L 9 Chemofossils <sterols; $^{13}C/^{14}C$, $^{34}S/^{32}S$ >

All of us want to leave a trace of some sort to prove we existed.
—Theresa Byrnes.[1]

Life can be recognized by its deeds—life is disequilibrium leaving behind the signatures of disequilibrium such as fractionated isotopes or complex molecules.
—E. G. Nisbet & N. H. Sleep, 2001.[2]

While the five elements (earth, fire, air, water, and ether) of the "panchabhota" of Hindu canon retain their charm, it is C, H, N, O, P, S, in middle the of the Periodic Table that are the six elements of biological systems. "These of low atomic number," Gautam R. Desiraju writes, "have attributes that lead readily to covalency, which in turn favours specificity and reversibility in the reactions in which the corresponding molecules can participate." [3]

Eukaryotes?

Sterols are a class of fatty molecules found in the membranes of eukaryotes, which organisms, with nucleated cells, began of their radiation into higher forms 1.0-1.2 Ga. Possibly 1.5 billion years or more earlier, eukaryotes (not necessarily with say chloroplasts and mitochondria) diverged from bacteria. Biomarkers for these, and of an aquatic setting sufficiently oxygenated for sterol biosynthesis, occur in oil trapped in quartz and feldspar during diagenesis and early metamorphism (probably before ~2.2 Ga) of a ~2.45 Gy fluvial metaconglomerate, Matinenda fm, Elliot Lake, Canada.[4] Also, an abundance of sterols in 2.7 Gy shale in northwestern Australia, persuades authoritative Jochen J. Brocks "for the presence of eukaryotes." If so, Archean ephemeral oxygen-oases are a possibility.[5]

Bacteria

The earliest Archean fossils that do exist are of bacterial life some of which were already advanced enough to be photosynthetic. Such are *autotrophic* (means: *self feeding*) organisms able to make their own nutrients: sugars, starches, lipids, and proteins. The theory of evolution predicts that the first life, which at a minimum, to quote David P. Mindell and Luis P. Villarreal, will exhibit, as even do viruses, "internal homeostatic controls promoting survival, structural organization based on heritable nucleic acids, and reproduction,"[6] would have been *heterotrophic* (means: *other feeding*) organisms which are completely dependent on an external source of nutrients. The simplest type of anaerobic bacteria (living fossils?) today exist in exotic natural environments as boiling springs, by submarine hydrothermal vents in lightless deeps, and within Earth's crust at extreme pressure 4 kilometers down.[7] The high temperature of these environments keeps them the exclusive preserves for thermally tolerant bacteria. In unlit submarine hydrothermal vent environments, chemosynthetic bacteria use dissolved H_2S (rather than H_2O as a source of electrons and hydrogen atoms) to produce carbohydrates from dissolved CO_2. In sunlit waters, anaerobic photosynthesis can fix CO_2 similarly. (*Note*: Unlike chlorophyll-driven photosynthesis, O_2 is not produced by anaerobic photosynthesis and so the environment is not oxygenated). In a world without free O_2, primitive anaerobic bacteria could have flourished in environments that were less extreme and at generally cool temperatures; even as Darwin in a letter to Hooker, 1871, envisioned for life's emergence in "some warm [tepid—as seawater surface temperature has declined to ~20 ºC since 0.8 Ga from ~70 ºC 3.5 Ga][8] little pond."

Before free O_2 fouled the nest, anaerobic organisms could swarm, converting, Oliver Sacks notes, "nitrogen to ammonia, sulfur to hydrogen sulfide, carbon dioxide to formaldehyde, and so forth. From formaldehyde and ammonia the bacteria could make every organic compound they needed."

The existence 2.6-2.7 Ga of microbial mats crusting ancient soils (paleosols) is evident from elemental ratios (C, H, N, P) and isotopic compositions of residues of this organic matter in calcareous shales that are the uppermost part of calcinated (weathered and calcareous stromatolite bearing) carbonate-free serpentinite in the Mpumalanga Province (Eastern Transvaal), South Africa. Yumiko Watanabe in 2000 found the paleosol profile there records processes essentially identical to those found for the formation of modern calcite-rich soils (calcrete) and dolomite-rich soils (dolocrete). The paleosols developed under surface conditions of rain puddling (and washing in of quartz and aluminous clays from a neighboring granite terrain), carbonate dissolution, and then drying. The microbial mats opportunistically populated rain puddles and encrusted wet soil surfaces.[9]

Until recently, the oldest signs of life were from the 3.5 billion year old sedimentary rocks in Australia and South Africa. These deposits, which contain fossils of microorganisms, also harbor isotonically light carbon that is judged to be a chemofossil (a molecular remnant of life). Chemical reactions in the cells of living organisms alter the natural carbon ratio, slightly favoring the light isotope. Organic remains in a sediment give the rock a carbon-13 (^{13}C) to carbon-12 (^{12}C) ratios that are lower than the international standard for these isotopes. (By contrast, metamorphism invariably increases the heavier isotope over the lighter one proportionately.)

Sulfate-reducing microbes when oxidizing organic matter or hydrogen with sulfate, produce sulfide much depleted in the sulfur isotope sulfur-34 (^{34}S) with respect to sulfur-32 (^{32}S). Barites dated at 3.47 billion years old, from North Pole, Australia, contain microscopic isotopically fractionated sulfide which, as analyzed by Yanan Shen in 2001, clearly record microbial sulfate reduction.[10]

Some of the oldest Earth rocks are gneisses from Akilia Island near Greenland. These contain carbon bearing apatite mineral grains that have not recrystallized since they grew 3.85 billion years ago.[11] In these, Stephen J. Mojzsis in 2002 reported carbon-13 to carbon-12 ratios ranged from 2 to 5 percent lower than the international standard.[12] As only organic process are known to create such ratios, this undisturbed relict is reasoned to be evidence of ancient microbial life. If so, organisms on Earth were evolved even when incinerating cosmic bombardment pummeled our planet's surface. However, Aivo Lepland revisiting the evidence in 2005 finds the apatite to be barren of carbon and so Mojzsis's results to be spurious.[13] ❑

Footnote L17.1 Torino index (numbers and colors) and Pelermo scale

It is very difficult to make predictions, especially about the future. —Bohr's favorite facetious remark.[1] But then, Eric Adelberger who experiments to reconcile general relativity with quantum mechanics no less, when interviewed, let slip: "We know there's something we don't know, but we don't what it is."[2]

Near Earth Object Hazard Index, devised in 1995 by Richard P. Binzel, assigns a number, 0 through 10, to a space object according to the probability of its collision with Earth and its kinetic energy (half-mass times the square of its encounter velocity). The same, called the *Torino Scale*, since being approved at the international conference on Near Earth Objects (NEOs) held in Turin (Torino), Italy, 1999, and revised to assign objects a color code according to their index number, is:

0. White - "Events having no practical consequences."

1. Green - "Events meriting careful monitoring" (as is so for 400-meter-wide asteroid MN4 that is expected to miss Earth by the distance of geostationary artificial satellites).

2, 3, 4. Yellow - "Events meriting concern" (since edited to read: "... meriting attention by astronomers" as for these there is no need to unduly alarm the public).[3]

5, 6, 7. Orange - "Threatening events."

8, 9, 10. Red - "Certain [to occur] collisions."

Large asteroids that threaten at any time are few. But, 20,000 untracked Earth-killers likely exist.

Palermo Technical Impact Hazard Scale, introduced in 2002 rates the chance of impact of each asteroid relative to the frequency with which objects of a similar size collide with Earth. This gives astronomers, Steven Chesley writes, "a way to look at a potential impact and to ask 'is it worth some big telescope time?'"[4] A Palermo rating of zero means that an impact is no more likely than a similar but as yet unidentified object striking Earth before the asteroid being studied is scheduled to arrive. The value is expressed as a logarithm to base 10, so −2 implies that a collision is 1% as likely as the 'background' probability, and a rating of 2 means that an impact is 100 times more likely.