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SOME IMPORTANT STAGES IN THE QUATERNARY DEVELOPMENT OF THE THAMES ESTUARY

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RÉSUMÉ

L'estuaire de la Tamise fut formé par suite de l'envahissement de la partie est du bassin de Londres par la transgression flandrienne. Le bassin avait été fortement modifié par le creusement de plusieurs vallées fluviales aux époques de régression et ces bassins hydrographiques, avec leurs terrasses, ont été cartographiés en utilisant des profils séismiques continus. Le tracé de ces rivières a été influencé par une série de plis monoclinaux de direction nord-sud, et par une ondulation monoclinale sud-ouest - nord-est, qui traverse l'extrémité de l'estuaire. En outre, des parties de la section aval de l'estuaire ont été affectées par les calottes glaciaires pléistocènes, qui ont provoqué la formation d'une série de chenaux sous-glaciaires allongés dus au surcreusement.

Les dépôts plus récents dans l'estuaire de la Tamise montrent une série de graviers résiduels de sédiments de marais intertidaux et de marais salants, avec finalement une couverture de sables marins.

1. INTRODUCTION

Although the most satisfactory method for the classification of estuaries is possibly a method based upon the salt-balance equation, other methods have been suggested in the past and at times have proved useful. One of these, based upon the mode of formation of the basin that the estuary occupies, Pritchard (1967), can certainly be applied to the Thames Estuary. Pritchard divided estuaries into four groups:

a) drowned river valleys;
b) drowned glacial valleys;
c) bar built estuaries;
d) estuaries formed by tectonic processes.

It will be shown that the Thames Estuary fits primarily in subdivision *a*) but that elements of *b*) and *d*) have had some influence.

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The Thames Estuary has been the object since 1964, of an intensive study by a group of workers, centred on a number of London colleges. This study, which is still continuing, has been concentrated on the outer reaches of the estuary, in the area east of Southend. Recently, feasibility studies for a Third London Airport, to be sited on reclaimed tidal flats at Maplin, within the estuary, allowed an immense amount of material to be examined. Much of this material has still to be "worked up," but some preliminary findings are proving useful towards the clarification of some aspects of the estuary's Quaternary development.

2. METHODS OF INVESTIGATION

Some 3 000 samples of the sediments flooring the estuary have been taken by grab and dredge. In addition some 50 shallow gravity cores and some 140 deep cores, most of the latter in connection with the Third London Airport feasibility study, have been examined. Also some 2 800 kilometres of continuous reflection seismic profiling which has been carried out since 1967, have added much to the knowledge of the underlying bedrock structure and the form of the overlying, probably Holocene, sedimentary layers. Studies of seabed sedimentary movement and bedform have been aided by 2 500 kilometres of "side-scan sonar" recording, obtained in the area over the same period of time.

3. GEOLOGICAL SETTING

Except for a narrow area offshore of the Isle of Thanet where the Chalk and Lower Eocene rocks of the Landenian stage outcrop, the whole of the estuary is floored by the London Clay which represents the Ypresian stage in the London Basin. However the underlying structure of this basin is not the simple model it was once thought; of a plunging synclinal, dipping gently towards the North Sea Basin. Instead a large monoclinal trending in an East-South-East direction from the region of Clacton-on-Sea, effectively completes the eastern margin of the London Basin. This monoclinal which has a steep South-South-West facing limb is a complex structure with a 3-step form. Preliminary work indicates that all the Tertiary formations thin over this structure, but whether this is due to phases of erosional activity or to initial condensed deposition is not yet certain. The London Clay is thickest, nearly 200 metres, in the synclinal to the south of the River Crouch but it thins to less than 30 metres over the monoclinal. Other structural elements consisting chiefly of a series of north to south trending folds affect the southern margin of the estuary (D'Olier, 1974).

4. PALAEODRAINAGE

Wooldridge (1960), suggested that the River Thames had run in a series of more northerly courses across the London Basin and had been progressively diverted to more southerly positions by successive advances of Pleistocene ice-sheets. Using the information provided by the seismic reflection profiler and from boreholes, a detailed reconstruction of the mostly buried and submerged valley system of the River Thames and its tributaries has been made possible (fig. 1). As might be expected, a buried river channel, complete with terraces, levees and other riverine features can be traced for each of the rivers presently draining the high ground surrounding the estuary. In addition, other river systems whose whole drainage area has been submerged, have been identified. In this way a drainage system comprising the offshore extensions of the river Thames, Medway, Crouch, Roach, Blackwater, Colne, Swale, Bishopstone, Kentish Stour and those rivers without a present-day counterpart, are seen to drain eastwards to join a deep channel, cut and at present exposed on the floor of the North Sea just to the east of the North and South Falls sandbanks. To the north another quite separate drainage system is the offshore repre-

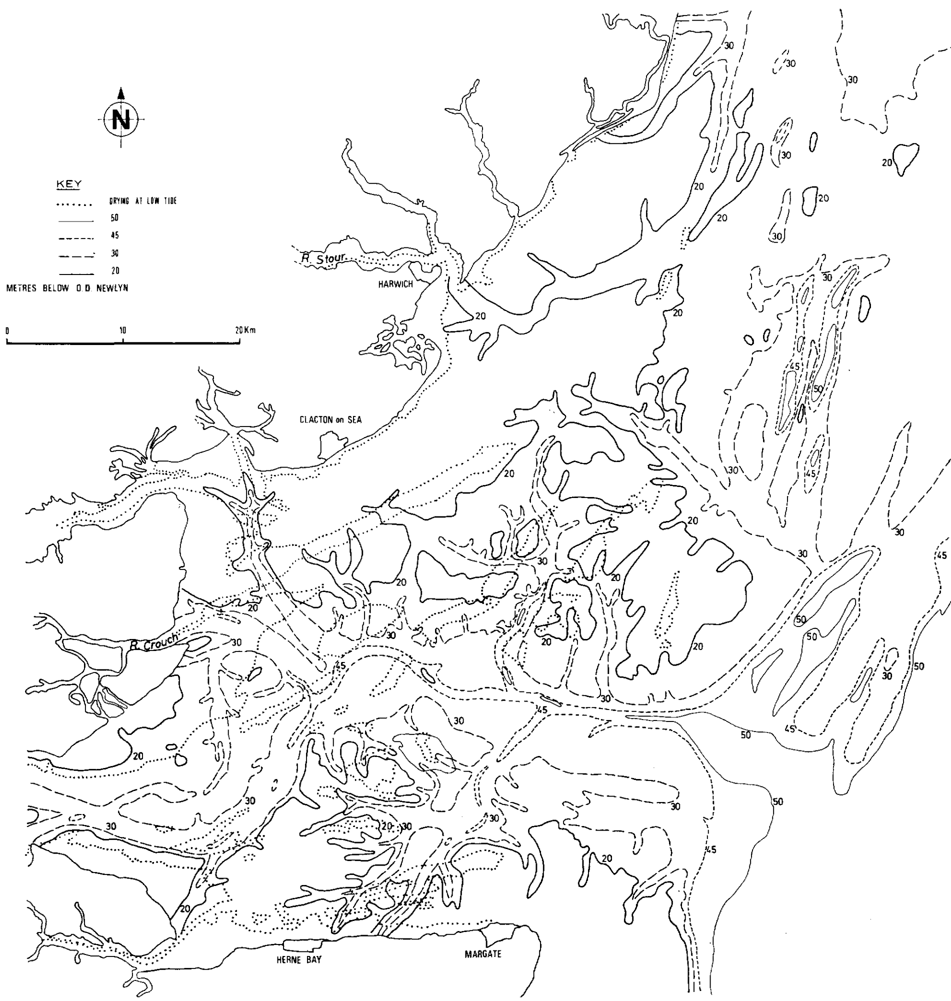

FIG. 1. — *The Thames Estuary. Contours of the bedrock surface.*

sentation of the Essex and Suffolk rivers: Stour, Orwell, Deben, Butley, and Alde. Two well developed terraces can be identified within all these river systems, one at approximately 15 metres, the other at 25 metres above the floor of the buried channel. From evidence (Wooldridge, 1955), obtained in the higher reaches of the River Thames, these two terraces would appear to be the Upper and Lower Flood Plain Terraces, the former of late Saalian, and the latter of early Weichselian, the buried channel is a late Weichselian feature. In fact all these features are the result of late Pleistocene sea-level fluctuations and no trace has yet been determined of the course of these rivers during the early Pleistocene when as mentioned previously the Thames and its tributaries were thought to have run a more northerly course. Evidence of an Eemian shoreline represented by a submerged cliff-line cross-cutting the Upper Flood-plain Terrace but not affecting the Lower Flood-plain Terrace, is found in some parts of the Estuary. It is best developed at a level of minus 24 metres Ordnance Datum, though differential subsidence appears to have had some effect upon it.

The Thames Estuary bears evidence of a more immediate presence of the Pleistocene ice sheets. Some 35-45 kilometres due east of Harwich and Clacton (fig. 1) is a series of "en échelon" over-deepened channels having the following features in common:

a) they run North-South or North-East - South-West;
b) they are very straight in course with flat bottoms and quite steep sides;
c) they have an undulating longitudinal profile;
d) they have steep closed ends.

They are of variable dimensions, being between 4-25 kilometres long, between 1,5-3,5 kilometres in width and between 30-72 metres in depth below O.D. (Newlyn). It would appear that these channels have all the characteristics of sub-glacial tunnel valleys formed by melting ice water flowing under great hydrostatic pressures, Valentin (1957), Woodland (1970), Dingle (1971), Donovan (1973). In addition, features closely resembling "ice-push ridges" are to be seen within the surface layers of the London Clay, in the vicinity of these channels. From their position, it would seem very possible that the normal eastward flowing drainage of the River Thames system was blocked by the ice lobe that caused the erosion of these over-deepened tunnel valleys. Some of the high level gravels found around the Thames Basin might well be shore-line deposits of the resulting ice-dammed lake. The age of this ice advance cannot, as yet, be determined although it is felt that it is most likely to be Saalian.

Consequent on the last sea-level rise, the river channels were steadily invaded by the advancing Flandrian sea. Over a basal lag gravel deposit of late Pleistocene age, a "fining up" sequence of sands, silts and clays were laid down. The old river channels remained for a long time as tidal inlets and creeks, whilst the interfluves became variously lower or upper tidal flats and saltmarshes. Tidal range was variable during this period from 9 600 B.P. to approximately 6,500 B.P., due to the rapidly changing shape of the basin over which the sea was transgressing. On the peripheries of the basin, this changing shape is expressed in a variable sequence of tidal flat and marsh sediments, Greensmith and Tucker (1971). However, in the more central parts the sequence is simpler, being a "fining upward" sequence with minor changes in character, unconformably overlain by a uniform spread of fine to medium sand. This is the kind of material which makes up the large linear tidal ridges or sandbanks that dominate the estuary at the present day. It is thought this marked change of sedimentary facies is due to the monoclinal being overtopped for the first time and consequently the strong North Sea tidal system beginning to operate within the estuary. Large supplies of sand reworked from glacial tills cloaking the North Sea floor to the north, were then able to move into the estuary under the influence of this tidal system. This action is continuing at the present day. Numerous sand ribbons and sand patches, Kenyon (1970), have been identified and these appear to be the pathways along which much sand is being transported into the estuary, D'Olier (1973).

5. CONCLUSIONS

The Thames Estuary which fits Pritchard's classification for a drowned river valley estuary, has a long history of development reaching back to Saalian times. As yet, an even earlier history has not been elucidated.

A large East-South-East trending monoclinal dominates the estuary having had a profound effect upon the sedimentary history of the Tertiary rocks comprising the bedrock and upon recent sediment patterns.

Fluctuating sea-levels during the Pleistocene have modified the form of the drowned river system, whilst the positive presence of an ice-lobe which caused the cutting of some deep tunnel valley and formed ice-push ridges has been identified.

Finally, sediment pathways bringing fine-medium sand into the estuary from the North Sea have been identified.

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DISCUSSION

K. H. CLAYTON. — *In view of his hypothesis for the origin of narrow depressions as subglacial, I should like to ask Dr. D'Olier how he explains the fact that the submerged channel of the Thames is full of sediment while the depressions are free of sediment.*

B. D'OLIER. — I have little evidence for the age of the ice "formed channels." They are quite fresh, which might suggest Weichselian age but there is no other evidence for that age. Saalian age seems more likely and they have retained their shape and features by being infilled. The Flandrian transgressive sea through being gentle, eroded out the infill but only after the strong North Sea tides began to operate after the overtopping of the Lincolnshire Dogger Bank-Holland Barrier about 8 500 B.P. The Eemian sea had been unable to do this as tidal velocities would have been too low.

J. I. S. ZONNEVELD. — *If the valleys in the North Sea bottom you mentioned are really subglacial valleys it must have been the Saal ice under which they were formed. The Saal ice did reach this area. The Weichsel ice did not. But how could you explain that the relatively fresh forms of the valleys remained despite the (eolian and fluvioglacial) deposition that must have occurred in the North Sea plain during the Weichsel period?*

B. D'OLIER. — At the present time even in areas of soft rock type and of very high tidal velocities the bed rock is not being eroded into linear, closed ended troughs. For example between the linear sandbanks resting on London clay in the Thames Estuary where the currents run very strongly this is not happening.

F. GULLENTOPS. — *Are these narrow trenches not to be explained as scoured out by tidal currents? Trenches like these exist under the Belgian Diest sands and tidal trenches may have steep sides and closed ends.*

B. D'OLIER. — The glacial channels are aligned to the dominant tidal direction at present and have been eroded of their contained sediment. The infilled buried channels are at right angles to the tidal flow and have therefore acted as a sediment traps. This is shown by those sections of the two buried channels that are aligned to tidal flow, and are also excavated or partially excavated.