INTERPLAY BETWEEN GRAIN SINTERING AND TRANSPORT-INDUCED ABRASION IN CREATING SAND-SIZED SEDIMENTS ON TITAN.

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Introduction: Based on morphology, Titan's equatorial dunes appear to have been active over the recent past (10s–100s kyrs) [1], and ongoing formation is further suggested by the presence of compositionally distinct interdune areas [2–3] and surface-change observations indicative of episodic equatorial storms [4] and dust plumes [5] at equinox. Concurrently, the organic materials that are thought to make up dune sands [e.g., 2, 6–7] are mechanically weak [8]. This indicates that dune sand could be highly susceptible to comminution (fining through abrasion) during transport on Titan – an apparent paradox that has led to the hypothesis that Titan's dune sand is likely derived locally [8].

From saltation mechanics, we know that grain sizes within the dune field should be narrowly distributed, and on Titan, are predicted to be around 200–300 μm in diameter [e.g., 9–10]. Finer grains are more prone to stabilizing interparticle interactions (including triboelectric charging) [11] that raise the wind speed required to mobilize them; in turn, coarser grains are heavier and thus also harder to move. On Earth, large dune fields are typically supplied with pre-sorted sediments from fluvial or coastal sands or sandstones [e.g., 12–15]. This results from the ability of rivers and waves to sort sediments by grain size very effectively [e.g., 16]. The source of sand on Mars is unclear [e.g., 17–18] but sedimentary recycling is known to occur [19] and many ancient fluvial outcrops could supply pre-sorted sand-sized materials [e.g., 20–23]. Furthermore, basaltic grains are mechanically strong such that Martian winds themselves could have sorted sands over billion-year timescales. Several mechanisms have been proposed to generate sand on Titan, such as the erosion of lithified materials in the mid-latitudes, sintering of photochemical airfall particles, flocculation, and evaporitic precipitation [24], although all of these processes likely produce poorly sorted grain mixtures that require further sorting to produce expansive dune fields.

Here, we explore the hypothesis that sand-sized organic grains could result from an interplay between alternating episodes of sintering (when sediments are not transported) and abrasion (when active fluvial or eolian transport occurs).

Methods: We combine the sintering model of Herring et al. (1950) [25] with the abrasion model of Trower et al. (2017) [26] for the abrasion of individual particles during fluvial transport to explore the interplay between both processes under Titan-like conditions. The sintering scaling relationship of [25] predicts the time it takes for a cluster of particles to sinter into a larger particle. Conversely, the model of [26] provides estimates of abrasion rate of individual impacting particles during fluvial sediment transport, including both bedload and suspended load sediments. We adjusted the model of [26] for Titan-relevant conditions and materials and predict particle-size reduction rates of organic grains in streams of CH_4/N_2 mixtures [27]. Owing to Titan's thick atmosphere, windblown sand transport is expected to be more analogous to sand transport by water on Earth than by air on Earth and Mars, with minimal importance of grain splash [28]. We thus obtain estimates of eolian abrasion rates from fluvial abrasion rates through a scaling analysis and accounting for typical saltation trajectories on Titan as predicted by [28].

Results & Discussion: Our preliminary results suggest that intermittent grain sintering and abrasion during transport are able to produce grains with 300-μm equilibrium sizes within relevant timescales, i.e., over much shorter durations than the inferred age of Titan's dunes and than the lifetime of CH_4 in Titan's atmosphere. Our proposed mechanism may thus readily explain the formation and evolution of sand-sized sediments on Titan, offering a plausible process to supply and sustain Titan's equatorial dunes over geological timescales. Our results offer further quantitative insights into the frequency of sediment transport events and relative importance of fluvial vs. eolian transport, providing a unique opportunity to constrain Titan's recent climate history.

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