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Fluid and melt weakening along subduction interface defines geodynamic regimes of intra-oceanic subduction

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The aim of this study is to characterize different geodynamic regimes of intra-oceanic subduction with our 2D coupled petrological-thermomechanical numerical model (I2ELVIS). We investigated systematically influences of fluid and melt weakening effects, which are responsible for the degree of plate coupling/decoupling and the mechanical strength of the overriding plate. Based on results of systematic experiments we distinguish the following three geodynamic regimes of intra-oceanic subduction a) retreating regime with either stable or episodic overriding plate extension, b) stable regime without compression and extension and c) advancing regime with fore-arc subduction.

a) Retreating subduction regime is characterized by a strong rheological weakening of the overriding plate mantle by hydration/serpentinization and melt propagation processes. A necking of the (fore) arc triggers initiation of the retreating subduction associated with the arc spreading. A deactivated remnant of the split arc (i.e. paleo-arc) remains on the opposite side of the growing backarc basin. In addition to the subduction related magmatic arc, the decompression melting in the backarc causes formation of large amount of MORB-like crust in the basin.

b) Stable subduction regime forms at the moderate degree of fluid and melt related weakening. The volcanic rocks in a stable subduction regime are mainly produced from the subducted oceanic crust and molten hydrated mantle. Some of the stable subduction regimes are characterized by development of a broad area of subduction mélange in which subducted basaltic crust is strongly mechanically mixed with the serpentinized fore-arc mantle. These intense mixing is promoted by increased degree of fluid related weakening.

c) Advancing subduction regime develops under condition of notably reduced fluid-related weakening that results in strong coupling between the plates in the fore-arc region. In some experiments we observed fore-arc subduction, which is triggered by its gradual mechanical disintegration resulting from the heterogeneous serpentinization process. Strong coupling between plates produces large stresses that are able to overcome the mechanical resistance of the serpentinized fore-arc mantle that starts to subduct together with the slab. Large amount of new basaltic crust forms at the surface as the result of enhanced fluid-fluxed melting of the mantle wedge that is triggered by dehydration of subducted serpentinized forearc fragments.