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Depth-dependent rifting and lithospheric counterflow control on magmatism at passive margins

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Extension of continental lithosphere may result in the formation of passive margins with various structural styles and magmatic activities. Classical models of rifting, such as pure-shear or simple-shear extension, often predict a simple breakup of the lithosphere and therefore associate the variation of magmatism to temperature change of sub-lithospheric mantle. However, observations have shown complex, depth-dependent extension and revealed large lateral variation of magmatism that is not explained by thermal effect alone. Type examples of depth-dependent rifting are defined at (1) the Iberia-Newfoundland conjugate margins (Type I, narrow) and (2) some central South Atlantic margins (Type II, wide). Here we use 2-D numerical models to investigate melt generation for margins with various rifting styles. We consider four end-member models (I-A/C, II-A/C) that focus on the effects of margin width (Type I versus Type II) and lithospheric counterflow (C models). We show that the crustal rheology is the key factor that controls the width of margin, and that both margin width and lithospheric counterflow have significant influence on magmatism. Model I-A develops narrow margins with normal magmatism, whereas model II-A develops wide margins with thick (>18 km) igneous crust without the presence of high temperature anomaly. Lithospheric counterflow may suppress magmatic activity, leading to the formation of narrow margins with exhumed continental mantle (model I-C) or non-volcanic wide margins with hyper-extended crust (model II-C). We illustrate that our models are comparable with observations at the Gulf of Aden, Iberia-Newfoundland and some central and southern South Atlantic conjugate margins.