Surface Fractures on Comet 67P/Churyumov-Gerasimenko. M. R. El-Maarry[1], N. Thomas[1], S. Marchi[2], M. Massironi[3], and the OSIRIS team*. [1]Physikalisches Institut, Sidlerstr. 5, University of Bern, CH-3012 Bern, Switzerland (Mohamed.elmaarry@space.unibe.ch). [2]Southwest Research Institute, Boulder, Colorado 80302, USA [3]Dipartimento di Geoscienze, University of Padova, via G. Gradenigo 6, 35131 Padova , Italy. [3]Centro di Ateneo di Studi ed Attivitá Spaziali, University of Padova, Italy.

Introduction: The OSIRIS camera onboard the Rosetta spacecraft has acquired images of the comet 67P/Churyumov-Gerasimenko (67P/C-G)'s nucleus at spatial resolutions down to ~0.17 m/px [1, 2]. Geomorphological analysis of these images [3] reveals that most of the comet's surface is dominated by consolidated materials, which are often fractured. We attribute most of these fractures to thermal insolation weathering. However, some of the fractures may be related to rotational/orbital induced regional stresses or activity. The implications of the presence of such fractures needs to be taken into account when interpreting the current estimate of the comet's low bulk density and recent surface temperature measurements.

Fracture patterns and distribution: Fractures are ubiquitous on the surface of the comet (Fig. 1) and are almost exculsively associated with strongly-consolidated materials. The fractures are either isolated or in networks. With the exception of two particular features (a 500 m-long linear fracture, and another 200 m-long angular system), fractures may be regularly oriented or irregular and most of them form intersecting networks creating polygonal, conjugate or even orthorombic patterns. Polygons, when present, are ~1–5 meters wide although in places they appear to be embedded in larger irregular polygons. The fractures are observed generally on exposed surfaces, ridges, and scarps but are also seen on some of the large (20–30 m-wide) boulders.

Possible formation mechanism(s): Fractures in consolidated materials generally represent brittle deformation that develops in response to the buildup of deviatoric (non-hydrostatic) stress in a material. Stresses may develop in the form of compression, tension, or shear stresses (possibly in combination) causing the material to lose cohesion along its weakest plane(s). Since there are numerous ways to create fractures in geologic materials, an analysis of the fracture patterns and their distribution coupled with a physical model of the parameters affecting the surface of the comet may help in constraining the number of possible formation mechanisms, and the physical properties of the fractured surface.

Fracture networks: This is the most common fracture type observed on the surface. The fractures are generally small (submeter to meters in length) and resemble mode-I tensile fractures that show little or no shear [5]. Tensile fractures develop in materials through two common processes [6]: 1) loss of volatile material (e.g. desiccation), and 2) thermal contraction/expansion. The near vacuum conditions and the high fluctuations in temperature on diurnal and seasonal scales (from <80 °K in shadow to ~350 °K in illuminated regions near perihelion) suggest that thermal contraction/expansion or insolation weathering is the most likely candidate in forming these types of fractures. Nonetheless, the effect of sublimation-driven desiccation of an ice-rich material should be further investigated to assess its feasibility and extent. Furthermore, a large network of fractures dominating the Hathor region may have formed through different processes involving erosion or collisional processes [7].

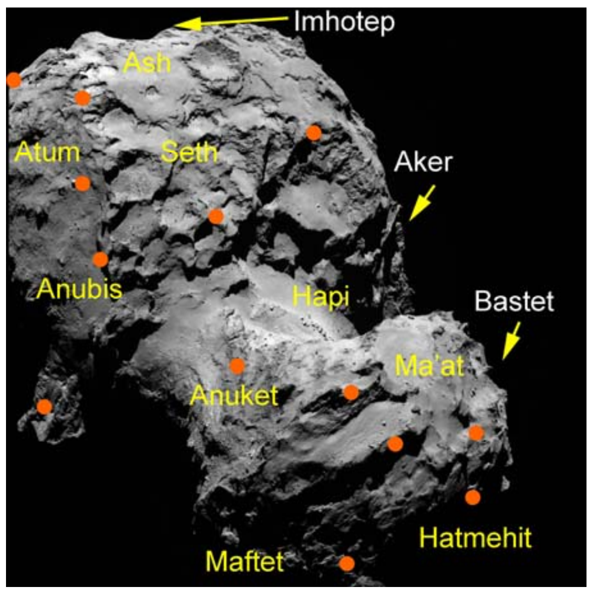

Fig. 1. OSIRIS Narrow Angle Camera (NAC) image showing a view of the comet taken on Aug 6, 2014, from a distance of ~125 km. Orange dots show the approximate location of some of the notable fractures observed on the surface. Labels refer to the names of the regions that have been defined on the surface. The yellow arrows show the approximate locations of the Aker, Bastet and Imhotep regions that are not viewable through this orientation. Refer to [4] for more information regarding the regions and their boundaries.

Other fracture systems: This class currently contains two features: 1) a 500 m-long fracture in the Anuket region, and 2) an angular fracture system in the Aker region. In the case of the Anuket feature, the morphology of the fracture and the lack of visible shear displacement suggests that it could be either tensile or compressive in nature. However, the length of the fracture and the fact that it does not display any additional fractures in its vicinity argues against common mode-1 processes that tend to create a widespread stress field that generates a network of cracks. Moreover, the location of the feature within the neck region between the comet's two major lobes suggests that the Anuket feature may possibly be caused by rotational- or orbital-induced stresses in that particular part of the comet or even by torques-inducing activity.

Similarly, the angular fracture system in Aker is an isolated feature in the context of the surrounding morphology. Moreover, it is the only feature that shows signs of out-of-plane shear displacement (mode III) in addition to mode I, which is suggestive of a highly complex yet localized stress field. Therefore, we conclude that this feature is also potentially a tectonic structure related to rotational/orbital induced regional stresses.

Conclusions & implications: Strongly-consolidated regions represent the most common region type on both lobes. Most of these regions show variable degrees of fracturing, which include irregular or regular systems as well as ,polygonal, conjugate, regularly intersecting or ortho-rhombic networks. The ubiquitous presence of fractured materials on the surface of the comet is of paramount significance for a body that displays a very low bulk density of ~0.5 kg/m^3 [2], and high surface temperatures suggestive of a dry, porous, and poorly thermal conductive surface [8]. The presence of fractures on the surface potentially formed by thermal insolation weathering may indicate considerable compositional and structural heterogeneity. Alternatively, it may indicate the presence of thin dusty coatings overlying materials of higher thermal inertia and ability to fracture. In addition, the Philae lander sent images prior to its hibernation showing a heavily fractured overhang (informally called perihelion cliff). Ongoing analysis of the Multi-purpose Sensors for Surface and Subsurface Science (MUPUS) penetrator data [9] or future Philae activities may further constrain some of the parameters and test our predictions of the consolidated materials' strength and its composition.

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Additional Information: *The OSIRIS team is H. Sierks, C. Barbieri, P.L. Lamy, R Rodrigo, H. Rickman, D. Koschny, H.U. Keller, and J. Agarwal, M.F. A'Hearn, F. Angrilli, A.-T. Auger, M.A. Barucci, J.-L. Bertaux, I. Bertini, S. Besse, D. Bodewits, G. Cremonese, V. Da Deppo, B. Davidsson, M. De Cecco, S. Debei, F. Ferri, S. Fornasier, M. Fulle, L. Giacomini, O. Groussin, P.J. Gutierrez, C. Güttler, S.F. Hviid, W.-H. Ip, L. Jorda, J. Knollenberg, J.-R. Kramm, E. Kührt, M. Küppers, F. La Forgia, L.M. Lara, M. Lazzarin, J.J. Lopez Moreno, S. Magrin. Marzari, M. Massironi, H. Michalik, S. Mottola, G. Naletto, M. Pajola, L. Sabau, J.-B. Vincent, K.-P. Wenzel.