REGOLITH HISTORY OF SIX LUNAR REGOLITH BRECCIAS DERIVED FROM NOBLE GAS ELEMENTAL AND ISOTOPIC ABUNDANCES.

P. Will, H. Busemann, M. E. I. Riebe and C. Maden
Institute of Geochemistry and Petrology, ETH Zürich, 8092 Zürich, Switzerland. patrizia.will@erdw.ethz.ch.

Introduction: The Moon offers an invaluable archive of planetary formation, magmatic, impact and regolith processing of our solar system [1]. Processes such as large impacts producing craters to erosion by particles producing sub-micron-sized pits are recorded in the lunar surface over billions of years, while solar wind and cosmic-ray particles produce effects at the atomic scale [2]. The nearside of the Moon was sampled by the Apollo and Luna missions [3], while samples from the farside are currently only available by meteorites. The evolution of the lunar regolith can probably best be studied by noble gases. The noble gas isotopic and elemental composition reveals for instance the composition and (potential) evolution of the solar wind, monitors the exposure to galactic cosmic rays, records impact events, and finally allows us to assess the transport history to Earth. Here we present noble gas data on six Antarctic and Northwest African lunar regolith breccias of different lithologies not studied for noble gases elsewhere so far [initial results given in 4], and discuss their lunar surface history and processes, possible pairing, and ejection events.

Samples: Northwest Africa (NWA) 10404 is classified as feldspathic regolith breccia and exhibits a mostly vitric and vesicular matrix [5,6]. NWA 11237 is a feldspathic breccia with mineral clasts and some sparse glass fragments in a finer-grained vesicular matrix [7]. Similarly, NWA 11273 is a feldspathic breccia composed of mineral and rare basaltic clasts in a finer-grained vesicular matrix [7]. Meteorite Hills (MET) 01210 represents a polymict regolith breccia containing mostly coarse-grained, low-Ti mare basalt and minor anorthositic highland clasts [8,9]. Mount DeWitt (DEW) 12007 is a polymict regolith breccia predominantly composed of glassy impact-melt breccia particles, gabbroic and feldspathic clasts in a fine-grained matrix and contains vesicular shock-induced glass veins [10]. Pecora Escarpment (PCA) 02007 is a polymict, dominantly feldspathic regolith breccia with some basaltic clasts, agglutinates and impact glasses in a fine-grained partially glassy matrix [9].

Methods: Noble gas analyses were carried out on interior sample splits. Fragments with weights of 1 to 100 mg were degassed at 100 °C in the UHV storage system for several days. The noble gases were extracted by melting to ~1700 °C for 30 minutes. Gas purification, separation and measurements followed the procedure described by [11]. Re-extractions at ~1750 °C confirmed complete degassing. Blank contributions were negligible.

Results: PCA, MET, NWA 10404 and DEW contain large amounts of solar wind (SW) He-Xe and are thus true regolith samples. PCA is the most mature regolith in terms of SW accumulation when compared to the regolith noble gas data reported so far [cf. 12] and contains extremely high abundances of e.g. $^{20}Ne_{SW}$ (1.5×10^{-3} cm^3 STP/g) and $^{132}Xe_{SW}$ (4.0×10^{-8} cm^3 STP/g). MET, DEW and NWA 10404 are less gas-rich (0.9 to 3.7×10^{-4} cm^3 STP/g $^{20}Ne_{SW}$, 3.3 to 17.3×10^{-9} cm^3 STP/g $^{132}Xe_{SW}$) and contain higher concentrations of cosmogenic nuclides relative to the trapped gases for instance evident in the Ne, Ar and Kr isotopic compositions. These breccias exhibit shorter surface regolith exposure to the solar wind. The $^4He/^{36}Ar$ and $^{20}Ne/^{36}Ar$ ratios in DEW, MET and NWA 10404 are lower than in PCA and mean Apollo, Luna 16 and Luna 20 samples [13] suggesting gas loss during regolith gardening [14]. Glassy clasts in NWA 10404 were indeed interpreted as impact spherules deformed by reheating of the regolith breccia [6].

NWA 11273 contains very low amounts of SW (2.8×10^{-6} cm^3 STP/g ^{20}Ne) and its Ne isotopes plot between Ne-SW and cosmogenic Ne. NWA 11237 does not contain any SW. Small cosmogenic noble gas contents in NWA 11237 and 11273 suggest short exposure to cosmic rays. However, low $^4He/^{36}Ar$ ratios of 0.05 to 0.07, $^{20}Ne/^{36}Ar$ ratios of 0.196 to 0.218 and very low ^4He concentrations (4.2 to 8.3×10^{-7} cm^3 STP/g) indicate that NWA 11237 and 11273 experienced strong and late He and Ne losses, which might have disturbed the radiogenic ^4He and cosmogenic noble gas inventory. Atmospheric contamination, neutron capture in halogens (^{80}Kr, ^{82}Kr and ^{128}Xe) and fission excesses are absent in all studied regolith samples. Regolith processing, averaged shielding depths, cosmic-ray exposure ages and possible pairing will be discussed at the meeting.

Acknowledgements: We thank the NASA Antarctic MWG for allocating samples PCA and MET, T. Irving and A. Wittmann for NWA 10404, K. Nishiizumi and R. Wieler for DEW and M. Schönbächler for providing splits of NWA 11237 and NWA 11273, purchased from the JNMC Zürich. This research is supported by the Swiss SNF.

References: [1] Barboni M. et al. (2017) *Sci. Adv.* 3:e1602365. [2] Taylor S. R. (1982) Planetary science: A lunar perspective. LPI, Houston. pp. 390. [3] Taylor S. R. (1975) Lunar science: A post-Apollo view. pp. 390. [4] Will P. et al. (2016) *Meteorit. Planet. Sci.* 51:A664. [5] Kuehner S. M. et al. (2016) *LPS XLVII*, Abstract #2246. [6] Wittmann A. et al. (2016) *Meteorit. Planet. Sci.* 51:A667. [7] Gattacceca J. et al. (2019) *Meteorit. Planet. Sci.* 54:469-471. [8] Arai T. et al. (2010) *Geochim. Cosmochim. Acta* 74:2231-2248. [9] Day J. M. D. et al. (2006) *Geochim. Cosmochim. Acta* 70(24):5957-5989. [10] Collareta A. et al. (2016) *Meteorit. Planet. Sci.* 51:351-371. [11] Riebe M. E. I. et al. (2017) *Meteorit. Planet. Sci.* 52:2353-2374. [12] Mészáros M. et al. (2018) *Meteorit. Planet. Sci.* 53:1-4. [13] Fegley B. and Swindle T. Resources of near-Earth space. University Arizona Press, Tucson, pp. 977. [14] Bogard D. D. and Hirsch W. C. (1975) *Proc. 6th Lunar Sci. Conf.*:2057-2083.