EPSC Abstracts
Vol. 6, EPSC-DPS2011-187-4, 2011
EPSC-DPS Joint Meeting 2011

Characterization of Ligeia Mare in the northern polar region of Titan

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Abstract

Enhanced images from the *Cassini-Huygens* mission reveal a large endorheic drainage basin in Titan's northeastern polar region encompassing Ligeia Mare and other northern lakes. Geologic features in surrounding areas are strikingly similar to Earth-like terrains where: 1) erosion processes are controlled by climate, latitude, topographic relief, and structural deformation; 2) stratified deposition or seasonal varves are predicted as seen on Earth and Mars; 3) structural deformation is apparent, although primarily visible as fractures and faults, and possible crustal shortening, thickening, uplift and downwarping; and 4) ephemeral fluvial and pluvial processes dominate and are clearly seasonal.

1. Introduction

Ligeia Mare, the second largest sea on Titan, occupies ~100,000 km^2 of the confined basin and is surrounded by rugged highlands (see Figure 1) [1,2]. In this study, we performed an extensive geologic characterization of Ligeia Mare and the mountains, valleys, and highlands that enclose the basin. Our researched focused on erosion processes which created the remnant mountain and valley systems and the potential sediment accumulation, the structural deformation which controls channels, river drainage systems, and the hydrogeology involved in the flooded and dry lakes, and crater alterations. In addition, we estimated the drainage flow capacity of key rivers and tributaries that flow into Ligeia Mare (Figure 2) and potential sediment volume accumulations into the basin through time.

2. Geologic processes

Comparisons between Earth and Titan's geologic and hydrologic features must be tempered with caution due to the vast differences in the internal structure, fluid and crust compositions, atmosphere, gravity, heat flux, and length of seasons. Erosion patterns reminiscent of both Earth and Mars, however, do provide a geologic analog for future planetary study.

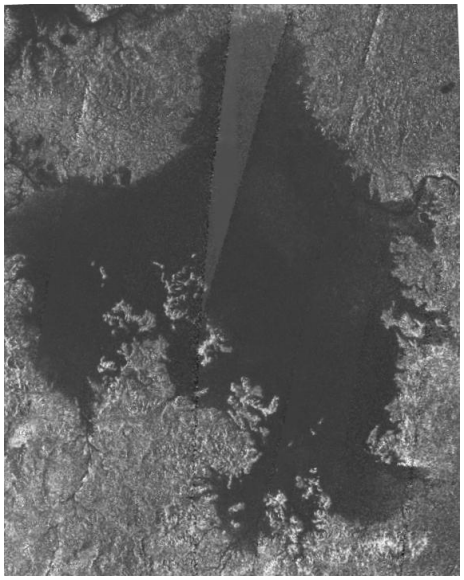

Figure 1: Ligeia Mare with diverse hydrologic surface processes unique to planetary bodies. Composite is from *Cassini* SAR swaths T25, T28, and T29 (22 Feb 2007, 10 April 2007, and 26 April 2007 respectively).

2.1 Erosion processes

The Ligeia Mare watershed is a major recharge source for the endorheic basin, fed by the numerous river systems that were examined in this study. Flow directions are predominately north-northwest with headwaters originating in the highlands. Minor flow contributions are afforded from internal drainage from the north, flowing south-southeast (Figures 2,3). The highlands also provide the primary sediment accumulation into the basin.

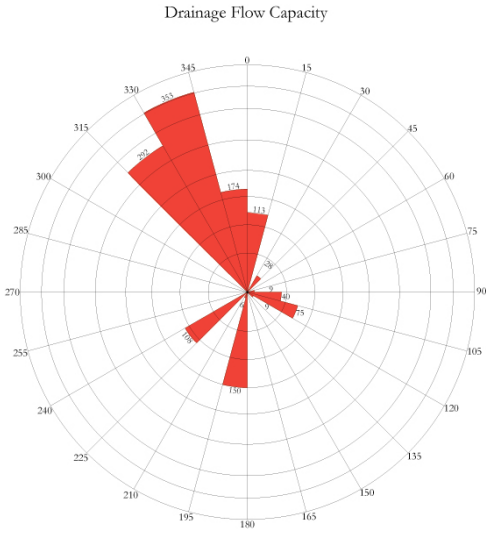

Figure 2: Rose diagram demonstrating that northwesterly flow direction dominates across the southern portions of the Ligeia Mare watershed; a southwesterly flow direction dominates in the North.

Evidence of erosion is not only limited to the carved drainage networks but can also be partially inferred from the lack of extensive cratering as seen on other saturnian satellites like Rhea and from the sediment that was evident in images provided by the *Huygens* probe.

2.2 Stratified deposits, varves, and sediment accumulations

Subaerial sedimentary layers are predicted in Ligeia Mare, as suggested by flow directions into the basin, presence of sediments on Titan, and by the erosion-produced valley forms. Higher-resolution RADAR images have provided estimates of the drainage capacity and areal coverage of rivers. Using key river area and RADAR altimetry estimates, sediment volumes accumulations through time have been predicted from these river valley systems (Table 1).

Table 1: Sediment volume

Direction of Flow* (as described)	Estimated Sediment Volume (10^9 m^3)	Area (km^2)
NE: 0-90	8.15	150
SE: 90-180	6.20	124
SW: 180-270	13.28	264
NW: 270-360	49.67	819

2.3 Structural deformation

Fracture or structural controlled drainage appears evident in portions of the Ligeia Mare basin (Figure 3). Flexure of Titan's crust and crustal shortening is predicted in an east-west direction based on Figure 2 flow directions and on the orientation of fractures and ridge and valley systems developed in Titan's icy crust. Subsidence from accumulation of sediments (Table 1) could also cause fracturing as a result of downwarping in the basin region. Additional evidence of structural controls includes the presence of the highland and lowland regions suggesting uplift or compression and crustal thickening.

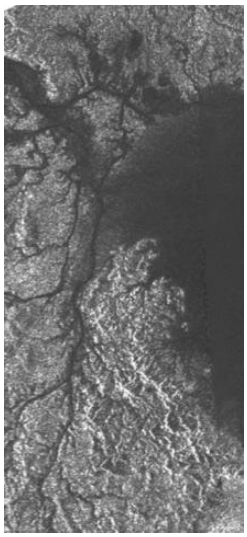

Figure 3: Deep channels can be seen within broad, filled or flooded fluvial valleys. Shallow lobate tributaries also suggest that low-lying tributaries are flooded; an ancient shoreline is absent.

2.4 Ephemeral fluvial processes

Fluvial and pluvial activity on Titan is strongly seasonal. Rain events have carved long, deep valleys; however, evidence of year-round flow or drainage from highlands to lowlands is lacking. It is probable that the water table intersects with the surface and contributes flow to many of the low-lying valleys and rivers. Although the present image resolution does not allow a definitive conclusion, ephemeral flow is suggested by the lack of fluid in the upland drainage valleys, the Titan weather patterns, and the dry river images from *Huygens* probe. Absence of ancient shorelines and extensive beach sediments, broad fluid-filled valleys, and high-angle shorelines suggest that Ligeia Mare was flooded during Titan's winter.

References

[1] Stiles, B.W., et al.: Determining Titan surface topography from Cassini SAR data, Icarus, Vol. 202, pp. 584-598, 2009.

[2] Stofan, E.R., et al.: The lakes of Titan, Nature, Vol. 445, pp. 61-64, 2006.