A Palaeoenvironmental Overview of the Merseyside Area

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Introduction

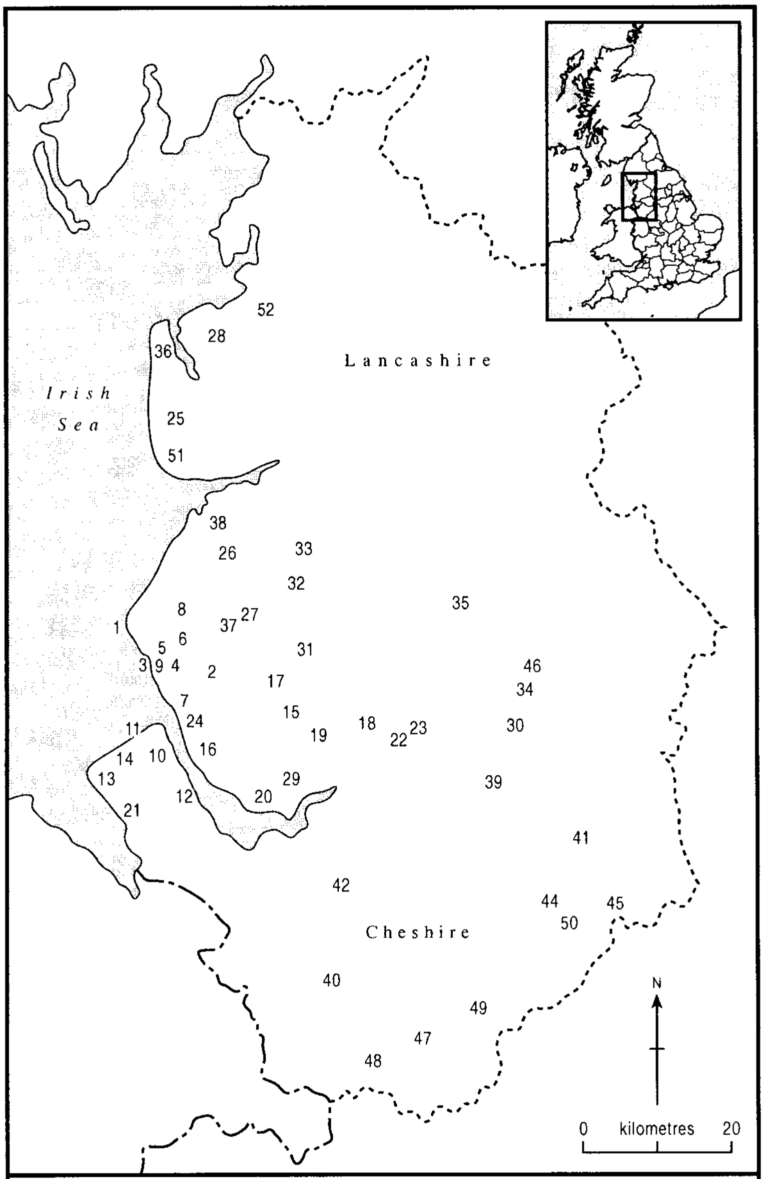
The theme of the first part of the paper is to examine the diversity and evolution of the natural palaeoenvironmental units in the Merseyside region, while the second part traces the influence of humans in responding to, and in modifying, their environmental context. Information derived from fossil pollen assemblages preserved in ancient sediments forms the basis for palaeoenvironmental studies (Barber 1993), allowing the reconstruction of past vegetation cover and its interpretation in terms of human impacts or natural environmental change (Cowell and Innes 1994, Chiverrell and Innes 2004). This is supported by radiocarbon dating of organic deposits and by the analyses of plant macrofossils and other fossils such as diatoms, molluscan and insect remains, as well as by the study of the stratigraphic sequence and the nature of the sediments. All of these are integrated with the archaeological record.

Since the publication of the environmental archaeology review (Innes and Tomlinson 1991), the North West Wetlands Survey and other authors have produced several detailed reports (Cowell and Innes 1994, Leah *et al.* 1997, Innes *et al.* 1999, Middleton *et al.* in press). This paper discusses the recently acquired pollen evidence in the light of new radiocarbon dating. It is important to stress, however, that although some of the Merseyside pollen evidence is detailed, providing a high resolution record of vegetation change, some of the area's many pollen investigations are less so. Those that were concerned with reconstructing general forest history may not have employed the large numbers of counted levels and close sampling intervals that are needed to investigate short-term ecological changes of the kind that follow human impact of limited extent and duration. Also, some time periods are poorly represented in the pollen record as few suitable sediments have survived for examination. The post-Roman period, for example, is less thoroughly researched as many of the deposits of that age have been destroyed by recent processes like land drainage and ploughing. Other aspects of palaeoenvironmental history also need to be studied much more closely, using a range of other techniques of reconstruction that complement the pollen data, so that a more integrated understanding of landscape development in the region is possible. Much more research, focused on time periods and areas that are presently under-represented, will be needed before a comprehensive record of palaeoenvironmental history in the Merseyside area can be achieved (fig. 1.).

The Glacial Foundation

North west England was heavily glaciated by successive ice advances during the last glacial stage (termed the Devensian in Britain) and at its maximum about 22,000 years ago (Eyles and McCabe 1989, Lambeck and Purcell 2001), ice cover extended to the whole of the region with the Lancashire-Cheshire plain buried beneath thick ice sheets (Worsley 1985, 1991). In relation to Merseyside, the nearest surviving environmental evidence for conditions prior to the glacial maximum occurs in south Cheshire in the form of rare organic layers exposed in quarry sections. These date from before and within the last Glacial period before the maximum ice advance (Worsley 1999). One of these, at Four Ashes, is a detrital peat underlying the glacial till. It contains high tree pollen percentages of *Quercus* (oak), *Alnus* (alder) and *Corylus* (hazel), as well as *Alnus*, *Taxus* (yew) and *Ilex* (holly) macrofossils, and may well date from the Ipswichian temperate interglacial (oxygen isotope stage 5e, about 120,000 BP) and the succeeding early Devensian cold stage. At Arclid a similar Ipswichian type pollen flora came from sediment associated with a mammoth tooth. Also in Cheshire, at Farm Wood Quarry, Chelford, organic silts and peat contained a *Pinus* (pine), *Picea* (spruce) and *Betula* (birch) tree pollen assemblage, as well as stumps of spruce trees, which suggests a brief period of expansion of temperate boreal woodland, probably spruce dominated, in the early Devensian around 80,000 years ago (Worsley 1999). Spruce is not native to Britain in the Holocene. A peat deposit correlated with the Farm Wood sediments was recovered from a borehole at Burland in Cheshire (Worsley 1999). The evidence from these sites gives a glimpse of the types of woodland that developed in the plains of Merseyside before the ice sheets stripped the landscape bare. Remains of components of the fauna that occupied such ancient environments at various times before the last full glacial have been preserved in caves on the edges of the Pennine upland and include animals such as hyena, bison and hippopotamus, to add to the Arclid mammoth (Thomas 1999). Hippopotamus suggests the warm climate of the full last (Ipswichian) Interglacial, but the others could represent a range of time periods and ecological conditions.

The major environmental significance of glaciation to Merseyside has been its legacy of erosional landforms and the subsequent deposition of a complex suite of sediments associated with the processes of deglaciation (Huddart and Glasser 2002). An Irish Sea ice lobe pushing across Merseyside in a south-easterly direction over-deepened river valleys such as the Mersey and Dee and established the current drainage alignment of the area (Glasser and Hambrey 1998, Huddart and Glasser 2002). Deposition of the, predominantly clay, glacial tills (Longworth 1985) provides the basis upon which all later sedimentation has been superimposed. These deposits are now termed the Stockport Formation in Cheshire and the Kirkham Formation in Lancashire (Thomas 1999, Worsley 1999) and are exemplified by the coastal exposures at Thurstaston on Wirral (Glasser *et al.* 2001). The surface of the till plain was made more diverse by the deposition of sediment transported by water from melting glaciers (fluvioglacial) and of material eroded under very cold climate conditions (periglacial) during deglaciation from about 18,000 BP. These were subsequently redistributed by geomorphological processes like wind and hillslope erosion until the end of the Late Glacial period about 10,000 BP. These sediments comprise clays, sands and gravels (Johnson 1985) and most significant in Merseyside are probably the Shirdley Hill coversands, discussed below, as well as gravel deposits in river valleys like the Mersey itself. Within the glacial sediment plain there are also outcrops of solid rock, mainly sandstones, which provide further diversity of parent material, particularly in the Wirral, Liverpool and Prescot/St. Helens areas. This mosaic of contrasting geological units has created a high degree of complexity in the surface geology of Merseyside, and in its topography and natural drainage systems. These aspects have in turn influenced later geographical patterns of soils and vegetation and hence, human activity.



1. Lifeboat Road, Formby
2. Aintree
3. Alt Mouth
4. Altcar
5. Flea Moss Wood
6. Ince Blundell
7. Murat St, Waterloo
8. Downholland Moss
9. Sniggery Wood
10. Bidston Moss, Wirral
11. Dove Point, Meols
12. Bromborough Courthouse
13. Newton Carr 11
14. Park Road, Meols
15. Knowsley Park
16. Moss Lake, Liverpool
17. Simonswood Moss
18. Parr Moss
19. Prescot Moss
20. Speke Hall
21. Thurstaston Hill
22. Bewsey Old Hall
23. Winwick
24. Rimrose Brook
25. Poulton-le-Fylde
26. Mere Sands Wood
27. Firswood Road
28. Fenton Cottage
29. Ditton Brook
30. Holcroft Moss
31. Holiday Moss
32. Hoscar Moss
33. Mawdesley Moss
34. Nook Farm
35. Red Moss
36. Rossall Beach
37. Clieves Hill
38. Churchtown Moss
39. Rostherne Mere
40. Peckforton Mere
41. Lindow Moss
42. Hatchmere, Cheshire
43. Four Ashes
44. Farm Wood Quarry, Chelford
45. Danes Moss, Cheshire
46. Chat Moss
47. Burland
48. Bar Mere
49. Arclid
50. Walker's Heath
51. The Starr Hills, Lytham
52. Winmarleigh Moss

Fig. 1. The location of the palaeoecological sites referred to in this paper. Sources for these sites are referenced in the appropriate place in the text. These sites represent only a selection of the total number of analysed sites that exist in the region.

The Shirdley Hill Sands

A key element of the geological complexion of northern Merseyside and south west Lancashire are the Shirdley Hill Sands which cover much of the till plain in these areas with varying depths of coarse grained sand. Although originally an ice meltwater (fluvioglacial) coversand deposited as the ice sheet retreated, these sands were subsequently redistributed by wind action (Tooley and Kear 1977, Wilson *et al.* 1981) under the severe cold conditions at the end of the Late Glacial and after destabilisation by human action at intervals in the Holocene (Innes 1986). De Rance (1869, 1871) first noted the sand as a discrete unit, and also noted that in many places it was interleaved with organic layers, as near Shirdley Hill itself. Travis (1909) studied plant remains from these organic layers within the sand at Aintree. The Late Glacial provenance of the sand has been proven by Godwin (1959) at Moss Lake, Liverpool who noted it stratified between organic lake muds of the Late Glacial temperate Interstadial (up to 11,000 BP) and the muds and peats of the succeeding Holocene postglacial (after 10,000 BP). Its pre-Holocene origin was confirmed by the dating of a peat layer beneath the sand to 10,455±110 BP at Clieves Hills near Ormskirk (Tooley 1978, Innes *et al.* 1989). Baxter (1983) reported similar ages for peats below Shirdley Hill Sand at several locations in the Mersey lowlands. The environmental context of the sand at Mere Sands Wood near Martin Mere has been

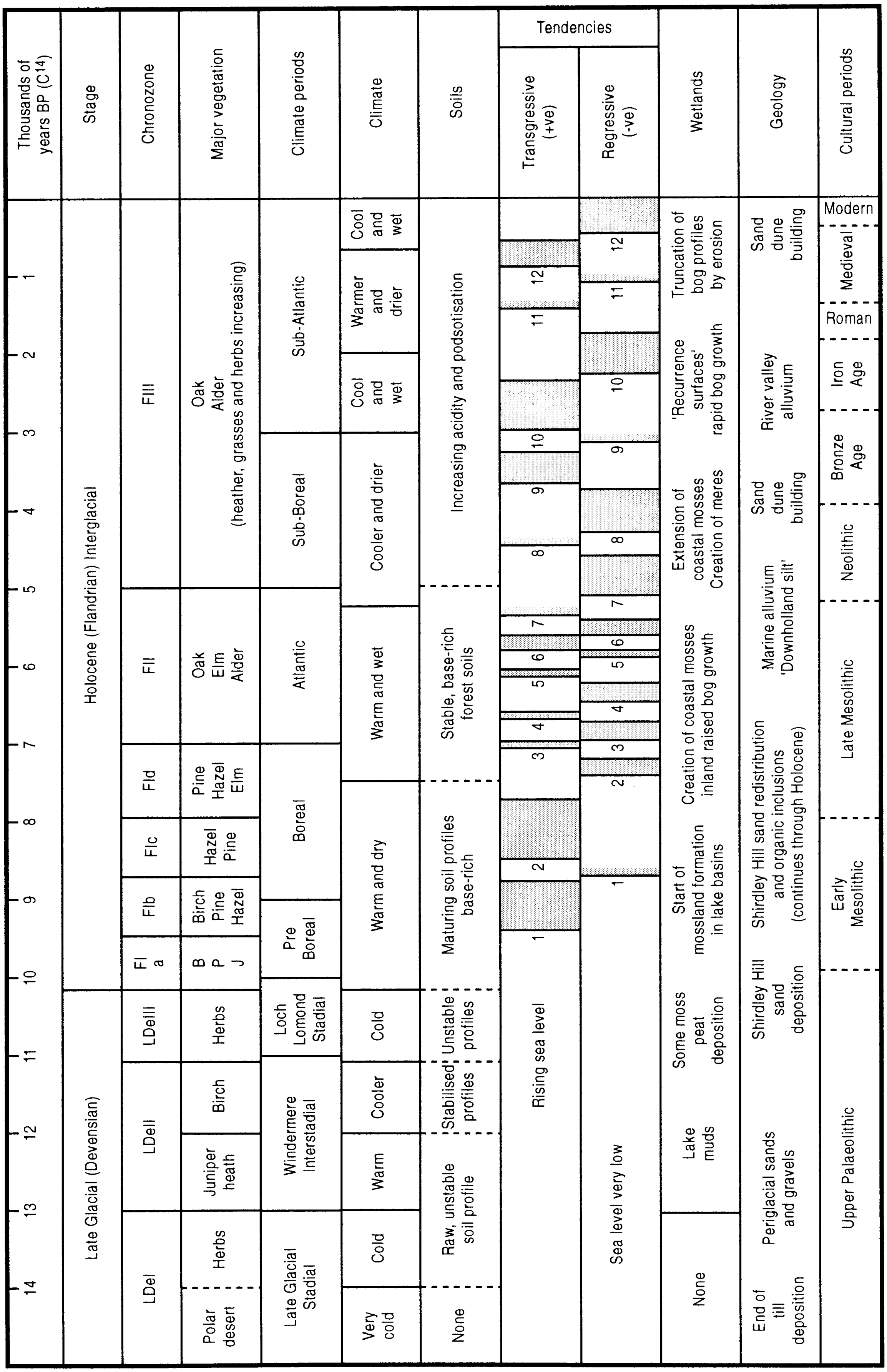
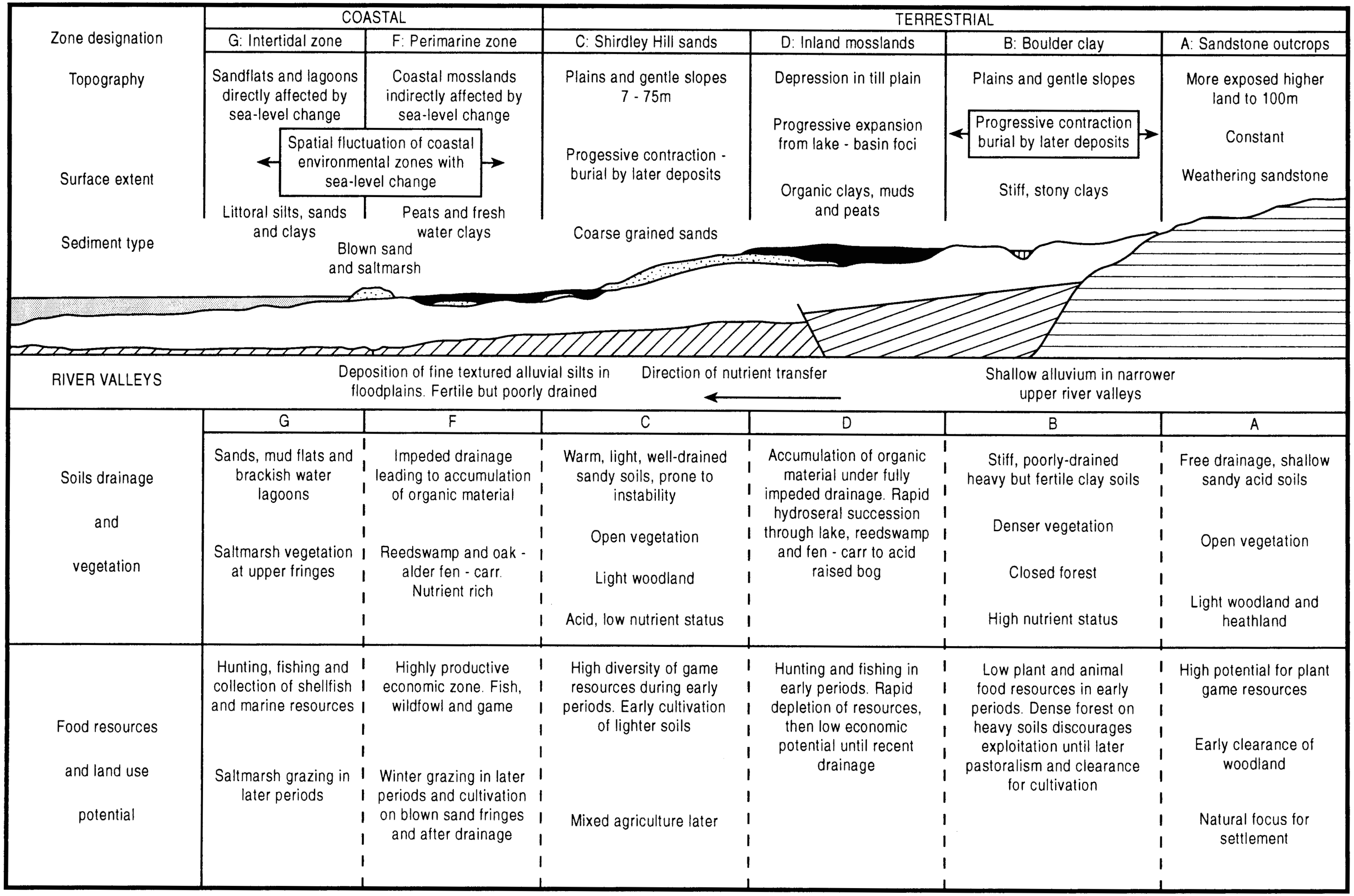


Fig. 2. Summary of the main environmental factors that have influenced landscape development in the Merseyside region since the start of the Late Glacial period, with correlation to archaeological cultures.



	COASTAL		TERRESTRIAL			
Zone designation	G: Intertidal zone	F: Perimarine zone	C: Shirdley Hill sands	D: Inland mosslands	B: Boulder clay	A: Sandstone outcrops
Topography	Sandflats and lagoons directly affected by sea-level change	Coastal mosslands indirectly affected by sea-level change	Plains and gentle slopes 7 - 75m	Depression in till plain	Plains and gentle slopes	More exposed higher land to 100m
Surface extent	Spatial fluctuation of coastal environmental zones with sea-level change		Progessive contraction - burial by later deposits	Progressive expansion from lake - basin foci	Progressive contraction burial by later deposits	Constant
Sediment type	Littoral silts, sands and clays	Peats and fresh water clays Blown sand and saltmarsh	Coarse grained sands	Organic clays, muds and peats	Stiff, stony clays	Weathering sandstone
RIVER VALLEYS	Deposition of fine textured alluvial silts in floodplains. Fertile but poorly drained			Direction of nutrient transfer ←	Shallow alluvium in narrower upper river valleys	
	G	F	C	D	B	A
Soils drainage and vegetation	Sands, mud flats and brackish water lagoons Saltmarsh vegetation at upper fringes	Impeded drainage leading to accumulation of organic material Reedswamp and oak - alder fen - carr. Nutrient rich	Warm, light, well-drained sandy soils, prone to instability Open vegetation Light woodland Acid, low nutrient status	Accumulation of organic material under fully impeded drainage. Rapid hydroseral succession through lake, reedswamp and fen - carr to acid raised bog	Stiff, poorly-drained heavy but fertile clay soils Denser vegetation Closed forest High nutrient status	Free drainage, shallow sandy acid soils Open vegetation Light woodland and heathland
Food resources and land use potential	Hunting, fishing and collection of shellfish and marine resources Saltmarsh grazing in later periods	Highly productive economic zone. Fish, wildfowl and game Winter grazing in later periods and cultivation on blown sand fringes and after drainage	High diversity of game resources during early periods. Early cultivation of lighter soils Mixed agriculture later	Hunting and fishing in early periods. Rapid depletion of resources, then low economic potential until recent drainage	Low plant and animal food resources in early periods. Dense forest on heavy soils discourages exploitation until later pastoralism and clearance for cultivation	High potential for plant game resources Early clearance of woodland Natural focus for settlement

Fig. 3. Summary landscape zones of the Merseyside region, based on topography, geology and soils, and their ecological characteristics.

reviewed by Chiverrell (2002a). Nowhere very thick, the surface veneer of sand has provided a different set of soil and vegetation factors in comparison with the heavier conditions of the till plain, with implications for human settlement in the area (Innes and Tomlinson 1983a,b). Delayed vegetation successions in the early Holocene on the sand at Knowsley Park (Cowell and Innes 1994, Innes 1996) and Holiday Moss (Innes *et al*. 1989) suggest that it may have remained unstable and poorly vegetated for several centuries after the start of the postglacial, whereas forest was established rapidly upon the more fertile and heavier clay soils (Hibbert *et al*. 1971, Cowell and Innes 1994). Periods of instability and sand blowing occurred throughout the Holocene, as at Firswood Road in the late Mesolithic period (Middleton *et al*. in press) and at Aintree during the Neolithic (Innes 1992a). Many of the pollen profiles used to reconstruct the vegetation history of Merseyside and environs are located in Shirdley Hill Sand areas where organic sediments are common (Cowell and Innes 1994, Middleton *et al*. in press), in contrast to the restricted environmental record from the till plain.

Macro-environmental factors

Several natural macro-environmental factors have greatly influenced the development of Merseyside's vegetation and landscape (Chiverrell *et al*. 2004). Climate and drainage and their effects upon soil development have been vital, whilst sea level change has had dramatic consequences in the coastal and lower fluvial zones. The influence of climate change in the region has been discussed by Musk (1985) and Huntley (1999). Dramatic climatic variations in the Late Glacial period are reflected in the tripartite sediment stratigraphy laid down at this time in the lake basins of the region (Godwin 1959, Birks 1965a). Organic sediments formed during the temperate conditions of the Late Glacial Interstadial between about 13,000 and about 11,000 BP are bracketed by minerogenic deposits of the preceding cold phase at the end of the glacial and the severe cold of the Loch Lomond Stadial between about 11,000 and about 10,000 BP (fig. 2). Insect assemblages (Ashworth 1972, Lowe and Walker 1997, Hughes *et al*. 2000), among the most sensitive indicators of past temperatures, suggest that warmest conditions occurred soon after 13,000 BP. Innes (2002a) has referenced several recent high resolution studies of ice-core and environmental data records which make it clear that while the simple threefold climatic division of the Late Glacial is valid at the broad scale, the climatic and environmental changes during this period were much more complex, with many finer-scale oscillations. Several minor climatic reversals of varying duration and intensity were present within the three major Late Glacial Stadial and Interstadial periods, operating at least at a millennial scale or even of shorter duration. These are too many and short-lived to be shown on fig. 2, which shows only the broad themes of environmental history.

In Merseyside, as elsewhere in the British Isles, the end of severe cold climate at 10,000 BP was abrupt, with a very steep thermal rise to the warm conditions of the Holocene Interglacial. In broad terms the early Holocene, before about 7500 BP, was characterised by mild winters and a dry continental climate (Musk 1985). More oceanic conditions occurred in the mid-Holocene between about 7500 and 5000 BP, with high rainfall and mean summer temperatures up to 3ºC higher than today. Reduced seasonal contrasts characterise the Later Holocene after about 4000 BP (Huntley 1999). Cool conditions ensued until about 3000 BP, after which a major deterioration took place lasting almost a millennium, with a colder, wetter and more maritime climate and a greatly increased incidence of storminess characterising the Late Bronze Age and Iron Age periods (fig. 2). Warm, dry conditions returned at about 2,000 BP and, with a cooler interlude between about 1500 and 1200 BP, persisted until about 700 BP, with Late Medieval times after about 1000 BP having a particularly congenial climate (Musk 1985). A decline to cold and wet conditions followed, with a particularly cold period between about 500 BP and 150 BP (about 1450-1800 AD) termed the "Little Ice Age'. Successive warmer or colder intervals characterise Holocene climatic history but there have also been fluctuations on the decadal scale superimposed upon the more long-term trends (Huntley 1999).

Soil development

Although soils began to develop in the Late Glacial, the disruption of soil profiles caused by the severe cold conditions of the Loch Lomond Stadial meant that most Merseyside soil types did not begin to evolve until the start of the Holocene warm period. Soil development would have proceeded at different rates on the contrasting surface geologies of the region (Hall and Folland 1967), with perhaps slower development and thinner, skeletal soils in the sand areas. By the mid-Holocene warm and wet climatic phase after about 7500 BP, mature brown earth forest soils would have occurred on the heavier clay tills, whereas on the more acid sandy substrates of the Shirdley Hill Sands and sandstone outcrops such as the Cheshire ridge forest podsols would have been more common (Kear 1985). Organic soil formation, and eventually peat soils, began to form in conducive locations under this warm, wet mid-postglacial climate. Lower temperatures and leaching in the later Holocene led to soil acidification (podsolisation), accelerated by human activities, and so to increased peat formation and general soil degeneration. To summarise, following Kear (1985), the till plain of Merseyside has developed fertile clay-loam soils with a tendency to elevated water tables (gleying) and, ultimately, waterlogging. In contrast, fluvioglacial sands, and the gravels of the major river valleys of the region, have developed generally free-draining, loamy brown sands. Gley soils prone to waterlogging have developed over the freshwater and marine alluvial silts along the Sefton and Wirral coasts and in the lower reaches of river valleys.

Highly significant in Merseyside has been the growth of organic soils as the endpoint of waterlogging processes, encouraged by the area's generally low relief. Thin organic soils must have been very widespread in the area until drainage in the last millennium and in many places organic accumulation continued until true peats formed, classified as the Altcar Formation (Hall and Folland 1970, Kear 1985). Lowland peats were particularly common in the coastal lowlands of Sefton and Wirral, but also occurred in basin situations in central Merseyside between Ormskirk and Knowsley (Shimwell 1985, Cowell and Innes 1994). In many of these inland basins, but also in places on the coastal plain, these centres of peat accumulation grew into acid raised mosses fed only by rainwater. These organic depositional environments have provided much of the environmental information used to reconstruct Merseyside's landscape history (Innes and Tomlinson 1980, 1983b, 1991, Cowell and Innes 1994).

A further macro-environmental influence on Merseyside's landscape has been the variation in sea level and coastal configuration. Melting of the ice sheets caused the sea level to rise rapidly in the Late Glacial and early Holocene periods. In the early Holocene this rise must have submerged many freshwater wetland sites to the west of the current Merseyside coast thus preserving both offshore and intertidal Late Glacial sediment sites. At Rossall Beach in Lancashire Late Glacial kettle-hole deposits exposed in the intertidal zone contain a Late-Glacial type pollen assemblage dominated by herbaceous plants and are dated to 12320±155 BP (Tooley 1985a). By the mid-Holocene around 7500 BP, in the Late Mesolithic period, the rate of rise had slowed considerably and the coastline was near its current location, and between about 6500 and 5000 BP high sea level carried the coast well to the east of its present position. Mid and late Holocene fluctuations in sea level, between about 6500 and 4000 BP, caused the deposition of successions of alternating marine and freshwater or terrestrial sediments in low lying areas such as Downholland Moss in Sefton (Tooley 1978), or on the north Wirral coast (Kenna 1986). These sediment sequences, and the exposure of peat beds in intertidal situations, have stimulated research on sea level history at least since the 19th century (e.g. Reade 1872, 1881, De Rance 1877, Morton 1891), continuing in the 20th (Erdtman 1928, Travis 1926, 1929) and particularly in recent decades (e.g. Tooley 1974, 1978, 1980, 1982, 1985a, b, Kenna 1986, Huddart 1992, Tooley et al. 2004). The sea level history of Liverpool Bay and the extensive literature on its research have been reviewed by Plater *et al*. (1993, 1999). Three major transgressive events, times of relative sea level rise, were recorded by Tooley (1978) in the Sefton and south west Lancashire lowlands culminating in high Late Mesolithic sea levels. These were replaced in the early Neolithic by a low sea level stand, expressed by the dating of many of Merseyside's 'submerged forests' to that time, as at the Alt Mouth (Tooley 1978). Sea level continued to rise slowly after that time although increased sedimentation in the coastal zone and the formation of coastal barriers, primarily sand dune systems (Pye 1990, Tooley 1990, Innes and Tooley 1993), have meant that later Holocene sea level rise after about 4000 BP has generally been unable to inundate coastal lowlands except perhaps in small embayments.

Environmental Zones

The diversity in the area's surface geology and its influence upon several other environmental factors has encouraged authors to identify a series of contrasting environmental zones with differing palaeoenvironmental conditions as Merseyside's landscape history developed (Innes and Tomlinson 1983a,b, Cowell and Innes 1994). These are shown in fig. 3 and form the basis of landscape units within which variability in soils, climate, vegetation and human land-use in the Holocene have all acted to alter depositional regimes. Central to this zonation is the altitudinal gradient from the upland rock outcrop areas to the estuarine and littoral areas of the coastal zone, with major river systems adding complexity to the intermediate lowland plains. Of particular importance are wetlands and their associated organic deposits as these were abundant in the region prior to the drainage of the last few centuries and added diversity within the larger zones in the landscape as well as forming important zones in their own right. They are also critical because of the range of diagnostic biological material that has been preserved for study. Detailed surveys of lowland wetland sediments in Merseyside and its vicinity (Shimwell 1985, Howard-Davis *et al*. 1988, Cowell and Innes 1994, Leah *et al*. 1997), have established the richness and diversity of the wetland sediment resource.

Depositional environments

The lake basin to raised bog succession

An important element of Merseyside's environmental resource is the record preserved within the numerous enclosed basins found in many parts of the area, which contain sediments formed under wetland depositional environments. All the stages of the ecological succession from open water lake to raised bog are found in these infilled basins (Shimwell 1985).

Lakes

Many depressions originated through glacial erosion or deposition and may have accumulated sediment since the early Late Glacial and in some cases right through the Holocene period. Their infill is mainly organic with interspersed lake mud, marl, silt, clay and coarser grained deposits. In many cases Holocene organics form the basal sediment in the shallower parts of basins, spreading from deeper centres or becoming waterlogged under wetter climate in the mid- and later Holocene after about 7500 BP. Some basins were formed in the post-glacial due to local events, as through salt solution subsidence in parts of north Cheshire (Reynolds 1979). Lake sediments dominate the early stages of many basins, but in Merseyside none have persisted as water bodies to the present day, the meres of the north Cheshire plain being the closest example (Reynolds 1979, Leah *et al.* 1997). Several lakes would still exist in Merseyside and its environs were it not for their deliberate drainage and reclamation, with Martin Mere the prime example but with others such as Gettern Mere near Formby also now dry (Tooley 1978, Coney 1992).

Raised bogs

Many basins have naturally passed through the various stages of succession and sediment infill until, by the later Holocene, they have developed into acid raised bogs; others remain in an intermediate stage (Tallis 1973). Some sites have developed into raised bogs over coastal marine clays (Tooley 1978, 1985a). Although most raised bogs in Merseyside, as elsewhere, have been extensively damaged by the cutting of their upper layers for fuel, where they survive as raised bogs reliant on rainwater for their growth, they preserve several indicators of changes in climate in their stratigraphic sequence. One example is a sequence of accelerated peat growth caused by a cooler, wetter period, known as a recurrence horizon, that may be of local or regional significance and perhaps these suggest wet shifts in climate history in north west England (Barber 1982). Radiocarbon dates of 2447±43 to 2345±45 BP from Lindow Moss in north Cheshire (Leah *et al.* 1997) and 2645±100 BP from Chat Moss in Greater Manchester (Godwin and Switsur 1966) are typical for the major change to cold and wet climate in Iron Age times. Other more detailed studies of peat stratigraphy examine the degree of decay of the organic material (humification), or succession of mire plant species (macrofossil stratigraphy) and provide a highly sensitive record of mire palaeohydrology, and hence palaeoclimate (Barber *et al.* 1998). The long pollen records recovered from these lake and mire sequences, particularly with good radiocarbon dating control as at Red Moss (Hibbert *et al.* 1971) and Knowsley Park (Cowell and Innes 1994, Innes 1996), have formed the basis for study of Holocene climate and vegetation change in the region and allowed regional overviews of environmental history (Innes *et al.* 1999).

Intertidal and Coastal Wetlands

The postglacial sea level rise carried the shoreline of Liverpool Bay to approximately its present position by the mid Holocene, around 7000 BP. (Tooley 1978, 1982, Plater *et al.* 1993) after which a suite of wetland depositional regimes became established in the coastal zone, with either a direct or indirect relationship with marine conditions and tide level. Under direct marine influence were the sand and mudflat environments of the lower intertidal zone where sands, silts and clays were deposited; and the upper intertidal vegetated saltmarsh zone in which increasingly organic sediments were laid down. Raised groundwater tables and reduced rates of river flow due to high sea level caused the creation of a belt of freshwater wetland environments between high tide level and higher ground. This ‘perimarine’ zone (Tooley 1985a), indirectly stimulated by sea level change and also accepting seasonal freshwater drainage from landward, was of considerable extent on the low gradient coasts around Liverpool Bay and penetrated well into the lower parts of the area’s river valley floodplains. This zone comprised a mosaic of groundwater-fed, nutrient-rich lagoons, swamps, fens and freshwater meres with complex organic sedimentary regimes. These were prone to rapid changes in water level and susceptible to penetration by marine conditions. The Downholland Moss and Martin Mere area of south west Lancashire provides a good example of the sedimentation history characteristic of these near-coastal wetland environments (Tooley 1978, 1985a,b, Chiverrell 2002b, Huddart 2002).

Some peat-forming systems in these coastal fringes of Merseyside progressed to raised bog communities (Tooley 1978). Low amplitude fluctuations in sea level, local changes in coastal morphology and sediment flux caused spatial readjustment of the coastal depositional environments, so that deep, complex stratigraphic sequences of alternating intertidal and perimarine peats, silts and clays accumulated in the coastal areas in small embayments, river valleys and adjacent to the open coast (Huddart *et al.* 1977, Tooley 1978, Kenna 1986, Innes *et al.* 1990, Huddart 1992, Cowell and Innes 1994, Middleton *et al.* in press). In these areas mid-Holocene marine sediments, dating from about 6500 to about 5000 BP are found well inland of the present coast. Clear geological evidence of fluctuating sea level and past coastal change lies in the peat beds of terrestrial origin which are exposed in the present day intertidal zone, as at the Alt Mouth, Hightown (Tooley 1978, Gonzalez and Huddart 2002b) or Dove Point, Meols (Kenna 1986, Innes *et al.* 2000). These contain remains of ancient woodland overtaken by rising sea level (Innes 1983, Kenna 1985). These intertidal ‘submerged forests’ were hitherto much more extensive than today (Reade 1872, De Rance 1877), and many have undergone severe recent erosion. Of widely differing ages, they are exposed analogues of the terrestrial elements of the intercalated coastal successions (Tooley 1978, 1985a, Innes *et al.* 2000). These were resource-rich environments that must have been very attractive to past human settlement and activity, as shown by abundant archaeological and palaeoecological evidence. Human settlement and activity was closely affected by shoreline development during several cultural periods

(Kenna 1979, Fulford *et al.* 1997). The exploitation of the coastal zone over a long period of time around Liverpool Bay has been shown from Formby (Gonzalez *et al.* 1997; Huddart *et al.* 1999a, 1999b, Roberts *et al.* 1996), where occasional finds of animal bone of several species, wild and domestic, have been recovered from intertidal sediments, some with cut marks. Human and animal footprints preserved in the estuarine silts from Mesolithic times onwards are direct evidence of human use of these productive coastal environments.

Eutrophic Reedswamp, Fen and Carr

A lowland region of generally gentle relief such as the Mersey plain would develop nutrient-rich (eutrophic) wetlands at the foot of hillslopes and in any water-receiving locations where drainage was slow and the soils therefore prone to waterlogging. Seasonal flooding would tend to maintain the marsh and fen environments. The higher sea level after about 7000 BP, coupled with a wetter climate, led to the stabilisation of river regimes with low gradients. These led to increasingly poorly drained soils in low lying areas, and fen and carr wetlands became ubiquitous fringing the alluvial floodplains. Eutrophic floodplain and valley mires often came to be dominated by alder carr woodland (Brown 1988) and these stable fen and fen-carr systems could persist for millennia, replenished by winter flooding, and depositing slowly forming peats and minerotrophic organic silts. The Gowy valley in north Cheshire is a good example of long-term persistence of valley fen wetland (Shimwell 1985). Superabundant alder pollen frequencies from valley fen peat, often well over 80% of total pollen, are maintained at some sites for thousands of years, as at Ince Blundell in the Alt valley (Cowell and Innes 1994). At other sites in the later Holocene, permanent waterlogging and marsh and fen sedimentation in valley bottoms could be easily stimulated by single events impeding local drainage. In many places eutrophic reedswamp, marsh and fen-carr wetlands would have attracted intensive human occupation and exploitation of these productive environments. Because of recent intensive drainage and farming in Merseyside many of the shallow peat deposits formed in eutrophic reedswamp and fen wetlands have not survived or have been reduced to thin organic soils.

Freshwater Alluvial Sediments

An important component of the Holocene sedimentary resource is that laid down within alluvial environments in the river systems of the Merseyside region, with water-transported sediment released from suspension as rivers' energy and rates of flow fall in their low gradient, lower reaches. Sequences of fluvially-derived minerogenic sediments occupy the river valleys and mainly reflect the past effects of climate on river discharge, although the influence of past human land-use in destabilising soil and allowing its erosion and incorporation into rivers is also important. Periods of river activity in the later Holocene after about 5000 BP can be matched to climatic changes and are marked by alluviation in their lower reaches as well as by terrace formation. Redeposition of fluvial sediment will have affected upper estuarine depositional regimes, particularly in the major estuaries of the Mersey, Dee and Ribble, from about 4000 BP onwards. Sedimentation is usually fine-grained but is coarser during more extreme climatic deterioration, as after about 3000 BP. The usual type of deposition appears to have been the transport of large packets of sediment deposited as discrete alluvial units during times of flooding rather than a more gradual transport of material. Extensive organic sedimentation took place in river valley wetlands usually under long-term alder carr communities (Brown 1988). Pollen diagrams from such valley peat in Merseyside are few but show this dominance of floodplain alder very well, as at Ditton Brook (Innes 2001) and at Rimrose Brook (Innes 1991). Alluvial sediments bury and preserve old land surfaces and often contain organic layers, providing a potentially rich, long-term data record within Merseyside's river valleys.

Hill Peat and Blanket Bog

As a mostly lowland area, Merseyside and the rest of the Lancashire-Cheshire plain which surrounds it has virtually no true hill peat or blanket bog, although the mainly sandstone upland outcrops in Wirral, north Cheshire, Liverpool and to the east of Upholland almost certainly developed heathland over shallow peat soils from as early as 7000 BP in the mid-Holocene (Kear 1985). Late Holocene climatic deterioration after about 5000 BP probably prompted hill peat inception but there is evidence from north west England that, on higher ground, disturbance of tree cover by humans from Mesolithic times onwards probably also initiated peat formation (Tallis and Switsur 1983). Such thin blanket peat may well have spread to cover most of the lower gradient, water-shedding slopes of the Merseyside region's higher land, as perhaps on Thurstaston Hill, Wirral. The major spread of such thin moorland peats was probably caused by the cold, wet climate in Iron Age times after about 3000 BP. Most such sediments in the area will have undergone erosion and few remain.

Wind blown sand

Although their original extent has been much reduced by modern development, dune sand formations are characteristic of the present day Merseyside coast, usually comprising a relatively thin dune barrier which fringes the shoreline with a wider, but shallow, blown sand apron to landward. Although narrow, the major dune ridge can be relatively high, approaching 30m in the Sefton dunes (Atkinson and Houston 1993). Dune systems are to be found draped over rock outcrops but also rest upon till or gravel ridges, or more usually on coastal peat or marine deposits. There is evidence that dune systems may have formed earlier in the Holocene but extant coastal dunes mostly lie upon mid-Holocene sediments that formed after about 5000 BP and so are one of the region's more recent geological formations (Tooley 1990).

The palaeoecological study of dune systems in Merseyside (Tooley 1978, Kenna 1986, Innes and Tooley 1993, Pye and Neal 1993) suggests that from about 5000 BP onwards dates of phases of dune emplacement may have varied locally. Periods of high sea level may have encouraged dune slack formation and system stability. Some periods, as after 3000 BP, do seem to have a high incidence of dune establishment, and the medieval period also seems to have been an important phase of dune building in Merseyside (Kenna 1986). Dating of dune emplacement is most often undertaken indirectly by extrapolation from radiocarbon ages on subjacent peat or wood and on intercalated dune slack organic layers. Such dates for sand emplacement can vary considerably over quite short distances, for example between Crosby and Formby, with 4510±50 BP at Sniggery Wood, Little Crosby, 2680±50 BP at Murat Street, Waterloo and 2335±120 at Lifeboat Road, Formby (Innes and Tooley 1993). More direct dating through optical luminescence techniques (Pye *et al*. 1995) has also been applied near Formby and the history of Formby Point has been investigated (Gonzalez *et al*. 1997, Gonzalez and Huddart 2002a). Dunes have also been dated relative to archaeological material beneath or within them. The Merseyside coastal dune systems have probably experienced many periods of stability, instability and erosion, in both the longer term and more recent times (Plater *et al*. 1993, Pye 1990, Pye and Neal 1993). Both natural and human factors have contributed to dune erosion (Pye and Neal 1994). Blown sand also occurs in inland locations, particularly where glacial coversands have been reactivated by climatic or human destabilisation. Such episodes occurred at intervals after about 7000 BP (Innes 1986). Merseyside is a most significant area, on a national scale, for inland sand reworking (Tooley 1978, Innes 1986).

Late Glacial vegetation history

Major climatic fluctuations over a range of temporal scales during the Late Glacial period (Huntley 1999) caused considerable and often rapid changes in the vegetation of Merseyside, characterised by transitional plant communities. Climatic amelioration from about 15,000 radiocarbon years ago prompted a transition from barren polar desert to snow bed and sedge-tundra biota as solifluction ceased and allowed the colonisation of raw skeletal soils by plant colonisers such as Poaceae (grasses), Cyperaceae (sedges) and *Salix herbacea* (dwarf willow). This pioneer grass-sedge tundra flora was joined by open ground species of *Rumex* (sorrel), *Artemisia* (mugwort) and *Thalictrum* (meadow rue) as conditions improved and soils became increasingly stable. In the few pollen records from the Merseyside region containing data from this early Late Glacial phase, some birch and pine pollen grains are present from the beginning of deposition. These probably represent long distance transport of pollen or local growth of dwarf birch (*Betula nana)*. The very open, broken-ground flora of this early phase diversified as the period progressed, with increases in herb taxa such as *Helianthemum (rockrose*) indicating a more closed, stable grassland type on base rich soils (Pennington 1977). Plant succession and increasing climatic improvement after about 13,800BP prompted the patchy spread of low shrubs *Empetrum* (crowberry), *Juniperus* (juniper) and *Hippophaë* (sea buckthorn), but plant cover was still mainly grass and tall herb steppe. These early pollen assemblages were characterised by low diversity of plant species. Shrub cover continued to thicken and in places tree birch seems to have been present before about 13,000 BP.

A very abrupt rise in temperature recorded in the Greenland ice-core data at 13,000 BP (Lowe *et al*. 1994) marking the start of the Late Glacial Interstadial climatic warm phase is reflected very clearly in lake basins at sites in the Merseyside region, with deposition changing from mainly inorganic to mainly organic sediments. The early part of this period had much the warmer climate and the rapid thermal rise at 13,000 BP (fig. 2) stimulated expansion of a rich vegetation cover. Herbaceous steppe tundra and tall herb associations on raw soils, with taxa such as *Helianthemum*, *Rumex* and *Thalictrum* characteristic as well as sedges and grasses, formed the initial Interstadial vegetation phase (fig. 2). Crowberry and juniper would also have been present, in low numbers at the start but spread quickly, while birch also moved into the area and began to expand. Copses of tree birch became established in most areas in a succession to birch-juniper park-tundra, although in many areas less favourable for tree growth juniper dominance may have continued. The development of increasingly dense birch-juniper parkland was interrupted by a brief period of colder climate for a few centuries before about 12000 BP (Lowe *et al*. 1994). Too brief to show upon fig. 2, this cold phase is recorded distinctly upon several northern England pollen diagrams (Innes 2002a). Vegetation successions went into reverse and tree birch and/or juniper temporarily declined sharply, being replaced by herbaceous tundra communities, before recovering their former abundance with the return of temperate conditions around 12000 BP.

The presence of human populations in north west England during the Late Glacial temperate Interstadial before 12000 BP is proven by cut marks on mountain hare bones from Derbyshire caves with AMS dates which cluster around 12500 BP (Housley 1991). Artifactual evidence for human presence and activity during the wooded Interstadial phase between about 12000 and about 11000 BP is recorded in the region, most notably at Poulton-le-Fylde where bone hunting projectile points are associated with elk bones (Hallam *et al*. 1973). Charcoal is also recorded from regional Late Glacial sediments (Leah *et al*. 1997, Hughes *et al*. 2000), although the effects of burning would have been localised and the fires cannot be assumed to have had a human origin.

The warmer climate that returned after about 12000 BP, although cooler than the initial temperature rise at 13,000 BP, initiated the maximum expansion and development of vegetation communities during the Late Glacial Interstadial across Merseyside, as in most of northern England (Innes 2002a). This period between about 12000 and about 11000 BP may be broadly correlated (Pennington 1977) with the main woodland phase in the latter part of the British Late Glacial Windermere Interstadial (c.f. Allerød Interstadial in mainland Europe) and with zone Late Devensian II on fig. 2. The expansion of birch woodland is the diagnostic vegetation change of this phase, at least in lowland areas, as time lags in ecosystem development and soil maturation ceased to restrain plant successions (Pennington 1986). This spread of tree birch occurs at all the sites in the Merseyside region of this age, e.g. Moss Lake, Liverpool (Godwin 1959), Bagmere and Chat Moss (Birks 1965a), with dated profiles in the wider region conforming to this pattern, as in north Cheshire sites (Leah *et al*. 1997, Hughes *et al*. 2000), although birch values are not high enough to suggest more than open woodland.

A return of severe cold climate conditions in the last millennium of the Late Glacial (fig. 2), between about 11000 and about 10,000 BP, brought major environmental changes. Designated zone Late Devensian (LDe) III on fig. 2, in Britain this cold phase is called the Loch Lomond Stadial, and is termed The Younger Dryas period in continental Europe. Vegetation reverted to a very thin and patchy steppe tundra herbaceous flora dominated by grasses and sedges, with a wide range of cold tolerant herbs of which *Artemisia* (mugwort) is the most diagnostic, particularly in the more arid phases of this cold event. Ruderal types (i.e. plants that are favoured by disturbed soils) such as Chenopodiaceae (fat hen family), Caryophyllaceae (chickweed family) and *Thalictrum* (meadow rue) are prominent among an arctic-alpine pollen suite of herbs. Juniper and tree birch did survive in north west England, mainly in sheltered lowland areas like south east Cumbria (Innes 2002a), but there is little evidence for this from Merseyside. The later part of the Loch Lomond Stadial cold event is marked by *Rumex* (sorrel) expansion which continued through crowberry and juniper succession into the birch woodland of the early Holocene about 10,000 BP. Several Merseyside sites preserve pollen data from this last cold phase of the Late Glacial, such as peat lenses within Shirdley Hill Sand, as at Clieves Hills near Ormskirk (Tooley 1978, Innes *et al*. 1989) or in several sites described by Baxter (1983). The deepest parts of the larger mosses of the area also contain environmental records from this period (Innes *et al*. 1999).

Holocene vegetation history

Forest Development and Dominance

The development of the postglacial forest followed the sudden climatic amelioration that defines the start of the Holocene at about 10,000 BP (fig. 2). Chronologies for the successive establishment of most individual tree taxa in Merseyside between 10,000 and about 6000 BP have been achieved by radiocarbon dating of major pollen zone boundaries on long pollen diagrams, supplemented by dates from many shorter profiles (fig. 2). Two key dated profiles are the north west England standard diagram from Red Moss to the east of the area (Hibbert *et al*. 1971, Chiverrell 2002c) and Knowsley Park in central Merseyside (Cowell and Innes 1994). Long but largely undated pollen diagrams such as Chat Moss in the Mersey valley, Holcroft, Lindow and Danes Mosses in north Cheshire (Birks 1964, 1965b, Davis and Wilkinson 2004), Moss Lake, Liverpool (Godwin 1959) and Hoscar Moss in the Douglas valley (Cundill 1981) provide supplementary data. In general, birch forest was established soon after 10,000 BP, hazel woodland by 9000 BP, elm and oak spread through the forest between 8500 and 8000 BP, pine became established soon after 8000 BP, alder increased sharply at around 7000 BP and lime increased around 6000 BP.

In the early Holocene transitional crowberry, juniper and willow shrub communities rapidly supplanted the grassland and tall herb associations with *Rumex* and *Filipendula* (meadowsweet) that had developed after the major rise in temperature (Innes *et al*. 1999, Innes 2002b) at the end of the Late Glacial. This occurred in Merseyside except on unstable sandy strata that had retarded soil development. This was primarily on the Shirdley Hill Sands as at Knowsley Park, where the early rich herbaceous vegetation remained important for several centuries into the Holocene (Cowell and Innes 1994), with a further example at Holiday Moss (Innes *et al*. 1989). By about 9800 BP birch woodland, although of an open nature, was established at Red Moss and major juniper expansion was short-lived, whereas at Knowsley Park the spread of birch forest was delayed until almost the end of the first millennium of the Holocene. This delayed immigration and spread of tree cover in the Shirdley Hill Sand areas is a theme which continued throughout the period of forest development, applying to all the main woodland trees in the early to mid-Holocene. Gradual immigration of hazel, pine, elm, oak, alder and lime took place in turn, although even in such a small area as Merseyside and its environs there were significant variations in forest composition because of soil and topographical factors. Birch, hazel and oak were favoured in the lighter woods on higher ground while elm and lime were more common on fertile lowland soils. Hazel became established in many places before 9000 BP, with a date at Hatchmere in Cheshire (Switsur and West 1975) as early as 9580±140 BP while at Knowsley Park it was delayed for a few hundred years until 9160±80 BP (Cowell and Innes 1994).

There was a similar variability in the establishment and importance of the other main members of the Holocene forest. Elm and oak immigrated soon after the rise of hazel in most areas with better soils. They formed mixed oak woods with a high hazel component which are characteristic of the Boreal early Holocene (before about 7000 BP, fig. 2) forest of north west England, with oak dominant except where conditions particularly favoured elm, as on calcareous nutrient rich soils. Pine became common across the region by the early mid-Holocene before 8000 BP, with early establishment on lighter sandy soils as at Knowsley Park at 8880±90 BP (Cowell and Innes 1994). On heavier soils on the till plain of Lancashire and Cheshire the spread of pine was several hundred years later, e.g. 8196±150 BP at Red Moss (Hibbert *et al*. 1971), although eventually pine became important almost everywhere. Pine may have been most common in areas with suitable soil conditions like the sandstone crests of Wirral and south Liverpool. Pine was replaced by alder across most of its range in the Merseyside region at some stage during the mid-Holocene between 7500 and 6500 BP, depending on local site conditions.

The rise to abundance of alder defines the start of post-Boreal mid-Holocene, the wetter 'Atlantic' climate period (fig. 2). Although many dates from north west England for the alder rise are close to an average of around 7,000 BP, like 7107±120 BP at the Red Moss type site (Hibbert *et al*. 1971) and 7180±120 BP at Walker's Heath in Cheshire (Leah *et al*. 1997), the date of alder expansion is diachronous and must relate to local environmental factors. At Hatchmere in Cheshire it occurred earlier at 7403±114 BP (Switsur and West 1975). In coastal Merseyside dates for the start of the alder pollen rise at Flea Moss Wood, Sefton and Bidston Moss, Wirral are about 7300 BP and in the Alt valley at Ince Blundell the replacement of pine by alder took place at 7130±110 BP (Cowell and Innes 1994). In these areas of lowland eutrophic wetland, conditions would have been very suitable for alder. At all sites oak, alder and hazel were the commonest taxa, with elm a lesser but very important member of the deciduous forest community, rivalling oak on better soils. While the components of the mixed oak forest were much the same across the region, their relative proportions varied on occasion according to site conditions. Lime, the last of the major trees of the mid-Holocene forest to spread, was much more common than its moderate frequencies in pollen diagrams would suggest, as lime produces relatively little pollen compared with most other forest trees (Greig 1982) and so is under represented in the pollen record. In the Lancashire-Cheshire plain it was probably co-dominant with oak and elm in favourable locations. Ash was present from early times but did not occur in significant populations until the more open woods of the later mid-Holocene, being unable to colonise the primary forest until it was assisted by disturbance. There seem to have been restricted areas where the Boreal forest early dominants were able to persist, pine remaining common in favourable areas of light sandy soils near the coast or on fluvioglacial outwash and shallow accumulating peat (Cowell and Innes 1994). By mid-Holocene times after about 7000 BP, therefore, all the elements of the fully developed mixed deciduous forest were in place and dense tree cover dominated Merseyside's vegetation, with only a few areas of bog or heath naturally breaking the tree canopy (Innes *et al*. 1999).

The spread of closed forest over almost the entire region during the Holocene severely restricted the area where heath and moor vegetation could survive although it is likely that soils formed on sand and gravel in Cheshire (Tallis 1973, Reynolds 1979) and north of the Mersey (Kear 1985, Cowell and Innes 1994) will have maintained some heathland during the Holocene. At Knowsley Park (Cowell and Innes 1994) on the Shirdley Hill Sand of Merseyside crowberry persists until about 8650 BP, often in high percentages, after which a continuous, relatively high *Calluna* (heather) curve occurs throughout the rest of the Holocene. It seems likely that the Shirdley Hill Sand areas allowed some persistence of heath vegetation throughout the forest period, forming a valuable element of diversity in the otherwise ubiquitous dryland tree cover. Coastal blown sand formations also provided refuge habitats for heath associations, as at Sniggery Wood, Sefton (Cowell and Innes 1994), and almost all of the lowland bogs of the region appear to have been colonised by heather during phases of drier climate after about 5000 BP in the mid-Holocene.

Although much of forest history must be deduced from pollen data, fossil remains of the postglacial trees themselves are preserved within sediments in several locations in the form of tree stumps, trunks and branches (Atkinson *et al*. 1999); beneath the area's basin mosslands (Leah *et al*. 1997), beneath coastal zone deposits (Travis 1926, Tooley 1977, Kenna 1986, Pye and Neal 1993, Clapham *et al*. 1997), and beneath valley floodplain alluvial sediments (Cowell and Innes 1994). Some long term wetland areas like raised bogs would have carried their own specialised climax vegetation of sphagnum or heather. Elsewhere, even upon river valley alluvial wetlands, some type of forest would have covered the entire landscape, although thin, unstable soils formed on sands or gravel may have carried lighter woodland and some heathland throughout the Holocene (Kear 1985).

Forest Disturbance, Decline and Clearance

The occupation of Merseyside by closed forest in the first half of the Holocene up to about 5000 BP does not mean that tree cover was undisturbed. Natural disturbance events of storm, flood and landslide would have created openings in the woodland and may have assisted the immigration of successive additions to the forest flora. Fire and human activity must have been two major sources of disturbance, however, and perhaps the former was often instigated by humans as well as being a natural feature of the environment. Wells (e.g. 1992), in the course of wetland stratigraphic survey, has recorded considerable quantities of macro and microscopic charcoal in the eutrophic earlier stages of Holocene peat development before 5000 BP throughout north west England, including Merseyside. Corresponding with the forest phase of Holocene vegetation history, typical examples include Simonswood Moss (Cowell and Innes 1994), Lindow Moss (Leah *et al*. 1997), Nook Farm (Hall *et al.* 1995) and Churchtown Moss (Middleton *et al.* in press). Almost every examined peat profile in the Lancashire and Cheshire plain appears to contain such carbonised plant remains in its lower levels, showing that fire, whether of natural or cultural origin, often influenced vegetation patterns. Deposition of macroscopic charcoal layers within sediment sequences before 5000 BP has also been recorded. In Merseyside a charcoal layer dated 5440±160 BP occurred in Simonswood Moss (Innes and Tomlinson 1983b, Simmons and Innes 1987) and charcoal lenses are common in peat profiles from Downholland Moss in south west Lancashire (Tooley 1978, 1985a, Middleton *et al.* in press). An early example from just north of the Ribble estuary is dated 8390±105 BP at The Starr Hills, Lytham (Tooley 1978). Cundill (1984) recorded a charcoal layer at the rise of alder pollen, and so dated about 7,000 BP, at Hoscar Moss in the Douglas valley, while a thick charcoal layer is present at nearby Mawdesley (Middleton *et al.* in press) in peat stratified soon after the alder rise. At Walker's Heath and Danes Moss in Cheshire (Leah *et al.* 1997) charcoal layers also occurred at alder rise levels. The coincidence of fire and major pollen zone boundaries suggests that the disturbance of the woodland by burning may have assisted the establishment of new taxa, causing long term changes in forest composition. Although difficult to prove, Mesolithic hunter-gatherers may have employed fire as a mechanism for diversifying forest ecosystems, increasing the food resources of the landscape through the productive post-burn regeneration vegetation (Simmons and Innes 1987). The coincidence of Late Mesolithic flint sites with the margins of river and mossland lowland wetlands in Merseyside and Lancashire (Middleton 1997) may offer some circumstantial support for human involvement in the proliferation of fire. Natural fires must also have occurred however.

Elm decline

A pollen zone boundary of major significance is the decline in *Ulmus* (elm) frequencies around 5000 BP defining the end of the mid-Holocene forest phase. It is a clear feature of almost all diagrams of that period in north west England and the dates now available for the Merseyside area conform to that age range. The type site of Red Moss (Hibbert *et al.* 1971) provides a typical date of 5010±80 BP but there is some variation around this mean value and the event is not synchronous. Dates are often a few centuries later than 5000 BP in the uplands and often earlier than 5000 BP in lowland areas (Innes *et al*. 1999, Innes 2002b) and Merseyside dates of 5290±80 BP at Knowsley Park and 5120±50 BP at Park Road, Meols (Cowell and Innes 1994) broadly support this pattern. In many cases the elm decline in the Merseyside region is accompanied by indications of forest opening and while some, like Hoscar Moss (Cundill 1981, 1984), are associated with charcoal, many are visible only through reductions in tree pollen and increases in open ground or agricultural indicator species such as *Plantago lanceolata* (ribwort plantain) and cereal type pollen. Red Moss (Hibbert *et al*. 1971), Chat Moss (Birks 1964), Holcroft Moss (Birks 1965b), Park Road, Meols and Newton Carr 11 (Cowell and Innes 1994) are examples of sites with evidence of forest clearance at the elm decline between the Mersey and the Ribble. Several others occur in adjacent north Cheshire and Lancashire (Leah *et al*. 1997, Middleton *et al*. 1995). The causes of the elm decline are uncertain, although climate change and elm disease are likely factors to add to that of human impact through early farming, and may produce similar pollen evidence (Perry and Moore 1987). A multi-causal hypothesis is probably correct (Parker *et al.* 2002) with different factors of greater importance at different sites.

Disturbance phases without macroscopic charcoal evidence also occur in the Merseyside region during the pre-Elm Decline pollen record (Howard-Davis *et al.* 1988, Innes and Tomlinson 1991, Cowell and Innes 1994). During the millennium before the Elm Decline at Sniggery Wood, in Sefton, there was a succession of clear declines in tree cover, which was replaced by open vegetation including pastoral weeds. Similar episodes of small scale opening of the woodland occur at Bidston Moss and Knowsley Park. Cereal type pollen grains have been reported from two of these pre-Elm Decline disturbance phases in Merseyside; at Bidston Moss dated 5840±70 BP and at Flea Moss Wood dated 5920±50 BP. The millennium prior to the *Ulmus* decline represents the period of the Mesolithic-Neolithic Transition, during which time hunter-gatherer economies were replaced by dominantly agriculturalist ones. The presence of cereal type pollen not long after 6000 BP suggests that the transition began very early in the pre-Elm Decline millennium in Merseyside, although whether by the adoption of cereal use by acculturating Mesolithic people or by the immigration of Neolithic settlers remains conjectural. Similar early cereal dates in the uplands to the east of Merseyside (Williams 1985, Wiltshire and Edwards 1993) lend credibility to the Merseyside examples and other identifications of pre-Elm Decline cereal type pollen in the Mersey lowlands also exist, as at Martin Mere (Tooley 1985a), although not dated. The pollen evidence therefore indicates that the introduction of cereal cultivation, although on a very small scale within the forested environment, occurred as early in Merseyside as anywhere in the British Isles

(Innes *et al*. 2003). By the time of the Elm Decline itself, archaeological sites with a clearly Neolithic culture occur in lowland north west England, and so the forest clearance that often accompanies the Elm Decline is very likely to have been caused by Neolithic farmers. Some Mesolithic flint sites in the Pennines (Switsur and Jacobi 1975) do, however, have radiocarbon dates equivalent to the lowland Elm Decline dates, so it is not impossible that the latest Mesolithic groups may have had some role to play in this phenomenon.

Post elm decline

The vegetational history of the five millennia since the Elm decline in the Merseyside region is characterised by increasing levels of forest clearance for agricultural land use, leading to the spread of grassland, heath and bog as well as cultivated areas. Local variations in the timing, character and intensity of land use occurred and often some regeneration to wooded conditions took place when cultural or environmental factors caused the intensity and distribution of farming to lessen. In general, however, an increasingly open and more intensively used landscape evolved in the later prehistoric and historic periods. Naturally caused changes in vegetation patterns must have taken place during the later Holocene, although it is difficult to evaluate any natural developments in the woodlands of Merseyside as the vegetation history of this more recent period has been so heavily influenced by the activities of people. Natural climatic and edaphic (water table) changes did occur, however, which caused changes in woodland composition. Major climatic deterioration around 4000 BP appears to have caused the final displacement of pine from its last refuges in marginal, low nutrient locations (Bennett 1984, Lageard *et al*. 1999). During the later Holocene there are pollen records from several sites in the Merseyside region (e.g. Chat Moss, Birks 1964; Red Moss, Hibbert *et al*. 1971) for the immigration of *Fagus* (beech) and *Carpinus* (hornbeam), presumably in low numbers since these trees are more suited to conditions well to the south. Other ‘secondary woodland’ trees and shrubs such as ash, birch, holly and hazel greatly increase in the late Holocene where they form woodland regeneration successions after human disturbance. At varying times around a mean of about 3500 BP lime became much less important in the regional woodlands. This will have been due in part to the climatic deterioration (fig. 2) in progress after 4000 BP (Davis and Wilkinson 2004) but is also likely to be the result of Bronze Age woodland clearance (Cowell and Innes 1994), which was a major regional event.

One aspect of the impact of Neolithic and later farming on the landscape is that of episodic and sometimes severe soil erosion and alluviation. Major forest clearance and soil erosion occurred at Prescot Moss in Merseyside between 4650±80 and 4520±140 BP (Tomlinson and Innes 1989, Cowell and Innes 1994, Innes and Tomlinson 1995) and a marked clearance phase at Hatchmere in Cheshire persisted from Elm decline times until 4693±90 BP (Switsur and West 1975). Birks (1965b) recorded significant Neolithic age disturbance at Holcroft Moss in the Mersey valley. Despite several examples of major activity and clearance, many lowland sites in the region only record sporadic, limited and low intensity disturbance of the forest (Leah *et al*. 1997). This may be an effect of the distance of the sampling site from the source of the Neolithic activity and thus its level of visibility in the pollen record. Also, pollen sampling sites are often located in permanently wet areas, which are the least likely to have been cleared for agriculture.

Many sites throughout Merseyside and adjacent areas record major increases in the intensity of forest clearance between about 4000 BP and 2800 BP, corresponding to the Bronze Age occupation of the region. In most locations this activity represents the first major reduction in forest cover and, with the greatly increased incidence of cereal type pollen, it points to the expansion of a mixed farming economy at this time. Of particular interest in the mid-fourth millennium BP is the major decline in lime percentages, in some cases to virtual absence, which is diachronous and often coincides with peak ribwort plantain and other agricultural indicator pollen records, sometimes including cereals, supporting the impact of Bronze Age farming activity as the cause. The first substantial clearances in the central mosslands of Merseyside, although without cereals, also occur at this time at Knowsley Park (Cowell and Innes 1994). The same pattern occurs at Parr Moss in the south of Merseyside, and at Fenton Cottage in Lancashire where there is a big increase in charcoal and heather pollen during the Bronze Age between 3790±100 and 3180±60 BP (Middleton *et al*. 1995). Where pollen can be recovered from archaeological deposits a more local indication of the environment can be obtained with associated artifactual dating. Thus, pollen analyses of the turves used in the construction of the barrow at Winwick in north Cheshire showed that an open, cleared landscape existed in the vicinity of the site in the Bronze Age (Tomlinson 1990) and help to confirm the evidence from the regional pollen data.

The impact of Iron Age and Romano-British land use on the woodland in the Merseyside region was variable but in general the earlier part of the period saw moderate scale episodes of clearance whereas the later Iron Age and Romano-British period was a time of increased deforestation. Extensive forest clearance occurred at Knowsley Park around 1680±50 BP and at Simonswood Moss after 2380±80 BP in Merseyside (Cowell and Innes 1994). In nearby north Cheshire woodland decline occurred after 2090±70 BP at Rostherne Mere (Leah *et al*. 1997) and after about 2240 at Lindow Moss (Oldfield *et al*. 1986, Branch and Scaife 1995). The pollen records for these and later periods are far fewer than for earlier times, due to a paucity of well preserved upper levels of peat, but greatly increased farming activity, with a major arable cultivation element, seems to have been the rule in most of north west England (Innes 2002b).

The pollen data suggest that arable cultivation provided habitats for a much greater number of weeds of broken ground and ruderal conditions than did pastoral land use. The weed assemblage moves beyond the ribwort plantain dominated grassland group and includes many which are more recognised as arable indicators, including *Rumex* (sorrel), *Artemisia* (mugwort), *Centaurea nigra* (lesser knapweed), *Taraxacum* (dandelion) type, Cruciferae (cabbage family), Chenopodiaceae (fat hen family), *Cirsium* (thistle), *Plantago major-media* (great plantain type), *Matricaria* (mayweed) type and *Stellaria* (chickweed). This arable community is well illustrated in the Iron Age pollen spectra from Lindow Moss in Cheshire (Oldfield *et al*. 1986, Branch and Scaife 1995), and also in Iron Age and Romano-British times on the sandstone ridges of mid-Cheshire where almost total replacement of oak woods by cultivation occurred around Bar Mere and Peckforton Mere (Leah *et al*. 1997). Oldfield *et al*. (1985) dated major clearance and soil erosion at Peckforton Mere to Romano-British times by mineral magnetic analyses. Crop plants diversified from *Triticum*/*Hordeum* (wheat/barley) types into other cereals such as *Avena* (oats) and *Secale* (rye), and other crops such as *Cannabis* (hemp), *Linum* (flax) and *Vici*a (bean). Associated crop weeds that had earlier occurred only sporadically, such as *Centaurea cyanus* (cornflower), *Spergula arvensis* (corn spurrey), and *Polygonum aviculare* (knotgrass) became more common.

Although undated, the later pollen record from Simonswood Moss B (Cowell and Innes 1994) must include Medieval times and shows major deforestation and cereal cultivation. Knowsley Park records similar conditions and central Merseyside must have been largely turned into a farming landscape during the Medieval period, as suggested by historical and other sources of evidence. In nearby west Lancashire at Winmarleigh Moss (Middleton *et al*. 1995) substantial clearance that began in late Roman times at 1680±80 BP persisted until 900±90 BP, with increasing cereal values. At nearby Fenton Cottage a gradual increase in clearance pressure from 1200±70 BP to 390±50 BP left the area under mixed agriculture and almost completely without tree cover in the Medieval period (Middleton *et al*. 1995). Several sites from Merseyside and nearby which are not radiocarbon dated also preserve long pollen records showing significant woodland clearance and agriculture throughout the late Holocene, extending probably into quite recent times. These include Chat Moss (Birks 1964), Holcroft Moss (Birks 1965b), Holland Moss and Hoscar Moss (Cundill 1981). It is likely that very few uncut mossland remnants have survived but these may well preserve an unbroken vegetation record up to the present day, as may other deposits of recent centuries formed in wet locations in river valleys or old woodlands (Atkinson *et al*. 1999). Such sediments should be investigated as we have few pollen records which record recent land use activities.

Moats and ditches associated with archaeological sites sometimes contain deposits with pollen and plant macrofossil evidence of the local vegetation from the time when the feature ceased to be cleaned out, usually the latter stages of its use and after its abandonment. Local examples include Bewsey Old Hall in Cheshire (Tomlinson and Innes in press) and Speke Hall in Merseyside (Innes and Innes 1992, Innes 1992b). In both cases, phases of agricultural activity and land use around the site were apparent from the pollen data, and the combined pollen and macrofossil data allowed reconstruction of the landscape at the site itself. Buried soils from beneath archaeological sites or deposits also contain valuable pollen and other data on local environmental conditions prior to site construction. Although undated, the buried soil from Bromborough Courthouse contained a valuable record of local vegetation history for that part of Wirral where few other pollen profiles exist (Innes and Tomlinson 1981). Pollen data from excavated site contexts have also been reported from Merseyside in association with data from adjacent natural sediments in an attempt to produce an integrated study of the environmental history of a site and its landscape, as at Ditton in south Merseyside (Innes 2001).

Conclusion

In the twenty five years since the initiation of an environmental survey of Merseyside (Innes and Tomlinson 1980, Sheppard *et al*. 1981) much has been learned about the environmental background and context to past human settlement and activity. The published research of many past and current workers has been supplemented by work designed specifically to address deficiencies in aspects of our understanding of the area's environmental history. The lowlands between the Dee and Ribble were once regarded as interesting only for research on major natural processes such as sea level change or forest history, but higher resolution study has now shown that a rich environmental record of human interaction with the environment is present, complimenting the realisation that the area has a rich and complex archaeology (Middleton and Innes 2004). This has been the major achievement of the years of survey research and over the last two and a half decades Merseyside's past has become increasingly relevant at a national and even international level. There is much still to be done, however, and Merseyside promises to remain a rich field area for many aspects of palaeoenvironmental research. The major task for the coming years must be the formulation of research aims and strategies which build upon the progress made to date and seek to answer the many new questions which have been identified in the course of the last quarter century of environmental survey and research.

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