Examining Rock Coatings with LIBS Spectral and Acoustic Data

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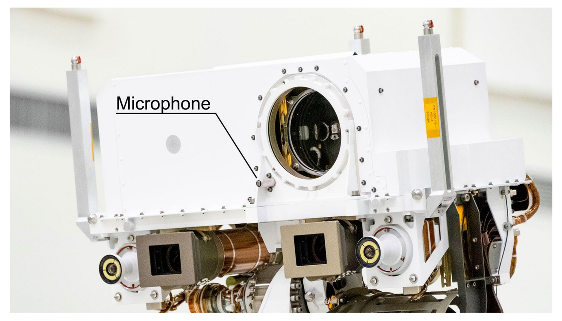

Abstract

Laser-induced breakdown spectroscopy (LIBS) is an analytical technique used by SuperCam on Mars to analyze the chemical composition of rocks. The laser heats the rock, transforming it into plasma, which generates a shockwave detectable by the SuperCam microphone. By ablating the sample, LIBS allows for investigating chemical stratification with depth. However, the LIBS spectra data is somewhat ineffective in detecting composition transitions between similar coatings and host bedrocks. The LIBS acoustic data provides additional information on rock properties, such as hardness. In this study, we compared the laboratory data of two rocks, one with a coating and the other uncoated, using both LIBS acoustic and chemical analysis. The results indicate that acoustics can identify the transition between the coating and the rock, offering a potential solution to overcome LIBS' limitations in discerning such transitions.

Introduction

Rock coatings are significant as they provide insights into the environmental modifications that have occurred on the rock surface [Lanza et al., 2015]. They also offer clues about the habitability of a region since they form through chemical weathering via aqueous alteration, which is important for habitability.

The SuperCam instrument on the Mars Perseverance rover has a laser induced breakdown spectroscopy (LIBS) instrument and a microphone. SuperCam is designed to analyze the mineral and chemical composition of rocks up to a distance of approximately 7 meters from the rover. In the LIBS technique, a laser is used to ablate small amounts of material (~micrograms) for chemical analysis. The laser heats the target, transforming it into plasma and exciting the electrons of the target atoms to higher electronic states. As these electrons return to their normal states, they emit photons at specific wavelengths. By capturing some of this emitted light, SuperCam can determine the chemical composition of the rock. Typically, the laser is pulsed with 30-150 shots at a single point, allowing for

Furthermore, LIBS analysis generates an acoustic signal along a depth profile. The plasma expansion, resulting from intense heat and pressure, creates a shockwave that is recorded by the SuperCam microphone and resembles a "pop" to the human ear

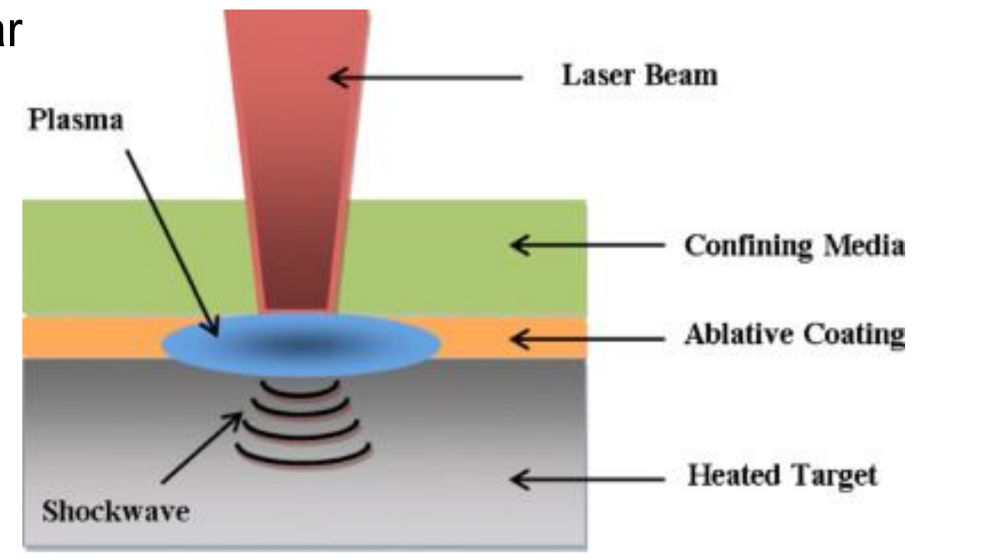

Figure 1: LIBS' laser heating up the rock to from plasma, which causes a shockwave

Experiments confirm that the decrease of the acoustic energy as a function of the number of shots is well correlated with the target hardness/density. Listening to LIBS sparks provides new information relative to the ablation process that is independent from the LIBS spectrum. [Chide et al., 2019].

LIBS is successful in detecting coatings when the bedrock and its coating differs by chemical composition. However, it is hard to use to detect rock coatings if the bedrock has a similar chemical composition as its coating. The laser-induced acoustic data are known to depend on rock physical properties as hardness [Chide et al., 2020] because the hardness of the rock affects the amplitude of the pop sound. Acoustics might be used to detect the transition between the coating and the rock if there is a gradient in hardness with depth. The goal of this project is to see if acoustics can be used to identify the transition between rock coatings and the rock.

Methodology

LIBS acoustic experiments were conducted using the SuperCam laboratory unit at Los Alamos. Rock samples were placed in a Mars acoustics chamber, simulating Mars' surface environment with low pressure and ambient temperatures. The SuperCam lab unit performed LIBS analysis, collecting spectral data, while a microphone similar to the one on SuperCam on Mars captured acoustic data within the chamber. The focus here is on one rock sample called N6B, a basalt rock with a rock varnish coating previously studied by Lanza et al. in 2012 and 2015. The collected LIBS spectral and acoustic data were preprocessed and normalized using methods consistent with SuperCam data from Mars.

To investigate the relationship between LIBS composition and acoustic data, the SuperCam tool called Display Spectra was used to extract LIBS spectral peak areas. The peak area of the Mn doublet (~403 nm) was used as a measure of LIBS composition, as rock varnish has high Mn content while basalt has low Mn content. Previous studies have shown a systematic decrease in Mn peak area for rock varnishes.

For each shot, the Mn peak area and the amplitude of the first acoustic waveform were examined. Two relationships were explored: peak intensity vs. shot (spectral data) and microphone amplitude vs. shot (acoustic data). The Mn peak areas were plotted against the number of shots, as well as the microphone amplitude. Additionally, a plot of peak area vs. microphone amplitude was generated to better understand the relationship between spectral and acoustic data.

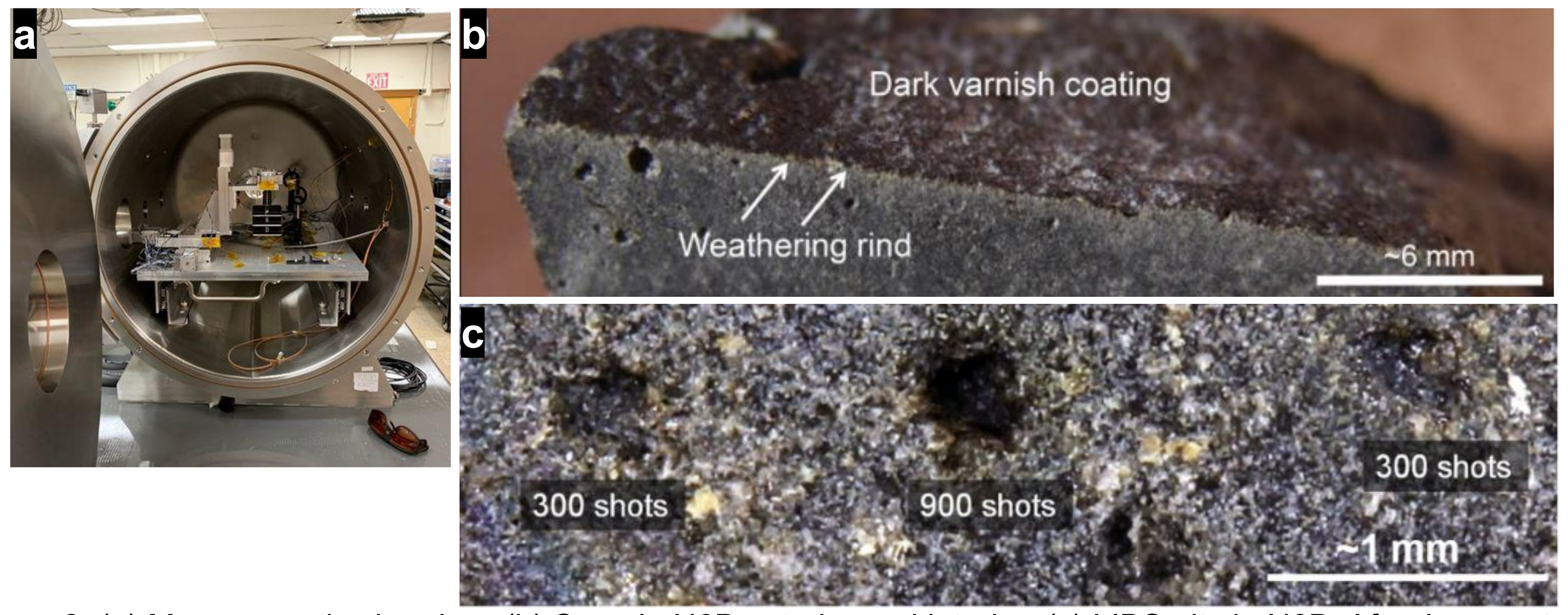

Figure 2: (a) Mars acoustic chamber; (b) Sample N6B exterior and interior; (c) LIBS pits in N6B. After Lanza et al., 2015.

Results

My results show that there is a relationship between the LIBS spectral and acoustic data. The Mn abundance decreases with shot (Fig. 3a). The acoustic amplitude decreases with shots in a similar way. (Fig. 3b). When plotted against each other, we can see that there is a clear relationship between Mn abundance and acoustic amplitude (Fig. 3c).

Both the mic amplitude vs. shot and peak area vs. shot graphs show a negative correlation between the variables. This makes sense because the coating is softer than the rock, so the graph would have a steeper slope at the beginning than at the end. Also, it is evident that there is a gradual attenuation of the signal over the shots, which is expected [Chide et al., 2019].

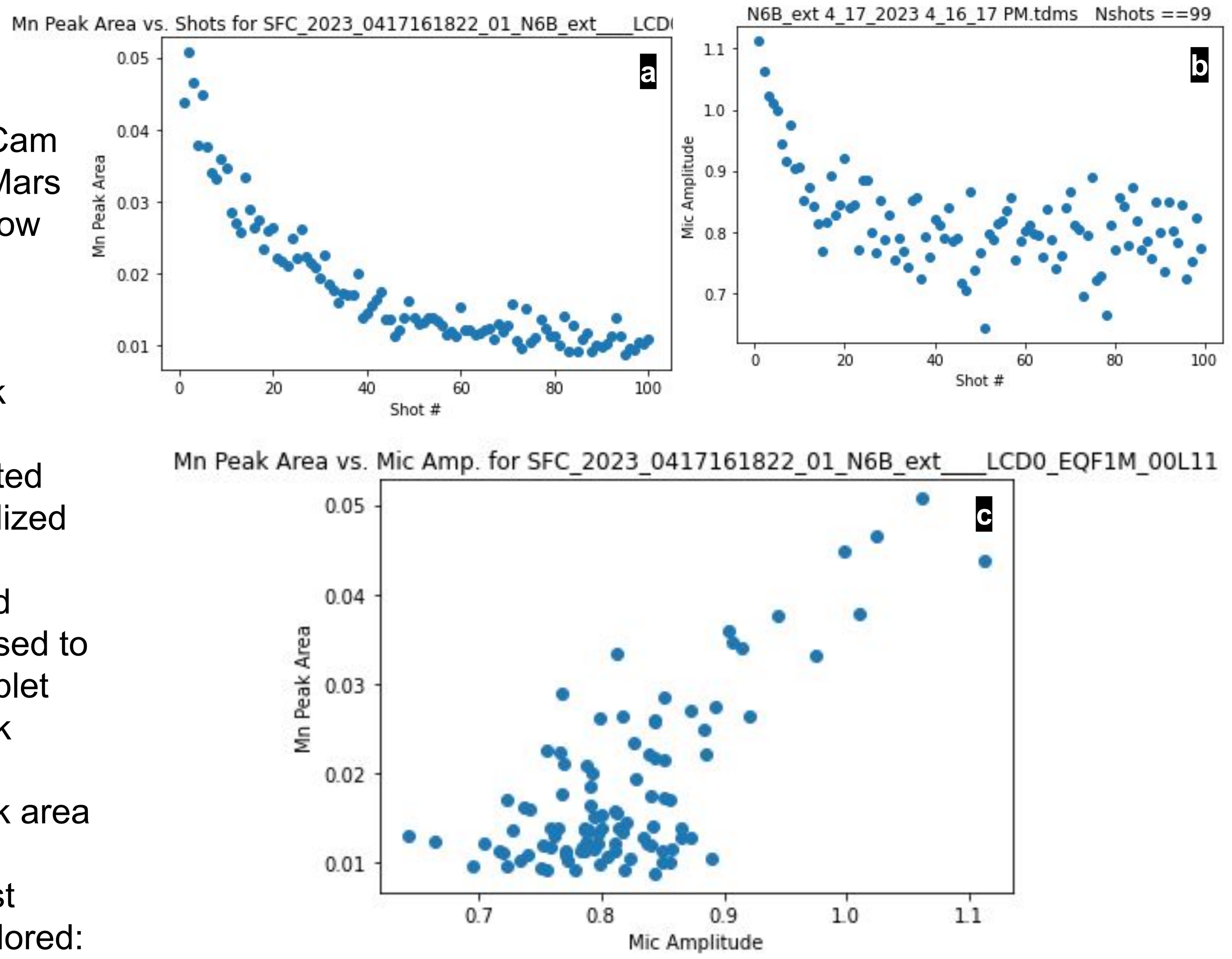

Figure 3: (a) Mn peak area (abundance) by shot; (b) Mic Amplitude by shot; (c) Relationship between Mn Peak Area and Mic Amplitude

Discussion

The graph for Mn peak area vs. mic amplitude shows a positive correlation. Therefore, the acoustic signal is directly correlated with the composition. This further validates the hypothesis that acoustics can be used to model the change in the rock properties over each shot. Therefore, acoustics can be used to identify rock coatings, and learn more about the difference in hardness between the rock and its coating.

References

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