A MICROBIOLOGICAL EXAMINATION OF SOME CARBONACEOUS CHONDRITES

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MICROSCOPIC-sized particles, resembling fossil algae, were found to be present in relatively large quantities in the Orgueil and Ivuna carbonaceous meteorites. No such particles were found in two ordinary stony meteorites, namely, in Holbrook and in Bruderheim.

There are nineteen known carbonaceous chondrites, all of which were observed to fall. Orgueil fell in southern France in 1864, Ivuna in Central Africa in 1938, Mighei in Russia in 1889, and Murray in the United States in 1950. Carbonaceous chondrites contain water and a few per cent of organic matter. Wiik[1] has shown that carbonaceous chondrites may contain as much as 20 per cent water. On the basis of his hydrogen isotope work, Boato[2] concluded that a large portion of this water in Orgueil and Ivuna is of extraterrestrial origin. Carbonaceous chondrites have thin fusion crusts. Mueller[3] and others found that after the development of the indigenous, hydrous-mineral components, the interior of these meteorites was not subjected to high temperatures. The interiors of some of the carbonaceous meteorites apparently have not been heated to temperatures higher than approximately 200° C.

Berzelius[4] and Wöhler[5] extracted organic matter from carbonaceous chondrites. Berthelot[6] obtained saturated hydrocarbons from a sample of Orgueil. In more recent years, Mueller extracted the Cold Bokkeveld meteorite and obtained organic matter which had high oxygen, nitrogen and sulphur content. Calvin[7] suggested that a compound resembling cytosine might be present in Orgueil, and Briggs[8] presented analyses which may indicate the presence of purines. Nagy, Meinschein and Hennessy[9] analysed hydrocarbons from Orgueil with a mass spectrometer and observed certain spectral features which resembled those of biogenic hydrocarbon mixtures.

Urey and Craig[10] concluded that the carbonaceous meteorites are typical members of the high iron group chondrites. These investigators reported that serpentine-type minerals and magnetite are present in carbonaceous chondrites. Kvasha[11] suggested that chlorite, a hydrous layer-lattice silicate, is a mineral component in Staroye Boriskino.

Five carbonaceous chondrite samples were examined during this work. One Orgueil sample (*A*), Ivuna and Mighei, were obtained from the American Museum of Natural History in New York, and another sample of Orgueil (*B*) was received from the U.S. National Museum in Washington, D.C. The sample of the Murray meteorite was obtained from the Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico. One of the two non-carbonaceous chondrites, Bruderheim, was received from the Department of Geology, University of Alberta, Edmonton, Alberta, and the other, Holbrook, was received from the American Museum of Natural History.

Grains of the meteorite samples were crumbled in water or in glycerol on glass slides. A microscopic examination of the two Orgueil samples and of Ivuna revealed the presence of particles which were dissimilar in morphology to any known mineral form. The 'organized elements' resembled, but were not identical to, the morphology of certain species of algae which live in water. (The aquatic algae are capable of producing hydrocarbons[12] comparable with those previously found in Orgueil[9].) One form of the organized elements was morphologically dissimilar to any known terrestrial organism. The organized elements did not show birefringence in polarized light, but they did show fluorescence (yellow) in ultraviolet light (Fig. 1). A few specimens of microbiological contaminants (common, airborne bacteria, algae, etc.) were present in the carbonaceous as well as in the non-carbonaceous meteorites. Organized elements were abundant in the Orgueil and Ivuna carbonaceous chondrites but were absent in Holbrook and in Bruderheim.

Somewhat similar but poorly defined particles were found in Murray and Mighei. Their lack of structure precluded identification with the organized elements from Orgueil and Ivuna (see Table 1).

Five types of organized elements have thus far been observed:

(1) Small, circular forms (Fig. 1), surrounded by double walls which showed thickening and occasional sculpturing with protuberances. Their diameter varied between 4 and 10μ and they appeared yellowish-green in transmitted light. The interior of the organized elements appeared to be either homogeneous or it was granulated.

(2) The second type (Figs. 2 and 3) resembled the first one; however, the surfaces of these organized elements were covered with spines, with other appendages or with a furrow. The appendages usually appeared to be tubular in shape, and occasionally they penetrated through the walls. The diameter of the appendages varied between 0·5 and 2μ, and that

Table 1. Organized Elements and Contaminations in Five Meteorites
(The numerical values represent the number of particles in 1 mgm. of sample)

Type of particles	Orgueil (*A*)	Orgueil (*B*)	Ivuna	Holbrook	Bruderheim
Organized elements	1650	1700	1680	—	—
Apparent contaminants					
(*a*) Bacteria	27	34	31	22	48
(*b*) Algae					
Achnanthes microcephala	1	—	—	—	2
Navicula sp.	—	1	—	—	—
Nitzschia palea	—	—	1	—	1
Trachelomonas volvocina	—	—	—	—	1
(*c*) Others					
Conidiospore	—	—	—	—	1
Sponge spicule	2	—	—	—	—
Starch granule	1	—	—	—	—
Cellulose fibre	4	6	6	22	50
Total contaminants	35	41	38	44	103

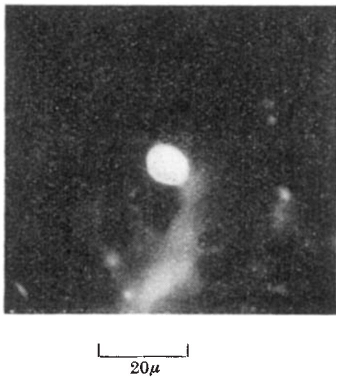

Fig. 1. Fluorescence effect in an organized element, type 1, in ultra-violet light

Fig. 2. Organized element of type 2 in the Orgueil meteorite

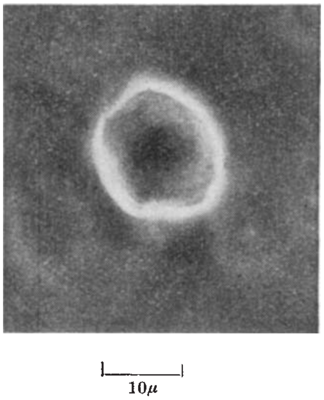

Fig. 3. Organized element of type 2 as seen under the phase-contrast microscope. Note internal structure of the organized element

of the organized elements was between 8 and 30μ. Solid appendages had club-like structures on their distal ends. Spines were arranged in pairs around the appendages. The furrow started at the single appendage on the apex of the organized elements.

(3) The third type of the organized elements had shapes like shields. They had no appendages. Their walls showed marked thickening and sculpturing; their average diameter was approximately 15μ.

(4) Cylindrical forms were seen which had thick walls and finely sculptured wall surfaces. Their length was approximately 20μ, their width was 10–12μ.

(5) An apparently hexagonal form was also observed (Fig. 4). This organized element may contain, however, 10–12 surfaces. Three of the surfaces were considerably thicker than the others and they served as the bases of the three, thick, tubular protrusions. The organized element seemed to be surrounded by a structureless halo, which was interrupted only by some matter that was protruding from two of the appendages. There were three vacuole-like and irregularly shaped bodies in the interior of the organized element.

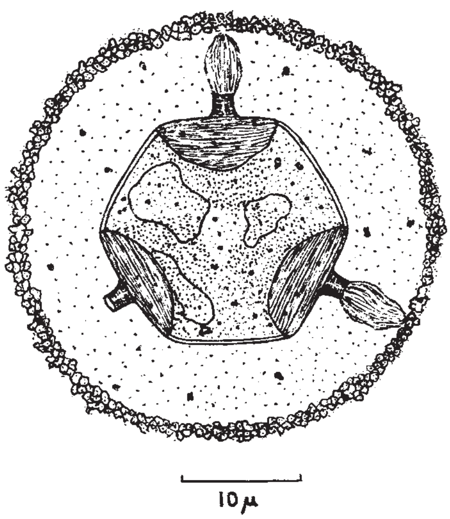

Fig. 4. Sketch of organized element of type 5. (Drawing is used because the original forms were not suitable for taking photographs)

The Orgueil meteorite samples contained each of the five organized element types. Only the first three types were present in Ivuna. Types 1 and 2 were by far the most abundant in both Orgueil and Ivuna.

There were other morphological features which should be mentioned. Several of the organized elements appeared to undergo 'cell-divisions'. Constrictions occurred in the middle portions of the elongated bodies in one form of this phenomenon, proceeding toward the interior and suggesting the formation of two 'daughter' bodies (Fig. 5). Several organized elements showed distortion and rupture of the walls. Often the interior appeared to be spilling out through the fractured walls.

Attempts were made to identify the chemical components of the organized elements with biological staining techniques; chlorzink-iodine, toluidine blue, methylene blue, Janus green *B*, Feulgen, Gridley, acid-carmine, periodic acid–Schiff, hæmatoxylin eosine and ninhydrin gave colour reactions. The reliability and the significance of the colour reactions in the organized elements are not known. It is interesting to note, however, that diffuse nuclear-staining material was found in the organized elements (Fig. 6).

From these morphological, optical and staining results we have interpreted the organized elements as possible remnants of organisms.

Although the origin of these organized elements cannot be answered at this time, indications of their

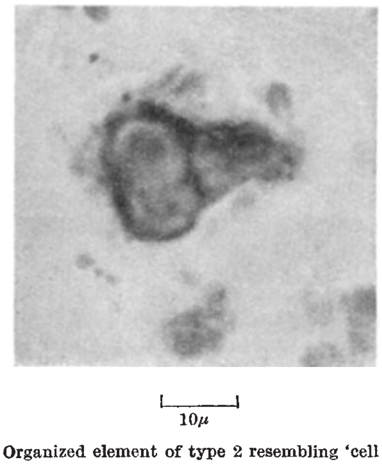

Fig. 5. Organized element of type 2 resembling 'cell division'

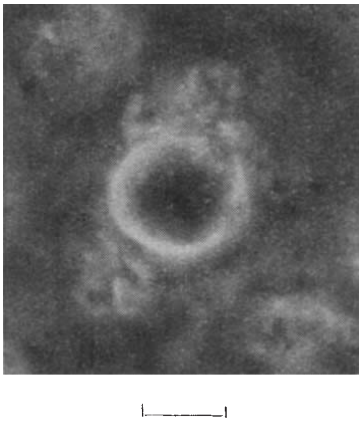

Fig. 6. Organized element of type 1 after Feulgen staining; note indications of diffuse nuclear material

origin may be summarized in the following observations:

(1) The high concentrations of the organized elements in Orgueil and in Ivuna could have developed only in an environment where moisture was continuously present for a prolonged period of time; yet the meteorite samples were kept in dry museum storage and would have disintegrated if subjected to an aqueous medium. Furthermore, they were outdoors for only a few hours after they had fallen. There are only traces, if any, of capillary water retained in the meteorites.

(2) The organized elements, types 1–4, resemble those species of Dinoflagellates or Chrysomonads which live only in water (in the sea or in lakes, and do not occur in the soils).

(3) Types 1–4 appear to be similar to but not identical with known terrestrial species. The fifth type of the organized elements is entirely dissimilar in its morphology to known terrestrial form.

(4) Terrestrial organisms resembling types 1–4 of the organized elements develop cysts under unfavourable conditions (such as a drying or dry environment). Only two or three of the organized elements in Orgueil and in Ivuna showed structures resembling cysts.

(5) The fact that the same types of organized elements were present in both Orgueil samples which fell in the temperate climate of southern France, and in Ivuna, which fell seventy-four years after Orgueil in an arid tropical region of Central Africa, renders unlikely contamination with morphologically identical, locally derived, micro-organisms.

The morphological similarities are of interest in the light of unpublished results of one of the authors[13] which indicate a chemical similarity between Orgueil and Ivuna.

We are of the opinion that these observations suggest that the organized elements may be microfossils indigenous to the meteorite.

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BRADYKININ

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BRADYKININ is a polypeptide discovered in 1949 by Rocha e Silva, Beraldo and Rosenfeld[1], who coined the name 'bradykinin' (slow-moving) because, when acting on the guinea pig intestine, it caused a delayed and slow contraction. They showed that it is formed by the action of certain enzymes, such as those in some snake venoms and trypsin, on plasma globulins. 'Kallikrein' is the name given to another group of enzymes which occur in the body and which act on the plasma globulins to form bradykinin-like activity. Much of the earlier work on these enzymes was that of Frey, Kraut and Werle, and was reviewed by them in 1950 [2]. A vasodepressor substance was shown to be present in urine[3], in pancreas[4], in blood[5] and in saliva[6], although it was not realized at that time that this vasodepressor substance was an enzyme, acting by the formation of a vasodilator polypeptide. The active principle in all these fluids was called 'kallikrein'. However, the kallikrein obtained from these various sources is not the same enzyme. Blood kallikrein, which is different from that in glands, behaves like the proteolytic enzyme plasmin[7] and is inhibited by proteolytic inhibitors[8]. The glandular kallikrein does not behave like a proteolytic