Geophysical Research Abstracts
Vol. 20, EGU2018-2443, 2018
EGU General Assembly 2018
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3D Thermomechanical Modeling of Rifted Margins with Coupled Surface Processes: the structural evolution of the North West Shelf, Australia

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Thermo-mechanical numerical models and analogue experiments with a layered lithosphere have emphasised the role played by the composition and thermal state of the lithosphere on the style of extension. The variation in rheological properties and the coupling between lithospheric layers promote depth-dependent extension with the potential for complex rift evolution over space and time. Local changes in the stress field due to loading / unloading of the lithosphere can perturb the syn and post-rift stability of the margins. We investigate how erosion of the margins and sedimentation within the basins integrate with the thermo-mechanical processes involved in the structural and stratigraphic evolution of the North West Shelf (NWS), one of the most productive and prospective hydrocarbon provinces in Australia. The complex structural characteristics of the NWS include large-scale extensional detachments, difference between amounts of crustal and lithospheric extension and prolonged episodes of thermal sagging after rifting episodes. It has been proposed that the succession of different extensional styles mechanisms (Cambrian detachment faulting, broadly distributed Permo-Carboniferous extension and Late Triassic to Early Cretaceous localised rift development) is best described in terms of variation in deformation response of a lithosphere that has strengthened from one extensional episode to the next. However, previous models invoking large-scale detachments fail to explain changes in extensional styles and overestimate the structural importance of relatively local detachments. Here, we hypothesize that an initially weak lithosphere would distribute deformation by ductile flow within the lower crust and that the interaction between crustal flow, thermal-evolution and sediment loading/unloading could explain some of the structural complexities recorded by the NWS. We present a series of numerical experiments coupling a 3D lithospheric-scale thermo-mechanical model (Underworld) with a plan-form 2D surface processes model (Badlands). We explore a range of realistic thermal and mechanical properties, as well as surface processes (erosion, sediments transport and sedimentation). This modeling approach aims to provide insights into the thermal and structural history of the NWS, and a better understanding of the complex interactions between tectonics and surface processes at the scale of the margin.