MINERALOGY AND PYROXENE COOLING RATE OF UNIQUE ACHONDRITIC METEORITE GRA 06129. T. Mikouchi and M. Miyamoto, Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN (mikouchi@eps.s.u-tokyo.ac.jp).

Introduction: A new US Antarctic meteorite, GRA06129 (and paired GRA06128) was recently announced as an unusual achondritic meteorite of an unknown origin [1]. It is a heavily weathered rock mainly composed of albitic plagioclase with smaller amounts of olivine and two pyroxenes. Although the oxygen isotopes are in the field of Earth, Moon and enstatite meteorites, GRA06129 is different from any of them. In this abstract we report a preliminary result of its mineralogy and petrology. We especially paid attention to exsolution textures of pyroxenes, and calculated its cooling rate to better understand its petrogenesis.

Petrography: The thin section studied (GRA06129,24) shows a granoblastic texture mainly composed of albitic plagioclase with smaller amounts of olivine and pyroxene (Fig. 1). The grain sizes of major constituent phases are variable ranging from 10 µm to over 1 mm. The modal abundances of minerals are 82 % plagioclase, 9 % olivine, 6 % augite, 1 % orthopyroxene, 1 % Ca phosphates, and 1% others. Some olivine and pyroxene grains show slightly wavy extinction, suggestive of minor shock metamorphism. Albite commonly shows lamellar twinning and reaches 2 mm in size. A large cluster (4 x 3 mm) of coarse albite grains (~1 mm) is present, but most albite grains are much smaller. Although droplets of Fe-Ni sulfides are scattered within albite grains, no obvious exsolution texture was found by the FEG-SEM observation. Pyroxene is present as augite and orthopyroxene. Augite contains thin exsolution lamellae of orthopyroxene (up to a few µm wide) (Fig. 2). Even thinner lamellae of Ti-rich chromite develop parallel to two directions in augite. Orthopyroxene does not show exsolution textures in a SEM scale. The size of augite is up to 1 mm, but orthopyroxene is smaller (~0.3 mm). Olivine is rounded or polygonal in shape (~0.5 mm) and usually present as composite grains. Large grains of these mafic minerals are present near the center of the thin section studied as vein forms (2 mm wide). Ca phosphates are present as both Cl-apatite and merrillite. Spinels are rare, but sometimes associated with ilmenite. Because weathering (probably terrestrial) is extensive for this meteorite, most grains were cut through by Fe-rich films or veins. Weathered Fe-Ni sulfides are scattered in the thin section, mostly up to 0.2-0.3 mm.

Mineral Chemistry: The albite composition is homogeneous ($Ab_{82-84}Or_2$). Although some albite grains reach 2 mm, the composition is identical to that of small granular grains. Olivine is also equilibrated at Fo_{40-42}. The CaO content in olivine is 0.05-0.10 wt%. Augite is $En_{39}Wo_{42}$, and contains 0.3-0.5 wt% TiO_2 and 0.4-0.5 wt% Al_2O_3. Orthopyroxene is $En_{55}Wo_2$. The TiO_2 and Al_2O_3 contents are 0.15-0.25 wt% and 0.15-0.2 wt%, respectively. The Cr_2O_3 content of augite is about 0.5 wt%, but is much smaller (~0.1 wt%) in orthopyroxene. The pair of low- and high-Ca pyroxene gives an equilibration temperature of about 750 °C [2]. The exsolution lamellae of orthopyroxene in augite have an identical composition to that of individual grains of orthopyroxene. Chromite is homogeneous, but Ti- and V-rich (TiO_2: 13 wt%, V_2O_3: 2.5 wt%). Exsolved chromite in augite also has a similar Ti-rich composition. Ilmenite contains ~2 wt% MgO.

EBSD Analysis: We analyzed several constituent phases in GRA06129 by electron backscatter diffraction (EBSD) technique using Hitachi S4500 FEG-SEM [3]. Although the surface roughness is sensitive for obtaining good EBSD patterns, the GRA06129 PTS studied did not have good surface. However, we found that orthopyroxene and augite grains can be indexed by the *Pbca* orthopyroxene and *C2/c* clinopyroxene structures, respectively (Fig. 3). We have not been successful for obtaining an EBSD pattern for orthopyroxene lamellae in augite, but found that the [111] direction of exsolved chromite lamellae is parallel to the *b* axis of the host augite.

Cooling Rate of Pyroxene: We carefully analyzed thin exsolution lamellae of low-Ca pyroxene in augite (Fig. 2) by electron microprobe. The width of the lamellae is up to a few µm. We employed a cooling rate calculation similar to [4] by using diffusion profiles of Ca traversing the lamellae. The estimated bulk augite composition shows that lamellae started growing at 800-850 °C and grew until 750 °C [2]. The obtained best-fit cooling rates are 20 °C/year for the temperature range of 850 to 750 °C, and 10 °C/year for 800-750 °C. The burial depths of these cooling rates are 15-20 m from the surface.

Discussion and Conclusion: The equilibrated, but variable grain sizes of the GRA06129 granoblastic texture composed of albite + olivine/pyroxenes is unique and somewhat similar to a few primitive achondrite group meteorites such as silicate inclusions in the Caddo County IAB iron [5] and LEW86220 [6]. However, the Fe-rich compositions of mafic silicates and the near absence of Fe metal in GRA06129 are quite different from primitive achondrites. The pyroxene and olivine compositions are rather similar to those of

nakhlite Martian meteorites, especially NWA998 and Lafayette [7]. Albitic plagioclase is also present in nakhlites in the mesostasis. Nevertheless, the GRA06129 texture is completely different from nakhlites, and the Fe/Mn ratios of olivine and pyroxenes are also distinct. The Fe/Mn ratios are intermediate between Martian and terrestrial values.

Unfortunately, brief mineralogical work presented here only shows that it is a new type of achondrite, and the origin and the relationship to other meteorite groups are still unknown. The cooling rate calculation of exsolved pyroxene suggests that the thermal metamorphism of GRA06129 took place about 15-20 m from the surface of its parent body. Probably, the granoblastic texture was produced when this pyroxene exsolution texture was formed.

References: [1] *Antarct. Meteorite Newsl.* (2007) 30 (2). [2] Lindsley D. H. and Andersen D. J. (1983) *Proc. 13th LPSC,* A887-A906. [3] Mikouchi T. et al. (2006) *LPS XXXVII,* Abstract #1855. [4] Miyamoto M. and Takeda H. (1994) *Earth and Planet. Sci. Lett., 122,* 343-349. [5] Takeda H. (2000) *Geochim. Cosmochim. Acta, 64,* 1311-1327. [6] McCoy T. J. et al. (1997) *Geochim. Cosmochim. Acta, 61,* 639-650. [7] Mikouchi T. et al. (2003) *Antarct. Meteorite Res., 16,*

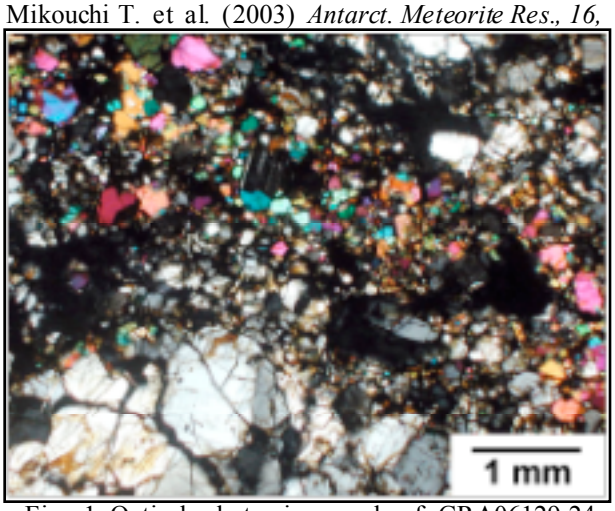
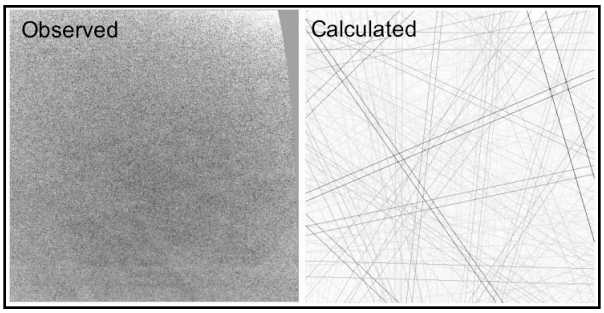


Fig. 1 Optical photomicrograph of GRA06129,24 (cross polarized light). Note the variation of grain sizes. A large cluster of albite grains is present in the lower side of the image,



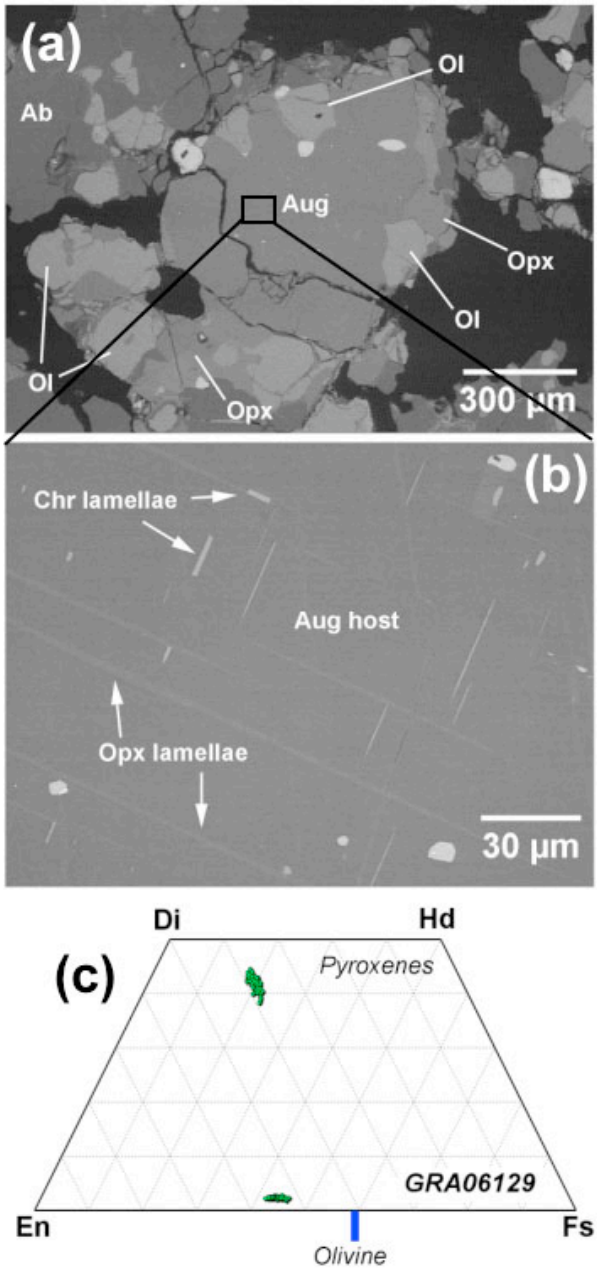


Fig. 2 (a) Back-scattered electron (BSE) image of augite. Aug: augite. Ol: olivine. Opx: orthopyroxene. Ab: albite. (b) Enlarged BSE image of the augite exsolution texture in (a). Note the presence of thin exsolution lamellae of orthopyroxene and chromite parallel to two directions. Opx: orthopyroxene. Chr: chromite. (c) Pyroxene and olivine compositions of GRA06129.

Fig. 3 Obtained (left) and calculated(right) EBSD patterns from an orthopyroxene grain. The calculated pattern using orthorhombic Pbca pyroxene structure matches with the observed pattern.