GEOCHEMICAL EXAMINATION OF NORTHEAST AFRICA 039 AND COMPARISON TO OTHER LOW-TI LUNAR BASALTIC METEORITES. M. L. Meier[1], S. M. Elardo[1], E. A. Pesar[1] and A. Griffis[1], [1]Department of Geological Sciences, University of Florida, Gainesville, FL 32611 (mckaylameier@ufl.edu)

Introduction: Lunar basalts showcase a wide diversity of bulk chemical compositions, textures, and isotopic compositions that communicate their formation and evolution. With this, low-Ti mare basalts (2-4 wt. % TiO_2) are the most abundant mare lithologies on the lunar surface, detailing the history of magmatic processes over lunar history [1]. This extends to the collection of mare basaltic meteorites, which are almost exclusively low and very-low in TiO_2.

This work examines the mineralogical, petrological, and geochemical properties of Northeast Africa (NEA) 039, from which we can determine the lunar sample's context within mare basaltic compositions and source regions. With the distinct characteristics of NEA 039, we additionally investigate relations between this sample and NWA 032, NWA 4734, and LAP 02205 (and associated pairs) [2-6], to assess geochemical similarities between low-Ti mare basalt meteorites. The examination of these meteorites expands our knowledge of compositional diversity, including distinguishing source regions and evolutionary processes.

Overall, we find that low-Ti mare basaltic meteorite NEA 039 reflects an unbrecciated lunar sample with textures and preliminary compositions similar to the LaPaz Icefield 02205 (LAP 02205) group [3, 5-6] as well as Northwest Africa 032 (NWA 032) [2-4, 6] and Northwest Africa 4374 (NWA 4734) [3], and we suggest that NEA 039 is source crater paired with those samples.

Methodology: In this study, the overall bulk rock and mineral compositions were determined to assess the formation and evolution within lunar basaltic compositions.

Bulk Rock Geochemistry. Major, minor, and trace element abundances were determined using an Element-2 magnetic sector inductively coupled plasma-mass spectrometry facility at the University of Florida (UF). Silica and other major and minor element abundances were verified by making a fused bead in the Florida Planets Lab's Deltech furnace at an fO_2 of IW and measured using the Oxford Ultim Max 100 mm^2 silicon drift detector energy dispersive X-ray spectrometry (SDD-EDS) on UF's Zeiss EVO MA10 scanning electron microscope (SEM).

Mineral Geochemistry. Major and minor elemental compositions of mineral phases were examined using point collection on the same SDD-EDS. Along with point geochemical analyses, elemental maps were generated using the SDD-EDS, showcasing the petrological textures and elemental differentiations. High resolution grayscale backscatter images were obtained to document textures.

Geochemistry: Bulk rock compositions for NEA 039 are listed in Table 1, in comparison to NWA 032, NWA 4374, and average LAP meteorites. Major elemental compositions of NEA 039 reflect indistinguishable from the other lunar low-Ti basalts listed, indicative of similar volcanic complex source. Additionally, NEA 039 Mg# (molar Mg/(Mg+Fe) x 100) falls within range of the other listed low-Ti mare basalts.

Table 1*: Bulk rock geochemistry of low-Ti basalts.*

	NEA 039	NWA 032	LAP Avg.	NWA 4734
SiO_2	45.6	44.7	45.3	47.2
TiO_2	3.17	3.00	3.11	3.14
Al_2O_3	9.84	9.32	9.79	9.65
Cr_2O_3	0.55	0.40	0.31	0.30
FeO	22.1	22.2	22.2	21.2
MnO	0.27	0.28	0.29	0.28
MgO	7.12	7.97	6.63	6.83
CaO	10.6	10.6	11.09	10.9
Na_2O	0.43	0.35	0.38	0.36
K_2O	0.03	0.09	0.07	0.16
P_2O_5	0.23	0.09	0.1	-
Total	99.9	99	99.3	99.9
Mg#	36	39	35	37

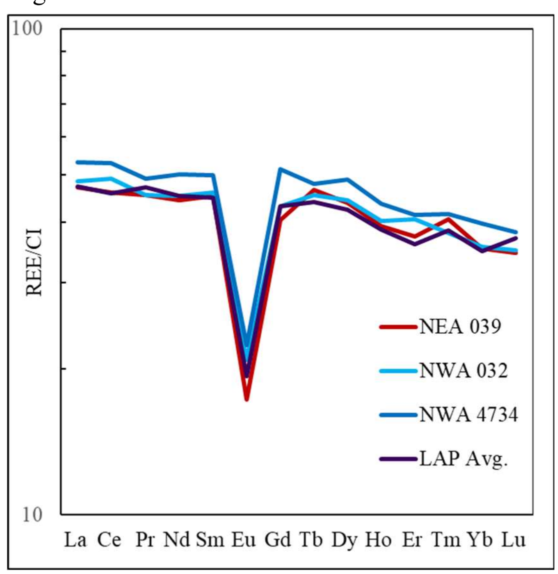

Figure 1: Chondrite-normalized REE patterns of select low-Ti mare basalts.

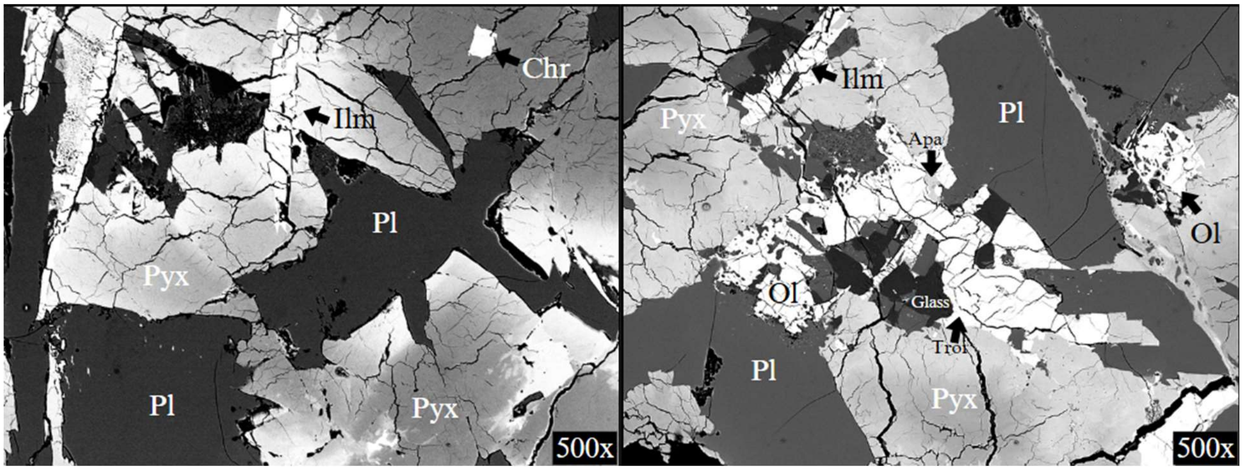

Figure 2: Backscatter electron images of NEA 039. Pl = Plagioclase, Pyx = pyroxene, Ol = olivine, Ilm = ilmenite, Chr = chromite, Apa = apatite, Troi = troilite.

NEA 039 follows similar trends to NWA 032, NWA 4374, and averaged LAP meteorites for rare earth element (REE) compositions [3]. Their REE values are all elevated in comparison to collected low-Ti basalts from Apollo 12 and 15 missions, with distinctly deeper Eu anomalies [7].

Mineralogy: NEA 039 exhibits an unbrecciated, holocrystalline texture of lunar basaltic mineralogy (Fig. 2). The minerals formed subophitic to intergranular crystallization with primary phenocrysts of plagioclase, pyroxene, and ilmenite.

Plagioclase. As prominent phenocrysts in NEA 039, plagioclase compositions are limited from An_{93} to An_{73}. Lath-shaped plagioclase co-crystallized with pyroxene grains, exhibiting limited zoning and minor twinning [8]. Some plagioclase grains appear glassy, reflecting shock-induced vitrification (maskelynisation).

Pyroxene. Massive pigeonite and augite grains reflect regular zoning from Mg-rich cores to Fe-rich rims. Within the zonation, pyroxene ranges in composition ($Fs_{8\text{-}86}Wo_{9\text{-}91}En_{0.6\text{-}32}$), reflecting an evolving melt to form Fe-rich rims. We hypothesize that the intergranular pyroxenes have cotectically crystallized with the euhedral plagioclase grains. Pyroxene endmember values (Fig. 3) overlap with the other listed low-Ti basalts, predominantly LAP and NWA 4734 compositions [3]. Pyroxene textures of NEA 039 are additionally aligned with the LAP and NWA 4734, likely indicative of slower re-equilibration times within lava flow interior or magma chamber (hence coarse-grained texture) as compared to NWA 032 [3,7].

Ilmenite. NEA 039 exhibits euhedral to subhedral elongated ilmenite grains throughout the sample, along with smaller ilmenites within mesostasis regions. The minimal ilmenite grains are likely a crystallization product of a low-Ti melt [8].

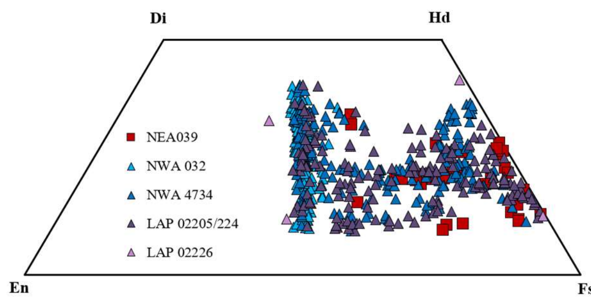

Figure 3: Composition of pyroxenes in select low-Ti mare basalts.

In addition to the major mineralogy, minor phases of olivine, troilite, apatite, chromite, and Si-K-rich glass are common throughout NEA 039. Fayalitic olivines are scattered throughout NEA 039 commonly in mesostasis regions from late-stage melt.

Magmatic History: Based on bulk rock and mineral compositions, NEA 039 is likely source crater paired and derived from the same volcanic province as NWA 032, NWA 4374, and LAP suite meteorites. These meteorites were likely emplaced in the mare region on the lunar nearside from a related evolved basaltic magmatic source [3, 6, 9].

References: [1] Giguere T. A. et al. (2000) *MAPS* 193-200. [2] Elardo S. M. and Shearer Jr C. K. (2014) *American Mineralogist*, *99*(2-3), 355-368. [3] Elardo S. M. et al. (2014) *Meteoritics & Planetary Science*, *49*(2), 261-291. [4] Borg L. E. et al. (2009) *Geochimica et Cosmochimica Acta*, *73*(13), 3963-3980. [5] Joy K. H. et al. (2006) *Meteoritics & Planetary Science*, *41*(7), 1003-1025. [6] Zeigler R. A. et al. (2005) *Meteoritics & Planetary Science*, *40*(7), 1073-1101. [7] Elardo S. M. et al. (2012) *LPS XLIII, 1659,* Abstract #2648. [8] Joy K. H. et al. (2005) *LPS XXXVI*, Abstract #1697. [9] Joy K. H. et al. (2005) *LPS XXXVI*, Abstract #1701.