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Magmatic control of extensional deformation at spreading ridges

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Plate separation along ocean ridges is achieved by a combination of plate-tectonic spreading and magmatic accretion. Interaction between the two mechanisms largely contributes to variation in ridge axial morphology and structures on the ridge flanks. Divergent plate boundaries characterized by voluminous magmatic source commonly develop steady-state and continuous magma chambers with dike intrusion focused and typically affecting most of the axial domain. Spreading across Iceland, the only emergent portion of the entire ridge system, develops within a plume-enhanced segment of the plate boundary, and thus involves a great component of extension accommodated by magma emplacement. The surface dimensions and trends of active volcanic fissures in Iceland show their spatial relation with fault systems. Study of the Fremri-Namur and Hengill volcanic systems shows that linear vent arrays marking recent fissures are tightly bound by vertical, segmented faults with evidence of normal frictional slip on their scarps. These faults have likely developed as a result of subsidence above a magmatic fissure experiencing episodic inflation and deflation. On the flanks of the fissure swarm extension is commonly accommodated by systems of normal faults with a large dilational component. These discontinuities are suggested to initiate as magma-filled vertical fractures at depth and grow upward and laterally as planar ruptures. As failures propagate into shallow crustal levels, they tend to change into inclined normal faults and eventually link with surface dilational fractures and cooling joints.

Spreading across divergent plate boundaries with limited magma supply requires a large component of tectonic stretching. Along such ridges smaller crustal chambers result in magmatism being highly partitioned and variable along ridge strike, promoting point-source constructs with dike intrusion only affecting the median valley locally. Most dikes do not reach the surface, but build up temporarily high horizontal compressive stress in the crust. Extensive systems of normal faults and tensional fractures develop on the both sides of the axial summit graben, particularly prominent on magma-starved segments of Atlantic Ocean and SW Indian Ocean ridge systems.

Analogue modeling employed in this study in addition to the field data interpretation, examines the relative roles of tectonic stretching and magmatic accretion in their contribution to ocean ridge spreading. The degree of the control of magma dynamics on the formation of a wide spectrum of structures along spreading ridges is analyzed for plate boundaries with abundant and low magmatic supply. The results of the modeling emphasize significant variations in the axial morphology and brittle deformation for different ridge segments resulting from magma focusing or partitioning.