EJECTA DEPOSITS OF COPERNICUS CRATER. Y. G. Shkuratov[1], L. V. Rohachova[1], V. V. Korokhin[1], V. G. Kaydash[1], Y. I. Velikodsky[1,2], D. G. Stankevich[1], and G. Videen[3], [1]Institute of Astronomy, Kharkiv V.N. Karazin National University, 35 Sumskaya St, Kharkiv, 61022, Ukraine, dslpp@astron.kharkov.ua, [2]National Aviation University, Cosmonaut Komarov Ave. 1, Kiev 03680, Ukraine, [3]Space Science Institute, 4750 Walnut St. Suite 205, Boulder CO 80301, USA.

Introduction: The crater Copernicus, 96 km in size, is located on the lunar near side. It is a bright, young crater, ~779 m.y. [1]. Figure 1a shows a portion of the Clementine mosaics at λ = 750 nm. The crater is optically heterogeneous. There is an amazing feature in the left upper quadrant of the crater, which is very well detected in color-ratio (red/blue) images. Figure 1b shows a color-ratio A(750 nm)/A(415 nm) image obtained with the Clementine mosaics. This very red feature was discovered many years ago by Whitaker [2]. Its unusual color results from a spectrum characterized by strong ultraviolet absorption. There are several very red formations [3] attributed to pre-mare material with unusual composition. A portion of such red spots could be surface manifestations of pre-mare basalts [e.g., 3,4]. Examples of red spots are the formation Helmet and Riffaeus Montes. These formations, perhaps, are rhyolite extrusions.

A question arises: do the Copernicus red spot and the red extrusions have commonalities besides their color characteristics?

Objective and source data: We study the crater Copernicus and its ejecta blanket near the rim, primarily using optical data, to confirm the hypothesis that the Copernicus red spot is a residual of a rhyolite extrusion that was involved in the impact formation process of the crater. The rhyolite material could be partially melted, crushed, and ejected to the crater vicinity. The described asymmetry (Fig. 1b) of the red ejecta can be related to the eccentricity, relative to the extrusion, of the impact and a to tilt trajectory of the impactor.

Clementine mosaics [e.g., 5] and LROC WAC data are used for the analysis as source data. We also apply Lucey's [6] and LSCC (Lunar Sample Characterization Consortium) [7] approaches to assess chemical/mineral composition of the studied area.

Results and discussion: First of all, it should be noted that there is no topography asymmetry in the ejecta blanket distribution related to the red spot. The map of slopes calculated from the topography data set GLD100 [8] clearly show this (Fig. 2a). Moreover, we note the complexity of the impact event, drawing attention to a symmetric slight red ring located immediately out of the crater rim (Fig. 1b). We do not find the red asymmetry in the distribution of the parameter OMAT (optical maturity degree) calculated by the corresponding Lucey equation [6] (see Fig. 2b). We obtain essentially the same results when we consider the optical roughness of the region. This parameter was calculated from LROC WAC images. We use all available images to find the phase function for each point of the scene:

$$A(\alpha, i, e) = A_n \exp(-\mu\alpha)\, D(\alpha, i, e), \qquad (1)$$

where A is the apparent albedo (radiance factor), A_n is the diffuse albedo (the normal albedo, if the opposition effect is absent), μ is the parameter of phase-curve slope, and D is Akimov's disk function [9]. For each point of the lunar surface, the parameter μ is calculated using the least-square method for several tens of source WAC images for wavelength 415 nm. Resulting map are presented in Fig. 3.

The results shown in Figs. 2b and 3 demonstrate that the red asymmetry probably was not formed during the evolution of the lunar surface, but arised in the process of the crater formation.

Using Lucey's approach [6] and the Clementine mosaics at λ = 415, 750 and 950 nm, we calculate the FeO and TiO_2 abundance presented in Fig. 4a,b. As one can see, low concentrations of ferrum oxide and titanium dioxide are observed on the crater floor and in the north portion of the ejecta blanket. The values are more typical for highlands than for maria, especially within the red anomaly.

To estimate mineral composition, we exploit the technique developed in [7]. We here use Eq. (1) in [7] to calculate the total pyroxene abundance and ratio of Pigeonite/Fe-pyroxene with lunar sample (LSCC) and Clementine data. Figure 5a,b shows the distribution of the mentioned characteristics over the scene. These images, especially, the ratio Pigeonite/Fe-pyroxene correlate with the color distribution (Fig. 1b). Pigeonite contains more Mg than Fe-pyroxene. Thus, the red spot contains an excess of Mg. Like in the case of FeO and TiO_2 distributions, the same mineral features are observed on the crater floor and in the north portion of the ejecta blanket.

The complex crater Copernicus is a typical example that demonstrates high occurrence of impact melt deposits. The impact events responsible for forming large craters may have generated melt that coated not only the crater floor, but the surroundings located within ~1 crater radius from the rim. The ejecta deposits of Copernicus contain a portion of melt and crushed bedrock material that may have composition and optical properties distinct from distant surroundings. This heterogeneity is due to the composition complexity of the target area. Perhaps, the red spot seen in Figs. 1b, 4a,b, and 5a,b and areas in-and-around the crater contain a large amount of melt and crushed rocks that are formed by including, in particular, target rhyolite material. In spite of evidence for efficient mixing of impact melt in complex craters, Dhingra et al. [10] document the mineral heterogeneity in impact melt deposits on a scale of tens of kilometers in the Copernicus floor and northern wall that are spectrally distinct from melt in its immediate vicinity. Our data in Figs. 4a,b and 5a,b are consistent with the conclusion [10].

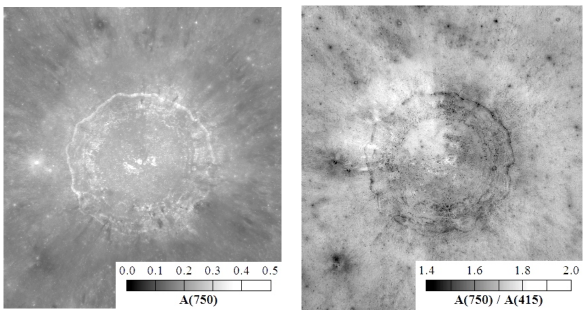

Figure 1 a,b. Copernicus crater. Albedo (750 nm) map (a) and color ratio (750/415 nm) image (b).

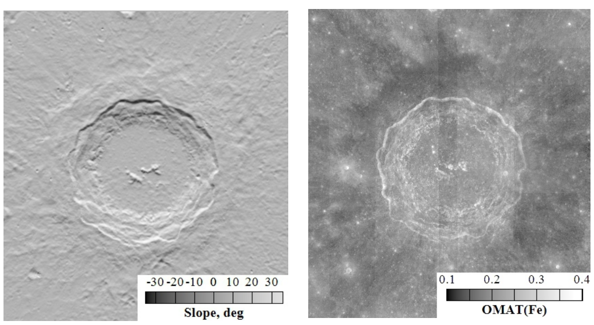

Figure 2 a,b. Map of slopes produced with GLD100 [8] data (a) and OMAT [6] distribution (b).

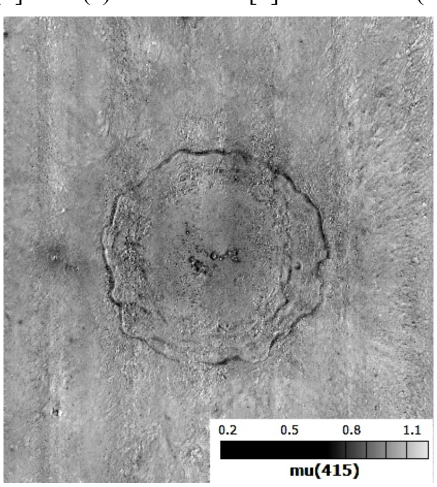

Figure 3. The distribution of the phase-curve slope μ(415 nm) (see Eq. 1) for the region under study. Bright color corresponds to higher slope.

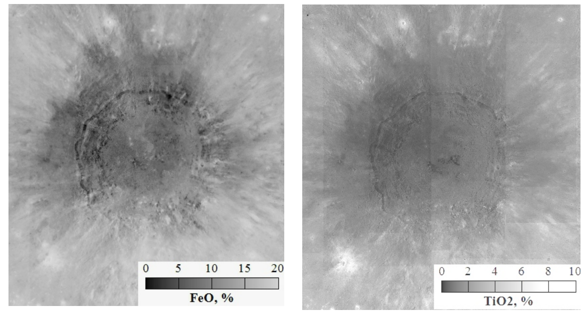

Figure 4 a,b. The distribution of the FeO (a) and $Ti0_2$ (b) abundance for the region under study.

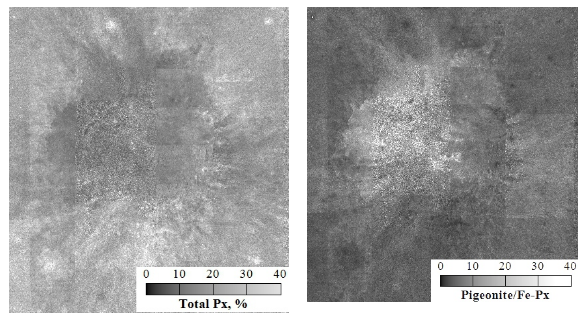

Figure 5a,b. The distribution of the total pyroxene (a) and the ratio Fe-pyroxene/Pigeonite (b) abundance for the region under study.

Conclusion: We demonstrate that the red asymmetry probably was not formed during the evolution of the lunar surface. We find several confirmations of the hypothesis that the Copernicus red spot can be a residual of a rhyolite extrusion that was involved in the impact process, in particular, in target material melting. The rhyolite body could be partially melted, crushed, and ejected to the crater north-western vicinity. The described asymmetry of the ejecta can be related to the eccentricity, relative to the extrusion, of the impact and a tilt trajectory of the impactor.

References: [1] Hiesinger H., et al. (2012) *JGR, 117*, E00H10, doi:10.1029/2011JE003935. [2] Whitaker E. (1969) *NASA SP-201*, 38-39. [3] Malin M. (1974) *Earth Planet. Sci. Lett. 21,* 331-341. [4] Hawke B., et al. (2002) *LPS, #1598*. [5] McEwen A. and Robinson M. (1997) *Adv. Space Res. 19*, 1523-1533. [6] Lucey et al. (1998) *JGR, 103,* 3701–3708. [7] Pieters C., et al. (2006) *Icarus 184,* 83-101. [8] Scholten et al. (2012) *JGR, 1117*, doi: 10.1029/2011JE003926. [9] Korokhin et al. (2014) *PSS*, *92,* 65–76. [10] Dhingra D., et al. (2013) *GRL, 40,* 1043–1048.