NON-NEBULAR ORIGIN FOR CAI RIMS; T.E. Bunch and S. Chang, Extraterrestrial Research Division; P. Cassen, R. Reynolds and J. Lissauer, Space Sciences Division; NASA-Ames Research Center, Moffett Field, CA 94035.

We reported earlier (1,2,3) that CAI rims probably resulted from a high temperature, short pulsed thermal event. After consideration of recent petrographic and SEM observations of coarse-grained CAI inclusions and other related objects in Allende, we reaffirm this conclusion and discuss pertinent observations together with a plausible model that involve a high temperature event acting upon refractory inclusions and "primitive" dust (see also a companion paper Cassen et al, this vol.).

We postulate that coarse-grained CAI's (Grossman Type A and B) have sustained thermal alteration ranging from limited melting of rims to complete melting of the object. "Classic" rims formed (4) in response to this thermal event yielding unmelted CAI's overlapped by alteration of mostly melilite and enrichment of Fe in selected rim phases by a gas enriched in Na, Cl, and Fe with migration outward of mostly Ca as suggested by (3,5). Further interaction with gas and dust produced the non-refractory rim components including material greatly resembling Type 1A and 1B olivine inclusions (6). A clear relationship is evident between the degree of melting (peak temperature and time of heating), with rim complexity, Na-metasomatism, fo_2, and degree and amount of dust interaction (summarized in Table 1). A type 6, not included in Table 1, could represent disruption of melted inclusions that produced many unusual, refractory inclusions within Allende,e.g., spinel-rich inclusions (9); alkali-rich spinel aggregates (4). From the characteristics in Table 1,a definite textural and compositional relationship is evident between "hot" CAI's and a thick dust mass. Kornacki and Wood (6) found minor amounts of Al, Ca, Ti in inclusion matrix olivine and olivine inclusions. We also find similar contents of these elements (and Cr) in those examples and in addition, in CAI olivine rims, rim "blisters" that greatly resemble Type 1A inclusions, and in "Wood dust",(7) which we feel is comparable to "inclusion matrix"(6). We agree mostly with their arguments for "inclusion matrix" formation, although we conclude that the rapid recrystallization of olivine occurred during the lower temperature regime of CAI thermal ablation-dust interaction.

To account for our observations, we require the following: 1) an initial population of CAI's; 2) a gas phase at moderate temperature containing Na, Cl, Fe, and S, and characterized by $fo_2 > 10^6$ times higher than solar composition; 3) a process that caused secondary heating of the exteriors of the CAI's to melt for short but variable times (< seconds); 4) a dust-rich environment with a bulk composition that is refractory element-depleted but otherwise primitive, also characterized by relatively high fo_2.

These requirements are satisfied by a model scenario involving parent body processes. We postulate an object, the unconsolidated and porous surface of which is composed of

fine-grained dust resembling but probably more primitive (less thermally altered) than dust found in "inclusion matrix". Associated with this body is a moderately hot atmosphere, probably transient and heavily laden with dust near the surface, produced by impact(s). CAI's were injected into this atmosphere at 1-4 km/s; they encountered a steep density gradient, underwent intense transient heating that led to surficial melting and phase alteration to various depths and degrees yielding the rims of CAI's. As the CAI surface cooled, interior and rim phases were metasomatised by Na and Cl in the atmosphere. When the CAI's fell onto the parent body, dust mantles were acquired on their previously melted and gas-altered exteriors. The dust may have been acquired on the very surface of the body or in a thick cloud suspended above the surface by impact(s) or both. In either case, metasomatism may have continued into this stage. The dust in a band contiguous to the hot rim was chemically altered to various degrees depending on the intensity of heating and depth of melting experienced by a CAI. For a similar reason, the dust residing in a band farther out from the CAI exterior was partially recrystallized to various degrees to yield coarse grained olivine. The relatively less altered band of dust external to the preceding olivine band closely resembles "Wood dust" or "inclusion matrix". Ablation in the atmosphere and the mechanics of incorporation of warm to very hot CAI's into the dusty parent body could have peeled off segments of rim and band material from any of the stages described above. Many of the unusual rimmed and unrimmed olivine inclusions found in Allende may have been derived from such segments. The role of impacts can also account for the dark inclusion features in Allende described previously by (10).

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TABLE 1. Characteristics of type examples of CAI's and associated "dust" arranged in order of increasing intensity of thermal alteration.

Stage:

(1) Nearly spherical CAI's, commonly shocked with little or no apparent annealing. Thin layered rim (<0.05% of CAI dia.). Simple rim sequence (± hibonite + TiAl-cpx + secondary Pv ± Fe-Sp + Hd-px). Low fo_2. Small amounts of thermally altered "dust."

(2) Classic core-rim CAI's. Rim ~ 1-3% of CAI dia. Outermost melilite subhedral grains truncated at rim interface. Layered rim sequence commonly = "orange" hibonite crystals with grain growth towards interior + Fe-Sp with Pv inclusions + Ti-cpx or Al-cpx or both ± Wo + Salitic px ± andradite + outer rim of granular Fe-ol + "blisters" similar to Type 1A and/or 1B olivine inclusions. Associated fine-grained granular dust (<5 um) in rim surface depressions. A mostly continuous layer of Ne-rich dust covers the rim. This dust termed "Wood dust" is after (7), is enriched in Na_2O (~ 2.0%) and depleted in sulfide and metal and is very similar to "inclusion matrix"(6). Na-metasomation limited mostly to outer 20% of CAI.

(3) Characteristics similar to 2 above. CAI's more thermally altered. Loss of spherical shape. Core is recrystallized into a hornfels matrix with porphyroblasts; vesicles lined with "whisker" Wo. More pronounced Na-metasomatism.

(4) Some very large (up to 2 cm) and mostly melted, convoluted masses, which have collapsed and reacted with enveloped pockets of dust. Significant plastic distortion of core-rim sequence.

(5) Totally melted. Splatter-shaped CAI clots set in large masses of secondary matrix (Hd-px and minor olivine) that grades outward through granular dust and finally into "Wood dust". A continuous thin rim of ragged Fe-Sp overlain by tiny ilmenite (<one um) and minor magnetite, included in unresolved silicates, encompasses the CAI. Alteration of the CAI interior is extensive with isolated irregular grains of Fe-Sp in altered melilite (replaced by nepheline and sodalite). Highest fo_2.

Key: cpx = Ca-pyroxene; Hd = hedenbergite pyroxene; fo_2 = oxygen fugacity; Pv = perovskite; Wo = wollastonite; Fe-Sp = Fe-bearing spinel; fe-ol = fe olivine; ne = nepheline.