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Plume head-lithosphere interactions (PLI) near intra-continental plate boundaries and heterogeneities: a model based on thermo-mechanically and thermo-dynamically realistic formulation for the lithosphere and mantle

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In continental domain, plume-Lithosphere Interactions (PLI) have complex topographic and magmatic signatures and are often identified near boundaries between lithospheric blocks and plates of contrasting age and structure (e.g., young orogenic plates and cratons). These boundaries represent important geometrical, thermal and rheological barriers that interact with the mechanisms of emplacement of the plume head (e.g., Archean West Africa, East Africa, Pannonian - Carpathian system). The observable PLI signatures are conditioned by plume dynamics but also by complex rheology and structure of lithosphere that may include old blocks embedded in younger settings. We address this problem by considering a free-surface thermo-mechanical numerical model of PLI with 2 or 3 stratified elasto-viscous-plastic (EVP) continental plates of contrasting age, thickness and structure. In addition to our previous models, this new formulation is fully thermo-dynamically coupled and takes into account mineralogical phase changes within major compositional units: plume head material, normal lithosphere mantle and crust, cratonic mantle, asthenosphere, and the convective upper mantle. The model confirms our previous results, in particular showing that (1) surface deformation due to PLI is poly-harmonic; it leads to alternating or simultaneous compression-extensional “tectonic-like" events at surface, and is dominated by basin-scale uplifts and subsidences preferentially located at cratonic margins; this

deformation is characterized by much smaller wavelengths (50-500 km) than that, which are commonly expected for PLI (>1000 km); (2) plume head flattening is asymmetric below intra-plate boundaries, which leads to mechanical decoupling of crust from mantle lithosphere, and to localized faulting at the cratonic margin; (3) in presence of several cratonic blocks, plume head material may be trapped in between provoking major localised magmatic events, faulting and surface deformation. The results show that gradual density variations associated with progressive (above 440 km depth) phase changes reduce gravitational instabilities at the base of the plume-lithosphere mantle boundary that were predicted by previous models. Specifically, cratons "become" more stable. However, Negative Rayleigh-Taylor instabilities in the lithosphere above the plume head are important and provide a mechanism for crustal delamination. In case of several cratonic blocks, the combined effect of subsidence and lithospheric thinning at cratons edges, while plume head material is being stocked in between the cratons, favours major magmatic events at cratonic margins. Field evidence (West Africa, Western Australia) underline the trapping effect of cratonic margins for formation of (e.g.) orogenic gold deposits, which require particular extreme P-T conditions. Location of gemstones deposits is also associated with cratonic margins, as demonstrated by the Tanzanian Ruby belt. Their formation depend on particularly fast isothermal deepening processes, which can be reproduced by slab-like instabilities induced by plume head-cratonic margin interaction. On the other hand, absence of magmatic events should not be interpreted as evidence for the absence of plume, as the PLI may induce strong crustal melting that may overprint deeper signatures since crustal melts are generated at lower temperatures than mantle melts, and produce light low-viscous rapidly ascending magmas. Drip-like down-sagging of the lithospheric mantle and metamorphic lower crustal material inside the plume head may contaminate the latter and also alter the geochemical signature of related magmas.