Plume-induced subduction initiation: single- or multi-slab subduction?

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The formation of new subduction zones is a key component of global plate tectonics. Initiation of subduction following the impingement of a hot buoyant mantle plume is one of the few scenarios that allow breaking the lithosphere and recycling a stagnant lid without requiring any pre-existing weak zones. According to this scenario, upon arrival of a hot and buoyant mantle plume beneath the lithosphere, the lithosphere breaks apart and the hot mantle plume materials flow atop of the broken parts of the lithosphere. This leads to bending of the lithosphere and eventually initiation of subduction. Plume-lithosphere interaction can lead to subduction initiation provided that the plume causes a critical local weakening of the lithospheric material above it, which depends on the plume volume, its buoyancy, and the thickness of the lithosphere. Previous modeling studies showed that plume-lithosphere interaction can result in initiation of multi- or single-slab subduction zones around the newly formed plateau. However, they did not explore the parameters playing key roles in discriminating between the single- and multi-slab subduction scenarios. Here, we investigate factors controlling the number and shape of retreating subducting slabs formed by plume-lithosphere interaction. Using 3d thermo-mechanical models we show that the response of the lithosphere to arrival of a mantle plume beneath it depends on several parameters such as age of oceanic lithosphere, thickness of the crust, large-scale lithospheric extension rate, relative location of plume head and plateau edge and mantle temperature. The numerical experiments reveal that plume-lithosphere interaction in present day Earth can result in three different deformation regimes: (a) multi-slab subduction initiation, (b) single-slab subduction initiation and (c) plateau formation without subduction initiation. On early Earth (in Archean times) plume-lithosphere interaction could result in formation of either multi-slab subduction zones, very efficient in production of new crust, or episodic short-lived circular subduction. Extension eases subduction initiation caused by plume-lithosphere interaction. Plume-induced subduction initiation of old oceanic lithosphere with a plateau with thick crust is only possible if the lithosphere is subjected to extension.