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Numerical experiments on the role of buoyancy and rheology during the formation of extension-driven gneiss domes

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Domal structures that are cored with crystallized partially melted crustal rocks are ubiquitous features in active and exhumed orogens. The exposure of these gneiss/migmatite domes at the Earth's surface represents an opportunity to study the mechanisms of flow within the deep crust, and the mode of emplacement of high-pressure rocks into the shallow crust. End-member gneiss dome types include (1) extension-driven domes that core metamorphic core complexes, and (2) buoyancy-driven domes that are exhumed by diapiric flow. Numerical models are ideally suited to test the relative roles of buoyancy and extension-driven mechanisms in dome dynamics, and therefore to explore the interaction of physical parameters involved in doming. To that end, this research utilizes a 2D visco-plastic thermomechanical modeling framework to undertake a parametric numerical experiment where the density (range of 2700-3100 kg.m3) and viscosity (range of 1E19-1E21 Pa.s) of the lower crust are systematically varied. The style and timing of "intrusion" of partially molten lower crust into non-molten lower crust is similar for densities of 2700-3100 kg.m̃3 across two lower crustal viscosities tested here (1E19 Pa.s, 1E21 Pa.s). However, dome development and upwards flow of lower crust material for a relatively high-density, middle-viscosity lower crust (2900-3100 kg.m̃3; 1E20 Pa.s) involves a significant upward translation of the Moho, relative to the low-density, middle-viscosity model results. In addition, the high-density, middle-viscosity model shows a decrease in the volume of partial melt in the lower crust, and distributed brittle faulting in the upper crust. Thus, this experiment suite illustrates that variations in density and viscosity of the lower crust influence (1) faults distribution in the upper crust, (2) flow patterns within the lower crust, (3) upward translation of the solidus into the lower crust, and (4) upward displacement of the Moho. The style of extension within the upper crust is therefore dependent on the viscosity structure of the middle and lower crust, including the capacity of gneiss domes to develop within the lower crust.