HIGH C AND H CONTENTS OF CHONDRULES. Pascal Hanon, Marc Chaussidon CRPG-CNRS, BP20 54501 Vandœuvre-lès-Nancy Cedex, France. François Robert M.N.H.N-CNRS, 61 rue Buffon, 75015 Paris, France.

Carbon and hydrogen concentrations (reported hereafter as [C] in ppm C and [H] in ppm H_2O) of 33 chondrules of all petrological types and sizes, and belonging to some of the least altered and metamorphosed chondrites were determined with the CRPG Nancy ion-microprobe. Special care was taken in order to efficiently get rid of the terrestrial contamination. Before analysis, each sampling area (Ø≈25µm and ≈50µm for the smaller chondrules) was sputtered by the O^{2-} primary beam (20nA) for 5 minutes. Precise chemical concentrations for H and C were obtained for a -60V offset applied to the sample, along with an energy filtering of ± 10V. Mass resolution (M/ΔM) of 1800 is sufficient to discriminate the $^{24}Mg^{++}$ signal from the $^{12}C^{+}$. Mid-ocean ridge basalts were used for calibration of C and H. Major element concentrations in phases were obtained by electron probe analysis. Then, in each chondrule, phase proportions were visually estimated allowing the calculation of a bulk concentration for the major elements. [C] and [H] were obtained by two methods : 1) using internal chondrule correlations between individual ion-probe spots for carbon (or H) and major elements contents or 2) by averaging all ion-probe [C] and [H] determinations.

Fig. 1 shows the results in a log-log scale : [H] of bulk chondrules are plotted against [C]. [C] of chondrules range from ≈100 to ≈5000 ppm. Note that [C] in chondrules is generally lower than in their respective whole-rocks but always of the same order of magnitude (See [1] and [2] for [C] in whole-rocks). Systematically, type I (reduced) chondrules contain more carbon (up to 4000-9000 ppm) than type II (oxidized) chondrules (up to ≈2000 ppm). There is no systematic relationships between bulk [C] and bulk major element concentrations.

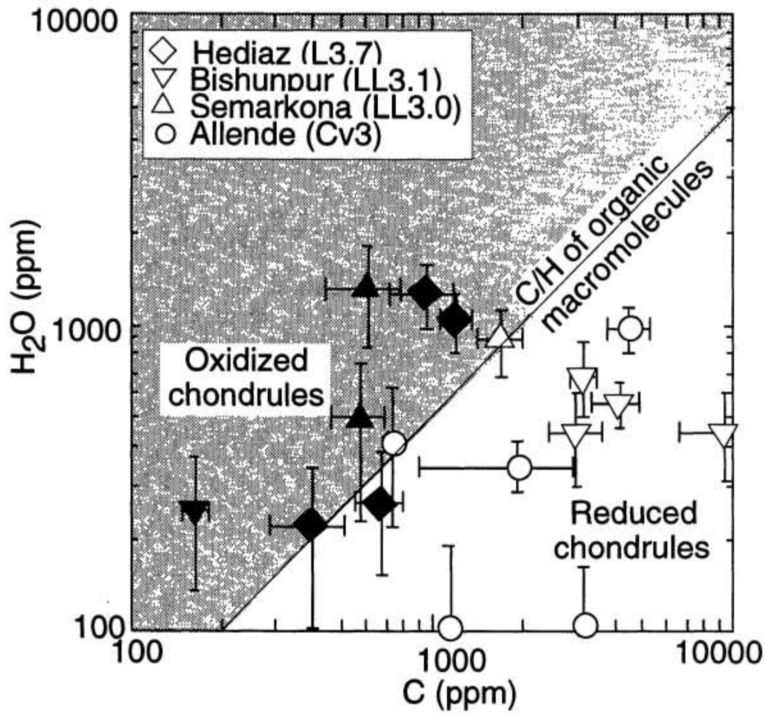
[H] range from ≈200 to ≈1000 ppm : exept for Clovis (not shown here), the [H] of the two chemical types of chondrules are indistinguishable. Almost all porphyritic olivine chondrules contain glassy regions with high and constant [H] while olivines have [H] < 200ppm (i.e. less than the background). Pyroxenes are concurently enriched in C and H (1000-2000 ppm C and H) regardless of type and texture.

It seems unlikely that matrix contamination occurred during the local and mild metamorphism of type 3 chondrites. For example, the smaller type I chondrules are systematically enriched in Na but not in H and the H-Na internal correlations shown by two chondrules from Hedjaz overlap those presented by chondrules from less metamorphosed chondrites like Semarkona. Our data are consistent with the presence of reduced C (and H?) grains among the nebular precursors of chondrules since : 1) [H] and [C] are well above their equilibrium solubilities between silicate melts and protosolar gaseous species at any pressure (even at 1 atm). 2) Organic grains found in carbonaceous chondrites have C/H ratios near 1.5 [3], a limit that distinguishes C/H ratios of type I chondrules from those of type II chondrules (See the solid line in fig. 1). 3) High [H] and [C] of pyroxenes seems difficult to explain unless C-H grains were trapped during their growth. 4) The extreme heterogeneity in [C] and in D/H inside mineralogical phases of chondrules, which is thus not due to partitioning during crystallization. Note also that typically extraterrestrial D/H ratios were found in chondrules from LL3 chondrites (see the companion abstract by Deloule & Robert), implying in turn that H does not result from silicate and glass alteration on Earth.

Broad calculations of volatilization (for CO_2 and H_2O during the melting of 1mm. chondrules) show that, for a given range of sizes and provided type I chondrules had similar thermal histories, chondrule precursors had higher amounts of C-H reduced grains than type II's. Moreover, in dynamic crystallization experiments 4 wt.% graphite is needed to completely reduce the San-Carlos olivines [4]. In other words, reduced carbon is likely to be responsible for the reduced state of type I chondrules.

Large scale chemical variations in solar nebula grains, pre-dating the formation of chondrules, is actually a plausible model to account not only for these volatile element concentrations but also for the chemical compositions of olivines. Such high concentrations in chondrules could strongly modify the H and C budgets of the primitive Earth.

Figure 1 :



Open symbols indicate reduced chondrules, while black symbols indicate oxidized chondrules

[1] GRADY, M.M., SWART, P.K. & PILLINGER, C.T. *Journal of Geophysical Research* **87**, A289-A296 (1982).
[2] KERRIDGE, J.F. *Geochimica et Cosmochimica Acta* **49**, 1707-1714 (1985).
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