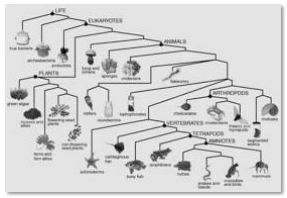
Species and Areas: History of Ideas

How do you choose between dispersalist and vicariance models?

Two important scientific advances – in the study of earth history and organismal history - revolutionized historical biogeography



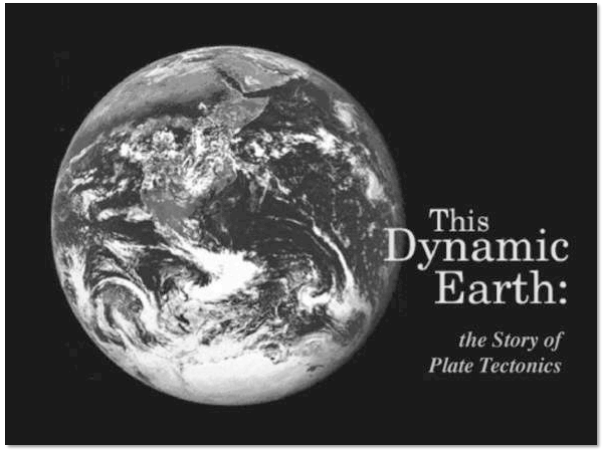
1. Acceptance of plate tectonics

Up until the 1960s, most persons considered the earth's crust to be fixed. Finally, in the 1960s the geological evidence was at hand that made continental drift irrefutable.

2. Development of new phylogenetic methods

Willi Hennig (1950) introduced the modern concepts of phylogenetic theory (first published in 1956). Using this methodology, hypotheses of historical lineages of species could be reconstructed.

Earth History: Plate Tectonics



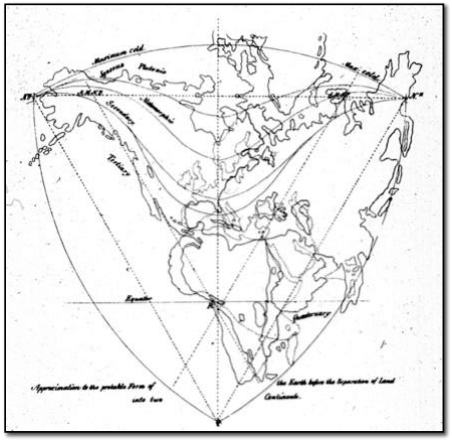
Earth History: Plate Tectonics

During the great world explorations of the 15th - 16th centuries, cartographers first began to entertain ideas of earth's mutability based on continental outlines

Abraham Ortellius' 1587 map with exaggerated fit of South American and African coastlines

Earth History: Plate Tectonics

With no known process to account for these patterns, a variety of imaginative mechanisms were proposed in the 19th and early 20th centuries:



Richard Owen's 1857
Tetrahedral Theory

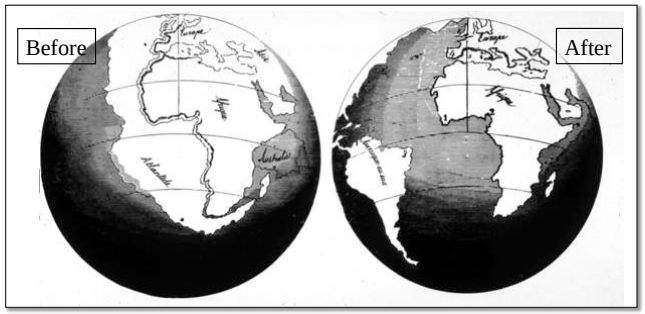
Continents were superimposed on each other (e.g., South America on Africa, Australia on Arabia) prior to their separation

"*This approximation, although involving great doubt, is given because it may facilitate the working of the problem which all desire to solve, regarding the earth's development*"

Key to the Geology of Globe

Earth History: Plate Tectonics

With no known process to account for these patterns, a variety of imaginative mechanisms were proposed in the 19th and early 20th centuries:



Antonio Snider's map of "before" and "after" the separation from 1858. Many of the mid 19th century models (like Owens' and Snider's) invoked catastrophism with indirect reference to a world-wide flood.

Earth History: Plate Tectonics

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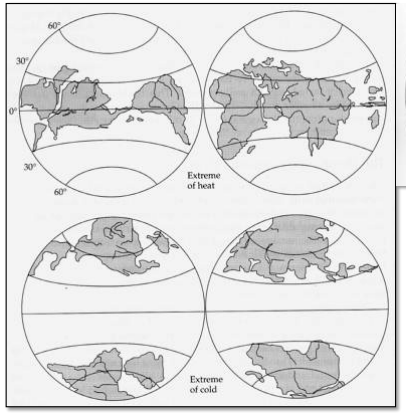


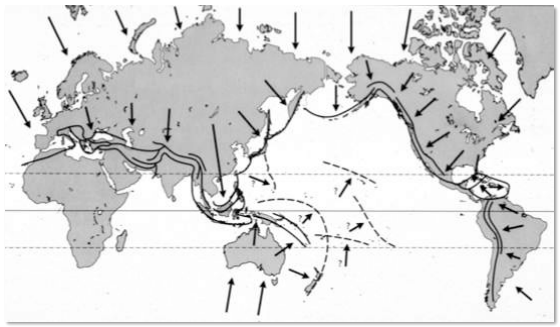
Charles Lyell's theory of *cycles of global climatic change*

Based on his observations of tropical fossils in Europe, Lyell realized that climate had changed and invoked repeated and concerted continental movements during times of heat and cold

(in *Principles of Geology*, 1830)

Earth History: Plate Tectonics

With no known process to account for these patterns, a variety of imaginative mechanisms were proposed in the 19th and early 20th centuries:



American geologist F. B. Taylor's idea of crustal movements in 1910. Continents were hypothesized to move, distorting crustal material to form mountains and leave oceans behind. His directions of movement are clearly wrong.

Earth History: Plate Tectonics

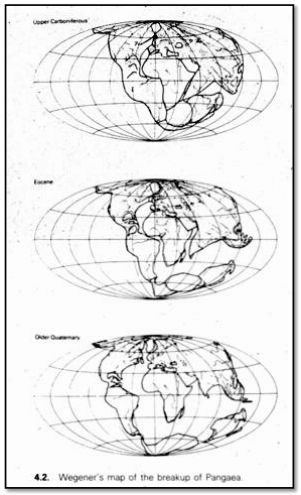
Alfred Wegener (with Rasmus Villumsen) - prior to their disappearance in the Arctic

Alfred Wegener (1880 - 1930)

Basic tenets of continental drift theory traces back to the German meteorologist, Wegener.

His views became widely known with the English publication of *The Origins of Continents and Oceans* in 1922 (first in German in 1915).

Earth History: Plate Tectonics



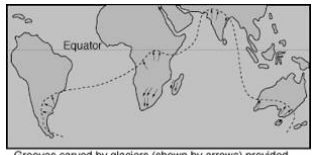
4.2. Wegener's map of the breakup of Pangaea.

Wegener used a variety of geological and biological evidence to refute the prevailing views that the earth's crust was fixed and thus the need to invoke land bridges and then to support his contention that continents drifted over time.

- land bridges defy the principle of isostasy
- elevations of earth's crust not random
- contiguous shape of continental shelves
- directions of ancient glacial striations
- geological strata continuous between continents
- fossil distributions between continents

Earth History: Plate Tectonics

- directions of ancient glacial striations

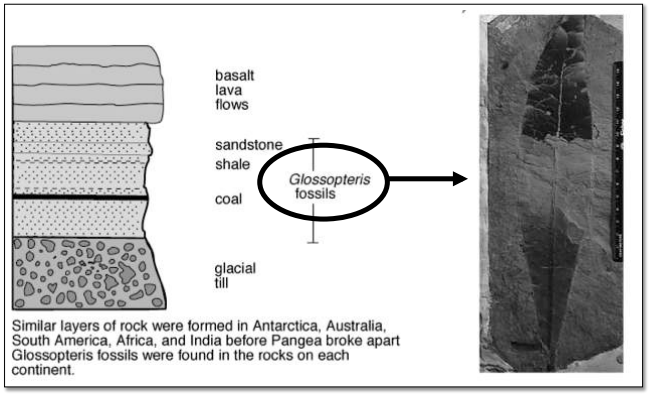


Grooves carved by glaciers (shown by arrows) provided evidence for continental drift. This diagram assumes the continents were in their present-day locations.

The distribution of glacial features can be best explained if the continents were part of Pangaea.

Earth History: Plate Tectonics

- geological strata continuous between continents
- fossil distributions between continents



Similar layers of rock were formed in Antarctica, Australia, South America, Africa, and India before Pangea broke apart Glossopteris fossils were found in the rocks on each continent.

Earth History: Plate Tectonics

- geological strata continuous between continents
- fossil distributions between continents

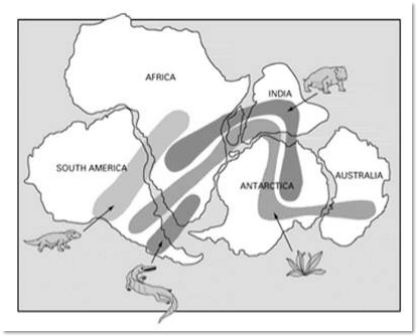
Wegener described both plant and animal fossil examples supporting his theory — he believed that this biogeographic data was the strongest evidence for his theory

Glossopteris - Permian "fern"

Mesosaurus - Permian freshwater reptile

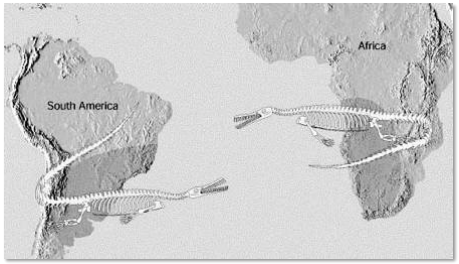
Cynognathus - Triassic land reptile

Lystrosaurus - Triassic land reptile



Earth History: Plate Tectonics

- geological strata continuous between continents
- fossil distributions between continents



Mesosaurus - Permian freshwater reptile

However, Wegener's critics argued that the amphi-Atlantic distribution of the freshwater (estuary) Permian reptile *Mesosaurus* was due to long distance swimming

Earth History: Plate Tectonics

Harry Hess, Professor at Princeton

Wegener and a few southern hemisphere scientists were unable to persuade the scientific community that the fixed continent hypothesis was incorrect

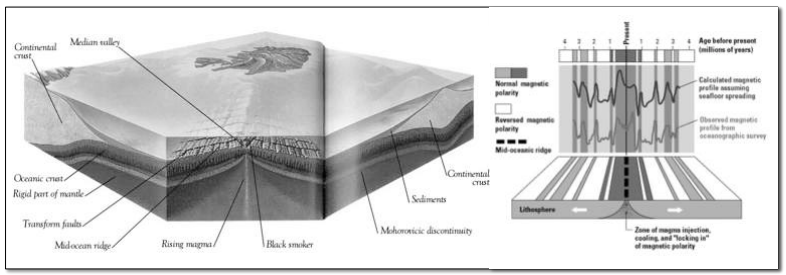
This bias against continental drift theory coalesced at a symposium of the American Association of Petroleum Geologists in 1928

. . . due in part to the inability of Wegener and others to identify or explain the forces that caused the movements of continents.

Harry Hess, Professor at Princeton, put the plate tectonic theory together using new evidence obtained starting during WWII. Between 1960 and 1970 the academic community finally accepted continental drift and the tectonic forces causing it.

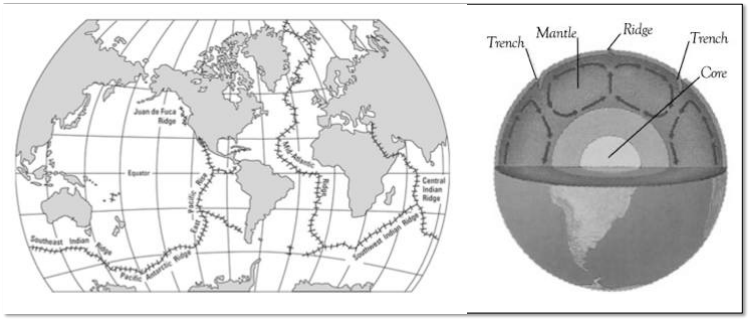
Earth History: Plate Tectonics

These lines of evidence allowed Harry Hess to propose the modern tectonic theory of sea-floor spreading. The theory proposes that when new magma from the mantle is added at the middle of the ocean ridge, the sea floor spreads apart and moves existing lithosphere away from the ridge.

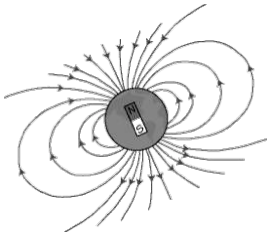


Earth History: Plate Tectonics

As new material is formed at the ridges, oldest material eventually gets subducted at trenches. Thus, despite the fact the ocean floor makes up more than 2/3rds of the earth's surface, no part of it is older than the Jurassic (200 Mya).

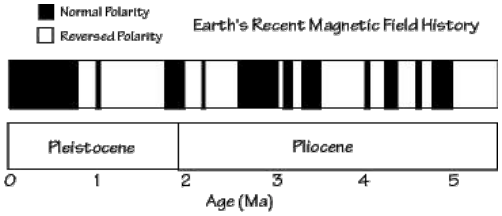


Earth History: Plate Tectonics

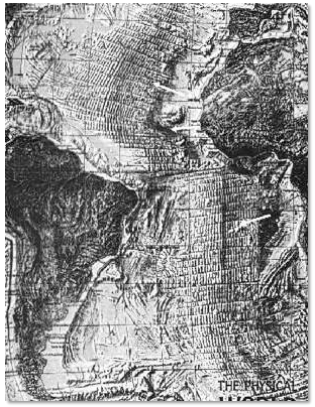


The first line of evidence involved the documentation that magnetic anomalies existed in the earth. Orientation of iron particles in solidifying lava rock appeared to reverse in an irregular basis back in time, indicating that the earth's magnetic polarity had switched from one pole to the other.

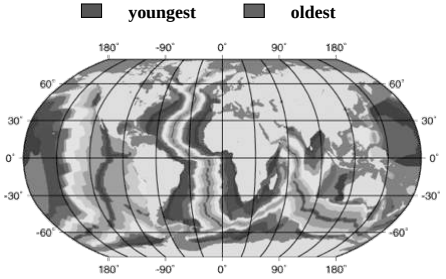
Vines and Matthews, 1962



Earth History: Plate Tectonics

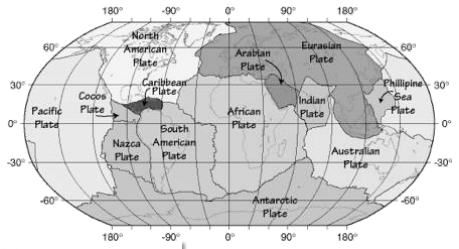


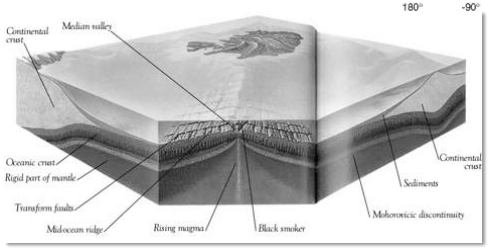
These reversals of magnetic polarity appeared as mirror images from the center ridge of the Atlantic Ocean going both west and east. Rock dating indicated that the youngest rocks were in the middle and got progressively older going both west and east



Earth History: Plate Tectonics

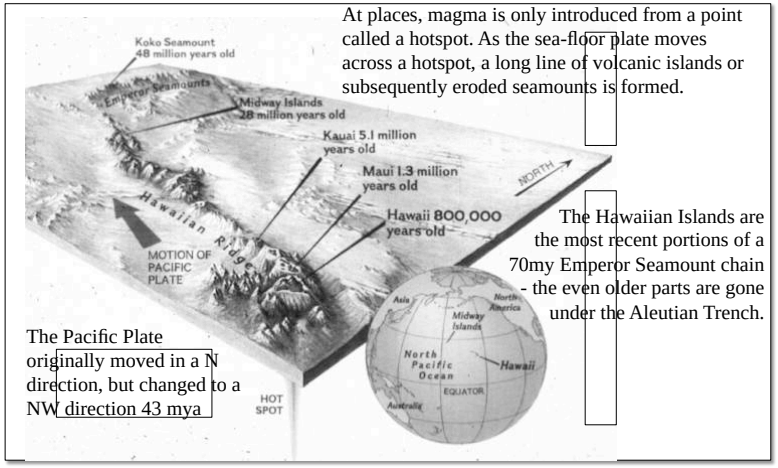
The concept of plate tectonics explains the movements of the continents. The earth's crust is divided into 7 major and a number of smaller plates. The plates are rigid and contain areas of continental crust.





As sea-floor spreading occurs, plates along with continents are moved away from the ridge like they were on a conveyor belt.

Earth History: Plate Tectonics



At places, magma is only introduced from a point called a hotspot. As the sea-floor plate moves across a hotspot, a long line of volcanic islands or subsequently eroded seamounts is formed.

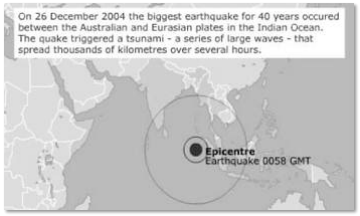
The Hawaiian Islands are the most recent portions of a 70my Emperor Seamount chain - the even older parts are gone under the Aleutian Trench.

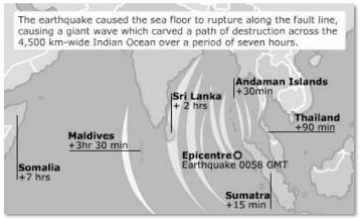
The Pacific Plate originally moved in a N direction, but changed to a NW direction 43 mya

Earth History: Plate Tectonics

Boundaries of these plates coincide with both volcanic and earthquake acitivity (the *Ring of Fire* in the Pacific basin)

The latest large earthquake in December 2004 occurred near the junction of 3 plates (Eurasian, Indian, Australian)

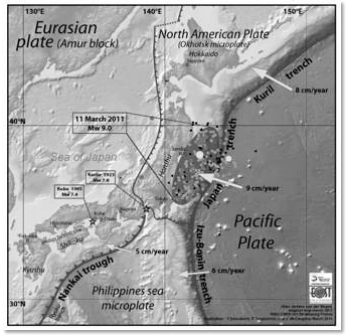




Earth History: Plate Tectonics

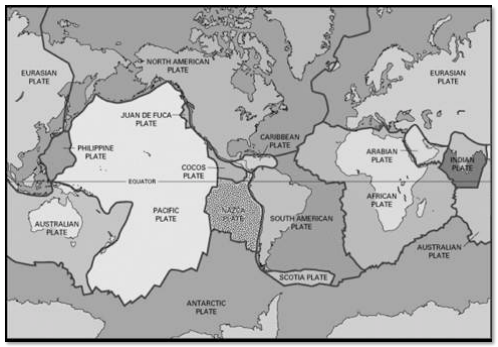
Boundaries of these plates coincide with both volcanic and earthquake acitivity (the *Ring of Fire* in the Pacific basin)

The latest large earthquake in March 2011 occurred near the junction of 3 plates

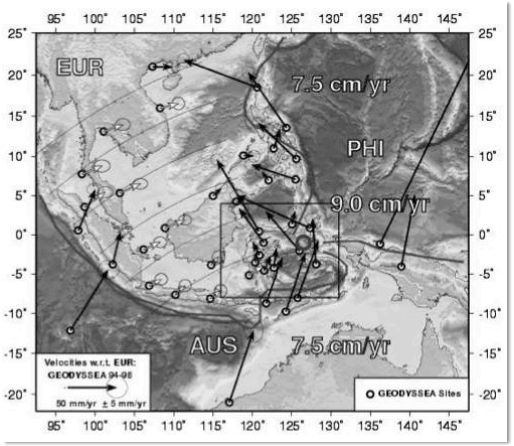


Earth History: Plate Tectonics

These plates can separate from each other (South American and African plates), shear past each other (Pacific and North American plates at California), or collide and subduct (Nazca and South American plates)

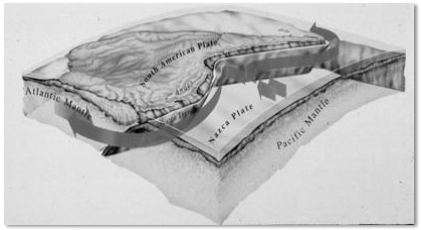


Earth History: Plate Tectonics

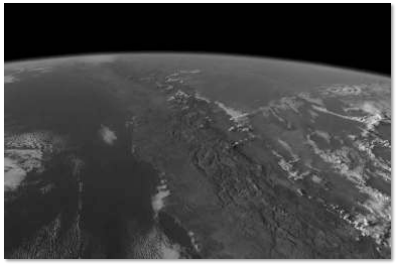


The plates move from 1 - 10 cm / year

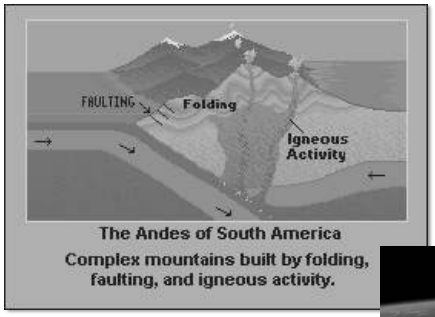
Earth History: Plate Tectonics



Major mountain building regions are in these subduction zones . . .

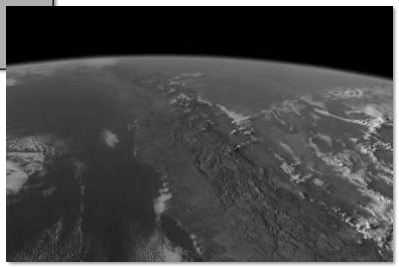


Earth History: Plate Tectonics



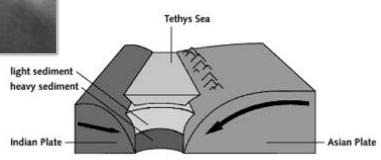
Major mountain building regions are in these subduction zones . . .

. . . such as the Andes formed by collision and subduction of the Nazca plate with the South America plate



Earth History: Plate Tectonics

and the Himalayan Range formed as the Indian plate collided and subducted under the Eurasian plate

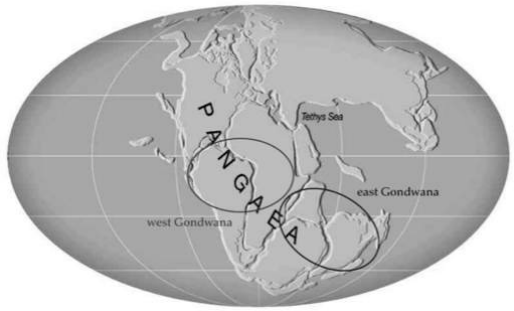


Sixty Million Years Ago

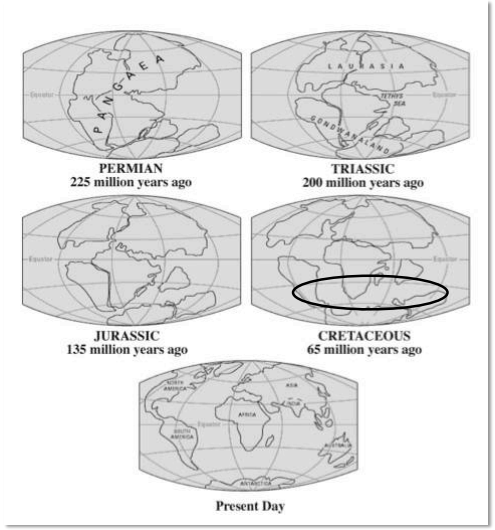
India collides into the Asian Plate. This movement is what eventually causes the Himalayan Range, as the two plates push against each other and the earth's crust is squeezed upwards.

Earth History: Plate Tectonics

- 230 million years ago in the Permian provides a starting point for a major portion of the steadily changing distributions of plants and animals
- 40% of the earth's surface represented by the supercontinent Pangaea
- 200 million years ago the splitting of Pangaea began



Earth History: Plate Tectonics



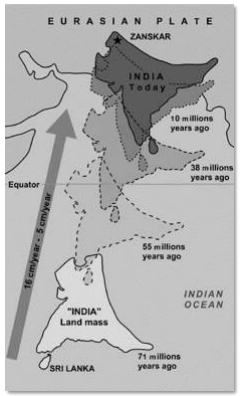
Biogeographic implications of these continental movements are enormous

We will deal later with the rise of land plants, rise of the angiosperms, and the Southern Hemisphere in some detail

These stories will involve continued connections of some continents . . .

Earth History: Plate Tectonics

. . . isolation of major continents or other plate masses for considerable amounts of time followed by collision with other lands



. . . bridging of once separated continents and subsequent faunal and floral inter-changes