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A K-Ar development based on UV laser for in situ geochronology on the surface of mars. Firsts results and isochrones.

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Abstract

We present a new analysis system for in situ K-Ar dating of martian rocks. This prototype is based on already spatialized technologies and instruments with some few improvements. The K-Ar geochronogical method has the best potential for rock dating at the surface of Mars thanks to the widespread basalts and to the potassium as a major element of this petrology. The Laser Induced Breakdown Spectroscopy (LIBS) determines the mineralogy and the concentration of K during the ablation of the sample. A quadrupole mass spectrometer (QMS) measures the quantity of ^{40}Ar released from this ablated volume. And an extensive database based on numerous measures allows us to estimate the ablated mass on different minerals. As a prototype, this experiment has for goal to estimate the capabilities of this method.

1. Introduction

One of the last major geological data that's still undone on Mars is the absolute dating of Martian rocks sampled on its surface. Even if this information has a high scientific interest, it still difficult to reach. Since 3 years, there is a bloom of a new generation of instruments in development for in situ rock dating on Mars. For K-Ar dating, they are 4 projects including this work. Farley et al. [1] at the JPL explores the double spike method. B. Cohen et al. [2] at the Marshall SFC, NASA and Y. Cho et al. [3] at the University of Tokyo adopt an equivalent method to this work, except that they are using an IR laser for the ablation in addition to their own specific protocols.

The idea of K-Ar development based on laser ablation is to measure in an ablated volume the concentration of K by LIBS, the quantity of ^{40}Ar by a quadrupole mass spectrometer (QMS) and it needs to determine the ablated mass. The density is deduced from of the target is based on various observations (LIBS, etc…). The dimension is depending of the target matrix (density, reflection, chemistry,…) so it can be deduced with the LIBS spectra and visual observations as we observe that the volume is reproducible for a similar matrix.

2. Instruments and calibrations

This prototype uses a Nd:YAG laser operating at 266 nm. It performs at 0,1 W per pulse a 14 ns pulse duration at 10 Hz and ablates a basaltic sample put at high vacuum (10^{-7} mbar). As many others projects using LIBS for geology, the optical spectrometer is an Ocean Optics HR2000+. The spectral range is from 385 to 835 nm. It allows the identification of many major elements including Ca, Fe, Mg, Na and O. The argon is detected by a QMS (SXP Elite system by VG with a part of the original devices replaced for our requirements).

The LIBS had been calibrated with Brammer standard of basalt, fused in oven and put at high vacuum. The QMS electron multiplier had been calibrated with Gl-O geochronogical standard [4]. The electrical response is adjusted via the signal of a calibrated volume of argon. Because of the wavelength of the laser, there is not thermal diffusion during the ablation (contrary to the IR laser) and so we assume that the argon released during the ablation only comes from the ablated volume. So the last parameter needed to calculate the age is the ablated volume. The shape and the dimensions depend mainly on the reflection, the chemistry, the surface roughness and so to the mineralogy. We suppose that if the sample has the same properties as our database model, the shape and the dimension should be

determined. We cross two methods to confirm these measures. As we worked on already dated rocks, the math of datation can be turned off to determine the ablated volume. The second way is to use optical instruments to measure the volume. This second option will be developed soon.

3. Protocol

A few millimeters thick sample of basalt is set in a vacuum chamber. Kept at 10^{-7}mbar by a turbo-molecular pump, the chamber is also baked at about 100°C in order to protect the viewport. After 2 or 3 days, depending of the signal of ^{40}Ar measured by the QMS, we decide to proceed to the ablation. So the UV laser vaporizes the basalt during 90 seconds. In the same time, about 10 spectra of LIBS are recorded and analysed. Then, the released gas is spread through a pneumatic valve to a getter in order to be purified during one minute. Finally, the gas (mainly^{40}Ar) is spread to the QMS to be analyzed. This signal is subtract to the mean of "blank of argon" done before and after the ablation protocol. The LIBS spectra and a visual observation of the sample give to us the mineralogy of the spot and so we estimate its density. In the same way, we also determine what is the closest sample of the database to estimate more accurately the ablated volume.

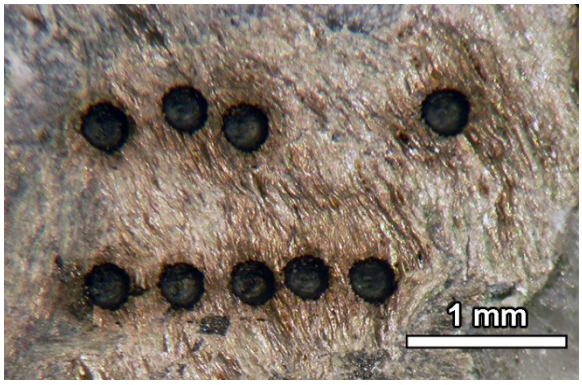

Fig. 1. Ablations spots on a pyroxene after 900 pulses at 0,1W per pulse.

4. First results

The main development is finished and so we are now learning the behaviour of the interactions between the UV laser and the basalt under secondary vacuum. We have worked on different mineralogy and petrology. Each of them has different properties which will be very important to consider the capability of dating. We already have measured about 400 dating measurements that we will develop soon. With these data, we are already able to discriminate what minerals have the best properties to get isochrones or ages.

5. Future work

The main error is due to the LIBS measure of K. In the literature, the measure of K at the atmospheric pressure is about 5 to 10%. Stipe et al. [5] has shown that the measure and the limit of detection can be enhanced with some specifics conditions. However under high vacuum, the behaviour of the plasma is different and so the LIBS spectra. And during the 90 seconds of ablation, many spectra are recorded and often show evolution of the signal (pikes, continuum). The understanding of these spectra and how to get a better precision of this measure during the ablation will be really important. A second point will be to complete the database of mineralogy to have the best estimation of the ablated volume.

6. Summary and Conclusions

The results that we'll be shown describe the influence of the minerals on the measurement. These first data enhance rock dating based on this method and indicate the way to follow for the upcoming work. As much for the target as for the technologies.

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