

PRELIMINARY INVESTIGATIONS ON COSMIC DUST COLLECTED BY 'MACDUC' EXPERIMENT FROM CENTRAL INDIAN OCEAN.

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Introduction: Cosmic spherules are micrometeorites of <1 mm size which undergo partial to complete melting during their hypervelocity entry into the earth's atmosphere and are recoverable as dark coloured, spherical, solidified droplets. These spherules have been collected from deep sea sediments, Antarctica, Greenland ice and ancient sediment deposits [1,2,3,4,5] and their extraterrestrial origin has been affirmed by chemical, mineralogical as well as isotopic studies [6,7,8,9,10]. In the present study, 1245 cosmic spherules along with unmelted micrometeorites have been collected from the deep sea floor using a magnetic rake. This effort ranks among the larger collections in the deep sea regions of world oceans.

Sample and methods: Cosmic dust for the present study have been collected from the Central Indian Ocean by an experiment which is acronymed here as MACDUC (Magnetic Cosmic Dust Collection). The equipment comprised of an assembly of aluminium panel carrying powerful (1400 gal) bar magnets and was clamped inside a dredge which was used for bulk collection of manganese nodules in the Central Indian Ocean Basin (CIOB). The panel containing the magnets in the MACDUC experiment would encounter the sediment ploughed by the dredge during its traverse on the deep sea floor and attracted the magnetic fraction. Fourteen operations were carried out in the CIOB during a 35-day cruise (AAS-22) during October-November 1999 onboard AA Sidorenko (a research vessel chartered by Govt. of India), each operation running for a duration of ~10 hours and the average distance traversed on the seafloor being ~ 4 km per operation at very slow ship speed. The collected magnetic fraction comprised of spherules and volcanic debris. Spherules have been handpicked from all the 14 tracks and observed for general external features using a binocular optical microscope and 168 spherules from five tracks were picked randomly and analyzed for detailed morphological and textural features using Scanning electron microscope (SEM). Subsequently, the spherules were mounted in epoxy, sectioned and polished to acquire major element data using INCA Energy dispersive x-ray spectrometer (EDS) at 20 keV acceleration and using Springwater olivine

standard (USNM 2566) provided by Smithsonian Institution, Washington [11].

Results and Discussion: In all, 1245 spherules were recovered from the 14 operations carried out. Spherule diameter varied from 55-650 μm at an average of 181.4 μm with ± 15 standard deviation. Most of the spherules were perfectly spherical whereas some were oval or bullet shaped. Appearance varied from very rough, earthy to smooth, shiny and spherules having metallic luster. All the three basic spherule types namely *I*, *S* and *G* type have been identified. The overall collection is dominated by *S*-type spherules (62%) however; the *I*-type spherules also contribute significantly (33%). There are three principal mineral phases in these spherules namely, olivine, magnetite and glass. *G*-type spherules are composed of dendritic magnetite in silicate glass mesostasis with or without metal core and show very high concentration of FeO with the mesostasis showing MgO, Al_2O_3 , SiO_2 , CaO and NiO in minor amounts. *S*-type spherules are mainly composed of olivine and magnetite crystals in interstitial glass. Subgroups of *S*-type spherules consist of relic grain bearing (RGB), porphyritic, barred and cryptocrystalline types. Barred olivine spherules show elongated, lath-shaped olivines which are not always fully equilibrated and show a wide range of MgO-FeO compositions. Porphyritic olivine spherules show euhedral to subhedral zoned olivine crystals (3-70 μm size range) with Mg-rich core (Fo_{62-88}) and Fe-rich rim. We found only one RGB spherule so far which contained a fairly large (43 μm) subhedral zoned chromite crystal. The general chemical composition of chromite grain $[\text{Cr}/(\text{Cr}+\text{Al}) = 0.748]$ indicates that this spherule may represent unequilibrated H or L chondrite parent body. The overall bulk compositions of the spherules are in conformity with the other large cosmic spherule collections from diverse environments [2,5,12,13,14]. These particles when plotted on Mg-Si-Fe (atom) ternary diagram display olivine normative

compositions dispersed around forsterite-fayalite line as seen in the deep sea spherules of Brownlee *et al.* [14]. The Si-normalized mean compositions for the elements Mg, Al, Ca, and Fe detected in the spherules are very close to the mean CI values but the elements like Cr, Mn and Ni though not detected in all particles show high degree of depletion relative to chondritic values.

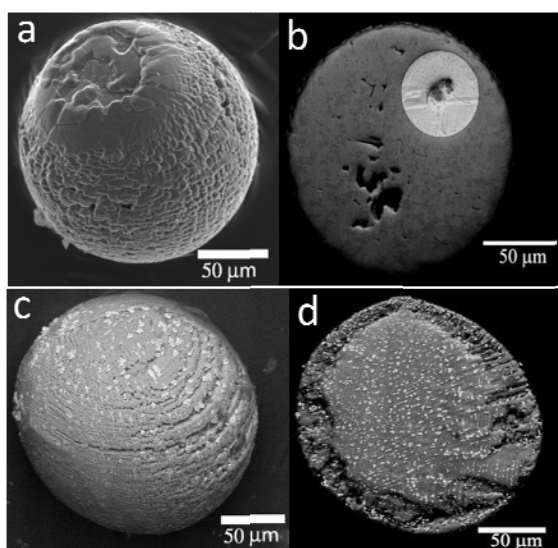


Figure 1; Scanning electron microscope images of cosmic spherules collected by MACDUC experiment. (a) *I*-type spherule showing brickwork of magnetite crystals on its outer surface. Protruding FeNi rich core can also be seen; (b) Polished section of same spherule showing intergrowths of magnetite (dark phase) and wustite (light phase), eccentric FeNi core of ~50 μm and voids caused by escaping of low temperature volatiles; (c) *S*-type spherule showing barred olivine (dark) and magnetite (bright). (d) Polished section shows peripheral etching effects where glassy matter is lost due to chemical action of sea water.

I-type spherules are composed of magnetite and wustite phases with varying amounts of Ni, Co and occasionally, some lithophiles. Majority of these spherules contain a FeNi metal bead. Some of the *I*-type spherules also show unique nuggets ranging in size from few hundred nanometers to few micrometers. They are dominantly Platinum group nuggets (PGNs) with varying compositions of Pt-group elements which are indicative of the process of heating and oxidation during atmospheric entry [15]. PGNs were first reported by Brownlee *et al.*, 1984 [15] in *I*-type spherules. Subsequently, Bonte *et al.*, 1987; Misava *et al.*, 1989 discovered them in *S*-

type spherules [16,17]. In addition, we also found Ni-rich and Ti-rich nuggets (Ti=2.0-2.5%) in some spherules which have not been observed earlier. The nuggets in our study although found only in *I*-type spherules, provide indication for chondritic and possibly, achondritic parent bodies as well. The presence of Ti nuggets can help in understanding the processes that refractory element nuggets in carbonaceous chondrites undergo.

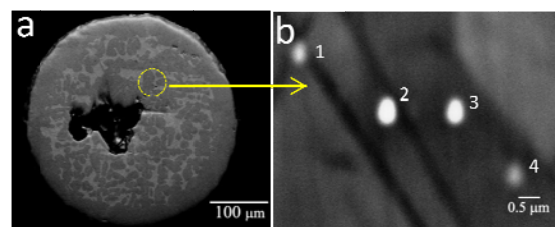


Figure 2; Backscattered electron image of *I*-type spherule containing platinum group element nuggets. (a) Spherule with intergrowth of magnetite & wustite. Shows large void space at centre and typical magnetite rim on periphery; (b) Four PGE nuggets (marked by yellow circle in fig. a) at very high magnification.

Acknowledgement: We thank the Director, NIO Goa for the encouragement and for the necessary facilities for carrying out this study. We are grateful to ISRO-PRL, Ahmedabad for financial support under the PLANEX programme.

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