Tectono-magmatic controls on hydrothermal activity at the Mid-Atlantic Ridge vent fields Logatchev and 5°S

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Introduction

We are investigating the relationships between tectono-magmatic processes at slow spreading ridges and the origin and nature of hydrothermal circulation. In particular, we will test if off-axis venting is a natural consequence of seafloor spreading in a tectonic phase, while on-axis venting occurs during magmatic dominated phases.

Background & Motivation

Slow spreading ridge segments undergo shifting periods of magmatic and tectonic phases (e.g. Escartin et al., 2008). Hydrothermal venting frequently occurs in off-axis regions as in the ultramafic hosted Logatchev hydrothermal field (e.g. Petersen et al., 2009). There a swarm of high seismicity events has been recorded a couple of km off-axis (Fig. 1), suggesting intense tectonic deformation along fault planes that are dipping towards the ridge axis.

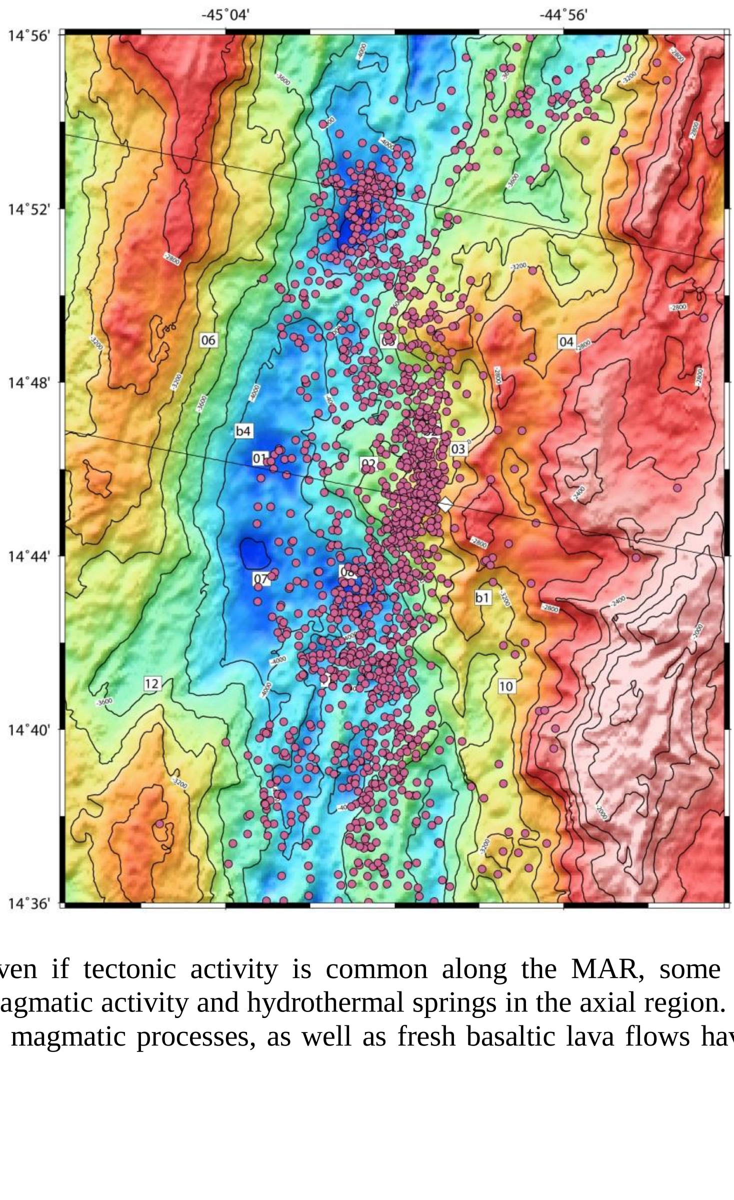

Figure 1: Cluster of recorded high seismicity off-axis in the Logatchev hydrothermal field at the Mid-Atlantic Ridge (from Grevemeyer, 2011 personal communication).

Even if tectonic activity is common along the MAR, some ridge segments show evident recent, magmatic activity and hydrothermal springs in the axial region. In the 5°S field seismic events, related to magmatic processes, as well as fresh basaltic lava flows have been observed along the ridge axis

(Haase et al., 2007). The contrasting styles of seafloor spreading and hydrothermal venting of the two described MAR systems Logatchev and 5°S make them ideal case studies for testing our key hypothesis about the tectono-magmatic state of slow spreading ridges controlling hydrothermal vent field location.

Modeling of seafloor spreading mechanics

We are currently developing a 2D lithosphere scale numerical model that resolves incompressible visco-elasto-plastic deformation of the seafloor at slow-spreading conditions. We use a Finite Element approach based on the MILAMIN solver with an unstructured, deforming, langrangian grid that consists of triangular seven-node elements. We are working on the implementation of plastic deformation in the code using the Mohr Coulomb yield stress formulation as in Kaus, (2010), including strain weakening. A key difficulty of incompressible codes is to handle volume changes, which occur in the zone of magmatic accretion in our model. Magma injection will be solved by the implementation of a dilation term like in Theissen-Krah et al., (2011).

Results
We will present the control of varying rates of magma supply to slow spreading ridge segments on the mechanics of seafloor extension. The outcomes from the mechanical model are expected to be similar to the ones of Buck et al., (2005). Moreover we will compare our results to the available seismic data on the Logatchev field. Two likely end-member scenarios are:

a. Phases of high magma supply, where the amount of magma added to the system is in equilibrium with the amount of oceanic lithosphere leaving the system due to extension of the seafloor. During this set-up the ridge is expected to behave similar to fast-spreading conditions with seafloor spreading occurring via crustal accretion and low degrees of faulting. These magmatic conditions are favorable for active hydrothermal venting along the ridge axis as seen at 5°S.

b. Phases of low magma supply, where the amount of magma added to the system is lower than the amount of oceanic lithosphere leaving it. This disequilibrium triggers intense tectonic activity, including brittle deformation and the development of large scale detachment faults reaching the surface in off-axis regions. Under these conditions spreading of the oceanic lithosphere happens via tectonic extension instead of magmatic crustal accretion. Hydrothermal circulation is expected to occur along fault structures with active springs in off-axis regions as observed in the Logatchev field.

We are using the above mechanical model in order to understand the large scale thermal and deformation fields and will use the outcomes as input for the hydrothermal model we will develop. Fully coupled simulations of deformation and fluid flow remain challenging. The different timescales of the two processes and the fact that hydrothermal systems are already intrinsically multi-phase pose significant difficulties.

Selected References

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