Making the Moon from the Earth – an internally consistent isotopic and chemical model

JON WADE AND BERNARD J. WOOD[1]

[1]Dept of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN
jon.wade@earth.ox.ac.uk, berniew@earth.ox.ac.uk

The fraction of the Moon made from Earth at the time of the moon-forming impact and the amount of impactor it contains are major questions concerning the origin of the Earth-Moon system. Earth's mantle and the Moon are distinctive in their FeO contents and some trace element ratios but identical in their isotopes of O, Si, W, Ti and Cr. The latter observations imply that Earth and Moon are made from exactly the same material but the former imply the opposite. We have made a large number of accretionary models of the Earth using experimental metal-silicate partition coefficients and combined these with impactors of different size and oxidation state. The most important constraints on accretion and impact turn out to be the similarity of Hf/W and $\varepsilon^{182}W$ in Earth and Moon. We find that the isotopic and chemical constraints are most readily met if the Moon was comprised of ~95% of a more oxidized Earth's mantle, this being the mantle at the time of impact. The impactor itself was reduced and ~15% Earth mass. After addition of ~15% M_E of impactor, the Earth underwent a small amount of post-impact core formation.

The overall process reproduces the current chemical and isotopic compositions of Earth and Moon. The partitioning of W between metal and silicate is highly dependent upon the mantle's FeO content, and this means that the more oxidized Moon cannot have received any significant metal from either impactor or proto-Earth because this would have resulted in a lower Hf/W than in Earth's mantle. The lower Nb/Ta ratio of the silicate Earth reflects a larger contribution from the impactor, as do the respective FeO contents. The lower Ni and Co contents of the lunar mantle are, however, consistent with a small amount of secondary S-rich core formation in the Moon.