Interaction of a mantle plume and a moving plate: insights from numerical modeling

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The impingement of a hot buoyant mantle plume onto the lithosphere can result in either breaking of the lithosphere, which might result in subduction initiation or in under-plating of the plume beneath the lithosphere. Key natural examples of the former and latter are formation of subduction along the southern margin of Caribbean and northwestern South America in the late Cretaceous as well as the hotspot chains of Hawaii, respectively. In previous studies the interaction of a buoyant mantle plume with lithosphere was investigated either for the case of stationary lithosphere or for moving lithosphere but ignoring the effect of magmatic weakening of the lithosphere above the plume head. In this study we aim to investigate the response of a moving lithosphere to the arrival of a stationary mantle plume including the effect of magmatic lithospheric weakening. To do so we use 3d thermo-mechanical models employing the finite difference code I3ELVIS. Our setup consists of an oceanic lithosphere, mantle plume and asthenosphere till depth of 400 km. The moving plate is simulated by imposing a kinematic boundary condition on the lithospheric part of the side boundaries. The mantle plume in our models has a mushroom shape. The experiments differ in the age of the lithosphere, rate of the plate motion and size of the mantle plume. For different combinations of these parameters model results show either (1) breaking of the lithosphere and initiation of subduction above the plume head or (2) asymmetric spreading of the plume material below the lithosphere without large deformation of the lithosphere. We find that the critical radius of the plume that breaks the lithosphere and initiates subduction depends on plume buoyancy and the lithospheric age, but not on the plate speed. In general, the modeling results for the moving plate are similar to the results for a stationary plate, but the shapes of the region of the deformed lithosphere differ.