Chapter 3 Hard-rock cliffs — GCR site reports

Introduction

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The selected hard-rock cliff GCR sites described in this chapter are formed in a wide range of rock types, from granites to sandstones, and, as described in Chapter 1, may be classified by overall rock resistance to denudation according to lithology and structure (see (Figure 1.3)). Strong lithological control and cliff development is seen where harder rocks form headlands and softer rocks form intervening bays, but rock structure and hinterland topography can be equally important. How far rocks at the coast depart from their overall mean position is a function of the importance of factors such as degree of rock jointing (which affects overall rock resistance to wave erosion) and/or the effectiveness of weathering processes, which may weaken the rock. Jointing and related structural controls are often involved in the development of headlands and bays, and over time lead to the isolation of headlands into islands, arches or stacks (see (Figure 2.8)). When stacks eventually collapse, their bases often survive for a time as reefs or skerries until these too merge into the developing coastal platform. In general, features such as arches and stacks are often found on actively eroding lengths of coast and on well-jointed rocks (see Chapter 2), but their absence is not necessarily an indication of slow coastal retreat. At a smaller scale, a wide range of features such as crevices, caves, clefts, and blowholes can form and even smaller-scale features such as tafoni and similar weathering forms also occur. Similarly, shore platforms have a range of features, from larger forms (ridges, scarps, runnels) related to structural controls to minor forms linked to abrasion or scouring (e.g. potholes and rock pools), those formed by weathering such as tafoni and solution basins on sandstones or limestones, and by bio-erosion, including the home scars and hollows of grazing molluscs.

The pattern of strata cropping out in cliffs affects their form (see (Figure 2.7)). In addition, the direction of the dip of rocks in relation to the coastline will affect cliff form. As occurs on inland slopes, steeper cliffs form where the strata are more of less horizontal; seaward dips result in a tendency to dip-slip rock failure and lower cliff angles. Unlike inland, these structural controls also affect the shore platform (the erosional stump left by a receding cliff), and study of the combined landforms over a wide range of rocks and structures should lead to a better understanding of the relationships involved. Intensely folded strata, as at Hartland Quay (north Devon) and on parts of the Pembrokeshire coast (see GCR site reports in the present chapter), can be eroded into complex forms that can be very different from the characteristic shore platforms and cliffs found nearby in the same strata without the folding. Some rock types develop characteristic cliff forms, such as the granite at the Bullers of Buchan or the sandstones of the Orkney Islands.

Just as local topography can fundamentally affect inland cliff form, the nature of the land adjacent to the coast affects coastal cliffs and rocky shores. Where coastal erosion has incised into former river valleys, a range of hanging valley features can occur, as at the Hartland Quay site in Devon. Submergence of previously glaciated landscapes creates a coastline of great diversity such as in the sea lochs of western Scotland or in the drowned, eroded glacial surfaces of Loch Maddy in the Western Isles.

The range of exposure to wave energy, the various geological strata involved, and the varying sea level history of these coasts, affected as they are by differential glacial unloading and different relative sea-level histories, form a good basis for future research work. Rates of cliff retreat and of platform lowering remain to be measured at almost all of these sites, though the existence of young features such as stacks imply that some coastal forms developed since the end of the last glaciation in spite of the host cliff coastline having been in existence for much longer and surviving several sea-level changes.

(Table 3.1) Hard-rock cliff GCR sites, including those sites described in other chapters of the present volume that include hard-rock cliffs in the assemblage.

Site*	**Main features**	**Main geological materials**	**Tidal range (m)**

St Kilda Archipelago. Western Isles	Plunging cliffs, submerged caves and platforms; structural controls	Igneous complex of granophyres, basalts and dolerites	3.0
Villians of Hamnavoe, Shetland	Structural controls, wave stripping, cliff-top boulder beaches	Devonian extrusive andesites and ignimbrites	1.5
Papa Stour, Shetland	Diversity of cliff forms, caves, stacks, arches; inherited cliffs	Devonian extrusive rhyolite and ignimbrite	1.5
Foula, Shetland	Higher cliffs, shore platforms, geos; exhumed cliffs stacks and geos	Devonian sandstones and Dalradian metamorphic rocks	1.5
West Coast of Orkney	Structural control of steep over- hanging cliffs; stacks arches; inherited cliffs; young individual features	Devonian Old Red Sandstone	3.0
Duncansby to Skirza Head, Caithness	Geos and stacks, shore platforms, blowhole	Devonian Old Red Sandstone	3.0
Tarbat Ness, Easter Ross	Weathering forms: tafoni and solution pits	Fault-controlled Devonian Old Red Sandstone	3.2
Loch Maddy–Sound of Harris coastline	Drowned surface of glacial erosion; rock basins, skerries and platform	Lewisian gneiss, faulted and crushed zones	3.5
Northern Islay, Argyll and Bute	Emerged shore platform and beach gravels	Precambrian quartzites and tillites; Dalradian Limestone	2.0
Bullers of Buchan, Aberdeenshire	Geos, caves, arches. stacks, platform, blowhole	Granite and dyke intrusions	3.5
Dunbar, East Lothian	Four shore platforms, some of which are glaciated	Devonian Old Red Sandstone, Carboniferous sandstone, igneous intrusions	4.5
St Abb's Head, Berwickshire	Steep cliffs, geos, fault-controlled inlets and headlands	Devonian extrusive felsites, tuffs, and grits; faulting	4.5
Tintagel, Cornwall	Longitudinal coast, structural control caves, arches, slope-over- wall cliff	Upper Devonian slates, siliceous sandstones, pillow lavas, tuffs and phyllites	6.5
South Pembroke cliffs	Structural controls, eroded karstic coast, stack, arch, cave, geo	Carboniferous limestones	6.0
Hartland Quay, Devon	Truncated valleys, waterfalls, slope-over-wall cliffs, shore platforms	Carboniferous interbedded fine-grained sandstones and shales	6.4
Solfach, Pembrokeshire	Ria, infilled ria	Cambrian and Ordovician flags and dolerites	5.9
Carmarthen Bay, Carmarthenshire	Ria, shore platforms	Old Red Sandstone and Carboniferous limestone	8.0
Furzy Cliff—Peveril Point, Dorset	Structural controls, longitudinal coast, slope-over-wall cliffs, truncated valleys	Portlandian and Purbeckian limestones and sandstones	1.9
Holy Island, Northumberland	Structural controls, shore platforms	Carboniferous sandstones and limestones	4.1

Upton and Gwithian Towans, Cornwall	Exhumed cliffs and stacks	Devonian slates	5.8
Hallsands, Devon	Emerged shore platform	Mica-schist and quartz- schist	4.4

*Sites described in the present chapter are in bold typeface

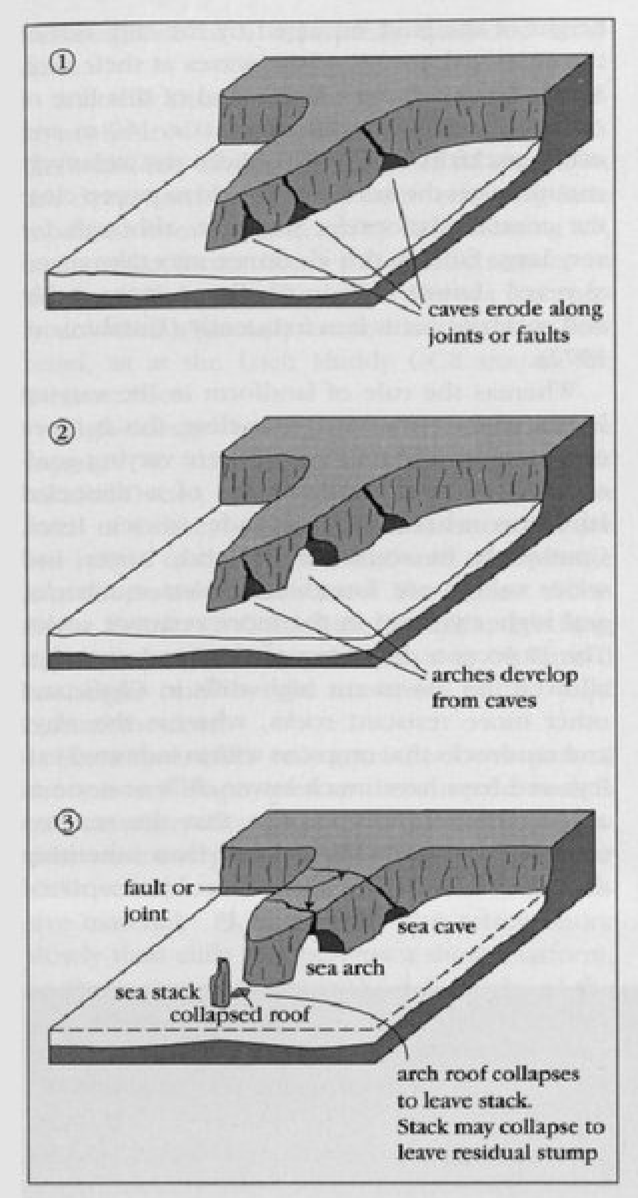
The conservation value of hard-rock cliff coasts

Unlike weaker-rock coasts, the pressure for coastal protection works is in general absent from hard-rock coasts and most sites will remain available for investigation without significant conservation activities. Nevertheless, it is also important to select a representative series of hard-rock cliff GCR sites to ensure that the Earth science conservation value, and geomorphological significance of such sites is recognized. Hard-cliff coasts are important to our understanding of the following processes:

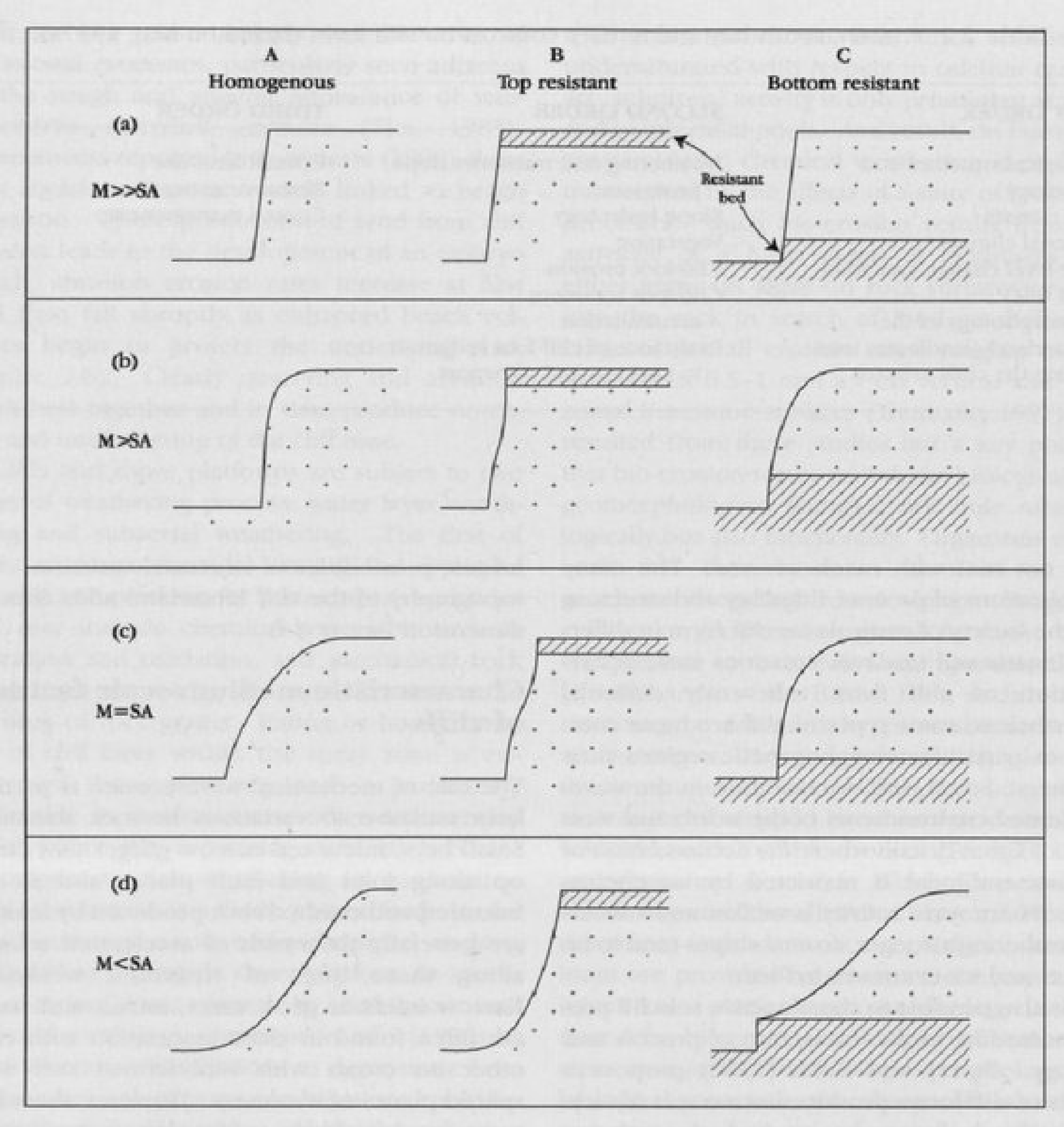
1. the processes of retreat in cliffs that are cut into rocks of varying resistance resulting from lithological and structural differences;
2. the effect of inheritance of cliffs and shore platforms from former sea levels
3. the controls on presence/absence of shore platforms and plunging cliffs
4. the detailed processes of wave quarrying, abrasion and weathering of rock surfaces at the coast
5. the processes of supply and transport of sediments from cliffs to beaches both below the cliffs and alongshore.

In the present chapter, the sites described represent a wide range of exposure to wave energy, a range of geological controls (structure and rock type) and varying sea-level histories. The order of the reports broadly reflects a reduction of wave energy and rock resistance, begin-nign in the north and west, moving southwards into softer lithologies and lower wave energies

(Figure 1.3) Relative rock resistance for 71 different outcrops (divided by lithology and age) was established through computer analysis of data on altitude, dissection, and geology for a grid of kilometre squares covering Great Britain and the surrounding continental shelf. Six consistent classes were established using up to 19 variables in various combinations. White areas are unclassified. (From Clayton and Shamoon, 1998, fig. 1).



(Figure 2.8) The development of caves, arches and stacks. Wave erosion is more effective along faults and joints where the rock is weaker, and so caves become excavated along these lines of weakness.



(Figure 2.7) A classification of active sea-cliff forms according to comparative rates of subaerial erosion and marine erosion (SA = subaerial erosion; M = marine erosion). Type 'A' profiles are for cliffs of uniform resistance to erosion; type 'B', where a more resistant rock layer is present at the top; and type 'C', where there is a layer of more resistant rock at the base. (Based on Hansom, 1988, after Emery and Kuhn, 1982.)

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