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WEATHERING OF SOME ANTARCTIC METEORITES: INFRARED SPECTROSCOPY

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Abstract: We studied the degree of weathering of some Antarctic meteorites using the integrated intensity of absorption bands near 3 μm to enlarge the data base of the degree of weathering. There is no clear correlation between the integrated intensity and the degree of weathering on the A-B-C scale. A rough correlation can be seen between the integrated intensity of absorption bands near 3 μm and the total amount of H_2O in a meteorite analyzed by a standard wet chemical analysis method. Some Yamato meteorites measured show weaker integrated intensities than the Allan Hills meteorites measured. Our method to determine the degree of weathering may be useful for choosing less weathered meteorites from among the Antarctic meteorite collection.

1. Introduction

Although the Antarctic meteorite collection has promoted great progress in meteorite studies, terrestrial weathering is one of the important problems involved in studying Antarctic meteorites. The degree of weathering is reported by using the A-B-C scale (*e.g.*, GOODING, 1986) for classification of Antarctic meteorites. The A-B-C classification system is qualitative. We developed a new method to quantify the degree of weathering using absorption bands near 3 μm (MIYAMOTO, 1988b). Quantified data may help us (1) in selecting less weathered meteorites from among the Antarctic collection, (2) in studying the influence of terrestrial weathering on Antarctic meteorites, and (3) in getting additional information on meteoritic terrestrial histories combined with the result of terrestrial age data.

Absorption bands (hydration bands) near the 3 μm wavelength region are sensitive to the presence of hydrates and/or hydroxyl ions (MIYAMOTO, 1988a), because the bands are due to OH stretching vibrations. Absorption features of hydration bands may be dependent on the degree of weathering, because terrestrial weathering produces hydrous minerals. Our method to determine the degree of weathering is based on the integrated intensity of absorption bands near 3 μm. In this study, we measured infrared spectral reflectances of some Antarctic meteorites to enlarge the data base of the degree of weathering.

2. Samples and Experimental Techniques

Antarctic meteorite samples used in our study were supplied by the National Institute of Polar Research and were powders from the cutting of the meteorites. These powders are carefully gathered to avoid contamination and stored in desiccators. The volume of powder produced is probably large enough to represent the overall nature of the meteorite, since the powder is produced by cutting across many different sections of the meteorite. Our samples included (ANTARCTIC METEORITE WORKING GROUP, 1981; YANAI and KOJIMA, 1985): YAMATO-(Y-)75028(H3), Allan Hills (ALH-)77182(H5), ALH-77271(H5), ALH-768(H6), ALH-78103(L6), ALH-78251 (L6), MET-78003(L6), Y-790448(LL3), Y-790964(LL), ALH-78132(eucrite).

Spectral reflectance measurements (2.5–25 μm) were made with a JASCO FT/IR-3 Fourier transform infrared spectrophotometer in a dry air atmosphere, equipped with a diffuse reflectance attachment. Spectra were taken from 3950 to 400 cm^{-1} at a resolution of 4 cm^{-1}. Scans were integrated 1000 times to enhance the signal-to-noise ratio. The incident angle of illumination was 45°, and an aluminum-coated mirror was used as a standard. Details of measurements are described in MIYAMOTO (1987b, 1988b).

We dried each powder sample at 110°C for 24 h to remove adsorbed water from the surfaces of grains. Each powder sample was placed in a hollow space 3.0 mm in depth. After setting the sample in the spectrophotometer, we left the sample in a

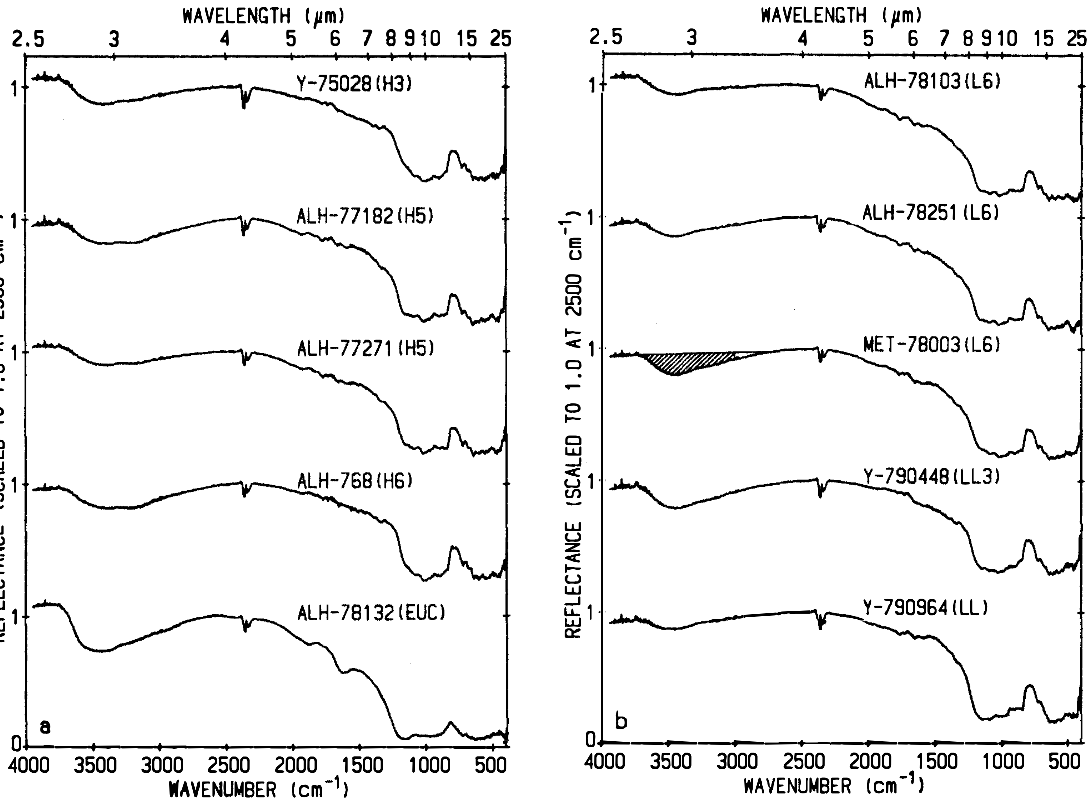

Fig. 1. Infrared reflectance spectra of some Antarctic meteorites. The shaded area represents the integrated intensity of absorption bands near 3 μm.

dry air atmosphere for one hour and measured the sample reflectance. Approximately 100 mg of each powder sample was used for measurements.

We define the integrated intensity of absorption bands near 3 μm as the shaded area in Fig. 1. The method to calculate the integrated intensity of absorption bands near 3 μm is described in MIYAMOTO (1988b).

Diffuse reflectance measurements do not require that a sample be mixed with KBr powder. This is favorable to studying hydration bands near 3 μm, because KBr tends to absorb water.

3. Results and Discussion

Figure 1 shows the results of reflectance spectra of some Antarctic meteorites. Sharp absorption at 2350 cm^{-1} is caused by atmospheric CO_2. Table 1 shows integrated intensities of absorption bands near 3 μm of some Antarctic meteorites measured in this study. Figure 2 compares spectral features near 3 μm of some meteorites which show different integrated intensities.

Figure 3 summarizes the results of integrated intensities of some Antarctic meteorites including those previously measured (MIYAMOTO, 1988b). Some Yamato meteorites measured show relatively weak integrated intensities compared with the Allan Hills meteorites measured. Integrated intensities near 3 μm vary widely among meteorites whose degree of weathering is reported to be A (MIYAMOTO, 1988b). There is no clear correlation between the integrated intensity and the degree of weathering on the A-B-C scale.

Many investigators have reported that the Allan Hills meteorites show older terrestrial ages than other Antarctic meteorites (*e.g.*, HONDA, 1981; NISHIIZUMI and ELMORE, 1985). Our results are consistent with their results, because more hydrous

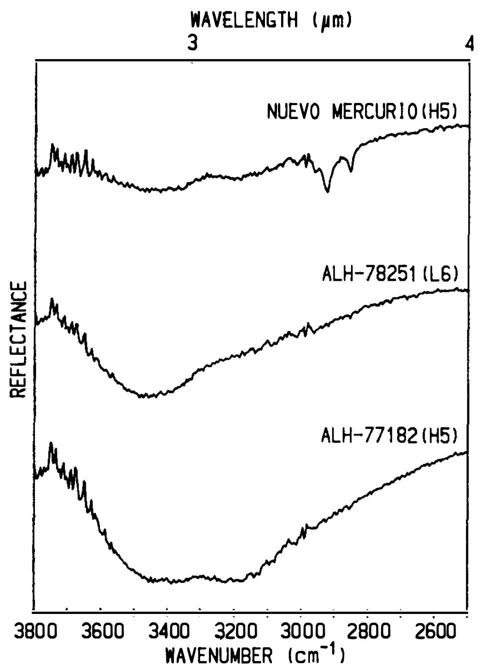

Fig. 2. Comparison of absorption features near 3 μm for some Antarctic meteorites which show different integrated intensities. Noisy spectra near 3700 cm^{-1} are due to residual H_2O in dry air. Absorption bands near 2900 cm^{-1} seen in the spectrum of Nuevo Mercurio are probably due to organic materials.

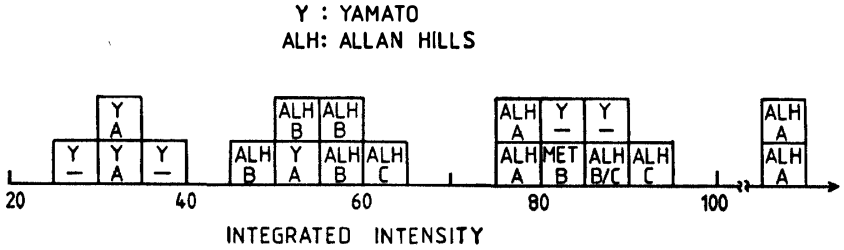

Fig. 3. Integrated intensities (cm^{-1}) of absorption bands near 3 μm of some Antarctic meteorites. ALH: Allan Hills meteorites; Y: Yamato meteorites; MET: Meteorite Hills meteorite. A, B, C, or B/C shows the degree of weathering on the A-B-C scale. "—" means that the degree of weathering is not reported.

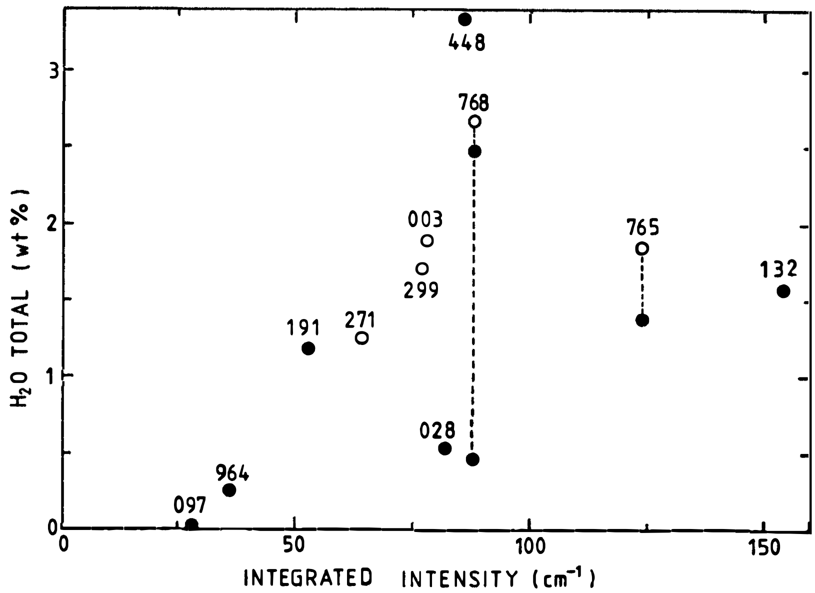

Fig. 4. Integrated intensities vs. H_2O contents for some Antarctic meteorites. Open and solid circles show chemical analysis data by JAROSEWICH *(1984) and* HARAMURA *et al. (1983 and unpublished data), respectively. Tie-lines connect the analysis data for the same meteorite. Numbers show the last three digits of names of Antarctic meteorites.*

minerals would be produced over longer periods of terrestrial age. Further studies combined with terrestrial age data are required to confirm this correlation between the integrated intensity and the terrestrial age and to study terrestrial history of Antarctic meteorites.

The integrated intensity of absorption bands near 3 μm is correlated with the amount of hydrates and/or hydroxyl ions. Figure 4 shows the correlation between the integrated intensity and the total amount of H_2O in some meteorites analyzed by the standard wet chemical analysis method. Chemical analysis data are from JAROSEWICH (1984) and HARAMURA *et al.* (1983 and unpublished data). Tie-lines in Fig. 4 connect the chemical analysis data of total H_2O contents for the same meteorite. The variation is probably due to the difference of location of the meteorite analyzed. A rough correlation can be seen between the integrated intensity and the total H_2O content, although we need more measurements in order to deduce a definite conclusion.

Degrees of weathering of some meteorites determined using the A-B-C scale appear to be inconsistent with those determined using other studies such as the integrated intensity near 3 μm, terrestrial age, or H_2O content. JAROSEWICH (1984) showed that ALH-77278(LL3) and ALH-77299(H3) contain considerable amounts of H_2O in spite of their being classified as A on the A-B-C scale. NISHIIZUMI and ELMORE (1985) showed that there is no clear correlation between the terrestial age of the Allan Hills meteorites and their degrees of weathering on the A-B-C scale. This apparent discrepancy may be explained by differences in weathering between different portions of a meteorite. The degree of weathering of a meteorite sample varies as a function of distance from the surface of the meteorite, because weathering proceeds from the surface to the center of a meteorite. In this study, we have tried to investigate the average degree of weathering of each meteorite. Abundant powders from cutting appear to be useful for getting "averaged" samples. Future studies should deal with the variation of weathering degree and its location inside the meteorite.

The ALH-765 and ALH-78132 eucrites show relatively strong integrated intensities (Table 1) in spite of A on the A-B-C scale. Degrees of weathering by the A-B-C scale for meteorites that do not contain metal are based mostly on overall rustiness (GOODING, 1986). Both polymict eucrites are similar in integrated intensity and this is consistent with the fact that they are thought to be samples of a single meteorite (DELANEY *et al.*, 1984).

SALISBURY and HUNT (1974) showed that for non-Antarctic meteorites there is an excellent correlation between a steepening slope in the visible (0.5/0.6 μm ratio) and a deepening of the 3.0 μm band (3.0/2.7 μm ratio). Average values of the 3.0/2.7-μm ratio for non-Antarctic meteorites are: 0.92 for C3&4 types (4 meteorites measured); 0.81 for E types (3 meteorites measured); 0.82 for H types (9 meteorites measured); 0.81 for L types (13 meteorites measured); and 0.80 for LL types (7 meteorites measured). Both chemistry and mineralogy vary among different chondrite groups. Although the amount of Fe^0, for example, varies widely among chondrite

Table 1. Integrated intensities (cm^{-1}) of absorption bands near 3 μm of some Antarctic meteorites.

Meteorite name	Class	Degree of weathering	
		Integrated intensity	A-B-C scale*
Yamato-75028	H3	82	—
ALH-77182	H5	90	C
ALH-77271	H5	64	C
ALH-768	H6	88	B/C
ALH-78103	L6	49	B
ALH-78251	L6	53	B
MET-78003	L6	80	B
Yamato-790448	LL3	86	—
Yamato-790964	LL	36	—
ALH-765**	EUC	124	A
ALH-78132	EUC	154	A

* YANAI and KOJIMA (1985).

** MIYAMOTO (1988b).

groups (*e.g.*, DODD, 1981), the average values of the 3.0/2.7-μm ratio are almost identical among E and ordinary chondrite groups. Our results show that the integrated intensity near 3 μm of ALH-77003(C3) is relatively large compared with Allende(C3) (MIYAMOTO, 1988b) and that the integrated intensity of both ALH-765(eucrite) and ALH-78132(eucrite) is even greater (Table 1), despite the fact that C3 chondrites and eucrites contain small amounts of Fe^0. These results imply that FeS is altered by terrestrial weathering in addition to iron. We cannot, however, exclude the possibility that some silicates are altered by terrestrial weathering (GOODING *et al.*, 1988). Olivine grains in heavily weathered Antarctic chondrites show reddish parts along cracks observed under a microscope. MIYAMOTO (1987a) showed that the integrated intensity near 3 μm is sensitive to the presence of hydrous minerals and that only 1 wt% of serpentine can be detected by the absorption feature of the 3 μm wavelength region in serpentine-olivine mixtures.

4. Conclusion

(1) A rough correlation can be seen between the integrated intensity of absorption bands near 3 μm and the total amount of H_2O in the meteorite.

(2) There is no clear correlation between the integrated intensity and the degree of weathering on the A-B-C scale.

(3) Integrated intensities near 3 μm vary widely among Antarctic meteorites whose degree of weathering is reported to be A (MIYAMOTO, 1988b).

(4) Some Yamato meteorites measured show weaker integrated intensities than the Allan Hills meteorites measured.

Acknowledgments

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