GLOBAL ALBEDO VARIATIONS ON THE MOON: CLEMENTINE 750-NM OBSERVATIONS;

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Overview. Clementine has provided the first global digital color and albedo observations of the Moon. We have processed about 50,000 frames acquired through the 750-nm filter at reduced scale (1 km/pixel). This provides the best albedo map produced to date for most of the far side. No 1-km or larger region of the far side has a very low albedo characteristic of titanium-rich dark mantle deposits or mature mare soils. The brightest extensive region corresponds to the region of highest elevations on the Moon, just north of the South Pole/Aitken basin. This region is bright at least in part due to a concentration of immature soils on bright ejecta blankets of Copernican craters, but an anorthosite-rich composition is also likely. Several far side basins are characterized by intermediate albedos in their interiors, perhaps due to cryptomaria or Mg-suite highland materials. Many new Copernican craters can be identified, and their albedos provide crude age estimates. The brightest crater seen on the Moon at this scale is Giordano Bruno, which must be one of the most recent large craters (> 20 km diameter) on the Moon, probably less than 50 million years old.

Data Processing

The USGS is in the process of producing a global base map of the Moon at 100 m/pixel with a potential geodetic accuracy approaching the pixel resolution [1]. This base map will be used to coregister other Clementine datasets and will also be useful for future lunar exploration. Most of the images for this base map will be 750-nm images from the UVVIS imaging system; thus, as part of this effort, we will also produce a 750-nm albedo map. In order to test processing procedures, find the best image coverage, and test the uncontrolled geodetic accuracy of the images, we have produced a preliminary mosaic at a scale of 1 km/pixel. Pre-flight calibration was used, which does not fully correct a brightness gradient across each frame, and this results in a north-south striping pattern. Use of in-flight flat-field corrections will eliminate this artifact. Short- and long-exposure image pairs were merged to maximize the signal-to-noise ratio. We applied a photometric normalization consisting of the Lommel-Seeliger function, a phase-angle correction derived from telescopic observations and the Lommel-Seeliger prediction, and, at phase angles less than 5°, we utilized the Clementine-derived function [2-3]. Previous attempts to apply Hapke photometric-function normalizations to the Moon [4-5] have produced poor results at high photometric latitudes, unless zero is used for the single-scattering albedo and macroscopic roughness parameters, which reduces the limb-darkening function to Lommel-Seeliger. Several gaps (~25 km wide), where 750-nm data are missing or have not been processed, were filled by interpolation. There is no 750-nm coverage over some of these gaps (covering less than 2% of the surface) due to a problem with the filter wheel; these gaps will be covered by 900-nm images for the final base map (but left blank for the 750-nm albedo map). Brightnesses are dominated by the albedos of surface soils everywhere except near the poles, where the brightness variations are primarily due to topographic shading. Several versions and projections of the mosaic have been produced. Lambertian equal-area projections at 1 km/pixel are centered on four views: near side, far side, northern hemisphere, and southern hemisphere. A color-coded version of the albedo map is in simple cylindrical map projection at 2 km/pixel resolution. Darkest to brightest surface areas are portrayed by the color sequence purple-turquoise-green-yellow-red.

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Interpretations

Albedo provides first-order information on surface compositions and/or soil maturity. The darkest materials (dark purple on color-coded image) correspond to titanium-rich mare lavas and dark-mantle deposits. These dark patches, which cover about 2% of the Moon's surface, are present only on the near side. Other dark areas (turquoise) also correspond to maria. Extensive greenish and yellowish areas correspond to highland terrains. Light turquoise/dark green areas often correspond to mixed mare-highland soils, such as much of the giant South-Pole Aitken basin (south-central far side). About ten Nectarian or Pre-Nectarian impact basins on the far side correspond to intermediate-albedo (light turquoise-dark green) areas. One such intermediate-albedo region, centered on the crater D'Alembert (50°N, 165°E), lies within a possible basin first described from Clementine altimetry [6].

The brightest (red) spots correspond to the most recent (younger Copernican) impact craters and ejecta, covering 2% of the lunar surface. Many new identifications of Copernican craters will be possible with the Clementine dataset, which will help us to understand the impact flux on the Earth and Moon during the past billion years and which has profoundly influenced the evolution of life on Earth. The brightest crater seen on the Moon at this scale is Giordano Bruno, which must be one of the most recent large craters (> 20 km diameter) on the Moon. Frequencies of superimposed craters (normalized to 1 km) [7] versus normal albedo [4], combined with some absolute age estimates (100 m.y. for Tycho), provides a means to estimate the age of a large crater from its albedo. Extrapolation to the albedo of Giordano Bruno suggests an age of only 8 m.y. for the impact event. Given realistic uncertainties and complications due to composition and presence of impact melt, we are probably safe to conclude that Giordano Bruno is less than 50 m.y. old.

The brightest extensive region on the far side corresponds to the region of highest elevations on the Moon, just north of the South Pole/Aitken basin. This region is clearly bright at least in part due to a concentration of immature soils on bright ejecta blankets of Copernican craters over relatively steep slopes and rugged topography, as was previously suggested from Galileo observations [4]. An alternative or additional interpretation, that this bright region is an iron-poor (anorthosite-rich) crustal province [8] may also prove correct. Specific evidence comes from several very bright craters such as Sharonov, which is almost as bright as Giordano-Bruno, yet lacks the albedo patterns indicative of fresh ejecta or rays, which characterize very young craters. Sharonov and similar craters probably expose a crustal layer of anorthosite.

References: [1] Duxbury, T., et al., 1994, Bull. Am. Ast. Soc. **26**, 1097. [2] Nozette, S., et al., 1994, Science **266**, 1835. [3] Buratti, B., 1994, Eos Suppl., Fall AGU, 400. [4] McEwen, A., et al., 1993, JGR **98**, 17,207. [5] Belton, M., et al., 1994, Science **264**, 1112. [6] Spudis, P. et al., 1994, Science **266**, 1848. [7] Neukum, G., and Konig, B., 1975, Proc. Lunar Sci. Conf. 7th, 2867. [8] Pieters, C., et al., 1993, JGR **98**, 17,127.