A HYDRATED INTERPLANETARY DUST PARTICLE: CHARACTERIZATION BY TRANSMISSION
ELECTRON MICROSCOPY
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INTRODUCTION: There is an unusual set of interplanetary dust particles
(IDPs) that resembles the CI and CM carbonaceous chondrite matrices.
Brownlee (1) reported that these IDPs contain hydrated silicates as the
major phase and are mineralogically different from typical 'chondritic'
IDPs. Fraundorf et al. (2), using infrared spectroscopy, showed that the
spectrum of one such hydrated IDP closely matches that of the Murchison
CM meteorite. Unfortunately, the mineral components of the hydrated IDPs
are poorly known and evidence to date as to their relationship to the
carbonaceous chondrites is inconclusive. Therefore, detailed mineral-
ogical characterization of a hydrated IDP might provide important insights
into the origin of IDPs and also of the carbonaceous chondrites.

We present here results of our transmission electron microscope
(TEM) observations of a hydrated IDP. We used a TEM both for high-
resolution imaging and for chemical analysis by X-ray energy dispersive
spectroscopy (EDS). Structure data are based on selected area electron
diffraction (SAED), convergent beam electron diffraction, and high-
resolution imaging. Qualitative chemical analyses were obtained from EDS
spectra; for a phyllosilicate and sulfides, we derived quantitative data
using thin-film corrections (3).

OBSERVATIONS: The TEM grid containing the IDP sample (NASA no. U2-21-2-1)
has nine major clumpy aggregates ranging in diameter from 2 to 6 μm. The
IDP has a relatively compact appearance, and it is apparently distinct from
the typical, chondritic IDPs. Its bulk composition is close to the
chondritic IDPs except that Ca is significantly depleted in the hydrated
IDP. All the aggregates of the hydrated IDP consist mainly of two phases:
(I) a fluffy silicate that contains Fe, Mg and Al, which we will call
'FMA-silicate', and (II) Fe-Ni sulfides.

(I) Phyllosilicate: Most of the FMA-silicate shows no significant
diffraction peaks. However, in places it displays a complex fibrous
texture typical of a layered material. High-resolution transmission
electron microscopy (HRTEM) showed that the fibrous FMA-silicate has an
interlayer spacing between 10 and 12 Å. All the FMA-silicates from
different aggregates show relatively similar compositions; averaged
cation to silicon ratios are 0.29 (Fe/Si), 0.46 (Mg/Si), and 0.07(Al/Si).
Based on the fringe spacing and the composition, the FMA-silicate is
probably a Mg- and Fe-rich member of the smectite or mica groups.

(II) Fe-Ni sulfides: Fe-Ni sulfide grains, ranging in diameter from 500 to
3000 Å, are abundant throughout the IDP aggregates. They are round to
irregular in shape, and some have euhedral morphologies. SAED patterns
and EDS analyses show that they are pyrrhotite and pentlandite. The IDP
pyrrhotite commonly contains a small amount of Ni (up to 3.5 atomic
percent) and has a hexagonal superstructure with a unit cell, a=2Å and
c=NC, where A and C are dimensions of the pyrrhotite subcell (A=3.45 Å
and C=5.75 Å), and N is a multiplicity of the superstructure. These
sulfide grains occur individually or as clustered aggregates.

Rectangular platelets, typically 100 to 300 Å thick and 500 to 3000 Å
long, are widespread and characteristic of this IDP. These platy crystals
contain only small amounts of Ni (<3 atomic percent). They display
diffraction patterns similar to pentlandite, and EDS analyses indicate that
the (Fe, Ni)/S ratios are close to pentlandite.

(III) Minor phases: Partly euhedral crystals (0.5 to 1.1 µm across) of forsteritic olivine occur. They are unusually large for olivines in IDPs. There are also smaller (~1000 Å) Mg-rich olivine crystals in association with the Fe-Ni sulfides. We did not observe any structural relationship between the olivines and the surrounding FMA-silicate, which suggests that there has not been alteration from one to the other. Pyroxene was not observed in this IDP.

Three rounded aggregates (0.6 to 1.0 µm across) of crystals containing Fe, Mg, Si, Ca and Mn were found. The mineral is unidentified, but such a phase has not been reported from other IDPs. An anhedral single crystal of magnetite (~0.6 µm across) and a few chromite grains (~1000 Å across) were identified.

DISCUSSION AND CONCLUSIONS: The phyllosilicate in the present IDP is distinct from the major phyllosilicates in the CI and CM carbonaceous chondrites. The CI and CM phyllosilicates have a ~7 Å interlayer spacing that corresponds to septime or serpentine (4-6).

Pyrrhotite and pentlandite also occur in close association in CM meteorites (5-7), but such submicron sulfides are less abundant in the meteorites than in this IDP. The majority of S in the CM matrices has recently been shown to occur in an unusual Fe-Ni-S-O mineral (8-10), and this mineral was not observed in the present IDP. The presence of low-Ni pentlandite is particularly interesting. Natural pentlandite shows a relatively restricted compositional range (11), and such low-Ni pentlandite is not known from terrestrial samples, although Ni-free pentlandite has been synthesized by vapor deposition at low pressure and 150°C (12).

This IDP differs from the hydrated IDPs that were reported by Brownlee (1) and Brownlee et al. (13). The particles described by them show strong X-ray diffraction peaks characteristic of the septime or serpentine minerals and contain clustered submicron magnetite grains resembling the 'framboidal magnetite' in the CI meteorites.

Overall, the mineralogy of the present hydrated IDP is unique among the IDPs and differs considerably from the mineralogy of the CI and CM carbonaceous chondrite matrices, which suggests this IDP cannot be directly related to these meteorites.

ACKNOWLEDGEMENT: We thank Drs. P. Fraundorf and R.M. Walker for providing the IDP sample and for their encouragement and discussions. This work was supported by NASA grant NAGW-143.