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Modeling the thermal and mechanical response of 3.4-2.2 Ga continental crust to the emplacement of sills

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Using the finite-element code Ellipsis, we build a two-dimensional model to explore the thermal and mechanical consequences of the intrusion of sills at different depths in a 40km-thick continental crust of density 2720 kg.m^{-3}. Frictional flow in the upper crust is described by Coulomb criteria with an angle of internal friction of 15° and a cohesion of 10 MPa. Beyond the plastic yielding, ductile flow is modeled by a temperature-dependent viscosity ($\eta = \eta_0 \cdot\ exp(-a \cdot\ T)$). We explore the response of the system under three different thermal regimes: Phanerozoic (last 545 Ma), early-Paleoproterozoic (2.5-2.2 Ga) and Mesoarchean (3.4-2.9 Ga) with Moho temperatures of 550°C, 680°C and 740°C respectively. We impose a constant temperature at the surface and a constant heat flow at the base of the model. Free-slip boundary condition is applied to all margins of the model and no forces are applied at any of the boundaries.

For each thermal regime, three sill emplacement depths are investigated: (1) on top of the crust, (2) at the brittle-ductile transition and (3) in the lower crust. Assuming a constant crustal volume, space for the emplacement of the sill is provided by upward displacement of the crust surface (1/3 of the sill thickness) and downward displacement of the Moho (2/3). The sill has a density of 2900 kg.m^{-3} and a viscosity ten times higher than the viscosity of the crust. The sill emplacement temperature is set at 1200°C. In the case of a sill emplaced at the surface of the crust, we assume a lower density and a lower viscosity to account for a sedimentary component, and the

temperature of emplacement is that of the surface of the crust.

For the early-Paleoproterozoic and Mesoarchean thermal regimes, we observed two pulses of crustal partial melting separated by several Ma. The first pulse is the response of contact metamorphism, and the second occurs at the base of the crust due to the relaxation and spreading of the thermal anomaly and to thermal insulation of the crust underneath sill. Partial melt remains in the system for a few tens of Ma. Moreover, lateral ductile flow is observed in all cases but with contrasting strain rates. Both melting and extensional processes could have implications for the eruption of late-Archean flood volcanics and the deposition of associated sedimentary rocks.