BHARATHIDASAN UNIVERSITY
Tiruchirappalli - 620 024
Tamil Nadu, India

Programme : 6 year Integrated M.Tech in Geological Technology and Geoinformatics

Course title : Marine Geology and Geoinformatics in Sea bed Exploration
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UNIT – I
Origin of seas and oceans

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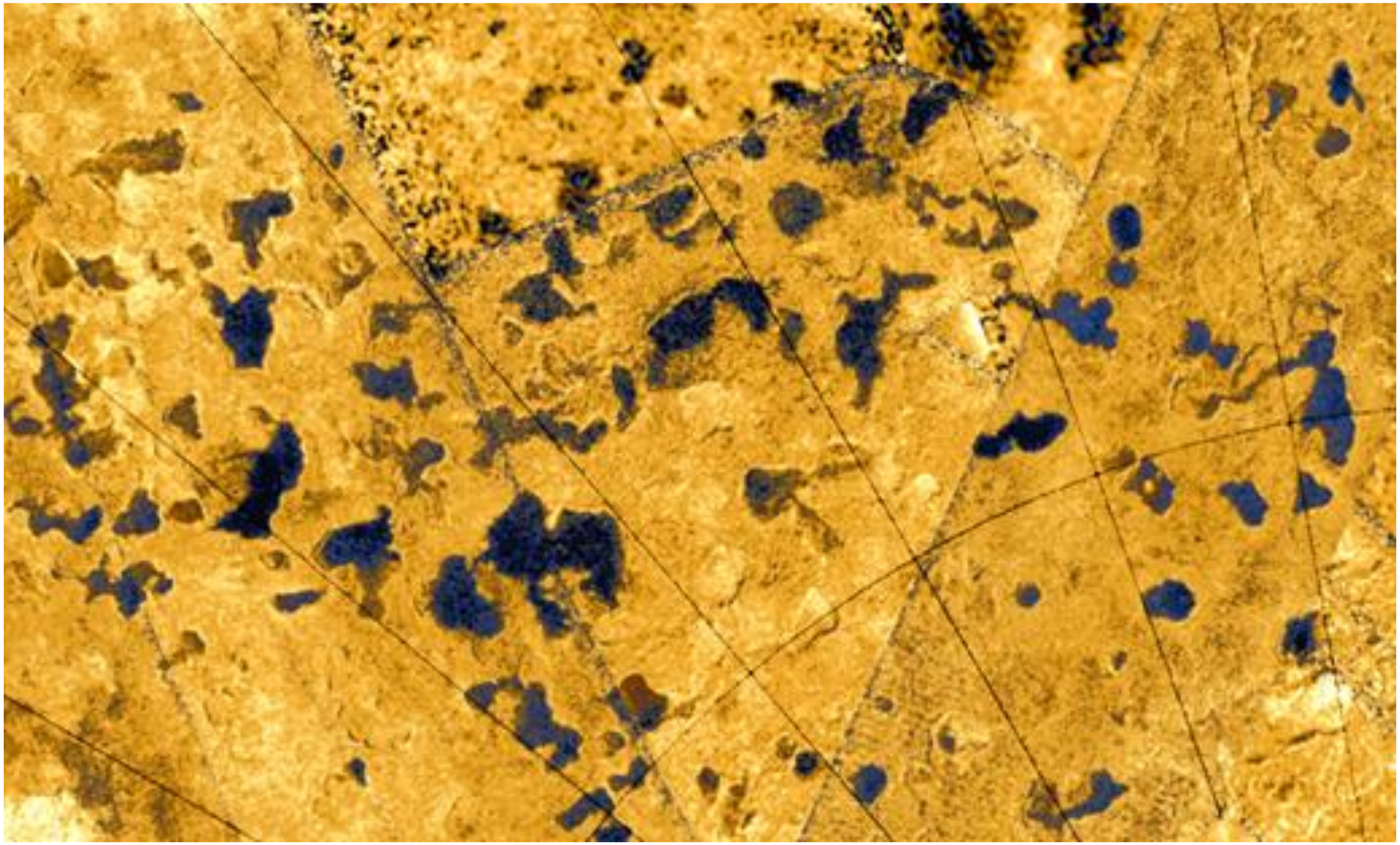
Ocean is the principal component of our Earth's hydrosphere, it is integral to life and influences climate and weather patterns. The World Ocean is the habitat of 230,000 known species, but because much of it is unexplored, the number of species that exist in the ocean is much larger, possibly over two million. The origin of Earth's oceans is unknown; and may have been the impetus for the emergence of life.

Apart from the our planet Earth, there are extraterrestrial oceans that may be composed of water or other elements and compounds. The only confirmed large stable bodies of extraterrestrial surface liquids are the lakes of Titan (moon of the planet Saturn).

The lakes of Titan, Saturn's largest moon, are bodies of liquid ethane and methane that have been detected by the Cassini–Huygens space probe, and had been suspected long before.



The Cassini–Huygens mission launched in 1997, commonly called Cassini, was a collaboration between NASA, the European Space Agency, and the Italian Space Agency to send a probe to study the planet Saturn and its system, including its rings and natural satellites.

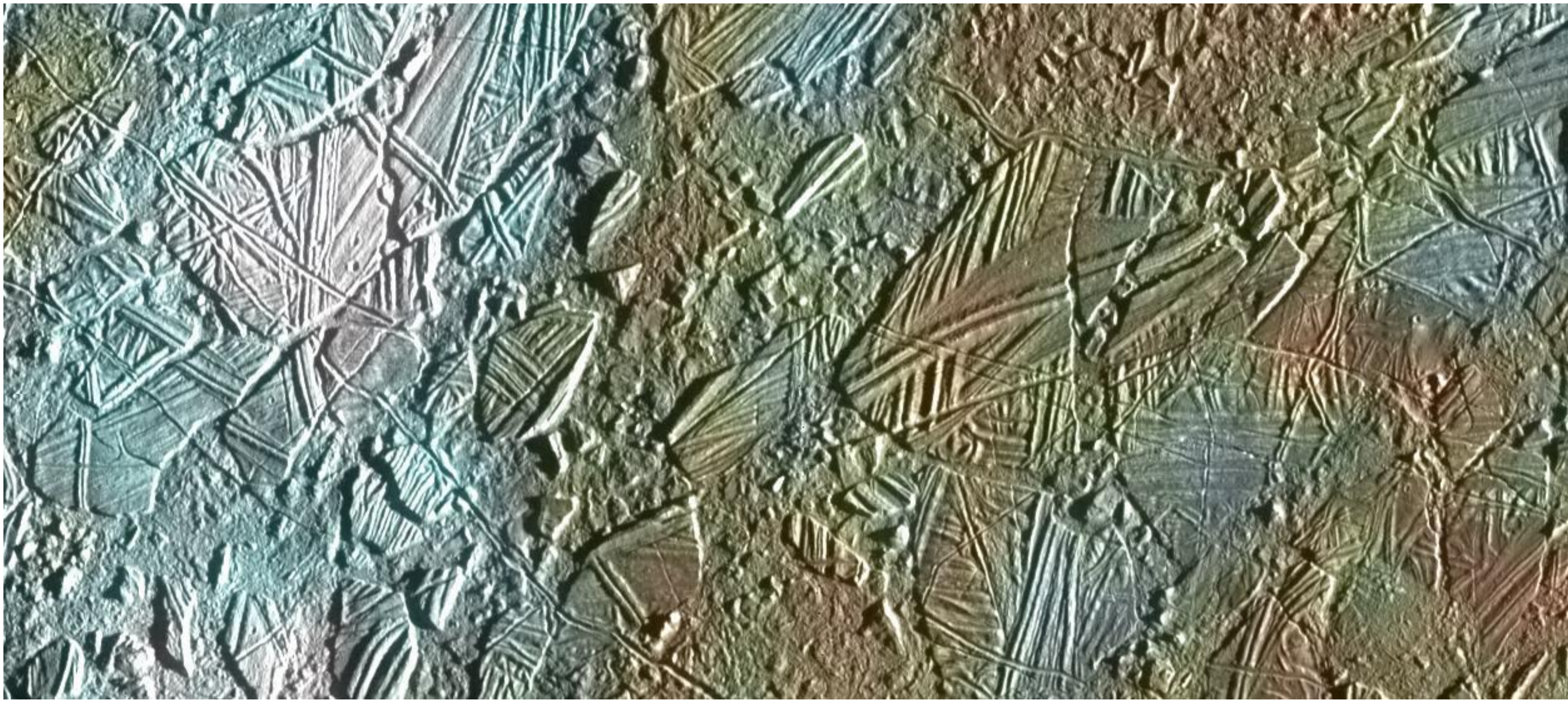
Early in their geological histories, Mars and Venus might have had large oceans. The Mars ocean hypothesis suggests that nearly a third of the surface of Mars was once covered by water, and a greenhouse effect may have boiled away the ocean of Venus.

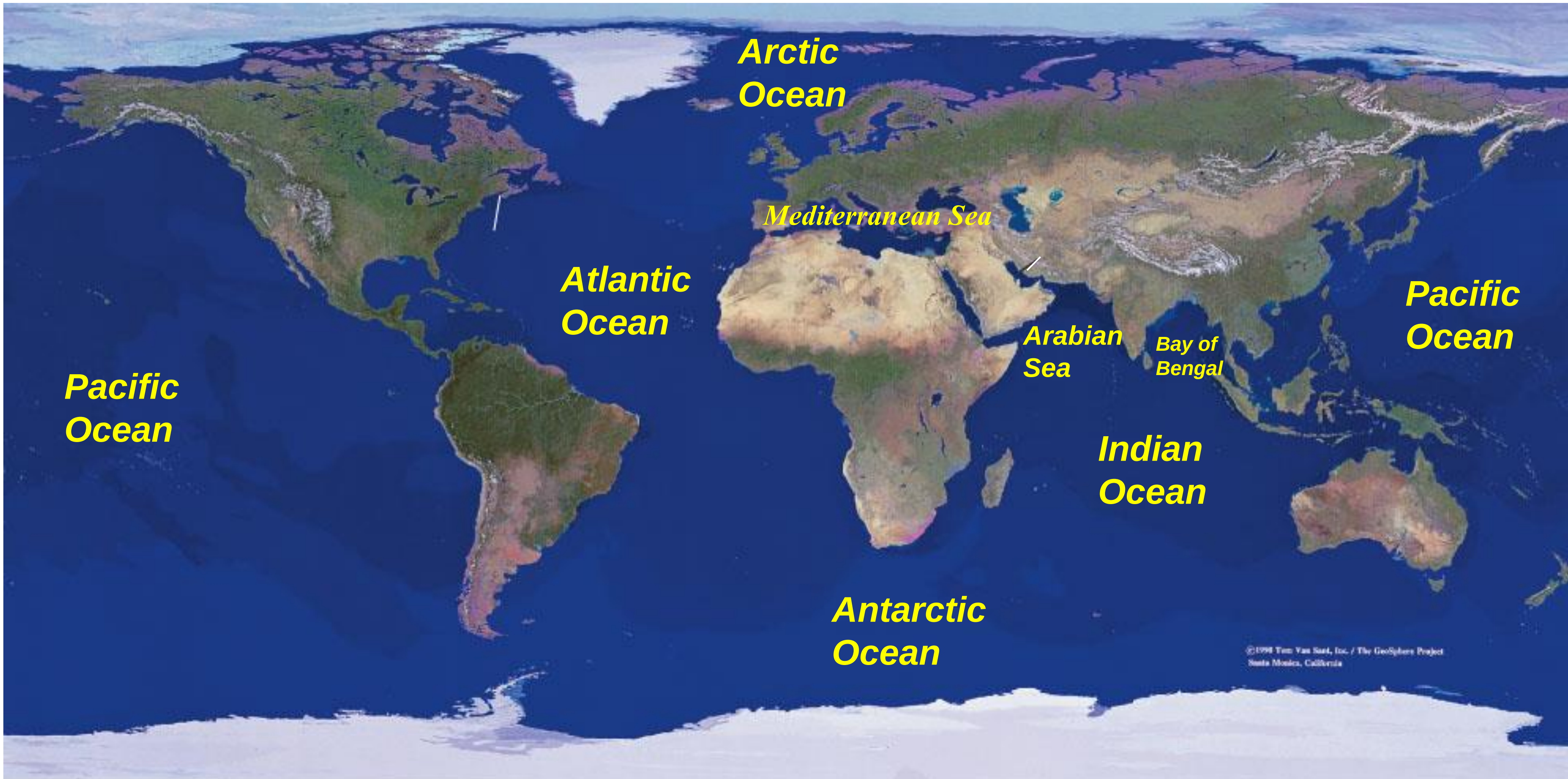
Compounds such as salts and ammonia dissolved in water lower its freezing point so that water might exist in large quantities in extraterrestrial environments as brine or as ice.

Unconfirmed oceans are speculated beneath the surface of many dwarf planets and natural satellites; notably, the ocean of Europa is estimated to have over twice the water volume of Earth.

The Solar System's giant planets are also thought to have liquid atmospheric layers of yet to be confirmed compositions. Oceans may also exist on exoplanets.

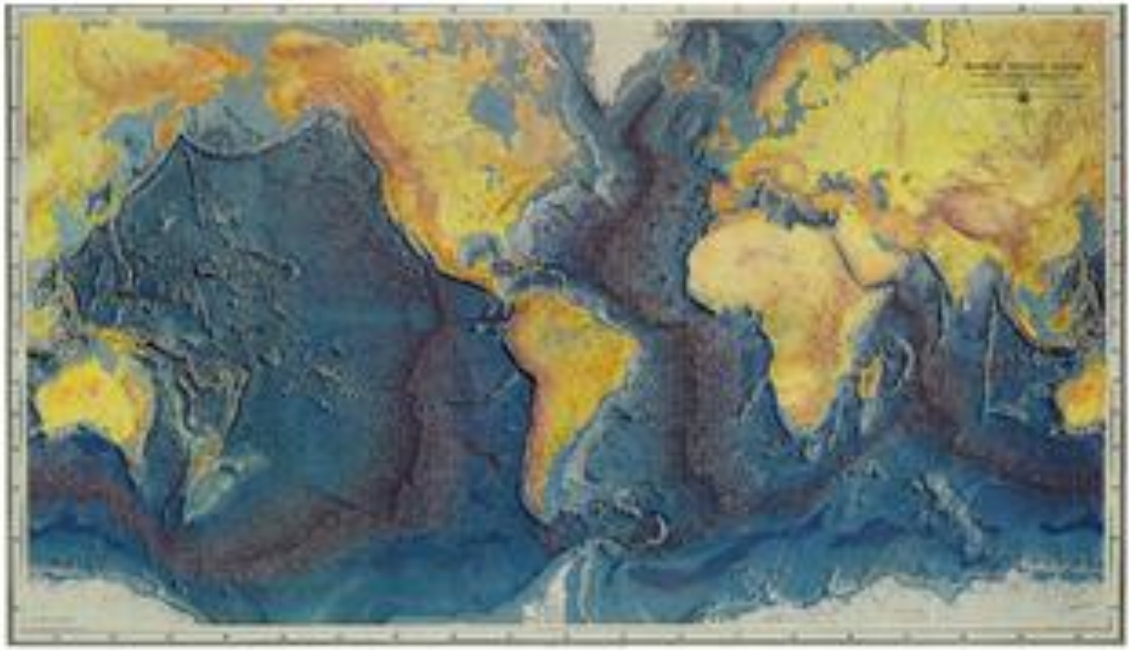
Thin, disrupted, ice crust in the Jupiter's moon Europa showing the interplay of surface color with ice structures.





Oceans cover 2/3 of the Earth's surface.

How old are the Earth's Oceans?



- Oldest rock formation found on Earth dated at about 4 billion (4,000 million years old)
- These rocks were deposited in an ocean environment
- Recall Earth is about 4.5 billion years old)

Origin of the ocean – we do not yet have an conclusive answer that everyone accepts.

The origin of the oceans goes back to the time of the earth's formation 4.6 billion years ago, when our planet was forming through the accumulation of smaller objects, called planetesimals.

There are basically three possible sources for the water.

- separated out from the rocks that make up the bulk of the earth;
- arrived as part of a late-accreting veneer of water- rich meteorites,
- arrived as part of a late-accreting veneer of icy planetesimals, i.e comets.

At the moment, the best model for the source of the oceans is the combination of water derived from comets and water that was caught up in the rocky body of the earth as it formed.

Origins of the Oceans
From the inside out: Volcanic Outgassing

- Water vapor and other gases trapped within Earth as it formed,
- Volcanic eruptions, which emit water vapor and gas, more plentiful in the geologic past,
- Much of this lost to solar wind. Accounts for perhaps 10% of the Earth's atmosphere and ocean material.

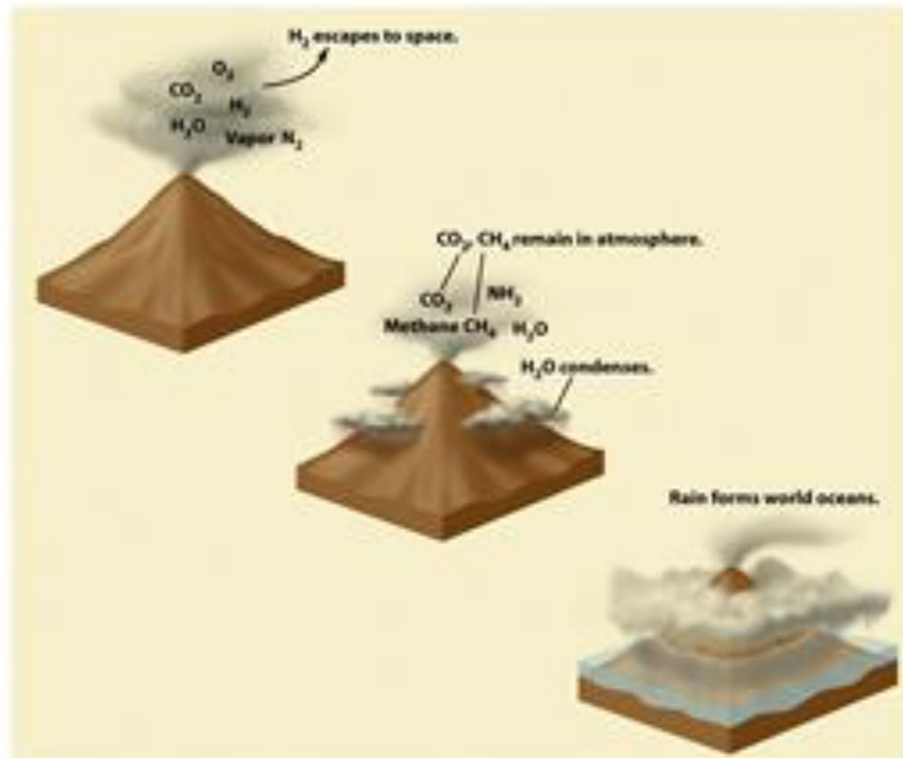


Figure 12.7a

Origins of the Oceans From the outside in: Cometary Water

- Volatiles lost from the Earth and other inner planets combined with debris from formation of solar system to form *comets*.
- Comets are composed mainly of rock and frozen gases, including water.
- Early solar system had many more comets than today.
- Current popular hypothesis is that atmosphere and oceans formed from impacts with comets and other planetary debris.

A lot of oceanographic expeditions and explorations have been conducted by several people / countries. All those investigations have helped over the years to understand the oceans to a great extent.

Still there are a lot of things found inside the deep oceans. The unexplored regions are more than the explored domains.

Oceans offer a lot of resources like mineral deposits, food resources and energy resources. These are much useful to the human of the whole globe to survive. It is necessary to understand the integrated aspects of the subject of oceanography with all the available scientific facts, principles, findings and observations.

Oceanic crust

Oceans and continents make up the crust, which is the outer layer of the earth. Although both are considered the crust, they have qualities that make them stand out from each other. Both oceanic crust and continental crust float on the mantle, but oceanic crust is denser than continental crust. This is partly explains why the continents are at a higher elevation than the ocean floor.

Oceanic crust is primarily composed of mafic rocks, or **SIMA**, which is rich in iron and magnesium. It is thinner than continental crust, or **SIAL**, generally less than 10 km thick; however it is denser, having a mean density of about 3.0 grams per cubic cm as opposed to continental crust which has a density of about 2.7 grams per cubic cm.

The surface beneath the oceanic waters is characterized by a lot of relief features. On the basis of bathymetric surveys and detailed oceanographic explorations, the morphology of ocean floors was studied by several workers. The morphology of the ocean floor is highly uneven and unique. The structure and distribution of relief features of the ocean floors vary from place to place.

Seas and oceans border the continents with two distinct regions.

One is the **Continental margin** and the other one is the **Deep Ocean basin**. The Continental margin includes the gently sloping **Continental shelf** & the rapid sloping, **Continental slope**.

The sediments transported by the major rivers of continents are deposited inside the seas, by forming underwater channels and canyons. They are called as the submarine canyons. Submarine canyons are identified based on their properties and their proximities to the coastal environments, including the deep sea deposits.

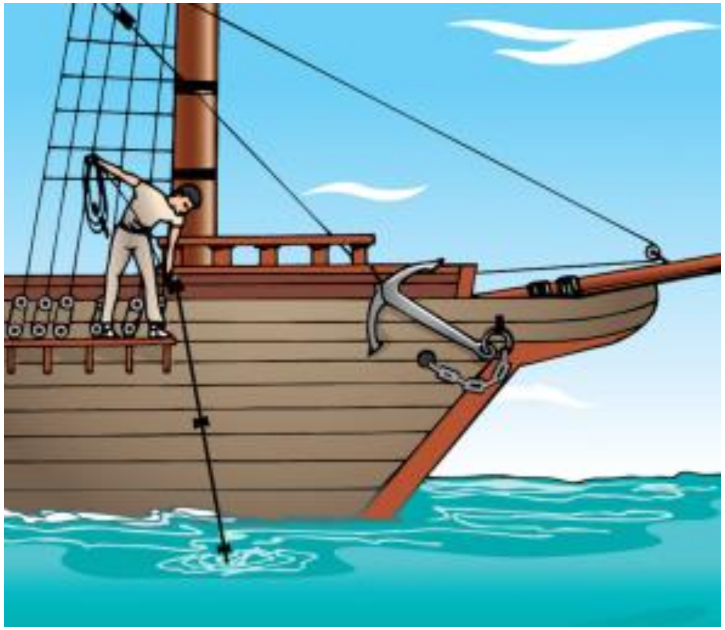
Techniques of sea floor Investigation

Throughout history, humans have wondered what lies beneath our waters. But until the 1800s, what lay below the surface was mostly a mystery.

Bathymetry refers to the depths of water bodies, including the ocean, rivers, and lakes. In the same way that topographic maps represent the features on land, bathymetric maps illustrate the land that lies underwater. Bathymetric maps depict variations in the sea-floor using color and contour lines called depth contours or isobaths.

Mapping water depths dates back to Egyptian methods from 1800 B.C. However, the last 100 - 150 years have seen immense advancements to the technologies and methodologies we use to map water bodies.

Ancient Egyptians using sounding pole

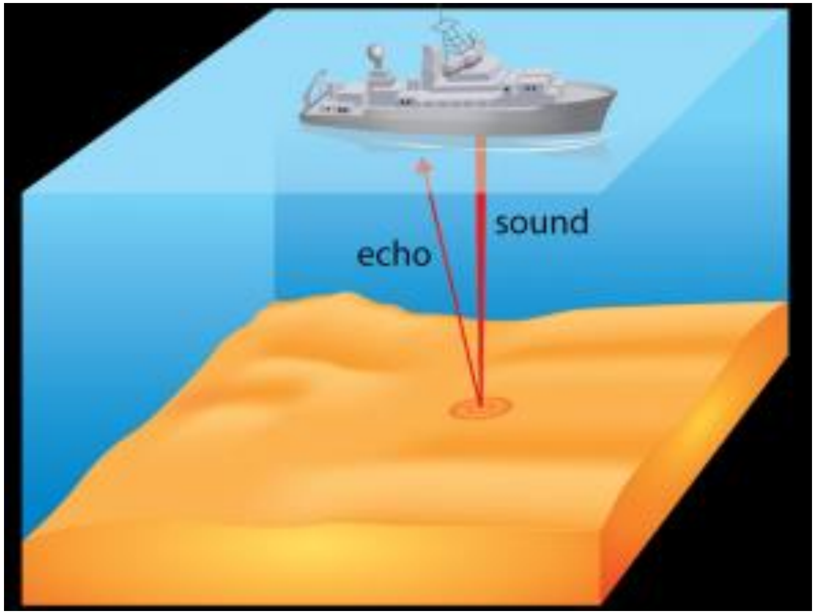


In the early 1800s, surveying of the ocean floor consisted of depths measured by lead lines (ropes with numbers marked along them and lead weights attached).

Depth sounding is the process of measuring the depth of a given point in a body of water. The earliest soundings were made by lowering rope into the water with a weight tied to one end. The rope was allowed to run freely until the weight struck the ocean floor.

The length of the rope let out was an approximate measurement of the water depth. Grease was often smeared on the weight to pick up sand and other sediments from the seafloor.

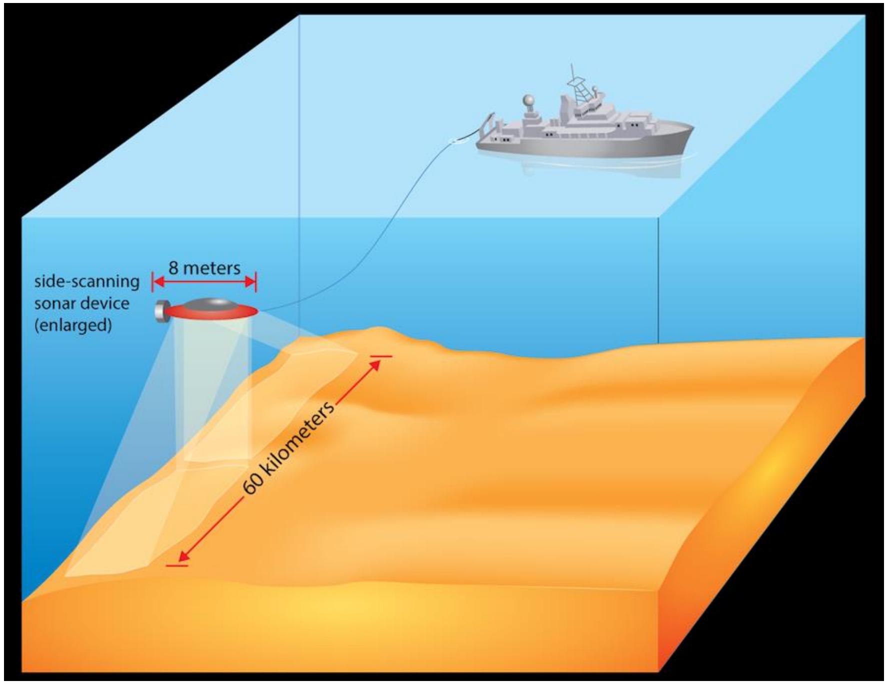
Ecosounders



The 1920s-1930s saw the development and implementation of single-beam echo sounders (sometimes known as sonars or fathometers) that used sound to measure the distance of the seafloor directly below a vessel.

By running a series of lines at specified spacing, single beam echo sounders greatly increased the speed of the survey process by allowing more data points to be collected. However, this method still left large gaps in collecting depth information.

Swath Mapping



Maps and models produced from single-beam sonar profiles lack the precision and detail needed for modern oceanography. Most single-beam profiles are made from lines spaced from 1 to 10 km apart.

Without more data, mapmakers can only guess what features lie between the sample lines. In the 1970s, a new seafloor-mapping technology was developed called **swath mapping**.

On a single transect, swath mapping can sound an area 10 to 60 km wide and as long as the distance traveled by the ship. Details in swath maps are very clear and small-scale features such as faults, craters, landslides, and submarine canyons can be clearly identified. Features as small as 1 cm across can be detected using swath mapping. One swath-mapping device, called multibeam sonar, sends out and tracks up to 16 closely spaced sonar beams at a time.

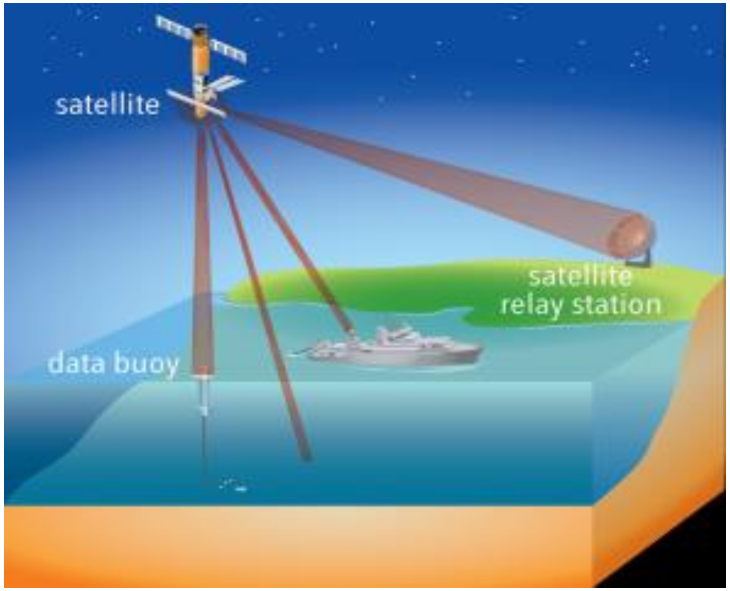
Computers translate the multiple echoes, assemble data from parallel transects, and then draw a detailed bathymetric contour map of that section of the seafloor.

Another swath-mapping device, called **side-scanning sonar,** uses computers to translate the multiple echoes into detailed three-dimensional images of seafloor features. The images look like photographs taken from an airplane. The difference is that sound waves, not light waves, are used to produce the images.

Light Detection And Ranging Systems (LiDAR)

LiDAR uses lasers (light waves) and GPS to determine the position of topographic features. LiDAR can be used to obtain very accurate measurements of the sea floor, often within a few centimeters. However, because lasers use light waves, LiDAR can not penetrate as deep as sound waves in water. Typically, LiDAR can be used to measure the depth of water and to map the sea floor to a depth of about 50 m. However, the exact depth depends on water turbidity; the less turbid (more clear) the water, the deeper LiDAR can penetrate.

Satellite Oceanography



Satellites are essential to mapping and measuring the oceans. Satellites equipped with communication devices and power sources make global communication possible by telephone and television. Satellites can link ships and airplanes to land stations and to each other. Navigation is more advanced because satellite communication systems help to determine exact latitude and longitude. Computers record seafloor measurements and locations and plot the data onto maps.

Some satellites are equipped with cameras that continuously take photographs of the earth's surface and relay them to receiving stations. The satellite weather maps in newspapers are a familiar example. For oceanographers and others who work or travel on the ocean, satellites provide up-to-date information about storms and other weather conditions at sea.

In 1957, the first artificial satellite (**Sputnik**) was launched which showed a new exploration way : **the Space**. Initial exploration phase begins in the 60's when geodetic satellites measure the first orbit calculated from distance measurements by laser telemetry.

Altimetry is a technique for measuring height. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield sea-surface heights.

The satellite altimetry is initially designed to measure the sea level by a combination of radar technique (used to measure the distance from the satellite to a reflecting surface) and a positioning technique (allowing a very precise location of the satellite on its orbit).

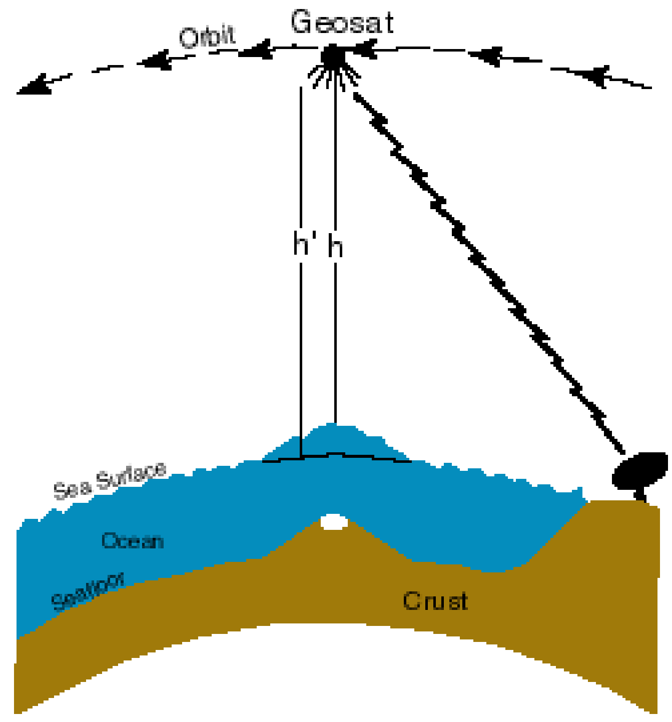
The first country to fly a satellite-borne altimeter was the United States, with the Skylab and GEOS 3 missions, The GEOS 3 (Geodynamics and Earth Ocean Satellite) was part of a geodetic mission series by NASA. It was launched in 1975 and continued operating until 1979. The spacecraft carried a radar altimeter for mapping of the oceans.

Satellite altimetry

Dips and bumps are due to variations in gravitational force.

Sea surface copies the ocean floor surface.

Differences are measured using the time radar signals take to travel through the atmosphere, hit the ocean's surface, bounce back, and travel back to the satellite.



Geosat satellite

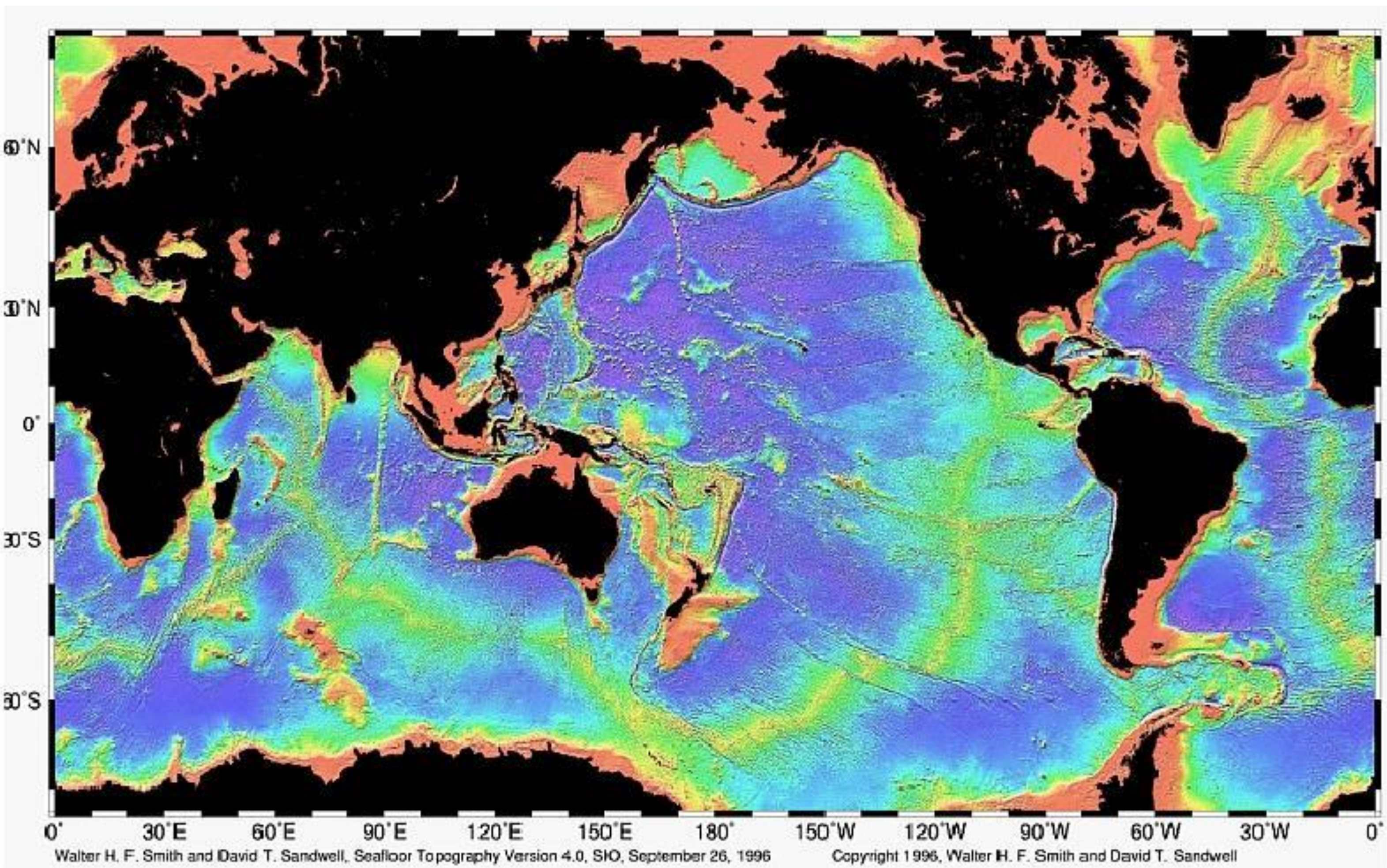
Launched in 1985

Orbits the Earth in about 14 hours

Satellite map of the Earth's topography.

For every increase of 1000 meters on the seafloor, there is 1 meter increase in height of water.

Geosat image of the ocean floor



Seasat was launched by NASA in 1978, the first satellite dedicated to oceanography. It allowed researchers to detect and map seafloor features around areas rarely visited by ships, like Antarctica. SEASAT mapped seafloor features indirectly by measuring sea height.

Geosat in 1985. ESA materializes the launch of ERS-1 in 1991 : successively implemented on 3 different orbits, it contains several instruments including a radar altimeter.

TOPEX/Poseidon - Launched in 1992, joint venture between CNES and NASA that measured ocean surface topography to an accuracy of 4.2 cm, enabled scientists to forecast the 1997-1998 El Niño, and improved understanding of ocean circulation and its effect on global climate. Planned for 3-years, TOPEX/Poseidon delivered an astonishing 13+ years of data from orbit. The mission ended in January 2006.

In those 13 years, it:

- Measured sea levels with unprecedented accuracy to better than 5 cm
- Continuously observed global ocean topography, Monitored effects of currents on global climate change and produced the first global views of seasonal changes of currents
- Mapped year-to-year changes in heat stored in the upper ocean Produced the most accurate global maps of tides ever
- Improved our knowledge of Earth's gravity field.

Jason-1

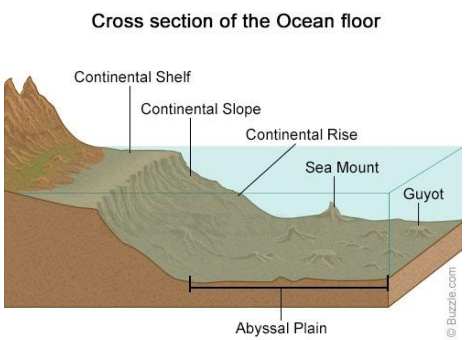
Jason-1 was the first follow-on to the highly successful TOPEX/Poseidon mission. This second joint NASA-CNES mission was built on a French spacecraft, and launched on an American Delta II rocket from Vandenburg Air Force Base in California in 2001. Jason 1 was operational for 12 years and decommissioned in 2013. Subsequently, Jason-2 (2008) and Jason-3 (2016) were launched and are still in operation.

Jason-1 had five 5 instruments:

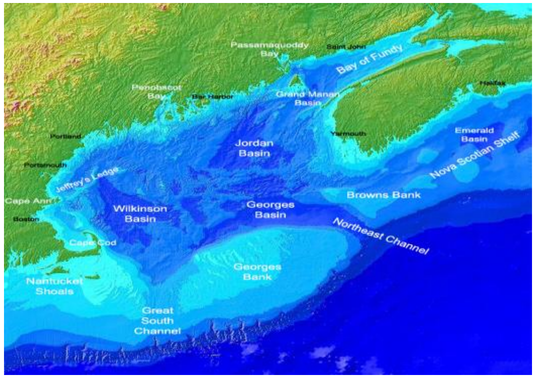
Poseidon 2 – Nadir pointing Radar altimeter using C band and Ku band for measuring height above sea surface.
Jason Microwave Radiometer (JMR) – measures water vapor along altimeter path to correct for pulse delay
DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) for orbit determination to within 10 cm or less and ionospheric correction data for Poseidon 2.
BlackJack Global Positioning System receiver provides precise orbit ephemeris data

The next ocean altimetry mission, launched in 2020, is called Jason Continuity of Service (Jason-CS) in collaboration with ESA.

Abyssal plain - a flat region of deep ocean basins.



An underwater plain on the deep ocean floor, usually found at depths between 3,000 m and 6,000 m. Lying generally between the foot of a continental rise and a mid-ocean ridge, abyssal plains cover more than 50% of the Earth's surface



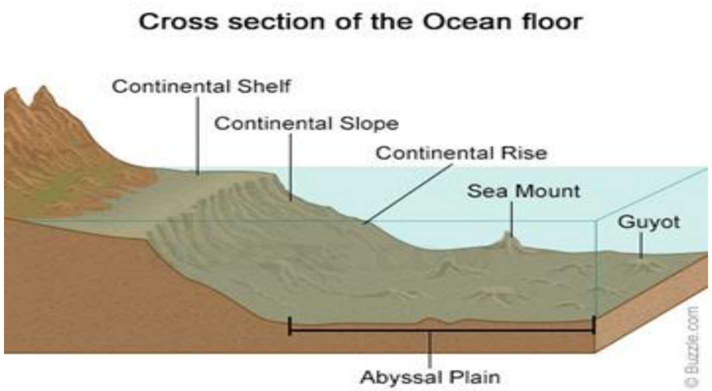
Bank or Ocean bank - is a part of the seabed which is shallow compared to its surrounding area, such as a shoal or the top of an underwater hill.

Bay - a recessed, coastal body of water that directly connects to a larger main body of water, such as an ocean, a lake, or another bay.

Cape - a large point or extension of land jutting into a body of water. A cape may be a peninsula or a hook of land.

Channel - a deeper part of a river or harbor that is navigable. The word is sometimes used to name a broad strait.

Coast - A strip of land bordering the sea.



Continental shelf - The land forming the shallow seafloor extending outward from the edge of a continent; submerged part of a continent extending outward 15 km to 50 km to the continental slope.

Continental slope - The sloping front of a continental shelf; the place where the continent ends. These are long slopes, often 20 km to 40 km wide or more. The bottom of the continental slope is the continental rise.

Continental rise - The area of the continental shelf between the continental slope and the deep seafloor where sediments from the continent accumulate.

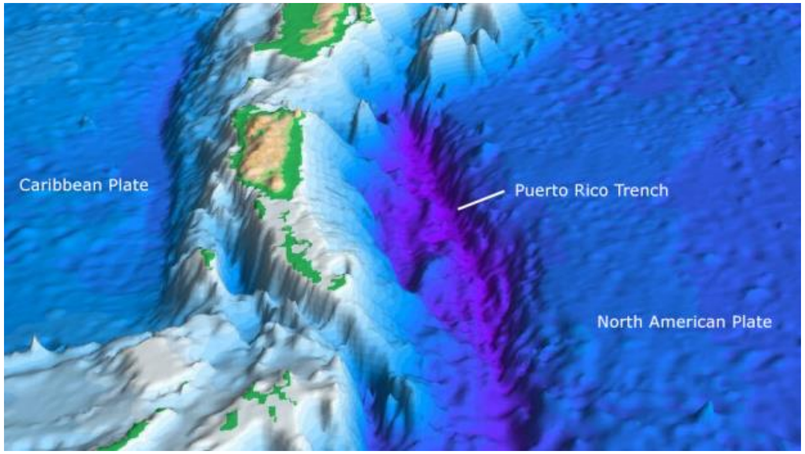
Guyot - A seamount with a flat top. Guyot tops are always below the ocean surface. Also called a table mount.

Headland - A cape or other landform jutting into the ocean. It is usually high above water and prominent when viewed from the sea.

Island chain - A group of islands formed by the same geological process (also called an archipelago).

Isthmus - A narrow strip of land connecting two larger landmasses.

Lagoon - A shallow body of water almost completely cut off from the open ocean by coral reefs, barrier islands, or barrier beach.



Ocean basin - A large depression in the earth's crust that holds the water of an ocean.

Ocean ridge - A long, continuous mountain range on the seafloor. Ocean ridges are often of volcanic origin at a point or line of separation in the earth's crust.

Ocean trench - A deep cut or trench in the seafloor, usually close to where continental shelves and seafloors meet.

Peninsula - A piece of land almost completely surrounded by water. It is usually connected to a larger land body by a narrow land strip called a neck or an isthmus.

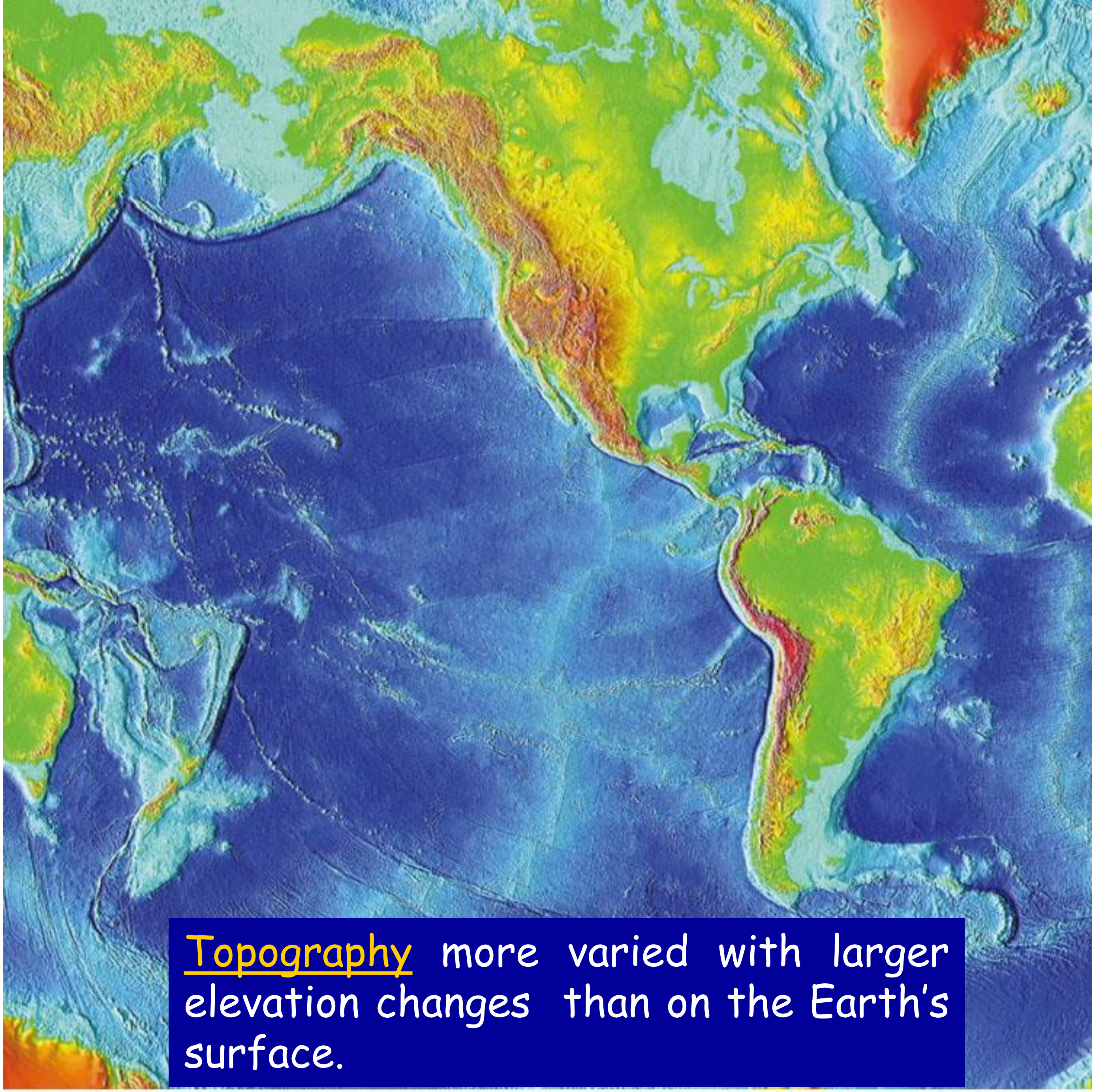
Point - The narrow tip-end of a cape, headland, peninsula, or other land feature jutting into a body of water.

Seamount - An isolated undersea hill or mountain. It is usually in the form of a cone.

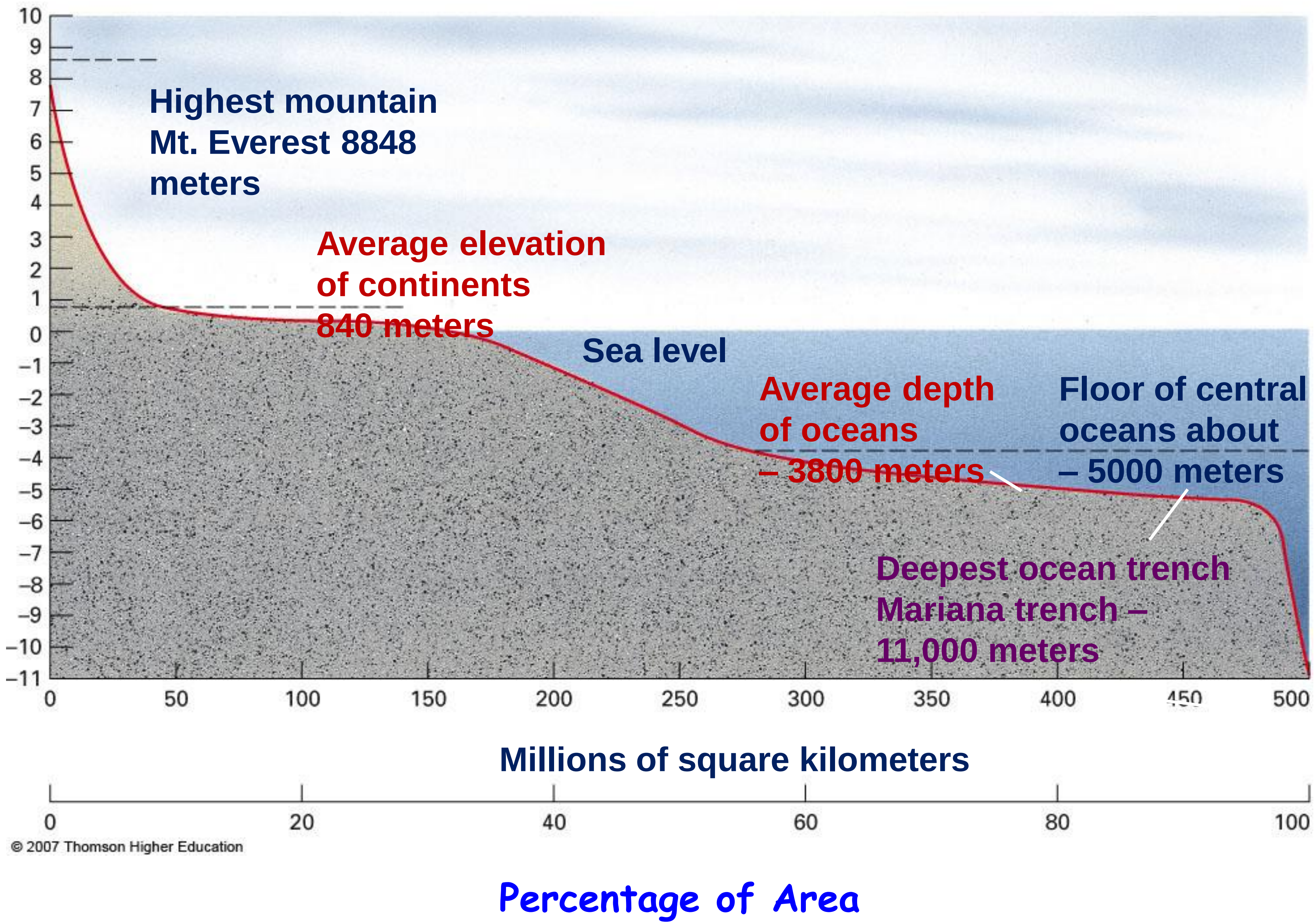
Shoal - An area of the ocean, such as a sandbar, that is too shallow to navigate.

Strait - A long, narrow water passage connecting two larger bodies of water.

Submarine canyon - A deep valley cut into the continental shelf and slope, often at the mouth of a large river.



Topography more varied with larger elevation changes than on the Earth’s surface.


Highest mountain
Mt. Everest 8848
meters
Average elevation
of continents
840 meters
Sea level
Average depth
of oceans
– 3800 meters
Floor of central
oceans about
– 5000 meters
Deepest ocean trench
Mariana trench –
11,000 meters
10
9
8
7
6
5
4
3
2
1
0
–1
–2
–3
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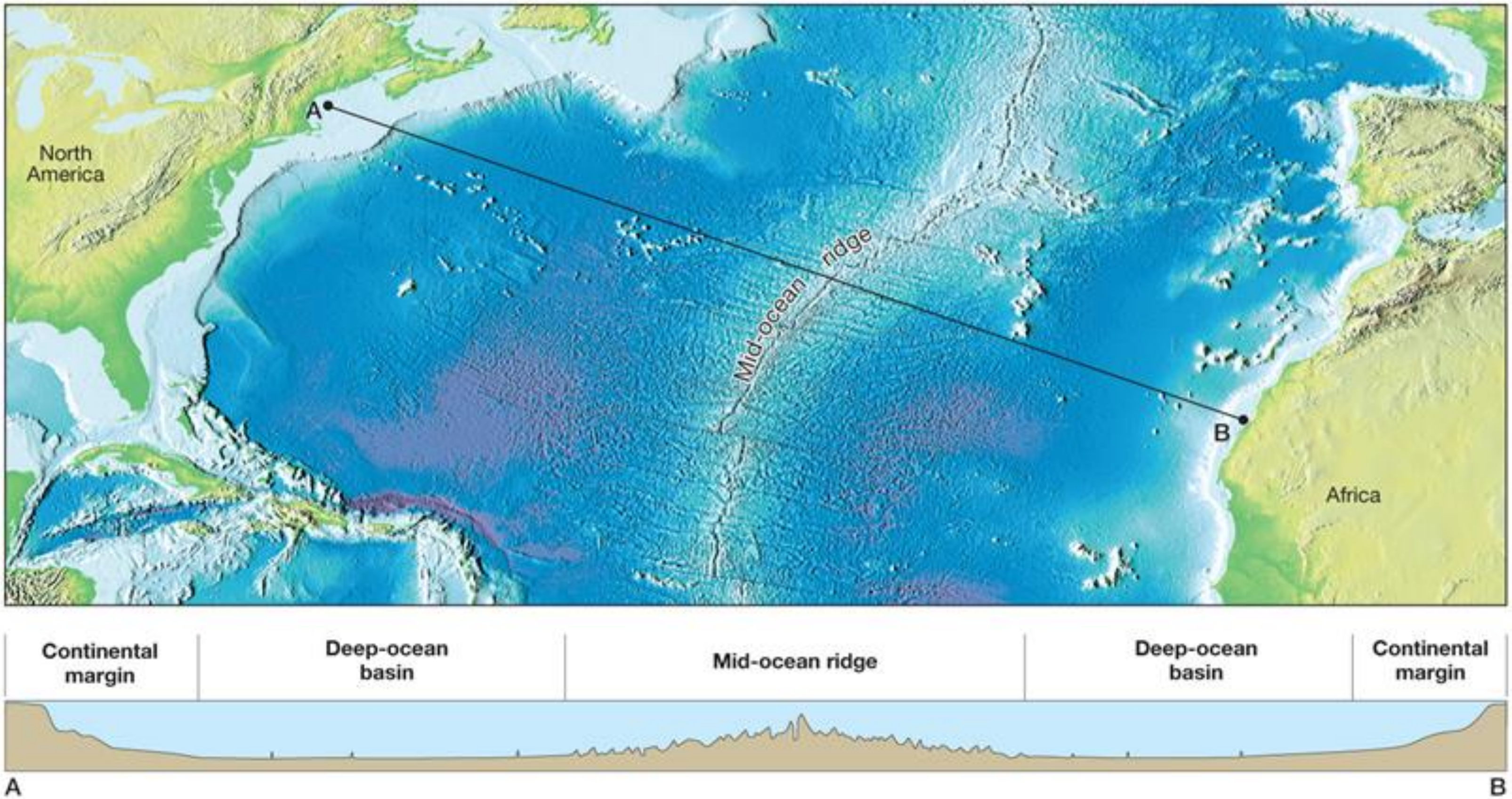
–5
–6
–7
–8
–9
–10
–11
0
50
100
150
200
250
300
350
400
450
500
Millions of square kilometers
0
20
40
60
80
100
Percentage of Area

Continental margins: where land meets the sea

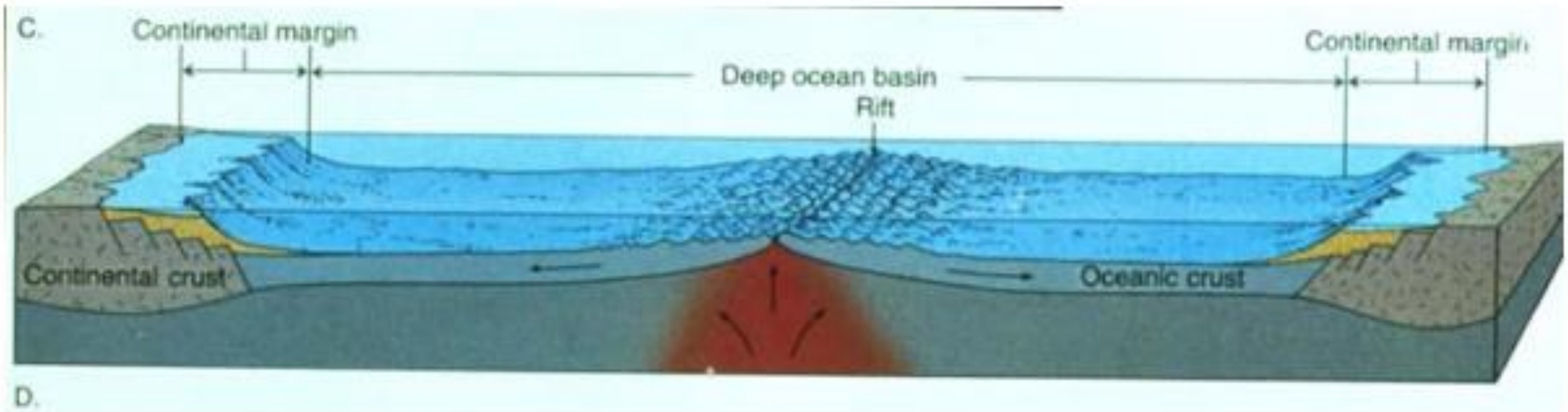


Atlantic Ocean: plate boundary is in the center of the ocean basin, away from the continental margin

The most striking division of the earth's surface is into continental and oceanic areas underlain by oceanic and continental crust of different density and thickness.

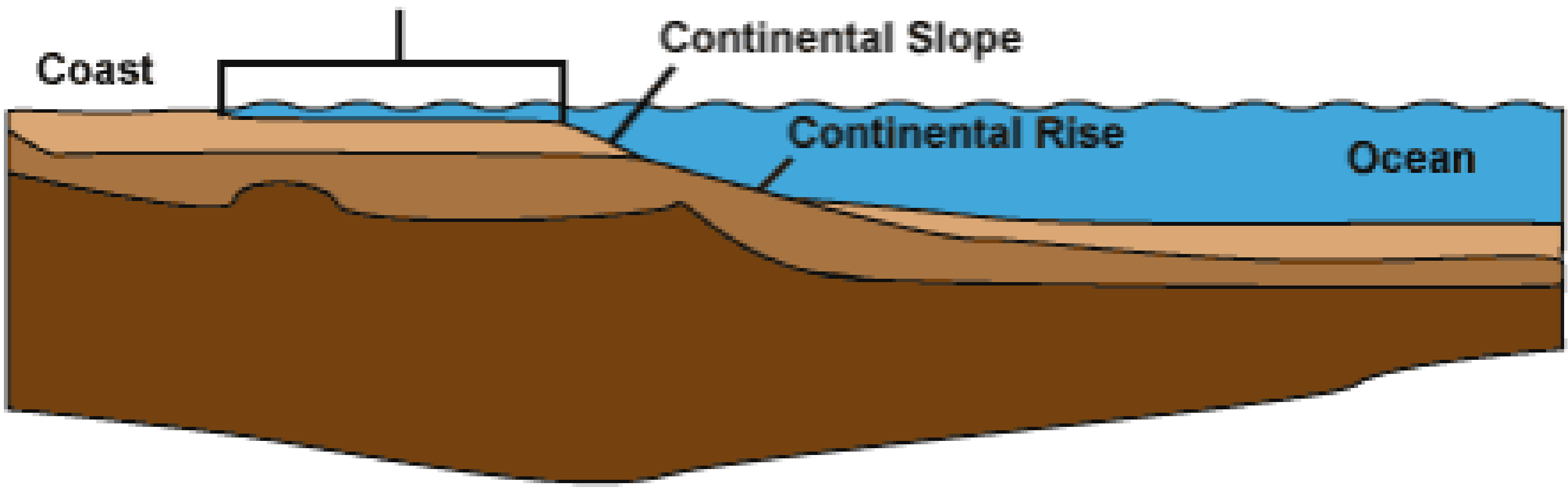
The major features of the sea floor are formed by tectonic processes of plate divergence, convergence, and transform faulting. Volcanic activity is also the dominant process on the surface of the sea floor and the final shaping is the emplacement of volcanic features over the tectonic patterns.

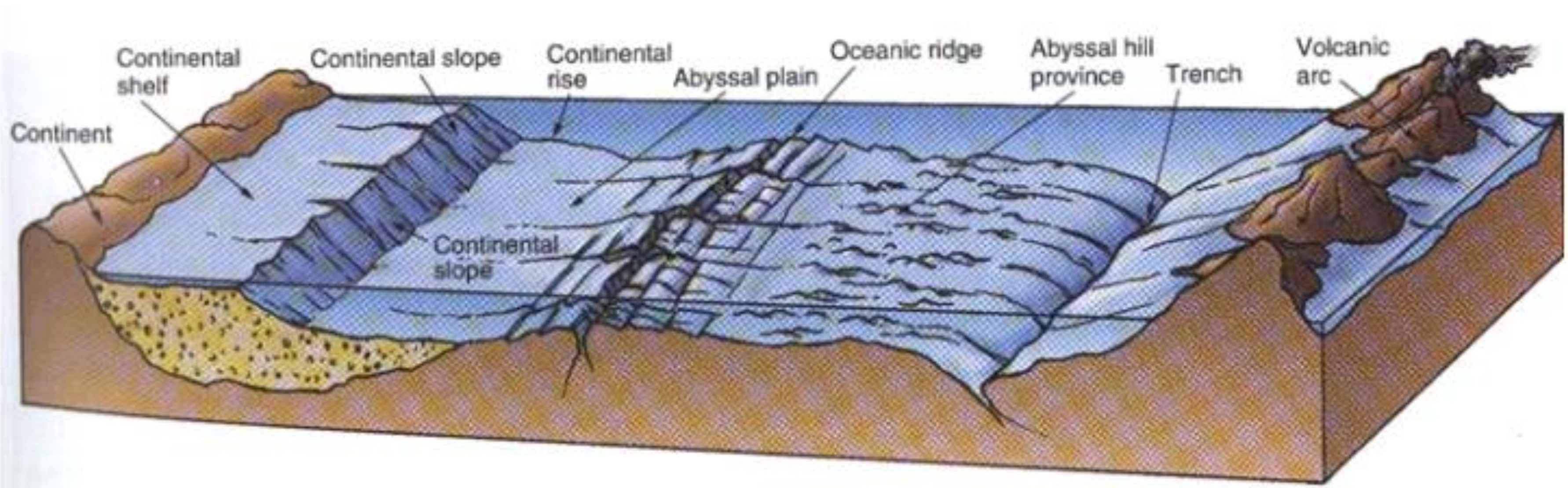
The continental margins covered by present sea level are on continental crust. The morphology of these surfaces results from tectonics, sediment deposition and a history of sea level changes.


C.
Continental margin
Continental margin
Deep ocean basin
Rift
Continental crust
Oceanic crust
D.

Continental Shelf and Slope

The continental shelf (extending from the shoreline to the shelf break) is part of the continental crust and water depths over the shelf are a function of sea level and isostatic change. The continental slope lies over and is caused by the transition from continental crust to oceanic crust.



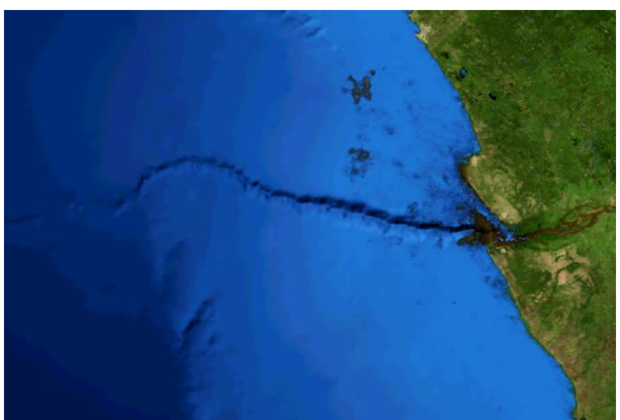


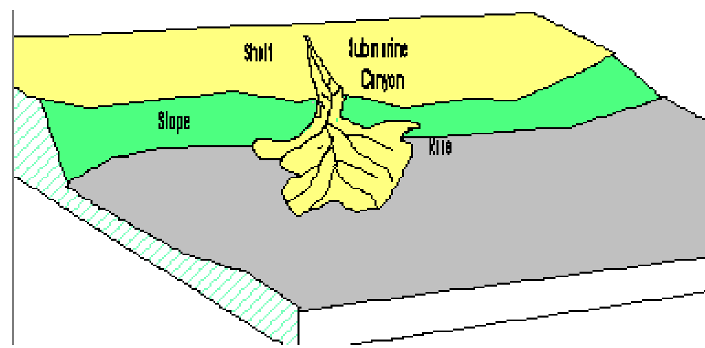
Continental shelf
Continental slope
Continental rise
Abyssal plain
Oceanic ridge
Abyssal hill province
Trench
Volcanic arc
Continent
Continental slope

The edge of the continental margin is incised by a number of valleys or submarine canyons that extend from the shelf to the deep sea floor. These erosional features were formed by scouring out a portion of the shelf.

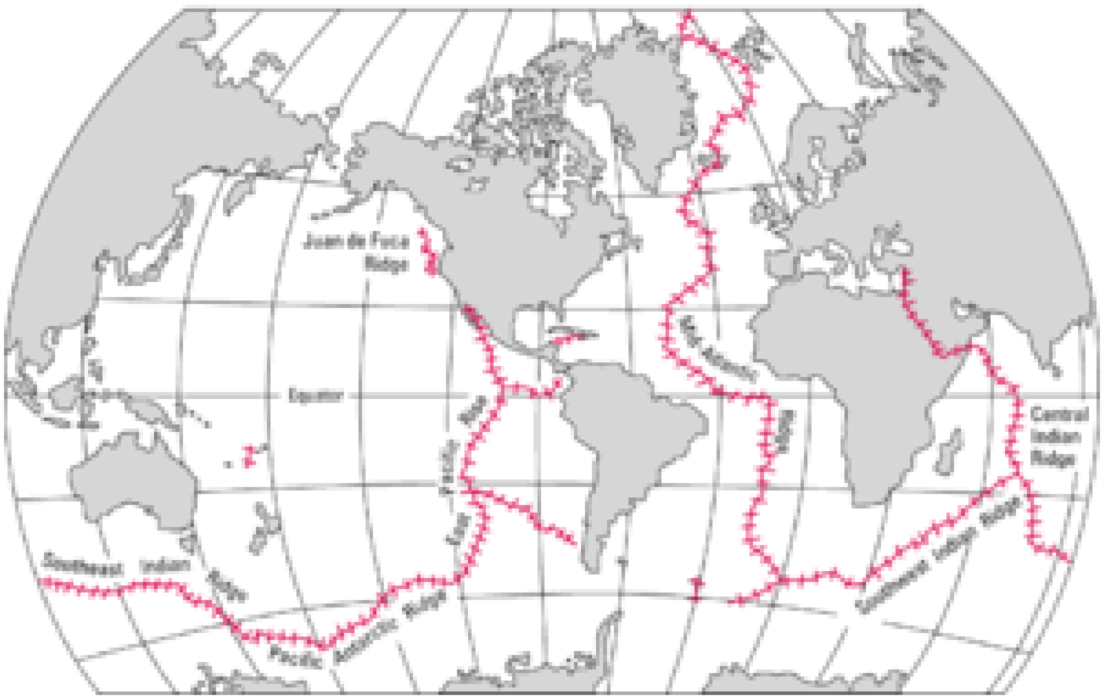
But what was the scouring agent?

One is that canyons were carved during a time when sea level was lower than present and rivers were able to flow out to the edge of the shelf. The presence of many (but not all) canyons offshore from major rivers supports this suggestion. Another theory is that canyons were carved by turbidity currents. These are dense, sediment-laden, currents that are triggered by earthquakes and flow down the continental margin. The speed and erosive power of these currents is considerable. Both processes may have been involved in forming the canyons.

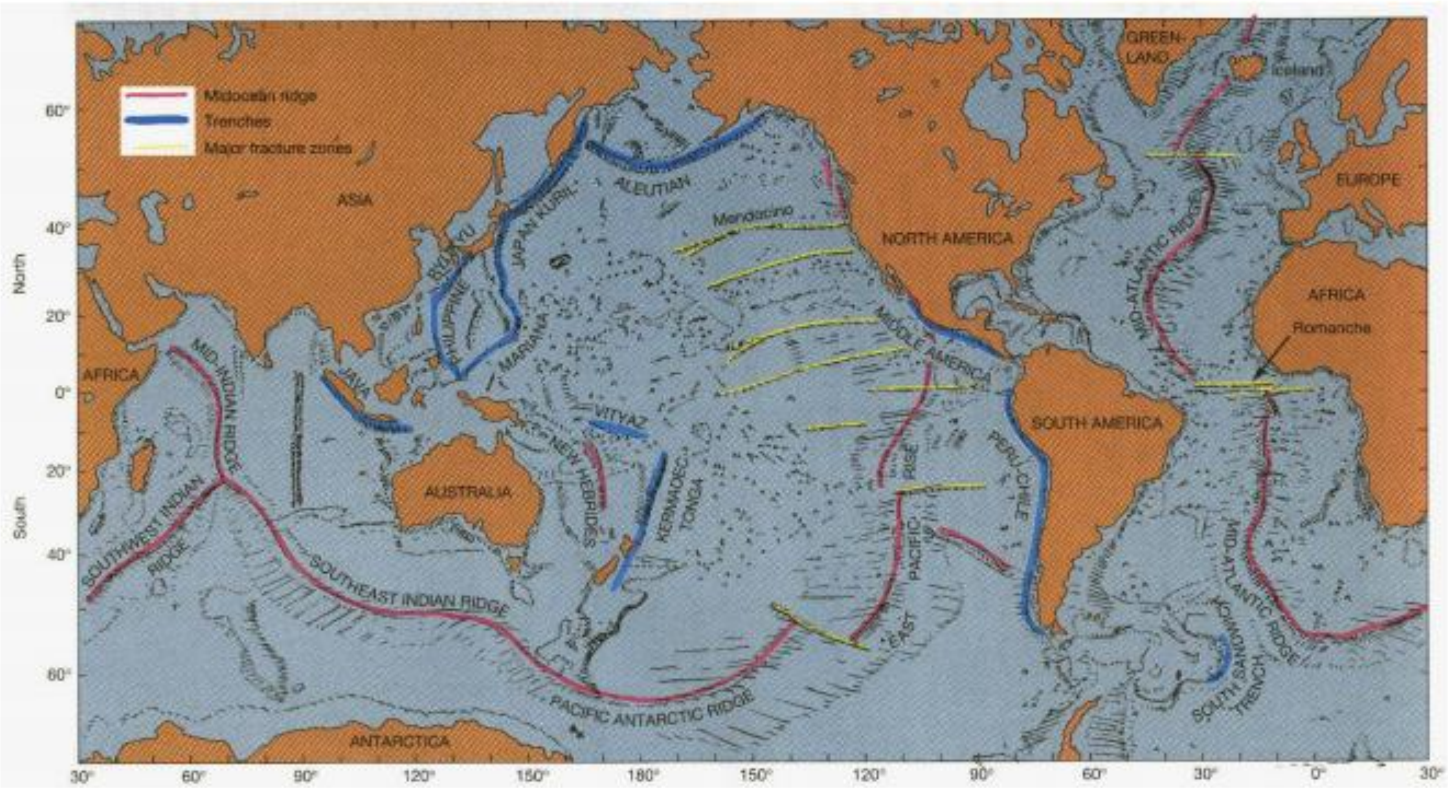




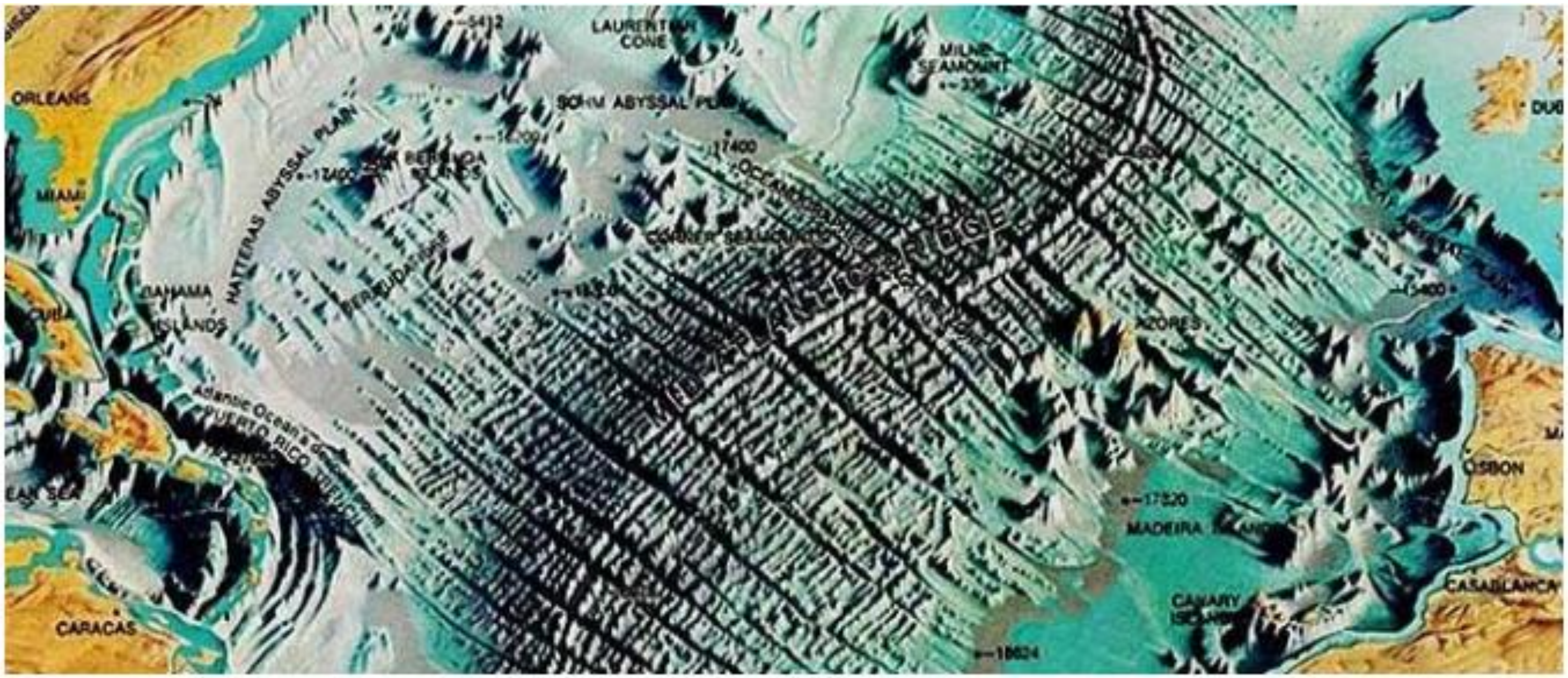
The mid-ocean ridges of the world are connected and form a single global mid-oceanic ridge system that is part of every ocean and the longest mountain range in the world. The continuous mountain range is 65,000 km long (several times longer than the Andes, the longest continental mountain range



These ridges extend as an almost continuous feature around the globe in the form of spectacular mountain ranges of volcanic basalts. The ridges are arched up and broken by numerous fault blocks to form linear hills and valleys. A prominent rift valley marks the crest of the ridge throughout most of its length.



The general character of the ridge is a function of the rate of plate separation. A slow rate of spreading produces a higher and more rugged oceanic ridge than when the spreading rates are more rapid. Rift valleys are also more prominent on ridges between slow moving plates.

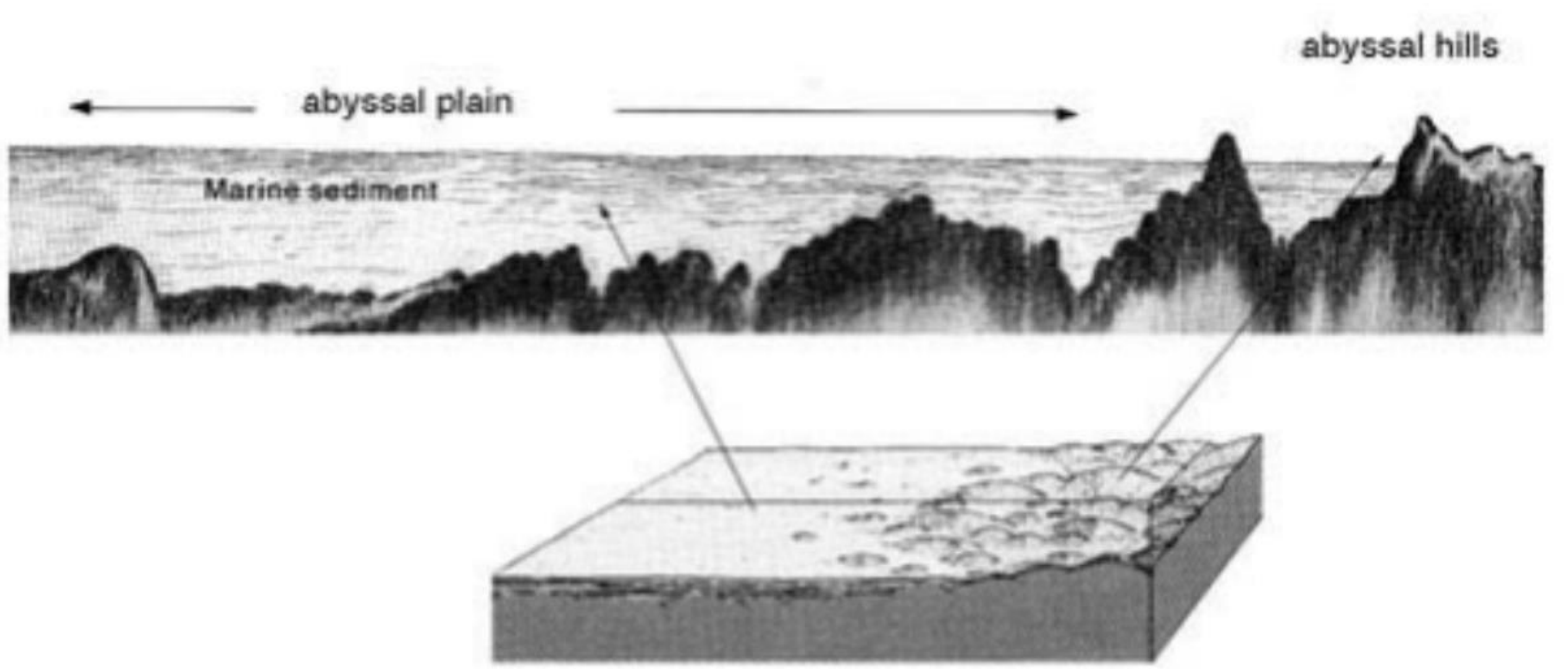


The oceanic ridge is cut by faults normal to the ridge. Although these are strike-slip faults, vertical displacement may form abrupt cliffs that can be traced for many kilometers . Horizontal movement on these transform faults is on the order of 1-2 cm/yr and the faults are marked by earthquake activity and vulcanism. The magnitude of the system and its nature indicates that it is related to major events and sources of energy in the Earth's interior.

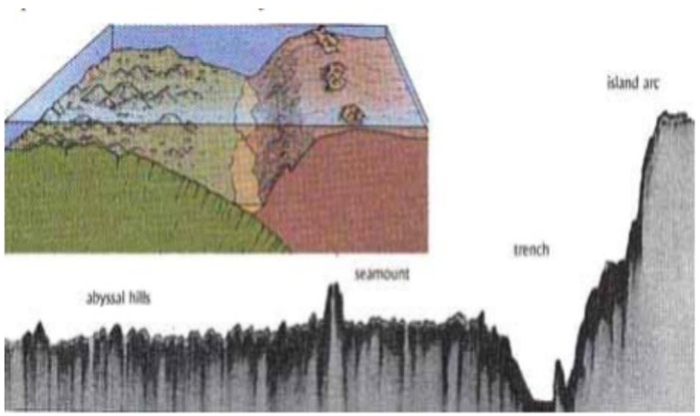
The abyssal hills have relatively low relief as they rise only 75 to 900 meters above the ocean floor. Abyssal hills were formed as an oceanic ridge. As the crust moved away from the spreading center, it cooled and sank to a lower depth.

The mountainous terrain of the oceanic ridge is maintained, becoming low-lying abyssal hills at depths of more than 6,000 m. The hills are usually covered with a blanket of unconsolidated sediments deposited which gradually modifies and smoothes the features but does not change the original volcanic ocean floor topography that formed at the ridge.

A flat featureless surface known as an abyssal plain occurs when the hilly sea floor has been covered by a thick fill of sediments, which were deposited by turbidity currents. These river-like flows of a sediment-water mix are carried along the sea floor from continental margins via submarine canyons which act as conduits for turbidity current transport.



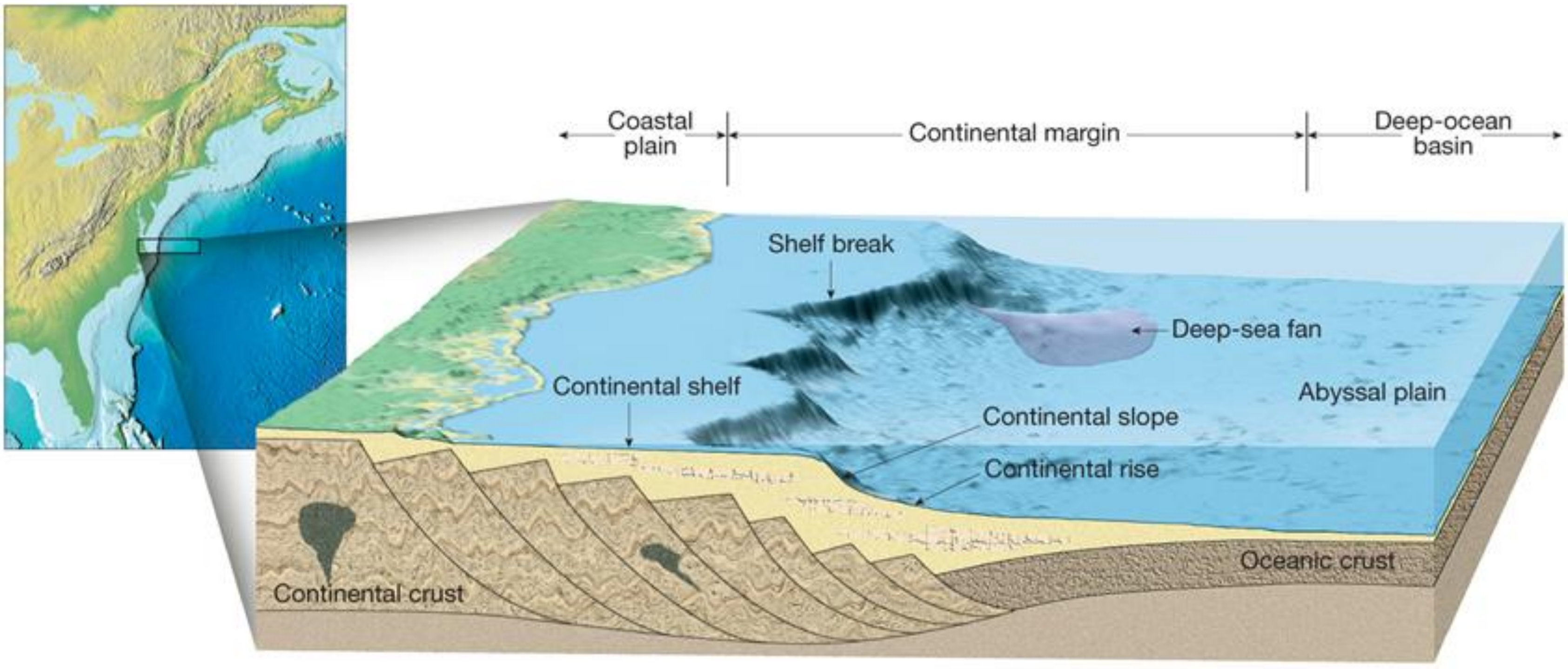
Subduction zone is where two lithosphere plates converge and one slab plunges into the mantle. Because of the drag, a trench is formed. Deep-sea trenches are long, narrow depressions in the ocean floor with depths greater than 6000 m and they can reach 11,000 m in depth. Trenches are found adjacent to land areas and associated with island arcs worldwide. They are more numerous in the Pacific Ocean.



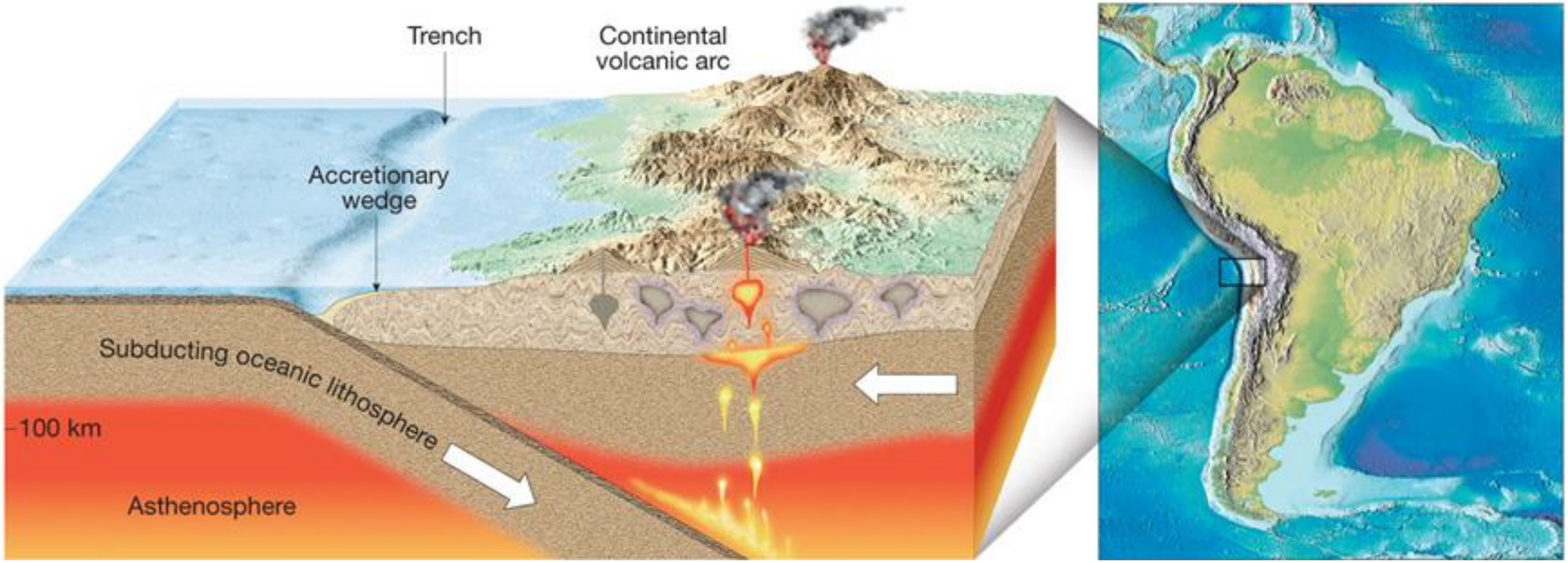
The trench is usually asymmetric, with the steep side toward the adjacent land mass. Where a trench occurs off continental margins, the turbidites from the slope are trapped, forming a hadal plain (The hadal zone is the deepest region of the ocean lying within oceanic trenches). The hadal zone is found from a depth of around 6,000 to 11,000 m on the floor of the trench).

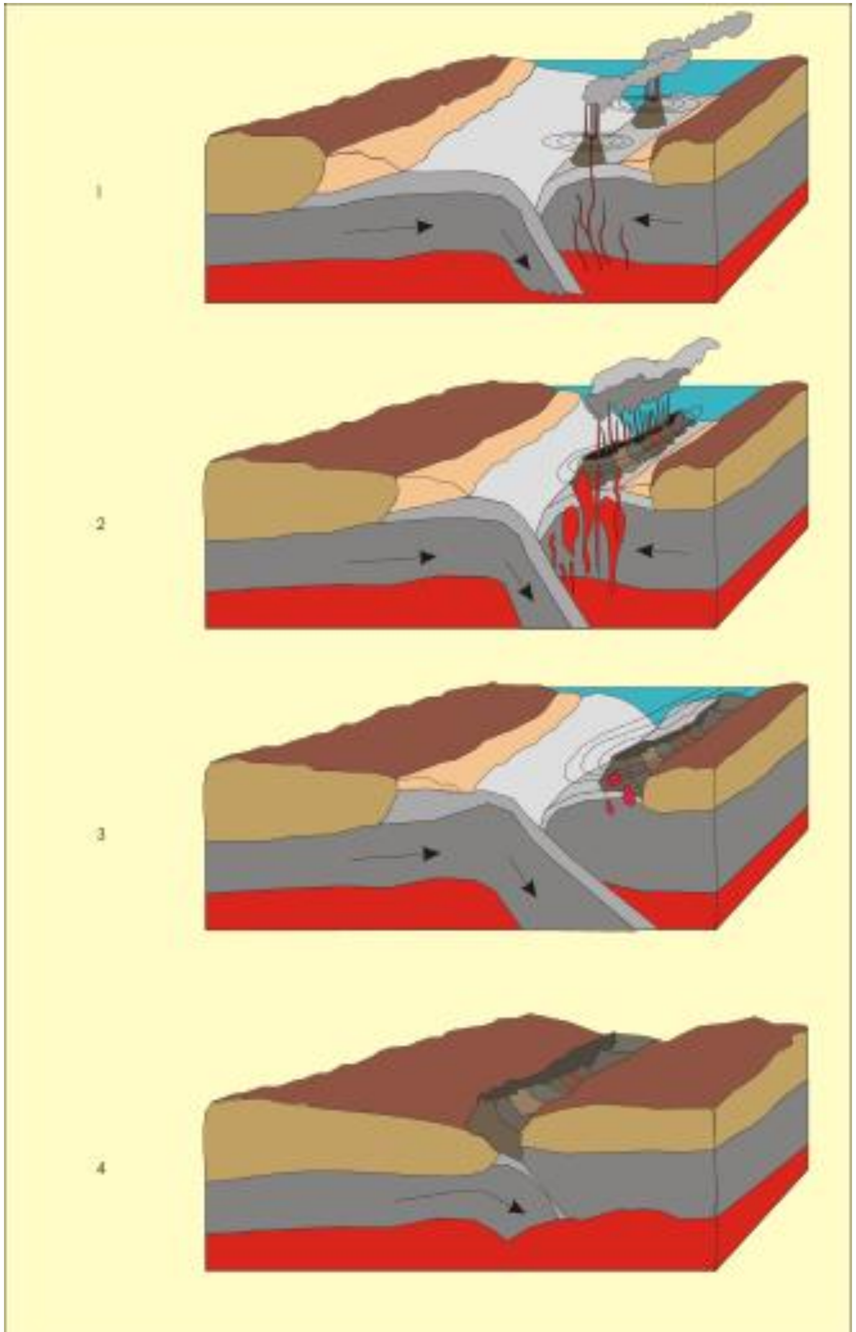
At the junction of continental and oceanic crust where there is no trench, sediments from the continental slope accumulate at the base of the slope to form a continental rise. The rises generally are adjacent to abyssal plains.

Passive margin: without a plate boundary



Active margin: contains a plate boundary

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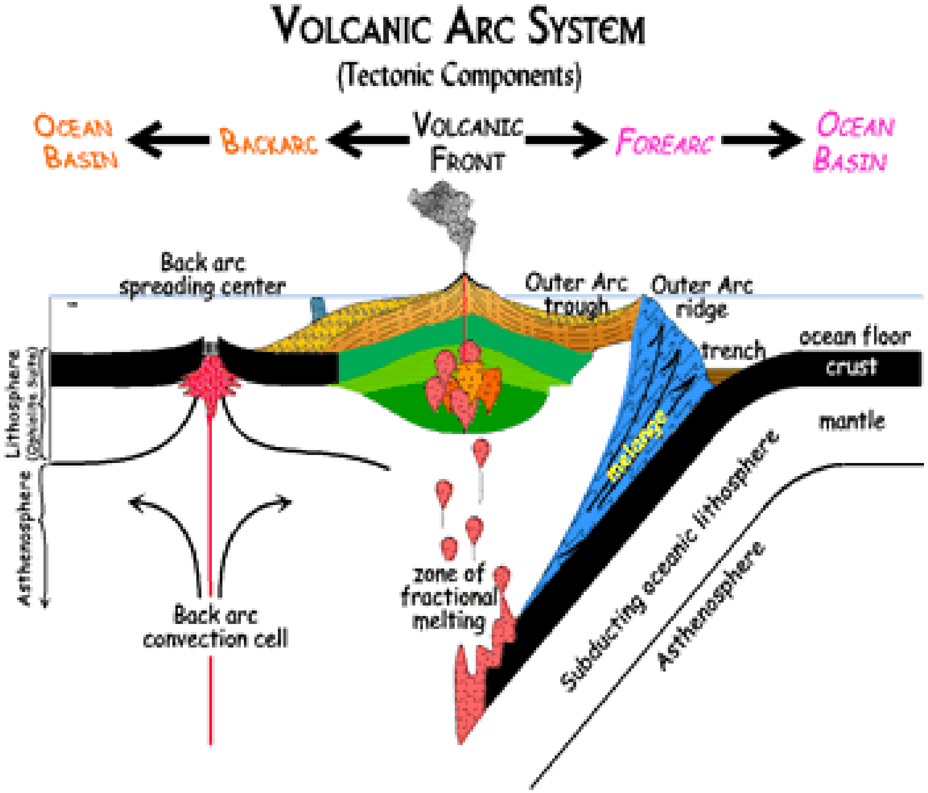
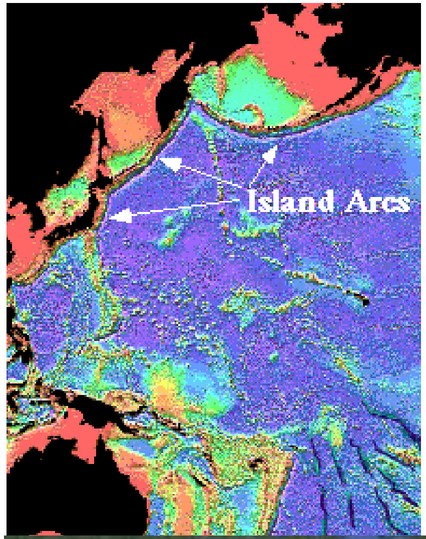
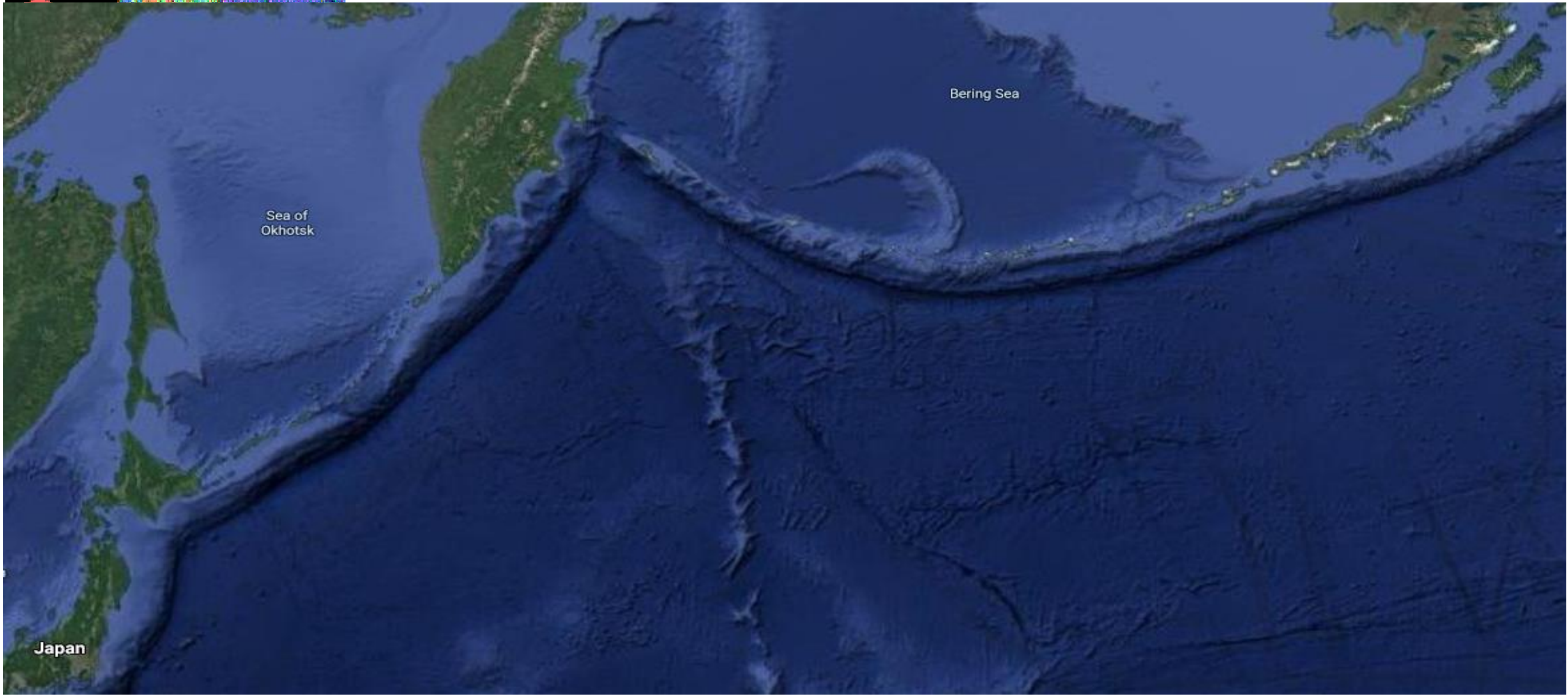


During subduction, an oceanic plate is thrust below another tectonic plate, which may be oceanic or continental. The subsiding plate melts in the upper mantle, creating magma that rises and penetrates the overriding plate, forming a volcanic arc. The weight of the down-going slab flexes the down-going plate creating an oceanic trench.

The area between the trench and the arc is the forearc region, and the area behind the arc (i.e. on the side away from the trench) is the back-arc region.

Benioff zone : This is a plane that dips under the overriding plate where intense volcanic activity occurs, which is defined by the location of seismic events below the arc. Earthquakes occur from near surface to ~660 km depth. The dip of Benioff zones ranges from 30° to near vertical.


Island Arcs


Bering Sea
Sea of
Okhotsk
Japan

Global relief model, sometimes also denoted as global topography model, combines **Digital Elevation Model (DEM)** data over land and **Digital Bathymetry Model (DBM)** data over water-covered areas (oceans, lakes) to describe Earth's relief. A relief model thus shows how Earth's surface would look like in the absence of water, forest or ice mass.

The relief is represented by a set of heights (elevations or depths) that refer to some height reference surface, often the mean sea level or the geoid. Global relief models are used for a variety of applications including visualization, geological, geomorphological analyses etc.

Global relief models are based on combinations of data sets from different remote sensing techniques. Because no single remote sensing technique would allow measurement of the relief both on land and water-covered areas. Elevation data over land is often obtained from LIDAR or InSAR measurements, while bathymetry is acquired based on SONAR and satellite altimetry techniques.

ETOPO1 relief of Africa

Spatial resolution

While digital elevation models describe Earth's land topography often with 1 to 3 arc-second resolution (e.g., SRTM or ASTER missions), the global bathymetry (e.g., SRTM30_PLUS) is known to a much lesser spatial resolution in the kilometer-range.

Therefore, global relief models are often constructed at 1 arc-minute resolution (corresponding to about 1.8 km). Some products such as the 30 and 15 arc-second resolution SRTM30_PLUS/ SRTM15_PLUS grids offer higher resolution to adequately represent SONAR depth measurements where available.

Public data sets

Data sets produced and released to the public include Earth2014, SRTM30_PLUS and ETOPO1.

ETOPO1 (2009)

The ETOPO1 1-arcmin global relief model, produced by the National Geophysical Data Center (Colorado), provides two layers of relief information. One layer represents the global relief including bedrock over Antarctica and Greenland, and another layer the global relief including ice surface heights. Both layers include bathymetry over the oceans and some of Earth's major lakes.

ETOPO1 land topography and ocean bathymetry relies on SRTM30 topography and a multitude of bathymetric surveys that have been merged. Historic versions of ETOPO1 are the ETOPO2 and ETOPO5 relief models (2 and 5 arc-min resolution).

Datum

The horizontal datum of ETOPO1 is WGS 84 geographic. All source elevation data used in building ETOPO1 were transformed to WGS 84 geographic prior to ETOPO1 development.

The vertical datum of ETOPO1 is “sea level”. Source elevation data were not converted to a common vertical datum due to the large cell size of ETOPO1 (1 arc-minute; ~2 km). This means that the vertical uncertainty of ETOPO1 elevations (greater than 10 meters) exceeds the differences between vertical datum near sea level (usually less than a meter).

Elevations in ETOPO1 are in meters.

ETOPO1 cannot be used for navigation, and products derived primarily from NCEI data are not subject to copyright protection in the United States .

The General Bathymetric Chart of the Oceans (GEBCO) is a publicly available bathymetric chart of the world's oceans. The project was conceived with the aim of preparing a global series of charts showing the general shape of the seafloor. Over the years it has become a reference map of the bathymetry of the world's oceans for scientists and others.

GEBCO operates under the joint auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Its work is done by an international group of experts in seafloor mapping who develop a range of bathymetric data sets and data product.

Global gridded bathymetric data sets:

GEBCO_08 Grid — a global bathymetric grid with 30 arc-second spacing, generated by combining quality-controlled ship depth soundings with interpolation between sounding points guided by satellite-derived gravity data.

GEBCO_2014 Grid — an update to the previously released GEBCO_08 Grid.

GEBCO_2019 Grid — an update to the previously released GEBCO_2014 Grid with 15 arc-second resolution.

GEBCO One Minute Grid — a global grid at one arc-minute intervals, based largely on the most recent set of bathymetric contours contained within the GEBCO Digital Atlas.