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CaliPhoto: a powerful method to identify rock powders on Mars

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■ Introduction

In order to study unaltered rocks, Mars rovers are equipped with abrasive and/or drilling devices. NASA's Spirit and Opportunity rovers were equipped with a Rock Abrasion Tool to remove the first mm of altered material [1]. NASA's Curiosity and Perseverance and ESA's Rosalind Franklin ExoMars rovers are equipped with drilling device to collect samples for in situ analysis and, for Perseverance, in preparation for a future Mars Sample Return mission [2-4]. During these drilling phases, a pile of rock powder, of varying size depending on the drilling depth, forms at the surface.

The objective of the ExoMars mission will be to search for past or extant biosignatures for which drill-cores will be collected from up to 2 meters deep; the depth at which organic matter is preserved from degrading UV and particle irradiation. The drill has a diameter of 3 cm. The cone of powder at the surface could thus represent more than 1.5 dm³, a relatively large quantity of material which will not be analysed by the instruments inside the rover but which could be observed by the CLUPI and PanCam cameras [4-6].

Powder can be considered as a textureless material when the grain size is lower than the spatial resolution of the photograph, which is the case for rocks drilled on Mars as observed by MSL [2]. Colour is then the only measurable data; however, this apparent colour is totally dependent on ambient light and on the camera itself. In order to solve this problem, we have developed a new method called CaliPhoto, for which a reference plate is added to the camera's field of view and then image processing is used to compensate for camera characteristics and lighting conditions [7,8]. The images thus obtained can then be compared with each other or with a reference database. Here, we used a series of analogue rocks to demonstrate the ability of the method to identify volcanic rock powders on Mars.

■ Materials and methods

The majority of rocks on the surface of Mars are volcanic [9,10] thus, for this study, 23 relevant samples were selected from the Massif Central, in France, in order to cover a large range of volcanic rock types, as designated in the compositional TAS diagram (Total Alkali Silica). The samples were then crushed and each powder was placed in the centre of the CaliPhoto reference plate and photographed. The CaliPhoto image processing was then used to “calibrate” the photographs and a database was created (see Fig. 1).



Figure 1: Images of the volcanic rock samples after CaliPhoto image processing.

Results and discussion

Different tests were carried out [8]. First, each sample was photographed twice in different lighting conditions, the first image was imported into the database and the second was used to test the identification procedure. For 50% of powders, the identification is exact, i.e., the studied powder corresponds to the highest matching identification from the database, in 77% of cases, the studied powder is in the top two matches, and in 95% of cases, it is in the top three. Moreover, when the studied powder is not in the first position, the best match occurs for a rock of similar or close composition.

The analogue rock ESA-01-E (picrobasalt), chosen by ESA for its physical and chemical similarities to known Martian rocks, was then used to test the ability of the method to evaluate the composition of a powder that is not in the database. The method successfully identified the sample as a picrobasalt.

The rocks were crushed at 4 different grain sizes in order to evaluate the effect of grain size distribution on the method. Indeed, the apparent luminosity of powder is known to increase with decreasing grain size. For 32% of the powders the identification is exact, i.e., the studied powder corresponds to the highest matching value. Moreover, for 91% of cases, a rock with a similar or adjacent composition as defined by the TAS diagram is in the top three matches, even when the powder is not in the database.

Finally, by coupling hand sample and powder colour vectors, the identification is exact for 68% of

rocks and the studied sample is in the top three matches in 100% of cases. Moreover, when the studied sample is only in the second or third position, the difference with the best match is always lower than 1%.

▪ Conclusion and perspectives

The CaliPhoto method could be very useful on Mars to help identify rocks during drilling without adding any new instrumentation except a specific colour plate that could be positioned near the powders. Unfortunately, Mars rovers are not equipped with such a plate. Thus we proposed to use the calibration targets present on the rovers to calibrate the colour of the martian floor before drilling then to use it as reference for the CaliPhoto method. The first tests were relatively conclusive.

Finally, with the postponement of the mission, the CaliPhoto colour plate could constitute a good complement to the ExoMars rover.

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