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Hydrocarbons in the Yamato-791198 Carbonaceous Chondrite from Antarctica

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Yamato-791198 yielded up to 44 aromatic hydrocarbons and related compounds in the range of naphthalene and pyrene, including almost all structural isomers of methyl- and dimethyl-naphthalene. Several predominant compounds were present at the level of 10^{-7} g/g. Normal alkanes(C_{12}- C_{22}) were predominant in the aliphatic hydrocarbons and were at the level of 10^{-8} g/g.

The first unambiguous evidence of organic compounds in carbonaceous chondrites was shown by the study of the Murchison carbonaceous chondrite which fell in 1969.$^{1)}$ In the same year, the Japanese Antarctic Research Expedition team found meteorites in Antarctica.$^{2)}$ Since this year, more than 8000 meteorites have been found in Antarctica, and several carbonaceous chondrites were analyzed for extraterrestrial organic compounds.$^{3-7)}$ Among these chondrites examined, the Yamato-791198 carbonaceous chondrite yielded the largest amount of amino acids.$^{6)}$ Accordingly, we analyzed the same chondrite for carboxylic acids to find a number of aliphatic and aromatic monocarboxylic acids.$^{7)}$ In this study, we further extended our analysis of the same chondrite for hydrocarbons and found both aliphatic and aromatic compounds.

The sample analyzed was Yamato-791198.60, a part of Yamato-791198, a C2 chondrite originally weighing 180 g. Of a total 1.8 g powdered sample, 0.5 g were used for extraction with 5 ml of 5% KOH-methanol(w/v) by refluxing in a degased-sealed glass tube at 80-90 °C for 3 h. After centrifugation the precipitate was washed with 2 ml of methanol twice and the residue was saved. These two methanol solutions were combined to the supernatant. To this combined solution were added 5 ml of water and the mixture was extracted with 3 ml of benzene three times which were combined together. The residue saved was extracted by sonication with 5 ml of a mixture of benzene and methanol(9:1 by volume) twice. To this extracted solution was added the combined benzene solution. The solution, thus obtained, was concentrated by careful evaporation and was applied to a silica gel chromatographic column. Hexane was used for the elution of aliphatic hydrocarbons followed by benzene for aromatic ones. The aliphatic and aromatic fractions were analyzed by GC and GC-MS. A fused-silica capillary column(50 m x 0.25 mm ID) coated with OV-1 was used for GC analysis. The mass spectrometer was equipped with a library search system containing fragmental patterns of 39750 compounds by NBS.

Organic solvents and water used were doubly distilled. KOH pellets were heated at 350 °C for 30 min and silica gel at 500 °C for 3 h to remove organic contaminants. Glassware was heated at 500 °C for 3 h just prior to use. Most of the analytical processes were carried out on a clean bench in a clean room. A procedural blank was carried out with 0.5 g of pre-ignited sand powder and the result showed a few insignificant peaks by GC(Figs. 1 and 2) which were ignored.

Figure 1 shows a gas chromatogram for aromatic hydrocarbons recovered from

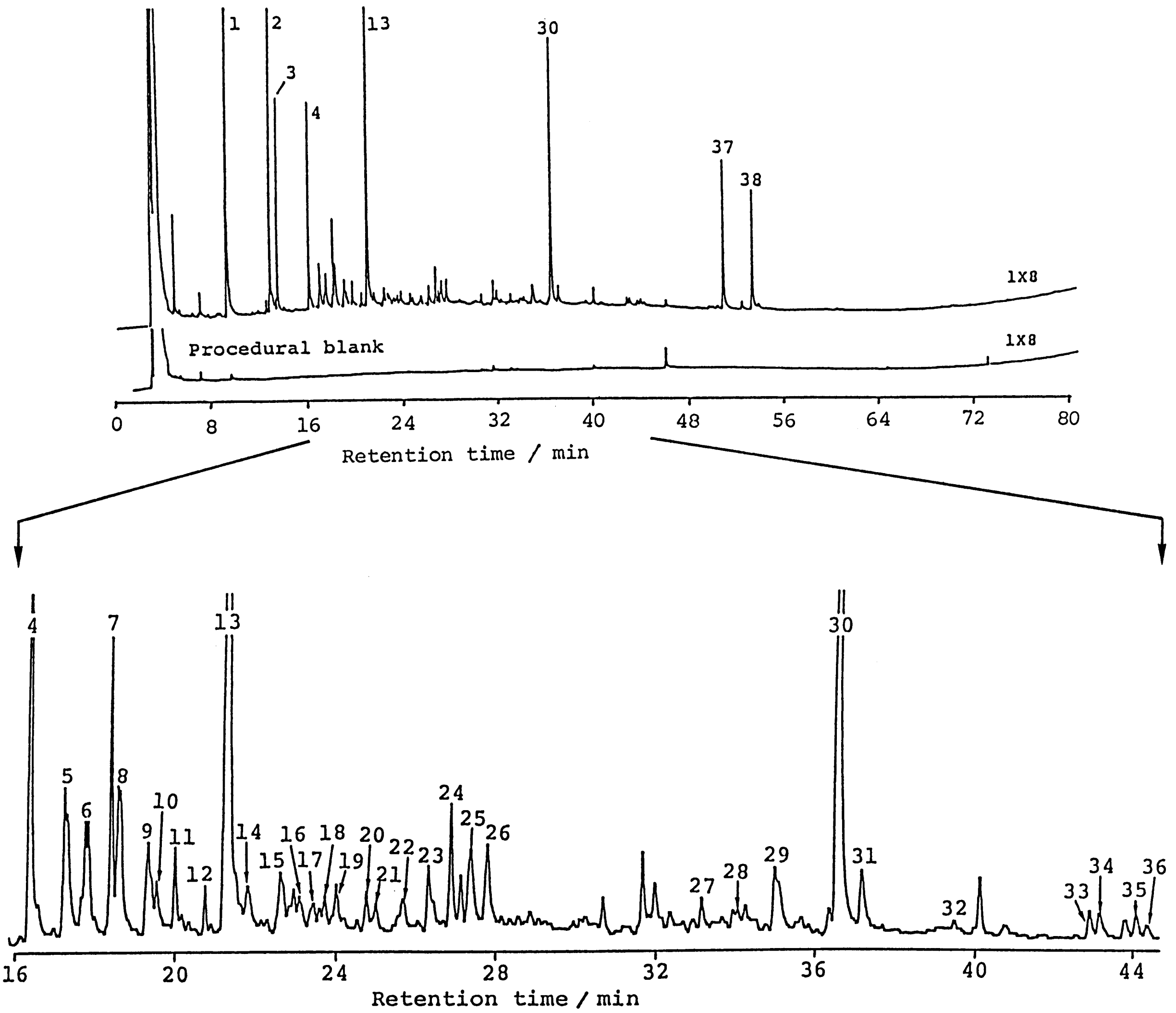

Fig. 1. Gas chromatogram of aromatic hydrocarbons in Yamato-791198.60
Peak No., 1. Naphthalene, 2. 2-Methylnaphthalene, 3. 1-Methylnaphthalene, 4. Diphenyl, 5. Ethylnaphthalene, 6. 2,6- and 2,7-Dimethylnaphthalene, 7. 1,3-Dimethylnaphthalene, 8. 1,7- and 1,6-Dimethylnaphthalene, 9. 1,4- and/or 1,5-Dimethylnaphthalene, 10. Acenaphthylene, 11. 1,2-Dimethylnaphthalene, 12. Methyldiphenyl, 13. Acenaphthene, 14. Methyldiphenyl, 15-22. C3-Naphthalene, 23. C3-Naphthalene and Fluorene, 24-26. Methylacenaphthene, 27. 9,10-Dihydrophenanthrene, 28. Fluoren-9-one, 29. Dibenzothiophene, 30. Phenanthrene, 31. Anthracene, 32. Carbazole, 33-36. Methylphenanthrene and/or Methylanthracene, 37. Fluoranthene, 38. Pyrene

Table 1. Aromatic hydrocarbons in Yamato-791198.60

No.[a)]	Compound	Content(g/g)
1	Naphthalene	8.6×10^{-7}
2	2-Methylnaphthalene	2.4×10^{-7}
3	1-Methylnaphthalene	1.6×10^{-7}
4	Diphenyl	1.7×10^{-7}
13	Acenaphthene	6.3×10^{-7}
30	Phenanthrene	5.1×10^{-7}
31	Anthracene	3.9×10^{-8}
37	Fluoranthene	3.7×10^{-7}
38	Pyrene	3.4×10^{-7}

a) Same numbers as shown in Fig. 1.

Yamato-791198. The library search system revealed 38 peaks of which 19 were identified further by the use of authentic compounds. Five among 38 peaks might be composits of two compounds, suggesting the presence of up to 44 compounds. Of these, 41 were aromatic hydrocarbons. The three other aromatic compounds were fluorene-9-one, dibenzothiophene, and carbazole.

The quantities of predominant compounds were estimated from peak heights on the chromatogram by comparison to those of authentic compounds. These quantities were mostly at the level of 10^{-7} g/g or nmol/g(Table 1), in which naphthalene was the most abundant followed by acenaphthene and phenanthrene. The rests of the compounds were present at the level of 10^{-8} g/g or less, judging from their peak heights.

The two structural isomers of methylnaphthalene were present. The abundance of 2-methylnaphthalene was 1.5 times more than that of 1-methylnaphthalene. The relative abundance of the two isomers suggested that they had been stabilized thermodynamically to a certain extent and had not maintained the effect of kinetic control upon their formation. Five peaks(Nos. 6,7,8,9, and 11) were assigned to dimethylnaphthalene. Three of these peaks might be composite of two isomers, and therefore, the maximum 8 of possible 10 isomers of the compound could be present. As to the rest two isomers, 2,3-dimethylnaphthalene might have been detected by more detailed analysis, though the presence of 1,8-dimethylnaphthalene was questionable because of its stability due to peri-effect. As tricyclic aromatic compounds, phenanthrene was about 13 times more abundant than anthracene. A similar distribution was observed, that is, while pyrene was present in amount easily detectable, there was no detectable chrysene. These various findings on the characteristic distribution of aromatic hydrocarbons from the chondrite clearly indicated that these compounds were not related to biological ones.

Aromatic hydrocarbons were reported from Murchison.[8)] The analysis found 22 possible compounds, while 44 compounds by our examination of Yamato-791198. The abundance of these compounds was approximately one order of magnitude more in Murchison than Yamato-791198. The 2-/1-methylnaphthalene ratio in Murchison was 1.6. Four isomers of dimethylnaphthalene were reported from Murchison, but 1,8-dimethylnaphthalene was not detected either. Our investigation of aromatic hydrocarbons is the first for Antarctic carbonaceous chondrites, doubling the number of the identified compounds for Murchison.

Figure 2 shows a gas chromatogram of aliphatic hydrocarbons recovered from Yamato-791198. From the chromatogram, it is clear that the homologous series of n-alkanes was predominant. These n-alkanes identified were in the C_{12} to C_{19} range, and were present at most at the level of 10^{-8} g/g. On the basis of retention time,

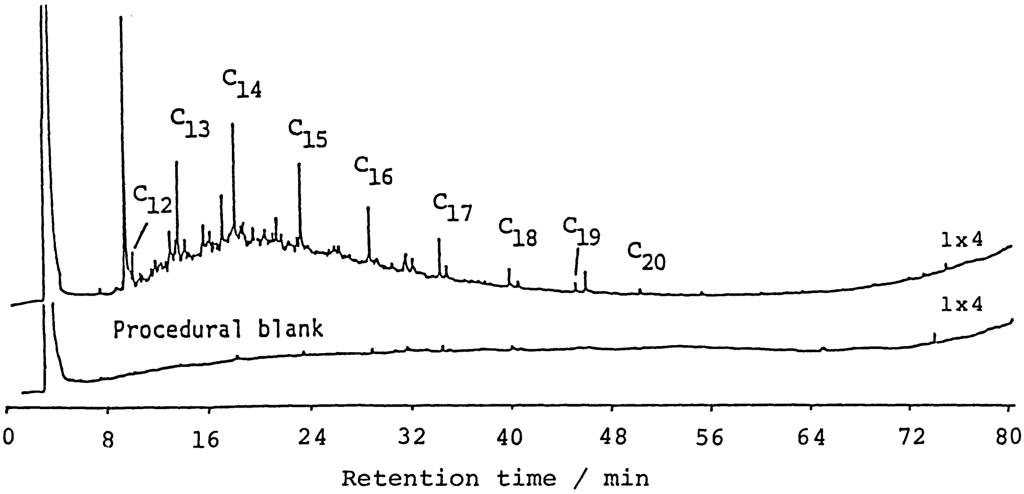

Fig. 1. Gas chromatogram of aliphatic hydrocarbons in Yamato-791198.60. Peaks shown by C_{12} to C_{20} are for n-alkanes.

n-alkanes of up to C_{22} were detected. The profile of these n-alkanes in the chondrite showed no predominance of odd or even carbon-numbered molecules. This result support the finding of the predominance of n-alkanes[9)] but not of various structural isomers[1)] in the aliphatic hydrocarbons of Murchison. These chain molecules with C_{12} and longer might have formed in the presence of heterogenous surfaces. If so, mineral grains in the chondrite probably provided such surfaces.

The analyses of organic compounds in Yamato-791198 revealed the presence of indigenous amino acids, carboxylic acids, and now hydrocarbons. The presence of these three classes of compounds identified in this laboratory indicates strongly that more numbers of different classes of organic compounds could exist in the chondrite. Further examination of those unrevealed compounds will add useful information on the better understanding of the organochemical reaction in the early solar system.

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