Marine geology

- Marine geology is a study of the character and history of that part of the Earth below the sea/ ocean.
- An area covers from from the beach, marine marshes and lagoons, across the continental shelf and down to the deepest part of the ocean.
- Philip Kuenen (1958) “No Geology without Marine Geology”. Most of the sedimentary rocks exposed on land were deposited in marine environments.

Course content

- Introduction
- Origin and development of an ocean
- Morphology and characteristic of an ocean
- Ocean circulation
- Ocean sediments
- Life in the ocean
- Paleoceanography
- Sea level changes
- Mineral resources

History of Marine Exploration

Pre-Challenger marine geology

1. Captain James Cooke

   3 expeditions to Pacific in 1770's

   a. navigation

   b. soundings

2. Sir John Ross (1810's) & Sir James Clark Ross (1830-1840's)

   a. first accurate deep (several hundred fathoms) soundings - at high latitudes (around Antarctica & the Arctic)

   b. collected sediment samples, deep-marine organisms

      i. similarity of Arctic & Antarctic deep-marine organisms showed continuity of deep ocean from pole to pole

3. Lt. Matthew Fontaine Maury (1842-1870's)

a. headed the Navy's U. S. Hydrographic Office

b. first submarine geologist

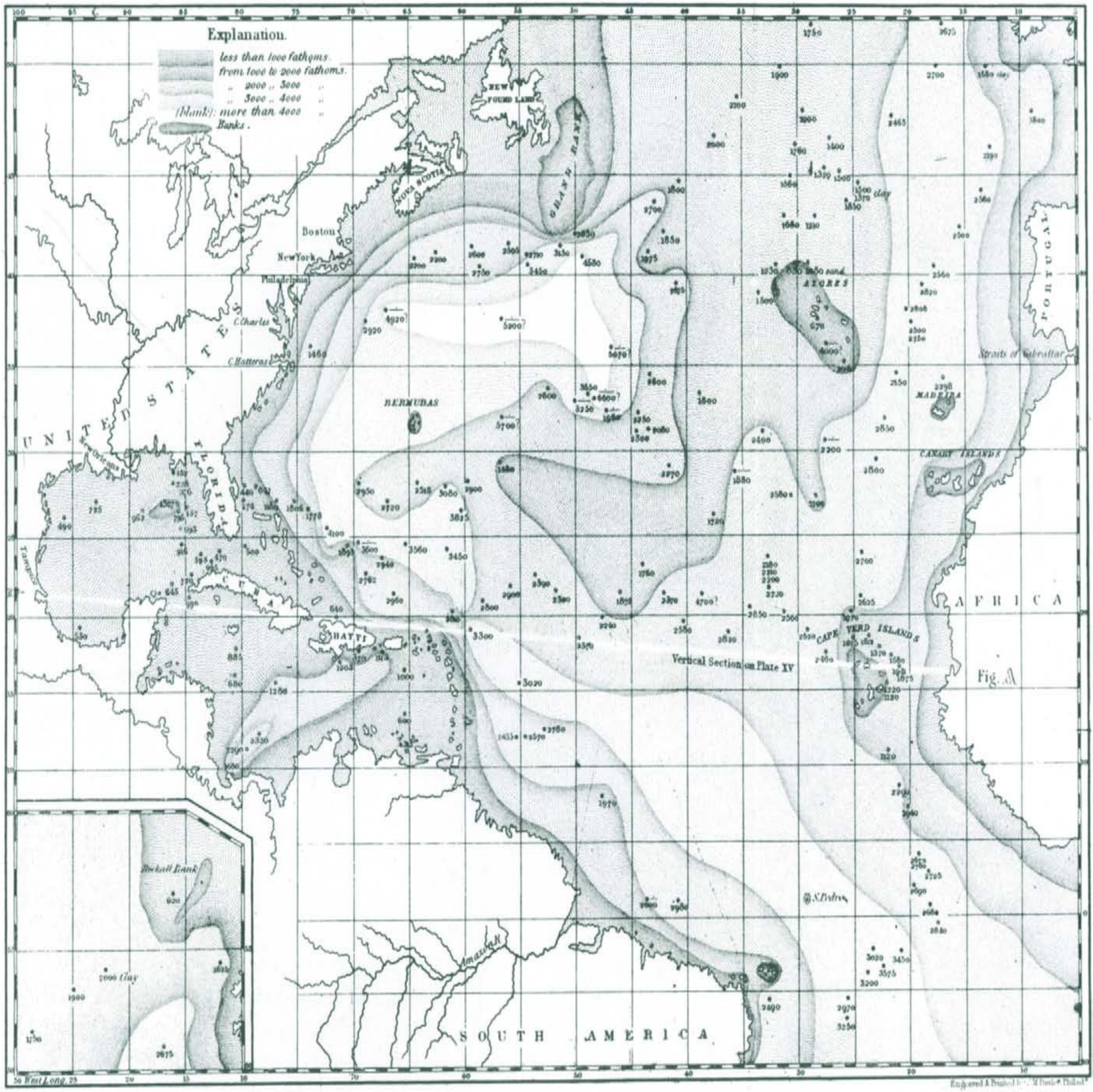
c. first deep-marine bathymetric map (of the North Atlantic)

i. recognized the Mid-Atlantic Ridge - called it Telegraph Plateau

ii. continuation of first serious extensive sounding associated with laying of telegraph cable linking North America & Europe

d. compiled Pilot Charts

- Map of north Atlantic bathimetry by
- Matthew Maury 1855



HMS Challenger Expedition (1872-1876)

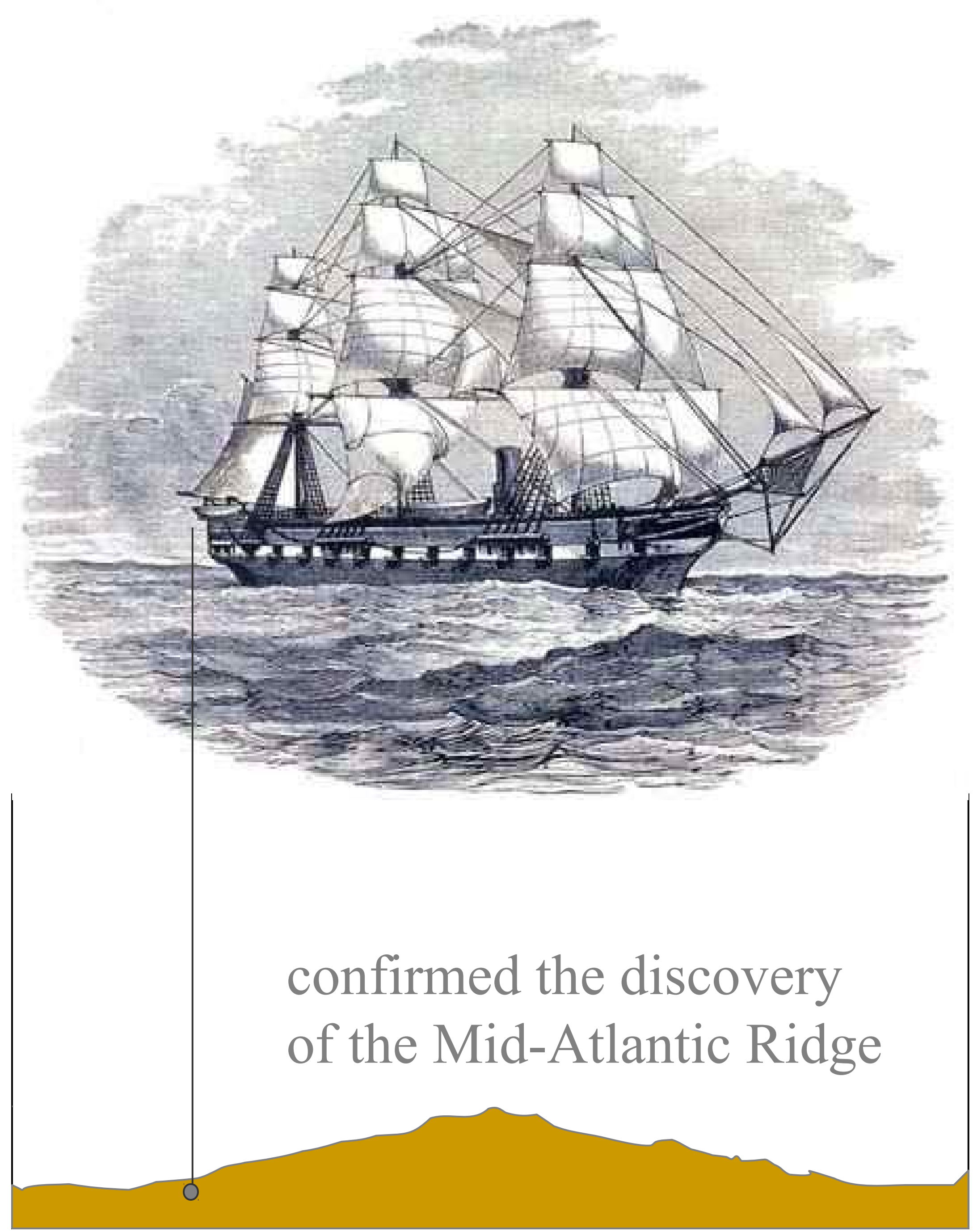
A. Charles Wyville Thomson, professor at University of Edinburgh, convinced the Royal Society of London to sponsor a global survey of the deep ocean & headed the cruise

B. Circumnavigated globe

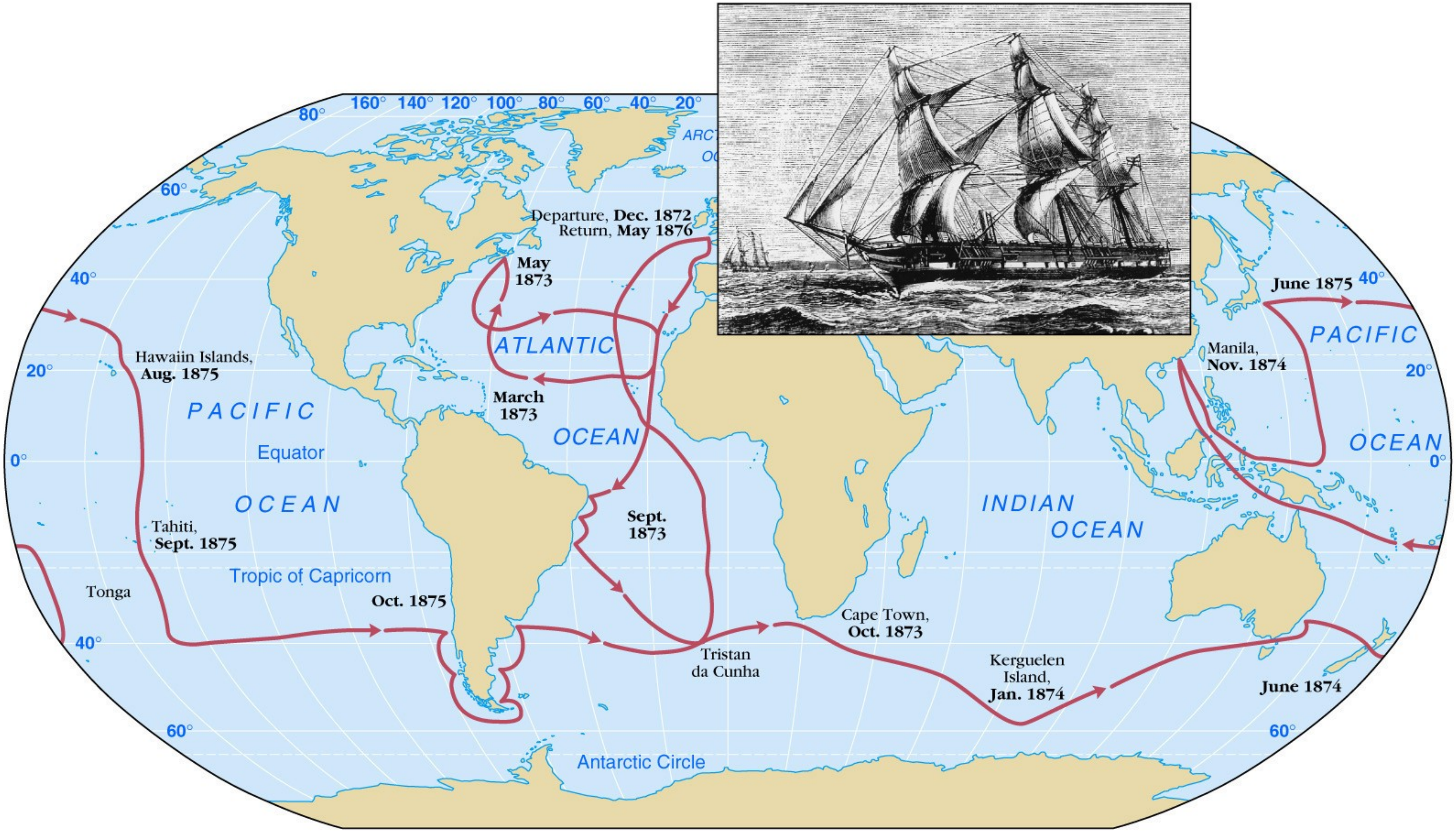
1. 362 stations
    a. made nearly 500 deep soundings
    b. dredged & cored rocks & sediments
    c. collected water samples
    d. measured water temperature, salinity, currents

HMS *Challenger* (1872-1876)

- made the first systematic attempt to chart the basins of the world ocean
- made 492 bottom soundings



Challenger Expedition



2. took 23 years to process & publish data

    a. Sir John <u>Murray</u> took responsibility for publication of the Challenger reports (50 volumes)

3. resulted in better understanding of:

    a. depths

    b. sediments

        i. distribution

        ii. some processes

        iii. pelagic vs. hemipelagic

A. Voyage of HMS <u>Challenger</u> (1872-1876) taken as beginning of modern marine geology.

Post-Challenger (1870's-1900)

1. Biologically oriented expedition

2. Other large national expeditions similar to Challenger

a. United State.

i. U. S. S. Albatross (1882) Alexander Agassiz - privately funded - sailed around east & west coasts of the U. S. & the eastern Pacific & Caribbean - investigation of coral reefs - biology & geology

ii. U. S. S. Blake (1883) John Pillsbury - current measurements in the Straits of Florida

b. Russia

i. Vitiaz (1886-1889) North Pacific

c. Germany

i. <u>Gazelle</u>, <u>National</u>, <u>Valdivia</u>, <u>Planet</u>, <u>Deutschland</u> (1874-1889) mostly in the Atlantic

d. Monaco

i. Prince Albert was very interested in deep sea exploration

ii. Outfitted several yachts for oceanographic research from 1884-1922

iii. Produced a series of deep sea bathymetric maps - used until after WWII for Atlantic & Pacific & until 1964 for the Indian Ocean

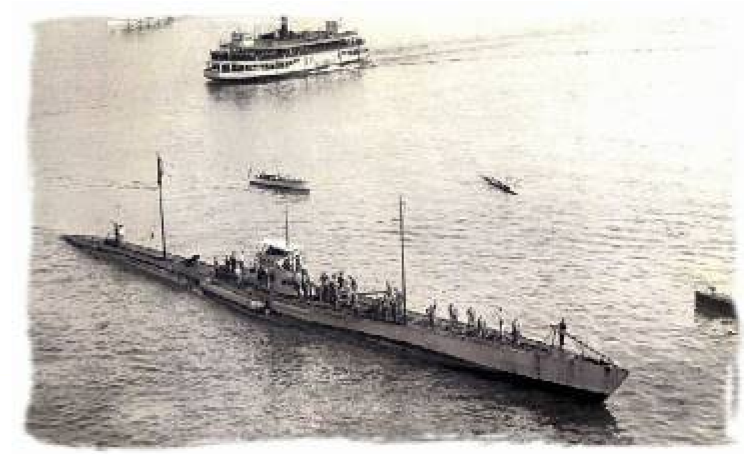
iv. Jacques Cousteau & the <u>Calypso</u> are associated with the still active Monaco oceangraphic tradition

- **e. Scandinavians**
- i. Fridjof Nansen sailed the <u>Fram</u> (a specially designed double hulled ship) to the Arctic, froze it into the ice, & drifted from 1893-1896, making meteorological & current measurements

- . U. S. Coast & Geodetic Survey used electronic echo sounding to map the shelf & uppermost slope off the U.S.during the 1930's
- mapped the heads of submarine canyons & opened up study of these interesting & important features
- The German ship <u>Meteor</u> first use the continuous recording echo sounder in the South Atlantic (1925-1927)
- further documented continuity of the Mid-Ocean Ridge in the Atlantic
- <u>Meteor</u> expedition also collected several 1-m cores in the South Atlantic & Indian Ocean that were studied by Wolfgang Schott

During **World War I** (1914-1918)

- used to detect enemy **submarines**



http://www.eastlanddisaster.org/uc97.jpg

<u>*Meteor* expedition (1925-1927)</u>

- used to study the seabed

http://oceanworld.tamu.edu/resources/ocng_textbook/chapter02/Images/Fig2-2s.jpg

Big boost to marine geology & geophysics 1948

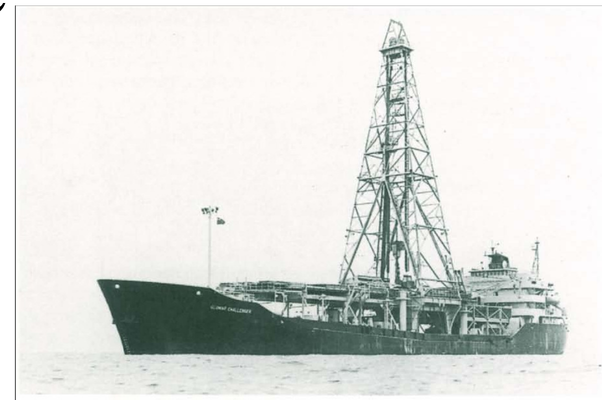
1. Founding of Lamont-Doherty Geological Observatory (LDGO) by Maurice Ewing in 1948 played large role in marine geology & geophysics led to discovery theory of Plate Tectonics
2. Increased funding for & interest in study of ocean bottom, particularly by the Navy
3. Development of Precision Depth Recorder (PDR)
4. Development of Piston Corer
5. Development of Marine Geophysical Techniques

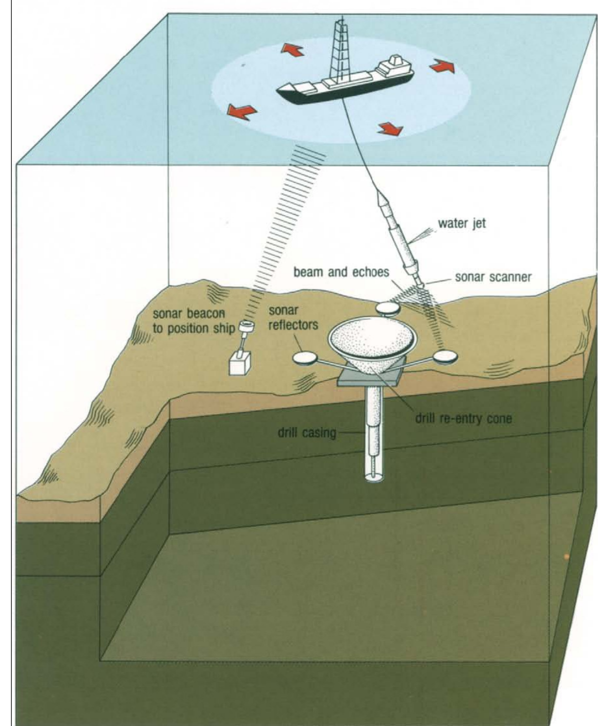
- German South Polar expedition (1901-1903) collected several 2-m cores that were studied by E. Philippi in 1910
- Other team of explorations
- Snellius (1929-1930)- Dutch
- Discovery (1930's) - British

- Swedish Deep Sea Expedition (1947-48) - Albatross
- Dutch Deep-Sea Expedition (1950-52) - Galathea
- The most important development was the formation of Joint Oceanographic Institutes for Deep Earth Sampling (JOIDES) in the 1960's-1980's
- Drilling vessel - Glomar Challenger drilled 624 sites during 96 legs
  - confirmed the validity of seafloor spreading & plate tectonics
  - great boost to paleoceanographic studies, petrology, tectonics.
  - continued with Ocean Drilling Program (ODP) in 1985.

Deepsea Drilling Project

- The Deep Sea Drilling Project (DSDP) was begun in the 1960s using the *Glomar Challenger* a ship that was specially equipped for drilling into the ocean floor beneath several kilometres of seawater.
- Many countries were taking part in this project mainly USA, UK, Japan, German, Russia, Australia, France, Canada and many other countries.

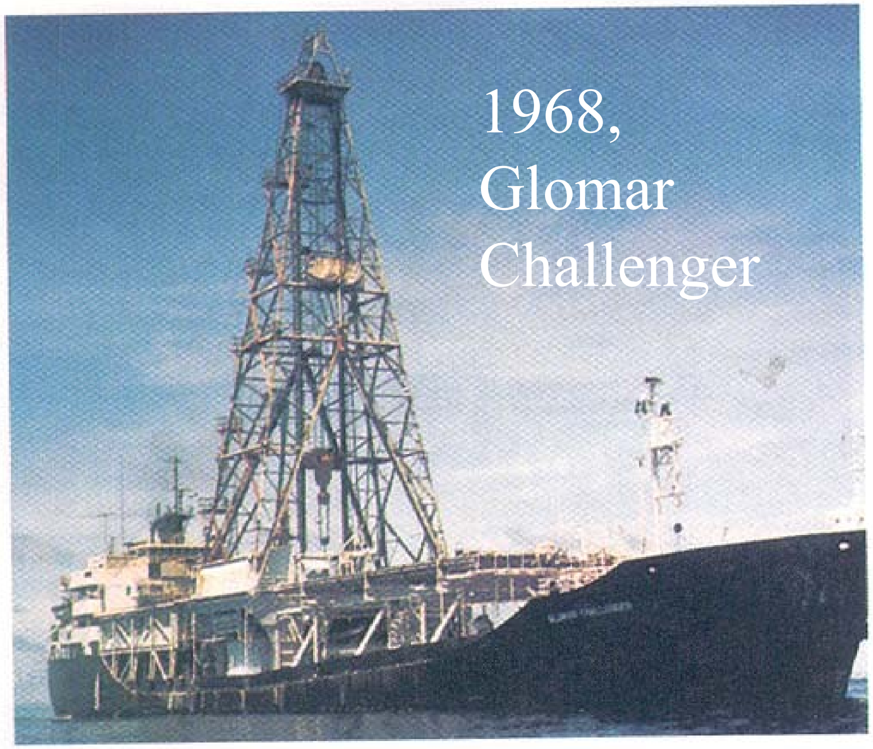




Ocean Drilling Project

- The *Glomar Challenger* was succeeded by a similar but better-equipped vessel, the *JOIDES Resolution,* which began operations in the international Ocean Drilling Program (ODP) since 1985.
- Ocean Drilling Vessel JOIDES *Resolution*.

- This scientific drilling ship is equippped to drill 5 miles below the ocean surface.
- To date, it has drilled over 500 wells worldwide.



(a)

(b)

Figure 1-18 **Deep-Sea Drilling Ships**

(a) The *Glomar Challenger* could produce 8800 continuous or 10,000 intermittent hp for propulsion and for operating drilling equipment. To remain over the drill site, the ship used dynamic positioning that could move the vessel in any direction. *(Photo courtesy of Victor S. Soleto, Deep Sea Drilling Project)*
(b) *JOIDES Resolution*, replaced the *Glomar Challenger* as the new drilling ship for the Ocean Drilling Program. *(Photo courtesy of the Ocean Drilling Program)*

Birth of Ocean Science- 19th Century

- Charles Darwin on the Beagle (1831-1836)
- Challenger Expedition (1872-1876)
  - Public interest in ocean life, geology
  - Depth measurements, water analyses, water movement, sampling of organisms and sea floor
  - Challenger Reports (50 volumes over 20 years)

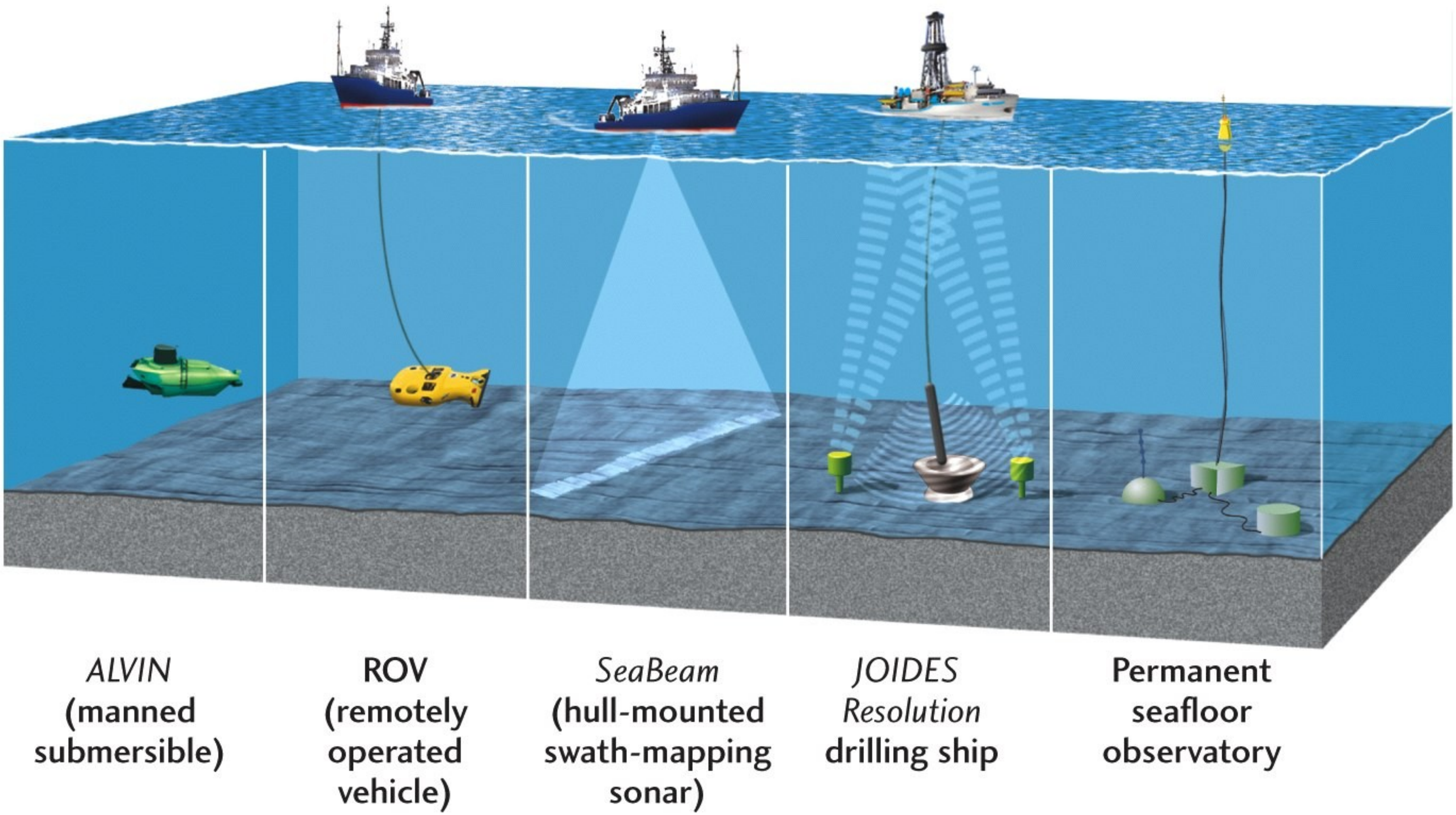
20th Century Oceanography

Better Technology: radar, sonar, echo sounding

Academic research facilities supported by government.

- Institutes such as:
  - Scripps, Woods Hole, Lamont-Doherty, others
- Ocean Drilling Project (continues)
- Satellites:
  - –precise positioning (GPS),
  - –measure ocean surface properties

Mapping of sea-floor



Discovery in the deep

- **1872-76**
  British ship Challenger sails the globe while lowering dredges and other gear into the deep, finding long mountain chains, puzzling nodules, and hundreds of animals previously unknown to science.
- **1920**
  Alexander Behm sails the North Sea and bounces sound waves off its bottom, advancing a new method of depth measurement known as echo sounding.

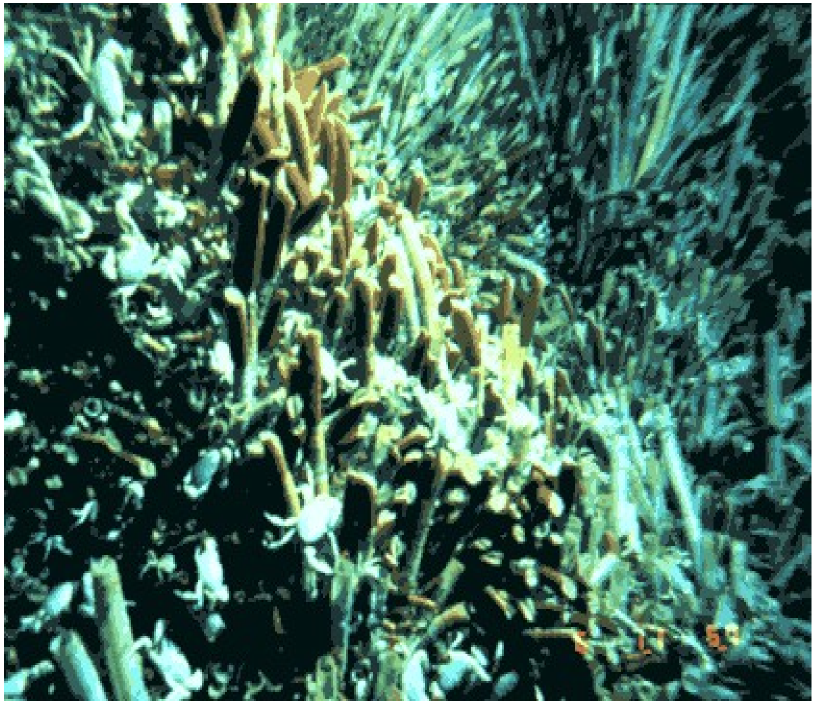
- **1951**
  British ship Challenger II bounces sound off the bottom, and near Guam finds what appears to be the sea's deepest area, its lowest point nearly seven miles down, subsequently named the Challenger Deep.
- **1952**
  Marie Tharp, studying echo soundings, discovers the Mid-Atlantic Ridge
- **1960**
  Jacques Piccard and Don Walsh dive in Trieste to bottom of Challenger Deep, seven miles down.

- **1961** Robert Dietz, studying echo soundings, proposes that the seabed's mountainous rifts are invisible scars where molten rock from the Earth's interior wells up periodically and spreads laterally to form new ocean crust, a process he calls seafloor spreading.
- **1967**
  Geologists, after fierce debate, agree that seafloor spreading involves a dozen or so huge plates that form the Earth's crust and move slowly over time, rearranging the land.
- 1974

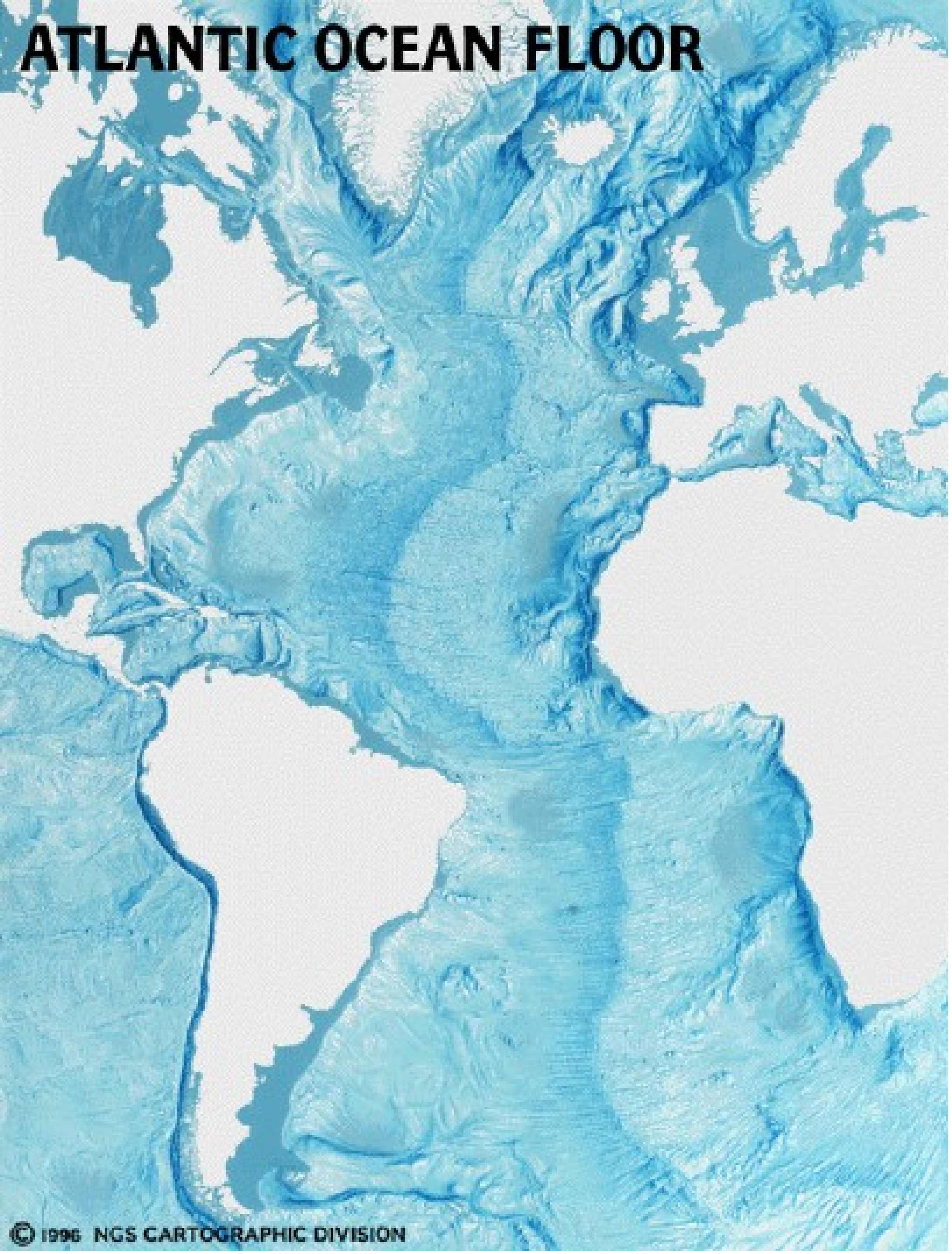
  French-American team dives to Mid-Atlantic Ridge and unexpectedly finds its rift valley paved with lava.

- **1977**
  American team dives in Alvin to a volcanic rift in the Pacific and discovers warm springs teeming with undescribed species of life, an ecosystem new to science that includes tubeworms, snakelike creatures standing upright in long tubes.
- **1980**
  Scientists propose that the seabed's hot springs are the birthplace of all life on Earth
- **1982**
  Volcanic seamounts in Pacific are found to be covered with rare metals, including cobalt
- **1992**
  Scientists, after a large seabed survey, conclude that the deep may hold ten million species of life, far more than are known on land.

Living organisms near the sea bed hot spring.



- **1995** American Navy releases seafloor gravity data, which civilian oceanographers turn into the first good public map of the global seabed.

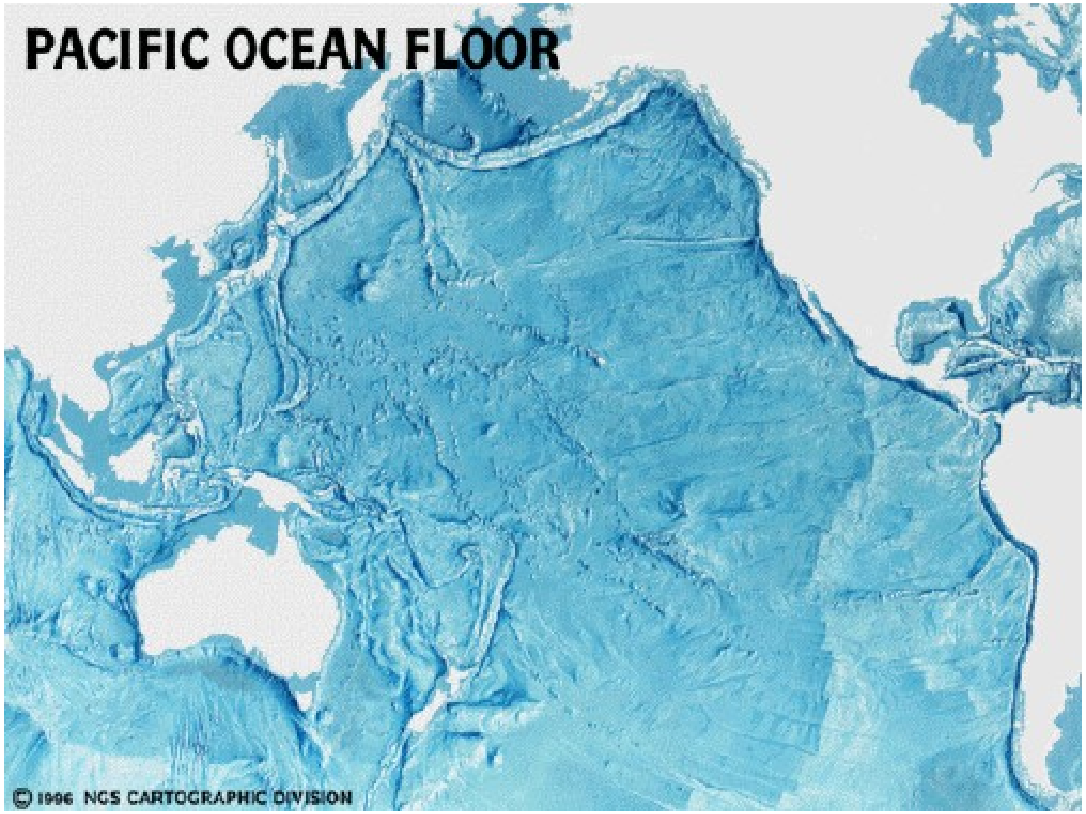


Symmetrical— continental margin/abyssal plains/MOR/ abyssal plains/continental margin

Formed by spreading of Americas away from Europe and Africa

Relatively few trenches and island arcs (Caribbean)

Marginal seas (Gulf of Mexico)

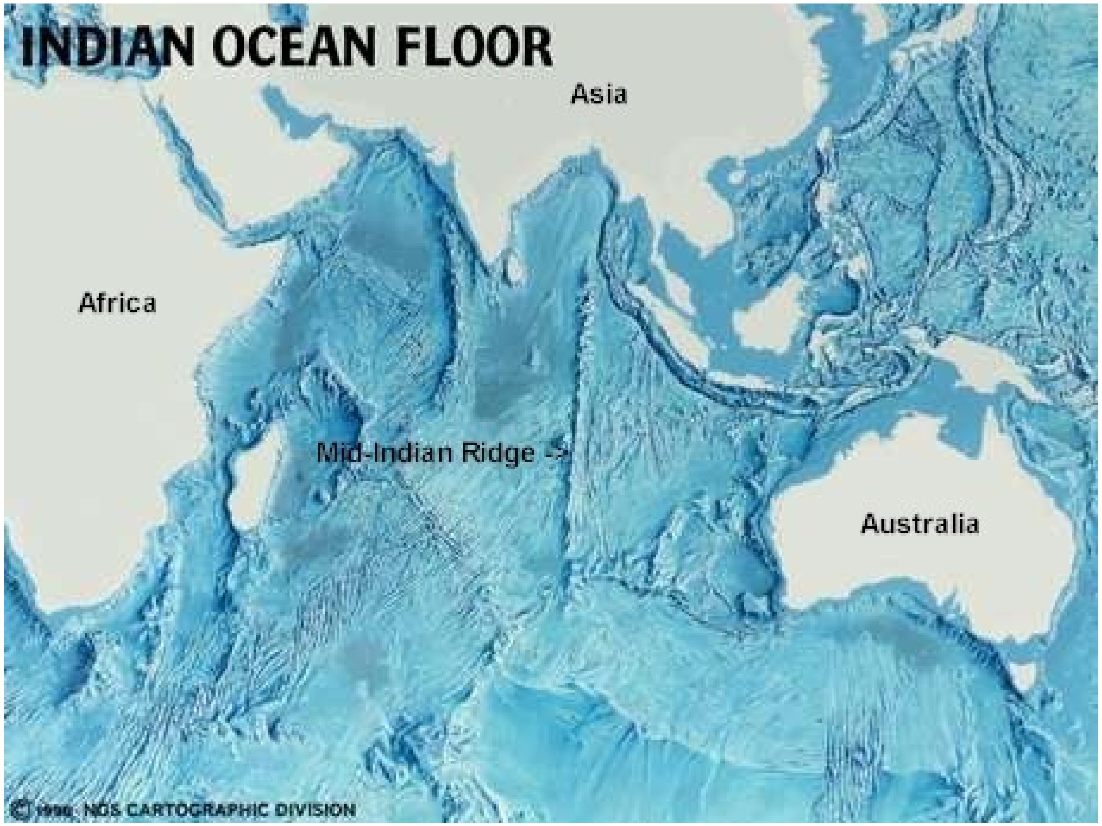


Largest and oldest ocean basin (but younger than continents)

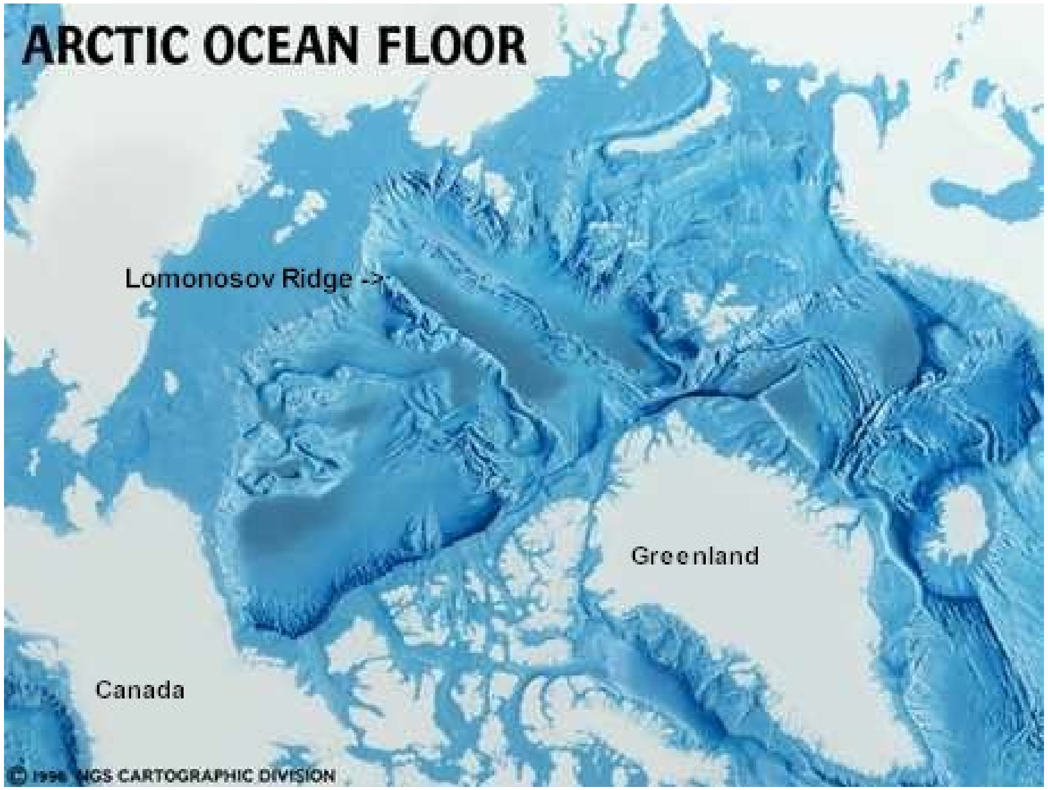
Asymmetrical—East Pacific Rise and Pacific-Antarctic Ridge

“Ring of Fire”—trenches, island arcs, and volcanic mountain ranges, such as Andes

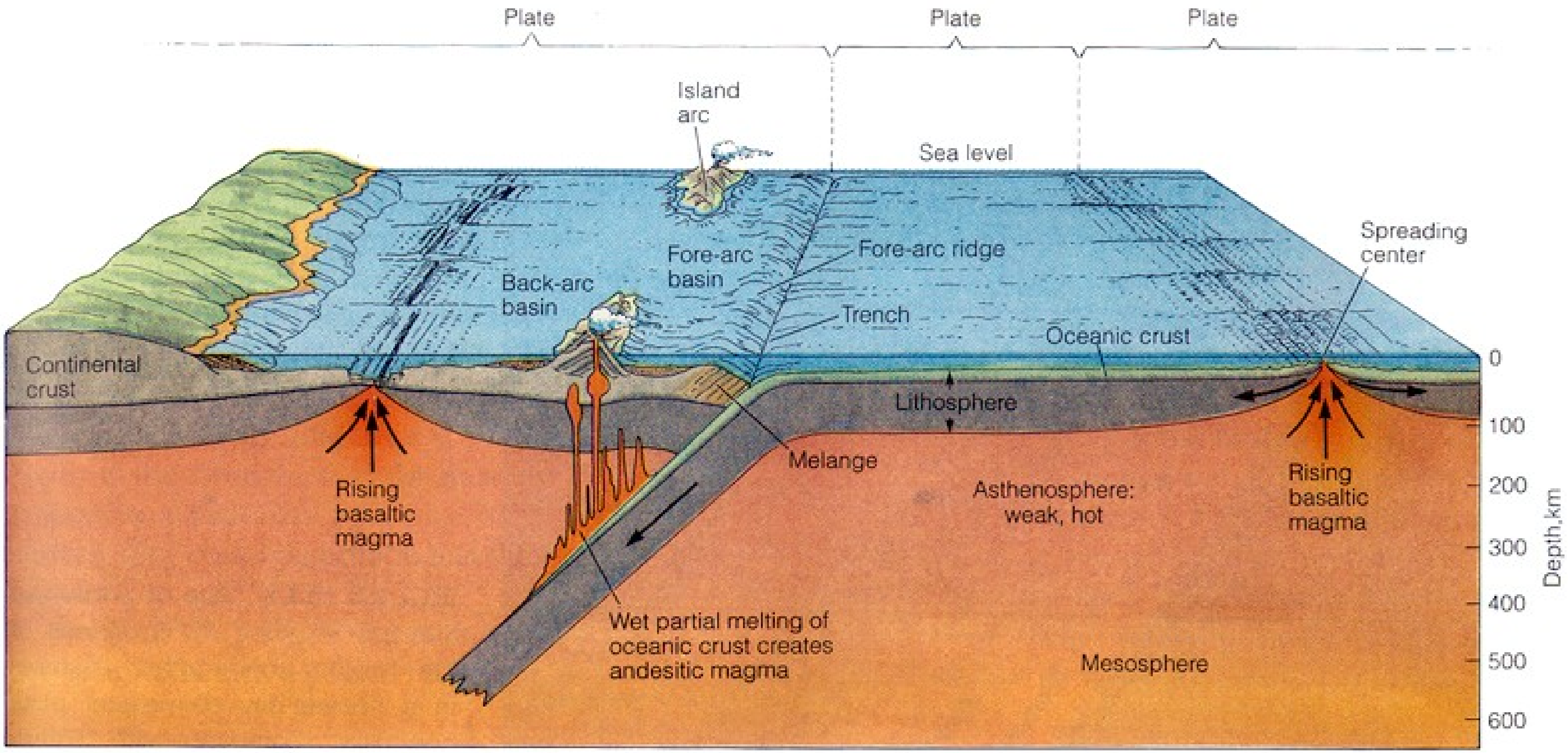
Many sea mounts and guyots



Similar to Atlantic, created by a “triple junction”
Mostly in southern hemisphere; Antarctic, African, Australian, Indian, and Asia plate movements
Java and other trench-island arc systems



- Smallest of the ocean basins
- Almost entirely land-locked except for its connection with the North Atlantic
- Very wide continental shelves
- Lomonosov Ridge divides the North American (Canadian) Basin from the Eurasian (Nansen)



<u>Components:</u>

- Oceanic plate
- Trench
- Fore-arc ridge (melange)
- Fore-arc basin, Island arc
  Back-arc basin (down-going plate melts / accom. of spreading)
- Oceanic Plate

Skinner and Porter, 2000

The importance of Marine Geology

- Marine geology involves geophysical, geochemical, sedimentological and peleontological investigations of the ocean floor and coastal margins.
- Marine geology has strong ties to physical oceanography and plate tectonic
- Marine geological studies were of extreme importance in providing the critical evidence for sea floor spreading and plate tectonics
- The deep ocean floor is the last essentially unexplored frontier and detailed mapping in support of both military (submarine) objectives and economic objectives drives the research.

- Marine geology provides very much information about the topography/ bathymetry, geological processes, and the history of the ocean.

Objective of study

- The main objective of the project work are:
- Understanding fundamentals of echo sounding, side scan sonar, high resolution seismic reflection techniques employed to study seabed and sub-seabed features of near offshore region
- Understanding fundamentals of Ground Penetrating Radar (GPR) technique employed to study sub surface onshore coastal features adjacent to near shore region
- Learning details of acquisition of bathymetry, sonography of the sea bed and seismic reflection data onboard survey boat.
- Learning procedure for processing the acquired raw data using standard software and interpretation of processed data.
- Synthesising details of the data acquisition , processing and interpretation.

ECHO SOUNDING METHOD

INTRODUCTION

- Echo sounding is a geophysical technique of finding depth of water by transmitting sound pulses into water. The time interval between emission and return of a pulse is recorded, which is used to determine the depth of water considering speed of sound in water.
- Lead line and sounding pole were the earliest methods used for directly measuring water depth.
- The Echo-sounding technique was developed by Professor Fassenden in 1914 and has been used in hydrographic surveying since then.
- Single Beam Echo Sounders (SBES) still remain the traditional equipment used on hydrographic surveys worldwide, however Multi Beam Echo Sounders (MBES) and Airborne Laser Sounding (ALS) systems now provide almost total seafloor coverage and depth measurement.

SOUND PROPAGATION IN SEA WATER

- The speed of sound C, is a function of temperature (T), pressure (P) and salinity (S). Following equation shows the dependence of sound speed on these factors:

$$C(T,P,S)=1449.2 + 4.6\,T + 0.055\,T^2 + 1.39(S-35) + 0.016\,D$$

Where, *C is in m/sec, T in ° Celsius, D (Depth) in metres and S in parts per thousand.*

- Sound propagation is in the form of attenuation, reflection and refraction.

ACOUSTIC PARAMETERS

- The characteristics of an echo sounder are determined by the acoustic parameters namely:

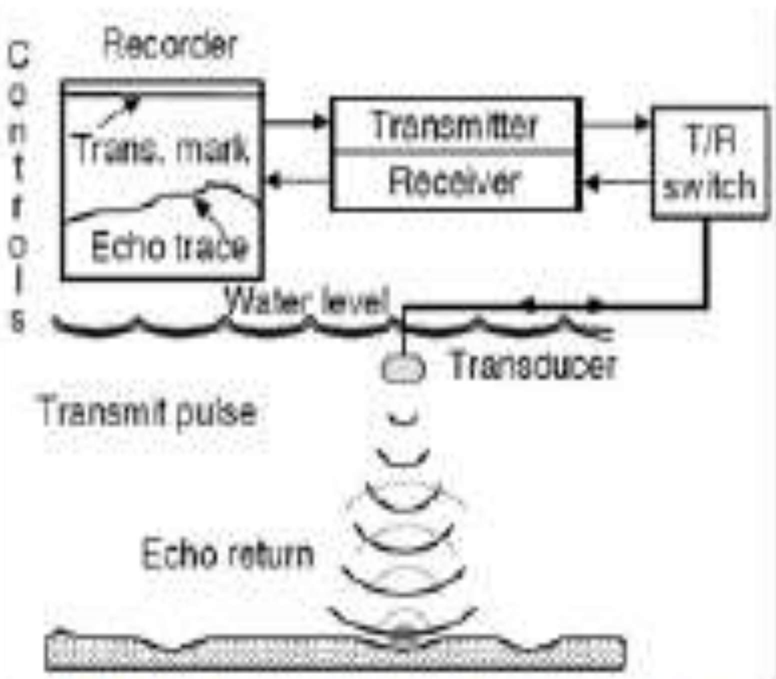
1. Frequency
2. Band width
3. Pulse length

- The transducers are one of the echo sounders' components; it is transducer characteristics which dictate some of the operating features of an echo sounder. The transducers are the devices used for transmission and reception of the acoustic pulses.

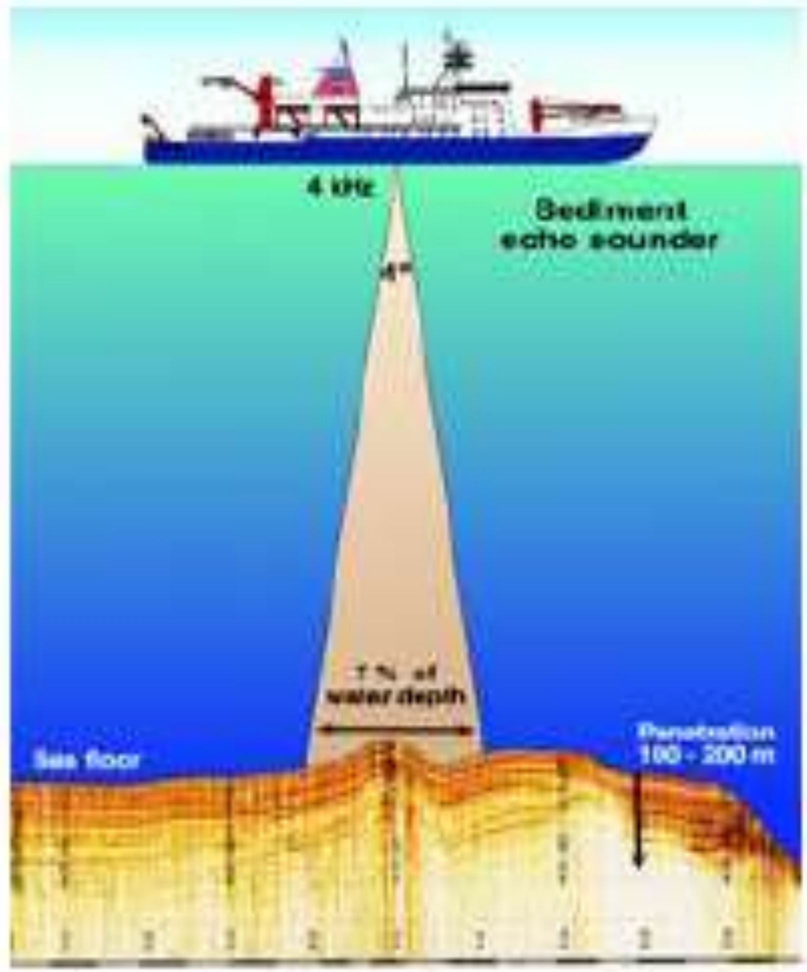
- Transducers are classified with regard to their operating principle, i.e. magnetostrictive, piezoelectric, and electrostrictive.

SINGLE BEAM ECHO SOUNDER

- These echo sounders are devices for depth determination by measuring the time interval between the emission of a sonic or ultrasonic pulse and the return of its echo from the seabed .
- An echo sounder works by converting electrical energy, from the pulse generator, into acoustic energy. As the transducers do not transmit in all directions, the acoustic energy is projected into the water in the form of a vertically oriented beam.
- The acoustic pulse travels through the water column and hits the seabed. The interaction with the seafloor results in reflection, transmission and scattering.
- The reflected energy which returns to the transducer, the echo, is sensed by the transducer.

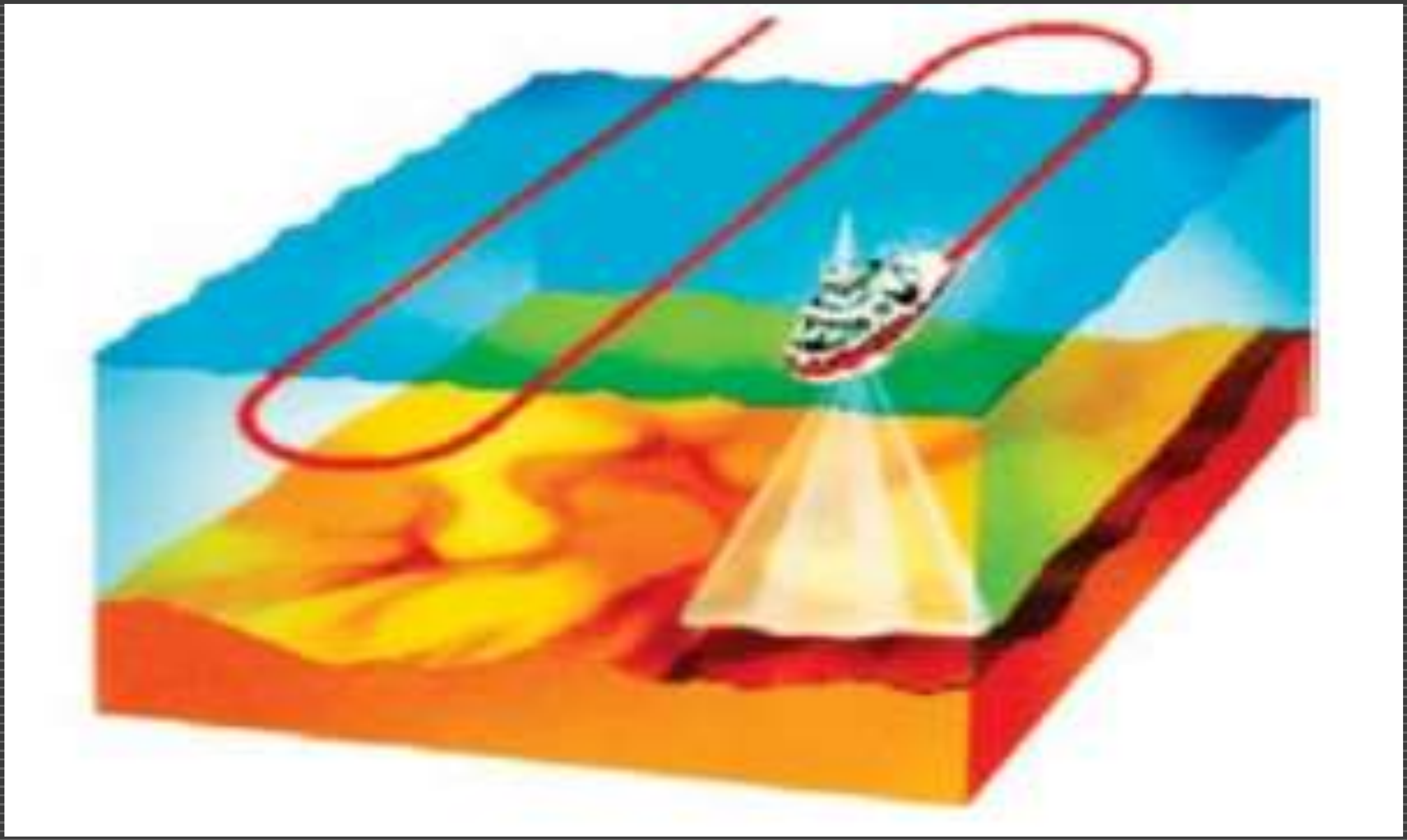


Pictorial view of a basic echo-sounder



MULTI BEAM ECHO SOUNDERS

- Multi Beam Echo Sounders (MBES) are a valuable tool for depth determination when full seafloor coverage is required. These systems may allow complete seafloor ensonification with the consequent increase in resolution and detection capability.
- Principle of operation of multi beam echo sounder is, in general, based on a fan shaped transmission pulse directed towards the seafloor and, after the reflection of the acoustic energy by the seabed; several beams are electronically formed, using signal processing techniques, with known beam angles.
- The intersections of those beams in the seafloor plan are the footprints (ensonified areas) for which the depths are measured.
- Multi beam systems with their capability of full seafloor ensonification contribute to a better seafloor representation and, when compared to SBES, to higher mapping resolution.
- However, as far as the depth measurements are concerned, resolution will depend on the acoustic frequency, transmit and receive beam widths and on the algorithm used to perform seabed detection .

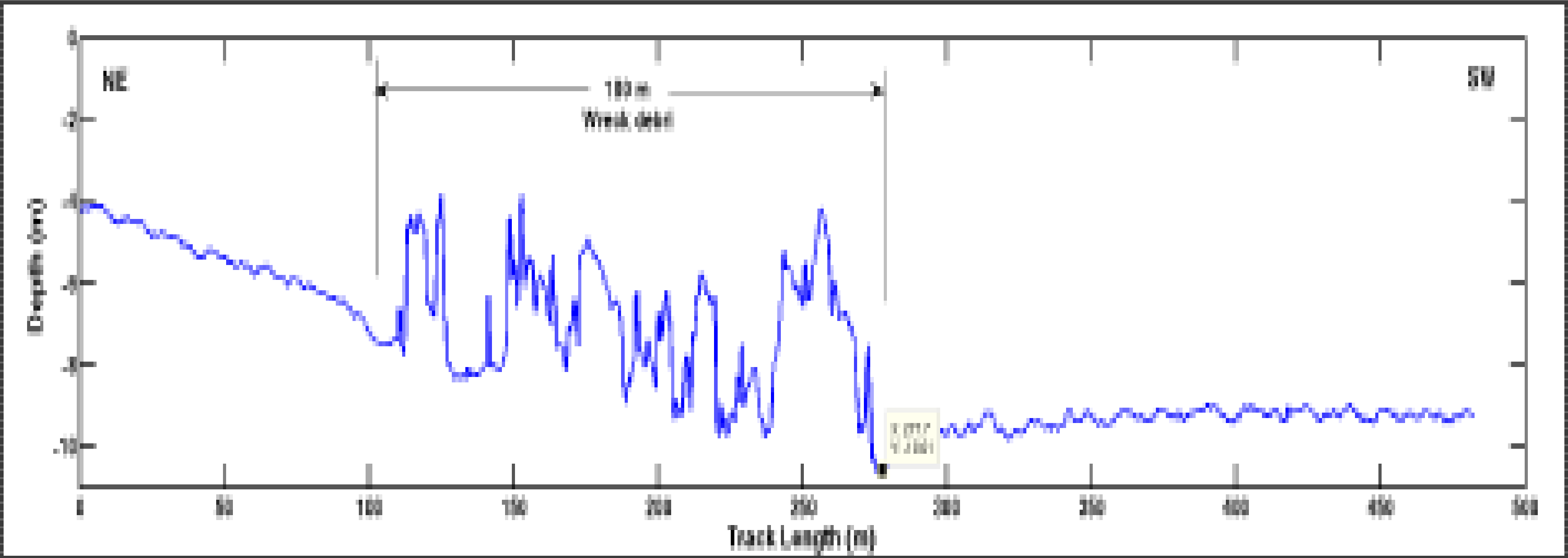


MULTI BEAM ECHO SOUNDER

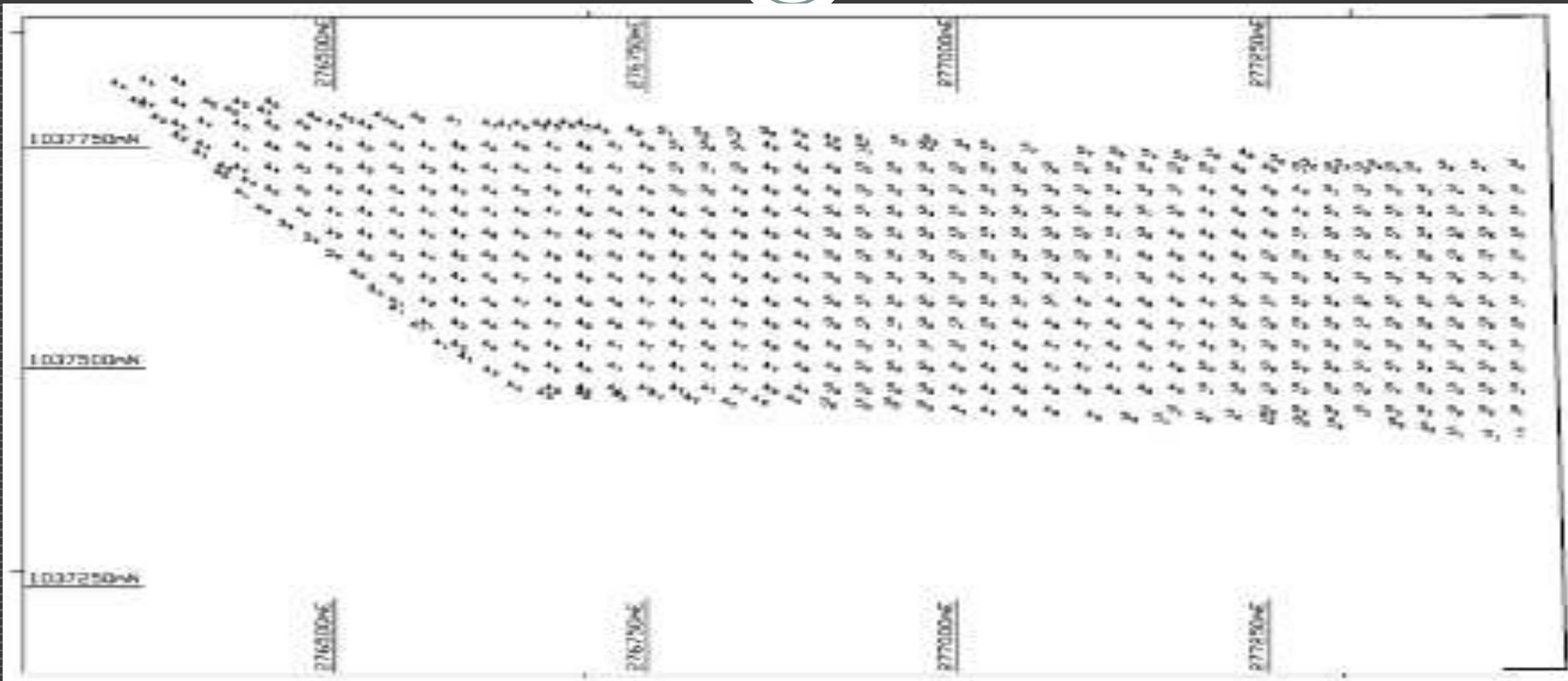
PROCESSING AND PRESENTATION OF DATA

- Acquired echo sounding data are required to be corrected for ship's motion, navigation, sound velocity, and tidal variations.
- In practice at most four processing steps, which are summarized below, are needed for the majority of acquired echo sounding data:
- Application of appropriate sound velocity profile
- Application of corrected tides
- Editing of spurious depth data
- Generation of gridded database
- The echo sounding data normally are presented in the form of:

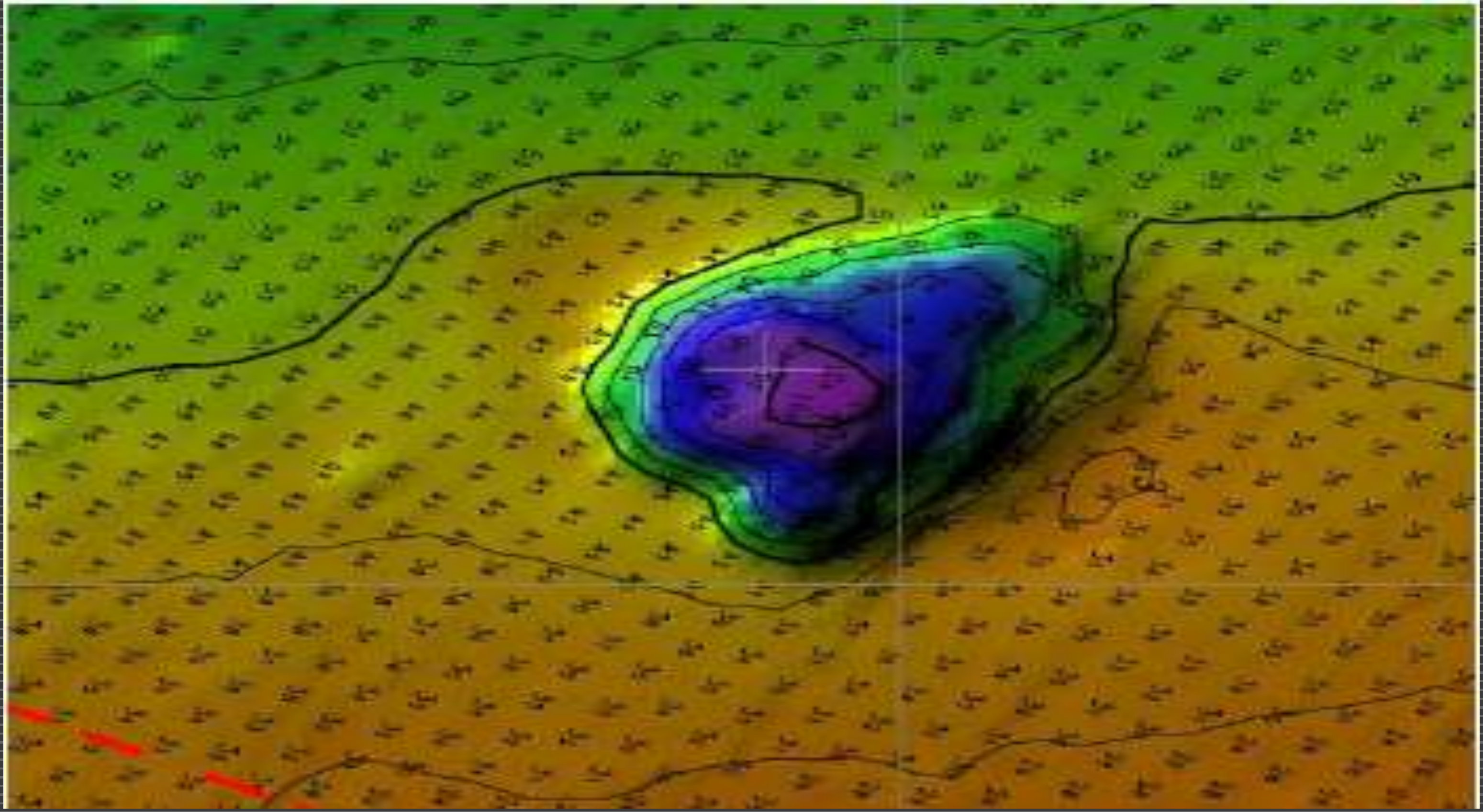
1. bathymetric profiles
2. bathymetric contour map (both 2D & 3D) and,
3. gridded bathymetry map.



Echo sounding profile off Candolim coast, Goa showing locally uneven seabed topography which corresponds to wreck debris of a grounded ship "MV River Princess" (after Chaubey et al., 2012).



Presentation of gridded bathymetry of a survey area showing water depth (m) at grid corner. Subscript of annotated number indicates depth in decimal meter (For example, 47 implies 4.7 m).



Presentation of gridded bathymetry (m), water depth contour (m) and colour coded bathymetry of a survey.

SIDE SCAN SONAR METHOD

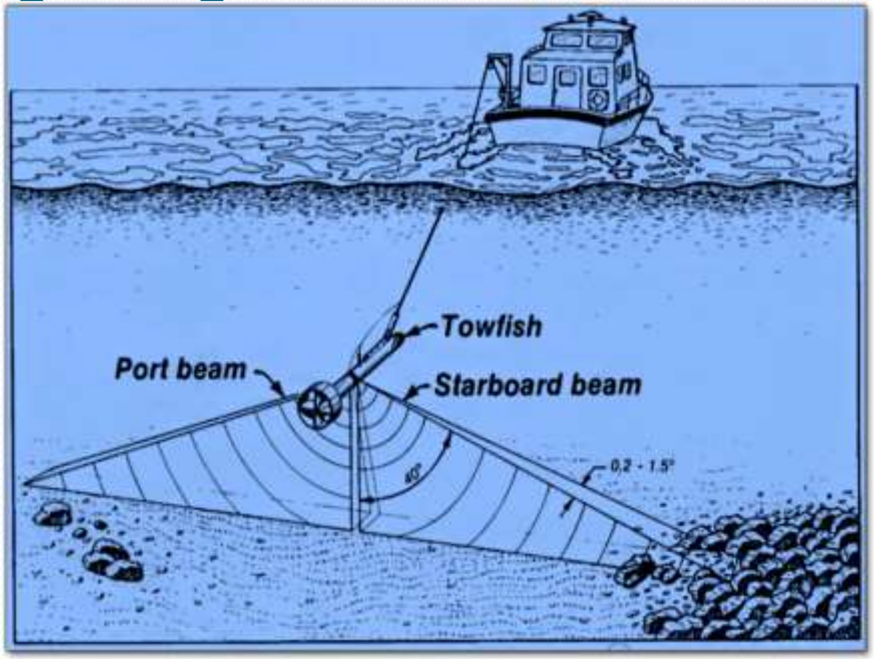
Introduction to Side Scan Sonar

- It is a high resolution seismic tool that provides coverage to both sides of a survey vessel's track.
- Side scan sonar was developed during World War II at the British National Institute of Oceanography, to detect submerged enemy submarines.
- It is an acoustical instrument that is normally towed behind a vessel and emits acoustical signals to both sides.

Side scan sonar towfish

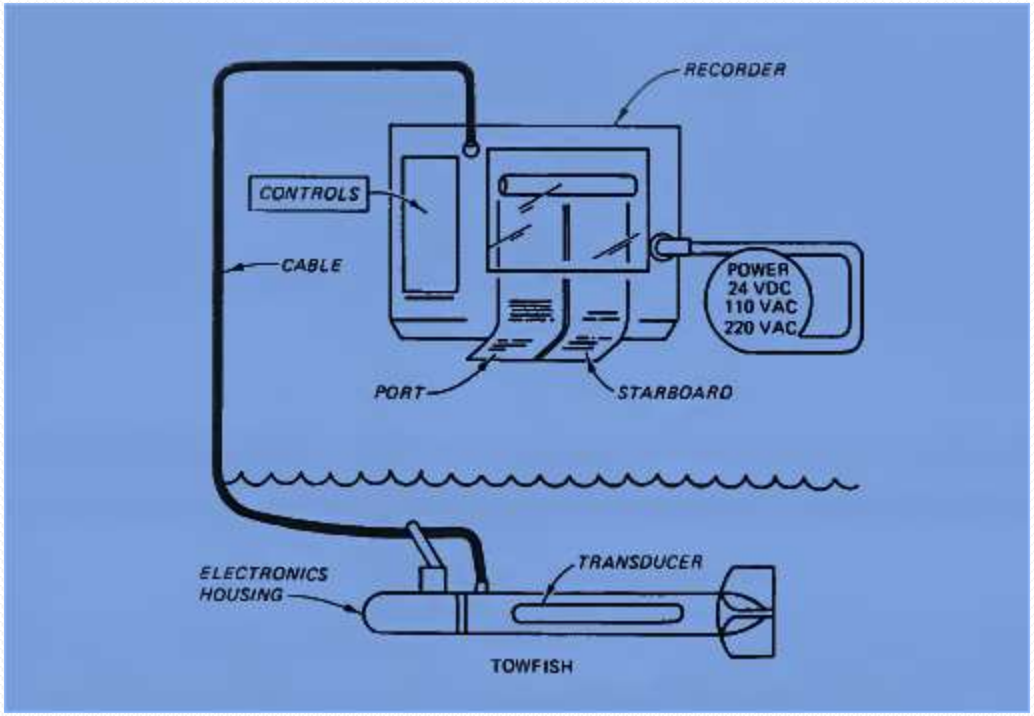
Working of Side

- In side-scan sonar systems, acoustical energy is projected laterally from a pair of transducers mounted in a towed cylindrical body or "towfish.“
- Electrical energy, supplied through the electromechanical tow cable, is applied to the piezoelectric transducers in the towfish.
- Side-scan sonar transducers typically vibrate at preselected frequencies from 50 kHz to 1 MHz.

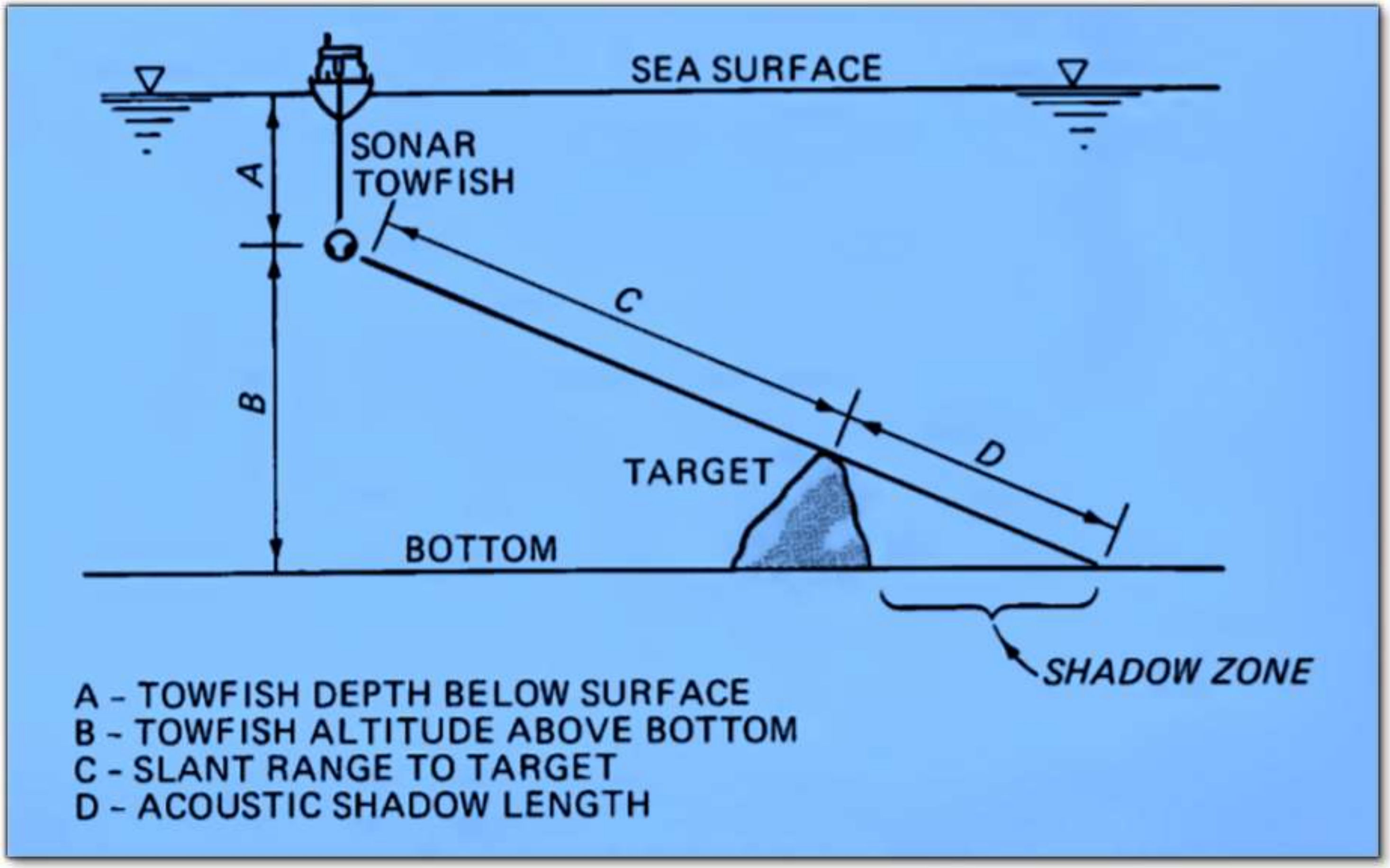


Side Scan Sonar in operation

Typical Side Scan Sonar Components

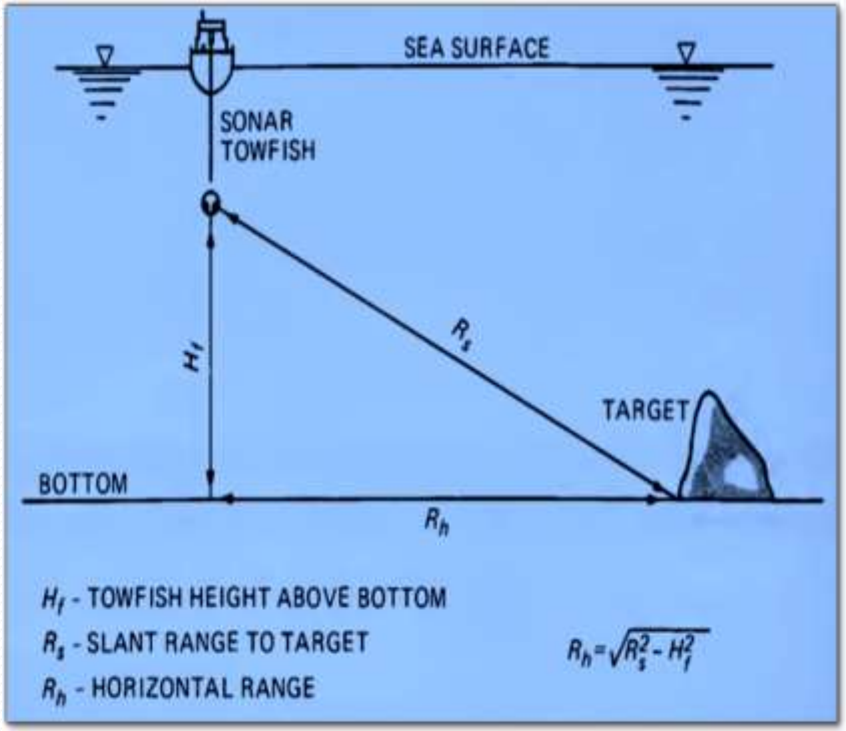


Side Scan Sonar Geometry



Cont..

- The distance of a target perpendicular to the line of travel can be calculated once the height of the towfish above the bottom is known (as shown in the figure) by simple trigonometry.



Calculation of slant range

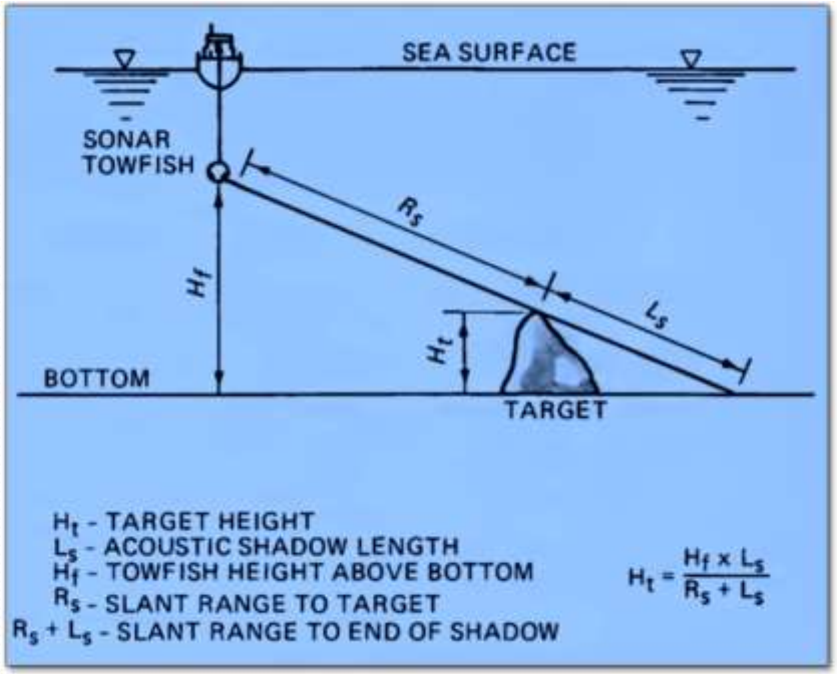
Cont..

- The height of a target can be calculated using similar triangles

$$\frac{H_t}{L_s} = \frac{H_f}{R_s + L_s}$$

which can be written as:

$$H_t = \frac{H_f \times L_s}{R_s + L_s}$$



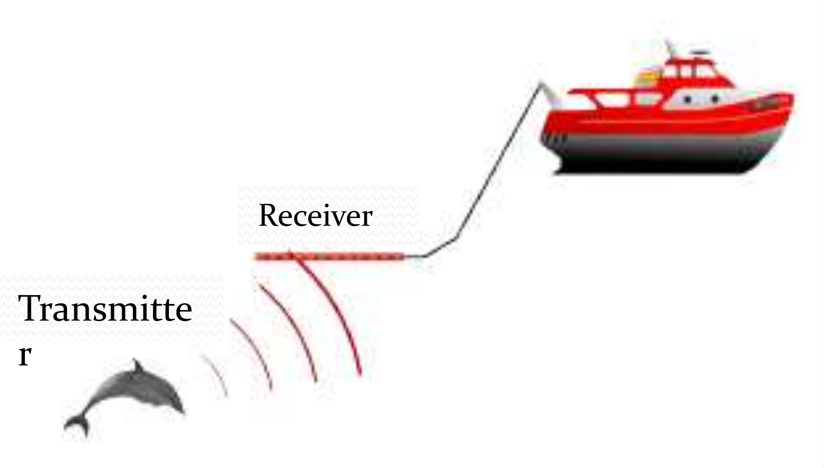
Calculation of target height

Principles of Side

There are two different operational modes for sonar:

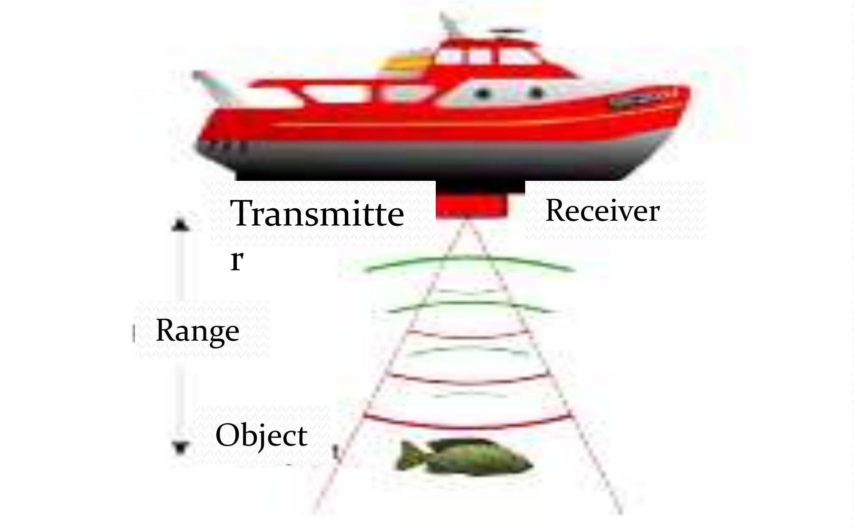
1) Passive sonar:

Where an acoustic noise source is radiated by the target, and the sonar only receives the acoustic signals



2) Active sonar:

Where the sonar itself transmits an acoustic signal, which again propagates to a reflector (or target), which again reflects the signal back to the sonar receiver

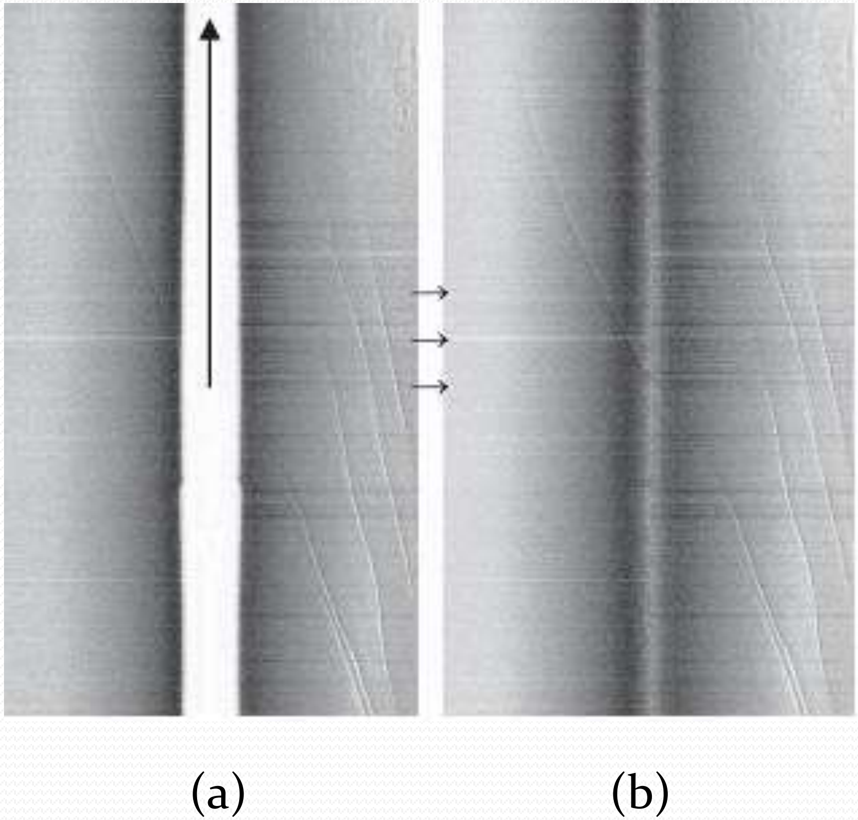


Processing of SSS Data

- The side scan sonar record is also known as a 'sonogram'. The sonogram is of varying shades with each shade a function of the intensity of the returning acoustical pulse. The stronger the returning pulse the darker the image.
- Sonogram often shows striking variations in brightness, caused by changing altitude of the towfish, making the images difficult to read. Hence processing of the SSS data is very important before they can be interpreted.
- It involves a number of steps including corrections for environmental and instrument noise and geometrical projections.
- In the present study, processing of the raw SSS data was carried out using SonarWiz5 software at the CSIR-National Institute of Oceanography, Goa.

Cont..

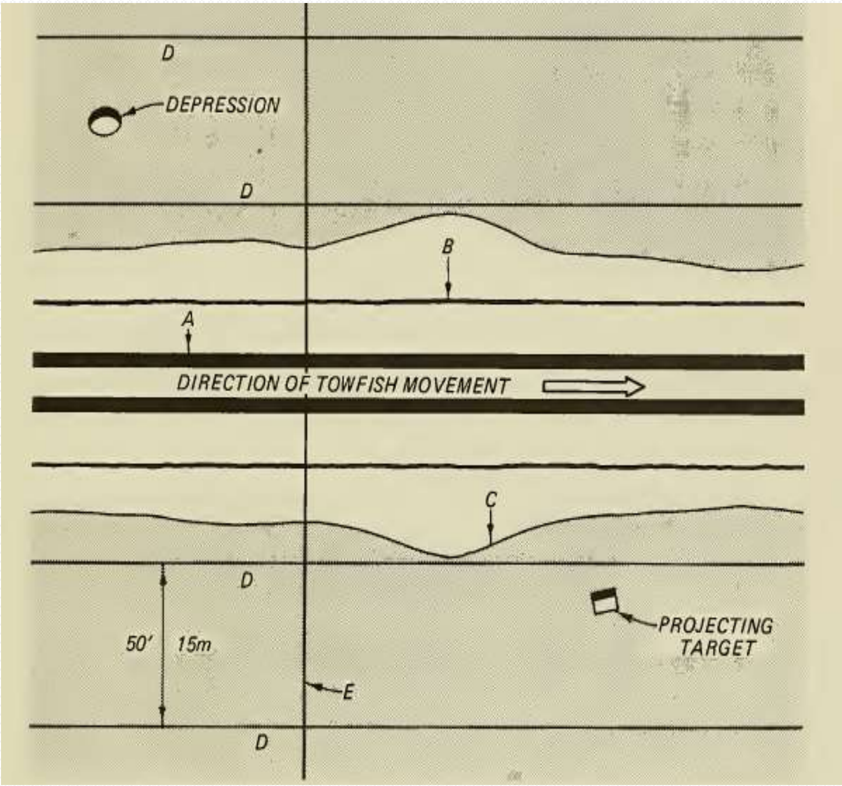
- Geometric Correction- Bottom Tracking, slant range correction, layback (cable out), offsets (DGPS)
- Signal processing- Applying gain to SSS data in order to present the best possible image (image enhancement).



Sonogram (a) pre- and (b) post-bottom tracking.

Interpretation of Side Scan Sonar Images

- Two dark parallel lines, representing the initial acoustical pulse, run just right and left of the center of the sonogram.
- The surface return (line B) is often the next line closest to the center line (line A).
- Line C, the initial bottom return, is recognizable as the start of the darker tone. Total water depth can be calculated by adding the distances on the sonogram of the output pulse to the surface (A to B) and the output pulse to the bottom (A to C).
- The dark line perpendicular to the line of travel (line E) is an event mark created for later reference.



Interpretation of a side scan sonar record.

Factors Affecting Interpretation of Sonar Images

- A number of factors affect the intensity of the returning signal, which includes: Acoustic reflectivity of the target, Slope of the target face, Contrast between the target and surrounding material, and the number of reflecting surfaces.

- **Target material and orientation influences**
- Acoustic Reflectivity is a function of the acoustic impedance of the material.

  Acoustic impedance = $\rho \times c$

  where ρ = material density

  c = speed of sound through the material
- The coarser the sediment, the higher the reflectivity.
- Therefore, gravel reflects more acoustic energy than sand, which reflects more than silt or clay.

Cont..

- **Vessel speed effects**

- Distortion parallel to the trackline of the towfish occurs due to varying boat speeds.

- Distortions perpendicular to the line of travel is a function of the height of the fish and the distance of the object from the fish and oscillations in these positions.

Limitations of Side Scan Sonar

- Wave effects:

  Periods for successful survey is limited to seasons of low wave energy i.e summer months.

- Current conditions:

  Major problem occurs when the current is perpendicular to the path of survey vessel.

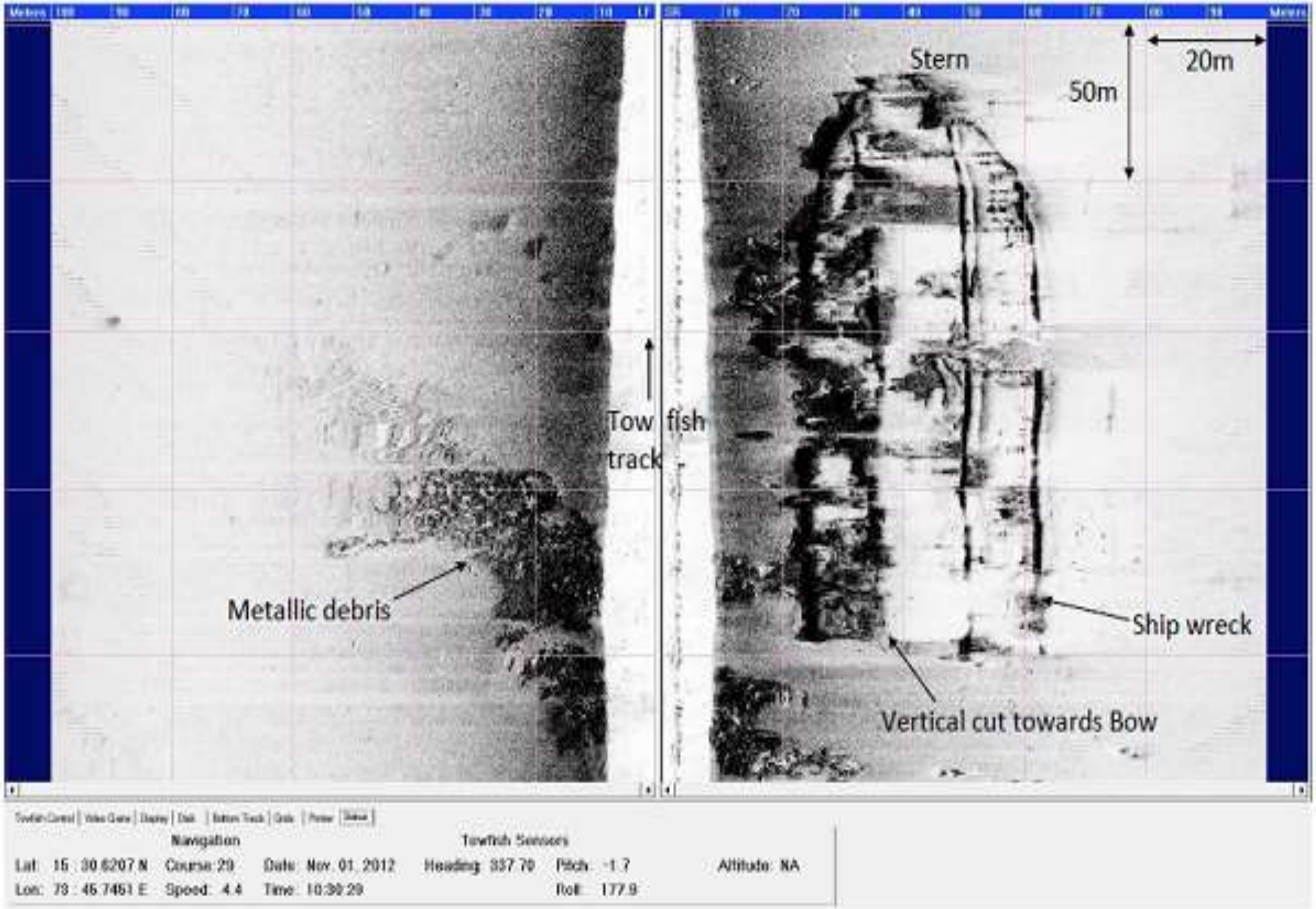
- Other site limitations:

  Maintaining constant speed and towfish elevation required for good results.

  Presence of other vessels can make it difficult to keep the vessel on track.

Engineering Application

- Side-scan sonar is a potentially useful tool for the reconnaissance and inspection for coastal structures.
- Side-scan sonar has been used for a variety of coastal engineering related applications. It is used to find out objects lying on the seafloor before starting construction of any offshore structures such as offshore platform, jetty, single point mooring, intake and outfall pipe line laying etc.
- It is proved to be an effective monitoring tool for monitoring disposal sites of dredged material at near shore and offshore sites. As the nearshore and offshore open-water disposal of dredged material becomes increasingly popular, the need to monitor these disposal sites will become more important.
- Pre and post-dredging sediment distribution mapping.
- Pipeline and cable route surveys.
- Site surveys for drilling rigs, bridges etc.
- Mapping seamounts, ocean ridges and other major tectonic features.



Sonogram showing underwater wreck debris of "**MV River Princess**" which grounded off Candolim coast, Goa during June 2000 (after Chaubey et al., 2012). It was detected during side scan sonar survey operation.

HIGH RESOLUTION SHALLOW SEISMIC REFLECTION METHOD

GENERAL BACKGROUND

Marine seismic reflection method is the most important geophysical methods employed in the offshore environment to obtain a comprehensive picture of the sea-floor morphology and underlying shallow stratigraphy.

TYPICAL APPLICATIONS

1. Mineral exploration

2. Foundation studies

3.Harbour development

4. Cable/pipeline surveys

5. It is also widely used to identify and characterize near-surface tectonic deformation in areas concerned with earthquake hazards.

ENGINEERING APPLICATION

High resolution seismic reflection surveying is the most widely used geophysical technique, since around 1980

THIS METHOD IS EXTENSIVELY USED TO CARRY OUT :

1. Foundation studies for offshore platforms
2. Harbour development
3. Cable/pipeline rooting
4. Seabed surveys for bridges
5. Mapping of lateral continuity of lithologic units
6. To obtain Water table
7. To locate Fracture.

HIGH RESOLUTION SHALLOW SEISMIC REFLECTION TECHNIQUE

* Seismic reflection method involves the measurement of the two-way travel time of seismic waves transmitted from sea-surface and reflected back to the surface from the interfaces between contrasting sub-surface layers.

* The reflected signal is detected on sea surface using an array of hydrophones.

THE FOUR BASIC COMPONENTS IN ANY SEISMIC REFLECTION SYSTEM ARE

1. A sound source that emits acoustic impulses or pressure waves.

2. An energy source to store energy for the sound source.

3.A hydrophone receiver that converts the reflected acoustic signals
to electrical signals.

4. A display unit that makes a permanent record of the reflected signals.

BASIC PRINCIPLE

The seismic method mainly uses sound waves, which are longitudinal or compressive waves (also called P-waves), in which motion direction of particles in the medium is parallel to the propagation direction of the wave.

In marine seismic work we are concerned primarily with pressure waves (P-wave) and the propagation velocity of such a wave is given by:

$$Vp = \sqrt{\frac{k + \frac{4}{3}\mu}{\rho}}$$

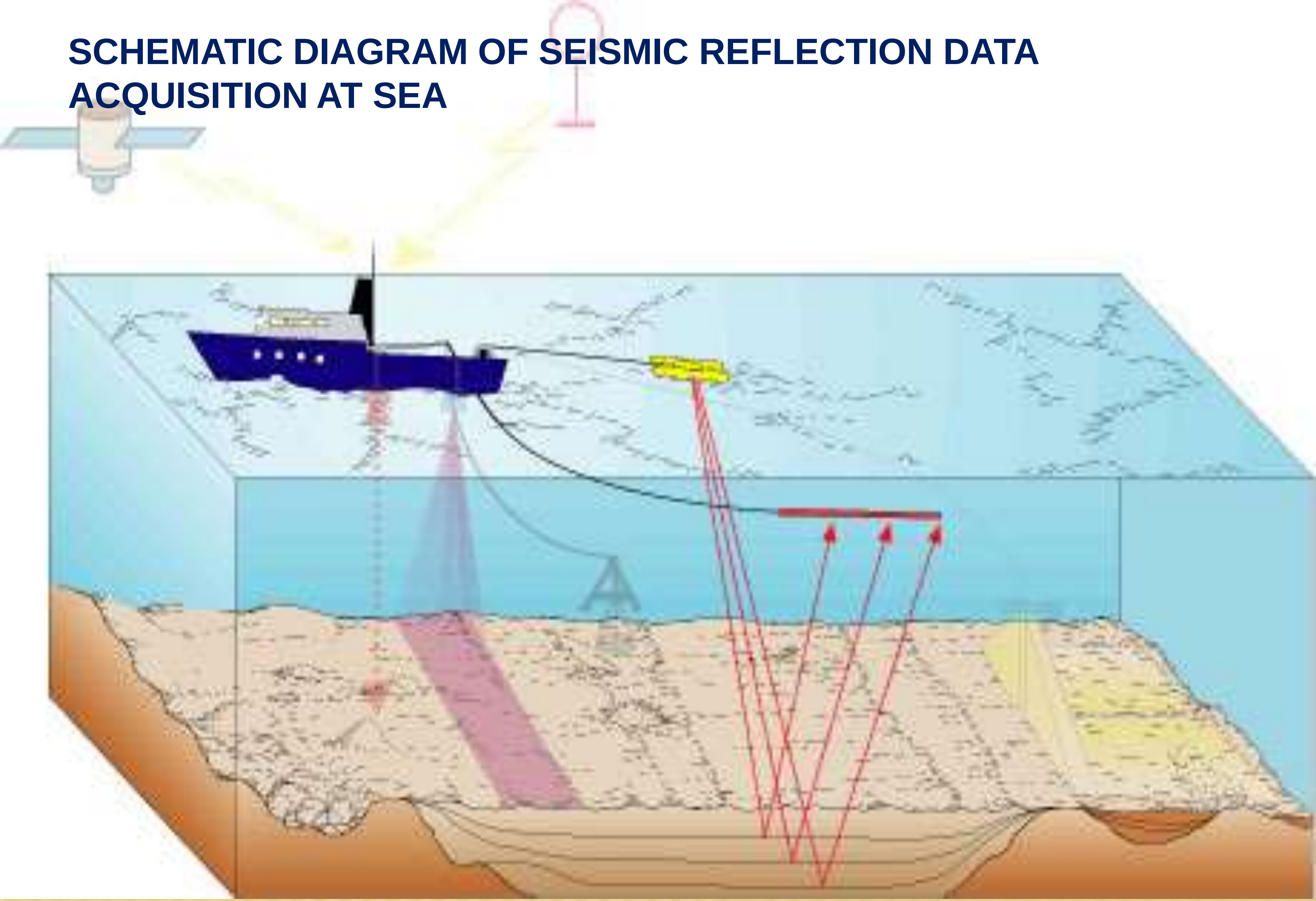
Where *Vp is velocity of P wave in the medium*

k is the bulk modulus.

μ is the shear modulus.

ρ is the density of the medium.

SCHEMATIC DIAGRAM OF SEISMIC REFLECTION DATA ACQUISITION AT SEA



SUB- BOTTOM PROFILER

The selection of an acoustic source is often based upon the requirements for resolution and depth of penetration.

However, equally important considerations are the cost, size, ease of operation, maintenance and availability of the energy source and acoustic source.

The acoustic source requires some form of primary energy (electrical), which is developed by the system onboard the survey platform (small boat or ship) and each employs a device in the water that converts stored energy to an acoustic pulse.

BOOMER

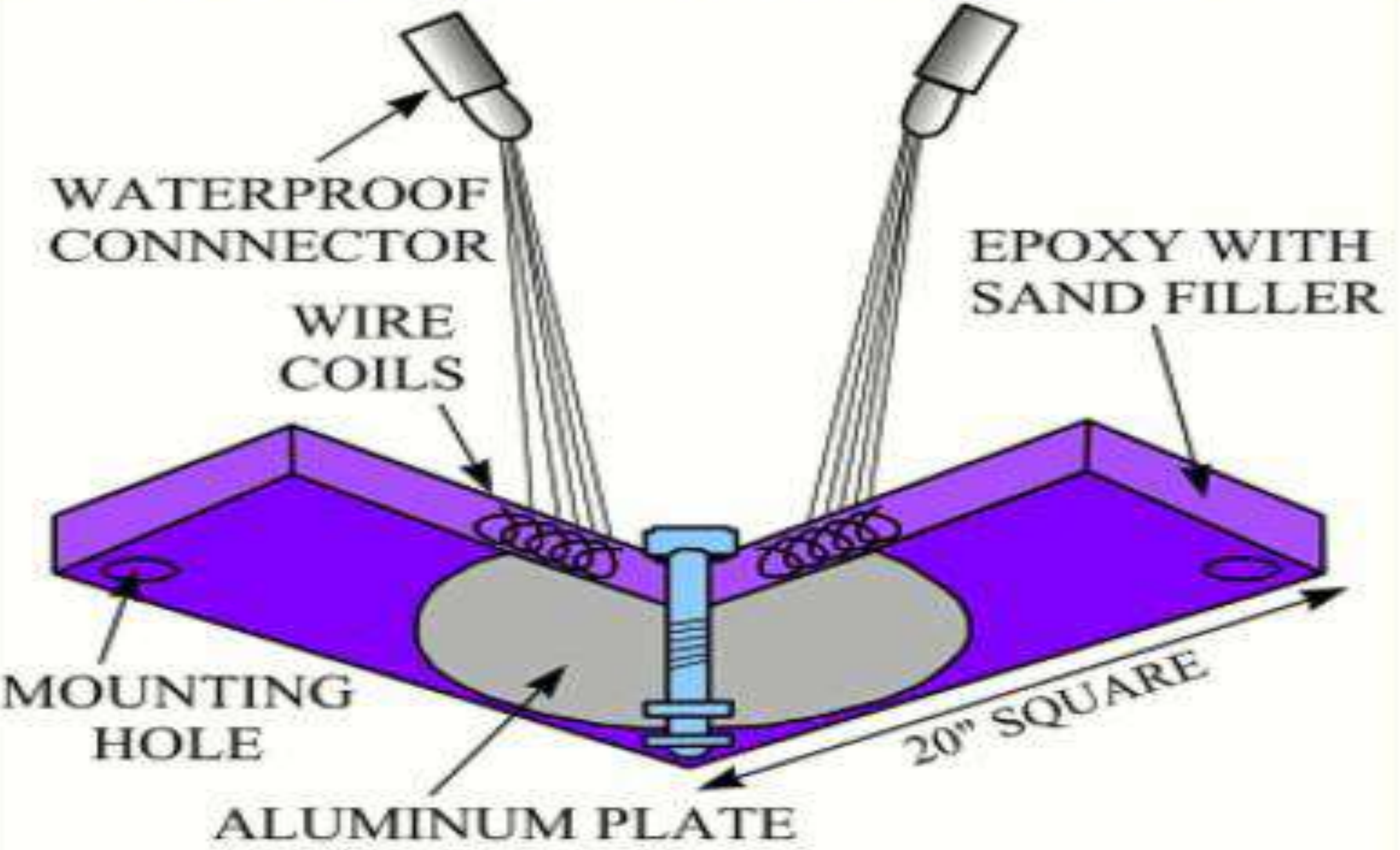
The boomer is often classed as displacement type device because the rapid movement of a flat, rounded aluminium plate against the water produces the acoustic signal.

The motion of the plate is produced when electrical energy stored in the power supply is rapidly discharged through the coil located in the transducer; a magnetic field is developed in the coil.

This magnetic field opposes the induced magnetic field generated in the aluminium plate, resulting in a rapid repulsion action of the plate .

The fields decay very rapidly and return spring forces the plate back to the initial position. The acoustic signature generated is of short duration and relatively high amplitude having a characteristic bandwidth of 400-4000 Hz.

COMPONENTS OF A BASIC BOOMER SYSTEM



MODIFIED FROM KRAMER AND OTHERS, 1980

SPARKER

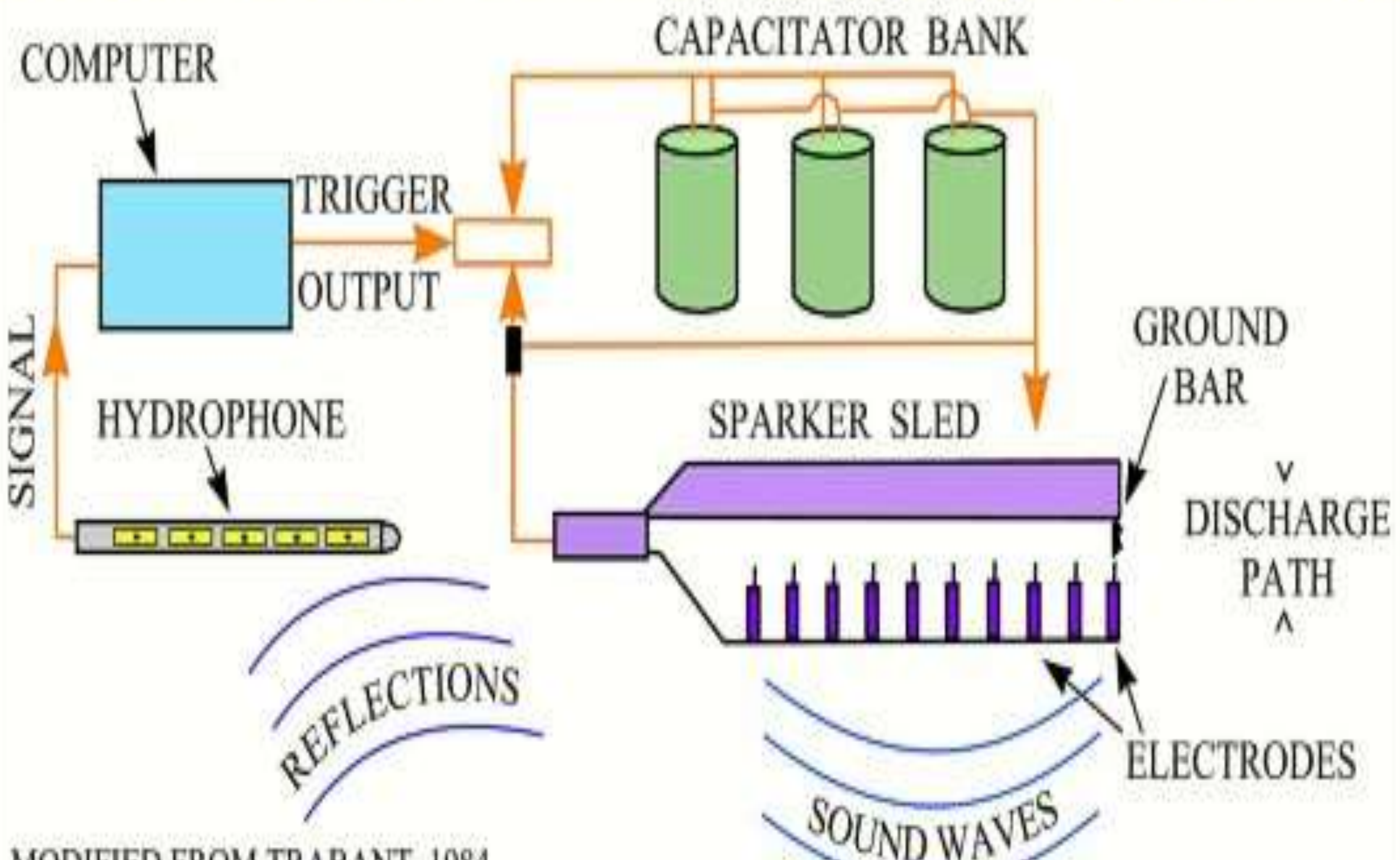
The sparker is a low frequency, relatively high-powered energy sound source utilized for deep penetration sub-bottom profiling in salt water.

Sparker systems are available which operates in the 100-200 kilojoules range, but these are used as sources with multi-channel seismic systems, not in continuous sub-bottom profiling.

Sparker sources used in profiling are usually limited to the range of 200-10,000 joules and generally there is little advantage to be gained in a further increase in energy beyond 3000 joules.

High resolution shallow seismic multi-tips squid spark

COMPONENTS OF A BASIC SPARKER SYSTEM



MODIFIED FROM TRABANT, 1984

HYDROPHONE

A hydrophone is a microphone designed to be used underwater for recording or listening to underwater sound.

Most hydrophones are based on a piezoelectric transducer that generates electricity when subjected to a pressure change. A hydrophone converts acoustic energy into electrical energy and is used in passive underwater systems to listen only.

Hydrophones are usually used below their resonance frequency over a much wider frequency band where they provide uniform output levels (Figure 4.6). Such piezoelectric materials, or transducers can convert a sound signal into an electrical signal since sound is a pressure wave in fluids

AN ARRAY OF HYDROPHONES ASSEMBLED IN FLUID FILLED CABLE

PROCESSING OF HIGH RESOLUTION SEISMIC DATA

The acquired seismic reflection data contains a lot of noise. These noises are removed by applying sophisticated processing techniques, mostly with state-of-art seismic
data processing software package.

The basic objective of all seismic processing is to convert the information recorded in the field into a form that facilitates geological interpretation.

The resultant processed data provides a structural image of the sub-surface, which allows one to map sub-surface distribution of seismic sequences, depositional environments, rock facies and structural trends.

The purpose of seismic data processing is to manipulate the acquired data into an image that can be used to infer the sub-surface structure.

Processing consists of the application of a series of computer routines to the acquired data guided by the processing geophysicist

In the present study Seisee software was used for processing , at CSIR-NIO

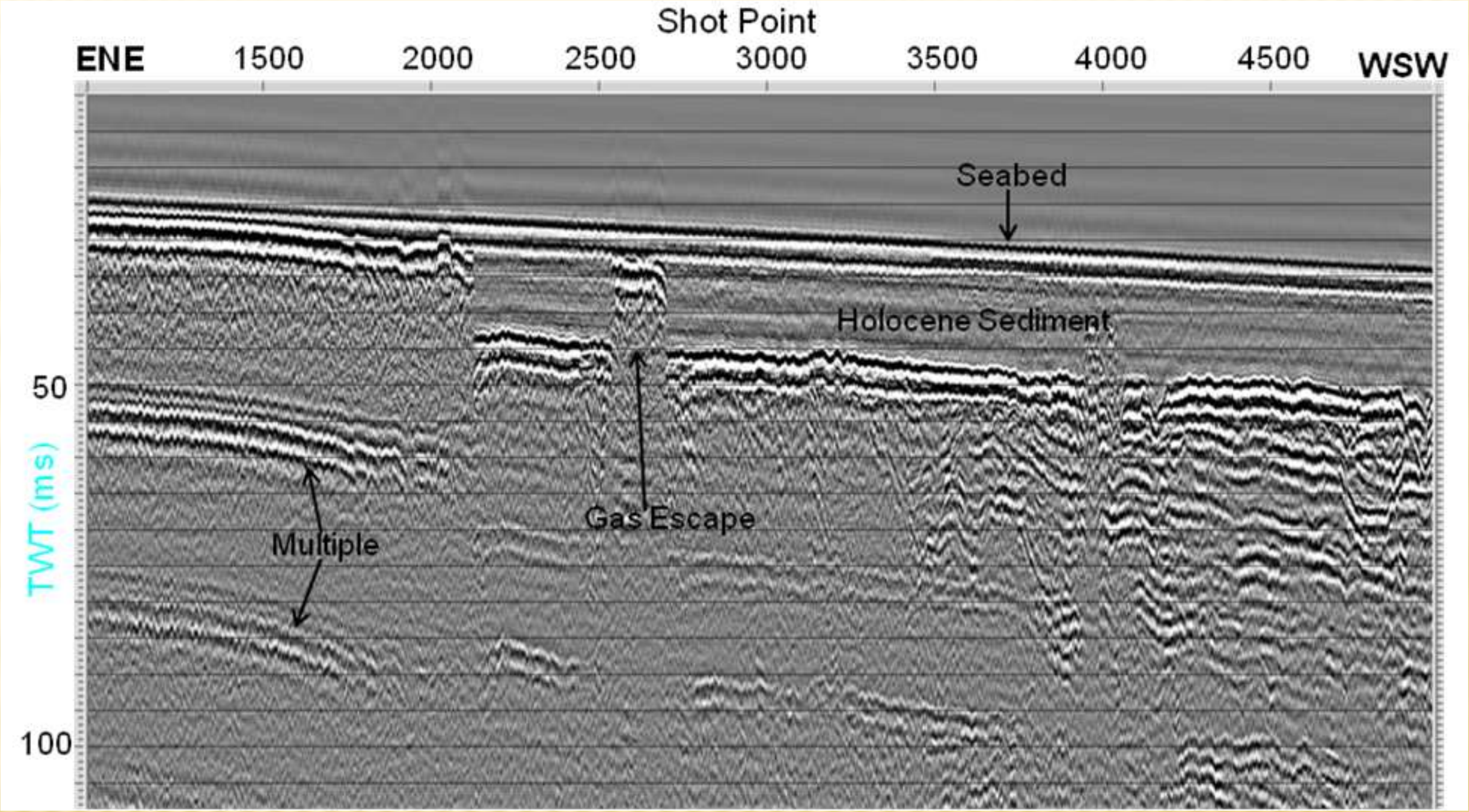
SEISMIC RESOLUTION

VERTICAL RESOLUTION :

seismic resolution is the ability to distinguish separate features; in other words, the minimum distance between two features so that the two can be identified separately rather than as one feature. normally we think of resolution in the vertical sense,

HORIZONTAL RESOLUTION :

Horizontal resolution refers to how close two reflecting points can be situated horizontally, and yet be recognized as two separate points rather than one. The area that produces the reflection is known as the First Fresnel Zone: the reflecting zone in the subsurface insonified by the first quarter of a wavelength. If the wavelength is large then the zone over which the reflection returns is larger and the resolution is lower.



High resolution shallow seismic section showing gas charged sediment and multiple reflections.

GROUND PENETRATING RADAR
OR
GPR METHOD

Introduction

- Ground penetrating radar (commonly called GPR) is a high resolution electromagnetic technique that is designed primarily to investigate the shallow subsurface of the earth, building materials, and roads and bridges
- Geophysical equipment uses RADAR (RAdio Detection And Ranging) pulses for imaging subsurface
- Uses electromagnetic radiation in the microwave band(300 MHz to 300 GHz) and detects the reflected signals from subsurface structures.
- Media includes rock, soil, ice, freshwater, pavements and structures

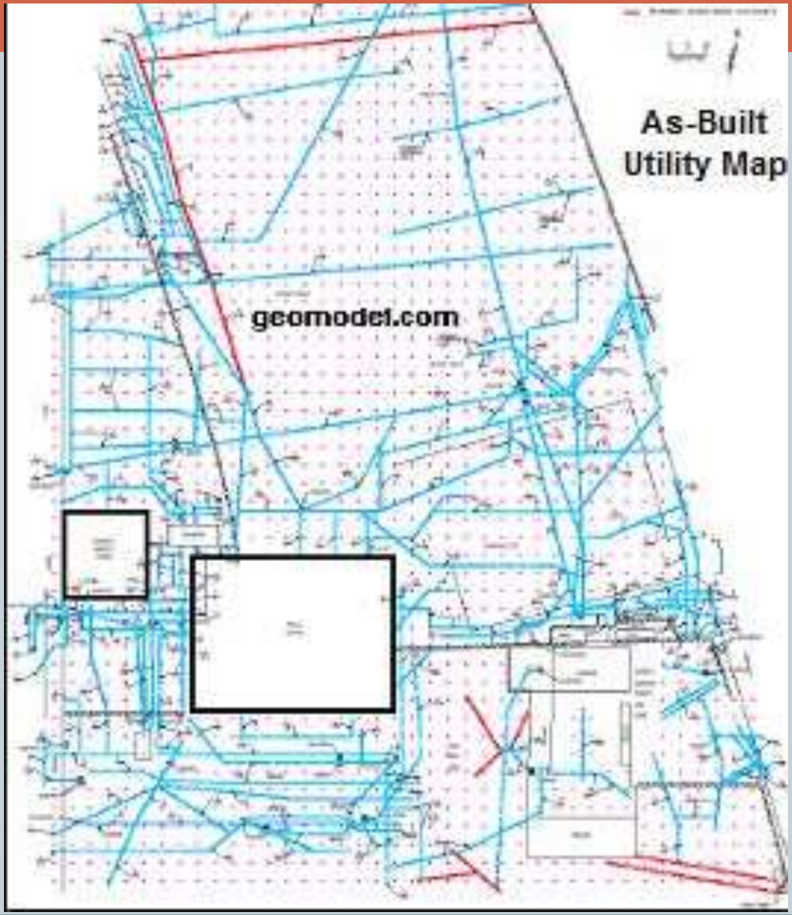
History

- The first use of Electromagnetic signals to locate buried objects is attributed to Hulsmeyer in a German patent in 1904.
- The first published description of such investigations was by Leimbach and Lowy in 1910 again in German patents
- The potential of GPR for civilian use was identified by Geophysical Survey Systems Inc.(GSSI)

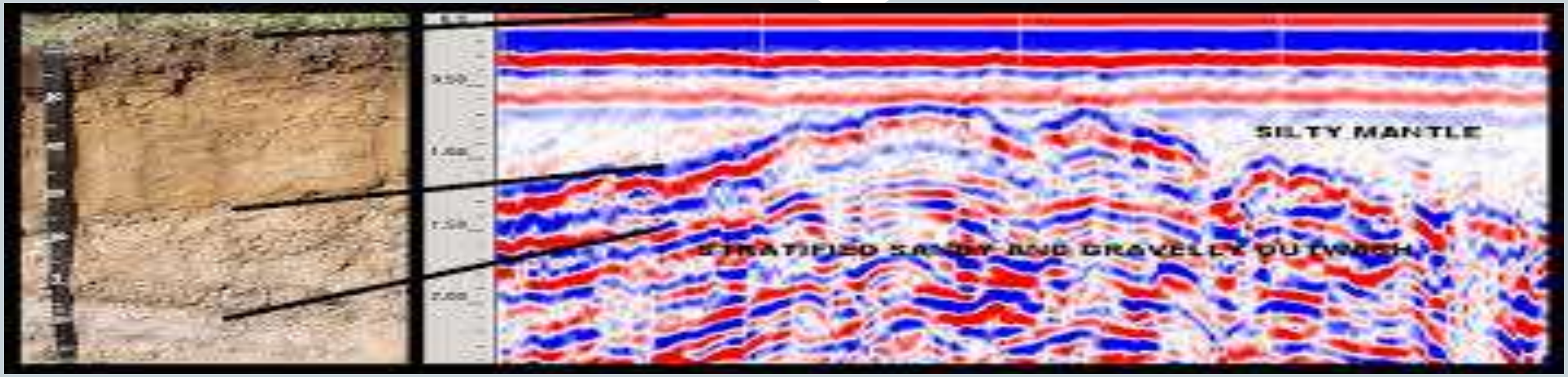
Engineering applications of GPR

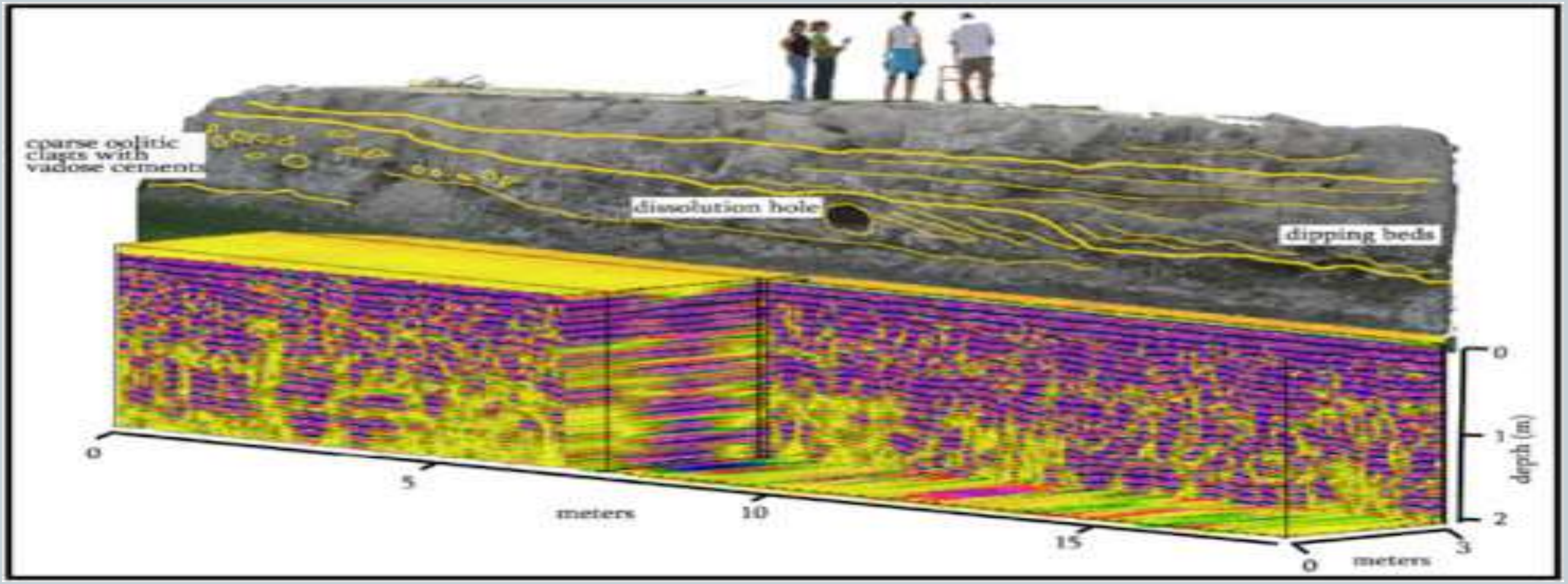
Utility Mapping

Utility mapping using GPR

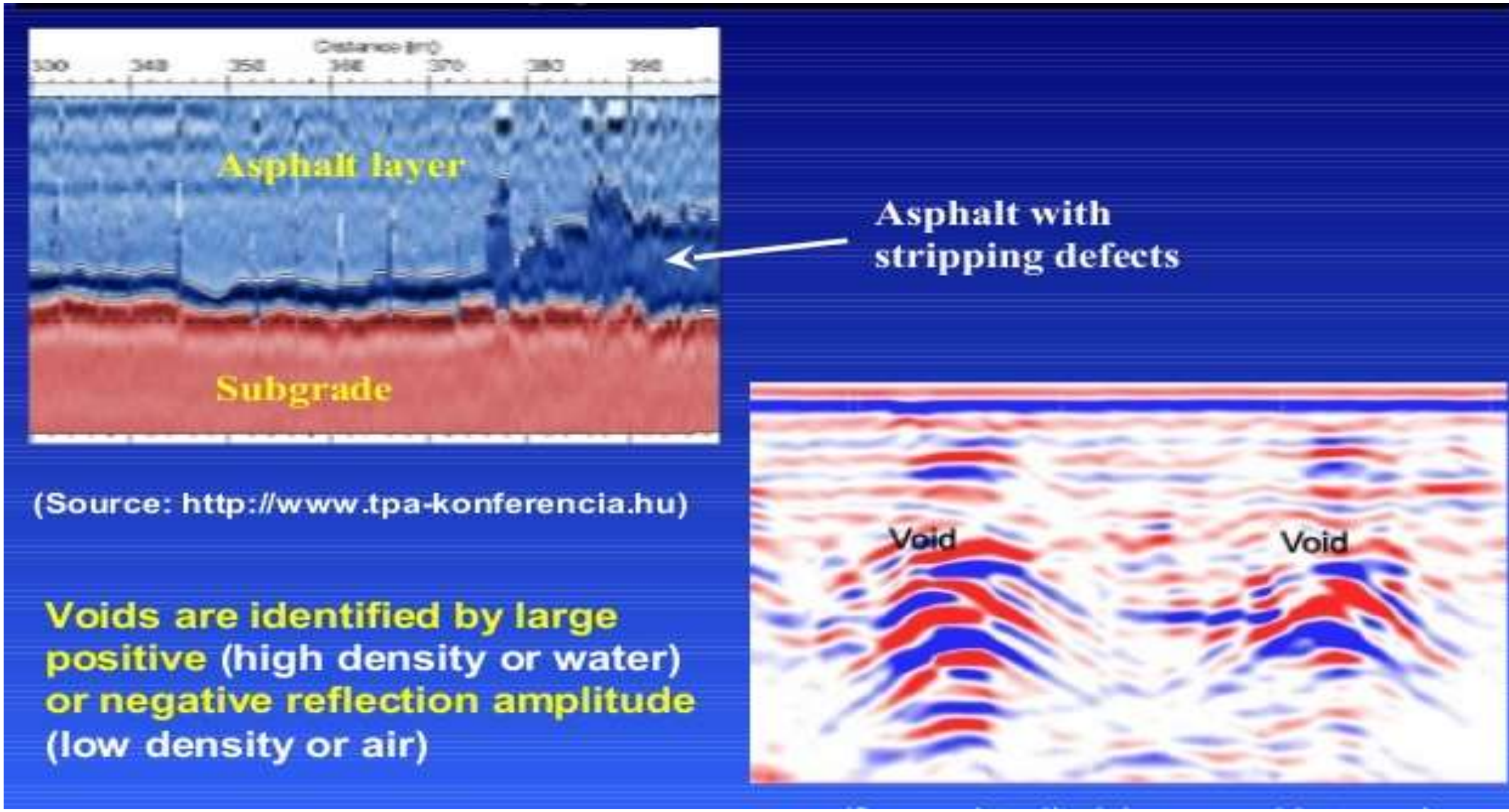


Identifying different layers in soil, rock, fill in geotechnical investigation

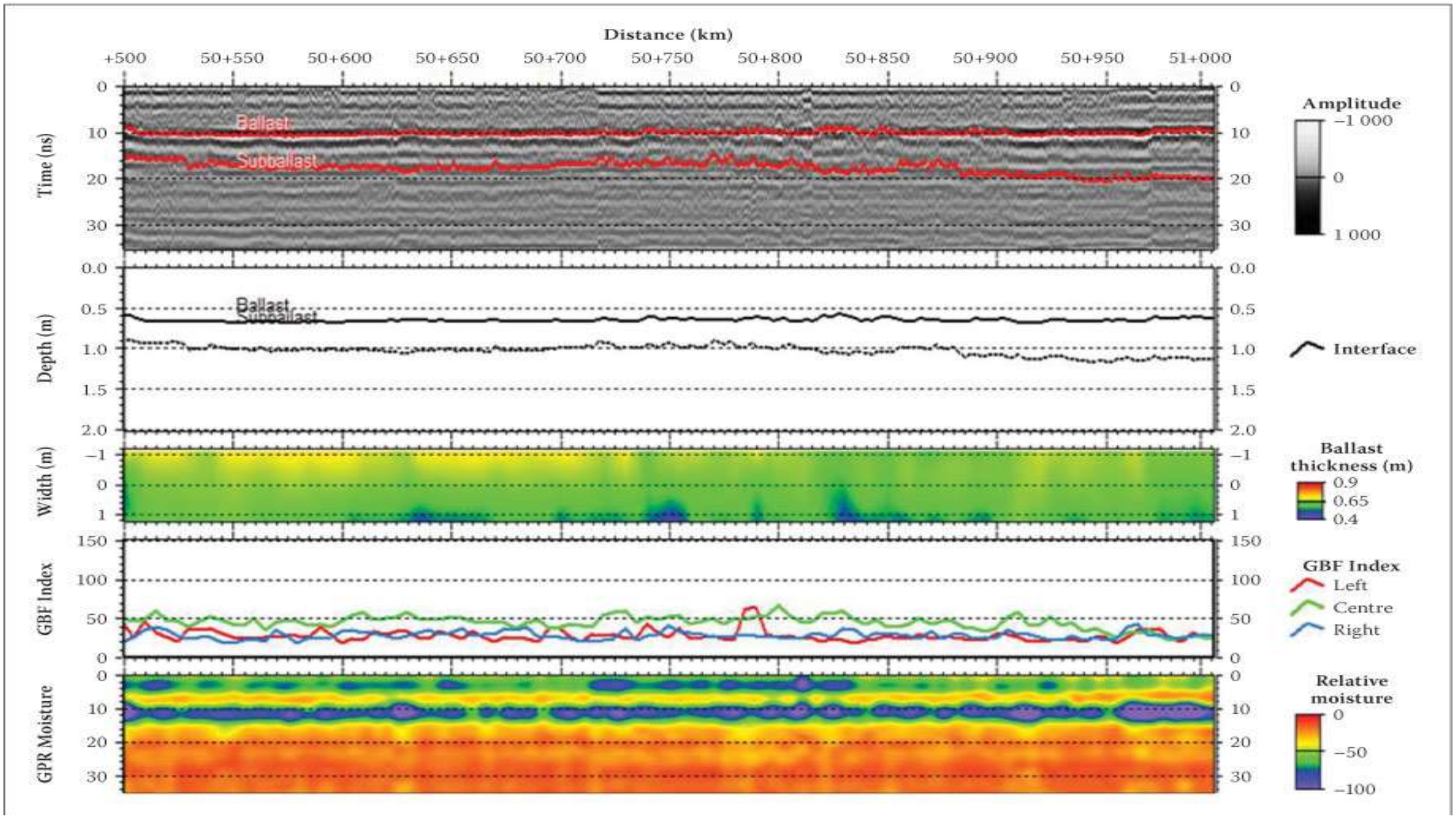




Pavement condition diagnostics
Mapping voids or cavities beneath roads, pavements



•Monitoring the condition of railway ballast



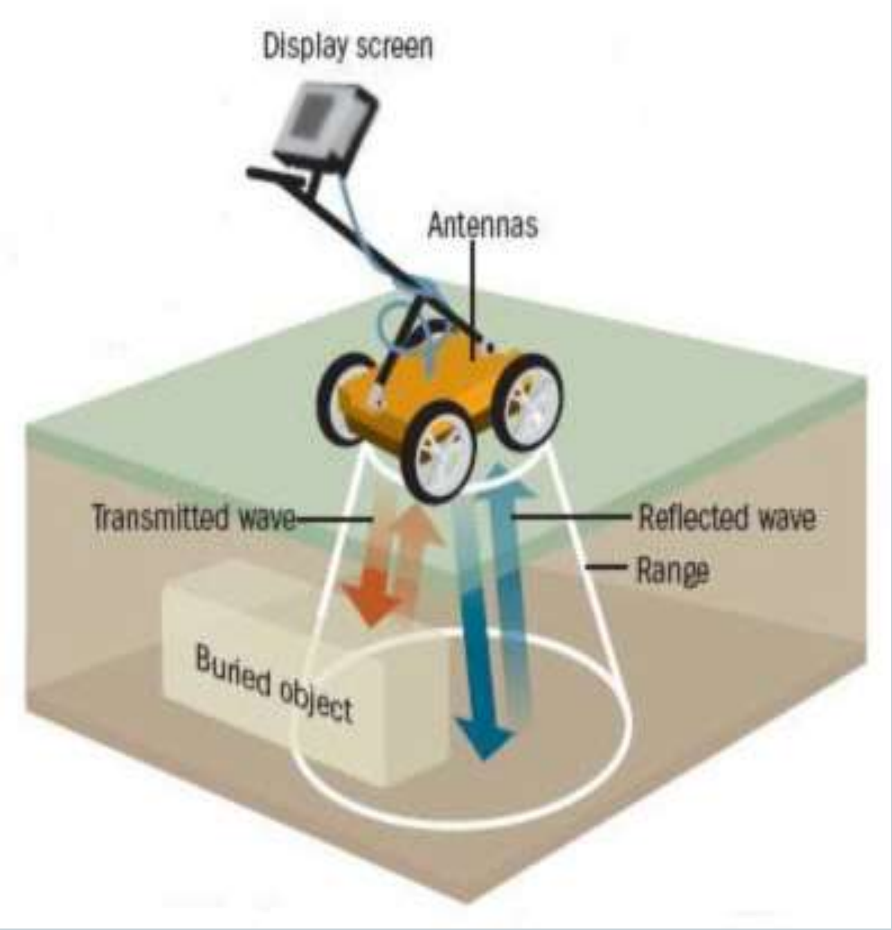
• Detailed inspection of concrete structures

- Inspection quality of precast concrete
- Detection of termite attack zones in timber
- Mapping zones of termite attack or fungal decay in trees
- Detection of faults , fracturing of rocks(BH- GPR)
- Determining thickness of snow and ice.
- Mapping archeological ruins
- Surveying sediments beneath bottoms and lakes and rivers

Principles of operation

A GPR instrument consists of :

- A control unit
- A recorder
- A transmitting antenna
- A receiving antenna



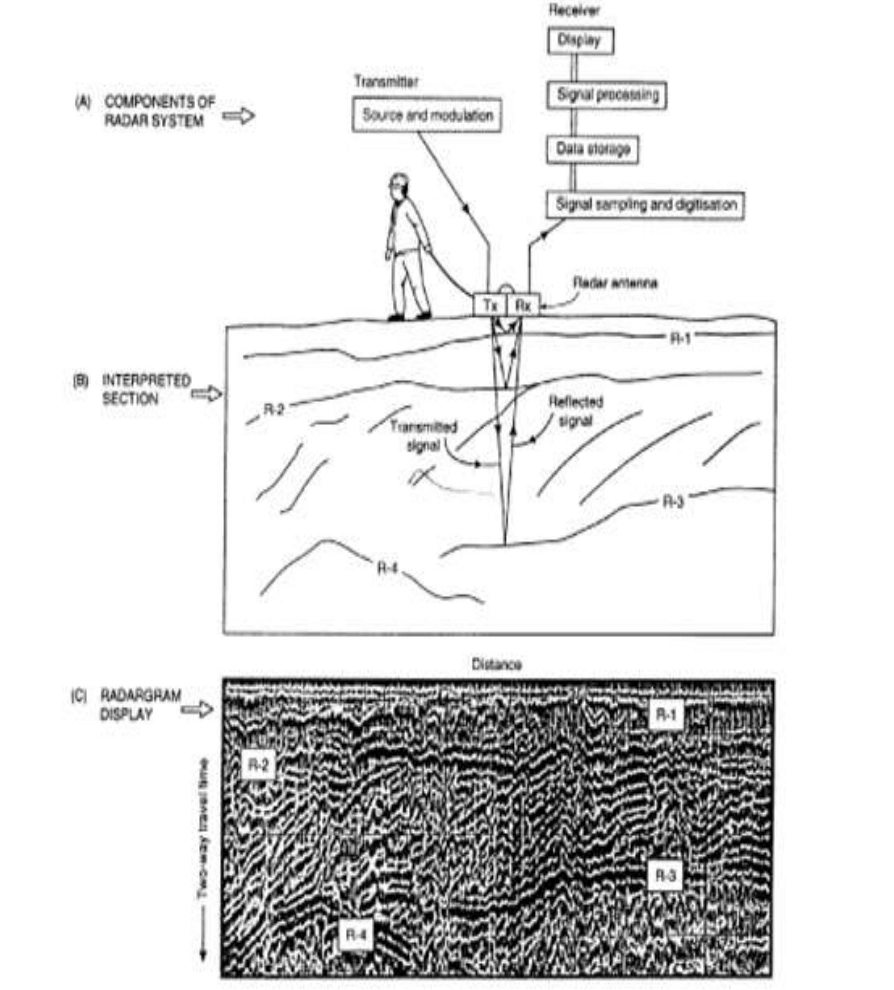
Principles of operation

❖ Antennae

Bistatic or Monostatic mode

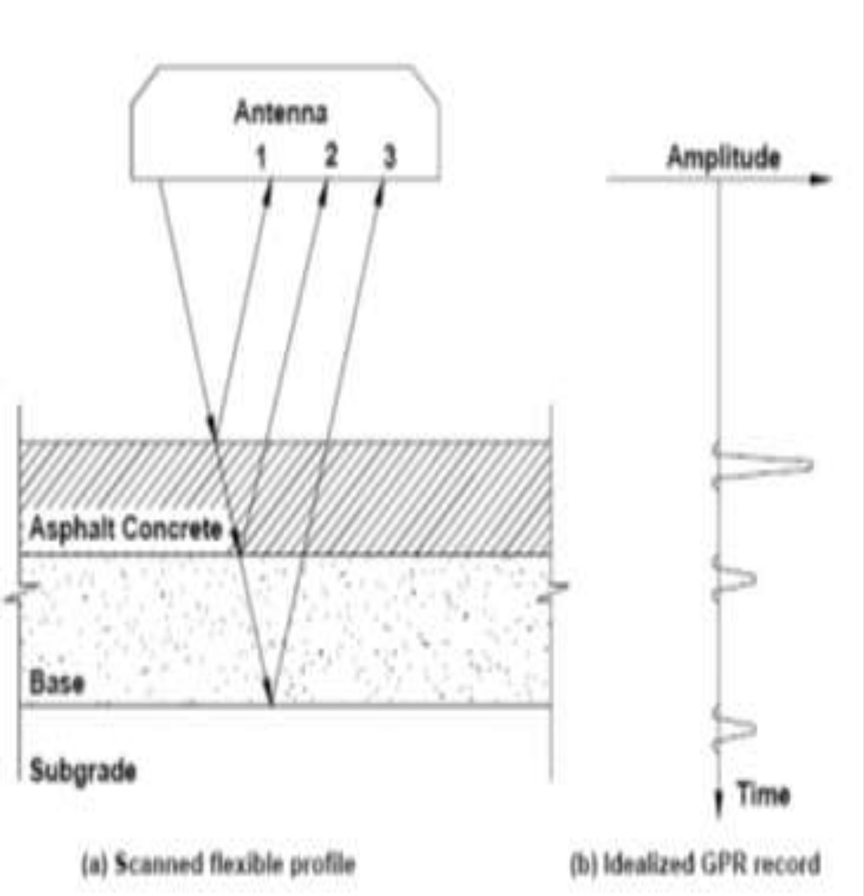
From figure:-

A. Transmitter antenna (Tx) & Receiving antenna (Rx)
B. Interpreted section
C. Radargram display



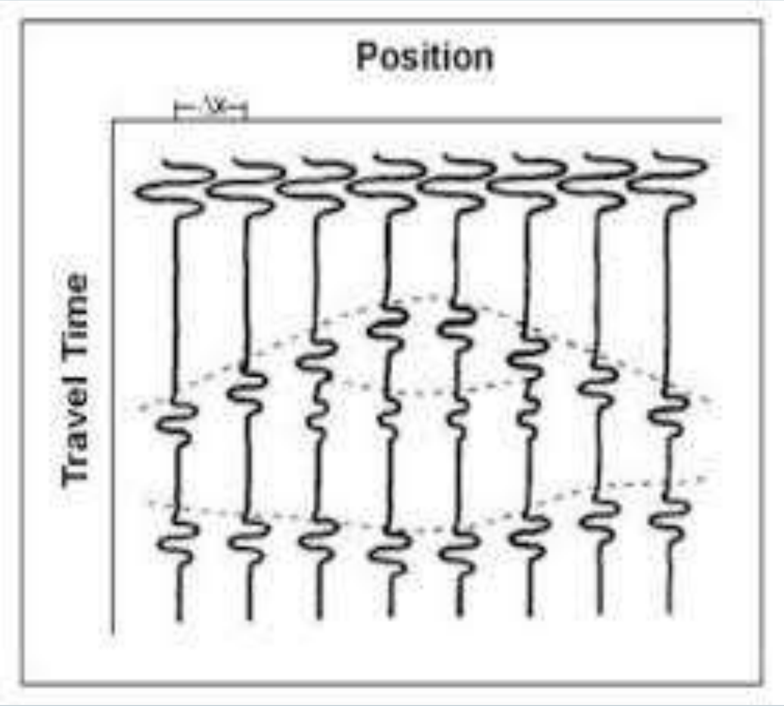
Principles of operation

- An Electro Magnetic pulse is sent through the antenna, penetrating into the surveyed material.
- A portion of the energy is reflected back to the antenna when an interface between materials of dissimilar dielectric constants is encountered.



Antenna and Frequency

- Different antennas provide different frequencies, which usually vary between 25 and 1,500 MHz
- Lower frequencies provide greater depth penetration but lower resolution
- Higher frequencies provide shallow depth penetration but high resolution.
- Displays are output in terms of variable area wiggle or wiggle trace only



Relative Dielectric Constant

- The **Relative dielectric constant** (ε_r) is the ratio of the permittivity of a substance to the permittivity of free space.
- Permittivity, also called electric permittivity, is a constant and is equal to approximately 8.85 x 10^{-12} farad per meter (F/m) in free space (a vacuum).

ε_r

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$$

$$= \varepsilon\ (1.13 \times 10^{11})$$

- The velocity of radio wave in a material is given by

$$Vm = \frac{c}{\sqrt{\varepsilon_r}}$$

Material	ε_r	V(mm/ns)
Air	1	300
Water (fresh)	81	33
Water (sea)	81	33
Permafrost	1-8	106-300
Coastal sand (dry)	10	95
Sand (dry)	3-6	120-170
Sand (wet)	25-30	55-60
Silt (wet)	10	95
Clay (wet)	8-15	86-110
Clay soil (dry)	3	173
Average 'soil'	16	75
Granite	5-8	106-120
Limestone	7-9	100-113
Basalt (wet)	8	106
Sandstone (wet)	6	112
Concrete	6-30	55-112
Asphalt	3-5	134-173
PVC, Epoxy, Polyesters	3	173

Relative dielectric constants and radio wave velocities for different materials*

**Data from Johnson et al. (1979), McCann et al. (1988), Morey (1974), Reynolds (1990,1991).*

- The reflected signal has information on:
  - how quickly the signal traveled
  - how much was attenuated
- The thickness of a layer is given by:

$$d_i = \frac{c}{\sqrt{\varepsilon_{r,i}}} \times \frac{t_i}{2}$$

where

d_i is the thickness of layer i,

t_i the total travel time through that layer,

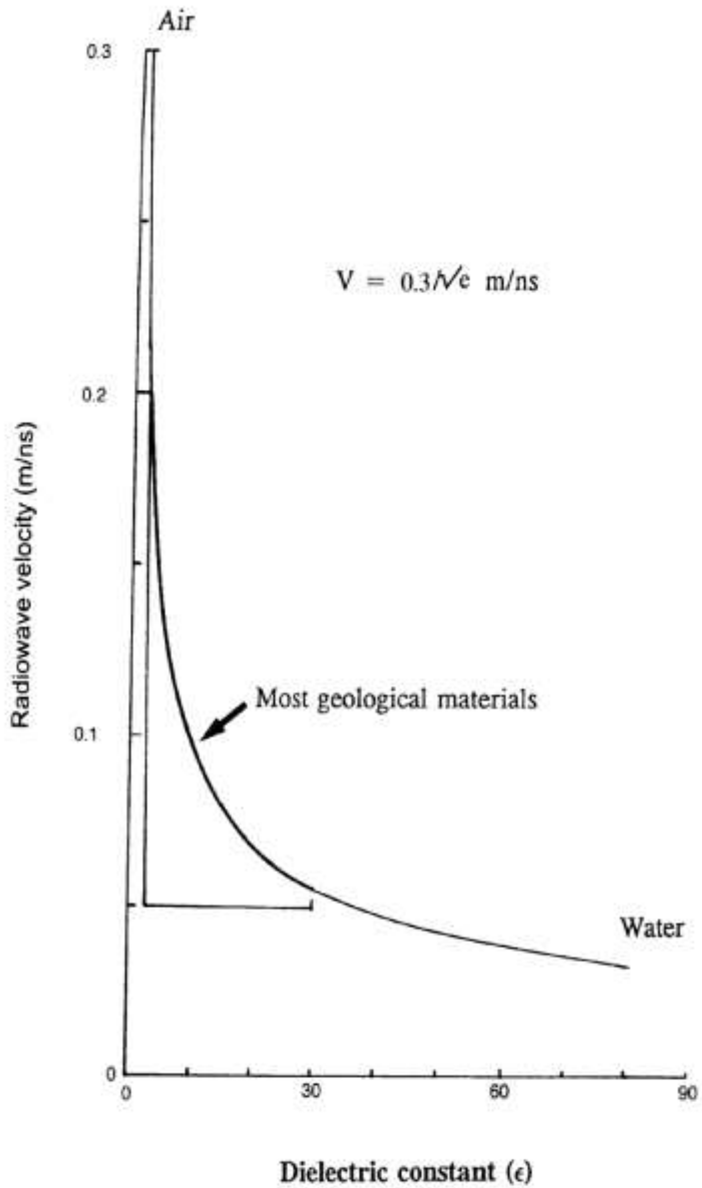
c is the speed of light and

$\varepsilon_{r,i}$ the dielectric constant of the layer i

- The amount of reflected energy at an interface is governed by:

$$\rho_{1,2} = \frac{\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}}{\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}}}$$

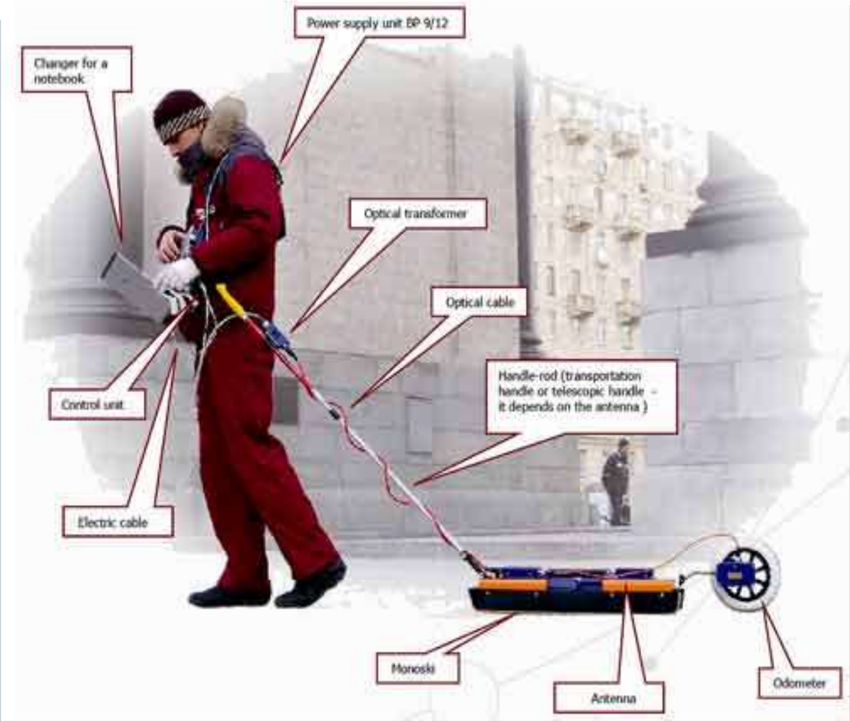
- where $\rho_{1,2}$ is the reflection coefficient and ε_{r1} and ε_{r2} are the dielectric constants

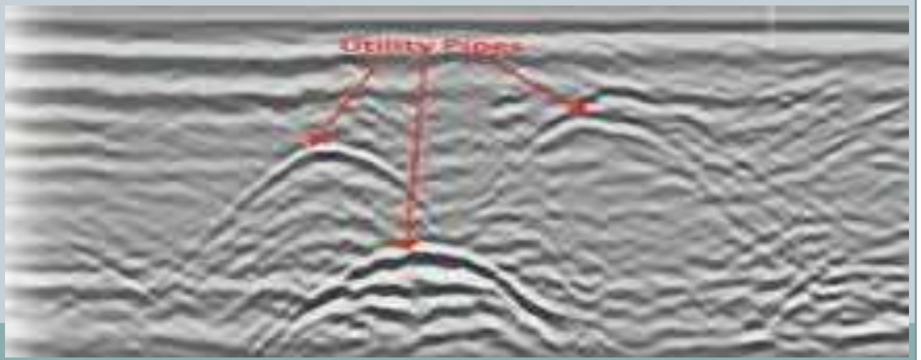


←Radiowavevelocities as a function of relative Dielectric constants

Data Acquisition

- GPR surveys are conducted by pulling the antenna across the ground surface at a normal walking pace.
- The recorder stores the data as well as presenting a picture of the recorded data on a screen.
- Resolution is the measure of ability to distinguish between to adjacent signals which depends upon the frequency of radio waves





Processing and Interpreting

- RADAN is GSSI's ground penetrating radar processing software.
- Stands for **RA**dar **D**ata **AN**alyser
- It has been developed over the last 20 years to aid in the processing and interpretation of GPR data.
- Runs on regular laptop or desktop computer
- Provides the user with many powerful tools to clean up and view data in 3D


RADAN Reader
GPR Reader - View Processed Data and Interactive Edits
Open
Close
File
Show
Interactive Status
JPG
Export 2D
View Depth Slices
Depth Slice Viewing
Location
File Header
Global Settings
Other Windows
Color Tables
Color Xforms
Display Gain: 0
Display
RADAN™
Reader
Properties
File Parameters
Auto Save Files
No
Source Directory
C:\Users\SABNA\Documents...
Output Directory
C:\Users\SABNA\Documents...
View Attributes
Display Channel
ALL
Marker Style
Short
Horiz. Scale
Show
Grid Lines
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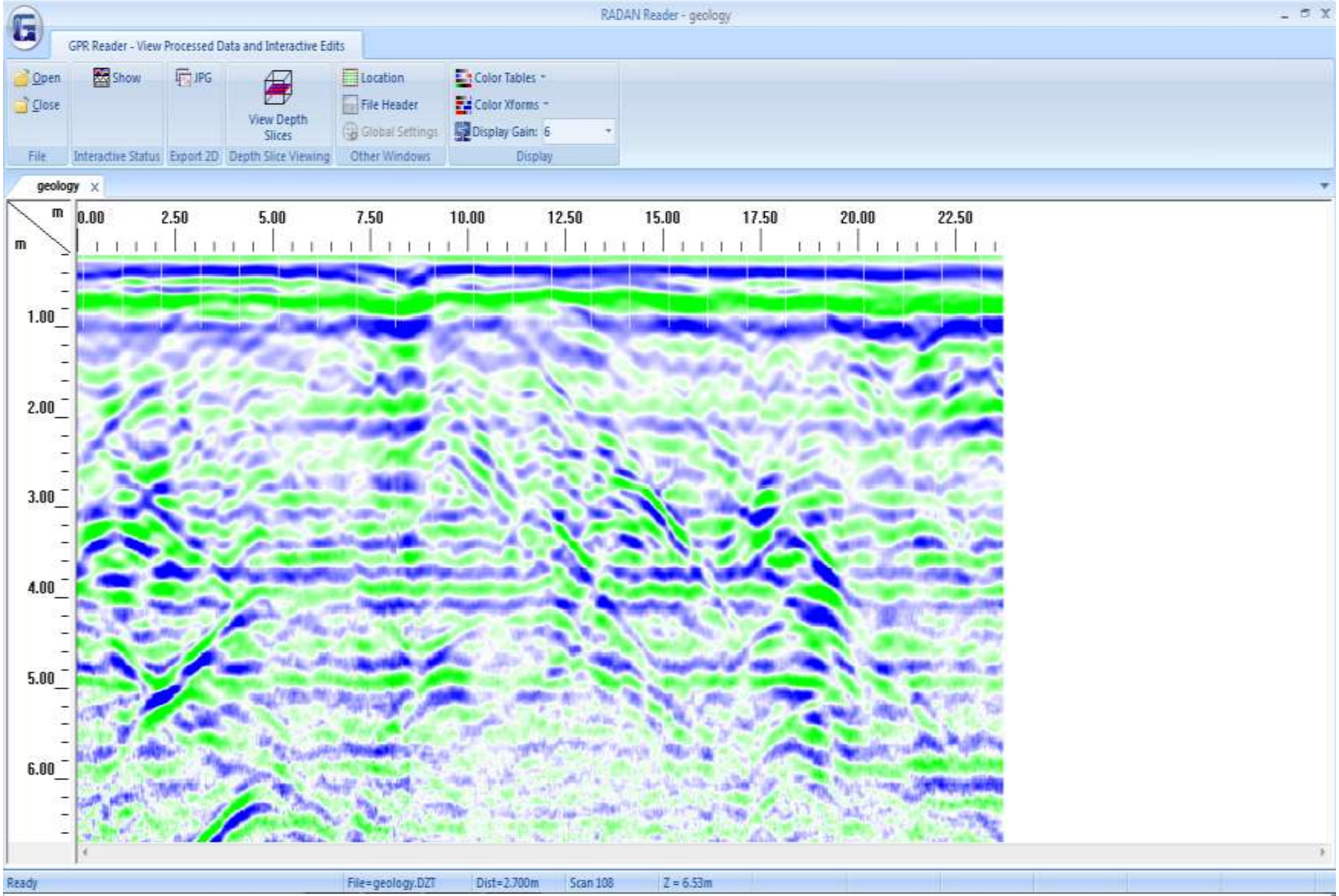
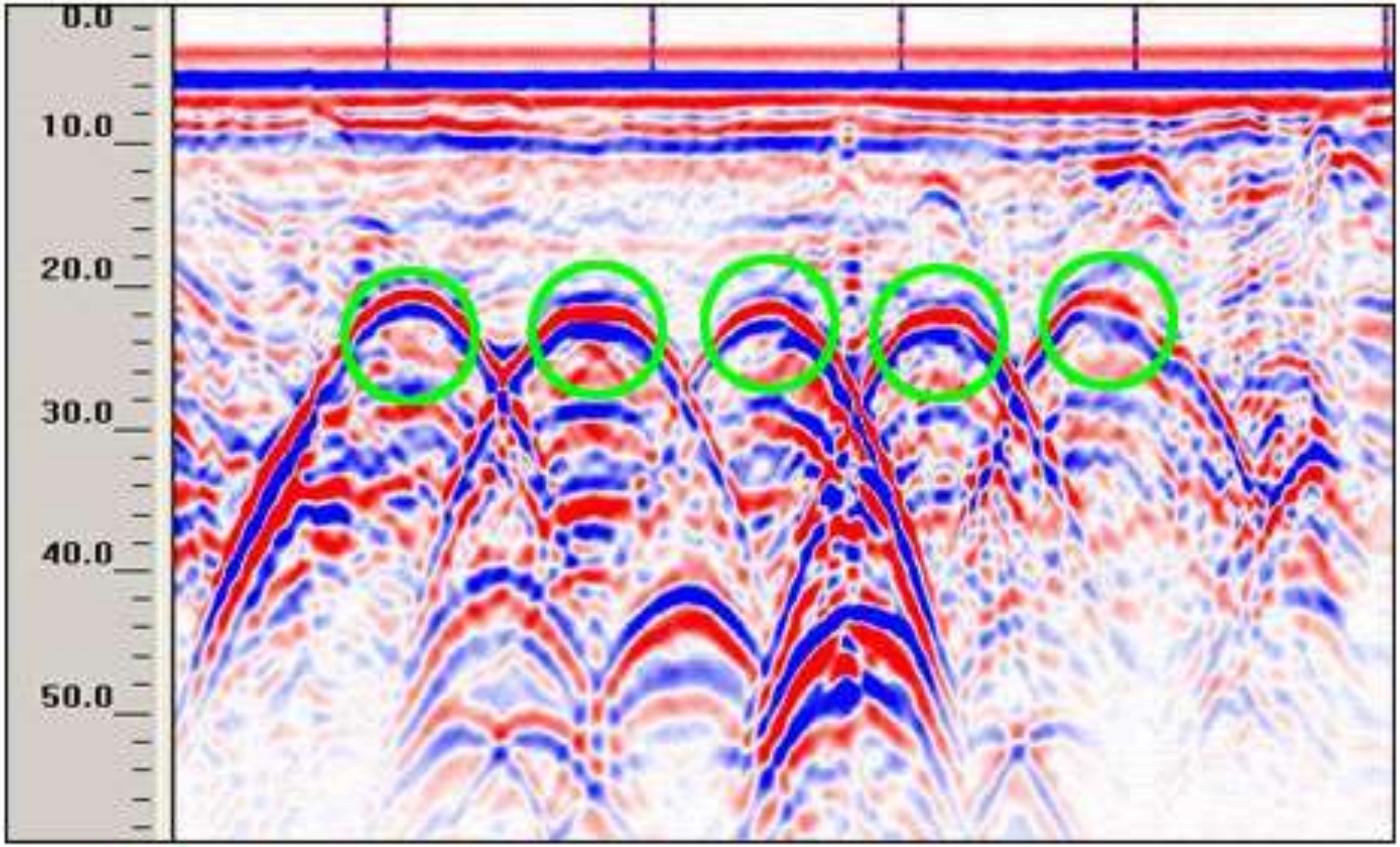
Application-Specific Display
Ready



Geology represented in colour scale with Gain value of 6



Tanks

Advantages and Limitations

- **Advantages**
- Wide area can be surveyed in very less time
- Non-destructive method
- As the information is obtain field itself anomalies can be marked on the ground
- It doesn't pose any kind of health hazard
- **Limitations**
- Cannot be used in saline water
- Cannot be used in clayey soils
- Gives ambiguous results if two materials have similar dielectric materials

Field visit

- A near shore data acquisition in the Mandovi River channel was carried out onboard ***MFB Phalguni*** by CSIR- NIO, Dona Paula.
- The survey vessel left from Captain of Ports, Betim on 3rd November 2014

Summary and Inferences

This study carried out at CSIR-NIO, Goa has provided and opportunity to acquire considerable information and knowledge in echo sounding, side scan sonar, seismic reflection and ground penetrating radar techniques which are of immense use in geotechnical engineering. The workshop on Ground penetrating Radar held in October 2014 at CSIR-NIO also helped us to understand its working principles and the agencies providing GPR equipment.

Some of the inferences drawn from the studies and work carried out during the project tenure are listed below:

- Echo sounding technique is found to be very useful to determine the water depth and bottom topography of water covered areas
- Side scan sonar technique is used to find out objects lying on the sea floor before planning construction of any offshore structure such as offshore platforms, jetties, harbour development, underwater pipeline for transporting oil and gas, fresh water, effluent discharge etc.
- High resolution shallow marine seismic reflection method is useful to determine sea floor morphology , subsurface features and underlying shallow stratigraphy for checking feasibility of site for construction of any offshore structure.
- GPR can be use for various engineering application like locating utility services, detection of voids or cavities, mapping bed rock depth or faults and fractured zones in rock.

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WAVES AND THEIR SIGNIFICANCE

CONTENTS:

INTRODUCTION:

Waves are energy in motion. Wave phenomena involve transmission of energy by means of cyclic movement through solid, liquid and gaseous medium. The medium does not travel, but the energy that travel and passes through the medium. The particles in the medium oscillate or cycle in a back and forth or up and down in orbital motion transmitting energy from one particle to another. In an orbital motion the particles in the medium move in closed circles as the wave passes.

Based on movements waves are classified as:

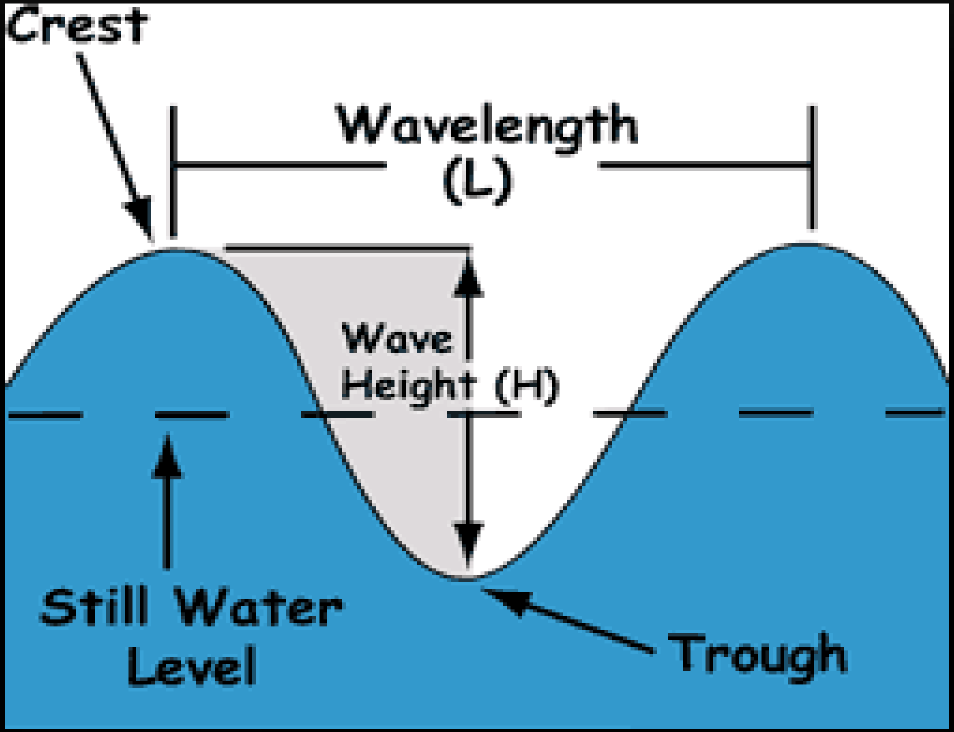
- Longitudinal waves
- Transverse waves

ORIGIN OF A WAVE

- waves are generated because of the introduction of a disturbing force. A pulse of energy is introduced and waves are produced by it. This disturbing force is called a generating force.
- Wind blowing across the ocean surface provides the disturbing force for wind waves.
- Landslides, volcanic eruptions or faulting of the sea floor associated with earthquakes are the disturbing forces for seismic waves(tsunamis).
- When the waves are sufficiently of large size, so that the restoring force of the earths gravity is more important than surface tension, the waves are called gravity waves
- The wind and surface tension create small waves called ripples or capillary waves

WAVE ANATOMY

- Wave Crest
- Wave Trough
- Wave height (*H*)
- Wavelength (*L*)
- Still water level
- Orbital motion



TYPES OF WAVES

- Deep water waves:-

The paths of water molecules in a wind wave are circular only when the wave is travelling in deep water. In greater depths, the smaller circles have little energy these waves are called as Deep water waves.

- Shallow water waves:-

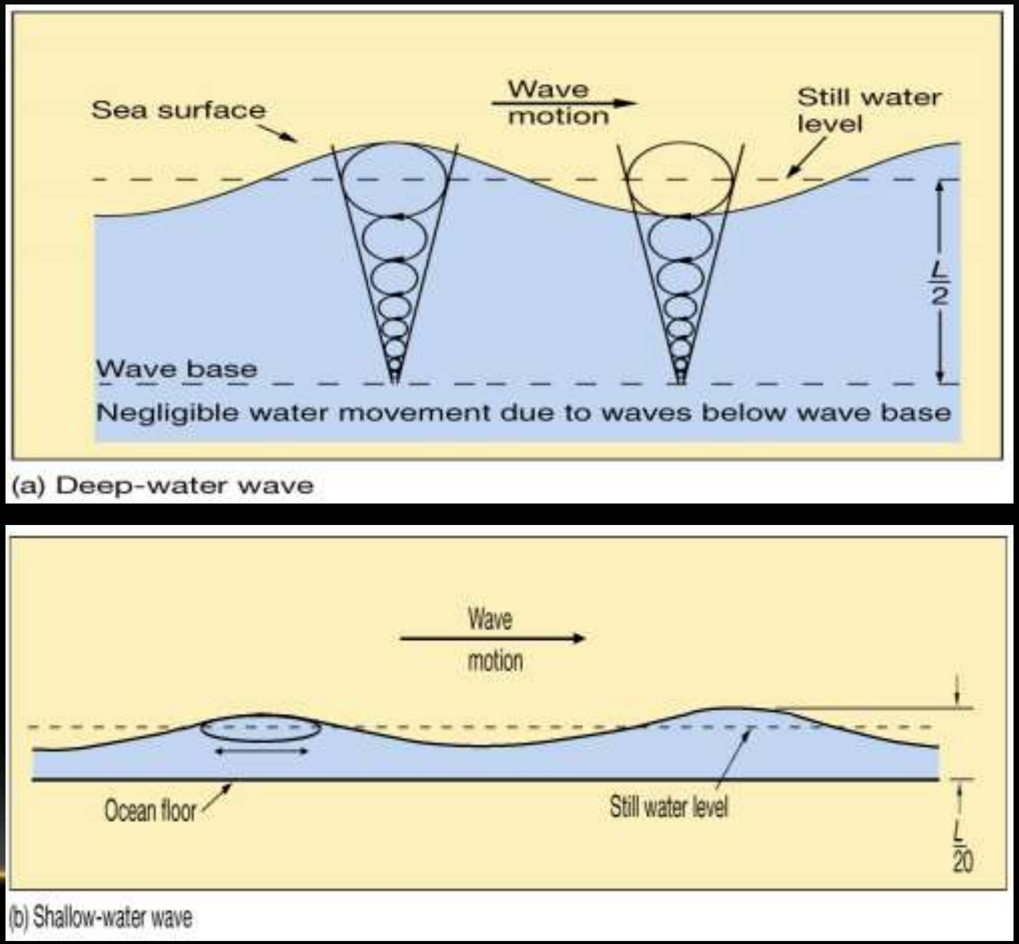
these are the waves where the depth(d) is less than 1/20 of the wavelength (L/20). A wave with a 20m wavelength will act as shallow water wave if the water is less than 1 m deep. Also called as long waves

- Intermediate depth water waves (Transitional Waves):-

they have wavelengths greater than twice the water depth but less than 20 times. In other words, they travel through water deeper than 1/20 their original length

DEEP- AND SHALLOW-WATER WAVES

- Deep-water waves
  - Water depth > wave base
- Shallow-water waves
  - Water depth < $^{1}/_{20}$ of wavelength
- Transitional waves
  - Water depth < wave base but also > $^{1}/_{20}$ of wavelength



WAVE SPEED (S):

- General formula: $$\text{Wave speed}\,(S) = \frac{\text{wavelength}\,(L)}{\text{period}\,(T)}$$
- Deep-water waves:
  - Wave speed (*S*) in meters per second = 1.56 *T* in seconds
  - Wave speed (*S*) in feet per second = 5.12 *T* in seconds
- Shallow-water waves: (*d* = water depth)
  - $$\text{Wave speed}\,(S)\text{ in meters per second} = 3.13\sqrt{d}\text{ in meters}$$
  - $$\text{Wave speed}\,(S)\text{ in feet per second} = 5.67\sqrt{d}\text{ in feet}$$

WAVE CLASSIFICATION

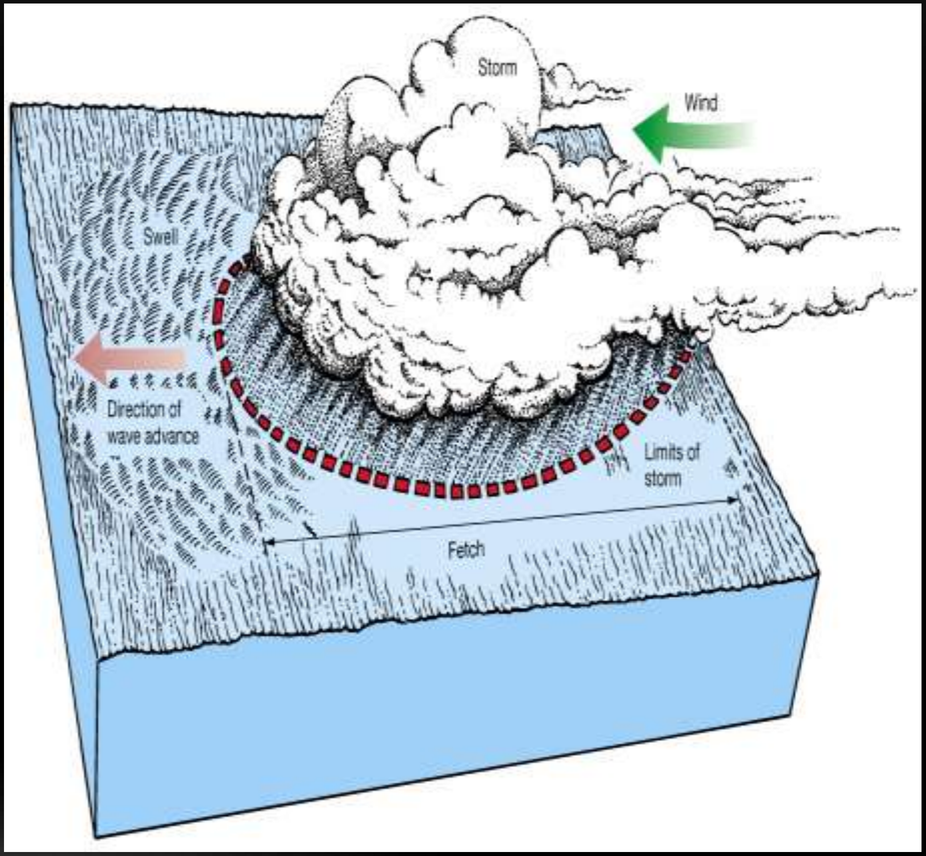
Ocean waves can be classified in various ways:

Disturbing Force- the forces which generate the waves.

1. **Meteorological forcing** (wind, air pressure); sea and swell belong to this category.
2. **Earthquakes**; they generate tsunamis, which are shallow water or long waves.
3. **Tides** (astronomical forcing); they are always shallow water or long waves.

THE “SEA” AND SWELL

- Waves originate in a “**sea**” area
- **Swell** describes waves that:
  - Have traveled out of their area of origination
  - Exhibit a uniform and symmetrical shape



TSUNAMI

It is a series of ocean waves commonly caused by violent movement of the sea floor by submarine faulting, landslides, or volcanic activity. speed is nearly equal to 500 miles per hour outward from the site of the violent- movement.

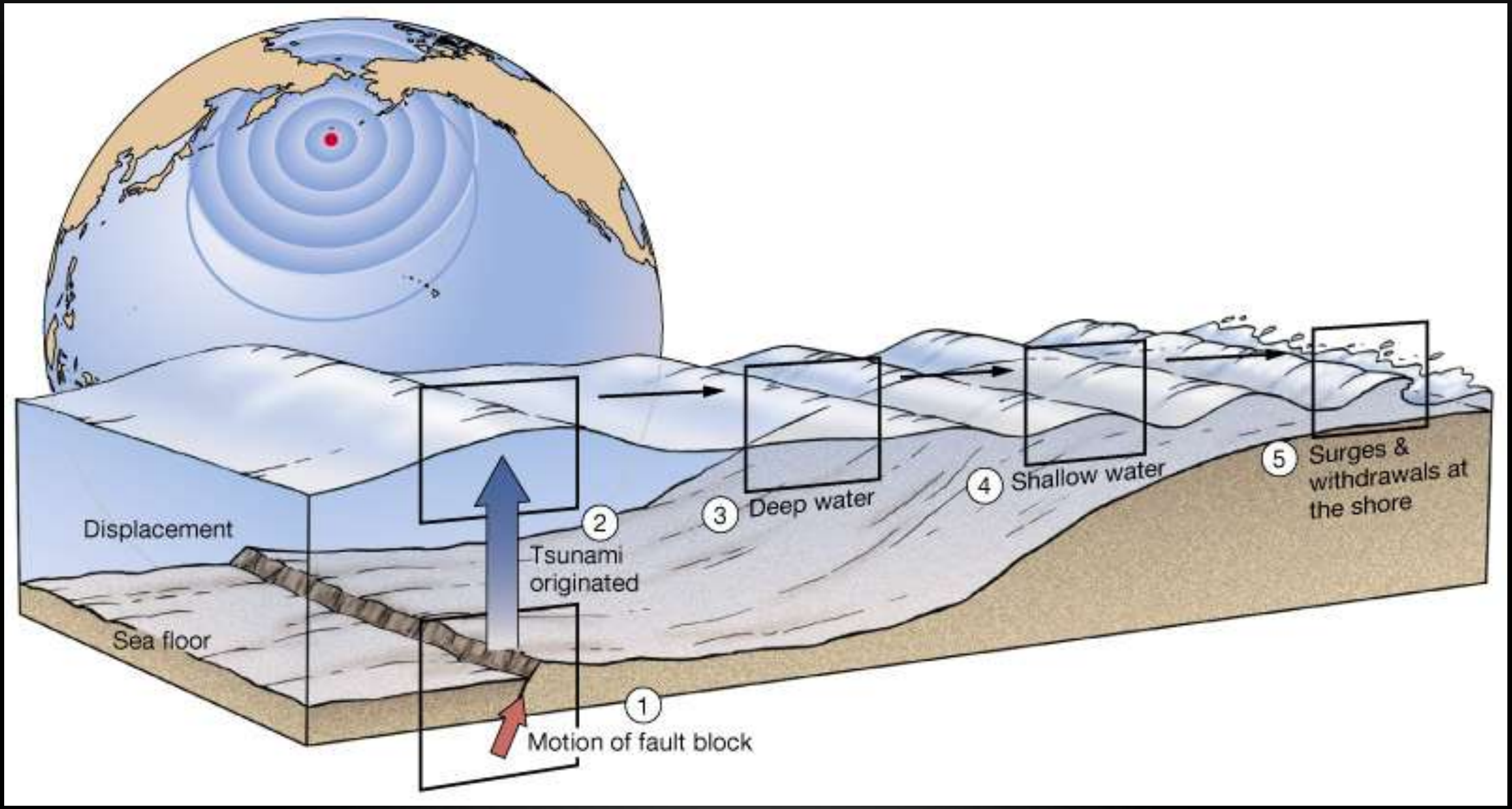
TSUNAMI TERMINOLOGY

- Often called “tidal waves” but have nothing to do with the tides
- Japanese term meaning “harbor wave”
- Also called “seismic sea waves”

Created by movement of the ocean floor by:

- Underwater fault movement
- Underwater avalanches
- Underwater volcanic eruptions

MOST TSUNAMI ORIGINATE FROM UNDERWATER FAULT MOVEMENT



TSUNAMI CHARACTERISTICS

- Affect entire water column, so carry more energy than surface waves
- Can travel at speeds over 700 kilometers per hour
- Small wave height in the open ocean, so pass beneath ships unnoticed
- Build up to extreme heights in shallow coastal areas

Free Waves, Forced Waves

- **Free waves-** a wave that is formed by a disturbing force such as a storm. Waves continue to move without additional wind energy
- **Forced wave-** a wave that is maintained by its disturbing force, e.g., tides

Wind Waves- gravity waves formed by the transfer of wind energy into water

- Wave height- usually <3m
- Wave length- 60-150m

Factors that affect wind wave development:

- Wind strength
- Wind duration
- Fetch- the uninterrupted distance the wind blows

WAVES APPROACHING SHORE

Types of Breaking Waves:

- Spilling breaker
- Plunging breaker
- Surging beaker
- Collapsing breaker

Factors that determine the position and nature of the breaking wave:

- Slope
- Contour
- Composition

CONTD..

- Spilling breaker: when there is only very gentle slope to the bottom incoming waves grow gradually toward breaking proportions
- Plunging breakers: plunging breakers are trough like structures and when waves (crest) enters they break and this type of breakers are common in beaches of steep slopes
- Surging breakers: the slope of the bottom may be so steep that a wave does not break until it reaches shore, these breakers that suddenly build up and break right at the shore is called surging breakers.
- Collapsing breaker: in collapsing breakers, breaking occurs over lower half of wave with little upward splash

CONCLUSION

- Just like wind mills and wind turbines that generate power and electricity from the wind, scientists are now working to generate power from the sea.
- The motions they create perform a vital role in transporting energy around the globe and shaping the coastlines.
- Navy uses waves to power sensors.

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2. www.alternative-energy-news.info
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Coastal Erosion And Mechanism

contents

- Terminologies
- Coastal affecting agents
- Coastal mechanism
- Erosional landforms of ocean
- Long shore drift
- Depositional landforms of ocean
- Effects of coastal erosion
- Conclusion
- References

Terminologies

- shoreline – It is the line along which the water meets the land.

- Coast – The area extending from the landward backshore boundary to the limit of ocean-related features like dunes.

Emergent and Submergent Coasts

- Emergent coast – coastline rises relative to sea level as a consequence of sea level decline or land uplift
- Submergent coast – coastline is lowered (covered by water) relative to sea level as a consequence of sea level increase or land subsidence
- Global warming and cooling and plate tectonic motion can obviously affect long-term sea levels.

Coastal Affecting Agents

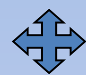
- Wind: The movement of air is called wind.
- Wave: Waves are the result of the wind blowing over the sea. As they approach land they break.
- Tide: periodic, rhythmic rise and fall of water along coastlines due to the gravitational tug of the Sun and Moon on the Earth.
- Currents: unidirectional flow of water and energy caused by wind, water density differences and water temperature differences.

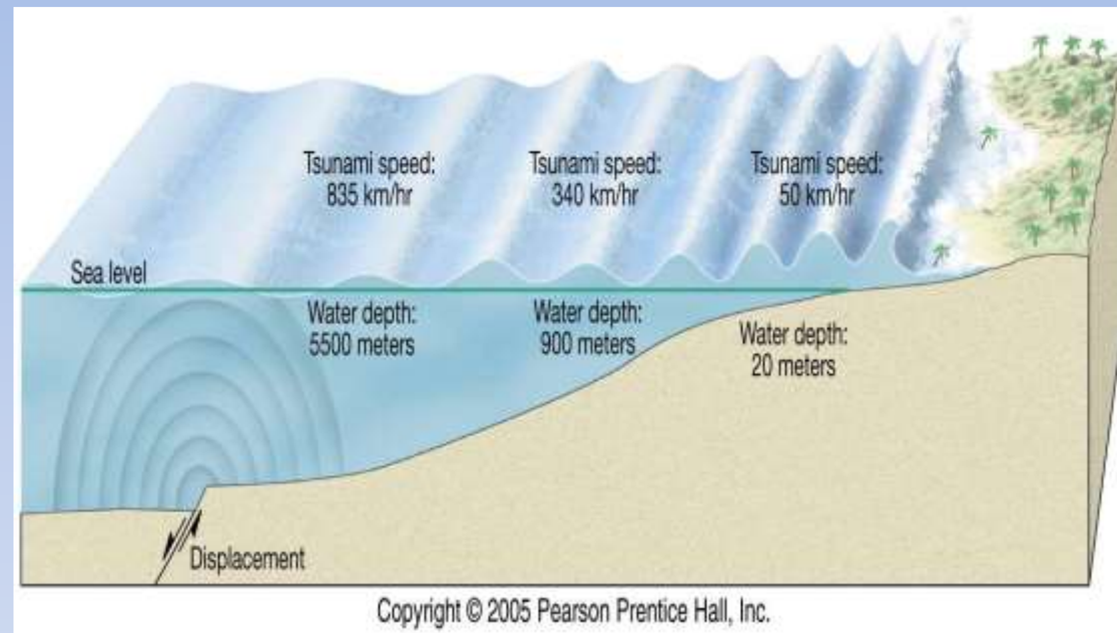
Why do waves break?

The bottom of the wave touches the sand and slows down due to increased friction. The top of the wave becomes higher and steeper until it topples over.

Types of waves

- <u>Tsunam waves</u>:

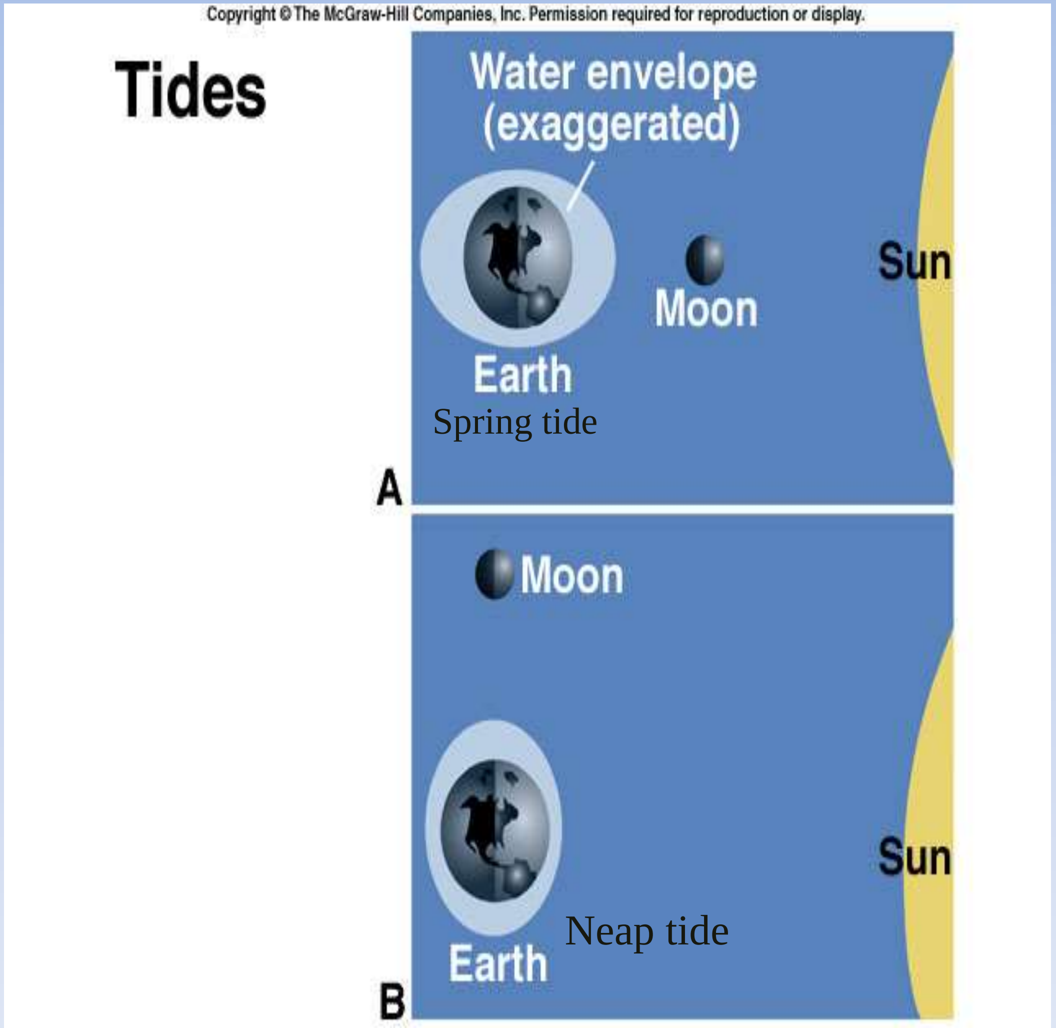
Omni directional () flow of water away from a central point caused by any event (e.g., seafloor earthquake, submarine landslide) that vertically displaces water from its equilibrium position.



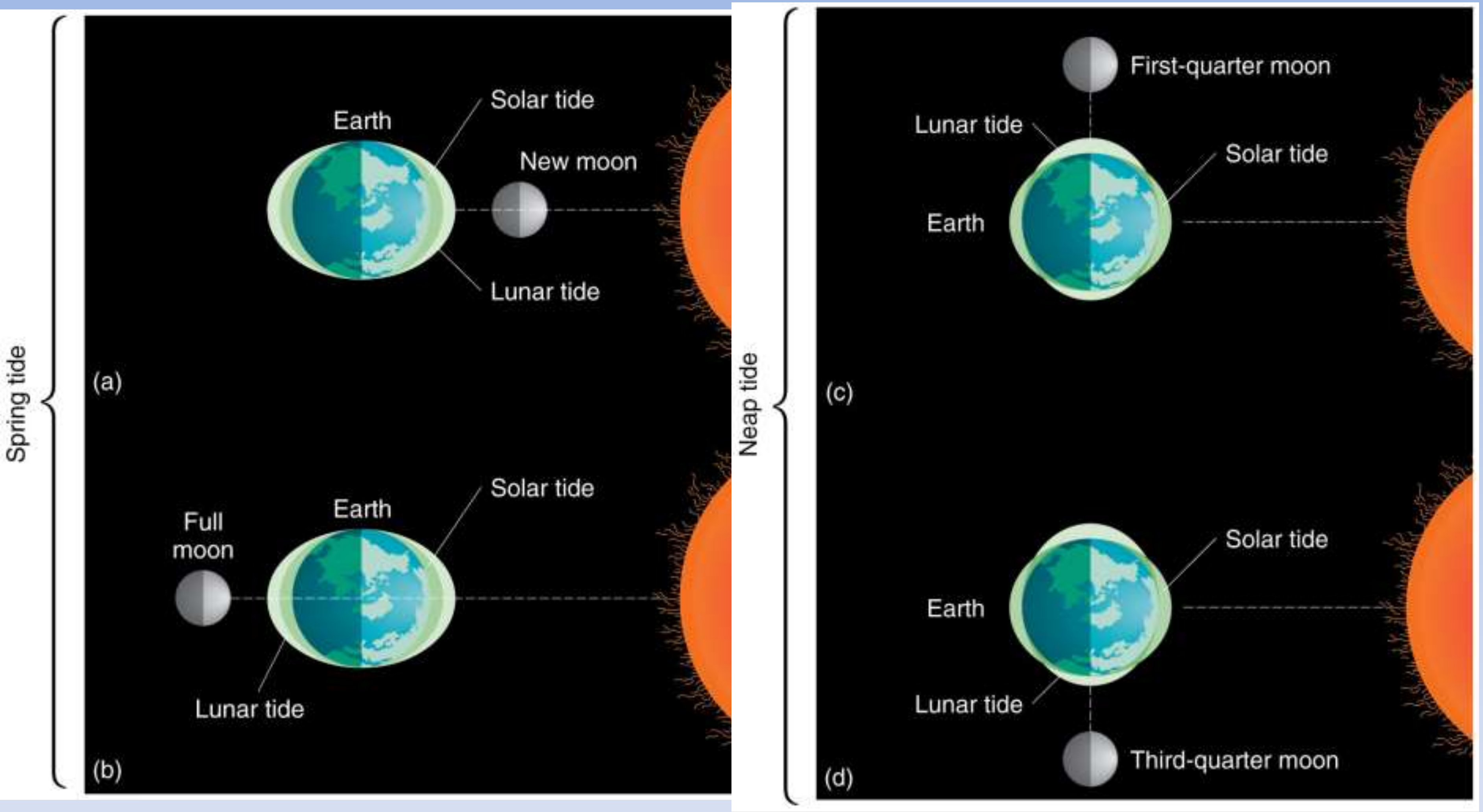
Earthquake triggered tsunami

Tides

- Tides are the high waves which are result of gravitational pull of moon and sun.
- Most oceanic coastlines experience two high tides and two low tides each day



Tidal forces



Tides enhanced during full Moon and new Moon
Sun-Moon-Earth closely aligned

Ocean Currents

An **ocean current** is a continuous, directed movement of ocean water generated by the forces acting upon this mean flow, such as wind, Coriolis effect, temperature and salinity differences and tides caused by the gravitational pull of the Moon and the Sun.

Coastal processes

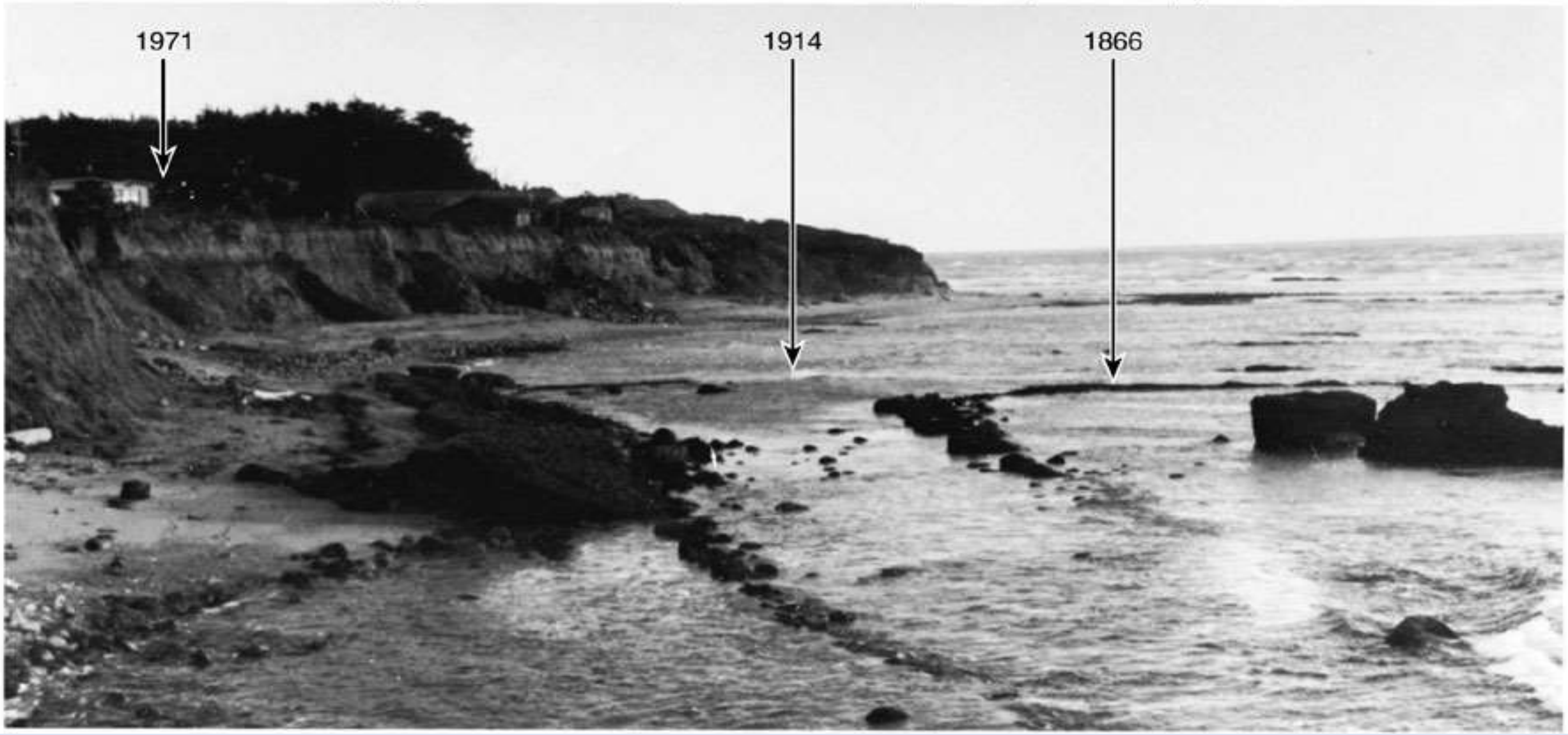
- Coastal processes are the set of mechanisms that operate along a coastline, bringing about various combinations of erosion and deposition.
- The land water interface along the coastline is always in a highly dynamic state and nature works towards maintaining an equilibrium condition.

Coastal Mechanism

- Coastal erosion
- Longshore drift
- Coastal deposition

Coastal Erosion

Coastal erosion is the wearing away of land, or the removal of beach, by wave action.



The rates of shoreline erosion

Processes of erosion

Processes of erosion

Attrition

Materials carried by the waves bump into each other and so are smoothed and broken down into smaller particles.

Hydraulic action

This process involves the force of water against the coast. The waves enter cracks (faults) in the coastline and compress the air within the crack. When the wave retreats, the air in the crack expands quickly, causing a minor explosion. This process is repeated continuously.

Corrosion

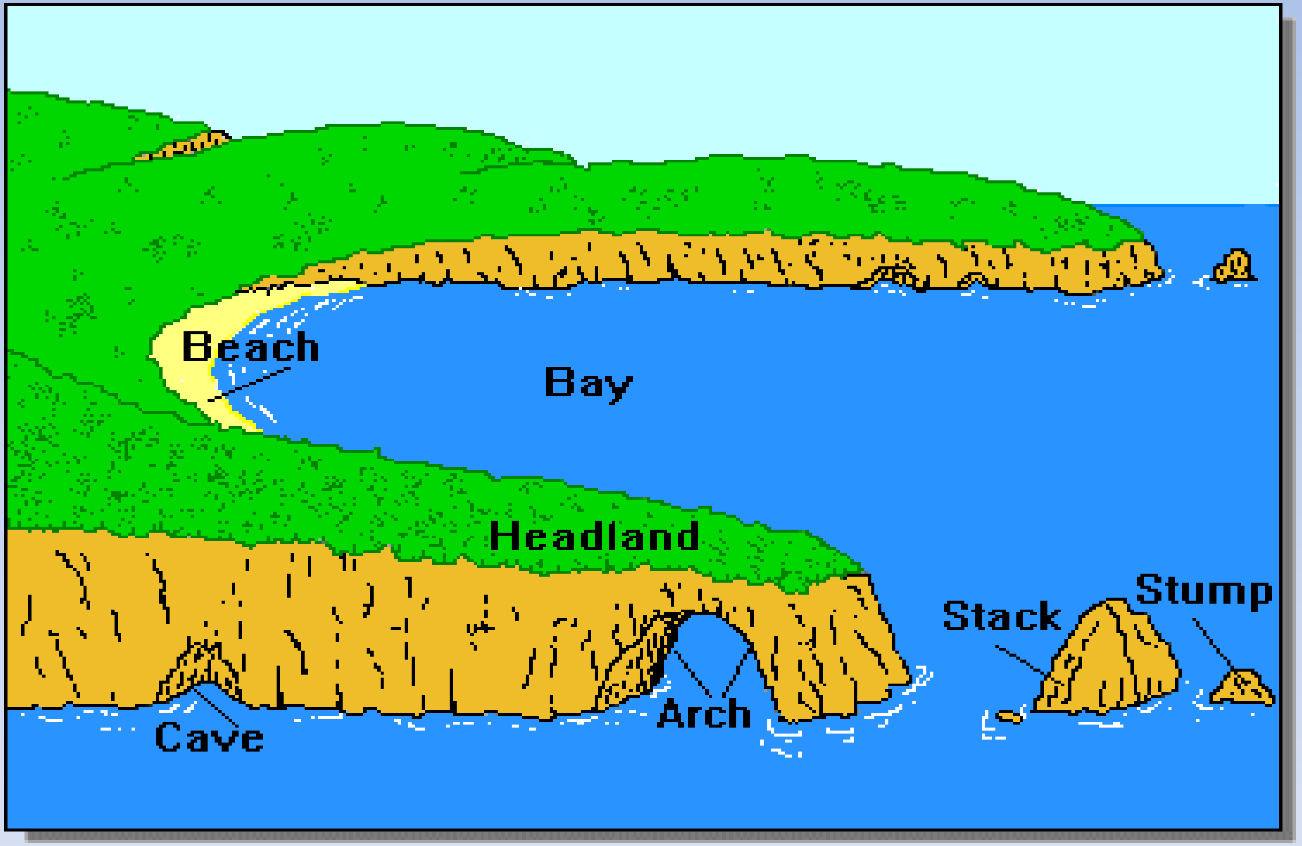
This is the chemical action of sea water. The acids in the salt water slowly dissolve rocks on the coast. Limestone and chalk are particularly prone to this process.

Abrasion/Corrasion

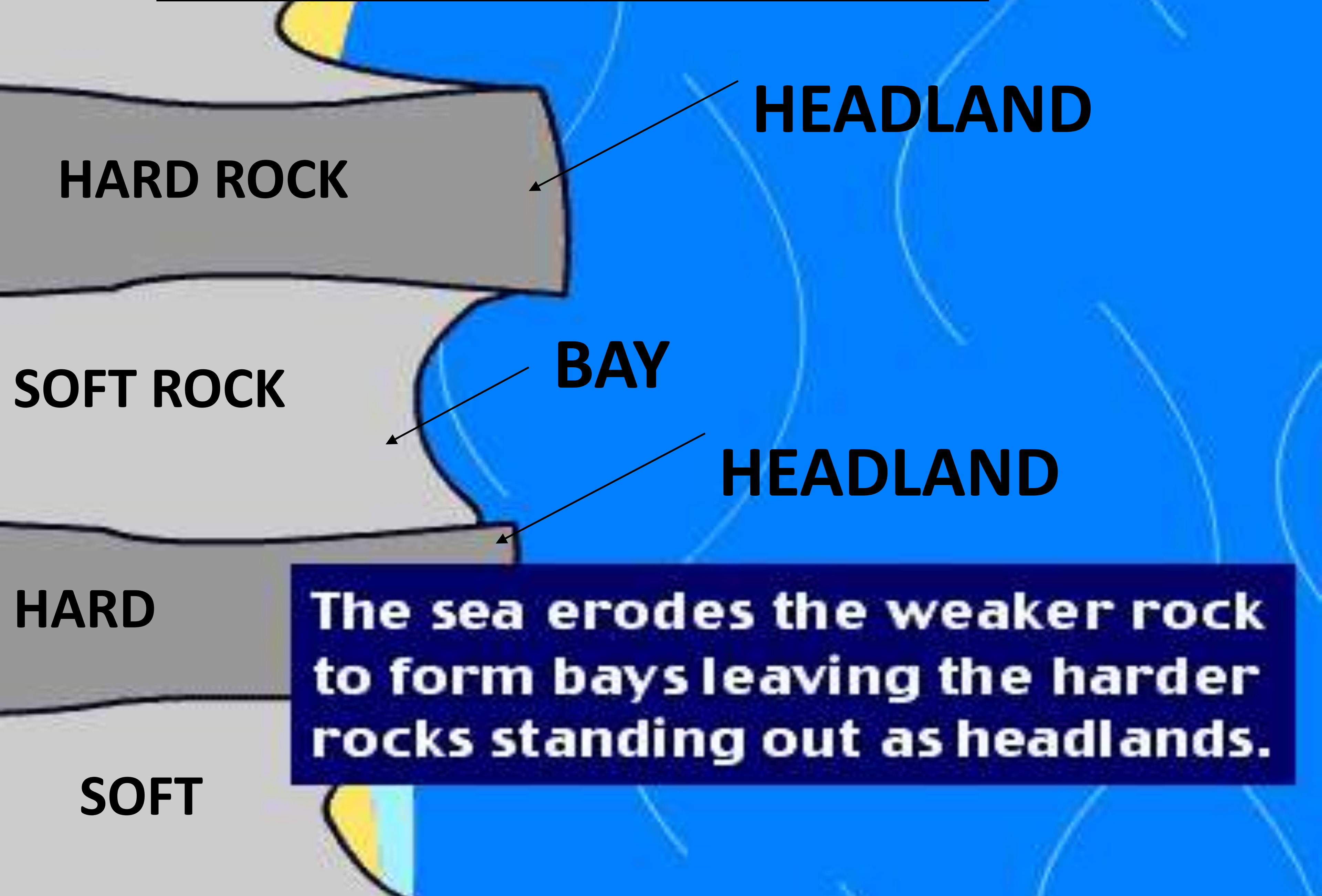
This is the process by which the coast is worn down by material carried by the waves. Waves throw these particles against the rock, sometimes at high velocity.

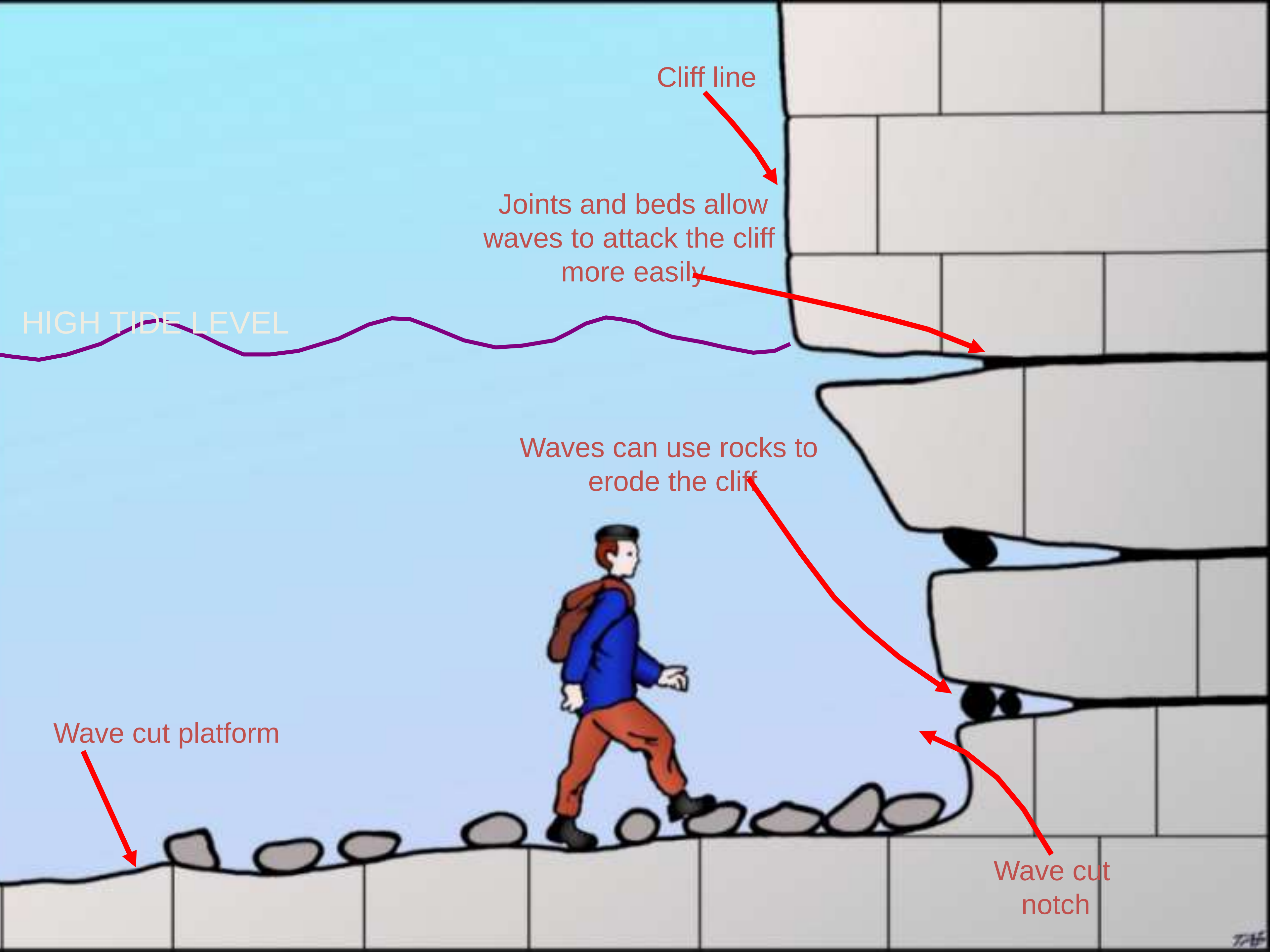
Erosional landforms of shores

- Headland
- Wave-cut cliff
- Sea cave
- Sea arch
- Sea stack



DISCORDANT COASTLINE




Cliff line
Joints and beds allow waves to attack the cliff more easily
HIGH TIDE LEVEL
Waves can use rocks to erode the cliff
Wave cut platform
Wave cut notch

cliff

crack

cave

arch

pillar

stack

stump

reef

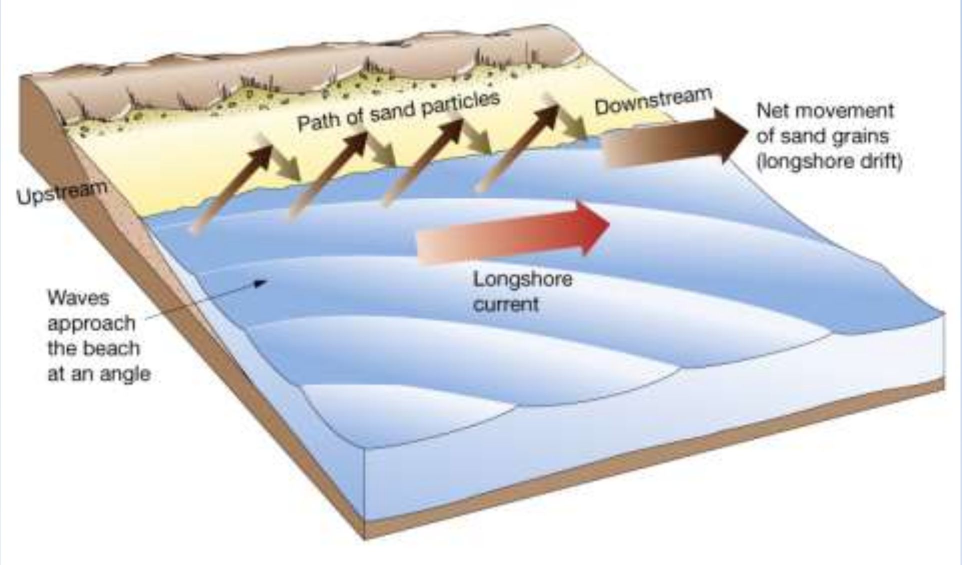
coastal retreat

original photo

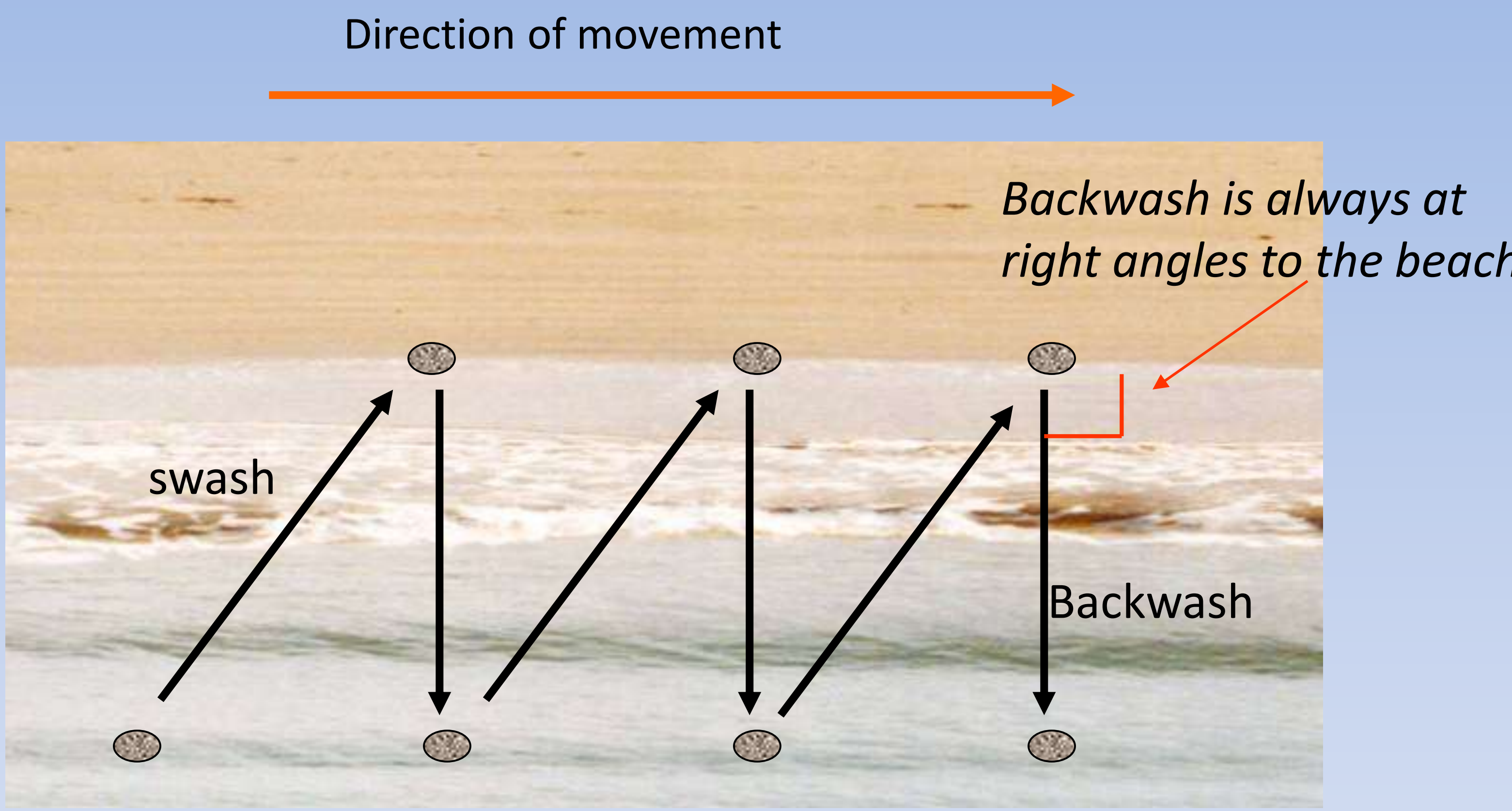
http://www.leler.com/hawaii/

Longshore current and longshore drift

- **Longshore current** - zigzag movement of water in the surf zone
- **Longshore drift** - movement of sediment caused by long shore current



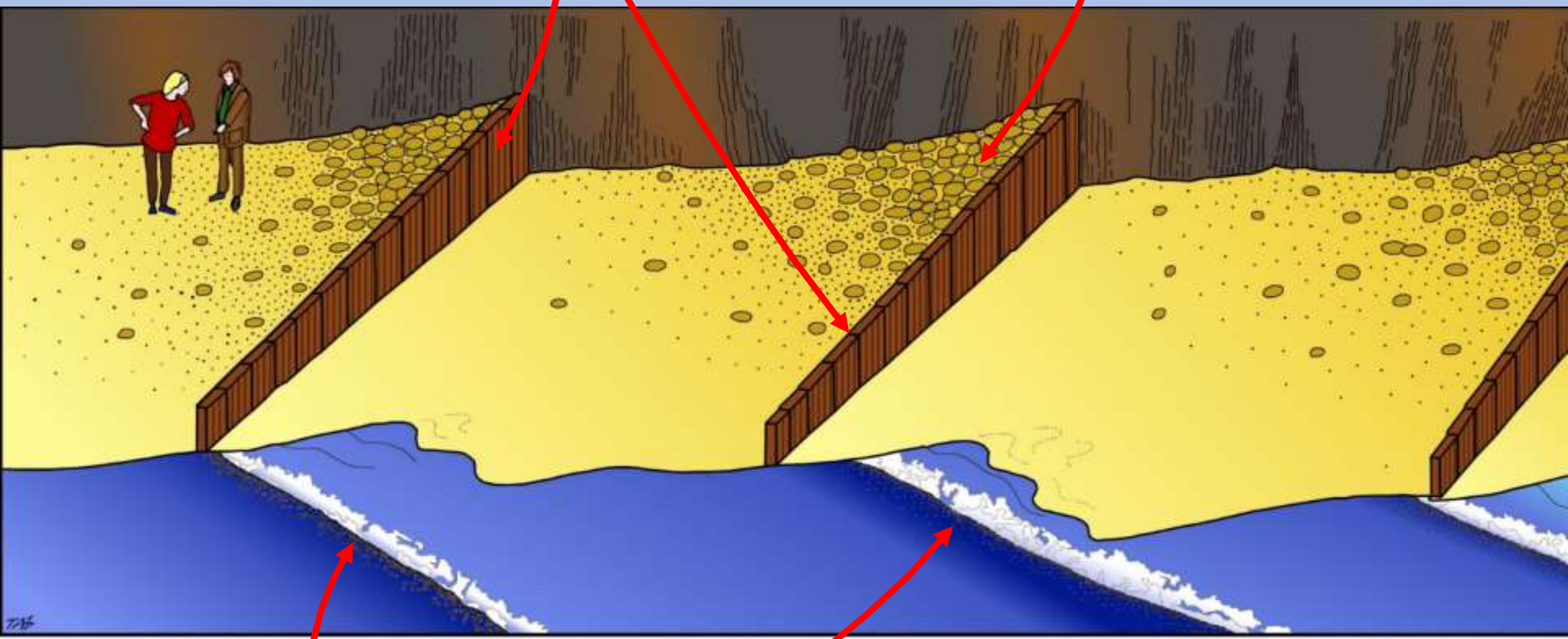
Longshore drift



This movement of sediment along the coastline is called **longshore drift**.

Groynes

Sediment accumulation due to Longshore Drift



Waves approach beach at oblique angle

Depositional landforms of ocean

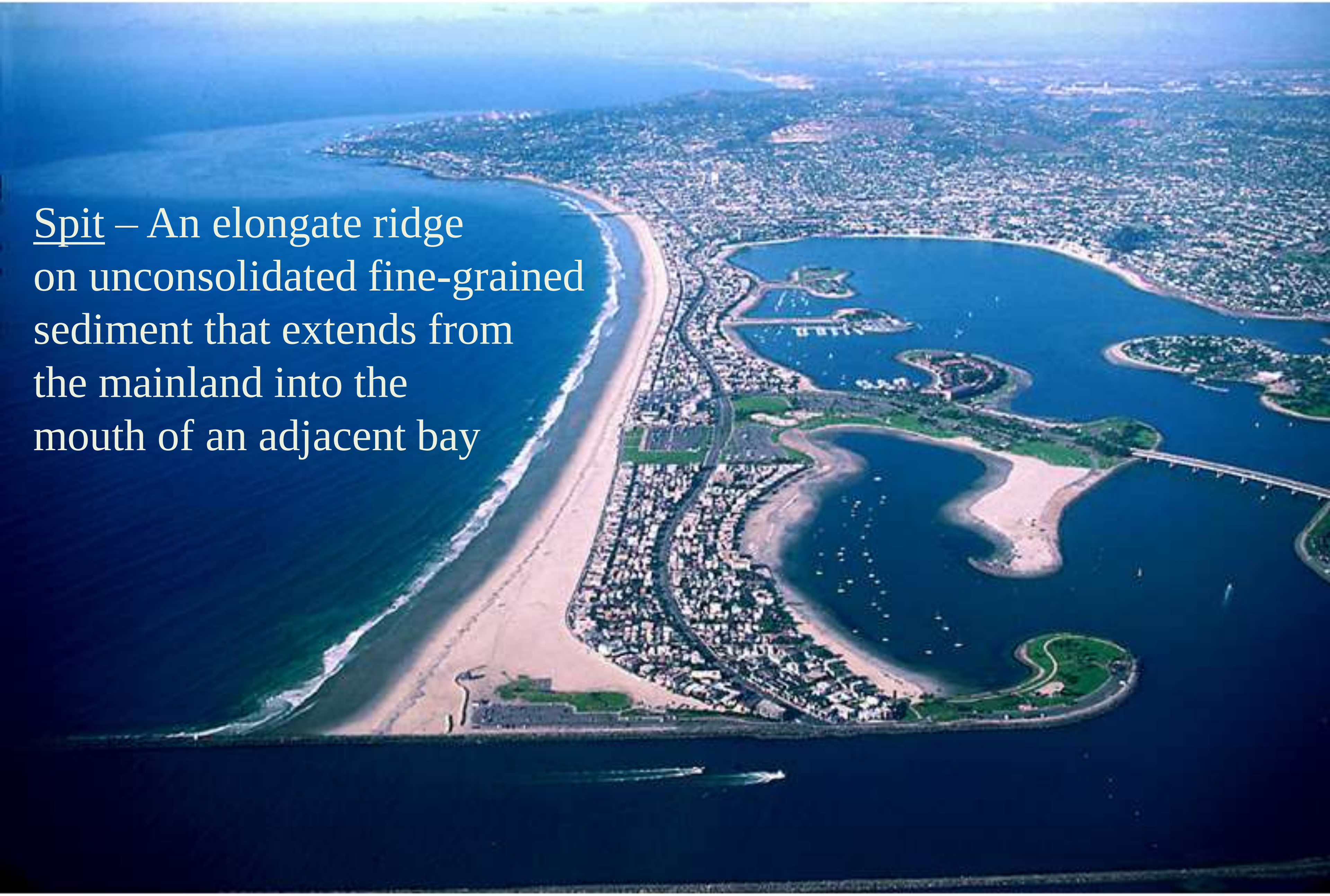
- Beach
- Spit
- Bay
- Tombolo
- Barrier island

Beach – An accumulation of unconsolidated sediment along the landward margin of a sea shore.

How are beaches formed?

Beaches form in sheltered environments, such as bays. When the swash is stronger than the backwash, deposition occurs.

Sometimes sand from offshore bars can be blown onto the shore by strong winds.



<u>Spit</u> – An elongate ridge on unconsolidated fine-grained sediment that extends from the mainland into the mouth of an adjacent bay

What is bar?

If a spit joins one part of the mainland to another it is called a **bar**.

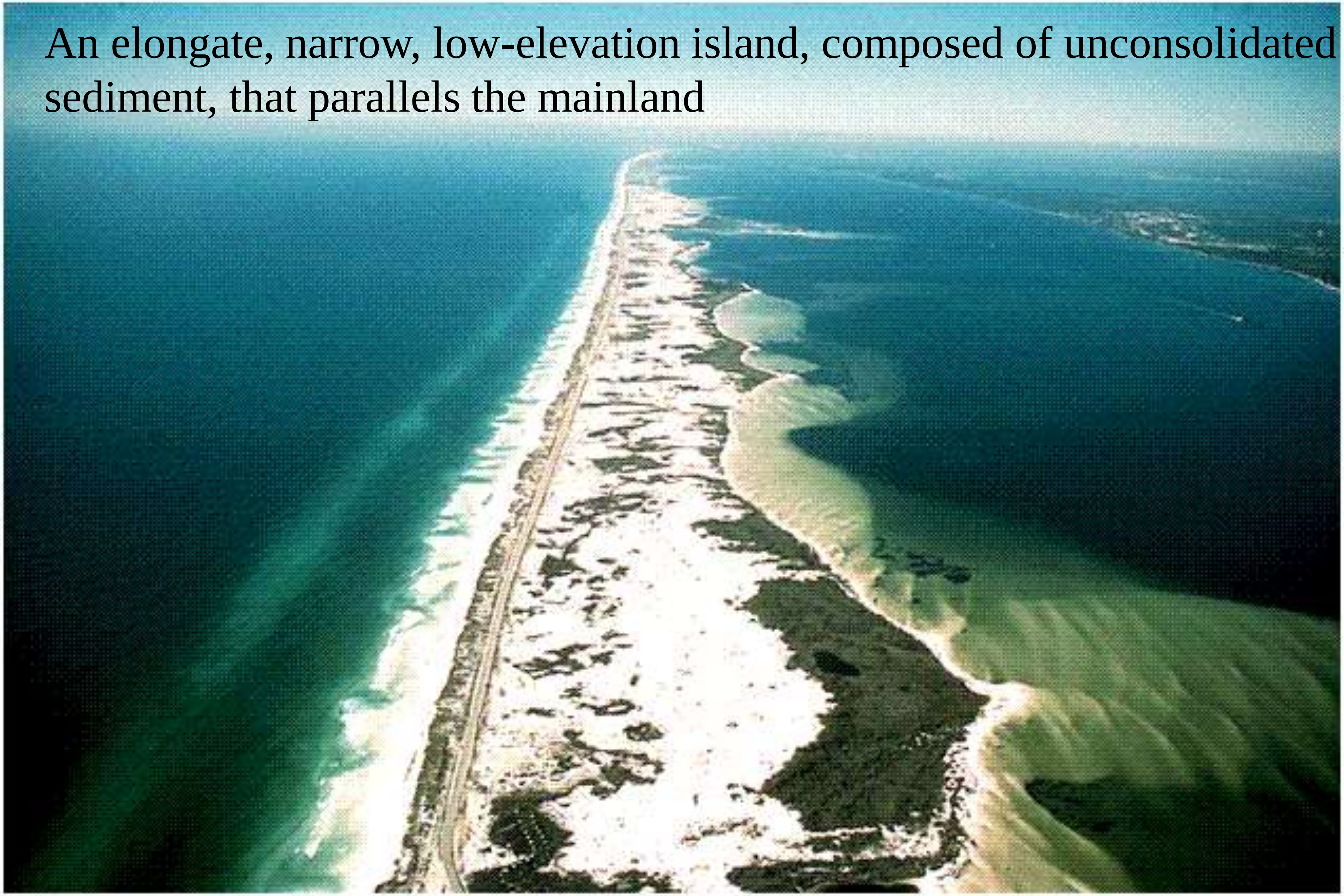
A lagoon is a body of water behind the barrier

Tombolo

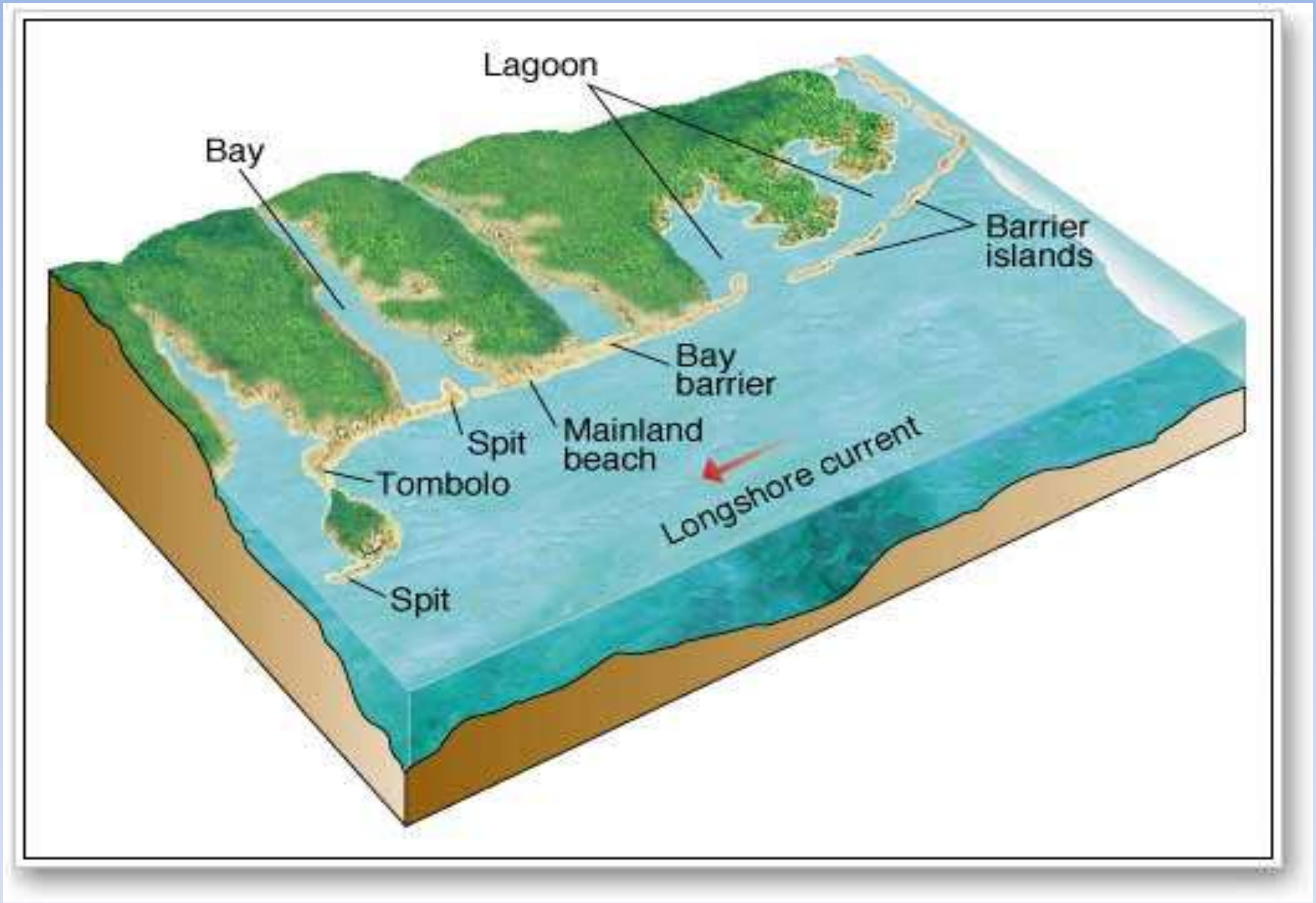
A tombolo occurs when sediment deposits connect the shoreline with an offshore sea stack or island

B

A Barrier Island



Barrier island, New Jersey


Lagoon
Bay
Barrier
islands
Bay
barrier
Mainland
beach
Spit
Tombolo
Longshore current
Spit

Effects of coastal processes

- Environmental quality
- Habitat sustainability
- Near shore destructions

Coastal erosion in India

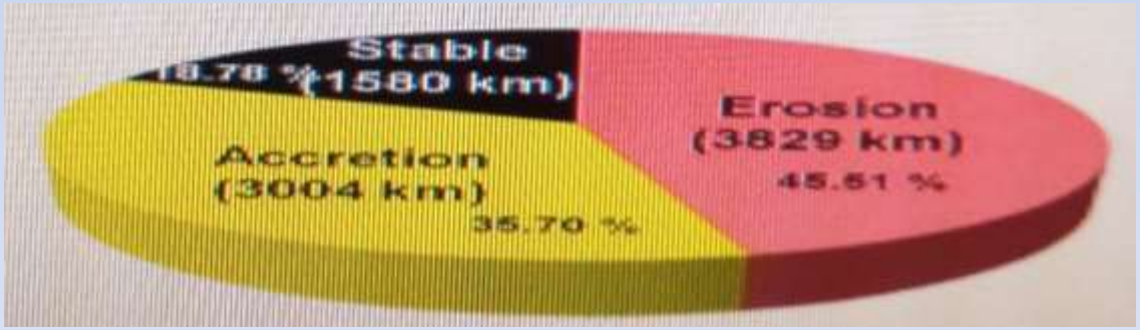


Table-2: Coastal length under erosion, accretion and as stable in different Maritime States/Union Territories of India (Excludes mouths of rivers/streams/creeks and their inner parts)

Maritime States and Union Territories* (UT)	Erosion Length (km)	Accretion Length (km)	Stable Length (km)	Total Length (km)
Gujarat, Daman* & Diu*	486.43	297.99	697.71	1482.1
Maharashtra	449.5	244.47	48.29	742.26
Goa	27.03	46.98	81.38	155.39
Karnataka	106.12	118.65	73.31	298.08
Kerala	218	294	73.6	585.6
Tamil Nadu and Puducherry*	281.56	514.11	29.25	824.92
Andhra Pradesh	443.88	186.94	340.45	971.27
Odisha	199	205	32.1	436.1
West Bengal	115.06	19.46	147.68	282.2
Lakshadweep Islands *	72.03	63.24	1.01	136.28
Andaman Islands*	740.37	944.84	36.83	1722
Nicobar Islands*	690.1	68.3	19.23	777.63
Total	3829.1	3004	1580.8	8413.9

conclusion

- Coastal processes are dynamic and highly unpredictable.
- Coastal affecting agents are wind , waves , tides , currents etc.,
- Major coastal erosional landforms are head lands, wave cut cliff, sea-caves, arch, stacks etc.,
- Major depositional landforms are –beaches, spills, bars, tombolo, barrier islands etc.,
- It Is very crucial to understand the near shore physical system, the consequent impact on sediment dynamics , and the coastline's response to it.
- Proper mitigation methods should be implemented in order to reduce coastal erosion.

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SEA LEVEL CHANGES

CONTENTS

INTRODUCTION

- Sea level change is a central concern of the geomorphologists.
- Sea level determines the base level for erosion . Besides , relative vertical movements of land and sea can greatly alter the area of land exposed by exogenic subaerial geomorphic processes.
- The study of sea level is important because it can provide key evidences of climatic change and can also provide a benchmark of estimating rates of tectonic.

EVIDENCES FOR SEA LEVEL CHANGE

A wide range of techniques can be used to unravel the complex history of
Sea level changes. For different time scales, there are different methods. As the time
period grows older , the task of reconstructing the record of sea level changes, either locally or globally becomes difficult.

In contrast to the direct information from tide gauge records, sea level changes, over longer periods of time, are based on indirect information. Relative falls in sea level are demonstrated by elevated shoreline features such as raised beaches, which provide deposits yielding material suitable for dating by radiometric techniques.

A relative rise in sea level is indicated by submerged coastal topography and by drowned river valleys or glacial troughs which, in some instances, can be traced seawards as submarine canyons and channel networks.

Changes in global sea level during the quaternary have been reflected in the oxygen isotope record preserved in the calcareous shells of microfossils, which have accumulated in the sediments deposited on the ocean floor. The recovery of cores drilled at various locations across the world's oceans have thus made it possible to monitor global sea level fluctuations over the last several

Sea level has varied a great deal over geological time, the evidence suggests that

- ❖ Average sea level over all the changes of the last few glaciations and interglacials has been about 50-60 m below it’s present level.
- ❖During the height of the last glaciation (about 18,000 years ago) it was between 110 m and 140 m lower than it is today; and the large areas of the continental shelves were dry land.
- ❖Sea level has risen through the post-glacial period(this is called the flandrian transgression).
- ❖The post-glacial sea level rise was initially fast , but it leveled off about 5,000 to 6,000 years ago.

CONTINUED

Sea level has remained relatively close to it's present position over the last 5,000 to 6,000 years.

Evidences of marine animals in the rocks of highest mountains are found and deep drilling has recorded shallow marine sediments hundreds and even thousands of meter below the modern sea level.

MECHANISMS OF SEA LEVEL CHANGES

The sea level fluctuations over the past 100 M.Y or so indicates that they have involved total movement in excess of 200 M. and have occurred over a wide range of time scales. These fluctuations have been caused by several possible mechanism. However the long-term changes can be grouped into three basic categories:-

1. Those that alter the volume of the world's ocean.
2. Those that change the volume of world's oceans.
3. Those that produce change in the geoid.

The various geological evidences suggest that the mass of water at the surface of earth has not changed significantly since precambrian time. The volume of seawater does vary both in the short-term of a few years, or even during a year, and to a much greater extent over the tens of thousands of year.

The Antarctic Ice sheet developed during the middle and late Tertiary and added it's effect to that of ocean-basin volume change. About 3 to 4 million years ago, extensive ice sheets developed for first time on the northern hemisphere continents and since then ice volume and ice extent have fluctuated widely . At it's most extreme, sea level may have fallen 200 m below that of the present , and risen 5-8 m above present levels.

If ice volume along controlled sea levels uniformly around the coasts , then the sea level evidences would uniformly follow a pattern imposed on it by climate. The sea level curves for the last 15,000 years would show a progressive rise from about 100-130 m below present levels to about the present level 6,000 to 40,000 years ago.

Impact of sea level changes

A rise or fall in the sea level has the most likely effect on land form development. This effects is through a change in the response of drainage basin ,and on the coastal regions . Thus , sea level change can lead to formation of rejuvenated land forms , marine terraces and coral reefs. Besides , the projected sea level change in the near future caused by global warming will have on effect on shrinkage of the land area and the wiping out of some islands because of drowning

Three types of impact of sea level changes

1. Impact of rise in sea level.
2. Impact of fall in sea level.
3. Impact of projected sea level rise.

IMPACT OF RISE IN SEA LEVEL

- A relative rise in sea level reduces the drainage basin area , the sea level fluctuations of the late Cenozoic caused major shifts in drainage area and the periodic sub mergence of extensive drainage systems in the relatively brief interludes of high interglacial sea level such as the one being experienced in the present day.

Impact of fall in sea level

- A fall in the level of the sea especially where the continental shelf is shallow will lead to greater aridity in the continental hinterland and a consequential reduction in runoff.
- A drop in the sea level causes ice caps and glacial tongues to be extended onto the shelf proper . In temperate and high latitude, flowing ice scored and plucked the shelf bottom. In some case, it smoothed out the tops of hills; In others, it gouged out irregular topography, including fjords, and created considerable local relief. Also, glaciers dumped debris on the shelf floor, forming blankets of till (unsorted deposits of boulders, sand, and mud) and hummocky hill deposits at their terminal.

IMPACT OF PROJECTED SEA LEVEL RISE

It is projected that the sea level will rise in the near future. There are many possible impacts of such rise , these include-

1. Damage to many important coastal ecosystem , including deltas , coral atolls and reefs.
2. Flooding of many densely populated areas.
3. Damage to port facilities and coastal structures.
4. Severe coastal erosion in many countries, including loss of beaches and dunes.
5. Decline of loss of production in up to one-third of the world's croplands .

CONCLUSIONS

- A wide range of techniques can be used to unravel the complex history of sea level changes. For different time scales, there are different methods. As the time period grows older, the task of reconstructing the record of the sea level changes, either locally or globally becomes difficult.

- Evidences of marine animal in the rock of highest mountains are found and deep drilling has record shallow marine sediments even hundred to thousands of meter below the modern sea level.

- The various geological evidence suggest that the water at the surface of the earth has not changed significant since Precambrian time.

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3. www.sealevelchanges.com
4. www.wikipedia.com

COASTAL REGULATION ZONE

BUILDING CODES AND BYE LAWS

| ABHISHEK JAIN | AKSHAY SURESH | ASHWINTH M | DIGVIJAY S BARDIA | | NIGEL DOS SANTOS | PALAK GUPTA | NEHA AMBATI | |UTKARSH SRIVASTAVA | VAISHNAVI BARGOTRA|

INTRODUCTION

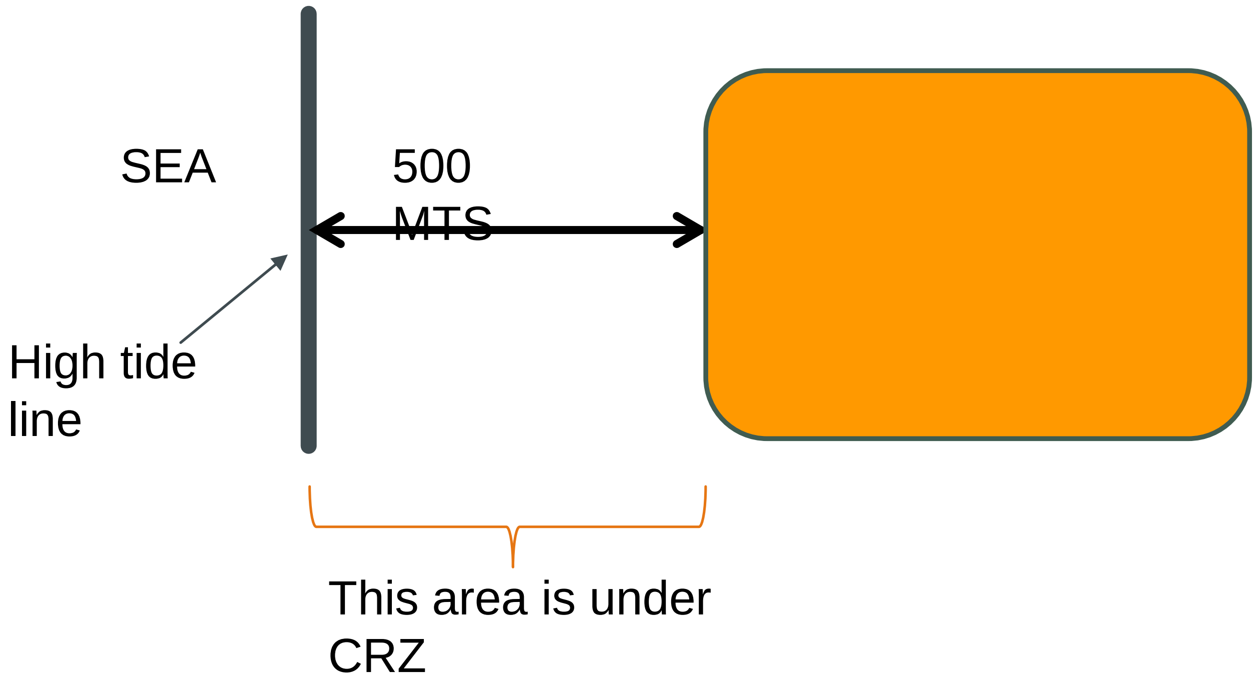
- The Government of India earlier issued instructions to all state governments to prohibit development activities within 500 M of coastal stretches of High Tide Line.
- This has been done after considering the need for protecting the coastal areas and beaches from environmental degradation.
- Prohibition of developmental activities of any kind has caused considerable problems to State Governments as there are existing developed areas within the stretch of 500 M.
- Keeping this in view and ensuring that the use and activities in the coastal areas are consistent with principles and requirements of environment conservation, the Government of India has proposed Coastal Regulations Zone and to impose restrictions on developmental activities.
- These regulations among other things permit developments in the area already developed/partly developed with certain restrictions and subject to land use and other regulations framed under the Town & Country Planning Act prevailing in the State.

TERMS

- HIGH TIDE LINE (HTL) : means the line on the land upto which the highest water line reaches during the spring tide.
- LOW TIDE LINE (LTL) : The lowest level of water on the shore.
- SEASHORE: An area of sandy, stony, or rocky land bordering and level with the sea. Area between HTL and LTL.

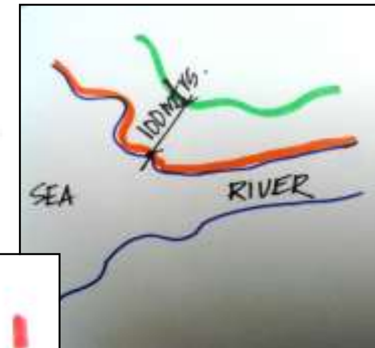
RESTRICTED AREAS (AREAS UNDER CRZ)

- The land area from high tide line (HTL) to 500mts on landward side along the sea front.



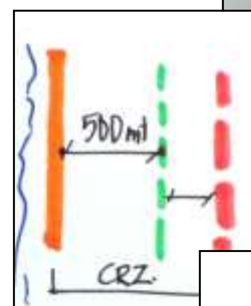
RESTRICTED AREAS (AREAS UNDER CRZ)

- CRZ shall apply to the land between the HTL to 100mts or width of the tidal influenced water bodies that are connected to the sea(whichever is lesser).

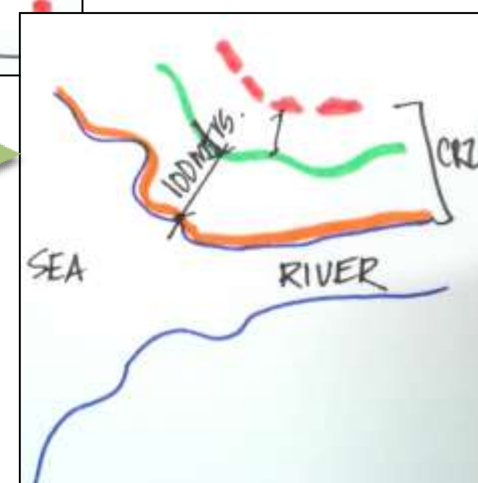


Plans

- The land area falling between the hazard line and 500mts from HTL – landward side in case of seafront



- The land area falling between the hazard line and 100 mts in case of tidal influenced water body



- The land area between the HTL and LTL (low tide level) will be termed as intertidal zone

Orange- HTL
Green- land zone
Red – hazard line

RESTRICTED AREAS (AREAS UNDER CRZ)

- The distance upto which development along tidal influenced water bodies is to be regulated shall be governed by the distance up to which the tidal effects are experienced which shall be determined based on the salinity concentration. Concentration levels of five parts per 1000.
- For lakes, minimum of 30 m buffer to be kept.

Width of creek	Width of CRZ belt
100m or less	Up to 100m or less
100-350m	100m
>350m	150m

WIDTH OF CRZ BELT IN CREEKS

What is the width of Coastal Regulation zone in case of sea and in case of creeks and rivers and backwaters ?

- for sea is 500mt. from the High Tide Line.
- for Creeks and backwaters

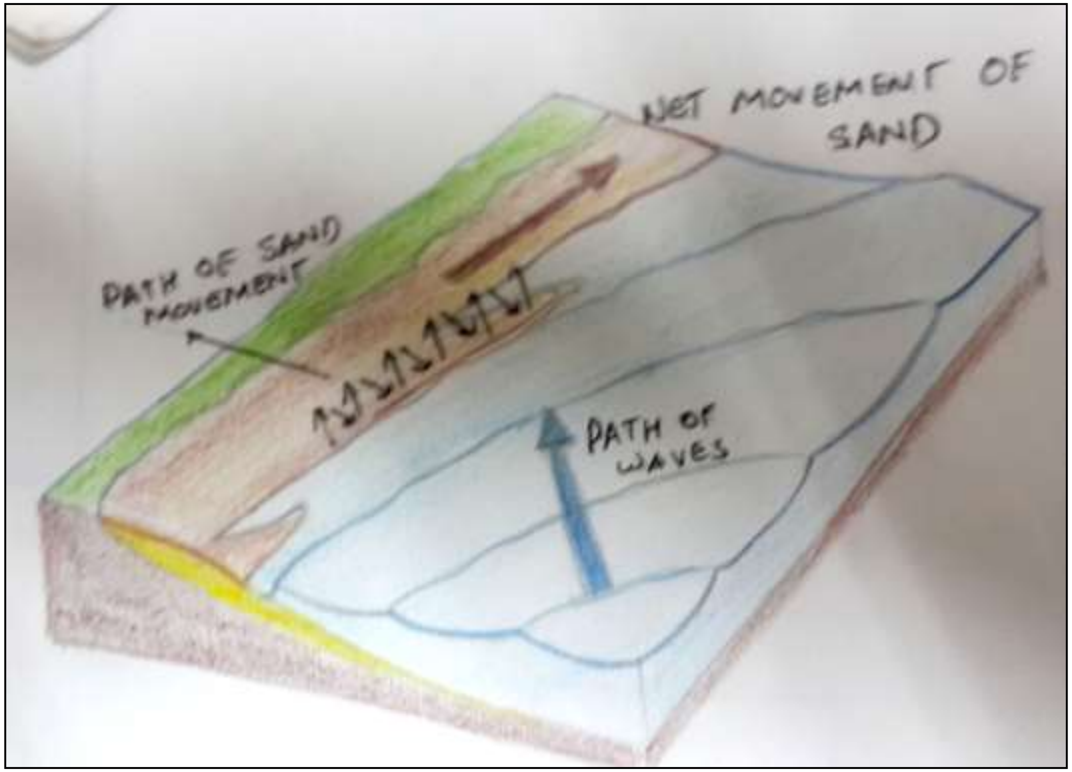
Width of creek	Width of CRZ belt
100m or less	Up to 100m or less
100-350m	100m
>350m	150m

C.Z.M.P.

What is Costal Zone Management Plan?

- Identifying coastal stretches & classifying them in different CRZ areas.
- Integrated development of these areas.
- State level coastal management authority responsible for monitoring

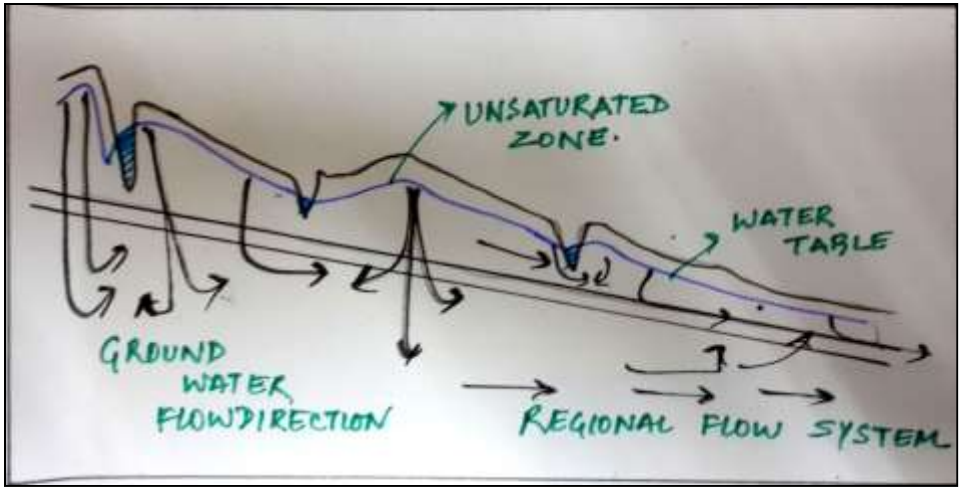
FLOW OF TIDES



Isometric view

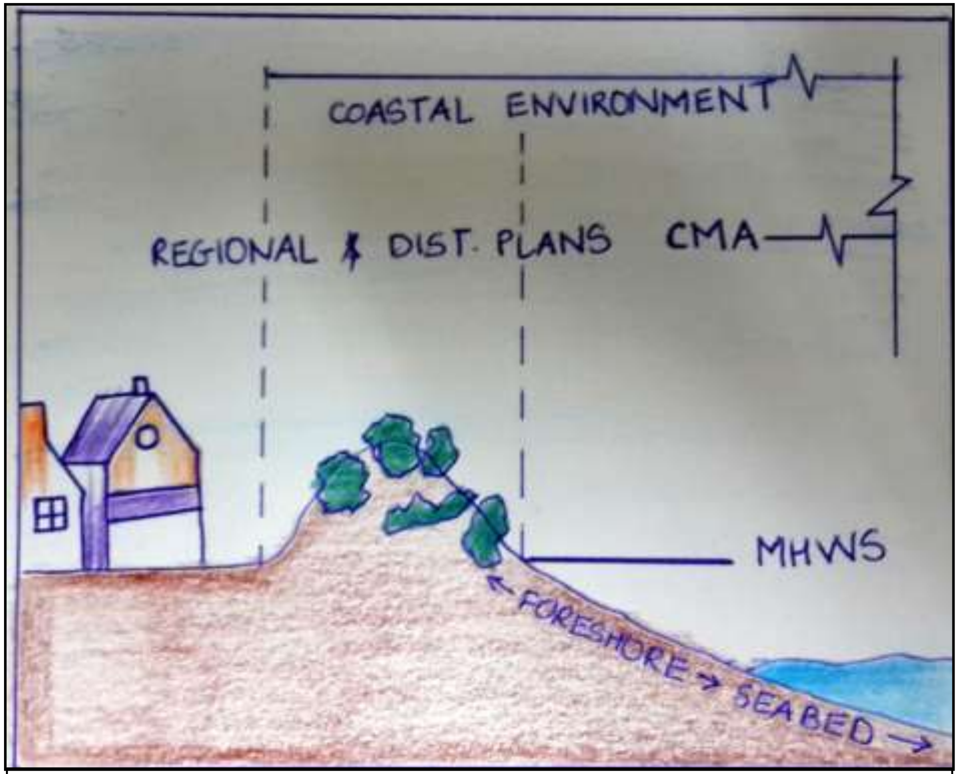
- The following diagram show the different layers in a coastal region.
- The diagram depicts to the layers to which a foundation is to be dugged for a better grip hold the stilts or the construction of the building.

SAND DUNES TO TRAP WATER DURING HIGH TIDE



- The ground water table plays an important role in the construction of the building.
- The ground water flow can put a tidal force on the foundation of the building.
- Thus the foundation should be designed so as to exert an equivalent force to the tidal force

PROTECTION FROM HIGH TIDES USING SAND DUNES

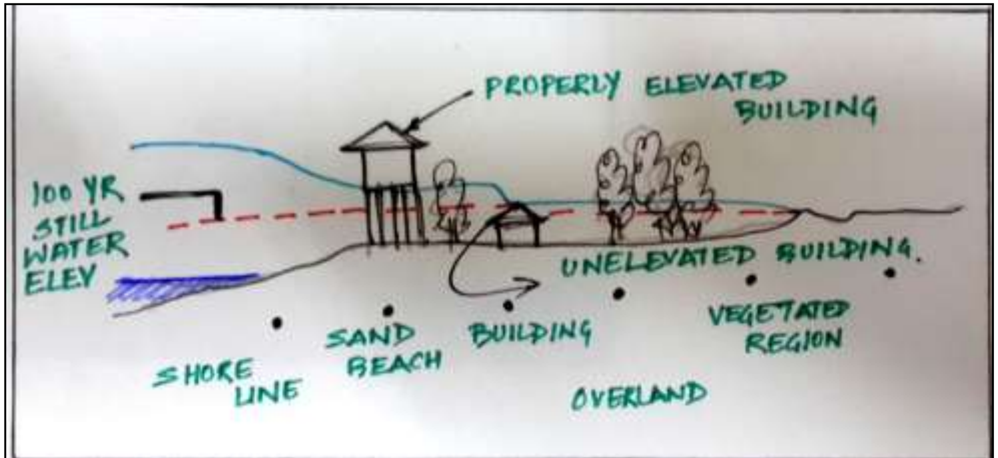


Section of seashore and sand dune

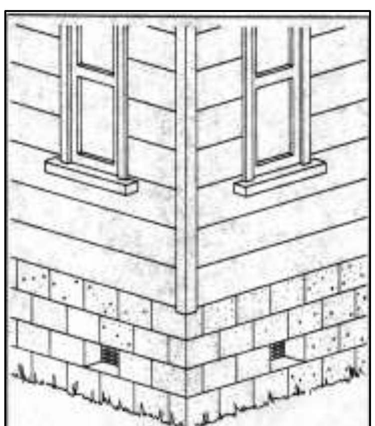
- There are various ways through which we can protect the construction in the coastal region.
  Different ways are:

- Building a huge sand dune in front of the house.
- Building an retaining wall.
- Construction over stilts.

CONSTRUCTION METHODS IN CRZ



Section



Foundation to a certain height made of bricks to give maximum support during high tides.

- The construction in coastal region should preferably be done on stilts so as to prevent the house from high and low tides, which can lead to destruction.
- Raising the houses on stilts not only prevent the tides but also helps in proper ventilation inside the house.
- The diagram shows the difference between an unelevated and an elevated house.
- The construction on sand is practically impossible as the sand recedes along with the water during high tides.
- Foundation and Stilts are the most important step in construction. With stronger foundation and stilts the destruction to the house can be minimal

PROHIBITED ACTIVITIES WITHIN CRZ

- Setting up of new industries and expansion of existing except:
  - Projects of Dept. of Atomic Energy
  - Facilities or generating power by non-conventional energy sources
  - Setting up of desalination plants except in CRZ I.
  - Reconstruction ,repair work of dwelling units of local communities

Those directly related to waterfront or directly needing foreshore facilities

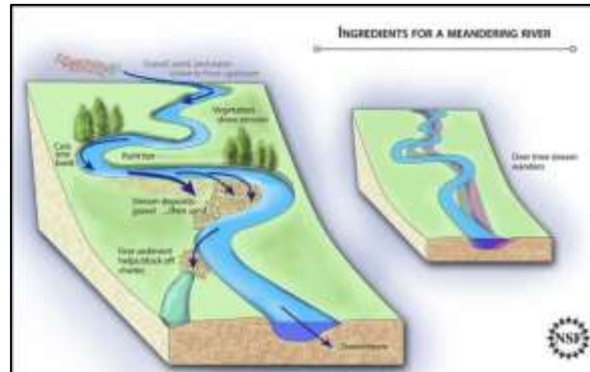
PROHIBITED ACTIVITIES WITHIN CRZ

- Manufacturing and handling of oil storage , disposal of hazardous substances except:

- Transfer from ships to ports, terminals and refineries and vice versa.
- facilities for receipt and storage of petroleum products and liquefied natural gas in the areas not classified as CRZ-I subject to implication of guidelines by the oil Industry Safety Directorate.

PROHIBITED ACTIVITIES WITHIN CRZ

- Setting up and expansion of fish processing units including warehousing except hatchery and natural fish drying permitted areas .
- Land reclamation ,bunding or disturbing the natural course of seawater except:
- required or setting up of expansion like ports ,harbors ,bridges.
- Measure for control of erosion
- Maintenance for clearing of waterways
- Measure to prevent sand bars ,installation of tidal regulators or structures or prevention of salinity



Formation of sandbars

Ports and harbours

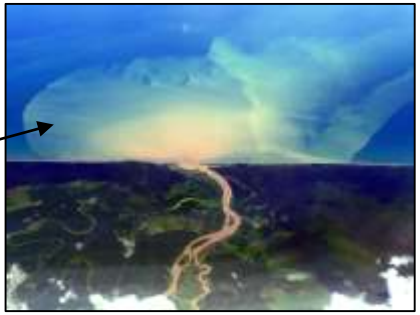
PROHIBITED ACTIVITIES WITHIN CRZ

- Setting up expansion of units or mechanism for disposal of water and effluents except:

- Discharging treated effluents into the water course with approval.
- Storm water drains and ancillary structures for pumping
- Treatment of waste and effluents from human settlement located in CRZ areas.

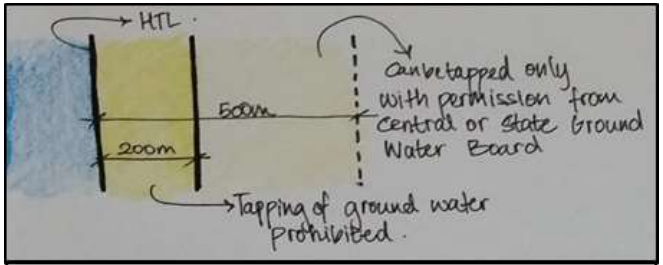
PROHIBITED ACTIVITIES WITHIN CRZ

- Discharge of untreated water and effluents from industries, cities and other human settlement.
- Dumping of cities or towns wastes including constructional debris, industrial solid waste, fly ash for the purpose of land filling.
- Port and harbour projects in high eroding stretches of the coast, except those projects classified as strategic and defence related.
- Reclamation for commercial purposes such as shopping and housing complexes, hotels and entertainment activities.
- Mining of sand, rocks and other sub-strata materials except



PROHIBITED ACTIVITIES WITHIN CRZ

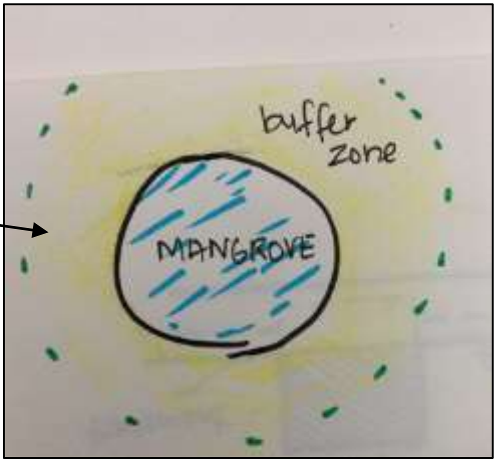
- Drawl of groundwater and construction related thereto, within 200mts of HTL; except the following:-
  - in the areas which are inhabited by the local communities and only for their use.
  - In the area between 200mts-500mts zone the drawl of groundwater shall be permitted only when done manually through ordinary wells for drinking, horticulture, agriculture and fisheries and where no other source of water is available.
- Dressing or altering the sand dunes, hills, natural features including landscape changes for beautification, recreation and other such purpose.
- Facilities required for patrolling and vigilance activities of marine/coastal police stations.

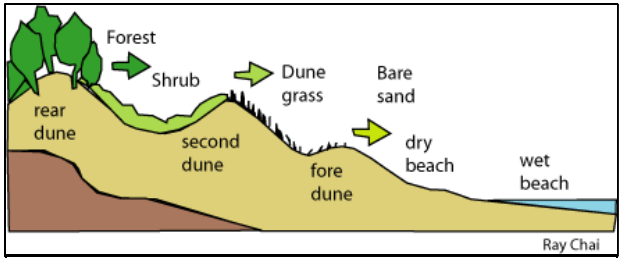


Tapping of ground water

CLASSIFICATION OF CRZ

- CRZ 1
- The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast,-
  - Mangroves, in case mangrove area is more than 1000 sq mts, a buffer of 50meters
  - Corals and coral reefs and associated biodiversity;
  - Sand Dunes;
  - Mudflats which are biologically active;
  - National parks, marine parks, sanctuaries, reserve forests, wildlife habitats and other along the mangroves shall be provided; protected areas under the provisions of Wild Life (Protection) Act, 1972 (53 of 1972), the Forest (Conservation) Act, 1980 (69 of 1980) or Environment (Protection) Act, 1986 (29 of 1986); including Biosphere Reserves;





Sand dunes

Mud flats

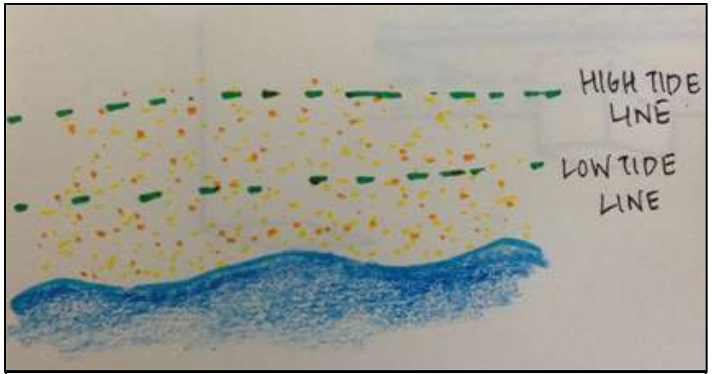
Coral reefs

CLASSIFICATION OF CRZ

- Salt Marshes;
- Turtle nesting grounds;
- Horse shoe crabs habitats;
- Sea grass beds;
- Nesting grounds of birds;
- Areas or structures of archaeological importance and heritage sites.

Sea grass beds

- The area between Low Tide Line and High Tide Line.



Plan

NORMS FOR REGULATION OF ACTIVITIES

CRZ-I

- no new construction shall be permitted in CRZ-I except,-
  - projects relating to Department of Atomic Energy
  - pipelines, conveying systems including transmission lines
  - facilities that are essential for activities permissible under CRZ-I
  - installation of weather radar for monitoring of cyclones movement and prediction by
  - construction of trans harbour sea link and without affecting the tidal flow of water,

NORMS FOR REGULATION OF ACTIVITIES

- Areas between LTL and HTL which are not ecologically sensitive, necessary safety measures will be incorporated while permitting the following, namely:-

- exploration and extraction of natural gas;
- construction of dispensaries, schools, public rainshelter, community toilets, bridges, roads, jetties, water supply, drainage, sewerage which are required for traditional inhabitants living within the biosphere reserves after obtaining approval from concerned CZMA.
- necessary safety measure shall be incorporated while permitting such developmental activities in the area falling in the hazard zone;
- salt harvesting by solar evaporation of seawater;
- desalination plants;
- storage of non-hazardous cargo such as edible oil, fertilizers and food grain within notified ports;
- construction of trans harbour sea links, roads on stilts or pillars without affecting the tidal flow of water.

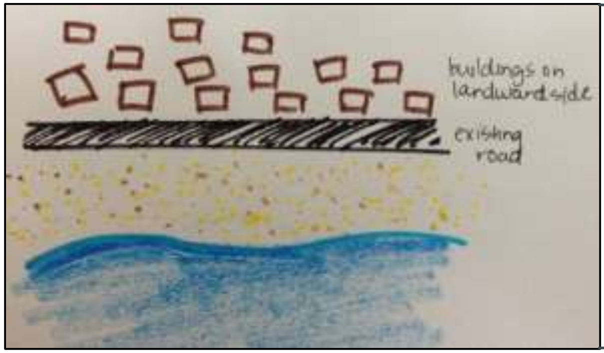
CLASSIFICATION OF CRZ

CRZ II

- The areas that have been developed upto or close to the shoreline.
- Developed area: area within the existing municipal limits or in other existing legally designated urban areas which are substantially built-up and has been provided with drainage and approach roads and other infrastructural facilities, such as water supply and sewerage mains

CRZ III

- Areas that are relatively undisturbed and those do not belong to either CRZ-I or II which include coastal zone in the rural areas (developed and undeveloped) and also areas within municipal limits or in other legally designated urban areas, which are not substantially built up.

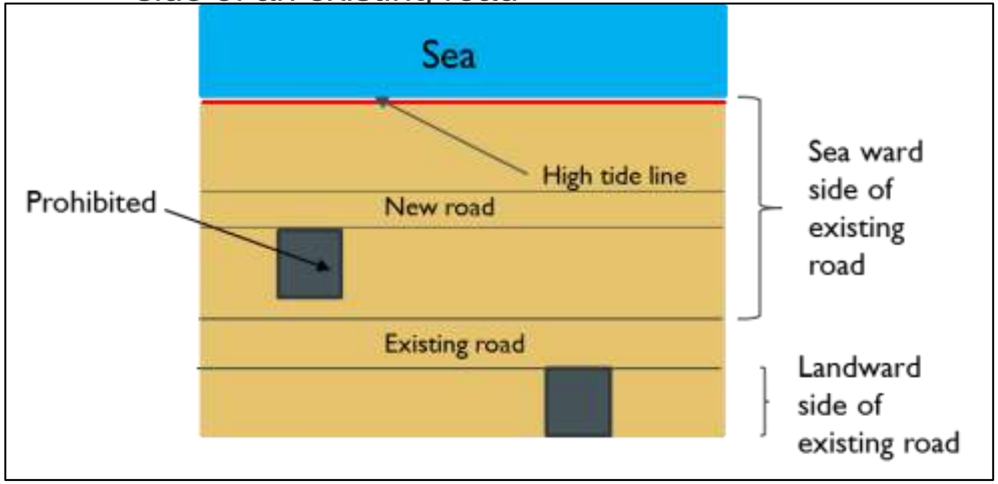


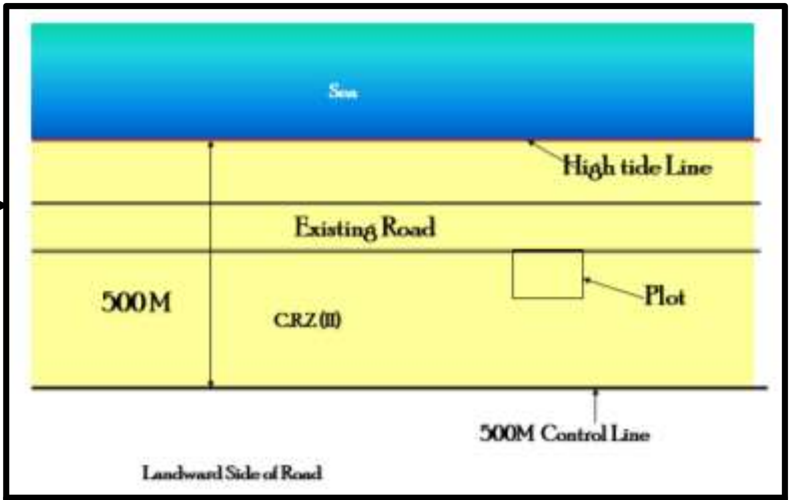
Buildings are only permitted on the landward side if there is an existing road in close proximity to the coastal line.

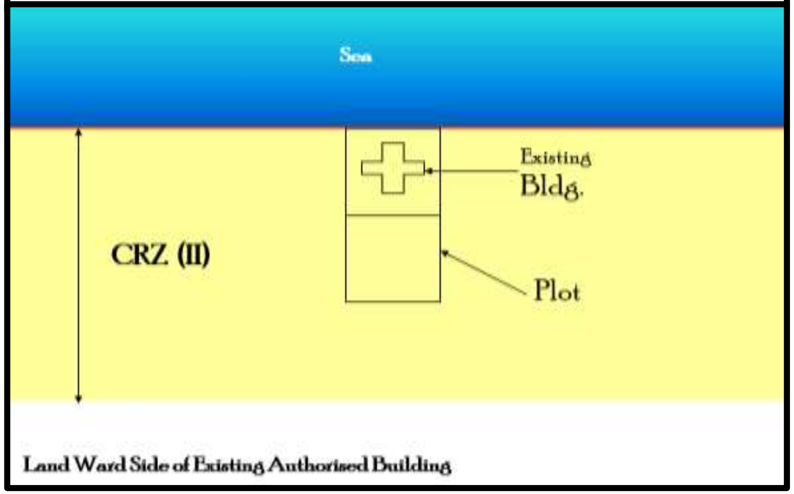
NORMS FOR REGULATION OF ACTIVITIES

CRZ-II

- buildings shall be permitted only on the landward side of the existing road, or on the landward side of existing authorized structures;
- Buildings shall be subject to the existing local town and country planning regulations including the ‘existing’ norms of Floor Space Index or Floor Area Ratio:
- Provided that no permission for construction of buildings shall be given on landward sideof any new roads which are constructed on the seaward side of an existing road







NORMS FOR REGULATION OF ACTIVITIES

- reconstruction of authorized building to be permitted subject with the existing Floor Space Index or Floor Area Ratio Norms and without change in present use
- facilities for receipt and storage of petroleum products and liquefied natural gas
- desalination plants and associated facilities;
- storage of non-hazardous cargo, such as edible oil, fertilizers and food grain in notified ports;
- facilities for generating power by non-conventional power sources and associated facilities;

NORMS FOR REGULATION OF ACTIVITIES

CRZ III

Area upto 200mts from HTL on the landward side in case of seafront and 100mts along tidal influenced water bodies or width of the creek whichever is less is to be earmarked as “No Development Zone (NDZ)”.

Construction/reconstruction of dwelling units of traditional coastal communities including fisherfolk may be permitted within 100-200 m by the government in consultation with the traditional coastal communities and concerned authorities.

the NDZ shall not be applicable in such area falling within any notified port limits;

- No construction shall be permitted within NDZ except:
  - repairs or reconstruction of existing authorized structure not exceeding existing Floor Space Index, existing plinth area and existing density and for permissible activities under the notification including facilities essential for activities.
  - Dwelling units for traditional coastal communities and fisher folk.

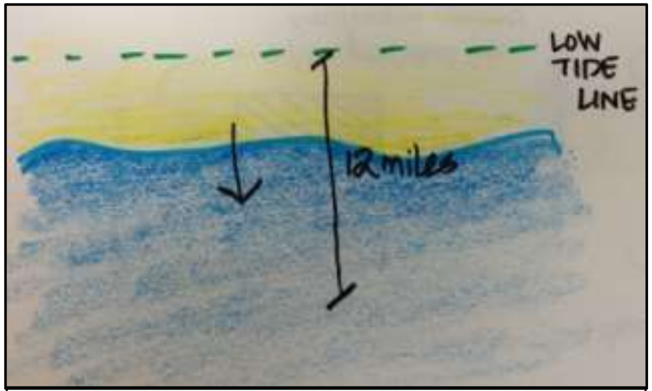
NORMS FOR REGULATION OF ACTIVITIES

- However, the following activities may be permitted in NDZ –
- agriculture, horticulture, gardens, pasture, parks, play field, and forestry;
- projects relating to Department of Atomic Energy;
- mining of rare minerals;
- salt manufacture from seawater;
- facilities for receipt and storage of petroleum products and liquefied natural gas as specified in Annexure-II;
- facilities for generating power by non conventional energy sources;
- Foreshore facilities for desalination plants and associated facilities;
- weather radars;
- construction of dispensaries, schools, public rain shelter, community toilets, bridges, roads, provision of facilities for water supply, drainage, sewerage, crematoria, cemeteries and electric sub-station which are required for the local inhabitants may be permitted on a case to case basis by CZMA;
- construction of units or auxiliary thereto for domestic sewage, treatment and disposal with the prior approval of the concerned Pollution Control Board or Committee;
- Facilities required for local fishing communities such as fish drying yards, auction halls, net mending yards, traditional boat building yards, ice plant, ice crushing units, fish curing facilities and the like;

CLASSIFICATION OF CRZ

CRZ IV

- the water area from the Low Tide Line to twelve nautical miles on the seaward side;
- shall include the water area of the tidal influenced water body from the mouth of the water body at the sea upto the influence of tide which is measured as five parts per thousand during the driest season of the year.



Plan

Backwaters – A tidal influenced water body

NORMS FOR REGULATION OF ACTIVITIES

CRZ-IV

- The activities impugning on the sea and tidal influenced water bodies will be regulated except for traditional fishing and related activities undertaken by local communities as follows:-
  - No untreated sewage, effluents, ballast water, ship washes, fly ash or solid waste from all activities including from aquaculture operations shall be let off or dumped. A comprehensive plan for treatment of sewage generating from the coastal towns and cities shall be formulated within a period of one year in consultation with stakeholders including traditional coastal communities, traditional fisherfolk and implemented;
  - Pollution from oil and gas exploration and drilling, mining, boat house and shipping;
  - There shall be no restriction on the traditional fishing and allied activities undertaken by local communities.

SPECIAL CONSIDERATION

CRZ V

A.

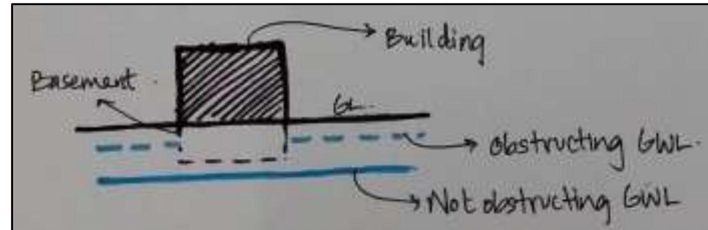
- CRZ area falling within municipal limits of Greater Mumbai;
- The CRZ areas of Kerala including the backwaters and backwater islands;
- CRZ areas of Goa.

B. Critically Vulnerable Coastal Areas (CVCA) such as Sunderbans region of West Bengal and other ecologically sensitive areas identified as under Environment (Protection) Act, 1986 and managed with the involvement of coastal communities including fishermen.

Sundarbans

CONSTRUCTION OF BEACH RESORTS OR HOTELS- CONDITIONS

Plan: The proposed constructions shall be beyond the hazard line or 200mts from the High Tide Line whichever is more.

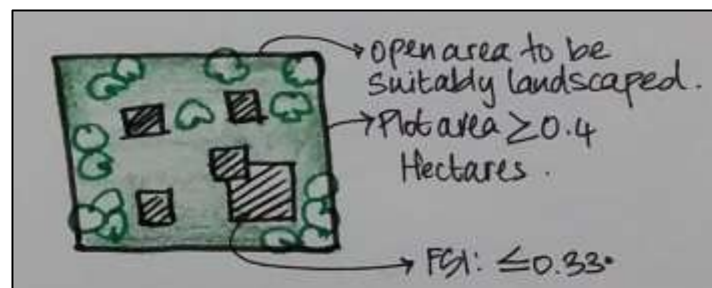


Section: Basement construction will not adversely affect fee flow of groundwater in that area

no permanent structures for sports facilities shall be permitted except construction of goal posts, net posts and lamp posts.

No flattening of sand dunes shall be carried out.

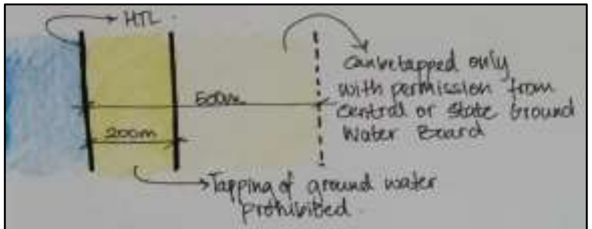
Live fencing and barbed wire fencing with vegetative cover allowed around private properties subject to the condition that such fencing shall in no way hamper public access to the beach.



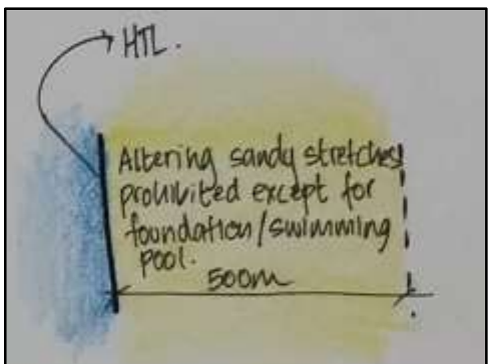
Plan of a coastal plot:

- Plot area: Not less than 0.4 hectares.
- FSI: Not more than 0.33

CONSTRUCTION OF BEACH RESORTS OR HOTELS- CONDITIONS



Plan: Tapping of ground water



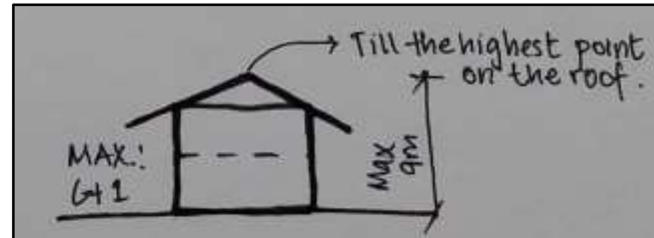
Plan: Altering sandy stretches

necessary arrangements for the treatment of the effluents and solid wastes must be made and it must be ensured

Floor Space Index: the area of entire plot including the portion which falls within the no development zone shall be taken into account.

If the project involves diversion of forestland for non-forest purposes, clearance as required under the Forest (Conservation) Act, 1980 shall be obtained and the requirements of other Central and State laws as applicable to the project shall be met with

approval of the State or Union territory Tourism Department shall be obtained



Elevation of a coastal building:
Overall height: 9m.
Max. floors: G + 1.

the construction shall be consistent with the surrounding landscape and local architectural style.

BIBLIOGAPHY

- http://www.moef.nic.in/downloads/public-information/CRZ-Notification-2011.pdf
- http://envfor.nic.in/