Chapter 8 The Holocene (Flandrian) history and record of northern England

Introduction

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Northern England contains major, contrasting geographical zones that, superimposed upon the legacy of glacial deposition (Johnson, 1985b), have encouraged great diversity in Flandrian sedimentation (Thomas, 1999). Basic to this diversity is the altitudinal gradient from the Pennines and other uplands to the estuarine and littoral areas of the coastal zone, with major river systems adding complexity to intermediate lowlands in The Vale of York, Northumbria, and the Lancashire, Cheshire and Shropshire plains. These major zones form the basis of landscape units within which variability in soils, climate, vegetation and human land use in Flandrian times have all acted to alter depositional regimes.

Flandrian sediments are common throughout northern England, but are increasingly subject to destruction by recent human activities such as ploughing, drainage, forestry, recreation and industry; with deposits of the last few millennia under particular threat. The overview provided here makes reference to key sites in order to describe the range, character and palaeoenvironmental value of the surviving Flandrian sediments. Particular attention is paid to wetland organic deposits because of the range of diagnostic biological data that they preserve and their abundance in the region, but also to associated clastic sediments where appropriate. A series of recent detailed surveys of lowland wetland sediments in north-west England and Humberside (e.g. Cowell and Innes, 1994; Van de Noort and Ellis, 1995a, b, 1999; Leah *et al.,* 1997) have proven the richness and diversity of the Flandrian geological resource. The broad development of Flandrian vegetation in northern England, and the evidence for the human role in changing it, are briefly summarized.

The lake basin to raised bog hydrosere

A key component of northern England's Flandrian geological resource is the sediment record preserved within the very numerous enclosed basins, which occur in all parts of the region, and which contain wetland depositional environments at all stages of hydroseral succession between lake and raised bog (Walker, 1970; Shimwell, 1985). Many depressions originated as a result of glacial erosion or deposition and have accumulated sediment since the early Late-glacial, but they also contain deep Flandrian successions, which are mainly organic but include gyttja, marl, silt, clay and coarser-grained deposits. In many cases Flandrian organic materials form the basal sediment in shallower basins, spreading from deeper centres or becoming waterlogged under wetter climate in the mid- and later Flandrian. Some basins were formed post-glacially as a result of local events, such as salt solution subsidence in the Cheshire Plain (Reynolds, 1979) or behind landslip features (Franks and Johnson, 1964; Simmons and Cundill, 1974b). Lacustrine sediments dominate the early stages of many basins, but only a few of the largest or deepest have persisted as water bodies to the present day, notably the large Lake District lakes, but also those in the upland rock basins of Cumbria (Pennington, 1964) and the meres of the Cheshire–Shropshire plain (Green and Pearson, 1977; Reynolds, 1979). Lake sediments in these areas have preserved sensitive chemical, diatom, mineral magnetic and other proxy records of environmental changes in their catchments (Pennington, 1970; Oldfield *et al.,* 1985), and diatom floras also can be interpreted in terms of recent climate history, as in recent lake sediments from Windermere, Cumbria (Barber *et al.,* 1999). Elsewhere extant lakes are isolated landscape features, such as Gormire Lake (Blackham *et al.,* 1981) or Malham Tarn (Piggott and Piggott, 1963) in Yorkshire. Many more smaller lakes would still exist were it not for their deliberate drainage and reclamation, as in Holderness (Sheppard, 1957; Flenley, 1987) where, compounded by coastal erosion (Gilbertson, 1984a), only Hornsea Mere survives (Beckett, 1981). Many basins have naturally passed through the various stages of hydroseral succession and culminated as acid raised bogs in the later Flandrian, although many remain in an intermediate stage (Tanis, 1973b). Some sites have developed to raised bogs over coastal marine days (Smith, 1958c; Oldfield, 1960a; Birks, 1982; Tooley, 1978a; Wells *et al.,* 1997). The long pollen records recovered from these lake and mire sequences, particularly those with good dating control (Godwin *et al.,* 1957; Hibbert *et al.,* 1971; Hibbert and Switsur, 1976; Wells *et al.,* 1997), form the basis for study of Flandrian climatic and vegetation change in northern England at focused (Walker, 1966b; Bartley *et al.,* 1976; Davies and Turner, 1979; Bartley *et al.,* 1990; Dumayne and Barber, 1994; Dumayne-Peaty and Barber, 1998) or more synoptic (Gilbertson, 1984a; Twigger and Haslam, 1991;

Cowell and Innes, 1994; Wimble *et al.,* 2000) scales. These data allow regional overviews of environmental history (e.g. Innes, 1999; limes *et al.,* 1999) and can be enhanced by other evidence such as insects (Buckland, 1979) or Mollusca (Keen *et al.,* 1988). Ombrotrophic raised bogs in northern England are crucial for the study of late Flandrian climate change. Recurrence horizons in bog stratigraphy, most notably the major mid-third millennium BP event, but others also, record wet shifts in climate history (Barber, 1982). Dates of 2447 ± 43 to 2345 ± 45 years BP from Lindow Moss in Cheshire (Leah *et al.,* 1997), 2685 ± 50 years BP from Featherbed Moss in the southern Pennines (Tanis and McGuire, 1972), 2730 ± 110 to 2530 ± 80 years BP from Fenton Cottage in Lancashire (Middleton *et al.,* 1995), 2686 ± 50 years BP from Rusland Moss in south Cumbria (Dickinson, 1975) and 2645 ± 100 years BP from Chat Moss in Greater Manchester (Godwin and Switsur, 1966) are typical for the major Iron Age acceleration in bog growth in northern England. More detailed studies of peat humification, macrofossil stratigraphy and other proxies provide a highly sensitive record of mire palaeohydrology (Dickinson, 1975; Barber, 1993; Barber *et al.,* 1998; Chiverrell and Atherden, 1999; Mauquoy and Barber, 1999b; Hughes *et al.,* 2000). The recognition of tephra layers in such peat sediments at Fenton Cottage (Pitcher and Hall, 1996) is an important recent development. Most raised mire systems in northern England have been extensively damaged by cutting (e.g. Oldfield, 1970), and sites in the whole range of the lake-to-raised-bog hydrosere have been damaged by drainage and other human activity.

Intertidal and coastal wetlands

Post-glacial rise in sea level carried the shoreline of northern England to approximately its present position by the mid-Flandrian (Tooley, 1982, 1978a; Plater, *et al.,* 1993; Zong and Tooley, 1996; Long, A.J. *et al.,* 1998; Shennan *et al.,* 2000a, b), after which a suite of wetland depositional regimes became established in the coastal zone – based upon altitude and salinity, which had 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, which deposited sands, silts and clays, as well as the upper intertidal vegetated saltmarsh zone, in which increasingly organic peat sediments were laid down. Raised groundwater tables and reduced rates of river flow owing 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, 1985), indirectly stimulated by sea-level change and also accepting seasonal freshwater drainage from landward, was of considerable extent on low-gradient coasts and penetrated well into the lower parts of the region's river valley floodplains. It comprised a mosaic of eutrophic lagoons, swamps, fens and freshwater meres prone to rapid water-level changes and sustaining complex organic sedimentary regimes, but susceptible to penetration by marine conditions. The Downholland Moss and Martin Mere area of south-west Lancashire is a good example of these littoral wetland environments (Tooley, 1978a, 1985). Some peat-forming systems in these coastal fringe locations progressed to raised-bog communities, as in north Lancashire (Smith, 1958c; Oldfield, 1960a; Middleton *et al.,* 1995), the Solway lowlands (Walker, 1966b), south-west Lancashire (Tooley, 1978a) and the Humberhead Levels (Dinnin, 1995). Low-amplitude fluctuations in sea level, local changes in coastal morphology and in sediment flux caused spatial readjustment of coastal depositional environments, so that deep, complex stratigraphical sequences of alternating intertidal and peri-marine peats, silts and clays accumulated in low-lying coastal areas. These occur particularly in the major river estuaries, such as the Humber (Metcalfe *et* at., 2000) and Tees (Plater *et al.,* 2000a), and also in small embayments and adjacent to flat open coasts, such as those of Lancashire and Merseyside (Huddart *et al.,* 1977; Tooley, 1978a; Kenna, 1986; Huddart, 1992; Cowell and Innes, 1994). In these areas mid-Holocene marine sediments 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 that are exposed in the present-day intertidal zone, often containing remains of ancient woodland overtaken by rising sea level. These intertidal 'submerged forests' were hitherto much more extensive than today (Reade, 1871), and many recently have undergone severe erosion. Of widely differing ages, they are exposed analogues of the terrestrial elements of the intercalated coastal successions (Tooley, 1985). Good examples exist in the Humber estuary (Long, A.J. *et al.,* 1998), in Merseyside (Tooley, 1978a), in Hartlepool Bay (Tooley, 1978b), and in Cumbria (Oldfield, 1965; Tooley, 1985). The resource-rich environments represented by the intercalated coastal deposits were very attractive to past human settlement and activity, as shown by abundant archaeological sites and palaeoecological evidence in these locations (Fulford *et al.,* 1997). Throughout northern England, from Cumbria (Bonsail *et al.,* 1994) to Wirral (Kenna, 1986), from Hartlepool Bay (Tooley, 1978b) to the Humber estuary (Crowther, 1987), there is evidence of human settlement and activity having been closely affected by shoreline development during several cultural periods. Human exploitation of coastal zone palaeoenvironments around Liverpool Bay is a good illustration (Gonzalez *et al.,* 1996; Huddart *et al.,* 1999a, b), where quantities of animal bone of several species, wild and domestic, have been recovered from intertidal sediments, many 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

Sedimentation within eutrophic peat-forming systems became a major element in northern England's mid- and later Flandrian depositional history, as such environments must have been abundant in lowland vales and valley bottoms prior to their large-scale drainage in recent centuries. Fen and carr wetlands fringing floodplain alluvial systems became ubiquitous after mid-Holocene higher sea level, wetter climate and river regime stabilization with low gradients led to increasingly poorly drained soils in low-lying areas. Eutrophic floodplain and valley mires often came to be dominated by *Alnus* associations (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 Cheshire is a good example of long-term persistence of valley fen wetland (Shimwell, 1985), but most such locations would have been similar. Superabundant alder pollen frequencies from valley fen peats, often well over 80% of total pollen, are maintained at some sites for thousands of years, as at Ince Blundell in the Alt valley, Merseyside (Cowell and Innes, 1994). At other sites in the later Flandrian, permanent waterlogging and marsh and fen sedimentation in valley bottoms could be easily stimulated by single events that impeded local drainage, as with possible beaver activity at Briarfield, Lancashire (Wells *et al.,* 2000). The most extensive areas of floodplain marshlands in northern England were probably those of the Humberhead Levels and southern Vale of York (Dinnin, 1997a; Lillie and Gearey, 1999), where between about 5000 years BP and 2500 years BP most of the dry-land plain through which the lower courses of the major Humber tributary rivers flowed was converted to eutrophic mire as a result of gradual waterlogging and peat formation. In some places, as at Thorne Waste and Hatfield Moors (Dinnin, 1997b), the process was so rapid as to drown woodland and preserve tree stumps beneath the peat. Eutrophic reedswamp, marsh and fen–carr wetlands also filled the Vale of Pickering lowland in north-east Yorkshire in the early Holocene, attracting intensive Early Mesolithic occupation and exploitation (Day, 1996; Mellars and Dark, 1998) of these productive environments. Star Carr and adjacent sites are classic locations for study of palaeoecology and environmental archaeology, but such eutrophic wetland areas must have existed in many parts of northern England during most of the Flandrian, although many of these deposits have not survived or have been reduced to thin organic soils.

Drainage channel mires

Deglaciation of northern England has left several areas with distinctive erosional meltwater channel features that comprise a valley depositional environment, and which have accumulated sediments during the Flandrian (Johnson, 1985b; Hemingway, 1993). Often these channels cut through low watersheds and form long but narrow linear hollows, which preserve a spatially continuous record of environmental change on adjacent dry-land areas. Laterally extensive charcoal or mineral inwash stripes, which reflect catchment events, are a characteristic feature of their sediment column (Simmons, 1969a, b; Simmons *et al.,* 1975). Many such features occur on the North York Moors, where key sites such as Ewe Crag Slack (Jones, 1978) and Fen Bogs (Atherden, 1976a) contain multiple inwash horizons within a long organic sequence, and they form a major part of the Flandrian palaeoenvironmental resource in that area. Meltwater channels occur in other parts of northern England also, although their potential has been less developed. They are abundant in the Pennines (Mitchell, 1991a) and the sediments of some in the Cheshire–Staffordshire area have been studied (Yates and Moseley, 1958; Johnson *et al.,* 1970). This category of site holds great potential for future research.

Upland hill peat and blanket bog

A conspicuous feature of the northern England sedimentary environment is the extensive tracts of hill peat and blanket bog that cover much of the uplands of the region, and which have developed and spread during the mid- and late Flandrian (Moore, 1988; Tallis, 1991). Mid-Flandrian climatic deterioration probably prompted the inception of blanket peat in northern England (Moore, 1988), but there is evidence that in most uplands of the region deforestation by humans from Mesolithic times onwards probably also initiated peat formation (Simmons and Cundill, 1974a; Pennington, 1975c; Squires, 1978; Talus and Switsur, 1983). Blanket peats are best developed on the flat plateaux watershed surfaces of the

Pennines, North York Moors and Cheviot Hills, often where they have spread from earlier foci of organic accumulation within shallow basins. Over wide areas, however, thinner blanket peats are unconfined and cover most of the low-gradient, water-shedding upland slopes (Conway, 1954). Although human activity is implicated in peat formation, major blanket peat spread seems to have occurred as a result of the cold, wet climate in Iron Age times after 3000 years BP (Gosden, 1968; Bartley, 1975; Tinsley, 1975). Upland blanket peats in northern England are highly sensitive to climatic change and have great potential for detailed reconstruction of later Holocene climate history through their palaeohydrology. Peat humifica-tion studies on moisture-shedding sites (Rowell and Turner, 1985) reflect past temperature and rainfall and such palaeoclimate studies, also using multi-proxy micro- and macrofossil indicators, are now available for the North York Moors and the south Pennines (Blackford and Chambers, 1991; Tanis and Livett, 1994; Tallis, 1995; Chiverrell and Atherden, 1999). Most northern England upland blanket peats are now undergoing erosion and in places this is severe (Tallis, 1985b, 1987), often accelerated by recent moorland fires (Maltby *et al.,* 1990).

Upland basin mires

This category of depositional environment is an important element in Flandrian upland sedimentation in northern England, for although it is much less widespread than the thinner, water-shedding blanket peats, it was a focus for earlier organic accumulation and contains a longer sedimentary record. Upland basin mires often formed the nucleus of peat formation from which blanket peats spread to cover intervening interfluves, and their deeper, basin deposits may be difficult to locate if masked by the later, general blanket peat cover of the uplands. Basin-mire sediments often are exposed at springheads by stream erosion and many preserve detrital stratigraphical evidence of environmental changes in their small catchments in the form of wood, charcoal and inwashed mineral layers. These sites provide much of the available ecological data regarding early and mid-Flandrian environmental conditions in upland northern England. A much researched example is North Gill near the watershed of the North York Moors, summarized by Innes and Simmons (1999), where focused, multi-core, high-resolution temporal and spatial pollen and stratigraphical analyses have recorded multiple episodes of mid-Flandrian forest disturbance during the late Mesolithic and Mesolithic–Neolithic cultural phases, and further human impacts during later periods. Several similar sites have been investigated in the Pennines (Conway, 1954; Tallis, 1975; Tinsley, 1975; Sturludottir and Turner, 1985; Williams, 1985) and the North York Moors (Innes and Simmons, 1988b) and many must exist in other parts of the region.

Alluvial sediments

An important component of the Flandrian sedimentary resource is that laid down within alluvial environments and stored within northern England's fluvial systems. Most of the eastern part of the region is drained by rivers of the Ouse Basin, which feeds into the Humber estuary. Deep sequences of fluvially derived sediments have been shown to be present in upland, piedmont and lower valley floor reaches of this river system and mainly reflect the past effects of climate on river discharge, although the effects of past human land use in releasing sediment to the system by soil erosion also are significant locally (Macklin *et al.,* 2000; Taylor and Macklin, 1998; Merrett and Macklin, 1999; Howard *et al.,* 2000; Taylor *et al.,* 2000). Redeposition of transported fluvial sediment may well have affected upper estuarine depositional regimes, as postulated for the Humberhead Levels by Buckland and Sadler (1985), and demonstrated by Rees *et al.* (2000), after major catchment deforestation (Van de Noort and Ellis, 1997; Long, A.J. *et al.,* 1998) from about 4000 years BP onwards. Similarly, in the Tees estuary, Plater *et al.* (2000b) have considered the role of variations in sediment flux from terrestrial systems through catchment changes during this period. Macklin *et al.* (2000) have identified several periods of river activity in the Yorkshire Ouse in the later Holocene that match climatic changes and are marked by either valley incision or alluviation. The latter usually is fine grained but is coarser during more extreme climatic deterioration, as after 3000 years BP Flood regimes and the transport of packets of sediment deposited as discrete alluvial units seem to be the norm, with allied organic sedimentation in riparian wetlands usually under long-term *Alnus* carr communities (Brown, 1988). Holocene alluvial histories comparable to that of the Ouse Basin after climatic and human deforestation stimuli have been reported from river valleys of widely different sizes in Northumbria (Macklin *et al.,* 1991; Macklin *et al.,* 1992; Passmore *et al.,* 1992; Tipping, 1992), in Shropshire (Brown, 1990), in the North York Moors (Richards, 1981; Richards *et al.,* 1987) and in the Howgill Fells of northwest England (Harvey, 1985). A good site example is at Seathwaite in Cumbria (Parker *et al.,* 1994), where human deforestation and farming, probably during the Norse settlement of the area, caused the burial of an organic soil by an alluvial debris fan. Alluvial sediments that bury and preserve old land surfaces can contain a rich, long-term data record within larger valleys and form a geological resource of major palaeoenvironmental importance.

Aeolian sand

Cordons of dune sand are characteristic of much of the low-lying coast of northern England, usu ally comprising a relatively thin dune barrier that fringes the shoreline and with a much wider but shallow blown-sand apron to landward, although blown sand can infill small embay-ments almost completely. Although narrow, the major dune ridge can be relatively high, approaching 30 m in the Sefton dunes of southwest Lancashire. Dune systems are to be found draped over rock outcrops in the northern part of the region, but they 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 Flandrian, but extant coastal dunes mostly lie upon mid-Flandrian sediments and so are one of the region's more recent categories of geological formation (Tooley, 1990). From the mid-Flandrian onwards, dates of phases of dune emplacement have varied considerably both within and between areas. Orford *et al.* (2000) studied phases of dune movement on the Northumberland coast and proposed a model for dune history in north-east England in which landward sand movement occurs under conditions of sea-level rise, often when deceleration in the rate of rise is under way, as in the mid-Flandrian and after. This model generally is supported by other workers' palaeoecological study of dune systems (Tooley, 1978a; Kenna, 1986; Innes and Frank, 1988; Innes and Tooley, 1993; Pye and Neal, 1993a, b; Shennan *et al.,* 2000a). It also is possible, however, that a relative sea-level fall may be required so that sand may be liberated from intertidal areas to support dune building, whereas high sea level may encourage dune-slack formation and system stability. Dates of dune-building phases tend to be site specific and not capable of wider correlation. Some periods, as after 3000 years BP, do seem to have a high incidence of dune establishment, and major dunes of the Cumbrian coast date from this period (Bonsall *et al.,* 1994). The medieval period also seems to have been an important phase of dune building, as in Merseyside (Kenna, 1986) or Northumberland (Innes and Frank, 1988). Dating of dune emplacement is most often indirectly by radiocarbon ages on subjacent peat or wood and on intercalated dune-slack organic layers, although such dates for sand emplacement can vary considerably over quite short distances, for example between Crosby and Formby in Merseyside, with 4510 ± 50 years BP at Sniggery Wood, Little Crosby, 2680 ± 50 years BP at Murat Street, Waterloo and 2335 ± 120 years BP at Lifeboat Road, Formby (Innes and Tooley, 1993). Similar variation continues along the rest of the coast of north-west England (Innes and Tooley, 1993). More direct dating through optical luminescence techniques (Pye *et al.,* 1995) also has been applied, also on the Merseyside coast near Formby. Dunes also have been dated relative to archaeological material beneath or within them. The north of England coastal dune systems probably have experienced many periods of stability, instability and erosion, in both the longer term and more recent times (Pye, 1990; Plater *et al.,* 1993; Pye and Neal, 1994; Orford *et al.,* 2000). Blown sand also occurs in inland locations, particularly where periglacial coversands have been reactivated by climatic or human destabilization in the mid- and late Flandrian. South-west Lancashire and south Yorkshire are the most significant areas for inland-sand reworking (Tooley, 1978a; Innes, 1986; Buckland, 1982), but smaller scale redeposition of sands has occurred locally in many parts of the region.

Buried soils

Buried soil horizons are a category of Flandrian deposit that has provided important environmental data, particularly in areas such as Yorkshire's limestone and challdands (Evans and Dimbleby, 1976; Smith, 1986) where few other sedimentary records may be available for study. Sealed beneath other sediments, which in many cases accumulated very rapidly, buried soils can preserve old ground surfaces that contain data on local environmental conditions, either natural environmental processes or human land-use activity. Brown Earth soils sealed beneath Bronze Age barrows in the Rossendales (Tallis and McGuire, 1972) and on the North York Moors (Dimbleby, 1962), areas now dominated by acid podsols, give insights into mid-Flandrian soil development and its relationship to vegetation change, forest clearance and agricultural history. Soil profiles in the Pennines buried beneath Roman earthworks at Fortress Dike (Tinsley and Smith, 1973) or a Roman road at High Moor (Brayshay, 1999) illustrate the landscapes in which those monuments were constructed. Northern England contains many instances of mineral or organic soil profiles buried as a result of rapid changes in depositional regime. Such soils are preserved beneath colluvial hillwash at Langdale and alluvial fans at Carlingill and Seathwaite, in Cumbria (Cundill, 1976; Harvey, 1985; Parker *et al.,* 1994), marine sediments at The Starr Hills, Lytham, Lancashire (Tooley, 1978a), blown dune sand at Wallasey in north Wirral (Kenna, 1986), landslides in

Longdendale in Derbyshire (Tallis and Johnson, 1980), reactivated periglacial coversands in Merseyside (Innes, 1986) and tree stumps and blanket peat in the Lake District (Pennington, 1965). Analyses of the preserved organic soil surfaces can date emplacement of overlying clastic strata, as with colluvial inwash burying peat at Skipsea Withow Mere in Holderness (Gilbertson, 1984a). Acid soils beneath upland peats can preserve information regarding pre-peat vegetation (Tanis, 1964a) and human occupation (Radley *et al.,* 1974).

The Flandrian landscape: forest development and dominance

The sedimentary record in northern England described above is the prime source for knowledge of the environmental changes that have taken place during the Flandrian. It is a story of the development and spread of forest communities over all but a few parts of the region in the early to mid-Flandrian, with progressive deforestation by natural and, in particular, human agency in the mid- and late Flandrian. Tree remains, including stumps, occur preserved by later sediments in many locations: beneath peat in the uplands (Tallis, 1975; Simmons and Innes, 1981, 1988b; Tallis and Switsur, 1983, 1990), beneath coastal zone deposits (Tooley, 1978b; Kenna, 1986; Pye and Neal, 1993a; Horton *et al.,* 1999b), within lowland basin peats (Lageard *et al.* 1995, 1999), and beneath valley floodplain alluvial sediments (Dinnin, 1997a). Although the highest parts of the Lake District may never have naturally carried forest (Birks, 1988), it seems probable from pollen studies that tree cover extended well up the Cumbrian fells (Pennington, 1965, 1970) and that the summits of the Pennines and all lower uplands were below the mid-Flandrian tree line (Turner and Hodgson, 1983; Tallis and Switsur, 1983, 1990; Turner, 1984) by the early mid-Flandrian forest maximum about 7000 years BP Coastal and long-term wetland areas would have carried their own specialized climax vegetation, but elsewhere forest dominance would have been the norm. Soils formed on sands or gravel may have carried some heathland throughout the Holocene Epoch, particularly where prone to instability as in the Cheshire or Lancashire plain (Tanis, 19736; Reynolds, 1979; Kear, 1985) and the southern Vale of York (Lillie and Gearey, 1999). Edaphic conditions on limestone and chalk geology, as in Upper Teesdale, Craven–Lonsdale or the Yorkshire Wolds, also may have limited tree expansion and allowed establishment of specialized grassland or heathland associations (Turner *et al.,* 1973; Smith, 1986; Bush and Flenley, 1987; Bush, 1993). The assembly of the post-glacial forest followed early Flandrian climatic amelioration, and chronologies for the successive establishment of individual tree taxa across northern England during the early and mid-Flandrian have been achieved by radiocarbon dating of major pollen zone boundaries on several standard long-pollen diagrams, supplemented by dates from smaller profiles. Among these key dated profiles (Greig, 1996) are Scaleby Moss in Cumbria (Godwin *et al.,* 1957), Din Moss on the Scottish Border (Hibbert and Switsur, 1976), Red Moss in Greater Manchester (Hibbert *et al.,* 1971), Knowsley Park in Merseyside (Cowell and Innes, 1994), Neasham Fen in Durham (Bartley *et al.,* 1976), Crose Mere in Shropshire (Beales, 1980), Askham Bog in the Vale of York (Gearey and Lillie, 1999) and Robinson's Moss in the Pennine uplands (Tanis and Switsur, 1990).

Transitional *Empetrum, Juniperus* and *Salix* shrub communities rapidly supplanted the grassland and tall herb associations with *Rumex* and *Filipendula* that developed under rapid amelioration of climate (Walker *et al.,* 1994; Lowe *et al.,* 1995b; Mayle *et al.,* 1999) at the start of the Flandrian. At Thorpe Bulmer in south-east Durham, for example, *Filipendula* was able to reach 20% of total land pollen before being shaded out by shrub taxa (Bartley *et al.,* 1976). Other than on the areas of specialized geology and soils cited above, only in the highest uplands (Pennington, 1970) did herbaceous vegetation remain important well into the Flandrian. A period of *Juniperus* abundance precedes a transition to wooded environments in much of the northern part of the area, such as Northumberland and Durham (Bartley, 1966; Turner and Kershaw, 1973; Bartley *et al.,* 1976), but in more southerly lowland areas such as the Vale of York and Holderness (Bartley, 1962; Beckett, 1981), the establishment of *Betula* woodland was rapid and restricted major juniper expansion except where sandy or calcareous soils retarded succession. As with almost all of the major Flandrian forest taxa, establishment of *Betula* was delayed in the uplands, as at Robinson's Moss (Tanis and Switsur, 1990) where it was not achieved until after *c.* 8900 years BR In the north of the region, at all altitudes, *Betula* woodland dominance was not always achieved, and at Langdale Combe (Walker, 1965), Din Moss (Hibbert and Switsur, 1976), Bradford Karnes (Bartley, 1966) and Cranberry Bog (Turner and Kershaw, 1973), for example, *Salix* and *Juniperus* remained important until *Corylus* and other forest trees became established. Gradual immigration of *Corylus, Pinus, Ulmus, Quercus, Alnus* and *Tilia* took place in turn, although even across small areas there were great variations in forest composition throughout northern England in both early and mid-Flandrian times (Turner and Hodgson, 1979, 1983) because of edaphic and topographical factors (Oldfield, 1965; Pennington, 1965; Turner *et al.,* 1973; Turner and Hodgson, 1981).

Betula, Corylus and *Quercus* were favoured in the lighter upland woods, whereas *Ulmus* and *Tilia* were more common on fertile lowland soils, although the latter was near the northern limit of its range in Cumbria (Piggott and Huntley, 1980). The region-wide differences in forest composition are reflected in the time-transgressive nature of the rise of the main tree types. *Corylus* had become established in many places before 9000 years BP, with some early dates to the south. In the Lancashire and Cheshire lowlands at Hatchmere (Switsur and West, 1975) the date is 9580 ± 140 years BP, at White Moss it is after 9230 ± 85 years BP (Lageard, 1992) and at Knowsley Park it is 9160 ± 80 years BP (Cowell and Innes 1994), whereas it is later at higher altitude in the southern Pennines at Robinson's Moss (Tanis and Switsur, 1990) at 8775 ± 90 years BP. In contrast dates in the north range from 9082 ± 90 years BP at Neasham Fen in the Tees valley (Bartley *et al.,* 1976) and 8940 ± 170 years BP at Din Moss at the Scottish Border (Hibbert and Switsur, 1976), to 8689 ± 50 years BP at Mordon Carr in Durham (Bartley *et al.,* 1976) and to after 8670 ± 70 years BP at Pow Hill in the north Pennines (Turner and Hodgson, 1981). There was a similar variability in the establishment and importance of the other main members of the Flandrian forest. *Ulmus* and *Quercus* immigrated soon after the rise of *Corylus* in most areas with better soils and formed mixed oak woods with a high hazel component, which are characteristic of the Boreal (Flandrian Chronozone I) forest of northern England, with *Quercus* dominant except where conditions particularly favoured elm. The timing of their rise to forest dominance was asynchronous, however, and in some areas with unsuitable soils they never became the major taxa. *Pinus* became common across the region by the early mid-Flandrian, with early establishment on lighter sandy soils as at White Moss, Cheshire at 8625 ± 50 years BP (Lageard, 1992) and at Knowsley Park, Merseyside at 8880 ± 90 years BP (Cowell and Innes, 1994). On heavier clay soils in areas such as east Yorkshire, Lancashire and Cheshire the spread of *Pinus* was later, e.g. 8196 ± 150 years BP at Red Moss (Hibbert *et al.,* 1971). Turner and Hodgson (1979) suggest that where *Corylus* and *Ulmus* formed the lowland woodland, *Pinus* was not able to become established easily. Eventually, however, pine became important almost everywhere. To the east, *Pinus* became abundant in local areas with suitable edaphic conditions, such as the sandstone crests of the North York Moors (Simmons *et al.,* 1993) or the limestone soils of east Durham (Bartley *et al.,* 1976). It remained dominant on poorer soils at high altitude in the Pennines well into the mid-Flandrian, as at Pow Hill and other sites in the north (Turner and Hodgson, 1981) and at Bradwell Sitch in Longdendale in the south (Tanis and Johnson, 1980). Although the decline of *Pinus* was delayed at higher altitude and in some areas of lowland northern England (Oldfield, 1965), it was replaced by *Alnus* across most of its range at some stage during the mid-Flandrian. *Alnus* had been present at many sites throughout the early Flandrian, as at Mordon Carr in the Durham lowlands (Bartley *et al.,* 1976), but its rise to abundance defines the start of post-Boreal Flandrian Chronozone II, the wetter mid-Flandrian Atlantic climate period. At some sites where *Pinus* was never common *Alnus* replaced other taxa, as at Scaleby Moss in Cumbria (Godwin *et al.,* 1957) where it replaced *Betula.* At most sites, however, such as Fellend Moss, Northumberland (Davies and Turner, 1979), *Alnus* directly replaces *Pinus* almost entirely, although in places the process is either delayed, as on the North York Moors with an *Alnus* rise at West House Moss of 6650 ± 290 years BP (Jones, 1977b), or gradual as at Din Moss in the Cheviot Hills (Hibbert and Switsur, 1976) where the *Alnus* rise begins around 7000 years BP but percentages do not rise sharply until 6710 ± 100 years BP The date of *Alnus* expansion is strongly diachronous and must relate to local environmental factors. In areas of lowland eutrophic fen–carr communities, where conditions would have been very suitable for alder, its expansion occurred very early. Dates of 7640 ± 85 years BP in the Vale of Pickering (Day, 1996), 7759 ± 67 years BP at Mordon Carr in Durham (Bartley *et al.,* 1976) and 7720 ± 50 years BP at Askham Bog in the Vale of York (Gearey and Lillie, 1999) reflect this early spread. Similar early dates occur in the southern Pennines upland, however, with 7675 ± 75 years BP at Robinson's Moss (Tanis and Switsur, 1990) and 7640 ± 40 years BP at Soyland Moor (Williams, 1985). In contrast several very late dates for the *Alnus* rise occur in the northern Pennines, ranging from 6120 ± 50 years BP at Quick Moss (Rowell and Turner, 1985) and 6150 ± 160 years BP at Red Sike Moss (Turner *et al.,* 1973) to 5400± 50 years BP at Fox Earth Gill (Harkness, 1981) and 5300 ± 40 years BP at Pow Hill (Turner and Hodgson, 1981). Suitable edaphic conditions rather than altitude seem to have been the major factor in alder expansion. Many dates from the region for this important biostratigraphical feature are close to an average date of around 7000 years BP, such as 7107 ± 120 years BP at the Red Moss, Greater Manchester type site (Hibbert *et al.,* 1971), 6962 ± 90 years BP at Neasham Fen in the Tees valley (Bartley *et al.,* 1976), 7180 ± 120 years BP at Walker's Heath in Cheshire (Leah *et al.,* 1997) and 6948 ± 131 years BP at Scaleby Moss in Cumbria (Godwin *et al.,* 1957). Even within small areas like the Craven district of west Yorkshire, however, the timing of *Alnus* expansion varies markedly between sites only a few miles apart, early at 7590 ± 70 years BP at White Moss on heavier soils and later at Martons Both on limestone soils at 6930 ± 90 years BP (Bartley *et al.,* 1990). *Tilia,* the final major tree of the Flandrian forest, was certainly more common than its underrepresentation in pollen diagrams would suggest (Greig, 1982) and was probably co-dominant with *Quercus* and

Ulmus in favourable locations. Lowland southern Yorkshire seems to have had substantial *Tilia* within the mid-Flandrian forest (Beckett, 1981; Lillie and Gearey, 1999) and in the lowland limestone area of south-east Durham it had become important as early as 6760 ± 120 years BP (Bartley *et al.,* 1976). In north Durham and Northumberland *Tilia* frequencies are much lower (Bartley, 1966; Donaldson and Turner, 1977) and the northern limit of *Tilia* as a major forest tree seems to have been the Tees lowlands. This corresponds well with the findings of Piggott and Huntley (1980) that *Tilia* was at its northern limit in Cumbria, although high percentages of lime comparable with those of southern England, have been recorded from sites in the south-east of the Lake District, as at Witherslack Hall (Smith, 1958c). *Tilia* seems never to have been a significant component of the upland forests of northern England (Greig, 1982; Turner and Hodgson, 1983; Tallis and Switsur, 1990).

The most recent pollen stratigraphical marker of significance throughout northern England is the decline in *Ulmus* frequencies around 5000 years BP, which defines the end of the mid-Flandrian forest phase. It is a clear feature of most diagrams of that period and the many dates now available generally conform to around that age. West of the Pennines the type sites of Red Moss, Greater Manchester (Hibbert *et al.,* 1971) and Scaleby Moss, Cumbria (Godwin *et al.,* 1957) provide good average dates of 5010 ± 80 years BP and 4980 ± 119 years BP, as does the date of 5099 ± 50 years BP at Gransmoor to the east (Beckett, 1981) and 5080 ± 110 years BP and 5010 ± 110 years BP at White Moss and Eshton Tarn in west Yorkshire (Bartley *et al.,* 1990), but there is much variation around this mean value and the event is not synchronous. Dates are often a few centuries later than 5000 years BP in the uplands and similarly earlier than 5000 years BP in lowland areas. Earlier lowland dates include 5440 ± 70 years BP at William-son's Moss (Tipping, 1994b) and 5340 ± 120 years BP at Barfield Tarn (Pennington, 1970, 1975c) in Cumbria, 5468 ± 80 years BP at Neasham Fen and 5305 ± 55 years BP at Mordon Carr in lowland east Durham (Bartley *et al.,* 1976), 5296 ± 150 years BP at Crose Mere, Shropshire (Beales, 1980) and 5290 ± 80 years BP at Knowsley Park, Merseyside (Cowell and Innes, 1994). In the case of these earlier dates a secondary elm decline may occur some centuries later (Oldfield, 1963; Walker, 1966b; Tipping, 1994b). Later upland dates from the Pennines include 4794 ± 55 years BP at Valley Bog (Chambers, 1978), 4875 ± 60 years BP at Robinson's Moss (Bartley *et al.,* 1990), 4770 ± 100 years BP at Hipper Sick (Hicks, 1971), 4865 ± 50 years BP at Soyland Moor (Williams, 1985), 4780 ± 50 years BP at Fox Earth Gill (Harkness, 1981) and 4900 ± 50 years BP at Quick Moss (Rowell and Turner, 1985). In the North York Moors dates of 4767 ± 60 years BP at North Gill and 4720 ± 90 years BP at Fen Bogs (Simmons *et al.,* 1993) and in the Cheviot Hills of 4690 ± 110 years BP at Yetholm Loch (Tipping, 1996) are comparable. Earlier upland dates seem to be related to better soils, often on limestone (Bartley *et al.,* 1990). There is a clear attitudinal dichotomy in age for this feature, which holds true throughout northern England.

The Flandrian landscape: forest decline and clearance

The non-synchroneity of all the major Flandrian pollen stratigraphical changes must be partly the result of natural factors such as regional variations in environmental conditions, competitive relationships amongst taxa and their rates of immigration. Disturbance of ecosystems by exogenic factors also has been very important in the Flandrian, in particular fire and anthropogenic activity, two factors that were often linked. Deposition of both macro- and microscopic charcoal within sediment sequences has been a regular event throughout the Flandrian in northern England, showing that fire, whether of natural or cultural origin, often influenced vegetation patterns. Visible layers of charcoal occur that record local burning and the pollen record usually reflects a major vegetation change, such as deforestation, at those levels. Such layers are most common in the limnic, reedswamp and fen stages of hydroseral succession, when detrital sediment systems are better able to accept inwashed material, and so are often correlated most clearly with Mesolithic and other prehistoric cultures. These productive environments also may have been more attractive to human activity than the later bog phases of mire development, although charcoal does occur in raised-bog contexts, from surface fires or blown in.

Conspicuous charcoal layers of Mesolithic or later age occur at Simonswood Moss in Merseyside (Simmons and Innes, 1987), Hoscar Moss (Cundill, 1981), The Starr Hills, Lytham (Tooley, 1978a) and Little Hawes Water (Taylor *et al.,* 1994) in Lancashire, Malham Tarn Moss (Piggott and Piggott, 1963) and Dunford Bridge (Radley *et al.,* 1974) in the central Pennines, Valley Bog in the northern Pennines (Chambers, 1978), Ewe Crag Slack and Kildale Hall in the North York Moors (Jones, 1977b, 1978), Walker's Heath in Cheshire (Leah *et al.,* 1997) and Willow Garth in the Yorkshire Wolds (Bush, 1988a) as well as many other sites. The most researched examples are probably from north-east Yorkshire, where charcoal layers are extensive at Star Carr and adjacent sites in the eastern Vale of Pickering (Cloutman and

Smith, 1988; Day, 1996; Mellars and Dark, 1998) and in the North York Moors upland at North Gill (Simmons and Innes, 1988a, 1996a; Innes and Simmons, 1999). Charcoal also often lies beneath the base of blanket and basin peats at various altitudes and may well have had a role in peat formation as a result of post-fire paludification. Mire Holes in Teesdale (Squires, 1978), May Moss (Atherden, 1979) and Collier Gill (Simmons and Cundill, 1974a) on the North York Moors, Great Close Pasture (Smith, 1986) and Extwistle Moor (Bartley and Chambers, 1992) in the Pennines, White Moss in Cheshire (Lageard, 1992) and Hatfield and Thorne Moors in the Humberhead Levels (Dinnin, 1997b), in the lowland cases with burned tree stumps, are all good examples. Although many sites preserve macroscopic charcoal, microscopic charcoal particles are very common indeed in Flandrian peats. They occur throughout early and mid-Flandrian upland peat in the Pennines at many sites, including Robinson's Moss and Alport Moor (Tallis and Switsur, 1990; Tallis, 1991), Lady Clough Moor (Tallis, 1975; Jacobi *et al.,* 1976) and Pawlaw Mire (Sturludottir and Turner, 1985), and in the North York Moors at Bonfield Gill Head and North Gill (Simmons and Innes, 1981, 1988a, b, 1996a). Microcharcoal is present throughout the mid-Flandrian *Pinus* peak at The King's Pool, Stafford (Bartley and Morgan, 1990) and detailed palaeoecological analyses have shown it to be present throughout eutrophic reedswamp and fen peat stages at Lindow Moss, Danes Moss and Walker's Heath (Leah *et al.,* 1997), Nook Farm (Hall *et al.,* 1995), Top Moss (Leah *et al.,* 1997), Knowsley Park and Simonswood Moss (Cowell and Innes, 1994), Fenton Cottage (Middleton *et al.,* 1995) and indeed virtually all of the surveyed lowland peats west of the Pennines. The same is true of the Mesolithic peats in the Vale of Pickering (Mellars and Dark, 1998). Fire consistently seems to have been part of the regional environment and had the effect of opening the woodland and creating transitional successional vegetation, often promoting particular taxa favoured by fire, such as *Pinus, Pteridium* and *Calluna* (Simmons and Innes, 1987). Charcoal is often recorded at the level of major pollen zone changes, as though fire had changed forest composition and given new taxa the opportunity to become established. Charcoal often accompanies the rise of *Alnus* pollen, for example, as at Walker's Heath in Cheshire (Leah *et al.,* 1997), Hoscar Moss, Lancashire (Cundill, 1981), Seamer Carr in the Vale of Pickering (Cloutman and Smith, 1988) or Malham Tarn Moss in the Pennines (Piggott and Piggott, 1963). Fire also has been suggested as encouraging the early Flandrian *Corylus* rise, as at Flixton in the Vale of Pickering (Walker and Godwin, 1954). Natural fire will have occurred, but it may well have been used deliberately by humans to change the vegetation, as has been suggested in particular for Mesolithic people (Jacobi *et al.,* 1976; Simmons and Innes, 1987), as well as for a range of other purposes. The primary association of charcoal layers with Mesolithic flints and activity at Star Carr, Dunford Bridge and many other sites suggests human agency, and at Bonfield Gill Head (Simmons and Innes, 1981, 1988b) and a number of other upland sites, microscopic charcoal is common in the Mesolithic age peat but not in the Neolithic age peat above, suggesting a correlation with the hunter–gatherer mode of land use. Charcoal peaks also often correlate with phases of intensified human activity in all cultural periods, such as at Lindow Moss in Cheshire in the Iron Age (Oldfield *et al.,* 1986) and at several sites during the Bronze Age and Iron Age in the North York Moors (Dimbleby, 1962; Simmons *et al.,* 1993), implicating humans in the use of fire.

In many cases the *Ulmus* Decline in northern England is accompanied by indications of forest opening and although some such as Hoscar Moss in Lancashire (Cundill, 1981) and Barfield Tarn in Cumbria (Pennington, 1975c), are associated with charcoal, many are manifest solely in the pollen stratigraphy as reductions in tree pollen and increases in open ground or agricultural indicator taxa, such as *Plantago lanceolata* and cereal-type pollen. Many disturbance phases without charcoal evidence did occur during the Flandrian prior to the *Ulmus* Decline, as at Quick Moss in the Pennines (Rowell and Turner, 1985) and at sites in the Cheviot Hills (Tipping, 1996), perhaps caused by Mesolithic activity. With or without charcoal, the frequency of disturbance seems to increase in the period leading up to the *Ulmus* Decline, often at the same site. Sturludottir and Turner (1985) have suggested that repetitive forest disturbance, especially using fire, may have caused the decline of elm at Pawlaw Mire and elsewhere in the Pennines as a result of soil degeneration, a process leading to spread of blanket bog and moorland in the uplands (Simmons and Innes, 1987). A few of the forest openings in the millennium before the *Ulmus* Decline in northern England contain cereal-type pollen, as at Little Hawes Water in north Lancashire (Taylor *et al.,* 1994) and Lismore Fields in Derbyshire (Wiltshire and Edwards, 1993), which may be the first evidence of the presence of at least partly agricultural land use in the region. Early dates of 5820 ± 95 years BP (Williams, 1985) at Soyland Moor in the Pennines and 5840 ± 70 years BP (Cowell and Innes, 1994) at Bidston Moss in Merseyside suggest that an incipient Neolithic style economy existed for several centuries before the *Ulmus* Decline, as well as several centuries after it. The *Ulmus* Decline therefore lies firmly within the Neolithic cultural period and itself may be a symptom of human activity, although disease and climate may be implicated. As suggested by Pennington (1970) and Tipping (1994a) for the Cumbrian plain, the *Ulmus* Decline is probably multi-causal and the result of local events.

The five millennia after the elm decline in northern England are characterized by increasing intensity of human agricultural land use, forest clearance and the spread of grassland, heath and bog. Regional variations in the timing, character and intensity of land use are apparent, but a progressively more open and intensively used landscape is a common theme, changing the nature and rate of depositional regimes. The sedimentary signature of this later Flandrian anthropogenic phase is increasingly severe episodic soil erosion and alluviation, from the Cheviot Hills (Mercer and Tipping, 1994) to the Cheshire–Shropshire plain (Twigger and Haslam, 1991), from Humberside (Gilbertson, 1984a; Buckland and Sadler, 1985) and the Yorkshire Wolds (Bush, 1993) to the Lake District (Pennington, 1970). A few areas record heavy woodland clearance in the Neolithic, as at Shibdon Pond in the Tyne valley (Passmore *et al.,* 1992), where it began after 4800 ± 80 years BP and resulted in major alluvial deposition. Major Neolithic clearances also occurred in north Northumberland at this time (Tipping, 1992). At 4543 ± 70 years BP at Mordon Carr in south-east Durham (Bartley *et al.,* 1976) there was major woodland clearance, with cereal pollen found and Tooley (1978b) records similar large-scale clearance at nearby Hartlepool Bay. In contrast in north Durham at Hallowell Moss (Donaldson and Turner, 1977) and at upland Northumbrian sites (Davies and Turner, 1979; Rowell and Turner, 1985) there is no evidence of Neolithic clearance. At Skipsea Withow Mere in Holderness major deforestation with cereal pollen found, occurs at the *Ulmus* Decline and then again until major colluviation after 4500 ± 50 years BP buries the profile (Blackham and Flenley, 1984). Similar major clearance and soil erosion occurred at Prescot Moss, Merseyside between 4650 ± 80 and 4520 ± 140 years BP (Cowell and Innes, 1994), and a marked clearance phase at Hatchmere in Cheshire persists until 4693 ± 90 years BP (Switsur and West, 1975). Later Neolithic people appear to have used fire to clear the upland woods in Cumbria (Walker, 1965; Pennington, 1970) and sites such as Williamson's Moss on the Cumbrian coastal plain record substantial woodland clearance for several centuries after the *Ulmus* Decline (Pennington, 1975c). Sites in the southern Pennines show little evidence for Neolithic activity in the pollen record, with the first clearances at Leash Fen (Hicks, 1971), Rishworth Moor (Bartley, 1975), Deep Clough (Tallis and McGuire, 1972) and Fountains Earth (Tinsley, 1975), for example, delayed until after *c.* 4000 years BP. An exception occurs around Eshton Tarn in the Craven district of West Yorkshire, where major woodland clearance with cereal pollen found, is dated to *c.* 4500 years BP (Bartley *et al.* 1990), although most sites in that area record only sporadic and short-lived low intensity clearance. Honeyman (1985) did, however, report significant clearance in Wensleydale dated 4550 ± 50 years BP Neolithic age woodland clearance on the North York Moors was also very low scale and sporadic (Simmons *et al.,* 1993). There is good macrofossil and pollen evidence for an expansion of tree cover in most of the uplands during the Neolithic (Tallis, 1975; Simmons *et al.,* 1993) and a rise in the height of the tree line. Despite some exceptions, such as Skipsea Withow Mere, coastal west Cumbria and some locations in the Mersey valley (Birks, 1965b), almost all lowland sites on both sides of the Pennines record only sporadic and limited Neolithic impact on woodland (Twigger and Haslam, 1991; Middleton *et al.,* 1995; Dinnin, 1995; Leah *et al.,* 1997; Gearey and Lillie, 1999). Neolithic impact in the north of England was mainly of a minor nature and significant forest clearance was probably very localized and poorly represented on most pollen diagrams. Some real diversity does exist in the Neolithic environmental record, however, a feature persisting through the late Flandrian.

The great majority of sites in all parts of northern England record major increases in the intensity of forest clearance between about 4000 and 2800 years Bp corresponding to the Bronze Age occupation of the region. In most locations this activity represents the first major reduction in forest cover, and the greatly increased incidence of cereal-type pollen points to the expansion of a mixed farming economy at this time. Individual site histories are too numerous to catalogue, but representative profiles may be cited from various areas. Of particular interest in the mid-fourth millennium BP is a major decline in *Tilia* percentages, in some cases to virtual absence (Beckett, 1981), which is diachronous and often coincides with peak cereal, *Plantago lanceolata* and other agricultural indicator pollen records, supporting Turner's (1962, 1965) recognition of Bronze Age farming as the cause. Turner (1964) dated the *Tilia* decline at Whixall Moss, Shropshire to 3238 ± 115 years BP and a cluster of similar dates are available from that area. Beales (1980) dated the feature to 3714 ± 129 years BP at Crose Mere and mosses and meres in the Baschurch area of Shropshire have provided dates of 3660 ± 50, 3550 ± 50 and 3190 ± 60 years BP (Barber and Twigger, 1987). The last date is similar to that at Top Moss (Leah *et al.,* 1997) of 3220 ± 50 years BP, which was preceded by a substantial phase of clearance at 3800 ± 55 years BR Local land-use variations caused the event to occur over several centuries in this small area. In south Yorkshire (Dinnin, 1997a), forest clearance episodes, where no cereal pollen has been found, on Hatfield and Thorne Moors have been dated to 3715 ± 70, 3685 ± 65, 3570 ± 70 and 3545 ± 70 years BP, the last two associated with charcoal, and burned and chopped tree stumps. Major clearance occurred in the lowlands of the north-east. *Tilia* declines sharply within a major clearance episode at Bishop Middleham in Durham at 3660 ± 80 years BP, followed by an extensive second clearance at 3360 ± 80 years Bp which left the local fertile east Durham limestone soils virtually deforested (Bartley *et al.,* 1976). Analogous events took place at nearby Hutton Henry at 3544 ± 80 years BP and Neasham at 3242 ± 70 years BP, and *Tilia* almost disappeared at Hallowell Moss near Durham City (Donaldson and Turner, 1977). The same process occurred in Northumberland at all altitudes. Davies and Turner (1979) record major clearance at Fellend Moss at 3688 ± 60 years BP, at Steng Moss at 3594 ± 45 years BP and 3015 ± 45 years BP and at Camp Hill Moss between 3510 ± 70 and 3110 ± 80 years BR Tipping (1996) reported major woodland clearance, with cereal pollen found, throughout the Bronze Age levels at Swindon Hill in the Cheviot Hills well before 3100 ± 50 years BR In this area Bronze Age clearance resulted in erosion and alluvial deposition (Tipping, 1992), as at Callaly Moor in mid-Northumberland between 3920 ± 70 and 2540 ± 110 years BP (Macklin *et al.,* 1991). On the North York Moors major upland clearance took place in this period (Simmons *et al.,* 1993) as shown by soil pollen analyses from beneath Bronze Age monuments (Dimbleby, 1962). Cereals were common and extensive deforestation occurred, which converted much of the upland to heather moor and bog permanently. Good dated examples are 3400 ± 90 years BP at Fen Bogs (Atherden, 1976a, b) and 3210 ± 90 years BP at Wheeldale Gill (Simmons and Cundill, 1974a). After 3970 ± 80 years BP at Willow Garth on the Yorkshire Wolds a low amount of *Tilia* falls to zero at a point where cereal pollen first appears and *Plantago lanceolata* peaks (Bush, 1993), suggesting mainly pastoral human activity and spread of grassland in this already poorly wooded area. In the Pennine uplands almost all sites experience their first significant deforestation in the Bronze Age. Major clearances occur at sites in Wensleydale at 3850 ± 50 and 3930 ± 50 years BP (Honeyman, 1985). The first major deforestation at Eshton Tarn (Bartley *et al.,* 1990) occurs at 3600 ± 100 years BP, followed by almost complete woodland removal and high values for cereals at 3160 ± 80 years BR Bartley (1975) dated the first major clearance in the uplands around Rishworth at 4010 ± 100 years BP, a date similar to those reported by Hicks (1971) for Leash Fen in Derbyshire, who reported a *Tilia* decline and increased clearance between 3740 ± 100 and 3450 ± 110 years BP, Tinsley (1976) who noted major woodland recession at Skell Moor in Nidderdale at 3880 ± 100 years BP, and Tallis and McGuire (1972) at Deep Clough in the Rossendales, with a date of 3540 ± 120 years BP The same process occurred throughout the Pennines. In the lowlands to the west at Fenton Cottage in Lancashire records show a large increase in charcoal and *Calluna* pollen during the Bronze Age between 3790 ± 100 and 3180 ± 60 years BP (Middleton *et al.,* 1995; Wells *et al.,* 1997), the earlier date also marking the deposition of the Hekla 4 tephra at that site, the only tephra layer recovered from northern England to date. In Merseyside (Cowell and Innes, 1994) the first substantial clearances in the central mossland region, although without cereal pollen being found, also occur at this time. Bronze Age clearance is also common in Cumbria (Wimble *et al.,* 2000), as at Ennerdale Water before 2996 ± 55 years BP (Pennington 1970, 1975c) and with a series of clearances at Rusland Moss before 2686 ± 50 years BP (Dickinson, 1975). The first significant clearances in the Solway lowlands, with substantial occurrence of cereals indicated by the pollen record, took place in the mid-Bronze Age (Walker, 1966b). In most of northern England the Bronze Age was a time of reduced forest cover and increased human activity. Only in areas with very heavy clay soils and lowland wetland environments, such as the Vale of York, might forest clearance have been very limited. For example, at St George's Field, York (Lillie and Gearey, 1999) environmental evidence indicates mature undisturbed woodland and alluvial wetlands between 3240 ± 70 and 2760 ± 65 years BP in the late Bronze Age.

The impact of Iron Age and Romano-British land use on the woodland in northern England was regionally 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 greatly increased deforestation, in places on a landscape scale (Turner, 1979). Soil quality determined the degree to which arable cultivation figured in local land use. Extensive deforestation took place in the east Durham lowlands, for example, with trees replaced by grassland almost completely at Hallowell Moss between 1956 ± 70 and 1355 ± 50 years BP (Donaldson and Turner, 1977). At Thorpe Bulmer and Hutton Henry (Bartley *et al.,* 1976) intensive deforestation occurred at 2064 ± 60 and 1842 ± 70 years BP respectively, the former associated with high values of cereal pollen and a peak of *Cannabis* pollen at 1730 ± 120 years BP where- as at Bishop Middleham on very fertile soils deforestation had been completed by the start of the Iron Age. In south Northumberland the land was still widely forested through the pre-Roman Iron Age, but became deforested during the Roman period, as at Fellend Moss where clearance took place at 1948 ± 45 years BP and Fozy Moss where massive and rapid clearance occurred from 1820 ± 45 years BP (Turner, 1979; Dumayne and Barber, 1994). Similar major tree removal is recorded in the Northumbrian hills at the same time, at Steng Moss (Davies and Turner, 1979) from 1970 ± 60 years BP, at Bollihope Bog and Steward Shield Meadow in Weardale from 1730 ± 100 and 2060 ± 120 years BP respectively (Roberts *et al.,* 1973) and at Quick Moss (Rowell and Turner, 1985) from 2035 ± 50 years BR The landscape of the Cheviot Hills also was almost cleared of trees during this period and several radiocarbon dates place phases of alluvial aggradation at Powburn (Tipping, 1992) to this time. Major woodland clearance with cereal pollen found preceded major alluviation in the lower Tyne valley after *c.* 2590 years BP (Passmore *et al.,* 1992). In all cases the clearance is prolonged as well as massive, lasting through the Roman period and after. A similar record occurs both in north Cumbria (Dumayne-Peaty and Barber, 1998), at Bolton Fell Moss at 1860 ± 60 years BP and Walton Moss with dates of 2000 ± 45 and 1925 ± 40 years BP, and in south Cumbria (Dickinson, 1975) at Rusland Moss, where a cleared landscape with cereals present persisted from 1963 ± 50 to 1361 ± 55 years BP. Supporting data from Helsington Moss (Smith, 1958c) at 1514 ± 100 years BP, Burnmoor Tarn at 1460 ± 130 years BP and Devoke Water after 1750 ± 130 years BP (Pennington, 1970) confirm that widespread clearance and cereal cultivation spread into all parts of Cumbria in the Romano-British period. Massive forest clearance took place on the North York Moors in Iron Age to Roman times, some with high cereal pollen values found, others apparently mainly for pasture (Simmons *et al.,* 1993). The best dated examples are Fen Bogs between 2280 ± 120 and 1530 ± 130 years BP (Atherden, 1976a, b) and after 2190 ± 90 years BP at Harwood Dale Bog (Atherden, 1989). Evidence from the Pennines is also clear, and Tallis and Switsur (1973) dated very substantial clearance and the presence of some cereal pollen between 2251 ± 50 and 1400 ± 50 years BP at Featherbed Moss in the southern Pennines, which corresponds well with more limited clearance at Leash Fen (Hicks, 1971) between 2120 ± 100 and 1500 ± 110 years BP Tinsley (1976) reported a major late Iron Age and Roman forest clearance with high cereal pollen values found dated after 2200 ± 80 years BP in Nidderdale, north Yorkshire Pennines. Bartley and Chambers (1992) recorded similar major woodland clearance between 2260 ± 100 and 1730 ± 75 years BP at Extwistle Moor, Lancashire, as did Mackay and Tallis (1994) between 2025 ± 40 and 1735 ± 45 years BP in the Forest of Bowland, whereas Cundill (1976) reports major clearance at Carlingill in the Howgill Fells as occurring after 2290 ± 80 years BP The same pattern of low-scale activity in the earlier Iron Age and then major deforestation in Roman times recurs throughout the Pennines, and is also the case in the lowlands of the southern part of the region. Representative examples are Fenton Cottage between 1940 ± 110 and 1590 ± 50 years BP and Winmarleigh Moss at 1680 ± 80 years BP in Lancashire (Middleton *et al.,* 1995), Knowsley Park around 1680 ± 50 years BP and Simonswood Moss after 2380 ± 80 years BP in Merseyside (Cowell and Innes, 1994), after 2090 ± 70 years BP at Rostherne Mere (Leah *et al.,* 1997) and after *c.* 2240 years BP at Lindow Moss (Oldfield *et al.,* 1986) in Cheshire, and after 2086 ± 75 years BP at Crose Mere (Beales, 1980) and around 2195 ± 50 BP at Top Moss (Leah *et al.,* 1997) in Shropshire, all with a consistent pollen curve showing cereal cultivation, intensified agriculture and woodland recession. Oldfield *et al.* (1985) dated major clearance and soil erosion at Peckforton Mere, Cheshire to Romano-British times by mineral magnetic analyses. Regional deforestation for arable agriculture also is a feature of the south Yorkshire lowlands, with a very open landscape indeed, causing major soil erosion and alluviation (Buckland and Sadler, 1985). This deforestation occurred around Thorne and Hatfield Moors after dated levels of 2085 ± 70, 2225 ± 70 and 2145 ± 65 years BP (Smith, 1985; Dinnin, 1997a). Bush (1993) also records a major switch to arable cultivation, indicated by high values of cereal pollen on the Yorkshire Wolds at Willow Garth after 2120 ± 50 years BP, replacing grassland and the little remaining woodland, and Kenward *et al.* (1978) report a sharp decline in oak and hazel and rise in grass and cereal pollen after 2010 ± 90 years BP at Askham Bog near York. Although a few areas, as around Baschurch in Shropshire (Twigger and Haslam, 1991), show some regeneration of woodland in Roman times, there is a similar pattern of major deforestation in late Iron Age and Romano-British times throughout northern England, partly perhaps for the timber itself as much as for farming land (Atherden, 1976a; Dumayne and Barber, 1994).

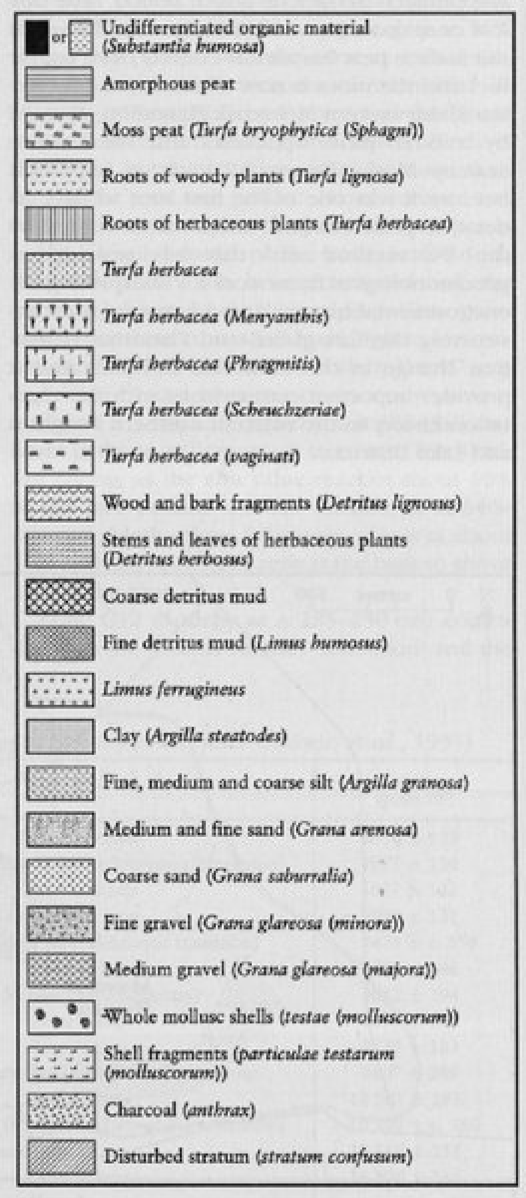
Fewer sediments of post-Roman age have survived than those of earlier periods and so a systematic view of landscape history in northern England for the past 1500 years is more difficult to attain. Several sites do preserve evidence of medieval and later land use, and these indicate continued forest clearance in all parts of the region with local interludes of regeneration. Woodland regeneration after the Roman period occurs in many places, but persistence of clearance also occurred, as at Baggy Moor in Shropshire (Brown, 1990), dated after 1375 ± 40 years BP but before 1190 ± 50 years BP. Supporting evidence comes from The King's Pool, Stafford (Bartley and Morgan, 1990), where the main arable phase with high values for cereal pollen is after 1370 ± 70 years BP. Beales (1980) and Barber and Twigger (1987) also suggest intensified agriculture in Shropshire from Anglian times onwards, but with an emphasis on pastoralism. At Winmarleigh Moss in west Lancashire (Middleton *et al.,* 1995) the substantial clearance that began in late Roman times at 1680 ± 80 years BP persisted until 900 ± 90 years BP with increasing cereal pollen values found. At nearby Fenton Cottage a gradual increase in clearance pressure from 1200 ± 70 to 390 ± 50 years BP left the area under mixed agriculture and almost completely without tree cover in the medieval period (Middleton *et al.,* 1995). On Thorne and

Hatfield Moors in south Yorkshire, Smith (1985) reported regeneration of woodland in the post-Roman period until after dates of 865 ± 60 years BP and 910 ± 65 years BP when there was a great expansion of mixed farming and an almost treeless landscape (Dinnin, 1997a). On the Yorkshire Wolds at Willow Garth (Bush, 1993) high cereal values and arable indicators in the pollen record from 1170 ± 50 years BP until modern times shows the intensively farmed nature of the area. At Askham Bog in the Vale of York (Kenward, *et al.,* 1978) peak values for cereal and *Cannabis* pollen occur before 470 ± 80 years BP, and so are medieval in age. In north-east England several dates averaging 1400 years BP are available, from sites such as Steng Moss and Fellend Moss (Davies and Turner, 1979), Quick Moss (Rowell and Turner, 1985), Hallowell Moss (Donaldson and Turner, 1977) and Fen Bogs (Atherden, 1976b; Chiverrell and Atherden, 1999), that indicate a region-wide regeneration of woodland after the Roman period. Exceptions do occur, as at Thorpe Bulmer (Bartley *et al.,* 1976) on the east Durham limestone, where tree recovery did not occur until 852 ± 60 years BP and at Steward Shield Meadow in Weardale (Roberts *et al.,* 1973) until 840 ± 100 years BP The first major clearance on the heavy soils in the Tees valley did not occur until 1213 ± 60 years BP at Neasham Fen (Bartley *et al., 1976*)*.* Most sites record massive clearance in the medieval period, at Fellend Moss from 945 ± 40 years BP onwards, at Camp Hill Moss in the Cheviot Hills (Davies and Turner, 1979) from 640 ± 80 years BP onwards and on the North York Moors at Fen Bogs from 1060 ± 160 years BP until 390 ± 100 years BP Pennington (1970) records major upland woodland clearance in Cumbria in Norse and later times, whereas in the north Cumbrian lowlands and Tyne valley Dumayne and Barber (1994) record sustained clearance for mixed farming at Glasson Moss after 960 ± 40 years BP and at Fozy Moss after 925 ± 45 years BP In the Lancashire Pennines Mackay and Tanis (1994) record consistently high values of cereal and grassland pollen after 840 ± 45 years BP, with major expansion and sharp decline in *Alnus* and *Corylus* values before a 210Pb date of AD 1847. A similar but less pronounced pattern occurs at Extwistle Moor, Lancashire after 905 ± 70 years BP (Bartley and Chambers, 1992). Tinsley (1975, 1976) in Nidderdale in the North Yorkshire Pennines recorded clearances for grassland pasture but with some cereals in phases after 1050 ± 80 and 480 ± 80 years BP Clearance on the upland limestone soils of west Yorkshire was earlier, before 1190 ± 40 years BP (Bartley *et al.,* 1990). The evidence from Featherbed Moss in the southern Pennines (Tallis and Switsur, 1973) is again for massive clearance, with high values of cereal and pastoral indicator pollen, and a very open medieval landscape from 1023 ± 50 years BP continuing beyond 491 ± 50 years BP. Many other sites in northern England, although undated, show similar massive deforestation in their near-surface pollen levels, which probably is of medieval and modern age, resulting in the present extremely open landscape.

Key to the stratigraphical symbols used in the pollen diagrams

The key below (Figure 8.1) is adapted from Troels-Smith (1955) and is used in most of the pollen diagrams in this chapter.

References



(Figure 8.1) Key to the stratigraphical symbols (modified after Troels-Smith, 1955).