Holderness, East Yorkshire

[TA 182 660]–[TA 142 190]

Potential GCR site

K.M. Clayton

Introduction

Cliffs cut into weak Quaternary rocks undergoing rapid erosion occur along the North Sea coast of Britain and locally around the Irish Sea. The Holderness Cliffs (see (Figure 4.1) for general location) stretch from Bridlington in the north some 60 km to Kilnsea in the south, where the coast continues southwards as a spit to Spurn Head (Figure 4.40). Most of this line of cliffs remains undefended, though walls and groynes have been built along relatively short frontages at Bridlington, Skipsea, Hornsea and Withernsea, and more recently at Mappleton (south of Hornsea) and in front of the gas terminal site at Easington close to Kilnsea. The contemporary rate of erosion increases from north to south; from less than 0.5 m a^{-1} just south of Bridlington to as much as 3 m a^{-1} at Easington. A feature of this coast is the sectors with an unusually low beach profile; these are locally known as 'ords' and over time they migrate southwards down the coast. As the ords pass by, waves are able to erode the cliffs more effectively and the rate of erosion speeds up, to slow down again when a higher and wider beach replaces the ord (Figure 2.1)c.

Description

The Holderness cliffs front an undulating till plain deposited during the last (Devensian) glaciation. The cliffs themselves cut through various till fades and related fluvioglacial gravels. They begin in the north at the exposed Sewerby cliff of Ipswichian age, where the Chalk cliffs of Flamborough Head end, and continue southward for 61.5 km to Kilnsea at the northern end of the Spurn Head spit. The average height is about 13.5 m, and the maximum cliff height 35 m. The highest cliffs are between Atwick and Roos, with a secondary peak at Holmpton, south of Withemsea. From Barmston, some 8 km south of Bridlington to the southern limit of the cliffs at Kilnsea, the –10 m submarine contour runs parallel to the coastline and some 600 m offshore.

(Table 4.4) Land-loss by natural sections of the Holderness coast, 1852–1952 (Valentin, 1954, 1971).

Section	**Annual cliff recession (m)**	**Shore length (m)**	**Annual land-loss (m^2)**	**Average cliff height (m)**	**Annual loss in volume (m^3)**
A. Sewerby to Earl's Dike	0.29	8100	2357	11.0	25 927
B. Earl's Dike to Hornsea	1.10	13 650	15 015	11.8	177 177
C. Hornsea to Withernsea	1.12	24 250	27 160	16.2	439 992
D. Withernsea to Kilnsea Warren	1.75	15 525	27 200	13.2	359 040
Entire coast (approx.)	1.20	61 500	72 000	14.0	1 000 000

Given the rapid rate of erosion along these cliffs and the consequent loss of land and buildings, accounts of the coastal erosion can be traced back over several centuries, although only over the last 150 years can these be regarded as reliable. Reid (1885) and Sheppard (1906) summarized knowledge at the time they wrote, while the Royal Commission on Coastal Erosion and Afforestation (1907–1911) early in the 20th century referred to the relentless erosion of this clif-fine, regarding it as 'the most serious around the coast of the British Isles'. The first account that deals comprehensively with the full length of the cliffs is by Valentin (1954). An independent account that was read to a Yorkshire Geological Society meeting in York a year earlier is Dossor (1955), but Valentin's paper is more detailed and far more widely quoted.

Valentin's account summarizes land-loss by rate of cliff recession, by area and volume (the last two on a parish basis). He divided the coast into four sections: Sewerby to Earl's Dike; Earl's Dike to Hornsea; Hornsea to Withernsea; and Withernsea to Kilnsea Warren. As Valentin's 1952 research post-dates the first edition of the six-inch map (1:10 560) by 100 years, he was able to summarize the pattern of erosion over a century ((Table 4.4), (Figure 4.41))

Valentin went on to discuss the reasons for the persistent cliff recession, concluding that wave attack was the dominant factor. Increasing exposure southwards (the northern sector being protected from the north by Flamborough Head) was thought to account for the steady increase in the rate of cliff recession from north to south.

Phillips (1962, 1964) described the ords and their relationship to coastal recession. The occurrence of these low beach sectors is of considerable importance in determining the local pattern of cliff recession, and their episodic migration down the coast eventually leads to their progression down the narrow spit at Spurn, threatening breaching as they pass southwards. More detailed studies of ord development and migration are to be found in Scott (1976).

The type of cliff failure varies with the lithology of the cliff materials, cliff height, the local water table, and rate of recession. These issues are addressed by Richards and Lorriman (1987), and from a soil mechanics standpoint in Robertson (1990), while the pattern in time and space is analysed by Pethick (1996). Most, though not all, authors link the passage of ords with increased rates of cliff recession.

Winkelmolen (1978) concluded from a study of lithological variations in samples collected from the cliffs, beach and offshore zone that the postulated north-south longshore drift of beach sediment could not be established, and concluded as a result that most erosion and sediment sorting was associated with easterly storms.

Short lengths of the cliffs in front of built-up areas have been protected for some 80 years, with groynes and sea-walls at Bridlington (4 km), Hornsea (2 km) and Withernsea (1.8 kin) and as recently as 1992 a short length at Mappleton south of Hornsea was added. Many proposals have been put forward to increase the length of protection along this coast, including the construction of an offshore barrier utilizing colliery waste and a proposal for defended headlands separating eroding bays. To date the defences have remained restricted to the small coastal towns as a result of national policies on the funding of coast-protection structures that result in the limitation of protection to built-up areas through cost-benefit tests (see also Ramsay *et al.,* 1977).

A general account, setting the Holderness coast in its wider setting, is provided by Pethick and Leggett (1993).

Interpretation

There is widespread (though not universal) agreement on the major controls operating along this coast; the importance of the protection provided from the north by Flamborough Head (and the Smithic sandbank offshore), and the role of the beach (including the progression of ords) in controlling the rate of cliff recession. Recent studies have tended largely to confum these features, while increasing the detail in which we understand the controlling coastal processes. However, the contribution from Winkelmolen (1978) shows that the field data are capable of alternative interpretations. His evidence does not preclude southerly littoral transport as surely as he claims — the effect of sporadic (in time and place) inputs of ill-sorted sediment derived from the rapid erosion associated with ords makes it unlikely that a north-south pattern of sediment size could develop. Pethick (1996) has provided a more detailed examination of the pattern in time and space of cliff recession, which is discussed below.

All authors agree that the recession along this coast has been occurring for a long period of time, no doubt moving landward rapidly during the earlier part of the Holocene transgression, and perhaps continuing at a relatively constant rate over the last 6000 years or so that sea level has stood close to its present elevation. Valentin utilized the recession rate for 1852–1952 to estimate that, 3000 years BP, the coast was some 7 km east of its present position at Dimlington, and perhaps half that distance at Skipsea. He also noted that the morainic ridge that forms the high ground at Dimlington declines westwards, and that while it reached 42 m on the 1852 map, the ridge top was at only 38 m at the cliff edge in 1952 and will be at only 30 m by 2052. Thus at the very least the present rate of erosion here is likely to continue and a much smaller volume of sediment will be contributed to the beach and offshore system in the future. Valentin notes that Sheppard (1912) regarded the Roman coastline (*c.* 2000 years BP) as lying 2.5 to 3.5 km east of the present-day cliffs, a view repeated by other authors since then.

The recognition of ords by Phillips (1962, 1964) has undoubtedly helped to explain variations in both the style and rate of cliff recession over time. Research on the Spurn Head spit showed the effects of an ord to be particularly noticeable. Similar features occurred in front of the cliffs farther north. Phillips reported their length as 45–55 m and that they were moved southwards by severe storms at an average rate of movement of about 1.6 km a^{-1}. She also noted that ords are unknown in Bridlington Bay (where a ridge and runnel beach occurs), but become common towards Hornsea, some 15 km south, explaining this by the southward increase in exposure to northerly waves. Phillips (1964) describes ords as a departure from a perceived normal beach form with a high upper berm and a lower beach ridge; where ords occur, the upper beach is missing.

It would seem equally legitimate, given the persistent erosion, to describe the low beach as the norm and the sectors with slower cliff recession where the beach is high as anomalous. However, Phillips' viewpoint was supported by Scott (1976) who studied ords in 1974–5 and noted that they had first been described (as 'hords') by Thompson (1824). In contrast to Phillips' 45–55 m, Scott found their average length to be 1–2 km, though they varied considerably. Approaching an ord from the north, the upper beach becomes lower and narrower, ultimately merging into the cliff foot beach. The lowest point of the ord has till exposed across the width of the beach. He noted that ords first appear between Skipsea and Hornsea, and are then found at intervals all the way south to Spurn Head. From aerial photograph analysis he identified ten ords along the coast in 1961, eight in 1966 and nine in 1972. The detailed field study of individual ords in 1974–5 established that though they might remain stationary for long periods, they never move to the north and in the long-term all of them moved southwards. Motion was by filling-in by southward-moving beach sediment at the northern end and the moving away of the higher beach at the southern limit of the ord by storm-wave induced longshore transport. Pringle (1981, 1985) reviewed the movement of an ord, first located in 1969, 250 m south of Withernsea, monitored between 1973 and 1976 (Pringle, 1985), and surveyed every six months from April 1977 to April 1983; it moved between 68 and 668 m in six months (with an annual average of 496 m) to the south. Where the ord occurred, the beach level was on average 3.9 m lower than elsewhere, allowing even neap tides to reach the cliff at high water. Cliff-top erosion of 10 m a^{-1} was associated with the passage of the ord (with a maximum of 15 m a^{-1}) and the site of maximum cliff recession moved southward as the ord passed by. The total till volume eroded from within the lengths affected by the migrating ord averaged 254 000 m^3 a^{-1} and from the inter-ord areas, 55 600 m^3 a^{-1}, despite the fact that the total length of inter-ord cliffs was nearly three times the length affected by the ord.

Description of the style of cliff failure and its development into a model of recession with active basal erosion is provided by Richards and Lorriman (1987). This includes a section based on cliff recession in Holderness: the process involves (a) toe erosion by marine action which both undercuts and steepens intact day and removes failure deposits; and (b) a range of mass movement mechanisms including relatively deep-seated wedge and rotational failures, slumps, spoiling and superficial mudflows. As in the case of the Norfolk cliffs (Cambers, 1976), there is a strong relationship between cliff recession rates and the frequency with which high tides reach the cliff base. The rate of recession is increased by the current rise in relative sea level, estimated as 2–3 mm a^{-1} (Suthons, 1963).

The changing nature of cliff recession as ords move along the coast was investigated by Robertson (1990). Although the cliffs of Holderness are appreciably lower than those of Norfolk, his description of the processes at work is very similar to the styles of recession observed in the Norfolk cliffs (Cambers, 1976). He found cliff height and beach volume to be the major controls on cliff failure, a relationship also identified by Valentin (1971; (Figure 4.41)). Cliff slope was generally 40–50°, because of the generally low pore-water pressures. The main method of recession is by deep-seated failure caused by weakening of the till by stress relief as a result of unloading and the removal of basal sediment by wave attack. Where the beach is high (between ords), recession is by mudslides and shallow slips. When a large landslip occurs, time is needed for it to be removed completely by wave action before further recession will occur at that point.

The changing nature of the beach fronting the Holderness cliffs was investigated by Mason and Hansom (1989). Using time-series surveys of a small stretch of coast at Atwick the occurrence and disappearance of areas of beach stripped of sediment (ords) was used to predict beach behaviour over different wave conditions and seasons. Using the Holderness beaches, they demonstrated that a Markov model was capable of describing and predicting transitions between beach types and different time periods.

Valentin's approximation of the sediment eroded from the Holderness cliffs as 1 000 000 m^3 a^{-1} has been refined and developed by later studies. Pringle (1985) noted that the average proportion of coarser sediment (sand and gravel) for the three tills present near Withernsea was 31.3%. A detailed field study of a 4 km length between Skipsea and Atwick by Mason and Hansom (1988) identified beach areas stripped of sediment and quantified changes in beach volume as well as inputs from cliff erosion over one year. They estimated an annual output (1850–1968) of 1 340 000 m^3 a^{-1}, and an input to the beach of 462 000 m^3 a^{-1} from the cliffs on the assumption that 33% of the eroded till was sand and gravel. Southward sediment movement by longshore drift in their sectors averaged 28 000 m^3 a^{-1} to the south. Offshore transfer from the two central beach sectors, each 1875 m long, averaged over 50 000 m^3 a^{-1}, an offshore proportion of two-thirds.

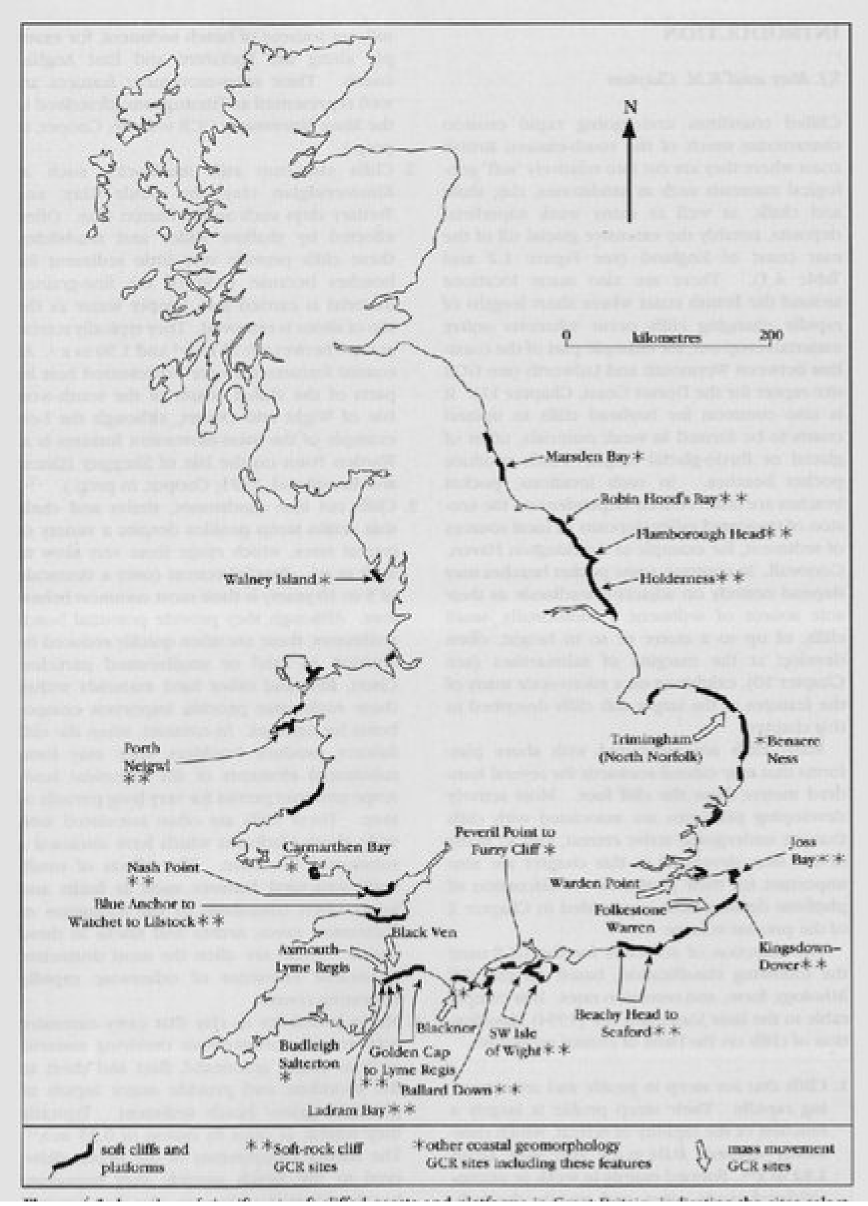
One outcome of Pethick's (1996) study was his estimate of 340 000 m^3 a^{-1} for the net annual potential longshore transport to the south. He estimated the non-cohesive sediment input at 280 000 m^3 a^{-1}, giving an excess potential longshore rate at the southern end of the system. He concluded that the orientation of the Holderness coast provides the maximum possible potential longshore sediment transport, and an excess of potential over actual that increases steadily to the north. He estimated the total sediment store in the Holderness beaches as about 2 000 000 m^3, the equivalent of only eight years of input from cliff recession.

An informative analysis of the variation of coastal cliff recession in time and space was provided by Cambers (1976) based on her work on the Norfolk cliffs. Pethick reached similar conclusions in his 1996 study, using the recession data collected by the local councils from the 'erosion posts' located every 500 m along this coast. Though installed in 1951, annual measurements run from 1957 and the database available to Pethick (1996) was thus 45 years. Given the limitations of this database he initiated the collection of more detailed measurements from 1993. Pethick concludes that apparent variations in cliff recession rates are better explained by the spacing of the measurements in time and space than by the progression of ords. While accepting that ords are linked to more rapid recession, he does not believe they explain the 5–8 year periodicity he found and that relatively small landslips produce a pattern of migrating embayments separated by inclined promontories, and that the southward migration of these embayments leads to the observed periodicity. At any one site, 2.7 cliff failures each leading to average cliff-top recession of 0.68 m yields the overall average recession of 1.82 m a^{-1}.

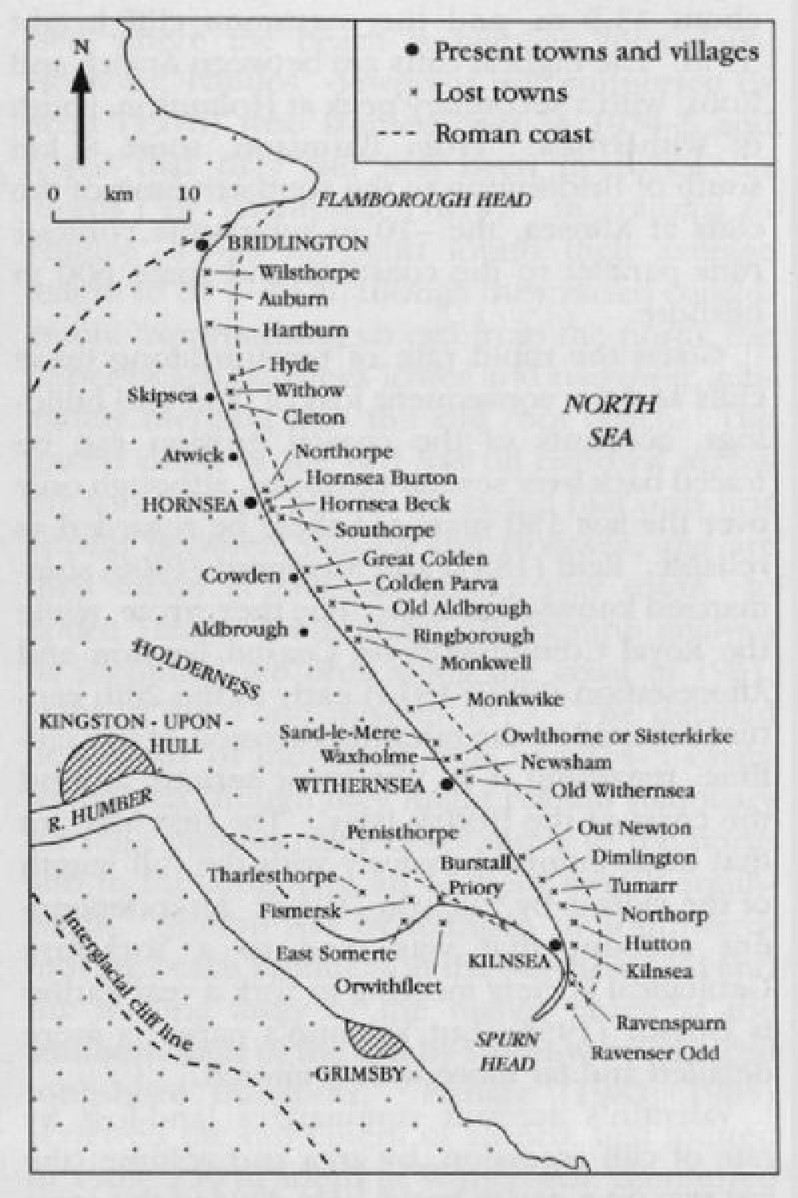
Conclusions

Holderness is the longest and least-defended length of rapidly eroding cliffs cut into weak sediments in Britain. It has been studied intermittently over the past 150 years or more and although in general the relationships between wave energy, beach volume and recession are understood, and the style of cliff failure has been related to the strength and pore-water pressures of the Quaternary sediments, there is no doubt much still to be learnt from such a natural and extensive site. In addition, little is so far known of the fate of the eroded sediment, or the processes which, by deepening the adjacent sea floor, have allowed recession to continue over a distance of as much as 10 km over the last 5000 years.

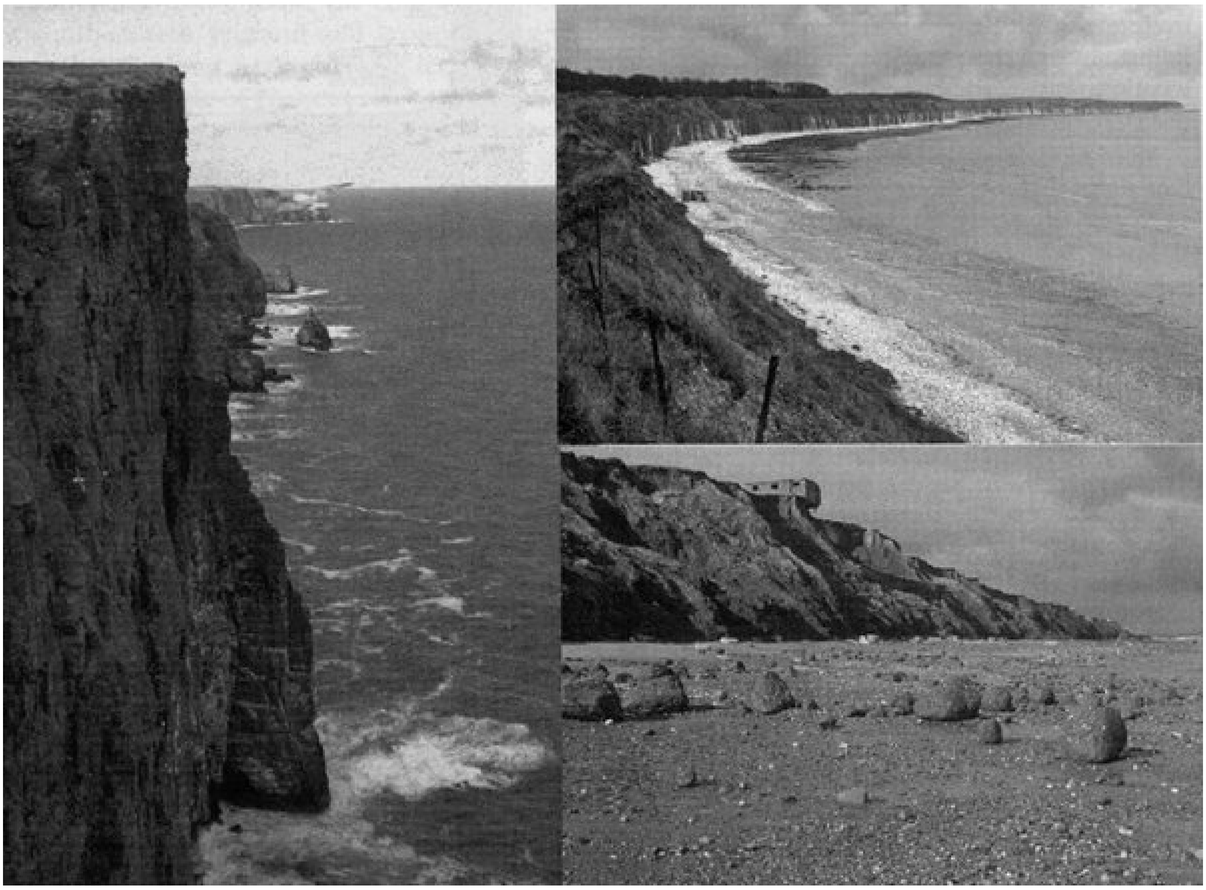
The short defended lengths of this coast produce sectors where little or no erosion has occurred since construction of the defences. However, immediately to the south of each defended section, accelerated erosion occurs where the beach is depleted because of the retention of sediment by groynes to the north and the lack of cliff input behind sea-walls. These limited interruptions to an almost continuous length of eroding cliffs totalling almost 60 km do not detract from the value of this site; the comparable cliffs of Norfolk are defended for all but a few kilometres. The largely rural nature of Holderness has made it difficult to justify the expenditure of public money on coastal defences and this is likely to remain the case for the foreseeable future. Further, the erosion of the cliffs provides the sediment that maintains the Spurn Head GCR site, and in addition are the likely source for sand arriving on the prograding North Norfolk Coast GCR site.



(Figure 4.1) Location of significant soft-cliffed coasts and platforms in Great Britain, indicating the sites selected for the GCR specifically for soft-rock cliff geomorphology. Other coastal geomorphology sites that include soft-rock cliffs and sites selected for the Mass Movements GCR 'Block' that occur on the coast are also shown.



(Figure 4.40) Lost villages of the Holderness coast. As the till has been easily eroded for hundreds of years at rates of 2 m a^{-1}, there has been substantial loss of agricultural land and villages. (After Hansom, 1988)



(Figure 2.1) (a) Clò Mór cliff (193m) to the east of Cape Wrath, Sutherland is a good example of a plunging chit with no shore platform development, which has been inherited from former sea levels. (b) Recession of the Chalk cliff at Sewerby, west of Flamborough Head, Yorkshire, has produced a steep lower cliff with a sloping shore platform whose upper junction is obscured by a gravel beach composed of chalk gravels together with glacial gravels derived from bevelling of the cliff-top till. (c) Rapid erosion of the soft and unconsolidated glacial till cliff at Atwick, Holdemess, Yorkshire, progresses by undercutting and rotational failure that is accentuated when the cliff-foot beach is thin or absent. This view looking north shows a very thin upper beach veneer over an area of exposed till shore platform (locally called an 'ord') whose surface is strewn with till blocks eroded from the cliff. (Photos: J.D. Hansom.)

HOLDERNESS, EAST YORKSHIRE (TA 182 660–TA 142 190)
POTENTIAL GCR SITE

K.M. Clayton

Introduction

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Figure 4.40 Lost villages of the Holderness coast. As the till has been easily eroded for hundreds of years at rates of 2 m a^{-1}, there has been substantial loss of agricultural land and villages. (After Hansom, 1988)

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Table 4.4 Land-loss by natural sections of the Holderness coast, 1852–1952 (Valentin, 1954, 1971).

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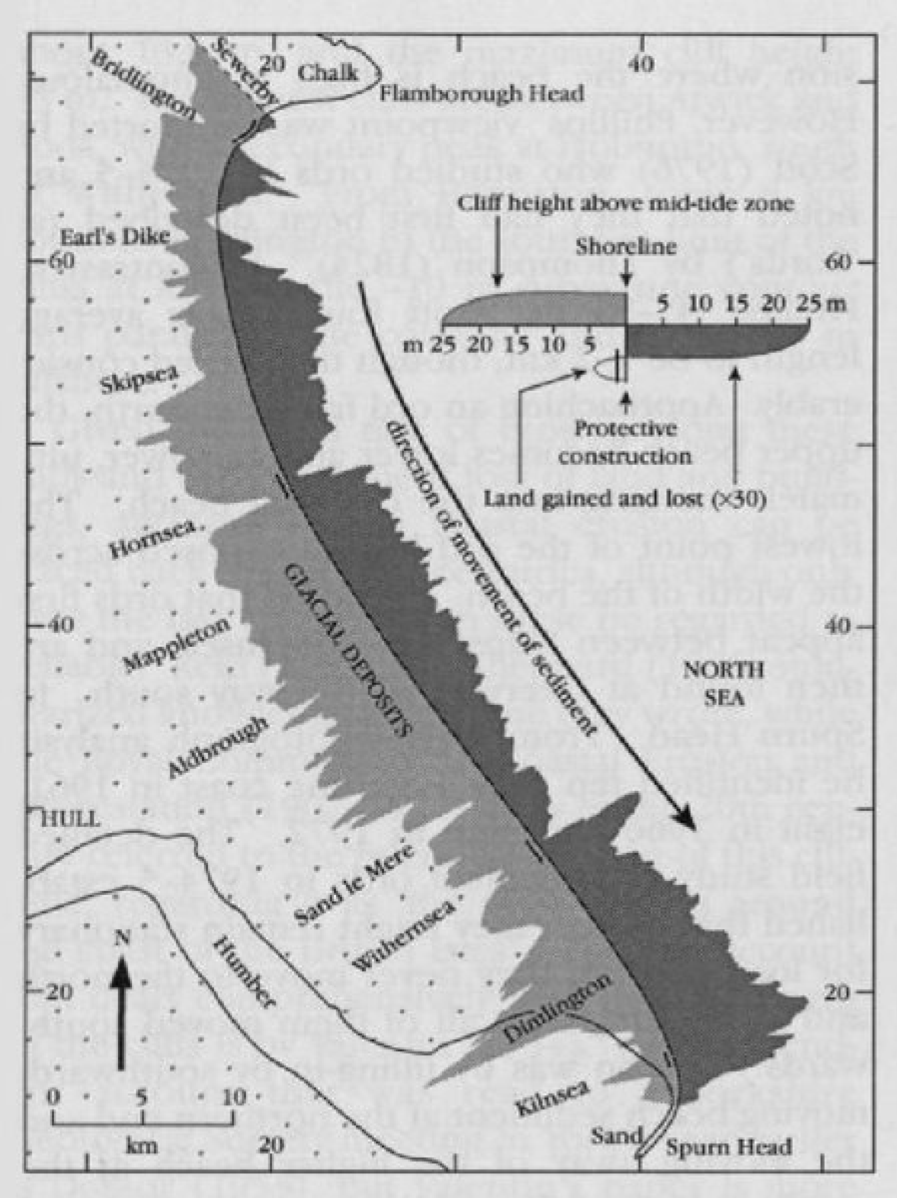

(Figure 4.41) The relationship between cliff height and erosion along the Holderness coast. (After Valentin, 1971, in Steers, 1971a). For the cliff height profile, the vertical exaggeration is x 30.