6.3.28

Timescales of chondrule formation, accretion and differentiation – the tale of Al-26

H. HAACK[1], M. BIZZARRO[1,2], K.L. LUNDGAARD[2] AND J.A. BAKER[2]

[1] Geological Museum, Øster Voldgade 5-7, 1350 Copenhagen K, Denmark (hh@savik.geomus.ku.dk)
[2] Danish Lithosphere Centre, Øster Voldgade 10, 1350 Copenhagen K, Denmark.

New high precission chronological data based on the shortlived isotope ^{26}Al [1,2] and absolute Pb-Pb ages [3] of chondrules and CAIs in two chondrites and separates from the eucrite Juvinas call for a revision of the timing of several main events in the early Solar System: Formation of chondrules, formation of CAIs, accretion of chondrite parent bodies, and accretion and heating of achondrite parent bodies.

In contrast to previous data we find that chondrules did not form later than CAIs but rather that the chondrule formation process was active for several million years unlike the CAI forming process that lasted ~0.6 Ma. Furthermore, we find that chondrules in different parent bodies formed at separate times. Chondrules with $\delta^{26}Mg^*$ excesses close to the canonical value are common in the carbonaceous chondrite Allende but absent in the ordinary chondrite DAG 313, which suggest that chondrules in ordinary chondrites formed several Ma after CAIs and chondrules in carbonaceous chondrites. This is consistent with the observation that CAIs are rare in ordinary chondrites but common in carbonaceous chondrites. At the time when the ordinary chondrules formed, CAIs were no longer common as individual particles in the nebula.

We have found a $\delta^{26}Mg^*$ excess in mineral separates from the eucrite Juvinas [2]. If ^{26}Al was homogenously distributed in the nebula this implies that the HED parent body accreted, heated and differentiated before the chondrules in ordinary chondrites formed. Although the heating and differentiation time scales are poorly constrained it is possible that accretion of achondrite parent bodies took place before CAI formation.

There are several significant implications of this new scenario: 1) ^{26}Al appears to have been the dominating heat source in the early Solar System. 2) If achondrites come from parent bodies that accreted prior to the formation of chondrules in ordinary chondrites then we may have no samples of the precursor materials. Although ordinary chondrites are the most abundant type of meteorite falling on Earth today they may be different from the material ~150 achondrite parent bodies accreted from.

References

[1] Bizzaro, M. et al. (2004) *Goldschmidt Conf. Abstract #1305*.
[2] Lundgaard, K.L.. et al. (2004) *Goldschmidt Conf. Abstract #250*.
[3] Amelin, Y. et al. (2004) *Goldschmidt Conf. Abstract #958*.

6.3.31

Chondritic levels of ^{26}Al were too low to melt asteroids

J. T. WASSON AND T. KUNIHIRO

University of California, Los Angeles, CA 90095-1567, USA. (jtwasson@ucla.edu; tky@ucla.edu)

Chondrules formed in the solar nebula. They were the last objects to melt before the accretion of asteroids. Recent studies of ordinary [1] and carbonaceous [2] chondrites indicate that these chondrite clans had ^{26}Al levels too low to melt enough material to cause differentiation. In Table 1 we summarize initial ratios, Al concentrations, and maximum attainable temperatures [2]. The carbonaceous chondrites were unable to produce any melt; the LL chondrites melted FeS (at 1260 K) but were unable to melt plagioclase (at 1390 K), as required to allow the separation of melts from solids. We used a heat capacity of 837 J kg^{-1} K^{-1} and a heat production of 3.16 MeV per ^{26}Al decay. Maximum temperatures are reached in the interiors of asteroids having radii >40 km.

Assuming that Al isotopes were well mixed, it can be argued that some chondritic matter accreted early enough to have appreciably higher ^{26}Al contents, and that these melted the parent asteroids and thus destroyed the Mg-isotopic evidence. This argument is dubious, since (a) ordinary and carbonaceous chondrites account for 85% of observed meteorite falls, (b) refractory inclusions, the only materials known to have had initial ^{26}Al levels high enough to have melted asteroids, are common only in carbonaceous chondrites whose chondrules record much lower $^{26}Al/^{27}Al$ ratios.

Another possibility is that Al isotopes were not well mixed, a view consistent with large variations in O isotopes between groups and within chondrites). Perhaps large amounts of ^{26}Al were in minor constituents. Although this may be correct, it leaves the uncomfortable situation of having no constraint on the amount of ^{26}Al initially present in bulk chondrites.

If ^{26}Al was inadequate, what caused the melting? One possibility is ^{60}Fe, but most reports indicate low levels that only raise temperatures an additional 140-180 K. Another possibility is impact heating, which is effective in targets having high-porosities. We suggest that IVA magmatic iron meteorites were formed by an impact onto an LL asteroid; these two groups have similar O-isotope compositions.

Table 1. Maximum temperatures produced by ^{26}Al decay.

group	$^{26}Al/^{27}Al$	Al (mg/g)	max T
CO	$3.8\bullet10^{-6}$	14.3	940
CV	$3.8\bullet10^{-6}$	17.5	1100
LL	$7.4\bullet10^{-6}$	11.9	1370

References

[1] Kita N. et al. (2000) *GCA* **64**, 3913.
[2] Kunihiro T. et al. (2004) *GCA* **68**, in press.