A KREEP CLAST IN THE LUNAR METEORITE DHOFAR 1180. Aicheng Zhang and Weibiao Hsu, Laboratory for Astrochemistry and Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China. aczhang@pmo.ac.cn, wbxu@pmo.ac.cn.

Introduction: KREEP rocks are impact-melt breccias or glasses that contain high concentrations of K, REEs, P, and other incompatible elements. These rocks were derived from the Procellarum-Imbrium region and were distributed over most of the lunar surface by the Imbrium impact event [1-3]. The abundance of KREEP component in a lunar rock would indicate the distance of its source region from the center of the Imbrium Basin [3]. The Apollo and Luna samples were collected within and around the Procellarum Terrane. They usually contain various amounts of KREEP rocks. On the other hand, most lunar meteorites (random samples of the lunar surface) contain low or no KREEP components. Up to date, only three lunar meteorites (SaU 169, Calcalong Creek, and Y983885) were reported containing KREEP components [4-6]. Here, we report a KREEP clast found in the lunar meteorite Dhofar 1180.

Results: Dhofar 1180 is a newly found lunar meteorite from Oman in 2005. Bunch et al. [7] reported its bulk composition of 22.6 wt% Al_2O_3, 9.3 wt% FeO, and 0.9 ppm Th. Zhang and Hsu [8] described its preliminary petrography and mineralogy. It is a basalt-bearing feldspathic regolith breccia that contains various types of lithic clasts, including gabbro, anorthositic gabbro, granulite, subophitic basalt, troctolite, Ti-rich clast, microporphyritic crystalline impact melt breccia and gabbroic anorthosite [8]. In the two thin sections studied, one KREEP clast was found. This clast is angular and about 30 μm in its largest dimension. The clast is composed of three portions with different textures: grey-colored glass on the left, light-colored glass on the right, and middle with a mixture of two immiscible glasses (Fig. 1a). On the BSE image, sub-micron dark glass spheres occur on the right edge of the right light-colored region. The middle part of the clast displays a vermiform texture. In the left grey region, fine-grained light glass spheres show a gradient variation of apparent sizes (up to ~1 μm). No crystals were observed in the clast. The glass shows no devitrification.

The light-colored glass on the right and the dark glass in the middle portion of the clast were analyzed with a focused beam. The grey-colored glass at the left side and the middle portion of the clast were analyzed with a defocused beam of 5 μm. The results are listed in Table 1. The right light-colored glass (R_l in Table 1) is an iron-rich melt and contains relatively high concentrations of Mg, Ca, Ti, and P; whereas the dark glass in the middle region (M_d in Table 1) is relatively rich in Si, Al, and K. Both the left grey glass (L in Table 1) and the middle portion of the clast (M in Table 1) have intermediate chemical compositions between R_l and M_d. The low total values may be due to the evaporation loss of Na and K from the glass under the high electron beam current used in the study, or may indicate the presence of other elements such as REEs.

X-ray mapping images of elements in the clast are shown in Fig. 1. The images reveal variation of element distributions in different portions of the clast, consistent with the EMP data. Furthermore, the X-ray mapping indicates that REEs are mainly concentrated in the right light-colored Fe-rich glass.

Discussion: EMP analyses and X-ray mapping demonstrate that the clast contains high concentrations of K, P, REEs, Ti, and Fe. This is broadly consistent with the chemistry of an average KREEP rock [9]. The KREEP clast in Dhofar 1180 is an impact-melt glass composed of two immiscible melts. KREEP clasts with the similar texture were also reported in Apollo and Luna samples [10-12]. In Apollo and Luna samples, the KREEP clasts with immiscible melts appear in the interstice of plagioclase crystals or were included in plagioclase crystals. They show varying chemical compositions of Si, Fe, Al, P, K, and Ti within the similar ranges of the clast in Dhofar 1180 (Table 1). KREEP components have been reported in three lunar meteorites. In SaU 169, the KREEP clast appears as a holocrystalline, fine-grained polymict impact-melt breccia [4]. The KREEP clasts in Calcalong Creek and Y983885 are lithic clasts composed of pyroxene and plagioclase with minor phosphate [5-6].

KREEP material is one of the three major components of lunar surface regoliths [1]. It potentially provides information about the formation and evolution of the lunar crust. The origin of KREEP rocks is still in debate. The lunar Prospector γ-ray spectrometer revealed that geochemically incompatible elements, such as K and Th, are concentrated in the Northwestern part of the nearside that coincides with Oceanus Procellarum [13]. This region was recognized as a major geological terrane (the Procellarum KREEP Terrane, PKT) on the lunar crust [2]. Haskin (1998) noted a relationship between Th concentration and the distance from the Imbrium basin [3]. With Th of 33 ppm, SaU 169 was inferred to have derived from the Lalande impact crater [4]. Y983885 and Calcalong Creek are relatively rich in Th (2 and 4 ppm respectively). Their source regions could be related to the PKT and SPAT areas [5,6]. Th in Dhofar 1180 is relatively low (0.9 ppm [8] and 0.7 ppm of our unpublished data). This indicates that Dhofar 1180 is probably derived from an area at a

distance of >2000 km from the center of the Imbrium Basin [3].

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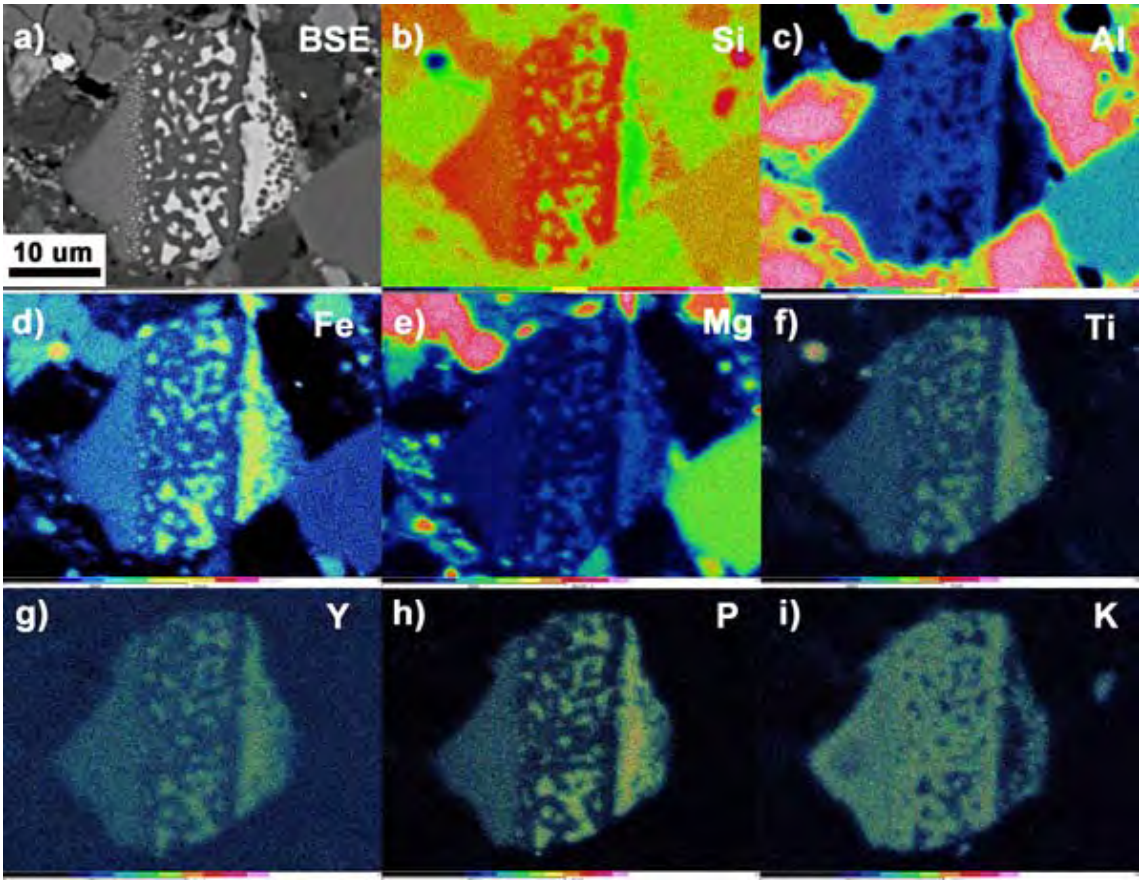

Figure 1. Back-scattered electron image of the KREEP clast in Dhofar 1180 and X-ray mapping of Si, Al, Fe, Mg, Ti, Y, P, and K.

Table 1. EMP analyses of the KREEP clast in Dhofar 1180 and comparison with Apollo KREEP rocks.

	Na_2O	K_2O	MgO	FeO	Al_2O_3	MnO	SiO_2	Cr_2O_3	TiO_2	CaO	P_2O_5	Total
R_l	0.15	0.70	5.49	27.96	6.61	0.36	35.10	0.12	6.02	9.14	6.25	97.90
M_d	0.63	2.91	1.56	9.53	12.66	0.14	60.24	0.02	2.36	5.70	1.61	97.36
M	0.51	2.75	2.60	13.96	10.99	0.18	52.22	0.04	3.25	7.10	2.82	96.42
L	0.48	3.08	2.34	12.54	11.72	0.21	54.03	0.07	2.77	6.35	2.90	96.49
15382,7a		0.86	2.57	36.92	2.84		29.58		8.95	9.49	8.97	98.48
15382,7b		5.11	-	0.72	11.86		75.33		0.87	1.74	-	95.62
15382,7c		4.99	0.24	6.39	11.00		67.73		1.44	3.21	0.73	95.60
KREEP*	0.86	0.83	10.61	10.55	16.63	0.14	47.91	0.19	1.67	9.51	0.78	99.68

R_l and M_d denote the light glass on the right and the dark glass in the middle of the clast shown in Fig. 1a, respectively, and M and L represent the middle portion and the left portion of the clast, respectively. 15382,7a, 15382,7b, and 15382,7c are average chemical compositions of Apollo 15 KREEP Fe-rich blebs, Si-rich glass and broad beam glass analyses, respectively [12]. KREEP* are average chemical compositions of Apollo KREEP rocks [9].