POSSIBLE EFFECTS OF GAMMA-RAY FROM SHORT-LIVED RADIOACTIVE NUCLIDES ON FORMATION OF ORGANIC MATTER DURING AQUEOUS ALTERATION.

Y. Kebukawa[1]*, S. Misawa[1], S. Asano[1], I. Yoda[2], H. Mita[3], Y. Muramatsu[4], S. Hamanaka[4], Y. Tobita[4], and K. Kobayashi[1], [1]Yokohama National University, 79-5 Tokiwadai, Hodogaya-ku, Yokohama 240-8501, Japan, [2]Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan [3]Fukuoka Institute of Technology, 3-30-1 Wajirohigashi, Higashi Ward, Fukuoka 811-0295, Japan, [4]University of Hyogo, 2167 Shosha, Himeji, Hyogo 671-2201, Japan (*Email: kebukawa@ynu.ac.jp)

Introduction: Carbonaceous chondrites contain up to a few wt.% organic matter (OM), and the most of organic matter (>70 wt.%) exists as in the form of solvent insoluble organic matter (IOM) which has complex macromolecular structures. Rest of the organic carbon is in the form of solvent extractable organic compounds with highly diverse molecular structures. Some of them, such as amino acids and nucleobases could have been contributed to the emergence of life in the early earth. OM in chondrites could have been originated from various astronomical environments including interstellar icy dust grains [e.g., 1] and aqueous alteration in planetesimals [e.g., 2]. We have conducted hydrothermal experiments simulating aqueous alteration and shown that various amino acids are produced simultaneously with IOM-like macromolecular organic solids from simple molecules such as formaldehyde and ammonia [3,4]. The most effective heat source during aqueous alteration is considered to be the decay of short-lived radioactive nuclides such as ^{26}Al [5]. Here we evaluate effects of gamma-ray from decay of short-lived radioactive nuclides on formation of OM during aqueous alteration.

Experiments: A mixture of water, formaldehyde and ammonia in ratio of 100 : 5 : 5 (mol) simulating primordial materials in comets and asteroids was irradiated by gamma-ray (up to 45 kGy) using ^{60}Co gamma-ray source at Tokyo Institute of Technology. The same solution was heated under various temperatures (80-150 °C) for comparison. The experimental products were analyzed using Fourier transform infrared spectroscopy (FTIR), C-K, N-K, O-K X-ray absorption near-edge structure (XANES), and electrospray ionization (ESI)-Orbitrap mass spectrometry (MS). Amino acid analyses were conducted using cation-exchange high performance liquid chromatography (HPLC) after acid hydrolysis (6M HCl, 110°C, 24h).

Results and Discussion: High-resolution ESI-MS spectra of the product solutions were analyzed by mass defect (MD) plots using Attributor software provided by F. R. Orthous-Daunay. The MD plots as well as FTIR and XANES spectra indicate that the reaction pathway and products of gamma-ray irradiation were significantly different from heating products. Various amino acids (glycine, alanine, β-alanine, α-amino butyric acid and glutamic acid) were detected after 45-kGy gamma-ray irradiation and its total concentration was ~200 µM. While, the total amino acid concentration after heating (150 °C, 72h) was ~200 µM, but ~90% of the products was glycine.

Total gamma-ray irradiation in parent bodies can be calculated as 3.8 MGy using canonical ^{26}Al/^{27}Al ratio of ~5 $\times 10^{-5}$ [6] and Al concentration of 1.14 wt.% (the value of Murchison [7]). Thus, assuming roughly 1% of total gamma-ray can be used for amino acid production, ~200 µM amino acids can be produced starting from comet-like ice composition. More importantly, gamma-ray from the decay of short-lived radioactive nuclides could have contributed to produce more diverse suite of amino acids during alteration.

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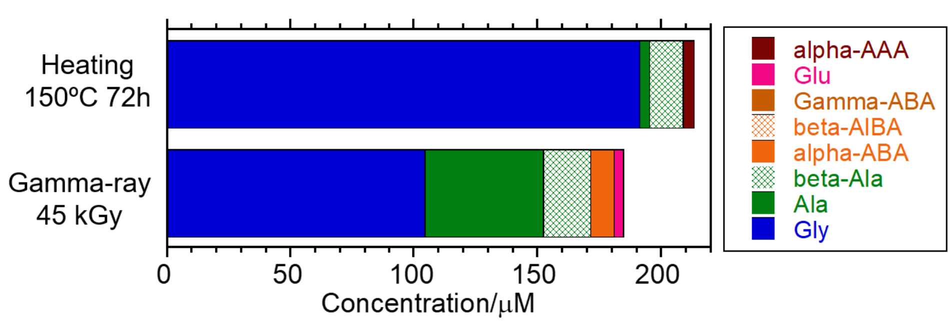

Fig. 1: Amino acid concentrations in the reaction products after acid hydrolysis. AAA: aminoadipic acid, Glu: glutamic acid, ABA: aminobutyric acid, AIBA: aminoisobutyric acid, Ala: alanine, Gly: glycine.