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UNUSUAL RADAR BACKSCATTER ALONG THE NORTHERN RIM OF IMBRIUM BASIN

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Lunar and Planetary Science Conference
13-17 March 2006

Overview

General Rule

Earth-based radar backscatter from the lunar terrae
is 2-4 times that of the maria.

The Largest (Most Conspicuous) Exception

The terra along the northern rim of Imbrium Basin,
the highlands that surround Sinus Iridum and crater Plato
have (3.8 cm. 70-cm and 7.5m) radar backscatter
that is comparable to, and sometimes weaker, the mare.

Possible Geologic Scenarios

- **Pyroclastic Mantling** - Gaddis et al. [1985] and Zisk et al. [1977];
- **Cryptomare** - Hawke et al. [1993] and Campbell et al. [2005]; and,
- **Rock-poor Crater Ejecta** - Ghent et al. [2005].

Summary/Conclusions (Bottom Line)

Rock-poor Crater Ejecta agrees with data and crater ejecta thickness models

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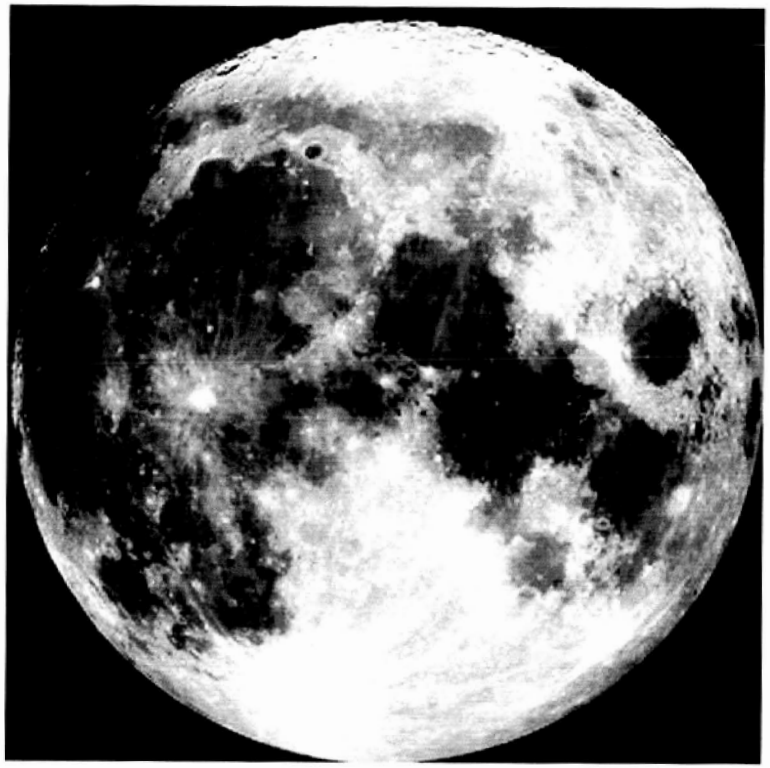
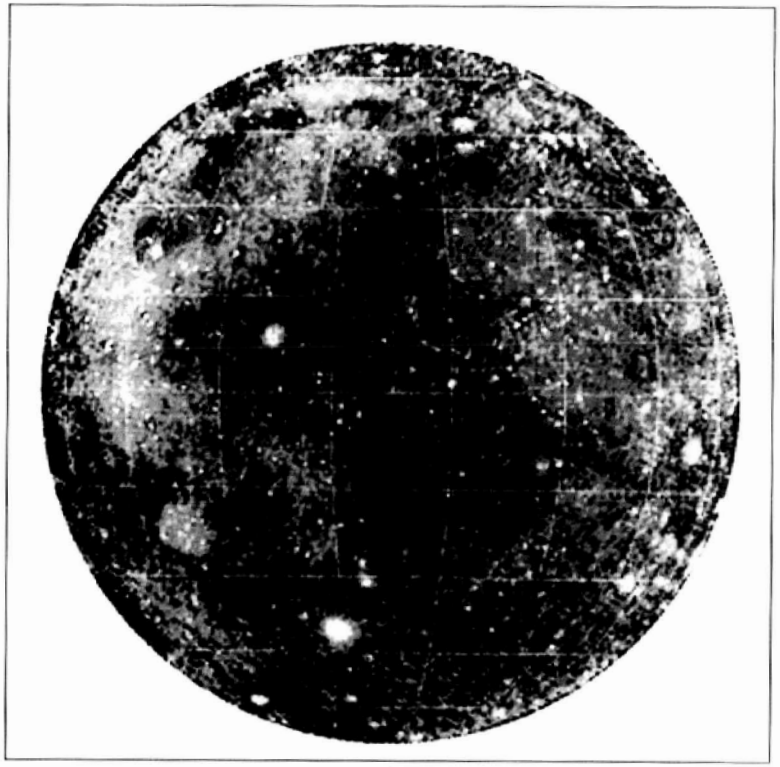
Visual and Infrared Observations of Moon

JPL





Montes Jura have usual terra behaviors at visual/IR wavelengths

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Radar Observations of Moon

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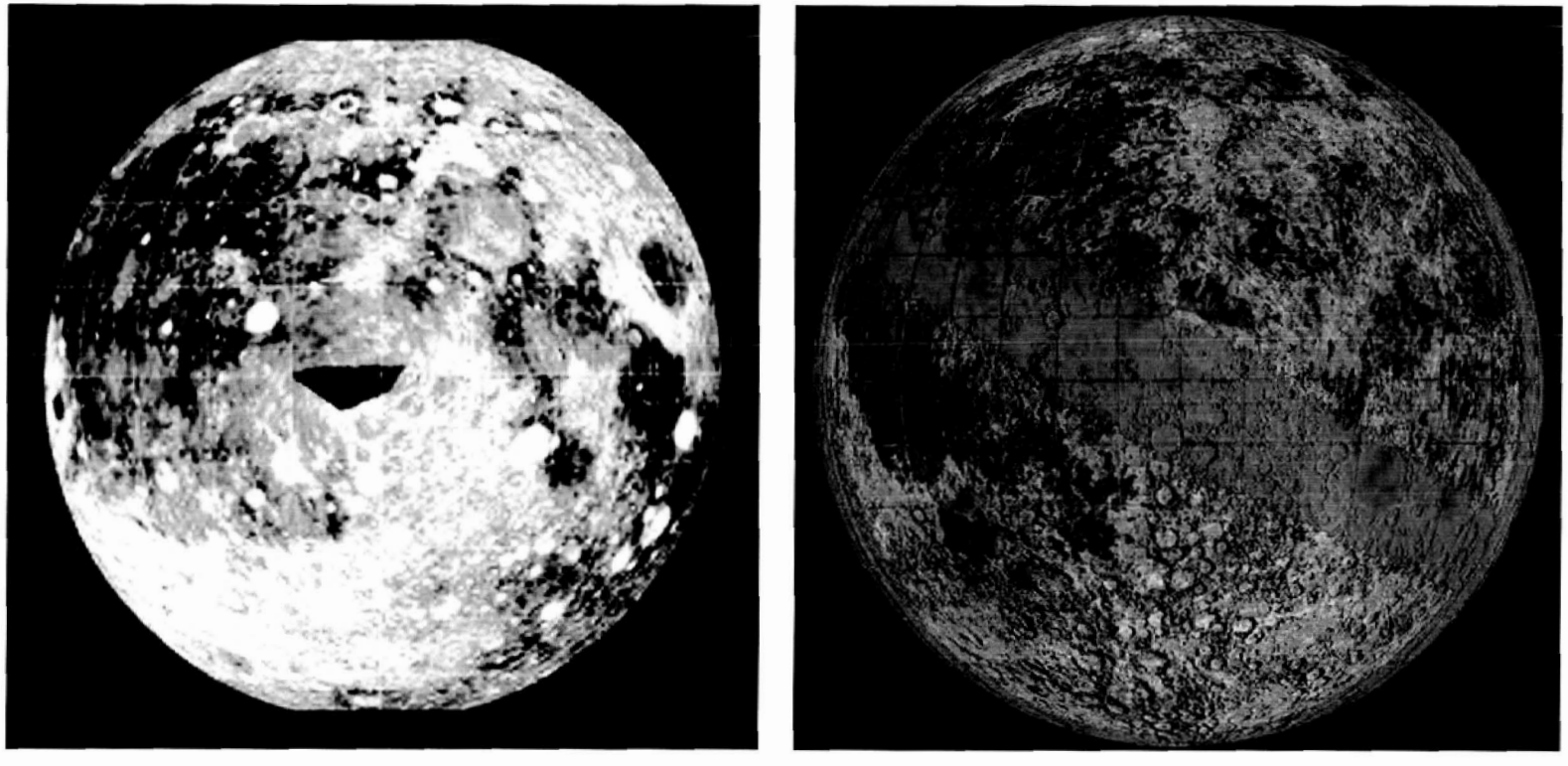

Montes Jura have unusual terra behaviors at radar wavelengths

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Lunar Orbiter Photographs
Geologic Setting

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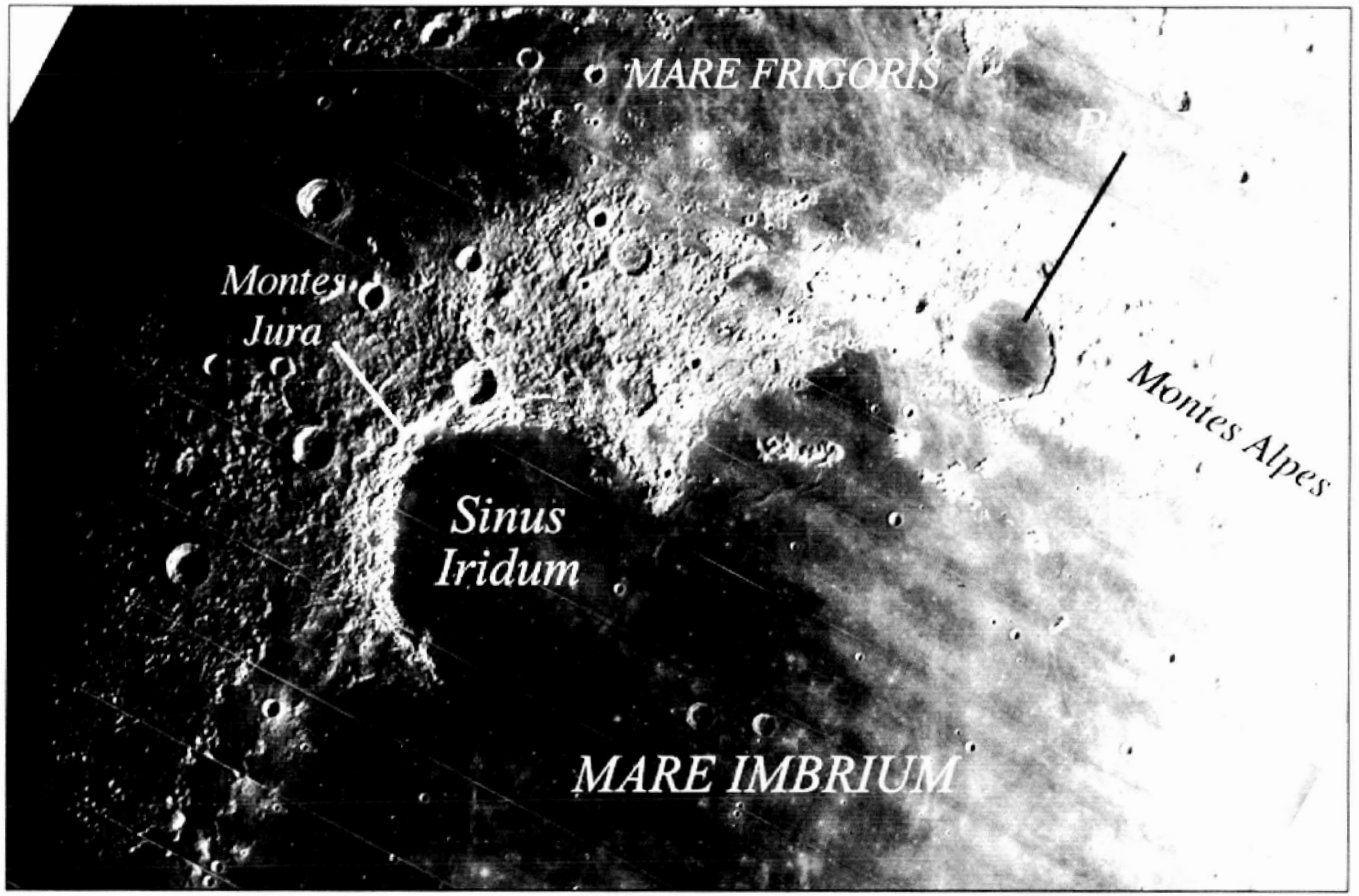

Lunar Orbiter IV Photograph

Unusual Radar Backscatter Properties Along the Northern Rim of Imbrium Basin

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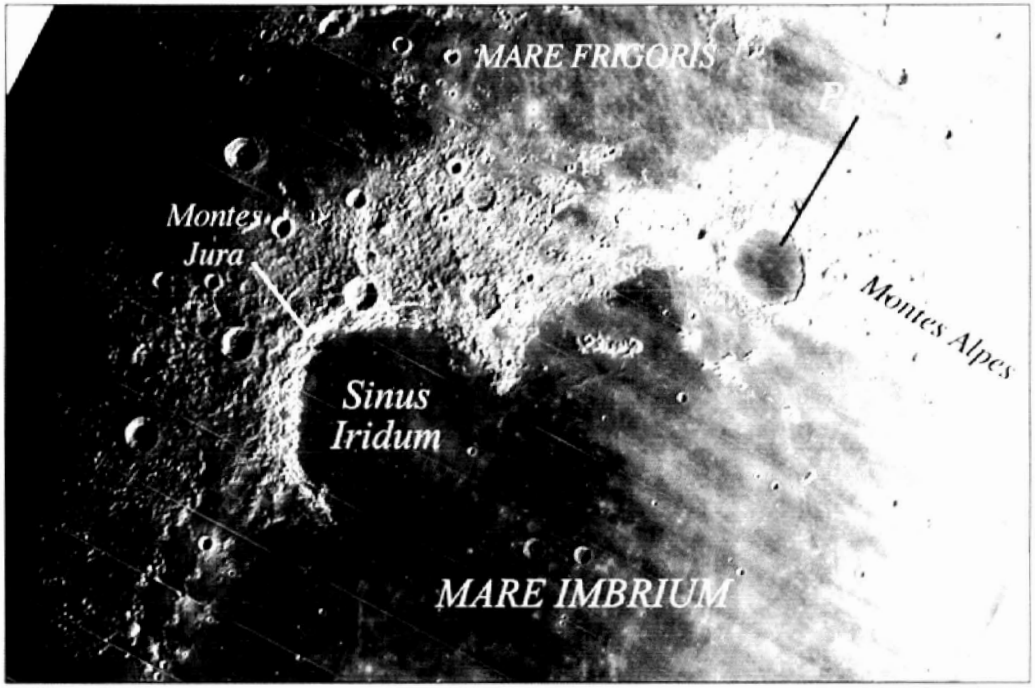
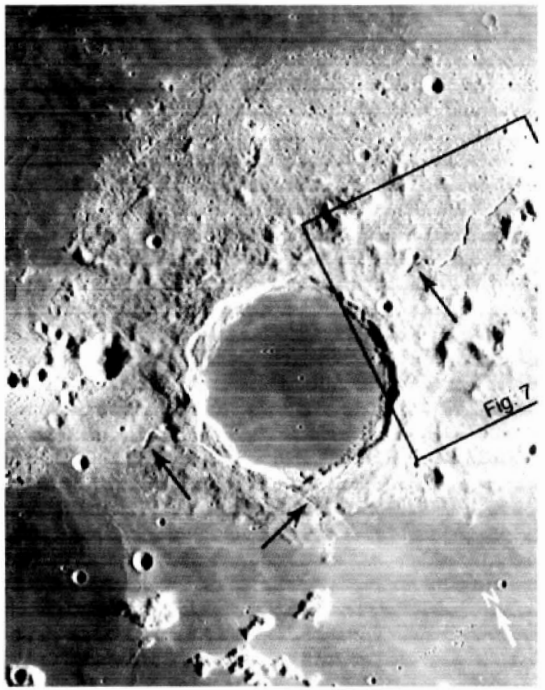
Lunar Orbiter Photographs
Geologic Setting

JPL





Lunar Orbiter IV Photographs

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70-cm Radar Data

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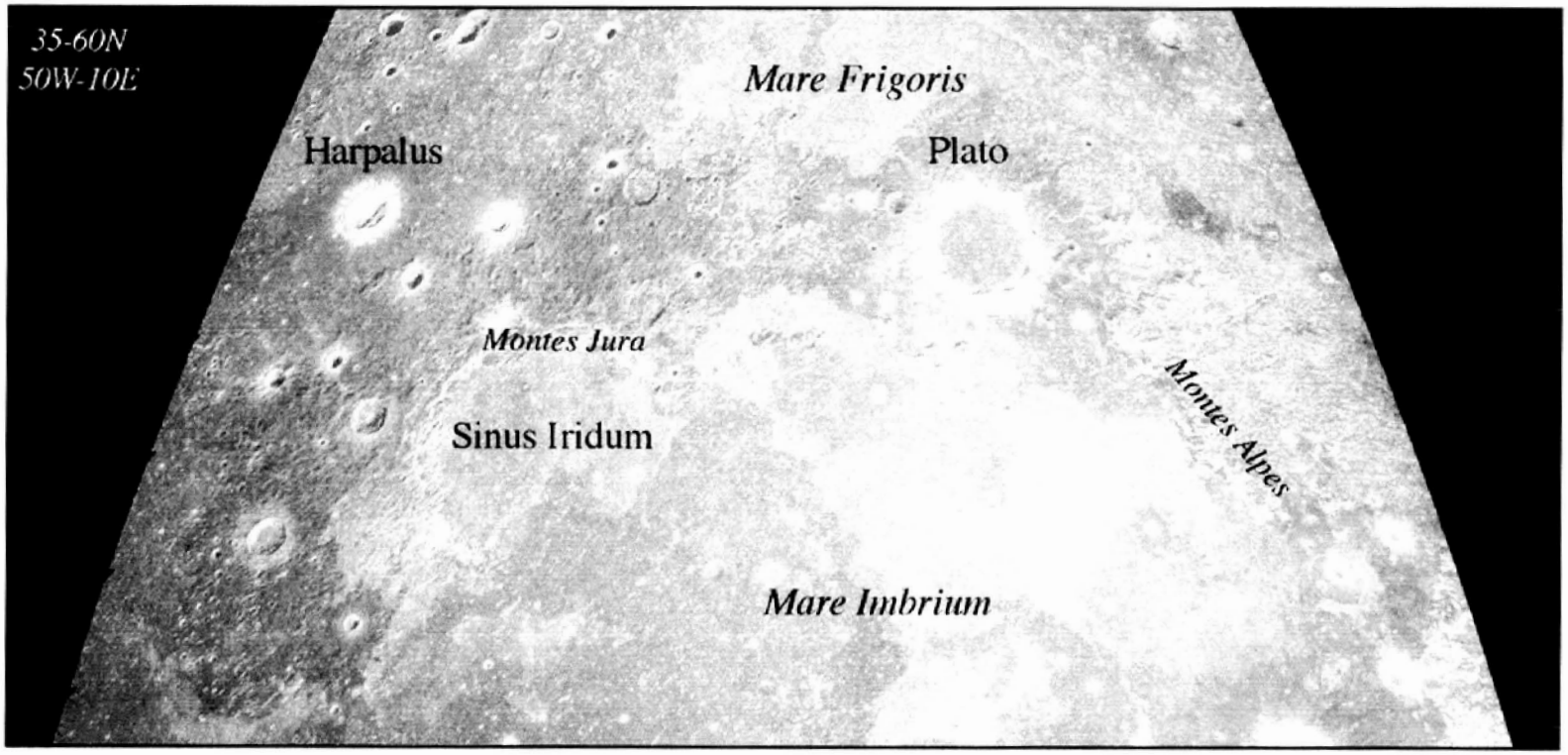
New Arecibo -> Green-Bank Bistatic Radar Observations



Same-sense Circular (SC, Depolarized) Radar Image of Northern Imbrium Region
(35°–60° N, 50° W–10° E) Sinusoidal Projection - Spatial Resolution ~500 m

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70-cm Radar Dark Halo Craters

JPL

New Arecibo -> Green-Bank Bistatic Radar Observations

Same-sense Circular (SC, Depolarized)

Radar Image

(25-85° N, 50° W–10° E)

Sinusoidal Projection
Spatial Resolution ~500 m

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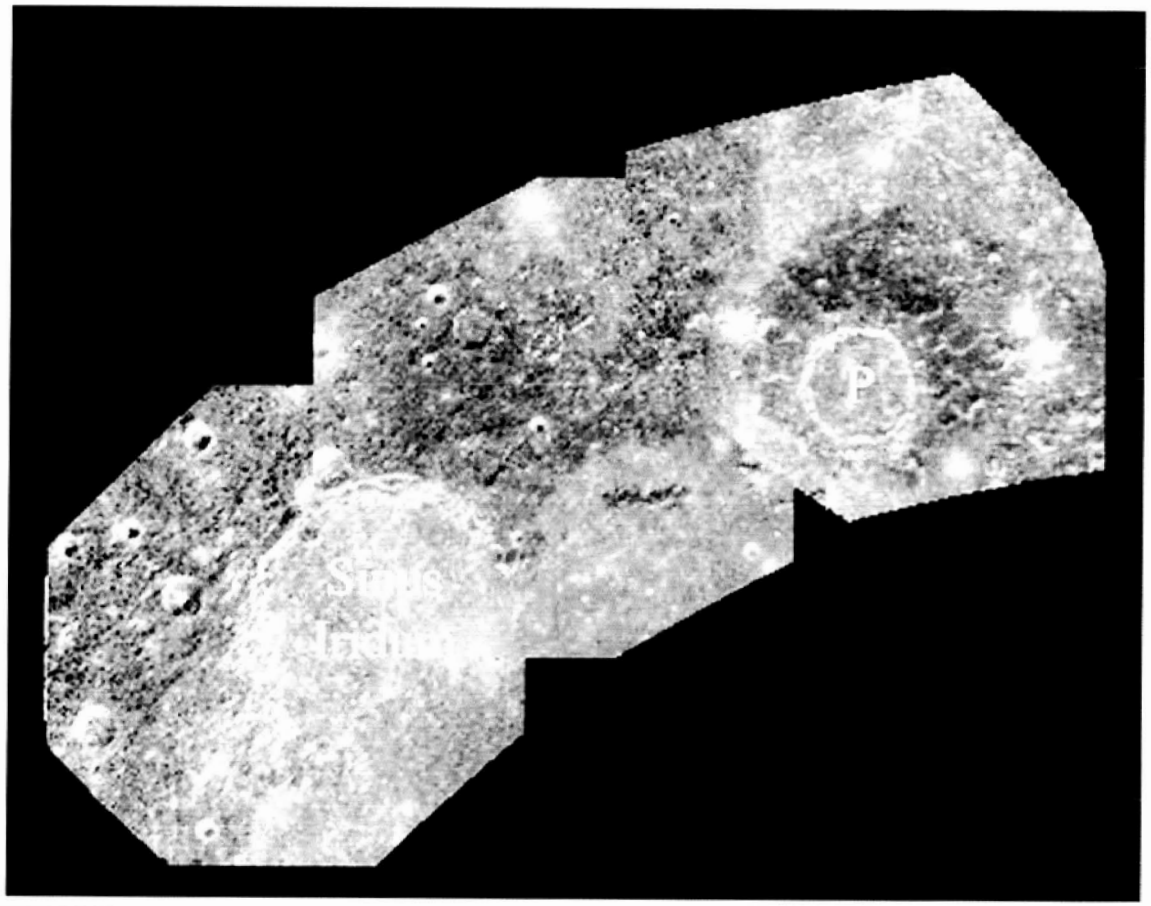
3.8-cm Radar Data

JPL



3.8-cm Wavelength, Same-Sense Circular (SC, Depolarized) Radar Image [Zisk et al., 1974]

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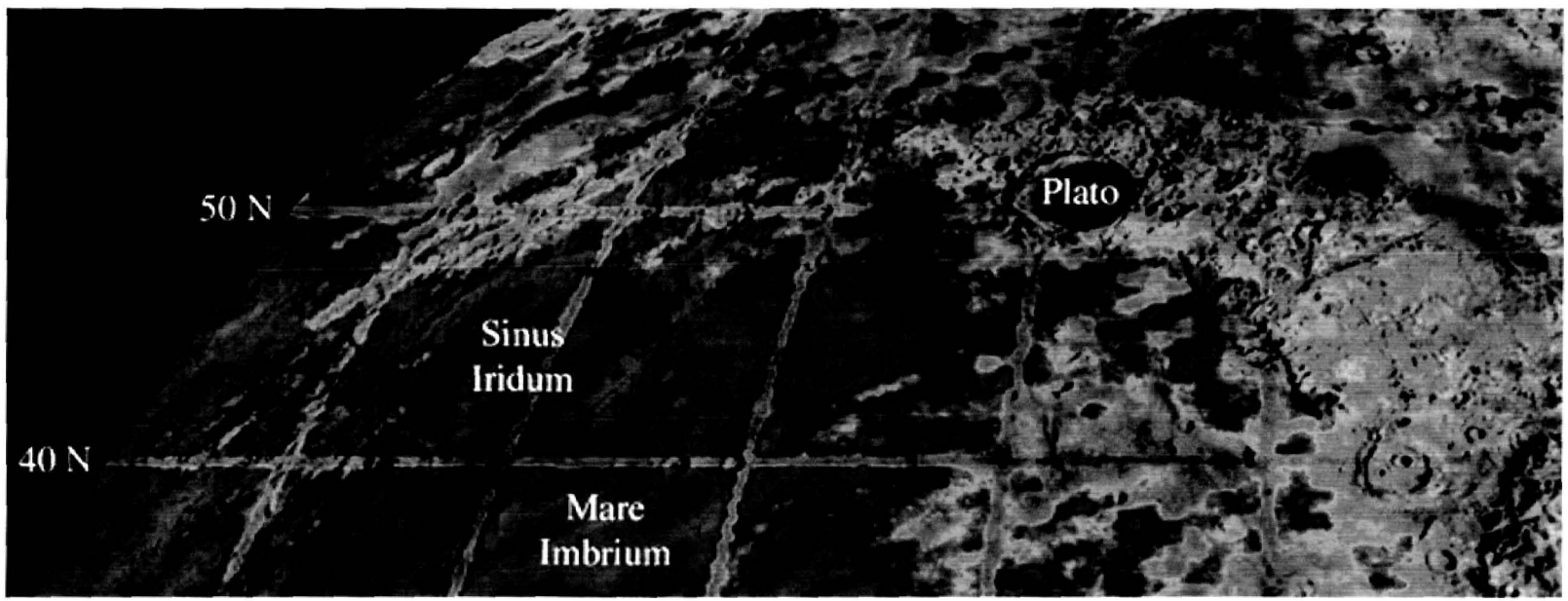
7.5-m Radar Data

JPL



7.5-m Wavelength, Opposite-sense Circular (OC, polarized) Radar Image of Northern Imbrium
Spatial resolution 10–30 km [Thompson, 1978]. Orthographic projection.
Color Overlay of 7.5-m Radar on USGS Shaded-Relief Map
(Lower echoes are purple or blue; Moderate echoes are green; High echoes are red)

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70cm, 3.8 cm and 7.5-m Radar Data

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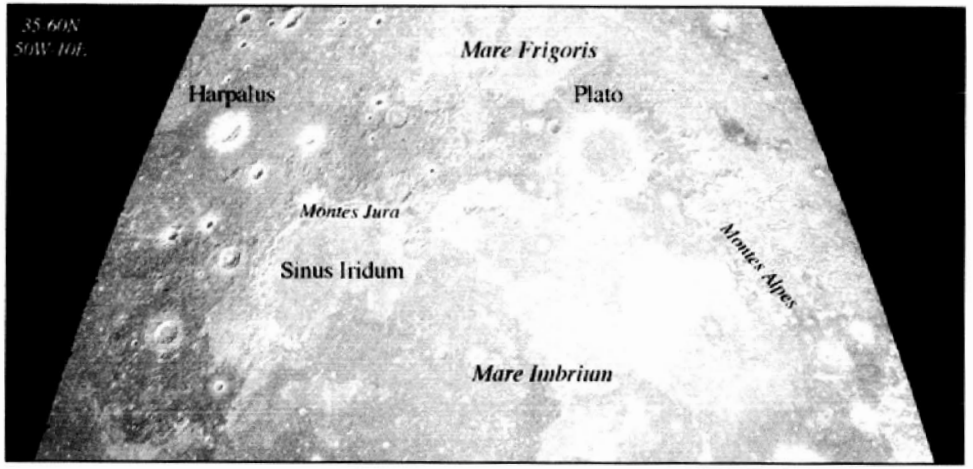

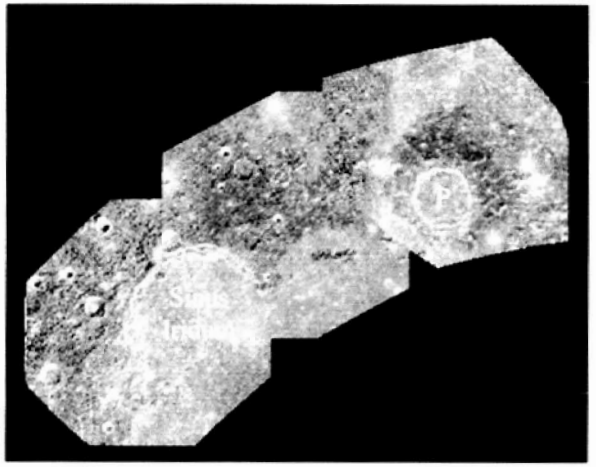

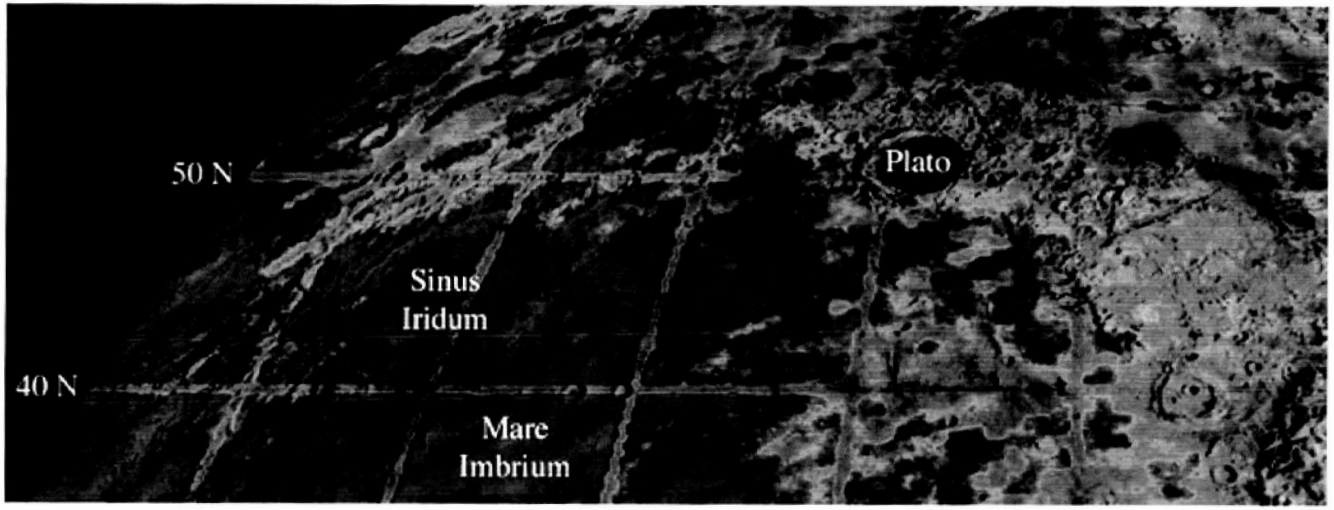

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Optical and Infrared Data

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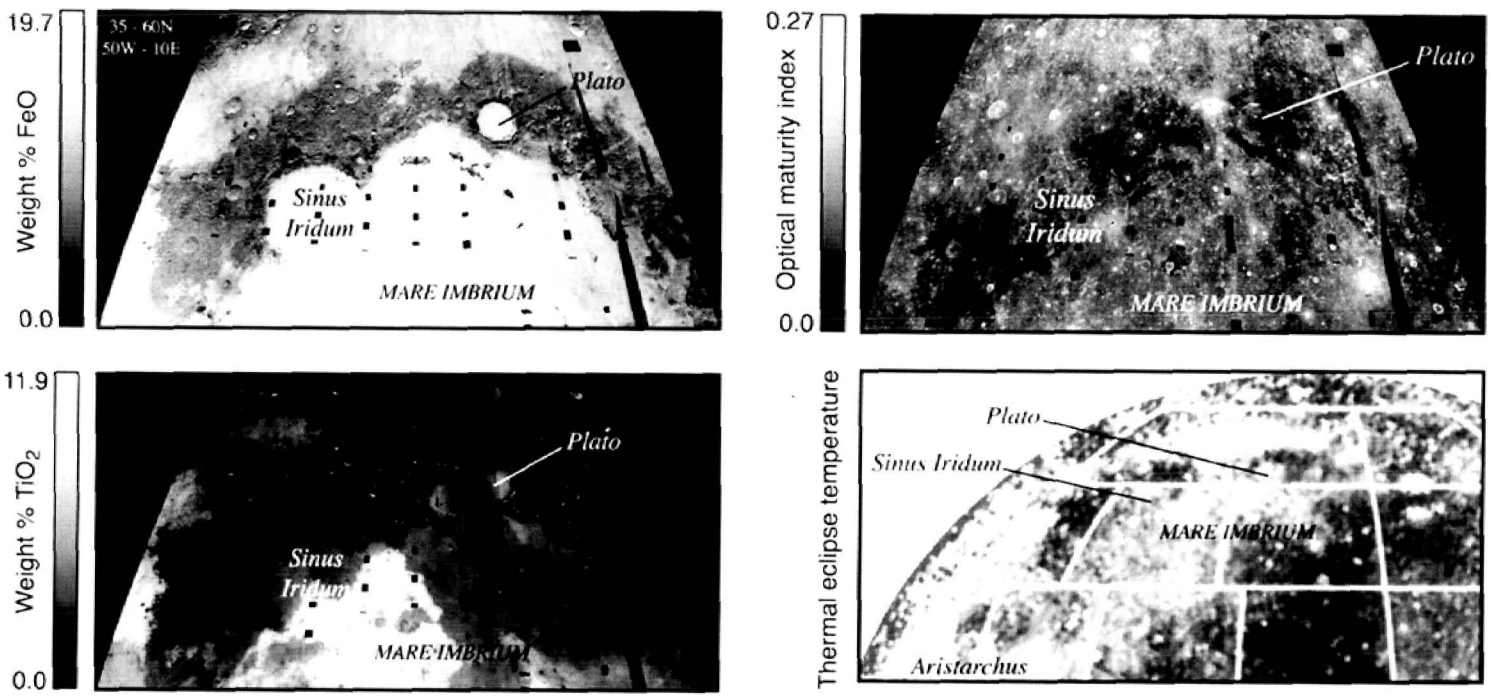

Maps of Infrared Properties derived from Clementine UV-VIS and Earth-based Eclipse Images
(a) FeO Weight Percentage [Lucey et al., 2000a], (b) TiO_2 Weight Percentage [Gillis et al., 2003],
(c) Optical Maturity Index (brighter areas denote immature terrain) [Lucey et al., 2000b],
(d) Infrared Eclipse Image (brighter areas correspond to more surface rocks >10 cm diameter) [Shorthill, 1973]
Differences in Mare TiO_2 Content Correlate with 70-cm Radar Scattering Differences attributed to Ilmenite Abundances

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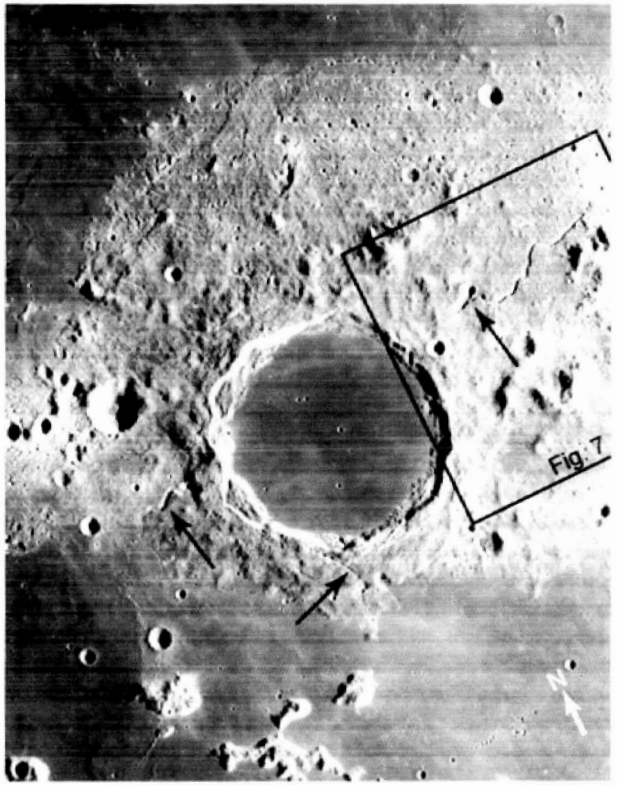
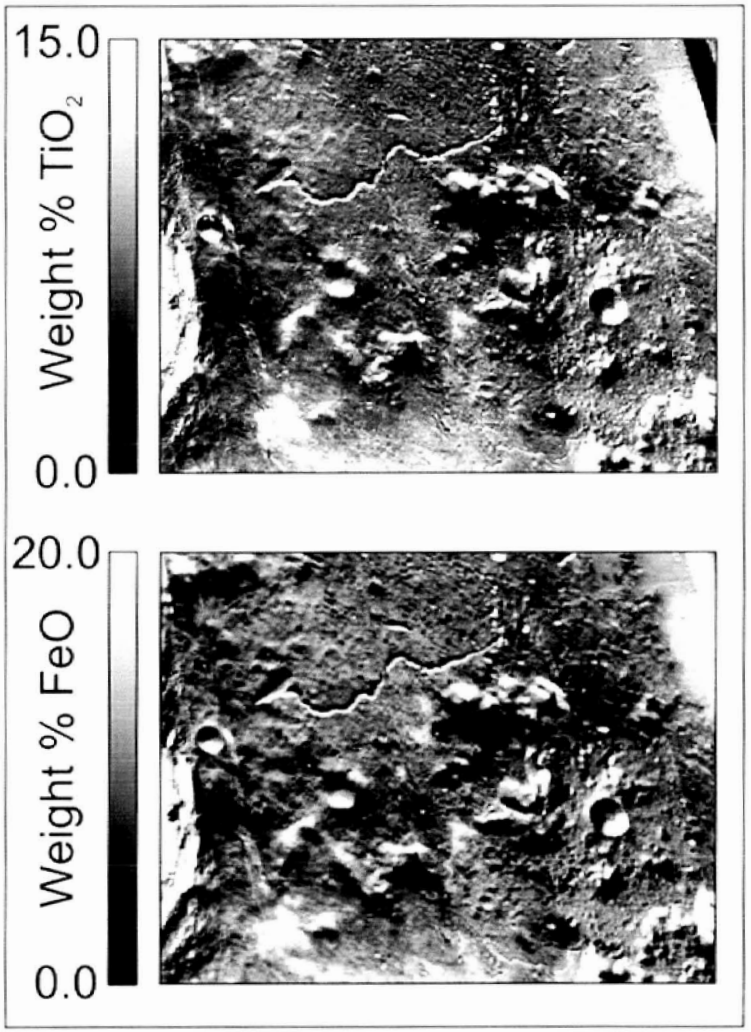
Plato Rilles

JPL



Pyroclastics are unlikely cause of low radar echoes



Unusual Radar Backscatter Properties Along the Northern Rim of Imbrium Basin

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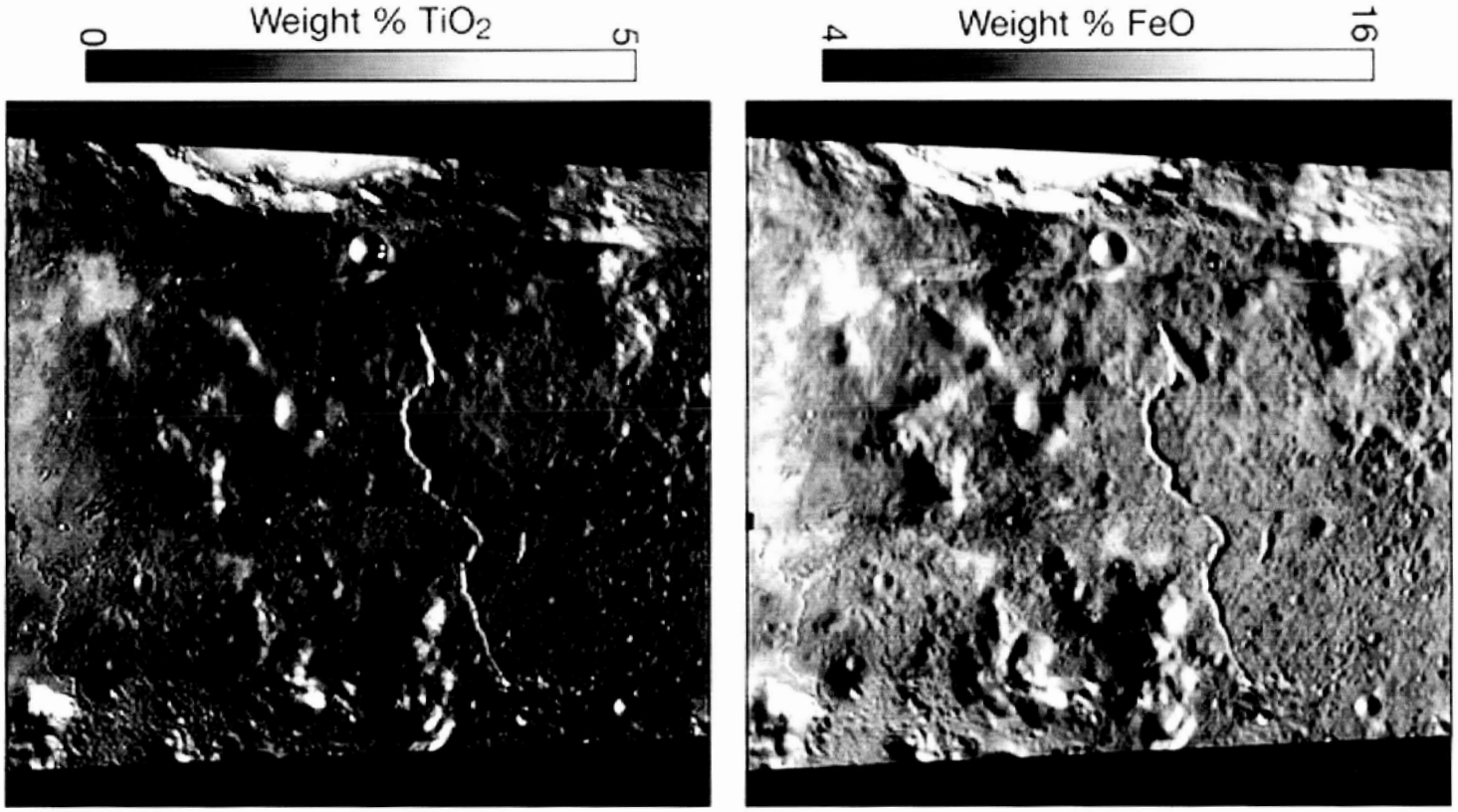
Plato Rilles

JPL



Pyroclastics are unlikely cause of low radar echoes

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Isopachs of Crater Ejecta

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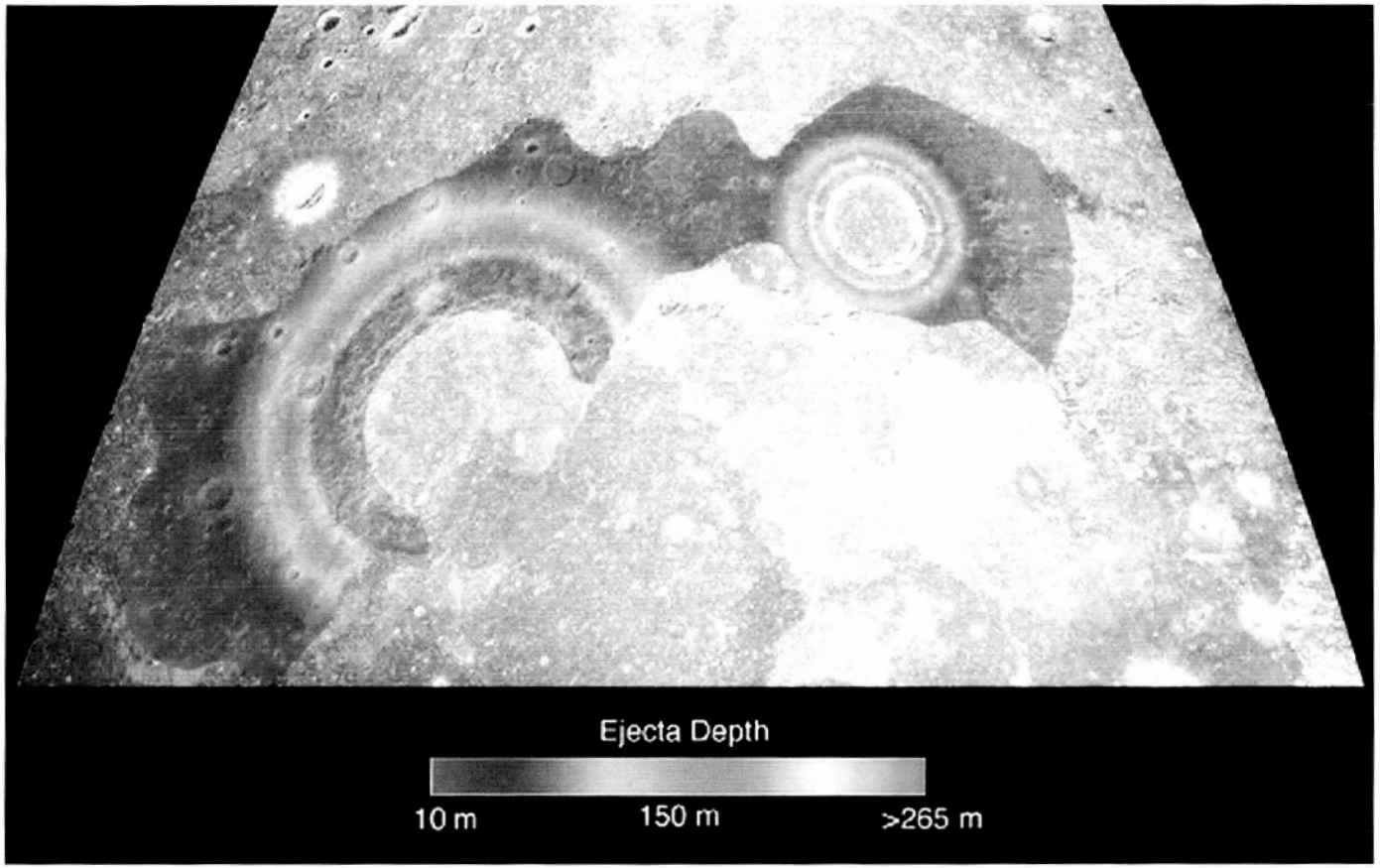

Deep Iridum and Plato Ejecta are sufficient
to explain the low radar echoes for this region

Unusual Radar Backscatter Properties Along the Northern Rim of Imbrium Basin

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Plato-like Craters

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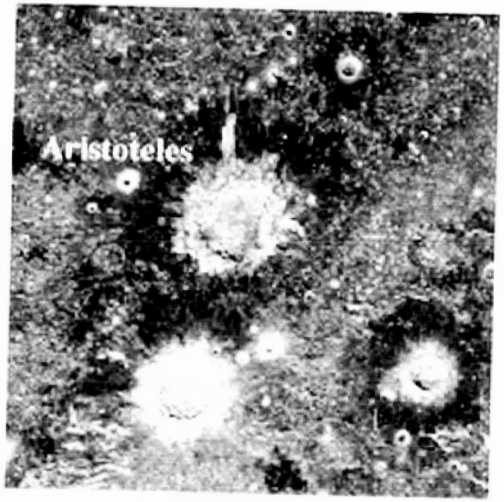
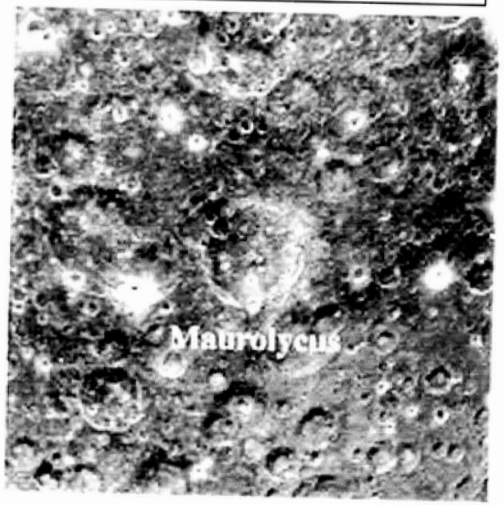
Aristoteles Diameter - 88 km Eratosthenian (Young)	Plato Diameter - 109 km Upper Imbrian (Middle Age)	Maurolycus Diameter - 114 km Nectarian (Old)





Based on analogies among Plato-sized craters,
the floor of Plato would have a strong 70–cm radar echo
if it weren't flooded by mare basalts

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Observation Summary

OBSERVABLE	COMPARISON TO OTHER TERRAE	REFERENCE
70cm OC (Depolarized) Radar Echo Strength	2-4 weaker echoes (as dark as the maria)	Campbell et al., 2005
3.8-cm OC (Depolarized) Radar Echo Strength	2-4 weaker echoes (as dark as the maria)	Zisk et al., 1974
7.5-m SC (Polarized) Radar Echo Strength	2-4 weaker echoes (as dark as the maria)	Thompson, 1987
Infrared Eclipse Temperatures	5-15 -degrees cooler that Maria - Typical Terrae	Shorthill, 1973
Clementine FeO Contents	About 5% - Typical Terrae	Lucey, et al., 2000
Clementine TiO2 contents	About 5% - Typical Terrae	Gillis, et al., 2003

SC - Same-Sense Circular (Depolarized) / OC - Opposite-Sense Circular (Polarized)

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Interpretation Matrix

RADAR POSSIBILITIES	GEOLOGIC IMPLICATION	LIKELYHOOD
A - Fewer m-sized blocks-rocks on the surface and in uppermost 10-m of subsurface	**Dark Radar Haloes-Consequence of large Plato and Sinus Iridum impact events**	**LIKELY - BEST FIT to radar, visual, IR and Clementine FeO and TiO data**
B- Higher electrical loss in ejecta from Plato and Sinus Iridum impact events	Preexisting and deep (10-km) mares at S-Iridium and Plato impact sites	**UNLIKELY** - Expect preexisting mare to be thin (about km thick at most)
C- Higher electrical loss in post Plato and Sinus Iridum mantling event	High electrical loss pyro-clastics blanket the terra to depths of 10-100 meters	**UNLIKELY** - FeO/TiO2 are low (Clementine data) not high - Also, no variation in Feo/TiO2 data
D - Fewer m-sized blocks-rocks in post Plato and Sinus Iridum mantling event	Relatively rock-block poor pruoclastics blanket the terra to 10-100 meters depth	**UNLIKELY** -Expect pyroclastics to be thin. No variation in Feo/TiO2 data

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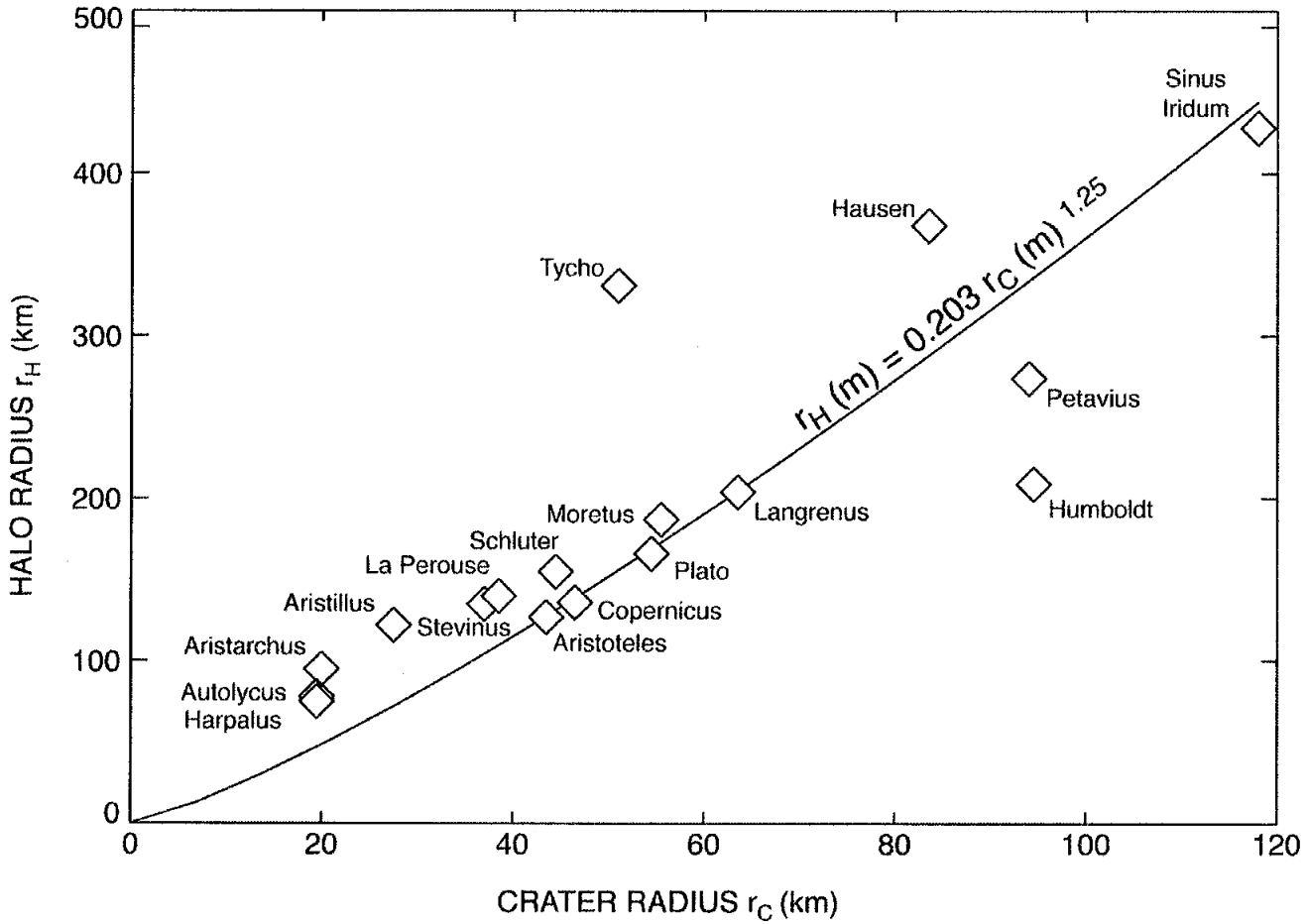
Dark Halo Diameters vs. Crater Size



Most Radar Dark Halo Diameters Occur when the Ejecta Depths are about 10 meters

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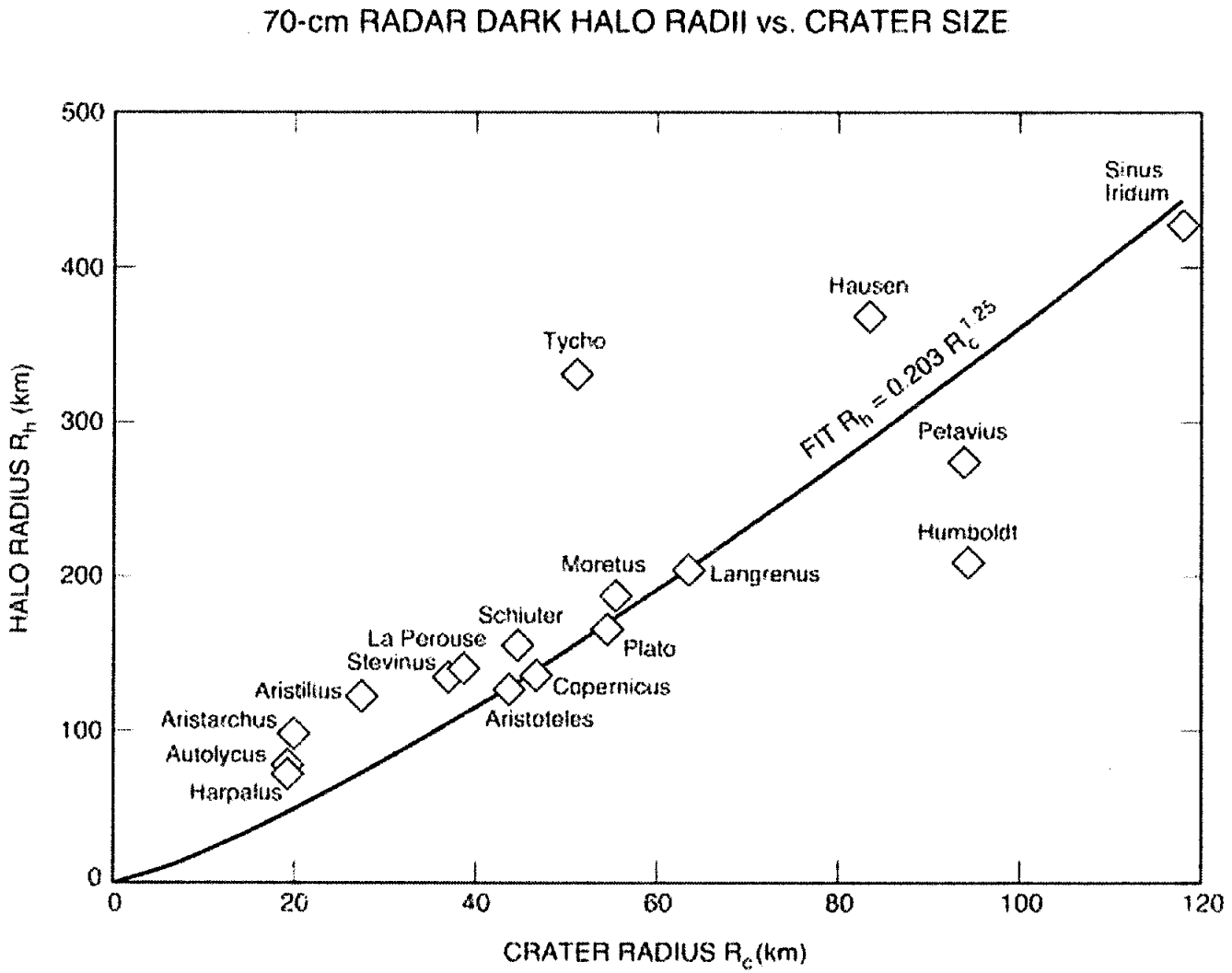
Dark Halo Diameters vs. Crater Size



Most Radar Dark Halo Diameters Occur when the Ejecta Depths are about 10 meters

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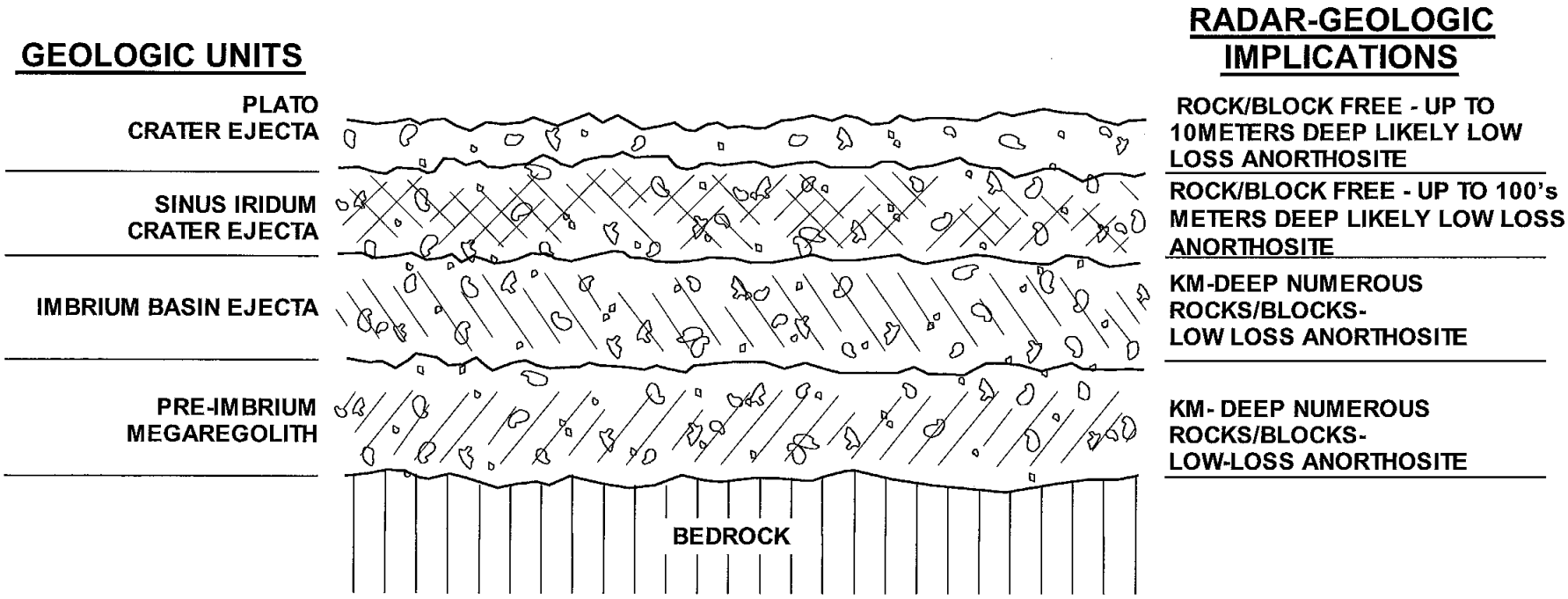
RADAR GEOLOGIC COLUMN

NORTHERN RIM OF IMBRIUM BASIN
(INCLUDING EJECTA OF PLATO AND SINUS IRIDUM)



VERTICAL NOT TO SCALE

Unusual Radar Backscatter Properties Along the Northern Rim of Imbrium Basin

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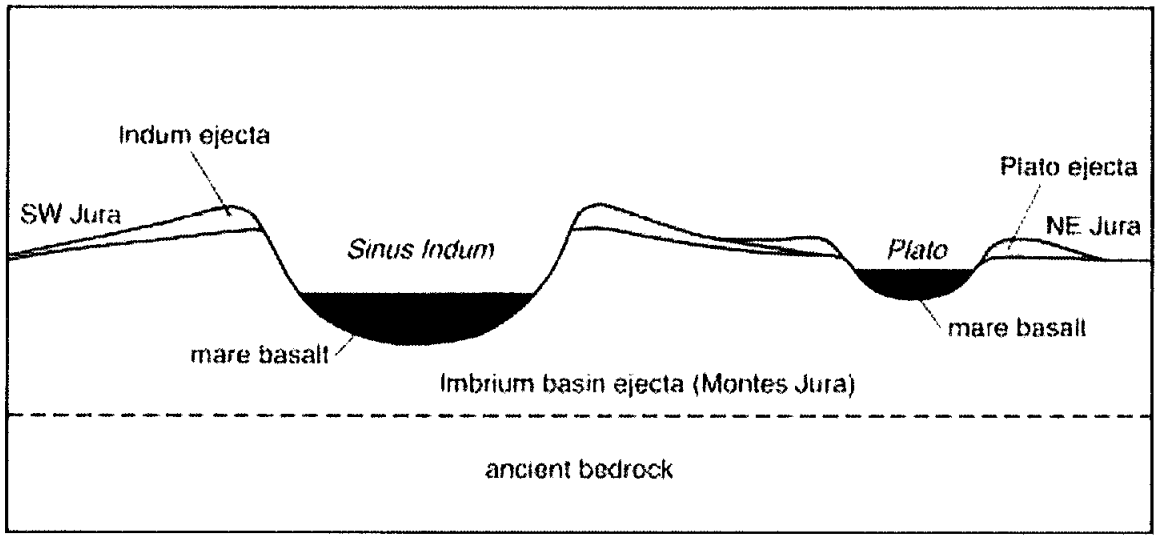
RADAR GEOLOGIC COLUMN

NORTHERN RIM OF IMBRIUM BASIN
(INCLUDING EJECTA OF PLATO AND SINUS IRIDUM)

GEOLOGIC CROSS SECTION OF MOON'S MONTES JURA REGION



The Radar, Infrared, Visual, and UV Signatures are determined primarily by the deep (tens to a few hundreds of meters) rock-poor distal ejecta of Iridum and Plato

Unusual Radar Backscatter Properties Along the Northern Rim of Imbrium Basin

References

- B.A. Campbell and B.R. Hawke, "Radar Mapping of Lunar Cryptomaria East of Orientale Basin," *J. Geophys. Res*, in press, 2005.
- 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.
- L.R. Gaddis, C.M. Pieters, and B.R. Hawke, "Remote sensing of lunar pyroclastic mantling deposits," *Icarus*, 61, 461–489, 1985
- 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.
- 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
- 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.
- 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.
- McGetchin, T.R., M. Settle, and J.W. Head, Radial thickness variations in impact crater ejecta: Implications for lunar basin deposits, *Earth Plan. Sci. Letters, 20*, 226-236, 1973
- T.W. Thompson, "High resolution lunar radar map at 7.5 m wavelength," *Icarus,* 36, 174–188, 1978.
- T.W. Thompson, "High Resolution Lunar Radar Map at 70-cm Wavelength," *Earth, Moon, and Planets,* v 37, 59–70, 1987.
- 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. 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.