Search for ancient and extraterrestial life forms

The Saga Begins

Kaźmierczak and Kremer use their biogeological background in astrobiological research

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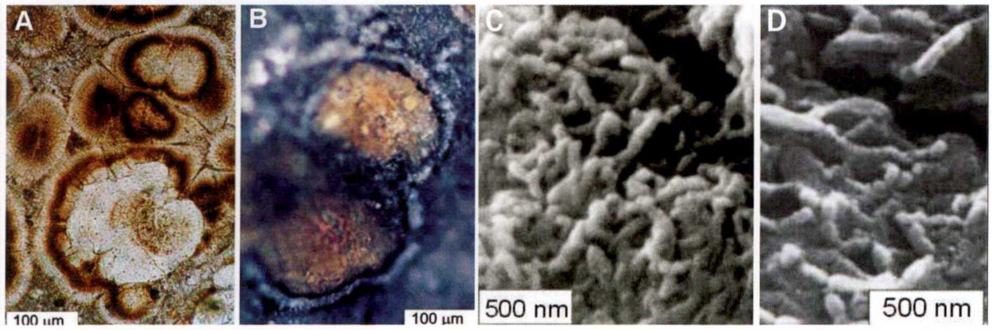
For decades, the search for alien life forms only used to excite science-fiction lovers. But now serious researchers - including Polish ones - are following in their footsteps

"A long time ago, in a galaxy far, far away..." Well, scientific papers on astrobiology don't usually start this way. Nevertheless, the subject is quite similar to the famous "Star Wars" saga. According to the definition given by NASA: "Astrobiology is the study of the origins, evolution, distribution, and future of life in the universe. It embraces the search for potentially inhabited planets beyond our Solar System, the exploration of Mars and the outer planets, laboratory and field investigations of the origins and early evolution of life. It studies the potential of life to adapt to future challenges, both on Earth and in space." The search for "other worlds" requires an interdisciplinary approach that combines molecular biology, ecology, planetary science, astronomy, information science, space exploration technologies and related disciplines. The broad nature of astrobiology compels us to strive for the most comprehensive and inclusive understanding of biological and cosmic phenomena. Such an understanding is vital in order to answer the three basic questions of astrobiology: How does life begin and evolve? Does life exist elsewhere in the universe? What is the future of life on Earth and beyond?

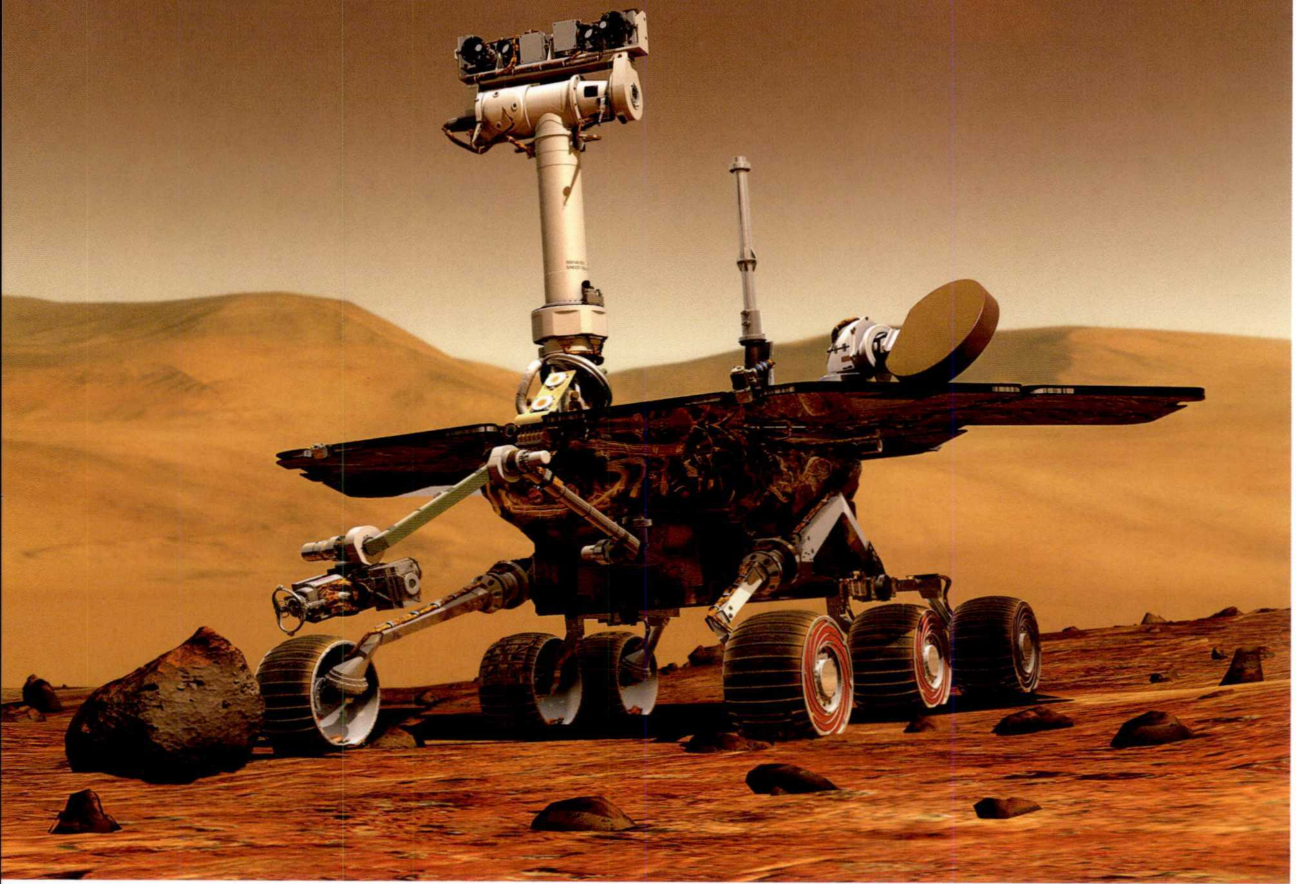
From biogeology to astrobiology

Research projects involving certain astrobiological aspects have been carried out for some time in the Biogeology Division of the Polish Academy of Sciences' Institute of Paleobiology in Warsaw. In cooperation with Professor S. Kempe from the Technical University of Darmstadt (Germany), we have proposed a model for the chemical evolution of the early Martian hydrosphere, based on a model of the early Earth ocean's chemical evolution. According to this model, the Martian hydrosphere may have for a long time been characterized by highly alkaline conditions. By analogy with sediments produced in terrestrial soda lakes, traces of the Martian alkaline hydrosphere may be found by remote sensing and/or landing missions. We have also proposed the same model for the potential ocean existing under a thick ice cover on Jupiter's moon Europa. Interestingly, recent discoveries about Europa - the probable existence of a sizeable ocean below its

Calcareous globules (A) from submerged (water depth 16 m) calcareous pinnacles from Lake Van growing at outlets of Calcium-rich groundwater springs. They closely resemble carbonate globules from the Martian meteorite ALH84001 (B). The Lake Van globules are composed of nanostructures (C) almost identical to those illustrated from ALH84001 globules (D) interpreted as putative fossil bacteria



Józef Kaźmierczak; NASA



NASA

Will Martian rovers find any life forms on the Red Planet?

ice crust, the detection of sodium carbonate, among other salts, and the calculation of a net loss of sodium from the surface - suggest the existence of such an alkaline ocean. Such an environment may have been favorable to biogenesis, since it may have provided the very low calcium ion concentrations mandatory for the biochemical function of proteins. A rapid loss of CO_2 from Europa's atmosphere may have led to freezing oceans. Alkaline brine bubbles embedded in ice in freezing and impact-thawing oceans could have provided a suitable environment for protocell formation and the large number of trials needed for biogenesis. An understanding of these processes could be central to assessing the probability of life on Europa. To further develop this research program we participate in the Europa Focus Group, acting under the auspices of NASA Astrobiology Institute (NAI) and NASA-Ames Research Center.

A Polish voice has also been raised in the more than 7-year-old lively discussion about the origin of the carbonate globules from the famous Martian meteorite ALH84001, containing ultra-small ovoids and sausage-like bodies interpreted as fossilized bacteria-like organisms. Together with Prof. Kempe, we have shown that modern carbonate globules, located in cracks of submerged volcanic rocks and in calcareous pinnacles in the alkaline Lake Van in Turkey, appear to be analogues for the ca. 3.9 billion-year-old globules from the ALH84001 meteorite. These terrestrial globules have similar diameters and are chemically and mineralogically zoned. Furthermore, they display surface and etching structures similar to those described from ALH84001, which were interpreted as fossilized microbial forms. These terrestrial carbonates were formed at low temperatures where calcium-rich groundwater enters the lake. Chemical, mineralogical, microbiological, and biomolecular methods were used in an attempt to decipher the process responsible for the genesis of these structures.

One of the present authors (J. Kazmierczak), in cooperation with Professor W. Altermann (University of Pretoria, RSA and CNRS, Orleans, France), discovered the oldest indubitable cyanobacterial microfossils from the ca. 2.58 billion-year-old Campbell Rand Subgroup in South Africa. This finding showed well-preserved remnants of the oldest colonial coccoid cyanobacteria, closely resembling some modern representatives of this group. It also demonstrates their ability to promote precipitation of carbonate and silicate minerals. The discovery also proves the significance of photosynthesising and biomineralising microbial communities in the genesis of large deposits of late Archean carbonate rocks. This finding represents the oldest evidence of significant biological control of the early Earth's climatic conditions through the uptake of excess carbon dioxide from the atmosphere.

Oldest fossils or artifacts?

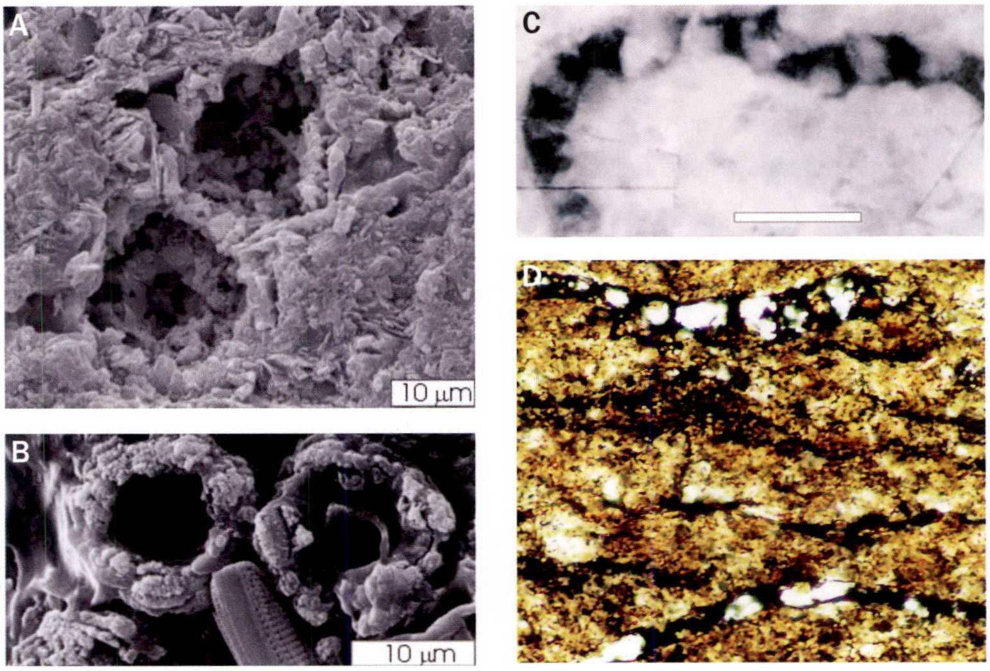
We have reported new discoveries in the study of early life, of revelance to astrobiological programs. Our work sheds light on the recent debate (known as the Schopf-Brasier controversy) about the biogenicity of carbonaceous structures from the 3.465 billion-year-old Apex Chert (Warrawoona Formation, Western Australia). For over decade they were accepted as the Earth's oldest fossils. J. William Schopf from the University of California in Los Angeles, who originally described these structures, interpreted them in 1993 as filamentous prokaryotic microbes. In 2002, however, Martin D. Brasier from the University of Oxford and his co-authors, who re-examined the structures, challenged Schopf's view and suggested that the structures were inorganically produced artefacts. We joined the debate after conducting detailed studies of variously thermally changed remnants of benthic coccoid cyanobacteria from early Silurian (ca. 410 million years old) black laminated cherts from the Bardo Mts., Poland. Our conclusion was that the carbonaceous filaments from the Apex Chert may represent similarly altered remains of coccoid cyanobacteria-like microorganisms. It has been shown that the thermal alteration of microbial remains embedded in a mineral matrix may significantly change the original morphology of fossilized microbes. This process may generate objects which, although morphologically resembling microbes, are nevertheless quite different from their living precursors.

The outset of Polish astrobiology

Institutes and centers of astrobiology have been founded in many countries in the past decade. They function either as independent research laboratories or as centers of excellence within larger universities. Poland wants to join the quickly developing net of astrobiological institutes in Europe. The 31st Meeting of the Polish Astronomical Society (Polskie Towarzystwo Astronomiczne - PTA) in Toruń on 8-12 September 2003 announced the creation of a Center for Advanced Studies in Astrobiology and Related Topics - CASA. The center is to promote, develop and coordinate interdisciplinary research programs related to astrobiology, i.e. the origin, distribution and evolution of life in the universe. CASA's main scientific purpose involves studies on the origin and evolution of life on Earth, and the development of advanced technologies necessary

Barbara Kremer

Outcrop of early Silurian radiolarian and siliceous shales in Żdanow village, Sudetes, Poland, enclosing thermally altered cyanobacterial microfossils



J. William Schopf; Józef Kaźmierczak

Mucilage capsules (A) from the 2.58 billion-year-old Nauga Fm. (South Africa) cyanobacterial mat mineralized by calcium carbonates and Al-Fe silicates. Similarly mineralized modern capsules (B) from Lake Vai Si'i, Tonga. Filamentous carbonaceous structures from the early Archean Apex Chert (C) compared to structures generated from thermally degraded subglobular colonies of early Silurian coccoid cyanobacteria (D). Scale bar for all 10 µm

to achieve this objective. One of the larger CASA programs to be promoted, "Through Cosmic Dust to DNA," encompasses such aims as: the search for planets beyond the Solar System; the origin, structure and evolution of planetary systems; the influence of ionising radiation on organic and inorganic molecules; the mutagenic action of ionising radiation; the search for life in extreme environments; and the restoration of environmental determinants for the origin of life in the early universe. The center affiliates five research groups from Szczecin University, and one from the Pomeranian Medical Academy in Szczecin. Several other research institutions have declared their interest in joining CASA. These include the Polish Academy of Sciences": Space Research Center, Nicolaus Copernicus Astronomical Center, Institute of Paleobiology and Toruń Center for Astronomy of the Nicolaus Copernicus University. Each group aims to pursue research programs concerned with selected branches of astronomy, astrophysics, the physics of macromolecules, statistical physics, cosmic physics, cosmology, medical genetics, microbiology, biogeology, biosedimentology and geomicrobiology.

Linking worlds and astrobiologists

CASA is also planning to extend its integration activities to East and Central European countries, and to initiate cooperation with astrobiological centers from Western Europe coordinated by the European Astrobiology Network Association. EANA was created in 2001 to coordinate the different European centers of excellence in exo/astrobiology, and the related fields previously organized in palaeontology, geology, atmospheric physics, planetary physics and stellar physics. As a European affiliate of the NASA Astrobiology Institute, EANA was established in 2002 at the Second European Workshop of Exo/Astrobiology in Graz. EANA's main aims involve coordinating active European researchers, linking their research programs, promoting research on extremophiles of relevance to environmental issues in Europe, promoting public interest, and educating the younger generation.

Thanks to Professor Aleksander Wolszczan, a member of the Penn State Astrobiology Research Center (NASA Astrobiology Institute), CASA will participate in the Space Interferometry Mission program, with access to large radio telescopes in Arecibo (Puerto Rico) and Effelsberg (Germany). CASA will also gain access to the 32-meter radio telescope in Toruń (Poland) and to the SALT telescope in South Africa, where 10-percent participation has been allocated for Polish astronomers.

The first Polish scientific conference session devoted entirely to astrobiology was held on 11 September 2003 during the Meeting of the Polish Astronomical Society (PTA). The lectures presented there by invited speakers illustrate CASA's main research topics well. We do hope that our joint effort will add some extra value to the ongoing debate on the origins and evolution of life - both on the Earth and beyond. ■

Further reading:

NASA Astrobiology page: http://astrobiology.arc.nasa.gov/
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