MINERALOGY AND COMPOSITION OF LUNAR IMPACT MELT BRECCIA NORTHWEST AFRICA 8651. J. Chen[1,2], B. L. Jolliff[2], P. K. Carpenter[2], R. L. Korotev[2], A. Wang[2], Z. C. Ling[1], X. H. Fu[1] and W. B. Hsu[3], [1] Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, Weihai, 264209, China (merchenj@mail.sdu.edu.cn), [2]Department of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University in St. Louis, MO, 63130, [3]Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, 210034, China.

Introduction: Lunar meteorites are impact ejecta sampling random and unknown regions of the Moon [1]. More than 300 lunar meteorites have been recorded in the Meteorite Bulletin Database so far [2]. They provide an important supplement to the inventory of lunar materials from sparse Apollo and Luna sampling sites, which only cover a relatively small area of the lunar nearside. We report here a preliminary mineralogical and compositional characterization of an impact-melt breccia lunar meteorite Northwest Africa (NWA) 8651 [3]. Similar chemical compositions suggest a pairing relationship between NWA 8651 and many other NWA stones [4].

Analytical Methods: A thick section of NWA 8651 (PMO-0315) was characterized using electron probe microanalyses (EPMA). BSE (backscattered electron) imaging, X-ray quantitative compositional mapping, and spot analyses were done using the JEOL JXA-8200 electron microprobe at Washington University in St. Louis. Quantitative compositional mapping for three areas (Fig. 1) used five wavelength dispersive spectrometers (WDS) (for elements including Na, Mg, Al, Si, K, Ca, Ti, Cr, Fe, Ni) and a silicon-drift energy dispersive spectrometer (SDD-EDS) (for elements including Mg, Al, Si, P, S, Ca, Fe, Ni). Spot compositional analyses were done using a 15 kV accelerating voltage and a 25 nA beam current. We used spot sizes ranging from 1 to 20 μm as appropriate for the target phases.

Results and Discussion:

Petrography. Microprobe examination of the polished thick section of NWA 8651 shows this sample to be an impact-melt breccia composed of individual plagioclase and anorthositic lithic clasts with shock melt in a homogeneous matrix of fine grained plagioclase, olivine, and pyroxene with accessory minerals including armalcolite, ilmenite, chromite, Fe-Ni metal, Fe sulfide, K-feldspar, phosphate, and tranquillityite (Fig. 2). The olivine and pigeonite within matrix presents poikilitic texture where larger pigeonite oikocrysts contain smaller olivine chadacrysts. Shock induced fractures spread around the matrix and extend into plagioclase clasts in which partial transformation into maskelynite occurred.

Mineral chemistry. Quantitative spot analyses confirm that the composition of poikilitic olivine and pigeonite grains have well equilibrated (olivine $Fo_{73.3-75.2}$, pigeonite $En_{71.8-75.0}Wo_{6.5-7.6}Fs_{18.4-21.0}$) within lithic clasts and matrix in area 1 and area 3, implying slow crystallization in an equilibrium system under a certain depth. The relatively coarse-grained plagioclase clasts may be relic plutonic texture. The augite observed in matrix has a composition of $En_{55.4}Wo_{29.3}Fs_{15.3}$.

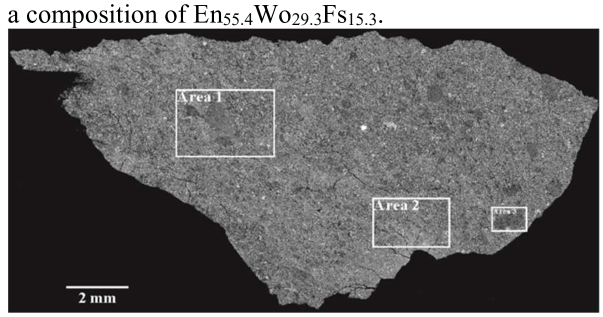

Figure 1. Backscattered-electron (BSE) mosaic image of NWA 8651 showing typical texture and three X-ray mapping areas.

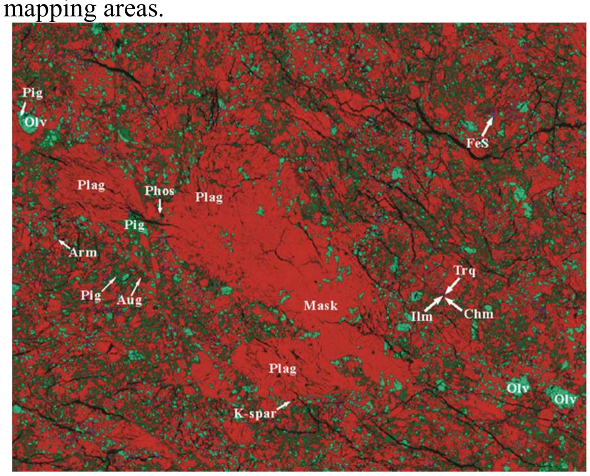

Figure 2. X-ray composite image of area 1, red-Al, green-Mg and blue-Fe. Plag = plagioclase, red, Mask = Maskelynite, fracture free, red, Pig = Pigeonite, medium green, Aug = Augite, dark green, Olv = olivine, light green, Arm = Armalcolite, FeS = Fe sulfide, Chm = chromite, K-spar = K-feldspar, Phos = phosphate.

The plagioclase is not equilibrated and retain chemical variations: $An_{91.7-96.8}Ab_{3.1-8.2}Or_{0.1-0.9}$. Slight reaction rims and ragged clast borders of the plagioclase clasts suggest reaction with the impact melt from which the matrix recrystallized. Maskelynite has no obvious compositional difference from surrounding plagioclase. K-feldspar has a composition of $An_{3.5}Ab_{6.2}Or_{90.3}$ and is present as small inclusions.

Aluminous chromite grains are found included within ilmenite grains as chromian cores. The composition of chromite and ilmenite host are both Mg-bearing, with chemical formulae of $(Mg_{0.22}Fe_{0.76})_{0.98}(Al_{0.36}Cr_{1.25})_{1.61}O_4$ and $(Mg_{0.25}Fe_{0.73})_{0.98}Ti_{0.98}O_3$, respectively. Compositional analyses of another opaque mineral, armalcolite, shows higher Mg content ($Mg_{0.43-0.47}Fe_{0.45-0.47}Ti_{1.86-1.93}O_5$).

The analyzed phosphate grain is merrillite: $((Mg_{3.5}Fe_{0.4})_{3.9}Ca_{15.9}(Y,REE)_xNa_{0.8}(P_{11.7}Si_{1.9})_{13.6}O_{56})$, although its REE concentrations have not yet been measured. The K-feldspar and merrillite tend to be inclusions within plagioclase clasts, suggesting possible origin from evolved residual melt trapped by plagioclase cumulates.

Bulk composition. The chemical composition of shock melt is commonly regarded as a proxy for bulk composition. We analyzed 10 spots along the shock melt in area 2 (Fig. 1) to derive an approximate bulk composition of NWA 8651 as listed in Table 1. The average FeO (5.4 wt.%), Cr_2O_3 (0.08 wt.%), and NiO (0.02 wt.%) contents of the impact melt are lower than the data obtained by INAA (6.09 wt.% FeO [5], 0.12 wt.% Cr_2O_3, and 0.06 wt.% NiO) and its CaO (14.82 wt.%), Na_2O (0.62 wt.%) and K_2O (0.14 wt.%) contents are higher than data obtained by INAA (13.6 wt.% CaO, 0.489 wt.% Na_2O and 0.12 wt.% K_2O).

Compositionally, this meteorite was grouped with NWA 8455 clan in which all members are described as Apollo 16 soil like in composition, but which include a texturally wide variety of coarse lithic-clast-rich impact breccias. Compared to bulk compositions of other meteorites in NWA 8455 clan and mature soils collected from Cayley Plains, NWA 8651 is almost indistinguishable from others, yet its Mg′ value (Mg/(Mg+Fe) * 100 = 71.0) is at the high end of the range for this group, and essentially the same as NWA 8455 (Table 1).

Based on bulk composition (Table 1), we calculated the abundances of normative minerals of NWA 8651 using a CIPW (Cross, Iddings, Pirsson and Washington) norm. The NWA 8651 has a high percentage of normative plagioclase (77.42 wt.%) and is olivine-rich (16.91 wt.%) while pyroxene is only 4.51 wt.%. According to the plagioclase, pyroxene, and olivine contents, it is on the border between troctolitic anorthosite and anorthositic troctolite.

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Table 1. Bulk compositions of NWA 8455 clan and typical mature Apollo 16 soils.

Sample	**NWA 8651**	**NWA 8455**	**NWA 8607**	**NWA 8727**	**La'gad**	**Apollo 16**
Reference	**This study**	**[3]**	**[3]**	**[6]**	**[7]**	**[8]**
SiO_2	44.03±0.23	44.6±1.1	44.18±2.80	44.35±0.66	45.8±1.2	45.0
TiO_2	0.50±0.04	0.59±0.53	0.58±0.35	0.93±0.28	0.63±0.37	0.595
Al_2O_3	27.44±0.29	26.1±3.2	24.44±4.70	29.06±1.06	27.3±4.8	26.7
Cr_2O_3	0.08±0.01	0.10±0.03	0.16±0.09	0.09±0.01	0.12±0.10	0.11
MgO	7.33±0.38	6.8±1.8	6.99±2.41	5.93±0.71	5.1±3.0	6.14
FeO	5.39±0.28	5.0±1.3	6.89±2.97	4.82±0.44	6.0±2.9	5.51
MnO	0.06±0.02	0.04±0.03	0.10±0.05	0.06±0.02	0.07±0.04	0.07
CaO	14.82±0.36	not reported	13.94±1.98	15.50±0.49	15.4±1.7	15.3
NiO	0.02±0.02	0.02±0.01	0.02±0.03	0.08±0.03	0.05±0.05	0.06
Na_2O	0.62±0.02	0.69±0.20	0.54±0.35	0.55±0.03	0.56±0.11	0.457
K_2O	0.14±0.01	0.19±0.04	0.15±0.07	0.12±0.01	0.14±0.05	0.12
Sum	100.42	84.13 (No CaO)	97.95	101.49	101.17	99.75
Mg′	71.0	71.0	64.6	68.6	60.5	66