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Constraining the composition and geological history of the main types of terrains found in the equatorial belt of Titan

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1. Introduction

Over these twelve past years, near-IR imaging data from the Visual and Infrared Mapping Spectrometer (VIMS) onboard Cassini [1] gave significant hints on the spectroscopic and geological diversity of the terrains on Titan's surface. The composition of those terrains still remains unconfirmed yet. Nonetheless, by applying a newly updated radiative transfer model [2,3], we provide excellent constraints on the composition and structure for the main IR-units present in the equatorial regions (±40°N/S) [4]. Indeed, by combining this method of correction with a spectral mixing model for water ice and tholins, we determine the main chemical species present within IR-units and relate them to the observed geomorphology. We therefore propose a scenario that could lead to the current distribution of the IR-units.

2. Methods and Data

To unveil the surface, it is imperative to remove the atmospheric effects (gases absorption and haze scattering) in the VIMS data. A radiative transfer model [2,3] is therefore used to evaluate those effects and retrieve the surface albedo in our considered IR-units, meaning the equatorial IR-bright, -brown and -blue terrains [5,6]. Those terrains were described as being compositionally and structurally distinct [4]. For comparison purposes, we use a spectral mixing model for water ice and tholins to produce a vast spectral library of linear mixtures, by varying the grain sizes and mixing fraction of both components. Water ice and tholins are thought to be abundant on Titan's surface, regarding studies from and prior Cassini-Huygens mission. We first calculate synthetic albedos based on the formalism developed by Hapke [7], and then compare them with those of IR-units. Thus by coupling both radiative transfer and spectral mixing models, we retrieve all the possible water ice and tholins mixtures in our terrains. Additionally, SAR swaths derived from the RADAR instrument are used for geomorphological identification and mapping purposes. Indeed, they provide details about the surface properties of the terrains of interest, and hence contribute in our geological interpretation.

3. IR-units' Composition

The spectral mixing model provides new relevant informations about the content and grain sizes of both water ice and tholins of IR-units. Here, we assume that tholins synthetized in the laboratories by Khare [8] are similar to the aerosols photochemically produced in Titan's atmosphere. Considering our results, IR-bright terrains appear to be strongly dominated by tholins of a few tens of microns in diameter. Those small grained tholins must result from the atmospheric fallout. Haze particles are produced in the atmosphere and fall down with a size reaching up to ten microns near the surface [9]. IR-brown terrains, for their part, are predominantly made of larger grained tholins, with possible traces of water ice. Finally, IR-blue terrains are also made of large grained tholins but present a slight enrichment in water ice relative to the other considered terrains.

4. Geological Interpretation

IR-bright might be mainly covered by haze particles that form organic sediment coating the icebed. IR-blue terrains surrounding impact craters are thought to result from the deposition of excavated icebed material after the impact [10]. Whereas those found in IR-bright terrains may correspond to icebed outcrops in strongly degraded SAR-bright terrains, such as mountains and craters flanks (i.e. rough terrains). After being eroded by methane rainfalls and winds, debris (icebed and organic materials) are transported via channels flowing across the plains to the margins and ending into IR-blue terrains, as suggested in previous studies [11-13]. This deposition could lead to the formation of outwash plains with icy blocks and pebbles, like those seen at the Huygens landing site [14]. As most icy debris are washed out in IR-blue terrains, the neighboring IR-brown terrains, corresponding to dunes in SAR swaths [4,15], should be mainly made of organic sand. Indeed, in IR-brown dunes areas, tholins grains are large enough to form dunes by saltation [16]. Thus, this distribution is very similar to that of a transition from mountains to stony and sandy deserts in Earth (Fig. 1). IR-blue terrains would be referred to terrestrial stony deserts, where icy blocks and pebbles are laying after erosion and deposition processes from the IR-bright terrains. Conversely, IR-brown dunes areas would be the sandy deserts that are mainly covered by longitudinal dunes in the case of Titan.

5. Conclusion

Our spectral mixing model helps in better constraining the compositional and structural relations between the IR-units present in the Titan's equatorial belt. Since large grained tholins are present in both IR-brown dunes areas and IR-blue terrains, this could explain their dark albedo relative to the IR-bright terrains. Indeed, the latter terrains are only made of small grained tholins, although their size can change with subsequent processes such as compaction and sintering [17]. Plus, variations between the IR-brown and -blue terrains must be associated with the water ice content, which is higher in IR-blue terrains. Finally, we propose a series of events that could lead to the current distribution of IR-units seen through imaging data from Cassini's instruments.

References

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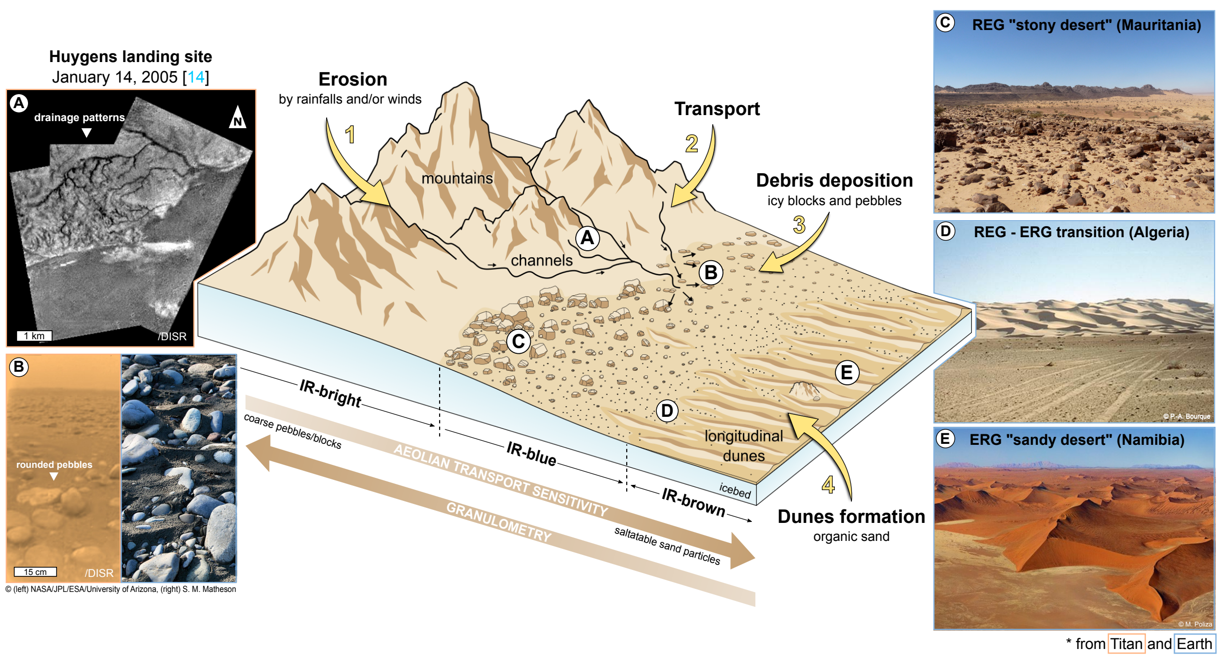

▲ **Figure 1** – Cartoon model illustrating a typical transition from the mountainous terrains to the dunes areas in Titan's equatorial regions, displaying similar landscapes than those observed in terrestrial deserts.