Magma production beneath mid-ocean ridges: Using numerical models to evaluate the solidus

Francesca Burkett[1] and James Conder[2]

[1]Southern Illinois University
[2]Southern Illinois University Carbondale

November 24, 2022

Abstract

Over 95% of volcanism on Earth occurs at mid-ocean ridges (MORs) where tectonic plates diverge. How melt is produced depends on the mineral composition and water content. However, it has proven challenging to understand how melting changes when one or more minerals have completely melted. This project examines differences on MOR melting that come with different assumptions in solidus changes with exhaustion of one of the component minerals, clinopyroxene (cpx). To do this, we constructed 2D numerical models of temperature, mantle flow, and melt production at MORs. We ran several models with different amounts of temperature shift in the solidus with loss of cpx. Using zero shift as a baseline, melting starts around 80km depth and peaks at 35km, exhausting cpx, lowering melt output. A second smaller melting region develops more shallowly where there is no cpx. Additional trials in changing the shift in solidus with loss of cpx were done with varying amounts of mantle hydration. For all trials, total melt decreases with larger shifts in solidus. The shallower melting disappears as greater shifts are made. Increasing hydration allows melting to start at deeper depths, but has little effect on the total amount of melt production.

Posted on 24 Nov 2022 — CC-BY-NC 4 — https://doi.org/10.1002/essoar.10506315.1 — This a preprint and has not been peer reviewed. Data may be preliminary.

Magma production beneath mid-ocean ridges: Using numerical models to evaluate the solidus

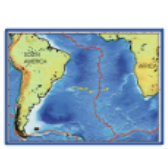
Francesca Burkett and James A. Conder
SIU Department of Geology

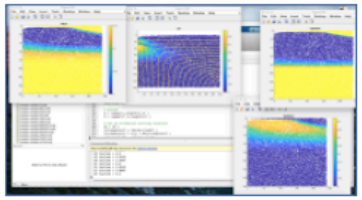
Introduction

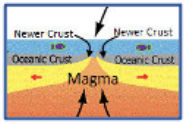
Over 95% of volcanism on Earth occurs at mid-ocean ridges (MORs) where tectonic plates diverge. How melt is produced depends on mineral composition and water content. It has proven challenging to understand how melting changes when one or more minerals have completely melted. This project examines differences on MOR melting with changes in solidus of exhaustion of clinopyroxene (cpx). This project allows us to not only model effects of changing hydration levels in the melt, but also allows us to examine what happens when we shift the temperature at which a mineral melts. We thought that the melt would have to shift upwards once it depleted the first mineral, in order to continue melting, or else stop melting above that region.

Set Up

- We constructed 2D numerical models of temperature, mantle flow, and melt production at MORs.
- We ran several models with different amounts of temperature shift in the solidus with loss of cpx.
- By creating a symmetric spreading across the model, we set a mid-ocean ridge model with a width of 240 Km and depth of 160km.
- The melting occurs on the tracers which are identified by location, hydration, amount of melt present, temperature, and Modal cpx. The initial Cpx is set at 15%.

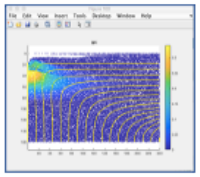


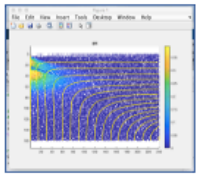


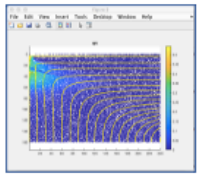


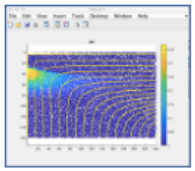
Methods

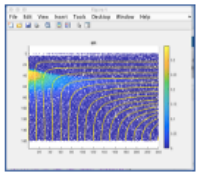
- Keeping parameters constant, we changed only the shift in solidus (the point at which the rock melts) with loss of Cpx for trials with varying mantle hydration : 0.01, 0.05, and 0.10.
- We examined the effects of shift in solidus between 0 and 200. to see what difference this caused in the melt production beneath mid-ocean ridges.

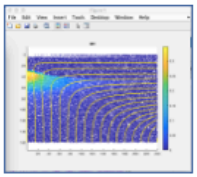






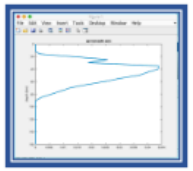


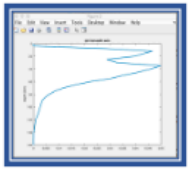


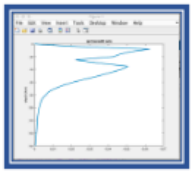


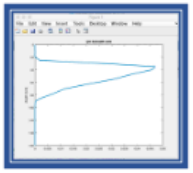
Results

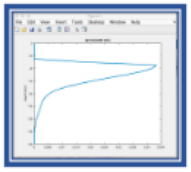
- Melting starts around 80km depth and peaks at 35km, exhausting cpx, lowering melt output. A second smaller melting region develops more shallowly where there is no cpx.
- For all trials, total melt decreases with larger shifts in solidus. The shallower melting disappears as greater shifts are made.
- Increasing hydration allows melting to start at deeper depths, but has little effect on the total amount of melt production.
- The highest decreases occur between 0 and 25, with melts around 107/108 dropping to around 94/95.
- Upper melt disappears from at 113/114 for hydration at 0.01, 114 for hydration at 0.05, and dtzol 114/115 for hydration 0.10. Hydration at 0.01 reaches a depth of 90. Hydration at 0.05 reaches a depth of 140. Hydration at 0.10 reaches depths below 160.

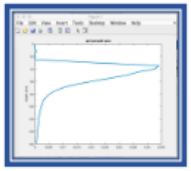




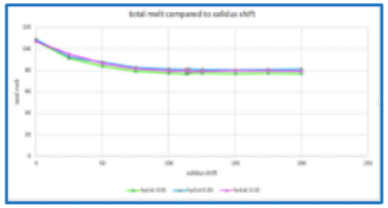








dtzol	hyd at 0.01	hyd at 0.0	hyd at 0.1
0	107.5197	108.7039	107.2935
25	91.5178	92.08	95.0322
50	83.985	87.7621	86.9243
75	79.2659	82.7388	81.4618
100	77.304	81.3641	79.6809
113	77.2166	80.8829	79.7624
114	77.181	80.8336	79.6056
115	77.5209	81.1845	79.4722
125	77.394	80.8336	79.4817
150	77.1138	80.336	79.5956
175	77.2608	80.7988	79.5956
200	76.9488	81.1833	79.4674



Conclusions

- Overall, we did not observe much overall increase in total melt, even with higher levels of hydration. What we did notice was that higher levels of hydration led to melting at greater depths, but it seems to just deplete mcpx faster, rather than increasing overall melt.
- We observed that the greater the shift in solidus, the less upper melt occurs.
- Rapid decreases occur with small shifts, with a drop of about 12% in total melt production for a shift of 25C.