REVISED GLOBAL ACCRETION RATES OF MICROMETEORITES IN THE LAST GLACIAL PERIOD.

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Introduction: The accretion rate of extraterrestrial material onto the Earth is a fundamental parameter needed to understand how extraterrestrial material interacts with the Earth's environment. It has been estimated from various sources, for example, as (30000±15000) x10^3 kg/a from Os isotopes in deep-sea sediments [1] or as (40000±20000) x10^3 kg/a from the density of hyper-velocity impact craters on the surface of the LDEF satellite [2]. Antarctic micrometeorites (AMMs), which are extraterrestrial dust particles 30-300µm in size, are one of the available extraterrestrial samples on the Earth [3]. An accretion rate for micrometeorites was estimated to be (2700±1400) x10^3 kg/a based on counting of spherules, melted AMMs, in sediments at the bottom of the South Pole water well [4]. Previously, we reported accretion rates based on numbers of handpicked AMMs; however, we didn't confirm whether some AMMs remained in the residues after handpicking [5]. Here, we present revised accretion rates for micrometeorites based on handpicked numbers of AMMs and noble gas concentrations in residues after handpicking [6].

Samples and methods: The samples in this study were collected by melting blue ice and filtering the melted water with 10, 40, 100, 238µm sieves at the blue ice field around Yamato Mts. in East Antarctica [7]. From twenty-four sampling points, five (M03, K02, K11, J09, and J10) were selected for this study. The snow-accumulation age for K02 and K11 is estimated to be 27-33kys BP, based on fitting the δ^{18}O pattern of ancient air bubbles contained in an ice core drilled close to these sampling points to that of a core drilled at the Vostok station. Based on the locations of the sampling areas and mountains, snow accumulation ages would get older in the order M03, K02 and K11, and J09 and J10.

First, possible AMMs were handpicked from the samples of >40µm size fractions under a stereomicroscope and analyzed qualitatively by SEM-EDS. For silicate particles, those showing EDS spectra with major peaks in Si, Mg, and Fe and minor peaks in Al, Ca, and S were identified as AMMs. For Fe-oxide particles, those with Ni peaks in their EDS spectra were identified as extraterrestrial.

The residues of each sample, after handpicking, were analyzed for He, Ne and Ar isotopes by noble gas mass spectrometry using the MM5400 at Kyushu University. Residues of the 40-100µm and 100-238µm size fractions were analyzed because these size fractions were enriched in AMMs. The analyses were performed in the same manner as that described by [8]

Results: From the handpicking, 155, 251, 257, 127, and 152 of AMMs were collected from M03, K02, K11, J09, and J10 samples, respectively; ~60% of these are unmelted AMMs. Each of the AMMs was measured in its mean diameter, which is an arithmetic average of the minor and major axes on its SEM image. Based on the calculated volumes of AMMs and their densities, which were assumed to be 3.0, 5.0, and 1.0g/cm^3 for silicate spherules, Fe-oxide spherules, and unmelted AMMs, respectively, the weight of the handpicked AMMs at each sampling point is determined as shown in Table 1.

Ne isotopic compositions of the residues of the samples are plotted on a Ne three isotope plot in Fig. 1. Most of the data plot around the value of solar energetic particles (SEP), which indicates that the residues are rich in AMMs. To estimate the AMMs concentrations in the residues, the solar ^{20}Ne contents in the residues were calculated by deconvolution of their ^{20}Ne contents into three components: solar wind (SW), SEP, and cosmogenic (C) for data plotting above a mixing line between SEP and C, and SEP, air, and C for data plotting below the mixing line. The solar ^{20}Ne concentration of a single AMM is from [9]. Finally, AMMs concentrations in the residues are calculated as shown in Table 1.

Discussion: A global accretion rate of micrometeorites F should be calculated in the following equation,

$$F = A_e \left[\left(\frac{m_c}{M_i} \right) f_s \right]$$

where A_e, m_c, M_i, and f_s represent the total surface area of the Earth (5.1×10^{18} cm^2), the gross weight of accumulated AMMs (g), the weight of melted ice (g), and the accumulation rate of snow (g/cm^2/a) for the blue ice of the sampling point at the time of deposition, respectively. The weights of the AMMs and the melted ice are shown in Table 1. The snow accumulation rate in the last glacial period was assumed to be 4.4±2.2 g/cm^2/a, based on the present rate in a glacial upstream area of the Yamato Mts.

Finally, we estimated the accretion rate of micrometeorites from each sample point as (16000±9300) x10^3 kg/a, (16000±9100) x10^3 kg/a, (11000±6600) x10^3 kg/a, (5300±3100) x10^3 kg/a, and (7900±4800) x10^3 kg/a for M03, K02, K11, J09, and J10, respectively. Air contamination observed in the He, Ne and Ar isotopic compositions of residues J09 and J10 indicate that terrestrial alteration during their long residence in glacial ice probably resulted in the loss of solar ^{20}Ne in their AMMs, so that their accretion rates should be lower limits. Thus, the data of M03, K02, and K11 should represent the actual accretion rates of micrometeorites in the last glacial period.

The accretion rates of this study are more than five times larger than the present accretion rate of (2700±1400) x10^3 kg/a, determined by [4], and about a third of the present influx of extraterrestrial materials, (40000±20000) x10^3 kg/a, estimated by [2]. Because the size distribution of spherules of [4] seems to be depleted in the smaller sizes relative to those of this study, their accretion rate may be underestimated. However, our accretion rates are comparable to an estimation of (10000±2000) x10^3 kg/a based on Ir abundances in particles in the Greenland ice core filtered by a 0.45μm Millipore filter [10]. Thus, the accretion rate during the last glacial period appears to be almost comparable to that of the present.

The lower accretion rates estimated from AMMs' concentrations relative to the influx of extraterrestrial materials can be explained by their evaporation during atmospheric entry heating. In situ aerosols analyses in the stratosphere indicate that the evaporated meteoric mass should to be (4000-19000) x10^3 kg/a [11]. The sum of the annual evaporated extraterrestrial materials and the global accretion rate of micrometeorites in this study is within the estimated error of the influx of extraterrestrial materials to the Earth.

The accretion rate estimated from Os isotopic studies of deep-sea sediments, (30000±15000) x10^3 kg/a, is almost equivalent to the influx of extraterrestrial materials [1], indicating that such studies succeed in recovering evaporated meteoric materials. However, the accretion rate estimated from the Ir abundances of the filtered fractions of the Greenland ice core does not seem to include the evaporated portion, implying that recondensates of evaporated extraterrestrial materials are smaller than 0.45μm.

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Table 1. The evaluated weights of AMMs and calculated accretion rates.

Sampling Point	M03	K02	K11	J09	J10
Melted Ice (10^3 kg)	0.91	0.90	1.86	1.11	1.01
Total glacial sand (mg)	13.8	11.3	8.17	10.4	6.06
Handpicked AMMs (mg)	0.248	0.282	0.357	0.137	0.256
AMMs in residues (mg)	0.409	0.346	0.596	0.126	0.099
AMMs conc. (10^{-10} g/g ice)	7.25	6.98	5.12	2.38	3.53
Error	1.26	1.39	0.93	0.46	0.90
Accretion rate (10^3 kg/a)	16000	16000	11000	5300	7900
Error	9300	9100	6600	3100	4800

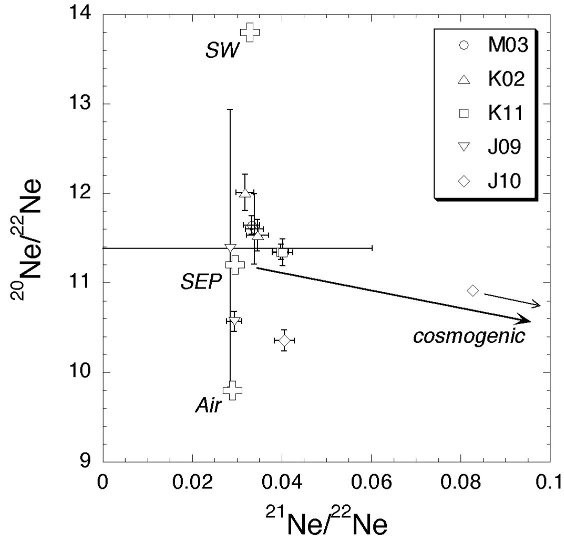

Fig. 1. Ne three isotope plot of samples' residues after handpicking. The data of two size fractions for each sample are plotted together. One of them (100-238μm of J10) plots outside the graph in the direction of the cosmogenic component. Errors are 1□.