CLASSIFYING THE UNKNOWN - THE LUNAR EDITION: NORTH WEST AFRICA 10401 A NEW TYPE OF THE MG-SUITE ROCK? A. Hilton[1,3], J. Gross[2,3], R. Korotev[4]; A. Calzada-Diaz[5]; [1]The College of Wooster, Wooster, OH 44691; [2]Rutgers University, Piscataway, NJ 08845; [3]American Museum of Natural History, New York, NY 10024; [4]Washington University, Saint Louis, MO 63130, Il.; [5]Birkbeck College, University of London, London WC1E 7HX, UK. Hilton@wooster.com; jgross@eps.rutgers.edu.

Introduction: The lunar crust provides a record of the planetary formation, early evolutionary processes, and contains a wealth of information about the origin and evolution of the Earth-Moon system [e.g., 1-4]. Lunar meteorites provide random sampling of the lunar surface including areas not visited by Apollo or Lunar missions, and thus are presumably representative, on average, of the whole lunar surface [4]. Therefore, studying lunar meteorites is crucial for understanding the evolution and development of the whole moon [5]. Rocks compositionally different from known Apollo and Luna samples are particularly desired for their insight into the diversity of the lunar surface. In this study, we investigated lunar meteorite North West Africa (NWA) 10401. Quantitative and qualitative analyses were performed to 1) confirm its lunar origin and potential grouping, 2) classify the rock, 3) place constraints on its crystallization history and source location, and 4) improve our understanding of unsampled areas of the Moon and expand our knowledge of lunar highland rock types.

Sample and Methods: NWA 10401 was purchased in Morocco, 2015. For this study we analyzed a thick section of the meteorite, with the dimensions of 6 x 12mm (Fig. 1). All minerals present were analyzed using the electron microprobe (CAMECA SX100) at the American Museum of Natural History (AMNH). Beam conditions were 15 kV accelerating voltage, 25 nA beam current and 1µm beam diameter (olivine, pyroxene, spinel, metal) and 10 nA beam current, 5µm beam diameter (plagioclase, glass). Standards included well described natural and synthetic materials. REE data were obtained with LA-ICP-MS on single mineral grains was conducted at the Lamont-Doherty Earth Observatory (LDEO) of Columbia University. Bulk chemistry was measured using INAA (instrumental neutron activation analysis) at Washington University and carried out as described in [6,7]. Modal mineralogy was calculated using qualitative elemental X-ray maps with two computational programs, IDRISI Selva [8] and XMapTools (MATlab) [9]. Potential source location was calculated using a computational program by [10].

Texture, Petrography, and Mineral Chemistry: The sample is composed of mainly Ca-bearing plagioclase/maskelynite (59-65%) with lesser olivine (23-26%), pyroxene (clinopyroxene and orthopyroxene) (12-15%), glass, and accessory phases spinel and metal. Texturally, single mineral grains and mafic clasts are set in a granular coarse grained matrix composed mainly of maskelynite (62%), olivine (25%), and pyroxene (14%). Larger (0.5-1.5mm) mafic clasts are aggregates of olivine and pyroxene set in granular fine grained matrix, composed of maskelynite (90.2%), olivine (2.3%), and pyroxene (7.4%). An impact melt vein (0.5-7.4 mm in length) crosscuts the sample. *Maskelynite:* $An_{92.1-97.6}Ab_{1.4-5.0}Or_{0-0.2}$; *Olivine:* $Fo_{78.7-84.4}$, *Clinopyroxene:* $Fs_{7-12}Wo_{33-44}En_{49-55}$. *Orthopyroxene*: $Fs_{14-19}Wo_{2-11}En_{71-84}$; *Spinel:* $Chr_{53-55}Sp_{25-27}Ulv_{20-21}$.

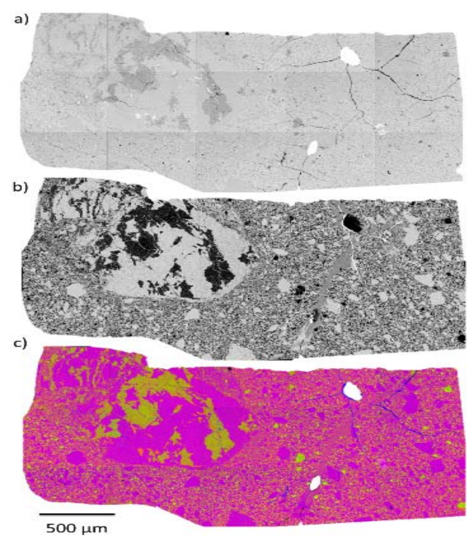

Fig. 1: *Mosaic X-ray elemental maps of the meteorite thick section. a) Si Kα map b) Ca Kα map d) combined RedGreeBlue (RGB-SiFeCa)) map. In general, blue-green = olivine; blue = orthopyroxene; light pink = clinopyroxene; pink = maskelynite; white = epoxy.*

Bulk Composition: INAA analyses and La-ICP-MS analyses on single grains show that the REE are low compared to Apollo samples with FeO 6.1 wt%, Na_2O 0.24 wt%; Sc 8.7, Cr 1300, Ni 124, La 0.65, Sm 0.38, Eu 0.55, Yb 0.37, Th 0.07, all in ppm (Fig 2).

Origin: The Fe/Mn ratio is widely used to categorize the basaltic source composition and is used as a characteristic fingerprint for planetary bodies and thus the sample's origin, e.g. Moon vs. Earth vs. Mars [e.g., 11]. The Fe/Mn ratios in olivine and pyroxene within NWA 10401 follow the trend of lunar rocks, confirming its lunar origin.

Pairing: Whole rock analyses of NWA 10401 and the composition of its melt veins are within error of the whole rock composition of NWA 5744 and the melt vein compositions reported for other NWA 5744 pairs. The Mg# [molar Mg/(Mg+Fe)] of the whole-rock bulk composition of the sample is Mg# = 82 which represents the highest known Mg# of known feldspathic meteorite samples so far but similar to NWA 5744 which has a Mg# = 80. Thus, based on textural and chemical evidence (Fig. 2), our sample is most likely paired to the lunar meteorite NWA 5744 clan.

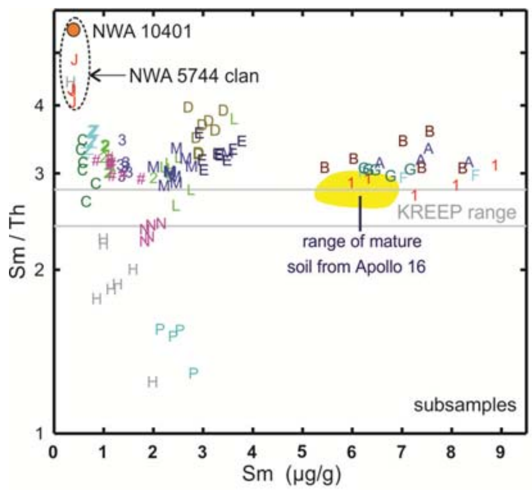

Fig.2: *Comparison of NWA 10401 to other feldspathic meteorites and the paired NWA 5744 clan. Modified from [12]*

Formation History and Implications: NWA 10401 is an anorthositic troctolitc breccia with a granulitic texture that has chemical charqacteristics similar to the NWA 5744 clan meteorites (Fig. 2). Pyroxene exolution lamellae of orthopyroxene and clinopyroxene [13] gives a temperature range of 900-1100°C. Due to the high plagioclase content (59-65%) it is most likely that NWA 10401 originated as part of the lunar feldspathic highlands. However, the Mg# of olivine/pyroxene vs. An% in plagioclase in this sample plot in the Mg-suite field, rather than the ferroan anorthosite field. Characteristic for rocks from the Mg-suite are their low alkali element content, highly magnesian olivine and pyroxene (Mg# >78), and highly elevated abundances of REEs [14]. The low alkali component in our sample, together with the high Mg# in the mafic component indicate that our sample originated somewhere near the Mg-suite source region, i.e., the Procellarum KREEP Terrain (PKT). This is supported by the Ni/Co content of olivine, indicating that at least part of the breccia has a Mg-suite component. However, despite these facts NWA 10401 is strongly depleted in REE, separating it from the Mg-suite of the PKT (also see Fig. 2). Caluclations on potential source locations also suggest that it is geographically distant from the PKT region, possibly originating on the lunar farside (Fig. 3).

The origin of the highly magnesian component in this meteorite could be represented by: (1) a magnesian suite unrelated to the PKT that is instead related in some part(s) to the Feldspathic Highland Terrane [15]. [14] show that Mg-suite rocks can be produced by placing hot, less dense early magma ocean cumulates into the plagioclase-rich primordial crust which would produce Mg-suite parent magmas. Thus, outside the PKT, Mg-suite magmas would not be required to have a KREEP signature. (2) A high Mg mantle component, such as dunites, could also be a possible constituent for a high Mg component. (3) NWA 10401 could represent a piece from the lower lunar crust which might be composed of olivine-rich feldspathic rock [16]. Further study of this rock is underway to distinguish between these potential source regions and areas of origin.

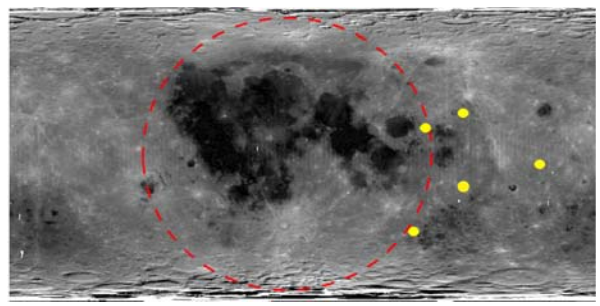

Fig. 3: *Potential source locations (yellow filled dots) of NWA 10401 based on the bulk composition. Red circle represents the lunar near side. Calculated based on [10].*

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