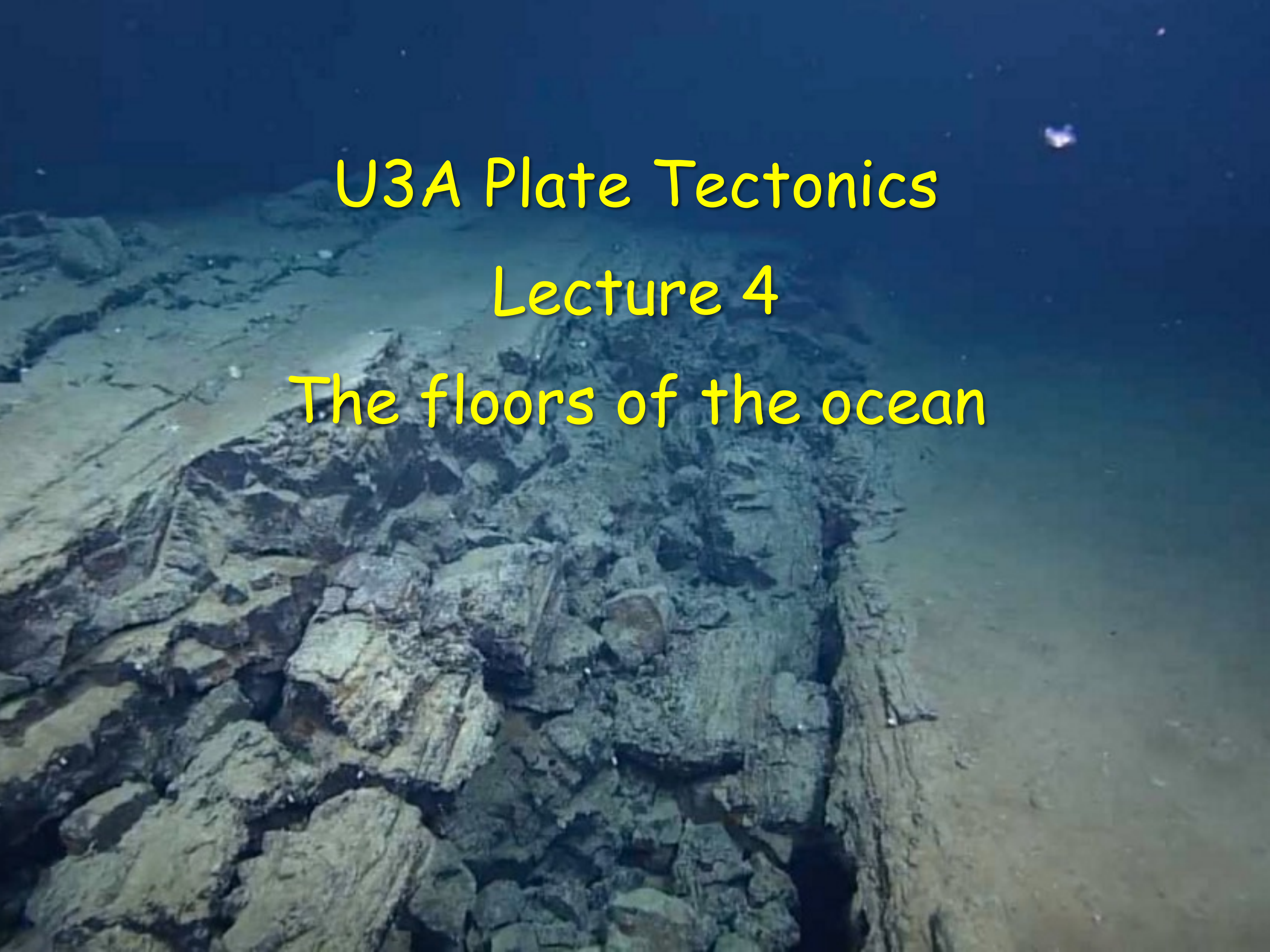
U3A Plate Tectonics

Lecture 4

The floors of the ocean



Introduction

- Up until the end of World War 2 → general belief → rocks underlying seafloor sediments were similar to those forming the continents
- in the 1950s, this was proven to be untrue → startling revelation
- the oceanic crust is fundamentally different to continental crust
- discovery led to a change of attitude towards the theory of continental drift

Studying the ocean floors

- The oceans cover 75% of the surface of the Earth
- not simply because they have lower elevation → 75% of the world crust has fundamentally different structure to the rest
- very little was known about the ocean floor until the last seventy years
- since the end of World War 2, a variety of methods have been developed to study the deep oceans e.g. sonar
- study of the oceans is crucial in developing the Theory of Plate Tectonics

The Earth

Studying the ocean floors

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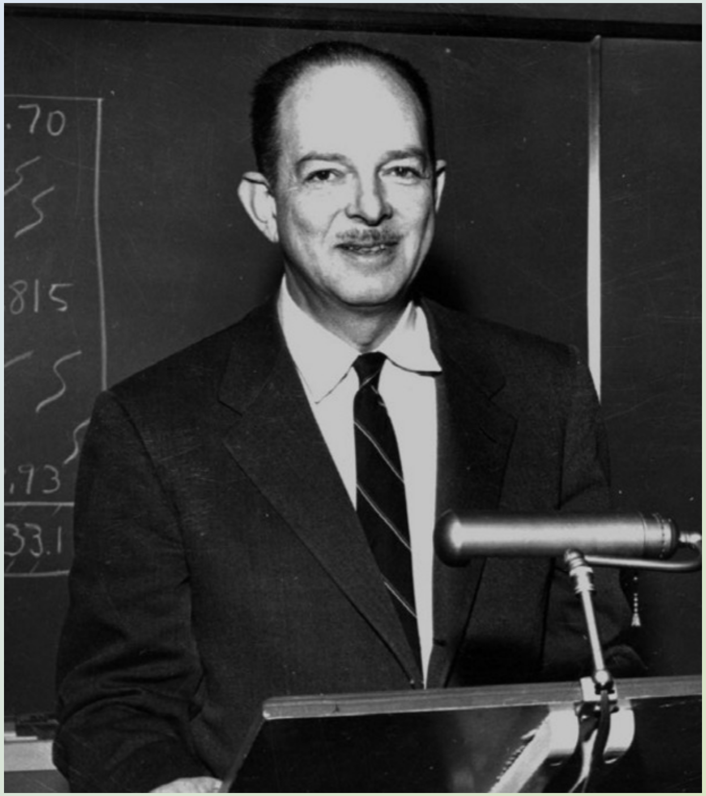
- very little was known about the ocean floor until the last seventy years
- since the end of World War 2, a variety of methods have been developed to study the deep oceans e.g. sonar, drilling
- study of the oceans is crucial in developing the Theory of Plate Tectonics

Harry Hess

- Harry Hess mapped the seafloor in the North Pacific using sonar
- observed that oceans are shallower in the middle and identified the mid-ocean ridge
- proposed theories on seafloor spreading and growth of oceanic crust along the mid-ocean ridge



Harry Hess

Modern investigations of the seafloor

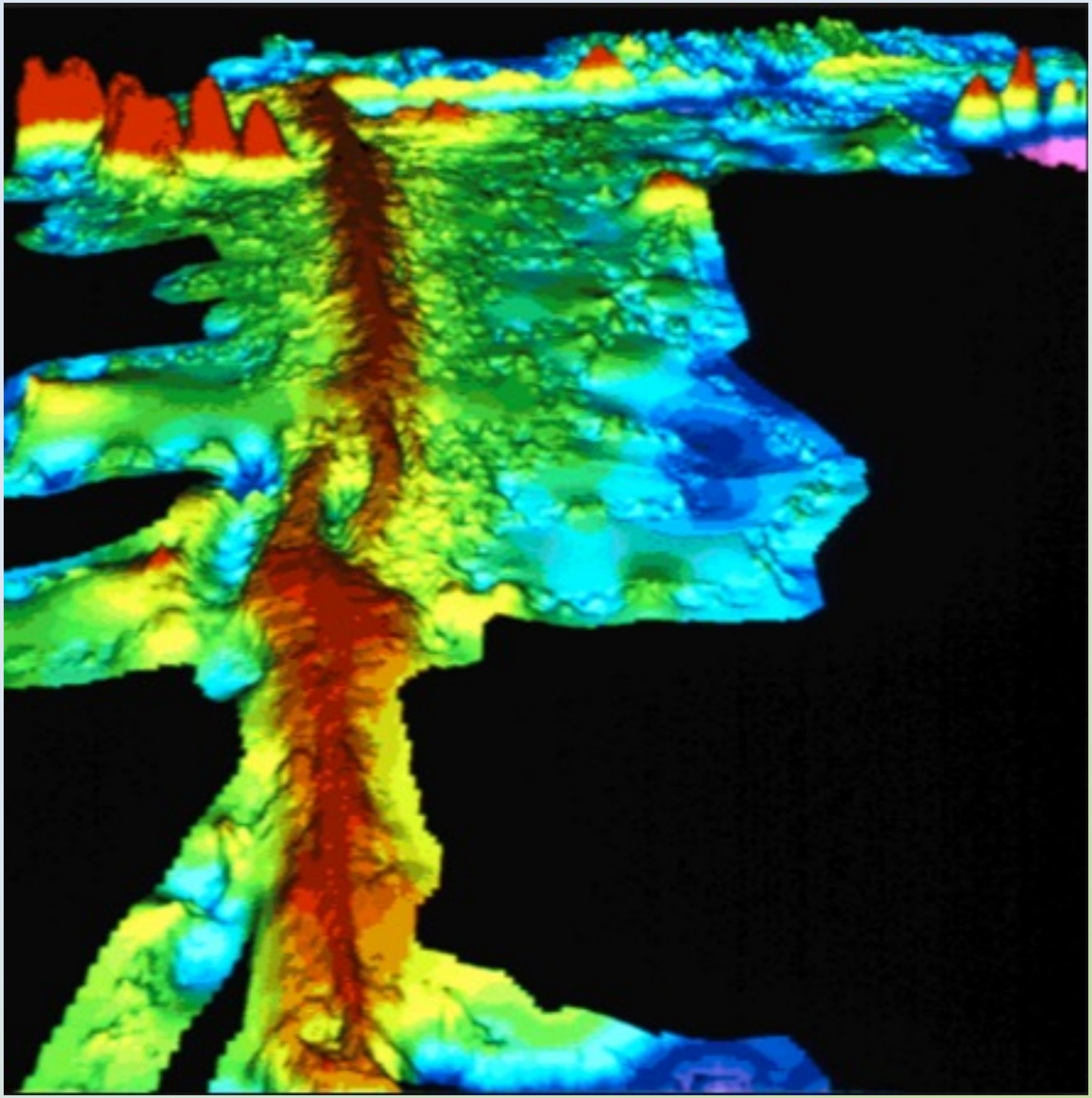
- Techniques developed during and post World War 2 came into use for investigating the seafloor e.g. sonar, magnetometers

- a large number of new data sets appeared in 1950s

- important technique developed → sonar → reflected sound waves from sea floor → produced cross section of depth of sea floor

- sonar has developed enormously over last 70 years → we now use modern multibeam sonar systems → illuminate large areas of sea floor → produce brilliant 3D images of sea floor topography

Multibeam sonar image of oceanic ridge

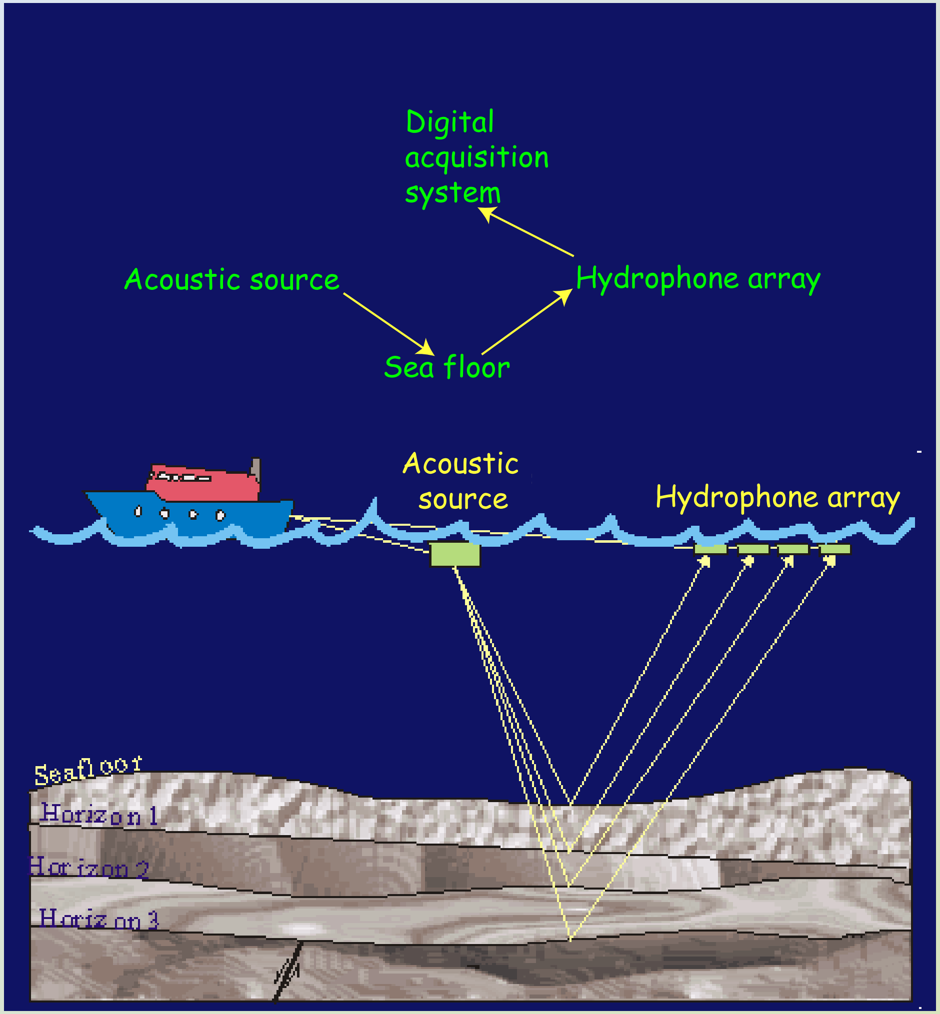


Multibeam sonar image of East Pacific rise

Seismic reflection

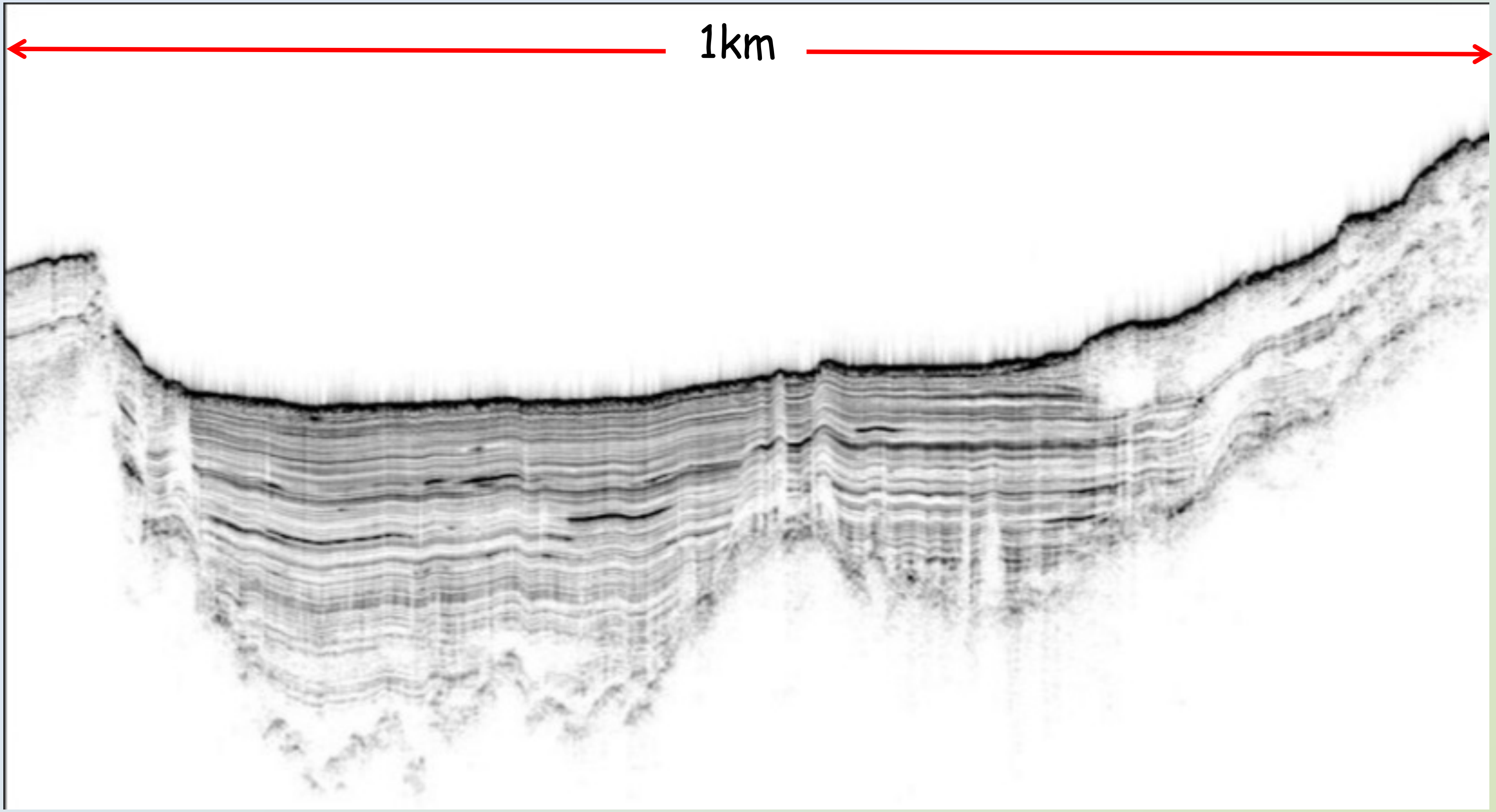
- Vessel tows a sound source that emits acoustic energy → accomplishes seismic profiling

- Seismic reflection → uses acoustic waves to map sub-surface rock structures



Seismic profile

Shock waves penetrate into ocean floor → image sub-surface structure

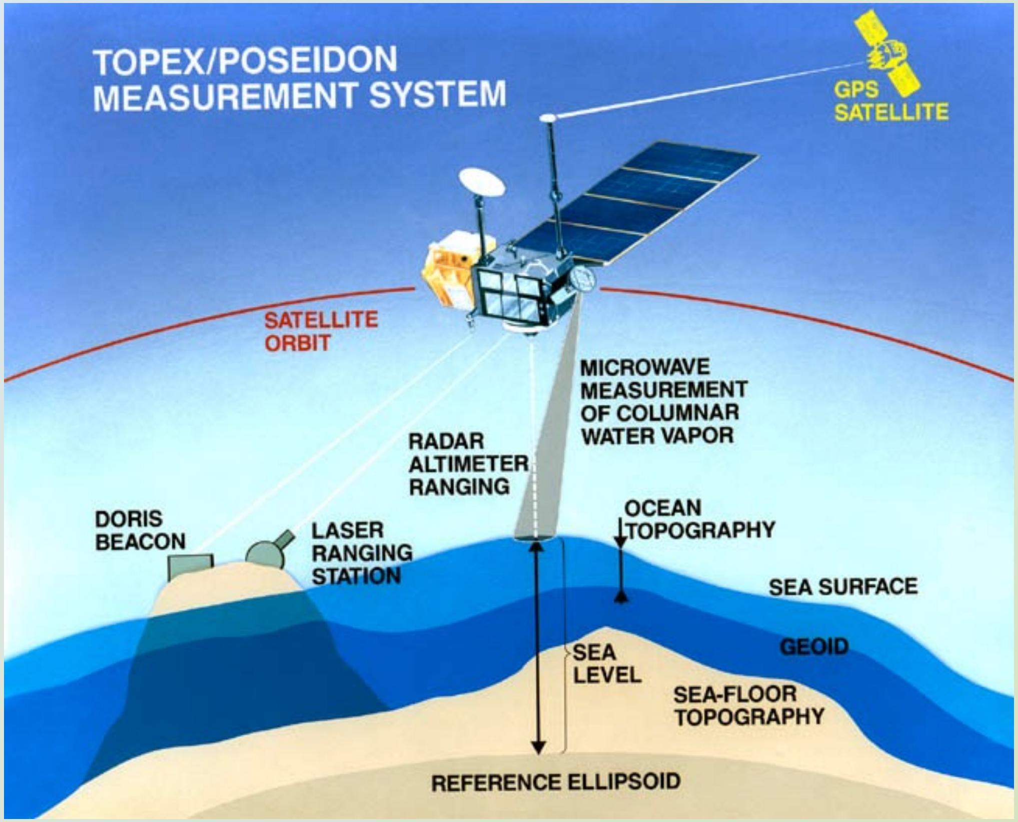


Satellite studies of the sea floor

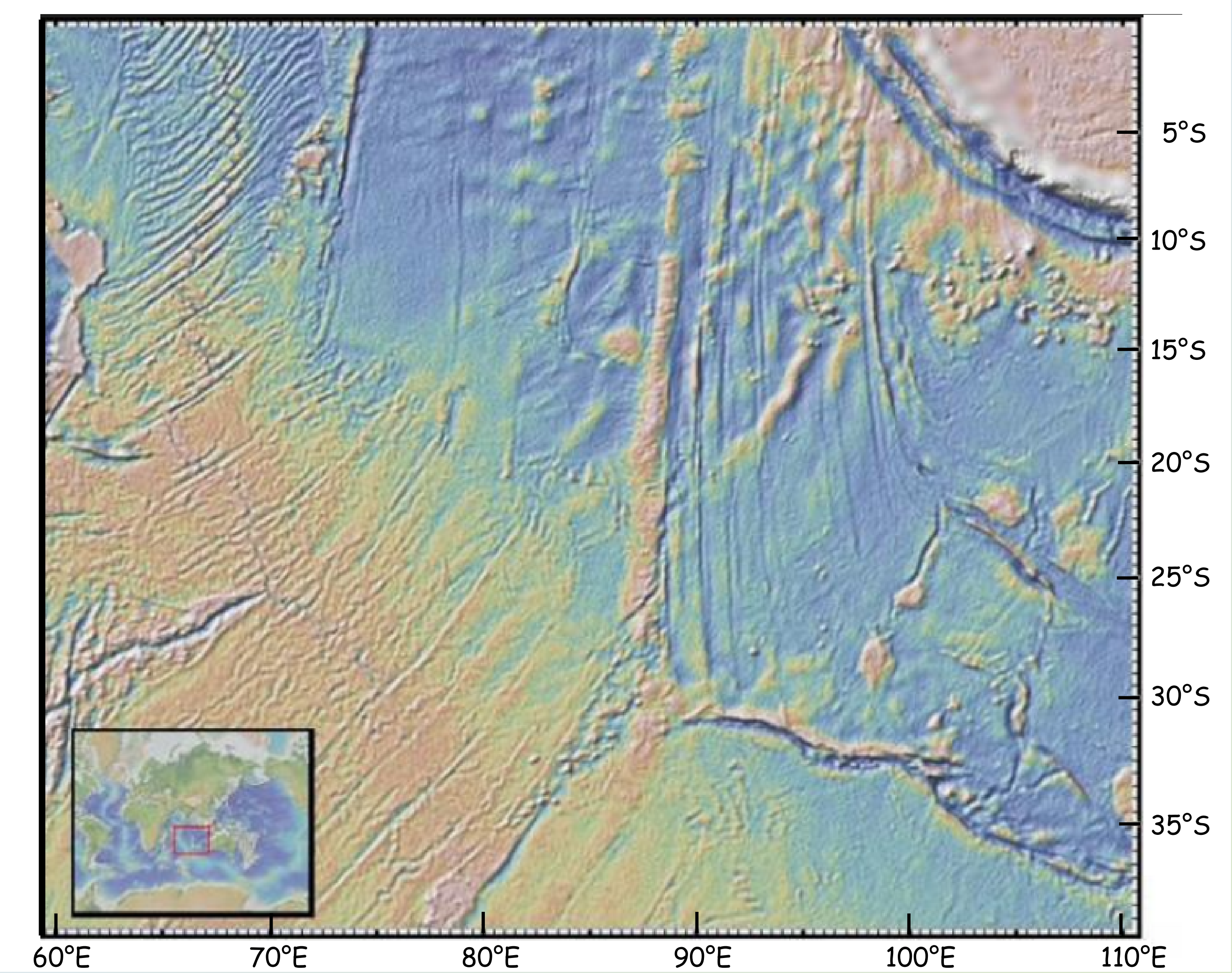
- The most recent method of studying the seafloor involves the use of satellite images from space (late 1980s)
- the method is called sea surface altimetry
- a narrow radar beam is used to measure the distance from the satellite to the sea surface → accuracy 4-5cm
- the height of the sea surface → closely reflects the shape of the sea-floor → contains bulges and depressions
- modern satellites (Jason-1 and OSTM/Jason-2) are specifically designed to perform this task
- satellites have mapped the entire seafloor in great detail

Sea surface altimetry

- The ocean surfaces contain bulges and depressions that reflect the shape of the sea floor
- higher elevations contain more mass therefore the local gravity field attracts more water
- seafloor mountains can form a bulge 30m high and sea floor troughs a depression up to 60m deep
- surface is imaged by downward pointing radar beam



Gravity image, central Indian Ocean



Direct sampling techniques

Dredging

- Grab sampling of ocean floor materials from ship

Coring

- samples of sediment collected in tubes driven into the sea floor

→ cores with about 10m of sediment

Soft sediment drill cores

Seafloor drilling programs

Drilling the sea floor

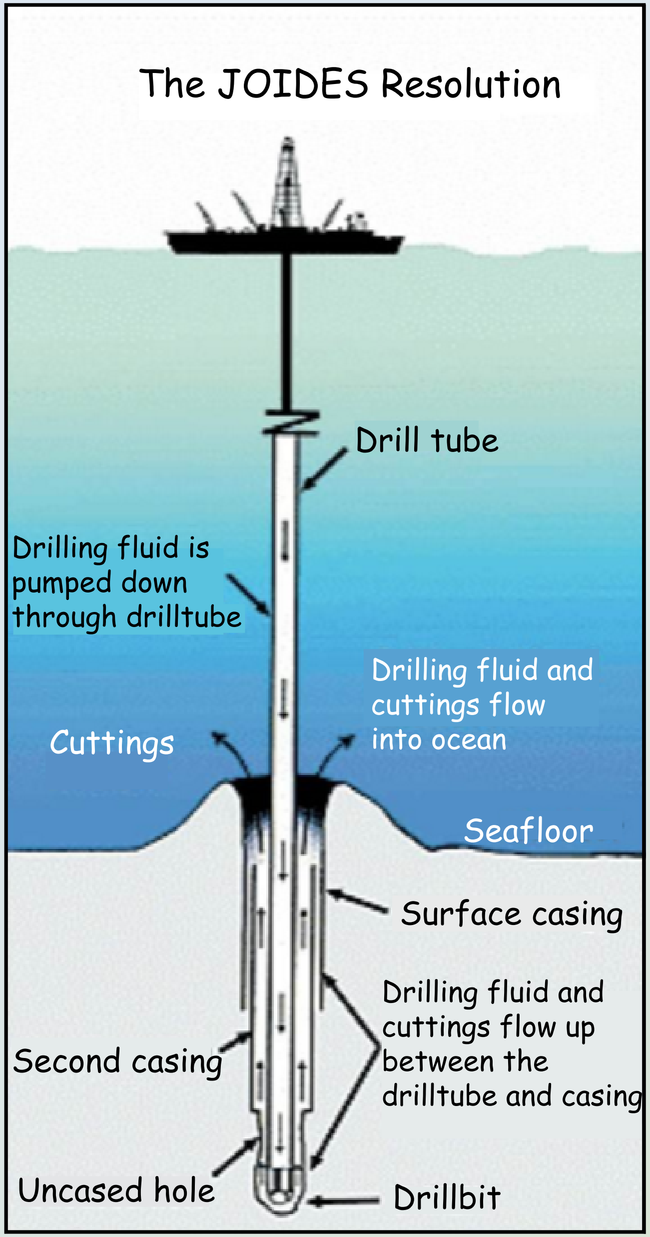
- Ongoing international co-operative drilling programs are conducted to explore and study the composition and structure of the ocean basins

  Joint Oceanographic Institutions of Deep Earth Sampling (JOIDES)

Deep Sea Drilling Project (DSDP)	1968-1983
Ocean Drilling Program (ODP)	1985-2004
Integrated Ocean Drilling Program (IODP)	2003-2013

- special ships have been used in the drilling of depths >2km below the ocean floor
- propose sites for drilling based on scientific merit
- >1500 holes drilled since the mid 1960s
- wealth of scientific information obtained from program (petrology, climate change, seafloor spreading)

Deep sea drilling of ocean crust



Ocean drilling programs

- JOIDES Resolution has advanced laboratories also high level computer network linked into global network by satellite communications
- is able to drill in middle of ocean → sail back to port → come back 10 years later and put drill down same hole
- has produced a wealth of scientific information to provide detailed understanding of sea floor

Ocean Drilling programs

Glomar Challenger – scientific drilling vessel used in the Deep Sea Drilling program (DSDP) from 1968-1983

Chikyu – scientific drilling ship built for the Integrated Ocean Drilling Program (IODP) entering service in 2005.

JOIDES Resolution – scientific drilling ship formerly used for oil exploration. Began work with the Ocean Drilling Program in 1985. Returned to service in 2007 after an upgrade

Visiting the sea floor

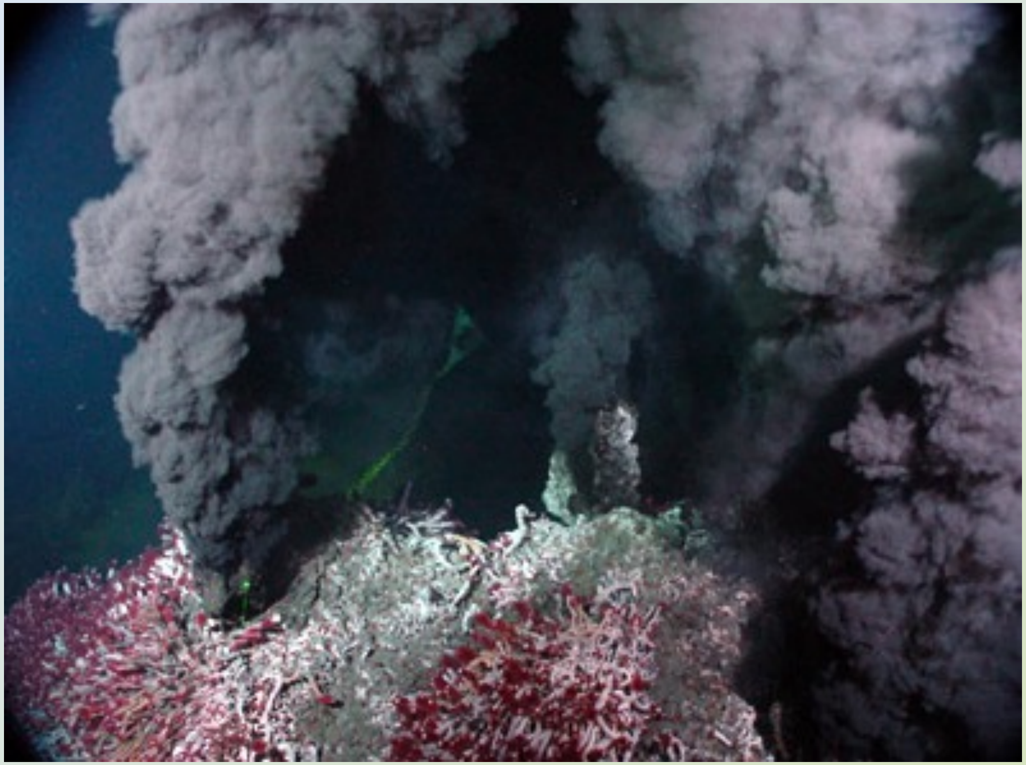
- Deep-diving submersibles such as ALVIN can dive to the deepest parts of the ocean
- they enable scientists to make detailed observations, take photographs and collect samples
- provide evidence not gained from sonar or drilling studies
- they have made remarkable discoveries of mineral-rich, hot springs in deep ocean with previous unknown fauna living around them

Alvin

Black smokers

- Black smokers – hot springs on sea floor
- first observed by deep sea submersibles
- hydrothermal fluids (~350°C) leach ions from ocean crust →
  precipitate minerals at cold water interface (4°C)
- metal sulphides and gypsum are dominant precipitates

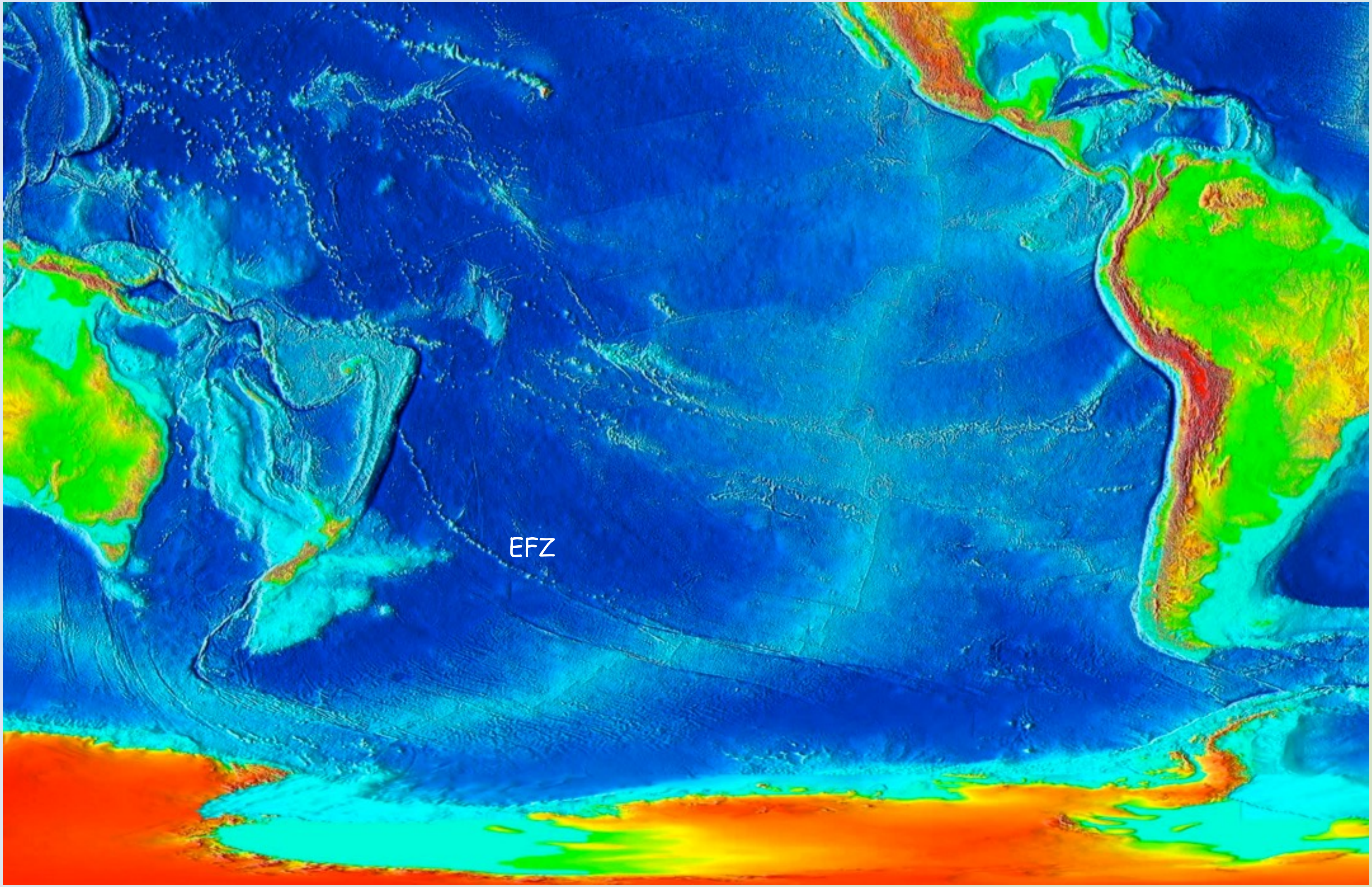
Black smokers,
East Pacific Rise



Major features of the ocean floor

- Ocean ridge system
- Transform faults and fracture zones
- Island arcs and trenches
- Abyssal plains
- Seamounts and guyots
- Linear seamount and island chains
- Oceanic plateaux

Relief map of south Pacific Ocean

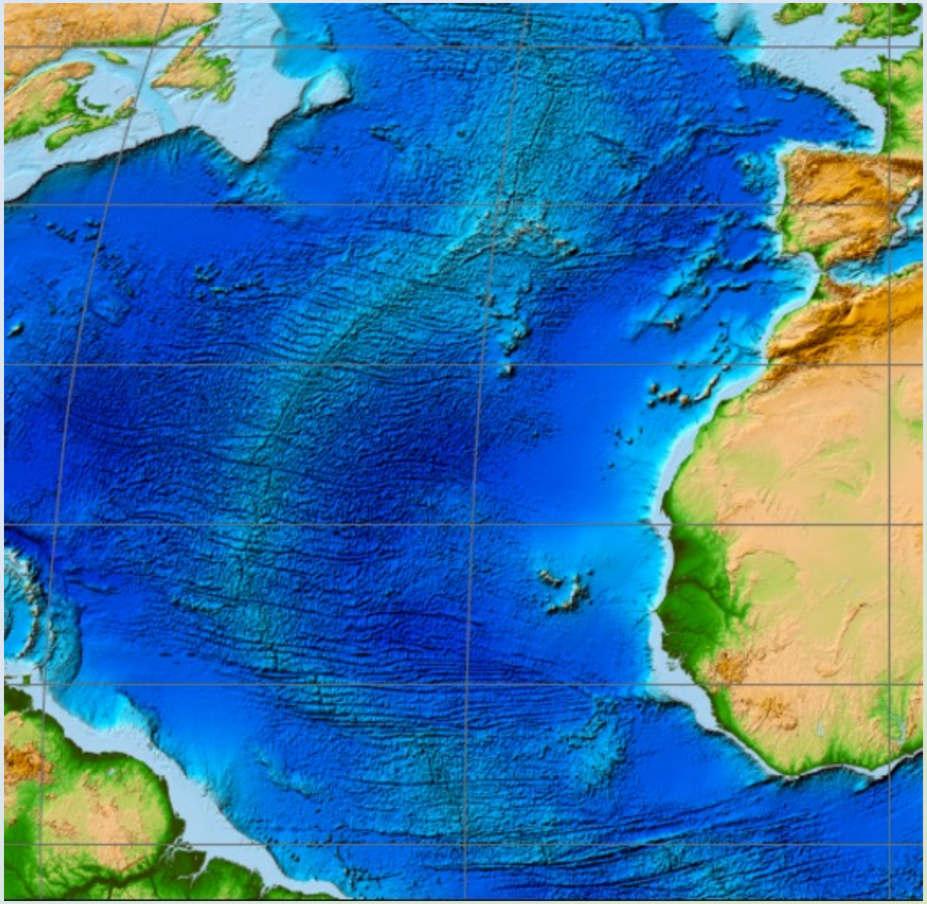


EFZ = Eltanin Fracture Zone

Ocean ridge system

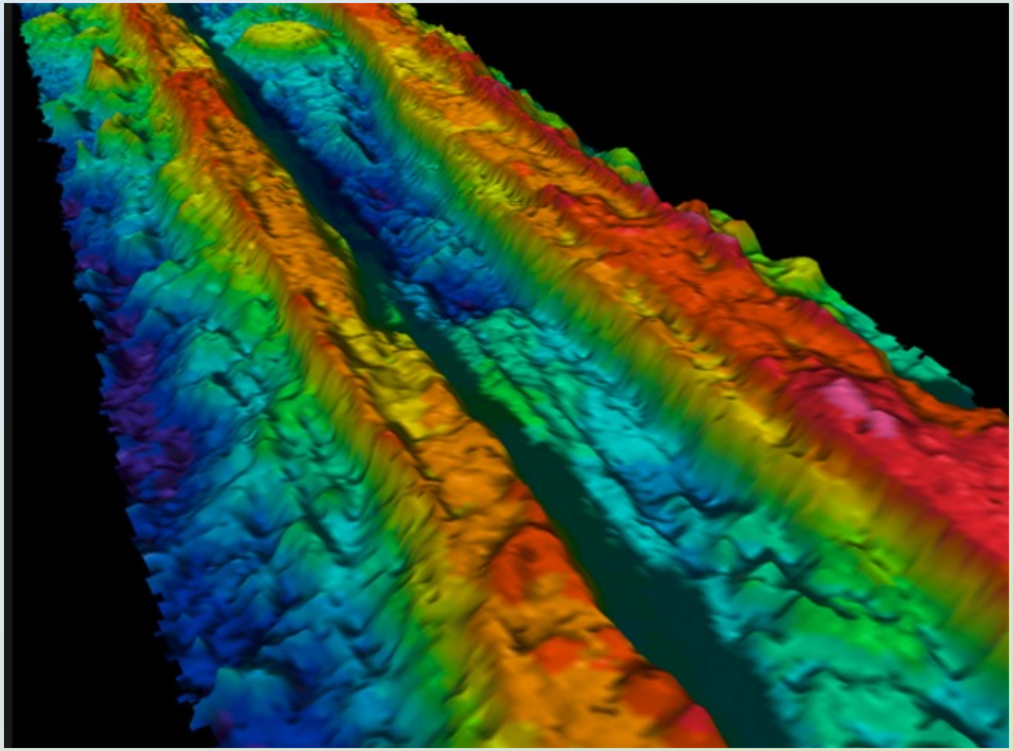
- Largest tectonic feature on Earth (larger than mountain chains)
- more than 1500km wide, 64,000km long
- rises to 2-3km high above the abyssal plane
- has a central rift valley
- composed of basalt rocks
- high heat flow and hydrothermal vents
- faulted but not folded
- shallow earthquakes occur along central rift

Mid Atlantic ridge



Echo sounding across Ocean ridge system

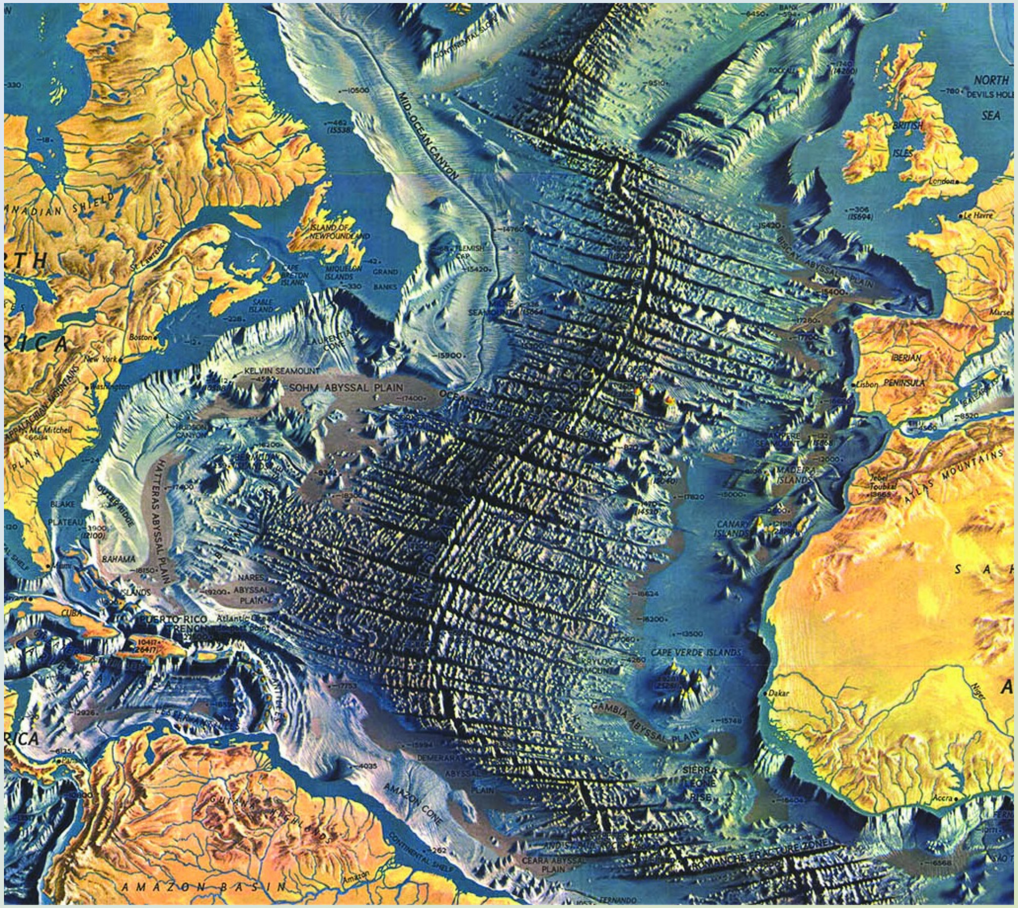
- Oceanic ridge 2-3km above abyssal plain
- rift valley runs down centre of oceanic ridge
- little sediments on it → sediments increase away from ridge
- composed almost entirely of basalt, high heat flow
- location of hot springs, focus of shallow earthquakes



Multibeam sonar image of ocean ridge

Transform faults and fracture zones

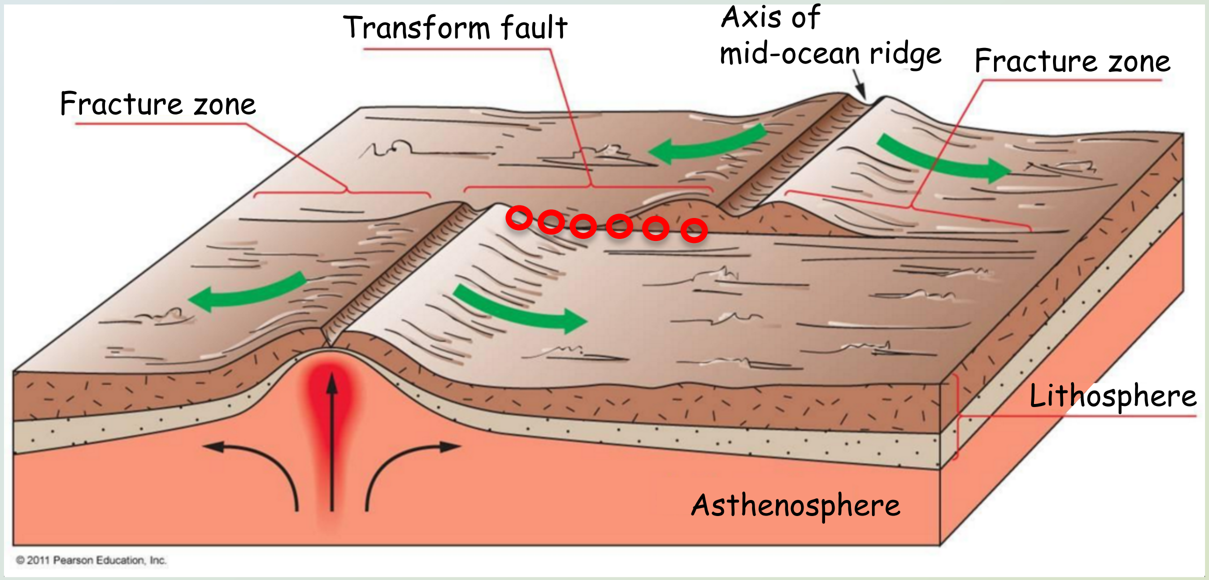
- Transform faults are large faults on the ocean floor that cut across oceanic ridge at right angles
- transform faults offset the axis of the oceanic ridge system
- transform faults → seismically active
- oceanic ridge continuously segmented
- fracture zones are the extensions of transform faults, far beyond the oceanic ridges



Transform faults offsetting mid Atlantic ridge

Transform faults

- Movements on transform faults occur only between the segments of the ridge crests
- shallow earthquakes occur along the median rift valleys and along transform faults
- pass laterally into fracture zones that are not seismically active and have no active movement

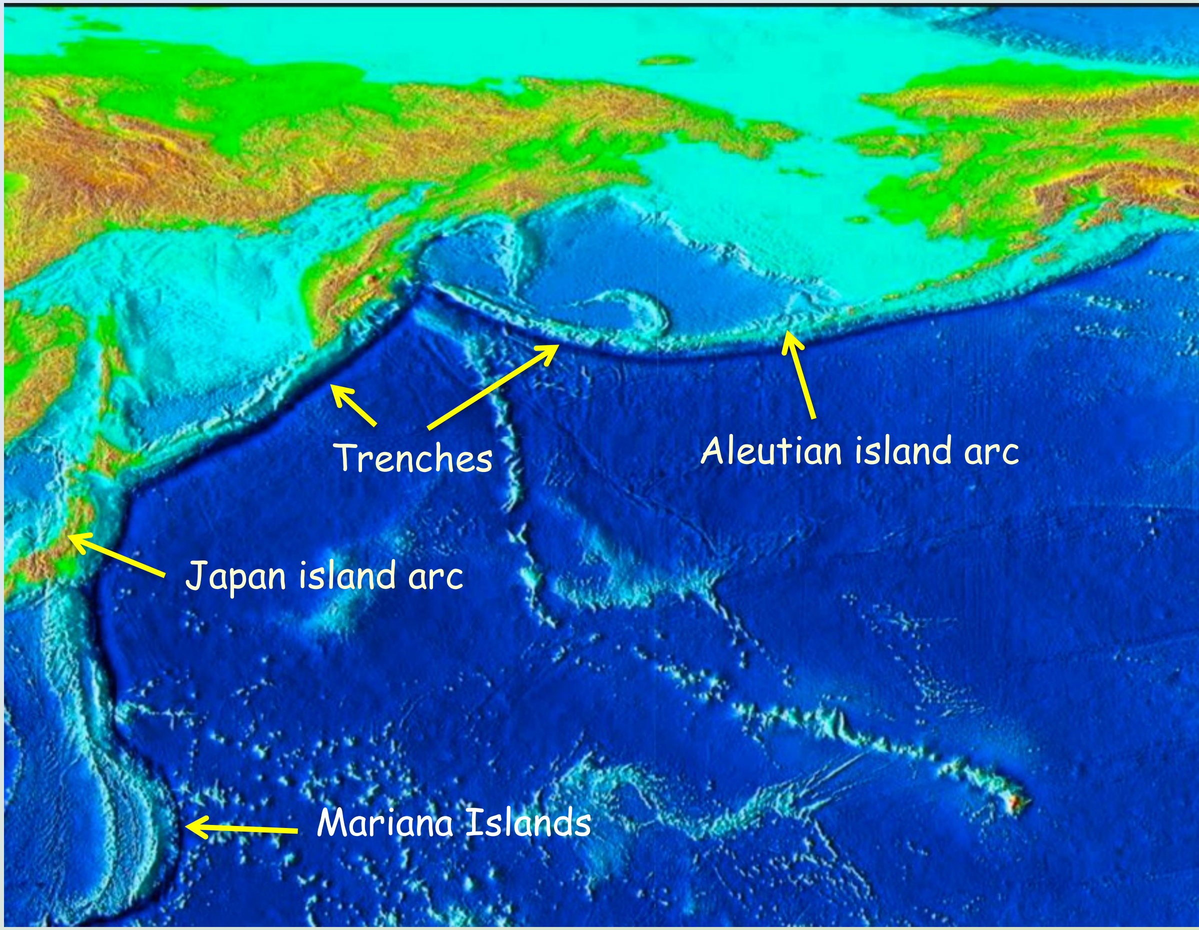


Island arcs

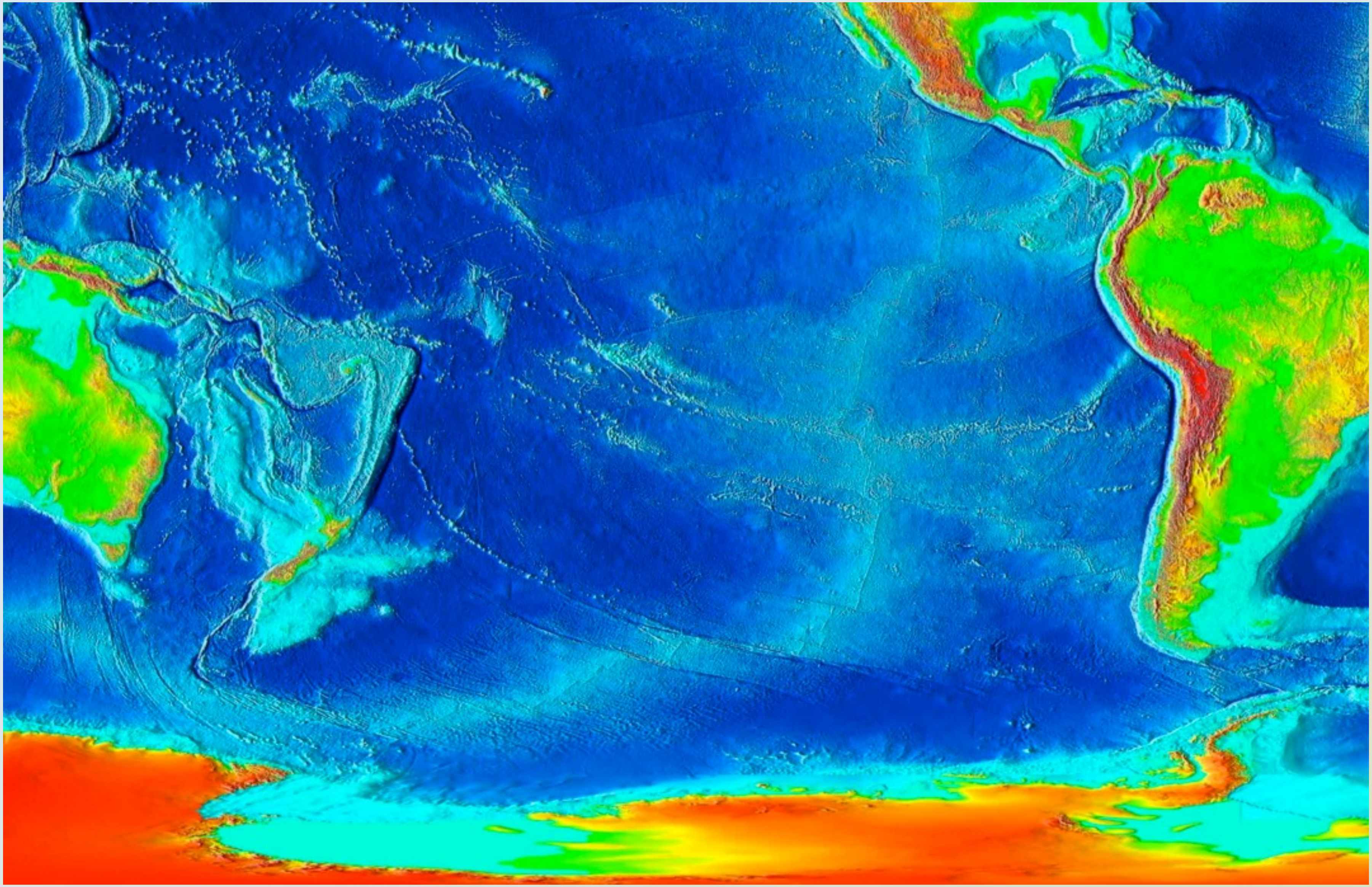
- Island arcs are chains of volcanically active islands at the edge of some oceans
- they are generally curved and convex oceanwards
- deep-sea trenches occur along the convex side
- typically composed of andesitic volcanoes
- numerous shallow, intermediate and deep earthquakes occur along these arcs

North Pacific

Ocean sea floor



Island arcs south Pacific



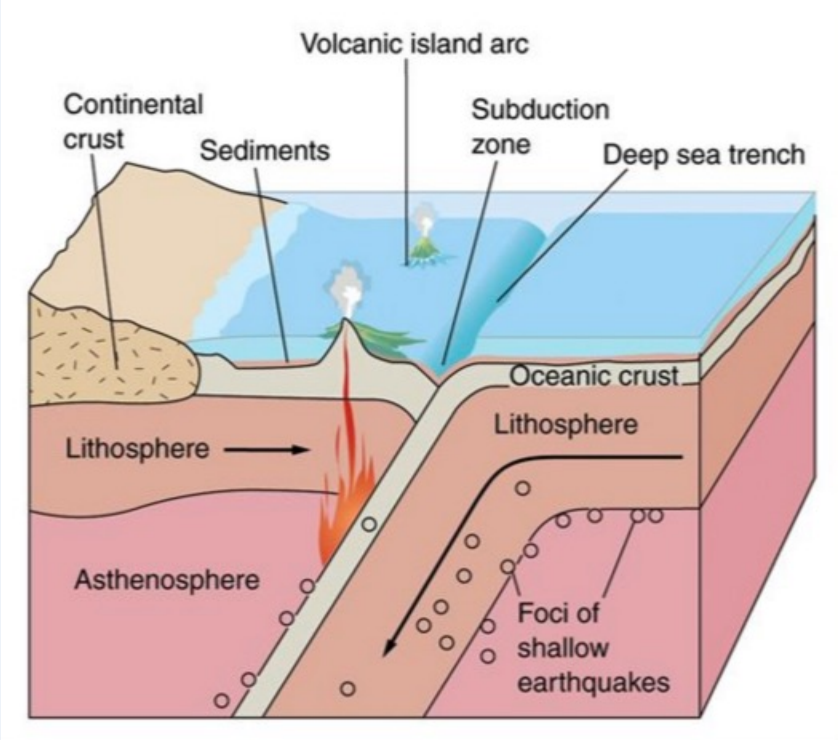
Ryuku Islands

The Ryuku Islands → chain of volcanic and limestone islands that extend 1,100km SW from Kyushu to Taiwan

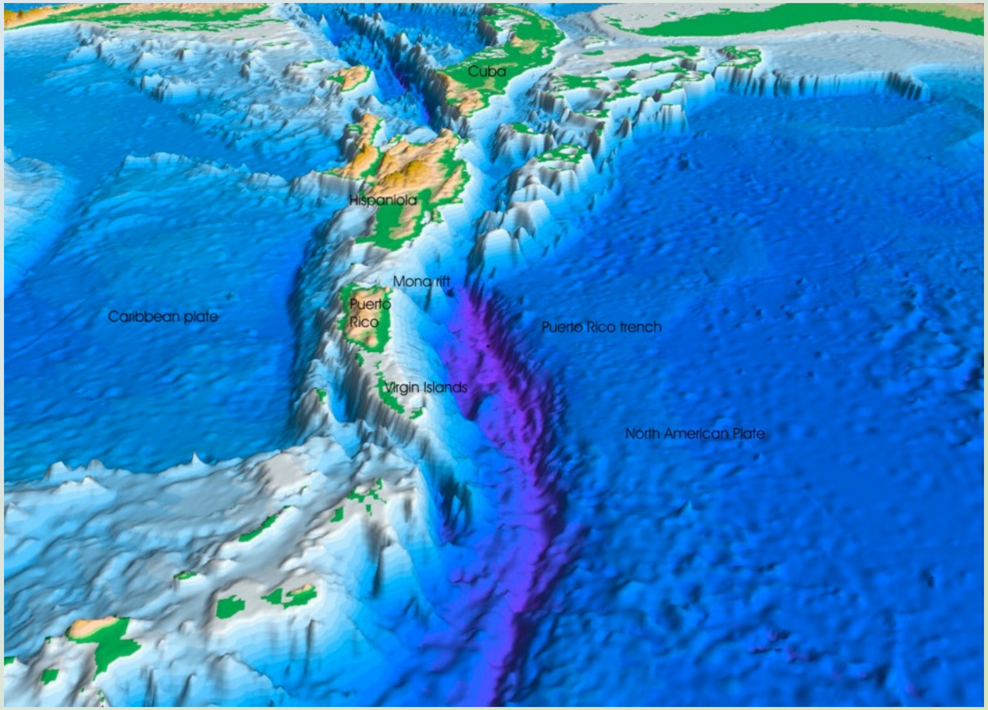
Mt Mayon

- Large andestic volcanoes occur within island arcs
- sometimes when mature, arc volcanoes join up → produce continuous stretches of land like Japan, Java or northern PNG

Deep sea trenches



Trench-Island arc model

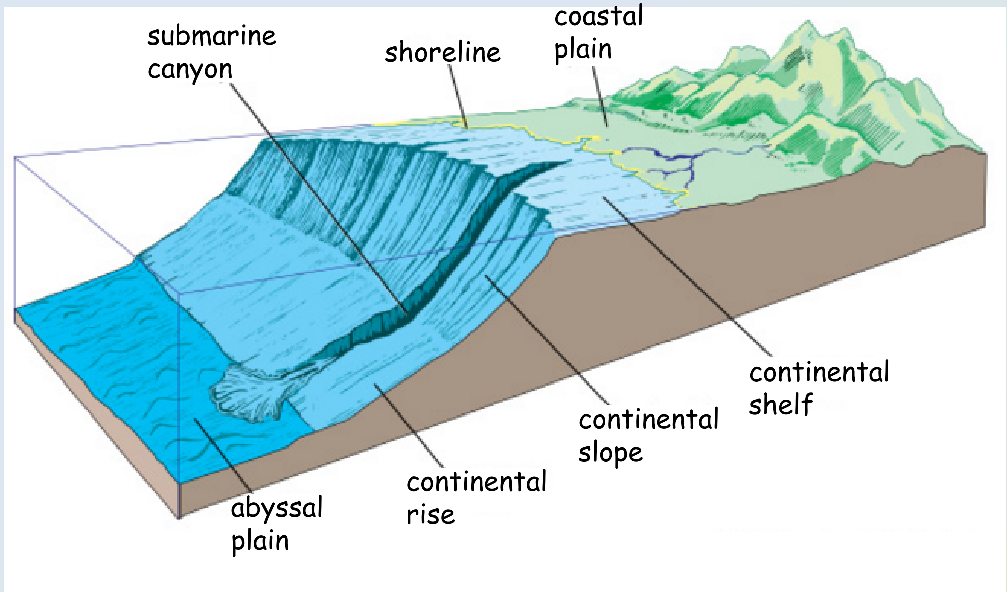


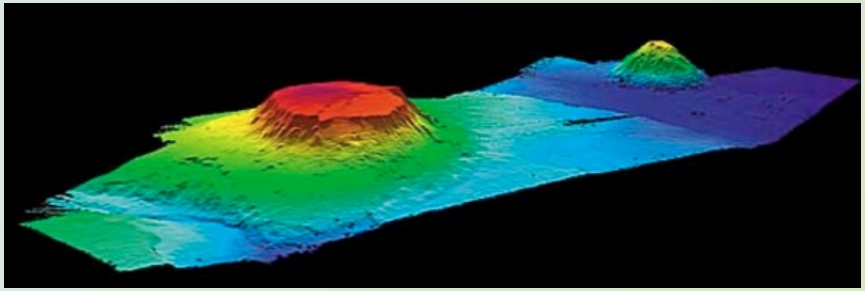
Topography of seafloor

- Puerto Rico Trench

Structures of the abyssal floor

- Deep, broad, flat floors of the ocean are called abyssal plains
- depth range: 4-6km
- abyssal plains are covered by a thin layer of sediment <1km thick
- oceanic islands → all bar one are basalt volcanoes (coral atolls)
- seamounts are oceanic islands not exposed above sea surface
- guyots are flat-topped seamounts

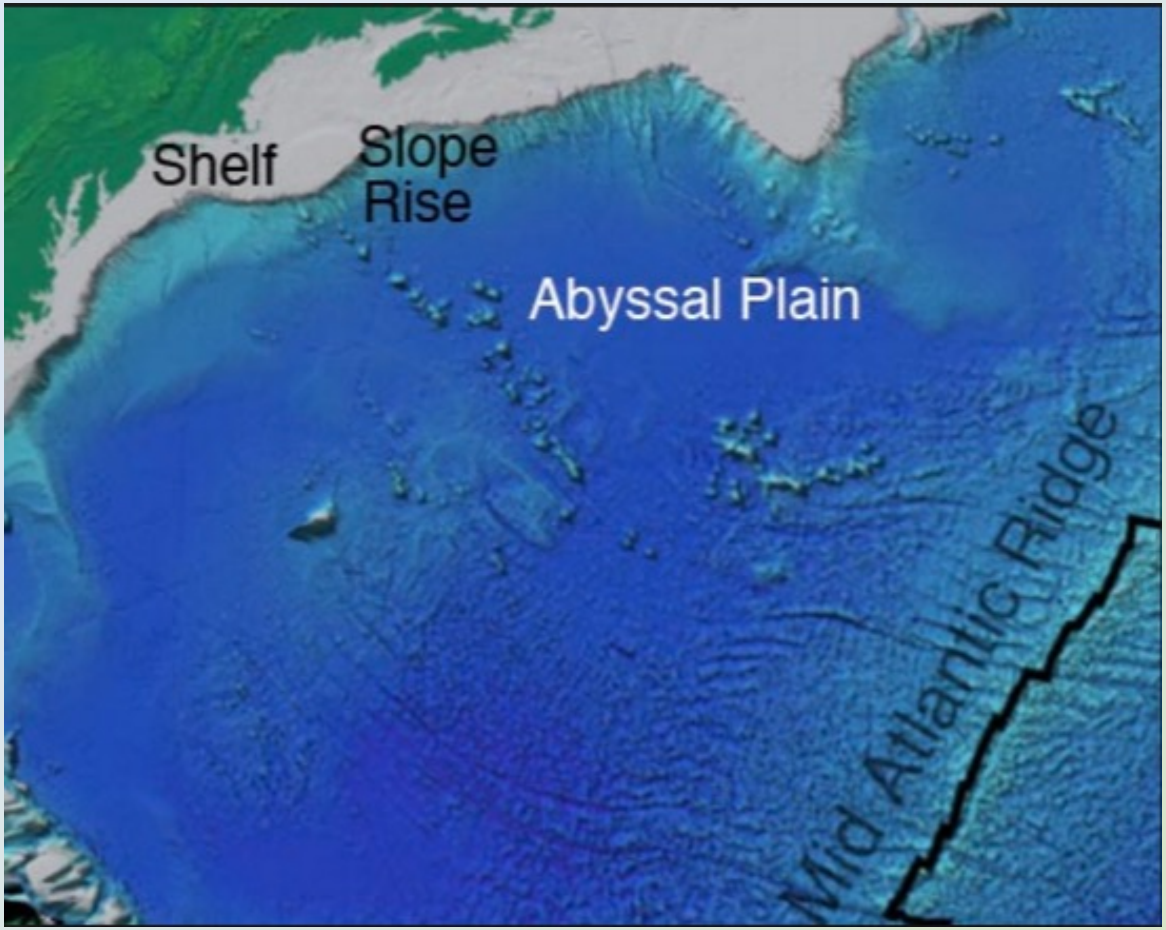




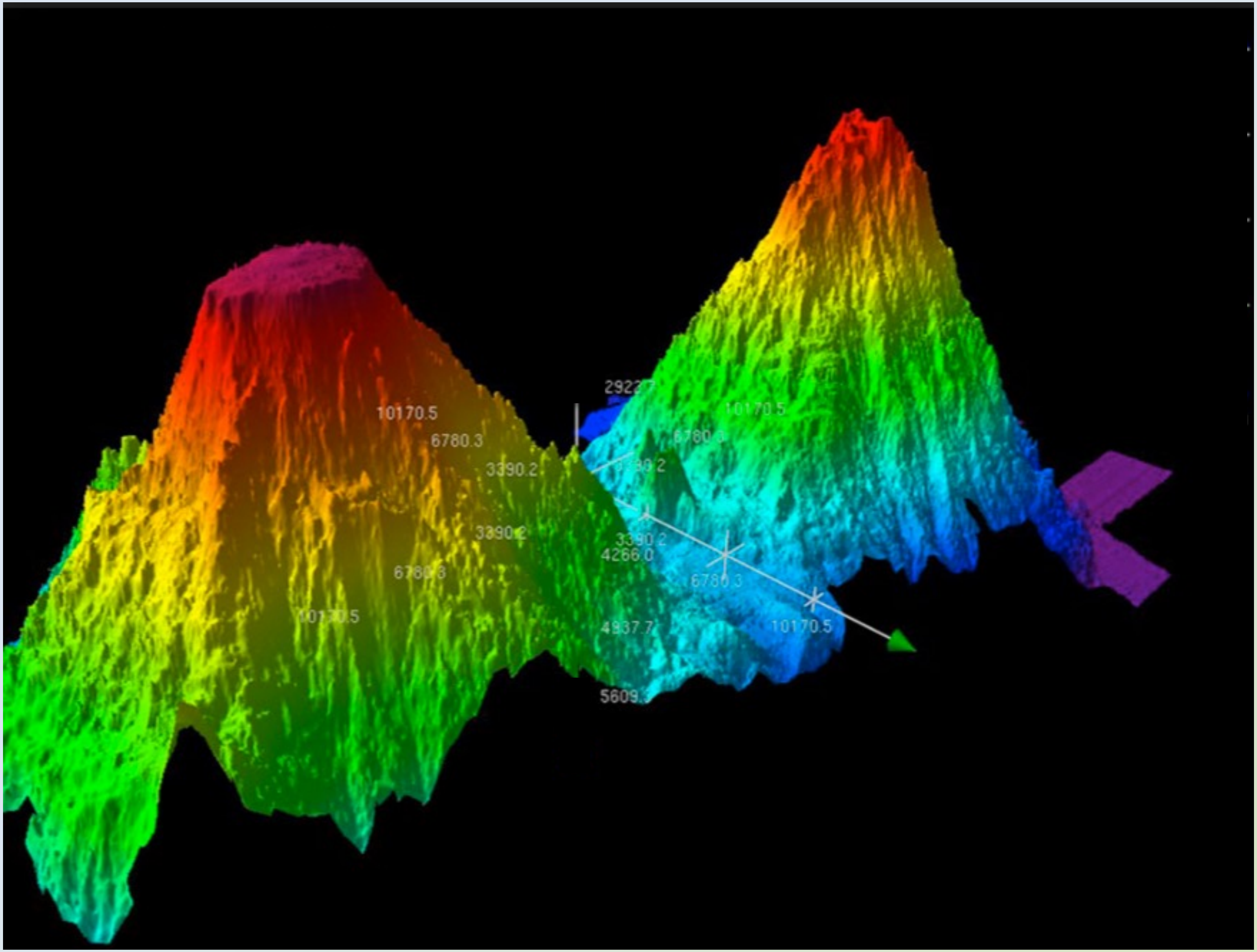
Guyot and seamount

Abyssal plain

- Broad plains blanketed by sediment ~1km thick
- sporadic seamounts (volcanoes that build up from the abyssal plain)
- flat topped seamounts are called guyots



Seamounts and guyots

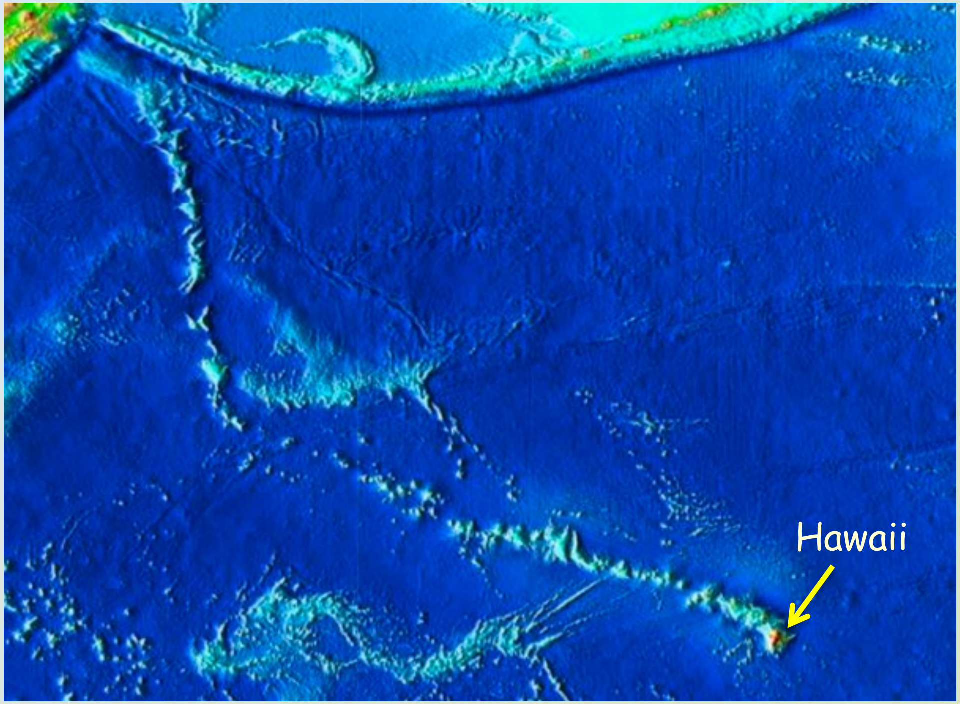


Linear seamount and island chains

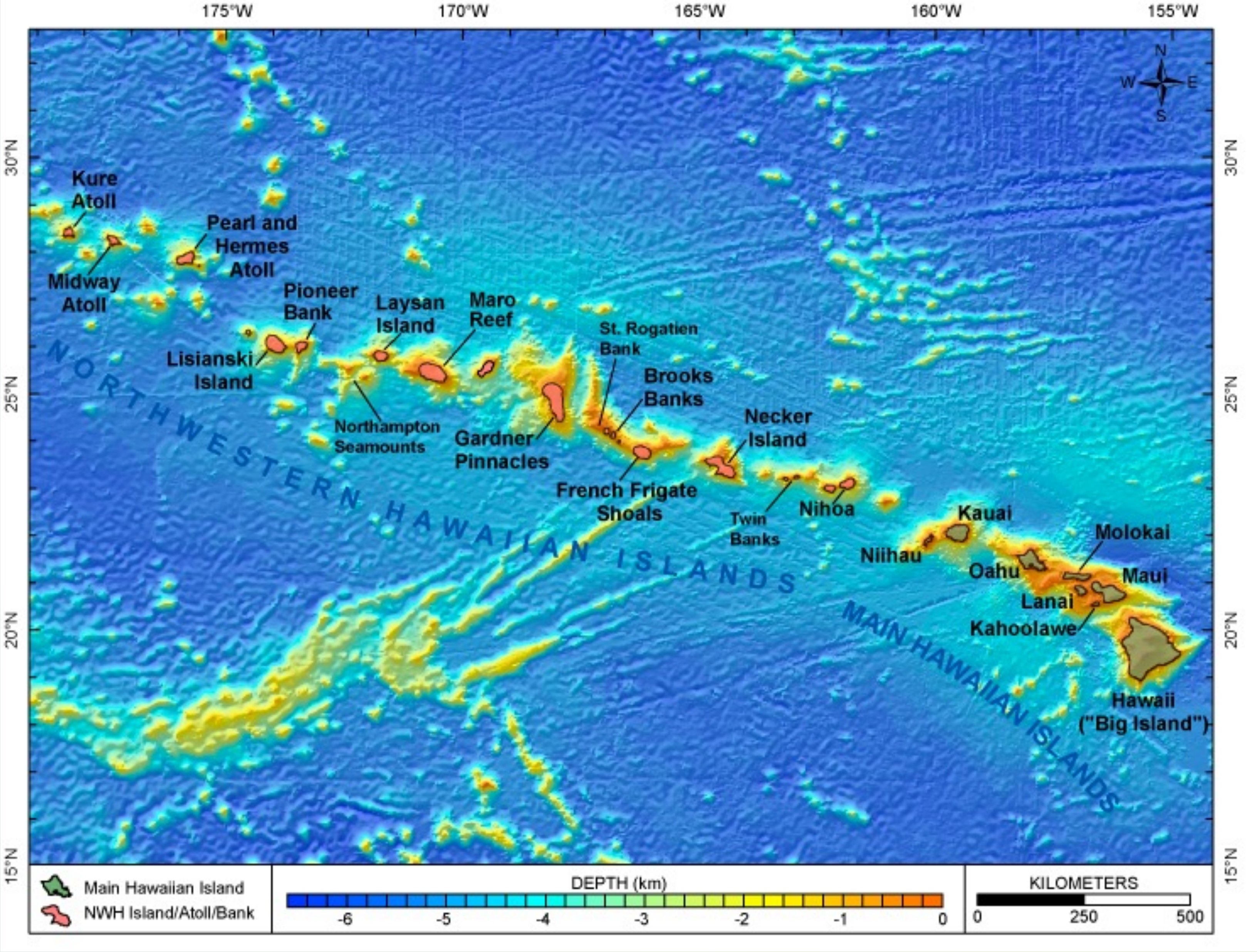
- Linear chains or ridges of seamounts and islands across ocean floor
- different in structure and composition to island arcs
- seismically inactive and much narrower than oceanic ridges
- often have an active volcanic island at one end
- Hawaiian islands – Emperor seamount chain is the best example

Hawaiian islands –

Emperor seamount chain



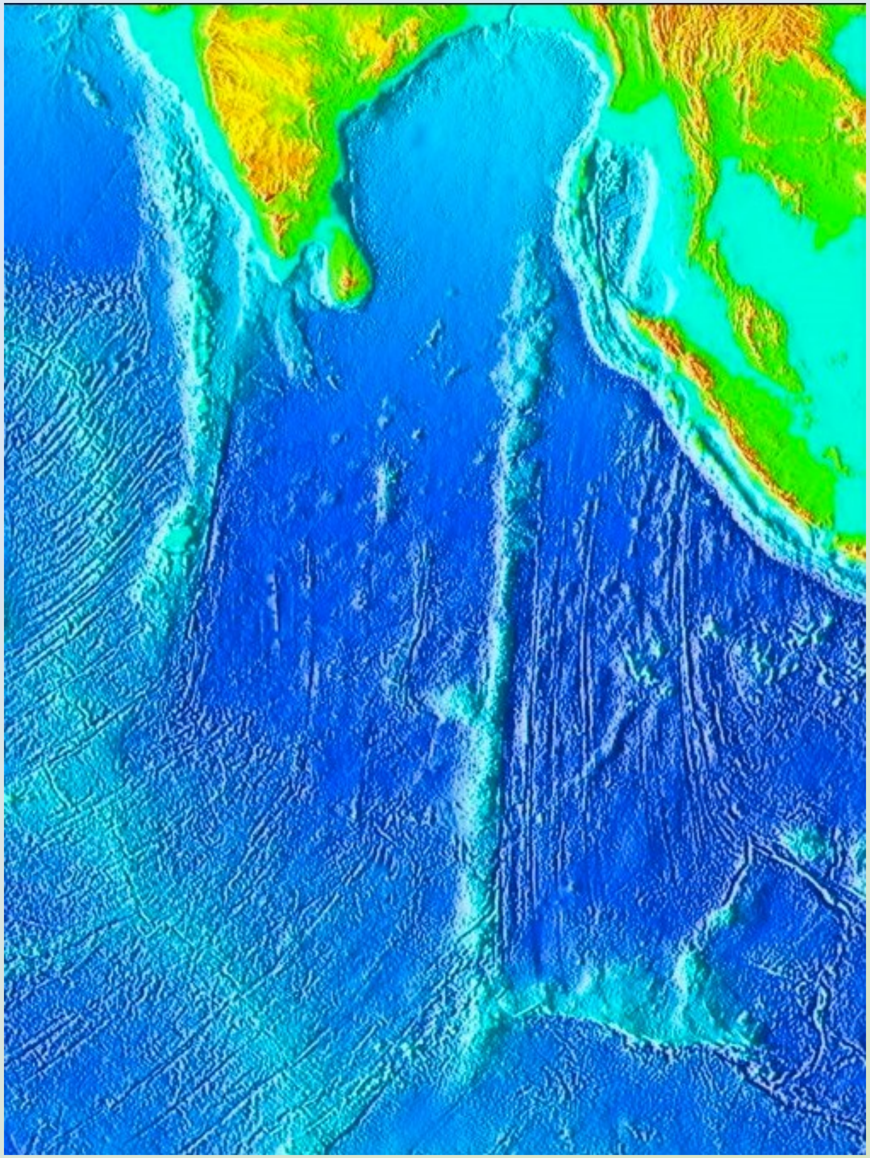
Hawaiian Island chain



Ninety East Ridge

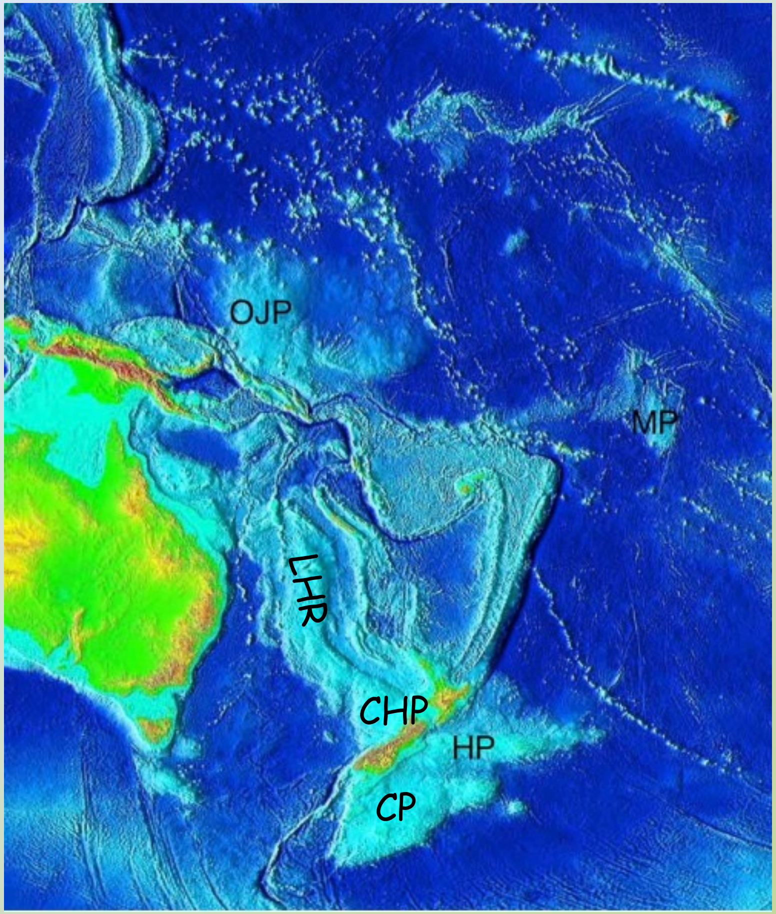
Ninety East Ridge

- Linear, age progressive, seamount chain in Indian Ocean
- extends from 33°S to Bay of Bengal
- 5000km long, ~200km wide
- ridge → composed of basalt
- 43Ma in south to 82Ma in north
- formed by hotspot under Indo-Australian plate



Oceanic plateaux

- Broad areas of the ocean floor are at relatively high elevations
- only 1-3km deep
- some are floored by thinned continental crust e.g. the Campbell plateau east of NZ
- others are floored by unusually thick oceanic crust e.g. Ontong-Java plateau, north of Solomon Islands



Topography of sea floor, Western Pacific

OJP = Ontong-Java Plateau

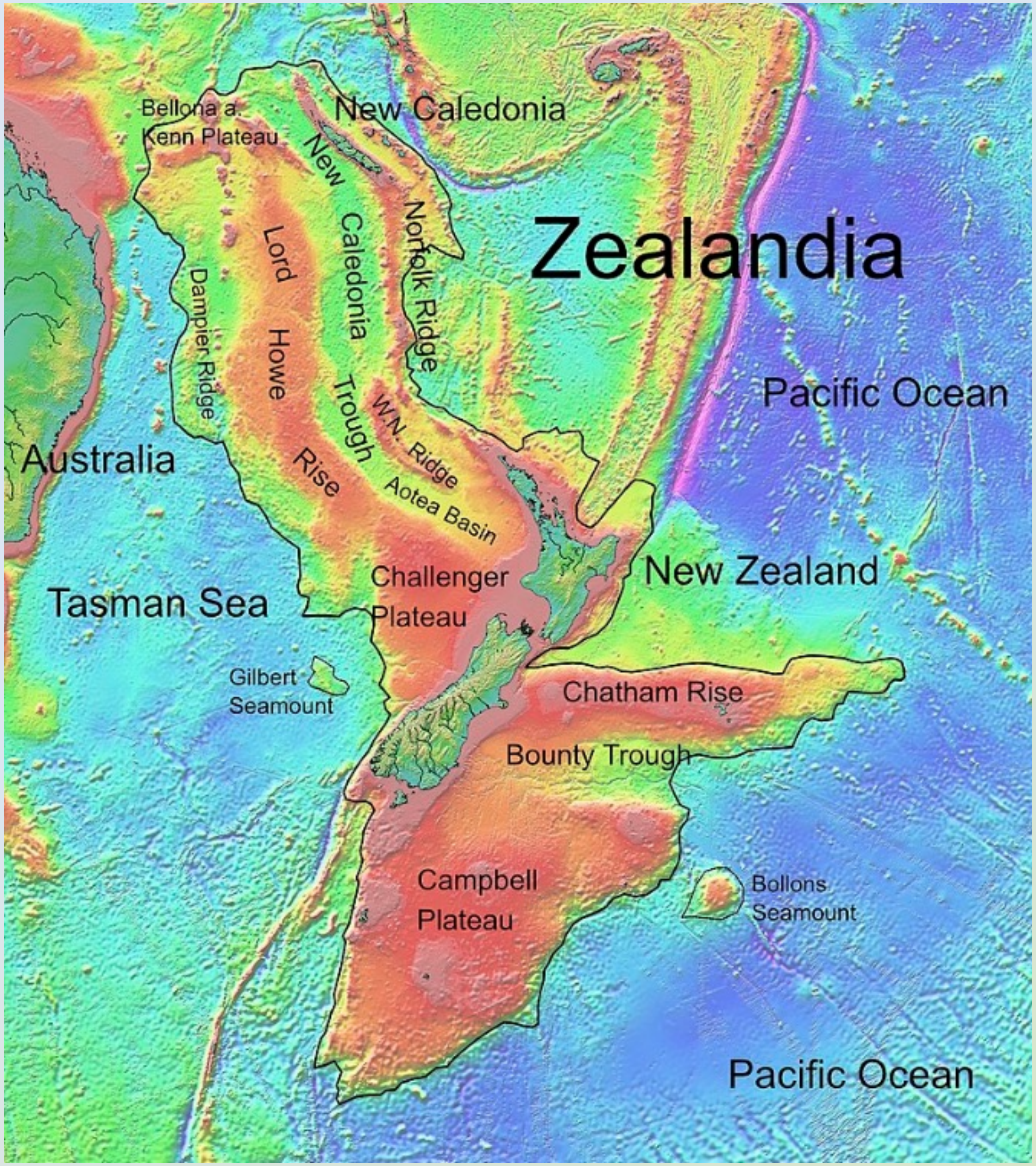
HP = Hikurangi Plateau

CP = Campbell Plateau

LHR = Lord Howe Rise

CHP = Challenger Plateau

Zealandia



Bellona a.
Kenn Plateau
New Caledonia
New Caledonia Trough
Norfolk Ridge
Zealandia
Lord Howe Rise
Dampier Ridge
W.N. Ridge
Aotea Basin
Pacific Ocean
Australia
Challenger Plateau
New Zealand
Tasman Sea
Gilbert Seamount
Chatham Rise
Bounty Trough
Campbell Plateau
Bollons Seamount
Pacific Ocean

Ontong-Java Plateau

- Giant volcanic feature → 1.9million km^2 located north of Solomon Is. attains a thickness of 30km, depth 2km
- composed of basaltic lava that erupted rapidly 125-120million years ago → consequence of volcanic activity above mantle hotspot

Ontong Java Plateau