Pb-Pb AGE OF GABBROIC LUNAR METEORITE NORTHWEST AFRICA 5000. Z. Bao[1],Y. Shi[1], P. Wang[1], W. Peng[1], K. H. Joy[2], M. D. Norman[3], A. Kennedy[4], X. Fu[5], A. Nemchin[6,1], X. Che[1], R. Fan[1], C.Wang[1], Y. Kang[1], H. Sun[1], Z. Wang[1], W. Zhang[1], D. Liu[1], [1]Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China (baozm@bjshrimp.cn; shiyuruo@bjshrimp.cn), [2]Dept. of Earth and Environmental Sciences, The University of Manchester, Manchester, M13 9PL, UK, [3]Research School of Earth Sciences, The Australian National University, Canberra ACT 2601 Australia, [4]John de Laeter Centre, Curtin University, Perth WA 6845, Australia, [5]Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, Weihai 264209, China, [6]School of Earth and Planetary Sciences, Curtin University, Perth, WA 6845, Australia.

Introduction: Northwest Africa 5000 (NWA 5000) is a large (11.528 kg) and fresh lunar meteorite found in southern Morocco in 2007. It is a feldspathic gabbroic polymict breccia with light-toned gabbroic clasts set in a dark fragmental matrix [1]. These clasts are composed of mostly plagioclase, pyroxene and olivine, with significant amounts of kamacite (Fe-Ni alloy), and glass, chromite, merrillite and troilite as accessory minerals [2,3]. The abundance of metal and the presence of meteoritic siderophile elements means that the sample is interpreted to be an impact melt [4,5]. The gabbroic clasts were injected with shock veins, demonstrating a complex impact history [1]. The mineralogy of the meteorite is unlike most of the feldspathic Apollo samples such as the relatively high concentrations of metal, and indicates that NWA 5000 possibly originates from an unsampled region of the Moon [6].

In this contribution, we present a preliminary study of the chronology of a gabbroic clast based the $^{207}Pb/^{206}Pb$ age of merrillite grains.

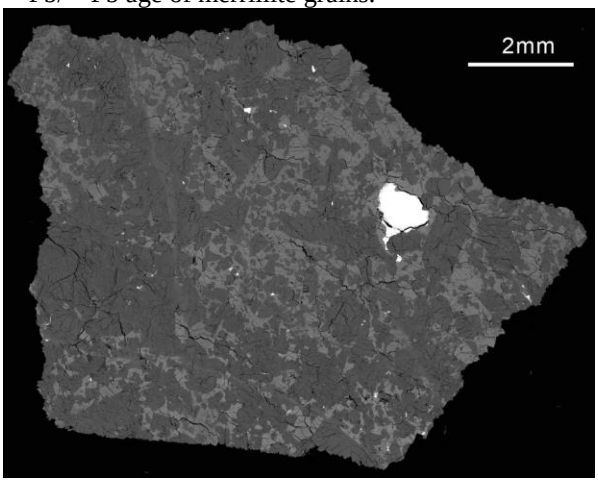

Figure 1. Backscattered electron (BSE) image of Northwest Africa 5000 analyzed in this study. The bright phase is a large FeNi metal grain.

Methods: *Initial sample imaging.* The sample was mapped using the Zeiss Merlin Compact Scanning Electron Microscope (SEM), with a beam current of 6.6 nA and an accelerating voltage of 23 kV.

U-Pb Chronology U-Pb dating analysis was performed on a Sensitive High Resolution Ion Micro Probe (SHRIMP II) at the Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences. An O_2^- primary ion beam of 1.1 nA was accelerated to 10 keV energy. In order to increase the stability of the dating, a Kohler focusing mode was used to obtain a uniform-density of 10-12 μm ion beam. Secondary ions were counted by electron multiplier for time intervals of 1~60 s on $^{175}Ca_2PO_4^+$, $^{204}Pb^+$, background, $^{206}Pb^+$, $^{207}Pb^+$, $^{208}Pb^+$, $^{238}U^+$, $^{248}ThO^+$ and $^{254}UO^+$. The BR5 apatite was used for dating (2040 Ma, used as Curtin University internal standard) and Durango was used for U concentration (U=9 ppm) as the calibration standards.

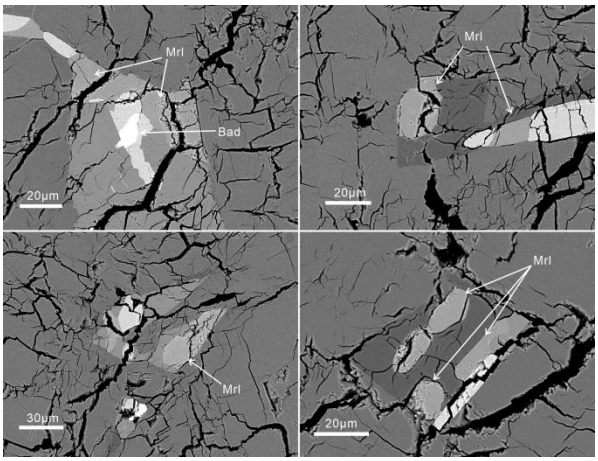

Figure 2. Close up BSE images of phases used for in-situ U-Pb dating. Mrl=merrillite, Bad=baddeleyite.

Results: Phosphates are merrillites, are euhedral (Fig. 2) and occur alongside ilmenite, glass and pyroxene. The pyroxene grains in this clast are mostly pigeonite and augite, with a small amount of low-Ca pyroxene. Plagioclase is relatively calcic ($An_{93-98}Ab_{2-7}$, n=7), and it is the most abundant mineral in the clast. The Mg# of pyroxene vs. An content in plagioclase in this clast overlaps between the Ferroan Anorthosite Suite (FAS) and Mg-suite (Fig. 3), which is consistent with that reported by Grange et al. [2] for a different

section of the NWA 5000 meteorite.

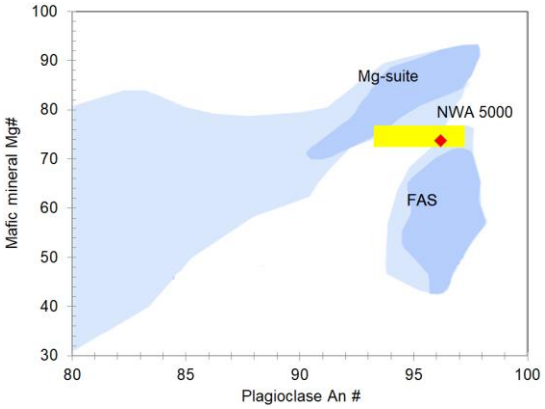

Figure 3. Mg# of pyroxene vs. An content in plagioclase of NWA 5000 compared to igneous lunar highlands rock suites. The yellow rectangle is the distribution of the minerals reported by Grange et al. [2], and the red symbol is what we have measured for the clast used in our study. Background fields for the ferroan anorthosite (FAS) and Mg-Suite are taken from Yamaguchi et al. [7] and refs therein.

Nineteen merrillite grain analyses form a concordant group in the Concordia diagram with a weighted mean $^{207}Pb/^{206}Pb$ date of 4155±5 Ma (MSWD=1.6, n=19) (Fig. 4). The U and Th contents in the merrillites (U=17 -180 ppm, Th=105-857 ppm, Th/U=3.8-10.8) are elevated relative to the apatites in Apollo 16 sample 67955 (U=1-74 ppm, Th=8-624ppm, Th/U=1.6-21.5), which date a basin-scale impact melting event on the Moon at 4.2 Ga [8].

Summary: The age of $^{207}Pb/^{206}Pb$ of merrillite is 4155±5 Ma, which coincides with the Nd-model age range of 4.1-4.2 Ga for the plagioclase in this meteorite reported by [3]. the presence of meteoritic siderophile elements and euhedral phosphate grains (Fig. 2) suggest that their Pb-Pb ages reflects the crystallization age of the impact melt sheet that formed the gabbroic anorthosite. The sample, therefore, likely reflects a large impact event which occurred in the Pre-Nectarian [9,10], at a time before many of the ~3.9 Ga aged Apollo 16 highland impact samples were formed [11]. Younger ^{40}Ar-^{39}Ar ages at 3.2 Ga and 0.5 Ga likely reflects later impact isotopic partial resetting events [12].

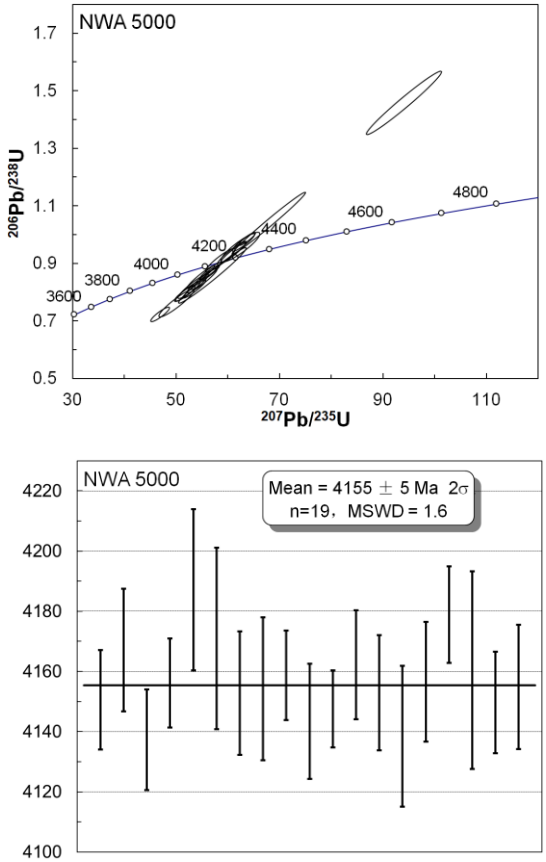

Figure 4. (a) Concordia diagram for merrillite analyses of NWA 5000 and (b) Weighted mean $^{207}Pb/^{206}Pb$ age of 19 merrillite grain analyses of this study.

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References: [1] Irving A. J. et al., (2008). *39th LPSC*, Abst. #2168. [2] Grange M. L., et al., (2016). *47th LPSC* Abst. #1784. [3] Grange M. L. et al., (2016). *79th AMMS* Abst. #6300. [4] Humayun & Irving, (2008). *GCA 72, 12S*, A402. [5] Worsham & Kleine, (2021). *Sci. Adv.* 7: eabh2837. [6] Nagurney A. B. et al., (2016). *47th LPSC*, Abst. #1103. [7] Yamaguchi A., et al., (2010). *GCA*, 74:4507-4530. [8] Norman, M. D. & Nemchin A. A., (2014). *EPSL*, 388: 387-398. [9] Norman, M. D., et al., (2016). *GCA*, 172: 410-429. [10] Masks, N. E., et al., (2019). *JGR:Planets*, 124(10): 2465-2481. [11] Niihara, T. et al., (2019). *MPS*, 54.4: 675-698. [12] Fernandes V. A., (2009). *Goldschmidt Conference*, Abst. A365.