C/H, C/N, and C/S ratios of the bulk silicate earth – magma ocean processing and the origin of Earth's major volatiles

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Earth's inventory of principle volatiles C, H, N, and S, is in part a legacy of the magma ocean stage of differentatiaon. Ratios of these volatiles are powerful tools for understanding these processes, as they monitor relative fractionations even when absolute concentrations are less-well defined. The C/H ratio of the bulk silicate Earth (BSE), defined from surface reservoirs and minimally degassed oceanic basalts is 1.3±0.3, which is 5-15 X lower than the C/H ratio of carbonaceous and enstatite chondrites and 2-5 X lower than ordinary chondrites. Explaining the strongly subchondritic C/H of the BSE by events post-dating the catastrophic era of terrestrial differentiation remains highly challenging, and therefore this ratio strongly argues that significant fractions of the BSE H inventory were delivered before or during the magma ocean stage of Earth history. The BSE C/N ratio is widely considered to be superchondritic, but previous estimates [1] [2] vary by nearly an order of magnitude. A reevaluation of oceanic basalt C and N derived from C/Nb and C/Ba ratios of oceanic basalts [3], combined with N derived from $N/^{40}Ar$ basalt ratios with the terrestrial K and Ar budgets, propagating all uncertainties, yields a revised C/N estimate of 42±12, which is ~2X greater than CI and CM chondrites, but plausibly similar to more degassed CO and CVs. This suggests an important role for parent body processing of C and N, but importantly, C is much more siderophile than N, and so core formation should greatly diminish C/N. The fact that the BSE is not strongly subchondritic seems to demand catastrophic selective loss of N from the BSE, presumably by atmospheric blow off of an N-rich, C-poor atmosphere. However, current constraints on C and N solubility and metal/silicate partitioning suggest that blow-off cannot create subchondritic C/N unless either core formation is a minor effect or the C/N ratio of precursor matierals was elevated compared to CI chondrites. The C/S ratio of the BSE is 0.5±0.1, which is similar to chondritic. Given that C is more siderophile than S, this likely argues for siginficant replenishment of C and S by a late veneer. Reconciling C/H, C/N, and C/S ratios of the BSE simultaneously presents a major challenge that almost certaintly involves a combination of parent body processing, core formation, catastrophic atmospheric loss, and partial replenishment by a late veneer.

[1] Halliday (2013) *GCA* **105**, 146-171. [2] Marty (2012) *EPSL* **313**: 56-66. [3] Rosenthal (2015) *EPSL* **412**:77-87.