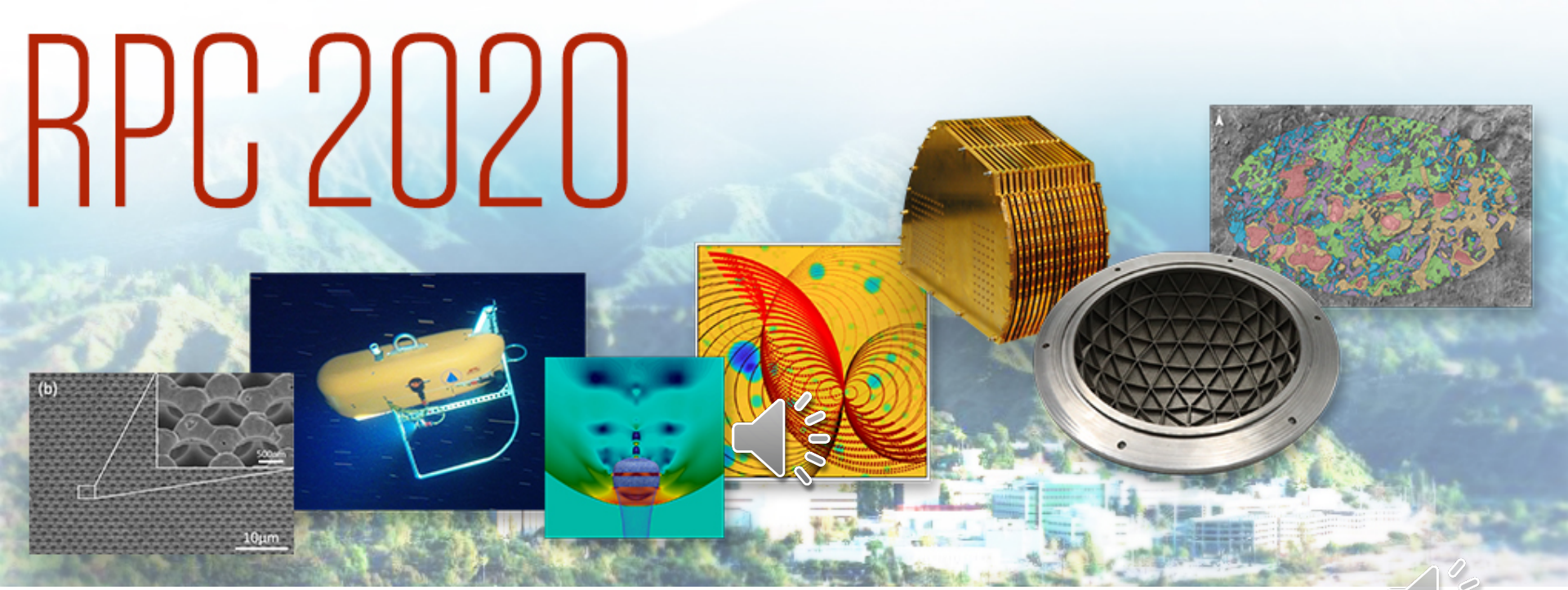
RPC 2020



Virtual Research Presentation Conference

Big Science out of Small Samples: Consortium Study in Support of Mars Sample Return Science

Principal Investigator: Yang Liu(322)
Co-Is: Brandi Carrier(394), John Eiler(Caltech), Francois Tissot(Caltech), Ken Farley(Caltech)
Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation # RPC-080

Tutorial Introduction

Abstract

Current and future sample return missions will only return a limited amount of sample mass. After saving specified amounts for future generations, the amount of sample available for science investigations will be highly constrained. *Preferential access to these precious samples is likely to be granted to consortia that can conduct multiple science investigations on small sample allocations with demonstrated excellence and efficiency.*

However, standard operations of consortia are not optimized for small samples. With MSR started by the successful launch of Mars 2020, the time for preparation of JPL's leadership in MSR science and planning is now. Toward this goal, a *JPL-Caltech team will establish a working procedure that demonstrates the state-of-the-art science that can be achieved by this consortium, to push the limits of what can be done using a limited sample mass while producing excellent science results*.

In this RTD, we will develop a working procedure that aims to share and save samples. We completed the most planned work for FY20, developed an initial procedure, and obtained baseline measurements. Results from the FY20 set the basis for executing and testing the working procedure in FY21.

Problem Description

Context and SOA

The amounts of Mars returned samples for science investigations will be very limited (possibly <7 g/sample for the whole community). Access to samples would be highly competitive and are most likely awarded to consortia. The current modus operandi of a consortium in the field is not suitable for the limited availability of the sample. Thus, a consortium with high science output per unit mass will have a competitive advantage in gaining access to these precious samples.

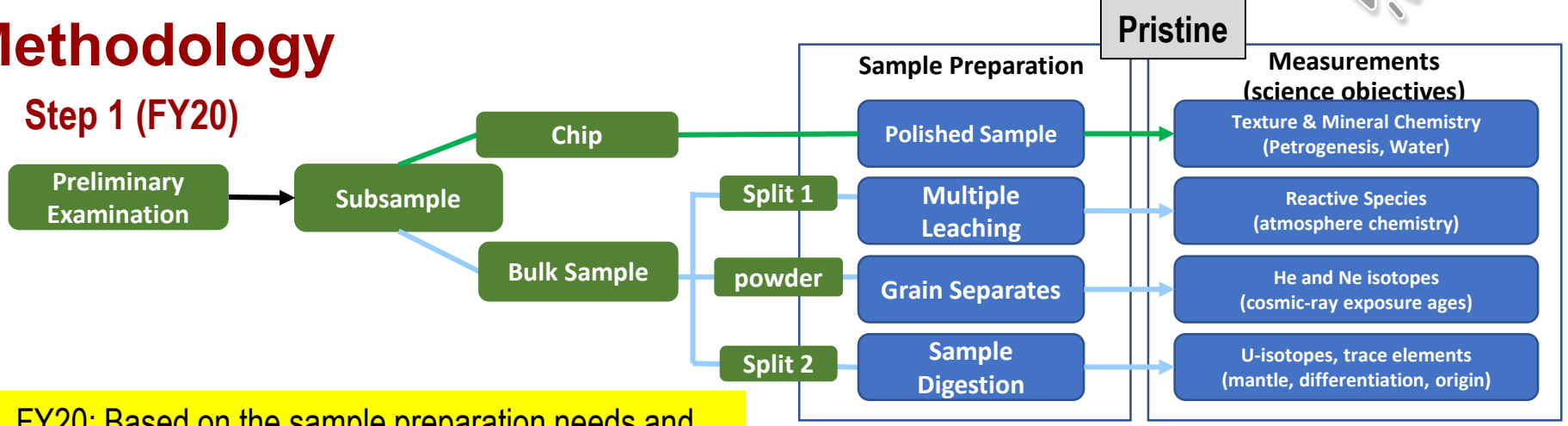
JPL-Caltech already hosts scientists that are leading experts in many of the key science areas relevant to MSR with state-of-the-art instrumentations. Although these scientists form a competitive consortium, an efficient working procedure that allows multiple science investigations on one small sample has yet to be established.

Relevance to NASA and JPL

Successful completion of the proposed research would place the JPL-Caltech team at the front of the field in pushing the limit of samples needed for the state-of-the-art instruments, as well as enhance infrastructure and human capital at JPL-Caltech. The optimized and tested working procedure of the nucleus team will first be used to compete for access to returned asteroid samples from the OSIRIS-REx mission, which are due to be returned in September 2023. Practice in competing for this mission and carrying out the subsequent analyses with excellence will then set the foundation for a leadership position in Mars sample return science and other future sample return missions.

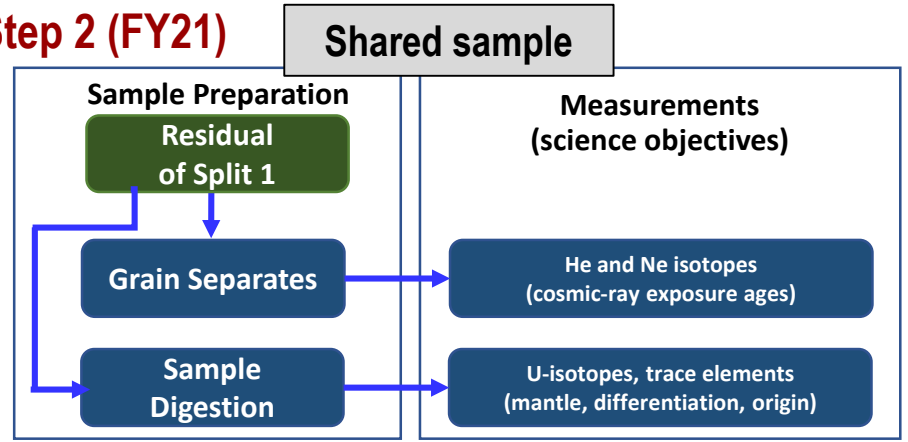
Methodology

Step 1 (FY20)



- FY20: Based on the sample preparation needs and the nature of each science investigation, we developed a working procedure that can share one aliquot of sample among different investigations.
- FY21: Effectiveness of this procedure is tested by comparing results between pristine and shared samples.
- FY22: improvements and modifications of the procedure will be made based on results from FY20.

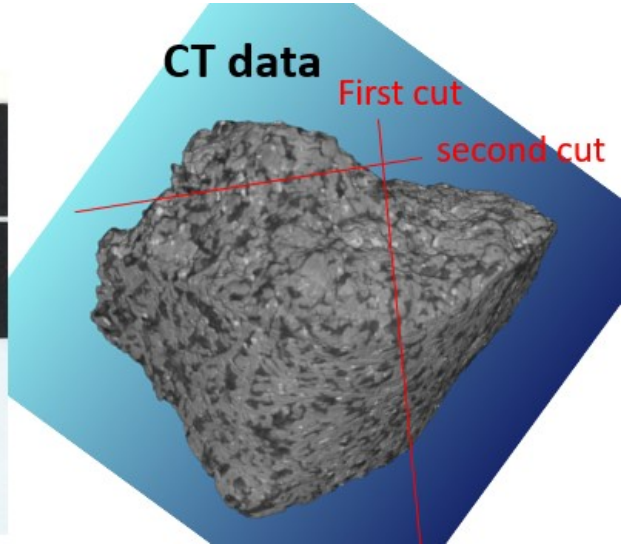
Step 2 (FY21)



Results-Overview

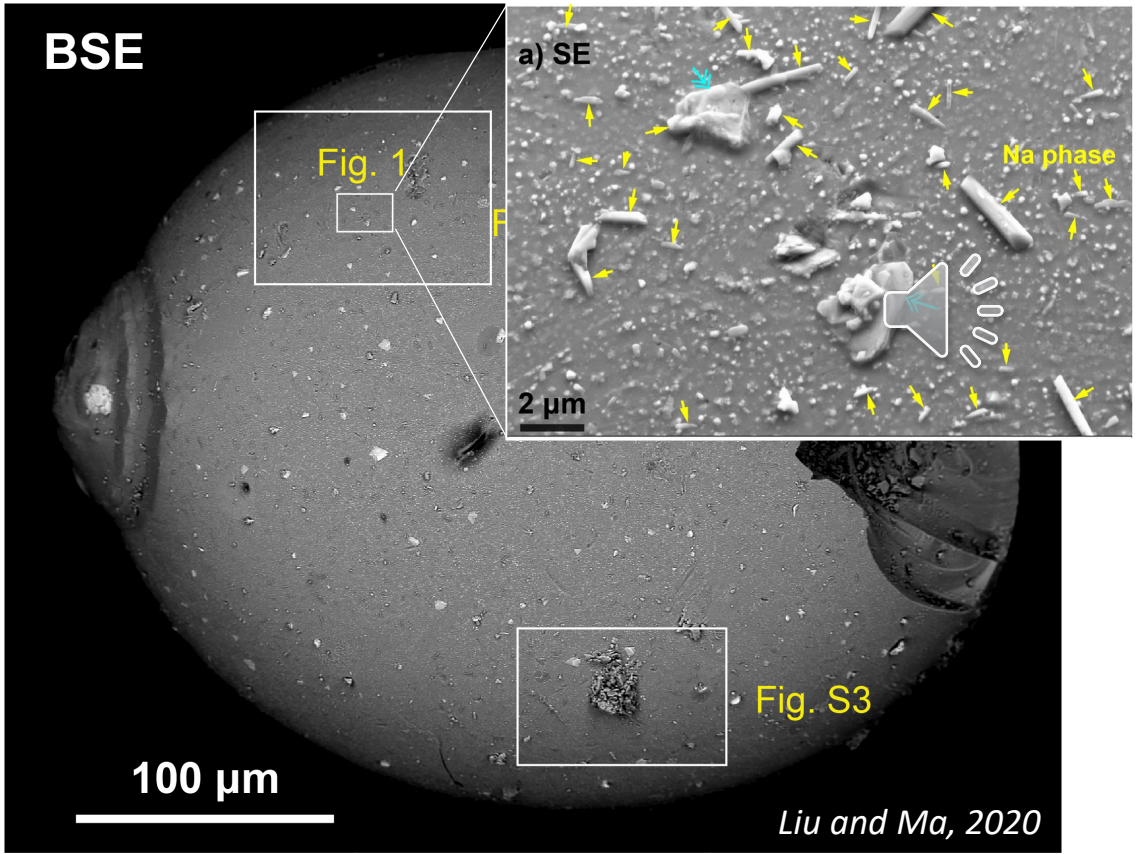
Planned	Accomplishments
1. Procure a Martian meteorite	1. Complete. Identified a new Martian meteorite for the project (NWA 13134,officially approved in Feb. 2020)
2. Preliminary examination of the samples	2. Completed. Performed CT scans [huge amount of data for collaboration]
3. Subdivide samples: one for polished sections, one for bulk analyses, one for curation	3. Completed. Subdivided samples based on CT data and delivered a representative sample to campus Co-Is
4. Preparing polished sections	4. Complete. The chip is cut and polishing started
5. Bulk sample analyses	5. Bulk sample: Completed He isotope analyses; Commenced sample preparations for reactive species and U-isotopes
	6. Two new directions: New discovery of lunar volcanic gas (Completed); Special glove-box (Functional, improvement will be implemented next year)

Results- Demonstrating the benefit of CT in preliminary examination (PE)



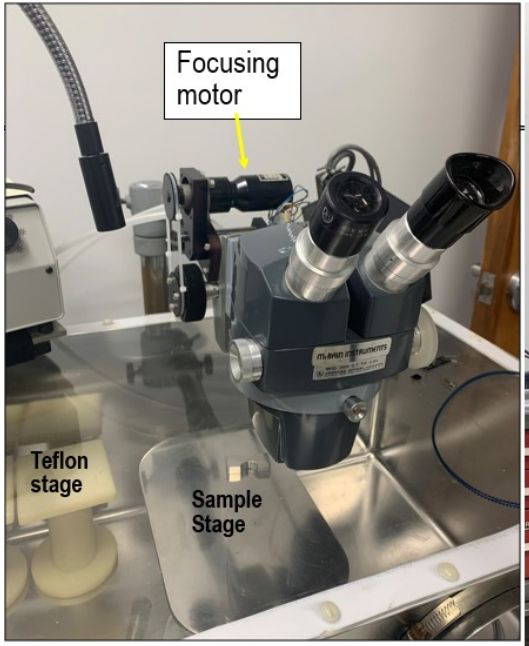
- CT analyses from JPL ATL provided superior high-resolution, non-destructive, 3D interior views of the meteorite
- Not only used as a PE tool for decisions about subsampling, but also provided PE results on mineralogy
- A huge dataset that inspired research projects in collaboration with JSC

Results- First discovery of volcanic K gas on lunar pyroclastic beads

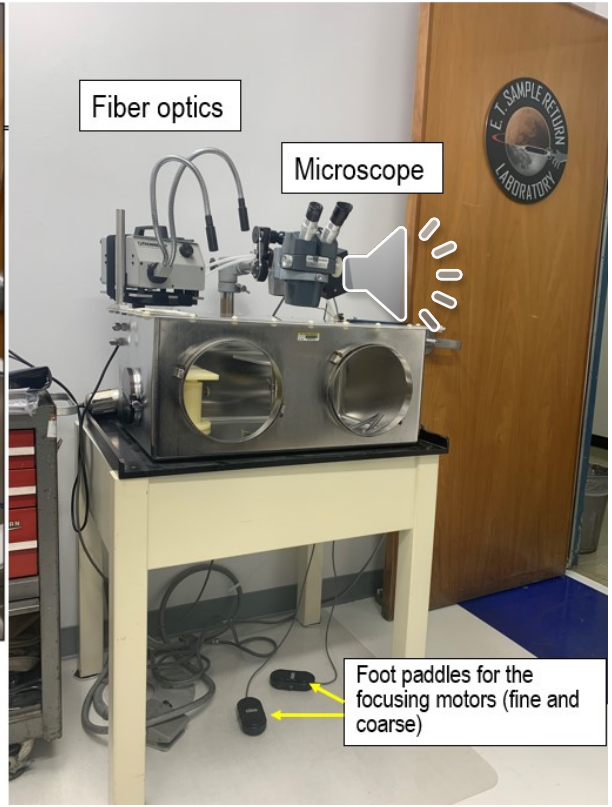


- Previous studies never identified hosts of condensed volcanic gas
- First discovery of volcanic outgassing of Na and K (Na-phase) on small lunar volcanic beads (< 30 μg each)
- Constraints on mechanisms of volatile loss on the Moon
- Impacts on current debate of when the Moon lost its volatiles
- Excellent demonstration of significant science can be made on small samples

Results- A customized glove box for handling small samples



Stainless steel interior, easy to clean



- Handling of returned samples requires prevention of alteration and contamination, e.g., in a glove box
- Commercial glove box is not suitable for viewing and manipulation of small samples
- Developing a new capability at JPL
- Enhancement of the infrastructure at JPL to support MSR science; improvement to an established E.T. Sample Return Laboratory (a sample preparation lab and a metal-free clean lab)

Significance

Our FY20 results from two subtasks are excellent examples of big science discoveries made out of small samples. Our finding of potassium in lunar volcanic gas is the first report of potassium degassing during lunar volcanic activities. Such a discovery is only possible through the study of individual volcanic beads (<30 µg) and the correct sample preparation method. This finding disproved a commonly accepted concept and provided new insights in volatile depletion on the Moon. In addition, from measurements of cosmogenic He in individual grains (<250 µg), we showed that previous studies using helium of bulk samples likely underestimated the cosmic-ray exposure ages. These results will have significant impacts on lunar and Martian science, respectively.

The custom-made glove box we use is uniquely designed for our experiments since commercial products were not suitable for handling microscopic samples. In the previous year, the PI constructed a dedicated sample preparation lab (183-212) for extra-terrestrial samples. Additionally, the PI also manages a metal-free wet-chemistry (183-256). Together with these E.T. Sample Return Laboratories (183-212 and 183-256), the development of this special glove box enhances the unique hardware capability at JPL, providing a competitive advantage in returned sample analyses.

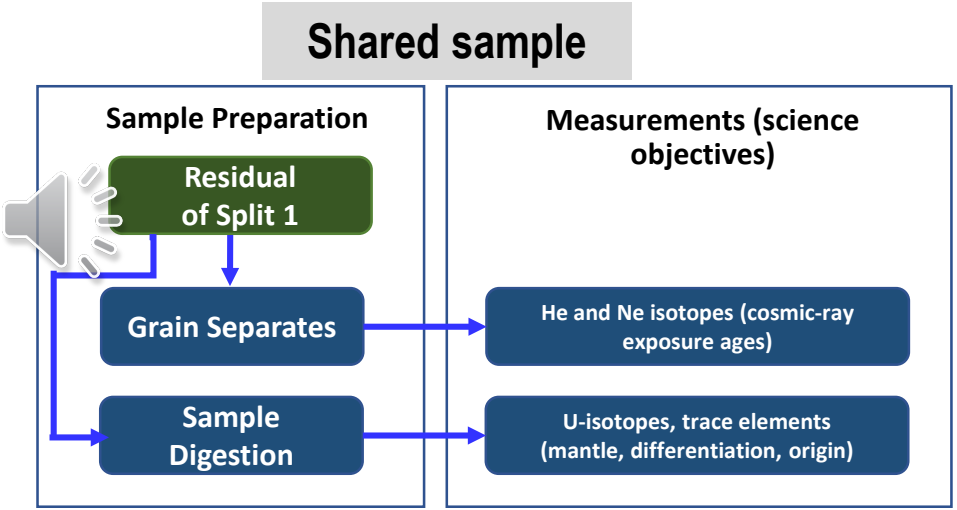
With the Mars 2020 on its way to Mars, the time for preparation of JPL's leadership in MSR science and planning is now. We expect the working procedure developed in FY20 to yield insights on how to better use samples among different science investigations. Testing this procedure in FY21 and subsequent improvement in the procedure or related hardware will place JPL-Caltech ahead of other teams in the field. Under the circumstances caused by COVID-19, the ability to complete most of the planned work for FY 20 (Year 1) demonstrates strong collaboration between JPL and campus.

The chosen Martian meteorite is a new sample and has not been studied previously. Therefore, the results obtained by this consortium will generate at least one publication in high-impact journals that will enhance the JPL-Caltech team visibility in sample related science.

Next Step

Planned
1. Finish analyses of reactive species and U-isotopes in pristine chips 2. Complete development of the customized glove box 3. Commence microbeam analyses for hydrogen isotopes in polished sections 4. Commence and complete analyses of the shared sample (see flow chart)

Step 2 FY21



Publications and References

[A] Liu, Y. and Ma, C. (2020) Discovery of a Na-K-sulfate on Apollo orange beads: Direct evidence of volcanic outgassing of Na and K on the Moon. *Science Advances* (submitted)

[B] Liu, Y., Fischer, W.W., Ma, C., Beckett, J.R., Tschauner, O., Guan, Y., Lingappa, U.F., Webb, S.M., Prakapenka, V.B., Lanza, N.L., Agee, C.B. 2020. Manganese oxides in Martian meteorites Northwest Africa (NWA) 7034 and 7533. *Geochimica et Cosmochimica Acta* (revised).

[C] Nicklas, R.W., Day, J.M.D., Vaci, Z., Udry, A., Liu, Y., Tait, K.T. 2020. Uniform ambient mantle oxygen fugacity and a highly oxidized lithospheric mantle on Mars. *Earth and Planetary Science Letters* (submitted)

[D] Liu, Y., Ma, C., Housley, R.M. (2020) Contrasting volcanic gases between pyroclastic eruptions on the Moon, 51st Lunar and Planetary Science Conference, #1166.