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Ancient Monuments Laboratory
Report 23/90

A PALYNOLOGICAL INVESTIGATION OF BRADWELL ON SEA, ESSEX.

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Summary

As part of the archaeological investigations at Bradwell on Sea, a series of delft cores were taken. Material from two of these cores were analysed for pollen and the results given in this report. The analysis revealed that while the terrestrial vegetation was dominated by deciduous woodland rich in Quercus and Tilia, there is little evidence of anthropogenic activity, although an increase in the importance of Corylus in one of the diagrams does point to some change in the woodland structure. Eustatic changes were an important factor in the development of the vegetation. A move from dry land to salt marsh conditions is seen at both sites, while there is also some evidence for the development of carr/fresh water mire conditions in the area.

Author's address :-

Andrew Evans

Ancient Monuments Laboratory
English Heritage
Fortress House
23 Savile Row, London
W1X 2HE

CONTENTS

A PALYNOLOGICAL INVESTIGATION OF BRADWELL ON SEA, ESSEX.

Section 1-Introduction.

1.A. Background.

During the archaeological investigations undertaken by Wilkinson (1987) in the area east of the Bradwell power station, which was being considered as a possible site for the storage of nuclear waste, a series of delft cores were taken as part of the study (see Figs. 1 and 2 for area of study and position of cores). A number of these cores revealed a series of buried peaty horizons, either resting on the former land surface or stratified within estuarine sediments. The aim of this study is to investigate whether pollen is present in these peats, and the sediments associated with them, and if so to provide data on the contemporary vegetation of the region. Two of the cores taken are investigated here, core 553 which was obtained in August 1988 and core 548 which was sampled in the January of the same year. Of the two cores 553 contained a larger amount of organic material, a sample of which was sent for dating by radiocarbon analysis.

1.B. Methodology.

The samples obtained for pollen analysis were treated using the standard pollen extraction techniques detailed in Moore and Webb (1978). It should be noted, however, that most of the sediments contained large amounts of silica which necessitated repeated treatment with hydrofluoric acid. Once prepared the samples were studied using a Zeiss phase contrast microscope, using x400 magnification for general counting and x1000 magnification where particular pollen grains presented problems. The pollen grains were identified with the aid of the keys by Moore and Webb (1978) and with reference to slides of known pollen types.

Section 2-Core 553

2.A. Stratigraphy.

The stratigraphy of the portion of the core investigated in this study is as follows (described by Scaife):

600cm - 611cm.	Grey, slightly firm estuarine clay. Occasional dark organic inclusions, more frequent towards base (eroded material?). Sharp lower boundary.
611cm - 622cm.	Peaty silt. Transitional lower boundary.
623cm - 640cm.	Firm, fine, grey silty sand. Small reddish brown mottles. Small very dark brown organic inclusions. Very rare 4mm pebbles.

2.B. Pollen Analysis.

Between the depths of 600cm to 611cm and 622cm onwards, samples were taken every other centimetre, while between 611 and 622cm samples were taken contiguously every centimetre. The amounts of pollen found and their state of preservation varied quite

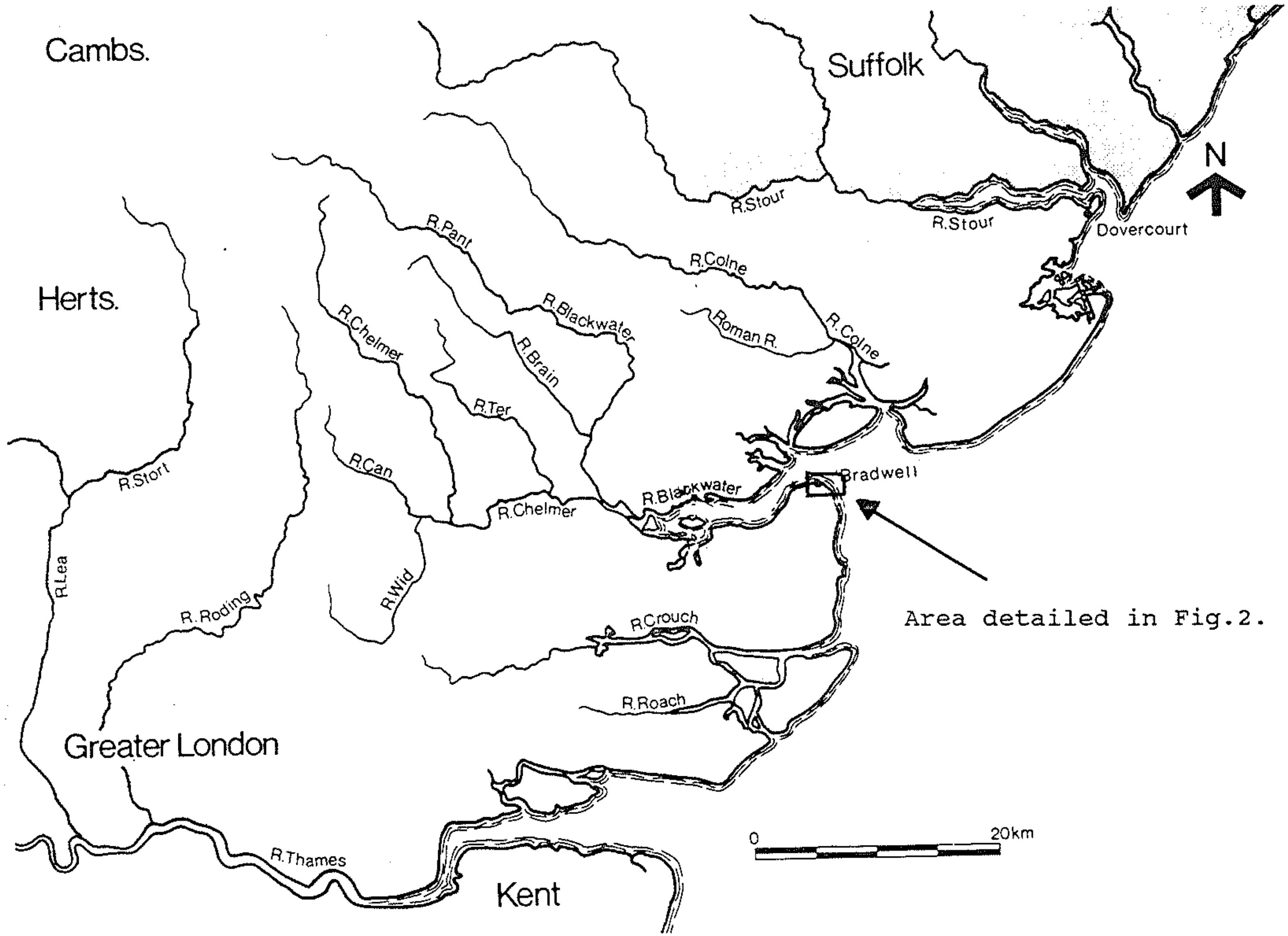


Fig. 1: Area of Study

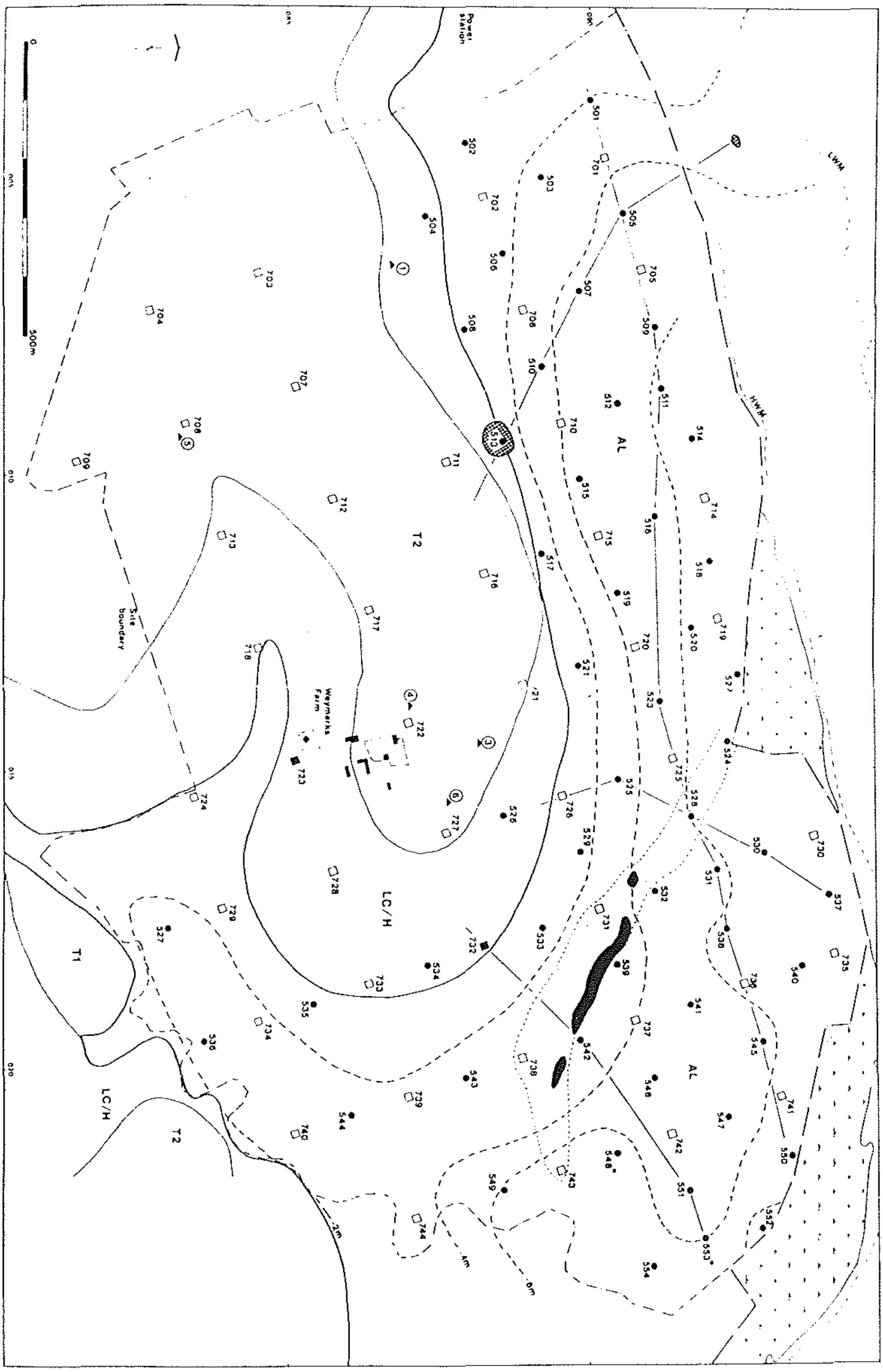


Fig. 2: Position of Delft Cores.

considerably through the stratigraphy; pollen was most frequent in the samples from the peaty band, less common above it, while below the depth of 623cm pollen was not present at levels high enough to allow counting. On average around 500 pollen grains and spores, other than *Potamogeton* type, were counted from each level. Large numbers of *Potamogeton* pollen were present in some levels. If this pollen type, presumably of local origin, had been included in a standard count of 500 grains it would have the effect of distorting the information about other pollen types, therefore it was noted separately. The results of this study are given in figure 3. In this pollen diagram the data is expressed as a percentage of the amended pollen sum (A.P.) which excludes *Potamogeton* type. *Potamogeton* type however is expressed as a percentage of total pollen and spores (T.P.).

2.C. Pollen Zonation.

The pollen was divided into 3 local pollen assemblage zones. These are described below:

Zone A. (Depth 623-619cm.)

This assemblage zone covers part of the transition from the top of the silty sand to the lower portion of the layer of silty peat. It can be seen that this is not a uniform assemblage, as the dominant species change in importance throughout its length. In the lower part of the zone *Corylus, Tilia*, Liguliflorae type and Filicales undiff. are the most numerous pollen types but they all drop in importance towards the end of the zone. *Corylus* drops from a peak of 35% A.P. to 7.5% A.P., *Tilia* from a maximum of 16% A.P. to 7% A.P., while Liguliflorae and Filicales drop from 20% and 10% A.P. respectively to less than 1% A.P.. In the upper part of the assemblage these are replaced in importance by *Quercus*, Chenopodiaceae type and *Bidens* type which reach maximum values of 21%, 34% and 22% A.P. respectively. *Pinus* is relatively frequent throughout the assemblage zone, its values remaining quite stable at an average of 7.5% A.P.. All other pollen types found in this assemblage are only present at values less than 5% A.P..

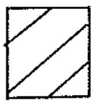
Zone B. (Depth 611-619cm.)

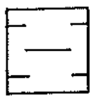
This assemblage zone covers the remaining portion of the peaty layer, it is best characterised by the high levels of *Quercus* and the increase in importance of *Potamogeton* type. Although some variation is seen, numerically *Potamogeton* type dominates this assemblage zone, rising from 10% T.P. at the start of the zone to a peak of 70% T.P.. As most of the other species included in this pollen type are found only in freshwater it is reasonable to assume that the species most likely to be represented here is the salt marsh species *Triglochin maritima*. Other (possible) halophytic species are clearly in evidence, Chenopodiaceae and *Bidens* (see discussion) types, although present in smaller numbers than at the end of the previous zone, are still important. *Plantago maritima* and *Armeria* types both increase quite markedly at the beginning of this zone, although *P.maritima* falls from a peak of 15% A.P. at the start of the assemblage zone to 1% A.P. at its end.

Fig.3 - Pollen diagram for Bradwell Core 553

All values expressed as percentages of the ammended pollen sum (Total Pollen - *Potamogeton*), except for values of *Potamogeton* which are expressed as percentages of the total pollen sum.

Key:

Estuarine Clay - 

Peat - 

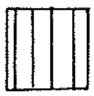
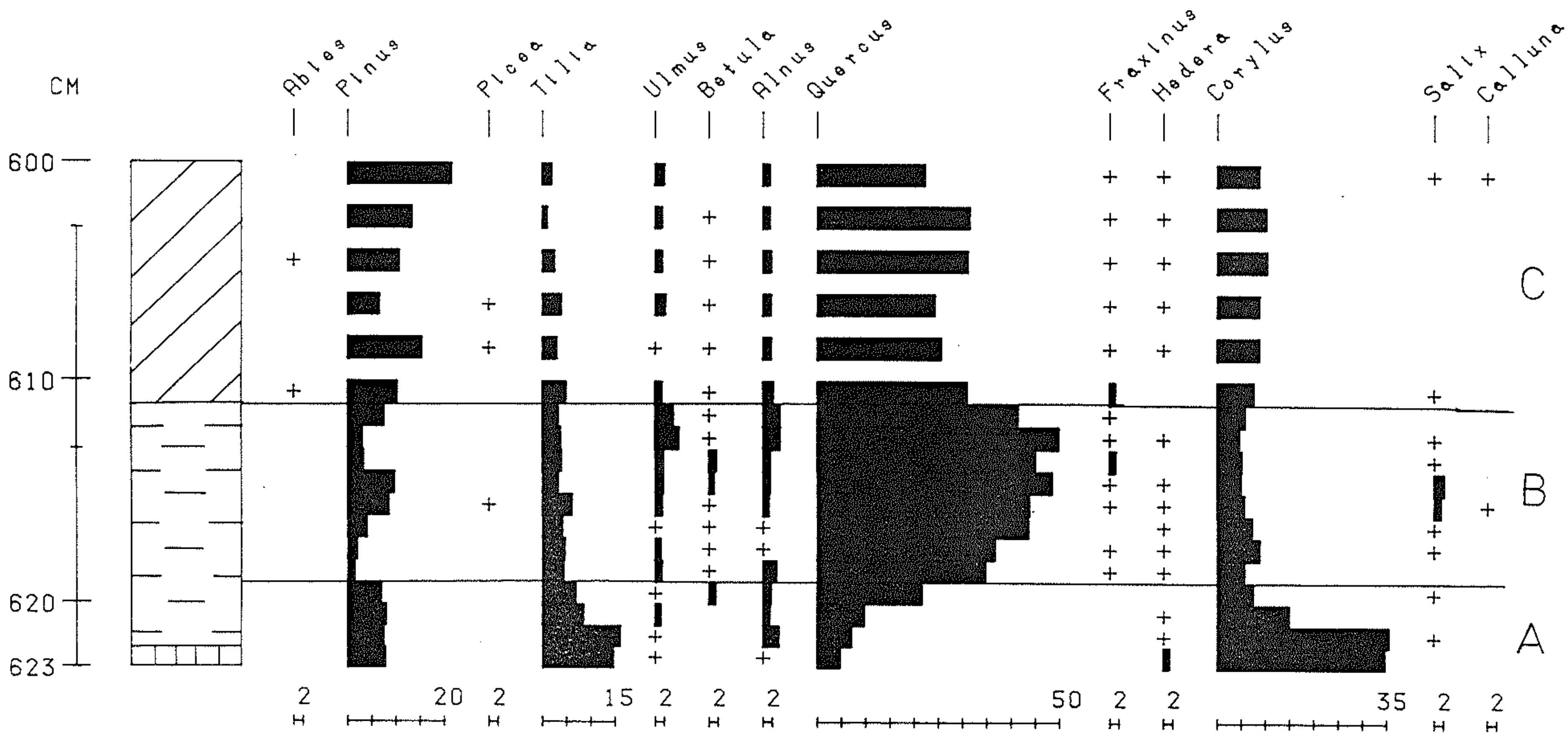
Silty Sand - 

Fig. 3– Bradwell Core 553



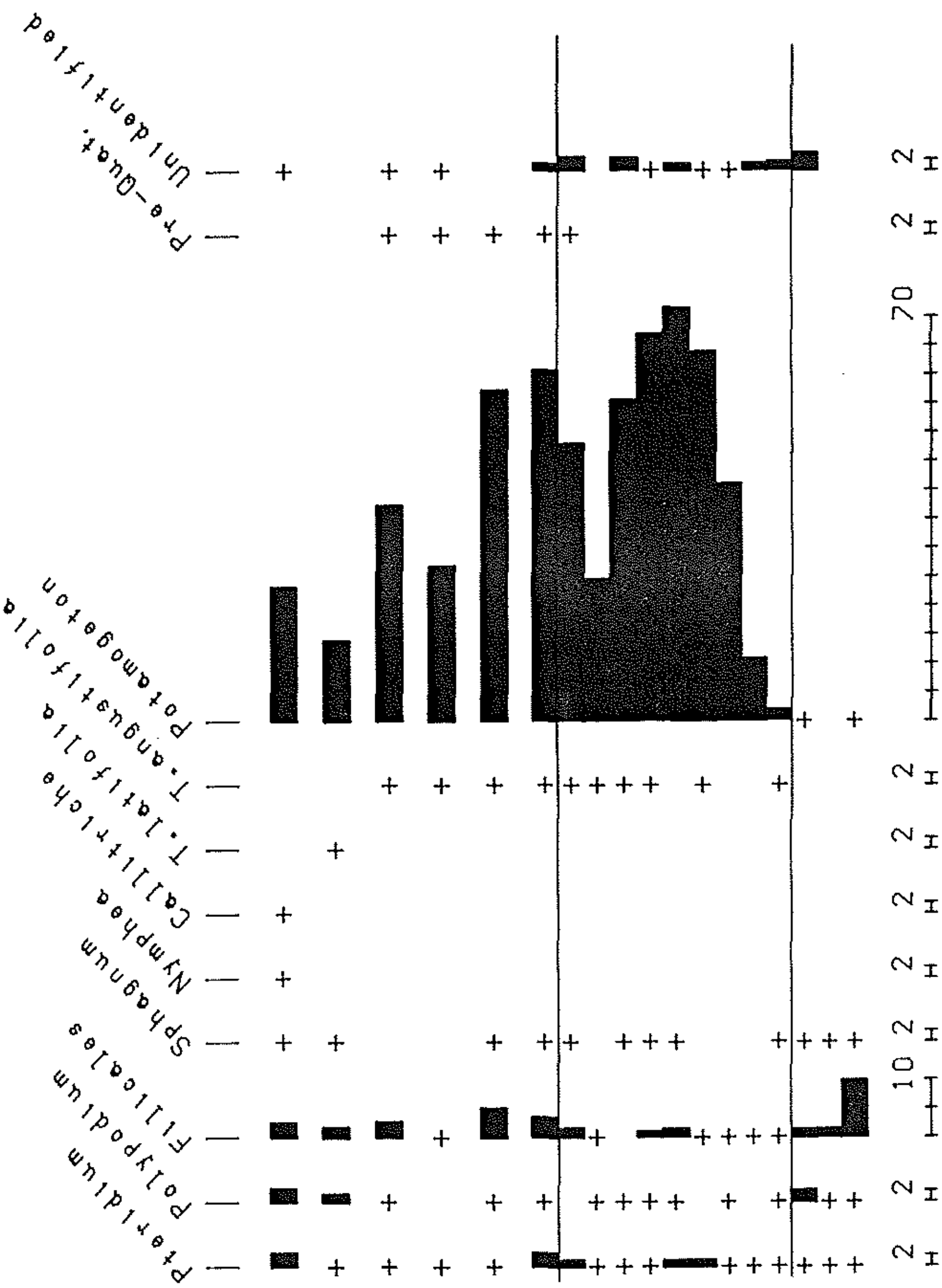

Pre-Quat. Unidentified
Potamogeton
T.angustifolia
T.latifolia
Callitriche
Nymphaea
Sphagnum
Filicales
Polypodium
Pteridium
70
10
2

Fig. 3 (cont.)

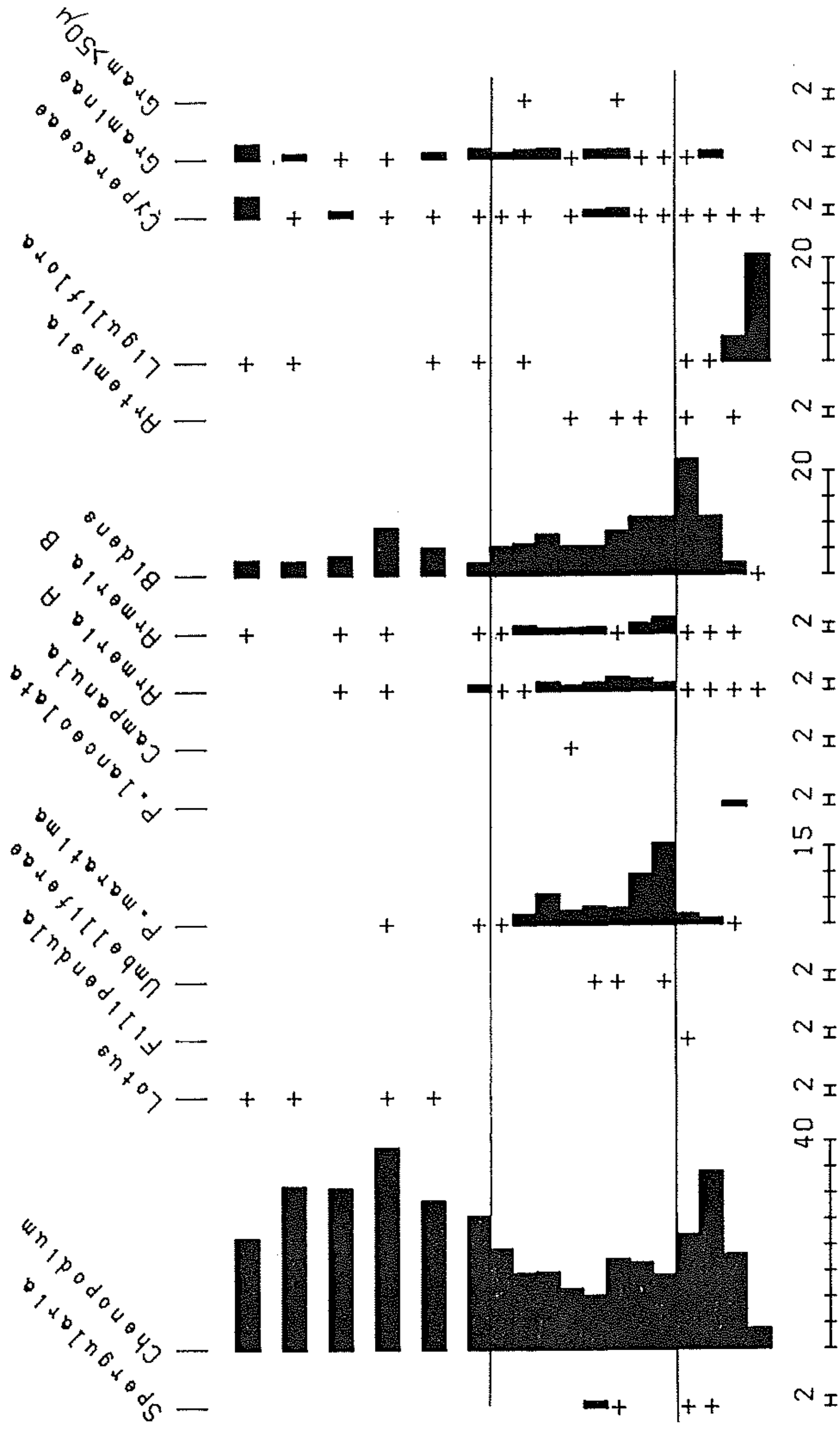

Gram>50μ
Graminae
Cyperaceae
Liguliflorae
Artemisia
Bidens
Armeria B
Armeria A
Campanula
P.lanceolata
P.maritima
Umbellifera
Filipendula
Lotus
Chenopodium
Spergularia

Fig. 3 (cont.)

Arboreal pollen types account for much of the rest of the assemblage, *Quercus* dominates making up between 35 to 50% A.P.. *Tilia* is less frequent than in the previous zone, averaging 4% A.P., while *Pinus* shows more variation in this zone fluctuating between 1% and 9% A.P.. *Ulmus* and *Alnus* both increase through the zone reaching values of 3 to 4 % A.P.. *Corylus* is stable through the whole of the zone averaging nearly 6% A.P..

Again the herbaceous spectrum is relativley restricted and no other pollen type achieving values as high as 5% A.P..

Zone C. (Depth 600-611cm.)

This zone consists of the sediments immediately overlying the peaty band and is most easily delimited by the change in sediment type at its start. The changes in the pollen assemblage are less marked than in the previous zone. In the arboreal spectrum, although stable, the average values of *Quercus, Tilia, Ulmus* and *Alnus* are seen to fall slightly to 28%, 3%, 1.5% and again 1.5% A.P. respectively. The values of *Corylus* are again relatively stable in this zone, averaging nearly 9% A.P., while *Pinus* increases through the assemblage reaching a maximum value of 22% A.P.. Although numerically *Potamogeton* type still dominates the assemblage it gradually declines in importance through this zone from a value of nearly 60% T.P. at the start of the zone to values of 14% and 23% T.P. by the end of the zone. Chenopodiaceae type is present at higher levels than in the previous zone and *Bidens* is still relatively important, however, *P.maritima* and *Armeria* types are both found far less frequently than in the previous zone. Again all other components of the pollen and spore spectrum are only present at relatively low frequencies, but it is worth noting that there is an increase in the levels of Filicales and Pre- Quaternary spores.

2.D. Discussion.

Zone A.

This pollen assemblage zone appears to show the transition from the wooded former land surface, to a maritime peat-forming system. The lower part of the assemblage strongly suggests the presence of deciduous woodland. If one takes into account the fact that *Tilia* is generally under-represented in pollen diagrams, as its pollen is largely dispersed entomophilously, then it would appear that this species dominates the local vegetation. The records of *Quercus, Ulmus*, and *Hedera* all suggest that they are also part of the local woodland. Whether *Pinus* is part of the local woodland is open to question, this pollen type is widely dispersed and often over- represented in pollen diagrams. If it is growing in the locality it will probably only be represented by a few individual trees. The high levels of *Corylus* could indicate that hazel scrub is present in areas where the tree canopy is incomplete. Although it is possible that this species is present in the shrub layer of woodland it flowers very poorly when shaded. It should be noted however that *Corylus, Tilia, Pinus*, Liguliflorae and Filicales are all pollen types that have a large sporopollenin content and are therefore relatively resistant to decay. Consequently the high frequencies of these pollen types could be in part due to differential decomposition in the pollen assemblage.

The changes seen through the assemblage zone reflect the growing influence of maritime conditions. It is in this assemblage zone that peat growth is initiated, probably as a consequence of waterlogging caused by rising sea levels, although other factors causing a rise in the water table cannot be ruled out. Macrofossil analysis of similar peats in the Blackwater Estuary show that they consisted of mainly estuarine plant detritus which accumulated on or near to saltmarsh (Wilkinson and Murphy, 1987). The pollen spectrum obtained from the peats supports those results. The high levels of Chenopodiaceae type are most likely to be derived from plants of the genus *Salicornia*, although one cannot be sure of this as it is not possible to distinguish the pollen of different species of the Chenopodiaceae from one another. It is also possible that the records of *Bidens* type pollen could represent *Aster*. The *Aster* and *Bidens* pollen types are separated only on the basis of size. It was noted by Scaife (1988) that it is possible that the conditions of preservation in and the methods used to extract pollen from sediments similar to those found here, could result in the shrinkage of pollen. The possible presence of these species together with the records of *Plantago maritima*, *Spergularia* and *Armeria* pollen types all show the growing influence of maritime conditions.

If, as the evidence seems to suggest, the former wooded land surface has become waterlogged and is developing into a open salt marsh system, there will be important implications for the taphonomy of the pollen entering the system. The decrease in *Tilia* and the increase in the better dispersed *Quercus* pollen seen here would be expected from such a change in crown cover even if generally the composition of the surviving local woodland had not changed.

Zone B.

In this assemblage zone, which covers the main period of peat formation, the influence of maritime plants is very strong. If, as would seem most likely, that *Triglochin maritima* is represented by the *Potamogeton* type pollen, it can be seen that together with the possible maritime species discussed earlier, halophytic plants dominate the whole of the pollen assemblage. Such an assemblage would be expected from a salt marsh habitat. It is also possible that the low levels of Graminae and Cyperaceae pollen could also be derived from this habitat.

The high levels of arboreal pollen suggests that there is still undisturbed deciduous woodland relatively close to the site. Although the percentage make up of the arboreal spectrum in this zone is markedly different from that seen in the previous zone, it is possible that the composition of the woodland has changed little. As previously touched on briefly in the discussion, the size of the site's pollen catchment area must be taken into account when interpreting any pollen assemblage. At the start of the first zone it would appear that the site was under a closed woodland canopy. Modern surface pollen studies have shown that under such conditions most of the pollen arriving at any point will have originated from within a radius of 30m. Only a small proportion of pollen will be derived from more regional sources. In this assemblage however it would appear that the site is under open salt marsh conditions. Stripped of canopy cover, the site will receive pollen from a much wider catchment area, therefore pollen types that show good dispersal qualities (most notably anemophilous species) will be better represented in the regional component of the pollen spectrum, than will pollen types that are poorly dispersed. *Quercus*, the dominant arboreal pollen type here is an anemophilous species while, as mentioned earlier, *Tilia* is largely dispersed entomophilously. Therefore *Tilia*, a species that is under represented even in a locally derived spectrum, will be even less well represented in an assemblage made up of more regional components. So even though *Tilia* pollen is present at much lower levels than that of *Quercus*, it is almost certain that in the actual woodland *Tilia* will be at least co-dominant if not still dominant. *Ulmus* and *Alnus* appear to increase in importance through the zone and *Fraxinus* and *Betula* would also seen to form part of the system, a feature that was not apparent in the previous zone.

As mentioned in the introduction a radiocarbon date has been obtained from this core. The sample sent for analysis consisted of material from the whole of the of the peat band from the depth of 6.11 - 6.22m, which covers the whole of this assemblage zone and a good proportion of assemblage zone A. Therefore this date can only serve as an indication of when the whole of the peat forming stage in the sedimentary record took place. The sample (Harwell ref. Har-9643) gave an age of 6670 +/- 130 years B.P.. This gave calibrated ranges (IML program, data of Stuiver and Reimer,1986) of 68% 5680 B.C. to 5460 BC and 95% 5830 BC to 5250 B.C.. This places the events seen here in the latter half of the Atlantic period, which is consistent with the dominance of thermophilic *Tilia* rich woodland as indicated by these pollen assemblages.

Zone C.

The fact that the sediment type changes at the boundary between this and the previous zone suggests that sea level rises have swamped the peat forming community and are burying it under new sediments. This new sedimentary regime also has implications for pollen recruitment: a greater proportion of the pollen and spores are now likely to have arrived at the site via water transport. The loss of the immediate cover of salt marsh plants is reflected in the decline of *Potamogeton, Plantago maritima* and *Armeria* types. However as *Potamogeton* and *Bidens* are still numerous and the levels of Chenopodiaceae increase suggests that salt marsh must still exist nearby.

Although present at slightly lower frequencies than in the previous zone the arboreal pollen types are still well represented. The major differences in the this spectrum are the increases in *Pinus* and *Corylus*, however these might be explained because of the differences in taphonomy now operating. *Pinus* pollen, because of the high numbers it is produced in, its excellent dispersal characteristics and the presence of air bladders on the body of the grain which aid floatation, is often over-represented in marine sediments, therefore with the change in sediment type an increase of this taxa might be expected.

It is possible that the increase in *Corylus*, and possibly *Pinus* to some extent, could be related to the increase in Filicales spores and the records of Pre-Quaternary spores in this assemblage zone. Filicales spores, like *Corylus* and *Pinus*, are relatively resistant to decay in soils and their presence in pollen diagrams can be an indication of soil erosion within a pollen catchment area. The presence of Pre-Quaternary spores indicate that there must be some reworking of sediments in the catchment, so it is possible that a proportion of the rest of the pollen spectrum is derived from reworked sediments dating from earlier in the quaternary period.

2.E. Conclusion.

This pollen diagram can be most easily summerised as showing the sequence of changes that take place as the conditions at the site move from dry land through to maritime. The dominant terrestrial vegetation type is deciduous woodland, presumably dominated by *Tilia* and *Quercus*, and there is no evidence of any anthropogenic activity. These features are consistant with the date provided by radiocarbon analysis. The theory that the peat was formed in or near a saltmarsh system is supported by the high levels of possible maritime pollen types.

Section 3-Core 548

3.A. Stratigraphy.

0- 20cm Missing.
20-139cm Grey/brown mottled clay becoming brown silt/fine sand.
139-423cm Grey clay with occasional organic/peaty inclusions.
423-430cm Dark brown/black humified, compacted peat with no structure.
430-440cm Clay with some organic matter and rootlets.
440-470cm Mottled dark clay with little organic matter.
470-500cm Grey clay with peaty inclusions.
500-510cm Peat/Dark black humified material.
510-587cm Firm grey silt coarsening with depth and changing colour to light brown/yellow.
587-593cm Gravelly layer.
593-630cm Grey Clay.
630-718cm Silt/fine sand.
718-721cm Humic/Organic horizon.

3.B. Pollen Analysis.

The portion of this core that was investigated in this study was that between 400 and 850 cm. It was decided that the organic/peaty bands would be analysed closely, the lowest of the three bands was sampled contiguously every centimetre, while samples were taken from the other two horizons at intervals of 1cm. The remaining sediments were only briefly looked at, using an interval of 50cm where possible, except for the more organic clays immediately below the uppermost organic band where some samples were investigated at an interval of 5cm. Pollen preservation varied through the core, the upper two organic layers and the sediments between them showed relatively good preservation, however the lower peat band only contained a limited, poorly preserved pollen flora and the non organic sediments from below 510cm contained either no pollen or too little to facilitate counting. Around 500 pollen and spores, excluding *Potamogeton* and *Typha angustifolia* types, were counted from each level. The only exception to this was the lower organic band, where due to the low numbers of grains present and nature of the assemblage, where only between 100 and 150 grains were counted. The pollen diagrams for this core are given in Fig. 4.

3.C. Pollen Zonation.

The diagram has been divided into five pollen assemblage zones:

Zone A. (Depth 718-722cm)

This zone consists of the lowest peaty/organic horizons. It can be seen that this assemblage zone consists of a very restricted range of species: it is almost entirely made up of *Pinus*, *Corylus* and Filicales together with a large number of unidentifiable grains. That the three commonest pollen types are all relatively resistant to decay suggests that this pollen spectrum is an example of an assemblage where differential decay has drastically altered its original make up.

Zone B. (Depth 502-511 cm.)

This zone consists of the middle organic band. The most frequently occurring species in this spectrum can be separated into two main groupings; an arboreal assemblage and a maritime assemblage. The levels of the arboreal spectrum remain relatively consistent throughout the assemblage zone, *Quercus* dominates the group averaging 32% A.P.. *Corylus* and *Tilia* are of second and third importance averaging 7% and 5% A.P. respectively, while *Pinus, Ulmus, Betula, Alnus* and *Fraxinus* are all frequently recorded. Of the possible `maritime' species represented, *Potamogeton* type increases dramatically through the zone from 4% to 48% T.P.. Values of Chenopodiaceae however, fall through the zone. *Bidens* is important through the zone, and there are also records of *Aster* type pollen. *Armeria* and *Plantago maritima* types are also present in relatively large numbers.

Zone C. (Depth 430-502 cm.)

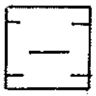
This assemblage zone covers the sediments that lie between the upper two organic/peaty bands. The start of this zone is not only delimited by the change in sediment type but also by the decline in some of the `maritime' taxa, notably *Plantago maritima, Bidens* and *Armeria* types, although it should be noted that the levels of Bidens type do increase towards the end of the zone. The two major halophytic types, *Potamogeton* and Chenopodiaceae, also show a degree of change. Chenopodiaceae increases through the zone to a maximum of 54% A.P., while *Potamogeton* type appears to drop initially then fluctuate in value. In the arboreal spectrum the values of *Quercus* fall through the zone from 33% to 9% A.P., as do the levels of *Tilia* which fall from 6% to 1% A.P., and *Ulmus* that is present at a level below 1% A.P. at the end of the zone. *Pinus* is present in noticably larger numbers, while *Corylus* and *Alnus* both show increases.

Fig. 4 - Pollen diagram for Bradwell Core 548

All values expressed as percentages of the ammended pollen sum (Total Pollen -(*Potamogeton* + *Typha angustifolia*)), except for *Potamogeton* and *T. angustifolia* which are expessed as percentages of total pollen.

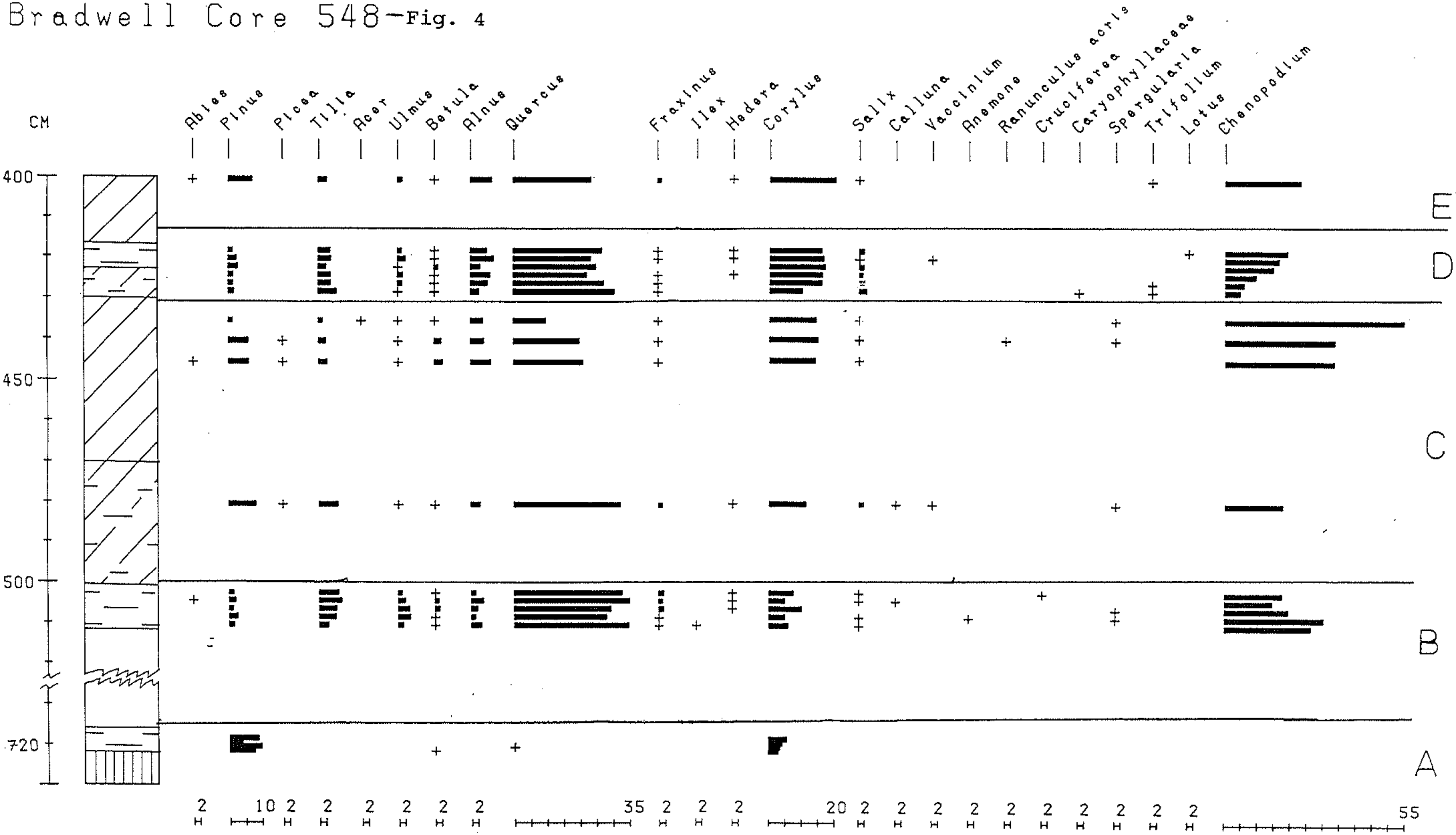
Key:

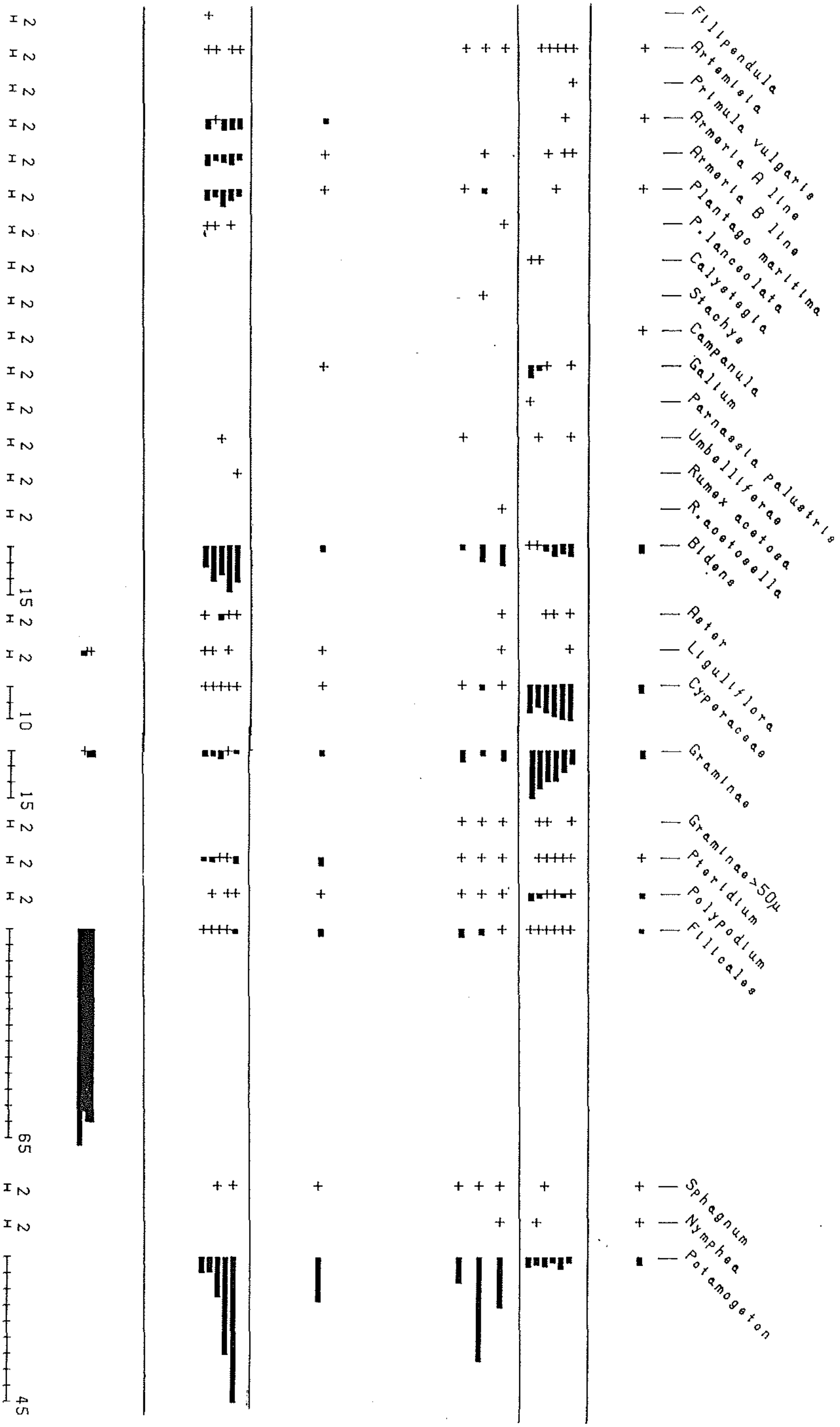
Estuarine Clay- 

Peat- 

Buried Soil- 

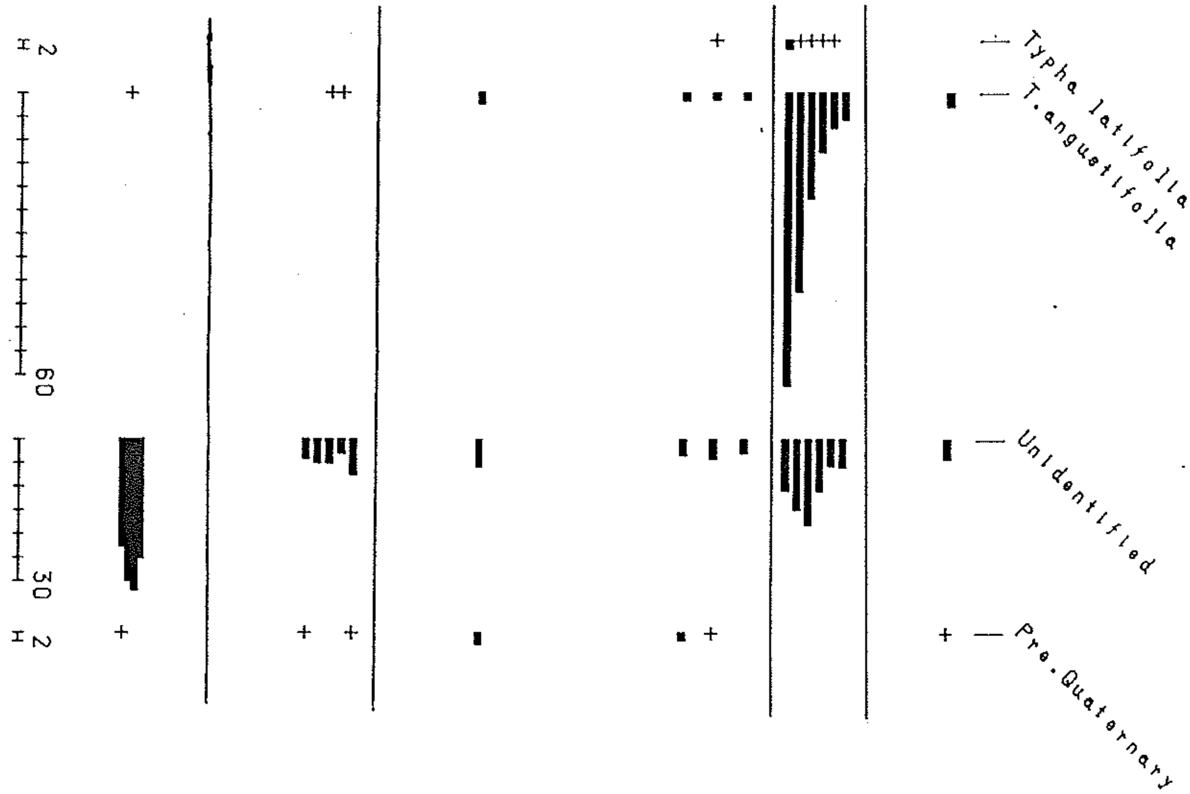
Bradwell Core 548—Fig. 4





Filipendula
Artemisia
Primula vulgaris
Armeria A line
Armeria B line
Plantago maritima
P.lanceolata
Calystegia
Stachys
Campanula
Galium
Parnassia palustris
Umbelliferae
Rumex acetosa
R.acetosella
Bidens
Aster
Liguliflora
Cyperaceae
Gramineae
Gramineae>50µ
Pteridium
Polypodium
Filicales
Sphagnum
Nymphea
Potamogeton

Fig. 4 (cont.)



Typha latifolia
T.angustifolia
Unidentified
Pre.Quaternary
2
60
30
2

Fig. 4 (cont.)

Zone D. (Depth 418-430cm.)

This zone covers the upper organic band. The most notable features of this assemblage are the increases in *Typha angustifolia* type, Gramineae and Cyperaceae, and the drop in levels of *Potamogeton* type and Chenopodiaceae. *T.angustifolia* shows the greatest increase, expanding from 1% T.P. at the end of zone C to 60% T.P. at the start of this zone. However, it rapidly falls again in value, accounting for only 5% T.P. by the end of this assemblage zone. Gramineae shows a similar pattern, achieving 16% A.P. at the start of the zone but falling 4% A.P. by its end. In contrast Cyperaceae maintains values of around 10% A.P. through most of the zone. *Potamogeton* is present at very low values compared with the previous zone, only averaging around 2% T.P.. The levels of Chenopodiaceae type account for only 5% A.P. at the start of the zone, but recover to almost 20% A.P. by its end. Apart from a 4% A.P. peak in *Galium* at the start of the zone, the only other herbaceous pollen type present with any frequency is *Bidens* type.

The levels of *Quercus* recover at the start of this zone, reaching 33% A.P., but they then show a downward trend reaching a minimum of 24% A.P.. *Corylus* and *Tilia* are generally present at higher levels than in the previous zone, averaging around 16% and 4% A.P. respectively. *Pinus* values, however, are lower than those seen in the previous zone. *Salix* is more frequently recorded in this zone, averaging around 2% A.P.. Zone E. 400-418cm. This assemblage consists of the single sample investigated from the sediments overlying the upper peat band. It can be seen that this level is largely made up of *Quercus, Corylus* and Chenopodiaceae types. The major differences between this and the previous zone are that *Pinus* is present at higher levels than seen in the previous zone, while Cyperaceae and Gramineae are both present at lower values than before.

3.D. Discussion.

Zone A.

Unfortunately, due to the limited nature of this assemblage, presumably altered through processes of differential decomposition, little can be surmised about the contemporary vegetation.

Zone B.

This assemblage, that covers the second of the three organic bands, shows a close similarity to zone B from core 553. The probable maritime origin of the peats is shown by the high levels of halophytic species; as in zone 1B, *Potamogeton* type is the most numerous pollen type, followed by Chenopodiaceae then *Bidens, Armeria* and *Plantago maritima* types. Again the presence of deciduous woodland in the region is indicated, the relationship between *Quercus, Tilia* and the other arboreal species is again very similar to that seen in zone 1B. It would therefore seem reasonable to conclude that these two horizons if not actually contemporary with each other, show the same vegetation types.

Zone C.

If the last zone can be seen to be equivalent to zone 1B, then this zone might be expected to show a degree of similarity to assemblage zone 1C. Indeed, similarities are seen, most notably the falls in *Armeria* and *Plantago maritima* types, the increase in *Pinus* and *Corylus* and the increase in records of Pre-quaternary spores. However it must be noted that this zone covers a far greater depth of sediment than investigated in the first core and therefore presumably a greater time. It is belived that these sediments were deposited in a low energy intertidal environment, which would imply that not all the pollen being incorporated into the sediments will be fluvially transported, but that a component of the pollen will arrive directly from nearby plants. The increases seen in Chenopodiaceae, *Bidens* and *Potamogeton* types, seen at the top of the zone could therefore suggest the possibility of an increase in the importance of salt marsh close to the site.

Again the importance of the arboreal spectrum suggests the presence of deciduous woodland on dryland in the vicinity. Although the levels of many of these pollen types fall towards the top of the zone this is probably just a statistical consequence of the high levels of Chenopodiaceae pollen present.

Zone D.

This assemblage, derived from the uppermost peat/organic horizon, suggests that the peat forming community represented here is rather different in nature to the one seen in zone B. Wilkinson (1987) stated that quite a number of the delft cores intercepted peats stratified within estuarine sediments at around this depth, and it was believed that this together with evidence from similar peats nearby that had been radiocarbon dated, showed that around 2300bc the sea level had stabilised allowing the formation of possible salt marsh. However the high levels of *Typha angustifolia* type pollen (a pollen type which includes *Sparganium*), and Cyperaceae together with the records of *Typha latifolia*, suggest that a freshwater mire community could be present in the nearby vicinity, if not actually at the site. The presence of such a vegetation type could be the result of the higher sea levels causing an increase in terrestrial water tables, leading to the formation of such a system. That *Alnus* and *Salix* are found more frequently in this assemblage than in zone B is likely to be connected with such a change as these species could be expected to form part of such a fen system.

That Chenopodiaceae and *Bidens* pollen types are still relatively numerous, and *Potamogeton, Plantago maritima, Aster* and *Armeria* types are all recorded show that salt marsh conditions do exist at or close to this site. It is probable that the higher levels of Gramineae are derived either from this or the more freshwater mire community. Although Gramineae pollen that falls into the size range of cereal pollen is noted in this assembalage (and in the previous, it should be noted that pollen in this size range is also produced by halophytic species such as *Elymus* and species associated with marsh conditions such as *Glyceria*.

The arboreal spectrum shows that deciduous woodland, with *Tilia* and *Quercus* as the most important elements, dominates the nearby terrestrial environment. However changes in the arboreal/shrub spectrum are seen when one compares this zone with zone B, most notably the increase in the levels of *Corylus* pollen. This implies that the area of *Corylus* scrub has expanded or that conditions are now more favourable for it to flower. It is possible that this could imply that there has been a loss of some of tree canopy, possibly through clearance, however no other features in this assemblage offer any supplementary evidence.

Zone E.

Again the sediments that the sample making up this assemblage zone were taken from suggest that there has been a further change in sea level, with the peat forming system being swamped and sealed beneath sediment. As in zone C this is reflected in the pollen assemblage by a drop in some of the species associated with the peat forming system such as Cyperaceae and Gramineae, together with an increase in *Pinus* and *Corylus* as seen in zone C.

3.E. Conclusion.

As with core 553, this diagram illustrates the affects of changing sea levels/water table on the site. No real information is given about the vegetation before the organic/peat band at depth 502-510cm which presumably represents a layer of peat that rests directly on the former land surface. Here as in the previous core the terrestrial vegetation represented appears to be dominated by a mixed deciduous woodland rich in *Tilia* and *Quercus*, while maritime pollen types, presumably derived from a salt marsh system, make up the rest of the spectrum.

The feature of most interest in this diagram is the uppermost peat band, where the increase in the number of presumable freshwater (or possibly brackish) mire types suggests that although most of the nearby terrestrial areas are still dominated by deciduous woodland, some of this area has become water logged through rising ground water tables, possibly related to changes in sea level, leading to the development of areas of marsh. It is possible that such a system is physically joined to salt marsh in the area with the vegetation gradually changing in response to increaseing salinity. The increase in *Corylus* pollen seen in this assemblage may indicate change in the actual structure of the woodland, but there is little evidence to suggest whether such a change is related to anthropogenic, climatic or other influences.

Section 4-Overall Discussion and Conclusions.

4.1 Core Correlation.

In the preliminary report of the archaeological investigations at Bradwell (Wilkinson, 1987), a diagram is shown in which the stratigraphy of a number of cores including 553 and 548 are correlated. However, in this figure the organic layer present at depth 6.10-6.22m in core 553 (represented in the pollen diagram as assemblage zones A and B from this core) is shown as being related to the organic layer present at 7.18-7.22m in core 548 (represented as pollen assemblage zone A in this core). The evidence from the pollen analysis disagrees with this interpretation of the stratigraphy, in that the organic layer present in core 553 shows a much greater similarity with the second organic layer present in core 548 at depth 5.00 to 5.10m (pollen assemblage zone B from this core). Both zones appear to have formed under salt marsh conditions but show that the nearby terrestrial vegetation was dominated by deciduous woodland rich in *Tilia* and *Quercus*. However, in the absence of radiocarbon dating of core 548, it is not certain that these two zones are actually contemporary with each other. The fact that the organic layers from which the pollen is derived occur at different levels separated by about 1 metre in depth, could be simply due to the topography of the former land surface, but it is possible that the two assemblages accumulated at different times but under similar conditions.

The possibility that these two layers are contemporary could have a number of implications for the interpretation of core 548. Firstly the lowest organic band could be considerably older than most of the peats encountered in the survey, but unfortunately the limited nature of the pollen assemblage obtained from this deposit gives few clues to the its age. Secondly, is the second layer of peat resting on a former land surface sandwiched between esturine clay? The fact that pollen is not preserved beneath this organic layer but is present in the sediments above it does point to a difference between the deposits.

Obviously, because of the difference in the extent of the sediments examined from the two cores, the time span covered by the diagram from core 548 is greater than that from core 553. It is possible that pollen assemblage zone C from core 553 is contemporary with the bottom portion of assemblage zone C from core 548, but this will be the uppermost point of overlap between the two cores.

4.2 Patterns of Vegetation Change.

What appears to be the earliest evidence from these two cores is the poorly preserved assemblage zone A from core 548. Although it appears that the pollen flora has been substantially altered by differential decomposition, the presence of *Pinus, Corylus* and Filicales do suggest the presence of some sort of woodland, however it is impossible to attempt any serious reconstruction of the contemporary vegetation from such limited data.

Evidence is then totally lacking from both cores untill the next organic band in core 548, and immediately prior to the similar deposit in core 553. Both these deposits tell of the presence of decidous woodland, characterised by the presence of *Quercus, Tilia* and *Corylus,* on the former land surface which is then replaced by salt marsh as the land is innundated, presumably due to eustatic changes.

Further rises in sea level seal the peats under estuarine deposits; the pollen data obtained from these sediments is not directly comparable with that from the peats as the differences in the taphonomy of the pollen incorporated into the estuarine sediments mean that a more regional picture of vegetation will be reflected. However, the terrestrial vegetation appears to be still deciduous woodland of a similar type to that seen previously, while pollen from salt marsh species is also present.

The presence of an upper peat band in core 548 (pollen assemblage zone D), suggests that there was a period of stable sea levels again allowing the formation of salt marsh at this site. Although the terrestrial vegetation represented is still predominately deciduous woodland, rich in *Quercus* and *Tilia* , changes are seen. *Corylus* has increased in importance, suggesting some change in the structure of the woodland, possibly an indication of anthropogenic activity. An increase in *Alnus* and the presence of pollen types such as *Typha latifola, Sparganium* and Cyperaceae, possibly representing a freshwater/brackish mire community, suggest a change in the terrestrial hydrology leading to waterlogging, possibly as a result of the eustatic changes.

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