MAGMATIC EVOLUTION MODEL FOR THE HOST MAGMA OF ROCKS IN PROCELLARUM KREEP TERRANE. S. Togashi[1], [1]Geological Survey of Japan, AIST (Central 7, Tsukuba 305-8567, Japan, s-togashi@aist.go.jp).

Introduction: Mg-suite rocks and KREEP (K-, Rare Earth Element-, and P-rich) basalts of the Procellarum KREEP Terrane (PKT) paradoxically contain both Mg-rich components and an incompatible element-enriched component [e.g., 1–3].

I previously estimated the concentrations of trace elements in the host magmas of plutonic rocks including Mg-suite rocks of the PKT region (i.e., the PKT host magma) based on the trace element compositions of plagioclase in Apollo (Ap) 14 samples determined by secondary ion mass spectrometry, and found that the PKT host magmas have high Ti and Ba concentrations (Fig. 1; [4]).

Here, I explore the formation of the PKT host magma and KREEP basalts from the bulk silicate moon (BSM) by applying two BSM evolution models: one from the lunar primitive upper mantle (LPUM [5]) and one from a crustal-component-enriched BSM with a sub-chondritic Ti/Ba ratio (cBSM), as previously proposed based on ferroan anorthosites (FANs [6]).

Polybaric multi-step BSM evolution model: I modeled the polybaric multi-step evolution of the BSM using MELTS software [7, 8] by extending the two-step model [6, 9] (Fig. 2). Ba and Sr concentrations were calculated based on the partition coefficients from model 2 of [10].

In the first step, an equilibrium melt of LPUM or cBSM composition and accounting for 40 wt% of the BSM was generated at high pressure (0.8 GPa), leaving early cumulates (S1). In the second step, the magma ascended to a shallow depth (0.3 GPa), where

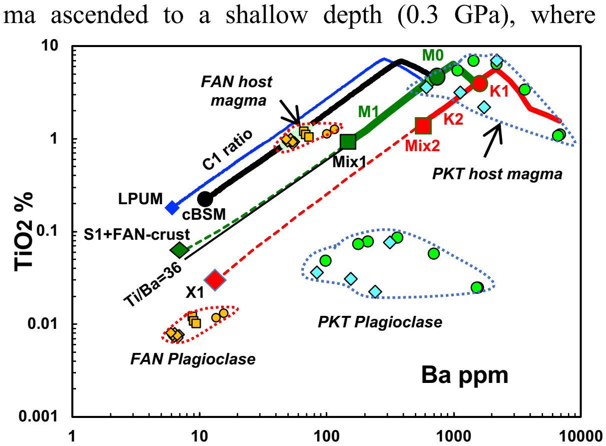

Fig. 1. TiO_2–Ba variations of the FAN host magma and PKT host magma estimated from plagioclase by assuming the partition coefficients [4, 6] and magmas evolved by polybaric multi-step evolution of the BSM from the LPUM or cBSM composition and subsequent AFC processes (only for cBSM) . See text for details.

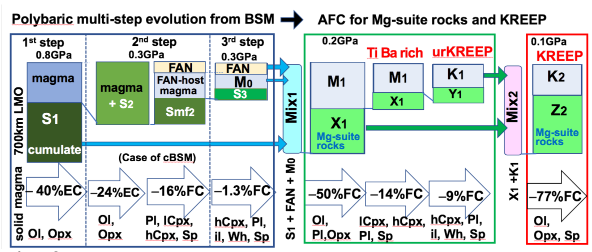

Fig. 2. Polybaric multi-step model of BSM evolution and subsequent AFC models to produce Mg-suite rocks and KREEP from the cBSM. See text for details.

it crystallized in equilibrium (equilibrium crystallization, EC) until the appearance of plagioclase (17 and 24 wt% melt for LPUM and cBSM, respectively), then evolved under fractional crystallization (FC) to form the FAN crust (–8 and –16 wt% melt for LPUM and cBSM, respectively). These melts represent the segregation of the FAN host magma from the FAN crust and mafic cumulates (Smf_2) [6].

The LPUM, with its chondritic Ti/Ba ratio, cannot reproduce the sub-chondritic Ti/Ba ratio of the FAN host magma estimated from plagioclase, whereas cBSM can (Fig. 1; [6]).

In a third step, the remainder further evolved via FC to the evolved magma (M_0) at Ti/Ba = 36 (0.8 and 1.3 wt% melt for LPUM and cBSM, respectively). This Ti/Ba ratio is the upper limit of those estimated for the PKT host magma based on plagioclase (Fig. 1; [6]) and the bulk rock composition of Ap14 Mg-suite rocks (Fig. 3; [3, 11–25]).

As magmas more evolved than M_0 have decreasing TiO_2 contents, FC via the polybaric multi-step BSM evolution model alone cannot produce the high-Ti and -Ba PKT host magma estimated from plagioclase (Fig. 1; [4]). Hence, I explored subsequent assimilation and fractional crystallization (AFC) processes for the genesis of the PKT host magma and KREEP basalt.

AFC processes:

AFC to produce the PKT host magma. AFC processes are required to reproduce the high Mg# and incompatible element compositions of Mg-suite rocks [1–3]. The source of the Mg suite (Mix_1) was assumed to be a mixture of three components: 1) the evolved magma (M_0) with Ti/Ba = 36 after crystallization of ilmenite, 2) an overturned early mafic cumulate (S1), and 3) the FAN crust (67075,11 [26]).

Crystallization of high-Mg# (>84) olivine coexisting with high-anorthite (X_{An} > 0.95) plagioclase via evolution of Mix_1 requires large amounts of mafic cumulate (40 wt% S1) and FAN crust (40 wt%) mixed with M_0.

Mix_1 probably would have melted at high temperature upon mantle overturn (e.g., [1]), and I assumed it fractionally crystallized under low pressure (0.2 GPa). The evolved magma (M_1) could have formed the PKT host magmas, leaving mafic cumulates such as Mg-suite rocks (Fig. 3). There was no significant difference in the M_1 trends between the results for the LPUM (not shown) and cBSM compositions after AFC because the Ti/Ba ratio of Mix_1 was the same for both cases. The evolved cBSM magmas (M_1 = 14 wt% FC; melt from Mix_1 through FC) can reach the high Ti and Ba concentrations of PKT host magmas (Fig. 1).

The further evolved melt (M_1 < 10 wt% FC*)* has higher TiO_2 and SiO_2 concentrations and lower MgO and Al_2O_3 concentrations relative to Ba than KREEP basalts (Fig. 3). Therefore, to reproduce the low Ti/Ba ratios (<15) of KREEP basalts, I applied a further AFC process to the evolved magma (M_1 = 9 wt% FC = K_1) at Ti/Ba = 15 (Fig. 3a; [18, 27–31]).

AFC to produce KREEP basalt. K_1 may correspond to 'urKREEP' [32], and assimilated 60 wt% of the overturned early cumulates (X_1 = the accumulated solids from melt M_1 after 50 wt% FC) to form the source mixture (Mix_2). Then, Mix_2 could fractionate typical KREEP basalts (K_2, Al_2O_3 < 19 wt%) under low pressure (0.1 GPa).

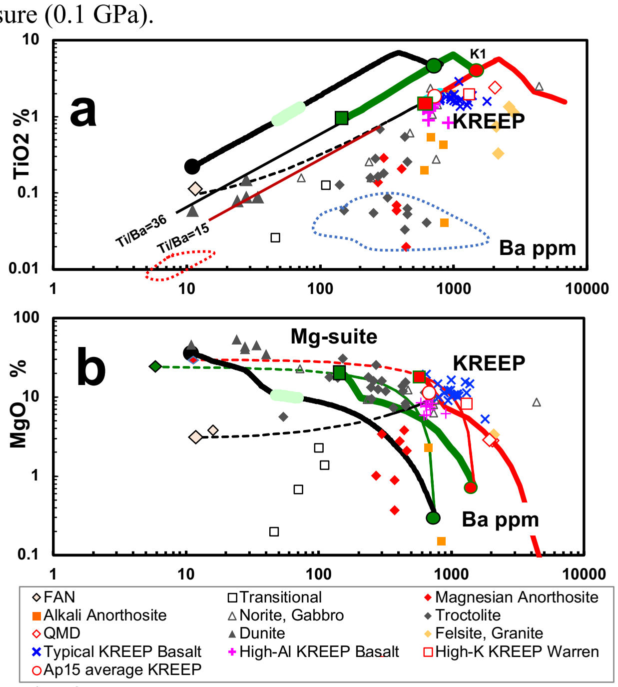

Fig. 3. Ba vs. (a) TiO_2 and (b) MgO variations of the bulk rock compositions of Ap14 plutonic rocks [3, 11–25], Ap14 typical KREEP basalts and Ap14 high-Al KREEP basalt [18, 27–30], high-K KREEP basalts [31], average Ap15 KREEP basalt [19], and modeled magmas evolved from the cBSM of this study. Symbols not shown in the legend are as in Fig. 1. See text for details.

The composition calculated for K_2 (77 wt% FC from Mix_2) corresponds to the average Ap15 KREEP basalt [29] (Table 1). Typical Ap14 KREEP basalts have slightly lower TiO_2 contents than K_2 (Figs. 1 and 3a), possibly due to the variable Ti/Ba ratios (5–15) of K_1. Al-rich Ap14 KREEP basalts can be explained by further assimilation of the FAN crust (Fig. 3).

Table 1. Compositions of modelled and observed KREEP basalts.

		SiO_2 wt%	TiO_2 wt%	Al_2O_3 wt%	FeOt wt%	MgO wt%	CaO wt%	*Mg#*	Sr ppm	Ba ppm
K_2: (77 wt% FC of Mix_2)	This study	51.1	2.0	15.6	9.0	10.0	10.4	66	215	788
Averaged Ap15	Snyder et al. [29]	51.1	1.9	15.5	9.9	9.7	9.5	64	200	720

Conclusions: The proposed model for the polybaric multi-step evolution of a cBSM magma and subsequent AFC processes could have formed the PKT host magmas and fractionated the Mg-suite rocks in the PKT region, and ultimately produced KREEP basalts. I note that my model is consistent with the high Ti and Ba contents of the PKT host magma estimated from plagioclase.

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