories. Fluvially transported material is usually dominated by silt-sized grains, so the two processes may be tentatively distinguished on this basis. The methods used are given in section 4.1, and the results of the particle size distribution for the eight samples analysed are given in Figures 4.5.1-4.5.3, expressed as weight percentage of the dry soil.

##### 4.5.1. Interpretation of results

Younis (1983) suggests that the Welsh (grey) till and the Irish Sea (reddish-brown) till are separable on the basis of their particle size distributions. The percentage of the coarse sand fractions is greater in the grey till than in the reddish till and the amounts of clay and silt are lower. He further suggests that these differences are due to differences in lithological composition. Dreimanis and Vagners (1971) have shown that coarser fractions tend to derive

from igneous and metamorphic minerals, that the silt content may come from limestones, and that shales can produce a silty-clay matrix.

Classification of the sediments according to their particle sizes based on a small sample size such as this is difficult. However, a few important points are evident from examination of the data.

1. All samples contain between 34 and 49% silt, a component which may derive from the local shales of the Denbigh Moors.
2. Sample PN51 from the Intermediate complex (Figure 4.5.2, graph 1), and sample PN55 from the Upper Clays and Sands (Figure 4.5.3, graph 1) both display a relatively equal distribution, and if the silt is locally derived (see point 1), this distribution may indicate a glacial source. The clay proportion is slightly lower than that expected in a till, but this could be explained by the effects of weathering under temperate conditions (Jenkins 1984). The higher percentage of material in the 2000-630um range (12.7%) in sample PN55 could indicate an influence from deposits of the Welsh till (Younis 1983).
3. Sample PN52 from the Lower Breccia (Figure 4.5.2, graph 2), displays a high silt and clay component, with very little coarse material. This may indicate a fluvial episode, perhaps a fluidization of the finer material from a till. The low level of coarse material in the profile could suggest an origin in the Irish Sea till for this layer (Younis 1983), which would be consistent with the findings of Livingstone (1986), although it could also be due to fluvial transport.
4. Samples PN53 and PN54 have similar size distribution profiles (Figure 4.5.2, graphs 3 and 4), both of which suggest a contribution from a fluvial source. Sample PN54, from the Upper Breccia, contains more medium sand and less clay than PN53, but they are both likely to be the product of a degree of fluvial action.
5. Sample PN56 from the top of the Upper Clays and Sands (Figure 4.5.3, graph 2), is a clay-rich layer, with a high silt component and little coarse material. This could suggest a fluvial episode which incorporated the clay, perhaps a slumped deposit? The low level of coarse material could suggest an influence from Irish Sea till, although heavy mineral analysis has shown this to be a mixed layer. The particle size distribution necessitates comparison with PN52.



6. Sample H1720, Layer 24 of the New Entrance (Figure 4.5.3, graph 3), has a relatively equal size distribution that may indicate a till source. The high proportion of material in the 2000-630um fraction could suggest an input from the Welsh till (Younis 1983).
7. Sample H1716, Layer 35 of the New Entrance (Figure 4.5.3, graph 4), has a bimodal size distribution that indicates a poorly sorted deposit. It has both a high silt and coarse sand component. This sort of profile could be derived from a gravel-type deposit with a fluvial input.

The difficulty in assigning the sediments to groups corresponding to their parentage probably reflects their having being formed from either a mixture of drift deposits, an inhomogenous drift or weathering and pedological processes, perhaps during deposition and transport to the cave.

|          |        | Mass (g)     | Mass (g) | Mass (g)   | % total    | Mass (g)  | % total   |
|----------|--------|--------------|----------|------------|------------|-----------|-----------|
| Layer    | Number | start weight | >2mm (g) | 2000-630um | 2000-630um | 630-200um | 630-200um |
| Int.     | PN51   | 15.39        | -        | 1.18       | 7.7        | 1.44      | 9.4       |
| LB       | PN52   | 18.3         | -        | 0.46       | 2.5        | 0.34      | 1.9       |
| Silt     | PN53   | 50.0         | -        | 2.58       | 5.2        | 1.85      | 3.7       |
| UB       | PN54   | 50.0         | -        | 2.78       | 5.6        | 3.69      | 7.4       |
| UCS      | PN55   | 50.0         | -        | 6.34       | 12.7       | 5.97      | 11.9      |
| UCS, top | PN56   | 40.0         | -        | 1.14       | 2.9        | 1.94      | 4.9       |
| Layer 24 | H1720  | 40.0         | -        | 5.73       | 14.3       | 2.77      | 6.9       |
| Layer 35 | H1716  | 40.0         | -        | 13.32      | 33.3       | 4.33      | 10.8      |

|        | Mass (g) | % total  | % total sand | % silt+clay | % total silt | % silt +clay | % total clay |
|--------|----------|----------|--------------|-------------|--------------|--------------|--------------|
| Number | 200-63um | 200-63um | 2000-63um    | 63-2um      | 63-2um       | <2um         | <2um         |
| PN51   | 3.34     | 21.7     | 38.8         | 61.0        | 37.4         | 39.0         | 23.9         |
| PN52   | 0.81     | 4.4      | 8.8          | 48.5        | 44.2         | 51.5         | 47.0         |
| PN53   | 4.35     | 8.7      | 17.6         | 59.5        | 49.1         | 40.5         | 33.4         |
| PN54   | 4.80     | 9.6      | 22.6         | 63.0        | 48.8         | 37.0         | 28.7         |
| PN55   | 8.18     | 16.4     | 41.0         | 65.5        | 38.7         | 34.5         | 20.4         |
| PN56   | 2.96     | 7.4      | 15.2         | 42.0        | 35.6         | 58.0         | 49.2         |
| H1720  | 5.45     | 13.6     | 34.8         | 53.0        | 34.5         | 47.0         | 30.6         |
| H1716  | 4.74     | 11.9     | 56.0         | 87.5        | 38.5         | 12.5         | 5.5          |

Particle size distribution of selected samples from Pontnewydd Cave

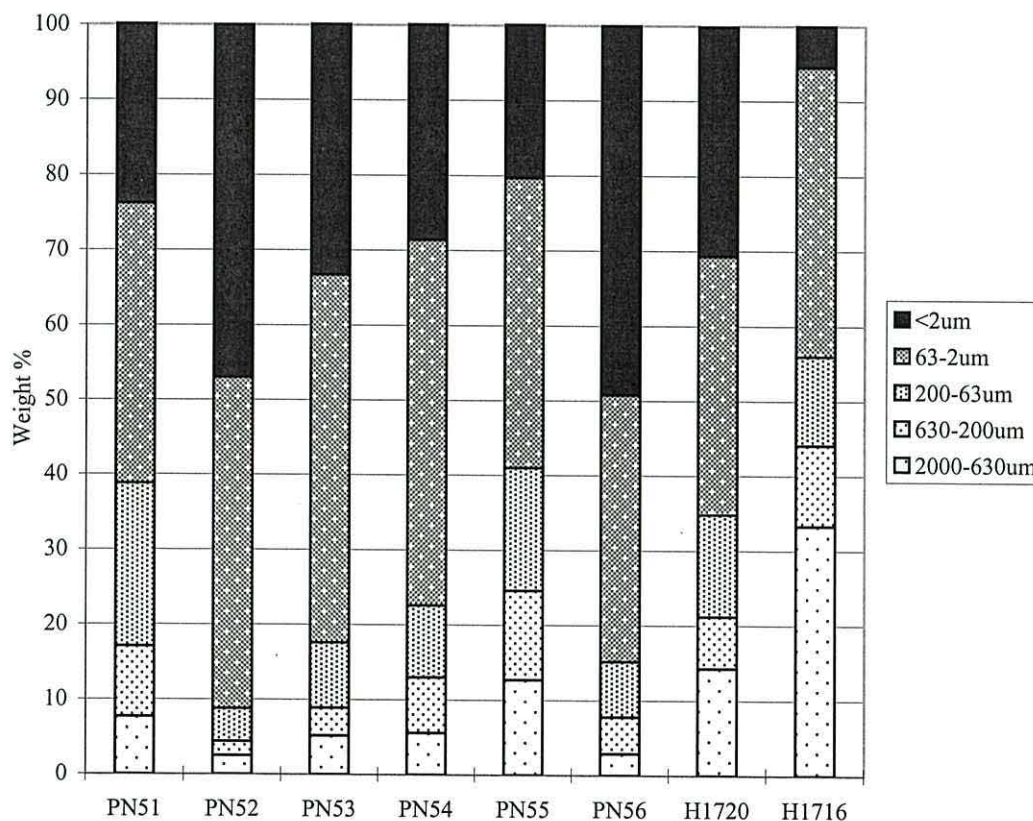


Figure 4.5.1. Particle size distribution of selected Pontnewydd samples, tabulated and graphical.



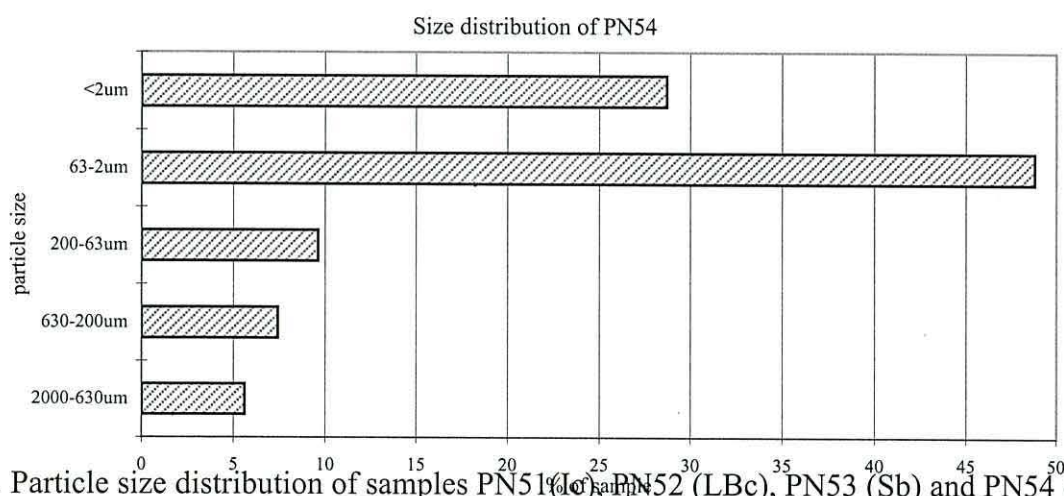
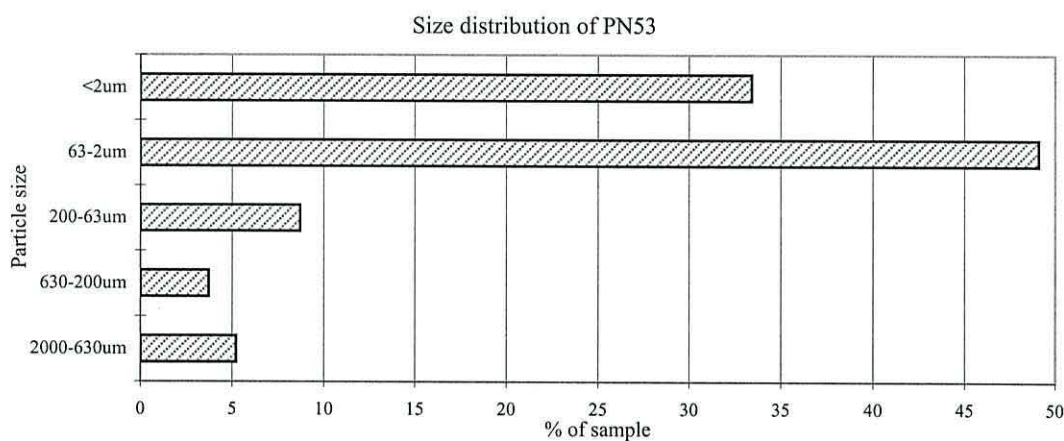
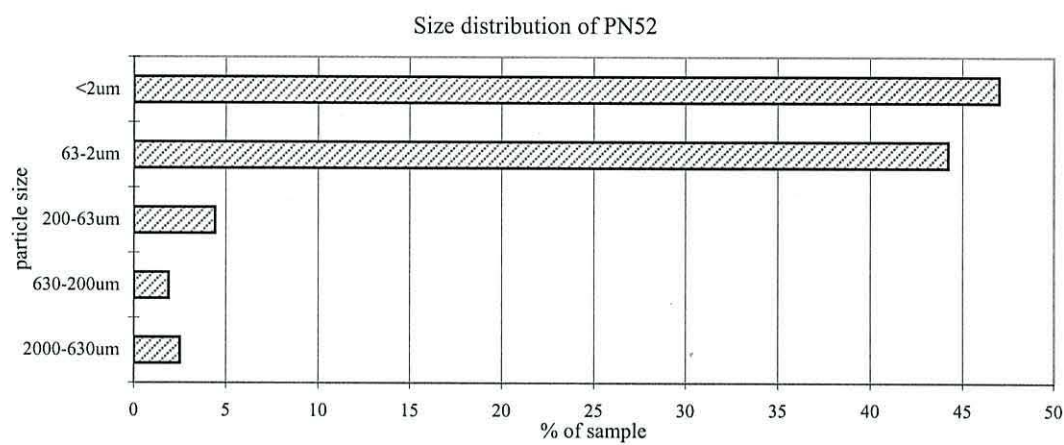
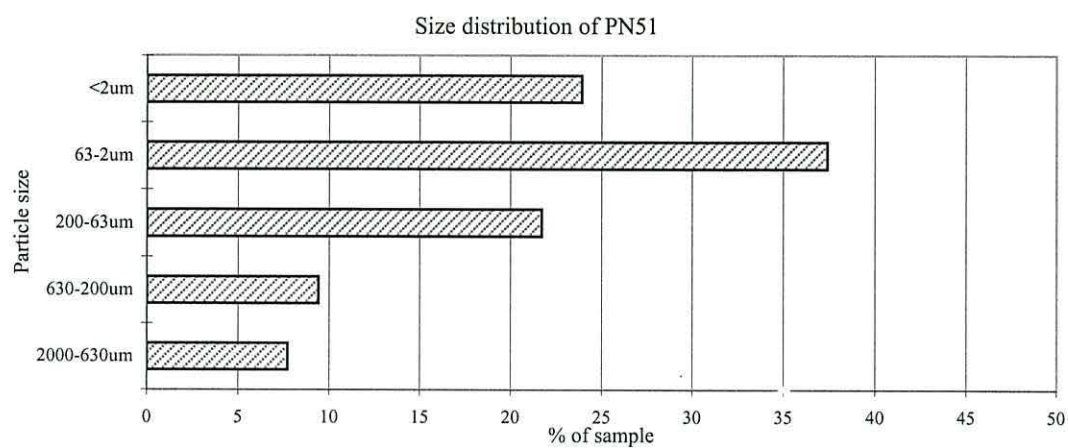


Figure 4.5.2. Particle size distribution of samples PN51(Ic), PN52 (LBc), PN53 (Sb) and PN54 (UB).

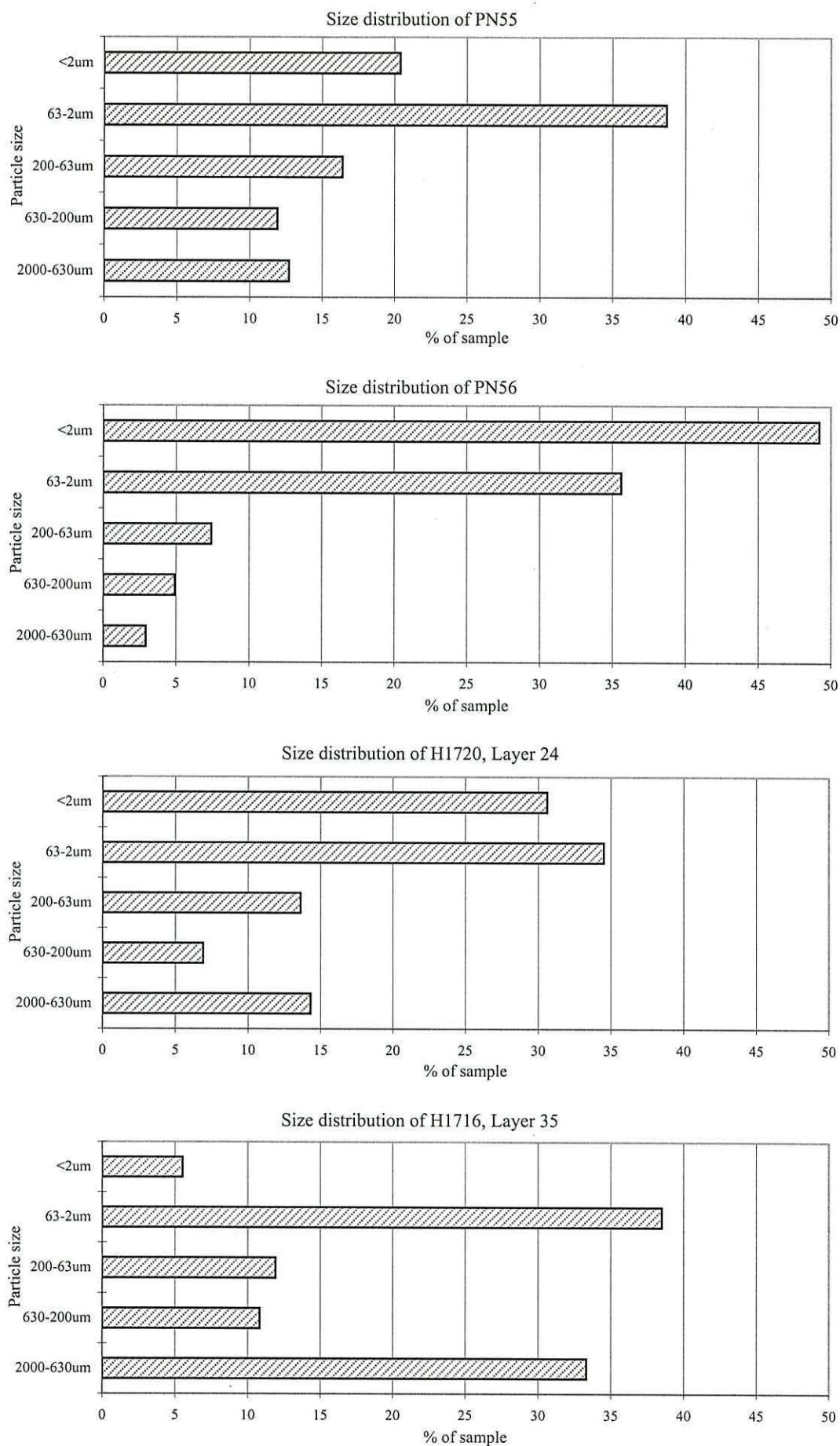


Figure 4.5.3. Particle size distribution of samples PN55 (UCS), PN56 (UCS), H1717 (Layer 29), and H1716 (Layer 35).



#### **4.6. Interpretation of the sediments from Pontnewydd Cave**

Heavy mineral content of soils from Carboniferous limestone sources, the bedrock at Pontnewydd, is extremely low, often less than 1% (Smithson 1953). Younis (1983) found that Carboniferous limestone made very little contribution to the heavy mineral assemblage of any of the soils studied, and it is therefore not likely to have contributed to the heavy minerals found in the sediments from Pontnewydd Cave.

The heavy minerals observed in the Pontnewydd sediments are therefore the products of contributions from non-local rocks, which have been brought into the Elwy Valley by the Irish Sea Ice and the Welsh Ice. Younis (1983) performed a study of soils from several areas in north Wales. He found that soils formed on drifts from Triassic rocks, an identified contributor to the Irish Sea till, tend to have high zircon, tourmaline, augite and garnet, with accessory staurolite, kyanite, andalusite, enstatite and glauconite.

Younis (1983) also examined soils formed on the Mona Schist in Anglesey. These were found to contain a high percentage of clinozoisite and glaucophane, rounded grains of zircon and tourmaline, and accessory staurolite, kyanite, and andalusite. These latter minerals again derive from the nearby Triassic material. Soil samples taken from above the Old Red Sandstone (which is absent in North Wales except for a small area on Anglesey) contained high proportions of zircon, tourmaline, garnet, and accessory staurolite or andalusite (Younis 1983). The resistate minerals probably derive from the Old Red Sandstone, but the metamorphic minerals are contamination from the Triassic.

Samples containing staurolite, kyanite or andalusite were consequently considered to be derived from the Irish Sea till. The effects of weathering on the sand and silt component should be considered when comparing the compositions of parent materials. From a survey of mineralogical work on podzols, Bateman and Catt (1985) proposed the following stability sequence for heavy minerals (least resistant first):

Apatite << brown hornblende < tremolite and actinolite < augite < enstatite << green hornblende << epidote < zoisite and clinozoisite << garnet << anatase, andalusite, brookite, kyanite, monazite, rutile, sillimanite, sphene, spinel, staurolite, topaz, tourmaline and zircon.

It must also be remembered that minerals of a relatively low specific gravity, such as kyanite, staurolite, chlorite, augite and tourmaline, are susceptible to aeolian transport, and may enter remote sediments in this way.

Using the heavy mineral evidence described in Sections 4.2-4.4, the particle size analysis described in section 4.5 and current data on the estimated chronology for Pontnewydd Cave (Embleton and Livingston 1989), the following sequence of events may be derived:

#### 4.6.1. Lower Sands and Gravels >250ka

A debris flow containing glaciofluvial material mainly derived from the local Silurian shales, with some contribution from a Welsh till source. Indicates the presence of a Welsh till at or near this time. A channel within this layer (PN9) contains deposits of Irish Sea till origin, this may relate to the 'Northern Drifts of Coventry' referred to by Embleton and Livingston (1989). The presence of erratics from the Irish Sea till within this deposit has been used to support the idea of an Irish Sea Ice glaciation from 300-250ka (Green 1984, Green 1988), and the heavy mineral evidence from the channel deposit supports this theory.

#### 4.6.2. Upper Sands and Gravels >225ka

A debris flow deposit derived from the Welsh till, indicating the presence of Welsh ice at around this time. Neither this nor the LSG show signs of temperate weathering, implying that the deposits were emplaced under glacial or periglacial conditions.

#### 4.6.3. Intermediate deposit >225ka

A series of debris flows each with a distinctive heavy mineral assemblage, which do not form a coherent stratigraphy. For example, in site F (PN51), the Orange Intermediate overlies the Buff Intermediate whereas in site D, the Buff Intermediate overlies the Orange Intermediate. The Dark Red Silt appears to be the basal layer of this complex, and contains local volcanic material and a contribution from a Welsh sandstone source, although one sample contains a kyanite grain. This first flow, therefore, incorporated Welsh till. Within site D, the lowest Ic layer is the Orange Intermediate, which is characterised by a high opaque component and a contribution from the Irish Sea till. The Buff Intermediate is the



uppermost in the Ic at site D and contains both Irish Sea and Welsh indicator minerals. Irish Sea till deposits were therefore present in the area at this time, although all layers within the Intermediate show signs of weathering, suggesting an interglacial phase during the deposition of these sediments. Furthermore, organic matter has been shown to contribute to the complexing of iron oxides, and the trends for dithionite-extractable and pyrophosphate-extractable Fe are consistent with those of brown calcareous Mediterranean type soils such as would have developed under Interglacial conditions (Jenkins 1997). The chronology would allow this layer to be ascribed to the Hoxnian Interglacial.

#### 4.6.4. Lower Breccia >225ka

A debris flow event bringing material derived from animal and hominid activity outside the cave. The lowest layer, LBc, is a weathered deposit containing mainly Welsh material with one grain of staurolite (which could be wind-blown) found in the study of three samples. The following layer, LBb, is a mixed deposit, consisting of local material, soliflucted Welsh and Irish Sea drift. The presence of fauna and the weathered nature of the basal layers, indicate an Interglacial Stage. The top layer, LBa, derives mainly from a soliflucted Welsh till source, with some Irish Sea till component. This unit illustrates the presence of both Irish Sea and Welsh till in the Elwy Valley immediately prior to 225ka.

#### 4.6.5. Silt deposit 80-10ka

A low-energy fluvial deposit, bringing a combination of Irish Sea and Welsh material into the cave. Water that supplied this deposit probably passed through several layers of till, collecting a mixed assemblage. The low sedimentation rate at this time suggests a glacial period, which is concurrent with Livingston and Embleton (1989) who suggest a Late Devensian re-advance, with Welsh Ice then Irish Sea Ice in the Elwy Valley, and fluvio-glacial events from wasting Welsh Ice.

#### 4.6.6. Upper Breccia 30-10ka

A debris flow event bringing soliflucted material from both the Irish Sea and Welsh till, possibly extending through the back of the cave to the New Entrance (Green *pers. comm*). This deposit indicates the presence of the Irish Sea and Welsh tills at the time of Upper Breccia emplacement. SEM analysis (Bull 1984) suggests that both the Upper and Lower

Breccias have undergone a fluvial transport phase, and the particle size analysis of this layer suggests that it is made up of 'flowed' till.

#### 4.6.7. Upper Clays and Sands <10ka

A recent glacial and post-glacial fluvial deposit with a highly varied source containing both Irish Sea and Welsh indicator minerals and a wide variety of additional minerals. This varied source probably results from the erosion of both tills and terraces.

#### 4.6.8. The New Entrance

Only a limited number of samples from the New Entrance were examined in this study, all contained a high percentage of opaque minerals, were frequently iron stained and contained many 'murky' altered minerals. An estimated sequence of events can not be suggested because samples were not taken from all layers within the sequence. The lowest sample taken was from Layer 35, which is a soliflucted gravel or terrace deposit derived from a Welsh source. The light fraction contained grains of mudstone and calcite indicating an input from the local limestones, mudstones and shales. Layer 29 derives from a more heterogeneous source, during preparation of the heavy minerals the intense yellow colour of this layer was noted, and the heavy mineral assemblage clustered with the sediments of the Upper Clays and Sands. This layer derives from a mixed source and has clearly suffered the type of temperate weathering observed by previous authors (Jenkins 1984) in the Intermediate complex.

Layer 28 is another debris flow that contains minerals primarily from a Welsh source. There was noticeable blackening at the surface of this layer, which may have been manganese, and the sediment contained many partially degraded ferric oxides. It has probably mainly derived from a sandstone source rich in ferro-magnesian minerals. Layer 26 is a debris flow containing some silicic igneous exotics, which appear in the heavy mineral fraction as grains of aggregates. This layer derives from a Welsh till containing predominantly material from igneous rocks. Both these layers contain around 20% bone and were therefore emplaced under interglacial conditions. Layer 24 is a limestone breccia that resembles the Upper Breccia from the main cave and derives from soliflucted Welsh till.



Overall the layers from the New Entrance seem to contain a greater component of local and Welsh till material than those within the main cave. However, the types of emplacement mechanisms seem to be the same (Green *pers. comm*), resembling the debris flow events (Colcutt 1984) of the main cave.

The mechanisms by which the deposits were mixed on the surface has not yet been established, but this analysis provides evidence that they once derived from acid igneous rocks and coarse-grained sandstones, and were transported by both rivers and glaciers.

#### **4.7. Conclusions**

The stratigraphy of both the main cave and the New Entrance are of great interest, not only because they have been the mechanism by which the artefacts, the evidence of human habitation, has been preserved in a region that has undoubtedly suffered several phases of glaciation outside the cave. The heavy mineral, and to a lesser extent, particle size analysis of the sediments, has provided evidence for these phases of glaciation. It has indicated the presence of both Irish Sea and Welsh tills in the area outside the cave, and has added support to the sequence of glaciations proposed by Embleton and Livingston (1989).

**Investigations into the Mineralogy and Petrology of the Sediments and  
Artefacts from the Lower Palaeolithic site of Pontnewydd Cave.**

**Chapter 5**

**CONCLUSIONS AND FURTHER WORK**



## 5.1. Conclusions

The purpose of this project was to undertake a petrological study of the artefacts and sediments from the Lower Palaeolithic site at Pontnewydd Cave.

The artefacts were studied in hand specimen and under a binocular microscope, and were divided into rough petrological groupings. These identifications were clarified by the study of some 167 thin sections (Appendix 1). The characteristic mineral assemblages observed in the thin sections were compared with published descriptions of Ordovician igneous rocks, primarily those from the Snowdonia area, and some thin sections from known localities. In some cases it was possible to ascertain the provenance of the rock, but whilst identification was generally straightforward, finding evidence of provenance was often elusive. The majority of exotics that could be traced back to their original source derived from North Wales, and principally the Snowdonia area, but a smaller number also derived from the English Lake District. These results are consistent with those of previous studies (Bevins 1984) and consequently have not greatly expanded our understanding of glacial input to the area. Further work (see below) could provide more accurate provenancing, but as the material was removed, probably selectively, from glacial drift, the artefacts may not provide an accurate reflection of the material available in the drift after each successive glacial stage and may not therefore warrant further study for geomorphological purposes.

Measurements of the dimensions of the volcanic artefacts were taken and these were added to extant measurements of the non-igneous materials, taken by Elizabeth Walker of the Archaeology and Numismatics Department of the National Museum of Wales. The typology of each artefact was identified by S. Aldhouse-Green, University of Newport. A database of the tool types used at Pontnewydd, their dimensions, and the corresponding rock types from which they are manufactured was compiled (Appendix 3.1). This database was then used to discuss whether some raw materials have been selected over others for artefact manufacture, and if so, whether different suites of raw materials have been used for certain tools. The results indicate that an overall preference has been exhibited for more silicic rocks, and that tools that required less refinement such as handaxes and cores were made on the denser lavas, whilst items that required retouch such as retouched flakes and scrapers were made on the more homogenous flint, chert and fine silicic tuff. This work is

broadly consistent with the patterns in the assemblage suggested by Green (1988), but examination of around 800 additional artefacts since that report has slightly altered some of the patterns of raw material use. Chi<sup>2</sup> analysis of the distribution of raw materials amongst the different typological groups indicated a degree of selectivity of raw materials, particularly in comparison with handaxes and the total use of each raw material.

Metrical data did not illustrate significant differences between many of the igneous materials, but did highlight a measurable difference in mechanical characteristics between flint, fine silicic tuff and the other igneous rocks used. In knapping experiments conducted on the artefacts, crystal tuff and rhyolitic tuff were found to be the easiest raw materials to work, and ignimbrite the most difficult. However, the use of ignimbrite did not follow its anticipated trend, as this raw material was used equally for both 'crude' and more refined tools.

Through optical microscopic studies of the heavy minerals from many of the layers within Pontnewydd Cave, it was possible to deduce which layers had derived from the Irish Sea till, which from the Welsh till, and which from a mixed source. Observation of the heavy minerals and the particle size distribution of the sediment also provided some information about the degree of weathering that the sediments were subjected to prior to their emplacement in the cave. This information supported the approximate chronology provided by Embleton and Livingston (1989) and provided new evidence for the source and environment of some of the layers from the New Entrance.

#### **Further work**

- Examination of the exotic pebbles found in the Upper and Lower Sands and Gravels to provide an indication of the quantity of each raw material that may have been available in the local drift deposits. Comparison with the rock types from the Pontnewydd lithic assemblage would then allow the degree of selectivity to be accurately assessed.
- Microprobe analysis, of individual grains within the heavy mineral suite, in order to provide accurate provenances for more of the examples observed.
- XRF analysis, particularly of the fine-grained rock types which are difficult to provenance texturally or mineralogically.



- Further, more formal knapping experiments, and rock mechanics experiments on the Pontnewydd raw materials, including measurements of flake scar count, and flake angle as produced experimentally and observed in the assemblage.
- An expanded study of particle size analysis of the sediments, particularly including the mineralogy and petrology of the larger fractions, and further heavy mineral studies on the other layers from the New Entrance.
- A more detailed assessment of the differences in the lithic assemblage between the Main Cave and the New Entrance.
- An assessment of the lithologies and typologies found within each layer and area of the Main Cave, and discussion of any variation observed.
- Further study of the clay minerals found in the Pontnewydd sediments. Some exploratory XRD analysis of clays was undertaken, but no significant differences were found between the samples analysed in this study.

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## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| <b>Find no.</b> | <b>Thin section</b> | <b>Lithology</b>              | <b>Petrological Description</b>  |
|-----------------|---------------------|-------------------------------|--|
| A102/1          | TS 33               | Crystal pumice? tuff          | Anhedral phenocrysts of sericitised feldspar and muscovite with possible pumice, in recrystallised, altered fine grained quartz-feldspar matrix.   |
| A109/3          | TS 60               | Silicic Tuff                  | Heavily altered, fine grained silicic tuff containing occasional shards and biotite.   |
| A124/1          | TS 34               | Rhyolite lava                 | Biotite-rich, invasively weathered rhyolite lava.  |
| A128            | TS 61               | Rhyolite lava                 | Silicic lava with flow foliation containing lumps of devitrified glass, biotite, large feldspar phenocrysts heavily sericitised, rare apatite and rounded zircon crystals.   |
| A17             | TS 51               | Crystal tuff                  | Randomly oriented subhedral crystals of feldspar and quartz, all crystals same size, rare skeletal opaques, devitrified glass and chlorite alteration. Contains epidote and pyroxene.  |
| A195            | TS 123              | Crystal tuff                  | Plagioclase feldspar with embayed outlines and infilled with chlorite. Crystals of epidote, quartz, chlorite and hornblende in a finely crystalline quartz-feldspar matrix.  |
| A223            | TS 35               | Ironstained siltstone         | Layered structure, fine grained, quartz-rich, iron-stained.  |
| A27             | TS 28               | Ignimbrite                    | Snowflake re-crystallisation, particularly in welded areas, parataxitic texture, with welding clearly enclosing feldspar crystals, chlorite alteration.  |
| A330            | TS 36               | Basalt                        | Fine grained groundmass containing magnetite, pyroxene and much plagioclase.   |
| A46             | TS 21               | Flow banded perlitic rhyolite | Flow banded silicic lava with perlitic texture and muscovite, small vein containing quartz and pyroxene crystals.  |
| A490            | TS 37               | Basaltic Tuff                 | Chlorite and muscovite pseudomorphing plagioclase feldspar. Aggregates of chlorite in almost all phenocrysts, feldspathic matrix. Altered basic. From Bedded Pyroclastic Formation.  |
| A50             | TS 29               | Pumice crystal lithic tuff    | Phenocrysts of recrystallised pumice, and other lithic fragments, large subhedral feldspars, in fine matrix.   |
| A532            | TS 211              | Fine silicic tuff             | Very fine matrix, with quartz crystals visible at high magnification. Aligned in layers.   |
| A548            | TS 250              | Vitric crystal tuff           | Cusped shards in quartz-feldspar matrix  |
| A549            | TS 274              | Crystal Vitric tuff           | Cusped shards, altered chlorite, parataxitic texture, no lithic clasts, few plagioclase phenocrysts. Capel Curig.  |
| A605            | TS 206              | Crystal tuff                  | Finely crystalline matrix with phenocrysts of zircon and pyroxene, no visible  |
| A611            | TS 253              | Fine silicic tuff             | Very fine matrix, with quartz crystals visible at high magnification. Aligned in layers.   |
| A625            | TS 251              | Corderite Hornfels            | Contact metamorphosed leopard skin spots in aligned quartz-feldspar matrix. From Mynydd Mawr or Tan-y-Grisiau.   |
| A66/11          | TS 52               | Ignimbrite                    | Eutaxitic texture, recrystallised quartz in snowflake pattern, contains subhedral plagioclase crystals.  |
| A66/2           | TS 78               | Crystal pumice tuff           | Iron oxides in high relief against a recrystallised quartz-feldspar matrix. Lithic fragments and recrystallised pumice-shaped areas both outlined by wisps of ?iron oxides. Chloritised pumice areas and partially recrystallised subhedral pyroxene and feldspar crystals |
| A66/22          | TS 88               | Ignimbrite                    | Parataxitic fabric and snowflake recrystallisation, chlorite crystals outline welded fabric. Many cubic pyrite crystals.   |
| A66/24          | TS 3                | Rhyolitic tuff                | Recrystallised unwelded silicic tuff fabric containing agglomerations of sericitised feldspar.   |
| A66/25          | TS 83               | Crystal tuff                  | Randomly oriented feldspar and clinopyroxene crystals with chlorite alteration and ?devitrified glass.   |
| A66/27          | TS 87               | Vitric tuff                   | Cusped shards infilled with chlorite, banded by areas of quartz recrystallisation with occasional feldspar phenocrysts and small crystals of muscovite.  |
| A66/30          | TS 30               | Fine silicic tuff             | Fine grained, unimodal, heavily iron stained, layered silicic tuff.  |
| A66/31          | TS 53               | Fine silicic tuff             | Fine grained, unimodal, heavily iron stained, layered tuff.  |
| A66/36          | TS 8                | Vitric tuff                   | Fine grained silicic tuff, containing recrystallised shards, which are outlined by wisps of chlorite. Capel Curig.   |
| A66/40          | TS 58               | FP Lava                       | Sericitised feldspar phenocrysts in a fine grained, flow-banded, plagioclase matrix. Muscovite highlighting flow foliation.  |



## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| Find no. | Thin section | Lithology                  | Petrological Description  |
|----------|--------------|----------------------------|---|
| A66/43   | TS 54        | Ignimbrite                 | Eutaxitic texture with feathery crystals of muscovite around the edges of enclosed crystals. Quartz-rich, partially recrystallised with plagioclase feldspar & colourless zircon.                             |
| A66/59   | TS 27        | Ignimbrite                 | Eutaxitic fabric containing plagioclase crystals in a fine silicic matrix.  |
| A66/6    | TS 89        | Rhyolitic tuff             | Unwelded rhyolitic tuff, partially recrystallised, in relict areas of pumice. Iron oxides follow the fabric, swirling around sericitised feldspar crystals. Chloritised.                                      |
| A66/76   | TS 55        | Rhyolite                   | Silicic lava, very altered, some devitrified glass, chlorite, altered clinopyroxene, partially recrystallised. Slight flow foliation, masked by alteration.   |
| A66/90   | TS 80        | Crystal pumice lithic tuff | Pumice flattened and devitrified, matrix v.fine, swirly tuff layering outlined by strings of opaques. One siliceous lithic fragment.  |
| A66/93   | TS 56        | Crystal lithic tuff        | Plagioclase feldspar, pyroxene altering to actinolite/chlorite, containing volcanic lithic fragments. Many twinned crystals of both clinopyroxene and feldspar.   |
| A66/94   | TS 57        | Fine silicic tuff          | Cryptocrystalline tuff with some quartz visible at high magnification.  |
| A68/5    | TS 31        | Fine grained basic lava    | Anhedral clasts of lava contained within a fine grained basic matrix with crystals of magnetite, pyroxene and amphibole. Provenance Cumbria.  |
| A68/6    | TS 93        | Crystal tuff               | Fractured feldspar crystals, weakly altered. Chlorite and biotite in finely crystalline quartz-feldspar matrix. Original undulating layering variably recrystallised.   |
| A68/8    | TS 95        | Vitric crystal tuff        | Cusped shards, recrystallised and chloritised on edges, devitrified glass fragments, feldspar crystals slightly altered, rounded zircons.   |
| A689     | TS 252       | Ignimbrite                 | Epidote and garnet crystals, plagioclase, eutaxitic texture, snowflake re-crystallization. Snowdonian ignimbrite.   |
| A73/?    | TS 7         | Crystal pumice lithic tuff | Lithic crystal tuff containing symplectite, pumice shards, altered plagioclase subhedral phenocrysts, chlorite, epidote and quartz crystals.  |
| A74/1    | TS 32        | Microdiorite               | Cryptocrystalline matrix containing many feldspar laths and crystals of pyroxene and apatite. Contains a small vein with chlorite and pumpellyite.  |
| A817     | TS 246       | Fine silicic tuff          | Finely crystalline tuff   |
| A86/9    | TS 91        | Crystal tuff               | Clinopyroxene replaced by actinolitic amphibole, opaques and epidote. Feldspar sericitised Heterogenous texture with iron staining highlighting original deformed layering.                                   |
| A99/10   | TS 59        | FP Lava                    | Dominated by large plagioclase feldspars, some recrystallised. Devitrified glass highlighting flow texture, clinopyroxenes altered to actinolite and chlorite.  |
| A99/12   | TS 79        | Silicic tuff               | Very fine silicic tuff containing biotite and devitrified glass with possible lenses of recrystallised pumice?  |
| A99/2    | TS 77        | Crystal pumice tuff        | Matrix devitrified glass with swirled tuff texture, many small opaque minerals, chlorite replacing flattened pumice shards which are recrystallised around the margins.                                       |
| A99/8    | TS 86        | Vitric tuff                | Fine grained quartz-feldspar matrix containing recrystallised t-shaped shards.  |
| A99/9    | TS 84        | Crystal tuff               | Highly silicic groundmass with myrekitic secondary crystallization, also containing stilpnomelane needles, no relict textures.  |
| B18      | TS 25        | Crystal Tuff               | Layered tuff texture containing anhedral crystals of sericitised feldspar, epidote, quartz, chlorite and hornblende in a finely crystalline felsic matrix.  |
| B20      | TS 5         | Crystal lithic tuff        | Large lithic fragment of fine crystalline rock, large lithic fragment of rhyolite, chlorite alteration, all in a finely crystalline quartz-feldspar matrix. Same as TS62.                                     |
| B20      | TS 62        | Crystal lithic tuff        | Large lithic fragment of fine crystalline rock, large lithic fragment of rhyolite, chlorite alteration, all in a finely crystalline quartz-feldspar matrix.   |
| B254     | TS 92        | Crystal Lithic Pumice Tuff | Flattened pumice shards, occasional silicic lithic fragments, clinopyroxene with minor chloritisation, sericitised feldspar. All crystals fractured in appearance. Strong, locally developed swirled texture. |

## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| Find no.     | Thin section | Lithology             | Petrological Description   |
|--------------|--------------|-----------------------|--|
| B259         | TS 2         | Crystal Lithic Tuff   | Unwelded tuff texture containing fine-grained lithic fragments, epidote, clinopyroxene, garnet, rutile and plagioclase feldspar crystals. Rutile may indicate Snowdonian origin?                                 |
| B265         | TS 38        | Basalt                | Fine feldspathic matrix with plagioclase feldspar and pyroxene phenocrysts.  |
| B278         | TS 64        | Dacite                | Chloritised, recrystallised, fine grained iron oxides following flow foliation, feldspar phenocrysts, very fine sericitised matrix.  |
| B280         | TS 17        | Feldspar-Porphyry     | Feldspar rich porphyritic rock containing a quartz band.   |
| B299/<br>300 | TS 39        | Quartzite             | Unaltered immature sandstone   |
| B302         | TS 11        | Vitric Tuff           | Highly iron stained tuff containing cusped and tabular shards and epidote.   |
| B309         | TS 1         | FP Lava               | Flow-banded silica-rich lava containing large feldspar phenocrysts and few lithic fragments.   |
| B310         | TS 49        | Andesite/Microdiorite | Pseudomorphed plagioclase phenocrysts, actinolite, matrix of microcrystalline plagioclase. Alignment characteristic of lava, clinopyroxene and orthopyroxene. Rhobell or Foel Fras.                              |
| B402         | TS 102       | Ignimbrite            | Euhedral phenocrysts of quartz, plagioclase feldspar and sanidine contained within a fine holocrystalline matrix. Sub parallel bands of re-crystallization occur across the sample, following the welded fabric. |
| B402         | TS 103       | Ignimbrite            | Same as TS102  |
| B402(L)      | TS 101       | Dolerite              | Altered dolerite containing biotite, altered plagioclase, a Mg rich orthopyroxene and actinolite.  |
| B403.A2      | TS 105       | Ignimbrite            | Eutaxitic fabric with occasional altered feldspar crystals in a holocrystalline quartz-feldspar matrix.  |
| B403.C       | TS 108       | Ignimbrite            | Same as TS105  |
| B403.E       | TS 109       | Vitroclastic tuff     | Cusped shards with occasional tabulate shards in a fine quartz-feldspar matrix.  |
| N            |              |                       | Contains fragments of finely crystalline volcanic rock.  |
| B403D        | TS 106       | Ignimbrite            | Same as TS105  |
| B404         | TS 110       | FP Lava               | Porphyritic lava with sericitised feldspar and chlorite in a fine quartz-feldspar matrix.  |
| B405         | TS 104       | Dolerite              | Sericitised feldspar, epidote, chlorite and clinopyroxene in a medium grained plagioclase matrix.  |
| B405         | TS 120       | Granite               | Biotite-rich, coarse-grained, quartz-rich igneous rock, with heavily altered feldspars.  |
| B405(S)      | TS 119       | Crystal lithic tuff   | Cryptocrystalline matrix containing glass shards and lithic fragments which may be finely crystalline tuffs.   |
| B415         | TS 122       | Crystal lithic tuff   | Cryptocrystalline matrix containing lithic fragments, biotite, ilmenite and other subhedral crystals in an unwelded tuff fabric. Partially recrystallised. Biotite suggests a Snowdonian origin.                 |
| B443         | TS 75        | Crystal lithic tuff   | Devitrified glass, skeletal opaques and lithic fragments in a partially recrystallised quartz feldspar matrix.   |
| B57          | TS 23        | Ignimbrite            | Eutaxitic texture containing magnetite and possible accretionary lapilli, with occasional plagioclase feldspar phenocrysts.  |
| B72          | TS 63        | Ignimbrite            | Parataxitic texture, recrystallised quartz feldspar matrix with prehnite and brown amphibole. Lake District?   |
| C1023        | TS 273       | Crystal lithic tuff   | Illustrated. Many large phenocrysts, mainly pyroxene. Much chlorite alteration, matrix of quartz and feldspar. Many vesicles and lithic fragments. Calc- alkaline tuff from the Lake District.                   |
| C13          | TS 9         | Mudstone              | Very fine grained sedimentary rock with quartz grains highlighting the inherent layers in the rock.  |
| C20          | TS 94        | Crystal Lithic Tuff   | Rare recrystallised cusped shards, angular silicic lithic fragments, secondary carbonate, pervasive iron staining following undulating layered fabric.   |
| C249         | TS 10        | Siltstone             | Fine grained sedimentary rock containing oriented quartz crystals.   |
| C303         | TS 76        | Crystal tuff          | Feldspathic matrix containing irregular fractured crystals of feldspar. Invasive chloritic alteration, with actinolitic amphibole of clinopyroxenes.   |
| C32          | TS 24        | Ignimbrite            | Eutaxitic texture containing no lithic fragments.  |



## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| <b>Find no.</b> | <b>Thin section</b> | <b>Lithology</b>     | <b>Petrological Description</b>   |
|-----------------|---------------------|----------------------|---|
| C60             | TS 85               | Crystal Tuff         | Pervasively sericitised feldspar-rich matrix following original undulating tuff layering containing few feldspar crystals.  |
| C61             | TS 20               | Crystal Lithic Tuff  | Glassy matrix containing anhedral crystals of epidote and an unwelded tuff texture.   |
| C78             | TS 16               | Basalt Lava          | Flow-banded lava containing other pieces of lava, hornblende, in a fine grained plagioclase rich matrix.  |
| D120            | TS 18               | FP Lava              | Large feldspar phenocrysts dominate, some twinned, in very fine quartz-feldspar matrix with patchy re-crystallisation, all altered. Some chlorite and devitrified glass.  |
| D1283           | TS 43               | Crystal Lithic Tuff  | Completely sericitised feldspars, pumice or lithic fragment replaced by recrystallised quartz.  |
| D155            | TS 82               | Crystal tuff         | Unaltered feldspar crystals in feldspar-rich quartz-feldspar matrix. Extensively recrystallised to spherulitic texture with secondary chlorite between the spherules.   |
| D1615           | TS 71               | Rhyolite lava        | Recrystallised quartz-feldspar matrix with perlitic texture, with subhedral slightly altered feldspar phenocrysts.  |
| D165            | TS 41               | Basalt lava          | Euhedral crystals of plagioclase feldspar, aligned within a flow-banded matrix of feldspar, with clinopyroxene, skeletal oxides and a small amount of devitrified glass. Tholeiitic basalt. Rhobell or Lake District.                     |
| D172            | TS 66               | Ignimbrite           | Snowflake re-crystallization, eutaxitic texture, with secondary mica alteration.  |
| D1886           | TS 40               | Fine silicic tuff    | Fine quartz-rich matrix with partial bands of iron staining   |
| D2476           | TS 50               | Vitric Tuff          | Cusate shards in fine tuff matrix.  |
| D279            | TS 67               | Rhyolite lava        | Rhyolite lava with flow texture, partially recrystallised and containing prehnite.  |
| D337            | TS 26               | Ignimbrite           | Parataxitic fabric containing plagioclase feldspar in a fine silicic matrix   |
| D3583           | TS 42               | Crystal Tuff         | Layered tuff texture containing occasional feldspar and epidote, very fine grained, iron stained.   |
| D384            | TS 19               | FP Lava              | Ilmenite, chlorite and plagioclase phenocrysts in a fine-grained matrix of quartz-feldspar crystals. Ilmenite is present in the Conwy Rhyolite formation.   |
| D3987           | TS 72               | FP Lava              | Flow-banded feldspar-rich lava with chloritised areas. Rutile present. Clinopyroxene altering to chlorite.  |
| D4355           | TS 220              | Flow banded rhyolite | Unwelded, recrystallised rhyolitic lava with relict vesicles now infilled with sericite, containing clinopyroxene, chlorite and opaque minerals.  |
| D4434           | TS 219              | Fine silicic tuff    | Very fine quartz-muscovite matrix with occasional quartz-feldspar re-crystallization  |
| D4441           | TS 214              | Dolerite             | Fine matrix of chloritised plagioclase, directionally oriented, indicating flow. Many opaques with skeletal texture. Contains highly altered clinopyroxene. Ordovician.   |
| D4455           | TS 201              | Sandstone            | Carboniferous medium grained sandstone, dominated by quartz, feldspar and mica.   |
| D4459           | TS 224              | Vitric tuff          | Cusate shards, quartz dominated with occasional s-shaped chloritised shards.  |
| D4470           | TS 217              | Rhyolite lava        | FP lava with quartz-infilled vesicle, chloritised. Feldspars in finely crystalline feldspar matrix. Euhedral crystals cemented by devitrified material with flow texture, no lithic fragments.  |
| D453            | TS 6                | Rhyolite lava        | Flow-banded silica-rich lava containing feldspar phenocrysts in fine quartz-feldspar matrix.  |
| D4743           | TS 225              | Crystal tuff         | Fine grained rock containing quartz, feldspar, pyroxene and little chlorite, with no textures.  |
| D4875           | TS 222              | Crystal lithic tuff  | Devitrified glass in rounded pieces, clasts of rhyolite and basalt in fine quartz-feldspar groundmass.  |
| D4902           | TS 218              | Flow banded rhyolite | Highly iron-stained, contains euhedral sericitised plagioclase crystals in unidirectional flow-fabric. Contains stilpnomelane needles, an indication of a Snowdonian origin. Possibly from the top of the Lower Rhyolitic Tuff Formation. |

## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| <b>Find no.</b> | <b>Thin section</b> | <b>Lithology</b>    | <b>Petrological Description</b>  |
|-----------------|---------------------|---------------------|--|
| D5/1            | TS 96               | Crystal tuff        | Homogenous fine grained quartz dominated tuff with minor secondary chlorite and muscovite. Contains needles of stilpnomelane and has locally developed welding textures.   |
| D5/2            | TS 65               | Fine Silicic Tuff   | Very fine silicic tuff containing much fine muscovite.   |
| D5/4            | TS 90               | Dacite              | Recrystallised dacite lava.  |
| D5311           | TS 215              | Silicic Vitric tuff | Highly silicified cryptocrystalline tuff fabric. Re-crystallized containing few shards and lots of chlorite.   |
| D5419           | TS 223              | Ignimbrite          | Goethite visible in hand specimen. Eutaxitic texture, heavily weathered on surface.  |
| D620            | TS 12               | Mudstone            | Iron stained along layers, very fine grained sedimentary containing some quartz grains.  |
| D655            | TS 68               | Silicic Tuff        | Fine silicic matrix of devitrified glass with all original crystals filled in with recrystallised quartz.  |
| D702            | TS 22               | Crystal Tuff        | Fine grained bimodal unwelded tuff with few crystals of quartz and epidote   |
| D749            | TS 13               | Brecciated rhyolite | Recrystallised silicic lava with ?consertal texture.   |
| D767            | TS 15               | Fine silicic tuff   | Fine grained, with a highly recrystallised silicic matrix.   |
| D800            | TS 81               | Crystal Tuff        | Patchy re-crystallization of quartz-feldspar matrix, containing stilpnomelane, quartz crystals and subhedral zircon.   |
| D807            | TS 14               | Ignimbrite          | Parataxitic tuff texture, but indicating rheomorphism, in fine grained quartz-feldspar matrix. Tryfan.   |
| D836            | TS 69               | Ignimbrite          | Quartz-feldspar matrix, with snowflake re-crystallisation. Parataxitic texture highlighted by small crystals of chlorite.  |
| D934            | TS 70               | Silicic Tuff        | Fine grained quartz-feldspar matrix containing quartz and feldspar crystals, partially recrystallised with some globular chlorite.   |
| F1230           | TS 205              | Crystal tuff        | Layered tuff, fine grained, highly iron stained, with phenocrysts of quartz in a finely banded matrix, crystals of amphibole and clinopyroxene also visible.   |
| F1254           | TS 203              | Silicified mudstone | Quartz spheres in fine silicic granular layered matrix. Iron oxides arranged in layers.  |
| F1314           | TS 244              | Microdiorite        | Euhedral pyroxene crystals common in plagioclase feldspar matrix with some apatite needles. Similar to the pyroxene-bearing microgranite on Lleyn or other outcrops at Garnfor, Penmaenmawr?, Garn Boduan and Garn Ddu.                                  |
| F1395           | TS 242              | Crystal pumice tuff | Blue-green amphibole, sericitised plagioclase, chlorite, no lithic fragments, devitrified glass shards, chlorite crystals in an unwelded tuff.   |
| F1430           | TS 277              | Ignimbrite          | Small pockets of spherical scoria in a eutaxitic texture with sericite patination.   |
| F1530           | TS 228              | Microdiorite        | Clinopyroxene-rich with much hornblende and biotite, sericitised feldspar, holocrystalline, aphanitic. Pseudomorphs after orthopyroxene (replaced). Likely origin the Lleyn coast. Croudace.   |
| F1666           | TS 232              | Crystal pumice tuff | No textures, much ghost re-crystallization by quartz, crystals of chlorite, epidote, amphibole, sericitised plagioclase, pyroxene being replaced by fibrous chlorite, many opaques and devitrified glass fragments.                                      |
| F1849           | TS 235              | Crystal tuff        | Many pyroxene and other crystals, subhedral, in tuff texture.  |
| F1862           | TS 200              | Fine silicic tuff   | Finely crystalline quartz-rich tuff. Location indeterminate.   |
| F1957           | TS 238              | FP lava             | Heavily iron-stained feldspar-phyric lava, much Goethite   |
| F2925           | TS 212              | Pumice crystal tuff | Sericitised feldspar, unwelded pumice shards, partially recrystallised. Small epidote crystals, damaged plagioclase phenocrysts, chlorite alteration around phenocrysts, pumice altered and recrystallised in places.                                    |
| F293            | TS 73               | Crystal lithic tuff | Skeletal opaques. Many large heavily sericitised feldspars, some containing  |
| F3056           | TS 243              | Rhyolite lava       | No textures, re-crystallization, phenocrysts or lithic inclusions.   |
| F3477           | TS 229              | Rhyolite Lava       | Flow texture containing lithic fragments with rutile, euhedral orthoclase, biotite filling in along a vein and thinly along both twinning and cleavage in the orthoclases, large quartz and chlorite crystals and oxides following the swirling texture. |
| F4475           | TS 226              | Crystal pumice tuff | Unwelded tuff with crystal fragments and wisps of devitrified glass.   |



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| Find no. | Thin section | Lithology                  | Petrological Description  |
|----------|--------------|----------------------------|---|
| F4519    | TS 245       | Fine silicic tuff          | Finely crystalline tuff.  |
| F4523    | TS 204       | Rhyolite lava              | Flow banded silica rich lava with feldspar phenocrysts, sericitised, some re-crystallization, chlorite embayment of crystals. Contains epidote, clinozoisite, small brown rounded tourmaline, zircon, rutile.   |
| F4534    | TS 216       | Vitric crystal tuff        | Cusate and tabulate shards in fine crystal matrix. Illustrated. Lower Crafnant Volcanic Formation. Phenocrysts of plagioclase in finely recrystallised quartz matrix. Cusate shards coarsely recrystallised. Textures highlighted by opaques gathering on shards. Phenocrysts act as centres for coarse re-crystallization. |
| F4573    | TS 204       | Rhyolite lava              | Flow banded lava with feldspar phenocrysts, of siliceous composition.   |
| F460     | TS 44        | Ignimbrite                 | Iron stained, very fine grained quartz-feldspar matrix with parataxitic texture, subhedral feldspar phenocrysts. Snowflake texture.   |
| F4700    | TS 240       | Ignimbrite                 | Eutaxitic fabric enclosing large pyroxene and plagioclase crystals, snowflake texture.  |
| F4888    | TS 208       | Crystal Vitric tuff        | Cusate and platy shards with a large laminar inclusion of pumice the walls of which have been replaced by quartz & feldspar crystals which has preserved the structure. Feldspar phenocrysts, unwelded, euhedral zircons and degraded iron oxides, in a fine tuff matrix.   |
| F4949    | TS 236       | Volcaniclastic sandstone   | Quartz grains and other fragments, altered  |
| F5188    | TS 234       | Vitric pumice tuff         | Contains altered chloritised glassy shards with cusate margins. Matrix composed of recrystallised shards. Feathery crystals of muscovite.   |
| F531     | TS 46        | Rhyolite lava              | Silicic lava containing large unaltered crystals of feldspar, patchy re-crystallisation highlighting flow foliation, some secondary carbonate and chlorite. Many large red-brown oxides. 'Clean' looking.   |
| F5499    | TS 241       | Flow banded rhyolite       | Large sericitised feldspar crystals in quartz-rich groundmass with clear directional flow and much fragmentary chlorite.  |
| F5566    | TS 272       | Chert                      | Spheroidal and conical fossils visible in lighter layers. Fine grained, aligned rounded quartz grains in darker layers.   |
| F5568    | TS 237       | Ignimbrite                 | Parataxitic texture, lithic and crystal components, snowflake re-crystallization.   |
| F5699    | TS 233       | Flow banded rhyolite       | Flow banded lava with feldspar phenocrysts, mainly unaltered, some with zoned composition, occasional small zircons in matrix of quartz and feldspar. Crosscutting vein perpendicular to flow direction contain epidote and piedmontite (brown/pink with inclined ext.). Indicates an origin in the Llanberis Pass.         |
| F589     | TS 45        | Crystal Pumice Lithic Tuff | Locally welded, contains flattened pumice fragments, fractured crystals of clinopyroxene, much devitrified glass, long wisps of muscovite particularly around crystals and rare lithic fragments  |
| F6026    | TS 210       | Crystal lithic tuff        | Extensively chloritised lithic fragments and plagioclase phenocrysts in felsic matrix. Phenocrysts damaged and not orientated, suggesting a tuff.   |
| F692     | TS 74        | Fine Silicic Tuff          | Very fine partially recrystallised quartz-feldspar matrix containing feathery muscovite trailing around a single feldspar crystal. Little chlorite. Recrystallised areas contain many small zircons.  |
| F959     | TS 47        | Re Crystallized Rhyolite   | Silicic recrystallised matrix containing biotite, microperthitic albite, hornblende and quartz.   |
| H1022    | TS 271       | Siltstone (tuffaceous)     | Highly silicified siltstone with little structure.  |
| H1926    | TS 270       | Fine silicic tuff          | Fine grained tuff with quartz-feldspar matrix, layered structure and iron staining.   |
| H2034    | TS 279       | Silicic tuff               | Very fine quartz-feldspar matrix, partially recrystallised, occasional biotite and zircon.  |
| H236     | TS 213       | Vitric crystal tuff        | Fine, mainly quartz-feldspar matrix with few small pyroxenes. No phenocrysts. Fragments of microvesicular glass and occasional cusate shards. Numerous angular fragments, cryptocrystalline matrix, some chlorite alteration.   |
| H2416    | TS 280       | Crystal lithic tuff        | Phenocrysts of chlorite, feldspar, amphibole, quartz in a fine quartz feldspar matrix with tuff texture and lithic fragments.   |
| H2634    | TS 268       | Crystal lithic pumice tuff | Devitrified glass and lithics of ?rhyolite in fine quartz-feldspar groundmass.  |
| H2771    | TS 269       | Sandstone, tuffaceous      | Fine grained quartz-rich sedimentary rock.  |

## **Appendix 1: Petrological Descriptions of Pontnewydd Artefacts**

| <b>Find no.</b> | <b>Thin section</b> | <b>Lithology</b>           | <b>Petrological Description</b>  |
|-----------------|---------------------|----------------------------|--|
| H2858           | TS 207              | Ignimbrite                 | Snowflake re-crystallisation. Contains lithic fragments and muscovite in welded matrix, chlorite alteration particularly around feldspar phenocrysts, zircon.  |
| H3022           | TS 256              | Silicic tuff               | Recrystallised quartz and feldspar rich, with relict depositional texture. Large pyrite crystals. Snowdonia?   |
| H3047           | TS 258              | Flow banded rhyolite       | Flow banded lava containing large feldspar phenocrysts, few sericitised & small zircons. Highly silicic matrix, vein containing epidote present. Almost identical to TS233, possible origin in the Llanberis Pass.                         |
| H3056           | TS 281              | Flow banded rhyolite       | Extensively recrystallised, flow-banded with actinolite crystals. Indicates a provenance in North Wales.   |
| H3142           | TS 278              | Pumice crystal lithic tuff | Contains flattened pumice shards, devitrified glass, heavily recrystallised, undulating deformed layering, feldspar crystals and occasional lithic clasts. Secondary carbonate.  |
| H360            | TS 231              | Crystal lithic tuff        | Contains subhedral garnets, recrystallised, large crystals of sericitised feldspar, epidote widely present, abutting, randomly oriented crystals, many large accessory minerals, altered tuff with a layered tuff texture.                 |
| H750            | TS 275              | Fine silicic tuff          | Finely crystalline silicic tuff, with some iron staining and devitrified glass.  |
| H797            | TS 255              | Ignimbrite                 | Paratactic fabric containing occasional feldspar phenocrysts in a recrystallised quartz-feldspar matrix.   |
| H9              | TS 209              | Dolerite                   | Large, randomly oriented twinned plagioclase laths in fine grained feldspathic groundmass. Rutile and augite crystals. Very fresh. Indeterminate ferric oxides and magnetite. From Tertiary volcanic centres in Wales or Northern Ireland. |



## Appendix 2

### Classification of the Lithologies found at Pontnewydd

#### I. Rhyolites.

A collective term for silicic volcanic rocks consisting of phenocrysts of quartz and alkali feldspar, often with minor plagioclase and biotite, in a microcrystalline or glassy groundmass. Rhyolites have a chemical composition similar to that of granite, although usually slightly higher in SiO<sub>2</sub>.

#### II. Tuffs.

These pyroclastic rocks consist of 100%-75% fragmented volcanic material, ejected into the atmosphere during explosive volcanic activity as solid fragments, which are fractured during the eruption. Upon consolidation this material becomes a tuff. Tuffs typically contain a predominance of fragments between 2 cm and 1/16 mm in diameter. The subgroups within this category derive their names from the characteristic fragments which constitute each tuff.

i) Crystal tuff. A tuff in which crystal fragments are the most abundant constituent.

ii) Crystal lithic tuff. A tuff containing both crystal and lithic fragments in approximately equal proportions. These lithic fragments may be previously erupted lava etc.

iii) Lithic Tuff. A tuff in which lithic fragments are more abundant than crystal or vitric fragments.

iv) Vitric tuff. A tuff in which porphyritic shards of glass are more abundant than either crystal or lithic fragments.

v) Fine silicic tuff. A specific tuff, occurring only in thin bands, it consists almost entirely of a crypto-crystalline silicic matrix. It produces a good conchoidal fracture, and is usually dark in colour.

vi) Silicic tuff. Light coloured tuff, chert-like in appearance, within which a degree of banding is often clearly visible.

#### III. Ignimbrites.

A special group of tuffs formed as a result of deposition by *nuees ardentes* at high temperatures, they consist of tuff material (including pumice, crystals, lithics and glass shards) which were deposited under such extreme temperatures that they have welded together. In many cases this feature produces a well marked banding, which is easily confused with flow-banding in rhyolites. In addition, some unwelded rhyolitic tuffs may be difficult to distinguish from welded ignimbrites without the use of a polarising microscope. Their composition is usually silicic to intermediate.

#### IV. Feldspar phyric lava.

A silicic lava containing characteristic large feldspar phenocrysts, visible in hand specimen.

#### V. Andesite

An intermediate volcanic rock, usually porphyritic, consisting of plagioclase feldspar, pyroxene, hornblende and /or biotite.

#### VI. Basalt.

A volcanic rock consisting essentially of calcic plagioclase and pyroxene. Olivine and minor interstitial quartz may be present.

#### VII. Dacite.

A volcanic rock composed of quartz and sodic plagioclase with minor amounts of biotite and/or hornblende and/ or pyroxene. Chemically equivalent to granodiorite.

#### VIII. Dolerite.

A rock intermediate in grain-size between basalt and gabbro and composed essentially of plagioclase and pyroxene often with ophitic texture, in addition to opaque minerals.

#### IX. Microdiorite.

On examination in hand specimen, this was originally thought to be a type of rhyolite showing an unusual brown weathering surface. An intermediate rock consisting of sodic plagioclase, commonly hornblende and often with biotite or augite.

X. Baked shale. A low grade metamorphosed argillaceous rock.

#### XI. Sandstones

i) Micaceous sandstone. A sandstone containing at least 10% mica.

ii) Tuffaceous sandstone. A sandstone which could equally be described as a tuffite, containing as it does between 75% and 25% pyroclastic material (the remainder being epiclastic). Average clast size extends from 2 mm to 1/16 mm.

iii) Volcaniclastic sandstone. A relatively immature sandstone made up of igneous lithic grains, often with chlorite cement.



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer   | Type Name                          | Raw Material                  | Measurements |         |         |           |
|----------|------|---------|------------------------------------|-------------------------------|--------------|---------|---------|-----------|
|          |      |         |                                    |                               | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A0       | 1978 | WWII    | Spall                              | Flint                         | 8.3          | 8.8     | 4.3     | 0.2       |
| A13      | 1978 | BD      | Flake fragment                     | Crystal Tuff                  | 46.4         | 36.5    | 14.2    | 22.7      |
| A17      | 1978 | BD/WWII | Handaxe                            | Tuff                          |              | 0.2     |         |           |
| A26      | 1978 | WWII/BD | Levallois flake                    | FP Lava                       | 80.3         | 63.8    | 21.6    | 115.4     |
| A26      | 1978 | WWII/BD | Levallois flake                    | FP Lava                       | 88.9         | 74.8    | 17.3    | 97.8      |
| A27      | 1978 | WWII    | Retouched flake                    | Ignimbrite                    | 66.6         | 63      | 22.5    | 101.7     |
| A28      | 1978 | WWII    | Handaxe                            | Rhyolite                      | 110.5        | 100     | 33      | 363.2     |
| A42      | 1978 | BD dump | Denticulate                        | Siltstone/fine sandstone      | 71.1         | 30.2    | 12.3    | 29.2      |
| A46      | 1978 | BD dump | Levallois core                     | Flow banded perlitic rhyolite | 82.2         | 87.3    | 45.7    | 355.3     |
| A47      | 1978 | BD dump | Handaxe                            | Rhyolitic lava                | 92.8         | 70.1    | 23.5    | 149.3     |
| A48      | 1978 | BD dump | Double convex side scraper         | Fine silicic tuff             | being drawn  |         |         |           |
| A49      | 1978 | BD dump | Handaxe                            | Carboniferous chert           | 60.2         | 37      | 29.5    | 54.8      |
| A50      | 1978 | BD dump | Single straight side scraper       | Pumice crystal lithic tuff    | 100.4        | 79.8    | 17.4    | 148       |
| A51      | 1978 | BD dump | Handaxe                            | FP Lava                       | 63.4         | 50.2    | 29      | 81.3      |
| A57      | 1978 | BD dump | Retouched flake                    | Flint                         | 42.2         | 71.9    | 16.6    | 50.6      |
| A59      | 1978 | BD dump | Crude core                         | FP Lava                       | 106.8        | 84.5    | 45.7    | 505.7     |
| A61      | 1978 | BD dump | Levallois core                     | Flint                         | 36.4         | 41.8    | 13.1    | 22        |
| A66/2    | 1979 | BD dump | Handaxe                            | Crystal pumice? tuff          | 130.5        | 77      | 48.9    | 428.3     |
| A66/3    | 1979 | BD dump | Handaxe roughout                   | Fine silicic tuff             | 180          | 102.8   | 46.7    | 775.8     |
| A66/4    | 1979 | BD dump | Handaxe on flake                   | Ignimbrite                    | 85.8         | 74.7    | 30.4    | 197.2     |
| A66/5    | 1979 | BD dump | Flake fragment                     | Rhyolite                      | 94           | 72.8    | 23.8    | 194.9     |
| A66/6    | 1979 | BD dump | Disc. core                         | Rhyolitic tuff                | 61.3         | 48      | 22.3    | 73.2      |
| A66/7    | 1979 | BD dump | Handaxe fragment                   | Fine silicic tuff             | 87           | 49.2    | 24.2    | 117       |
| A66/8    | 1979 | BD dump | Handaxe                            | Ignimbrite                    | 79.6         | 61.7    | 29      | 125.9     |
| A66/9    | 1979 | BD dump | Handaxe                            | Fine silicic tuff             | 67           | 44      | 27.7    | 64.9      |
| A66/11   | 1979 | BD      | Flake                              | Ignimbrite                    | 69.8         | 50.6    | 17.3    | 62.7      |
| A66/12   | 1979 | BD      | Levallois flake (outrapasse)       | Siltstone                     | 106.3        | 51.4    | 13.8    | 87        |
| A66/13   | 1979 | BD dump | Transverse scraper (on lev. flake) | FP Lava                       | 60.1         | 73.4    | 21.4    | 117.7     |
| A66/14   | 1979 | BD dump | Truncated blade                    | Tuff                          | 32.2         | 19.2    | 5.1     | 4.1       |
| A66/15   | 1979 | BD dump | Chopping tool                      | FP Lava                       | 39.2         | 77.3    | 33.5    | 186       |
| A66/16   | 1979 | BD dump | Naturally backed knife             | Rhyolite                      | 77           | 72.3    | 14.3    | 74.8      |
| A66/17   | 1979 | BD dump | Flake fragment                     | Fine silicic tuff             | 37.3         | 65      | 31.3    | 65.5      |
| A66/18   | 1979 | BD dump | Natural chunk                      | Rhyolite                      | n/a          | n/a     | n/a     | 53.4      |
| A66/22   | 1979 | BD dump | Discoidal core                     | Ignimbrite                    | 73           | 65.2    | 33.1    | 153.5     |
| A66/23   | 1979 | BD dump | Levallois flake                    | Rhyolite                      | 68           | 66.6    | 15.8    | 70.2      |
| A66/24   | 1979 | BD dump | Retouched flake                    | Rhyolitic tuff                | 97.2         | 68.7    | 19.5    | 164.7     |
| A66/25   | 1979 | BD dump | Flake                              | Crystal tuff                  | 61.4         | 52.2    | 11.4    | 38.3      |
| A66/26   | 1979 | BD dump | Retouched flake                    | Fine silicic tuff             | 54.2         | 51.7    | 8.9     | 33.9      |
| A66/27   | 1979 | BD dump | Flake                              | Vitric tuff                   | 82.3         | 52.3    | 21.3    | 79.2      |
| A66/28   | 1979 | BD dump | Handaxe trimmer                    | Rhyolite tuff                 | 54           | 57.3    | 11.3    | 37.1      |
| A66/29   | 1979 | BD dump | Flake                              | Flint                         | 46           | 32.4    | 13.8    | 13.2      |
| A66/30   | 1979 | BD dump | Retouched flake                    | Fine silicic tuff             | 59           | 29.1    | 17      | 25.4      |
| A66/31   | 1979 | BD dump | Flake                              | Fine silicic tuff             | 46.9         | 29.7    | 12.7    | 22.4      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer   | Type Name                        | Raw Material        | Measurements |         |         |           |
|----------|------|---------|----------------------------------|---------------------|--------------|---------|---------|-----------|
|          |      |         |                                  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A66/32   | 1979 | BD dump | Retouched flake                  | Fine silicic tuff   | 57.3         | 48.9    | 13.6    | 35        |
| A66/35   | 1979 | BD dump | Flake fragment                   | Crystal lithic tuff | 92           | 52.8    | 29.7    | 149.9     |
| A66/36   | 1979 | BD dump | Flake                            | Vitric tuff         | 84.3         | 56.5    | 36.2    | 119.3     |
| A66/37   | 1979 | BD dump | Ret. flake                       | Fine silicic tuff   | 43.3         | 34.5    | 9       | 14.5      |
| A66/38   | 1979 | BD dump | Flake                            | Chert               | 41.4         | 38      | 12.1    | 16.9      |
| A66/39   | 1979 | BD dump | Single concave side              | Fine silicic tuff   | 37           | 46.5    | 11.9    | 23        |
| A66/40   | 1979 | BD dump | Flake                            | FP Lava             | 41.6         | 54.1    | 13.2    | 32.3      |
| A66/41   | 1979 | BD dump | Naturally backed knife           | Rhyolite            | 82.5         | 41      | 25.9    | 93.3      |
| A66/42   | 1979 | BD dump | Flake                            | Fine silicic tuff   | 37.2         | 47.2    | 10.1    | 19.7      |
| A66/43   | 1979 | BD dump | Flake                            | Ignimbrite          | 59.4         | 60.9    | 22.5    | 67.3      |
| A66/45   | 1979 | BD dump | Flake fragment                   | FP Lava             | 58.5         | 41.8    | 8.5     | 26.1      |
| A66/48   | 1979 | BD dump | Flake fragment                   | Silicic tuff        | 56.5         | 30.7    | 14.7    | 26.8      |
| A66/52   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 32.2         | 40.7    | 5.1     | 8.3       |
| A66/54   | 1979 | BD dump | Flake fragment                   | FP Lava             | 56           | 44.2    | 9.3     | 29.8      |
| A66/56   | 1979 | BD dump | Handaxe flake                    | Fine silicic tuff   | 53.6         | 44.1    | 12.5    | 28.8      |
| A66/57   | 1979 | BD dump | Flake                            | FP Lava             | 70.8         | 51.8    | 20.2    | 82.9      |
| A66/58   | 1979 | BD dump | Flake                            | FP Lava             | 47.4         | 35.9    | 17.3    | 29.9      |
| A66/59   | 1979 | BD dump | Retouched flake                  | Ignimbrite          | 88.6         | 58.5    | 22.2    | 100.7     |
| A66/60   | 1979 | BD dump | Retouched flake                  | Carboniferous chert | 36.9         | 41.2    | 11.3    | 14.6      |
| A66/61   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 23.9         | 28.2    | 6.6     | 5.7       |
| A66/62   | 1979 | BD dump | Retouched flake                  | Crystal tuff        | 53.7         | 59.5    | 11.2    | 34        |
| A66/63   | 1979 | BD dump | Flake                            | Fine silicic tuff   | 34.1         | 50.5    | 14.7    | 26.1      |
| A66/64   | 1979 | BD dump | Flake                            | Rhyolite            | 30.8         | 46.7    | 9.8     | 13.4      |
| A66/66   | 1979 | BD dump | Flake                            | Flint               | 22.5         | 24.2    | 9.9     | 4.7       |
| A66/67   | 1979 | BD dump | Flake                            | Rhyolite            | 29           | 36      | 10.7    | 9.4       |
| A66/68   | 1979 | BD dump | Flake fragment                   | Rhyolite            | 15.9         | 29.8    | 8.5     | 4.2       |
| A66/70   | 1979 | BD dump | Flake fragment                   | FP Lava             | 33.6         | 36.5    | 8.2     | 13        |
| A66/71   | 1979 | BD dump | Truncated blade (on silet flake) | Fine silicic tuff   | 40.1         | 21.5    | 6.8     | 5.2       |
| A66/72   | 1979 | BD dump | Flake                            | Fine silicic tuff   | 38.2         | 24.4    | 6.1     | 5.6       |
| A66/73   | 1979 | BD dump | Flake fragment                   | Flint               | 32.5         | 24      | 10.2    | 9.2       |
| A66/74   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 35.9         | 35.6    | 7.7     | 11.9      |
| A66/75   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 37.5         | 39.4    | 7       | 8.1       |
| A66/76   | 1979 | BD dump | Flake                            | Rhyolite            | 61.3         | 45      | 11.5    | 36.7      |
| A66/77   | 1979 | BD dump | Flake fragment                   | Crystal tuff        | 62.6         | 37.8    | 9.7     | 23.1      |
| A66/78   | 1979 | BD dump | Flake                            | FP Lava             | 64.6         | 73.5    | 13.4    | 68.9      |
| A66/79   | 1979 | BD dump | Pseudo-Levallois point           | Crystallithic tuff  | 34.9         | 34.1    | 12.9    | 11.5      |
| A66/80   | 1979 | BD dump | Flake fragment                   | FP Lava             | 41.5         | 40.5    | 12.3    | 23.6      |
| A66/81   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 34.1         | 16.1    | 8.1     | 4         |
| A66/86   | 1979 | BD dump | Flake fragment                   | FP Lava             | 25.5         | 39      | 14.6    | 19        |
| A66/90   | 1979 | BD dump | Naturally backed knife           | Crystal pumice tuff | 60.2         | 38.2    | 14      | 30.2      |
| A66/93   | 1979 | BD dump | Flake                            | Crystal lithic tuff | 45.6         | 40.4    | 10.4    | 24.6      |
| A66/94   | 1979 | BD dump | Flake fragment                   | Fine silicic tuff   | 30.3         | 34      | 12.5    | 11.2      |
| A66/95   | 1979 | BD dump | Flake                            | Rhyolite            | 51.8         | 40      | 9.1     | 17.5      |
| A66/96   | 1979 | BD dump | Flake                            | Flint               | 69.2         | 37.5    | 21.1    | 45.4      |
| A66/99   | 1979 | BD dump | Flake                            | Ignimbrite          | 25           | 21.4    | 4.3     | 1.9       |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer     | Type Name                             | Raw Material                   | Measurements |         |         |           |
|----------|------|-----------|---------------------------------------|--------------------------------|--------------|---------|---------|-----------|
|          |      |           |                                       |                                | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A68      | 1979 | WWII      | Flake fragment                        | Fine sandstone                 | 21.2         | 17.5    | n/a     | (11.4)    |
| A68/1    | 1979 | WWII      | Handaxe                               | FP Lava                        | Being drawn  |         |         |           |
| A68/2    | 1979 | WWII      | Flake fragment                        | FP Lava                        | 65.1         | 49.3    | 12.5    | 37.6      |
| A68/3    | 1979 | WWII      | Flake                                 | Flint                          | 91           | 78.4    | 18      | 118.1     |
| A68/3    | 1979 | WWII      | Flake                                 | chert                          | 42.3         | 35      | 16.8    | 25.8      |
| A68/4    | 1979 | WWII      | Flake                                 | Fine silicic tuff              | 41.3         | 37.5    | 11.1    | 23        |
| A68/5    | 1979 | WWII      | Clactonian notch                      | Fine grained basic lava basalt | 70.3         | 56      | 28.3    | 129       |
| A68/6    | 1979 | WWII      | Lev. flake                            | Crystal tuff                   | 75.1         | 51.7    | 16.2    | 65.1      |
| A68/7    | 1979 | WWII      | Lev. flake                            | Fine silicic tuff              | 32.4         | 36      | 6.2     | 8.2       |
| A68/8    | 1979 | WWII      | Single convcave side scraper fragment | Vitric crystal tuff            | 31.5         | 39.4    | 7.2     | 12.6      |
| A68/10   | 1979 | WWII      | Flake                                 | Crystal pumice tuff            | 54.1         | 42.2    | 14.5    | 37        |
| A68/11   | 1979 | WWII      | Retouched flake                       | Fine silicic tuff              | 80.3         | 61.2    | 17.5    | 87.6      |
| A68/12   | 1979 | WWII      | Mis-hit Lev. core                     | Ignimbrite                     | 111.7        | 123.3   | 52.2    | 721.1     |
| A68/13   | 1979 | WWII      | Flake fragment                        | Rhyolite                       | Being drawn  |         |         |           |
| A68/15   | 1979 | WWII      | Flake fragment                        | Flint                          | 13           | 17.5    | 4.2     | 0.7       |
| A68/19   | 1979 | WWII      | Flake fragment                        | Fine silicic tuff              | 12.9         | 39.3    | 5.9     | 4.5       |
| A68/20   | 1979 | WWII      | Ret. flake                            | Flint                          | 28           | 18.6    | 4.6     | 1.7       |
| A71/2    | 1979 | Yellow    | Ret. flake                            | Flint                          | 44.2         | 33.4    | 14.4    | 14.4      |
| A73      | 1979 | Yellow    | Flake                                 | Crystal pumice lithic tuff     | 118.3        | 73.4    | 36.2    | 265.3     |
| A74/1    | 1979 | WWII 1    | Disc. core                            | Microdiorite/ Andesite         | 67           | 62.3    | 32      | 165.9     |
| A74/2    | 1979 | WWII 1    | Flake fragment                        | Ignimbrite                     | 53.2         | 32.2    | 13.7    | 21        |
| A76      | 1980 | WWII      | Flake                                 | Crystal tuff                   | 44.4         | 31      | 8.8     | 13.5      |
| A79/1    | 1980 | WWII      | Side scraper on ventral side          | Fine silicic tuff              | 57.4         | 59.1    | 19      | 61.7      |
| A79/2    | 1980 | WWII      | Flake                                 | Crystal tuff                   | 60.6         | 51.8    | 13.2    | 43.4      |
| A79/3    | 1980 | WWII      | ret. flake (siret burin)              | Fine silicic tuff              | 46.5         | 35.5    | 11.5    | 20.5      |
| A79/4    | 1980 | WWII      | Flake fragment                        | Flint                          | 8.7          | 28.9    | 5.1     | 1.2       |
| A79/4a   | 1980 | WWII      | Retouched flake                       | Ignimbrite                     | 54           | 76.5    | 13.3    | 59.9      |
| A84      | 1980 | WWII      | Flake                                 | Flint                          | 20.5         | 37.9    | 15.1    | 6.8       |
| A86/1    | 1980 | WWII      | Discoidal core                        | FP Lava                        | 55.8         | 46.8    | 34.9    | 85.8      |
| A86/2    | 1980 | WWII      | Flake                                 | Fine silicic tuff              | 29           | 27.6    | 5.2     | 4.4       |
| A86/3    | 1980 | WWII      | Retouched flake                       | Flint                          | 36.7         | 20.7    | 9.3     | 5.3       |
| A86/4    | 1980 | WWII      | Reduced Lev. converted to disc core   | Flint                          | 49.5         | 38.7    | 13.6    | 19.4      |
| A86/5    | 1980 | WWII      | Flake fragment                        | Flint                          | 30.5         | 31.3    | 5.8     | 6.5       |
| A86/6    | 1980 | WWII      | Naturally backed knife                | Fine silicic tuff              | 27           | 36.3    | 8.3     | 7.2       |
| A86/7    | 1980 | WWII      | Flake                                 | Fine silicic tuff              | 26.6         | 41.2    | 11.3    | 12.9      |
| A86/8    | 1980 | WWII      | Flake                                 | Ignimbrite                     | 42.7         | 26.6    | 6.3     | 7.5       |
| A86/9    | 1980 | WWII      | Flake                                 | Crystal lithic tuff            | 74.7         | 41      | 15.6    | 49.9      |
| A86/10   | 1980 | WWII      | Flake                                 | Tuff                           | 64           | 45.6    | 16.4    | 47.1      |
| A86/11   | 1980 | WWII      | Crude Core                            | Ignimbrite                     | 55           | 49.5    | 32.1    | 103.6     |
| A86/12   | 1980 | WWII      | End notched piece                     | Rhyolite                       | 51.2         | 46.5    | 14.2    | 33.3      |
| A95      | 1980 | N section | Handaxe                               | FP Lava                        | 87.4         | 57.9    | 40.2    | 188.8     |
| A96/1    | 1980 | Surface   | Chopping tool                         | Rhyolite                       | 54.8         | 54.2    | 34.4    | 114.8     |
| A96/2    | 1980 | WWII      | Straight sided scraper on Lev. flake  | FP Lava                        | 55.6         | 65.3    | 13.9    | 52.5      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer        | Type Name   | Raw Material                     | Measurements |         |         |           |
|----------|------|--------------|---|----------------------------------|--------------|---------|---------|-----------|
|          |      |              |   |                                  | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A99      | 1980 | WWII         | Flake fragment                                    | Flint                            | 8.9          | 21      | 5.3     | 1         |
| A99/1    | 1980 | WWII         | Discoidal core                                    | FP Lava                          | 64.3         | 58      | 32.8    | 124.2     |
| A99/2    | 1980 | WWII         | Handaxe   | Crystal lithic tuff              | 112.7        | 80.4    | 36.7    | 289.6     |
| A99/3    | 1980 | WWII         | Handaxe trimming flake<br>(with proximal retouch) | Flint                            | 48           | 51.2    | 10.5    | 22.2      |
| A99/4    | 1980 | WWII         | Flake fragment                                    | Flint                            | 22.7         | 32.6    | 9.7     | 6.3       |
| A99/6    | 1980 | WWII         | Flake   | Flint                            | 55.2         | 20.4    | 10.3    | 14.1      |
| A99/7    | 1980 | WWII         | Handaxe trimming flake                            | Fine silicic tuff                | 50           | 68      | 11.5    | 43.3      |
| A99/8    | 1980 | WWII         | Levallois flake                                   | Crystal vitric tuff              | 48.3         | 74.1    | 17.2    | 57.8      |
| A99/9    | 1980 | WWII         | Flake   | Crystal tuff                     | 69.1         | 48.5    | 11.7    | 48        |
| A99/10   | 1980 | WWII         | Flake   | FP Lava                          | 44.2         | 67.6    | 10.3    | 49        |
| A99/11   | 1980 | WWII         | Chunk   | FP lava                          | 97.7         | 39.1    | 19      | 74.1      |
| A99/12   | 1980 | WWII         | Levallois flake (outrepassé<br>lev. flake)        | Silicic tuff                     | 80.5         | 53.3    | 13.2    | 54        |
| A102/1   | 1980 | WWII/BD      | Handaxe trimming flake                            | Crystal pumice? tuff             | 72           | 56.3    | 22.6    | 85.5      |
| A102/2   | 1980 | WWII/BD      | Discoidal core fragment                           | Sandstone                        | 81.2         | 41.8    | 18.3    | 65.9      |
| A102/3   | 1980 | WWII/BD      | Discoidal core                                    | Fine silicic tuff                | 47.6         | 48.9    | 22.1    | 52.4      |
| A102/4   | 1980 | WWII/BD      | Flake   | Crystal pumice tuff              | 37           | 51      | 9.3     | 16.6      |
| A102/5   | 1980 | WWII/BD      | Scraper   | Rhyolite                         | 61.4         | 41.7    | 23.2    | 63.9      |
| A102/6   | 1980 | WWII/BD      | Levallois core                                    | Flint                            | being drawn  |         |         |           |
| A105/2   | 1980 | BD dump      | Flake   | Fine Silicic Tuff                | 47.9         | 40.8    | 10.7    | 16.6      |
| A105/3   | 1980 | BD dump      | Discoidal core                                    | Fine Silicic Tuff                | 36.8         | 36      | 22      | 22        |
| A105/4   | 1980 | BD dump      | Flake fragment                                    | FP Lava                          | 35           | 42.1    | 16.6    | 25.2      |
| A105/5   | 1980 | BD dump      | Levallois flake                                   | Fine Silicic Tuff                | 31.1         | 50.8    | 8.8     | 18.2      |
| A105/6   | 1980 | BD dump      | Retouched flake                                   | Fine Silicic Tuff                | 55.3         | 37.1    | 11.4    | 22.2      |
| A105/8   | 1980 | BD dump      | Retouched flake                                   | Crystal pumice tuff              | 76.1         | 51.1    | 17      | 79.6      |
| A105/10  | 1980 | BD dump      | Core fragment                                     | Ignimbrite                       | 76.2         | 63.7    | 20.6    | 93.3      |
| A108     | 1980 | WWII         | Discoidal core                                    | Ignimbrite                       | 65.1         | 58.5    | 35.2    | 135.4     |
| A109/1   | 1980 | BD Dump      | Scraper (ventral ret &<br>notched)                | Fine Sandstone                   | 52.6         | 52.6    | 23.5    | 80.1      |
| A109/2   | 1980 | BD Dump      | Flake   | Sandstone                        | 51.3         | 54.3    | 11.2    | 23.8      |
| A109/3   | 1980 | BD Dump      | Flake   | Silicic Tuff                     | 50.3         | 56.5    | 21.6    | 54.6      |
| A112/1   | 1980 | BD Dump      | Single convex side scraper                        | FP Lava                          | 49.1         | 43.7    | 9.2     | 31.4      |
| A112/2   | 1980 | BD Dump      | Flake   | FP Lava                          | 67.5         | 42.2    | 12      | 33.7      |
| A112/3   | 1980 | BD Dump      | Flake   | Tuff                             | 37.6         | 31.5    | 8       | 10.3      |
| A112/4   | 1980 | BD Dump      | Flake   | Ignimbrite                       | 51.8         | 36.1    | 11.1    | 20.1      |
| A112/5   | 1980 | BD Dump      | Denticulate                                       | Flint                            | Being drawn  |         |         |           |
| A115/2   | 1980 | WWII         | Flake   | FP Lava                          | 38           | 38.7    | 10      | 13.5      |
| A122     | 1980 | WWII         | Discoidal core                                    | Flint                            | 51.6         | 39.2    | 14.1    | 25.6      |
| A124     | 1980 | Backfill     | Flake   | Sandstone with fine<br>Siltstone | 70.4         | 65.8    | 13.5    | 70.1      |
| A124/1   | 1980 | Backfill     | Flake   | Rhyolite lava                    | 67.3         | 48.5    | 14.4    | 44.4      |
| A124/2   | 1980 | Backfill     | Flake   | Fine Silicic Tuff                | 26.2         | 39.3    | 10.3    | 9.1       |
| A125     | 1978 | Dump         | Pseudo-Levallois point                            | FP Lava                          | 51.7         | 42.8    | 12.2    | 32.2      |
| A126     | 1978 | Dump         | Discoidal core                                    | Ignimbrite                       | 97.7         | 81.6    | 31.4    | 256.4     |
| A127a    | 1978 | Unstratified | Handaxe   | FP Lava                          | 55.8         | 37.7    | 21.5    | 42.2      |
| A127b    | 1978 | Unstratified | Flake fragment                                    | Silicified limestone             | 45           | 44.9    | 14.5    | 24.6      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer        | Type Name                        | Raw Material          | Measurements |         |         |           |
|----------|------|--------------|----------------------------------|-----------------------|--------------|---------|---------|-----------|
|          |      |              |                                  |                       | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A128     | 1978 | Dump         | Flake                            | Rhyolite lava         | 54.1         | 75.1    | 14.7    | 65.1      |
| A129     | 1978 | Dump         | Flake                            | FP Lava               | 60.6         | 71.9    | 17.5    | 80.7      |
| A135     | 1982 | Unstratified | Flake fragment                   | Ignimbrite            | 79.6         | 62.1    | 13.4    | 38.2      |
| A136     | 1982 | Unstratified | Flake                            | Rhyolite              | 37           | 40.6    | 10.7    | 17.9      |
| A140     | 1982 | WWII dump    | Handaxe                          | Dacite Lava           | 93           | 56.7    | 31.6    | 168.7     |
| A141     | 1982 | WWII Dump    | Handaxe                          | Fine silicic tuff     | 95.4         | 61.5    | 18      | 100.3     |
| A147     | 1982 | WWII Dump    | Chopping tool                    | FP Lava               | 66.4         | 80.5    | 39.7    | 261.2     |
| A148     | 1982 | WWII Dump    | Flake fragment                   | Fine Silicic Tuff     | 32.8         | 21.7    | 3.5     | 3.1       |
| A149     | 1982 | Unstratified | Crude core (ret. thru. pat.)     | Rhyolitic Tuff        | 65.4         | 61.2    | 24.3    | 86.8      |
| A155     | 1982 | WWII         | Handaxe                          | Rhyolite              | 116.7        | 71.1    | 37.8    | 240.9     |
| A156     | 1982 | WWII         | Handaxe                          | Rhyolitic Lava        | 141.5        | 80.9    | 45.2    | 489.3     |
| A158     | 1982 | WWII         | Indet. scraper fragment          | Fine Silicic Tuff     | 42.1         | 14.1    | 10.3    | 6.1       |
| A160     | 1982 | WWII         | Flake                            | Rhyolite              | 77.5         | 64.2    | 17.5    | 81.6      |
| A161     | 1982 | WWII         | Flake                            | Rhyolitic Tuff        | 70.7         | 57.1    | 26.2    | 84.6      |
| A163     | 1982 | WWII         | Flake                            | Flint                 | 28           | 32.1    | 5.8     | 4.6       |
| A173     | 1982 | WWII         | Flake                            | Rhyolite/Dacite       | 76.1         | 89.8    | 20.6    | 150.8     |
| A182     | 1982 | WWII         | Hand-axe trimmer flake           | Ignimbrite            | 62.1         | 76.6    | 18.5    | 78.5      |
| A183     | 1982 | WWII         | Flake fragment                   | Ignimbrite            | 41.8         | 28.2    | 7.7     | 12.6      |
| A184     | 1982 | WWII         | Flake                            | Rhyolite              | 35.2         | 33      | 13.1    | 17.2      |
| A185     | 1982 | WWII         | Flake fragment                   | Fine Silicic Tuff     | 14.5         | 18.6    | 3.2     | 1         |
| A199     | 1982 | WWII         | Retouched Flake                  | Ignimbrite            | 94.1         | 78.8    | 25.6    | 183       |
| A200     | 1982 | WWII         | Flake fragment (siret retouched) | FP Lava               | 52.8         | 47      | 20.1    | 48.8      |
| A201     | 1982 | WWII         | Flake fragment                   | Rhyolite/Dacite       | 70.2         | 64.2    | 9       | 46.3      |
| A203     | 1982 | BD Dump      | Levallois flake                  | Fine Silicic Tuff     | 65           | 42.3    | 11.6    | 33.7      |
| A204     | 1982 | BD Dump      | Handaxe                          | Rhyolite              | 87.2         | 65.6    | 35.1    | 166.2     |
| A205     | 1982 | BD Dump      | Flake fragment                   | Fine Silicic Tuff     | 44.3         | 51.1    | 12      | 25.6      |
| A206     | 1982 | BD Dump      | Levallois flake fragment         | Ignimbrite            | 39.5         | 46.8    | 9.7     | 26.6      |
| A207     | 1982 | BD Dump      | Flake                            | Mudstone              | 101.5        | 74.3    | 107.5   | 176.2     |
| A208     | 1982 | BD Dump      | Flake                            | Rhyolitic tuff        | 50           | 72      | 16.8    | 56.7      |
| A220     | 1982 | BD Dump      | Flake fragment                   | Rhyolitic tuff        | 43.5         | 60      | 16      | 47.4      |
| A223     | 1982 | BD Dump      | Flake fragment                   | Ironstained siltstone | 62.5         | 45.5    | 12.5    | 34.5      |
| A244     | 1982 | BD Dump      | Flake fragment                   | Carboniferous chert   | 18.3         | 23.1    | 7.8     | 3.2       |
| A245     | 1982 | BD Dump      | Discoidal core                   | Rhyolite              | 83.7         | 68      | 29      | 177       |
| A246     | 1982 | BD Dump      | Flake                            | Fine Silicic Tuff     | 57.7         | 50.4    | 11.8    | 34.5      |
| A247     | 1982 | BD Dump      | Levallois point core             | Fine Silicic Tuff     | 71.1         | 65.5    | 23.5    | 122.6     |
| A252     | 1982 | BD Dump      | Discoidal core                   | Rhyolitic Tuff        | 62.3         | 56.1    | 35.1    | 126.5     |
| A253     | 1982 | BD Dump      | Bifacially retouched scraper     | Rhyolitic Lava        | 95.8         | 60.7    | 25.9    | 154.2     |
| A254     | 1982 | BD Dump      | Core                             | Rhyolite              | 126.2        | 74.9    | 39.2    | 332.3     |
| A255     | 1982 | BD Dump      | Flake                            | Fine Sandstone        | 22           | 12      | 4.5     | 1.1       |
| A256     | 1982 | BD Dump      | Flake fragment                   | Rhyolite              | 34           | 24.5    | 6.4     | 6.2       |
| A273     | 1982 | BD Dump      | Flake                            | Rhyolitic Tuff        | 72.5         | 58.2    | 20.3    | 83.1      |
| A280     | 1982 | BD Dump      | Notch                            | Fine Silicic Tuff     | 53.5         | 53.1    | 13.6    | 39.8      |
| A281     | 1982 | BD Dump      | Levallois flake fragment         | Rhyolite              | 53.8         | 69.5    | 17.7    | 65.3      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer   | Type Name                                   | Raw Material        | Measurements |         |         |           |
|----------|------|---------|---|---------------------|--------------|---------|---------|-----------|
|          |      |         |   |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A282     | 1982 | BD Dump | Flake                                       | Rhyolite            | 70.9         | 52      | 21.8    | 78.1      |
| A283     | 1982 | BD Dump | Flake with extensive crushing (edge damage) | Rhyolite            | 59.4         | 44.8    | 10.2    | 30        |
| A284     | 1982 | BD Dump | Flake                                       | Flint               | 37.8         | 34.2    | 9.2     | 11.7      |
| A288     | 1982 | BD Dump | Retouched flake                             | Fine Silicic tuff   | 21.8         | 11.8    | 4.1     | 1.3       |
| A304     | 1982 | BD Dump | Flake fragment                              | Dacite Lava         | 31           | 34      | 8.7     | 11.4      |
| A319     | 1982 | BD Dump | Flake                                       | Ignimbrite          | 56           | 56.6    | 13.4    | 34.8      |
| A328     | 1982 | BD Dump | Discoidal core                              | FP Lava             | 63           | 55.6    | 26.6    | 98.5      |
| A329     | 1982 | BD Dump | Retouched flake                             | Fine Sandstone      | 77.3         | 59.5    | 20.3    | 111.4     |
| A330     | 1982 | BD Dump | Flake fragment                              | Basalt              | 56.8         | 52.3    | 26.6    | 81.1      |
| A332     | 1982 | U/S     | Retouched flake                             | Rhyolitic Tuff      | 39.5         | 28.9    | 11      | 13.9      |
| A334     | 1984 | U/S     | Handaxe trimmer flake                       | Fine Silicic Tuff   | 79.3         | 76.8    | 13.5    | 78.1      |
| A355     | 1984 | WWII    | Flake                                       | Fine Sandstone      | 17           | 18.7    | 5.2     | 1.8       |
| A373     | 1984 | U/S     | Flake                                       | Flint               | 44.2         | 36.5    | 18.9    | 28.6      |
| A462     | 1985 | WWII    | Levallois flake                             | Rhyolite            | 50.8         | 46      | 10.2    | 24.2      |
| A477     | 1985 | WWII    | Discoidal core                              | Ignimbrite          | 71.1         | 71.7    | 19.5    | 109.3     |
| A485     | 1985 | WWII    | Flake                                       | Carboniferous Chert | 45.5         | 27.2    | 6.9     | 9.6       |
| A490     | 1985 | WWII    | Levallois flake                             | Basaltic Tuff       | 67.2         | 65.7    | 13.6    | 73.6      |
| A497     | 1985 | WWII    | Levallois flake                             | Rhyolite            | 100          | 80      | 14      | 144.5     |
| A513     | 1985 | WWII    | Flake fragment                              | Sandstone           | 88.4         | 102.4   | 24.2    | 205.6     |
| A515     | 1988 | U/S     | Convergent convex scraper                   | Crystal tuff        | 40.2         | 32.7    | 10.9    | 18.2      |
| A516     | 1988 | U/S     | Natural                                     | Quartz              | n/a          | n/a     | n/a     | 53.2      |
| A531     | 1995 | BD      | Natural                                     | Limestone           | n/a          | n/a     | n/a     | 203.6     |
| A532     | 1995 | BD      | Disc core (2 phases patina)                 | Fine silicic tuff   | 60.6         | 50.6    | 18.3    | 57.5      |
| A533     | 1995 | BD      | Handaxe                                     | Rhyolitic tuff      | 115.8        | 65      | 36.1    | 236.3     |
| A535     | 1995 | BD      | Flake frag                                  | Rhyolitic tuff      | 57.5         | 72.7    | 17.2    | 62.7      |
| A536     | 1995 | BD      | Chunk                                       | Rhyolitic tuff      | 47.8         | 24      | 12.9    | 11.6      |
| A537     | 1995 | BD      | Levallois flake                             | Rhyolitic tuff      | 70.4         | 41.4    | 14.6    | 52        |
| A539     | 1995 | BD      | Flake fragment                              | Basalt lava         | 47.8         | 47.8    | 12.1    | 27.1      |
| A541     | 1995 | BD      | Disc core frag                              | Fine silicic tuff   | 46.6         | 45.7    | 17.2    | 31        |
| A543     | 1995 | WW11    | Flake                                       | Fine silicic tuff   | 24.3         | 17.9    | 6.4     | 2.8       |
| A546     | 1995 | WW11    | Flake                                       | Rhyolitic tuff      | 127.8        | 71.2    | 35      | 305.1     |
| A546     | 1995 | WW11    | Flake                                       | Rhyolitic tuff      | 99.9         | 61.5    | 24.1    | 155       |
| A547     | 1995 | BD      | Handaxe                                     | Silicic tuff        | 75.7         | 45.3    | 16.1    | 52.2      |
| A548     | 1995 | BD      | Natural clast?                              | Vitric crystal tuff | n/a          | n/a     | n/a     | 252       |
| A549     | 1995 | BD      | Flake                                       | Crystal vitric tuff | n/a          | n/a     | n/a     | 306       |
| A550     | 1995 | BD      | Levallois flake                             | Microdiorite        | 56.1         | 52.2    | 13      | 35.9      |
| A551     | 1995 | BD      | Flake fragment                              | Flint               | 10           | 11.8    | 2.6     | 0.2       |
| A559     | 1995 | BD      | Flake h/a trimmer                           | Ignimbrite          | 58.5         | 54.7    | 12.3    | 34.5      |
| A566*    | 1995 | BD      | Single straight side scraper                | Rhyolitic tuff      | 83.2         | 61.9    | 15.5    | 99.9      |
| A567     | 1995 | BD      | Flake fragment                              | Flint               | 27.8         | 41.4    | 12.4    | 14.8      |
| A569     | 1995 | BD      | Chunk                                       | Fine silicic tuff   | 18.7         | 13.7    | 5.6     | 1.2       |
| A589     | 1995 | BD      | Levallois flake                             | Fine silicic tuff   | 67           | 49.3    | 9.7     | 35.3      |
| A600     | 1995 | BD      | Flake fragment                              | Flint               | 34.9         | 25.6    | 11.2    | 8.3       |
| A604     | 1995 | BD      | Flake frag                                  | Crystal tuff        | 34.6         | 37.7    | 10.2    | 15.7      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer  | Type Name                      | Raw Material          | Measurements |         |         |           |
|----------|------|--------|--------------------------------|-----------------------|--------------|---------|---------|-----------|
|          |      |        |                                |                       | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A605     | 1995 | BD     | Levallois flake                | Tuff                  | 52.4         | 43      | 10.5    | 27.9      |
| A606     | 1995 | BD     | Flake frag.                    | Rhyolite lava         | 56.4         | 76.4    | 20.8    | 85.8      |
| A610     | 1995 | BD     | Flake                          | Rhyolite              | 34.9         | 53.3    | 11.7    | 20.6      |
| A611     | 1995 | BD     | Levallois blade (1)            | Fine silicic tuff     | 73.1         | 36.7    | 11.3    | 34.4      |
| A614     | 1985 | BD     | Flake fragment                 | Flint                 | 35.2         | 15      | 9.9     | 4.4       |
| A617     | 1995 | BD     | Flake fragment                 | Rhyolite              | 86.6         | 53.5    | 20.5    | 77.7      |
| A625     | 1995 | BD     | Disc core                      | Hornfels, metamorph.  | 66.7         | 63.3    | 18.7    | 89.7      |
| A627     | 1995 | BD     | Flake fragment                 | Sandstone, tuffaceous | 34.1         | 19.6    | 9.2     | 5.7       |
| A643     | 1995 | BD     | Flake fragment                 | FP lava               | 58           | 37.4    | 13.9    | 32.5      |
| A646     | 1995 | BD     | levallois flake                | Rhyolite              | 82.1         | 95.9    | 26.5    | 162.3     |
| A652     | 1995 | BD     | Handaxe                        | Crystal lithic tuff   | 160          | 116.6   | 39.1    | 936.8     |
| A656     | 1995 | BD     | Flake frag.                    | Ignimbrite            | 34.5         | 48      | 12.8    | 15.4      |
| A657     | 1985 | BD     | Artefact frag                  | Rhyolite              | 62.3         | 50.3    | 13.7    | 50.5      |
| A657     | 1985 | BD     | Discoidal core                 | Ignimbrite            | 80.5         | 82.7    | 25.8    | 197.6     |
| A658     | 1985 | BD     | Flake                          | Rhyolitic Tuff        | 47.5         | 36      | 13      | 22.8      |
| A659     | 1995 | BD     | Flake fragment                 | FP lava               | 40.9         | 22.9    | 14.2    | 12.2      |
| A660     | 1995 | BD     | Flake fragment                 | Ignimbrite            | 42.5         | 45.1    | 16.4    | 28.5      |
| A666     | 1985 | BD     | Side scraper with ventral ret. | Rhyolitic tuff        | 44.9         | 41.4    | 12.7    | 22.8      |
| A670     | 1995 | BD     | Disc core fragment             | Flint                 | 40.7         | 41      | 16      | 24.4      |
| A672     | 1985 | BD     | Flake fragment                 | Ignimbrite            | 38.4         | 37.2    | 9.5     | 16.1      |
| A676     | 1995 | BD     | Flake fragment                 | Silicic tuff          | 28.3         | 29      | 7.6     | 6         |
| A681     | 1985 | BD     | Flake                          | Rhyolite              | 89           | 54.6    | 17      | 86.7      |
| A683     | 1985 | BD     | Flake                          | Sandstone             | 65.1         | 68.5    | 22.5    | 95.8      |
| A684     | 1985 | BD     | Offset scraper                 | Andesite              | 65.5         | 91.6    | 23.2    | 132.6     |
| A685     | 1985 | BD     | Flake handaxe trimmer          | Rhyolite lava         | 113.5        | 98.2    | 13.9    | 144.5     |
| A688     | 1985 | WWII   | Disc. core                     | Fine sandstone        | 58.9         | 53.7    | 15.1    | 49.4      |
| A689     | 1985 | WWII   | Single concave side scraper    | Ignimbrite            | 81           | 65      | 24.2    | 110.6     |
| A697     | 1985 | BD     | Bifacial scraper               | Flint                 | 37.4         | 48.2    | 9.2     | 19.2      |
| A706     | 1986 | U/S    | Flake                          | Flint                 | 41.2         | 29.2    | 3.5     | 3.5       |
| A713     | 1995 | BD     | Flake fragment                 | FP lava               | 29.5         | 24.1    | 6.2     | 5.3       |
| A714     | 1995 | BD     | Chunk                          | Rhyolite lava         | 12.9         | 11.8    | 5.2     | 0.9       |
| A717     | 1995 | BD2    | Retouched flake                | Fine silicic tuff     | 59.2         | 33.9    | 27.7    | 45        |
| A717     | 1995 | BD     | Retouched flake                | Flint                 | not found    |         |         |           |
| A724     | 1995 | BD     | Chip                           | Flint                 | 7.2          | 5.9     | 3.3     | 0.1       |
| A731     | 1995 |        | Flake                          | Flint                 | 17.2         | 15.6    | 4.1     | 0.7       |
| A738     | 1995 | BD     | Flake fragment                 | FP lava               | 29.6         | 25.8    | 10.6    | 7.8       |
| A739     | 1995 | WWII 1 | Microolith ()                  | Flint                 | 19.9         | 4.5     | 4.6     | 0.3       |
| A744     | 1995 | WWII 1 | Flake fragment                 | Flint                 | 15           | 11.1    | 2.4     | 0.2       |
| A749     | 1995 | WWII 1 | Natural                        | Flint                 | n/a          | n/a     | n/a     | 0.5       |
| A754     | 1995 | WWII 1 | Chip                           | Flint                 | 4.2          | 8       | 3.4     | 0.1       |
| A757     | 1995 | WWII 1 | Flake fragment (burnt)         | Silicic tuff          | 51.7         | 38.6    | 9.5     | 18.8      |
| A758     | 1995 | WWII 1 | Flake fragment                 | Flint                 | 8.3          | 11.2    | 3.1     | 0.2       |
| A763     | 1995 | WWII 1 | Flake fragment                 | Flint                 | 17.5         | 19.2    | 5       | 1.8       |
| A765     | 1995 | WWII 1 | Handaxe                        | Rhyolite lava         | 85.7         | 59.2    | 43.2    | 225.8     |
| A766     | 1995 | WWII 1 | Handaxe (tip missing)          | Rhyolite              | 63.5         | 55      | 31.4    | 117.9     |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer   | Type Name                           | Raw Material          | Measurements |         |         |           |
|----------|------|---------|-------------------------------------|-----------------------|--------------|---------|---------|-----------|
|          |      |         |                                     |                       | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| A784     | 1995 | BD      | Flake fragment                      | Fine silicic tuff     | 17           | 21.1    | 7.2     | 1.7       |
| A786     | 1995 | BD      | Flake fragment                      | Rhyolitic tuff        | 11.2         | 5.9     | 3.3     | 0.2       |
| A792     | 1995 | BD      | Chip                                | Rhyolite lava         | 10.5         | 11.6    | 6.6     | 0.8       |
| A796     | 1995 | BD      | Chunk                               | Flint                 | 11.7         | 6.7     | 4.3     | 0.3       |
| A800     | 1995 | BD2     | Chip                                | Flint                 | 8.2          | 3.7     | 2.5     | <0.1      |
| A802     | 1995 | USG7    | Natural                             | Flint                 | n/a          | n/a     | n/a     | 0.9       |
| A803     | 1995 | USG7    | Chip                                | Flint                 | 4            | 5.5     | 3.1     | <0.1      |
| A804     | 1995 | USG7    | Natural                             | Flint                 | n/a          | n/a     | n/a     | 0.1       |
| A806     | 1995 | WWII    | Chip                                | Flint                 | 6.4          | 8.5     | 2.2     | 0.1       |
| A807     | 1995 | BD/WWII | Flake fragment                      | Fine silicic tuff     | 29.7         | 25.3    | 5       | 5.2       |
| A808     | 1995 | BD/WWII | Flake fragment                      | Flint                 | 28.6         | 27.5    | 8.4     | 5.5       |
| A812     | 1995 | BD/WWII | Chip                                | Flint                 | 8.2          | 4.6     | 2.6     | 0.1       |
| A815     | 1995 | BD/WWII | Chip                                | Flint                 | 4.9          | 3.3     | 1.2     | <0.1      |
| A817     | 1995 | BD/WWII | Flake                               | Fine silicic tuff     | 46.6         | 37.6    | 16.4    | 28.3      |
| A825     | 1995 | BD/WWII | Cobble frag                         | Silicic tuff          | 78.2         | 45.2    | 29      | 92.6      |
| B3       | 1978 | USG     | Flake                               | Fine Sandstone        | 40           | 37.2    | 13.2    | 17.5      |
| B4       | 1978 | Br      | Levallois flake (re-struck)         | FP Lava               |              |         |         |           |
| B5       | 1978 | Br      | Flake                               | FP Lava               | 53.8         | 41.4    | 8.4     | 14.6      |
| B9       | 1978 | Br      | Single convex side scraper          | FP Lava               |              |         |         |           |
| B10      | 1978 | Br      | Flake                               | Flint                 | 27.5         | 15.9    | 7       | 2.8       |
| B18      | 1978 | Br      | Handaxe                             | Crystal Tuff          | 64           | 43.6    | 20.4    | 53.3      |
| B19      | 1978 | Br      | Handaxe                             | Siltstone             | 62.6         | 43.9    | 22.3    | 49.8      |
| B20      | 1978 | Br      | Flake                               | Crystal lithic tuff   | 61.9         | 43.7    | 12.3    | 39.9      |
| B22      | 1978 | Br      | Handaxe trimming flake              | FP Lava               | 66.5         | 78.1    | 17.3    | 94.9      |
| B23      | 1978 | Br      | Handaxe                             | Rhyolite              | 92.9         | 75.3    | 38.9    | 236       |
| B25      | 1978 | Br      | Flake                               | Fine Silicic Tuff     | 40.2         | 83.2    | 15.8    | 64.4      |
| B32      | 1978 | Br      | Handaxe trimming flake              | Fine Silicic Tuff     | 36.6         | 49.3    | 7.4     | 12.6      |
| B33      | 1978 | Br      | Flake fragment                      | Crystal Tuff          | 29.9         | 23.7    | 7.7     | 7.4       |
| B42      | 1978 | Br      | Handaxe trimmer                     | Fine Silicic Tuff     | 58.8         | 64.9    | 14.7    | 60.2      |
| B48      | 1978 | Br      | Natural chunk                       | Fine grained rhyolite | n/a          | n/a     | n/a     | 6.7       |
| B49      | 1978 | Br      | Flake                               | Ignimbrite            | 45.8         | 43.4    | 15.5    | 32.4      |
| B57      | 1978 | Br      | Levallois core (unstruck)           | Ignimbrite            | 61.5         | 61.2    | 26.1    | 102.8     |
| B61      | 1978 | Br      | Abrupt ret. side scraper with notch | Flint                 | 32.5         | 22.2    | 4.7     | 2.9       |
| B70      | 1978 | Br      | Levallois core                      | FP Lava               | 61.3         | 53.3    | 17.2    | 61.9      |
| B72      | 1978 | UB      | Flake                               | Ignimbrite            | 75           | 44.2    | 25      | 65.3      |
| B116     | 1979 | RCE     | Flake                               | Ignimbrite            | 55.3         | 64      | 24.2    | 76.5      |
| B117     | 1979 | UB      | Flake                               | Flint                 | 29           | 19.8    | 8.4     | 3         |
| B118     | 1979 | UB      | Flake                               | FP Lava               | 57.7         | 48.5    | 11.7    | 32.4      |
| B120     | 1979 | LB      | Flake                               | Fine Silicic Tuff     | 127.7        | 78      | 23.8    | 290.9     |
| B150     | 1979 | LB      | Retouched flake                     | Fine Silicic Tuff     | 46.4         | 42.2    | 12.5    | 19.2      |
| B167     | 1979 | Int.    | Natural chunk                       | Flint                 | n/a          | n/a     | n/a     | 1.5       |
| B172     | 1979 | UB      | Crude core                          | Ignimbrite            | 97           | 59.1    | 53.6    | 277.8     |
| B203     | 1979 | LB      | Core fragment                       | Rhyolite              | 60.2         | 71.2    | 26.5    | 127.4     |
| B215     | 1979 | LB      | Spall                               | Flint                 | 2.7          | 5.9     | 3.2     | 0.2       |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No.  | Year | Layer   | Type Name                                    | Raw Material               | Measurements |         |         |           |
|-----------|------|---------|--|----------------------------|--------------|---------|---------|-----------|
|           |      |         |  |                            | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| B221      | 1979 | UB      | Levallois flake                              | Fine Silicic Tuff          | 66.2         | 49.6    | 14.6    | 57.2      |
| B222      | 1979 | UCS     | Flake fragment                               | Fine Silicic Tuff          | 72.1         | 73.4    | 17.8    | 56.3      |
| B223      | 1979 | UCS     | Flake  | FP Lava                    | 34.8         | 39.5    | 12.2    | 18.4      |
| B226      | 1979 | LB      | Naturally backed knife                       | Silicic Tuff               | 89.4         | 48.9    | 24.7    | 109.9     |
| B227      | 1979 | Br      | Retouched flake                              | Flint                      | 56.8         | 50.1    | 15.6    | 41        |
| B232      | 1979 | LB/Int. | Flake fragment                               | Vitric Tuff                | 50.5         | 35.3    | 11      | 20.6      |
| B236      | 1979 | Br      | Levallois core                               | Rhyolite                   | 78.7         | 74.9    | 20      | 152.4     |
| B240      | 1979 | Br      | Retouched flake                              | Flint                      | 35.4         | 50      | 10.7    | 15.9      |
| B244      | 1979 | Br      | Flake  | Flint                      | 26.8         | 11.1    | 7.3     | 2.3       |
| B254      | 1979 | UB      | Levallois point                              | Crystal Lithic pumice Tuff | 71           | 59.5    | 10.7    | 55.4      |
| B255      | 1979 | UB      | Flake  | FP Lava                    | 60.3         | 35      | 12.1    | 32.2      |
| B258      | 1979 | UB      | Handaxe                                      | FP Lava                    | 79.6         | 50.9    | 46.4    | 142       |
| B259      | 1979 | UB      | Flake  | Crystal Lithic Tuff        | 67.2         | 65.3    | 20.2    | 78.7      |
| B261      | 1979 | LB/Int  | Flake fragment                               | Flint                      | 20.1         | 14.8    | 5.8     | 1.9       |
| B265      | 1979 | Br      | Discoidal core                               | Basalt                     | 68           | 58.6    | 27.8    | 118.2     |
| B267      | 1979 | Br      | Flake with ventral ret.                      | Fine Silicic Tuff          | 92.9         | 63.6    | 18.5    | 141.8     |
| B268      | 1979 | Br      | Crude core fragment                          | Ignimbrite                 | 60           | 40.1    | 25.5    | 50.3      |
| B270      | 1979 | Br      | Levallois core (unstruck)                    | Siltstone                  |              |         |         |           |
| B278      | 1979 | UB/UCS  | Retouched flake                              | Dacite                     | 46.8         | 36.5    | 17.4    | 21.4      |
| B280      | 1979 | UB      | Crude core                                   | Feldspar-Porphyry          | 109.3        | 76.8    | 59.8    | 579.8     |
| B295      | 1979 | UB      | Flake  | Ignimbrite                 | 36.5         | 29.2    | 7.6     | 8.9       |
| B298      | 1979 | UB      | Chopper                                      | Rhyolitic Tuff             | 101.3        | 132.2   | 33.4    | 564.3     |
| B299      | 1979 | UB      | Flake  | Quartzite                  | 49.9         | 42.3    | 13.3    | 27.1      |
| B301      | 1979 | UB      | Blade fragment                               | Crystal Tuff               | 47.4         | 28.6    | 7.5     | 13.3      |
| B302      | 1979 | UB      | Natural chunk                                | Vitric Tuff                | n/a          | n/a     | n/a     | 55.7      |
| B309      | 1979 | UB      | Flake  | FP Lava                    | 77.8         | 40.3    | 12.2    | 41.3      |
| B310      | 1980 | UB      | Flake  | Microdiorite               | n/a          | n/a     | n/a     | 286.1     |
| B315      | 1979 | UB      | Levallois core                               | Rhyolite                   | 81.6         | 74.3    | 29.3    | 169.3     |
| B318      | 1979 | UB      | Flake  | FP Lava                    | 79.5         | 31      | 12.5    | 28.8      |
| B325      | 1979 | Br      | Core fragment                                | Flint                      | 23.6         | 12.4    | 13.6    | 4.6       |
| B333      | 1979 | UB      | Natural chunk                                | Flint                      | n/a          | n/a     | n/a     | 2.1       |
| B353      | 1979 | LB      | Natural chunk                                | Ignimbrite                 | n/a          | n/a     | n/a     | 111.3     |
| B369      | 1979 | USG     | Flake fragment                               | Fine crystal Tuff          | 28.9         | 28.5    | 13.2    | 6.2       |
| B385      | 1979 | LB      | Core fragment                                | Flint                      | 12.4         | 10.9    | 5.3     | 0.9       |
| B395      | 1979 | Int.    | Levallois blade                              | Dacite                     |              |         |         |           |
| B402      | 1981 | USG     | Natural stone                                | Ignimbrite                 | n/a          | n/a     | n/a     | n/a       |
| B402(L)   | 1981 | USG     | Natural stone                                | Dolerite                   | n/a          | n/a     | n/a     | n/a       |
| B403 A2,D | 1981 | USG     | Natural stone                                | Ignimbrite                 | n/a          | n/a     | n/a     | n/a       |
| B403E     | 1981 | USG     | Natural stone                                | Vitroclastic tuff          | n/a          | n/a     | n/a     |           |
| B404      | 1981 | USG     | Natural chunk                                | FP Lava                    | n/a          | n/a     | n/a     | 77.3      |
| B405(S)   | 1981 | USG     | Natural stone                                | Lithic tuff                | n/a          | n/a     | n/a     | n/a       |
| B415      | 1981 | USG     | Natural stone                                | Crystal-lithic tuff        | n/a          | n/a     | n/a     | n/a       |
| B443      | 1983 | UB      | Handaxe roughout                             | Crystal lithic tuff        | 127.6        | 105.5   | 48.8    | 885.7     |
| B446      | 1983 | U/S     | Flake fragments (2 frags. of the same flake) | Rhyolite                   | n/a          | n/a     | n/a     | 4.5       |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer     | Type Name  | Raw Material        | Measurements |         |         |           |
|----------|------|-----------|--|---------------------|--------------|---------|---------|-----------|
|          |      |           |  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| B449     | 1983 | LB        | Cleaver (diminutive)                               | Flint               |              |         |         |           |
| B450     | 1983 | LB        | Retouched flake                                    | Fine Sandstone      | 56           | 29      | 15.5    | 18.7      |
| B595     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.5       |
| B602     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.5       |
| B603     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.1       |
| B603     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.2       |
| B604     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.3       |
| B605     | 1993 | USG       | Natural. Angular fragment                          | Chert               | n/a          | n/a     | n/a     | n/a       |
| B605     | 1993 | USG       | Natural. Fragments x2                              | Fine silicic tuff   | n/a          | n/a     | n/a     | n/a       |
| B606     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | n/a       |
| B607     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.2       |
| B608     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | <0.1      |
| B609     | 1993 | USG       | Natural  | Flint               | n/a          | n/a     | n/a     | 0.6       |
| C8       | 1978 | U/S       | Handaxe  | Tuff                | 84.2         | 57      | 29.5    | 130.5     |
| C13      | 1978 | UCS       | Discoidal core fragment                            | Mudstone            | 53.8         | 27.4    | 14.4    | 25.2      |
| C20      | 1978 | UB        | Retouched flake                                    | Crystal Lithic Tuff | 35.7         | 31.4    | 8.3     | 10.9      |
| C22      | 1978 | Breccia   | Flake  | Rhyolite            | 25.8         | 49      | 9.6     | 12.6      |
| C23      | 1978 | Breccia   | Flake  | sandstone           | 20.9         | 28.9    | 5.1     | 3.3       |
| C26      | 1979 | LB        | Single straight side scraper<br>(on h/axe trimmer) | Fine Silicic Tuff   | 56.9         | 42.6    | 14      | 35.2      |
| C32      | 1979 | LB        | Crude core   | Ignimbrite          | not found    |         |         |           |
| C53      | 1979 | LB        | Handaxe  | Rhyolite            | 95.3         | 55.9    | 34.9    | 178.1     |
| C56      | 1979 | LB        | Flake fragment                                     | Fine Silicic Tuff   | 58.2         | 54.3    | 22.2    | 70.4      |
| C60      | 1979 | LB        | Discoidal core                                     | Crystal Tuff        | 113          | 98.6    | 38.9    | 481.7     |
| C61      | 1979 | LB        | Flake  | Crystal Lithic Tuff | 60.8         | 80.8    | 20.8    | 98.9      |
| C69      | 1979 | Disturbed | Flake fragment                                     | Fine Silicic Tuff   | 29.2         | 67.9    | 12.6    | 30.7      |
| C78      | 1979 | LB        | Flake  | Basalt Lava         | 52.5         | 71.6    | 20.6    | 74.1      |
| C92      | 1979 | LB        | Crude core   | Ignimbrite          | 60.2         | 66.8    | 50      | 148.3     |
| C104     | 1979 | LB        | Flake fragment                                     | FP Lava             | 44.1         | 62.1    | 19.2    | 41.7      |
| C111     | 1979 | LB        | Flake  | Ignimbrite          | 62           | 42.9    | 13.9    | 47.6      |
| C115     | 1979 | LB        | Levallois core                                     | Fine Silicic Tuff   | 50.6         | 45.5    | 16.8    | 49.5      |
| C122     | 1979 | LB        | Flake fragment                                     | Fine Silicic Tuff   | 45           | 48.1    | 11.1    | 26.1      |
| C131     | 1979 | LB        | Flake fragment                                     | FP Lava             | 63.5         | 54.2    | 14      | 49.4      |
| C136     | 1979 | LB        | Core fragment                                      | FP Lava             | 86.1         | 52      | 29.5    | 148       |
| C141     | 1980 | LB        | Flake fragment                                     | Crystal Tuff        | 31.4         | 24.4    | 6.5     | 5.4       |
| C169     | 1980 | LB        | Retouched flake                                    | Fine Silicic Tuff   | 57.2         | 56.2    | 16      | 42.6      |
| C202     | 1980 | LB        | Pick   | Fine Silicic Tuff   | 90           | 45.9    | 43.8    | 167       |
| C204     | 1980 | LB        | Discoidal core                                     | Carboniferous Chert | 43.9         | 33.9    | 19.9    | 29.1      |
| C216     | 1980 | LB        | Flake fragment                                     | Fine Silicic Tuff   | 24.6         | 14.6    | 3.2     | 1.5       |
| C230     | 1980 | LB        | Handaxe trimming flake                             | FP Lava             | 68.9         | 43.2    | 14.2    | 50.2      |
| C249     | 1980 | LB        | Natural pebble                                     | Siltstone           | n/a          | n/a     | n/a     | 4.1       |
| C299     | 1980 | LB        | Flake  | Silicic Tuff        | 49.1         | 27.2    | 13      | 16.1      |
| C303     | 1980 | LB        | Flake  | Fine Tuff           | 93.3         | 83.3    | 17.1    | 147.8     |
| C382     | 1980 | LB        | Crude core   | Rhyolite            | 140.1        | 100     | 65.1    | 834.3     |
| C383     | 1981 | UB        | Flake  | Fine silicic Tuff   | 47.6         | 47.8    | 10.4    | 20.6      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No.          | Year | Layer        | Type Name                    | Raw Material        | Measurements |         |         |           |
|-------------------|------|--------------|------------------------------|---------------------|--------------|---------|---------|-----------|
|                   |      |              |                              |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| C1003             | 1983 | UB/LB        | Flake                        | Rhyolite            | 70.3         | 62.7    | 12.6    | 59        |
| C1004             | 1983 | Pond         | Levallois flake              | FP Lava             | 86.3         | 61.1    | 14      | 91.5      |
| C1005             | 1983 | LB           | Handaxe roughout             | FP Lava             | 90.8         | 78      | 29.4    | 254.5     |
| C1023             | 1993 | LB           | Chunk                        | crystal lithic tuff | 54.2         | 63      | 20.5    | 67.4      |
| D No.<br>(81.5)   | 1979 | ??           | Flake                        | FP Lava             | 41.5         | 41.4    | 14.1    | 22        |
| D No.<br>(83.107) | 1980 | ??           | Flake fragment               | Fine Sandstone      | 43           | 32      | 12.7    | 14.6      |
| D5/1              | 1979 | Modern tip   | Single straight side scraper | Crystal tuff        | 92.6         | 55.3    | 15.7    | 95.3      |
| D5/2              | 1979 | Modern tip   | Flake                        | Fine Silicic Tuff   | 88.5         | 54.1    | 17.5    | 76.2      |
| D5/3              | 1979 | Modern tip   | Discoidal core               | Ignimbrite          | 86.7         | 87.3    | 27.5    | 205.5     |
| D5/4              | 1979 | Modern tip   | Discoidal core               | Dacite              | 103.7        | 83.4    | 44.2    | 403.1     |
| D9                | 1979 | LB           | Single convex side scraper   | Fine Silicic Tuff   | being drawn  |         |         |           |
| D21               | 1979 | LB           | Flake                        | Rhyolite            | 51.1         | 68.5    | 11.7    | 34.9      |
| D107              | 1979 | LB           | Flake                        | Fine Silicic Tuff   | 33.8         | 30.8    | 9.6     | 8.9       |
| D120              | 1979 | LB           | Levallois flake              | FP Lava             | 58.2         | 43.5    | 13.6    | 44.1      |
| D143              | 1979 | Unstratified | Naturally backed knife       | Fine Silicic Tuff   | 71           | 40      | 18.3    | 62.5      |
| D155              | 1979 | UB           | Levallois flake              | Crystal tuff        | 77.9         | 38.3    | 12.3    | 42.4      |
| D160              | 1979 | UB           | Flake (chipped thru. pat.)   | Fine Silicic Tuff   | 47.1         | 39      | 10.5    | 23.4      |
| D165              | 1979 | UB           | Flake                        | Basalt              | 77.1         | 66.5    | 22.2    | 96.6      |
| D169              | 1979 | UB           | Flake                        | FP Lava             | 58           | 35.7    | 10      | 26.3      |
| D170              | 1979 | UB           | Discoidal core               | FP Lava             | 56.6         | 56.8    | 16.9    | 71.3      |
| D172              | 1979 | UB           | Flake                        | Ignimbrite          | 59.7         | 30.7    | 12.1    | 22.3      |
| D184              | 1979 | UB           | Flake fragment               | Rhyolite            | 26.8         | 36.8    | 9.8     | 8.9       |
| D199              | 1979 | LB           | Retouched flake              | Flint               | 42.4         | 38.8    | 16      | 20.1      |
| D215              | 1979 | Cleaning     | Flake fragment               | Ignimbrite          | 58.3         | 41.7    | 13      | 30.5      |
| D231              | 1979 | LB           | Retouched flake              | Flint               | 37.4         | 29.8    | 16.4    | 16.6      |
| D233              | 1979 | LB           | Spall                        | Flint               | 9            | 9.5     | 6.2     | 0.4       |
| D257              | 1980 | LB           | Flake cleaver                | Rhyolitic Lava      | 69.2         | 109.3   | 33      | 284.7     |
| D262              | 1980 | Modern dump  | Flake                        | FP Lava             | 39.7         | 46.5    | 11.6    | 23.3      |
| D279              | 1980 | UCS/UB       | Flake                        | Rhyolite lava       | 62.8         | 47      | 11.9    | 32.3      |
| D295              | 1980 | UB           | Crude core                   | Crystal Pumice Tuff | 111.7        | 89.5    | 42.3    | 430.5     |
| D298              | 1980 | UB/LB        | Flake                        | Crystal Lithic Tuff | 28.3         | 27.5    | 8.7     | 7.6       |
| D305              | 1980 | UB           | Flake fragment               | Rhyolitic Tuff      | 29.5         | 41.2    | 13      | 18.1      |
| D306              | 1980 | UB           | Levallois core               | Rhyolitic Tuff      | 57.9         | 62.8    | 31.5    | 125.1     |
| D309              | 1980 | LB           | Levallois flake fragment     | Fine Silicic Tuff   | 40.5         | 43.6    | 11.3    | 24.4      |
| D326              | 1980 | Unstratified | Discoidal core               | Ignimbrite          | 55.9         | 41.8    | 14.9    | 42.3      |
| D330              | 1980 | LB           | Flake                        | Flint               | 13.6         | 26.3    | 14      | 4.3       |
| D337              | 1980 | LB2          | Denticulate                  | Ignimbrite          | 103.3        | 66.1    | 20.4    | 141.4     |
| D349              | 1980 | LB2          | Flake                        | Ignimbrite          | 83.2         | 63.8    | 15.1    | 85.4      |
| D366              | 1980 | LB2          | Naturally backed knife       | FP Lava             | 46.2         | 27      | 16      | 19.3      |
| D374              | 1980 | LB2          | Flake                        | FP Lava             | 39.5         | 36.8    | 6.2     | 12.4      |
| D384              | 1980 | LB           | Flake fragment               | FP Lava             | 93.9         | 79.9    | 26.7    | 190.7     |
| D400              | 1980 | LB           | Flake                        | FP Lava             | 51.2         | 85.2    | 22.9    | 95.4      |
| D402              | 1980 | LB           | Levallois core               | FP Lava             | 82.7         | 58.1    | 38.2    | 188.8     |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer        | Type Name                                  | Raw Material        | Measurements |         |         |           |
|----------|------|--------------|--|---------------------|--------------|---------|---------|-----------|
|          |      |              |  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D453     | 1980 | UB           | Flake                                      | Rhyolite            | 90.4         | 76.3    | 22.6    | 200.3     |
| D456     | 1980 | UB           | Flake fragment                             | Fine Silicic Tuff   | 45.9         | 21.5    | 9.6     | 10.7      |
| D481     | 1980 | LB2          | Handaxe                                    | Ignimbrite          | 95.7         | 84.6    | 32.5    | 238.6     |
| D502     | 1980 | LB2          | Flake                                      | Fine Silicic Tuff   | 47.8         | 44.4    | 9.4     | 16.4      |
| D517     | 1980 |              | Natural                                    | Flint               | n/a          | n/a     | n/a     | 3.4       |
| D540     | 1980 | LB           | Handaxe fragment                           | FP Lava             | 61.9         | 68.7    | 38      | 160.1     |
| D601     | 1980 | UB/LB        | Handaxe                                    | Rhyolite            | being drawn  |         |         |           |
| D609     | 1980 | Breccia B    | Flake                                      | Fine Silicic Tuff   | 37.9         | 23.8    | 19.3    | 11.8      |
| D617     | 1980 | LB           | Natural chunk                              | Flint               | n/a          | n/a     | n/a     | 103.2     |
| D620     | 1980 | BI/OI        | Natural pebble                             | Mudstone            | n/a          | n/a     | n/a     | 24.4      |
| D632     | 1980 | LBI          | Handaxe trimmer flake                      | Fine Silicic Tuff   | 33.7         | 23.8    | 7.1     | 5.4       |
| D633     | 1980 | LBI          | Crude core                                 | Siliceous Sandstone | 90           | 72      | 46.3    | 289       |
| D639     | 1980 | LBI          | Handaxe                                    | FP Lava             |              |         |         |           |
| D647     | 1980 | LBI          | Levallois point                            | Feldspar Porphyry   | 74.9         | 64.3    | 17      | 71.5      |
| D649     | 1980 | LBI          | Flake fragment                             | Rhyolite            | 56.3         | 54.8    | 22.5    | 73.5      |
| D655     | 1980 | LBII         | Flake                                      | Silicic Tuff        | 53.8         | 38      | 10.5    | 21.9      |
| D664     | 1980 | LBII         | Flake                                      | FP Lava             | 34.6         | 46.1    | 9.8     | 14.9      |
| D683     | 1980 |              | Natural chunk                              | Flint               | n/a          | n/a     | n/a     | 30.1      |
| D687     | 1980 | BI           | Discoidal core                             | Flint               | 41.7         | 34      | 21      | 29.6      |
| D702     | 1980 | LBI          | Natural chunk                              | Fine silicic Tuff   | n/a          | n/a     | n/a     | 20        |
| D710     | 1981 |              | Natural chunk                              | Flint               | n/a          | n/a     | n/a     | 2.3       |
| D714     | 1981 | LB           | Handaxe                                    | Sandstone           | 104.5        | 73.3    | 42.2    | 291.1     |
| D728a    | 1981 | LB           | Chip                                       | FP Lava             | 14.4         | 23.7    | 8.4     | 2.2       |
| D749     | 1981 | LB           | Flake fragment                             | Brecciated rhyolite | 15.1         | 26.4    | 9       | 3.5       |
| D767     | 1981 | LB           | Natural pebble                             | Mudstone            | n/a          | n/a     | n/a     | 8         |
| D775     | 1981 | LB           | Spall                                      | Flint               | 4.5          | 4.6     | 2.2     | <0.1      |
| D781     | 1981 | Intermediate | Natural chunk                              | Siltstone           | n/a          | n/a     | n/a     | 21.1      |
| D800     | 1981 | LB           | Levallois flake (with silet fracture)      | Crystal Tuff        | 74.6         | 49.6    | 12.8    | 68.7      |
| D807     | 1981 | LB           | Natural pebble (burnt)                     | Brecciated rhyolite | n/a          | n/a     | n/a     | 6.4       |
| D830     | 1981 | LB           | Mousterian point on handaxe trimming flake | Fine Silicic Tuff   |              |         |         |           |
| D836     | 1981 | LB           | Flake                                      | Ignimbrite          | 32.2         | 34.3    | 8.7     | 10.1      |
| D862     | 1981 | UB           | Flake                                      | FP Lava             | 59.2         | 34      | 7.7     | 18.3      |
| D867     | 1981 | BI           | Chip                                       | Micaceous Sandstone | 9.5          | 10.3    | 3.1     | 0.3       |
| D873     | 1981 | UB           | Discoidal core                             | Rhyolite            | 67.2         | 56.7    | 22      | 81.9      |
| D874     | 1981 | Unstratified | Retouched flake                            | FP Lava             | 48.4         | 55.8    | 10      | 24.3      |
| D880     | 1981 | UB           | Flake fragment                             | Crystal Tuff        | 32           | 31.5    | 8.4     | 7.2       |
| D921     | 1981 | LB           | Flake                                      | FP Lava             | 73           | 38.3    | 30      | 75.2      |
| D922     | 1981 | UB/Pond      | Flake                                      | FP Lava             | 47.6         | 24.9    | 11.6    | 11.9      |
| D927     | 1981 | UB/Pond      | Natural chunk                              | Flint               | n/a          | n/a     | n/a     | 3         |
| D929     | 1981 | LB           | Crude core                                 | Ignimbrite          | 108          | 80.9    | 40.7    | 293.5     |
| D930     | 1981 | LB           | Handaxe                                    | Fine Silicic Tuff   | 60           | 45.8    | 23      | 62.5      |
| D931     | 1981 | LB           | Handaxe                                    | FP Lava             | 79.5         | 66.9    | 43.8    | 207.3     |
| D934     | 1981 | LB           | Flake fragment                             | Silicic Tuff        | 29.8         | 39      | 9.5     | 11.2      |
| D965     | 1982 | UB           | Flake fragment                             | Rhyolite            | 43.8         | 25      | 12      | 12.6      |
| D995     | 1982 | UB           | Flake fragment                             | Fine Silicic Tuff   | 41           | 26.1    | 9.4     | 12.1      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer      | Type Name                        | Raw Material        | Measurements |         |         |           |
|----------|------|------------|----------------------------------|---------------------|--------------|---------|---------|-----------|
|          |      |            |                                  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D1049    | 1982 | UB         | Crude core                       | Vein Quartz         | 74.1         | 80.7    | 35.7    | 270.2     |
| D1088    | 1982 | UB/LB      | Chopping tool                    | Ignimbrite          | 74.2         | 89.6    | 47.7    | 384.9     |
| D1117    | 1982 |            | natural                          | sandstone           | n/a          | n/a     | n/a     | 9.2       |
| D1123    | 1982 | UB/Trample | Flake                            | Rhyolitic Tuff      | 58.1         | 48.9    | 24.2    | 69.6      |
| D1181    | 1982 | LB         | Crude core                       | Carboniferous Chert | 88.8         | 61.2    | 42.7    | 210.7     |
| D1244    | 1982 | UB/Trample | Spall                            | Flint               | 11.4         | 12.8    | 3.2     | 0.5       |
| D1255    | 1982 | UB/Pond    | Flake fragment                   | Rhyolite            | 14.1         | 21.3    | 4.5     | 1.7       |
| D1255    | 1982 | UB/Pond    | Flake fragment                   | Rhyolite            | 13           | 24      | 6.6     | 2.3       |
| D1283    | 1982 | UB         | Flake fragment                   | Crystal Lithic Tuff | 48.8         | 46.3    | 11.5    | 27.4      |
| D1321    | 1982 | LB         | Flake fragment                   | Rhyolite            | 19.1         | 26.8    | 9.8     | 5         |
| D1326    | 1982 | UB/Pond    | Convex side scraper              | Ignimbrite          | 67           | 61      | 19.5    | 83.4      |
| D1336    | 1982 | Pond/UB    | Flake                            | Rhyolitic Tuff      | 43.9         | 32      | 14.1    | 19.7      |
| D1416    | 1982 | LB         | Retouched Flake                  | Rhyolite            | 70.7         | 60      | 19.6    | 66.8      |
| D1440    | 1982 | UB/Pond    | Discooidal core                  | Andesite            | 90.5         | 82      | 34      | 297.3     |
| D1451    | 1982 | LB         | Flake fragment                   | Fine Silicic Tuff   | 34           | 18.8    | 6.8     | 4         |
| D1453    | 1982 | LB         | Discooidal core                  | Rhyolitic Tuff      | 92.9         | 68.9    | 44      | 263.6     |
| D1465    | 1982 | LB         | Levallois flake fragment         | Dacite Lava         | 68.6         | 65.4    | 12.8    | 69.5      |
| D1477    | 1982 | UB         | Flake                            | Rhyolite            |              |         |         |           |
| D1480    | 1982 | Pond       | Flake                            | Ignimbrite          | 59.3         | 57.7    | 15.2    | 54.7      |
| D1480    | 1982 | Pond       | Flake                            | Ignimbrite          | 51           | 52      | 8.7     | 27.2      |
| D1496    | 1982 | LB         | Levallois flake                  | Rhyolitic Lava      | 95.6         | 58.2    | 12      | 66.6      |
| D1510    | 1982 | LB         | Crude core                       | Carboniferous Chert | 83.9         | 49.2    | 40.3    | 153.5     |
| D1526    | 1982 | LB         | Retouched flake                  | Ignimbrite          | 81.1         | 47      | 14.3    | 43.5      |
| D1527    | 1982 | LB/Pond    | Chunk                            | Ignimbrite          | 56.2         | 30.7    | 29.1    | 47.7      |
| D1541    | 1982 | LB         | Flake fragment                   | Ignimbrite          | 32.5         | 29.8    | 9       | 8.9       |
| D1548    | 1982 | LB         | Flake                            | Ignimbrite          | 33.7         | 31      | 9       | 10.8      |
| D1553    | 1982 | LB         | Crude core                       | Ignimbrite          | 56.6         | 59      | 32.5    | 97.7      |
| D1564    | 1982 | LB         | Handaxe roughout                 | Fine Silicic Tuff   | 139.2        | 96.6    | 31.2    | 443.7     |
| D1598    | 1982 | LB         | Convex side scraper              | Ignimbrite          |              |         |         |           |
| D1615    | 1982 | LB         | Flake fragment                   | Rhyolite?           | 45.6         | 44.4    | 9       | 21.3      |
| D1643    | 1982 | UB/Pond    | Retouched piece                  | FP Lava             | 74.2         | 107.4   | 30.5    | 184.6     |
| D1671    | 1982 | LB         | Levallois flake                  | Rhyolite            |              |         |         |           |
| D1712    | 1982 | LB         | Flake fragment with ventral ret. | Rhyolitic Tuff      | 81.7         | 50.7    | 21.4    | 102       |
| D1853    | 1982 | BI         | Chunk flake or natural           | Rhyolite            | n/a          | n/a     | n/a     | 45.4      |
| D1882    | 1982 | LB         | Flake                            | Fine Silicic Tuff   | 39.5         | 37.8    | 13.6    | 18        |
| D1886    | 1982 | Pond/LB    | Chunk flake or natural           | Unknown             | 54.8         | 38.9    | 17.5    | 28.3      |
| D1934    | 1982 | LB         | Flake                            | Siltstone           | 82.9         | 32.1    | 13.9    | 47.9      |
| D1935    | 1982 | LB         | Flake                            | Rhyolitic Lava      | 54           | 60.5    | 9       | 21.3      |
| D1938    | 1982 | LB         | Naturally backed knife           | Rhyolitic Tuff      | 56.3         | 26.5    | 11      | 17.6      |
| D2076    | 1983 | LB         | Flake                            | Rhyolitic Tuff      | 65.4         | 54.6    | 14.8    | 42        |
| D2079    | 1983 | LB         | Handaxe fragment                 | Rhyolitic Tuff      | 62.9         | 50.2    | 18.5    | 60.8      |
| D2080    | 1983 | LB         | Flake                            | Flint               | 32.1         | 23      | 9.5     | 6.2       |
| D2114    | 1983 | LB         | Flake                            | Dacite              | 63.3         | 48      | 15.7    | 52.6      |
| D2168    | 1983 | LB         | Retouched flake                  | Rhyolitic Tuff      | 62.5         | 28.8    | 10.1    | 23.1      |
| D2175    | 1983 | LB         | Handaxe                          | Rhyolitic Lava      | 121.2        | 68.3    | 40.3    | 296.3     |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer       | Type Name                          | Raw Material        | Measurements |         |         |           |
|----------|------|-------------|------------------------------------|---------------------|--------------|---------|---------|-----------|
|          |      |             |                                    |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D2182    | 1983 | LB          | Flake                              | Ignimbrite          | 50.2         | 42.7    | 9.5     | 19.1      |
| D2189    | 1983 | LB          | Chunk                              | Sandstone/Siltstone | 77.4         | 54.1    | 19.5    | 87.1      |
| D2243    | 1983 | LB          | Flake fragment                     | Rhyolite            | 76.5         | 92.2    | 25      | 138.9     |
| D2339    | 1983 | LB          | Retouched flake                    | Fine Sandstone      | 39.3         | 30.6    | 8.9     | 11.7      |
| D2423    | 1983 | LB          | Discoidal core                     | Sandstone           | 94.5         | 65      | 44.7    | 260.3     |
| D2424    | 1983 | LB          | Discoidal core (on flake)          | Ignimbrite          | 85.1         | 68.3    | 31.5    | 198.5     |
| D2425    | 1983 | UB          | Levallois flake                    | Rhyolite            | 71.3         | 66.1    | 18.9    | 99.3      |
| D2426    | 1983 | UB          | Flake fragment                     | Ignimbrite          | 47           | 51.1    | 18.8    | 40.3      |
| D2476    | 1983 | LB          | Handaxe                            | Vitric Tuff         | 76           | 57.8    | 34.8    | 169.8     |
| D2480    | 1983 | LB          | Flake fragment                     | Ignimbrite          | 50.5         | 44.1    | 22      | 49        |
| D2504    | 1983 | LB          | Flake fragment                     | Flint               | 25.9         | 16.8    | 5.9     | 1.7       |
| D2536    | 1983 | LB          | Crude handaxe                      | Rhyolitic Tuff      | 90.9         | 70.9    | 28.6    | 194.8     |
| D2561    | 1983 | Pond/LB     | Retouched flake fragment           | Fine Silicic Tuff   | 19.9         | 15      | 5.1     | 1.9       |
| D2571    | 1983 | Pond/LB     | End scraper on Lev. flake          | Rhyolitic Tuff      | 70           | 54.7    | 15.7    | 69.7      |
| D2579    | 1983 | LB          | Flake                              | Flint               | 22.1         | 12.5    | 5.9     | 1.1       |
| D2583    | 1983 | LB          | Spall                              | Flint               | 11.3         | 6.9     | 4.2     | 0.2       |
| D2598    | 1983 | LB          | Handaxe trimming flake             | Ignimbrite          | 39.5         | 55.5    | 12.6    | 31.4      |
| D2657    | 1983 | LB/Pond     | Flake                              | Carboniferous Chert | 37.8         | 22      | 8       | 7.8       |
| D2698    | 1983 | LB          | Discoidal core                     | FP Lava             | 75.3         | 58.1    | 28      | 136.1     |
| D2737    | 1983 | LB          | Levallois flake                    | Flint               | 32.1         | 17.1    | 9.4     | 4.8       |
| D2759    | 1983 | LB          | Retouched flake                    | Rhyolitic Tuff      | 62.7         | 47.8    | 13.5    | 44.8      |
| D2967    | 1984 | LB          | Flake fragment                     | Ignimbrite          | 34.4         | 25.1    | 9.3     | 9.5       |
| D2970    | 1984 | UB          | Flake                              | Sandstone           | 68.1         | 48.3    | 21.8    | 69.2      |
| D2971    | 1984 | Pond        | Handaxe (on flake)                 | FP Lava             | 89.5         | 63.7    | 21.1    | 141.1     |
| D2974    | 1984 | LB          | Double convex scraper (alter-nate) | Siltstone           | 68.5         | 60.3    | 20.7    | 103.9     |
| D3025    | 1984 | LB          | Flake fragment                     | Ignimbrite          | 41.2         | 41      | 9.4     | 16.9      |
| D3227    | 1984 | LB/BI       | Spall                              | Flint               |              |         |         |           |
| D3287    | 1984 |             | Spall                              | Flint               | 6.7          | 5.2     | 0.7     | <0.1      |
| D3434    | 1984 | Pond/LB     | Single stright side scraper        | Dacite Lava         | 60.3         | 38.8    | 17      | 33.2      |
| D3464    | 1984 | LBd         | Flake fragment                     | Rhyolite            | 27.5         | 26.4    | 5.1     | 3.8       |
| D3516    | 1984 | LB          | Flake fragment                     | Ignimbrite          | 49.3         | 40.8    | 8.2     | 14        |
| D3521    | 1984 | LB          | Side scraper with a thinned back   | Rhyolitic Lava      | 87.2         | 57      | 20.2    | 106.3     |
| D3547    | 1984 | LB          | Flake fragment                     | Rhyolitic Tuff      | 82.1         | 54.1    | 15      | 64        |
| D3583    | 1984 | LB          | Flake fragment                     | Crystal Tuff        | 36.5         | 33.1    | 9.2     | 10.3      |
| D3596    | 1984 | UB/Pond     | Retouched Flake                    | Fine Silicic Tuff   | 58.3         | 52.8    | 11.2    | 36.7      |
| D3613    | 1984 | UB/Pond     | Flake                              | Rhyolitic Tuff      | 75.9         | 109     | 25.5    | 250.3     |
| D3666    | 1984 | LB          | Flake                              | Tuff                | 144.5        | 138     | 29.5    | 549.9     |
| D3667    | 1984 | LB          | Natural                            | Tuff                | n/a          | n/a     | n/a     | 272.4     |
| D3722    | 1984 | LB/Pond mix | Single straight side scraper       | Carboniferous Chert | 60.7         | 54.2    | 16.2    | 47.9      |
| D3749    | 1984 | LBc         | Flake/chip                         | Fine Sandstone      | 10.7         | 7.5     | 2.5     | 0.2       |
| D3750    | 1984 | LBc         | Flake                              | Fine Silicic Tuff   | 44.3         | 41.8    | 9.4     | 14.1      |
| D3818    | 1984 | LB          | Handaxe                            | Tuff                |              |         |         |           |
| D3862    | 1985 | LB          | Flake                              | Rhyolitic Tuff      | 66.3         | 57.2    | 16.1    | 61.9      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer       | Type Name  | Raw Material                  | Measurements |         |         |           |
|----------|------|-------------|--|-------------------------------|--------------|---------|---------|-----------|
|          |      |             |  |                               | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D3866    | 1985 | LB          | Bifacially retouched flake                                 | Tuff                          | 95.3         | 51      | 19.4    | 108.9     |
| D3944    | 1985 | BI          | Flake fragment   | Carboniferous Chert           | 40.6         | 21.6    | 16      | 14.8      |
| D3948    | 1985 | BI          | Flake  | Flint                         | 16.6         | 9.4     | 6.3     | 1         |
| D3987    | 1985 | UB          | Flake  | FP Lava                       | 57.6         | 38.2    | 13.7    | 31.7      |
| D3993    | 1987 | UB          | Natural  | Limestone                     | n/a          | n/a     | n/a     | 10.4      |
| D4271    | 1987 | UB          | Natural  | Limestone                     | n/a          | n/a     | n/a     | 21.1      |
| D4322    | 1987 | UB/sbm      | Flake  | Tuff                          | 67.1         | 42.1    | 13.8    | 31        |
| D4335    | 1987 | LB          | Convex transverse side scraper (bif. ret.)                 | Crystal tuff                  |              |         |         |           |
| D4346    | 1987 | UB/sbm      | Flake fragment   | Microdiorite                  | 45           | 28.7    | 7.3     | 11.4      |
| D4355    | 1987 | UB/sbm      | Flake  | flow banded rhyolite          | 42.6         | 56.5    | 13.9    | 34        |
| D4360    | 1987 | LB          | Handaxe  | Ignimbrite                    | 56.7         | 40.6    | 14.6    | 41        |
| D4383    | 1987 | UB          | Core fragment  | Crystal pumice tuff           | 51.8         | 34.7    | 13.9    | 23.2      |
| D4397    | 1987 | LB          | Natural  | Sandstone                     | n/a          | n/a     | n/a     | 231.4     |
| D4404    | 1987 | LB          | Notch  | Silicic tuff                  | 55.9         | 53.4    | 11.7    | 27        |
| D4425    | 1987 | LB          | Levallois blade  | Silicic crystal tuff          | 45.2         | 23.8    | 8.1     | 9.1       |
| D4434    | 1987 | LB          | Levallois flake  | Fine silicic tuff             | 61.6         | 45.1    | 10      | 26.6      |
| D4441    | 1987 | LB          | Levallois flake retouched, thru pat to single side scraper | crystal tuff                  | 73           | 57      | 15.8    | 72.8      |
| D4445    | 1987 | LB          | Handaxe  | Rhyolitic tuff                | 80.8         | 62.7    | 37.7    | 202.1     |
| D4455    | 1987 | LB          | Cobble frag  | Sandstone                     | 133.5        | 97.2    | 43.5    | 665.9     |
| D4459    | 1987 | LB          | Handaxe  | Silicic tuff                  | 104          | 86      | 28      | 231.7     |
| D4462    | 1987 | LB          | Levallois flake  | crystal tuff                  | 51.4         | 62.7    | 14.5    | 42.4      |
| D4470    | 1987 | LB          | Flake  | Rhyolite lava                 | 108.7        | 94      | 23.1    | 223.9     |
| D4490    | 1987 | UB/sb       | Retouch on ventral face                                    | Flow banded rhyolite          | 58           | 72.5    | 32.4    | 119.1     |
| D4505    | 1987 | UB/sbm      | Chunk  | Fine silicic tuff             | 38.5         | 20.4    | 13.7    | 7         |
| D45150   | 1985 | UB          | Flake  | Rhyolite                      | 46.5         | 27.6    | 10.5    | 15.6      |
| D45160   | 1985 | UCS         | Flake  | Rhyolite                      | 93.6         | 60.5    | 22.6    | 113.1     |
| D45230   | 1985 |             | Natural  | slightly silicified limestone | n/a          | n/a     | n/a     | 70.3      |
| D45310   | 1985 | UB          | Retouched flake  | Ignimbrite                    | 58.5         | 61.3    | 20.6    | 80.3      |
| D4551    | 1987 | LB          | Core fragment  | Flint                         | 28.9         | 25.8    | 16.8    | 8.7       |
| D45650   | 1985 | UB          | Flake fragment   | Fine Silicic Tuff             | 18           | 36.8    | 8       | 5.9       |
| D45670   | 1985 | UB          | Flake  | Fine Silicic Tuff             | 50.5         | 54.8    | 11.7    | 33.7      |
| D45690   | 1985 | UB          | Discoidal core   | Sandstone                     | 57.3         | 58.4    | 22      | 82.6      |
| D45720   | 1985 | UB          | Retouched flake  | Rhyolite                      | 112          | 78.3    | 26.9    | 295.9     |
| D45790   | 1985 | UB          | Flake  | Andesite                      | 58.2         | 34.2    | 10.1    | 21.6      |
| D4583    | 1987 | UB/sb       | Chunk  | Silicic tuff                  | 50.5         | 67.6    | 24.2    | 89.5      |
| D46020   | 1985 | UB/Red clay | Flake fragment   | Ignimbrite                    | 50.6         | 36.2    | 10.2    | 17.3      |
| D46210   | 1985 | LB          | Flake  | Ignimbrite                    | 33.8         | 36.4    | 11.2    | 15.7      |
| D4623    | 1987 | LB          | Handaxe  | Silicic tuff                  | 56.7         | 46.3    | 18.6    | 52.8      |
| D46370   | 1985 | UB          | Crude core   | Tuff                          | 58.5         | 46.9    | 30.8    | 75.4      |
| D46460   | 1985 | UB          | Natural  | Flint                         | n/a          | n/a     | n/a     | 15.3      |
| D46620   | 1985 |             | Natural  | Flint                         | n/a          | n/a     | n/a     | 3.6       |
| D4708    | 1987 | OI          | Flake (probably handaxe trimmer)                           | Crystal lithic tuff           | 41.6         | 61      | 14.2    | 37.1      |
| D4726    | 1987 | UB/sb       | Flake  | Ignimbrite                    | 47.6         | 61      | 26      | 83.3      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer       | Type Name              | Raw Material                       | Measurements |         |         |           |
|----------|------|-------------|------------------------|------------------------------------|--------------|---------|---------|-----------|
|          |      |             |                        |                                    | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D4740    | 1988 | LB          | Chip                   | Flint                              | 7.8          | 9       | 2.6     | 0.2       |
| D4743    | 1988 | LB          | Levallois flake frag   | Crystal tuff                       | 45.8         | 50.7    | 11      | 25.9      |
| D4755    | 1988 | LB          | Flake                  | Chert?                             | 68.3         | 44      | 18.8    | 44.6      |
| D4777    | 1988 | LB/Red clay | Handaxe                | Rhyolitic tuff                     | 108.1        | 72      | 37.7    | 266.4     |
| D4783    | 1988 | LB          | Flake                  | Rhyolite                           | 66.7         | 49.4    | 18.8    | 59.3      |
| D4785    | 1988 | LB          | Handaxe                | Crystal lithic tuff                | 120.6        | 85.4    | 63.6    | 861.2     |
| D4786    | 1988 | LB          | Handaxe                | Fine tuff                          | 147.2        | 101.5   | 44.1    | 715.3     |
| D4805    | 1988 | LB          | Levallois flake        | Rhyolite                           | 61.5         | 50.8    | 20.2    | 60.5      |
| D4808    | 1988 | LB          | flake frag             | Silicic crystal tuff               | 37.7         | 39      | 10.4    | 11.8      |
| D4811    | 1988 | LB          | Core (indet.)          | Quartz                             | 57.8         | 53      | 34.8    | 88.3      |
| D4857    | 1988 | LB-Pond M   | Natural                | Quartzite                          | n/a          | n/a     | n/a     | 44.8      |
| D4871    | 1988 | LB          | Handaxe                | FP lava                            | 147.6        | 96.2    | 43.1    | 820.2     |
| D4873    | 1988 | LB-Pond M   | Chunk                  | Flint                              | 31.1         | 26.2    | 19.1    | 11.2      |
| D4875    | 1988 | LB          | Flake                  | Crystal lithic tuff                | 74.7         | 49.1    | 16.5    | 57.4      |
| D4902    | 1988 | LB          | Flake frag             | Flow banded rhyolite               | 55.9         | 59      | 17.1    | 64.2      |
| D4904    | 1988 | LB          | Flake frag             | Flint                              | 21.1         | 21      | 14.3    | 4.6       |
| D4911    | 1988 | LB          | Core                   | FP lava                            | 119.7        | 74.6    | 68.3    | 778.8     |
| D4914    | 1988 | LB          | Split cobble ( ? core) | Quartz                             | 153          | 78      | 61.5    | 1208.4    |
| D4915    | 1988 | LB          | Flake                  | Crystal lithic tuff                | 64.4         | 75.3    | 27.7    | 139.4     |
| D4936    | 1988 | LB          | Flake frag.            | Ignimbrite                         | 27.7         | 32.3    | 10.9    | 9.1       |
| D4938    | 1988 | LB-Pond M   | Handaxe                | FP lava                            | 98.8         | 56.7    | 31      | 194.7     |
| D4940    | 1988 | LB-Pond M   | Natural                | Limestone                          | n/a          | n/a     | n/a     | 8.1       |
| D4950    | 1988 | LB-Pond M   | Flake frag             | Rhyolitic tuff                     | 60           | 53.4    | 18.6    | 52.9      |
| D4959    | 1988 | LB          | Handaxe                | Silicic tuff                       | 106.3        | 83.6    | 27.7    | 231.6     |
| D4990    | 1988 | LB          | Flake frag             | Silicic tuff                       | 39.7         | 54.2    | 16.2    | 29.5      |
| D5035    | 1988 | Basal LB    | Natural                | Flint                              | n/a          | n/a     | n/a     | 4         |
| D5053    | 1988 | Basal LB    | Flake fragment         | Flint                              | 16.2         | 21.1    | 7.7     | 1.8       |
| D5306    | 1989 | UB/Pond     | Flake fragment         | Flint                              | 10.2         | 9.1     | 4.7     | 0.3       |
| D5311    | 1989 | UB-Pond M   | Retouched flake        | Silicic tuff                       | 70.3         | 84.1    | 13.1    | 81.5      |
| D5346    | 1989 | LB          | Disc core              | Rhyolite                           | 67.7         | 51.2    | 23.1    | 72.6      |
| D5406    | 1993 | LB          | Handaxe                | Part ignimbrite, part silicic tuff | 99.2         | 67.9    | 42.3    | 272       |
| D5419    | 1993 | Base sb     | Naturally backed knife | Ignimbrite                         | 100.6        | 59.6    | 23      | 143.9     |
| D5483    | 1993 | BI          | Chunk                  | Sandstone, meta.                   | 26.4         | 15.8    | 11.1    | 6.6       |
| D5486    | 1993 | LB          | Chunk (or natural)     | Flint                              | 6.9          | 6.4     | 6       | 0.2       |
| D5636    | 1994 | LB          | Flake                  | Flint                              | 29.6         | 24.7    | 6.8     | 4         |
| D5715    | 1994 | LB          | Flake?                 | Ignimbrite                         | 46.3         | 36.2    | 10.9    | 18.8      |
| D5791    | 1994 | LB          | Flake                  | Crystal tuff                       | 42.6         | 26.1    | 11.5    | 13        |
| D5808    | 1994 | UB/rm       | Core ? (or natural)    | Quartz                             | 69.6         | 63      | 50.5    | 213.4     |
| D5837    | 1994 | LB          | Globular core          | Rhyolite                           | 115.5        | 102.6   | 80.6    | 823.6     |
| D5855    | 1994 | Top LB      | Handaxe trimming flake | Rhyolite                           | 43.8         | 58.4    | 16.8    | 50.5      |
| D5900    | 1994 | UB/sbm      | Flake fragment         | Silicic tuff                       | 33.6         | 34.6    | 9       | 9.9       |
| D5916    | 1995 | LB          | Chunk                  | Tuff                               | 5.8          | 9       | 4.9     | 0.2       |
| D6060    | 1995 | LBa         | Natural                | Sandstone                          | n/a          | n/a     | n/a     | 571.4     |
| D6064    | 1995 | UB/Pond     | ?Flake                 | Ignimbrite                         | 31.1         | 39.6    | 9.4     | 9.9       |
| D6067    | 1995 | LB/Blm      | Artefact fragment      | Rhyolite lava                      | 11           | 10      | 4.7     | 0.7       |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer        | Type Name                                   | Raw Material             | Measurements |         |         |           |
|----------|------|--------------|---|--------------------------|--------------|---------|---------|-----------|
|          |      |              |   |                          | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| D45000   | 1985 | UB           | Chunk                                       | Flint                    | 33.9         | 30.1    | 22.2    | 17.2      |
| D45010   | 1985 | UB           | Flake                                       | Limestone                | 63.3         | 75      | 18      | 65.4      |
| F1       | 1983 | Unstratified | Flake                                       | Tuff                     | 64.6         | 39      | 26.5    | 69.1      |
| F28      | 1983 | UB           | Core fragment                               | Rhyolite                 | 37.2         | 16.2    | 13.1    | 6.7       |
| F43      | 1983 | UB           | Spall                                       | Flint                    | 8.2          | 11.6    | 6.1     | 0.4       |
| F58      | 1983 | UB           | Core fragment                               | Ignimbrite               | 79.3         | 45.5    | 36.8    | 160.2     |
| F107     | 1983 | UB           | Flake fragment                              | Fine Sandstone           | 40.2         | 14.7    | 11.8    | 6         |
| F143     | 1983 | UB           | Levallois flake                             | FP Lava                  | 42.6         | 31.3    | 7.6     | 15.3      |
| F146     | 1983 | UB           | Flake                                       | FP Lava                  | 35           | 26.6    | 8.3     | 9         |
| F293     | 1983 | UB           | Flake                                       | Crystal lithic tuff      | 67.8         | 34.7    | 20.1    | 48.3      |
| F371     | 1983 | UB           | Flake                                       | Siltstone                | 47.3         | 37.1    | 13.2    | 24        |
| F377     | 1984 | UB           | Retouched flake                             | Ignimbrite               | 79.4         | 63.6    | 25.2    | 122.3     |
| F405     | 1984 | UB           | Handaxe                                     | Carboniferous Chert      | 106.5        | 62.5    | 33.3    | 239.3     |
| F418     | 1984 | UB           | Flake                                       | Sandstone                | 39.7         | 48      | 18.2    | 24.8      |
| F444     | 1985 | UB           | Flake                                       | Siltstone                | 65           | 50.4    | 19.2    | 69.6      |
| F445     | 1985 | UB           | Flake                                       | Tuff                     | 48.8         | 44      | 16.7    | 39.2      |
| F460     | 1985 | UB           | Flake fragment                              | Ignimbrite               | 51           | 47.1    | 17.9    | 49.1      |
| F461     | 1985 | UB           | Flake                                       | FP Lava                  | 24           | 21.1    | 4.4     | 2.7       |
| F475     | 1985 | UB           | Flake                                       | FP Lava                  | 51           | 116.8   | 19.6    | 119.8     |
| F492     | 1985 | UB           | Flake fragment                              | Rhyolitic Lava           | 48           | 45      | 13.7    | 19.7      |
| F528     | 1985 | UB           | Side / ? end scraper                        | FP Lava                  | 47.3         | 46.5    | 17.3    | 40.8      |
| F531     | 1985 | UB           | Flake                                       | Rhyolite                 | 43.7         | 40.2    | 8.3     | 18.3      |
| F532     | 1985 | UB           | Flake                                       | Ignimbrite               | 60.7         | 60.2    | 14.5    | 54.9      |
| F536     | 1985 | UB           | Flake fragment                              | Non-Carboniferous Chert  | 40           | 25.4    | 6.3     | 6.3       |
| F586     | 1985 | UB           | Handaxe fragment                            | Rhyolite                 | 94.3         | 69      | 32.7    | 159.6     |
| F589     | 1985 | UB           | Flake fragment                              | Crystal Lithic Tuff      | 26.4         | 34.2    | 6.9     | 6.5       |
| F605     | 1985 | UB           | Flake                                       | Ignimbrite               | 49           | 96.8    | 16.8    | 89.6      |
| F642     | 1985 |              | Natural                                     | Limestone                | n/a          | n/a     | n/a     | 18.3      |
| F643     | 1985 | UB           | Flake                                       | Fine Silicic Tuff        | 46.7         | 41.1    | 17.8    | 40.1      |
| F658     | 1985 | UB           | Flake                                       | Rhyolitic Tuff           | 24.5         | 31.5    | 8.8     | 6.1       |
| F692     | 1985 | UB           | Flake fragment                              | Fine Silicic Tuff        | 38.3         | 31.5    | 9.6     | 13        |
| F710     | 1985 | UB           | Flake                                       | Tuff                     | 28.2         | 47.3    | 9.4     | 13.6      |
| F741     | 1985 | UB           | Flake                                       | Tuff                     | 48.6         | 27.1    | 12.7    | 20.7      |
| F755     | 1985 | UB           | Flake                                       | Tuff                     | 42.5         | 28.4    | 11.4    | 16.2      |
| F842     | 1985 | UB           | Levallois flake fragment                    | Rhyolitic Tuff           | 55.1         | 42      | 15.1    | 38.1      |
| F843     | 1985 | UB           | Handaxe                                     | FP Lava                  | 75.6         | 52.7    | 26.6    | 131.9     |
| F847     | 1985 | UB           | Flake                                       | Tuff                     | 78.8         | 64      | 16.3    | 92.5      |
| F854     | 1985 | LB           | Flake fragment                              | Sandstone                | 76.1         | 68.1    | 22.4    | 150       |
| F860     | 1985 | LB           | Single convex side scraper<br>on Lev. flake | Sandstone                | 81.7         | 65.3    | 14      | 84.2      |
| F912     | 1985 | LB           | Flake fragment                              | Rhyolitic Tuff           | 66.5         | 64.5    | 18.9    | 73.3      |
| F959     | 1985 | LB           | Handaxe                                     | Re Crystallized Rhyolite | 98.6         | 58.2    | 35.9    | 203.2     |
| F986     | 1985 | UB           | Discoidal core fragment                     | Ignimbrite               | 75.1         | 60.4    | 28      | 106.8     |
| F1991    | 1988 |              | Core fragment                               | Flint                    | 50.9         | 32      | 16      | 18.8      |
| F1103    | 1987 | UB           | flake frag                                  | FP lava                  | 61           | 32.2    | 14.9    | 37.6      |
| F1130    | 1987 | UB           | Flake                                       | FP lava                  | 57.3         | 35.4    | 14.5    | 31.4      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer                                 | Type Name                | Raw Material        | Measurements |         |         |           |
|----------|------|---------------------------------------|--------------------------|---------------------|--------------|---------|---------|-----------|
|          |      |                                       |                          |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| F1132    | 1987 | UB                                    | Flake                    | Rhyolitic tuff      | 39.5         | 48.2    | 18.2    | 30.2      |
| F1194    | 1987 | UB                                    | Flake                    | Crystal tuff        | 47.6         | 43.3    | 13.1    | 29.8      |
| F1230    | 1987 | UB                                    | Disc core                | Crystal tuff        | 70           | 73.5    | 20.9    | 114.2     |
| F1241    | 1987 | UB                                    | Flake (siret)            | FP lava             | 46.7         | 37.2    | 18.1    | 31.8      |
| F1254    | 1987 | UB                                    | Flake fragment           | Fine silicic tuff   | 53.3         | 56.2    | 15.2    | 36.4      |
| F1290    | 1987 | UB                                    | Core fragment            | Flint               | 40.6         | 40.5    | 16      | 24.4      |
| F1314    | 1987 | UB                                    | Levallois flake (broken) | Microdiorite        | 75.2         | 48.1    | 10.3    | 47.8      |
| F1315    | 1987 | UB                                    | Flake fragment           | Fine silicic tuff   | 40           | 43      | 13.3    | 26        |
| F1340    | 1987 | UB                                    | Levallois flake          | Microdiorite        | 91.4         | 56.5    | 14.3    | 71.8      |
| F1352    | 1987 | UB                                    | Flake                    | Rhyolite            | 71.6         | 65.2    | 29      | 122.5     |
| F1356    | 1987 | UB                                    | Flake                    | FP lava             | 77.2         | 65      | 14.1    | 72.8      |
| F1395    | 1987 | UCS                                   | Flake                    | Crystal pumice tuff | 69.5         | 65.7    | 20      | 96.2      |
| F1430    | 1987 | UB                                    | Cobble frag              | Ignimbrite          | 80.4         | 50.8    | 20.3    | 94        |
| F1435    | 1987 | UB                                    | Flake fragment           | FP lava             | 22.4         | 23.5    | 5.4     | 3         |
| F1437    | 1987 | UCS                                   | Flake fragment           | crystal pumice tuff | 41.1         | 58.5    | 18.2    | 42.4      |
| F1439    | 1987 | UB                                    | Flake                    | Ignimbrite          | 48           | 47.6    | 13.4    | 38.2      |
| F1499    | 1987 | UB                                    | Levallois flake          | Rhyolite lava       | 77.2         | 64.6    | 16.2    | 87.6      |
| F1501    | 1987 | UB                                    | Flake fragment           | Ignimbrite          | 46.3         | 59.4    | 13.1    | 27.3      |
| F1529    | 1987 | UB                                    | Chunk                    | Quartzite           | 11.6         | 9.8     | 6.6     | 0.6       |
| F1530    | 1987 | UB                                    | Levallois flake (broken) | Microdiorite        | 54.9         | 61.2    | 13.5    | 52.6      |
| F1611    | 1988 | UB / sbm                              | Flake                    | Crystal tuff        | 69.3         | 44.5    | 14.2    | 52.7      |
| F1644    | 1988 | UB                                    | Flake fragment (siret)   | Ignimbrite          | 100.3        | 33.5    | 17.7    | 59.3      |
| F1654    | 1988 | UB                                    | Flake                    | Rhyolite            | 59.5         | 58.9    | 11.5    | 42.7      |
| F1666    | 1988 | UB / sbm                              | Flake fragment           | Crystal pumice tuff | 53.2         | 44.1    | 8.2     | 24.4      |
| F1699    | 1988 | UB                                    | Flake fragment           | Rhyolite            | 23.9         | 43.9    | 15.3    | 15.1      |
| F1772    | 1988 | UB / sbm                              | Levallois flake          | Microdiorite        | 68.8         | 61.1    | 14.6    | 69.9      |
| F1822    | 1988 | UB / sbm                              | Flake fragment           | Flint               | 30.7         | 17.6    | 7.5     | 3.6       |
| F1825    | 1988 | UB / sbm                              | Handaxe                  | Crystal lithic tuff | 85.1         | 57.1    | 24.5    | 123.2     |
| F1833    | 1988 | UB                                    | Flake                    | FP lava             | 110          | 53.3    | 29      | 179.1     |
| F1836    | 1988 | UB                                    | Flake fragment           | Flint               | 10.6         | 19.9    | 6.2     | 1.3       |
| F1843    | 1988 | UB                                    | Flake fragment           | Sandstone           | 40.5         | 30      | 6.8     | 9.4       |
| F1849    | 1988 | UB                                    | Cobble frag              | Crystal tuff        | 94.8         | 66.6    | 29.5    | 137.3     |
| F1850    | 1988 | UB / sbm                              | Flake                    | Ignimbrite          | 79.6         | 81.1    | 21.1    | 134.3     |
| F1862    | 1988 | UB                                    | Probable core (rolled)   | Fine silicic tuff   | 53.2         | 47.7    | 22.5    | 54.6      |
| F1869    | 1988 | UB                                    | Flake fragment           | Fine silicic tuff   | 58           | 33      | 16.5    | 33.4      |
| F1876    | 1988 | UB / sbm                              | Flake (?levallois)       | Fine silicic tuff   | 65           | 50.6    | 11      | 38.3      |
| F1879    | 1988 | UB / sbm                              | Flake fragment           | Rhyolite lava       | 49.5         | 49.5    | 20.8    | 42.9      |
| F1880    | 1988 | UB / sbm                              | Flake fragment           | Rhyolite lava       | 54.1         | 25      | 13.7    | 18.7      |
| F1884    | 1988 | UB                                    | Natural                  | Limestone           | n/a          | n/a     | n/a     | 126.7     |
| F1908    | 1988 | UB / sbm                              | Flake fragment           | Ignimbrite          | 37.1         | 49.8    | 13.1    | 28.8      |
| F1940    | 1988 | UB /sbm                               | Levallois flake frag     | FP lava             | 57.2         | 37.6    | 9.1     | 25.9      |
| F1949    | 1988 | UB / sbm                              | Natural                  | Limestone           | n/a          | n/a     | n/a     | 32.2      |
| F1957    | 1988 | UB / sbm                              | Flake fragment           | FP lava             | 35.3         | 52.7    | 8.2     | 16.5      |
| F2010    | 1988 | Pond/ instru.<br>sand under<br>Stal A | Flake ( h/a trimmer)     | Crystal lithic tuff |              |         |         |           |
| F2022    | 1988 | UB                                    | Flake                    | Rhyolite lava       | 54           | 88.2    | 21.8    | 88.5      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer    | Type Name  | Raw Material          | Measurements |         |         |           |
|----------|------|----------|--|-----------------------|--------------|---------|---------|-----------|
|          |      |          |  |                       | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| F2042    | 1988 | UB       | Natural  | Limestone             | n/a          | n/a     | n/a     | 54.7      |
| F2077    | 1988 | LB-Clay  | Flake fragment   | Fine silicic tuff     | 21.7         | 25.4    | 6.8     | 4.3       |
| F2112    | 1988 | UB / sbm | Flake fragment   | Rhyolitic tuff        | 71           | 50.8    | 13.2    | 40.3      |
| F2422    | 1989 | UB / sbm | Discoidal core (made on earlier artefact)                | Fine Silicic Tuff     | 60.9         | 49.2    | 25.9    | 89.7      |
| F2486    | 1989 | LB       | Discoidal core   | Fine Silicic Tuff     | 75.5         | 68      | 16.6    | 118.6     |
| F2511    | 1989 | UB / sbm | Artefact fragment  | FP lava               | 11           | 9       | 5.1     | 0.5       |
| F2610    | 1989 | LB       | Flake  | Ignimbrite            | 47           | 39.6    | 11.6    | 25.4      |
| F2640    | 1989 | LB       | Natural  | Flint                 | n/a          | n/a     | n/a     | 1         |
| F2668    | 1989 | LB       | Flake  | Rhyolitic tuff        | 58           | 68.8    | 15      | 53        |
| F2726    | 1989 | LBc      | Natural starch fracture                                  | Flint                 | n/a          | n/a     | n/a     | 28.7      |
| F2733    | 1989 | Pond     | Natural  | Quartzite             | n/a          | n/a     | n/a     | 52.1      |
| F2795    | 1989 | LBc      | ? Hammerstone (cobble with abraded ends)                 | Ignimbrite            | 134.3        | 107.3   | 87.2    | 1768.9    |
| F2796    | 1989 | LB       | Single convex side scraper<br>on Lev. flake (outrepasse) | Fine Silicic Tuff     | 75.5         | 58.7    | 20.1    | 84.7      |
| F2799    | 1989 | LB       | Levallois point  | Crystal tuff          | 52.5         | 55.9    | 15      | 30.2      |
| F2802    | 1989 | LB       | Natural  | Limestone             | n/a          | n/a     | n/a     | 28.5      |
| F2805    | 1989 | LB       | Levallois flake  | Microdiorite          | 52.8         | 46.7    | 12.9    | 40.9      |
| F2840    | 1989 | LBc      | Burnt fragment of pebble                                 | Flint                 | 16.8         | 16.3    | 9       | 2.1       |
| F2860    | 1989 | LBc      | Handaxe  | Ignimbrite            | 77.7         | 61.4    | 32.7    | 147       |
| F2925    | 1989 | LBa      | Handaxe  | flow banded rhyolite  | 95.4         | 68.2    | 38.3    | 251.4     |
| F2928    | 1989 | LBd      | Natural  | Rhyolitic tuff        | n/a          | n/a     | n/a     | >600      |
| F2952    | 1989 | LBa      | Flake  | Microdiorite          | 70.6         | 79.1    | 15.2    | 95.3      |
| F3011    | 1993 | LB       | Chunk  | Flint                 | 11.2         | 7.1     | 6.7     | 0.6       |
| F3025    | 1993 | UB       | Natural  | Sandstone             | n/a          | n/a     | n/a     | 12.8      |
| F3056    | 1993 | UB / sbm | Offset scraper   | Rhyolite lava         | 56.8         | 40.1    | 20.9    | 52.5      |
| F3062    | 1993 | LB / sbm | Flake fragment   | Sandstone, tuffaceous | 24.7         | 19.8    | 4.4     | 2.3       |
| F3096    | 1993 | LB       | Flake fragment (burnt)                                   | Flint                 | 14.5         | 13.4    | 6.2     | 0.9       |
| F3114    | 1993 | LBc      | Chunk  | Flint                 | 10.2         | 8.7     | 6.8     | 0.7       |
| F3133    | 1993 | LBc      | Flake fragment   | Fine silicic tuff     | 49.6         | 64.9    | 24.4    | 75        |
| F3145    | 1993 | LBc      | Flake  | Crystal lithic tuff   | 83.6         | 61.5    | 23.3    | 109.1     |
| F3148    | 1993 | LBc      | flake frag   | Rhyolite              | 63.2         | 50      | 17.7    | 52.6      |
| F3186    | 1993 | LBc      | Natural  | Limestone             | n/a          | n/a     | n/a     | 3.3       |
| F3190    | 1993 | BI       | Natural  | Flint                 | n/a          | n/a     | n/a     | 0.3       |
| F3231    | 1993 | LBc      | Chip   | Chert                 | 7.5          | 6.2     | 4.2     | 0.2       |
| F3263    | 1993 | BI       | Chunk  | Crystal tuff          | 35.8         | 28.5    | 12.9    | 13.2      |
| F3437    | 1993 | BI       | Natural  | Flint                 | n/a          | n/a     | n/a     | 0.6       |
| F3477    | 1993 | LBc      | Flake fragment   | Rhyolite Lava         | 64           | 35.8    | 11      | 30.6      |
| F3484    | 1993 |          | Natural  | Flint                 | n/a          | n/a     | n/a     | 2.2       |
| F3491    | 1993 | BI       | Natural  | Flint                 | n/a          | n/a     | n/a     | 0.4       |
| F3503    | 1993 | LBc      | Chunk  | Flint                 | 11           | 7.8     | 5.1     | 0.3       |
| F4048    | 1993 | BI       | Chip   | Fine silicic tuff     | 9.7          | 5.5     | 3       | 0.1       |
| F4049    | 1993 | BI       | Natural  | Flint                 | n/a          | n/a     | n/a     | 0.6       |
| F4050    | 1993 | LBc      | flake  | Rhyolite lava         | 43.1         | 41      | 13.7    | 24.9      |
| F4054    | 1993 | LBc      | Flake fragment   | Flint                 | 18.6         | 11.1    | 6.6     | 0.8       |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer    | Type Name                | Raw Material        | Measurements |         |         |           |
|----------|------|----------|--------------------------|---------------------|--------------|---------|---------|-----------|
|          |      |          |                          |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| F4058    | 1993 | LBc      | Pebble frag.             | Ignimbrite          | 104.5        | 61.1    | 22.4    | 179       |
| F4060    | 1993 | LBc      | Chunk                    | Fine silicic tuff   | 27.8         | 14.5    | 11.2    | 6.2       |
| F4098    | 1993 | LBc      | Flake frag.              | Fine silicic tuff   | 15.6         | 13.9    | 5.3     | 0.8       |
| F4111    | 1993 | LBc      | Flake fragment           | Fine silicic tuff   | 34.6         | 35      | 6.4     | 9.1       |
| F4112    | 1993 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | 0.4       |
| F4113    | 1993 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | 2.3       |
| F4122    | 1993 | LBc      | Chip                     | Flint               | 7.8          | 7.5     | 5.1     | 0.3       |
| F4132    | 1993 | LBc      | Flake fragment           | Flint               | 3.7          | 8.6     | 4.6     | 0.1       |
| F4134    | 1993 | LBc      | Chunk                    | Flint               | 7.4          | 6.2     | 5.3     | 0.2       |
| F4135    | 1993 | LBc      | Chunk                    | Rhyolite lava       | 7.1          | 8.9     | 4.2     | 0.4       |
| F4142    | 1993 | LBc      | Chunk                    | Flint               | 8.2          | 6       | 4.5     | 0.1       |
| F4146    | 1993 | LBc      | Chip                     | Flint               | 4.8          | 2.6     | 2.3     | <0.1      |
| F4149    | 1993 | UB / sbm | Chunk                    | Fine silicic tuff   | 7.6          | 5.8     | 4.1     | 0.2       |
| F4196    | 1993 | LBc      | Chip                     | Flint               | 8.9          | 3.8     | 3.9     | 0.1       |
| F4199    | 1993 | LBc      | Spall                    | Flint               | 7            | 5.2     | 1.4     | <0.1      |
| F4206    | 1993 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | 1.2       |
| F4208    | 1993 | O bluff  | Chip                     | Flint               | 7.6          | 12.3    | 6.4     | 0.7       |
| F4215    | 1993 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | 0.1       |
| F4248    | 1993 | LBb      | Natural                  | Flint               | n/a          | n/a     | n/a     | 0.8       |
| F4308    | 1993 | LBc      | Chip                     | Flint               | 4.6          | 4.3     | 2.9     | <0.1      |
| F4346    | 1994 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | n/a       |
| F4361    | 1994 | LBc      | Natural                  | Flint               | n/a          | n/a     | n/a     | n/a       |
| F4401    | 1994 | LBc      | Flake                    | Rhyolitic tuff      | 56.8         | 62.8    | 21.6    | 87.9      |
| F4475    | 1994 | LB       | Flake                    | crystal pumice tuff | 56           | 42      | 12.7    | 33.6      |
| F4482    | 1994 | LBc      | Chip                     | Flint               | 9.7          | 5.9     | 4.6     | 0.2       |
| F4490    | 1994 | LB       | Handaxe                  | Ignimbrite          | 143.5        | 81.5    | 36      | 430.7     |
| F4496    | 1994 | LB       | Natural                  | Sandstone           | n/a          | n/a     | n/a     | 15.9      |
| F4519    | 1994 | LB       | Truncated blade          | Fine silicic tuff   | 53           | 29.5    | 11      | 19.3      |
| F4523    | 1994 | LB       | Flake fragment           | Fine silicic tuff   | 13.7         | 9.5     | 4.6     | 0.3       |
| F4534    | 1994 | UB       | Core fragment            | Vitric crystal tuff | 55.1         | 72      | 73.7    | 74.4      |
| F4544    | 1994 | UB       | Handaxe                  | FP lava             | 87.5         | 68.6    | 32.8    | 233.3     |
| F4546    | 1994 | LB       | Pseudo-levallois point   | FP lava             | 25.9         | 29.3    | 6.2     | 4.8       |
| F4573    | 1994 | UB       | Levallois flake (1)      | Rhyolite lava       | 40           | 47      | 11      | 18.3      |
| F4597    | 1994 | LB       | Levallois flake (1)      | Crystal tuff        | 61.8         | 42.7    | 10.5    | 31.6      |
| F4630    | 1994 | LBc      | Chip                     | Flint               | 6            | 6.2     | 2.6     | 0.1       |
| F4652    | 1994 | LB       | Flake                    | Rhyolite lava       | 44.6         | 52.6    | 12.5    | 40.2      |
| F4657    | 1994 | LBc      | Flake fragment           | Fine silicic tuff   | 34.5         | 36.5    | 21      | 21.6      |
| F4690    | 1994 | LBc      | Levallois flake frag (1) | Fine silicic tuff   | 55.2         | 33.5    | 13.5    | 20.5      |
| F4700    | 1994 | UB / sbm | Flake                    | Rhyolite            | 49.2         | 43.4    | 11.7    | 23.1      |
| F4749    | 1994 | LB       | Flake                    | Flint               | 40.9         | 40.2    | 21      | 25.5      |
| F4812    | 1994 | LBb      | Flake fragment           | Flint               | 8.9          | 15.6    | 3.2     | 0.5       |
| F4827    | 1994 | LBc      | Chunk                    | Fine silicic tuff   | 24.1         | 20.5    | 8.2     | 3.8       |
| F4884    | 1994 | LBc      | Natural                  | Sandstone           | n/a          | n/a     | n/a     | 7.3       |
| F4885    | 1994 | LBc      | Natural                  | Sandstone           | n/a          | n/a     | n/a     | 3.7       |
| F4888    | 1994 | LBb      | Unfinished handaxe       | Crystal vitric tuff | 123.7        | 63.4    | 29.1    | 256.4     |
| F4904    | 1994 | LBb      | Natural                  | Unknown             | n/a          | n/a     | n/a     | 2.3       |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer    | Type Name                          | Raw Material             | Measurements |         |         |           |
|----------|------|----------|------------------------------------|--------------------------|--------------|---------|---------|-----------|
|          |      |          |                                    |                          | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| F4907    | 1994 | LBb      | Flake                              | Rhyolite                 | 23.1         | 33.9    | 7.2     | 6.3       |
| F4912    | 1994 | LBb      | Chip                               | Flint                    | 6            | 4.5     | 3.1     | 0.1       |
| F4915    | 1994 | LBc      | Chip                               | Flint                    | 8.7          | 4.7     | 3       |           |
| F4934    | 1994 | LBc      | Flake fragment (?burnt)            | Chert                    | 19.2         | 17.6    | 9.7     | 3         |
| F4949    | 1994 | LBd      | Disc core                          | Volcaniclastic sandstone | 59.6         | 78.7    | 21.8    | 107.6     |
| F4953    | 1994 | LBc      | Core fragment                      | Rhyolitic tuff           | 58.3         | 32.1    | 20.6    | 43.2      |
| F4955    | 1994 | LBb      | Flake fragment                     | Flint                    | n/a          | n/a     | n/a     |           |
| F4955    | 1994 | LBc      | Flake frag.                        | Ignimbrite               | 58           | 45.9    | 10.5    | 31.2      |
| F4978    | 1994 | LBc      | Chip                               | Flint                    | 5.5          | 5.7     | 4       | 0.1       |
| F5003    | 1994 | LBc      | Chip                               | Flint                    | 3.5          | 4.6     | 3.1     | <0.1      |
| F5069    | 1994 | LBc      | Natural                            | Rhyolite lava            | n/a          | n/a     | n/a     | 35.8      |
| F5093    | 1994 | LBb      | Flake/handaxe trimmer              | Rhyolitic tuff           | 67           | 50.9    | 11.1    | 33.7      |
| F5149    | 1994 | LBc      | Chip                               | Flint                    | 8.6          | 6.1     | 3.6     | 0.1       |
| F5188    | 1994 | LBc      | Cobble frag                        | Vitric pumice tuff       | 76.1         | 60.4    | 35      | 191.8     |
| F5191    | 1995 | LBc      | Chip                               | Flint                    | 6.7          | 5.9     | 4.4     | 0.1       |
| F5239    | 1995 | LBc      | Flake fragment                     | Rhyolite lava            | 19           | 5.8     | 4.2     | 2         |
| F5241    | 1995 | UB / sbm | Chip                               | Flint                    | 6.1          | 3.6     | 2.2     | <0.1      |
| F5266    | 1995 | LBc      | Chunk                              | Flint                    | 9.8          | 6.2     | 3.6     | 0.2       |
| F5280    | 1995 |          | Chunk                              | Flint                    | 9.1          | 5.6     | 6.6     | 0.3       |
| F5281    | 1995 | LB / BI  | Chip                               | Flint                    | 6.6          | 5.3     | 6.1     | 0.2       |
| F5292    | 1995 | UB / Red | Flake fragment                     | Rhyolite                 | 20.3         | 17.3    | 4.2     | 1.7       |
| F5303    | 1995 | UB / sbm | Flake fragment                     | Fine silicic tuff        | 34.2         | 58.7    | 15.6    | 42        |
| F5322    | 1995 | LBa      | Chunk                              | fine silicic tuff        | 4.6          | 5       | 2.1     | <0.1      |
| F5433    | 1995 | LBc      | Chunk                              | Fine silicic tuff        | 8.2          | 8.4     | 3.3     | 0.2       |
| F5477    | 1995 | LBc      | Handaxe roughout                   | FP lava                  | 106.5        | 67.1    | 50.6    | 347       |
| F5478    | 1995 | LBc      | Levallois flake                    | Silicic tuff             | 60.5         | 35.9    | 16.5    | 34.1      |
| F5499    | 1995 | LBc      | Core/handaxe roughout              | Flow banded rhyolite     | 90.8         | 58.7    | 24      | 140.5     |
| F5511    | 1995 | LBc      | Flake fragment                     | Flint                    | 9.4          | 7.9     | 2.9     | 0.1       |
| F5544    | 1995 | LBc      | Flake                              | FP lava                  | 89.1         | 65      | 20.5    | 127.7     |
| F5566    | 1995 | LBd      | Flake fragment                     | chert                    | 54.4         | 43.1    | 13.5    | 29.8      |
| F5568    | 1995 | LBc      | hammerstone                        | ignimbrite?              | 99.3         | 57.7    | 45      | 360.5     |
| F5570    | 1995 | LBd      | naturally backed knife             | Sandstone                | 46.1         | 37.7    | 9       | 21        |
| F5598    | 1995 | LBd      | Flake                              | Ignimbrite               | 53.1         | 50      | 14.5    | 36.2      |
| F5657    | 1995 | LBc      | Flake                              | Rhyolitic tuff           | 73           | 63.3    | 20.4    | 84.6      |
| F5680    | 1995 | LB       | Side scraper with bifacial retouch | Rhyolitic tuff           | 74.1         | 52.1    | 26.2    | 100.4     |
| F5699    | 1995 | LBd      | Core fragment                      | Flow banded rhyolite     | 68           | 51.2    | 29.4    | 100.5     |
| F5748    | 1995 | LBb      | Chunk                              | Flint                    | 8.7          | 8.3     | 4.2     | 0.3       |
| F5770    | 1995 | LBc      | Discoidal core frag./handaxe frag. | FP lava                  | 55           | 54.5    | 44.7    | 121.6     |
| F5825    | 1995 | LBc      | Flake (in 3 pieces)                | Rhyolitic tuff           | 80.1         | 60.2    | 3.4     | 62.5      |
| F5826    | 1995 | BI       | refit with F5826                   | Rhyolitic tuff           |              |         |         |           |
| F5870    | 1995 | LBc      | Natural                            | Flint                    | n/a          | n/a     | n/a     | 0.7       |
| F5901    | 1995 | LB/BI m  | Chopping tool                      | Silicic tuff             | 48.8         | 77.8    | 28.5    | 108.6     |
| F5985    | 1995 | LBc      | Chunk                              | FP lava                  | 27.8         | 17.8    | 13.5    | 6         |
| F5989    | 1995 | LBc      | Handaxe                            | Rhyolitic tuff           | 130.5        | 86.3    | 28.8    | 342.8     |
| F6026    | 1995 | LB/OI    | Cobble fragment                    | Crystal lithic tuff      | 87           | 80.4    | 34.8    | 194.2     |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer   | Type Name                                      | Raw Material        | Measurements |         |         |           |
|----------|------|---------|--|---------------------|--------------|---------|---------|-----------|
|          |      |         |  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| F6040    | 1995 | LBc     | Natural  | Crystal tuff        | n/a          | n/a     | n/a     | 6.5       |
| F6067    | 1995 | BI      | Flake fragment                                 | Crystal lithic tuff | 55.4         | 34.6    | 12.9    | 29.4      |
| F6070    | 1995 | LBc     | Flake fragment                                 | FP lava             | 68.5         | 40.7    | 14.2    | 44.5      |
| F6098    | 1995 | LBc     | Flake fragment                                 | Flint               | 8.9          | 5.6     | 3.6     | 0.1       |
| F6098    | 1995 | LBc     | Flake fragment                                 | Flint               | 7.6          | 1.4     | 4.7     | 0.3       |
| F6099    | 1995 | LBc     | Chip   | Flint               | 7.7          | 6.4     | 3.7     | 0.1       |
| F6430    | 1995 | LBc     | Knapped cobble                                 | Ignimbrite          | 130          | 98      | 60.5    | 832.7     |
| F7002    | 1995 | LB/BIIm | Spall  | Flint (black)       | 5.7          | 4.1     | 1.9     | <0.1      |
| F7016    | 1995 | LB/BIIm | Chip   | Flint               | 4.3          | 4.5     | 3.2     | 0.1       |
| F7017    | 1995 | LBc     | Flake  | Flint               | 38.5         | 35.3    | 6.5     | 8.8       |
| F7021    | 1995 | LBa     | Chip   | Flint               | 3            | 3       | 1.7     | <0.1      |
| F7026    | 1995 | LBa     | Chip   | Flint               | 4.1          | 3.6     | 1.4     | <0.1      |
| F7027    | 1995 | LBc     | Chip   | Flint               | 10.8         | 5.2     | 4.1     | 0.3       |
| F7040    | 1995 | BI      | Flake fragment                                 | Ignimbrite          | 5.9          | 10.2    | 1.7     | <0.1      |
| F7043    | 1995 | LBc     | Chunk  | Chert               | 29           | 15.6    | 11.8    | 4.7       |
| F7063    | 1995 | OI      | Chunk  | Flint               | 10.1         | 10.1    | 7.8     | 0.8       |
| F7064    | 1995 | LBc     | Natural  | Flint               | n/a          | n/a     | n/a     | 0.9       |
| F7073    | 1995 | LBc     | Flake fragment                                 | fine silicic tuff   | 10.3         | 6.1     | 3       | 0.2       |
| F7075    | 1995 | LBc     | Flake fragment                                 | Flint               | 10.3         | 6.8     | 3.7     | 0.3       |
| F7091    | 1995 | LBc     | Flake fragment                                 | Flint               | 11.1         | 11.5    | 3.5     | 0.4       |
| F7101    | 1995 | LBc     | Chunk  | Fine silicic tuff   | 5            | 7.7     | 2.2     | <0.1      |
| G61      | 1989 | LB (3)  | ? Flake or natural<br>(massively edge-crushed) | Flint               | 84.2         | 50.6    | 28.8    | 79.4      |
| G70      | 1989 | LB (3)  | Natural  | Flint               | n/a          | n/a     | n/a     | 4         |
| G116     | 1993 | UB/sb   | Flake fragment                                 | Flint               | 9.2          | 5       | 1.9     | <0.1      |
| G147     | 1993 | LB      | Natural  | Flint               | n/a          | n/a     | n/a     | 0.8       |
| G201     | 1993 | LB      | Chunk  | Flint               | 11.3         | 4.5     | 3.8     | 0.2       |
| G206     | 1993 | LB      | Flake fragment                                 | Fine silicic tuff   | 10.2         | 8.7     | 3.8     | 0.4       |
| G210     | 1993 | LB (3)  | Natural  | Flint               | n/a          | n/a     | n/a     | 1.1       |
| G211     | 1993 | LB      | Chunk  | Fine silicic tuff   | 43.5         | 38.7    | 11.6    | 20.9      |
| S546     | 1989 | LB (3)  | Chip   | Flint               | 8.8          | 4       | 2.5     | <0.1      |
| H0       | 1986 | U/S     | Flake fragment                                 | Flint               | 47           | 29.4    | 3.2     | 5.2       |
| H9       | 1986 | U/S     | Handaxe  | Dacite              | 136.6        | 85.6    | 37.7    | 400.8     |
| H58      | 1987 | 20      | Flake fragment                                 | Chert               | 17.5         | 22.3    | 5.2     | 2         |
| H132     | 1987 | 23      | Convergent double convex<br>scraper            | FP lava             | 143.5        | 41.7    | 9.7     | 23.2      |
| H144     | 1987 | 23      | ? Core fragment                                | Banded chert        | 25.2         | 25.3    | 8.8     | 6.4       |
| H151     | 1987 | 23      | Core (globular)                                | Quartz              | 69.3         | 61.6    | 57.8    | 226.2     |
| H166     | 1987 | 23      | Flake fragment                                 | Baked shale         | 29.3         | 20      | 11.3    | 5.9       |
| H192     | 1987 | 23      | Disc core                                      | Rhyolitic tuff      | 64           | 53      | 20      | 70.7      |
| H217     | 1987 | 23      | Flake  | Flint               | 21.6         | 27      | 6.8     | 3.2       |
| H236     | 1987 | 23      | Levallois flake                                | tuff                | 67.8         | 60.4    | 9.2     | 40.4      |
| H237     | 1987 | 24      | Levallois flake                                | FP lava             | 48.5         | 49      | 12.6    | 25.2      |
| H244     | 1987 | 26      | Flake fragment                                 | Crystal tuff        | 13           | 14.8    | 3.9     | 0.9       |
| H314     | 1988 | 24      | Disc core                                      | Silicic tuff        | 70.6         | 64.6    | 34.4    | 169.9     |
| H321     | 1988 | 24      | Flake fragment                                 | Crystal tuff        | 20.5         | 18.1    | 4.2     | 1.1       |
| H323     | 1988 | 23      | Flake fragment                                 | Flint               | 11           | 9       | 2.6     | 0.2       |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name                            | Raw Material         | Measurements |         |         |           |
|----------|------|-------|--------------------------------------|----------------------|--------------|---------|---------|-----------|
|          |      |       |                                      |                      | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H351     | 1988 | 24    | Levallois flake (1)                  | Crystal tuff         | 59           | 52.4    | 9.9     | 34.7      |
| H360     | 1988 | 24    | Flake                                | Crystal lithic tuff  | 56.2         | 51.4    | 22.6    | 53.2      |
| H363     | 1988 | 23    | Flake fragment                       | Microdiorite         | 14.6         | 16.6    | 5       | 1         |
| H368     | 1988 | 26    | Levallois flake (1)                  | Quartzite            | 37           | 31.3    | 9.5     | 9.5       |
| H381     | 1988 | 26    | Core (beach pebble)                  | Flint (burnt)        | 41.9         | 46.4    | 17.4    | 19.4      |
| H386     | 1988 | 26    | Convex scraper fragment              | Flint                | 23           | 17.8    | 6.7     | 2.5       |
| H435     | 1988 | 24    | Flake fragment                       | Rhyolitic tuff       | 34.7         | 18.7    | 5       | 4.6       |
| H441     | 1988 | 24    | chunk                                | Rhyolite lava        | 12.3         | 6.9     | 3       | 0.3       |
| H442     | 1988 | 23    | Flake fragment                       | Quartz               | 59.6         | 47      | 19.6    | 48.8      |
| H454     | 1988 | 26    | Flake fragment                       | Rhyolite lava        | 13.7         | 11.3    | 4.3     | 0.7       |
| H477     | 1988 | 26    | Flake                                | Ignimbrite           | 21.5         | 30.2    | 4.3     | 3.3       |
| H499     | 1988 | 24    | Flake fragment                       | FP lava              | 23.5         | 21.3    | 5.7     | 3.4       |
| H500     | 1988 | 24    | Flake fragment                       | Flint                | 20.5         | 20.8    | 5       | 1.3       |
| H507     | 1988 | 24    | Handaxe                              | Quartz               | 78.2         | 44.3    | 30.2    | 94.3      |
| H509     | 1988 | 26    | Levallois flake fragment (1)         | Rhyolitic tuff       | 60.3         | 64.7    | 14.3    | 52.7      |
| H511     | 1988 | 26    | Levallois flake                      | Rhyolitic tuff       | 56.5         | 53.6    | 14.8    | 51.4      |
| H513     | 1988 | 24    | Core                                 | Flint (burnt)        | 44.4         | 32.2    | 14.2    | 19.6      |
| H525     | 1988 | 26    | Levallois flake-blade (1)            | Rhyolitic tuff       | 63.9         | 37.6    | 8.7     | 23.5      |
| H532     | 1988 | 26    | Flake fragment                       | Rhyolitic tuff       | 37.4         | 44.6    | 11.6    | 27.3      |
| H552     | 1988 | 26    | Core (re-struck thru. pat.)          | Tuff                 | 84.5         | 56.9    | 34.2    | 169.4     |
| H591     | 1988 | 27    | Flake                                | Fine silicic tuff    | 35.3         | 28.6    | 11.5    | 10.5      |
| H603     | 1988 | 26    | Rabot (on broken core)/handaxe frag. | Ignimbrite           | 87.1         | 74.8    | 39.5    | 289.9     |
| H632     | 1988 | 28    | Flake fragment                       | Rhyolitic tuff       | in breccia   |         |         |           |
| H640     | 1988 | 26    | Flake fragment                       | baked shale          | 35.1         | 35.6    | 8.2     | 13.2      |
| H646     | 1988 | 26    | Flake fragment                       | Baked shale          |              |         |         |           |
| H651     | 1988 | 26    | Levallois flake (1)                  | Fine silicic tuff    | 34           | 33.4    | 11      | 10.8      |
| H658     | 1988 | 26    | Levallois fragment flake             | Flint                | 44.3         | 32.4    | 9.5     | 10.4      |
| H662     | 1988 | 28    | Flake                                | Ignimbrite           | 42.3         | 32.3    | 10.6    | 11        |
| H680     | 1988 | 23    | Core                                 | Banded chert (burnt) | 38.9         | 29.8    | 14.3    | 14.1      |
| H685     | 1988 | 26    | Blade fragment                       | Rhyolitic tuff       | 49.8         | 25.5    | 7       | 10.6      |
| H693     | 1988 | 26    | Flake                                | Flint                | 24.9         | 24.4    | 8.9     | 3.2       |
| H703     | 1988 | 26    | Levallois flake                      | Microdiorite         | 80.6         | 47.7    | 14.6    | 67.8      |
| H705     | 1988 | 26    | Flake fragment                       | Baked shale          | 22.8         | 21.9    | 5.2     | 2.9       |
| H712     | 1988 | 26    | Flake                                | Crystal lithic tuff  | 52.7         | 29.2    | 11.6    | 16.9      |
| H741     | 1988 | 26    | Flake fragment                       | Fine silicic tuff    | 24.9         | 35.7    | 7.3     | 5.5       |
| H750     | 1988 | 20    | Chunk                                | fine silicic tuff    | 42.5         | 55.1    | 18.5    | 44.4      |
| H754     | 1988 | 26    | Levallois flake (siret)              | Rhyolitic tuff       | 37.8         | 14.6    | 5.7     | 3.1       |
| H759     | 1988 | 24    | Flake                                | Siltstone            | 49           | 29.1    | 10.2    | 14.7      |
| H764     | 1988 | 24    | Flake fragment                       | Silicic tuff         | 31.6         | 28      | 4.6     | 5.5       |
| H767     | 1988 | 23    | Flake                                | Fine silicic tuff    | 16.2         | 17.8    | 3.1     | 1         |
| H773     | 1988 | 23    | Misc (truncated facetet piece)       | rhyolitic tuff       | 95.1         | 52.4    | 26.1    | 122.9     |
| H777     | 1988 | 24    | Chunk                                | FP lava              | 54           | 36.2    | 26.5    | 34.9      |
| H780     | 1988 | 24    | Blade fragment                       | Crystal tuff         | 25.6         | 12.7    | 3.4     | 1.4       |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name  | Raw Material           | Measurements |         |         | Weight(g) |
|----------|------|-------|--|------------------------|--------------|---------|---------|-----------|
|          |      |       |  |                        | L (mm)       | Br (mm) | Th (mm) |           |
| H782     | 1988 | 28    | Flake fragment                                       | Ignimbrite             | 29.4         | 40.8    | 10.7    | 11.8      |
| H797     | 1988 | 24    | Levallois flake with inverse ret.                    | Ignimbrite             | 77.5         | 95      | 17.8    | 165.8     |
| H806     | 1988 | 26    | Flake fragment                                       | Microdiorite           | 32.3         | 30.6    | 8.6     | 8.3       |
| H807     | 1988 | 26    | Flake fragment                                       | Silicic tuff           | 32.7         | 29.7    | 9.3     | 13.1      |
| H832     | 1988 | 28    | Levallois flake (1)                                  | Microdiorite           | 62           | 41.3    | 17.9    | 41.9      |
| H845     | 1988 | 24    | Flake fragment                                       | FP lava                | 41.7         | 45.1    | 21.6    | 45        |
| H851     | 1988 | 26    | Flake fragment                                       | FP lava                | 67           | 53.3    | 13.2    | 35.1      |
| H857     | 1988 | 26    | Flake fragment                                       | FP lava                | 18.6         | 19.9    | 4.9     | 1.8       |
| H858     | 1988 | 26    | Flake fragment                                       | FP lava                | 21           | 12.3    | 4.6     | 1.4       |
| H859     | 1988 | 28    | Chopping tool  | Crystal lithic tuff    | 73.6         | 85.2    | 48.2    | 268.8     |
| H872     | 1988 | 26    | Flake  | Rhyolitic tuff         | 72.4         | 63.9    | 19.3    | 70.2      |
| H882     | 1988 | 26    | Flake fragment                                       | Rhyolitic tuff         | 27.7         | 17.6    | 7.2     | 4.2       |
| H897     | 1988 | 28    | Flake fragment                                       | Flint                  | 32.2         | 25.3    | 6.3     | 5.4       |
| H902     | 1988 | 28    | Flake fragment                                       | Flint                  | 16.1         | 22.6    | 4.6     | 1.3       |
| H939     | 1988 | 23    | Core (indet.)  | Flint                  | 47.4         | 27.8    | 12      | 11.3      |
| H940     | 1988 | 28    | Levallois flake blade                                | Flint                  | 46.1         | 20.4    | 6.8     | 6.2       |
| H944     | 1988 | 28    | Scraper fragment                                     | Flint                  | 14.6         | 10.9    | 3.4     | 0.2       |
| H947     | 1988 | 26    | Flake fragment                                       | Rhyolitic tuff         | 24.9         | 39.8    | 5.2     | 5.4       |
| H948     | 1988 | 26    | flake frag (siret)                                   | Baked shale            | 42.7         | 56.6    | 14.1    | 19.2      |
| H951     | 1988 | 28    | Discoidal core                                       | Ignimbrite             | 66.7         | 47.5    | 30.8    | 80        |
| H968     | 1988 | 27    | Flake fragment                                       | Rhyolitic tuff         | n/a          | n/a     | n/a     | 9.8       |
| H994     | 1988 | 28    | Flake fragment                                       | Flint                  | 12           | 14.1    | 3.7     | 0.4       |
| H1006    | 1988 | 28    | Flake fragment                                       | Flint                  | n/a          | n/a     | n/a     | 0.2       |
| H1022    | 1988 | 28    | Levallois (siret)                                    | Siltstone (tuffaceous) | 75.3         | 44.2    | 10.7    | 39.4      |
| H1035    | 1988 | 26    | Flake fragment                                       | Rhyolitic tuff         | 41.8         | 61.7    | 15.8    | 29.2      |
| H1080    | 1988 | 26    | Flake (siret)  | Rhyolitic tuff         | 98.6         | 65.3    | 13.3    | 67.4      |
| H1088    | 1988 | 26    | Crude core (flaked flake)                            | Quartzite              | 51           | 36.6    | 25      | 30.3      |
| H1148    | 1988 | 26    | Flake  | FP lava                | 42.3         | 36.6    | 7.7     | 11.2      |
| H1151    | 1988 | 26    | Single straight side scraper<br>(on levallois flake) | FP lava                | 55.6         | 32.6    | 12.6    | 32.6      |
| H1159    | 1988 | 26    | Flake fragment                                       | Flint                  | 19.6         | 19.5    | 4       | 1.4       |
| H1168    | 1988 | 26    | Flake fragment                                       | Rhyolitic tuff         | 12.2         | 14.3    | 6.1     | 1.1       |
| H1188    | 1988 | 26    | Flake fragment                                       | Siltstone              | n/a          | n/a     | n/a     | 11.1      |
| H1189    | 1988 | 26    | Flake fragment                                       | Siltstone              | 48.4         | 49      | 7.9     | 21.3      |
| H1191    | 1988 | 26    | Flake fragment                                       | crystal tuff           | 22.8         | 13.7    | 7       | 2         |
| H1262    | 1989 | 29    | Chunk  | flint                  | 18.8         | 16.8    | 6.5     | 1.9       |
| H1276    | 1989 | U/S   | Handaxe  | Ignimbrite             | 105.1        | 54.8    | 35.1    | 236.5     |
| H1504    | 1989 | 29    | Modified pebble                                      | Ignimbrite             | 154          | 123.9   | 50      | 1051      |
| H1558    | 1989 | 29b   | Flake fragment                                       | Flint                  | 27.6         | 23.5    | 7.7     | 4.6       |
| H1578    | 1989 | 32    | Flake fragment                                       | Rhyolitic tuff         | 49.6         | 30.6    | 9.2     | 14.2      |
| H1609    | 1989 | 29    | Naturally backed knife                               | Meta. sandstone        | 87.5         | 50.5    | 27.2    | 142.5     |
| H1630    | 1989 | 33    | Chip   | Flint                  | 7.8          | 3.5     | 3       | <0.1      |
| H1631    | 1989 | 33    | Chip   | Flint                  | 6.1          | 7.7     | 2.3     | <0.1      |
| H1647    | 1989 | 50    | Chunk  | Flint                  | 5.9          | 5       | 4       | <0.1      |
| H1648    | 1989 | 36    | Spall  | Flint                  | 5            | 5.8     | 1.4     | <0.1      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer      | Type Name  | Raw Material        | Measurements  |         |         |           |
|----------|------|------------|--|---------------------|---------------|---------|---------|-----------|
|          |      |            |  |                     | L (mm)        | Br (mm) | Th (mm) | Weight(g) |
| H1678    | 1989 | 36         | Single straight side scraper                         | Ignimbrite          | 60.3          | 44      | 19.3    | 54.9      |
| H1704    | 1989 | 35         | (doubtful) Chunk                                     | Flint               | 16.6          | 22.1    | 11.6    | 3.3       |
| H1731    | 1989 | U/S        | Natural  | Sandstone, dark.    | n/a           | n/a     | n/a     | 189.1     |
| H1732    | 1993 | 20/23      | Flake fragment                                       | Chert               | 15.6          | 9.3     | 4       | 0.6       |
| H1737    | 1993 | 20,23,24   | Natural  | Flint               | n/a           | n/a     | n/a     | 1.4       |
| H1738    | 1993 | 20,23,24   | Spall  | Flint               | 5.9           | 6       | 1.7     | 0.1       |
| H1739    | 1993 | 24         | Spall  | Flint               | 5.5           | 5.3     | 1.3     | <0.1      |
| H1740    | 1993 | U/S        | Chunk  | Flint               | 28.2          | 13      | 10.6    | 3.7       |
| H1742    | 1993 | 24         | Spall  | Flint               | 3.1           | 3.2     | 0.1     |           |
| H1744    | 1993 | 26/28, U/S | Natural  | Flint               | n/a           | n/a     | n/a     | 2.2       |
| H1746    | 1993 | U/S        | Natural  | Siltstone           | n/a           | n/a     | n/a     | 111.8     |
| H1751    | 1993 | U/S        | Flake  | Flint               | 33.5          | 27.1    | 12.6    | 14.1      |
| H1752    | 1993 | 6/8        | Natural  | Flint               | n/a           | n/a     | n/a     | 3.8       |
| H1878    | 1993 | 50a        | Naturally backed knife                               | Ignimbrite          | 60            | 45      | 18.5    | 54.9      |
| H1885    | 1993 | 35         | (doubtful) Chunk                                     | Flint               | 10.3          | 4.1     | 5.5     | 0.2       |
| H1926    | 1994 | 24         | Single convex side scraper                           | baked shale         | 49.9          | 23.3    | 13.3    | 14.2      |
| H1930    | 1994 | 24         | Artefact?  | baked shale         | in concretion |         |         |           |
| H1934    | 1994 | 24         | Flake fragment                                       | Flint               | 26.4          | 12      | 5.6     | 1.4       |
| H1935    | 1994 | 24         | Single straight side scraper<br>(on core tuff flake) | FP lava             | 58.7          | 45.6    | 26.6    | 57.4      |
| H1965    | 1994 | 24         | Bifacially ret. piece                                | Banded chert        | 34.5          | 26.7    | 14.1    | 10.9      |
| H1966    | 1994 | 24         | Chunk  | Flint               | 8.7           | 4       | 5.1     | 0.1       |
| H1980    | 1994 | 23         | Chunk  | crystal pumice tuff | 41            | 28.9    | 13.4    |           |
| H1981    | 1994 | 23         | Flake  | FP lava             | 45.9          | 41.2    | 16.3    | 31.8      |
| H1990    | 1994 | 20         | Natural  | Flint               | n/a           | n/a     | n/a     | 2.3       |
| H1997    | 1994 | 24         | Flake  | Quartz              | 53.3          | 34.7    | 10.4    | 28.2      |
| H2013    | 1994 | 23         | Flake  | Rhyolitic tuff      | 48.4          | 24.9    | 6.5     | 9.7       |
| H2025    | 1994 | 23         | Levallois flake (fragment)                           | Fine silicic tuff   | 42.7          | 33.6    | 11.2    | 16        |
| H2034    | 1994 | 26         | Flake fragment                                       | Silicic tuff        | 73.9          | 50.5    | 8.4     | n/a       |
| H2036    | 1994 | 26         | Re-touch levallois flake fragment                    | Crystal tuff        | 35.4          | 42      | 8       | 13.2      |
| H2039    | 1994 | 23         | Chopping tool  | Crystal tuff        | 101.7         | 79.6    | 47.9    | 421.8     |
| H2044    | 1994 | 26         | Flake fragment                                       | crystal lithic tuff | 25.2          | 25.1    | 5.4     | 3.3       |
| H2067    | 1994 | 26         | Flake fragment                                       | Ignimbrite          | 53.1          | 62.8    | 18.6    | 59.9      |
| H2068    | 1994 | 23/24      | Discoidal core                                       | FP lava             | 67.5          | 60.2    | 22.1    | 109.6     |
| H2075    | 1994 | 24         | Natural  | Mudstone            | n/a           | n/a     | n/a     | n/a       |
| H2080    | 1994 | 26         | Hand-axe trimmer                                     | Rhyolitic tuff      | 29.3          | 35.7    | 7.4     | 8.4       |
| H2085    | 1994 | 28         | Flake fragment                                       | Flint               | 10.4          | 20.2    | 5.5     | 0.9       |
| H2086    | 1994 | 26         | Burnt flake fragment                                 | Flint               | 24.6          | 10.8    | 7.7     | 1.5       |
| H2086    | 1994 | 26         |  | Flint               | 13.9          | 10.8    | 4.7     | 0.7       |
| H2097    | 1994 | 26         | Indet. (in concretion)                               | Flint               |               |         |         |           |
| H2110    | 1994 | 26         | Flake fragment                                       | Baked shale         | 36.5          | 27.8    | 8.4     | 6.6       |
| H2117    | 1994 | 23         | Handaxe trimmer                                      | Rhyolitic tuff      | 64.4          | 46.9    | 12.9    | 35.8      |
| H2119    | 1994 | 28         | Single straight sided scraper (on chunk)             | Crystal pumice tuff | 80            | 49.9    | 26      | 88.9      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No.      | Year | Layer | Type Name                           | Raw Material         | Measurements |         |         |           |
|---------------|------|-------|-------------------------------------|----------------------|--------------|---------|---------|-----------|
|               |      |       |                                     |                      | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H2135*        | 1994 | 29    | ? Failed handaxe                    | Sandstone, tuff.     | 79.1         | 46      | 32.8    | 164.5     |
| H2137         | 1994 | 26    | Flake fragment (in breccia)         | Baked shale          | 32.5         | 24      | 5.6     | 6.9       |
| H2138         | 1994 | 26    | Flake (in concretion)               | Siltstone            | 27.2         | 30.1    | 4.2     | 10.2      |
| H2152         | 1994 | 29    | Flake?                              | Ignimbrite           | 48.5         | 61.8    | 13.9    | 45.4      |
| H2187         | 1994 | 26    | Flake                               | Rhyolitic tuff       | 77.3         | 46.8    | 22.2    | 80        |
| H2194         | 1994 | 23    | Flake frag.                         | Ignimbrite           | 23.7         | 37.2    | 10.7    | 8.9       |
| H2220         | 1994 | 26    | Flake fragment                      | Ignimbrite           | 26.1         | 35.7    | 10.5    | 10        |
| H2221.1       | 1994 | 28    | Flake fragment                      | Flint                | 8            | 5.2     | 2.5     | <0.1      |
| H2221.2       | 1994 | 28    | Flake fragment                      | Flint                | 8.3          | 5.4     | 2.3     | 0.2       |
| H2221.3       | 1994 | 28    | Flake fragment                      | Flint                | 4.3          | 3.2     | 2.6     | <0.1      |
| H2224         | 1994 | 23    | Chip                                | Flint                | 3.4          | 7.2     | 1.7     | <0.1      |
| H2227         | 1995 | 23    | Natural                             | Flint                | n/a          | n/a     | n/a     | 1.4       |
| H2230         | 1995 | 26    | Flake(small)                        | crystal lithic tuff  | 12.2         | 8.4     | 2.8     | 0.3       |
| H2235         | 1995 | 23    | Flake fragment                      | Flint                | 19.1         | 11.3    | 5.4     | 0.8       |
| H2243         | 1995 | 28    | Flake fragment (with breccia)       | Siltstone            | 41.7         | 35.3    | 16.8    | 21.8      |
| H2245         | 1995 | 23    | flake frag                          | Ignimbrite           | 36.8         | 17.5    | 6.3     | 4.5       |
| H2250         | 1995 | 24    | Flake fragment                      | fine tuff            | 9.2          | 3.1     | 2.3     | <0.1      |
| H2253         | 1995 | 24    | Abrupt alt. ret.                    | Silicic tuff         | 41.2         | 36.4    | 9.3     | 14.7      |
| H2256         | 1995 | 24    | Flake fragment                      | Silicic crystal tuff | 21.4         | 21.3    | 5.3     | 1.3       |
| H2259         | 1995 | 26    | Chip                                | Flint                | n/a          | n/a     | n/a     | <0.1      |
| H2263         | 1995 | 28    | Flake fragment                      | Fine silicic tuff    | 52.1         | 43.5    | 6.8     | 16.1      |
| H2268         | 1995 | 26    | Chip                                | FP lava              | 6.3          | 5.9     | 2       | <0.1      |
| H2279         | 1995 | 26    | Spall                               | Rhyolitic tuff       | 7.2          | 5       | 1.2     | <0.1      |
| H2283         | 1995 | 26    | 2 flake frags                       | fine silicic tuff    | n/a          | n/a     | n/a     | 0.1       |
| H2293         | 1995 | 26    | Chunk                               | Rhyolitic tuff       | 18.6         | 10.3    | 8       | 1.9       |
| H2296         | 1995 | 23    | Chunk                               | Flint                | 6.8          | 6.2     | 5.7     | 0.2       |
| H2300         | 1995 | 26    | ? Flake fragment (in breccia)       | Ignimbrite           | 36.8         | 29.5    | 10.8    | 18        |
| H2308         | 1995 | 24    | Spall                               | Flint                | 12.8         | 12.3    | 2       | 0.2       |
| H2314         | 1995 | 26    | Flake fragment                      | Rhyolitic tuff       | 30.3         | 21.3    | 11.6    | 8.4       |
| H2316         | 1995 | 20    | Flake/chip                          | Rhyolite lava        | 14           | 5.7     | 4.5     | 0.3       |
| H2317         | 1995 | 24    | Natural                             | FP lava              | n/a          | n/a     | n/a     | n/a       |
| H2320         | 1995 | 26    | Flake                               | Ignimbrite           | 59           | 34.7    | n/a     | 71        |
| H2321         | 1995 | 24    | Flake fragment                      | Degraded flint?      | 27.4         | 16      | 10      | 1.8       |
| H2325         | 1995 | 26    | Flake fragment                      | Flint                | 17.5         | 11.1    | 3.8     | 0.4       |
| H2327         | 1995 | 28    | Flake fragment                      | fine silicic tuff    | 15.7         | 8.1     | 3       | 0.4       |
| H2328         | 1995 | 28    | Flake fragment                      | fine silicic tuff    | 21.8         | 12.9    | 4.2     | 1.1       |
| H2330 & H2563 | 1995 | 26    | Offset scraper on ? levallois flake | Flint                | 56           | 36      | 9.2     | 38.5      |
| H2331         | 1995 | 24    | Artefact frag, retouched            | Silicic tuff         | 31.3         | 35.2    | n/a     | 83.5      |
| H2340         | 1995 | 26    | Single convex side scraper          | Flint                | 43.6         | 37.9    | 9.6     | 14.6      |
| H2341         | 1995 | 23    | Flake fragment                      | Crystal tuff         | 35.5         | 26.1    | 7.8     | 7.5       |
| H2346         | 1995 | 26    | Levallois flake                     | Ignimbrite           | 65           | 57.7    | 13.3    | 41.9      |
| H2350         | 1995 | 26    | Flake                               | FP lava              | 40.6         | 24.5    | 17.5    | 13.1      |
| H2351         | 1995 | 24    | Flake                               | Ignimbrite           | 44.4         | 32      | 9       | 11.2      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name                             | Raw Material         | Measurements |         |         |           |
|----------|------|-------|---------------------------------------|----------------------|--------------|---------|---------|-----------|
|          |      |       |                                       |                      | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H2352    | 1995 | 24    | Flake (not fully visible, in breccia) | Flint                | n/a          | 10.3    | n/a     | 44.4      |
| H2357    | 1995 | 24/26 | Chip                                  | Flint                | 9.5          | 4.9     | 3.6     | 0.1       |
| H2361    | 1995 | 24    | Dent.                                 | Rhyolite             | 32.5         | 26.8    | 9.2     | 8.1       |
| H2365    | 1995 | 23    | Chip                                  | Flint                | 4            | 6.4     | 2.8     | <0.1      |
| H2366    | 1995 | 23    | Flake fragment                        | Ignimbrite           | 22.9         | 35.3    | 8.3     | 5.7       |
| H2370    | 1995 | 23/24 | Natural                               | Sandstone            | n/a          | n/a     | n/a     | 31.9      |
| H2371    | 1995 | 26    | Flake fragment                        | Flow banded FP lava  | 32.8         | 26.6    | 13.5    | 13.5      |
| H2387    | 1995 | 28    | Edge fragment of ? disc core          | Fine silicic tuff    | 30.1         | 13.4    | 10.5    | 4.3       |
| H2390    | 1995 | 23    | Chip                                  | Flint                | 4.8          | 3.1     | 2.2     | <0.1      |
| H2396    | 1995 | 28    | Flake fragment                        | Flint                | 7.7          | 3.8     | 2       | <0.1      |
| H2397    | 1995 | 28    | Flake fragment                        | Flint                | 7.7          | 7.4     | 2.5     | 0.1       |
| H2403    | 1995 | 28    | Levallois flake                       | Rhyolitic tuff       | 48.5         | 61.2    | 11      | 31.4      |
| H2411    | 1995 | 28    | Flake fragment                        | Quartz               |              |         |         |           |
| H2416    | 1995 | 29    | Handaxe                               | Crystal lithic tuff  | 170          | 76.7    | 40.6    | 558.8     |
| H2420    | 1995 | 24    | Core                                  | Quartz               | n/a          | n/a     | n/a     | 103.7     |
| H2427    | 1995 | 24    | Core fragment                         | Flint                | 24.2         | 27.2    | 3.9     | 4.5       |
| H2430    | 1995 | 28    | Chunk                                 | Flint                | 11.5         | 5.2     | 4.8     | 0.3       |
| H2436    | 1995 | 24    | Spall                                 | fine silicic tuff    | 7.8          | 4       | 2       | <0.1      |
| H2437    | 1995 | 26    | Chip                                  | Flint                | 4.1          | 2.9     | 0.1     | <0.1      |
| H2439    | 1995 | 26    | Flake fragment                        | ? Chert              | 9.4          | 8.6     | 2.9     | 0.2       |
| H2443    | 1995 | 26    | Flake fragment                        | Rhyolite lava        | 47.9         | 29.7    | 13.1    | 23.7      |
| H2444    | 1995 | 26    | Flake fragment                        | Rhyolitic tuff       | n/a          | n/a     | n/a     | 1.5       |
| H2445    | 1995 | 26    | Flake fragment                        | Crystal tuff         | 34.2         | 36.1    | 17.4    | 19.8      |
| H2446    | 1995 | 24    | Indet. core                           | Flint                | 38.8         | 29.9    | 21.2    | 19.2      |
| H2451    | 1995 | 28    | Notch                                 | Fine silicic tuff    | 37           | 56.2    | 15.5    | 21.8      |
| H2459    | 1995 | 20    | Flake fragment                        | Rhyolite             | 17.1         | 12      | 3.9     | 1.1       |
| H2460*   | 1995 | 26    | Levallois flake (breccia adhered)     | Flow banded rhyolite | 41.8         | 44.4    | 13.2    | 24.4      |
| H2461    | 1995 | 28    | Flake                                 | Ignimbrite           | 35.1         | 21.2    | 7.8     |           |
| H2461    | 1995 | 28    | Flake                                 | Ignimbrite           | 41.6         | 23.1    | 13.5    | 10.5      |
| H2462    | 1995 | 23    | Flake fragment                        | Crystal tuff         | 15.7         | 24.4    | 6.3     | 2         |
| H2463    | 1995 | 28    | Flake fragment                        | Crystal tuff         | 8.5          | 10.8    | 1.7     | 0.2       |
| H2466    | 1995 | 26    | Flake fragment                        | Flint                | 4.4          | 13.4    | 2.7     | 0.1       |
| H2479    | 1995 | 28    | Spall                                 | Flint                | 7.2          | 9.1     | 2.5     | 0.1       |
| H2480    | 1995 | 28    | Flake fragment                        | Siltstone            | 9.2          | 10.6    | 2       | 0.2       |
| H2483    | 1995 | 23    | Chunk                                 | Flint                | 2.8          | 6.7     | 5.8     | <0.1      |
| H2484    | 1995 | 28    | Flake                                 | Crystal tuff         | 16.4         | 38.6    | 7.4     | 5         |
| H2485    | 1995 | 26    | Flake fragment                        | Flint                | 7.4          | 7.2     | 2.1     | 0.1       |
| H2487    | 1995 | 23    | Flake                                 | Ignimbrite           | 22           | 16.8    | 6.2     | 2.6       |
| H2490    | 1995 | 28    | Flake fragment                        | fine silicic tuff    | 8.4          | 9.7     | 1.1     | <0.1      |
| H2492    | 1995 | 26    | Flake fragment (hand-axe trimmer)     | Rhyolitic tuff       | in breccia   |         |         |           |
| H2493    | 1995 | 26    | Flake fragment                        | fine silicic tuff    | 15.6         | 9.7     | 5.3     | 1.2       |
| H2500    | 1995 | 28    | Levallois flake                       | Ignimbrite           | 35.8         | 38.8    | 8.1     | 14        |
| H2505    | 1995 | 26    | Levallois flake Debitage              | Quartz               | n/a          | n/a     | n/a     | 28.6      |
| H2513    | 1995 | 20    | Flake fragment                        | Crystal tuff         | 8.5          | 4.6     | 2.2     | <0.1      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name                                   | Raw Material               | Measurements |         |         |           |
|----------|------|-------|---|----------------------------|--------------|---------|---------|-----------|
|          |      |       |   |                            | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H2515    | 1995 | 24    | Crude core                                  | Quartzite                  | 49.8         | 60.1    | 28.7    | 83.4      |
| H2521    | 1995 | 24    | Spall                                       | Flint                      | 5.3          | 7.7     | 2.2     | <0.1      |
| H2524    | 1995 | 28    | Flake                                       | Fine silicic tuff          | 50.3         | 26.5    | 14.4    | 16.8      |
| H2532    | 1995 | 26    | Debitage (chips)                            | Sandstone                  | n/a          | n/a     | n/a     | 1.6       |
| H2537    | 1995 | 28    | Flake fragment                              | Flint                      | 23.7         | 27.4    | 10.4    | 6         |
| H2540.1  | 1995 | 28    | Chip  | Flint                      | 6.4          | 5.2     | 2.3     | 0.1       |
| H2540.2  | 1995 | 28    | Flake fragment                              | Flint                      | 5.3          | 9.8     | 3.6     | 0.2       |
| H2547    | 1995 | 28    | Hand-axe trimming flake                     | Rhyolitic tuff             | 58.5         | 37.6    | 15      | 32.9      |
| H2548    | 1995 | 23    | Spall                                       | Flint                      | 6            | 4       | 1.7     | 0.1       |
| H2560    | 1995 | 28    | Flake fragment                              | Fine silicic tuff          | 32.3         | 20.7    | 7.3     | 5.4       |
| H2561    | 1995 | 24    | Levallois flake fragment                    | crystal tuff               | 34.7         | 21.2    | 8       | 6.3       |
| H2562    | 1995 | 24    | Flake fragment                              | Ignimbrite                 | 20.7         | 21.8    | 7.8     | 4.9       |
| H2563    | 1995 | 26/28 | See H2330                                   | Flint                      |              |         |         |           |
| H2564    | 1995 | 28    | Chip ( in breccia)                          | Fine silicic tuff          | 7.9          | n/a     | 2.6     | n/a       |
| H2569    | 1995 | 24    | Chunk                                       | Ignimbrite                 | 37.4         | 23.5    | 15.3    | 10.1      |
| H2573    | 1995 | 24    | Spall                                       | Flint                      | 9            | 7.9     | 2.4     | 0.1       |
| H2584    | 1995 | 26    | Flake fragment                              | Fine silicic tuff          | 6.8          | 14.6    | 6       | 0.5       |
| H2585    | 1995 | 23    | Flake frag                                  | FP lava                    | 32.3         | 36.5    | 8.7     | 11.6      |
| H2603    | 1995 | 26    | Flake                                       | Fine silicic tuff          | 45           | 29.8    | 12.1    | 14.2      |
| H2606    | 1995 | 26    | Crude core                                  | Ignimbrite                 | 97.2         | 67.4    | 48.4    | 244.2     |
| H2608    | 1995 | 20    | Fragment of H3001,found<br>section cleaning | Crystal tuff               | 18.7         | 15.5    | 6.6     | 2.1       |
| H2610    | 1995 | 20    | Flake fragment                              | Chert                      | 27.5         | 22.9    | 6.7     | 3.9       |
| H2627    | 1995 | 26    | Natural                                     | Quartz                     | n/a          | n/a     | n/a     | n/a       |
| H2634    | 1995 | 26    | Hand-axe fragment (in<br>breccia)           | Crystal lithic pumice tuff | 47.8         | 44.5    | 21.5    | 73.3      |
| H2636    | 1995 | 26    | Spall                                       | Rhyolitic tuff             | 10.1         | 10.1    | 2.3     | 0.2       |
| H2713    | 1995 | 29    | Natural                                     | Flint                      | n/a          | n/a     | n/a     | 0.9       |
| H2771    | 1995 | 29b   | ? Unfinished handaxe                        | Sandstone, tuffaceous      | 95           | 67.4    | 29.1    | 168       |
| H2791    | 1995 | 6/8   | Natural                                     | Flint                      | n/a          | n/a     | n/a     | 1.2       |
| H2858*   | 1995 | 24/26 | Crude core                                  | ignimbrite                 | 104          | 48.8    | 39.5    | 193.1     |
| H2872    | 1995 | 28    | Chunk                                       | Flint                      | 5.5          | 6.8     | 4       | 0.1       |
| H2875    | 1995 | 28    | Core trimming flake                         | FP lava                    | 46.8         | 22.9    | 16.6    | 14.1      |
| H2876    | 1995 | 29    | Chip  | Flint                      | 5.2          | 3.6     | 2.5     | <0.1      |
| H2886    | 1995 | 26/28 | Chunk                                       | Fine silicic tuff          | 10.5         | 10.4    | 4.9     | 0.6       |
| H2897    | 1995 | 33    | Chunk                                       | Flint                      | 7.5          | 11.7    | 6.6     | 0.5       |
| H2900    | 1995 | 33/34 | Flake fragment                              | Flint                      | 7.5          | 8.2     | 3.2     | 0.4       |
| H2914    | 1995 | 33    | Flake                                       | ignimbrite                 | 59.6         | 60.6    | 18.3    | 56.3      |
| H2927    | 1995 | 33    | Natural                                     | Flint                      | n/a          | n/a     | n/a     | 1.1       |
| H2931    | 1995 | 34    | Artefact chip                               | Flint                      | 7.5          | 4.2     | 3.3     | <0.1      |
| H2953    | 1995 | 38    | Chip  | Flint                      | 5.1          | 2.3     | 2.5     | <0.1      |
| H2956    | 1995 | 34    | Flake fragment                              | Flint                      | 30           | 17.7    | 4.5     | 1.8       |
| H2957    | 1995 | 38    | Chip  | Flint                      | 6.6          | 4       | 3.1     | <0.1      |
| H2958    | 1995 | 38    | Chip  | Flint                      | 3.9          | 5.3     | 4.2     | <0.1      |
| H2960    | 1995 | 34    | Chip  | Flint                      | 4.5          | 4.4     | 3.2     | <0.1      |
| H2961    | 1995 | 34    | Flake fragment                              | Crystal lithic tuff        | 10.6         | 15.8    | 4.1     | 1         |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No.      | Year | Layer | Type Name                         | Raw Material               | Measurements |         |         | Weight(g) |
|---------------|------|-------|-----------------------------------|----------------------------|--------------|---------|---------|-----------|
|               |      |       |                                   |                            | L (mm)       | Br (mm) | Th (mm) |           |
| H2968         | 1995 | 28    | Flake fragment                    | Flint                      | 9.1          | 5.6     | 3.6     | <0.1      |
| H2992         | 1995 | 29    | Chip                              | Flint                      | 4.1          | 4.5     | 1.6     | <0.1      |
| H2993         | 1995 | 38    | Chip                              | Flint                      | 7.1          | 5.4     | 3.6     | <0.1      |
| H3001         | 1995 | 20    | Side scraper (broken, fits H2608) | Crystal tuff               | 43.8         | 33.9    | 11.6    | 19.4      |
| H3022         | 1995 | 23    | Handaxe (? unfinished)            | silicic tuff               | 77           | 49.3    | 26      | 105.9     |
| H3035         | 1995 | 33    | Flake fragment                    | Crystal pumice tuff        | 27.5         | 26.2    | 6.6     | 5.4       |
| H3047         | 1995 | 28    | Core                              | flow banded rhyolite       | 59           | 48.8    | 38.3    | 123.8     |
| H3050         | 1995 | 23/24 | Flake                             | Flint                      | 29.2         | 18.9    | 8.5     | 2.6       |
| H3055         | 1995 | 24    | a/a ret. on levallois flake       | Tuff                       | 57.5         | 53.5    | 17.2    | 49.6      |
| H3056         | 1995 | 24    | Levallois flake                   | Flow banded rhyolite       | 58.9         | 52.4    | 14      | 38.3      |
| H3059         | 1995 | 24    | ? Levallois flake fragment        | Crystal lithic tuff        | 57.8         | 53.9    | 14.8    | 51        |
| H3064         | 1995 | 24    | Flake                             | Rhyolitic tuff             | 40.1         | 36.7    | 18.5    | 20.1      |
| H3069         | 1995 | 24    | Flake                             | Ignimbrite                 | 56           | 61.8    | 19.8    | 69.7      |
| H3072.1       | 1995 | 34    | Chip                              | Flint                      | 4.8          | 4.4     | 1.8     | <0.1      |
| H3072.2       | 1995 | 34    | Chip                              | Flint                      | 4.7          | 5.1     | 3.1     | <0.1      |
| H3093         | 1995 | 24/26 | Indet. retouched flake            | crystal tuff               | 70.9         | 53.3    | 11.8    | 48.6      |
| H3099         | 1995 | 24    | Ret. flake                        | Ignimbrite                 | 65.9         | 38      | 16.1    | 44.6      |
| H3100         | 1995 | 24    | Flake fragment                    | Fine silicic tuff          | 35.2         | 9       | 5.7     | 2.5       |
| H3105         | 1995 | 24/26 | Indet. retouched flake            | Crystal tuff               | 28.2         | 46.4    | 7       | 10.5      |
| H3114         | 1995 | 24    | Chunk                             | Ignimbrite                 | 46.4         | 39.8    | 14.4    | 23.2      |
| H3115         | 1995 | 23    | Discoidal core                    | Ignimbrite                 | 83.4         | 64.3    | 21.5    | 142.6     |
| H3120         | 1995 | 24    | Chunk                             | FP lava                    | 43.5         | 46.8    | 24.5    | 47.4      |
| H3122         | 1995 | 24    | Levallois flake                   | crystal lithic tuff        | 84.5         | 50.3    | 18      | 71.5      |
| H3124         | 1995 | 24    | Flake                             | crystal lithic tuff        | 33           | 55      | 26.7    | 51.9      |
| H3142 & H3374 | 1995 | 23    | Flake (? handaxe trimmer)         | Pumice crystal lithic tuff | 62.1         | 47.1    | 12.2    | 30.2      |
| H3154         | 1995 | 26    | Flake fragment                    | fine silicic tuff          | 68           | 52.8    | 17.2    | 87.4      |
| H3155         | 1995 | 24    | Naturally backed knife            | Crystal tuff               | 76.5         | 55.7    | 13.6    | 52.3      |
| H3156         | 1995 | L 6/8 | Cobble frag                       | Sandstone, meta.           | 51.7         | 84      | 41.3    | 176.6     |
| H3159         | 1995 |       | single straight sided scraper     | Crystal tuff               | 43.6         | 31.8    | 17.5    | 24.9      |
| H3159         | 1995 | 24/26 | Indet.                            | Flint                      |              |         |         |           |
| H3164         | 1995 | 24    | Flake fragment                    | Flint                      | 7.9          | 7.1     | 3.1     | 0.1       |
| H3169         | 1995 | 23    | Natural                           | Sandstone                  | n/a          | n/a     | n/a     | 81.4      |
| H3170         | 1995 | 26    | Flake fragment                    | Rhyolite                   | 20.3         | 29.3    | 9.8     | 5.7       |
| H3181         | 1995 | 24    | Crude core                        | Rhyolitic tuff             | 55.9         | 55.6    | 22.4    | 74        |
| H3182         | 1995 | 26    | Flake                             | Siltstone                  | 30.6         | 36      | 10.6    | 8.4       |
| H3184         | 1995 | 26    | Levallois flake                   | Flint                      | 28           | 32      | 9.2     | 6.3       |
| H3185         | 1995 | 24    | Flake fragment                    | Fine silicic tuff          | 27.1         | 10      | 7.2     | 1.8       |
| H3186         | 1995 | 26    | Flake fragment                    | Flint                      | 9            | 9.8     | 2.9     | 0.2       |
| H3190         | 1995 | 24    | a/a ret.                          | Ignimbrite                 | 43.9         | 42.8    | 10.2    | 18.4      |
| H3197         | 1995 | 26    | Single convex side scraper        | Baked shale                | 35.6         | 21.5    | 10.2    | 8.3       |
| H3200         | 1995 | 26    | Flake fragment                    | Rhyolitic tuff             | 35.9         | 27.6    | 9.2     | 6.5       |
| H3203         | 1995 | 24/26 | Flake                             | FP lava                    | 57.2         | 38.7    | 16      | 31.4      |
| H3204         | 1995 | 24/26 | Flake (in concretion)             | Rhyolitic tuff             | n/a          | n/a     | n/a     | 11.1      |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name                                | Raw Material        | Measurements |         |         |           |
|----------|------|-------|--|---------------------|--------------|---------|---------|-----------|
|          |      |       |  |                     | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H3214    | 1995 | 26    | Single convex side scraper               | Rhyolite            | 23.5         | 16.4    | 9.6     | 4.3       |
| H3228    | 1995 | 23    | Flake fragment                           | Rhyolitic tuff      | 38.4         | 38.9    | 12.2    | 15.9      |
| H3229    | 1995 | 23    | Single convex side scraper on Levallois. | Microdiorite        | 78.2         | 57.5    | 18      | 83.5      |
| H3231    | 1995 | 24    | Flake fragment                           | Rhyolitic tuff      | 12.2         | 20.3    | 4       | 1         |
| H3233    | 1995 | 24    | Flake fragment                           | Silicic tuff        | 46.2         | 33      | 12.2    | 17.4      |
| H3237    | 1995 | 24    | Chunk                                    | Silicic tuff        | 41.9         | 37.5    | 18.8    | 31.2      |
| H3242    | 1995 | 24    | Levallois (flake) core                   | Ignimbrite          | 85.7         | 7.4     | 54      | 426       |
| H3243    | 1995 | 24    | a/a ret. Levallois flake                 | crystal tuff        | 41.6         | 26.5    | 8.5     | 9.6       |
| H3246    | 1995 | 33    | Chunk                                    | Flint               | 23.3         | 10      | 6.2     | 1.6       |
| H3248    | 1995 | 34    | Chunk                                    | Quartz              | 39.2         | 22.1    | 17      | 14.7      |
| H3250    | 1995 | 34    | Chip                                     | Flint               | 2.1          | 2.2     | 1.5     | <0.1      |
| H3251    | 1995 | U/S   | Chunk                                    | fine silicic tuff   | 12.5         | 11.3    | 6.3     | 0.7       |
| H3252    | 1995 | U/S   | Chunk                                    | fine silicic tuff   | 8.8          | 8.9     | 7.3     | 0.6       |
| H3253    | 1995 | U/S   | Flake fragment                           | Crystal lithic tuff | 14.3         | 10.6    | 4       | 0.5       |
| H3254    | 1995 | U/S   | Chip                                     | fine silicic tuff   | 5.1          | 3.6     | 2.6     | <0.1      |
| H3263    | 1995 | 38    | Core fragment                            | Flint               | 14.4         | 17.8    | 8.5     | 1.6       |
| H3267    | 1995 | 20    | Spall                                    | Rhyolitic tuff      | 7            | 6.8     | 2.3     | <0.1      |
| H3269    | 1995 | 23    | Spall                                    | Flint               | 4.7          | 4.6     | 1.3     | <0.1      |
| H3270    | 1995 | 20    | Spall                                    | Flint               | 4.1          | 3.3     | 1.8     | <0.1      |
| H3271    | 1995 | 20    | Chip                                     | Rhyolitic tuff      | 3.7          | 2.4     | 0.8     | <0.1      |
| H3272    | 1995 | 20    | Artefact fragment                        | ? Flint             | 8.5          | 7.6     | 5.5     | 0.3       |
| H3273    | 1995 | 20    | Spall                                    | Flint               | 9.4          | 6.1     | 1.4     | 0.1       |
| H3276    | 1995 | 23    | Chunk                                    | Flint               | 7.7          | 8.7     | 6.5     | 0.5       |
| H3277    | 1995 | 23    | Flake fragment                           | Rhyolite lava       | 12.2         | 10.4    | 4.2     | 0.6       |
| H3278    | 1995 | 41    | chunk                                    | fine silicic tuff   | 7.7          | 8.2     | 5.9     | 0.4       |
| H3279    | 1995 | 24    | Spall                                    | Flint               | 7.5          | 4       | 3       | 0.1       |
| H3282    | 1995 | 41    | Flake Fragment                           | Flint               | 8.8          | 7.6     | 2.6     | 0.2       |
| H3286    | 1995 | 29b   | 2 Chips                                  | Flint               | 2            | 2       | 1       | <0.1      |
| H3287    | 1995 | 29b   | Artefact fragment                        | Flint               | 3.4          | 4.4     | 2.3     | <0.1      |
| H3289    | 1995 | 33    | Chip                                     | Flint               | 4.1          | 4.9     | 1.7     | <0.1      |
| H3291    | 1995 | 34    | chip                                     | Rhyolitic tuff      | 7            | 4.6     | 4.3     | 0.1       |
| H3293    | 1995 | 34    | Chip                                     | Flint               | 7.6          | 3.4     | 3.5     | <0.1      |
| H3294    | 1995 | 34    | Chunk                                    | Flint               | 10.5         | 5.9     | 5.2     | 0.2       |
| H3295    | 1995 | 34    | Spall                                    | Flint               | 5.6          | 5.6     | 1       | <0.1      |
| H3296    | 1995 | 34    | Spall                                    | Flint               | 4.5          | 4.2     | 1.2     | <0.1      |
| H3301    | 1995 | 33    | Spall                                    | Flint               | 3.6          | 3.5     | 1.5     | <0.1      |
| H3302    | 1995 | 34    | Core fragment                            | Flint               | 11.7         | 9.8     | 6.1     | 0.6       |
| H3304    | 1995 | 34    | Artefact chip                            | Chert               | 5            | 4       | 1.7     | <0.1      |
| H3307    | 1995 | 29b   | ? Artefact chip                          | Flint               | 3.9          | 3.5     | 2       | <0.1      |
| H3309    | 1995 | 29b   | Chunk                                    | fine silicic tuff   | n/a          | n/a     | n/a     | <0.1      |
| H3311    | 1995 | 34    | Chip                                     | Flint               | 7            | 3.8     | 2.2     | <0.1      |
| H3317    | 1995 | 24    | Spall                                    | Flint               | 5.1          | 5.1     | 1.2     | <0.1      |
| H3319    | 1995 | 24    | Flake fragment                           | FP lava             | 6.8          | 13.5    | 3.4     | 0.3       |
| H3321    | 1995 | 23    | Chip                                     | Flint               | 8.2          | 4       | 2.5     | <0.1      |
| H3322    | 1995 | 23    | Chip                                     | Flint               | 5.4          | 2.8     | 2.1     | <0.1      |



### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No. | Year | Layer | Type Name         | Raw Material               | Measurements |         |         |           |
|----------|------|-------|-------------------|----------------------------|--------------|---------|---------|-----------|
|          |      |       |                   |                            | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H3323    | 1995 | 23    | Chip              | tuff                       | 9            | 4.6     | 2.1     | <0.1      |
| H3330    | 1995 | 23    | Denticulate       | Flint                      | 17.5         | 23.5    | 5.1     | 1.7       |
| H3335    | 1995 | 24    | Flake fragment    | sandstone (tuff.)          | 11.1         | 16.2    | 5.3     | 0.6       |
| H3339    | 1995 | 41    | Chip              | Flint                      | 4.8          | 4.7     | 2       | <0.1      |
| H3342    | 1995 | 41    | Chip              | Flint                      | 3.6          | 4.5     | 2.1     | <0.1      |
| H3346    | 1995 | 24    | Spall             | Flint                      | 5.8          | 3.9     | 2.2     | <0.1      |
| H3348    | 1995 | 24    | Spall             | Flint                      | 5            | 3.8     | 2       | <0.1      |
| H3352    | 1995 | 24    | Spall             | Flint                      | 3.1          | 3.1     | 2.1     | <0.1      |
| H3353    | 1995 | 24    | Flake fragment    | Flint                      | 6.5          | 10.9    | 3.7     | 0.1       |
| H3354    | 1995 | 24    | Flake fragment    | Flint                      | 18.6         | 19.2    | 8.2     | 2.6       |
| H3359    | 1995 | 24/26 | Notch             | Rhyolitic tuff             | 28.5         | 26.7    | 7.4     | 6.4       |
| H3367    | 1995 | 26    | Chip              | limestone                  | 5.1          | 7.5     | 2.2     | <0.1      |
| H3369    | 1995 | 23    | Flake             | Flint                      | 21.5         | 12.5    | 5.4     | 1.6       |
| H3372    | 1995 | 26    | Spall             | Flint                      | 3.1          | 9       | 3.1     | <0.1      |
| H3373    | 1995 | 26    | ? Chip or natural | Flint                      | 10.5         | 5.3     | 4.2     | 0.2       |
| H3374    | 1995 | 23    | refit with H3142  | Pumice crystal lithic tuff |              |         |         |           |
| H3375    | 1995 | 24    | Spall             | Flint                      | 9.3          | 7.4     | 3.5     | 0.2       |
| H3378    | 1995 | 26    | Chip              | Flint                      | 7.8          | 5.5     | 2.9     | 0.1       |
| H3383    | 1995 | 24/26 | Flake fragment    | Fine silicic tuff          | 17           | 17.5    | 5       | 1.6       |
| H3385    | 1995 | 24    | Spall             | Flint                      | 6.9          | 5.4     | 2.6     | 0.1       |
| H3394    | 1995 | 24    | Spall             | Flint                      | 6.3          | 4.7     | 2.3     | 0.1       |
| H3395    | 1995 | 24    | Spall             | Flint                      | 4            | 3.2     | 1.8     | <0.1      |
| H3400    | 1995 | 23    | Chip              | Silicic tuff               | 4.5          | 7.7     | 1.5     | <0.1      |
| H3402    | 1995 | 26    | Flake fragment    | Sandstone, tuff.           | 19.3         | 15.5    | 7.5     | 2.2       |
| H3403    | 1995 | 26    | Flake fragment    | Flint                      | 27.3         | 37.6    | 5.4     | 4.7       |
| H3405    | 1995 | 24    | Denticulate       | Fine silicic tuff          | 36           | 31.7    | 8.1     | 10.5      |
| H3408    | 1995 | 24    | Spall             | Flint                      | 5.7          | 4.7     | 1       | <0.1      |
| H3410    | 1995 | 23/24 | Chip              | Ignimbrite                 | 5            | 4.5     | 2.6     | <0.1      |
| H3411    | 1995 | 23/24 | Spall             | Flint                      | 6.2          | 7.4     | 1.9     | 0.1       |
| H3414    | 1995 | 26    | Artefact          | Quartz                     | 25.3         | 39.2    | 17      | 18.1      |
| H3415    | 1995 | 26    | Chip              | Flint                      | 6.8          | 4.2     | 2.1     | <0.1      |
| H3418    | 1995 | 26    | Chip              | Flint                      | 5.2          | 4.1     | 2.3     | <0.1      |
| H3419    | 1995 | 26    | Chip              | Flint                      | 5.6          | 4.5     | 2.3     | <0.1      |
| H3420    | 1995 | 24    | Spall             | Flint                      | 7.4          | 4.9     | 1.7     | <0.1      |
| H3423    | 1995 | 26    | Chip              | Flint                      | 3.8          | 4       | 2.7     | <0.1      |
| H3425    | 1995 | 26    | Chip              | Flint                      | 5.4          | 2.7     | 1.6     | <0.1      |
| H3429    | 1995 | 26    | Chip              | Flint                      | 4.2          | 3.5     | 1.8     | <0.1      |
| H3433    | 1995 | 24/26 | Flake fragment    | Flint                      | 11.8         | 6.2     | 3.1     | 0.2       |
| H3435    | 1995 | 38    | Spall             | Crystal tuff               | 8            | 6.3     | 2.3     | 0.1       |
| H3436    | 1995 | 38    | Chip              | Flint                      | 3.8          | 3.8     | 1.5     | <0.1      |
| H3437    | 1995 | 24    | Flake fragment    | FP lava                    | 43.1         | 17.5    | 7.5     | 6.6       |
| H3440    | 1995 | 24    | Spall             | Ignimbrite                 | 11           | 4.8     | 3.1     | 0.1       |
| H3441    | 1995 | 24    | Flake fragment    | Ignimbrite                 | 16.5         | 17      | 4       | 1.2       |
| H3443    | 1995 | 24    | Spall             | Flint                      | 3.1          | 2.6     | 1.6     | <0.1      |
| H3444    | 1995 | 24    | Flake             | Sandstone                  | 16           | 17      | 7.5     | 2.4       |

### Appendix 3.1. Pontnewydd Cave Artefact Database

| Find No.   | Year | Layer | Type Name                    | Raw Material            | Measurements |         |         |           |
|------------|------|-------|------------------------------|-------------------------|--------------|---------|---------|-----------|
|            |      |       |                              |                         | L (mm)       | Br (mm) | Th (mm) | Weight(g) |
| H3446      | 1995 | 24    | Core Fragment                | Flint                   | 8.1          | 6.4     | 5.6     | 0.3       |
| H3447      | 1995 | 24    | Spall                        | Flint                   | 4.1          | 7.2     | 2.1     | <0.1      |
| Unnumbered |      |       | Natural                      | fine silicic tuff       | n/a          | n/a     | n/a     | 4.1       |
| 68.88/1    |      |       | Flake                        | Rhyolite                | 37.8         | 57.3    | 16.9    | 29.1      |
| 68.88/2    |      |       | Transverse Scraper           | fine silicic tuff       | 50.2         | 67.8    | 18      | 66.2      |
| 68.88/3    |      |       | Flake                        | Ignimbrite              | 43.8         | 29.6    | 10.4    | 13.7      |
| 68.88/5    |      |       | Single straight side scraper | Carboniferous chert     | 41           | 25      | 10.1    | 13.2      |
| 68.88/6    |      |       | Flake                        | Non-carboniferous chert | 38.1         | 18      | 8.7     | 5.6       |
| 68.88/7    |      |       | Flake                        | Sandstone               | 29.9         | 35.7    | 10.7    | 9         |
| Z1         |      |       | Flake fragment               | Flint                   | 21.6         | 17.4    | 5.6     | 1.4       |
| Z2         |      |       | Crude core                   | Flint                   | 54.3         | 48.5    | 25.7    | 81.7      |



| <b>Appendix 3.2</b>  |             |            |                |            |
|--|-------------|------------|----------------|------------|
| Measurements from a replica handaxe made on Rhyolitic tuff by T.Ace, 1999. |             |            |                |            |
| Flake shape  | Length (mm) | Width (mm) | Thickness (mm) | Weight (g) |
| Handaxe  | 137         | 78.8       | 46.4           | 665.9      |
| Large cortical flake   | 119         | 67.7       | 29             | 229.4      |
| Large flake  | 105         | 78.3       | 32.3           | 210.5      |
| Large angular flake  | 94.2        | 51.8       | 28.5           | 118.52     |
| Angular, square  | 67.8        | 47         | 22.35          | 81.4       |
| Angular, pointed   | 82.5        | 61.3       | 19.42          | 71.23      |
| Long, broad  | 73.3        | 45.4       | 17.33          | 45.81      |
| Long, broad, pointed   | 63.6        | 32.9       | 13.28          | 26.61      |
| Large angular  | 65.6        | 38         | 12.09          | 24.04      |
| Broad, triangular  | 33.6        | 32.4       | 17.41          | 19.14      |
| Short, square  | 47.8        | 26.9       | 12.08          | 18.96      |
| Broad, rounded   | 39.3        | 29.2       | 13.41          | 18.32      |
| Broad, pointed   | 44.6        | 27.2       | 17.01          | 14.6       |
| Long   | 40.9        | 24.4       | 12.37          | 14.23      |
| Long, pointed  | 41.6        | 27.1       | 12.35          | 12.65      |
| Thin, long   | 44.5        | 19.2       | 9.35           | 10.76      |
| Long, thin, pointed  | 47.5        | 37.9       | 11.23          | 10.6       |
| Rounded, flat  | 39.4        | 34.5       | 8.32           | 10.55      |
| Long flat  | 51.4        | 27.4       | 7.19           | 10.02      |
| Pear-shaped  | 41.6        | 31.5       | 8.11           | 9.14       |
| Small, pointed   | 33.4        | 27.5       | 9.26           | 8.98       |
| Angular, pointed   | 44.6        | 27.9       | 10.21          | 8.53       |
| Rounded  | 31          | 28.1       | 8.38           | 8.45       |
| Short, pointed   | 42          | 28.9       | 8.05           | 7.38       |
| Small, rounded   | 36.4        | 26.3       | 8.01           | 6.46       |
| Flat, sub-angular  | 33          | 25.1       | 7.08           | 6.11       |
| Triangular, pointed  | 36.3        | 29         | 10.24          | 5.91       |
| Short, pointed   | 32.6        | 21.3       | 6.44           | 5.2        |
| Square   | 28.3        | 22.9       | 6.32           | 4.39       |
| Rounded  | 26.8        | 21         | 9.2            | 4.21       |
| Small, flat, round   | 29.9        | 25.9       | 5.43           | 3.68       |
| Small, angular   | 20.8        | 28         | 6.18           | 2.46       |
| Small, pointed   | 23.4        | 17.8       | 6.3            | 2.35       |
| Very small   | 21.5        | 14.6       | 6.47           | 1.67       |
| Jagged, flat pointy  | 24.3        | 26.7       | 4.44           | 1.65       |
| Small, thin, flat  | 19.9        | 16.8       | 5.48           | 1.26       |
| Bag of small flakes  | -           | -          | -              | 50.52      |
|  |             |            | Total Wt (g)   | 1751.59    |

| Sample  | PN15*                                  | PN16                                       | PN17  | PN18  | PN19                             | PN20*                         |
|---|--|--|---|---|----------------------------------|-------------------------------|
| Date  | 1982                                   | 1982                                       | 1982  | 1982  | 1982                             | 1982                          |
| Site  | D (north)                              | D (north)                                  | D (north)   | D (north)                                   | D (north)                        | D (north)                     |
| Layer   | Lower Breccia (a)                      | Lower Breccia (b)                          | Lower Breccia (c)   | Lower Breccia (c)                           | Buff Intermediate (a)            | Buff Intermediate (b)         |
| Zircon  | y                                      | Colourless euhedral or pink rounded        | Euhedral  | Colourless subrounded, yellow,              | Colourless, yellow & pink        | y                             |
| Rutile  | Yellow & Pink/blue-black, yellow/brown | y Subhedral blue, pink/green, straw/brown  | y Dark green/pale green, blue/cless, brown/black, straw/brown | y Green/black, blue/colourless, straw/brown | y Pink-brown/black & straw-brown | y Straw/brown & cless/green   |
| Anatase   | n                                      | y  | y   | y   | n                                | y                             |
| Brookite  | n                                      | n  | n   | n   | n                                | n                             |
| Titanite  | n                                      | y  | n   | y   | n                                | n                             |
| Apatite   | Bone noted                             | y  | y   | y   | y                                | Bone present                  |
| Garnet  | y                                      | Colourless etched                          | y   | Some euhedral                               | Small, pale pink                 | Pink or cless                 |
| Clinop yx   | y                                      | Pale brown, green & colourless, all etched | Titanaugite, etched   | Augite, etched                              | y                                | y                             |
| Clin ozois ite  | y                                      | y  | High %  | High %                                      | y                                | y                             |
| Amphi bole  | y                                      | Dark blue-green/green                      | Green   | Straw/green-brown, blue-green/yellow-green  | Brown & blue-green/green         | Colourless & blue-green/green |
| Epidote   | y                                      | y  | y   | y   | y                                | y                             |
| Pale  | y                                      | Dominant                                   | y   | y   | Fretted edges                    | y                             |
| Dk chl.   | y                                      | n  | y   | y   | n                                | y                             |
| Gl-phane  | n                                      | n  | n   | n   | n                                | n                             |
| Chloritoid  | n                                      | n  | n   | n   | n                                | n                             |
| Staurolite  | n                                      | y  | y   | n   | n                                | n                             |
| Kyanite   | n                                      | y  | n   | n   | y                                | n                             |
| Andalusite  | n                                      | n  | n   | n   | n                                | n                             |
| Orthopyx.   | n                                      | n  | n   | n   | n                                | n                             |
| Glauconite  | n                                      | n  | n   | n   | n                                | n                             |
| Others  | n                                      | n  | Zoisite   | Monazite, euhedral quartz                   | Monazite                         | n                             |
| Ferric oxides   | Magnetite                              | 32.4% opaques                              | 48.9% opaques   | 35.5% opaques                               | 45.5% opaques                    | y                             |
| Comments  | No sample available                    | High % bone, excluded from % calculation   | 50% bone overall, excluded from % calculation                 | High % bone, excluded from % calculation    |                                  | No sample available           |
| <i>*denotes samples not described in this study, descriptions from DA Jenkins</i> |  |  |   |   |                                  |                               |



| Sample   | PN22  | PN24*                      | PN25*   | PN26   | PN27                                 |
|--|---|----------------------------|---|--|--------------------------------------|
| Date   | 1982  | 1982                       | 1982  | 1982   | 1982                                 |
| Site   | D (north)   | D (north)                  | D (north)   | D (north)  | D (north)                            |
| Layer  | Dark red silt,<br>Intermediate                            | Buff Int.                  | Dark red silt,<br>Intermediate                    | Orange Intermediate  | Orange Intermediate                  |
| Zircon   | y   | y                          | Cless & rarely<br>pink                            | Euhedral   | Subrounded cless &<br>pink           |
| Rutile   | y   | y                          | y   | y  | Yellow                               |
| Tourmaline   | Straw/brown,<br>colourless/green,<br>pink/blue-black      | y                          | Cless/blue,<br>pink/dark<br>green, straw<br>brown | 25% pink/dark green,<br><br>75% pale/brown                           | Brown/green &<br><br>pink/dark green |
| Anatase  | y   | n                          | Yellow, blue                                      | y  | n                                    |
| Brookite   | n   | n                          | n   | n  | n                                    |
| Titanite   | n   | n                          | n   | n  | n                                    |
| Apatite  | y   | y                          | y   | y  | Yellow                               |
| Garnet   | y   | y                          | y   | y  | Colourless, some                     |
| Clinop<br>zois<br>ite<br>yx  | y   | y                          | y   | 5% pale green &<br>etched, 90% pale<br>brown & v.etched, 5%          | Etching - slight to<br>skeletal      |
| Clin<br>zois<br>ite  | Slightly etched, large,<br>clear, colourless              | y                          | y   | y  | High %                               |
| Amphi<br>bole  | Dark green/pale green,<br>green/brown, slightly<br>etched | Brown (1 on<br>DAJ scale)  | Green (2 on<br>DAJ scale),<br>brown (2 on         | 48% pale green/brown, y<br>21% pale/dark green,<br>3% blue/green, 8% |                                      |
| Epidote  | y   | y                          | y   | y  | y                                    |
| Pale   | Good condition  | y                          | y   | 8% oxidised margins  | Fretted edges                        |
| Dk chl.  | n   | y                          | y   | n  | y                                    |
| Gl-phane   | n   | n                          | n   | n  | n                                    |
| Chloritoid   | n   | n                          | n   | n  | n                                    |
| Staurolite   | n   | y                          | n   | y  | y                                    |
| Kyanite  | n   | y                          | y   | y  | y                                    |
| Andalusite   | n   | n                          | n   | n  | n                                    |
| Orthopyx.  | n   | n                          | n   | n  | n                                    |
| Glauconite   | n   | n                          | n   | n  | n                                    |
| Others   | Etched calcite, quartz                                    | n                          | n   | n  | n                                    |
| Ferric<br>oxides   | 68.8% opaques, high<br>% reddish brown                    | y                          | y   | 51.5% opaques  | 69.3% opaques                        |
| Comments   |   | No sample<br><br>available | No sample<br><br>available                        | 6% aggregates  | aggregates 5%                        |
| *denotes samples not described in this study, descriptions from DA Jenkins |   |                            |   |  |                                      |

| Sample                | H1716                           | H1717  | H1718  | H1719                                    | H1720  |
|-----------------------|---------------------------------|--|--|--|--|
| Date                  | 1989                            | 1989   | 1989   | 1989                                     | 1989   |
| Site                  | H                               | H  | H  | H  | H  |
| Layer                 | Layer 35                        | Layer 29   | Layer 28   | Layer 26                                 | Layer 24   |
| Zircon                | Subhedral                       | y  | Subhedral colourless & pink                                    | Colourless & pink                        | Euhedral cless, rounded pink or large                |
| Rutile                | y                               | Golden-yellow  | Red & orange   | y  | Yellow & red   |
| Tourmaline            | Pink/dark green, straw/brown    | Euhedral blue/ brown zoned, dark green/pink, round straw/brown | Straw/brown, pink/ dark green, blue-brown twinned, green/black | Blue, straw/brown, pink/dark green       | Cless/blue, pink/dark green, straw/brown, blue/brown |
|                       | Anatase                         | Blue or grey green   | Angular yellow, y  | y  | y  |
| Brookite              | n                               | n  | n  | n  | y  |
| Titanite              | n                               | y  | y  | y  | n  |
| Apatite               | y                               | 8.8% bone  | 21.3% bone   | 23.2% bone                               | 20.1% bone   |
| Garnet                | Pink                            | Rounded pink &   | y  | y  | y  |
| Clinop<br>zois<br>ite | Green, few etched grains        | Dusty-brown, colourless or green                               | Small etched & large green unetched                            | Colourless or etched dusty brown         | Bubbly' colourless or dusty brown                    |
|                       | y                               | y  | y  | y  | y  |
| Amphibole             | Green/blue-green                | Bright green/green-brown, pale green/ blue-green, brown        | Fresh looking hornblende                                       | Blue-green/yellow-green, or ragged brown | Colourless, green & weathered brown                  |
| Epidote               | Large                           | y  | y  | y  | y  |
| Pale                  | Oxidised margins                | y  | y  | y  | y  |
| Dk chl.               | n                               | n  | n  | y  | y  |
| Gl-phane              | n                               | n  | n  | n  | n  |
| Chloritoid            | n                               | n  | y  | n  | n  |
| Staurolite            | n                               | y  | n  | n  | n  |
| Kyanite               | n                               | n  | n  | n  | n  |
| Andalusite            | n                               | y  | n  | n  | n  |
| Orthopyx.             | n                               | y  | n  | n  | n  |
| Glauconite            | n                               | n  | n  | n  | n  |
| Others                | Biotite                         | Zoisite  | Zoisite  | n  | n  |
| Ferric oxides         | Much Fe staining, 63.8% opaques | 63.7% opaques  | 54.4% opaques  | 43.8% opaques, bone Fe stained           | 48.8% opaques  |
| Comments              | 18.3% murky                     | 17.6% murky  | 13.4% murky  | 8% crystalline                           | 8.5% murky unknown                                   |
|                       | unknown minerals                | unknown minerals   | unknown minerals   | rhyolitic aggregates                     | minerals   |



| Sample  | H1721               | PN51                                 | PN52                     | PN53                                       | PN54   |
|---|---------------------|--------------------------------------|--------------------------|--|--|
| Date  | 1989                | 1998                                 | 1998                     | 1998                                       | 1998   |
| Site  | H                   | F (north)                            | F (north)                | F (north)                                  | F (north)  |
| Layer   | Layer 23            | Intermediate                         | Lower Breccia (c)        | Silt deposit                               | Upper Breccia  |
| Zircon  | y                   | Colourless                           | y                        | Pink & yellow                              | Subhedral colourless                                       |
| Rutile  | y                   | y                                    | y                        | y  | y  |
| Tourmaline  | y                   | Rounded straw/brown, pink/dark green | Blue/cless & brown/cless | Straw/brown, colourless/blue & pink        | Pink/dark green & straw/brown                              |
| Anatase   | y                   | n                                    | n                        | y  | y  |
| Brookite  | n                   | n                                    | n                        | y  | n  |
| Titanite  | n                   | y                                    | n                        | n  | y  |
| Apatite   | y                   | Fe stained                           | 14.9% bone               | y  | y  |
| Garnet  | y                   | y                                    | y                        | Etched pink                                | y  |
| Clinop yx   | y                   | Pale green etched                    | y                        | Dark green/brown & colourless, both etched | 0.2% aegerine augite, 0.4% dusky brown, both highly etched |
| Clin ozois ite  | y                   | y                                    | y                        | y  | Twinned colourless   |
| Amphi bole  | y                   | Pale green/brown                     | y                        | Blue-green/green                           | Green, colourless, 0.4% total brown                        |
| Epidote   | y                   | y                                    | y                        | y  | y  |
| Pale  | y                   | y                                    | y                        | Dominant                                   | y  |
| Dk chl.   | y                   | y                                    | n                        | y  | y  |
| Gl-phane  | n                   | n                                    | n                        | n  | n  |
| Chloritoid  | n                   | n                                    | n                        | y  | n  |
| Staurolite  | n                   | n                                    | n                        | y  | y  |
| Kyanite   | y                   | n                                    | n                        | y  | n  |
| Andalusite  | n                   | n                                    | n                        | n  | n  |
| Orthopyx.   | n                   | n                                    | n                        | Etched                                     | n  |
| Glauconite  | n                   | n                                    | n                        | n  | n  |
| Others  | n                   | n                                    | n                        | Zoisite                                    | n  |
| Ferric oxides   | y                   | Haematite, 78.1% opaques             | 48.6% opaques            | 20.6% opaques                              | 64.3% opaques  |
| Comments  | No sample available | 8% fine grained silicic aggregates   | 4.3% aggregates          |  |  |
| <i>*denotes samples not described in this study, descriptions from DA Jenkins</i> |                     |                                      |                          |  |  |

| Sample        | PN55                                    | PN56   |
|---------------|---|--|
| Date          | 1998                                    | 1998   |
| Site          | F (north)                               | F (north)  |
| Layer         | Upper Clays and Sands (Red Cave Earth?) | Upper Clays and Sands, top of layer  |
| Zircon        | Colourless, euhedral & rounded          | Euhedral colourless, yellow & pink   |
| Rutile        | Yellow & red                            | y  |
| Tourmaline    | Pale green/dark green                   | Colourless/blue, bright blue, pale green/dark green, colourless/ brown, straw/brown & pink/green |
| Anatase       | Blue                                    | y  |
| Brookite      | n                                       | y  |
| Titanite      | y                                       | n  |
| Apatite       | y                                       | y  |
| Garnet        | Colourless & pink                       | y  |
| Clinopyroxene | Pale green & pink-brown etched          | y  |
| Clinopyroxene | y                                       | y  |
| Amphibole     | Brown & green                           | Green-blue, pale green/dark green & brown/green  |
| Epidote       | y                                       | Large  |
| Pale          | y                                       | Dominant   |
| Dk chl.       | y                                       | y  |
| Gl-phane      | n                                       | n  |
| Chloritoid    | n                                       | n  |
| Staurolite    | y                                       | y  |
| Kyanite       | y                                       | y  |
| Andalusite    | n                                       | y  |
| Orthopyx.     | y                                       | y  |
| Glauconite    | n                                       | n  |
| Others        | n                                       | Zoisite  |
| Ferric oxides | 62.9% opaques                           | 21.5% opaques  |
| Comments      | Similar to PN5a                         |  |
|               |   |  |



Aldhouse-Green, S., Jackson, H. & Young, T. Lithics, raw materials and ochre: interrogation of data from the Middle Pleistocene hominid site of Pontnewydd Cave, Wales, Europe. In E. Walker, F. Wenban-Smith and F. Healy (eds) *Lithic Studies in the Year 2000*. London: Lithic Studies Society.

## **Lithics, raw materials and ochre: interrogation of data from the Middle Pleistocene hominid site of Pontnewydd Cave, Wales, Europe**

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### **Abstract**

Pontnewydd Cave was visited by early Neanderthals on one or more occasions towards a quarter of a million years ago. They left behind a hard rock industry, in which flint is only a minor component. The present paper reviews both the suite, or suites, of raw materials used by the early hominids and assemblage compositions in the Main Cave and New Entrance to enquire whether these assemblages may represent separate events. A further question concerns that of modern behaviours. Pontnewydd presents evidence for several such behaviours. Here the evidence for possible symbolic expression, in the form of the presence of ochre as a potential colorant, is considered.

### **The Research Context**

This paper is in part a reflection on aspects of an earlier paper on raw material selection at Pontnewydd (Green 1988), in part an *esquisse préliminaire*<sup>1</sup> looking forward to the final monograph. It is one of three generated by a presentation to the Lithic Studies Society's millennium conference (Aldhouse-Green 2001a-b). Our purpose here is to deal primarily with matters lithic. A brief word is necessary, however, to set Pontnewydd within the context of its wider research project, 'Hunters at the Periphery of the Pleistocene World', and of changing discourses in the later Pleistocene. Fieldwork at Pontnewydd began in autumn 1978 and ended in the summer of 1995. During that same year, the 1960s excavations of Charles McBurney and John Clegg at Coygan were published (Aldhouse-Green *et al* 1995). The following year saw the completion of work on the Pembrokeshire caves of Hoyle's Mouth and Little Hoyle. A season of work at Goat's Hole, Paviland, in 1997, led to the publication of a definitive monograph on that site (Aldhouse-Green (ed) 2000). The final monograph on Pontnewydd is now in active preparation.

When work began at Pontnewydd, the study of the earlier palaeolithic was becoming greatly influenced and changed by the impact both of new dating techniques and of taphonomic studies. Handaxes had, however, become less matters of style than

lumps of rock responding to raw material constraints. All that is now beginning to change and handaxes 'of deliberately imposed form' are being restored, at least in some cases, as the conscious products of self-aware human groups (White 1998; Wenban-Smith 2000). Paradoxically, we have a growing problem with identifying constructed shelters -- none can be relied upon in Europe before the Gravettian it seems -- but John Wymer is giving some of us confidence to challenge that view (Kolen 1999; Mussi *et al.* 2000, 1; Wymer 1999, 36). More important still is the recognition, at least by African archaeologists, that people developed modern human behaviours over a period of perhaps 300,000 years and that the Upper Palaeolithic creative explosion, so strongly characterised by the appearance of art and so beloved of European archaeologists, may have been no more than a local socio-ecological event (Zilhão 2001: 40 and *passim*). The question is not, however, whether we should seek, in the behaviours of the Upper Palaeolithic, patterns of humanity comparable to those of the modern or recent non-Western world, but how far we may be able to perceive such behavioural patterns in the Middle Stone Age/Middle Palaeolithic of Africa, Europe and Asia (Barham 2000; Barham and Robson-Brown *in press*; McBrearty and Brooks 2000; Aldhouse-Green 2001b). One such behaviour involves the early use of coloured pigments before 200,000 years ago. Until AD 2000 we had not recognised these at Pontnewydd. However, in that year a search was made for ochres in the site's lithic archive and a number of pieces were located. As we write, their interpretation remains ambiguous but a more comprehensive review of the site's petrological collection is shortly to be made.

### **Hominid presence at Pontnewydd**

Pontnewydd Cave occupies a geographical position on the periphery of the Pleistocene world. It is special in other ways, too. These include not just its remoteness but also its isolation; its hard rock industry; and above all its remains of early Neanderthals. All of the archaeological and hominid finds were emplaced by debris flows (table 1). The range of artefacts present includes handaxes, Levallois flakes, blades and points, and a limited range of types of transverse scraper (Green 1984). There is evidence of the selection of raw materials for particular artefact types and of curation (Green 1988). A major question for the final monograph is the unravelling of how many phases of occupation there may have been and over what period. Can we really distinguish such phases of hominid presence in the differing assemblages of the Main Cave and the New Entrance (Aldhouse-Green 1998), and does the Main Cave assemblage itself represent a single 'event' or, indeed, a complex of events?

### **Raw Materials and artefacts**

The raw materials used at the site (Bevins 1984; Clayton 1984) are all allochthonous and have probably reached the cave or its vicinity through the processes of glacial, periglacial and fluvial transport. The lithologies are very similar to those in unworked specimens in the cave deposits, and these in turn closely match the Ordovician rocks in Snowdonia, the Arenig Mountains of Gwynedd and those exposed in some areas of the Lake District. The raw material was obtained in the form of cobbles not normally greater than 25-30 cm in diameter.

### **Petrology and mineralogy**

The assemblage from Pontnewydd requires petrological examination to provide an



accurate identification of the material and its provenance. The raw materials used are silicic volcanic rocks that suffered low-grade metamorphism and deformation during the Caledonian Orogeny. As a consequence they have developed a variable fabric, which has had a greater impact on some original rock types than others. The rocks were therefore classified in a manner that, whilst broadly in line with standard IUGS nomenclature, took into account the impact of this alteration. This classification scheme should enable the maximum information to be derived from the artefacts.

In addition, after the material had been discarded by the hominids, it was subjected to transport -- and, so, potentially to damage -- within debris flows and to post-emplacement solutional rounding. In consequence, most of the artefacts have acquired weathered surfaces additional to the cortical surfaces already present, further complicating identification from hand specimens alone.

### **Choice of rock type**

The choice of rock type is dependent upon three main factors: its suitability for the purpose, the ease with which it can be worked, and its availability. Not all the erratics that occur in drift in the Elwy Valley area were used for artefact manufacture. Those avoided include local limestones and shales, weak weathered granites and some basic rocks, which would have been unsuitable for knapping. An element of selection has therefore been exhibited.

The physical properties of the rock determine how well a sharp cutting edge will be retained, or how long a hammerstone may stand up to repeated impacts. Stones that fracture conchoidally are the most desirable for flaking, and fracture is influenced by the percentage of silica within a raw material; for example, flint (100% silica) fractures conchoidally. The second desirable feature in a raw material is its homogeneity. A homogenous rock lacks differences in texture, cracks, planes, flaws and other obstacles to the forces of impact that pass through the material. The best rocks for knapping are therefore usually cryptocrystalline in nature, as in theory larger crystals will divert the impact force from its path. Rocks must also contain a degree of elasticity in order to carry the force through the body of material and produce a flake. Even within petrological categories, the suitability of rocks for knapping may be highly variable, depending on their homogeneity, any metamorphism that they may have suffered, and the extent to which they have been weathered. The final choice of material is often a compromise as the most durable rock may also be the hardest to work.

### **Choice of raw material in the Elwy Valley**

Chi2 analysis has shown that raw materials were not used equally for all artefact types, and that the proportion of raw material used for each typology does not parallel the total use of that raw material throughout the assemblage. Both handaxes and flakes had significantly different profiles of rock use to the majority of other artefacts and in general, handaxes were preferentially made on FP lava, rhyolite lava and crystal lithic tuff, the rock types that on the basis of geological considerations should allow for the least refinement. Chi2 analysis also showed that cores and Levallois flakes showed significant differences in their profiles of rock use to the rest of the assemblage. Cores have been made on greater quantities of ignimbrite, the most highly silicic of the non-flint materials in the assemblage, but also the hardest to work. Were these cores abandoned attempts at producing artefacts, or the result of



a functional need to produce durable utilizable flakes from a difficult raw material? Levallois flakes appear significantly different because of the use of two less common rock types, crystal tuff and microdiorite. These rocks are less silicic than many of the other materials but are extremely homogenous, and seem to have suffered less internal weathering than some of the others. Indeed, in an informal knapping experiment, crystal tuff proved the most desirable of the available materials. Overall, discussion of the macroscopic trends in the assemblage and the chi2 analysis leads to the conclusion that there is a degree of selectivity in the rock types that are used for tool manufacture at Pontnewydd. Profiles of rock type use are confused by the dominance of rhyolite and ignimbrite in the assemblage, and the lack of appropriate data to facilitate the comparison of the whole assemblage with the rock types available in the local area at the time of the habitation of Pontnewydd Cave.

The physical properties of these raw materials, including silica content and homogeneity can be used to account for the profiles of rock use for different typologies as seen in this assemblage (see Fig 2). Whilst this interpretation necessitates a lumping together of the geological categories into larger groupings, it must be remembered that the Neanderthals did not have the benefit of a petrological microscope and that the visual appearance of both FP lava and rhyolite lava, and ignimbrite and rhyolitic tuff is almost identical.

### **Lithological influence on flake dimensions**

Having established a degree of selectivity in the raw materials, analysis of the measurements was undertaken in order to provide further clarification. It was hoped that the rock types would be clearly divisible on the basis of their mechanical attributes, for example the thickness, length and breadth of the artefacts produced. The variance about the mean of flint artefacts (as shown by the f-test), for all dimension measurements, was significantly different to all other raw materials. This was largely due to the very small size of many of the flint artefacts. The mean dimensions of artefacts of fine silicic tuff were significantly different to those of all other rock types (as shown by the t-test). Generally speaking this was also related to the relatively small size of artefacts of fine silicic tuff.

The feature that appears to divide the artefacts into the clearest groupings is that of thickness. It is also the category that provides groupings that are mirrored by the data obtained from examination of macroscopic trends as shown above. The rock types group together based on their mean thickness as shown in Fig.3.

### **Choice of blanks in the Elwy Valley**

Many of the artefacts at Pontnewydd show evidence of manufacture by striking flakes off pebbles, rather than angular blocks, and the shape of the blanks available must have played a part when deciding which materials to work. At La Riera in Spain pebble size seems to have affected the choice of raw material (Strauss 1980). White (1995) demonstrated that the shape of handaxes in southern Britain is largely dependent on the dimensions of the primary form of the raw materials i.e. the shape of the handaxe is determined by the shape and size of the blank. Ashton and McNabb (1994) were able to reconstruct the size and shape of large cutting tool blanks and therefore indicate to what extent this shape had affected the finished artefact. This is concurrent with the work of Fish (1979) who illustrated that the main constraint on



tool manufacture is blank sizes available, rather than raw materials present.

At Pontnewydd, fine silicic tuff occurs in tabular fragments, which provide the perfect blanks, whereas the majority of rhyolite available would have been in the form of glacially rounded boulders. The size of the rhyolite cobbles may have limited the possibilities for thinning and refining, resulting in thicker pieces (Maloney *et al.* 1988). When experimentally flaking both glacially weathered pebbles and river washed cobbles from the Pontnewydd area, one of the authors (HJ) found the rounded cobbles more homogeneous and lacking in flaws than those directly from the glacial drift. Perhaps the action of water has broken cobbles along lines of weakness highlighted during glacial transport, leaving relatively predictable cobbles. Certainly it is likely that rather than extracting materials directly from the glacial drift, cobbles would have been collected from talus slopes at the base of the limestone cliffs or stream-bed deposits. It is also worth remembering that the effects of solifluction processes, vegetation and snow cover would have made different areas within the Elwy valley suitable for collecting materials at different times of year.

Whether the raw materials at Pontnewydd derived directly from the glacial till or were collected from the banks of the river Elwy, it is clear that they would have been readily available within the local 'foraging radius' (Mellars 1996). This is consistent with the raw material procurement patterns on Middle Palaeolithic sites in southwestern France (Geneste 1988, Turq 1988) which reveal a strong predominance of material derived from very local sources. In addition, all stages of the lithic reduction sequence at Pontnewydd are represented, from the initial importation of cobbles to the production of finished tools. This indicates that knapping took place at the cave and is consistent with the use of raw materials derived from the most local foraging zone of 4-5km from the site (Geneste 1988). It is likely that cobbles were subjected to trial flaking before transportation back to the cave, because as with many glacially weathered rocks, it would be difficult to tell the texture from the outward appearance of a pebble.

Many experiments, both formal and informal have been conducted on the viability of non-flint materials for knapping (Newcomer 1984, Jones 1979, Maloney *et al.* 1988) and the influence of raw material on morphology in the Acheulian (Ashton and McNabb 1994, Clark 1980, Toth 1982, White 1995). Jones (1979) replicated handaxes and cleavers from the Olduvai Gorge and suggested that raw material fracture properties and least-effort flaking strategies influenced aspects of biface morphology. By making and then using, bifaces of basalt and phonolite, he indicated that hominids had responded to the raw material mechanical properties by varying the intensity of retouch performed on the raw materials. This had the result of making some of the artefacts appear 'cruder' than others, a point which is paralleled in the assemblage at Pontnewydd. Experiments by Newcomer (1984) seem to demonstrate that the raw materials at Pontnewydd did not limit the tool types present, rather they may have limited the possible levels of refinement.

The following trends were observed in percentage plots of the total data set of the Pontnewydd artefacts (figure 1):



### *Raw materials*

1 The rock types used in the greatest quantities are rhyolite and ignimbrite. It is not known whether this is a reflection of their availability in the local landscape, as no comparative external deposits have been (or can now be) studied. Previous studies (Livingston 1986) were not able to correlate any extant drift deposits with those from Pontnewydd Cave, and the inhomogeneity of the drift would also render such comparisons spurious. Analysis of exotic pebbles from the Upper and Lower Sands and Gravels provides a possible comparison (Bevins 1984).

2 The different rock types exhibit characteristic patterns of use:

**Flint** is mainly used for retouched flakes (17%), cores (17%) and miscellaneous artefact fragments (11%). At Pontnewydd, 10% of the worked material from the Main Cave is of flint but, in the New Entrance, the frequency is 20% (table 2; figure 2). The presence there of abundant small debitage, in contrast to the Main Cave, may arise from activity at a quite different date (Aldhouse-Green 1998, 140-41) or may reflect the likelihood that the bulk of the New Entrance deposits has not been moved far by natural agencies with consequential loss of the fines (Colcutt 1984, 76; D. Case & R. Mourné pers. comm.). Flint has been recovered from the basal units of the cave deposits and it may also have been available nearby in the Irish Sea drift (Clayton 1984) or the local river gravels, as many pieces show evidence of water transport. It is present also in the Green Silt layer in the nearby Cefn caves (Green 1986, 38-39; Green and Walker 1991, 44-47) in a pre-Ipswichian context.

**Siliceous sandstone and siltstone** are mainly used for discoidal cores (19%) and retouched flakes (11%).

**Ignimbrite** is mainly used for discoidal cores (14%), crude cores (14%) and retouched flakes (13%).

**Rhyolite** lava is predominantly used for handaxes (23%), Levallois flakes (19%) and cores (7%). Rhyolitic tuff is mainly used for handaxes (19%), and Levallois flakes (12%). **Feldspar-phyric lava** is mainly used for handaxes (19%), and Levallois flakes (11%).

**Crystal tuff** is mainly used for Levallois flakes (25%), retouched flakes (12%) and handaxes (12%).

**Crystal lithic tuff** is used mainly for handaxes (25%).

**Fine silicic tuff** is mainly used for retouched flakes (18%), Levallois flakes (16%), and tool reuse (12%).

### **Artefact types in the Main Cave and New Entrance**

It can be seen that raw materials differ between the Main Cave and the New Entrance (table 2; figure 1). However, they differ in detail also between the stratified areas of the Main Cave (sites B, C, D, F, of which B is closest to the entrance and F deepest into the system). Thus, commonest rocks used as raw materials for artefacts are: B/C -- fine silicic tuff; D -- rhyolitic tuff; F -- ignimbrite. The commonest rock type in the New Entrance is flint but this comprises mainly small debitage; otherwise the next three commonest rock types in descending order of frequency are rhyolitic tuff, ignimbrite and crystal tuff -- a result very similar to the range of the Main Cave. It is clear, however, that the taphonomic contexts of deposition of these two areas were different and this is undoubtedly a key factor in their differentiation. It will be interesting to map the changing hyperspatial (involving typology and biography) configurations of artefact-types and raw materials, as part of the ongoing research, to see whether inferences are possible regarding chronological or spatial variation in activities.



A review of the frequencies of artefact types in the Main Cave and New Entrance shows variation which may be explicable in terms of chronology, as proposed in Aldhouse-Green (1998, 140-41), but which may also be interpreted either in terms of spatial variation in activities or in stochastic terms, arising from the potentially complex taphonomic history of the debris flows from which the artefacts were recovered. Study of the different areas of the Main Cave (Table 3) shows a predictable variation which may be interpreted in the terms just adumbrated. The results are, however, more comparable than those between the Main Cave as a whole and the Main Cave and the New Entrance compared (Table 4). The chronological evidence, such as it is, would make sense of the New Entrance assemblage as a fully Middle Palaeolithic industry in which handaxes, if not actually derived, are relatively rare.

### **Reconnaissance search for haematite specimens amongst the lithics from Pontnewydd Cave**

All the residues from the Lower Breccia with a sieve size >9mm have been examined. None of these contained any "exotics", defined for working purposes on site as all rocks excluding limestone and mudstone. In addition, approximately 70% of the "exotics" collection has been examined, including any non-Lower Breccia material contained therein (table 5). The total yield of haematitic material with grain size greater than approximately 6mm was only 47.5g. Of this 3 pieces (4.6g) came from Upper Breccia, 1 piece (19.8g) from the Silt beds and 5 pieces from Lower Breccia (23.1g). In addition there were various smaller soft red grains from various contexts which were really too small for handlens identification .

The material could be divided into several petrographic types. The most important was a quartz-bearing haematite ore (34.7g total), but there were also iron oxides derived from oxidation of iron sulphides, and what appeared to be haematized sandstones. There was, in addition to the rest of the haematite material, one pebble of an Ordovician sedimentary ironstone, which could have been derived from Snowdonia or Anglesey (context: World War II dump). All the haematitic material occurred apparently as water-worn pebbles.

On casual inspection the origin of this material was not apparent; larger pieces would be required before the textures would be useful. Potential source areas include fissures and caves within the Carboniferous limestone of North Wales where Triassic/Jurassic haematites are locally developed (e.g. in Dyserth Quarry, 8km NE [SJ 062789] and Bodfari Quarry, 8km E [SJ 095702]). The distribution of such features outside the major quarries is currently not known, and would require some primary fieldwork to determine. Similar material could also be glacially-derived from Cumbria, where almost identical ores occur on the opposite side of the Morecambe Bay basin. It seems likely that these sources could be differentiated chemically in appropriate material, but there is little comparative data currently available (compared, for instance with the large body of data now constructed for the Bristol Channel Orefield). The small size of most of the pieces would make an analytical programme difficult, but by no means impossible.

Given the small size of the pieces<sup>2</sup>, their rounded pebble form, and the low-levels of abundance, there is no evidence as to whether these materials were, or were not, derived through human agency. The pilot study tells us that pigments were present but there is so far no evidence that they were introduced by humans. In order to determine whether this material may have been derived by human agency, it would be necessary either to locate humanly modified pieces or to demonstrate that the Pontnewydd haematite clasts were unlikely to have originated in the contemporary Pleistocene drift. A fuller study is now planned. A conclusion that ochres were in use at Pontnewydd over 200,000 years ago would be exciting indeed. However, just as significant would be a conclusion that such ores were available locally but were not used by the hominids at the cave.

## Conclusion

We have raised here several questions regarding the integrity of the lithic assemblage. As far as the Main Cave is concerned, we see no reason to move from the view expressed by Green in the 1984 monograph, with which Colcutt (1984, 75) concurred on sedimentological grounds, to the effect that the artefacts stratified in the Main Cave represent, substantially, a single industry of OIS 7 age. However, the presence of a limited number of pieces retouched through earlier patina suggests that a number of separate episodes of hominid presence are involved there. Accordingly, reassessment of this question will form a part of the final research design. The evidence is not, however, inconsistent with the view that the assemblage from the New Entrance represents a different and potentially rather younger event, perhaps *c* 175 ka (Aldhouse-Green 1998). This tentative interpretation is based on differences in assemblage composition, raw materials and on the admittedly ambiguous evidence of TL dates (Aldhouse-Green 1995, 44; fig 3, p. 39). The significance of the recently discovered ochres from the Main Cave is not yet clear and remains to be comprehensively assessed.

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## List of Illustrations

Figure 1. Pontnewydd. Percentage breakdown of raw materials used for each tool type. xtal lithic tuff = crystal lithic tuff; F-S tuff = fine silicic tuff; rhy lava = rhyolite lava.

Figure 2. Pontnewydd. Rock types used in the Main Cave and New Entrance (site H).

Table 1. Pontnewydd. The Main Cave: stratigraphic succession.

Table 2. Pontnewydd. Raw materials by area. Site A comprises 19/20 Century dumps.

Table 3. Pontnewydd. Typological variation between areas of the Main Cave.

Table 4. Pontnewydd. Artefact frequencies in the Main Cave and New Entrance.

Table 5. Pontnewydd Cave: pigments. Summary of significant pieces from the exotics collection. LB = Lower Breccia; UB = Upper Breccia.

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<sup>1</sup> I borrow this phrase from Glyn Daniel who had used it of his work on the chamber tombs of France. Daniel, of course, was responsible as Editor of *Antiquity* for publishing, in 1981, 'The First Welshman', one of the first papers to appear on the current research programme.

<sup>2</sup> In comparison most of the Paviland pieces were >10g (Young 2000). But these had not, of course, been emplaced within debris flows. Also, the Paviland pieces were probably mostly picked out by hand whereas the Pontnewydd ochres so far identified were retrieved from the wet sieving programme.