HEATING OF CAI's IN THE ENVIRONMENT OF AN ACCRETING BODY; P. Cassen, R. Reynolds, J. Lissauer, Space Sciences Division; T. Bunch, S. Chang, Extraterrestrial Research Division; NASA-Ames Research Center, Moffett Field, CA 94Ø35.

CAIs apparently were subjected to heating events some time after their formation (see abstract by Bunch et al). These events had effects ranging from the formation of thin crusts (rims) to the complete melting of the inclusion. The thin rims appear to have been produced by heating from the outside to the melting point of the inclusion, but for a very short time interval, on the order of a few seconds. Longer heating intervals would have allowed the heat pulse to penetrate the inclusion, causing alterations that are not seen in these types of CAIs. Rapid transport of the CAI between different nebula thermal regimes would require implausibly steep nebular temperature gradients and/or very high velocities of the inclusions relative to the gas. It does seem possible that the inclusions were heated aerodynamically by rapid deceleration in a medium much denser than the ambient solar nebular encountered at high relative velocity. There are at least two ways that this might happen: passage of the CAI through a shock wave in the nebular medium, or entry of the CAI into the atmosphere and/or regolith of a planet or planetesimal. There are a number of reasons for favoring heating in a planetesimal environment.

First, very high nebular desities (at least 10^{17} particles/cm^3) would be required for shocks to be able to decelerate the CAI at the rate necessary to heat it to the melting point and sustain that temperature for only a few seconds. Second, the intimate association of relatively large amounts of dust with both rimmed and completely remelted CAIs suggests that they encountered an unusually dusty environment while still hot, which is most plausibly accounted for by heating in a dusty atmosphere or impact with a dusty surface. Third, high oxygen fugacities and other chemical evidence indicate that the CAIs were not heated in a normal solar abundance nebula gas. Fourth, the host meteorites also contain chunks of rim material that have apparently been separated from heated CAIs; for them to wind up in a meteorite in proximity to other CAIs implies that they were broken off under circumstances that did not allow them to become dispersed in space. This would be the case if all material were collected at a surface during or shorthly after the heating events. Finally, it appears that deceleration in a planetary or planetesimal atmosphere is capable of fulfilling the high temperature/short duration characteristics of the heating events suffered by CAIs. Although it must be admitted that the conditions in such atmospheres are very uncertain, further study of CAIs and other rimmed objects in Allende may prove informative.

Although theoretical modeling of collisions between CAIs and loosely packed planetesimal regolith is difficult, we note that experiments within the parameter range of interest may well be feasible.

We suggest that the evidence for heating of CAIs may eventually justify their use as probes of primitive atmospheres and regoliths. For the case of aerodynamic heating, calculations indicate that entry velocities of 1-10 km/sec and scale heights of less than 10 km could result in aerodynamic heating over the required time intervals. The figure shows the entry velocity V (in km/sec) as a function of isothermal scale height h (in km) that would result in heating intervals of 1, 2, 5, and 10 seconds. The heating interval is defined to be the time for which the surface temperature exceeds the melting temperature (taken to be 1700K). The calculations were done for a spherical inclusion with radius 1/2 cm and density 3 gm/cm^3. The effects of ablation were ignored; they would lead to greater deceleration and therefore shorter heating intervals. For (Vo,h) below the straight line, melting does not occur. Further constraints can be placed upon the atmospheric conditions by the requirement that CAIs encounter the surface while still hot or molten. These conditions can then be related to theoretical models of the formation and structure of primitive atmospheres around accreting bodies.