

# IN SITU INSTRUMENT OPPORTUNITIES

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## Nomenclature

- While “in situ” and “remote” are the common designations, *planetary surface* vs. *orbital* (or deep space) instruments may be a more useful distinction
- *Sensor* suggests a transducer, while *instrument* is a means to perform an experiment, including sample handling.
- In addition to chemistry (inorganic and organic), biology, mineralogy, also have physical properties (size, shape, density, hardness, thermal conductivity, etc.) and atmospheric sciences

## What is in the roadmap: Table 1 (SIOSS challenges)

- Instruments
  - Integrated/miniaturized sensor suites
- Sampling
  - Subsurface sampling to >1 m, cores to 10 cm
  - Preservation of sample biological and chemical integrity
  - Temperature control of frozen samples
  - Unconsolidated material handling in microgravity
- Long term
  - Nothing 2017-2022
  - Extreme environment technologies (vacuum, microgravity, radioactive, high/low temperature, high pressure, caustic...

## What is in the roadmap: Table 5 (Planetary Science needs)

- Mini spectrometer, filters, coatings
- Pulsed lasers (Raman, LIBS) and tunable CW (NIR/IR)
- Gas and elemental composition, APXS, IR, gamma, Raman, XRD, neutron...
- Geochronology
- Biological sensing
- Sample handling
- High power, extreme environments

# What is in the roadmap: Table 8 (Sensor technology)

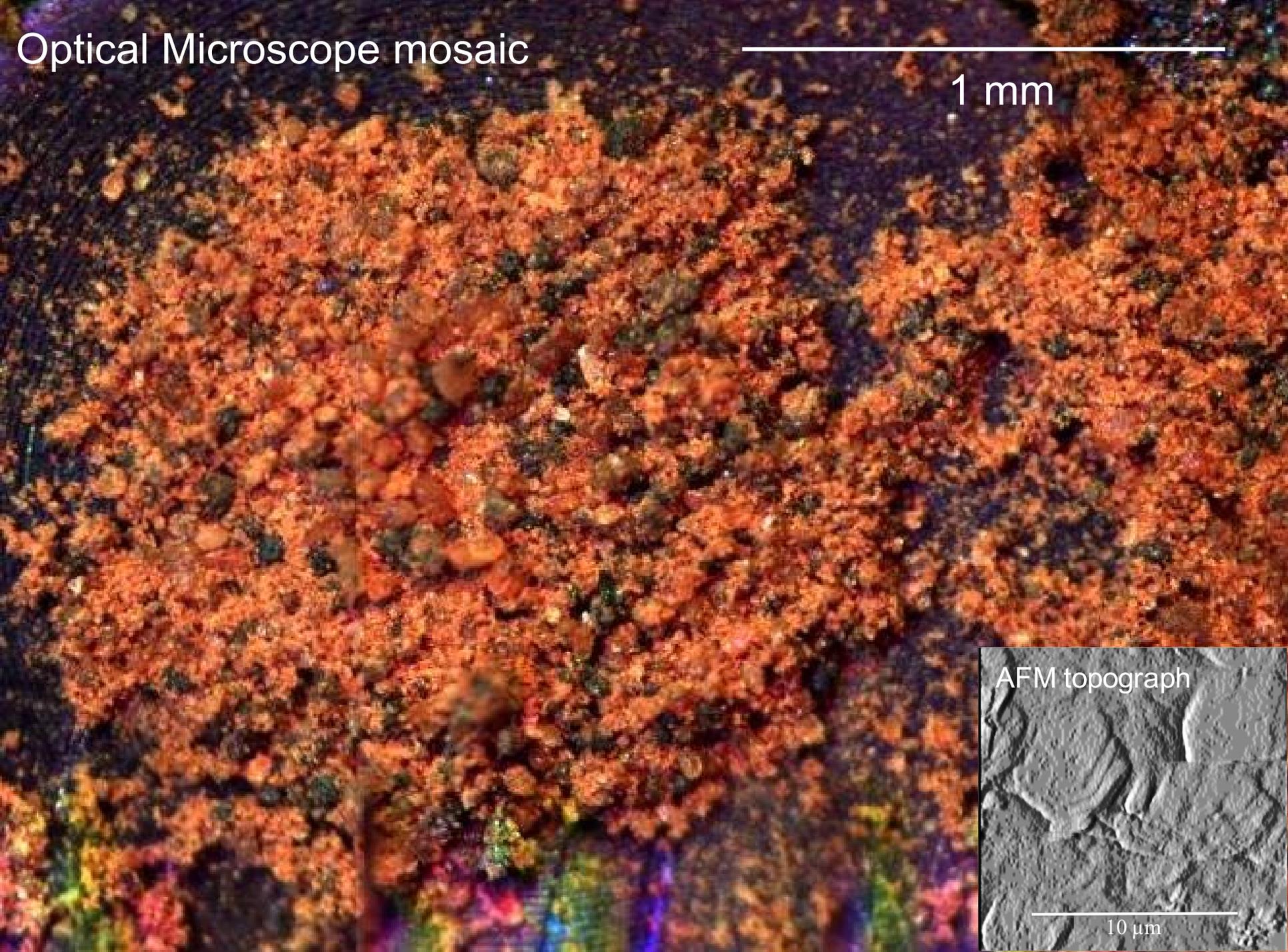
- Particles, fields, waves
- Sample Handling
  - Acquisition (subsurface and cores)
  - Transfer and delivery
  - Cryogenic & sealing (preserve volatiles, control and monitor cross-contamination)
- Chemistry and Mineralogy (beyond APXS)
  - Wet chemistry (measure dry weight, dissolved ions to ppm)
  - Elemental composition (LIBS, XRF) with spatial resolution
  - Mineralogy (Raman, XRD, IR/UV ) with spatial resolution
  - Microscopy (SEM, hyperspectral)
- Organics and biology
  - Ppb detection (requires contamination control)
  - Mass range and resolution (<0.1 amu!)
  - Biomarker detection
- Planetary protection

## Top *sensor* challenges (not in roadmap are **yellow**)

- Imaging with chemical identification, microscopic to macroscopic
- *In situ* geochronology
- *In situ* biomarker detection
- Ultra-high resolution mass spectroscopy (resolve isobars)
- Lower degree of difficulty:
  - Atmospheric instruments
  - Physical property instruments
  - Geophysics (seismometry, heat flow)
  - Terrestrial *in situ* instruments

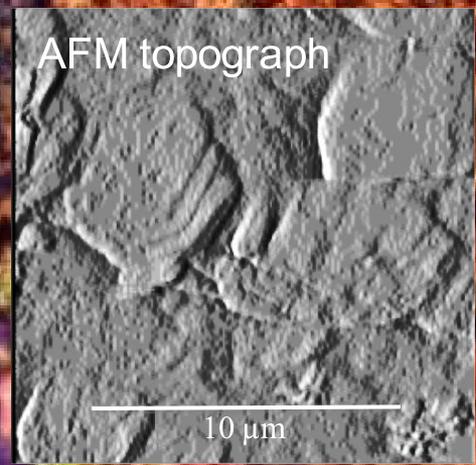
Optical Microscope mosaic

1 mm

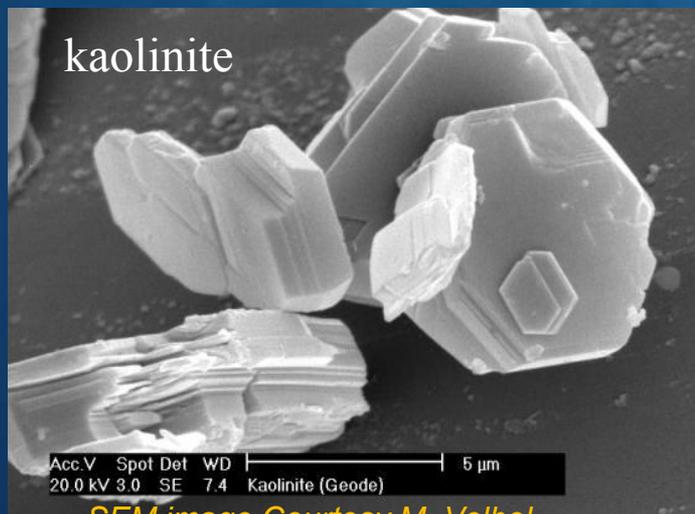
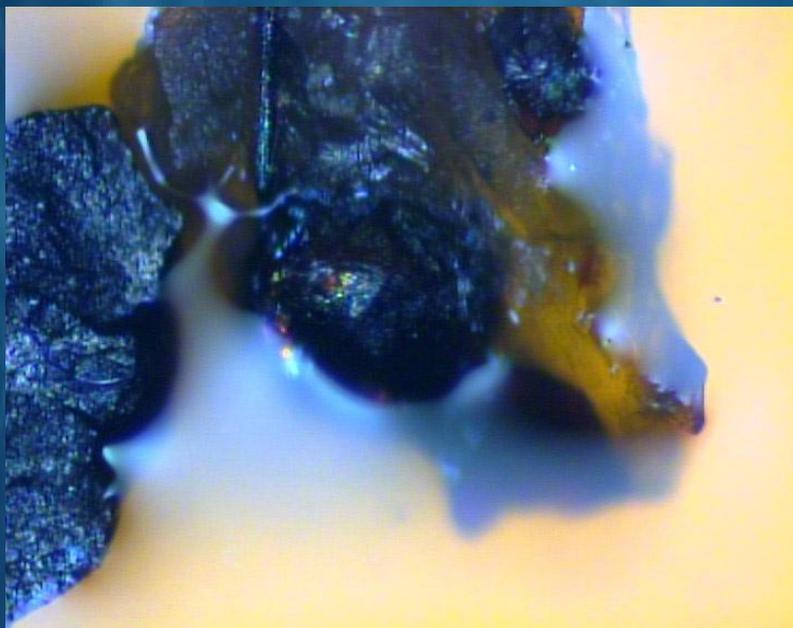


AFM topograph

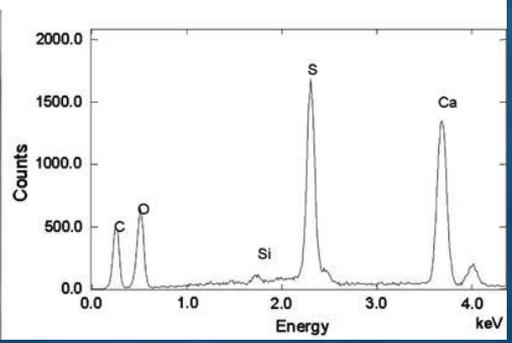
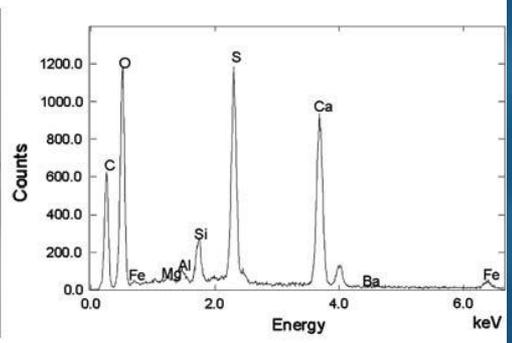
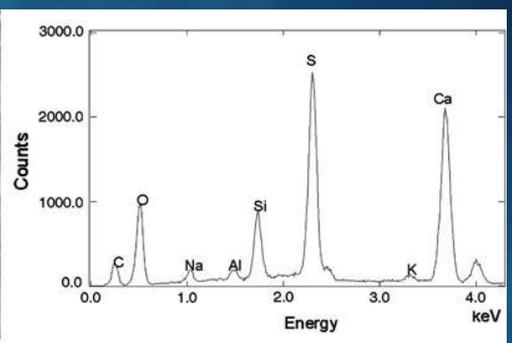
10  $\mu\text{m}$



# Micro Analysis



SEM image Courtesy M. Velbel



ESEM/EDX of Calcium sulfate airborne particles (Iordanidis et al., Environ Geochem Health 30, p. 391, 2008)

# Ultra High Resolution tholin mass spectra (ICR)

*Distinguishing isobaric species allows identification of chemical pathways*

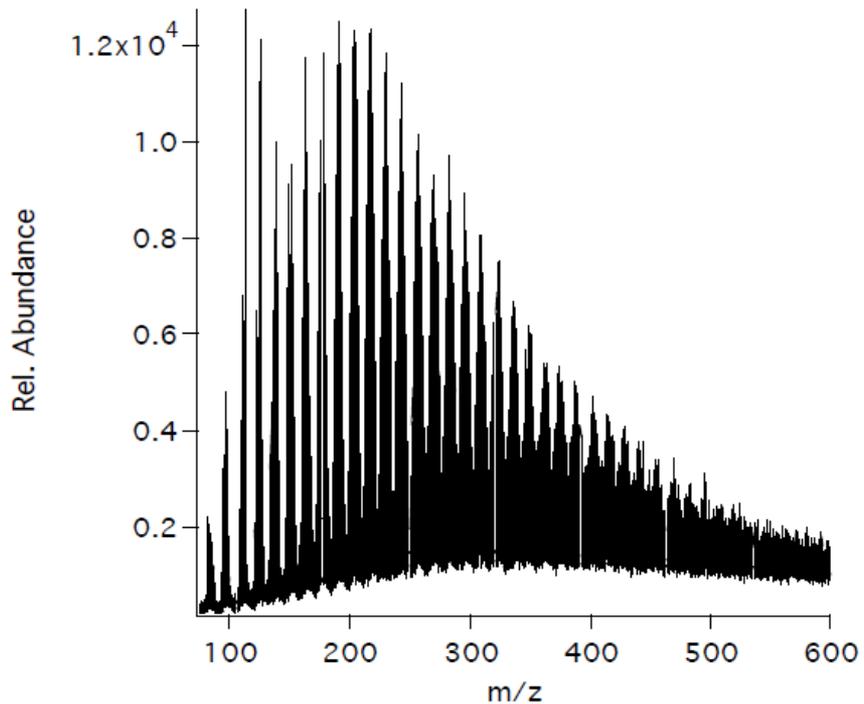
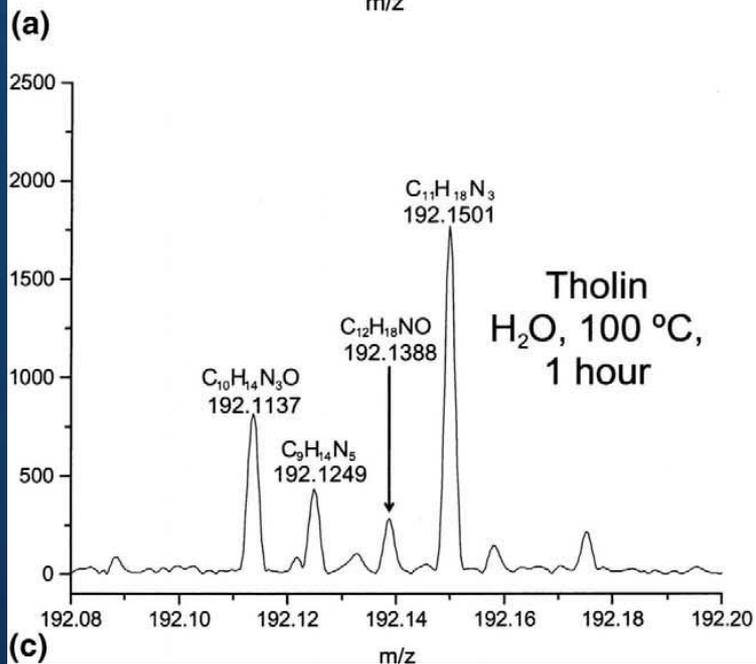
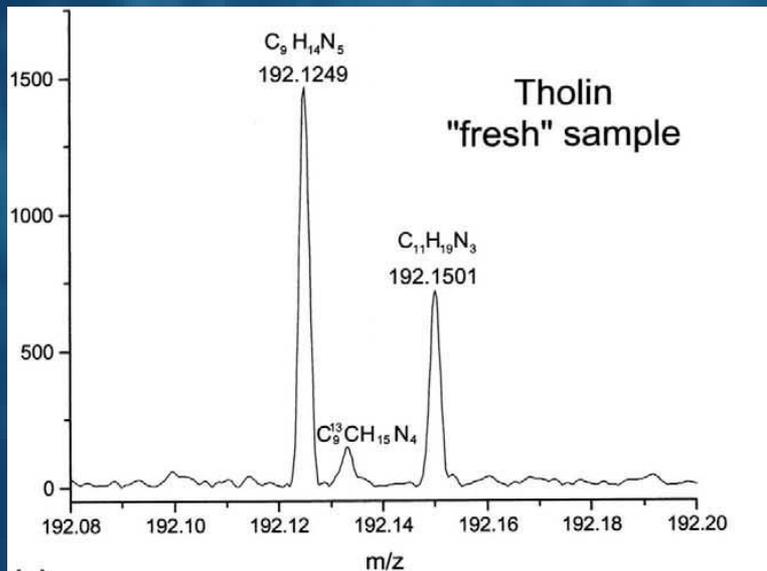


Figure 1.1 Laser desorption ionization mass spectrum of  $CH_4 + N_2$  tholins.

## Top *system* challenges (not in roadmap are **yellow**)

- MSR curation (in situ)
  - **Need to avoid alteration** as well as loss of volatiles and cross-contamination. Requires thermal control
- Excavation technologies (rock, soil, ice)
- **Extreme environments (Venus, Titan)**
- **Power technologies**
  - kW and mW power sources
  - **Non-solar, non-nuclear (e.g. wind, thermal, chemical)**
- Planetary Protection and Contamination Control
  - **Full-spacecraft sterilization**

# High Priority Sensor Technology Areas (non-biological)

- Liquid phase analysis
  - Wet chemistry
  - Lab-on-a-chip
  - Ice/water analysis
- Mass spectroscopy
  - Isobar-resolving (>100K resolving power)
  - Laser ablation mass spectroscopy
  - Geochronology
- Chemical microscopy
  - SEM/EDX
  - Small spot scanning XRF
  - Spectroscopic imaging
  - Chromophor microscopy

# Lower priority sensor technology areas (non-biological)

- Sounding
  - Lidar and scanning lidar
  - LIBS and Raman
  - Neutrons and gammas
  - Acoustics
  - Seismometry
  - GPR
  - NMR
  - Remote thermal properties
- Other
  - Physical properties
  - Atmospheres
  - XRD
  - Electric and magnetic fields

## Alignment with NASA capabilities, role, competitiveness

- All sensor and system technologies listed above could be well addressed by NASA with appropriate levels of R&A funding, except possibly:
  - Extreme environment operation (large investment, opportunity for cost-sharing)
  - Full-spacecraft sterilization

## Game changing technologies (near tipping point is **yellow**)

- Ability to do things relegated to sample return, e.g.
  - **In situ geochronology**
  - **Advanced life detection**
  - **Micro-analysis**
- Non-nuclear power sources (e.g. thermal, chemical)
- Extreme environment operation (esp. Venus)
- New architectures:
  - Extreme surface mobility
  - **Broadened access to deep space (flying instruments)**
  - Ability to collect and store massive amounts of data and samples with high autonomy, uploading “apps” for data mining and analysis.
  - Fleets of miniature payloads

## For discussion

- Time horizons for insertion
- Payoffs, risk, technical barriers and chance of success