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Introduction: The Moon reveals a negative polarization branch that was first observed by Lyot (1929) [1]. Figure 1 shows the main parameters of this branch using data of laboratory measurements of a lunar sample [2]. These parameters are $|P_{\text{min}}| \approx 1\%$, $\alpha_{\text{inv}} \approx 23^\circ$, and $h$ is the curve slope at the inversion. These polarimetric parameters have only barely been studied over a few selected areas.

Until now, only Earth-based lunar polarization observations have been carried out [e.g., 3-6]. The Korea Pathfinder Lunar Orbiter (KPLO), scheduled for launch in July 2022 as the first phase of the Korean Lunar Exploration Program, will orbit the Moon at an altitude of 100 ± 30 km during its nominal mission of up to 12 months. It will map the polarization characteristics of the Moon using the Wide-Angle Polarimetric Camera (PolCam). These polarimetric mappings can be reduced to map the polarimetric parameters at large phase angles, in addition to the characteristics $\alpha_{\text{inv}}, |P_{\text{min}}|$, and $h$ [6,7].

Observations and data processing: In preparation of the KPLO data, we perform mapping of the polarimetric parameters using data of photometric and polarimetric observations of the Moon, which were conducted 28 August - 25 October 2010 in the Maidanak Observatory (Uzbekistan) using the 60-cm Zeiss-600 telescope. For the lunar observations we used a CMOS camera with a 22.2x14.8 mm array (5184x3456 pixels) with light filters R(0.61 µm), G(0.52 µm), and B(0.48 µm). We here used data obtained at 0.52 µm. The camera has a rotated polarizer. A series of observations of a site consists of 8-20 full rotations of the polarizer. In each rotation, 8 positions of polarization axis are used for measurements.

We study here a North-West portion of the lunar nearside, which comprise the Reiner-gamma formation (Fig. 2a), using 6 series of measurements at the following phase angles: 10.3° (23 October), 22.5° (24 October), 31.4° (25 October), 39.0° (26 September), 46.0° (28 August), 57.6° (29 August) with formal spatial resolution 0.16" per pixel and real resolution near 0.7".

The primary image processing includes accounting for dark current, separation of filters, and flat field. The latter was calculated from observations of the evening or morning sky. Instrumental polarization parameters have been assessed using the star-polarimetric standards and measuring the Arago point, the point in the sky near sunset or sunrise, wherein the degree of polarization is close to zero.

We made a convolution of images with a Gaussian core with $\sigma = 3$ in order to decrease the noise contribution. Next, all images were coregistered with the rubber-sheet algorithm [8] and averaged for each position polarizer axis, in each filter. Then, the relative intensity $I$ and polarization degree $P$, and the orientation of the polarization plane were calculated. The last parameter was small, with a distribution resembling noise.

Figure 2. (a) A map of the equigonal albedo at $\alpha=22.5^\circ$; (b) A map of the parameter $|P_{\text{min}}|$ calculated with polarimetric measurements at 6 phase angles.

The next step was coordinate identification. For this, the LRO WAC mosaic was transformed into a
projection, at which our observations were carried out. Using WAC images we identified about 20 locations in our images that could be used to determine coregistration parameters. The observed images could then be transformed into a standard projection. We use here an orthographic projection with zero parameters of libration.

We carried out a photometric calibration using the Akimov disk function as discussed in detail in [9]. Finally, we used the least-square method and carried out an approximation of the phase dependences of polarization degree in each image pixel with a polynomial of third degree with zero at \( a = 0 \):

\[
P(a) = a \alpha^3 + b \alpha^2 + c \alpha.
\]

This allows computation of the parameters \( \alpha_{\text{inv}} \), \( |P_{\text{min}}| \), and \( h \).

\[\begin{align*}
\text{Figure 3. Maps of the parameters } & \alpha_{\text{inv}} \text{ and } h, \text{ respectively, calculated with polarimetric measurements at 6 phase angles.} \\
\end{align*}\]

Results and Discussion: Figure 2a shows a map of the equigonal albedo (see definition in [9]) at \( \alpha = 22.5^\circ \). The Reiner-Gamma formation is located near the center of the region. A map of the parameter \( |P_{\text{min}}| \) calculated with polarimetric measurements at 6 phase angles is displayed in Fig. 2b. This map does not reveal a clear boundary between mare and highland regions. Several areas with intermediate albedo are more apparent using this parameter, including the Reiner-Gamma formation. This may indicate the presence of dust component of the lunar regolith [5].

We show maps of the parameters \( \alpha_{\text{inv}} \) and \( h \) in Figs. 3a,b. As could be anticipated, the Reiner-Gamma formation has not only relatively high \( |P_{\text{min}}| \), but also a larger inversion angle than the surrounding region. There are a few places where the inversion angle is relative small (dark spots in Fig. 3a), which appear independent of albedo. We may suggest that these areas consist of regolith having larger concentrations of coarse particles. This feature is characteristic of immature regions. A map of the parameter \( h \) shown in Fig. 3b inversely correlates with the albedo map of Fig. 2a, as one may expect. Indeed, this correlation is the basis of using the polarimetric method of albedo determination of asteroids [10]. Another unusual feature seen in Fig. 3b is that the Reiner Gamma formation here is almost not visible.

Conclusion: We present initial results of mapping the polarimetric parameters \( P_{\text{min}} \), \( \alpha_{\text{inv}} \) and \( h \) for the North-West portion of the lunar nearside. The Reiner-Gamma formation is clearly seen in the parameters \( P_{\text{min}} \) and \( \alpha_{\text{inv}} \), but not in \( h \). There are several areas with relative low values of \( \alpha_{\text{inv}} \) that may indicate coarser, and perhaps younger, regolith.