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Thermal state and radioactive elemental composition of the lunar interior

E.V. Kronrod, **V. A. Kronrod,** O. L. Kuskov
Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow, Russia,
va kronrod@mail.ru

1. Introduction

This work is about estimation of lunar thermal conditions, surface heat flow values and bulk concentrations of radioactive elements in the Moon. We have suggested the probable temperature profile of the lunar mantle that satisfied geophysical and geochemical constraints and determined possible uranium content in the Moon and surface heat flows.

2. Computer simulation and result

The following issues have been discussed: (2.1) Estimation of probable temperature distributions in the lunar mantle, (2.2) Estimation of heat flows and radioactive source intensity.

2.1 Estimation of probable temperature distribution in the lunar mantle.

I. ***Constrains on the temperature profile from seismic velocities.*** We determine the probable temperature from seismic velocities [1] inversion temperature profile [2,3]

The minimal temperature in the upper mantle. The range of probable temperature variations in the mantle was obtained in the works [2,3]. We have found the minimal temperature in the upper mantle. The minimal temperature of 500^{o}C at a depth of 150 km satisfies limitations on the mass, moment of inertia and seismic velocities [4,5].

The gradient dT/dH in the mantle. Absence of density inversion is a natural requirement for the hydrostatic equilibrium in the satellite. From numerical modeling temperature profile with gradient ***dT/dH =1,05-0,0006*H, (H – km)***, was selected. Such a ***dT/dH*** gradient satisfies almost zero gradient of density with acceptable accuracy.

The mantle temperature can be described by an equation: $T=1.05*H-0.0003H^2+C$. Temperature gradient at the depth of 150-1000 km accurate within 1^{o}C, $\delta T_{1000-150} = T_{1000} - T_{150} = 600^o$.

The probable temperature profile. Correlating all of ***constraints on the temperature profile*** we find probable temperature profile of the lunar mantle at the depth less than 1000 km: $\mathbf{T_{pm}{}^oC = 449+1,05*H-0,0003H^2}$, **H** – depth in kilometers.

2.2 Estimation of heat flows and radioactive source intensity.

To calculate the radioactive source intensity one-dimensional stationary model of thermal conductivity has been used. We propose the following model of the Moon. It consists of the crust, the upper mantle with a heat source Q_{up}, the lower mantle with a heat source Q_{low} and the core. The crust has the depth of 40 km and the density of 2580 kg/m^{-3} [6]. The lower boundary of the upper mantle is within the limits of 500-1000 km depth, the radius of the core is 350 km. The aim of the study is to find values of the heat flow sources corresponding to the set of temperature distribution in the mantle. As a result, the simple analytical relations were obtained. These relations enable to determine the temperature distribution in the mantle. Based on the assumption that Th/U=3.7, K/U=2000 [7], heat conductivity coefficient k=4 W m^{-1}K^{-1}, we have estimated uranium concentration in the upper (C_{Uup}) and lower mantle (C_{Ulow}, C_{Ulow}= C_{Ubulk}), surface heat flow (J_s) (Figs. 1, 2) and the corresponding temperature distributions in the lunar mantle (Fig. 3)

2.3. Conclusions

Assuming that the U concentration in the crust is 150-180 ppb, the estimated bulk lunar U_{bulk} abundances range within 19-21 ppb, upper mantle U_{up} abundances range within 4.7-8.9 ppb, surface heat flow J_{moon}=7.6-8.4 mW/m^2.

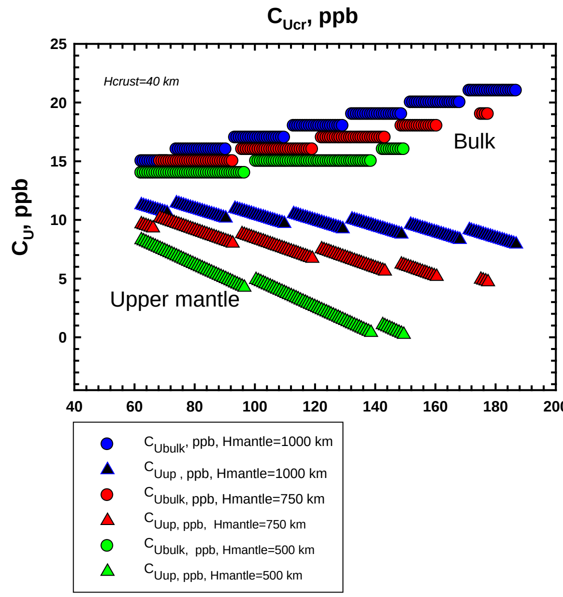

Figure 1: Calculated uranium concentration in the upper mantle (C_{Uup}) and in the lower mantle (C_{Ulow}, C_{Ulow}= C_{Ubulk}). The range of the depth of the boundary between upper and lower mantle H_{mantle} was 500-1000 km, the depth of the crust H_{cr}=40 km, the density of the crust ρ_{cr}=2600 kg/m^3

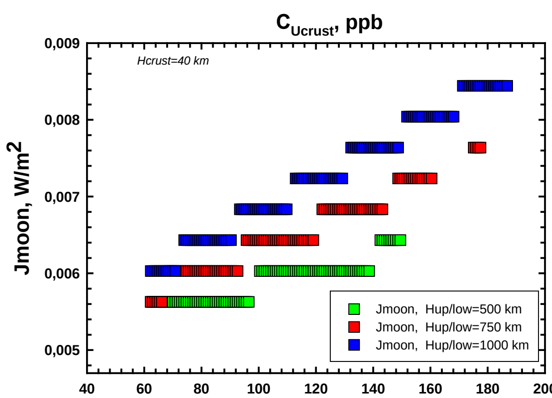

Figure 2: Calculated surface heat flow range. The depth of the crust H_{cr}=40km, the density of the crust ρ_{cr}=2600 kg/m^3

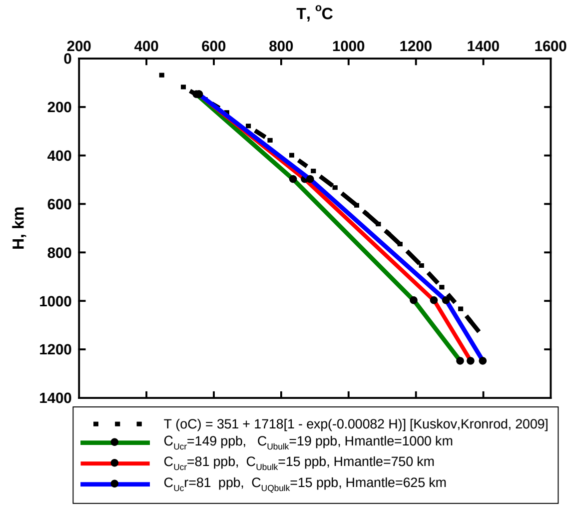

Figure 3: Temperature distributions in the lunar mantle corresponding to calculated surface heat flow

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