

CHEMICAL ROCK TYPES, CRYSTALLIZATION SEQUENCE AND POSSIBLE TYPES OF PRIMARY MELTS OF MARE CRISIUM  
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The magmatic rocks from Mare Crisium are specific mare basalt series (1, 2, 3, 4, 5) that is rich in  $Al_2O_3$ , low in  $TiO_2$ , alkalis, REE and other lithophile elements. A such of geochemical unity is believed to be a result of derivation of all Luna 24 mare basalts from common sources and by common processes. The whole Luna 24 rock population can be subdivided into a number of types with different chemical and mineral composition, texture, etc. (4). Based upon chemical composition they have been combined in to five groups (fig. 1, table 1): four groups of mare basalts (groups 1-4) and one of nonmare rocks (group 5). Among mare rocks we have picked out the following types: magnesian basalts (group 1), basalt with intermediate (groups 2, 3) and high (group 4) alumina contents. Groups 2, 3 and 4 have more high FeO/MgO ratios (~2-3) in comparison with groups 1 and 2. The variety of chemical composition's succession of Mare Crisium rock groups may be a result from the formation of different melts by partial melting of some source (or sources) or by fractionation of single melt at the depths. The latter process is possible to be complicated by cumulate phase redistribution during upraising, effusion on the lunar surface and solidification. In this case the variability of rock's compositions must depend on the variations of quantities of cumulate phases and of "primary" melt that is the same for the rock series forming by the cumulative processes.

To identify the "primary" liquid compositions we have used the computer model of equilibrium crystallization of basaltic magmas proposed by Frenkel and Ariskin (6). The model is based upon the experimental data on the equilibria olivine-liquid (7), plagioclase-liquid (8), high-Ca pyroxene-liquid and low-Ca pyroxene-liquid (9). Proposed procedure is a numerical solution of the mass action law relationships at a given degree of solidification. Thus the model allows to define the liquidus phases, their compositions, temperature and proportions of crystallizing minerals based on the liquid composition only. As the result we are able to simulate the evolution of melt's and solid phase's compositions in the course of equilibrium crystallization (equilibrium melting). It was shown that calculations by means of the procedure are in a good agreement with available experimental data. The procedure was used to model equilibrium crystallization of 61 melted rock fragments from Mare Crisium. The crystallization was calculated from 0 to 40 vol.%; the liquid's temperatures and compositions were monitored with 2% increment. After that we defined the rock fragments having similar composition of liquid at almost the same temperature. Some results of our calculations are shown on fig. 2 and table 2.

As a result of the modelling we concluded that various samples of Mare Crisium basaltic rocks may be presented by combination of different quantities of olivine and (or) plagioclase and some ferrous basaltic liquid ("primary" melt). Those samples are the rocks of group 2 (olivine basalts enriched in cumulate olivine), group 3 (basalts with high FeO/MgO ratios that are not far from the "primary" melt in chemical composition) and group 4 (alumina basalts enriched in cumulate plagioclase). Faint geochemical differentiation of Luna 24 mare basalt series in spite of marked fractionation of the main components (2) may be naturally explained by the cumulative model. The picritic basalts which are enriched in magnesium (group 1) are characterized significantly by more high liquidus (olivine) and cotectic temperatures and different crystallization sequences. The rocks of nonmare type (group 5) have the more high liquidus (plagioclase) and cotectic temperatures. These rocks probably crystallized from different primary melts.

Table 1. Average chemical composition of the rock types from Mare Crisium

	The rock types				
	1	2	3	4	5
$SiO_2$	45.46	45.11	46.75	46.58	45.82
$TiO_2$	0.62	0.91	0.99	0.85	0.18
$Al_2O_3$	8.00	11.60	12.85	17.26	28.28
$Cr_2O_3$	0.62	0.36	0.22	0.19	0.08
FeO	19.09	21.16	18.99	15.45	4.64
MnO	0.31	0.27	0.26	0.25	0.07
MgO	17.01	8.29	6.56	5.48	7.40
CaO	8.68	11.87	13.02	14.03	15.04
$Na_2O$	0.14	0.29	0.26	0.45	0.40
$K_2O$	0.05	0.06	0.03	0.06	0.06
$P_2O_5$	0.02	0.08	0.06	0.06	0.03
Total	100.00	100.00	100.00	100.00	100.00

Table 2. Comparison between Luna-24 fragment compositions and model liquid compositions calculated for their melting at 1130°C

	Sample 2-109,56-59			
	a	b	c	d
$SiO_2$	46.0	45.82	45.0	46.71
$TiO_2$	0.84	1.49	0.75	1.51
$Al_2O_3$	15.8	13.00	10.1	12.93
$Cr_2O_3$	0.21	-	0.42	-
FeO	15.5	19.52	22.4	19.82
MnO	0.15	-	0.26	-
MgO	5.8	5.58	10.5	5.48
CaO	13.9	13.29	10.8	13.27
$Na_2O$	0.30	0.31	0.21	0.28
$K_2O$	0.03	-	0.015	-
$P_2O_5$	0.04	-	-	-
Total	98.63	-	101.46	-

\* The sample 2-109,56-59: liquidus phase is plagioclase at  $T=1195^\circ C$ ; the sample 24077,4: liquidus phase is olivine at  $T=1275^\circ C$ . For both liquidus: paragenesis at  $1130^\circ C$ .  
 a) - High Ca Px - low Ca Px. a, c - initial rock composition; b - melting 72%,  $T=1130^\circ C$ ;  
 d - melting 74%,  $T=1130^\circ C$ .

## PRIMARY MELTS OF MARE CRISIUM

Yaroshevsky A.A. et al.

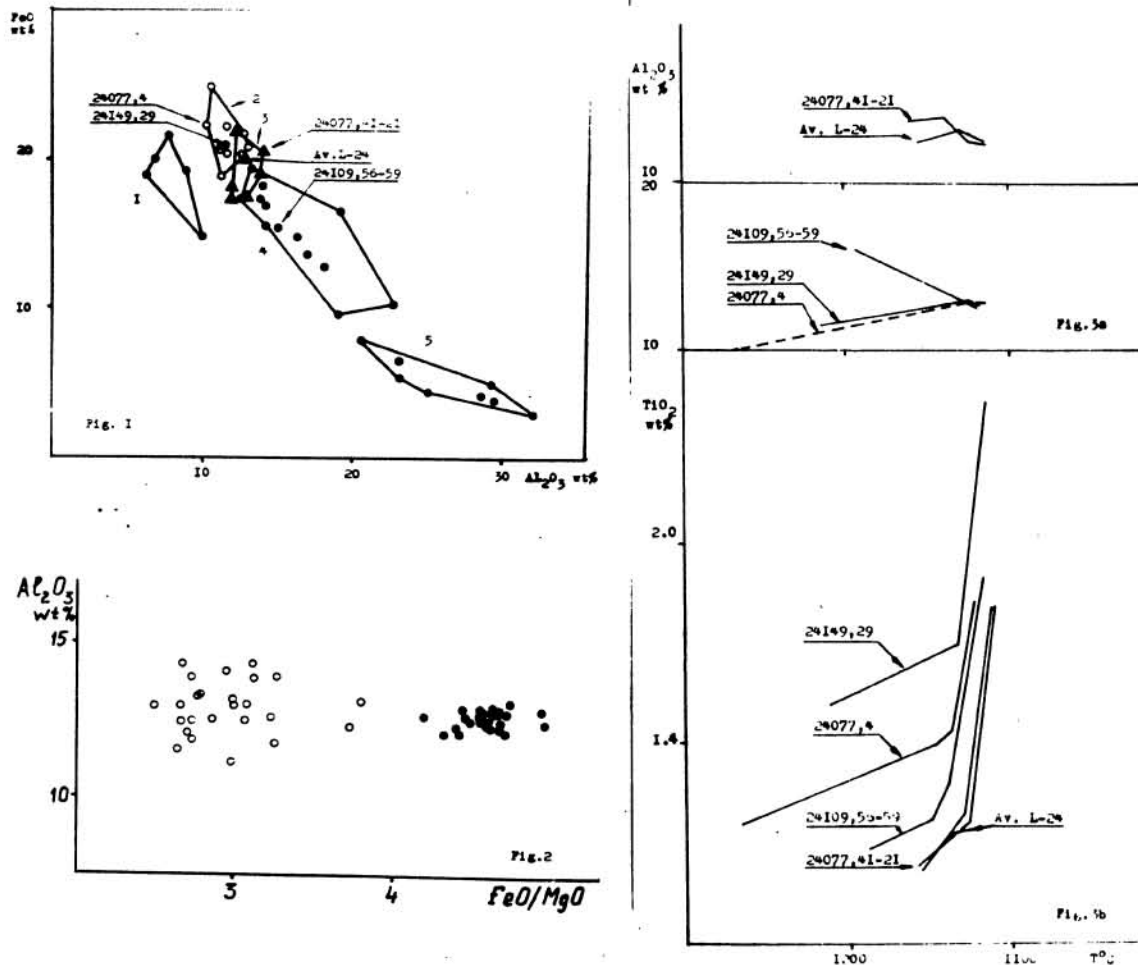


Fig. 1. The groups 1-5 of Luna 24 rock compositions on the diagram FeO-Al<sub>2</sub>O<sub>3</sub>. Sample numbers correspond to samples used for calculation. Av.L-24 is average from ten basaltic glasses (10).

Fig. 2. The composition of Luna 24 rocks (o) and corresponding to them, liquids at 1120°C (●). The liquid composition field is localized.

Fig. 3. Resemblance of compositions of some Luna 24 rock melts in region of low temperatures in coordinates (a) Al<sub>2</sub>O<sub>3</sub>-temperature; (b) TiO<sub>2</sub>-temperature.

The conclusion on the possibility of formation of the main Mare Crisium rock types in the result of cumulative processes from common "primary" melt (or some melts) is based on similarity of cotectic compositions at almost the same temperatures. It is not trivial because different phases crystallizing from melts of various composition are of variable (not constant) composition. But a degree of this similarity must be tested by more complex analysis including incompatible elements and requires of further investigation.

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