SURVIVAL AND DESTRUCTION OF INTERSTELLAR SOLIDS DURING THE FORMATION OF THE SOLAR SYSTEM; K. M. Chick and P. Cassen, NASA-Ames Research Center, Moffett Field, CA 94035-1000.

Major fractions of the primitive meteorites experienced temperatures high enough to melt or evaporate them. Ubiquitous chemical fractionations are plausibly the result of an early, hot epoch of solar nebular evolution [1,2,3], and chondrules are apparently the products of localized heating in the proto-solar environment. Yet such processed components coexist with interstellar grains, some of which are essentially unscathed by cosmogonic events [4]. Such grains must have avoided or survived at least three potentially destructive environments through which most solar system material passed: the collapsing protosolar cloud, the accretion shock, and the nebula itself. We are examining theoretical models of these environments with the aim of determining what factors affect interstellar grain survival; what patterns one might expect to find in the abundances, type and composition of interstellar material in primitive meteorites; and what can be deduced about the formation of the solar system if such patterns exist. Rigorous calculations of radiative heat transfer in model protosolar envelopes are used to determine the pre-shock survival distances of interstellar components. Shock destruction is evaluated from the detailed shock models of Neufeld and Hollenbach [5]. Nebula midplane temperatures are calculated from simple radiative models [6,7], extended to include the backheating effects of the envelope. The primary environmental determinant of survivability is the accretion rate through the nebula, which affects the thermal state of both the nebula and the collapsing cloud. During periods of rapid accretion, silicate grains might survive collapse and the accretion shock to within 2 AU, but would be destroyed in the nebula to distances beyond the terrestrial planet region. During periods of very slow accretion (mass buildup in the disk), those grains could remain intact to well within 1 AU.

To calculate grain survival in the envelope, it is necessary to determine the radiation field accurately through the severe opacity discontinuities caused by grain evaporation, and over a large dynamic range of optical depth. Diffusion-type approximations are not always adequate. We solve the transport equation in two-dimensions (radius and azimuth) using a lambda iteration method [8], augmented by: relaxation techniques to promote convergence, domain decomposition to handle the extended spatial and optical depth ranges, and a two-group (optical and thermal) treatment of the frequency domain. A hydodynamic collapse model [9,10] is used to specify the envelope density distribution and accretion shock and disk luminosities. The shock structure calculations of [5] are consistent with this model. Opacities are taken from Pollack et al. [11]. Allowance is made for the existence of an optically thin cavity produced by a stellar wind. Calculations were performed for several combinations of cloud collapse rates, rotation rates, and disk accretion rates. Emission from the star and nebula is modeled in two extremes: efficient mass transfer through the nebula, so that disk accretion matches cloud collapse, and inefficient mass transfer, with buildup of material in the nebula. The first condition results in high luminosities (30-100 $L_\odot$), while the second condition, although it cannot persist indefinitely, yields luminosities (1-2 $L_\odot$) more commensurate with those inferred for embedded protostars in the Taurus star-forming region [12]. The location of the destruction fronts in the envelope were found for several interstellar constituents, as defined in [11]: silicates, iron, troilite, refractory organics (kerogen), volatile organics and H_2O ice. These were compared with the shock destruction locations in [5] to determine which provided the more severe constraint. The envelope temperatures along the surface of the nebula were used as boundary conditions to calculate temperatures within the nebula.

The effect of backheating of the nebula (short wavelength radiation emitted from the inner disk and the Sun, which shines back on the nebula after being reprocessed in the envelope to longer wavelengths) is important, especially at the high luminosities. Near 1 AU, it may increase the temperature of the nebula by as much as several hundred degrees, and push the ice

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condensation location to well beyond 10 AU. Within several AU, backheating flattens the nebula surface temperature distribution from the usual $r^{-0.75}$ power law (for steady disk accretion) to something like $r^{-0.6}$. The effect of a wind-carved cavity is the opposite (it reduces temperatures, because it allows radiation to freely escape), but is generally not as pronounced as the backheating effect. Higher cloud rotation rates spread the envelope density distribution and dilute somewhat the accretion shock luminosity, and therefore tend produce lower temperatures, which favor survival.

For accretion rates in the range $3 - 10 \times 10^{-6}$ $M_{\odot}$/year), typical destruction distances *above the nebula* are as follows:

		efficient disk accretion	inefficient disk accretion
silicates	1050 K	1 - 2 AU	< 0.3 AU
iron	994	1 - 2	< 0.3
troilite	680	1.5 - 3	0.2 - 0.4
kerogen	575	2 - 4	0.4 - 0.7
volatile organics	375	3 - 8	1 - 2
H_2O ice	125	15 - 25	5 - 7

The low end of the ranges apply to lower accretion rates and the existence of a polar cavity. The locations of destruction fronts *within* the nebula depend on nebula optical depths, but are never at radii less than that given above (until collapse ceases), and, for efficient disk accretion, can be considerably further.

It is clear that there were vast regions of the outer nebula in which all non-volatile interstellar species could have survived incorporation into solar system bodies with minimal modification. Thus their presence in meteorites might simply be "contamination" from the outer nebula, produced as dust migrated inward. However, if major elemental fractionations in meteorites are the result of accumulation in a hot, inner nebula, the abundances of material with interstellar signatures might be correlated in some way with the fractionations, since both would then reflect the cooling history of the nebula. Results such as those presented here will be used to investigate this possibility.

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