Romney Marsh: Coastal and Landscape Change through the Ages
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2. Late Pleistocene/Early Holocene Environmental Change in the Romney Marsh Region: New Evidence from Tilling Green, Rye

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New stratigraphic data are presented which provide information on the late Pleistocene/early Holocene evolution of the lower Tillingham Valley, near Rye. During the late Pleistocene the Tillingham experienced channel incision (with the bedrock channel below -25 m OD), sediment movement (solifluction) and aggradation (the deposition of gravels). Organic sediment accumulated during the early Holocene. Pollen analysis shows the vegetation of the Tillingham Valley to have been dominated by Corylus avellana *from* c. *9700 to* c. *9200 cal. yr BP. Marine/brackish diatoms are recorded immediately prior to the deposition of clastic sediments. A transgressive contact at -24.65 m OD provides the earliest sea level index point from the Romney Marsh region. Rapid rates of relative sea-level rise (c. 12 mm* yr^{-1}*) are recorded between* c. *9200 and 7800 cal. yr BP during which time* c. *16 m of fine-grained sediment was deposited in the lower Tillingham Valley. A thin intercalated peat records an expansion of freshwater communities* c. *7800 cal. yr BP. Explanations for the occurrence of this deposit are outlined. From* c. *7800 to 6000 cal. yr BP the rate of relative sea-level rise declined to* c. *4 mm* yr^{-1}*.*

Introduction

With relative sea level (RSL) below *c.* -30 m OD at the opening of the Holocene, sediment deposited in the Romney Marsh area in response to early Holocene sea-level rise is likely to be deeply buried. Long *et al.* (1996) investigated material recovered during a borehole survey for a proposed road by-pass for Rye. The sequences recorded between -25 and -12 m OD are composed of clastic sediments, deposited under estuarine conditions. The absence of organic material between these depths negated robust chronological control and prevented the type of detailed palaeoenvironmental reconstruction that has been so successfully undertaken from the mid and late Holocene sediments of the marshland. Organic material of early Holocene age does, however, exist in this region. While at Pannel Bridge (Waller 1993; Waller 2002) sediment of this age (at *c.* -8.50 m OD) accumulated well above rising sea level, a borehole record from Tilling Green, Rye (Shephard-Thorn 1975) describes organic material at depth.

In 1971 Kent County Council (KCC) drilled several boreholes on the Tilling Green housing estate (Fig. 2.1), one of which (here referred to as TGA) recorded bedrock at a depth of *c.* -25.40m OD (28.80 m below the surface) and two deep organic layers. The lowest was described as a black peat with grey silt and occurred at a depth of between -24.60 to -24 m OD. This layer was overlain by coarse clastic sediments, a further laminated peat (between -23.10 to -22.10 m OD) and fine clastic sediments which extended to -3.6 m OD. A sample of the upper of the two peats at *c.* -22.65 m OD was provided to the British Geological Survey (BGS) and a radiocarbon date of 11200-10506 cal. yr BP (9565±120 yr BP; Welin *et al.* 1974) obtained. No biostratigraphic data were collected to complement this sequence. Nevertheless, the TGA borehole offers the prospect of the presence of organic material

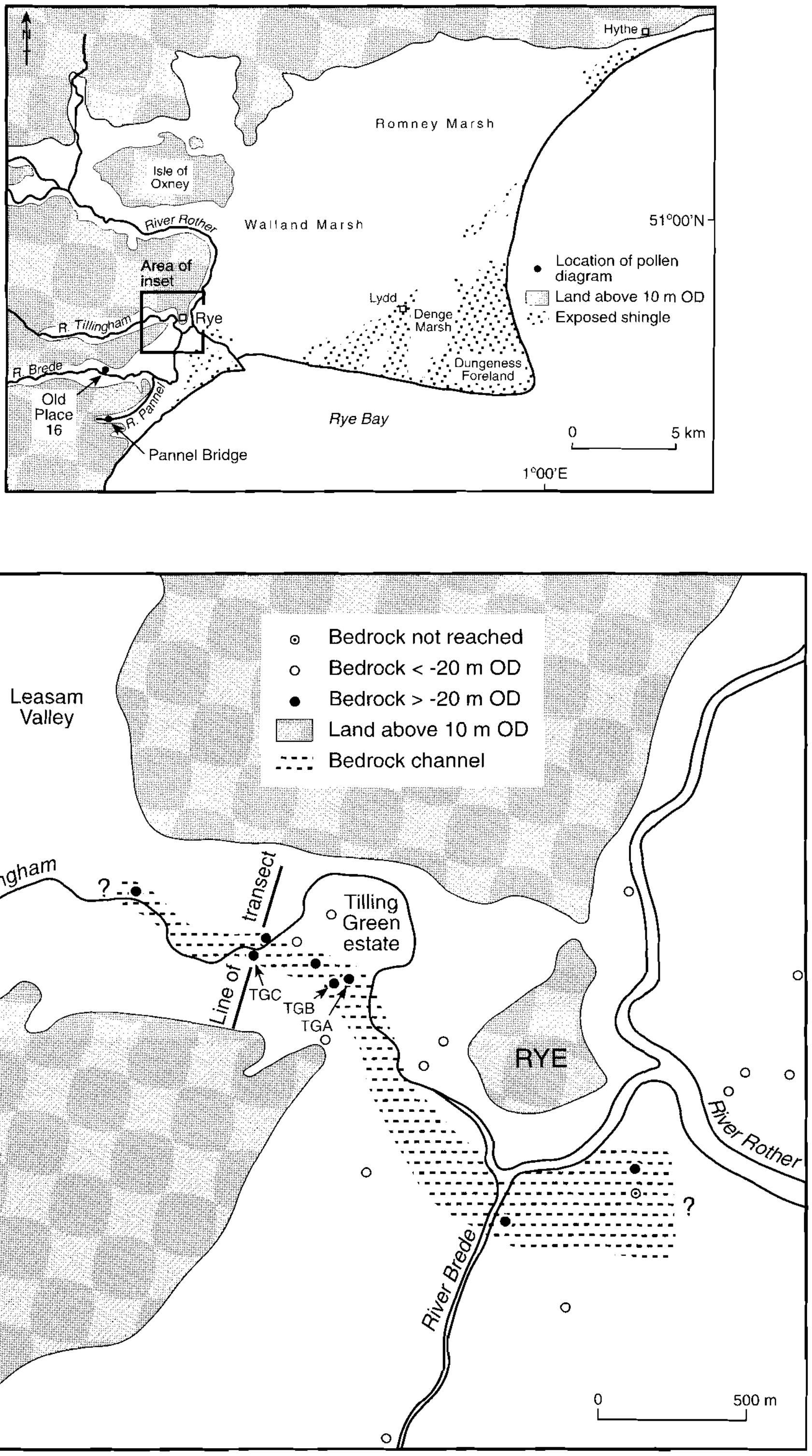


Fig. 2.1. Location of sites mentioned in the text: The Romney Marsh region with inset of the lower Tillingham Valley showing the line of the hand auger transect, the location of drilled (including commercial) boreholes and the approximate position of the bedrock channel.

dating not only from the earliest Holocene but potentially also the late-glacial (the deeper organic layer) at the base of the lower Tillingham Valley.

This paper reports on investigations to recover the deep organic, and immediately adjacent, deposits recorded in the TGA borehole. The aim was to provide a detailed chronology for the early Holocene deposits of the lower Tillingham Valley and to collect palaeoenvironmental data (using standard microfossil techniques) that would elucidate early Holocene sea level change, coastal evolution and vegetation history.

Although a detailed record of RSL change exists in the Romney Marsh area for the mid Holocene (Long and Innes 1993; Long *et al.* 1996; Long *et al.* 1998 and Waller *et al.* 1999), pre 6500 cal. yr BP data are absent. Indeed, for the eastern English Channel as a whole such information is only available for Langley Point near Eastbourne (Jennings and Smyth 1987), where a thin peat dated to 10145–9555 cal. yr BP (8770±50 yr BP) is overlain by marine/brackish sediments at a depth of -24.70 m OD. While it is clear that marine/brackish conditions must have advanced rapidly landward in the early Holocene, the influence and interaction of RSL rise with a number of other processes is poorly understood. Major changes in coastal configuration, the pattern of sediment movement and tidal range are likely to have occurred. Of particular interest is the possible early development of coastal barriers which Dix *et al.* (1998) suggest are more likely to have occurred at restricted localities close to the present shoreline, rather than extending across Rye Bay.

Only two radiocarbon dated early Holocene pollen diagrams have been published from the south-eastern corner of England; Pannel Bridge (Waller 1993; Waller 2002) and Holywell Coombe (Bennett and Preece 1998). Pollen analysis of peat of the same age as the upper of the two layers recorded in TGA would present a rare opportunity to expand this database. Of particular interest is precise information on the timing of the arrival of tree taxa in the region, as it has been suggested that the expansion of *Pinus* and *Ulmus* into the British Isles occurred via south-eastern England (see Birks 1989; Bennett 1995). In addition, the early Holocene history of *Alnus glutinosa* in Britain has been the subject of considerable debate (see Bennett and Birks 1990), with the Pannel Bridge pollen diagram unusual in indicating this taxon was present at the opening of the Holocene. Collaborative data, particularly from a deeply buried site where contamination would be unlikely, are needed. Although late glacial pollen diagrams are available from the chalklands of south-eastern England, the lower TGA peat, if of late-glacial age, would offer the first opportunity to reconstruct the vegetation of this period for the Romney Marsh region.

The precise location of the TGA borehole has subsequently been built over. Initial lithostratigraphic investigations therefore included a borehole survey (using hand augering techniques) undertaken across the valley adjacent to the Tilling Green housing estate. This transect was necessary to establish the lateral extent of the deep (below *c.* -12 m OD) palaeovalley of the lower Tillingham as well as details of the upper-part of the Holocene fill. Subsequently a drilling rig was used to obtain deep material from a location close to the TGA borehole (inside the estate) and a site situated approximately in the middle of the valley.

Methods

The initial lithostratigraphic survey of the lower Tillingham Valley was undertaken using a gouge auger. Sediments were described using the system of Troels-Smith (1955) and levelled to Ordnance Datum. A heavy-duty mechanical drilling rig operated by Site Investigation Services was employed to recover sediments from the deeper parts of the valley.

Standard laboratory techniques were used to prepare 1 cm^3 samples of sediment for pollen analysis (Moore *et al.* 1991), with the addition of *Lyopodium* tablets to enable the calculation of pollen concentration (Stockmarr 1971). Pollen grains were identified using reference material held at the School of Earth Sciences and Geography, Kingston University. The nomenclature for the pollen taxa follows Bennett (1994). The computer programs TILIA and TILIA*GRAPH (Grimm 1987, 1993) have been used to calculate percentages (using a Total Land Pollen (TLP) sum), perform numerical zonation, and display the pollen data (Fig. 2.3 and 2.4).

For the preparation of the diatom samples, subsamples of 1 cm^3 of sediment were subjected to hydrogen peroxide digestion and mounted on slides using naphrax (Barber and Haworth 1981; Palmer and Abbott 1986). Species were identified using Van der Werff and Huls (1958–1974), Hendey (1964), Germain (1981) and Simms (1996). Diatom nomenclature follows Hartley (1986) with the data expressed as a percentage of Total Diatom Valves (TDV). Interpretations are based on the salinity group classifications of Vos and de Wolf (1988; 1993) and the ecological scheme of de Wolf (1982) and Denys (1991; 1994).

Three samples were submitted to Beta Analytic for radiocarbon dating by accelerator mass spectrometry (AMS). All radiocarbon dates quoted in the text have been calibrated using the updated (4.3) version of the program CALIB (Stuiver and Reimer 1993) and are expressed as the mean of the calibrated date range in calendar years before present (cal. yr BP).

Lithostratigraphy

The transect across the lower Tillingham Valley immediately to the west of the Tilling Green estate (GR TQ 91252105 to TQ 91052040; Fig. 2.2) reveals the bedrock (sandstone) sub-surface to be shallow and uneven on the northern side of the valley (TG1–3). The deepest sediment recorded in cores TG6, 7 and 9 was a stiff olive green-grey silty clay with sand and sandstone fragments. Similar material has been described from the adjacent Brede and Rother valleys (Waller *et al.* 1988). These deposits mantle the bedrock and are likely to be of colluvial origin. The pre-Holocene surface was not attained, descending below *c.* -12 m OD, across the centre of the valley (between TG5 and 9). The Holocene lithostratigraphy is comparable to the sequence of sediments now well established for the

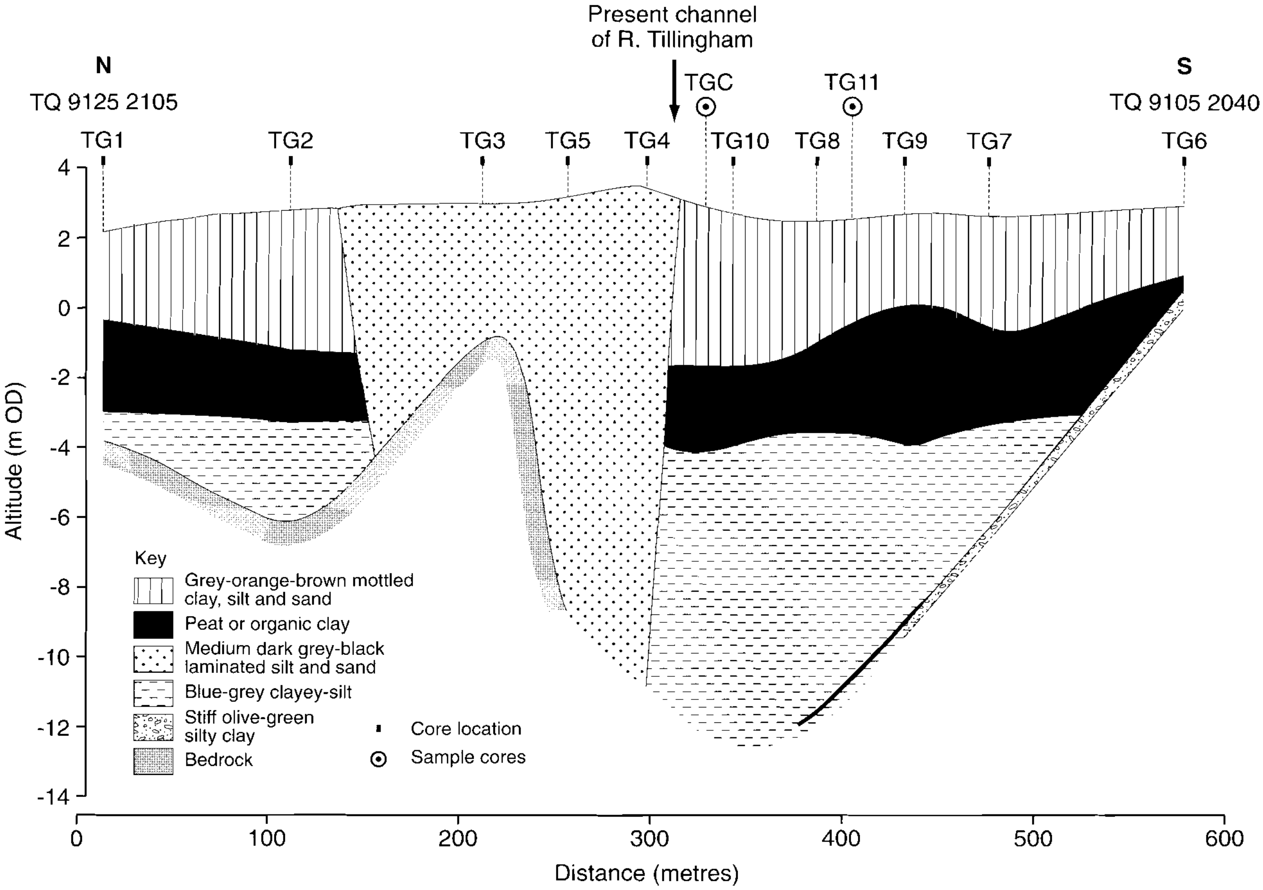


Fig. 2.2. Schematic lithostratigraphy of the lower Tillingham Valley derived from hand auger investigations.

western side of the Romney Marsh depositional complex (Waller *et al.* 1988; Waller 1994; Long and Innes 1995). The deepest sediment (recorded between -12.60 and -3.03 m OD) was generally a blue-grey silty clay which contained occasional shell fragments and *Phragmites* remains. A thin organic rich clayey silt with abundant *Phragmites* occurs above the colluvium in borehole TG9. Similar organic material was also recorded intercalated within the silty clays (between -11.25 and -11.20 m OD) in TG8. A much more substantive peat layer is found between -4.06 and +0.13 m OD. It consists of a mixture of fine and coarse detritus with an abundance of wood and *Phragmites* remains. Thin clay rich layers were also noted. This is the mid-Holocene "main marsh peat" which occurs at a similar altitude in the adjacent Brede (Waller 1994) and Rother (Waller *et al.* 1988) valleys and on Walland Marsh (Long and Innes 1995). Peat is absent from the centre of the valley (TG3, 4, 5) where a sequence of dark grey sand rich laminated (probably channel or channel margin) deposits extend from a depth of -7.97 m OD to the modern surface. Elsewhere an upper oxidised clayey unit overlies the main peat.

With the bedrock profile unknown between TG5 and 9, a distance of 175 m, a single borehole could easily fail to recover material from the deepest part of the valley. It was therefore decided to investigate the possibility of drilling on the Tilling Green estate. A suitable site (a grass verge at GR TQ 91422059) was located only *c.* 8 m away from the original TGA borehole. The upper part of the sequence from this borehole (here referred to as TGB) revealed a lithostratigraphy similar to the cross-valley profile and the TGA borehole. The main peat (recorded between -4.04 and -1.94 m OD) was underlain by a thick layer of blue-grey silty clays with a sand content that increased with depth (to -19.49 m OD). Unfortunately bedrock was attained at a depth of only -20.09 m OD (Table 2.1). The overlying material (at between -20.09 and -19.49 m OD) contained thin layers of detrital organic material. The latter appeared not to be *in situ* and therefore biostratigraphic investigations have not been undertaken from this site.

Subsequently a further attempt was made to retrieve the deep organic sediments using a drilling rig west of the estate along the line of the hand auger transect. Penetrometer readings indicated a depth to bedrock immediately south of the river of -25.8 m OD, and 30 m to the south of the river, of -24.15 m OD. A borehole (TGC) was therefore sunk adjacent to the former location (GR TQ 91142071). The expected stratigraphy was recorded to a depth of -24.5 m OD. The sediments recovered from below this depth included an organic silt containing abundant plant macrofossil remains including wood, seeds and *Phragmites* rhizomes (Table 2.1). The chronostratigraphic and biostratigraphic investigations undertaken from sediments below -24 m OD at this site are detailed in the following sections.

In addition, the detection of the organic clayey silt at a depth of *c.* -11.00 m OD, during the hand augering, offered a further opportunity to refine the sea-level history of the Romney Marsh region. Organic sediment at a similar altitude (between -11.74 and -10.49 m OD) had only previously been recorded from a short section of the Brede valley (Waller 1987; Waller 1994; Waller *et al.* 1988). Material (-10.22 to -10.27 m OD) from this deposit in the lower Tillingham Valley was therefore collected for biostratigraphic and chronological analyses from a location adjacent to TG8 (TG 11, GR TQ 91132048) using a piston corer (Table 2.1).

Pollen Analysis

In the lower Tillingham Valley, pollen analysis has been undertaken from the deep basal organic and the adjacent overlying sediments in TGC and the thin intercalated layer recovered from TG11. Data previously obtained (Waller 1987) from the thin organic bed in the Brede Valley (GR TQ 88091783 Old Place 16, Waller *et al.* 1988), which might be contemporary to the latter, are presented here (Table 2.1, Fig. 2.4) for comparative purposes.

TGC

The pollen diagram from the basal sediments (Fig. 2.3) of TGC has been divided into 3 local pollen assemblage zones (prefixed TGC) using the CONISS program (Grimm 1987). The main features of these zones are:

TGC-1 (28.06–27.65 m) Corylus avellana*-type,* Quercus *zone.*
An assemblage dominated by *Corylus avellana*-type pollen (96–65% TLP). *Quercus* is one of the few other taxa to be recorded consistently though values decline to a minimum of 1% TLP mid-zone. Herb pollen is particularly scarce (generally <2% TLP).

TGC-2 (27.65–27.52 m) Corylus avellana*-type,* Quercus, Pinus sylvestris, *Poaceae, Chenopodiaceae, pre-Holocene spores and pollen zone.*
Corylus avellana-type pollen values are consistently lower during TGC-2 (47–30% TLP) and *Quercus* frequencies higher (26–16% TLP). Initial peaks are recorded in *Pinus sylvestris* pollen (maximum 26% TLP), fern spores (*Pteridium aquilinum* and Pteropsida (monolete) indet.) and in pre-Holocene spores and pollen (maximum 36% TLP+Group). High Chenopodiaceae (12% TLP) and Poaceae (13% TLP) values are recorded towards the top of the zone.

TGC-3 (27.52–27.38 m) Corylus avellana*-type,* Quercus, *Poaceae, Chenopodiaceae zone.*
An assemblage dominated by four taxa. *Corylus avellana*-type values recover to 55–43% TLP, while the higher values for *Quercus*, Chenopodiaceae and Poaceae recorded in TGC-2 are maintained.

The TGC-1 pollen assemblage is likely to be derived largely from vegetation growing on the slopes of the Tillingham Valley. However, communities in the narrow valley bottom will also have contributed, and the consistent presence of pre-Holocene spores and pollen indicates some reworking of palynomorphs from older sediment stores. The very high *Corylus avellana*-type pollen percentages demonstrate hazel was abundant during the accumulation of the organic sediments (Units 3 and 4). *Quercus* (with values of 13% TLP at the base of the diagram), is also likely to have been present, along with *Ulmus*, though at least in the vicinity of the pollen diagram, these taxa played subsidiary roles. *Betula* and *Pinus sylvestris* are both over-represented in the pollen record and frequencies of less than <2% TLP in TGC-1 indicate these trees were rare or absent. In contrast, *Salix* and *Cornus sanguinea* are not well represented and, as confirmed by macrofossils for the latter, are likely to have grown in the Tillingham Valley. Although, herb pollen frequencies remain low, the representation of a number of taxa (notably Poaceae, Cyperaceae and Chenopodiaceae) increases at the top of TGC-1. Their appearance is likely to be an indication of the proximity of transitional open marine/brackish habitats immediately prior to the change in lithostratigraphy.

The deposition of the coarse clastic material (Unit 5) coincides at the base of TGC-2 with an assemblage indicative of extensive reworking. Secondary (pre-Holocene spores and pollen) and resistant (Pteropsida (monolete) indet., *Polypodium*) types increase. A marine/brackish influence is indicated by an increase in the pollen of Chenopodiaceae and other herbs (with *Plantago maritima* present). The high *Pinus sylvestris* and *Pteridium aquilinum* values are likely to be the result of the ability of these grains/spores to float over long distances. The shift from *Corylus avellana*-type to *Quercus* at the top of TGC-1 and during TGC-2 could also reflect inwash of the latter from more distant sources. Alternatively, it may be the result of the inundation of hazel dominated communities occurring on the valley floor. If the latter was the case, then oak was clearly regionally more abundant than might be inferred from the very low values during TGC-1. With the deposition of fine clastic sediments (Unit 6) the reworked types decline and the contribution from the marine/brackish communities increases.

TGC-3 is characterised by a recovery in *Corylus avellana*-type pollen values. The continued decline in secondary types suggests this assemblage is less obviously influenced by reworking. However, it is difficult to interpret TGC-3 in terms of the contemporary vegetation of the Tillingham Valley due to uncertainties over the origin of much of the pollen. The degree to which the frequencies of the main taxa represented (particularly *Corylus avellana*-type and *Quercus*) have been influenced by long-distance marine transportation/reworking cannot be determined and minor taxa (e.g. *Pinus sylvestris, Alnus glutinosa, Juniperus communis*) may owe their presence entirely to these processes.

The Intercalated Peats

The assemblages from the thin intercalated peats (Fig. 2.4) have not been sub-divided and have been given the notation TG11–1 (for the Tillingham Valley) and OP16–1 (for the Old Place site in the Brede Valley).

TG11–1 (12.74–12.68 m) Quercus, Corylus avellana-*type, Poaceae, Cyperaceae zone.*
Four taxa attain percentages of *c.* 20% TLP or above. *Quercus* and Poaceae pollen values decline slightly towards the top of the zone, while Cyperaceae values rise. *Corylus avellana*-type frequencies are more variable. *Ulmus, Tilia, Alnus glutinosa* and *Pteridium aquilinum* are also consistently well represented (up to *c.* 5% TLP). High basal *Pinus sylvestris* and Chenopodiaceae values are recorded.

OP16–1 (13.75–13.60 m) Corylus avellana-*type,* Quercus, *Poaceae, Cyperaceae zone.*
High basal Poaceae values (*c.* 32 % TLP) are replaced by rising *Corylus avellana*-type frequencies that attain a maximum 43% TLP at the top of the diagram. Cyperaceae values peak mid-zone (15% TLP) while *Quercus* percentages are more consistent (at *c.* 20% TLP). *Ulmus, Alnus glutinosa* and, towards the top of the zone, *Sparganium emersum*-type pollen, is also well represented (at *c.* 5% TLP and TLP+Aq.)

The TG11–1 and OP16–1 assemblages are remarkably similar. The tree pollen percentages, in particular the low *Corylus avellana*-type values (compared with early Holocene assemblages, see Waller 2002) and low *Tilia* and *Alnus glutinosa* frequencies (compared to mid-Holocene assemblages, see Waller 2002), indicate they are at the very least broadly contemporary.

During the formation of these layers the local environment was clearly dominated by reedswamp, as indicated by the presence of *Phragmites* macrofossils and high Poaceae pollen values, and the pollen of emergent aquatics (e.g. *Sparganium emersum*-type, Cyperaceae). Such vegetation would be expected to occur as fringe between upper saltmarsh and dryland woodland, promoted by freshwater seepage. The spread of these communities onto the floodplain is indicative of an increased freshwater influence. Such conditions should also have favoured *Alnus glutinosa*. With pollen values of 5% TLP, alder is likely to have been present. Its local failure to expand can probably be attributed to this episode being short-lived.

With the herb taxa likely to have been derived from freshwater or brackish environments, the adjacent dryland areas seem to have been well wooded during TG11–1 and OP16–1. *Quercus* and *Corylus avellana*-type appear to be the main woodland components. However, *Tilia* is likely to have been more prominent than the pollen values suggest, as it is under-represented (see Waller 2002). For the same reason *Fraxinus* was probably also present regionally. The *Ulmus* values (*c.* 5% TLP) are typical for this region prior to the mid-Holocene decline in elm, and support suggestions that this taxon (it has a high pollen representation) was a relatively minor woodland constituent (Waller 1993, 1994).

Diatoms

Diatom analyses have been conducted from the top of the organic (Unit 4) and the immediately overlying sediments in TGC and from the intercalated organic layer (Unit 2) and its transitions in TG11 in order to provide detailed information on the local depositional environment and water level fluctuations.

TGC

Below 27.68 m no diatoms are preserved. Between 27.68 and 27.30 m diatom preservation is good with marine (60% TDV) and brackish (40% TDV) taxa dominating. The main species present are *Nitzschia granulata, Nitzschia navicularis* (marine/brackish benthic, epipelon) and *Paralia sulcata* (planktonic), and their relative frequencies are consistent throughout. Subordinate marine/brackish benthic epipelic species include *Diploneis didyma, Nitzschia punctata* and *Scoliopleura tumida*. Less common marine planktonic taxa include *Pseudopodosira westii, Thalassiosira eccentrica* and *Podosira stelliger*. Epiphytic taxa form *c.* <2% TDV.

This assemblage closely resembles the *Melosira sulcata* and *Navicula digitoradiata var. minima* group of Vos and de Wolf (1988). The dominance of planktonic taxa (likely to be inwashed) and benthonic epipelic species (probably the *in situ* mud dwelling population) along with few epiphytic forms suggests deposition within a low saltmarsh/intertidal mudflat environment, proximal to tidal channels. These results, (coupled with the pollen evidence for a marine/brackish influence from the base of TGC-2) indicate that the lithostratigraphic transition between Unit 4 and 5 (at -24.65 m OD) is a transgressive contact.

TG11

In TG11 shifts in the relative frequency of marine and freshwater diatoms mirror the changes in lithostratigraphy. In the minerogenic unit below 12.74 m marine and brackish diatoms predominate with *Paralia sulcata* (marine plankton) and *Diploneis didyma, Nitzschia navicularis,* and *Nitzschia punctata* (brackish epipelon) the main taxa. Between 12.73 and 12.70 m (Unit 2) the marine and

Table 2.1. The lithostratigraphy of the deeper sections of the TGB, TGC, TG 11 and Old Place 16 boreholes.

TGB

Unit	Depth m (below surface)	Depth m OD	Lithology
5	Above 22.00	Above -19.04	Soft blue-grey silty clay with sand, organic detritus and *Phragmites* rhizomes. Nig. 2, Strf. 0, Elas. 0, Sicc. 2; As3, Ag1, Ga+, Dg+, Th^1 (*Phrag.*)+
4	22.00 to 22.45	-19.04 to -19.49	Soft light-medium grey silty clay, with organic detritus and *Phragmites* rhizomes. Nig. 2, Strf. 0, Elas. 0, Sicc. 3, Lim. sup. 0; As3, Ag1, Dg+, Th^1(*Phrag.*)+
3	22.45 to 22.91	-19.49 to -19.95	Medium grey silty clay with faint layers of detrital organic material. Nig. 2+, Strf. 1, Elas. 0, Sicc. 3, Lim. sup. 0; As3, Ag1, Sh+, Dg+
2	22.91 to 23.05	-19.95 to -20.09	Stiff medium grey silty clay with woody organic detritus (including a *Corylus avellana* nut) and finely laminated (bands *c.* <1 mm) organic partings and olive green sandstone (bedrock) clasts. Nig. 2, Strf. 1, Elas. 1, Sicc. 3, Lim. sup. 0; As3, Ag1, Gg+, Dg+, Dh+, Sh+
1	23.05 to 24.00	-20.09 to -21.04	Stiff light-brown mottled grey sandstone (bedrock) Nig. 2, Strf. 0, Elas. 0, Sicc. 3, Lim. sup. 1; Ag2, As1, Ga1

TGC

Unit	Depth m (below surface)	Depth m OD	Lithology
8	Above 25	Above -22.01	Soft, grey silty clay with occasional organic fragments. Nig. 2, Strf. 0, Elas. 0, Sicc. 3; As3, Ag1, Ga+, Th^1+
7	25 to 27.49	-22.01 to -24.5	Dark grey silty clay with occasional roots. Nig. 2, Strf. 1, Elas. 0, Sicc. 3, Lim. sup. 0; As3, Ag1, Ga+, Th^1+
6	27.49 to 27.59	-24.5 to -24.6	Grey silt with abundant roots and some detrital organic material. Nig. 2, Strf. 0, Elas. 0, Sicc. 2, Lim. sup. 0; Ag4, As+, Th^1+, Dg+
5	27.59 to 27.64	-24.6 to -24.65	Yellowish-grey, stiff silt with clay and sandstone fragments. Nig. 2, Strf. 0, Elas. 0, Sicc. 3, Lim. sup. 0; Ag3, As1, Ga+, Gg+
4	27.64 to 28	-24.65 to -25.01	Light grey organic silt containing abundant plant macrofossils; including *Corylus avellana* wood, *Phragmites* rhizomes, leaf fragments and *Corylus avellana* and *Cornus sanguinea* nuts. Nig. 2, Strf. 0, Elas. 0, Sicc. 2, Lim. sup. 0; Ag3, Sh1, As+, Th^1(*Phrag.*)+, Dh+, Dl+,
3	28 to 28.08	-25.01 to -25.09	Grey-brown slightly organic sandy silt with wood (*Corylus avellana*) at base. Nig. 2, Strf. 0, Elas. 0, Sicc. 2, Lim. sup. 0; Ga2, Ag2, Gg+, Dl+, Dh+, Sh+
2	28.08 to 28.80	-25.09 to -25.81	Dark grey wet gravel in loose silty/sandy matrix. Nig. 2, Strf. 0, Elas. 0, Sicc. 1, Lim. sup. 0; Gg2, Ga1, Ag1, Gs+
1	Below 28.80	Below -25.81	Stiff grey silt with sandstone concretions (bedrock). Nig. 2, Strf. 0, Elas. 0, Sicc. 3, Lim. sup. 0; Ag2, Ga1, As1, Gg+

TG 11

Unit	Depth m (below surface)	Depth m OD	Lithology
3	Above 12.69	Above -10.22	Soft blue-grey silty clay with occasional plant and shell fragments. Nig. 2, Strf. 0, Elas. 0, Sicc. 2; As2, Ag2, Th^1(*Phrag.*)+, test.(moll.)+
2	12.69 to 12.74	-10.22 to -10.27	Light brown organic clayey silt with *Phragmites* remains. Nig. 2, Strf. 0, Elas. 0, Sicc. 2, Lim. sup. 1; Ag2, As1, Sh1, Th^1(*Phrag.*)+
1	Below 12.74	Below -10.27	Blue-grey silty clay with occasional *Phragmites* rhizomes. Nig. 2, Strf. 0, Elas. 0, Sicc. 2, Lim. sup. 0; As2, Ag2, Th^1(*Phrag.*)+

Table 2.1. continued.

OLD PLACE 16

Unit	Depth m (below surface)	Depth m OD	Lithology
3	Above 13.60	Above -10.79	Grey sandy silty clay. Nig. 2, Strf. 0, Elas. 0, Sicc. 2; As 2, Ag2, Ga+
2	13.60 to 13.78	-10.79 to -10.97	Greyish-brown organic silty clay. Nig. 2, Strf. 0, Elas 0, Sicc 2, Lim. sup. 0; Dg2, As2, Ag+, Th^1(*Phrag.*)+
1	Below 13.78	Below -10.97	Grey sandy silty clay. Nig. 2, Strf. 0, Elas 0, Sicc. 2, Lim. sup 0; As2, Ag2, Ga+, Th^1(*Phrag.*)+

brackish influence declines and freshwater species dominate (maximum 55% TDV). The main species recorded here are *Fragilaria virescens, Fragilaria pinnata,* and *Fragilaria construens var. venter* (all freshwater plankton). From 12.68 m and into the overlying silty clay, marine (*c.* 45% TDV) and brackish diatoms (*c.* 55% TDV) resume dominance. The main marine planktonic species are *Paralia sulcata* and *Podosira stelliger* with *Nitzschia navicularis* and *Diploneis didyma* the predominant brackish epipelic taxa.

The assemblages recorded from the clastic units and transitions are mainly brackish epipelic taxa of the *Navicula digitoradiata var. minima* group (Vos and de Wolf 1988), while freshwater planktonic species from the *Fragilaria construens* group increase within the organic rich material. These shifts indicate a transition from an intertidal mudflat environment through to high supratidal saltmarsh/freshwater reedswamp (possibly also lagoonal) conditions, followed by the return to mudflat.

Chronology

Details of the three AMS radiocarbon dates (two from plant macrofossils and one bulk date) obtained from the lower Tillingham Valley as part of these investigations and the original (conventional assay) BGS Tilling Green date (Welin *et al.* 1974) are provided in Table 2.2.

The dates from TGC are compatible with the high *Corylus avellana*-type pollen values recorded in the TGC-1 assemblage. Such frequencies occur across southern England during the early Holocene lasting, for example, from *c.* 10200 to 8200 cal. yr BP at Pannel Bridge (Waller 1993; Waller 2002) and *c.* 10700 to 8400 cal. yr BP at Holywell Coombe Folkestone (Bennett and Preece 1998). Although not as temporally diagnostic, the TV11-1 assemblage (with *Tilia* and *Alnus glutinosa* both present) is compatible with a date of 7935–7674 cal. yr BP (Beta-153521).

Discussion

Landscape Evolution During the Late Pleistocene/Early Holocene

Boreholes drilled for commercial purposes have long demonstrated the existence of channels deeply incised into the bedrock of the river valleys that drain into the western side of the Romney Marsh depositional complex. Combining the investigations described in this paper with the KCC borehole information and data previously collated from boreholes sunk as part of road schemes (Waller 1987; Long *et al.* 1996), it is possible to identify the approximate location of the Tillingham bedrock channel in the vicinity of Rye (Fig. 2.1). Over much of Brede Levels and the western side of Walland Marsh the bedrock surface consistently lies at between -15 and -20 m OD. In the Tillingham Valley the deep (> -20 m OD) channel occurs close to the modern river along the line of the hand auger transect, before continuing east into the Tilling Green estate, cutting through the neck of the modern meander. The boreholes that record bedrock below -20 m OD immediately to the south and east of Rye, are likely to represent the eastward continuation of this system. The bedrock channel of the Brede probably runs east across the middle of the Brede Levels towards Camber Castle (Waller 1987).

The bedrock profile of the Tillingham Valley appears to contain several channels. The detailed sub-surface profiles constructed from the upper, shallower, parts of the valleys (e.g. at Brede Bridge, Waller 1994) also contain evidence for several phases of incision. Incision will have occurred during periods of high fluvial discharge and low sea level such as the last glacial maximum, or periods of low sediment supply. The buried channel between TG1 and 3 in the Tillingham Valley transect (Fig. 2.2) is also likely to be the product of a former course of a tributary emerging from the Leasam valley. In the base of most of the deep boreholes, a sand and gravel unit overlies bedrock. This change from erosion to sedimentation is likely to have been produced by a combination of declining discharge and increasing sediment supply (Rose *et al.* 1980). The colluvial sediments that mantle the lower slopes of both the Tillingham and Brede valleys demonstrate the

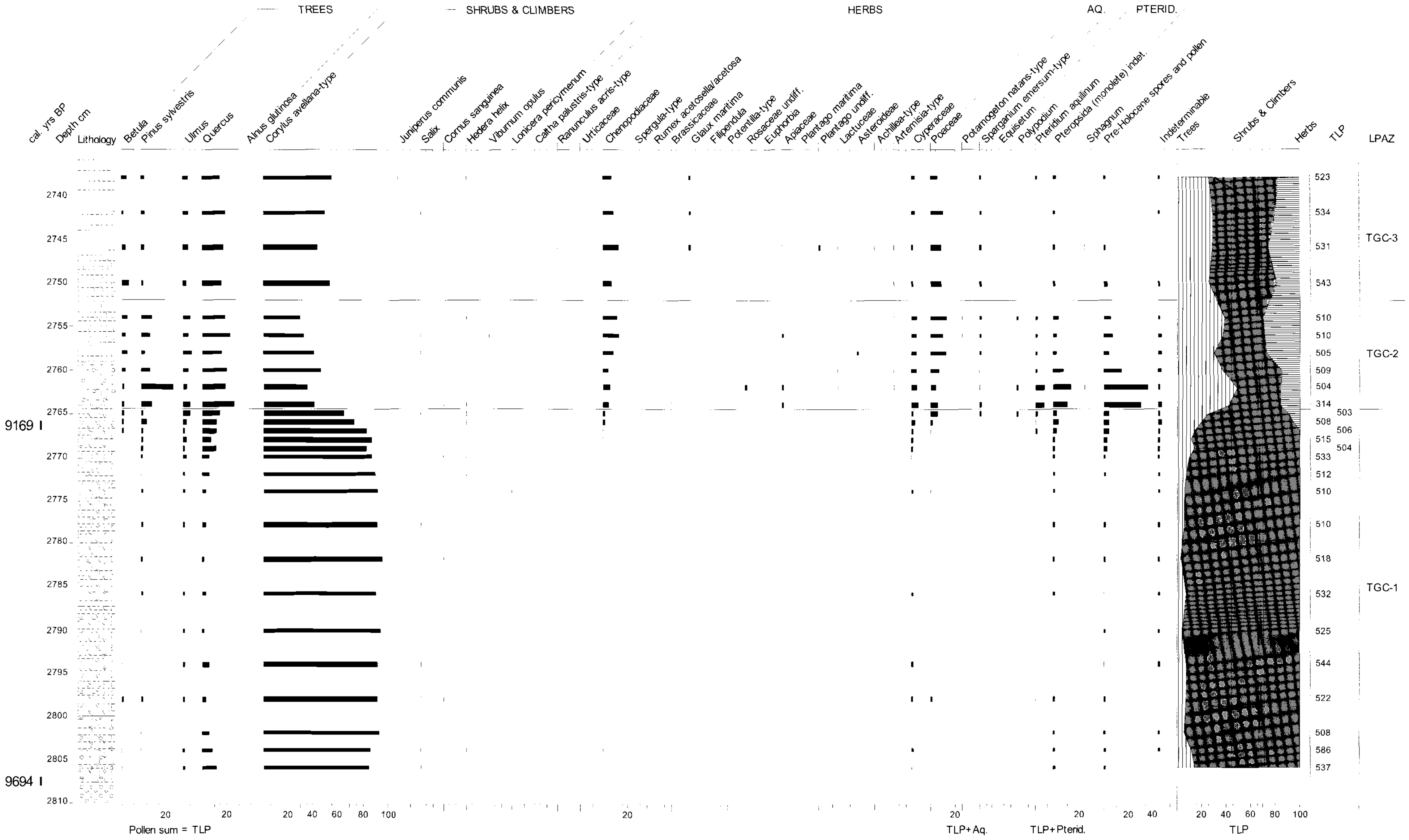
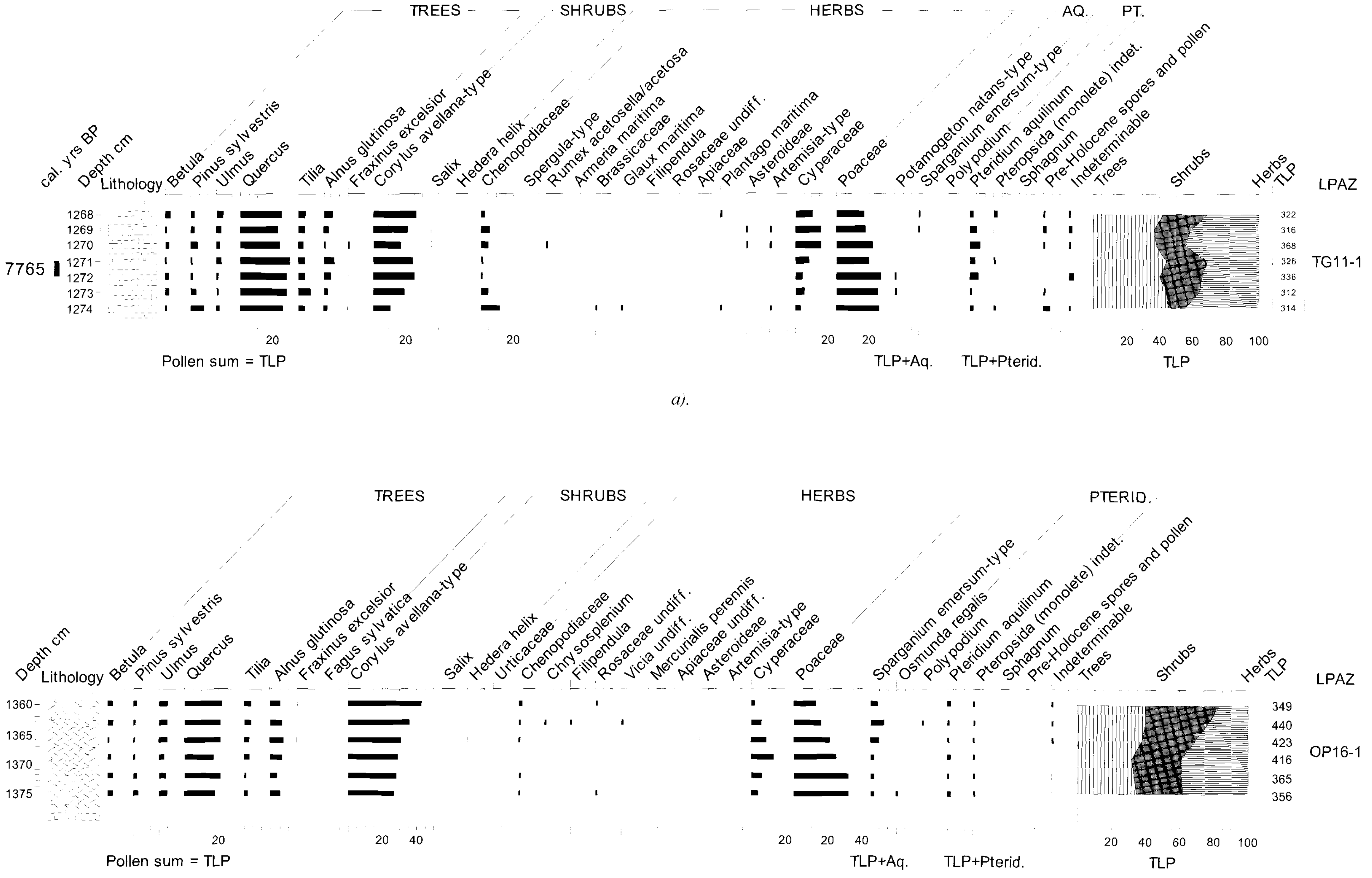


Fig. 2.3. Percentage pollen diagram from the basal units of TGC.



a).

b).

Fig. 2.4. Percentage pollen diagrams from the intercalated peats. a) Tillingham Valley (TG11) and b) Brede Valley (OP16).

Table 2.2. Radiocarbon dates from the lower Tillingham Valley.

Borehole	Depth (m)	Altitude (m OD)	Lab. Code	Material	Age ± 1σ error (^{14}C yr BP)	Mean calibrated age with 2σ range (cal. yr BP)
TG 11	12.71 to 12.72	-10.24 to -10.25	Beta-153521	*Phragmites* peat	6980±50	7765 (7935–7674)
TGC	27.66 to 27.67	-24.67 to -24.68	Beta-153522	*Cornus sanguinea* nut	8240±80	9169 (9470–9011)
TGC	28.07 to 28.08	-25.08 to -25.09	Beta-155394	*Corylus avellana* wood	8720±40	9694 (9905–9550)
TGA	*c.* 26.00	*c.* -22.65	IGS-C14/116	Laminated peat	9565±120	10, 950 (11200–10506)

capacity of the adjacent slopes to supply sediment in the pre-Holocene. These deposits appear not to interdigitate with the Holocene deposits, contain little or no organic matter or microfossils (Waller 1987) and are likely to have been produced by gelifluction during a cold climate. The replacement of sands and gravels by organic detritus mixed with fine grained clastic material indicates a further decline in discharge during a period of more extensive vegetation cover and hence a warmer climate (such as the early Holocene).

Both TGA and TGC contain these basic sediment types. However, correlation is difficult (Fig. 2.5). The deeper organic and overlying coarse clastic layer in TGA may represent the climatic fluctuations of the late-glacial as indicated in the introduction to this paper (with warmer conditions interrupted by the brief return of a cold climate prior to the opening of the Holocene). The cold conditions at the end of this period could have produced localised incision, thus allowing the organic sediments of TGC to accumulate at a similar altitude in the Holocene. However, it is difficult to reconcile the presence of an older Holocene organic layer in TGA (indicated by the date of 11,200–10,506 cal. yr BP) several metres higher than the younger Holocene organic layer in TGC. Possible explanations include a phase of incision during early Holocene, errors in the measurement of altitude and, with the radiocarbon dates in TGC supported by the biostratigraphy, either the upper organic layer in the BGS borehole not being *in situ* or incorporating older carbon. The uppermost coarse clastic layer, at least in TGC, can be shown through biostratigraphic evidence to be associated with the subsequent marine transgression (see below). Given this complexity and the cost of sinking boreholes to a depth of > -25 m OD it is unlikely that, in the absence of a substantial number of deep boreholes being sunk as part of a major engineering project, the sequence recorded in TGA can be recovered.

Early Holocene Sea-level Change

The record of RSL change in the Romney Marsh region is well documented for the period 6500–2000 cal. yrs BP (Long and Innes 1993; Long *et al.* 1996; Long *et al.* 1998; Waller *et al.* 1999) with 40 sea-level index points (SLIPs) providing a wide spatial coverage. However, there were no reliable pre *c.* 6500 cal. yr BP index points from the region prior to this study. With its value limited by the lack of supporting biostratigraphic information, the BGS date from Tilling Green (Welin *et al.* 1974) could only be used as a maximum value for RSL (Long *et al.* 1996). The new data from Tillingham Valley are presented here (Fig. 2.6), along with the pre-existing data from the mid and late Holocene, to provide the most complete record RSL change in the Romney Marsh region available to date.

With the errors associated with the altitude of these SLIPs likely to be over a metre (see below), neither the indicative meaning of the sample points (see Shennan 1986) nor the effects of palaeotidal change have been quantified. In this analysis, the OD sample heights of the transgressive and regressive samples used are assumed to approximate to MHWST (reference tide level) at the time of deposition (Tooley 1978; Shennan 1986). The height of MHWST varies along the coast. To enable comparison with other existing data (from the Romney Marsh region and Langley Point) all SLIPs have been reduced to MSL by subtracting the appropriate value for MHWST obtained from the nearest tide gauge station (Admiralty Tide Tables 2001). Recent work shows the reference water level for transgressive and regressive contacts varies between MHWST and MHWST+HAT/2 (see Horton *et al.* 2000). However, this difference in tide level is inconsequential in the context of millennial scale RSL change of tens of metres during the early Holocene. In addition, although the integrity of each SLIP has been verified using diatom analysis, no data set exists of modern diatom distributions from the Romney Marsh region that might enable more precise quantification of indicative meaning. The error bars assigned in this analysis (see below) are large enough to account for potential differences in reference water level between SLIPs.

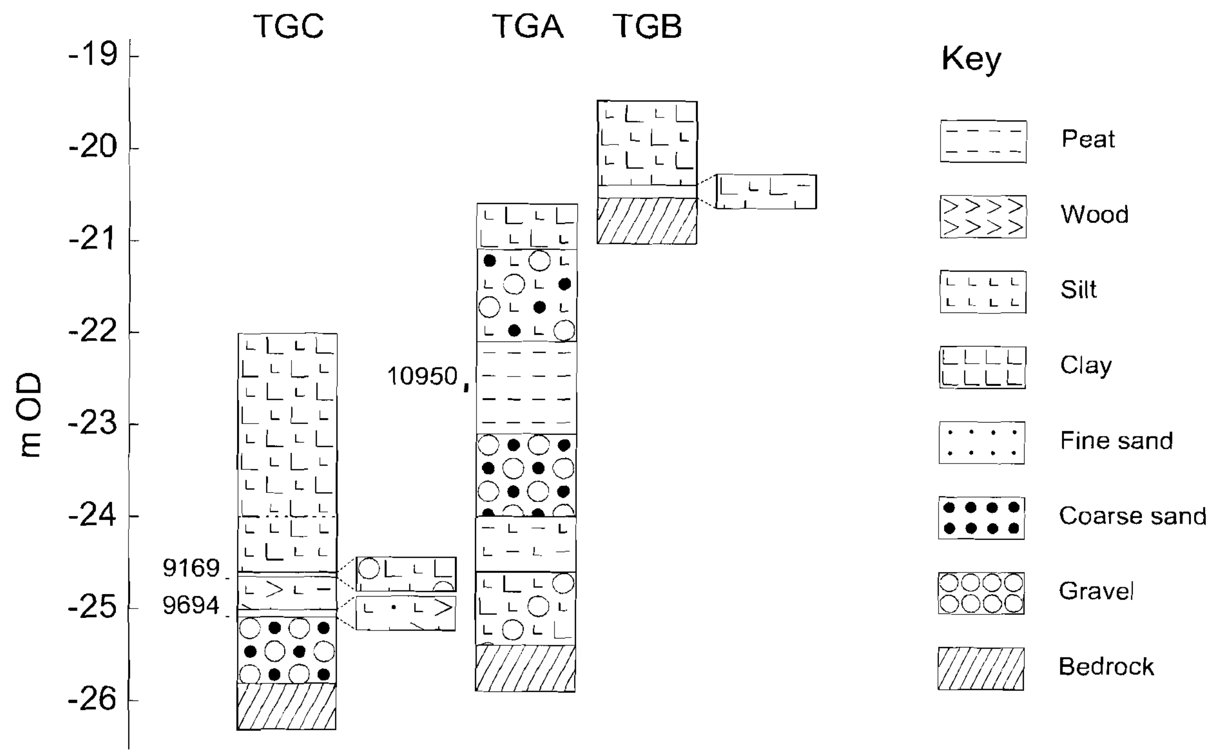


Fig. 2.5. Simplified lithostratigraphy of the three boreholes sunk to a depth of below -20 m OD in the vicinity of the Tilling Green estate. The radiocarbon data are the means of the calibrated date ranges in cal. yr BP.

The altitudinal error associated with SLIPs is usually assumed to be between 0.5 and 1.5 m (e.g. Long 1992; Shennan *et al.* 2000). Recent work suggests the effects of sediment compaction may be significantly greater (e.g. Haslett *et al.* 1998; Allen 1999; 2000). However, estimating this error is problematic. A geotechnical model capable of accurately decompacting stratigraphic sequences comprising the highly heterogeneous sediments recorded in the lower Tillingham has yet to be developed. The altitude of SLIPs can also be corrected for autocompaction by comparing a basal peat chronology (where sediments directly overlie an undeformable substrate) with in-core dates (see Törnqvist *et al.* 1998; Gehrels 1999). However, no such chronology exits for the Romney Marsh area. The SLIPs points are therefore shown here with a vertical error band of +1.5/-0.5 m in accordance with previous studies from the region.

Due to compaction, SLIPs are likely to be lower than their original elevation (see Shennan *et al.* 2000) which is reflected by the greater upwards vertical error margin. Wider vertical errors have been assigned to the basal sample from TGC as it is from a freshwater context. This sample can be used as a limiting point, constraining the maximum altitude of MSL. The TG11 index point has clearly been affected by compaction as the altitude of the intercalated organic layer from which it derives deepens away from the valley side (Fig. 2.2). Assuming an approximately horizontal surface during deposition, rather than the measured altitude at TG11 (-10.22 to -10.27 m OD) the altitude of *c.* -8.50 m OD (derived from TG9 where the layer overlies relatively uncompressible colluvium), has been used in Fig. 2.6 and in the calculation sea-level rise and sedimentation rates. When adjusted to MSL, the altitude of the intercalated organic layer is -12.04 m OD. The age uncertainty of the SLIPs is represented by the 2 sigma calibrated age range of the dated sample.

RSL in the Romney Marsh region was below -28.65 m OD prior to *c.* 9700 cal. yr BP (Fig. 2.6). The first reliable SLIP (from the trangressive contact in TGC) shows MSL *c.* 9200 cal. yr BP at an altitude of -28.24 m OD. Sea level then rose rapidly (*c.* 12 mm yr^{-1}) until *c.* 7800 cal. yr BP when MSL had reached -12.04 m OD. The rate of RSL rise subsequently (between *c.* 7800 and 6000 cal. yr BP) slows down to *c.* 4 mm yr^{-1}. A further deceleration follows, from *c.* 2–4 mm yr^{-1} between *c.* 6000 and 4000 cal. yr BP to less than 1 mm yr^{-1} thereafter (Long and Innes 1993; Long *et al.* 1996).

From this analysis the date derived from TGA (Welin *et al.* 1974) appears to be anomalous, occurring as a distinct outlier on the time/altitude graph. It now seems clear that, if *in situ*, this deposit represents an earlier phase of peat accumulation independent of sea-level rise. It is therefore recommended that this data point be no longer used in any discussion of early Holocene sea level history.

The only data available for the early Holocene from

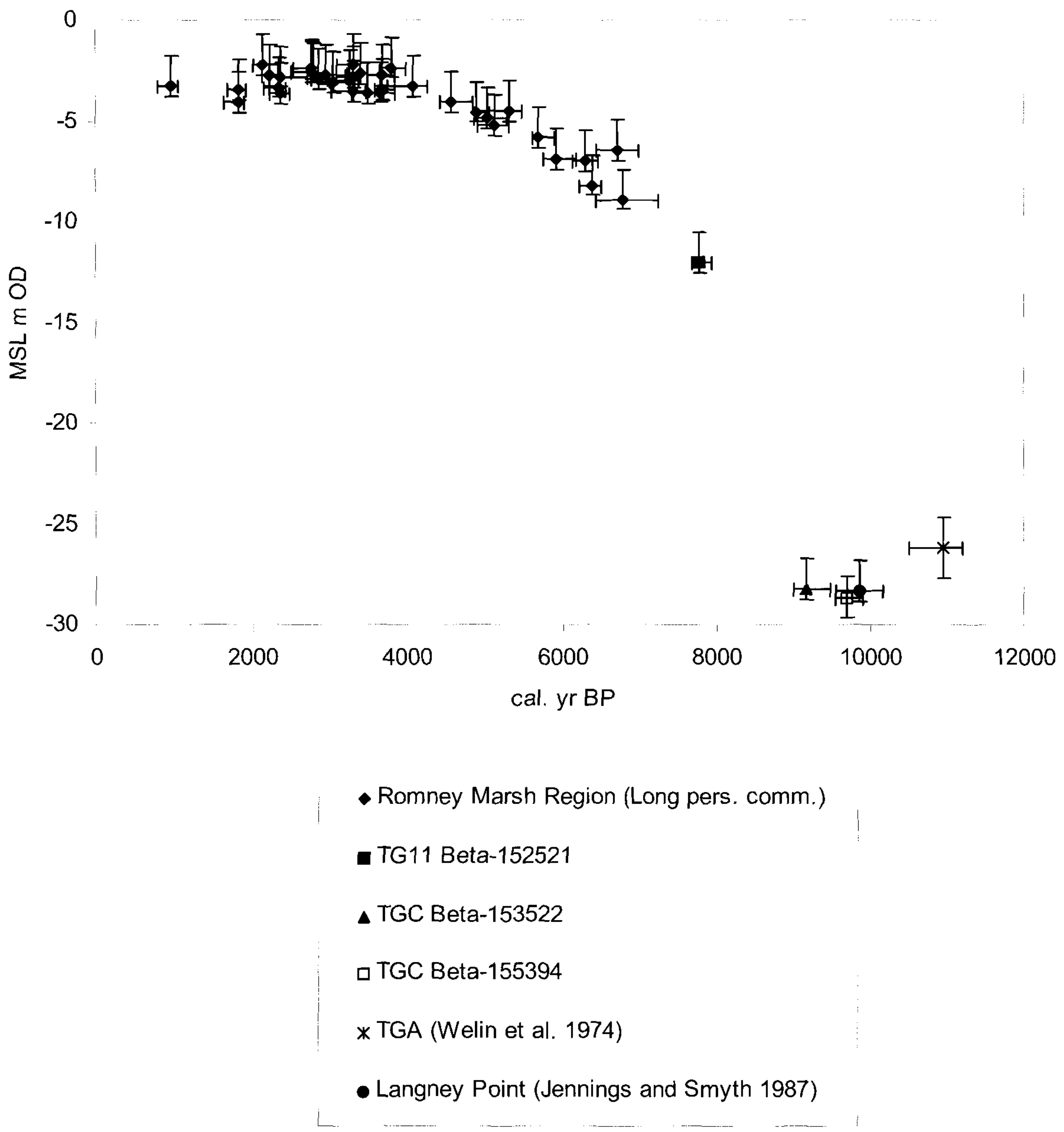


Fig. 2.6. Plot of sea-level index points for the Romney Marsh region. A single date from Langley Point, East Sussex, is included for comparison.

the East Sussex/Kent region with which the new data can be compared is the single SLIP (a transgressive contact) from Langney Point (Jennings and Smyth 1987). The latter shows MSL *c.* 10,000 cal. yr BP at -28.32 m OD and is thus in good agreement with the limiting date from TGC (Fig. 2.6). The similarity in altitude between transgressive contacts at Langney Point and TGC (given the *c.* 800 year age difference) during a period of rapid sea level rise can be attributed to effects of differential compaction.

Early Holocene Coastal Evolution

Organic material was clearly accumulating in the Romney Marsh region at inland localities independent of rising base levels during the very early Holocene (e.g. Pannel Bridge, Waller 1993). Given the absence of biostratigraphic evidence for marine/brackish conditions, organic sedimentation at base of the TGC sequence also appears to have commenced prior to any direct sea-level influence. However, it seems likely that, given the short interval over which the deposition of organic sediment occurred (*c.* 500 calendar years), the accumulation of the organic silts (Unit 4) at the base of TGC was promoted by rapidly rising sea level. Under such conditions seawards draining water is liable to pond up, resulting in the flooding of the channel at the base of the Tillingham Valley, the deposition of silt and the preservation of organic material.

The occurrence of the pollen of herb taxa associated with saltmarsh conditions (including the Chenopodiaceae) and marine-brackish diatoms towards the top of Unit 4 provides, at *c.* 9200 cal. yr BP, the first evidence for marine/brackish conditions in the Romney Marsh region. However, the initial inundation of the site is likely to be marked by the deposition of the clayey silt with sandstone fragments (Unit 5). The deposition of sandstone fragments can probably be attributed to the change from a fluvial to a tidal system. The ability of the river to transport locally derived catchment material would be reduced as tidal waters penetrated up river with this sediment deposited on the floodplain/emerging tidal flats and subsequently buried by fine clastic material. Erosional processes are also likely to be associated with this period of rapid flooding and shoreline retreat, with invasive tidal creek networks cutting into and reworking the organic deposits resting at the base of the Tillingham Valley. Such processes could also account for the presence of the sandstone fragments, the secondary and resistant pollen grains in TGC-2, and are likely to be responsible for the occurrence of eroded organic material at the base of the TGB borehole. With the coarse clastic material recorded in Unit 5 locally derived and associated with the initial stage of marine transgression it is unlikely to have formed part of a coastal barrier system. The influence of barriers on coastal evolution in East Sussex during the early Holocene has been stressed by Jennings and Smyth (1987; 1990) who used high values of *Juniperus communis* pollen in the Langney Point peat as evidence for the occurrence of sand barriers. In the Romney Marsh area, Dix *et al.* (1998), from offshore data, concluded that any early Holocene barrier is also likely to have been composed of sand rather than gravel and to have occurred at restricted localities close to the present shoreline. No evidence for the presence of such barriers in the vicinity of the lower Tillingham has been found. The lithostratigraphic (the predominance of fine-grained clastic sediments in the deep boreholes) and biostratigraphic (the diatoms, which suggest deposition within a low saltmarsh/mudflat environment) evidence, and the rapid landward advance of marine conditions during the early Holocene, argue against the local development of sand barriers during the initial stages of the marine transgression. The location and nature of any early Holocene barriers in the Romney Marsh area remains uncertain.

Between *c.* 9200 and 7800 cal. yr BP, with rising RSL providing the accommodation space, *c.* 16 m of fine clastic sediment was deposited at a rate of *c.* 12 mm yr^{-1}. The lack of lithostratigraphic information precludes discussion of the inundation of the lower Tillingham Valley, though with MHWST at *c.* -8.50 m OD by *c.* 7800 cal. yr BP tidal penetration is likely to have reached Brede Bridge in the Brede Valley (Waller 1987; 1994) and Bodiam in the Rother Valley (Burrin 1988).

The presence of the thin intercalated organic rich layer in TG11 indicates a brief interruption of intertidal marine/brackish conditions around 7800 cal. yr BP. From the biostratigraphic evidence it is clear that reedswamp expanded out across the Tillingham Valley. The absence of this layer from several boreholes suggests the maintenance of open water towards the centre of the valley. It is also possible that a localised system of erosive tidal creeks developed in the post-peat period. The upper contact of the organic material was irregular in TG11 though the consistency of the pollen assemblage argues against erosional truncation. The similarity between the pollen sequences (Fig. 2.4) and the comparable altitude of the peats supports the suggestion that this layer is contemporaneous with that reported by Waller (1987, 1994) from the Brede Valley. This brief increase in the freshwater influence may well therefore have registered widely in the valleys of the western marshland. The absence of evidence from other areas (e.g. the lower Rother Valley) is in part likely to reflect the scarcity of boreholes sunk to this depth for the purpose of palaeoenvironmental reconstruction (it is likely to have gone unrecorded in many commercial boreholes).

There are a number of possible explanations for the occurrence of this deposit. Such thin organic layers can arise through local processes including the interplay between the rate of RSL rise and the rate of sedimentation. If the rate of sediment supply outpaces the rate of RSL rise, the process of terrestrialisation will be initiated enabling freshwater vegetation to encroach upon areas of former mudflat (Wilks 1979). This process will be reversed when the rate of RSL rise exceeds the pace of organic sedimentation (see examples in Shennan *et al.* 1983; Gerrard *et al.* 1984). Any increase in freshwater discharge could also result in the seawards advance of peat forming communities.

Changes occurring in Rye Bay could have affected conditions within the river valleys. The contemporaneous deposition of large quantities of sand in Rye Bay creating extensive sand flats and banks may have reduced tidal penetration into the lower valleys and produced an increased freshwater influence. Long *et al.* (1996) report a coarsening upwards trend in borehole evidence south-east of Rye for which a shell date of 7930–7664 cal yr. BP provides a minimum age. This probably reflects an increase in tidal flow velocity related to rapid RSL rise and may also be associated with an increase in tidal amplitude following the opening of the Strait of Dover. The higher energy conditions resulted in the progressive influx of sediment (particularly sand) into Rye Bay from the east after *c.* 8000 cal. yr BP (Austin 1991; Long *et al.* 1996; Dix *et al.* 1998). Diatom evidence from Unit 2 possibly supports this suggestion as Vos and de Wolf (1988) state that the *Fragilaria construens* group is often associated with freshwater lagoonal environments.

The occurrence of organic deposits of similar age elsewhere along the south coast of England hints at a regional driving mechanism such as changes in RSL or sediment supply. Long (1992) reports a thin intercalated peat in the East Kent Fens dated to 7509–7169 cal. yr BP (at *c*. -8.65 m OD) and Godwin *et al*. (1958) a peat dated to 8377–7883 cal. yr BP (at -12.8 m OD, context unknown) from Poole Harbour. Altitudinal comparison is hampered by these deposits being deeply buried and therefore heavily compacted, and also by the large changes in tidal amplitude (up to 2 m) that occurred after the opening of the Dover Strait (Austin 1991). Any vertical fall in RSL cannot have been large or prolonged given the general rising trend of RSL from *c*. 9200 to 6500 cal. yr BP (see Fig. 2.6). However, it is possible that this deposit formed in response to a reduction in the rate of RSL rise. Topographic control may also be influential here as marginal valley sites, such as those noted above, are likely to be the most sensitive areas to small adjustments in RSL. Unfortunately the data presently available from the south coast of England are insufficient for this hypothesis to be fully tested.

Early Holocene Vegetation History

With the TGC pollen diagram spanning a time period covered in only two other radiocarbon dated profiles from the south-eastern corner of England it should contain important information on the arrival of tree taxa in this region during the early Holocene. The consistent presence of *Ulmus* in the TGC sequence does support the suggestion that this taxon was present in south-eastern England prior to *c*. 9500 cal. yr BP. In addition, the diagrams from the intercalated peats (particularly OP16–1) indicate *Fraxinus* was present by *c*. 7800 cal. yr BP. However, the TGC diagram in particular falls within a rather unfortunate time interval. It begins after the arrival of *Corylus avellana* and *Quercus* (*c*. 10,500 and 10,300 cal. yr BP respectively) and ends before the expansions in *Tilia* and *Alnus glutinosa* (*c*. 7800 cal. yr BP) at Pannel Bridge (Waller 1993), and thus adds little extra information. Given the controversy over its presence in the early Holocene (Bennett and Birks 1990; Waller 2002) this is particularly disappointing in the case of *Alnus glutinosa*. In contrast to the early Holocene record at Pannel Bridge only a few pollen grains of *Alnus glutinosa* were recorded from TGC (beginning at the top of TGC-1). However, the period covered by the Tilling Green diagram coincides with the lowest Holocene frequencies (and only gap in the record) of *Alnus glutinosa* recorded at Pannel Bridge. From the Pannel Bridge sequence more consistent frequencies of *Alnus glutinosa* and the presence of *Tilia* might be expected in the TGC profile from *c*. 9500 cal. yr BP. These discrepancies can, however, be attributed to the rapid inundation of the lower Tillingham Valley and TGC-2 and 3 assemblages originating from marine/brackish sediment (in contrast to the slow accumulation of organic material at Pannel Bridge).

The assemblages from TGC are dominated by *Corylus avellana*-type pollen. High hazel pollen frequencies occur throughout Britain during the early Holocene (Godwin 1975). As noted previously, the dates from TGC (at between *c*. 9700–9200 cal. yr BP) are comparable to the other sites investigated in south-eastern England. Many hypotheses have been offered to account for this abundance of hazel (see Huntley 1993). The data from both Tilling Green and Pannel Bridge indicate that *Quercus* and *Ulmus* were present in the Romney Marsh region during the period of high *Corylus avellana*-type pollen frequencies. It is generally assumed that pollen production and dispersal by hazel is greater when this species occurs as a canopy forming species. Therefore any explanation for the high values has to account for hazel having a competitive advantage over these taxa. Amongst the more plausible hypotheses are that *Corylus avellana* was the most competitive species on certain (more fertile) soil types until the arrival and expansion of *Tilia* (Waller 1993), or that the climate (the relatively cold winters and cool summers) of the early Holocene favoured *Corylus avellana* (Huntley 1993). *Quercus* and *Ulmus* are likely to have been confined to the sandier and more acidic soils.

The occurrence (pollen and macrofossils) of the shrub *Cornus sanguinea* (formerly *Thelycrania sanguinea*) in the TGC diagram is also of interest. The species was recorded at Pannel Bridge during the early Holocene, but has not been noted in any of the mid or late Holocene pollen diagrams from the region. Today this species shows a preference for open stands and flowering is inhibited by shade. The *Corylus avellana* woodland of the early Holocene may therefore, even if canopy forming, have been of relatively low stature.

The formation of the intercalated peats *c*. 7800 cal. yr BP coincides with increases in the representation of *Tilia* and *Alnus glutinosa* at Pannel Bridge (Waller 1993; Waller 2002). The absence of any rise in *Tilia* during TG11–1 and OP16–1 may simply be a result of the short time-span these sequences cover. Unfortunately, this still leaves the relationship between the decline in *Corylus avellana* (from the very high values recorded in the early Holocene) and the rise in *Tilia* (with high frequencies recorded in the mid-Holocene) in need of clarification. Diagrams covering the period *c*. 9500–8000 cal. yr BP are required. The opportunity for the expansion of *Alnus glutinosa* *c*. 7800 cal. yr BP is likely to have been greater in the Pannel Valley than at the sites in the lower Brede and Tillingham valleys. With the Pannel Bridge site at a higher altitude and therefore not directly affected by the preceding period of very rapid sea-level rise, *Alnus glutinosa* was probably locally present and thus able take advantage of the favourable conditions. The subsequent replacement of *Alnus glutinosa* by Cyperaceae at Pannel Bridge is attributable to the further landward advance of marine/ brackish conditions and associated increase in wetness after the deposition of the thin intercalated peat.

Conclusions

The KCC (TGA) borehole offered the prospect of extending detailed palaeoenvironmental reconstructions from the Romney Marsh region back to the earliest Holocene and possibly the late glacial. Unfortunately it has not proved possible either to replicate the TGA sequence or to establish correlation with the newly collected stratigraphic information. When exposed in section late glacial/early Holocene sediments from similar contexts can be seen to be locally highly complex reflecting several phases of aggradation and channel incision (e.g. Rose *et al.* 1980). Such intricacy, when combined with the logistical difficulties and expense of coring below -20 m OD, argues against further attempts to replicate the TGA sequence.

Despite these problems, the bedrock channel of the lower Tillingham Valley has now been much more closely defined and the sediments recovered have enhanced our understanding of aspects of the early Holocene environmental history of the region. Of particular importance is a phase of basal organic sedimentation lasting from *c.* 9700 to *c.* 9200 cal. yr BP. Pollen analysis from this layer confirms the dominance of *Corylus avellana* and the presence of *Quercus* and *Ulmus* in the early Holocene woodlands of the region. Biostratigraphic investigations have also demonstrated that the boundary between this layer and the overlying clastic sediments is a transgressive contact and is therefore the earliest record of marine/ brackish conditions from the region. The landward advance of coast during the early Holocene was rapid and, as the presence of sandstone and peat fragments attest, accompanied by the erosion and reworking of locally derived material.

A second, thin intercalated, organic layer recovered from the lower Tillingham Valley and dated to *c.* 7800 cal. yr BP is also important in constraining the pattern of early Holocene sea-level rise. MSL rose from -28.24 m OD at *c.* 9200 cal. yr BP to -8.50 m OD at *c.* 7800 cal. yr BP at a rate of *c.* 12 mm yr^{-1}. Subsequently this rate declined to *c.* 4 mm yr^{-1} between *c.* 7800 and 6000 cal. yr BP and remained between 2–4 mm yr^{-1} from *c.* 6000 to 4000 cal. yr BP. Thereafter, the rate of RSL rose at less than 1 mm yr^{-1}.

The importance of these data is enhanced by the lack of information on early Holocene sea-level change from south coast of England as a whole. The dates derived from the basal organic layer in the Tillingham Valley are broadly comparable with a transgressive contact previously dated at Langney Point. The date from TGA is an outlier and now clearly of little value in this context. Organic layers dating close to *c.* 7800 cal. yr BP have previously been recorded from East Kent and Dorset, however, the processes underlying the formation of the thin intercalated peat found in the Tillingham Valley, and also the Brede Valley, are not fully understood. Given the rate at which sea level was still rising, alternative explanations including changes in the pattern of sediment influx, possibly as a consequence of the opening of the Strait of Dover, or purely local processes, may be required.

Acknowledgments

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