CORE FORMATION AND THE Fe/FeO RATIO OF THE EARTH, MARS AND VESTA: CONSTRAINTS FROM THE ^{182}Hf-^{182}W SYSTEM. Gang Yu[1], Stein B. Jacobsen[1], [1]Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA, 02138 (gyu@eps.harvard.edu).

Introduction: It is generally assumed that the abundances of the siderophile elements in the terrestrial planet's mantle are the result of core formation. High pressure experimental metal－silicate partitioning data for Ni, Co, V, Cr, Nb, Mn and Mo etc. were used to investigate the geochemical consequences of a range of models for core formation on Earth and the most popular model is a "deep magma ocean" model where newly segregated core material is assumed to have equilibrated at the bottom of the magma ocean [1-6]. Recently reported high pressure W partition coefficients also suggest that deep magma oceans exist in the Earth, Mars and Vesta during core formation [7]. This model is inconsistent with the "global magma ocean" model used for interpretation of the W isotope data of the Earth, Mars (Martian meteorites) and Vesta (Eucrites parent body) [8].

Here we present a dynamic core-formation model with a deep magma ocean and a solid lower mantle for the Hf-W system, which can match the partitioning of Ni, Co and W in mantles of Earth, Mars and Vesta only when these planet's magma oceans have bottom pressure of 54 GPa, 14 GPa and 0.05GPa respectively. This model require a upper mantle Fe content of 4.8% (Earth), 21%(Mars) and 10.6% (Vesta). This suggests that during core formation the Earth's upper mantle more iron was reduced to metal than in the mantles of Mars and Vesta, possibly because the Earth was big enough to possess a H_2-He atmosphere during core formation. Moreover, based on the reported $\varepsilon_{W(CHUR)}(0)$ of planets, our model yields mean age of formation of Earth, Mars and Vesta of 12 Myr, 8 Myr and 3Myr respectively.

Model: We constructed a "deep magma ocean" model that employs a continuous accretion and core formation process [9]. High pressure metal-silicate partition coefficients of Ni, Co and W come from [5, 6, 7]. We assume partition coefficients of elements of interest between upper magma ocean and additions to lower solid lower mantle are equal to 1. All parameters used for calculation in our model are listed in Table 1 for Earth, Mars and Vesta.

Results and Discussion: The depth of magma ocean in Earth, Mars and Vetsta can be estimated by matching the D_{Ni} and D_{Co} in planet's mantle (Table 1). First we assume that the Fe content of the planet's magma ocean is fixed by the values of the whole mantle in Table 1. The D_{Ni} and D_{Co} yield bottom pressures of magma oceans in Earth, Mars and Vesta of 54 GPa, 14 GPa and 0.05 GPa respectively. However, we find that calculated $f_{Hf/W}$ in the planet's mantle do not match the observed values (Table 1), even taking account of their uncertainties. For Earth and Vesta, the calculated $f_{Hf/W\ (whole\ mantle)}$ (9 and 12.4) are slightly smaller than their observed $f_{Hf/W\ (whole\ mantle)}$ (12±2 or 15±2 [8]), but Mars has calculated $f_{Hf/W}$ of 7-11 larger than observed $f_{Hf/W}$ value (1.2-7 [8]). [5] and [6] have found that the Earth's mantle should have a lower Fe content (1% or 2%) during early stage of core formation to reproduce partitioning of Vanadium in Earth's mantle. Because of lacking knowledge of how and when terrestrial planets increase its oxidation state, we assume that deep magma oceans in terrestrial planets have a unknown constant Fe content, balanced by the lower mantle content to yield the average values in Table 1. Therefore, in Fig. 1, the $f_{Hf/W}$ in the Earth, Mars and Vesta's mantles can fit the "required" range but only if the Earth's magma ocean (upper mantle) has an average Fe content of 4.8 %, Martian magma ocean 21 % and Vesta's magma ocean 10.6% during core formation, which suggests that generally the Earth has a more reduced magma ocean than Mars and Vesta during core formation. The calculated Fe contents of the planet's solid lower mantles are: 7.4% for Earth, 7.9% for Mars and 12.4% for Vesta.

The variation of $f_{Hf/W}$ in planet's mantles during core formation shown in Fig. 1, together with their corresponding $\varepsilon_{W(CHUR)}(0)$ in Table 1, can be used to calculate planet's mean ages of formation if an exponential accretion process is employed as described in [8]. The evolution curves of $\varepsilon_{W(CHUR)}(t)$ in mantles of the Earth, Mars and Vesta, which match $\varepsilon_{W(CHUR)}(0)$ in Table 1, has been produced and shown in Fig. 2 and also constrain a mean age of 12 Myr for Earth, 8 Myr for Mars and 3 Myr for Vesta after formation of the Solar System.

Table 1 paraments used in our modeling for Earth，Mars and Vesta

	Core mass fraction	Core Fe%	Mantle Fe%	Mantle D Ni	Mantle D Co	Mantle $f_{Hf/W}$	Mantle $\varepsilon_{W\ (CHUR)}(0)$	References
Earth	0.323	85.5	6.26	~26	~24	12±2	1.9±0.2	[8,10]
Vesta	0.215	91.78	11.5	~2068	~277	15±2	19±2	[8,12]
Mars-S source	0.215	77.8	13.9	~190	~53	2.0±0.8	2.23 ± 0.21	[8,11,13]
Mars-NC source	0.215	77.8	13.9	~190	~53	6±1	5.15 ± 0.50	[8,11,13]

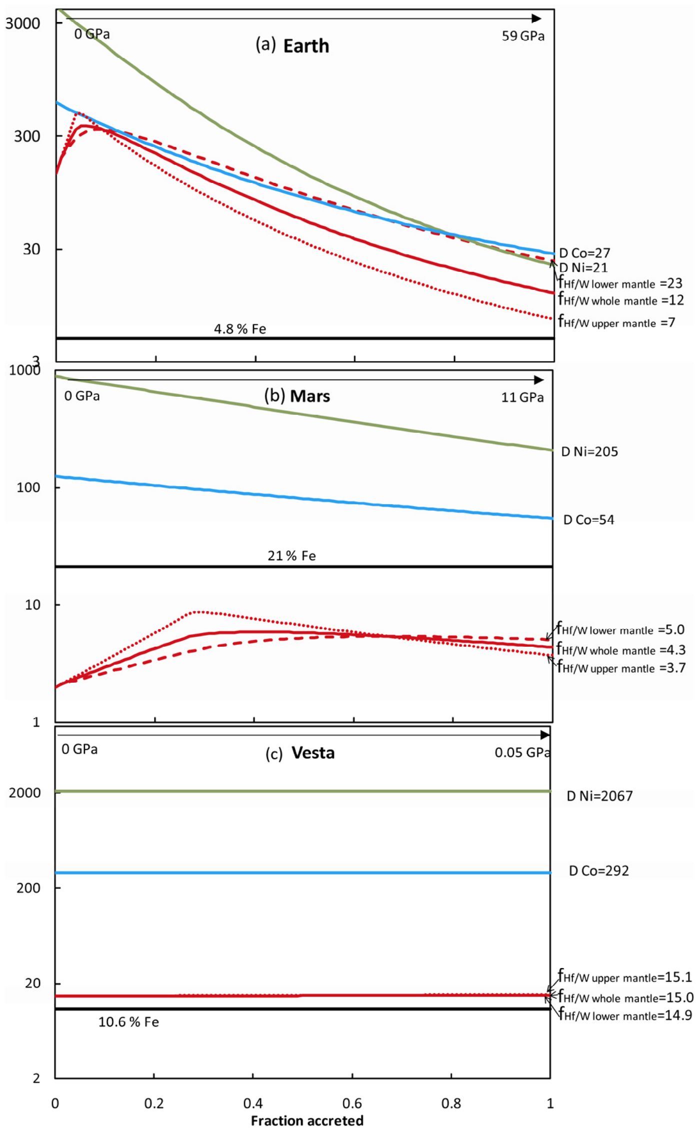

Fig. 1 Calculated partitioning of Ni, Co and W into the core for the Earth, Mars and Vesta with fixed Fe content (4.8% for terrestrial magma ocean, 21 % for martian magma ocean and 10.6 % for Vesta's magma ocean).

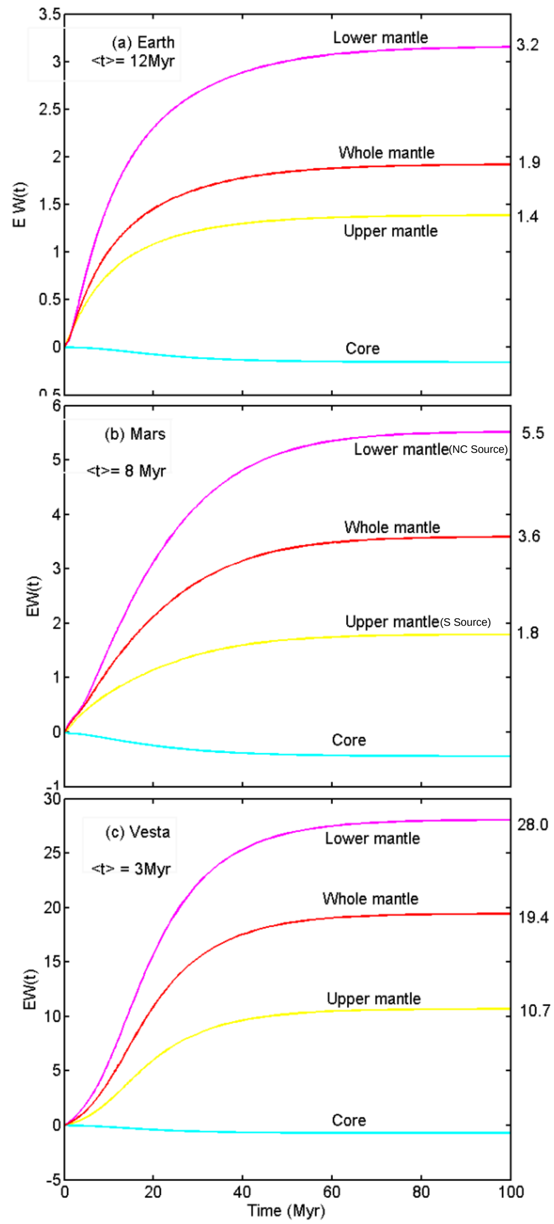

Fig. 2 $\varepsilon_{W(CHUR)}$ (t) evolution in mantles of Earth, Mars and Vesta from our "deep magma ocean" model which matches the partitioning of Ni, Co and W into the core.

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