Investigation of exceptionally radar-dark regions on the lunar nearside

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Lunar radar imaging

In a previous lunar radar imaging study[3] using the 49.92 MHz Jicamarca radio telescope we discovered two regions with anomalously low depolarized return. The regions were both terrae, one between Mare Imbrium and Mare Frigoris in the northern hemisphere, the other surrounding the ancient impact basin Schiller-Zucchius. In this study, we aimed to explain the underlying surface characteristics causing the reduction in depolarized power in these two regions.

Planetary radar studies

Radar studies of planetary surfaces are a powerful remote sensing tool for exploring the environment and surface of other solar system bodies[1]. As radar waves can penetrate into the subsurface layer, it is possible to study the structure of the upper layers of planetary crusts with this tool. Polarimetric information carried in the radar echo can also help identify the texture and composition of a surface.

Selenology

The lunar terrain can be separated into two distinct types: the terrae and the maria. Terrae are visually bright and are primarily composed of anorthosites, providing a large penetration depth. Maria are remnants of volcanic lakes, composed of dark, high-iron basalts, which leads to low penetration depths.

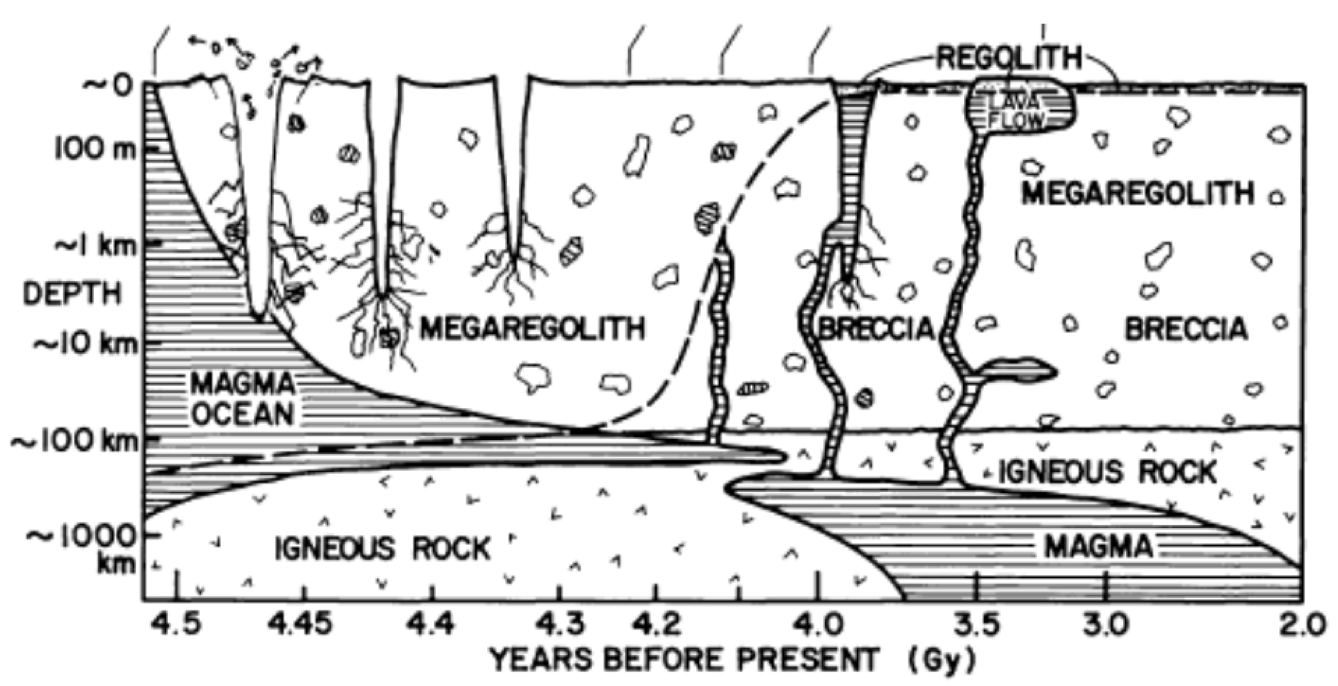

Fig. 1: This figure shows the different stages in the lunar crust's development.

Under the surface, there is a third type of terrain. If terra material has been supplanted onto a mare, the surface will have characteristics of terrae, but the volume will have the characteristics of maria. These are called cryptomaria, and are often visually bright, but with low penetration depths.

The loss tangent of lunar soil can be found as[2]:

$$\tan\delta = 10^{(0.045[\%\mathrm{TiO_2}+\%\mathrm{FeO}]-2.754)}. \qquad (1)$$

Measurements of iron and titanium content of the lunar soil is therefore critical to understanding the penetration depth in the lunar environment.

Radar maps

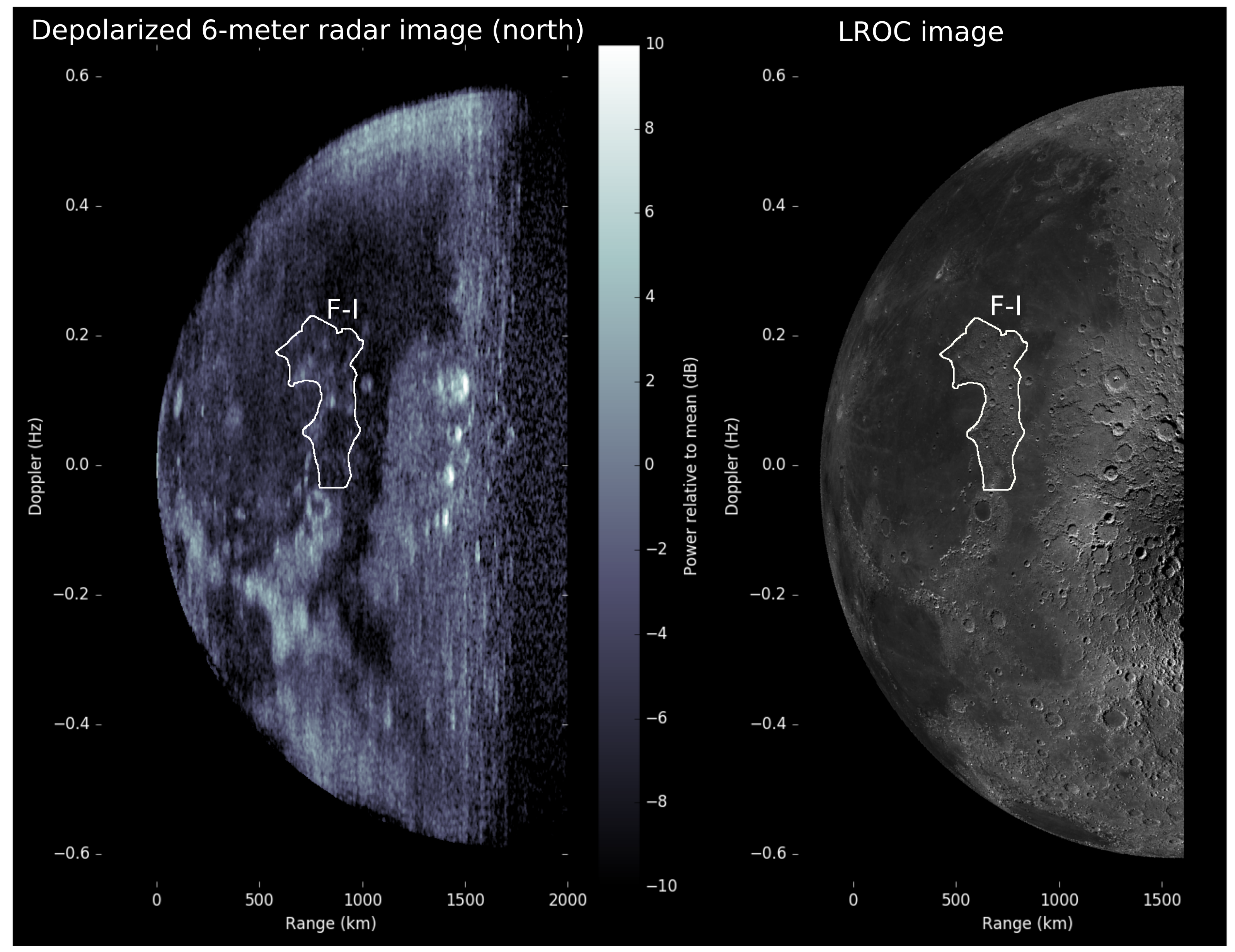

Fig. 2: Northern half of lunar nearside. Radar image to the left and visual image mosaic from LROC database on the right. Terra region between Mare Imbrium and Mare Frigoris indicated.

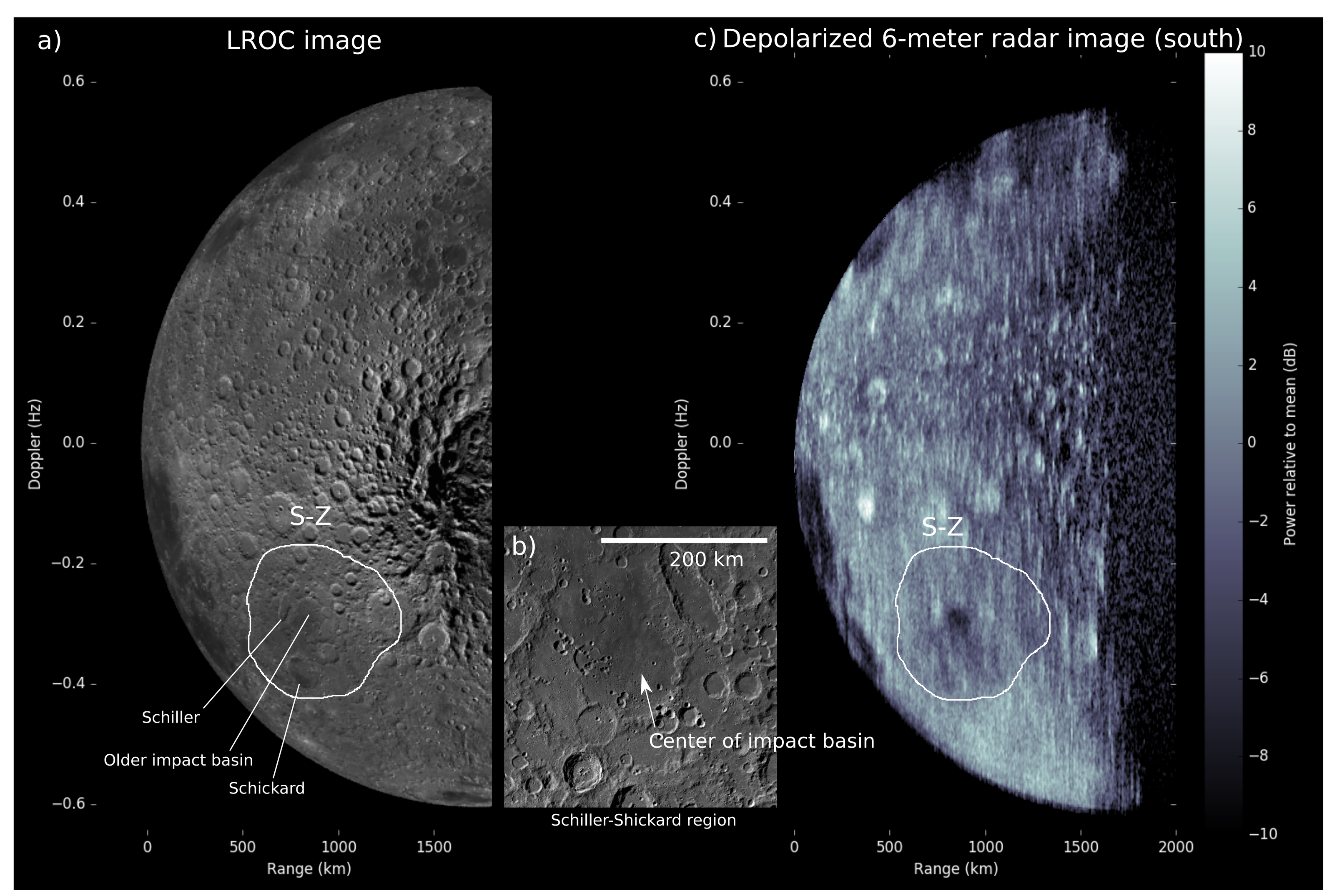

Fig. 3: Southern half of the lunar nearside. Schiller-Zucchius impact basin outlined in white.

Results

We found that the depolarized return from the S-Z region could be explained by a reduction in penetration depth caused by the presence of iron in the soil, consistent with visual studies of the area. In the northern F-I region, however, surface concentrations of iron are too low to explain the reduced power. We posit that there is an increase in loss-causing chemicals in the deeper surface layers, possibly caused by volcanism that has since been covered. The area shows no signs of large cryptomare structures. Neither area shows titanium concentrations above detection limit.

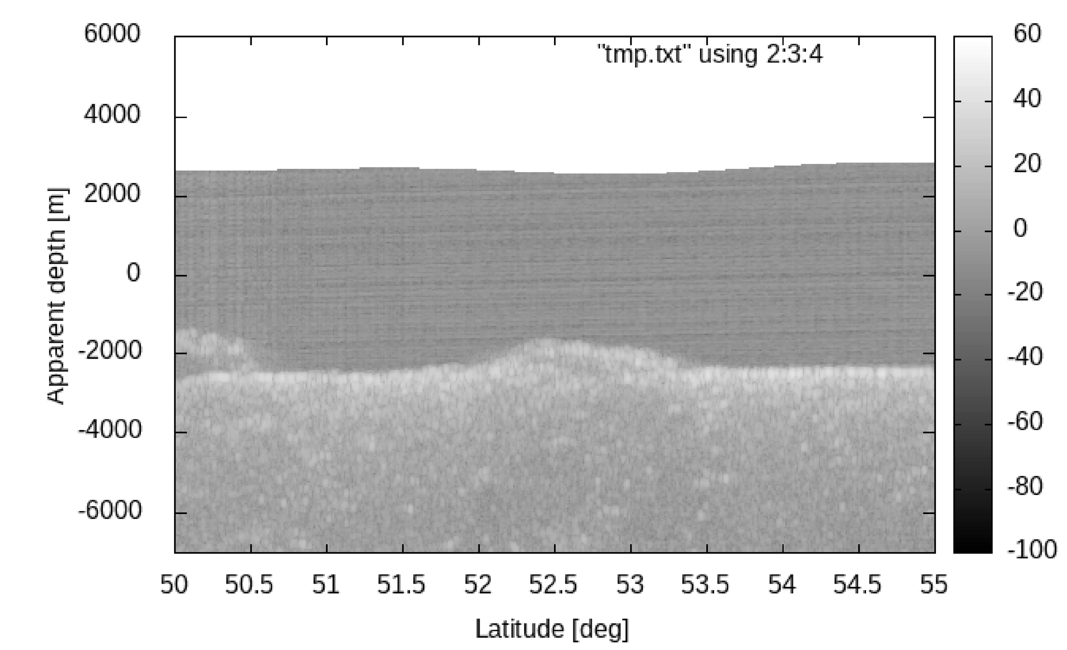

Fig. 4: Potential cryptomare subsurface on the western edge of the F-I region.

EISCAT 3D

The EISCAT 3D facility is an exciting new opportunity for Earth-based radar studies of planetary objects. The facility uses a wavelength not previously used for lunar studies, and the steering capability of the radar array allows for an unprecedented integration time.

- Interesting wavelength (good balance between SAR resolution and penetration depth)
- Full polarization capability, we can measure polarimetric scattering characteristics
- Long interferometric baselines, which allow good interferometry

Acknowledgements

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References

[1] Bruce A Campbell. *Radar remote sensing of planetary surfaces*. Cambridge University Press, 2002.

[2] Grant H Heiken, David T Vaniman, and Bevan M French. "Lunar sourcebook-A user's guide to the moon". In: *Research supported by NASA,. Cambridge, England, Cambridge University Press, 1991, 753 p. No individual items are abstracted in this volume.* (1991).

[3] Juha Vierinen et al. "Radar images of the Moon at 6-meter wavelength". In: *Icarus* 297 (2017),