A BURIED AEOLIAN LAG DEPOSIT AT AN UNCONFORMITY BETWEEN THE MURRAY AND STIMSON FORMATIONS AT MARIAS PASS, GALE CRATER, MARS H.E. Newsom[1], K.S. Edgett[2], D.M. Fey[2], R.C. Wiens[3], J. Frydenvang[4], S.G. Banham[5], S. Gupta[5], A.J. Williams[6], J.P. Grotzinger[7], N. Mangold[8], J. Schieber[9], F. Rivera-Hernandez[10], I. Belgacem[1]. [1]U. New Mexico, Albuquerque, NM 87131, USA (Newsom@unm.edu); [2]Malin Sp. Sci. Sys., San Diego, CA, [3]Los Alamos Nat. Lab, NM; [5]Imperial College, UK; [6]Towson U., MD; [7]Caltech/Jet Prop. Lab, CA; [8]IRAP/CNRS, FR; [9]Indiana U., IA; [10]U.C. Davis, CA.

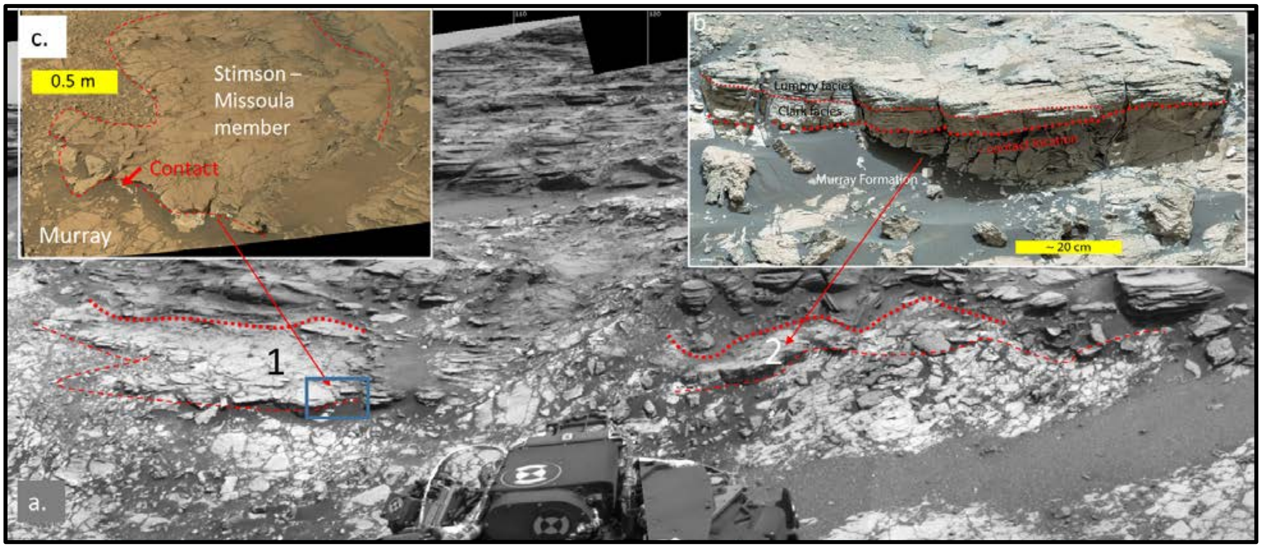

Fig. 1. The Missoula lens of the Stimson Formation forms a coherent layer containing light toned clasts above the contact with the eroded Murray Formation lacustrine beds and below the Stimson cross-bedded sandstones. Area labeled "2" (inset c.) was investigated with ChemCam LIBS analyses and MAHLI close-ups. Area labeled "1" (inset b.) contains a similar resistant layer just above the contact with the Murray that is also interpreted to be Missoula lens based on Mastcam images that also show light toned clasts (Fig. 2). We interpret the Missoula lens to be a thin aeolian lag deposit, consisting of fragments of Murray sediments and Ca-sulfate veins with a matrix of Stimson formation material, based on ChemCam analyses.

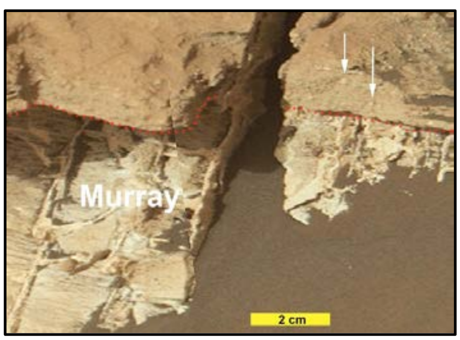

Fig. 2. Close up of a portion of Area 1 (blue box in **Fig. 1)**, showing the unconformable contact (red dots) between Murray Formation and the Missoula lens. Area 1 is similar to Area 2 in containing light-toned clasts (white arrows), and subtle horizontal layering at the lower edge of the Missoula lens.

Introduction: The Mars Science Laboratory rover Curiosity reached the Marias Pass area, on Sol 992 as part of an effort to reach the contact between the Murray Formation mudstone and sandstone lake deposits and overlying cross bedded aeolian Stimson formation. A discrete layer or lens of material above the contact is outlined in the images (**Figs. 1, 2**). We conducted an intensive study with ChemCam, MAHLI and APXS observations of a portion of this lens dubbed "Missoula/Ronan" (Area 2 in **Fig. 1**), where the contact between the Missoula lens and the Murray Formation is fully exposed [1].

Geology of the outcrop: The Murray Fm was first studied at the Pahrump Hills, located 2-3 meters stratigraphically below the rocks exposed at Marias Pass. At Marias Pass, the Murray also consists of finely laminated mudstones and sandstones, suggesting lacustrine deposition [2]. The units above the contact are more complicated, but an intense study of the images and chemical data has led to a greater confidence in the interpretation of the materials in this area [3]. The lowermost Stimson just above the contact consists of an erosionally resistant layer or lens, up to 5 cm thick, designated the Missoula lens, confirmed to exist only in the areas mapped in **Fig. 1**. This lens contains small rounded mm size lustrous and polished lithic mineral grains (**Fig. 3**). The lower 2.5 cm of the Missoula lens, called the Clark facies, also contains discontinuous horizontal layering and a concentration of irregular-shaped light-toned clasts (**Fig. 1b, Fig. 2, 3**). The light-toned clasts are probably pieces of mudstone (fine-grained with pores, e.g. **Fig. 4**) and fragments of calcium sulfate veins derived from the underlying Murray Fm. However, ChemCam analyses of the lens material shows that the matrix sandstone supporting the clasts has a Stimson chemical signature, and the lens is properly part of the Stimson Formation. Further complicating the story is the evidence for diagenetic silica enrichment in the lower most Clark facies along with occurrences of Ca-sulfate cement (**Figs. 3, 4**) within the Missoula lens and along the contact.

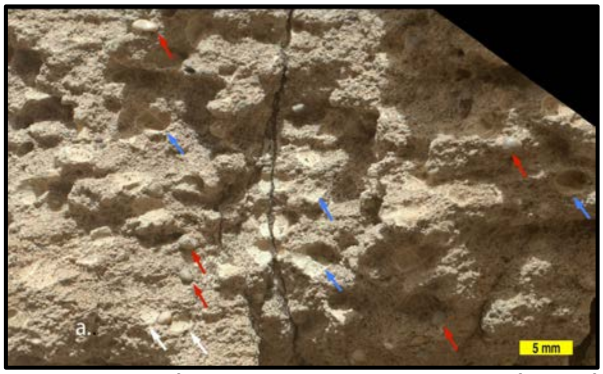

Fig. 3. Portions of MAHLI Clark mosaic. The Clark facies of the Stimson forms the lowermost layer of Stimson above the contact with the Murray formation. Some of the light-toned areas indicated with blue arrows appear to be white coated Ca-sulfate cement sockets where clasts, possibly of Murray mudstone have been partially eroded out. Areas marked by white arrows could be angular pieces of calcium sulfate veins or Murray mudstone. Red arrows mark rounded lithic clasts.

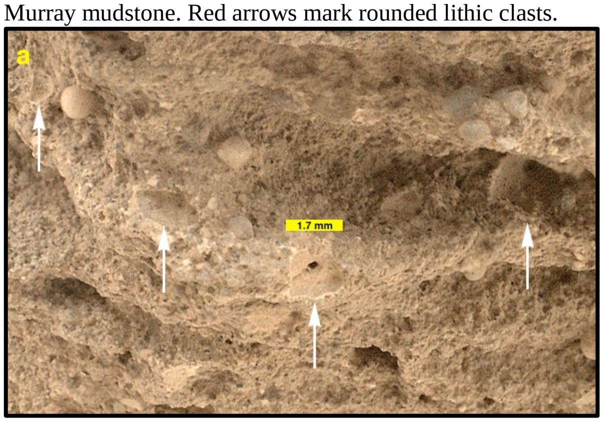

Fig. 4 Portion of the Lumpry MAHLI observation of the Clark facies area. Note the irregular shapes denoted by white arrows. These appear to be Ca-sulfate cement casts in some cases with remnants of Murray mudstone. One clast, 1.7 mm across in the center of the image is surrounded by a white rind (probably calcium sulfate), with widths of 1 to 2 pixels for a maximum thickness of approximately 55 microns. The pit in the central clast is ~12 pixels across for a width of ~ 330 microns. Note the recessed eroded nature of the clasts denoted by arrows. The strikingly spherical particle on the left could be an impact melt droplet (e.g. [6]).

Discussion: The sequence of events leading to the formation of the deposits in Marias Pass is complicated and provides evidence of a sedimentary cycle operating in the Martian past [4]. The initial deposition of the lacustrine of the Murray formation was followed by formation of abundant Ca-sulfate veins. Subsequent erosion of the Murray resulted in a surface now forming the contact with the overlying Stimson. However, there is no evidence from ChemCam analyses of weathering or paleosol alteration of the Murray close to the contact [3]. Deposition of the Stimson Fm on the contact began with the Missoula Lens in the area shown in Fig. 1. The Missoula lens consists of a lag of light-toned clasts of mudstone and eroded fragments of calcium sulfate veins eroded from the Murray [3]. We have observed fractures in the Murray, which contain sand-size material of Stimson composition (Seeley target [3]), that are consistent with the introduction of Stimson composition material onto the surface of the eroded Murray. Although the Missoula lens has a Murray component, the matrix has chemical signatures of the overlying Stimson Formation (e.g. K_2O/Al_2O_3), and the lens represents the initial deposition of Stimson formation material.

The nature of the Missoula lens is best explained as a lag deposit of eroded Murray material in small swales and depressions that was buried by encroaching Stimson sands, much like the situation near the current Bagnold dunes. An analogous lag of eroded material is present on many areas of Murray Formation today (e.g. **Fig. 5**). Aeolian processes can result in evenly spaced angular or rounded clasts, being buried by a layered fine-grained matrix. Only after burial of the lag deposit, did cross-bedded Stimson deposits begin to form.

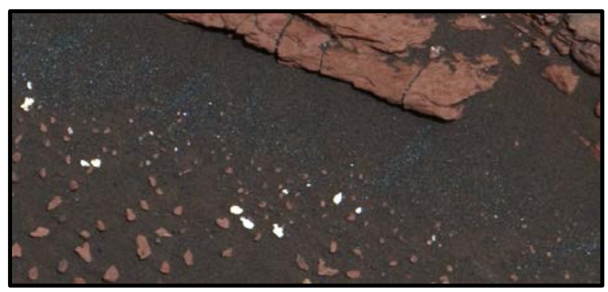

Fig. 5. Possible modern analogue for the Missoula lens of the Stimson Formation. Note the evenly distributed rock fragments, including pieces of Ca-sulfate, surrounded by aeolian sands. Fine layering is also evident in the distribution of different grain sizes. Portion of Mastcam 100 mm image mcam08201 from sol 1605, ~8 cm across.

Following Stimson deposition, diagenesis of the lowermost Missoula lens involved emplacement of calcium sulfate veins along the contact and enrichment of SiO_2 up to 75 wt% in the Clark facies just above the contact [3, 5]. Ca-sulfate is also present in veins along contact and locally intruded the Stimson matrix locally cementing the sandstone.

References: [1] Newsom et al., 2016, LPSC. [2] Rivera-Hernandez et al., 2018, LPSC, this meeting. [3] Newsom et al. 2018, in preparation. [4] Edgett *et al.* (2018) LPSC, this meeting. [5] Frydenvang et al., 2017, GRL 44, 4716-4724. [6] Newsom et al. 2015, Icarus 249, 108-128.