

Continued Use of Exogenic Materials found on Mars as Planetary Research Tools
Submitted to: 2023-2032 Decadal Survey on Planetary Science and Astrobiology

References:

- Ashley J. W. (2015a) The study of exogenic rocks on Mars — An evolving subdiscipline in meteoritics. *Elements*, 11.
- Ashley J. W., Golombek M. P., Christensen P. R., Squyres S. W., McCoy T. J., Schroder C., Fleischer I., Johnson J. R., Herkenhoff K. E., and Parker T. J. (2011) Evidence for mechanical and chemical alteration of iron-nickel meteorites on Mars: Process insights for Meridiani Planum. *Journal of Geophysical Research-Planets*, 116.
- Ashley J. W., Ruff S. W., Christensen P. R., and Leshin L. A. In-situ Martian and laboratory thermal infrared spectroscopy of dust-coated iron-nickel meteorites – an assessment of dust thickness and behavior on Mars. In preparation.
- Ashley J. W., Velbel M. A., and Golombek M. P. (2015b) Weathering-induced fragmentation as a possible contributor to anomalous stony meteorite scarcity on Mars — Insights from Antarctica and MER. Lunary and Planetary Science Conference XLVI, Planetary Science Institute, The Woodlands, TX.
- Ashley J. W., Ruff S. W., Trubea Knudson A., and Christensen P. R. (2009) Mini-TES measurements of Santa Catarina-type, stony-iron meteorite candidates by the Opportunity rover. Lunar and Planetary Conference XL, The Woodlands, TX, abstract No. 2468.
- Beaty D. W., Grady M. M., McSween H. Y., Sefton-Nash E., Carrier B. L., Altieri F., Amelin Y., Ammannito E., Anand M., Benning L. G. and others. (2019) The potential science and engineering value of samples delivered to Earth by Mars sample return. *Meteoritics & Planetary Science*, 54: 667-671.
- Beech M. and Coulson I.M. (2010) The making of Martian meteorite Block Island. *Mon. Not. R. Astron. Soc.*, 404: 1457–1463.
- Bertelsen P., Goetz W., Madsen M. B., Kinch K. M., Hviid S. F., Knudsen J. M., Gunnlaugsson H. P., Merrison J., Nornberg P., Squyres S. W. and others. (2004) Magnetic Properties Experiments on the Mars exploration Rover Spirit at Gusev crater. *Science*, 305: 827-829.
- Burckle L. H., and Delaney J. S. (1999) Terrestrial microfossils in Antarctic ordinary chondrites. *Meteoritics & Planetary Science*, 34: 475-478.
- Chappelow J. E., and Golombek M. P. (2010) Event and conditions that produced the iron meteorite Block Island on Mars. *Journal of Geophysical Research-Planets*, 115.
- Chappelow J. E., and Sharpton V. L. (2006) Atmospheric variations and meteorite production on Mars. *Icarus*, 184: 424-435.
- Chappelow J. E., and Sharpton V. L. (2006b) The event that produced Heat Shield Rock and its implications for the martian atmosphere. *Geophysical Research Letters*, 33.
- Cronholm A., and Schmitz B. (2010) Extraterrestrial chromite distribution across the mid-Ordovician Puxi River section, central China: Evidence for a global major spike in flux of L-chondritic matter. *Icarus*, 208: 36-48.
- Daubar I. J., Atwood-Stone C., Byrne S., McEwen A. S., and Russell P. S. (2014) The morphology of small fresh craters on Mars and the Moon. *Journal of Geophysical Research*, 119.
- Daubar, I., Lognonné, P., Teanby, N.A. et al. Impact-Seismic Investigations of the InSight Mission. *Space Sci Rev* 214, 132 (2018). <https://doi.org/10.1007/s11214-018-0562-x>

- Eigenbrode J. L., Summons R. E., Steele A., Freissinet C., Millan M., Navarro-González, Sutter B., McAdam A. C., Franz H. B., Glavin D. P. and others. (2018) Organic matter preserved in 3-billion-year-old mudstones at Gale crater, Mars. *Science*, 360: 1096-1101.
- Fleischer I., Brückner J., Schröder C., Farrand W., Tréguier E., Morris R. V., Klingelhöfer G., Herkenhoff K., Mittlefehldt D. W., Ashley J. W. and others. (2010) Mineralogy and chemistry of cobbles at Meridiani Planum, Mars, investigated by the Mars Exploration Rover Opportunity. *Journal of Geophysical Research*, 115.
- Fleischer I., Farrand W. H., Schröder C., Jolliff B. L., Ashley J. W., and Klingelhöfer G. (2009) Cobbles at Meridiani Planum. European Planetary Science Congress.
- Fleischer I., Schroder C., Klingelhofer G., Zipfel J., Morris R. V., Ashley J. W., Gellert R., Wehrheim S., and Ebert S. (2011) New insights into the mineralogy and weathering of the Meridiani Planum meteorite, Mars. *Meteoritics & Planetary Science*, 46: 21-34.
- Freissinet C., Glavin D. P., Mahaffy P. R., Miller K. E., Eigenbrode J. L., Summons R. E., E. B. A., Buch A., Szopa C., Archer P. D. and others. (2015) Organic molecules in the Sheepbed mudstone, Gale crater, Mars. *Journal of Geophysical Research*, 120: 495-514.
- Gattacceca J., Bouvier A., Grossman J., Metzler K., and Uehara M. (2019) The Meteoritical Bulletin, No. 106. *Meteoritics & Planetary Science*, 54: 469-471.
- Goderis, S., Brandon, A.D., Mayer, B. and Humayun, M., 2016. Ancient impactor components preserved and reworked in martian regolith breccia Northwest Africa 7034. *Geochimica et Cosmochimica Acta* 191, 203–215.
- Golombek M. P., Grant J. A., Crumpler L. S., Greeley R., Arvidson R. E., Bell III J. F., Weitz C. M., Sullivan R. J., Christensen P. R., Soderblom J. M. and others. (2006) Erosion rates at the Mars Exploration Rover landing sites and long-term climate change on Mars. *Journal of Geophysical Research*, 111.
- Golombek, M., K. Robinson, A. McEwen, N. Bridges, B. Ivanov, L. Tornabene, and R. Sullivan (2010), Constraints on ripple migration at Meridiani Planum from Opportunity and HiRISE observations of fresh craters, *Journal of Geophysical Research* 115, E00F08, <http://dx.doi.org/10.1029/2010JE003628>.
- Gronstal A., Pearson V., Kappler A., Dooris C., Anand M., Poitrasson F., Kee T. P., and Cockell C. S. (2009) Laboratory experiments on the weathering of iron meteorites and carbonaceous chondrites by iron-oxidizing bacteria. *Meteoritics and Planetary Science*, 44: 233-247.
- Hassler, D. M., Zeitlin, C., Ehresmann, B., Wimmer-Schweingruber, R. F., Guo, J., Matthiä, D., et al (2018). Space weather on the surface of Mars: Impact of the September 2017 events. *Space Weather*, 16, 1702–1708. <https://doi.org/10.1029/2018SW001959>.
- Heck P. R., Schmitz B., Bottke W. F., Rout S. S., Kita N. T., Cronholm A., Defouilloy C., Dronov A., and Terfelt F. (2017) Rare meteorites common in the Ordovician period. *Nature Astronomy*, 1: 0035.
- Heck P. R., Ushikubo T., Schmitz B., Kita N. T., Spicuzza M. J., and Valley J. W. (2010) A single asteroidal source for extraterrestrial Ordovician chromite grains from Sweden and China: High-precision oxygen three-isotope SIMS analysis. *Geochimica et Cosmochimica Acta*, 74: 497-509.
- Johnson J. R., Meslin P.-Y., Bell III J. F., Wiens R. C., Maurice S., Gasnault O., and Rapin W. (2020) Progress on iron meteorite detections by the Mars Science Laboratory. *Lunar and Planetary Science Conference*, LPI, The Woodlands, TX.

- Joy K. H., Zolensky M. E., Nagashima K., Huss G. R., Ross D. K., McKay D. S., and Kring D. A. (2012) Direct Detection of Projectile Relics from the End of the Lunar Basin-Forming Epoch. *Science*, 336: 1426-1429.
- Lanza N.L., Gasda P.J., Ollila A.M., Delapp D., Bodine M., Wiens R.C., Clegg S.M., Agee C., Meslin P.-Y., Newsom H.E, and Maurice S. (2017) Analyzing natural meteorite exteriors with laboratory LIBS for comparison to meteorites encountered by Curiosity in Gale crater, Mars. Meteoritical Society Meeting, July 24-28, Santa Fe, New Mexico.
- Lasue J., Meslin P.-Y., Cohen B. A., Sautter V., Bridges J. C., Lewin E., Wiens R. C., Beck P., Cousin A., Forni O. and others. (2020) Gretna Green, a possible chondrite detected at Glen Torridon in Gale crater. In: *Lunar and Planetary Science Conference*, LPI, The Woodlands.
- Meslin P.-Y., Johnson J.R., Forni O., Beck P., Cousin A., Bridges J., Rapin W., Cohen B., Newsom H., Sautter V., Lewin E., Nachon M., Wiens R.C., Payre V., Gasnault O., Maurice S., Fairen A.G., Schroeder S., Mangold N., Thomas N. (2017) Egg Rock encounter: Analysis of an iron-nickel meteorite found in Gale crater by Curiosity. *Lunar Planet. Sci. XLVIII*, 2258, The Lunar and Planetary Institute, Houston, TX.
- Meslin P.-Y., Wellington D., Wiens R.C., Johnson J.R., Van Beek J., Gasnault O., Sautter V., Maroger I., Lasue J., Beck P., Bridges J.C., Cohen B., Ashley J.W., Fairen A.G., Newsom H., Cousin A., Forni O., Calef F., Rapin W., Maurice S., Chide B., Schroeder S., Goetz W., Mangold N., Gabriel T., Lanza N., and Pinet P. (2019) Diversity and areal density of iron-nickel meteorites analyzed by ChemCam in Gale crater. 50th *Lunar and Planetary Science Conference*, 3179.
- Pack A., Höweling A., Hezel D. C., Stefanak M. T., Beck A.-K., Peters S. T. M., Sengupta S., Herwartz D., and Folco L. (2017) Tracing the oxygen isotope composition of the upper Earth's atmosphere using cosmic spherules. *Nature Communications*, 8: 15702.
- Ruff S. W., Christensen P. R., Blaney D. L., Farrand W. H., Johnson J. R., Michalski J. R., Moersch J. E., Wright S. P., and Squyres S. W. (2006) The rocks of Gusev Crater as viewed by the Mini-TES instrument. *Journal of Geophysical Research*, 111.
- Schröder C., Bland P. A., Golombek M. P., Ashley J. W., Warner N. H., and Grant J. A. (2016) Amazonian Chemical Weathering Rate Derived from Stony Meteorite Finds at Meridiani Planum on Mars. *Nature Communications* 7, 13459.
- Schröder C., Herkenhoff K. E., Farrand W. H., Chappelow J. E., Wang W., Nittler L. R., Ashley J. W., Fleischer I., Gellert R., Golombek M. P. and others. (2010) Properties and distribution of paired candidate stony meteorites at Meridiani Planum, Mars. *Journal of Geophysical Research-Planets*, 115.
- Schröder C., Rodionov D. S., McCoy T. J., Jolliff B. L., Gellert R., Nittler L. R., Farrand W. H., Johnson J. R., Ruff S. W., Ashley J. W. and others. (2008) Meteorites on Mars observed with the Mars Exploration Rovers. *Journal of Geophysical Research*, 113.
- Tait A. W., Gagen E. J., Wilson I. E., Tomkins A. G., and Southam G. (2020) Eukaryotic colonization of micrometer-scale cracks in rocks: A "microfluidics" experiment using naturally weathered meteorites from the Nullarbor Plain, Australia. *Astrobiology*, 20.
- Tait A. W., Tomkins A. G., Godel B. M., Wilson S. A., and Hasalova P. (2014) Investigation of the H7 ordinary chondrite, Watson 012: Implications for recognition and classification of Type 7 meteorites. *Geochimica Et Cosmochimica Acta*, 134: 175-196.
- Tait A. W., Wilson S. A., Tomkins A. G., Gagen E. J., Fallon S. J., and Southam G. (2017) Evaluation of meteorites as habitats for terrestrial microorganisms: Results from the Nullarbor Plain, Australia, a Mars analogue site. *Geochimica Et Cosmochimica Acta*, 215: 1-16.

- Tomkins A. G., Bowlt L., Genge M., Wilson S. A., Brand H. E. A., and Wykes J. L. (2016) Ancient micrometeorites suggestive of an oxygen-rich Archaean upper atmosphere. *Nature*, 533: 235-238.
- Tomkins A. G., Genge M. J., Tait A. W., Alkemade S., Langendam A., Perry P., and Wilson S. (2019) High Survivability of Micrometeorites on Mars: Sites with Enhanced Availability of Limiting Nutrients. *Geophysical Research Letters - Planets* 124: 1802-1818.
- Wellington D. F., Meslin P.-Y., Van Beek J., Johnson J. R., Wiens R. C., Calef F. J. III, Bell J. F. III (2019) Iron meteorite finds across lower Mt. Sharp, Gale Crater, Mars: Clustering and implications. In: *Lunar and Planetary Science Conference*, LPI, The Woodlands, TX.
- Wiens R.C., Meslin P.-Y., Wellington D.F., Johnson J.R., Fraeman A.E., Gasnault O., Maurice S., Forni O., Beck P., Cohen B.A., Newsom H.E., Bridges J.C., Sautter V., Gasda P., Lanza N., Ollila A., Johnstone S.E., and Fairen A. (2017) Composition and morphology of iron meteorites found in Gale crater, Mars. *Meteoritical Society Meeting*, July 24-28, Santa Fe, New Mexico.
- Yen A. S., Gellert R., Morris R. V., Ashley J. W., Berger J. A., Clark B. C., Cohen B. A., Ming D. W., Mittlefehldt D. W., O'Connell-Cooper C. D. and others. (2019) Understanding martian alteration processes by comparing in-situ chemical measurements from multiple landing sites. In: *Ninth International Conference on Mars*, Pasadena, CA.
- Yen A. S., Mittlefehldt D. W., McLennan S., Gellert R., Bell III J. F., McSween J. H. Y., Ming D. W., McCoy T. J., Morris R. V., Golombek M. and others. (2006) Nickel on Mars: Constraints on meteoritic material at the surface. *Journal of Geophysical Research*, 111.