COSMIC DUST IN MANGANESE NODULES
Pictures from the Report on "DEEP-SEA DEPOSITS" of the H.M.S. Challenger's Expedition

JACQUES JEDWAB

Among the most famed discoveries of geological importance made during the *H.M.S. Challenger* Expedition are the deep-sea manganese nodules and the cosmic spherules which are intimately associated in their deposits: the latter were found included in the former, as well as in the red clay surrounding the nodules. Very soon after these discoveries, it was demonstrated by J. Murray (1876), and later by J. Murray and A. Renard (DEEP-SEA DEPOSITS) that the magnetic (cosmic) spherules often contained a droplet of native iron, suggesting an extraterrestrial origin. These discoveries were from then on considered as a milestone in the study of cosmic matter on earth, on a par with analysis of the larger meteorites. The literature of the topic is immense, and several bibliographies have been published.

Two *Challenger* stations in the South Pacific (276 and 285) were outstanding for their yields of spherules. Murray and Renard observed that they were systematically associated with manganese nodules, but also with shark teeth, cetacean earbones, zeolites and altered volcanic fragments. They also observed that these stations were precisely those which were the most distant from continents and their terrigenous deposits.

After recalling that several researchers had already concluded that the metallic fragments found in atmospheric precipitations were of cosmic origin (as cited: Ehrenberg, Daubrée, Reichenbach, Nordenskiöld, Tissandier), Murray and Renard said that "...serious objections may be raised against the origin of a large number of so-called cosmic dusts" (NARRATIVE, p. 809). Indeed, the possible presence of native iron in volcanic (basaltic) rocks and metallurgical dust leaves intrinsic doubts on the extraterrestrial origin of native iron.

The association of the spherules with 5 other components, typical of stations with low terrigenous influx, and their finding as inclusions in the slow-growing manganese nodules, were considered by Murray and Renard as definitive proof of a disconnection from continental sources.

More recent studies of the spherules, including nodules from these same stations and from other places, have confirmed the past observations and extraterrestrial origin (Finkelman, 1970, 1972; Jedwab, 1970). Finkelman (1972) showed in particular that spherules are indeed highly concentrated in manganese nodules, in comparison with any other sediment (arctic ice, salt deposits, shale, clay, deep-sea sediments). The number of spherules > 100 μm per kg manganese nodule exceeds that of the other environments by factors from 5 to 5000.

The seminal discoveries by Murray and Renard gave us an access to an inexhaustible terrestrial source of cosmic dust devoid of doubt, and amply sufficient for more advanced scientific studies (Jedwab, 1975a; 1975b; Brownlee, 1984). The last plate presented here shows such a cosmic spherule, with its typical morphology, mineralogy and chemical composition.

The *Challenger's* cosmic spherules have been depicted in an exquisite chromo-lithographic Plate XXIII in the volume or the "Report" devoted to "DEEP-SEA DEPOSITS" (1891). They obviously deserve a wider access than the rare original reports. To our knowledge, this plate has not been reproduced in any modern

source: a search for the pictures, accessible on the World Wide Web with the help of the current search engines, yielded no link. Thus it occurred to me that it would be appropriate to display facsimile reproductions of the original pictures through this medium.

One will find here a copy in B/W of the whole PLATE XXIII with its complete layout, in which the figure numbering and the written indications have been re-typed for legibility. The line of text printed at the bottom of the Plate XXIII as been deciphered as follows:

A.Renard del. (*delineavit*=drawn by A. Renard)
Lith. v. Dr J. Heintzmann (lithographed by Dr. J. Heintzmann)
K. k. Hof-u.Staatsdruckerei Wien (*Kaiserliche und königliche Hof- und Staatsdruckerei Wien*= Imperial-Royal Court and State printing-house in Vienna).

The other frames display a selection of the pictures which have been re-arranged according to a layout differing from the original PLATE XXIII for the following reasons:

1°) The pictures related to silicate spherules (Figs. 2, 10, 11 and 13) have not been reproduced: Murray and Renard have themselves expressed their misgivings about the cosmic origin of the formers (PLATE XXIII caption of Fig. 2: "Although presenting some of the characters of chondres [sic] of bronzite, somewhat like that shown in fig. 11, the origin of this spherule must be regarded as doubtful"). However, it is not excluded that they could after all be related to chondrite ablation or to tektites.

2°) The phillipsite nodule depicted in Fig. 3 has not been reproduced either, since it belongs more directly to the pictures of the interiors of kindred nodules presented in Plate XXII. This rejection of the phillipsite figure to PLATE XXIII was perhaps due to a lack of space, or intended to show a regular associate of the spherules.

3°) The pictures in PLATE XXIII are obviously arranged according to a purposeful layout, serving the lithographic constraints, but which is not required for a web presentation. One has thus grouped some pictures according to a logic based on object kinship: Figs. 1-4-5-8; Figs. 6-12; Figs. 7-9.

4°) The figure captions are reproduced verbatim beneath or beside each corresponding picture, and not as a full, separate type-set page, as in the Report.

5°) The magnifications for the original pictures are given by the authors within the text of the captions as "*magnified xx diameters*". In order to account for modifications introduced by the scanning of the originals, the available space, and the final screen display, the true dimensions of the objects have been recalculated in actual micrometers (µm), and typed in *italic* between brackets [...] after the original captions.

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Captions of PLATE XXIII reproduced from the DEEP-SEA DEPOSITS Report

Fig. 1. Magnetic spherule of cosmic origin from Station 285; 2375 fathoms, South Pacific. This spherule was extracted from a manganese nodule, and has a coating of black magnetic iron, with a brilliant and shagreened surface (magnified 90 diameters). [*313 μm*]

Fig. 2. Magnetic spherule from Station 276; 2350 fathoms, South Pacific. It is regular in form, but has not a central nucleus. The figure shows a broken surface, which is blue-black, with a dull aspect. The structure presents many somewhat regular cleavages. Although presenting some of the characters of chondres of bronzite, somewhat like that shown in fig. 11, the origin of this spherule must be regarded as doubtful (magnified 90 diameters).

Fig. 3. Spherule composed of crystals of phillipsite from Station 276; 2350 fathoms, South Pacific. The crystals are terminated by the faces of domes or pyramids. This shows the external aspect of the spherules seen in section in Plate XXII. figs. 2 and 3 (magnified 90 diameters).

Fig. 4. Cosmic magnetic spherule from Station 285; 2375 fathoms, South Pacific. The external aspect of this spherule is similar to that shown in fig. 1, but the figure exhibits the caracteristic cupule present in nearly all the cosmic spherules (magnified 90 diameters) [*380 μm*]

Fig. 5. Cosmic magnetic spherule from interior of nodule from Station 276; 2350 fathoms, South Pacific. A part of the external layer has been removed to show the grey metallic nucleus of native iron (magnified 90 diameters) [*340 μm*]

Fig. 6. Cosmic magnetic spherule from Station 276; 2350 fathoms, South Pacific, embedded in a mass of little crystals of zeolites (magnified 90 diameters) [*spherule diam. =105 μm*]

Fig. 7. Metallic nucleus of a cosmic spherule from the same Station 276. This nucleus has a grey metallic lustre; it has taken a discoidal form under pressure in an agate mortar. When placed in an acid solution of sulphate of copper, no copper is precipitated, and it is probably an alloy of iron, nickel and cobalt (magnified 90 diameters) [*major axis =392 μm*]

Fig. 8. Cosmic spherule from Station 285; 2375 fathoms, South Pacific, a portion of the crust having been removed to show the metallic nucleus (magnified 90 diameters). [*366 μm*]

Fig. 9. Metallic nucleus of cosmic spherule from Station 276; 2350 fathoms, South Pacific. The black coating has been removed, and the particle has assumed a discoidal appearance under pressure in an agate mortar. When placed in an acid solution of sulphate of copper, the copper was at once precipitated over the whole surface, which indicates that the nucleus was composed of native iron (magnified 90 diameters). [*major axis=340 μm*]

Fig. 10. (See fig. 13).

Fig. 11. Chondre from Globigerina Ooze, Station 338; 1990 fathoms, South Atlantic. This chondre is about 1 mm in diameter. In reflected light under the microscope it has a bronze metalloid reflection. It is formed by the juxtaposition of a great number of lamellae, which start from an excentric point, where there is a depression in the form of a cupule. The characters are quite analogous to chondres of meteorites (magnified 37 diameters).

Figs. 13 and 10. Microstructure of one of the lamellae of the chondre represented in fig. 11. These are formed of an accumulation of little colourless prisms, about 0.05 mm. in diameter. The prisms follow two directions, cutting each other at an angle of 70°. The lamellae have many dark-coloured inclusions in the form of crystallites, which are probably magnetite, arranged regularly following the direction of the little prisms (magnified 390 diameters).

Fig. 12. Appearance of the magnetic particles extracted from Radiolarian Ooze, Station 274; 2750 fathoms, Mid Pacific, after being broken down in an agate mortar, and treated with an acid solution of sulphate of copper. The black partricles are fragments of magnetite and coatings of the cosmic spherules, while those on which copper has been deposited are malleable particles of native iron (magnified 37 diameters). [*max. length=2130 μm*]

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LIST OF FRAMES

Frame A: Copy of whole Plate XXIII
Frame B: Cosmic/magnetic spherules of Figs. 1-4-5-8
Frame C: Magnetic spherules and irregular particles of Figs. 6-12
Frame D: Metallic nuclei of cosmic spherules reacted with Cu sulfate.
Frame E: Modern view of a cosmic spherule included in a Mn-nodule

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Brownlee, D.E., Bates, B.A. and Wheelock, M.M. (1984): Extraterrestrial platinum group nuggets in deep-sea sediments. Nature, 309(5970), 693-695.

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Director of the civilian scientific staff on board, and now of John Murray, one of the naturalists of the expedition. Deep-Sea Deposits. Published by order of Her Majesty's Government. Printed for Her Majesty's Stationery Office. 1891, 1110 pp. Published by order of Her Majesty's Government. Printed for Her Majesty's Stationery Office. 1891,

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Jedwab, J. (1975b): Cosmic flakes in manganese nodules. Meteoritics, v.10, 191-207.

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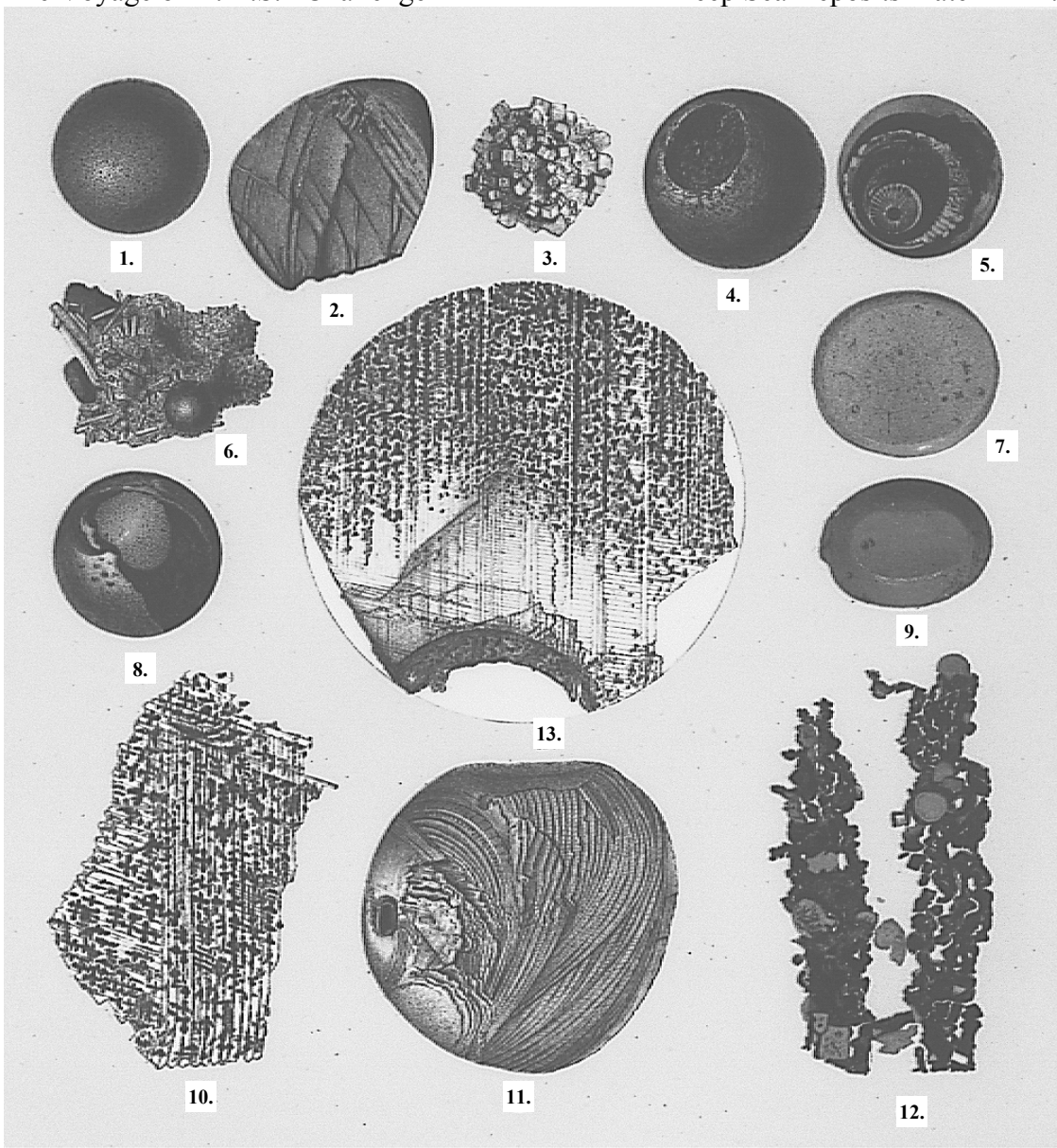
The loan of Challenger Expedition samples by The Natural History Museum-London is gratefully acknowledged. J.J.

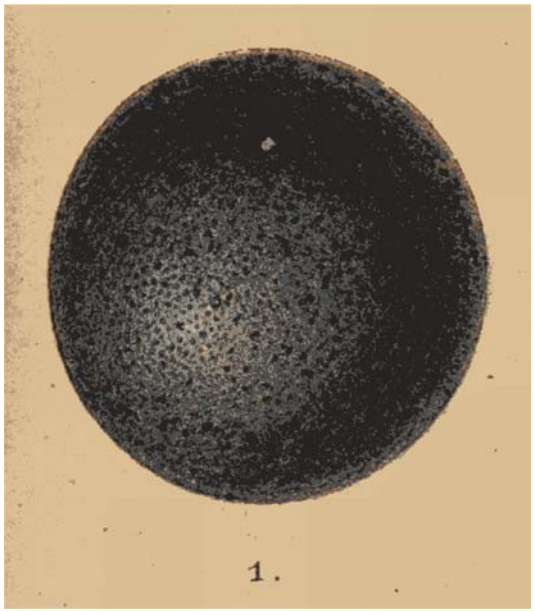
Frame A

The Voyage of H.M.S. «Challenger » Deep Sea Deposits Plate XXIII.



A. Renard del. Lith.v.Dr J. Heitzmann K.k.Hof-u.Staatsdruckerei Wien

Frame B



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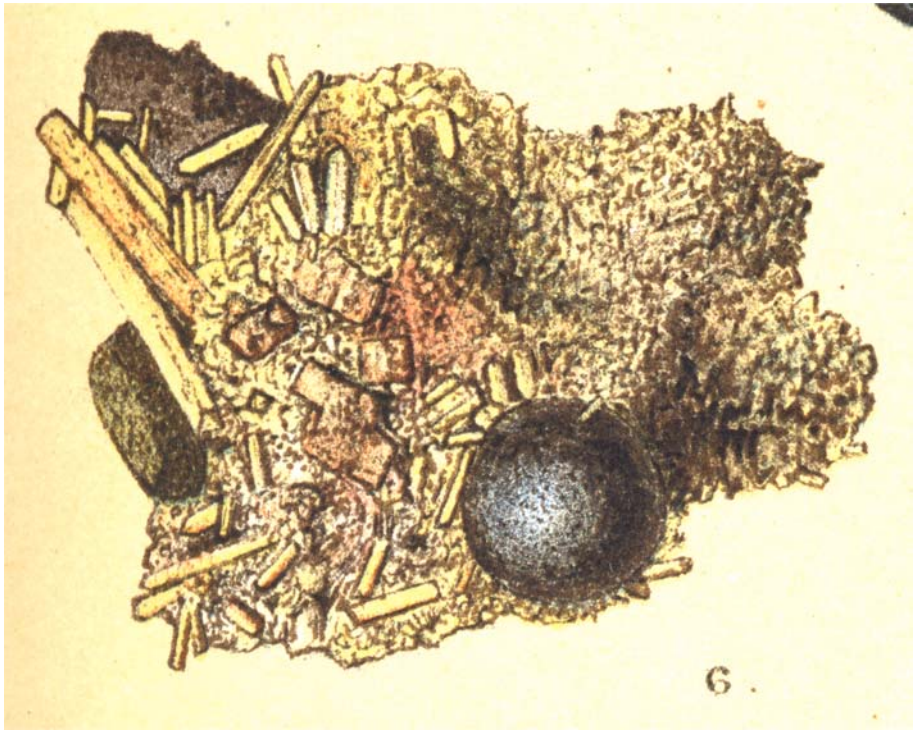
Frame C



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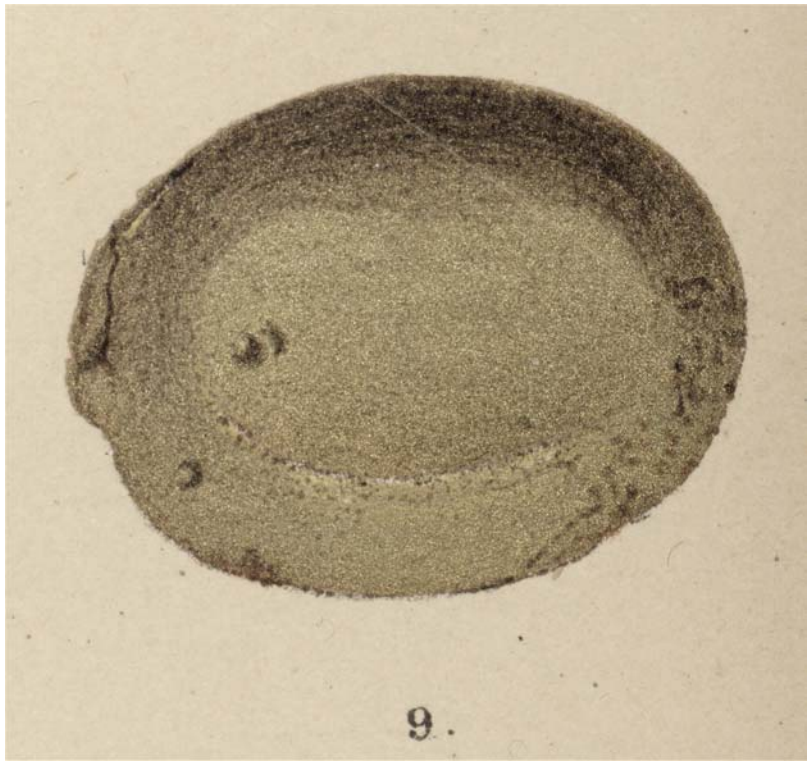
Frame D



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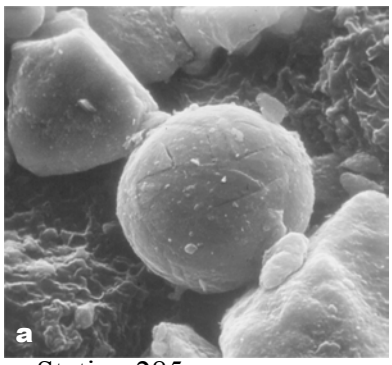
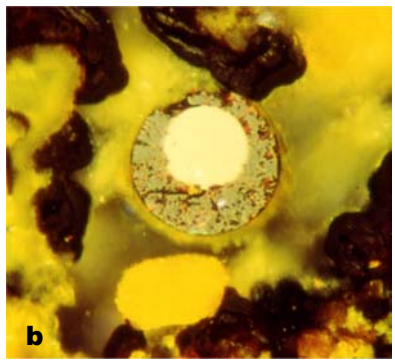
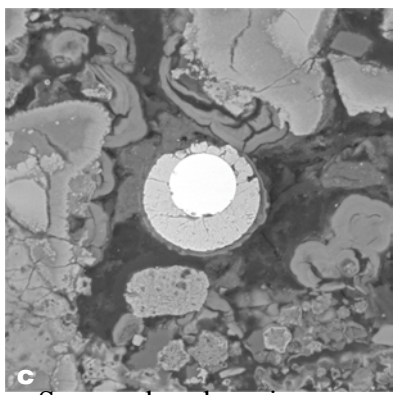
Frame E



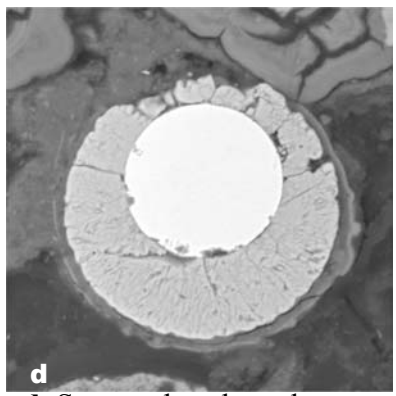
a. Station 285.
Magnetic spherule extracted from powdered Mn-nodule.
SEM-second. mode.
Diam. of spher.=22 µm.



b. Station 285.
Polished section of a Mn-nodule fragment. Diam. of spher.=90 µm
Reflected light microscope, oil immersion, polarized light.
Internal reflections in red in the crown of the spherule suggest that it is composed of hematite.



c. Same spherule as in a.
SEM-back scattered mode.
Notice difference of BS-yield between metallic nucleus and oxide crown.



d. Same spherule and same conditions. Notice late deposit of Mn-oxihydroxide on the oxide crown.

Chemical analyses (EDS-semi-quantitative)

wt %	Metallic nucleus	Oxidic crown	
Fe	89.48	Fe2O3	98.97
Co	0.50	CoO	0.00
Ni	9.97	NiO	0.21
Mn	0.00	MnO2	0.52
Cr	0.00	Cr2O3	0.32