MODAL ABUNDANCES OF CARBON IN UREILITES: IMPLICATIONS FOR THE PETROGENESIS OF UREILITES. Y. Nakamuta, Kyushu University Museum, Kyushu University, Fukuoka 812-8581, Japan, e-mail address: nakamuta@museum.kyushu-u.ac.jp.

Introduction: Ureilites comprise a meteorite group of achondrites, being mainly composed of olivine and pigeonite. They are unique among achondrites in containing relatively a large amount of primordial noble gases and carbon occurring as graphite and diamond. The primordial noble gases are thought to be exclusively contained in carbon minerals [1]. It has been a problem to reconcile the primordial natures as chondritic abundances of noble gases to igneous or metamorphic natures as coarse-grained recrystallized olivine and pyroxenes. To resolve the problem and give a constraint to the petrogenesis of ureilites it may be important to know the form and the mode of occurrence of carbon minerals in ureilites. So far, carbon minerals are thought to be interstitial material, often referred to as matrix or vein material together with metal, sulfide and minor fine-grained silicates.

Recently, large, mm-sized, euhedral graphite crystals were found in some ureilites [2] and diamond in ureilites was shown to have formed from well-crystallized graphite by shock at the time when the ureilite parent body or bodies broke up [3].

In this study, polished thin sections (PTSs) of fifteen Antarctic ureilites having variable olivine-core mg# (Mg/(Mg + Fe) molar%) were observed by an optical microscope in reflected light and morphologies and modal abundances of graphite were analyzed in order to know the petrogenesis of ureilites.

Experiments: PTSs of fifteen Antarctic ureilites, Y-791839, Asuka 881931, Y-74130, MET 78008, ALH 78262, ALH 78019, Y-8448, Y-790981, Asuka 87031, Y-82100, Y-74154, Y-74123, ALH 77257, Y-791538 and Y-74659, were observed and photographed by an optical microscope in reflected light. Graphite grains were marked on the photographs of each PTS by hand and their shapes and modal abundances were analyzed by using an image-processing program on a personal computer. C-rich grains selected from disaggregated samples of each ureilite preserved in NIPR were X-rayed by using a Gandolfi camera and carbon minerals composing them were identified based on their X-ray powder diffraction patterns. Raman spectra were also obtained in order to identify tiny crystals in some PTSs by using a laser-Raman spectrometer with 1 micrometer-beam radius.

Results: ALH 78019 and Y-8448 contain only well-crystallized graphite as a carbon mineral, Y-8448 and Y-74659 contain both well-crystallized graphite and grains composed of graphite and diamond, which are thought to have formed by partial conversion of graphite to diamond by a later shock-event [3], and other eleven ureilites exclusively contain carbon grains composed of graphite and diamond.

Graphite in PTSs shows tan-gray color and metallic luster. Graphite that was partially converted to diamond shows black in color in PTSs, however, almost preserves external forms of graphite. Graphite in ureilites occurs in olivine or pyroxene crystals or interstitially as blade-like, lath or amoeboid shapes.

Fig. 1 shows the plots of modal abundances of the sum of graphite and graphite/diamond grains (**a**) and averaged fractal dimensions of graphite shapes (**b**) vs. mg# of olivine-core of each ureilite. Fig. 1a reveals that modal abundances of graphite and graphite/diamond decrease with the increase of mg# in two regions, that of mg# between 75 and 79 and that between 86 and 93. Y-82100 and Y-74154 having intermediate mg# do not belong to the two groups and may make a distinct group. Berkley et al. [4] proposed a classification of ureilites based on mg# and distinguished three groups. The results of this study also suggest three subgroups of ureilites, having mg# of 75-79, 79-86 and 86-93, respectively in which the boundary between subgroups II and III is at the lower mg# side than the previous one [5,6].

Fig. 1b shows that the averaged fractal dimensions of graphite shapes are smaller in ureilites of subgroup I than those of subgroups II and III. The fractal dimension becomes smaller for a crystal with a straight outline and greater for a crystal with an irregular one. Graphite crystals in ureilites occur as blade-like, lath or amoeboid shapes. Then, Fig. 1b objectively represents that graphites in subgroup I ureilites tend to take blade-like or lath shapes and those in subgroup II and III ureilites tend to take an amoeboid shape.

Discussion: The mode of occurrence of carbon minerals in ureilites and the origin of diamond have been controversial [1]. The intimate relations of the modal abundances and the crystal shapes of graphite to olivine-core mg#, revealed in this study, clearly suggest that graphite is a mineral that occurred through igneous or metamorphic processes together with olivine and pyroxenes and diamond formed by a later shock-event.

Smelting reactions were suggested for the igneous or metamorphic petrogenesis of ureilites [7]. At a higher pressure, smelting reaction will be more suppressed and the olivine mg# will be smaller, i.e. olivine will be iron-rich, and the modal abundance of carbon will be greater, i.e. carbon will be less lost. Then, the inverse relations between modal abundances of carbon and mg#s, shown in Fig. 1a, confirm the smelting reactions in ureilites and suggest that ureilites having a higher modal abundance of carbon and a lower mg# of olivine may have formed at a higher pressure, i.e. at a deeper part of a parent body. Fig. 1a clearly shows that subgroups I and III are plotted along two different inverse trends, respectively. The result strongly suggests that subgroup I and III ureilites came from different parent bodies.

Fig. 1b suggests that graphite in subgroup I ureilites tends to have a lath shape and graphite in subgroup II and III ureilites an amoeboid shape. The lath-shaped graphite appears as euhedral crystals, but euhedral-appearing graphite crystals can also form during metamorphism, for example, graphite flakes in marble [8]. It may be reasonable to think that lath-shaped graphite crystals formed in a condition near to metamorphism since lath-shaped graphite occurs mainly at grain boundaries among silicate minerals. Amoeboid-shaped graphite can be though to have formed in a condition where liquid phase was much abundant since rounded olivine crystals were enclosed in amoeboid graphite. The results are consistent with higher temperature formation of subgroup II and III ureilites than subgroup I ureilites [5].

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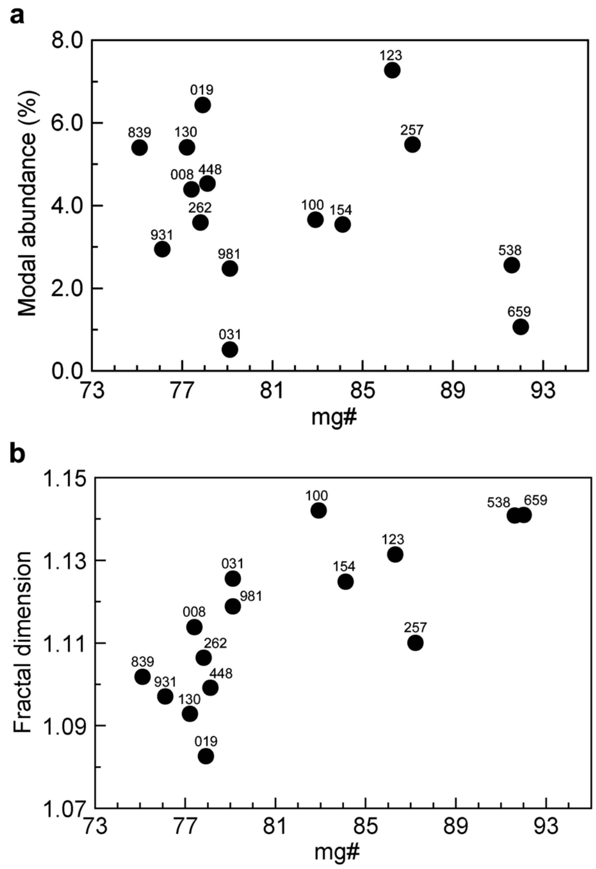

Fig. 1 Plots of modal abundances of carbon (**a**) and fractal dimensions of graphite shapes (**b**) vs. mg# of olivine-core. Numbers shown with each plot are last three digits of each meteorite name.