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ORIGIN OF CHONDRULES, G.Kurat (1) and H.Palme (2), (1) Naturhistorisches Museum, Postfach 417, A-1014 Vienna, Austria; (2) Max-Planck-Institut für Chemie, Saarstraße 23, D-65 Mainz, FRG.

Ever since chondrules have been recognized almost 200 years ago there was the wish to decipher their message and arrive at a consistent model for their origin. In mastering the making of chondrules we should be able to solve the problem of the genesis of chondrites. Since the latter are the by far most abundant meteorites they carry informations on the most common processes having been active in the early solar system.

Chondrules are peculiar objects. They must have been once (partly) molten, freely floating droplets which crystallized before accretion into a rock. They are old (1,2) and hence primitive but their mineralogical and chemical compositions are highly fractionated (3,4). These fractionations are incompatible with magmatic processes. They are chaotic and best explained by statistical processes ("sampling fractionation", e.g. (5,6)). Oxygen isotope data (7) support that view and in addition clearly show that oxygen must have been sampled from different reservoires in different proportions by each individual chondrule. Thus most properties of chondrules reflect chaotic conditions (as do the chondrites) which in the light of modern data can best be provided by the solar nebula (8). Although the memory of each chondrule extends beyond the final heating event which created the liquid droplets, most of the detailled information has been destroyed in that event. Relics are common (9, 10) but appear to be pre-processed or altered by the droplet-forming process. Our view therefore is fogged and does not allow a detailed reconstruction of the sequence of events.

The recent discovery of an unique chondritic rock in Allende, All-AF (11,12), allows us to look back into the history of chondrules (and related aggregates). The most common components of this rock are silicate-rich aggregates. They are aggregates of fluffy stacks of partly intergrown platelets (10 um wide) of olivine and highly variable amounts of round to lobate shaped silicate-sulfide-metal aggregates (Fig.1). The olivine stacks range in size from about 20-500 um, are very rich in pore space, part of which is filled by nepheline, and are intergrown with each other and the silicate-sulphide-metal aggregates. Typically the centers of the silicate-rich aggregates are poor in silicate-sulfide-metal aggregates, very similar to aggregates and chondrules in Allende (Fig.2) and other chondrites. However, the olivine in All-AF aggregates not only is highly porous and of peculiar shapes but has unique properties: it has a brown color, has a low birefringence and sectoral extinctions and is very rich in minor elements. Contents of Al_2O_3 reach up to 3 wt.-% as do the Cr_2O_3 contents. The properties of olivines in All-AF are incompatible with a magmatic genesis but are what could be expected for olivines grown from vapor. The silicate-sulfide-metal aggregates in addition give evidence for vapor deposition of metal into the pore space of fluffy olivines and at their surfaces. Apparently, All-AF is a chondritic rock that consists of objects which escaped the heating event experienced by aggregates and chondrules of CCs and OCs. It can easily be visualized that a sintering event could convert a typical silicate-rich aggregate of All-AF (Fig.1) into a typical aggregate of Allende (Fig.2). That process will lead to recrystallization of the fluffy olivines into well-crystallized grains, they will intergrow with each other, nepheline will form small amounts of glassy matrix, the pore space will be lost, and the silicate-metal aggregates will coagulate and metal will separate and form droplets.

We believe that All-AF shows us a possible way for chondrules to be formed locally in the solar nebula. Beside morphological similarities between All-AF aggregates and aggregates and chondrules of CCs and OCs all geochemical pecularities of chondrules appear to be straightforward consequences of the model outlined above: the lithophile-siderophile element fractionation, the sampling fractionations, the absence of fractionations among refractory elements, the old age and other features. However, some chondrule data (13) indicate additional processing of early condensates or vastly different environments during condensation (e.g.high S fugacity).

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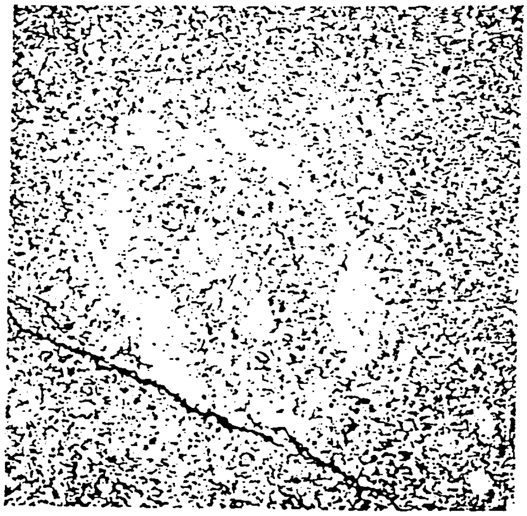

Fig.1: Aggregate in All-AF (1.1 mm)

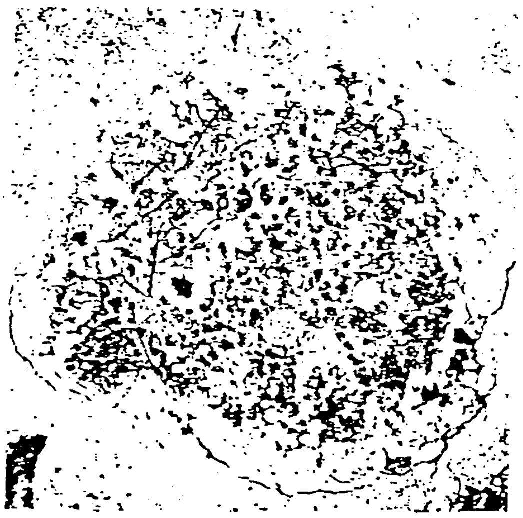

Fig.2: Aggregate in Allende (1.7 mm)