Comprehensive Investigation of Factors Enhancing Microbially Generated Coal Bed Methane

RPSEA 07122-14

COLORADOSCHOOLOFMINES

EARTH • ENERGY • ENVIRONMENT

Participants

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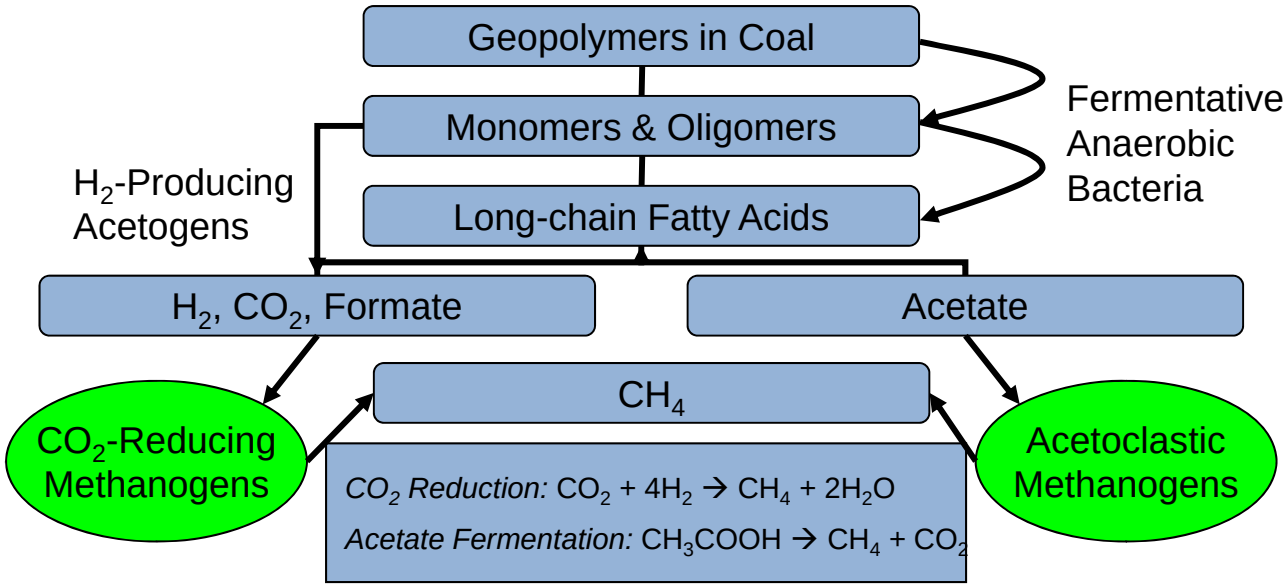
- U.S. Geological Survey
  - S. Harris
- Industrial partners
  - Coleman Oil and Gas
  - Pinnacle Gas Resources
  - Pioneer Natural Resources

Overview

- Much coal bed methane is microbial in origin.
- Enhancement of microbial methane production from coal has shown promise.
- Fundamental factors influencing methane generation from coal are not well understood.



Adapted from Flores R. M.,et al., 2008. *Int. J. Coal Geol.* **76**, 52-75.

Potential Impact

- Previous laboratory experiments showed that methane associated with coal can be increased from 60 SCF/ton to over 300 SCF/ton.
- Example: if 1% of the coal in the Powder River Basin could be converted to methane, approximately 30 TCF of gas would be produced.
- Gas could be produced without dewatering the coals.

$\Rightarrow$ Substantial energy reserve with a relatively minor environmental impact

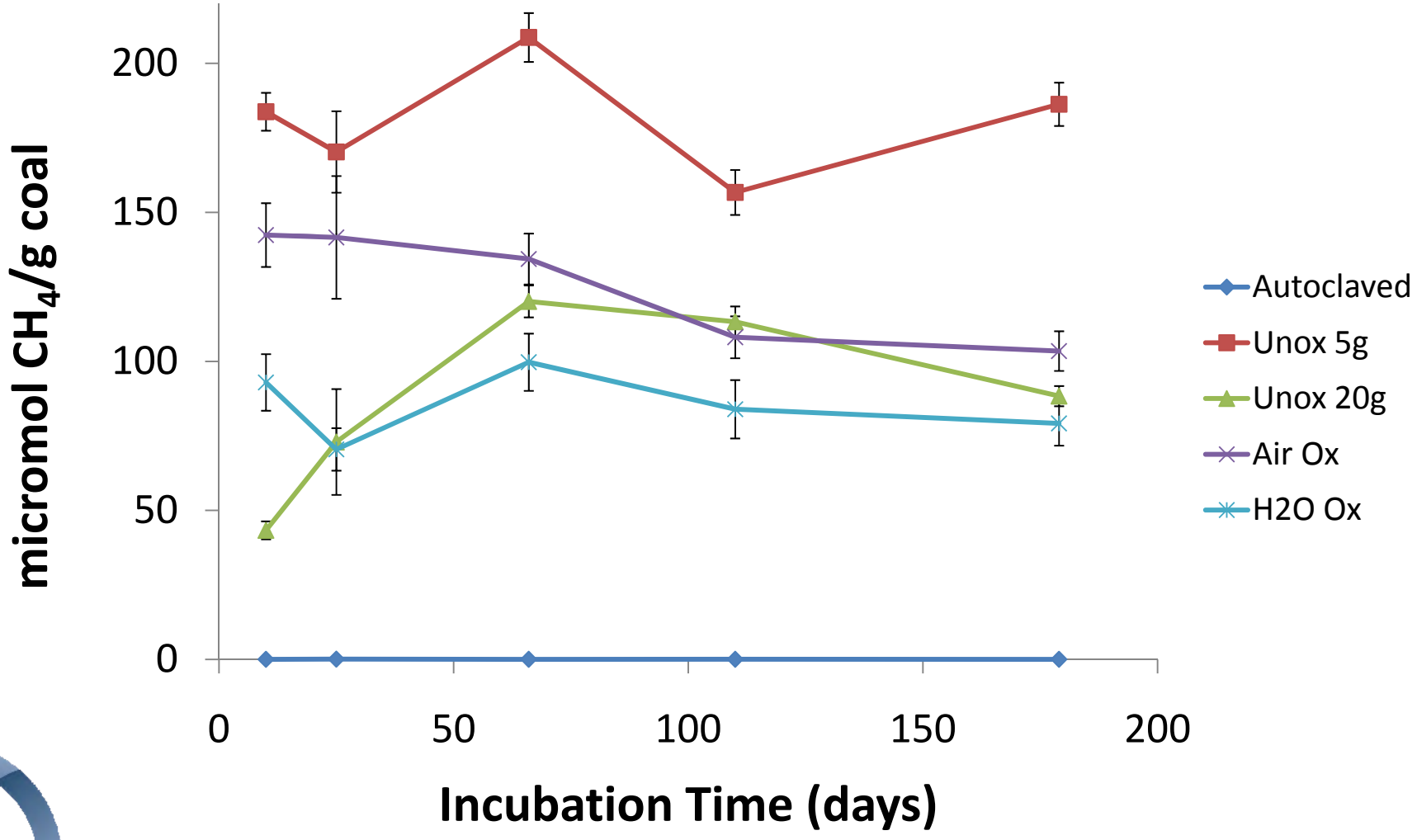
Project Objectives and Goals

- Identify chemical constituents of coal that are bioconverted
- Identify organisms associated with biogas generation from coal
- Characterize the influence of culture growth amendments and conditions on biogas generation
- Determine impacts of coal pre-treatment on levels of biogas precursor compounds, microbial communities, and ultimate methane generation
- Determine the rate limiting step(s) of microbial methane generation from coal
- Capture chemical and microbial dynamics observed in a computer model, to allow comparisons of different incubation scenarios

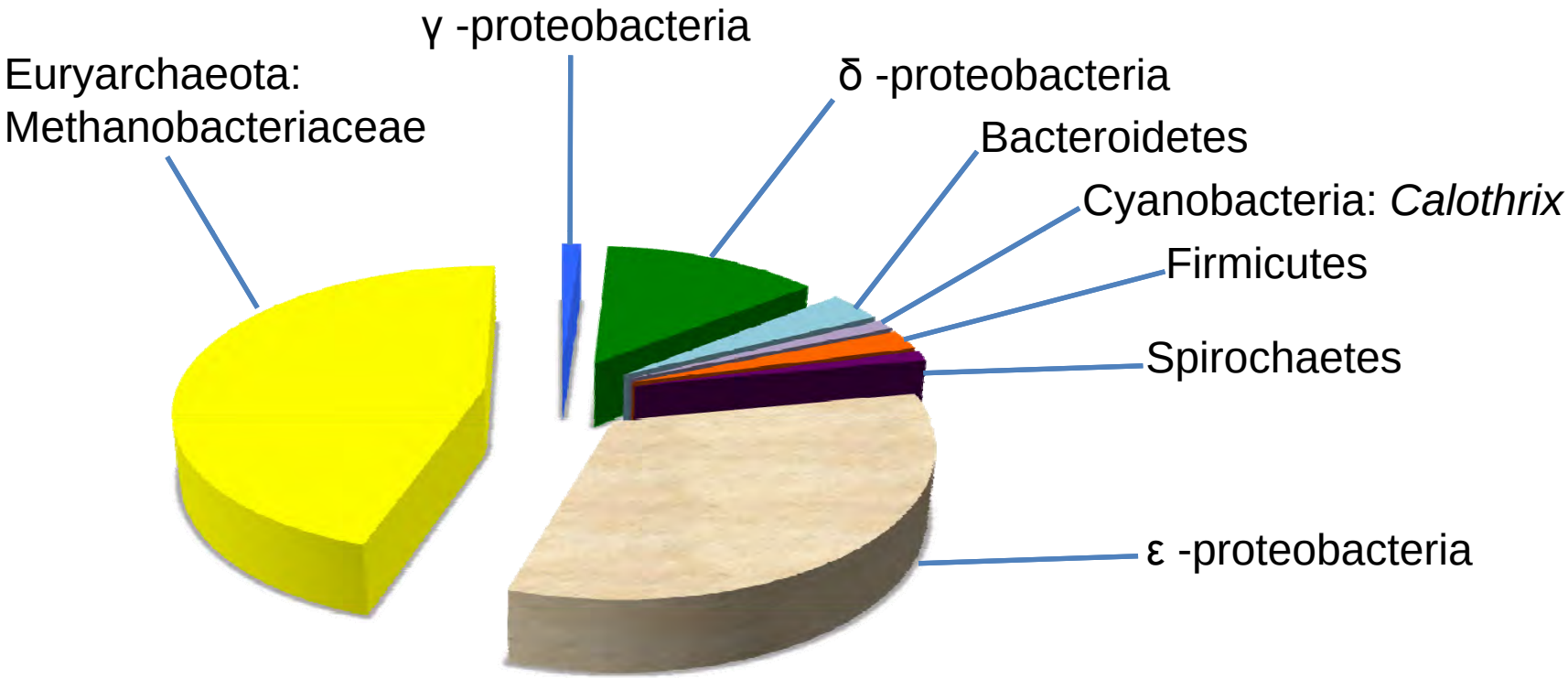
Progress to Date

- Coal samples collected
- Incubations established, methane generated
- Microbial analyses initiated
- Analyses of soluble coal constituents, coal solvents conducted

Methane Production: oxidized vs. unoxidized coal

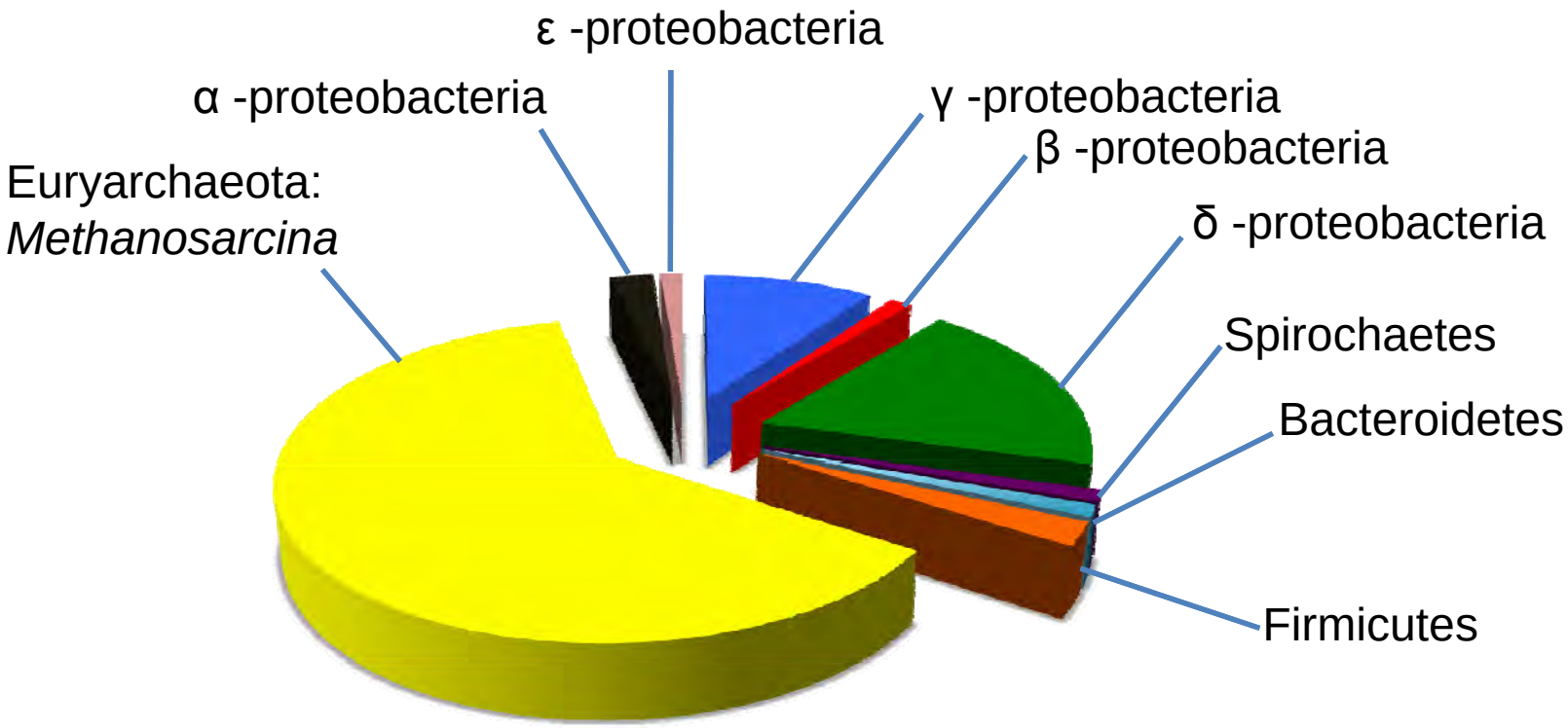


Microbial Community: enrichment



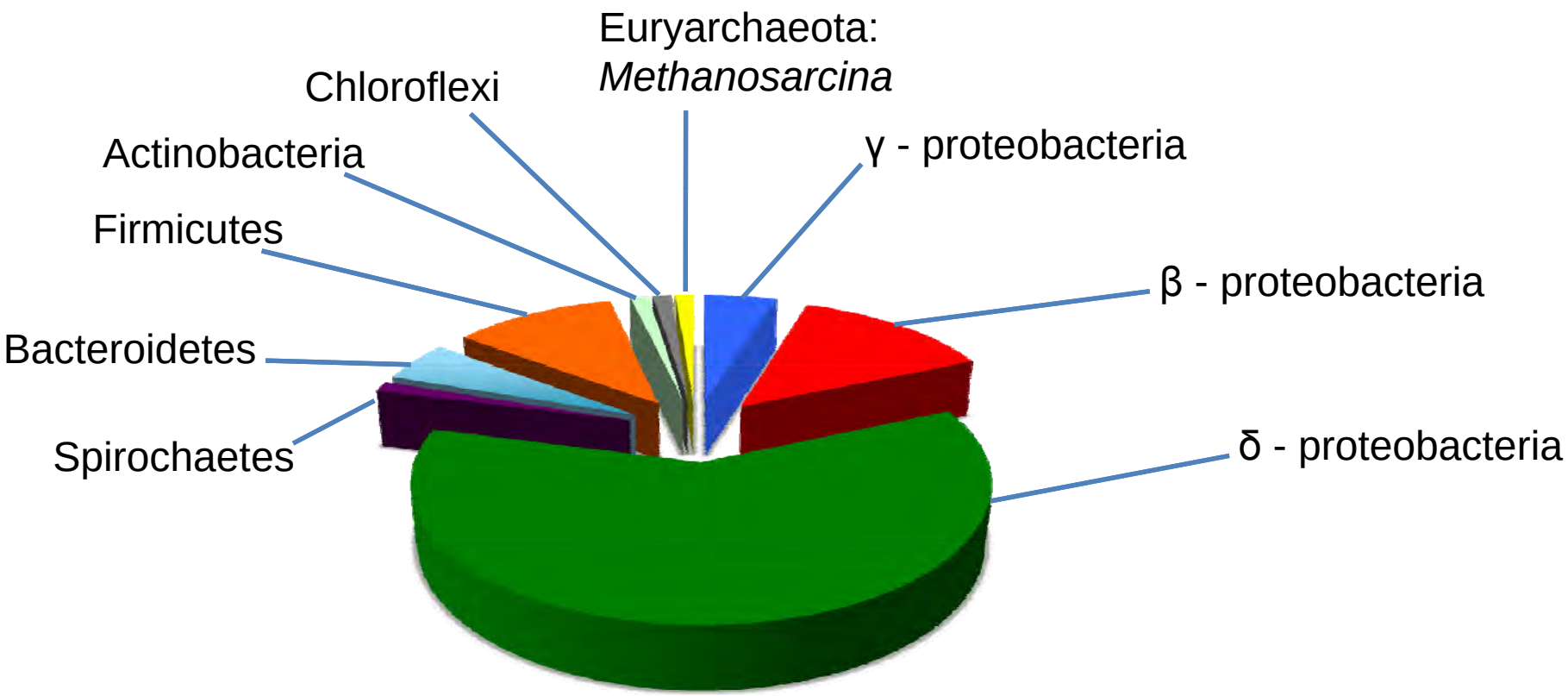
Acetobacterium, Desulfovibrio, Pelobacter, Sulfospirillum, Pseudomonadaceae

Microbial Community: high methane

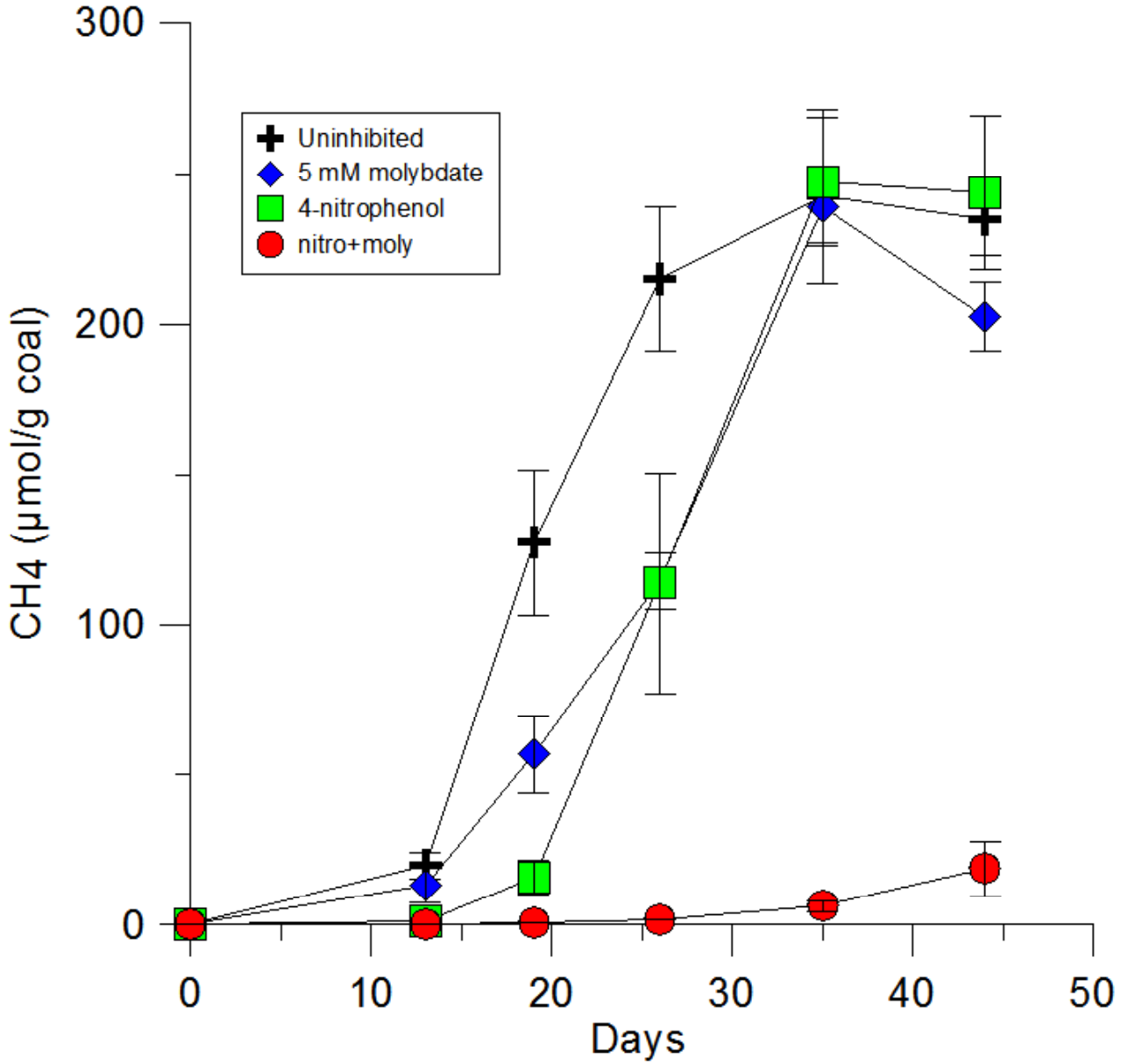


Acetobacterium, Bradyrhizobiaceae, Delftia, Desulfovibrio, Desulfuromonas, Pelobacter, Sulfurospirillum, Psychrobacter, Pseudomonas, Acidaminobacter

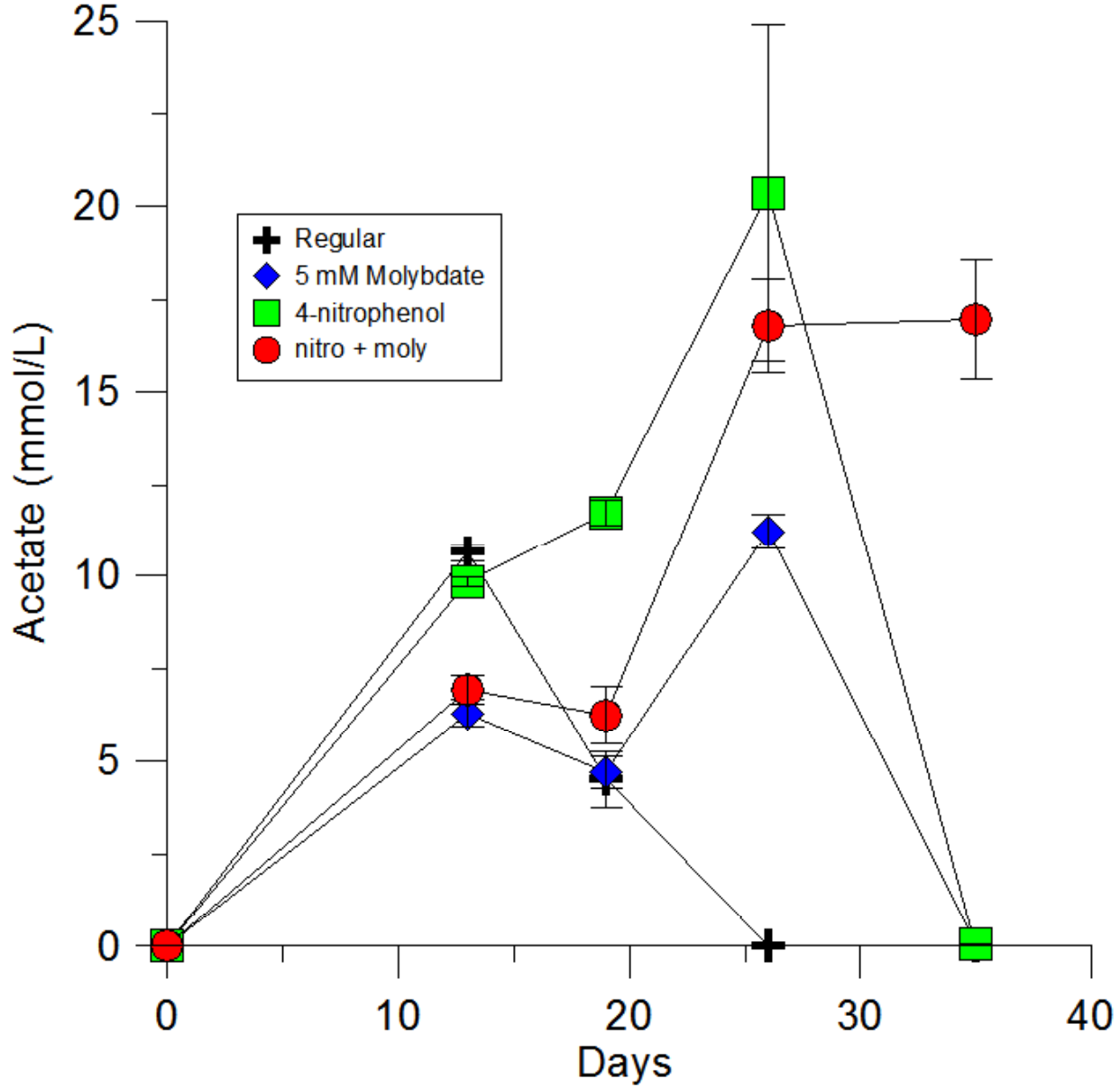
Microbial Community: low methane



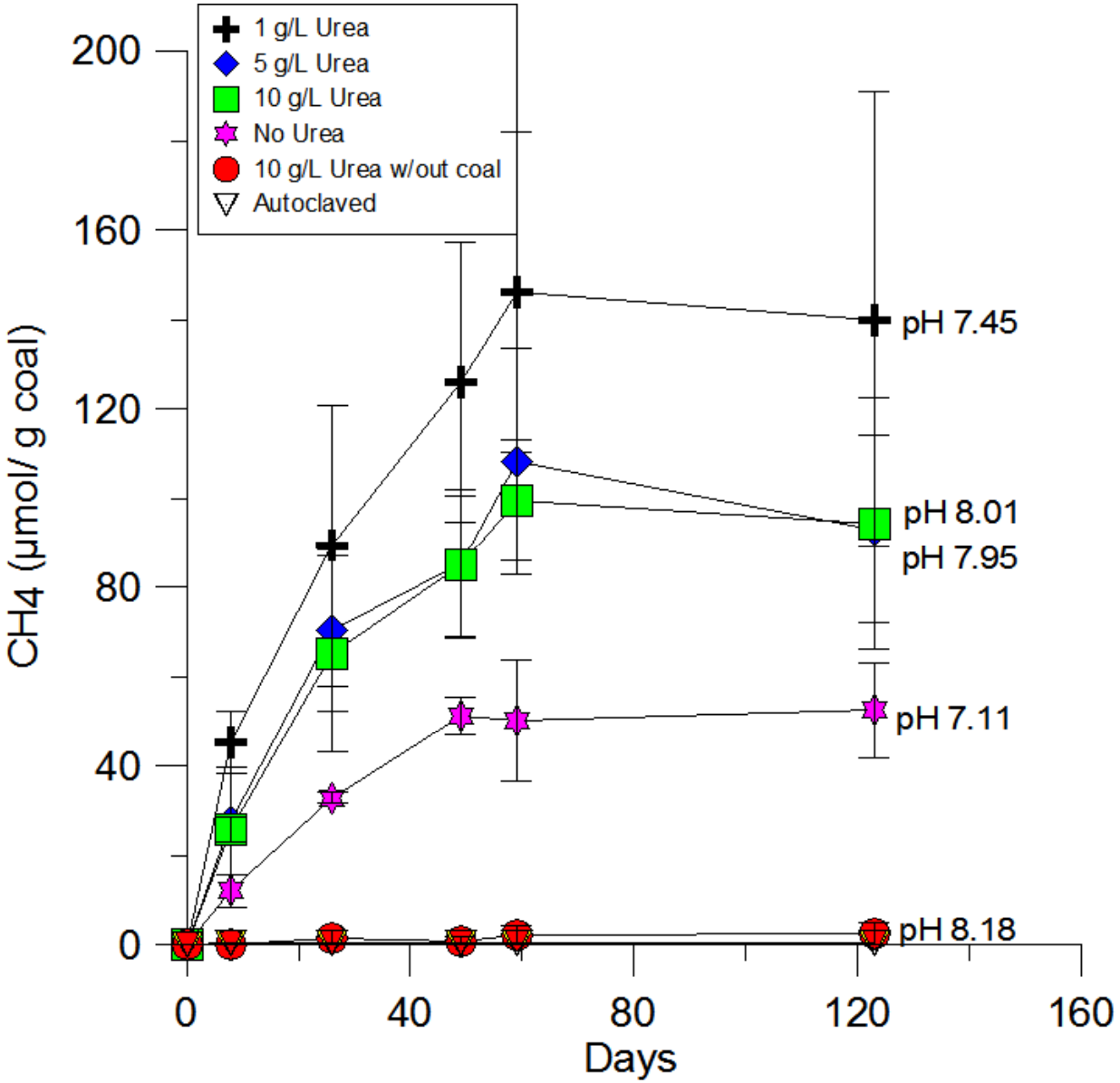
Inhibition Experiments: methane



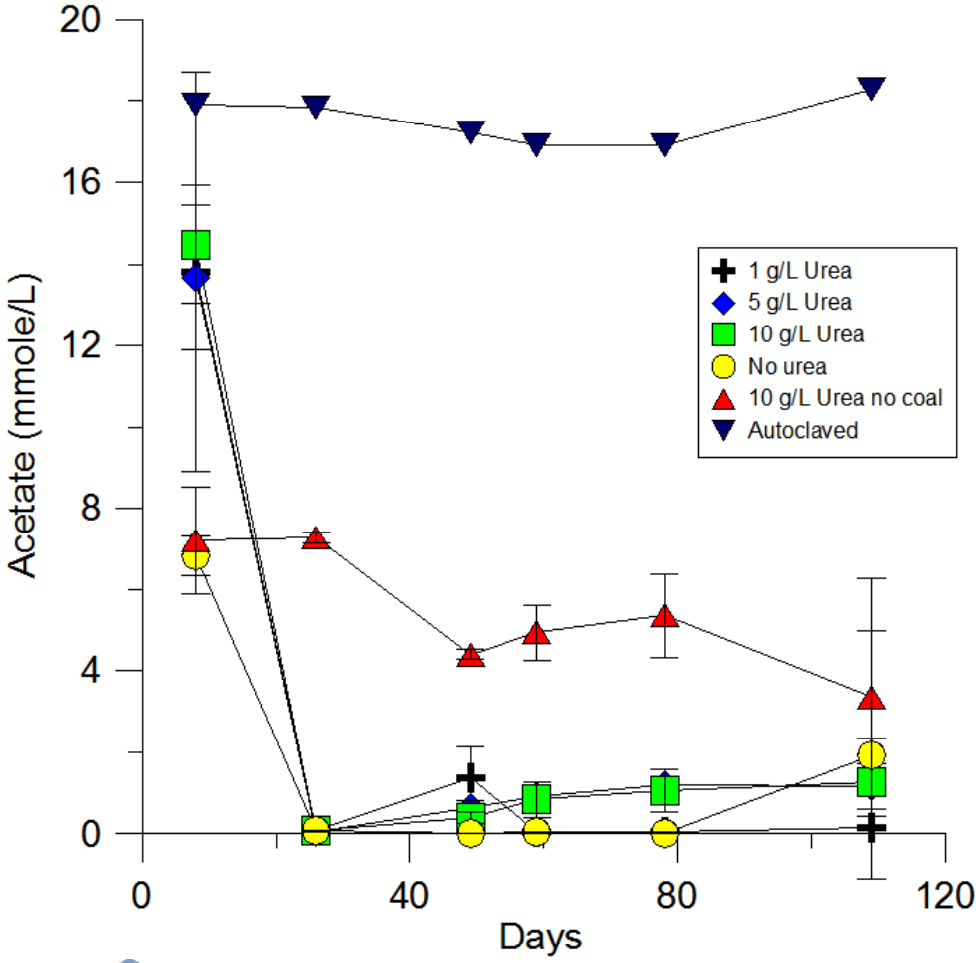
Inhibition Experiments: acetate

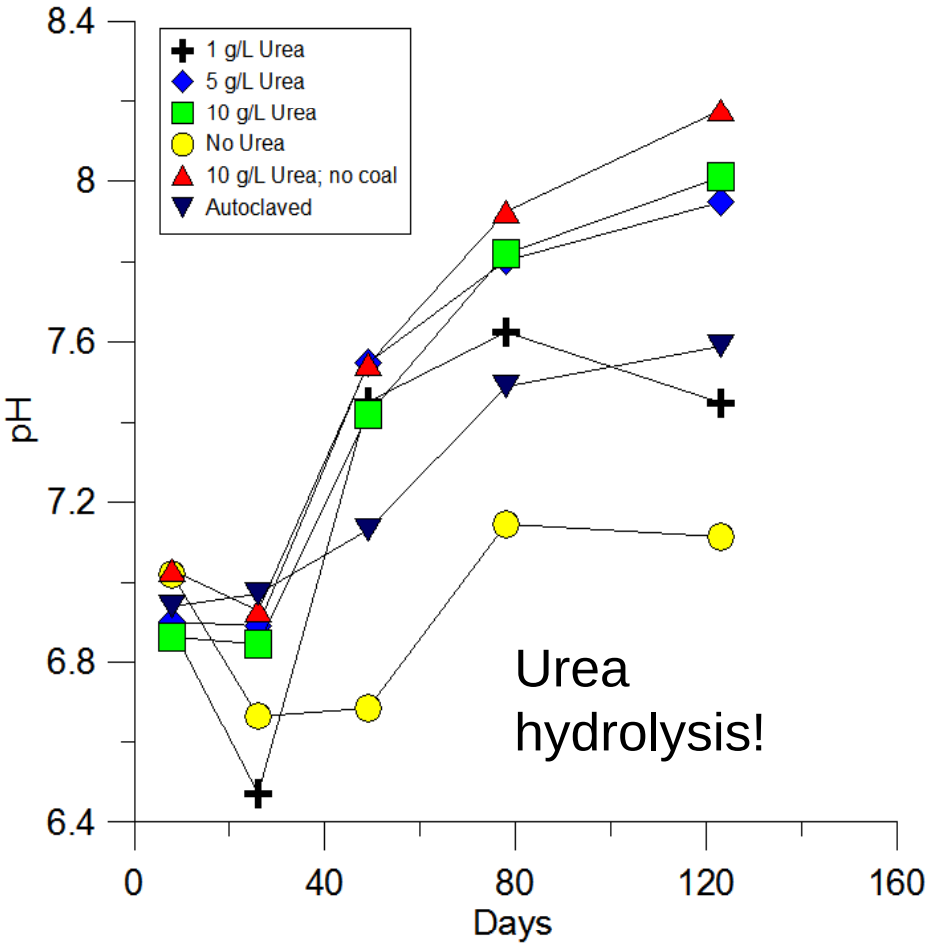


Urea Amendment: methane



Urea Amendment: acetate

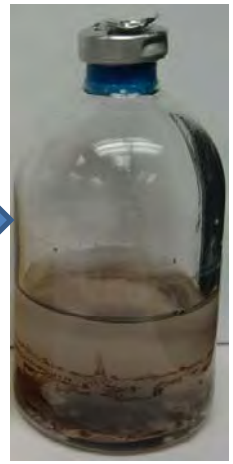




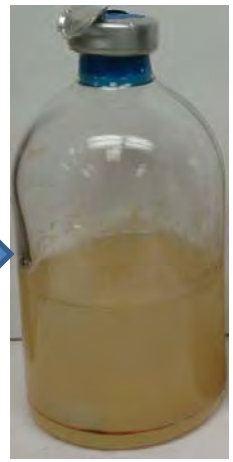
Coal Characterization: asphaltene and maltene extracts

$CHCl_3$ extract

Asphaltene
polyaromatic
MW > 500

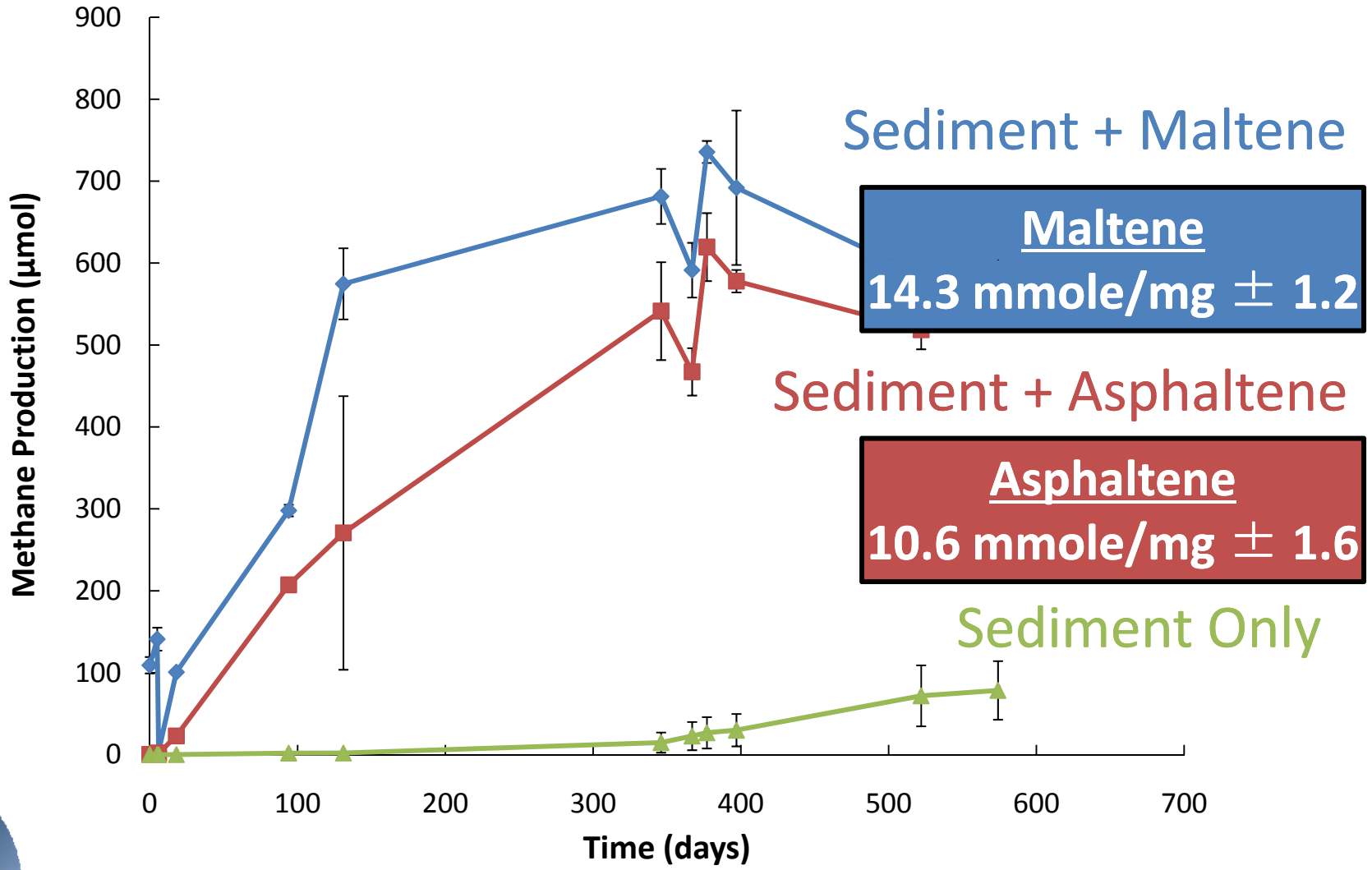


Maltene
saturated ≤ C_{40}
aromatic & *NOS*

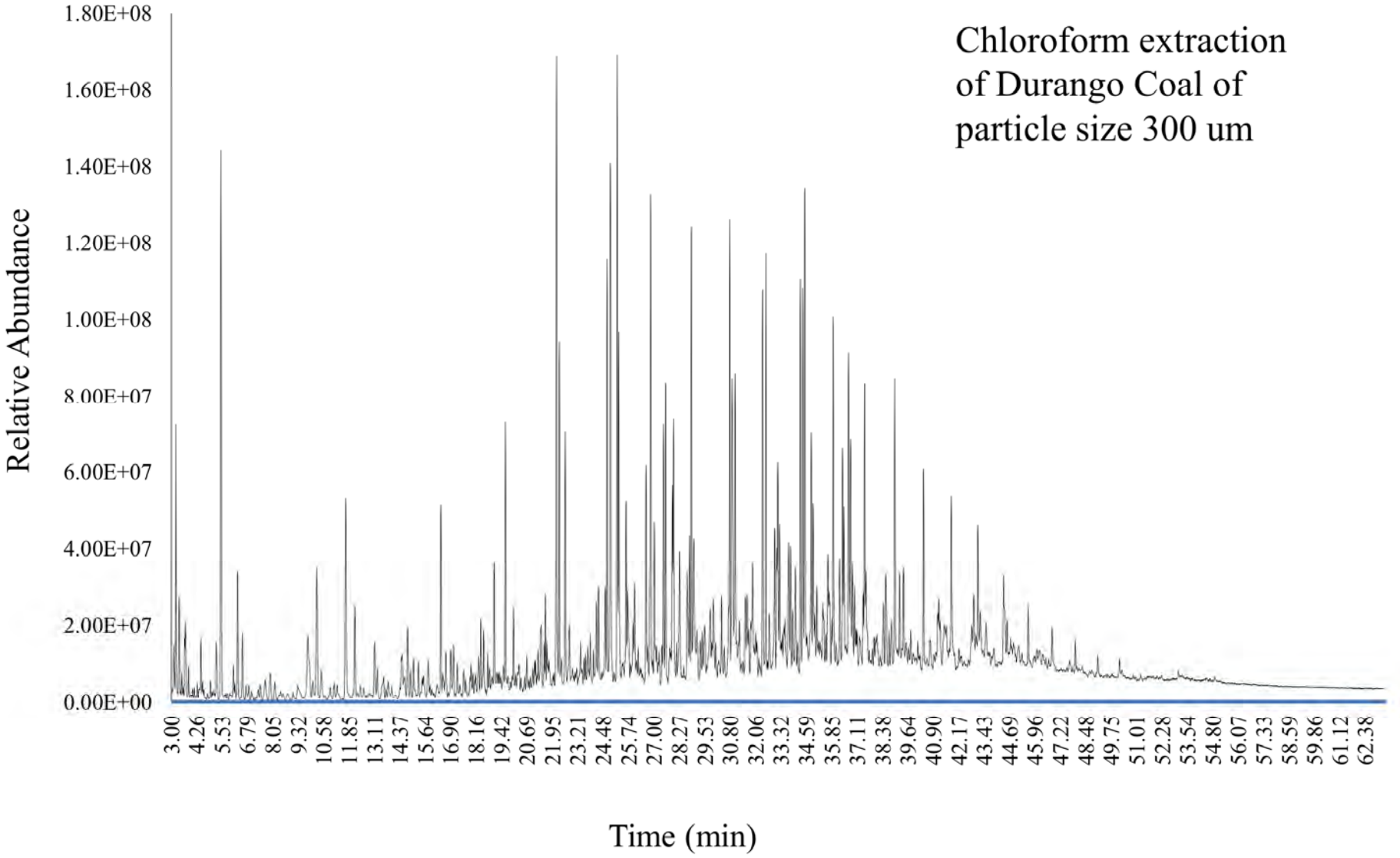


Anoxic creek sediment added to bottles

Methane Production



GCMS Characterization



Compounds Identified (tentative)

RT	Aliphatic Compound
6.52	Nonane
12.11	Decane
12.12	3 Ethyl-3 methylheptane
15.03	2-Methyl-Decane
16.40	Undecane
18.52	2-Methyl-Undecane
19.60	Dodecane
20.00	2,6-Dimethyl-Undecane
21.36	2-Methyl-Dodecane
21.59	2,3,7-Trimethyl-Octane
22.28	Tridecane
24.66	Tetradecane
26.83	Pentadecane
28.86	Hexadecane
30.76	Heptadecane
40.40	Tricosane
41.78	Tetracosane

RT	Aromatic Compounds
5.46	o-xylene
6.29	m-xylene
9.78	1-ethyl-2-methyl-benzene
10.22	1,2,3-Trimethyl-benzene
19.05	Naphthalene
22.14	2-methyl-Naphthalene
24.23	Biphenyl
25.17	2-methyethyl-Naphthalene
26.6	Diphenylmethane
28.65	Fluorene
35.65	Fluoranthene
41.16	Chrysene
42.91	Benz(a)anthracene

RT	Heteroatomic Compound
29.96	Benzidine
31.03	N-2-Fluorenylacetamide
33.7	4,4'-methylene bis - Benzamine
34.5	Bitoscante
36.37	2,4-bis (1,1-dimethylethyl) Phenol

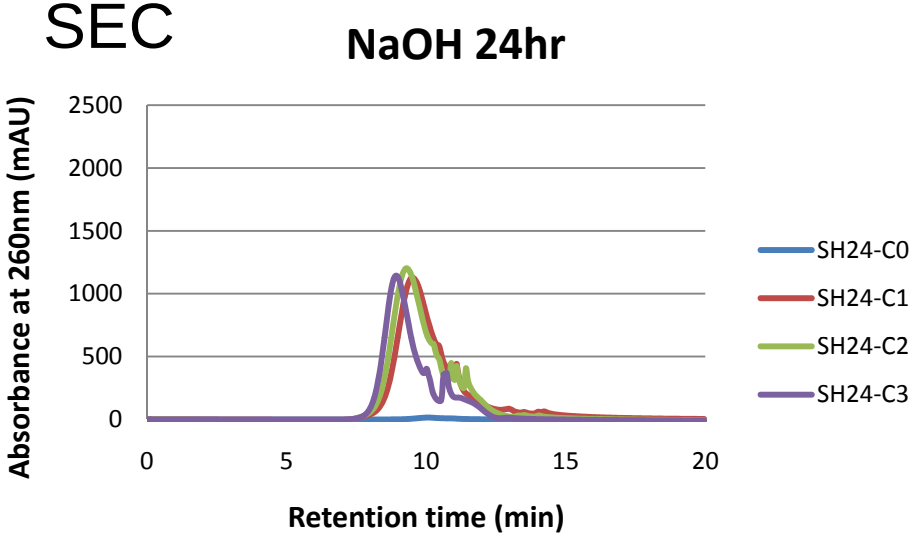
Chemical Pre-treatment

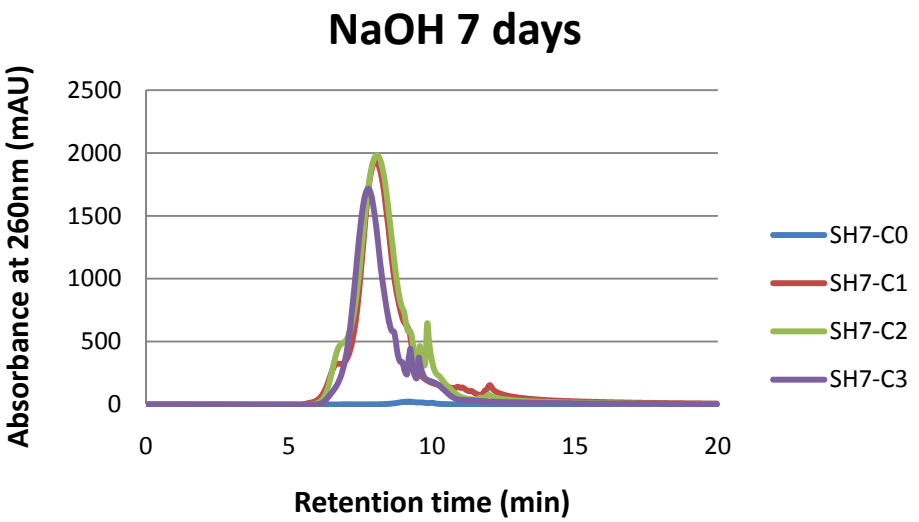
Chemicals	C0	C1 (M)	C2 (M)	C3 (M)
NaOH (SH)	0	0.13	0.67	1.33
HNO_3 (NA)	0	0.33	1.67	3.33
H_2O_2 (HP)*	0	0.032	1.62	3.24
$KMnO_4$ (PP)	0	0.01	0.05	0.1

*Fe(II) at a final concentration of 0.027M was added as catalyst

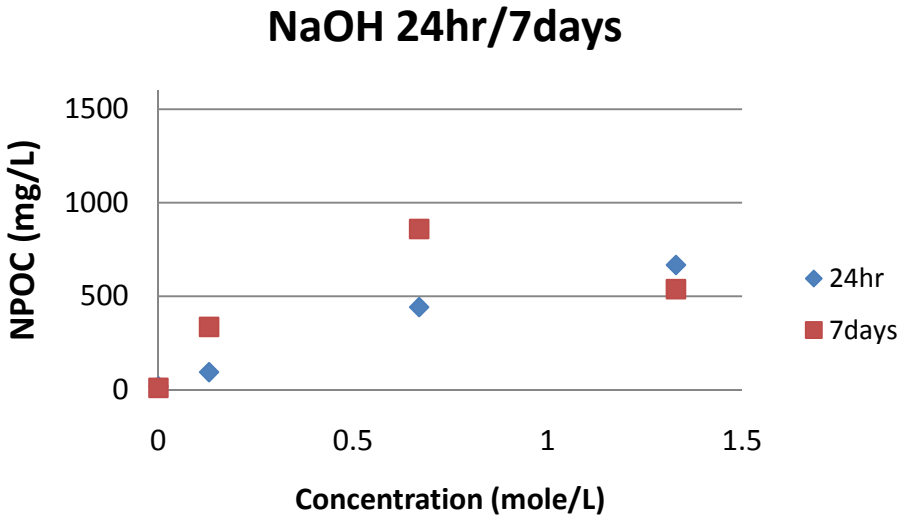
Sodium hydroxide

SEC



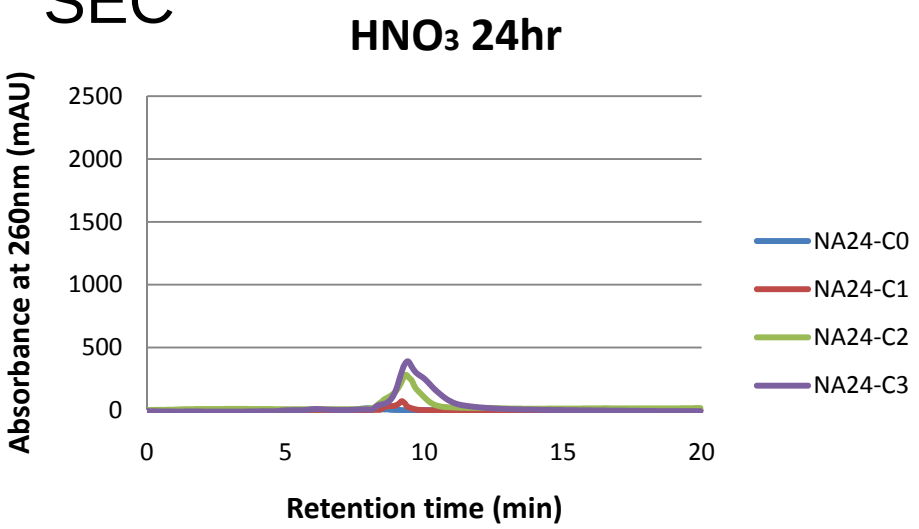


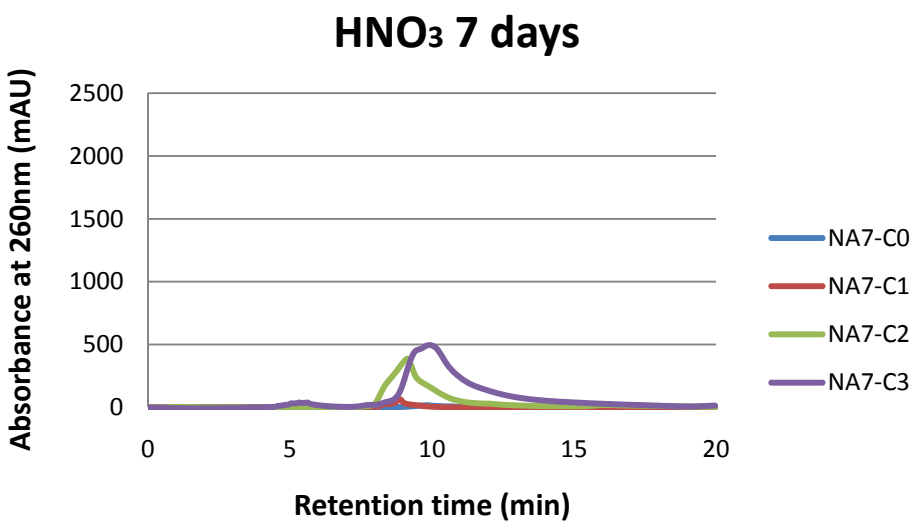
NPOC



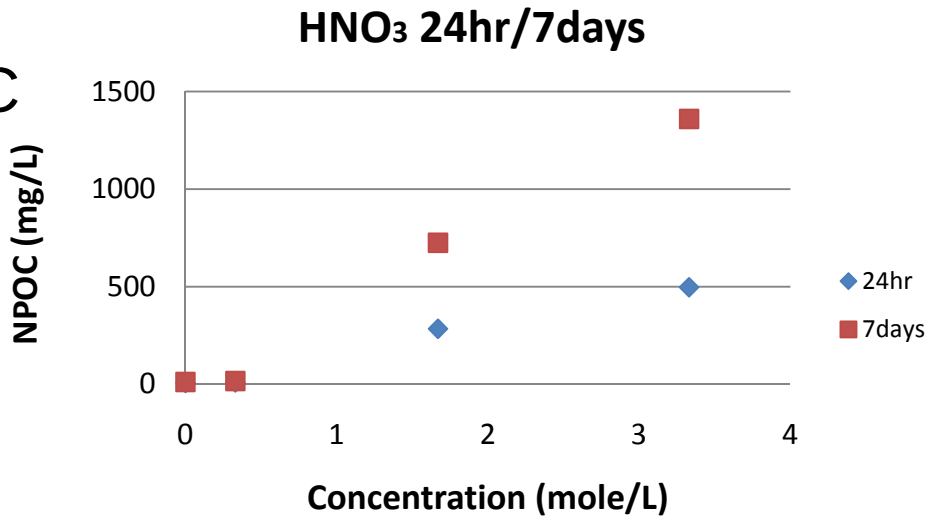
Nitric acid

SEC

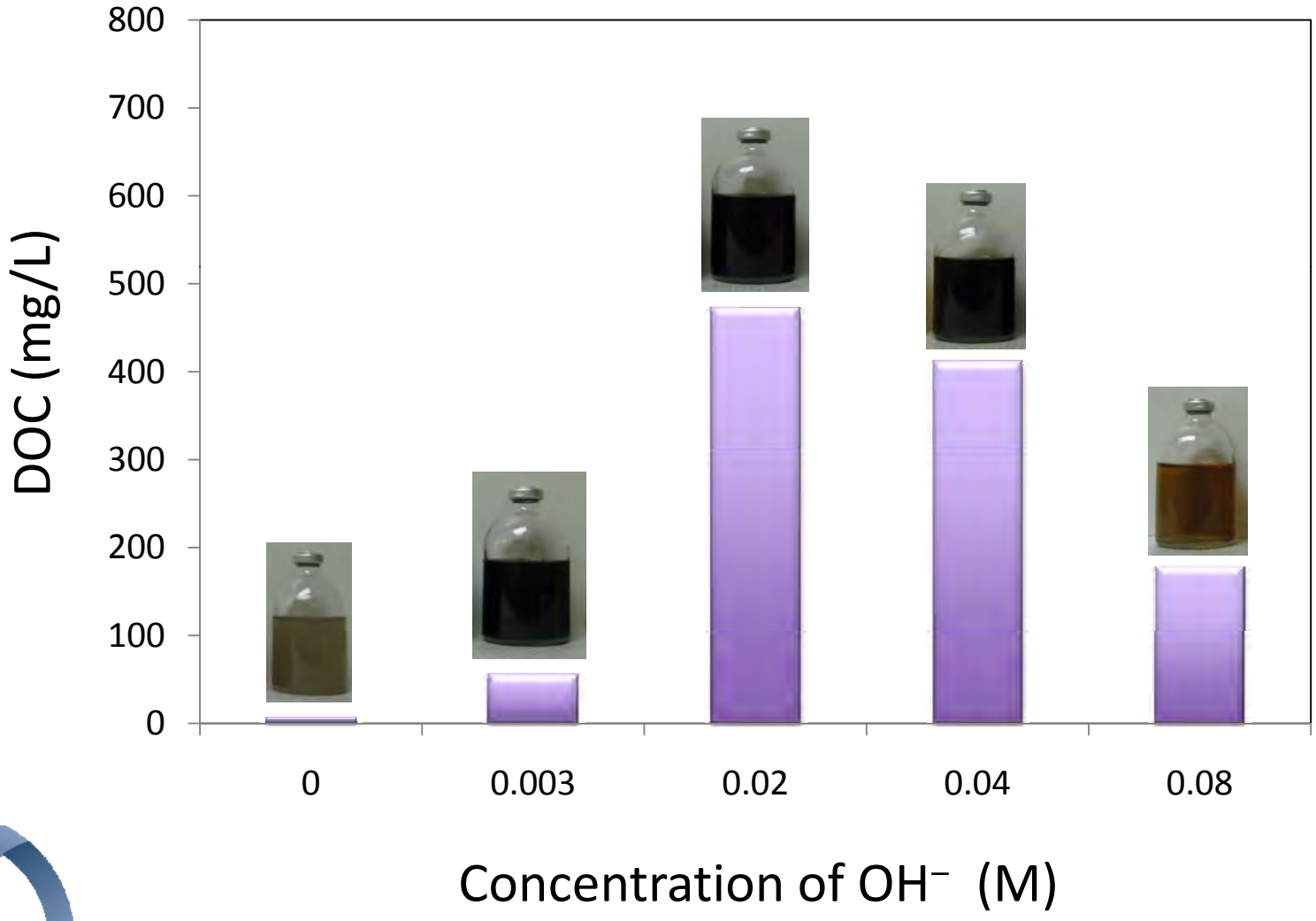




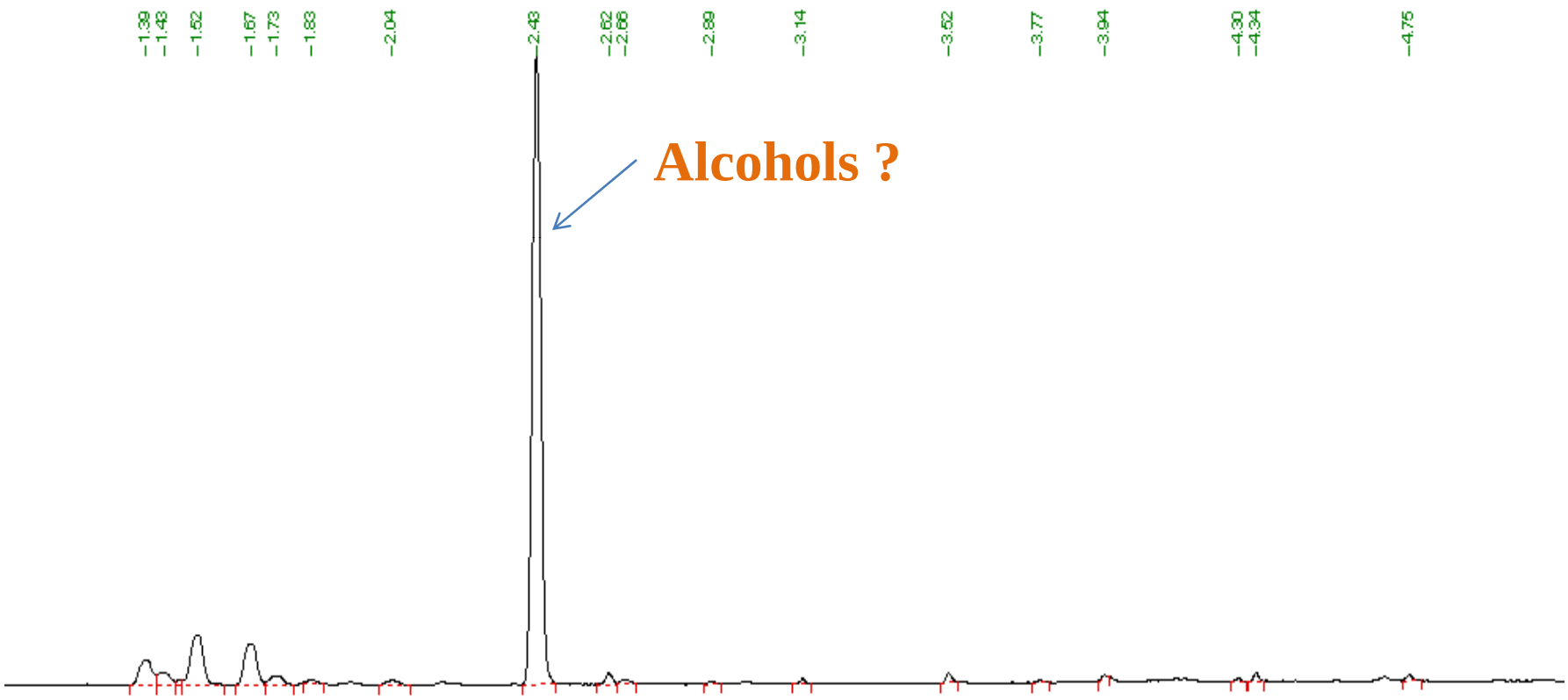
NPOC



NaOH Extract from Anaerobic Coal



GC-FID Analysis of NaOH Extract

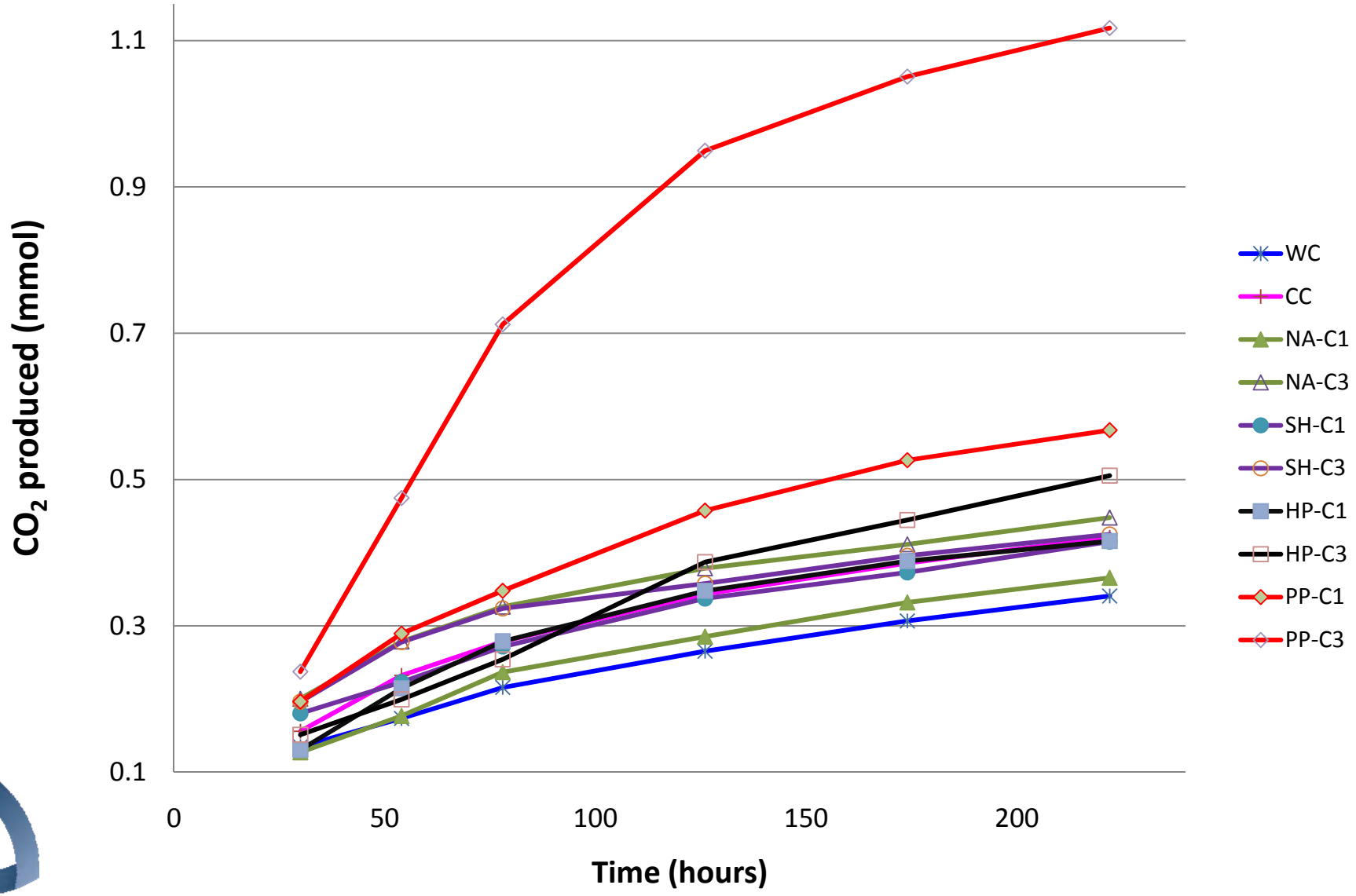


Bioavailability Experiment

	HNO_3		NaOH		H_2O_2		$KMnO_4$		CC
	C1	C3	C1	C3	C1	C3	C1	C3	
Conc. (M)	0.33	3.3	0.13	1.3	0.32	3.2	0.01	0.1	
NPOC (mg/L)	8.8	170.1	239.6	1262.6	24.9	60.9	85.6	370.4	6.4

- *Pseudomonas putida F1* (pH 7-8), 1mL
- Filtered water extraction sample, 15mL
- Sorensen's phosphate buffer, pH=7, 2mL
- KOH (0.05N) in side arm for CO_2 capture
- Titration to measure CO_2 production

Cumulative CO_2 Production



Conclusions

- *Methanosarcina* appears to be critical for methane generation in these systems; others?
- Urea may enhance methanogenesis
- Both low MW and polyaromatic hydrocarbons may support methanogenesis
- NaOH, HNO_3 or $KMNO_4$ are the most effective pre-treatment agents based on SEC, NPOC or aerobic CO_2 production, respectively