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Numerical experiments on the influence of melt and serpentinization on passive margin structure

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Passive margins are often classified as magma-rich or magma-poor, with distinctly different crustal architectures. For example, end-member magma-rich margins have thick sequences of seaward-dipping reflectors, short necking zones, and thick oceanic crusts, whereas many magma-poor margins have wide necking zones, hyper-extended crust, and exhumed serpentinized mantle. Melt and magmatic processes can strongly affect the mantle and crust during various stages of extension. At late stages of extension, serpentinization of upper mantle rocks will also affect crustal strength. We aim to study the influence of melt and serpentinization on structures developed during passive margin formation.

Melt and serpentinization are two processes that can alter crust and mantle rheologic properties during different stages of extension. Introducing melt into a rift system will alter the thermal field, rheology, and density of crust and lithosphere. The presence of large amounts of melt (7-8%) in upper mantle rocks will significantly lower the viscosity. In addition, depleted mantle rocks can have significant loss of water that would result in raising the viscosity by about a factor of 100. Intrusion and underplating of magma to the lower crust can cause metamorphism and thus density and rheological changes of the surrounding crust. Furthermore, analogue experiments have shown that magmatic underplating will induce strain localization in the crust during extension.

In regions such as the magma-poor margins of the North Atlantic, the serpentinization of mantle peridotites after sufficient thinning of continental crust can lead to strain localization that will subsequently affect the margin architecture. Upper mantle rocks become serpentinized at temperatures lower than 400 degrees when seawater infiltrates. The lower frictional properties that serpentinized peridotites have at these temperatures work to localize strain and allow detachment faults to form.

We use 2D numerical experiments to test the influence of melt processes and serpentinization on passive margin evolution from undeformed continental lithosphere to seafloor spreading. Our experiments are performed with a thermo-mechanical finite element code using viscous-plastic rheologies. Melt formation, migration, and crystallization and serpentinization processes are included to examine the effect they have on the resulting passive margin structure. We will present our first set of geodynamic models that express the relationship between melt, serpentinization, and passive margin architecture.