A CLASSIFICATION FOR SOME SMALL CHONDRITES IN THE YAMATO-74 AND -75 METEORITES

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Abstract: Electron microprobe studies have been made of olivines and pyroxenes in six Yamato chondrites collected in 1974 and 1975. On the basis of histograms of iron contents of olivines and pyroxenes, they are classified as follows: Yamato- (Y-) 75260 is a C2 carbonaceous chondrite; Y-74183 is an L6 ordinary chondrite; Y-74187, H6; Y-74198, H6; Y-74202, H5-6; and Y-74234, H4-5. In order to examine in detail the Mg-Fe chemical variation within the olivine or pyroxene grain found in some shocked ordinary chondrites, the Back-scattered Electron Image (BEI) observation has been carried out for several olivine grains in Yamato-74234. A larger percent mean deviation of olivine for these meteorites than what is expected from their texture, can be attributed to the presence of Fe-rich inclusions in the olivines.

1. Introduction

As a part of the work to make a catalog of the Yamato meteorites, a preliminary examination of some small meteorites among the Yamato meteorites collected in 1974 and 1975 (YANAI, 1978; MATSUMOTO, 1978) has been carried out. The classification of the small meteorites as well as the large meteorites is necessary because of the following purpose. (1) To know the frequency distribution of meteorite groups among the Yamato meteorites, (2) to prove the existence of meteorite showers in Antarctica, (3) to clarify the mechanism of the concentration of meteorites in Antarctica, and so on.

For this classification very small amounts of meteorite samples have been supplied because the original meteorites are small. On the basis of the microprobe analyses of olivines and pyroxenes contained in the meteorites, the classification has been made by the method similar to that described in YANAI *et al.* (1978).

2. Samples and Experimental Techniques

The samples supplied for this study from the National Institute of Polar Research are as follows (the numbers in parentheses are total weight of the meteorites found): Y-74183 (3.0 g), Y-74187 (6.7 g), Y-74198 (5.7 g), Y-74202 (8.1 g), Y-74234 (25.9 g), and Y-75260 (4.0 g). Some of very small fragments supplied were covered with crusts of iron oxides or hydroxides, and even in the interior of many samples, some oxidized portions were found.

Each fragment was mounted in epoxy resin, and a 0.2 to 0.5 mm thick slice was cut and cemented by araldite. The polished thin sections of the grains were prepared for microprobe analyses. The quantitative chemical analyses of olivines and pyroxenes were made with a JEOL JXA-5 electron probe X-ray microanalyzer with a 40° take-off angle. The method was the same as that described by NAKAMURA and KUSHIRO (1970).

The classification method for ordinary chondrites used was the one proposed by DODD *et al.* (1967), which is based on the histograms of iron contents in olivines and pyroxenes contained in the meteorites and the presence of large recrystallized polygonal plagioclase grains (VAN SCHMUS and WOOD, 1967). The details of the method used for this study are described in YANAI *et al.* (1978).

In order to make clear the limitation and the point at issue for this classification method, we carried out the observation of compositional images by Back-scattered Electron Image (BEI) method for the Y-74234 sample with a JEOL JXA-733 microprobe.

The X-ray powder diffraction study was made for Y-75260 to determine whether it contains serpentine (C2 carbonaceous chondrite) or olivine (C3).

3. Results

The histogram of olivine compositions of Y-75260 is shown in Fig. 1. On the basis of the olivine data and the texture (Fig. 2), Y-75260 is a C2 carbonaceous chondrite, though this meteorite has been reported to be a ureilite by FREDRIKSSON (private communication) according to his observation in the hand specimen.

The histograms of iron contents, in atomic percent, of olivines and orthopyroxenes for five Yamato-74 ordinary chondrites (Y-74183, Y-74187, Y-74198, Y-74202, Y-74234) are given in Fig. 3 together with the ranges of atomic percent

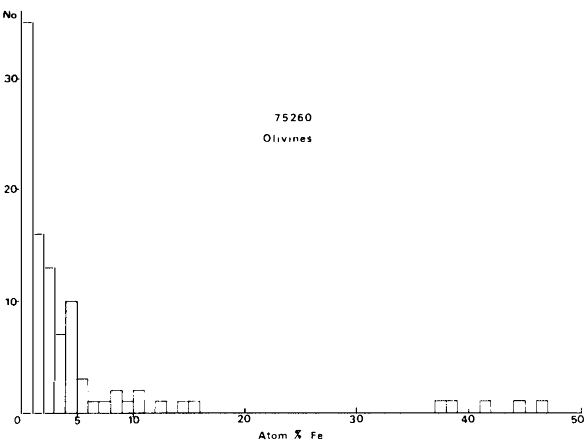


Fig. 1. Iron contents of olivines in Yamato-75260.

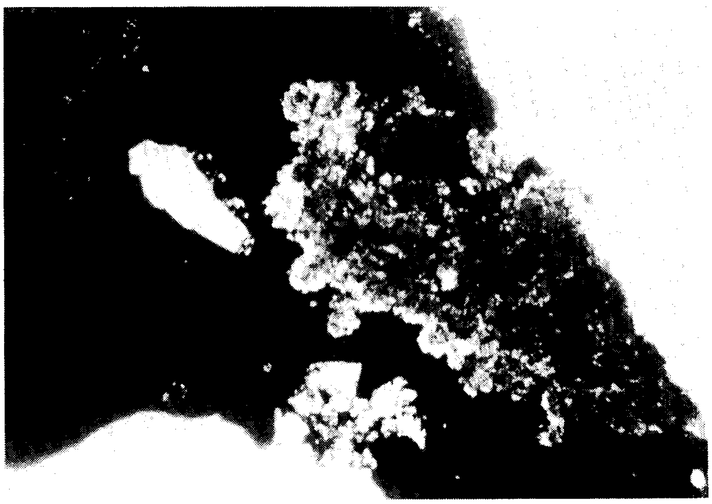


Fig. 2. Photomicrograph of Yamato-75260. Width is 3 mm.

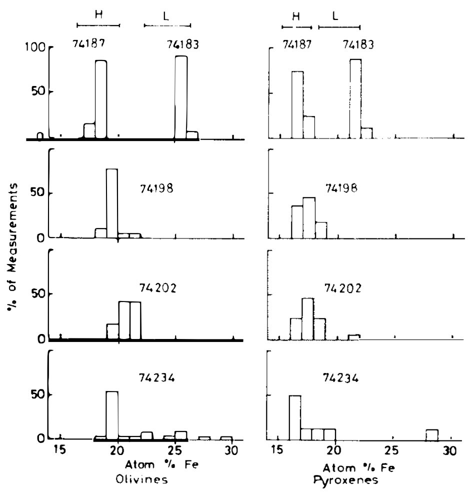
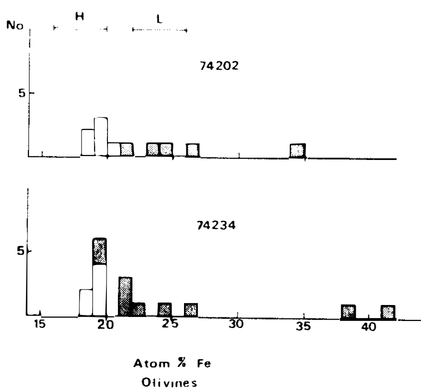


Fig. 3. Iron contents of olivines and pyroxenes. The numbers are names of the Yamato meteorite samples.

Fig. 4. Photomicrograph of Yamato-74234. Width is 3 mm.



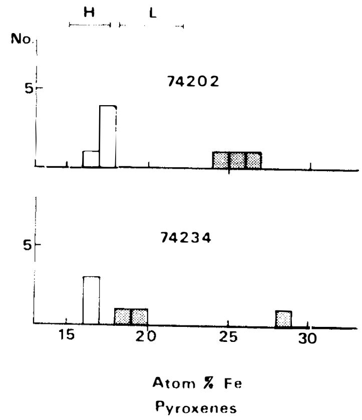


Fig. 5a. Iron contents of olivines of Yamato-74202 and -74234. Shaded area is high Fe peak due mainly to Fe-rich inclusions.

Fig. 5b. Iron contents of pyroxenes of Yamato-74202 and -74234.

of iron for the known H6, L6 type chondrites on top of the figure. On the basis of these olivine and pyroxene data, the presence of the plagioclase grains and the microscopic observation of polished sections, they are classified as follows: Y-74183 is an L6 ordinary chondrite; Y-74187, H6; Y-74198, H6; Y-74202, H5–6; Y-74234, H4–5.

Although Y-74234 is classified as H4–5, a large cryptocrystalline chondrule with distinct outline has been observed in a thin section (Fig. 4).

More detailed examinations with the electron microprobe were performed on some olivine and pyroxene grains in Y-74202 and Y-74234, which show the variable iron concentration values. The results are given in Figs. 5a and b. In these figures, open area shows the most Mg-rich composition within each olivine or pyroxene grain, and shaded area shows more Fe-rich composition in the grain.

4. Discussion

The difficulty in classifying these meteorites lies in the fact that the samples supplied from the curator for this study are very small fragments with the oxidized crusts because the original meteorites are small, and that even the interior of the samples is stained with the oxidized iron.

The histogram of iron concentrations of olivines contained in Y-75260 has a prominent peak at <1% fayalite (Fig. 1). Because the distribution of olivine compositions for a C3 carbonaceous chondrite is broad and unpeaked (WOOD, 1967), Y-75260 is probably a C2 carbonaceous chondrite rather than C3. In order to confirm whether this meteorite is a C2 or C3, the X-ray powder diffraction study for this meteorite has been carried out to detect the presence of serpentine. Because the amount of the sample used for this study is not enough, the diffraction lines for serpentine cannot be detected. The very weak lines for olivine were detected.

From our experience in classifying the ordinary chondrites on the basis of a histogram of iron concentrations of olivines and pyroxenes obtained by the microprobe technique, we can raise several points in addition to those stated in YANAI *et al.* (1978). In typical equilibrated ordinary chondrites (type 5 or 6), we can easily determine the chemical-petrologic type because of the fact that the histogram has a prominent peak.

This classification method may encounter some problems when the distributions of olivine and pyroxene compositions are broad and unpeaked (KIMURA *et al.*, 1979; YANAI *et al.*, 1979). In many cases, if we can recognize very sharply- or well-defined chondrules in the thin section of a meteorite by the optical observation, we can classify it as type 3 or 4. However, in certain cases, though the optical observation clearly shows the type 5- or 6-like texture, that is, poorly-defined chondrules or recrystallized matrix texture, the distributions of olivines and pyroxenes give rise to broad peaks.

A possible interpretation for this apparent discrepancy is the brecciation processes on the surface of the chondrite parent body or bodies. In the light of the recent studies on breccias in the lunar samples and the achondrite meteorites, we now know that the polymict breccias can be formed on the planetary surfaces by the impact processes. It is not fortuitous to find polymict breccias among the different chemical-petrologic groups of chondrite (WILKENING *et al.*, 1971).

According to their histograms (Fig. 3), Y-74202 and Y-74234 may be classified as type 3 or 4 because the distributions of olivine and pyroxene compositions in these meteorites are broad. However, these meteorites show the equilibrated texture except for one well-defined chondrule in Y-74234 (Fig. 4) in the microscopic observation of the thin section. The Mg-Fe compositional variations of olivines and pyroxenes obtained by more detailed measurements on Y-74202 and Y-74234 given in Figs. 5a and b show that they vary not only among the grains but also within a grain. These variations are not due to the core-rim zoning. A possibility that it is a patchy zoning cannot be excluded. The place in the grain where it is tinged with red as observed under the microscope tends to show the high iron concentration.

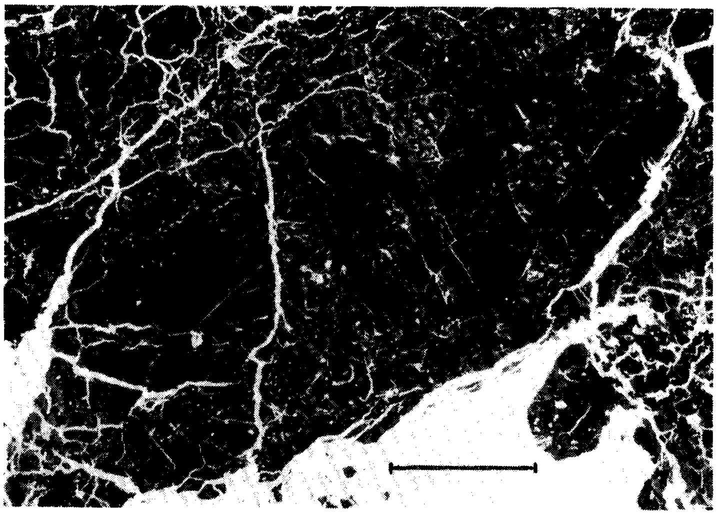


Fig. 6. Photograph of compositional image by BEI method of Yamato-74234. Scale bar 100 microns.

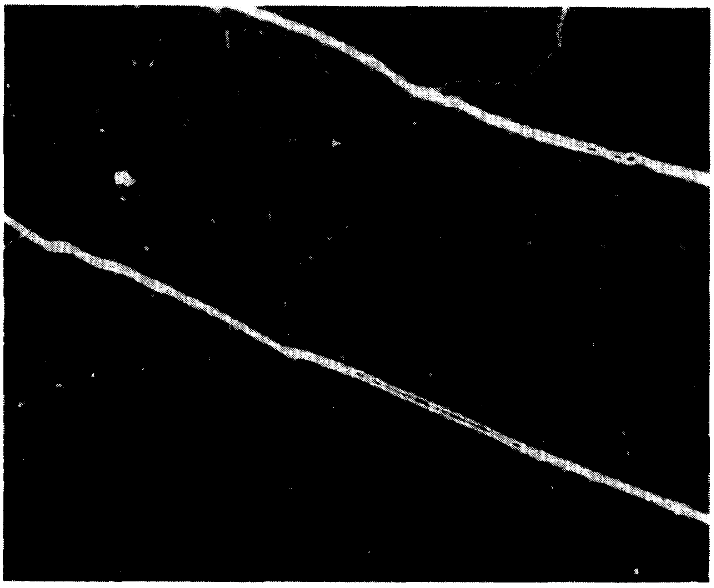


Fig. 7. Photograph of compositional image by BEI method of Yamato-74234. Scale bar 10 microns.

In order to investigate into this fact thoroughly, the BEI observation study for several olivine grains was carried out with a JEOL JXA-733 microprobe. In the microphotographs of compositional images of olivine grains in Y-74234 by the BEI method (Figs. 6 and 7), the white area may correspond to higher iron concentration than the dark area. This image is not due to a fortuitous one produced by a high contrast imaging, because the presence of iron was confirmed by the microprobe scan. Fig. 6 shows the Fe grains and the grain boundaries have higher iron content, and shows the areas which have slightly higher iron concentration exist within the olivine grain, namely, this grain seems to show the Mg-Fe variation within the grain. Many white fine lines within the grain in Fig. 6 correspond to the fractures in the grain observed by the optical method.

Fig. 7 is a higher magnification photograph of another olivine grain in Y-74234. Two thick lines which show the higher iron content correspond to the fractures within this olivine grain. Many fine lines in Fig. 7 probably correspond to the fractures, though these lines cannot be clearly confirmed by the optical technique. Fig. 7 also shows the presence of a lot of high Fe fine inclusions less than 1 micron in size. It seems likely that these fine inclusions are formed within the fractures. The Fe$K\alpha$ scanning image revealed that the white large spots are the iron-rich materials.

The BEI observation revealed that the high iron content values may be obtained if the electron beam irradiates the area which covers over these fractures or fine inclusions, because the diameter of the area excited by an electron beam is estimated to be about 5 microns.

One may think that the high Fe values obtained by analyzing a portion containing fine Fe-rich inclusions or Fe-filled fractures may be detected by examining a total weight percentage of the oxides or stoichiometry of the pyroxene and olivines. Because the routine analyses for the meteorite classification are performed by analyzing CaO, MgO and FeO only, and accepting an estimated (by adding SiO_2) total weight percentage of 95 to 102%, a considerable increase in the FeO wt.% may not affect too much the total values.

The problems have been left unsolved whether these iron-rich fractures and fine inclusions originate from the formation processes of the ordinary chondrites in the primitive solar nebula or the oxidation process after the fall on the earth's surface. It is suggested to examine the chondrites in detail by the BEI techniques and select a point to be analyzed where it is not much oxidized under the earth's atmosphere. In many cases, such iron staining is not easily detected by the microscopic observation.

In spite of these complex Mg-Fe variations of olivines and pyroxenes and the existence of a well-defined chondrule (Fig. 4) of Y-74234, the optical observation of the sections we examined shows the equilibrated texture on the whole.

To summarize our interpretation of the results by BEI observation, we can explain that if the classification is carried out on the basis of the histogram of iron concentrations of olivines and pyroxenes chosen at random in the section, the results would have a tendency to give a lower petrologic type of the ordinary chondrites due to the fine Fe-rich inclusions than that obtained by the optical observation. However, we may be able to obtain the better chemical and petrologic type of the ordinary chondrite by avoiding the portion contaminated by iron stain with the BEI technique. We suggest that the petrologic type of the ordinary chondrite obtained by the data of the more Mg-rich part of the peak of the histogram may agree well with that obtained by the optical observation.

Acknowledgments

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