Bennu's Global Geologic Map Reveals the Last Epoch of Resurfacing

*Erica R Jawin[1], Timothy J McCoy[1], Kevin John Walsh[2], Harold C Connolly[3], Ronald L Ballouz[4], Andrew Joseph Ryan[4], Maurizio Pajola[5], Olivier S Barnouin[6], Hannah H kaplan[7], Vicky E Hamilton [2], Josh P Emery[8], Daniella N Dellagiustina[4], Daniel Jay Scheeres[9], Michael G Daly[10], Carina A Bennett[4], Dathon R Golish[4], Mark Perry[6], R Terik Daly[6], E Beau Bierhaus[11], Michael C Nolan[4], Heather L Enos[4], Dante S Lauretta[4]

1. Smithsonian National Museum of Natural History, 2. Southwest Research Institute, 3. Rowan University, 4. University of Arizona, 5. INAF-Astronomical Observatory of Padova, 6. Johns Hopkins University Applied Physics Laboratory, 7. Goddard Space Flight Research Center, 8. Northern Arizona University, 9. University of Colorado, Boulder, 10. York University, 11. Lockheed Martin Space

Asteroid (101955) Bennu, the target of NASA’s OSIRIS-REx mission, is a rubble-pile asteroid with a surface dominated by boulders. We mapped its global geology to better understand its global characteristics and surface evolution. Our global geologic map of Bennu will facilitate future analyses of the asteroid and will contextualize the returned sample. We present the results of our analysis and the implications for the heterogeneous evolution of Bennu’s surface.

Bennu’s small size and rubble-pile nature have led to subdued topography with few distinct stratigraphic contacts. As such, our mapping methodology included first mapping major topographic features, geologic features, and surface texture variation, and then integrating these three products to define geologic units.

Bennu’s topographic features include two dominant structures: the equatorial bulge, between approximately 20°N and S latitude, and four longitudinal ridges (dorsa) and adjacent troughs (fossae) that span both hemispheres and the equator. The geologic features of Bennu that we mapped include craters >10 m in diameter, boulders >20 m in diameter, lineaments, particle ejection source regions, and morphologies associated with mass movement (e.g., imbricated or buried boulders). Craters are abundant on the equatorial bulge, which suggests that the bulge is an old feature. There are more large boulders in the southern hemisphere than the northern hemisphere or the equatorial region. Mass movement features appear to be spatially correlated with large boulders (many large boulders are partly buried) and are concentrated in fossae bound by lineaments. Bennu’s surface texture variation is controlled by the abundance of boulders. The surface can be divided into two dominant morphologies: (1) smooth or knobby with few boulders, and (2) rugged with abundant boulders.

To define geologic units, we integrated the maps of topographic features, geologic features, and surface texture variation, resulting in two geologic units we refer to as the “Smooth Unit” and the “Rugged Unit”. The Smooth Unit contains few large boulders or mass movement features and can occur on both dorsa and fossae. The mission’s sample collection site (Nightingale) and several particle ejection source regions are located in the Smooth Unit. The Rugged Unit contains 89% of the mapped large boulders and 85% of mass movement features, which are mostly located in fossae. The surface of Bennu can therefore be effectively characterized by only two geologic units that represent end-member characteristics. The two units are also distinct in other global maps of Bennu, including surface roughness, slopes, and certain spectral maps.

The relative concentration of mass movement features in the Rugged Unit, which likely formed in the last few hundred thousand years, suggests that resurfacing may have been more concentrated in the Rugged

Unit than the Smooth Unit. In addition, the distribution of the reddest (believed to be the youngest) craters on Bennu shows that the Rugged Unit contains fewer red craters, by a factor of ~3 per unit area relative to the Smooth Unit. This difference suggests the Rugged Unit may have experienced more resurfacing in the recent past (~500,000 years) relative to the Smooth Unit, which may have been less active.

The equatorial bulge, dorsa, and fossae appear to be the oldest features on Bennu due to their crater abundance. Both geologic units cross the equatorial bulge, suggesting that it has not greatly affected Bennu’s surface evolution. Large boulders are abundant in fossae and may be linked to their evolution, but some large boulders are also present on dorsa, which suggests that topography is not the only control on the boulder distribution. Surface modification in the form of impact cratering, mass movement, and particle ejection continued after the formation of the equatorial bulge, dorsa, and fossae, and over time, enhanced resurfacing in certain regions led to the formation of the Rugged Unit.

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