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THE IMPORTANCE OF CAPTURING UNMODIFIED CHONDRITIC POROUS MICROMETEORITES ON THE SPACE STATION.

Frans J. M. Rietmeijer, Lockheed/EMSCO, Mail Code C23, NASA Johnson Space Center, Houston, TX 77058.

The survival of interplanetary dust particles (IDP's) during deceleration by the Earth's atmosphere is determined by their entry parameters, velocity, size and mass [1]. These IDP's reach their terminal velocity at about 55-95 km altitude before they gradually settle to 18-21 km altitude where they are collected by high flying aircraft [2]. Chondritic porous IDP's (also called Chondritic Porous (CP) aggregates) show properties consistent with an extra-terrestrial origin [3, 4] [TABLE 1]. It is conceivable that CP aggregates may be collected above the Earth's atmosphere using capture devices on a Space Station or satellite. In order to preserve 'pristine' CP aggregates, i.e. aggregates with minimal perturbation or degradation of its particulate matter, it is necessary to transfer the kinetic energy on impact so that a minimum amount of energy is dissipated into the impacting particle [this report]. It is likely that low-temperature minerals (e.g. layer silicates), volatile phases (e.g. sulfides), structural defects (e.g. nuclear tracks) and hydrocarbons in CP aggregates are sensitive to the efficiency of kinetic energy dissipation. Before we can evaluate information contained in particulate matter on capture devices, we need a complete understanding of the mineralogy of CP aggregates.

Chondritic porous aggregates may be cometary debris representing unaltered remnants from the early history of the solar system [1, 5, 6]. In addition, some CP aggregates may derive from the asteroid belt since dust from this belt may be in Earth-crossing orbits [7]. The physical, chemical and mineralogical properties of CP aggregates and carbonaceous chondrites suggest the existence of a continuum between these two types of primitive extraterrestrial materials [4, 8]. In this scenario CP aggregates are pristine solar system materials that have not been subjected to metamorphosis in a parent body as opposed to the primitive meteorites.

Chondritic porous aggregates have a varied and complex mineralogy of Mg-rich olivine, Ca-poor and Ca-rich pyroxenes, layer silicates, sulfides (low-Ni pentlandite and pyrrhotite), metallic FeNi, metal-oxides (magnetite, Ti- and Al-oxides), FeNi-carbides and minor amounts of phosphides and sulfates [4, 9-15]. These minerals are embedded in carbonaceous material including hydrocarbons and poorly graphitised carbon [16, 17]. The mineralogy of CP aggregates typically forms a heterogeneous mixture of high- and low-temperature minerals; some are predicted by solar nebula condensation models, but others may have formed at low temperatures prior to or after accretion of the dust into a (proto-) planetary body [12, 18, 19].

It is possible that the original heterogeneous mixture of minerals in CP aggregates could form because of turbulent conditions in a cooling solar nebula [20]. Indeed the proximity of reduced and oxydised phases (low-Ni Fe-metal, magnetite and low-Ni Fe-sulfides) suggests chemical disequilibrium. Alternatively, the proximity of these phases may indicate unique equilibrium conditions in a cooling solar nebula [13]. Physical properties of individual minerals in CP aggregates may be related to specific processes. For example, enstatite whiskers and platelets and platey magnetite grains suggest that these minerals formed by condensation from the solar nebula gas [21, 22].

Filamentary carbon indicates that heterogeneous catalysis occurred after accretion [23]. Solar flare tracks in olivine [24] show that CP aggregates resided in small bodies during solar system sojourn.

The size and shape of grains in CP aggregates also contain information of processes that occurred in early history of the solar system. Grain sizes in CP aggregates range between 1nm to <~10um [5] but larger grains may be present in some CP aggregates [1, 13]. Most solar nebula condensation models assume that crystalline solids form directly from the vapor phase. However, it is possible that these condensates are really amorphous solids. The issue has considerable impact on processes that take place in the final stages of solar nebula condensation, e.g. formation of hydrated silicates [25]. The mineralogy of carbonaceous chondrites is inconclusive on this point but CP aggregates may still contain information about the nature of solar nebula condensates. Thus, Mg-rich glass [26] and a chemically complex, proto-crystalline phase [13] in two CP aggregates suggest that amorphous condensates were indeed present in the early solar system.

The grains in the proto-crystalline phase display a range of size and shape: grains <~30nm in size tend to be (sub-) rounded while larger grains tend to form sub- to euhedral, thin (<1.5nm), often slightly elongated, hexagonal and octagonal plates [13]. These observations are comparable with changes of grain size and shape observed during experimental annealing of amorphous to proto-crystalline Mg-SiO smokes [27]. Thus, structural evidence in CP aggregates shows that annealing of amorphous solar nebula condensates may have been a necessary part of early solar system evolution [13].

I have only considered the mineralogy and certain physical properties of minerals in CP aggregates which contain information about conditions in the solar nebula and early solar system. This information is obliterated in primitive meteorites due to metamorphic processes after accretion of the dust into planetary bodies. In addition, during deceleration of CP aggregates in the Earth's atmosphere these particles reach flash-heating temperatures of ca 300-400°C [12, 15]. Although this thermal event apparently does not destroy CP aggregates, it affects some of the aggergate mineralogy [15]. This selection effect will be eliminated by capturing CP micrometeorites above the atmosphere and reduces the collection of unmodified ('pristine') particles to a technical challenge. We need 'pristine' micrometeorite samples in order learn about solar nebula condensates, low-temperature reactions towards the end of the condensation history (e.g. formation of layer silicates and hydrocarbons [16]) and in the very early stages of protoplanet formation. Thus, a high degree of 'pristinity' for particles collected on impact devices is desirable.
Presently. a technique for capturing intact, 'pristine', particles is not available but it is encouraging that unshocked and unfractionated Mg-rich olivine single crystals have been retrieved from the Solar Max satellite [28].

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TABLE 1: EVIDENCE FOR AN EXTRATERRESTRIAL ORIGIN OF CP AGGREGATES

BULK COMPOSITIONS OF CP AGGREGATES RESEMBLE "SOLAR" ABUNDANCES FOR CONDENSIBLE ELEMENTS [1].

IR FEATURES OF SOME CP AGGREGATES RESEMBLE IR SPECTRAL SIGNATURE OF INTERPLANETARY DUST.

^{4}HE CONTENTS OF SOME CP AGGREGATES INDICATE "SATURATION" BY SOLAR WIND [29].

XE CONTENTS OF SOME CP AGGREGATES RESEMBLE THOSE OF CARBONACEOUS CHONDRITE ACID RESIDUES [30].

D/H RATIOS OF CP AGGREGATES RESEMBLE THOSE OF CARBONACEOUS AND UNEQUILIBRATED CHONDRITES; HIGHE RATIOS IN SOME CP AGGREGATES SUGGEST THEY MAY BE EVEN MORE PRIMITIVE THAN THESE METEORITES [31, 32]

NUCLEAR TRACKS IN CP AGGREGATES ARE EVIDENCE FOR EXPOSURE IN SPACE [26].