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

Principal Investigator: Yang Liu (322);
Co-Investigators: John Eiler, Francois Tissot, Michael Kipp, Ken Farley (GPS, Caltech)

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Objectives

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).

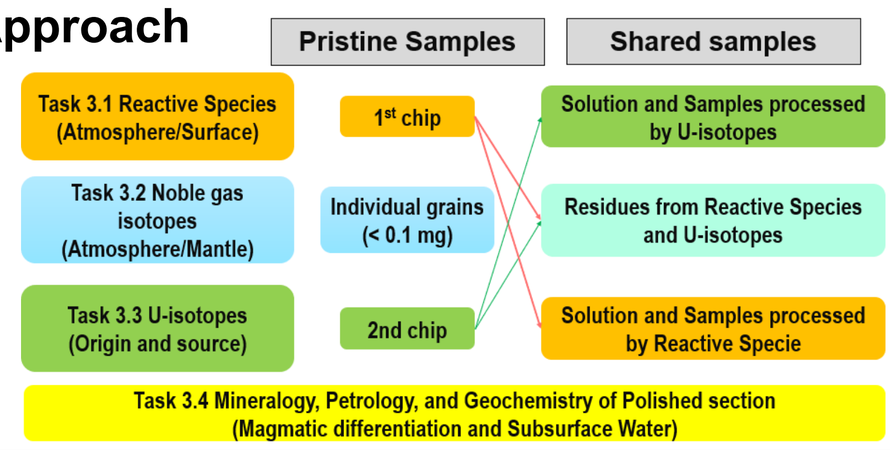
2) establish an efficient working procedure for the JPL-Caltech nucleus team that leads to publications in high impact journals.

3) In the proposed period, we expect to develop new analytical procedures or hardware relating to small sample preparation.

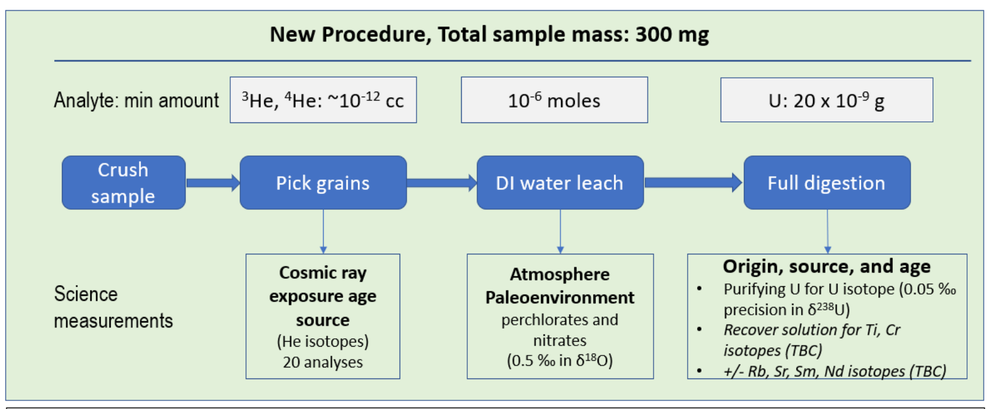
Background

- 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$_i$)

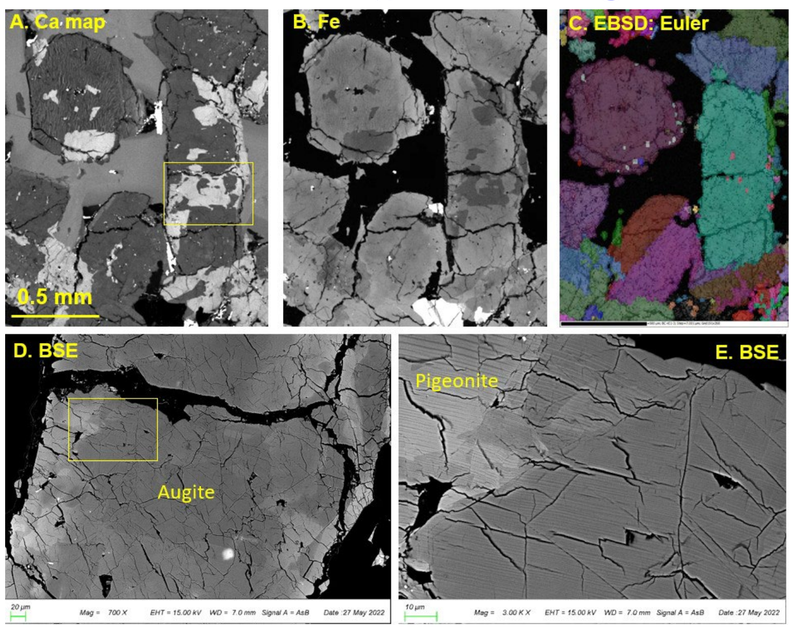
Approach



Results: Significant mass saving



Results: 5th gabbroic shergottite (out of >330 Martian meteorites), interesting Ca zoning



Results

We completed the mineralogy and petrography study of the polished section [A] and is preparing the manuscript [C]. NWA 13134 is a new and fifth member of gabbroic shergottites. An interesting new feature is the intergrowth of two pyroxenes in the sample and the presence of exsolution lamellae.

We mostly completed the planned bulk analyses. Helium isotope analyses consumed only 2 mg of sample for 10 duplicate measurements of pyroxene and maskelynite. The leaching by weak acetic acid (1% concentration) of the sample showed that phosphate was selectively dissolved. Since U is hosted in phosphate, this result suggests that we should use deionized water for the extraction of perchlorates and nitrates (e.g., [1]). NWA 13134 contain 181 ng U and we obtained δ^{238}U with 0.04 ‰ precision with 243 mg sample. With these results, we developed **a sample preparation procedure that enables sample sharing among different analyses (Fig. 1).**

Estimate of sample mass: The desired precision and concentration of the analyte determines sample mass. Based on the literature data (0.2‰ difference in δ^{238}U [2]), we expect that a precision of 0.05‰ is sufficient, which requires ~20 ng of U [3]. For 100 ppb U, ~200 mg of sample is needed. For perchlorate and nitrate, 1 nanomole of analytes is needed for ~0.5‰ in δ^{18}O, which is sufficient to discern high versus low temperature origin. For a sample with 1 ppm perchlorates or nitrates, this indicates a sample mass of ~100 mg. Clearly, the U-isotope analysis is the mass-controlling measurement. Based on Mars 2020 data and Martian meteorite data [4, 5], we conservatively assumed that U concentration of returned samples is ~60 ppb, suggesting a sample mass for all our planned analyses is ~300 mg. After U was extracted, we expect the remaining solution can be used for Ti and Cr isotope analyses and possibly Rb, Sr, Sm, and Nd analyses (to be tested in next year). **From the above estimates, the total sample mass for the investigations by our team is ~300 mg.**

Significance

- This SRTD project had made significant progress towards the goal of maximizing science out of a small sample. The developed procedure will provide a large mass saving. If perchlorate and U-isotope analyses were run in parallel, the total sample mass need is >400 mg of samples. Additionally, if Ti, Cr, Rb, Sr, Sm and Nd analysis [7-9] was run in parallel, the total mass would be 600-900 mg. **Thus, the proposed procedure from this SRTD project, streamlining the sample processing and enabling the reuse of the sample solution, saves 30% to 50% sample mass.** The developed procedure also ensures all analyses were performed on the same sub-sample, thus minimizing the uncertainty in interpreting results caused by heterogeneity among different subsamples.
- With the successful collection of the samples in the Mars 2020 mission, this project has produced results that is preparing JPL's leadership in MSR science. We expect to publish the procedure and the resulted bulk analyses in one to two years.

References [1] Samuel P. Kounaves, Brandi L. Carrier, Glen D. O'Neil, et al., *Icarus,* 229, 206-213, 2014. [2] Alexander Goldmann, Gregory Brennecka, Janine Noordmann, et al., GCA, 148, 145-158, 2015. [3] François L. H. Tissot, Mauricio Ibanez-Mejia, Patrick Boehnke, et al., *J. Ana. Atom. Spec.,* 34, 2035-2052, 2019. [4] Yang Liu, Mike M. Tice, Mariek. E. Schmidt, et al., *Science,* 10.1126/science.abo2756, 2022.[5] Arya Udry, Geoffrey H. Howarth, Christopher D. K. Herd, et al., *JGR-Planets*, 125, e2020JE006523, 2020. [6] Liping Qin, Conel M. O'D Alexander, Richard W. Carlson, et al., GCA, 74, 1122-1145, 2010. [7] Anne Trinquier, Tim Elliott, David Ulfbeck, et al., Science, 324, 374-376, 2009. [8] Lars. Borg, Lawrence E. Nyquist, Lawrence. A. Taylor, et al., *GCA,* 61, 4915-4931, 1997. [9] Vinciane Debaille, Alan D. Brandon, Qin Z. Yin, et al., *Nature,* 450, 525-528, 2007.

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Publications:

[A] David Burney, Y. Liu, Michael A. Kipp, John Eiler, Francois L.H. Tissot, Ken Farley, "A new martian gabbroic shergottite, Northwest Africa (NWA) 13134". 53rd Lunar and Planetary Science Conference, the Woodland, TX, 2022.
[B] Yang Liu and Chi Ma, "Direct evidence of volcanic outgassing of Na and K on the Moon from Apollo orange beads". *Icarus* https://doi.org/10.1016/j.icarus.2022.115044, 2022.
[C] Yang Liu, David Burney, D., Michael A. Kipp, Francois L.H. Tissot, John Eiler, Ken Farley. "A new martian gabbroic shergottite, Northwest Africa (NWA) 13134. MAPs (in prep), 2023.
[D] Scott Eckley, Richard Ketcham, Yang Liu, "Skeletal olivine in shergottites reveals the dynamics of martian basaltic magmatism". Nature Geosciences (in prep) (2022).

PI/Task Mgr. Contact Information: Email: Yang.Liu@jpl.nasa.gov