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Raman and XRF analysis of the new NWA 11273 Lunar meteorite.

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Abstract

Until today, there are not scientific publications about the geochemical composition of the NWA 11273 Lunar meteorite, officially included in Meteoretical Bulletin Database in 2017. However, its analysis could give more data about the geo-chemical composition of the lunar surface and the conditions suffered by the meteorite until its arrival to the Earth. Considering this, Raman spectroscopy and X-Ray Fluorescence were employed in order to obtain a first map of the elemental and mineralogical composition of this meteorite. In this way, several silicates, phosphates and sulphates were detected.

1. Introduction

Apollo and Luna missions brought to Earth Moon surface samples which still are under analysis to gain knowledge [1]. The collected samples and the Lunar Meteorites are the extraterrestrial materials used to answer the questions arisen along the time about the composition, origin and evolution of the Earth natural satellite. Nowadays, despite of the fact that the composition of the mantle is still debated, the feldspar is fairly sure to be the main compound in the surface. These feldspars appear in certain areas together with the so-called mare basalts. To provide more data about the composition of the Moon, the NorthWest Africa (NWA) 11273, a recently (2017) included Lunar Meteorite in the Meteoretical Bulletin Database, has been studied in this work. Until now, there are not scientific works published about this meteorite so far. Therefore, this study will be focused on the analysis of the mentioned specimen by using non-destructive analytical techniques to ascertain the elements contained in the surface and the different mineral phases, as a first step to further accomplish the analysis inside the body of the different specimens in our hands.

2. Sample description

The NWA 11273 meteorite is a Lunar feldspathic breccia [2]. It was found buried in Algeria in 2017. It is said to be composed by clasts of anorthite, olivine, pigeonite, augite, chromite, Ti-Cr-Fe spinel, kamacite, taenite and troilite. Rare basalt clasts and glass fragments are said to be also present. However, no official peer reviewed works extend this information.

The analyzed specimen is a polished slice without crust belonging to the University of the Basque Country (collection of the IBeA research group).

3. Materials and methods

In order to obtain as much information as possible but preserving the sample for further analysis, non-destructive analytical techniques were employed as a first step of the specimen study. In this way, Raman spectroscopy, for obtaining molecular information, and X-Ray fluorescence (XRF), for elemental analysis, were selected as the most suitable techniques [3]. The Raman spectroscopy analyses were performed using a InVia confocal micro-Raman spectrometer (Renishaw, UK), provided with a 785 and 532 nm excitation lasers and a CCD detector working in both point by point and Raman image mode, using laser power filters to avoid thermal transformations, with a resolution of 1 cm^{-1}. The XRF analyses were conducted with a M4 TORNADO micro-spectrometer, in point-by-point and image modes with spatial resolution down to 25 µm, for Mo Kα radiation, that can be increased up to 200 µm.

4. Results and discussion

By means of XRF analysis it was seen that the major elements (beyond a 0.1% w/w) present in the sample were Si, Ca, Al, Fe and Mg (Figure 1). Moreover, other minor elements were also detected such as Mn, Ti, K, Ni, S, Na, Cr, Sr and Zr. Some metallic areas were also distinguished composed by Fe and Ni.

Raman spectroscopy gave us the molecular (mineralogical) composition in the different areas of the surface of NWA 11273. It has to mention that anorthite was the main detected phase together with olivine, augite and other pyroxenes, as it was expected [2]. It is worthy to point out that the olivine ranges, calculated from the two main Raman bands, are in concordance with those ranges stated in the unique information source about this meteorite [2]. In this study, the olivines ranged from Fo56-Fa44 to Fo83-Fa17 and in the mentioned source [2], went from Fo40.3-Fa59.7 to Fo91.3-Fa8.7. This is in agreement with the pink color distribution, seen in Figure 1 that corresponds to the areas where magnesium is the major element.

Apart from the expected ones, other mineral phases such as zircon and apatite were also found. The case of the zircon deserves a special mention since the Raman band appeared at 1006 cm^{-1} instead of 1008-1010 cm^{-1} where the non-shocked zircon appears. This band shift occurs when the zircon has been subjected to pressures around 20 GPa [4]. This pressure effect is also observed in the zircon band at 439 cm^{-1} which is shifted in the zircon detected in this work to 441 cm^{-1}. This finding proves that the specimen was subjected to high pressures probably when ejected from the surface of the Moon.

In addition, a sulphate with its main Raman band at 987-988 cm^{-1} was detected. This is an important discovery as no sulphates have been so far related to the Moon composition. Unfortunately, no secondary Raman bands were clearly detected in our study and therefore the exact identification of the sulphate resulted impossible. Notwithstanding, by overlapping Raman and XRF results on the area where the sulphate was detected, it was seen that the main elements were sulphur and nickel; therefore, it can be thought that the detected compound was a nickel sulphate. Actually, the main Raman band could coincide with dwornikite ($NiSO_4 \cdot H_2O$) or regertsite ($NiSO_4 \cdot 6H_2O$). However, this hypothesis must be sustained with further analyses to confirm the presence of water of crystallization.

Besides, calcite and hematite were identified in the surface of the meteorite. They are thought to appear due to weathering process. For instance, calcite is always related to veins and cracks. Regarding hematite, it could appear by the oxidation of the mentioned metallic areas as its presence is only as minor grains.

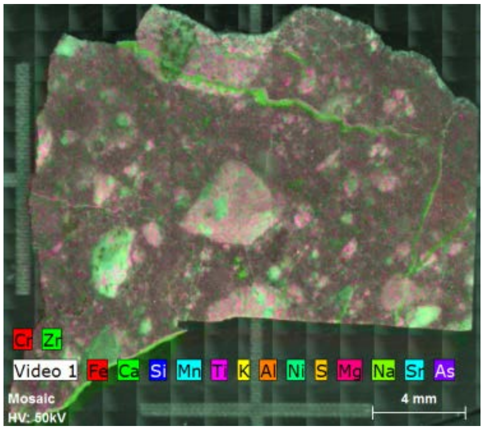

Figure 1. XRF image of the NWA 11273 meteorite showing the distribution of the major elements.

5. Conclusions

As a conclusion, it can be said, that the analysis of new meteorites could provide valuable data about the original composition and the physical-chemical processes that are taking place in our natural satellite. It is also crucial to distinguish between the weathering processes that a meteorite suffered once in the Earth with the weathering processes that the rocks suffer in the past on the Moon surface. Finally, it should be pointed out the importance of the apatite and sulphate findings, arisen from the study of the NWA11273 Lunar meteorite.

Acknowledgements

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