MAGNESIAN FELDSPATHIC CRUST AND GEOCHRONOLOGY OF EVOLVED MARE BASALT IN FELDSPATHIC LUNAR BRECCIA METEORITE DHOFAR 1428. Zhuqing XUE[1], Long XIAO[1], and Yigang XU[2], [1]Planetary Science Institute, China University of Geosciences, Wuhan, China (2533149235@qq.com, longxiao@cug.edu.cn), [2]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences.

Introduction: Dhofar 1428 is an incompatible trace element(ITE)-poor feldspathic lunar regolith breccia meteorite. The complex textures and compositions make it a unique sample for investigating the magmatic history, impact history, and early evolution of lunar crust. Previous works have done some petrologic and geochemical works on it and find some KREEPy(a abbreviation of potassium(K), rare earth element(REE) and phosphorus(P) rich rock) and quartz monzogabbro(QMG)[1]. However, the total variety of clast components has not been clearly demonstrated because of its complicated breccia texture and limited sample allocation. This study, we present detailed mineralogical, petrological, geochemical and geochronological survey of one section of the Dhofar 1428 and hope these new data can provide more clues for better understanding the evolutionary history of the ancient lunar crust.

Analytical methods: One thin section of lunar meteorite Dhofar 1428 was examined by field emission scanning electron microscopes(FE-SEM), major elements of minerals were obtained with electron probe micro-analyzers(EPMA) at China University of Geoceiences(Wuhan).

Secondary ion mass spectrometry(SIMS-1280) analyses were used to obtain in-situ U-Pb age of apatites at the Institute of Geology and Geophysics(CAS) in Beijing. An O_2 primary ion beam of ~200 pA was accelerated to -13 keV. The Gaussian illumination mode was used to obtain a small beam size of ~10 μm. A single electron multiplier was used in ion-counting mode to measure secondary-ion beam intensities by a peak jumping sequence, including isotopes of Pb^+, Th^+, U^+, ThO^+, UO^+, UO^{2+} and $^{40}Ca_2{}^{31}P^{16}O_3{}^+$ to produce one set of data. Each measurement consists of 10 cycles, and the total analytical time is ca. 20 min. The mass resolution power was fixed at 9000 (defined at 50% peak height). The mass fractionations of Pb isotopes and Pb hydrides(requiring a mass resolution >30,000) were considered insignificant because these two effects are negligible and there appears to be amutual cancelation effect.

Results:

Lithological mineral inventory. Dhofar 1428 is feldspathic regolith breccia with several lithic and mineral clasts setting in the glassy matrix(Fig.1). Lithic clasts include impact melt breccias(IMBs), granulites, anorthosites, mafic lithologies, and basalts. Monomineralic fragments include plagioclase (approximately 70% by modal abundance), pyroxene(~25%), and olivine(~4%), Other less common mineral grains include ilmenite, spinel, troilite, and Fe-Ni metal grains.

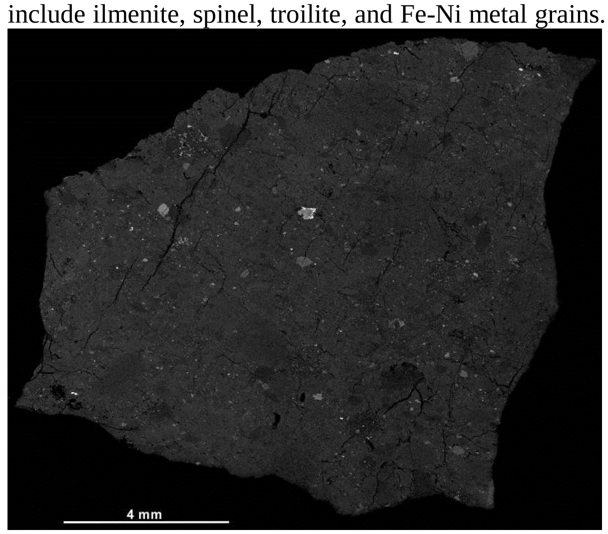

Fig.1 Back scatter electron (BSE) image of lunar meteorite Dhofar 1428.

Anorthosites range from noritic anorthosites to troctolitic anorthosites, and mafic rocks from norite, gabbro to olivine gabbro, all of them have ilmenite and chromite accessories and well-preserve igneous textures(Fig. 2). Granulites include noritic, troctolitic and gabbric anorthosites with granoblastic to poikiloblastic textures. Most IMBs are noritic/gabbroic/troctolitic anorthosite with multiple textures(e.g. intersertal, poikilitic, and microporphyritic). There are also one KREEPy olivine norite belonging to High Magnesian Suite(HMS) and one evolved coarse low-titanium(LT) basalt which are observed for the first time within this meteorite.

The cataclastic ITE-rich magnesian olivine norite is coarse-grained and evolved with Si, K-rich glass and apatites. Basalts are all very low- very low titanium (LT-VLT) according to the zonation of pyroxene. There is one coarse-grained LT basalt which is ITE-rich and evolved with several apatites, baddeleyite, Si, K-rich glass, K-feldspar, Fe-rich pyroxene, and symplektite(Fig. 2).

In the diagram of An of plagioclase vs $Mg^{\#}$ of coexisting mafic minerals, in addition to those well within the Apollo FAN field, some anorthosites and granulites are more magnesian or ferroan than typical FAN

(Fig.3). The magnesian olivine norite is well within the Apollo HMS field.

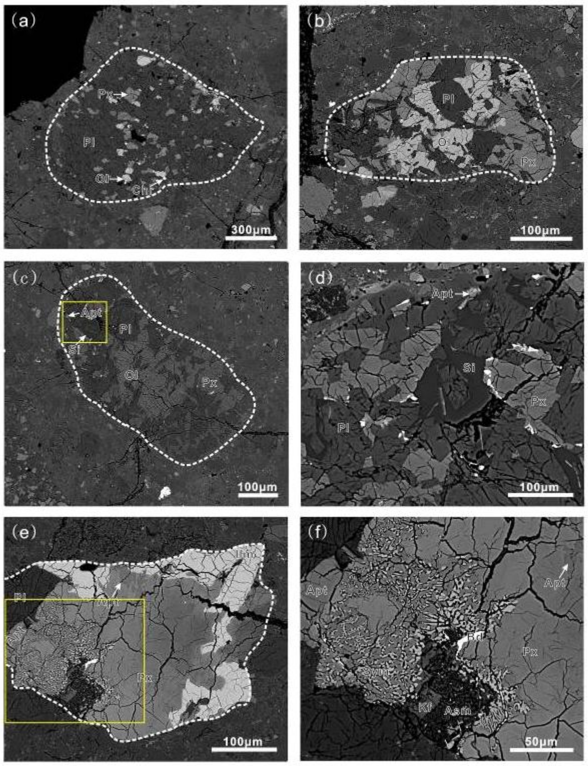

Fig. 2. BSE images of several lithic clasts within Dhofar 1428: (a) Anorthosites with cosrse-grained intergranular texture. (b) Coarse-grained olivine norite. (c, d) Olivine(Ol) norite belonging to the HMS, containing Si, K-rich glass(Si) and apatites(Apt). The yellow rectangle area in (d) is enlarged in (c). (e, f) Coarse-grained ITE-rich LT basalt showing zoned pyroxenes, elongated ilmenites and apatites. (f) Enlarged view of rectangle in (e) showing fine-grained Si-K-Al assemblages(Asm) and symplektite(Sym). Pl-plagioclase, Chr-chromite, Kf-K-feldspar, Bd-baddeleyite.

U-Pb age of the evolved LT basalt. The in-situ U-Pb age of apatites in the LT basalt is 3968 ± 15 Ma, we consider it's the crystallization age of the basalt and is the oldest LT basalt that has been found in lunar meteorites[2].

Discussion and conclusion: The magnesian anorthosites and granulites are similiar with those identified in other lunar meteorite samples and may come from the farside highland[3,4]. While these extremely ferroan ones are within the extended field of FAN, similar to the hyperferroan anorthosite from ALHA 81005 described before[5].

The ITE-rich magnesian olivine and evolved LT basalt may be related to KREEP and thus were ejected into the source region of Dhofar 1428 from the Procellarum KREEP Terrane(PKT, [6]). Further trace element and isotope analysis may uncover their genesis and relationships with KREEP. Age data of the evolved basalt gives further meteoritic evidence of old magmatism on the moon.

The exiguity of KREEPy characters and feldspathic nature of the sample suggest that Dhofar 1428 may be derived from the Outer-Feldspathic Highlands Terrane (FHT-O, [6]), far distant from the PKT, and even a farside origin is possible. More detailed mineralogical, petrological, geochemical, and geochronologic study of this sample could provide us with better understanding of the complex composition and evolutionary history of lunar crust.

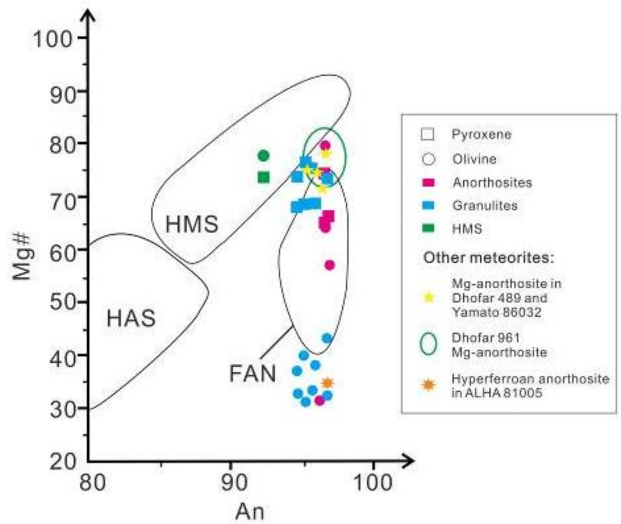

Fig. 3. Mg# in mafic minerals versus An in plagioclase for Dhofar 1428 in context of fields showing pristine Apollo rock suites[7]. Mineralogy of other meteorites are shown for comparison, including magnesian anorthosite clasts from Dhofar 489, Yamato-86032 and Dhofar 961[3,4], and hyperferroan anorthosite in ALHA 81005[5].

References: [1] Hidaka, Y. et al. (2014) *Meteoritics & Planet. Sci, 49*, 921-928. [2] Terada, K. et al. (2007) *Earth and Planetary Science Letters*, *259*, 77-84. [3] Yamaguchi, A. et al. (2010) *Geochimica et Cosmochimica Acta, 74*, 4507-4530. [4] Korotev, R.L. et al. (2006) *Geochimica et Cosmochimica Acta*, *70*, 5935-5956.[5] Goodrich, C.A. et al. (1984) *Journal of Geophysical Research: Solid Earth*, *89*, 87-94 [6] Jolliff, B.L. et al. (2000) *Journal of Geophysical Research: Planets*, *105*, 4197-4216. [7] Joy, K.H. et al. (2014) *Meteoritics & Planetary Science*, *49*, 677-695.