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THE OC PUZZLE: PRE- AND SYNACCRETIONARY PROCESSES OFFER A SOLUTION; G.Kurat, Naturhistorisches Museum, A-1014 Vienna, Austria.

The concept of "metamorphism" of ordinary chondrites (OC's) has been revived mainly to account for the high oxidation state of the OC's which is impossible to achieve in an unfractionated solar nebula gas (1,2). This concept apparently also easily accounted for the second major problem of OC's the generally homogenized chemical compositions of the major silicate phases ol and opx (3). Subsequently a scheme was constructed (4) which roughly linked the degree of chemical homogeneity of the major silicates to sort of a "degree of recrystallization", e.g. "metamorphism". Although this scheme quickly became very popular (and therefore strongly influenced directions of research) it was questioned by a few students of meteorites (5-9 as earliest examples). Meanwhile a tremendeous amount of data has been acumulated which is incompatible with the concept of metamorphism. The most important facts are:

The dilemma:A) Chondrule chemical and mineralogical compositions are highly diverse in unequilibrated ordinary chondrites (UOC's) which preclude equilibration without recrystallization as is often observed (e.g.Bjurböle) (7,9). B) Many (probably all) "equilibrated" OC's (EOC's) contain non-equilibrated phases irrespectively of their degree of "metamorphism" (8,10-19). The same holds for E chondrites (20-21). On the other hand, most, if not all, UOC's contain equilibrated objects (e.g. 7,22). C) FeNi metal despite of its higher diffusivity as compared to silicates is commonly not equilibrated in EOC's (23-25) and the metallographic cooling rates are unrelated to the "degree of metamorphism" (26). D) The presence of abundant sulfides (mainly FeS) in OC's has never been a major point for discussion although FeS is a stable phase in the solar nebula only at very low T (< 700 K;2) The "equilibration" T recorded by the silicates, however is > 1000 K (27) and for UOC's even higher (e.g. 22) and the porosities and permeabilities of OC's are generally high, providing an open system during heating (28). E) Major and minor phases in OC's are not equilibrated with respect to minor elements (29). F) Condrules and other objects frequently have non-equili- brated oxygen and nitrogen isotopic compositions, regardless of the "degree of metamorphism" of the host (30, 31). G) Radiogenetic gases are not depleted in chondrules despite "metamorphism" and slow metallic cooling rates (32,33).H) Volatile trace element abundances, indicators of "accretion T's", are similar in EOC's of different "metamorphic" degree (34) with some highly recrystallized ones even being enriched in these elements ("mysterite", 35,"Holy Smoke", 36). The retention of substantial amounts of Hg in OC's is totally incompatible with metamorphism (37).This is an incomplete list of observations which are simply incompatible with a "metamorphic" history of OC's. A similar list can easily be compiled also for the EC's and other chondrite-related meteorites.

The way out, a proposal: I offer the following tentative model which I believe can solve the OC puzzles and probably also some more. The key mechanism of this model is pre-accretionary metasomatism, an exchange of chemical species between condensed grains and agglomerations thereof and the ambient vapor. Metasomatic exchange reactions are omnipresent in meteorites but they can easily be identified only where the reactions remained incomplete. This is the case in carbonaceous chondrites (CC's) where metasomatic "alterations" are easily identified but observations on OC's are also steadily accumulating. Exchange of the most common elements between solids (or liquids) and the ambient vapor has been observed sofar: Fe^{2+}-Mg^{2+} (and related Mn^{2+}, Ca^{2+}, Al^{3+}, Cr^{3+}) (38-41), alkalis (40), H2O (formation of phyllosilicates 42,43), oxygen (38,43,44), and sulfur (38). In most of these cases it has been shown that the exchange reactions ("alterations") are pre-accretionary. Clearly, metasomatic reactions are common and fundamental pre-accretionary phenomena in the solar nebula. Accepting vapor-solid (liquid) exchange reactions as the second major process in the solar nebula beside evaporation-condensation, a simple model for the origin of chondrites can be constructed: condensed grains agglomerate to mm-sized fluffy aggregates, are compactes by continuing condensation (reduction of pore space, 45,46), experience a heating event under high partial pressure of volatiles (formation of chondrules and recrystallized aggregates, 41,47), continuosly exchanged chemical species with the cooling vapor (Fe-Mg "equilibration", sulfurization etc.) and start to accre-

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te to larger chunks with vapor-solid reactions and condensation continuing. The result will be blocks of chondritic matte with properties of a typical EOC. This rudimentary and incomplete, maybe poetic, model nevertheless can "explain" OC's (and some more) easily (refer to "Dilemma" above): (A) Metasomatic exchange and emplacement of the most mobile elements (low charge) will make use of the existing crystals, will change their chemical compositions, but not their shapes. (B) Non-equilibrated objects in OC's could have simply escaped pre-accretionary "equilibration". Accreting mostly "equilibrated" ones will result in EOC's, the other way around UOC's. (C) Effective shielding (by dense, non-porous silicates) from the ambient vapor will result in a preservation of the original metal composition. Since all objects are on their own fate, cooling rates should be different and independent of the degree of crystallinity. (D) The px "equilibration T" records the cessation of Fe-Mg-Ca diffusion in px. Sulfurization of metal can take place later but still before accretion. (E) Minor element contents of major phases are high because these phases provided the only sinks during condensation. Reequilibration with the vapor and redistribution into other phases (phosphates) was hampered by the immobility of these elements (high charge, e.g. REE). (F) Crystal structures of the major silicates are principally made of densely packed oxygen which therefore is fairly immobile. Exchange reactions with the ambient vapor are probably only possible at high T (during melting event) (G) The high radiogenic gas contents document early formation and early "equilibration". (H) The content of volatile elements of a particular chondrite will depend on the size, porosity, and permeability of the accretionary chunks in contact with vapor. Communicating voids will provide the ideal cold traps for the volatile elements, regardless of the degree of crystallinity of the rock. It is no surprise to find volatiles in all OC's (and others). Hugh.

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