FLAMBOROUGH HEAD

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Introduction

Flamborough Head is the largest promontory on the North Sea coast of north-east England, projecting some 10 km eastwards from the Holderness coastline, which is undergoing rapid erosion, to its south (see Figure 4.1 for general location). Flamborough Head is treated as a separate site from Holderness because of its importance as one of the suite of Chalk cliff sites. Holderness is discussed separately owing to its importance as a cliff undergoing rapid retreat.

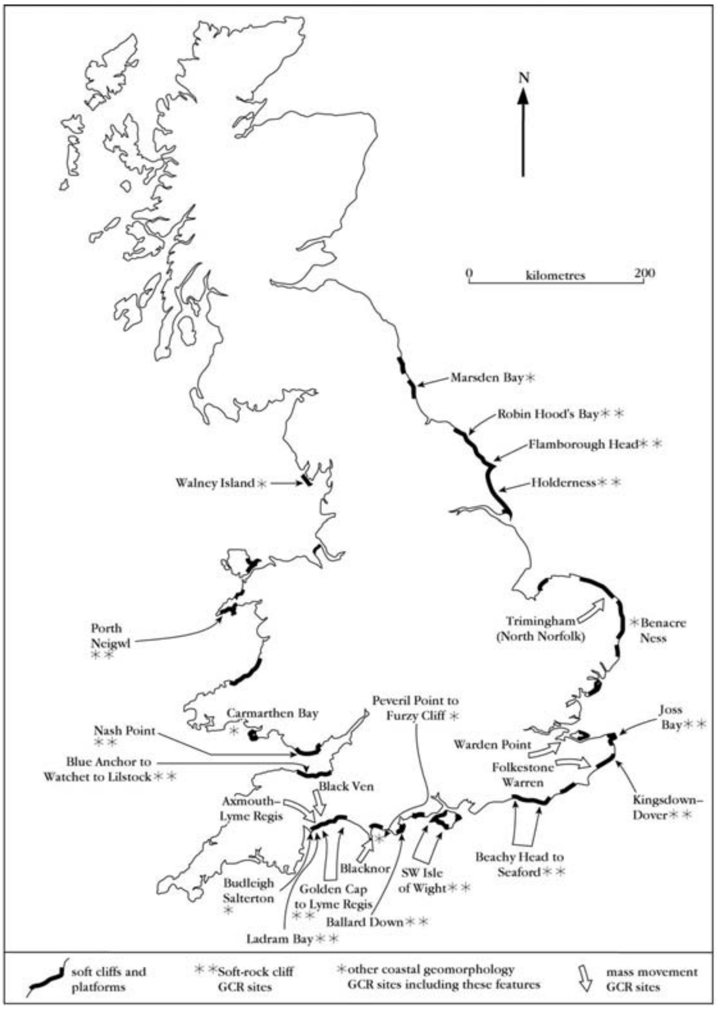

Figure 4.1: Location of significant soft-cliffed coasts and platforms in Great Britain, indicating the sites selected for the GCR specifically for soft-rock cliff geomorphology. Other coastal geomorphology sites that include soft-rock cliffs and sites selected for the Mass Movements GCR 'Block' that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

Flamborough Head is the northernmost coastal outcrop of the Chalk and the most extensively affected by glacial conditions. Like the Chalk cliffs of the North Downs in Kent, Ballard Down in Dorset and Tennyson Down in the Isle of Wight, the cliffline at Flamborough Head cuts across the Chalk cuesta and many different parts of the Chalk succession are exposed. This situation, combined with the effects of different levels of exposure to wave action, has brought about considerable variety of coastal forms within the site.

Flamborough Head forms part of the GCR network of Chalk coastlines and it lies within the zone of North Sea wave climate, unlike the majority of other GCR sites, which are partly or wholly affected by Atlantic swell and English Channel wave climates. Winds are generally offshore, but important secondary wind and wave directions are from the south, east and north-east, the latter being important in winter. The fetch for many waves generated in the southern North Sea is generally less than 700 km, whereas waves generated from a northerly sector may have a fetch extending into the Arctic area. As a result, much of the site is affected by long-refracted swell (Figure 4.33; see also GCR site reports for Holy Island, Chapter 11, and Marsden Bay, Chapter 7). It is also the only GCR coastal geomorphology Chalk locality that is extensively overlain by glacial deposits. The northern cliffs are relatively simple, both in plan and profile (Figure 4.34); they feed small amounts of flint to their fringing beaches. The Chalk is extensively faulted, with some 1340 faults within one 6 km length (Peacock and Sanderson, 1993, 1994). Many excellent examples of caves, arches and stacks are associated with this faulting, and a number of blowholes have developed where the overlying till has collapsed into caves that intersected the Chalk–till junction. One contributing factor to the large numbers of caves has been the hardness of the Chalk. Secondary diagenetic deposition of calcium carbonate in the chalk pore spaces has produced chalk cliffs that are much more resistant to erosion than the Chalk of similar age in southern England. Shore platforms are well-developed both in this area and along the southern shoreline, where the beach is mainly sandy, and lacks flints. Marine processes vary from north to south: the southern cliffs are less active than those to the north.

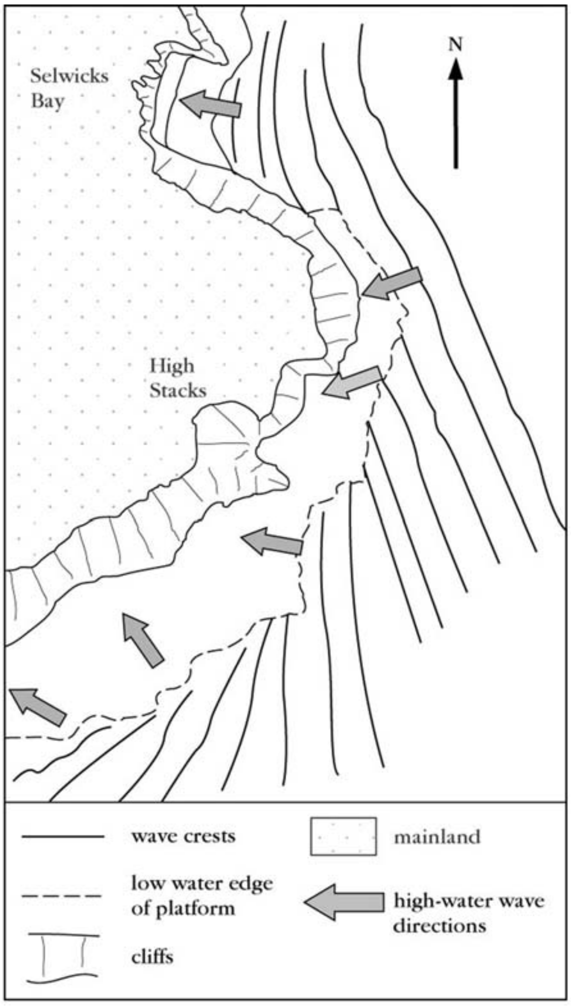

Figure 4.33: Wave refraction at Flamborough Head, showing variations in wave direction crossing the platform owing to wave refraction. See Figure 4.34 for location. (Based on aerial photographs in Pethick, 1984.)

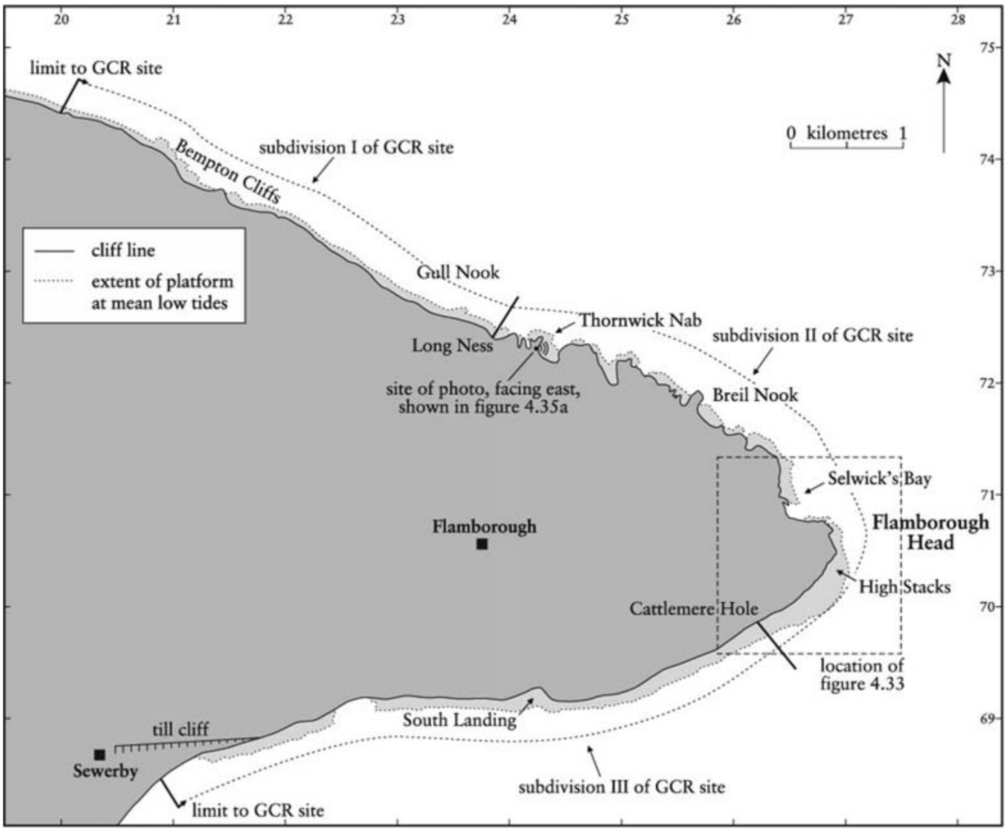

Figure 4.34: Sketch map of the Flamborough Head coastal geomorphology GCR site, showing the three main divisions of the locality.

As with many cliffed coastlines, there are more passing references to Flamborough Head in the literature than detailed studies of it. Nevertheless, the nature of both its cliffs and platforms has been commented upon in more general descriptions of the coast (Steers, 1946a; Straw and Clayton, 1979; Pethick, 1984) and discussions of platform morphology (for example, Trenhaile, 1974b).

Description

This site has three main subdivisions (Figure 4.34):

1. The northern cliffs between Bempton (TA 182 746) and Long Ness (TA 228 725), where the dip of the Chalk is to landward at about 20° (Figure 4.35b);

Figure 4.35: Flamborough Head, (a) looking east from Thornwick Nab. The upper cliff is in Devensian tills, the lower cliff in chalk with numerous caves, arches and platforms. (b) Looking WNW at Bempton Cliffs; steep cliffs with a short upper vegetated facet in tills. Pipe-like forms extend down the whole height of chalk cliff; the cliffs have a narrow platform with a cobble and boulder beach. (Photos: V.J. May.)

2. the complex coastline around Flamborough Head itself between Long Ness (TA 228 725) and Cattlemere Hole (TA 256 703; Figure 4.35a); and

3. the southern cliffs from TA 256 703 to the western boundary of the site at Sewerby, where the dip of the strata in the cliffs is to seaward (Figure 2.1b).

Figure 2.1: (a) Clò Mór cliff (193m) to the east of Cape Wrath, Sutherland is a good example of a plunging cliff, 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, Holderness, 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.)

The northern cliffs, known as 'Bempton Cliffs', fall southwards from about 110 m at the northern edge of the site to about 65 m at Long Ness (TA 228 725). A narrow platform, Chalk and flint shingle beach and debris from rockfalls extend about 75 m from the foot of the cliff seawards to the low tide mark (Figure 4.35b). Both their plan and profile are simple. Straw and Clayton (1979) have suggested that wave erosion has been particularly severe on this coastline 'where, opposite a long northern fetch, the Bempton cliffs rise a sheer 130 m'. Steers (1946a) described the cliffs as being in greatly contorted flinty Chalk, but the contorted nature of the Chalk has not affected the cliff-form to any significant extent. At Staple Nook, there is a slight indentation of the coast associated with weaker contorted Chalk.

The central cliffs are cut in the Middle and Upper Chalk (*Terebratulina lata–Micraster coranguinum* biozones) and are characterized by numerous caves, arches and stacks. There are well-developed, structurally controlled, platforms with many vertical joints and small faults exposed both in the surfaces of the platforms and in the cliffs (Figure 4.35a). Marine erosion along the joints and faults has been especially effective in developing a very large number of erosional forms. There are some 50 distinct inlets along this section of the coast. They vary in nature from caves and narrow steep-sided geo-like forms to small bays, over 55% of which are aligned towards the NNE and north-east and about 15% towards WNW. Devensian till cappings give the upper cliffs a complex profile that has been much affected by landslips. The lower part of the profile is steep, often with a tendency to overhang at its base. The plan of the cliffs is affected both by the erosion of the many structural weaknesses and by the form of the subglacial surface. Where former valleys have been truncated by the sea, and also where the dip of the Chalk brings the subglacial boundary closer to sea level, the sea has been able to erode inlets and bays more effectively. The dolomitized Chalk has also been affected by periglacial processes and much of it is deeply shattered, thus reducing its general resistance to present-day weathering and marine erosion.

There are several blowholes within large hollows in the till. These have developed where caves in the Chalk have grown upwards to the boundary between the Chalk and the till. Whereas the blowhole outlet would remain small if it were in the Chalk, the lower slope stability of the clay material in the till overlying the Chalk has produced more open hollows. On the north side of Selwicks Bay several blowholes appear to have merged and the intervening Chalk has collapsed to produce a complex inlet (Figure 4.36). Some of the caves are associated with gullies across the platform on the line of the joint or fault controlling the development of the cave. Other caves lack this relationship, their floors being formed by slightly dipping beds of more resistant Chalk standing above the general level of the platform.

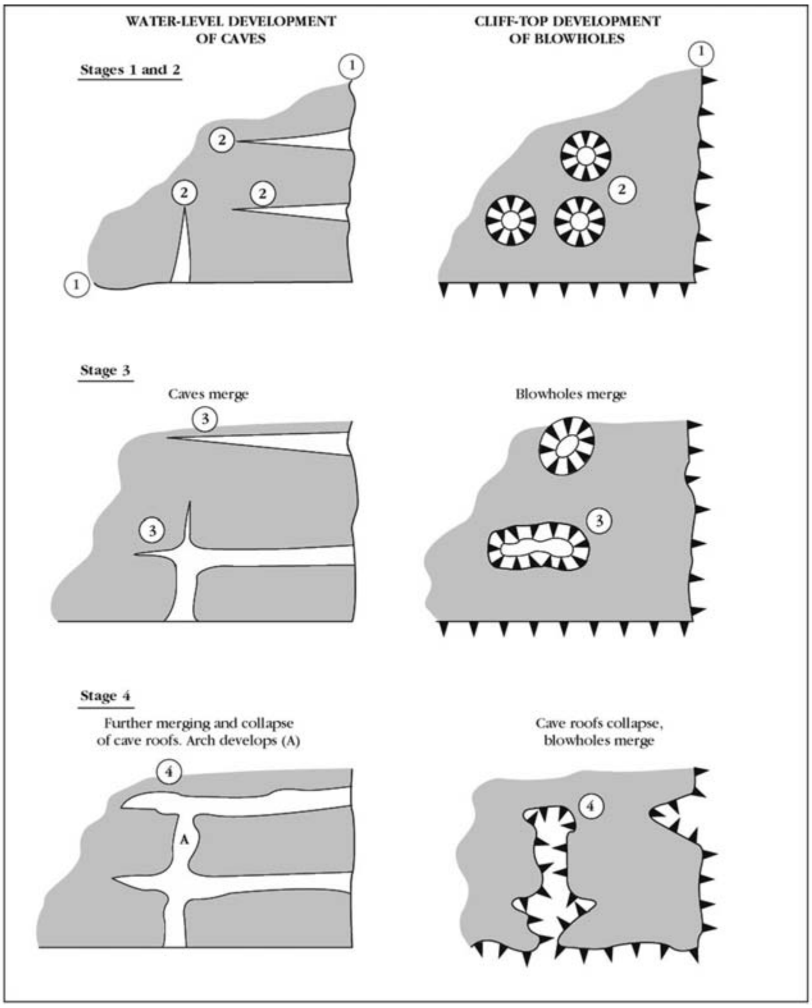

Figure 4.36: Cave and blowhole development at Flamborough Head, shown schematically in plan view. There are several stages in the development of blowholes here. Stage 1: caves develop along major joints or faults. Stage 2: caves extend upwards into the overlying till, which begins to collapse allowing hollows to appear in the till. Stage 3: caves merge and blowholes coalesce. Stage 4: Further merging of caves, cave rooves collapse, arches and/or geos develop. Subsequently, isolated blocks or stacks may develop.

The cliffs on the southern side of Flamborough Head are simple in plan and profile, but are less active than those to the north at Bempton (Figure 2.1b). Sheppard (1912) placed the coastline of Roman times 2000 years BP over 1.6 km offshore from Sewerby and close to the present shoreline south of Flamborough village. There is, however, no direct evidence to corroborate this, although farther south documentary evidence emphasizes the large land-losses since Roman times. Steers (1946a) noted that the rate of retreat was small because of the hardness of the Chalk forming the cliffs and platform and because the old pre-glacial cliff was still being exhumed. Valentin (1954) estimated that the cliffs at Sewerby retreated by 18 m between 1852 and 1952. The upper part of many of these southern cliffs is well-cloaked with vegetation, with a lower angle of slope reflecting the presence of the till above the very steep Chalk cliffs. There is a preponderance of small falls of Chalk, rather than the more substantial rockfalls of the northern cliffs. The platform is a true abrasion platform: it is not structurally controlled since it cuts uniformly across the strata (Figure 2.1b). Where backed by Chalk cliffs, the platform is cut into chalk, but is replaced by a till platform of the same gradient and width at Sewerby where the cliffs are in till. The beach has two elements, an upper narrow beach mainly of chalk pebbles, and patchy, but few, flints, and a thin, sandy veneer resting on the platform. Trenhaile (1974b) has shown that the gradients of the platforms around Flamborough Head are higher than at any other part of the north-east Yorkshire coastline and other Chalk coastlines in England. The dominance of waves from northerly directions means that most waves are refracted around the headland and approach these southern cliffs from the east (Figure 4.33). As a result, this part of the site tends to be swept clear of much of its surface sediment, which is transported southwards. Erosion rates are relatively slow (less than 0.3 m a^{-1}) and so there is only a small input to the Holderness sediment budget.

Interpretation

This site contains the largest assemblage of active coastal erosional forms anywhere in the English Chalk, coast protection works having removed most of the very complex features on the north coast of the Isle of Thanet at Birchington. The situation at Flamborough Head, like others on the English coast, presents a puzzling question concerning the apparent resistance of a promontory that is otherwise riddled with structural weaknesses. The many faults have given rise only to the large number of inlets because the Chalk is sufficiently hard to prevent collapse. It behaves more like a hard limestone coast than a weaker chalk coast. Thus despite the deep incision by caves and other inlets into the cliffs, it is the most prominent feature of the eastern coastline of England north of the Wash. In part its form is accentuated by the rapid erosion of the weak materials forming the coastline of Holderness to the south. The southern side of the promontory has certainly undergone some erosion because it cuts across the Ipswichian shoreline at Sewerby (Catt, 1977). Nevertheless, the central section described above does not appear to be undergoing rapid erosion. Comparison of the photograph of Selwicks Bay in Steers (1946a) with the present cliffs suggests that although there have been small changes, there have been no major changes. The dip of the Chalk here varies between 10° and 15° but the coastline is so complex that there is no simple relationship between the cliff-forms and the local dip. The platforms are complex with considerable variation in relief both towards the sea and along the platforms. The development of the cliffs cannot be considered without discussion of the platforms because they affect the distribution of wave energy over each tidal cycle, most particularly in reducing the energy available for marine erosion of the foot of the cliff and the removal of talus from its foot.

Trenhaile (1974b) demonstrated that the platform gradient here was higher than might be expected from consideration of both the geology and the morphogenic environment. Analysis of covariance shows that tidal range correlates strongly with platform gradient, but this correlation is not dependent upon rock type. For the same *Micraster coranguinum* Chalk biozone and a similar fetch and tidal range, the platforms at Flamborough Head have much greater gradients than those around the Isle of Thanet. This variation could be attributed in part, however, to differences in the lithology between geographically separate parts of the same biozone, an issue not discussed by Trenhaile. He has suggested that waves that approach with the least energy, owing to refraction, are most significant for platform development. This must, however, be modified by the roughness of the platform and surrounding intertidal areas. Much of the intertidal area in the central section of this site is distinguished by rocky outcrops that owe their features to the differential action of marine and sub-aerial processes upon them. There have been no detailed field surveys of these features, but the very rough nature of the surfaces has been observed to have the effect both of channelling water flow, particularly during backwash of waves and drainage on falling tides, and of dissipating much of the energy contained within waves crossing the intertidal area. The channelled flow of water along joints, into and out of inlets and caves, has a very localized effect.

When the sides of such channels are undercut sufficiently they may collapse, but the length of many of the channels and caves suggests that the penetration along them is carried out much more efficiently than widening of them. Most waves approaching Flamborough Head are strongly refracted. Their behaviour in crossing the intertidal area is very complex and, except during periods of storms, inefficient in attacking the innermost parts of the bays. As a result it could be argued that it is the very complexity of the coastline here that contributes to its relative resistance to recession. In contrast, the platform along the southern shoreline of Flamborough Head westwards to Sewerby shows many of the features that have usually been associated with shore platforms. Its slope is not complicated by strong micro-relief or debris accumulations. Most waves that affect it are strongly refracted around the headland and tend to approach from the south-east and east thus travelling at an angle across the platform rather than at a normal orientation to the cliffs. This area lacks flints in the Chalk and most of the sediment available to be used by the natural system as erosional tools is sand or chalk pebbles. This area thus raises important questions for the debate concerning platform development, which further modelling and observation should consider.

Conclusions

Flamborough Head is a very important site for the following reasons. First, it is the most complex cliffed Chalk coastline in England, with numerous caves and arches. Second, it is the largest such site that has been affected by glacial processes, which have not necessarily contributed directly to the coastal forms but may have affected the nature of the Chalk itself. The Chalk is overlain with Devensian tills, a combination that gives this site further interest because of the effects this has on the nature of the cliff-forms. Third, it exemplifies well the effects of different wave climate upon coastal forms. Fourth, it provides an excellent site for the study of coastal erosional processes and the linkage of cliff–beach–platforms processes that Pethick (1984) suggests is needed if platforms are to be placed in context and better understood. Finally, it is the only Chalk cliff GCR site that is affected solely by North Sea wave systems.

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