Study of the Extraterrestrial Materials in Antarctica (VI) Cosmic Dust Collected from the Glacier Ice of the Meteorite Ice Field, Yamato Mountains

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南極における宇宙物質に関する研究 (VI) やまと山脈いん石氷原の氷河氷より採集された宇宙塵

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要旨： 南極やまと山脈のいん石氷原より採取された氷河氷から，各種の宇宙塵を回収し，検討を行った．この研究の主目的は，異常な集積(濃集）を示すやまと隕石と宇宙塵との相互関係を調べることであった．しかし，予想に反して，特に宇宙塵の濃集は認められず，宇宙塵の降下量は，全地球に換算し年間 (2.9－5.0)×10⁴ t であった．この値は昭和基地周辺の大陸氷（氷河氷）とほぼ同じである．この事実はやまと隕石が，シャワーとして落下した可能性の低いことを示唆しているといえよう．また，回収された宇宙塵は，その色と形態から a) 黒色微球体，b) 赤色，黄色，灰色ないし無色透明なガラス質微球体，c) 不定形微球体に分けられる．a) の主成分は Fe (60－65%) である．この試料は第15次日本南極地域観測隊（JARE 1973－75）のやまと隕石探査隊により，1974年12月に裸氷の表面付近から採取されたものである．

Abstract: Black spherical microparticles, glassy microparticles and other irregular-shaped particles were collected from the glacier ice, sampled in December 1974, of the Meteorite Ice Field, Yamato Mountains. Their chemical and physical properties were compared with those of previously collected cosmic dust at various places in the world, and the relationship of these particles to the Yamato meteorites fall was also studied. Any specific particles associated with the Yamato meteorites were not confirmed. The annual accretion rate of black spherical microparticles on the whole earth is estimated at 2.9 to 5.0×10^4 t/year. This value agrees with the annual fall rate of cosmic dust collected from the Antarctic ice near Syowa Station.

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1. Introduction

Antarctica is the last continent that remained beyond the bounds of civilization. Being covered with thick ice, it has been considered one of the most suitable places for collection of extraterrestrial materials (SHIMA and YABUKI, 1968), and we have published on the study of extraterrestrial materials (cosmic dust, tektites and meteorites) in Antarctica (SHIMA, 1966; SHIMA and YABUKI, 1968; SHIMA *et al.,* 1969; YABUKI and SHIMA, 1971). As shown in Table 1, many studies concerning cosmic dust in Antarctica have been also published (YABUKI and SHIMA, 1971; BIBRON *et al.,* 1974).

Table 1. Estimates of annual accretion rate of cosmic dust at polar regions.

	Source	Size of element	Accretion rate (t/year)	Remarks
Dust	Arctic air	$3\mu m$	5×10^5	HODGE *et al.*, 1958
	Antarctic snow	$15\mu m$	1.8×10^5	THIEL *et al.*, 1961
	Antarctic snow	$10\mu m$	1.2×10^5	SCBMIDT, 1963
	Greenland ice	$5\mu m$	2×10^5	WRIGHT *et al.*, 1963
	Greenland snow	$5\mu m$	9.1×10^5	LANGWAY, 1963
	Greenland ice Greenland firm	$5\mu m$	2.1×10^5 6.6×10^5	LANGWAY *et al.*, 1965
Element	Greenland air	Cl^{36}	10^6	TILLES, 1966
	Greenland ice	Al^{26}	3.2×10^5	NCCORKELL *et al.*, 1967
	Antarctic ice	Ni	$3\text{-}10\times10^6$	BROCAS *et al.*, 1967
Dust	Antarctic ice	$10\mu m$	3×10^4	SHIMA *et al.*, 1968
	Antarctic air	$10\mu m$	1.3×10^6	SHIMA *et al.*,1969
Element	Antarctic ice	Mn^{53}	10^5	BIBRON *et al.*, 1974

The meteorites which fell on the ice or snow in the Antarctic region are expected to have escaped extensive erosion, owing to the low temperature and meager rainfall. Until 1968, however, only four meteorites were discovered (two irons, one stony iron and one stone), because of the difficulty imposed by the vast expanse and severe climate of Antarctica. In 1969, the inland traverse party of the 10th Japanese Antarctic Research Expedition (JARE-10) found 9 meteorites lying on the ice sheet at the southeast end of the Yamato Mountains (YOSHIDA *et al.,* 1971). Then in 1973, 12 samples and in 1974, 663 samples were collected in the same area by the JARE-14 and JARE-15 parties, respectively (YANAI, 1975, 1976).

The number of the Yamato meteorites is surprisingly large, in view of the fact that the number of meteorites found in the world up to now is only about

1,500 to 2,000. The cause of high concentration of meteorites in this area is now under investigation. If a meteoritic shower is assumed, many meteoritic debris ought to be found in the ice of the area. The amount of microparticles in the area of the meteorites and their physical and chemical properties will provide valuable information on this problem.

2. Samples

Search for meteorites in the southeast area of the Yamato Mountains was carried out from November 24 to December 29, 1974, along the traverse route shown in Fig. 1, and 663 samples which seemed to be meteorites were collected. At the same time, ice samples were also collected near the surface of bare ice (blue ice) at three points in the Meteorite Ice Field as indicated in Fig. 1. Descriptions of the samples are given in Table 2.

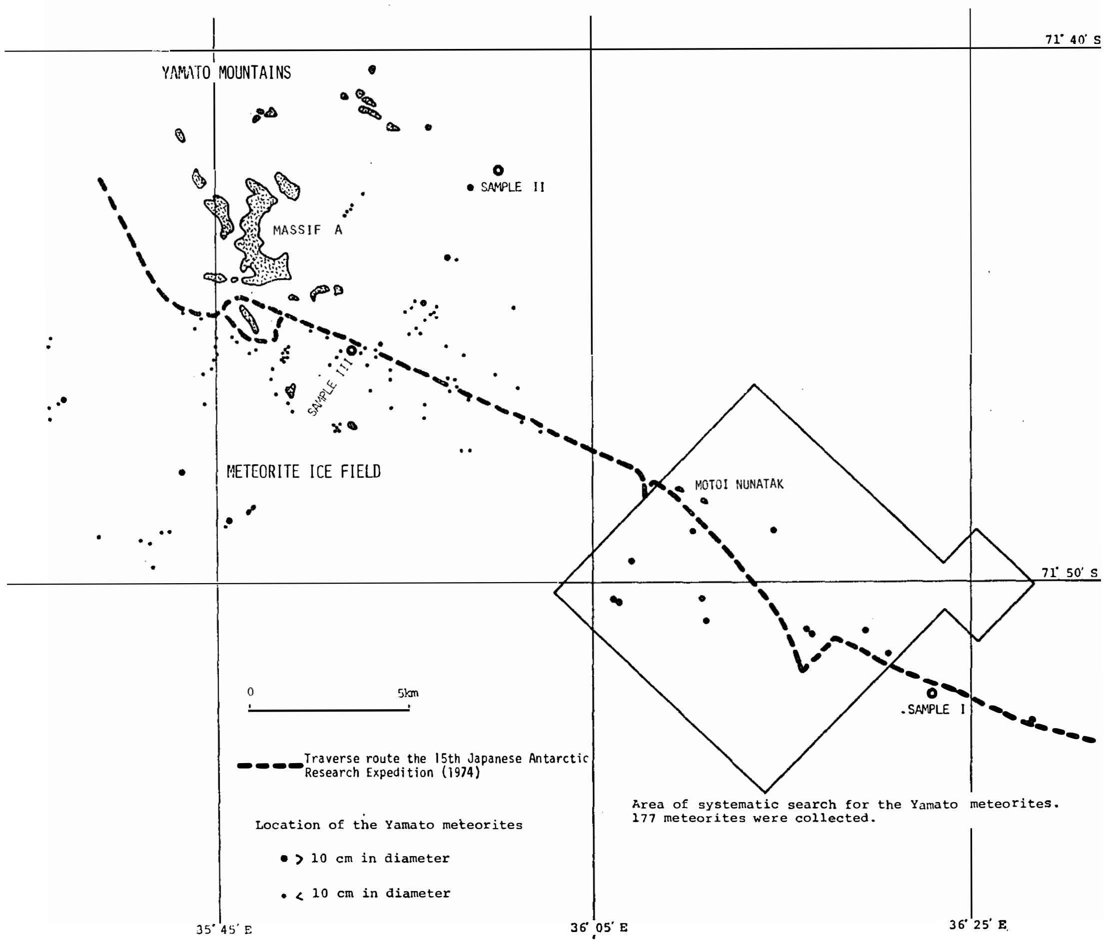

Fig. 1. Sampling localities (open circle) of the glacier ice of the Meteorite Ice Field, Yamato Mountains (open circle).

Table 2. Description of the samples.

Sample No.	Date in 1974	Sample weight (kg)	Nnmber of particles collected	Average diameter (μm)	Calculated accretion rate on the whole earth (t/year)
I*	December 29	1.5	18	25.3	5.0×10^4
II**	December 27	4.8	93	17.9	3.0×10^4
III***	December 22	7.2	85	20.8	2.9×10^4

* Near the systematic searching area enclosed by solid line in Fig. 1.
** East of Yamato Mountains massif A.
*** South of Yamato Mountains massif A, the area of high meteoritic concentration.

The samples were carefully wrapped in polyethylene film, brought back to Japan and kept in the freezing chamber at the National Institute of Polar Research. After melting the ice in a polyethylene beaker at room temperature, the water was filtered through 0.8 μm Millipore membrane filters. Scanning under the binocular microscope (×60), black spherical microparticles, glassy spherules and other particles were separated using molybenum needles. All procedures were carried out carefully avoiding contamination.

3. Results and Discussion

3. 1. Black spherical microparticles

The number of black spherical microparticles collected from the ice samples No. I, II and III was 18, 93 and 85, respectively. Photographs of the spherical microparticles are shown in Fig. 2. Their size distribution shows a similar tendency to that of previously collected cosmic dust samples at various places in the world (Fig. 3).

Assuming that the accumulation rate of snow in the Yamato Mountains is 20 g/year and that the specific gravity of the microparticles is 5 g/cm^3, the annual

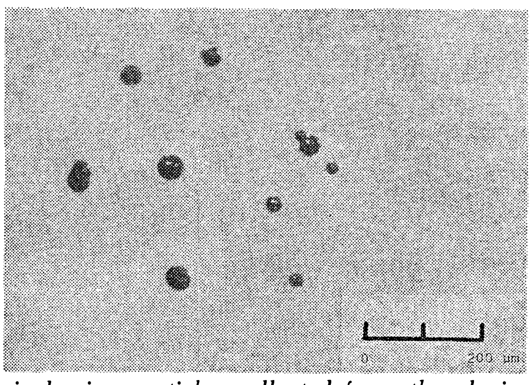

Fig. 2. Black spherical microparticles collected from the glacier ice of the Meteorite Ice Field, Yamato Mountains.

accretion rate of these microparticles on the whole earth is estimated for the samples No. I, II and III to be 5.0×10^4, 3.0×10^4 and 2.9×10^4 t/year, respectively (see Table 2).

These results agree with the annual fall rate of 3.0×10^4 t/year of cosmic dust (SHIMA and YABUKI, 1968) calculated from the observation on Antarctic ice near Syowa Station. The chemical composition of the black spherical microparticles was semi-quantitatively determined using Electron Probe X-Ray Microanalyzer, by mounting them into resin, polishing their surfaces and covering with carbon film. Fe was the main component occupying about 60–65%; Mn, Ni, Si, Ti and Mg were not detected.

Debye-Scherrer X-ray photographs were taken for 4 particles mounted on the top of fine glass tube, by using filtered Fe-Kα radiation. They showed the reflection of magnetite only.

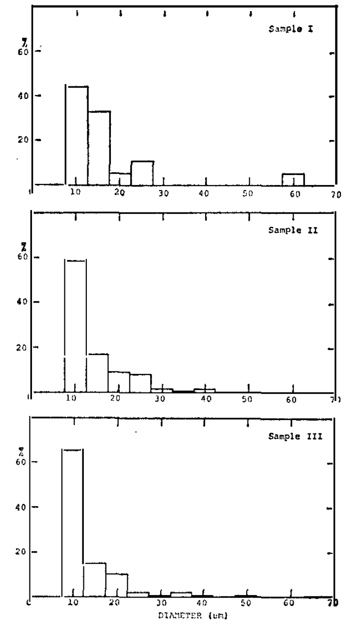

Fig. 3. Size distribution of black spherical microparticles collected from the glacier ice of the Meteorite Ice Field, Yamato Mountains.

It seems reasonable to conclude that the black spherical microparticles collected from the Meteorite Ice Field are not the debris characteristics to the Yamato meteorites but are the same kind of cosmic dust falling on the earth.

3. 2. Glassy microparticles

Glassy microparticles also exist in the sample: numerous colorless spheroids, spherules colorless to amber in color and spherules of red, yellow and grey color. It is notable that the colorless spheroids were found particularly in large numbers in sample I, not so many in sample III, and scarcely exist in sample II. They were about 50 μm in size. In contrast, the glassy microparticles found in the glacier ice near Syowa Station were mostly spherical and were larger than 100 μm in diameter (SHIMA and YABUKI, 1968). Chemical analysis and age determination of these glassy microparticles may reveal their origin.

3. 3. Other particles

Besides the black spherical microparticles and glassy microparticles, many irregular-shaped microparticles exist in the glacier ice. The glacier ice of the Meteorite Ice Field contains greater numbers of microparticles than that near Syowa Station. Several kinds of silicate minerals, clay minerals and metal oxides are recognized under microscope. The particle size is generally smaller than 100 μm, but some particles are a few hundred μm in diameter. X-ray powder analysis of some relatively large-sized particles show magnetite and goethite. One particle with metallic luster showed the diffraction pattern of α-iron, but the diffraction lines were not so clear because of the small size of the particle. In the course of the repeated X-ray analysis, it was oxidized into goethite.

If the Yamato meteorites had fallen in the same region where they were found, relatively large meteoritic debris would be expected to exist in the glacier ice of the region. However, all the Yamato meteorites found till 1975 are stones, and so it is impossible to distinguish the small-sized meteoritic debris from terrestrial rocks which are transported with ice sheet movement.

4. Conclusion

It is of great interest to explain the anomalous high concentration of meteorites within the limited area near the Yamato Mountains. Systematic search for meteorites was therefore performed in the area of 9 km^2, 10 km south of Yamato Mountains massif A, because 20 meteorites found by the JARE-10 and JARE-14 parties were lying on the traverse route that ran through this area. The JARE-15 party which undertook systematic search, collected 177 meteorites within the area enclosed by the solid line in Fig. 1. They found meteoritic clusters in four different areas of 200 to 300 m^2: two clusters with 200 meteorites and other two with 20 meteorites.

As the meteorites belonging to one cluster have similar petrographic features, occurrence of a meteoritic shower may be suggested. On the other hand, the structure of the ice sheet of the Meteorite Ice Field suggests that the distribution of meteorites is related to glacier movement. The glacier slopes down stepwise toward the east of the southeastern end of the Yamato Mountains and meteorites lay scattered on the lowest floor of the ice sheet. Moreover, some shear moraine fields are developed sporadically in the neighbourhood of the area.

Judging from the circumstances, meteoritic shower did not necessarily fall on the ground in this area. The meteorites may have been transported from other place, or it is even possible to think that the meteorites after landing were broken to pieces by mechanical weathering.

The fact that no materials characteristic of the Yamato meteorites were found in the glacier ice of the Meteorite Ice Field, may also suggest the transportation of meteorites by glacier. The amount of ice samples, however, was too small to offer any definite conclusion on the fall of the Yamato meteorites in this investigation. It is desirable to examine a larger amount of ice of the area to discuss the relationship between the microparticles in the glacier ice and the

Yamato meteorites.

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