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GEOLOGY

8

Új Magyarország FEJLESZTÉSI TERV

A Műszaki Földtudományi Alapszak tananyagainak kifejlesztése a TÁMOP 4.1.2-08/1/A-2009-0033 pályázat keretében valósult meg.

VIII. DIVERGENT PLATE MARGINS

1. EVOLUTION OF DIVERGENT PLATE MARGINS

Divergent (in other terms accretional) plate margins are the boundaries of lithosphere plates, along which two plates move apart. These plate margins mark the growing edges of plates, along which new lithosphere is created by basaltic volcanism. Divergent plate margins can be the boundaries either of two plates that are both covered by continental crust or of two plates covered by oceanic crust. However we do not know of any divergent plate margins along which one plate is covered by continental crust and the other is covered by oceanic crust.

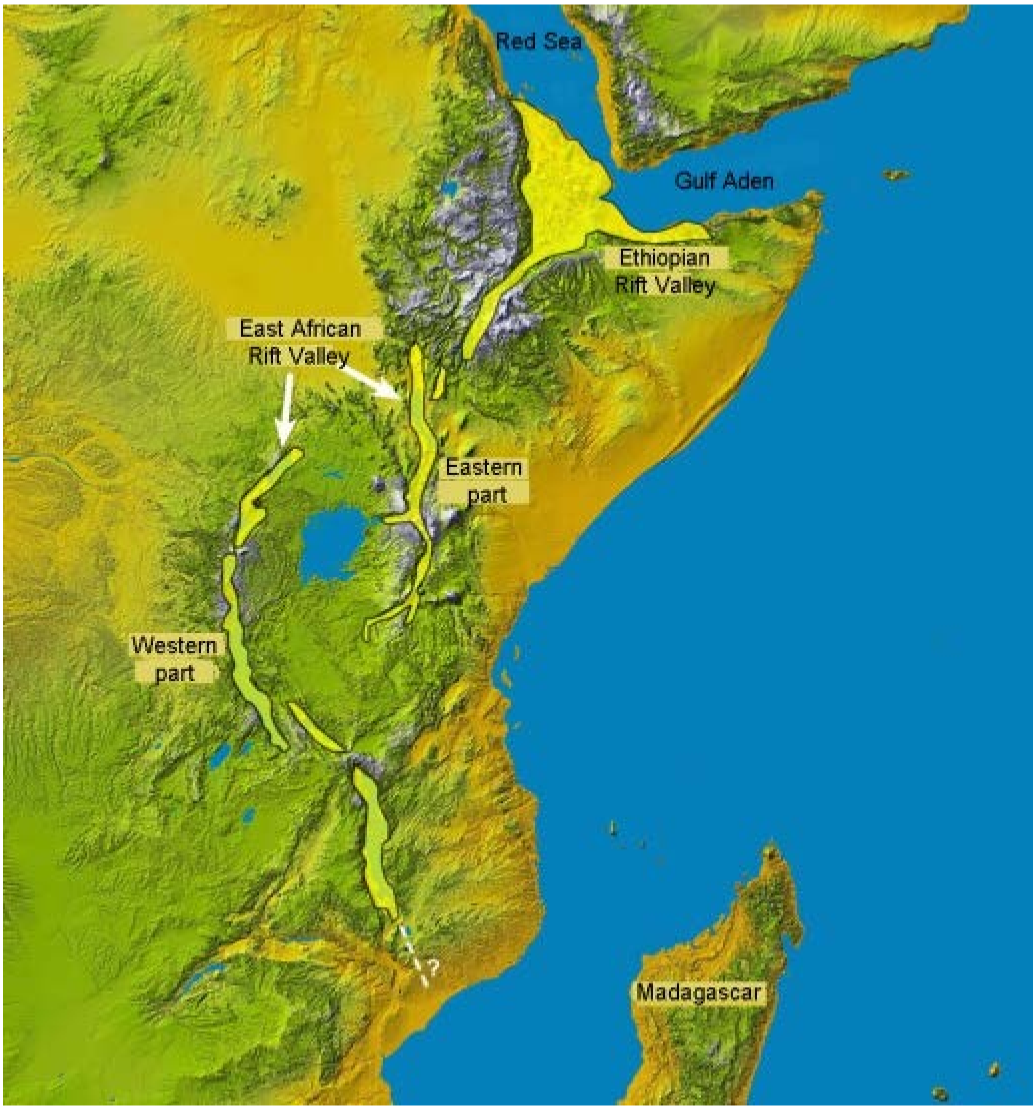
The fragmentation and drift of the plates are controlled by the asthenospheric *convectional currents*. The steps of the development of spreading are detailed below.

Uplift and rifting

In the continental areas the early phase of the splitting of lithosphere plates is called **rifting**.

The development of divergent plate margins starts with the elevation of crust. Basaltic magma is associated with formation of a new spreading edge that splits the continent (or ocean basement), heating and expanding the lithosphere so that a plateau forms with an elevation of as much as 2.5 km above sea level. Tensional forces cause normal faults and form a rift so that there is a pronounced topographic relief between the plateau and the floor of the rift.

Before the rift floor sinks enough for seawater to enter, *clastic non-marine sediments* such as conglomerates and sandstones are shed from the steep valley walls and accumulated in the rift. Associated with these sediments are *basaltic lavas, dikes*, and *sills*, all formed by magma rising up the normal faults. In the early phase of volcanism, the magma is rhyolitic in the continental areas, but with the further development of volcanic activity it becomes basaltic.



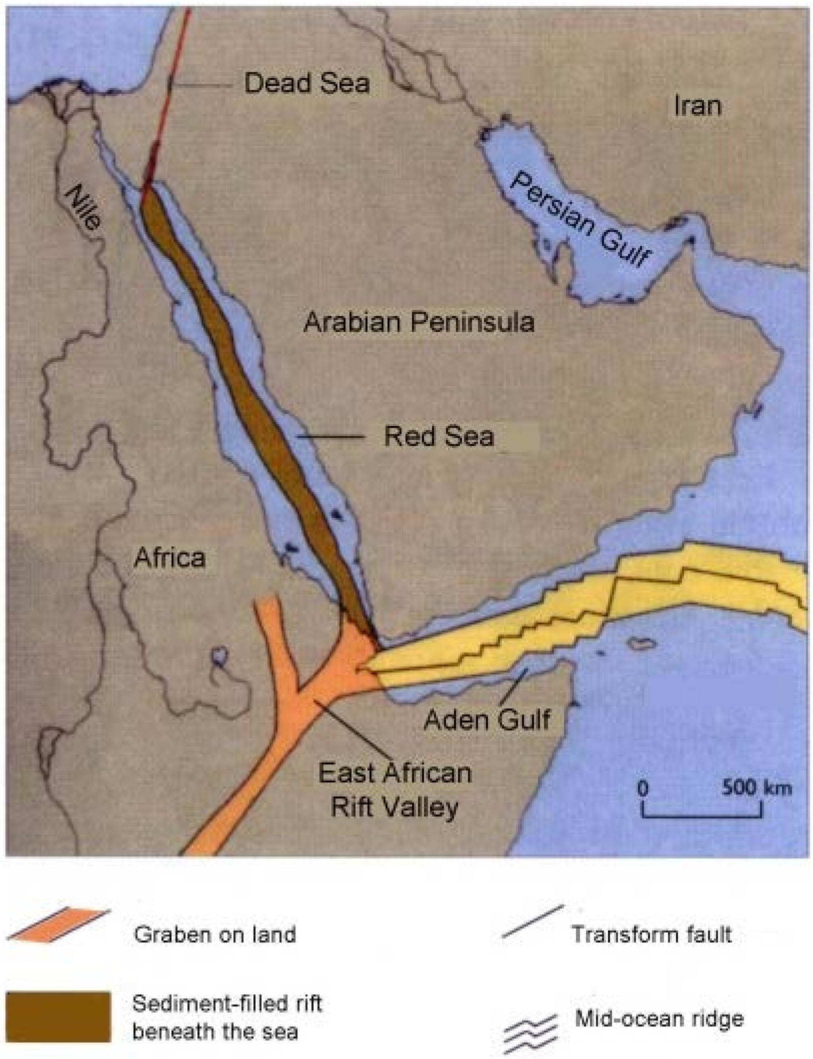
The East African Rift Valley

This is the best-known example of the early phase of the evolution of divergent plate margins.

A part of the East African Rift Valley in Kenya [i]

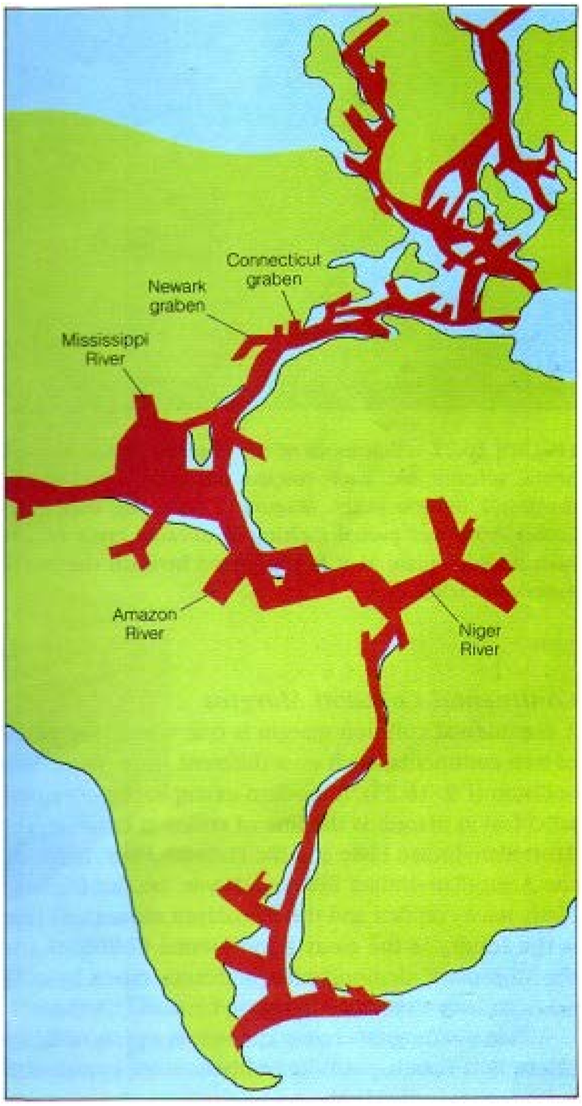
Formation of seas

As the rift widens, a point is reached where seawater enters. The early flow is restricted, and the water is shallow, resembling a shallow lake more than an ocean. In the arid areas, since the rate of evaporation is high, salts are deposited on the top of the clastic non-marine sediments. Finally, as rifting continues and the depth of the seawater increases, normal clastic marine sediments are deposited.



Three spreading centres meet at a triple junction
The Gulf of Aden and the Red Sea are actively spreading. The African Rift appears to be a failing rift that will not develop into an open ocean.

It frequently occurs that three opening rifts meet at angles of 120°. Such a meeting point is called plate triple junction. In a triple junction usually two of the spreading edges remain active while the third one will not evolve into an ocean. It remains a long, narrow sequence of grabens filled primarily with non-marine sediments. Some of the world's largest rivers, like the Mississippi, Amazon and Niger, flow down valleys formed by undeveloped rifts associated with the opening of the Atlantic Ocean.

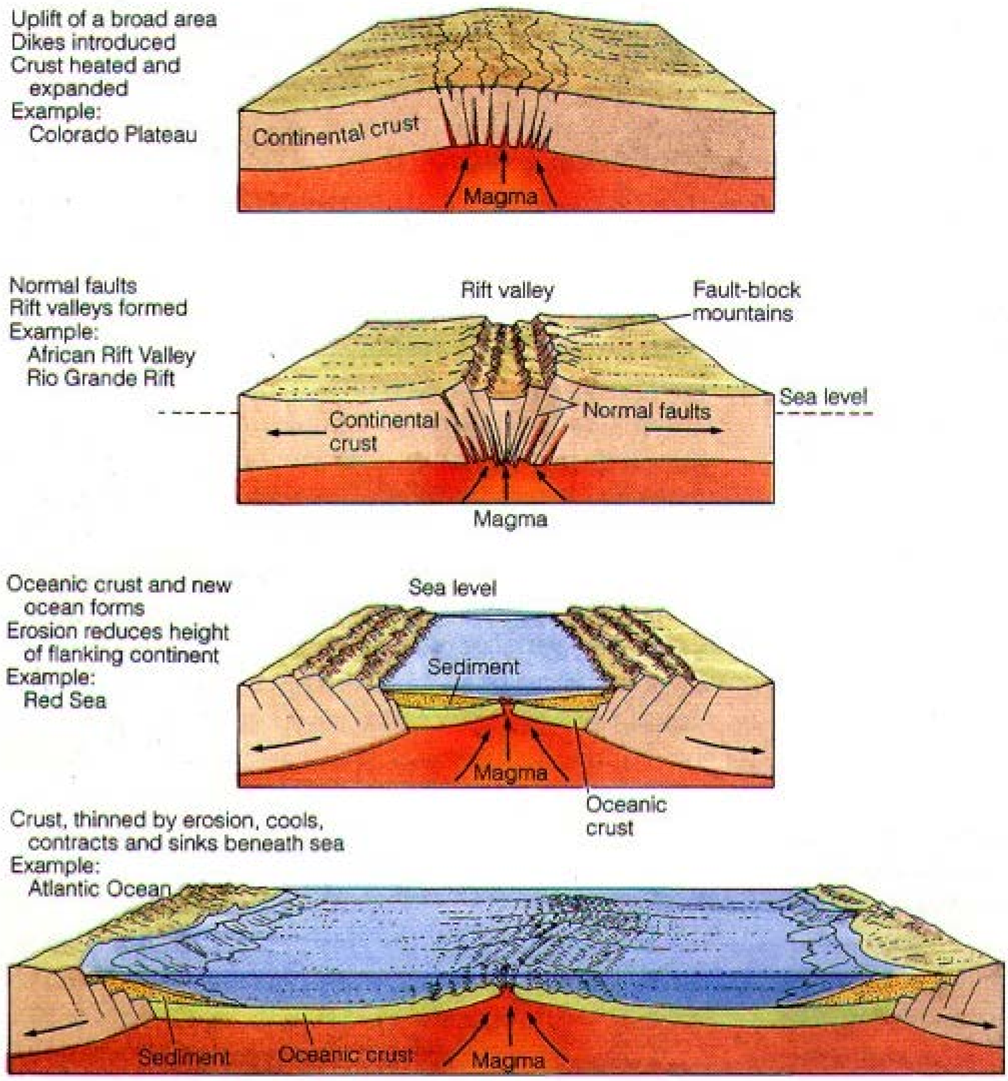


***Map of a closed Atlantic Ocean* [ii]**

This shows the rifts formed when the Pangea was split by a spreading centre. The rifts on today's continents are now filled with sediment. Some of them serve as the channelways for large rivers.

Oceans and mid-oceanic ridges

In the following phase of evolution, new oceanic basement is continuously created, and along the boundary of the two spreading plates a mid-oceanic ridge is formed. These oceanic ridges are widespread in the world's oceans and their peaks are usually 1-2 km below sea level. In some cases, e.g. in Iceland, the highest points can emerge from the ocean level.



***The evolution of divergent plate margins* [iii]**

The rifting can cease at any stage.

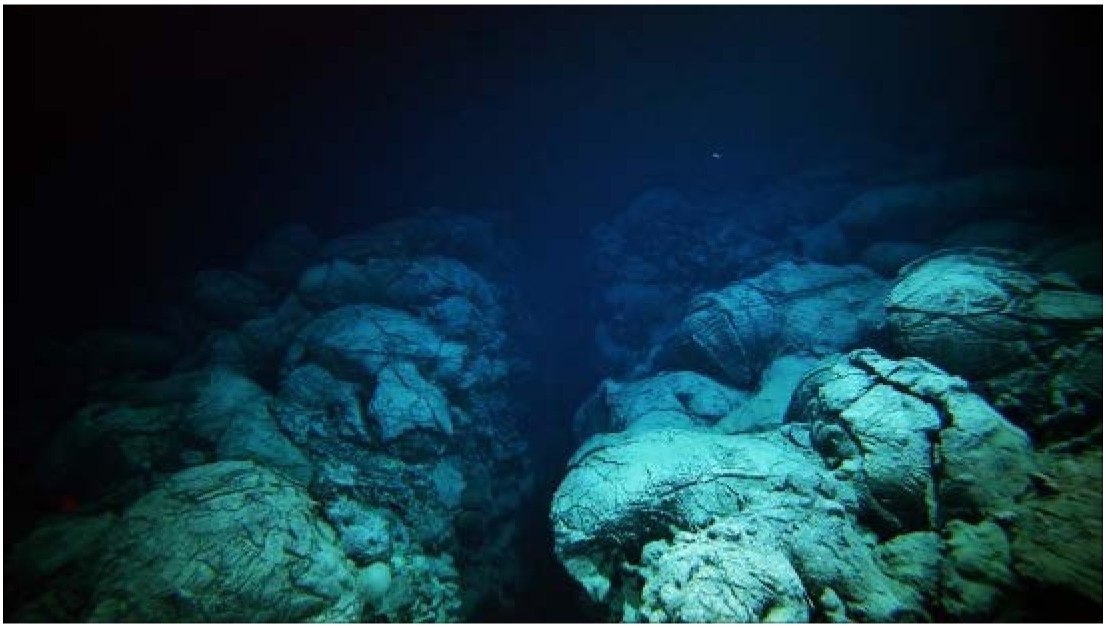
2. Topography of the seafloor

The topography of seafloor is controlled by the growth and movement of plates. Two prominent features in particular are related to spreading centres: **mid-oceanic ridges** and **ocean floor**.

Mid-oceanic ridges

The shape of any ridge is strongly influenced by the rate of spreading. Fast spreading rates of 9-18 cm/years mean that new oceanic crust is being created very rapidly. This in turn means that magma must rise rapidly and continuously from below and that large magma chambers must lie at shallow depths below the centre of the ridge. As a result, a fast-spreading centre is cooler and less inflated.

The overall ridge at a slow centre still stands high above the deep ocean floor, but the central rift is wider and more pronounced than the central rift in a fast-spreading centre. The basaltic magma along the ridges comes to the ocean bottom in form of pillow lava.

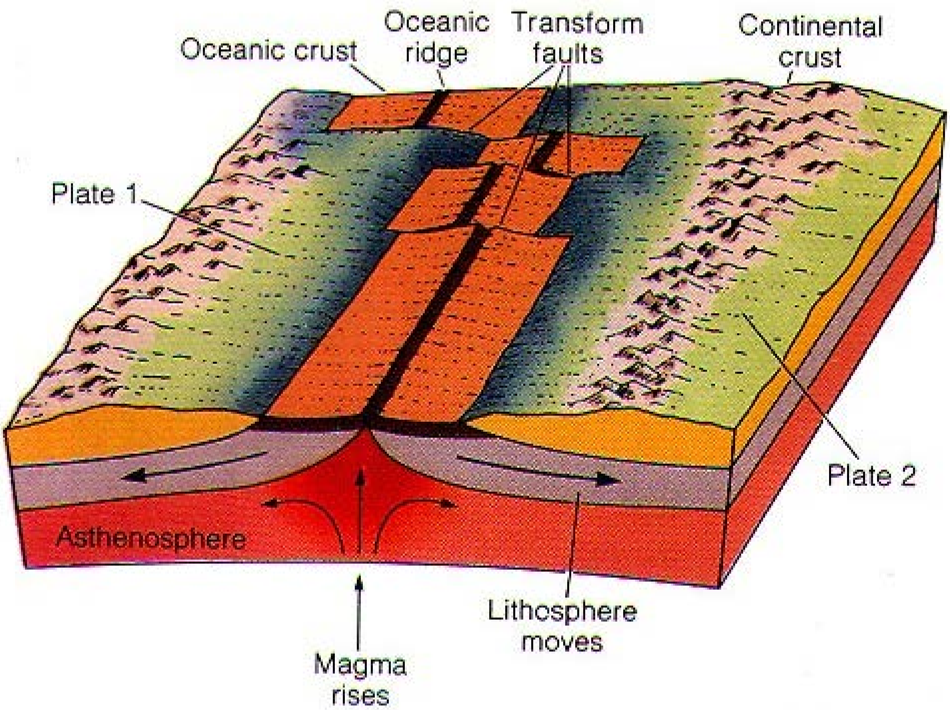


Pillow lava at the Mid-Atlantic Ridge [iv]

Transform faults

The mid-oceanic ridges are not continuous. They are cut into segments by transform faults, along which the segments can move laterally from a few hundred meters to one hundred kilometres.

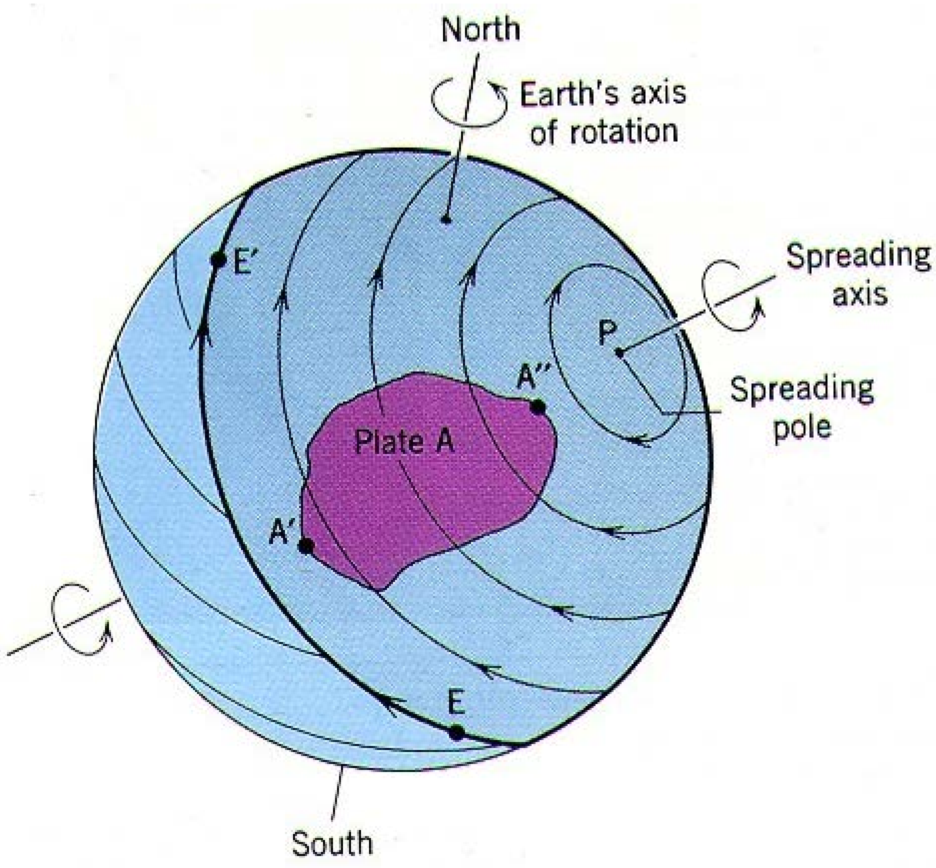
Transform faults are huge, vertical strike-slip faults cutting down into the lithosphere. The plates on either side of the transform fault smash and abrade each other. As a result, the faults are marked by zones of intensely shattered rocks.



Transform faults are formed when the oceanic ridge forms [v]

One might think that all points on a plate move at the same velocity, but this is incorrect. Our intuition would be correct only if the lithosphere plates were flat and moved over a flat asthenosphere. If this were true, then all points on the plate would move with the same velocity. In fact, plates are shells on a spherical Earth; they are curved, not flat.

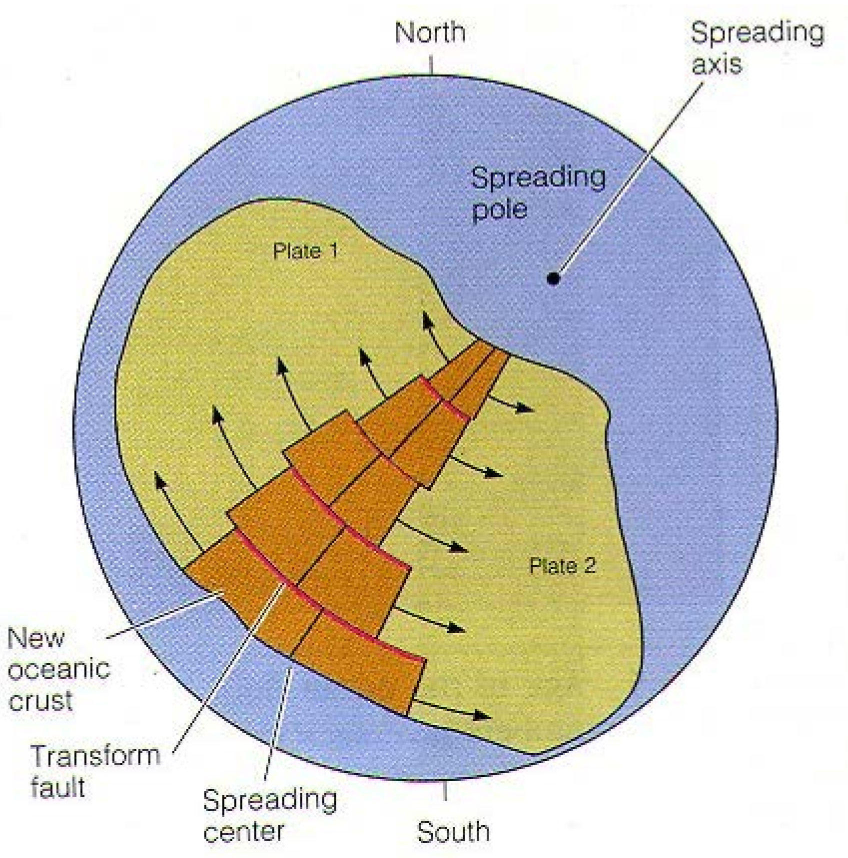
In the geometry of a sphere, any movement on the surface is a rotation about an axis of the sphere. A consequence of such rotation is that different parts of a plate move at different velocities. As a consequence, the oceanic ridges are broken into segments because of the rigid character of the lithosphere plates. The boundaries between the segments are the transform faults along which the segments can move laterally.



***Movement of a curved plate on a sphere* [vi]**

The movement of each lithosphere plate on the Earth's surface can be described as a rotation about the plate's own spreading axis. Point P has zero velocity because it is the fixed point around which rotation occurs. Point A' at the edge of the plate, closest to the equator EE', has a high velocity. Point A'', closest to the pole, has a low velocity .

The motion of each lithosphere plate can be described in terms of rotation around a spreading axis, and the velocity of each point on the plate depends on its distance from the spreading pole.



***Relation between spreading axis, oceanic ridge and transform faults* [vii]**

Plate 1 and 2 have a common spreading centre, displaced by transform faults (red). Each segment of the oceanic ridge lies on a line of longitude that passes through the spreading pole. Each transform fault lies on a line of latitude with respect to a spreading pole. The width of the new oceanic crust increases away from the spreading pole.

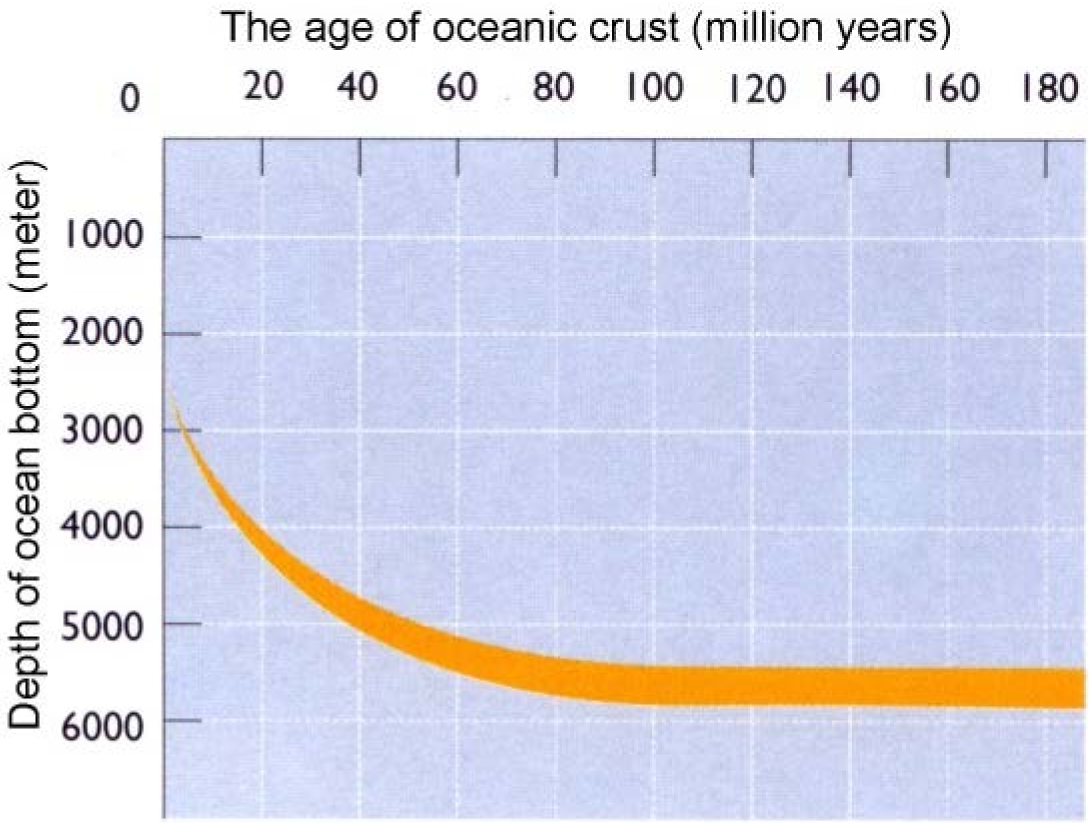
One consequence of different plate velocities is that the width of new oceanic crust bordering a spreading centre increases with distance from the spreading pole.

A second consequence is that the projection of a spreading centre passes through the spreading pole. Such a projection is analogous to a line of longitude.

A third consequence is that each transform fault lies on a line analogous to a line of latitude around a spreading pole.

Ocean floor

A large fraction of the heat that escapes from the Earth's interior does so along spreading centres. As a result, not only the mid-oceanic ridges but also adjacent portions of the seafloor are high points because lithosphere beneath them is thermally expanded. As lithosphere moves away from a ridge, it cools and contracts. As contraction occurs, the distance of the seafloor below sea level increases. A constant depth below sea level is reached after about 100 million years, by which time the oceanic lithosphere has cooled and reached thermal equilibrium. To a first approximation, the depth of the ocean floor provides an estimate of the age of the oceanic crust.



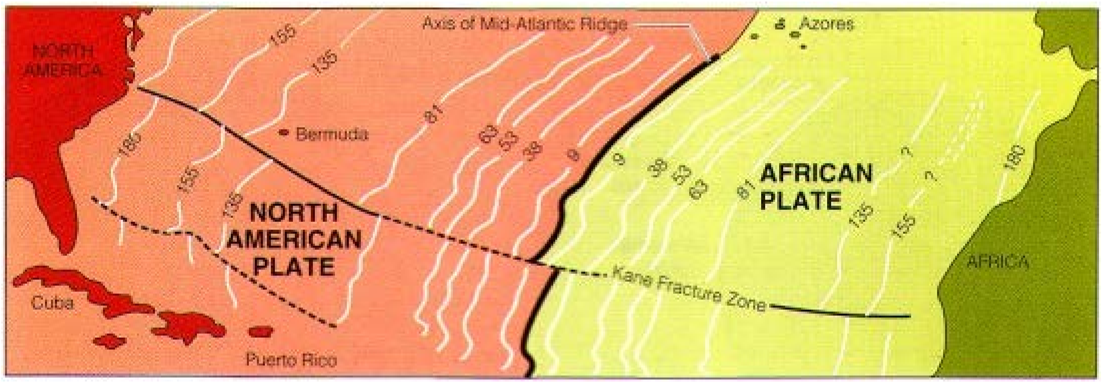
Depth and age of the ocean floor *[viii]*

Depth of the seafloor in the world oceans as a function of the age of oceanic crust. Near the spreading centre, young lithosphere is thermally expanded. As it moves away from the mid-ocean ridge, the lithosphere cools and contracts. The ocean becomes deeper as a result.

3. The relative speed of spreading

The relative speed of two spreading plates can be calculated on the *magnetic pole reversals*. The most recent magnetic reversal recorded near the crest of a mid-oceanic ridge occurred 730,000 years ago. The oldest reversal so far found in oceanic crust date back to the middle Jurassic, about 165 million years ago.

The relative velocities of some plates are much higher than others. The differences in speed appear to be related to the amount of continental lithosphere in a plate. Plates with only oceanic lithosphere tend to have high relative velocities. This is the case for the Pacific and Nazca plates. Plates with thick continental lithosphere, such as the African, North American and Eurasian plates have low relative velocities.



The age of the ocean floor deduced from magnetic stripping *[ix]*

From the numbers the relative velocity of spreading can be calculated. Numbers give the age of ocean floor in millions of years before the present. The Kane Fracture Zone is a huge transform fault.

BIBLIOGRAPHY:

[i] http://myjam.eu

[ii] Skinner& Porter, 1995

[iii] Skinner& Porter, 1995

[iv] http://irrelevantaxiom.wordpress.com

[v] Skinner& Porter, 1995

[vi] Skinner& Porter, 1995

[vii] Skinner& Porter, 1995

[viii] Skinner& Porter, 1995

[ix] Skinner& Porter, 1995