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## The Late Devensian and Holocene of industrial Severnside and the Vale of Gordano: stratigraphy, radiocarbon dating and palaeoecology

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With the aid of a series of locally defined pollen assemblage zones and some new radiocarbon dates, the paper summarises the nature of vegetational changes which have occurred in the Vale of Gordano and Severnside areas from the beginning of the Loch Lomond Stadial of the Late Devensian to the modern day. The vegetational history of the area matches that found elsewhere in southern Britain but two variations attributable to location conditions are evident, especially within the enclosed basin of the Vale of Gordano. Firstly, a two-stage "elm decline" is evident, dated to about 5260 and 5000 years BP. Secondly, the deposits at the base of the Holocene coastal alluvium include freshwater and carr peats whereas the thin peats interbedded within the main coastal alluvium appear to have accumulated on salt marshes.

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### Introduction

This paper summarises the results of palynological and radiocarbon studies of Late Devensian and Holocene peat and clay sequences which occur at various locations on the margins of the Severn Estuary in the Vale of Gordano, beneath industrial Severnside and below Ordnance Datum on the Gravel Banks (Fig. 1). The sites provide valuable and comprehensive insights into the nature of Holocene sea level changes, estuarine and perimarine sedimentation and ecological change, as well as issues of geotechnical importance (Hawkins 1984).

The detailed interpretation of the palaeoenvironment of Holocene deposits in the region has been limited by a number of inter-related problems. There is no general model of the stratigraphy of the Holocene deposits and a lack of radiocarbon dates for the sequences for which palaeoecological information has been published (eg. the Vale of Gordano, Jefferies *et al.* 1967 and Avonmouth, Seddon 1965). On the other hand, much of the published information on the radiocarbon dated buried peats is not accompanied by the palaeoecological information necessary to identify how and where

the peat formed in relation to the contemporary shoreline (eg. Skempton 1970; Hawkins 1971). To date progress has also been impeded by the absence of a "reference pollen diagram" from this area which covers the entire Holocene. Such information would provide a reliable basis for pollen-based biostratigraphic correlations as well as palaeoenvironmental reconstruction.

The Vale of Gordano study (Jefferies *et al.* 1968; Willis and Jefferies 1959) covers the Late Devensian (Zone III - Loch Lomond Interstadial) and the mid-late Holocene and modern vegetation but does not cover the Early Holocene. Despite the long history of pioneering palynological studies in the Somerset Levels and Bristol Channel area summarised in Godwin (1975) and by later workers, neither of these regions have yielded a pollen diagram spanning the Holocene, with the early Holocene being particularly poorly known.

### Methods

In June 1984 a 60mm diameter auger core was taken from within wet woodland on Walton Moor in the Vale of Gordano (ST 436729) (Fig. 1). The core stratigraphy is described in full in Mills (1984). This site lies close to core "D.B.2" taken by Jefferies *et al.* (1968). Both cores derive from deposits which have accumulated on the upstream side of the enclosed subsurface topographic basin formed by the crossvalley sand bar identified opposite Weston in Gordano by Jefferies *et al.* (1968, Figs 1 and 2). The relationships were observed in the field at ICI Avonmouth, the MS Avonmouth Bridge and the Gravel Banks in the Severn Estuary. The alluvial sequences beneath Avonmouth and Portbury have been established by interpreting commercial borehole records as well as examination of the published records of Seddon (1965), Hawkins (1967, 1971), Skempton (1970) and Gilbertson and Hawkins (1980, 1983a, b).

The radiocarbon dates for the Severnside peats were provided by the former Institute of Geological Sciences. The five radio-carbon dates from Walton Moor in the Vale of Gordano were authorised by the NERC Radiocarbon Panel and measured at the NERC Radiocarbon Laboratory, East Kilbride. The ages reported for each suite are expressed in conventional radiocarbon years BP (before AD 1950) and at the  $\pm$  standard deviation confidence level. In view of the proximity of carbonate-rich bedrocks in the Vale, the NERC Laboratory first digested the samples in dilute mineral acid to remove any traces of "geologically" old carbonate from the sediment matrix. This pre-treatment also removed the more soluble organic materials which might have contaminated the sample horizons by diffusion through the sediment profile. Although the measured ages have confidence ranges ( $\pm$  term) which reflect the limited amounts of pretreated carbon available for radiometric assay, it is considered highly

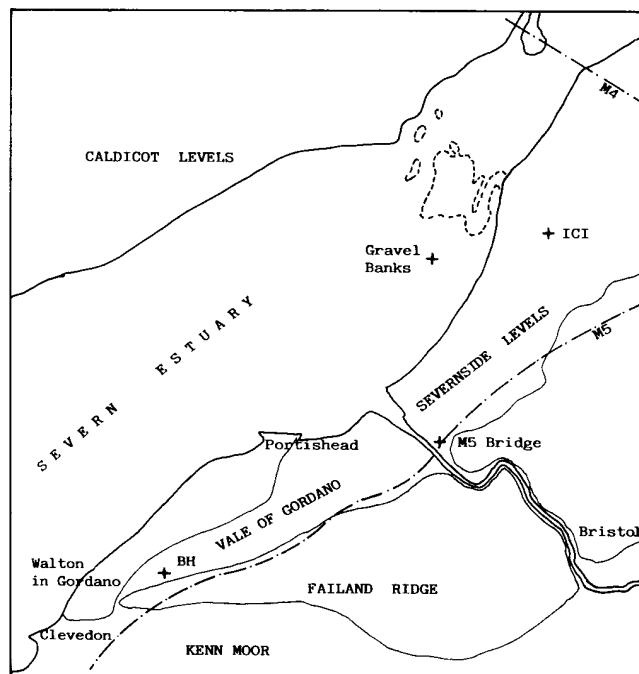


Figure 1. Location of places mentioned in the text.

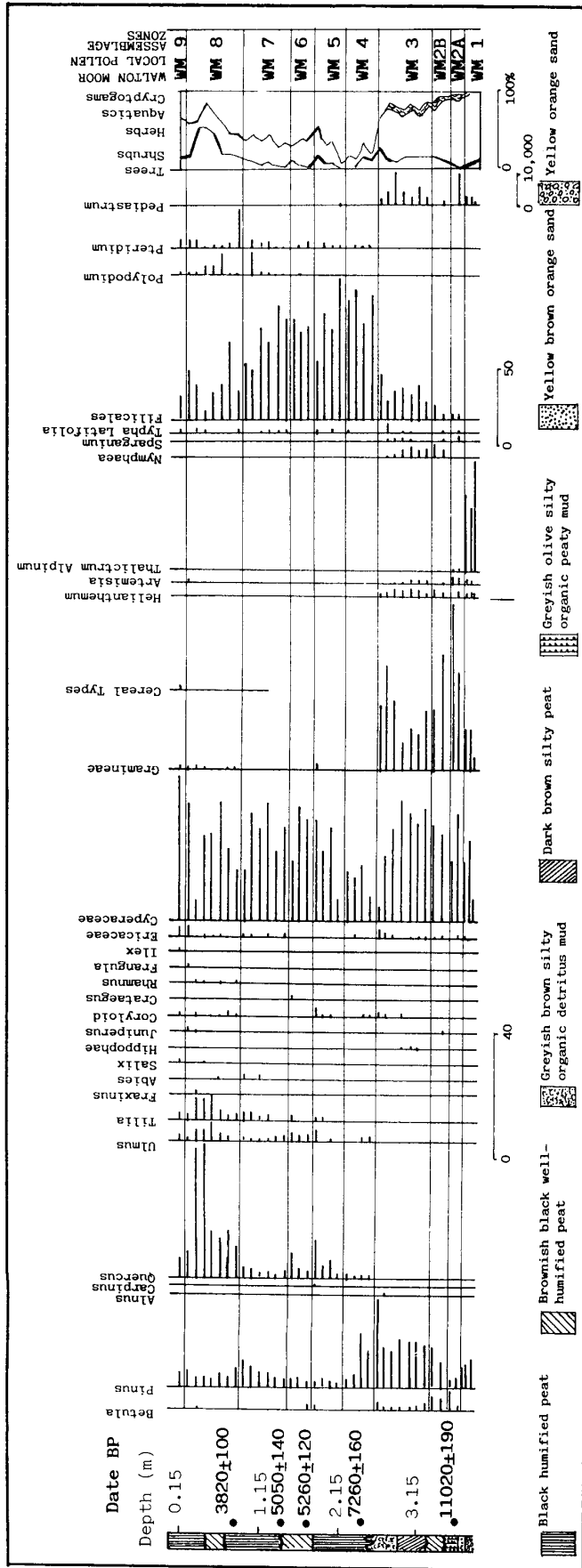


Figure 2. Summary pollen diagram showing relative frequencies of selected pollen and spore types from Vale of Gordano (ST 436729) displayed as percentage of total pollen and spores counted at each level. Further details given in Table 1.

Table 1. Summary table setting out: (a) the radiocarbon determinations of the boundaries between Local Pollen Assemblage Zones (LPZ) determined for the Late Devensian and Flandrian sequence in the Walton Moor core, Vale of Gordano; (b) a description of the local pollen assemblage zones recognised- at Walton Moor (WM); (c) palynologically-studied and radiocarbon-dated peats from beneath Industrial Severnside; and (d) their correlation with local pollen assemblage zones (KM1 - KM10) at the nearby site of Kenn Moor, Clevedon.

*WM9 Pinus-Quercus-Tilia- "Cereal-type"zone.* *Pinus*, *Tilia* and *Ulmus* continue at previous percentage frequencies, while *Quercus* shows a slight decline. Herbaceous plants are dominant, and cereal-type pollen is recorded for the first time in the Walton Moor sequence; above 0.2m depth.

\_\_\_\_\_ ? precise antiquity uncertain ? \_\_\_\_\_

*WM8 Quercus-Ulmus-Tilia-Pinus-Gramineae zone.* *Quercus*, *Ulmus* and *Tilia* show major increases and declines through this zone, *Pinus* continues with modest percentages. Gramineae present in consistent but low proportions; depth 0.90-0.20m. Includes ICI-Avonmouth 3110±100 BP (IGS C14/27); correlative assemblage zones KM8-KM 10 dated at 3510±100 BP (IGS C14/26) and 3410±100 BP (IGS C14/37).

\_\_\_\_\_ approx. 3820±100 BP (SRR-3199) \_\_\_\_\_

*WM7 Pinus-Quercus-Tilia-Ulmus-Filicales zone.* *Pinus* and *Tilia* increase through this zone. *Quercus* and *Ulmus* have a consistent but small representation, Filicales is in slow decline from previous high proportions; depth 1.5 - 0.90m. Includes ICI Avonmouth 3905±100 BP (IGS C14/28); correlates with KM4-6, possible correlative assemblage zone KM6 ends at 4145±100BP (IGS C14/38) at Avonmouth 4180 BP (See Skempton 1970).

\_\_\_\_\_ approx. 5050±140 BP (SRR-3200) \_\_\_\_\_

*WM6 Quercus-Ulmus-Filicales zone.* *Quercus* is present throughout, but is most abundant at the top of this zone. *Ulmus* and *Tilia* are present in small quantities, and also increase later in the zone. Coryloid is entirely absent. Filicales continue to be abundant; depth 1.80 - 1.50m. Includes ICI - Avonmouth 5100±100 BP (IGS C14/29); ?correlates with KM3.

\_\_\_\_\_ approx. 5260±120 BP (SRR-3201) \_\_\_\_\_

*WM5 Quercus-Ulmus-Coryloid-Filicales zone.* *Quercus* and *Ulmus* increase markedly to peak at top of zone, Coryloid reaches its highest frequency at the top of this zone; *Tilia* appears, in general *Pinus* has low values; depth 2.20 - 1.80m. Correlates with KM4, and with KM3 at 6100±100 BP (IGS C14/39); includes Gravel Banks 7030±115 BP (1-4903) and Portbury 7280±130 BP (IGS C14/33)

\_\_\_\_\_ ? precise antiquity uncertain ? \_\_\_\_\_

*WM4 Pinus-Quercus-Ulmus-Filicales zone.* *Pinus* is still the dominant tree pollen, *Quercus* and *Ulmus* appear in small quantities, Filicales rise to 60% of the total pollen and spores, very few herbs are recorded; depth 2.60 - 2.20m.

\_\_\_\_\_ approx 7620±160 BP (SRR-3202) \_\_\_\_\_

*WM3 Betula-Pinus-Coryloid-Gramineae zone.* *Betula* decreases, *Pinus* increases to over 12% of total pollen and spores, Coryloid pollen appears, there are a wide variety of terrestrial and aquatic herbs; depth 3.22 - 2.60m.

\_\_\_\_\_ ? precise antiquity uncertain ? \_\_\_\_\_

*WM2B Pinus-Betula-Gramineae sub-zone.* *Pinus* increases to 8-13% total pollen and spores, *Betula* is present at about 4% total pollen and spores, Gramineae are abundant, with a wide variety of terrestrial and aquatic herbs; depth 3.22-3.55m.

FLANDRIAN/HOLOCENE  
 \_\_\_\_\_ (By "convention" at 10,000 BP) \_\_\_\_\_

#### LATE DEVENSIAN

*WM2A Betula-Artemisia-Gramineae sub-zone.* *Betula* appears and reaches greatest relative frequencies in this zone, Gramineae are abundant, *Artemisia* reaches highest frequencies and a wide variety of terrestrial and aquatic herbs are also present; depth 3.55 – 3.71m. Correlates with the Loch Lomond Stadial.

\_\_\_\_\_ approx. 11,020±190 BP (SRR-3203) \_\_\_\_\_

*WM1 Thalictrum alpinum-Pinus zone.* *Thalictrum* is abundant exceeding 30% of total pollen and spores. *Pinus* exceeds 5% total pollen and spores; below 3.71m. Correlates with the Windermere Interstadial.

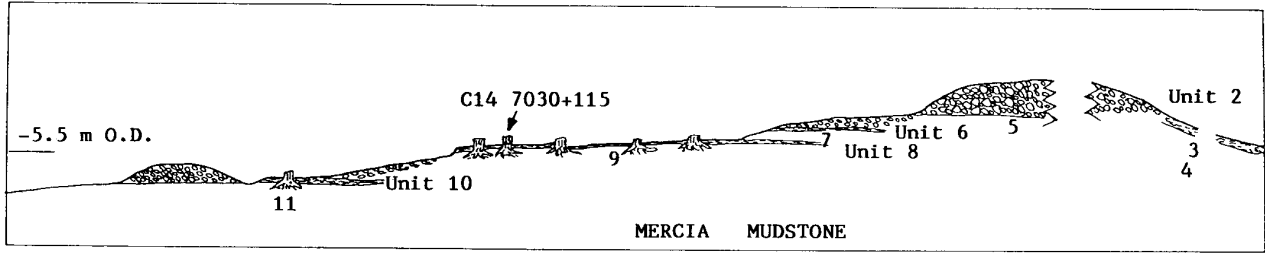


Figure 3. Topographic and stratigraphic relationships of Holocene peats at Gravel Banks, Severn Estuary.

unlikely that the results are significantly influenced by contamination from either younger or older sources of foreign carbon.

Details on preparation, identification, counting and interpretation of the absolute and relative frequency pollen diagrams are given in Mills (1984). The local pollen-biostratigraphic assemblage zones recognised are set out in Table 1 and in the conventional pollen diagram (Fig. 2). The restricted spatial scale of the Local Pollen Assemblage Zone (LPAZ) is particularly important in view of the unusual topography and relative isolation of the valley noted by Jefferies *et al.* (1968).

Late Devensian and Holocene deposits at Walton Moor, Vale of Gordano

The sequence established in 1984 has many similarities with that recorded in the earlier study. The origins of the basal yellow-orange sands are not clear but they are probably either intertidal/sea-bed or aeolian; their microfauna being almost identical to those in the sands at Holly Lane, interpreted by Gilbertson and Hawkins (1983a) as being wind blown. This is consistent with their containing a subarctic pollen suite dominated by open ground light-demanding herbs (Fig. 2). The overlying grey-olive silts and biogenic deposits are attributable to quiet, lacustrine sedimentation.

The basal radiocarbon date of 11,020 ± 190 (SRR-3203) is consistent with the palynological evidence, which indicates that these basal silts accumulated in a cold to sub-arctic climate in the latter stages of the Windermere Interstadial (ie. Pollen Zone II of Godwin 1975) and into the Loch Lomond Stadial (Pollen Zone III). The pollen flora of LPAZ WM1 (Table 1 and Fig. 2) suggest sub-arctic herb vegetation growing in open conditions with unstable soils. This pre-dates about 11,000 radiocarbon years BP (Fig. 2). The taxa found are well known for the Late Devensian (Godwin 1975).

LPAZ WM2 post-dates about 11,000 radiocarbon years BP and is characterised principally by the presence of the pollen of *Betula*, *Artemisia* and grasses. The prevailing environment appears to have been very cold with sub-arctic or arctic shrub and herbs occurring on or around a wet valley floor. This assemblage zone appears to represent the very cold Late Devensian Loch Lomond Stadial (Zone III of Godwin 1975). Similar quantities of birch pollen occur in the Late Devensian at Hawks Tor,

Bodmin Moor (Conolly *et al.* 1949). The grains of *Betula* may derive from sub-arctic dwarf birch communities, although tree birch certainly lived in eastern England during this period (Gilbertson 1984).

The Holocene sequence is composed of biologically rich lacustrine peaty muds interbedded with marsh peats, which are eventually replaced by carr peats and fen peaty. The overall Holocene sequence therefore represents a freshwater lake basin infilling with biogenic sediments as a result of deposition and the encroachment of vegetation. At present there is no reason to assume the sedimentation rate was either constant or uninterrupted. The start of the Holocene at the base of LPAZ WM2B has been identified on the basis of notable increases in the relative and absolute abundances of *Pinus* with the continued presence of *Betula* and grasses. An open landscape is indicated with trees becoming more frequent. No radiocarbon dates are available for the base of the biogenic deposits at the bottom of LPAZ WM2B, which corresponds approximately to the commencement of the Holocene, set by convention at 10,000 years BP. Significant numbers of microfossils of wetland and aquatic plants, particularly *Nymphaea*, indicate the presence of a lake in this area of the Vale.

This trend of increasingly dense but open woodland of pine and birch with herb meadows and the valley floor occupied by an infilling lake and fen continues through LPAZ WM3; the assemblage zone correlating with Godwin's Zone IV. In LPAZ WM4 the initial arrival of pollen of the forest trees *Quercus* and *Ulmus* is also associated with an absolute decrease in the numbers of grains of *Betula* and *Pinus*, suggesting the impact of competition for light. The "Filicales" spores might be associated with the development of the new forest type. In the Vale of Gordano this zone begins shortly before 7600 radiocarbon years BP.

In LPAZ WM5 the mixed oak forest contained *Quercus* with subsidiary *Ulmus* and *Tilia*. By this time the lake appears to have been largely infilled. Both the upper and lower boundaries of this assemblage zone may have been affected by unrecognised erosional episodes. LPAZ WM5 displays the properties of both Zones VIc and Vila of the Godwin scheme; the lack of clear distinction being caused by the relative rarity of *Alnus* and Coryloid grains in this particular Walton Moor core. Two episodes of decline in both *Quercus* and *Ulmus* pollen, separated by a period of increasing relative frequency, delineate the upper and lower limits of LPAZ WM6. These episodes date to approximately 5260 and 5050 radiocarbon years BP (Fig. 2)

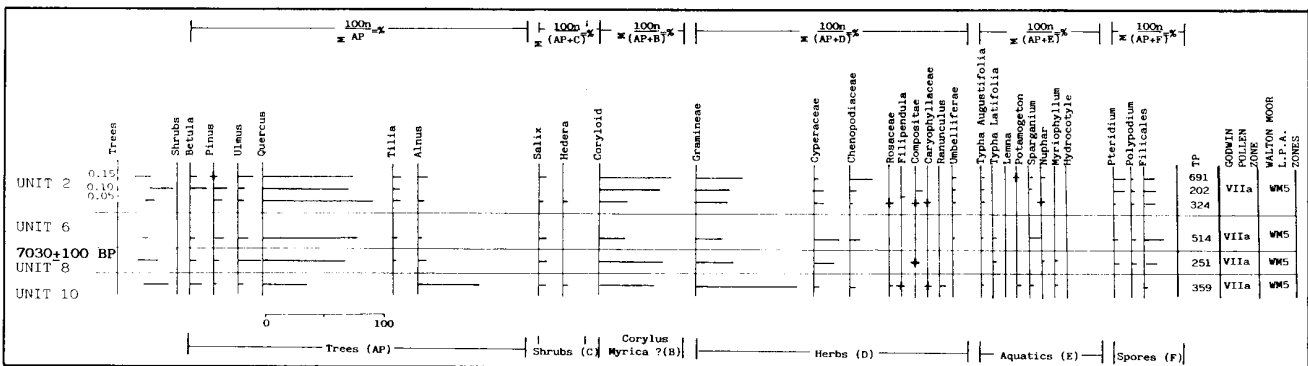


Figure 4. Summary pollen diagram for the Holocene peats at gravel Banks (see Figure 3).

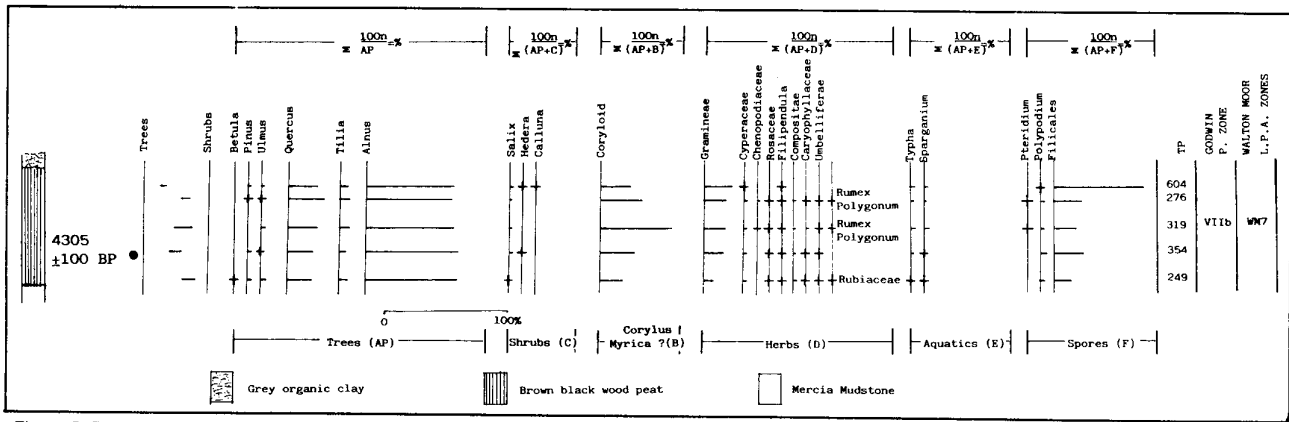


Figure 5. Summary pollen diagram for the Holocene peats at Avonmouth M5 Bridge.

which closely parallels the antiquity detected elsewhere of this widespread and enigmatic phenomenon (Huntley and Birks 1983). This distinct "two phase" decline at Walton Moor has also been identified elsewhere in the pollen record (eg. Oldfield 1963). However, in the present study the "declines" do not appear to be associated with any unequivocal evidence of possible causal agents, such as forest clearance by people, ancient cultivation or other human activity. The detection of ancient pathogens - such as Dutch Elm Disease - is not possible from the present evidence.

*Pinus* and *Tilia* show small recoveries in percentage frequencies through LPAZ WM7, whilst *Quercus* and *Ulmus* values remain low. The concentrations per ml of all pollen types through this zone are low, generally 10-50% of those reached in the previous zone (Mills 1984). The explanation would seem to be rapid rates of biogenic sedimentation occurring in a marsh or lake, as suggested by the presence of pollen of wetland taxa, such as *Typha*, and the spores of aquatic algae. Conditions appear to change notably at about 3820 radiocarbon years BP. There is a substantial increase and then decrease in the proportions and actual abundances of woodland indicators such as *Quercus*, *Ulmus* and *Tilia* and woodland ferns (*Polypodium*). There is no reason to suspect that the inferred recovery of the woodland is other than a genuine feature reflecting an increased abundance of trees in the area. The subsequent decline is associated with increased numbers of indicators of open ground, and wet or acid ground conditions. The final episode, LPAZ WM9, suggests the presence of wetland conditions similar to those which prevail today, with fen and carr, as well as the first record in this core of "cereal-like" pollen.

Holocene deposits of Severnside and Gravel Banks

Examination of the unpublished and borehole record indicates that the "grey" clays of the coastal alluvium are seen to interdigitate with relatively thin layers of peat, which merge at their landward margin to produce a

"basal" peat which rests upon the bedrock. In principle, these peats might be deposited in a number of different depositional environments. They may indicate episodes where biogenic sediments developed at or behind the shorelines; and/or they suggest that impeded freshwater surface and sub-surface drainage occurred which gave rise to the formation of peats, especially the basal peat at locations further inland. Whilst Murray and Hawkins (1976) found that the grey alluvial silts and clays beneath one area of coastal alluvium accumulated principally on intertidal mudflats and saltmarshes, a universal interpretation of the sequence based on the assumptions that "clay" indicated estuarine and "peat" terrestrial/ freshwater deposits, is unrealistically simplistic.

Basal peats and clays

Detailed examinations of the sequence and palaeontology of the basal peats and clays immediately overlying bedrock were possible at two locations. At the intertidal Gravel Banks (Fig. 1) a complex interdigitation of peats and clays occurred, with distinct sets of deposits occurring in adjacent shallow depressions on the former ground surface (Fig. 3). The molluscan faunas recovered from some of the clay bands present in the Gravel Banks sequence are dominated by the saltmarsh-brackish water taxon *Hydrobia ventrosa* with *Ovatella myosotis*, whereas in other clays where freshwater taxa, less tolerant of brackish conditions (*Lymnaea peregra*, *Anisus leucostoma*, *Armiger crista*) were more abundant. The palynological data point to a similar interpretation (Fig. 4). Some clays yielded significant quantities of pond and wetland indicators (*Typha*, *Potamogeton*, *Sparganium*, and *Cyperaceae*), whereas in others there were many grains of the *Chenopodiaceae* which might indicate the proximity of saltmarsh vegetation. In the lowermost clays the putative molluscan and palynological saltmarsh "indicators" were notably less abundant; with freshwater swamp and alder carr being dominant. The sequence therefore suggests the interaction of (a) intermittent obstruction of freshwater drainage, leading to freshwater ponds and peat

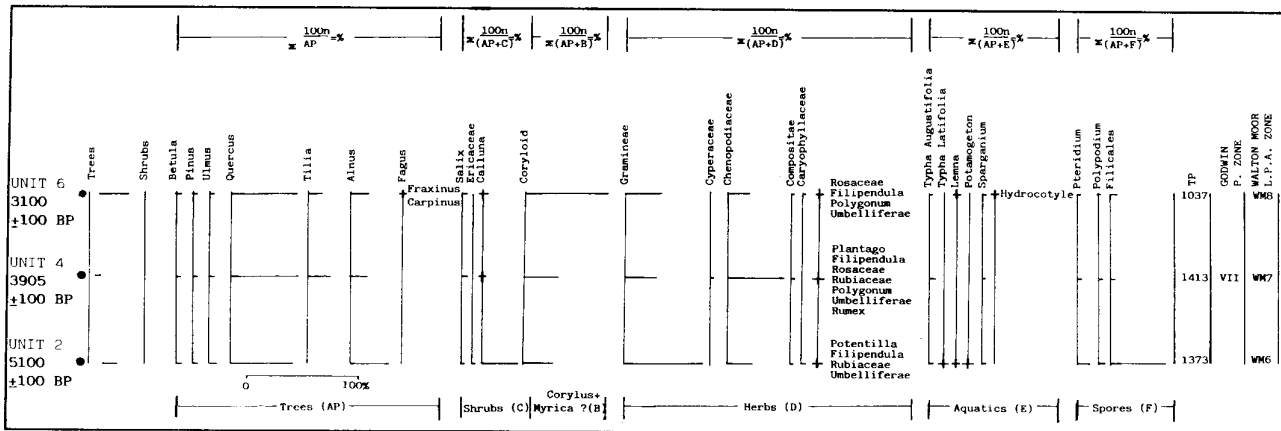


Figure 6. Summary pollen diagram for the Holocene peats at ICI Avonmouth.

growth which engulfed the early Holocene landscape; and (b) incursions of the sea associated with the gradual inundation of the land by the rising sea.

At the Avonmouth M5 Bridge site, peat similarly rests directly upon the Mercia Mudstone bedrock. The upper boundary of the peat is erosional. The pollen present (Fig. 5) indicate the presence of freshwater swamp and alder *can* (*Alnus*, *Typha*, *Sparganium*, *Filipendula*). There are very small peaks in the abundance of Chenopodiaceae in the upper part of the pollen diagram. However, whilst members of this "goosefoot" family are common in saltmarshes, they also occur in other open-ground habitats. Hence in these contexts and frequencies, they do not necessarily imply the proximity of the shoreline. Similarly, the non-tree pollen and the erosional upper contact indicate that there is no necessary link between the radiocarbon date from this deposit and the altitude of the rising Holocene sea level.

### Thin peats interbedded with clays

In contrast, the thin peats interbedded with grey clays found beneath Portbury and at ICI Avonmouth (Fig. 4) all contained significant quantities of grains of the Chenopodiaceae, as well as open ground taxa suggesting saltmarsh or swamp conditions at or close to the contemporary shoreline. Therefore the radiocarbon dates from these layers are likely to bear more closely on issues of former sea level position. Intense bioturbation, however, is evident in some of these thin peats and this may partially explain the comparatively wide range of pollen types (including heath and grains of *Fagus*) recovered from them.

### Discussion

There are now a number of radiocarbon dates with associated palynological data from Severnside, the Vale of Gordano and the adjacent Kenn Moor site (see Fig. 1, Table 1 and Butler 1985, 1987). These provide insights on several related issues of which two are important here. In broad outline the pattern of tree migration and vegetational development observed in the Vale of Gordano and the Severnside sites is seen to follow the general scheme summarised in Godwin (1975). It is evident that the Late Devensian-early Holocene is covered in the new core from Walton Moor described here. The dates have facilitated the construction of Table 1 which proposes a correlation and comparison of the local pollen records for this region. The impact of the peculiar local topographic and ecological situation of the Vale of Gordano are evident. In particular, comparisons between the Walton Moor core, and the data presented by Jefferies *et al.* (1986) from this same area of the Vale of Gordano, as well as with nearby Kenn Moor (Fig. 1; Butler 1985, 1987) indicate significant variations in the abundance of the biostratigraphically-critical tree/shrub taxa which are critical in the Godwin (1975) scheme - specifically *Corylus/Myrica* and *Alnus*. For example, at about 7000 radiocarbon years BP, the relative abundance of *Corylus/Myrica* and *Alnus* varies considerably from approximately 1-5% *Corylus/Myrica* and 0-5% *Alnus* of arboreal pollen in the three cores from Walton Moor, through 30% *Corylus/Myrica* and 9% *Alnus* at Portbury, to 20-30% *Corylus/Myrica* and 5-50% *Alnus* at Gravel Banks. These data point to local variations in abundance of these taxa on the ancient land surface, and perhaps to significant differences in taphonomy.

### Conclusions

The infill deposits at Walton Moor in the Vale of Gordano extend from the end of the Windermere Interstadial in the Late Devensian to the present, confirming the observations of Jefferies *et al.* (1968). The general pattern of climatic, vegetational and environmental change identified in this core parallels that for other sites in eastern and northern Britain. In the Loch Lomond Stadial, the Walton Moor area of the Vale was occupied by a large lake and surrounded by herb-rich vegetation. In the warm climates of the Holocene the lake progressively infilled with biogenic sediment, associated with fen and carr environments. There is a clear pattern in the recolonisation of the area by tree taxa. A sequence of local pollen assemblage zones, some of which have been radiocarbon-dated, will facilitate future pollen-based biostratigraphic correlation for the Vale of Gordano, Severnside and northern

Somerset Levels areas. Of local interest is the recognition and radiocarbon dating of two declines in the frequencies of both *Ulmus* and *Tilia* at approximately 5260 and 5050 radiocarbon years ago.

The pollen and spore content of the Holocene peats and clays from the coastal alluvium has broadly supported the conclusions of the Walton core study. The peats and clays at the Holocene/bedrock contact are shown to be complex in origin. They may be associated with freshwater, brackish or estuarine sedimentation, and occur in micro-topographic situations which had complex relationships with the rising Holocene sea level. On the other hand, "thin" peats interbedded within the estuarine clay sequence appear to be associated with saltmarsh depositional environments. The comparative abundance of radiocarbon dates from this area, has indicated the presence of local variations in pollen frequencies of biostratigraphically important tree taxa. These variations complicate the use of more widely-based pollen-biostratigraphic correlation schemes as well as the use of the Walton Moor sequence itself.

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