1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Landforms — Landforms Formed by Waves and Currents – Part 4
Module Id	kegy_10704
Pre-requisites	Basic knowledge about the landforms developed by the action of Wave and Currents
Objectives	After reading this lesson, learners will be able to: • Acquire the knowledge and understanding of coastal landforms. • Students will be able to understand the mechanism of coastal erosion. • Students will be able to understand the landforms formed by erosional and depositional activities of sea waves and currents.
Keywords	Sea – Cliffs, Wave – Cut Platforms, Sea Cave, Sea Stacks, Sea Arches, Sea Beaches, Barrier Islands, Spits.

2. Development Team

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Introduction

Coastal processes are the most dynamic and hence most destructive. So, don't you think it is important to know about the coastal processes and forms? The shape and character of the coasts are determined partly by the movements of elevation and depression which have affected the earth's crust, partly by the action of the sea waves, currents and other denuding agencies. They depend also to a large extent upon the nature of the materials which form the land. The coastline, under the constant action of the waves, tides and currents, is undergoing changes from day to day. On a calm day, when the winds are slight, waves do little damage to the shoreline and may instead help to build up beaches and other depositional features. It is in storm that the ravages of the waves reach their greatest magnitude. Coastal landforms are produced by the joint action of oceanic waves, currents and tides on the coastline along with the combination of processes, sediments, and the geology of the coast itself. Among all of these factors, waves are the most important of all in carving out the coastal landforms.

The coastal environment of the world is made up of a wide variety of landforms manifested in a spectrum of sizes and shapes ranging from gently sloping beaches to high cliffs, yet coastal landforms are best considered in two broad categories: erosional and depositional. In fact, the overall nature of any coast may be described in terms of one or the other of these categories.

Some of the changes along the coasts take place very fast. At one place, there can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves. When waves break, the water is thrown with great force onto the shore, and simultaneously, there is a great churning of sediments on the sea bottom. Constant impact of breaking waves drastically affects the coasts. Storm waves and tsunami waves can cause far-reaching changes in a short period of time than normal breaking waves. As wave environment changes, the intensity of the force of breaking waves changes. Other than the

action of waves, the coastal landforms depend upon (i) the configuration of land and sea floor; (ii) whether the coast is advancing (emerging) seaward or retreating (submerging) landward. Assuming sea level to be constant, two types of coasts are considered to explain the concept of evolution of coastal landforms: (i) high, rocky coasts (submerged coasts); (ii) low, smooth and gently sloping sedimentary coasts (emerged coasts).

High Rocky Coasts

Along the high rocky coasts, the rivers appear to have been drowned with highly irregular coastline. The coastline appears highly indented with extension of water into the land where glacial valleys (fjords) are present. The hill sides drop off sharply into the water. Shores do not show any depositional landforms initially. Erosion features dominate. Along high rocky coasts, waves break with great force against the land shaping the hill sides into cliffs. With constant pounding by waves, the cliffs recede leaving a wave-cut platform in front of the sea cliff. Waves gradually minimise the irregularities along the shore.

The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments and roll to roundness, will get deposited in the offshore. After a considerable period of cliff development and retreat when coastline turns somewhat smooth, with the addition of some more material to this deposit in the offshore, a wave-built terrace would develop in front of wave-cut terrace. As the erosion along the coast takes place a good supply material becomes available to long shore currents and waves to deposit them as beaches along the shore and as bars (long ridges of sand and/or shingle parallel to the coast) in the near shore zone. Bars are submerged features and when bars show up above water, they are called *barrier bars*. Barrier bar which get keyed up to the headland of a bay is called a *spit*. When barrier bars and spits form at the mouth of a bay and block it, a *lagoon* forms. The lagoons would gradually get filled up by sediments from the land giving rise to a coastal plain.

Low Sedimentary Coasts

Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas. The coastline appears smooth with occasional incursions of water in the form of lagoons and tidal creeks. The land slopes gently into the water. Marshes and swamps may abound along the coasts. Depositional features dominate. When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily building bars, barrier bars, spits and lagoons. Lagoons would eventually turn into a swamp which would subsequently turn into a coastal plain. The maintenance of these depositional

features depends upon the steady supply of materials. Storm and tsunami waves cause drastic changes irrespective of supply of sediments. Large rivers which bring lots of sediments build deltas along low sedimentary coasts. The west coast of our country is a high rocky retreating coast. Erosional forms dominate in the west coast. The east coast of India is a low sedimentary coast. Depositional forms dominate in the east coast. What are the various differences between a high rocky coast and a low sedimentary coast in terms of processes and landforms?

Mechanism of Coastal Erosion

As discussed earlier, waves are usually the most important agents modifying the coastline. Their origin is due to sweeping of winds over the water surface, which sets a series of undulating swells surging forward. A normal wave in a open sea may measure 20 ft high and 400 ft long; during storms this is greatly increased, depending on the speed and duration of winds. Tides are also effective, first, because they raise and lower the plane of action of the waves, and secondly, because of the currents associated with them. Currents due to winds are usually too week, where they actually make the contact with the shore, to have any direct influence.

The erosive work of the sea depends upon the;

i. Size and strengths of the wave
ii. Seaward slope
iii. Height of the shore between low and high tides,
iv. Composition of rocks,
v. Depth of water,
vi. Human interference in coast protection etc.

Other effects such as vulcanicity, glaciations, earth movement and organic accumulations have also to be considered while understanding the coastal landforms. The waves exert a pressure to a magnitude of 3,000 to 30,000 km per square km. This wave pressure compresses the air trapped inside rock fissures, joints faults etc., forcing it to expand and rupture the rock along week points. This is how rocks get worn down under wave action. Waves also use rock debris as instruments of erosion. These rocks fragments carried by waves themselves get worn down by sticking against the coast or against one another. The solvent or chemical or solvent action of wave is another mode of erosion, but it is pronounced only in case of soluble rocks like limestone and chalk.

Marine agents of erosion operate in the following way to transform the coastal landscape.

Corrasive action (Corrasion)

Waves armed with boulders, pebbles and sands are hurled against the coast by breaking waves and this causes undercutting and rock break-up.

Hydraulic Action

When water is thrown against the shore, by breaking waves, it causes the air in the cracks and crevices to be compressed suddenly. When the waves retreat, the air expands suddenly often explosively. This cause to shatter ad cracks becomes enlarge and extended.

Attrition action

As boulders and rocks are hurled against the shore and against each other by breaking waves, they gradually break up into smaller pieces. The particles are themselves worn down by friction and impact, and become finer and finer.

Solvent action

The minerals in some rocks react chemically with the sea water. This causes the rocks to become less resistant to erosion for example limestone coasts.

Erosional Landforms

Sea cliffs

Sea Cliff is an erosional landform, generally any very steep rock face adjoining the coast forms a cliff (Fig. 1). The rate of recession will depend on its geological structure that is the stratification and jointing of the rocks and their resistance to wave attack.Imagine a newly drowned land surface. Marine erosion will begin to cut a notch (the point of wave attack at the base of cliff) in the land where see meets it. As erosion proceeds, the notch is further developed and the first sign of a cliff appear. Further, landward recession of the notches results in the further development of a cliff. The cliff base is steepened by wave erosion but while this is going on, the cliff face above high tide level is attacked by weathering processes. And mass wasting becomes dominant. This causes the cliff face to become less steep. In front i.e., seaward of a cliff of this type is called as wave cut platform The platform develops over the cliff recedes and the as the rock debris, in part from marine erosion and in part from mass wasting, is swept backwards and forwards by breaking waves. Some of the debris settles on the platform forming continuous cover. The rest of the debris is either carried out into the deeper waters of the offshore zone or is carried to shore to areas where less active waves deposit it as a beach.

Fig.1: Sea cliff at Marsh island

https://upload.wikimedia.org/wikipedia/commons/8/8d/Sea_Cliffs.JPG

As cliffs retreats further, the wave cut platform becomes wider, and if the process continues, it becomes sufficiently wide to prevent waves from reaching the cliff base because the water over the platform is too shallow to allow the waves to proceed to the coast.

Wave-cut platforms

At the base of most cliffs along a rocky coast one finds a flat surface at about the mid-tide elevation. This is a benchlike feature called a wave-cut platform, or wave-cut bench. Such surfaces may measure from a few metres to hundreds of metres wide and extend to the base of the adjacent cliff. They are formed by wave action on the bedrock along the coast. The formation process can take a long time, depending on the type of rock present. The existence of extensive wave-cut platforms thus implies that sea level did not fluctuate during the periods of formation. Multiple platforms of this type along a given reach of coast indicate various positions of sea level.

Fig.2: Wave-cut platform at South Wales

https://upload.wikimedia.org/wikipedia/commons/6/63/Wavecut_platform_southerndown_pano.jpg

Sea cave

A sea cave, also known as a littoral cave, is a type of cave formed primarily by the wave action of the sea. The primary process involved is erosion. Sea caves are found throughout the world, actively forming along present coastlines and as relict sea caves on former coastlines. The driving force in littoral cave development is wave action. Erosion is ongoing anywhere that waves batter rocky coasts, but where sea cliffs contain zones of weakness, rock is removed at a greater rate along these zones. As the sea reaches into the fissures thus formed, they begin to widen and deepen due to the tremendous force exerted within a confined space, not only by direct action of the surf and any rock particles that it bears, but also by compression of air within. Blowholes (partially submerged caves that eject large sprays of sea water as waves retreat and allow rapid re-expansion of air compressed within) attest to this process. Adding to the hydraulic power of the waves is the abrasive force of suspended sand and rock. Most sea-cave walls are irregular and chunky, reflecting an erosional process where the rock is fractured piece by piece. However, some caves have portions where the walls are rounded and smoothed, typically floored with cobbles, and result from the swirling motion of these cobbles in the surf zone.

Some of the largest wave-cut caves in the world are found on the coast of Norway, but are now 100 feet or more above present sea level. These would still be classified as littoral caves. By contrast, in places like Thailand's PhangNga Bay, solutionally formed caves in limestone have been flooded by the rising sea and are now subject to littoral erosion, representing a new phase of their enlargement..

Fig.3: Ryugu Sea cave

https://upload.wikimedia.org/wikipedia/commons/8/81/Ryugu_Sea_Cave_20121010_a.jpg

Sea stacks

Erosion along rocky coasts occurs at various rates and is dependent both on the rock type and

on the wave energy at a particular site. As a result of the above-mentioned conditions, wave-cut platforms may be incomplete, with erosional remnants on the horizontal wave-cut surface. These remnants are called sea stacks, and they provide a spectacular type of coastal landform. Some are many metres high and form isolated pinnacles on the otherwise smooth wave-cut surface. Because erosion is a continual process, these features are not permanent and will eventually be eroded, leaving no trace of their existence.

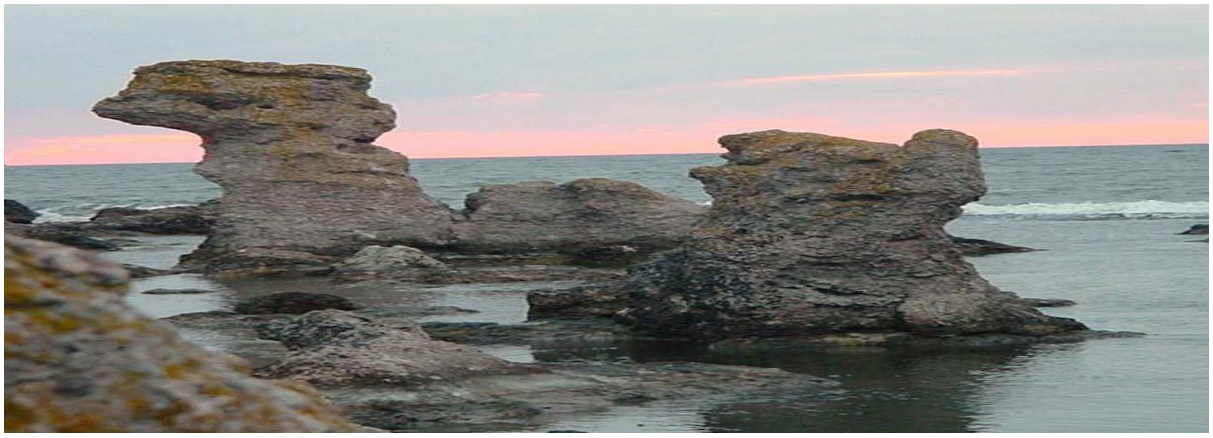

Fig.4: Sea Stacks in Silurian reef limestone, Sweden

https://upload.wikimedia.org/wikipedia/commons/b/b0/Seastacks.JPG

Sea arches

Another spectacular type of erosional landform is the sea arch, which forms as the result of different rates of erosion typically due to the varied resistance of bedrock. These archways may have an arcuate or rectangular shape, with the opening extending below water level. The height of an arch can be up to tens of metres above sea level.

Fig.5: Sea arch near Portrush

https://upload.wikimedia.org/wikipedia/commons/4/49/Sea_arch_near_Portrush_-_geograph.org.uk_-_1115474.jpg

Depositional Landforms

Beaches

'The sediment in motion along a shore is the beach- A. Bloom (1979)'.

Beaches are characteristic of shorelines that are dominated by deposition, but may occur as patches along even the rugged shores. The best known and most common depositional landform is beach. This is the most dominant form of the constructive work of the sea. Sand shingle, boulders, gravels and mud loosened from the land are moved by waves to be deposited along the shore as *beaches*. The eroded material is transported along the shore in several distinct ways. The materials which makes up the beaches comes from eroded headlands and other beaches through the action of *longshore drift*, and all of it is sorted by the action of *swash* and *backwash*. The strong swash of a constructive or spilling wave usually pushes the coarsest material up the beach. At the same time, the backwash removes parts of the material seawards along the bed of the sea, and deposits it on the off-shore terrace and even beyond. Finer material such as silt and mud are deposited in the shallow waters of a sheltered coast .

The constant action of the waves automatically sorts out the shorelines deposit in graded manner. The coarser materials (cobbles and boulders) are dropped by the waves at the top of the beach. The finer material (pebbles and sand grains) which are carried down the beach by the backwash are dropped closer the sea. On the smooth lowlands, beaches may continue for kilometers, like those of the east coast of west Malaysia, but in upland regions where the land descends abruptly into the sea, such as the Chilean coast, long beaches are absent.

Fig.6: Champagne Beach Vanuatu

https://upload.wikimedia.org/wikipedia/commons/5/58/Champagne_Beach.jpg

Just behind the beach, the sands lifted and winnowed from over the beach surfaces will be deposited as sand dunes. Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts.

Fig.7: Beach Sand Dunes

https://upload.wikimedia.org/wikipedia/commons/1/1b/East_Beach_Sand_Dunes_-_geograph.org.uk_-_703147.jpg

Bars, Barriers and Spits

A ridge of sand and shingle formed in the sea in the off-shore zone (from the position of low tide waterline to seaward) lying approximately parallel to the coast is called an *off-shore bar*. An off-shore bar which is exposed due to further addition of sand is termed a *barrier bar*. The off-shore bars and barriers commonly form across the mouth of a river or at entrance of a bay. Sometimes such barrier bars get keyed up to one end of the bay when they are called *spits* (Fig. 5). Spits may also develop attached to headlands/hills. The barriers, bars and spits at the mouth of the bay gradually extend leaving only a small opening of the bay into the sea and the bay will eventually develop into a lagoon. The lagoons get filled up gradually by sediment coming from the land or from the beach itself (aided by wind) and a broad and wide coastal plain may develop replacing a lagoon.

Fig.8: Shingle Spit at the Mouth of the River Otter

https://upload.wikimedia.org/wikipedia/commons/c/c4/Shingle_Spit_at_the_Mouth_of_the_River_Otter_-_geograph.org.uk_-_638893.jpg

Do you know

The coastal off-shore bars offer the first buffer or defence against storm or tsunami by absorbing most of their destructive force. Then come the barriers, beaches, beach dunes and

mangroves, if any, to absorb the destructive force of storm and tsunami waves. So, if we do anything which disturbs the 'sediment budget' and the mangroves along the coast, these coastal forms will get eroded away leaving human habitations to bear first strike of storm and tsunami waves.

Summary

- Coastal landforms are formed by the action of waves, currents and tides, of which waves are the most important.
- Waves are caused by wind. In deep water the wave move forward with the wind, but the individual water particle moves in circular paths, returning almost to their original positions.
- Sediments used by sea to erode the land come from river, glacier and the mass wasting of slopes.
- The coast line is the highest level that the sea reaches on land.
- The shore is the land between the coastline and the shoreline (the lowest level reached by the sea).
- Waves erode by hydraulic action (impact and pressure on waves) and by abrasion (grinding the material moved by waves).
- Only about one percent sediments come directly from wave erosion; most wave erosions occur during large storms.
- Longitudinal drift, one of the most important shoreline processes, is generated as waves strike the shore at an angle, water and sediment move obliquely up to the beach face but return with backwash directly down the beach, perpendicular to the shore line. This results in net transport, parallel to the shore.
- Erosion along coasts results from the abrasive action of sand and gravel moved by the water and currents and, to a lesser extent, from solution and hydraulic action. The undercutting action of wave currents typically produces sea cliffs. As a sea cliff recedes, a wave cut platform develops. Minor erosional landforms associated with the development of sea cliffs include sea caves, sea arches, and sea stacks.
- Sediment deposited between the coastline and the shoreline is called a beach.
- A constructive wave is one that deposits sediment; a destructive wave is one that removes sediments.
- Waves effect erosion by abrasion, hydraulic action, and attrition.