YAMATO-74 METEORITES COLLECTION, ANTARCTICA FROM NOVEMBER TO DECEMBER 1974

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Abstract: 663 new Yamato meteorites have been found around the Yamato Mountains, East Antarctica, during the period from November to December 1974 by the meteorite searching team of the 15th Japanese Antarctic Research Expedition. In 1974, 1975 and 1976 more than 158 pieces had been found by a systematic search on the bare ice surface of an area of 10 km square where only 18 pieces were found in 1969 and 1973. Besides ordinary cases, there were two meteorites showing different modes of occurrence, one was found buried in the ice and the other lay on the firn (compact snow). This collection with specimens ranging in weight from 5,575 to 0.1 grams, was named Yamato-74 meteorites and the specimens were designated as Yamato-74001 to Yamato-74663 in order of discovery. They comprised one stony-iron (pallasite), 24 achondrites and many chondrites including carbonaceous chondrites, but no iron meteorite was found as was the case with earlier findings. Field occurrences and features of Yamato-74 meteorites are described in some detail, and a possibility of discovery of more meteorites is suggested.

1. Introduction

The meteorite search was initiated as a direct result of some accidental discoveries in 1969 and 1973 due to the dense concentration of meteorites on bare ice adjacent to the Yamato Mountains, East Antarctica. In the same bare ice field, 663 new extraterrestrial materials have been found and collected by the meteorite searching team of the 15th Japanese Antarctic Research Expedition 1973–1975 (JARE-15). Search for meteorites and geological survey were assigned to the team consisting of one geologist and three field assistants. The team concentrated its efforts on searching and collecting meteorites in the continental bare ice field (between 71°29′S and 71°53′S in latitude and between 34°35′E and 36°27′E in longitude) in the south to the west of the Yamato Mountains for 16 days during a period from October 25 to December 30, 1974. Collected materials were all meteorites and were officially named "Yamato-74 meteorites".

A preliminary classification of these meteorites revealed that they consisted of one stony-iron meteorite, carbonaceous chondrites, achondrites and chondrites. No iron meteorite was found.

The present paper describes the occurrences of meteorites and features of the bare ice field. In addition to field observations, the concentration mechanisms of meteorites and the relationship between moraines and meteorites are discussed.

2. Earlier Discovery of Meteorites

The Yamato meteorites are not the first meteorites found in the Antarctic Continent, but the number of meteorites found before 1969 was only four throughout the continent (Table 1). Therefore, it is a surprising and interesting fact that 21 pieces of meteorites were obtained from a very limited area in the vicinity of the Yamato Mountains.

Table 1. Antarctic meteorites found before 1969.

Name	Type	Original weight (kg)	Latitude Longitude	Date of find	Remarks
(1) Adélie Land	Chondrite	1 (2 lb $4^1/_2$ oz)	67°11'S 142°23'E	December 5, 1912	Found on snow
(2) Lazarev	Iron	10	71°57'S 11°30'E	January 21, 1961	Found in rocky area. 3,000 m in altitude
(3) Thiel Mts.	Pallasite	28.6	85°23.5'S 86°35.4'W	December 7, 1961	Found in morainal debris on ice
(4) Neptune Mts.	Iron	1.070	83°15'S 55°W	February 1964	

(1): BAYLY, P. G. W. and STILLWELL, F. L. (1923): The Adélie Land meteorite. Australasian Antarct. Exp., 1911–1914, Sci. Rep., Ser. A, **4**, Geology, 1–13.

(2) and (4): HEY, M. H. (1966): Catalogue of Meteorites, 3rd ed., London, The British Museum (Natural History), 637 p.

(3): FORD, A. B. and TABOR, R. W. (1971): The Thiel Mountains pallasite of Antarctica. U.S. Geol. Survey Prof. Paper, 750–D, D56–D60.

Some details of the discovery and collections of the meteorites in the Yamato Mountains region were described. On December 21, 1969, two pieces of stony meteorite were found on bare ice unexpectedly by the JARE-10 (1968–1970) Yamato traverse party on the route southeast of the Yamato Mountains. It was the first discovery of meteorites in this region and the fifth locality in the Antarctic Continent. By December 26, 1969, the party found seven more stony meteorites at closely spaced localities. These meteorites, later officially named "Yamato meteorites", were lying on the surface of bare ice free from snow cover as if they remained after ablation of snow and ice. Their localities were between 71°51'S, 36°28'E and 71°48'S, 36°12'E, within 11 km along the traverse route.

YOSHIDA *et al.* (1971) reported these findings, and KUSUNOKI (1975) gave a summary of this collection.

This collection was designated initially as Yamato (a) to Yamato (i) in alphabetical order, but the designation was later revised as Yamato-691 to Yamato-699 in order of discovery. Four large pieces have been classified petrologically as follows: Yamato-691(a) is enstatite chondrite (E), Yamato-692(b) is Ca-poor achondrite (diogenite), Yamato-693(c) is carbonaceous chondrite and Yamato-694(d) is bronzite chondrite(H) (Masako SHIMA *et al.*, 1973; Makoto SHIMA *et al.*, 1974). The rest are chondritic meteorites.

The Yamato traverse party of the JARE-14 (1972–1974) also found a total of twelve new pieces of stony meteorite in the same bare ice area and at the location 30–40 km east-northeast of the JARE-10 sampling sites. Four large pieces were designated as Yamato (j), (k), (l) and (m), and the rest small ones as Yamato (n) through Yamato (u). Recently these names were changed to Yamato-7301 to -7312 in order of finding.

A preliminary petrological study of four large specimens was carried out and they were classified as follows: Yamato-7301(j) bronzite chondrite(H4), -7304(m) and -7305(k) hypersthene chondrite(L5), and -7308(l) achondrite (howardite). The rest 8 specimens are chondritic meteorites. Iron and stony-iron meteorites have not been found.

A total of twenty-one meteorites were collected before the systematic search of the Yamato Mountains region was started in 1974.

3. Features of the Yamato Mountains and Surrounding Area

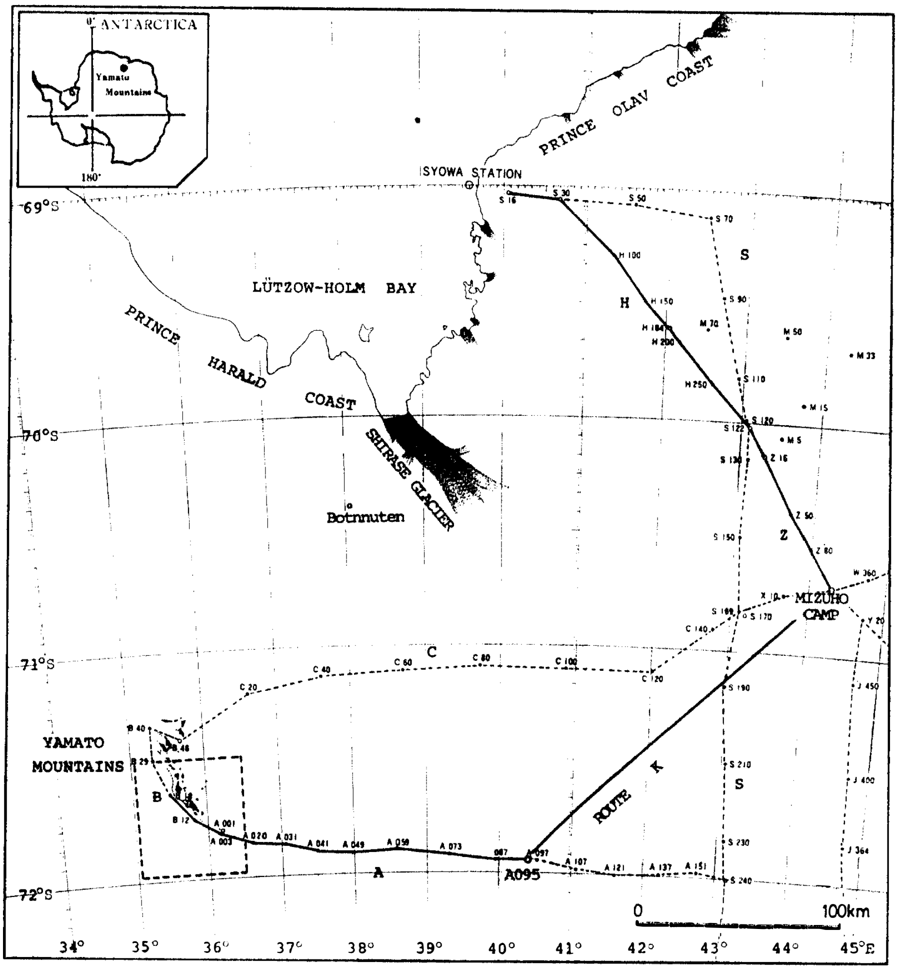


Fig. 1. Location of the Yamato Mountains, East Antarctica and area of search for meteorites.

The Yamato Mountains, at 300 km south-southwest inland from Syowa Station in East Antarctica, are located between 71°15′S and 72°05′S in latitude and 34°45′E and 36°15′E in longitude (Fig. 1). The mountains are arcuate, extending 50 km north-south and 2,000–2,500 m in altitude, rising 100–800 m

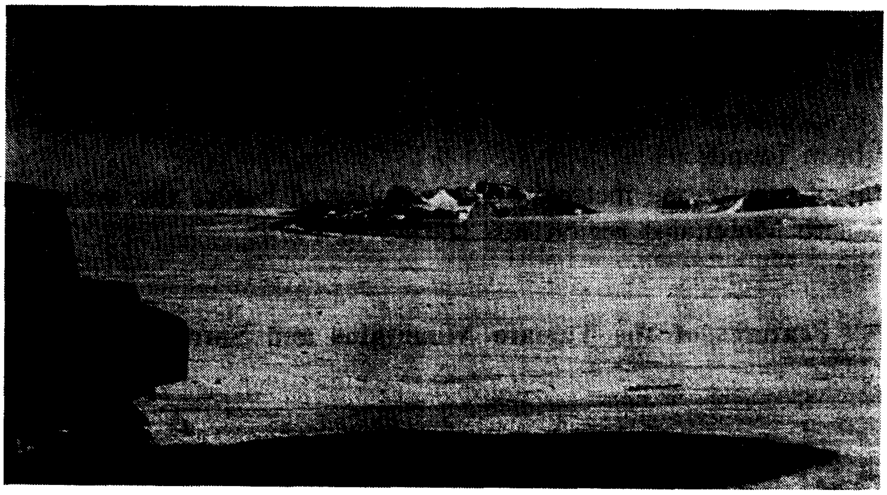


Fig. 2. Yamato Mountains and moraine band viewed from the west.

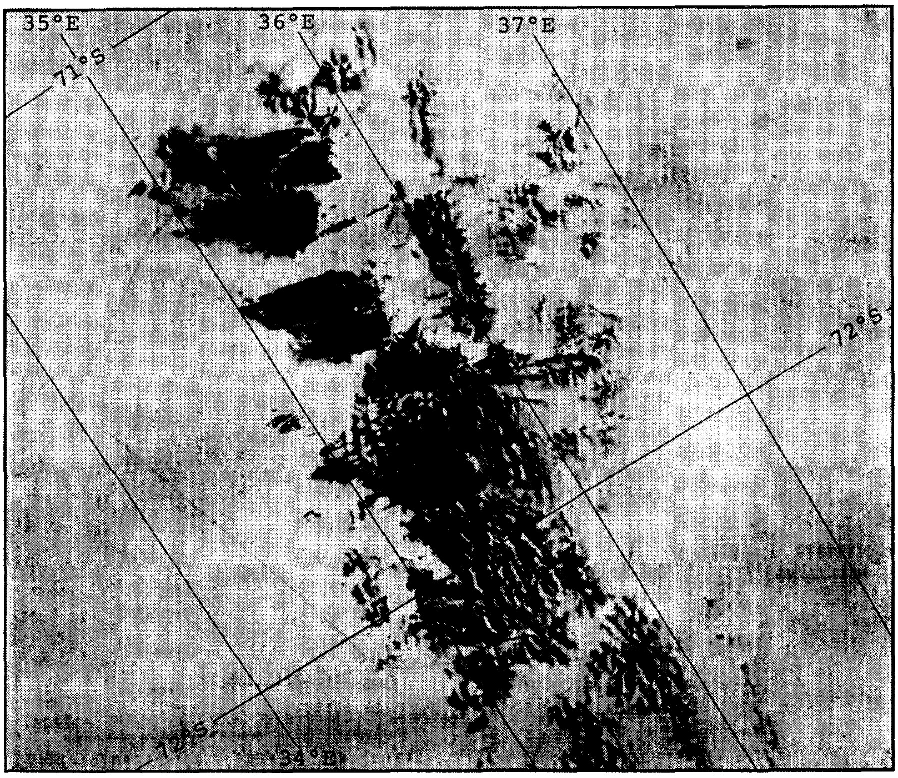


Fig. 3. Bare ice field, later named "Meteorite Ice Field", surrounding the Yamato Mountains, by Landsat image dated December 15, 1973. About 4,000 square km.

from the ice sheet surface, and comprise seven massifs (named A, B, C, D, E, F and G) and several small nunataks separated by outlet glaciers. Geologically the Yamato Mountains are involved in the basement complex of East Antarctica and consist mainly of banded gneissic and granitic rocks of Late Precambrian to Early Palaeozoic ages. Most of the rocks are reddish to pinkish and white to pale grey in color except for small amounts of dark-colored metabasites.

Moraines and detritus were formed around the nunataks and massifs. One of the largest moraine fields is located on the west side of Massifs A, B and C, extending 20–25 km north-south (Fig. 2). Massif A is covered mostly with morainic deposits, but other Massifs are less covered. Moraines consist of various kinds of rocks which were derived not only from the neighboring rocky areas but also from the basement under the continental ice sheet. In most cases, moraine occurs as a thin layer directly covering bare ice and rocky areas.

The area surrounding the Yamato Mountains is one of the largest bare ice fields in the Antarctic Continent, with an area of about 4,000 square kilometers. The bare ice field is shown in Fig. 3 based on Landsat (ERTS: Earth Resources Technology Satellite) image, and it seems to extend 30 km south beyond the south end of the image.

4. Operations of the Yamato Traverse and Search for Meteorites

The Yamato traverse party of the JARE-15 consisted of four men, author (geologist), S. Kaneko (technician of snow vehicle), H. Kosakai (cook and field assistant) and K. Terai (logistics and field assistant). Since the main purpose of the party was the search for meteorites in the bare ice field and geological

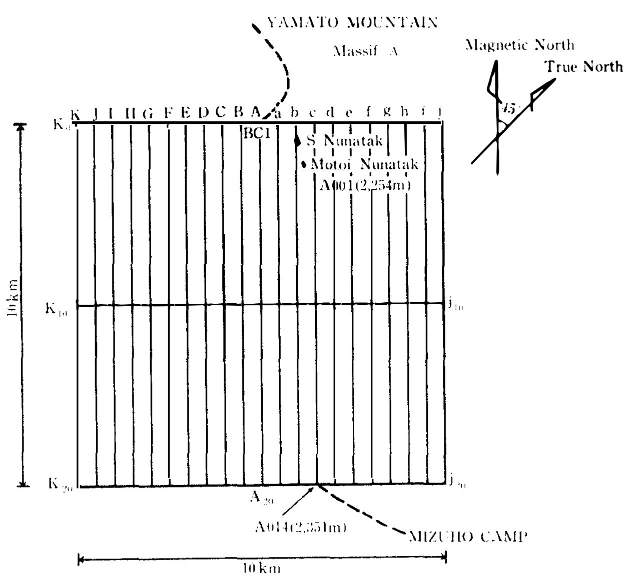


Fig. 4. Grid for the detailed search (systematic search) for Yamato meteorites.

survey of the Yamato Mountains, it was the important point that the party could reach the Yamato Mountains without mishap. The traverse routes, the location of the Yamato Mountains and the area of meteorite search are illustrated in Fig. 1. The party left Syowa Station on October 25, 1974. Hampered often by big troubles the party arrived at the Yamato Mountains on November 24, via Routes S, H, Z, Mizuho Camp, Routes K and A. After searching for meteorites and surveying geology in the Yamato Mountains region, the party returned to the Station on January 17, 1975.

The meteorites searching team carried out systematic search of the bare ice field where 21 meteorites had been previously found quite accidentally in a limited area. As shown in Fig. 4 the team set up the grid of 10 km square for the detailed search at a locality 20 km southeast of Massif A. The searching in the grid was successful, so that the team extended the area of search in the wide bare ice field west of the Yamato Mountains and surrounding Massif A.

Besides searching for meteorites, the team observed the relations of concentration mechanisms between meteorites and moraines which are similar to meteorites in occurrences, and the geology of Massifs B, C and moraines was observed for comparative study.

During the field work in the Yamato Mountains region in November and December 1974, the time available for meteorite search was very limited because of harsh weather conditions where the temperature was -19.2°C at the lowest, -13.5°C on the average at 1200 local time, and the wind velocity was 20.5 m/s in the maximum and 14 m/s on the average. Blizzard and white-out were often encountered. In addition to the unfavorable weather, many crevasses on the ice sheet made it impossible for the team to approach all bare ice areas. Their activities were also limited by shortage of fuel.

5. Search for Yamato Meteorites in November and December 1974

On November 24, 1974 the traverse party of the JARE-15 collected two pieces of chondrite lying on the surface of the bare ice along the course of over-snow traverse where meteorites had been discovered in December 1969 and December 1973. Photographs of this field, later named "Meteorite Ice Field", are shown in Fig. 5. The firn area is almost white in color and the bare ice area is pale blue to whitish-blue at the surface, while meteorites covered with fusion crust are commonly dark-colored. This contrastive feature makes it easier to find meteorites. Details of meteorites search are described in the following chapter.

5.1. Systematic search for Yamato meteorites in the grid

The party maintained a base camp (BC1) on the bare ice 1.7 km northwest from Motoi Nunatak, from November 24 to December 7. On November 25, the party started the detailed search in the grid of 500 m span, by slowly driving the snow vehicle and stopping at intervals of 500 m, to look for meteorites either

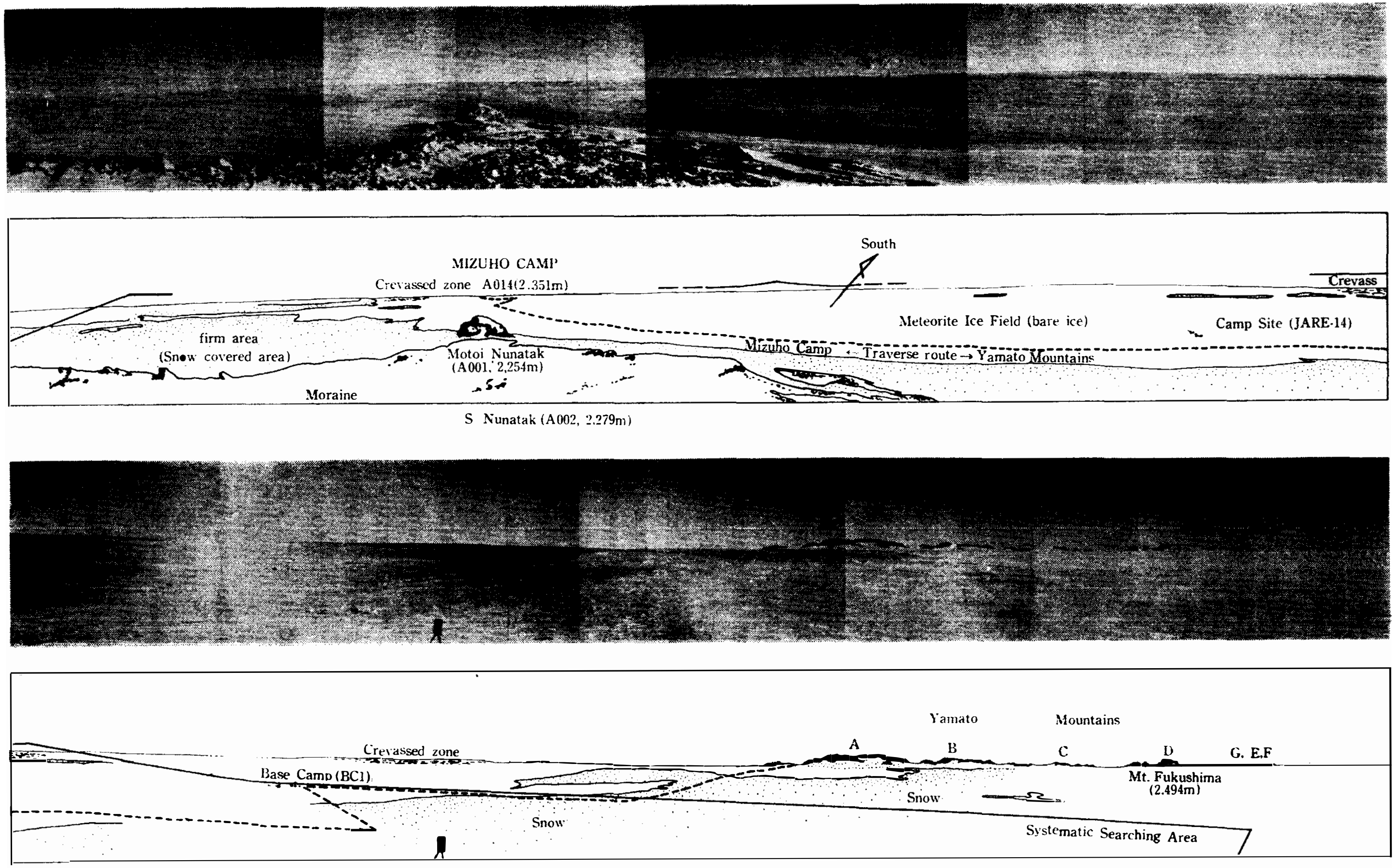


Fig. 5. Geomorphological features of the grid (systematic searching area) surrounding Motoi Nunatak at the south end of the Yamato Mountains.

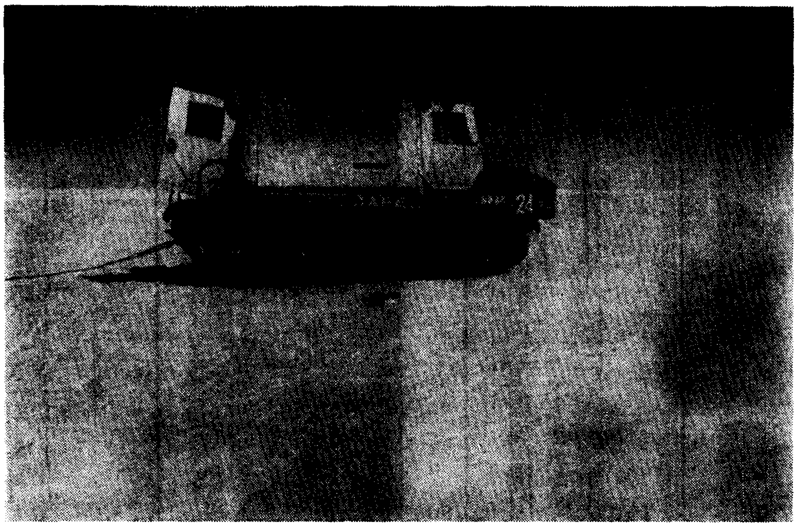


Fig. 6. Snapshot of the meteorite search on the bare ice field near the Yamato Mountains. Black material is Yamato-74371 meteorite 5.032 kg in weight.

with the naked eye or with the aid of a ten-power binoculer from the roof of the snow vehicle. On account of the contrasting features, even very small meteorites, less than 1 cm in diameter, were easily recognized, but the party might have missed meteorites existing in the inter-span parts where the search was hampered by the rough surface of the ice and the bad weather, for the JARE-16 party later has found numerous specimens in the same grid (MATSUMOTO, 1977). A snapshot of the meteorites search is shown in Fig. 6. The party searched for meteorites often on foot in a narrow area near the campsite (BC1).

By December 7, the party collected 158 pieces of extraterrestrial materials from the surface of the bare ice in the grid and near the campsite after 217.2 km of snow vehicle driving. No meteorites were found in the firn area. All meteorites collected were sitting on the surface of the bare ice. They were classified into stony-iron meteorite, achondrites and chondrites. Iron meteorite was not found in the grid the same as in the previous cases of finding.

Most of the meteorites occur usually as isolated pieces of complete or fragmental forms, but in rare cases ten to several tens of fragments occur concentrated in a very limited area, and in such cases the fragments are similar in kind and appearance.

Terrestrial materials in the grid have their source in bedrocks and moraines adjacent to Motoi and S Nunataks. Small rock fragments also abound on the surface of bare ice adjacent to the nunataks and on the lee of the nunataks. These fragments seem to have been moved from the nunataks to the bare ice area by strong wind, because they are very similar in kind to those at the adjacent nunataks. On the other hand, on the windward southeast side of the nunataks several dark spots were found to be all meteorites excepting dust which was raised and scattered by the traverse parties.

5.2. Searching in the southwest area of Massifs A and B

On December 8, the party approached Massif B along the western side of the moraine band, and maintained a base camp (BC2) on the bare ice near the moraine band adjacent to Massif B. In this area seven meteorites were found by rough searching. Geological survey of Massif B, Massif C and several moraines was carried out, but no meteorite was found there. This fact does not mean that no meteorite exists in these areas, since the main task of the party was geological survey as mentioned above. Meteorites are easily distinguished from ordinary rock fragments when they are lying on the surface of bare ice field, but it is very difficult even for meteorite specialists to detect a few pieces of extraterrestrial materials among abundant terrestrial fragments in moraine fields or rocky areas because they are very similar in many points of their features (Fig. 7).

The campsite (BC2) was on the ice sheet southwest of Massif B, and meteorites search was carried out between BC2 and Kabuto Nunatak, and in the northwest area where an extensive bare ice field stretched. In the three-day field work, the party found many chondritic meteorites lying on the surface of the bare ice field but none in the firn area. No iron meteorite was found either. Later, however, the JARE-16 party has found one iron meteorite on the bare ice near the moraine band in the south of BC2 (MATSUMOTO, 1977).

On December 19, the party returned to Massif A along the moraine band and set up a base camp (BC3) for two days on the bare ice at the southwest foot of Massif A. Meteorites search was carried out in the bare ice field between Massif A and the crevassed zone located 20 km southwest of it. At X1 position 2.5 km southeast of BC3, the party found dense concentration of meteorite

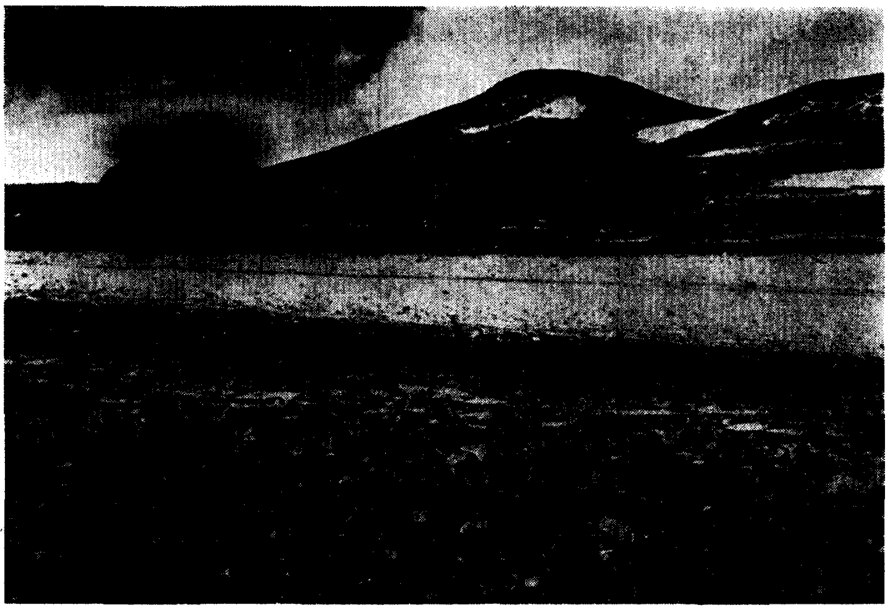


Fig. 7. Geomorphological features of the moraine area on the west side of Massif C, central Yamato Mountains. Thin layer of moraine covers the rocky area and bare ice.

pieces in a very limited area of about 200 m square. Over one hundred fragments of meteorites were collected from this locality.

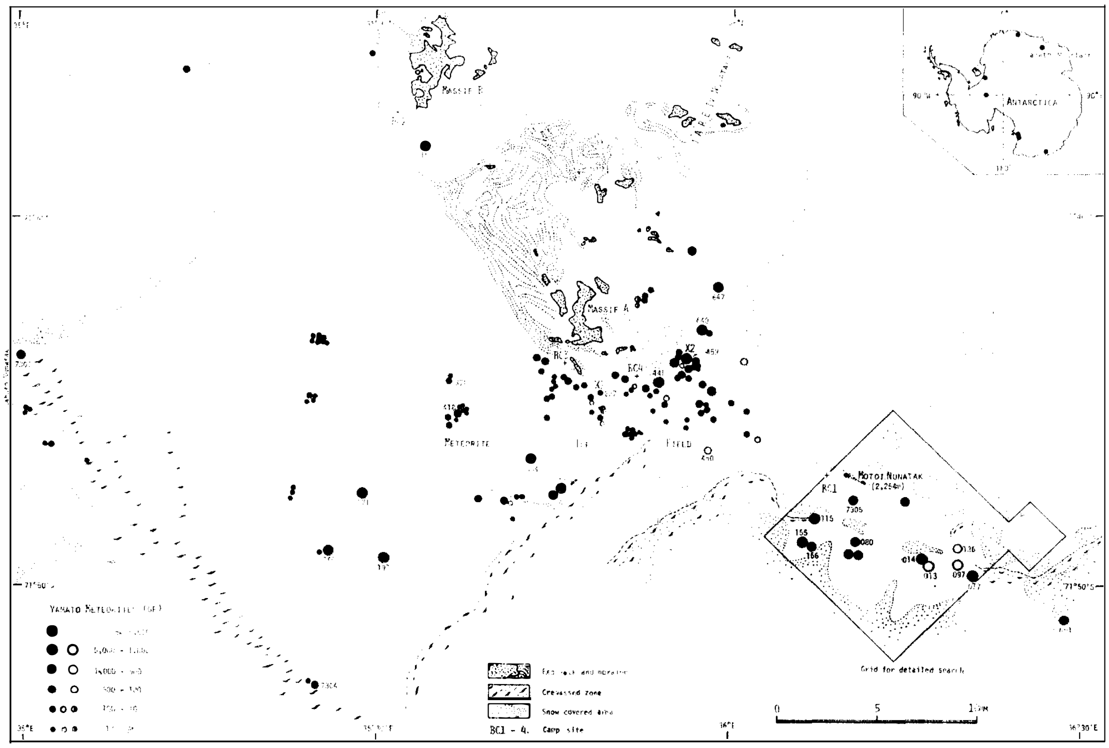
Two new singular occurrences were recognized in this area; one is a small meteorite fragment sitting on the surface of the compact firn, and the other was buried in ice a few centimeters below the surface. Details of these occurrences are given in later chapters.

By December 21, a total of 284 specimens were collected in these areas.

5.3. Searching in the southern areas of Massif A

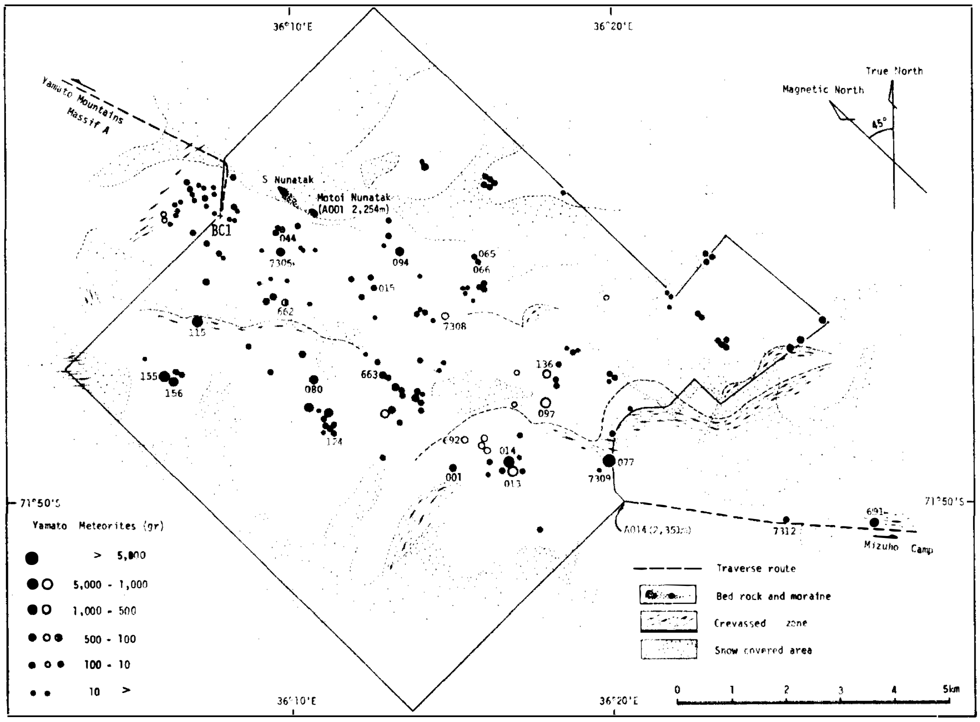
The party maintained a camp (BC4) at the southeast end of the Yamato Mountaines from December 21 to 29, carrying out meteorites search for four days in the eastern to southeastern areas of Massif A. The party found densely concentrated occurrence of meteorite pieces at X2 position in a limited area of 200 to 300 m square. These pieces are chondrite fragments including one achondrite and one complete chondrite specimen covered entirely by fusion crust. At another place in this area carbonaceous chondrites were collected. After searching for four days the party collected 211 specimens including a few achondrites. All meteorites collected in this area were sitting on the bare ice surface.

On December 30, the party returned to 10 km east of the grid on the traverse



●: Chondrite, ○: Achondrite, ◑: Carbonaceous chondrite.

Fig. 8. Sampling sites of Yamato meteorites and searching routes in the Meteorite Ice Field, southern Yamato Mountains. Those of 1973 collection are also shown.



●: Chondrite, ○: Achondrite, ◑: Conbonaceous chondrite, ◉: Stony-iron (Pallasite).

Fig. 9. Sampling sites and routes of the systematic search of Yamato meteorites in the Meteorite Ice Field, southeastern end of the Yamato Mountains. Those of 1969 and 1973 collections are also shown.

route (Route A, see Fig. 1). On that day the party collected ten stony meteorites on the surface of the bare ice including one carbonaceous chondrite. The meteorites search was finished by the end of this year after collecting a total of 663 meteorites.

5.4. Result of meteorite searching

The locations of the Yamato-74 meteorites are shown in Figs. 8 and 9, together with those in 1969 and 1973 collections.

Some photographs of larger specimens (heavier than 1 kg in weight) are shown in Fig. 10. In order to help to visualize the mode of meteorite occurrence in the field, some photographs taken *in situ* are presented in Fig. 11. Details of occurrences will be given later.

Preliminary analysis revealed that one specimen was pallasite, 24 were achondrites and the rest were chondrites of various petrological types. Identified specimens are shown in Table 2, and some of the specimens are reported by YANAI *et al.* (1978), TAKEDA *et al.* (1978), KIMURA *et al.* (1978) and YABUKI *et al.* (1978).

6. Feild Occurrences of the Yamato-74 Meteorites

Yamato meteorites are characteristic in occurrence as their distribution is limited almost to the bare ice field with one exception. The majority of the

Table 2. List of Yamato-74 meteorites, heavier than 1 kg in weight, collected in November to December 1973.

No.	Designation	Initial sample number	Original weight (g)	Size (cm)	Date of find (1974)	Classification	Remarks
1	Yamato-74077	1974112911	5575.1	20×18.5	Nov. 29	Chondrite (H)	See Figs. 10a and 11a Found on bare ice grid
2	Yamato-74371	1974122024	5032.5	18×12	Dec. 20	Chondrite (H)	See Figs. 10b and 11b Found on bare ice
3	Yamato-74362	1974122007	4175.0	15×13	Dec. 20	Chondrite (L)	See Figs. 10c and 11c Found on bare ice
4	Yamato-74190	1974121006	3188.7	13×12.5	Dec. 10	Chondrite (L)	See Figs. 10d and 11d Found on bare ice, few fragments scattered around the main body
5	Yamato-74155	1974120702–1	3073.4	15×14	Dec. 7	Chondrite (H)	See Figs. 10e and 11e Found on bare ice in the grid, broken into half
6	Yamato-74354	1974121908	2721.1	14×11	Dec. 19	Chondrite (L)	See Figs. 10f and 11f Found on bare ice, weathered surface
7	Yamato-74014	1974112512	2367.9	15×12	Nov. 25	Chondrite (H)	See Figs. 10g and 11g Found on bare ice in the grid, complete form
8	Yamato-74647	1974122809	2323.8	12×11.5	Dec. 28	Chondrite (H)	See Figs. 10h and 11h Found on bare ice
9	Yamato-74445	1974122203	2293.2	14×12	Dec. 22	Chondrite (L)	See Fig. 10i Found on bare ice
10	Yamato-74097	1974120205	2193.9	16×11	Dec. 2	Achondrite (Diogenite)	See Figs. 10j and 11i Found on bare ice in the grid, broken
11	Yamato-74013	1974112511	2059.5	15×10	Nov. 25	Achondrite (Diogentie)	See Figs. 10k and 11j Found on bare ice in the grid, broken
12	Yamato-74193	1974121701	1818.5	12× 8.5	Dec. 17	Chondrite	See Figs. 10l Found on bare ice
13	Yamato-74459	1974122314	1719.7	13×11	Dec. 23	Chondrite (H)	See Figs. 10m and 11k Found on bare ice
14	Yamato-74191	1974121007	1091.6	12×10	Dec. 10	Chondrite (L)	See Figs. 10n and 11l Found on bare ice
15	Yamato-74640	1974122802	1065.9	12×10	Dec. 28	Chondrite (H)	See Figs. 10o and 11m Found on bare ice
16	Yamato-74115	1974120301	1045.1	12.5×10.5	Dec. 3	Chondrite (H)	See Figs. 10p and 11n Found on bare ice in the grid on steep slope

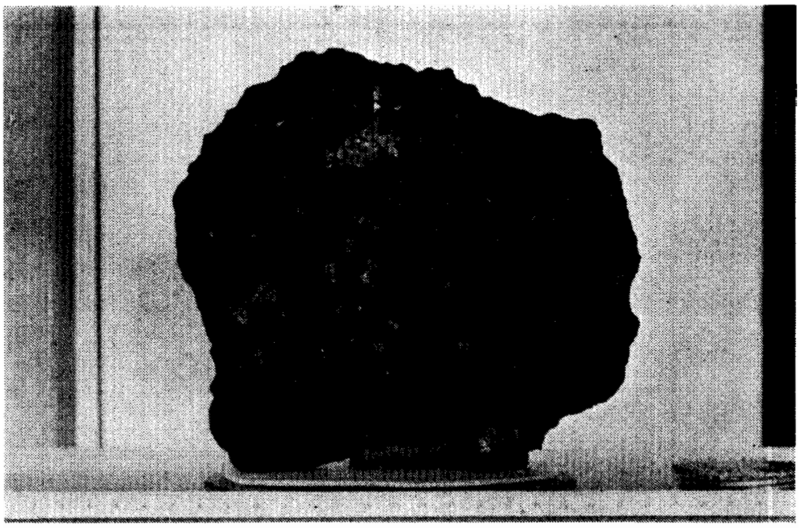


Fig. 10a. Yamato-74077 chondrite, 5,575.1 grams. Largest one in the 1974 collection, exhibiting a spherical shape with fused surface and thumbprints.

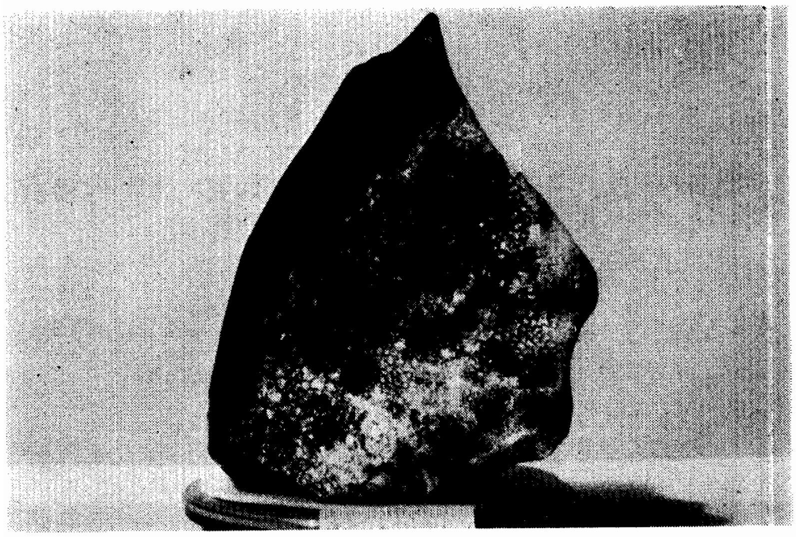


Fig. 10b. Yamato-74371 chondrite, 5,032.5 grams. White mineral on the surface is nesquehonite ($MgCO_3$–$3H_2O$).

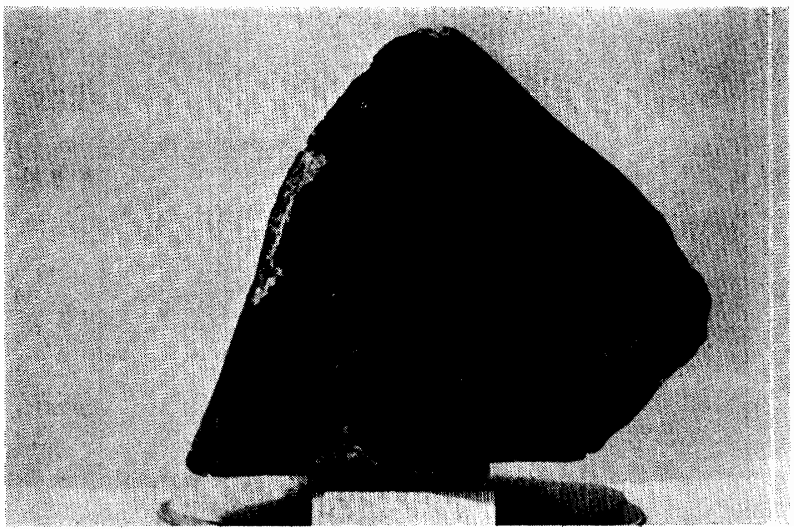


Fig. 10c. Yamato-74362 chondrite, 4,175.0 grams.

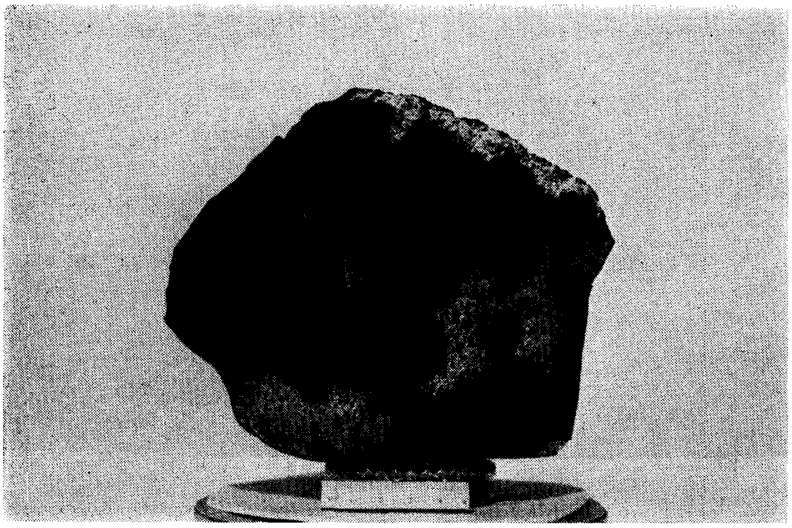


Fig. 10d. Yamato-74190 chondrite, 3,188.7 grams.

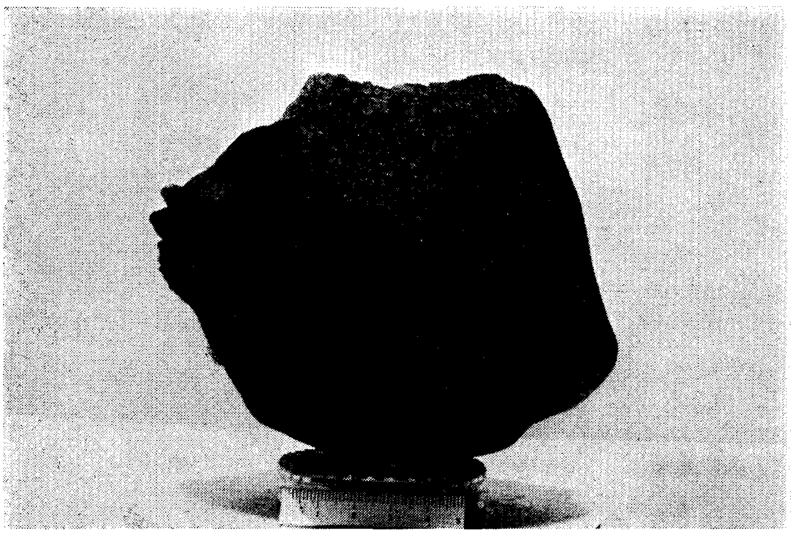


Fig. 10e. Yamato-74155 chondrite, 3,073.4 grams.

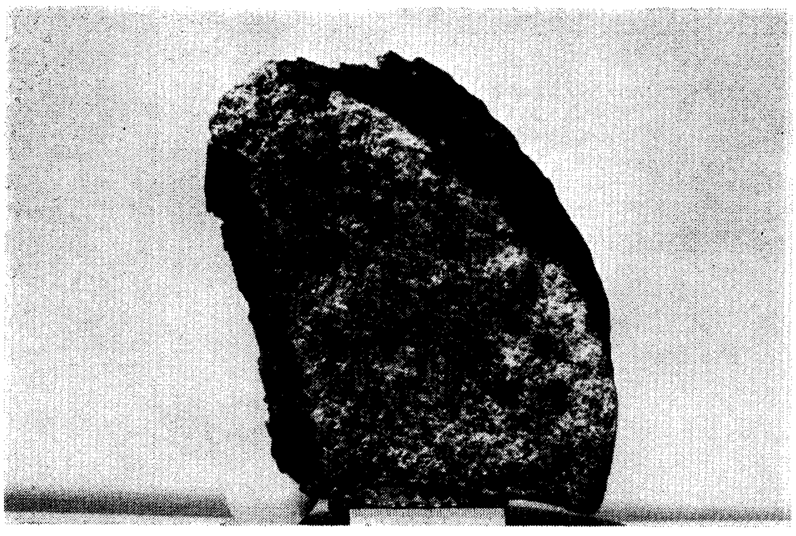


Fig. 10f. Yamato-74354 chondrite, 2,721.1 grams, showing weathered surface.

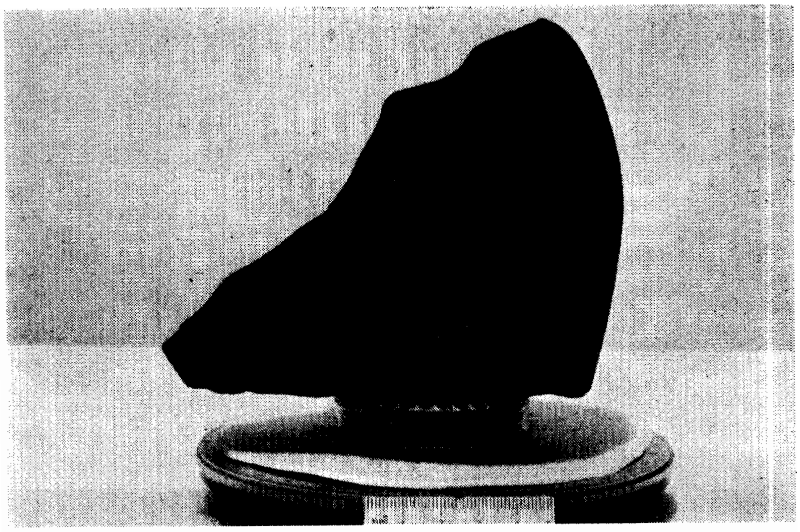


Fig. 10g. Yamato-74014 chondrite, 2,367.9 grams, complete form with two stages of fusion crust.

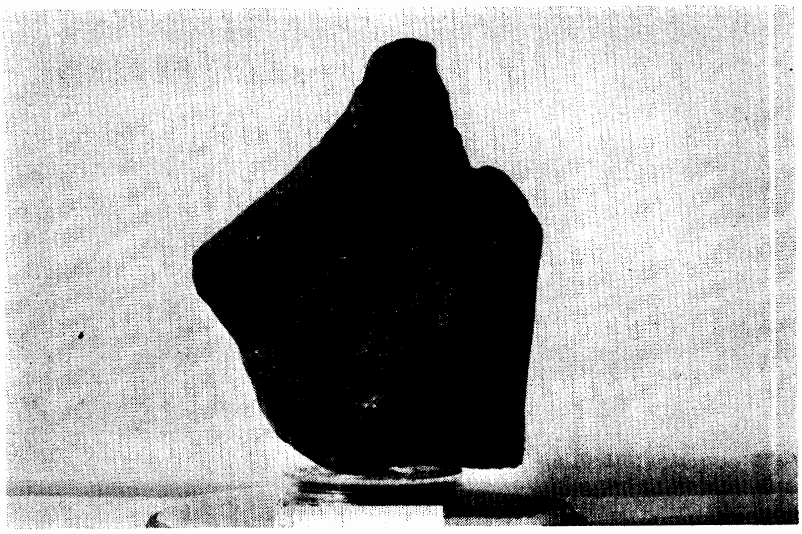


Fig. 10h. Yamato-74647 chondrite, 2,323.8 grams, complete form with thumbprints.

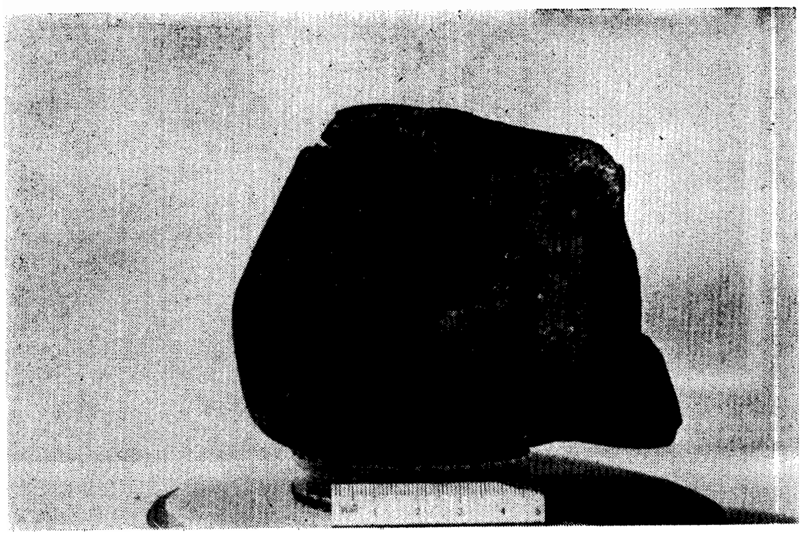


Fig. 10i. Yamato-74445 chondrite, 2,293.2 grams, with irregular traverse cracks.

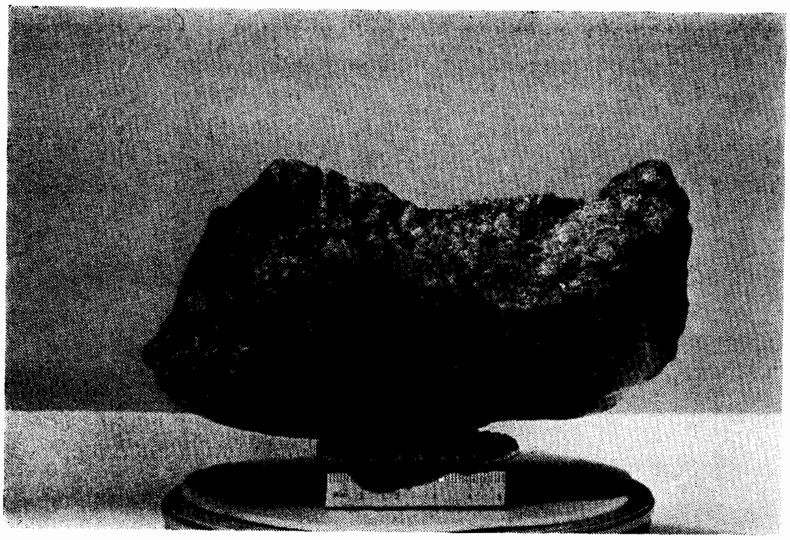


Fig. 10j. Yamato-74097 achondrite, 2,193.9 grams, exhibiting a broken feature without fusion crust. Fresh surface has olivine color in which are scattered large crystals of chromite.

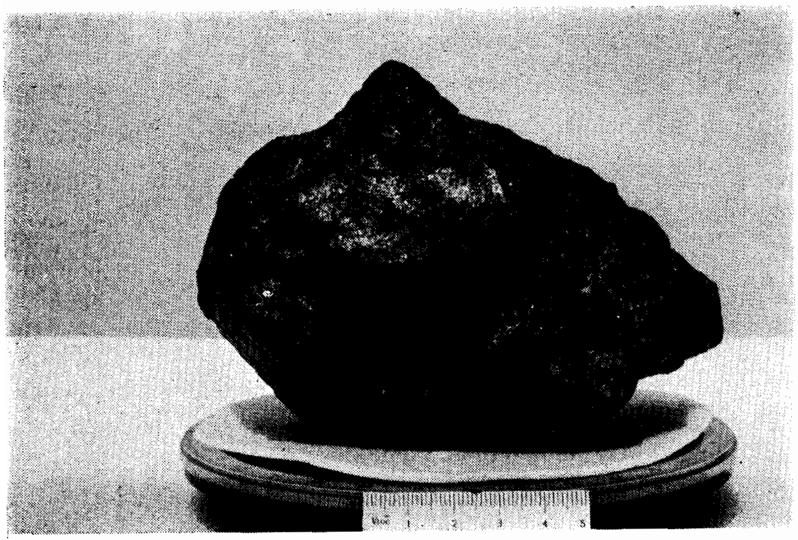


Fig. 10k. Yamato-74013 achondrite, 2,059.5 grams, similar to Yamato-74097 achondrite.

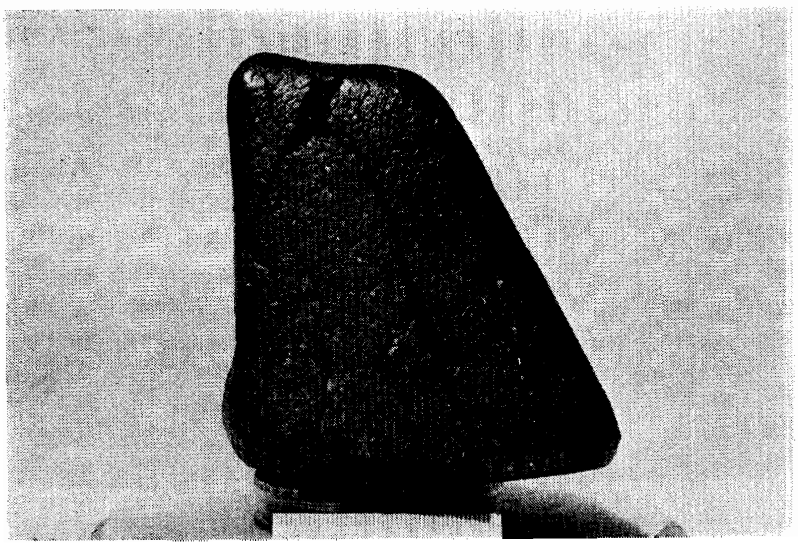


Fig. 10l. Yamato-74193 chondrite, 1,818.5 grams, complete form traversed by some irregular cracks.

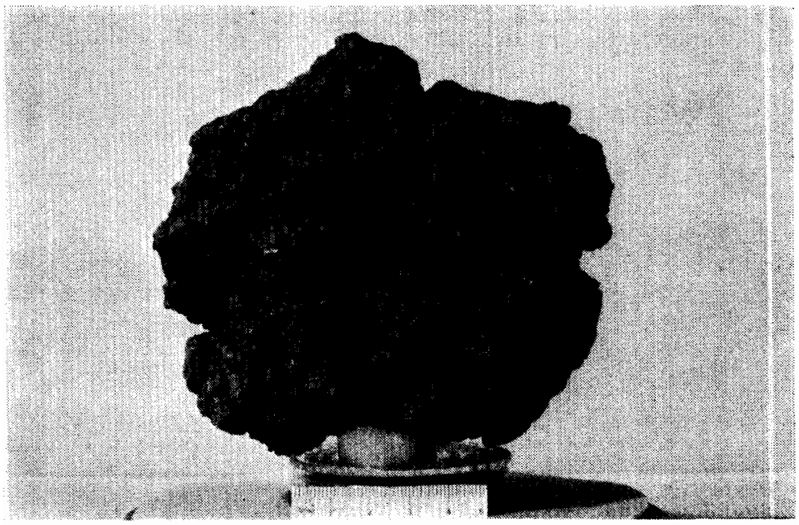


Fig. 10m. Yamato-74459 chondrite, 1,719.7 grams, showing no fusion crust.

Fig. 10n. Yamato-74191 chondrite, 1,091.6 grams.

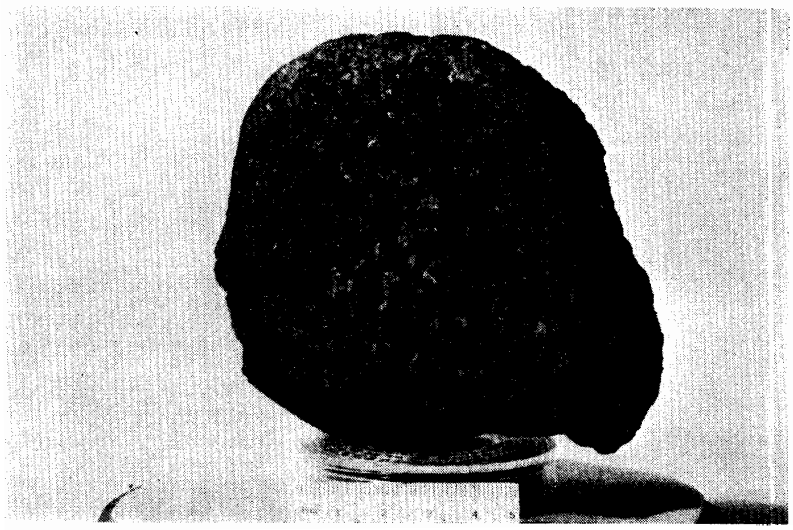


Fig. 10o. Yamato-74640 chondrite, 1,065.9 grams.

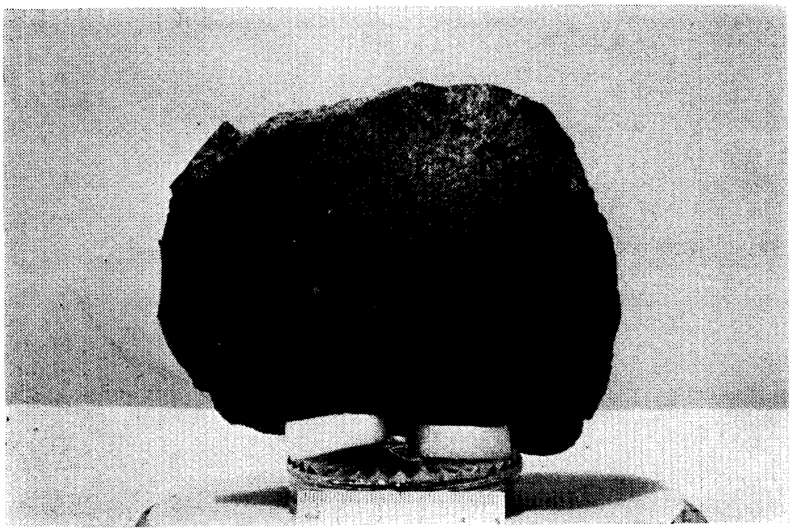


Fig. 10p. Yamato-74115 chondrite, 1,045.1 grams.

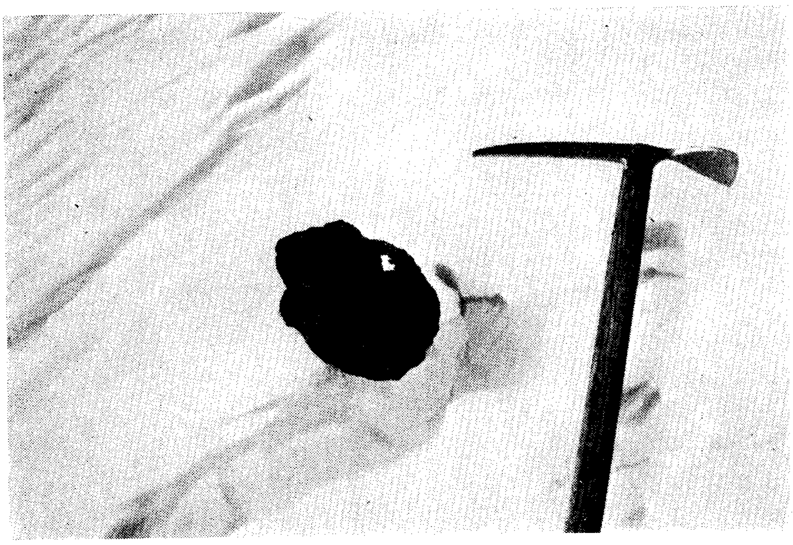


Fig. 11a. Yamato-74077 chondrite, 5,575.1 grams, collected on November 29.

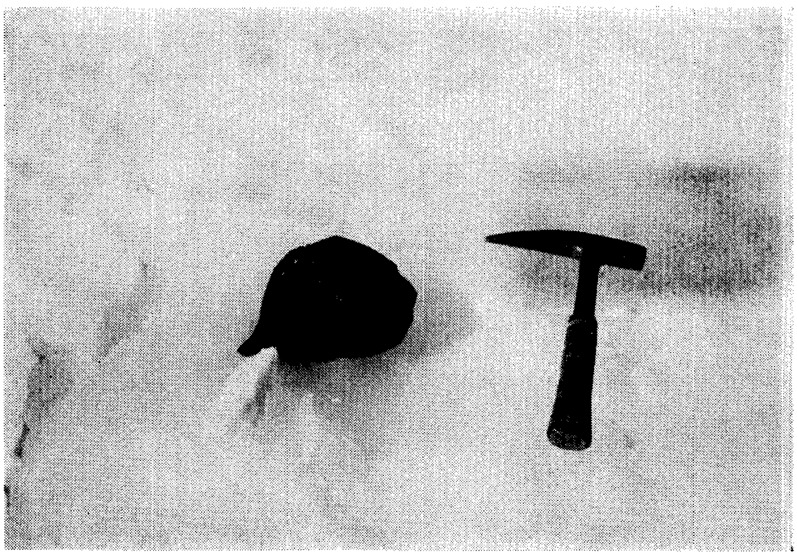


Fig. 11b. Yamato-74371 chondrite, 5,032.5 grams, collected on December 20.

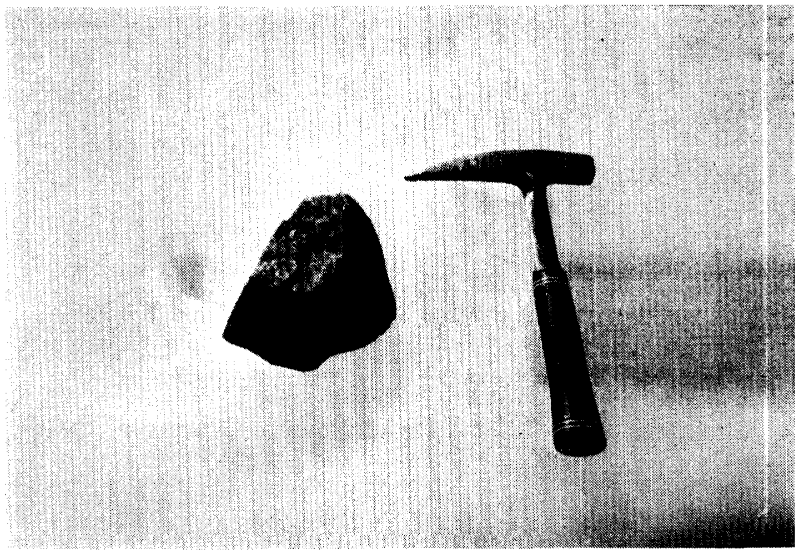


Fig. 11c. *Yamato-74362 chondrite, 4,175.0 grams, collected on December 20.*

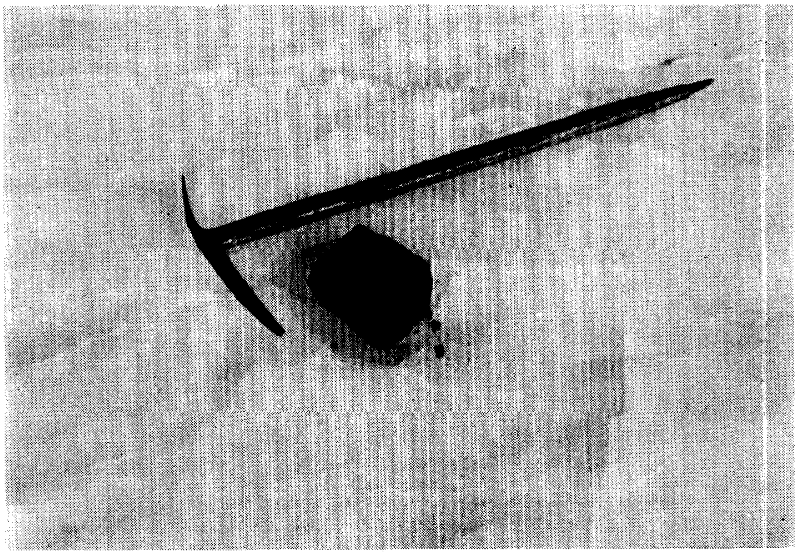


Fig. 11d. *Yamato-74190 chondrite, 3,188.7 grams, collected on December 10.*

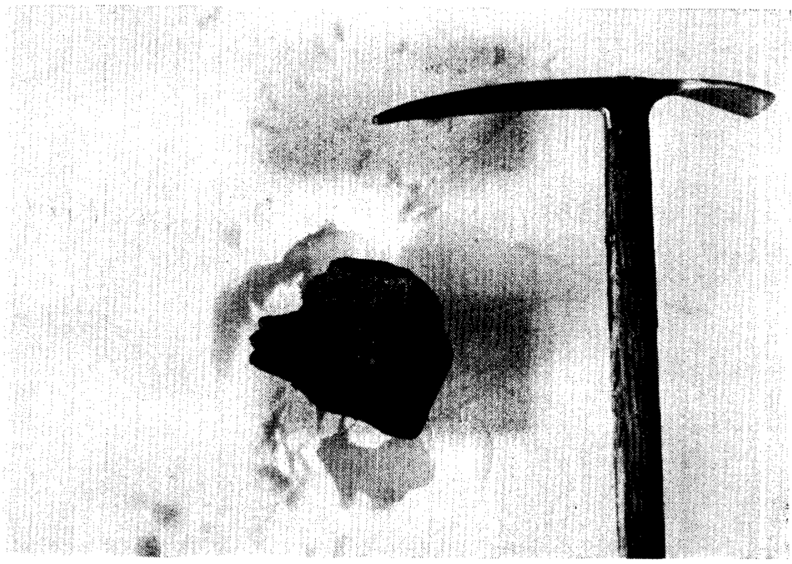


Fig. 11e. *Yamato-74155 chondrite, 3,073.4 grams, collected on December 7.*

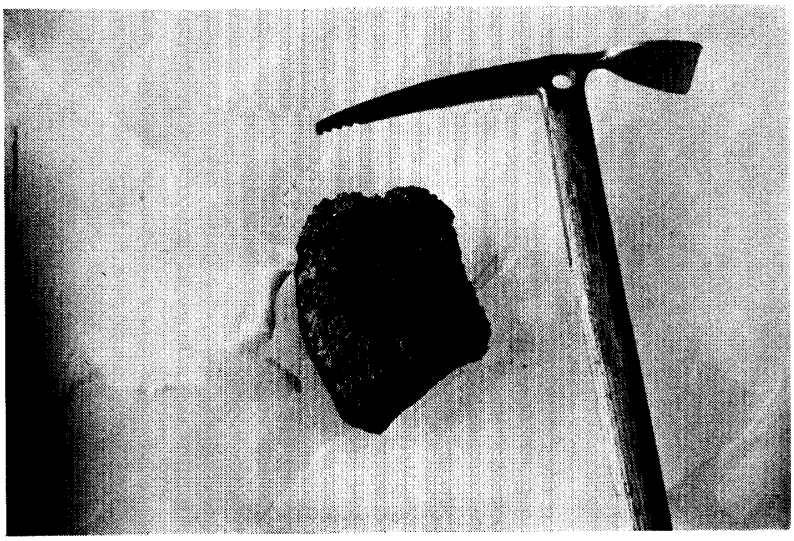


Fig. 11f. *Yamato-74345 chondrite, 2,721.1 grams, collected on December 19.*

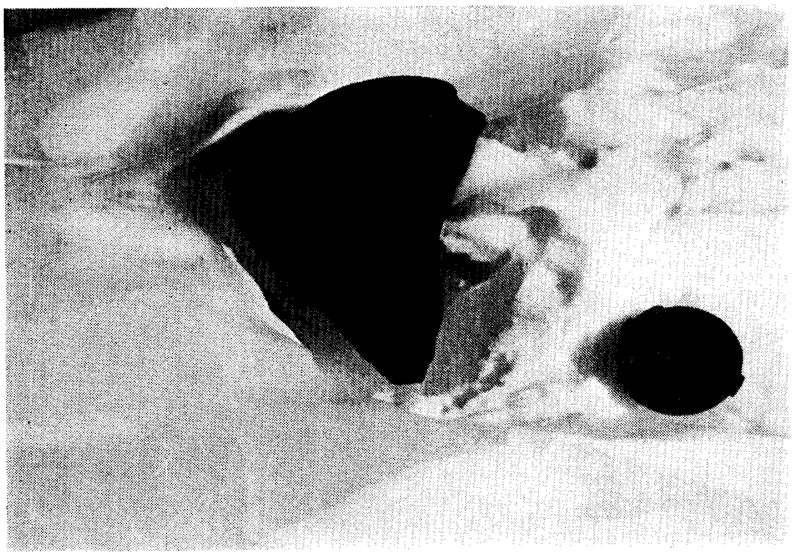


Fig. 11g. *Yamato-74014 chondrite, 2,367.9 grams, collected on November 25.*

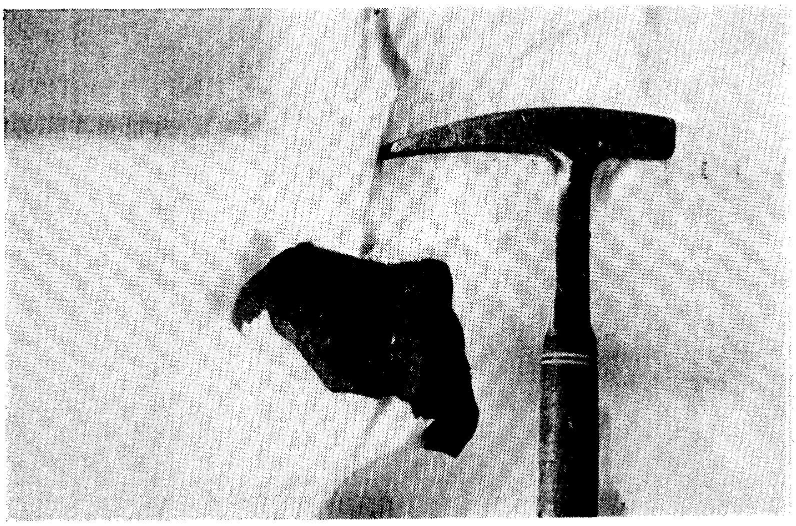


Fig. 11h. *Yamato-74647 chondrite, 3,323.8 grams, collected on December 28.*

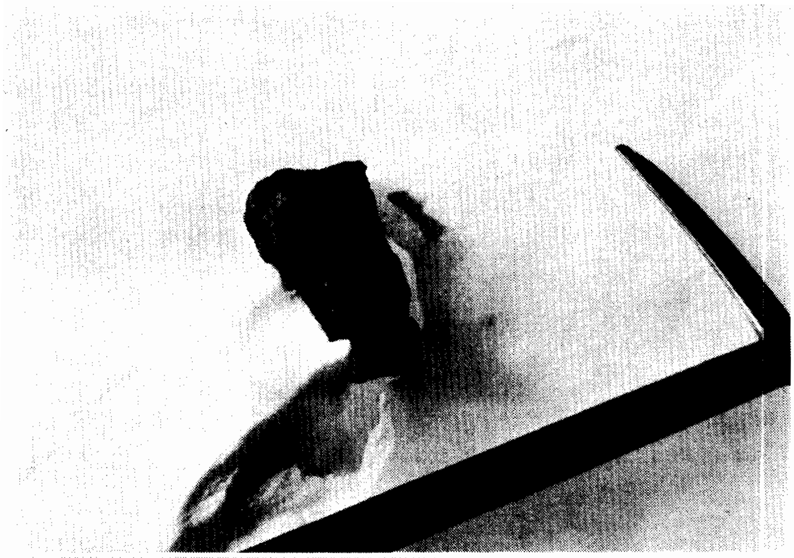


Fig. 11i. Yamato-74097 achondrite, 2,193.9 grams, collected on December 2.

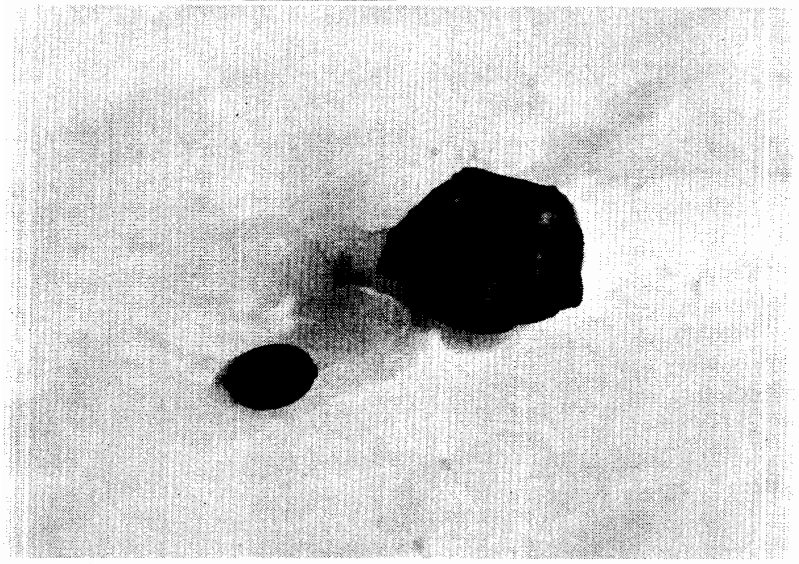


Fig. 11j. Yamato-74013 achondrite, 2,059.5 grams, collected on November 25.

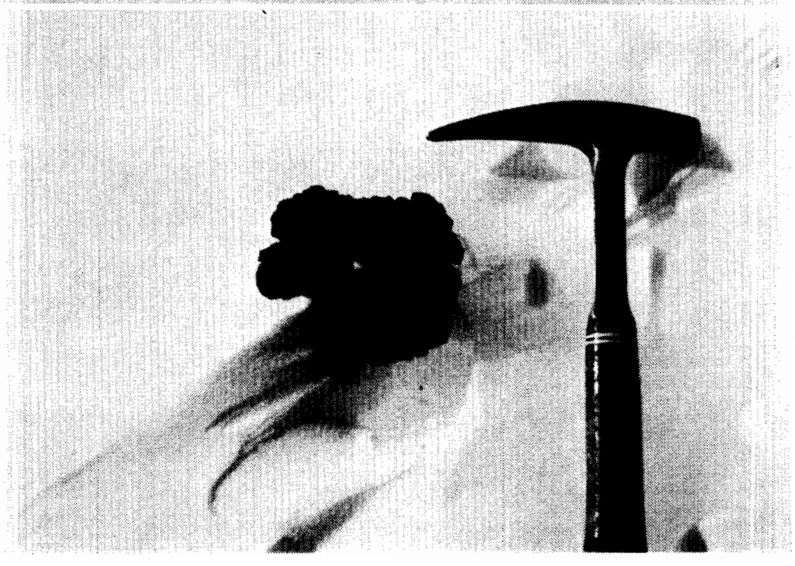


Fig. 11k. Yamato-74459 chondrite, 1,719.7 grams, collected on December 23.

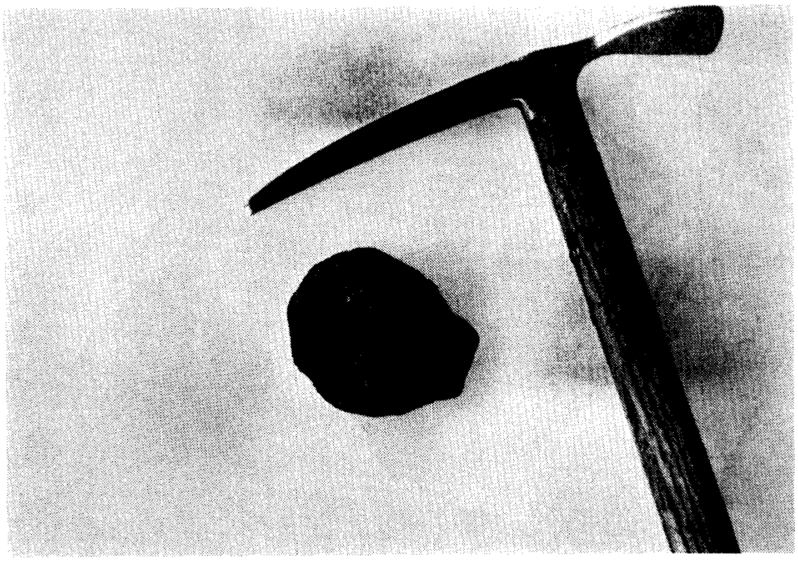


Fig. 11l. Yamato-74191 chondrite, 1,091.6 grams, collected on December 10.

Fig. 11m. Yamato-74640 chondrite, 1,065.9 grams, collected on December 28.

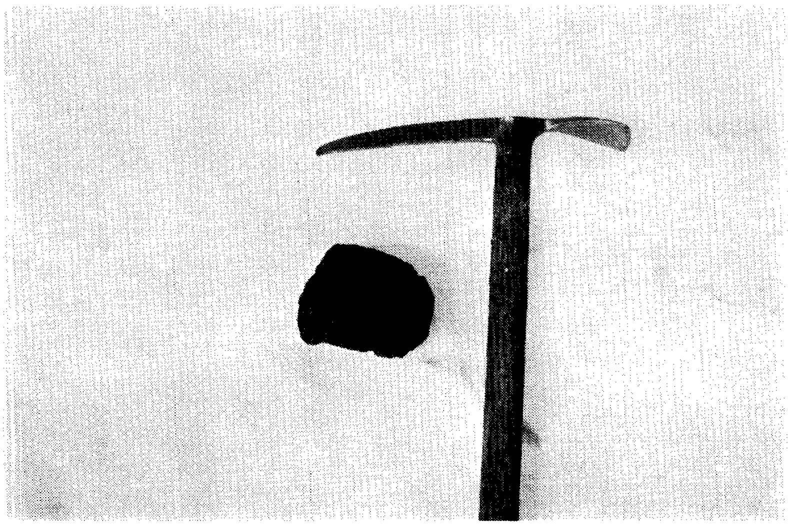


Fig. 11n. Yamato-74115 chondrite, 1,045.1 grams, collected on December 3.

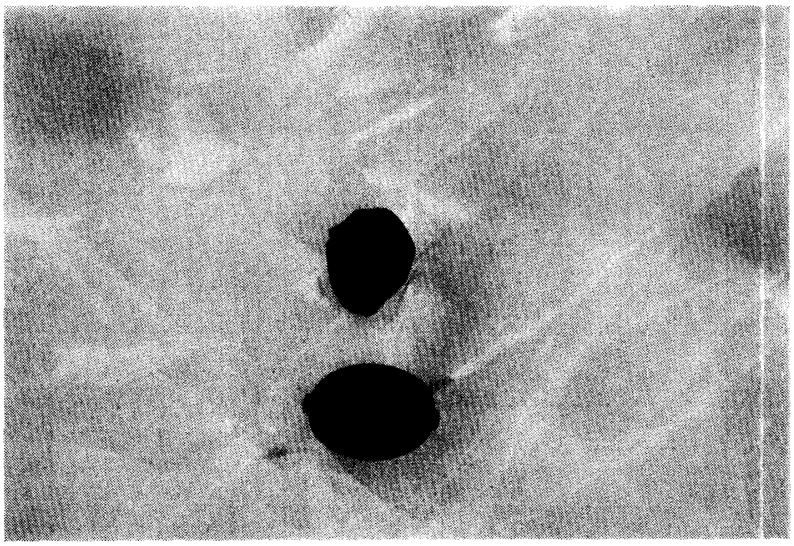


Fig. 12a. *Yamato-74015 meteorite photographed in situ, "remainder" on the surface of the bare ice after ablation.*

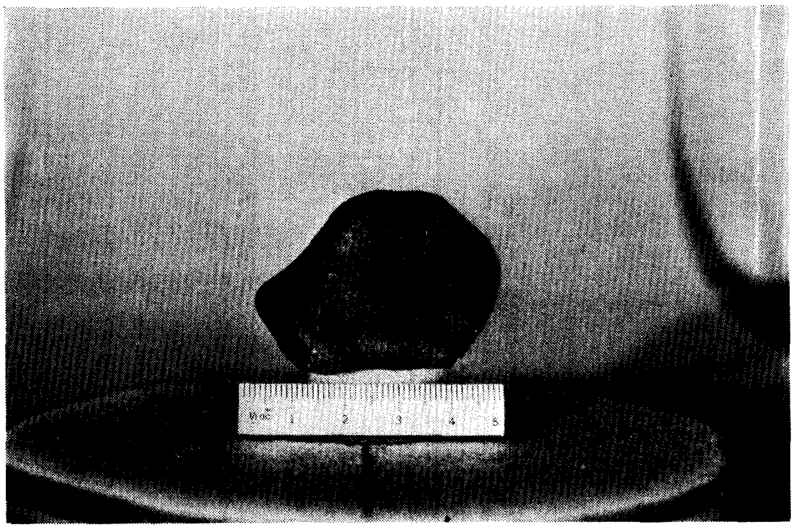


Fig. 12b. *Ditto, chondrite 88.0 grams in weight, complete one entirely covered with fusion crust.*

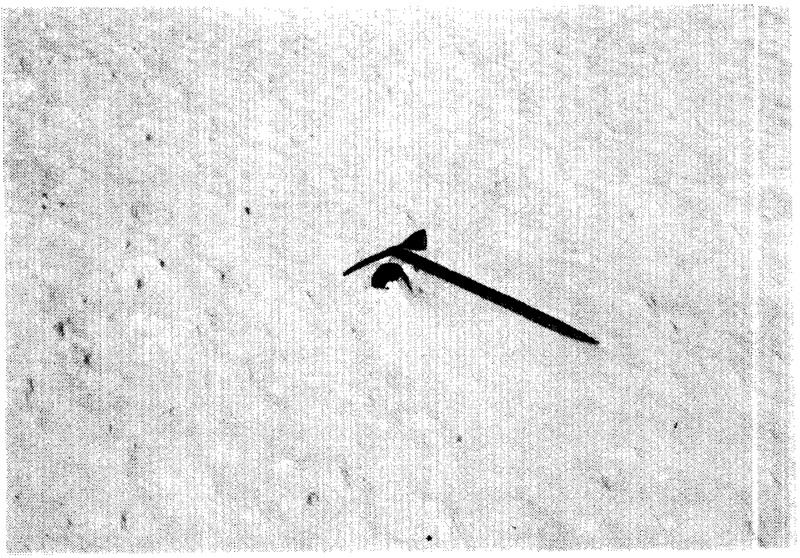


Fig. 13a. *Yamato-74094 meteorite photographed in situ, bottom part sank in the hollow of rough surface of bare ice.*

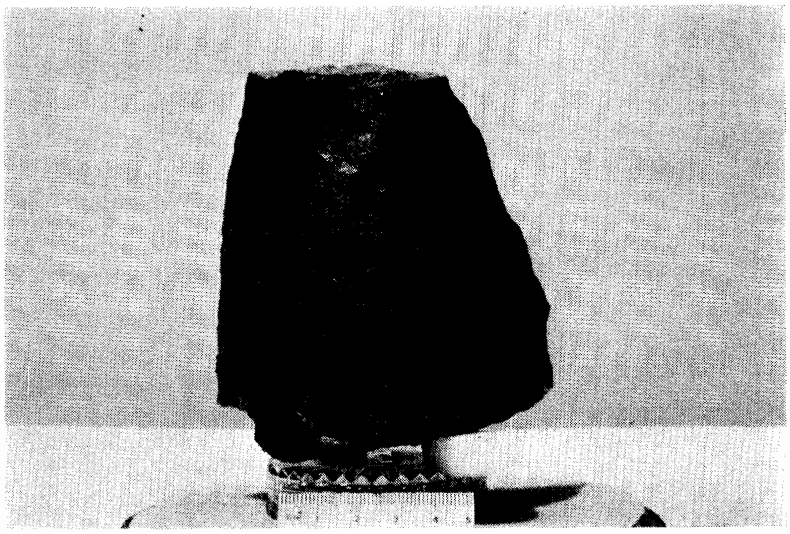


Fig. 13b. Ditto, chondrite 867.2 grams in weight, one block broken apart from the other.

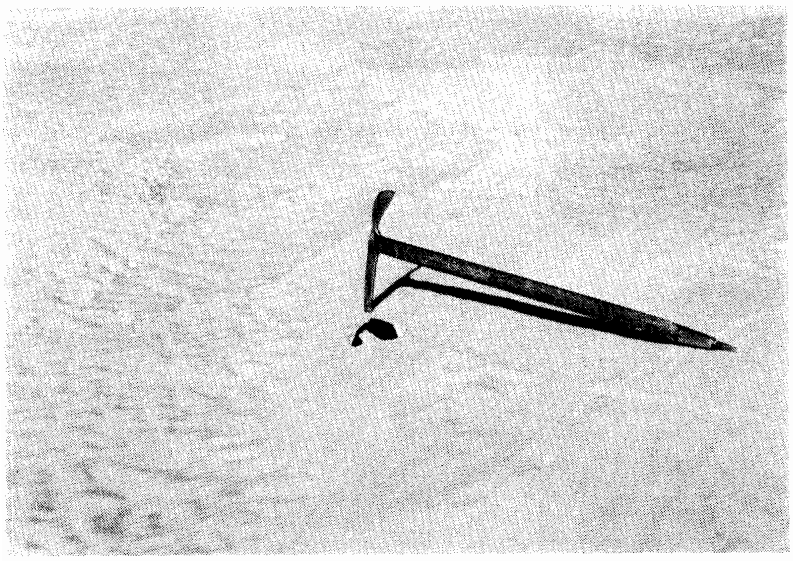


Fig. 14a. Yamato-74080 meteorite photographed in situ, bottom half buried in compact firn (not bare ice).

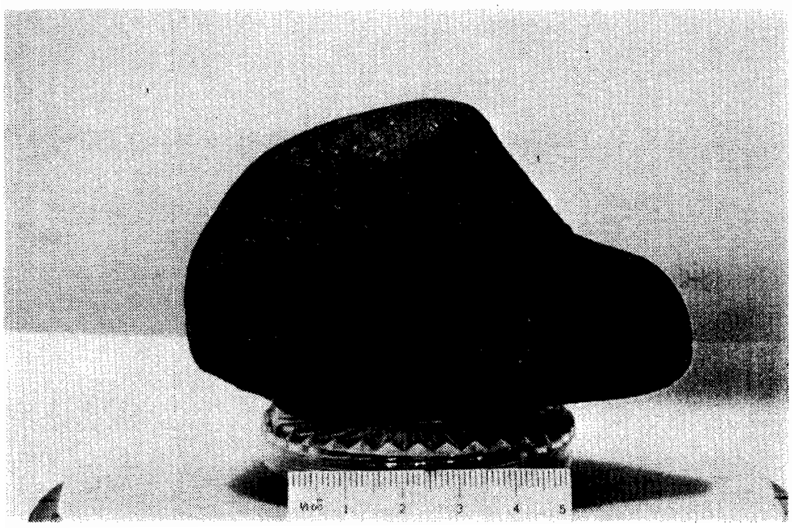


Fig. 14b. Ditto, chondrite 5369 grams in weight, complete one entirely covered with fusion crust.

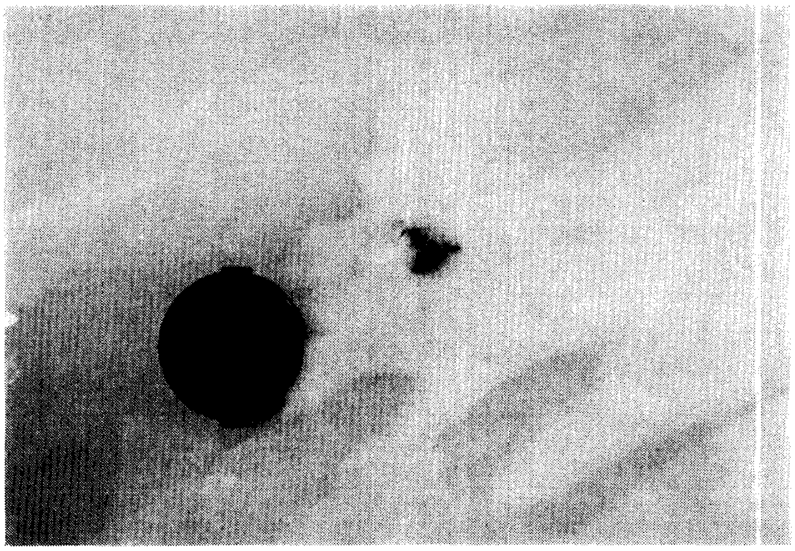


Fig. 15a. *Yamato-74066 meteorite photographed in situ, buried in soft snow.*

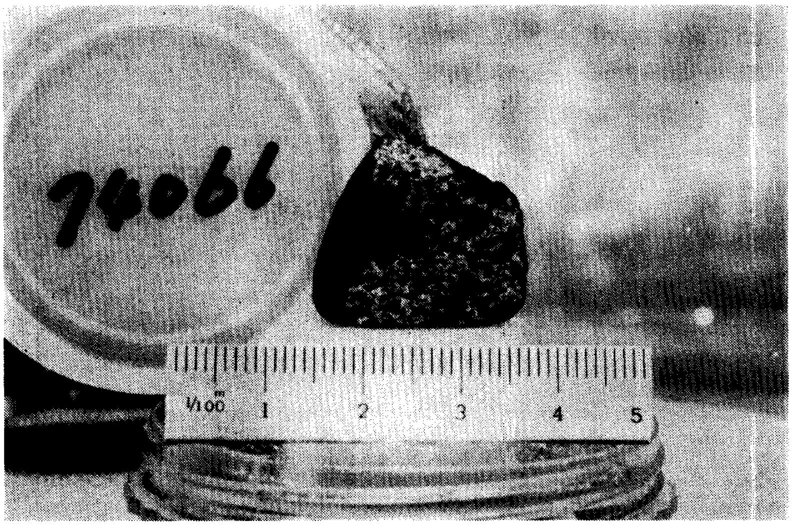


Fig. 15b. *Ditto, chondrite 12.4 grams in weight, broken half having many chondrules on the surface.*

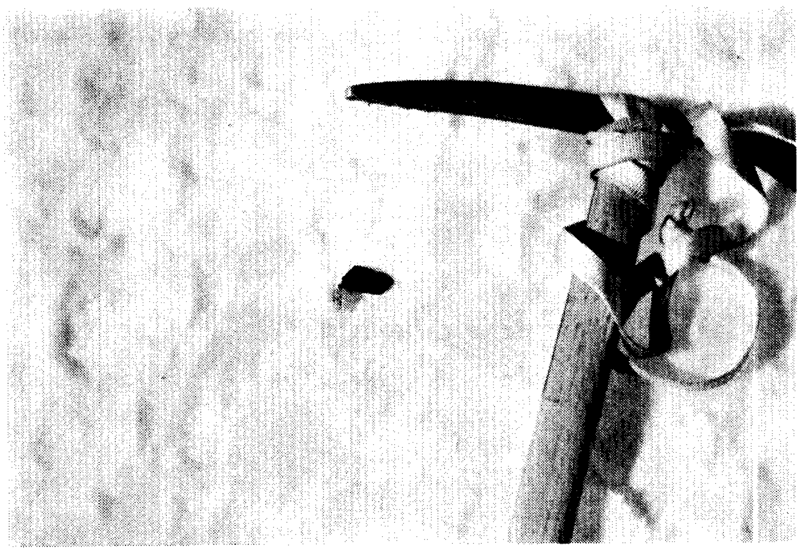


Fig. 16a. *Yamato-74227 meteorite photographed in situ, sitting on the surface of compact firn at the south foot of Massif A.*

Fig. 16b. *Ditto, location of Yamato-74227 meteorite, showing thin layer of compact firn adjacent to bare ice.*

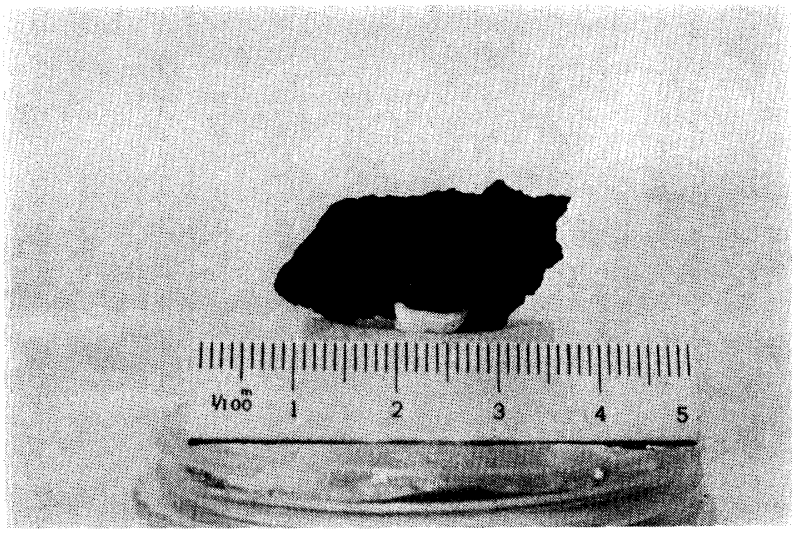


Fig. 16c. *Ditto, chondrite 9.0 grams in weight, broken fragmentary piece.*

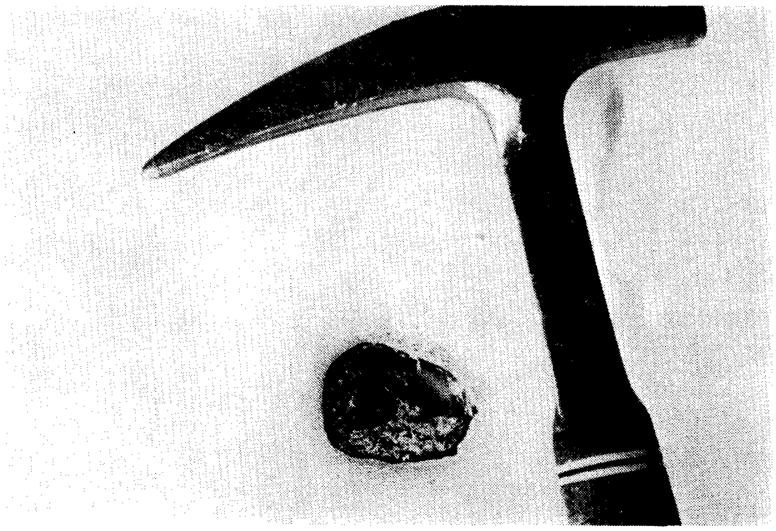


Fig. 17a. *Showing a dark material (meteorite) buried in ice at southwest of Massif A near the moraine band.*

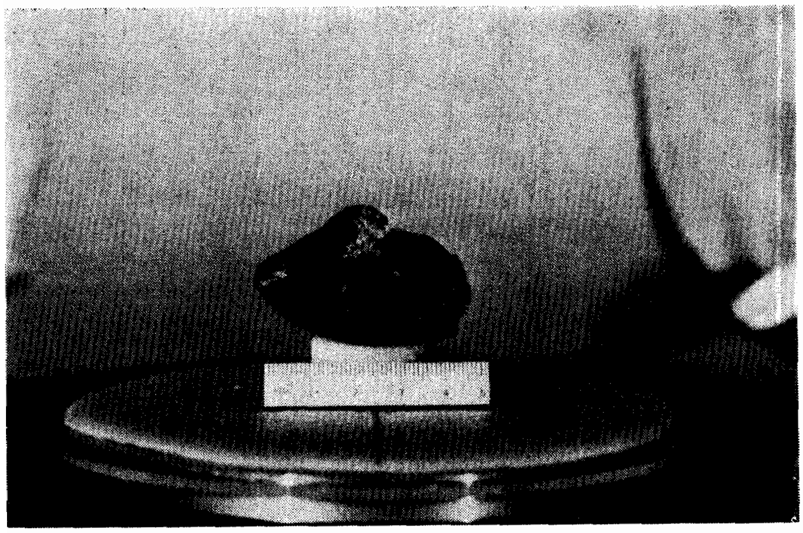


Fig. 17b. Ditto, Yamato-74372 chondrite, 84.6 grams in weight, almost entirely covered with fusion crust of two stages.

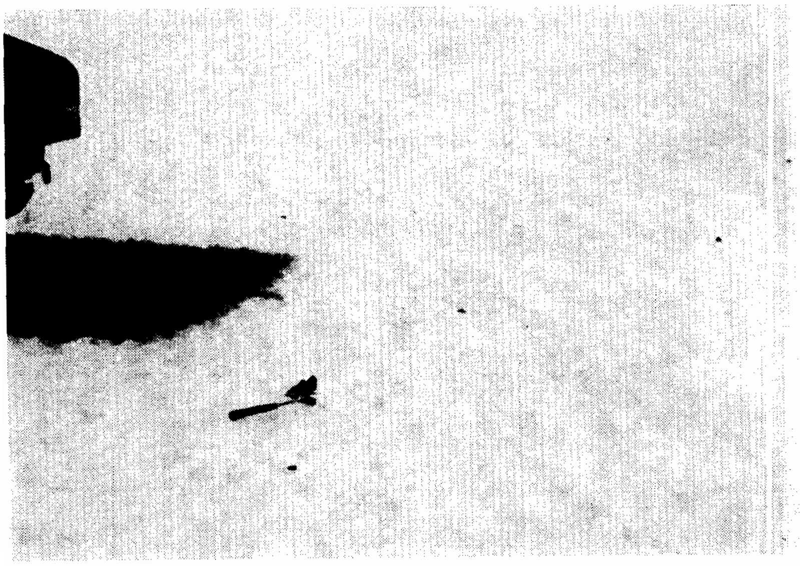


Fig. 18. Showing the distribution of meteorite pieces scattered on the bare ice surface southwest of Massifs A and B. The largest one is Yamato-74418 chondrite, 567.2 grams in weight.

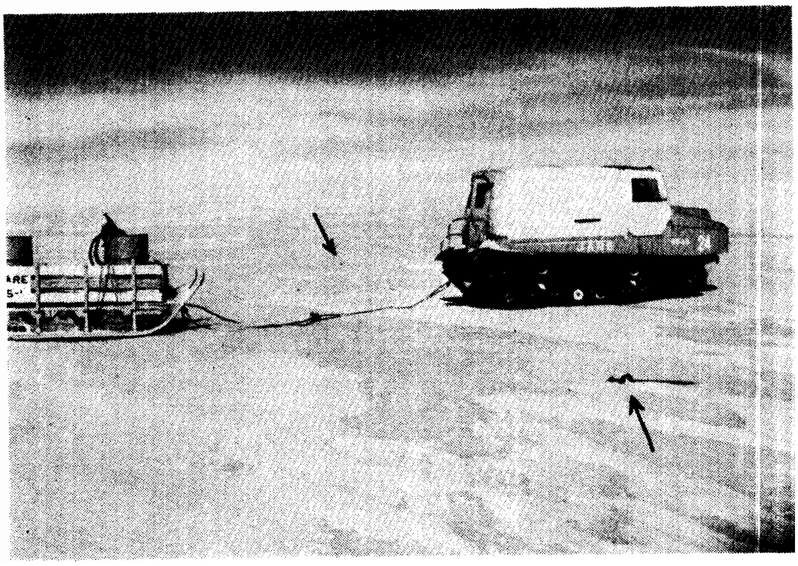


Fig. 19a. Showing the field occurrences of Yamato-74155 chondrite on the bare ice surface in front of snow vehicle, and Yamato-74156 chondrite at the back of snow vehicle.

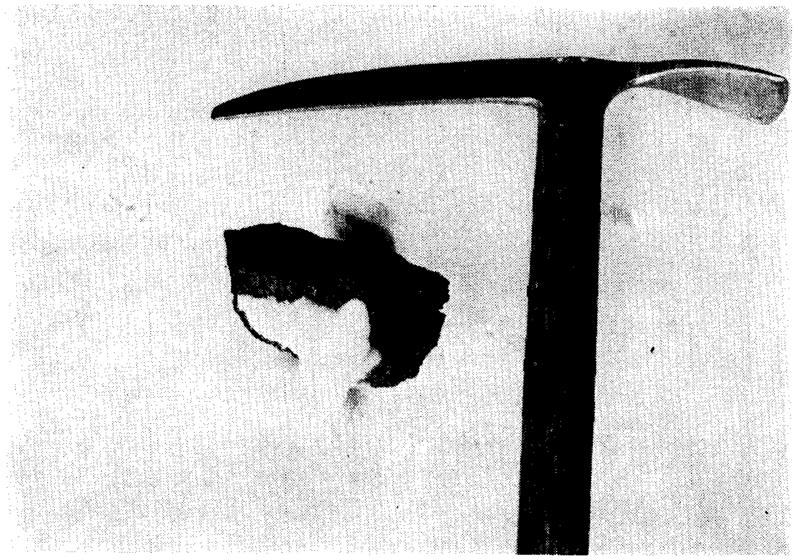


Fig. 19b. Ditto, Yamato-74156 chondrite, 714.7 grams in weight, photographed in situ, showing a broken feature.

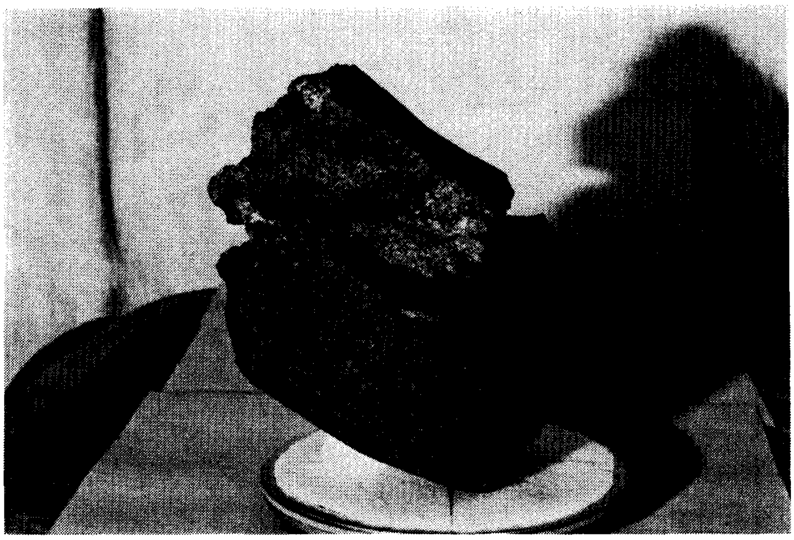


Fig. 19c. Ditto. Showing the two blocks (Yamato-74155 and -74156) joined to one specimen, but a quarter of it is missing.

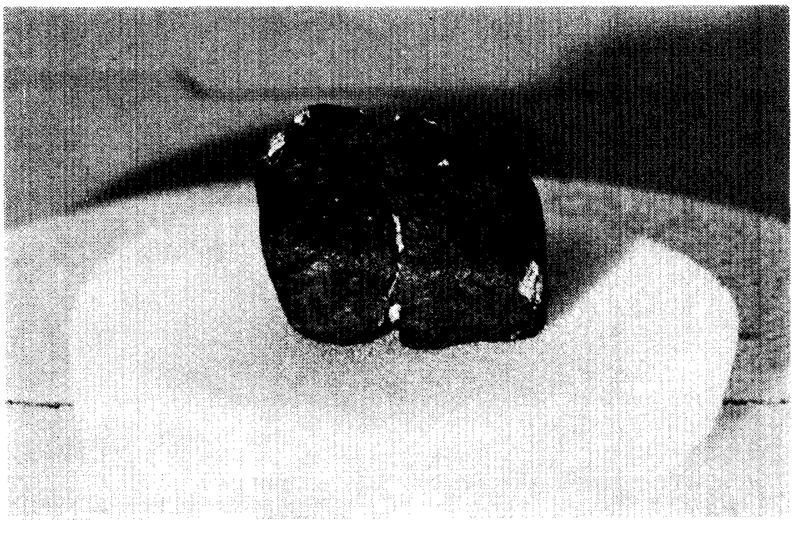


Fig. 20. Showing the pieces can be joined together (Yamato-74065 and -74066 chondrite).

Yamato-74 meteorites occur usually in single pieces covered with fusion crust and/or in fragmental pieces separated from one another, but in rare cases ten to hundred fragments were concentrated in a limited area. In the later case several fragmental meteorites are very similar in kind and shape. The features of their occurrence are described in detail as follows.

6.1. Meteorites sitting on the bare ice

Most of Yamato meteorites pieces collected in 1974 were sitting on the surface of the bare ice. As shown in Fig. 12a it looks as if the meteorites were left on the bare ice surface due to ablation. Fig. 13a indicates that the bottom part of the meteorite sank in a hollow of rough surface of the bare ice. Fig. 14a shows the meteorite buried in firn (hard snow) for the lower half. Fig. 15a shows a meteorite buried in soft fine-grained snow and was moved from place to place by wind. The former two cases may be essential occurrence. The third case is not common, but this appearance may indicate that meteorite was buried by firn, as is the case of marginal zone of the bare ice field at the lower part of glacier in the northwest part of the Yamato Mountains.

6.2. Meteorite on the firn layer

At the southern foot of Massif A, a meteorite fragment was found sitting just on the surface of the compact firn. This occurrence is the only case ever found in the Yamato Mountains. Similar occurrence was reported for the Adélie Land meteorite which was the first discovery of meteorite in the Antarctic Continent (BAYLY and STILLWELL, 1923), but details of the occurrence are not known.

The meteorite is one of the densely concentrated pieces at the X1 position. As shown in Figs. 16a, b and c the meteorite lay on the surface of the compact firn layer of several centimeters in thickness, 1 meter from the bare ice which yielded abundant meteorites fragments in a limited area.

This occurrence may not mean that the fragment was settled on the firn directly from space, because its appearance is very similar to terrestrial fragments settled on the bare ice and snow including firn. Probably the fragment had been moved from the bare ice area to the firn area by wind.

6.3. Meteorite buried in the bare ice

There is only one case that the meteorite was found buried in the bare ice at a few centimeters in depth. The meteorite was found unexpectedly. As shown in Fig. 17a, the party driving the snow vehicle found by chance a dark material buried below the surface of bare ice a few hundred meters from the moraine band southwest of Massif A. Terrestrial materials were scattered on the bare ice there, and some of them were buried by ice. The dark material when picked up was recognized as meteorite.

SHIRAISHI *et al.* (1976) reported similar occurrence of a meteorite which was partly buried in the bare ice, but it is not clear whether the meteorite is sinking in the ice or emerging on the surface of the bare ice.

Materials buried in ice are not rare but common occurrence in the moraine areas, because it is thought that the materials were coming up on the surface of the bare ice due to ablation and upward movement of ice. If Yamato meteorites did not fall on the bare ice *in situ*, the majority of them may have come from the interior of ice sheet by the same mechanism as moraine.

6.4. *Scattered occurrence*

As shown in Fig. 18 some meteorite pieces are scattered in a very limited area on the surface of the bare ice. At X1 and X2 in Fig. 8 about 200 pieces of meteorites were found in a very limited area of about 200 m square. At another locality ten to several tens of pieces were distributed in an area of several tens meters square. These pieces are commonly fragmental and similar in feature. However, achondrite (diogenite) and chondrite entirely covered with fusion crust were found among abundant fragments of chondrite, as at X1. Most of these densely concentrated fragments are thought to have originated from one mother body, because of their similarity in kind and shape.

6.5. *Joint pieces*

The occurrence of Yamato-74155 and -74156 chondrite is shown in Figs. 19a, 19b and 11e. They were found 15 m apart, and were assigned to the same geographic coordinates. The two specimens can be joined into one as shown in Fig. 19c, but each lacked a quarter which was not found at the same locality. These pieces were designated separately because they were found at separate localities under different date and the party did not know then that they came from one meteorite.

Yamato-74065 and -74066 chondrite (Figs. 15a and 15b) also were of the same occurrence, and they can be joined into one complete specimen (Fig. 20). Yamato-74013 (Fig. 10k), -74097 (Fig. 10j) and -74136 achondrite were found a few tens to few hundred meters apart from each other, but they belonged to one specimen though incomplete, as shown in Fig. 21.

7. Features of the Yamato-74 Meteorites

Meteorites collected around the Yamato Mountains are characteristically fragmental. As previously mentioned (6.4), many fragmentary meteorites were concentrated in a limited area, as seen at X1 and X2. They might have been broken either by impact when they hit the surface of bare ice or by mechanical weathering after their fall. To the naked eye they are similar in features. There were also larger pieces of broken meteorites as mentioned before (6.5, Figs. 19c and 21).

The greater part of the Yamato-74 meteorites show common features of "meteorite" almost entirely covered with fusion crust (see Figs. 10a, 10b, 10c, 10g, 10h, 10l, 12b and 14b), and some broken meteorites have chondrules on

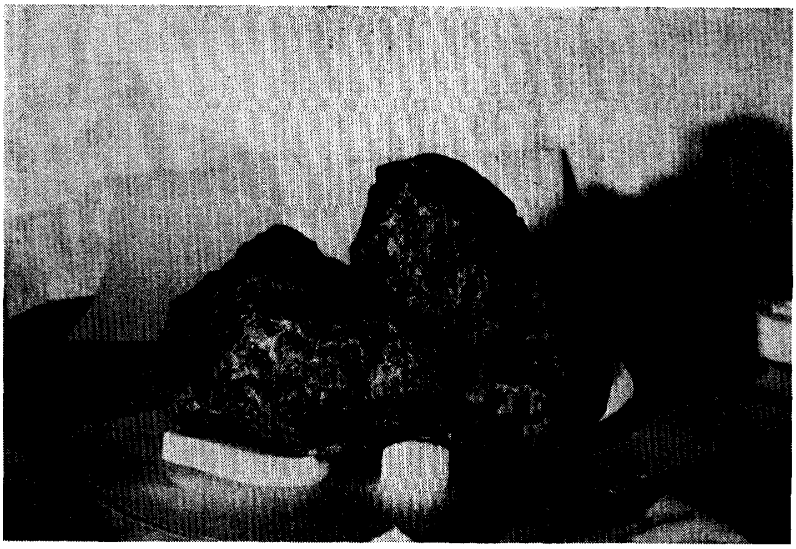


Fig. 21. Showing Yamato-74013, -74097 and -74136 achondrites are joined to one achondrite body, but they do not make a complete specimen.

Fig. 22. Showing many chondrules on the face of broken meteorite (Yamato-74124 chondrite, 62.3 grams in weight).

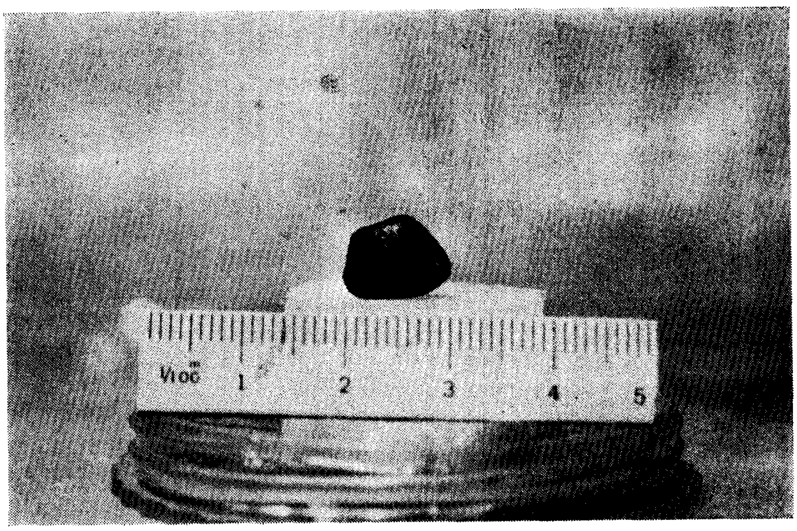


Fig. 23. Yamato-74087 chondrite, one of the smallest meteorites, collected in the grid, 0.783 grams in weight entirely covered with fusion crust.

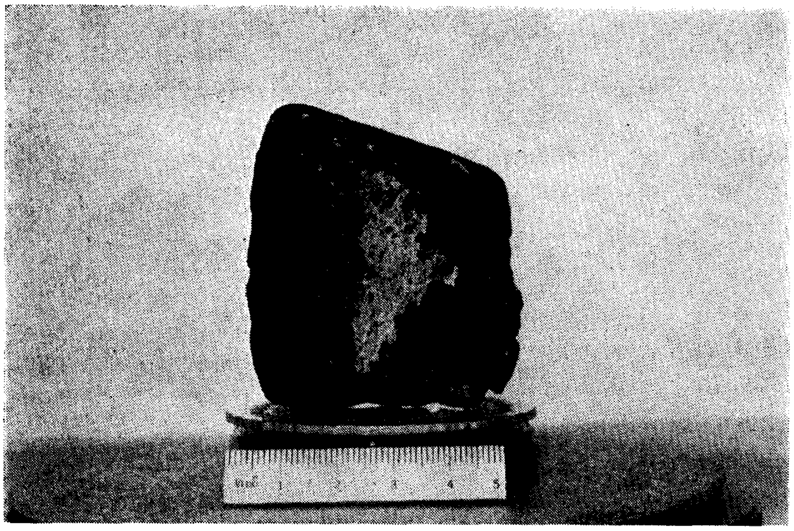


Fig. 24. *Yamato-74450 achondrite, 235.6 grams in weight, showing the radial flow lines on the surface and shiny black color.*

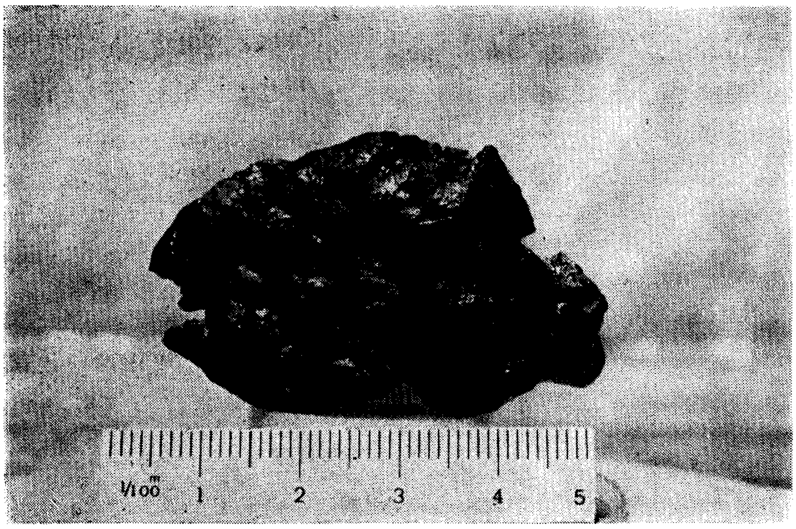


Fig. 25. *Yamato-74044 stony-iron (pallasite), showing the characteristic porphyritic texture of olivine crystals.*

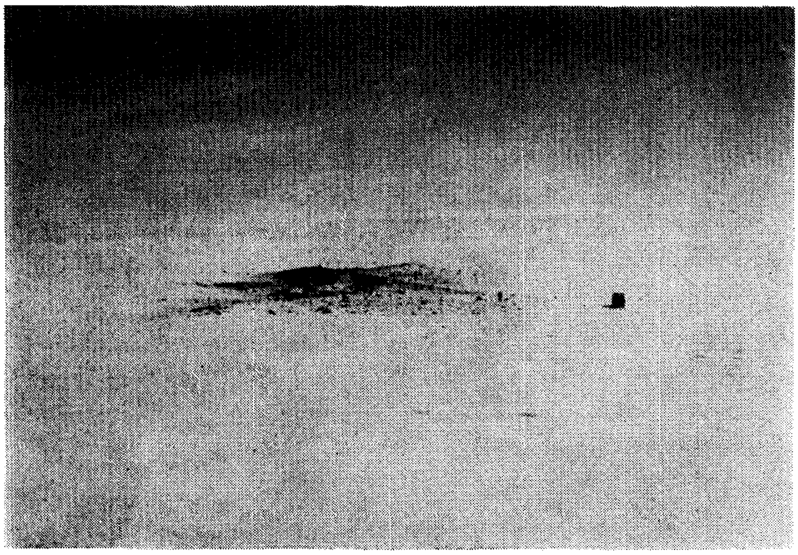


Fig. 26. *Small moraine located in the central part of the bare ice field 10 km west of Massif A. A thin layer of moraine covers a narrow area of bare ice. No meteorite was found in this moraine.*

Table 3. Frequency of mass of Yamato-74 meteorites.

Weight range (g)	Numbers (%)	Total weight (g)
— 10.0	395 (59.6)	1676.8
10.1— 20.0	88 (13.3)	1237.3
20.1— 50.0	75 (11.3)	2453.6
50.1— 100.0	38 (5.7)	2791.2
100.1— 200.0	24 (3.6)	3346.5
200.1— 500.0	15 (2.3)	3707.7
500.1—1000.0	12 (1.8)	7940.9
1000.1—2000.0	5 (0.8)	6740.8
2000.1—5000.0	9 (1.4)	24443.5
5000.1—	2 (0.3)	10643.0
Total	663 (100)	64981.3

their surfaces (Fig. 22). Most of the meteorites covered with fusion crust have smooth surfaces, occasionally exhibiting finger prints (thumbprints). As shown in Fig. 10a, Yamato-74077 meteorite shows characteristic fused surface and thumbprints. This specimen is the largest one collected in 1974 with a diameter of 20 cm and weighting 5.575 kg, and is one of the representative meteorites in the Yamato meteorite collections.

Yamato-74087 meteorite shown in Fig. 23 is one of the small meteorites with fusion crust. It weighs 0.783 grams and is almost entirely covered with fusion crust. In spite of its small size, the specimen was very easily discerned due to the contrasting blackish color to the white ice surface.

The Yamato-74 meteorites are characterized also by small fragments and small crusted specimens. As shown in Table 3 the greater part of the Yamato-74 meteorites are less than 10 grams in weight.

Many of fragmented pieces of meteorities are covered only partially with fusion crust. Therefore, they might have been broken after their fall. Some meteorites show different stages of fusion crust. As shown in Figs. 10g and 10h, the fusion crust of the arcuate surface appears to have been formed at an earlier stage and the other crust at a later stage after the meteorite was broken when it was entering into the earth's atmosphere. These features may suggest a meteorite shower.

Commonly the fusion crust is black in color, but the color varies from brown to black within the same petrological group (see Figs. 10a, 10c, 10g and 10h). Achondrites have a glossy black color. As shown in Fig. 24 Yamato-74450 achondrite exhibits radial flow lines on the surface and its crust is shiny black. On the other hand, Yamato-74013 (Fig. 10k), -74097 (Fig. 10j) and -74136 achondrite were hardly covered with fusion crust on the rounded outsides. They are very similar to terrestrial dunite having olivine color and no chondrules. Therefore, it is very difficult to distinguish such specimens from terrestrial rocks in the field, but fortunately there were no terrestrial rock fragments in the areas surveyed except for a few dubious materials. In careful examination, small patches of fusion crust were recognized in hollowed parts of the rounded exterior of these specimens and some thumbprints were also noticed on the surface. It is possible, therefore, that the fusion crust of these meteorites was abraded by strong wind while exposed on the bare ice surface.

As shown in Fig. 25 Yamato-74044 is stony-iron (pallasite) characterized by porphyritic texture of olivine crystals and heavier density. But it is not clear wheather this was previously covered with fusion crust.

8. Relations between Moraine and Meteorite in the Field

Moraines in the Yamato Mountains region contain ground moraine and detritus which consists of many rock fragments. Moraines cover some of the rocky areas (for example, Massif A) and bare ice near nunataks in the form of a thin layer or scattered. As shown in Figs. 2 and 7, a moraine band elongates about 30 km north-south along the western side of the mountain range. In some places a small moraine occurs in the wide bare ice field where no nunataks are found (Fig. 26).

Most of rock types constituting moraines were of similar kinds to those in adjacent nunataks. Some of those rocks were rounded in the ice sheet, and often carry glacial striae on their rounded surfaces. Moraines also contain materials resembling glacial clay. Therefore, the majority of those rocks were derived probably from adjacent nunataks, but some were brought by the ice movement from the bedrock under the thick ice sheet.

On the other hand, meteorites differ from moraines in features except in rare cases when they are not covered with fusion crust. Namely, meteorites do not have glacial striaes and are not associated with glacial clay. Distribution of them is not so dense as that of moraines. Nevertheless, their occurrences are alike in some points. For example, both meteorites and moraines are distributed in the same bare ice field and are exposed on the surface of the bare ice.

It is an important fact that no meteorites were found in moraine areas except for a few questionable cases, though moraine areas have not been searched thoroughly as yet. Therefore, the relations between meteorites and moraines are not clear. Only some phenomena observed in the field are described in this chapter.

9. On Concentration of Yamato Meteorites

As mentioned earlier, a total of 684 meteorites were concentrated in a very limited area of the bare ice field in the Yamato Mountains region and they occurred almost limitedly on the surface of bare ice. These facts are important for meteorite searching in Antarctica. It is also noted that the Yamato meteorites are wide-ranged petrologically. These facts were recognized also in the other bare ice field (YANAI, 1978), but it does not mean that meteorites will be find commonly in every bare ice field of the Antarctic Continent.

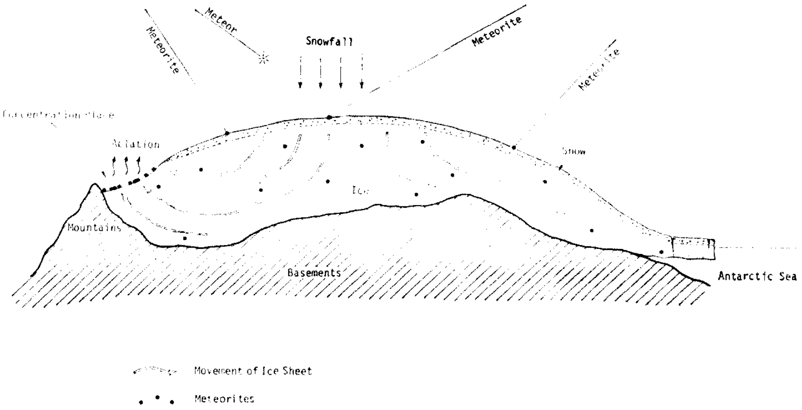


Fig. 27. A hypothetical figure for concentration mechanism of Yamato meteorites.

Nevertheless, it is an unshakable fact that meteorites were concentrated in the bare ice field of the Yamato Mountains region, where at least a few thousand pieces of meteorites are supposed to occur judging from the 1969, 1973, 1974 and 1975 collections. The Yamato Mountains region is one of the singular localities of meteorites in Antarctica and in the world.

The above facts may be interpreted as follows:

(a) Meteorite fall in the Yamato Mountains region *in situ* (multiple single falls and/or showers)→*accumulation* of meteorites

(b) Meteorite fall in the Antarctic interior (multiple single falls and/or showers) → transportation of meteorites by movement of ice sheet → ablation of snow and ice in the Yamato Mountains → *concentration* of meteorites on bare ice around the Yamato Mountains

The above interpretations are rather qualitative.

A hypothetical figure for interpretation (b) is presented in Fig. 27. The figure shows that meteorites had fallen on the surface of snow which covers the Antarctic interior where the upper part of flowing ice sheet is located, and the meteorites were transported by the ice-flow toward the costal areas of the Antarctic Continent. When the ice-flow approaches the mountain range, it changes from downward flow to upwelling due to the barrier. The ice sheet (ice mass) is ablated several centimeters per year (SHIRAISHI *et al.*, 1976). Ice mass is consumed continuously, but meteorites and rocks remain on the ice surface. As a result, meteorites of large numbers and various kinds are concentrated in the limited bare ice field.

10. Summary

The collection, field occurrence, characteristic features of Yamato-74 meteorites and possibility of finding more meteorites are summarized as follows.

a. In addition to 21 meteorites previously found, 663 new pieces of meteorites were found around the Yamato Mountains during the period from November to December 1974.

b. 158 pieces of meteorites were found in the grid, 10 km square, by systematic search at the same locality where meteorites had been collected in 1969 and 1973.

c. Collected specimens were named Yamato-74 meteorites and designated as Yamato-74001 to Yamato-74663 in order of discovery.

d. The specimens were identified as one stony-iron (pallasite), 24 achondrites and many chondrites of various petrological types including carbonaceous chondrites.

e. Iron meteorite was not collected as in the previous cases.

f. Meteorites were collected in the bare ice field except one which was found on compact firn.

g. Occurrence of meteorites was limited to the bare ice surface except one meteorite buried in ice.

h. No meteorite was found in moraines and in rocky areas, though these areas have not been thoroughly searched.

i. Wide bare ice fields of several thousand square km around the Yamato Mountains have a high possibility of discovery of more meteorites.

j. Meteorites are petrologically wide-ranged.

k. Most of meteorites were almost entirely covered with fusion crust.

l. In the grid for detailed search, a total of 200 pieces of meteorites were collected since 1975, the rate of discovery being 1 piece/0.5 square km.

m. Total area of bare ice fields around the Yamato Mountains amounts to about 4,000 square km.

n. Taking the above two facts into consideration, possibility of meteorite discovery in the Yamato Mountains region can be very high; at least several thousand pieces are expected to be found there.

o. In Antarctica the bare ice is a deepfreeze storehouse for meteorites.

p. In several years, many meteorites exposed on bare ice will be buried in deep snow transported by flowing ice sheet, because bare ice occurs very limitedly and moves toward the snow area.

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