PINNACLES ON THE SURFACE OF THE 67P/CHURYUMOV-GERASIMENKO COMET NUCLEUS

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Keywords:
Pinnacles, comet, 67P, Churyumov-Gerasimenko, sublimation.

Introduction:
Pinnacles, which are local promontories of various shapes including spires with pointed tops, are known in several geologic environments on Earth [e.g., 1]. They mostly represent erosional remnants created by a loss of material surrounding spots of the more-erosion-resistant material. On comet nuclei they were first briefly described on the nucleus of comet Wild 2 [2] and then discussed along with other surface features by [3] and [4]. In the case of comet nuclei, the pinnacle-forming erosion is most probably sublimational loss of surface material to coma and further to open space. Such mechanism of pinnacle formation suggests that their maximum heights on the nucleus represent a measure of minimum depth of the surface erosion and their number and sizes provide information on degree of inhomogeneity of the nucleus material. On the nucleus of comet 67P/Churyumov-Gerasimenko, pinnacles (Figure 1) were first identified and described in its northern part by [5]. The current paper briefly discuss progress in studying of the 67P pinnacles achieved through the comprehensive analysis of the OSIRIS camera [6] images and high-resolution shape model SHAP7 [7] of the total nucleus surface.

Analysis of pinnacles on the surface of 67P
Inhomogeneity of a nucleus structure can be observed on different size levels. The highest level of inner inhomogeneity forms are regional ridges and depressions. These ridges have about a hundred meters in width and a few hundreds of meters length. Lower level of the material inhomogeneity can be observed in the surface structure of individual boulders and finer. In the current work, medium size of inhomogeneity (pinnacles) is considered (fig.1).

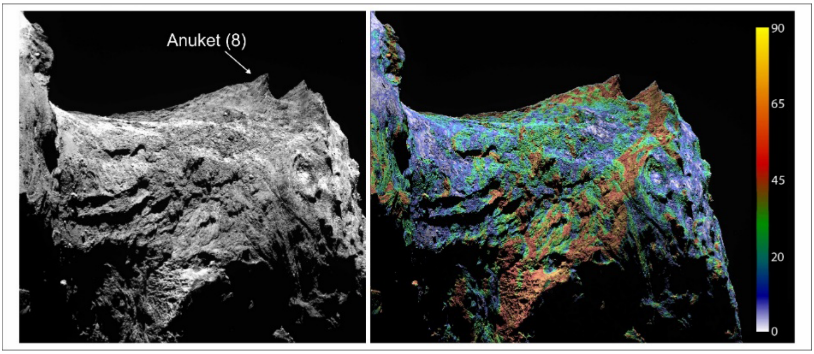

Fig. 1. Fragment of OSIRIS NAC image (left) and image with superposed color-coded values of the slope steepness (90°—vertical, 0° — horizontal) (right) with pinnacle Anuket-1 in the Anuket region (OSIRIS image N20160127T232331219ID30F41).

Using the mentioned high-resolution data, 166 pinnacles were identified on the surface of the nucleus. For these pinnacles, morphometric measurements were made — one of them is measuring of the interval in the base of pinnacle in smaller (d) and bigger (D) planimetric directions. The pinnacles were divided into two types: 1) those with rounded planimetric shape (d/D>0.7) and 2) local ridges (d/D ≤0.7). 54 rounded pinnacles with heights from 10 to 93 meters, with mean ratio of high (h) to smaller axes (d) ~0.4 and 112 ridges with heights from 9 to 137 meters with mean dependence of h/d ~0.6, were observed (fig.2).

In lateral views, pinnacles are typically asymmetric and have both gentle and steep slopes with the average slopes' angle to be ~60°. Pinnacles typically deviate from plumb line suggesting that their shapes almost do not controlled by gravitational forces. Inclination of pinnacles from plumb line is sufficiently high. Mean deviation from the plumb line is ~34° with standard deviation ±20° (±1σ) and statistical dispersion near 90°.

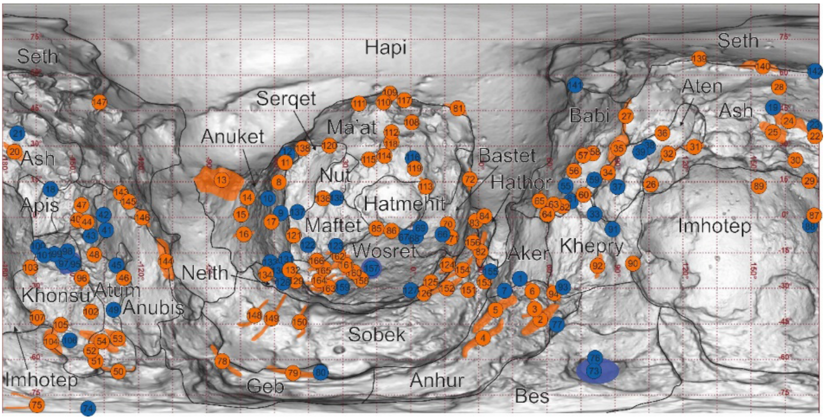

Fig. 2. Global map of the pinnacle distribution with separation them in the rounded ones (violet) and local ridges (orange).

Analysis of the OSIRIS images of the 67P nucleus shows that pinnacles represent outcrops of consolidated material with knobby texture, similar to consolidated material outside of pinnacles. In the south hemisphere of the 67P nucleus at the base of pinnacles' boulders were observed. Frequently, in the northern regions, pinnacles are usually surrounded by both smooth material and boulders. It is assumed that boulders around pinnacles are fragments of pinnacle material.

The observed heights of pinnacles vary on regional scale, which makes it possible to estimate a minimum thickness of lost material in different regions. The average height of 10 highest pinnacles were calculated for regions mainly with solid material (generally in south hemisphere) was found to be 80±8 m thickness and, for regions with smooth material, (generally in northern hemisphere) -98±13 m. So, estimates of minimum thickness of the erosionally lost material in the nucleus south and north are practically the same. Using a thickness of lost material, a time period needed for these processes can be calculated.

Acknowledgment:
KSS supported by DeutscherAkademischerAustauschdienst. Work of KSS and BAT was partly supported by grant 0137-2018-0038, Program I.28 by Presidium of Russian Academy of Sciences. Yu.S. thanksthe Deutsche Forschungsgemeinschaft (DFG) for support undergrant SK 264/2-1.

References

[1] Migon P. Rock and earth pinnacle and pillar. // Encyclopedia of Geomorphology Routledge, A.S. Goudie, ed., Taylor and Francis Group. 2004. 876.

[2] Brownlee D.E., Horz F., Newburn R.L., Zolensky M., Duxbury T.C., Sandford S., Sekanina Z., Tsou P., Hanner M.S., Clark B.C., Green S.F., Kissel J. Surface of young Jupiter family comet 81 P/wild 2: view from the Stardust spacecraft // Science.2004. 304 (5678), 1764–1769.

[3] Basilevsky A.T. and Keller H.U. 2006. Comet nuclei: morphology and implied processes of surface modification. Planet. Space Sci. 54 (8), 808–829.

[4] Cheng A.F., Lisse C.M., A'Hearn M., 2013. Surface geomorphology of Jupiter family comets: a geologic process perspective. Icarus 222, 808–817.

[5] Basilevsky A.T., Krasilnikov S.S., Mall U., Hviid S.F.S., Skorov Yu.V., Keller H.U. 2017. Pinnacles on the 67P comet nucleus: Evidence for large scale erosion and hierarchical agglomeration of the nucleus. Planet. Space Sci. 140. 80–85.

[6] Keller, H.U., Barbieri, C., Lamy, P., et al., 2007. OSIRIS – The Scientific Camera System Onboard Rosetta. Space Sci. Rev. 128, 433

[7] Preusker F., Scholten F. et al. 2017. The global meter-level shape model of comet 67P/ Churyumov-Gerasimenko. A&A 607, L1. 5.