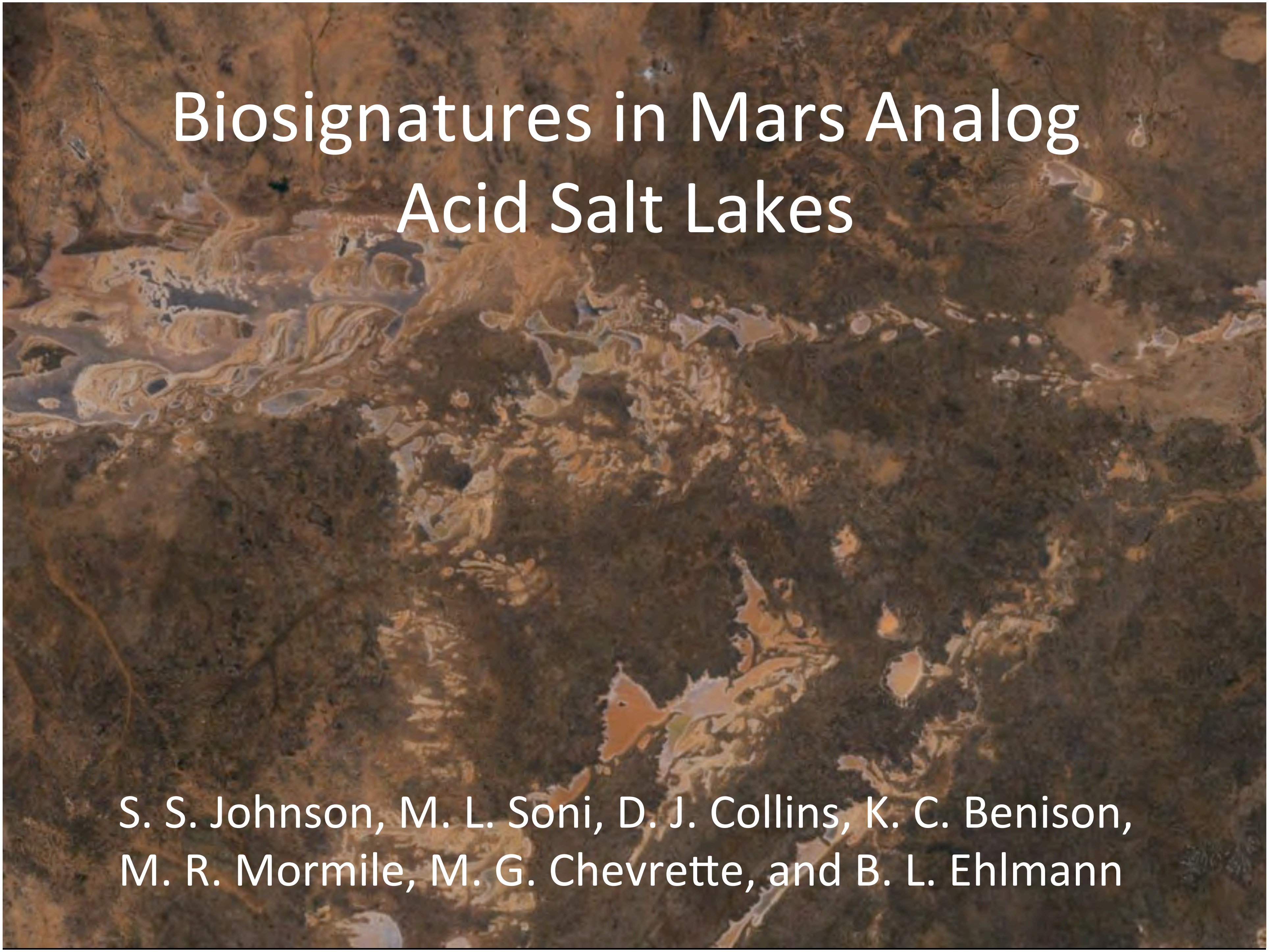
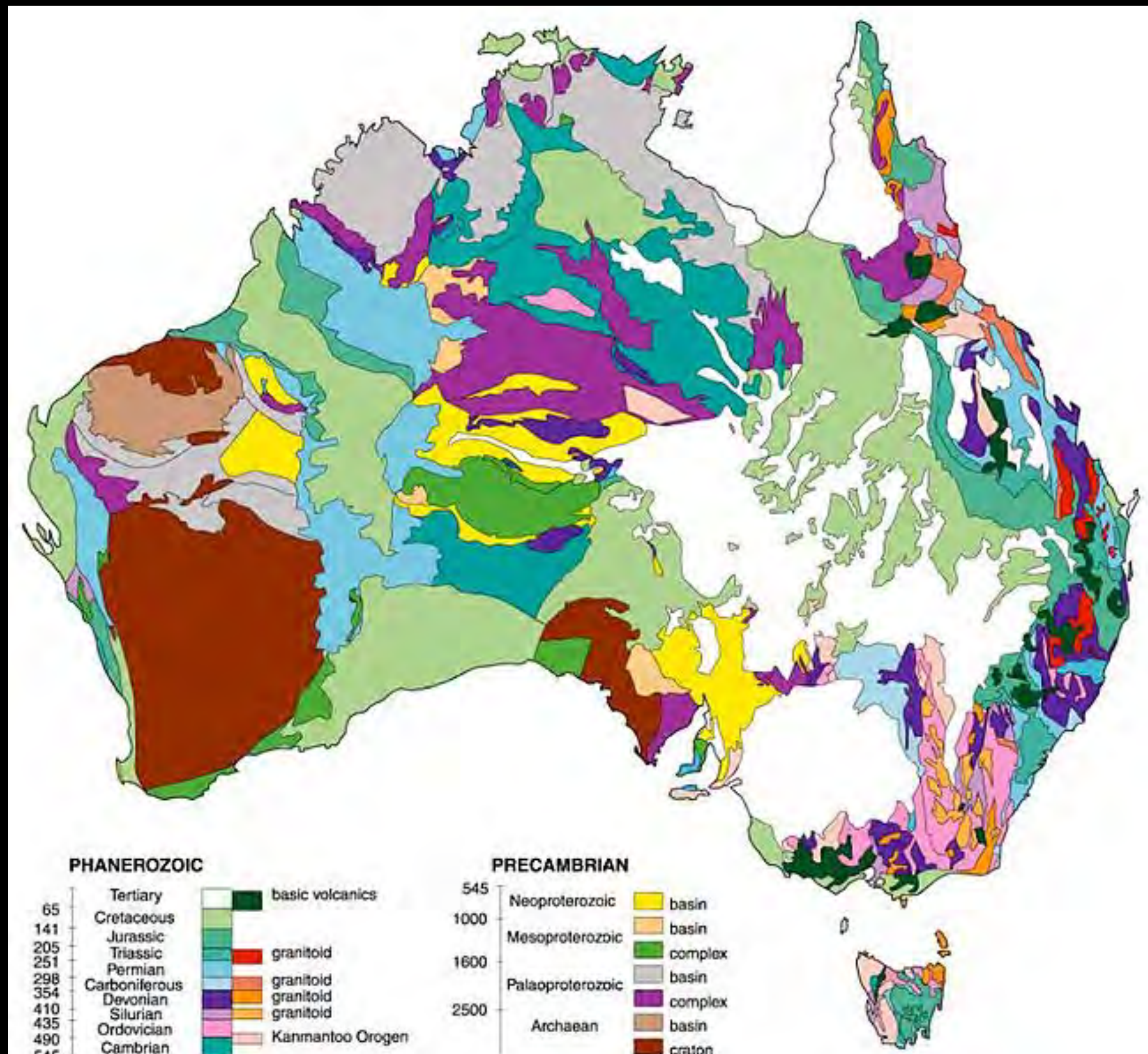


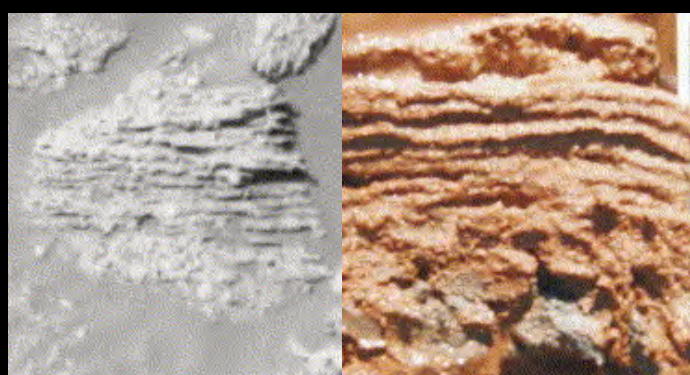
Biosignatures in Mars Analog Acid Salt Lakes

S. S. Johnson, M. L. Soni, D. J. Collins, K. C. Benison, M. R. Mormile, M. G. Chevrette, and B. L. Ehlmann

Yilgarn Craton



Sedimentary Similarities to Mars

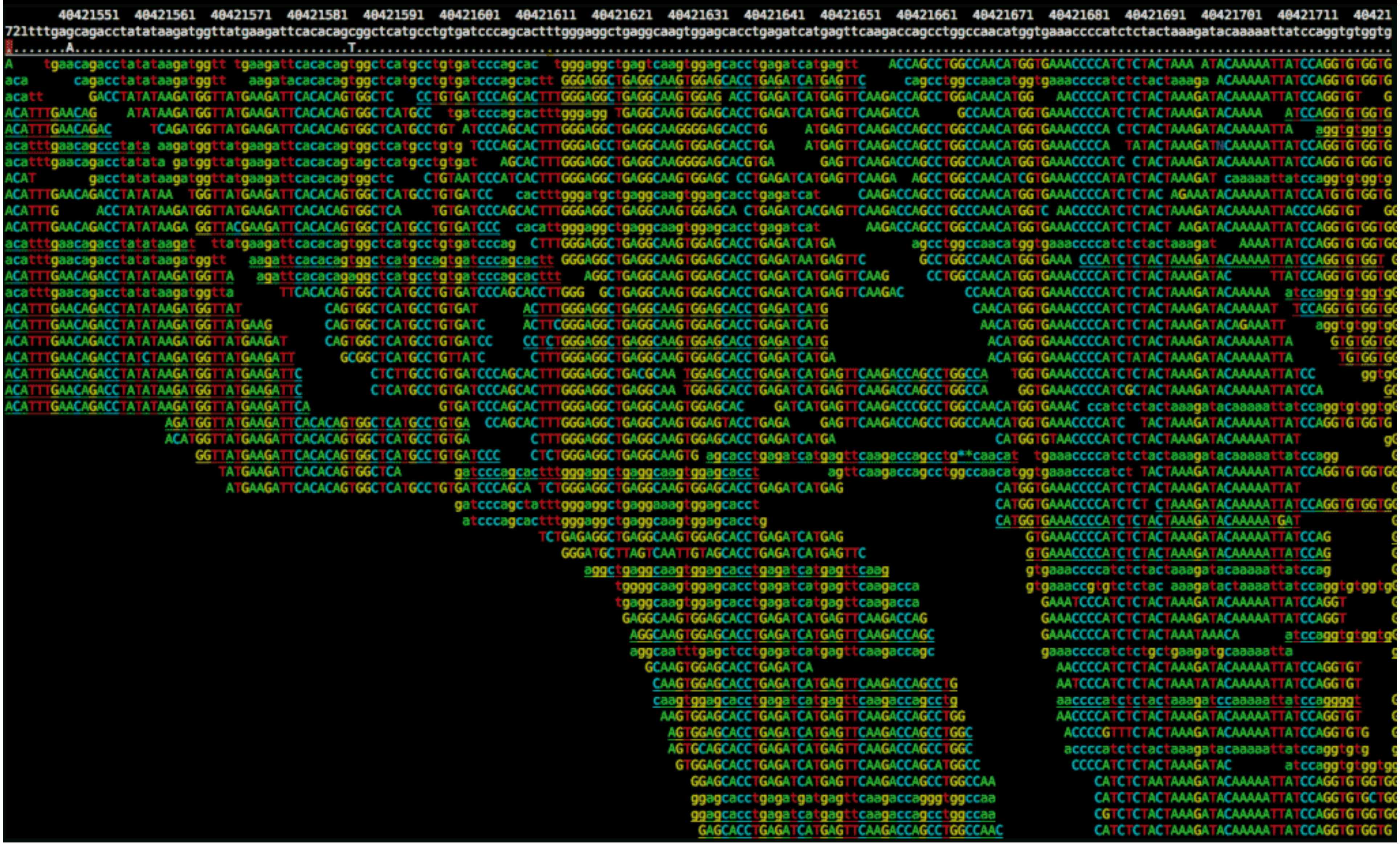


Benison et al., 2006, *Icarus*

Geologic Setting

- Redbeds hosting ephemeral sulfuric acid saline lakes m^2 - km^2 in size
- Sulfates (gypsum, alunite, jarosite), iron oxides (hematite and goethite), phyllosilicates (kaolinite, smectite, palygorskite-sepiolite), halite, etc.
- pHs as low as 1.4
- Salinities as high as 32% TDS

High-throughput Methods



Metagenomics

Johnson et al., 2015, *PLoS ONE*

Sequences associated with sulfur metabolism.

Total reads assigned	Unique taxa assigned	Pipeline	KEGG orthology	Description	Gene	Most specific taxon assignment	Clade
1,536	6	BLAST, nr*	K00958	Sulfate adenylyltransferase	*sat*	*Acidithiobacillus*	*Acidithiobacillia*
						Prokaryotae	*Unclassified*
						Halobacteriaceae	*Halobacteria*
						Leifsonia	*Actinobacteria*
						Sphingobium	*Alphaproteobacteria*
						Mycobacterium	*Actinobacteria*
763	4	BLAST, nr	K00303	Sulfur oxidation protein soxB	*soxB*	*Bacillus*	*Bacilli*
						Actinomycetes	*Actinobacteria*
						Rhizobium	*Alphaproteobacteria*
						Burkholderia	*Betaproteobacteria*
761	7	BLAST, nr	K17230	Fumarate reductase flavoprotein subunit	*fccA*	*Purple photosynthetic bacteria*	*Gammaproteobacteria*
						Prokaryotae	*Unclassified*
						Halobacteriaeaceae	*Halobacteria*

e.g. the SOX Pathway

- Sulfur oxidation pathway found in both photosynthetic and non-photosynthetic sulfur-oxidizing bacteria, thiosulfate oxidized to sulfate via a series of sox genes
- Microbial activity generating acidity, affecting local geochemical conditions

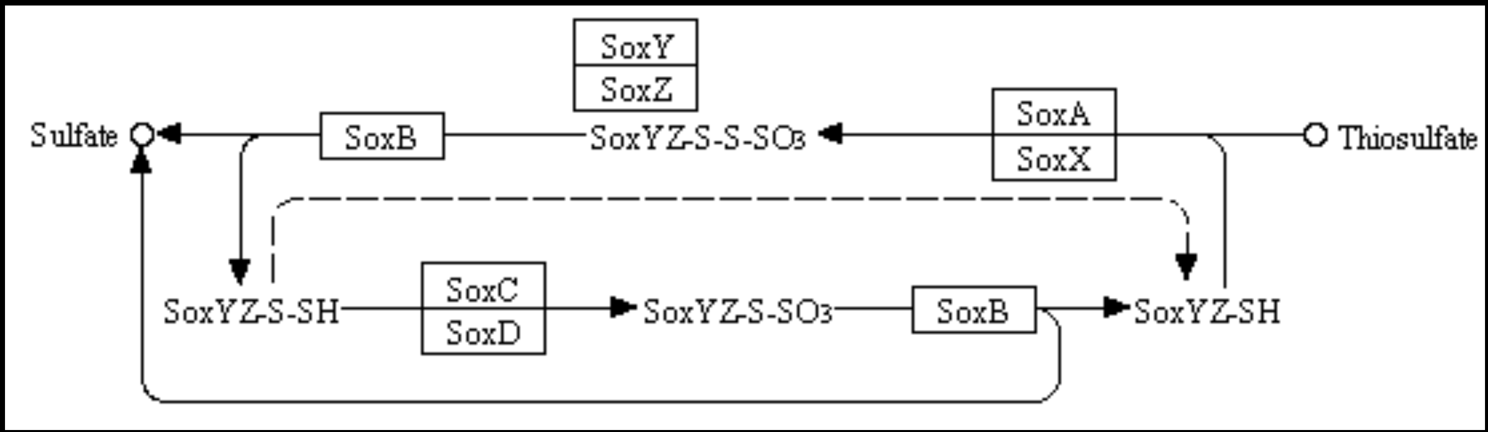
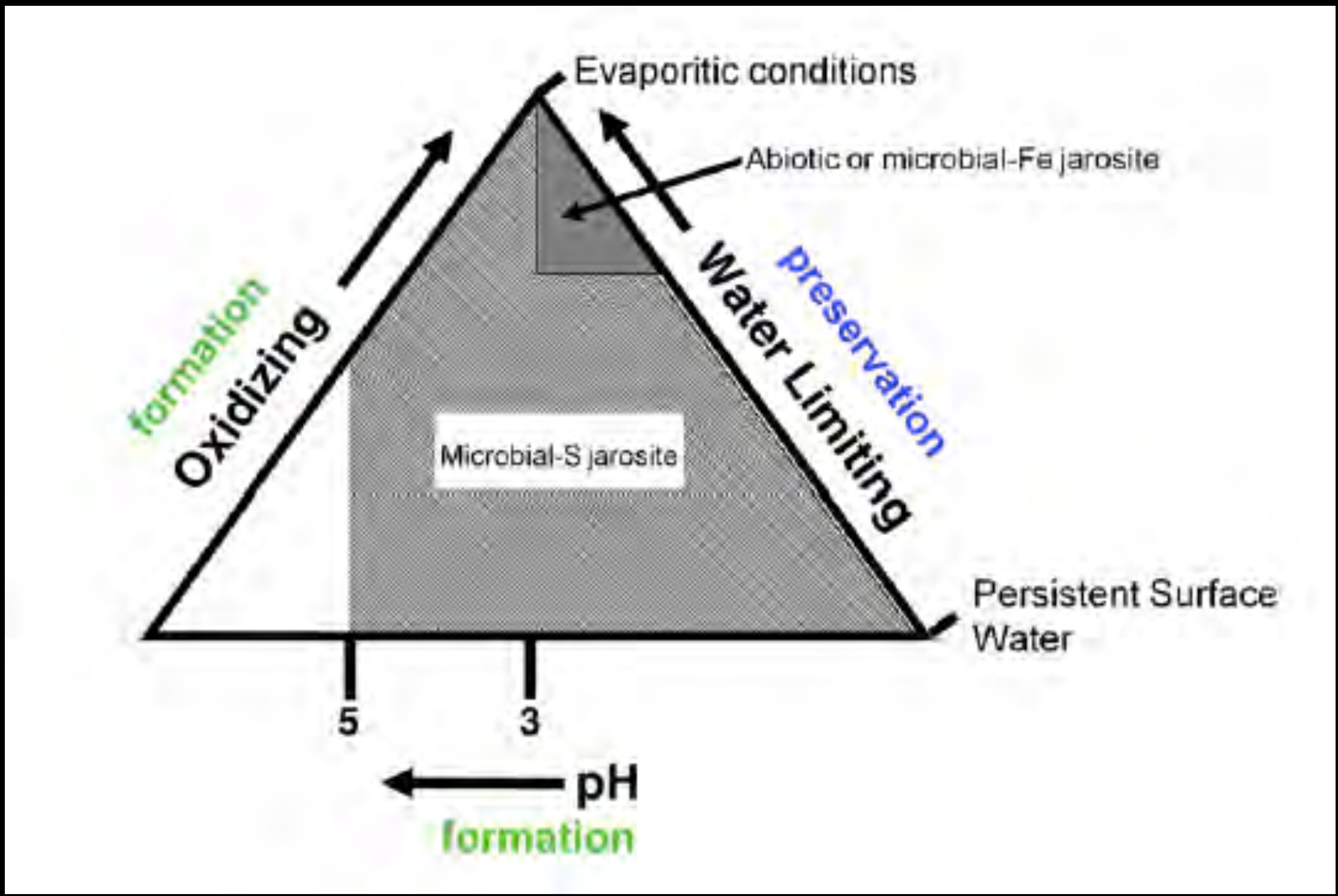
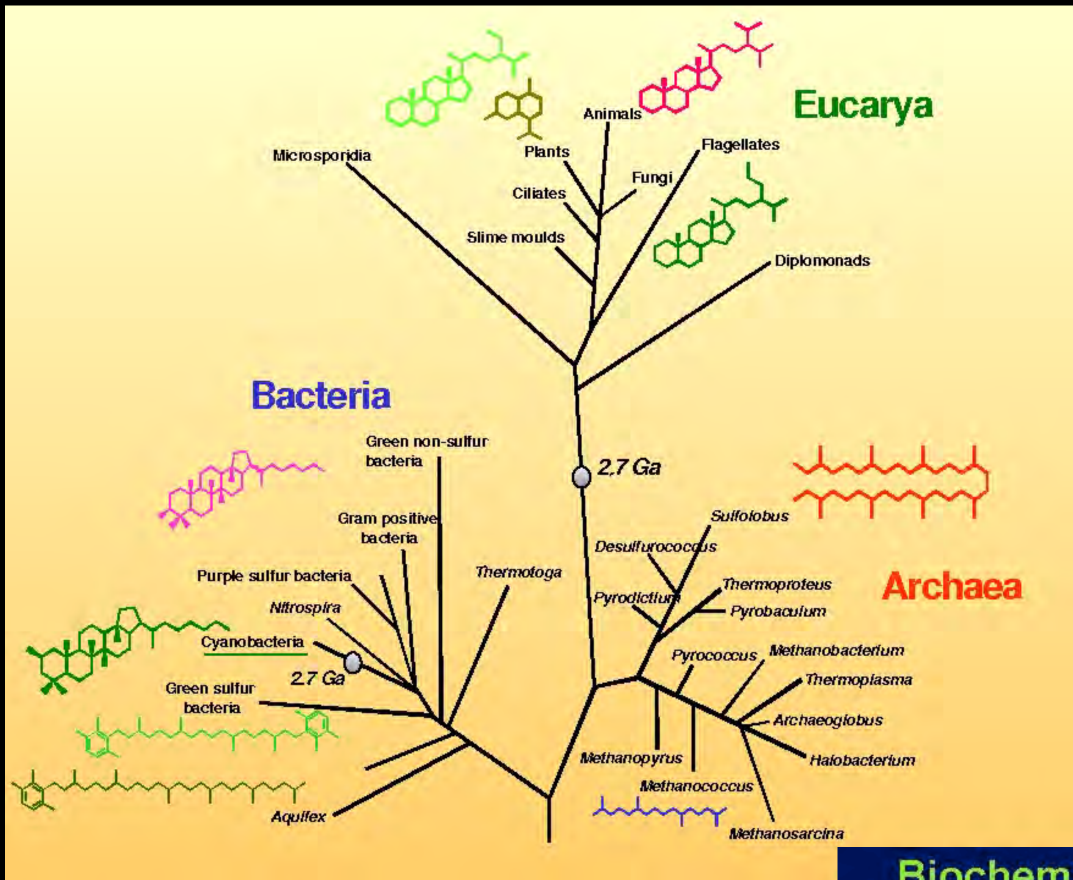


Image: KEGG

Microbially Precipitated Sulfates



Norlund et al., 2010, *Chemical Geology*



Molecular Fossilization

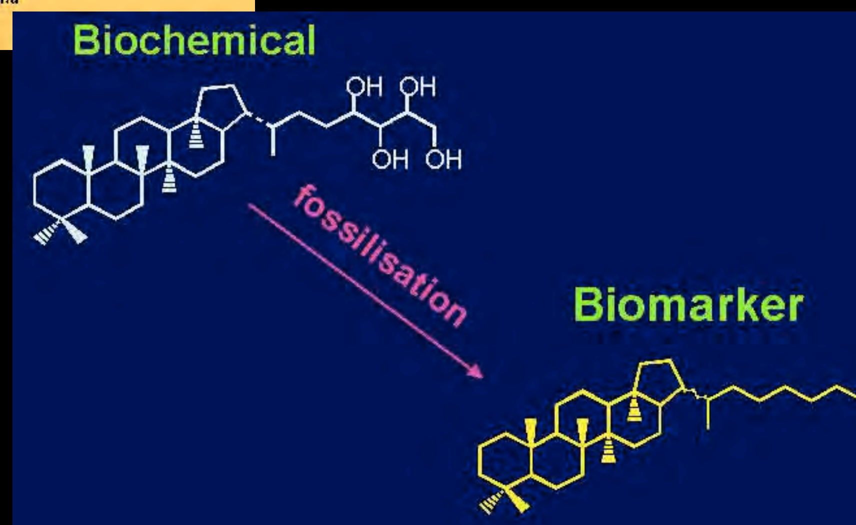
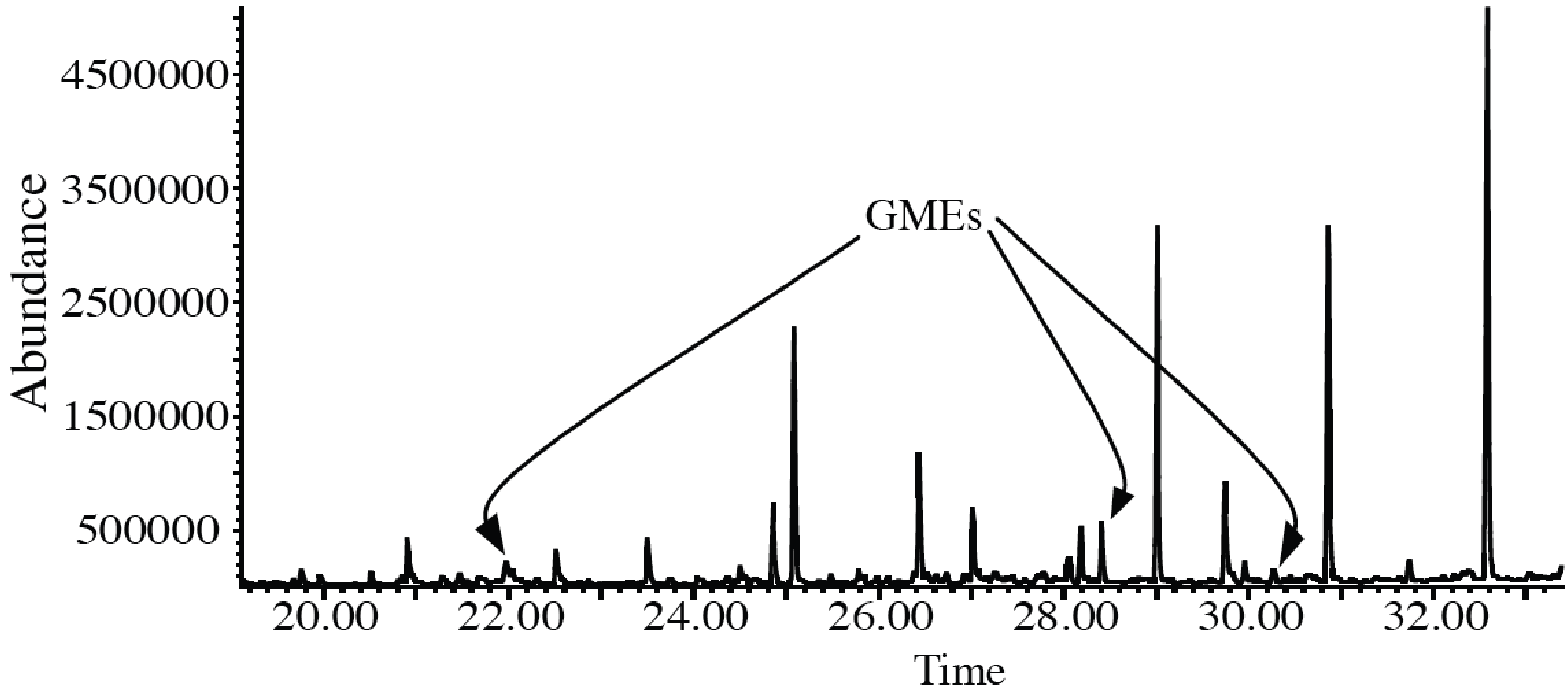
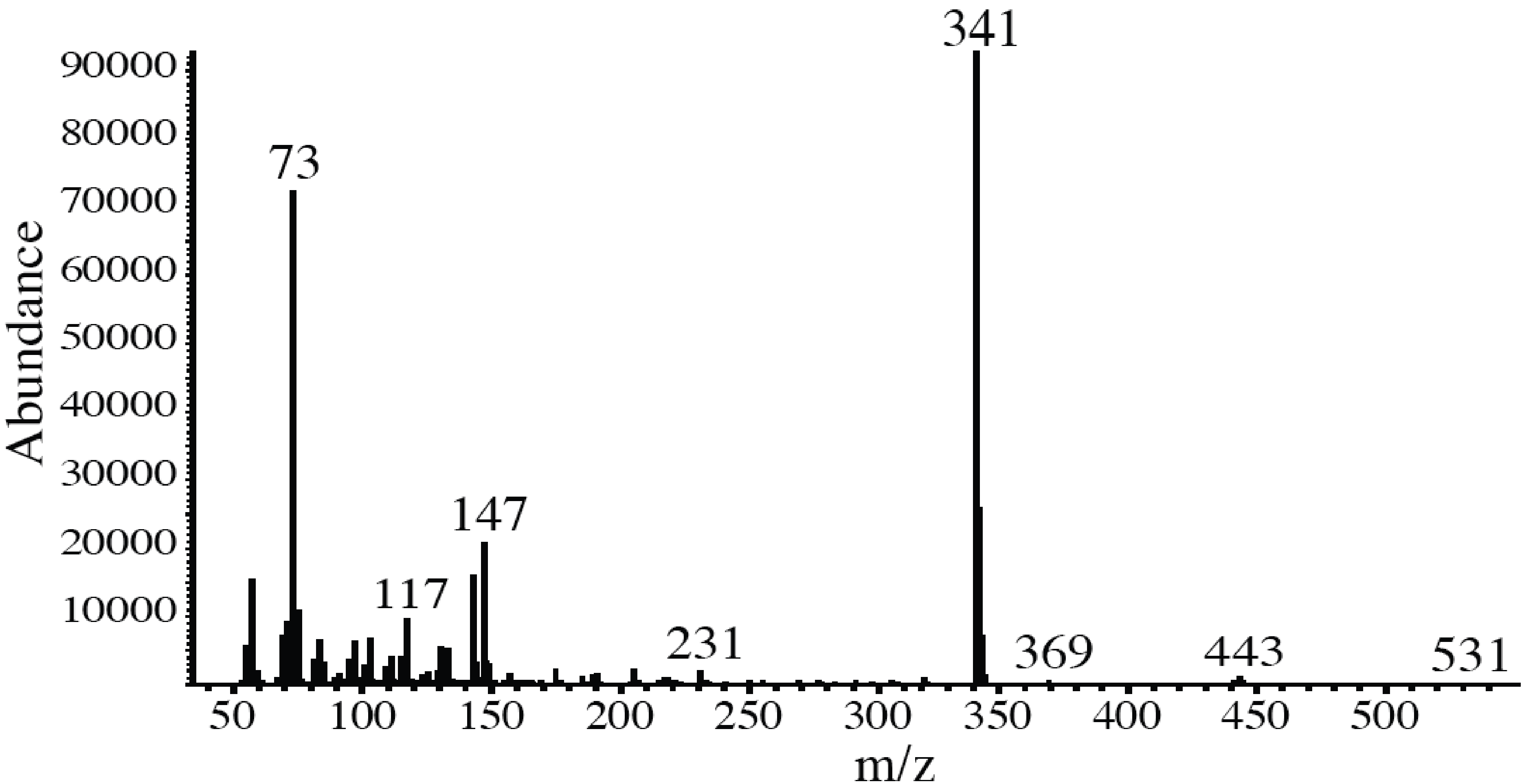


Image: http://www.science.org.au/

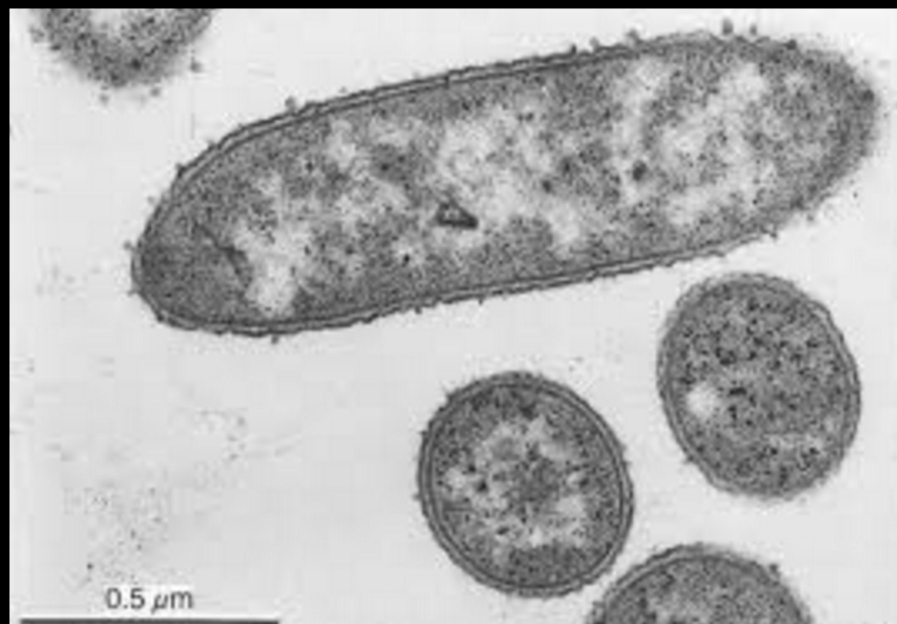
Bacterial glycerol monoethers



1-*O*-alkylglycerol



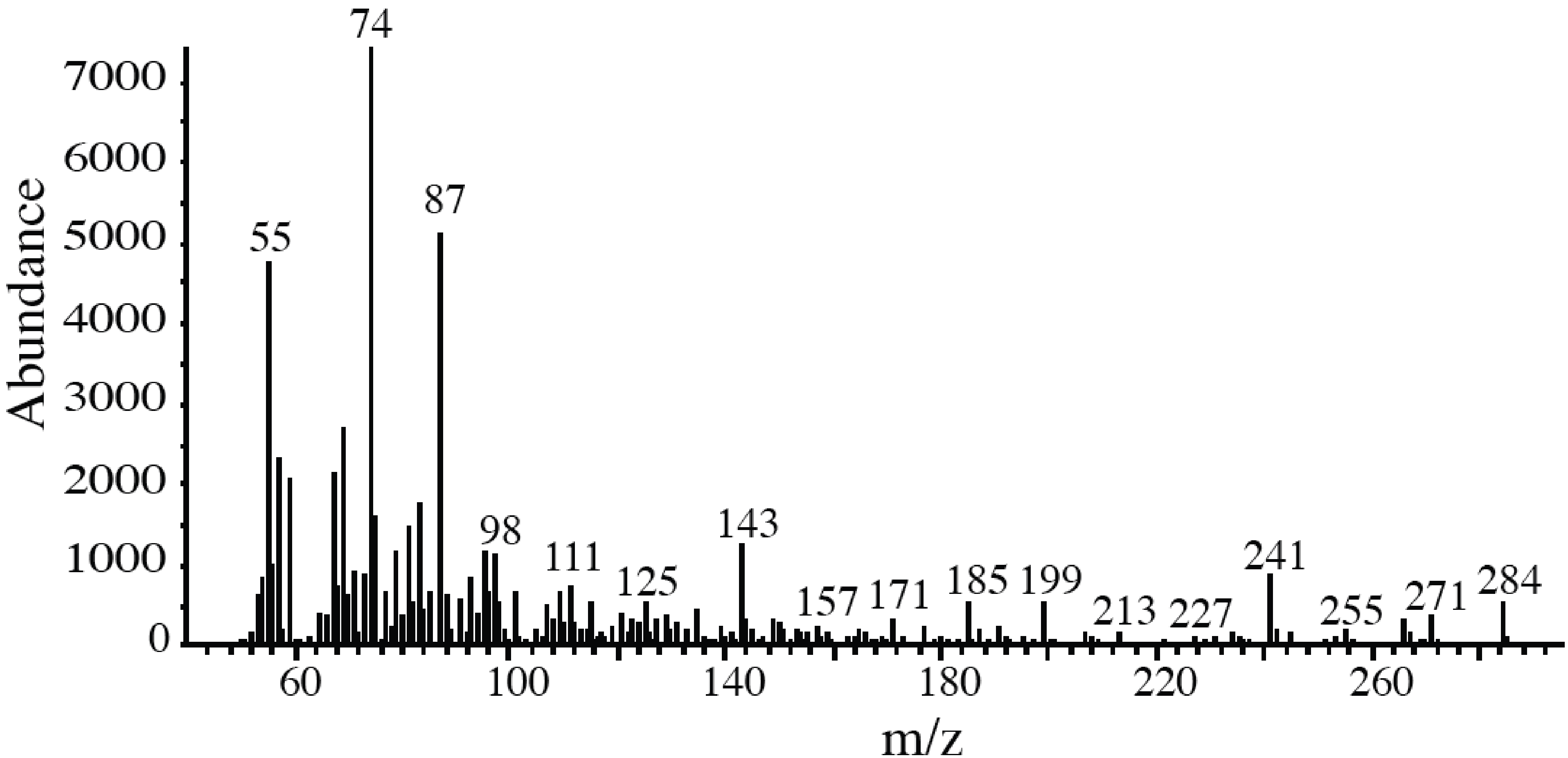
Diagnostic of Microbes



Aquifex, Ammonifex, Thermodesulfobacteria and certain extremophilic δ-proteobacteria

Image: Bergey's Manual of Systematics

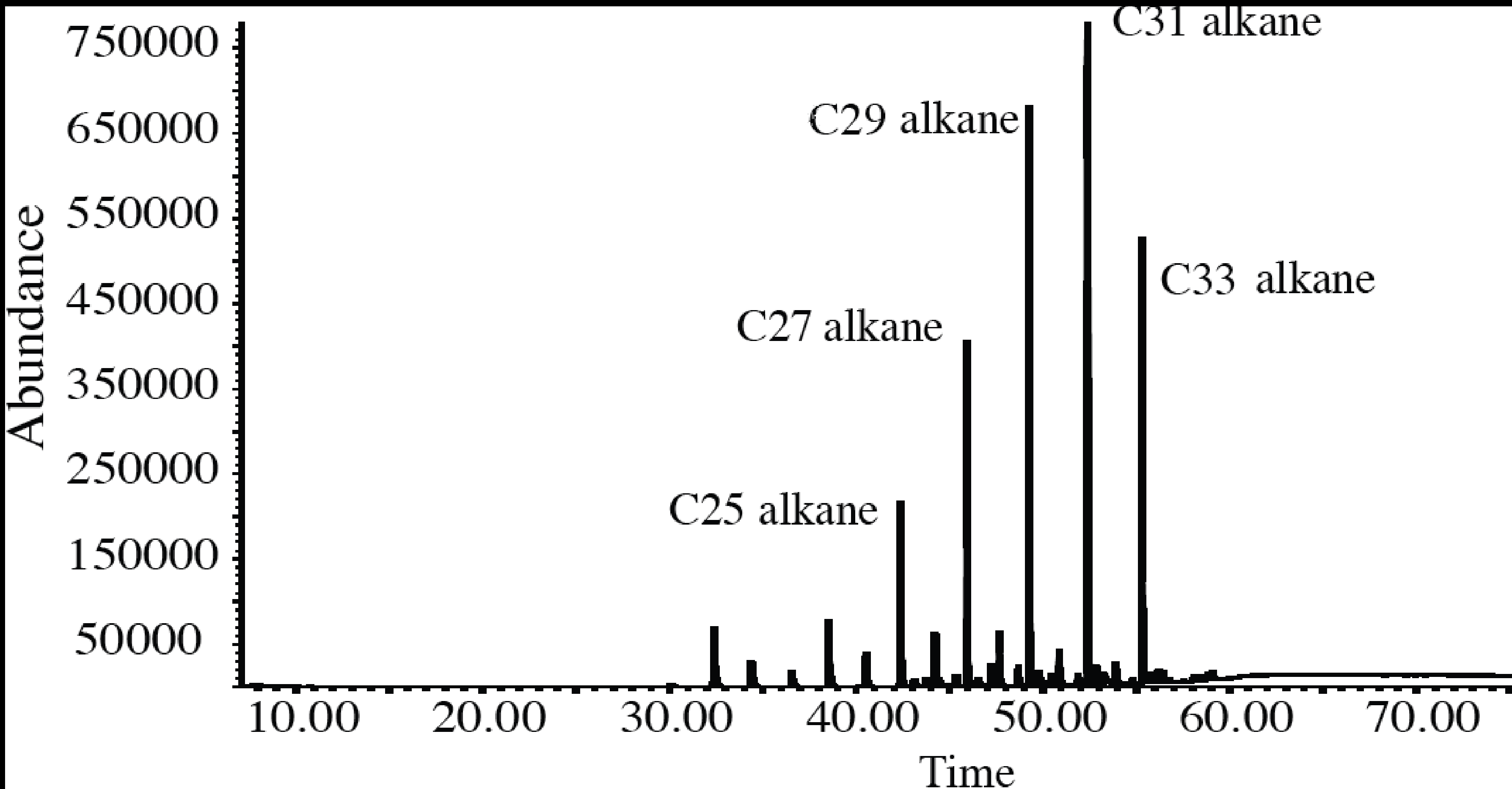
C_{15} and C_{17} iso- and anteiso-branched fatty acids



Sulfate-reducing bacteria, sulfur oxidizing bacteria

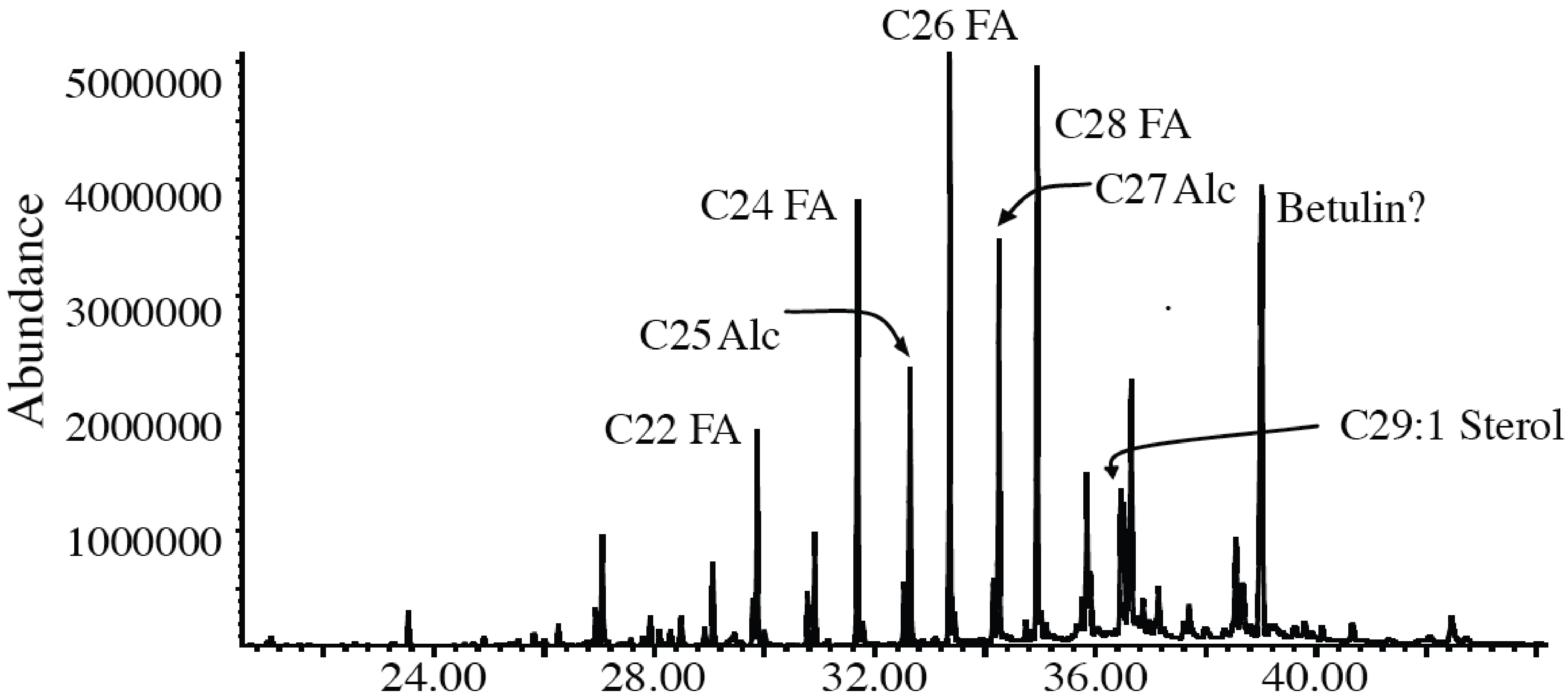
Images: lbl.gov, opencourses.uoa.gr

Long chain *n*-alkanes



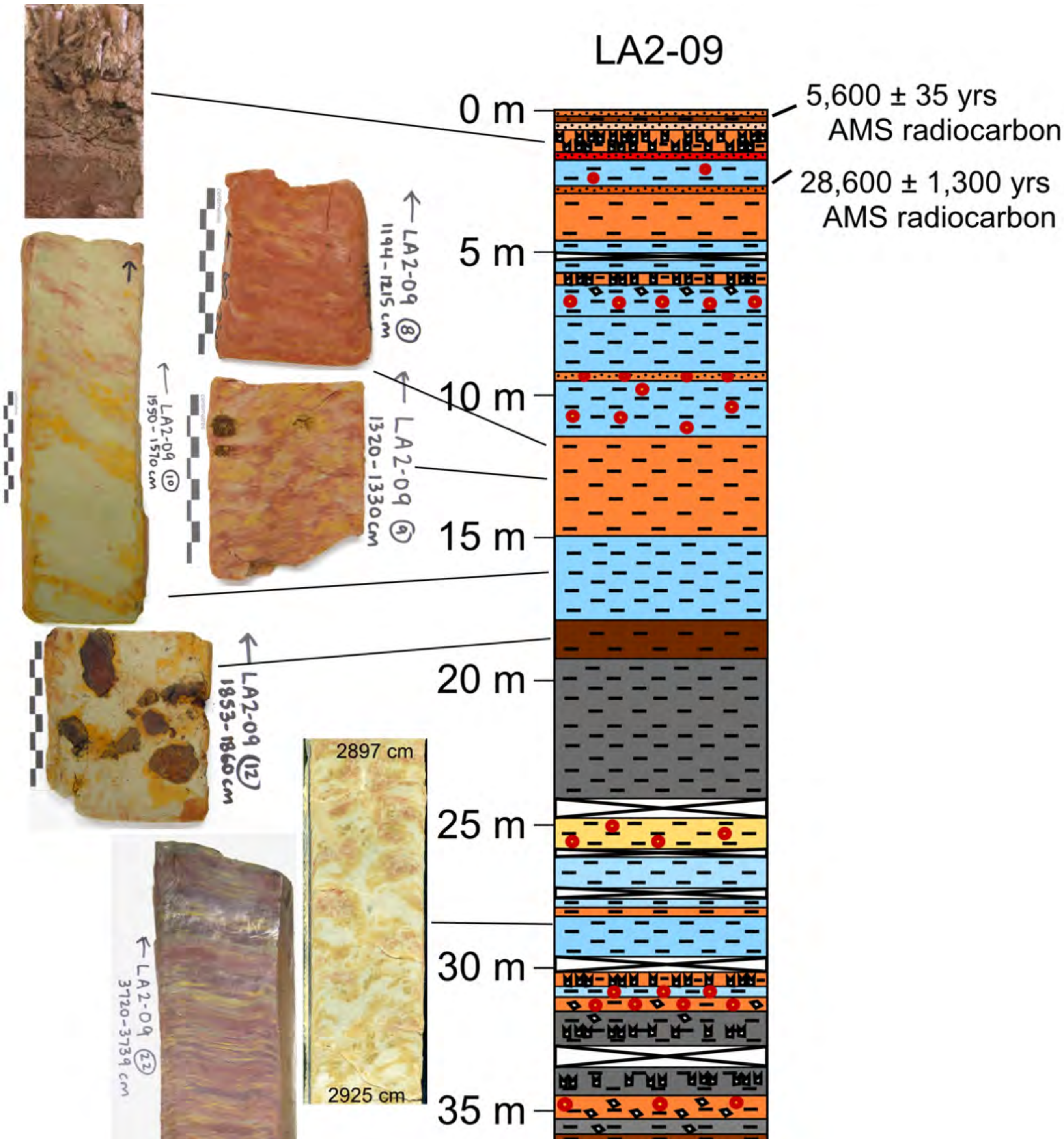
Terrigenous origin, cuticular waxes?

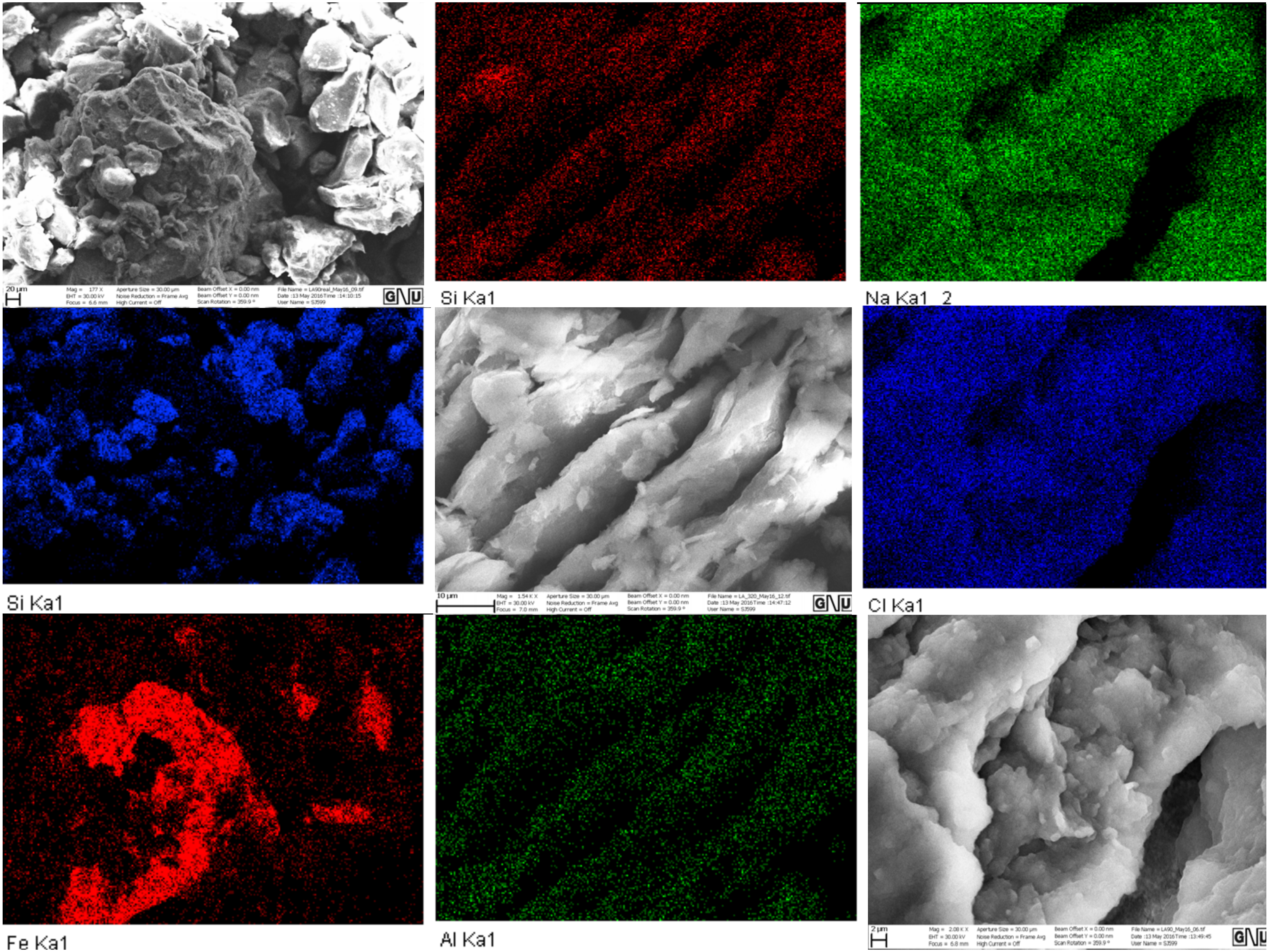
C_{29} Sterols



Also oleanic acid, betulin, higher plant leaf waxes?

What's happening through time?


LA2-09
0 m
5 m
10 m
15 m
20 m
25 m
30 m
35 m
5,600 ± 35 yrs
AMS radiocarbon
28,600 ± 1,300 yrs
AMS radiocarbon
LA2-09 1194-1215 cm 8
LA2-09 1320-1330 cm 9
LA2-09 1550-1570 cm 10
LA2-09 1853-1860 cm 12
2897 cm
2925 cm
LA2-09 3720-3739 cm 22



20 µm
Si Ka1
Na Ka1_2
Si Ka1
10 µm
Cl Ka1
Fe Ka1
Al Ka1
2 µm

Conclusions

- Mineral biosignatures
- Biotic mineral precipitation
  - i.e. jarosite under certain environmental conditions as a biomarker for microbial S oxidation?
- Power of sequencing
- Preservation potential of a range of mineral assemblages, not only clays
- Preservation potential of salts