CLASSIFYING CHONDRULES BASED ON CATHODOLUMINESENCE. T. C. Cristarella[1, 2] and D. W. Sears[2, 3], [1]Department of Chemistry and Physics, Saint Mary's College, Notre Dame, IN 46556 [2]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701, [3]Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701

Introduction: The original classification schemes for chondrules in meteorites involved describing textures as observed by optical microscopy [1]. However, such schemes were not purely descriptive but involved terms that carried interpretative implications. The McSween-Scott-Jones scheme classifies chondrules as type I and II, these being those with FeO poor olivine and FeO rich olivine, respectively [2]. These two classes are then subdivided into A, mostly olivine; B, mostly pyroxene; and AB, a mix of both olivine and pyroxene. However, when the chondrite is at or above petrologic type 4, the FeO compositions homogenize and there is no clear distinction between FeO rich and FeO poor chondrules.

The scheme proposed by Sears et. al. [3] uses electron microprobe analysis to classify chondrules. The paper uses data from DeHart [4] analysis of chondrules. It analyzes the mesostasis and olivine (or pyroxene, if olivine is not abundant enough) compositions. If the chondrule has bright cathodoluminesence (CL), then it is an A chondrule and dull or no CL is a B chondrule. These are further subdivided into A1-5 and B1-3 based on plots of the olivine and mesostasis composition. Table 1 shows how the chondrule groups are defined by CL color.

The compositional classification scheme received criticism from Scott et. al [5], who objected to the compositional boundaries defining the CL types andfrom Grossman and Brearley [6] who also argue that electron beam vaporized Na from the chondrules and therefore the mineral compositions of the mesostasis are incorrect. The present paper evaluates this situation and discusses the current status of the Sears et al. [3] scheme.

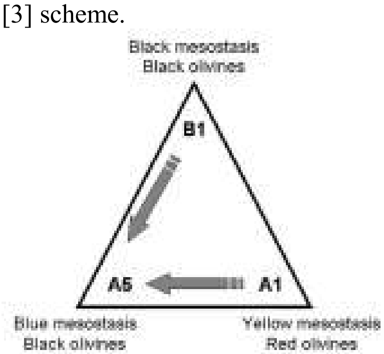

Fig. 1: Cathodoluminescence classification of chondrules. The arrows refer to trajectories caused by metamorphism. The challenge is to express this as mineral compositions.

Cathodoluminesence: During electron microprobe analysis, a CL image of the thin section can be taken. A CL photograph of a chondrite thin section shows different colors based on composition. The mesostasis and grains can be seen with different colors, and each chondrule is classified based on those colors. Figure 1 shows how the CL colors relate to the scheme classification. The CL color and intensity relate to the composition of the chondrules, which is how the composition plots relate to the CL [3].

Table 1. Chondrule groups defined in terms of cathodoluminescence and mesostasis composition.

	Mesostasis*	Chondrule grains
A1	yellow	red
A2	yellow	none/dull red
A3	blue	red
A4	blue (An > 50)	none/dull red
A5	blue (An ≤ 50)	none
B1	none/dullblue (Qz ≥ 50)	none/dull red
B2	dull-blue (Qz 30-50)	none/dull red
B3	purple)Qz 15-30)	none

*An and Qz refer to normative anorthite and quartz (mol %) calculated from defocused electron-beam microprobe analysis.

Olivine Composition: The olivine is plotted based on the CaO vs. FeO present in the mineral grains. Figure 2a shows the original olivine boundaries which are based on data from DeHart (1992). However, these boundaries were criticized by Scott et al. [3], as they are only reflective of the DeHart data. Figure 2b is the revised olivine plot from Sears et al. (1995) [7] which is more inclusive of possible data. Arrows on the plot show the direction of metamorphism.

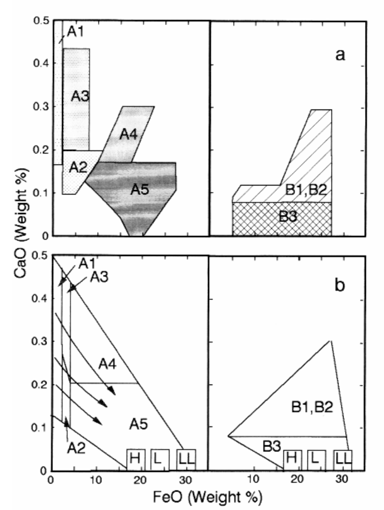

Fig 2: (a) The original olvine plot and (b) the revised plots as published in Sears et al. (1995).

Mesostasis: The mesostasis composition is plotted in a ternary diagram based on quarts, albite and anorthite composition. The mineral compositions are calculated with the CIPW norm from oxide wt% data from the electron microprobe. Figure 3 shows five ternary diagrams of Semarkona mesostasis data, all from different sources. [8, 9, 4] data all have similar data dispersement. Refs. 5 and 6 have data which plot lower in the ternary diagram than the other data. Scott (1994) attributes this disparity to different beam conditions. Grossman and Brearley [6], however, believe that the differences are due to different sodium values. They believe that the DeHart [4] data are sodium deficient because the electron beam vaporized it out of the sample during analysis.

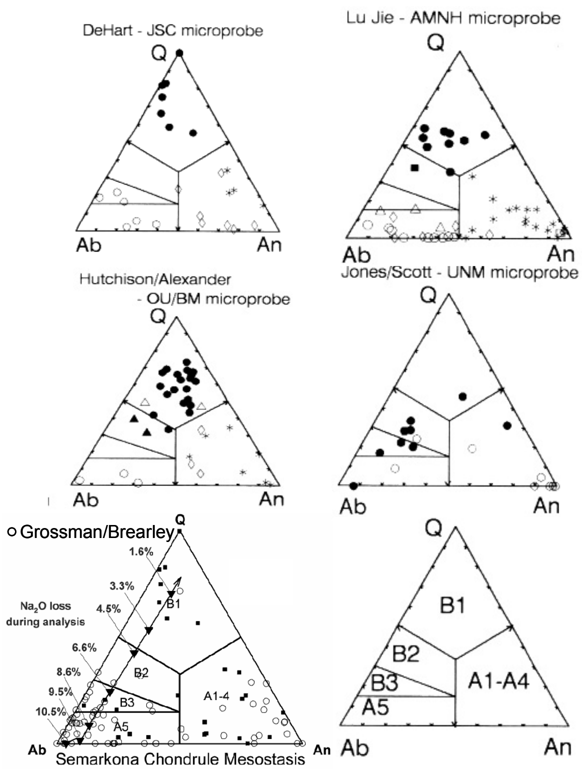

Fig. 3: Ternary diagrams of mesostasis data of Semarkona for DeHart [4] and other sources.

Discussion: If the DeHart [4] data are deficient in sodium, then a solution would be to lower the boundaries on the ternary diagram to better reflect the data. However, even if the Grossman and Brearley [6] data is not sodium deficient, there is still a point that plots high in the original B1 region, which is low in sodium and high in silicon. This point makes it difficult to lower boundaries or cut off the ternary, as there may be other chondrules that will plot near this point. It also supports the possibility that the Grossman and Brearley [6] data is looking only at high sodium chondrules. This is further supported by the fact that the DeHart [4] data was looking at cathodoluminesence, and therefore picked chondrules based on a broad range of CL properties rather than random chondrules.

While Scott et al. attributed differences to analytical technique, the largest difference in analytical technique between the studies is beam size and analysis time. Whether the Grossman/Brearley technique is superior or not is still unclear, however their sodium values are significantly larger than those of DeHart [4] and Lu Jie [8]. This could be accounted for by the possibility that the Grossman/Brearly study is looking at high sodium chondrules. However, it is possible that the small beam diameter of the other studies is causing significant volatile loss from the chondrule samples.

Conclusion: Currently, there is insufficient data to change the boundaries of the mesostasis ternary diagram nor claim the current boundaries are correct.

Future Work: To reconcile the Sears et al. [3] scheme, a thin section should have both a CL image and EMP data analyzed separately to classify based on the current classification system. The two results can then be compared to see if the ternary is reflective of the CL classification. We also suggest that probe conditions that minimize Na loss are identified and applied to the scheme.

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