COMPUTER SIMULATION OF THERMAL HISTORY AND MAGMATIC DIFFERENTIATION OF THE MOON. M. Ya. Frenkel, A. A. Ariskin and A. A. Yaroshevsky, V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, USSR Academy of Sciences, Moscow, USSR.

Equations of heat conduction and mass transfer for thermal history and early magmatism of the Moon were solved numerically by computer. Related calculations have been carried out by many authors (for example [1, 2, 3]). Our model has differences from the precursors in next points. (1) We do not suppose a priori the existence of Lunar Magma Ocean, instead we simulate the process of planet growth to be accompanied by accretional heating. The heat source is given by $q(r,t)=(A+Bt)\exp(-a(R-r))$, where R is radius of the growing planet, A, B and a are selected to give rise to partial melting in outer part of the planet. (2) We do not adopt the assumption of fast convective mixing within appeared zones of melting. Within the zones a phase composition of the substance was determined on the basis of linearized ternary diagram Px-Pl-Ol [4]. Then solution of mass transport equations was carried out. The movement of solid phases relative to the liquid was assumed to be the major mechanism of mass transfer. This is either free settling (floating) of minerals under high degrees of melting (>40 vol.%) or pressing-out of the liquid and concentrating of crystal mush if degree of melting was not too much (5-40 vol.%). The transport of major components of melt and of trace elements (in particular, of sources of radiogenic heat) is considered in the model. (3) The model involves also such mechanism of a mass transport, as effusive magmatism, which is modelled in the following way. When during calculations the density of some layer of the matter come to be less than the average density of the overlying rocks and the degree of melting of that layer was more than 10 vol.%, then whole spherical layer was transferred instantly from melting zone to the surface.

Other properties of the model are : 1. Initially the planet is assumed to be uniform and has composition by Taylor and Bence. 2. Heat conductivity as a function of the temperature was taken from [5]. 3. The solidus and liquidus temperatures and eutectic melt composition is considered to change with depth. The transformation of the stable mineral associations (the appearance of spinel and garnet) at pressures in the range of 8 up to 20 kbar were assumed. That is followed by the appearance of normative clinopyroxene in the melt.

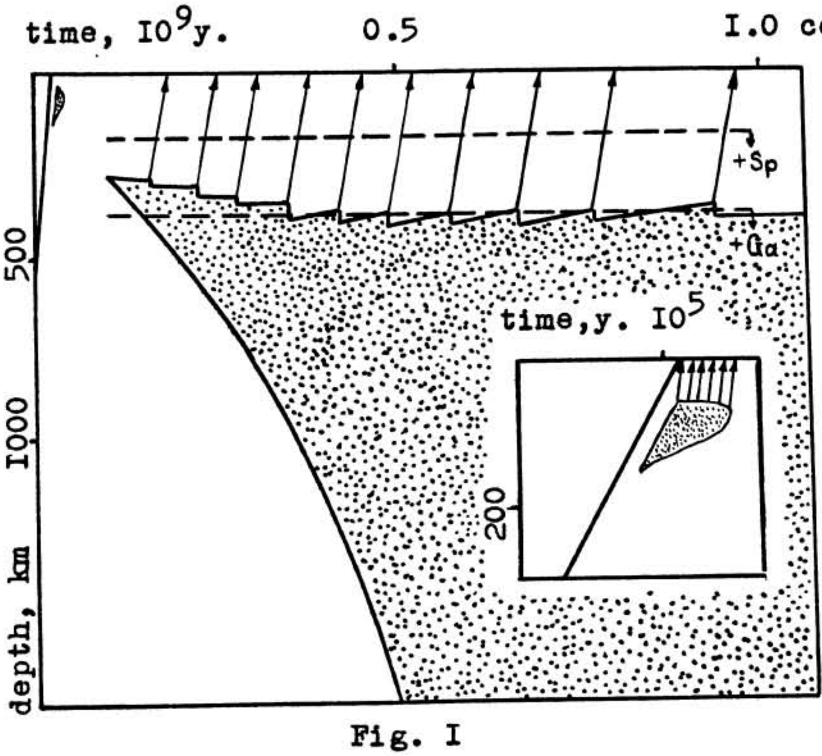

Fig. I

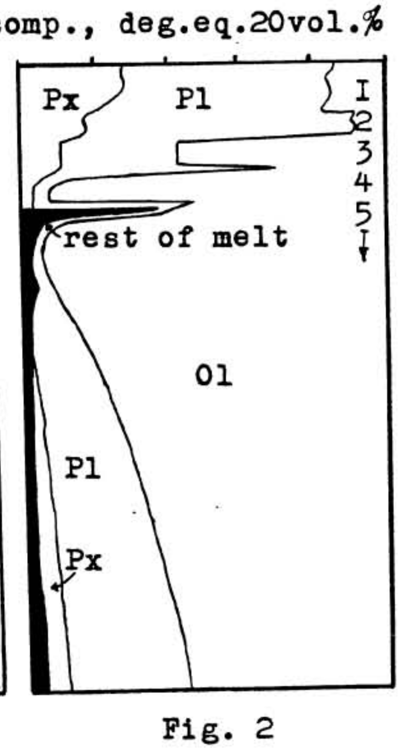

Fig. 2

Fig. 1 : Melting diagram for lunar model. Shaded regions--zones of partial melting; the arrows show effusions; dashed lines--stability boundaries of Sp and Ga; the early melting zone is shown in the insert.

Fig. 2 : Normative composition of rocks in section of the model planet at t=1.2 x 10^9y.; 1--quenched melts from deeper zone of part. melting (with normative Ca-rich Px); 2--quenched melts from early melting zone; 3--unmelted zone; 4--the rest after early melting; 5--zone of the generation for second type of the melts.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

COMPUTER SIMULATION OF THERMAL HISTORY

Frenkel M.Ya. et al.

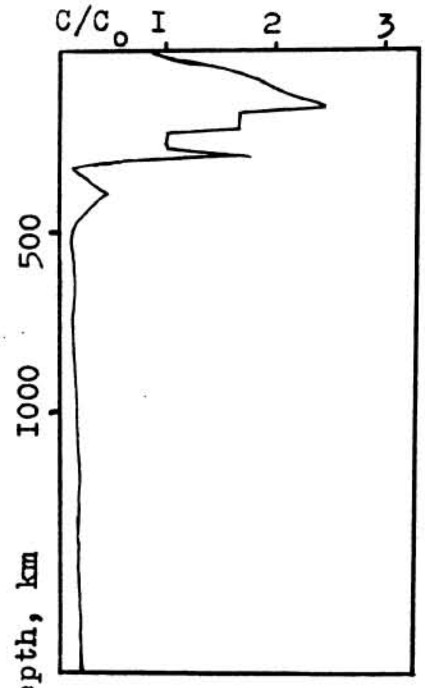

Fig. 3

Fig. 3 : Relative abundance of incompatible elements (U, Th, K) in section of the model planet at t=1.2 x 10^9y.

Fig. 1, 2 and 3 illustrate some results of the calculations. Most interesting results of the modelling are involved in the existence of two types of the magmatic eruptions (fig. 1) having the differences in the depth of the magma generation. The magmas of the first type ascend from the shallow depths, where the zone of almost complete melting was formed as a result of accretional heating. The chemical composition of the former magma type is determined by the separation of the unmelted olivine and in the minor extent by the flotation of plagioclase. As a result the effusive material in comparison with the initial composition is slightly enriched in U, Th, K and is greatly enriched in plagioclase with the normative clinopyroxene being almost completely absent.

The second type of effusive materials have been formed as a result of filter-pressing process within the prolonged time interval (~10^9y.). The normative melt compositions are nearly the eutectic composition in the model phase diagram. These melts are markedly enriched in incompatible elements (fig. 2 and 3). The normative clinopyroxene occurs as a result of stability of spinel and garnet in the region of magma generation.

Taking into account the age and the chemical pecularities of the two magma types they are considered as the initial materials for the highland and mare lunar magmatic rocks. A formation of the rocks likely involves the additional stage of the differentiation in the crust. In present time we cannot simulate the latter process being out from the framework of our model (the elementary layer of the matter to be quenched by the effusion at the planet surface is considered to have thickness more than 8 km!).

[1] J.A. Wood (1972) Icarus, 16, 229; [2] S.C. Solomon, J. Longhi (1977) PLSC 8th, 503; [3] J.W. Minear, C.R. Fletcher (1978) PLSC 9th, 269; [4] M.Ya. Frenkel (1978) Geoch. Int., 15, 162; [5] J.F. Schatz, G. Simmons (1972) J. Geophys. Res., 77, 6966.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System