VOLATILE DEPLETION AND CHONDRULE FORMATION

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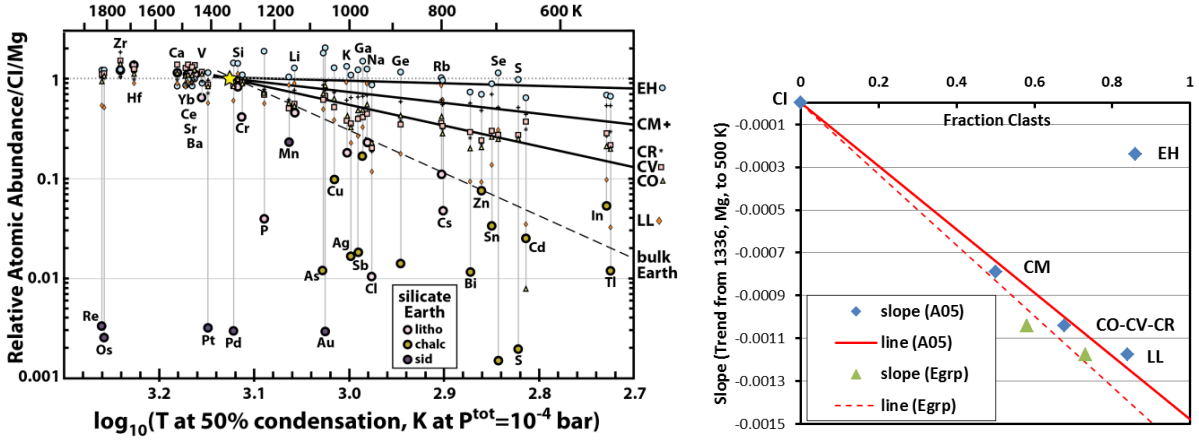
Introduction: The cause of the volatile depletion of the Earth and asteroidal materials has been a subject of intense research for many decades [1,2,3]. The possible connection of chondrule and refractory inclusion (clast) formation to volatile depletion in meteorite parent bodies remains enigmatic. Here, we review the correlation between clast abundance and volatile depletion in the CI, CM, CO, CV, CR and LL chondrites and speculate upon its meaning for early solar system processes.



Left: CI chondrite [4] and Mg-normalized element abundances in bulk silicate Earth [5] and meteorite groups [6,7], plotted against 50% condensation temperature [$T_{50\%}$, 8]. Elements are chosen for which abundance data in all the objects plotted was available. Trend lines are by visual inspection.

Right: Slopes of volatile trend lines between 1336 K ($T_{50\%}$ of Mg) and 500 K against fraction of clasts. Data "A05" is from [9, Table 1], while data "Egrp" is from [10,11,12]. The solid line shows regression of points "A05"; dashed line substitutes "Egrp" data for LL and mean CO-CV-CR in the regression. The EH chondrites are not regressed, because under their highly reduced formation conditions, the condensation temperatures of many elements are likely be very different from those calculated by [8, cf. 13].

Discussion: While [14] concluded that the abundances of volatile elements in meteorites were "largely controlled by the abundance of a volatile-rich precursor component", the combination of data presented above indicates that if chondrules and matrix formed from single reservoirs, then the amount of material made into chondrules was directly related to the degree of depletion in moderately volatile elements. This points the way toward dynamical models that strip volatile-bearing gas from regions where volatile elements have been lost from solids due to heating (e.g., chondrule formation). Such models require dynamic decoupling of gas and small solids, which is difficult [15].

References: [1] Wai C. M. and Wasson J. T. (1977) *Earth and Planetary Science Letters* 36:1-13. [2] Anders E. (1977) *Earth and Planetary Science Letters* 36:14-20. [3] Albarède F. (2009) *Nature* 461:1227-1233. [4] Lodders K. et al. (2009) In *Landolt-Börnstein, New Series*, Vol. VI/4B, pp. 560-630, Springer. [5] McDonough W. F. (2003) In *Treatise on Geochemistry*, v. 2, pp. 547-568, Elsevier. [6] Lodders K. and Fegley B. Jr. (1998) *The Planetary Scientist's Companion*, Oxford U. Press. [7] Wasson J. T. and Kallemeyn G. W. (1988) *Philosophical Transactions of the Royoal Society London* A325:535-544 [8] Lodders K. (2003) *Astrophysical Journal* 591: 1220-1247. [9] Alexander C. M. O'D. (2005) *Meteoritics and Planetary Science* 40:943–965. [10] Lobo A. et al (2014) *LPS XLV*, Abstract #1423. [11] Bayron J. et al. (2014) *LPS XLV*, Abstract #1225. [12] Ebel D. S. et al. (2016) *Geochimica et Cosmochimica Acta* 172: 322-356. [13] Ebel D. S. and Alexander C. M. O'D. (2011) *Planetary and Space Science* 59:1888-1894. [14] Jones R. H. (1994) *Geochimica et Cosmochimica Acta* 58:5325-5340. [15] Hubbard A. and Ebel D. S. (2015) *Icarus* 245:32-37.

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