A Research Framework for the Archaeology of Wales
Environmental Archaeology

Note: - This paper was first prepared as an all Wales paper for the series of regional seminars held in 2002, but will form the basis of discussion at the September 2004 national seminar.

Introduction

For the purposes of this paper environmental archaeology will be considered in its broadest sense, encompassing both those areas of research that are focused explicitly on archaeological issues, and in which a human dimension is central, and those that are essentially palaeoenvironmental but have implications for archaeology. An understanding of past environments is important in order to assess the extent to which human communities may have been constrained or have adapted to changing conditions and the extent to which environmental conditions may be a result, directly or indirectly, of human activity. Apart from providing the environmental context, both on a regional and local scale, and indicating the interrelationship between people and the environment, other information that can be obtained from environmental studies includes evidence about palaeoeconomies and diet, funerary and ritual practices, social organisation and trade.

As in other areas of archaeology in recent years there have been various publications, either arising from conferences or by individual researchers, suggesting directions for future investigations in environmental archaeology (e.g. Bayley 1998, Edwards and Sadler 1999, Howard and Macklin 1999, Brown 1997, Bell 2001). This paper takes account of this work and has been prepared by Astrid Caseldine in collaboration with Professor Mike Walker, Professor Martin Bell, Dr John Crowther, Professor Frank Chambers, Professor Mark Macklin, Professor John Allen and Dr Paul Hughes. The paper is confined largely to environmental aspects of archaeological science, although dating techniques are briefly considered because a good chronological framework is as essential for palaeoenvironmental studies as it is for other areas of archaeology, and lipid analysis is referred to as it clearly overlaps with other aspects of palaeoeconomic research and diet. Human bone evidence is not included apart from recent studies using stable isotope analysis, which are of wider dietary, economic and environmental significance.

This paper follows the original remit that the environmental evidence should be reviewed on a pan-Wales basis, but takes into account the four regions, i.e. the northwest, the northeast, the southwest and the southeast. Of necessity, given that all time periods are considered, only a brief evaluation of the strengths and weaknesses of the existing data will be presented here, but a full review of the environmental evidence will be given in *Environmental Archaeology in Wales* 2nd edition (Caseldine in prep.). Opportunities for future research opportunities are suggested, including possible approaches. Threats are considered briefly and finally recommendations and key priorities are outlined.

Environmental Data

This is very much dependent on there being the necessary conditions for survival.

Pollen: Strengths and weaknesses

One of the strengths of palaeoenvironmental studies, particularly pollen, is the ability to provide a record of continuity and change in the landscape. In Wales the peaty acid soil conditions favour the preservation of pollen and over 400 pollen

sites have been examined. A wealth of environmental evidence is available to the archaeologist, at least in broad landscape terms, but a more detailed examination of the evidence reveals that there are significant gaps in the distribution of the sites and that the quality of the data is variable. The former reflects not only the availability of suitable deposits but concentrations of sites frequently reflect specific research projects and the work of individual research students. Hence in north Wales there are clusters of sites in Snowdonia, Ardudwy and western Rhinogau, Mynydd Hiraethog and the Berwyns, whilst further south there are concentrations in the Cambrian Mountains and the lowlands to the west. In south Wales concentrations of sites lie in the Preseli area and the Black Mountain, Brecon Beacons and Abergavenny Black Mountains. Certain individual site areas have, because of their high scientific value, been the focus of repeated investigation, notably Tregaron Bog (Cors Caron) and Borth Bog (Cors Fochno). Along the coast, again there are 'hot spots' of research activity, most noticeably in the area of the Gwent Levels of the Severn Estuary (Walker *et al* 1998; Bell *et al* 2000), but other areas where there has been some research, although of a less intensive nature, include the coast of Pembrokeshire (Lewis 1992) and north-west Wales (Bedlington 1994). Investigation of peat deposits associated with riverine alluvial sediments has been very limited, but examples include the Ilston valley (Saunders *et al* 1989) and Caldicot (Nayling and Caseldine 1997).

The usefulness of a particular pollen diagram to the archaeologist also depends on the length of time represented and the number of levels counted which also vary considerably, again partly dependent on the nature of the deposit and the research emphasis. Hence at Llanllwch Bog, near Carmarthen, Thomas (1965) produced a diagram covering the Holocene, whilst Donald (1987) concentrated on the Late-glacial Loch Lomond Stadial and early Holocene and, more recently, Rosen (1998) has undertaken a detailed investigation of the upper deposits concentrating on the last 500 years only. Related to this is the question of an independent chronological control, with around 25% of all pollen records in Wales having 3 or more radiocarbon dates and the remainder having either none or only one or two dates; the result is that landscape changes can be more accurately related to the archaeological record in some areas than others. Hence in southeast Wales a well-dated Late-glacial diagram is that from Llanilid (Walker and Harkness 1990; Walker *et al* 2003), whilst the Holocene pollen sequence Site 1 at Goldcliff (Smith and Morgan 1989) is particularly well-dated and at other sites in the inter-tidal area and Gwent Levels there are a number of dated diagrams, building up a good chronology for the area as a whole. Another area for which there is excellent dating evidence is Waun-Fignen-Felen (Cloutman 1983) in the Black Mountain Range. In mid-Wales Tregaron is also well dated with dates from several sites within the bog. The earlier deposits at Nant Ffrancon (Hibbert and Switsur 1976) in Snowdonia are well dated but the latest date is 4255±50 BP (Q-907), limiting interpretation of the later changes in the record. At Llyn Cororion (Watkins 1990), by contrast, in lowland Gwynedd dates range from c 9700 BP to 800 BP, providing a better chronological control in relation to archaeological and historical events. Radiocarbon dating is unsuitable for dating landscape changes within the last 300-400 years and the use of other dating techniques, such as ^{210}Pb and carbonaceous particles, has only been applied in a few instances (Jones *et al* 1985, Rosen 1998, Chambers *et al* 1999). Similarly, although tephra has been identified at sites in the Cambrian Mountains, the use of tephrochronology as a means of dating and correlating peat sequences in Wales has yet to be fully developed (Buckley and Walker 2002).

Much of the pollen work has been undertaken independently of any archaeological work and, in a number of cases, consideration of the role of anthropogenic activity, if considered at all, is secondary to the main aim of the research, although the results may have significant value for archaeology, for example in

sea-level studies. In recent years there have been an increasing number of integrated pollen and archaeological studies, frequently involving other lines of environmental evidence as well, particularly from wetland sites such as Caldicot (Nayling and Caseldine 1997) and Goldcliff (Bell *et al* 2000) in the Severn Estuary, Abercynafon (Earwood and Caseldine forthcoming) in upland south Wales and Prestatyn (Bell *et al* in prep.) in north Wales. Other examples of integrated studies include the work of Barton *et al* (1995) at Waun-Fignen-Felen building on the earlier work of Smith and Cloutman (1988), Nant Helen (Chambers *et al* 1990), Ardudwy (Chambers *et al* 1988) and Cefn Graeanog (Mason 1998), Brenig (Lynch 1993), the Breiddin (Musson 1991), Carneddau (Walker 1993), and Corn Du and Pen-y-fan (Chambers and Lageard 1998), but the number of investigations involving archaeological excavation, on-site and off-site palaeoenvironmental analyses are still comparatively few. Other weaknesses of the data include a lack of high-resolution analyses, although there are exceptions as in recent work at Tregaron (Hughes *et al* 2001). Much palynological research is not readily accessible as it is in unpublished PhDs or is in the 'grey literature' of unpublished reports prepared for developers as part of the planning process.

In relation to the main archaeological periods there are very few pre Late Devensian pollen sites. Studies of Late-glacial sites number fewer than 30 with the greatest concentration in Snowdonia. In general they have provided evidence on climate and associated vegetation changes, but indicators of climatic oscillations recorded in some diagrams are not recorded in others, which suggests that either these events were of such short duration that they did not affect the local plant communities or insufficient resolution in pollen sampling. In addition not all of the sites have produced a full Late-glacial record, e.g. Hendre-fach and Dolau-duon (Donald 1987) in southwest Wales. Although dating control is poor for many of the sites several of the pollen profiles have been closely dated, eg Llanilid (Walker and Harkness 1990, Walker *et al* 2003, Nant Ffrancon (Hibbert and Switsur 1976) and Llyn Gwernan (Lowe 1981, Lowe and Lowe 1989). Possible evidence for human activity, notably fires, has received little attention, although the anthropogenic significance of charcoal, particularly at this time, is debatable.

A number of pollen records cover the early-mid Holocene and much of the focus of investigations has been on the arrival and expansion of vegetation species reflecting an ameliorating climate, which has implications as far as the resources available for exploitation are concerned. Sites where it is suggested Mesolithic environmental impact can be identified are still relatively few and are mainly from upland areas, for example Waun-Fignen-Felen (Smith and Cloutman 1988, Barton *et al* 1995) and Pen Rhiw-wen (Cloutman 1983). Before the work by Lewis (1992) in west Wales and Bell and colleagues at Goldcliff (Bell *et al* 2000) in the Severn Estuary investigation of coastal sequences was largely focused on sea-level change rather than exploitation by Mesolithic communities. Further work is currently in progress at Goldcliff East and Redwick in the Severn Estuary and at Prestatyn (Bell *et al* in prep.) in north Wales. Evidence of Mesolithic activity from inland lowland sites is generally lacking with, for example, only tentative evidence from Llyn Mire (Moore 1978).

A number of studies have been concerned with blanket peat formation and the impact of human activity and have demonstrated the variable date for peat initiation in Wales (Caseldine 1990, Chambers 1996). Evidence from sites such as Waun-Fignen -Felen (Smith and Cloutman 1988) demonstrates that ombrogenous peats began to form as early as the Mesolithic, but at other sites peat development began during the Neolithic and Bronze Age and even later (Chambers 1981) The variation in dates for peat initiation suggests that it cannot

be accounted for by a purely climatic hypothesis and it is considered that anthropogenic activity, as well as local site factors, is likely to have been important.

Evidence for pre-elm decline cultivation is scarce and there is the added problem of the uncertain identification of cereal pollen. The evidence for small-scale Neolithic clearance is widespread but much of the evidence is from the uplands rather than the lowlands and there is a lack of evidence from the river valleys and from sites close to the main concentrations of Neolithic tombs and other sites (e.g. Pembrokeshire, Gower, Anglesey, etc.). Evidence for cereal cultivation is limited as is evidence from archaeological sites. One problem is the probable under-representation of cereal pollen in sites some distance from the activity, especially if it is small-scale in a largely wooded landscape.

Pollen sequences from the Bronze Age suggest increasing clearance activity but there appears to be some variation in the extent and timing of the activity (Mighall and Chambers 1995, Caseldine *et al* 2001). A predominantly pastoral economy is indicated but there is some evidence for cereal cultivation, including the uplands, for example at Bryn y Castell (Mighall and Chambers 1995) and the Berwyns (Bostock 1980) in north Wales and the Brecon Beacons (Chambers 1982) and Nant Helen, Mynydd y Drum (Chambers *et al* 2000) in south Wales. Although there have been studies involving investigation of Bronze Age monuments and nearby peat deposits these have been relatively few. Further palaeoenvironmental work is currently in progress as part of the Cadw Funerary and Ritual Sites project to enhance our understanding of the landscape context of these monuments. Apart from the recent work at Cwmystwyth (Mighall and Chambers 1993, Mighall *et al* 2002), little is known about the impact of Bronze Age mining activity on the surrounding landscape. Equally, until recently, pollen work in coastal areas has concentrated on sea-level change rather than the environments available for exploitation and their use.

Pollen records again suggest variation in clearance activity during the later Bronze Age and Iron Age. Evidence from some areas suggests substantial clearance occurred in the late Bronze Age and that they remained largely open into the Iron Age, for example at Bryn y Castell (Mighall and Chambers 1995) and Llyn Morwynion (Caseldine *et al* 2001), whilst in other areas there is evidence for some woodland regeneration followed by further clearance during the Iron Age or Romano-British period such as at Cefn Gwernffrwd in mid-Wales (Chambers 1982) and in Ardudwy (Chambers *et al* 1988). Indeed one of the problems is that frequently radiocarbon dates are fewer for later prehistory and, more particularly, historic periods with the result that it is sometimes unclear whether, for example, changes should be attributed to Roman influence or the changes had already occurred before that period or in the post-Roman period. A predominantly pastoral environment is suggested although there is also evidence of arable activity, for example at Bryn y Castell (Mighall and Chambers 1995). Pollen evidence from archaeological sites is largely from northwest and southwest Wales, apart from the Breiddin hill fort in northeast Wales and the recent work at Goldcliff in southeast Wales. Of the former two areas it is mainly sites in northwest Wales where off-site as well as on-site analyses have been undertaken. Again it is only recently that the exploitation of coastal wetlands has been investigated and this has largely been confined to work in the Severn Estuary. The impact of iron working has only specifically been investigated at a few sites, notably Bryn y Castell (Mighall and Chambers 1997) and Crawcwellt (Chambers and Lageard 1993). The environmental context of Late Bronze Age/early Iron Age hoards has received little attention apart from at Llyn Fawr and most recently at Princetown (Jones *et al* 2003).

Apart from investigations in northwest Wales and on the Gwent Levels in southeast Wales, pollen evidence from sites of Romano-British date is relatively scarce and, as already mentioned, dating of longer sequences is often poorer for this and for later periods so that inferences about continuity and change and regional variations are restricted. The same applies to early medieval and later sequences, although a post-Roman woodland regeneration can be identified in a number of areas (Caseldine forthcoming). Proxy climatic data are limited but there is some evidence for climatic deterioration c 1400 BP, for example from the Migneint (Blackford and Chambers 1991). Although many diagrams cover the medieval period, comparatively little pollen work has been undertaken on medieval archaeological sites with few attempts to put either castles, rural, urban or ecclesiastical sites into a broader landscape context. The usefulness of pollen and other studies in interpreting medieval rural sites is demonstrated by the results from Cefn Graeanog (Chambers 1982) and more recently from Ynys Ettws (Caseldine forthcoming) as part of the Cadw Deserted Rural Settlement Project. In general the opportunity has not been taken to test historically derived ideas against the palaeoenvironmental record. A few palaeoenvironmental investigations have been concerned with the impact of industrial activity (e.g. Rosen 1998, Rosen and Dumayne-Peaty 2001), although such multi-proxy approaches are not without problems.

Plant macrofossils: strengths and weaknesses

Because of the survival of charred material on dry land sites a relatively large number of sites have yielded charred plant remains but the quality of the evidence varies both from period to period and spatially within Wales. The main contribution has been in providing palaeoeconomic information, particularly about crop husbandry practices. The main weakness has been the lack of sieving/flotation programmes to recover evidence. Substantial sieving programmes have been carried out at only a handful of sites, for example, Llawhaden (Williams and Mytum 1998) and Cefn Graeanog (Fasham *et al* 1998). Furthermore, the absence of detailed chronostratigraphic control on some sites means that interpretation of changes in crop husbandry is sometimes limited. In addition in some cases samples have been taken but a lack of funding, particularly applicable to developer sites, has resulted in samples remaining unprocessed, whilst in other cases analyses remain unpublished

Apart from hazelnut shells from a few sites, little is known about the exploitation of other plant resources during the Mesolithic period. This is at least partially a result of there being few attempts to recover material by sieving programmes, although exceptions are Prestatyn (Bell *et al* in prep.) and Goldcliff (Bell *et al* 2000). The number of Neolithic sites from which plant macrofossil evidence has been recovered is few and the assemblages are generally poor. Exceptions are the middle Neolithic site at Plas Gogerddan (Caseldine 1992) and the Late Neolithic Capel Eithin (Williams 1999) while the assemblage from Gwernvale (Caseldine in prep.) is of particular note because of the remains being associated with a settlement of early Neolithic date below a chambered tomb. The evidence from southeast Wales for cultivars during this period is especially limited being confined to emmer wheat and Celtic bean impressions from Ogmore on Sea (Webley 1969) and Ogmore (Hillman 1981), respectively. By the Bronze Age there are more sites but the assemblages are still generally small, although again there are exceptions with, for example, a relatively rich assemblage from the middle Bronze Age site of Glanfeinion (Britnell *et al* 1997). Evidence from northwest Wales is scarce while, in contrast to the previous period, there is more from southeast Wales, including data from wetland sites. Evidence from the Iron Age is similarly scarce and in some cases even scarcer than in the Bronze Age particularly, for example, in southeast Wales. Even in southwest Wales, at the Llawhaden group of enclosures (Williams and Mytum 1998), although there is

more Iron Age evidence than at most sites, there is still more Romano-British than Iron Age evidence from Dan-y-coed. Uncertainty of the date of contexts from late prehistoric through to the Romano-British period is an added problem. The possible impact of the Romans on agricultural production is difficult to assess when there is alack of evidence for what went before. This is particularly the case in southeast Wales. Certainly there is more evidence available for the Romano-British period but the database is still limited, restricting inter-site comparisons and the identification of the adoption or rejection of agricultural strategies and regional diversity. Early medieval evidence is scarce with, at most, only one or two sites per regional area. Hence the possible effect on farming of the withdrawal of the Romans is difficult to assess. Although more information is available from medieval sites and a range of types of site have been examined, again the conclusions that can be drawn are much more limited when the evidence is considered by regional area, or the relationship between different types of site, for example castles/towns and their regional hinterlands, is examined. Very little evidence is available from urban sites compared with England.

Faunal remains: strengths and weaknesses
As with plant remains, animal bone assemblages, with the exception of assemblages from Palaeolithic cave sites in Gower, South Pembrokeshire, the Wye Valley and northeast Wales, are generally poor until the Romano-British period. In most cases bone has been recovered by hand rather than sieving so that small mammal, bird and fish bone are under-represented in the faunal record. Assemblages cannot always be accurately assigned to specific periods. Relatively few of the earlier faunal studies involved the quantitative assessment of the species represented, age and sex data, and metrical analyses. Interpretations were therefore limited, whereas more recent reports are much more informative.

Faunal studies have made a major contribution to environmental reconstruction during the Palaeolithic; the majority of evidence being from cave sites such as Pontnewydd (Green 1984), Coygan (Currant and Jacobi 1997) and Paviland (Aldhouse-Green 2000). The main weakness is the uncertain provenance of the remains from many of the caves, and this applies to later periods as well. Bone assemblages for the Mesolithic through to the Iron Age are generally poor because of the acid nature of the soils over much of Wales. Apart from caves, the main source of bone evidence for the Mesolithic is coastal deposits where preservation is good although evidence is sparse. The importance of sieving programmes is demonstrated by the recovery of fishbone from Goldcliff (Ingrem 2000). The discovery of animal footprints in the Severn Estuary provides an additional source of evidence (Allen 1997). Further examination of the use of animal resources in coastal environments during the Mesolithic and later is currently in progress by Bell and colleagues. Evidence from the Neolithic is scarce, particularly from southeast Wales, with poor assemblages. The same applies to the Bronze Age with again small assemblages and little evidence from some regions. Next to no evidence is available from northeast Wales whereas slightly more evidence is available from southeast Wales than in the previous period and where at inertial sites such as Redwick both bone and footprints have been found and work is currently in progress. Several late Bronze Age assemblages from wetland sites in the southeast region, notably Caldicot (McCormick 1997), have enhanced the state of knowledge significantly. In general Late Bronze Age/ Iron Age assemblages are relatively poor although an increased size of the later Iron Age assemblages is recorded at some sites with a major increase occurring in Romano-British times, e.g. Coygan Camp (Westley 1967). At Collfryn the reverse applies where a large Iron Age and smaller Romano-British assemblage was recovered (Jones 1987). A substantially greater

amount of bone has been identified from Roman sites but much of this evidence comes from only a few locations, notably Caerleon, Caerwent, Segontium, and Loughor and there is little evidence for the relationship of these sites to the surrounding rural area and to native sites. As with the plant macrofossil evidence only limited conclusions can be reached as far as changes in agricultural practice and regional differences are concerned. The only early medieval site to have yielded a large assemblage is Dinas Powys (Gilchrist 1987), which limits any understanding of wider agricultural practices. Larger assemblages have been recovered from medieval sites with relatively good information available from castles and towns. However, assemblages from ecclesiastical and rural sites are much scarcer and the relationship between, for example, towns/castles and rural sites has received little attention. Although post medieval assemblages can provide valuable information about the development of modern breeds of livestock, in general little consideration has been given to them.

Mollusca: strengths and weaknesses
Mollusc evidence is relatively limited because of the comparatively restricted distribution of the generally calcareous contexts suitable forth survival of terrestrial molluscs in Wales, but there are abundant areas of coastal deposits in which marine molluscs can be found. Significant studies of non-marine Mollusca of Mesolithic date include Cwm Nash in south Wales (Evans at al 1978) and Prestatyn in north Wales (Bell *et al* in prep), while at Stackpole Warren land Mollusca associated with Iron Age field systems and overlying dunes (Evans and Hyde 1990) and land and freshwater assemblages from the late Bronze age site at Caldicot (Bell and Johnson 1997) have been investigated. An early-Holocene freshwater assemblage was obtained from Llangorse (Walker *et al* 1993). Marine molluscs are important as indicators of diet and most of the evidence is from Roman or later sites and generally has involved identification with little further analysis. The only certain middens of Mesolithic date are from Prestatyn (Bell *et al* in prep) with a possible Mesolithic midden at Nanna's Cave on Caldey (Lacaille and Grimes 1955). Investigation of the growth lines of cockles at Prestatyn has produced evidence of seasonality (Fancourt 1999). At Stackpole Warren middens date from the later Bronze Age through to the medieval period (Cole 1990) and at Ty Mawr there is a detailed study of a midden considered to date from the end of the first millennium BC (Evans and Evans 1986). Marine Mollusca have also been used in amino acid dating of Pleistocene deposits, especially in Gower (Henry 1984, Bowen *et al* 1985, Bowen 1999).

Stable isotope analyses: strengths and weaknesses
A recent important development has been the application of stable isotope analyses to human skeletons in Wales, thereby providing information on diet and, in turn, issues of seasonality and subsistence which are of particular value in earlier prehistory. Results suggest the importance of marine resources in the diet of later Mesolithic individuals from caves in south and north Wales (Schulting and Richards 2000), whilst the evidence from human remains from an earlier Neolithic chambered cairn in south Wales suggests there was minimal use of marine resources and terrestrial animals were most important in the diet (Richards 1998, Schulting and Richards 2000). Neolithic and Bronze Age skulls from the Severn Estuary also suggest minimal use of marine resources whereas an Iron Age/early Roman skull shows slightly more and a medieval skull indicates that around 40-50% of dietary protein was from marine resources (Richards and Schulting 2000). The main weakness is the limited application of this technique so far and the need for analyses from a wider range of locations and in tandem with faunal and botanical analyses. AMS dating is important to support this work. Stable isotope analysis has also recently been used to correlate Late-glacial climatic events at Llanilid (Walker *et al* 2003).

Insects, mites etc: strengths and weaknesses
Comparatively few investigations of insects and mites have been undertaken in Wales but they have provided valuable information, not only about the environment and land use, but also about the use of buildings/structures. The paucity of studies is at least partly restricted by the availability of suitable waterlogged contexts but coastal peat deposits, for example, are widespread and offer potential for further work.

Investigations of changes in Late-glacial climate and environment include work at Glanllynnau (Coope and Brophy 1972) in northwest Wales and Llanilid (Walker *et al* 2003) in southeast Wales. Work directly associated with archaeological investigations in southeast Wales, for example, includes that at inter-tidal sites in the Severn Estuary ranging in date from the Mesolithic to the Iron Age (Smith *et al* 2000) and palaeochannel deposits at the late Bronze Age Caldicot (Osborne 1997), whilst studies in the northeast Wales archaeological region include those at the Breiddin hill fort (Smith 1991) and, further south in the Brecon Beacons, the upland Neolithic wetland site at Abercynafon (Panagiotakopulu forthcoming) and Corn Du and Pen-y-fan Bronze age cairns,(Robinson 1998), in southwest Wales the late Iron age site at Penycoed (Girling 1985) and Whitland Roman road(Caseldine *et al* 1997) and in northwest Wales analysis of a peat sample (Osborne 1987) from near the Neolithic site of Trefignath.

Charcoal and wood studies; strengths and weaknesses
Charcoal has been identified from a large number of sites, providing some information about the woodland resources available, but there have been few detailed studies, except that from Cefn Graeanog (Thompson 1998), of intra-site distributions. There has been a major development of wood studies during the last decade but most of this has taken place only around the Severn Estuary. Work has included analysis of the submerged forest environments as well as analysis of wood from structures ranging from Bronze Age trackways to medieval boats. Similarly, there has been a significant increase in dendro-chronological dating in Wales in the last decade. There are relatively few prehistoric archaeological sites in England and Wales, which have produced dendrochronological dates, but dates have now been obtained from the Neolithic upland site of Abercynafon (Nayling forthcoming), the Bronze Age site at Caldicot (Hillam 1997) and from Bronze and Iron Age sites at Goldcliff (Hillam 2000). Further work is in progress, particularly in relation to Mesolithic submerged forests, in the Sever Estuary. Dates from Roman sites include Caerleon (Hillam 1993) in southeast Wales and Prestatyn (Morgan 1989) in northeast Wales. A number of medieval buildings have now been dated by dendrochronology. However, the main weakness remains the limited application of this technique on prehistoric sites and the need to extend the dendrochronological record for Wales.

Soils: strengths and weaknesses
Apart from the investigation of buried palaeosols at a number of sites, other soil studies have been more limited but have included phosphate, magnetic susceptibility and soil micromorphological analyses. Phosphate analysis has been undertaken on several sites of Neolithic and Bronze Age date to confirm the presence of burials and cremations. Phosphate analysis, either alone or with magnetic susceptibility measurements, has also been used to identify activity areas such as at the lithic scatters site at Boncyn Ddolin north Wales (Crowther 2001), or to determine the use of buildings, phases of activity or land use at several sites ranging in date from the later prehistoric through to medieval times, such as Moel y Gerddi and Erw-wen (Conway 1988), Llawhaden (Crowther 1998) and Cefn Drum (Kissock 2000). Redistribution of phosphorus has been examined in cave sediments from the lower Palaeolithic site of Pontnewydd (Jenkins 1997). Soil micromorphology has been comparatively little used but has included work

on soils from the Hiraethog Moors (Lascelles 1995), the Mesolithic soil and organic layers from Iron Age buildings and palaeochannel fills at Goldcliff (Macphail and Cruise 2000a, 2000b), and cave sediments from Pontnewydd (Jenkins 1997).

Geoarchaeological studies/geomorphology and sediments; strengths and weaknesses
The most thorough investigation of sedimentary sequences in relation to archaeological remains has taken place in the Severn Estuary (Allen 1987,2000, Allen and Rae 1987), but the investigation of coastal alluvial sequences elsewhere has largely focused on sea-level changes and crustal movement. Recent studies in the Severn Estuary have included the examination of the silts for the presence of tidal laminations and groupings of laminations into bands in order to help identify horizons of unusually large rates of annual accumulation (Allen and Haslett 2002). These rapidly accumulated sediments are very favourable for the preservation of evidence such as animal footprint-tracks. High-resolution grain-size analyses of tidal silts complement for aminiferal analysis and provide good evidence on rates and senses of sea-level change.

The alluvial archaeology of non-tidal rivers in Wales has been considerably under-researched in comparison to other parts of the UK. Only a handful of sites has been investigated in relation to archaeology including the Ilston Valley (Saunders *et al* 1989), Rheidol Valley (Macklin and Lewin 1986, Vyrnwy (Lewin 1992), Dyfi (Johnstone *et al* 2002), Welshpool (Taylor and Lewin 1996), Buttington (Macklin *et al* 2002) and Caldicot (Taylor 1997), but at the last-named there was also a tidal influence. A number of other studies of river systems including the upper Severn, Teifi, Dee, Dyfi, Twyi and Rheidol, independent of archaeological investigation, are currently in progress by Macklin and colleagues and have implications for archaeology but there needs to be closer co-operation between archaeologists and geomorphologists and sedimentologists.

Diatoms, foraminifera, ostracod, testate amoebae: strengths and weaknesses
These analyses have been less frequently used in Wales and mostly in palaeoenvironmental reconstructions that have been undertaken independently of archaeological studies, notably in investigations of sea-level change. However, with the increase in archaeological work in and around the Severn Estuary some of these fossils are now being routinely examined from archaeological sites. Diatom analysis has been more widely applied than either foraminifera or ostracod analyses, which generally have been under used. Similarly, there have been few studies in Wales using testate amoebae either as sea-level indicators, for example in the Taf estuary (Roe *et al* 2002), or as palaeohydrological and palaeoclimatic indicators, for example at Figyn-blaen-brefi (Buckley 2000).

Lipid analysis: strengths and weaknesses
Complementing plant macrofossil and faunal analyses from sites, organic residue analysis provides additional information about dietary habits. This technique has so far been used on relatively few sites, for example the Walton Basin (Dudd and Evershed 1999).

Dating: strengths and weaknesses
One of the strengths of radiocarbon dating is its wide applicability and the possibility of dating both on-site and off-site events to enable correlations to be made. The development of AMS dating, which allows very small samples of material (including single entities) to be dated, the refinement of calibration curves by which ^{14}C dates can be converted to calendar years, and the application of a range of statistical methods (e.g. Bayesian analysis) have significantly strengthened its use. However, as has already been mentioned a large number of

pollen diagrams in Wales are either undated or are poorly dated. There are also relatively few instances where off-site peat cores and nearby archaeological sites have been independently dated to enable correlation. Chronological control on sites is also often poor which results in limited interpretation of crop husbandry and other agricultural/economic changes. Single entity dating of charred plant remains from archaeological sites should improve this and help to provide a better chronological framework for sites.

The main strength of dendrochronology is the provision of ages in calendar years and, as has been discussed above, the main weaknesses are that mastercurves for the prehistoric period are still being developed and that in Wales very few prehistoric sites have been dated using this technique.

Other techniques which have been used to varying degrees in Wales include ^{210}Pb which is used to date very recent sediments, thermoluminescene used to date mineral grains and burnt flint, optically stimulated luminescence used to date sands, e.g. Aeolian sediments, Uranium-series used to date cave sediments, and cosmogenic nuclides (based on isotopes as a result of cosmic radiation) used to date deglaciation. Relative ages have been obtained from amino-acid racemisation on marinemolluscs, while tephra analysis may eventually provide a basis for correlation of peat deposits. This technique has recently transformed palaeoecological research in the north of Ireland.

Research Opportunities

The strengths and weaknesses of the individual data sets have been briefly summarised and opportunities for research will now be considered on athematic basis. Some of the research opportunities identified here are specifically archaeological issues whilst others are, in essence, palaeoenvironmental but are of relevance to archaeological issues. Suggestions as to how these research questions maybe approached are also included.

Environmental resource exploitation and agricultural change: the development of agriculture and changing agricultural practices

1. Any Palaeolithic site with environmental evidence requires exhaustive investigation, even when there is no direct evidence of human presence. Such work needs to be closely linked with Quaternary research on non-archaeological sites. The relative paucity of interglacial deposits means that they should receive a high priority.

An interdisciplinary approach is required, including detailed work on geomorphology, sedimentary sequences and all associated biota to provide a basis for environmental reconstruction and to enable landscape and predictive modelling.

2. Although there have been a few studies concerned with the possible influence of Mesolithic communities on the environment the evidence is scarce. These have largely been in the uplands with only recently work on coastal landscapes. The way in which Mesolithic communities may have been using different landscapes is imperfectly understood and both the question of seasonality and the nature of the Mesolithic economy require further exploration.

There is a need for the investigation of sites in a range of landscapes. Studies should focus on sites where the lithic and palaeoenvironmental evidence can be closely correlated. Buried land surfaces beneath reservoir edges, former shorelines of natural lakes, inter-tidal submerged surfaces and riverside sites, especially ecotonal sites, offer opportunities for investigation. High resolution

pollen analyses, plant macrofossil analyses, charcoal and wood studies, faunal and insect analyses, supported by an adequate dating programme, including dendrochronology if possible, should be undertaken. Stable isotope analyses of human skeletons should also be undertaken whenever suitable material is found.

3. The evidence covering the Mesolithic-Neolithic transition is scarce. A few pollen records exhibit pre-elm decline 'cereal-type' pollen. When did cereal cultivation begin in Wales during the Mesolithic-Neolithic transition? Early Neolithic 'clearance' episodes generally appear to be small scale. To what extent do they represent opportunistic exploitation of naturally occurring clearings, ie to what extent are early Neolithic economic strategies a development of late Mesolithic intensification of wild plant food husbandry (cf Brown 1997)? At what point did purposive clearance occur? When did animal husbandry begin in Wales?

Pollen records with pre-elm decline 'cereal-type' pollen need to be dated but, because of the uncertainty of 'cereal-type' pollen, recovery and dating of charred plant remains from securely stratified contexts is vital. Pollen analysis from small sites, for example the edge of palaeochannels in river valleys, is required. Coastal wetland sites of Mesolithic-Neolithic date may provide the evidence for the beginnings of animal husbandry. Excavation of Mesolithic-Neolithic sites with sampling, sieving and analysis of environmental evidence is needed. Stable isotope analyses of human skeletons indicate changes in the use of resources and further studies should be undertaken.

4. Occasional 'cereal-type' pollen grains and charred grain, generally in low amounts, indicate some cereal cultivation during the Neolithic and earlier Bronze Age, but what was the extent and spatial location of crop growing during this period? What was the relative importance of arable/pastoralism?

Pollen studies in different landscape zones, including small sites, river-edge and wetland/dryland edge sites in the lowlands are required. Pollen sites with different pollen source catchments within an area need to be investigated. Sampling and sieving programmes to recover charred grain need to be carried out during excavations.

5. The development of field systems during the 2nd and 1st millennia BC and the associated palaeoenvironmental evidence has received comparatively little attention and requires further investigation.

Archaeological investigations should be accompanied by palaeoenvironmental analyses, including pollen/ mollusc studies, soil micromorphology, phosphate analysis and radiocarbon dates.

6. Changes in clearance activity are recorded during the Bronze Age. A number of pollen records show extensive clearance during the later Bronze Age and Iron Age and charred cereals suggest a change from emmer to spelt but when did the latter change occur and are there regional differences? What was the relative importance of arable farming compared to pastoralism? Are there regional and subregional differences in farming regimes during this period?

On-site and off-site analyses (pollen, plant macrofossils, animal bone), sieving and dating programmes are needed to allow inter-site comparisons and to determine the date of changes in agricultural activity.

7. A greater amount of plant macrofossil and animal bone evidence has been recovered from sites dating from the Romano-British period in Wales but insufficient to say clearly what impact the Romans had on agricultural production,

the extent to which new agricultural strategies were adopted and whether regional differences are discernible. Pollen diagrams are frequently inadequately dated as are the archaeological contexts of the macrofossil evidence from Iron Age/Romano-British sites.

As for the previous period, on-site and off-site analyses (pollen, plant macrofossils, animal bone), sieving and dating programmes, are needed to allow inter-site comparisons and to determine the date of changes in agricultural activity.

8. In contrast to the preceding and the following periods, evidence is scarce for the early medieval period. Continuity and change and the nature of the early medieval economy have hardly begun to be explored.

Integrated archaeological/ palaeoenvironmental studies (on-site and off-site) supported by adequate radiocarbon dating programmes are required.

9. Plant macrofossil and faunal evidence is more plentiful for the medieval period but further investigations are required to determine regional differences in animal and crop husbandry and to allow inter-site comparisons, for example the relationship between castles and towns and their rural hinterland. Relatively little information has been recovered from ecclesiastical sites, e.g. granges, or rural sites. What was the effect of markets elsewhere in Britain?

Combined archaeological, documentary, palaeoenvironmental, archaeobotanical and archaeozoological studies are required.

10. The examination of environmental evidence from deserted medieval rural settlements has been very limited, but such evidence can help to determine whether they were permanently or seasonally occupied farms. Similarly, upland cultivation during medieval times and later has not been fully investigated.

Archaeological survey and excavation combined with palaeoenvironmental and documentary studies, including place-name evidence, and supported by radiocarbon and/or other dating techniques is needed.

11. Relatively limited work has been undertaken on urban sites. Work on urban sites needs to be targeted at certain areas. One area that would deserve attention is urban waterfronts, which offer considerable environmental potential.

Environmental analyses supported by sieving programmes, as appropriate, are required.

12. Although recent work at sites in the Sever Estuary has increased our knowledge of woodland management, the importance of woodland management in prehistory has yet to be fully explored.

Investigations should include on-site and off-site pollen, plant macrofossil and insect analyses, wood studies and dendrochronology.

13. One of the most significant developments in Wales during the last decade has been the development of wetland archaeology. Wetland sites offer a much greater potential for the investigation of resource exploitation and agricultural activity either in the surrounding wetland or on the adjacent dry land.

Wetland sites should be thoroughly investigated and a full range of palaeoenvironmental techniques should be employed. Investigations should include radiometric dating and, if possible, dendrochronology.

14. Further work is required on the involvement of human agency in upland peat formation and needs to be related to archaeological evidence in the area.

Pollen and soil studies, including soil micromorphology, supported by radiocarbon dates are required.

Funerary and Ritual

1. There have been relatively few investigations specifically concerned with the environmental conditions at and surrounding funerary and ritual monuments. The visibility of prehistoric burial and ritual monuments in the Welsh landscape requires further investigation and this is currently in progress as part of the Funerary and Ritual Sites project.

On-site and off-site palaeoenvironmental investigations are required, supported by radiocarbon dates combined with archaeological survey and excavation.

2. The role that plant and animal remains may have played in burial and ritual practices both in prehistory and later periods in Wales has received comparatively little attention and requires further investigation.

Animal bone, plant macrofossil and pollen studies need to be undertaken along with archaeological excavation.

3. The deposition of Late Bronze Age/Iron Age metalwork hoards in wetland contexts is well established. However, the investigation of the environmental context of such hoards in Wales has been limited.

The excavation of such sites should include palaeoenvironmental studies (pollen, insect, plant macrofossil and animal) supported by an adequate radiocarbon dating programme.

Mining activity and industrialization

1. There have been very few integrated archaeological/ palaeoenvironmental studies concerned with the impact of Bronze Age copper mining in Wales and further investigations are required.

On-site and off-site studies should include pollen, wood/charcoal, plant macrofossils, insect, sedimentalogical, and geochemical analyses.

2. Recent studies have given some indication of the impact of iron working on the landscape but this could be explored further.

Pollen, wood/charcoal, plant macrofossil, insect, sedimentological, and geochemical analyses should be included.

3. There have been very few studies concerned with identifying the impact of industrialisation on the surrounding environment. Although there has been some investigation of the impact of industrialisation in the Lower Swansea Valley (Rosen and Dumayne-Peaty 2001), there is scope for further work on the impact of processing sulphide ores as part of the copper-smelting industry. The possible impact of coal mining in South Wales on valley alluviation remains largely unexplored. Similarly, only some exploratory work has been done on the loss of

coal dust into the tidal environment at the exporting ports and there is much more to be learned.

Pollen, soil, sedimentological and geochemical analyses supported by appropriate dating techniques should be undertaken.

Climate Change: The influence of climate on human communities
Most palaeoenvironmental studies of climate change in Wales have been carried out independently of any archaeological investigation and the implications for archaeology in terms of settlement patterns, exploitation and agricultural activity have generally been a secondary consideration. The main exception is the Palaeolithic period where the reconstruction of past climatic conditions, particularly through faunal analyses, has been central to the investigations.

1. Further investigations are required to determine the complexity of climate change during the Late glacial in Wales.

Investigation of sites with a full Late glacial sequence using a multi-proxy approach including good dating control is required.

2. There have been relatively few studies in Wales, compared with some other parts of Britain, that have used peat deposits, specifically the plant macrofossil and testate amoebae records, as proxy climatic indicators. Specific areas for future research include investigation of the palaeoenvironmental evidence for a general worsening of climate in the later Bronze Age, a 'deterioration' in climate *c*400-600 AD and the implications for human communities at these times. Is there any evidence for a 'Little Ice Age' in the palaeoenvironmental record?

Proxy climatic studies using bog surface wetness combined with good chronostratigraphic dating control are required.

Alluviation in non-tidal river valleys
Until recently there has been very limited work on the history of alluviation in river valleys in Wales compared with other parts of Britain and the alluvial archaeology of non-tidal river valleys in Wales has been considerably under-researched. There are two main aspects to this work, i.e. locational and palaeoenvironmental, both of which have implications for archaeology.

1. How has river development in Wales been influenced by late Pleistocene and earlier glaciations and what are the implications for the archaeological record (Macklin 1999)?

2. What have been the effects of channel and floodplain development during the Holocene on the archaeological record (Macklin 1999)? How have they affected settlement and land use as well as the preservation and visibility of the alluvial archaeological record?

3. What is the relationship between river alluviation and erosion episodes and climate and land-use change (Macklin 1999)? To what extent can phases of intensified river activity in Wales be linked to wetter and/or cooler periods of climate? When did valley floor deforestation occur?

4. What impact did extreme flood events during the Holocene have on settlement and ritual practices/ landscapes in river valleys?

5. What are the taphonomic factors that influence artefact movement and preservation in river systems?

A multidisciplinary approach should be adopted to elucidate the history and dynamics of human settlement in river valleys. Geomorphological survey should normally precede archaeological survey of river valleys. Data collected need to be compatible and of the appropriate spatio-temporal scale for evaluating cause-and-effect relationships, and representative reaches over an entire basin need to be examined (cf. Macklin and Lewin 2003).

Coastal alluviation and sea-level change
Most studies have been concerned with sea-level rise *per se* and have been undertaken independently of any archaeological investigations. There are a number of research questions that are essentially palaeoenvironmental but are of relevance to archaeology

1. To what extent are the transgressive and regressive episodes of sea-level tendency in Wales coeval from site to site, and region to region (Bell 2001) and how has this affected exploitation of coastal areas in different parts of Wales at different times?

2. What are the factors driving transgressive and regressive episodes locally as well as regionally and to what extent have long-term processes and catastrophic events determined the pattern of coastal environmental change (Bell 2001)?

3. What was the character of the pre-inundation Mesolithic environment and the role of human agency (Bell 2001)?

4 The besanding of settlements is well known but more precise chronologies need to be established for dunes in Wales.

5. The investigation of boats and waterfronts would provide information about the transport of goods.

Multidisciplinary studies are required. A full range of palaeoenvironmental analyses including sediment, diatoms, foraminifera, rhizopods, pollen, plant macrofossils, beetles and animal bones need to be applied to study changing environmental conditions. These investigations need to be underpinned by high-precision radiocarbon dating and dendrochronological dating. Investigation of well-stratified Mesolithic sites, especially midden sites, is of high priority.

Threats
The range of threats is similar to that for other aspects of archaeology and includes drainage of wetland sites, sand and gravel extraction, liming of sites, afforestation of uplands, road and industrial developments, natural coastal erosion, and erosion caused by leisure and recreational pressures.

Another problem, if not a threat, is the often limited resources available on developer funded sites which result in under-funding, if indeed any funding, of environmental work. This is perhaps most apparent in urban areas where sampling is either not undertaken or, if samples are recovered, they are not analysed resulting in a loss of evidence.

Recommendations for the future and key general priorities

A Welsh environmental archaeology database already exists but this could be upgraded and extended to include human bone data, radiocarbon lists and more detailed palaeoenvironmental data, for example, additional pollen site data indicating the time period covered could be included. This needs to be more

closely integrated with other databases such as the NMR and SMRs and the recently produced Holocene alluvial database produced by Macklin and Lewin for Wales, Scotland and England.

The recording of the environmental potential of sites should be standard practice during archaeological survey work, as it is now on Cadw projects, for example the Funerary and Rituals Sites project.

There should be closer interdisciplinary collaboration, particularly between archaeologists and earth scientists.

Environmental archaeologists/earth scientists should be involved in the planning and field stages of projects, especially where fellow scientists can benefit from the time-depth perspective provided by archaeological sites (Bell 2001).

Of high priority is the need for more integrated studies involving excavation and survey combined with on-site and off-site analyses.

Similarly, multi-proxy approaches need to be used to provide more comprehensive environmental reconstructions and, where the sources of evidence are in agreement, to increase the level of confidence regarding the interpretation.

Finally, it is essential that palaeoenvironmental work, whether on-site or off-site, is supported by an adequate radiometric dating programme. Sieving programmes of occupation horizons are vital not only to recover palaeoeconomic evidence but also to recover material for dating, especially 'single-entity' dating, i.e. AMS dates from single pieces of wood, bone or seeds.

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