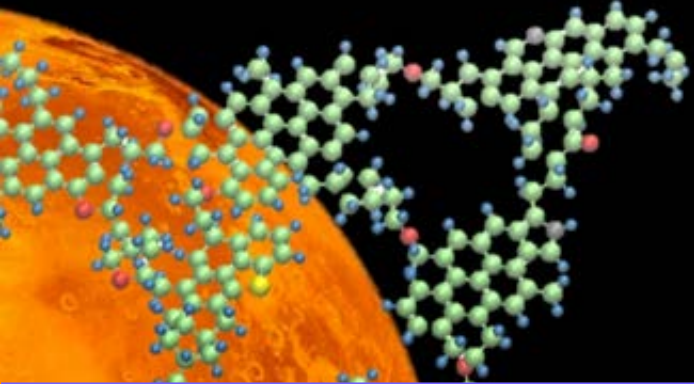


Life Detection on Mars in the 2020s: Designing Instruments to Search for Molecular Signs of Life

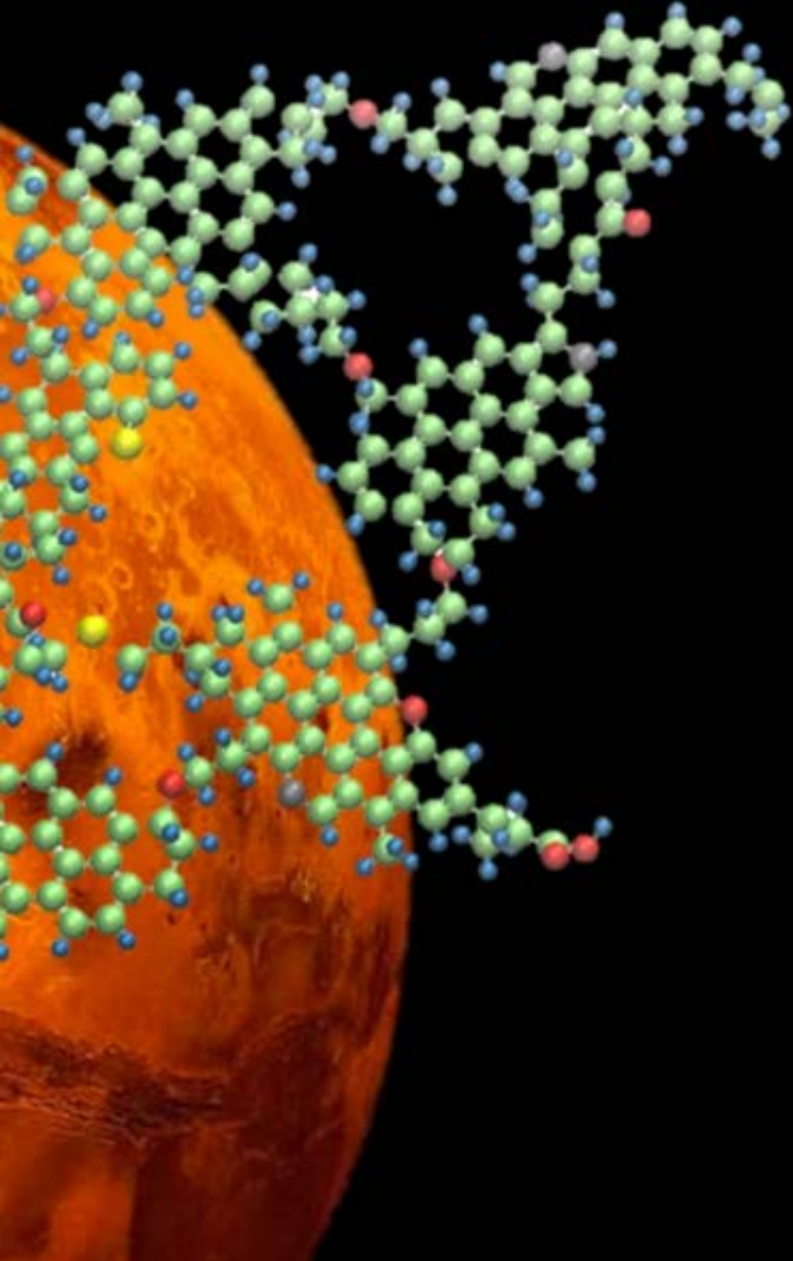


Life Search Science and Technologies on Mars
Planetary Science Decadal Survey 2022-2032
February 16, 2021



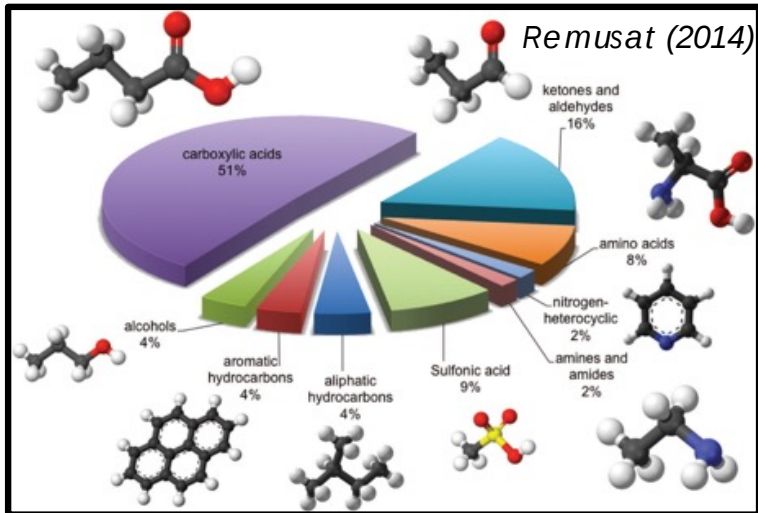
Dr. Mary Beth Wilhelm
Space Science and Astrobiology Division
NASA Ames Research Center
Moffett Field, California

Life Detection Strategy on Mars



1. Mars was most habitable early in its history (pre- to late- Noachian); evidence of life there will inform our search for life elsewhere in the Solar System.
2. Preserved organic matter bearing origin-diagnostic molecular features is one of the best indicators of past life.
 - Hydrocarbons detected in ~3 Gyr Martian mudstones (*Eigenbrode et al., 2018; Freissinet et al., 2015*) highlights the preservation potential for organics on Mars.
3. Sediments from long-habitable regions are ideal targets to search for preserved organics.
 - Understanding preservation processes in these environments is key to finding indicators of life.

Targeting Geologically Robust Molecular Signatures of Life



Lipids:

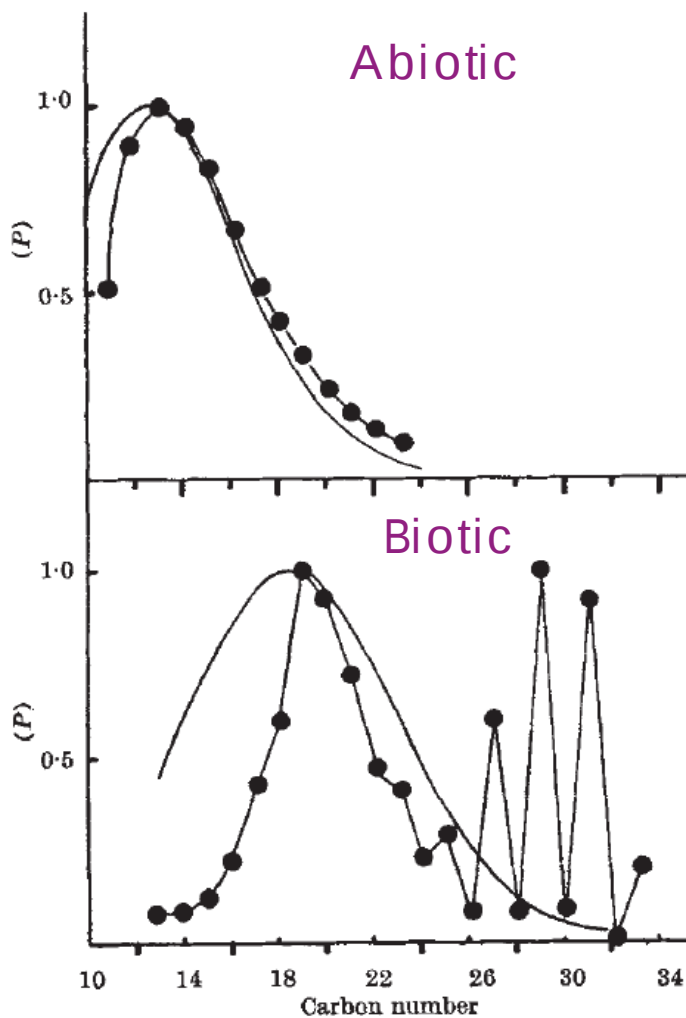
- Required for life (compartmentalization; membranes)
- Most abundant organics found in meteorites
- Longest preservation potential of any biomarker (~3 Gyr)
- Ancient-Mars relevant

Geological Longevity of Major Molecular Biosignatures

		BILLIONS OF YEARS AGO:				
ORGANIC CLASS	CHEMICAL STRUCTURE	0	1	2	3	4+
DNA		~1 Myr				
Amino Acids (Enantiomeric Excess)		~10 Myr				
Proteins		~100 Myr				
Lipids		~1.6 Gyr <i>oldest confirmed syngenetic age</i>		~3.4 Gyr		
Kerogen		~2.7 Gyr <i>oldest confirmed syngenetic age</i>			oldest potential age	

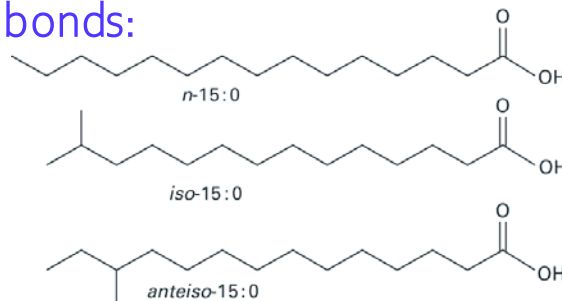
Origin-Diagnostic Lipid Features

1) Patterns in chain length/molecular weight:

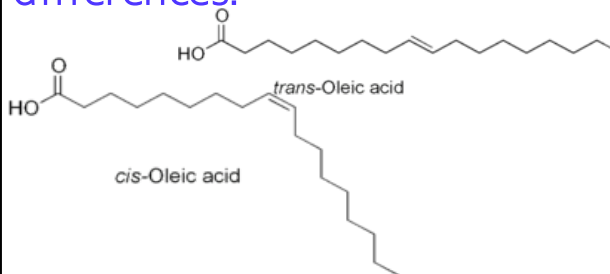


(Lovelock, 1965)

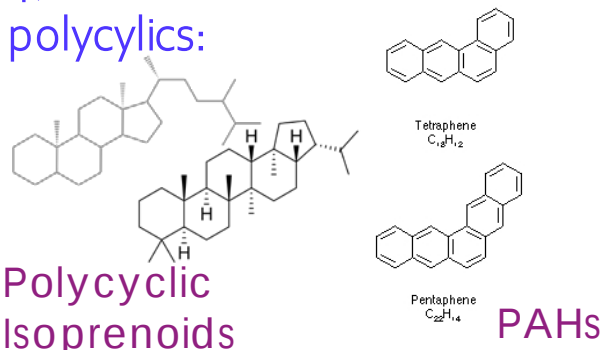
2) Patterns in position, number of branch points and double bonds:



3) Isomerization differences:



4) Structural differences in polycyclics:



Diagnostic patterns and features in molecular classes and structures will distinguish deviation from abiotic “baseline”

(e.g., Lovelock, 1965; Mißbach et al., 2018)

1. molecular weight and chain length
2. chain features (e.g., branching points, double bonds)
3. isomerization
4. aromaticity, unsaturations, and their structural consequences

➤ **Origin-diagnostic lipid features are best revealed through solvent extraction techniques.**

Key Challenges to Characterizing Origin-Diagnostic Features

1. Inorganic Interference & Organic Matter Complexity

- E.g., Oxidants, salts, sulfurous minerals (e.g., *Mechlinska et al., 2012; Sephton et al., 2014; Tan et al., 2018*)
- Molecular interactions of organics with minerals or in macromolecular matrices (e.g., see review: *Kiel and Mayer, 2014; Lee et al., 2021*)

2. Low Abundance & Geologic Heterogeneity of Biomarkers

- Common challenge in naturally occurring organic matter on Earth, especially in hyperarid deserts (e.g., *Goordial and Whyte, 2014; Wilhelm et al., 2017*)

3. Automation of Laboratory Sample Processing Techniques

- Sample prep is key to revealing origin-diagnostic features and overcoming inorganic interference, low abundance.



Sample Processing Techniques

Current Flight Extraction Technique: Pyrolysis (e.g., SAM, MOMA)

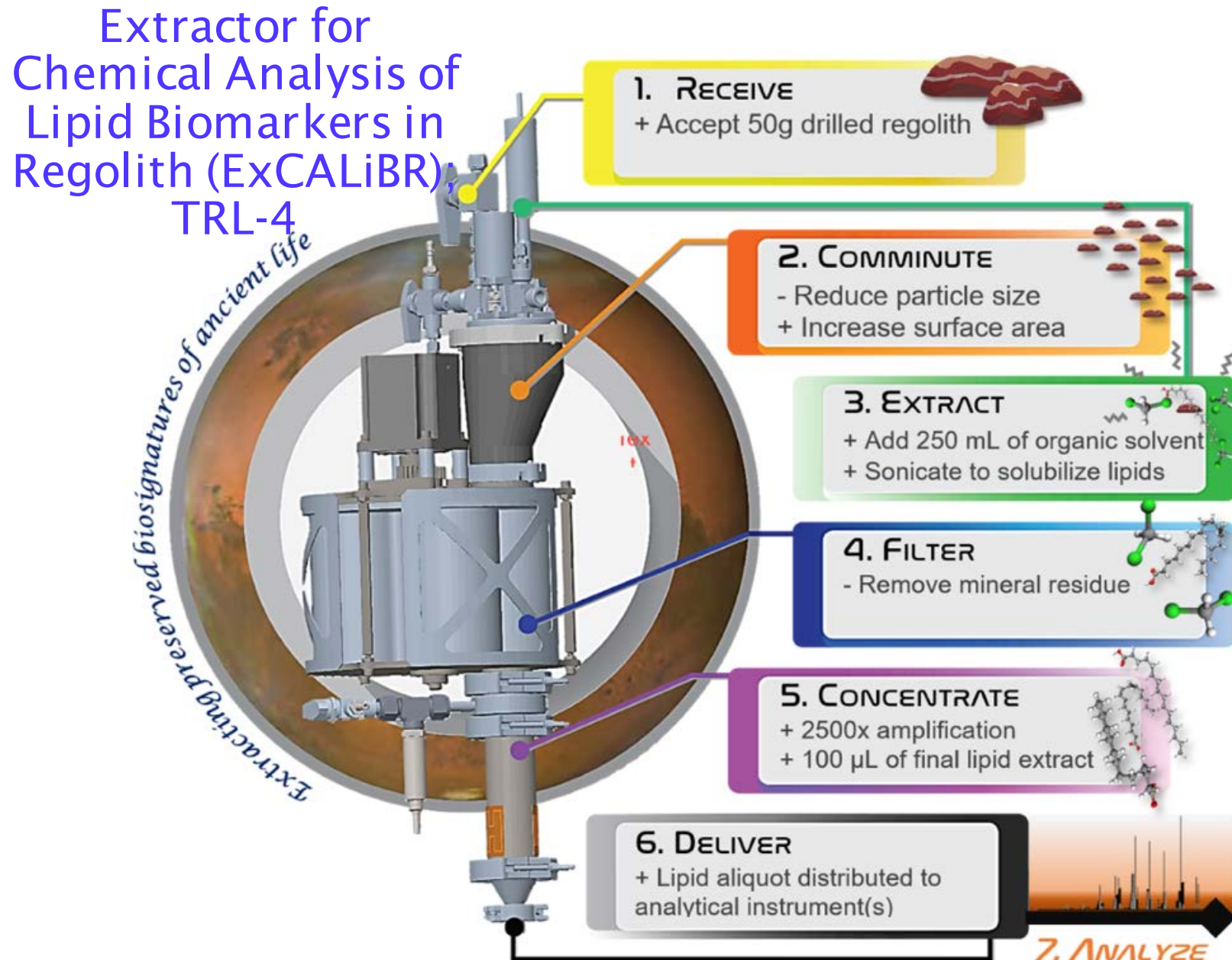
- + • Operationally more simple
- • High temperatures can be destructive to origin-diagnostic features

“Gold Standard” Laboratory Technique: Solvent Extraction

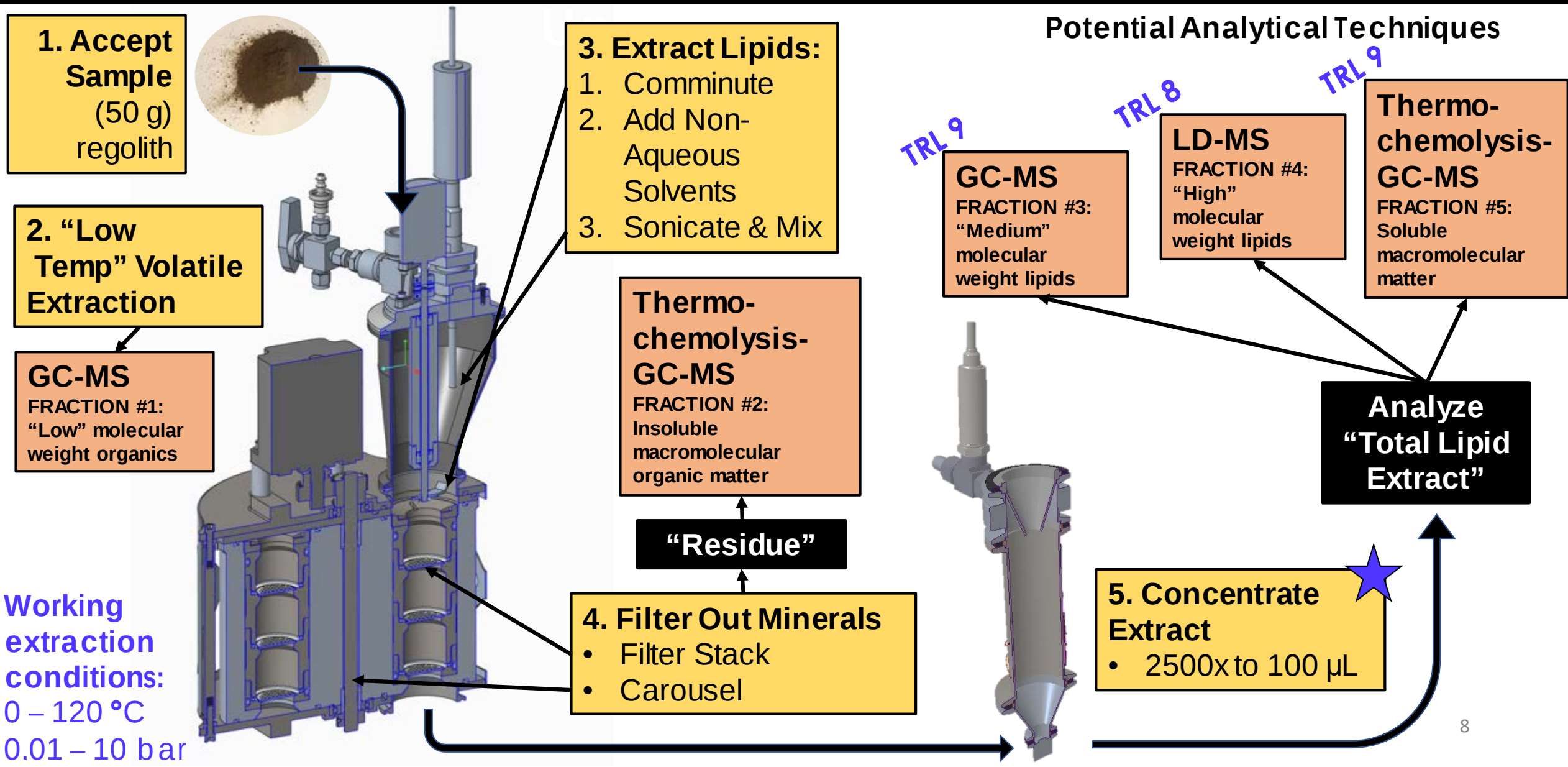
- + • Efficient, preserves origin-diagnostic features for delivery to analytical system, overcomes challenges with inorganics, used for over 70 years on complex, natural organic matter
- • Laborious, human operator dependent

Translating Sample Prep from Lab to Planetary Instrument

- Fluidic technology for fundamental biology and astrobiology flown on ISS and small sat payloads
(e.g., Ricco et al., 2007; 2011; Nicholson et al., 2011; Padgen et al., 2020).
- Translating this technology to ExCALiBR enables extraction of origin-diagnostic molecules.



ExCALiBR ConOps Enabling Comprehensive 5-Stage Analysis with Preservation of Origin-Diagnostic Features and

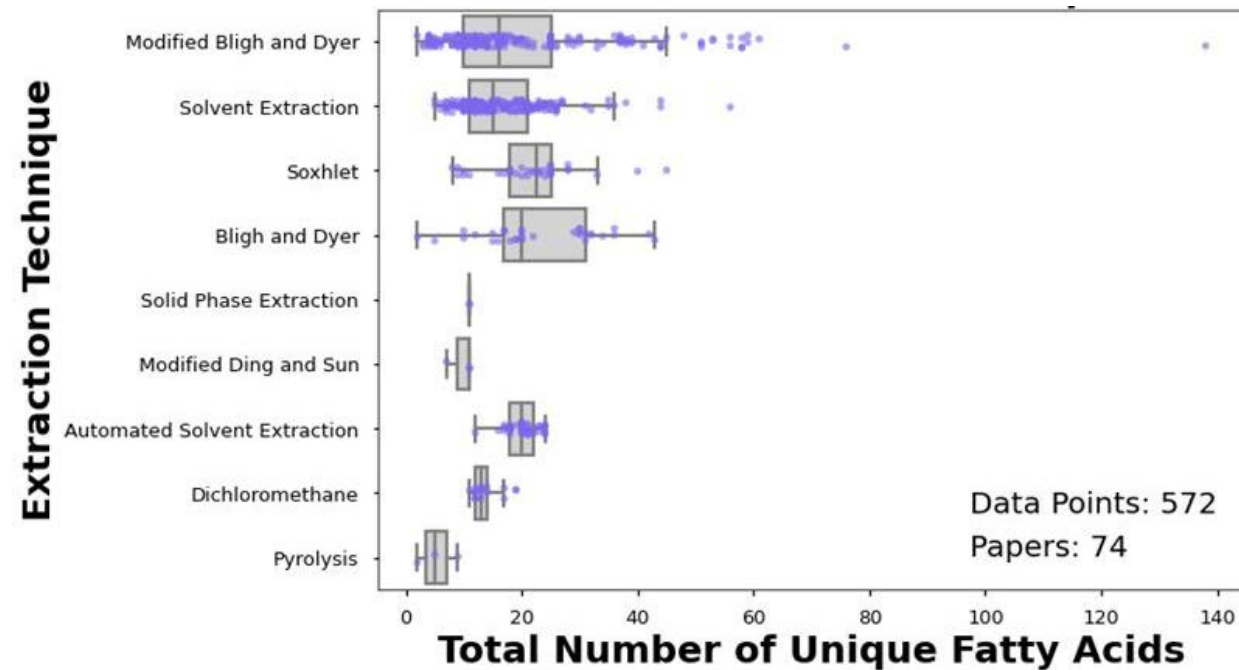


BACKUP

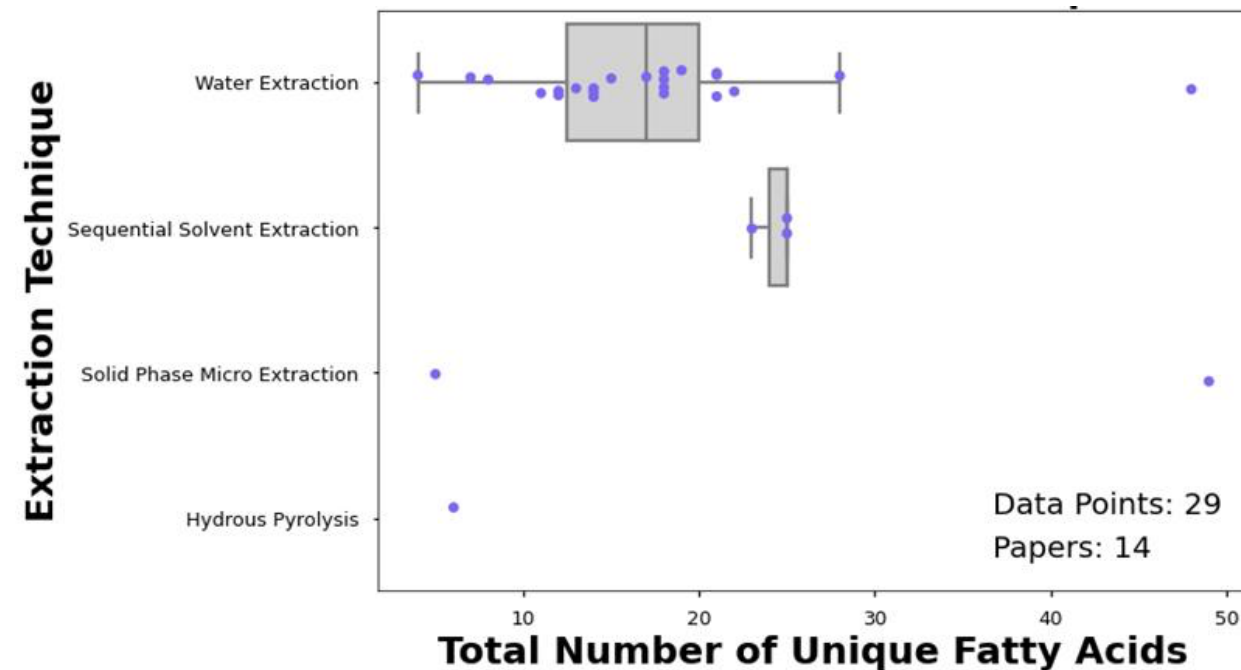
Literature Review of Lipid Extraction

- Liquid extraction techniques have been used successfully for over 70 years to investigate the organic content of complex, natural samples.

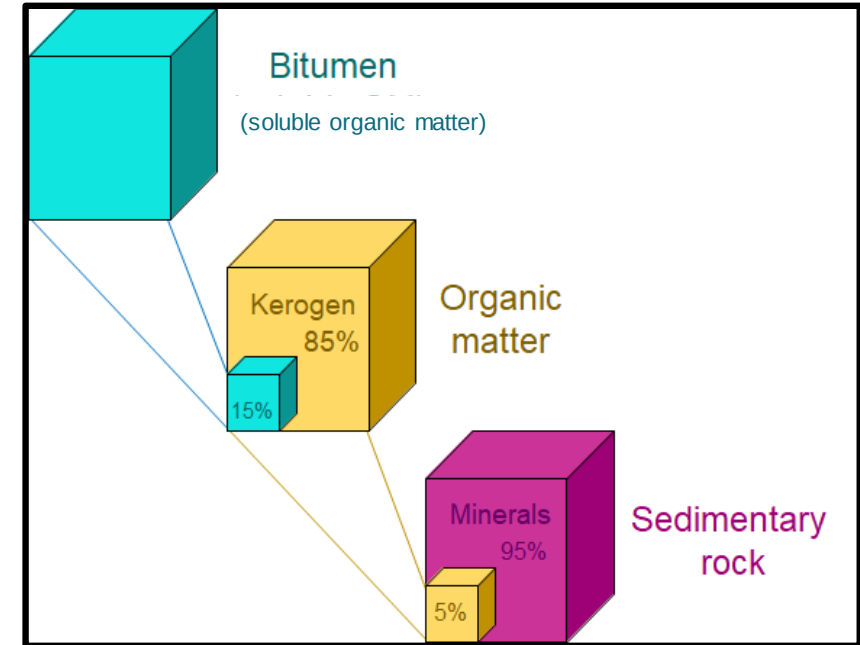
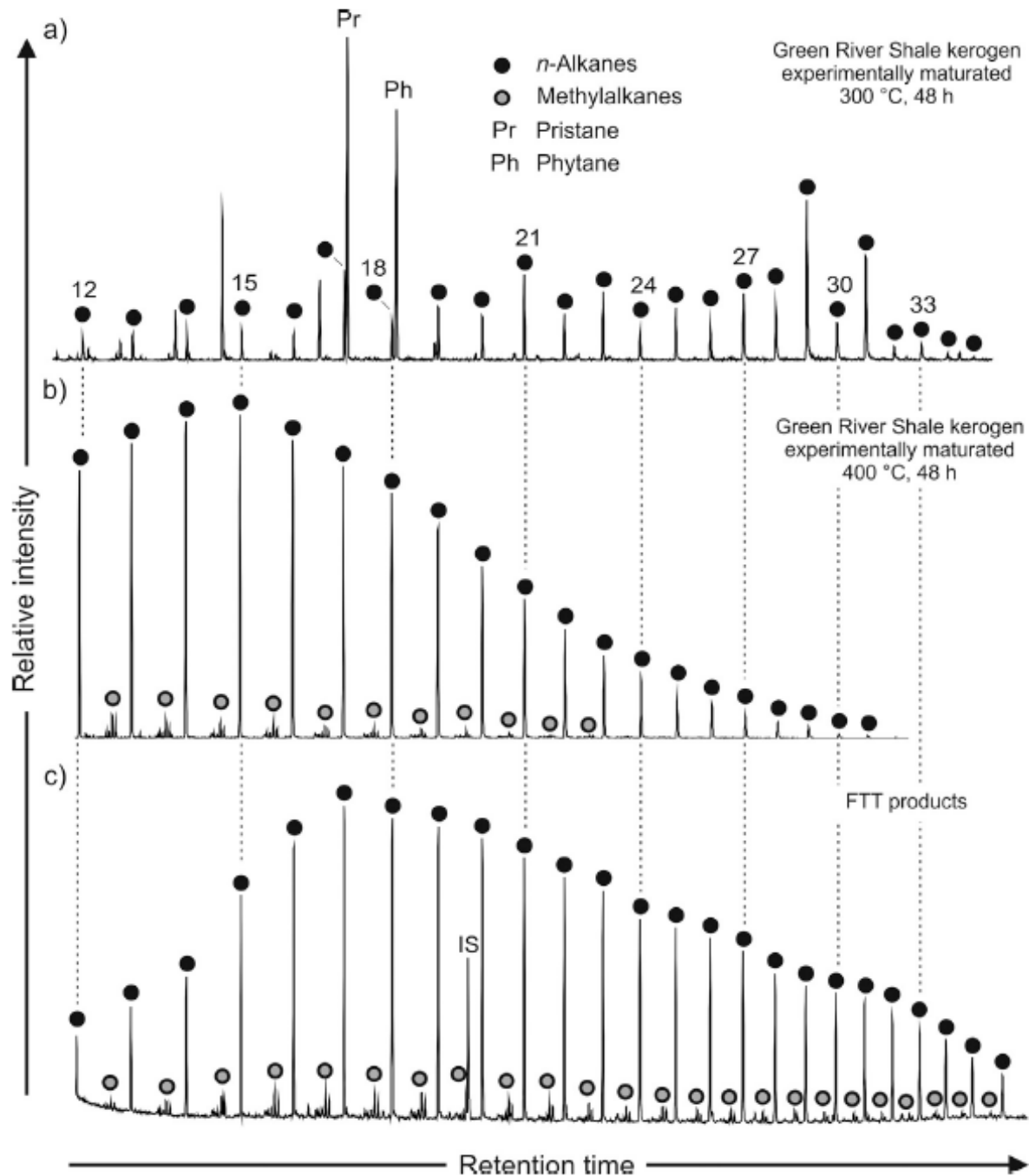
Biological Samples



Meteorite Samples



Preliminary results from Buckner et al., in prep



Courtesy
of Carina Lee