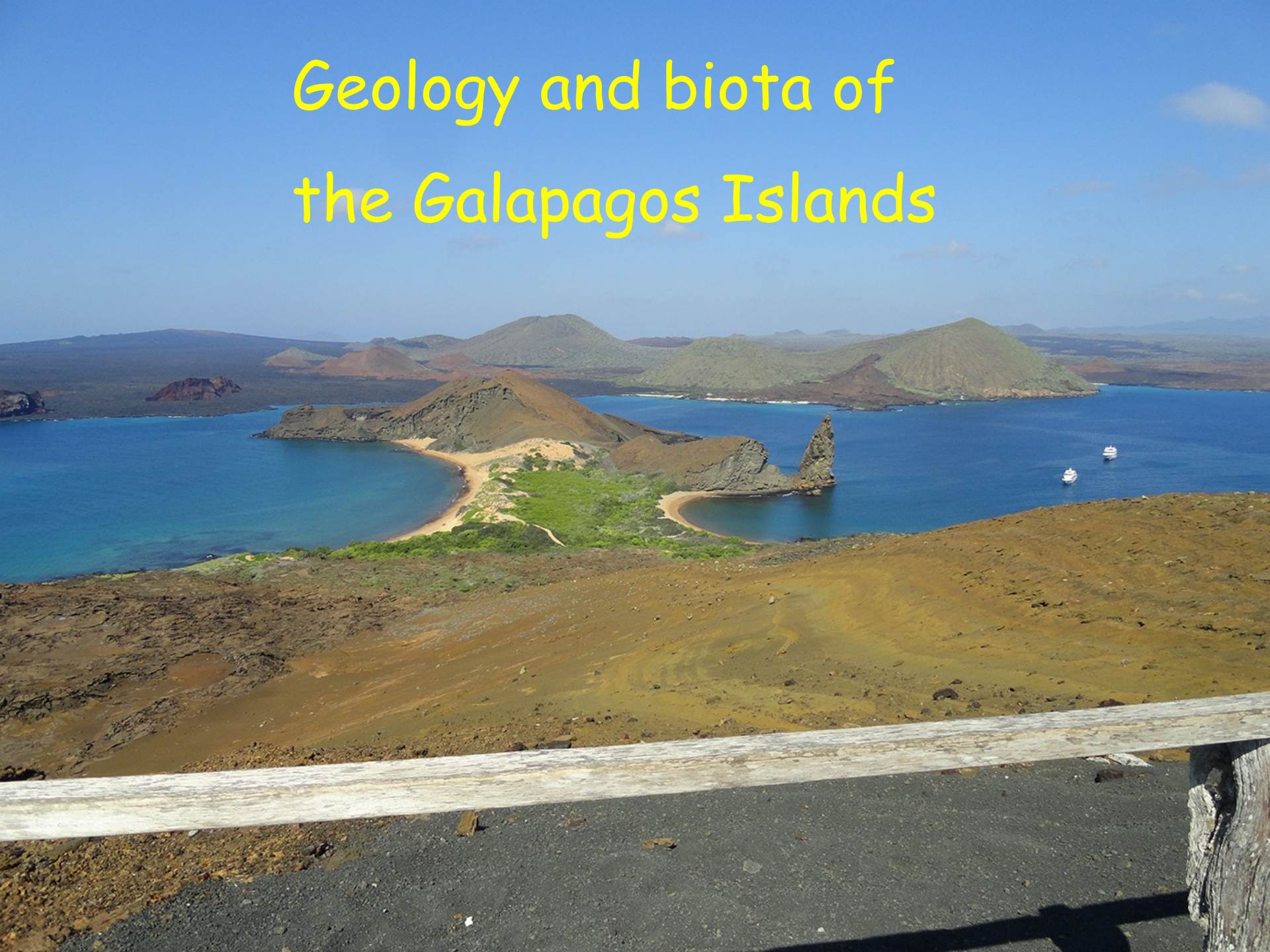
Geology and biota of the Galapagos Islands



Introduction

- The Galapagos Islands is an archipelago of volcanic islands located approximately 1000km off the coast of Ecuador, South America
- the archipelago comprises 13 volcanic islands and 16 islets as well as numerous tiny sub-islets
- the islands are made famous due to studies there by Charles Darwin in 1835 that formed the basis for his theories of evolution
- the islands contain classical basaltic volcanic features and a great variety of endemic animal and plant life

Location of Galapagos Islands

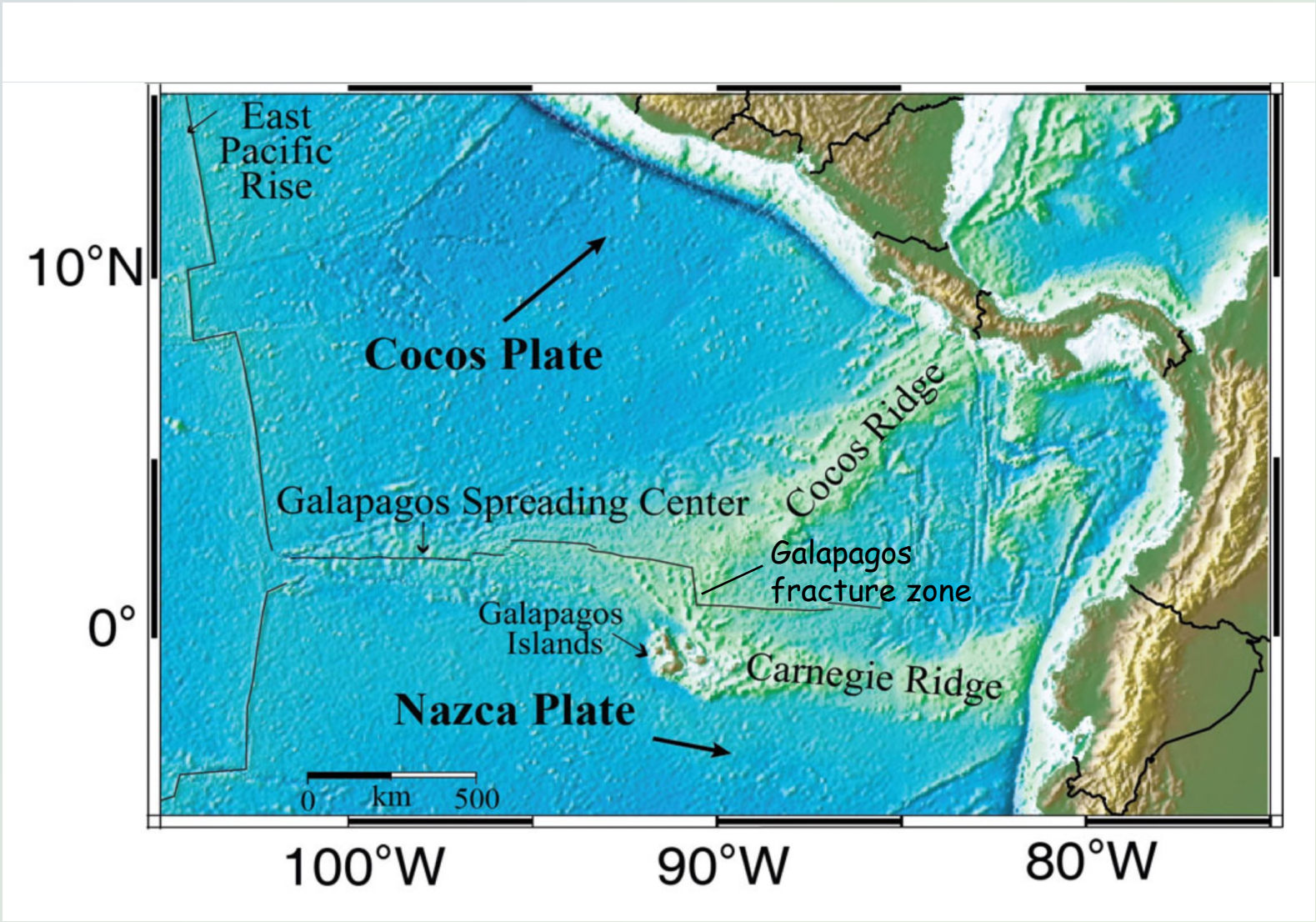
Map of Galapagos Islands

Geological setting

- Galapagos Islands have a total land surface of ~8,000km^2
- Isabela Island is the largest island in the archipelago (4,588km^2) Volcan Wolf on Isabela is highest point in the islands (1,707m ASL)
- all Galapagos Islands are volcanic, there are 21 emergent volcanoes, 13 of which are still active
- volcanism is occurring above a hotspot produced by a mantle plume, with the oldest extinct volcanoes located in SE of the archipelago
- islands stretch over 320km diameter perched on a basalt oceanic platform (Galapagos Platform) that creates relatively shallow water depth (360–900m)

Galapagos rift (spreading centre)

EW trending spreading ridge between the Cocos plate to the north and the Nazca plate to the south



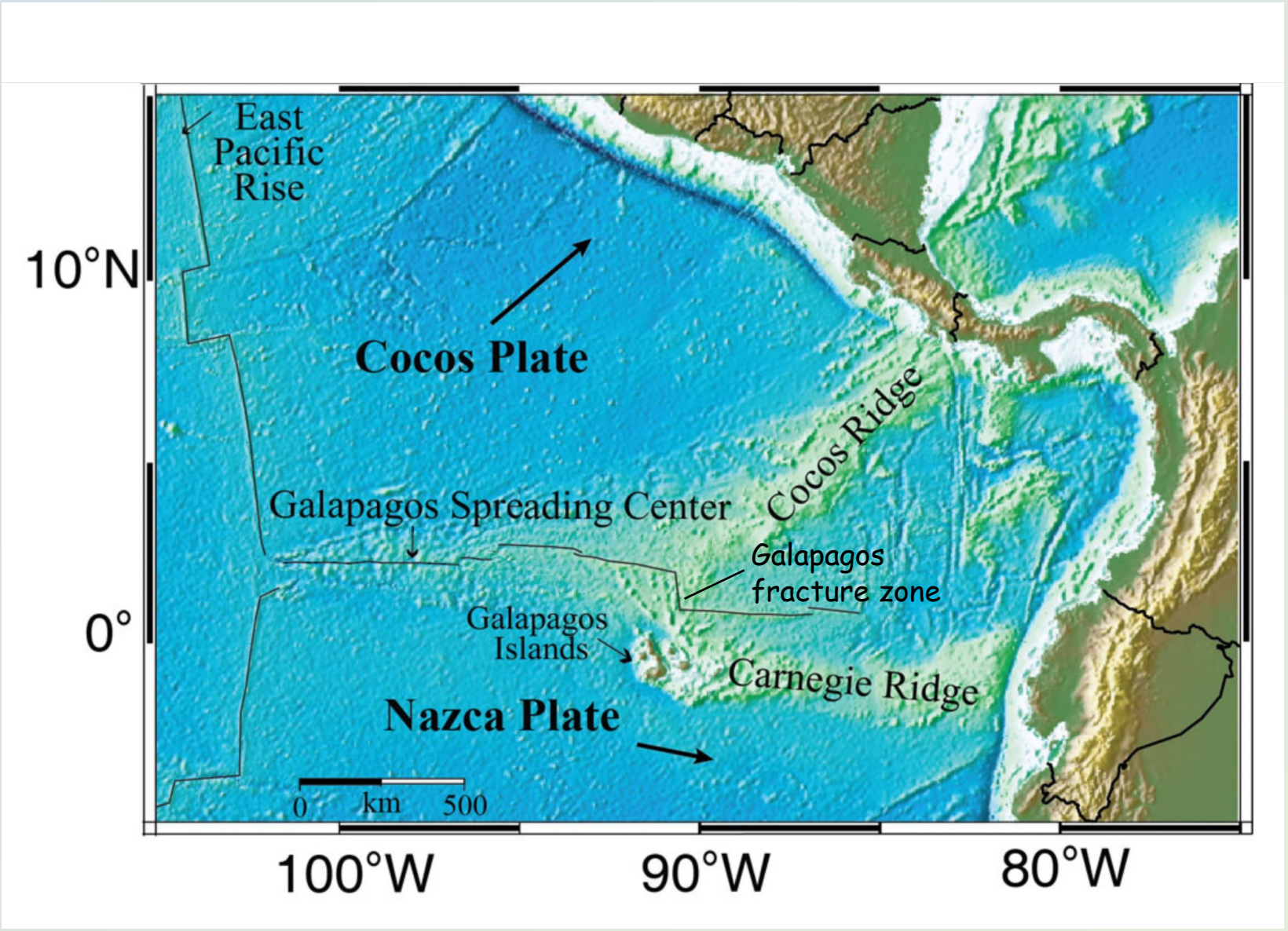
Geological setting

- The ocean crust at the Galapagos Rift can reach up to one-and-a-half times the thickness of ordinary oceanic crust that diminishes gradually to the east and west over 300-400km along the ridge
- upon the ridge are many very small seamounts and a fault-bounded linear valley (graben)
- smaller but much more frequent eruptions become more common as the hotspot is approached → more difficult to build seamounts
- the present islands are of different ages, the older to the east e.g. San Cristobal (2.5-4Ma) and the youngest to the west Fernandina (0.03-0.75Ma)

Tectonic setting

- Galapagos Islands are located near a triple junction with a transform fault located just north of the Galapagos
- the Nazca and Cocos Plates are subducting beneath the South American and Caribbean plates
- Galapagos Islands are located within the Nazca Plate that is moving ESE at 5-7cm/yr
- the islands produced by the hotspot, increase in age to the ESE producing a chain of seamounts → Carnegie Ridge
- a second seamount chain, the Cocos Ridge, extends from the Galapagos spreading centre (Galapagos Rift)

Tectonic setting

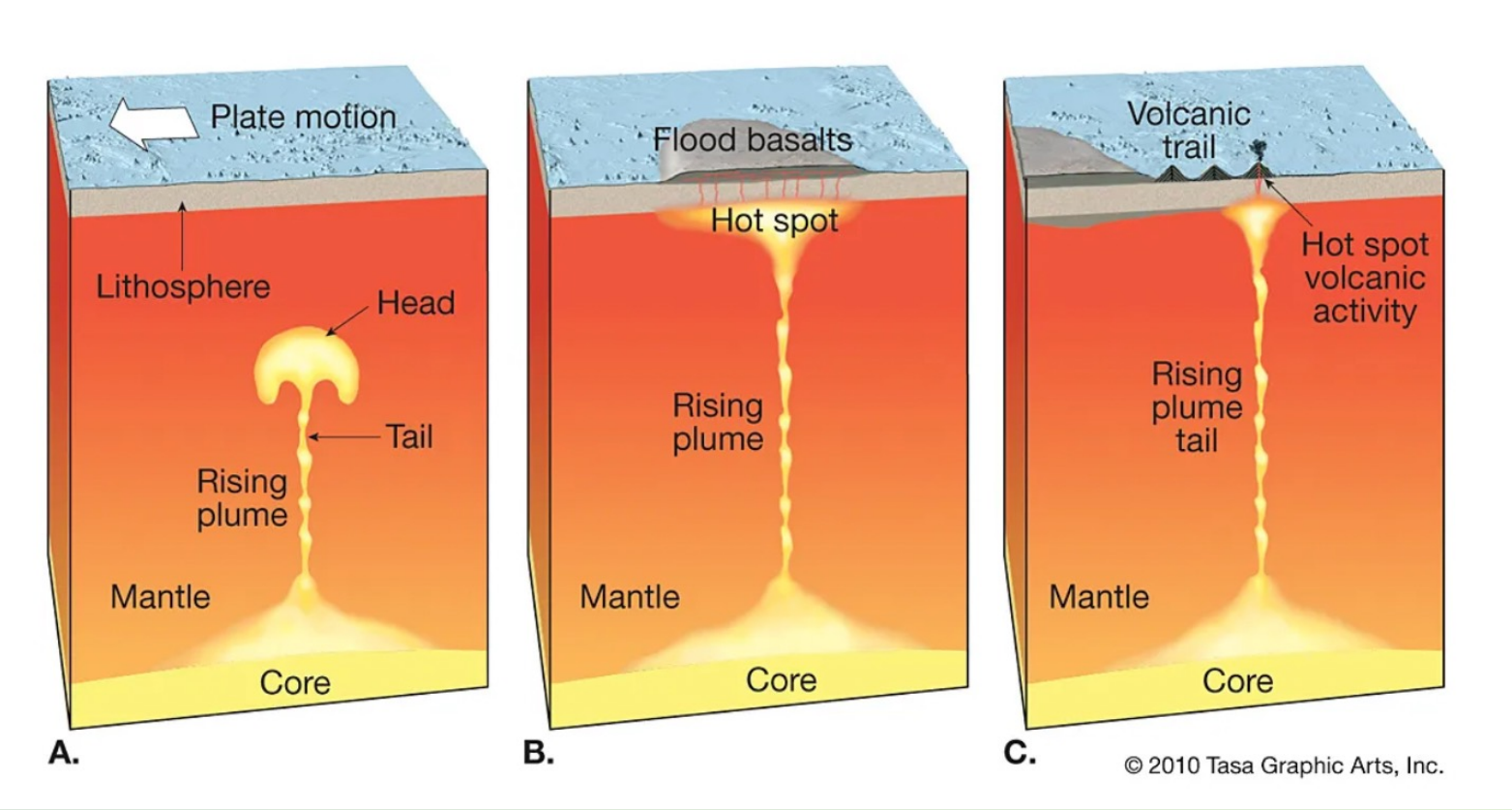


Tectonic setting

- The Cocos ridge was produced by the Galapagos plume → up to 5Myr ago the Galapagos Rift Zone was located directly over the mantle plume
- the rift zone has since migrated to the north producing a volcanic chain on the Nazca Plate
- many of the seamounts comprising ridges were once islands → both Carnegie and Cocos ridges disappear into subduction zones
- it is uncertain how old the mantle plume is, a 1990 oceanographic survey located 8myr seamount on Carnegie Ridge → once an island
- scientists think that the mantle plume is responsible for abundant Cretaceous rocks in Caribbean and NW margin of South America

Mantle plume

- Mantle plume → hot rock that has upwelled within mantle
- as mantle plume reaches crust → melts slightly and pushes through any fractures in crust that is known as a hotspot
- magma outpouring solidifies to form a basaltic oceanic platform



Galapagos mantle plume

- Like many oceanic islands, the Galapagos Islands are products of a mantle plume that is a column of hot rock, roughly 100km in diameter that rises within the Earth
- plumes rise because they are up to 200°C hotter than the surrounding rocks and ascend ~10cm/yr
- one reason that scientists believe that they originate from great depth is that they remain fixed relative to one another for 10s of millions of years even though the above lithospheric plates above them move thousands of km in that time
- the distance between active Galapagos and Hawaiian Islands → fixed even though their volcanoes travel in different directions

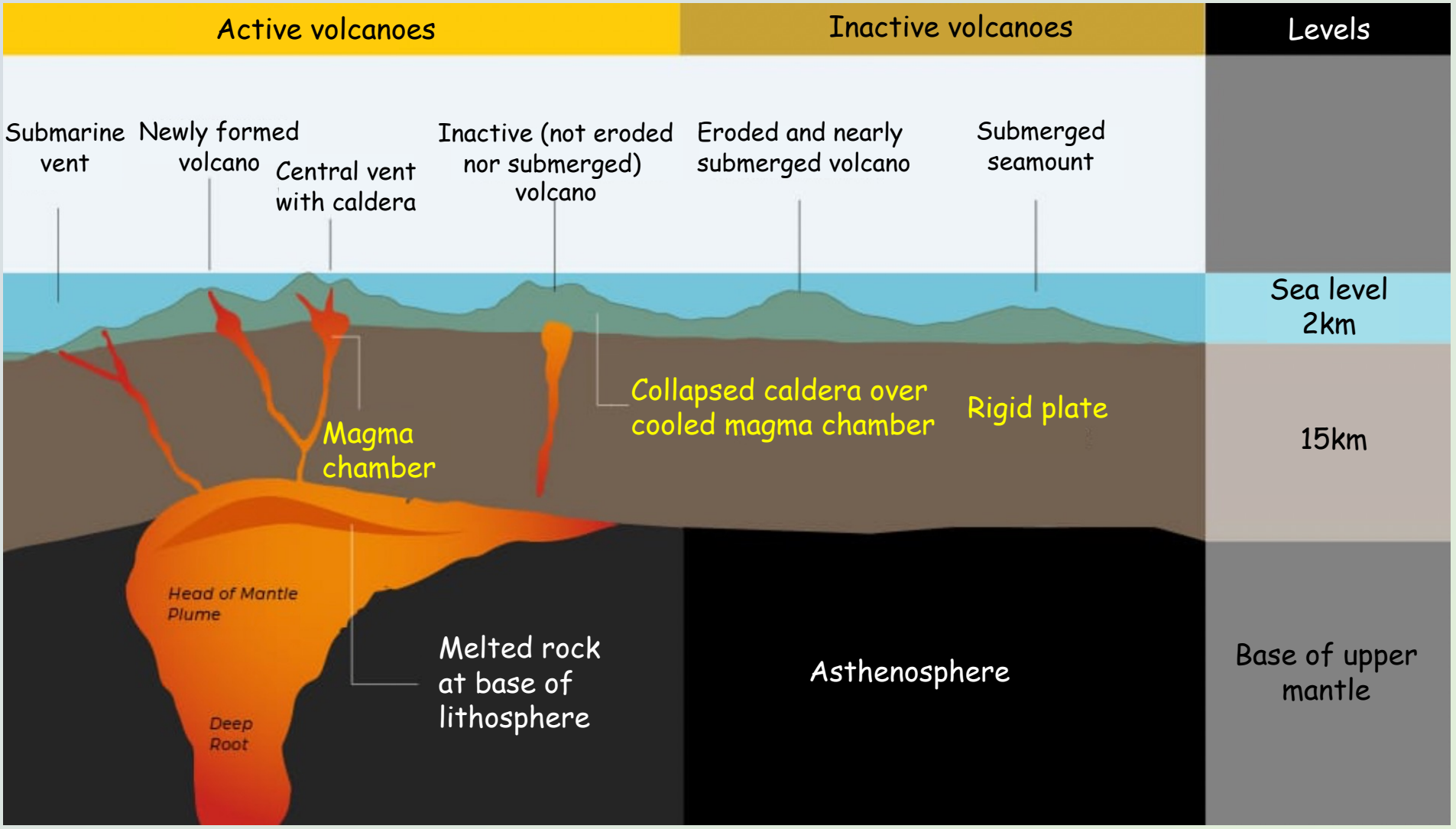
Magma generation and volcanism

- As plumes approach the surface they begin to melt due to decompression
- melting probably begins at depths of 150km or so and continues until the plume is prevented from further rising by overlying lithosphere
- lithosphere below the Galapagos is young and relatively thin ~15km
- region of melting beneath Galapagos probably extends from depths of 100-150km to 15km
- temperatures at these depths ~1400°C → by the time that the melts reach surface they have cooled to 1100-1200°C

Magma generation and volcanism

- The plume does not melt completely, only 20% of it melts
- because it is less dense than surrounding rock, the melt quickly aggregates and begins to rise to surface
- it eventually becomes trapped in large pools → magma chambers at depths of 10s of km below the surface
- occasionally magma in chamber forces its way to the surface → volcanic eruptions→ hundreds of thousands of years → volcano
- upward motion of mantle plumes pushes lithosphere upwards producing Galapagos Platform

Hotspot generation of islands and ridge



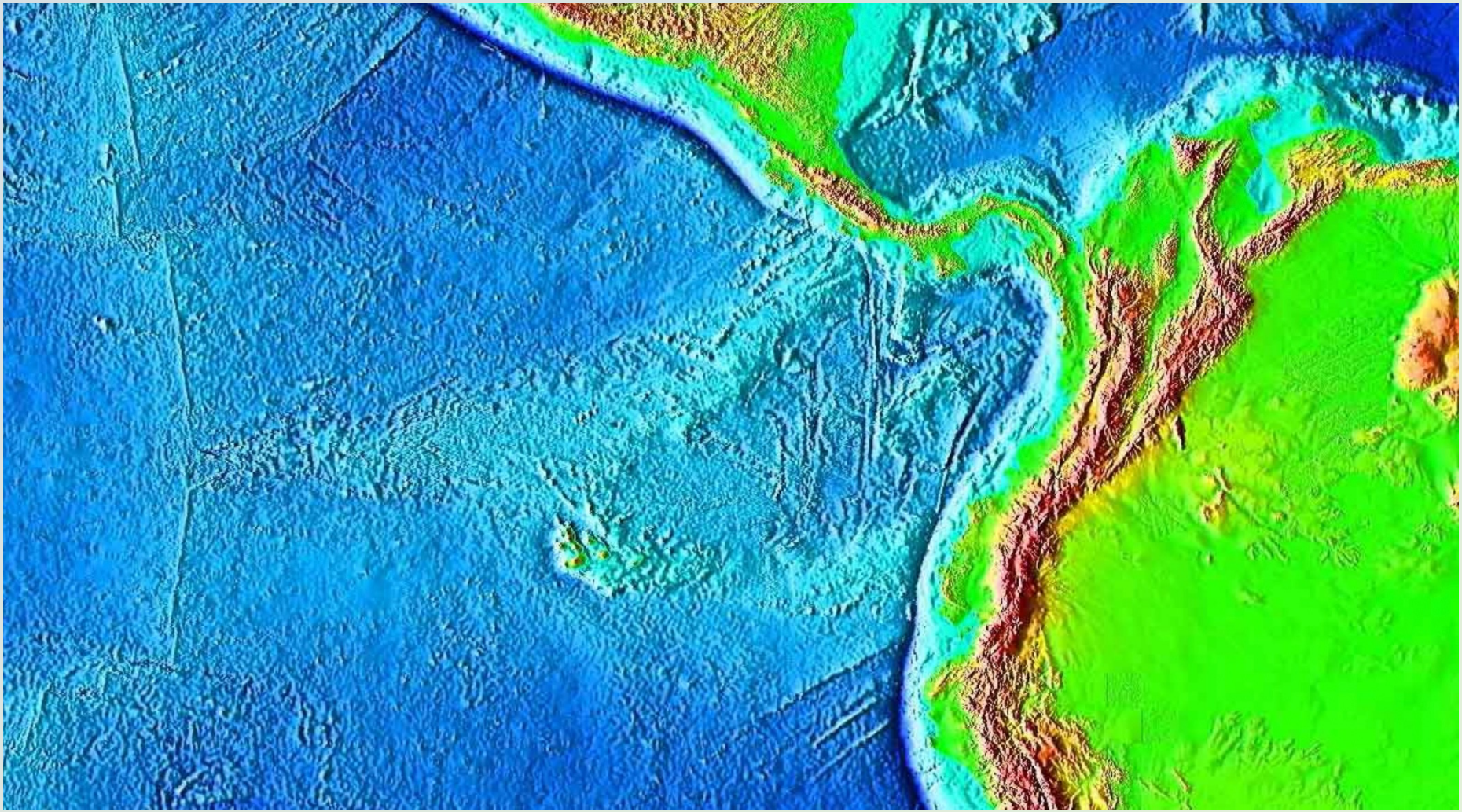
Geological formation of the Galapagos Islands

- The geological origin of the Galapagos Islands can be traced back to at least 70Ma to initiation of the hotspot
- Galapagos Islands appear to be the result of interaction between a hotspot and plate boundary
- the islands are on the Nazca plate that is diverging from the Pacific Plate at the East Pacific Rise and subducting beneath the South American Plate to the east
- north of the islands lies the Cocos Plate that is subducting beneath Central America
- along the Galapagos Rift, the Nazca and Cocos Plates are diverging
  → Nazca Plate moving ESE, Cocos Plate NE

Geological formation of the Galapagos Islands

- Examination of sub-surface shows → Galapagos Islands linked to each other under water representing chain of islands rising from the islands
- long underwater ridges extend from the islands
- the hotspot was once under the Cocos Plate forming Cocos Ridge as plate moved NE towards Costa Rica
- at some point, the Galapagos Rift (divergent boundary between Cocos and Nazca plates) passed over hotspot
- hotspot now under ESE moving Nazca Plate, forming Carnegie Ridge and Galapagos Islands

Topographic map showing Cocos and Carnegie ridges



Galapagos volcanism

- Historic eruptions have occurred on many Galapagos volcanoes with submarine volcanoes active at this time
- the Galapagos volcanoes are shield volcanoes characterized by their basaltic eruptions that tend to be mildly peaceful
- lava fountains produce the numerous cinder cones that are observed on the islands
- another characteristic of the western volcanoes is the large size of their calderas c.f. size of volcano
- most recent example of a caldera collapse was in 1968 when the Fernandina volcano erupted → N part of 800m deep caldera dropped additional 350m

Galapagos volcanoes

- Two distinct volcanic types occur in the Galapagos
- in the west on Fernandina and Isabela → large volcanoes with deep calderas occur
- in the east, smaller shield volcanoes occur
- west of the Galapagos fracture zone, lithosphere is older and thicker → able to support load of large volcano
- east of fracture zone zone lithosphere is too young and too weak to support large volcanic edifices

Volcanic features

- Because the hotspot is penetrating the oceanic crust, the lava in the Galapagos is basaltic, flowing out from large shield volcanoes
- generally individual islands form from a single shield volcanism however, the largest island, Isabella is composed of 6 volcanoes
- basaltic volcanism is in contrast to the more explosive stratovolcanoes of the Andes and Cascades
- Galapagos continues to be an active zone with 55 eruptions since the first European visit
- there are many volcanic features such as craters, calderas, fumaroles, spatter cones, cinder cones and lava tubes

Volcanic cones on Bartolome and Santiago Islands

Cinder cones and spatter cones

Lava fountain Kilauea, Hawaii

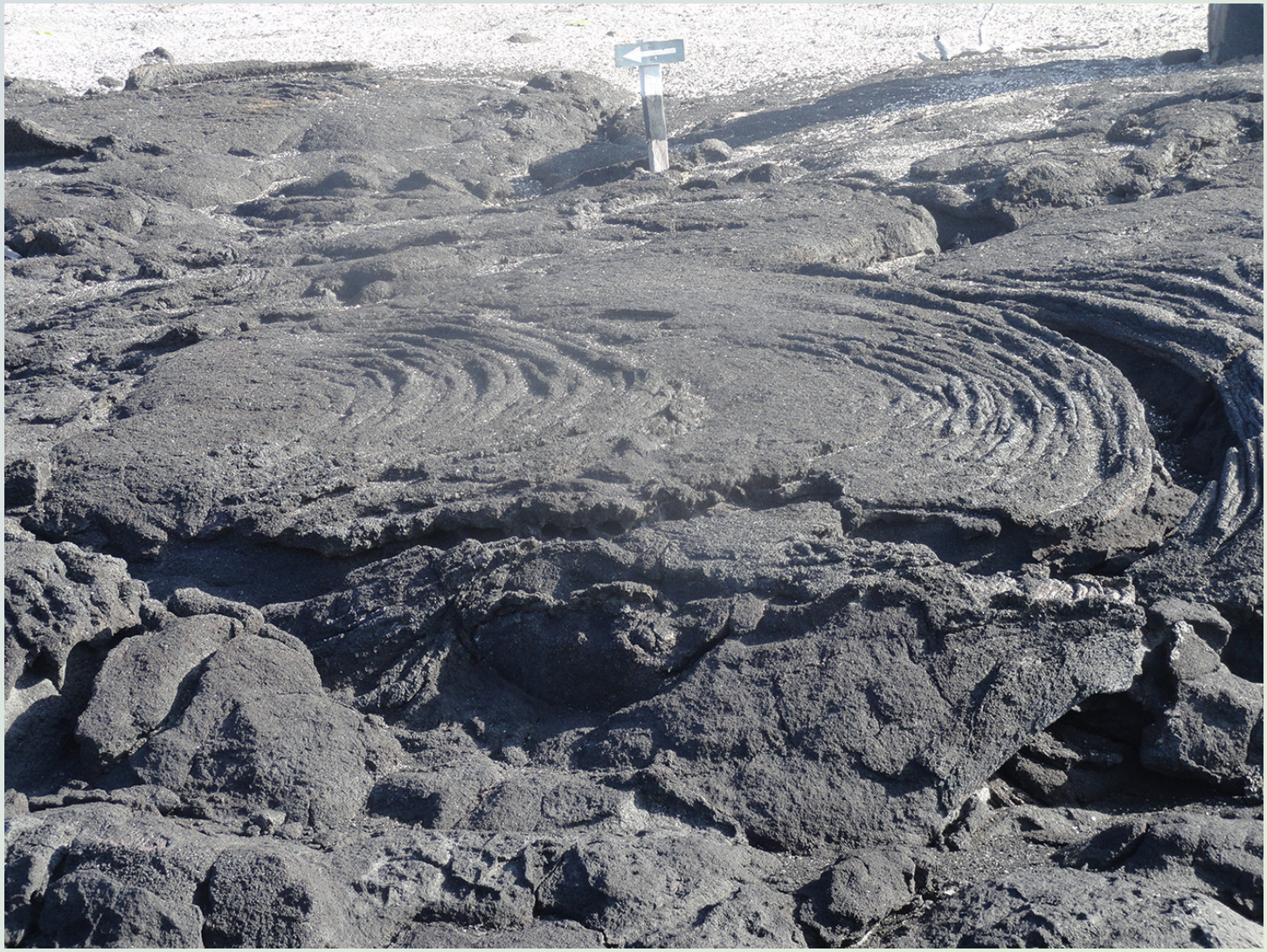
Form cinder cones and erupt loose pyroclastic material (cinders and scoria)

Spatter cones build around a vent where escaping gases blow out blobs of lava that tear apart flying through the air

Spatter cone Bartolome Island, Galapagos Islands

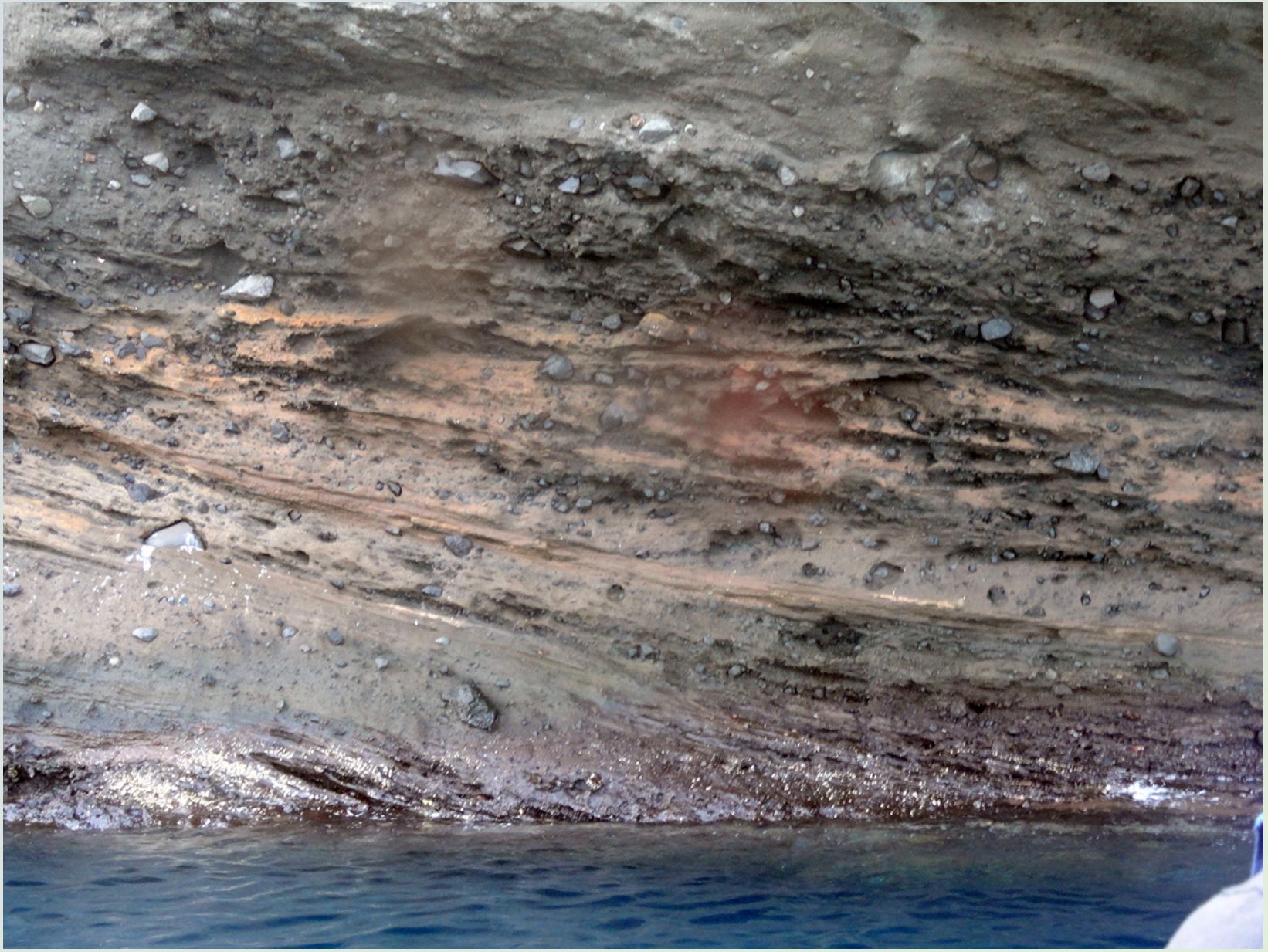
Lava spatter, Peurta Egas

Pahoehoe lava flow



Interbedded scoria and basalt lava flows

Basaltic lithic tuff, Targus Cove, Isabela Island



Darwin Lake caldera, Isabela Island

Pinnacle Rock, Bartolome Island

Marine iguanas

Land iguana, Galapagos Islands

Sally Lightfoot crabs

Hermit crab

Banded Galapagos snake

Lava lizard (male)

Lava lizards

Lava lizard (female)

Lava lizard on post Puerta Egas

Giant tortoises

"Lonesome George"

- Male Pinta Island tortoise, the last of his sub-species
- transferred to Darwin Research Centre on Santa Cruz Is. 1971
- died 2012 aged 101-102years

Lonesome George,
post taxidermist

Young tortoises, Darwin Research Centre

1yr old tortoises

5yr old tortoises

Galapagos birds

Flamingo

Black-necked Stilt

Great Blue Heron

Blue-footed Booby

Galapagos birds

Galapagos fly catcher

Lava Gull

Galapagos Hawk

Flightless comorants

Galapagos birds

White Cheek Pintail Duck

Galapagos Penguin

Swallow-tail Gull

Brown Pelican

Galapagos birds

Female Frigate bird

Male Frigate bird

Sanderlings

Sea lions

Sea lion on rocks Punta Vincente Roca

Sea lions on wharf Punta Ayora

Galapagos Islands - Cacti

Lava cactus

Prickly pear

Opuntia cactus