Lecture Notes 12.001 Magmatic Rocks

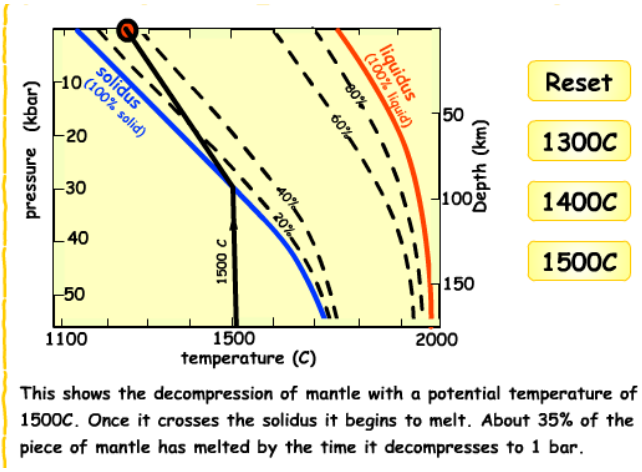
O.Jagoutz

Magmatic rocks. If we want to understand the origin and evolution of magmatic rocks we need to know two things: how does the Earth melt and how does the melt evolve (differentiate)?

Part I

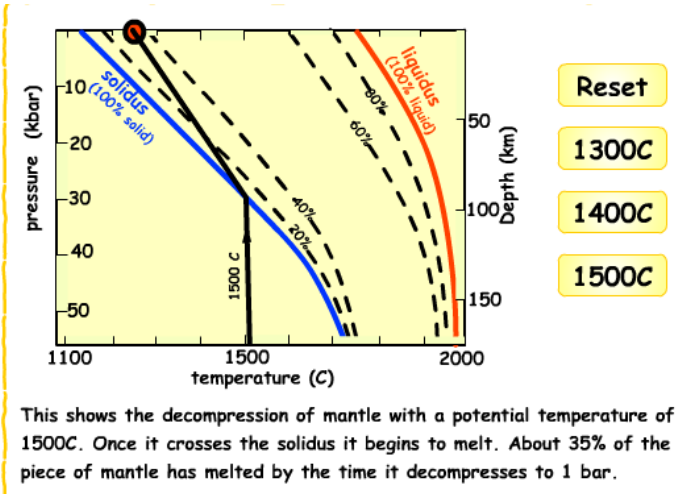
How does the Earth melt?

Show the topographic map and ask students which volcanoes they know. Ask them why they think that these volcanoes are there. Point out ridges, subduction zones and hotspots. Discuss a bit the characteristics of volcanic eruptions, why do we enjoy looking at an eruption in Hawaii whereas Mt St. Helens and Krakatau weren't really very pleasant for the people that experienced it.



This shows the decompression of mantle with a potential temperature of 1500C. Once it crosses the solidus it begins to melt. About 35% of the piece of mantle has melted by the time it decompresses to 1 bar.

Courtesy of Rob Butler. Used with permission.



This shows the decompression of mantle with a potential temperature of 1500C. Once it crosses the solidus it begins to melt. About 35% of the piece of mantle has melted by the time it decompresses to 1 bar.

Courtesy of Rob Butler. Used with permission.

Show mantle phase diagram (Langmuir et al.), show solidus and liquidus and indicate the location of the Earth's mantle in P,T space. Ask how we can melt the mantle? Ask if they think that we can ever melt the mantle completely? Probably not - an exception could be extremely high energy events like meteorite impacts.

Show the different mechanisms by which we could melt the mantle: decompression, heating and flux melting. Draw in the hydrous solidus - indicate that this is the temperature at which the mantle melts when it's saturated with H_2O. Explain the difficulty we have experimentally in locating the hydrous solidus and that estimates range from ~ 750 -800 C to 1100C.

Explain the concept of mantle potential temperature and the adiabat, explain that the slope of an adiabat is due to thermal expansivity and heat capacity.

T(z) =T0 exp(alpha*g/Cp * (z-z0)

To account for the T change with decreasing pressure after we crossed the solidus we have to include heat of fusion terms in the eq, which we don't do here. But this is what changes the slope as we lose energy to the melting process.

Explain how the degree of melting varies with different melting temperatures, and use this to introduce the discussion that this might have changed through time. That determining the degree of partial melting of melts is a possible tool to constrain the thermal state of the upper mantle and that we can use the geological record to constrain the thermal evolution of the earth. Explain that an important parameter is MgO content of these primary melts, which is thought to relate to degree of melting and therefore temperature. And people try to constrain the change in MgO content through time. Ask them why this is difficult. Explain that degree of melting is also composition-dependent and, as we have seen, water changes the story completely. So connecting degree of melting to temperature is possible but involves a lot of

assumptions. Draw a diagram of MgO content and time and that we try to relate this to temperature.

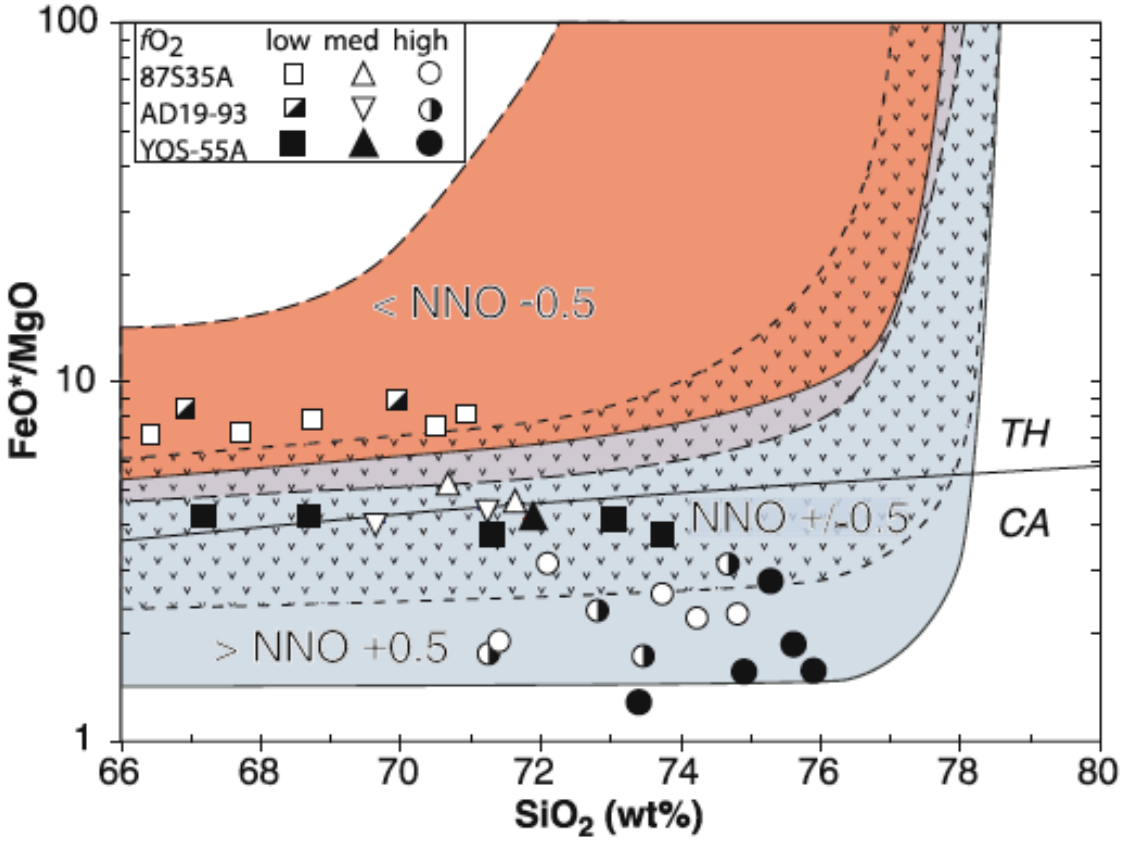
Discuss the different geodynamic settings in which we can melt the mantle. Show ridges. Subduction volcanism and hotspots.

Part II

What happens to the melt? It either gets stuck somewhere in the crust or erupts on the surface. What is the profound difference for the rock? Crystal size. Aim at understanding the temperature difference the melts have to adapt too. Than draw the diagram of nucleation rate vs. growth rate.

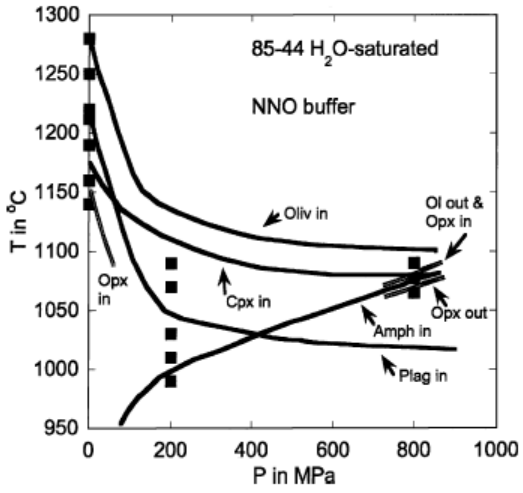
How does melt differentiate?

So now that we formed a melt and we extracted it from the mantle it will encounter a decreasing temperature gradient. What will happen? Let's do a thought experiment - we take our graduate student slave which in our case is our beloved TA Ben and we send him to two places in the world. We send him to dive down to the Oceanic ridges, and we send him to Oregon to sample magmatic rocks from the different volcanoes. So when he comes back we treat him nicely and we send him into the lab and he does chemical analyses for us. So than we sit down and plot the results and we realize a profound difference between the rocks we analyzed.



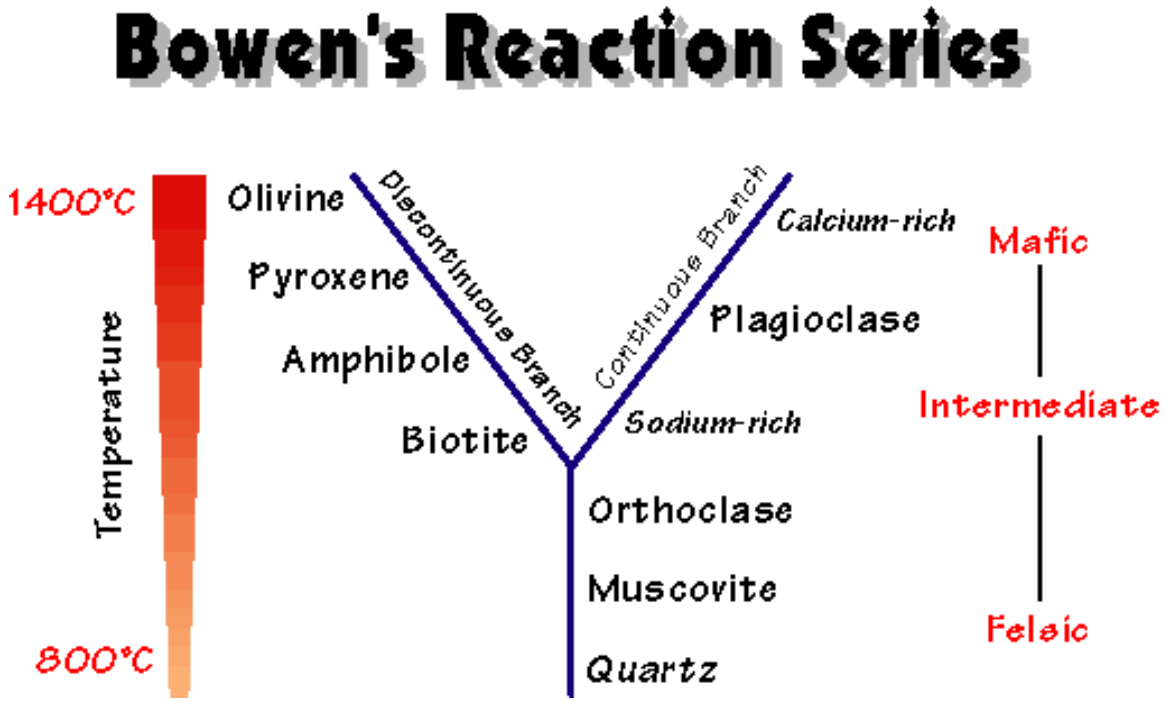
Explain calc-alkaline (effect of water - arcs) and tholeiites (no water – mid-ocean ridges)

Draw Tim's diagram and explain the concept of crystal fractionation. Draw a schematic magma chamber and explain cumulates and liquid separation. This results in chemical differentiation.



Point out the importance of textures and draw a schematic diagram of a rocks that follows the high P vs. low P fractionation.

Say that this has long been recognized – initially by a guy named Bowen who was a student here at MIT. The relations he noticed are now called Bowen's reaction series.



Courtesy of Mike Strickler. Used with permission.

12.001 Introduction to Geology
Fall 2013