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Relative land–sea-level changes in southeastern England during the Pleistocene

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Introduction

During the Pleistocene, a period covering the last two million years, sea level is known to have risen above and fallen below the present sea level. The evidence for such fluctuations comes from marine and estuarine sediments, including beaches, far above present sea level and from freshwater sediments, beaches and valley systems now submerged. In southeast England there are Lower Pleistocene marine deposits at 183 m O.D. at Netley Heath in Surrey and upper Pleistocene freshwater sediments at −35 m O.D. in the Channel. Thus we have in this area evidence of an amplitude of sea-level fluctuation relative to the present sea level of some 218 m.

While such limits of relative sea-level fluctuation are not so difficult to identify, very considerable difficulties arise in determining the relation of sea-level change to the passage of time, and in the analysis of sea-level change – whether it be a real lowering of sea level relative to land, or an uplift of land relative to sea level. Let us briefly consider each of these two fields of difficulty.

To date a particular stand of sea level, we have to know the relation of a particular deposit, say beach or shallow marine sediment to sea level at the time, and we have to know the correlation of this deposit to a part of the sequence of geological events which make up the Pleistocene. Both of these aspects may be problematical. It may not be certain what depth of water a deposit was formed in, and the age and correlation of the deposit may be doubtful.

To analyse the course of sea-level change we must be able to distinguish fluctuation of world-wide sea level, the so-called eustatic component, from local subsidence or upwarping of the earth's crust. Upwarping may be caused by the glacial isostatic effect, where uplift results from release of crustal load on the melting of large-surface ice sheets, as is now occurring in Scandinavia and northern Britain subsequent to the melting of the ice sheets of the Last Glaciation 10000 years ago, or it may be related to longer term earth movements, as is subsidence.

In southeast England, we are south of the limit of the Last Glaciation and there is no evidence for a glacial isostatic uplift since the Last Glaciation. Such effects may have been present in the earlier glaciations which reached south to the Thames catchment, but they have not been identified. On the other hand, there is very substantial evidence for subsidence during the Pleistocene in the southern part of the North Sea Basin, and southeast England occupies the southwestern margin of this area. We therefore have to take into account the possibilities of earth movement in our consideration of relative land–sea-level changes in southeast England.

The second factor which we must also take into account is the eustatic component of sea-level change. In northwest Europe the Pleistocene is characterized by its climatic changes. Cold stages often accompanied by glaciation, alternate with temperate stages, the interglacials, which show a climate much like that of the present day. During the cold periods eustatic sea levels are lowered by some 100 m because the expansion of the world's ice sheets withdraws water from the oceans. During the temperate stages, eustatic sea levels rise as the ice sheets melt, and in each a certain sea-level height is reached.

The observation that flights of raised beaches, the oldest at the top and the youngest nearer present sea level, occur in certain coastal areas in Europe, beyond the areas affected by isostatic uplift, has led to the assertion that eustatic sea levels in the Pleistocene during the temperate stages have fallen continuously. Thus the beaches of the Lower Pleistocene temperate stages are above 100 m O.D., while the youngest are only a few metres above O.D. The present state of knowledge does not really demonstrate the truth of this assertion. Beaches or marine sediments are rarely datable with enough accuracy to maintain it. Nevertheless, it seems clear that Lower Pleistocene sea levels were considerably higher than present sea levels, even though the sequence of eustatic high levels reached during successive temperate stages is open to doubt.

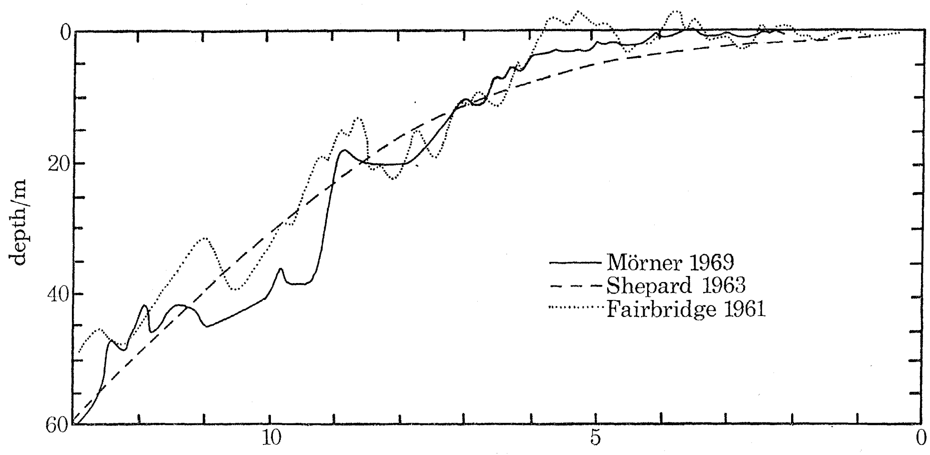

FIGURE 1. Curves for the Flandrian eustatic sea level rise (Mörner 1969).

The eustatic change of sea level best documented is that which has occurred in the last 10000 years since the Last Glaciation. The principal evidence for the curve of change comes from radiocarbon dated horizons with a definite relation to their contemporary sea levels. The results of accumulated data of this sort are seen in figure 1. It will be seen that each authority has his own curve of eustatic sea-level change. This epitomizes the difficulties of determining sea-level changes from such data. A number of factors interfere with any simple valid reconstruction, such as differing tidal ranges in different areas, differing isostatic, upwarping or subsiding elements in each area, and possible errors in radiocarbon dating.

In all these studies of eustatic and other elements concerned in relative land–sea-level change, there is the abiding difficulty of the absence of any certain datum level. Is there any part of the Earth's crust, in a coastal area or otherwise, that has been stable long enough for it to be used as a reference point for assaying sea-level changes?

Bearing these points in mind, it is now possible to examine the situation in southeast England. We have to take into account eustatic change and the longer term earth movements which are known to have occurred, and to determine how each may have contributed to the curve of sea-level change during the Pleistocene. The low sea levels which occurred during the cold stages are not mentioned further except for that which occurred at the end of the Last Glaciation (the Devensian stage). Evidence for particular still-stands associated with each earlier cold stage is not sufficient at present to merit detailed discussion.

Evidence for relative land–sea-level change in southeast England

A stratigraphical treatment of the evidence is necessary. We can divide the Pleistocene for our present purpose into four distinct parts, as follows:

age/years	
	The Flandrian stage, covering the period of eustatic rise since the melting of the ice of the Last Glaciation, and comprising the present temperate (interglacial?) stage
10000 to ? 350000	A period of three glacial stages and of two interglacial stages, the Ipswichian (70000 to 95000) and the Hoxnian (? 150000) stages. The terraces of the Thames are associated mainly with this period
? 350000 to ? 500000	A period covered by the deposition of the Cromer Forest Bed series in the coastal area of East Anglia, with two temperate stages, Cromerian and Pastonian, divided by a cold stage
? 500000 to ? 2 Ma	A period of marine deposition (the Crags) in the East Anglian basin during the Lower Pleistocene.

We now have to consider evidence for sea-level change during each of these periods. The periods are shown linked to the British sequence of Pleistocene stages in figure 2.

					Age (B.P.)
Pleistocene	Upper	Flandrian (≡Holocene)	t	Flandrian	10000
		Devensian (≡Weichselian)	c, g	glacials and interglacials	
		Ipswichian (≡Eemian)	t		
		Wolstonian (≡Saalian)	c, g		
	Middle	Hoxnian (≡Holsteinian)	t		
		Anglian (≡Elsterian)	c, g		
		Cromerian	t	Cromer Forest Bed Series	?350000
		Beestonian	c, p		
		Pastonian	t		?500000
	Lower	Baventian	c, p		
		Antian	t		
		Thurnian	c		
		Ludhamian	t		
		Pre Ludhamian	t	Red Crag	*ca.* 2000000
Pliocene				Coralline Crag Lenham Beds	

Figure 2. Stages of the British Pleistocene, with continental equivalents. t, temperate stage; c, cold stage; g, glacial deposits known; p, permafrost known. On the right are shown the four parts of the sequence during which sea-level changes are considered.

The Crag period (figure 3)

The evidence for sea level in the Lower Pleistocene comes from the marine Crag deposits in the East Anglian basin and from certain outliers of fossiliferous Crag in more inland areas. The Plio/Pleistocene boundary in Britain is placed within the Crag sequence. The Coralline Crag is

Pliocene, the Red Crag Pleistocene. The outcrop of Coralline Crag is a few tens of square kilometres centred on Orford, Suffolk. Its height extends not far above or below O.D. The sediment is a shelly sand with comminuted Bryozoan remains and often obliquely bedded. It was evidently laid down in an area of strong tidal currents. Similar sediments are found at depths of 80 to 95 m in the English Channel today (described by Murray 1971). The Red Crag is the earliest Lower Pleistocene deposit. In its type area in northeast Essex and south Suffolk it is a red shelly sand with strong cross-bedding, found near O.D. in south Suffolk and at increasing heights towards the west and the southwest, that is, towards the margin of the Crag basin (figure 3).

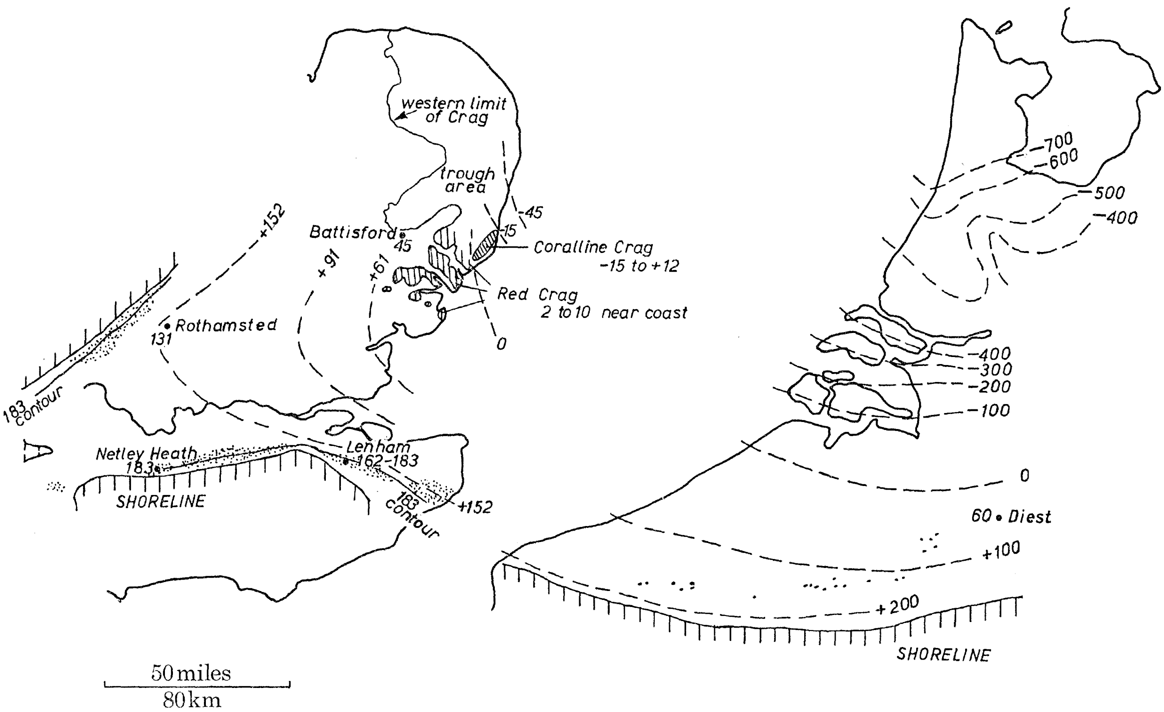

FIGURE 3. Sketch-map of southeast England and the Low Countries. The dashed lines are contours (m) of the base of the Pliocene in southeast England (after Wooldridge & Linton 1955) and in the Low Countries (after van Voorthuysen 1954). Crag sites and areas mentioned in the text are shown with their heights. The Pliocene shoreline shown is after Wooldridge and Linton and van Voorthuysen. The stippled areas show the Pliocene shelf of Wooldridge & Linton. Pliocene outliers in the Low Countries are dotted. The 183 m (600 ft) contour bordering the Thames valley is also shown.

Thus a beach with a Red Crag fauna occurs at 45 m O.D. at Battisford, Suffolk, sandstone with casts of marine shells indicative of Red Crag is at 131 m O.D. at Rothamsted, Herts (Dines & Chatwin 1930) and ferruginous sand with casts of marine shells at 183 m O.D. at Netley Heath, Surrey (Chatwin 1927). At the two latter sites the sandstone may not be *in situ*. All these Red Crag deposits show a rather similar facies, suggesting shallow marine deposition with drifting sand.

At much greater depth in central Suffolk at Stradbroke a silty facies of the Red Crag occurs in a trough in the Chalk from −15 m to −40 m O.D. (Beck, Funnell & Lord 1972).

Casts of marine shells are also found in the Lenham Beds of north Kent. These are ironstones occurring in solution hollows in the Chalk along its escarpment, at heights from 162 to 183 m O.D. (Wooldridge 1927), and their age, indicated by the marine fauna, is considered to be equivalent to the Diestian of the Low Countries, and older than the Coralline Crag.

On the continent Pliocene deposits at high levels are found in Belgium in the area of Diest and westwards, on the southern margin of the subsiding area in the central and northern Netherlands (figure 3).

Any attempt to synthesize these few observations in terms of changing sea levels is fraught with difficulty, because both the relative age of the deposits and the depth of water in which they were formed are uncertain. However, it is necessary to make an attempt.

Pliocene

Reid (1890) thought the Lenham Beds to be laid down at a depth of 60 to 100 m, a similar depth to that which he suggested for the younger Coralline Crag. The Lenham Beds lie at *ca.* 180 m O.D., the Coralline Crag at +12 m to −15 m O.D. Differential movement between Orford and Lenham of the order of 180 m (600 ft) is required, or a regression of sea level of the same order. Both factors may have contributed to the present difference in height.

Red Crag

The similarity of lithology of the Red Crag in its shallow water facies at its various outcrops has already been mentioned. We might assume a uniform depth of deposition, with heights for the sediment ranging from below O.D. in east Suffolk to 183 m O.D. at Netley Heath. The extent of time covered by the Red Crag is unknown; sea level may have changed during that time, and a regressive sea level may account in part for the slope of the deposits to the northeast. But such an explanation for the whole apparent tilt is hardly likely. It is equally possible, if not more probable in the light of the differences of level of the Pliocene deposits already mentioned, that relative subsidence to the northeast accounts for the present differences in levels, with the same trend of tilt, and a similar degree of tilt that may be distinguished in the Pliocene.

If we assume that eustatic changes played a major part in these differences of level rather than subsidence, we are then led to supposing a fall in sea level during the Pliocene, a recovery of sea level at the end of the Pliocene and a further regression during Red Crag times. Such a complex sequence would require much further evidence to substantiate it, and at present it seems preferable to hold to the view that subsidence played a major part in producing the present differences of level of the Pliocene and Lower Pleistocene deposits in southeast England. Nevertheless, the sea-level difference indicated by the shallow water Crag at Netley Heath and the deeper water at Lenham Beds, both now at the same height, argues for a eustatic fall which took place around the Plio/Pleistocene boundary. A very rough estimate of this fall might be 50 m.

According to Wooldridge & Linton (1955) the Pliocene transgression left its mark in planations and sands and gravels at heights between 168 and 198 m O.D. in the Thames region, with the Pliocene sea forming a channel coaxial with the London Basin, extending westwards and possibly open to the Atlantic in that direction. If we start off with a sea level above 183 m O.D. in Pliocene times, we have the deposition of the Lenham Beds, then the Coralline Crag. As discussed above, it appears that differential warping has subsequently tilted these deposits. The troughs of the Crag basin (Beck *et al.* 1972) are not known to contain Coralline Crag. These troughs may have developed, perhaps by scouring, in late Pliocene or early Pleistocene time, subsequent to the formation of the Coralline Crag, and in an ancient channel coaxial with the London Basin and extending northeast. The gradual blocking of this channel by the eustatic fall already referred to, with possibly some uplift in the west Wealden region, may have been responsible for the silting-up of the troughs and the deposition of the Red Crag in shallower marginal areas, early in the Pleistocene. Wooldridge & Linton (1955) considered that no transverse warping of the Pliocene shelf was demonstrable within the Thames region, so that eustatic fall at the beginning of the Pleistocene may have been the responsible factor alone. The isolation of the southern North Sea from the Atlantic in this way may have been responsible partly for the change in fauna between Red Crag and Coralline Crag times.

Cromer Forest Bed Series

This sequence of freshwater and marine sediments outcrops along the east Norfolk and north Suffolk coasts, at about O.D. (West & Wilson 1966). The sea-level changes associated with this sequence are as follows:

stage	deposit	sea-level movement
Anglian (cold)	freshwater sediments	regression
Cromerian (temperate)	tidal silts freshwater muds	transgression
Beestonian (cold)	fluviatile sediments	regression
Pastonian (temperate)	tidal silts freshwater muds	transgression regression
Baventian (cold)	marine sands and silts	

The transgression contacts between freshwater and marine sediments occurs in both the Cromerian and Pastonian temperate stages in the middle of each stage. The sea-level changes that we see in the sequence are likely to be of eustatic origin, with relatively high sea-levels in the middle and late parts of the temperate stages.

In the coast sections, the Pastonian transgression is at about O.D. in the Happisburgh area, rising by a few metres at Sheringham, near the northeast margin of the Crag Basin. In this northern area of the Crag Basin, Pastonian tidal sediments are found near O.D. or slightly higher. If, as seems likely, the Chillesford Beds and parts of the Norwich Crag in south Suffolk are to be correlated with the Pastonian, the estuarine facies of this stage is found up to 9 m O.D. near the southern margin of the basin at Chillesford. Thus it appears that the transgression sediments have been warped down in the northern central part of the basin at a date later than the Pastonian.

The Cromerian transgression contact remains near O.D. from West Runton to Kessingland, and Cromerian tidal deposits are not found in the coastal sections above 3 to 4 m O.D. They are found at their highest at West Runton, and are nearer O.D. farther south. They are not known south of Kessingland.

Thus we have a widespread transgression over the Crag Basin in the Pastonian, with some evidence of downwarping in the Happisburgh area compared with Chillesford and Sheringham, and a lesser transgression in the Cromerian, within an area bounded by the older Crag sediments.

If we are to believe that Mediterranean sea levels reflect eustatic sea levels in the Middle and Lower Pleistocene, and further that the Cromerian is to be correlated with a high sea level of 55 to 60 m O.D. (Zeuner 1959) or according to other authorities even higher, then this amount of downwarping must have occurred in eastern East Anglia since the Cromerian. But it is extraordinary that the Cromerian transgression contacts, where they have been identified, are at a similar height near or slightly above O.D. over a distance of some 80 km (50 m) of coast, in the direction from the margin (West Runton) to the centre of the basin (Kessingland). Either the coastline follows in part an isobase of downwarping or no depression has occurred and the correlation with the eustatic sea levels as enunciated and dated by Zeuner (1959) in the Mediterranean is faulty.

Hoxnian and Ipswichian interglacial temperate stages

The vegetational histories of these two interglacials is relatively well known in the southeast of England (West 1968). Both freshwater and estuarine facies are known from both interglacials, and the transgression contacts can be dated by pollen analysis.

Hoxnian

Evidence for sea-level height during this interglacial is summarized in figure 4. Transgression took place in the latter half of the interglacial and can be explained on a eustatic basis. Estuarine and marine clays are found at Clacton from 3 to 9 m O.D. (Pike & Godwin 1953; Kerney 1971) and in the Nar Valley from 5 to 20 m O.D. (Stevens 1960). The transgression at

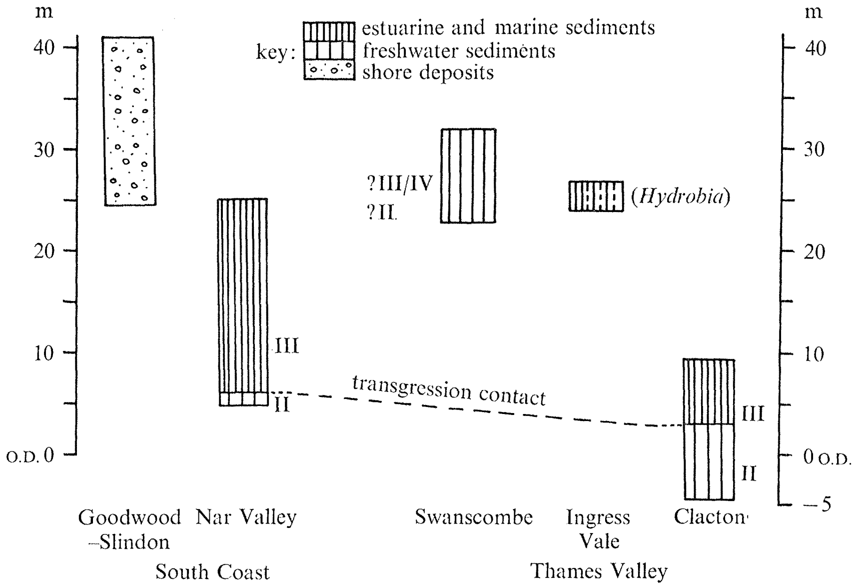

FIGURE 4. Sections indicating land–sea-level relations during the Hoxnian interglacial stage. The Roman figures refer to pollen zones, and the dashed line indicates correlation.

both these sites, at 3 m O.D. at Clacton and at 6 m O.D. at Horse Fen in the Nar Valley, took place in Zone Ho III at Clacton and near the end of Zone Ho II at Horse Fen. The difference in the heights of the transgression and its timing between Clacton and the Nar Valley suggest a small amount of downwarping between Clacton and the Nar Valley since the Hoxnian. In the Nar Valley the marine clay reaches a height of at least 20 m O.D. The depth of deposition indicated by the sediment is at least 3 m, giving a minimum estimate for the maximum sea level reached of 23 m O.D.

The major part of the aggradation of the Boyn Hill ('100 ft') Terrace of the Lower Thames took place during Hoxnian times. The evidence for sea level at the time of terrace formation is not as strong as at Clacton and the Nar Valley. At Dierden's Pit, Ingress Vale, near Swanscombe, shells of the brackish water genus *Hydrobia* and the vertebra of a dolphin have been found at about 25 to 27 m O.D. (Kerney 1971). The aggradation of the terrace deposits, linked with the very gentle slope of the terrace in the Lower Thames, is conformable with evidence of high sea levels from the Nar Valley.

On the south coast, at Goodwood and Slindon in Sussex, beach deposits form the so-called '100 ft' beach, with a temperate marine fauna, found at heights from 25 to 40 m O.D. Palaeolithic implements have been found associated with these deposits. It is likely that these beach deposits are in part of Hoxnian age. Their height brings them within the range of the transgression height known from the Hoxnian deposits of the Nar Valley and the Boyn Hill Terrace.

In summary, in the Hoxnian there is evidence of a high eustatic sea level of at least 23 m O.D. reached during the later half of the interglacial. There is some evidence of relative downwarping in the Clacton area.

Ipswichian

Evidence for sea-level height in this interglacial is summarized in figure 5. At Selsey, Sussex, a marine transgression at −1.8 m O.D. is recorded in zone Ip IIb of the interglacial (West & Sparks 1960). Estuarine deposits of this zone are overlain by the beach gravels of the Selsey peninsula. This raised beach shingle reaches an elevation of 7 m O.D. on the coast west of Selsey

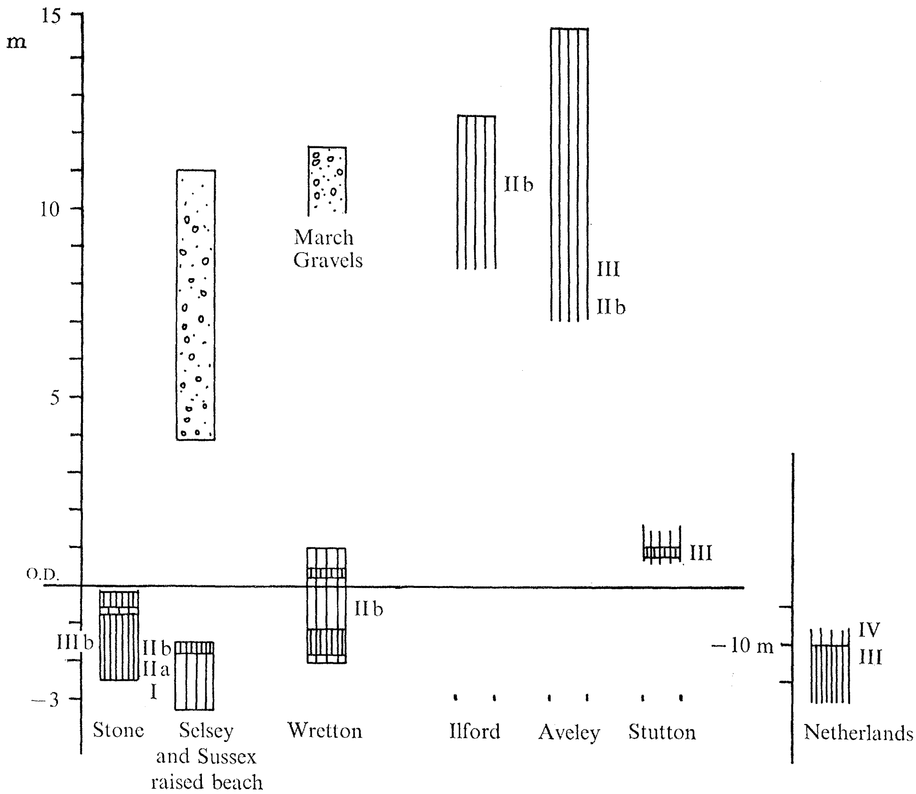

Figure 5. Sections indicating land–sea-level relations during the Ipswichian interglacial stage. The Roman figures refer to pollen zones. Key as in figure 4.

Bill. Raised beach shingle is known from many neighbouring localities, mostly in the east between Littlehampton and Brighton, at about this elevation in the Sussex coastal plain, and has been usually described as the '15 ft' beach. The related former shoreline is to be found at Black Rock, Brighton, where Smith (1936) recorded maximum elevation of 11.5 m O.D. for the top of the shingle. The maximum height of wave activity may be taken as about 12 m O.D., this representing probably an elevation of about 1 m above high spring tide level. At present Brighton has a maximum tidal range of about 6.7 m, so that mean sea level during the formation of the beach was probably about 7.5 m above the present one. This level may then represent the high eustatic level reached during the last interglacial, and which, from evidence on the continent, is known to have occurred in pollen zones *f* and *g* (equivalent to our zones Ip IIb and III), covering respectively the mixed oak forest and hornbeam zones of the warmest part of the interglacial.

The Ipswichian site at Wretton, Norfolk (Sparks & West 1970), shows brackish horizons in zone Ip IIb between −1.95 m and +0.45 m O.D. in a mainly freshwater sequence. This elevation and timing of the transgression is very similar to that at Selsey. The March Gravels (Baden-Powell 1934) are widespread in central Fenland and are generally considered to be of last interglacial age. They have a rich marine fauna, and range up to 10 to 12 m O.D., a level very much the same as the highest elevations reached by the Sussex gravels. Their height agrees well with what might have been expected from the height of the last interglacial aggradation in the Cam valley (Sparks & West 1959) to about 12 to 13 m or a little above in the Histon Road deposits.

There is thus reasonable evidence for a higher than present sea level in the Fens and on the south coast during the Ipswichian Interglacial. But at certain other sites a different situation obtains. But at Bobbitshole, Ipswich (West 1957) freshwater deposits of zones Ip IIa and b extend from −2.5 m to +1.0 m, with no signs of marine influence. It may be concluded that the Ipswich area has been downwarped relative to the Sussex coast since the beginning of the Last Interglacial, at least enough to bring the zone IIb deposits below the transgression levels seen at Selsey and Wretton. At Stutton, Suffolk, 8 km to the south, zone Ip III sediments have a mollusc fauna which shows a slight brackish influence at about 1.0 m O.D. with no brackish indications above or below (Sparks & West 1963). This level may approximate to the limit of salt-water influence and cannot be lower than the highest level reached by the tides. If the tidal range in the area is assumed to have remained unchanged, this means a sea level not above 1.2 m below O.D. at the time. It seems probable that the level with the brackish molluscs is that of the highest sea level reached during the interglacial. The regression is known on the continent to have occurred in a zone later than the hornbeam zone, zone Ip III. If this assumption is correct, then a downwarping of the Stutton area relative to Selsey of about 9 m has taken place since the middle of the Last Interglacial.

Sites of Ipswichian age in the lower Thames Valley present a different picture. At Ilford, alluvium (brickearth) aggrades to 13 m O.D. in the late part of the interglacial (West, Lambert & Sparks 1964). At Aveley (West 1969) and Crayford aggradation takes place to a height of 15 m O.D. These heights are slightly in excess of the suggested maximum sea level for this interglacial. Are we to conclude that uplift has occurred in this region, relative to Selsey, since the end of the last interglacial? Is this uplift related to movement of the Purfleet anticline?

In summary, we see evidence in the Ipswichian for an eustatic rise in sea level up to 7.5 m O.D., evidence of downwarping of the Ipswich and Stutton areas, and perhaps slight evidence for uplift in the Ilford and Purfleet areas.

Flandrian

The rise of sea level in the Flandrian is well-documented. Figure 1 shows the general agreement about the trend of the rise and its timing and also the disagreement as to details. Figure 6 shows the rise of sea level in an area off the south Devon coast (Clarke 1970) and in the Netherlands (Jelgersma 1961). Even though subsidence may have affected the Netherlands curve more than the Devon curve, there is general agreement between them. The origin of the course of the curve must be principally in the eustatic component of sea-level change, a result of the melting of the world's ice sheets since the last glaciation. The available data indicate, then, a rising sea level in Flandrian times, with a slowing down of the rise around 6000 B.P. There is some doubt whether the present position was reached only recently or by about 3600 B.P. There is disagreement about whether or not the Flandrian sea level has been higher than now. Regarding the eustatic level in the last 100 years, evidence has been brought forward that a rise of 10 cm has taken place in this time (Jelgersma 1961).

In the area of southeast England little exact data is available concerning the rate of rise of sea level. Figure 6 shows some radiocarbon dated coastal freshwater (or perhaps brackish) deposits and their position relative to sea level. Assuming the organic deposits dated were formed in relation to a rising sea level, the dates and levels in general conform to the eustatic curve. The stratigraphical information is not sufficient to make a close relation of the dated samples to contemporary sea level.

In the southern North Sea Jelgersma (1961) has constructed a curve of rise of sea-level based on pollen-analytical dating. This curve is also shown in figure 6.

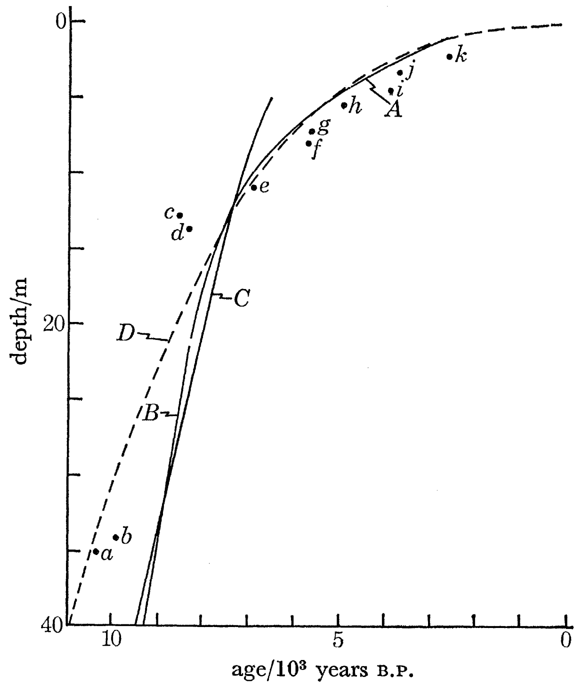

FIGURE 6. Curves for the Flandrian eustatic rise of sea level. *A*, in the Netherlands (Jelgersma 1961); *B*, in the southern North Sea (Jelgersma 1961); *C*, off the coast of south-east Devon (Clarke 1970); *D*, curve of Shepard (from figure 1). Date sample numbers as follows: *a*, NPL 103; *b*, NPL 101, both in the English Channel: *c*, I 2826; *d*, I 2828; *j*, I 2827, all in the Aldeburgh area: *e*, Q 790; *f*, Q 791; *g*, Q 811; *h*, Q 810; *i*, Q 792; *k*, Q 793, all at Tilbury.

The problem before us is whether or not subsidence has played a substantial part in determining the course of the curve in our area. The similarities of the curves in figure 6 suggest that the eustatic curve has not been greatly transformed by subsidence in the Flandrian. Even in the Netherlands, nearer the centre of thick sediment accumulation in the Pleistocene, subsidence has probably not exceeded 1.5 to 3.4 cm per century (Jelgersma 1961), making a total in the Flandrian of between 1.5 and 3.4 m, a negligible amount in terms of the eustatic rise.

This conclusion does not agree with Churchill's (1965) deductions concerning subsidence in southeast England. A figure of 6 m of vertical displacement downwards since 6500 B.P. was suggested in the Tilbury area based on the Flandrian sequence exposed during dock excavations. But the datum for sea-level at 6500 B.P. was taken to be −3 m O.D., based on observations in South Africa, whereas according to curves of sea-level change in our area (and elsewhere), the level at 6500 B.P. was approximately −9 m O.D., indicating that the Tilbury sequence has not yet been demonstrated to have undergone subsidence in the Pleistocene.

On the other hand, farther north in the Great Yarmouth area, evidence has been put forward for subsidence in the Late Flandrian. At Great Yarmouth Green & Hutchinson (1965) suggest a subsidence of some 4 m (13 ft) since 1287 A.D., based on the present level of silt formed during a great flood in that year.

In summary we can say that in the southeast there is no clear geological evidence that subsidence has played a significant part in determining the course of sea-level rise. Much more evidence of the dates and levels of transgression and regression contacts is required to clarify further the elements concerned in these relative land–sea-level changes over the past 10000 years.

Conclusions

The changes we have viewed are those which have occurred on the southwest margin of the basin of subsidence in the North Sea. In the northwest Netherlands the Pleistocene reaches a thickness of over 600 m. In East Anglia in the deepest part of the Crag basin near Great Yarmouth depths of over 70 m are recorded. The Crag thins to the south and west, till we reach the limit of the basin in central Norfolk and Suffolk and in northern Essex. In the same way, the

age B.P. years	Period considered		net downwarping estimated amount (m)	expressed from	to	Eustatic change (referring to highest recorded sediments)
0–10000	Flandrian					45 m rise to present sea level in this period
10000–?350000	Glacials and Interglacials	Ipswichian	10	Selsey	SE Suffolk	rise to 7.5 m above present sea level
		Hoxnian	3	Nar Valley	Clacton	rise to > 23 m above present sea level
?350000–?500000	Cromer Forest Bed Series	Cromerian	[> 55	E. Anglia	Mediterranean]	rise to 3–4 m above present sea level
		Pastonian	5	Chillesford	Happisburgh	rise to 8 m above present sea level
Pleistocene ?500000–2000000	Red Crag		183	Netley Heath	SE Suffolk	fall of 50 m
Pliocene	Coralline Crag Lenham Beds		183	Lenham	SE Suffolk	

Figure 7. Summary of land–sea-level changes in southeast England.

marine interglacial deposits of the Holstein (= Hoxnian) and Eemian (= Ipswichian) interglacials occur at depth in the Netherlands. Thus the maximum sea level reached in the Eemian appears to be now at −10 m below present sea level (figure 5), whereas the Ipswichian deposits in southeast England show transgression above present sea levels, as we have discussed.

This marginal area would have been particularly sensitive to sea-level changes, both those caused by eustatic changes and those caused by warping. The conclusions brought forward in this account are summarized in figure 7. We must stress that, like all conclusions concerning relative land–sea-level change, they are open to controversion on the basis of the interpretation of data used and assumptions made. They are certain to be modified by future work.

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