A New View of the Moon

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'When the facts change, I change my mind" J. M. Keynes, economist

The origin of the Moon remains in a state of flux although some variant of the giant impact model seems likely to survive [1] to account for this stochastic event.

The only firmly established difference of the Moon from the Earth at present is the depletion of volatile elements shown both by the bulk low K/U ratio and analyses of mare basalts, although the latter come from cumulate zones. and may not be representative of the bulk mantle. The low value of LUNI (initial 87Sr/86Sr) also suggests that this depletion occurred much earlier than during the giant impact. This is supported by the absence of volatilization shown by the potassium isotopes (41K/39K ratio) that are similar throughout the inner solar system [2] but this study has never been repeated. The heavy isotopes of zinc are enriched by 1.5 per mil in the Moon attributed to vaporization during the giant impact (but strangely not for the Earth if both bodies were homogenized). Perhaps the lighter isotopes were lost on eruption of the mare basalts [3]. The more readily volatilized potassium isotopes do not show any effect.

The isotopic compositions of O, Si, Cr and Ti [4] are identical between the Earth and Moon. Oxygen is the largest ion (we are standing on a packing of O anions), so the silicate fractions of both the Earth and impactor were apparently homogenized? If so why are they now so different? One cannot lose volatiles from only one body if both were homogenized.

These data are sometimes interpreted as indicating that "the Moon was derived from the Earth" but the real question is different. Why are the Earth and Moon now so different in their content of volatile elements and when did this happen? A reasonable model is that the Earth acquired its budget of volatile elements and water following the giant impact, but while it was still molten. This late accretion, that missed the Moon, has led to a totally different geological evolution for the two bodies

Some previously long-held assumptions about lunar composition need revising. Whether the refractory elements are enriched in the Moon relative to the Earth remains uncertain. The Al abundance depends on the thickness of the anorthosite layer in the highland crust and on geophysical models whether the crust is layered and becomes more basic with depth. Surface seismic data in addition to the GRAIL results are needed to resolve this.

The abundance of FeO in the lunar mantle that is generally estimated at about 13% but this is also uncertain as it is derived following standard petrological conventions from the Mg/Mg + Fe ratios from lunar basalts. But these come from cumulate zones enriched in Fe and such values derived from cumulate zones seem unlikely to be representative of the bulk lunar mantle.

[1] Canup, R. (2012) Science, 338, 1052-1055 [2] Humayun, M. and Clayton, R. (1995) GCA, 59, 2131-2148. [3] Paniello, R. C. et al. (2012)Nature, 490, 376-379
[4] Armytage, R. M. G. et al. (2012) GCA, 77, 504-514 ; Zhang, J. et al. (2012)Nature Geoscience, 5 , 251-255; Weichert, U. et al (2001) 294, 345-348.