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3D thermo-mechanical models of continental breakup and transition from rifting to continental break-up and spreading

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We conducted high-resolution 3D thermo-mechanical numerical modeling experiments to explore evolution and styles of plume-activated rifting in presence of preexisting far-field tectonic stress/strain field and tectonic heritage (in form of cratonic blocks embedded in «normal lithosphere»). The experiments demonstrate strong dependence of rifting style on preexisting far-field tectonic stress/strain field and initial thermo-rheological profile, as well as on the tectonic heritage. The models with homogeneous lithosphere demonstrate strongly non-linear impact of far-field extension rates on timing of break-up processes. Experiments with relatively fast far-field extension (6 mm/y) show intensive normal fault localization in crust and uppermost mantle above the zones of plume-head emplacement some 15-20 Myrs after the onset of the experiment. When plume head material reaches the bottom of the continental crust (at ~25 Myrs), the latter is rapidly ruptured (<1 Myrs) and several steady oceanic floor spreading centers develop. Slower (3 mm/y) far-field velocities result in disproportionally longer break-up time (from 60 to 70 Myrs depending on initial isoterm at the crust bottom). Although in all experiments with homogeneous lithosphere spreading centers have similar orientation perpendicular to the direction of far-field extension, their number and spatial location are different for different extension rates and thermo-rheological structures of the lithosphere. On the contrary, in case of normal lithosphere containing embedded cratonic block, spreading zones develop symmetrically, embracing cratonic micro-plate along its long sides. Presence of cratonic blocks leads to splitting of the plume head onto initially nearly symmetrical parts, each of which flows towards beneath the craton borders. This craton-controlled distribution of plume material causes the crustal strain localization and uprise of plume material along the craton boundaries. Though there is a net tendency, in all models, of more rapid transition to spreading in case of more intensive far-field forcing, the presence of «cratonic» blocks seemingly leads to certain «acceleration» of break-up processes. Thus, lithospheric heterogeneities play important role in spatial distribution of plume-induced spreading centers and in the timing of break-up processes.