PROVENANCE OF LUNAR BASALTIC METEORITE NORTHWEST AFRICA 8632 AND RELATED METEORITES. A. Madera[1] and J. Gross[1,2,3,4], [1]Deptartment of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ, 08854; [2]Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY 10024. [3]ARES, NASA Johnson Space Center, Houston, TX 77058; [4]Lunar and Planetary Institute, Houston TX 77058; (am1505@eps.rutgers.edu).

Introduction: The Apollo missions returned 382kg of samples from a geologically unique part of the lunar crust that is not chemically representative of the entire Moon. Lunar meteorites represent a random sampling of the lunar surface [1], and are thus critical for our understanding of lunar evolution through space and time. However, the launch location of most meteorites remains unknown, making it difficult to fully interpret their geologic history and the geology of the region of the Moon from which they originated.

Northwest Africa (NWA) 8632 is a porphyritic, low-Ti lunar basaltic meteorite [2,3]. Recently reported $^{40}Ar/^{39}Ar$ ages of NWA 8632 indicate the sample is one of the youngest dated lunar basalts with ages ranging from 2772 ± 41 Ma to 2877 ± 34 Ma [3]. NWA 8632 is within age range of the texturally and chemically similar lunar basaltic meteorite NWA 032 [3]. Bulk compositions of these meteorites are similar in major elements but vary in certain trace elements [2,4]. Other young meteorites with similar textures but varying chemical compositions are low-Ti, porphyritic mare basalts NWA 4734 and the LaPaz Icefield (LAP) 02205 clan [e.g., 4-7]. Low-Ti basaltic rocks are the most common basalt type on the Moon based on remote sensing observations, but are underrepresented in the Apollo sample collections [8].

While it seems that these meteorites are not paired with each other [2,3], it is debated if they have a common launch pair history, and thus have a geologic relationship [8,9] either through originating from the same lava flow or following a similar path in magma genesis and eruption-style to the lunar surface [2,3,8]. In this study, we are utilizing remote sensing observations in combination with geochemical data to provide potential source location(s) for the meteorites and better understand any potential relationships between them. Understanding the potential provenance and possible relationships between these young lunar meteorites can provide insights into the timing, duration, and location of this type of lunar volcanism, and thus, provide insights into the thermal history of the Moon.

Method: In this study, we developed a computational program similar to that of [10] using Python and ArcGIS to locate potential source locations of NWA 8632, NWA 032, NWA 4734, and the LAP meteorite clan (LAPs 02205, 02224, and 02226) on the lunar surface. The average FeO, TiO2 and Th concentrations of the bulk meteorites (with a STDV of 5) were used as input, computationally compared and matched with the 2° pixel (i.e., 60km/pixel) elemental composi-

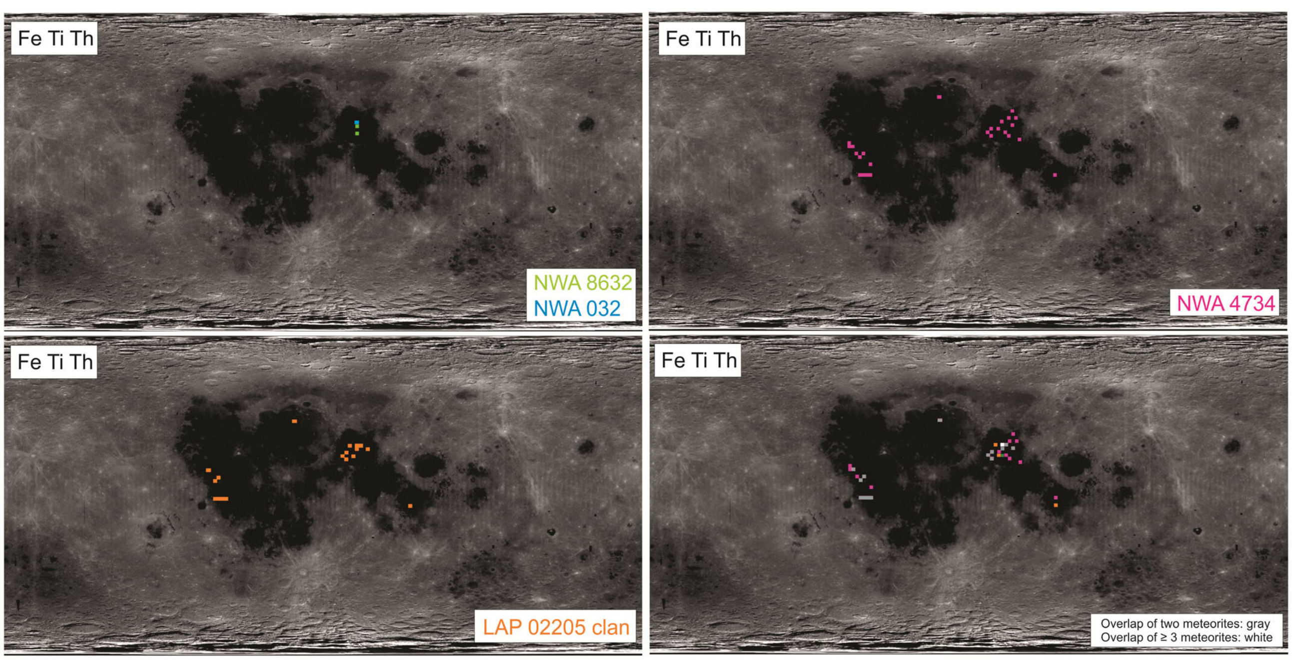

Figure 1: *Potential source locations of NWA 8632 (green), NWA 032 (blue), NWA 4734 (pink), and LAP 02205 clan (orange). Light gray pixel represent compositions on the lunar surface that match at least 2 meteorites; white pixel match ≥ 3 meteorites. Images were then projected over a Clementine 750nm base map for easy visualization [11].*

tion reported by remote sensing data sets from the Lunar Prospector mission gamma ray spectrometer [11].

Samples: Meteorites NWA 8632, NWA 032, NWA 4734, and the LAP clan (LAPs 02205, 02224, 02226) are low-Ti lunar basaltic meteorites with similar textures, bulk compositions, and ages but varying mineral modal abundances [e.g., 3-9]. Reported radiometric ages are presented in table 1.

Table 1: *Ages [in Ma] of meteorites used in this study. Data are from [3,4,12] and references therein.*

Meteorite	Ar-Ar	Pb-Pb	Rb-Sr	Sm-Nd
NWA 8632	2772±41 2877±34			
NWA 032	2991±92			
NWA 4734	2717±10 2720±40 3190± 190	3073±15	3083±42	3024±27
LAP 02205 clan	29855±16	3039±12	2990±36	2992±170

Results and Discussion: Combining remote sensing observations with geochemical data to provide potential source location(s) for the meteorites can be a powerful tool in order to place the small scale petrographic observations of samples into the larger scale petrogenetic scheme of the Moon [e.g., 10]. Global FeO maps derived from remotely sensed data can be used broadly to differentiate between basaltic and feldpathic materials. Similarly, the global Th maps can be used to identify KREEPy materials. The TiO_2 maps can be used to distinguish between Ti-rich and Ti-poor basalts. Thus, these three elements can used in concert to constrain the provenance of a lunar meteorite. However, when using remote sensing data to match lunar surface composition with lunar meteorite compositions, two limitations need to be taken into account: (1) The lunar surface has been bombarded for 4.5 Ga, which has led to mixing of surface materials that affects the ability to unambiguously identify ancient source locations, and (2) the pixel size of the remote sensing datasets are on the scale of 10s of km and will always encompass many lithologic types and often represent multiple physiographic features. Thus, when a compositional match is found, the results should not be used to place constraints on small scale surface features as a source area, e.g., a single lava flow, but rather be used to constrain a larger region.

Potential source regions: We observe three broader mare regions as potential source locations for the meteorites in this study (Fig. 1): Oceanus Procellarum, Mare Serenitatis, and Mare Fecunditatis. We can further narrow down the potential source regions by comparing the radiometric ages measured for the meteorites (Table 1) with the modeled ages of the lunar surface [13] (Fig. 2). While the outskirts of the Oceanus Procellarum region and Mare Fecunditatis match the composition of LAP 02205 clan and NWA 4743, the modeled ages of this region do not match the reported radiogenic ages of those meteorites (3.3-3.4 Ga for Oceanus Procellarum [13]; 3.34-3.71 Ga for Mare Fecunditatis [14,15]).

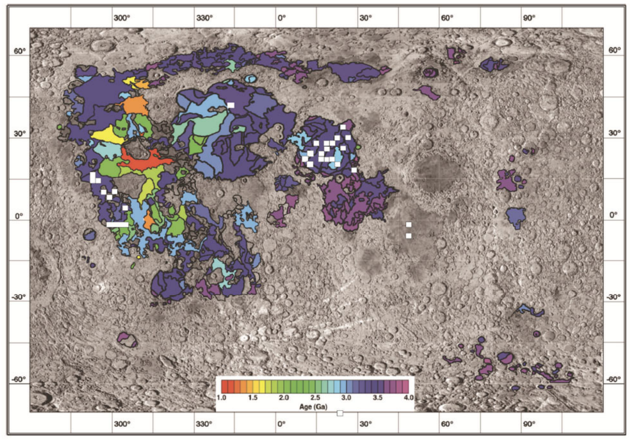

Figure 2: *Potential source locations of meteorites from this study (white pixel) overlaid on a map of modeled ages of lunar mare from [13].*

Mare Serenitatis is the only region in which all four meteorites plot. Modeled ages of individual lava flows in this region range from 2.8 - 3.0 Ga [13], which overlap with the radiometric ages of the meteorites, indicating that a petrologic link between the meteorites and this area on the Moon might exist.

Conclusions: A geologic relationship between the meteorites and Mare Serenitatis appears likely. Similar magma genesis and eruption styles could have produced a stack of compositionally similar lava flows in the basin over a short time period, from which these meteorites might have originated. Future calculations of parental melt compositions as well as modelling crystallization sequences of the different meteorites will help us place further constraints on any potential relationship between these lunar samples.

References: [1] Korotev (2005) *Chem. Erde,* 65, 297–346. [2] Korotev et al. (2015) *LPSC 46th*, #1195; [3] Fagan et al. (2018) *LPSC 49th*, #2083; [4] Elardo et al. (2014) *MaPS 40,* 261-291; [5] Elardo et al. (2014) *Am.Min.* 99, 358-368; [6] Day et al. (2006) *GCA* 70, 1581-1600; [7] Zeigler et al. (2005) *MaPS* 40, 1073-1101; [8] Jolliff et al. (2004) *LPSC* 35th, #1438; [9] Korotev et al. (2004) *LPSC 35th*, #1416; [10] Calzada-diaz et al. (2015) *MaPS* 50, 214-228; [11] Prettyman et al. (2006) *JGR* 111, 1-41; [12] Wang et al. (2012) *GCA* 92, 329-344; [13] Hiesinger et al. (2011) *GCA,* 477, 1-51; [14] Joliff et al. (2000) *JGR* 115, 4197-4216; [15] Hiesinger et al. (2006) *LPSC 37th*, #1151.