Supplemental Material: Annu. Rev. Earth. Planet. Sci. 2019. 47:91-118
https://doi.org/10.1146/annurev-earth-053018-060332
The Sedimentary Cycle on Early Mars
McLennan, Grotzinger, Hurowitz, and Tosca

Supplemental Table 1. Summary of major sedimentary rock sequences/deposits studied in situ on Mars by the *Spirit*, *Opportunity* and *Curiosity* rovers.

Sedimentary Rock Unit	Age	Brief Description	Provenance History	Depositional History	Diagenetic History	Selected Refs
Meridiani Planum / Endeavour Crater (Opportunity Rover)						
Matijevic formation	Noachian	- >1m thick; observed in several locations - coarse- to very coarse-grained sandstone - abundant 2-4mm spherules	- basaltic source with higher Si & P than average crust	- Pre- Endeavour crater impact or volcanic lapilli-rich proximal airfall deposit	- lithified - late Ca-sulfate veins - aluminous clay-bearing “boxwork” veins of likely hydrothermal origin	1-5
Shoemaker formation	Late Noachian	- ~4m thick; observed in several locations - overlies Matijevic formation - massive polymict clast-rich to clast-poor breccias	- highly variable basaltic compositions - local Fe-phyllosilicates of detrital &/or diagenetic origin	- Endeavour crater-related impact breccia; suevite	- lithified - late Ca-sulfate veins	
Grasberg formation	Late Noachian-Early Hesperian	- ~2m thick; observed in several locations - overlies Shoemaker formation - very fine-grained sandstone to mudstone; locally laminated - upper 0.5m light-toned	- basaltic source with lower Mg and higher Fe/Mg than average crust	- inadequate exposure for depositional model - low energy, possibly distal airfall	- weakly lithified - late diagenetic Ca-sulfate veins - light-toned upper 0.5m may be diagenetic alteration zone or pre-Burns fm paleosol	
Burns formation	Late Noachian-Early Hesperian	- multiple 5-10m sections over >25km traverse distance - younger than (in vicinity of Endeavour crater overlies) Grasberg formation - well sorted coarse- to medium-grained (in places bimodal) sandstone; local mudstone (playa facies) - multiple scales of cross-bedding, including ripple cross-laminations	- sand grains composed of sulfate-cemented altered basaltic mud derived from contemporaneous playas - basalt sources of typical Mars crustal composition - 0-6% meteoritic component - substantial chemical weathering of basaltic sources under circum-neutral conditions	- dry to wet aeolian depositional system - dune; sand sheet; interdune; playa (mudstone) facies - persistent evaporative conditions during deposition/diagenesis	- extensive groundwater diagenesis; deep groundwaters likely anoxic; near-surface groundwaters oxidized, low pH (<4), low a_w - Ca-Mg-Fe-sulfate cements; 2° fabric selective porosity ; hematitic concretions; nodules; cement overgrowths; soft sediment deformation	6-33

Sedimentary Rock Unit	Age	Brief Description	Provenance History	Depositional History	Diagenetic History	Selected Refs
Gusev Crater- Columbia Hills/Inner Basin (Spirit Rover)						
Home Plate	Noachian	- ~ 2m section - lower (0.5 m) unit of thick bedded to massive, poorly sorted clastics (incorporating a bomb sag) - upper unit of moderately- to well-sorted, cross-bedded sandstones	- basaltic source with higher Mg, lower Fe/Mg and higher P than average crust - no significant difference in provenance for lower vs. upper units	- lower unit – explosive volcaniclastic deposit, possibly within volcanic vent - upper unit – aeolian reworked pyroclastic surge deposit	- lithified - diagenetic processes likely obscuring clastic textures in lower unit - mineralogical/geochemical evidence for aqueous diagenetic to hydrothermal overprint	34-37
Opaline Silica Deposits	Noachian(?)	- scattered outcrops of opaline silica - nodular and mm-scale digitate morphologies; possible halite encrustations	- unknown; consistent with silica derived from basalt alteration	- hot spring/geyser silica sinter - alternative model is hydrothermal residual deposit	- absence of evidence for crystalline micro- or mega-quartz suggests limited burial and/or aqueous diagenesis	38-40
Peace Class Rocks	Noachian	- isolated outcrops (float?) - mm- to cm-scale bedded, poorly sorted pebbly sandstone	- ultramafic source for clastic components - cements likely derived from basaltic aquifer	- insufficient exposure for depositional model	- lithified - cemented by Mg-Ca-sulfates (likely hydrated)	41-43

Sedimentary Rock Unit	Age	Brief Description	Provenance History	Depositional History	Diagenetic History	Selected Refs
Gale Crater (Curiosity Rover)						
Bradbury group	Late Noachian – Early Hesperian	- ~60m of section (base not exposed) measured over ~8km - interbedded conglomerates, sandstones and mudstones - cross-bedding common; rare clinoforms - subdivided into Yellowknife Bay; Kimberley formations; unnamed units and named outcrops	- basaltic provenance similar to average crust - localized influence of K-rich basaltic sources - approx.4.2Gyr provenance age (K-Ar) - little to no chemical weathering of sources	- dominantly braided fluvial-deltaic with interspersed lacustrine deposition - rare aeolian facies	- redox-related diagenetic mineral transformations - early diagenetic features: pre-filling cements, filled and hollow nodules, subaqueous shrinkage cracks, early raised ridges/veins - late diagenetic features: vuggy porosity, sedimentary dike, extensive networks of Ca-sulfate veins	44-81
Mt. Sharp group – Murray formation	Late Noachian – Early Hesperian	- >150m of section over ~8km - thickly to thinly laminated mudstones - overlies Bradbury group - interspersed medium-coarse, moderately well sorted, cross-bedded sandstones and sandstone clinoforms; local conglomerate - likely desiccation cracks at one location	- basaltic provenance broadly similar to average crust - localized influence of K-rich basaltic sources - approx. 4.1Gyr provenance age (K-Ar) - modest and variable chemical weathering of sources; significantly greater weathering influence than for Bradbury fm	- redox stratified lake deposit (mudstones) with interspersed fluvio-deltaic sandstone facies - lacustrine facies equivalent of (i.e., interfingering with) Bradbury fluvial-deltaic sequence	- redox-related diagenetic mineral transformations; groundwaters anoxic/alkaline - minor (late?) jarosite suggesting local low pH conditions - dendritic concretions, prismatic crystal pseudomorphs - post-cementation silica-rich alteration halos along fractures - extensive networks of post-lithification Ca-sulfate veins	
Stimson formation	Late Noachian – Hesperian	- multiple 5-20m sections over <1km traverse distance - where exposed, unconformably overlies Mt. Sharp group - m-scale planar/trough cross-bedded, medium-coarse-grained (bimodal) sandstone	- basaltic provenance with composition very similar to average crust - one facies composed of recycled Murray fm mudstone clasts - minor chemical weathering of sources	- dry aeolian depositional system - part of crescentic (locally complex) dune field	- circum-neutral pH groundwater-related cementation - concretion-rich (20-30mm) facies related to cementation - post-cementation silica-rich alteration halos along fractures; possibly low pH	82-85

Formations, members and groups are informal assignments and so lowercase is used.

SUPPLEMENTAL TABLE 1 REFERENCES

Matijevic, Shoemaker and Grasberg formations

1. Arvidson RE, Squyres SW, Bell III JF, Catalano JG, Clark, BC, et al. 2014. Ancient aqueous environments at Endeavour crater, Mars. *Science* 343:1248097.
2. Crumpler LS, Arvidson RE, Bell J, Clark BC, Cohen BA, et al. 2015. Context of ancient aqueous environments on Mars from in situ geologic mapping at Endeavour*. J. Geophys. Res. – Planets* 120:538-69.
3. Fox VK, Arvidson RE, Guinness, EA, McLennan SM, Catalano JG, et al. 2016. Smectite deposits in Marathon Valley, Endeavour Crater, Mars, identified using CRISM hyperspectral reflectance data. *Geophys. Res. Lett.* 43:4885-92.
4. Mittlefehldt DW, Gellert R, van Bommel S, Ming DW, Yen AS, et al. 2018. Diverse lithologies and alteration events on the rim of Noachian-aged Endeavour crater, Meridiani Planum, Mars: In situ compositional evidence. *J. Geophys. Res. – Planets* 123:1255-306.
5. Squyres SW, Arvidson RE, Bell JF, Calef F, Clark, BC, et al. 2012. Ancient impact and aqueous processes at Endeavour crater, Mars. *Science* 336:570-6.

Burns formation:

6. Arvidson RE, Ashley, JW, Bell III JF. Chojnacki M, Cohen J, et al. (2011) Opportunity Mars rover mission: Overview and selected results from Purgatory ripple to traverses to Endeavour Crater. *J. Geophys. Res.–Planets*, 116:E00F155.
7. Arvidson RE, Bell III JF, Catalano JG, Clark BC, Fox VK, et al. (2016) Mars Reconnaissance orbiter and Opportunity observations of Burns formation and underlying strata: Crater hopping at Meridiani Planum. *J. Geophys. Res.–Planets*, 120:429-51.
8. Cino CD, Dehouck E, McLennan SM. 2017. Geochemical constraints on the presence of clay minerals in the Burns formation, Meridini Planum, Mars. *Icarus* 284:137-50.
9. Clark BC, Morris RV, McLennan SM, Gellert R, Jolliff, B, et al. 2005. Chemistry and mineralogy of outcrops at Meridiani Planum, *Earth Planet. Sci. Lett.* 240:73-94.
10. Edgar LA, Grotzinger JP, Hayes AG, Rubin DM, Squyres SW, et al. 2012. Stratigraphic architecture of bedrock reference section, Victoria crater, Meridiani Planum, Mars. In *Sedimentary Geology of Mars*, ed. JP Grotzinger, RE Milliken, pp.195-209. SEPM Spec. Publ. 102. Tulsa, OK:SEPM.
11. Edgar, LA, Grotzinger JP, Bell III JF, Hurowitz JA. 2014. Hypotheses for the origin of fine-grained sedimentary rocks at Santa Maria crater, Meridiani Planum. *Icarus* 234:36-44.
12. Hurowitz JA, Fischer WW, Tosca NJ, Milliken RE. 2010. Origin of acidic surface waters and the evolution of atmospheric chemistry on early Mars. *Nature Geosci.* 3:323-6.
13. Farrand WH, Bell, III JF, Johnson JR, Jolliff BL, Knoll AH ,et al. 2007. Visible and near infrared multispectral analysis of rocks at Meridiani Planum, Mars by the Mars Exploration Rover Opportunity. *J. Geophys. Res.*–Planets 112:E06S02.
14. Glotch TD, Bandfield JL, Christensen PR, Calvin WM, McLennan SM, et al. 2006. Mineralogy of the light-toned outcrip rock at Meridiani Planum as seen by the Miniature Thermal Emission Spectrometer and implications for its formation. *J. Geophys. Res.–Planets* 111:E12S03.
15. Grotzinger JP, Arvidson RE, Bell III JF, Calvin W, Calvin W, et al. 2005. Stratigraphy and sedimentology of a dry to wet eolian depositional system, Burns formation, Meridiani Planum, Mars. *Earth Planet. Sci. Lett.* 240:11-72.
16. Grotzinger JP, Bell III J, Herkenhoff K, Johnson J, Knoll A, et al. 2006. Sedimentary textures formed by aqueous processes, Erebus crater, Meridiani Planum, Mars. *Geology* 34:1085-88.

17. Hayes AG, Grotzinger JP, Edgar LA, Squyres SW, Watters WA, et al. 2011. Reconstruction of eolian bedforms and paleocurrents from cross-bedded strata at Victoria crater, Mericiani Planum, Mars. *J. Geophys. Res.–Planets* 116:E00F21.
18. Klingenhöfer G, Morris RV, Bernhardt B, Schröder C, Rodionov DS, et al. 2004. Jarosite and hematite at Meridiani Planum from Opportunity's Mössbauer spectrometer. *Science* 306:1740-5.
19. Knoll AH, Carr M, Clark B, Des Marais D, Farmer J, et al. 2005. An astrobiological perspective on Meridiani Planum. *Earth Planet. Sci. Lett.* 20:179-89.
20. Knoll AH, Jolliff B., Farrand WH, Bell III JF, Clar, BC, et al. 2008. Veneers, rinds, and fracture fills: Relatively late alteration of sedimentary rocks at Meridiani Planum, Mars. *J. Geophys. Res.–Planets* 113:E06S16.
21. McLennan SM, Bell III JF, Calvin WM, Christensen PR, Clark BC, et al. 2005. Provenance and diagenesis of the evaporate-bearing Burns formation, Meridiani Planum, Mars. *Earth Planet. Sci.Lett.* 240:95-121.
22. Metz JM, Grotzinger JP, Rubin DM, Lewis KW, Squyres, SW, Bell JF. 2009. Sulfate-rich eolian and wet interduen deposits, Erebus crater, Meridiani Planum, Mars. *J. Sed. Res.* 79:247-64.
23. Sefton-Nash E, Catling DC. 2008. Hematitic concretions at Meridiani Planum, Mars: Their growth timescale and possible relationship with iron sulfates. *Earth Planet. Sci. Lett.* 269:365-75.
24. Squyres SW, Grotzinger JP, Arvidson RE, Bell III JF, Christensen PR, et al. 2004. In-situ evidence for an ancient aqueous environment on Mars. *Science* 306:1709-14.
25. Squyres SW, Arvidson RE, Bollen D, Bell III JF, Brückner J, et al. 2006. Overview of the Opportunity Mars Exploration Rover Mission to Meridiani Planum: Eagle Crater to Purgatory Ripple. *J. Geophys. Res.–Planets* 111:E12S12
26. Squyres SW, Knoll AH, Ardivson RE, Clark BC, Grotzinger JP, et al. 2006. Two years at Meridiani Planum: Results from the Opportunity Rover. *Science* 313:1403-7.
27. Squyres SW, Knoll AH, Arvidson RE, Ashley JW, Bell III JF, et al. 2009. Exploration of Victoria crater by the Mars rover Opportunity. *Science* 324:1058-61.
28. Tosca NJ, McLennan SM, Clark BC, Grotzinger JP, Hurowitz JA, et al. 2005. Geochemical modeling of evaporation processes on Mars: Insight from the sedimentary record at Meridiani Planum. *Earth Planet. Sci. Lett.* 240:122-48.

Alternative Models for the Burns formation may be found in:

29. Amundson R. 2018. Meteoric water alteration of soil and landscapes at Meridiani Planum, Mars. *Earth Planet. Sci. Lett.* 488:155-67.
30. Amundson R, Ewing S, Dietrich W, Sutter B, Owen J, et al. 2008. On the in situ aqueous alteration of soils on Mars. *Geochim. Cosmochim. Acta* 72:3845-64.
31. Knauth LP, Burt DM, Wohletz KH. 2005. Impact origin of sediments at the Opportunity landing site on Mars. *Nature* 438:1123-8.
32. McCollom TM, Hynek BM. 2005. A volcanic environment for bedrock diagenesis at Meridiani Planum on Mars. *Nature* 438:1129-31.
33. Niles PB, Michalski J. 2009. Meridiani Planum sediments on Mars formed through weathering in massive ice deposits. *Nature Geosci.* 2:215-20.

Home Plate

34. Arvidson RE, Ruff SW, Morris RV, Ming DW, Crumpler L., et al. 2008. Spirit Mars Rover mission to the Columbia Hills, Gusev Crater: Mission overview and selected results from the Cumberland Ridge to Home Plate. *J. Geophys. Res.–Planets* 113:E12S33.
35. Lewis KW, Aharonson O, Grotzinger JP, Squyres SW, Bell JF, et al. 2008. Structure and stratigraphy of Home Plate from the Spirit Mars Exploration Rover. *J. Geophys. Res.–Planets* 113:E12S36.
36. Schmidt ME, Farrand WH, Johnson JR, Schröder C, Hurowitz JA, et al. 2009. Spectral, mineralogical, and geochemical variations across Home Plate, Gusev Crater, Mars indicate high and low temperature alteration. *Earth Planet. Sci. Lett.* 281:258-66.

37. Squyres SW, Aharonson O, Clark BC, Cohen BA, Crumpler L, et al. 2007. Pyroclastic activity at Home Plate in Gusev crater, Mars. *Science* 316:738-42.

Opaline Silica Deposits

38. Ruff, SW, Farmer JD, Calvin WM, Herkenhoff KE, Johnson JR, et al. 2011. Characteristics, distribution, origin, and significance of opaline silica observed by the Spirit rover in Gusev crater, Mars. *J. Geophys. Res. – Planets* 116:E00F23.
38. Ruff, SW, Farmer JD. 2016. Silica deposits on Mars with features resembling hot spring biosignatures at El Tatio in Chile. *Nature Comm.* 7:13554.
40. Squyres SW, Arvidson RE, Ruff S, Gellert R, Morris RV, et al. 2008. Detection of silica-rich deposits on Mars. *Science* 320:1063-7.

Peace Class

41. Gellert R, Rieder R, Brückner J, Clark B, Driebus G, et al. 2006. The alpha-particle X-ray spectrometer (APXS): Results from Gusev crater and calibration report. *J. Geophys. Res.–Planets* 111:E02S05.
42. Ming DW, Mittlefehhldt DW, Morris RV, Golden DC, Gellert R, et al. 2006. Geochemical and mineralogical indicators for aqueous processes in the Columbia Hills of Gusev crater, Mars. *J. Geophys. Res.-Planets* 111:E02S12.
43. Squyres SW, Arvidson RE, Blaney DL, Clark BC, Crumpler L, et al. 2006. Rocks of the Columbia Hills. *J. Geophys. Res. – Planets* 111:E02S11.

Bradbury and Mt Sharp Groups

44. Anderson R, Bridges JC, William A, Edgar L, Ollila A, et al. 2015. ChemCam results from the Shaler outcrop in Gale crater, Mars. *Icarus* 249:2-21.
45. Bridges JC, Schwenzer SP, Leveille R., Westall, R, Wiens RC, et al. 2015. Diagenesis and clay mineral formation at Gale Crater, Mars. *J. Geophys. Res.–Planets* 120:1-19.
46. Bristow TF, Bish DL, Vaniman DT, Morris RV, Blake DF, et al. 2015. The origin and implications of clay minerals from Yellowknife Bay, Gale crater, Mars. *Amer. Mineral.* 100:824-36.
47. Caswell TE, Milliken RE. 2017. Evidence for hydraulic fracturing at Gale crater, Mars: Implications for burial depth of the Yellowknife Bay formation. *Earth Planet. Sci. Lett.* 468:72-84.
48. Dehouck E, McLennan SM, Meslin PY, Cousin A. 2014. Constraints on abundance, composition and nature of X-ray amorphous components of soils and rocks at Gale crater, Mars. *J. Geophys. Res.–Planets* 119:2640-57.
49. Edgar LA, Gupta S, Rubin DM, Lewis KW, Kocurek GA, et al. 2017. Shaler: in situ analysis of a fluvial sedimentary depost on Mars. *Sedimentology* 65:96-122.
50. Farley KA, Malespin C, Mahaffy P, Grotzinger J, Vasconcelos P, et al. 2014. In-situ radiometric and exposure age dating of the Martian surface. *Science* 343:1247166.
51. Frydenvang J, Gasda PJ, Hurowitz JA, Grotzinger JP, Wiens RC, et al. 2017. Diagenetic silica enrichment and late-stage groundwater activity in Gale crater, Mars. *Geophys. Res. Lett.* 44:doi:10.1002/2017GL073323.
52. Grotzinger J, Gupta S, Malin MC, Rubin DM, Schieber J, et al. 2015. Deposition, exhumation, and paleoclimate of an ancient lake deposit, Gale crater, Mars. *Science* 350:aac7575.
53. Grotzinger JP, Sumner DY, Kah LC, Stack K, Gupta S, et al. 2014. A habitable fluvio-lacustrine environment at Yellowknife Bay, Gale Crater, Mars. *Science* 343:1242777.

54. Hurowitz JA, Grotzinger JP, Fischer WW, McLennan SM, Milliken RE, et al. 2017. Redox stratifification of an ancient lake in Gale crater, Mars. *Science* 356:eaah6849.
55. Johnson JR, Bell JF, Bender S, Blaney D, Cloutis E, et al. 2016. Constraints on iron sulfate and iron oxide mineralogy from ChemCam visible/near-infrared reflectance spectroscopy of Mt. Sharp basal units, Gale Crater, Mars. *Amer. Mineral.* 101:1501-14.
56. Le Deit L, Mangold N, Forni O, Cousin A, Lasue J, et al. 2015. The potassic sedimentary rocks in Gale crater, Mars, as seen by ChemCam onboard Curiosity. *J. Geophys. Res.–Planets* 121:784-804.
57. Léveillé RJ, Bridges J, Wiens RC, Mangold N, Cousin A, et al. 2014. Chemistry of fracture-filling raised ridges in Yellowknife Bay, Gale Crater: Window into past aqueous activity and habitability on Mars. *J. Geophys. Res.–Planets* 119:2398-415.
58. Mangold N, Forni O, Dromart G, Stack K, Wiens RC, et al. 2015. Chemical variations in Yellowknife Bay formation sedimentary rocks analyzed by ChemCam onboard the Curiosity rover on Mars. *J. Geophys. Res. – Planets,* 120:452-82.
59. Mangold N, Schmidt ME, Fisk MR, Forni O, McLennan SM, et al. 2016. Classification scheme for sedimentary and igneous rocks in Gale crater, Mars. *Icarus* 284:1-17.
60. Mangold N, Thompson LM, Forni LM, Williams AJ, Fabre J, et al. 2015. Composition of conglomerates analyzed by the Curiosity rover: Implications for Gale crater crust and sediment sources. *J. Geophys. Res.–Planets* 121:353-87.
61. Martin PE, Farley KA, Baker MB, Malespin CA, Schwenzer SP, et al. 2017. A two-step K-Ar experiment on Mars: Dating the diagenetic formation of jarosite from Amazonian groundwaters. *J. Geophys. Res.–Planets* 122:2803-18.
62.McLennan SM, Anderson RB, Bell III JF, Bridges JC, Calef III F, et al. 2014. Elemental geochemistry of sedimentary rocks at Yellowknife Bay, Gale Crater, Mars. *Science* 343:1244734.
63. Ming DW, Archer Jr. PD, Glavin DP, Eigenbrode JL, Franz HB, et al. 2014. Volatile and organic compositions of sedimentary rocks in Yellowknife Bay, Gale Crater, Mars. *Science* 343:1245267.
64. Morris RV, Vaniman DT, Blake DF, Gellert R, Chipera SJ, et al. 2016. Silicic volcanism on Mars evidenced by tridymite in high-SiO_2 sedimentary rock at Gale crater. *Proc. Nat. Acad. Sci.* 113:7071-6.
65. Morrison SM, Downs RT, Blake DF, Vaniman DT, Ming DW, et al. 2018. Crystal chemistry of martian minerals from Bradbury Landing through Naukluft Plateau, Gale crater, Mars. *Amer. Mineral.* 103:857-71.
66. Nachon M, Clegg SM, Mangold N., Schröder S, Kah LC, et al. 2014. Calcium sulfate veins characterized by ChemCam/Curiosity at Gale Crater, Mars. *J. Geophys. Res. – Planets* 119:1991-2016.
67. Palucis MC, Dietrich WE, Hayes AG, William RME, Gupta S, et al. 2014. The origin and evolution of the Peace Vallis fan system that drains to the Curiosity landing area, Gale Crater, Mars. *J. Geophys. Res.–Planets* 119:705-28.
68. Rampe EB, Ming DW, Blake DF, Bristow TF, Chipera SJ, et al. 2018.Mineralogy of an ancient lacustrine mudstone succession from the Murray formation, Gale crater, Mars. *Earth Planet. Sci. Lett.* 471:172-85.
69. Rice MS, Gupta S, Treiman AH, Stack KM, Calef F, et al. 2017. Geologic overview of the Mars Science Laboratory rover mission at the Kimberley, Gale crater, Mars. *J. Geophys. Res.–Planets* 122:2-20.
70. Schieber J, Bish D, Coleman M, Reed M, Hausrath EM, et al. 2017. Encounters with an unearthly mudstone: Understanding the first mudstone found on Mars. *Sedimentology* 64:311-58.
71. Schmidt ME, Campbell JL, Gellert R, Perrett GM, Treiman AH, et al. 2014. Geochemical diversity in first rocks examined by the Curiosity Rover in Gale crater: Evidence for and significance of an alkali and volatile-rich igneous source. *J. Geophys. Res.–Planets* 119:64-81.

72. Siebach KL, Grotzinger JP, Kah LC, Stack KM, Malin M, et al. 2014. Subaqueous shrinkage cracks in the Sheepbed mudstone: Implications for early fluid diagenesis, Gale crater, Mars. *J. Geophys. Res. – Planets* 119:1597-613.
73. Siebach KL, Baker MB, Grotzinger JP, McLennan SM, Gellert R, et al. 2017b. Sorting our compositional trends in sedimentary rocks of the Bradbury group (Aeolis Palus), Gale crater, Mars. *J. Geophys. Res. – Planets* 122:295-328.
74. Stack KM, Grotzinger JP, Kah LC, Schmidt ME, Mangold N, et al. 2014. Diagenetic origin of nodules in the Sheepbed member, Yellowknife Bay formation, Gale Crater, Mars. *J. Geophys. Res.–Planets* 119:1637-64.
75. Stein N, Grotzinger JP, Schieber J, Mangold N, Hallet B, et al. 2018. Desiccation cracks provide evidence of lake drying on Mars, Sutton Island member, Murray formation, Gale Crater. *Geology* 46:515-8.
76. Sutter B, McAdam AC, Mahaffy PR, Ming DW, Edgett KS, et al. 2017. Evolved gas analyses of sedimentary rocks and eolian sediment in Gale Crater, Mars: Results of the Curiosity rover's sample analysis at Mars instrument from Yellowknife Bay to the Namib Dune. *J. Geophys, Res.–Planets* 122:2574-609.
77. Thompson LM, Schmidt ME, Spray JG, Berger JA, Farien AG, et al. 2016. Potassium-rich sandstones within the Gale impact crater, Mars: The APXS perspective. *J. Geophys. Res.–Planets* 121:1981-2003.
78. Tosca NJ, Ahmed IAM, Tutolo BM, Ashpitel A, Hurowitz JA. 2018. Magnetite authigenesis and the warming of early Mars. *Nature Geosci.* In press.
79. Treiman AH, Bish DL, Vaniman DT, Chipera SJ, Blake DF, et al. 2016. Mineralogy, provenance and diagenesis of a potassic basaltic sandstone on Mars: Chemin X-ray diffraction of the Windjana sample (Kimberley area, Gale Crater). *J. Geophys. Res.–Planets* 121:75-106.
80. Vaniman DT, Bish DL, Ming DW, Bristow TF, Morris RF, et al. 2014. Mineralogy of a mudstone on Mars. *Science* 343:1244734.
81. Vasconcelos PM, Farley KA, Malespin CA, Mahaffy P, Ming D, et al. 2016. Discordant K-Ar and concordant exposure dates for the Windjana sandstone, Kimberley, Gale Crater, Mars. *J. Geophys. Res.–Planets* 121:2176-92.

Stimson formation

82. Banham SG, Gupta S, Rubin DM, Watkins JA, Sumner DY, et al. 2018. Ancient Martian aeolian processes and palaeomorphology reconstructed from the Stimson formation on the lower slope of Aeolis Mons, Gale crater, Mars. *Sedimentology* 65:993-1042.
83. Frydenvang J, Gasda PJ, Hurowitz JA, Grotzinger JP, Wiens RC, et al. 2017. Diagenetic silica enrichment and late-stage groundwater activity in Gale crater, Mars. *Geophys. Res. Lett.* 44:doi:10.1002/2017GL073323.
84. Hausrath EM, Ming DW, Peretyazhko TS, Rampe EB. 2018. Reactive transport and mass balance modeling of the Stimson sedimentary formation and altered fracture zones constrain diagenetic conditions at Gale crater, Mars. *Earth Planet. Sci. Lett.* 491:1-10.
85. Siebach KL, McLennan SM, Fedo, CM. 2017. Geochemistry of the Stimson sandstone, Gale crater, Mars. *48th Lunar Planet. Sci. Conf.,* Abst. #2499. Houston:LPI (Abstr.).