Buried layers beneath south rim of Valles Marineris revealed by central uplift of impact craters

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Introduction:

Mars Orbiter Camera (MOC) revealed over the last decade light-toned deposits at the surface of Mars [1]. These deposits outcrop mainly between 30°N and 30° S, i.e. in the equatorial regions [2]. They are observed in distinct contexts : 1) In the Valles Marineris canyon system with as thick as 4 km of light toned layers inside the canyons [3], and a few meter thick sequence of light-toned material over the lava plateaus surrounding Valles Marineris [4]. 2) In the chaotic regions like in Aram Chaos or Iani Chaos. 3) Inside impact craters where they formed a bulge of light-toned material interpreted as post impact filling 4) Over plains like in Terra Meridiani or Arabia Terra[1].

Both hyperspectral imagers OMEGA (MEX) and CRISM (MRO) have revealed hydrated minerals such as sulfates or phyllosilicates. These minerals, evidence of past water activity, are always in correlation with light-toned material [i.e. 5]. However, not all the light-toned outcrops over the planet have hydrated minerals spectral signatures. However, these un-observations are difficult to interpret, because they may be explained either by no signature, or by the boundary of the detection.

Oudemans crater is a 120km diameter impact crater located just south of Valles Marineris. MOC pictures revealed fractured light-toned layers exposed in the central uplift of the impact [6]. These observations imply the presence of deeply buried layers below the plateau of Valles Marineris. Are they related to the layers exposed in Valles Marineris ? Some authors use these layers as evidence that Valles Marineris Interior Layered Deposits (ILD) are part of the Noachian basement [7]. However, OMEGA has not yet detected hydrated minerals signatures over Oudemans, as the spectrometer did on the ILD of Valles Marineris [5].

The current MRO mission is doing a real effort in targeting the impact crater with central uplifts. On Mars, the transition between simple crater shape and central peak type would occur at 3km in diameter and the ring peak features occur since 45 km in diameter [8]. It means that lots of Martian impact craters could expose a central peak. However, as the Martian geological history is intense, lots of crater floors are now filled by either post impact lava flows or sedimentary deposits. It reduces considerably the observations at the surface of Mars of impact crater with a preserved central uplift.

In the present study, we did a survey of central peaks of craters pictured by HIRISE to check at buried layers exposed in the central peak and we then, when possible, studied the CRISM hyperspectral and multispectral data to assess the mineralogy. Is Oudemans an isolated case? How deep would the layers be? What is the mineralogical composition of these layers? What does this imply for the past Martian history?

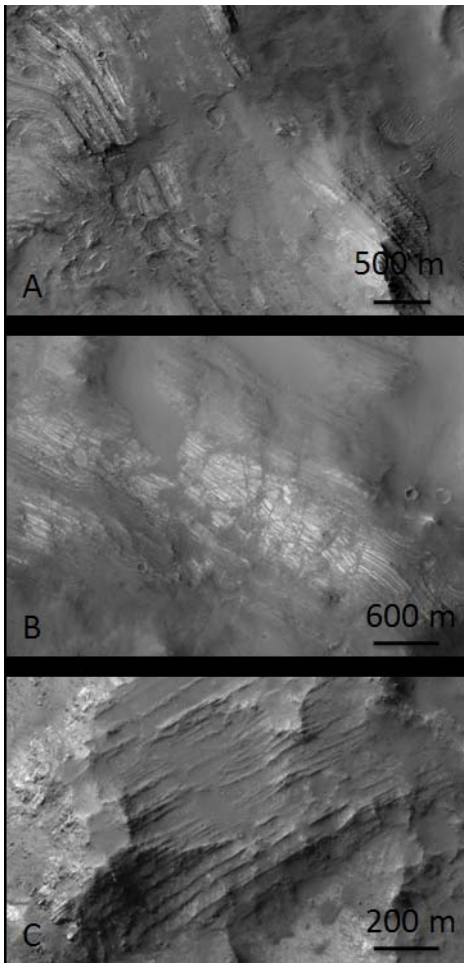

Figure 1 : HiRiSE pictures showing layering in the central peak of A) Oudemans crater, B) Mazamba crater, C) Unnamed crater south of Capri Chasma.

Location of impact craters exhuming layers:

During our survey over the whole planet, we found seven impact craters that expose well preserved layers in their central peak on the south rim of Valles

Marineris. We observed tilted, fractured and folded layers in central peak of Oudemans crater, Martin crater, Mazamba crater, and 4 others yet unnamed craters. On HiRiSE pictures, these layers are highly deformed (folds, large scale fractures, vertical deepening….), evidence of the impact shocks (figure 1).

The diameters of these craters range from 28 to 122 km. Oudemans is the largest crater. These craters emplaced on the south rim of Valles Marineris, that corresponds to a deepening plateau from west to east; from elevations 5800 m near Oudemans crater to elevations around 1000 m above the mean surface at the extreme east. We estimated the stratigraphic uplift of these layers from their diameter according the following relationship: $SU=0.06D^{1,1}$ where SU is the Stratigraphic Uplift, and D the Diameter of the crater [8]. This relationship is returned from terrestrial studies. We then estimated the average elevation of the exposed layers to assess the absolute elevation of the buried layers.

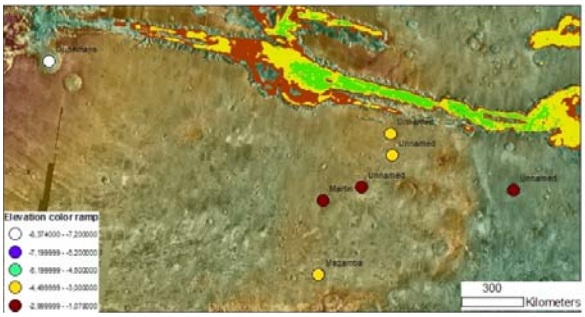

Figure 2: Location of the impact craters with layers in their central uplift and the associated depth they originated from. On purpose, corresponding elevation inside Valles Marineris have been mapped in same color than the origin elevation of the exhumed layers.

As presented in figure 2, the origin elevations of the layers range from -8 km to -1 km. The deepest layers exposed are at the extreme west in Oudemans crater. The -8km origin depth doesn't correspond to any elevation exposed in Valles Marineris canyons. However, the group of six impact craters located just south of Coprates Chasma has exhumed layers from -4 km to -1 km. These absolute elevations are exposed in Valles Marineris as shown in Figure 2.

Origin of the exhumed layers:

The concentration of exposed layers in central peak on the south rim of Valles Marineris suggests widespread continuous layers below the Valles Marineris plateau. However, the large range of origin elevations is more difficult to interpret. These results could be explained by several hypotheses: 1) there is a stack of continuous horizontal layers between -8km and -1km. This hypothesis is difficult to test because there is no surveyed impact crater with diameter able to assess the gap between Oudemans crater size and the other ones. 2) The layers are continuous and deformed with a large bulge south of Coprates Chasma. 3) These layers correspond to unrelated and localized events and there is no sense to correlate them.

In comparison with Valles Marineris ILD, the -8km layers correspond to elevations not exposed in Valles Marineris. However, the set of elevations between -4 and -1km corresponds to the elevations of the ILD in Melas Chasma and to the distribution of OMEGA sulfate in Melas Chasma [9]. The question raised now is the mineralogical nature of these layers exposed in central peaks in comparison to ILD of Valles Marineris.

Mineralogical nature of exhumed layers:

More than 20 hyperspectral and 40 multispectral cubes covering the central peak of the above mentioned craters were analyzed. The used data are processed for instrumental effects, converted to I/F and the atmosphere is removed using a ratio with a CRISM scene of Olympus Mons, scaled to the same column density of CO_2. Some of the central uplifts of these craters are olivine rich and some others display remarkable spectral types that are being compared to Valles Marineris ILD spectral signatures. This work is ongoing and the results will be presented at time conference.

Conclusion:

Our study of exhumed layers in the central peak of impact craters revealed extended buried layers below the southern plateau of Valles Marineris. Our results show that these layers may be geometrically related to those inside Valles Marineris but we don't know yet if they are genetically related. If mafic mineral is the main composition of these layers, a volcanic origin will be preferred, what would differ from ILD of VM, that show evidence of water-related activity.

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