MODAL ABUNDANCES AND CHEMISTRY OF CLASTS IN THE RENAZZO (CR2) CHONDRITE BY X-RAY MAP ANALYSIS. J. M. Bayron[1,2], I. R. Erb[3], D. S. Ebel[2,4], S. Wallace[2], H. C. Connolly Jr.[4,5,2]. [1]Dept. Geography, Hunter College, City University of New York, NY, NY 10065 (jbayron@hunter.cuny.edu) [2]Dept. Earth & Planetary Sci., American Museum of Natural History, Central Park W. at 79th St., NY, NY 10024 (debel@amnh.org, swallace@amnh.org) [3]Yale University, New Haven, CT (isabelle.erb@yale.edu) [4]Earth and Env. Sci., Graduate Center, CUNY, NY, NY 10016. [5]Dept. Phys. Sci., Kingsborough Community College CUNY, Brooklyn, NY 11235.

Introduction: Chondritic meteorites contain Ca-, Al-rich inclusions (CAIs), amoeboid olivine aggregates (AOAs), chondrules and other inclusions embedded in a fine-grained matrix. Chondrules are igneous components that resulted from repeated transient heating events in th0065 protoplanetary disk [1, 2, 3] whereas CAIs and AOAs contain refractory minerals that appear sintered but not fully melted. Matrix contains minimally processed materials [4]. The coexistence of these components, accreted into rocks with bulk chondritic element ratios, rem ains mysterious. Here, we provide and explore new data on component abundances and compositions in CR chondrites.

CR chondrites are among the most primitive chondrites, and thus preserve information about the young solar system [5]. Matrix has been reported to make up 35-40% of Renazzo (CR2), with 54-62% chondrules or chondrule fragments, and 1-2.6% refractory inclusions [6, 7].

Methods: Techniques similar to those of [8-10] were employed. AMNH #4905A, a polished ~6mm thick slab of Renazzo, was mapped on both sides for Mg, Al, Ca, Ti, Ni (WDS), and Mg, Si, S, Fe (EDS) with a Cameca SX-100 electron microprobe, at 15 KeV, 20 nA, and (ps1A, 14943347 pxls) 6 µm/pixel, 20 ms dwell or (ps1B, 18156210 pxls) 5 µm/pxl, 25 ms. Stitched together maps and RGB composites were overlaid and used to hand trace >1000 clasts (inclusions) that were defined by their chemical boundaries and subdivided into clast types. Analyzed area totaled 992 mm^2. ImageJ and custom software were used to analyze clast area abundances, composition of each individual clast and matrix, and clast size (reported in [10]). Element abundances in each pixel in each clast, and matrix, were normalized by dwell time. Isolated metal grains larger than 180 µm^2 (5 pxls), dark inclusions, and all isolated olivine grains, were considered as part of the matrix.

Pyroxene/olivine ratios in chondrules were estimated based on the Mg and Si abundances in element maps, using criteria of [11]. Chondrules rich in mesostasis are designated Al-rich (CCH). Pixel-by-pixel analysis would enable automated typing of chondrules, but has not yet been implemented in algorithms.

Results: Chondrules, CAIs, AOAs, and matrix make up 60.5%, 0.43%, 1.03% and 38.0% of the entire area respectively. Porphyritic olivine (PO, 10%), porphyritic olivine-pyroxene (POP, 57%), and porphyritic pyroxene (PP, 27%) make up the majority of the chondrule area. Type C (CCH, 1%), miscellaneous (MCH, 2%), and barred olivine (BO, 3%) chondrules are minor. Dark inclusions, isolated olivine, and metal grains are 8.6, 1.4 and 1.3% of the matrix area, respectively. The matrix-inclusion ratio is 0.613, which is within the range reported by [7]. The combined data set contains 1135 chondrules (26% PP, 46% POP, 11% PO, 1% Al-rich, 16% 'miscellaneous'), 28 AOA, and 59 CAIs.

Table 1: Comparison with previous work on Renazzo and CR chondrites [12]. Data in area %.

	W+95 [7]	W+95 [7]	M77 [6]	SK03 [12]	this work
	Renazzo	Renazzo*	Renazzo	CR	Renazzo
chondrules	54	60	61.9	50-60	60.5
CAI+AOA	1		2.6	0.5	1.5
matrix+DI	45	40	36.6	30-50	38.0
(mat+DI)/inclusions	0.82	0.67	0.57	0.5 - 1.0	0.61
	* estimated using O isotopic data				

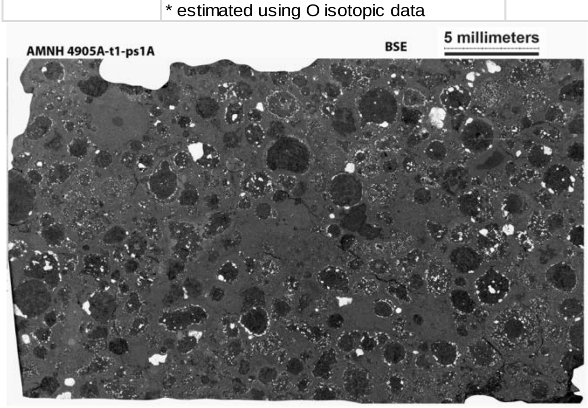

Fig. 1: Back-scattered electron (BSE) image of masked, analyzed area of Renazzo ps1A. Image is de-resolved from original 100 dpi.

Major element abundances in each clast yield a rich dataset. Figure 2 shows counts/pixel for 1135 chondrules (mean = red diamond), matrix (purple square), and for all ~3.3x10^7 pixels (yellow circle). While individual chondrules, AOAs and CAIs show a huge scatter, the chondrules are generally enriched in both Mg and Si relative to matrix.

In figure 3, Ti/Al count ratios are plotted against Al. Horizontal line is bulk Ti/pxl, and the curve is calculated for constant (bulk) Ti/pxl, for varying Al/pxl.

Inset are (left) details of the data, and (right) similar data from [13].

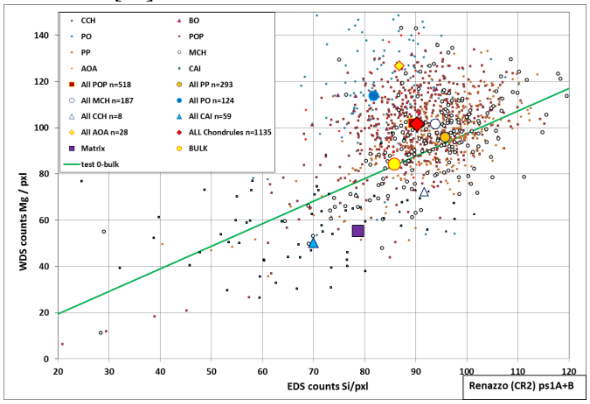

Figure 2: Counts/pixel Mg and Si. All inclusions, averages over inclusion types, matrix, and bulk (all pixels) are plotted.

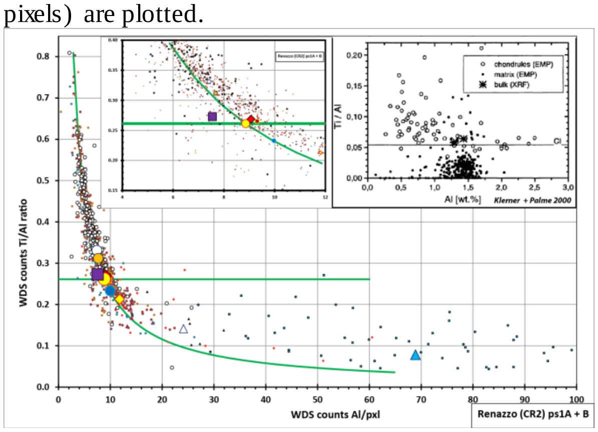

Fig. 3: Counts/pixel ratio Ti/Al vs. Al. Symbols as in Fig. 2.

	Si	Mg	Al	Ca	Ti	Fe	Ni	S
chondrules	64.5	73.9	63.9	61.3	64.9	57.1	53.2	39.9
AOA + CAI	1.2	1.6	4.3	3.3	1.9	0.8	0.7	0.9
matrix	34.2	24.5	31.8	35.4	33.2	42.2	46.2	59.3

Table 2: Fraction of element counts in components.

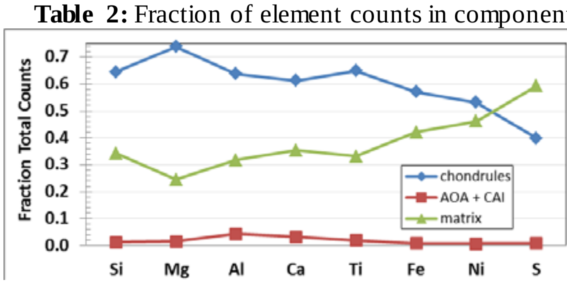

Fig. 4: Fraction of total counts of each element from specific components (data of Table 2).

Discussion: Modal abundances of inclusions and CAIs are consistent with previous work based on point counting (n~2000) [6, 7]. Here, the number of "points" and area coverage is larger. X-ray map analysis may reveal slightly more matrix material than was observable using optical methods to determine boundaries between clasts and matrix. The abundance of AOAs and CAIs, with AOAs ~2x CAIs, is likely incorrect across all studies, following the analysis of [14].

Results for Mg-Si illustrate the complementary nature of chondrules and matrix [15, 16]. Results for Ti and Al are less clear. Ti/Al ratios are almost identical in matrix and mean chondrule, with bulk Ti/Al pulled down and to higher Al by CAIs (blue triangle) and AOAs (yellow diamond).

Conclusion: Results confirm and support previous work demonstrating the complementary nature of chondrules and matrix in CR chondrites [13-16]. The solar Mg/Si and refractory budget of CR [12, 16] required inclusions and matrix to combine "just so", implying their formation from a local, solar mixture of precurosors. This result provides a critical constraint on chondrule formation models, and for models describing the accretion of parent bodies in the disk from which the worlds we know emerged.

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