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Cosmogenic noble gases in lunar meteorites: unravelling the history of the lunar regolith

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1. Introduction

We are conducting a survey of the cosmogenic noble gas isotope record of lunar meteorite samples, to determine their exposure and closure ages and constrain their depth of burial on the Moon.

Lunar regolith meteorites are ejected from the Moon by asteroidal and cometary impacts and delivered to Earth [1]. We are initially investigating twelve lunar meteorites from the ANSMET meteorite collection. Lunar meteorites represent material that is sourced from random localities on the Moon that are previously unsampled, including our only samples from the lunar farside. Thus, these meteorites are from mixed provenances, which include feldspathic rocks, basaltic rocks and mixed feldspathic and basaltic types: this is to investigate the regolith in different types of crustal terrains.

2. The Lunar Regolith Archive

Regolith is a term used for the layer of fragmental and unconsolidated material that covers most of the lunar surface, and also applies to many other Solar System bodies. This layer is created by repeated and continuous bombardment of impacts, which acts to rework and mix the surface creating a predominantly fine-grained layer [2]. This process causes the frequent burial, exhumation and the overall transport of individual grains from depth, known as the ‘gardening’ process.

The Moon lacks an atmosphere to protect it from the energetic particles released from the Sun and those that are incident from outside of our Solar System. Therefore, the regolith acts as a boundary between the Moon and the dynamic energetic space environment, preserving a record of this history [3, 4, 5].

The lunar regolith, thus, contains a wealth of information about the types of processes that have modified the lunar crust through time [2]. Understanding the properties and processes of the regolith is an important tool when it comes to exploration on the Moon. This knowledge is vital for determining landing sites for possible robotic and human exploration and understanding the potential resources within the regolith for human exploration of the Moon [6].

3. Cosmic Ray Exposure Ages

Galactic and Solar cosmic rays (GCRs and SCRs respectively) directly interact with surface-exposed regolith material on the Moon, producing cosmogenic isotopes [7]. Rocks and minerals obtained and ejected from the top few meters of the lunar surface have all experienced some exposure to cosmic rays. Exposure ages are calculations of the length of time a rock/mineral has resided at or within the top few meters of the regolith. The study of these cosmogenic isotopes and exposure ages is an important tool for understanding the formation and evolution of a planetary crust [8], the interaction with the space environment and the cratering history of the Moon [2].

We will measure the cosmogenic noble gas isotopes of lunar meteorites (i.e., ^{3}He, ^{21}Ne, ^{38}Ar, ^{83}Kr, ^{126}Xe) using the Isotope Geochemistry and Cosmochemistry Group’s (University of Manchester) Mass Analyser Products (MAP) 215 mass spectrometer coupled to a resistance furnace. To calculate the cosmic ray exposure age the production rates, which depend on the depth and chemical composition of the target rock, as well as the shielding depth needs to be known [e.g., 9, 10].

Therefore, to characterise the chemistry and mineral makeup of each meteorite a fraction of each sample will also be analysed using a Phillips (FEI) FEG-SEM with EDAX Genesis (EDS) system and Cameca SX 100 EMPA WDS. The FEG-SEM datasets include back-scatter electron images and element maps (Fig. 1) for petrographic characterisation, providing constraints for the calculations of the cosmogenic nuclide production rates.

4. Scientific Goals

Our aim is to determine the residence time, ejection age (duration of exposure), closure age (time of burial [11]), and the average depth (shielding depth) of each sample as it resided on or near the lunar regolith prior to excavation. This will help to further understand the processes that manage to construct, destroy and evolve the lunar regolith in areas remote from the Apollo landing sites.

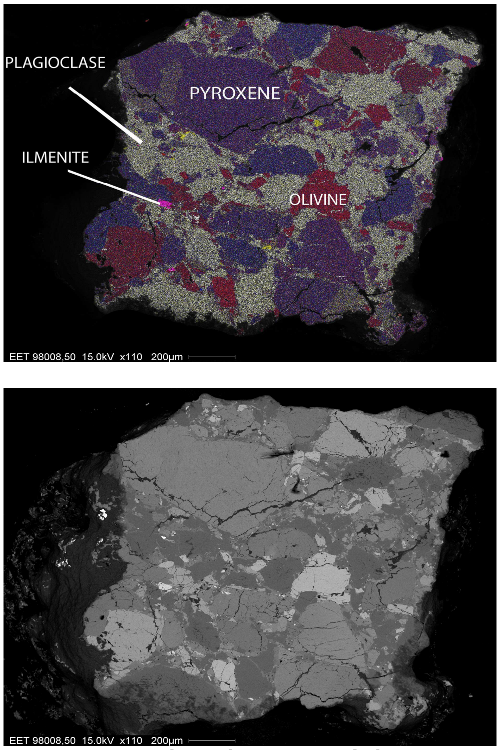

Figure 1: Petrographic and compositional characterisation of one example of the lunar meteorites under study. (Top) False-colour map of EET 96008,50 polished block. Map has been colourised to show chemical variation with mineral association: in this colour scheme Ca = yellow, Mg = green, Si = blue, Fe = red, Al = white, Ti = pink, and K = cyan. (Bottom) Montaged back-scattered electron image of EET 96008,50 showing mineral diversity and textural relationships.

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