A classification system that clarifies fundamental relationships among apparently different objects is especially useful. The traditional classification system for Allende Ca,Al-rich inclusions (CAI's) and amoeboid olivine aggregates (AOA's) (collectively referred to as refractory inclusions) emphasizes differences between discrete classes of objects [1-3]. But it obscures the fact that there are chemical, mineralogical, and textural continua among many refractory inclusions and olivine-rich chondrules in C3 chondrites, because they contain varying proportions of three fundamental constituents: rimmed concentric objects, porous chaotic material, and mafic inclusion matrix [4,5]. I have developed an alternate classification system (based on a comprehensive survey of 189 Allende refractory inclusions) that clarifies relationships among CAI's, AOA's, and olivine chondrules in Allende [5-7].

There are two texturally-distinct varieties of olivine-rich inclusions in Allende: unrimmed olivine aggregates (Type 1 inclusions) and rimmed olivine aggregates (Type 5 inclusions). Type 5 inclusions have prominent internal and external rims of granular olivine and frequently contain Ca,Al-rich "insets" that are complex aggregates of smaller concentric objects [3, 5]. Both types of inclusions contain abundant inclusion matrix, their bulk compositions overlap [8], and they grade into each other texturally. Type 5 inclusions appear to be metamorphosed equivalents of Type 1 inclusions [5].

Three types of CAI's can be distinguished. In this classification system the size and abundance of the constituent concentric objects, not mineral grain size, are the most important criteria for distinguishing among types of CAI's. Simple CAI's consist of a single concentric object. Complex CAI's are aggregates of concentric objects ± chaotic material and inclusion matrix.

Unrimmed complex CAI's (Type 2 inclusions; equivalent to irregular fine-grained CAI's of [2]) are aggregates of all three constituents: tiny spinel-rich concentric objects (and their debris), chaotic material, and inclusion matrix. Type 2 inclusions are often mineralogically zoned, but they lack prominent internal or external rims visible by optical microscopy.

The other two types of CAI's have prominent external or internal rims because they consist primarily of larger and (usually) coarser-grained concentric objects than those that constitute Type 2 inclusions. Rimmed complex CAI's (Type 3 inclusions) are contorted, convoluted, botryoidal-to-sinuous aggregates of several concentric objects [7]. Simple CAI's (Type 4 inclusions) consist of individual concentric objects [7]. Rimmed complex CAI's and simple CAI's are further subdivided according to a mineralogical criterion: the presence or absence of abundant melilitite. Rimmed complex CAI's and simple CAI's can have any grain size (fine, medium, or coarse).

Chemically, mineralogically, and texturally, two suites of objects can be recognized. The first suite spans the range olivine-rich aggregates → unrimmed complex CAI's → (spinel-rich) rimmed complex CAI's. The second suite (which are igneous objects) is simple CAI's → olivine-rich chondrules.
There is a continuous gradation in the mineralogy, composition, and texture of irregular, fine-grained refractory inclusions in Allende [5]. This has also been noted for fine-grained refractory inclusions in C3(0) chondrites, the bulk chemistry of which vary continuously between olivine-normative and spinel + clinopyroxene-normative end members [9,10]. The class Type FAO was coined by [11] for fine-grained Allende inclusions mineralogically intermediate between olivine aggregates (his Type AO) and unrimmed complex CAI's (his Type F), inclusions that contain (respectively) olivine-rich inclusion matrix and spinel-rich concentric objects in abundance.

Irregular fine-grained CAI's usually have highly-fractionated (Group II) REE patterns and are depleted in many refractory trace elements [12]. These chemical patterns were also found in a group of olivine-rich inclusions characterized by [13] as "fractionated AOAs" (they did not distinguish between the two types of olivine-rich aggregates), which they suggested were mixtures of an olivine-rich component (=inclusion matrix) and Group II CAI material (=spinel-rich concentric objects). A "fractionated AOA" was initially identified on a slab surface by [14] as a fine-grained CAI, suggesting that this object was an unrimmed (rather than a rimmed) olivine aggregate.

As the volume abundance and size of their spinel-rich concentric objects increases, unrimmed complex CAI's grade chemically, mineralogically, and texturally into (spinel-rich) rimmed complex CAI's. The bulk composition of a coarse-grained (spinel-rich) rimmed complex CAI analyzed by [15] is similar to (and its Group II REE pattern is identical to) those of irregular fine-grained CAI's [14] that simply contain smaller spinel-rich concentric objects.

The second suite of objects is simple CAI's (=Type B [1] and Type I [16] 'CAI's) olivine chondrules. The mineralogy (anorthite + Al-clino.pyroxenes ± spinel) and core + rim structure [5,16] of melilite-poor simple CAI's are evidence that these igneous objects may be related to rimmed, melilite-rich simple CAI's (Ti-Al-pyroxene + spinel + melilite ± anorthite): they may have crystallized from Ca,Si-rich partial melts that became separated from Mg,Al-rich residues during distillation—our proposed origin of concentric objects.

Type 4 "inclusions" appear to be Ca,Al-rich chondrules. The bulk compositions of Ca,Al-rich chondrules and olivine-rich chondrules barely overlap [17], but this is probably an artifact of the condensation/distillation sequence. Comparable amounts of Ca-Al and Mg+Si would be stable as condensates or distillation residues only over a very restricted temperature interval (~1440-1450 K). At all lower temperatures, almost all of the far more abundant Mg+Si would be condensed (forming chondrules); at all higher temperatures, Mg+Si would be vaporized (forming CAI's) [Wood, pers. comm.].

Acknowledgements: This research was supported by NASA Grant NGL 09-015-150 to J.A. Wood.