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THE MID AND LATE HOLOCENE EVOLUTION OF ROMNEY MARSH AND THE THAMES ESTUARY

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This paper reviews evidence for the mid and late Holocene evolution of two coastal lowlands in southern England; the Romney Marsh depositional complex and the Thames Estuary. During this interval sedimentation at both sites is dominated by a protracted period of organic sedimentation which lasted several thousand years and ended with an expansion of tidal mudflat and saltmarsh conditions. In the initial phase, between c. *6000 and 4000 ^{14}C yrs BP, basal and intercalated peats developed simultaneously at both sites, demonstrating that relative sea level (RSL) was rising during this interval. Spatial and temporal variations in vegetation communities, as well as the nature of organic sedimentation, reflect variations in the altitude of the pre-Holocene surface, proximity to open marine influences, as well as the influences of groundwater pathways and precipitation. Stratigraphic variability is greatest within the lower part of the Thames Estuary where transitional reedswamp and saltmarsh communities appear more susceptible to tidal inundation compared with the more established fen carr communities which flourished in parts of the mid and inner Thames (as well as the Romney Marsh complex). The gross stratigraphic similarities between these sites points to a regional forcing mechanism; initial peat expansion coincided with the onset of a decline in the rate of RSL rise, whilst the late Holocene inundation most probably records renewed RSL rise coupled with sediment reworking and poor conditions for organic accumulation and preservation.*

Introduction

Evidence exists for major changes in coastal evolution during the mid and late Holocene in the coastal lowlands in southern England and neighbouring regions of the southern North Sea. As the long-term rate of relative sea-level (RSL) rise began to slow, prompted by a reduction in the release of meltwater to the world's oceans, so many coastal regions experienced an expansion of coastal wetlands and the widespread accumulation of freshwater and saltmarsh organic deposits. This was frequently associated with the development of protective coastal barriers of sand and or gravel, but also occurred in more open coastal settings in large estuaries. Wetland communities flourished for several thousand years before their destruction during the late Holocene, although debate exists regarding the cause of their demise; some favour an acceleration in the rate of RSL, others a change in sediment supply, coastal configuration, climate or perhaps a combination of factors.

This paper focuses on this period of change, the mid and late Holocene between about 6000 and 2000 radiocarbon years before present (BP), by reviewing recent research in two large coastal lowlands in southeast England: Romney Marsh and the Thames Estuary. Each is a very different coastal setting, the former protected by an extensive sand and gravel barrier known as Dungeness Foreland, and the latter a large open estuary. By comparing these wetlands it is possible to explore spatial variability in the timing and nature of coastal change during the mid and late Holocene, and thereby assess the relative importance of local *versus* regional factors in influencing the dramatic changes in coastal environment that occurred during this interval.

Romney Marsh

The Romney Marsh depositional complex comprises a series of coastal lowlands (Romney Marsh, Walland Marsh, Pett Level) and valleys (the Brede, Pannel, Tillingham and Rother) as well as the degraded gravel and sand barrier of Dungeness Foreland, which together extend across an area of 27,000 ha (Figure 1). Early investigations of Dungeness Foreland (Lewis 1932; Lewis and Balchin 1940) involved surveying the altitude and configuration of the storm beaches whilst much of our understanding of the finer-grained marsh deposits that accumulated in the lee of this foreland stemmed from the seminal investigation of the soils of Romney Marsh by Green (1968) and colleagues at the British Geological Survey (Green and Askew 1958a, 1958b, 1959, 1960). Green (1968) recorded four strati-

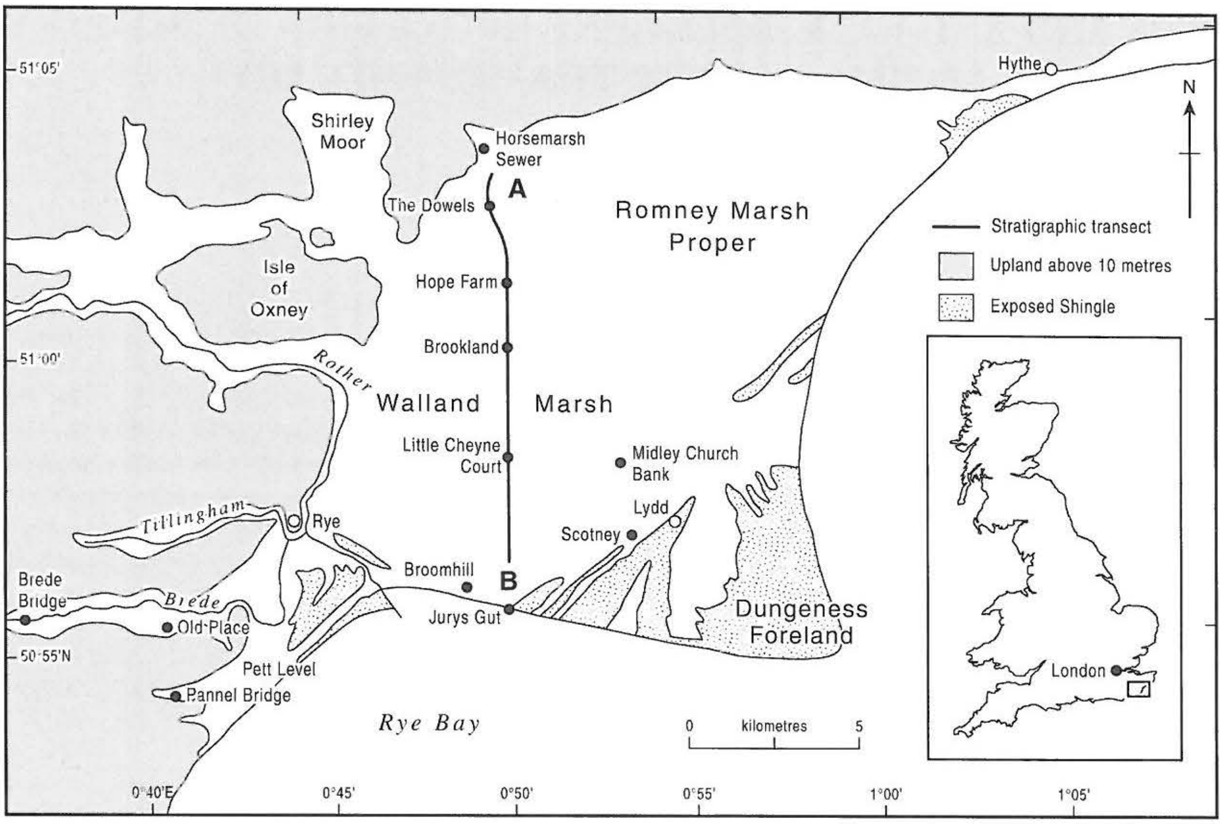


Figure 1: Location map of the Romney Marsh depositional complex showing the position of the Long and Innes (1995) stratigraphic transect.

graphic units on the marshes above bedrock: Midley sand, blue clay, the main marsh peat and the younger alluvium. In places the Midley sand outcrops at the marsh surface, and the southwest – northeast configuration of these deposits led Green (1968) to interpret them as the remnants of an early coastal barrier behind which the blue clay and main marsh peat formed. The Midley sand was therefore pivotal to his and other more recent (e.g. Greensmith and Gutmanis 1990) models of coastal evolution. Much of the emphasis of the Soil Survey work was on the upper 0.4 m of sediment, but Green (1968) also provided a wealth of information regarding the deeper sediments of the marshlands. This included a map depicting the spatial extent, thickness and depth of peat across the area, as well as discussion of the effects of differential sediment compaction on the deeper sequences and present marsh topography.

Established in 1987, the Romney Marsh Research Trust (RMRT) co-ordinates and supports research into the evolution, occupation and reclamation of the Romney Marsh region and adjoining areas. Since its establishment, the RMRT has encouraged over two hundred research projects concerning the history of the region, such that today it represents one of the most intensively studied coastal lowlands in the UK. Much sedimentological emphasis has been placed on reconstructing the pattern of coastal change during the mid and late Holocene, during which the main marsh peat accumulated. This has involved analysis of the deep sediment sequences of the marsh which formed immediately before peat accumulation, establishing the chronology and depositional origin of the main marsh peat, and linking the evolution of the marshland with the development of Dungeness Foreland.

Waller *et al.* (1988) note that relatively limited information exists regarding the nature of the bedrock subcrop beneath the Romney Marsh depositional complex. Recent work, utilising a sequence of deep boreholes sunk in the vicinity of Rye, indicate an undulating bedrock surface between *c.* –27 m OD and –15 m OD (Long, A. *et al.*, 1996). The deepest sediments above bedrock comprise fine-grained silt clays with a sand fraction. These extend upwards to *c.* –12 m OD above which the sedi-mentary sequence becomes coarser and dominated by sands which are in turn overlain by finer-grained blue grey silt clays that pass upwards into the equivalent of Green's (1968) main marsh peat. Peat usually occurs between –5 m OD and 0 m OD. The post peat sediments, equivalent to Green's (1968) younger alluvium, comprise clays, silts and sands with the sand fraction decreasing towards the present surface.

The switch to sand rich sediments above *c.* –12 m OD occurred shortly before *c.* 6000 BP and may record a change in nearshore tidal flows following the full connection of the English Channel with the North Sea (Long, A. *et al.*, 1996). This is followed by a return to shallower conditions before peat formation. This change most probably reflects the development of a barrier across the study site and the regional reduction in the rate of long-term RSL rise. The exact composition of such a barrier is debated. Recent stratigraphic studies at the type site of the Midley sand (Innes and Long 1992; Long and Innes 1993) demonstrate that the surface deposit of sand here post-dates the formation of the main peat bed. These findings reinforce concerns regarding the age of this deposit expressed by Tooley (1995) who observed that Green (1968) had mapped the Midley sand lying between the lows that separate gravel beach ridges on Broomhill Level and must, therefore, post-date their deposition. Together, these observations point towards the sand and gravel beach ridges of Dungeness Foreland as the initial barrier behind which the mid Holocene sedimentary sequence of the Romney Marsh complex accumulated, and the Midley sand as a much younger element of the stratigraphic sequence.

The first biostratigraphic investigations into the depositional origin of the mid Holocene peat employing micro- and macrofossil data are reported by Waller (1987), Waller *et al.* (1988) and Tooley and Switsur (1988). The former studies concentrated in the valleys to the west of the complex where a single peat is widespread and thickens up-stream in the Brede and Rother valleys. In most cases the peat overlies blue-grey silt clays of marine origin but in several places, either passing up-valley or towards the valleys margins, it directly overlies bedrock (e.g. in the Rother Valley above Bodium (Burrin 1988) and at Shirley Moor (Long, D. *et al.*, 1988), and also at Horsemarsh Sewer (Tooley and Switsur 1988) on Romney Marsh proper (Figure 1). The stratigraphic and chronologic relationship between these basal peats and the connecting intercalated peats is important, since it demonstrates that during the early stages of accumulation, peat formation was occurring against a backdrop of strongly rising watertables (a product of RSL rise), a point confirmed by various age/altitude graphs of RSL change for the area during this interval (Long and Innes 1993; Waller *et al.*, 1999).

At Panel Bridge (Figure 1) localised organic accumulation began at *c.* 10000 BP, with more widespread development after *c.* 8500 BP (Waller 1993). Between 8500 and 6000 BP sedge fen and *Alnus* carr communities developed extensively in response to waterlogging ahead of RSL rise, after which a more stable community comprising *Alnus*-dominated taxa became established and persisted until *c.* 4000 BP. Away from the main valleys, Tooley and Switsur (1988) present palynological data from Broomhill and Horsemarsh Sewer, each located at opposite peripheries of the marsh. The litho-, bio- and chronostratigraphy from these sites differ significantly; at Horsemarsh Sewer peat initiation commenced at *c.* 5500 BP whereas further south at Broomhill, closer to the open coast, a short-lived episode of peat accumulation began at *c.* 3500 BP. The vegetation communities also differ with *Alnus* carr dominating the vegetation succession at Horsemarsh Sewer and more open transitional aquatic and saltmarsh communities at Broomhill.

Following further local analyses of the main peat deposit at Midley (Long and Innes 1993; 1995), a more expansive stratigraphic sampling strategy was adopted with the objective of better defining the depositional origin and age of the main marsh peat across the wider area of Walland Marsh. Waller *et al.* (1988) had previously demonstrated the potential of long stratigraphic transects across the marshland as a means to reveal large scale sedimentary successions and, in this spirit, Long and Innes (1995) presented a 10 km stratigraphic transect linking Broomhill and Horsemarsh Sewer. Their results supported the observations of Green (1968) regarding the spatial extent of the main marsh peat, but added new details regarding the nature and age of the organic sediments themselves. Three distinct stratigraphic sequences occur in their transect (Figure 2); sites in the north (or back marsh) where more than one peat is found, sites from the mid marsh (including Brookland) where a single peat bed is present, and sites south of an extensive spread of laminated sands and silts (the former course of a large tidal channel known as the Wainway) where relatively thin deposits of peat abut, and in places overlie, the gravel subcrop (such as at Broomhill). Pollen analysis from a mid marsh site at Brookland reveals that *Alnus* carr dominated during the early phase of peat accumulation which began here at *c.* 4400 BP, but that later in the sequence a shift to more open and perhaps more acidic conditions took place before the end of peat formation at *c.* 1800 BP.

The possible identification of a switch to more acidic conditions in the Brookland pollen core had

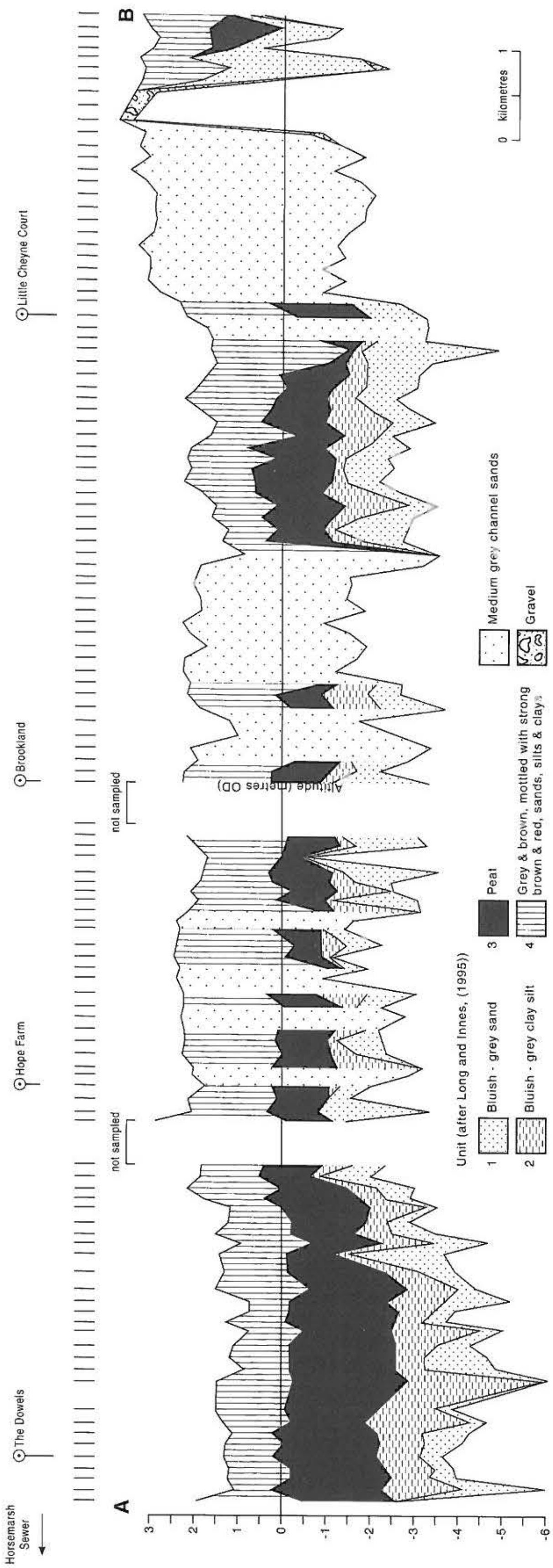


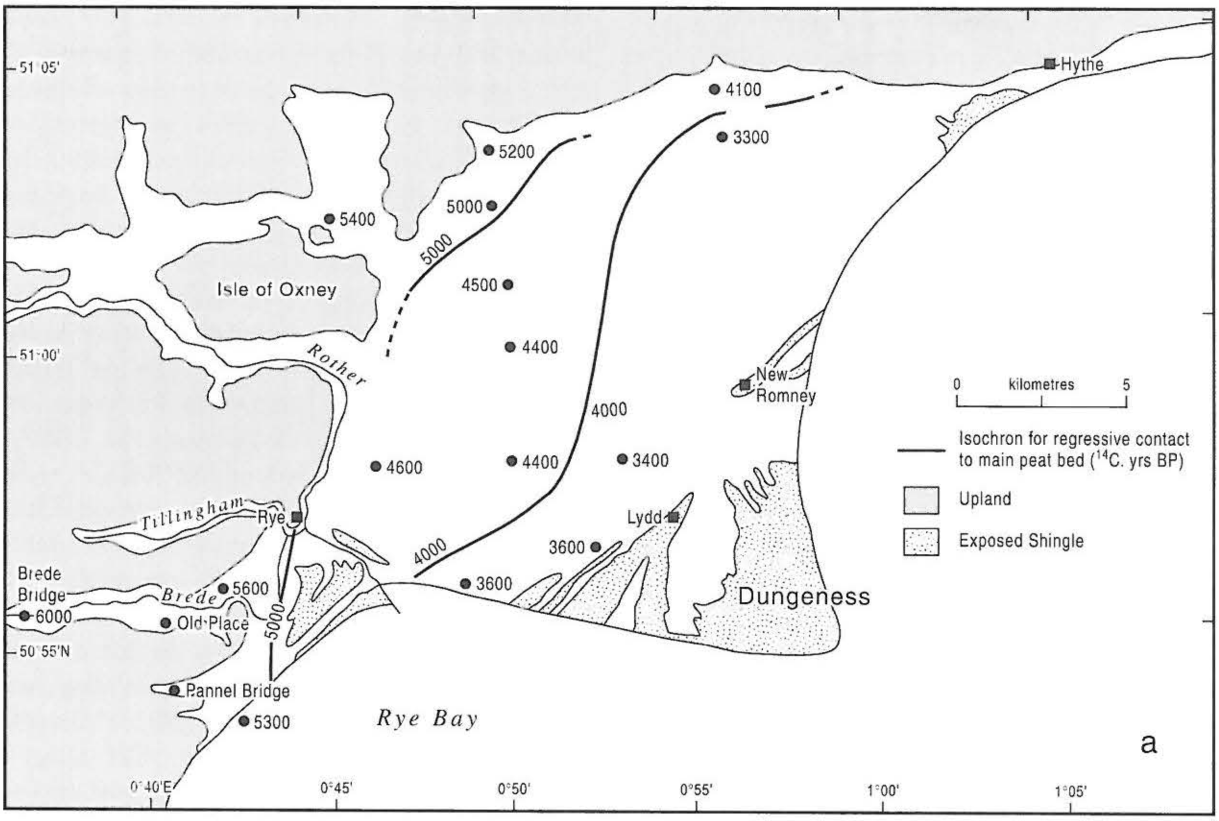
Figure 2: Schematic lithostratigraphy of Walland Marsh (after Long and Innes 1995).

resonances in the stratigraphy reported by Long and Innes (1995), with macrofossil remains of *Sphagnum* recorded in several cores south of Brookland. Moreover, an unpublished pollen diagram from the peat deposit at Cheyne Court by Everett (1985) also reveals high frequencies of *Sphagnum* and other acid tolerant taxa. To better resolve these spatial differences, Waller *et al.* (1999) undertook pollen, diatom, and plant macrofossil analyses at a further four sites on the Long and Innes (1995) transect. This work firmly establishes the spatial and temporal variations in the plant communities which existed during the period of peat formation on Walland Marsh (and part of Romney Marsh proper). In the north, fen carr communities flourished during the mid Holocene, with *Alnus* sustained by the flow of base rich waters from the Wealden catchment. More acid tolerant vegetation, including ombrotrophic bog, developed at more southerly sites (especially at Little Cheyne Court). Bog communities flourished here after *c.* 2900 BP, enjoying spatial and hydrological isolation from the upland waters flowing to the north (Waller *et al.*, 1999).

The vegetation records detailed above contrast the more spatially restricted open communities at sites close to the western and northern limits of Dungeness Foreland. For example, Spencer (1996) casts significant light on the spatial relationship between the low energy marsh deposits and the higher energy deposits of gravel and sand at Scotney Court near Lydd. Peat accumulation here, as at Broomhill, was short-lived compared with the sites on Walland Marsh, with vegetation communities reflecting more open reedswamp and saltmarsh conditions.

The emerging picture of vegetation changes from Walland Marsh was in contrast to the relatively impoverished record from Romney Marsh proper. To rectify this, Long, A. *et al.* (1998) presented two further lengthy stratigraphic transects across Romney Marsh proper, together with pollen and diatom analyses and radiocarbon dating from two locations. These confirmed the existence of fen carr communities in the north of Romney Marsh proper, whilst the absence of more open communities in the central part of the marsh suggested widespread post-depositional erosion of peat across the central and perhaps southern part of Romney Marsh proper during the late Holocene.

The new data from Romney Marsh proper also allowed the development of two maps (Figures 3a,b) which depict the spatial and temporal pattern of peat accumulation during the mid and late Holocene in



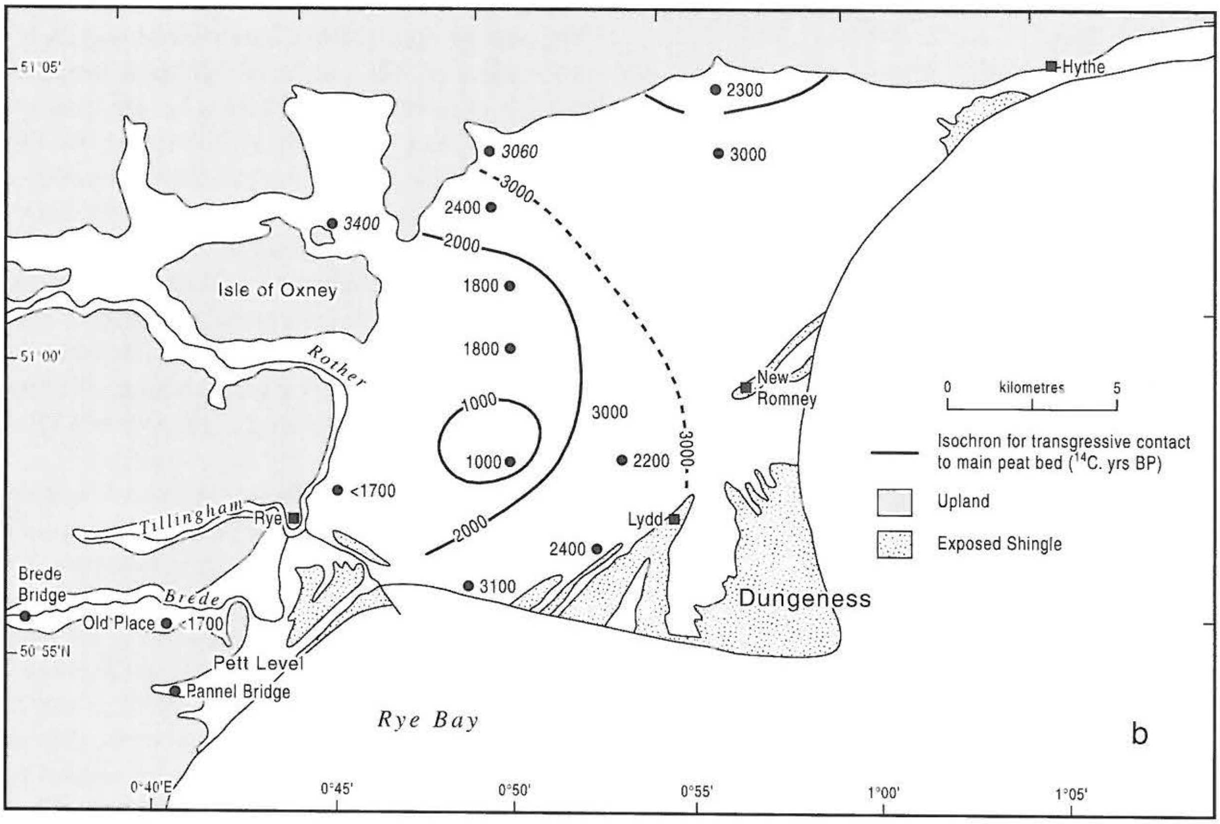


Figure 3 (a,b): Maps depicting the timing of the beginning and end of peat formation across the Romney Marsh depositional complex (after Long, A et al., *1998). Ages are in radiocarbon years before present, rounded to the nearest 100 years.*

the Romney Marsh depositional complex (Long, A. *et al.*, 1998). Dates for the onset of peat accumulation show a progressive easterly extension of peat forming communities from the valleys in the west of the study area after *c.* 6500 BP. These communities reached their maximum spatial extent, covering much of Walland and Romney Marshes, at *c.* 3500 BP. Shortly after this the first evidence for a reversal to this trend occurs, with peat forming communities on the north of Romney Marsh proper being inundated at *c.* 3200 BP. Marine conditions returned across Romney and Walland Marshes over the next two millennia, with the final stronghold of ombrotrophic bog at Little Cheyne Court inundated at *c.* 1000 BP. These data suggest that the expansion and subsequent contraction of peat forming communities across the depositional complex occurred over several millennia. The spatial patterns point towards the long-term persistence of a tidal inlet in the northeast of the study area towards Hythe, and this probably remained open throughout much of the mid Holocene. Importantly the demise of the freshwater peat-forming communities appears to have been associated with a gradual return of tidal conditions, and not a catastrophic inundation such as one might expect due to barrier breaching (Long, A. *et al.*, 1998).

The sand and gravel barrier complex of Dungeness Foreland clearly afforded a significant degree of protection to these low energy depositional environments, for within the peats across much of the area we see no evidence for storm deposits or for erosional phases which might be linked to temporary episodes of barrier breaching. Only to the south of the Wainway Channel, in the fore-marsh sites such as at Broomhill and Scotney, is there evidence for a more disturbed stratigraphy and even here some of these changes may record much later phases of erosion and flooding (Tooley and Switsur 1988; Long and Innes 1995). The relative stability of the Dungeness Foreland must also have been attractive to prehistoric peoples, forming an upstanding, dry and open landscape during much of the mid Holocene, when the wetland environments of the marshes behind must have been relatively inhospitable. Evidence for prehistoric activity on the foreland includes a Late Bronze Age axe hoard reported from Lydd (Needham 1988).

The Thames Estuary

The Thames Estuary is a profoundly different depositional environment compared to the Romney Marsh complex. Moreover, the strategies adopted in the analyses of its sedimentary sequences also differ significantly; with the exception of Devoy's (1979) work, most recent studies have been closely linked to developer-funded initiatives. Despite these differences, significant developments have been made regarding the evolution of the Thames, especially during the mid and late Holocene when the combined importance of sedimentological and archaeological data are increasingly being realised (e.g. Meddens and Sidell 1995; Bates and Barham 1995; Meddens 1996; Thomas and Rackham 1996; Sidell *et al.,* 1995, 2000; Wilkinson *et al.,* 2000).

Several factors accentuate the difference between the areas, two of which are now considered. First, the scale of the two systems is very different. Palaeoenvironmental data today are available for almost the entire length of the tidal Thames, from sites in the outer Estuary such as the Isle of Grain, through central London and beyond, providing a east-west transect of *c.* 50 km (Figure 4). This spatial coverage clearly incorporates a wide range of contemporary and Holocene depositional environments which have altered significantly through time. Moreover, many sites in the west of the area lay above the influence of the tidal and freshwater Thames for much of the Late Glacial and early to mid Holocene. These sediments accumu-lated above the influence of the tidal Thames but are frequently overlain by mid and late Holocene sequences which are closely linked to changes in tidal influence. An additional complication introduced by the scale of the system is the potential for local processes to influence the sedimentary record. Thus, whilst Devoy (1979) developed a broad stratigraphic model for the lower estuary (see below), recent work associated with local excavations suggest that more varied stratigraphic sequences are common (Bates and Barham 1995).

Second, the pre-Holocene sediments in the area (mostly Devensian sand and gravels: Devoy 1979; Bridgland 1994) vary significantly in elevation. With the exception of incised palaeovalleys, the general surface of the Late Devensian gravels at the Isle of Grain occur at *c.* –25 m OD, at Tilbury at *c.* –9 m OD, whilst at sites west of Dartford they rise to *c.* –5 m OD. Deep boreholes from the Romney Marsh complex are limited but those around Rye suggest a basement elevation between *c.* –27 and –15 m OD (see above). Only close to the upland margin does the basement here rise to above *c.* –5m OD. These differences presumably reflect the fact that marine erosion across the Romney

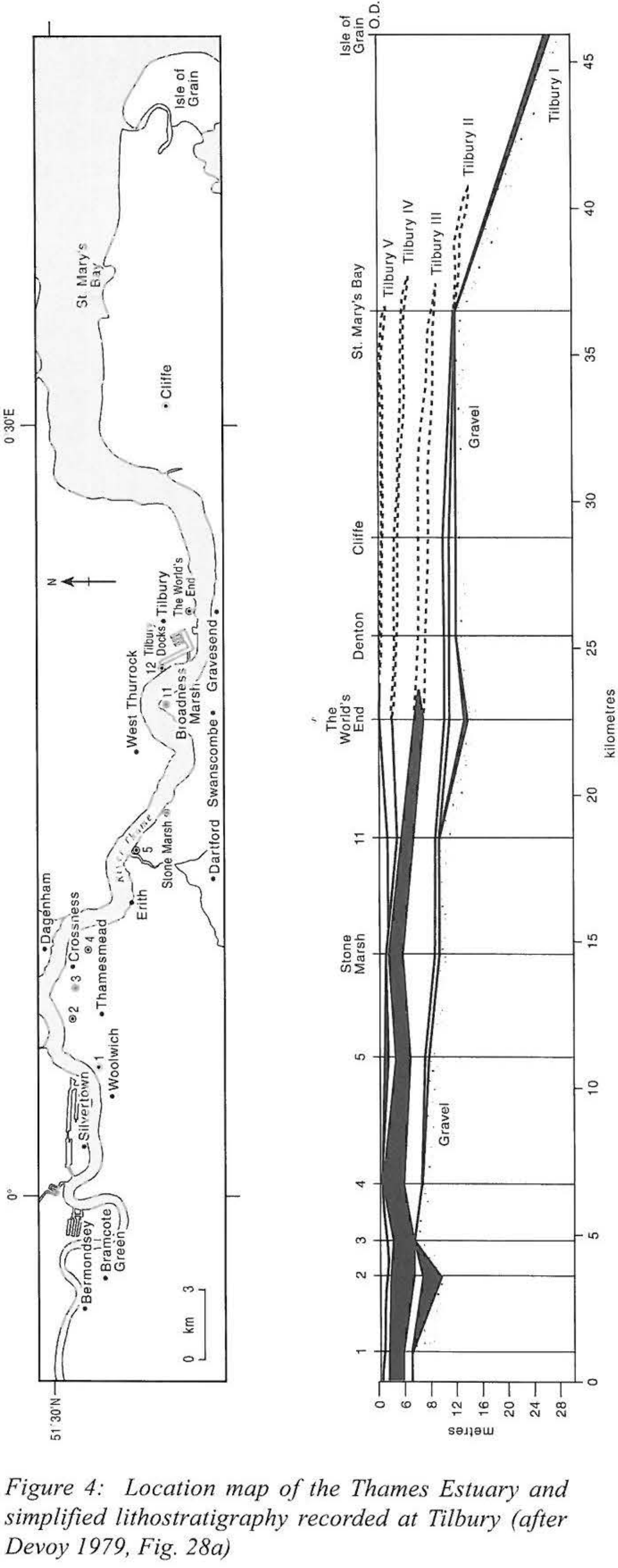


Figure 4: Location map of the Thames Estuary and simplified lithostratigraphy recorded at Tilbury (after Devoy 1979, Fig. 28a)

Marsh complex has been more extensive during earlier times, perhaps when a more open coastal setting existed. As we shall see, the elevation differences within the Thames have an important influence on the overlying sedimentary sequences, especially the relationship between basal and intercalated peats.

Together, these factors complicate efforts to simplify the stratigraphic architecture of the estuary into a single coherent model, a task which is much easier in the smaller depositional complex of Romney Marsh. Several authors (e.g. Bates and Barham 1995; Wilkinson *et al.,* 2000) have cautioned against the simplisic transfer of stratigraphic schemes from one part of the estuary to another (e.g. Tyers 1988), especially where chronological and other palaeoenvironmental data are limited. Whilst bearing this in mind, in the following review, emphasis is placed on the broad scale patterns of sedimentation during the mid and late Holocene in an effort to distill what are the more significant elements of the Thames stratigraphy. The inform-ation provided by lengthy stratigraphic transects, often across the width of the estuary, such as those provided by Devoy (1979) and Bates and Barham (1995), are of particular use here.

The deepest sequences in the Thames occur to the east of Dartford. Extensive exposures made available during the excavation of the docks at Tilbury at the end of the 19th century (Whitaker 1889; Spurrell 1889) and the early part of the 20th century (King and Oakley 1936) led to the recognition by the latter authors of Tilbury as a site of critical importance to the estuary. The extensive accum-ulation of peat and estuarine silts and clays at this site became referred to as the 'Tilbury Stage' and it was no surprise that Devoy (1979) also adopted Tilbury as the 'type site' for the estuary (Figure 4). The sedimentary sequence here was 'most fully developed and representative' (Devoy 1977, 149) with five organic units (termed Tilbury I-V) intercalated with five minerogenic deposits (Thames I-V). Devoy (1979) presented stratigraphic and microfossil data from a further four principal sites which together constitute a west to east transect of

c. 30 km extending from Crossness in the west to the Isle of Grain in the east (Figure 4).

Devoy's (1979) data demonstrate that the mid Holocene was a period of major change. In the lower Thames, where the pre-Holocene gravels are deepest, the mid Holocene begins with the deposition of an extensive accumulation of estuarine silts and clays known as Thames II. This deposit extends across much of the area covered by Devoy's (1979) analysis, being thickest in the east (at Tilbury the deposit is c. 3 m thick) and thinning in an westerly direction (to c. 1 m at Woolwich: see Devoy 1979, his fig. 28). Stratigraphic cross-sections across the Thames at Barking and Erith reveal the extensive accumulation of Thames II across much of the width of the valley floor. Although laterally extensive, the deposit is typically between 1 m and 3 m thick and in many instances, especially on the north side of the current river, lies directly above gravel. Diatom data from TII at the Tilbury type site indicate a strong polyhalobion (marine) influence throughout its deposition (Devoy 1979) and radiocarbon dates from the top of Tilbury I and the base of Tilbury III provide bracketing ages for this deposit of between c. 6575±85 BP (Q1429) and 5410±80 BP (Q1342) (Devoy 1979).

The earliest evidence of a major change in the mid Holocene in the Thames is the replacement of estuarine and then saltmarsh conditions by *Alnus*-carr at Tilbury. The onset of organic accumulation is dated here to 6200±90 BP (Q1430) and is followed, at Broadness Marsh and Stonemarsh, by the widespread accumulation of peat after 5410±80 (Q1342) and 4930±110 BP (Q1336) respectively. At each of these sites the peat forming communities formed above estuarine deposits, but in the west, where the pre-Holocene surface rises, mid Holocene organic accumulation occurs directly above late Devensian and early Holocene fluviatile sediments. Thus, at Crossness, the most westerly of Devoy's (1979) principal sites, organic sediments began forming above sands and gravels at –3.65 m OD at 5640±75 BP (Q1282). Similar occurrences of mid Holocene peats forming directly on sands and gravels occur upstream of Crossness, such as at Silvertown where Wilkinson *et al.* (2000) date the onset of mid Holocene peat accumulation at c. –2 m OD to between c. 5700 and 4800 BP.

The stratigraphic and chronological relationship of these mid Holocene organic deposits indicate peat formation against a backdrop of rising RSL, at least during the initial period of sedimentation. In the lower estuary at Tilbury, Broadness Marsh and Stonemarsh, peat accumulation was clearly outstripping the continuing upward trend in RSL. West of Dartford, a rising freshwater table caused waterlogging of the late Devensian sands and gravels and created conditions suitable for the accumulation and preservation of fluviatile minerogenic sediment as well as fen carr peats.

Pollen and plant macrofossil analyses of the mid Holocene peats demonstrate important spatial differences. In the east, Devoy (1979) notes a prevalence of abundant remains of *in situ Phragmites* and Cyperaceae leaves and stems with saltmarsh deposits common. Moving upstream the deposits change to form more substantial *Quercus-Alnus* fen wood peats with abundant macrofossil remains of wood, leaves and fruits. Moreover, west of Broadness Marsh the sites reveal a more extensive vegetation succession, with a transition from wood fen peats to reedswamp and saltmarsh conditions at the start and end of peat formation. This trend is supported by data from Silvertown where humified wood peats with abundant remains of *Alnus* are common (Wilkinson *et al.*, 2000). The latter authors suggest peat accumulation in a back-swamp environment at the margins of the Thames floodplain which was subject to periodic flooding, as demonstrated by the presence of thinly laminated organic muds during the early phase of peat formation. The importance of riverine influences during peat formation is significant elsewhere in the estuary sequences; Devoy (1979) notes that spatial variability in the thickness, composition and number of organic units within the lower estuary reflects, in part at least, the effects of river flooding, whilst the high gyttja component in many of the mid Holocene peats is indicative of sedimentation under still or slowly moving water.

Recent research in central London demonstrate extensive peat accumulation in sites during the mid and late Holocene as well (Bates and Barham 1995; Thomas and Rackham 1996). Bramcote Green, Bermondsey, provides a good example of a site where initial sedimentation occurred independent of the tidal influence of the Thames. Here, a large lake developed in a depression within the Late Devensian surface and became infilled with organic and calcareous sediments from the onset of the Late Glacial. Several hiatuses interrupt the early Holocene sequence, with the site coming under the indirect influence of the tidal Thames from about 5000 BP onwards, initially with the deposition of freshwater clays and sands and then extensive accumulations of fen carr with *Alnus* carr peat from *c.* 4000 BP. Peat accumulation continued until *c.* 2000 BP when waterlogging and inundation of the site and depositon of silts and clays of probable estuarine origin (Thomas and Rackham 1996). Although the stratigraphy at this site is complex, with several hiatuses and channel incision phases, it is clear that the widespread development of freshwater peat forming communities during the mid and late Holocene is a defining element of the stratigraphy here.

In some instances peat formation in these westerly sites occurred directly on late Devensian sands and gravels as basal peats. For example, elsewhere in Bermondsey, Bronze Age peat-forming communities developed on the south side of the current Thames on the sand islands or eyots of north Lambeth, and much of Southwark (e.g. Tyers 1988; Sidell *et al.,* 2000). Moreover, Meddens (1996) reports extensive deposits of peat (basal and intercalated) developing across Newham, Barking and Dagenham, an area termed the north-east London wetlands. Radiocarbon dating of these deposits indicate their proliferation from *c.* 5500 BP to 2000 BP.

These peat-forming communities must have had a profound impact on the geometry of the estuary. As Long, A. *et al.* (2000) argue, the widespread accumulation of peat significantly reduced the spatial extent of intertidal environments. At Crossness, Tilbury III overlies the estuarine deposit of Thames II across almost the entire width of the estuary, narrowing the intertidal and subtidal area from *c.* 4.7 km to 0.7 km. This contraction in estuarine conditions was accompanied by a major expansion of the freshwater wetlands in the Thames floodplain, for not only did they replace former estuarine environments, they also developed on the higher sands and gravels west of Crossness.

A chronology for the end of peat formation is poorly developed. In Devoy's (1979) analysis, the transgressive contact to his Tilbury III peat is dated at three sites: Crossness (4195±100, Q1333), Stonemarsh (4085±45, Q1334) and Tilbury (3850±80 BP, Q1431). At West Thurrock the main phase of peat accumulation ended sometime after 3795±115 BP (IGS C14/151) and at Broadness Marsh sometime before 2836±85 BP (Q1340). Though close in age, these dates suggest a diachronous end to peat formation, with a short-lived return of estuarine conditions between 4000 and 3000 BP. Devoy (1979) identifies two laterally impersistent peat deposits in the late Holocene sedimentary sequence of the lower Thames, termed Tilbury IV and V. Of these only TIV is radiocarbon dated; it developed locally (at Stonemarsh and Broadness Marsh for example) following the brief return of estuarine conditions associated with the inundation of Tilbury III. The regressive and transgressive contacts to this deposit are dated at Tilbury to 3240±75 BP (Q1432) and 3020±65 BP (Q1433) respectively.

These late Holocene peats are not laterally persistent (Devoy 1979) and several authors have cautioned against the simple transference of the Devoy stratigraphic scheme up-estuary to sites in the inner estuary (see Thomas and Rackham 1996; Wilkinson *et al.,* 2000). At Silvertown, for example, the end of the main period of peat formation is dated to *c.* 2500 BP. Minor organic units in the overlying estuarine sediments here are considerably younger than Devoy's (1979) TIV unit.

So, between *c.* 6000 and *c.* 3000 BP, the Thames Estuary witnessed a major expansion of peat-forming communities. Beginning in the lower estuary, the initial phase of peat development saw the replacement of estuarine mudflat by saltmarsh and reedswamp conditions as the rate of organic sedimentation outstripped the rate of RSL rise. As the freshwater table rose and waterlogged the late Devensian and Holocene sand and gravel deposits at sites further west, so extensive accumulations of freshwater silts and clays, as well as basal peats developed. In these more westerly sites *Alnus*-carr was the dominant component of the local vegetation, thriving in the waterlogged and often flooded environments which characterised the expanding floodplain of the Thames. Between 4000 and 3000 BP the saltmarsh and reedswamp peat forming communities of the lower estuary sites were inundated once more, with the *Alnus* and *Quercus*-dominated fen communities of the middle and inner estuary inundated somewhat later. Oscillating conditions in the lower estuary were associated with a temporary and spatially restricted inundation of the main organic sequence but dating control on this episode is limited. Local complexities to this pattern are common and are not unexpected given local changes in channel course and site topography. What is clear though, is that by *c.* 2500 to 2000 BP almost all of the once extensive peat forming communities throughout much of the study area had been replaced by intertidal conditions. Once again the tidal Thames developed extensive flanking mudflats and salt-marshes.

Discussion

This review demonstrates that the mid and late Holocene were indeed periods of profound change in the dynamics of the Romney Marsh depositional complex and the Thames Estuary. Despite their obvious differences, both sites record a major expansion and then contraction of freshwater peat-forming communities during this interval. In both the initial expansion of these communities occurred against a backdrop of rising RSL, with each recording the contemporaneous accumulation of basal and intercalated peats during the early period of organic accumulation.

There are also differences between the sites. Take, for example, the lithostratigraphic sequences. For some time sea-level researchers have advocated the identification and correlation of sea-level tendencies as a way of defining the importance of local and regional controls on coastal evolution. Put simply, a positive tendency records an increase in the proximity of marine conditions and a negative tendency the reverse. If local tendency chronologies correlate between sites one can be confident that a regional forcing mechanism is probably responsible. But in large depositional systems such as the Thames (and to a lesser extent the Romney Marsh complex), more complex coastal responses to a single regional forcing are to be expected. The resulting stratigraphic sequences will therefore also vary. To illustrate this point, let us consider the variable nature of coastal evolution in the Thames between *c.* 4000 to 2000 BP. In the lower parts of the estuary the main mid Holocene peat (Devoy's (1979) TIII) is temporarily inundated before the onset of renewed organic sedimentation associated with TIV. However, stratigraphic investigations at many sites to the west of Devoy's (1979) sites record a major period of peat formation during this interval. This is no surprise and reflects an increase in waterlogging favouring peat accumulation on inner estuary sites whilst tidal inundation occurred in downstream sites. This reinforces the need to avoid simplistic correlations of stratigraphic sequences from site to site in large depositional complexes which may respond in a diverse manner to a single forcing mechanism.

The lithostratigraphic sequences also differ in other ways as well. In the Romney Marsh complex (except the upper parts of the valleys – see below) the main peat deposit has a high organic content with abundant wood and other plant macrofossil remains. The amount of inorganic matter within the sequences is generally not high whilst gyttja is almost never recorded except in locations close to the Broomhill – Lydd barrier (see Tooley and Switsur 1988; Spencer 1996). Even in the north of the complex, across which the nutrient–rich waters of the Wealden catchment drained, the organic content of the peats remains high. Contrast this with the stratigraphy of the Thames, where several authors report significant contributions of fluviatile and estuarine minerogenic matter to the organic deposits. Devoy (1979), for example, observes that the Tilbury III peat at Stonemarsh and Dartford Tunnel comprises a silty monocot peat, whilst at Crossness lenses of silt clay locally form a silt clay fraction within the equivalent deposit. Wilkinson *et al.* (2000) also note that the mid Holocene peats at Silvertown comprise organic muds rather than true peats. The importance of fluvial/estuarine flooding in the Thames may go some way to explain the more complicated sequence of thin, laterally impersistent peats which characterise some parts of the late Holocene sedimentary sequence, such as that recorded at Bramcote Green, Bermondsey (Thomas and Rackham 1996).

In the upstream sites within the valleys that drain into the Romney Marsh complex we see a transition from freshwater peats to freshwater silts, clays and sands which can attain several metres in thickness (Burrin 1988; Waller *et al.,* 1988). These minerogenic sediments formed above the direct influence of the rising watertable and, although rich in pollen indicative of *Alnus*-carr environments, have a low organic content. Similar sequences are recorded in upstream sites in the Thames, such as at Bramcote Green (Bermondsey) where freshwater silts and clays with a low organic content accumulated only to be buried beneath extensive peat deposits which formed after *c.* 4000 BP (Thomas and Rackham 1996).

From a biostratigraphic perspective there are also marked differences between the sites. Most notable is the absence of ombrotrophic communities in the Thames estuary compared with the Romney Marsh complex. Clearly, the substantial protection afforded by Dungeness Foreland coupled with the spatial separation of sites on Romney Marsh from the base-rich groundwater table here facilitated the development of acidophilous vegetation including ombrotrophic bog after *c.* 4000 BP. In addition there is a relative paucity of marginal and long-lived reedswamp peat-forming communities in the Romney Marsh complex compared with the Thames. Devoy (1979) notes that Broadness Marsh represents an ecological divide in the mid Holocene Thames wetlands; with sites to the east developing reed-swamp and saltmarsh peats and sites to the west more established wood fen peats. The equivalent reedswamp communities are not well represented in the Romney Marsh complex where most vegetation sequences record an initial rapid transition from saltmarsh to reedswamp and then fen carr or poor fen (Waller *et al.,* 1999). Although the peat thins in an easterly direction across the area, even on Romney Marsh proper the pollen data demon-strate the development of poor fen communities (Long, A *et al.,* 1998).

Lastly, from a chronological perspective the sequences in each area also differ in detail. Although both areas witness a major expansion of freshwater communities after *c.* 6000 BP, the timing for the cessation of peat formation differs significantly. In the Romney Marsh complex the maximum extent of peat forming communities is reasonably tightly defined at *c.* 3000 BP. By this time several sites in the lower Thames, including the type site at Tilbury, had been temporarily inundated by Thames III. This may point towards the operation of more local factors associated with the end of peat formation, perhaps reflecting the variable influence of the Thames, perhaps the varying resilience of fen carr versus reedswamp and saltmarsh communities to RSL change. But when seen in the broader context it is clear that the major change in sedimentation within the area is associated with the inundation of the organic deposits in the lower estuary (the TIII and locally TIV deposits of Devoy (1979)) and the extensive wetlands upstream of Crossness after *c.* 3000 BP (Tyers 1988; Bates and Barham 1995; Thomas and Rackham 1996; Wilkinson *et al.,* 2000). If we view this as the major change in sedimentary behaviour within the estuary, and tolerate some diachroneity across such a wide area, then the changes in coastal environment recorded in both the Thames and the Romney Marsh depositional complex become broadly reconciled.

These broad-scale similarities suggest that the changes observed owe themselves to a common driving mechanism. Indeed, that a similar phase of mid Holocene wetland expansion is recorded in both Southampton Water and the Severn Estuary at this time (Long, A. *et al.* 2000) and also further afield, such as in Holland where the 'Holland Peat' formed (Ver der Valk 1992; Denys 1999), points to a regional driving mechanism. The obvious contender for the initiation of peat formation is the regional inflection in many RSL curves from southern England and the southern North Sea Basin between *c.* 6000 and 4000 BP. In the Romney Marsh complex the rate of RSL rise fell from 2 to 4mm a^{-1} to less than 1 mm a^{-1} whilst similar decelerations are observed at this time in Holland and Belgium (Denys and Baetman 1995). In the open estuaries such as the Thames and the Severn, this slow-down would have encouraged the expansion of saltmarsh and then freshwater communities across areas of former intertidal mudflat. In other locations a decrease in the rate of RSL rise combined with the development of extensive coastal barriers to provide extremely protected coastal lowlands.

Processes responsible for the end of peat formation and the renewed expansion of intertidal sedimentation are more equivocal. One possibility is that the changes also record a regional increase in the rate of RSL rise. However, the source of any such an acceleration is not clear, especially if we assume minor "eustatic" contributions due to ice melt at this time and a linear trend to crustal subsidence in the region. A second possibility is that the change reflects the impacts of human activity in the coastal zone and adjacent catchments, notably by the release of minerogenic sediment into the systems following vegetation clearance (e.g. Jennings and Smyth 1987). A third possibility is that a reduction in the rate at which accommodation space was being created, itself a product of the relatively low rate of RSL and watertable rise (compared with rates prior to 4000 BP), caused a slow-down in rates of peat accumulation. Moreover increased humification of the peats might have rendered them susceptible to consolidation and hence inundation by tidal waters (Haggart 1995). It is noteworthy that the onset of a return of marine conditions in the east of the Romney Marsh complex at *c.* 3000 BP coincides with an almost total cessation in the vertical accretion of peats in the valleys to the west. Such a slow-down, combined with increased oxidation would have rendered these environments increasingly vulnerable to coastal inundation.

Conclusions

Our understanding of coastal change during the mid and late Holocene relies on the reconstruction of habitats, landforms and processes many of which are almost impossible to observe and measure at first hand. Stratigraphic and palynological data provide important pointers as to how these elements of the coastal zone operated, and together they indicate mid and late Holocene coastal environments which were very different to those of today. A comparative analysis of Romney Marsh and the Thames Estuary demonstrates a set of profound changes in coastal environment associated with the expansion and subsequent demise of coastal wetlands. These wetlands proliferated as the RSL slowed down after *c.* 6000 BP and, in the Romney Marsh case, benefited additionally from the protective embrace afforded by Dungeness Foreland. Organic sediments dominate the depositional record during much of the mid and late Holocene, forming under a range of conditions including saltmarsh, reedswamp, fen carr, poor fen and, locally on the Romney Marsh depositional complex, raised bog communities.

Stratigraphic differences exist both within and between the case areas and in attempting some broader comparisons this paper does not seek to under-estimate their importance. In the Thames the differences are perhaps most profound, with thick sequences of basal peats initiated by plaudification of the floodplain ahead of rising RSL, and one or more intercalated peats forming in sites in the lower and mid estuary where the pre-Holocene surface is sufficiently depressed, or in the inner parts of the estuary where Late Devensian and early Holocene sediments accumulated independent of RSL forcing. Basal and intercalated peats also developed in Romney Marsh, but the geometry of the pre-Holocene surface in the two areas differs and this goes some way to explaining the relatively limited occurrence of basal peats here. Differences in vegetation communities are also important; in the Thames the most significant contrast is between the fen carr woodlands which developed west of Broadness Marsh and the reedswamp and saltmarsh peats which were more prevalent downstream. Here the control on vegetation succession appears to be a combination of site elevation and proximity to the freshwater or estuarine waters of the Thames. Within the Romney Marsh complex the main differences reflect the spatial and vertical isolation of communities from base-rich groundwater draining from the Weald.

The end of peat formation is, in both areas, associated with a return of marine conditions. There is some difference in the timing of this inundation, such that sites in the lower Thames estuary experienced an initially short-lived and then more permanent inundation after *c.*3000 BP, after which time many more sites in the mid and inner estuary were also inundated. Diachroneity is also recorded on the Romney Marsh complex but here the differences reflect site proximity to a tidal inlet in the northeast of the area from which the marine influence expanded westwards. Local variations in the topography of the peat surface due to variations in vegetation community also influenced the timing of inundation. Thus, the last area of peat to be inundated is at Little Cheyne Court, where an upstanding area of raised bog withstood flooding until *c.*1000 BP (Waller *et al.*, 1999).

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Bibliography

Bates, M.R. and Barham, A.J. (1995) Holocene alluvial stratigraphic architecture and archaeology in the Lower Thames area, in Bridgland, D.R., Allen, P. and Haggart, B.A. (eds.) *The Quaternary of the Lower Thames*, Durham: The Quaternary Research Association, 85-98.

Bridgland, D.R. (1994) *Quaternary of the Thames.* Geological Conservation Review Series 7, Chapman and Hall, London.

Burrin, P.J. (1988) The Holocene floodplain and alluvial fill deposits of the Rother Valley and their bearing on the evolution of Romney Marsh, in Eddison, J. and Green, C. (eds.) *Romney Marsh: Evolution, Occupation and Reclamation*, Oxford: Oxford University Committee for Archaeology Monograph, 24, 31-52.

Denys, L. (1999) Diatom and radiocarbon perspective of the palaeoenvironmental history and stratigraphy of Holocene deposits between Oostende and Nieuwpoort (western coastal plain, Belgium), *Geologica Belgica*, 2, 111-140.

Denys, L. and Baeteman, C. (1995) Holocene evolution of relative sea level and local mean high water spring tides in Belgium – a first assessment. *Marine Geology*, 124, 1-19.

Devoy, R.J.N. (1977) *Flandrian sea level changes and vegetational history of the Lower Thames Estuary.* PhD Thesis, University of Cambridge.

Devoy, R.J.N. (1979) Flandrian sea level changes and vegetational history of the Lower Thames estuary. *Philosophical Transactions of the Royal Society of London* Series B, 285, 355-407.

Everett, R.J.C. (1985) *Environmental changes indicated by Flandrian deposits in Walland Marsh, Kent.* BSc Dissertation, University of Durham.

Gibbard, P.L. (1985) *Pleistocene history of the Middle Thames Valley*. Cambridge: Cambridge University Press.

Green, R.D. (1968) *Soils of Romney Marsh.* Harpenden. Bulletin of the Soil Survey of Great Britain No. 4.

Green, R.D. and Askew, G.P. (1958a) Kent. *Report of the Soil Survey of Great Britain*, 9, 27-30.

Green, R.D. and Askew, G.P. (1958b) Kent. *Report of the Soil Survey of Great Britain*, 10, 22-25.

Green, R.D. and Askew, G.P. (1959) Kent. *Report of the Soil Survey of Great Britain*, 11, 22-27.

Green, R.D. and Askew, G.P. (1960) Kent. *Report of the Soil Survey of Great Britain*, 12, 1-35.

Greensmith, J.T. and Gutmanis, J.C. (1990) Aspects of the late Holocene history of the Dungeness area, Kent. *Proceedings of the Geologists' Association*, 101, 225-237.

Haggart, B.A. (1995) A re-examination of some data relating to Holocene sea-level changes in the Thames Estuary, in Bridgland, D.R., Allen, P. and Haggart, B.A. (eds.) *The Quaternary of the Lower Thames*, Durham: The Quaternary Research Association, 329-338.

Innes, J.B. and Long, A.J. (1992) A preliminary investigation of the 'Midley Sand', Romney Marsh, Kent. *Quaternary Newsletter*, 67, 32-29.

Jennings, S. and Smyth, C. (1987) Holocene evolution of the gravel coastline of East Sussex. *Proceedings of the Geologists' Association*, 102, 306-308.

King, W.B.R. and Oakley, K.P. (1936) The Pleistocene succession in the lower parts of the Thames valley, *Proceedings of the Prehistoric Society*, 2, 52-76.

Lewis, W.V. (1932) The formation of Dungeness foreland, *Geographical Journal*, 80, 309-324.

Lewis, W.V. and Balchin, W.V.G. (1940) Past sea-levels at Dungeness, *Geographical Journal*, 96, 258-285.

Long, A.J. and Innes, J.B. (1993) Holocene sea-level changes and coastal sedimentation in Romney Marsh and Dungeness, southeast England, U.K., *Proceedings of the Geologists' Association*, 104, 223-237.

Long, A.J. and Innes, J.B. (1995) The back-barrier and barrier depositional history of Romney Marsh, Walland Marsh and the Dungeness foreland, Kent, England. *Journal of Quaternary Science*, 10, 267-283.

Long, A.J., Plater, A.J., Waller, M.P. and Innes, J.B. (1996) Holocene coastal sedimentation in the eastern English Channel: new data from the Romney Marsh region, United Kingdom, *Marine Geology*, 136, 97-120.

Long, A.J., Waller, M.P., Hughes, P. and Spencer, C. (1998) The Holocene depositional history of Romney Marsh proper, in Eddison, J. Gardiner, M. and Long, A. (eds.) *Romney Marsh: environmental change and human occupation in a coastal lowland*, 45-63. Oxford: Oxford University Committee for Archaeology Monograph, 46.

Long, A.J., Scaife, R.G. and Edwards, R.J. (2000) Models of estuary evolution and stratigraphic architecture: new data from Southampton Water, in Pye, K. and Allen, J.R.L. (eds.) *Coastal and Estuarine Environments: sedimentology, geomorphology and* geoarchaeology, London: Geological Society Special Publications, 175, 253-279.

Long, D., Waller, M.P. and McCarthy, P. (1988) The vegetation history, stratigraphy and pollen data for the Shirley Moor region, in Eddison, J. Gardiner, M. and Long, A. (eds.) *Romney Marsh: environmental change and human occupation in a coastal lowland*, 31-44. Oxford: Oxford University Committee for Archaeology Monograph, 46.

Meddens, F.M. (1996) Sites from the Thames Estuary wetlands, England, and their Bronze Age use. *Antiquity*, 70, 325-334.

Meddens, F.M. and Sidell, E.J. (1995) Bronze Age trackways in east London. *Current Archaeology*, 12, 412-416.

Needham. S. (1988) A group of early Bronze Age axes from Lydd, in Eddison, J. and Green, C. (eds.) *Romney Marsh: Evolution, Occupation and Reclamation*, Oxford: Oxford University Committee for Archaeology Monograph, 24, 77-82.

Sidell, E.J., Scaife, R.G., Tucker, S. and Wilkinson, K.N. (1995) Palaeoenvironmental investigations at Bryan Road, Rotherhythe. *London Archaeologist*, 7, 279-285.

Sidell, E.J., Wilkinson, K., Scaife, R.G. and Cameron, N. (2000) *The Holocene evolution of the London Thames.* Museum of London Archaeological Service Monograph 5.

Spencer, C. (1996) *The Holocene evolution of Romney Marsh: a record of sea-level change in a back-barrier environment,* PhD Thesis, University of Liverpool.

Spurrell, F.C.J. (1889) On the estuary of the Thames and its alluvium, *Proceedings of the Geological Society*, 11, 210-230.

Thomas, C. and Rackham, J. (1996) Bramcote Green, Bermondsey: a Bronze Age trackway and palaeoenvironmental sequence. *Proceedings of the Prehistoric Society*, 61, 221-253.

Tooley, M.J. (1995) Romney Marsh: the debatable ground, in Eddison, J. and Gardiner, M. (eds.) *Romney Marsh: the debatable ground*, 1-7. Oxford: Oxford University Committee for Archaeology Monograph, 41.

Tooley, M.J. and Switsur, R.V. (1988) Water level changes and sedimentation during the Flandrian Age in the Romney Marsh area, in Eddison, J. and Green, C. (eds.) *Romney Marsh: Evolution, Occupation and Reclamation*, Oxford: Oxford University Committee for Archaeology Monongraph, 24, 53-71.

Tyers, I.G. 1988. The prehistoric peat layers (Tilbury IV). In Hinton, P.J. (ed) *Excavations in Southwark 1973-76 Lambeth 1973-79*, London, London and Middlesex Archaeological Society and Southwark Archaeological Society Joint Publication 3, 5-12.

Van derValk, L. (1992) *Mid and late Holocene coastal evolution in the beach-barrier area of the Netherlands*, PhD Thesis, University of Amsterdam.

Waller, M.P. (1987) *The Flandrian vegetational history and environmental development of the Brede and Pannel valleys, Sussex*, PhD Thesis, Polytechnic of North London.

Waller, M.P. (1993) Flandrian vegetational history of south-eastern England. Stratigraphy of the Brede valley and pollen data from Brede Bridge, *New Phytologist*, 126, 369-392.

Waller, M.P., Burrin, P.J. and Marlow, A. (1988) Flandrian sedimentation and palaeoenvironments in Pett Level, the Brede and Lower Rother valleys and Walland Marsh, in Eddison, J. and Green, C. (eds.) *Romney Marsh: Evolution, Occupation and Reclamation*, Oxford: Oxford University Committee for Archaeology Monograph, 24, 3-30.

Waller, M.P., Long, A.J., Long, D. and Innes, J.B. (1999) Patterns and processes in the development of coastal mire vegetation: multi-site investigations from Walland Marsh, southeast England, *Quaternary Science Reviews*, 18, 1419-1444.

Whitaker, W. (1889) *The Geology of London*, Memoirs of the Geological Survey, 1, 454-477.

Wilkinson, K.N., Scaife, R.G. and Sidell, E.J. (2000) Environment and sea level changes in London from 10,500 BP to the present: a case study from Silvertown, *Proceedings of the Geologists' Association*, 111, 41-54.

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