FOREWORD

Department of Ocean Development (DOD) expressed a desire to bring out a short illustrated booklet on ocean sciences for the information of the general public. It also wanted the booklet to be printed initially in the five languages of English, Hindi, Kannada, Marathi and Telugu.

The Geological Society of India has as one of its main objectives, the popularization of science, but for various reasons it has not been possible to promote this line of activity. The suggestion from the DOD has come at the right time and plodded the Society into action. After pooling all available resources, the Society has now been able to prepare the first booklet on 'Oceans'. Prof. K.V. Subbarao of the Indian Institute of Technology, Mumbai, Dr. R. Shankar, Department of Marine Geology, Mangalore University and a few others have taken special interest and it is my pleasant duty to express the grateful thanks of the Society to all of them. We sincerely trust that the booklet will excite the interest of school going children and make them take greater interest in ocean exploration and the development of its resources.

(B.P. Radhakrishna)
President, Geological Society of India

"I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

- Sir Isac Newton

1642-1727, British Scientist, Mathematician0

O C E

Story of the Oceans

Know more about Oceans

Oceans have always influenced the life and history of man. From time immemorial, man has been using oceans in several ways. According to our mythology, the *suras (Gods)* and *asuras (Demons)* churned the ocean (*samudra manthan*) and extracted *amrita*, the elixir of life. Even in the *Kal Yuga*, we get many mineral-, food- and energy resources from the oceans.

The oceanic part of the world has an area of about 361 million sq km (that is, 71% of the globe), an average depth of about 3,730 m, and a total volume of about 1,347,000 million cubic km. The deepest part of the oceans is the Mariana Trench (11,516 m) in the Pacific Ocean. Compare this with the 8,849 m above sea level of the highest peak, the Mt. Everest. With these breath-taking statistics, you must indeed be astounded at the vastness of the oceans! Because of its vastness and interplay of processes, oceans control the atmosphere and global climate besides being a vast storehouse of resources necessary for sustenance of life on earth.

How are Oceans important to us?

Oceans are a huge storehouse of resources like minerals (metals, oil, natural gas, chemicals etc.), food (fish, prawns, lobsters etc.) and energy (waves, water currents, tides etc.). We have been using oceans for transporting goods (in ships and oil tankers) and for recreation purposes (beaches, water sports etc.). We have also been using oceans to dump all municipal waste, industrial effluents, pesticides used in agriculture etc. resulting from activities of the ever-growing population.

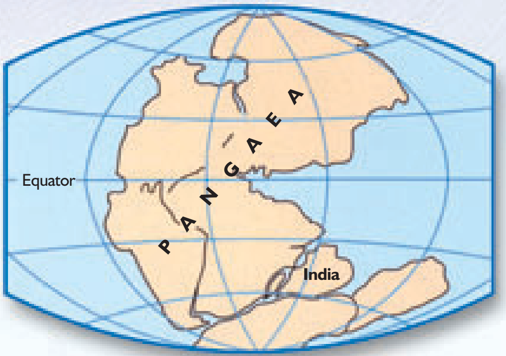
In addition, oceans control weather and climate and thus considerably influence the environment. Even the quality of air that we breathe depends greatly on the interaction between the oceans and the atmosphere. Oceans have served as channels of adventure and discovery. From expeditions to seas far and near, we have understood how Mother Earth works, how the sea-floor is formed and, how parts of the continents have moved thousands of kilometers over a long period.

Thus, there are many reasons to study the oceans and benefit from it.

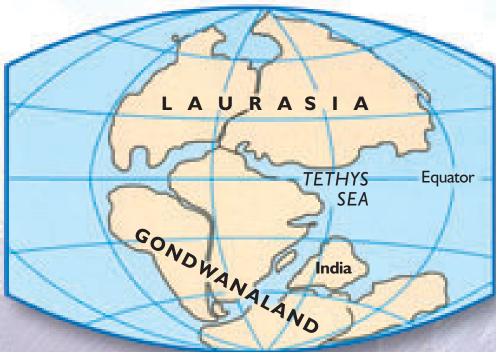
Off-shore oil platform

Sea-floor spreading and drifting Continents

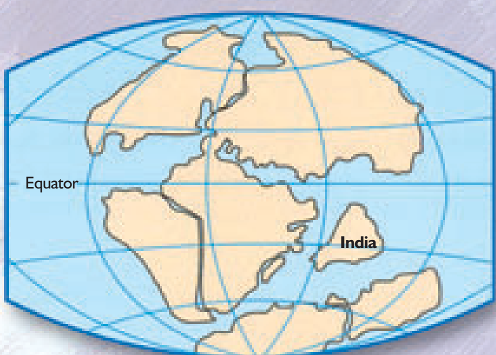
Way back in 1912, a German astronomer and meteorologist, Alfred Wegener proposed that continents are slowly moving relative to each other and shifting their positions. If we move Africa and South America near to each other, the opposite coasts, including continental shelves fit together so well. Fossils like *Glossopteris (a plant fossil)* and *Lystrosaurus (a fossil reptile)*, which were extinct 200 million years ago, which are essentially land inhabitants are now scattered across several continents. All these suggest that once upon a time, there was one single landmass for which the name PANGAEA - meaning all Earth- has been given. Look at the pictures carefully and you would notice how India migrated from the icy Southern hemisphere to Northern hemisphere by crossing the equator calculated at an average speed of about 5 cm per year! You would also notice that huge oceans are formed due to separation of continents from one another. This involves the spreading of ocean-floor on either side of the mid-oceanic ridges (huge mountain chains buried under ocean water - *see figure on page no.8*) and creation of new crust at the spreading centres.



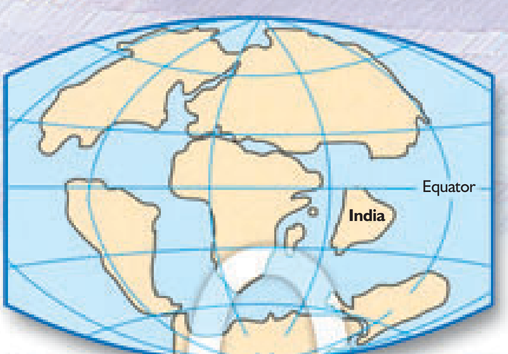
About 225 million years ago(Triassic Period)



About 200 million years ago(Jurassic Period)

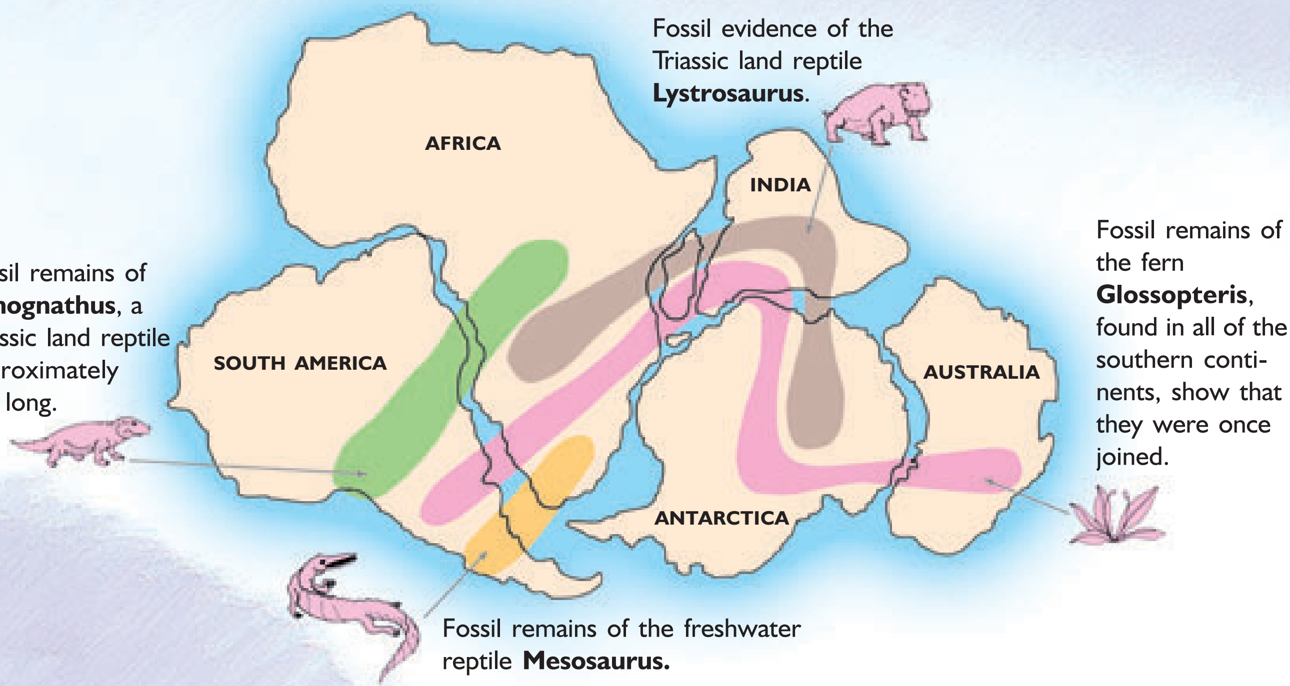


About 135 million years ago (Cretaceous Period)



About 65 million years ago (beginning of Paleogene Period)

Today



If the continents are joined together (about 200 million years ago) we can also trace certain fossils of plants and animals across the continents as shown in the above figure as coloured bands. This is one of the outstanding contribution of Snider-Pellegrini and Wegener.

It is the break-up of PANGAEA, a large rigid slab- a *plate,* into many plates and their drifting away due to *tectonics* - an internal dynamic force, that has led to the present disposition of the continents. This process is called plate tectonics, a concept which was introduced some 40 years ago. Continents are made up of more than one plate, along with parts of ocean basins. The map shows the shapes and locations of these plates and the directions in which they move. Most earthquakes and volcanoes occur where plates collide.

The Pieces of the Puzzle

Earth's crust is like a gigantic puzzle made up of a dozen or so pieces. The map shows the shapes and locations of these pieces, and the directions in which they move. Most earthquakes and volcanoes occur where plates collide.

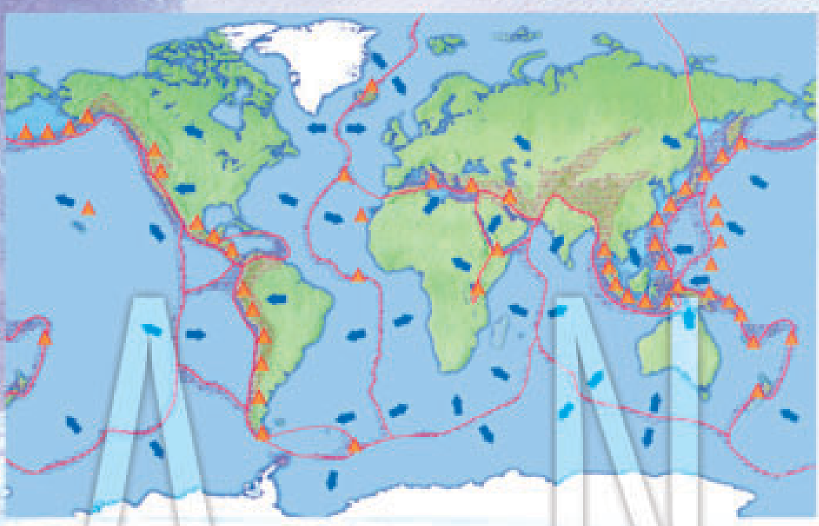
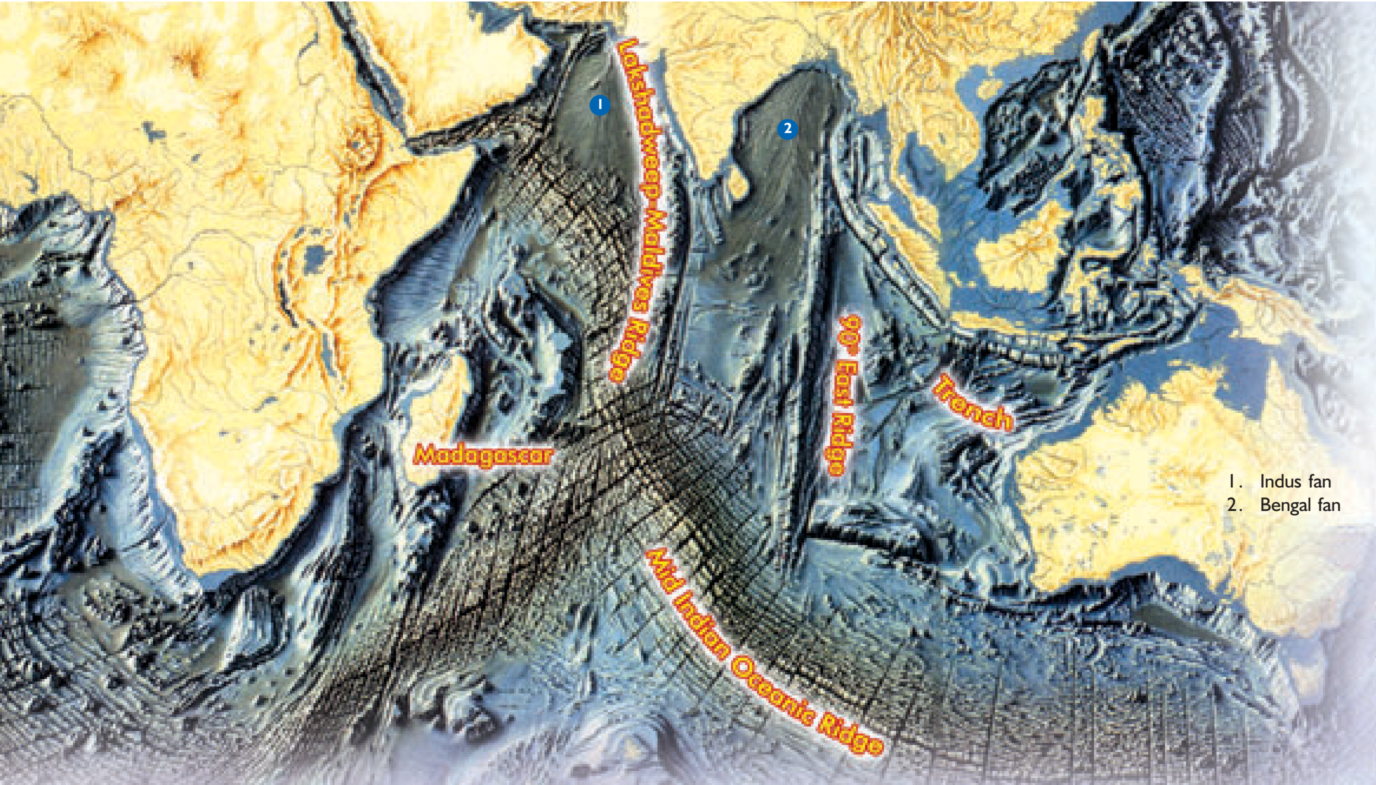


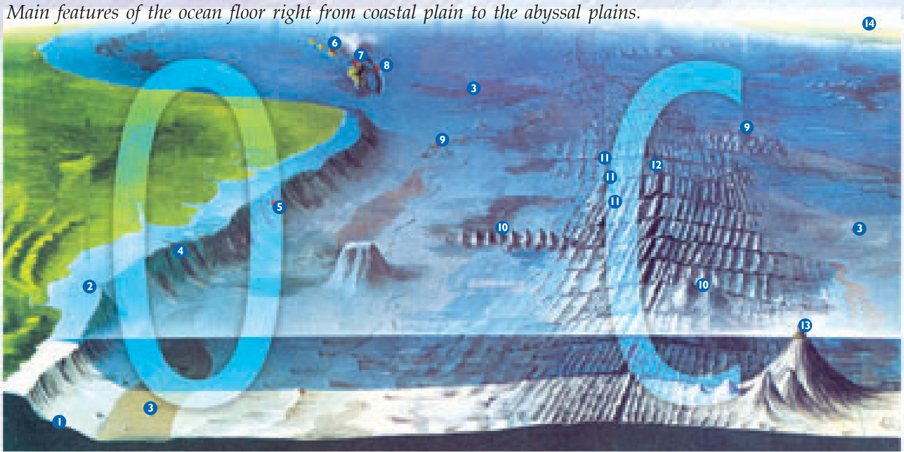
Plate boundaries
Direction of plate movement
Volcanoes
Earthquake zones



How does the Ocean-floor look like?

The ocean-floor looks very much like our land. It has soaring mountains, plunging valleys and rolling plains. There are mountain chains that are mightier than the Himalaya, called the *mid-oceanic ridges*, which run in the middle of all the major oceans for a total length of about 74,000 km. Mid-oceanic ridges are centres of sea-floor spreading where new ocean crust is created by outpouring of lava. This new crust continuously spreads away from the mid-oceanic ridges - something like a conveyor belt! Finally the oceanic crust descends or gets pushed down into deep *trenches* which are about 3 to 6 km deeper than the adjacent sea-floor *(see figure above)*. This is how the destruction of oceanic crust occurs. All along the *trenches*, lava comes out at temperatures of above 800° to 1000° C and builds up a chain of volcanic islands (along landward side), followed by frequent earthquakes.

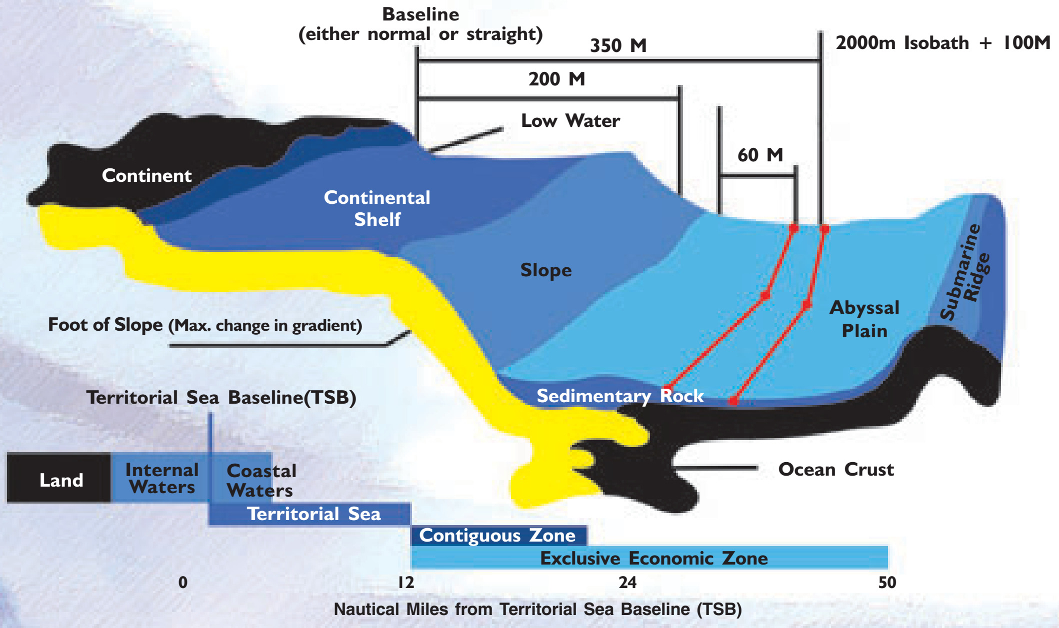
Main features of the ocean floor right from coastal plain to the abyssal plains.

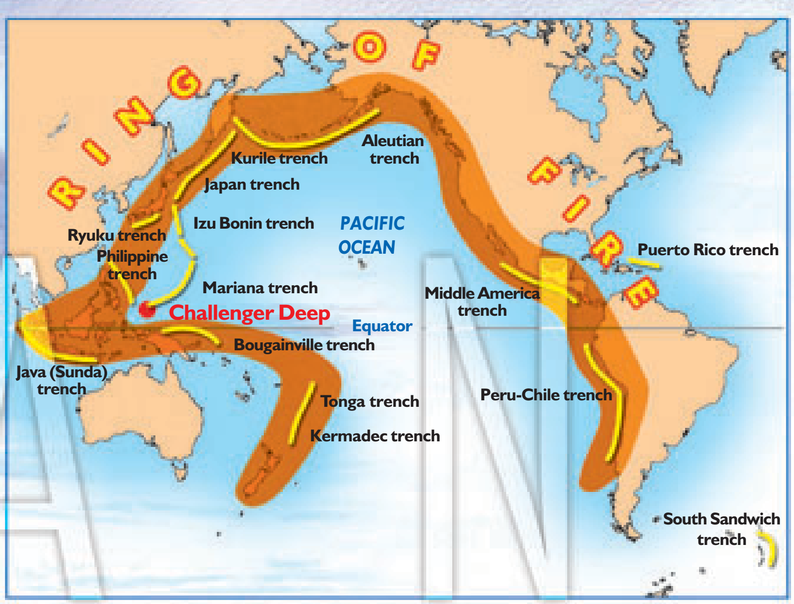


This zone is also known as *island arc* or *Ring of Fire* *(see figure at the bottom)*. Volcanic rocks are found mainly on mountains and ridges, but other areas of the sea-floor are covered by sediments or mud giving a smooth appearance. For most part of the ocean, sea-floor is dark as sunlight reaches only up to 200 meters from the sea surface. The water in the deep parts of oceans (about 1,000 meters) is very cold (2 to 4^{0}C)!

Cross section of the Ocean: Land to deeper parts of the ocean

If we take a geophysical traverse from Mumbai westwards across the Arabian sea we will find different levels of the ocean floor telling us all the mysteries of the submerged lands and also unexplored fascinating deeps. Our new petroleum deposits are indeed located on the continental shelf, west of Mumbai.





Ring of Fire

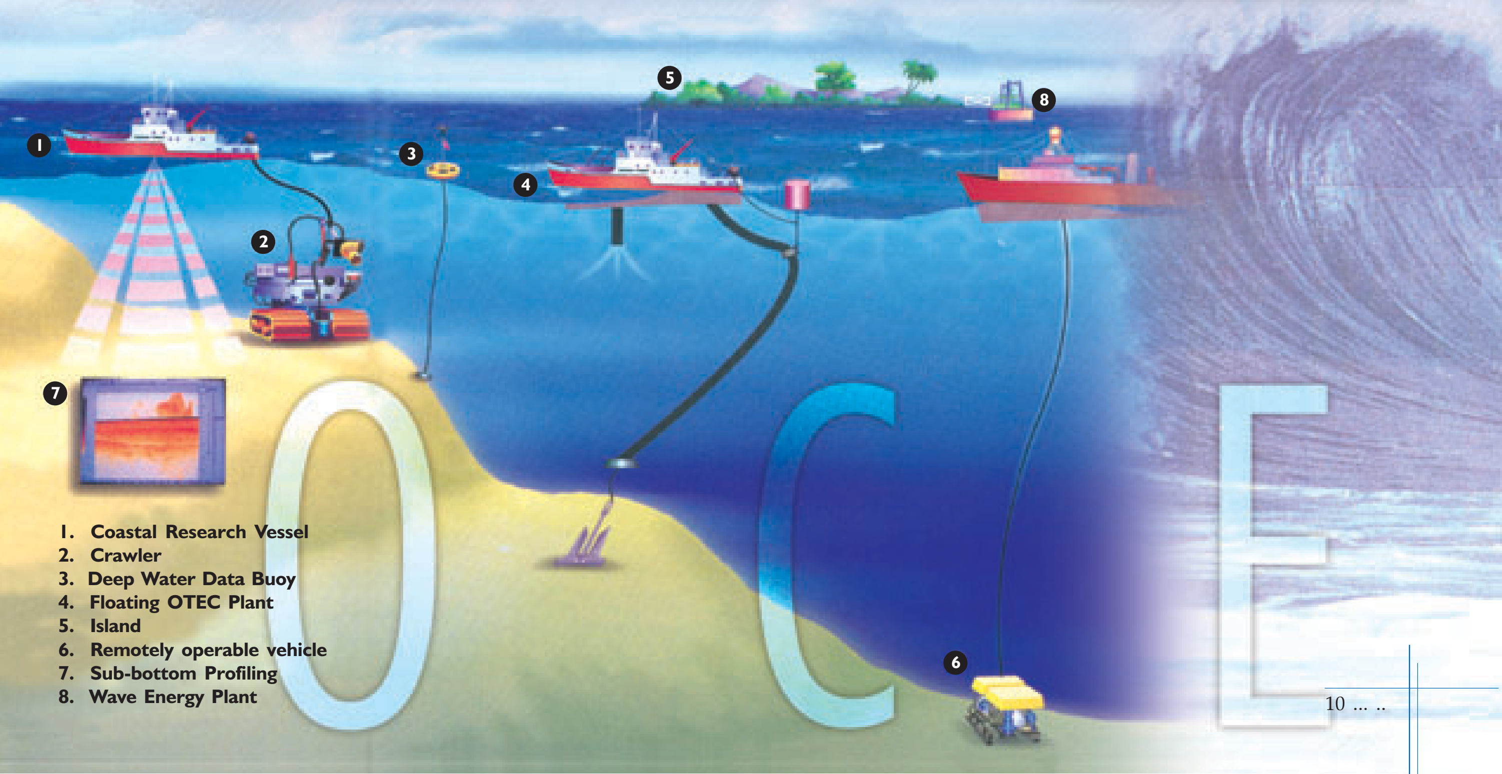
Aleutian islands in the Gulf of Alaska and Java trench in South East Asia are classic examples for zones of island arc - *Ring of Fire*.

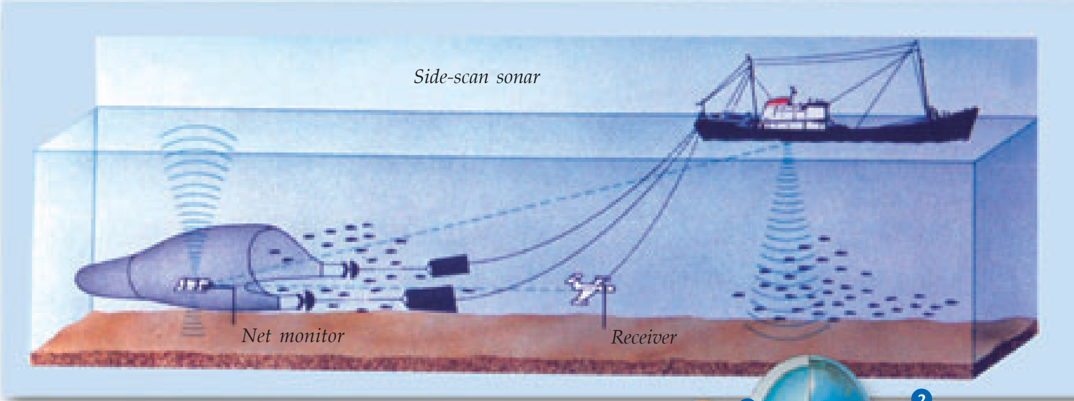
How do scientists study the Oceans?

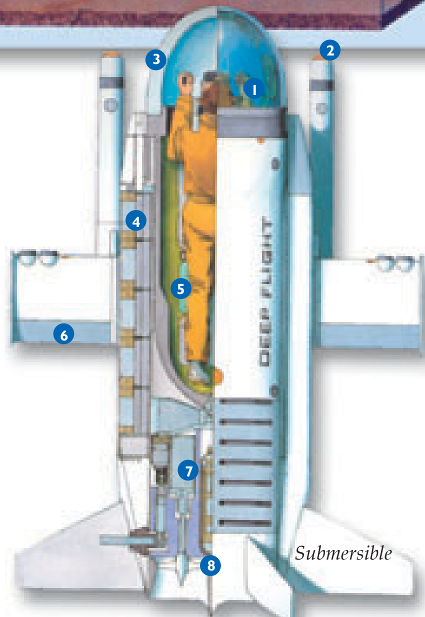
A well-equipped research ship is the most important mobile research station required to study the sea. Looking at the oceans extending up to the horizon is both amazing and interesting. As the ship moves away from the coast towards the deeper part of the ocean, the muddy/greenish colour turns to a deep blue colour and dolphins and flying fish may be seen jumping out of water. Rough weather can sometimes make the scientists on board the ship feel sea-sick. But the voyage is generally adventurous and challenging.

Ocean scientists known as oceanographers map the sea-floor features by using an *echo sounder*. It emits sound pulses from the ship towards the bottom from where they are reflected to the surface, and the time taken is recorded. Knowing the velocity of sound in ocean water, they find out the water depth below the ship. Present day multi-beam echo sounders provide wide coverage of the sea-floor depths simultaneously. A *side-scan sonar* deployed at shallow water depths gives a picture of the features of the sea-floor and sunken ships and similar objects.

What lies beneath the sea-floor? Sound of different frequencies can penetrate through the sea-floor, get reflected and come back to the







1. The pilot guides the submersible using these hand controls.
2. These powerful lights help the pilot to find his way.
3. This part is see-through, so the pilot can look around.
4. Deep Flight gets its power from ten batteries (five along each side).
5. Bottles filled with oxygen allow the pilot to breathe.
6. These wings don't move. They keep the submersible steady in the water.
7. Engines, called thrusters, turn the propellers.
8. Propellers spin around quickly, pushing the submersible forward.

ship. Through such *seismic investigations*, scientists are able to figure out what materials are there below and what their structures are.

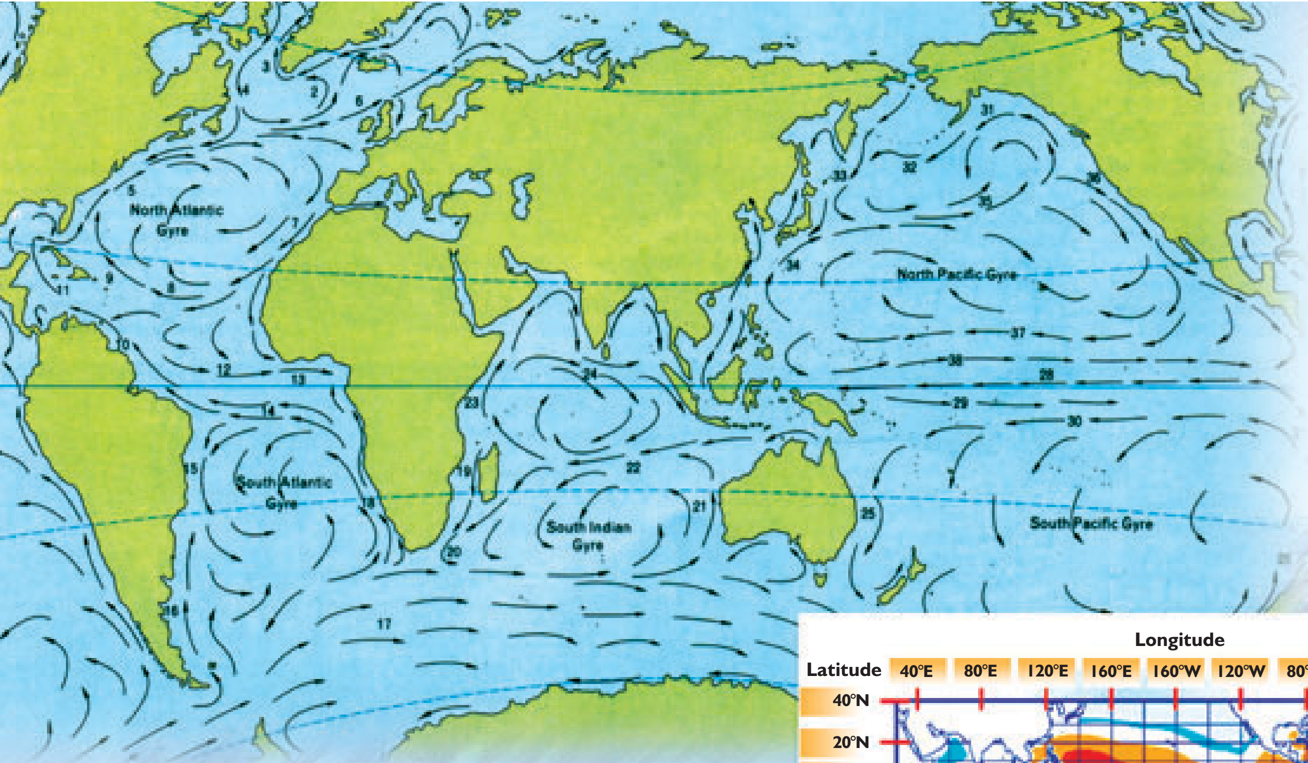
Scientists use a specially designed *grab* to collect samples from the sea-floor sediment or mud. Long, cylindrical samples (cores) of sediments are obtained using a *corer*.

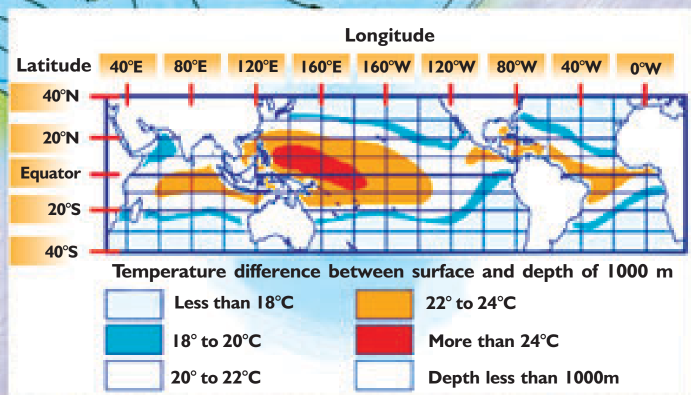
A *sediment trap* is used to "trap" sediment particles that are settling through sea water. They provide information on the processes going on in the water column.

Nets are used to capture relatively small organisms that live at/near the sea surface. Scientists study the types and abundances of these organisms and understand their ecology.

Measuring properties of water at various depths in the ocean helps in understanding how ocean water moves at different depths. This can be done by lowering instruments from the sea surface to sea-bottom, which continuously measure the temperature, salinity and other properties of seawater. Scientists go down the sea in '*submersibles*' to directly observe seafloor features and make various other observations of marine life and nature of sediments.

Fans : *(see top fig. on page 8)* It is interesting to note that in the Bay of Bengal, there is a huge fan called "Bengal Fan" which is made up of sediments brought in by the Ganges and Brahmaputra rivers. This is considered to extend for nearly 3000 km with a maximum width of about 1400 km. Similarly, the Arabian sea is fed by voluminous sediments by the mighty Indus river draining the Himalayan ranges. The sediment thickness exceeds 10 km and covers nearly 1500 km in length with a width of about 960 km. This beautiful structure in the Arabian sea is known as "Indus Fan".





Do Ocean water masses move?

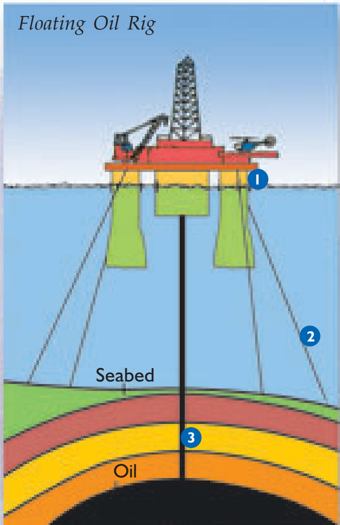
Oceans are not just a body of stagnant water. Ocean water moves from one place to another. Waters at different depths move in different directions and at different speeds. Surface waters move because of wind. Waters at depths also move because of differences in density, temperature and salinity. Such are called *currents*. Gravitational attraction, primarily of the moon and the sun, produces *tides*.

Currents are like rivers in the oceans. They can carry enormous amounts of water. For example, the *Antarctic Circumpolar Current* can transport 100 million cubic metres of seawater per second! Some currents containing mud travel at speeds of 4m/sec. They are known to have transported blocks weighing as much as 9,000 kg!

Water currents transport heat, sediment particles, dissolved oxygen and nutrient elements from one place to another. This is crucial because all forms of marine life needs oxygen and nutrients for their growth.

Do the Oceans hold any economic potential?

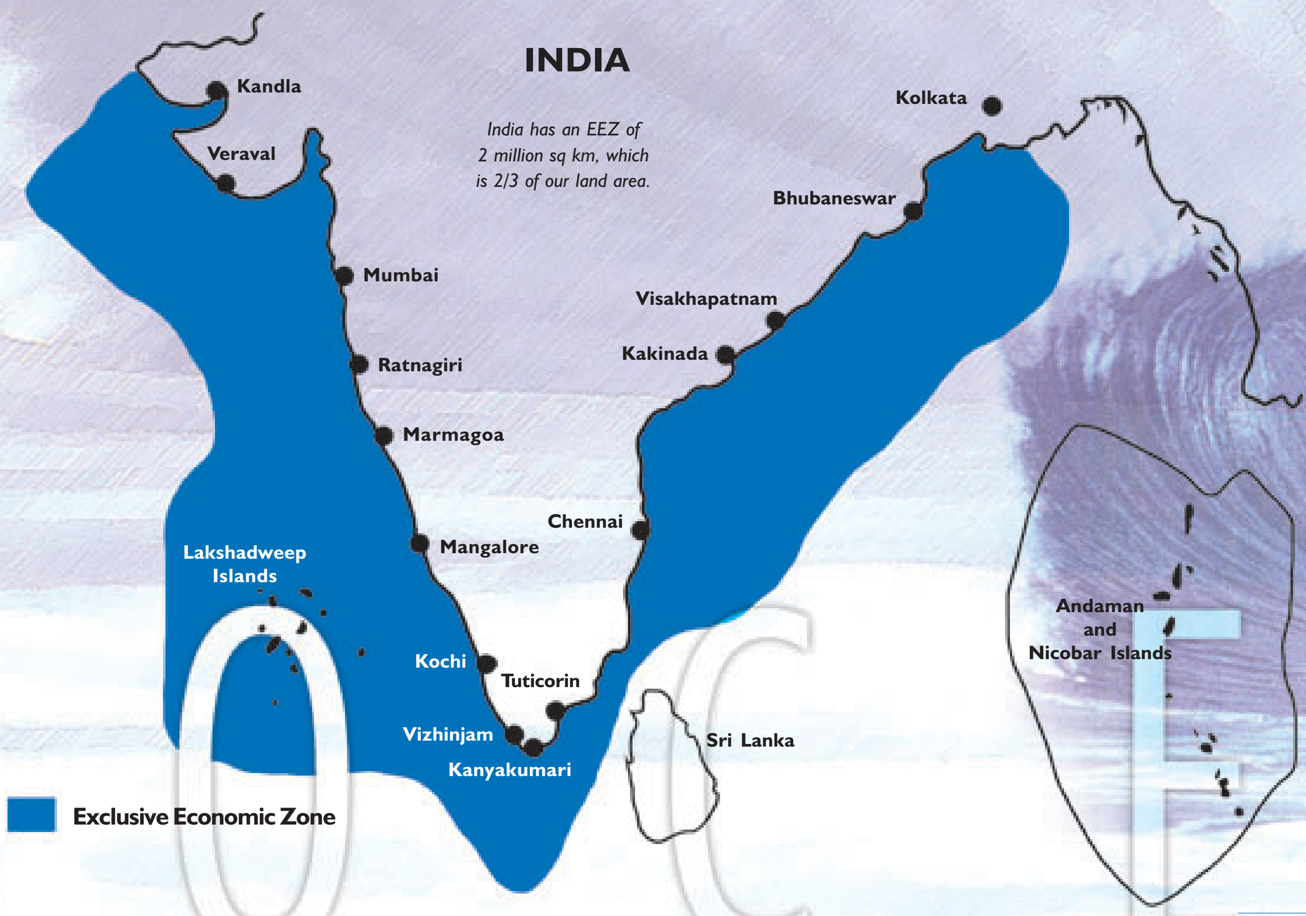
Oceans contain a wide spectrum of mineral, energy- and food resources. They are the earth's biggest storehouse of minerals including oil and gas. Although these are available on land, our demand for resources has been rising continuously because of rapid increase in world population and demand for comforts and amenities. Besides, mineral resources are not renewable, once mined and used, they are lost. To form again, it takes several millions of years and this is the reason why they are known as "non-renewable" resources.



1. These floats stop the rig from sinking.
2. Cables with anchors on them stop the rig from moving.
3. This pipe goes into the seabed as far as the oil. The oil is then pumped up.

Who owns these resources and who can utilize them?

The United Nations held three conferences (between 1967 and 1982) on this aspect and finally the *United Nations Convention on the Law of the Sea* was signed in 1982. The Convention laid down rules and regulations to rationally manage oceanic resources and conserve them for future generations. The oceans have been divided into several zones: *Territorial sea* (12 nautical miles (n.m.) from coastline), *Exclusive Economic Zone* (EEZ; 200 n.m. from coastline ; *see sketch below*), and the *International Area of the Seabed (beyond the EEZ)*. Coastal nations have exclusive rights to explore and exploit all the resources within their respective EEZ's. Resources in the international area are a common heritage of mankind.



Manganese nodules on board the Indian research vessel

Cut section of the Manganese Nodule

Manganese Nodule recovered from the seabed

Mineral wealth of the Oceans

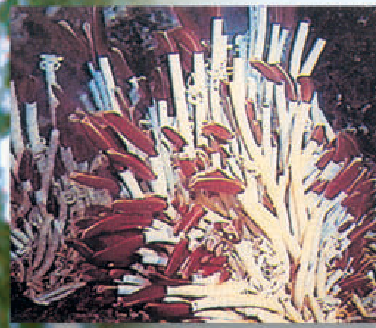
Manganese Nodules

Large areas of the sea-floor are covered by black, potato like objects called *manganese nodules*. Growing at unbelievably slow rates (a few mm in 1 million years!), they contain metals like copper, nickel, cobalt, iron, manganese etc. that are precipitated as oxides/hydroxides from sea water. Scientists have estimated that several billion tons of nodules are present on the world ocean-floor.

India was granted exclusive rights by the UN to explore for nodules in an area of 1,50,000 km^2 in the Central Indian Ocean, and has already conducted surveys and established nodule resources to the extent of 9.5 million tons of Cu, Co and Ni in an area of 75,000 km^2 within the economic zone.

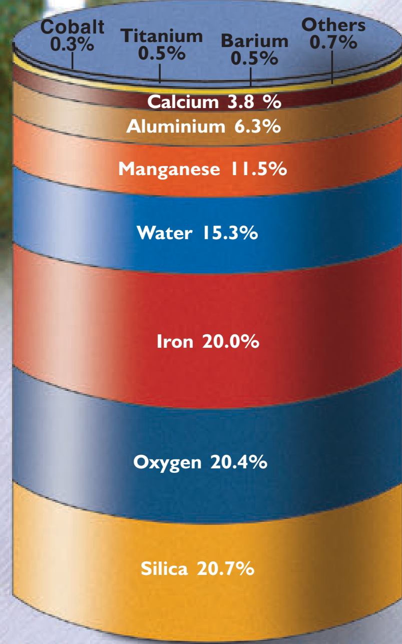
The cold sea water percolating through cracks present in oceanic rocks in the subterranean volcanic and mid-oceanic ridge regions, gets heated and leaches metals like iron, manganese, copper, nickel etc. This water rises and comes out of the sea-floor as hot springs at

Metal rich material from the hot springs area



A colony of tube worms clustered around an ocean floor hot spring

Contents of the Manganese Nodule



temperatures of up to 380° C! The dissolved metals are precipitated sometimes in the cracks of rocks to form metal sulphide ores. Sometimes chimneys of sulphide materials exist on the sea-floor.

There are also several types of animals living in such warm environments. Life at these great depths (approximately 2500m) where sun light does not reach, is sustained by *chemosynthesis*, in which energy during chemical reactions is used for synthesizing food by microbes. For example, *thermophilic bacteria*, generally found in the hot spring areas of the sea-floor, can tolerate high temperatures (thermo=heat; philic=loving). These bacteria are eaten by bigger animals and they, in turn, are eaten by still bigger animals and so on. That's how the food chain is established here. Underwater hot spring areas are home to many new species that were not known to man earlier.

Some times the dissolved metals are precipitated in the water column as metal sulphides or oxides. On settling to the sea-bottom, the precipitates form layers of sediment, rich in metals. Rich deposits of such *metalliferous sediments* are found in the Red Sea. One of them contains 100 million tons of metalliferous sediments in which 2.5 million tons of Zn, 0.5 million tons of Cu, 9000 tons of Au and other metals are present.

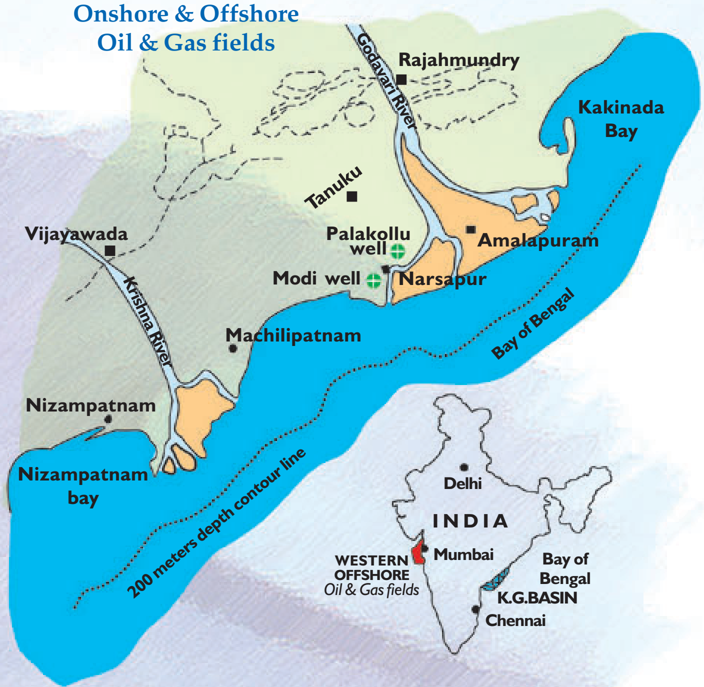
Oil and Gas

Ocean sediments are repository of vast oil (petroleum) and natural gas deposits. They form when organic matter of dead micro-organisms is buried by mud on the sea-floor. Due to high temperatures and pressures at great depths, this organic matter is converted into oil and natural gas. India has several offshore oil and gas fields in Bombay High, Gulf of Cambay, Cauvery, Krishna-Godavari and Mahanadi basins.

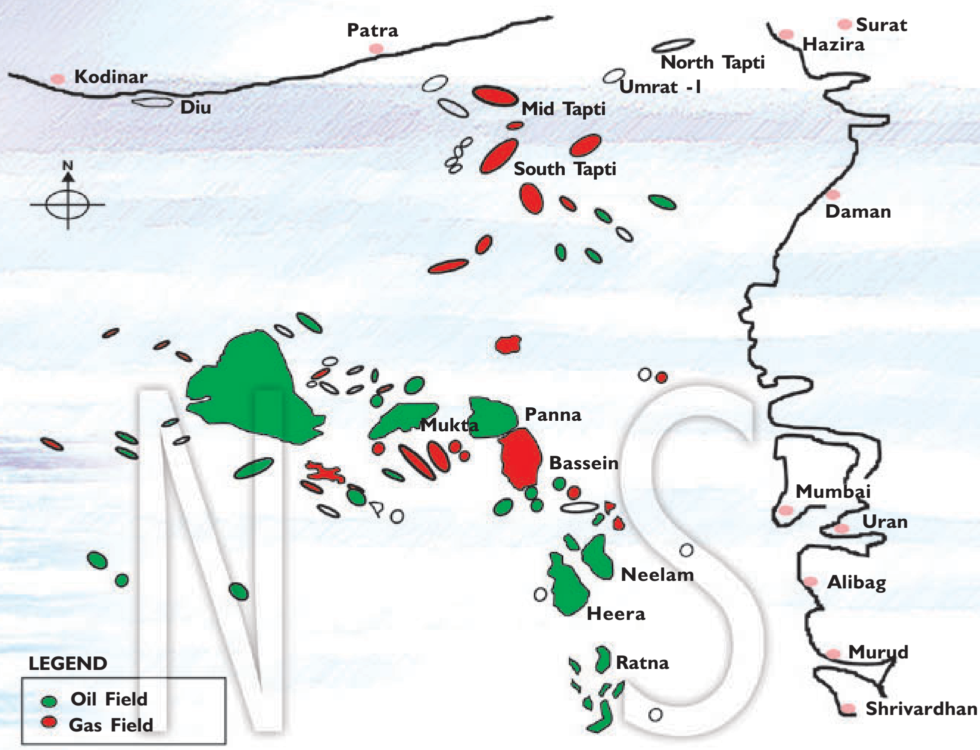
Gas Hydrate

At low temperatures and high pressures, natural gas (methane) gets into water molecules to form ***gas hydrate***, a relatively newly discovered mineral deposit that occurs in ocean sediments. One cubic meter of gas hydrate, when brought to the surface is expected to yield 164 cubic meters of natural gas!. This can be done and utilised as a future resource.

Location Map
Krishna Godavari (K.G.)
Onshore & Offshore
Oil & Gas fields



Location Map
Western Offshore Oil & Gas fields



Placer Deposits

Certain heavy minerals brought by rivers from weathered rocks and sediments on land are sorted according to their density and deposited on beaches and along the coast, away from coastline. Such ***placer deposits*** contain gold, tin, thorium, rare earth elements, iron, zirconium etc. Rich placer deposits are found along the coastlines of Kerala, Maharashtra, Orissa, Andhra Pradesh and Tamil Nadu.

Phosphorite Deposits

There are ***phosphorite deposits*** too on the ocean-floor, which are formed by inorganic precipitation of phosphorus or by replacement. Phosphorite deposits occur on land also, though formed earlier on ocean floor. Phosphorites are used in the manufacture of fertilizers and phosphorus compounds.

East coast beach placers at Visakhapatnam

Salt farming
West coast of India

Salt

Sea-water contributes bulk of the salt which mankind uses. Salt is one of the main resources recovered by man since early times. Each cubic mile of sea water weighs approximately 4.7 billion tons and holds 166 million tons of dissolved solids, comprising 140 million tons of common salt (sodium chloride) and 25 million tons of magnesium salts besides others.

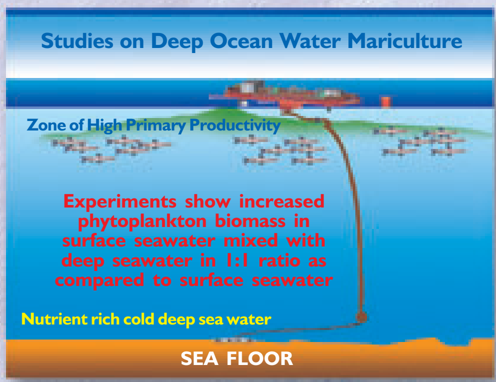
Why is the sea water salty?

The sea-water is salty because it contains dissolved salts. Salinity, or the salt content of sea-water is about 3.5%. Most significant constituent of the salts is table salt or sodium chloride. Where does all the salt in the sea come from? When rocks are weathered on the continents, salt and other chemicals are dissolved by rainwater and carried by rivers to the oceans. After millions of years, much salt has accumulated in the oceans by breaking down of mountain ranges and scoured by several rivers during the past millions of years. Very little is taken out by natural processess or by man which makes the sea-water ever salty.

Trace elements	0.01%
Flouride (F^-)	0.003%
Strontium(Sr^{++})	0.04%
Boric acid (H_2BO_3)	0.07%
Bromide(Br^-)	0.19%
Bicarbonate (HCO_3^-)	0.41%
Potassium(K^+)	1.10%
Calcium(Ca^{++})	1.16%
Magnesium(Mg^{++})	3.69%
Sulfate($SO_4^=$)	7.69%
Sodium(Na^+)	30.61%
Chloride(Cl^-)	55.04%

Eleven Major Constituents account for more than 99% of the salt content of normal seawater. Many are present in solution in the form of free ions. The overall salinity of sea water may vary regionally and with depth, but the ratio of the constituents remains constant.

A rich haul of finfish



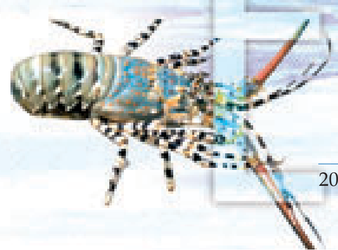
Oceans as a source of food

Indeed oceans are primary source of staple food to large coastal communities. A large number of finfish and shellfish including shrimps, lobsters, squid, cuttlefish, prawn etc. are harvested along the entire coastline. Our nation is in the front rank of global fish production. The country's estimated potential for production is about 3.93 million tonnes of fish and shellfish. India is a major exporter of sea food items like squid, cuttlefish, lobster and a variety of fish, besides shrimp. Export of marine products amounted to 2,90,000 tonnes valued at Rs. 3501 crores in 1995-96 and has increased to 4,24,000 tonnes valued at Rs. 5957 crores in 2001-2002.

Acoustic surveys (using echo sounder) have been used in recent times to locate dense populations of fish. The country has initiated a multi-disciplinary and multi-institutional programme aimed at making an assessment of the marine living resources beyond 70m water depth.

Mariculture

Mariculture is an alternative for increasing the production of over-harvested or depleted stocks. Creation of artificial reefs and sea-farming projects are good for replenishing resources that are degraded.



Medicinal plant

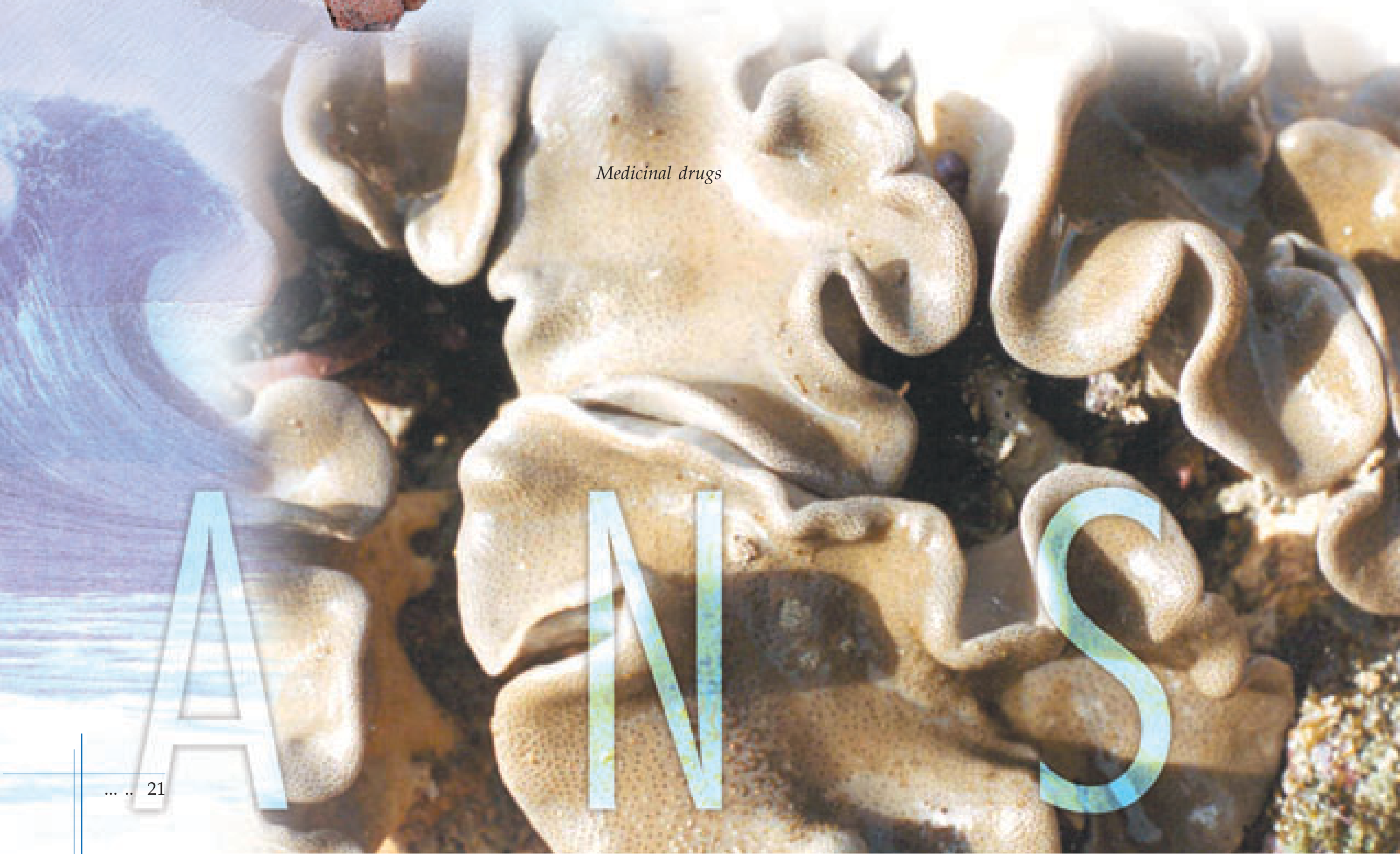
Medicines and Sea vegetables from the Ocean

About 30% of the faunal and floral species of our planet inhabit in the sea. It is believed that life originated in oceans. Some compounds extracted from marine organisms have shown to be anti-viral, anti-tumour, anti-biotic and may be developed into drugs.

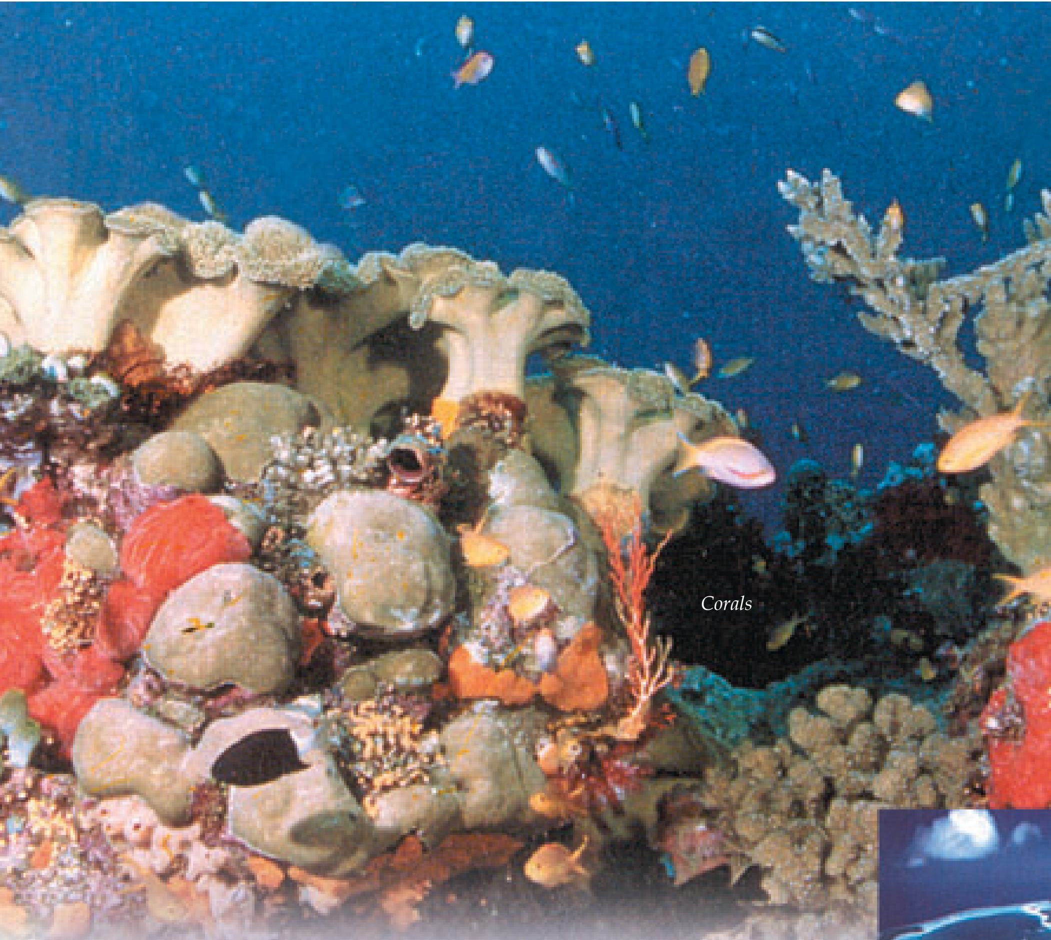
Exploration and recovery of such drugs are one of the important goals of our marine exploration programme.

Sea vegetables are used as food, animal feeds, dyes, medicines and cosmetics. Sea weeds (*algae*) are rich in protein - higher than even in meat, and highly enriched in calcium (*higher than in milk*).

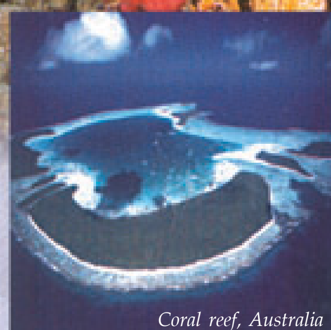
These are also used as a possible prevention against cancer, blood pressure and other illnesses. Some of the well known sea vegetables are *arame, bladderwrack, dulse, hijiki, kelp, kombu, nori and wakame.*



Medicinal drugs



Corals



Coral reef, Australia

What are Coral Reefs?

Reefs are solid limestone structures created on the shallow sea bed mainly by dead biological communities - coral and algae are the common ones known to us. Coral larvae secrete calcareous shells of their own and succeeding ones grow on the shells of the dead corals. Coral reefs in the shallow waters create a varied, colourful and fascinating ecosystem.

They develop in shallow depths of tropical seas with ample sunshine where the temperature ranges between 18^0 and 32^0 C. Lakshadweep islands are made up of coral reefs developed on oceanic basement.

Extensive coral reefs also occur in the Andaman and Nicobar islands, Gulf of Mannar and Gulf of Kutch. The Great Barrier Reef on the east coast of Australia is the longest animal-made structure, extending for about 3,000 km.

Energy from the Oceans

Ocean Thermal Energy Conversion

In the present day conditions of severe power shortage, it is important to develop alternate non-conventional energy resources. Oceans offer a variety of environments for the production of energy, which are renewable and non-polluting.

Using cold sea-bottom water and warm surface water, it is possible to harness energy. Such a programme is called *Ocean Thermal Energy Conversion* (OTEC). Ocean is a large collector of solar energy which is mainly responsible for generating currents. India will be deploying very soon a 1-Megawatt floating OTEC technology demonstration pilot plant, 60 km off Tuticorin in Tamil Nadu.

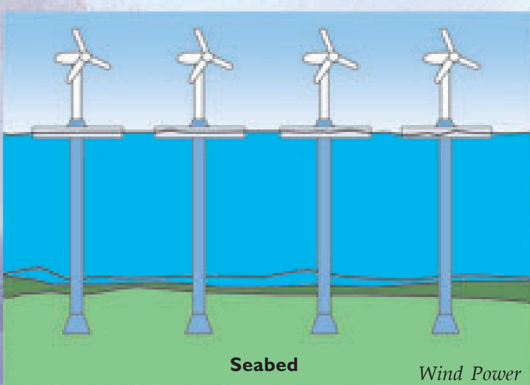
Wind blowing across the ocean surface produces *waves*. Ocean waves can be used to produce electrical energy. This is made possible using the temperature difference between warm surface water and cold deep water. A small wave energy plant has been installed at Vizhinjam in Kerala.

Sea level rises and falls mainly due to *gravitational attraction* of the Sun and the Moon. These are called *tides*. As a result, sea water gushes into rivers during high tide and goes back to the ocean during low tide twice everyday. By constructing a dam, water can be stored during high tide and on its flowing back to the ocean can be made to run turbines for producing electricity.

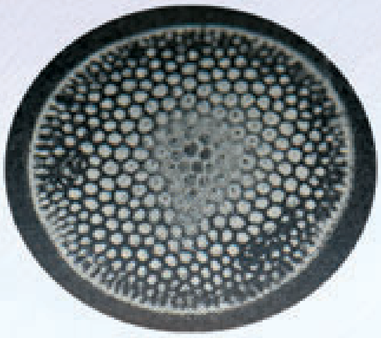
The surface of the sea is often windy. Big windmills, called wind turbines, could be attached to the seabed and used to make electricity from the wind.

Wind blowing across the sea turns the windmill blades.

The spinning blades power a machine called a turbine inside the windmill, which produces electricity.



Wind Power



Diatoms with silica shells

Life in the Oceans

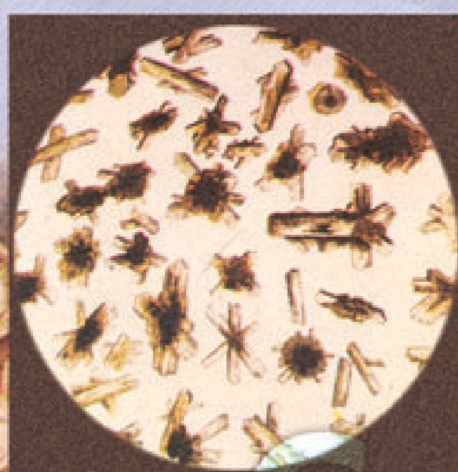
Life originated in the oceans. Marine scientists are carrying out research on sediments from hot spring areas to understand how life originated on the Earth. Oceans have supported life in a variety of forms - from microscopic algae to gigantic blue whales. Of an estimated 30 million species of flora and fauna on our planet, oceans contribute to nearly 20% (about 5,00,000 species).

What are marine sediments made up of?

Mud or sediment that covers large areas of the ocean floor is made up of (1) clays and sands brought by rivers, (2) the shells and organic matter of dead organisms that once lived in sea surface waters, (3) chemical compounds that are precipitated from sea water, (4) particles that form near hot spring areas and (5) sediments formed from the disintegration and decomposition of ocean floor rocks. About 3.8 million tons of dust from outer space is estimated to reach the ocean floor every year.

Certain parts of the sea-floor contain large amounts of calcareous ($CaCO_3$) and siliceous (SiO_2) shells, which are useful to man. In addition to having economic value, marine sediments enable us to understand the conditions under which they were laid down on the sea floor.

Microscopic calcium carbonate shells of organisms



Crystals in ocean sediments

Can we know the climates of the past?

Yes, this is what some marine scientists attempt. Because of widespread pollution by industries, automobiles etc., large amounts of carbon dioxide (CO_2) and certain other gases are being added to the atmosphere. These gases allow solar heat to come in but do not allow the heat to go back to outer space resulting in the *green house effect*.

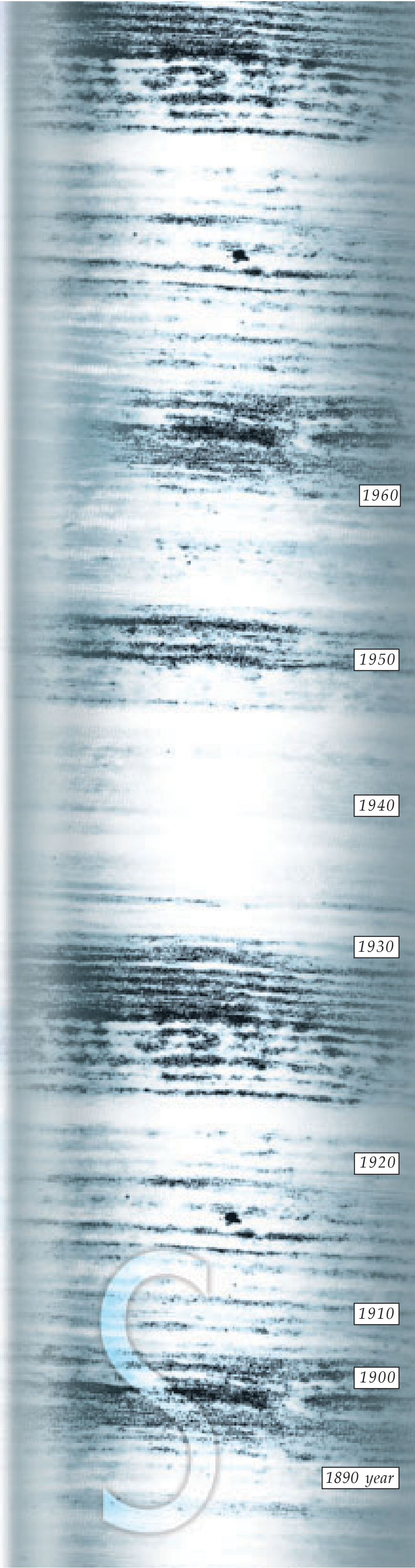
The CO_2 level has increased by ~30% since 1800's (from 280 to 360 parts per million; for short, ppm). It is predicted to amount to ~560-1000 ppm by 2100 AD. This will have an effect on the volume of sea-water and rise of sea level.

If the present trend of CO_2 emission continues, the earth's health would be greatly affected, and the consequences may be disastrous. By the end of the present century, global atmospheric temperature may rise by an average of 1.4-5.8^o C and the sea level by 9-88 cm (10-20 cm rise in the last century). There will be frequent storms. Global climate will change and so will the agricultural pattern. To make and improve such predictions it is necessary to know variations in the past climate. Study of changes of temperature of the oceans becomes a matter of utmost importance.

Climatic conditions related to temperature, rainfall etc., during the last one hundred years are known from instruments. We can also get a certain amount of information from historical data. But how to know the conditions of the distant past, is a crucial question.

Marine sediment samples provide an excellent window into the climatic history. The remains of marine organisms embedded in them, the type of clay minerals present and the chemical composition of sediments give information on the age of the sediment and how the climate was when the sediment was deposited. In this way, oceanographers have reconstructed climatic and oceanographic conditions of the past several million years!

Studies of marine sediment cores have revealed interesting information of the past climate. About 11,000 years ago, the sea level was lower by 100 m or even more. The earth's climate fluctuated between cold and warm with periodicities of 23000, 41000 and 100000 years. Severe climatic conditions that wiped off dinosaurs that once roamed on the earth's surface are recorded in marine sediments.



Deep sea sediment core.. note different layers of sand, shale, sandstone, limestone with organic remains!

The absence of oxygen causes refractory parts of the organic debris to be left undecomposed and the sediment to remain undisturbed in the annual layers. The dark layers are the densest and represent winter sedimentations. The lighter and less dense layers are composed of diatoms and represent spring and summer sedimentation.

Chariot

Dwaraka undersea expedition photographs

Pottery

Acoustic image of a possible river course

Heritage in the Oceans : Are there man-made objects and structures on the sea bed?

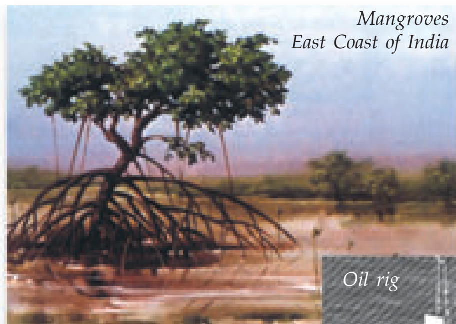
Surprisingly, evidences of earlier heritage are to be found in the oceans also. It is the marine archaeologists who study underwater cultural heritage; they deal with material remains in the form of submerged ancient habitation/port installations and ships that sank due to accidents or during wars. We find ancient port towns like Dwaraka, Bet Dwaraka and Somnath off Gujarat and Poompuhar off Tamil Nadu, which got submerged as the sea level rose during the past 11,000 years. Archaeological structures were discovered at depths of 40 m, 30 km off Gujarat coast in the Gulf of Khambat in Gujarat. More than 2,000 artifacts (man made objects) have been collected. These include broken pottery, semi-precious stones and stone ornaments with holes. A number of anchors of different varieties suggest that Bet Dwaraka was a potential site of a proto-historic settlement. House basement-like features, channel like features indicating good drainage, and tanks with steps have also been found.

Under water archaeological structures

Are Our Oceans polluted?

With a large population concentrated in coastal areas, we are polluting the oceans in several ways through discharge of industrial and urban wastes, harbour activities (like fish landing, cargo handling, dumping of ship washings, spillage of oil and ores), oil exploration, oil slicks, land run-off etc. Toxic metals like cadmium, copper, lead, mercury, nickel, zinc etc. reach the oceans through industrial discharges.

Human activities in coastal regions are already having a serious impact on the marine environment and marine life. The time has come for co-ordinated efforts to protect coastal areas and monitor the health of the oceans. This is mainly because estuaries, lagoons, beaches, sand dunes, mangroves and coral reefs along the coast are some of our most important heritages. They serve varied purposes but most importantly as incomparably rich sources of biological diversity.



Mangroves East Coast of India

Oil rig

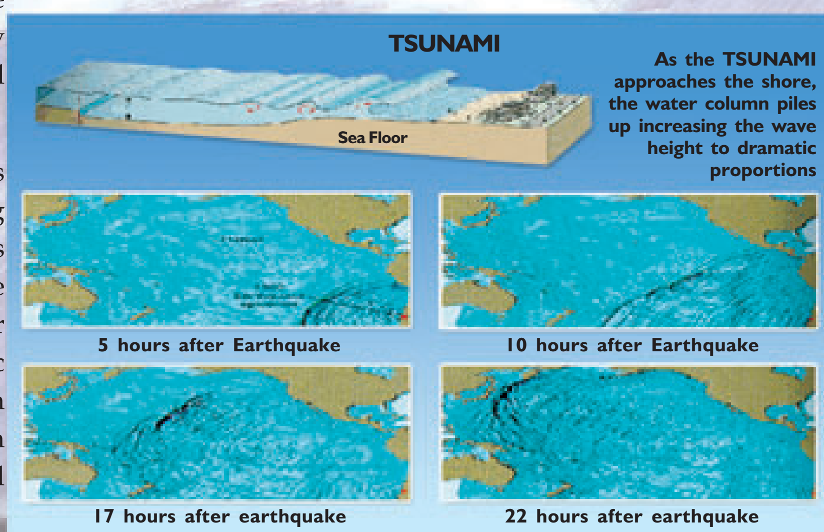
Estuary carrying pollutants!

Does the benevolent Ocean get furious?

During monsoon, winds are strong, producing huge waves. When they strike the coast, the waves cause considerable damage to property and life and erode beaches. This is called *coastal erosion* that is prevalent in many coastal areas. Often, man-made structures near ports and harbours add to the problem of coastal erosion.

Tsunami damage, Alaska

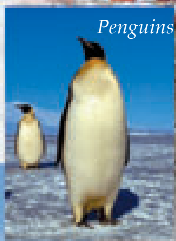
Tsunamis are large, rapidly moving ocean waves triggered by a major disturbance of the ocean floor. They are usually caused by an earthquake but sometimes can be produced by submarine landslides or volcanic eruptions. These waves typically travel at speeds of about 600 mph. As they reach shallow water, the waves slow down but greatly increase in height (3-20m), and the distance between them shrinks. They cause enormous damage to coastal population and property.



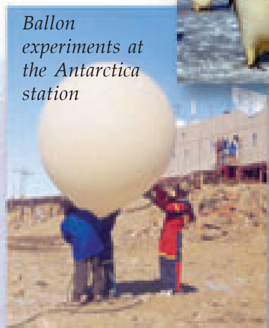
Violent volcanic eruptions in the oceans sometimes send out materials ranging from boulders to fine ash. Fine particles go up to several kilometers and are transported around the globe. For example, the 1883 Krakatoa volcanic explosion in Indonesia released so much dust into the atmosphere that the earth was plunged into darkness for several days!

Explosive volcano

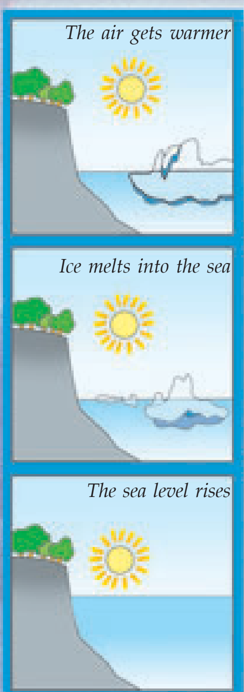
Maitri research station at Antarctica



Penguins



Ballon experiments at the Antarctica station



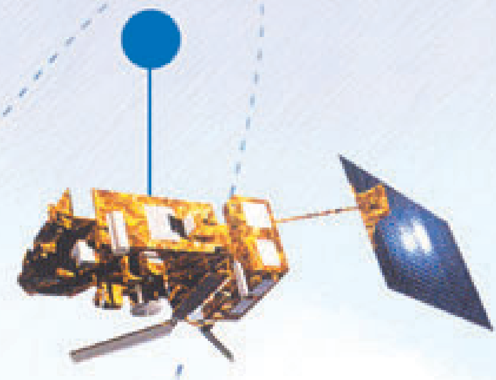
Melting Ice
As the atmoshpere warms up, the ice in the Arctic and Antarctic starts to melt. The water goes back into the oceans, making the sea level rise.

How important is Antarctica to us?

The icy continent of Antarctica and the surrounding ocean, called the Southern Ocean, provide vital insights into the tectonic history of the earth and intricate processes like global warming, sea level rise and ozone depletion, which have a direct bearing on the sustenance of man on this planet. The Southern Ocean is also important in the context of cycling of nutrient elements and climate because it contains sites of deep water convection and also because its surface waters contain large amounts of unutilized nutrients. Shrimp-like *krill* is an important source of food. If due to atmospheric warming up, Antarctic and Arctic ice start melting this will considerably rise the sea level (*see figure at the left*) and result in the submergence of part of coastal plains all over the world.

Antarctica is perhaps the least polluted part of the earth. Study of some of the parameters of its environment forms the data base to understand the changes that have taken place in some of its earlier neighbours, which moved out, over a long period of time extending over about 200 million years. A number of studies have been initiated by different countries in different parts of this continent.

Realising the scientific importance of this region, India has engaged herself in Antarctic research. A research station called *Dakshin Gangotri* was established in Antarctica in 1983, while a second station *Maitri* was set-up in 1991. The country launched its first expedition to Antarctica in 1981. Scientists from several organisations and institutions have participated in 23 such expeditions so far from India to gather samples and data for scientific research.



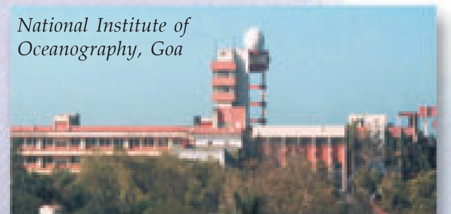
What is Satellite Oceanography?

Satellite Oceanography is the study of the oceans using satellite imageries. The digital reflectance data obtained by special sensors of the Landsat, SPOT, Indian Remote Sensing (IRS) and other satellites are processed to get varied pictures of the ocean surface to interpret the temperature, chlorophyll content, salinity, turbidity etc. and also to demarcate areas of abundant fish and other faunal population, ocean currents, oil slicks etc. Temporal data help in the periodic monitoring of the different parameters.

Career opportunities

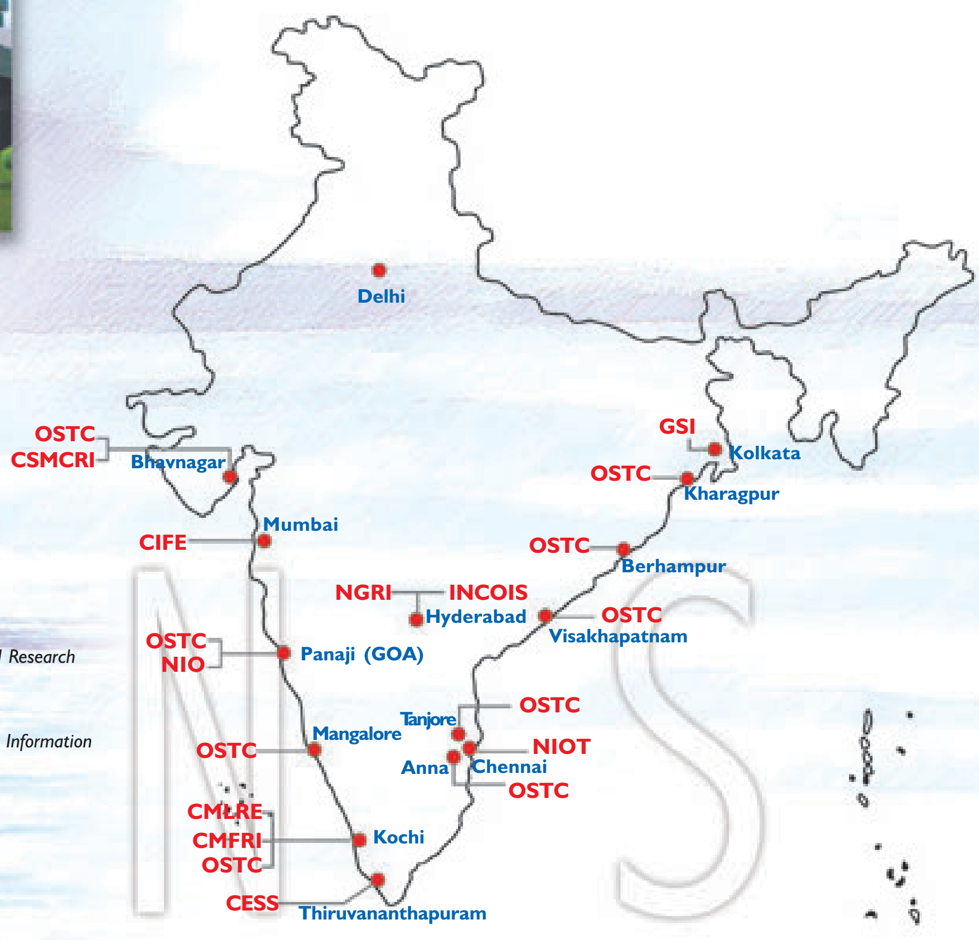
Educational and Research Institutions

Several institutions offer M.Sc. courses in ocean-related fields for science graduates: Universities of Mangalore, Goa, Cochin, Andhra and Berhampur, Central Institute of Fisheries Education (*CIFE*) etc. Besides these, marine research is conducted at the National Institute of Oceanography (*NIO, Goa, Mumbai, Cochin, Visakhapatnam*), Geological Survey of India (*GSI, Kolkata, Visakhapatnam, Mangalore*), National Center for Antarctic and Oceanic Research (*NCAOR, Goa*), National Institute of Ocean Technology (*NIOT, Chennai*), Ocean Science and Technology Cells (*OSTC*) of Department of Ocean Development at nine places (*see map below*), National Geophysical Research Institute (*NGRI, Hyderabad*), Oil and Natural Gas Commission (*ONGC*), Indian Institute of Technology (*IIT, Mumbai, Chennai, Kharagpur*), Banaras Hindu University (*BHU, Varanasi*), Centre for Earth Science Studies (*CESS, Thiruvananthapuram*), College of Fisheries (*CF, Mangalore*), Central Marine Fisheries Research Institute (*CMFRI, Kochi*) and a few other places.



National Institute of Oceanography, Goa

National Institute of Ocean Technology , Chennai



CSMCRI - *Central Salt and Marine Chemical Research Institute, Bhavanager*

INCOIS - *Indian National Centre for Ocean Information Centre, Hyderabad*

Save the Oceans!

Oceans are important to us in many ways. We are dependent on them for resources. Oceanic processes directly or indirectly control the climate and our environment. Marine resources, environment and ecosystem need to be protected from man-made influences. Although man has conquered the outer space, he has not yet fully understood the oceans - our inner space. Large parts of the oceans are still unexplored. There are still many gaps in our understanding; several mysteries of the oceans have yet to be unravealed. The nation looks to bright and enthusiastic students like you to continue the exciting and fascinating journey of ocean exploration.

Glossary

Acoustic methods

Methods that use propagation of sound waves for various studies.

Bathymetry

Measurement of ocean water depth.

Continental margin

The ocean floor adjacent to continents including shelf, slope and rise.

Continental shelf

The shallow gently sloping sea-floor extending from the shoreline to a zone where the slope markedly increases.

Crust

The outermost layer of the earth. Its thickness is about 10 km beneath the oceans and 30-35 km beneath the continents. (see figs.1 & 3)

Currents

Currents, more specifically, ocean currents are ocean water masses that move from one part of the ocean to another. They move at different water depths and are due to winds, and differences in temperature and density of sea water.

Earthquake

A violent disturbance at the earth's crust or mantle felt and/or recorded above the ground.

Ecology

The study of how living creatures interact in the environment.

Echo-sounder

An instrument used for measuring ocean water depths using sound energy.

Erosion

The transport of rocky or weathered material by ice or water or wind.

Estuary

The mouth of a river where fresh water from the river and sea water mix.

Exclusive Economic Zone (EEZ)

An area extending up to 200 nautical miles from coastline. A coastal nation has sovereign rights over the mineral resources of this region.

Fault

A fracture (in a rock) along which the two blocks of rock have moved relative to each other. (see fig. 2)

Fossil

An imprint of an animal or plant preserved in sedimentary rocks.

Gas hydrate

A deposit that forms when molecules of natural gas are locked up in a water molecule at high pressure and low temperature. At surface temperature and pressure, it expands 164 times.

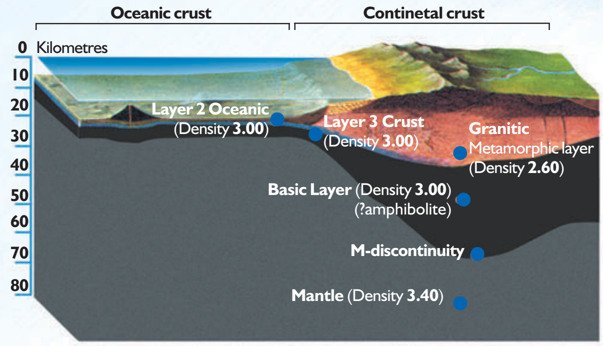


Fig. - 1

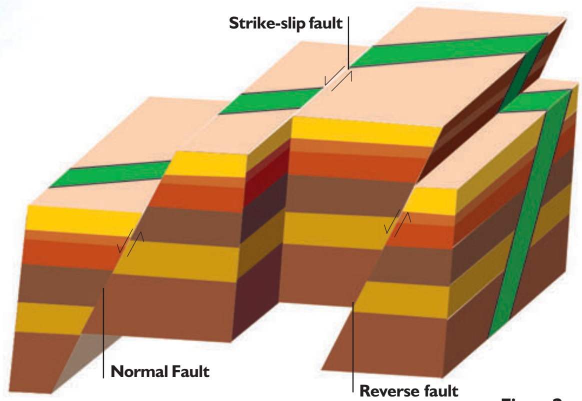


Fig. - 2

Grab

An instrument used for collecting samples of surface sediments from the ocean floor.

Greenhouse effect

The effect of atmospheric carbon dioxide and other gases that allow solar radiation to pass through but prevent the long - wavelength radiation from going out to space, thus increasing atmospheric temperature. It is similar to the effect in a greenhouse that is used to grow plants in temperate regions. Hence the term "greenhouse effect".

International Area of the Seabed

The area of the sea-floor beyond the Exclusive Economic Zone.

Lava

Molten rock material that is brought up to the surface by a volcano or along a fissure.

Magma

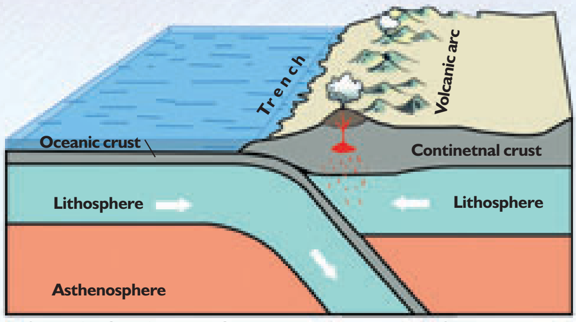
Molten rock material that is below the earth's surface.

Mid-oceanic ridges

Submarine mountain chains that run in the middle of all the major oceans. They are characterised by volcanic and earthquake activity. (see fig.4)

Multibeam echo sounder

An instrument that uses a number of individual narrow beams of sonic energy to get a detailed and accurate topographic map of the seafloor.



Oceanic Continental Convergence - Fig. - 3

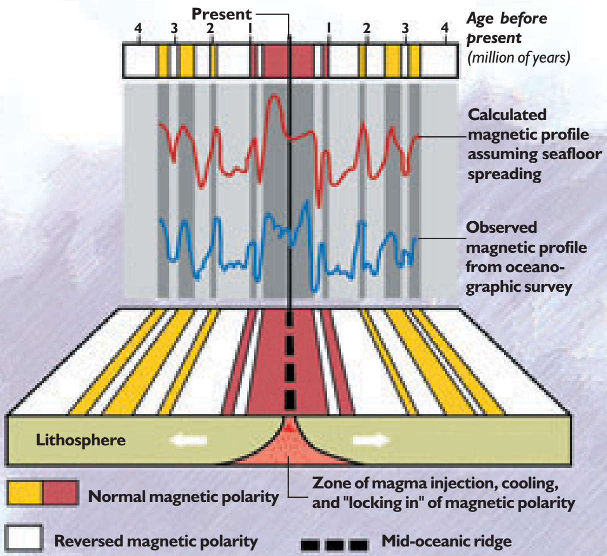


Fig. - 4

Nautical mile

It is equal to 1.15 statutory mile or 1852m or 1.852 km

Nutrients

Elements other than carbon, hydrogen and oxygen that are required for the synthesis of organic matter. Common nutrients are nitrates and phosphates.

Oceanography

Study of the oceans/seas

Ocean trench

A narrow, deep depression on the sea-floor, usually several thousand kilometers long and up to 10 km deeper than the adjacent seafloor. Here, the oceanic plate goes down beneath the adjacent plate. (see fig.3)

Placer minerals

Minerals with high specific gravity and high resistance to chemical weathering which are deposited in rivers, lakes, beaches and near shore regions. They contain many valuable elements like thorium, rare earth elements, titanium, zirconium and iron. Placer deposits found in offshore regions and as raised beaches indicate sea level changes.

Phosphorite

A mineral deposit found in more than 1000 m water depth, which contains phosphorus and rare earth elements.

Radiation

Transport of energy from one region to another without a medium i.e., heating of the earth by the sun's rays.

Salinity

The amount of dissolved salt present in seawater expressed in parts per thousand.

Sea

An enclosed or semi-enclosed body of saline water that is large compared to most estuaries and embayments but small compared to oceans.

Sea-floor spreading

A process that is driven by sea-floor volcanism whereby oceanic crust is created (at mid-oceanic ridges) and destroyed (at the trenches). The spreading is recognised by investigations on magnetic polarity. (see fig.4)

Seismic investigations

Investigations that are carried out to find out the structure of sediments / rocks beneath the seafloor.

Seismic

Related to earthquake or vibrations of the earth.

Seismic waves

Waves that are generated by earthquakes or man-made explosions.

Side scan sonar

An instrument that is towed behind a ship at shallow water depths to obtain information on sea-floor features. (see fig. on page 11)

Submersible

An underwater vehicle (manned or unmanned) equipped with instruments to collect samples and data of the sea-floor and water column. (see fig. on page 11)

Tonne

Equal to 0.984 tpm (1000 kgm)

United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS sets out the rules and regulations pertaining to the utilization of oceanic mineral resources and to the preservations of the marine environment.

Volcanoes

A vent or fissure on the earth's surface or sea-floor thorugh which lava comes out.

Amazing facts about the Oceans

FACTS

The amount of water contained by the oceans is around 326 million cubic miles (1.4 billion cubic km).

The five Oceans (biggest to smallest) are the Pacific, Atlantic, Indian, Southern (Antarctic), and the Arctic.

The Pacific Ocean is the biggest of the five oceans. It covers an area of more than 63 million sq.miles (163 million sq. km).

Sea is smaller than ocean. About 54 seas are recognised.

Salinity The saltiness (salinity) of the ocean is measured in parts per thousand (ppt). The average salinity is 35 ppt, which means 35 units of salt in every 1,000 units of water.

Temperature varies widely in the ocean. It ranges from 28°F (-2°C) in the Arctic and Southern oceans to 97°F (36°C), during the summer, in the Arabian Gulf.

Fastest Fish in the sea is the sailfish. (110kph or 70mph).

Biggest coral reef in the world is great barrier reef of Australia.

Diatoms are a kind of plankton. Their shells are used to make dynamite.

Killer whale 7 m (23 ft) long.

Penguins are good swimmers and can stay underwater for about 18 minutes.

Deepest diver Sperm whale-can reach depths of 9,800 ft (3,000m).

Tallest seaweed Giant kelp - nearly 197 ft (60 m) tall.

Biggest marine animal Blue whale - recorded length 102 ft (31 m), weight is 193 tons.

RECORDS

Highest recorded wave The greatest wave ever recorded was created by a massive landslide in an inlet in Alaska (July 9, 1958). The falling rock caused a wave to surge up the opposite side of the bay, which reached a height of 1,740 ft (530 m).

Deepest part of the ocean The Challenger Deep in the Mariana Trench, between Japan and Papua New Guinea, has a maximum recorded depth of 36,198 ft (11,033m).

Biggest tides The difference in height between high and low water in the Bay of Fundy, in Canada, is 53.5 ft (16m).

Highest submarine mountain The top of Mount Kea in the Pacific Ocean is 33,476 ft (10,203 m) above the seafloor. It is signficantly higher than Mount Everest, the tallest mountain on land, (29,037 ft or 8,850 m).

EXPLORATION:

1831-36 Charles Darwin travels on his famous voyage on board the *Beagle*, making observations (regarding wildlife) that led to the revolutionary theory of natural selection.

1872-76 The voyage of the *HMS Challenger*- the first comprehensive oceanographic research expedition.

1920 Echo sounding equipment first used.

Ocean Websites

www.noaa.gov/	www.jncc.gov.uk/mermaid/
www.ocean.udel.edu/deepsea/	www.mcsuk.org/
www.usborne-quicklinks.com	www.bbc.co.uk/nature/blueplanet/

Geological Time Scale / Ocean Highlights

Eon	Period	Million Years BP	Ocean Highlights
Cenozoic	Quaternary *(Pleistocene +Holocene)	1.6 million years to 10,000 Yr BP	**c. 2.5 million years ago** *Primitive human beings appear*
	Neogene	23	
	Paleogene	65	**65 million years ago** *Primitive whales swim in the oceans*
Mesozoic	Cretaceous	135	**100 million years ago** *The age of reptiles, dinosaurs on land, and ichthyosaurs and plesiosaurs in the ocean.*
	Jurassic	205	**200-180 million years ago** *Supercontinent Pangaea begins to break up*
	Triassic	250	
Paleozoic	Permian	290	
	Carboniferous	355	**300 million years ago** *The age of fish*
	Devonian	410	
	Silurian	438	
	Ordovician	410	
	Cambrian	570	**500 million years ago** *Life exists only in oceans*
Precambrian	Proterozoic	2500	
	Archean	4000 *million years*	**3,800 million years ago** *The condensation of atmospheric water causes the true oceans to form*
			4,600 billion years ago *Earth forms*

**Pleistocene period has highest record of glaciations*
BP = Before Present

EPILOGUE

Dear Friends,

Our country is gifted with vast oceans around us and the resources are indeed enormous! With the passage of time, we shall depend more and more on our oceans for food, energy and transportation.

Oceans have remained a mystery for long. However, with the advent of multi-disciplinary ocean sciences and technologies, our understanding of various interesting and amazing processes, which influence oceans, is improving.

Compiling wide ranging aspects of ocean in a lucid and illustrative form demands significant efforts, sincerity and dedication. Many colleagues have put in their ideas and this booklet is an outcome of their untiring efforts. My special thanks are due to Prof. K.V. Subbarao and the Geological Society of India.

Through this booklet, an attempt is made to stimulate younger generation and attract them to learn about oceans.

10th September 2003

Harsh Gupta
Secretary
Department of Ocean Development

Research Team

K.V. Subbarao
Indian Institute of Technology, Mumbai

R. Shankar
Mangalore University, Mangalore

Advisors

J.C. Mohanty
Governament of Andhra Pradesh, Hyderabad

M.P. Wakdikar
Department of Ocean Development, New Delhi

V. Sampath
National Institute of Ocean Technology, Chennai

G.S. Rautela

Umesh Kumar
Nehru Science Centre, Mumbai

R.Vaidyanadhan

M.S. Rao
Geological Society of India, Bangalore

Concept and Design

Priyadarshini Advertising Pvt. Ltd.
Hyderabad

Printing

Pragati Art Printers
Hyderabad

Acknowledgments

Our special thanks to children, in particular Saranya and Sailesh, for their uninhibited and frank criticism of earlier drafts of this booklet, which vastly improved both text and illustrations.

We owe a debt of gratitude to the reviewers who have given their valuable time and expertise; B.P.Radhakrishna, R.Vaidyanadhan, Harsh Gupta, J.C.Mohanty, C.V.R.K.Prasad, K.Sreenivasa Rao, Christine Walsh, M.S.Rao, R.K. Sharma & colleagues from DOD, G.S. Rautela and Umesh Kumar. M.P.Wakdikar ably co-ordinated from the Dept. of Ocean Development.

B.P.Radhakrishna is the moving spirit behind the project on popularization of science at all levels. Harsh Gupta initiated this programme and took keen interest in bringing out this booklet. R.Vaidyanadhan patiently read through several drafts and rendered invaluable help. V.Sampat and B.R.S.Subramanian provided valuable information. We are deeply grateful to all of them.

Grateful thanks are due to the authors and publishers of the following childrens' books and websites for stimulating information and illustrations on various aspects of oceans. We have liberally used some of the figures and text in a revised form to the benefit of the children; The Usborne Internet - linked first Encyclopedia of Seas & Oceans (EDC Publishing), Guide to the Oceans (D.K.Publishing, Inc), Rocks & Minerals (Readers' Digest Children's Publishing, Inc), Souvenir Guide - National Maritime Museum, A guide to the Royal Observatory Greenwich, The Story of the Earth, Geological Museum, This Dynamic Earth, The Story of Plate Tectonics (U.S.Dept of Interior).

The entire layout has been most efficiently and patiently handled by the young team at Priyadarshini Advertising Pvt. Ltd, who also co-ordinated the printing of the booklet through Pragati Art Printers. The Geological Society of India is grateful to the entire team.

The publication of the booklet is made possible through a special grant from the Department of Ocean Development.

Story of the Oceans

K.V.Subbarao and R.Shankar

Published by the Geological Society of India,
P.B. 1922, Gavipuram P.O., Bangalore-560 019

Pages : 36

Year : 2003

ISBN : 81-85867-60-7

Popular Science Series No.1

Geological Society of India and Department of Ocean Development