Brocks, JJ, GA Logan, R Buick and RE Summons, 1999. Archean Molecular Fossils and the Early Rise of Eukaryotes. *Science 285:1033-1036 DOI: 10.1126/science.285.5430.1033*

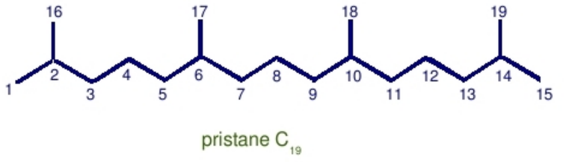
Abstract

Molecular fossils of biological lipids are preserved in 2700-million-year-old shales from the Pilbara Craton, Australia. Sequential extraction of adjacent samples shows that these hydrocarbon biomarkers are indigenous and syngenetic to the Archean shales, greatly extending the known geological range of such molecules. The presence of abundant 2α-methylhopanes, which are characteristic of cyanobacteria, indicates that oxygenic photosynthesis evolved well before the atmosphere became oxidizing. The presence of steranes, particularly cholestane and its 28- to 30-carbon analogs, provides persuasive evidence for the existence of eukaryotes 500 million to 1 billion years before the extant fossil record indicates that the lineage arose.

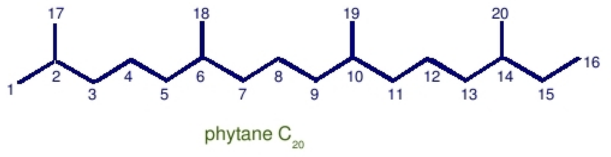
Excerpt of Table 2 from Brocks et al. 1999.
Abundances and isotopic compositions of kerogens and individual compounds. Numbers in subscript refer to the number of carbon atoms in the biomarker.

	Mam1	**Roy1**	**Roy2**	**Roy5**	**Roy3**
Depth (m)	665.4	679.4	681.9	696.9	718.2
Ratio pristane/n-C_{17}	0.2	0.3	0.4	0.5	0.3
Ratio phytane/n-C_{18}	0.1	0.2	0.3	0.5	0.2
Hopanes (ppm)	230	300	75	–	110
Steranes (ppm)	180	280	190	–	120
Carbon isotopes ($\delta^{13}C$ per mil PDB)					
n-C_{17}	−26.2	−26.2	−26.0	–	−27.0
n-C_{18}	−26.5	−26.1	−27.4	–	−26.3
Pristane	−28.8	−29.4	−29.8	–	−28.9
Phytane	−29.6	−29.5	−30.1	–	−27.8

Notes:
n-C_{17} and n-C_{18} are alkanes (saturated hydrocarbon chains with 17 and 18 carbons)



pristane C_{19}



phytane C_{20}

Steranes are derivatives of sterols and steroids
$\delta^{13}C = [^{13}C/^{12}C(\text{sample}) - {}^{13}C/^{12}C(\text{standard})] / {}^{13}C/^{12}C(\text{standard}) \times 1000$; photosynthesis and other biochemical processes prefer ^{12}C over ^{13}C
Syngenetic: formed at the same time as the enclosing rocks
Indigenous: originated in place, native to the location

Lipid Biomarkers

Biological lipids survive diagenesis (physical and chemical alterations that occur in sediments over geological time, but with lower heat and pressure than formation of metamorphic rocks). Oil-bearing shale formations over a billion years old have recognizable biomarkers that can give insights into the composition of these ancient microbial communities.

The 1999 paper by Brocks et al. caused scientists to re-evaluate the timing of key events in the history of life on earth, such as when oxygenic photosynthesis began, when atmospheric oxygen began to accumulate, and when eukaryotes first evolved. The paper stimulated research into “molecular fossils” or biomarkers based on lipid signatures in oil-bearing rock formations.

1. Pristane and phytane are isoprenoid chains. Could they have been derived from bacterial membranes?

2. Were these lipids of biogenic or abiotic origin? What is the evidence?

3. Hopanoids are present in the lipid membranes of bacteria; 2α-methylhopane is a particular variant that was thought to be characteristic of cyanobacteria. What are cyanobacteria?

4. What is the evidence that eukaryotic cells were present among the organisms that formed these hydrocarbon deposits?

5. What data suggest that molecular oxygen (O_2) was present in these ocean waters 2.7 billion years ago?

Group Members Names:

Microaerobic steroid biosynthesis and the molecular fossil record of Archean life

1. Jacob R. Waldbauera,1,2,
2. Dianne K. Newmanb,c,d,3, and
3. Roger E. Summonsd

+ Author Affiliations

1. *[a]Joint Program in Chemical Oceanography, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, Cambridge, MA 02139;*
2. *[b]Howard Hughes Medical Institute and*
3. *[c]Department of Biology, Massachusetts Institute of Technology, Cambridge, MA 02139; and*
4. *[d]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139*

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Abstract

The power of molecular oxygen to drive many crucial biogeochemical processes, from cellular respiration to rock weathering, makes reconstructing the history of its production and accumulation a first-order question for understanding Earth's evolution. Among the various geochemical proxies for the presence of O_2 in the environment, molecular fossils offer a unique record of O_2 where it was first produced and consumed by biology: in sunlit aquatic habitats. As steroid biosynthesis requires molecular oxygen, fossil steranes have been used to draw inferences about aerobiosis in the early Precambrian. However, better quantitative constraints on the O_2 requirement of this biochemistry would clarify the implications of these molecular fossils for environmental conditions at the time of their production. Here we demonstrate that steroid biosynthesis is a microaerobic process, enabled by dissolved O_2 concentrations in the nanomolar range. We present evidence that microaerobic marine environments (where steroid biosynthesis was possible) could have been widespread and persistent for long periods of time prior to the earliest geologic and isotopic evidence for atmospheric O_2. In the late Archean, molecular oxygen likely cycled as a biogenic trace gas, much as compounds such as dimethylsulfide do today.