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Toward self-consistent tectono-magmatic numerical model of rift-to-ridge transition

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Natural data from modern and ancient lithospheric extension systems suggest three-dimensional (3D) character of deformation and complex relationship between magmatism and tectonics during the entire rift-to-ridge transition. Therefore, self-consistent high-resolution 3D magmatic-thermomechanical numerical approaches stand as a minimum complexity requirement for modeling and understanding of this transition. Here we present results from our new high-resolution 3D finite-difference marker-in-cell rift-to-ridge models, which account for magmatic accretion of the crust and use non-linear strain-weakened visco-plastic rheology of rocks that couples brittle/plastic failure and ductile damage caused by grain size reduction. Numerical experiments suggest that nucleation of rifting and ridge-transform patterns are decoupled in both space and time. At intermediate stages, two patterns can coexist and interact, which triggers development of detachment faults, failed rift arms, hyper-extended margins and oblique proto-transforms. En echelon rift patterns typically develop in the brittle upper-middle crust whereas proto-ridge and proto-transform structures nucleate in the lithospheric mantle. These deep proto-structures propagate upward, inter-connect and rotate toward a mature orthogonal ridge-transform patterns on the timescale of millions years during incipient thermal-magmatic accretion of the new oceanic-like lithosphere. Ductile damage of the extending lithospheric mantle caused by grain size reduction assisted by Zenner pinning plays critical role in rift-to-ridge transition by stabilizing detachment faults and transform structures. Numerical results compare well with observations from incipient spreading regions and passive continental margins.