

THE ROLE OF THE VAPORIZATION PROCESS IN THE IMPACT-ACCRETION HISTORY OF THE MOON. Markova O.M., Yakovlev O.I. (V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, 117334, U.S.S.R.), Belov A.N., Semenov G.A. (Department of Chemistry, Leningrad State University, Leningrad, 199004, U.S.S.R.)

Introduction. Some data on lunar rocks and soils point out the nonisochemical character of impact process due to vaporization-condensation phenomena. However, the scale of possible chemical shifts is still unclear, that demands experimental study of the phenomena. The vaporization of several types of the material simulating the rocks of the lunar crust and compositions of the melt of proposal magmatic ocean were studied using the Knudsen effusion cell. The brief description of the technique was given elsewhere /1/. The experiments were carried out in the step-wise heating regime till the complete vaporization of the sample under study. The temperature step was 70° , duration of the temperature step 15 min. The studied samples include: anorthite (I), lunar leucocratic basalt 68415,40 (II), gabbroanortosite (III), troctholite (IV), alumina basalt (V), lherzolite (VI) and chondrite Krymka (LL3) (VII), (table 1). as the result of this study were determined: forms of the components in vapor, partial pressures of the main components over the residuals (see /2/ for the compositions I-IV), compositions of residual melts (see table 2 for the compositions V and VI), compositions of complementary vapor, partial pressure of oxygen, total pressure of the components in vapor over the residual melts and activities of components in these melts.

Results. In all studied cases along with the increasing of temperature and vaporization degree the residual melts are depleted in Na, K, Fe and Si and are enriched in Ca, Ti and Al. The trends of the compositional evolution (fig.1) contrast with the well-known trends typical for crystallization differentiation. For example, the ratio $FeO/FeO+MgO$ decreases in residual vaporization melts and increases in crystallization melts. The vaporization of the compositions imitating the lunar highland rocks (II-IV) tends to the leaving the field of the lunar highland rocks already at mass losses $< 5\%$. That allows to suppose that the bombardment of ANT rocks didn't cause radical changes in their compositions. The vaporization of the high alumina basalt (V) having SiO_2 content higher than in typical lunar highland rocks leads to ANT compositions. During the vaporization of the basalt at $T = 1600 - 1700^{\circ}C$ (mass losses 15-35%) the residual composition crosses the ANT field. So, the composition of the lunar highland rocks may be received by high temperature vaporization possibly in the intensive impact process. Experimental data also point out the improbability of receiving these compositions by the vaporization of ultramafic samples (VI and VII) considered as compositions of initial magma in many hypotheses of magmatic ocean. However, it isn't excepted that the vaporization and depletion of initial magma in Si, Na, K and other relative volatile elements took place during impact influence on the ultramafic composition. And the following magmatic differentiation of such deficient in volatiles magma may result in formation of the observed spectrum of the highland rocks. The comparison of experimental data concerning the higher volatility of silica relatively to magnesium with the data on the content of these elements in the lunar material (insignificant deficit of silica and absence of any sign of magnesium depletion /3/) permits to put some limitations on the average temperature of the supposed impact melts and probably that of magmatic ocean. If the temperature of the lunar surface (magmatic ocean) and vapor $\approx 1500^{\circ}C$ silica is partially in vapor as Mg is completely in melt.

Discussion. Vaporization process is not enough for the depletion of the Moon in volatile elements as a whole. It is necessary to take out this material from the planet. Using the experimental forms of components in vapor (and their masses) during the vaporization of the silicate melts /2/ permits to evaluate the level of dissipation under ideal conditions. The calculation shows that losses of petrogenic elements at temperature $\approx 1500^{\circ}C$ from the recent Moon is improbable. Only for Na the level of dissipation reaches $\approx 2\%$, for the others it is significantly less than $\approx 1\%$. So, we can conclude, that vaporization on the final stages of the lunar accretion could lead only to the redistribution of volatile substances within the lunar body the material loss from the surface was principally possible but rather noneffective. The dissipative loss of material increases with the decreasing of the lunar mass. Curves of the dissipation levels of the volatile petrogenic components in dependence on temperature for the lunar mass $3.53 \cdot 10^{25} g$ are shown in fig.2. This mass corresponds to the escape velocity 1.88 km/sec and the radius of the Moon by 400 km less than the recent one (400 km is the assumed value of the magmatic ocean depth /3,4/). Curves of Na, K, SiO and Fe begin from the temperatures at which pressures of their vapors $\geq 10^{-4} \text{tor}$ (the pressures have been taken from the basalt vaporization experiment). It may be seen, that at temperatures $1500^{\circ}C$ the level of

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dissipation for SiO-2%, K-3%, Na-14%. So, that termal dissipation on the stage of beginning of generation of the magma ocean could provide the depletion of the melt in alkalis and silica. The dissipation on the early stage of the magma ocean formation should obviously be followed by the effects of mass fractionation. In fact, the considerable depletion of the lunar material in Na comparative to chondrites ($\times 30$), less K, and insignificant - Si, is noted /3/. As the experiments show, iron is more volatile than silica, but we haven't any signs of its depletion. The possible cause of this may be the low possibility of its escape due to relatively large mass of its atom.

References 1. Yakovlev O.I. et al 14th LPS (1983) 869; 2. Markova O.M. et al 14th LPS (1983) 460; 3. Ringwood A.E. Origin of the Earth and Moon. 1979 Springer-Verbag, New York; 4. Walker D. 6th PLSC (1975) 1103-1120

Fig.1. THE TRENDS OF THE COMPOSITIONAL EVOLUTION DURING THE VAPORIZATION IN COMPARISON WITH THE COMPOSITION OF LUNAR HIGHLAND ROCKS

Fig.2. CURVES OF THE DISSIPATION LEVELS OF THE VOLATILE PETROGENIC COMPONENTS IN DEPENDENCE ON TEMPERATURE FOR THE LUNAR MASS 3.53×10^{25} g AND ESCAPE VELOCITY 1.88 km/sec

CHEMICAL COMPOSITIONS OF THE INITIAL SAMPLES TABLE 1

oxide	I	II	III	IV	V	VI	VII
SiO ₂	42.94	45.40	42.36	42.43	50.01	41.94	41.10
TiO ₂	0.0	0.32	0.05	0.12	0.95	0.07	0.10
Al ₂ O ₃	30.03	28.03	26.72	19.50	18.29	4.34	2.00
FeO	0.55	4.25	3.99	1.49	3.93	5.73	25.90
Fe ₂ O ₃			1.50		5.59		2.14
MnO		0.06	0.09	0.13	0.20	0.14	
MgO	0.11	4.33	3.27	14.97	5.95	34.72	25.60
CaO	19.16	16.39	14.31	10.37	12.36	6.62	1.90
Na ₂ O	0.55	0.41	1.26	0.71	2.39	0.16	0.90
K ₂ O	0.06	0.06	0.11	0.03	0.42	0.04	0.07
	100.05	99.9	99.25	96.90	100.10	95.9	97.17

COMPOSITIONS OF THE RESIDUAL MELTS DURING THE VAPORIZATION OF THE COMPOSITION VI AND V TABLE 2

T°C	M, g	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	T°C	M, g	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO
0	0	44.02	4.56	5.74	30.44	6.95	0	0	52.32	19.13	9.37	6.25	12.93
1475	1.46	44.40	4.62	7.01	30.92	7.05	1476	1.17	52.46	19.15	8.63	6.25	12.94
1492	4.16	44.90	4.75	5.38	37.72	7.25	1544	4.89	52.74	20.12	7.01	6.54	13.59
1632	9.74	44.90	5.05	3.23	39.06	7.70	1640	14.41	50.90	22.35	4.46	7.17	15.11
1726	21.80	41.77	5.83	1.57	41.95	8.9	1719	37.17	40.45	29.51	1.97	3.11	19.95
1796	38.35	35.57	7.39	1.11	44.67	11.27	1790	53.53	22.94	41.13	1.03	7.20	27.66
1883	65.21	13.60	13.09	1.79	46.61	16.34	1869	66.01	4.43	50.29	0.32	1.69	37.27
1960	86.05	1.17	32.64	1.66	16.34	43.20	1957	69.35	0.15	62.13	0	0	37.72
2038	89.25	1.09	42.10	0.41	0	56.40	2030	71.33	0	65.62	0	0	34.3
2118	91.81	0.23	53.05	0.14	0	46.59	2119	76.19	0	74.21	0	0	25.29
2207	95.51	0	79.28	0.04	0	21.64	2200	83.68	0	81.43	0	0	18.57
2291	98.84	0	74.65	0	0	25.36	2255	97.99	0	79.49	0	0	20.51

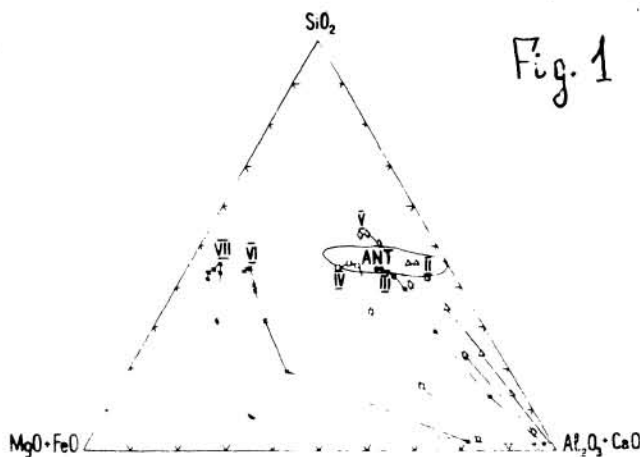


Fig. 1

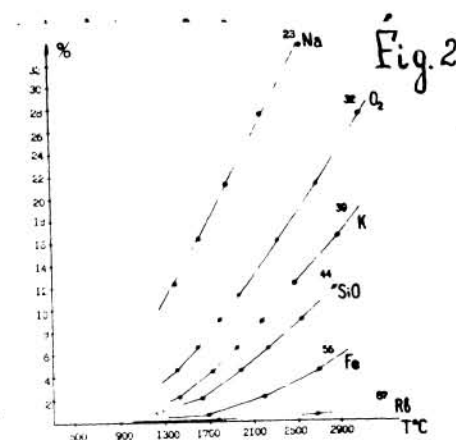


Fig. 2