Comment on “Ancient Asteroids Enriched in Refractory Inclusions”

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Sunshine et al. (Reports, 25 April 2008, p. 514) reported that certain asteroids contain 30 ± 10 volume percent calcium- and aluminum-rich inclusions (CAIs). We contend that the amount of CAIs in CV chondrites is two to three times as low as the 10 volume percent assumed by the authors; thus, we question whether the CAI-rich bodies they studied are indeed older than known asteroids or formed before the injection of 26Al into the solar nebula.

Sunshine et al. (1) reported the finding of certain asteroids that they claim to consist of 30 ± 10 volume % of calcium- and aluminum-rich inclusions (CAIs). CAIs are the oldest objects found in chondrites, up to 1.2 million years (My) older than more common chondrules [e.g., (2–4)]. CAIs are a diverse group of objects and occur in variable abundances in the different chondrite groups. The formation conditions of the different types of CAIs are highly debated, and it is unclear how CAIs could have been stored for up to 2 My before being incorporated into asteroids together with chondrules. The finding of Sunshine et al. (1) that some asteroids have high abundances of CAIs is of great importance, because these might indicate that CAIs formed in a separate region of the nebula. Some CAIs might then have escaped from this region, moved to other areas, and become trapped in asteroids that formed in regions that may have lacked any CAIs. This would strengthen the picture of a solar nebula with regions of different physical and chemical conditions, each favoring different components to form. However, we contend that the modal abundances of 30 ± 10 volume % CAIs proposed for certain asteroids by Sunshine et al. (1) are based on incorrect assumptions for chondrite CAI modal abundances and therefore may be too high.

Sunshine et al. (1) combined spectral observations of a set of asteroids with modeling of the observed spectra from laboratory spectra obtained from different chondritic materials. In particular, they measured spectra from CAIs within the Allende CV3 meteorite, CAI-free Allende matrix, and different types of CAIs. They used the spectra to model the bulk Allende chondrite. Their modeling results indicate a CAI abundance of 10% in bulk Allende, which the authors note is in excellent agreement with the known abundance of CAIs in CV3 meteorites. This is because the authors assume 10 volume % of CAIs for CV chondrites [taken from table 3 in (5)]. That table contains a column designated “Refractory inclusion abundance," which is described in the table caption as “Refractory inclusion abundance includes CAI+AOI." The superscripted “2" is added to the 10 volume percentage for CV3 meteorites. This is because the authors assume 10 volume % of CAIs for CV and 13 volume % CAIs for CO chondrites of a single chondrite group and that CAI modal abundances in Allende could be higher than 3.0 ± 0.1 volume %. However, if Al as a representative refractory element were concentrated only in CAIs, Allende could not have more than 9.3 volume % CAIs (14). Because much of the Al in Allende is concentrated in chondrules and matrix, the value Sunshine et al. use for Allende is about two to three times too high. This means either their model used to calibrate their spectra needs a correction or something is missing in the interpretation of their spectra. One misconception could be that some CV chondrites do contain abundant spinel in their matrix (15, 16), opposite to what Sunshine et al. state, “In meteorites, abundant aluminous spinels are only observed in CAIs ...”

In conclusion, we encourage Sunshine et al. (1) to check their calibration and calculations using a new assumption that Allende contains around 3 volume % CAIs. The asteroids they measured may still have unusually high CAI modal abundances, but perhaps not as high as 30 volume %; a range of 10 to 15 volume % would better agree with previous results (17). From the CAI modal abundances we obtained for carbonaceous chondrites, we calculate that CAIs contribute <10% to the Al budget of chondrites, with the exception of CV, where CAIs contribute ~25% to the Al budget. Even if the CAI modal abundance in all these chondrites were about three times higher, a large fraction of Al would still be contained in chondrules and matrix. CAIs are therefore not the dominant carrier of Al or possible 26Al. As a result, the enhanced abundance of CAIs in the asteroids reported by Sunshine et al. (1) do not necessarily require that these asteroids were melted, if all CAIs in them had canonical initial 26Al of 5 × 10−5. This means that these asteroids need not necessarily be older than other asteroids from which we have samples or that their CAIs formed before a possible injection of 26Al in the protoplanetary nebula. Whether this asteroid family provides the best candidates for sample-return missions may also need to be reconsidered.

References
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