

INTERACTION BETWEEN ORGANIC MATTER AND MINERALS IN METEORITE PARENT BODIES DURING THERMAL PROCESSES

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Introduction: Carbonaceous chondrites and some primitive ordinary chondrites contain up to a few wt.% of organic matter. The chemical structures and compositions of organic matter reflect the physical and chemical environments in meteorite parent bodies [1,2]. Minerals could have some effects on molecular structural changes of organic matter during parent body processes. Although the possibility of organic reactions on the surface of some minerals was pointed out [3], experimental studies evaluating effects of minerals were limited [4,5]. In this study, heating experiments of organic matter with/without minerals were conducted. Kebukawa et al. [2] showed that carbonyl groups (C=O) were a good tracer to understand both the degrees of thermal metamorphism and chemical environments in parent bodies. The changes in C=O groups were thus particularly focused on in this study to investigate the effects of minerals on changes in organic matter during thermal processes.

Experiments: Molecular cloud organic material analog (hereinafter referred to as MC), which is a mixture of various organic compounds prepared by the method of Kouchi et al. [6], was heated in an autoclave with/without minerals (olivine and montmorillonite powders). The starting materials were (1) MC 5 g, (2) MC 0.25 g + olivine 0.25 g and (3) MC 0.25 g + montmorillonite 0.25 g. Each sample was put in a Pyrex glass tube without sealing and the tube was placed in the autoclave. The autoclave was purged with N₂ + H₂ gas (99 : 1, v/v) for three times at 60 atm to eliminate air. The samples were heated at 200°C, 300°C, or 400°C in the autoclave for 5 hours. The pressures were initially set at the normal pressure and room temperature. The gas pressures were approximately 1-8 atm during heating.

Experimental products were analyzed by using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), gas chromatography mass spectrometry (GC/MS) and scanning electron microscope equipped with energy dispersive X-ray spectroscopy (SEM-EDS).

Results and Discussion: The IR absorption spectra of C=O changed significantly, particularly with montmorillonite, with increasing heating temperature. The increases in the intensity ratios of C=O/aromatic C=C of MC + montmorillonite products at 200°C was smaller than that of MC heated products and MC + olivine products (Fig. 1). The intensity ratios of MC + montmorillonite products at 300°C and 400°C were much lower than those of MC heated products and MC + olivine products. The GC/MS results of MC heated products showed the changes of C=O were relevant to long-chain carboxylic acids. The XRD showed that MC was intercalated into the interlayer of montmorillonite. These results indicate that decarboxylation and/or cracking of long-chain carboxylic acids could be promoted by Lewis and Brønsted acid sites of montmorillonite. Al³⁺ and/or Fe³⁺ ions in octahedral sheets of montmorillonite are known to contribute to producing CO₂ [7]. Cracking is known to be catalyzed by Brønsted acid sites [8]. On the other hand, olivine did not show significant effects on decomposition of MC compared with montmorillonite.

Decreases of C=O would result in the decreases of O/C ratios of organic matter in meteorites. Our results further imply that the smaller O/C ratios of insoluble organic matter in heated CM chondrites than those in ordinary chondrites, CO and CV chondrites with similar H/C ratios [1] might be due to co-existing phyllosilicates during the thermal processes.

SEM-EDS analyses indicated the possibility of alteration of the olivine surface to hydrated phase during the heating experiments. The hydration could be triggered by the dehydration of MC. These results suggest that organic matter could have contributed to hydration of minerals in meteorite parent bodies, particularly in dry environments.

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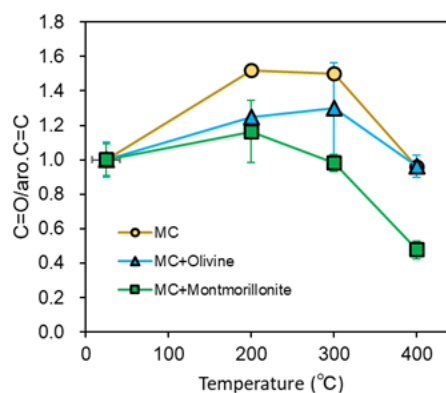


Figure 1. Changes in C=O/aromatic C=C peak height ratios with temperature.