Dynamics of Landslides on Comet 67P/Churyumov–Gerasimenko: Ejecta from Imhotep Region and the Places of their Depositions. L. Czechowski[1] and K.J. Kossacki[2].
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Introduction: The phenomenon of landslide is a form of the gravity movement. Comets have weak gravity field, so it is believed that probability of landslides is very low. However observations from space missions to comets 9P/Tempe 1 and 67P/Churyumov – Gerasimenko revealed existence of these mass motion.

The causes of landslides are usually related to instabilities of slopes. It is often possible to indicate a few causes of the landslide but usually only one factor is considered to be a trigger. Causes are the factors responsible for making the slope unstable in respect to small disturbances. Some causes could also trigger landslides [1].

In the present paper we consider comet 67P/Churyumov–Gerasimenko. Investigation of its nucleus indicated existence of deposits typical for landslides.

Slopes of the surface:
On the small bodies of spherical shape the area with large slope (in respect to the local gravity) is rather limited. The different situation could be observed on highly asymmetric bodies [2].

The gravitational field of 67P/Churyumov–Gerasimenko comet is very complicated. There are several regions of different slopes of the physical surface in respect to the gravity. The most of the surface (~74%) has the slope in the range $0 < \alpha < 40^o$. The slope in the range $40^o < \alpha < 70^o$ is found on ~17% of the surface.

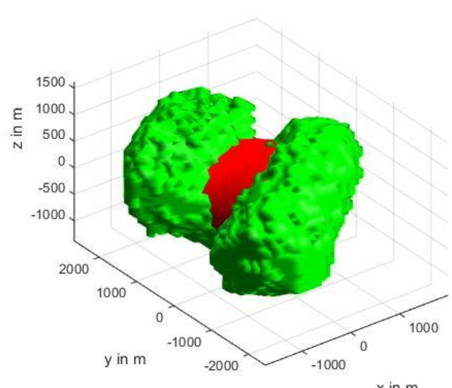

Fig. 1. Assumed mass distribution in the comet (green volume) and the surface of the constant value of the gravitational potential (red surface) for -0.45 $m^2 s^{-2}$. The green surface contains mass used for the modelling the gravity of the comet and it is close (but not identical) to the physical surface of the comet. Note highly non-spherical shapes of cometary surface of constant potential [2].

Mechanism of ejection

There are some similarity of slow ejecta (i.e., with velocity lower than escape velocity) and landslides. Both are forms of gravity movement. After landing ejecta can be still moving like a 'regular' landslide. On the other hand, the motion of landslides can include free falling without contact with the ground ('ballistic' landslides).

A simple model of processes leading to the formation of slow ejecta is assumed – Fig. 2. The phase transition heats a certain underground volume [3, 4]. It leads to vaporization of volatiles. Eventually a cavity is formed. If the pressure in the cavity exceeds some critical value then the crust could be crushed and its fragments will be ejected in space. Some parts of depression in Imhotep region (on the large lobe of the comet) could be a result of such processes.

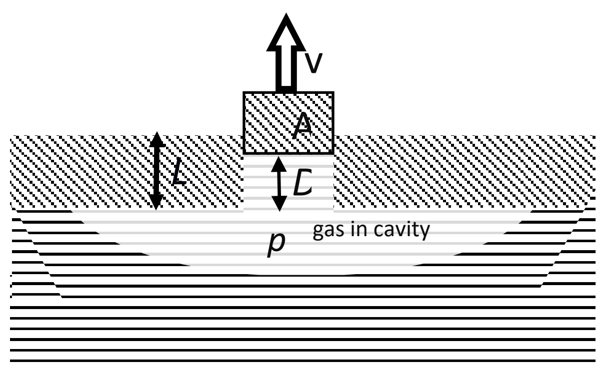

Fig. 2. A simple model of processes leading to the formation of slow ejecta.

Results and conclusions
In paper [5] slow ejecta from depression Hathemit (on the small lobe) are discussed. We found that ejecta with the velocity 0.3 m s^{-1} (or lower) land close to the starting point. Ejecta faster than 0.5 m s^{-1} have complex trajectories and could land far from the starting point. For the velocity in the range 0.5 – 0.6 m s^{-1} the most of the ejecta from depression Hatmehit falls in a wide belt on one comet's hemisphere. These results are confirmed by observations: southern and northern hemisphere surfaces are clearly different [6].
In the present research we discuss slow ejecta from the large lobe. Fig. 3 presents 11 trajectories of test parti-

cles ejected with velocity 0.6 m s^{-1} from different places on this lobe. Most of them eventully have landed also on the same lobe.

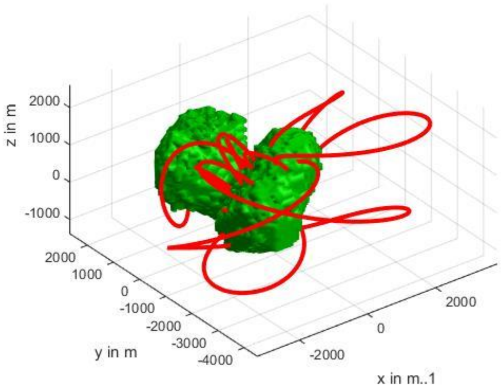

Fig. 3. Assumed mass distribution in the comet (green volume) and the trajectories of motion of the matter (red lines) ejected vertically (in respect to the physical surface) from 11 positions on the large lobe (right hand part on the figure) with the velocity 0.6 m s^{-1}. Note that the starting points of ejecta are on the upper surface of the lobe. Most of the landing points are on the upper surface on the large or small lobes. However, some trajectories reach also other sides of the comet.

We concentrated on ejecta from region of Imhoteb. The large morphological changes was observed in this region. These changes could give rise to slow ejecta. The trajectories of test particles ejected with the velocity 0.7 m s^{-1} from different parts of Imhoteb are given in Fig. 4. Note that ejecta are deposited mainly in two different regions, one in the large lobe and another in the small lobe – Fig. 4.

Ejecta landing on the highly inclined surface could trigger another landslide. It depend on angles of landing and the properties of the material of the comet. In [5] we indicate that majority ot the place od deposition are probably stable.

Determining the places of deposition of the material ejected from Imhoteb or Hatmelib will allow to determine the composition of the comet's interior under these regions without the need for drilling. This would be particularly important if the CEASAR mission will be launched. It will return a sample from the nucleus.

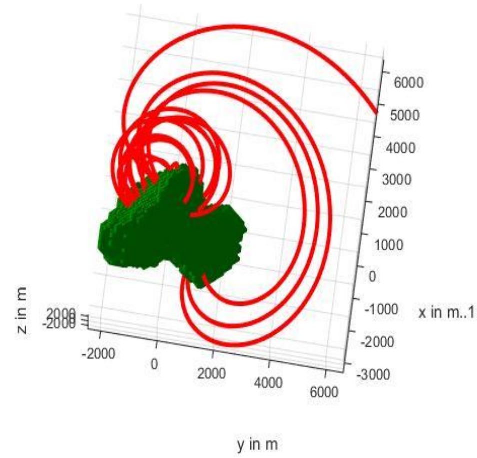

Fig. 4 The trajectories of motion of the matter ejected from Imhotep (on the large lobe) with the velocity 0.7 m s^{-1}. Note that deposition of ejecta are concentrated mainly in two regions.

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