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Effects of rheological weakening by fluids and melts for defining geodynamic regimes of oceanic-continental subduction

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The dynamics of subduction under an active margin is analyzed by using a 2D coupled petrological-thermomechanical numerical model of an oceanic-continental subduction process. This model includes spontaneous slab bending, dehydration of the subducted crust, aqueous fluid transport, partial melting of both crustal and mantle rocks and melt extraction processes resulting in magmatic arc crust growth. Based on our models we identify the following five geodynamic regimes of subduction which may potentially from at active margins: (1) stable subduction with no backarc spreading center and without plumes in the mantle wedge, (2) retreating subduction with the focused backarc spreading center and without plumes, (3) retreating subduction with distributed intra-arc extension and trans-lithospheric sedimentary plumes, (4) advancing subduction with underplating (laterally extending) sub-lithospheric plumes, (5) stable to advancing subduction with stationary (laterally limited) sub-lithospheric plumes. Transitions between these different regimes are mainly caused by the concurrence of rheological weakening effects of (1) aqueous fluids percolating from the subducting slab into the mantle wedge and (2) melts propagating from the partially molten areas formed in the mantle wedge toward the surface. The aqueous fluids mainly affect the forearc region. Strong fluid-related weakening promotes plates decoupling and reduces subduction drag causing stacking of sediments in the accretion prism. In contrast, reduced weakening by fluids results in strong coupling of the plates and leads to advancing collision-like subduction with enhanced subduction erosion. Thickening of the overriding plate and large sedimentary plumes in the mantle wedge are the consequences. On the other hand, melts are extracted from the hot regions above the slab and rheologically weaken mainly the lithosphere below the arc controlling overriding plate extension/shortening processes. Strong rheological weakening by melts in combination with low coupling of the plates trigger retreating subduction with a pronounced backarc spreading center. Also, weakening of the continental lithosphere by melts extracted from trans-lithospheric sedimentary plumes, generates a weak channel through which these structures may emplace into the crust below the arc. If the absence of sufficient melt-related weakening the plumes can not ascend but extend horizontally, underplating the lithosphere.