SIZE-DISTRIBUTION OF NEBULAR COMPONENTS IN CO3 CHONDRITES: HITS AT AN HETEROGENEOUS ACCRETION HISTORY. G.A. Pinto1,2, Y. Marrocchi3, F. Olivares3, K. Soto³, M.E. Varela4 and R. Martínez5, 1CRPG, CNRS, Université de Lorraine, UMR 7358, Vandoeuvre-lès-Nancy, 54501, France (gabriel.pinto@univ-lorraine.fr), 2INCT, Universidad de Atacama, Copayapu 485, Copiapó, Chile, 3Facultad de Ciencias, Instituto de Ciencias de la Tierra, Universidad Austral de Chile, Valdivia, Chile, 4Instituto de Ciencias Astronómicas, de la Tierra y el Espacio, ICATE-CONICET, San Juan, Argentina 4Museo del Meteorito, San Pedro de Atacama, Chile

Introduction: A key question regarding the structure and evolution of the protoplanetary disk is related to the distribution of nebular components prior to planetesimal accretion [e.g. 1]. The abundance and size of chondrules, calcium aluminium-rich inclusions (CAIs), olivine amoeboid aggregates (AOAs) and isolated olivine grains (IOGs) have been largely determined in different meteorite groups [e.g. 2,3,4]. In this study, we selected all nebular components (i.e. CAI; AOAs; FeO-rich and FeO-poor chondrules; and IOGs) larger than ~20 µm in 3 carbonaceous CO3 chondrites found in the Atacama Desert: El Médano 216 (EM 216, N=2112); El Médano-397 (EM 397, N=1740); and El Médano 463 (EM 463, N=3665). A specific attention has been paid to fine-grained rim (FGR) material surrounding refractory inclusions, chondrules and IOGs.

Methods: X-ray compositional maps (Fe, Ni, Al, Mg, Ca, Si, S, Cr) and backscattered electron (BSE) image were acquired at moderately high-resolution (2.48 µm/pixel) for two polished carbon-coated sections: EM 397 (~134 mm²) and EM 463 (~96 mm²). We used a JEOL JSM-6510 SEM equipped with a Genesis EDX detector at the Centre de Recherches Pétrographiques et Géochimiques (CRPG-CNRS, Nancy, France), operating with a 3 nA electron beam accelerated at 20 kV. The BSE image of EM 216 (~27 mm²) was acquired at high-resolution (1.12 µm/pixel) using a JEOL 6400 in Naturhistorisches Museum (NHM, Vienna) with a 1 nA electron beam accelerated at 15 kV.

Image Analysis. We prepared mosaics of all samples using the GNU image manipulation program. The particle size measurement was performed using Fiji/ImageJ open software [5]. For compositional maps the quality of particle borders was increased using Fiji/imageJ function mean filter (at 1 pixel) as well image contrast (at 1.0%) was enhanced with an equalizer option (Fig. 1B). Repetitive measurements of the same object were acquired to compute the standard deviation. Each particle was recorded in a mask layer by free-hand selection (Fig. 1C). Refractory components in EM 216 were not differentiated between AOA, CAI type A or B.

Data processing. Each particle diameter was calculated assuming that their total area was a circular cross section. The median and mean diameters were calculated assuming a 3D spherical particle. For the size estimation of rimmed particles, we measured individual objects (i.e. particle) as well as the objects including the surrounding FGR (i.e. particle+rim).

Figure 1. A) X-ray compositional map of EM 463, with Mg, Al, Ca and Fe as red, blue, green and white. B) compositional map using a mean filter and enhanced contrast function in Fiji/ImageJ software. C) Mask layer of free-hand selected particles showing the outlines color.

Results and discussion: Our results show that there is a significant difference between the median spherical diameter of type I and type II chondrules: 94.16 µm vs. 145.54 µm (Fig.2A). This is different to previous results showing similar median size for both type I and type II: 40.05 µm vs. 49.13 µm [2]. This may be related to the fact that we did not consider particles of sizes smaller than 20 µm. However, the mean spherical diameters (1σ) of all chondrules (128.92 ± 111.56 µm, N=5316) is in good agreement with that estimated in ALHA 77307 (CO3.0; 123+115/-59 µm, [6]).

Our data show that CAIs display different mean spherical diameters (90.86 ± 67.30 µm, for CAI A and 108.33 ± 73.31 µm, for CAI B) as compared to previous estimates in the CO3 DaG 190 (128 µm, [7]) as well as Colony + Kainsaz (55.24 ± 41.910 µm and 60.00 ± 11.73 µm, for CAI type A and B, respectively [2], Fig. 2B). This could be influenced by 3 facts: (i) the selected polished section area; (ii) the thermal metamorphism and terrestrial weathering degree; and (iii) the remaining small CAIs to be classified due to the limited pixel resolution.

Different size-distribution was also found for AOAs (mean of 183.68 ± 78.29 µm) compared to previous research (with apparent diameter ranging from 100 to 500 µm in ALHA 77307 [8]). However, a spherical diameter of 116.90 ± 88.95 µm was also reported in Colony + Kainsaz by [2].
A comparison of IOG (Fig.2C), reveals a bimodal distribution of type II IOG, with two peaks at ~190 µm and ~80 µm, respectively. In addition type II IOGs are twice larger on average (median spherical diameter of 83.55 µm) compared to type I IOGs (39.50 µm).

Figure 2. Probability density function of spherical diameter [µm] compared to data for Colony + Kainzas chondrites from [2]. A) Compared data of type I and II chondrules. B) Compared data of refractory components (CAI A and B). C) Compared data of IOG (type I and II). Solid lines represent this study and dashes lines reference data. n= number of analyzed components.

Our results indicate that the modal abundance of type I and II IOGs are 1.7 and 0.4 vol%. The abundance of IOGs seem to be chondrite-dependent with (i) 2.6 and 1.6 vol% in the CO3 ALHA 77307 [4] and (ii) 0.28 and 0.09 vol% [2]. Such difference could be related to (i) ambiguity for differentiating IOGs from chondrules [4], or (ii) an intrinsic heterogeneity between the different chondrites. The latter is supported by the different abundance of type I IOGs estimated in EM 397 and EM 463 with the same methods (1.2 and 2.1 vol%, respectively).

Our results show that the majority of the particles are unrimmed, with just a ~1.5% of objects with evident FGR. The relative abundance of rims in Fe-rich objects is larger than Mg-rich. Previous results show major abundance (15% in Allende, CV3, [3]) of rim-texture chondrules. This supports the notion that individual nebular components retain different signatures related to temporal and/or heliocentric distance where they evolved before planetesimal accretion. Although, it has also been suggested that chondrules rims can be produced after parent body formation [9]. If this is the case, the low percentage of particles with FGRs could be explained by a limited fluid circulation onto the CO parent body. Nevertheless, our study show a positive correlation among rim thickness vs. chondrule size that has been observed in other carbonaceous chondrites (Allende, [3] and Murchison, [10]). Also, the considerable abundance of presolar material into CO and CM chondrule rims [e.g. 11,12] support a prior agglomeration of fine-grained material before the final planetesimal accretion. The high abundance of nebular components (~60 vol%) in CO chondrites could indicate that fine-grained particles or vapor condensation were restricted, and probably controlled by a high regimen of coarse-grained particles/gas ratio. The reduced modal abundance of rim-texture chondrules may be related to a low gas-drag aggregation along their growth-heliocentric distance, i.e., small particles travel slow and brief distance assuming a weakly turbulent nebula [e.g. 13].

These findings suggest that in general the size-sorting of nebular components into CO3 chondrites show large variations. These results point towards a heterogeneous parent body, with a complex accretion history related to a variable particles/gas accretion-ratios.