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Magma Oceans and the Early Evolution of Rocky Planets

Rocky planets were probably hot when they formed. Heat of accretion and radiogenic decay can significantly heat terrestrial bodies early in the solar system. At the end of planetary accretion, collisions of large planetary embryos produced giant impacts. The giant impact that gave birth to the Earth-Moon system probably involved an impactor the size of Mars. Such giant impact is able to entirely melt the proto-Earth and the early Moon. After impact, molten rocky mantles are called magma oceans.

During the magma ocean stage, metal-silicate equilibration sets the composition of the core. Primordial H_20 or CO_2atmospheres that degas from the magma ocean can either build-up or be desiccated. Fractional solidification of the mantle can generate mantle heterogeneities that shapes the long-term solid-state mantle dynamics. These mantle heterogeneities could also affect the composition of the lavas that erupt throughout the history of the planet. Magma oceans set the initial conditions for the long-term evolution of terrestrial planets. However, magma ocean dynamics remains poorly understood.

The first magma ocean models were proposed in the late 70s based on samples retrieved during the Apollo missions. Recently, magma oceans are receiving a growing attention due to major advances in high pressure mineral physics, ab-initio molecular dynamics, isotopes geochemistry and geophysical fluid dynamics. Applications of the magma ocean concept is not restricted to the Moon. Magma oceans are rather invoked as a general framework to describe the early dynamics of rocky planets.

I will first introduce the canonical magma ocean model. Understanding magma ocean physics requires an interdisciplinary approach that includes, among others, fluid dynamics, high pressure thermodynamics, and mineral physics. Indeed, the most challenging aspects of magma ocean emerge from strong coupling between fluid dynamics and chemistry. After presenting the methods I developed to tackle these challenges, I will present a more recent picture of magma ocean dynamics with several applications to planets in our solar system.