

## Aqueous alteration and shock metamorphism of Antarctic CR chondrites.

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### Introduction:

CR chondrites are the group of carbonaceous chondrites that best preserve records of formation of their components in the solar nebula. Although they are affected by aqueous alteration, many chondrules and CAIs are well-preserved, suggesting they have experienced little thermal metamorphism [e.g., 1]. We have been investigating the petrologic variations among the CR chondrites in the NIPR Antarctic meteorite collection. We focused particular attention on the petrology of amoeboid olivine aggregates (AOAs) in order to understand secondary alteration on the CR chondrite parent body. AOAs are composed of fine-grained forsteritic olivine and refractory minerals formed by condensation in the solar nebula, and can be used as sensitive indicators of secondary alteration processes [2;3]

**Methods:** Polished thin sections of Antarctic CR chondrites were studied using JEOL JSM-7100F FE-SEM and JEOL JX-8200 EPMA at NIPR. The extent of aqueous alteration was estimated from preservation of glass in chondrule mesostasis, textural replacement of chondrule phenocrysts, alteration of primary anorthite and metal in AOAs, and olivine compositions in AOAs. The degree of thermal metamorphism of the meteorites was examined using Raman spectra of matrix grains collected with a JASCO NRS-1000 Raman Spectrometer at NIPR.

### Results and Discussion:

Eight samples of Antarctic CR chondrites in this study were divided into four groups based on alteration of chondrules and Raman spectra. AOAs were not identified in all samples, but where present, were used to assess alteration/metamorphism. Alteration of glass in mesostasis and partial replacement of phenocrysts in chondrules were used as indicators of aqueous alteration, as suggested by Harju et al [4].

**Group 1.** Chondrules with unaltered phenocrysts and mesostasis glass: little aqueous alteration (Y-791498, A-881828)

**Group 2.** Minor replacement of chondrule phenocrysts: early-stage aqueous alteration (Y-8449, Y-793261, Y-790112)

**Group 3.** Mesostasis glass replaced by phyllosilicates: extensive aqueous alteration (Y-793495, A-881595)

**Group 4.** Foliation of chondrules and compact matrix: Shock metamorphosed (Y 982405)

### Raman characteristics

Raman spectroscopy is very sensitive to the degree of structural order of polyaromatic organic matter (OM). The typical Raman spectrum of such a material exhibits several bands, including G-band ( $\sim 1600\text{cm}^{-1}$ , from graphite) and D-band ( $\sim 1350\text{cm}^{-1}$ , from defects). It has been shown that FWHM-D (full width at half maximum of the D-band) decreases with increasing maturity of OM, and

$I_D/I_G$  (ratio of intensities of the D- and G-bands) is sensitive to heating conditions [5]. As metamorphic subtype increases, Raman FWHM-D decreases and  $I_D/I_G$  increases in ordinary chondrites [5], and the same is apparently true of CO and CV chondrites [6; 7].

Matrices from all CR chondrites exhibit D- and G-bands. Raman spectra from Y-791498, A-881828, Y-8449, Y-793261, Y-790112, Y-793495, and A-881595 all have FWHM-D  $\sim 260\text{--}420\text{ cm}^{-1}$  and  $I_D/I_G < 1.0$ . These characteristics are similar to primitive (unmetamorphosed) chondrites [e.g., 6; 7].

In contrast, Raman spectra of matrix areas in Y 982405 have narrower FWHM-D ( $\sim 170\text{ cm}^{-1}$ ) and higher  $I_D/I_G$  ratio ( $\sim 1.1$ ) than those of the other CRs studied, suggesting they are thermally metamorphosed. Raman spectra indicate only minor thermal effects for groups 1-3, but some heating for group 4.

### Matrix textures and thermal metamorphism

Matrices of CR chondrites are composed of fine-grained phases such as amorphous silicates, magnetite, sulfides, calcites, and phyllosilicates. The abundance of magnetite varies among the CR chondrites. The fine-grained matrix texture of CR chondrites is similar to weakly metamorphosed CVs and COs. The presence of lath-shaped phyllosilicates in A-881599 indicates significant aqueous alteration of this sample.

The matrix of Y 982405 is different from other samples, having compact (little porosity) and homogeneous textures. Y 982405 is characterized by minor replacement of chondrule phenocrysts typical of early stage of aqueous alteration (Group 2). Y 982405 AOA olivines are slightly Fe enriched compared to those of other samples.

Raman characteristics of Y 982405 are consistent with metamorphic heating. Similar Raman spectra are also reported in the CR chondrites GRO 03116 and GRO 06100 and are attributed to short-duration impact heating [8]. Y 982405 shows foliation of chondrules and compact matrix texture consistent with shock deformation and short-duration impact heating of Y 982405.

Our observations of eight CR chondrites suggest that they have experienced variable degrees of aqueous alteration at low parent body temperatures. Local increases in temperature in the CR parent body were caused by impact heating.

**References:** [1] Krot A. N. et al., (2002) *MaPS*, 37:1451-1490. [2] Chizmadia L. et al. (2002) *MaPS*, 37:1781-1796. [3] Komatsu M. et al. (2015) *MaPS*, 50:1271-1294. [4] Harju E. R. et al. (2014) *GCA*, 139:267-292. [5] Quirico E. et al. (2003) *MaPS*, 38: 795-811. [6] Bonal L. et al. (2006) *GCA*, 70:1849-1863. [7] Bonal L. et al. (2007) *GCA*, 71:1605-1623. [8] Briani G. et al. (2013) *GCA*, 122:267-279.