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Geomorphological descriptions of seasonal processes on Mars: Linear Gullies and Recurrent Diffusing Flows on the intra-crater dunes fields

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Abstract

Linear Gullies are seasonal processes located on the intra-crater dunes fields. They are mainly located between 43°40'S and 52°2'S on dunes with a slight slope (~ 13°) facing SSW (mainly between 150°N and 260°N). The progression of Linear Gullies happens every years between the end of winter and the beginning of spring (between Ls 167.4° and Ls 216.6°), when the CO_2 finally defrosts on the dunes fields. Each year, a Recurrent Diffusing Flow spreads on Linear Gullies area from the end of winter (Ls 167.4°) to the beginning of autumn (Ls 21.9°), with a maximum activity between Ls 167.4° and Ls 192.3°. This flow takes an active part in the Linear Gullies creation/upkeep and could participate to the pits development. We highlight an albedo decrease of 42% during the pits activity. This important and very transient decreasing could be hardly explained by a dry movement only. We thus suggest that the Recurrent Diffusing Flows could be linked to the presence of a fluid or a liquid spreading in the shallow sub-surface. A link between CO_2 cycle and the Linear Gullies could be consistent with their development timing. Brines participation can't be excluded.

1. Introduction

Since 2006, HiRISE instrument provides recurring high resolution images of the Martian surface. Numerous seasonal processes have been observed but the origin of most of them is still unclear.
Linear Gullies (LG), present on intra-crater dunes fields, are long and narrow channels, more or less sinuous, with or without alcove and finishing by one or more circular depression(s) called "pit(s)" (Fig. 1D). No similar processes are observed on Earth and their presence on dunes is intriguing. LG on dunes fields were previously estimated to several million years [1][2].However, recent studies have suggested that these processes are still active today and are probably seasonal [3].

Several hypotheses have been suggested for the formation of LG on dunes fields: (i) Water-supported debris flow [1][4][2]. (ii) Defrosting processes, glacial-like creep and rolling sand-ice (CO_2 and H_2O) aggregates [5], (iii) CO_2 blocs sliding [3], (iv) CO_2 sublimation [6].
Dark features, called "Recurrent Diffusing Flows" (RDF) (Fig. 1BC) in this paper, are often associated with LG on dunes (Fig. 1). They never have been studied precily, just mentioned [3]. The origin of these low albedo flows is still unclear and raises several problems [3].
The aim of this study is to: (i) Determine the relation between RDF and LG; (i) Make a precise, systematic and complete study of RDF and LG on dunes fields which have not been studied. (iii) Discuss hypotheses of RDF and LG formation.

2. Methods

The morphological study was mainly done by the investigation of HiRISE images as well as HiRISE Digital Terrain Models (DTM). We made a global research on Mars dunes and we studied HiRISE images available where LG are situated. Successive HiRISE images provide us a morphological and temporal monitoring. 344 groups of LG have been identified and 5034 observations of LG were made.
HiRISE Digital Terrain Models (DTM) provides information about the altitude and the slopes of dunes in two studied craters (Kaiser and Proctor). Slopes have been measured on each active area of LG and on dunes which not displaying any activities. 225 topographic measurements were realized.
We also use HiRISE data to investigate the variations of relative albedo of the RDF. Thanks to IDL/ENVI, representative regions were sampled in the RED (570-830 nm) HiRISE RDR products.

3. Observations

3.1 Distribution

These active processes are mainly located in a restricted latitudinal interval ranging from 43°40S to 52°2S. We focus our study on 6 dunes fields located in: Rabe, Kaiser, Unnamed (47°18; 34°15'E E), Proctor, Matara, and Hellespontus Montes.

3.2 Orientations and slopes

We observed that these seasonal processes occur only on the South-facing slopes of the dunes (between 90°N to 270°N) and mainly on the South-Southwest facing slopes (between 150°N and 260°N).
For dunes with LG/RDF activity, we obtain slopes on the highest part of the dunes (where the gully formation starts) of about 20° and 13° for the complete dunes. The average slopes of the complete dune are lower of at least 4° to 6° on inactive south facing slope than on active south facing slope. For the North facing slopes, no significant slope differences exist with the south facing dunes where seasonal surface activity occurs.

3.3 Timing

Within the 6 intra-craters dunes fields studied in details, the progression of LG happens every year between the end of the winter and the early spring (between Ls 167.4° and Ls 216.6°). RDF are present at the end of winter (Ls 167.4°) up to early autumn (Ls 21.9°). It's mainly active between Ls 167.4° and Ls 192.3°.

3.5 Albedo

The average relative albedo between active diffusive flow and the surrounding unchanged dune is about 10%. In Matara crater, some very dark stain can be observed on HiRISE image (Fig. 1C). These spots are about 42 % darker than the surrounded virgin dune. They appear below a LG on a dune area which not display any changes in the previous images. On next image these dark stains are replaced by new pits. These very dark stains thus seem to be at the origin of the pits formation.

4. Summary and Conclusions

RDF take an active part in the creation or upkeep of LG. The pits formation could be linked to the presence of a RDF. These pits show a difference in albedo with the dune of 42%. This result is consistent with the presence of a fluid or a liquid. Brines appear to be a good candidate to interpret these phenomena. As LG activity begins each year during the thawing of CO_2, a link between LG and CO_2 is probable. The CO_2 is also a serious candidate.

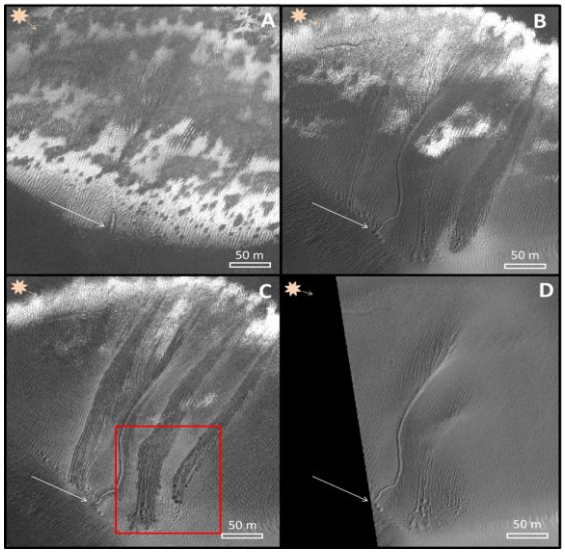

Figure 1: LG and RDF seasonal evolution. A) CO_2 frost on LG (HiRISE ESP_028616_1305); B) C) RDF spread (HiRISE ESP_028972_1300 and ESP_029038_1305); D) Creation of news LG (HiRISE ESP_029394_1300). The white arrow shows a reference point.

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