ARE THE S-TYPE ASTEROIDS THE PARENT BODIES OF ORDINARY CHONDRITE METEORITES?: EVIDENCE FROM THE INTERPLANETARY DUST RECOVERED FROM THE EARTH'S STRATOSPHERE:

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The observation of dust bands associated with the Koronis family of S-type asteroids demonstrates that this family produces abundant interplanetary dust. Because of the low inclinations and eccentricities of the orbits of Koronis family members, dust from the Koronis family is enhanced in near-Earth collections. Kortenkamp et al. [1] estimate that the Koronis family and the C-type Themis family together contribute 55% of the interplanetary dust particles (IDPs) incident on the Earth. Comparison of the chemical, physical, and mineralogical properties of the IDPs collected in the stratosphere with those properties of ordinary chondrite meteorites show few similarities, suggesting the S-type Koronis asteroids produce IDPs distinctly different in composition and structure from ordinary chondrites and that these S-asteroids are not parent bodies of ordinary chondrite meteorites.

Comparison of astronomical reflection spectra of asteroids with laboratory reflection spectra of meteorites has produced plausible identifications of parent bodies for most types of meteorites. However, the ordinary chondrites, the most abundant type of meteorite among the terrestrial falls, have no spectral match among the asteroids. It has been suggested that surface weathering might alter the reflection spectra of S asteroids, and that S-type asteroids may be parent bodies of the ordinary chondrite meteorites.

The Koronis family of S-type asteroids is associated with a major dust band, identified by the IRAS spacecraft, and is thus a known contributor to the interplanetary dust. Because of the low inclinations and eccentricities of the orbits of Koronis family members, gravitational focusing results in a significant enhancement of the flux of dust from the Koronis family near the Earth. Kortenkamp et al. [1] modeled the dust contributions from the bands detected by IRAS, and concluded that 55% of the interplanetary dust particles (IDPs) incident on the Earth are derived from the S-type Koronis family and the C-type Themis family of asteroids. Thus, we should expect a significant fraction, perhaps one-quarter, of the IDPs collected from the Earth's stratosphere to be derived from the S-type Koronis family. If so, detailed comparison of the chemical compositions, mineralogies, and physical properties (eg. grain size, porosity, and density) of the IDPs from the Earth's stratosphere with those properties of the ordinary chondrite meteorites should resolve the question: "Are the S-type asteroids the parent bodies of the ordinary chondrites?"

Comparison of IDPs with Ordinary Chondrite Meteorites

The IDPs collected from the Earth's stratosphere range from ~5 to >50 microns in diameter. Preliminary characterization (EDX spectra, optical properties and sizes) of these stratospheric particles is performed at the NASA Johnson Space Center, and individual particles are then made available for detailed analysis. A large majority of these IDPs have major element compositions (Mg, Al, Si, Ca, Cr, Fe, and Ni) similar to chondritic meteorites. These chondritic IDPs are similar to ordinary chondrites in major refractory elements. However, the carbon contents measured in all 71 chondritic IDPs analyzed by Thomas et al. [2] and an additional 30 chondritic IDPs by Schramm et al. [3] each significantly exceed the carbon content of any type of ordinary chondrite meteorite. The volatile elements S, Na, P, K, Cu, Zn, Ga, Ge, Se, and Br are also more abundant in most chondritic IDPs than in ordinary chondrites [4].

Bradley et al. [5] measured the visible and near-infrared reflection spectra, from 380 to 800 nm, of five individual chondritic IDPs. Some of these IDPs had flat reflection spectra, similar to the C-type asteroids, while others showed a pronounced rise in reflectivity in the red, similar to the P-type or D-type asteroids, and most chondritic IDPs appear black when viewed in the optical microscope. Both the spectral shapes and the low albedos of these IDPs are inconsistent with the observed spectra and albedos of S-type asteroids.

The chondritric IDPs are generally extremely fine-grained (typical grain size <1 micron), have significant porosity, and many contain unequilibrated mafic silicates. The ordinary chondrites, on the other hand, are coarse-grained, have low porosity, and are generally well equilibrated. Thus, most (or all) of the chondritic IDPs are chemically, mineralogically, physically, and spectrally different from the ordinary chondrite meteorites.

Comparison of IDPs With Separated Matrix and Chondrules

The ordinary chondrites are dominated by chondrules and chondrule fragments and contain a few percent fine-grained matrix. The fragmentation of inhomogeneous parent bodies, consisting of a weak matrix and stronger crystalline phases, has not been well studied. Since the typical IDP recovered from the Earth's stratosphere is smaller than the mean grain-size of the ordinary chondrites, it seems appropriate to compare the IDPs with separated matrix and chondrule fragments from the ordinary chondrite meteorites.

The anhydrous chondritic IDPs are chemically and mineralogically distinct from the anhydrous matrix found in most ordinary chondrites. The average carbon and volatile contents of the anhydrous IDPs are significantly higher than ordinary chondrite matrix, the mean grain size in the IDPs is significantly smaller than in ordinary chondrite matrix, and most anhydrous IDPs show a much wider range of compositions of their olivines and pyroxenes than is seen in the matrix of ordinary chondrites.

Two unusual ordinary chondrites, Semarkona (LL3) and Bishunpur (L3), have some matrix which is similar in mineralogy and grain-size to the hydrated chondritic IDPs [6]. However, the Semarkona matrix is different in chemical composition and in detailed mineralogy [7] from the hydrated IDPs. The most distinctive difference is the carbon content, which is <1 wt% in Semarkona matrix [7], significantly lower than in any chondritic IDP measured. Bishunpur matrix, not yet analyzed for carbon, is also likely to have a low carbon content compared to chondritic IDPs.

The majority of the chondrules in ordinary chondrites are composed of olivine, which would produce olivine fragments upon breakup. Mafic silicates, including olivines, are found on the stratospheric collectors. These particles, usually recognized because they are transparent, are not routinely picked during curation. No systematic study of the mafic silicates collected from the stratosphere has yet been conducted. However, Scanning Electron Microscope examinations have not shown obvious microcraters, which would be expected on surfaces exposed in space for the duration of the transit from the main-belt to Earth. The absence of microcraters is consistent with classification of these olivines as terrestrial, but some have fine-grained chondritic material adhering to their surface, suggesting an extraterrestrial origin. More detailed study of mafic silicates from the stratospheric collectors, including examination for solar flare tracks, could establish their origin. If they are extraterrestrial, then detailed chemical comparison of these mafic silicates with crystals from ordinary chondrites and carbonaceous chondrites could be undertaken. Since some of the larger (>100 micron diameter) micrometeorites recovered from the Antarctic ice have chemical compositions suggesting similarity to ordinary chondrites [8], more detailed study of the olivines on stratospheric collectors is desirable.

Conclusions

The chondritic IDPs collected from the Earth's stratosphere differ in mineralogy, chemistry, reflection spectrum, porosity and grain-size from bulk ordinary chondrites, and no significant population among these chondritic IDPs matches either the bulk or separated matrix material of the ordinary chondrite meteorites. In the absence of detailed study of the olivine and pryroxene crystals collected from the Earth's stratosphere, the possibility that these crystals are the IDPs from the Koronis family of asteroids cannot be excluded. However, the absence of obvious microcraters on the surfaces of these crystals is consistent with a terrestrial origin. If the olivines are terrestrial, then either the Koronis family makes an insignificant contribution to the 5 to 50 micron diameter dust collected from the Earth's stratosphere or the S-type Koronis asteroids are significantly different in chemistry, mineralogy, and physical properties from ordinary chondrites and the S-type Koronis family is not a plausible parent body of ordinary chondrite meteorites.

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