PSU McNair Scholars Online Journal

Volume 5
Issue 1 *Humans Being: People, Places, Perspectives and Processes*

Article 16

2011

Optical Microscopy – Preliminary Classification of Two R Chondrites

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Abstract

CML 215 and CML 392 are two unclassified meteorites that belong to the class of Rumuruti (or R) chondrites. Using optical thin section microscopy both specimens were preliminary classified as R3-5. Both meteorites contain hydrous phase amphibole, which indicate interaction of the parent body (or bodies) of these meteorites with OH^- oxidant. Presence of this phase in CML 215 and 392 brings the number of amphibole-bearing R chondrites to three. At this point is uncertain whether CML 215 and 392 are paired.

Introduction

Rumuruti, or R, chondrites have been identified as a new meteorite class 16 years ago. With only few dozen known meteorites in the class, R chondrites represent a fifth class of undifferentiated meteorites (Rubin and Kallemeyn 1994; Weisberg et al. 2006). R chondrites differ from other primitive chondrites by many different factors, some of which include high oxidation state, low chondrule/matrix ratio and absence of metallic Fe, Ne (Greenwood et al. 2000; Schulze et al. 1994; Weisberg et al. 1991). Over the years new geochemical data have shed light on the composition of R chondrites. High S fugacity found in these meteorites indicate a S-enriched origin of formation (Isa and Rubin 2010), and presence of hydrous phases, such as hornblende and biotite, indicate presence of water during the parent body formation (McCanta et al. 2007; McCanta et al.

2008; Mikouchi et al. 2007). $\delta^{17}O$ compositions, highest among all of the meteorites, also suggests unique environment of R chondrite formation (Greenwood et al. 2000).

Petrographic characteristics can also help shed light on the formation history of R chondrites. For this reason two unclassified R chondrites have been chosen for detailed optical microscopy studies. This paper summarizes research that has been conducted on the samples so far and emphasizes on new findings.

Methods

Two R chondrite specimens chosen for the study, CML 215 and CML 392, are courtesy of Cascadia Meteorite Laboratory (CML). They were studied using petrographic microscope Leica DM 2500, also a courtesy of CML. Total of four double-polished thin sections from both specimens (CML215-2; CML392-2A, 2B, and 2C) were studied using transmitted, cross polarized, and reflected lights, as well as with flatbed and thin section scanners.

Lithic clasts in meteorites were identified using primarily reflected light mode and hand specimens. Preliminary petrologic states were obtained using petrographic identification techniques of Weisberg et al. (2006), Huss et al. (2006), and Berlin and Stöffler (2004).

Shock deformation of olivine grains was studied using cross-polarized light of the petrographic microscope. Large (> 50 microns), clean grains with high birefringence colors were chosen for the analyses. Whenever possible at least twenty grains were chosen for classification of each clast. Shock classification stages were assigned based on criteria provided by Stöffler et al. (1991), Schmitt (2000), and Schmitt and Stöffler (2000). Based on the suggestions from above mentioned authors, 25% of the grains with the highest shock stage were chosen to assign a shock stage. Shock classification of CML 215 was made based on the only thin section CML 215 -2, while CML 392 was classified based on studies made on all three thin sections (-2A, -2B, -2C).

Results

Overall Petrography

CML215

CML215 has a brecciated appearance with dark/light clasts embedded in a brown clastic groundmass. Twenty one lithic clasts were identified in CML215-2 thin section (Figure 1) with clasts ranging in size from 600 µm in diameter to 1.0x1.4 cm in apparent size. Some clasts contain transparent matrix, have no twinned pyroxene, glass, or zoned olivine, and contain plagioclase feldspar. Observations of these clasts could be consistent with petrologic type 4 or 5 (Huss et al. 2006; Weisberg et al. 2006). Other clasts contain twinned pyroxene, and feldspathic glass (in some cases partially devitrified), and what appears to be zoned olivine. With no plagioclase feldspar found in them, these clasts are considered to be to be petrologic type 3. Host portion of CML 215 is enriched in chondrules and in chondrule and clastic fragments and shows indicators of different petrologic types. Major minerals present in CML215 are olivine, plagioclase, pyroxenes, and oxide minerals that have not yet been identified. Accessory minerals are composed of opaques that are believed to be sulfide, metal, and chromites.

Figure 1. Reflected light micrograph mosaic of CML215-2 thin section shows prominent outlined clasts.

CML392

Optical microscopy studies of CML392 revealed only eleven prominent clasts with their size ranging from 750 µm to 6.3 mm in diameter (Figure 2). Presence of isotropic glass, sharp chondrule-host boundaries, presence of twinned pyroxene in both host and some of the clasts indicate that CML392 probably belongs to the petrologic type 3 (Huss et al. 2006; Weisberg et al. 2006).

One clast stands out from the rest of the lithic clasts in CML392. Clast 10 is feldspathic in composition, has appearance of a shock melt, and reaches 1x1.4mm in apparent size. Besides plagioclase feldspar, it contains tiny speckles of opaque phases that are chromites and Fe oxides. Clast 10 also contains glassy matrix and appears to flow around adjacent grains and clastic fragments of high and low Ca pyroxene, some of which are enclosed poikilitically within the clast (Figure 3).

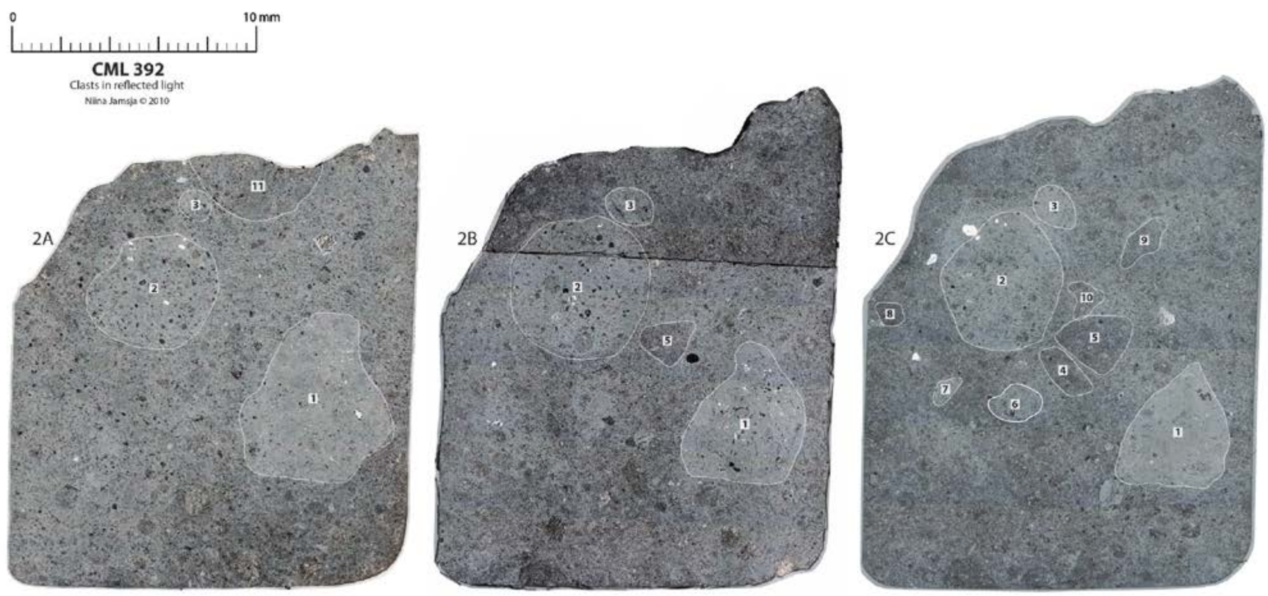

Figure 2. Three thin sections of CML 392 show prominent clasts. These three consecutive thin sections provide valuable insight on the morphology and arrangement of clasts in third dimension.

Similarly to CML215, host portion of CML392 is difficult to assign to a single petrologic type due to mixed criteria in different regions. In general the host is composed of fine-grained, somewhat transparent groundmass that contains abundant chondrules, chondrule and clastic fragments. Presence of glass, partially devitrified glass, zoned olivine grains, and twinned pyroxene indicate petrologic type 3, while coarse plagioclase grains, disintegrated chondrule-host boundaries, recrystallized groundmass and in some places altered appearance of chondrule fragments and grains might indicate to petrologic state closer to 5. Until chemical composition (which will reveal exact range of petrologic types present) is obtained, CML392 is tentatively classified as possibly R3-5.

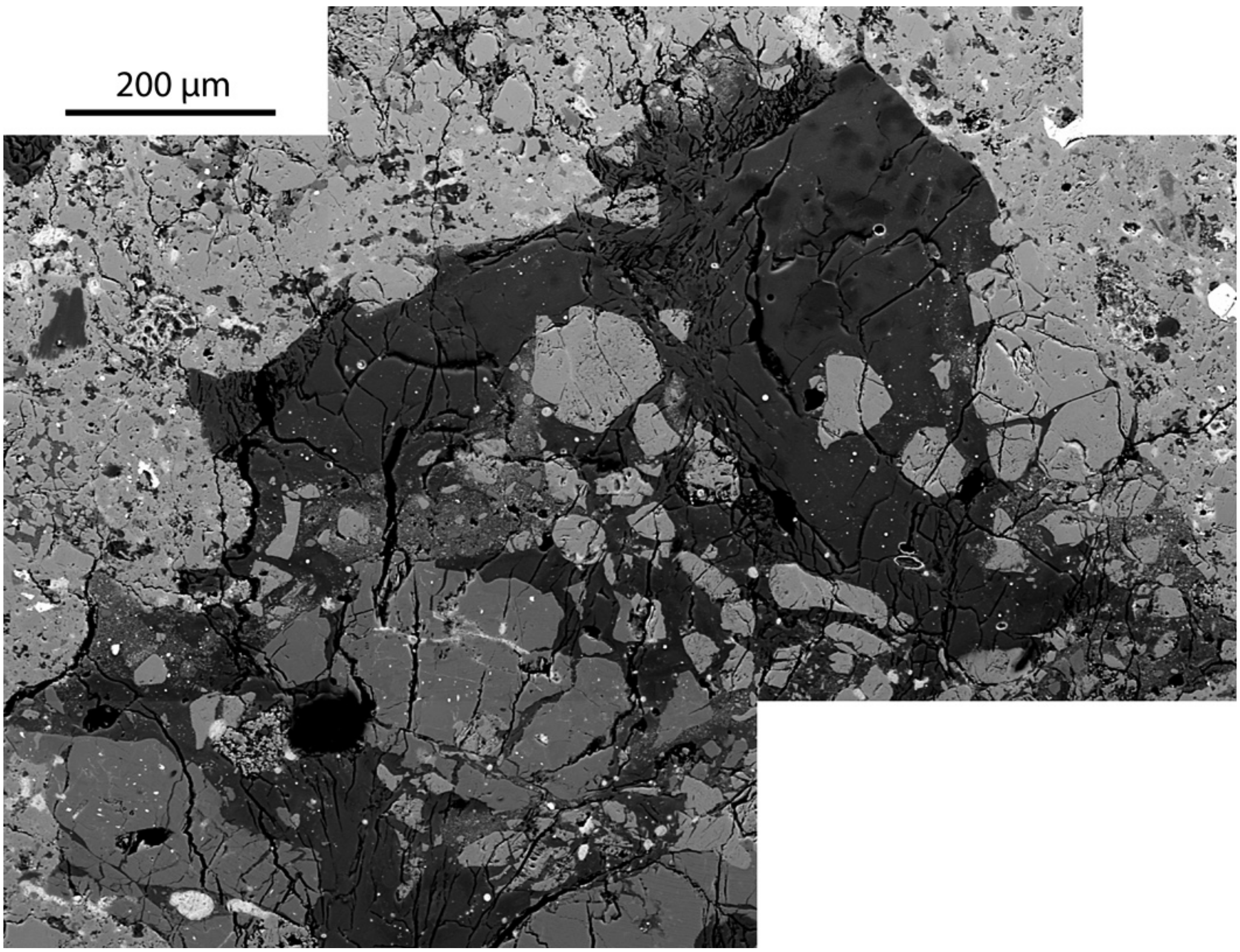

Figure 3. Backscatter electron micrograph of clast 10 shows feldspathic shock-melt (dark grey) which poikilitically encloses olivine and pyroxene fragments (light and medium grey, respectively) and is surrounded by oxidation products (white).

Amphibole

CML392 and CML 215 both contain amphibole. This is the second reported occurrence of amphibole in R chondrites which is believed to form in the parent body during metamorphism (McCanta et al. 2007). According to the pleochroic and absorption colors, and grain shape (MacKenzie and Adams 1994) amphibole phase found CML392 and 215 is most likely a hornblende. Observed grains in CML 215 and CML392 (11 grains and 4 grains, respectively) are strongly pleochroic, range in size from 50 to 200 microns and occur as isolated euhedral grains. All of the grains show planar fractures, but do not exhibit characteristic for amphibole 120˚ cleavage (MacKenzie and Adams 1994; McCanta et al. 2007).

Similarly to observations of Mikouchi et al. in LAP 04840 meteorite (2007), hornblende in CML 215 and 392 is often present adjacent to plagioclase feldspar grains. Hornblende is only found inside the host portion of the rock and does not appear inside clasts. These findings are different from the only other report of hornblende in LAP 04840, where authors have reported presence of amphibole in the host as well as inside chondrules of the meteorite (McCanta et al. 2007; Mikouchi et al. 2007).

Two hornblende grains in CML215 coexist with a very large (~350 µm) high-Ca pyroxene grain in the same vicinity. This, along with the fact that high-Ca pyroxene is present in CML215 suggests that the amphibole phase does not have to form at the expense of low-Ca pyroxene, as was previously suggested (McCanta et al. 2007).

Discussion

Both CML 215 and 392 show a range of shock and metamorphic effects. Despite this fact no evidence of post-accretionary thermal or collision processes have been observed. Coexistence of material of different petrologic types in the same spatial vicinity and lack of cross-cutting relationship between clasts, chondrules and the host material are some of the facts supporting this idea. Presence of feldspathic clast 10, which would have experienced recrystallization or underwent thermal annealing during post-accretionary processes, is also an indicator that there is no history of significant thermal or shock events after the lithification process was complete. This suggests that lithic clasts and fragments, chondrules, and the host material all have unique origin of formation and sustained majority of thermal and shock alteration elsewhere prior to being agglomerated together.

Although all of the chondritic components in both meteorites are believed to have formed elsewhere in the solar system prior to being accreted together, at this point it is difficult to determine whether CML392 and 215 were derived from the same parent body. Chemical compositions, when obtained, might help shed light on the compositional differences or similarities between the two meteorites. However the very nature of CML215 and 392 being brecciated meteorites makes it difficult to state with certainty whether the parent body origin of these meteorites is the same.

Presence of amphibole in CML215 and 392 is indisputable evidence that a hydrous oxidant was present in the region of R chondrite parent body formation. At this point it is uncertain what was the state if the oxidant (i.e., was it liquid water, ice, or water vapor). However, because studied meteorites presumably do not reach petrologic state higher than 4 in most regions, it is inferred that high degree metamorphism is not a necessary condition for the formation of the amphibole, as previously believed (Mikouchi et al. 2007).

Conclusion

CML 215 and 392 are best described as genomic breccias belonging to the class of R chondrites. Both specimens are preliminary classified as R3-5 and contain what is believed to be an amphibole phase. This discovery puts the total number of amphibole-bearing R chondrites to three and supports the idea that R chondrite parent body/bodies had interaction with water at some point in their formation or alteration (Treiman and MaCanta 2010). The fact that petrologic types of the specimens do not reach type 6 and the fact that high-Ca pyroxene was found coexisting with amphibole show that amphibole does not have to form at the expense of the high-Ca pyroxene and that excessive metamorphism is not a requirement to form it. At this point it is uncertain if both meteorites are paired (i.e., belong to the same parent body) or have originated from different extraterrestrial bodies.

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Aknowledgements:

The author would like to thank Edwin Thompson for the generous donation of both samples and Cascadia Meteorite Laboratory for the access to optical microscopy equipment.