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Letter to Editor

Cosmochemical/Space Petroleomics and Meteoritic Metallopetroleomics as Novel Approaches for Meteorite Genesis Studies, Evolutionary Organic Astrochemistry and Prebiological Chemical Evolution Reconstruction

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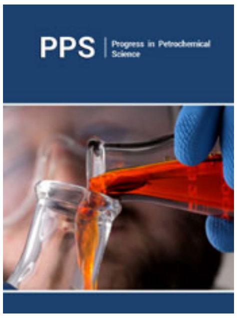

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Abstract

This Letter emphasizes the interconnection between terrestrial and extraterrestrial petroleomics and highlights the potential for using advanced analytical techniques to explore fundamental questions about the origins of life and composition of cosmic materials. The terms “cosmochemical petroleomics”, “cosmochemical metallopetroleomics” (or, equivalently, “astrochemical petroleomics”, “astrochemical metallopetroleomics”), “meteoritic petroleomics”, “meteoritic metallopetroleomics”, “space petroleomics” and “space metalloproteomics” have been introduced. The tools and methods used in terrestrial petroleomics, such as ultrahigh-resolution mass spectrometry (including FT-ICR MS and Orbitrap), are equally applicable to astrochemical and cosmochemical studies. The aggregation of PAHs into larger structures (referred to as “islands” or “archipelagos”) may have played a vital role in the “PAH world” or “aromatic world” scenario at different stages of chemical evolution and can be compared to biomolecular/prebiological self-assembly processes. Asphaltenes are known to be frequently produced during various abiotic syntheses, including early versions of the Miller-Urey experiment and Fischer-Tropsch synthesis and might have participate in the “messy chemistry” processes at the earliest stages of prebiological chemical evolution of organic matter.

Keywords: Asphaltenes; PAHs; FT-ICR MS; Orbitrap; Petroleomics; Cosmochemical petroleomics; Cosmochemical metallopetroleomics; Astrochemical petroleomics; Astrochemical metallopetroleomics; Meteoritic petroleomics; Meteoritic metallopetroleomics; Space petroleomics; Space metalloproteomics; Redox-petroleomics; Aromatic world; PAH world

Letter to Editor

It is well known that hydrocarbons (both aliphatic [1-3] and aromatic [4,5] ones) are frequently found in meteoritic samples. The most known examples are: hydrocarbons (predominantly aromatic ones) in the Murchison meteorite [4-7] (usually together with abiogenic amines and amino-acids [5-7], monocarboxylic acids [8-10]), hydrocarbons in Orgueil meteorite (comparable with the terrestrial hydrocarbon samples [11]). In many meteorites (such as Pavel and Goumoshnik) not only normal but also isoprenoid hydrocarbons can be found [12,13]. Polycyclic Aromatic Hydrocarbons (PAHs) were also detected in Murchison [14-18] and Allende [19] meteorites, Antarctic carbonaceous chondrites [16,20], Martian meteorites [21-24] and asteroids (such as Ryugu [25]). Amino acids and hydrocarbons were found in the Paris meteorite, the most primitive CM chondrite [26-28]. It is of great interest for the origin of life studies (and panspermia hypothesis refutation) that all the above hydrocarbons and their derivatives are of almost abiogenic origin [29,30]. It is noteworthy that to date many different schemes have been proposed to explain the hydrocarbon genesis in meteoritic samples, including those with the meteorite hydrocarbon formation upon thermal decomposition of siderite (FeCO3) [31] which has also been proposed as a possible way of abiogenic formation of hydrocarbons and oxygenated compounds in prebiotic conditions of the early Earth [32].The presence of PAHs in meteorites is consistent with the "PAH world" hypothesis in the origin of life studies [33-35] and with the photobiochemically relevant hypothesis on the role of archetypal melanin-like PAHs from the insoluble organic matter in chondrites in the origin of life [36-41] (which in turn correlates well with the "messy chemistry" concept [42-46]). In the meteoritic hydrocarbon matter not only "abiogenic episemantides" (the term of Pauling L et al. [47]) can be found, but also "abiogenic semantide" precursors and components, such as purines and pyrimidines-the most important building blocks for genetic code carriers and bioenergetics [48]).

PAHs themselves (and other hydrocarbon molecules in meteorites similar to those found in bituminous coals and oil shale [18]) are classical objects of petroleomics studies [49-53]. Asphaltenes (as a general object of petroleomics [54-58]) are frequently detectable products in different abiotic syntheses (from the unseparable products of the early Miller-Urey experiments to the Fisher-Tropsch wax [59-63]). Their aggregates (also the well-known key objects of petroleomics studies [64]) might have been the fundamental actors in the "PAH world" / "aromatic world" chemical evolution processes at different stages and spatial localizations [65-79]. Molecular orbital calculations and optical transitions in PAHs and asphaltenes are well studied and can be added to the petroleomics data as complementary descriptors [80-83]. Several prerequisites for "NMR petroleomics" of PAHs in asphaltenes are also developed [84,85]. The influence of the asphaltene matrix on the thermal evolution of PAHs is experimentally proved and well correlates with the geochemical conditions of the asphaltene genesis [86]. It is well known that "islands" or "archipelagos" in asphaltenes can be formed through the PAH dimer formation and high-level aggregation (in fused polycyclic aromatic hydrocarbons as model asphaltene compounds aggregation is usually simulated with dispersion interactions) [87,88]. Similar aggregation effects can be detected in biomolecular and protobiological systems and their models, so it is possible to draw the line between prebiological aggregation during chemical evolution within the "PAH world" or "aromatic world" and biomolecular self-assembly of amphiphilic molecules at early protobiological evolution stages. The role of metals in prebiological system formation in the "PAH world" (including photosensitive and catalytically active metal complex formation) can also be described within the framework of cosmochemical petroleomics and petroleomics of Fe-enriched meteorites or carbonaceous chondrites. This research trend is known as "metallopetroleomics" [89,90] (and for the possible redox-metabolism model studies-"redox-petroleomics" [91]).

Due to the similarity between the objects studied, the main instrumental tools and methods applied for terrestrial petroleomics [92-94] and its astrochemical/cosmochemical/meteoritic analog must be equal. It is well known that the most suitable instrumental tool for on-Earth petroleomics is ultrahigh-resolution mass spectrometry [95-97], such as FT-ICR MS [98-107] (invented by Melvin B. Comisarow and Alan G. Marshall at the University of British Columbia; Alan G. Marshall is also a founder of petroleomics and the term "petroleomics" itself) and Orbitrap [108-110]. Real time-mass spectrometry technique can also be used for these purposes [111]. Data processing pipelines and data interpretation methods for conventional petroleomics are well developed and customized for Web applications, laboratory information systems and database-assisted computational search resources [112-114], so cosmochemical/astrochemical petroleomics and metallopetroleomics research can be easily implemented by many scientists and amateurs interested in the origin of life, chemical evolution and composition of the cosmic matter.

Disclaimer

The author of this article has no relation to the Russian oil and gas industry and has never been working in this sanctioned area. The experience of working with petrochemicals and the pool of ideas expressed in this article were developed by him during his affiliation at the mass spectrometric center of the Russian Academy of Sciences and earlier (2010) in the Laboratory of Carbon Geochemistry of Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences.

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