MINERALOGY AND BULK COMPOSITION OF LUNAR MARE BASALT NORTHWEST AFRICA 12008.
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Introduction: Among the 150 or so known lunar meteorites, mare basalts are quite rare, numbering only 12 at this writing. Even more remarkable in this the 50th anniversary of the Apollo 11 landing in Mare Tranquillitatis is the fact that so far no lunar meteorites have been recovered which match the high-Ti basalts sampled at the Apollo 11 and Apollo 17 sites. On the other hand only some of the mare basalt meteorites (which must represent random ejecta from lunar near-surface regions) closely resemble those at the other landing sites.

Figure 1. *Cut NWA 12008 stone. © Neil Buckland.*

Northwest Africa 12008: Found in southern Morocco, this 577 gram specimen consists of small olivine phenocrysts (stained orange-brown) set in an intersertal groundmass composed mainly of zoned clinopyroxene and elongate lath-like maskelynite ($An_{86.8-87.6}Or_{0.4-0.3}$) together with accessory skeletal ilmenite, Ti-chromite, Cr-Ti-Fe spinel, troilite, rare kamacite and minor secondary barite (see Figures 1-5). Olivine (cores $Fa_{36.6-42.3}$, rim $Fa_{90.0}$, FeO/MnO = 96-99) contains inclusions of chromite and quenched melt inclusions (surrounded by radial cracks) composed of Al-Ti-bearing augite ($Fs_{28.8}Wo_{50.1}$, FeO/ MnO = 71, Al_2O_3 = 10.5 wt.%, TiO_2 = 5.3 wt.%) plus K-bearing glass (see Figure 5).

Pyroxene shows extensive compositional zoning (see Figure 6) from pigeonite ($Fs_{31.1}Wo_{14.0}$, FeO/MnO = 50) to subcalcic augite ($Fs_{25.9-71.4}Wo_{28.6-23.1}$, FeO/MnO = 50-75) to augite ($Fs_{23.2}Wo_{39.7}$, FeO/MnO = 49) to ferropigeonite on rims ($Fs_{80.1}Wo_{19.5}$, FeO/MnO = 79).

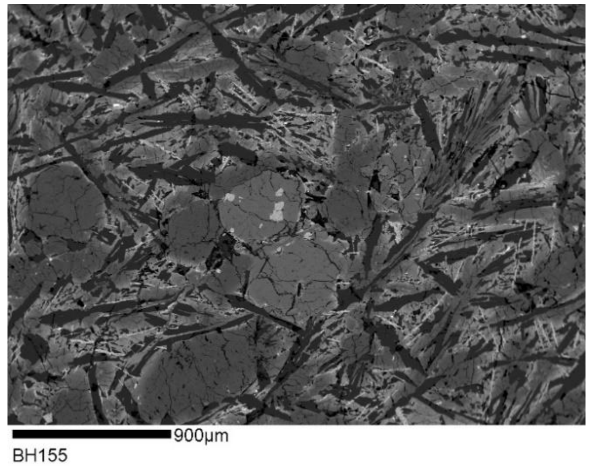

Figure 2. *Overview BSE image of NWA 12008*

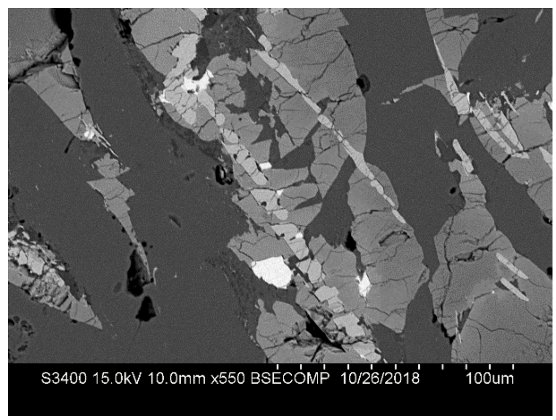

Figure 3. *Detail of skeletal ilmenite grains with pyroxene, maskelynite and troilite*

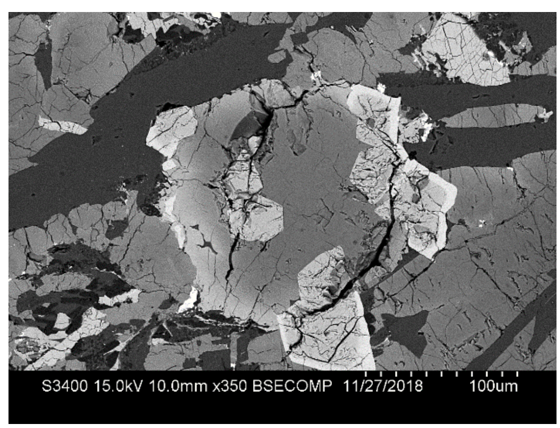

Figure 4 (right). *Possible xenocrystic aggregate of olivine+Cr-Ti-Fe spinel with more ferroan reaction rims*

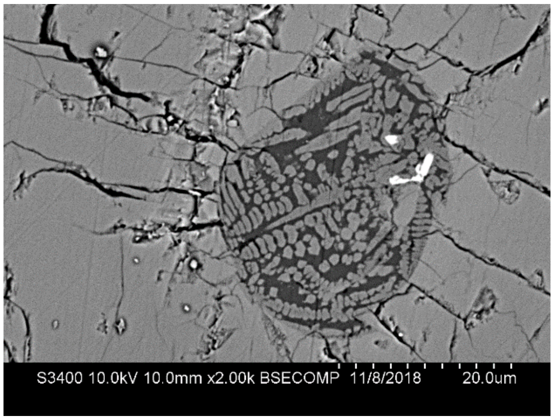

Figure 5. *Crystallized melt inclusion within olivine containing skeletal pyroxene and Cr-Ti-Fe spinel. Note the radial post-shock expansion cracks.*

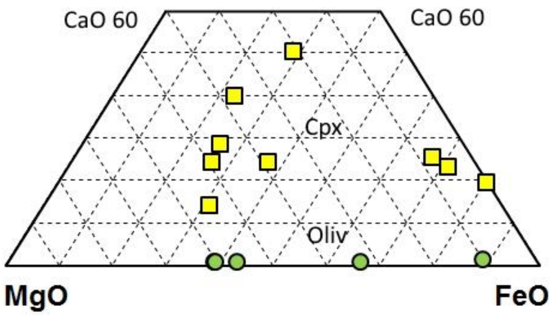

Figure 6. *Molar plot of pyroxene and olivine compositions in NWA 12008*

Bulk Major and Trace Elements: Clean representative dust produced by cutting the specimen on an Isomet saw was analyzed for major elements by lithium metaborate fusion ICP-OES at UPS and for trace elements by quadrupole ICP-MS at Notre Dame (Table 1).

Table 1. Whole Rock Major Element (in weight%) and Trace Element Abundances (in parts per million)

SiO_2	45.18	La	10.78	Ba	257
TiO_2	3.02	Ce	29.86	Sr	96
Al_2O_3	9.21	Pr	3.98	Rb	2.0
Cr_2O_3	0.36	Nd	20.25	Sc	53.3
FeO	22.72	Sm	6.45	V	137
MnO	0.31	Eu	1.12	Ni	47
MgO	8.12	Gd	8.26	Y	54
CaO	10.43	Tb	1.52	Nb	12.9
Na_2O	0.40	Dy	10.09	Zr	172
K_2O	0.01	Ho	2.31	Hf	5.1
P_2O_5	0.12	Er	6.30	Th	1.8
SUM	99.89	Yb	5.79	U	0.49
mg	0.389	Lu	0.82	Sb	0.8

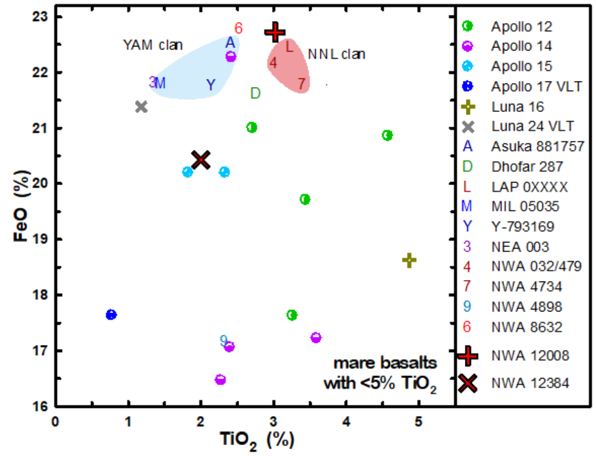

Figure 7. *Variation of bulk TiO_2 and FeO in lunar mare basalts. Data from [1] and unpublished compilation by Randy Korotev.*

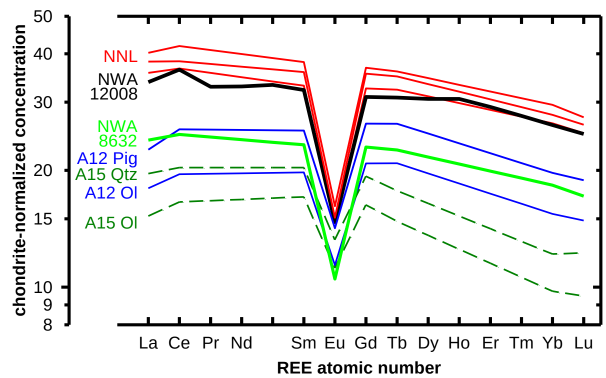

Figure 8. *Chondrite-normalized REE plot*

Discussion: NWA 12008 is a low-Ti mare basalt with compositional similarities (see Figures 7, 8) to mare basalt meteorites NWA 032/479, NWA 4734 and the LAP stones [2, 3], yet it is petrologically different from those specimens. It is quite different in both respects from NWA 8632 [4] and recently-described mare basalt breccia NWA 12384 [5]. Although similar in bulk TiO_2 content to some Apollo 12 olivine-bearing mare basalts, NWA 12008 differs in being more ferroan, and also has more elevated REE abundances than found in Apollo 12 basalts (see Figure 8). The positive Ce anomaly implies some terrestrial contamination in an oxidizing environment.

References: [1] Papike J. et al. (1998) *In* Planetary Materials, *Rev. Mineral.* **36**, Min. Soc. Amer. [2] Korotev R. http://meteorites.wustl.edu/lunar/moon_meteorites_list_alumina.htm [3] Elardo S. et al. (2013) *MaPS* **49**, 261-291 [4] Korotev R. et al. (2015) *LPS* **XLVI**, #1195 [5] Carpenter P. et al. (2019) *LPS* **L**, this conference.