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First-order surface topography of subduction zones in numerical models: the roles of subducting slab age and dip

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Using two-dimensional computational fluid dynamics (CFD) simulations we produced subduction zones in numerical models to investigate the role of subducting slab dip (α) and age (T) in controlling their first-order surface topography. We have employed an Arbitrary Lagrangian Eulerian (ALE) scheme to track the moving model surface, and reconstruct the resultant topographic development during subduction. Based on the ratio of fore-arc wedge to back-arc basin widths, our model topography allows us to recognize two principal types of subduction zones: accretionary and non-accretionary types. For the accretionary type, this ratio is greater than 1, but less than 1 for the non-accretionary type. Two sets of simulation experiments were performed with α as shallow (15°), gentle (30 and 45°) and steep (60°), and T as young (30 Ma), intermediate (60 Ma) and old (90 Ma). The reference experiment (α = 45°; T = 60 Ma) shows significant roll back motion of the subducting slab, which gives rise to localization of horizontal tensile stresses in the fore-arc region. The tensile stress regime propagates into the back-arc with progressive subduction. The roll back commensurate with the time dependent topographic variations, marked by a trench retreat. Fore-arc, arc and back-arc basins development are the most characteristic elements of first-order topography in subduction zones. For α = 15°, the back-arc basin narrows down with time. Conversely, steeper dips (α = 30, 45 and 60°) open the back-arc basin in course of the subduction. Our models show that the basin development is also sensitive to subducting slab age. Young (T = 30 Ma) slabs hardly promotes the growth of back-arc basins, but facilitates the fore-arc wedge to broadens with progressive subduction. In contrast, old slabs (T = 60 and 90 Ma) widen the back-arc basin to a large extent. Our model results suggest that younger and shallow-dipping slabs give rise to the accretionary type of subduction, whereas relatively old and steep slabs would form the non-accretionary type. There can be a broad spectrum showing the transition between these extreme conditions. We support our model findings with the back-arc opening rates from several natural subduction zones.