Reappraisal of the Stratigraphic Position of Light Toned Materials in Juventae Chasma, Mars. Ranjan Sarkar¹, Kenneth S. Edgett², Pragya Singh³, Alok Porwal⁴, ¹Geology and Mineral Resources Group, CSRE, Indian Institute of Technology, Bombay, (ranjan.s@iitb.ac.in; ranjan888@gmail.com); ²Malin Space Science Systems, Inc., P.O.Box 910148, San Diego, CA 92191-0148 USA, (edgett@msss.com).

Introduction: The stratigraphic position of light toned materials in Juventae Chasma on Mars is revaluated. Juventae Chasma is an isolated box canyon located north-east of the main Valles Marineris canyon system. It contains four separate mounds of light-toned layered material labeled A, B, C, and D (Fig. 1). Layering style varies from layered, bedded, terraced, cliff-and-bench to massive. Mineralogically these are hydrated sulphate bearing [1,2,3] although other minerals not captured in VNIR-SWIR spectra could also be present. Features such as jagged edges, kilometres-tall mounds, steep escarpments, sharp crested spur-and-gullies, wind-cut cuspatte ridges and yardangs, and non-diffuse contacts between adjacent layers of contrasting albedo indicate that the material is rigid and indurated; presence of repetitive layering, without associated, unambiguous volcanic or pyroclastic features, suggests that these mounds are composed of sedimentary rock. Thermal inertia values (350 and 850 J m⁻² s⁻¹/² K⁻¹) also suggest these to be dust covered sedimentary rocks [1]. Also few boulders in a rather smooth (at HiRISE resolution) talus apron at the base of scarps and the commonplace occurrence of yardangs and wind-eroded ridges and knobs indicates that this material erodes as a fine grained rock would.

In this work we reevaluate the stratigraphic position of these light toned materials in Juventae Chasma in view of two competing hypotheses that suggest, respectively, that the light toned materials:

1. pre-date the opening of the chasm and thus are older than the darker-toned layered rock of which the upper west walls of the chasm are composed [5,1], or
2. post-date the opening of the chasm and therefore are younger than the wall rock, chaotic terrain blocks, and the events that created the outflow channel (Maja Valles) that extends northward from Juventae Chasma [5,6,2].

The first hypothesis considers them remnants of formerly buried material; the latter hypothesis entails deposition of the light toned materials into the chasm after it formed. The latter hypothesis has been envisaged as two models: the ‘bathtub’ and ‘bucket’ model [2]. The first of these explains the four mounds to be eroded parts of a larger deposit that filled the entire chasm; the second considers the mounds to have formed in sub-basins within the chasma.

Problems with the second hypothesis: The volume of sulphate salts and water required to fill the entire chasm is unrealistically large, in fact the summit of Mound C is almost at par with the chasm ‘pour point’ [1]. Bishop et al., (2006) [2] argue that Mounds A and B may have evolved as a single unit, but C and D required separate origin. The hydrated mineral stratigraphy differs from mound to mound [3]. Average layer thicknesses are similar for A and C (~ 2-3 m) but significantly different for B (> 80m) [7]. Deformational features are also different for Mound B compared to the rest [8]. Layers from one mound cannot be traced across the voids between them. These observations indicate that the four mounds may not have been parts of a singular stratral package, unless subsequent intense deformation and erosion have obscured their common traits. This seems infeasible unless there has been some overburden to exert pressure. Moreover, there are widespread occurrences of isolated outcrops of light toned material distant from the main mounds (Fig. 1), which are difficult to explain if the mounds formed in isolated sub-basins (or ‘buckets’). The above observations do not favour either the ‘bathtub’ or ‘bucket’ models. Finally, if the light toned mounds are lithified sedimentary rocks, they would require certain amount of burial for their diagenesis and lithification.

Datasets and methodology: Our research utilizes high resolution (≤ 6m) panchromatic datasets (HiRISE, CTX and MOC). Tone is used as the main criterion for identifying these mounds, but tone can vary due to dust covers, shadows and illumination, sub-resolution roughness, and variations in composition. Mineralogy is difficult to ascertain at many locations because of inconsistent hyperspectral coverage by CRISM, surface degradation and dust cover. Some physical expressions, particularly certain erosional features revealed in high resolution images (for e.g. ‘chiseled’ surfaces), are unique and common to all light toned mound-forming materials, even those beyond Valles Marineris. These features were cross-validated with spectral information to confirm that these belonged to the light toned materials.

Observations: Mound D has a spearhead-shaped feature within Juventae Chasma chaotic terrain (Fig. 1). We find:

1. Light toned materials terminate at lower edges of wall rock capping of the chaotic terrain mounds.
2. Talus slides and erosional alcoves on chaos mound flanks reveal a light toned interior, below wall rock capping (Fig. 2).
3. Numerous scattered light toned outcrops exposed under similar conditions (as in points 1 and 2 above) across the entire chaotic terrain to the north of Mound C (Fig. 1).
4. The apex of Mound D juts out from a roughly oval-shaped unit of chasm wall-rock material that has broken away from the adjoining wall and is in an initial state of chaos formation (Fig. 3).

Mound A is emergent from within the chasm wall. Here we see:
1. Light toned materials sharply terminating below the lower edges of wall rock extending as spurs towards the main light toned mound (Fig. 4).

2. Wall-rock material superposed on light toned material (Fig. 4).

Discussion: The observations suggest that Mound D is emergent from beneath a broken-up mass of overlying, erosion resistant and darker-toned wall rock, and Mound A is part of the chasm wall and is emergent from it. Thus the first hypothesis seems to be favoured.

Juventae Chasma cuts across Lunae Planum a Hesperian surficial unit. These plains-forming materials units were recognized as early as initial Mariner 9 global geologic mapping [9] and are implied to overlie filled and buried craters and valleys that are otherwise exposed in the heavily cratered, Noachian-aged terrains of Mars, as exposed to the east of Juventae Chasma in Xanthe Terra. The volume beneath the plains cut by the chasm must contain craters which were filled with materials (some of which could be light-toned and layered) similar to Croommelin, Firsoff, Becquerel, Danielson, Trouvelot etc., in western Arabia, but in this case are buried under Lunae Planum. Any erosional window could expose such materials in forms that include the light-toned mounds in Juventae Chasma. Also, since these deposits would be confined within individual craters, or lows between craters, they would not necessarily be of the same age nor laterally extensive. Burial several hundred meters beneath the Lunae plains would have also provided the conditions to lithify sediment to become rock.

The present geometry and configuration of the light toned mounds would be a function of the high energy chaos-forming events and the differential erosion that occurred during and after it. Wind was likely the primary erosional agent after the chaos, and Maja Vallis to the north, had formed. The light-toned mounds are less resistant to erosion than the wall rock material, and where they occur below the wall rock unit, their erosion and removal leads to undermining of the overlying resistant wall rocks causing them to collapse and expose more of the light toned material, setting off a positive feedback loop. However, due to their position under a protective covering of resistant wall rock, their removal is decelerated, despite being mechanically weaker than the wall rocks. This phenomenon is exemplified by the emergence of Mound D from the chaotic terrain. The other mounds may have completely lost their resistant overburden. Hence the stratigraphy that is exposed today is entangled with the erosional history of closely associated rocks of different physical properties.

Conclusion: Light toned materials exposed as mounds in Juventae Chasma seem to stratigraphically underlie and be emergent from with the chasm wall rock. These light toned materials could represent the sediments that filled depressions within the Noachian cratered ‘volume’ and later buried under Hesperian units. However this model does not necessitate that the four different mounds were parts of a singular stratal package. Disentangling stratigraphic relations from the effects of differential erosion is of paramount importance.


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Figure 1: Location of light toned Mounds and outcrops. Black oval shape indicates possible buried extent of Mound D under chaotic terrain.

Figure 2: Light toned material inside chaos mound exposed through an erosional alcove (blue arrow). Brown area is wall rock cap. PSP_008998_1780

Figure 3: 3D view of Mound D and the adjacent chaotic terrain unit. Vertical exaggeration is 7x. Black line demarcates Mound D, green line demarcates the oval chaotic terrain unit which is possibly covering up a sizeable portion of Mound D. Purple line highlights the continuity of slope from chaotic terrain unit to Mound D. Black arrows point to outcrops of light toned materials. Mound C towards bottom. Please view the figure sideways.

Figure 4: Sharp termination below wall rock (brown area). Mound A. PSP_005557_1755