PHOBOS: IMPACT CRATER MORPHOLOGY AND REGOLITH STRUCTURE FROM MARS-EXPRESS IMAGES. C. Lorenz[1], A. Basilevsky[1], T. Shingareva[1], J. Oberst[2,3], M. Waehlisch[3], K. Willner[2], G. Noekum[3], [1]Vernadsky Institute of geochemistry, 119991, Kosygin St., 19, Moscow, Russia, c-lorenz@yandex.ru; [2]Technical University, Berlin, Germany; [3]Institute of planetology, DLR, Berlin, Germany; [4]Free University, Berlin.

Introduction: The surface of Phobos is heavily cratered and deposition of crater ejecta played a decisive role in formation of its regolith and determined heterogeneity of the surface spectral properties in the Vis and NIR diapasons [1, 2]. Monitoring craters having a complex internal structure in the domain of small craters is an important tool for determination of vertical heterogeneity of the near-surface materials. In particular, their shape is a function of the ratio of the crater diameter and the thickness of the loose surface layer - regolith [3]. Some craters of complex structure in the range of diameters of 100 - 500 m were observed on Phobos earlier [1, 4]. Analysis of images, obtained by High Resolution Stereo camera on board Mars-Express, allowed us to identify and study more craters of the complex internal morphology having diameters from 60 to 3500 m on the entire surface of Phobos and evaluate local variations of the regolith thickness.

Data and results: The images obtained in the period up to March 2011 cover the entire surface of Phobos with a resolution of 4 to 70 m/pixel. Most of the observed craters have a simple a bowl-shaped and some times conical morphology. Three types of craters with a complex morphology were observed (in order of increasing of their number): central-mound craters; flat-bottomed craters; concentric craters. On total 57 such craters have been identified. Images of 34 craters have been taken at the most favorable conditions. On them complex morphology of each of these craters is seen most clearly in several images taken from the same orbit or different orbits and they were selected for further detailed analysis. For the simplified estimates of the dimensions of the crater structure it was decided that the usual crater have a form of a segment of sphere surface and its depth / diameter is about 0.2, that agrees with observations and analysis of digital elevation models [4, 5]. The shape of complex craters was determined by eye in the images. The thickness of the regolith surface layer, excavated by complex craters was estimated on the basis of considerations [3] and elementary geometric considerations, without involvement of the data of the solar illumination angle and imaging geometry. So, under consideration are two craters with central mounds (Fig.1A), seven flat-bottomed (Fig. 1B) and 25 concentric ones (Fig.1C).

The two *central-mound craters* have diameters (D) 350 and 2000 m. Gentle sloped hills (the mounds) are observed on their floors. Foots of these hills meet the relatively steep inner crater slopes and probably the mounds completely cover the crater primarily flat floors. Estimates of the thickness of the surface layer (Hs) for these craters are 60 and 350 m, respectively.

Seven *Flat-bottomed craters* have diameters ranging from 70 to 2380 m. Landslides, which are asymmetric opposite to the central mounds, complicate the flat floors of some these craters. On a flat floor of the largest of these craters dark isometric spot is observed, which can be interpreted as an impact melt. Assessment of Hs for flat-floor craters ranges from 10 to 420 m. The diameter to Hs ratio varies from 5.6 to 8.1. Two flat-floor craters (one with D =70 and another one with D = 250 m) are located inside grooves; their Hs are 10 and 50 m respectively. The first of these craters is located on the central axis of the groove, the width of which (~ 280 m), is almost equal to the crater diameter. The second crater is at the flat floor of the degraded groove whose width is 260 m.

Concentric craters are characterized by the presence of concentric scarp on their inner slope. Diameters of most of the craters are in the range of 60 - 600 m, except the crater Reldresal (3500 m). Their Hs varies from 10 to 380 m depending on the diameter. The diameter to Hs ratio in concentric craters is in the range of 7.3 - 11.1.

Discussion: A relation Hs to D in studied craters of different morphology is somewhat smaller than that established by [3] experimentally, most probably, due of modification processes. Concentric craters are most distributed than other observed complex craters; the Hs values, estimated in all complex craters are in a range of 1/6-1/12 of D. The less or more thick upper layers were not recognized. This phenomenon may be due to the fact that with increasing relative height of the strength scarp in the wall of the crater above the floor it becomes less prominent [3], and the scarps located close to the upper edge of the crater rims are not observed. Landslide materials and/or later regolith covers can hide the scarps close to the crater floor.

Regolith layers observed in one crater are not seen in the neighboring craters of the same size and, most likely, the deduced regolith layers are declined and do not have a regional distribution. These layers can be individual ejecta blankets lithified in varying degrees. Earlier it was shown that Phobos regolith processed to considerable depths [1], so it is more likely that even in the kilometer-sized craters with complex morphology we also see layers of debris of different lithification degree derived from some preexisting craters, but not the rocky basement

Flat-bottomed craters, formed inside grooves, show that under a layer of loose material with thickness of a few tens of meters, spread on the bottom of the groove, there is a more coherent basement. At the floor of the mentioned crater with the diameter 250 m probably the true floor of the groove is exposed (Fig. 2), the depth of which thus could be 50 m. Assessment of the Hs in the mentioned crater with diameter 70 m is ~10 m, which seems to be insufficient in the case if debris, filling the groove with width ~260 m, only sliced from the inner walls. More likely, that groove is covered by a thin regional blanket – of ejecta or reaccreted material.

Theoretical models show that if Phobos contained water ice during its formation, it is possible that frozen material is still remained at depths 270-740 m at the equator, and at tens of meters in higher latitudes [6]. Our earlier observations of several fresh craters with fluidized-like ejecta [7] may serve an indication of ice existence in the subsurface layers of Phobos rocks. So, one of the reasons of the concentric craters formation may be exposure of ice-contained rocks during an impact with following formation of a secondary bowl at the crater floor as a result of ice sublimation. However, observed intensive impact reworking of Phobos up to a deep ~1 km [1] remains not too many possibilities for the occurrence of ice close to present surface of Phobos.

Conclusion: Observations on Phobos of craters with complex morphology showed that in addition to the areas covered by vertically relatively homogeneous regolith, processed to sufficient depth, there are areas where the regolith could consist of interlayering lenses of debris with different strength properties, which thickness varies in the range of hundreds meters. The most likely that these layers can be a stratified crater ejecta deposits consolidated in varying degrees at the expense of thermal metamorphism. Multiple events of lateral transportation and mixing of materials from different depths, and different degree of lithification can be one of the factors responsible for the observed color differences of the Phobos surface.

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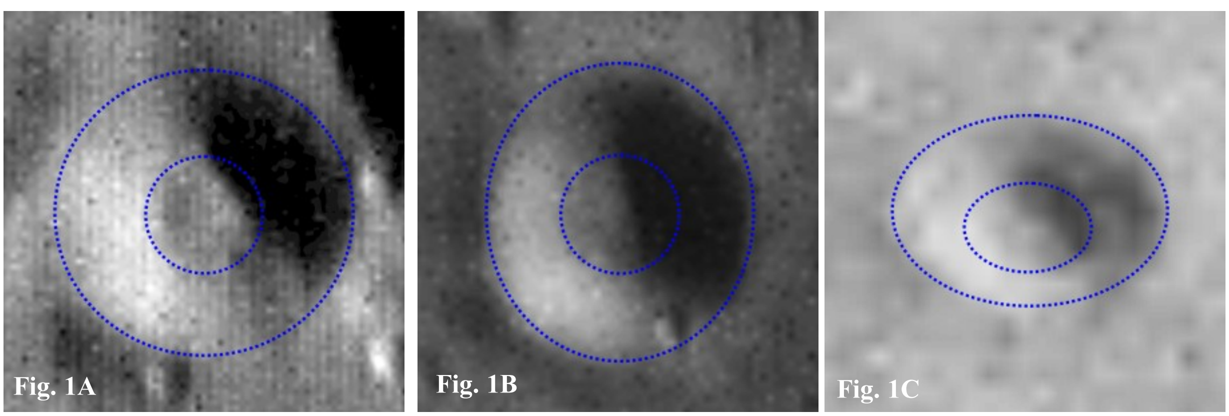

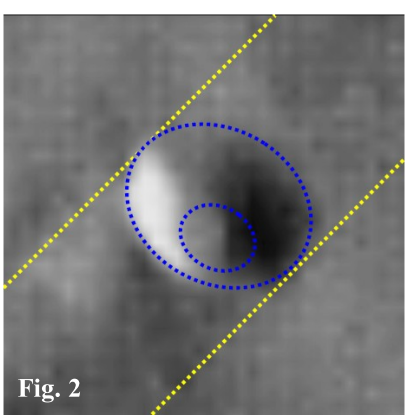

Fig. 1. Craters of complex morphology: A) central-mound (D~350 m); B) flat-bottomed (D~480 m); C) concentric crater (D~65 m). Outer circles indicate the crater rims, inner ones – the margins of crater walls and bottoms (A, B) and the edge of concentric scarp (C).

Fig. 2. Flat-bottomed crater of 280 m in diameter, disposed in a groove. The crater exposes a consolidated layer of debris on a deep ~50 m under a weak regolith, filling the groove. Circles indicate a crater rim and bottom; yellow lines show the edges of groove.