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# Origin of eclogitic clasts in a CR2 chondrite: Evidence of frequent collisions and disruptions of large planetesimals?

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Achondritic clasts found in the Northwest Africa 801 (NWA801) CR2 chondrite have significant importance in planetary science (Sugiura et al., 2008; Kimura et al., 2010, 2013): (i) it provides strong evidence that achondrites formed earlier than chondrites, (ii) the clasts contain eclogitic high mineral assemblages (garnet and omphacite), suggesting formation at a high pressure (~3 GPa and ~1000 C; Kimura et al., 2013), and (iii) the clasts contain two lithologies, graphite-bearing (GBL) and graphite-free (GFL), and the presence of graphite in GBL implies some relations to ureilite.

We performed ion microprobe studies of oxygen isotopes and rare earth element (REE) abundances for selected minerals in the clasts (Hiyagon et al., 2014). Based on the newly obtained data and diffusion calculations, we discuss possible origin of the clasts, esp., whether they formed under a static high pressure in a large planetesimal or formed under a shock high pressure.

Key observations are as follows. (1) Olivine (ol) grains in the clasts (~20 micrometers in size) are chemically homogeneous with Mg# 66-68. (2) Most of orthopyroxene (opx) grains (~20 micrometers in size) are homogeneous with Mg# 70-75, but a few large opx grains (50-80 micrometers in size) have Mg-rich cores with Mg# 78-87. (3) Various geothermobarometers (7 equations for mineral pairs of opx-cpx, garnet-cpx, garnet-opx and garnet-olivine) consistently give a high P-T condition of 940-1080 C and 2.8-4.2 GPa. (4) All the oxygen isotopic data of ol and opx fall on a correlation line with a slope of ~0.6. Data for GFL (ol) are homogeneous with delta18O ~+5 permil, located close to the CCAM line and the ureilite field, but data for GBL (ol +opx) are variable with delta18O from +2.4 to +4.3 permil. (5) Major host minerals of REEs are chlorapatite (both LREEs and HREEs) and garnet (for HREEs). The estimated bulk REE patterns for GBL and GFL are almost flat (unfractionated) with ~1.2 x CI and ~1.8 x CI, respectively.

We consider that the presence/absence of graphite in the two lithologies may be due to absence/presence of smelting reactions, FeO (in silicates) + C (graphite) = Fe (metal) + CO (gas). This means that GBL might form at a deeper portion and GFL might form at a shallower portion, respectively, of a planetesimal.

We consider two different models: a shock high-P model and a static high-P model. Based on careful diffusion calculations, we argue that (1) almost homogeneous Fe/Mg ratios in ol and opx (with some Mg-rich cores) can be explained by heating at 1000 C for 120-800 years, (2) oxygen isotopic variations in GBL must have established before homogenization of Fe/Mg ratios in olivine, (3) consistency of different geothermobarometers requires equilibration of different elements among different mineral pairs, strongly suggesting a static high-P model, (4) in a static high-P model, ~3 GPa corresponds to the pressure at the center of a large planetesimal with a radius of ~1500 km, almost the size of the Moon, (5) consistency of different geothermobarometers also suggests a rapid cooling after heating several hundreds of years at ~1000 C at ~3 GPa, suggesting possibe disruption of the parent body.

In conclusion, the present results suggest frequent collisions and disruptions of a large planetesimals at a certain stage of the solar system evolution.

References: Kimura M. et al. (2010) (abstract) Meteoritics and Planetary Science 45, A105; Kimura M. et al. (2013) American Mineralogist, 98, 387-393; Sugiura N. et al. (2008) (abstract) Meteoritics and Planetary Science 43, A149. Hiyagon H. et al. (2014) in preparation.

Keywords: eclogite, CR chondrite, oxygen isotopes, rare earth elements, collisions of planetesimals, diffusion