# CARBONACEOUS PHASES IN GOALPARA.

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**Introduction:** Ureilites comprise the second largest group of achondrites. Most ureilites are unbrecciated monomict rocks with coarse-grained igneous textures and are thought to represent the mantle of a partially melted, carbon-rich asteroid [e.g., 1, 2]. The C contents vary significantly, from 0.2 to 6 %, because the contents of matrix vary [3]. Ureilites show highly fractionated igneous features, and at the same time show primitive characteristics, including planetary-type noble gases [e.g., 4-8] and O-isotopic compositions [e.g., 9-11]. Silicates and oxides in ureilties have been extensively studied. In this study, we focus on carbonaceous part of ureilites to better understand the origin and evolution of ureilties.

**Experimental and Discussion:** 2.85 g of Goalpara, provided by The Smithsonian National Museum of Natural History, was treated alternately with HF-HCl and HCl to remove silicates followed by the $H_3BO_3$ treatment to completely dissolve fluorides. The residue was oxidized with $HClO_4$ at 205°C for two hours four times to ensure that reactive carbonaceous materials were destroyed. We examined the oxidized residue with a field-emission scanning electron microscope JEOL JSM-7000F at The University of Tokyo. Of the 67 grains examined, 54 grains were carbonaceous, 12 grains were Si-rich grains, and one grain was Al-Mg-Fe-Si-rich oxide. We note that the fraction of carbonaceous grains would have been higher because our analysis was biased toward finding non-carbonaceous grains.

We examined Raman spectra of 82 grains in the oxidized residue. Many grains show broad features, monotonically increase intensity throughout the analysis range and it can ben attributed to photoluminescence [see Fig. 1 by 12]. Photoluminescence indicates the presence of unsaturated carbonaceous molecules with conjugated double bonds [12]. The most abundant is grains showing both the diamond and graphite peaks, showing the peaks at 1320 – 1332 $cm^{-1}$ and 1564 – 1599 $cm^{-1}$, respectively. Since the peak of diamond is expected to be at 1332 $cm^{-1}$, and the G band of graphite is ~1580 $cm^{-1}$, the peaks were shifted downward and this might be due to laser-induced heat [13].

Three grains are Si-rich. They show peaks at 787 – 788 $cm^{-1}$ and 967 – 968 $cm^{-1}$ and these peaks agree with those of 6H-SiC [14]. Presolar SiC grains are present in primitive chondrites. Those in Goalpara are very different from presolar SiC grains. Two polytypes dominate presolar SiC grains. Of the 303 SiC grains from Murchison, 80% of Murchison SiC grains are cubic 3C-SiC, 2 % are hexagonal, and 17 % are 2H/3C intergrowth [15]. In contrast, all Goalpara SiC grains we examined are 6H-SiC. Second, the Goalpara SiC grains show a very smooth surface, while presolar SiC grains are fluffy, both of which experienced the same harsh chemical treatment.

Silicon carbide is industrially produced by the Acheson process below.

$SiO_2 + C \rightarrow SiC + CO$ at 2500 – 2700 K

Silicon carbide prepared by this method has a large grain size and its crystal structure is mainly of the alpha (hexagonal or rhombohedral) type [e.g., 16]. We speculate that SiC was produced by the same reaction in the UPB (ureilite parent body): $SiO_2$ was produced from olivine and reacted with carbon, producing SiC and CO. The temperature of the Acheson process at atmospheric pressure is too high to be accounted in the UPB. But different pressures would result in different temperatures. The presence of SiC grains in a Goalpara indicates very reducing conditions the UPB experienced. Although Fe-Cr-carbide has been observed in NWA 766 [17], SiC grains have never been observed in ureilites. This is the first report that SiC grains are present in a ureilite, and that they formed in the early stage of the solar system evolution. We also identified graphite whiskers. They show a prominent peak at 1570 $cm^{-1}$ with a small peak at 1332 $cm^{-1}$, indicating that the grain is well-crystalized graphite. The history of the UPB was also imprinted in the carbonaceous phases in a ureilite.

**References:**

[1] Goodrich C. A. et al. (2004) *Chem. Erde* 64:283-327. [2] Mittlefehldt D. W. et al. (1998) In *Planetary Materials,* (Parike J. J.) Mineralogical Society of America, Washington, D. C. 4-01 - 04-195. [3] Goodrich C. A. (1992) *Meteoritics* 27:327-352. [4] Mazor E. et al. (1970) *Geochim. Cosmochim. Acta* 34:781-824. [5] Göbel R. et al. (1978) *J. Geophys. Res.* 83:855-867. [6] Ott U. et al. (1984) *Meteoritics* 19:287-288. [7] Goodrich C. A. et al. (1987) *Meteoritics* 22:191-218. [8] Rai V. K. et al. (2003) *Geochem. Cosmochim. Acta* 67:4435-4456. [9] Clayton R. N. and Mayeda T. K. (1988) *Geochim. Cosmochim. Acta* 52:1313-1318. [10] Clayton R. N. and Mayeda T. K. (1996) *Geochim. Cosmochim. Acta* 60:1999-2017. [11] Kita N. T. et al. (2004) *Geochem. Cosmochim. Acta* 68:4213-4235. [12] Wopenka B. (1988) *Earth Planet. Sci. Lett.* 88:221-231. [13] Kagi H. et al. (1994) *Geochim. Cosmochim. Acta* 58:3527-3530. [14] Okumura H. et al. (1987) *Journal of Applied Physics* 61:1134-1136. [15] Daulton T. L. et al. (2002) *Science* 296:1852-1855. [16] Morito H. and Yamane H. (2013) *Journal of the Ceramic Society of Japan* 121:930-933. [17] Goodrich C. A. et al. (2014) *Geochim. Cosmochim. Acta* 135:126-169.