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Icy structures and terrain in comet 67P/Churyumov–Gerasimenko

Max K Wallis (1,2), N Chandra Wickramasinghe (1,2,3)
(1) Buckingham Centre for Astrobiology, University of Buckingham, Buckingham MK18 1EG, UK, wallismk@cf.ac.uk
(2) Institute for the Study of Panspermia and Astroeconomics, Gifu, Japan
(3) University of Peradeniya, Peradeniya, Sri Lanka

Abstract

Rosetta's remarkable images show several indicators of an underlying icy morphology underlying the very black crust. Smooth, planar 'seas' and flat-bottomed craters are features seen also on comet Tempel-1. Surfaces peppered with mega-boulders are like comet Hartley-2. Parallel furrowed terrain appears as a new ice feature. Modelling indicates the 'seas' and crater lakes are refrozen bodies of water overlain with organic-rich debris (sublimation lag) of order 10 cm. The parallel furrows reflect ice fracturing from flexing of the asymmetric and spinning two-lobe body. The mega-boulders are hypothesised to arise from bolide impacts into ice. The outgassing evident at 3.3AU, with surface temperature peaks of 220-230K, implies loosely bound H_2O and/or unconsolidated organic mixtures. Increasing rates of gassing as Rosetta follows comet 67P around its 1.3 AU perihelion will hopefully reveal the activation of possible micro-organisms as well as the nature and prevalence of near-surface ices.

1. Introduction

The old comet model of frozen elementary gases, perhaps combined with H_2O in clathrates and condensed in the early solar system, has not been tenable since the 1986 missions to comet Halley. Comets evidently have high fractions of carbonaceous and mineral solids, and are well-processed bodies, with a geology that reflects their past history and particularly their orbits within the inner solar system. The distinct types of terrain are grouped by Thomas et al [1] into five categories: dust covered terrain, regions exhibiting brittle surface material with pits and circular structures, large-scale depressions, and smooth exposed surfaces. Such features are not consistent with the Whipple dirty snowball model of a comet, with layer by layer peeling off on perihelion passages when solar heating sets in. Rather, comets develop surface crusts that severely restrict gas escape. They also suffer meteorite impact 'weathering.

Comets have long been seen as low-density bodies, 67/P's density of 0.45 (450kg/m^3) constrains the bulk material to have high porosity with its dust component more carbonaceous than mineral.

Despite low density, comets are coherent bodies shown by long features and proud-standing mega-boulders. The 'spotty' appearance in Fig.1 comes from 20-50m boulders and their shadows.

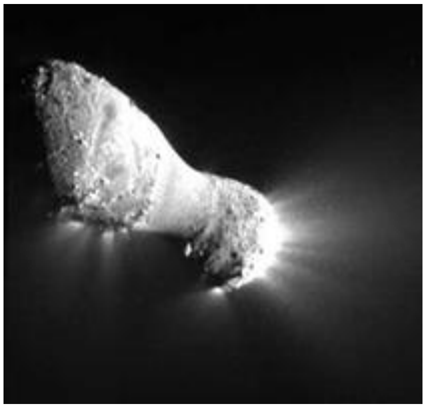

Figure 1 Comet ***Hartley-2*** *NASA News Release 4 Nov.2010:* size ~2km long with 0.4km wide 'neck'. Note the 400m furrow (left end) and a longer sinuous ravine to its left indicating large scale coherence. The neck area of the 2-lobed structure appears devoid of boulders and craters, a property shared with comet 67/P.

Flatbottomed craters and smooth sea-like areas on comet Tempel-1 [2] both indicate bodies of once-molten ice. The main 'tadpole' sea on comet Tempel-1 is a plateau, curving around the nucleus. As on Mars, any ice-covered water body develops sublimation lag as a protective coat. Icy-carbonaceous material outgasses and its residues consolidate under solar radiation into a crust, as discussed earlier in the comet context [3,4].

2. Key Rosetta Images

Comet 67P has a large smooth area like a 'sea' surrounded by an elevated rugged terrain (Fig. 2).

Exposed water would rapidly freeze over and develop a protective regolith, in a new impact crater. But this cometary sea must have been sub-surface from the start [4].

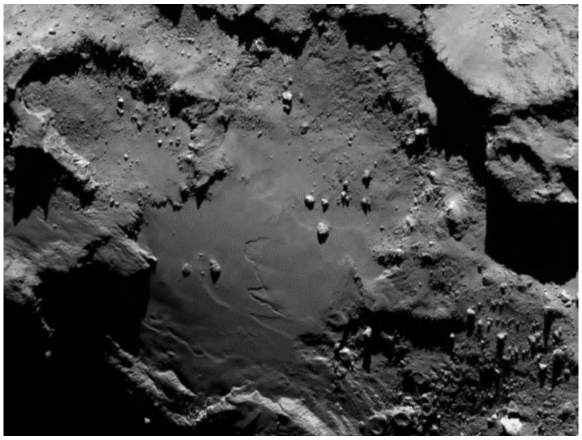

Figure 2 The large planar 600 x 800m Cheops 'sea' located in the Imothep region. It curves away into shadow approaching the terminator at bottom left. The plateau at the top right corner (semi-circular) is a few 100m higher than the sea and appears to have shed debris at the cliff-foot. The cluster of boulders beyond most debris suggests larger fragments roll further over a rigid surface (ESA/Rosetta/MPS for OSIRIS Team).

Fig. 3 shows striking terrain to the right of a largely smooth area, with rocky terrain on both sides. The dark furrows are aligned rather close (20°) to the solar direction and appear metres-deep, so may penetrate the protective crust well into underlying ice. Their position on the 'neck' suggests that the system of cracks and furrows above them are generated by flexing of the two lobes as the comet rotates – as also for comet Hartley-2 (Fig.1). The aligned furrows are reminiscent of cracks on Europa, generated by tidal flexing of that icy satellite, driving ice cracking, creep and convection. Though comet 67P lacks Europa's internal ocean, its furrows would still be sites for active outgassing and jet emissions.

3. Discussion

Rosetta allows us for the first time to watch ice-related changes that relate to comet activity and evolution. Quiescent outgassing such as seen from Comet 67P in July 2014 at 3.9 AU from the Sun is evidence of near-surface icy materials under a weathered crust. More distant episodes of H_2O outgassing from comets, like comet 67P in Nov 2007 at 4.3AU, may be triggered by bigger meteorite impacts; but the low probability of such an event and the observed tendency for repetitive outbursts (eg. of Hale-Bopp at 6.5AU) favour another cause [2]. Chemoautotrophic microorganisms released into the transient lakes laden with organics would rapidly metabolise and replicate, releasing heat that might increase the initial melt volume by a factor of 10-30. Methane or carbon dioxide produced by bacteria as metabolic products can then build up to be eventually released through fissures in the overlying ices or at the lake edges, in the furrows, cracks in ice (sea or craters), bottoms of crater pits, or at the feet of exposed rocks. We argue [2] for consideration of insolation-related biological activity close to the exposed surface of the comet, generally associated with icy features.

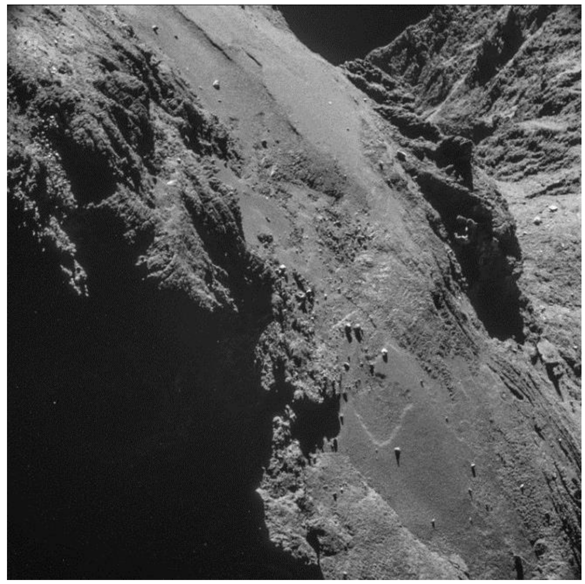

Figure 3 Terrain close to the 'neck' between the two comet lobes (see Fig. 5); the smaller lobe rises in the background. The parallel furrows with 5-10m spacing give the appearance of flexing or compression. (NAVCAM top 10 at 10 km, no. 9 ESA/Rosetta/ NAVCAM – CC BY-SA IGO 3.0; full image size 857m square).

References

[1] Thomas, N., Sierks, H., Babieri, C., et al, 2015. Science, 345(6220), aaa 0440-1

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[4] Wallis M.K., Wickramasinghe, N.C. 2011 *Icy Morphologies of Comet Tempel-1 imply past lake-habitats for Life*, ISSOL paper P7-21.