Origin, Structure and Evolution of the Moon

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It is widely accepted that the Moon formed 4.5 Ga ago following a giant impact of a Mars size body on the Earth. This scenario allows for a hot formation of the Moon, early differentiation into a metallic core and a silicate mantle, and the formation of a magma ocean. Crystalization of the magma ocean resulted in the formation of the ancient highland crust which was later inundated in the mare impact basins by mare basalts. These basalts were derived from layers at various depths of the partly crystallized magma ocean. The depth of the mare basalt sources is reflected in the chemistry of these basalts. Thermal history calculations based on 3-D convection models suggest that partial melt survived at depths between 100 and 200 km for up to 2 Ga. These models also suggest some rejuvenation of the crystallizing magma ocean due to convective mixing between its lower layers and primitive deeper mantle material. The interior structure of the Moon is only loosely constrained by the available geophysical data. An iron-rich core of about 400 km radius is suggested by the moment of inertia factor of 0.393 but is not absolutely required. A core is consistent with the magnetization of the crust which suggests an early planetary magnetic field. Thermal history models suggest that the dynamo died after about 1 Ga of operation when the core had cooled to a stably stratified state. These models suggest that the core is presently still completely fluid. This perhaps surprising result stems from the Moon's cooling by thickening its lithosphere while the deep interior cooled comparatively little. Cooling by lithosphere thickening appears to be characteristic of one-plate planets lacking plate tectonics. A completely fluid core removes the diffculty of explaining the absence of a magnetic field when the core is freezing at the present time, as is the core of the Earth. Growth of an inner core can provide an effective energy source to drive a dynamo. The hypothesis that the core is fluid is supported by the libration data although these data do not require a completely fluid core. A fluid lunar core is also consistent with the magnetism of the other terrestrial planets. For Mercury, the freezing of the core can hardly be avoided because of the low concentration of sulphur in its core as suggested by cosmochemical evidence. On Earth, plate tectonics provides an effective means of cooling the deep interior. On Venus and Mars, the magnetic fields are probably missing because their imobile lithospheres prevents effective cooling of the deep interior while sufficient sulphur is available to lower the melting temperature of the core alloy and to prevent the formation of an inner core. On Ganymede we are probably seeing a planet that formed the core only late in its history and which currently experiences the phase of magnetic field generation that the Venus, Mars and Moon experienced early in their histories.