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# ELEMENTAL DEPLETIONS IN ANTARCTIC MICROMETEORITES AND ARCTIC COSMIC SPHERULES: COMPARISON AND RELATIONSHIPS

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Antarctic micrometeorites (MMs) and Arctic cosmic spherules (CSs) have bulk compositions comparable to those of chondritic meteorites. However, abundances of Na, Ca, Mn, Ni, Co, and S are commonly lower in MMs and CSs as compared to chondrites. Our SEM, EMP, and INAA studies suggest that these elemental depletions in unmelted MMs are likely to be due to leaching of soluble components from the MMs in the upper atmosphere and the melt ice water. Depletions in CSs appear to be mainly due to volatilization during melting in the atmosphere or to sampling bias during aggregate formation or parent rock break-up.

It was shown by several authors (e.g., /1-5/) that MM and CS abundance patterns display various exceptions from their more or less chondritic composition. Besides enrichments, which have been observed for volatile elements like K and Br (also observed in stratospheric interplanetary dust particles) and are currently explained by contaminations produced in the atmospheric E-Layer /6/, a variety of depletions are present. Unmelted, fine-grained phyllosilicate-bearing micrometeorites (PHs), which consist of a matrix-like material similar to that present in CI and CM chondrites, have depletions in Na, Ca, Ni, Co, S and often in Mg and Mn. The same holds for partially melted, scoriaceous particles (SCs). Completely melted CSs show depletions in Na, sometimes in Ca, and commonly in Ni and Co. Depletions of Na and also of Ni and Co tend to be stronger in CSs than in MMs. On the other hand larger depletions of Ca, Mg and Mn are observed in MMs. Both MMs and CSs have +/- flat chondrite normalized REE patterns. Volatile elements (such as Na and S) can be removed from CSs and SCs by volatilization during atmospheric entry while this cannot be the case for unmelted PHs. For CSs depletions in Ni and Co are suggestive of metal-silicate-fractionation. Such a process should yield Ir/Ni-ratios <CI. This is observed for some CSs but others and also some PHs even show Ir/Ni-ratios >CI. Alternatively Ni and Co depletions could be produced by loss of an Ir-free Ni-bearing phase which must have taken place before entry into the atmosphere. Probably this is a primordial pattern and resembles that observed in some chondrules /3,7/.

To understand depletions in Ca, Mg and Mn the Fe/Mn-ratios of MMs and CSs may give us a hint. Phyllosilicates in carbonaceous chondrites in equilibrium with carbonate (e.g., dolomite) are usually poor in Mn because Mn strongly partitions into the carbonates /8/. In contrast to CM and CI chondrites PHs have no detectable carbonates but display depletions in Ca, Mg and Mn. Mn-poor phyllosilicates in MMs can therefore indicate a former phyllosilicate-carbonate coexistence. We conclude that carbonates have been a part of the original mineral assemblage in PHs which have been lost by leaching /4/. Leaching could take place with sulfuric acid aerosols in the upper atmosphere or with melt water in ice. For CSs this leaching-model is unlikely because carbonates are destroyed during melting. However, carbonates or they breakdown products could have been lost due to ablation or by chance sampling of the precursor rock. Carbonates are not equally distributed in chondritic phyllosilicate matrices (like most sulfides) and therefore it depends on the part of the precursor grain that has been lost whether the final spherule has a chondritic Ca (Mg, Mn) abundance or not. Also, Ca (Mg,Mn)-enrichments can be produced this way. That most CSs were formed by melting of phyllosilicate precursors is evident in Fig. 1 where Fe vs. Mn contents are plotted. Crystalline, unmelted micrometeorites (XX), which consist mainly of anhydrous silicates such as pyroxene and olivine have low Fe/Mn-ratios (<65) while matrices of carbonaceous chondrites display higher ratios (≈ 75-200 /15/). Compositions of CSs straddle the chondritic ratio line indicating a derivation from variable mixtures of phyllosilicate, carbonates and anhydrous olivine and pyroxene.

A characteristic feature of CI and CM chondrites are veins of sulfates /11/. They are interpreted as in situ-formed reaction products of phyllosilicates with an aqueous medium on the chondrite parent body /9/. On Earth these compounds appear as efflorescences which cover the exposed surface of meteorites /e.g., 10/. We performed neutron-activation-analysis of such efflorescences from CI chondrite Orgueil. Results are given in the Table. Please note the high contents of Na and Ni. Fig. 2 shows CI-normalized patterns of siderophile elements of these efflorescences, in PHs and CSs. Orgueil efflorescences have a complementary pattern of MMs. Ni-sulfate has been verified in efflorescences by X-ray powder-diffraction. We also found Ni-rich sulfates covering grains of the CM chondrite Grosnaja. Such covers are not observed on MMs and cannot be expected on them because MMs have been exposed to melt ice water.

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Depletions in Na, Co and Ni can be explained by leaching of sulfates which should have been a component of the original MMs (if the analogy to carbonaceous chondrites is correct). In this case iridium values remain chondritic as has been observed in many CSs and PHs. For unmelted PHs leaching of sulfates is a plausible process for loss of Na, S, Co and Ni (see also /14/ for elemental loss from weathered meteorites). A sampling fractionation of phyllosilicates and sulfates is also possible. Another aspect is that carbonaceous chondrites are not homogenous on the scale of a few hundred micrometers.
In summary, most compositional differences between MMs and carbonaceous chondrites can be ex-plained by interaction processes between the micrometeoroids/-meteorites with the atmosphere and melt ice water. Another source of depletions is the biased sample set of MMs which probably does not fully represent the composition of the parent rock. Although there is an affinity to CI and especially to CM chondrites some differences remain in the composition of anhydrous silicate phases e.g., the higher FeO contents of olivines /12/ and pyroxenes and the high pyroxene olivine ratio /13/. This could indicate that the MM population may represent a new class of extraterrestrial matter not represented among the meteorite classes.

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Fig. 1: Fe vs. Mn in carbonaceous chondrite matrix and bulks of PHs, XX, SCs and CSs

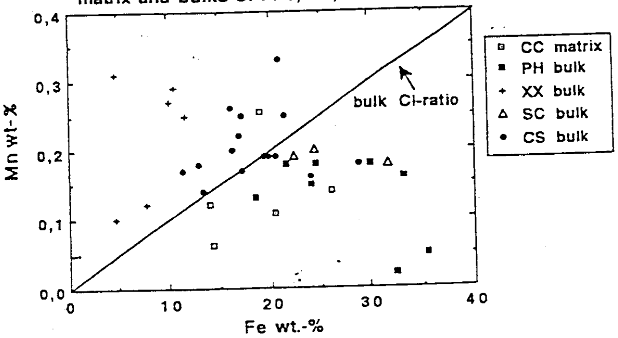

Table: Efflorescences of CI-chondrite Orgueil. INAA data. In paranthesis correc-ted data for contamination by ≈30% CI (Orgueil) chondritic material (based on Sc, Cr and Ir contents)

| | *ppm* | *sample/ bulk CI /16/* |
|---|---|---|
| Na | 6907 (7800) | 1.38 (1.55) |
| K | 230 (94) | 0.44 (0.18) |
| Sc | 1.9 (0) | 0.32 (0) |
| Cr | 828 (0) | 0.31 (0) |
| Mn | 887 (445) | 0.49 (0.24) |
| Fe | 6.3 % (0.6 %) | 0.34 (0.03) |
| Co | 390 (337) | 0.78 (0.67) |
| Ni | 1.78 % (2.06 %) | 1.6 (1.9) |
| Zn | 102 (0) | 0.29 (0) |
| As | 0.63 (0.05) | 0.34 (0.03) |
| Se | 11 (7.3) | 0.58 (0.38) |
| Br | 2.29 (1.69) | 0.64 (0.47) |
| Sb | 0.21 (0.25) | 1.62 (1.92) |
| La | 0.19 (0.05) | 0.4 (0.1) |
| Sm | 0.07 (0.03) | 0.45 (0.19) |
| Eu | 0.04 (0.03) | 0.69 (0.52) |
| Ir | 0.16 (0) | 0.33 (0) |
| Au | 0.06 (0.02) | 0.43 (0.14) |

Fig. 2 Siderophile elements in PHs, CSs and efflorescences of Orgueil