EPSC Abstracts
Vol. 11, EPSC2017-777-1, 2017
European Planetary Science Congress 2017

Evidences of Shear Deformations on Comet 67P/Churyumov-Gerasimenko: probing the internal structure of the nucleus

C. Matonti (1), N. Attree (1), O. Groussin (1), L. Jorda (1), S. Viseur (2), D. Nebouy (1), A-T. Auger (1), P. Lamy (1) and the OSIRIS team
(1) Aix Marseille Univ, CNRS, LAM, Laboratoire d'Astrophysique de Marseille, Marseille, France (matonti.christophe@free.fr), (2) Aix-Marseille Université, GEREGE, IRD, CNRS, Planétologie et Terre interne, Marseille, France.

Abstract

In this work we emphasize the occurrence of structures that can be explained by shear deformation on the nucleus of comet 67P. For supporting our interpretations we digitalized about 3000 lineaments from 11 OSIRIS-NAC images. We first show that the majority of the lineaments correspond to fractures arranged in a network characteristic of shear deformation. These deformations are preferentially located in or near the neck regions. They have likely participated in the mechanical breakdown and the erosion of the nucleus. These results may have implication for deciphering the nucleus internal structural down to hundreds of meters and for inferring the nucleus material mechanical properties.

1. Introduction

Fractures and faults are widespread and pervasive in Earth crustal and sedimentary rocks. They result from deviatoric stresses applied on brittle materials. The Rosetta spacecraft orbited comet 67P for two years and acquired images of the nucleus surface with a spatial resolution down to 20 cm/pixel.

On 67P, most of the observed fractures have been interpreted as relating to current tensile stress at the lobes boundary or to thermal stress creating isotropic meter scale polygonal fracture networks. In this work, we provide new structural interpretations of the decameter to hectometer scale lineaments observed on the surface from the OSIRIS NAC Camera images.

2. Preliminary results

Our analysis mainly focused on the Southern hemisphere of the nucleus. It is characterized by less to no dust deposits compared to the Northern hemisphere, thus exhibiting more continuous outcrops of brittle material, prone to fracturing. Lineaments were digitalized as polylines in 2D using vectorial drawing software and then projected onto the 3D surface of 67P's shape model (Fig.1).

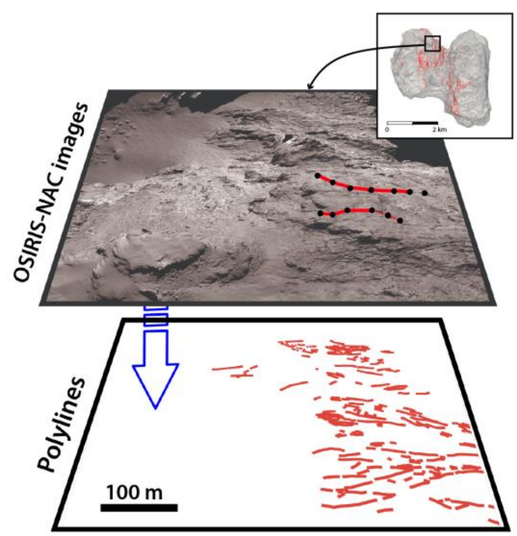

Figure 1: Example of OSIRIS-NAC image with digitalized fractures lineaments (in red).

We emphasized first that, close to the neck center, decameter to hectometer long lineaments are structural discontinuities. Indeed, they crosscut – therefore postdate– highly parallel lineaments that have been interpreted as layers (e.g. [1]). Moreover, they are arranged in patterns that nicely fit classical sheared zones structures known on Earth and telluric planets as duplexes blocks, anastomosing network or "*en-échelon*" array. These fractures are mainly composed of two sets showing two principal directions, forming an angle of about 30°, and oriented at low angle with respect to the neck middle plane. These two fracture sets directions are characteristic of Riedel P and R shear fractures [2] and are representative of mechanical parameters of the nucleus material, such as the internal friction angle. The fractures trace lengths follow a power law distribution with a slope coefficient comparable to the length distributions usually found on Earth [3].

Images of the neck borders or neck deepest point allowed the observation of these fractures along their vertical direction and to assess their occurrence to at least a depth equal to the maximum neck depth. It appears that individual fractures develop height up to 190 m and that fracture networks propagate at least down to 500 m below the surface (Fig. 2). The fracture aspect ratios (Length/Height) on the comet seem to fit of what exist on earth for unrestricted/non strata bounded fracture and faults (2 < L/H < 3).

Finally, in the northern hemisphere fractures seem to exhibit two principal directions, similar to those observed in the Southern hemisphere, although the fractures are less visible due to dust cover in the central neck area. The fact that all these structures are principally located near (less than 1 km from) the neck and are sub-parallel to it is consistent with an increased shear stress at the boundary between the two nucleus lobes (e.g. [4]). This could possibly be induced by torque/differential rotation forces.

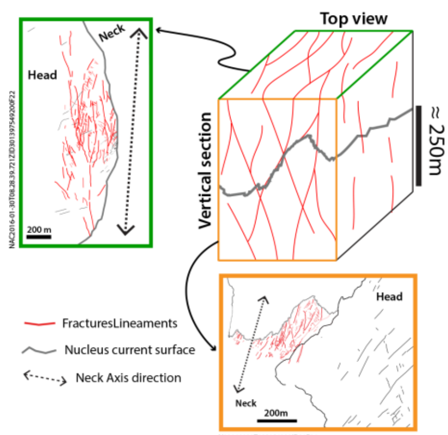

Figure 2: Conceptual scheme of the nucleus internal fractured structure.

3. Discussion on nucleus internal structure and evolution

The existence of the shear structures observed here in 3D implies the following interpretations about the nucleus structure. These are: (i) the nucleus interior is structured by decameter to hectometer fractures network; (ii) the nucleus material apparently remains sufficiently brittle below the surface to allow fracturing, even at depths of several 100's of meters; and (iii) although the nucleus material exhibits layering, it is mechanically homogenous enough for fractures to propagate freely at depth, without being stopped by mechanical boundaries.

At the Neck border, the cliff directions that follow the two main fracture directions indicate that these deformations very likely contributed to the mechanical breakdown and erosion of the nucleus and its current shape acquisition. This process might have amplified the initial neck topography through time, allowing significant erosion even in the regions exposed to less insolation, and explaining the neck asymmetry, i.e the depth difference between the Northern and Southern hemispheres.

In this work, we may thus underline the competition between two erosion processes; the local mechanical breakdown, and the broader erosion from sublimation.

Acknowledgements

OSIRIS was built by a consortium of the Max-Planck-Institut für Sonnensystemforschung, Göttingen, Germany; CISAS University of Padova, Italy; the Laboratoire d'Astrophysique de Marseille, France; the Instituto de Astrofísica de Andalucia, CSIC, Granada, Spain; the Research and Scientific Support Department of the ESA, Noordwijk, Netherlands; the Instituto Nacional de Técnica Aeroespacial, Madrid, Spain; the Universidad Politéchnica de Madrid, Spain; the Department of Physics and Astronomy of Uppsala University, Sweden; and the Institut für Datentechnik und Kommunikationsnetze der Technischen Universität Braunschweig, Germany. The support of the national funding agencies of Germany (DLR), France (CNES), Italy (ASI), Spain (MEC), Sweden (SNSB), and the ESA Technical Directorate is gratefully acknowledged. We thank the Rosetta Science Operations Centre and the Rosetta Mission Operations Centre for the successful rendezvous with comet 67P/Churyumov-Gerasimenko. N. Attree and D. Nebouy have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 686709.

References

[1] Penasa, L., Massironi, M., Ferrari, S., et al., MNRAS, submitted. [2] Riedel, W., Zentral blatt für Mineralogie: Geologie und Paläontologie, p. 354–368, 1929. [3] Cladouhos, T.T., and Marrett, R., Journal of Structural geology, v. 18, p 288–293, 1996. [4] Hirabayashi, M., Scheeres, D.J., Chesley, S.R., et al., Nature 534, p 352–355, 2016.