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CARBON ABUNDANCES, MAJOR ELEMENT CHEMISTRY, AND MINERALOGY OF HYDRATED INTERPLANETARY DUST PARTICLES. L. P. Keller, K. L. Thomas, and D. S. McKay, SN4 and SN, NASA Johnson Space Center, Houston, TX 77058 and C23, Lockheed, 2400 NASA Rd. 1, Houston, TX 77058.

Introduction. Hydrated interplanetary dust particles (IDPs) comprise a major fraction of the interplanetary dust particles collected in the stratosphere. While much is known about the mineralogy and chemistry of hydrated IDPs, little is known about the C abundance in this class of IDPs, the nature of the C-bearing phases, and how the C abundance is related to other physical properties of hydrated IDPs. Here we report bulk compositional data (including C and O) for 11 hydrated IDPs that were subsequently examined in the TEM to determine their mineralogy and mineral chemistry. Our analysis indicates that these hydrated IDPs are strongly enriched in C relative to the most C-rich meteorites. The average abundance of C in these hydrated IDPs is 4X CI chondrite values.

We determined the bulk compositions (including C and O) of 11 hydrated IDPs by thin-window, energy-dispersive x-ray (EDX) spectroscopy of the uncoated IDPs on Be substrates in the SEM (procedures described in detail in [1]). As a check on our C measurements, one of the IDPs (L2006H5) was embedded in glassy S, and microtome thin sections were prepared and placed onto Be substrates (see [2], this volume). Thin-film EDX analyses of multiple thin sections of L2006H5 show good agreement with the bulk value determined in the SEM [2]. Following EDX analysis, the mineralogy and mineral chemistry of each IDP was determined by analyzing ultramircotome thin sections in a TEM equipped with an EDX spectrometer.

Mineralogy. Table 1 summarizes the major mineralogy and mineral chemistry of the 11 hydrated IDPs analyzed in this study. All of our hydrated IDPS are low porosity objects that are dominated by abundant phyllosilicates (from ~30 to 80% by volume) and fine-grained Fe-Ni sulfides. The phyllosilicates are usually Fe-bearing saponites with Mg/Mg+Fe > 0.5, but in two of the IDPs, serpentine is the phyllosilicate phase. Generally, there is detectable Al in the saponites as well, so that the saponites contain a small component of dioctahedral smectite (montmorillonite). Fine-grained sulfides are ubiquitous in hydrated IDPs. Electron diffraction patterns show that the sulfides are mainly pyrrhottite or pentlandite. Pentlandites show a range of Ni contents extending up to 30 wt.% Ni. Typically, sulfide grains in hydrated IDPs show a range of Fe/Ni.

Minor phases in our hydrated IDPs include anhydrous silicates (olivine, enstatite, high-Ca cpx), Mg-Fe carbonates, kamacite, chromite, and magnetite. The anhydrous silicates such as pyroxenes and olivines are generally a minor component or are entirely absent in our set of hydrated particles. Olivine and pyroxene compositions vary over a wide range of Mg/Mg+Fe but most are concentrated near very magnesian compositions. Distinct Mg-Fe carbonates occur in only 3 of the 11 analyzed IDPs. Their compositions span a wide range of Mg/Mg+Fe values from 0.3 to 1. Ca and Mn are detectable in the carbonates, but are uniformly low in abundance (typically <0.5 wt.%). In the heated IDPs, magnetite commonly occurs as discontinuous or complete polycrystalline rims up to 200 nm thick surrounding the particles.

Bulk Compositions. Element abundances for major elements (including C and O) in the 11 hydrated IDPs are given in Table 2. Several other elements not listed in Tab. 2 (e.g. P, K, Ti, Cr, and Mn) were analyzed for and detected in most of the particles, but at concentrations below 0.5 wt.%. As a group, our IDPs are well within a factor of 2 of CI abundances for all elements with the exception of C which is systematically enriched by 2 to 6X CI levels. L2005P13 is the only particle in this study which does not show the strong depletion in Ca that has been used as a diagnostic feature of hydrated IDPs [3].

Heating effects during atmospheric entry. The 11 IDPs show a range of mineralogical and chemical changes in response to atmospheric entry heating, ranging from prominent magnetite rims, degraded crystallinity of phyllosilicates, and Zn depletions [4] in strongly heated IDPs; to pristine particles that lack mineralogical evidence for any significant heating during atmospheric entry and show chondritic Zn levels. Moderately heated IDPs exhibit thin, discontinuous magnetite rims yet retain well-crystalline phyllosilicates. In Table 1, the IDPs are classified as unheated, mildly heated with discontinuous magnetite rims, or strongly heated with continuous magnetite rims. The strong heating experienced by some of the hydrated IDPs may result from relatively high entry velocities [5].

The lack of a correlation between C and S abundance and the degree of entry heating suggests that there was no appreciable loss of these elements during the transit of the IDPs through the atmosphere.

The nature of carbon in hydrated IDPs. Our measured bulk carbon abundances for the group of 11 IDPs ranges from 6 to 22 wt.% (Table 1), with an average of ~13 wt.% C (nearly 4X CI levels). With the exception of the few cases where distinct carbonate grains are observed, other discrete carbon-rich phases have not been identified. Fine-grained carbonates could account for some but not all of the measured C abundances. Thus, we believe that C-rich materials such as poorly-graphitized or amorphous C must be finely dispersed throughout the hydrated IDPs.

Hydrated IDPs are generally believed to be derived from asteroidal sources that have undegone some degree of aqueous alteration. However, the high C contents of hydrated IDPs determined in this study indicate that they are probably not derived from asteroidal sources sampled by the known chondritic meteorites.

References. [1] Thomas, K. L. *et al.* (1993) *GCA*, in press. [2] Bradley, J. P. *et al.* (1993) *LPSC XXIV*, this volume. [3] Schramm L. S. *et al.* (1990) *Meteoritics* 24, 99. [4] Flynn, G. J. *et al.* (1992) *LPSC XXIII*, 375. [5] Flynn, G. J. (1990) *Proc. 20th LPSC*, 363. [6] Anders, E. and Grevesse, N. (1989) *GCA* 53, 197.

Table 1. Mineralogical data for 11 hydrated IDPs.

IDP	phyllo type1	Mg# of phyllos	Ni in sulfide	heated ?	Mt rim2	Other phases
L2005L6	sap	0.5	22-28	Y	D	chromite, no anhydrous silicates
L2005P9	serp	-	2-28	Y	W	low-Ca pyx, extremely heated
L2005P13	serp	-	4-6	Y	W	olivine, low-Ca & high-Ca pyx
L2006H5	sap	0.5-0.8	~5	N	U	enstatite, magnetite, Mg-carbonates
L2005R7	sap	0.5-0.6	0-25	N	U	no anhydrous silicates
L2006C12	sap	-	variable	Y	D	Ni-rich sulfides
L2006E10	sap	0.2-0.5	5-50	N	U	kamacite
L2006F10	sap	0.5	4	Y	D	no anhydrous silicates, Mg-Fe carbonates
L2006F12	sap	-	4-7	Y	W	kamacite, no anhydrous silicates
L2006G1	sap	0.4	3-23	N	U	distinct carbonate grains
L2006J14	sap	0.4-0.6	1-14	Y	D	no anhydrous silicates

1 sap = saponite, serp = sepentine.
2 U=unheated, D=discontinuous magnetite rim, W=well-developed mt rim

Table 2. Element abundances in 11 hydrated IDPs.
Orgueil data from [6].

	Element Abundances (in wt.%)									
IDP	C	O	Na	Mg	Al	Si	S	Ca	Fe	Ni
L2005L6	12	29	0.8	10.2	0.9	12	3.1	1.4	27	2.5
L2005P9	20	29	0.8	8.0	1.3	10	2.1	0.1	28	0.7
L2005P13	11	28	0.5	11.4	1.0	14	3.2	2.4	25	1.4
L2006H5	8	36	0.9	8.5	1.2	17	7.3	0.2	18	1.1
L2005R7	9	35	0.9	12	1.4	19	2.9	0.1	19	0.8
L2006C12	6	33	0.8	6.2	1.2	8.8	3.2	0.1	40	0.3
L2006E10	11	37	1.3	11	1.3	15	2.1	0.5	18	1.6
L2006F10	15	40	1.5	10	1.0	14	3.9	0.1	13	0.8
L2006F12	7	36	1.5	9	1.3	13	2.3	0.4	27	1.1
L2006G1	20	38	1.5	9.6	0.8	13	4.0	0.7	12	0.8
L2006J14	22	38	1.4	12	1.1	13	1.6	0.2	10	0.6
Average	13	34	1.1	9.8	1.1	14	3.2	0.6	22	1.1
Orgueil	3.5	46	0.5	9.5	0.9	10.7	5.2	0.9	18.5	0.6