TOMOGRAPHIC STUDY OF SHAPES AND METAL ABUNDANCES OF RENAZZO CHONDRULES. J. Hertz[1], D. S. Ebel[2], and M. K. Weisberg[3]. [1]The Columbia Preparatory School, 5 W. 93rd St., New York, N.Y., 10025, [2]Dept. Earth and Planetary Sci., American Museum of Natural History, NY, NY 10024 (debel@amnh.org), [3]Dept. Physical Sciences, Kingsborough College of CUNY, 2001 Oriental Blvd., Brooklyn, NY 11235.

Introduction: The origin of metal in the metal-rich, highly primitive, CR2 chondrites is vigorously debated [1-7]. In some Renazzo chondrules, metal has an approximately solar Ni:Co ratio which led [2] to suggest that it is a product of solar nebula condensation. Additionally, in many chondrules, metal occurs in two locations: as one or two large metal grains in the chondrule interior and as numerous smaller metal grains along the chondrule rim. In other chondrules, metal is more evenly dispersed in smaller grains. Interior metal generally has higher concentrations of the more refractory siderophile elements than metal in the rim, which tends to be enriched in volatile metals [1]. This difference may be due to (1) partial evaporation and rapid recondensation of metal [1]; (2) condensation of core metal at higher temperatures, suggesting accretionary growth of the chondrules as temperature decreased [2]; or (3) late Fe addition to the metal on the chondrule rims due to FeO reduction from the adjoining silicates [3]. [4] analyzed PGE distribution in CR chondrite metal and argued that rim metal may have formed by a reaction with the surrounding silicates at the time of chondrule formation. [5] showed that Ni and Co concentrations in the metal grains of the least circular, finest-grained chondrules do not follow a condensation trend. This implies that the relative amounts of Ni and Co in the interior grains were gradually established during chondrule melting due to Fe oxidation or reduction.

More recently, [6] observed that chondrules that appear more circular in thin section outline also have coarser metal and silicate grains and a more clearly defined compositional differentiation between rim and core metal grains. These textures were interpreted as reflecting a higher degree of partial melting and "maturation" of the chondrules, as measured by lower fayalite content in olivine and higher P and Ni concentrations of interior metal. To quantify the degree of melting of chondrules, [6] measured a convolution index (CVI) for each chondrule. The CVI, ranging from 1 to 2, is defined as the ratio of the measured perimeter of the chondrule to the perimeter of a circle with the same area as that measured for the chondrule. Correlation of the CVI with chemical data led [6] to conclude that Renazzo chondrules formed "by aggregation of numerous droplets in a dust-rich environment".

We applied 3-D microtomography to three chondrules from Renazzo to better characterize the shapes of, and modal abundances of metal in, CR chondrules, and compare the results with thin section analysis.

Method: A tetragonal prism ~8x8x15mm was cut from Renazzo (AMNH #588). Density structures were computed from images collected using 50 KeV x-rays on the GEOCARS computer-aided microtomography beamline of the Advanced Photon Source at Argonne National Laboratory in Illinois. A stack of "slices", images with spatial resolution of 17.1 μm/pixel, 17.1μm apart, resembling BSE images in 256 grayscales, was produced from the density structure. In this stack, complete individual chondrules were identified for study. Using the ImageJ software package, slices were cropped manually to isolate the chondrule of interest in each slice where it appeared. Using identical thresholding techniques for each chondrule, the relative numbers of pixels contributing to metal and silicate portions in each slice were measured. The surface area and perimeter were also measured, and the CVI calculated, for each slice of the chondrule.

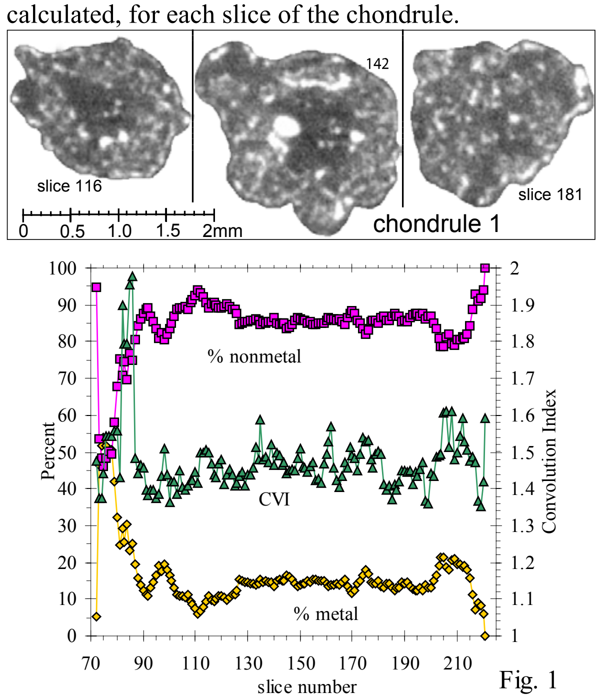


Fig. 1

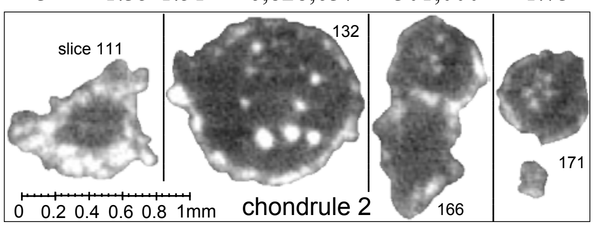
Using the Imaris software package, we determined the volume of each chondrule in its entirety, measured in volumetric pixels (voxels, Table 1). We then measured the surface area in voxels, and calculated the

3dCVI, defined as the ratio of this 3D surface measurement to that of a sphere with the same volume as the chondrule (all in voxels). This entire process was completed on all three chondrules.

Results: For each chondrule, slices and measurements are illustrated in figures and graphs below. For example, slices 72 to 220 of the Renazzo prism contain chondrule 1, and three slices are illustrated (Fig. 1). This chondrule appears as two separate entities in the plane of the slices 81-85, as does chondrule 2 in slices 171 and 172 (Fig. 2). The maximum and minimum CVI observed in the central 50% of all slices of each chondrule are tabulated in Table 1, with 3-D volumes and surface areas measured in voxels, and 3-D convolution indices (3dCVI3) as defined above.

Table 1: Slice and shape measurements of chondrules.

chon	CVI range	volume	surface	3dCVI3
1	1.40-1.59	4,147,800	167,281	1.34
2	1.32-1.60	2,355,344	131,949	1.54
3	1.35-1.51	6,828,637	301,000	1.73



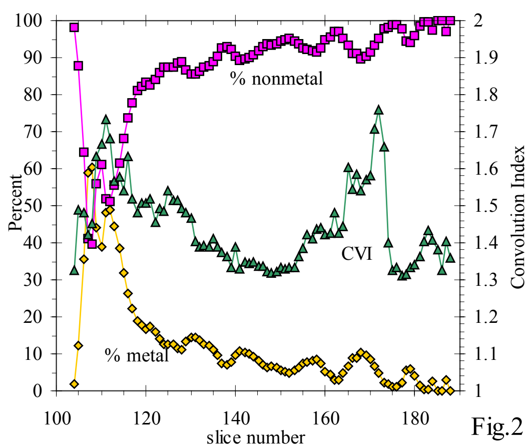
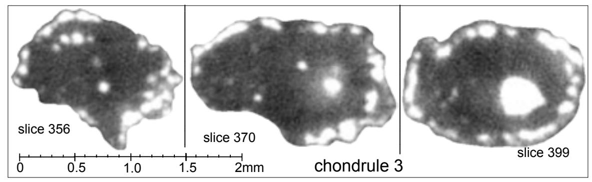


Fig.2

Discussion: Each of the three chondrules studied here could be ranked as more, less or least convoluted, hence melted, in any order, based on a single randomly chosen thin section measurements of each of their CVI. The CVI does not make use of information about metal grain size or metal distribution. Our observations of metal grain size and abundance by slice indicate that any such measurements should also be made from 3D data. Chondrule 3, with a very large metal grain and abundant perimeter metal, appears to meet the criteria for 'most melted' of [6], yet its 3dCVI measurement is greatest. Perhaps convolution is not tightly correlated with degree of melting and metal agglomeration. Alternatively, chondrule convolution may be related to total volume. As a chondrule's surface area increases, it has more opportunity to have a large 3dCVI. Voxel measurements should, if consistently applied, overestimate 3dCVI for smaller chondrules, and be most accurate for larger ones, if spatial resolution is the same for all.



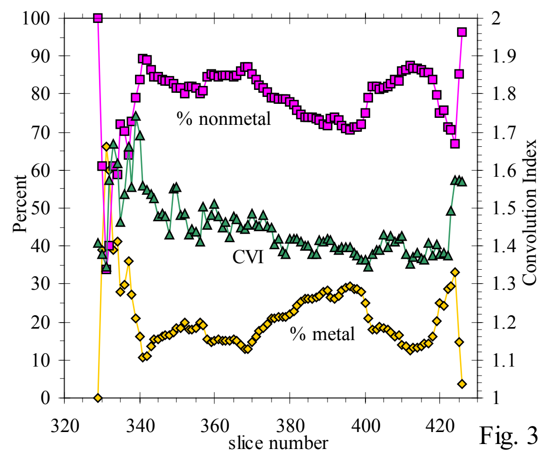


Fig. 3

Conclusion: The CVI and modal amount of metal in CR chondrules vary significantly depending upon which random two dimensional slice of the chondrule is measured. Neither the CVI, nor the 3dCVI defined here, appears to adequately characterize the degree of melting and 'chemical maturation' of a chondrule in the paradigm of [6]. The hypotheses of [6] are not, however, negated by this conclusion, but could be more rigorously explored by analysis of metal grain size and location, and other properties of these chondrules, in conjunction with refinement of the CVI. Clearly, these phenomena can be quantified accurately only by three dimensional analysis and not by the study of thin sections alone.

References: [1] Campbell A.J. *et al.* (2002) *GCA,* **66**-S1, A117. [2] Weisberg M.K. *et al.* (1993), *GCA,* **57**, 1567. [3] Lee M.S. *et al.* (1992), *GCA,* **56**, 2521. [4] Connolly H.C. Jr. *et al*. (2001), *GCA*, **65**, 4576. [5] Zanda B. *et al*. (1993), *Meteoritics* **28**, 466. [6] Zanda B. *et al*. (2002), *LPSC* **XXXIII**, Abs. #1852. [7] Wood J.A. (1963) *Icarus* **2**, 152.
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