

Collection of Yamato Meteorites, Antarctica, in December 1973

Kazuyuki SHIRAISHI*, Renji NARUSE** and Kou KUSUNOKI***

1973年12月におけるやまと隕石の採集

白石和行*・成瀬廉二**・楠 宏***

要旨: 1969年12月, 9箇の石質隕石がやまと山脈の南東端付近で発見された (Yamato (a) から Yamato (i) と命名). 引き続き 12 箇の石質隕石が 1973 年 12 月, 第 14 次南極観測隊の旅行隊によってほぼ同地域で発見された. 12 箇中, 大型のもの 4 箇 (重量 500~900 g) は Yamato (j), (k), (l), (m) と命名され, Yamato (l) は achondrite, 他は chondrite である; 残りの 8 箇 (4~40 g) は Yamato (n) から Yamato (u) と命名された. 採集現場での産状写真を示すとともに, 地形や氷状についても述べた. 将来, さらに発見される可能性があり, やまと山脈南端の限られた裸氷域に隕石が集中している原因や機構の解明のため, 将来室内研究と現場での研究の必要なことを述べた.

Abstract: In addition to 9 meteorites, designated as Yamato meteorites, discovered in December 1969 at the SE end of the Yamato Mountains, East Antarctica, 12 stoney meteorites were found in December 1973 in nearly the same area by the traverse glaciology party of the 14th Japanese Antarctic Research Expedition. Eight pieces among 12 were found at the same site as the 1969 collection and the rest were found on the SW side of the Yamato Mountains. Relatively large 4 samples, weighing between 500 and 900 grams, were designated as Yamato (j), (k), (l), and (m), among which Yamato (l) was achondrite and the rest were chondrites; other 8 samples, weighing 4 to 40 grams, were designated as Yamato (n) to (u) in alphabetical order. Geomorphological and glaciological features of the sampling sites are described, suggesting a further extensive search for more meteorites and glaciological research which may account for the concentration of the meteorites.

* 北海道大学理学部地質学鉱物学教室. Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, Sapporo 060.

** 北海道大学低温科学研究所. The Institute of Low Temperature Science, Hokkaido University, Sapporo 060.

*** 国立極地研究所. National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

1. Introduction

In December 1969 a total of 9 stoney meteorites were discovered unexpectedly near the Yamato Mountains in East Antarctica. These meteorites, later designated as "Yamato meteorites", were found on the surface of ice sheet free from snow (bare ice) in a very limited area of about 5×10 km centered at $71^{\circ}50'S$ and $36^{\circ}20'E$ with an average elevation of 2,300 m. The collection was made when the glaciological traverse party of the 10th Japanese Antarctic Research Expedition (JARE) approached the SE end of the Yamato Mountains with which a glaciological triangulation chain along the parallel of $72^{\circ}S$ was tied. Two authors of the present paper were the members of the 10th JARE, that is, KUSUNOKI as the leader of the Expedition and NARUSE as a member of the glaciological traverse party. A preliminary petrological analysis of 9 samples revealed that they consisted of 8 chondrites and 1 achondrite. These findings were reported by YOSHIDA *et al.* (1971) and, KUSUNOKI (1975) also gave a summary of this 1969 collection and results of laboratory studies of late years.

Comparatively large 4 pieces of Yamato meteorites were subjected to a more detailed chemical and petrological analysis by Masako SHIMA *et al.* (1973) and Makoto SHIMA *et al.* (1974). These samples were designated as Yamato (a), (b), (c), and (d) and classified as enstatite chondrite, Ca-poor achondrite, Type-III carbonaceous chondrite, and olivine-bronzite chondrite, respectively. The remaining 5 samples were designated as Yamato (e), (f), (g), (h), and (i).

The glaciological traverse party of the 14th JARE (1972–1974) was assigned to resurvey the 1969 triangulation chain in the austral summer of 1973–1974. The party consisted of 10 men: R. NARUSE (leader), Y. ABE, M. AYUKAWA, S. KOBAYASHI, M. KUWASHIMA, Y. MURAYAMA, K. SHIRAISHI, H. SHIRANE, S. SIGA, and K. YOKOYAMA, including the first two authors of the present paper.

During the oversnow traverses near the Yamato Mountains in December 1973, though the time allocated to meteorite search was very limited, a total of 12 meteorite samples were discovered in the southern part of the Yamato Mountains. The present paper describes the occurrence of meteorites and relevant information of geomorphological and glaciological features of the sampling sites.

2. Occurrence of Meteorites

Since the main task of the glaciology party of the 14th JARE was the resurvey of the triangulation chain installed along $72^{\circ}S$ in 1969, no extensive search for

meteorites was planned in advance. But, of course, the party could foresee the find of meteorites in the Yamato Mountains area and paid keen attention during the oversnow traverses in this area.

In Fig. 1, traverse routes and locations of meteorites sampled in December 1973 are illustrated. The glaciological party left Syowa Station on November 10, 1973 and returned to the station on February 2, 1974. The party approached the Yamato

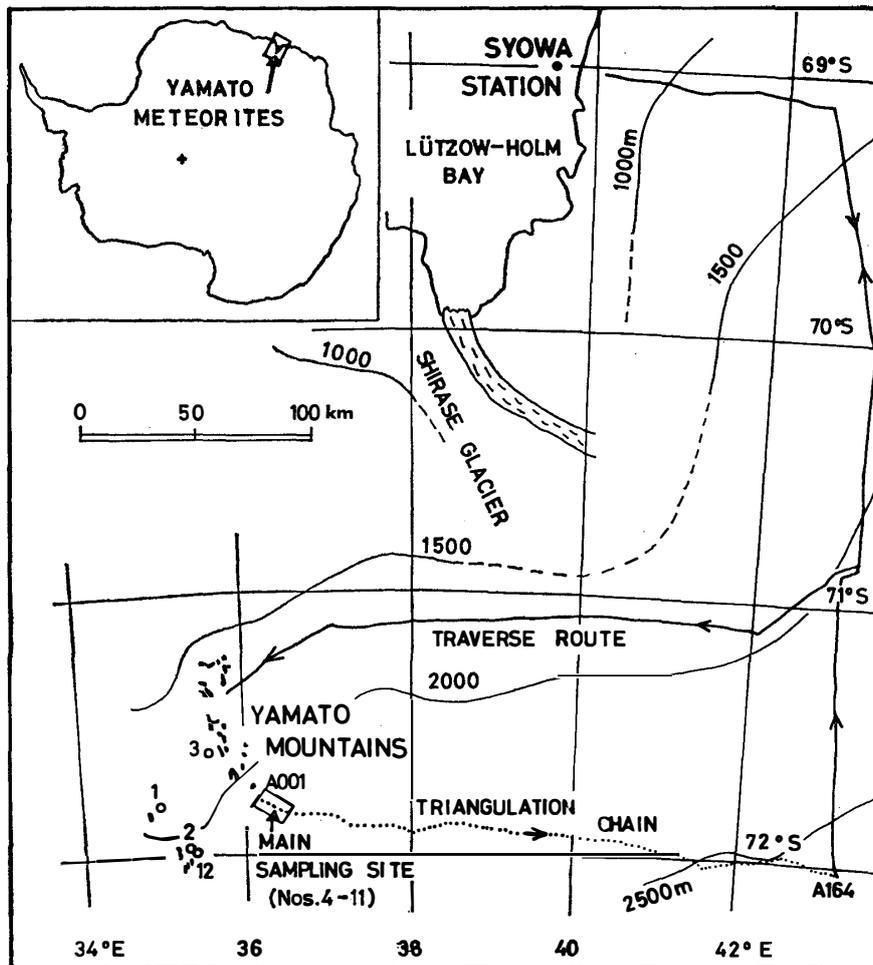


Fig. 1. Location of Yamato meteorites collected in 1969 and 1973.

Mountains from the north, taking the reverse route covered in 1969 and travelling along the parallel of 71°S. The party maintained a base camp at 71°19'S and 35°38'E from November 27 to December 12, carrying out such scientific research disciplines as glacial-geology, surface and upper weather observations, terrestrial survey, gravity, geomagnetism, and ULF signals. Since the camp site was on the ice sheet between Massif-E and Massif-G of the Yamato Mountains, glacial-geological

survey was carried out at Massifs-D and -F besides Massifs-E and -G.

There were many bare ice fields in the northern Yamato Mountains, but none of meteorite was found in these areas. This fact does not necessarily deny the possibility of the existence of meteorites in the area, because the main task was the above-mentioned research, not the meteorite search. It is to be added that the identification of meteorite samples from ordinary rock fragments in moraine fields and detritus in exposed nunataks is very difficult.

Having finished the research in the northern Yamato Mountains, the party approached the southern end, travelling along the western side of the Mountains. In Fig. 1, there are two main sampling sites of the meteorites; one in the south-western part of the Yamato Mountains and the other at the south-eastern end. The former area was visited at first in the present occasion and the latter was the same area as the 1969 collection.

From December 13 to 18, a 3-man party (K. SHIRAIISHI, K. YOKOYAMA, and H. SHIRANE) was dispatched to carry out the first reconnaissance survey of nunataks located at about 30 to 40 km SW from the southern Yamato Mountains. They collected 3 meteorite samples lying on the surface of bare ice during the course of oversnow traverses, while the main glaciological party collected one sample in the west of Massif-B of the Yamato Mountains. The size of the smallest pieces was about 2 cm in diameter, so that the pieces were barely discernible within a visual range of less than 50 m. It was rather easy to spot a tiny dark object lying on the whitish-blue ice surface.

On December 20, the glaciological party commenced the resurvey of the 1969 triangulation chain which was tied to datum points A001 and A002 on the exposed rocks at the SE end of the Yamato Mountains. By December 26, the party found 8 samples lying on the bare ice area where the first discovery was made in December 1969. No meteorite was found in the compact firn area east of about 36.5°E.

A total of 12 stoney meteorite samples collected in the southern Yamato Mountains in December 1973 are listed in Table 1, including the designation of Yamato (j) to (u) in alphabetical order for these samples.

Photographs of the samples are shown in Fig. 2. In order to offer aid to visualize a scene of occurrence at the sampling sites, photographs taken *in situ* are presented in Figs. 3a and 3b. Preliminary analysis of relatively large 4 samples, about 10 cm in diameter, revealed that 3 samples were chondrite and one was achondrite, giving the designation of Yamato (j), (k), and (m) and Yamato (l),

Table 1. List of Yamato meteorites collected in December 1973.

Designation	Initial sample number	Weight in grams	Date (December)	Classification	Remarks
Yamato (j)	1	650	14	Chondrite	Found at a site about 300 m from the margin of a moraine field; few fragments scattered around the main body lying on the bare ice surface in a gentle trough (see Fig. 3a-1)
Yamato (k)	4	900	21	Chondrite	Found on the bare ice (Fig. 3a-2, 3)
Yamato (l)	7	480	22	Achondrite	Found on the bare ice (Fig. 3a-6)
Yamato (m)	12	500	17	Chondrite	Found near the Minami-Yamato Nunataks
Yamato (n)	2	4	17		Ditto
Yamato (o)	3	11	16		Found on the bare ice near Massif-B
Yamato (p)	5	4	21		See Fig. 3a-4
Yamato (q)	6	18	22		A quarter of the bottom part was buried in the bare ice (Fig. 3a-5)
Yamato (r)	8	9	23		Near the crest of rather steep slope with small crevasses (Fig. 3b-1)
Yamato (s)	9	7	23		See Fig. 3b-2
Yamato (t)	10	21	23		See Fig. 3b-3,4
Yamato (u)	11	40	26		Found in crevassed area (Fig. 3b-5,6)

respectively (Makoto SHIMA, personal communication, February 1975). Identification of other 8 samples is not yet finished.

3. Geomorphological and Glaciological Features of the Locality

In Fig. 4 the locations of 4 samples collected in the western area of the Yamato Mountains are shown. As mentioned earlier, the samples except for sample No. 3 were found on the bare ice surface on the way of the traverse to the nunataks about 40 km SW of Massifs-A. It should be pointed out that many bare ice areas, almost in continuation, existed between the Yamato Mountains and the newly visited nunataks. Since those samples were found only on the traverse routes, it is quite probable that more meteorites will be found in the area shown in Fig. 4. Three samples, Nos. 1, 2, and 12 were collected in a trough-like area where the confluence of moraines was observed in an alignment of SSE to NNW. This area is about 200 m lower than the eastern side of the Yamato Mountains, which indicates the flow of ice sheet from E to W of SE to NW, also suggesting the transport of meteorites by glacier movements.

Figure 5 shows the locations of most of the Yamato meteorites sampled in 1973

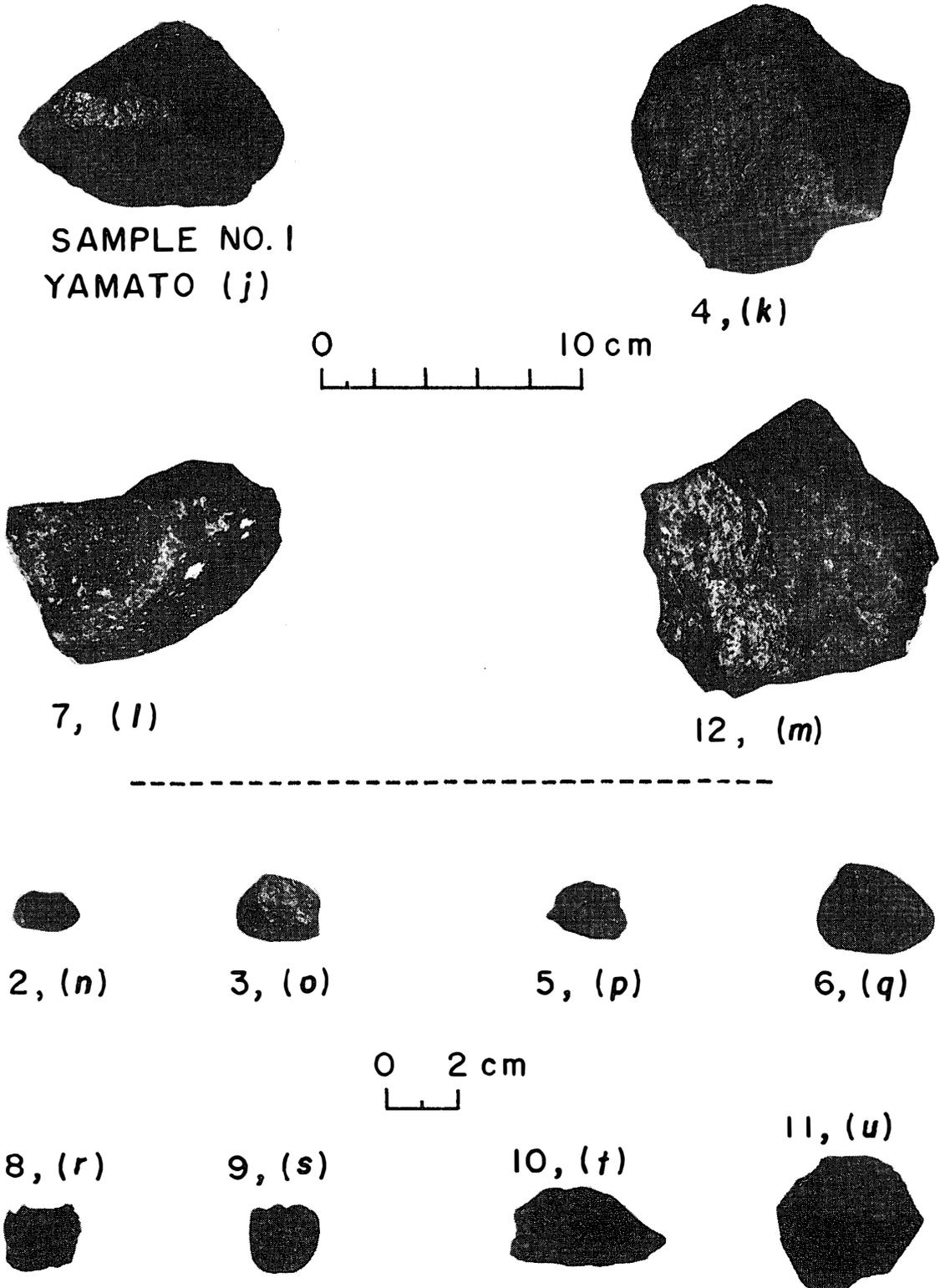
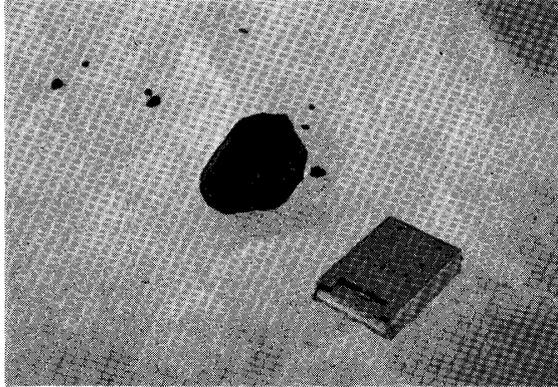
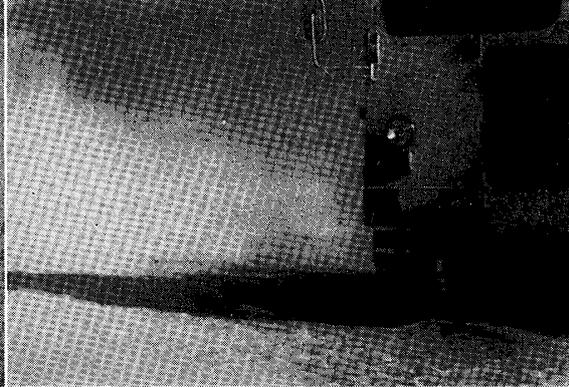


Fig. 2. Photographs of Yamato meteorites, Yamato (j) to Yamato (u), collected in December 1973.



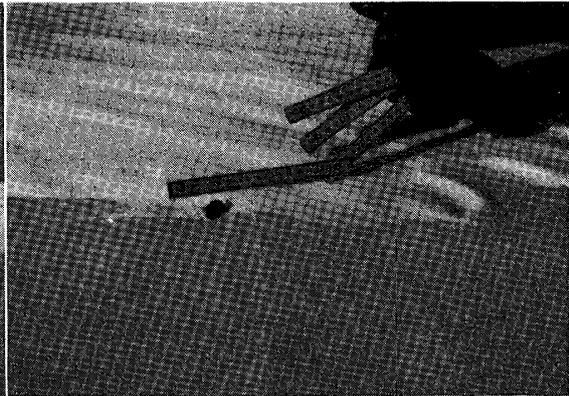
1. *Yamato (j)* (Sample No. 1).
Taken by K. SHIRAIISHI, December 14, 1973.



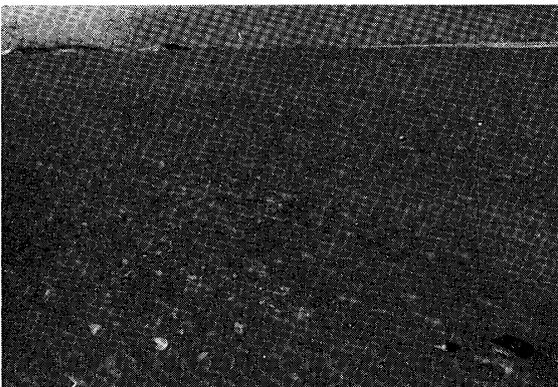
2. *Yamato (k)* (Sample No. 4).
Taken by Y. MURAYAMA, December 21.



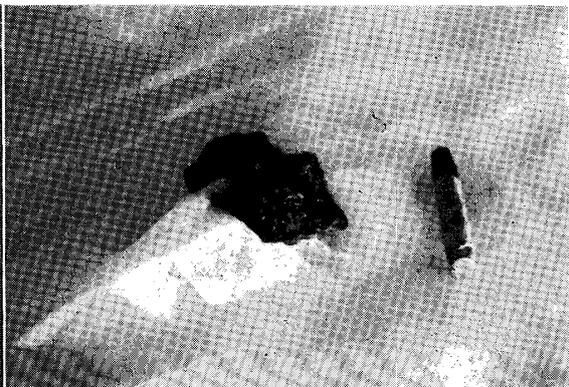
3. *Yamato (k)* (Sample No. 4).
Taken by S. KOBAYASHI, December 21.



4. *Yamato (p)* (Sample No. 5).
Taken by S. KOBAYASHI, December 21.

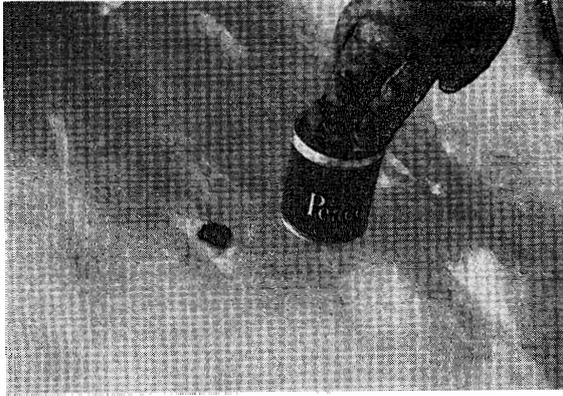


5. *Yamato (q)* (Sample No. 6).
Taken by K. SHIRAIISHI, December 22.

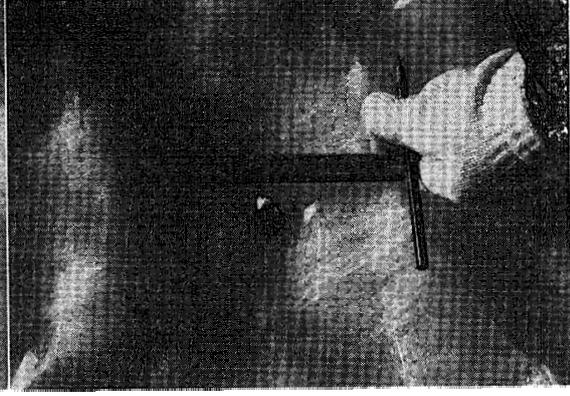


6. *Yamato (l)* (Sample No. 7).
Taken by K. SHIRAIISHI, December 21.

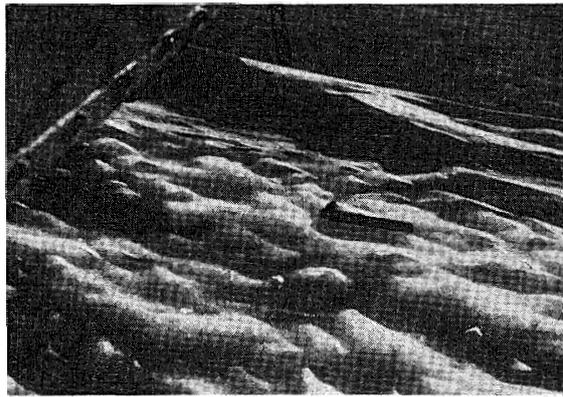
Fig. 3a. *Yamato meteorites photographed in situ.*



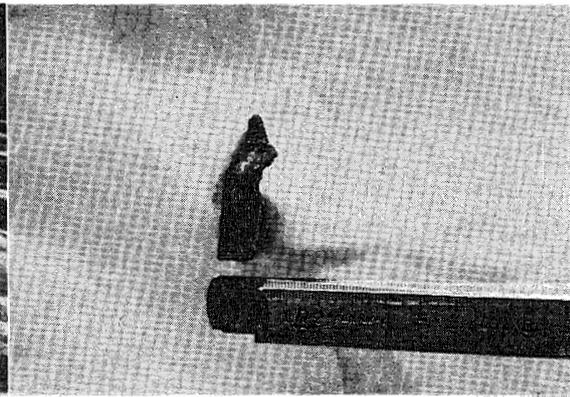
1. Yamato (r) (Sample No. 8).
Taken by K. SHIRAISHI, December 23.



2. Yamato (s) (Sample No. 9).
Taken by S. KOBAYASHI, December 23.



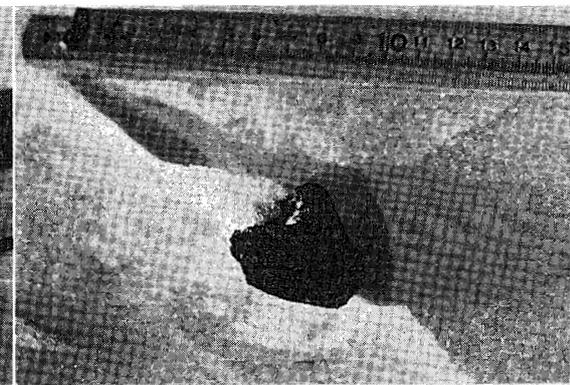
3. Yamato (t) (Sample No. 10).
Taken by K. YOKOYAMA, December 23.



4. Yamato (t) (Sample No. 10).
Taken by K. YOKOYAMA, December 23.



5. Yamato (u) (Sample No. 11).
Taken by Y. MURAYAMA, December 26.



6. Yamato (u) (Sample No. 11).
Taken by K. SHIRAISHI, December 26.

Fig. 3b. Yamato meteorites photographed in situ.

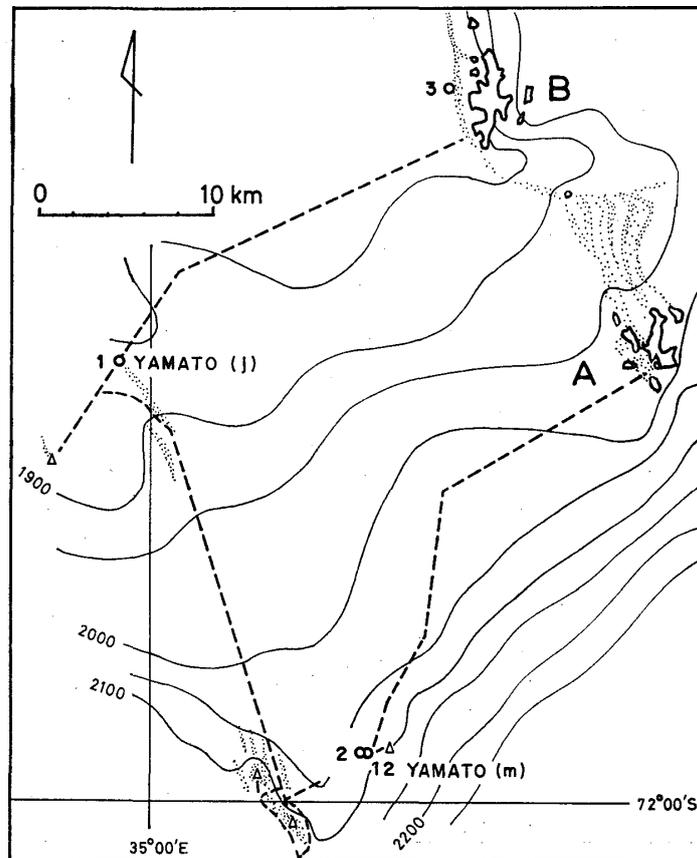


Fig. 4. Sampling site of Yamato meteorites near the Minami-Yamato Nunataks and the southern Yamato Mountains.

at the southeastern end of the Yamato Mountains; this figure also indicates the locations of the 1969 samples and trails of surveyors who made resurvey of the triangulation chain established in 1969. Contours of the surface elevation were derived from the survey of triangulation chain and the barometric heights of datum points A001 and A002 established on the exposed rocks. The surface feature of the bare ice field near the datum points will be recognized in Fig. 3a-5. The main sampling area shown in Fig. 5 is practically free from snow and has a fairly steep slope lowering towards NE, from 2,380 m at the eastern margin to 2,230 m around the datum points. It is very remarkable that about a score of meteorites, so far in 1969 and 1973, were found on the bare ice within such a limited area as of about 5×10 km.

In view of the experience of the collection in two years, it became confident that more meteorites will be found in the southern part of the Yamato Mountains. Again, it is to be noted that the collection in 1969 and 1973 was made only on the survey trails within a visual range of about 50 m. In November and December

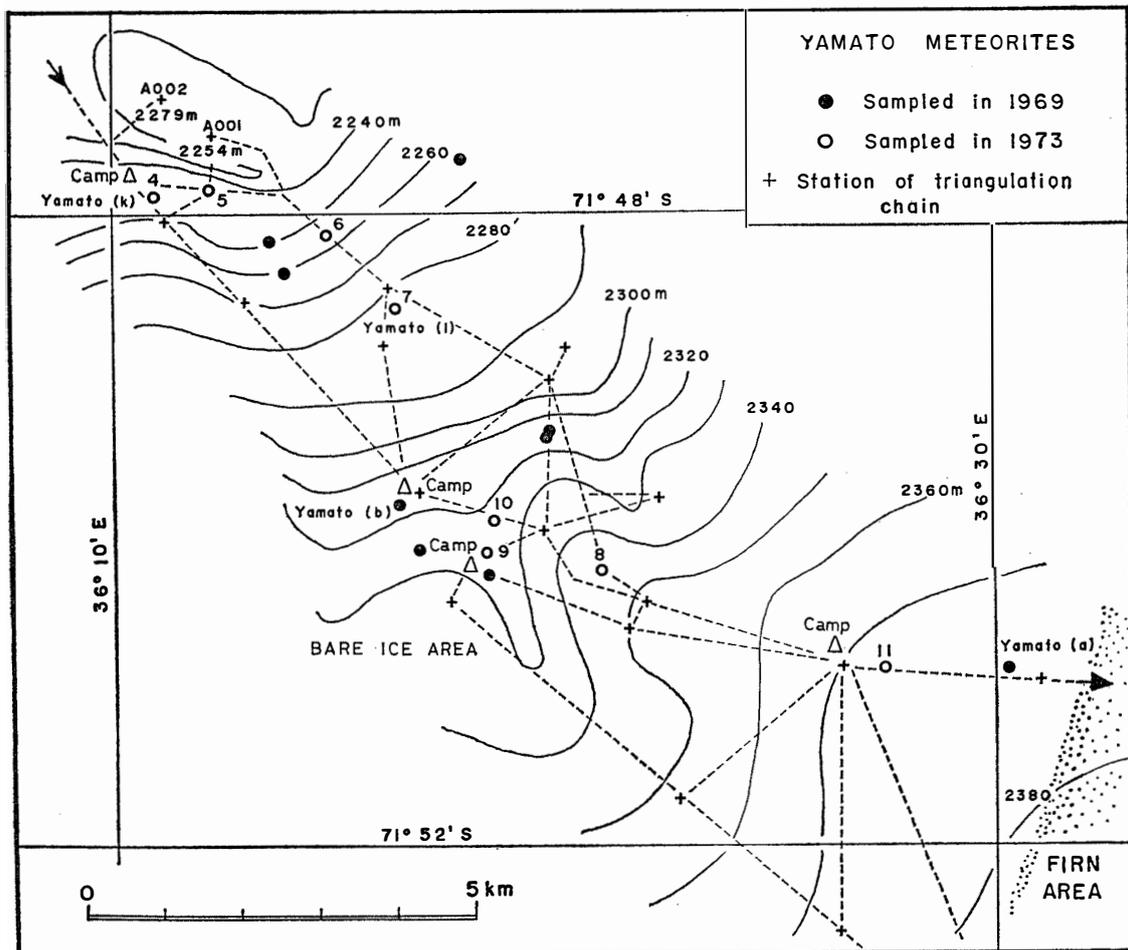


Fig. 5. Main sampling site of Yamato meteorites at the south-eastern end of the Yamato Mountains.

1974, a systematic search for meteorites in this area was carried out by a 4-man party of the 15th JARE (1973–1975); the party was rewarded by the collection of 663 stoney meteorite samples among which the largest one was about 20 cm in diameter. Details of this search will be reported in the very near future.

Several hypotheses have been suggested on the reason and mechanism of the concentration of meteorites in the southern Yamato Mountains area. YOSHIDA *et al.* (1971) suggested some mechanism of ice sheet movements contributing to the concentration of meteorites. SHIMA *et al.* (1974) measured the K/Ar solidification ages of the Yamato (a), (b), (c), and (d) with different values ranging from 23×10^6 years to 154×10^6 years; they were also in favor of the contribution of the ice sheet flow which brought the meteorites that had fallen in the upstream area into this particularly limited area near the Yamato Mountains.

Glaciological information of the area shown in Fig. 5 may account for the concentration of the meteorites. KUSUNOKI (1975) reported on the preliminary results of survey of the triangulation chain. Recently the detailed results of resurvey were reported by NARUSE and others (NARUSE, 1975). In Fig. 6 the surface ice flow vector and annual net ablation are indicated. In the eastern part of this area shown in Fig. 6, the surface flow speeds were less than 2 m/year which is about 1/8 of the values at about 37°E. This may suggest the deceleration of the ice sheet motion due to the presence of the Yamato Mountains. The decrease in the speed near the datum points is clearly seen in Fig. 6. Computation of heights of triangulation stations indicated vertical upward movement of ice sheet, giving an average of 5 cm/year between 1969 and 1973, which exhibits a striking contrast to non-vertical or downward motion in the more eastern part in firn area. Upward ice movement is

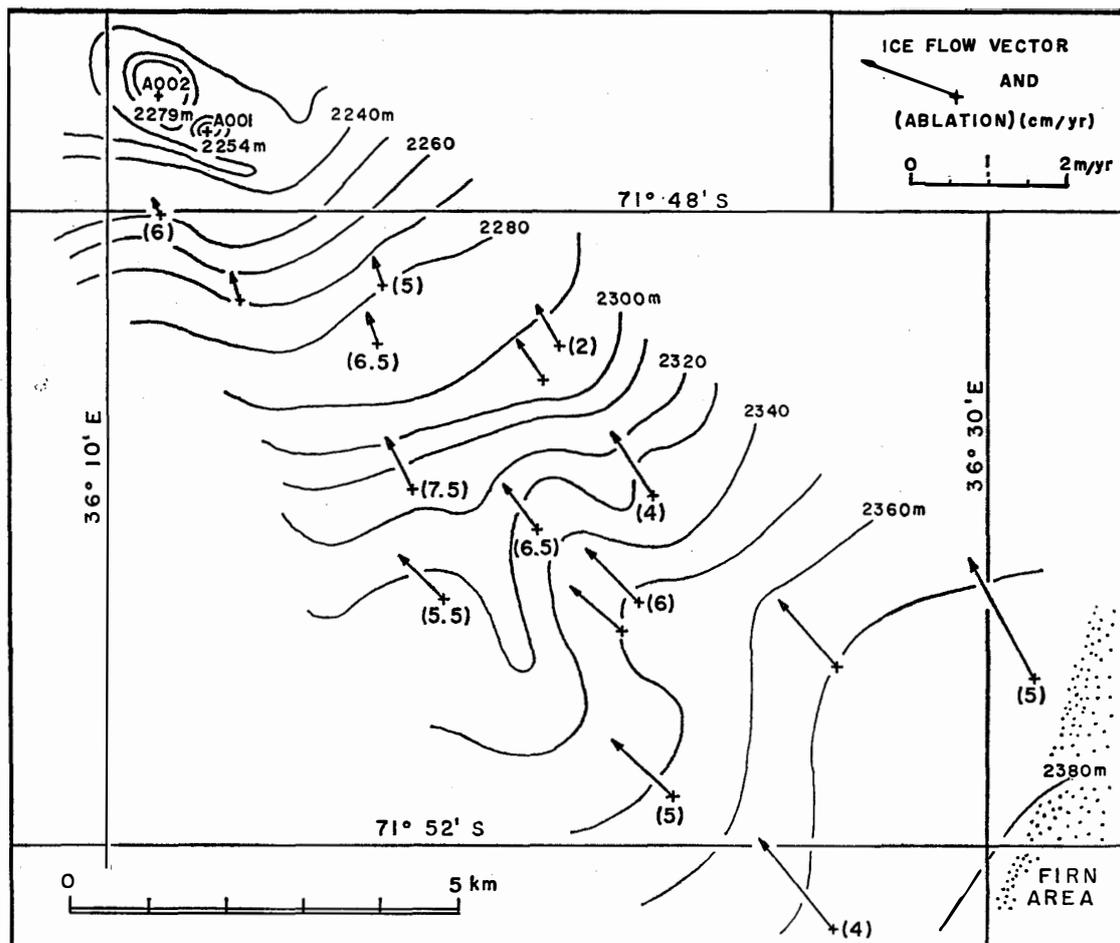


Fig. 6. Surface ice flow vectors and ablation at the main sampling site of Yamato meteorites.

in favor of the exposure of ice-buried meteorites.

The area shown in Fig. 6 has an average net ablation of 5.2 cm/year. This will also aid the exposure of meteorites buried in the ice. In order to give a more detailed interpretation of mechanism of the concentration of meteorites into this particular area, a more extensive search for meteorites and glaciological research of the vicinity and the hinterland drainage should be carried out. In order to verify the exposure of ice-buried meteorites onto the ice surface, the oversnow traverse party of the 16th JARE (1974–1976) visited the same area shown in Fig. 5 and was instructed to wipe out a certain area in expectation of appearance of meteorites in the future. It is, of course, necessary to continue laboratory studies of the meteorite samples, now totaling nearly one thousand.

Acknowledgements

We are very grateful to the members of the oversnow party of the 14th Japanese Antarctic Research Expedition for their assistance in the collection of meteorites.

References

- NARUSE, R. *ed.* (1975) : Glaciological research program in Mizuho Plateau–West Enderby Land, East Antarctica. Part 3, 1973–1974. JARE Data Rep., **28** (Glaciology), 121 pp.
- KUSUNOKI, K. (1975) : A note on the Yamato meteorites collected in December 1969. Mem. Natl. Inst. Polar Res., Special Issue, **5**, 1–8.
- SHIMA, M(asako), A. OKADA and M(akoto) SHIMA (1973) : Study of the extraterrestrial materials in Antarctica, III. On the Yamato meteorites. *Antarct. Rec.*, **47**, 86–97 (In Japanese).
- SHIMA, M(akoto), A. OKADA and M(asako) SHIMA (1974) : Study of the extraterrestrial materials in Antarctica, IV. On the Yamato meteorites. *Antarct. Rec.*, **48**, 91–99 (In Japanese).
- YOSHIDA, M., H. ANDO, K. OMOTO, R. NARUSE and Y. AGETA (1971) : Discovery of meteorites near Yamato Mountains, East Antarctica. *Antarct. Rec.*, **39**, 62–65.

(Received January 26, 1976)