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Plume-lithosphere interactions in passive margins tectonic settings: Inferences from thermo-mechanical modelling

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We present the results of a thermo-mechanical modelling study of plume-lithosphere interaction in a rifted margin setting. We demonstrate that inherited lithospheric structure is a key parameter. Both the configuration of this transition between oceanic and continental lithosphere of rifted margin as well as localized weak zones inside them are important factors in localizing the deformation and the mode of the plume emplacement We have constructed models for plume emplacement at three locations transecting the margin system: under the oceanic part of the passive margin system, under the area affected by lithospheric thinning by passive rifting and under this continental lithosphere at the onshore part of the margin not affected by lithospheric thinning preceding the plume emplacement. It appears that the impact of the initial plume position is much more important than plume size, and plume rheology. For a strong rheology of the overlaying lithosphere in this transitional area between oceanic and continental lithosphere, the effect of plume emplacement is mainly restricted to deeper crustal and lithospheric levels. For a weak lithosphere in this area, plume emplacement has a most more dramatic surface expression and can lead to exhumation of mantle material. Initially a hot plume weakens the overlying lithosphere, whereas at the late stage of development frozen mantle plume material is embedded into lower part of the lithosphere, forming dense and high-velocity bodies such as commonly observed in the passive margins systems. Inherited rheology also affects the geometry of plume emplacement inside the lithosphere, with a dominant mode of vertical emplacement in case of weak lithosphere, whereas a strong lithosphere shields the rising plume leading to significant horizontal propagation over a wide area.

A comparison with the Northern Atlantic volcanic rifted margin province shows that observed plume distribution with southward propagation up to 400 km can be reproduced by a 3D model containing pre-imposed zones of lithospheric thinning along transform faults (East Jan Mayen Fracture Zone and Denmark Strait Fracture Zone). Compressional domes offshore the British Isles and Mid-Norway can be explained by ridge push effect on continental lithosphere weakened by hot material of Iceland plume lobes.