MAGNESIOWÜSTITE/MELT AND MAJORITE/MELT PARTITIONING AND THE EARLY THERMAL HISTORY OF THE EARTH; Elisabeth A. McFarlane and Michael J. Drake, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; Claude Herzberg, Department of Geological Sciences, Rutgers University, New Brunswick, New Jersey 08903.

Introduction: The proposal that the early Earth was molten during and immediately subsequent to accretion may be tested against the approximately chondritic ratios of a variety of elements with different geochemical affinities in the upper mantle. If the elements in each pair exhibiting chondritic ratios have sufficiently different partition coefficients from one another, the element pairs may be used to limit possible mineral addition into the upper mantle [1].

McFarlane *et al.* previously reported [2,3] partition coefficients for elements with chondritic ratios from high pressure experiments between olivine and melt and beta-spinel and melt at 75, 100, and 165 kbars, and for partitioning between majorite garnet and melt at 165 kbars. This contribution focuses on an experiment done at 160 kbars and 2225°C and reports partition coefficient values between majorite garnet and melt and magnesiowüstite and melt, and discusses their implications for the early melting history of the Earth.

Procedures and Results: Aliquots of ground mantle analogue material KLB-1 were doped with 1 wt. % each of the following elements: Ni, Co, Ga, Sc, Ge, P, Mo. The sample was loaded into a rhenium capsule, placed inside a lanthanum chromite furnace within a standard MgO octagon pressure medium, and inserted into a uniaxial-split sphere cubic anvil pressure apparatus (USSA-2000). Pressure was applied cold, and the charge was heated to 2225°C after attaining 160 kbars. The resulting phase assemblage includes coexisting magnesiowüstite and majorite garnet. Partition coefficients between majorite garnet and melt are given in Table 1. There is good agreement between the 160 kbar experiment and previous experiments performed by our group [3] and by other workers [4,5]. There are no significant deviations between results for any element.

We also report magnesiowüstite/melt partition coefficient values (Table 2). Agee [6] has also reported results for experiments performed at a much higher pressure (260 kbars) and lower temperature (2050°C) using Allende as a starting material. Our experiments yield higher Mg and Al partition coefficients and a lower Fe partition coefficient compared with values from Agee.

Discussion: Partition coefficient values of an element pair can be used to determine the maximum amount of fractionation of a phase, assuming the initial element ratio is known. Previous work including an examination of Mg/Al, Mg/Si and Ni/Co ratios which are inferred to have been approximately chondritic in the primitive upper mantle of the Earth [2,3,5] has shown that significant majorite garnet fractionation from an early magma ocean [7] has not occurred because such fractionation would yield non-chondritic ratios. The present study confirms this conclusion. This conclusion is also in accord with that of [8] based on major element considerations.

Similar logic can be applied to magnesiowüstite fractionation. The partition coefficient value between magnesiowüstite and melt for Mg is 2, for Al is 0.3, for Si is 0.007, for Ni is 3.4 and for Co is 2.6 (Table 2). If significant fractionation of magnesiowüstite had occurred these ratios would be altered from the inferred chondritic initial ratio (Figure 1). Therefore, we conclude that significant amounts of magnesiowüstite fractionation have not occurred unless compensated by fractionation of other phases.

The other main phase that has been proposed to be involved in fractionations in the mantle of the Earth is Mg-perovskite. Similar conclusions concerning a lack of Mg-perovskite fractionation have been drawn by [9] using the only published Mg-perovskite partition coefficients. We have successfully completed a Mg-perovskite/melt partitioning experiment which awaits analysis.

The implication of these experiments and those of [2,3,5,9,10] is that the Earth did not undergo extensive fractionation during and immediately following accretion. This lack of extensive fractionation may imply that the Earth was never substantially molten. If so, the accretional process must have delivered gravitational potential energy more slowly than current theory predicts, and an origin of the Moon in a giant impact would be unlikely. Alternatively, if the Earth was substantially molten, then some mechanism must have suppressed significant mineral fractionation. Vigorous convection has been proposed as a means of suppressing segregation of minerals from magma [11]. In either case, the lack of mineral fractionation implies that the high Mg/Si ratio in the Earth relative to most classes of chondritic meteorites is intrinsic to the Earth. This in turn implies that the accretional process did not mix material efficiently between 1 AU and 2-4 AU where most chondritic meteorites are presumed to originate.

TABLE 1. Majorite/Melt Partition Coefficients. * = not measured

	1	2	3	4
Mg	0.9	*	*	0.8
Al	2.5	2.5	3.06	3.1
Si	1.1	*	*	1.1
P	1.0	*	*	0.8
Ca	0.6	0.6	0.47	0.6
Sc	1.5	1.7	1.64	1.5
Cr	1.5	*	2.33	1.4
Fe	0.3	0.6	0.42	0.3
Co	0.3	*	*	0.3
Ni	0.2	*	0.15	0.2
Ga	0.8	*	*	0.7

1 McFarlane *et al.* [3] 165 kbar; 2260°C
2 Kato *et al.* 1988 [5] ~160 kbar; ~2100°C
3 Ohtani *et al.* 1989 [4] 160 kbar; 1950°C
4 This work 160 kbar; 2225°C

TABLE 2. Mg-wüstite/Melt Partition Coefficients. * = not measured

	1	2
Mg	2.0	0.7
Al	0.3	0.09
Si	0.007	0.01
Ca	*	0.06
Sc	0.1	*
Cr	2.2	1.3
Mn	*	1.8
Fe	1.5	2.7
Co	2.6	*
Ni	3.4	3.9
Ga	0.63	*

1 This work: 160 kbar; 2225°C
2 Agee,C.B. 1990 [6] 260 kbar; ~2050°C

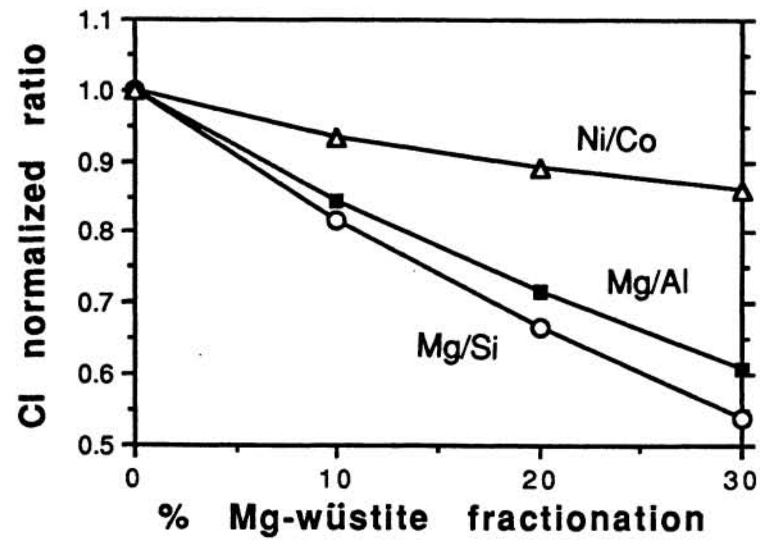

Figure 1. The curves exhibit the variation in the Mg/Si, Mg/Al, and Ni/Co ratios in the upper mantle of the Earth which would result from fractionation of 10%, 20%, and 30% magnesiowüstite from an early magma ocean assuming equilibrium crystallization and using values from Table 2. Ratios are normalized to CI chondrites.

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