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

Carsten Münker\textsuperscript{1}, Chris Ballhaus\textsuperscript{2}, Raul Fonseca\textsuperscript{2}, Toni Schulz\textsuperscript{3}
\textsuperscript{1}Institut für Geologie und Mineralogie, Universität zu Köln, Germany
\textsuperscript{2}Steinmann Institut, Universität Bonn, Germany
\textsuperscript{3}Department für Lithosphärenforschung, Universität Wien, Austria

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 elements such as Ti \textsuperscript{1} and Cr \textsuperscript{2}. After a decade of research, it has also been established that both bodies exhibit the same W isotope composition \textsuperscript{3}. Following the revision of the terrestrial Hf/W ratio \textsuperscript{4}, it is now known that the silicate Earth and the silicate Moon also overlap in their Hf/W\textsuperscript{[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 \textsuperscript{6}), limiting the amount of impactor material in the Moon to ca. 50\%, in agreement 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 \textsuperscript{e.g., 7}, the low Nb/Ta may rather be a signature of incomplete metal-silicate equilibration during accretion \textsuperscript{8}. A combination of recent experimental data for a number of volatile elements such as Pb \textsuperscript{[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 volatile elements like Rb, where only ca. 10\% could have been added to account for the unique Rb/Pb ratio of the silicate Earth \textsuperscript{[10]}. The Moon may be an analogue to a volatile depleted early Earth.

\textsuperscript{1} Zhang et al. 2012 Nature Geoscience 5 \textsuperscript{2} Lugmair & Shukolyukov 1998 GCA 62 \textsuperscript{3} Touboul et al. 2007 Nature 450 \textsuperscript{4} König et al. 2011 GCA 75 \textsuperscript{5} Münker 2010 GCA 74 \textsuperscript{6} Münker et al. 2003 Science 301 \textsuperscript{7} Corgne et al.2008 GCA 72 \textsuperscript{8} Münker et al. 2013 Min. Magazine 77(5) \textsuperscript{9} Wood & Halliday 2010 Nature 465 \textsuperscript{10} Ballhaus et al. 2013 EPSL 362.