PETROLOGY AND GEOCHEMISTRY OF THE LUNAR BASALTIC METEORITE NORTHWEST AFRICA 4734. Ying Wang[1], Weibiao Hsu[1], and Yunbin Guan[2], [1]Laboratory for Astrochemistry and Planetary Sciences, Purple Mountain Observatory, Nanjing, 210008, China (y_wang@pmo.ac.cn), [2]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

Introduction: Northwest Africa (NWA) 4734 is an unbrecciated mare basalt found in Morocco in 2001 [1]. Preliminary studies show that NWA 4734 share many chemical, petrologic and geochronologic characteristics with LaPaz Icefield (LAP) 02205/02224/02226/02436/03632/04841 and the two meteorites are potentially paired [1-2]. LAPs are an important representative of young (~3.0 Ga), evolved, incompatible element-enriched lunar lavas unlike any samples available in the Apollo or Luna collections, and have been extensively studied before [3-7]. On the other hand, studies on NWA 4734 are rather limited. To get a deeper understanding of the petrogenesis of NWA 4734, and to place a better constraint on the genetic relationship between NWA 4734 and LAPs, we carried out detailed petrological, mineralogical and geochemical studies on NWA 4734.

Results: NWA 4734 is a medium- to coarse-grained, subophitic-textured mare basalt. It is predominantly composed of pyroxene (58.0 vol%) and plagioclase (30.6%), with minor olivine (3.8%), ilmenite (2.2%), silica (1.5%), chromite and ulvöspinel (0.7%). The mesostasis, accounting for ~2%, is composed of fayalite, ilmenite, silica, apatite, whitlockite, Si,K-rich glass, and accessory baddeleyite, zirconolite, tranquillityite, FeNi metal and sulfide. NWA 4734 experienced moderate shock metamorphism. Plagioclase was partly converted to maskelynite. Pyroxenes with irregular fractures, and shock-induced melt veins and pockets are observed.

Pyroxene ($Fs_{21-66}Wo_{10-42}En_{5-57}$) and plagioclase ($An_{79-92}Or_{0-3}Ab_{8-18}$) in NWA 4734 exhibit large compositional ranges and intra-grain chemical zoning. Pyroxenes display a HREE-enriched pattern with a pronounced negative Eu anomaly (Fig. 1a). The Fe-rich rim ($En_{12}Wo_{36}$) has higher REE abundances than the Mg-rich core ($En_{37}Wo_{29}$), and the $(La/Lu)_{CI}$ ratio varies from 0.27 in the core to 0.15 in the rim. Plagioclase exhibits LREE-enriched ($[La/Lu]_{CI}$: 11-12) patterns with large positive Eu anomalies (Fig. 1b). The overall REE abundance increases with decreasing An content of plagioclase. Olivine occurs as forsteritic phenocrysts (Fa_{38-52}), inclusions (Fa_{48-72}) in minerals, and fayalite grains (Fa_{84-98}) in the mesostasis. Ilmenite are nearly pure $FeTiO_3$. Compositions of spinel follow a narrow fractionation trend from Al-chromite to Cr-ulvöspinel, and to nearly end member ulvöspinel. Whitlockite grains are highly enriched in REEs (6.5 wt% in total) and exhibit LREE-enriched ($[La/Lu]_{CI}$: 2.2) patterns with large negative Eu anomalies (Fig. 1c).

Due to the small sample weight we hold, bulk compositions of NWA 4734 were not determined here. Because shock-melt veins generally retain the overall geochemical compositions of basalts [4], the average REE composition of shock-melt veins is taken as a pseudo-bulk one. NWA 4734 has marginally higher REE concentrations (except Eu) than LAPs, and exhibit a slightly LREE-enriched ($[La/Lu]_{CI}$: 1.6) pattern with a pronounced negative Eu anomaly (Fig. 2).

Discussion: NWA 4734 and LAPs have similar petrologic texture and mineralogy. Both are medium- to coarse-grained, subophitic mare basalts composed of tabular pyroxene, plagioclase, minor olivine, ilmenite, silica, spinel and accessory mesostasis phases [3-4]. Modal abundances of NWA 4734 are very similar to those of LAPs [5]. Pyroxene and plagioclase in NWA 4734 have similar REE concentrations and patterns to those of LAPs. The REE abundances (2,400 to 27,000 × CI) of whitlockite in NWA 4734 are ~70% higher on average than those in LAPs, which could be due to coexisting apatite with lower REEs [3]. NWA 4734 has similar REE concentrations (except Eu) to LAPs, indicating that they all originated from highly fractionated magmas. Previous study has shown that the crystallization ages of NWA 4734 (3074±16 Ma) and LAPs (3041±12 Ma) are almost identical within analytical errors [2]. In summary, NWA 4734 has high affinities to LAPs in petrography, mineralogy, REE geochemistry and geochronology; these meteorites were most likely derived from the same source crater on the Moon.

Assuming that REEs did not redistributed in chemically zoned silicates since crystallization, we estimated the REE compositions of parent magmas that equilibrated with the cores of augite and plagioclase in NWA 4734, respectively, using the REE partition coefficients (Ds) in [8]. As shown in Fig. 2, the melt calculated from the pyroxene core is highly LREE-enriched ($[La/Lu]_{CI}$ = 4.6) and has ~50% more REEs (except Eu) than the shock-melt veins. Because the Ds of pyroxene vary considerably with chemical compositions and differently for each REE [9], minor intragrain homogenization in pyroxene will result in higher REE contents of the calculated melt and an artificially LREE-enriched pattern [10]. The melt calculated from the pyroxene core in NWA 4734 strongly suggests that REEs in pyroxene had been re-equilibrated after crystallization. On the other hand, the Ds for plagioclase are relatively insensitive to chemical variations during fractional crystallization [11]. Even if plagioclase is partly re-equilibrated, the calculated melt will have higher REE abundances but with a pattern parallel to that of the parent melt [10], i.e., the calculated REEs represent upper limits of the initial melt. In NWA 4734, the melt calculated from the plagioclase core exhibits a pattern parallel to the shock-melt veins and has ~50% lower REE contents than the estimated whole rock (Fig. 2). It is evident that the original melt of NWA 4734 has much lower REE abundances than the whole rock, indicating an open system during its fractionation crystallization.

The incompatible element enrichment of mare basalts can be attributed to assimilation and fractional crystallization processes [4]. Our study of REE systematics in NWA 4734 is consistent with the assimilation mechanism. And the baddeleyite grains with older ages than its host rock found in LAPs also support this hypothesis [2]. Our study indicates that the assimilation process in NWA 4734 occurred in the late stage of crystallization, probably after the formation of plagioclase. The REE compositions (except Eu) of shock-melt veins in NWA 4734 can be approximately modeled by mixing of 5% SaU 169 (i.e., KREEP-rich material) to the original magma (Fig. 2), which has similar REE compositions to the average Apollo 12 olivine basalt [12-13]. Similarly, the LAP parent magma was suggested to have mixed 1-2 wt% SaU 169 to Apollo 12 low-Ti olivine basalt [7].

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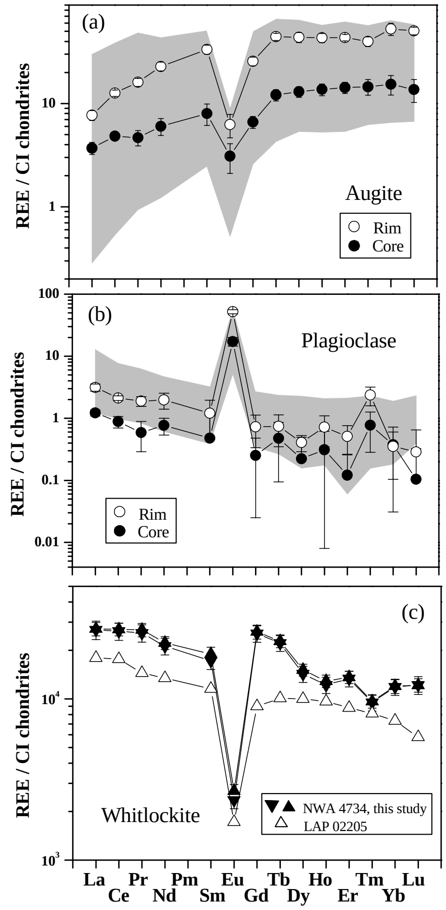

Fig.1 CI-chondrite-normalized REE patterns for minerals in NWA 4734. The shaded regions are the REE-content ranges of minerals in LAPs [3-7].

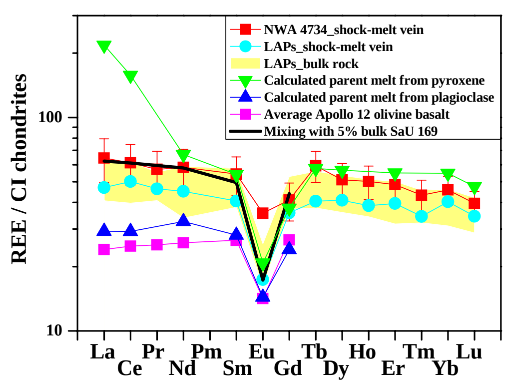

Fig. 2 CI-chondrite-normalized REE patterns for shock-melt veins in NWA 4734 and LAPs, and for calculated melts equilibrated with the cores of pyroxene and plagioclase of NWA 4734. Data for LAPs and Apollo 12 olivine basalts are from [3-9] and [12-13], respectively.