National Aeronautics and Space Administration

NASA Astrobiology Institute 2016 Annual Science Report

Team Report:

Changing Planetary Environments
and the Fingerprints of Life,
SETI Institute

Changing Planetary Environments and the Fingerprints of Life

Lead Institution:
SETI Institute

Team Overview

Principal Investigator:
Nathalie A. Cabrol

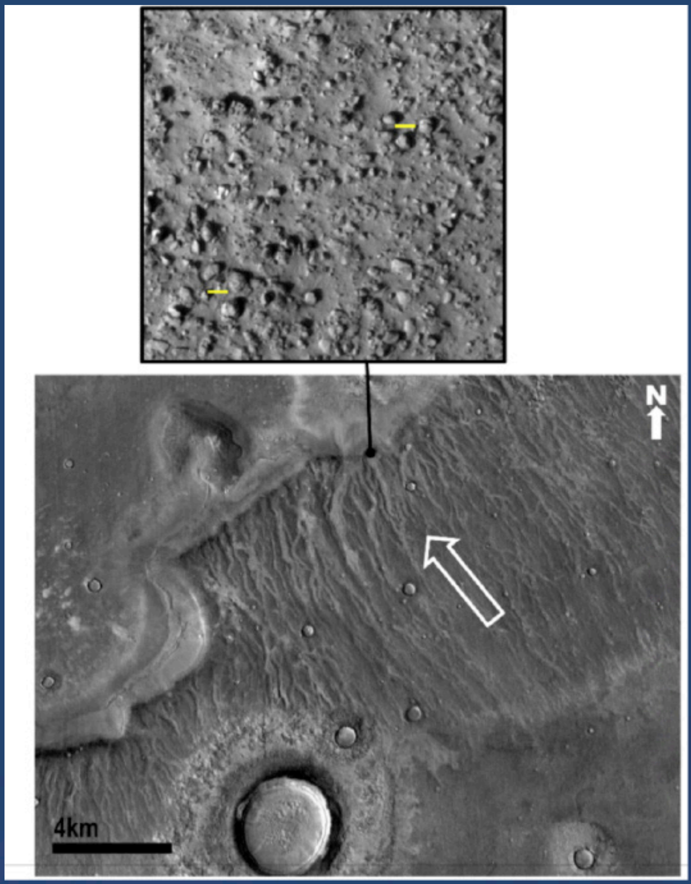
The SETI Institute Changing Planetary Environments and the Fingerprints of Life Team is developing a roadmap to biosignature exploration in support of NASA's decadal plan for the search for life on Mars – with the Mars 2020 mission providing the first opportunity to investigate the question of past life on Mars. In an ancient Mars environment that may have once either supported life as we know it, or sustained pre-biological processes leading to an origin of life, the Mars 2020 mission is expected to be a *Curiosity*-class rover that will cache samples for return to Earth at a later date. Our Team will address the overall question "How do we identify and cache the most valuable samples?"

Understanding how a biogeological record was transformed through the loss of atmosphere, increased biologically-damaging ultraviolet radiation, cosmic rays, and chaotically-driven climate changes, our Team's research focuses on these three themes:

- Where to search for the right rocks on Mars?
- What to search for?
- How to search?

2016 Executive Summary

Our search for signatures of habitability on Mars extends from megascale imaging down to microscale and molecular analysis. We are producing megascale to mesoscale surveys, extending from orbit to the surface to characterize environments on Mars that may have provided water-rich habitats for ancient life. Using visible/near-infrared (CRISM), high resolution (HiRISE) instrument data from Mars Reconnaissance Orbiter, and more regional stereo views of the surface from the HRSC camera on Mars Express, we created mosaics of Digital Terrain Maps and used them to analyze valleys and channel networks for evidence of long-term water activity. Detailed surface mapping and age dating characterized fluid discharges of valley and channel systems of the Navua Valles region, Mars; a region which has experienced repeated catastrophic and persistent fluvial activity from the late Noachian to the Amazonian (Co-I's Bishop, Gulick, Wray).



Backwash channels formed on Mars Tsunami deposits. Bouldery flow boundary shown in the enlarged image. Large white arrow shows flow direction.

Using Mars data sets as a guide, four sites in the Chilean Andes that are relevant to the Mars 2020 mission candidate-landing sites were selected for field exploration. 2016 activities focused on the collection of multi- and hyperspectral orbital imagery and the preparation of 3D-models using these images. The data products are equivalent to those being produced by the current Mars missions, or planned for the 2020 mission. One of the key goals of the field campaign was to identify and characterize data and knowledge gaps from orbit to the ground in search of habitats and biosignatures. To that end, drones were deployed at each site, and used to acquire imagery at integrated scales and resolution to understand the thresholds of detectability that can allow a mission to transition from the characterization of environmental habitability to the discovery and investigation of habitats and biosignatures (Co-I's, Cabrol, Moersch, Wettergreen).

Three-dimensional model constructed of 92 stereo image pairs captured by the Stereo Panoramic Imager at Geysers of El Tatio, Chile.

Lake Untersee field site, 71°20'37.6" S, 13°26'23.0"E in the Otto-von-Gruber-Gebirge (Gruber Mountains) of central Dronning Maud Land Antarctica.

Other Mars analog sites explored in 2016 included Ellesmere and Axel Heiberg Island in the Arctic and Lake Untersee in the Antarctic, and were used to address questions relevant to biosignature preservation and thresholds of detectability for habitats and biosignatures in remote sensing data (Co-Is Andersen, Sobron). Additional work focused on acidic iron-silicon precipitating, and acidic silica precipitating, hot springs in Yellowstone National Park which represent silica-rich Martian environments (Co-Is Hinman and Cady), sulfate-rich playa evaporites of the late Miocene/early Pliocene Verde Formation, central AZ (Co-I Farmer), and evaporitic basins in hyperarid environments in Chile (Co-I Davila).

Tying Mars mission data to our field work, we are experimentally examining, at molecular scales, synthetic and natural samples returned from these Mars analog environments. Coordinated lab investigations are underway to characterize the individual and combined role played by water, minerals and soil matrices, UV, and cosmic rays in organic preservation potential on Mars. Data on organics, mineralogical, and chemical composition of physical and biological samples were collected in the field and laboratory analyses are underway to identify and characterize detection thresholds that might not be reachable with current field/mission instrumentation (Co-Is Cady, Ertem, Hinman, Parro, Quinn, Summers).

Team Members

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Ray Arvidson
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Sherry Cady
Jean Chiar
Jack Craft
Alfonso Davila
Edna DeVore
David Des Marais
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Uwe Feister
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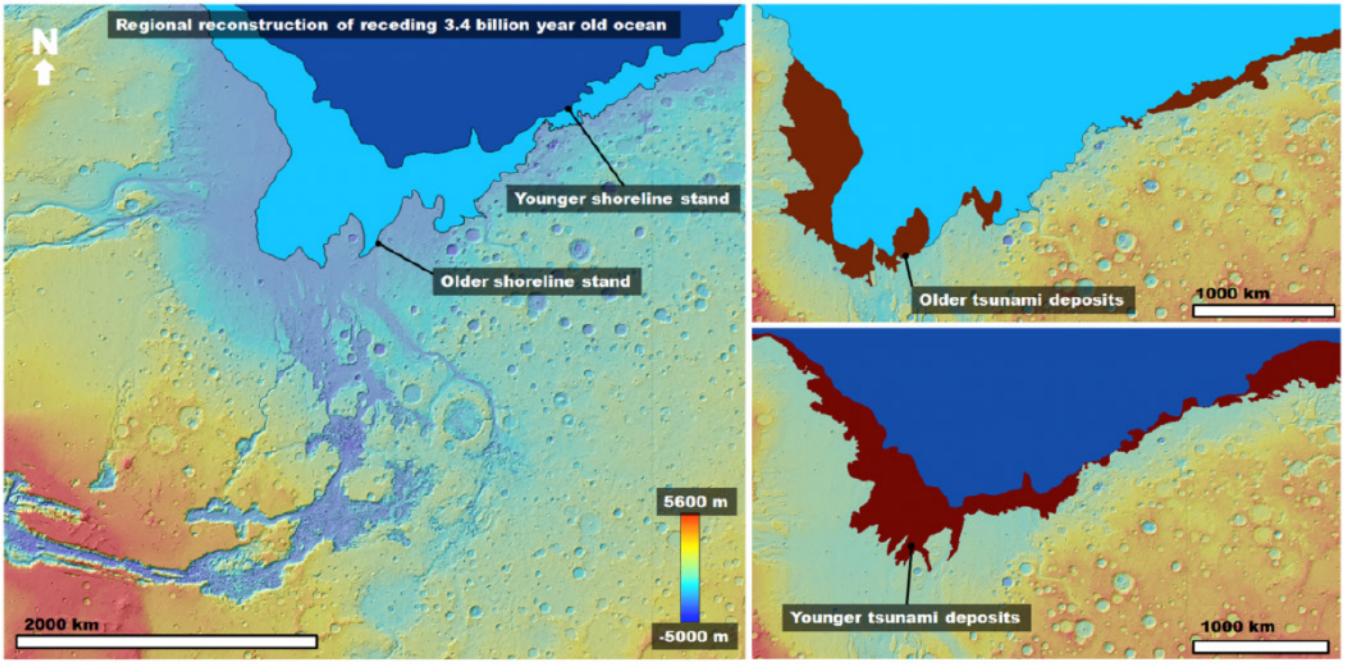
Cynthia Phillips
Wayne Pollard
Richard Quinn
Philippe Sarrazin
Trey Smith
Pablo Sobrón
David Summers
Cristian Tambley
David Wettergreen
Mary Beth Wilhelm
James Wray
Kris Zacny

Evidence for Tsunamis in an Ancient Martian Ocean - Where to Search

Ginny Gulick and her team identified deposits from two separate tsunami events associated with an early ocean on Mars.

Geomorphic and thermal image mapping combined with numerical modeling of Mars shows evidence for two mega-tsunami events that happened approximately 3.4 billion years ago. These produced widespread, landward facing flow deposits and associated backwash channels extending for tens to hundreds of kilometers into the cratered highlands. Such deposits would have provided new and extensive astrobiological sites for the preservation of any fossils and biosignatures that may have existed in the ocean (Rodríguez et al. 2016).



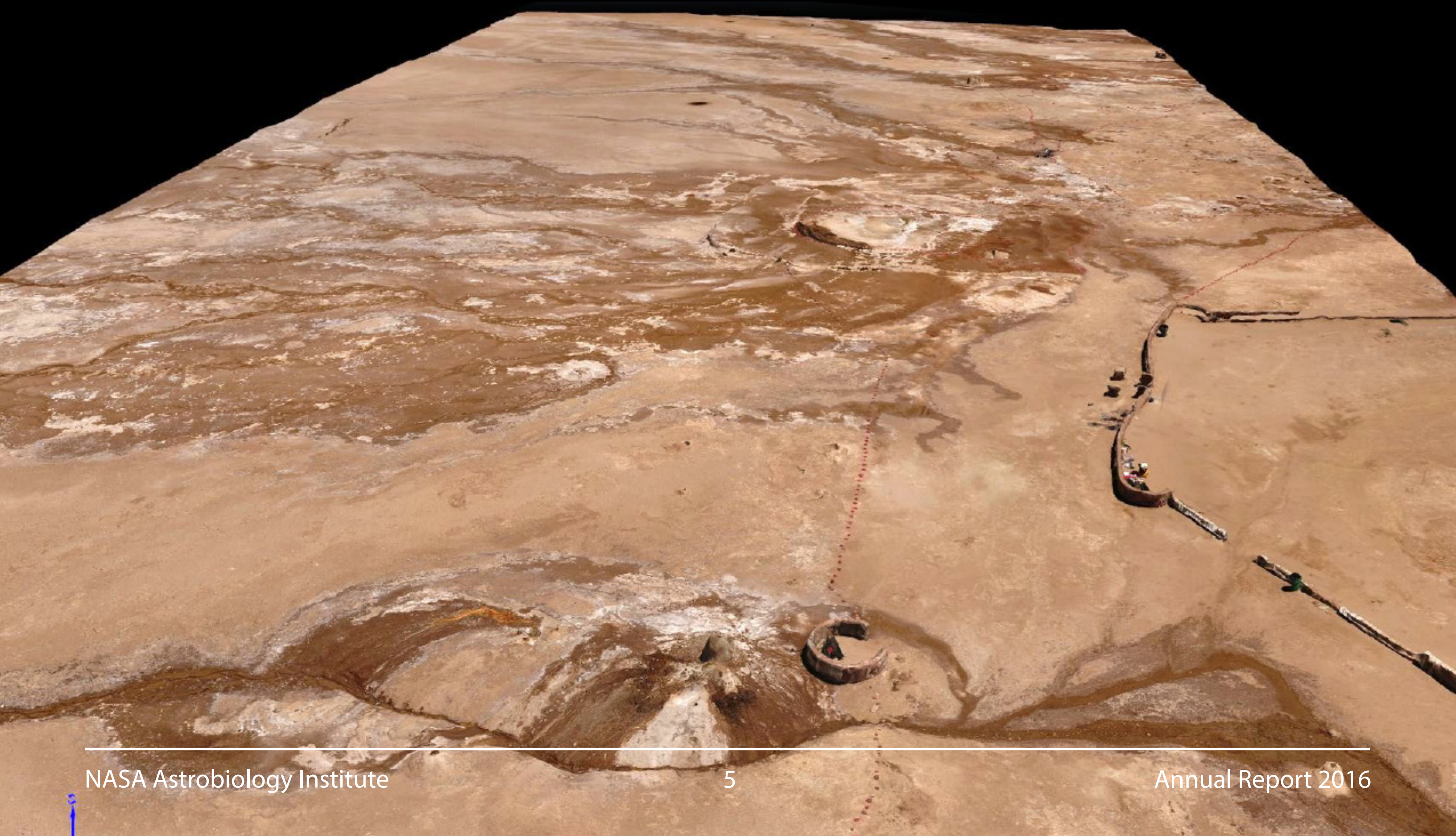
Maps show reconstruction of ancient ocean shorelines and areal extent of both younger and older tsunami events.

3D Surface Modeling of Mars Analog Environments in the Atacama Desert - How to Search

Jeffrey Moersch along with other SETI NAI Team investigators participated in field campaigns to the Atacama Desert and collected data to address questions about thresholds of detectability for habitats and biosignatures in remote sensing data.

The Team collected low-altitude aerial images and ground-based spectra in the field at Mars analog habitats in the Atacama Desert, Chile. Data sets were used to produced high-resolution orthophotomosaics and digital elevation maps used for geologic context and for determining thresholds of detectability for analogous habitats on Mars.

3D textured surface model of a portion of the El Tatio geyser field constructed from 813 individual aerial images acquired by a multicopter flying 20 meters above the surface. The orthophotomosaic and digital elevation model constructed from these data have 672 megapixels each, with a pixel resolution of 8 mm on the ground. These high-resolution data will be used to determine a set of features that are diagnostic of hydrothermal mounds in image data. The images will then be degraded to find the spatial resolution thresholds of detectability for these diagnostic features.



The Chilean Atacama - Where, What, and How to Search

Nathalie Cabrol led the SETI NAI Team in a major field campaign in the Chilean Atacama, Altiplano, and High Andes (October 15-November 9, 2016) to conduct studies of terrestrial analogs to candidate landings sites for the Mars 2020 and ExoMars missions. The sites included: Salar Grande, an evaporitic basin (halite); Salar de Pajonales, a basin with an ancient and active section (gypsum, carbonate, volcanic, sedimentary domes, endoliths, stromatolites); El Tatio (hydrothermal springs, geysers, spring mounds, microbial constructs, endoliths, chasmoliths); Laguna Lejía, a volcanic/hydrothermal environment (Pleistocene paleoterraces, phyllosilicates, carbonates, fossils including stromatolites).

One of the key goals of the field campaign was to identify and characterize data and knowledge gaps from orbit to the ground in search of habitats and biosignatures. To that end, Cabrol's team successfully deployed drones at each site, and acquired imagery at integrated scales and resolution to understand the thresholds of detectability that can allow a mission to transition from the characterization of environmental habitability to the discovery and investigation of habitats and biosignatures.

At each site, the Team deployed *in situ* instrumentation relevant to these missions (Raman, LIBS, Visible and IR imagery, UV, and environmental sensing). They collected 200+ spectra *in situ*, over 216 samples that were brought back for follow-up analysis, and over 45 core samples. Data and samples were collected in a manner relevant to Mars 2020.

Samples from the field campaign have now been labeled and prepared for a round-robin analysis within the Team, which has started at the beginning of 2017. Upon completion of that analytical phase, the samples will be shared with other NAI Teams, and with Mars Mission Instrument PIs who have expressed interest. The Raman spectral library is well underway, and the SETI NAI Team's effort to augment it with the new samples will be pursued in 2017.

Spring mounds at El Tatio, Chilean Altiplano, October 2016.
Credit photo: Victor Robles, Campoalto, the SETI Institute NAI Team

Artic and Antarctic Field Campaigns - What to Search for and How to Search

Large conical stromatolites up to 0.5m tall surrounded by cuspate (pinnacle) and prostrate mats of Lake Untersee; these modern stromatolites and benthic mats are the main source of biomass to sediments in the lake and paleo-sediments found around the lake.

Dale Andersen led field campaigns in the Arctic (Ellesmere and Axel Heiberg Islands) and Antarctic (Lake Untersee) to conduct analog studies and address questions relevant to biosignature preservation and thresholds of detectability for habitats and biosignatures in remote sensing data.

While in the Arctic Andersen's team mapped sites of interest using unmanned Aerial Vehicles. Using previously-acquired aerial and orbital remote sensing data to guide field work, the team collected low-altitude aerial images at the analog field sites. With the collected imagery, they produced high-resolution orthophotomosaics and digital elevation maps that will be used for geologic context by the whole Team, and for determining thresholds of detectability for analogous habitats on Mars.

In Antarctica at Lake Untersee, using a Leica Nova TM50 we began mapping paleo-shoreline features around the lake and in a nearby cirque valley which at one time held an ice-covered lake similar to Lake Untersee but has since evaporated away. Paleo-sediment samples were collected at these sites. At Lake Untersee, water column profiles and samples were collected underwater using standard limnological techniques and via scientific diving. All samples are being returned for analysis, including identifying and characterizing diagnostic lipid biomarkers that may be present.

Changing Planetary Environments and the Fingerprints of Life: 2016 Publications

Barge, L.M., Branscomb, E., Brucato, J.R., Cardoso, S.S.S., Cartwright, J.H.E., Danielache, S.O., Galante, D., Kee, T.P., Miguel, Y., Mojzsis, S., Robinson, K.J., Russell, M.J., Simoncini E., and Sobron, P. (2016). *Thermodynamics, Disequilibrium, Evolution: Far-from-Equilibrium Geological and Chemical Considerations for Origin-of-Life Research*. OLEB. DOI: 10.1007/s11084-016-9508-z

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Bishop, J. L. and Rampe, E. B. (2016). Evidence for a changing Martian climate from the mineralogy at Mawrth Vallis. *Earth and Planetary Sci. Lett*., 448, 42-48. DOI: 10.1016/j.epsl.2016.04.031

Cabrol, N. A., (2016). Searching for Habitable Worlds and Life Beyond Earth. In: *Aliens: Science Asks: Is There Anyone Out There?* Chapter 16, Al-Khalili, J., ed., Profile Books, 178-187. ISBN: 1781256810*

Davila, A.F., Hawes, I., Araya, J.G., Gelsinger, D.R., DiRuggiero, J., Ascaso, C., et al. (2015). In Situ Metabolism in Halite Endolithic Microbial Communities of the Hyperarid Atacama Desert. *Frontiers in Microbiology* 6. DOI: 10.3389/fmicb.2015.01035

Davila, A.F., and Schulze-Makuch (2016). The last possible outposts for life on Mars. *Astrobiology*. 16, 159–68. DOI: 10.1089/ast.2015.1380

Ehlmann, B.L. and 46 coauthors including Wray, J.J. (2016). The sustainability of habitability on terrestrial planets: Insights, questions, and needed measurements from Mars for understanding the evolution of Earth-like worlds (Invited Review). *Journal of Geophysical Research – Planets*, 121, 1927-1961. DOI: 10.1002/2016JE005134

Ehlmann, B. L., Swayze, G. A., Milliken, R. E., Mustard, J. F., Clark, R. N., Murchie, S. L., Breit, G. N., Wray, J. J., Gondet, B., Poulet, F., Carter, J., Calvin, W. M., Benzel, W. M., & Seelos, K. D. (2016). Discovery of alunite in Cross Crater, Terra Sirenum, Mars: Evidence for acidic, sulfurous waters. *American Mineralogist*, 101, 1527–1542. DOI: 10.2138/am-2016-5574*

Häder, D-P., Feister, U., and Cabrol, N.A. (2015) Response: Comment on record solar UV irradiance in the tropical Andes. *Frontiers in Environmental Science*. DOI: 10.3389/fenvs.2015.00068

Karunatillake, S., Wray, J. J., Gasnault, O., McLennan, S. M., Rogers, A. D., Squyres, S. W., Boynton, W. V., Skok, J. R., Button, N. E., and Ojha, L. (2016). The association of hydrogen with sulfur on Mars across latitudes, longitudes, and compositional extremes. *Journal of Geophysical Research Planet*s 121, 1321–1341. DOI: 10.1002/2016JE005016*

Komatsu, G., Okubo, C. H., Wray, J. J., Ojha, L., Cardinale, M., Murana, A., Orosei, R., Chan, M. A., Ormö, J., and Gallagher, R. (2016). Small edifice features in Chryse Planitia, Mars: Assessment of a mud volcano hypothesis. *Icarus*, 268, 56–75. DOI: 10.1016/j.icarus.2015.12.032*

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Rodriguez, J.A.P., Hernández, M.Z., Santiago, R.L., Gulick, V.C., Weitz, C., Jianguo, Y., Fairen, A.G., Platz, T., Baker, V. R., Kargel, J., Glines, N., Higuchi, K. (2016). Groundwater flow induced collapse and flooding in Noctis Labyrinthus. *Mars. Planetary and Space Science*, 124, 1-14. DOI: 10.1016/j.pss.2015.12.009

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