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Partner Work

Mid Ocean Ridge Setting

Tectonic Magmatic Setting

A mid ocean ridge forms as the result of the divergence of two lithospheric plates. Mid ocean ridges are the surface feature associated with divergent boundaries that have spread apart to such an extent that water has filled the newly formed basin between the previously conjoined lithospheric plates. The initial driver leading to the divergence is slab pull at the opposite ends of the plate which is diverging in the middle. The ends of the plate begin to subduct under other lithospheric plates due to differences in densities. A rift zone begins to form along the weakest points in the center of the plate being subducted at both ends. The result is crustal thinning to the degree that magma generation can take place resulting in volcanism along the rift zone.

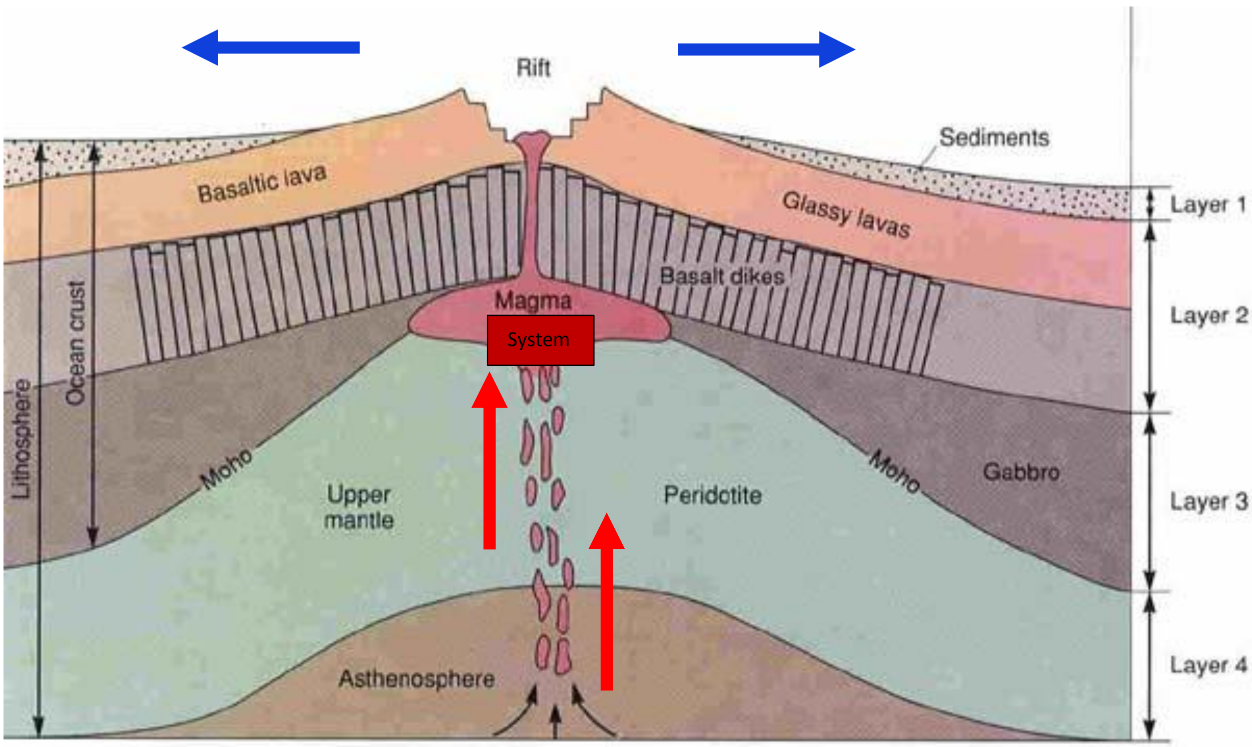

Figure 1: A cross section depiction of a mid ocean ridge showing the path of magma (red) and the directions of divergence (blue). The layers of the setting from the shallow mantle up are shown with labels indicating general compositions and names. (University of Oregon)

Continual volcanism in concert with divergence creates a dynamic tectonic magmatic setting that creates new oceanic lithosphere as the older material is moved away from the rift zone. The physiography of mid ocean ridges is determined by the rate at which the two, now separated plates are moving apart. Due to the fact that the setting is dynamic and constantly being recharged, a rift valley forms where the youngest volcanism occurs, the neo-volcanic zone. To either side of valley the topographic highs that are referred in the setting name as ridges form as the result of crustal bulging from upwelling in the crust and shallow mantle.

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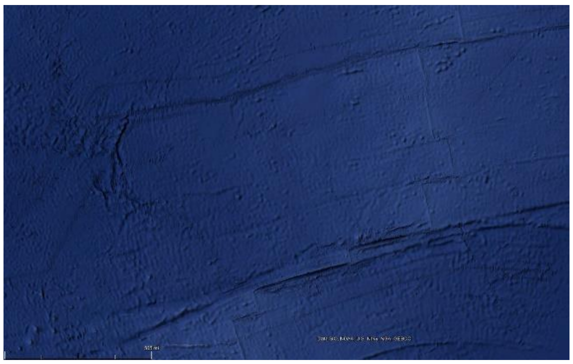
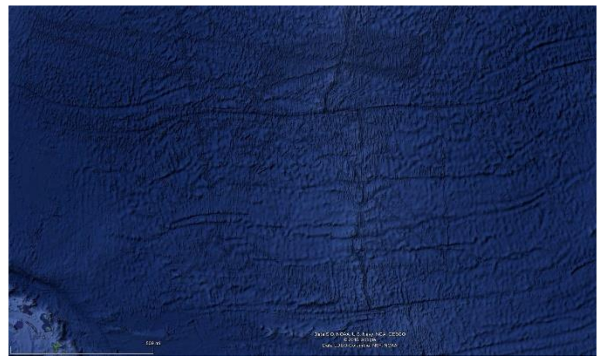
Physiography/Landforms

The physical appearance of a mid ocean ridge is dictated first and foremost by the rate at which it is spreading. Rate of spreading also affects the type of magma is extruded at the neo-volcanic zone. This in turn affects the landforms found at mid-ocean ridges of certain spreading rates. Half and full spreading rates are the two figures that are referred to when determining whether a ridge is characteristically “fast” or “slow”. A rift spreading at 5 cm/annum or 5 centimeters per year or faster is considered a fast spreading ridge.

Figures 2 & 3: The image on the left shows the smooth, gradational physiography of a fast spreading ridge (East Pacific Rise) and the right image shows the fractured, distorted physiography of a slow spreading ridge (Mid Atlantic Ridge).

The data set used in this exhibit encompasses values attributed to ridges from around the globe including fast and slow ridges displaying the full range of tectonic, physiographic, and geochemical signatures. Faster spreading ridges reflect high levels of magma recharge and a higher thermal budget. The increased temperature causes topographically higher ridges due to stronger bulging. Faster ridges have smoother flanks moving away from the rift zone because high recharge rates guarantee continual magma emplacement and thus, smoother transitions in in formations. At slow ridges, extensional deformation can occur between the episodes of volcanism. Slow ridges are therefore likely to have choppier and more disjoint landforms and surface textures. They will also not bulge as much as fast ridges, as slow ridges receive magma recharge in intervals with extended periods of no volcanism or inconsistent volcanism. The latter is manifested in the formation of seemingly erratically positioned seamounts. These seamounts tend to have relatively wide range of compositions with no homogeneity due to the nature of magma generation at slow spreading ridges. Faster ridges are both physiographically and geochemically more homogenous than slow ridges.

Smaller scale landforms that occur at mid ocean ridges are pillow basalts, which generally compose the shallow to surface layers of crust. They form as the result of volcanism dampened by the water column and water temperature. More consistent volcanism can result in black smoker vents forming which tend to be iron sulfide hydrothermal vents fueled by heat from magma below.

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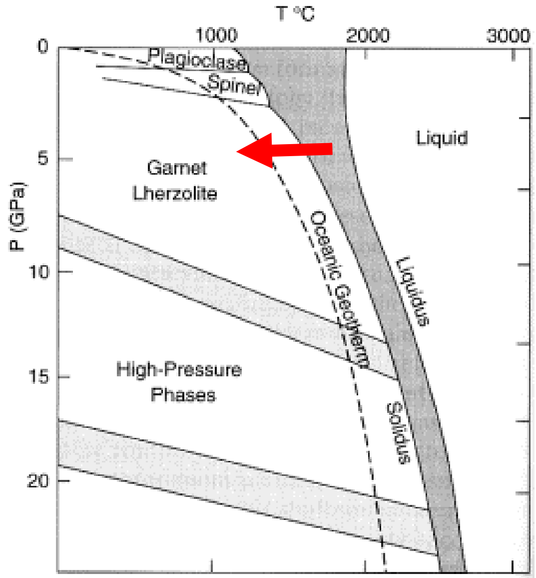
Magma Generation

Under normal mantle conditions magma cannot be generated without a shift in the geotherm or mantle solidus. The two lines must come in contact for even a small melt fraction to form.



At mid ocean ridges the key to creating melt is lowering the pressure at a constant depth resulting in constant temperature. This is achieved by thinning of the lithospheric plate at the rift zone. Slab pull thins the lithospheric plate enough to reduce pressure to a degree that melting can take place. The process is called decompression melting.

Figure 2: A generalized phase diagram for the mantle showing that without other intervention not melt can form. (University of Colorado Boulder)

The solidus is shifted to the left by the reduction of pressure at constant temperature. The melt fraction that can form, and therefore, the composition of the melt, is determined by what temperature decompression melting occurs. This is assuming that the majority of the source rocks for magma generated at mid ocean ridges is the shallow, depleted mantle. At slow ridges however, stagnant magma systems and heterogeneity result in a wider range of source rocks from which melts can be produced. This is reflected in the aforementioned seamounts.

Geochemical Data Analysis and Interpretation

MgO composition deceases the fastest of any element with an increase in SiO2, with FeO, P2O5, and CaO also decreasing very quickly. Al2O3 increases slowly, but will start to drop at about 50 wt% SiO2. There is a low concentration of TiO2 in the system, which does drop fairly rapidly for its small portion of composition. The alkali elements, K2O and Na2O increase with the SiO2 increase. These trends imply that in this system, MgO is the most compatible element in the less evolved melts with low SiO2, with FeO and CaO also being very compatible. Al2O3 is compatible after a certain point in the evolution of the melt, and the Alkalis are incompatible in the system.

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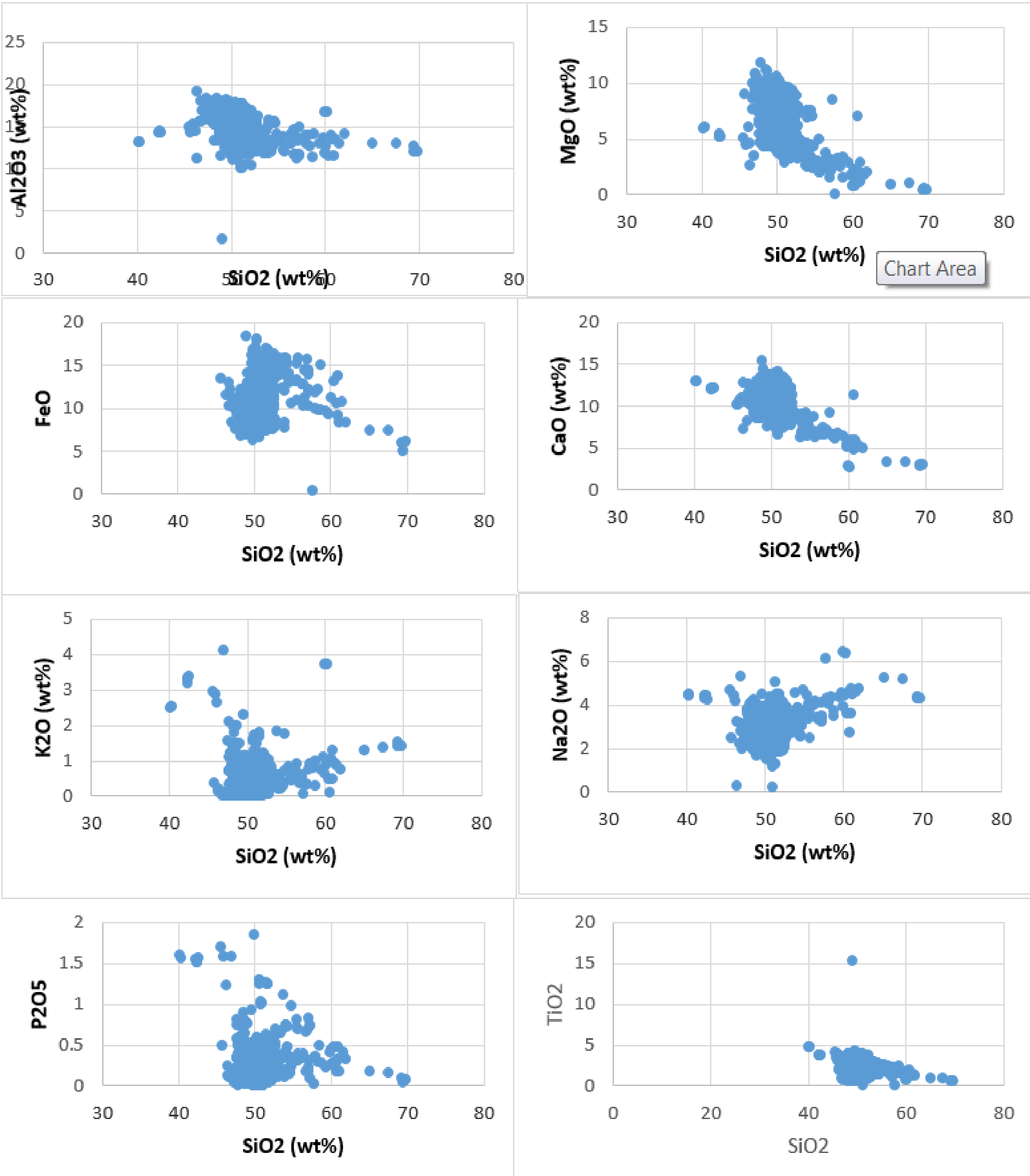

Figure 3. Harker Variation Diagrams for 6364 analyzed volcanic rocks from Mid-Ocean Ridges. Data compiled by PetDB.

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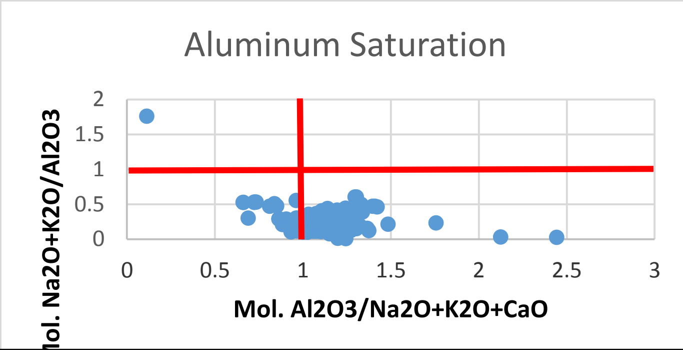

Figure 4. Alumina saturation indices of volcanic rocks from Mid-Ocean Ridges. Data compiled by PetDB.

The Aluminum Saturation indices place the majority of the MORBs in the Peraluminous portion with some samples being metaluminous. Being on the transition from Peraluminous to Metaluminous melt sourcing implies a reduced evolution of the melt overall in the system, however some evolution has occurred.

The alkali vs silica diagram shows a highly subalkaline concentration. This implies a strongly depleted mantle source, where the incompatible elements, Na2O and K2O have been overall removed from the system. This depleted source material means there has been evolution of the melt source.

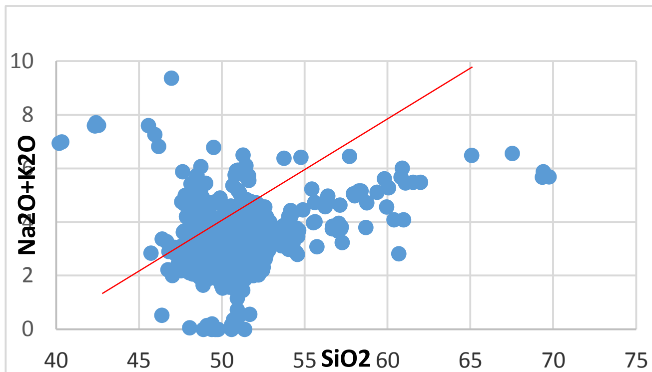

Figure 5. Alkali vs. Silica diagram of volcanic rocks from Mid-Ocean Ridges. Data compiled by PetDB.

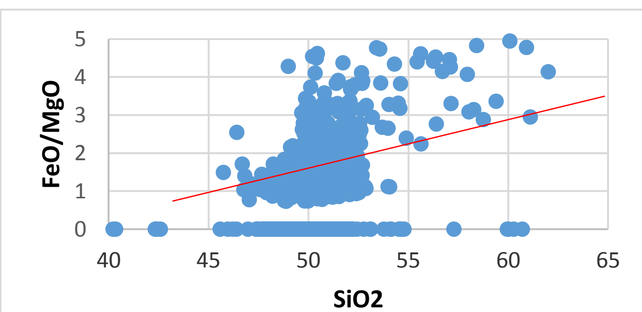

Figure 6. FeO/MgO vs. Silica diagram of volcanic rocks from Mid Ocean Ridges. Data compiled by PetDB.

The FeO/MgO vs. Silica graph shows the samples being on the border between Tholeiitic and Calk-Alkaline. The samples being very close to the border between Tholeiitic and Calk-Alkaline imply that there is a slight evolution of the melt, causing an increase in the slightly less compatible FeO.

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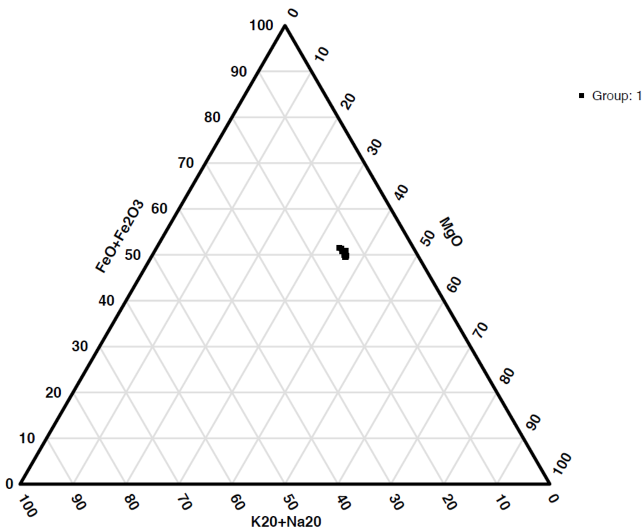
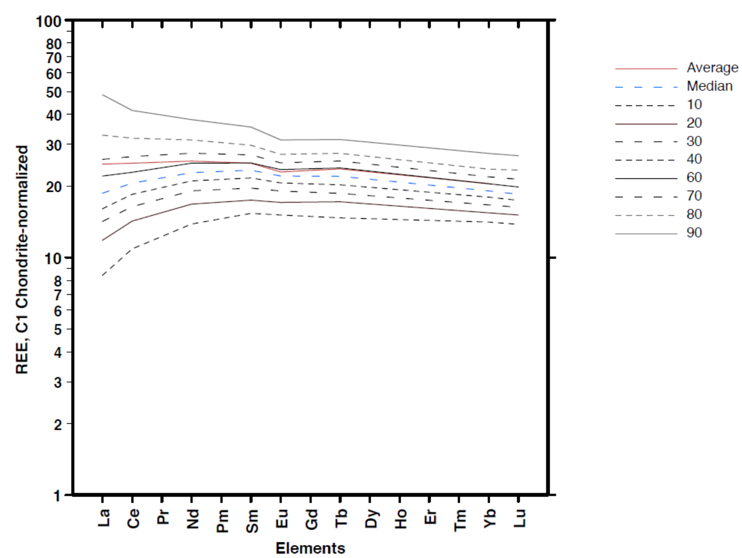


The AFM Ternary diagram shows these samples are heavily concentrated in Iron, with over 50%, a large amount of MgO, 35-40%, and very little alkali content. The higher iron content causes shows some minor evolution of the melt. Since the melt is moving in the direction of iron concentration, it is only slightly evolved. A more evolved melt will trend towards the Alkali corner, but show only evolution to the Iron corner. This is a melt close to a primary magma, but evolved past that point.

The REE Chondrite-normalized Spider diagram shows a fairly even distribution of incompatible and compatible elements. This even distribution shows a high melt fraction. A large proportion of rock is being melted in the mantle and diluting the concentration of incompatibles that are extracted from the crystals in the mantle source.



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