The evolution of the Earth-Moon system constrained from refractory and volatile trace elements

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The Earth and the Moon exhibit a unique inventory of refractory and volatile elements that permits valuable insight into early accretion, the giant impact event and late volatile addition. There is a remarkable similarity between the Earth and the Moon in the isotope composition of many refractory elemens such as Ti [1] and Cr [2]. After a decade of research, it has also been established that both bodies exhibit the same W isotope composition [3]. Following the revision of the terrestrial Hf/W ratio [4], it is now known that the silicate Earth and the silicate Moon also overlap in their Hf/W[4,5], thereby explaining their identical W isotope composition by an efficient re-equilibration of Hf-W during the giant impact event. Remarkable features of the silicate Earth and the Moon are their low Nb/Ta ratios (ca. 14 and 17, respectively [6]), limiting the amount of impactor material in the Moon to ca. 50%, in agrrement with the most recent physical modelling results. Alternative to earlier views, explaining the low Nb/Ta of the silicate Earth by initial accretion and core formation at more reducing conditions [e.g., 7], the low Nb/Ta may rather be a signature of incomplete metal-silicate equilibration during accretion [8]. A combination of recent experimental data for a number of volatile elements such as Pb [9,10] now provides clear evidence that the Earth's inventory of highly volatile elements such as Pb is to > 90% supplied during or after the final stages of core formation by a late veneer. This mass balance is markedly different for more moderately volatiles like Rb, where only ca. 10% could have been added to account for the unique Rb/Pb ratio of the silicate Earth [10]. The Moon may be an analogue to a volatile depleted early Earth.

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