The effect of magmatism on faulting and axial morphology at mid-ocean ridges: Modeling the transition from rift valley to axial high

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Traditionally the differences in axial morphology and faulting at fast- and slow-spreading ridges have been attributed to variations in spreading rate between these environments. Fast-spreading ridges are characterized by a narrow axial high that is 5-10 km wide and 200-400 m high, while slow-spreading ridges typically display a 1-2 km deep and 20-30 km wide axial rift valley. However, recent observations along the Galapagos Spreading Center, the Southeast Indian Ridge, and the Juan de Fuca Ridge show that dramatic changes in axial morphology can occur over short along-axis distances on an individual ridge without large changes in spreading rate. In these regions, it appears that variations in the rate and distribution of magma to the crust are the dominant influence on axial morphology and faulting. Yet, while previous studies have focused on the effects of magma supply and spreading rate on ridge-axis thermal structure and morphology, few have integrated the thermal as well as mechanical effects of diking on lithospheric stress and faulting. In this study, we develop a thermomechanical model of diking in an extending 2-D elastic-viscoplastic layer using the Fast Lagrangian Analysis of Continua (FLAC) technique. Dike injection is simulated by widening a vertical column of model elements located within the crust and adding heat in proportion to the rate of dike opening. For cases in which the rate of dike opening is equal to the far-field spreading rate a narrow axial high develops. The height and width of the axial high are proportional to both the lithospheric thickness and the ridge-perpendicular variation in lithospheric thickness, which are in turn controlled by the spreading rate and the rate of conductive cooling. For cases in which the rate of dike opening is less than the spreading rate a rift valley develops. The width and depth of the rift valley as well as the height and spacing of the abyssal hills are again found to be proportional to the lithospheric thickness. Our calculations suggest that the magmatic accommodation of lithospheric extension associated with dike injection plays a greater role in controlling axial morphology and faulting than does the addition of heat to the ridge axis via magmatic accretion.