Petrology of Amoeboid Olivine Aggregates in Antarctic CR chondrites: Evidence for Aqueous Alteration and Shock Metamorphism.

M. Komatsu[1,2], T. J. Fagan[2], A. Yamaguchi[3], T. Mikouchi[4], M. Yasutake[1,3], and M. E. Zolensky[5]

[1]SOKENDAI, The Graduate University for Advanced Studies, Kanagawa, Japan (komatsu_mutsumi@soken.ac.jp), [2]Dept. Earth Sciences, Waseda University, Japan, [3]National Institute of Polar Research, Japan (NIPR), [4]Dept. Earth and Planetary Science, The University of Tokyo, Japan, [5]ARES, NASA Johnson Space Center, Houston, USA

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 eight CR chondrites Y-790112, Y-791498, Y-793261, Y-793495, Y 982405, A-8449, A-881828, and A-881595 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. The Raman constraint on metamorphic temperature is based on the G- and D-bands (associated with graphite and defects, respectively) in carbonaceous matter. With increasing metamorphic temperature, the full-width at half-maximum (FWHM) of the D-band decreases and the intensity ratio I_D/I_G increases [4].

Results and Discussion:

The CR chondrites in this study were divided into four groups based on alteration of chondrules and Raman spectra (Table 1). 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 [5]. Raman spectra indicate little thermal effects for groups 1-3, but some heating for group 4.

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

AOAs in these samples consist of forsteritic olivine, anorthite, Al-diopside, and metal. Enstatite is present in an AOA in Y-791498 (Fig.1a,b). AOAs in these samples are similar to AOAs in type 3.0 carbonaceous chondrites. Low-Fe, Mn-enriched (LIME, MnO/FeO >1.0)) olivine, which is interpreted as an indicator of relatively low-T condensation and minimal subsequent metamorphism [6;7], is also observed in AOAs in both samples.

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

AOAs were only identified in Y-793261. Replacement of some Fe,Ni-metal by Fe-oxide in the Y-793261 AOAs may be due to aqueous alteration or terrestrial weathering. Anorthite and LIME compositions in olivine are preserved in the AOAs, indicating that aqueous alteration was not severe (Fig.1c).

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

Two AOAs were observed in A-881595, but none were found in Y-793495. Anorthite crystals in the A-881595 AOAs are replaced by phyllosilicates; phyllosilicate rims around AOAs also occur (Fig.1d). Y-793495 is classified as petrologic subtype 2.8 in [5], suggesting a more primitive condition than our results. This discrepancy may be due to heterogeneous distribution of aqueous alteration products at ~cm-scale, or multiple lithologies in Y-793495 with variable degrees of aqueous alteration.

4. Shock metamorphosed (Y 982405)

Y 982405 shows 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, and no LIME (or LIME-like) olivines are detected (Table 1). Raman spectra of matrix areas in Y 982405 have lower FWHM-D and higher I_D/I_G ratio than those of the other CRs studied. 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., (2004) Chem. Erde, 64:185-282. [2] Chizmadia L. et al. (2002) MaPS, 37:1781–1796. [3] Komatsu M. et al. (2015) MaPS, 50:1271–1294. [4] Bonal L. et al. (2006) GCA, 70:1849-1863. [5] Harju E. R. et al. (2014) GCA, 139:267-292. [6] Weisberg M. et al. (2004) MaPS, 39:1741-1753. [7] Ebel D. et al. (2012) MaPS, 47:585-593. [8] Briani G. et al. (2013) GCA, 122:267-279.

Table 1. CR chondrites in this study and AOA characteristics

Name	host meteorite		AOA characteristics			
	Mafic silicate alteration	Aqueous alteration of host meteorite	no. of AOAs	Olivine composition	LIME olivine	AOA alteration
Y-791498	none	little	1	Fo_{96-100}	present	none
A-881828	none		1	Fo_{96-100}	present	none
Y-8449	little	Early to intermediate	not observed	-	-	-
Y-793261	little		8	Fo_{93-100}	present	none
Y-790112	little		not observed	-	-	-
Y-793495	altered	high	not observed	-	-	-
A-881595	altered		2	Fo_{97-100}	present	phyllosilicates
Y 982405	little	thermally altered	3	Fo_{87-99}	absent	none

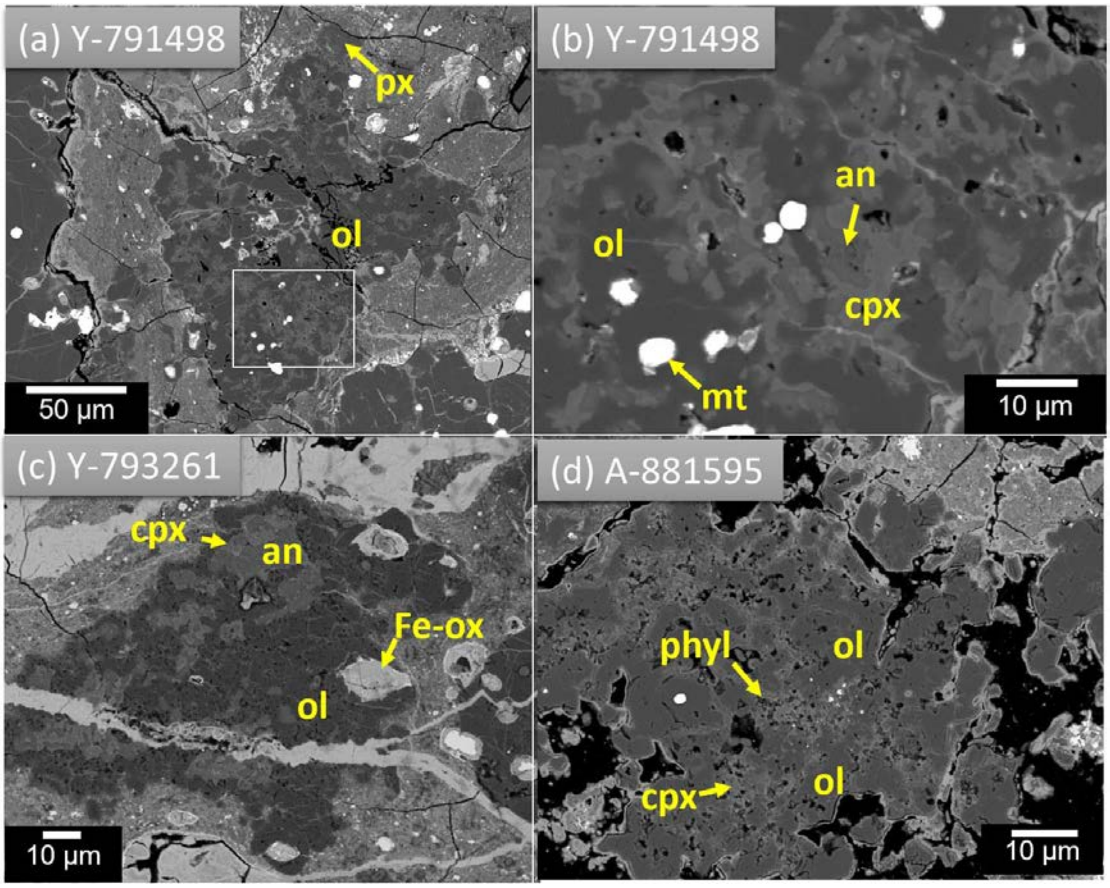

Fig.1. BSE image of AOAs. (a, b) AOA from the sample with little alteration. (c) AOA from the sample with intermediate alteration. (d) AOA from severely aqueously altered sample. ol=olivine; cpx=Al-diopside; an=anorthite, mt=FeNi-metal; Fe-ox=Fe oxide; phyl=phyllosilicate.