COMPARATIVE STUDY OF CRUSTAL PRODUCTION RATES OF MARS, VENUS AND THE EARTH;

Takafumi Matsui[1] and Eiichi Tajika[2], [1]Dept. of Earth and Planetary Physics, Univ. of Tokyo, Bunkyo-ku, Tokyo 113, Japan, [2]Geological Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

BACKGROUND: Recent planetary explorations of Venus and Mars have revealed that tectonic and volcanic features of both planets are very different from those of the Earth. Both Venus and Mars have no global plate tectonics but show surface features with temporally and spatially widespread tectonic and volcanic activities. One of the most important quantities to understand the differences in such surface features between these planets is the magma eruption rate, which is directly related to crustal growth and affects also degassing history. In this study we attempt to constrain magma eruption rate and crustal production of Mars, Venus and the Earth by modeling the degassing history of ^{40}Ar coupled with the thermal evolution of the mantle.

MODEL: Volatile degassing occurs concurrently with volcanism and thus degassing rate is dependent on magma eruption rate. ^{40}Ar is considered to be the best tracer to trace such a degassing history. In this study we used the ^{40}Ar degassing model coupled with the thermal evolution of the mantle by Tajika and Matsui [1]. They take into account the effects of elemental partitioning and solubility during both melt generation and bubble formation processes. However we modified the Tajika and Matsui model for Mars and Venus, because tectonic style of these planets is different from that of the Earth. Since Mars and Venus have no global plate tectonics, the degassing is assumed to occur due to hot spot type volcanism. We consider mantle plume model and use the volume flux of ascending mantle material F_V as a model parameter. Then degassing flux F_D for these planets is given by $F_D = [f(X)F_V/V_{mantle}](^{40}Ar)_{mantle}$, where $f(X)$ is the fraction of ^{40}Ar degassed to the atmosphere to the amount originally included in the mantle plume, X is melt fraction as a function of the mantle potential temperature, V_{mantle} is the volume of mantle, and $(^{40}Ar)_{mantle}$ is the amount of ^{40}Ar in the mantle. T_P can be estimated from the average mantle temperature T_m, which is estimated from the thermal evolution of the planets. We used the parameterized convection model to calculate the thermal hisotry of the mantle. For Mars and Venus, we took into account the lithospheric growth in the parameterized convection model [2]. We also considered removal of heat sources from the mantle in association with melt generation, i.e., concentration of heat sources into crust [3].

NUMERICAL RESULTS: The magma eruption rate $F_{melt} = XF_V$ decreses with cooling of the mantle as shown in Fig. 1. The average magma eruption rate can be calculated from total volume of erupted magma devided by 4.6Ga. The amount of ^{40}Ar degassed into the atmospere is related to the average magma eruption rate as shown in Fig. 2. Using the observed value of ^{40}Ar in the atmosphere, a parameter F_V is determined, and then we can estimate the average magma eruption rate. In Fig. 3 are summarized the possible ranges of average magma eruption rate for Mars, Venus and the Earth.

DISCUSSION: Greely [4] estimated the temporal variation of magma eruption rate of Mars. Our estimate gives higher total magma eruption volume than his estimate (Table 1). This is because our estimate includes the volume of both extrusive and intrusive magmas, but Greeley's estimate is only for the extrusive one. The crustal thickness calculated for Venus suggests rather thin crust, which is much thinner than that given by Parmentier and

CRUSTAL PRODUCTION OF MARS, VENUS AND EARTH: Matsui, T. and Tajika, E.

Hess model [5]. This means that their model would be inconsistent with the ^{40}Ar content in the atmosphere of Venus. Namiki and Solomon [6] also calculated the ^{40}Ar degassing and crustal production rate on Venus. Their estimate of crustal thickness also gives thicker crust than ours. Our model suggests that episodic global resurfacing by catastrophic events [7] due to Parmentier and Hess type model seems implausible as the hypothesis for the history of surface removal on Venus.

REFFERENCES: [1] Tajika, E. and Matsui, T. (1993) Geophys. Res. Lett., 20, 851-854. [2] Schubert, G. et al. (1979) Icarus, 38, 192-211. Stevenson, D. J. et al. (1983) Icarus, 54, 466-489. [3] Schubert, G. et al. (1992) In Mars (Eds. H. H. Kieffer et al., Univ. of Arizona Press, Tucson), pp.147-183. Spohn, T. (1991) Icarus, 90, 222-236. [4] Greeley, R. (1987) Science, 236, 1653-1654. Greeley, R. and Schneid, B. D. (1991) Science, 254, 996-998. [5] Parmentier E. M., and Hess P. C. (1992) Geophys, Res, Lett., 20, 2015-2018. [6] Namiki, N. and Solomon, S. C. (1993) LPSC, XXV, 971-972. [7] Schaber, G. G. et al. (1992) J. Geophys. Res., 97, 13257-13301.

Table 1. Results of the most plausible cases for Mars, Venus and the Earth.

Planets	X (%)	F_V(km^3/yr)	F_{melt}(km^3/yr)	V_{melt} (km^3)	d_{crust} (km)
Earth	15.5	170.4	26.41	1215.0	238.2
Venus	10.1	35.7	3.58	164.5	35.7
Mars	8.7	1.4	0.12	5.4	3.8

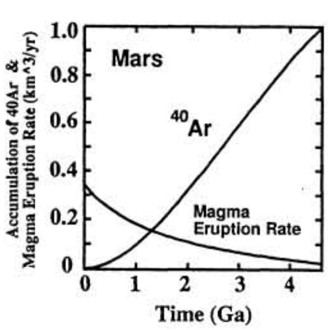

Fig. 1.

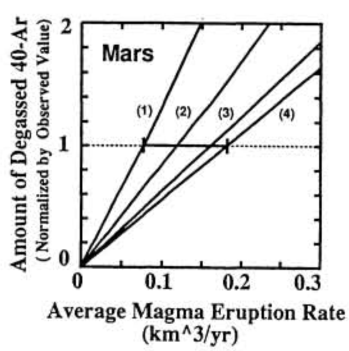

Fig. 2.

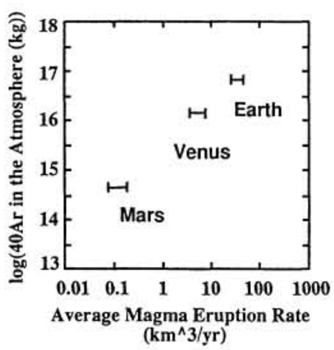

Fig. 3.

Fig. 1. Temporal variations of ^{40}Ar in the atmosphere and magma eruption rate on Mars.

Fig. 2. Probable range of average magma eruption rate on Mars determined from the thermal evolution with deifferent model parameters (T_m^0, initial mantle temperature; χ, crustal fractionation parameter [3]). (1) T_m^0=1500K, χ=0.003, (2) T_m^0=2000K, χ=0.003, (3) T_m^0=1500K, χ=0, (4) T_m^0=2000K, χ=0.

Fig. 3. Relation between ^{40}Ar in the atmospheres and estimated ranges of average magma eruption rate for Mars, Venus and the Earth.