EPSC Abstracts
Vol. 13, EPSC-DPS2019-686-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Surface lineaments on Bennu

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Abstract

The first global mapping of lineaments on the asteroid (101955) Bennu shows a diverse set of features that include the unique long, longitudinal high-standing ridges, scarps, grooves, smaller troughs, and ridges. Here, we review these features, and we will assess their orientations to determine whether they are associated with surface features or possess a random distribution. Preliminary assessments are consistent with a rubble-pile asteroid that may contain large subsurface blocks or some other form of interior rigidity.

1. Introduction

The surfaces of asteroids display many types of linear features, or lineaments, and these provide information on the internal structure and history of the body [c.f., 1, 2]. On some asteroids, lineaments and grooves are orientated such that they can be associated with craters, providing evidence for internal stiffness. In a few instances, lineaments are remnants of mass slumps. and represent regions of stress readjustment. Long linear grooves are seen on other asteroids and are considered evidence for structural coherence.

Using images from the cameras [3] on board the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx [4]) spacecraft, we identified an initial set of lineaments on Bennu. The images are also used to build digital terrain models (DTMs) [5, 6] that provide topographic detail on the observed lineaments.

2. Lineament categorization

We map candidate linear features across the surface of Bennu using the Small Body Mapping Tool [7]. The lineaments are identified primarily from images, with topography then used to assess a confidence level to the candidate lineaments. The confidence criteria are useful because of the challenges involved in identifying lineaments on asteroids [1,2], and these challenges are exacerbated on small, ruble-pile, rock-strewn-surface asteroids such as Bennu.

We classify lineaments by their shape. Table 1 shows the classes that have been found on Bennu. The list includes a new type of lineament, long high-standing ridges, that has not previously been observed on asteroids [5]. We have not yet found narrow grooves or fractures, common on Eros but not observed on smaller asteroids such as (25143) Itokawa and Ryugu.

Table 1. Lineament classification

Type	Note
Large ridges	Structural ridges. Large, mostly wide and oriented north-south
Trough	Wide, with small length-to-width ratio
Ridge	Line of elevation higher than surroundings
Boulder trail	Line of rocks or boulders without other topographic expression
Scarp	Bank or slope; one-sided ridge or trough
Mass flow	Ledges associated with mass-flow edges (similar to scarps but with clear movement)
Combina-tion	Linear arrangement of at least two of these: rocks, topography, and albedo features

3. Results

The initial mapping contains nearly 100 lineaments at scales from 25 m to 300 m. 80% of these have a high confidence level, with future mapping expected to locate more features. Future mapping will also involve higher-resolution images with pixel scales of 1 to 2 cm, and we expect those searches to locate shorter features, particularly in the smoother areas, which may be younger [8]. Although the global distribution is nearly

uniform, the northern hemisphere contains slightly more lineaments, 60% to 40%. This may be due to the higher abundance of rocky surfaces in the southern hemisphere [9], a surface characteristic that can mask smaller features.

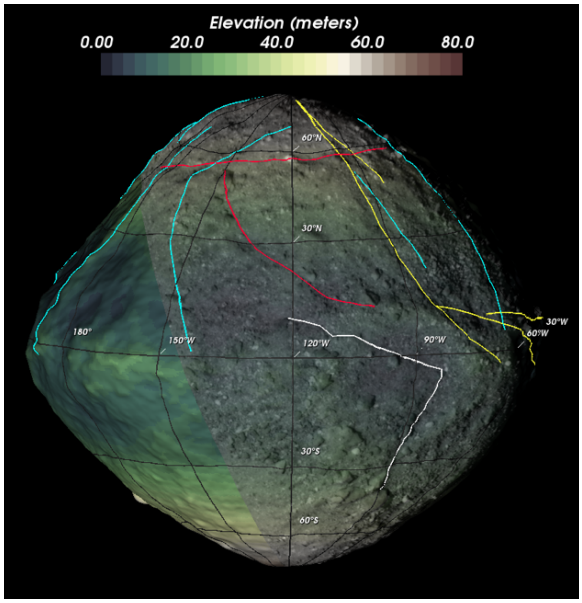

Fig. 1. An OCAMS image (20181127t064814s125_pol, from 27 November 2018) overlain on the Bennu shape with elevations and showing some of the longer, global-scale lineaments, including the northern-hemisphere ridges (cyan), and long troughs (yellow), scarps (red), and mass flow (white).

4. Preliminary assessment

Bennu's surface possesses a large suite of surface lineaments, which are much more prevalent than on other small asteroids such as Itokawa but appear to be similar in density to lineaments on (433) Eros. As on Eros, there are lineaments that span large portions of an entire hemisphere. More common are shallow troughs that cut across the surface of Bennu, and their predominantly east-west orientation and location in the mid-latitudes may be related to slope creep [10].

Our analyses include investigations of the global orientation of lineaments using approaches established in previous studies [e.g. 2]. We determine whether lineaments have preferred or random orientations, and we will apply this knowledge to constrain the internal attributes of Bennu.

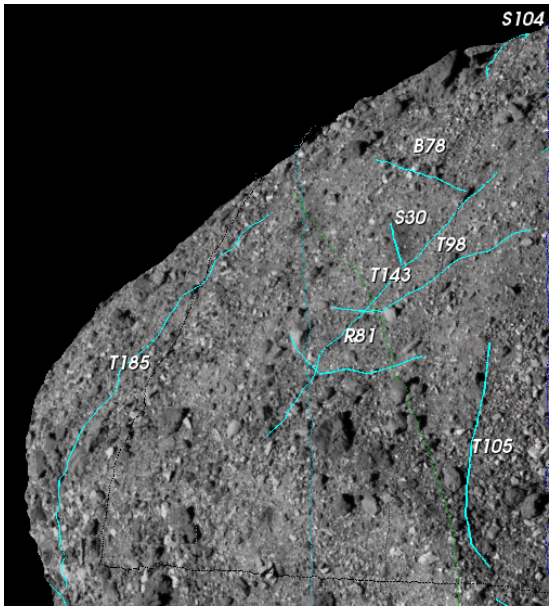

Fig. 2. Another OCAMS image (20181202t064126 s794_pol_iofl2pan_63811, from 2 December 2018) overlain on the Bennu shape with shorter examples of several types of lineaments including ridges, grooves, scarps, and boulder trails. This view, which includes the limb, covers the equator to 40 N with longitudes from 200 E to 260 E. The pixel scale is 32 cm/pixel. The dark ridge that starts in the lower-right corner and extends up and left is a crater rim, and these are not included in lineaments.

Acknowledgements

This material is based upon work supported by NASA under Contracts NNM10AA11C, NNG12FD66C, and NNG13FC02C issued through the New Frontiers Program. We also acknowledge the funding of the Canadian Space Agency to the Canadian institutions on this effort. M. Pajola was supported for this research by the Italian Space Agency (ASI) under the ASI-INAF agreement no. 2017-37-H.

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