MID OCEAN RIDGES

Neena Francis[*]

Mid ocean ridge is an interconnected system of undersea volcanoes that meander over the earth like the raised seams on a baseball. It continues kilometres encircles the earth and bisects its oceans. Mid ocean ridge system is understood only since 1960s when the plate tectonic theory is explained and accepted. This represents an area where tectonic plates move apart by the magma pushing up from the mantle where theory of plate tectonics plays the role. Hence mid ocean ridge system is an example of divergent plate boundary. The shape of MORs are depending on their spreading rates, how active they are magmatically and volcanically and how much tectonic stretching and faulting is takes pace. As a whole this morphological variation is primarily due to the variation in strength of the ocean crust and how cold and brittle the upper part of the tectonic plate changes.

There are two types of Mid Ocean Ridges: fast spreading and slow spreading. Fast spreading ridges are at the northern and southern poles. The Mid Atlantic Ridge curves from the Arctic Ocean southward through Iceland down the centre of the Atlantic and around the bottom of Africa. As magma lies beneath the ridge axis, this is hotter and more volcanically active area. Because the plate under the ridge crest is hotter and the plate responds to the divergent spreading process more fluidly, the ridge behaves like hot taffy being pulled apart. So the ridge crest does not have a chance to subside. Slow spreading ridges like the Mid Atlantic Ridge have large, wide, rift valleys sometimes as wide as 10 to 20 kms and very rugged terrain at the ridge crest

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[*] M Sc Geology, Pondicherry University

that can relief of upto 3.2kms.The Mid Atlantic Ridge moves at an average of 2.5cm per year. Compared to fast spreading, the slow spreading ridges are cool and it forms ridges and valleys due to the cracks formed when it pull apart. As the sheets of oceanic crust move away from the mid-ocean ridge, the rock is cooled and thus becomes heavier. After about 200 million years, the cooled lithospheric plate has become heavier than the asthenosphere that it rides over, and it sinks, thereby producing a subduction zone.

Most of the Mid Ocean Ridges are divided into hundreds of segments by fracture zones which are the offsets found in many places of the Mid Ocean Ridges due to zones of weakness in the pre-existing continents before it is rifted apart. These fracture zones occur at an average interval of 55 kms.

The depth over the oceanic ridges is correlated with the age of the oceanic crust. Specifically, the ocean depth is directly proportional to the square root of the crustal age. Theory explaining this relation holds that the increase in depth with age is due to the thermal contraction of the oceanic crust and upper mantle as they are carried away from the seafloor spreading centre in the oceanic plate. The mid-oceanic ridges rise 3000 meters from the ocean floor and are more than 2000 kms wide. The mapping of the seafloor also revealed that these huge underwater mountain ranges have a deep trench which bisects the length of the ridges and in places is more than 2000 meters deep. It is revealed that the heat flow from the ocean floor was centered at the crests of these mid-oceanic ridges. Seismic studies show that the mid-oceanic ridges experience an elevated number of earthquakes. All these observations are the indications of intense geological activity at the mid-oceanic ridges.
Gravity anomaly: The mid ocean ridges are characterised by positive free air gravity anomalies.

This is not entirely ruled out by the limited information available. Thus in interpreting the global gravity field, the role of lithosphere as a layer of finite strength is considered. The surface measurements indicate anomalies over the ridges that are of shorter wavelength than the satellite observations. The gravity anomalies may be the consequence of flow in the asthenosphere or may be the result of density anomalies of lithosphere. It is found that the anomalies over the ridges are of shorter wavelength than the major features in the global gravity field. There is also a tendency for anomalies to be strongly positive when the spreading rates are low and to become smaller or approaches zero as the spreading rate increase. In general, surface measurements do not reveal the long wavelength features clearly. Because, unless very dense coverage is available, rugged relief of the ocean ridges as well as the smoothed profiles causes rapid variations in free air gravity anomaly.

Anomalies along ridges always show maximum but their wavelengths are shorter than those found in the global solution. But, there must be negative anomalies over the rising limb of the convection cell because of the mass deficiency in the rising current. There are two competing effects about this mass deficiency. There is mass deficiency due to low density and also an upward deformation at the same time. This is explained as if the lithosphere acts as a free boundary then the anomaly would be positive but if it acts as a fixed boundary then it would be negative. At the same time the lithosphere could contribute to the gravity anomaly in the following ways:

1) Mass anomalies in the lithosphere, which is supported by the finite strength of the layer.

2) Mass anomalies occur in the lithosphere, which is the consequence of asthenosphere flow.

3) Mass anomalies in the lithosphere supported by the asthenosphere.

Hence it can be concluded that if the gravity anomalies represented by harmonics of degree 9 and above are supported by lithosphere. But this mechanism can explain the short wavelength gravity anomalies by surface measurements but cannot explain the longer wavelength anomalies over global solutions. The second possibility could arise from the intrusion of hot asthenospheric material into the lithosphere results in the thermal expansion of the layer. The third possibility certainly requires some form of convection in the asthenosphere and consequently a separation of the part of the anomaly in the lithosphere from that due to convection is not possible from gravity measurements alone.

TOPOGRAPHY: Ocean ridges mark accretive or constructive plate margins where new oceanic lithosphere is created. They represent longest linear uplifted features of the Earth's surface and can be traced by a belt of shallow focus earthquakes that follows the crustal regions and transform faults between offset ridge crests. The topographic expression of mid ocean ridges is typically between 1000 and 4000 km in width. Their crests are commonly 2-3 km higher than the neighbouring ocean basins locally topography can be rugged and runs parallel to the crests. The morphology of the ridge is controlled by separation rate and the spreading rate varies at different points. Therefore many of the essential characteristics of the ridges such as topography, structure, and rock types vary as a function of spreading rate. The topography of East Pacific Rise is smooth which is fast spreading and Mid Atlantic ridge of rugged topography which has a median rift valley at its crest is a slow spreading. The axis of spreading is marked by a narrow zone of volcanic activity. Away from this volcanic region, the topography is controlled by vertical tectonics on normal faults. Beyond 10-25 km from the axis, lithosphere becomes stable and rigid. This stable region bound the area where oceanic lithosphere is generated known as plate boundary zone.

HEAT FLOW: The half space model of lithospheric cooling with age predicts that the heat flux through the ocean floor on ridge flanks vary in proportion to the inverse square of its age, but the older ocean floor favouring a plate model. It shows variation in heat flow values slower than this. According to the age depth relation model GDH1 by Stein and Stein, the observed values are very much less than the values predicted by the models. There is a large scatter in magnitude near the crest of ocean ridges. Mostly thermal lows occur in flat-floored valleys and highs within the areas of rugged topography. Sediment cover is not a cause for the low heat flow because the troughs are within the least sedimented areas of the ridge and the youngest hence the hottest. This phenomenon is explained by the proposal that the pattern of heat flow is controlled by the circulation of sea water through the rocks of oceanic crust.

Even if the hard rock water circulation seems rarely, the thermal contraction can induce sufficient permeability for the efficient convective flow. Cracks are predicted to advance rapidly and cool a large area in a shorter period of time so that intense localised source of heat are produced at the surface. Active geothermal systems that are driven by water circulation coming in contact with near molten material are expected to be short lived but this gentle circulation of cool water driven by the heat conducted from below persist for some time. However the subsided oceanic crust which is moved away from the ridge crest is blanketed by impermeable sediments and the cracks and pores are filled by the minerals deposited by the circulation of water. Ultimately the heat flux by conduction alone. Hence normal heat flow measurements are obtained. The sealing age of oceanic crust would be approximately 60 Ma. According to heat flow surveys on Galapagos ridge revealed that the pattern of large scale zoning and the wide range of individual values are consistent with hydrothermal circulation. Small scale variations are arise from variation in near surface permeability and large scale variations are due to major convection pattern which exist in a permeable layer influenced by topography, local venting and recharge at basement outcrops. It is thought that the hydrothermal circulation of seawater in the crust beneath the ridges transports about 25% of the global heat loss.

The chemistry of hydrothermal springs on East Pacific Rise and Mid Atlantic ridge is similar, in spite of the great difference in spreading rates and suggest that they have equilibrated with a green schist assemblage of minerals. Perhaps because of the cooler environment at the ridge crust, there are high levels of hydrothermal activity at certain locations of ultra slow spreading ridges. This results from the focus of magmatic activity at these points, producing higher temperature at shallow depths. Further evidence for hydrothermal circulation comes from the presence of metalliferous deposits in which metals are hydrothermally mobile and must have been leached by seawater permits their extraction in hot, acidic, sulphide-rich solution. On coming into contact with cold sea water the solution precipitate base metal sulphide deposits. The presence of these metals is corroborated by studies of ophiolites.

SEISMICITY: The global mid-oceanic ridge system is one of the longest active seismic belts where most of the earthquake epicenters are located continuously within a narrow axial zone. Geological and geophysical observations revealed a partitioning of the ridge by numerous discontinuities of several orders, which is reflected in the seismicity. There are two kinds of first order segments, transform faults and the spreading centers which shows different seismic regime. The contribution of seismic moment release by the transform fault which is one-two order higher into the total seismic budget of MOR increases with higher spreading rate. The relationships between the seismic moment release, fault length and spreading rate are quite different for transform and rift parts of MOR. This confirms the difference in the geometry of their respective earthquake source volumes. But the ultimate factor controlling the ridge seismicity is the thermal structure of the lithosphere. More detailed location of epicenters and focal depths acquired great significance in the studies of magmatism, hydrothermal circulation and fracturing on MOR. As the oceanic lithosphere is formed at spreading centers, mid-ocean ridge seismicity directly reflects the evolution of the oceanic lithosphere. The mechanisms of these earthquakes show the basic kinematics of ridges and transforms and provides key evidence for the thermal-mechanical process that controls the evolution of the oceanic lithosphere.

Seismic studies over ridges can help to locate the position of magma chamber. Studies over East Pacific rise revealed that the evidence for magma chamber below the seafloor at a place where low seismic velocity is observed. It suggest an inverse relation between magma chamber depth and spreading rate. They considered that only the volume in which P-wave velocity is less than 3 km/s is regarded as melt lens and those which is greater than 5km/s includes much of the low velocity zone , behaves as solid. But in contrast to this, they couldn't find any evidence for magma chamber at the same depth of low velocity zone at the slowly spreading Mid Atlantic Ridge.

In 1935 Charles F developed Richter magnitude scale as a mathematical device to compare the size of earthquakes. The earthquake magnitude is determined from the logarithm of the amplitude of waves recorded by seismographs. The magnitude in Richter Scale is expressed as whole numbers and decimal fraction Richter's original magnitude scale (M_L) was then extended to observations of earthquakes of any distance and of focal depths ranging between 0 and 700 km. The waves are constrained to follow the natural wave guide of the Earth's uppermost layers, because earthquakes excite both body waves, which travel into and through the Earth, and surface waves. So two magnitude scales evolved - the m_b and M_S scales.

The standard body-wave magnitude formula is

$$m_b = \log_{10}(A/T) + Q(D, h) ,$$

where A is the amplitude of ground motion in microns

T is the corresponding period (in seconds)

$Q(D, h)$ is a correction factor that is a function of distance

D (degrees), between epicenter and station and focal depth

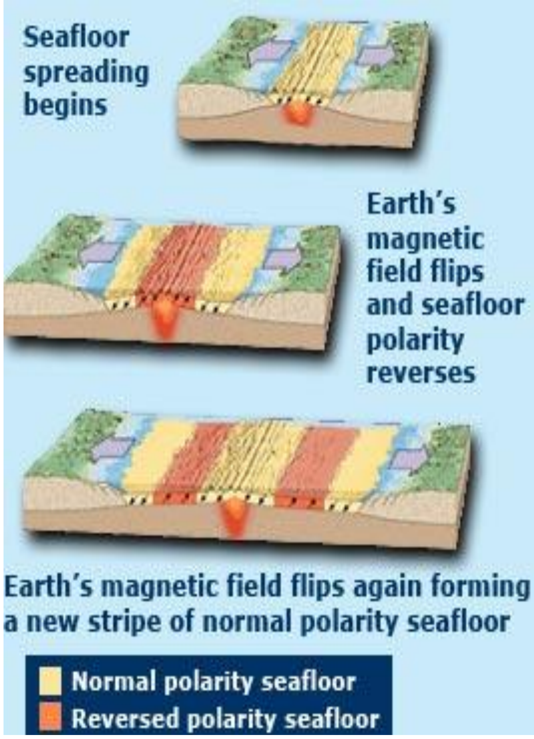
h (in kms) of the earthquake.

The standard surface-wave formula is

$$M_S = \log_{10} (A/T) + 1.66 \log_{10} (D) + 3.30$$

There are many variations of these formulas that take into account effects of specific geographic regions, so that the final computed magnitude is reasonably consistent with Richter's original definition of M_L. Negative magnitude values are permissible.

MAGNETIC ANOMALY: At Mid Ocean Ridges, lava erupts at it axis, cools and turns into hard rock. As it cools it becomes permanently magnetised in the direction of Earth’s magnetic field. It is discovered that the Earth, s magnetic field reversed its polarity hundreds of times during the past several hundred million years. A polarity reversal means the magnetic pole flips to where the South Pole is. At the spreading axis, these flips in the direction of Earth’s magnetic field are recorded in the magnetisation of lava. This creates a symmetrical pattern of magnetic stripes of opposite polarity on either side of the mid ocean ridges.



This pattern provides the history of seafloor spreading which is a magnetic anomaly measured using magnetometer. At slow spreading ridges, the anomalies are squeezed tighter together and where the anomalies are broader the spreading rate is faster. But the basic pattern is quite similar.

BASALT VOLCANISM: At the spreading centers, the plates are pulled apart by convection in the upper mantle, and lava intrudes to the surface to fill in the space or the lava intrudes to the surface and pushes the plates apart. Mostly it is a combination of these two processes. This is how the oceanic plates are created. The lava produced at the spreading centers is the most common rock type on the Earth’s surface, Mid Ocean Ridge Basalt. There are two major evidences for the spreading along the Ridges.

1) The MORB right at the ridge is younger and as we move away on either side from the axis gets older.

2) Sediments are very thin near the ridge crust and they thicken on either side of the ridge.

Mid ocean ridges are not continuous and it is segmented into various scale reflecting breaks in volcanic plumbing systems that feed the axial zone of magmatism. Shallowest and widest portions are rich in magmatism and deeper and narrow regions are magma starved. The unusual elevated segments of some ridges are related to the influence of nearby mantle plumes or hotspots. Lava morphology on slow spreading ridges is dominantly bulbous, pillow lava, which constructs hummocks, hummocky ridges, or small circular seamounts that coalesce to form axial volcanic ridge along the valley floor of axial rift zone. On fast spreading ridges lavas are dominantly oblong, oblate flows that vary from flat and thin to ropy and jumbled varieties.

When compared to continental crust, the oceanic crust formed at spreading ridges is relatively homogenous in thickness and composition. Primarily the MORB is generated by the partial melting of upper mantle which is believed to be rock type termed peridotite which composed of minerals like olivine, pyroxene, and minor spinel or garnet. The minerals that crystallise from MORB magmas are not only depend on the composition of the melt but also the temperature and pressure during crystallisation. Because the majority of MORB magmas have relatively same major mineral composition but the textures vary according to the nucleation and the crystallisation rates. During the ascent from the mantle, and cooling in the crust primary mantle melts are subjected to variety of physical, chemical processes such as fractional crystallisation, magma mixing, crustal assimilation, and thermogavitational diffusion that modify and differentiate the original melt.

CONCLUSION

These undersea mountain ranges and a major part of ocean crust is formed as result of complex interplay between magmatic processes such as eruption of lava, intrusion of magma at depth and the tectonic processes such as faulting, thrusting, rifting of solid parts of earth.

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