HUMBER HOLOCENE CHRONOLOGY

Solid Geology

The solid geology of the area has been extensively described in a number of previous publications (BGS, 1982; Gaunt, 1994; Gaunt et al. 1992; Berridge & Pattison, 1994; Jones, 1988). It is summarised pictorially in Figure 1.

Holocene Geology

This section focuses on the changes that have taken place within the basin defined by the solid geology and how this may continue to evolve in the future. The chronology of the Holocene development in the Humber basin is summarised in Table 1.

Table 1. Holocene chronology

Time BP	Chronology of Events
pre 18000	Ice cover
18000-16000	Outer channel scoured out by ice melt waters out to -25mODN contour
post 16000	Outer channel continues to be scoured by fluvial waters
14000-10000	End of last glacial period Sea levels below -45mODN Lake Humber infills with fresh water sediments from land runoff Sill at Hull creates either a complete barrier or more likely a waterfall to a lower level river which flows on to the North Sea (see Figure 4)
10000	Sea level somewhere between -16m and -30mODN Possible that fluvial incision is formed in sill at Hull Lake remains fresh water
8500	Garthorpe suite begins to develop in outer estuary (see Figure 6 for details of how suites relate to take up of accommodation space)
8000	Sea level somewhere between -12 and -14mODN Lower crest of sill overtopped by tidal waters (sill now at -12mODN but it may have been subject to further erosion since initial tidal breakthrough – see Figure 4) Lake begins to exhibit brackish influence
7400	Deposition of Newland and Butterwick suites within the lake upstream of the sill. This is overlain by the Garthorpe suite from about 6600, reflecting the progressive marine influence Extensive saltmarsh
6500	Sea level about -8mODN Peats at the end of Spurn (at -7mODN) suggest a period of marine regression and narrowing of the estuary; possibly linked with the marked slowing in the rate of sea level rise.
6000-3600	Full channel flow established Lake becomes part of the tidal headwaters and marine influence begins to dominate flora, fauna and sediments Plenty of accommodation space for sediment infilling, which probably meant that the channel maintained a stable alignment. Upstream of Trent Falls the channel may not have followed its present day alignment but there are insufficient data to properly map any change.
4000-1600(?)	Sea level rises from -4 to -2mODN (a rate of 1mm/year) Extensive sandflats and mudflats as the Saltend suite is laid down in an environment with pronounced channel switching
1600(?)-600	Return to a more stable channel alignment and saltmarsh habitat. The Sunk Island suite begins to be laid down in this period (from at least 800BP – see Figure 6) Climatic optimum occurs from 900-700BP (1100-1300AD)
600-200	Deposits are once again largely channel sediments (sand and mudflats) with channel incision and migration Anthropogenic reclamation and sea walls may have removed some of the available accommodation space. Little Ice Age occurs from 450-250BP (1550-1750AD)
150-50	Sediment continues to infill the channel but sea walls limit take up of accommodation space
50-present	Sea level in estuary rising at between 1 and 2mm/year Erosion of channel in outer and middle Humber

The pre-Holocene basin initially comprised an ice melt/fluvial channel from the North Sea to Hull, where a sill held back much of the fresh water in the Humber Lake. This is shown as a perspective view in Figure 4. As sea level rose so the sea began to occupy the river channel and the estuary started to migrate landwards. During this phase the channel is likely to have been wide and shallow, allowing sediments to deposit at the margins, so beginning to infill the pre-Holocene basin; see Figure 5. The channel is likely to have followed a fairly stable alignment and given the rate of infilling, was almost certainly flood dominant, importing marine sediments as well as receiving fluvial run-off sediments.

The process of sediment deposition takes up space within the basin, referred to as accommodation space. Changes in this space are instructive in helping to understand how the estuary has evolved. The general pattern for the Humber as a whole is illustrated in Figure 6. The rapid take-up of sediment in the early period is clearly evident. It is also worth noting that an analysis based on subdividing the basin in to a number of smaller areas indicates a similar pattern of infilling. Whilst other factors such as climate change and deforestation have been examined, these changes do not correlate with borehole data, such that it would appear that accommodation space may be the controlling influence on channel migration.

River flows progressively scoured the sill and at the same time, sea levels were rising. In the end the overflow of freshwater at the Hull sill (a sort of waterfall) became a tidal channel, with fully marine conditions being established in the inner part of the basin by about 6000 years BP.

Based on evidence from other estuaries, the reduced rate of sea level rise at about this time enabled the system to adjust to something close to a steady state (i.e. to catch-up with itself). One might therefore have expected a slow down and switch to ebb dominant conditions some time after about 6000 years BP. This does not appear to have happened, possibly because the break through to the inner basin at roughly the same time would have created an additional demand for sediment (possibly indicated by the flattening of accommodation space curve over the period from 6000-4000 years BP, Figure 6).

Such a change does however appear to have happened after about 4000 years BP, as accommodation space reduces. Over the interval -8 to -4mODN, the sides of the Holocene basin become steeper, particularly in the reach from Paull to Ferriby. This would have constrained the channel, possibly keeping more material in suspension and increasing the potential for channel migration. This is reflected in:

i) The sediments of the Saltend suite, which comprise of laminated muds and fine grained sands, characteristic of sand and mudflats; and
ii) The erosional contact with the Garthorpe suite, which suggests channel migration away from the present day alignment.

As accommodation space increases (from about 1600 years BP) due to high level widening of the Holocene basin (from about -4mODN), so the channel stabilised and the saltmarsh habitat was re-established[1]. Some time, possibly in the interval 800 to 200 years BP, the channel migrated again and the most recent suite of sediments (Sunk Island suite) are once again dominated by sands and muds characteristic of sand and mudflats.

[1] The relationship between accommodation space and channel sinuosity has long been recognised within fluvial environments (Allen, 1985; Selley, 1988) and studies (Dalrymple *et al.* 1992) have shown that channel migration is most common in transitional parts of the estuary where river currents become dominated by tidal currents.

The accommodation space has been calculated for this study by (a) lowering a horizontal surface based on the relative sea level curve and (b) lowering the existing channel bathymetry in the same way. This approach has been adopted because one of the outstanding difficulties is to define the size and position of the channel through the Holocene. The sediments reveal that the channel has moved about and in part define a boundary to that movement (based on the erosional contact between suites of sediment). Defining the changes in volume of the channel is, however, going to require more detailed modelling of the palaeo-tidal changes in the estuary.

One other important contribution from the Holocene studies is the improved definition of the thickness of the Holocene sediments, which have now been mapped for the entire Humber basin and out along the palaeo-channel to New Sand Hole. This is shown as a contoured map of sediment thickness in Figure 7. The plot illustrates where the sediments are thin or non-existent, so that erosion is likely to be constrained by the underlying Pleistocene deposits of till material, and where there is a substantial thickness of Holocene sediment, presenting the possibility for future channel migration.

Overall the estuary has undergone landward transgression under influence of a, largely, monotonically increasing sea level. Within this period there will have been oscillations and stands in the rate of sea level rise and the importance of these within human time scales should not be underestimated. Indeed the forecast increase in rate as a consequence of global warming could be just such a fluctuation. Such an increase might be expected to increase the take-up of accommodation space, providing an environment for a stable channel alignment and saltmarsh development. The presence of sea walls will, however, limit the available accommodation space, so that the system may retain its present form of incised migrating channels with extensive sand and mudflats. In the longer term (centuries) one might expect the estuary to encroach into some of the accommodation space currently behind the sea walls.

Estuary Features

Mouth

Recent work by Balson (1999) develops the possible Holocene evolution from that presented by (Berridge & Pattison, 1994). This suggests that the north bank of the estuary followed the line of the palaeo-channel out to New Sand Hole. Under the influence of rising sea levels the seaward point has retreated in line with the retreat of the Holderness coast, Figure 8.

This is not to say that the spit necessarily existed in its present form in this seaward position. A borehole taken on the southern end of Spurn shows the presence of a peat (dated as 6500 years BP at –7m ODN), overlaying shelly gravel, which extends down to the till surface at about –17mODN. Seismic records of the palaeo-channel indicate that rounded beach gravels have overspilled from the north into the channel along much of its length. It is possible that at some point prior to 6500 years BP, a recurve spit formed to seaward with its distal end terminating at the current most southerly point of the spit. Alternatively, recognising the lower sea level at this time, wave exposures would have been very different. The Dogger Bank would still be limiting fetches from the north, so that the longest fetches would have been from the east and south-east. Consequently alongshore drift on a north-east to south-west oriented coast would have been into the estuary and may have formed a gravel beach along the northern side of the channel.

The peat horizon at about 6500 years BP suggests that extensive mudflats formed in the sheltered area behind the spit or barrier beach. Subsequently the system has rolled back over the mudflats, exposing mudflat and peats to seaward, from where they have been eroded. This reflects the current structure of sediments along Spurn, which form two distinct lengths, Figure 9. Over the more northerly length, mudflat overlies the till surface and is exposed on the seaward beach face. The surficial spit is formed from a small volume of blown sand. In contrast to the south, there is a substantial volume of sand and gravel forming the beach face and extending out to the Binks. This mass of sediments protects the mudflat sediments to the rear and is overlain by the blown sand, which again forms surficial spit as seen on OS maps. The crucial difference between these two lengths is that whilst the one to the north can erode and realign, the length to the south is protected.

This pattern of evolution is broadly consistent with the one proposed by Pethick (IECS, 1992), although he suggests that the protection is in part provided by a glacial moraine along the edge of the channel. It also accommodates the movements noted by (de Boer, 1964), recognising that he focused on maps of the surficial spit rather than the underlying structure as discussed above.

Meanders

The meandering form of the channel from Hull out to the North Sea was probably cut into the tills by ice melt and subsequently fluvial flows at the end of the last glaciation. Why it took this form is not clear but one suggestion is that the ice front may have halted or re-advanced to a line roughly following the north bank. Thereafter tidal waters progressively occupied the channel and began the process of infilling the basin, as described above. Whether the alignment has been maintained because of the resistance of the underlying tills (where exposed), or the presence of glacial moraines, deposited along the line of the ice front, is not clear.

Rivers

The major change within what is now the river section of the Humber, is clearly the transition from a fresh water lake to a brackish lake before it finally became the head waters for the estuary itself. Comparing the present day channel alignment with the depths of the pre-Holocene basin it would appear that the channel for the Ouse may have migrated southwards between Trent Falls and Goole. There are however only a few boreholes in this area and the true extent of the pre-Holocene basin may not have been reproduced in the model of this surface.

Delta

As a mobile feature resulting from contemporary processes, the development of the estuary delta would have to be inferred from the nature of underlying sediments. Information in the vicinity of the mouth is however scarce and whilst the locations of some sub and intertidal sandbanks have been suggested (Berridge & Pattison, 1994) nothing has been reported on the ebb/flood delta. Some recent work using seismic data along the palaeo-channel from Spurn to the New Sand Hole (Balson, 1999), shows some evidence of scour holes. This may reflect the landward migration of the mouth and it is to be expected that any delta would have followed this migration.

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Acknowledgements

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2 See also (Rees et al. 2000).

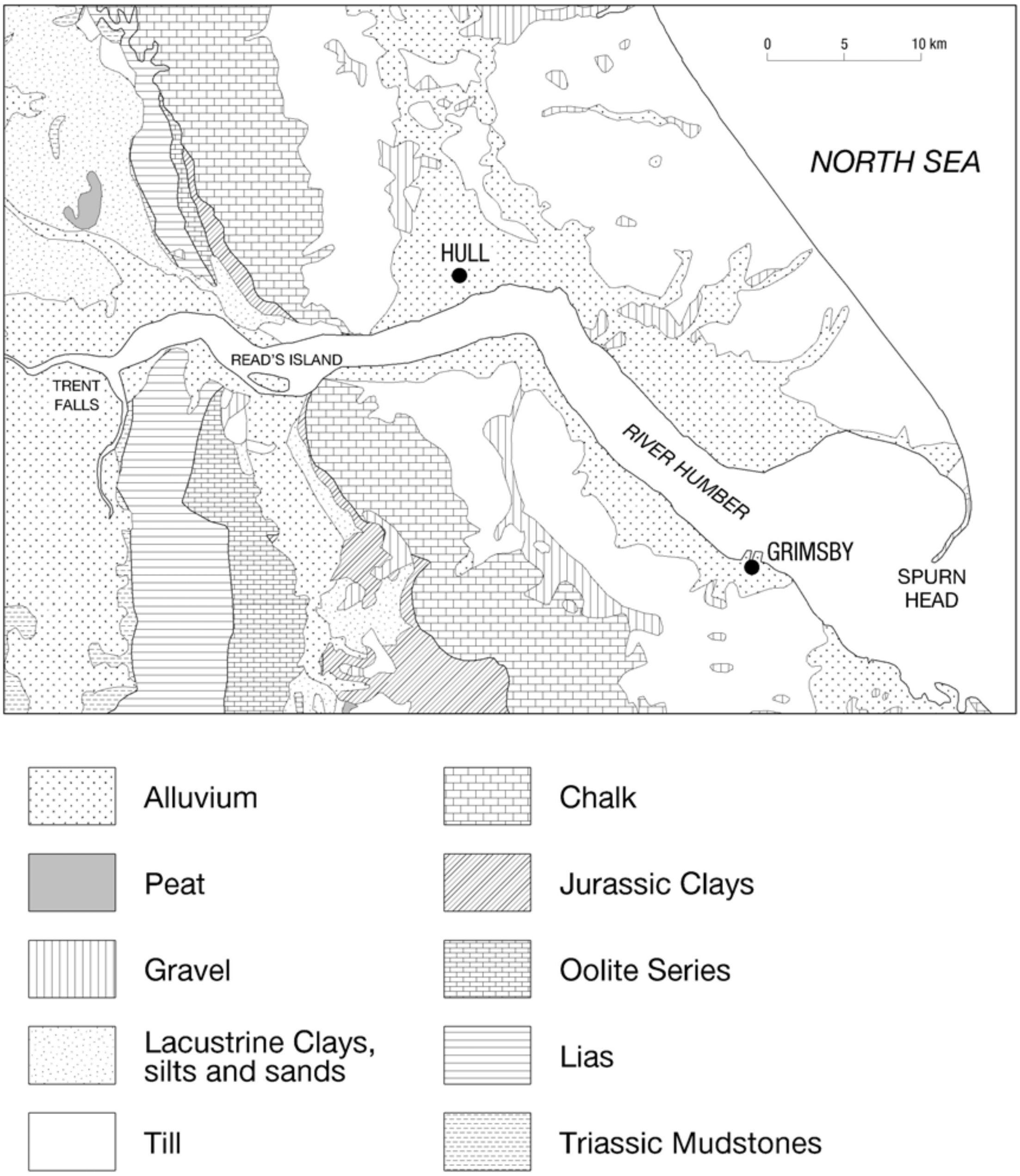

Figure 1. Solid geology (BGS)

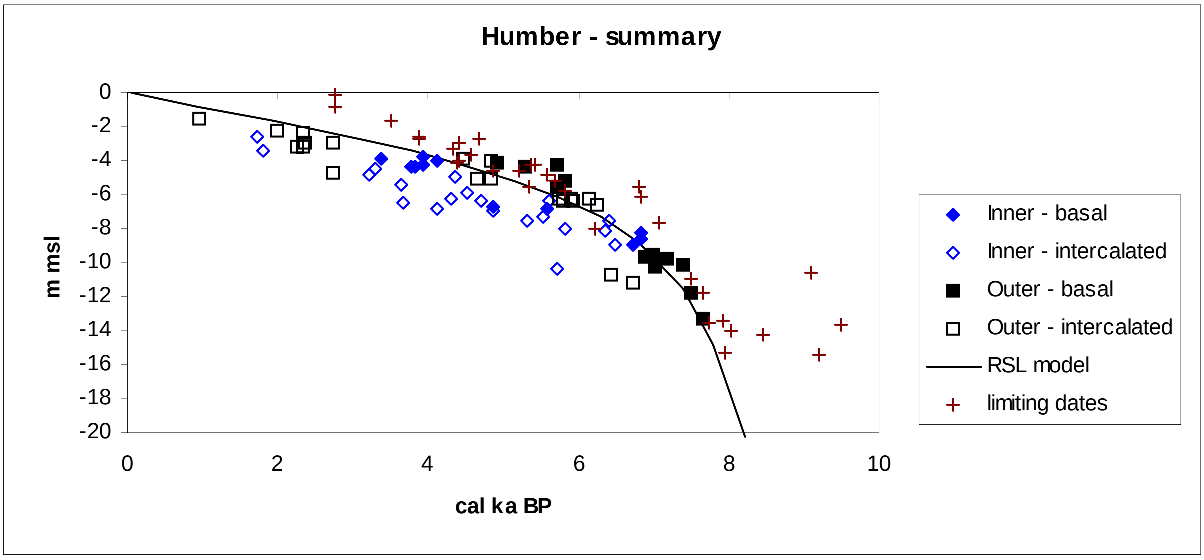

Figure 2. **Regional sea level curve for the Humber**

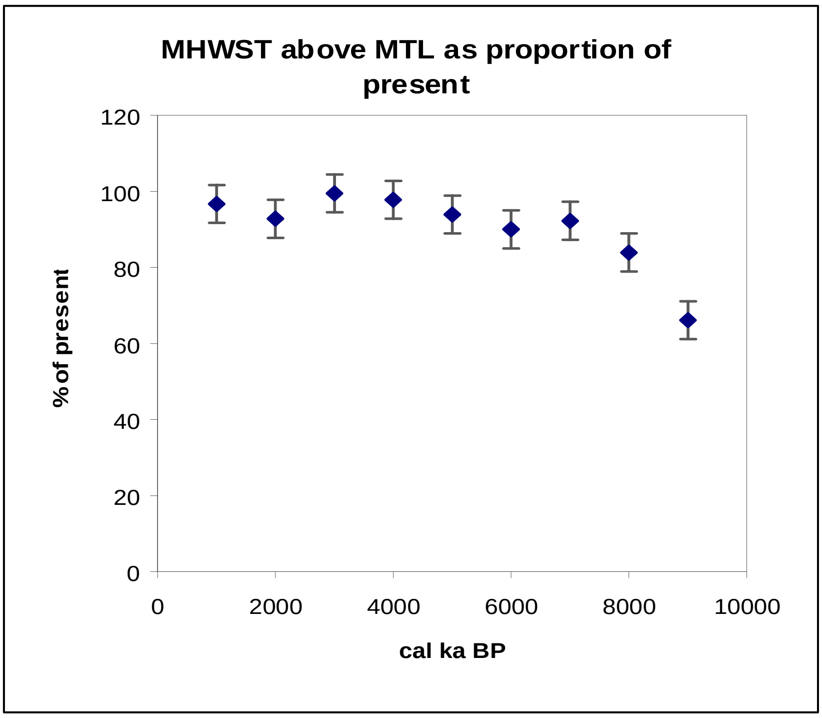

Figure 3. **Changes in high water over the Holocene**

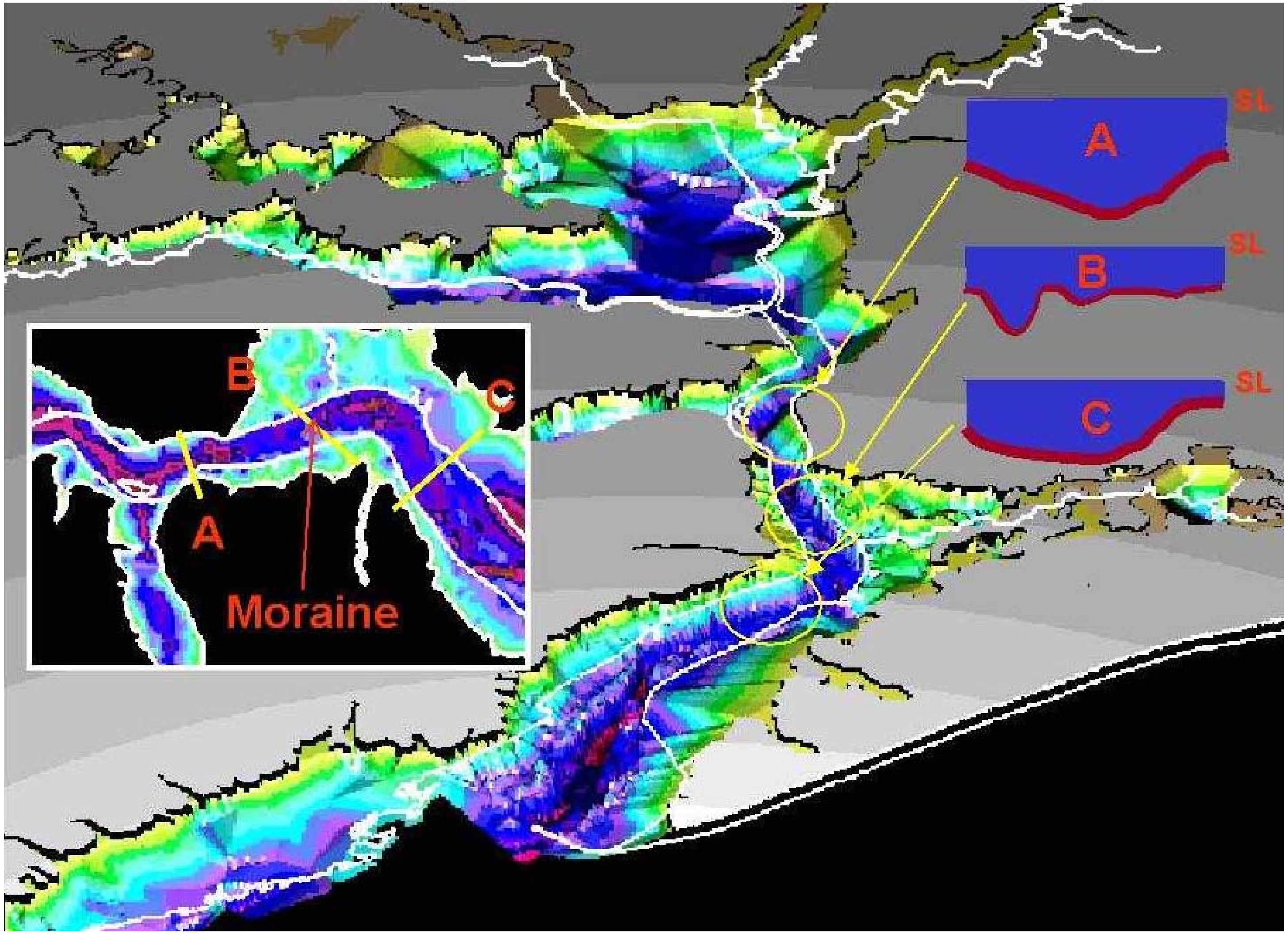

Figure 4. **Perspective view of pre-Holocene basin**

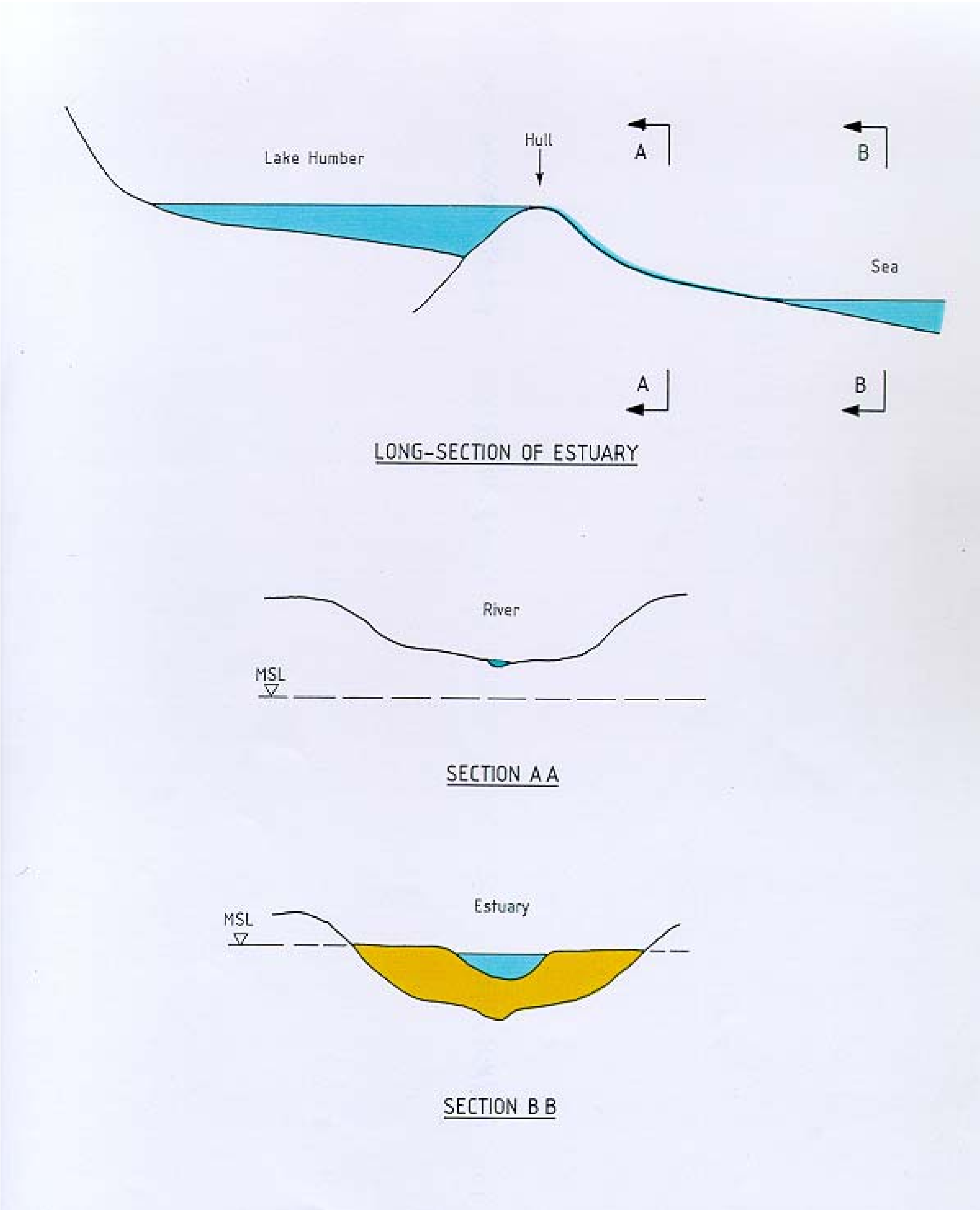

Figure 5. **Sketch of Humber basin pre 6000 years BP**

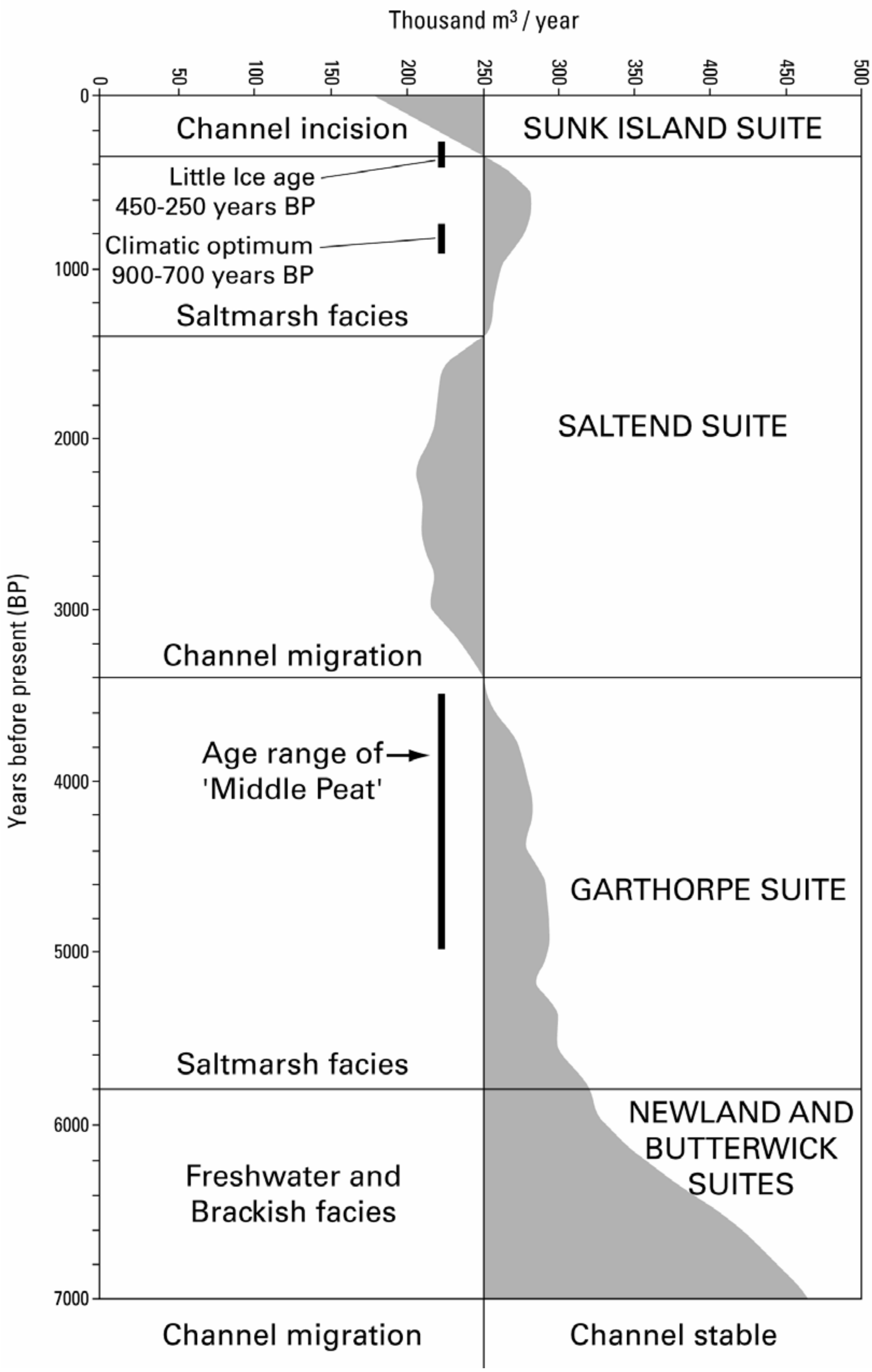

Figure 6. Holocene infilling of the Humber basin

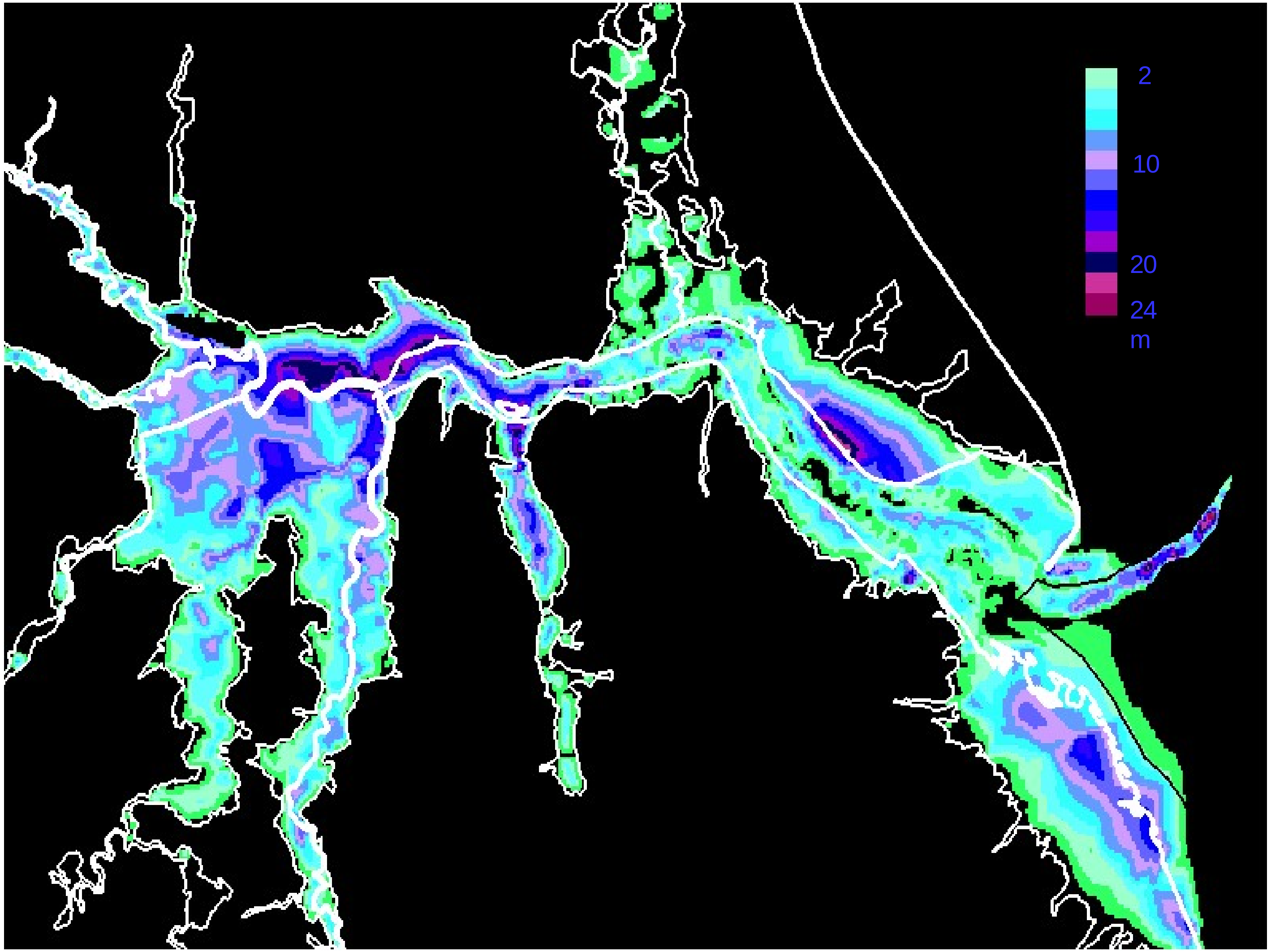

Figure 7. **Thickness of Holocene sediments**

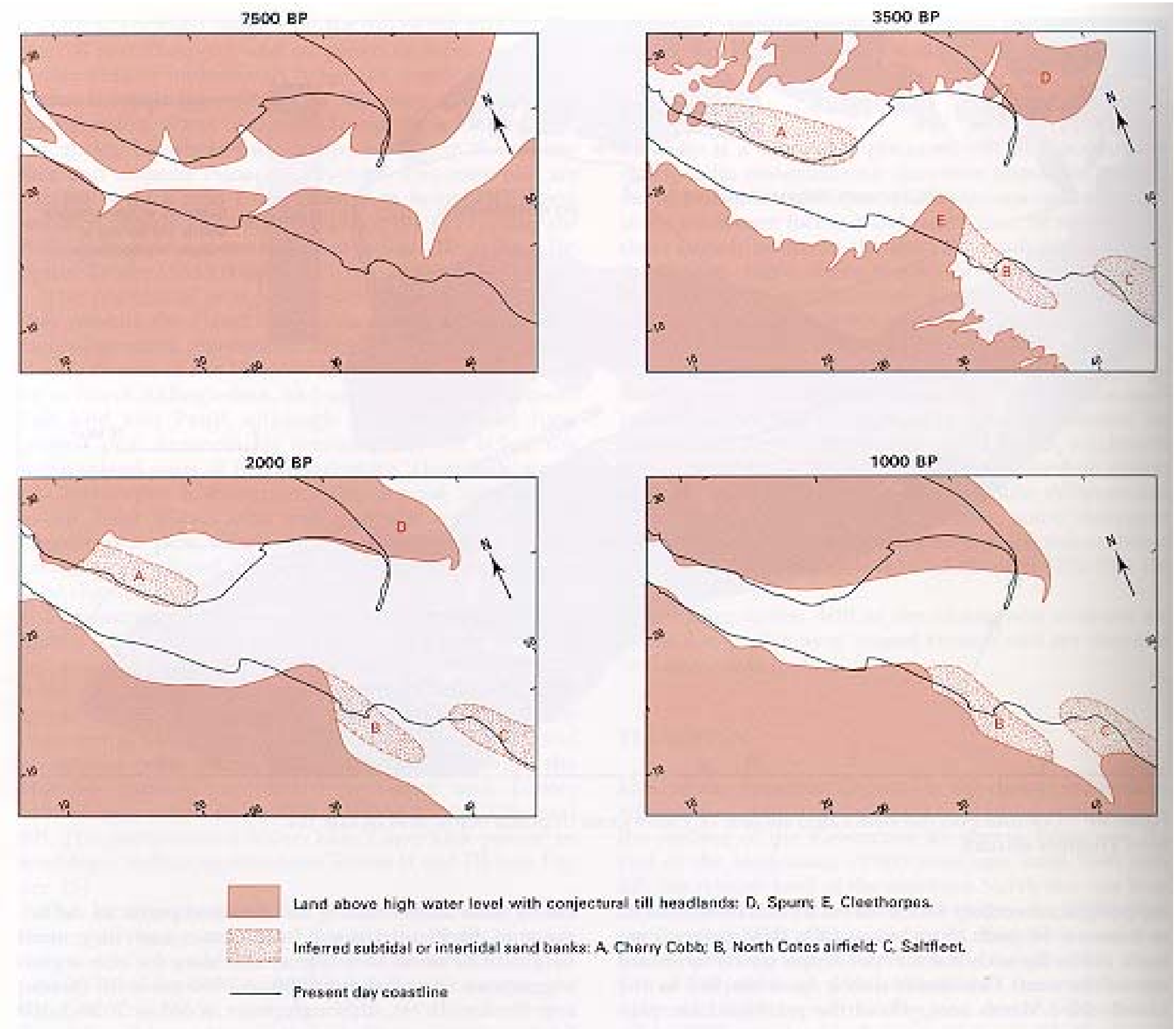

Figure 8. Conjectural evolution of the outer Humber estuary during the Holocene (Berridge and Pattison, 1994)

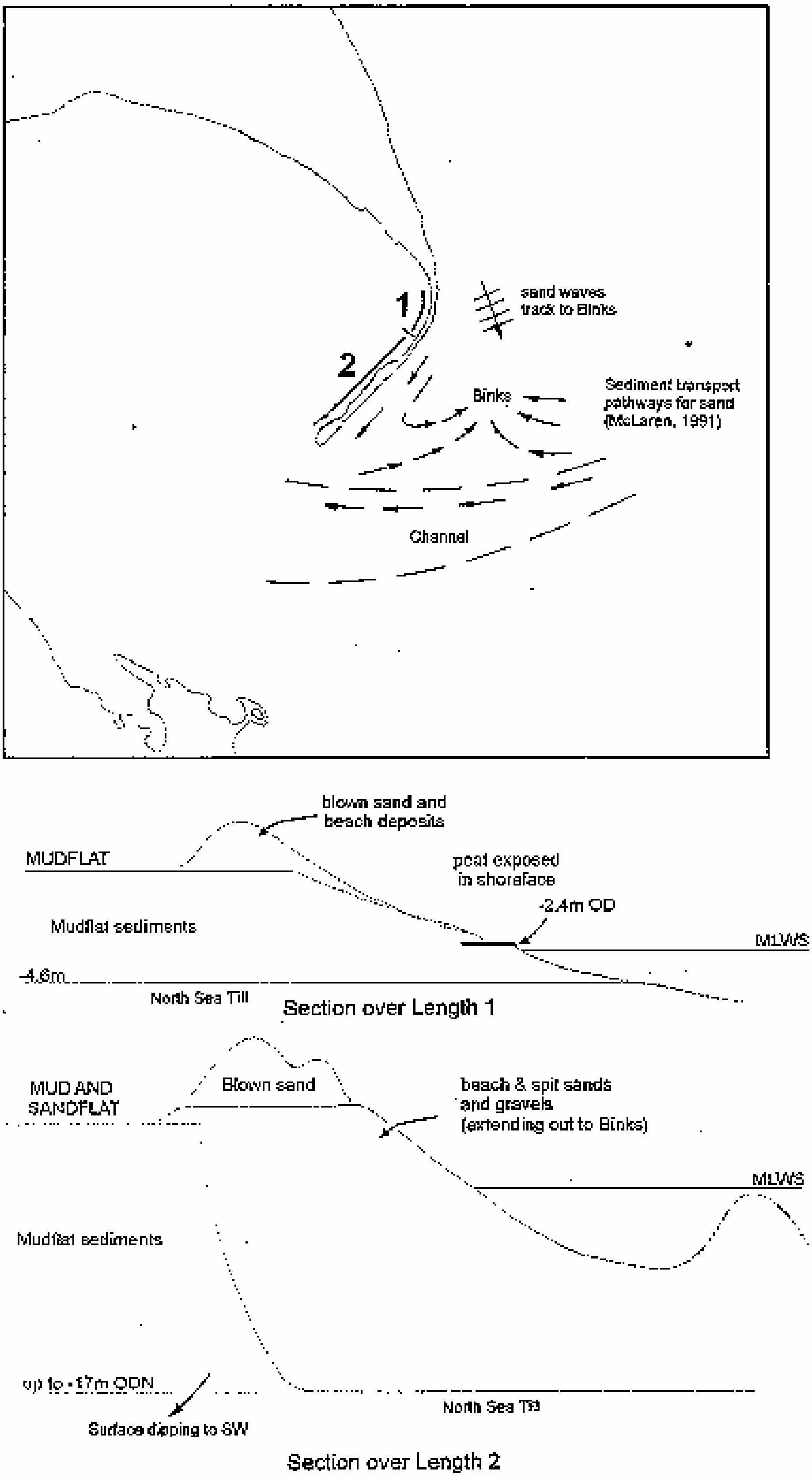

Figure 9. Sedimentary structures of Spurn Head