AMPPIPHILIC COMPONENTS OF THE MURCHISON CARBONACEOUS CHONDRITE: SURFACE PROPERTIES AND MEMBRANE FORMATION

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(Received 10 May, 1988)

Abstract. We have investigated physicochemical properties of amphiphilic compounds in carbonaceous meteorites. The primary aim was to determine whether such materials represent plausible sources of lipid-like compounds that could have been involved as membrane components in primitive cells. Samples of the Murchison CM2 chondrite were extracted with chloroform-methanol, and the chloroform-soluble material was separated by two-dimensional thin layer chromatography. Fluorescence, iodine stains and charring were used to identify major components on the plates. These were then scraped and eluted as specific fractions which were investigated by fluorescence and absorption spectra, surface chemical methods, gas chromatography-mass spectrometry, and electron microscopy. Fraction 5 was strongly fluorescent, and contained pyrene and fluoranthene, the major polycyclic aromatic hydrocarbons of the Murchison chondrite. This fraction was also present in extracts from the Murray and Mighei CM2 chondrites. Fraction 3 was surface active, forming apparent monomolecular films at air-water interfaces. Surface force measurements suggested that fraction 3 contained acidic groups. Fraction 1 was also surface active, and certain components could self-assemble into membranous vesicles which encapsulated polar solutes. The observations reported here demonstrate that organic compounds plausibly available on the primitive Earth through meteoritic infall are surface active, and have the ability to self-assemble into membranes.

1. Introduction

Investigations of chemical reactions occurring in conditions simulating those of interstellar molecular clouds suggest that organic molecules would have been ubiquitous products (Hagen et al., 1979; d'Hendecourt et al., 1986). It is likely that at least some of these formed grain mantles on interstellar dust particles which in turn became incorporated into comets and planetesimals in solar accretion disks (Kerridge, 1983; Delsemme, 1984; Kerridge and Chang, 1985; Kerridge, 1986). Carbonaceous meteorites, which represent samples of the chemical components of the early solar system, contain amino acids and various hydrocarbon derivatives (Mueller, 1953; Anders et al., 1973; Allamandola et al., 1987) whose isotope composition strongly supports this contention (Kerridge, 1983; Yang and Epstein, 1984). It follows that meteoritic organics are likely to have contributed.

to the carbonaceous material available on the prebiotic earth, particularly in the late accretion phases following crust formation and the condensation of oceans (Delsemme, 1984; Anders, 1973). Because of the possible role of meteoritic organics in prebiotic chemical evolution, their chemical and physical characteristics are of considerable interest.

The content of amino acids, monocarboxylic acids and hydrocarbon derivatives in carbonaceous meteorites has been the subject of several prior investigations (Kvenholden et al., 1970; Cronin and Moore, 1971; Oró et al., 1971; Studier et al., 1972; Lawless and Yuen, 1979; Anders and Hayatsu, 1980; Deamer, 1985; Basile et al., 1984). However, the question of possible amphiphilic molecules and pigments has not been thoroughly addressed. In earlier work (Deamer, 1985) samples of the Murchison carbonaceous chondrite were extracted under conditions expected to solubilize lipid-like compounds, and amphiphilic substances were found. In the present study we observed that the chloroform-soluble components are readily separated by two-dimensional thin layer chromatography. Investigations of the separated fractions with surface chemical techniques, GC-MS and electron microscopy enabled us to address the following questions: (1) What is the chemical composition of the material soluble in chloroform, and which components are surface active? (2) What are the physical properties of the surface active material? (3) Do any of the components form true membranes with the ability to encapsulate solutes?

2. Methods

2.1. METEORITE SAMPLES

Samples of the Murchison CM2 meteorite were obtained from two sources. The first was a gift of Dr. W. Compston of the Department of Earth Sciences, the Australian National University. This represented partially crushed material that had been separated by a density gradient on ethylene tetrabromide. The heavier fraction was taken for mineralogical studies, and the lighter fraction was used for some of the experiments reported here. The second sample was a pristine 90 g stone obtained from Dr. Edward Olsen, curator of the Field Museum Mineralogical Collection, Chicago IL. The stone had its fusion crust intact, except for one chip about two cm across. After reaching our laboratory at UC Davis, it was handled only with cleaned metal forceps and stored under argon. Samples were taken from interior regions after fracturing the stone, so that the content of fusion crust in the material to be extracted was minimized.

Three controls ruled out major contamination introduced by preparation and extraction procedures. The first control procedure involved parallel extractions of the Allende C3 chondrite, and the Murray and Mighei CM2 chondrites. The Allende meteorite is relatively low in organic content, while the Murray and Mighei extracts should resemble the Murchison in organic content. Any components appearing in all four sources in similar amounts would be suspect. Gas chromatography/mass spectrometry (GC-MS) was carried out on several of the fractions, and the procedural blanks, which included the