

Coastal Cliffs of India

Inside....

- *Rock cliffs*
- *Overview of sea cliffs*
- *Formation of cliffs*
- *Coastal cliffs on different types of rocks*
- *Cliffed coasts of India*
- *Ecological and social importance of the cliff system*

Vol.16 (1) October 2016 - March 2017

ISSN:2393-8978



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CONTENTS

1

Rock Cliffs

1

Overview of Sea Cliffs

2

Formation of Cliffs

4

Coastal Cliffs on Different Types of Rocks

9

Cliffed Coasts of India

13

Ecological and Social Importance of the Cliff System

Cover Design & Layout

Ms. S. Sathya

Information Officer - ENVIS,

Institute for Ocean Management,

Anna University, Chennai - 600025

Printed at: Houston Graphics, Chennai

Coast track

Issues and Challenges in Coastal Management

Cliffs are common coastal features formed by the combination of erosion and weathering. The weathering process works on the upper parts of the cliff and erosion occurs on the base of the cliff. Steep cliffs are formed where the land consists of hard, more resistant rocks, and their height obviously being determined by the difference between the sea level and the level of the land. Hard rocks erode and weather slowly and the less fractured rock is the better, it will resist breaking down. Igneous rocks such as granite and basalt form rugged vertical cliffs. Softer rocks, such as clay, shale and some sandstones erode more easily and can create more gently sloping cliffs although this is not always the case. Sedimentary rocks that have been laid down in distinct strata may dip towards the sea or away from it. This has the effect of either presenting a smooth surface towards the sea or a rough broken surface. A smooth angled surface will better resist waves than a rough broken surface, so the same rock can form different types of cliff according to how the rock surfaces face the sea. Generally though, remember that hard rocks form steep cliffs and soft rocks and badly broken/ fractured rocks form more gently sloping cliffs.

This issue of Coast Track provides an insight about the rock cliffs, overview of the sea cliffs, formation of cliffs, coastal cliffs on different types of rocks, cliffed coasts of India and the ecological and social importance of the cliff system.

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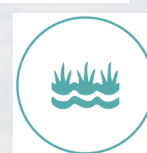
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Important Days

Feb 2 nd	World Wetland Day
Feb 28 th	National Science Day
Mar 2 th	World water Day
April 5 th	Maritime day
April 22 th	Earth day
June 5 th	World environmental day
June 8 th	World Ocean Day
July 26 th	National tree day \Mangrove Day
Oct 3 rd	World natural day
Oct 24 th	International days of climate action
Nov 21 th	World fisheries day
Dec 2 nd	National pollution control day
Dec 4 th	National navy day





ROCK CLIFFS

In geographical and geological terms, a cliff is a vertical or near vertical rock exposure, formed as erosion landforms due to the processes of erosion and weathering. Cliffs are common on coasts, mountainous areas, escarpments and along rivers. Cliffs are usually formed by rock that is resistant to erosion and weathering. Sedimentary rocks are most likely to form cliffs which include sandstone, limestone, chalk, and dolomite, whereas Igneous rocks such as granite and basalt also often form cliffs. An escarpment is a type of cliff, formed by the movement of a geologic fault or a landslide. Many cliffs also feature tributary waterfalls or rock shelters. Coastal erosion may lead to the formation of sea cliffs along a receding coastline. Some of the largest cliffs on Earth are found underwater. Coastal cliffs are the most conspicuous geomorphic features that characterize several strips of the Indian coasts. In certain parts of Kerala coast, valuable lands are getting depleted due to cliff erosion. In India, only a few investigations pertaining to slumping of permeable cliffed shoreline has taken place (Nair, A.S.K. (2005) *Cliff slumping of permeable cliffed shorelines*, in: "Landslides", (Ed.)

Dr. G. Victor Rajamanickam, SASTRA University, Thanjavur, pp. 81-88)

OVERVIEW OF SEA CLIFFS

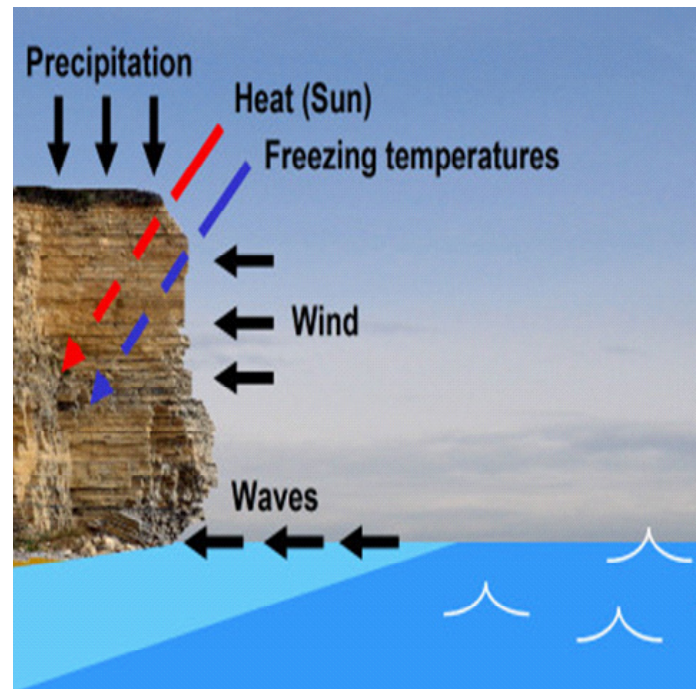
Sea cliffs are high, rocky coasts that plunge down to the sea's edge. These harsh environments are subject to the battering of waves, wind and salt-laden sea spray. Conditions on a sea cliff vary as you move up the cliff, with waves and sea spray playing larger parts in shaping the communities at the base of a sea cliff while wind, weather and sun exposure are the driving forces that shape the communities towards the top of a sea cliff (<http://animals.about.com/od/cliffsanddunes/p/seacliffs.htm>). The term "coastal cliff" refers to a steeply sloping surface where elevated land meets the shoreline. Like virtually all landforms, modern coastal cliffs are a "work in progress" continually acted upon by a broad assortment of offshore (marine or lacustrine) and

terrestrial processes that cause them to change form and location through time. An important consequence is that coastal cliffs "retreat" (that is, move landward) and the adjacent coastal land is permanently removed as they do so. Retreat can be slow and persistent, but on many occasions it is rapid and episodic (<http://norcalgeol.site.aplus.net/SpeakerInfo/2005/June%2005%20Speaker%20Info.pdf>).

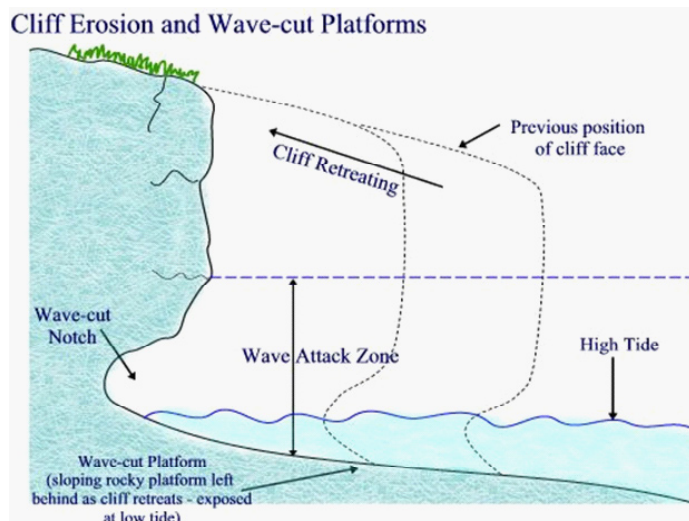
Coastal cliff is a general term that refers to steep slopes along the shorelines of both the oceans, where they are commonly called "sea cliffs". Coastal cliffs typically originate by marine or lacustrine erosional processes, particularly as the shoreline transgresses landward with a rise of water level (pubs.usgs.gov/pp/pp1693/pp1693.pdf).

FORMATION OF CLIFFS

Cliffs are large mass of rocks formed near the ocean-mountains as well as the walls of canyons and valleys. They are very high and are almost vertical or straight up – and – down rock masses. The formation of cliffs and wave cut platforms are due to the destructive waves eroding a steep coastal slope through processes like hydraulic action and abrasion. The waves erode along lines of weakness in the rock face to form a notch. This notch gets enlarged due to continuous erosion which in turn causes its roof to collapse and a cliff is formed. Further undercutting at the base of the cliff results in an overhanging cliff which eventually collapses. As the steep cliff retreats landwards, a flat terrace at the foot of the cliff gets exposed



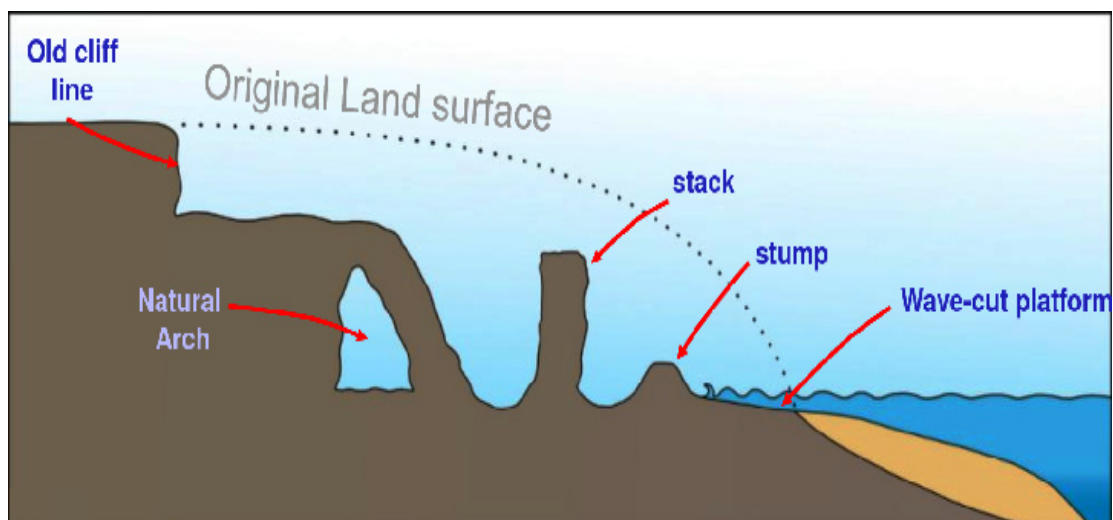
(Source: http://www.discoveringfossils.co.uk/coastal_geomorphology2.jpg)



Cliff erosion and wave – cut platforms

(Source: <https://ih-igcse-geography.wikispaces.com/2.2.+Coastal+features>)

to form a wave-cut platform. The eroded materials from this area get transported away and may be deposited in the sea to form an offshore terrace. Most scientists and mountaineers think the Rupal Flank of Nanga Parbat, a mountain in the Himalayas, is the highest cliff in the world. The Rupal Flank extends to 4,600 meters (15,092 feet) above its base. Others say the highest cliff in the world is the east face of Great Trango, in the Karakoram mountain range, which is 1,340 meters (4,396 feet) tall and one of the most difficult rock-climbs in the world. Both Nanga Parbat and Great Trango are located in Pakistan (http://education.nationalgeographic.com/education/encyclopedia/cliff/?ar_a=1).



Cliff erosion and wave-cut platforms

(Source: <https://ih-igcse-geography.wikispaces.com/2.2.+Coastal+features>)

ROCKY CLIFFED COAST

On a rocky cliffed coast made up of material which is relatively resistant to erosion (sandstone, limestone or granite) a flat rocky wave-cut platform or abrasion platform is formed in front of the cliff. This formation represents the foot of the cliff preserved at and below the level of water table.

In such types of coasts, if there is a tectonic uplift, these abrasion platforms can be raised to form coastal terraces, from which the amount of uplift can be calculated from their elevation relative to the sea level, taking into account any eustatic sea level changes.

Moreover, on a cliffed coast which is made up of material which is only fairly or even hardly resistant to erosion no wave-cut platform will be formed, in such cases a beach is formed in front of the sea cliff.

If waves cut notches at a narrow point on both sides of a promontory on the rocky cliffed coast, a natural arch may be formed. When the arch collapses as the coastline recedes further a stack is left behind on the wave-cut platform.

Further, a more, on a rocky cliffed coast wave action is not the only driving force for coastline retreat. General weathering of the bedrock is almost equally important.

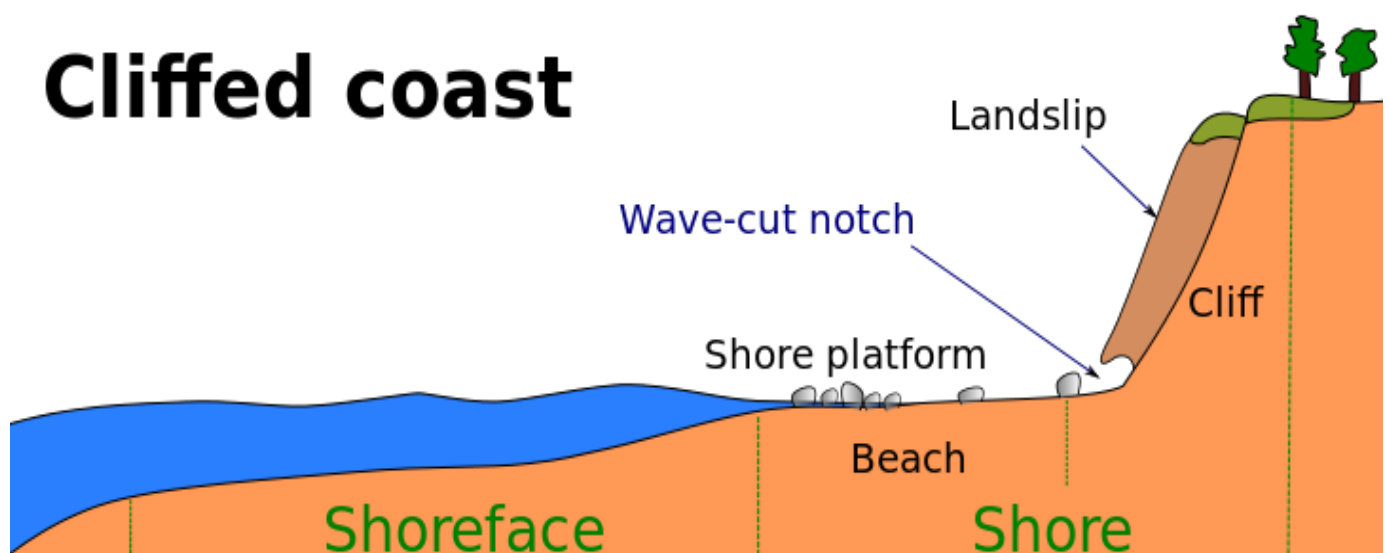


(Source: <https://golearngео.files.wordpress.com/2010/08/cliff.jpg>)

LIVING AND DEAD CLIFFS

“Living cliffs” are those on a coast that is still active, i.e. that is being eroded and is receding. A “dead cliff”, by contrast, is only reached by very high marine waves and is therefore subjected to very little change. A clear indication of a lack of activity at a dead cliff is a covering of vegetation that appears on the cliff as wave action against it subsides (http://en.wikipedia.org/wiki/Cliffed_coast).

Cliffed coast



(Source: https://upload.wikimedia.org/wikipedia/commons/thumb/2/29/Cliffed_coast_%28schematic_view%29.svg/330px-Cliffed_coast_%28schematic_view%29.svg.png)

COASTAL CLIFFS ON DIFFERENT TYPES OF ROCKS

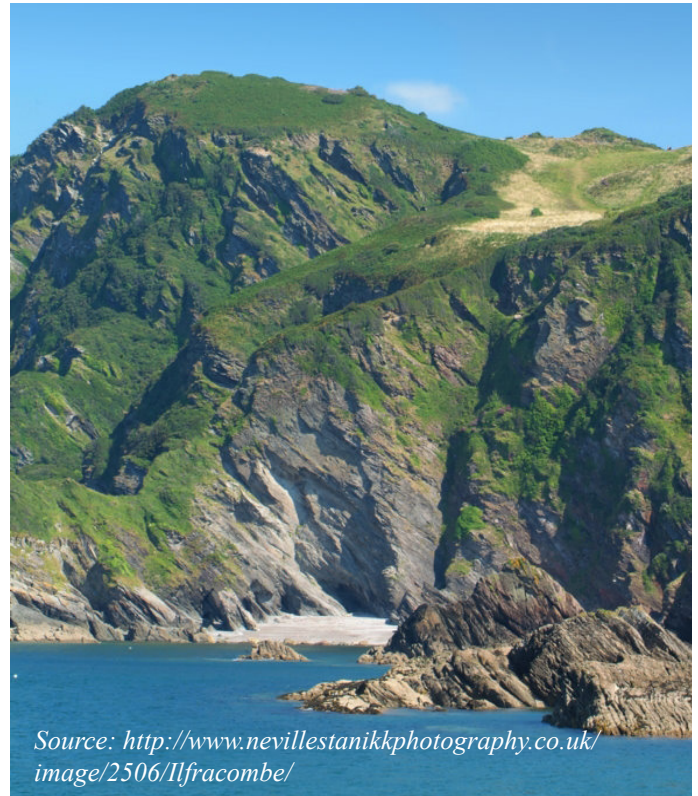
Coastal cliffs are very steep rock faces near the sea that are greater than 5 m in height. They may ascend in steps and have ledges, crevices and overhangs. Coastal cliffs may rise directly from the sea or be separated from it by a narrow shore.

1. COASTAL CLIFFS OF ACIDIC ROCK

Acidic rocks are primarily granite and gneiss, hard sandstones (including greywacke, mudstones), and rhyolite. Cliffs and outcrops provide many varied habitats: from bare rock colonized only by mosses and lichens to deeper soils supporting woody vegetation; from highly exposed situations to heavily shaded and sheltered habitats; and from very dry to permanently wet surfaces. Coastal cliffs are influenced by salt spray, particularly near their bases and halophytes (salt-tolerant plants) often characterize these habitats.

NOTABLE FLORA AND FAUNA :

Threatened plants include the nationally critical thick-leaved tree daisy (*Olearia pachyphylla*), the nationally endangered, forget-me-not (*Myosotis petiolata* var. *pansa*), pygmy button daisy (*Leptinella nana*), native sow thistle (*Picris burbidgeae*), the nationally vulnerable Cook's scurvy grass (*Lepidium oleraceum*), Napuka (*Hebe speciosa*), purple plume grass (*Dichelachne micrantha*), *Pimelea tomentosa*, the declining coastal mahoe (*Melicytus crassifolius*), the relict shore puha (*Sonchus kirkii*), the naturally uncommon Lyall's carrot (*Anisotome lyallii*), Lindsay's daisy (*Celmisia lindsayi*) and Beddie's tussock (*Chionochloa beddiei*).



Source: <http://www.nevillestanikkphotography.co.uk/image/2506/Ilfracombe/>

THREATS :

Erosion is one of the main threats (although it is a natural process). However, coastal cliffs on hard rocks like granite or gneiss are less frequently undermined by the sea than cliffs composed of softer and more incoherent sandstone or mudstone. Landslides resulting from marine erosion are even more frequent where the rocks are unconsolidated, such as shattered greywacke. The greater openness of cliffs increases susceptibility to weed invasion. There may be some grazing at the top of sea cliffs. Near urban centres, and coastal cliff top also are desirable locations for dwellings, and further rubbish dumping. (<http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems/coastal/coastal-cliffs-of-acidic-rocks>).



Source: www.pv-magazine.com

2. COASTAL CLIFFS OF BASIC ROCKS

Basic rocks include basalt, andesite, diorite, gabbro, and tuffaceous mudstones and sandstones. Cliffs and outcrops provide many varied habitats: from bare rock colonized only by mosses and lichens to deeper soils supporting woody vegetation; from highly exposed situations to heavily shaded and sheltered habitats; and from very dry to permanently wet surfaces. Coastal cliffs are particularly influenced by salt spray, with halophytes and succulents.

NOTABLE FLORA AND FAUNA :

Threatened plants include the nationally critical *Leptinella rotundata*, Lyttelton forget-me-not (*Myosotis lytteltonensis*), *Pimelea actea*, the nationally endangered *Myosotis petiolata* var. *pansa*, the nationally vulnerable purple plume grass (*Dichelachne micrantha*), *Pimelea tomentosa*, Cook's scurvy grass (*Lepidium oleraceum*), napka (*Hebe speciosa*), the gradually declining pygmy forget-me-not (*Myosotis pygmaea* var. *pygmaea*), a native buttercup (*Ranunculus recens*), coastal mahoe (*Melicytus* aff. *crassifolius*), shore spurge (*Euphorbia glauca*), the relict shore puha (*Sonchus kirkii*), the naturally uncommon mawhai (*Sicyos* aff. *australis*), Beddie's tussock (*Chionochloa beddiei*), Stewart Island forget-me-not (*Myosotis rakiura*), *Senecio glaucophyllus* subsp. *basinudus*, Akaroa harebell (*Wahlenbergia akaroa*) and Lyall's carrot (*Anisotome lyallii*). Spotted shags (*Stictocarpa punctatus*) nest on cliff ledges. Although not threatened, sooty shearwaters (*Puffinus griseus*) attempt to breed on Banks Peninsula but are preyed upon. Spotted skinks (*Oligosoma lineocellatum*) and 'Canterbury geckos' (*Hoplodactylus* aff. *maculatus*) usually occurred on the mainland cliffs but in the coastal zone are now confined to off-shore stacks.



Source: <http://en.paperblog.com/blowing-rocks-preserve-jupiter-fl-317203/>

THREATS :

Weed invasion is a serious threat and are dominated by weeds including, gorse (*Ulex europaeus*), ice plant (*Carpobrotus edulis*), pig's ear (*Cotyledon orbiculata*), boneseed (*Chrysanthemoides monilifera*), and Chilean rhubarb (*Gunnera tinctoria*). Livestock may graze the cliff tops, but apart from goats, they pose no serious threat because most areas are too steep for grazing. Coastal cliff tops are desirable locations for dwellings near urban centres. Erosion (although it is a natural process), combined with subsequent invasion by weeds, may be a problem for native species (<http://www.landcare.research.co.nz/publications/factsheets/rare-ecosystems/coastal/coastal-cliffs-of-basic-rocks>).



Source: <http://www.vagabondish.com/turning-australias-great-ocean-road-into-a-great-ocean-road-trip>

3. COASTAL CLIFFS OF CALCAREOUS ROCKS

Coastal cliffs are very steep rock faces near the sea that are greater than 5m in height. They may ascend in steps and have ledges, crevices and overhangs. Coastal cliffs may rise directly from the sea or be separated from it by a narrow shore

Calcareous rocks are primarily limestone and marble. Coastal cliffs are influenced by salt spray, particularly near their bases, with halophytes and succulents (e.g. *Disphyma australe subsp. australe*), silver tussock (*Poa cita*) and herbs (e.g. *Einadia triandra*) characteristic of these habitats. Woody plants are frequently stunted and wind-shorn and commonly include divaricating shrubs such as *Coprosma* species. Native species that have been lost from neighboring habitats may find refuge on coastal cliffs.

NOTABLE FLORA AND FAUNA :

Rare and threatened plants include the nationally critical kaka beak (*Clanthus puniceus*) and *Pachycladon exile*, the nationally endangered coastal tree broom (*Carmichaelia muritai*), native hawkweed (*Picris burbidgei*) and *Melicytus aff. crassifolius* (CHR 279358; 'cliff'), the relict mawhai (*Sicyos aff. australis (a)* (AK 252822) and shore puha (*Sonchus kirkii*); the naturally uncommon Castlepoint daisy (*Brachyglottis compacta*), Beddie's tussock (*Chionochloa beddiei*), *Elymus sacandros*, *Hebe stenophylla var. hesperia*, *Craspedia (k)* (CHR 283173; coast) and *Craspedia (r)* (CHR 313349;).

THREATS :

Only a few weed species are present, e.g. stock (*Matthiola incana*), but others are approaching from urban centres (e.g. *Senecio glastifolius*). Farming practices do not threaten these systems, which are mostly too steep for sheep grazing, but goats can be a problem. Coastal cliff tops are desirable locations for dwellings near urban centres. As limestone is a softer rock, erosion, although it is a natural process, may be more of a problem than on coastal cliff types of harder rock types, such as granite. Most limestone mining is inland, so is not a threat to coastal calcareous cliffs. Increased erosion and inundation may result from climate change (<http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems/coastal/coastal-cliffs-of-calcareous-rocks>).



4. COASTAL CLIFFS OF ULTRABASIC ROCKS

Ultrabasic (also known as ultramafic) rocks contain very little quartz or feldspar and are composed essentially of ferro magnesium silicates, metal oxides, and native metals (Anon 1962) that weather to soils with low concentrations of major nutrients and high concentrations of toxic metals such as nickel, chromium, and cobalt.

Cliffs and outcrops provide many varied habitats: from bare rock that can only be colonised by mosses and lichens to deeper soils supporting woody vegetation; from highly exposed situations to heavily shaded and sheltered habitats; and from very dry to permanently wet surfaces. Coastal cliffs are influenced by salt spray, particularly near their bases, with halophytes often characteristic. Vegetation often consists of matted small-leaved shrubs such as wire-netting bush (*Corokia cotoneaster*), naturally uncommon *Cassinia amoena*, and Mingimingi (*Leptecophylla juniperina*). Native species that have been lost from neighboring habitats may find refuge on cliffs and scarps.

NOTABLE FLORA AND FAUNA :

Threatened plants include the nationally critical hook grass (*Uncinia perplexa*), the nationally endangered kohuhu (*Pittosporum serpentinum*), the nationally uncommon North Cape sedge (*Carex ophiolithica*), *Coprosma distantia*, *Coprosma spathulata* subsp. *hikuruana*, *Geniostoma ligustrifolium* var. *crassum*, haloragis (*Haloragis erecta* subsp. *cartilaginea*), *Hebe brevifolia* mingimingi (*Leucopogon xerampelinus*), North Cape native jasmine (*Parsonsia praeruptis*), *Pittosporum pimeleoides* subsp. *majus*, *Pomaderris paniculosa* subsp. *novae-zelandiae*, *Pimelea* aff. *tomentosa* (b) (AK 130893), and *Pseudopanax* aff. *lessonii* (AK 46066).

THREATS:

The spread of pampas grass (*Cortaderia selloana*), downy hakea (*Hakea gibbosa*), and prickly hakea (*H. sericea*) on cliffs is of concern. In shrubby ecosystems, fire poses a moderate threat (<http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems/coastal/coastal-cliffs-of-ultrabasic-rocks>).



5. COASTAL CLIFFS ON QUARTZOSE ROCKS



Source: <https://thesnipertakesaim.wordpress.com/2014/03/11/the-rocks-of-aragunnu/>

Quartzose is a granular metamorphic rock consisting essentially of quartz and it is extremely infertile. Coastal cliffs are influenced by salt spray, particularly near their bases, and halophytes (salt tolerant plants) often characterize these habitats.

NOTABLE FLORA AND FAUNA :

There are no known threatened plants on these cliffs. Formally, these sites would once have had large colonies of sea birds such as petrels.

THREATS :

Cliffs (although it is a natural process) but hard rocks like some quartzites are less frequently undermined by the sea than cliffs composed of softer and more incoherent sandstone or mudstone. Landslides resulting from marine erosion are even more frequent where the rocks are unconsolidated, such as shattered greywacke. The greater openness increases susceptibility to weed invasion. There may be some grazing at the tops of sea cliffs. Near urban centres, coastal cliff tops also are desirable locations for dwellings, and the resulting rubbish dumping, but quartzose cliffs are far from such centres

(<http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems/coastal/coastal-cliffs-on-quartzose-rocks>).



Source: <http://il3.picdn.net/shutterstock/videos/6765115/thumb/1.jpg?i10c=img.resize>

CLIFFED COASTS OF INDIA

The shoreline of rocky coasts is defined by rugged or relatively resistant lithology. Estimations indicate that cliffs occur along 80 % of the world's coastlines and are formed in all latitudes. The cliffs along the East coast of India are highly limited due to major deltaic basins and are mostly in Andhra Pradesh & Southern Tamil Nadu. West Coast being faulted coast consists of many cliff sections in all states.

CLIFFS OF ANDHRA PRADESH

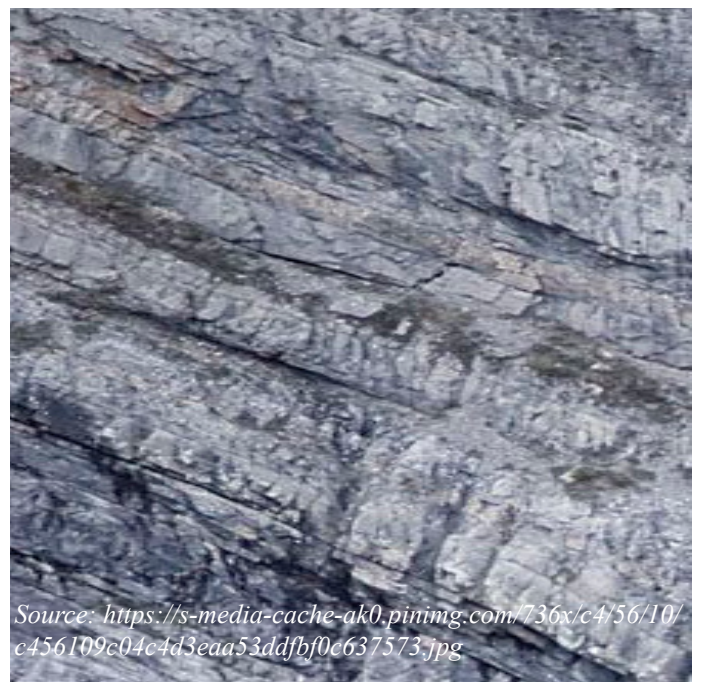
Northern Andhra Pradesh coast exhibits spectacular cliffs in a 150 km stretch from Pudimadaka to Pentakota, characterized by rocky headlands plunging steeply into the sea which are very common between Baruva and Pudimadaka. The Visakhapatnam coast is primarily rocky with many headlands and irregularly curved intervening bays. The Dolphin nose, on the southern side of the Visakhapatnam harbour is a steep plunging cliff. The principal rock types of these cliffs are khondalites, charnockites and granite gneisses.



Source: www.easydestination.net

CLIFFS OF TAMIL NADU

Tamil Nadu is characterized by marine cliffs/terraces with different rock formations and are prominently seen in Mannar coast. 3m coral terrace are seen at Pamban & Appa Island, whereas 2.5 - 3m calcareous sandstone cliff are seen from Valinockkam to Therukumukkaiyur. Tiruchendur shows calcareous sandstone cliff which are 6m high and Manapad exhibits calcareous sandstone cliff of 8m. High sandstone terrace of 3m are seen at Idinthakarai. Kanyakumari is characterized by Precambrian cliffs of 2 - 3 m. Along Kanyakumari - Thenkaipattinam coast, Tamil Nadu, several cliff sections of 5 - 30 m with Precambrian crystalline rocks are seen.



Source: <https://s-media-cache-ak0.pinimg.com/736x/c4/56/10/c456109c04c4d3eaa53ddf0c637573.jpg>

CORALLINE ROCK CLIFFS IN RAMESHWARAM



Low Cliff at Valinokkam, with 3 stage marine terrace. Height 3.5 m.

Image Courtesy : Dr.P.Seralathan,Consultant, Institute for Ocean Manement, Anna University.



Low coralline and beach rock cliffs in the Mannar coast

Image Courtesy : Dr.P.Seralathan,Consultant, Institute for Ocean Manement, Anna University.



Manapad cliff, South of Tiruchendur



Image Courtesy : Dr.P.Seralathan, Consultant, Institute for Ocean Manement, Anna University.

CLIFFS OF KERALA COAST

The 560km long Kerala coast is characterized by long barriers with narrow beaches and steep cliffs. Distribution of cliffs are from nine sections which measures a cumulative length of 63.5 km. The cliff sections in the southern coast comprise both permeable and impermeable rocks, whereas those along northern coast are comprised of either Precambrian crystalline and/or Tertiary formations. Notches, caves and even small arches are developed in Cannanore, Dharmadam and Kadadi cliffs, where only primary laterites are exposed to wave attack. Stacks composed of laterite and Precambrian crystallines found in nearshore of cliffed coast indicate recession of shoreline. Mass wasting, mudslide and mudflow type of cliff failures are common in permeable to semi-permeable rocks, whereas rotational sliding, rock fall and toppling failure are found in hard rock cliffs.



A hard rock cliff section south of Vizhinjam coast

Image Courtesy : Dr.P.Seralathan, Consultant, Institute for Ocean Manement, Anna University.



A steep cliff section in Varkala, Kerala

Image Courtesy : Dr.P.Seralathan, Consultant, Institute for Ocean Manement, Anna University.



Lateritic/ Sandstone cliffs , Varkala, Kerala

Image Courtesy : Dr.P.Seralathan, Consultant, Institute for Ocean Manement, Anna University.

ECOLOGICAL AND SOCIAL IMPORTANCE OF THE CLIFF SYSTEM

There is an extensive literature on the conservation of coastal habitats saltmarsh, sand dune and shingle (gravel) structures. By comparison, there appears to be much less information on sea cliffs, especially the more resistant 'hard' rock cliffs. Sea cliffs are clearly an extensive and important formation world wide. They support a wide variety of vegetation from ephemeral communities to dense woodland with a diverse fauna.

Climatic effects are a distinct feature in coastal locations. The shape of wind-pruned trees and shrubs, characterize some of the most exposed locations. In other areas, oceanic effects may ameliorate the climate, influencing the vegetation some distance inland. Moisture-laden air, derived from onshore winds, also affects coastal forests in many parts of the world. Sheltered steep-sided coastal valleys and the lee slopes of coastal cliffs may support ancient woodland. By contrast, to these wooded cliffs, salt spray can also have a significant influence. This may include grazed turf with salt tolerant communities, or further inland species rich limestone grassland. Exceptionally, hurricane storms can force salt spray up to 90m in the air helping to create unusual communities such as those of the megacliffs. Soft rock boulder clay cliffs can erode rapidly. With the instability a different set of interest develops, including rare and specialist invertebrates (<https://www.hope.ac.uk/cliffs/>).

Coastal soft cliffs have been a very neglected wildlife habitat, and much of the resource has already been altered or lost behind coastal protection schemes, or degraded through inappropriate management. In their natural state, soft cliffs do not require any management to maintain their wildlife riches.

The natural processes of erosion that shape the soft cliffs and maintain the important habitats such as bare ground and pioneer plant communities must be allowed to continue to function naturally. If these processes are prevented or reduced through cliff protection then local extinctions of specialized invertebrates will follow. Soft cliff habitat can also be damaged through insensitive cliff top management and artificial drainage. Climate change also poses a threat to soft cliffs and their invertebrate riches.



Source: <http://www.mytourntrip.com/images/Varkala%20Beach4.jpg>

GEOMORPHIC EXPRESSION OF LATE QUATERNARY SEA LEVEL CHANGES ALONG THE SOUTHERN SAURASHTRA COAST, WESTERN INDIA

Geomorphic expression of land-sea interaction is preserved in the form of abandoned cliffs, marine terraces, shore platforms and marine notes along the southern Saurashtra coast. These features have been used to ascertain the magnitude of sea level changes during late Quaternary. Notch morphology and associated biological encrustation have been used to estimate the magnitude and duration of palaeo-sea strands. Marine notches and other erosive features occurring between 12 and 15m above the present Biological Mean Sea Level (BMSL) are attributed to the last interglacial corresponding to the Marine Isotopic Stage 5 (MIS-5). However, 6 to 9m upliftment of the coastal fringe is attributed to this sea level. The second major high sea strand was identified during the mid-Holocene when the sea rose 2m above the present level. Notches corresponding to this high sea level are recorded 4 to 5m above the present BMSL

Marine notches definition and mechanism

Notches or nips are 'U' or 'V' shaped grooves, few centimetres to several metres deep, cut into the bed rocks and corresponding to the prevailing sea level. Their morphology (recumbent 'U' or 'V' shape) accords well with the tidal range (Pirazzoli 1986; Rust and Kershaw 2000). These features have received significant attention to enable the study of imprints of past sea levels. Recently, notches have been used to estimate land-sea interactions along the Mediterranean coastline (Pirazzoli 1986; Pirazzoli et al 1996; Rust and Kershaw 2000; Kershaw and Guo 2001).

From the process point of view, marine notches can be formed by a combination of physical, chemical and biological processes. Physical abrasion aided by

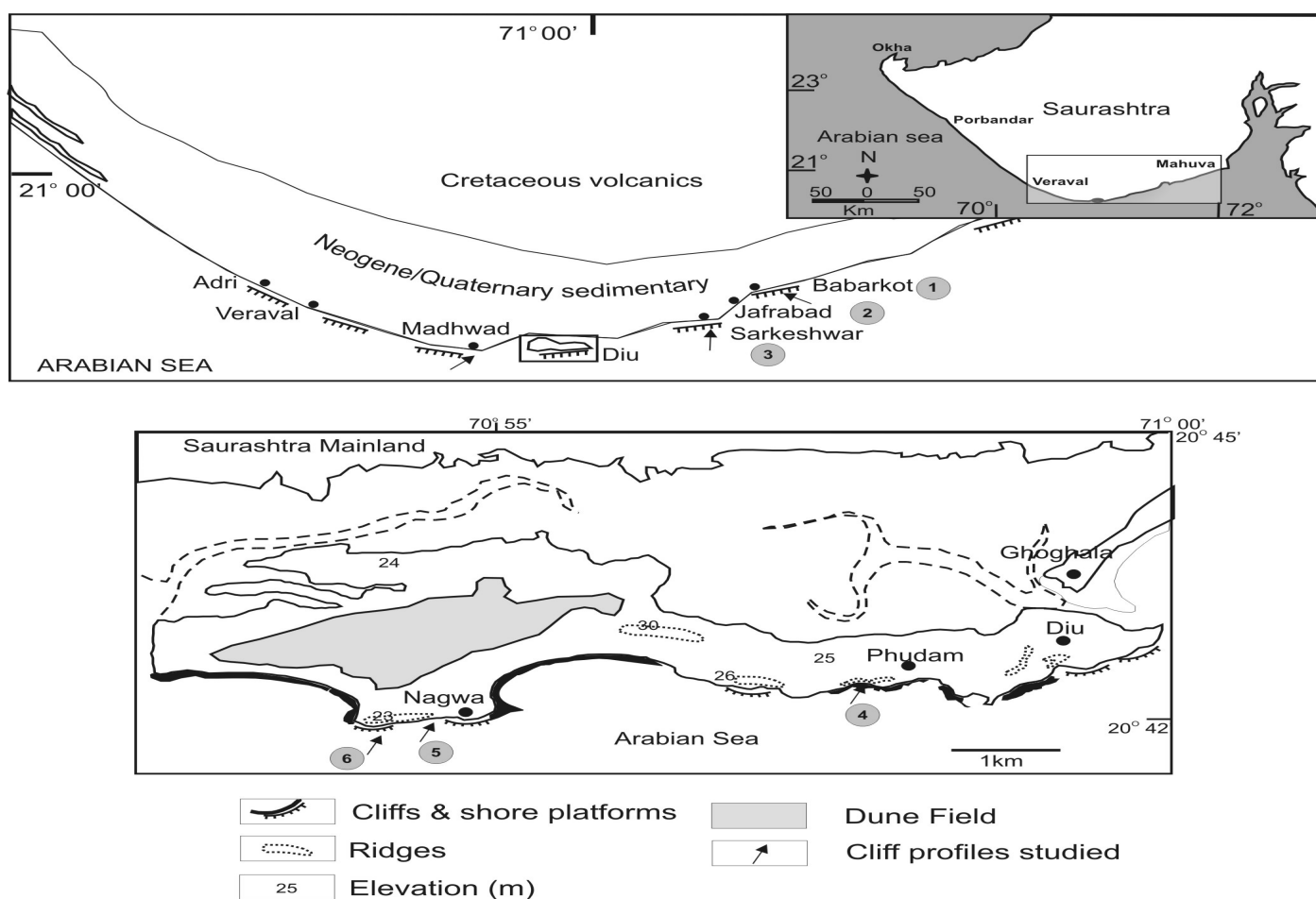


Figure 1. Map showing general coastal geomorphic features of south Saurashtra and locations of the cliff profiles studied. Lower box is an enlarged window of the Diu area.

sand and gravel enhances the process of marine notch formation giving rise to 'U' or 'V' shaped inundations that are easy to distinguish from the chemically or biologically formed notches by the development of a polished face on the notches (Rust and Kershaw 2000). Pirazzoli (1986) suggested that in addition to physical processes, biological activity in the form of bio-encrustation (algal and vermetid reef) plays an important role in the formation of marine/tidal notches. According to him the notches can develop in the infra-littoral zone which experiences complete immersion, the mid-littoral zone that is characterised by

intermittent immersion and the supratidal zone that is above high tide level (figure 2).

The infra-littoral and mid-littoral zones show a distinct difference in the amount and type of biomass. Their boundary has been regarded as Biological Mean Sea Level (BMSL) that can be used as dependable datum in the study of cliff profiles to interpret the past sea levels (Stiros et al 2000). As the tide range varies along the Saurashtra coast, the estimate of the mean sea level becomes difficult in the field. In view of this, the BMSL has been used as a standard datum in the present study.

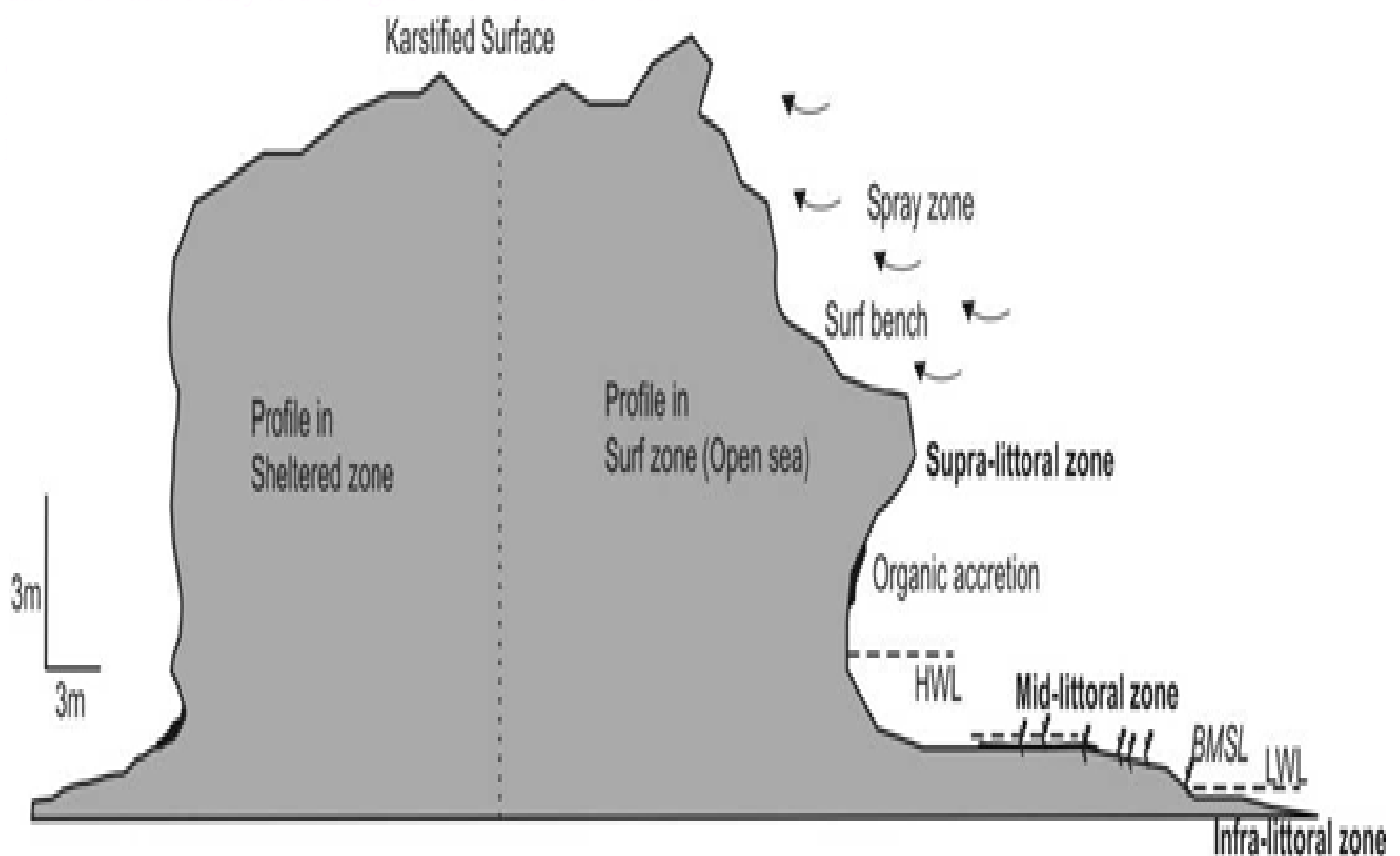


Figure 2. Schematic representation of the typical coastal cliff profile and its relation with the coastal bathymetric zones (after Rust and Kershaw 2000). HWL: High Water Line, LWL: Low Water Line and BMSL: Biological Mean Sea Level.



Figure 3.

- (A) A raised marine platform and associated notch at Babarkot. The cliff height from BMSL is 10 m;
- (B) Active and ancient shore platforms encountered at Jafrabad light house (height of person 1.65 m);
- (C) Biological encrustation on the roof of a notch at Balana near Sarkeshwar (length of hammer head 10 cm);
- (D) Bio-erosive marking on the recrystallised limestone unit near Sarkeshwar (length of the pen is 10 cm);
- (E) Conspicuous level of Lithopaga borings as seen on about 8 m high shore platform near Nagwa, Diu (height of cliff is 14 m);
- (F) A cliff near sunset point showing ancient marine notch with prominent roof and floor (height of a person is 1.65 m);
- (G) The highest occurrence (15 m from BMSL) of shore platform in the study area near Madhwad west of Diu (height of a person 1.65 m);
- (H) A closer view of the window shown in (G) showing the abraded nature of the platform and bio-erosive features (length of hammer shaft 30 cm).

Conclusion

The cliffy coast of southern Saurashtra has preserved a record of the sea level changes during the late Quaternary. Based on the geomorphic positions of the notches two major palaeo-sea strands have been identified. The older sea strand lies at an elevation ranging from 12 to 15 m above the present BMSL and has been attributed to the last interglacial (MIS-5). Following this, a major tectonic upthrow of about 6 to 9 m was experienced by the southern cliffy coast. The Holocene sea level was recorded at 4 to 5 m which is about 2 m higher than the general MIS-1 sea level. These data are in accordance with the regional sea level curves obtained from other parts of the globe

source : https://www.researchgate.net/publication/225837913_Geomorphic_expression_of_late_Quaternary_sea_level_changes_along_the_southern_Saurashtra_coast_western_India



source : <https://stockarch.com/images/places/great-britain/rocky-cliffs-6907>

ANDHRA PRADESH COAST FACES EROSION; EAST GODAVARI, VIZAG MOST AFFECTED

DECCAN CHRONICLE

Published :Jan 6, 2017, 2:51 am IST

Srikakulam is the only district in the state that shows the maximum accretion.



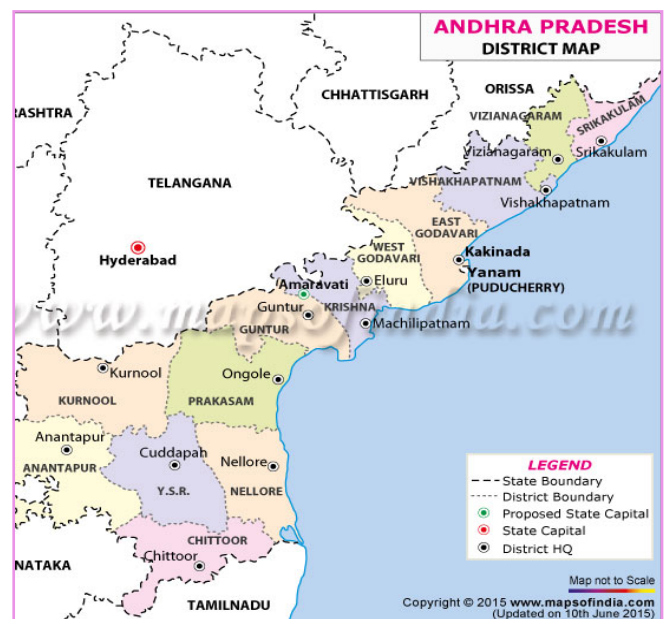
The southern coast, which is from Nellore to Sriharikota, is mostly stable or accreting nature.

Visakhapatnam: Around 275 km of coastline of the total 974 km along Andhra Pradesh is subjected to erosion over the years. Analysis of long and short term shoreline changes along Andhra Pradesh coast using Remote Sensing and GIS techniques done by researchers of Chennai-based National Institute of Ocean Technology (NIOT) revealed that 275-km shoreline was under erosion, 417 km has shown accretion and 153 km coastline is under stable condition. East Godavari and Visakhapatnam districts show high erosion.

Srikakulam is the only district in the state that shows the maximum accretion. Also 49 km of shoreline in Srikakulam district falls under stable category. 75 per cent of the coast from Ichchapuram to Kongavaniapalem was observed with sand dunes and sandy beach, and analysis reveals that the coast is in a stable condition.

The southern coast, which is from Nellore to Sriharikota, is mostly stable or accreting nature. Further in northern parts, Ichchapuram to Beemunipatanam coast does

does not depict any significant change as it is covered with sand dunes and sandy beach. Andhra coast is known for diverse coastal geomorphic features like deltas, dune system, rocky cliff, red sediments, beach rock etc.



“East Godavari and Visakhapatnam districts show high erosion. More than 50 per cent of shoreline in both districts exhibit high erosion. In East Godavari district, high erosion was observed in the coastal stretch between Uppada and Kakinada. From Kakinada to Machilipatnam, both erosion and accretion was observed in many places; however results are largely influenced by Godavari and Krishna river course. In Visakhapatnam district, major erosion prone area is Beemunipatnam. Even though the coastal stretch between Beemunipatnam and Visakhapatnam consist of well developed dunes, some pockets in this stretch are showing erosion,” stated the study conducted by R.S. Kankaraa,

S.Chenthamil Selvana, Vipin J. Markosea, B.Rajana and S. Arockiaraja of NIOT. In Nellore district, 53.64 km of shoreline shows erosion pattern and 83 km of shoreline comes under accretion. In Prakasam district, erosion is less and a major part of coastline, 62.66 km, exhibits accretion pattern.

The entire coastal stretch of 32 km of Guntur district falls under accretion category. In West Godavari district, shoreline erosion and accretion are equally distributed.

Tags: national institute of ocean technology, east godavari, ap coast erosion

Location: India, Andhra Pradesh, Vishakhapatnam

source: <http://www.deccanchronicle.com/nation/current-affairs/060117/andhra-pradesh-coast-faces-erosion-east-godavari-vizag-most-affected.html>

COASTAL EROSION STUDY COULD HOLD VALUABLE LESSONS FOR CLIMATE CHANGE MITIGATION

Imperial College London

Published : November 16, 2016

Summary : The erosion rates of cliffs along the Sussex coast in England have rapidly sped up in the last 200 years, a new study has found.



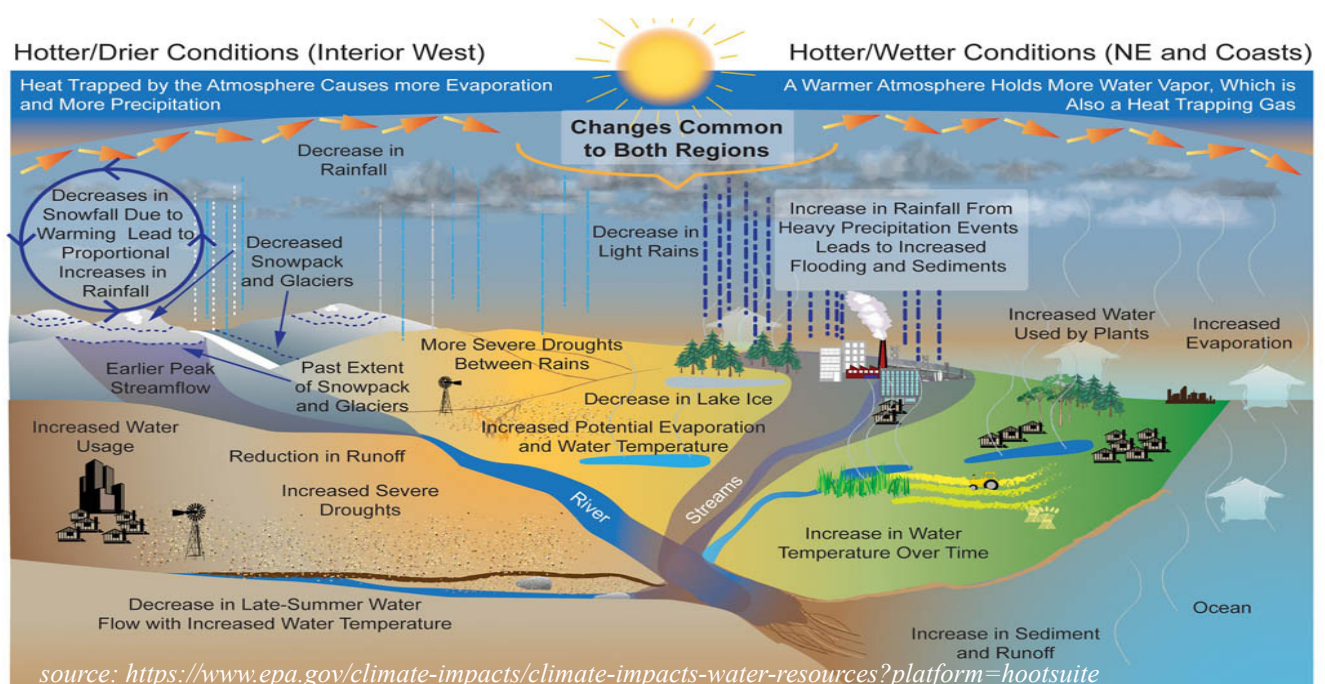
The erosion rates along Beachy Head and Seaford Head in Sussex had remained relatively stable for thousands of years. However, around 200 to 600 years ago the rates rapidly accelerated, increasing to between 22 and 32 centimetres each year. Image courtesy :Imperial College London

“The erosion rates of cliffs along the Sussex coast have rapidly sped up in the last 200 years, a new study has found.”

The research shows that the erosion rates along Beachy Head and Seaford Head in Sussex had remained relatively stable, at around two to six centimetres each year, for thousands of years. However, around 200 to 600 years ago the rates rapidly accelerated, increasing to between 22 and 32 centimetres each year. The authors suggest that rising sea levels and increasingly severe storms have rapidly eroded the Beachy Head and Seaford Head shorelines. The loss of beach means that the cliffs are exposed to the eroding wave action forces, which is causing them to collapse into the sea. The researchers suggest this erosion process is probably happening along other coastlines in the UK and elsewhere around the world, with implications for how coasts will respond to climate change and what we can do to manage the impact on important coastal infrastructure. Dr Dylan Rood, co-author from the Department of Earth Science and Engineering at Imperial College London, said: "The coast is clearly eroding, and Britain has retreated fast. Our study on British coasts leaves no question that coastal cliff retreat accelerated in the recent past. A nearly ten-fold increase in retreat rates over a very short timescale, in geological terms, is remarkable. The UK cannot leave the issue of cliff erosion unresolved in the face of a warming world and rising sea levels. Cliff erosion is irreversible; once the cliffs retreat, they are gone for good."

The scientists used a process called cosmogenic dating to learn how the chalk cliffs at Beachy Head and Seaford Head have eroded. Cosmogenic dating allows scientists to analyse the build-up of a rare isotope of beryllium (beryllium-10). This isotope is created when cosmic radiation reacts with oxygen atoms in the exposed flint rock, so by measuring its accumulation, it acts as a kind of 'rock clock' to show the rate of rock erosion. Since the rate of accumulation has previously been relatively constant, measuring rock samples from across the shore platforms allowed researchers to build a record of how coastal erosion has proceeded over the last 7000 years or so. Dr Rood added: "Cosmogenic isotopes including beryllium-10 are advancing the science of retreating coastlines in Great Britain and worldwide. These new tools provide a rare insight into how dramatically environmental change and human impact affected sensitive coastal landscapes. We still need to better understand how other rocky coastlines have re-sponded in the past, and cosmogenic isotopes are the key to unlocking this mystery." The researchers now hope to use their observations to create a more accurate predictive model of how climate change will affect coastal erosion in the future, which could help authorities make more informed decisions about coastal management.

source: <https://www.sciencedaily.com/releases/2016/11/161116100454.htm>



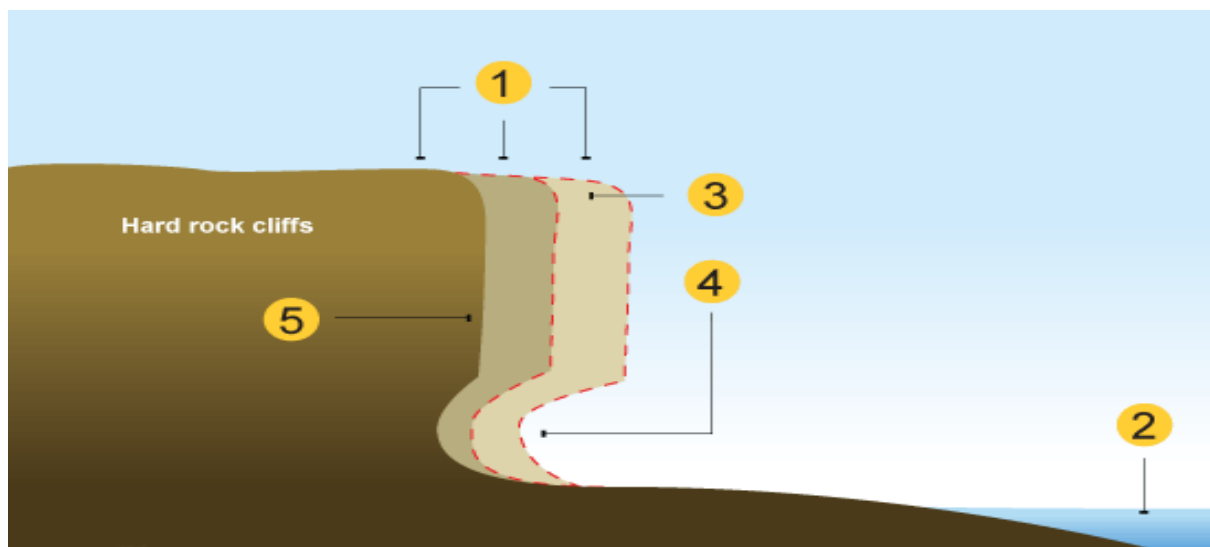
TID BITS

Cliffs, wave-cut platforms and notches are features created by erosion

One of the most common features of a coastline is a cliff. Cliffs are shaped through a combination of erosion and weathering - the breakdown of rocks caused by weather conditions. Soft rock, eg sand and clay, erodes easily to create gently sloping cliffs. Hard rock, eg chalk, is more resistant and erodes slowly to create steep cliffs. Soft rock, eg sand and clay, erodes easily to create gently sloping cliffs. Hard rock, eg chalk, is more resistant and erodes slowly to create steep cliffs.



Seven Sisters chalk cliffs on the East Sussex



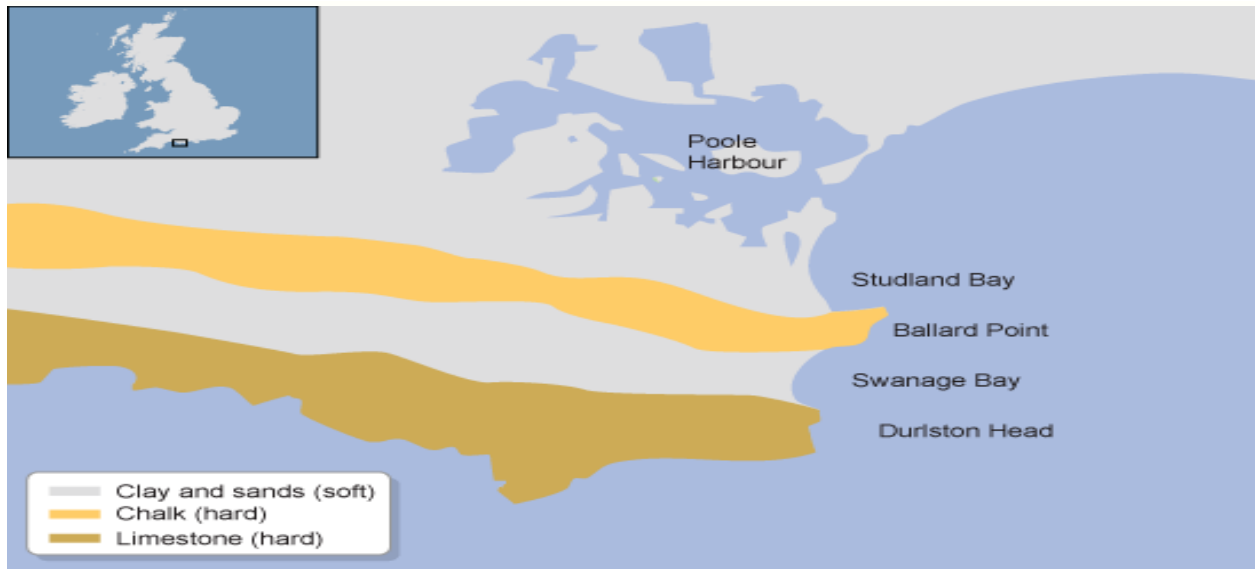
The erosion of cliffs

The process of cliff erosion

- 1** Weather weakens the top of the cliff.
- 2** The sea attacks the base of the cliff forming a wave-cut notch.
- 3** The notch increases in size causing the cliff to collapse.
- 4** The backwash carries the rubble towards the sea forming a wave-cut platform.
- 5** The process repeats and the cliff continues to retreat.

Headlands and bays

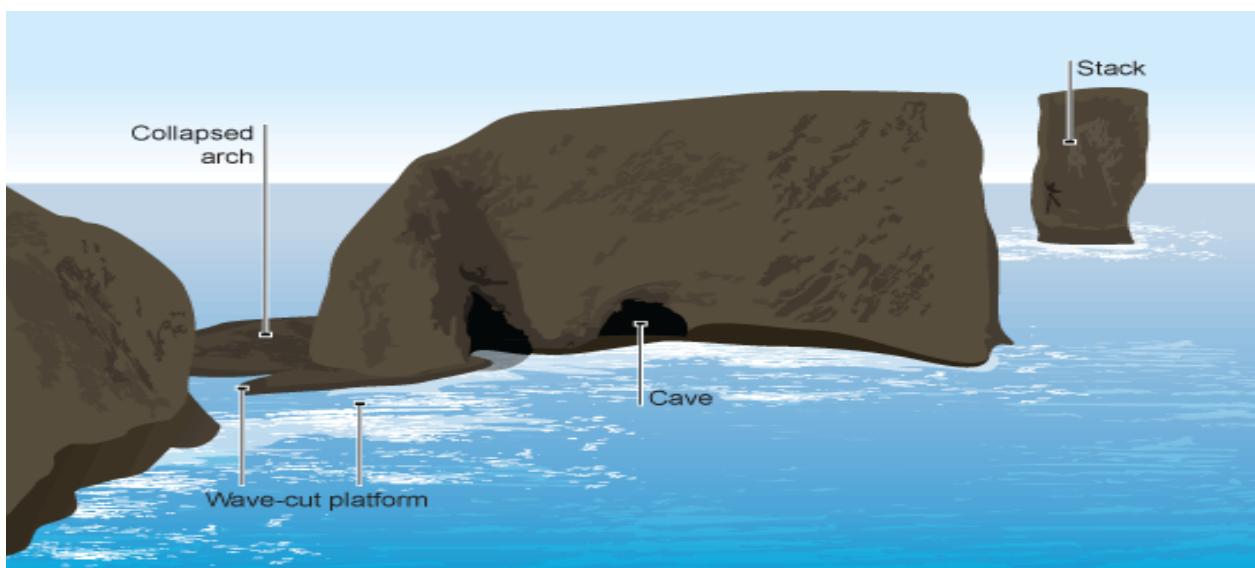
Headlands are formed when the sea attacks a section of coast with alternating bands of hard and soft rock. The bands of soft rock, such as sand and clay, erode more quickly than those of more resistant rock, such as chalk. This leaves a section of land jutting out into the sea called a headland. The areas where the soft rock has eroded away, next to the headland, are called bays. Geology is the study of the types of rocks that make up the Earth's crust. Coastlines where the geology alternates between strata (or bands) of hard rock and soft rock are called discordant coastlines. A concordant coastline has the same type of rock along its length. Concordant coastlines tend to have fewer bays and headlands.



Discordant and concordant coasts in Dorset

Along the coastline of the Isle of Purbeck in Dorset, there are both discordant and concordant coastlines. The discordant coastline has been formed into Studland Bay (soft rock), Ballard Point (hard rock), Swanage Bay (soft rock) and Durlston Head (hard rock). After Durlston Head, the strata stop alternating and the coastline is made up of hard rock. This concordant coast has fewer features.

Caves, arches, stacks and stumps



Platform, arch, cave and stack

Weathering [weathering: The gradual breakdown of rocks due to the effects of weather.] and erosion [erosion: Erosion is the process whereby rock or soil is worn away by the action of the wind, waves or water.] can create caves, arches, stacks and stumps along a headland. Caves occur when waves force their way into cracks in the cliff face. The water contains sand and other materials that grind away at the rock until the cracks become a cave. Hydraulic action [hydraulic action: Erosion caused by waves hitting the cracks on a cliff face. The air in the cracks becomes compressed and then explodes outwards, breaking off bits of rock.] is the predominant process. If the cave is formed in a headland, it may eventually break through to the other side forming an arch. The arch will gradually become bigger until it can no longer support the top of the arch. When the arch collapses, it leaves the headland on one side and a stack (a tall column of rock) on the other. The stack will be attacked at the base in the same way that a wave-cut notch is formed. This weakens the structure and it will eventually collapse to form a stump. One of the best examples in Britain is Old Harry Rocks, a stack found off a headland in the Isle of Purbeck.

(source: http://www.bbc.co.uk/schools/gcsebitesize/geography/coasts/erosional_landforms_rev2.shtml)

LATEST EVENT

WORLD WETLANDS DAY - 2017



ENVIS – Centre for Coastal Zone Management and Coastal Shelter Belt, Institute for Ocean Management, Anna University, Chennai – 600 025, celebrated the World Wetlands Day – 2017, On the theme “Wetlands for Disaster Risk Reduction”; the event started with a panel discussion on the theme. Panel Member Mr.J.Sankar, Consultant - IOM, Anna University addressed the gathering and discussed the “Wetlands and its aspects on Geomorphology”, Dr.V.Ram Mohan, Consultant - IOM, Anna University, gave a brief introduction on “Evolution of Coastal and Inland Wetlands”. Dr. Amali Infantina, Programme Officer ENVIS – CZM & CSB, discussed the “Benefits and Conservation of Wetlands”. The M.Tech – Coastal Management students of IOM, Anna University shared their views and objectives of their projects related to the wetlands. The program ended after issuing neem seeds to the student representatives of Anna University and participants, as to recompense the severe destruction caused by uprooting trees due to cyclone Vardah.

CHENNAI ENNORE OIL SPILL



ENVIS - Centre for Coastal Zone Management and Coastal Shelter Belt, Institute for Ocean Management, Anna University, organized a Field Trip on Saturday, February 4th to the Ennore, R.K.nagar stretch joining hands along with the M.Tech - Coastal Management students of Anna University, the team ENVIS and Students meet the Coastal Guard officials and discussed about the oil spill and its impacts on marine ecology. Some of our volunteers took part in the clean up activity.

LATEST EVENT

COASTAL CLEAN UP AT MARINA BEACH



ENVIS – Centre for Coastal Zone Management and Coastal Shelter Belt, Institute for Ocean Management, Anna University, Chennai – 600 025, organized a coastal clean - up activity at Marina Beach, Chennai on February 11th 2017. Our ENVIS team member and our M.Tech coastal Management students participated in the clean-up activity. As a initiative we started this clean-up activity for a 2 kms stretch at Marina, for the upcoming years we are planning to cover above 5 kms stretch. We started the event around 8 am in the morning and started collecting the plastics, dusts and etc. in a separate garbage bags and disposed in the dustbins finally.

CHENNAI SCIENCE FESTIVAL -2017



Our ENVIS centre participate in the “ Chennai Science Festival 2017 “ organised by the science city on the theme “Sustainable Water Mangement And Agriculture” at the Queen mary’s college, chennai from 9th February to 12th February, 2017.

LATEST EVENT

National Workshop of ENVIS Centres



National Workshop of ENVIS Centres: Summary Evaluation and Roll out of the Revamped ENVIS Scheme is held on 17th-18th March, 2017 at Mahatma Mandir Convention & Exhibition Centre, Gandhinagar, Gujarat.

CHIEF EDITOR

Prof. Dr. R. Ramesh

Institute for Ocean Management,
Anna University, Chennai &
Director, NCSCM,
Anna University Campus, Chennai.

EDITORS

Prof. Dr. S. Srinivasalu

Co - ordinator, ENVIS - IOM ,
Director, Institute for Ocean Management &
Additional Controller of Examinations,
Anna University , Chennai.

ASSOCIATES

Ms. S. Sathya

Information Officer - ENVIS,
Institute for Ocean Management,
Anna University , Chennai.

Mrs. K. Rajalakshmi

Information Assistant - ENVIS,
Institute for Ocean Management,
Anna University , Chennai.

Mr. P. Kumaravel

Project Assistant,
Institute for Ocean Management,
Anna University , Chennai.

Cover page image courtesy:

Mr. M. Prem Anand,
Project Assistant,
Institute for Ocean Management,
Anna University , Chennai.

Please send your valuable suggestions, comments and
queries to:

ENVIS CENTRE

**Centre for Coastal Zone Management and Coastal
Shelter Belt**

**Institute for Ocean Management, Anna University
Chennai - 600 025, Tamil Nadu, India.**



: iom-env@nic.in

Visit us at: www.iomenvis.nic.in

Contact :



+91 (44) 2235 7506 / 8448/ 7486



+ 91 44 2220 0158



**iom-env@nic.in, iom@envis.nic.in,
ponmozhisrini2001@yahoo.com**

IMPORTANT WEBSITES

**Institute for Ocean Management (IOM) -
www.annauniv.edu/iom/home.htm**

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