WORKSHOP REPORT
GROUND TRUTH FROM MARS:
SCIENCE PAYOFF FROM A SAMPLE RETURN MISSION
April 20 – 23, 2008
Albuquerque, New Mexico
Prepared by Charles Shearer, Carl Agee, and David Beaty, June 4, 2008

Mars Sample Return is again on the horizon and endorsed as a logical continuation of the "Follow the Water" strategy of the National Aeronautics and Space Administration's (NASA) Mars Exploration Program. This strategy has tied together the search for life and potential habitats for life, evolution of the martian atmosphere, nature of martian surface processes, and the thermal-magmatic evolution of the martian mantle and crust. Orbital and surface missions have revealed that Mars' surface is far more diverse than was imagined only a decade ago, with a plethora of distinct environments– each of which presents different sorts of samples, with different potential scientific returns. Returning samples from these martian environments and analyzing them in the best terrestrial labs available will provide an unparalleled perspective of Mars not yet achieved. Data derived from sample returned from the martian surface would provide both ground truth for interpreting observations made during past orbital and surface missions and insightfulness in planning for future missions. There would likely be few sample return missions, and so the few targets must be chosen to maximize the likelihood of answering fundamental questions about Mars. There is a delicate balance between science return and mission complexity. To address these issues, this workshop was designed to explore the science and science value that could be extracted from a Mars samples return, illustrate the important science linkages between previous-ongoing missions and potential sample return missions, and discuss the requirements needed to ensure the record preserved in the samples would be undisturbed during sampling, return, and curation.

This workshop was convened by Charles (Chip) Shearer (*University of New Mexico),* Carl Agee (*University of New Mexico)* and David Beaty (*Jet Propulsion Laboratory).* Sponsors included NASA, the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM), Lunar and Planetary Institute, Mars Exploration Program Analysis Group (MEPAG), and the Institute of Meteoritics. The scientific organizing committee consisted of David Bish (*University of Indiana),* James Farquhar *(University of Maryland),* John Grotzinger *(California Institute of Technology),* Virgil Lueth, *(New Mexico School of Technology),* Chris McKay *(NASA Ames),*Glenn MacPherson (*Smithsonian),*Doug Ming *(Johnson Space Center),*Dimitri Papanastassiou *(Jet Propulsion Laboratory),* James J. Papike, *(University of New Mexico),* Dawn Y. Sumner (*University of California Davis),* Allan Treiman (*Lunar and Planetary Institute),* and David Vaniman, *(Los Alamos National Laboratory).* The scientific organizing committee was responsible for identifying session themes, inviting speakers, and chairing sessions.

The two and a half day workshop was held April 20 – 23, 2008 at the Hotel Albuquerque at Old Town in Albuquerque, New Mexico. The workshop was attended by 105 participants with interests in Mars related science and potential Mars sample return missions. The workshop consisted of 6 sessions: ENABLING SAMPLE RETURN: PRIORITIES, MISSIONS, AND STRATEGIES (Chairs: D. W. Ming and A. H. Treiman), SAMPLE REQUIREMENTS FROM THE ASTROBIOLOGY POINT OF VIEW (Chairs: C. P. McKay and G. J. MacPherson), SULFATES AS RECORDERS OF MARS NEAR SURFACE PROCESSES AND THE MER SITES AS FIRST SAMPLE RETURN LOCALITIES (Chairs: V. W. Lueth and J. J. Papike), UNDERSTANDING THE EVOLUTION OF MARS' CORE, MANTLE, CRUST, SURFACE, ATMOSPHERE (Chairs: J. Farquhar and D. A. Papanastassiou), HYDROUS MINERALS AS RECORDERS OF FLUID-ATMOSPHERIC EVOLUTION AND SECONDARY ALTERATION (Chairs: D. L. Bish and D. T. Vaniman) and a POSTER SESSION (Chairs: C. Agee and C.K. Shearer). The recommended bibliographic citation for this report is presented at the end of this document. Sixty-two presentations were made during these sessions. The outline of each session is presented in the Appendix. Abstracts for each presentation can be accessed at http://www.lpi.usra.edu/ meetings/msr2008/ and selected presentations can be viewed at http://www.lpi.usra.edu/captem/. A brief summary of each session follows.

ENABLING SAMPLE RETURN: PRIORITIES, MISSIONS, AND STRATEGIES: This first session emphasized the

fundamental importance of sample return for understanding Mars, the rich array of important questions that could be answered with a sample return mission, the science linkages between orbital and surface missions and sample return in terms of potential sample targets and establishing ground truth, and the relationship between mission scale and science return. Dave Des Marais (#4037) and Charles Shearer (#4004) illustrated the scientific richness linked to a Mars sample return mission that provided a perspective to understanding Mars that was different from the viewpoint reached from previous missions or scientific studies of martian meteorites. Presentations by Murchie (#4035), Bibring (#4061), Ming (#4016), and Crisp (#4047) illustrated the complexity of Mars revealed by previous orbital and surface missions, the approaches being used by future missions to further explore surface environments of Mars, and the impact these observations could have in defining Mars sample return. Des Marais (#4037) emphasized that sample return with mobility would result in the collection of a diversity of samples required to answer a very large number of scientific questions. Hausrath (#4039) suggested diversity across interfaces between weathered and unweathered lithologies would provide insights into the history of Mars surface processes. On the other hand, Jones (#4002), Jones et al. (#4020; poster) and Clark (#4051; print only) emphasized much simpler missions that would address a smaller number of scientific questions and test technologies required for sample return from the martian surface. Significant discussion focused on the importance of placing samples within a geological context and the approaches that should be used to accomplish this goal. Most attendees considered geologic context important, but there was no clear consensus of the extent or methodology (return to a previous site, documentation during MSR mission with a variety of tools). Finally, Clive Neal (#4026) introduced the workshop to the sample collection and storage steps that must be taken to insure samples preservation upon return to Earth.

SAMPLE REQUIREMENTS FROM THE ASTROBIOLOGY POINT OF VIEW: Kraft (#4049) and Allen (4011) identified potential sampling sites on Mars (northern plains, possible ancient hydrothermal springs) that would be important in testing the possibility of life on Mars. Andy Steele (invited, no abstract) presented a very broad view on the procedures and protocols for the collection of martian samples with the purpose of protecting and preserving the biological record. Chris McKay (#4033) proposed that a non-mobile Mars sample return mission could provide insights into the habitability of Mars both in the past and for humans in the future. Conley (#4060) presented planetary protection considerations for any Mars sample return mission. This led to a long discussion on the protection of the scientific value of samples, the fulfillment of planetary protection constraints, and the establishment of curation-allocation procedures for martian samples. Penny Boston (#4053) and Mike Spilde (#4045) presented terrestrial studies that illustrated the potential mineral-rock environments that could be targets during a sample return mission. Boston showed microorganism communities closely associated with sulfates. Spilde showed that coatings on rocks and mineral surfaces might contain fingerprints of biological activity. Monica Grady (#4062) presented terrestrial lab methodology and measurements to illustrate the presence and distribution of carbon in martian meteorites, whereas Kotler (4054) illustrated the usefulness of using laser desorption fourier transform mass spectrometry to search for astrobiology relevant materials on the martian surface.

SULFATES AS RECORDERS OF MARS NEAR SURFACE PROCESSES AND THE MER SITES AS FIRST SAMPLE RETURN LOCALITIES: Numerous presentations in this session emphasized the geologic record preserved in sulfates (Lueth, #4027,#4040; Burger, #4010; King, #4017; Hyde, #4042). Many of these presentations focused upon the environment of precipitation and history of water revealed by sulfates (conditions of precipitation, history and geochemistry of water, groundwater-atmosphere interactions). Mittlefehldt (#4031) and Morris (#4048) illustrated the wealth of science that could be extracted from the MER sites with a sample return mission to these previously visited sites. This is an overall approach that would address the problem of placing samples within a geologic context defined by both orbital and surface exploration. Dave Vaniman (#4025) provided detailed insights into the stability of sulfates, sulfate-clay interactions and the caution needed in collecting and storing samples to minimize science loss. Finally, Mike Zolensky (#4007) demonstrated the range of science that could be accomplished using microbeam analytical approaches for the study of martian dust. These techniques could be used to look for microfossils in the martian dust.

UNDERSTANDING THE EVOLUTION OF MARS' CORE, MANTLE, CRUST, SURFACE, ATMOSPHERE: This afternoon session focused on much broader themes than the previous sessions. One of the invited speakers, John

Valley, illustrated the usefulness of microbeam stable and radiogenic isotopic analysis to analyze the geological record preserved in individual mineral grains. He illustrated the usefulness in two examples: analysis of carbonates in ALH 84001 and analysis of some of the oldest terrestrial zircons. A follow-on presentation by Jim Greenwood further illustrated the use of microbeam analyses to look for the record of reservoirs of water in phosphates in martian meteorites. In addition to microbeam approaches for analyzing stable isotopes, James Farquhar (#4057) illustrated the broad array of information about the martian atmosphere, reaction pathways for the precipitation of sulfates, temperatures of weathering processes, and fingerprints for life that could be extracted from returned samples using a battery of stable isotope systems. Don Bogard (#4003) and Larry Nyquist (#4014) illustrated the importance of sample return in establishing the martian chronology. Further, they illustrated the undesirable approach of in situ dating on the martian surface. Draper (#4021) gave examples of how experimental studies on returned samples could be used to understand the early differentiation of Mars. This is particularly powerful approach when used in conjunction with isotopic and geochemical measurements. Measurement of cosmogenic nuclides could only be done in terrestrial labs and these measurements could potentially answer questions such as crater ages, erosion rates, and rates of deposition (Nishiizumi. #4028). Ballentine (#4044) illustrated that noble gas measurements on returned samples would be critical to understanding the nature and evolution of different reservoirs on Mars and critical for establishing a martian chronology. Samples returned from Mars could also be utilized to measure geophysical properties and to then be used to reconstruct the history of the martian magnetic field and the martian core (Weiss, #4024). Collection of a diverse sample suite might be obtained through the sampling terrain excavated by recent impacts (Swindle, #4029). Dimitri Papanastassiou (#4009) concluded from his comparison between past sample return from the Moon and a potential future Mars sample return that we are missing the complexity of that exists in martian samples by in situ analysis on the surface of Mars. Substantially more insight into these complexities would be gained in terrestrial labs.

HYDROUS MINERALS AS RECORDERS OF FLUID-ATMOSPHERIC EVOLUTION AND SECONDARY ALTERATION: This session focused on hydrous minerals from the point of view of their geological occurrence on Mars and the geological record preserved in clays based on terrestrial and experimental studies. Mustard (#4038), Milliken (#4013), and Michalski (4018) reviewed the planetary distribution of hydrated silicates on Mars, their composition, and potential environments of formation. Bish (#4022) illustrated that clay composition and mineral assemblage could be used to reconstruct the environment under which it formed and to date the clay-forming event. Further, he illustrated that clays responded incrementally to changes in their environment during sampling and storage and that careful scrutiny must be used to evaluate the balance between science loss and the cost of preservation. Velbel (#4019) further illustrated the importance of clay mineral composition and textures during alteration in terrestrial environments, the protection required to protect delicate textures, and application to understanding alteration conditions on Mars. Muttik (#4013) demonstrated the nature of clay mineralogy associated with impact induced hydrothermal systems. Results of experimental studies presented by Rietmeijer (#4008) illustrated potential processes not considered above that could lead to the formation of ferric iron-rich sheet silicates.

POSTER SESSION: The poster session contained an exceedingly wide range of sample return relevant topics from sample return strategies to instruments on sample return missions to examples of fundamental science extracted from martian meteorites. Presentations by Zacny (#4001), Karcz (#4059), Jones (#4020), and Wiens (#4032) demonstrated new analytical or sampling technologies that would enable sample return. These included sample caching on MSL, LIBS instrumentation to select sample stations from a distance and thereby reduce roving time, sampling from orbit, and sampling-handling technologies. Newsom (#4041) discussed the attributes of sampling a previously visited site for MSR, while Rampe (#4034) suggested the northern plains would be an important target for sample return. Ashley (#4046) and Thomson (#4043) explored the rationale for the collection of meteorites on the martian surface. Kashiv (#4055), Walker (#4015) and Spivak-Birndorf (#4050) illustrated the usefulness of cosmogenic radioisotopes, siderophile elements, and boron isotopes for interpretating of interior and surface processes on Mars.

Observations of the conference discussions by the conveners

There were several overarching points reached from presentations and discussions during this workshop:

- The presentations at the workshop showed that a wonderful variety of compelling scientific objectives would be possible via Mars sample return.

- In many cases, the different possible sample-related scientific objectives discussed at the conference would require different kinds of samples, and/or samples from different geologic setting. Difficult choices would need to be made regarding which questions we choose to answer with the first MSR, and which to defer. Thus, for the first MSR mission it would be imperative to consider carefully: (1) The choice of the landing site, and (2) The nature of the sample selection and the surface operations (especially mobility and stay time) capabilities.
- There is a large untapped reservoir of sample scientists with a wide range in background (i.e., terrestrial) that are poised to participate in and contribute to MSR.
- Within the sample analysis community, the use of analytical technology to extract more information from samples continues to improve. Part of the power of MSR is that it would take advantage of this tidal wave of development that is happening in many associated fields. Therefore, the best instruments would be used to analyze returned samples, not the best available at the end of mission design reviews and the measurements could be modified as logic and technology dictate over extend periods of time following the mission.
- There was an increased realization that important samples from the surface of Mars might be both fragile and reactive. The strategy for sample collection, storage, preservation, curation, and allocation must be deliberated in exacting detail.
- Conference participants discussed a spectrum of possible MSR missions ranging from options that would be relatively simple (with a focused and limited set of science goals) to relatively complex (with a much broader set of science goals).
- There were no presentations at the conference relating to mission cost or potential budget availability. However, there was quite a bit of unconstrained discussion about how to strike the right balance between relatively simple and relatively complex versions of MSR.

APPENDIX
Outline of Sessions

Monday, April 21, 2008
ENABLING SAMPLE RETURN: PRIORITIES, MISSIONS, AND STRATEGIES
8:00 a.m. Alvarado ABC

Chairs: D. W. Ming
A. H. Treiman

Welcome and Introduction

MEPAG ND-SAG Team *
Possible Science Priorities for Mars Sample Return **[#4037]**

Murchie S. * McEwen A. Christensen P. Mustard J. Bibring J.-P. [INVITED]
Discovery of Diverse Martian Aqueous Deposits from Orbital Remote Sensing **[#4035]**

Bibring J.-P. * [INVITED]
OMEGA/Mars Express Feed Forward to MSR **[#4061]**

Ming D. W. * [INVITED]
2003 Mars Exploration Rover Mission: Robotic Field Geologists for a Mars Sample Return Mission **[#4047]**

Crisp J. A. * Grotzinger J. P. Vasavada A. R. Karcz J. S. MSL Science Team [INVITED]
Mars Science Laboratory: Science Overview **[#4016]**

Karcz J. S. * Beaty D. W. Conley C. A. Crisp J. A. Des Marais D. J. Grotzinger J. P. Lemke L. G. McKay C. P. Squyres S. W. Stoker C. R. Treiman A. H.
Science Definition of the Mars Science Laboratory Sample Cache **[#4058]**

Shearer C. K. * Borg L. E. Treiman A. King P.
If We Already have Samples from Mars, Why Do We Need Sample Return Missions? The importance of Martian Meteorites and the Value of Mars Sample Return **[#4004]**

Neal C. R. *
Mars Sample Return: Which Samples and Why **[#4026]**

Jones J. H. *
Mars Sample Seturn: 20+ Years After the First Mars Sample Return Workshop **[#4002]**

Hausrath E. M. * Navarre-Sitchler A. K. Moore J. Sak P. B. Brantley S. L. Golden D. C. Sutter B. Schröder C. Socki R. Morris R. V. Ming D. W.
Mars Sample Return: The Value of Depth Profiles **[#4039]**

Monday, April 21, 2008
OVERALL THEME: SAMPLE REQUIREMENTS
FROM THE ASTROBIOLOGY POINT OF VIEW
1:30 p.m. Alvarado ABC

Chairs: C. P. McKay
G. J. MacPherson

Steele A. * [INVITED]
Talk Development of Procedures and Protocols for the Collection and Characterization of Martian Samples. Experience from the Field and Lab

McKay C. P. * [INVITED]
Astrobiology with a Groundbreaker Sample Return Mission **[#4033]**

Kraft M. D. * Rampe E. B. Sharp T. G.
The Biological Potential of the Northern Plains for Mars Sample Return **[#4049]**

Boston P. J. * Spilde M. N. Northup D. E. Todd P.
Extremophile Microorganism Communities in Sulfates and Other Sulfur Minerals a Sample Return Target Materials **[#4053]**

Allen C. C. * Oehler D. Z.
Sample Return from Ancient Hydrothermal Springs **[#4011]**

Kotler J. M. * Hinman N. W. Richardson C. D. McJunkin T. Scott J. R.
Geochemistry and Astrobiology Science Payoff Using Laser Desorption Fourier Transform Mass Spectrometry (LD-FTMS) Techniques for Mars Sample Return **[#4054]**

Spilde M. N. * Boston P. J. Northup D. E. Odenbach K. J.
Rock Coatings: Potential Biogenic Indicators **[#4045]**

Grady M. M. * Pearson V. K. Gilmour I. Gilmour M. A. Verchovsky A. B. Watson J. Wright I. P.
Identification (or Otherwise) of Martian Carbon in Martian Meteorites **[#4062]**

Conley C. A. * [INVITED]
Planetary Protection Considerations for Mars Sample Return **[#4060]**

Monday, April 21, 2008
POSTER SESSION
6:00 – 8:00 p.m. Alvarado D

Chairs: C. K. Shearer
C. B. Agee

MEPAG ND-SAG Team
Possible Science Priorities for Mars Sample Return **[#4037]**

Karcz J. S. Cappuccio M. Demo A. G. Eisen H. J. Feldman J. Gheno K. Kruger C. E. Liu M. Reimer J. H. Santos O. Serviss O. E. Tong P. K.
The Implementation of the Mars Science Laboratory Sample Cache **[#4059]**

Jones S. M. Jurewicz A. J. G. Wiens R. Yen A. Leshin L. A.
Mars Sample Return at 6 Kilometers per Second: Practical, Low Cost, Low Risk, and Ready **[#4020]**

Thomson B. J. Bridges N. T. McCanta M. C.
Meteorites on Mars: Implications for Sample-Return Strategy **[#4043]**

Wiens R. C. Clegg S. Maurice S. ChemCam Team
ChemCam as the Instrument to Select Samples and Enable Mars Sample Return **[#4032]**

Zacny K. Paulsen G. Davis K. Mumm E. Gorevan S.
Honeybee Robotics Sample Acquisition, Transfer and Processing Technologies Enabling Sample Return Missions **[#4001]**

Kashiv Y. Paul M. Collon P.
Determining Production Rates of Cosmogenic Radioisotopes on Mars **[#4055]**

Rampe E. B. Kraft M. D. Sharp T. G.
The Importance of an Investigation of the Northern Plains **[#4034]**

Walker R. J. Puchtel I. S. Brandon A. D. Irving A. J.
Highly Siderophile Elements Abundances in SNC Meteorites: An Update **[#4015]**

Spivak-Birndorf L. J. Wadhwa M. Williams L. B.
Boron Isotopic Composition of Igneous Minerals and Secondary Alteration Products in Nakhla **[#4050]**

Ashley J. W.
Scientific Rationale for Consideration of Chemically Altered Meteorites in a Mars Sample Return Mission **[#4046]**

Newsom H. E. Lanza N. L. Ollila A. M.
Landing Site Selection for the Mars Science Laboratory and Implications for Mars Sample Return **[#4041]**

Tuesday, April 22, 2008
SULFATES AS RECORDERS OF MARS NEAR SURFACE PROCESSES AND THE MER SITES AS FIRST SAMPLE RETURN LOCALITIES
8:00 a.m. Alvarado ABC

Chairs: V. W. Lueth
J. J. Papike

Lueth V. W. * [INVITED]
Encoding of Water-Rock-Atmosphere Interactions in Jarosite: Implications for Mars **[#4040]**

Burger P. V. * Papike J. J. Shearer C. K. Karner J. M.
Interpreting Mars Surface Fluid History Using Minor and Trace Elements in Jarosite: An Example from Post Pit, Nevada **[#4010]**

King P. L. * Lane M. D. Hyde B. C. Dyar M. D. Bishop J. L.
Fe-Sulfates on Mars: Considerations for Martian Environmental Conditions, Mars Sample Return and Hazards **[#4017]**

Hyde B. C. * King P. L. Spilde M. N. Ali A.-M. S.
Characterization of Fe-Sulfate Minerals: Preparation for Mars Sample Return **[#4042]**

Lueth V. W. Campbell A. R. Papike J. J.
Stable Isotope Characterization of a Terrestrial Kieserite with Comparisons to Other Sulfate Minerals **[#4027]**

Zolensky M. E. * Nakamura-Messenger K.
What Can You Do with a Returned Sample of Martian Dust? **[#4007]**

Vaniman D. T. * Bish D. L. Chipera S. J.
Salt-Hydrate Stabilities and Mars Sample Return Missions **[#4025]**

Mittlefehldt D. W. * [INVITED]
Mars Sample Return from Meridiani Planum **[#4031]**

Morris R. V. * [INVITED]
What We Might Know About Gusev Crater if the Mars Exploration Rover Spirit Mission were Coupled with a Mars Sample Return Mission **[#4048]**

Tuesday, April 22, 2008
OVERALL THEME: UNDERSTANDING THE EVOLUTION OF MARS' CORE, MANTLE, CRUST, SURFACE, ATMOSPHERE
1:30 p.m. Alvarado ABC

Chairs: J. Farquhar
D. A. Papanastassiou

Valley J. W. * Ushikubo T. Kita N. T. [INVITED]
Two Generations of Carbonate in ALH 84001: Three Oxygen Isotopes and OH **[#4023]**

Greenwood J. P. *
Evolution of Water on Mars: Mars Sample Return Considerations for Hydrogen Isotope Measurements **[#4030]**

Farquhar J. *
Mars Sample Return: Stable Isotope Targets with Return Samples **[#4057]**

Bogard D. D. * [INVITED]
Martian Chronology and Atmospheric Composition: In Situ Measurements Versus Sample Return **[#4003]**

Nyquist L. E. * Shih C.-Y. Reese Y. D. [INVITED]
Prospects for Chronological Studies of Martian Rocks and Soils **[#4014]**

Swindle T. D. * Tornabene L. L. McEwen A. S. Plescia J. B.
Using Recent Impact Craters as a Sampling Mechanism for a Mars Sample Return Mission **[#4029]**

Papanastassiou D. A. *
Why an "Early" Mars Sample Return: Lessons from Apollo **[#4009]**

Draper D. S. * Agee C. B.
Fundamental Importance of Returned Samples to Understanding the Martian Interior **[#4021]**

Nishiizumi K. * Caffee M. W. Herzog G. F. Reedy R. C.
Measurements of Cosmogenic Nuclides In and Their Significance for Samples Returned from Mars **[#4028]**

Ballentine C. J. Burgess R. Edwards S. Gilmour J. D. *
Science Payoff from Noble Gas and Associated Halogen Analysis: Towards a Sample Wish List **[#4044]**

Weiss B. P. * Garrick-Bethell I. Kirschvink J. L.
Magnetic Studies of Returned Samples from Mars **[#4024]**

Wednesday, April 23, 2008
OVERALL THEME: HYDROUS MINERALS AS RECORDERS OF FLUID-ATMOSPHERIC EVOLUTION AND SECONDARY ALTERATION
8:00 a.m. Alvarado ABC

Chairs: D. L. Bish
D. T. Vaniman

Bish D. L. * Vaniman D. T.
Clay Mineralogy as a Guide to Alteration Environments on Mars **[#4022]**

Mustard J. F. * Murchie S. L. Ehlmann B. Milliken R. E. Bibring J.-P. Poulet F. Bishop J. Noe Dobrea E. Roach L. Seelos F. McKeown N. K.
Hydrated Silicate Minerals and Their Geologic Environments from Oribt **[#4038]**

Milliken R. E. * Mustard J. F. Ehlmann B. Bishop J. L. Murchie S. CRISM Science Team [INVITED]
Interpreting and Constraining the Composition and Depositional Environments of Phyllosilicates on Mars **[#4036]**

Michalski J. R. * Bibring J.-P. Poulet F. Fergason R. Mangold N. Loizeau D. Noe Dobrea E. Bishop J. L. [INVITED]
Clay-bearing Rocks in the Mawrth Vallis Region, Mars **[#4018]**

Muttik N. * Kirsimäe K. Somelar P.
Clay Minerals Formation in Impact Induced Hydrothermal Systems: Source of Hydrous Phases on Mars **[#4013]**

Noe Dobrea E. Z. * Bishop J. L. McKeown N. K. Swayze G. Michalski J. R. Poulet F. Bibring J.-P. Mustard J. F. Ehlmann B. L. Arvidson R. Morris R. V. Murchie S. Malaret E. Hash C. CRISM Team
Transition Between Altered and Non-Altered Minerals in Mawrth Vallis and Arabia Terra **[#4052]**

Rietmeijer F. J. M. * Thiel K.
An Experimental Study of Phyllosilicate Modification in Comets During Perihelion Could be Relevant to Ferric Iron-rich Layer Silicate Formation at the Martian Surface **[#4008]**

Velbel M. A. *
Clay Minerals in Returned Samples and Alteration Conditions on Mars **[#4019]**

PRINT ONLY

Papike J. J. Spilde M. N. Karner J. M. Shearer C. K.
Fumaroles on Mars: Lessons Learned from the Valley of Ten Thousand Smokes, Alaska **[#4005]**

Papike J. J. Burger P. V. Karner J. M. Shearer C. K.
Martian Sulfates: Gypsum Crystal Chemistry and Characterization of Two Terrestrial Analogs **[#4006]**

Clark B. C.
Affordable MSR: Constraining Requirements on Sampling and Sample Preservation **[#4051]**

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