Project Report: Building a habitable planet: the geological record

Project Investigator:	***Roger Buick***

Project Progress

Research continued in the following six areas: late Archean – early Paleoproterozoic hydrocarbon biomarker molecules, early Archean sulfur isotopes, metamorphism of early Archean biosignatures, nutrient availability (N, P) in Archean oceans, geochronology of a late Archean flood basalt province, and diamond drilling of astrobiologically significant Archean and early Proterozoic sedimentary horizons in the Pilbara Craton of Australia . Field–work was conducted on early Archean supracrustal rocks of the Warrawoona and Coonterunah Groups in the Pilbara Craton, Australia . Principal outcomes were:

- Publication of complete results on hydrocarbon biomarker molecules in late Archean and early Paleoproterozoic sediments, showing that cyanobacterial and eukaryotic geolipids were present in rocks half a billion years before other fossils of these groups appear in the geologic record, and that molecular fossils can survive for much longer under high–temperature regimes than previously expected.
- A thorough review of the Archean sulfur cycle and constraints upon sulfur isotopic fractionation confirmed the existence of microbial dissimilatory sulfate reduction in ~3.5–billion–year–old oceans, establishing that complex metabolic pathways and peripherally branching bacterial phyla had already evolved.
- Analysis of carbon isotopes in 3.52–billion–year–old sedimentary rocks show that, despite low–grade metamorphism (greenschist facies), isotopic fractionations resembling those imparted by Calvin–Benson cycle Rubisco autotrophy and by methanogenesis, survive in carbonates and cherts.
- U–Pb dating of zircons in felsic tuffs and volcanics interbedded with late Archean flood basalts constrained the age of the oldest–known reversal of the Earth's magnetic field and allowed calculation of continental drift rates, implying very rapid horizontal tectonic processes on the early Earth.
- Planned deep diamond drill coring of three well–preserved sedimentary intervals (Hamersley–Fortescue, Warrawoona–Coonterunah, and Tumbiana) in the Archean Pilbara Craton will test syngenicity of

hydrocarbon biomarkers and provide unweathered geochemical samples for redox−sensitive environmental indicators.

Fig. 1 Graham Logan, Roger Summons, Jochen Brocks and Roger Buick using gas chromatography−mass spectrometry to investigate hydrocarbon biomarkers of cyanobacteria and eukaryotes in 2.7 Ga kerogenous shales

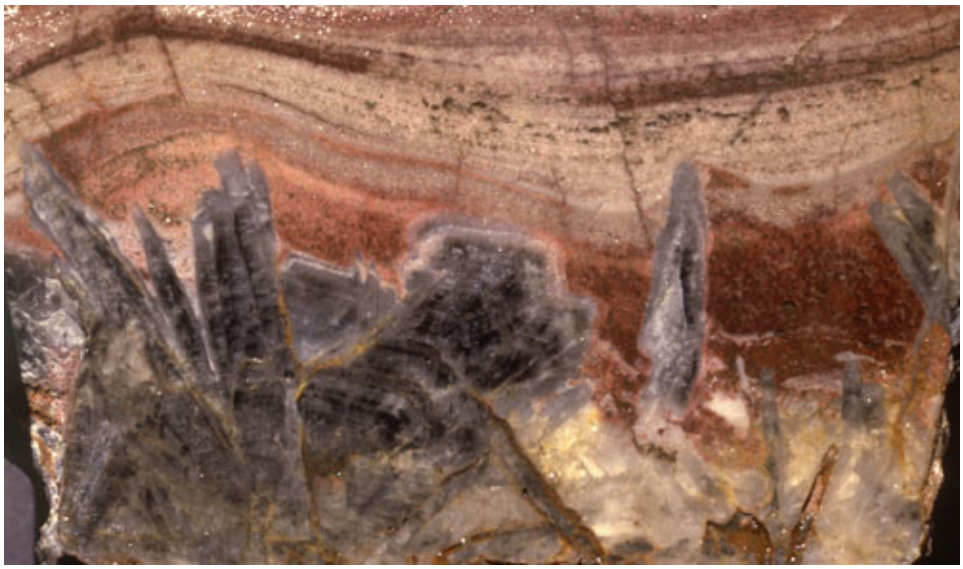

Fig. 2 Bedded barite from North Pole, Australia containing microcrystalline pyrite with fractionated sulfur isotopes indicating bacterial sulfate reduction at 3.45 Ga

Highlights

- A full documentation of the molecular biomarker record from late Archean – early Paleoproterozoic rocks from the Hamersley Basin, Australia (Brocks et al., 2003a, 2003b, 2003c) shows that cyanobacteria

and eukaryotes evolved early in Earth history, allowing reconstruction of ancient ecosystems (Fig. 1).
- A thorough review of the early Archean sulfur isotope record (Shen and Buick, 2004), shows that dissimilatory sulfate reduction arose early in Earth history, allowing time calibration of the Tree of Life, and providing a potential biosignature for primordial life on other sulfate–bearing planets, i.e., Mars (Fig. 2).

Roadmap Objectives

- ***Objective No. 4.1:*** Earth's early biosphere
- ***Objective No. 4.2:*** Foundations of complex life
- ***Objective No. 7.1:*** Biosignatures to be sought in Solar System materials

Field Expeditions

Field Trip Name: Pilbara	
Start Date: 27 July 2003	***End Date:*** 17 August 2003
Continent: Australasia	***Country:*** Australia
State/Province: Western Australia	***Nearest City/Town:*** Marble Bar
Latitude: 21S	***Longitude:*** 119E
Name of site(cave, mine, e.g.): Coonterunah Group	***Keywords:***
Description of Work: mapping metamorphic gradients in early Archean biosignature–bearing sediments	
Members Involved:	

Cross Team Collaborations

Roger Summons (Ames, URI): papers on Archean biomarkers, abstract on Archean drilling Ariel Anbar (PSU, Colorado): 3 abstracts on Archean drilling Jay Kaufman (PSU): abstract on Archean drilling Tim Lyons (PSU): abstract on Archean drilling Mark Barley (PSU): manuscript on Archean geochronology Steve Mojzsis (UCLA, Colorado): abstract on Archean drilling