CHONDRITIC METEOR DEBRIS IN ABYSSAL SEDIMENTS. D. E. Brownlee[1], P. W. Hodge[2], M. B. Blanchard[3], T. E. Bunch[3] and F. T. Kyte[3], [1]The Lunatic Asylum, Div. of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; [2]Dept. of Astronomy, Univ. of Washington, Seattle, WA 98195; [3]NASA Ames Research Center, Moffett Field, CA 94035.

Atmospheric entry is a filter which only permits meteoroids with appropriate masses, structural properties and entry parameters to survive and become conventional meteorites. This process inhibits survival of certain meteoroid types such as the low density material associated with cometary meteor streams. Meteoroids which do not survive entry in the conventional sense are, however, not totally destroyed and some of the material from these objects is converted to melted or partially melted sub-millimeter debris. This meteor debris is probably the most common form of meteoritic material on the earth.

In spite of the low influx and small size of meteor debris, this material can be collected from deep ocean sediments where low sedimentation rates (10^{-4}cm yr^{-1}) and the relative scarcity of large terrestrial particles greatly simplify the recovery problem. Most of the extraterrestrial particles can be extracted magnetically because magnetite is produced during ablation of iron-bearing silicates. Extraterrestrial particles from sediments have been studied for over a century (1) but most studies dealt only with strongly magnetic nickel iron spherules composed of metal, magnetite and wustite. A few investigators (2,3,4) reported finding silicate spherules but very little work was done on them.

To investigate the non-nickel iron fraction of meteor debris, we magnetically extracted particles from 100 kg of pacific red clay and 3 kg of globigerina ooze. Over 700 spheroidal particles (150μm-800μm) were handpicked from the magnetic separate and examined optically and in the SEM-EDX. X-ray diffraction patterns were taken of 30 spheres and 150 particles were sectioned and polished. Roughly half of the examined spheres contain quasi-chondritic elemental abundances. The interiors of some spheres contain good chondritic abundances for elements more abundant than Ti (including S). Many of the particles, however, have moderate deviations from a true chondritic pattern, often in the form of enrichments of Fe and depletions of S, Ca and Ni. The deviant particles are otherwise identical to the good chondritic particles and we feel that in most cases compositional abnormalities can be explained either by leaching in the sediment or by alteration during atmospheric entry.

In almost all cases, the spherules are composed of submicron to micron-sized magnetite crystals and 1μm to 50μm subhedral to euhedral olivine crystals. In some particles, the pore spaces between crystals are filled with glass but usually the glass has been partially to totally dissolved out. Large olivine crystals are zoned (iron-rich rims) and some contain central voids. Some of the coarse-grained spherules contain euhedral olivine crystals randomly distributed in a porphyritic texture while olivine grains in some of the fine-grained spheres are aligned over large fractions of the particles forming brickwork-type textures. Magnetite in the spheres sometimes is in the form of small octahedra forming intricate dendritic structures. In addition to magnetite and olivine, most of the particles contain occasional

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chromite grains and approximately 10% of the spheres contain Ni-rich troilite and pentlandite. Some of the spheres are vesicular. The assemblages of olivine, magnetite and glass observed in the spheres is essentially identical to chondrite fusion crusts and materials artificially ablated in laboratory meteor simulations(5,6). We feel that this similarity in elemental composition, mineralogy and texture is very strong evidence that most of the chondritic and quasi-chondritic spheres we analyzed are solidified melt generated by ablation of meteoroids with chondrite-like elemental compositions. A conflicting interpretation, indicating that similar spherules are true micrometeorites, has been given by Parkin et al. (4).

Meteor debris in sediments is valuable extraterrestrial material because it may be material from unknown meteoroid types and because it is deposited in a stratographic sequence dating back more than 10^8 years. The difficulty, of course, with sediment particles is that they have been altered both by ablation and burial in sediment. In terms characterizing the parent meteoroids, it is very significant that rare spheres contain particles which appear to be unmelted, relict grains. One such sphere was collected which consists of a 100μm forsteritic olivine grain surrounded by a 10-20μm layer of olivine-magnetite-glass fusion crust material. The central olivine grain is irregular and contains several micron-sized blebs of Fe metal with 6% Ni. Other rare deep-sea spherules were found that contain what appear to be relict grains of enstatite, olivine, troilite, pentlandite and a yet unidentified Al,Mg oxide.

A curious aspect of the deep-sea spherules is that many of them have internal textures very similar to porphyritic and barred-olivine chondrules. Small particles which melt during atmospheric entry are cooled on a time scale of seconds and possible supercooling followed by rapid crystallization can produce chondrule-like objects. The olivine-glass, deep-sea spherules differ from meteorite chondrules primarily in that the deep-sea particles contain magnetite (presumably a result of oxidation during ablation). This appears to be a unique, natural example of the terrestrial production of chondrules. It is interesting that analogous production of chondrules in the solar nebula could occur if environments existed where high velocity particles could impinge onto a gas which had a large enough density gradient to induce frictional melting. As demonstrated by the earth's atmosphere, such a process can be very efficient in converting extraterrestrial material into chondrule-like objects.

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