**DEPTHS OF THE LUNAR COPERNICAN CRATERS.** E. A. Feoktistova[1] and S. I. Ipatov[2], [1]Sternberg Astronomical Institute of M.V. Lomonosov Moscow State University, Moscow, Russia, hrulis@yandex.ru, [2]V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry of Russian Academy of Sciences, Moscow, Russia, siipatov@hotmail.com,

**Introduction:** Morphometry of lunar craters has been the subject of a number of studies [1-3]. Pike [1-2] analyzed Copernican and Eratosthenian craters (with an age smaller than 3.2 Ga) based on the Apollo photogrammetric data. He concluded that large mare craters do not differ systematically from large highland craters and that fresh complex craters on the lunar highlands are deeper (at the same diameters) than those on the maria. Considering craters of the Copernican and Eratosthenes periods of formation, Kalynn et al. [3] selected those craters that seemed to them to be more "fresh". According to their results, the *h/D* value for "fresh" complex craters (for the Copernican and Eratosthenes formation periods) located on the highlands of the Moon is greater than that for craters located on the maria. Kalynn et al. [3] suggested that the difference in *h/D* for highland and mare craters is related with various properties of the underlying surface.

We studied the dependence of the ratio *h/D* of the depth of the crater to its diameter on the diameter for the lunar craters whose age does not exceed 1.1 billion years. The ages and diameters of the lunar craters were taken from [4] and [5]. We used altitude profiles constructed using the LOLA altimeter on the LRO probe (https://ode.rsl.wustl.edu/moon/) to estimate the depth *h* of the Copernican craters taken from [5] and [4].

The database of lunar craters from [5] contains 66 craters with a diameter greater than 10 km and with an age of ≤ 1.1 billion years. Information on the age of the craters in the catalog is based on data from [6,7].

Mazrouei et al. [4] identified 111 Copernican craters on the Moon with 10≤ *D* <100 km between 80°N and 80°S, with ejecta blankets that have rock abundance values high enough to distinguish them from the background regolith.

Analyzing the data for Copernican craters we obtained the formulas for approximation of the dependences of the ratio *h/D* of the depth of a crater to its diameter on the diameter for craters on the highlands and the maria. To do this we used linear and power approximations. For these approximations (regression) we used the software from https://planetcalc.ru/5992/.

We sorted the craters as "simple" and "complex" craters depending on the values of *h/D*. We did not analyze the form of craters, but we formally separated craters into two groups based only on the ratio of *h/D*.

According to our results for all highland Copernican craters considered in [5] $h/D \geq 0.16$ at $D \leq 15$ km, $h/D=0.125$ at $D=16$ km, and $h/D \leq 0.122$ at $D \geq 22.1$ km (there are no craters with $16<D<22$ km). We have $h/D \geq 0.15$ at $D \leq 18$ km (Fig.1) if we exclude the point ($D=16$, $h/D=0.069$), and $h/D \leq 0.103$ at $D \geq 19$ km for all highland Copernican craters considered in [4]. It was found that complex highland Copernican craters have diameters $D \geq 19$ km, though both "simple" and "complex" craters can be at $16 \leq D \leq 18$ km.

We have $h/D>0.15$ for mare craters with $D<14$ km (Fig.1). As Pike [2], we suppose that mare craters with $D<15$ km are simple craters. Mare craters with $15<D<18$ km are in an agreement with approximation curves for both simple and complex craters, but mare craters with $D>18$ km are in a better agreement with the curve for complex craters. Mare craters with $15<D<18$ km are in an agreement with the approximation for both simple and complex craters. Mare craters with $D>18$ km are in a better agreement with the approximation for complex craters.

The transition from simple to complex craters in [2] took place at $D=15$ km for the maria and at $D=21$ km for the highlands, and at $15<D<21$ km simple highland craters were deeper than complex mare craters for the same diameter. Our estimates of the transition diameters between simple and complex craters differ a little from the estimates by Pike in [2]. For example, we consider complex highland craters with $D \geq 19$ km, not with $D \geq 21$ km, as Pike in [2].

The power approximation of *h/D* is described by the expression:

$$h/D=k \cdot D^{\alpha},$$

where $k$ and $\alpha$ are some coefficients. We obtained $k=0.196$ and $\alpha=-0.01$ for simple craters from [1]. For complex craters from [2] we obtained $k=1.028$ and $\alpha=-0.683$ for highland craters and $k=0.819$ and $\alpha=-0.659$ for mare craters. According to Kalynn et al. [3] $k=1.558$ and $\alpha=-0.746$ for highland craters and $k=0.870$ and $\alpha=-0.648$ for mare craters. The difference in $k$ and $\alpha$ between the values from [1,2] and [3] was greater for highland craters than for mare craters. Our values of $k$ and $|\alpha|$ were smaller (by about a factor of 2) for highland craters than those for mare craters:

$$h=0.271D^{0.653}, \quad h/D=0.271D^{-0.347}$$

for highland craters and

$$h=1.213D^{0.211}, \quad h/D=1.213D^{-0.789}$$

for mare craters. We also used the linear approximation in the form $h/D=b \cdot D+c$, where $b$ and $c$ are some coefficients.

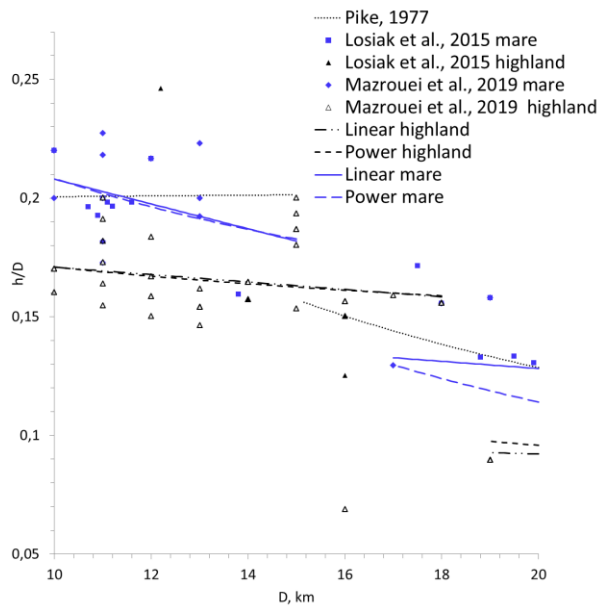


Fig. 1. Dependence of the *h/D* ratio of a crater depth to its diameter for Copernican craters with a diameter *D*≤19 km for the highlands and for the maria.

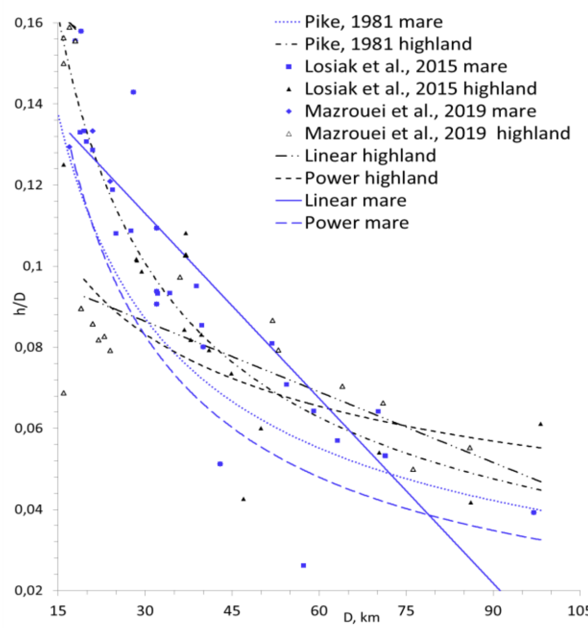


Fig. 2. Dependence of the *h/D* ratio of a crater depth to its diameter for Copernican craters with a diameter *D*≥20 km for the highlands and for the maria.

For linear approximations we have $h/D=-0.00105D+0.1335$ for the highland craters, and $h/D=-0.00159D+0.1598$ for the mare craters. The lines cross each other at *D*=48.7 km. It was found that mare simple craters are a little deeper than highland simple craters for the same diameter. The values of *h/D* for our approximation curves are mainly smaller than the values of the curve by Pike [1] at *D*<15 km. Only for mare craters at *D*<11 km, our line is a little higher that the curve in [1].

**Conclusions:** We found that the values of the ratio *h/D* of the depth of the crater to its diameter for craters from [4] and [5] for different diameters are either higher or lower than for the dependences obtained in [1,2]. In most cases, they are located below the curve obtained in [3] for craters on the highlands, i.e., they are better consistent with data from [1] and [2] than with data from [3].

According to our results, at *D*<18 km there are mainly “simple’ craters, but some “complex” craters can have diameters *D*≥16 km.

It was found that mare craters with *D*<14 km have *h*>0.15*D*. As Pike [2] we suppose that mare craters with *D*<15 km are simple craters. Mare craters with 15<*D*<18 km are in an agreement with both approximation curves for simple and complex craters. Depths of mare craters with *D*>18 km are in a better agreement with the approximation curve of *h/D* vs. *D* for complex craters than for simple craters.

Mare craters are deeper than highland craters at the same diameter for *D*<40-50 km and highland craters are deeper for *D*>50 км. The values of *h/D* for our approximation curves are mainly smaller than the values of the curve by Pike in [1] at *D*<15 km. Only for mare craters at *D*<11 km our line is a little higher that the curve by Pike in [1]. For our power approximations, the values of *h/D* obtained for complex craters are greater than those obtained by Pike in [1] at *D*>53 km for highland craters, and at *D*<19 km for mare craters.

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**References:** [1] Pike R.J. (1977) In *Impact and Explosion Cratering: Planetary and Terrestrial Implications*, 489–509. [2] Pike R.J. (1981) *LPS XII, 845-847*.[3] Kalynn J. et al. (2013) *GRL, 40,* 38- 42. [4] Mazrouei et al. (2019) *Science, 363*, 253-255. [5] Losiak et al. (2015) https://www.lpi.usra.edu/lunar/surface/Lunar_Impact_Crater_Database_v08Sep2015.xls (2015). [6] Wilhelms D.E. (1987) *The geologic history of the Moon*: U.S. Geological Survey Professional Paper. 1348, 302 p. [7] Wilhelms D.E. and Byrne C.J. (2009) http://www.imageagain.com/Strata/StratigraphyCraters.2.0.htm.