Investigating polycyclic aromatic hydrocarbon transport in natural systems

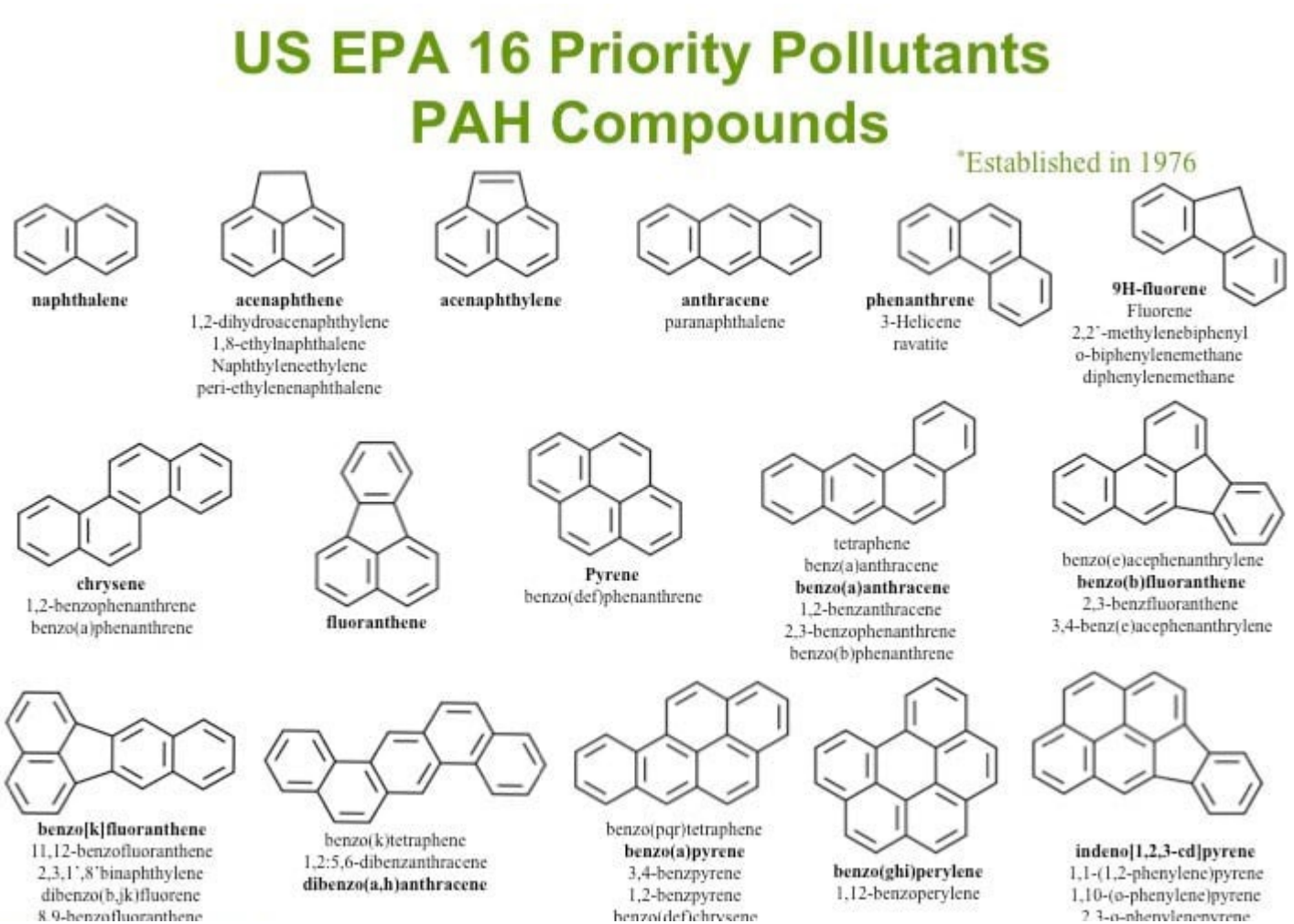
Cathy A. Trejo***, Bronwyn L. Teece**, Arezoo Khodayari*, Laura M. Barge**, and Jessica M. Weber****

*Department of Civil Engineering, California State University, Los Angeles

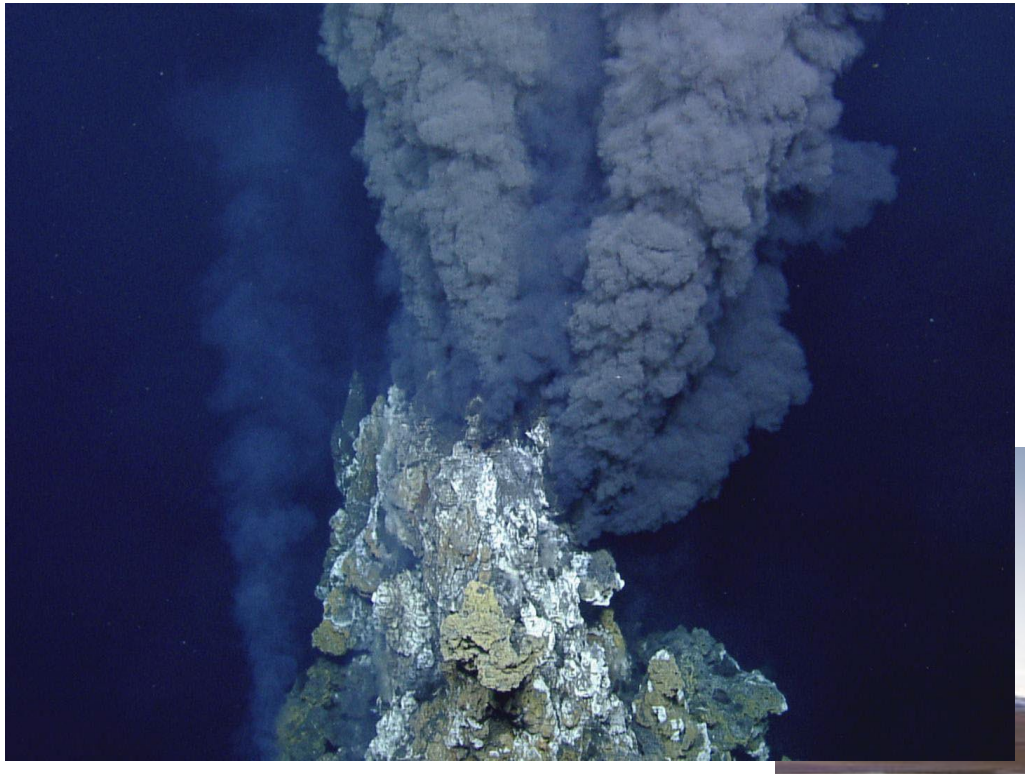
** NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Polycyclic aromatic hydrocarbons (PAHs)

- Organic compounds
- Ubiquitous pollutant
- Low solubility in water



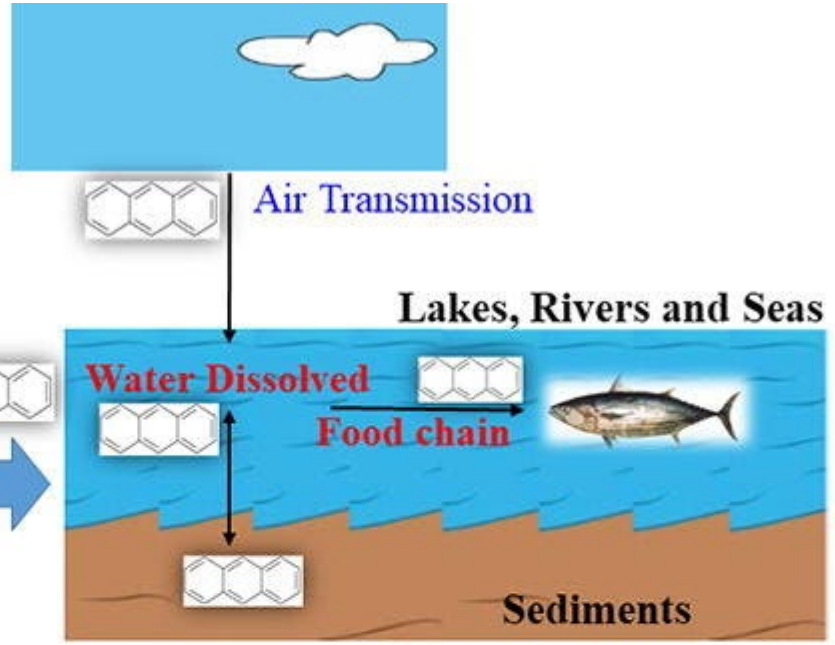
Environmental Research Relevance – Engineering



Environmental Research Relevance – Engineering

Environmental Research Relevance – Engineering

Natural and Anthropogenic Activities



Cancer

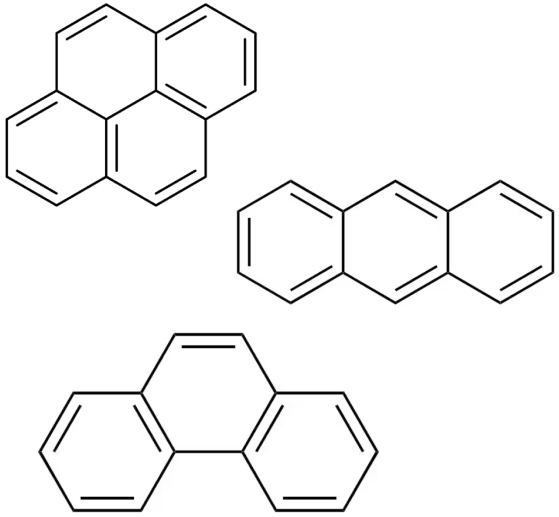
Liver damage

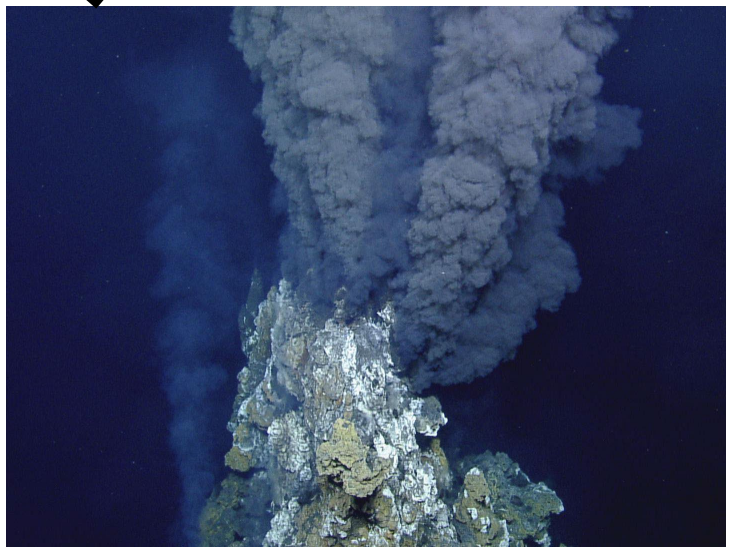
Cardiovascular disease

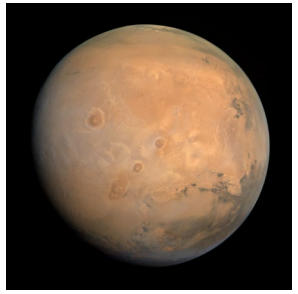
Mojiri, A., Zhou, JL., Ohashi, A., Ozaki N., Kindaichi T. (2019) Comprehensive review of polycyclic aromatic hydrocarbons in water sources, their effects and treatments. Sci Total Environ, vol 696:133971.

Environmental Research Relevance – Engineering

Polycyclic aromatic hydrocarbons

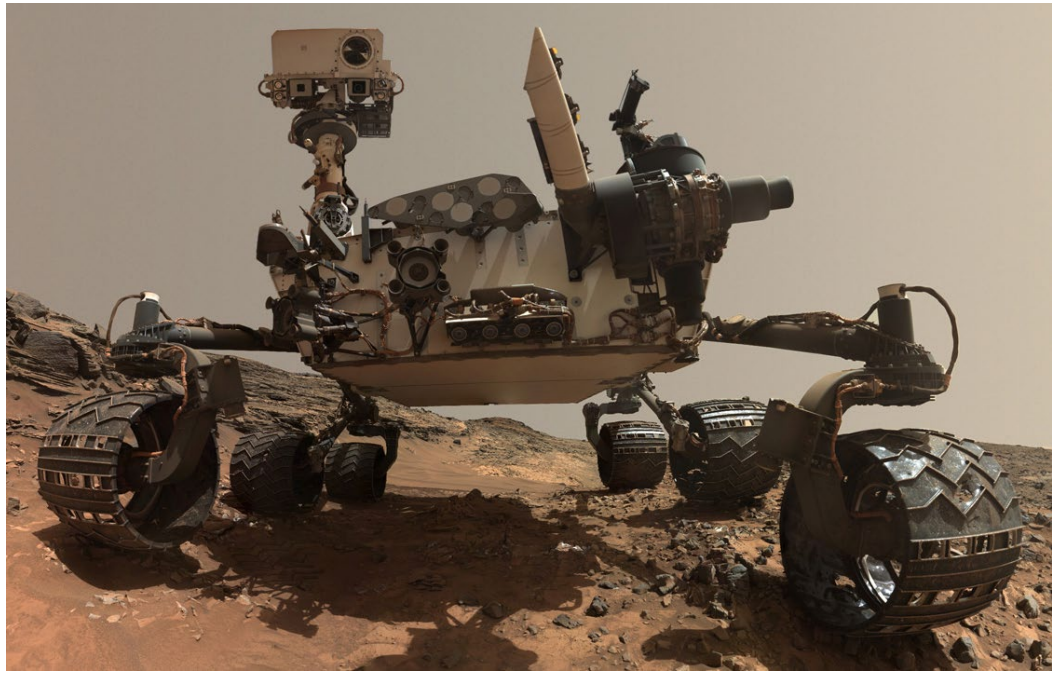






Research Relevance – Astrobiology

Curiosity Mars Rover



<u>Mission</u>

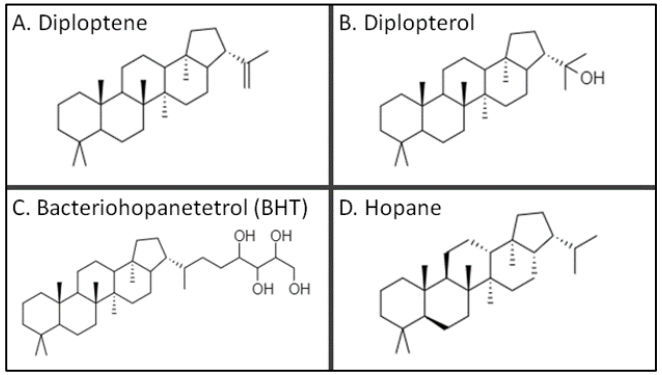
Understanding the past and present habitability of the martian environment

Yen, A. S., Morris, R. V., Ming, D. W., Schwenzer, S. P., Sutter, B., Vaniman, D. T., et al. (2021). Formation of tridymite and evidence for a hydrothermal history at Gale crater, Mars. Journal of Geophysical Research: Planets, 126, e2020JE006569

Research Relevance – Astrobiology

Biosignature

"an object, substance, and/or pattern whose origin specifically requires a biological agent."



Biomarker organics

Macro structures/textures

Minerals

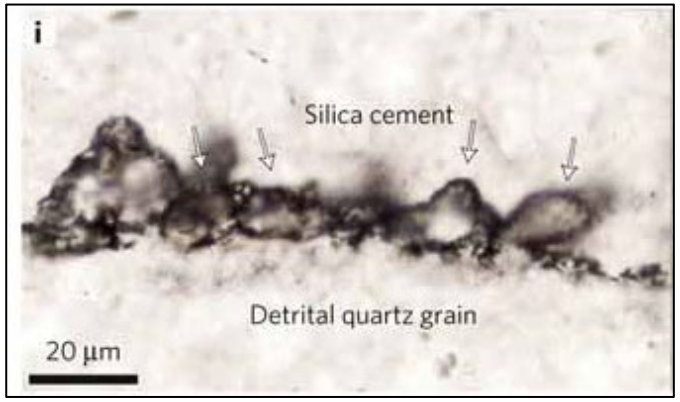


Image credits: Wacey et al., 2011

Microfossils

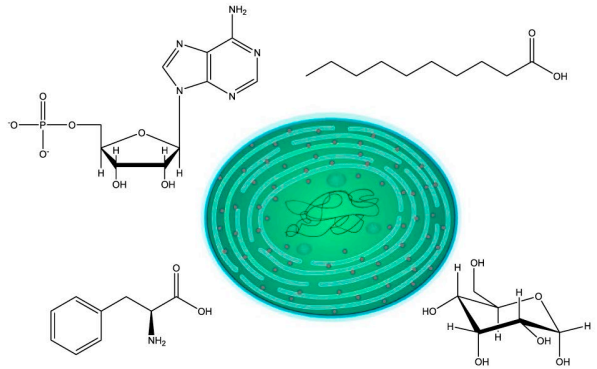
Hays, L.E., Graham, H.V., Des Marais, D.J., Hausrath, E.M., Horgan, B., McCollom, T.M., Parenteau, M.N., Potter-McIntyre, S.L., Williams, A.J., Lynch, K.L., (2017). Biosignature Preservation and Detection in Mars Analog Environments. Astrobiology 17, 363-400.

Wacey, D., Kilburn, M., Saunders, M. et al. (2011) Microfossils of sulphur-metabolizing cells in 3.4-billion-year-old rocks of Western Australia. Nature Geosci 4, 698-702.

Research Relevance – Astrobiology

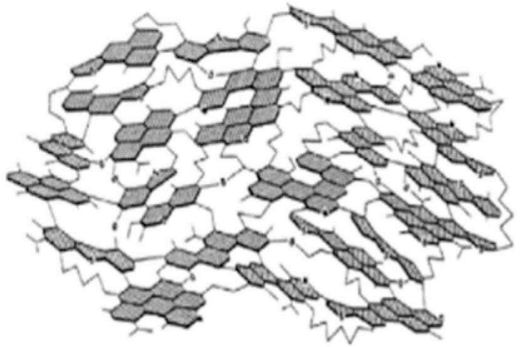
Pressure

Biological organic matter



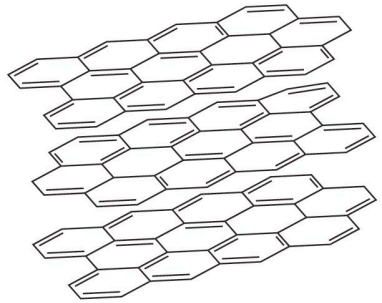
carbon
hydrogen
oxygen
nitrogen
sulphur

Inert graphitic carbon



carbon
hydrogen
oxygen
nitrogen
sulphur

Crystalline graphite



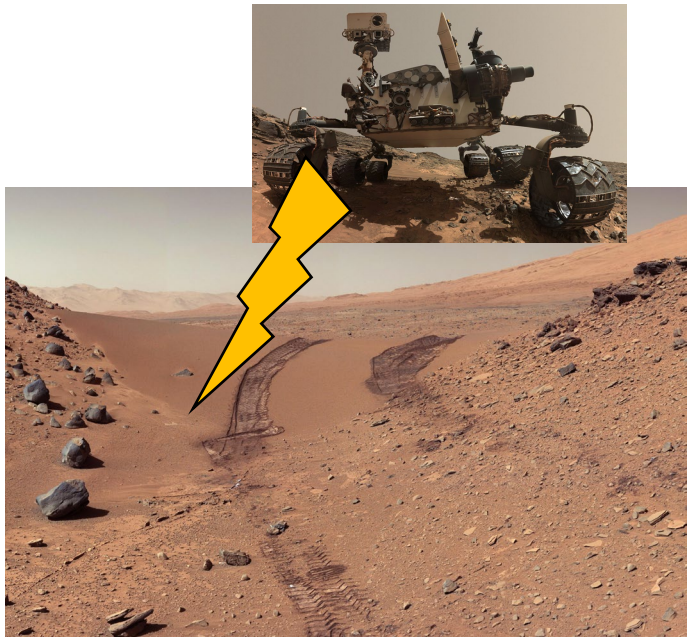
pure
carbon

Lower thermal maturity

Higher thermal maturity

Alleon, J. and Summons, R.E. (2019) Organic geochemical approaches to understanding early life. Free Radical Biology and Medicine, vol 140: 103-112.

Research Relevance – Astrobiology



What compounds are we seeing?
Where do they come from?

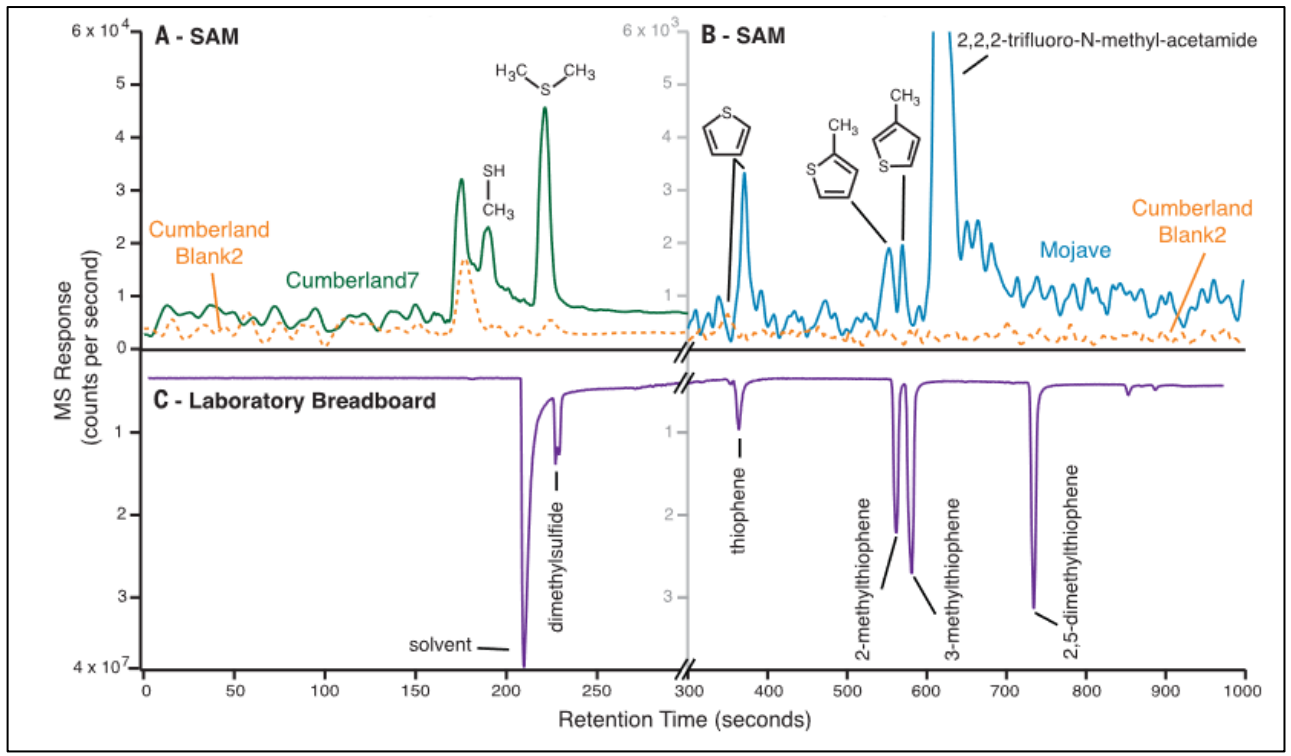
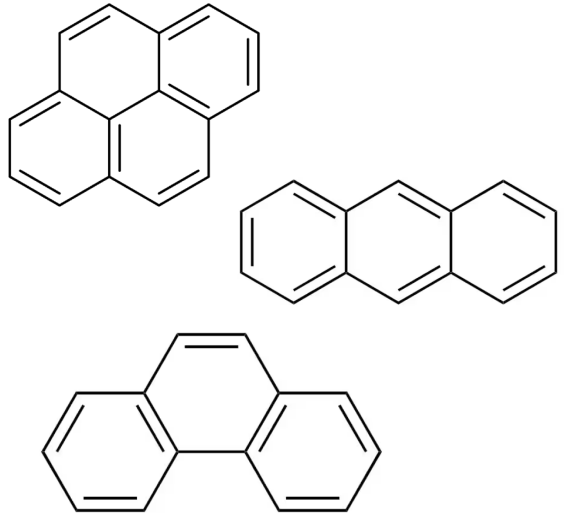


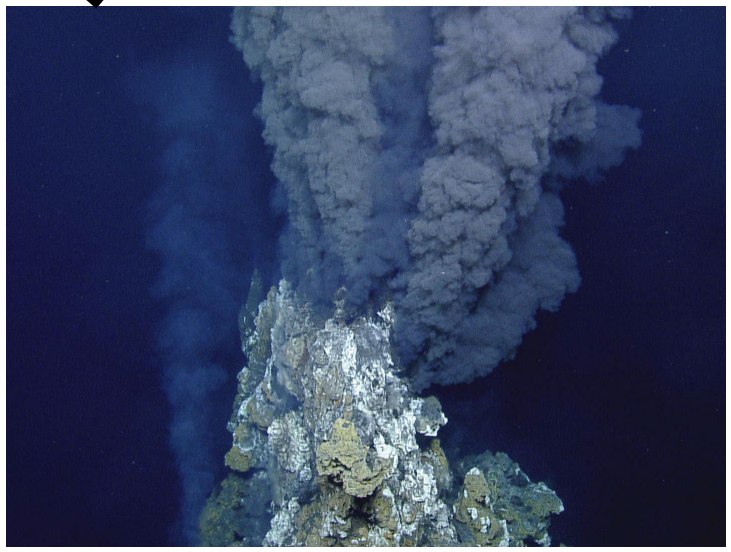
Image credits: Eigenbrode et al., 2018

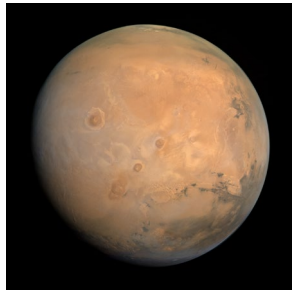
Eigenbrode, J.L., Summons, R.E., Steele, A., Freissinet, C., Millan, M., Navarro-González, R., Sutter, B., McAdam, A.C., Franz, H.B., Glavin, D.P., Archer, P.D., Mahaffy, P.R., Conrad, P.G., Hurowitz, J.A., Grotzinger, J.P., Gupta, S., Ming, D.W., Sumner, D.Y., Szopa, C., Malespin, C., Buch, A., Coll, P. (2018). Organic matter preserved in 3-billion-year-old mudstones at Gale crater, Mars. Science 360, 1096–1101.

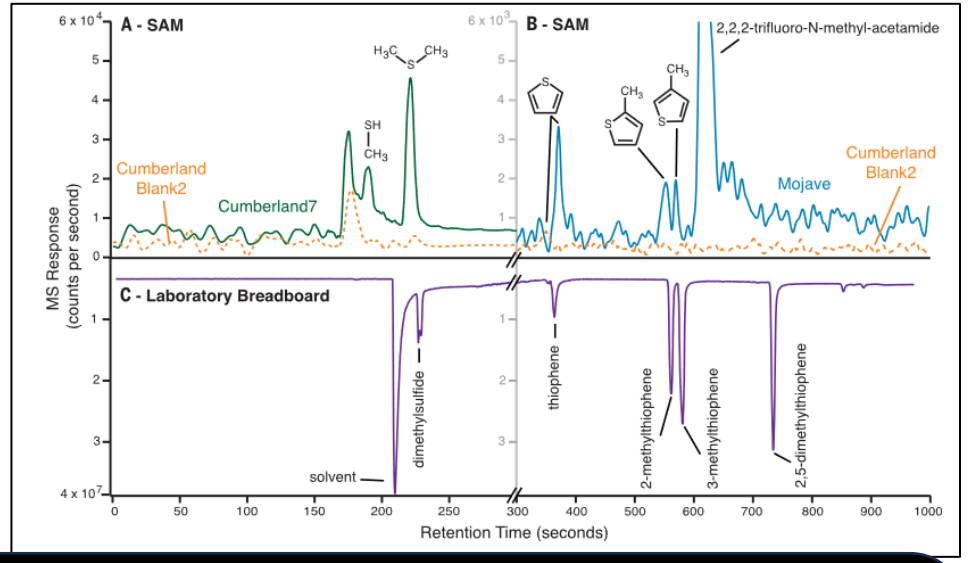
Research Relevance – Astrobiology

Polycyclic aromatic hydrocarbons







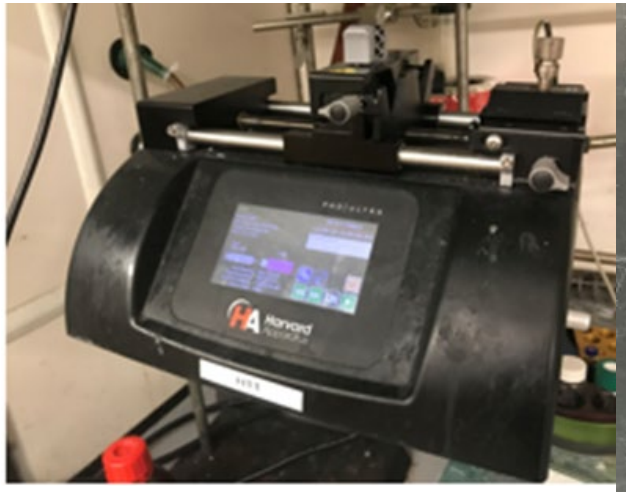


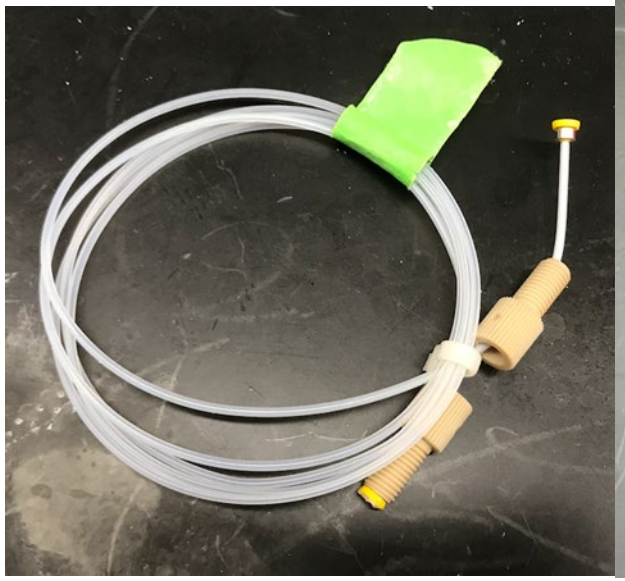
Origin of organic matter harder to discern

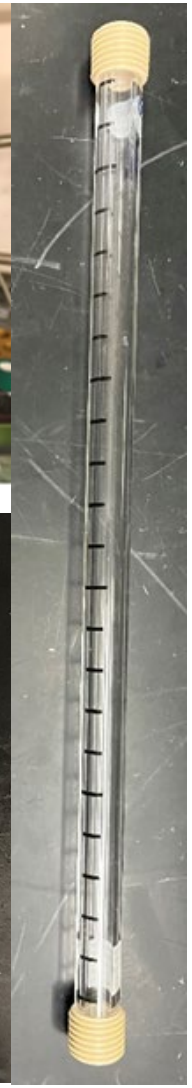
Research Objective:

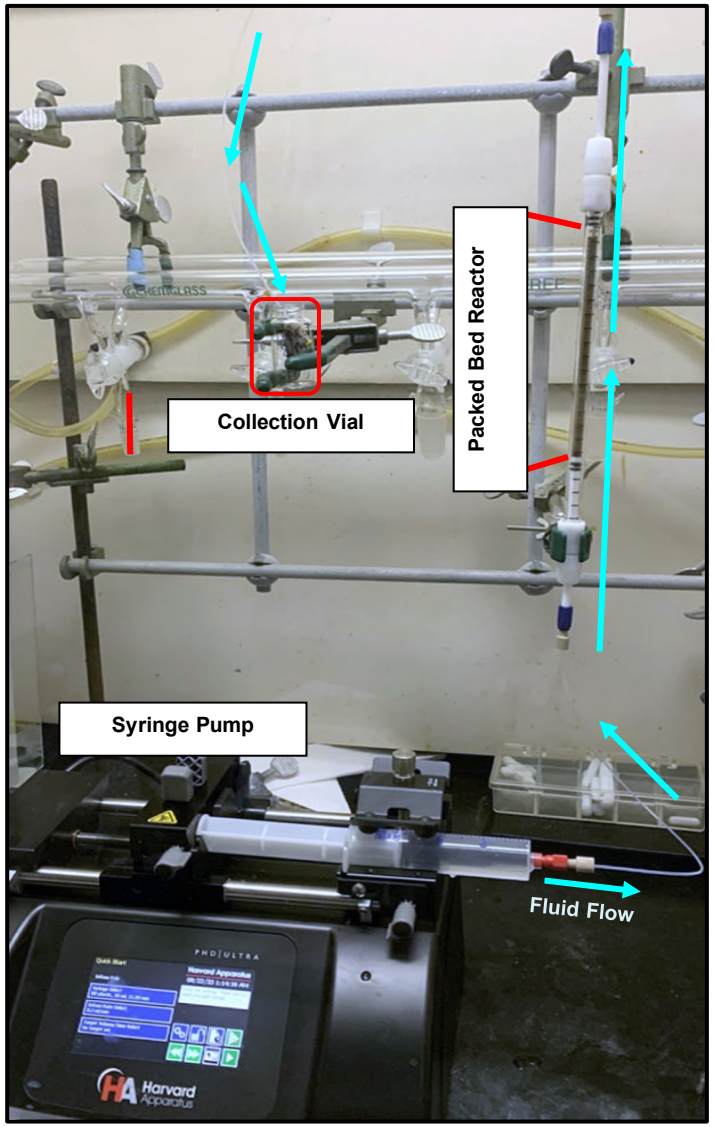
Investigate geochemical conditions that affect polycyclic aromatic hydrocarbon mobility in hydrothermal systems using a continuous flow reactor

Continuous Flow Chemistry







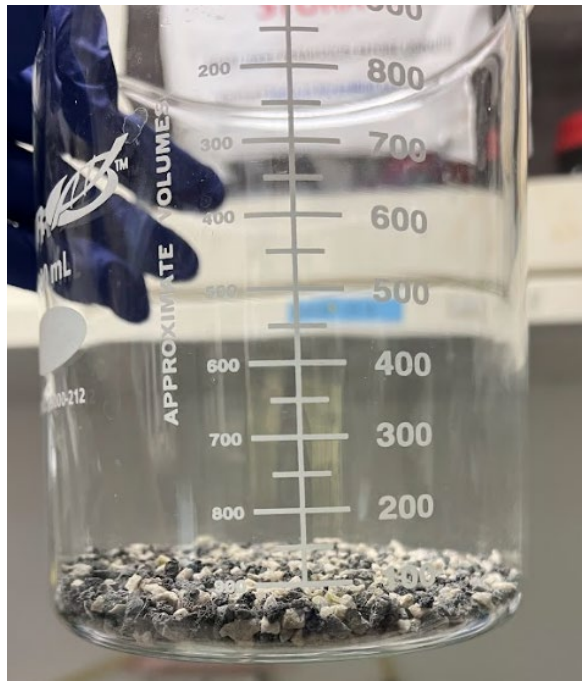


- Simulate hydrothermal fluids flowing through mineral bed
- Automated and consistent fluid flow throughout the experiment

Packed Bed

Mars Global Simulant Coarse (MGS-1 Coarse)

- Basaltic regolith on Mars
- Similar mineral composition to Earth's basalt



Fluid Solutions

Ultra Pure MilliQ water

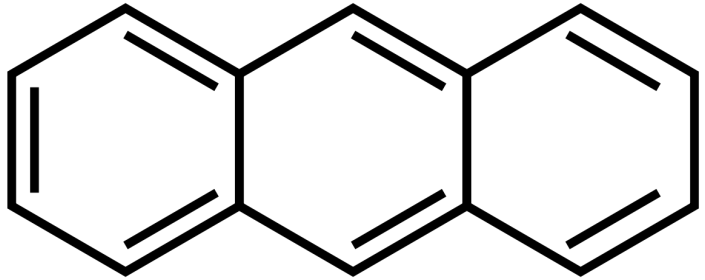
- pH = 6.5 – 7.5
- Standard pressure/temperature

Hydrothermal Fluid (HTF)

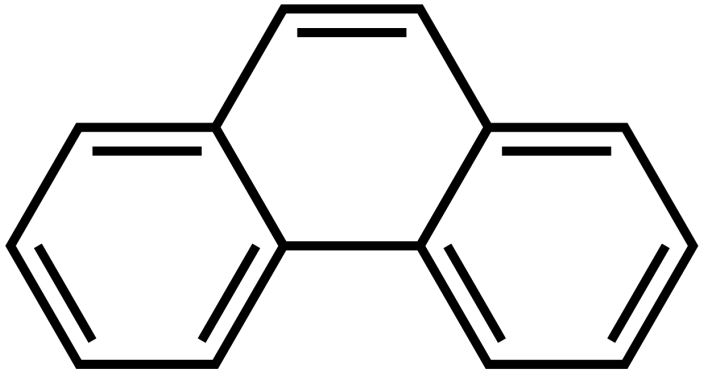
- Synthetic, non-heated
  - 4 mM NaCl
  - 0.3 mM $CaSO_4$
  - 100 mM $NaSiSO_4$
- pH = 11.8
- Standard pressure/temperature

Organics – PAHs

Anthracene



Phenanthrene



- Structural isomers (MW: 178.23 g/mol)
- Common in hydrothermal systems
- Highly studied in PAH removal techniques

Organic Mixtures – 10 mM in system

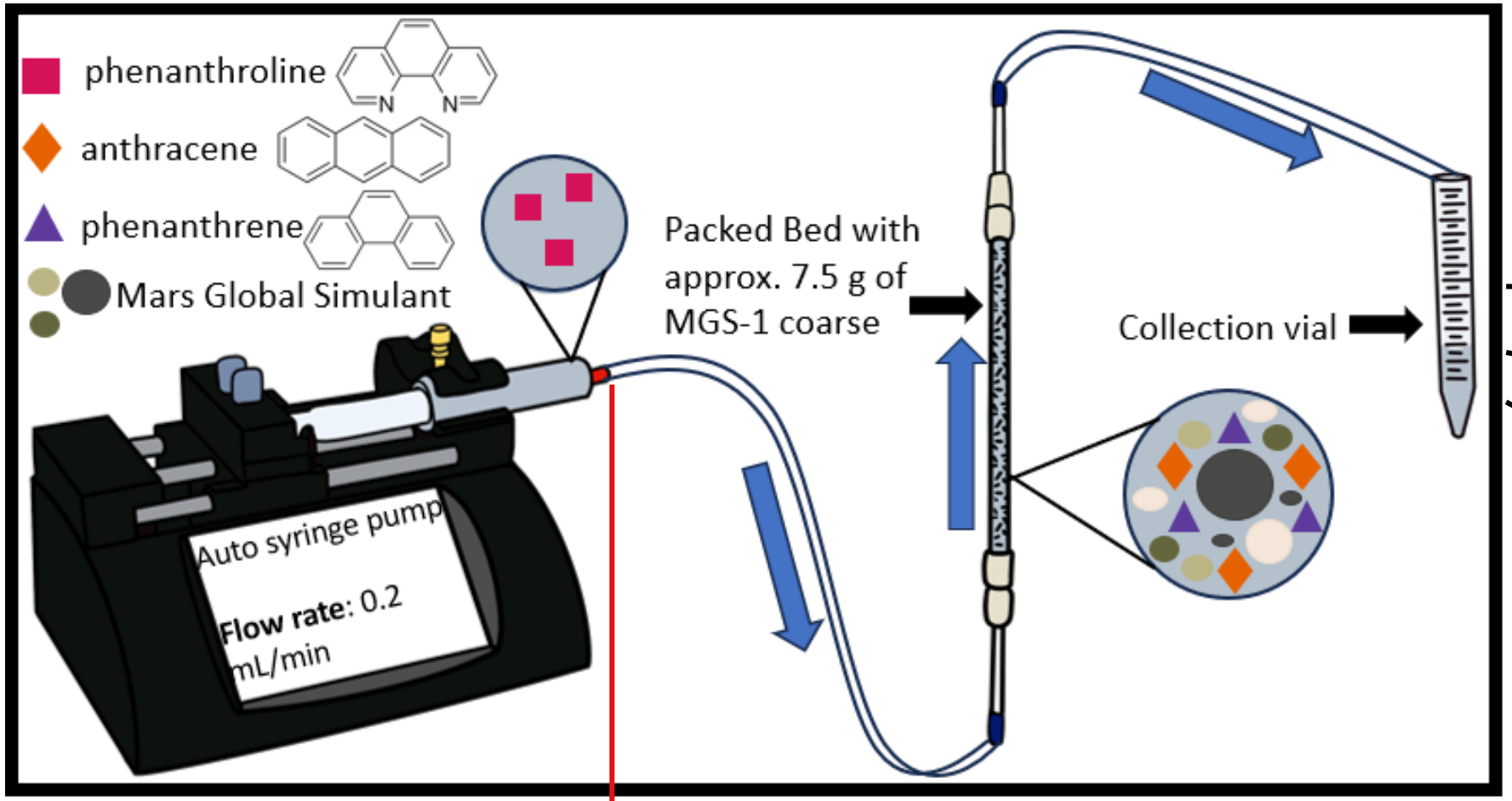
Packed Bed

- Phenanthrene
- Anthracene
- Phenanthroline

Fluid Solution

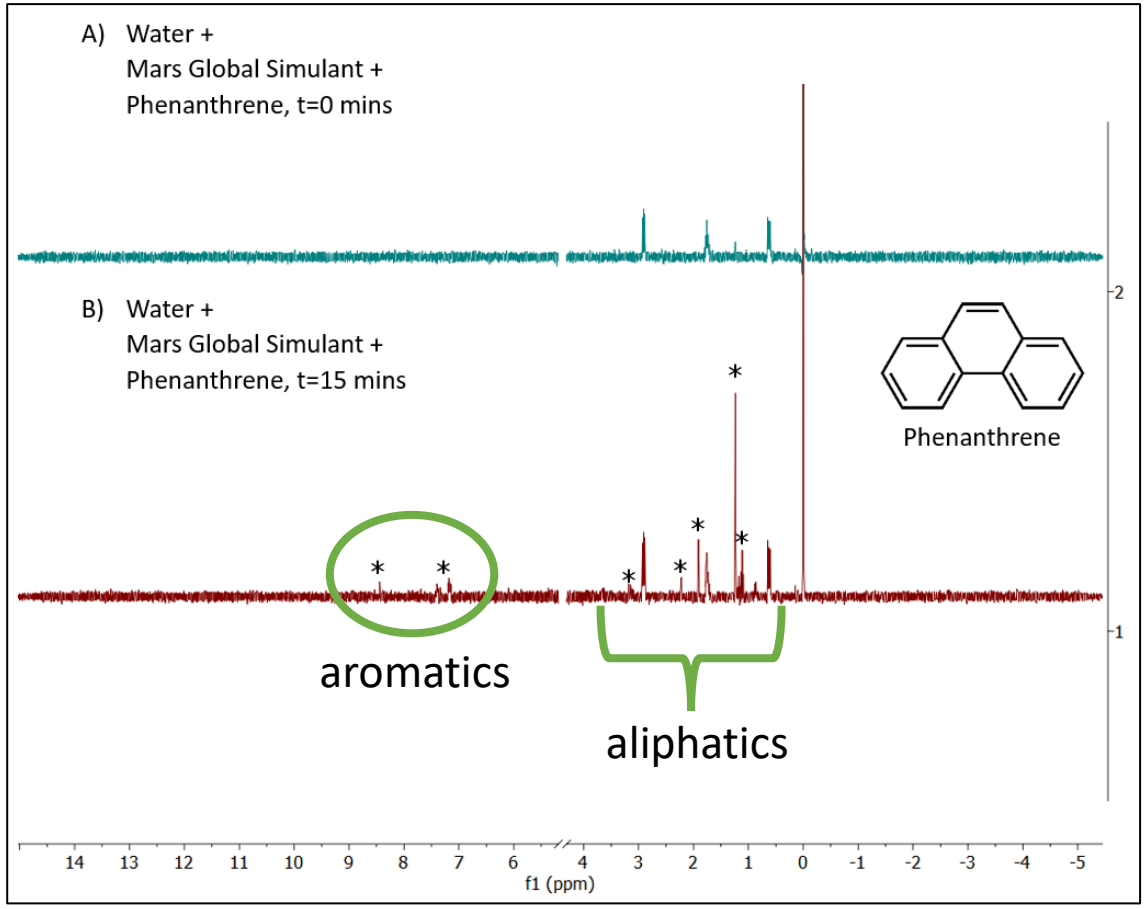
- Phenanthroline

Experiment Schematic

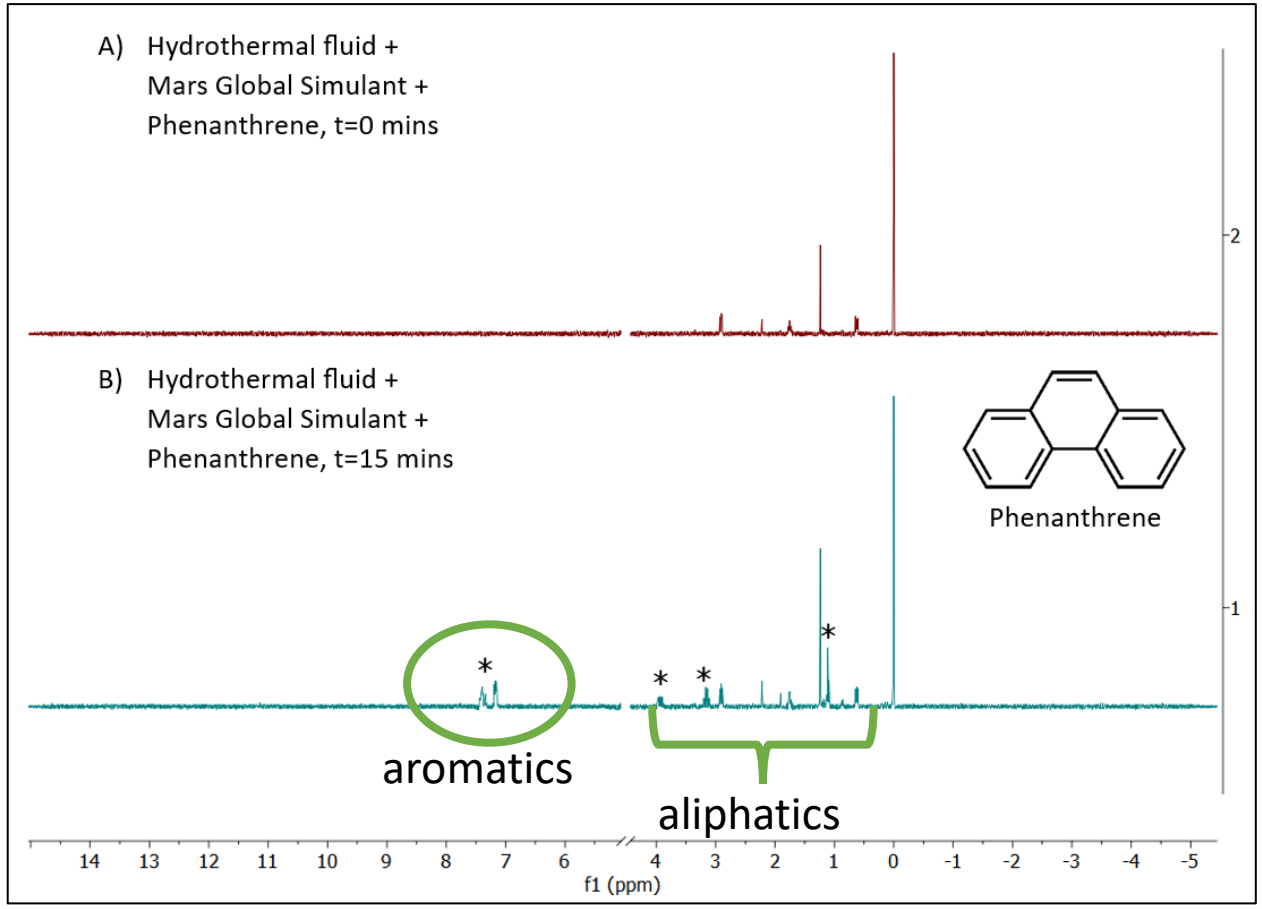


Fluid Analysis – Phenanthrene

MilliQ-Water

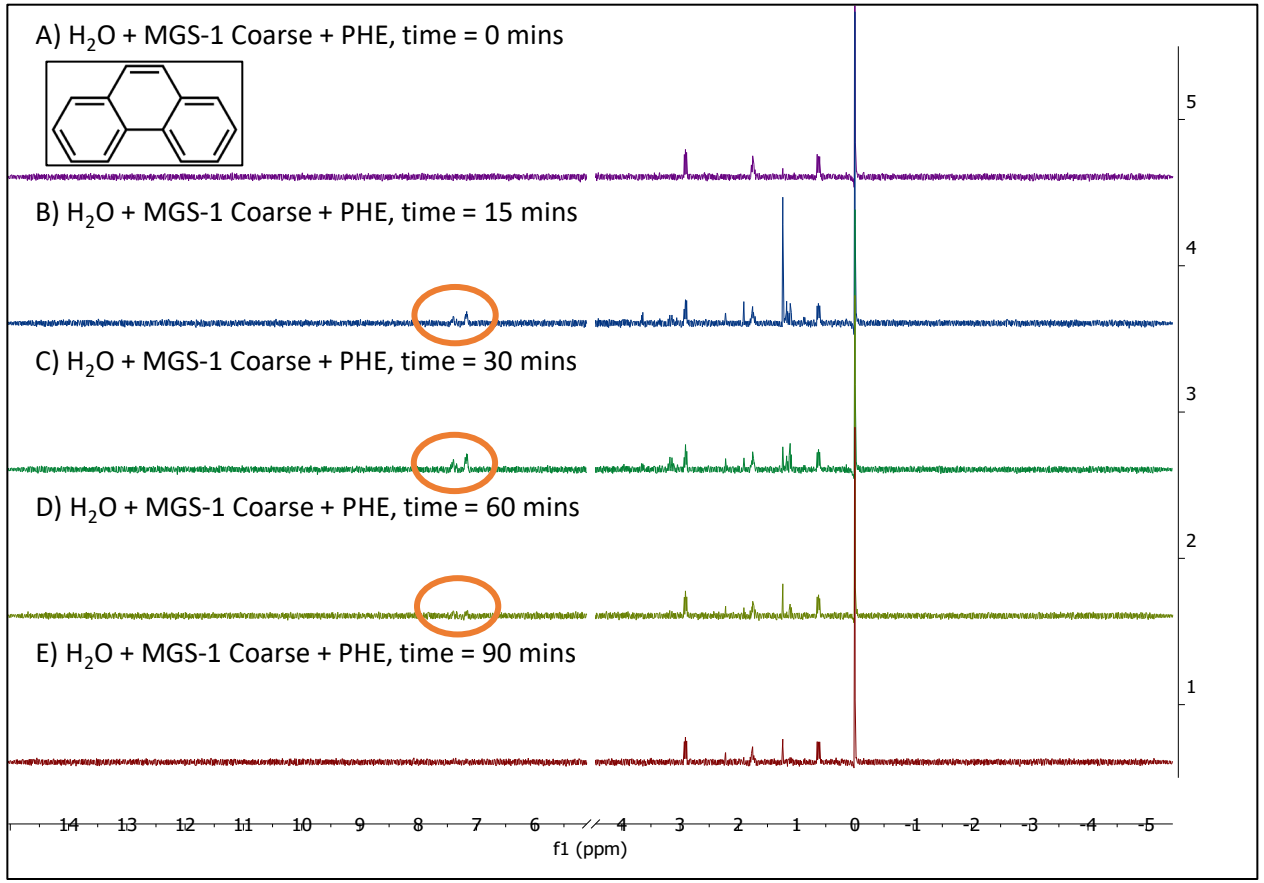


Hydrothermal Fluid

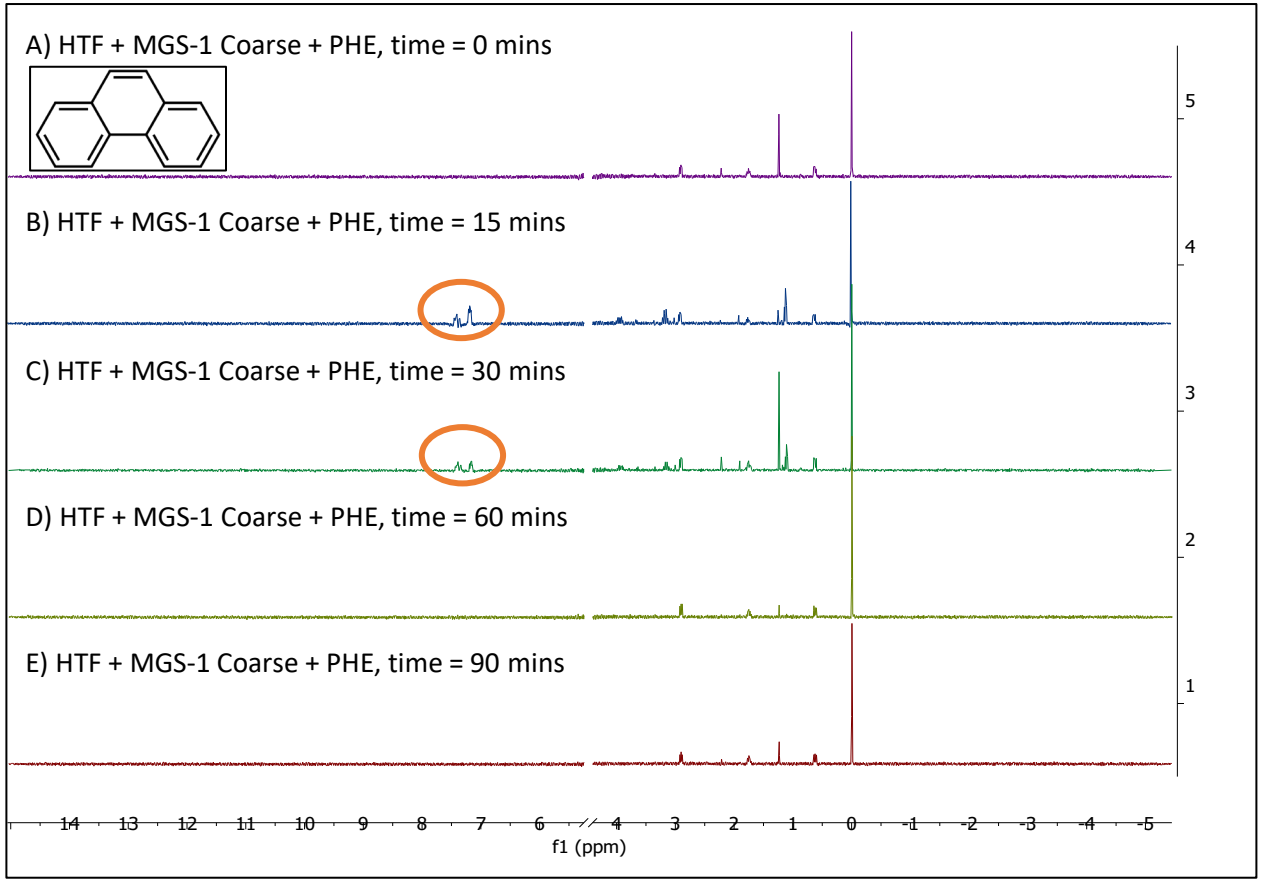


Fluid Analysis – Phenanthrene

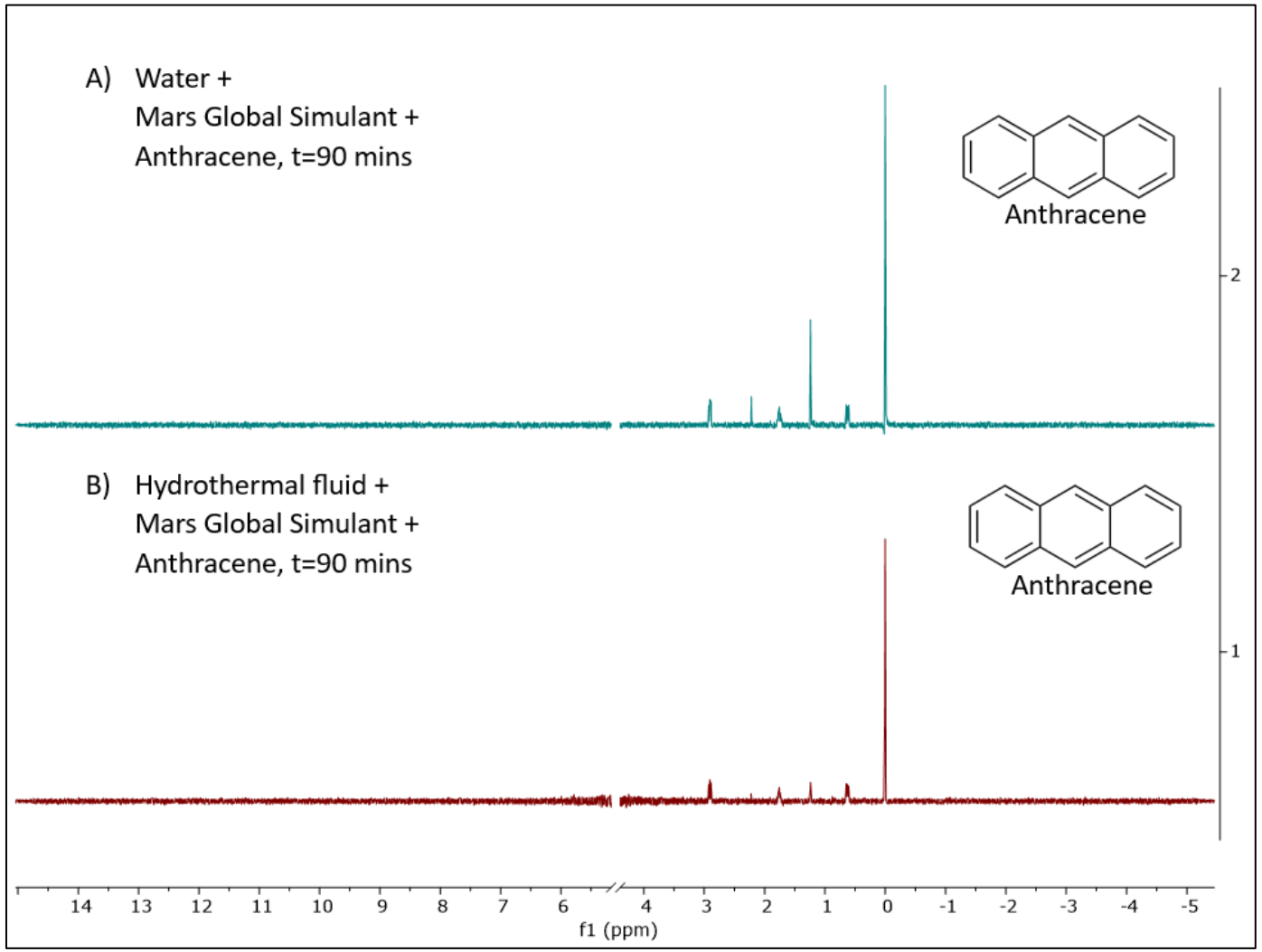
MilliQ-Water



Hydrothermal Fluid



Fluid Analysis – Anthracene



- No aromatic peaks at any timepoint

Conclusions – Environmental Engineering

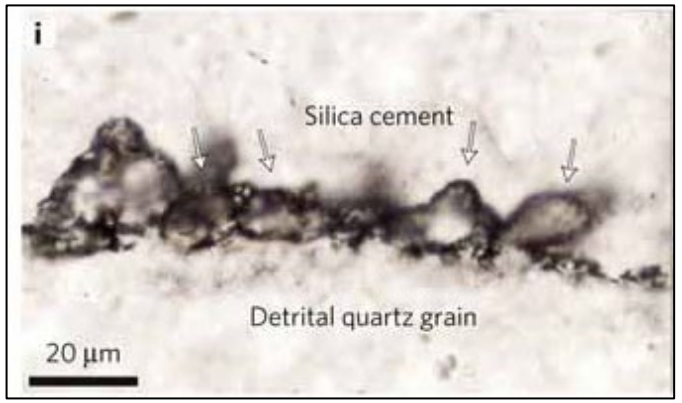
- At baseline conditions, we're seeing some phenanthrene decomposition with the continuous flow set up.

- We still have phenanthrene and anthracene left with the organics.

We know phenanthrene decomposition products is likely to be present in contaminated water streams.

Implications – Astrobiology

- Phenanthrene decomposition products could potentially overlap with biomarkers.
  - Need other biosignatures to help confirm biomarkers



We know a set of geochemical conditions that PAH mobility can affect Martian organic analyses.

Acknowledgments

Dr. Jessica M. Weber

Dr. Bronwyn L. Teece

Dr. Arezoo Khodayari

Dr. Laura M. Barge

Dr. Katherine Dzurilla

ORIGINS AND HABITABILITY LAB

Jet Propulsion Laboratory
California Institute of Technology

CAL STATE LA
CALIFORNIA STATE UNIVERSITY, LOS ANGELES