DIATOMS IN COMETS

Hoover, R[1], F.Hoyle[2], M.K.Wallis[2] and N.C. Wickramasinghe[2]

[1]Marshall Space Flight Center, Huntsville, Al 35812, U.S.A.
[2]Department of Applied Mathematics and Astronomy
University College, Cardiff CF1 1XL, Wales, U.K.

ABSTRACT

The fossil record of the microscopic algae classified as diatoms suggests they were injected to Earth at the Cretaceous boundary. Not only could diatoms remain viable in the cometary environment, but also many species might replicate in illuminated surface layers or early interior layers of cometary ice. Presumably they reached the solar system on an interstellar comet as an already-evolved assemblage of organisms. Diatoms might cause colour changes to comet nuclei while their outgassing decays and revives around highly elliptical orbits. Just as for interstellar absorption, high resolution IR observations are capable of distinguishing whether the 10μm feature arises from siliceous diatom material or mineral silicates. The 10-30μm band and the UV 2200Å region can also provide evidence of biological material.

1. THE UBIQUITOUS DIATOMS

If microbial life exists and replicates on comets, (Hoyle 1984; also in Hoyle & Wickramasinghe, 1984 [p.189]), it is very likely that viable spores or hibernating forms could reach the Earth's surface encased in meteoroid fragments or Brownlee particles. So one could expect certain terrestrial life forms adapted to cometary environments - species that survive and grow in frozen water, able to carry out photosynthesis intermittantly at a low light level. Such facilities characterise many species of diatoms, the most abundant siliceous organisms on Earth and by far the major life form able to replicate in polar ice at sub-zero temperatures. Diatoms comprise a class of microscopic, unicellular, golden-brown algae. As reviewed by Hoover et al. (1985), certain diatoms live heterotropically on organic sediments in total darkness. Some can switch to a heterotropic mode and consume a wide variety of foods, including amino acids as are found in carbonaceous chondrites (Cronin & Moore, 1971). Others rest or hibernate in darkness but recommence photo-synthesis when light reappears. Many form resting spores and cysts, resistant to dessication and space radiation.

There are two distinct communities of diatoms living in polar ice (Hoover et al. 1985). One inhabits the bottom of many metre-thick ice layers, the second community lives between newly-fallen snow and old pack-ice. The former depends on available nutrients and possibly on interstitial water. It would be adapted to comets accreted early from supernova remnants with sufficient radiogenic heat source (^{26}Al) to create liquid/vapour interiors (Wallis 1980). The second community may grow in complete absence of liquid water, being adapted to the 200 K snowy surface layers of comets.

2. PUZZLE OF THE FOSSIL RECORD

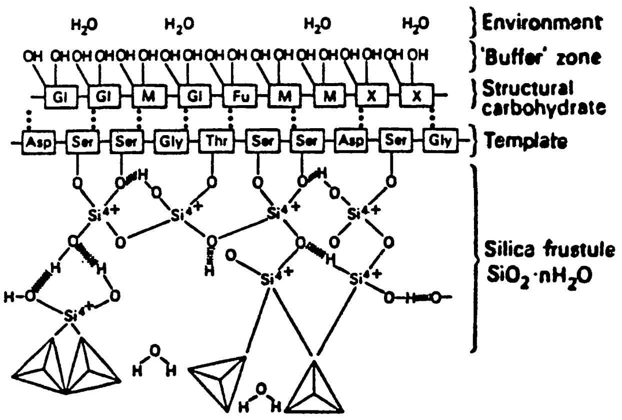


Figure 1.

Model of the layers in the cell wall of a diatom. Complex siliceous biopolymer in the silica frustule of a diatom is overlain with a layer of protein template for polycondensations of $Si(OH)_4$. The template contains amino acids and an upper layer of polysaccharides (redrawn from Hecky et al. 1973).

In the fossil record, the silicified shells of diatoms first appear abruptly at the Cretaceous boundary 112 million years ago. On the other hand, structured organic material occurs in the earliest sedimentary rocks, at least 3800 million years old (Pflug 1981). Some 70 genera and 300 species of Cretaceous diatoms have been identified, having intricate and varied cell organisation. How can such diversity evolve without leaving traces of a long line of fossil precursors? If, as argued, their siliceous shells had dissolved, why did the similar shells of radiolarians remain intact (Hoover et al. 1985)? An evolutionary jump whereby pre-diatoms gained their siliceous wall has been proposed (Round & Crawford 1981), not very plausibly as the wall structure is specific and complex (Fig.1) and many species have shown little or no evolution subsequently. The fossil record is far more suggestive of an abrupt injection to Earth of a highly-evolved assemblage of diatoms. The occurance of several species at both poles yet not within ±58° latitude is also understandable on the injection hypothesis.

This sudden appearance could correspond to the Earth's chance collision with a comet, as hypothesised to be the cause of various geological boundaries. However, cometary collisions doubtless occurred earlier, so that epoch would presumably mark the arrival of diatoms in the solar system, on this particular interstellar comet or via 'infected' solar system comets. Maybe, it corresponds to the solar system's encounter with a particular giant molecular cloud containing comets and protoplanets (Clube & Napier 1982) where diatoms had first evolved. Comets captured from that could provide the most probable transfer mechanism.

3. PHOTOMETRIC AND SPECTROSCOPIC EVIDENCE

Cometary grains may be studied spectroscopically analogously to interstellar grains. Such studies over the 3-4μm, 8-12μm, and 15-30μm regions in the infrared and over the 1800-2400Å region in ultraviolet have been used to suggest that interstellar grains have a biological-type composition (reviewed by Hoyle & Wickramasinghe 1984). Laboratory data for a mixture of diatoms and bacteria in the mass ratio ~2:1 shows absorption features at 8-20μm (Fig.2), that accord well with interstellar data for the Trapezium nebula. Biological material had earlier been shown to fit the 3-4μm feature (C-H stretch mode) when observed at the highest resolution in the galactic centre source IRS-7 (Fig.3). Biological material is preferred too for fitting the 2200Å interstellar absorption feature, on grounds that the peak position is very sensitive to size of the canonical graphite particles (Hoyle et al. 1985), yet the widely-observed and reproducible feature does not show such sensitivity.

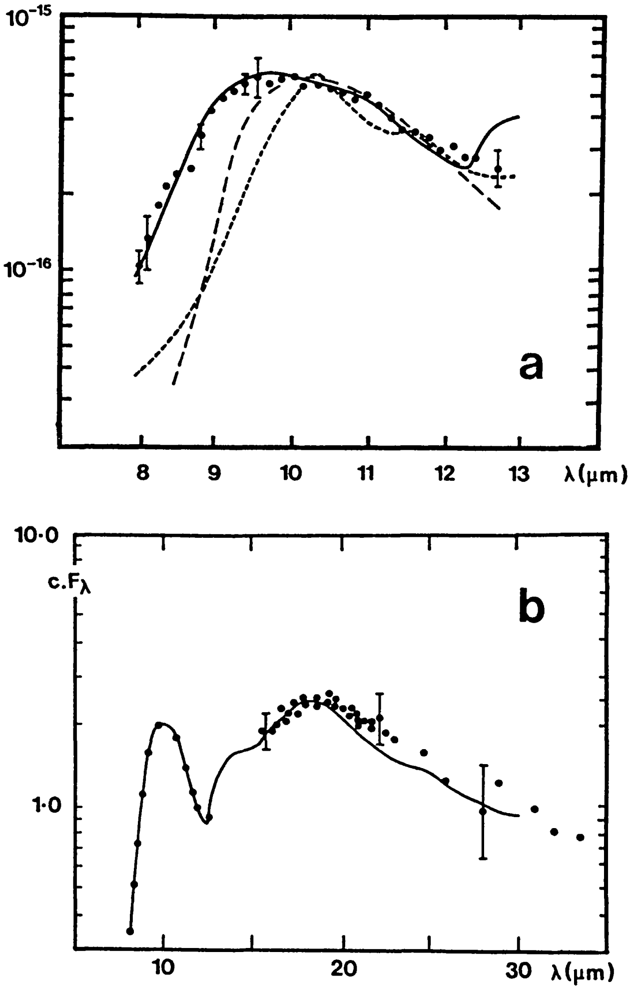
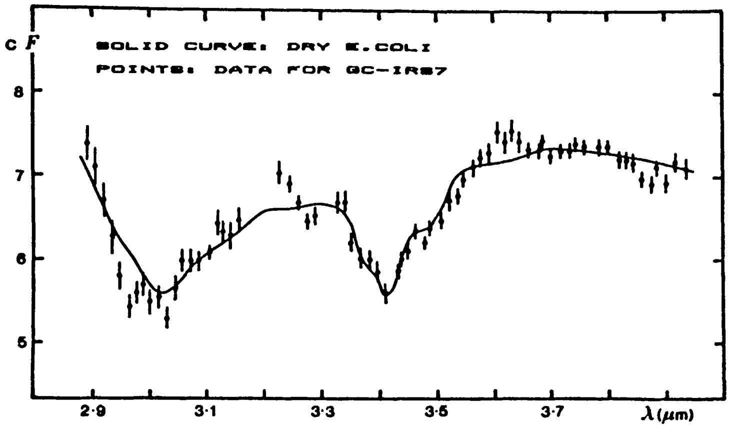


Fig.2

Observed flux from the Trapezium nebula compared with theoretical flux calculated from models of a mixture of diatoms (solid curve) at a temperature of 175 K. In Fig. 2a, normalization is to 6×10^{-16} W/cm^2. μm at λ=9.5μm. The other curves are for 175 K silicate grain models, composed of amorphous Mg_2SiO_4 [long dashes] or $(Mg,Fe)_6Si_4O_{10}(OH)_8$ [short dashes]. illustrating how mineral silicate models do not reproduce the broad peak with 8-9μm "shoulder". In Fig. 2b, the further parameter of optical depth of diatom material is chosen to give a best fit over the wider 8-30μm range.

The "silicate" feature observed in comet Kohoutek (Ney 1974), but few other comets, can correspond to siliceous diatoms just as to mineral material, for the photometry cannot distinguish. Comet emission features would differ in detail from Fig.2a because of variation with scattering angle. The available higher resolution data from comet IRAS-Araki-Alcock 1983d (Hanner et al. 1985) did not show a significant 10μm feature, so cannot be used to distinguish between the diatom and inorganic silicate hypotheses. Evidently, further high resolution IR observations are potentially capable of testing the biological possibility.

Fig.3



A composite of the observed infrared flux from the galactic centre source IRS-7 represented by the dots (data from Willner et al. 1979; Allen & Wickramasinghe 1981) and the dashed curve (data from Woolf 1973). The solid curve is the model flux from the diatom mixture.

How might diatoms relate to gross changes in the comet nucleus as it orbits the Sun? During the visit of an intermediate-period comet (e.g. Halley's) to the inner solar system, it loses several metres of surface material, so exposing fresh deep layers to solar radiation. If the diatom colonizing time-scale is a year or more, then cometary particulate emission would contain more diatom material preperihelion than postperihelion. If the time-scale is under a century, diatoms would have significant effect on the colour of the nucleus (certainly more effective than photo-processing or interplanetary dust impacts - Wallis & Wickramasinghe 1985), so causing the albedo to be lower on the preperihelion than on the postperihelion leg of the orbit.

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