Numerical Modeling of Orogenic Styles since the Archean

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Although the signature of subduction is recognized with some confidence in the Phanerozoic continental geological record, evidence for subduction becomes less certain further back in time. To improve our understanding of plate tectonics on the Earth in the Precambrian we have used 2D petrological-thermomechanical numerical modeling to perform two series of experiments for oceanic plate subduction and continental collision, respectively, and we have systematically investigated the dependence of tectono-metamorphic and magmatic regimes on upper-mantle temperature, lithosphere thickness, degree of lithospheric weakening and other parameters. For oceanic plate subduction, we have identified a first-order transition from a "no-subduction" tectonic regime at high upper-mantle temperatures (horizontal movements of small deformable plate fragments) through a "pre-subduction" tectonic regime (shallow underthrusting of the oceanic plate under the continental plate) to the modern style of subduction. The link between geological observations and model results suggests that this transition might have occurred during the Mesoarchean–Neoarchean (3.2–2.5 Ga). The crucial parameter controlling subduction is the degree of lithospheric weakening induced by emplacement of sub-lithospheric melts into the lithosphere. For continental collision, we have identified a transition to a "hot collision" regime at about 100K above present-day upper-mantle temperatures. This regime is characterized by the appearance of melt-bearing hot mantle in the mantle wedge, which promotes development of a hot orogen. The formation of UHPM rocks is hampered by such hot conditions and only small complexes of UHPM rocks are emplaced inside complex structures of volcanic and metamorphic rocks. Where the amount of melt-bearing hot mantle exceeds a critical value (~150K above the present-day upper-mantle value) UHPM rocks are not exhumed to the surface and get stuck in the mantle. The transition from the "hot collision" regime to the modern style of collision may correspond to the appearance of UHPM rocks in the continental geological record since 620 Ma.

Keywords: Subduction; Collision; Precambrian; Numerical modeling.