National Aeronautics and Space Administration

Big science out of small samples: Consortium study in support of Mars sample return science

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Enabling Mars Sample Return Science at JPL**

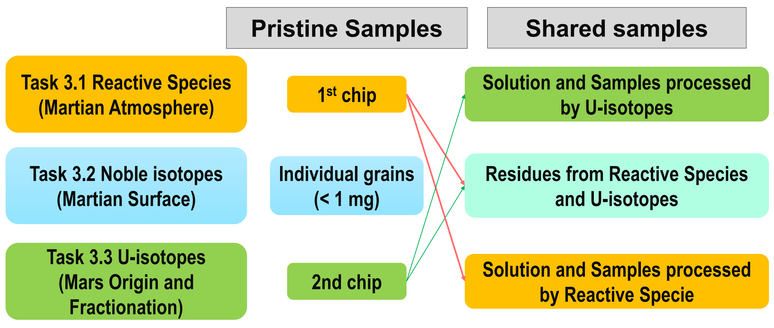
Objectives

For the proposed period, our objectives are: 1) decrease the current standard mass requirement of samples for multiple science investigations by up to 50% while maintaining the science quality of the investigations (maintaining measurement resolution, sensitivity, and precision); 2) establish an efficient working procedure for the JPL-Caltech nucleus team that leads to publications in high impact journals. In the proposed period, we expect to develop new analytical procedures or hardware relating to small sample preparation.

Background

- The amounts of future returned samples will be small.
- Allocations of samples are most likely awarded to consortiums.
- Teams that can produce high quality scientific results on a smaller sample mass have competitive advantages.
- Traditionally, each member in the consortium gets their own pristine samples to investigate (total mass = Σ mass$_i$).
- Our proposal aims to develop a new working procedure that different investigations produce measurements on a shared sample (total mass = Max of mass$_i$)

Approach



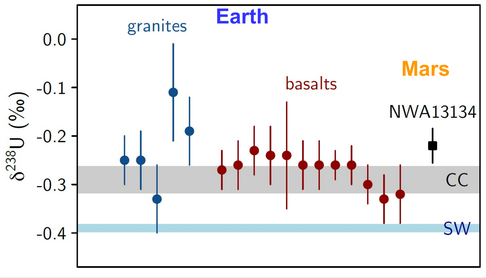
The team plans to measure bulk samples to study reactive species for understanding Martian atmosphere processes, cosmogenic isotopes for understanding the surface processes, and U-isotopes for understanding the origin of Mars, and to measure polished sections to study texturally correlated mineralogy and subsurface water stored in impact melt pockets. Since the proposed investigations of bulk samples use similar sample preparation methods, we will develop a procedure that enables multiple investigations to share one bulk sample. Each team member will analyze a piece of sample and then will analyze those prepared by other team members. We will compare the results to determine at which step the results diverge. The final working procedure will be developed based on the results.

In parallel, we will study polished samples to provide mineralogy and textural context for interpreting bulk data and for constraining the origin of the sample. A Martian meteorite, NWA 13134, was used for the project. Additionally, the PI is pursuing directions that enhance the science of small samples and continue to showcase JPL's sample science.

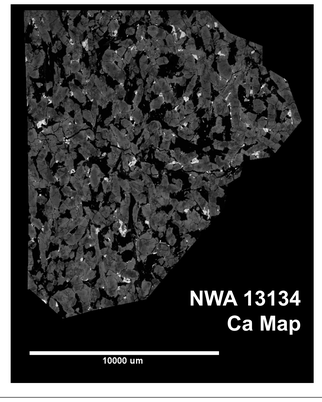
Results I

We completed the analyses of the pristine samples and results are interesting:

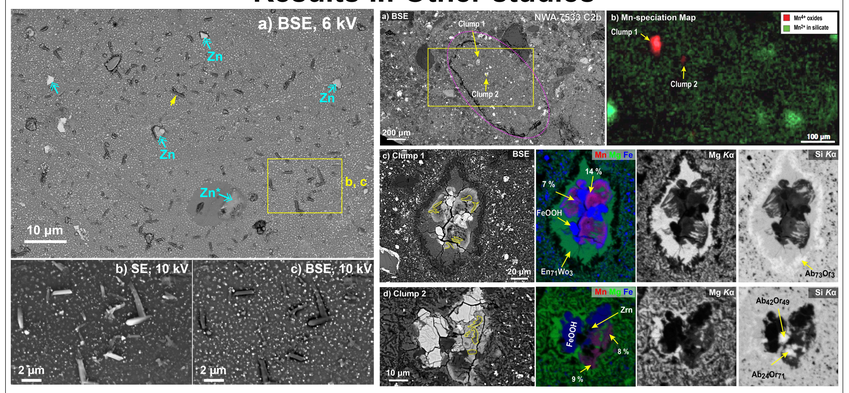
- NWA 13134 is an enriched shergottite with minerals similar to others in the same group. The sample contains a number of impact melt pockets that will be used to study subsurface water on Mars.
- Measurements of helium isotopes were conducted on individual grains (pyroxene and maskelynite), each of which is < 1 mg. Results suggest the sample was launched from Mars at ~3x10^6 years ago. This is the first analysis of helium isotopes of individual grains.
- The U-isotope of the sample (δ^{238}U) is slightly higher than terrestrial basalts (Fig. 1). This interesting difference shows a great potential of using U-isotopes to understand the evolution history of Mars.



First U-isotope analysis for Martian samples, showing slight enrichment than terrestrial basalts. Several potential causes and highlighting the need of more investigations

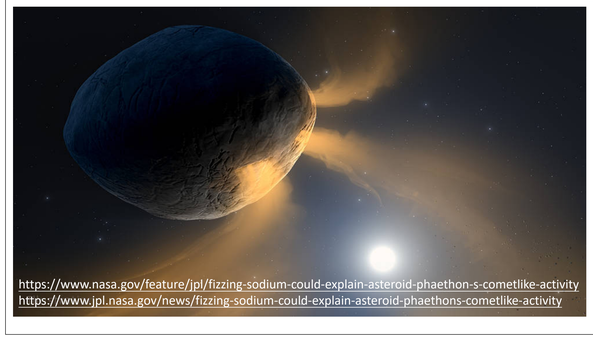


Results II: Other studies



First discovery of Na-K-sulfate on the surface of lunar beads, offering a new way to study lunar volcanic gas that [A].

First discovery of Martian Mn-oxides [B], suggesting a long-lasting, highly-oxidizing aqueous environment on Mars at 1.3 x 10^9 years ago



Experimental proof that sodium volatilizes at temperatures consistent with low-perihelia asteroids [C], which is important for the DESTINY+ mission that will visit Phaethon (a low-perihelia asteroid).

Significance

Results of original samples are of high science interests but also offer the important baseline in verifying the work procedure for sharing one sample among different investigations. With the successful collection of the samples in the Mars 2020 mission, the preparation of JPL's leadership in MSR science and planning is important. We expect the working procedure from this project to yield insights on how to more efficiently use samples among different science investigations. Streamlining and maximizing the sample processing and subsequent datasets will only deliver more on investment with future missions. Testing this procedure in FY22 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 21 (Year 2) demonstrates strong collaboration between JPL and campus.

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Publications: *[A] Yang Liu and Chi Ma "Discovery of a Na-K-sulfate on Apollo orange beads: Direct evidence of volcanic outgassing of Na and K on the Moon," Icarus (in revision), 2021. [B] Yang Liu, Woodward W. Fischer, Chi Ma, et al., 'Manganese oxides in Martian meteorites Northwest Africa (NWA) 7034 and 7533', Icarus, 364, 114471, 2021. https://doi.org/10.1016/j.icarus.2021.114471. [C] Joseph R. Masiero, Björn J. R. Davidsson, Yang Liu, et al., 'Volatility of Sodium in Carbonaceous Chondrites at Temperatures Consistent with Low-perihelion Asteroids', The Planetary Science Journal, 2 (4), 165, 2021. 10.3847/psj/ac0d02.*

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