Plume-induced subduction triggered transition from plume-lid tectonics to plate tectonics

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Modern plate tectonics is critically driven by subduction and oceanic spreading, however how this tectonic regime started and what geodynamic regime was before remains controversial. Most present-day subduction initiation mechanisms require acting plate forces and/or pre-existing zones of lithospheric weakness, which are themselves the consequence of plate tectonics. Here, we focus on plume-lithosphere interactions and spontaneous plume-induced subduction initiation, which does not require pre-existing lithospheric fabric and is viable for both stagnant lid and mobile/deformable lid conditions. We present results of 2D and 3D numerical modeling of plume-induced deformation and associated crustal growth resulting from tectono-magmatic interaction of ascending mantle plumes with oceanic-type lithosphere. We demonstrate that weakening of the lithosphere by plume-induced magmatism is the key factor allowing for its internal deformation and differentiation resulting in continental crust growth. We also show that plume-lithosphere interaction can enable subduction and embrionic plate tectonics initiation at the margins of a crustal plateau growing above the plume head. We demonstrate that three key physical factors combine to trigger self-sustained subduction: (1) a pre-existing strong, negatively buoyant oceanic lithosphere; (2) focused magmatic weakening and thinning of lithosphere above the plume; and (3) availability of surface water enabling lubrication of the slab interface by hydrated crust. We furthermore suggest that a distinct Venus-like plume-lid tectonics regime operated on hotter early Earth before plate tectonics, which was associated with ultraslow oceanic spreading, lithospheric delamination, eclogitic drips, and widespread tectono-magmatic heat and mass exchange between the internally convecting crust and the mantle.