Is the composition of the moon consistent with the giant impact hypothesis?

S. R. Taylor

Department of Nuclear Physics, Australian National University, Canberra, Australia

Current versions of the giant impact hypothesis for the origin of the Moon call for the impact to occur when the Earth is about two thirds of its present size. The material in the Moon is derived mostly from the mantle of the impactor, although less than 10% of the impactor finishes up in the Moon. The metallic core of the impactor accretes to the Earth. Accretion of the last third of the Earth occurs subsequently to lunar formation. The Moon suffers nett erosion rather than accumulation during this stage.

This model is examined in the light of the lunar composition. The Moon has a density indicative of a low content of metallic iron, is bone-dry (the water ice detected by Clementine and Prospector is a trivial late addition from comets) and is depleted in the very volatile elements (e.g. Bi,Tl) relative to abundances in the solar nebula. The alkali elements are depleted relative both to the Earth and the solar nebula. The FeO content of 13% in the bulk Moon is intermediate between that of Mars with 18% and the terrestrial mantle with 8% FeO. There is no sign of a late veneer on the Moon that probably contributed the excess siderophile signature to the terrestrial mantle. Lunar trace siderophile elements are very low in abundance, consistent with the low metallic iron content. Relative to the Earth, there is a probable enrichment of refractory elements (eg. Ca, Al, Ti, *REE*, U, Th) in the Moon, based on heat flow data, seismic velocity profiles, their high near-surface concentrations and the presence of a thick aluminous crust. Those elements with condensation temperatures above 1100–1200 K (e.g. *REE*) are present in the Moon in their solar nebular ratios.

The volatile element depletion and enrichment of refractory elements is thus generally consistent with the giant impact hypothesis, although the material now in the Moon was not subjected to extreme temperatures. The lunar FeO content is too high to come from the terrestrial mantle. The lack of fractionation effects in the potassium isotopes rule out evaporative loss of potassium by Raleigh-type distillation processes during the giant collision. The formation of tektites during much smaller scale collisional events provides some analogues. Relative to their source material, tektites have lost H_2O, and elements more volatile than Cs (e.g. Pb, Tl, Bi), but display no fractionation of the potassium isotopes. The depletion of the bone-dry Moon in these elements thus may have occurred during the giant collision, but not by Raleigh fractionation as indicated by the absence of variations in isotope ratios. Possible compositions for the impactor include a body with an iron-rich mantle, intermediate between that of Earth and Mars, but with a low Rb/Sr ratio and a low volatile content. A possible analogue for the impactor is the Eucrite Parent Body (4 Vesta), because the depletions in the siderophile elements, alkali elements and more volatile elements in low-Ti lunar mare basalts are similar to their abundances in eucrites.