The 50th

GRC International Frontier Seminar

Title: The Legacy of Earth-Moon Formation for Earth's Internal Evolution and Present Day Structure

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Date: 05.15.2014 (Thur.) 17:00 – 18:30

Venue: Meeting Room #486, Science Research Bldg 1, Ehime Univ.

Recent developments in planetary formation and giant impact models are providing new insights into the dynamics of processes in the early solar system that affected Earth's initial composition and thermal state, and which in principle controlled the subsequent thermal and chemical evolution of our planet. Planetary formation theory favors accumulation of dust and debris to form planetesimals, which then continue to accrete further into an "oligarchic stage" in which larger differentiated bodies collide violently and coalesce to form planets. Recently improved giant impact models show that increasingly larger differentiated impactors will deposit and mix their kinetic energy deeper inside a proto-Earth, also accompanied by extensive mixing between (presumably molten) silicates and metals at deeper levels. Much of the mantle's residual composition appears to reflect partitioning between metals and silicates at pressures corresponding to ~1,000 km depth in the present Earth's mantle. However, there is also much evidence that Earth's Moon was formed in a great finale of accretion: a giant impact between a Mars-sized planet and the proto-Earth. Simulations suggest that giant impacts large enough to form a Moon yield extensive mixing at the proto-Earth's core-mantle boundary (CMB), in addition to direct injection of a substantial portion of the impactor core into the proto-Earth's core. Such models may help explain how Earth's liquid core became very well-mixed, and additionally imply the initial presence of stratified liquid layers at the base of the mantle and top of the core. These, in turn, offer potential solutions to some of the most vexing paradoxes in Earth's thermal, chemical, and magnetic evolution, as well as providing a simple explanation for both large- and small-scale structures presently inferred in the deep mantle and outermost core by seismological analysis. Such paradoxes include the large thermal conductivity of iron inferred by theory and experiments, which implies a large degree of secular core cooling to sustain convection and a geodynamo since at least 3.5 Ga. It also can explain how a dense melt could have formed at the base of the mantle, which then underwent gradual fractional crystallization to produce Fe-rich solid and mushy residues presently observed in the deep mantle as large low shear velocity provinces (LLSVP, beneath Africa and the Pacific) and ultralow-velocity zones (ULVZ), respectively. LLSVP and ULVZ are the deep mantle analogues of continental lithosphere and crust, and their characteristics are broadly compatible with fractionation of deep mantle melts formed after a moon-forming giant impact, and which is an unavoidable consequence of the high temperatures required in the early core to power a geodynamo by thermal convection.

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