Microfossils in Carbonaceous Meteorites

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Carbonaceous meteorites are messengers from space. The Orgueil (CI1-France,1864) and Murchison (CM2-Australia, 1969 contain high percentages of extraterrestrial water (3–20%) and carbon (2-5 %), mainly in the form of an insoluble organic matter (IOM) chemically similar to terrestrial kerogen. Early reports [1] of the detection of amino acids and possible microfossils in the Orgueil meteorite were dismissed as the result of pollen and other terrestrial bio-contaminants and the search for evidence for microfossils in meteorites was abandoned possible nanofossils were found in ALH84001. In 1997, Scanning Electron Microscopy studies carried out by Hoover at NASA/MSFC [2] in the US and by Rozanov in Russia at the Borissiak Paleontological Institute (RAS) [3] resulted in the independent discovery of recognizable filamentous cyanobacteria in freshly fractured surfaces of the Murchison CM2 meteorite. SEM studies carried out during the ensuing decades detected well-preserved remains of diatoms, cyanobacteria and a great diversity of other prokaryotic and eukaryotic microorganisms in Orgueil and other carbonaceous meteorite [4-6].

Investigations of carbonaceous meteorites with modern instruments reveal 10 of 20 protein amino acid and 3 (Guanine, Adenine, Uracil) of 5 nucleobases essential for all life. Sensitive PCR studies show DNA is absent in the meteorites proving they are not contaminated by post-arrival terrestrial microorganisms [7]. Carbon isotope studies found the Murchison nucleobases to be indigenous, extraterrestrial and indicative of a cometary parent body [8]. Galimov [9] found that extraterrestrial carbon isotopes in the Murchison proteinogenic amino acids had biological fractionation analogous to terrestrial microalgae. The Polonnaruwa/Aralaganwila meteorites that were observed to fall on 12/29/2012 contain oxygen isotopes far away from the terrestrial fraction line, an astonishing diversity of diatoms and exotic microbiota, Wadsleyite and Maskelynite (high pressure polymorphs of plagioclase); fractured zircons, Ilmenite and Olivine indicative of pressures ~20-30 GPa. NAA studies found these low density (0.8), high porosity (70-90%) stones had very high content of the Heat Producing Elements ^{40}K, ^{238}U and ^{232}Th [10]. They are similar to the dark, low-density weak boulders (~Gargoyle Saxum) just discovered on asteroid (101955) Bennu by OSIRIS REx. Rozitis et al. [11] concluded *"The weaker boulder type probably would not survive atmospheric entry and thus may not be represented in the meteorite collection."* Our calculations [12] along with the existence of the Polonnaruwa/Aralaganwila meteorites indicate these fragile bodies could survive transit through the Earth's atmosphere and may provide important clues to the distribution of Biospheres throughout the Cosmos.

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Richard B. Hoover – Biography

Professor Richard B. Hoover began his NASA career in 1966 at the George C. Marshall Space Flight Center (MSFC) in Huntsville, Alabama working on Fraunhoffer Diffraction and Scatter Fringe Interferometery. He developed Advanced Optical Systems and Laser Retroreflectors for tracking Saturn V moon rockets. In 1967, Dr. Hoover was appointed Co-Investigator for the Apollo Telescope Mount ATM Experiment S-056 X-Ray Telescope that was flown on *SKYLAB.* This experiment produced 25,000 high resolution soft x-ray images of the Sun and new information on plasma physics of Solar Flares, Coronal Loops and X-ray bright points. He invented and patented several x-ray telescopes, microscopes, collimators and spectrometers and his Normal Incidence Multilayer X-ray Telescope produced the first high resolution images of the Sun using Bragg Diffraction with multilayer x-ray mirror. The resulting research paper was featured in *Science* with a high-resolution Fe IX/Fe X image of the Sun on the cover. In 1992, his *Multi-Spectral Solar Telescope Array* (MSSTA) Observatory produced simultaneous soft x-ray/EUV images of the Solar Photosphere, Chromosphere and Corona. Prof. Hoover holds 13 US and 2 International Patents and was selected *1991 MSFC Inventor of the Year* and the *1992 NASA Inventor of the Year* and *Nominee for National Inventor of the Year*. In 1997, he established the Astrobiology program at NASA/MSFC and led scientific expeditions to many of the most hostile environments on Earth. He conducted collaborative Astrobiology research on microbial life in Deep Vostok Ice Cores with Dr. Sabit Abyzov (INMI-RAS) and ancient permafrost with Dr. David Gilichinsky of the Laboratory for Soil Science and Photosynthesis in Pushchino. This research resulted in the discovery and valid publication of 1 new Family; 6 new Genera and 15 new species of extremophile bacteria and archaea previously unknown to Science. Forscientific expeditions to Antarctica, Siberia, Alaska, Iceland, South Africa and Patagonia and his discovery of new forms of life, he was elected *Fellow National* of the *Explorers Club* in 2001.

In 1997, Prof. Hoover initiated research on microfossils in ancient rocks and carbonaceous meteorites at NASA/MSFC and began a longstanding collaboration with Academician Alexei Yu. Rozanov, Director of the Paleontological Institute (RAS) Using State-of-the-Art Scanning Electron Microscopes at NASA/MSFC and the Paleontological Institute (RAS), they well-preserved fossilized remains of cyanobacteria, acritarchs, diatoms and other microalgae in diverse carbonaceous meteorites. He pioneered the application of Energy Dispersive X-Ray Spectroscopy for measuring life-critical Bio-Element ratios (C/O; C/N; C/S an C/P) for distinguishing ancient indigenous biological from modern bio-contaminants. Prof. Hoover continues this research on microfossils with Academician Rozanov and colleagues at the *Astrobiology Sector, LRB, JINR* in Dubna, Russia. Their Volume: *ATLAS OF MICROFOSSILS: The Orgueil Meteorite* was published in January, 2021. He continues this research at PIN and LRB/JINR as well as investigations of the element composition of diverse meteorites and terrestrial and lunar rocks by Neutron Activation Analysis (NAA) methods in collaboration with Dr. Marina Frontasyeva at JINR.

Professor Richard B. Hoover has Authored/Edited over 50 Books and Monographs and 450 scientific papers on X-ray Optics, Solar Physics, Diatoms, Bacteria, Microfossils and Meteorites. He is NASA/Emeritus-Docent, *United States Space & Rocket Center* in Huntsville, AL; Visiting Research Professor, *University of Buckingham Centre for Astrobiology*, Buckingham, UK and *Honorary Life Member* of the *Planetary Studies Foundation*, Chicago, IL, USA. Prof. Hoover served on the *Board of Directors of SPIE* (1989-2002); *2001 SPIE President* and he was awarded the *SPIE Gold Medal of the Society* in 2009. His explorations and scientific research are featured in many films produced by the *History Channel, Ancient Aliens, The Science Channel, NASA's Unexplained Files, NHK Japan Television, National Science Foundation: "Science Nation: Extremophiles", BBC, Discovery Channel* and *National Geographic.* Prof. Richard Brice Hoover will be awarded the Title: *Doctor Honoris Causa of the Russian Academy of Sciences* in a Ceremony at the Presidium of the Russian Academy of Sciences on October 21, 2021.