UNUSUAL RADAR BACKSCATTER ALONG THE NORTHERN RIM OF IMBRIUM BASIN

Thomas. W. Thompson[1] **Bruce A. Campbell**[2]

[1]*Jet Propulsion Laboratory*
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099 USA
twthompson@jpl.nasa.gov

[2]*National Air and Space Museum*
Smithsonian Institution
MRC 315, P.O. Box 37012
Washington, DC 20013 USA
campbellb@nasm.si.edu

INTRODUCTION

In general, radar backscatter from the lunar terrae (the Moon's rugged highlands) is 2–4 times that of the maria (the Moon's flat lowlands). One extensive exception to this is the terra along the northern rim of Imbrium Basin, as the highlands that surround Sinus Iridum and crater Plato have radar backscatter comparable to or lower than that from the adjacent maria. We are studying new 70-cm radar images and earlier multi-spectral data to better constrain the regional geology of this region.

RADAR DATA

Opposite-sense (OC) circular-polarized radar echoes from the northern rim of Imbrium were recently collected using the Arecibo radio telescope [1]. These new data have a spatial resolution of 300–600 m per pixel (Fig. 1) and show the low radar echoes from the terrae being equal to the echoes from Mare Frigorus to the northwest and weaker than the echoes from Mare Imbrium to the south. The 70-cm radar dark area around crater Plato are also seen in 3.8-cm radar images [2], (Fig. 2) and in 7.5-m radar maps of the Moon [3].

This area of the Moon is viewed at higher incidence angles (55–70 degrees), where radar echoes are dominated by diffuse scattering. At 70-cm wavelength, diffuse scattering is controlled by the number of meter-sized rocks that the radar "sees" on the surface or in the upper ~10 m of the subsurface. At 3.8-cm wavelength, diffuse scattering is controlled by the number of centimeter-sized rocks that the radar "sees" on the surface or in the upper meter of the subsurface. At 7.5-m wavelength, diffuse scattering is controlled by the number of rocks that are 10 m in size in the upper 100 m of the subsurface. In general, mare-terrae differences in diffuse radar backscatter seen elsewhere on the

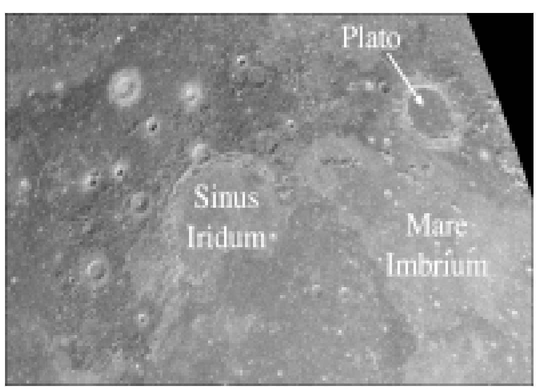

Fig. 1. 70-cm opposite-sense circular polarization radar image of the northern rim of Imbrium basin, showing Sinus Iridum (236-km diameter) and crater Plato (109-km diameter). Image resolution is 400–600 m per pixel. Note the overall low return from terrae north and northwest of Mare Imbrium. The terra radar echoes are equal to those of Mare Frigorus to the northwest and weaker that the Mare Imbrium echoes to the south.

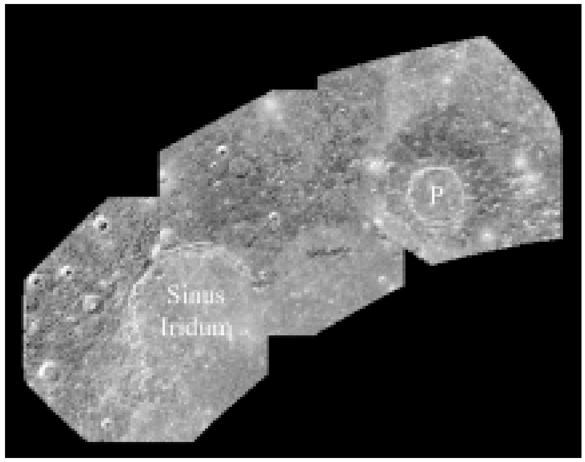

Fig. 2. 3.8-cm same-sense circular radar image (~2 km resolution) showing Sinus Iridum (236-km diameter) and crater Plato (109-km diameter) [2]. Low radar return associated with the environs of Sinus Iridum and Plato are observed.

Moon are attributed to lower electrical losses in the terrae material, which permit more reflections from the subsurface rocks. However, the lunar subsurface along northern Imbrium, is dominated by the ejecta from cratering events that created Plato and Sinus Iridum to depths of 100s of meters. The low radar echoes for this terra is consistent with these ejecta being rock poor, as is seen with other larger lunar craters [4].

INTERPRETATIONS: POSSIBLE GEOLOGIC SCENARIOS

Previous studies of lunar terrae with low radar reflectivities provide several possible geologic scenarios for the low radar echoes associated with the northern rim of Imbrium Basin. These scenarios include:
pyroclastic manteling material described by Gaddis et al. [5] and Zisk et al. [6]; cryptomare described by Hawke et al. [7] and Campbell et al. [8]; and, rock-poor distal crater ejecta described by Ghent et al. [4].

Pyroclastic Mantling Deposits

Gaddis et al. [5] studied 3.8-cm radar data for the northern rim of Imbrium Basin. Also, low radar echoes are seen for the pyroclastic deposits associated with the Aristarchus Plateau [6]. Pyroclastic deposits on the Moon, produced by fire-fountaining during the early stages of mare volcanism, are typically rock-poor and have moderate to high iron content. Due to the lack of small surface rocks, as well as higher loss tangents, they have low radar echoes at 3.8-cm wavelength. 70-cm echoes are low in areas of relatively thick mantling (e.g., several meters or more). Based on the low 3.8-cm radar return, the presence of numerous sinous rilles within the terrae, and mapping of a possible mantling deposit by Gaddis et al. [5] suggested that the area near Plato is mantled by “fine-grained pyroclastic material of intermediate albedo.”

However, recent Clementine FeO and TiO_2 [9,10] maps of the northern rim of Imbrium Basin have typical low FeO and TiO_2 contents implying that a high-loss pyroclastic mantle in this area of the moon is unlikely.

Cryptomaria

Cryptomaria are patches of basaltic mare material that have been buried by or incorporated into terrae regoliths during basin or large crater formation. These areas can have lower 70-cm and 7.5-m radar echoes than typical terrae if the buried or mixed basalts have significant ilmenite content. For example, a large radar-dark terrae area north of Mare Humorum and west of Gassendi is attributed to cryptomare [7]. A radar dark area in the terrae west of Oceanus Procellarum is attributed to a veneer (up to 50 m thick) of Orientale ejecta overlying a preexisting tongue of Oceanus Procellarum maria [8].

Other cryptomare deposits are identified on the basis of dark halo craters (DHCs), which excavate the near-surface basalt, or the presence of small iron and titanium enhancements in the terrae [7]. We observed no dark-halo craters nor small craters with iron or titanium enhancements across northern rim of Imbrium Basin. Also, there is no evidence that the areas of low radar return follow topographic features such as ridges, as is observed for cryptomaria east of Orientale [8]. The regional FeO and TiO_2 maps show no evidence for localized patches of mixed highland and mare debris.

Based on this, we conclude that cryptomare deposits cannot explain the low 3.8 cm, 70-cm, and 7.5-m radar echoes associated with northern rim of Imbrium Basin near Sinus Iridum and Plato.

Rock-Poor Crater Ejecta

Ghent et al. [4] showed that larger Copernican, Erathostenian, and some Imbrium craters with diameters greater than 10 to 20 km have radar dark ejecta distal to the rugged near-rim terrain; they inferred that these ejecta are rock-poor. This provides a basis for examining the northern rim of Imbrium Basin as the radar dark ejecta of the Imbrium-aged Sinus Iridum and crater Plato impacts.

When we compare the three geologic scenarios for the low radar echoes associated with the northern rim of Imbrium Basin (i.e., whether they are the pyroclastic mantling described by Gaddis et al. [5] and Zisk et al. [6], or the cryptomare described by Hawke et al. [7] and Campbell et al. [8], or the rock-poor distal crater ejecta described by Ghent et al. [4]), the rock-poor distal ejecta is the most promising.

Summary

It is noted that if the radar darkness associated with the northern rim of Imbrium Basin are due to rock-poor ejecta, then Sinus Iridum is the largest lunar crater with a radar-dark halo. In addition, radar-dark haloes for Sinus Iridum and crater Plato overlap. The embayment of these radar-dark haloes by Mare Imbrium to the south and Mare Frigoris to the north and west provides a situation not encountered with the radar-dark halo craters described by Ghent et al. [4]. In addition, a large low-reflectivity area on the eastern limb of the Moon on the eastern limb of the Moon) noted by Thompson [11] may result from overlapping 70-cm radar-dark ejecta haloes of large craters Langrenus, Petavius, Humboldt, and Stevinus.

References

[1] B.A. Campbell, D.B. Campbell, and J. Chandler, "New 70-cm radar mapping of the Moon," *Lunar and Planetary Science Conference XXXVI,* Abstract 1385, 2005.

[2] S.H. Zisk, G.H. Pettengill, and G.W. Catuna, "High-resolution radar maps of the lunar surface at 3.8-cm wavelength," *The Moon*, 10, 17–50, 1974.

[3] T.W. Thompson, "High resolution lunar radar map at 7.5 m wavelength," *Icarus,* 36, 174–188, 1978.

[4] R.R. Ghent, D.W. Leverington, B.A. Campbell, B.R. Hawke, and D.B. Campbell, "Earth-based observations of radar-dark crater haloes on the Moon: Implications for regolith properties," *J. Geophys. Res*., 110, E2005, doi:10.1029/2000-4Jee002366, 2005.

[5] L.R. Gaddis, C.M. Pieters, and B.R. Hawke, "Remote sensing of lunar pyroclastic mantling deposits," *Icarus*, 61, 461–489, 1985.

[6] S. H. Zisk, C.A. Hodges, H.J. Moore, D.E. Wilhelms, R.W. Shorthill, T.W. Thompson, and E.A. Whitaker, "The Aristarchus-Harbinger region of the Moon: Surface geology and history from recent remote sensing observations," *The Moon*, 17, 59–99, 1977.

[7] B.R. Hawke, C.A. Peterson, P.G. Lucey, G.J. Taylor, D.T. Blewett, B.A. Campbell, and P.D. Spudis, "Remote sensing studies of the terrain northwest of Humorum Basin," *Geophys. Res. Letters*, 20, 419–422, 1993.

[8] B.A. Campbell and B.R. Hawke, "Radar Mapping of Lunar Cryptomaria East of Orientale Basin," *J. Geophys. Res*, in press, 2005.

[9] P.G. Lucey, D.T. Blewett, and B.D. Joliff, "Lunar iron and titanium abundance algorithms based on final processing of Clementine UV-Visible images," *J. Geophys. Res.,* 105, 20,297–20,306, 2000.

[10] J.J. Gillis, B.L. Joliff, and R.C. Elphic, "A revised algorithm for calculating TiO_2 from Clementine UVVIS data: A synthesis of rock, soil, and remotely sensed TiO_2 concentrations," *J. Geophys. Res., 108*, doi:10.129/2001JE001515, 2003.

[11] T.W. Thompson, "High Resolution Lunar Radar Map at 70-cm Wavelength," *Earth, Moon, and Planets,* v 37, 59–70, 1987.

Acknowledgments

This work was supported in part by a grant from the NASA Planetary Geology and Geophysics Program. Research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the National Aeronautics and Space Administration.