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The composition and homogeneity of the Allende matrix

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Abstract

We present the analyses of 19 elements in a sample of Allende meteorite, measured with a laser ablation/ionisation mass spectrometer (LMS). The high spatial resolution of the instrument allowed to analyse the meteorite matrix exclusively. We present our results on the element composition and mineralogy of the matrix. In addition, we conclude on the meteorite formation process from a sound analysis of the matrix homogeneity.

The LMS is suitable for being operated on a planetary lander or rover, where it would allow for such high performance in-situ studies of rocks on the planetary surface.

1. Introduction

The knowledge of the chemical composition of moons, comets, asteroids or other planetary bodies is of particular importance for the investigation of the origin and evolution of the Solar System. High resolution in situ studies on planetary surfaces can yield important information on surface heterogeneity, basic grain mineralogy, chemical composition and age of surface and subsurface. In turn, these data are the basis for our understanding of the physical and chemical processes which led to the formation and alteration of planetary material [1].

2. Method

We present a highly miniaturised laser ablation/ ionisation mass spectrometer (LMS) that was designed and built for space research at the University of Bern [2, 3]. The instrument is suitable for its application on a planetary lander [4] or rover. With the LMS, we investigated a sample of the Allende meteorite with a spatial resolution of about 10 µm in lateral direction. The high sensitivity and high dynamic range of the LMS allow for quantitative measurements of the abundances of the rock-forming and minor and trace elements with high accuracy [3, 5].

3. Analysis

The chemical composition and mineralogy of a sample of Allende meteorite [6] was investigated with high spatial resolution. The comparison of optical images with element maps served as a tool for the identification of matrix material [7]. Fig. 1 shows an example from the various measurements

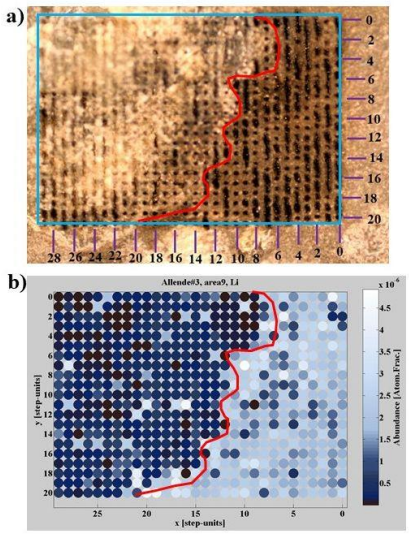

Figure 1: Element maps
Optical image of a measurement area (a) and the resulting map of Li abundance (b).

carried out on the sample. Fig. 1a shows the optical image after the measurements with the LMS in a rectangular pattern of 30 x 21 positions and Fig. 1b shows the abundance of Li in these positions, where darker colour corresponds to lower abundance. Using maps, similar to this example shown, 1012 analyses were identified as matrix material out of a total of 1651 measurements. From these analyses the abundances of C, O, S, Na, K, Li, Mn, P, Cr, Si, Fe, Mg, Ni, Co, V, Ca, Al and Sc in the Allende matrix were derived.

The large number of measurements on the meteorite matrix, partly covering areas in the mm^2 range, allowed for a study of the matrix homogeneity by using a sliding average filter. Using this method, the deviation of a single measurement to the average of all measurements covered by the current position of the sliding average serves as a measure for the homogeneity. Fig. 2 shows these standard deviations for the analyses of V. When increasing the sliding average grid size from 1x1 to 7x7, the width of the distribution is clearly decreasing, which is in first order due to the improvement of the statistical accuracy. In addition, we developed a method to distinguish the statistical accuracy increase, when including more measurements, from that part that is attributed to the homogeneity of the material itself.

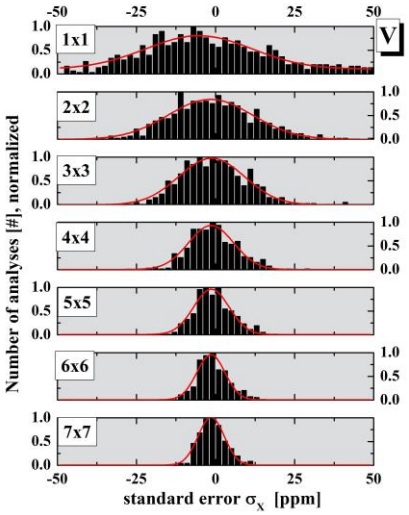

Figure 2 Homogeneity Analysis
Standard deviation of the abundance of V in Allende matrix for seven different sizes of moving average.

4. Summary and Conclusions

We present a comprehensive study of the composition and homogeneity of the Allende matrix. The LMS instrument allows measurements of the element composition and mineralogy of the meteorite matrix in-situ without any sample treatment prior to the measurements. The high dynamic range of the LMS allows analyses of rock-forming, minor and trace elements in one measurement. In agreement with previous studies on Allende we find that the meteorite matrix has a higher abundance of volatile elements, while the chondrules are made up of minerals with a higher content of refractory elements. In addition, our study show that the matrix is highly homogeneous, particularly for the rock-forming elements. We show that this implies that the process that lead to the formation of the meteorite, i.e. to the compound of chondrules and matrix, cannot be explained by a sticking process, but rather by a fast collapse.

The LMS is a small and light weight instrument, designed for operation on a planetary lander or rover. With our studies of the meteorite as an example, we show that the LMS would be a suitable instrument for high-quality quantitative chemical composition measurements on the surface of a celestial body like a planet, moon or asteroid.

Acknowledgements

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