OXYGEN-ISOTOPE COMPOSITIONS OF CHONDRULES IN METAL-RICH CARBONACEOUS CHONDRITES FOUNTAIN HILLS AND SIERRA GORDA 013. A. N. Krot[1*], K. Nagashima[1], M. A. Ivanova[2], D. S. Lauretta[3], G. Libourel[4], B. C. Johnson[5], M. D. Cashion[5], M. Bizzarro[6] [1]University of Hawai‘i, HI, USA. *sasha@higp.hawaii.edu, [2]Vernadsky Institute, Russia. [3]University of Arizona, AZ, USA [4]Université Côte d'Azur, France. [5]Purdue University, IN, USA. [6]Centre for Star and Planet Formation, University of Copenhagen, Denmark.

Introduction: Metal-rich CB and CH carbonaceous chondrites are texturally and mineralogically diverse but apparently genetically related groups, which are considered to be the members of the CR clan meteorites [1]. They have similar bulk chemical and O-isotope compositions but show large variations in Fe,Ni-metal abundances (40–70 vol% in CBs vs. ~20 vol% in CHs), chondrule textures, and chondrules sizes; the interchondrule matrix is virtually absent.

Largely based on sizes of Fe,Ni-metal grains and chondrules, the CBs are currently subdivided into two subgroups – CB_a and CB_b. The CB_as (Bencubbin, Gujba, Quebrada Chimborazo 001, Weatherford, and Miller Range 05082) consist almost entirely of the cm-sized Fe,Ni-metal±sulfide nodules and magnesian silicate nodules having skeletal olivine (SO) textures. The CB_bs (MAC 02675, QUE 94411/94627, and Hammadah al Hamra 237) are finer-grained than CB_as. In addition to the CB_a-like components, the CB_bs contain chemically-zoned and unzoned Fe,Ni-metal grains, magnesian olivine-pyroxene-normative cryptocrystalline (CC) chondrules, and rare and mostly ^{16}O-depleted igneous Ca,Al-rich inclusions (CAIs), and hydrated chondritic clasts [2–4]. The magnesian non-porphyritic chondrules in CBs have a limited range of Δ^{17}O, –2.2 ±0.7‰ (2SD) [5].

The CHs are much finer-grained than CB_bs. In addition to the CB_b-like components, which make ~ 30–50 vol% of the CHs, they contain abundant chondrules with porphyritic textures, rare ferroan CC chondrules, ^{16}O-rich CAIs and amoeboid olivine aggregates (AOAs), fragments of igneous meteorites, and metamorphosed chondrites [5–8]. The magnesian CC and SO chondrules in CHs have very similar O-isotope compositions to those in CBs [5]. The CH porphyritic chondrules have magnesian, ferroan, Al-rich, and silica-rich bulk chemical compositions and show a significant range of Δ^{17}O (from ~ –7 to ~ +5‰); some of them contain relict ^{16}O-rich CAIs [5,6].

Two metal-rich carbonaceous chondrites, Fountain Hills (FH) and Sierra Gorda (SG) 013 are classified as the anomalous CB_a meteorites [9–11]. They contain abundant Fe,Ni-metal nodules and coarse-grained porphyritic chondrules (PO, POP, PP)/ igneous clasts, barred olivine (BO) and SO chondrules. Refractory inclusions and CC chondrules are absent. Fountain Hills and SG 013 are interpreted as the impact-plume produced materials [9] or as the impact-modified CB_a chondrites [10,11].

It has been previously suggested that (*i*) magnesian SO and CC chondrules and ^{16}O-depleted igneous CAIs in CBs and CHs formed in the impact-generated gas-melt plume 4562.52±0.44 Ma [6,12]. (*ii*) At least one of the colliding bodies was differentiated [13,14]. (*iii*) Most porphyritic chondrules in CHs formed by incomplete melting of solid precursors, most likely prior to the impact plume event, and possibly by a different mechanism [5,15]. Here we report on the mineralogy, petrography, and O-isotope compositions of porphyritic and non-porphyritic chondrules in FH and SG 013.

Analytical procedure: Oxygen isotopes were measured with the UH Cameca ims-1280 using ~1.2 nA primary Cs^+ ion beam focused to ~7 µm. Secondary ions of $^{16}O^-$, $^{17}O^-$, and $^{18}O^-$ were measured simultaneously in multicollection mode; $^{16}O^-$ and $^{18}O^-$ were measured by multicollector Faraday cups with low mass resolving power (MRP ~ 2000), while $^{17}O^-$ was measured using the axial electron multiplier with MRP of ~ 5600, sufficient to separate the interfering $^{16}OH^-$ signal. ^{16}Contribution of $^{16}OH^-$ onto $^{17}O^-$ was corrected based on a peak/tail ratio. Typical uncertainties for δ^{17}O, δ^{18}O, and Δ^{17}O were ~0.6, 0.7, 0.7‰, respectively.

Mineralogy and Petrography: *Fountain Hills* contains abundant magnesian chondrules and their fragments with porphyritic, granular, radial pyroxene, and BO textures, large (up to 1 mm) isolated olivine grains, and ~25 vol% of interstitial Fe,Ni-metal; fine-grained matrix is absent (Fig. 1a). Chrome-spinel grains are exceptionally rare; sulfides are absent. Chondrule sizes range from 400 to 4200 µm in diameter, with the average diameter of ~ 1300 µm. Olivine and pyroxenes are magnesium-rich: $Fa_{2–4}$ and $Fs_{3.3–3.8}Wo_{\sim 3}$ and contain 0.48–0.58 and 0.9–1.4 wt% Cr_2O_3, respectively. Chondrule plagioclase is nearly pure anorthite (An_{99}). Chrome-spinel grains contain ~60 wt% Al_2O_3, 2.8 wt% FeO, 25 wt% MgO, and 11 wt% Cr_2O_3 [9,10]

Sierra Gorda 013 contains two lithologies with chondritic (lith. 1; Fig. 1b) and achondritic (lith. 2) textures [11]. The lithology 1 is similar to CB_as and is mainly composed of Fe,Ni-metal nodules (~ 80 vol%) up to 0.9 mm in size, and magnesian chondrules/clasts having BO, SO, and porphyritic textures; duabreelite, schreibersite, and Cr-spinel are minor. Most chondrules contain Cr-spinel that occurs as euhedral grains and as symplectitic intergrowths with high-Ca and low-Ca pyroxenes. The peripheral parts of many SO, BO and PO chondrules are enriched in tiny Cr-spinel grains and low-

Ca pyroxene, indicative of gas-melt interaction under relatively oxidizing conditions. Lithology 2 contains a lower abundance of Fe,Ni-metal nodules, ~25 vol%, which are evenly distributed between coarse-grained olivine, low-Ca pyroxene, and Cr-spinel, and interstitial high-Ca pyroxene and anorthitic plagioclase. Both lithologies are characterized by similar chemical compositions of olivine ($Fa_{\sim3}$, 0.25±0.14 wt% Cr_2O_3), low-Ca and high-Ca pyroxenes ($Fs_{3.5\pm0.2}Wo_{1.4\pm0.2}$, ~1 wt% Cr_2O_3 and $Fs_{\sim2}Wo_{\sim45}$, ~1.2 wt% Cr_2O_3), Cr-spinel (in wt%, ~14, Al_2O_3; 6, FeO; 18, MgO; 60, Cr_2O_3), and plagioclase/mesostasis ($An_{96}Ab_4$; up to 1 wt% MgO) [11].

Oxygen isotopes: Oxygen isotopic compositions of olivine, low-Ca pyroxene, and Cr-spinel in chondrules from FH and SG 013 are shown in Figs. 1c,d. In contrast to porphyritic chondrules in CHs [5] and other carbonaceous chondrites [16], those in FH and SG 013 show a very limited range of $\Delta^{17}O$, –2.2±0.5‰ (2SD) and –2.4±0.9‰ (2SD), respectively. They are compositionally similar to the SO and Mg-CC chondrules in CBs and CHs, interpreted as the impact plume products [5]. We suggest that magnesian porphyritic and non-porphyritic chondrules in FH and SG 013 are possibly related to the impact plume produced materials sampled by CBs and CHs. High fraction of porphyritic chondrules/clasts in FH and SG 013 compared to those in CBs may reflect their different thermal histories in different parts of the plume. Physical modeling of impact plume evolution and measurements of bulk Cr and Ti isotopic compositions of CBs, CHs, FH, and SG 013 could potentially provide additional constraints on their genetic relationships. This work is in progress.

References: [1] Weisberg M. et al. (2006) In *MESS II*, pp. 19–53. [2] Krot A. et al. (2010) *GCA* 74:2190. [3] Krot A. et al. (2017) *GCA* 201:185. [4] Greshake A. et al. (2002) *MAPS* 37:281. [5] Krot A. et al. (2022) *MAPS*, in press. [6] Krot A. et al. (2017) *GCA* 201:155. [7] Nakashima D. et al. (2020) *GCA* 290:180. [8] Zhang et al. (2020) *GCA* 275:48. [9] Lauretta D. et al. (2009) *MAPS* 44:823. [10] Weisberg M. & Ebel D. (2009) *MAPS* 44:201. [11] Ivanova M. et al. (2022) in press. [12] Bollard J. et al. (2015) *MAPS* 50:1197. [13] Fedkin A. et al. (2015) *GCA* 164:236. [14] Oulton J. et al. (2016) *GCA* 177:254. [15] Krot A. et al. (2007) *Chem. Erde* 67:283. [16] Tenner T. et al. (2018) In *CPD*, pp. 196–247.

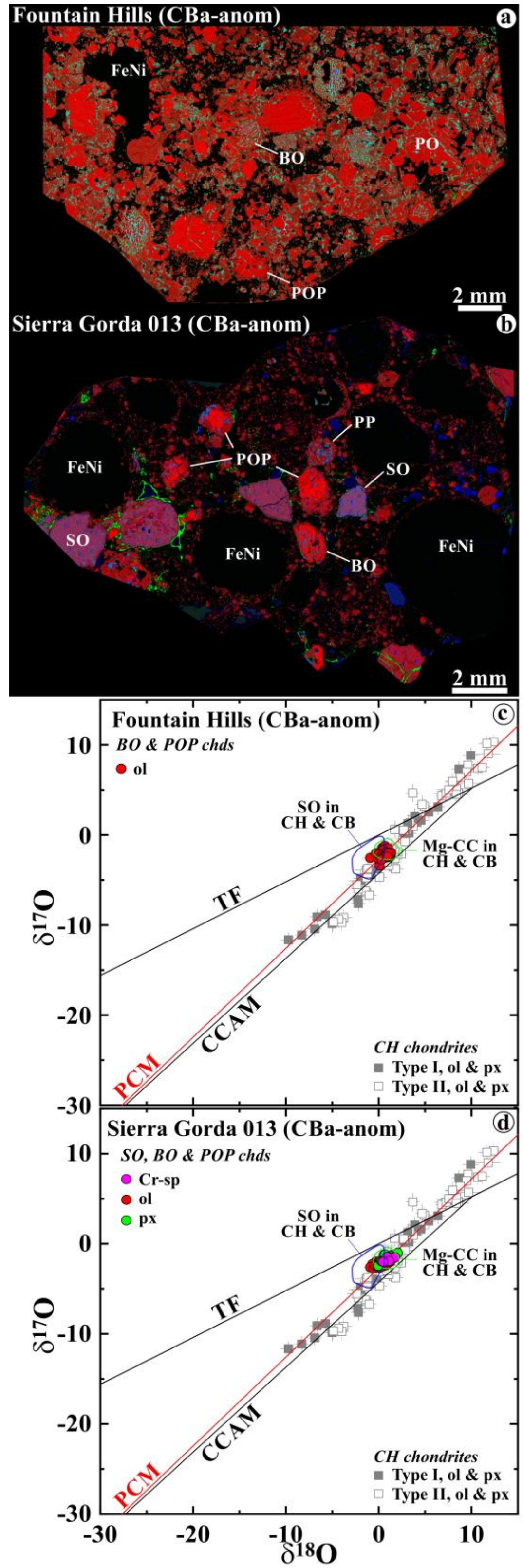

Fig. 1. (a, b) Combined x-ray maps in Mg (red), Ca (green), and Al (blue) of the CB_a-like chondrites FH and SG 013. (c, d) $\delta^{17}O$ *vs.* $\delta^{18}O$ of olivine, low-Ca pyroxene, and Cr-spinel in chondrules from these meteorites, as well as olivine and low-Ca pyroxene in Type I and Type II chondrules from CHs. Compositional ranges of the magnesian CC and SO chondrules from CHs and CBs are outlined. CCAM: carbonaceous chondrite anhydrous mineral line; PCM: primitive chondrule mineral line; TF: terrestrial fractionation line. This work is supported by Emerging Worlds NASA grant 80NSSC20K0422 (BJ, PI) and RFBR grant #20-05-00117 (MI, PI).