KESS KESS HYDROTHERMAL MOUNDS IN MOROCCO: A UNIQUE ANALOG FOR EXPLORING POSSIBLE FOSSIL OR EXTANT LIFE ON MARS. F. Franchi[1,2], B. Cavalazzi[2], A. P. Rossi[3], M. Pondrelli[4], R. Barbieri[1], Dipartimento di Scienze della Terra e Geologico Ambientali, Università di Bologna, Italy fulvio.franchi2@unibo.it. [2]Department of Geology, University of Johannesburg, Johannesburg, South Africa. [3]Jacobs University, Bremen, Germany. [4]International Research School of Planetary Science, Università d'Annunzio, Pescara, Italy.

Introduction: The recent discovery of mound fields on Mars surface [e.g. 1-3] gave new inputs to the astrobiological study of the terrestrial mounds. Based on their geological, physical, morphological and compositional characteristics which bear a striking resemblance to mud volcanoes and spring deposits, terrestrial mound-like structures on Mars have been recently proposed as fluid escape features [1-3]. Furthermore, their supposed hydrothermal genesis [1, 4] would make them suitable environments for the microbial communities to flourish and to be preserved.

Aim of this study – coupled with the results presented in [5] - is to compare the geological features, morphologies and processes linked to fluid flow at multiple scales on the spectacular field of mounds in the southern Arabia Terra (Mars equatorial region) and the Kess Kess conical mounds in the Eastern Anti-Atlas of Morocco (Fig. 1). The data obtained from Mars remote-sensing are restricted to the Firsoff crater characterized by high abundance of mounds within the hydrothermal Equatorial Layered Deposits (ELDs) [2, 5].

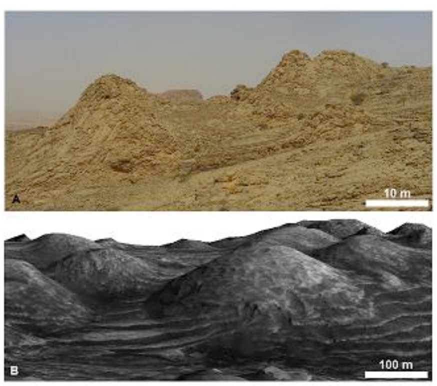

Figure 1: A) View of a major fault system along the Kess Kess ridge. The cut exhumes the inner facies of the mounds. B) Panoramic view of the Firsoff crater mound field (HiRISE ESP_020679_1820).

The Moroccan mound field is one of the most ancient and well preserved, subaerially exposed terrestrial field of mound. The value of Moroccan Devonian mounds as a Mars analogue is highlighted by the similar morphology and – where observable due to limited resolution of Mars images - textures of the structures and by the fluid escape origin that has been proposed to interpret both mound families. Sound microscopic evidences in correspondence of the fluid flow-related Kess Kess structures provided evidence of fossil life. These results encourage to deepen the investigations in order to test the reliability of the analogy between the two forms.

Geological Setting: The Firsoff impact crater is located in the equatorial southern highlands of Arabia Terra centered at 2,6°N – 350,8°E. Here the ELDs deposits overlays Noachian volcano-clastic sediments and are flooded by a thick basaltic formation Hesperian in age [5]. These two formations constrain the ELDs in the Upper Noachian age [2, 6].

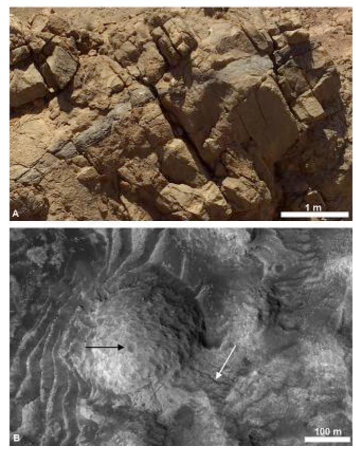

Figure 2: A) Dike cutting a Kess Kess buildup. B) Characteristic mound in the Firsoff region whit apical hole (black arrow) settled on a fractures (white arrow) (HiRISE ESP_020679_1820).

The Kess-Kess buildups grew on the top of a 100 meters thick crinoidal limestones unit deposed during the Pragian and the early Emsian in an epicontinental sea after a punctual submarine volcanic event [7]. The bottom of the Kess Kess succession is composed by high devitrified basaltic breccias locally affected by neomorphic crystallization of hydrothermal quartz. Many veins and dikes branch out from this dome-shaped volcanic body and cut across the whole succession (Fig. 2A) up to the nodular limestones, deposed after the drowning of the mounds, which close the Kess Kess succession.

Discussion: The Firsoff crater buildups, asymmetrical in shape with the down-slope flank always steeper than the up-slope flank, range from 500 and 20 meters, with an average dimension of 100 meters. These mounds always occur within the ELDs and locally are settled along kilometer long fractures and more often have a well rounded apical hole and fractures that branch out from the buildups bases (Fig. 2B). The mounds density is higher where the ELDs show a peculiar "pool and rim" pattern which is comparable with the terrestrial travertine pools [5]. The buildups are strictly correlated with these ELDs structures, to which they seem to be linked via conduits or channels. When the erosion exposed the inner facies the mounds show a clear internal stratification concordant with the mound morphology (Fig. 3B).

Figure 3: *A) Section of a Kess Kess mound showing the internal (crude) stratification and their strong asymmetry. B) Small asymmetric mound in the Firsoff crater. The internal stratification follows the mound morphology (HiRISE ESP_020679_1820).*

Also the Kess Kess conical mounds are settled in correspondence of tectonic lineaments and show a strong asymmetry and a crude internal stratification concordant with the mound morphology (Fig. 3A). A broad pattern of fractures and veins, which connected the volcanic rocks with the surface while the mounds were developing, allowed the fluids circulation. The low-temperature hydrothermalism was supported even by the δO^{18} isotopic composition, which is extremely depleted in the primary micrite, suggesting temperature up to 45°C during the development of the mounds.

Conclusive remarks: Based on morphological characteristics the two families of mounds have the same conical shape, internal stratification and show a similar asymmetry (Fig. 3). The terrestrial and Martian mound fields are settled along an area characterized by normal tectonic lineaments which could have driven a (deep) vents and fluid seepage. The mutual relation between veins, fractures and hydrothermal circulation is clear in the Kess Kess succession for which we have the evidence of a hydrothermal genesis. In the Firsoff crater mounds the data at the outcrop and microscope scales are lacking, but on the base of the comparable morphological and geological characteristics, this genetic model could explain at least some aspects of the ELDs mounds formation.

Their hydrothermal-related genesis makes the Kess Kess suitable environments for the bacterial communities to flourish and most of all for the preservation of the microbial signatures. Microbial fabric and structures were already described in the dikes [8] and new evidences suggest the microbial activity in peculiar facies of the mound buildups affected by the hydrothermal fluids seepage. Particularly along the veins walls and in the veins infilling were described stromatolite-like fabrics, clotted micrite and EPS structures (Fig. 4) and other signatures were founded in the neomorphic quartz and goethite precipitated directly from the hydrothermal fluids.

The hydrothermal activity changing the chemo-physical condition of the environment generated the perfect habitat for extremophiles communities and catalyzed the precipitation of the minerals which preserved the microbial signatures and cemented the buildups in an early stage stabilizing the abrupt conical morphologies of the buildups.

The plausible fluid escape related genesis of the Martian Firsoff mounds make them very interesting in an astrobiology perspective and suitable as a future Mars landing site [9].

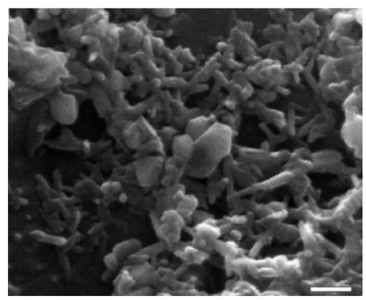

Figure 4: *A) SEM micrographs across oncolite laminations from the veins of the Kess Kess succession (scale bar 0,5 µm) [4].*

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