CORE FORMATION ON THE TERRESTRIAL PLANETS: COMPARATIVE PLANETOLOGY OF THE EARTH, MOON, MARS, VESTA, AND VENUS. J.H. Jones, KR, NASA/JSC, Houston, TX 77058 (john.h.jones@nasa.gov)

The Boundary Conditions: Basalts from the Earth, the Moon, Mars, and Vesta are strongly depleted in elements that prefer to reside in the metallic state (siderophile elements). Therefore, it is believed that all these bodies have metallic cores. We do not yet have siderophile element analyses of venusian basalts, but we assume that Venus, too, as a terrestrial planet, has a metallic core. For the Earth, Moon, and Mars, the moments-of-inertia of these bodies are consistent with metallic cores of various sizes. Because Venus rotates so slowly, it may be difficult to determine the moment-of-inertia of Venus in order to confirm this assumption.

Experimental Constraints: The fundamental experimental constraint on core formation at low pressure comes from the work of Stolper [1] on eucrites. He found that, in order to saturate eucritic liquids with metallic iron, it was necessary to achieve oxygen fugacities of ~IW-1 (a log unit below the iron-wüstite oxygen buffer). This makes good physical-chemical sense. Eucrites are not wüstite-saturated, and therefore require redox conditions significantly below the IW buffer before they can come into equilibrium with metallic iron.

A second fundamental experimental constraint comes from Walker et al. [2], who noted that lunar mare basalt compositions that were experimented on in pure iron capsules at 1-bar to 30-kbar did not gain or lose FeO. This implies that lunar basalts are nearly saturated in metallic iron at about IW-1. This is corroborated by the frequent presence of metallic iron in the mesostases of lunar mare basalts [3].

Finally, Jurewicz et al. [4] found that partial melts of chondrites held at IW-1 [one-bar gas-mixing] contained about 18 wt.% FeO. Therefore, the origin of basalts with 18-20 wt.% FeO seems well constrained at low pressure.

Generalizations: Both lunar basalts and eucrites have the general property that they have FeO contents of ~18-20 wt.%. Combining the work of [1,2,4], it seems clear that, at low pressure (< 50 kbar), planets such as the Moon and Vesta conspire to produce basalts with 18-20 wt.% FeO if their source regions were in equilibrium or near-equilibrium with iron metal at IW-1.

A third planet that produces basalts with 18-20 wt.% FeO, and which is known to have a metallic core, is Mars. We know the FeO content of martian basalts by analyses of martian meteorites, and we know that Mars has a metallic core from its moment of inertia. By inference therefore, it is likely that martian basalts also come from source regions that once had an oxygen fugacity of ~IW-1. Oxygen fugacity measurements on primitive martian meteorites confirm this inference. Spinel-ilmenite assemblages in primitive martian meteorites yield oxygen fugacities in the vicinity of IW [5] and these oxygen fugacities should be upper limits to that of the source regions of these basalts [6].

Therefore, the Moon, Mars, and Vesta are consistent with low pressure (< 30 kbar) experiments that constrain the initial conditions of core formation on these bodies to have been at ~IW-1, with the subsequent production of basalts that have 18-20 wt.% FeO.

The Earth and Venus: The exceptions to this self-consistent picture are the Earth and Venus. Basalts on these planets have FeO contents of 8-10 wt.% [7] — roughly half that of the "self-consistent" group.

The most assured difference between the Earth and Venus on the one hand and the "self-consistent" terrestrial planets on the other is size and mass. Mars is the largest "self-consistent" planet and it may generate core-mantle-boundary pressures in the vicinity of 250 kbar [8]. Alternatively, the Earth and Venus may have core-mantle pressures of ~1400 kbar [9].

This observation suggests that the Earth and Venus have FeO contents that are dominated by high-pressure, rather than low-pressure, equilibria. Various authors have speculated on the cause of the FeO content of the Earth's mantle, but common themes have been to ascribe the Earth's FeO abundance either to pressure [e.g., 10] or to heterogeneous accretion [e.g., 11].

Perhaps the strongest argument against heterogeneous accretion is that most terrestrial bodies, i.e., the Moon, Mars and Vesta, do not manifest any indication of such. For example, the Moon, which appears to have formed in proximity to the Earth, has the FeO content and oxygen fugacity that would be predicted from eucrite experiments [1]. Therefore, there is at least circumstantial evidence that the FeO contents of the Earth and Venus are determined by high pressure equilibria [10].

Mechanisms?: The simplest mechanism for reducing the FeO content of an Earth-sized body is for FeO to become soluble in liquid iron metal [10]. In other words, the core could become a sink for FeO, reducing the FeO content of the mantle. Alternative mechanisms involving metal-perovskite-magnesiowüstite equilibria seem less likely.

Implications: One immediate contrast is the difference in FeO content between lunar and terrestrial basalts. Both bodies presumably formed near 1 AU and formed from the same feeding zone of planetesimals. If, for example, the Moon formed from the Earth by a giant impact, then this event must either have occurred before high-pressure equilibria had the opportunity to deplete the Earth's mantle in FeO or the bulk silicate Moon is dominated by material from the impactor.

References: [1] Stolper E.M. (1977) *Geochim. Cosmochim. Acta* **41**, 587-611. [2] Walker D. et al. (1977) *Proc. Lunar Sci. Conf. 8th*. 1521-1547. [3] Taylor S.R. (1982) *Planetary Science: A Lunar Perstpective*. pp. 481. [4] Jurewicz et al. (1991) *Science* **252**, 695-698. [5] Herd C.D.K. et al. (2001) *Am. Min*. **86**, 1015-1024. [6] Herd C.D.K. (2007) *Oxygen in the Solar System*. Chapter 19, 527-553. [7] Fegley B. et al. (1997) *Venus II*. p. 601. [8] Bertka C. and Fei Y. (1998) *Science* **281**, 1838-1840.. [9] Lambert W.D. and Darling F.W. (1951) In *Internal Constitution of the Earth*, pp. 340-363. [10] Ringwood A.E. (1979) *The Origin of the Earth and Moon*. [11] Wänke H. and Dreibus G. (1988) *Philos. Trans. R. Soc. London*, **A325**, 545-557.