SMITH COLLEGE

Memo

From: Jay Frothingham
To: EGR 390 class participants
Date: October 19th, 2022
Subject: A Memo on Lunar Penetrating Radar

Introduction

Students in the course EGR 390, a seminar on remote sensing, have been exposed to the basic technical principles of Ground Penetrating Radar (GPR) and had the opportunity to use donated GPR equipment. With this background, students are equipped to understand and discuss published journal articles related to GPR and its applications. The purpose of this memo is to summarize one such article, giving engineering students a more detailed understanding of advanced applications of GPR.

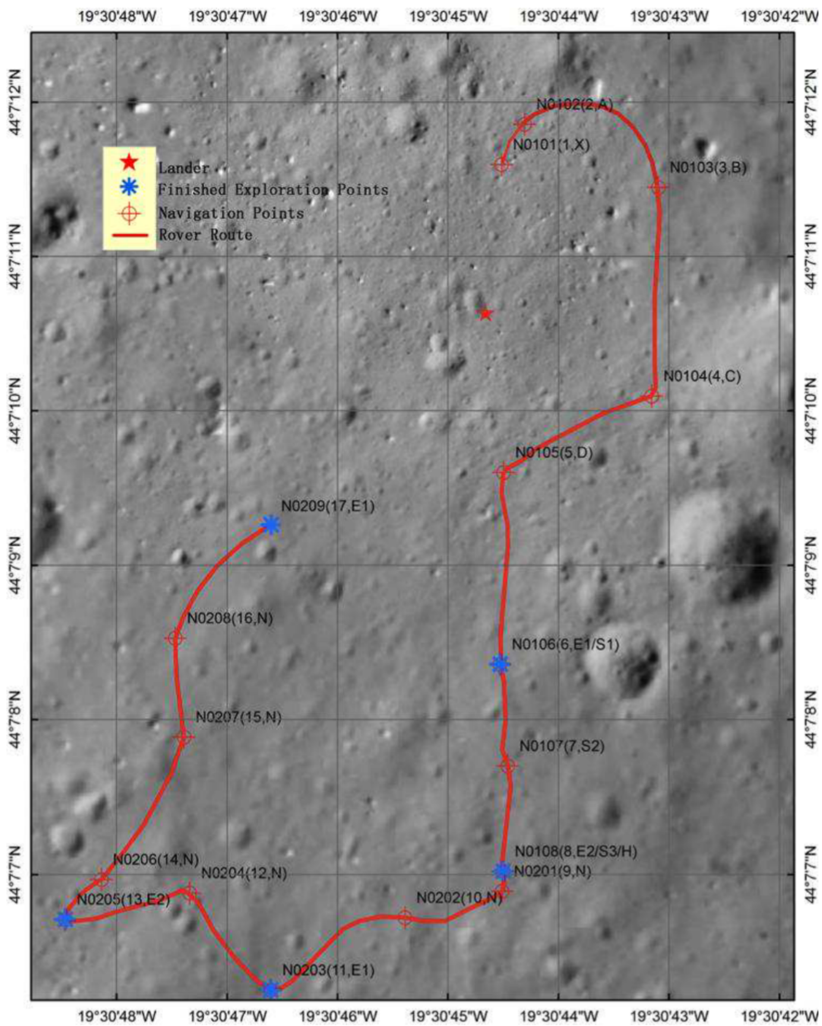
Paper description

Yan, Su, et al. "Data processing and initial results of Chang'e-3 lunar penetrating radar." *Research in Astronomy and Astrophysics*, vol. 14, no. 12, 2014, pp. 1623-1632, doi: 10.1088/1674–4527/14/12/010.

Understanding how Earth's moon originally formed and has since evolved is significant in improving our understanding of how similar bodies and systems may be found and studied. The Chang'e-3 (CE-3) lunar rover utilized Lunar Penetrating Radar (LPR), which operates on the same principles as high-resolution GPR, to image the lunar subsurface. As described by Yan, Su, et al., "There are three main goals in using radar to observe the Moon: firstly, to explore the lunar landscape including polar regions; secondly, to probe for water ice at the lunar pooles based on high resolution mapping; thirdly, to analyze and study lunar subsurface structures such as the thickness of regolith."

LPR data was collected continuously while the rover was in motion. While the rover was stationary, the data were sent back to Earth. Along with radar echo signal intensity, instrument parameters such as system gain and number of radar echo signals were also recorded and encoded into the data.

Figure 1. Route traversed by the lunar rover, with marked science and navigation stops.



The researchers processed the raw data by decoding the information transmitted by the rover, normalizing and eliminating systematic effects, and filtering. Tests of the equipment on Earth and in orbit were used to characterize instrumental effects.

To produce images, the researchers transformed radar observations from one coordinate system to another. Next, they edited the dataset to remove invalid data. A surprising amount of data was invalid; only 13% of the data was valid. Further data transformation involved removing background noise, smoothing data spliced between different observations, and performing gain resetting to amplify weaker signals.

Figure 2. Result using 60MHz channel. The arrows indicate prominent reflectors at a depth of about 330m. It is assumed that basalt has a relative dielectric constant of 7.

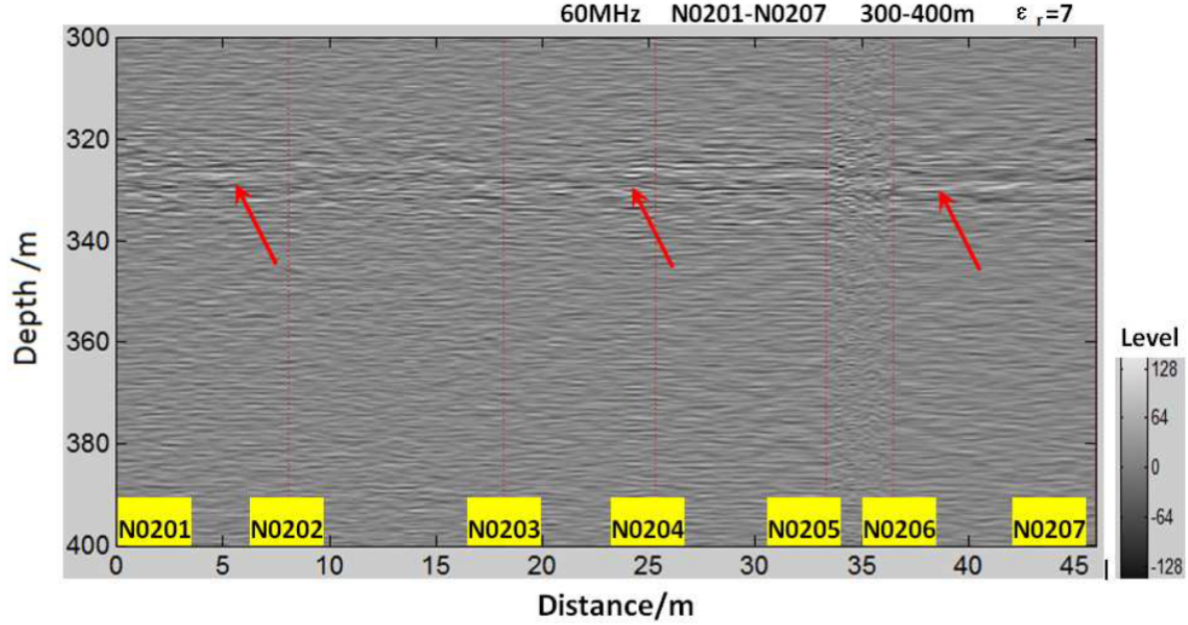
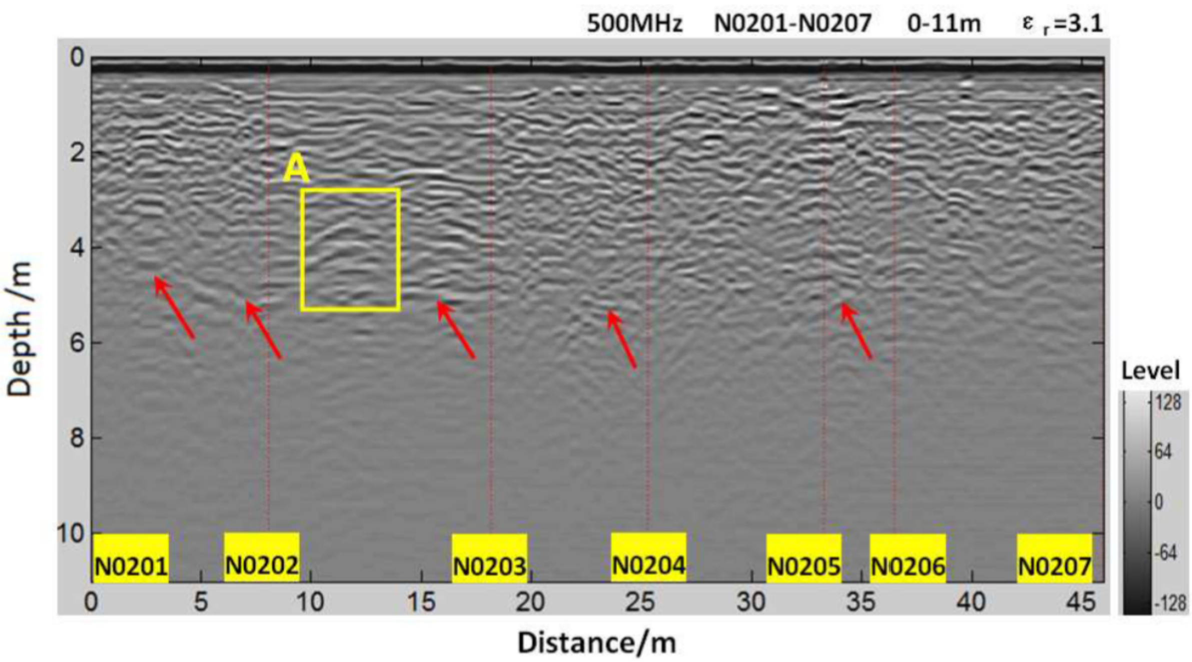


Figure 3. Result using 500MHz channel. The arrows indicate a layer of 4-6m regolith. The boxed region labeled by A indicates the possible location of a rock. It is assumed that the regolith has a relative dielectric constant of 3.1.



The rover's findings indicated layers below the moon's surface, possibly of regolith buried under basalt, which could support or inspire geological theories about the moon. However, this research was more focused on the validity of Lunar Penetrating Radar (LPR) than on investigating the structure of the moon.

In that regard, the researchers were successful. They showed that ground penetrating radar techniques can be applied on the lunar surface, and demonstrated possible methods of handling the resulting LPR data.

Thoughts

I chose this article because I am interested in astronomy and found it really exciting that GPR techniques have been used on the lunar surface. This research is fairly broad in scope. The results not only provide valuable information on the structure and formation of our moon, but also show the success of GPR techniques in unique situations. If GPR can be used successfully on the moon, that suggests that it can be utilized in a much broader array of environments and use cases here on Earth as well.

Overall, I think this was a “good” paper. I found it very clearly organized and easy to understand without skimping on the technical aspects of the research. The authors included enough context to highlight the significance of their results and compare to previous surveys performed with different techniques, but kept the content of the paper focused on their research. This made it easy to follow the authors’ reasoning throughout the paper. My main criticism of the paper is that the authors were good at including details about the methods used for data processing and analysis, but were less good at motivating why those methods were used. It may be that the authors assumed their readers have a certain technical background that I lack. However, this assumption did not impede my ability to read and understand the research, which indicates a well-written paper.

If I had the opportunity to go back in time and pick a different paper, I would absolutely still choose this one. I think it’s incredibly exciting that GPR can successfully be used on the moon without requiring significant changes to the data collection and analysis techniques. The paper was very interdisciplinary, discussing signal processing, electrical engineering, and lunar geology. Even with a strong background in some of those topics, there was a lot I learned from this paper.

Conclusions

The purpose of this memo is to explain an advanced application of GPR. In this memo, I have summarized a paper presenting work on how GPR has been used on the moon to determine information about the structure of the moon below its surface. This work is valuable for its discussion of GPR data processing and for showing a truly unique use of ground penetrating radar. This memo enriches students’ understanding of GPR’s applications and potential.