NEBULAR OR PARENT BODY ALTERATION OF CHONDRITIC MATERIAL: NEITHER OR BOTH?

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Most chondrite classes contain indications of alteration since the formation of their solid components. In some cases it is clear that the alteration occurred after aggregation of the present meteorite materials, for example recrystallization of the metal grains so that they interdigitate silicates. However, in most cases it is unclear where the alteration occurred and often the discussion centers on whether the locale was the "parent body" or the "nebula". If it appears that the alteration involved one of the reactants being in the gas phase, then it is usually assumed that the locale was the nebula. We have been exploring the idea that chondrules and chondrites formed in the regoliths of asteroid-sized bodies made dynamic by the passage of gases from the interior [1]. Figure 1 describes our proposal as it might apply to LL chondrites, but a similar situation applies to the other chondrite classes, except perhaps the CI and CM chondrites where metal is absent and bulk Fe/Si values are solar. The interior is assumed to be CI- or CM-like in its high volatile contents (10–20 wt% water). Radioactive or impact heating causes the release of these volatiles and the larger components are temporarily suspended by the aerodynamic drag of the upward flowing gases. Smaller particles like metal can be carried through the pore space to the surface, thereby creating a zone of material below the surface (the "LL chondrite region" in the figure) in which there is an enrichment of chondrules and depletion of metal. The degree of separation of metal, and whether the metal particles rise to the surface or sink the bottom of the regolith, is determined by the relative force of gravity and aerodynamic drag. The scenario we propose seems to explain the size-sorting of components, and the Fe/Si values characteristic of the major chondrite classes (qualitatively in all cases, quantitatively in some). It also provides a reasonable environment for the formation of chondrules by impact [2]. Here we point out that a dynamic regolith also provides a "planetary" environment for producing a great many alterations requiring a gas phase. In this sense it has elements of both nebula and planetary properties. Some points for discussion:

- If chondrule rims ("accretionary rims") were produced by the recondensation of volatiles lost by chondrules [3,4], then the temporary atmosphere would be a reservoir to retain volatiles long enough for recondensation on chondrule surfaces without invoking unusually high gas and dust agglomerations in the nebula.

- Formation of chondrules by impact into such a loosely consolidated regolith would readily explain why chondrules are so highly oxidized, why many cooled in a atmosphere rich in Na and other volatiles, why cooling rates were so slow and why chondrule densities were so high [2].

- The gas causing the regolith to be dynamic will be largely H_2O (with minor CO_2), and thus a convenient oxygen-bearing reservoir for isotopic exchange [5].

- The dynamic regolith creates an environment in which a large number of liquid and gas phase reactions involving major, minor and trace minerals occurred [e. g., 6,7].

- Chronologies. The time interval between formation of first planetesimals and chondrules, which is very long by nebula standards (several million years, ref. 9), is explained as the interval between formation of parent body and time at which impacts have sufficient energy for chondrule formation [8].

If accretion was of long duration (several million years), then the regolith dust layer would also be an accretionary layer and classical nebular and parent body processes would be occurring simultaneously. However, whether the dynamic regolith idea has any merit or not, it does illustrate a need to consider environments other than the simple “nebula” and “parent body” scenarios commonly discussed.

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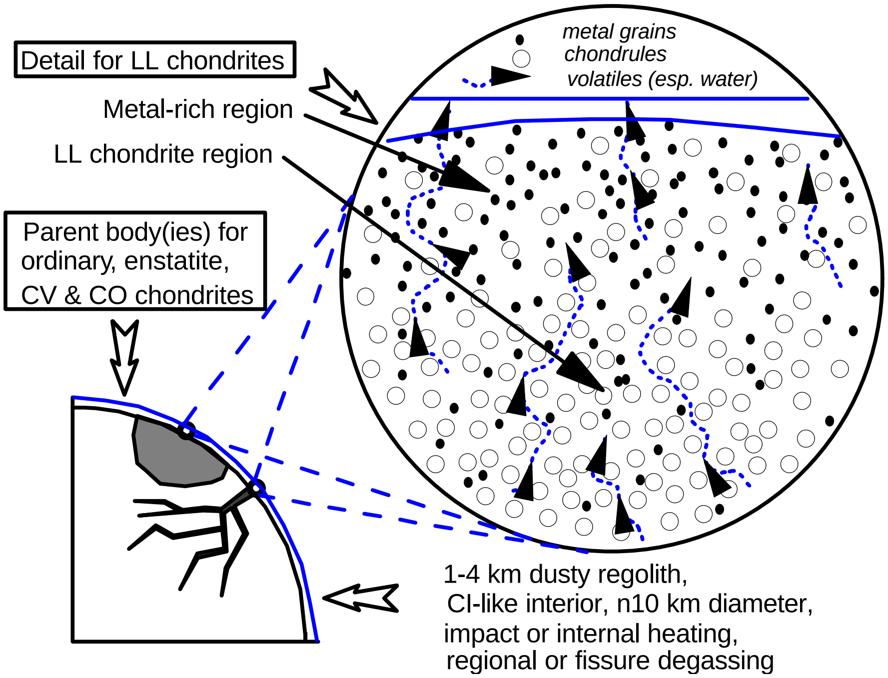

Fig. 1.