

Modeling the origin of oceans and continental crust production in the Hadean and Archean eons

STEPHAN V. SOBOLEV^{1,2} AND CHARITRA JAIN¹

¹GFZ German Research Centre for Geosciences

²University of Potsdam

The oceans and continental crust are closely related to the onset and operation of plate tectonics, as well as the origin of life on Earth. Geochemical data indicate that the oceans and continental crust have existed on Earth since at least the middle Hadean eon, with around 50% or more of the current mass of the continental crust potentially formed (and partially recycled) during this period. However, the origin of surface oceans and their role in the formation of early continental crust remains a topic of debate. Recent studies also suggest that after the solidification of the magma ocean, the average concentration of water in Earth's mantle may have exceeded a thousand ppm, and the extraction of some of it led to the formation of surface oceans.

We present the results of modeling Earth's evolution during its first 2 billion years, focusing on the water cycle and continental crust formation. We use the geodynamic code StagYY in a 2D spherical annulus geometry, allowing for the generation of basaltic and felsic melts, accounting for core cooling, and incorporating enhanced water treatment. Based on experimental data and thermodynamic calculations, we also include the effects of water on the density and viscosity of crustal and mantle materials.

The masses of the generated surface ocean and continental crust depend on the initial water concentration in the mantle and the rheology of the lithosphere. Models that produce oceans with masses ranging from 1.5 to 2 times recent ocean masses and continental crust mass roughly equivalent to recent continental crust mass during the Hadean eon align well with new geochemical data on isotope and trace element compositions in melt inclusions from olivine crystals in Archean komatiites (Vezinet et al., in review). All models consistent with geochemical observations require substantial but highly variable subduction activity during the Hadean and Archean eons. Tectonic regimes with absent or low subduction activity, such as stagnant-lid, plutonic squishy-lid, or episodic-lid with rare resurfacings, are inconsistent with the geochemical data.