Links Between Magma Supply Axial Relief and Faulting at Mid-ocean Ridges

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Several new kinds of tectonic features have been discovered along the mid-ocean ridge system in the last few decades. These include oceanic core complexes with strongly rotated faults, the so-called "smooth terrain" with large fault relief and ultra slow spreading centers with alternating volcanic and exposed mantle sections along the axis of spreading. Observations have outstripped theory, in that we lack models that produce both these patterns of faulting and the related along- and across-axis relief. Simple models that vary the fraction of plate separation accommodated by dike widening, often termed M, are successful in reproducing the range of fault offsets and patterns observed. However, such models fail to produce the observed range of axial valley relief. Ito and Behn (2008) dealt with this problem by assuming different rates of viscous rebound of the axis for different ridges or parts of ridges. It is not clear what this viscous rebound represents.

In this talk I suggest an approach to reconciling fault style and axial relief involving the distribution of magma with depth and distance along a spreading axis. A basic idea is that dikes open not only in the strong, brittle elastic axial lithosphere but they also open some distance into the underlying ductile crust or even mantle. The shallow part of the dike accommodates lithospheric separation, while the deeper, slower cooling part of the dike produces gabbros. The deeper the axis the lower the magma pressure in the dike so that less magma is intruded at depth to produce gabbros. If this is right more magma would be available to accommodate plate separation fro a deeper axial valley. This can be included in numerical models of plate spreading if M increases with axial depth. The steady-state axial depth is reached when M=1. Small oscillation in magma abundance are needed to produce modest offset normal faults and fault offset should scale with extrusive layer thickness.

In this new model production of large offset normal faults only occurs if M is less than zero even when the axial valley reaches the maximum tectonically controlled depth. This limiting axial depth is related to the thermally controlled strength structure of the axial lithosphere, as discussed by Qin and Buck (2006). A way of simulating along-axis variations in axial valley relief, fault offsets and crustal thickness is based on the idea that magma is supplied from a magma chamber at the center of a spreading segment. A further assumption is that the along-axis topographic gradient required to drive dikes from the center to the ends of segments depends on the size of the low-viscosity region surrounding the central magma chamber (see Buck, Einarsson and Brandsdottir, 2006).

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