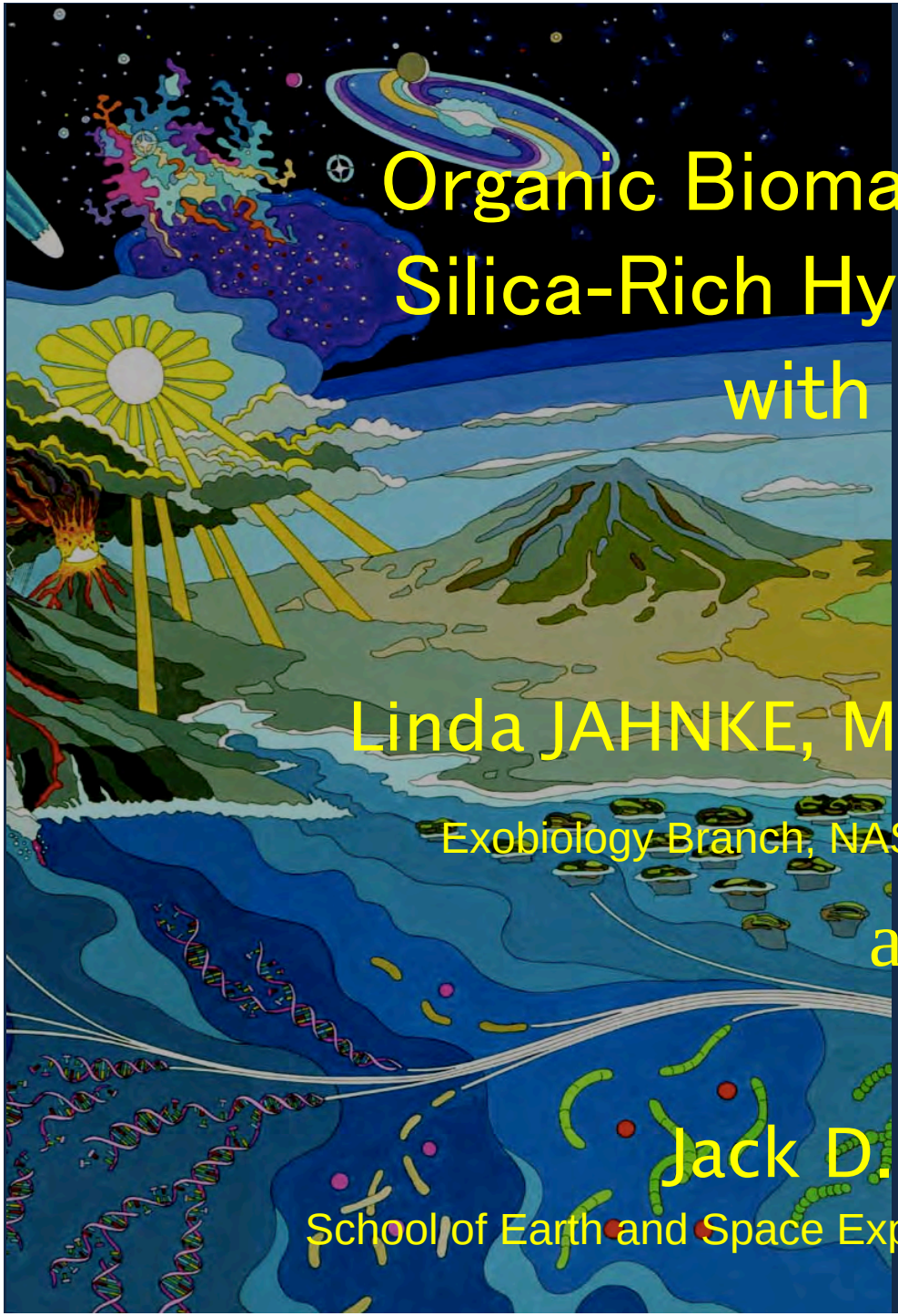

Organic Biomarker Preservation in Silica-Rich Hydrothermal Systems with Implications to Mars

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Overview

- Amorphous silica deposits and thermal features have been identified on Mars
- Hydrothermal springs may have been habitable on early Mars
- Thermal silica-depositing springs on modern Earth host microbial ecosystems, biomarker deposition & preservation
- Preservation studies of organic matter in hydrothermal microbial ecosystems support future Mars exploration

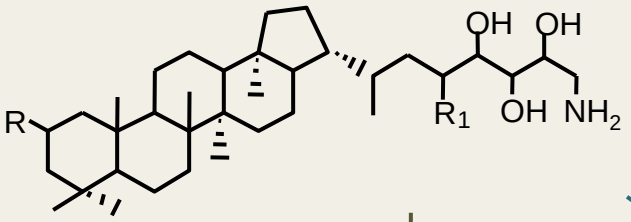
Target Biomarker ~ Hopanoids

- Hopanoids are definitive molecular fossils dating back at least 1600 my & are Earth's most abundant organic biomarker
- Hopanoids as membranes lipids modulate thermal fluidity and assist in stress tolerance
- Hopanoids are abundant in hydrothermal environments and hydrothermal bacteria, particularly cyanobacteria
- Prior to evolution of eukaryotic algae, cyanobacteria played the major role in primary productivity for early Earth microbial ecosystems, and potentially also early Mars

CYANOBACTERIAL BACTERIOHOPANEPOLYS (BHP)

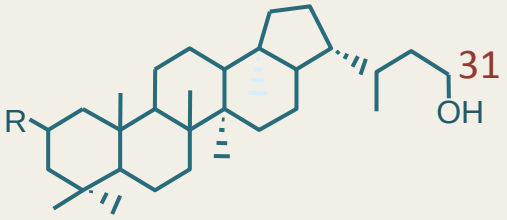
Natural & Laboratory Degradation Products

R = CH_3 or H



R_1= OH

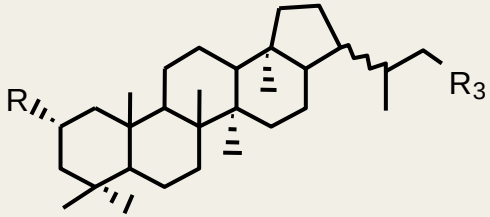
Oxidation & reduction



R = H = C_{31} hopanol

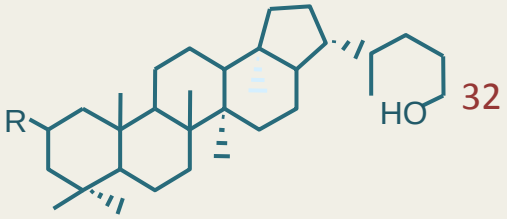
R = CH_3 = 2MeC_{31} hopanol

Burial & Diagenesis



R_3 = H, CH_3 to n- C_5H_{11}

R_1= H



R = H = C_{32} hopanol

R = CH_3 = 2MeC_{32} hopanol

Photosynthesis Upper Temperature Limits in Geothermal Environments

Archaea

Chemolithotrophic bacteria

Anoxygenic / ***Chloroflexus***

Oxygenic / Cyanobacteria ***Synechococcus*** spp.

Filamentous/***Phormidium***-like Oxygenic Eurkaryote Algae

Anoxygenic Rhodobacteracea

Calothrix spp

114°

90°

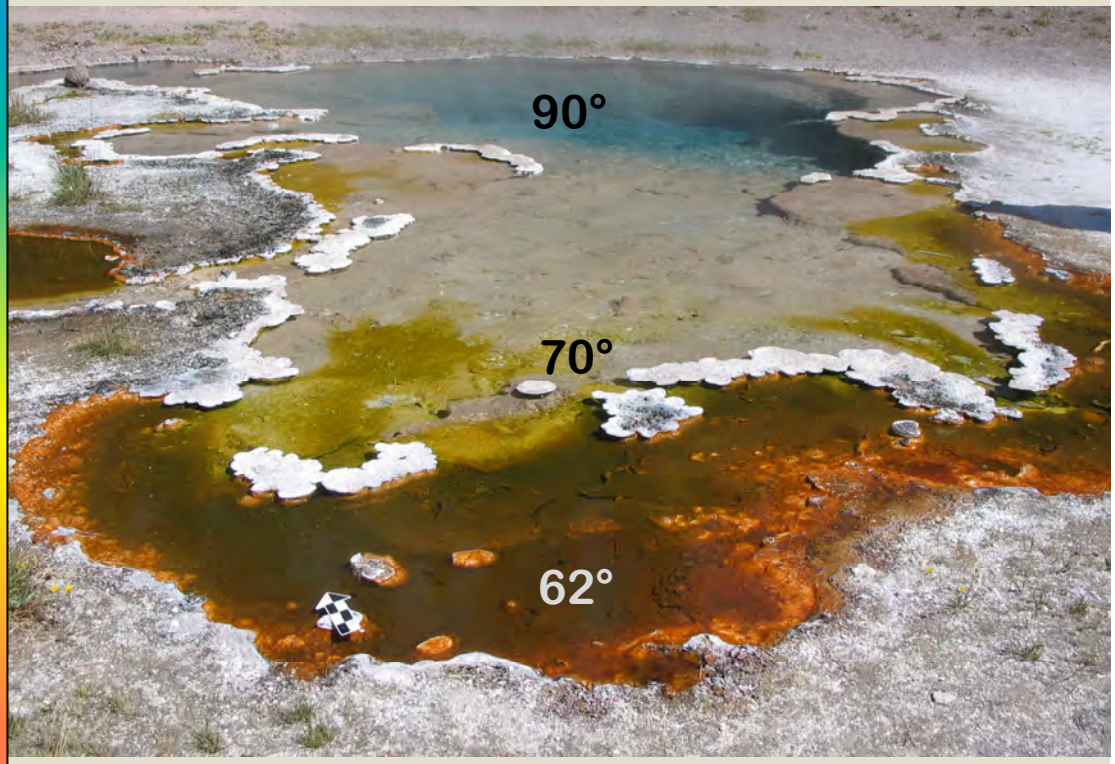
74°

66°

58°

47°

35°



Octopus Spring, YNP

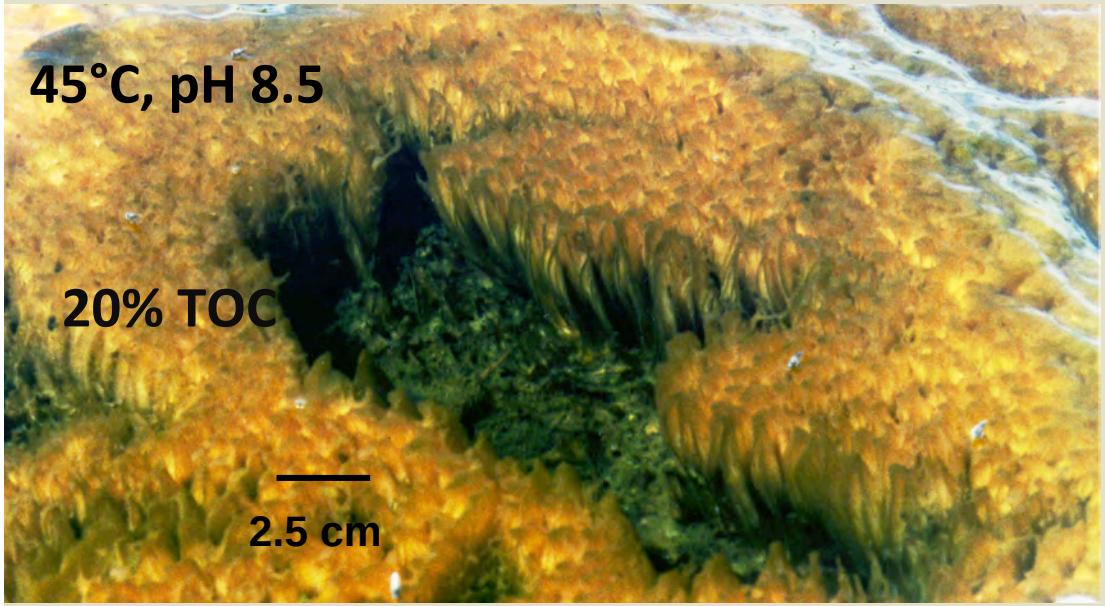
Summons et al. 1996 Ciba 202

Comparison of cyanobacterial lipid biomarker diversity

Cyanobacterium	Source[a]	Alkanes			Bacteriohopanepolyols (BHP)			
		normal-	Methyl-	Dimethyl	2MeC$_{31}$	C$_{31}$	2MeC$_{32}$	C$_{32}$
Synechococcus lividus	ATCC27180	+	–	–	–	–	+	+
Cyanothece RCB4	YNP	+	–	–	–	–	+	+
Phormidium RCG3	YNP	+	+	+	–	–	–	+
Phormidium FPG4	YNP	+	+	+	–	–	–	+
Phormidium FPOS4	YNP	+	+	–	+	+	+	+
Phormidium OSS4	YNP	+	+	±	+	+	±	±
Oscillatoria amphigranulata	OSU	+	+	–	+	±	+	±
Phormidium RCO4	YNP	+	–	–	–	–	–	–
Calothrix spp.	J.Dillion	+*	±	–	+	+	+	+

* Major alkanes monounsaturated normal chain (*n*-17:1, *n*-18:1, *n*-19:1, *n*-20:1)


Fountain Paint Pot, YNP
Clepsydra Geyser Outflow

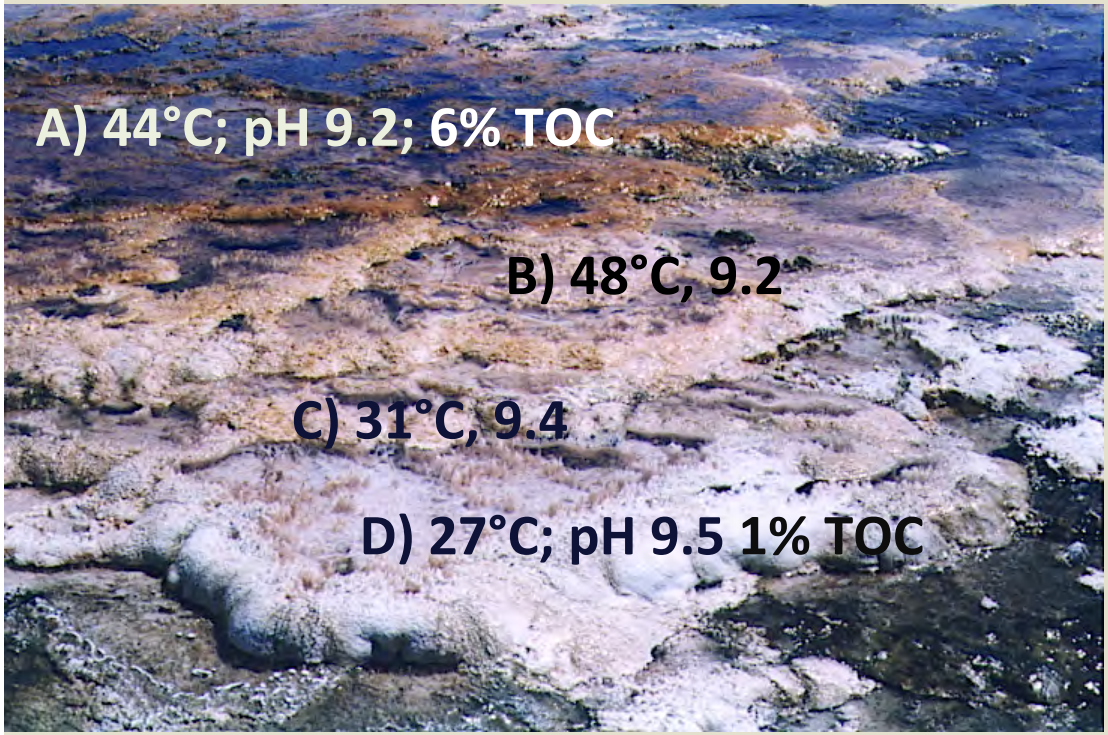


Fountain Paint Pot Terraces

Submerged Tufted Mat
Orange surface
0.35 mg BHP & 11.7 mg FAME/g TOC

Lower Green Tuft
2.23 mg BHP & 8.20 mg FAME/g TOC

Jahnke et al. Geobiology2004



Silicifying Tufted Mat Sinter

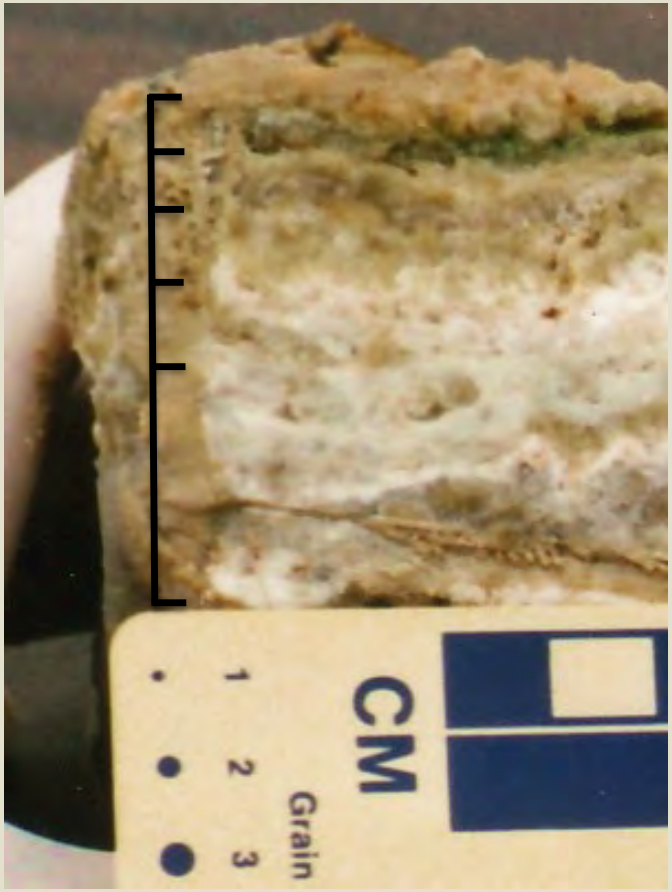
	BHP mg/g TOC	Fatty Acid mg/g TOC
A	1.60	16.9
B	1.75	22.3
C	1.48	12.7
D	1.72	22.6

Sheet flow sinter forms in cooler distal margins of Fountain Paint Pot thermal area. Below 30°C the filamentous cyanobacterium, *Calothrix*, forms 'palisade' sinter mat (*Walter et al. 1996*)

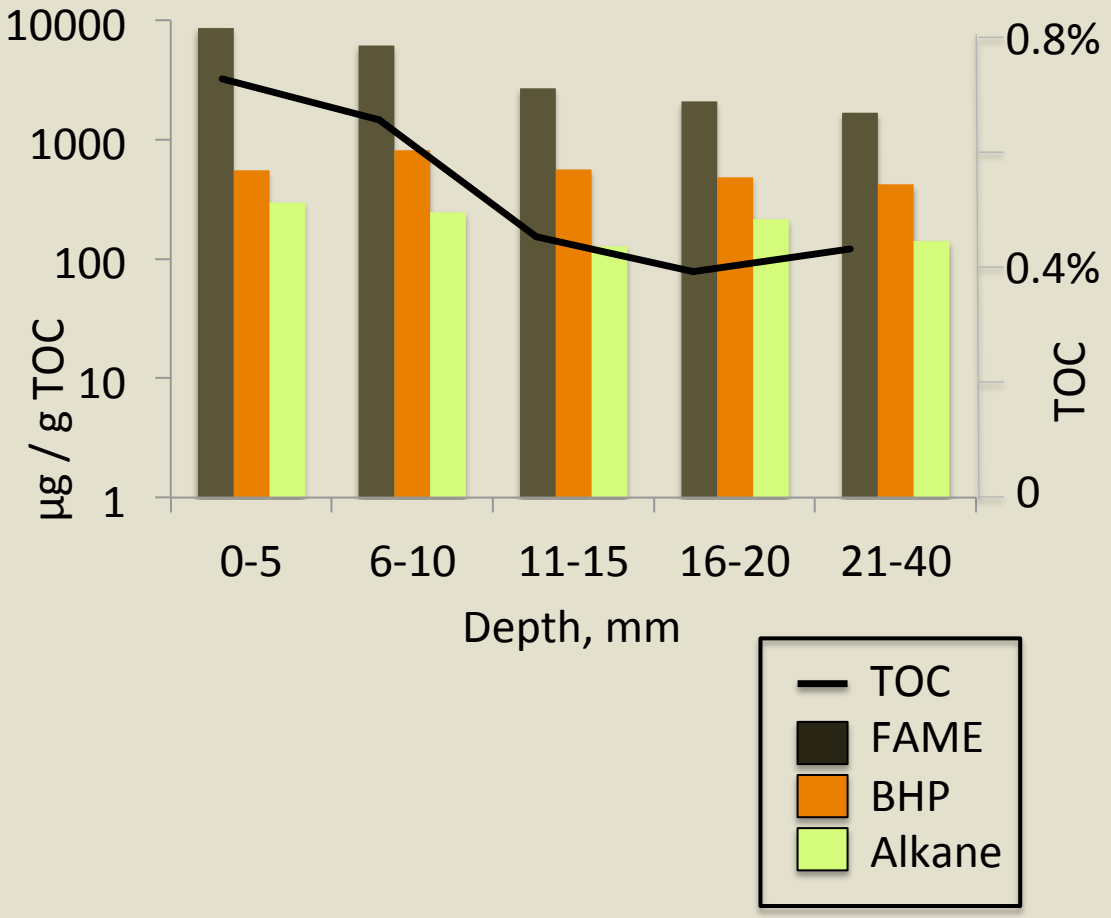
Sheet Flow Sinter

Fountain Paint Pot, YNP

Calothrix Mat Cross Section

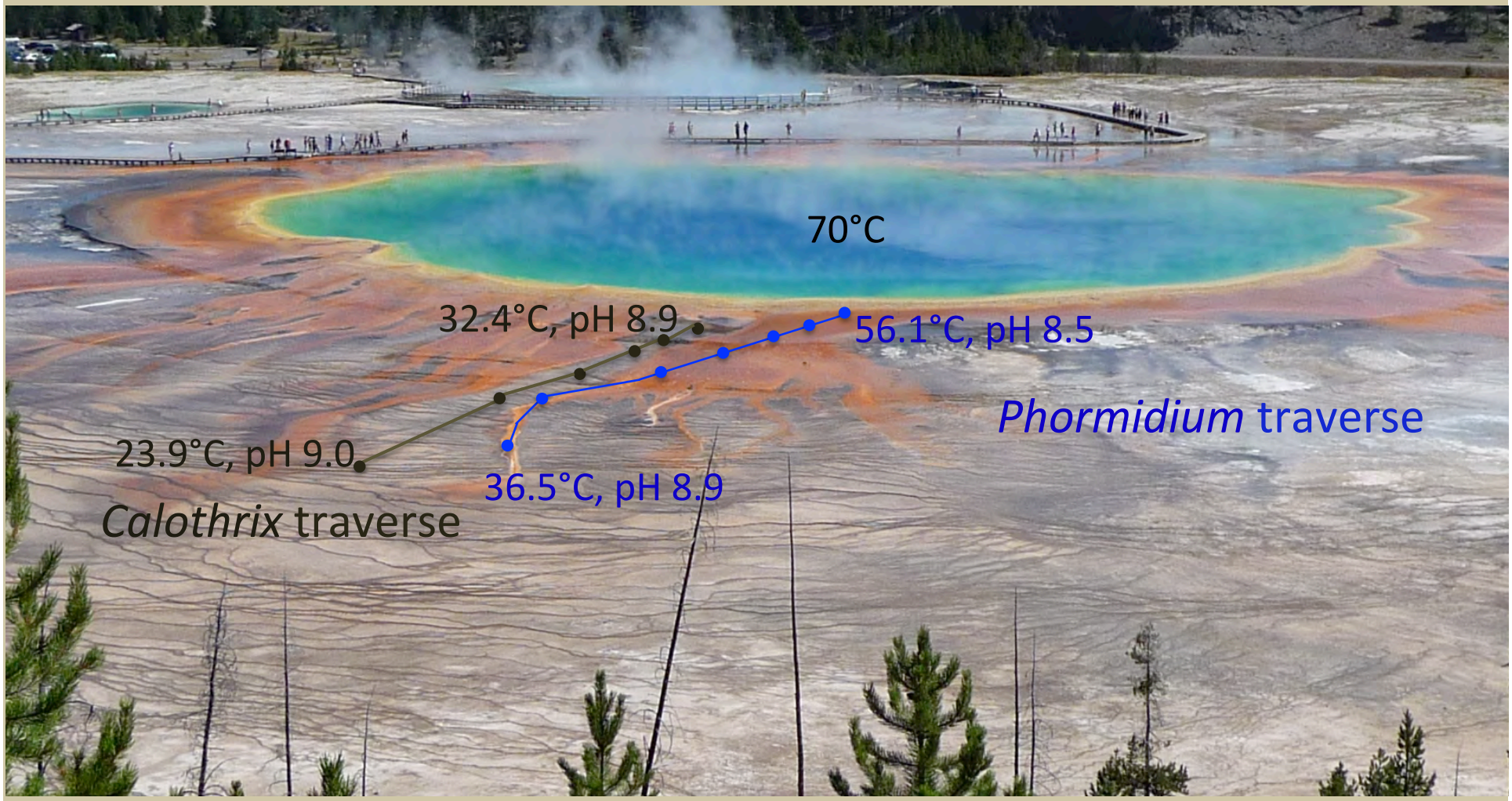


Lipid Biomarker Distribution with Depth



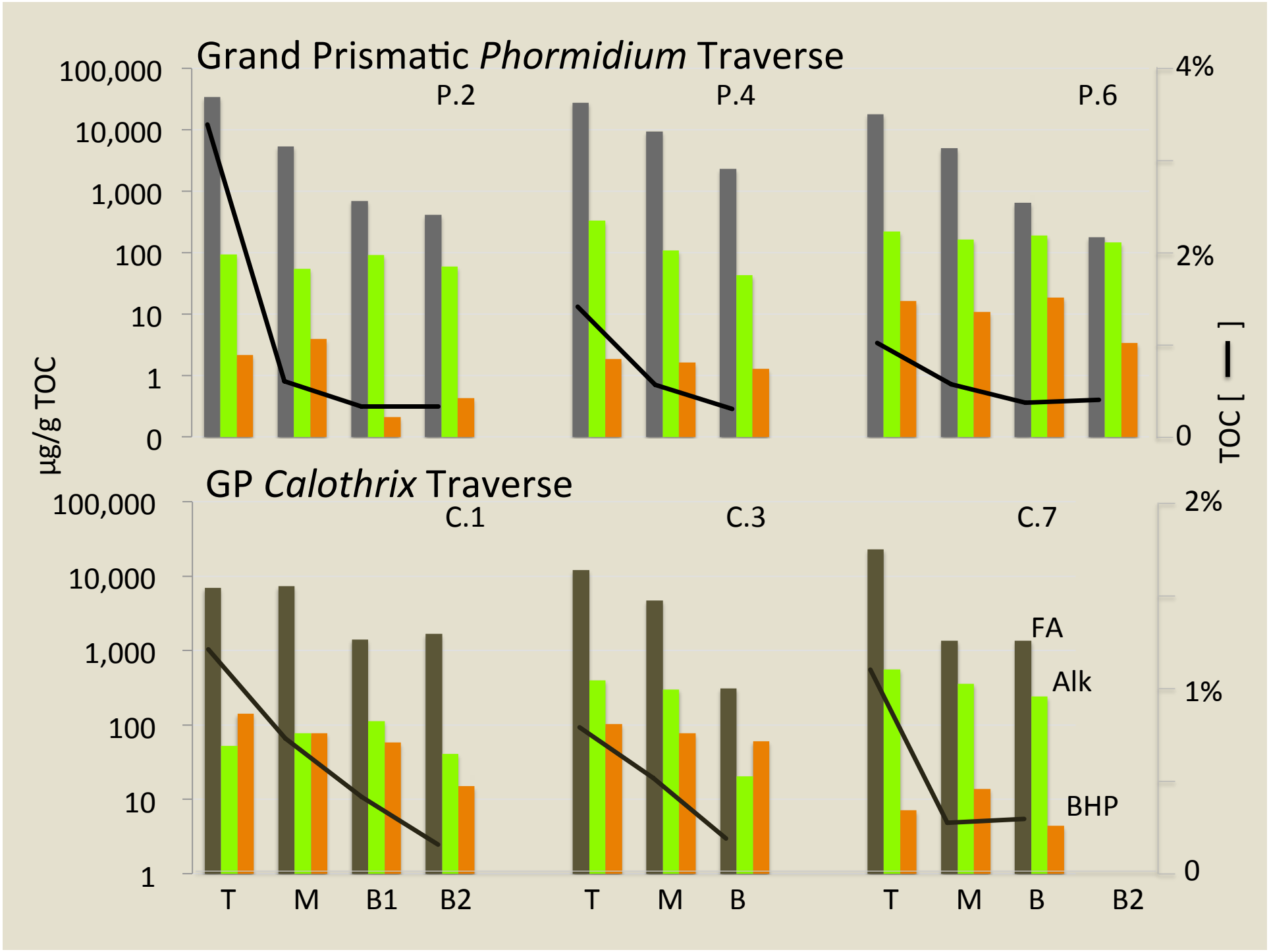
Grand Prismatic Spring, YNP

Summertime and the tourists are roamin’



Calothrix Traverse - Lower Tape Flag 4 Site

Green Streamer and Upper *Phormidium* Pool (Flag 2)


Grand Prismatic *Phormidium* Traverse
P.2
P.4
P.6
100,000
10,000
1,000
100
10
1
0
µg/g TOC
4%
2%
0
TOC [ ]
GP *Calothrix* Traverse
C.1
C.3
C.7
100,000
10,000
1,000
100
10
1
2%
1%
0
FA
Alk
BHP
T
M
B1
B2
T
M
B
T
M
B
B2

Comparison of Bacteriohopanepolyol Abundance in Surface Mat Samples in Silica Depositing Geothermal Environments, YNP

Mat Type	Location	Temp °C	BHP, µg/g TOC
Synechococcus	Octopus Spring	64	838
Phormidium coniform	" "	46	700
Phormidium tuft-orange	Fountain Paint Pot	45	352
Phormidium tuft-green	" " "	"	2230
Phormidium silicified	" " "	–	1700
Calothrix sheet sinter	" " "	25	550
Synechococcus elongatus	Grand Prismatic	58	3
Phormidium sinter P.1	" "	56	4.9
Phormidium sinter P.6	" "	40	2.1
Calothrix sinter C.1	" "	32	143
Calothrix sinter C.7	" "	24	7

CONCLUSIONS

- Thermal sinters are a rich source of cyanobacterial lipid biomarkers such as hopanoids and branched alkanes
- The presence and abundance will however depend on the diversity and nature of the deposition site
- Distribution in ancient sinter may be highly variable but detection should be possible