

**DARK SPOT AND DARK FLOW DEVELOPMENT DURING THE SEASONAL FROST RETREAT ON THE RUSSELL CRATER MEGADUNE, MARS** E. Gardin<sup>1</sup>, C. Quantin<sup>1</sup>, P. Allemand<sup>1</sup> and P. Thollot<sup>1</sup>, Laboratoire des Sciences de la Terre, Université de Lyon, Ecole Normale Supérieure de Lyon, Université Claude Bernard Lyon 1, CNRS, France, Bat Géode, 43 bd du 11 Novembre, 69622 Villeurbanne cedex, France ([emilie.gardin@univ-lyon1.fr](mailto:emilie.gardin@univ-lyon1.fr))

**Introduction:** Defrosting features have been observed on the megadune of Russell Crater (54.6°S; 12.4°E). Throughout spring, the south polar CO<sub>2</sub> cap retreats and leads to dalmatian spots named dark spots [1], spiders [2], fans [3] and polygonal crack patterns [4]. [5] proposed a semi-quantitative model to explain all of these processes. The dark spots, fans and spiders are probably formed by the venting of sub-ice CO<sub>2</sub> gas under pressure. This model implies a pure CO<sub>2</sub> ice slab and solar rays responsible for heating and defrosting the lower part of the ice slab by translucency [5].

The high resolution images of Russell Crater, first by MOC, and then by HiRISE, display features never observed further north in the southern hemisphere. Some south-facing scarps in middle latitudes are partly frosted during the local winter and are able to record the defrosting sequence during the spring retreat. This is the case in Russell Crater, a large crater of the southern hemisphere with a large dune field in its center. The aim of this work is to describe the active features produced by the defrosting on the megadune of Russell Crater and to discuss the possible mechanisms that are responsible for these features.

**Data set:** MRO (Mars Reconnaissance Orbiter) targeted HiRISE images acquired at different times throughout the two acquisition years over Russell Crater megadune. We studied the HiRISE images and described our observations throughout the defrosting period (Table 1).

Season	HiRISE	Ls	res.(cm/px)	Low d.s	Up d.s	D.f	Polygons	D.D
Winter	PSP_1440_1255	136.3°	50					
	PSP_1981_1255	157.7°	50					
	PSP_2337_1255	172.6°	25					
	PSP_2482_1255	178.9°	25					
Spring	PSP_2548_1255	181.8°	25					
	PSP_2904_1255	197.9°	25					
	PSP_3326_1255	217.7°	25					
	PSP_3748_1255	238.4°	25					
	PSP_4038_1255	252.7°	25					
	PSP_4249_1255	263.1°	25					
Summer	PSP_5238_1255	310.3°	25					
	PSP_5383_1255	316.8°	25					
Autumn	PSP_6873_1255	17.2°	50					
	PSP_7018_1255	22.5°	25					
	PSP_7229_1255	30.1°	50					
Winter	PSP_9879_1255	122.2°	100					
	PSP_10090_1255	130.1°	100					
	PSP_10301_1255	138.1°	100					
	PSP_10446_1255	143.7°	50					
	PSP_10868_1255	160.6°	50					
Spring	PSP_11580_1255	191.5°	50					

Table 1: List of processed HiRISE images on the Russell Crater megadune (54.6°S and 12.4°E) with their local season time, solar longitude (Ls) and spatial resolution of acquisition in cm/px. The vertical bars symbolize evidence of the observing features. "Low d.s": dark spots, which appear in the lower part of the megadune's slope. "Up d.s": dark spots located in the upper part of the megadune and on the plateau. "D.f": dark flows located in the upper part of the megadune. "Polygons": evidence near the brink of the megadune. "D.D": occurrence of dust devil tracks on the megadune.

**Regional context:** Russell is a 134 km diameter crater located to the west of Hellas Basin (fig. 2). This crater hosts a 1,704 km<sup>2</sup> dune field with an unusual megadune on its north-eastern boundary. This megadune, visible on MOLA data is around 500 m high and is highly studied because its south-facing scarp displays gullies [6-7-8]. The south-facing slope of the asymmetric megadune is steep with an average slope of 30°. Many ripples (1-3 m in height) are present all over the slope.

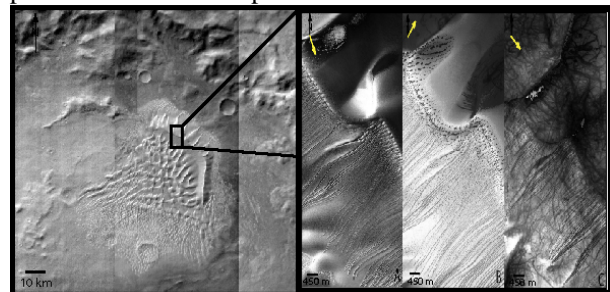


Figure 2: On the left: Mosaic of THEMIS IR images of the Russell Crater dune field. On the right: HiRISE images of the south-facing megadune's slope during the defrosting season. A: Ls 158°, B: Ls 182° and C: Ls 215°. Yellow arrows are the solar incidence angles.

**Distribution of defrosting features:** At the beginning of the defrosting sequence, several features appear over the Russell Crater megadune and are visible on many HiRISE images. During the early winter, we observe polygonal structures in the upper part of the alcoves forming the submittal part of the south-facing slope of the megadune. These polygonal structures are only visible between Ls 122.2° and Ls 130.1°.

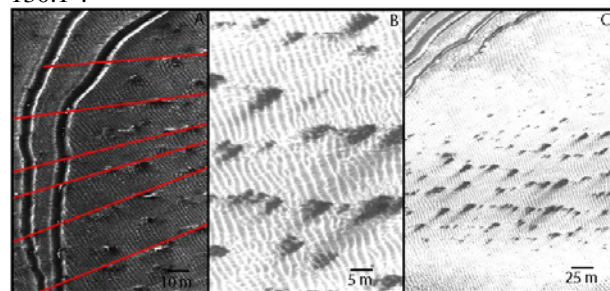


Figure 3: Dark spots in the lower part of the megadune's slope. A: Dark spots are aligned and independent of the gullies' location. B: Dark spots and their dust tracks. C: Alignment of dark spots and dust that has been blown by the wind.

From Ls 130°, dark spots appear in the lower part of the megadune with diameters between 5 and 10 m. At full spatial resolution they seem to be aligned and independent of the gullies' presence (fig. 3A). They

appear as diffuse patches (fig.3 B-C), where the dust has been blown by the wind. Throughout the season, the dark spots grow reaching diameters up to 25 m. From Ls 143.7°, the dark spots also develop in the submittal part of the megadune (Table 1). The distribution of these dark spots follows lines parallel to the iso-elevations in the slope whereas on the plateau, the dark spots distribute perpendicular to the brink (fig. 4). On the upper part of the megadune's slope the dark spots appear on up-facing scarps and on the plateau, they appear on meter scale araneiform cones.

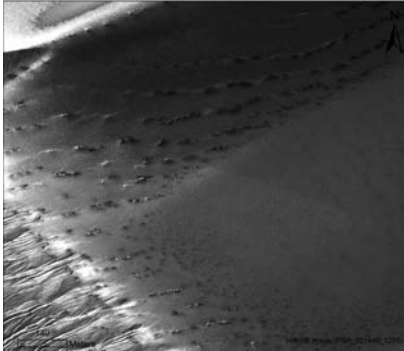


Figure 4: HiRiSE image at Ls 136.3°: dark spots in the upper part of the Russell Crater megadune and on the plateau. Dark spots are aligned and perpendicular to the brink on the plateau.

From Ls 172.6°, on the upper part of the megadune, in addition to the growing of the dark spot, dark streaks develop down the slope. These dark streaks are channelized. Comparing HiRiSE images very few days apart, the dark streaks are growing, spreading more and more down the slope and more channels. On the latest HiRiSE images, we observe that the large dark streaks are composed by darker and fresher individual streaks overlapping oldest and relatively lighter toned dark streaks. These albedo variations attest of refrosting processes (Table 1 and fig. 5). The observation also argues for short and repeated events more than a viscous and continuous spreading. The hypothesis is also supported by the observations at Ls 181° of single dark streak channels that are overlapping few meter high ripples. A minimum velocity is required to explain such a run-up. These dark spreading streaks that we will call “dark flows” in the rest of the paper, are the last features observed during the defrosting sequence. At Ls 217.7°, dust devil tracks (Table 1 and [10]) re-appear attesting of the complete frost retreat at this time in the area.

**Spectral analysis:** A CRISM observation data set is also available on the studied location of Russell Crater megadune at this period. The multiple spectra taken in winter and during the early spring present the characteristic signatures of the CO<sub>2</sub> frost, mixed with a small amount of water ice consistent with the

atmospheric composition. From Ls 242°, no more CO<sub>2</sub> or water frost is present in the spectra.

**Discussion:** We interpret the dark spots as dust depositions consecutive to small eruptions of dust through a frost slab as proposed by [5]. We propose that the dark spots are growing with successive eruptions and depositions as the season advances. The distribution of the dark spots is correlated to araneiform cones on the plateau and up-facing scarps on the slope. Even if these small scale topographies are observed in summer, we do not know if the defrosting features created these topographies or if the dark spots are located on the warmer north-facing scarps of these little topographies. At the end of the defrosting process and only at the steep submittal part of the megadune, dark flows develop. We interpret these features as avalanches of dust mixed with CO<sub>2</sub> and water vapour released under pressure. The same process creates dark spots of flat terrain but would trigger avalanches in case of steep slopes. This hypothesis is supported by the asymmetry of the dark flows. The flows develop only down the slope. The CO<sub>2</sub> and water vapour released with the dust at time of eruption is unstable as regard to the surface conditions and may play a role in the avalanche development and channelization.

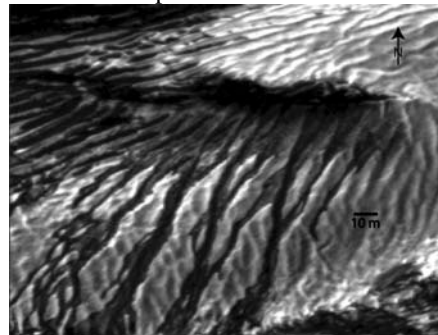


Figure 5: HiRiSE image taken at Ls 197.9°. Dust of dark flows spreading down the CO<sub>2</sub> frost on the Russell Crater megadune.

**Conclusion:** Dark spots and dark flows on steepest slopes mark the transitional period between the seasonal frost and its complete retreat. The channelized dark flows observed for the first time on the Russell Crater megadune, may be new flow mechanisms implying unstable vapour. We do not know yet the relationship between this newly highlighted flow mechanism and the underlying gullies.

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**References:** [1]: Bridges et al. (2001), *LPS XXXII*. [2]: Piqueux et al (2003), *JGR*. [3]: Piqueux and Christensen (2008), *JGR*. [4]: Kossacki et al. (2004), *Icarus*. [5]: Kieffer (2007), *JGR*. [6]: Mangold et al. (2003), *JGR*. [7]: Costard et al. (2002), *Science*. [8]: Reiss and Jaumann (2003), *GRL*. [10]: Verba et al. (2009), *LPS XXXX*.