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4-D Numerical Modeling of Crustal Growth at Active Continental Margins

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Crustal growth and topography development in subduction-related arcs are intimately related to magmatic processes and melt production above subducting slabs. Lateral and temporal variations in crustal thickness and composition have been observed in nature, but until now no integrated approach has been developed to comprehensively understand magmatic activity in subduction-related arcs. Here we investigate the 4-D spatial, temporal and compositional character of continental crustal growth at active margins using a new 4-D (space-time) petrological-thermomechanical numerical model of a subduction-related magmatic arc. Based on a series of numerical experiments we demonstrate that crustal growth inside the arc is inherently clustered in both space and time. The characteristic wavelength of variations in crustal thickness and topography along the arc is defined mainly by plate convergence velocity: faster subduction favors longer wavelength. The clusters of new crust are formed mainly by basaltic melt episodically extracted from partially molten peridotite due to lateral variation of water release and transport in the mantle wedge. Melts derived from subducted oceanic crust and sediments could contribute up to 15-50 vol% to the arc crust growth and their relative proportion is maximal at the onset of subduction. The total amount of newly formed crust correlates mainly with the amount of convergence since the beginning of subduction and is not strongly influenced by the plate convergence velocity. Indeed, slower subduction and lower melt extraction efficiency helps partially molten sediments and oceanic crust to be transported into the mantle wedge by hydrated, partially molten diapiric structures. For our modeled type of stable subduction, the maximum crustal additional rate (25-40 km**3/km/Myr) occurs when amount of convergence reaches around 700 km. Mantle wedge structures developed in our models correlate well with available geophysical (seismological) observations for the Alaskan subduction zone. In particular, partially molten mantle plumes found in our models could explain low seismic anomalies in the mantle wedge, whereas mobile water and water release patterns could reflect paths and sources for magmatic activity evidenced by seismic b-value and Vp/Vs ratio analysis.