COLLISIONAL HEATING OF CHONDRITIC ASTEROIDS. Alan E. Rubin, Dept. Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA. (aerubin@ucla.edu)

Ordinary chondrites (OC) comprise three major related groups (H, L, LL) derived from three separate asteroids that together constitute 69% of observed meteorite falls. The discovery of numerous fossil L chondrites and disaggregated L-chondrite chromite grains embedded in Ordovician limestone indicates that OC have been pelting Earth for at least 470 Ma, i.e., ≥10% of the planet's history. Because some recent L-chondrite falls were shock heated 470 Ma ago (when the parent body may have disrupted), it is clear that fragments of the same L-chondrite asteroid have long been a major contributor to the meteorite flux. It is likely that OC asteroids constitute a significant fraction of the bodies in the inner main asteroid belt; they are plausibly identifiable with the S(IV) asteroid spectral class. Inferences about the internal structure of OC parent bodies should be applicable to those of many chondritic asteroids.

Different OC vary in their degree of thermal metamorphism, ranging from unrecrystallized, mineralogically unequilibrated type-3.0 to highly recrystallized, mineralogically uniform type-6 samples. Because excess ^{26}Mg (the decay product of ^{26}Al, $t_{½}$ = 730,000 years) is present within some chondrules and rare refractory inclusions in OC (as well as in carbonaceous chondrites), it has commonly been assumed that chondritic asteroids were internally heated by the decay of ^{26}Al. If instantaneous accretion had occurred, then the inferred initial abundance of ^{26}Al in OC chondrules could have provided sufficient heat in OC asteroids to have caused thermal metamorphism to type-6 levels, i.e., to temperatures of ~900°C. Such a heat source would probably have resulted in an asteroid with an "onion-shell" structure, with the most-metamorphosed type-6 samples residing near the center of the body and progressively less-metamorphosed samples (type 5 to type 3) residing in nested concentric spherical shells closer to the surface. Such structures readily lend themselves to thermal modeling (if impact heating is ignored).

The most deeply buried materials in an internally heated OC asteroid should have cooled the slowest; however, OC metallographic cooling rates do not show the expected inverse correlation between cooling rate and petrologic type. The most deeply buried materials should also have taken longer to reach their closing temperatures and hence should have younger radiometric ages. Although one study found the expected inverse correlation between petrologic type and radiometric age for eight H chondrites, a larger data set (n=13) that includes these samples shows no correlation.

An alternative mechanism for metamorphism is via collisional heating. Essentially all low-shock (stage S1-S2) type-4-6 OC exhibit petrographic features indicative of higher shock stages. This suggests that these rocks were shocked and annealed; rapid diffusion in olivine healed the crystal lattices but left other shock features in the meteorites relatively undisturbed. In the case of one LL6 chondrite (MIL 99301), annealing occurred 4.23 Ga ago. This period exceeds 400 ^{26}Al half-lives, leaving impact heating as the only viable heat source at this late epoch. Additional evidence supporting impact heating for OC includes (a) a positive correlation between petrologic type and mean shock stage for 1651 OC and (b) the observation that chondrite groups with few or no highly metamorphosed members also have few or no highly shocked members.

Impact heating would not be a global process. Instead, thermal metamorphism could have occurred in hot ejecta blankets produced during cratering events on porous asteroids; i.e., the same impact that shocks the meteorites would be indirectly responsible for their subsequent annealing. Collisional kinetic energy on porous bodies would be distributed through relatively small volumes of material and efficiently converted into heat via pore collapse. Because many asteroids appear to be low-density, high-porosity rubble piles, it seems likely that impact cratering was at least partly responsible for thermal metamorphism on chondritic asteroids. Petrologic evidence for post-shock annealing has also been reported for CK, EH and EL chondrites.

These observations do not rule out ^{26}Al decay as a contributory heat source. TEM studies of olivine microstructures suggest that some OC were shocked while they were already warm. Initial heating of these rocks could have resulted from prior collisions, the decay of ^{26}Al, or both mechanisms.