THE MOON'S REGOLITH ARCHIVE IN LUNAR METEORITES. N. M. Curran[1], K. H. Joy[1], H. Busemann[1], R. Burgess[1] [1]School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK (natalie.curran@manchester.ac.uk).

Overview: A number of lunar regolith meteorites have been selected to assess the impact flux on the lunar surface through time. We will assess the surface maturity and calculate the cosmic ray exposure (CRE) ages of each sample to determine their regolith history. Our sample suite includes samples of feldspathic highland breccias, mare basalts and mixed feldspathic-basaltic breccias, some have never previously been analysed for their complete cosmogenic noble gas inventory.

Surface Maturity and CRE Ages: The surface of the Moon is a very dynamic environment. As the Moon has no atmosphere, the regolith is exposed to bombardment from micrometeorites (<1 mm), particles from the sun (solar wind, SCRs – solar cosmic rays) and the wider galactic environment (GCRs – galactic cosmic rays) [1]. Micrometeorites and solar wind particles only interact with the immediate surface (top few mm) and increased exposure to these particles results in the maturation of the regolith [2]. Trapped noble gases (e.g., ^{36}Ar) correlate well with other maturity indices such as the I_s/FeO index (the intensity of ferromagnetic resonance normalised to the bulk Fe content) (Fig. 1), which has been shown to be proportional to the duration of surface exposure [2, 3]. Only for three lunar meteorites (MAC 88104/5, ALHA 81005 and QUE 93069) have I_s/FeO values been published [4, 5] and the technique is not currently used. Therefore, determination of the trapped gases in the meteorites will be critical to assessing the maturity of the samples. In contrast to micrometeorites and solar wind, SCRs and GCRs penetrate up to a few cm to meters into the regolith, respectively [1]. Cosmogenic isotopes are produced during this interaction and the CRE age is defined as the duration the sample has been exposed to these cosmic rays, in the lunar regolith or during transfer as a meteoroid in space. To calculate this age, the production rates for each cosmogenic nuclide is needed, which depends mainly on the chemistry and depth of the target rock [6, 7]. The trapped noble gases and CRE age can be determined to understand the history of the sample during its lifetime in the lunar regolith.

Lunar regolith meteorites are ejected from random localities across the Moon, by asteroidal and cometary impacts [8, 9]. All lunar meteorites have experienced some exposure to cosmic rays either while residing in the top few meters of lunar regolith (2π irradiation), during transit to Earth (4π irradiation), or both [8, 10]. As a result, lunar meteorites provide the opportunity to look at the exposure history and regolith archive on a global scale, compared with the Apollo and Luna sample collection [11].

Analytical Technique: We have developed a micro-furnace technique to analyses the noble gas isotope concentrations of small (1-10 mg) bulk lunar rock chips and soils. A low volume resistance filament furnace, for higher sensitivity and low blanks, is connected to a VG5400 noble gas mass spectrometer. Noble gases are released in temperature steps (from ~600°C up to ~1500°C) to distinguish the surface-correlated trapped gases from the volume-correlated cosmogenic gases. This technique is being applied to determine: (i) the cosmic ray exposure age, (ii) the shielding depth, (iii) the closure age and (iv) the duration of surface exposure (i.e., maturity) of each meteorite.

The petrology and mineral chemistry of the samples are assessed using polished blocks made from sub-splits of each sample (~3-6 mg). A Philips FEG-SEM with EDAX Genesis EDS system is used to produce back-scatter electron images and false-colour element maps and a Cameca SX 100 EMPA was used to determine mineral chemistry. These data will be used to test the consistency of the mineral chemistry with the reported bulk rock chemistry. Production rates of cosmogenic noble gas isotopes can then be determined from bulk rock compositions and used to calculate the cosmic ray exposure age of samples.

Apollo Regolith Record: Regolith breccias collected at different Apollo landing sites generally fall into two categories: young and ancient breccias (as measured by the antiquity indicator $^{40}Ar/^{36}Ar_{tr}$) [12, 13]. The ancient breccias have closure ages (breccia formation ages) of >3.5 Ga and are from immature (i.e., low I_s/FeO, $^{36}Ar_{tr}$) soils with exposure ages of only a few million years (Fig. 2) [12]. Younger regolith breccias <3.5 Ga typically exhibit greater degrees of maturity (i.e., high I_s/FeO, $^{36}Ar_{tr}$) with a range of CRE ages (Fig. 2). The difference between the types of regolith breccias is possibly associated with the changing impact flux on the lunar surface through time. The ancient regolith breccias relate to a period of intense large-scale basing-forming events and rapid overturn of the regolith [12, 13]. Whereas the younger regolith breccias have been exposed to more less energetic but more frequent impacts (e.g., micrometeorites) and reprocessed on a smaller scale over a longer period of time.

Scientific Goals: Our goal is to test if lunar meteorites display the same or similar link between their level of maturity and their breccia formation age. Assessing the impact flux at different periods in lunar history can provide an archive of regolith processes through time [14, 15].

The initial results of our noble gas study will be presented at this meeting and added to the current growing data-set from lunar meteorites providing new constraints on the global context of the evolution of the lunar regolith.

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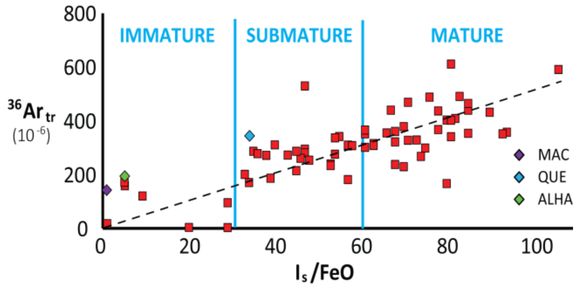

Figure 1: Apollo soil literature data for the maturity indices Is/FeO and trapped 36Ar. Increased maturity is associated with increased surface exposure (top few mm). Data for lunar meteorites MAC 88104/5, QUE 93069 and ALH 81005 are also shown [4, 5].

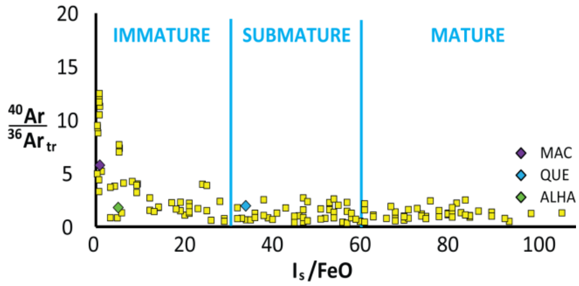

Figure 2: Apollo soil and breccia literature data for the maturity indices Is/FeO and trapped 40Ar/36Ar values. Data for lunar meteorites MAC 88104/5, QUE 93069 and ALH 81005 [4, 5, 15] are also shown.