VOLATILE ELEMENT ABUNDANCES IN MICROMETEORITES: EVIDENCE FOR THE LOSS OF COPPER, GERMANIUM, AND ZINC DURING ATMOSPHERIC ENTRY HEATING.

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We have analyzed 20 fine-grained micrometeorites from Antarctica (EUROMET 1994 collection of micrometeorites) in the range of 200-250 μm and 14 fine-grained 100-150 μm-sized micrometeorites from Devon Island, Canada (Canadian Arctic Meteorite Project 1990) for volatile elements by Proton-Induced-X-Ray-Emission. We observe a depletion of Ni, Cu, Ge, S, Zn and S relative to CI in the antarctic as well as in the canadian micrometeorites. The antarctic particles show also a depletion of Ca. Comparing the data to those of heating experiments on meteorite fragments and pyrrhotite grains we conclude that (1) the depletion of Ni is the result of terrestrial weathering, (2) the depletion of Cu is most probably preterrestrial, (3) the depletion of Se and S is caused by terrestrial weathering and atmospheric entry heating, and (4) the depletion of Cu, Ge, and Zn is mainly caused by atmospheric entry heating.

INTRODUCTION. Most micrometeorites and interplanetary dust particles suffer severe heating on entering the Earth's atmosphere. The degree of heating depends on their entry velocity, entry angle, density and size [1, 2]. Love and Brownlee [2] calculated for 100 μm-sized particles with an entry velocity of 12 km/sec (typical for asteroidal particles), an entry angle of 45-80° and a density of 3 g/cm³ peak temperatures of 1000-1400°C. Keeping the physical parameters constant 200 μm-sized particles are heated to 1150-1500°C. Particles heated to T < 1200°C survive as unmelted micrometeorites. According to our heating experiments on fragments of the Orgueil (CI) meteorite at 1200°C we would expect depletions of Cu, Ga, Ge, Se, Zn and S for the micrometeorites [3, 4].

SAMPLES. For our study 20 fine-grained (Fig. 1) 200-250 μm-sized micrometeorites from Antarctica and 14 fine-grained ~ 100 μm-sized micrometeorites from Devon Island, Canada were used. The antarctic particles were collected during the 1994 EUROMET collection of micrometeorites by M. Maurette and co-workers [5] and kindly provided for this studies. The particles from Devon Island are extracted from cryoconite collected during the 1990 Canadian Arctic Meteorite Project and kindly provided by R. Grieve [6].

EXPERIMENTAL. In order to remove the organic compounds from the cryoconite the samples were treated by H2O2. The micrometeorites were then hand-picked from the residue. After this we have carried out trace element analyses of the antarctic and the canadian micrometeorites by Proton-Induced-X-Ray-Emission (PIXE). The energy of the protons used for our measurements was 2 MeV. The probe current was 600 pA and the beam diameter ~ 1 μm. These parameters provide non-destructive analysis of the particles. Finally, the particles were polished for mineralogical studies.

RESULTS. The averages of the element concentrations normalized to CI abundances are shown in Fig. 3 and 4. The error bars show the standard deviation of the averages. Magnesium in the antarctic particles was analyzed by Analytical Scanning Electron Microscopy. In the micrometeorites from Devon Island the concentrations of all elements up to Mn (condensation temperature 1190 K) except Ni are close to the CI-values. The fine-grained antarctic micrometeorites are also depleted in calcium. The depletion of Ni can be explained by terrestrial aqueous alteration of sulfates and sulfides in the ice and the cryoconite, respectively [7-9]. Low Ca-content of the particles is most probably preterrestrial [10-12]. None of these elements exhibit volatile behaviour during our heating experiments. The volatile elements Cu, Ge, Se, Zn, and S are depleted in the fine-grained antarctic and canadian micrometeorites. Relative to CI the loss of Cu is about 45%, the loss of Ge about 70%, the loss of Zn about 65%, the loss of Se 75%, and the loss of S 95% in the canadian as well as in the antarctic particles. Gallium is not depleted in both sets of analyses.

DISCUSSION. Analyses reported here show that micrometeorites are depleted in Ca, Ni, Cu, Ge, S, Zn, and S. Whilst the depletion of Ca is probably preterrestrial [10-12] the depletion of Ni, S, and Se is attributed to the leaching of sulfides and sulfates in the ice water [8, 9]. Analyses of sulfides have shown that they do not contain significant amounts of Cu, Ge, and Zn [13]. So, the loss of these elements cannot be explained by leaching of the sulfides. Heating experiments demonstrate that volatile elements like Cu, Ge, Se, Zn, and S can be lost from 100 μm-sized meteorite fragments at temperatures and in times applicable to the atmospheric entry heating. The correlation of Ge and Zn (Fig. 2) confirms that the same process is responsible for the depletion in Ge and Zn. We conclude that the depletion of sulphur and selenium is due to the leaching of sulfides and sulfates in the ice and to atmospheric entry heating. We also conclude that the depletion of Cu, Ge, and Zn can either be attributed to weathering of some unknown host phase(s) or more likely to the atmospheric entry heating process.

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Figure 1. BSE-image of a typical fine-grained micrometeorite.

Figure 2. Correlation of Ge and Zn.

Figure 3 and 4. Element abundances of antarctic and canadian micrometeorites relative to CI.