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Origin of igneous clasts with graphite-bearing and graphite-free lithologies found in NWA801 (CR2) chondrite

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Introduction: We found three igneous clasts in a primitive CR2 chondrite, NWA801. The clasts contain eclogitic mineral assembrages (garnet and omphacite), suggesting formation at a high pressure [1]. The origin of the high pressure could be either due to shock loading or static pressure in deep interior of a large planetesimal. We discuss here the origin of the clasts based on mineralogy, bulk chemistry, oxygen isotopes and REE abundances. Preliminary results and arguments are given in [2]. Analytical procedures for oxygen isotopes using a CAMECA ims-1280 ion microprobe at the University of Wisconsin-Madison are given in [3] and those for REE and Ba abundances are briefly described in [2] (also see [4]).

Two lithologies: The igneous clasts have two different lithologies: graphite-bearing (GBL) and graphite-free (GFL). The constituent minerals are olivine, Ca-poor pyroxene, Na-Al-rich pyroxene (omphacite) and garnet, with minor minerals such as graphite (in GBL), phlogopite (in GFL), chlorapatite, Fe-Ni metal, troilite and pentlandite. The mineral assemblages and compositions are similar to those in terrestrial eclogite. The formation condition of the clasts is estimated to be ~3GPa and ~1000C based on a set of conventional geothermobarometers [1].

Bulk chemical compositions of both GBL and GFL are nearly chondritic (not very different from those of CR chondrites). This suggests that the igneous fractionation is not as extensive as that of ureilites.

Phosphate shows very high LREE abundances (140-200 x CI) and gradual decrease from Gd to Lu (down to 30-50 x CI). Garnet shows rapid increase toward HREE with Lu abundance ~100 x CI for GFL garnet (consistent with garnet/melt partition) but only to ~20 x CI for GBL garnet. Omphacite in GFL shows REE abundances of ~1 x CI. The estimated bulk REE abundances for GFL and GBL show almost flat patterns with ~2 x CI and ~1.5 x CI, respectively. This also suggests that the igneous fractionation is not as extensive as that of ureilites.

Oxygen isotopic compositions of olivine and pyroxene are distributed along a slope ~0.6 line with one end near the ureilite field [5] and the other near the CR chondrite field [6]. The GFL data are tightly clustered at the upper-right end of the distribution (delta-18O ~5 permil and delta-17O ~0.7 permil), whereas the GBL data are more scattered along the line (with delta-18O from +2.4 to +4.3 permil and delta-17O from -1.0 to +0.2 permil). There is no particular difference between olivine and pyroxene data.

Discussion: The formation conditions estimated from several geothermobarometers gave consistent results (~3GPa and ~1000C [1]). This suggests that equilibration has been attained among different mineral assemblages. This favors a static high pressure model. However, the REE and oxygen isotope data show noticeable heterogeneity within and/or between the two lithologies. This seems to support a shock-induced high pressure model, though 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. In any case, rather large planetesimals and their disruptions must be required to produce two different lithologies of the igneous clasts, to stick them together, and mix them with chondrules and matrices to form a CR chondrite.

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