Igneous clasts in the Northwest Africa 801 CR2 chondrite: REE and oxygen isotopic studies. H. Hiyagon[1], N. Sugiura[1], N. T. Kita[2], M. Kimura[3], T. Mikouchi[1], Y. Morishita[4] and Y. Takehana[1], [1]Department of Earth and Planetary Science, The University of Tokyo, Tokyo 113-0033, Japan; [2]WiscSIMS, Department of Geoscience, University of Wisconsin-Madison, WI 53706, USA; [3]Faculty of Science, Ibaraki University, Mito 310-8512, Japan; [4]National Institute of Advanced Science and Technology, Tsukuba 305-8567, Japan.

Introduction:

Mineralogical study of the achondritic clasts found in the NWA 801 CR2 chondrite showed that they contain eclogitic mineral assembrages (garnet and omphacite), suggesting their formation at a high pressure [1]. Such mineral assemblages have not been previously observed in meteorites. The origin of the high pressure could be either due to shock loading or static pressure in deep interior of a large planetesimal, but mineralogical study alone cannot answer this question. Here we report REE abundance and oxygen isotopic data for these clasts and discuss their origin.

Brief description of the igneous clasts:

Detailed mineralogical descriptions of the clasts are given in [1]. We found three igneous clasts (1-3 mm in size) in the NWA 801 CR2 chondrite. The clasts have two different lithologies: graphite-bearing (GBL) and graphite-free (GFL) (see Fig.1). The constituent minerals are omphacite, pyrope-rich garnet, olivine and pyroxene, with minor minerals such as graphite (for GBL), phlogopite (for GFL), chlorapatite, Fe-Ni metal, troilite and pentlandite. Plagioclase or spinel group minerals, frequently found in chondrites, are not found in the clasts. The mineral assemblages and compositions are similar to those in terrestrial eclogite, except for the occurrence of olivine and some difference in mineral chemistry. Based on a set of conventional geothermobarometers, Kimura et al. estimated the formation condition of the clasts to be ~3GPa and ~1000C [1]. The size of the graphite laths is up to ~25 micrometer long and ~5 micrometer wide, and their abundance is ~1% by volume, less than those in ureilites. The GBL and GFL may have affinity to ureilites and basaltic achondrites, respectively.

Analytical Methods:

Rare earth element (REE) and Ba abundances of apatite, garnet, omphacite and phlogopite were analyzed with a CAMRCA ims-1270 ion microprobe at AIST, Tsukuba, Japan. The analytical conditions were similar to those described in [2], but ^{44}Ca, ^{138}Ba and only 17 peaks of REEs were measured instead of measuring all the peaks between 135 and 180. An energy offset of -60eV was applied to reduce the interfering peaks.

Oxygen isotopic compositions of olivine and pyroxene in both GBL and GFL were measured with a CAMECA ims-1280 ion microprobe at the University of Wisconsin-Madison. The analytical conditions were similar to those described in [3].

Results

REEs:

The obtained REE abundances (normalized to CI) for various minerals are shown in Fig. 2. Also shown in Fig. 3 are the bulk REE abundances of GBL and GFL, calculated from REE abundances of the constituting minerals (Fig.2) and their modal abundances in the two lithologies.

Phosphate shows very high LREE abundances (>100 x CI) but shows gradual decrease toward HREE (from Gd to Lu). Garnet, on the other hand, shows rapid increase toward HREE; Lu abundance reaches to ~100 x CI for GFL garnet (garnet#2B), which is consistent with garnet/melt partition, but it reaches only to ~20 for GBL garnet (garnet#1B). Omphacite in GFL shows REE abundances of ~1 x CI; The higher abundances in GBL (esp., for HREE) are due to contamination of garnet in the analytical spots. The estimated bulk REE abundances both for GFL and GBL are almost flat with ~2 x CI and ~1.5 x CI, respectively (Fig. 3).

Oxygen isotopes:

Oxygen isotopic compositions of olivine and pyroxene in the clasts are distributed along a line with a slope of ~0.6 and are located between the ureilite field and the CR chondrite field (Fig. 4). No achondrite has been known to have oxygen isotopic composition in this area. The GFL data are tightly clustered at the upper-right end of the distribution, whereas the GBL data are more scattered along the line. There is no particular difference between olivine and pyroxene data.

The observed correlation (slope ~0.6) may be interpreted as a mass-fractionation line (slope =0.5) if analytical uncertainty is taken into account. However, since oxygen isotopic compositions of achondrites are usually confined to a much narrower range (<2‰ for δ^{18}O [5]), it seems more reasonable to interpret it as a mixing line between the two endmembers. One possibility is that, in the case of an impact-induced high pressure model, the two endmembers could be GBL and GFL before the shock event.

Discussion:

The formation conditions estimated from several sets of conventional geothermobarometers gave consistent results from 2.8 to 4.2 GPa and 940 to 1080C [1]. This seems to support the idea that equilibration has been attained among different mineral assemblages to give consistent temperature and pressure, consistent with a static high pressure model. However, the present REE and oxygen isotope results seem to give a different view. Both REE data and oxygen isotope data show noticeable heterogeneity within and/or between the two lithologies, GBL and GFL. These observations are difficult to reconcile with a static high-pressure model, and seem to support a shock-induced high pressure model for the origin of the clasts. At present, however, it is not certain if a shock heating event with a rather short heating duration (~10 sec) could produce all the observed features of the igneous clasts.

References:

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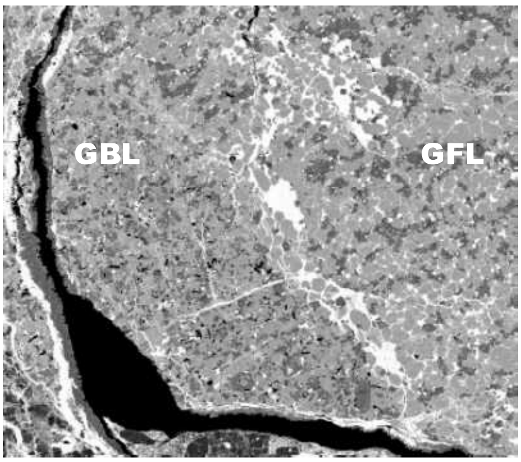

Fig. 1 Back-scatterd electron image of a part of the achondritic clast found in the NWA 801 CR2 chondrite. Two different lithologies, graphite-bearing (GBL) and graphite-free (GFL), are recognized. Tiny thin black grains in GBL are graphite.

Fig. 4 (right) Oxygen three-isotope diagram. GFL and GBL are shown by squares and circles, respectively. Pyroxene in GBL is shown by blue and olivine by red. The range of ureilite isotopic compositions [4] is shown by elongated ellipsoid and bulk CR chondrite data [5] are also shown by small diamonds. Terrestrial fractionation (TF) line, CCAM (carbonaceous chondrite anhydrous minerals) line [6] and Young and Russell line [7] are also shown for reference.

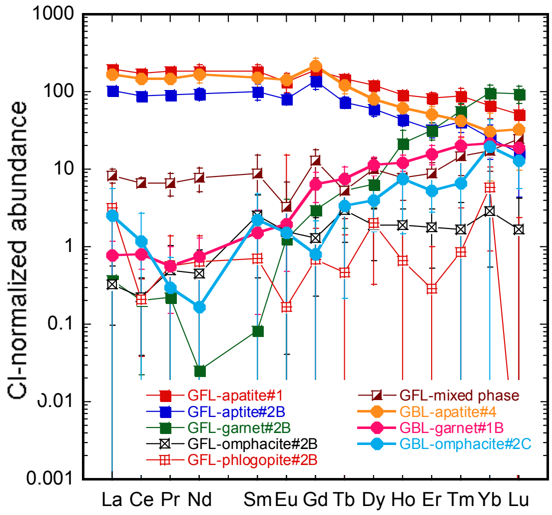

Fig. 2 Rare earth element abundances normalized to CI abundance.

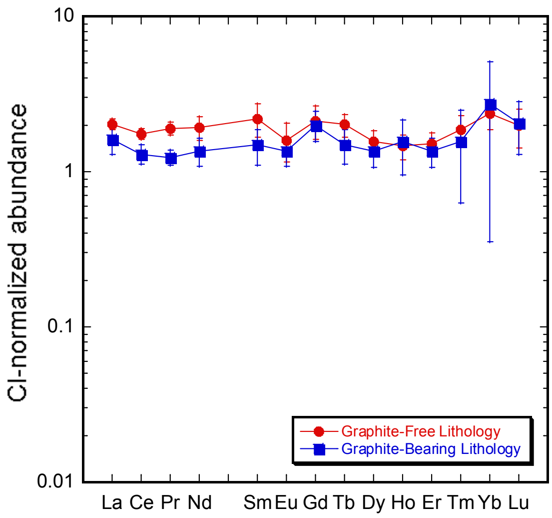

Fig. 3 Bulk REE abundances of GBL and GFL calculated from the observed REE abundances of the constituting minerals (Fig.2) and their modal abundances in the two lithologies.