Infrared Micro-spectroscopy of Organic and Hydrous Components in Some Antarctic Micrometeorites.

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Introduction: Micrometeorites extracted from Antarctic ice are a major source of extraterrestrial materials available for study in the laboratory. Materials in this size range are important because the peak in the mass flux distribution of extraterrestrial particles accreted by the Earth occurs for particles ~200 μm in diameter with a mass accretion rate estimated at ~40×10^6 kg/year [1]. It has been suggested that micrometeorites may have contributed much pre-biotic organic matter to the early Earth [2], but the types and abundances of organic material in micrometeorites are poorly known. We have conducted infrared (IR) micro-spectrocopy of small micrometeorites (about 100 μm in size) in order to characterize organic matter that is present in the particles. The obtained results were compared with IR signatures of representative carbonaceous chondrites.

Sample Preparation and Experimental Technique: We used a fine writing-brush to pick individual particles and transfer them to a copper plate – the selected particles include micrometeorites (both melted and unmelted) and terrestrial particles such as quartz grains, rust particles from the ice melting procedure [3], and penguin feathers. We analyzed these particles using a scanning electron microscope (SEM). For each particle, we collected a secondary electron image (Fig.1) and an energy-dispersive X-ray (EDX) spectrum to select particles with approximately chondritic bulk compositions. Following the SEM analysis, micrometeorites were selected from the copper plate and were slightly pressed between two Al-foils for FT-IR measurements by JASCO FT-IR 620 + IRT30. The Al-foils were opened and one side with pressed particles was set onto the FT-IR microscope. Absorption spectra in the 4000 – 1000 cm^{-1} range were collected at room temperature with a 100x100 or 200x200 μm aperture.

Results and Discussion: We analyzed IR spectra of 13 Antarctic micrometeorite (AMM) particles and compared them with those of carbonaceous chondrites from Murchison (M), Orgueil (O) and Tagish Lake (TL). All the IR spectra for AMMs (Fig.2) show absorption peaks from CH_3 and CH_2 stretching and C-H bending at 2960, 2925 and 1460cm^{-1}, respectively. They also indicate the presence of a broad OH absorption band around 3400 cm^{-1}. The Si-O stretching band around 1200 cm^{-1} is a common feature of AMMs, indicating that they consist mainly of silicate grains.

CH_2 and CH_3 stretching features: In order to examine the relation between the absorption intensities (peak heights) of 2925 cm^{-1} due mainly to CH_2 stretching and 2960 cm^{-1} due mainly to CH_3 stretching, they were plotted in Fig.3 relative to Si-O peak heights. Most of AMMs are on the 1:1 line indicating the equal presence of CH_3 and CH_2. However, P2P5 shows a very low CH_3/CH_2 ratio, while P1E8 a very high one. (Fig.3). P2P5 may have long chain aliphatics such as lipids, which are main components of bio-membranes. In contrast, P1E8 may have abundant end methyl groups.

CH_2 and H_2O stretching features: The broad absorption band at 3400 cm^{-1} is mainly due to liquid-like molecular water [4]. The relative intensity of this band to Si-O is plotted against the CH_2/Si-O in Fig. 4. Most of AMMs are close to the 1: 1 line, showing that aliphatic CH rich ones are richer in water. However, P2P5 shows a low H_2O/CH_2 raio, indicating aliphatic abundance over water. On the other hand, P2T5 show a high H_2O/CH_2 ratio, indicating water abundance over aliphatics (Fig 4).

Comparison with Carbonaceous Chondrites: In order to compare these IR features of AMMs with those of representative carbonaceous chondrites, CH stretching and bending peak heights are plotted relative to 2925 cm^{-1} peak height (Fig.5). Most of AMMs have similar intensities of CH_3 stretching and CH bending. Some particles deviate from these clusters (P2O9-1, P1O6-1, P1E8). These AMMs have slightly lower bending/stretching ratios than Orgueil. The distribution of these AMMs are mostly reproduced in Murchison, while that of Tagish Lake shows 2 distinct groups with one (TL-1) slightly richer and another (TL-2) much richer in CH_3 stretching. Since polyester-like organic globules similar to bio-membrane were reported in Tagish Lake (TL-1)[5], these CH_3 rich characters of Tagish Lake can be indicative of the presence of methyl-rich aliphatics. AMM P1E8 shows a very high CH_3/CH_2 ratio (Fig.3) and has a high stretching/bending ratio, but its character is somewhat different from Tagish Lake (Fig.5).

The IR water/aliphatic ratios of AMMs are plotted in Fig.6 together with those of carbonaceous chondrites. Most of AMMs are poor in liquid-like water. Orgueil and Murchison are slightly richer in water than these AMMs. Tagish Lake shows again 2 groups with extended distributions and they are richer in water and aliphatics. P1E8 and P2T5 are distributed close to Tagish Lake, showing their aliphatic-rich character.

These IR characteristics of organic and hydrous components in AMMs and carbonaceous chondrites can be discussed in relation to aqueous alteration and thermal history, by comparing these results with kinetic heating experiments of organics [6].

Conclusions: IR micro-spectroscopy of aliphatic and hydrous components of AMMs suggests that this type of study can be a possible classification method for micrometeorites. Some AMMs show distinct characteristics for these components. Among them, P2P5 is rich in aliphatics with abundant CH_2 groups. P1E8 shows abundant methyl groups (CH_3) with somewhat similar character to Tagish Lake.

References: [1] Love, S. G. and Brownlee, D. E. (1993) *Science*, 262, 550. [2] Anders, E. (1989) *Nature*, 342, 255. [3] D. Brownlee, pers. Comm. [4] Ito, Y. and Nakashima, S. (2002) *Chem. Geol*. **189**, 1.
[5] Nakamura, K. et al., (2003) *Intl. J. Astrobiology*. **1**, 179.
[6] Kebukawa, Y. et al. (2005), *LPSC2005 abstract*.

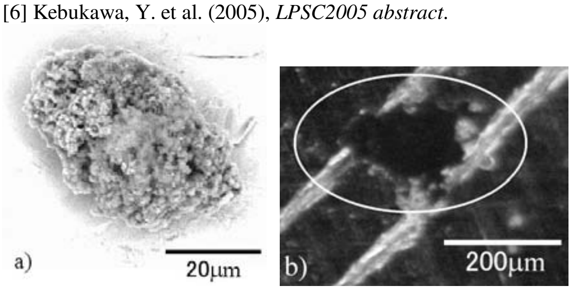

Fig.1: a) The secondary electron image of one of AMM particles (66 x 21μm). b) The same sample on a Al-foil for IR micro-spectroscopy.

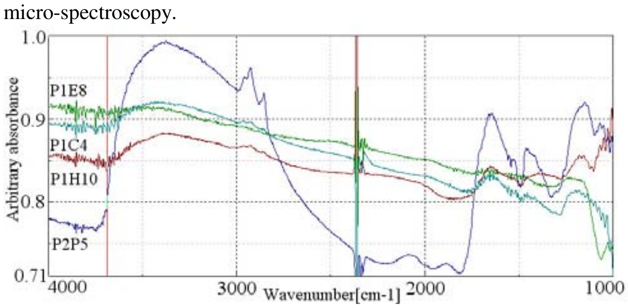

Fig.2 Representative IR spectra of AMM particles. The vertical axis is arbitrary absorbance and the horizontal axis is wavenumber.

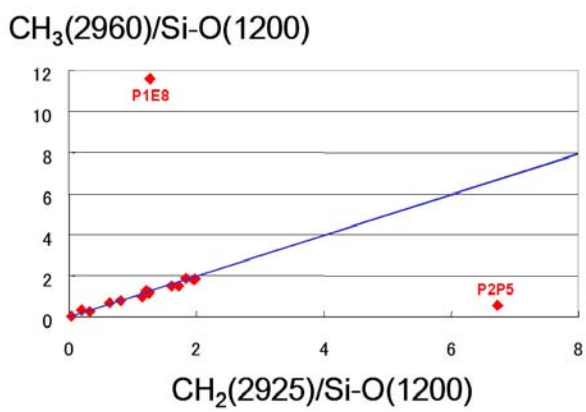

Fig.3: The relation between CH_2 (2925 cm^{-1}) and CH_3 (2960 cm^{-1}) IR peak heights relative to Si-O peak (1200 cm-1) of AMMs.

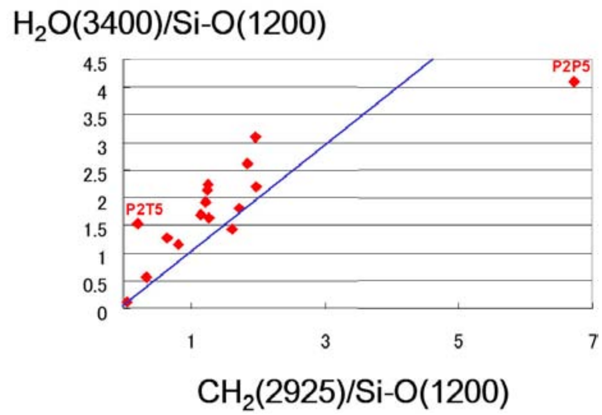

Fig.4: The relation between CH_2 (2925 cm^{-1}) and H_2O (3400 cm^{-1}) IR peak heights relative to Si-O peak (1200 cm-1) of AMMs.

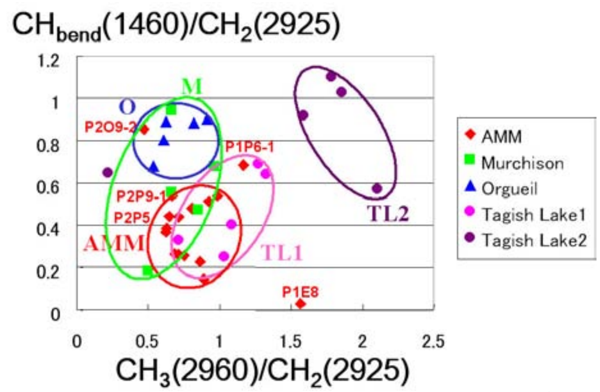

Fig.5: The relation between aliphatic CH_3 stretching (2960 cm^{-1}) and C-H bending (1460 cm^{-1}) IR peak heights relative to CH_2 streething one (2925 cm^{-1}) of AMMs together with carbonaceous chondrites .

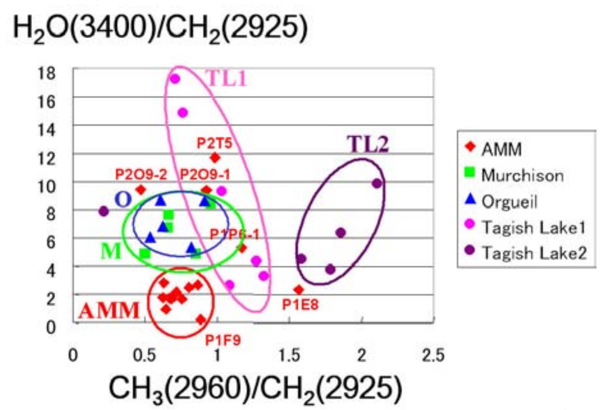

Fig.6: The relation between aliphatic CH_3 stretching (2960 cm^{-1}) and OH stretching (3400 cm^{-1}) IR peak heights relative to CH_2 streething one (2925 cm^{-1}) of AMMs together with carbonaceous chondrites