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MICROMETEORITES IN THE « GLACIAL » PLEISTOCENE OF THE MEDITERRANEAN RIDGE (*)

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RIASSUNTO

In una carota a pistone (KS09) prelevata sulla cresta della « Dorsale Mediterranea », nel Mar Ionio, è stato rinvenuto un livello molto ricco di « Black Magnetic Spherules » che, dallo studio mineralogico, chimico, morfologico e strutturale, sono interpretabili come micrometeoriti.

Il livello che li contiene è ubicato a 1218 cm dalla sommità della carota, al disotto di 7 orizzonti sapropelitici riferibili al Pleistocene superiore (Epoca di Brunhes).

In base a correlazioni, interpolazioni ed estrapolazioni, l'età di questo livello è stimata ad oltre 500.000 anni.

Le caratteristiche delle B.M.S. fanno ritenere che la loro origine sia dovuta ad un evento eccezionale e non al normale fall-out cosmico.

ABSTRACT

A level rich in Black Magnetic Spherules has been found in piston core KS09 from the crestal area of the Mediterranean Ridge in the Ionian Basin (Lat. 35° 09′ N; Long. 20° 09′ E; water depth 2800 m).

Mineralogical, chemical, morphological and structural studies demonstrate that the BMS are micrometeorites of extraterrestrial origin.

The micrometeorites-bearing level lies approximately 1218 cm below the top of the core. It underlies 7 discrete sapropel layers of the late Pleistocene. Interpolations, extrapolations and multiple correlations allow determination of the age of this level, which is in excess of 5×10^5 y.

The above observations and the peculiarity of BMS indicate that their accumulation is not the result of the normal cosmic fall-out but of an exceptional extraterrestrial event.

INTRODUCTION

Black magnetic spherules of extraterrestrial origin are not unusual in deep-sea sediments (LAEVASTU & MELLIS, 1955); their occurrence in deep-sea sediments from some areas of the Mediterranean Sea has been pointed out quite recently (DEL MONTE, 1973).

The record of a layer very rich in BMS within a long piston core being studied paleoclimatically with different techniques (CITA & VERGNAUD-GRAZZINI *et alii,* in press) was considered interesting enough to motivate the present paper essentially for two reasons. *First* the micrometeorites-bearing level

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is considered the sedimentary expression of a definite extra-terrestrial event and not of the normal cosmic fall-out, as shown by abundance, dimension, chemistry, mineralogy and structural features of the black magnetic spherules, thus providing a possible marker horizon for (high precision) isochronous correlations over a wide area, and *second* because micrometeorites like those observed in core KS09 have not been recovered previously in Pleistocene sediments of the Eastern Mediterranean, as resulting from the pertinent literature and from personal communications to one of the present writers by KELLER & RYAN.

GEOLOGICAL SETTING AND STRATIGRAPHY OF CORE KS09

Core KS09, to which reference is made, was recovered during the interdisciplinary Cruise Polymède 2 in April, 1972, from the French Oceanographic Vessel JEAN CHARCOT. The location of this piston core is in the crestal area of the Mediterranean Ridge in the Ionian Sea, south-west of Crete. The coordinates are: Lat. 35°09′ N; Long. 20°09′ E. The water depth is 2800 m.

Core KS09 is 1628 cm long and thus one of the longest piston cores recovered in the Mediterranean and certainly the longest in pelagic sediments.

The sediments consist essentially of foraminiferal ooze of whitish to pale brown color. Seven discrete sapropelitic intercalations are recorded (fig. 1).

Sapropels are related to cyclically repeated stagnant cycles which occurred in the Eastern Mediterranean (see PARKER, 1958; OLAUSSON, 1961, 1965; RYAN, 1969, 1971; RYAN, HSÜ *et alii*, 1973).

Volcanic intercalations, essentially consisting of shards of volcanic glass, are also present in the upper part of the sedimentary column: at 41 cm a layer of volcanic ash which can be correlated with the *Ischia tephra* of KELLER & NINKOVICH (1972) (*Lower Santorini tephra* of NINKOVICH & HEEZEN, 1965) has been identified. This tephra horizon as well as the sapropelitic layers are considered basin-wide in extension and strictly isochronous, thus allowing precise correlations (RYAN, 1971; CITA *et alii*, 1972). Fig. 1 shows the correlation here proposed of core KS09 with two piston cores previously investigated by RYAN (1969; 1971) from the Mediterranean Ridge, namely core RC9-185 from the Ionian Basin and core RC9-181 from the Levantine Basin. The former is interesting because of its location very close to core KS09, the latter because it is considered by RYAN (*op. cit.*) as a standard record for the Eastern Mediterranean, due to its virtually constant sedimentation rate. The columnar logs of the three cores, drawn at exactly the same scale, have been aligned at the level of the *Ischia tephra*. This correlation shows that the stratigraphic record of core KS09 does not start from time 0 or from the sea-floor. In other words, the topmost part of the stratigraphic succession, including the Holocene and the postglacial sapropel (dated at 9000 y by OLSSON, 1959; MENZIES *et alii*, 1961) is missing, corresponding to the stratigraphic expression of some 10.000 y.

The climatic curve to the right of the columnar log of core RC9-185 is after RYAN (*op. cit.*, fig. 9). The correlation of this curve with EMILIANI's « isotopic » stages (1955, 1966) and to ERICSON *et alii* (1961) faunal stages U-Z, as defined in the Caribbean, permit a precise chronological evaluation of the

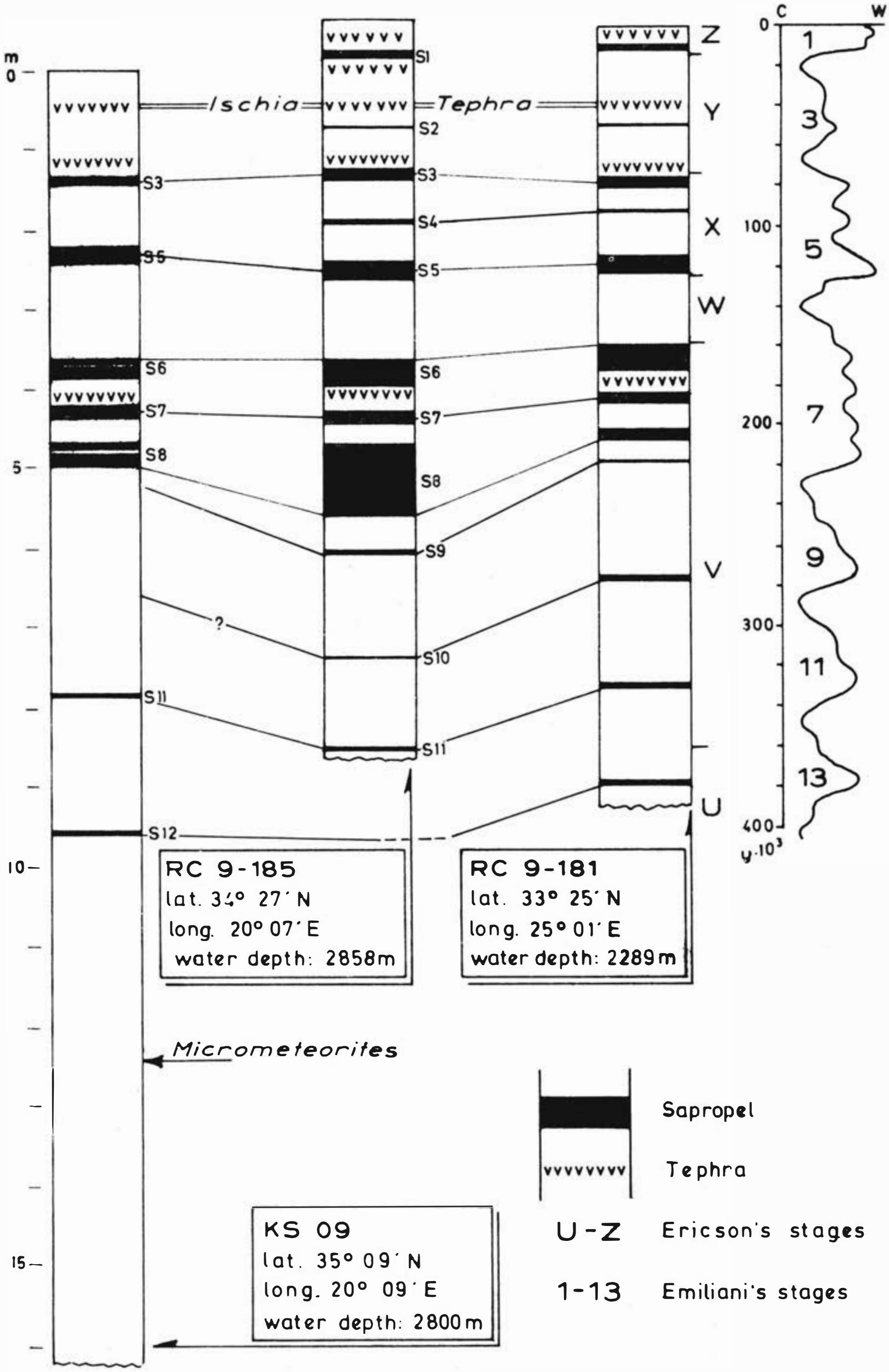

fig. 1 — Cross-correlation of three Eastern Mediterranean deep-sea cores, based on isochronous lithologies (tephra layers and sapropels).

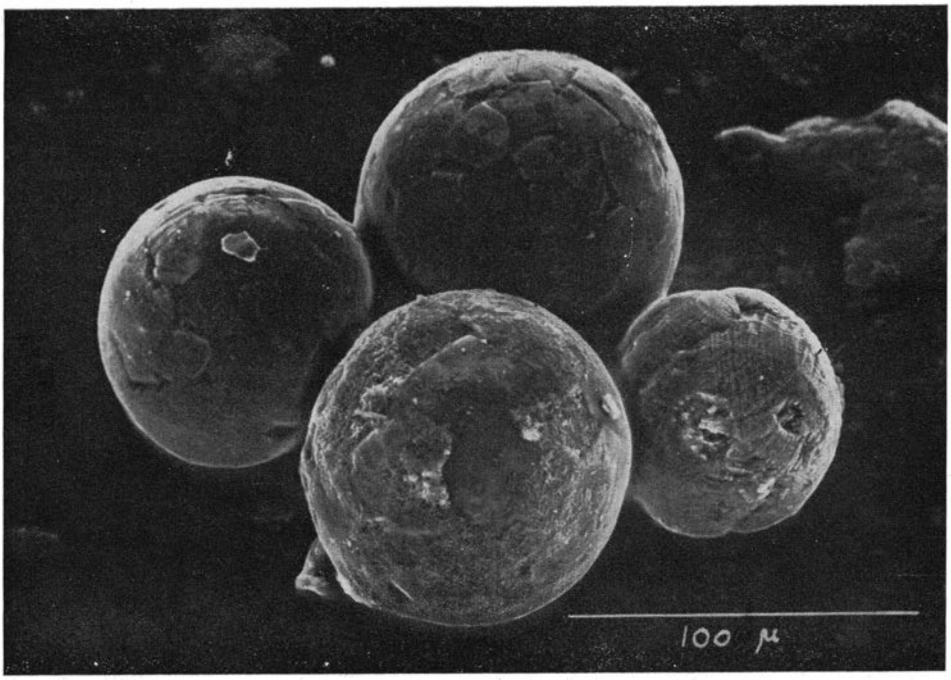

fig. 2 — Perfectly spherical spherules showing the two superficial structures described in the text: polygonal (centre; left) and skeletal (right). One spherule is encrusted by carbonates.

fig. 3 — External surface with polygonal magnetite plates.

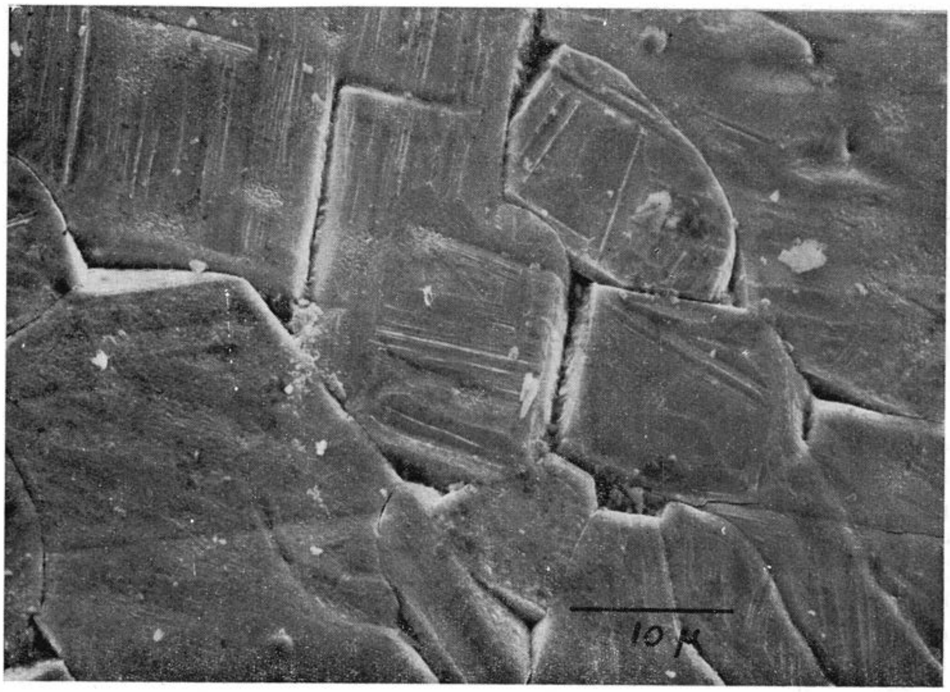

fig. 4 — Enlarged detail of fig. 2: octahedral magnetite crystals and their accretion lines.

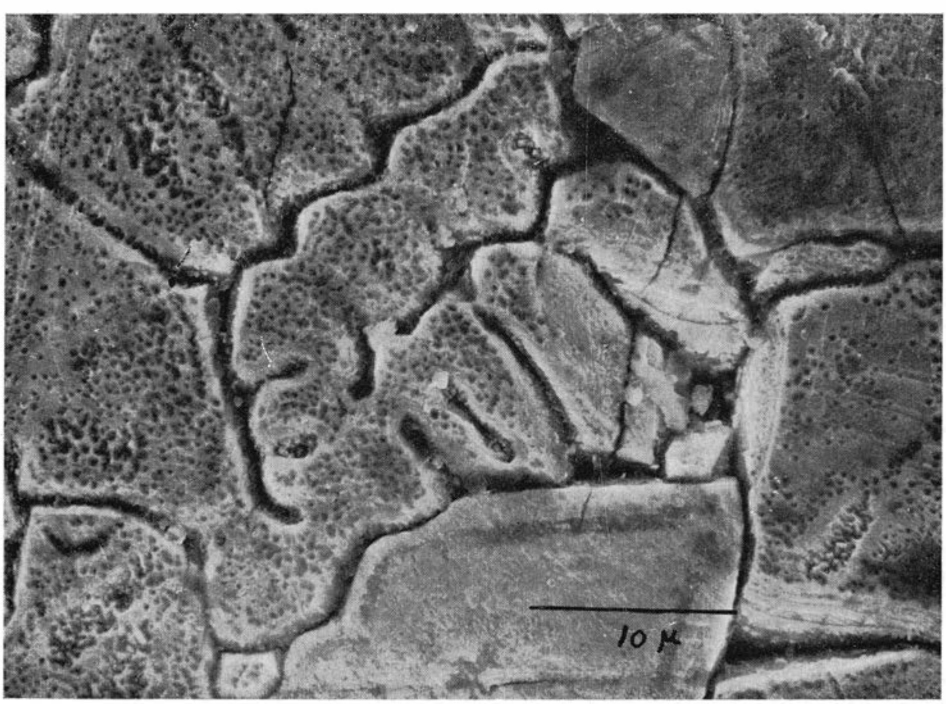

fig. 5 — Polygonal magnetite plates with unusual « spongy » aspect.

Pleistocene sections considered, since some points of the climatic curves considered have been dated radiometrically (see KU & BROECKER, 1966; BROEKER & VAN DONCK, 1969), thus permitting the construction of a realistic time-scale, as indicated at the right of fig. 1.

RYAN's chronological evaluation extends down to the U/V stage boundary, which has an interpolated age of approximately 370.000 y. The U/V stage boundary immediately overlies the lowest sapropel recovered in core RC9-185, which sapropel was recorded in core KS09 at 985 cm. As a consequence, the sedimentary succession lying beneath the sapropel at 985 cm predates the U/V boundary and has to be older than 370.000 y.

The micrometeorites-bearing level lies at 1231 cm or some 235 cm below the oldest sapropel in a succession of pale brown foraminiferal ooze, very uniform and structureless.

If we assume that the rate of sedimentation is uniform for the entire core, and extrapolate downwards the value calculated for the upper part of the core (25 m/m.y.), then we obtain for the micrometeorite-bearing level an age in excess of 5×10^5 y. The investigations or Core KS09 (see CITA *et alii*, in press) show that this level virtually coincides with the U/T boundary of ERICSON & WOLLIN (1968), based on the frequency changes in populations of the *Globorotalia menardii* group, and with the boundary between stages 16 and 17 of EMILIANI (in SHACKLETON & OPDYKE, 1973), based on isotopic changes recorded in tests of *Globigerinoides ruber*.

The sedimentation rate calculated as above is consistent with that resulting from the studies carried out on the Plio-Pleistocene succession penetrated in a nearby area on the crest of the Mediterranean Ridge at DSDP Site 125 (see RYAN, HSÜ *et alii*, 1973; CITA *et alii*, 1972; CITA, D'ONOFRIO & ZOCCHI, 1974).

TEXTURES AND MINERALOGY OF THE BLACK MAGNETIC SPHERULES

Several tens of black magnetic spherules were isolated from the sediment fractions greater than 50 microns and greater than 125 microns respectively, from the level at 1231 cm in core KS09.

They consistently have a subspherical shape. The dimension range from 80 to 500 microns.

The external surface displays either a polygonal structure or a skeletal one (fig. 2).

The former consists of polygonal plates with various shapes and dimensions (fig. 3): octahedral crystals with growth lines are clearly visible on the plates (fig. 4), (see CAVARRETTA *et alii*, 1972). Some plates, devoid of these characters, show surfaces with a « spongy » aspect (fig. 5).

The latter structure is characterized by a regular arrangement of small skeletal crystals in superimposed aggregates. When intersecting the surface of the spherule, the crystals show edges with an apparent octahedral symmetry (fig. 6).

Inside the spherules, the occurence of isolated or of coalescent cavities is consistently recorded, especially in the largest ones. The jointed cavities are recorded more commonly than the isolated ones, and are often excentric (fig. 7).

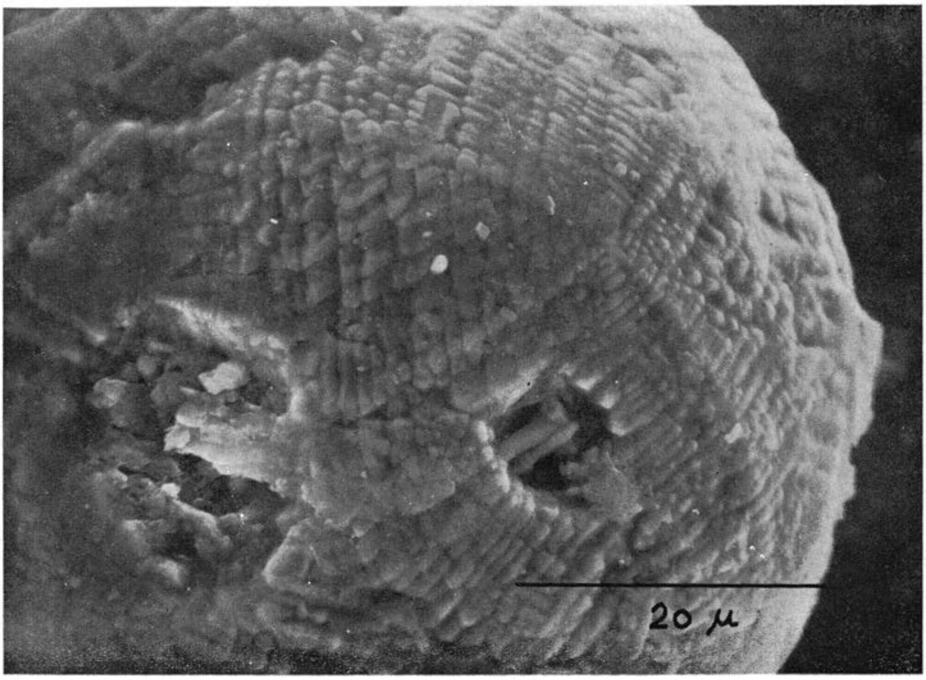

fig. 6 — Detail of fig. 1: « skeletal structure » with regular arrangement of magnetite crystals.

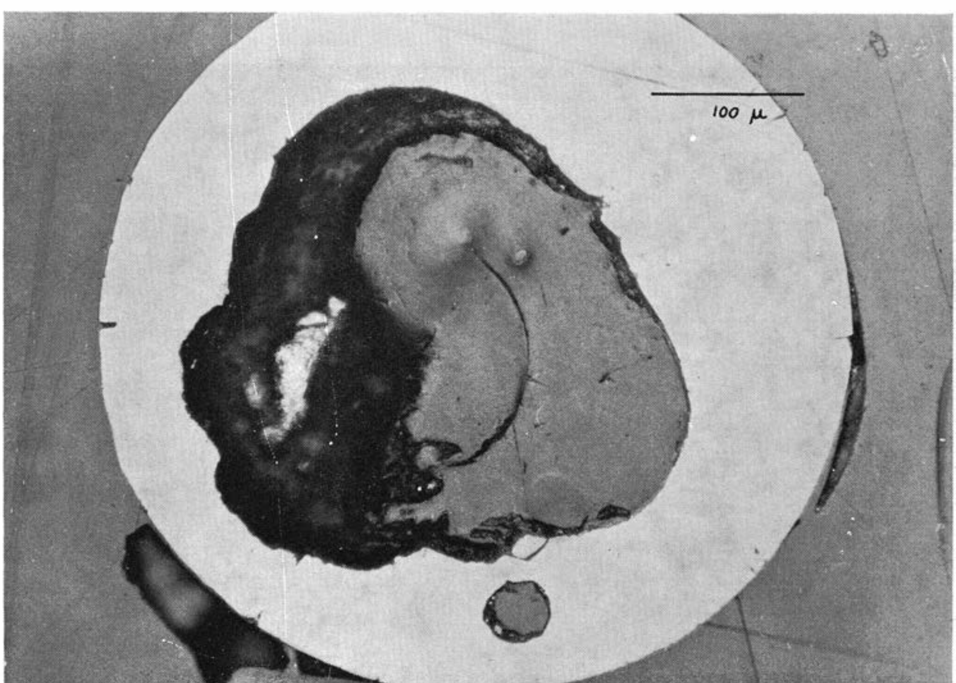

fig. 7 — Polished section; hollow magnetite spherule with excentric cavities.

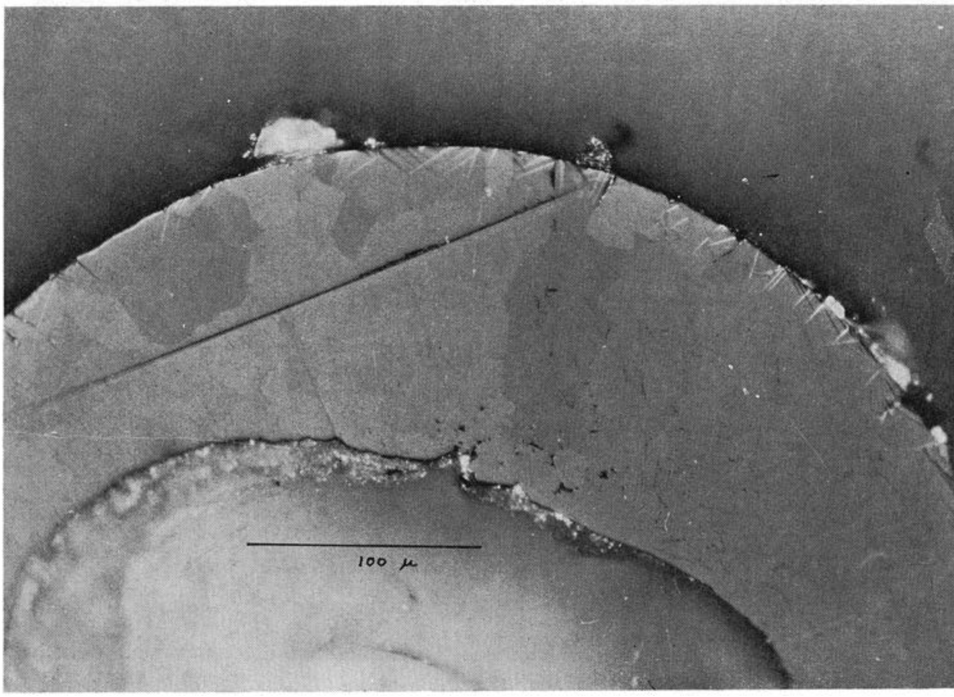

fig. 8 — Polished section, crossed nicols, oil; anisotropic magnetite with mosaic structure. On the cortical portion are clearly visibles hematite flakes.

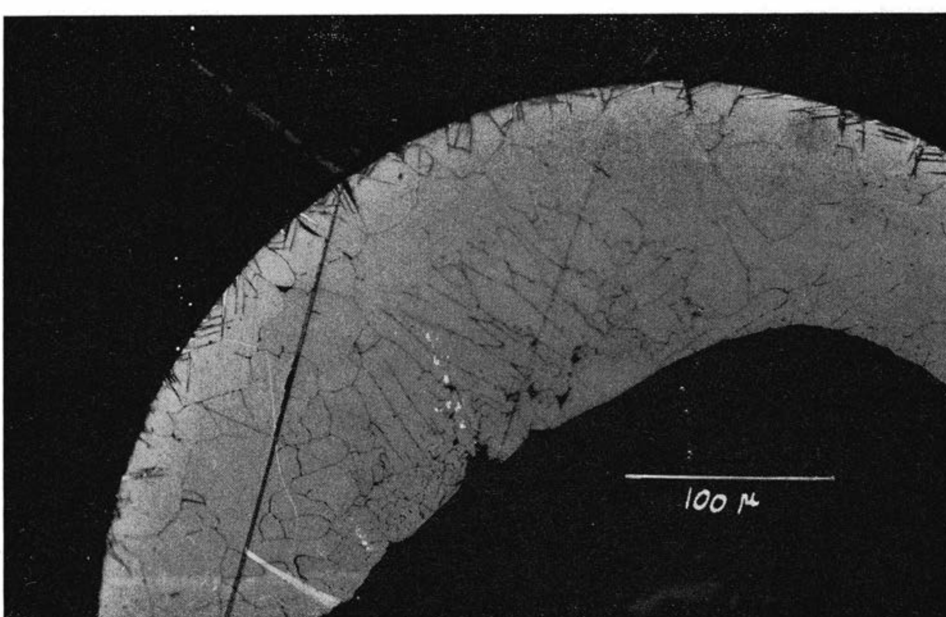

fig. 9 — Polished section, crossed nicols, oil; after etching (HCl vapours) is clearly shown the subgranular structure of magnetite grains.

Polished sections cut along the maximum diameter of the BMS allowed determination of their composition: they consist essentially of magnetite, with mosaic structure. The anisotropy of this mineral is evident in air. It is even more evident in oil, thus permitting recognition of discrete granular crystals (fig. 8).

Etching them with HCl vapour reveals complex subgranular shapes (fig. 9).

A process of martitization (see EL GORESY, 1968; SCHIDLOWSKI and RITZKOWSKI, 1972) lead to the formation of hematite in laminae disposed according to the growth planes of magnetite.

In the BMS under examination, the process involves the cortical portion alone (see fig. 8).

Microprobe analysis (1) revealed that the magnetite of the BMS is essentially pure. No significant content of elements other than iron could be noted.

Microbe analysis for such elements as Cr, Zn, Ni, Co, V and rare earths (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb) did not give any significant data.

TABLE 1

MICROPROBE ANALYSIS OF MAGNETITE OF BMS

	Fe_2O_3	Al_2O_3	CaO	MgO	MnO	TiO_2	tot. %
M 1 . . .	99.14	0.02	0.03	0.00	0.19	0.04	99.42
M 2 . . .	98.91	0.44	0.02	0.00	0.33	0.08	99.78

The results of the microanalysis led to the conclusion that the marked anisotropy of magnetite cannot be related to the presence of guest elements (*little guests*, see RAMDHOR, 1969). It is considered the result of « chilled » reticular tensions (SCHIDLOWSKI & RITZKOWKI, 1972).

CONCLUSIONS

The BMS as above described show external and internal structures very similar to those previously described by several authors (SCHMIDT & KEIL, 1966; CAVARRETTA *et alii*, 1972; *El Goresy*, 1968; CARUSI *et alii*, 1972; SCHIDLOWSKI & RITZKOWSKI, 1972). They have been interpreted essentially as product of partial or complete fusion of cosmic material, later rapidly cooled.

Contact with the atmosphere and/or the development of internal gas bubbles rich in oxygen would resul in partial or even complete transformation of the type Fe-Wustite-Magnetite-Hematite, eventually « chilled » as a consequence of a rapid cooling.

(1) Cambridge « Microscan IV » of the Department of Geology and Mineralogy, University of Aberdeen, Scotland, analyst Mr. G. D. TAYLOR.

The marked anisotropy recordered in the magnetite is interpreted as the response to the above described processes.

The recorded absence of « little guests » (Ni, Co, V), previosuly observed by several Authors in extraterrestrial spherules (FIREMAN & KISTNER, 1960, EL GORESY, 1968; SCHIDLOWSKI & RITZKOWSKI, 1972) suggests an origin by ablation from crusts of meteorites rather than a normal cosmic fall-out.

The recorded absence or the very low content of Ti in the analysed magnetites should exclude a possible volcanic origin (EL GORESY, 1968). The above observational data strongly support the assumption that the BMS under discussion do not represent the « normal » cosmic fall-out. Other data consistent with this interpretation are: (*a*) their relative abundance in the level under discussion, compared with the recorded absence in all the other levels investigated from Core KS09, and (*b*) their dimensions, well above those of BMS of cosmic fall-out.

The sediment in which the BMS were recorded is a « normal » biogenic ooze, without indications of either hard-grounds or reduced sedimentation. As a consequence, we believe that the high concentration of BMS is the result of an exceptional extraterrestrial event which, in itself, should be of more than local significance.

We look forward to finding again the sedimentary expression of this event in piston cores or drill cores from the Eastern Mediterranean. In other words, in addition to tephra layers and sapropel layers, we believe that this represents one more kind of isochronous lithology which can hopefully provide precise correlations.

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