VANADIUM, Cr, Si, AND THE Mg/Si RATIO IN THE EARTH Michael J. Drake, Kenneth Domanik, and Edward Bailey, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721-0092, U.S.A. drake@lpl.arizona.edu

Abstract: *Experiments investigating the partitioning of V, Cr, and Si between metal and silicate at various pressures, temperatures, redox state, and composition demonstrate that V and Cr are always more siderophile than Si. The relatively high abundances of V and Cr in the Earth's upper mantle indicate that the high Mg/Si ratio of the Earth's upper mantle cannot be attributed to extraction of Si into the core and must be an intrinsic bulk property of the silicate Earth.*

Introduction: It has long been known that the Mg/Si ratio of the Earth's primitive upper mantle (PUM) is elevated relative to most types of chondrites (Fig. 1). Some workers attribute this to extraction of Si into the Earth's core [1, 2]. The abundances of V and Cr are well established in planetary mantles (Fig. 2) and are depleted relative to Si. If Si were extracted into planetary cores, elements more siderophile than Si should be as well. Drake and Righter [3] note that the few experiments that exist suggest that Si remains lithophile under redox conditions pertaining to Earth's core formation. They argue that the Mg/Si ratio of PUM is the bulk planet ratio, with profound implications for the accretion of Earth and the width of the "feeding zones" during accretion in the inner solar system. Understanding whether Si can be extracted into planetary cores is also important to interpreting chemical analyses of surface rocks on other planets, either from orbital data, *in situ* analysis, meteorite analysis, or returned sample analysis.

Results: Drake *et al.* [4] systematically investigated the partitioning of V and Cr between metal and silicate at 1260 °C and one bar as a function of oxygen fugacity. While Si was present in their charges, it was not reported for metal because of fluorescence effects from Si in surrounding silicate. We have carefully reanalyzed these samples for V, Cr, and Si using the electron probe, specifically avoiding the fluorescence problem using the techniques developed in our group [5, 6]. Further, we have discovered that Si at very low concentrations can only be measured accurately within a few hours of polishing and carbon-coating, as Si from silicone vacuum pump oil builds up on the sample rapidly with time and increases the background counts.

Conclusions: These results, when taken in concert with those reported by Wade and Wood [7], Kilburn and Wood [8], and Gessmann and Rubie [9] (Table 1) indicate that under all experimental conditions for which data exist (1 bar to 250 kbar, 1260 °C - 2300 °C, redox states of IW to IW-5), V and Cr are always more siderophile than Si. Had Si been extracted into the Earth's core, presumably during metal/silicate equilibration in a magma ocean event, the abundances of V and Cr in the Earth's mantle would be much lower than observed. This result leads inexorably to the conclusion that the Mg/Si ratio of the Earth's upper mantle is an intrinsic bulk property of the silicate Earth and that Earth accreted from material which in aggregate is distinct from material accreting to Mars and the asteroids.

References: [1] Wänke H. (1981) *Phil. Trans. Roy. Soc. London A* **393**, 287-302. [2] Allegre C.J., Poirer J-P., Humler E., and Hofmann A.W. (1995) *Earth Planet. Sci. Lett* **134**, 515-526. [3] Drake M.J. and Righter K. (2002) *Nature* **416**, 39-44. [4] Drake M.J., Newsom H.E., and Capobianco C.J. (1989) *Geochim. Cosmochim. Acta* **53**, 2101-2111. [5] Capobianco C.J. and Amelin A. (1994) *Geochim. Cosmochim Acta* **58,** 125-140. [6] Chabot N.L. and Drake M.J. (2000) *Meteoritics and Planetary Science* **35**, 807-816. [7] Wade J. and Wood B.J. (2001) *Nature* **409**, 75-78 (2001). [8] Kilburn M.R. and Wood B.J. (1997) *Earth Planet. Sci. Lett* **152**, 139-148. [9] Gessmann C. and Rubie D. (1998) *Geochim. Cosmochim Acta* **62,** 867-882. [10] Righter K. and Drake M.J. (1997) *Earth Planet. Sci. Lett* **146**, 541-554.

Table 1. Metal/silicate partition coefficients for Si, V, and Cr. Physical state of metal is given in last column.

REF	EXPT #	P	T	ΔIW	D(Si)	D(V)	D(□□	metal
4	16a	1 bar	1260°C	-5.1	0.001	2.95	4.24	solid
4	18b	1 bar	1260°C	-5.3	0.03	4.84	0.55	solid
4	16b	1 bar	1260°C	-5.6	0.01	4.85	0.40	solid
4	6b	1 bar	1260°C	-5.7	0.003	1.37	0.38	solid
4	16a	1 bar	1260°C	-5.1		66.0	68.0	liquid
4	18b	1 bar	1260°C	-5.3		55.7	2.25	liquid
4	16b	1 bar	1260°C	-5.6		133	4.78	liquid
4	6b	1 bar	1260°C	-5.7		30.2	4.39	liquid
7	NB2	25 kbar	1750°C	-3.8	0.08		6.00	liquid
8	MKX1	25 kbar	1750°C	-4.0	0.02		11.5	liquid
8	MKX15	25 kbar	1750°C	-4.6	0.10		22.4	liquid
7	NB3	25 kbar	1750°C	-5.0	0.57		14.0	liquid
8	MKX12a	25 kbar	1750°C	-6.0	0.46		89.1	liquid
8	MKX	25 kbar	1750°C	-6.0	0.45		56.2	liquid
8	MKX3	25 kbar	1750°C	<-6.6	1.26		>72	liquid
9	1358	90 kbar	2000°C	-2.7	0.02	1.42	4.41	liquid
9	1457	90 kbar	2100°C	-2.7	0.04	0.43	1.67	liquid
9	1200	90 kbar	2200°C	-2.7	0.05	0.68	2.26	liquid
9	1547	90 kbar	2300°C	-2.3	0.01	0.54	2.00	liquid
9	1312	90 kbar	2400	-2.0	0.00	0.23	0.70	liquid
7	3	250 kbar	2300°C	-1.1	0.00	n.d.	0.07	liquid
7	6	250 kbar	2300°C	-2.0	0.02	0.38	1.34	liquid
7	5	250 kbar	2300°C	-3.2	0.34	2.06	7.00	liquid
7	4	250 kbar	2300°C	-3.6	0.84	19.8	65.7	liquid

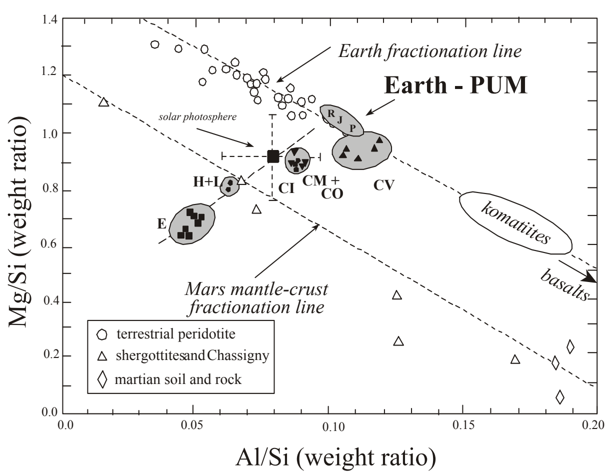

Fig. 1 Mg/Si vs. Al/Si diagram for a variety of solar system objects [3].

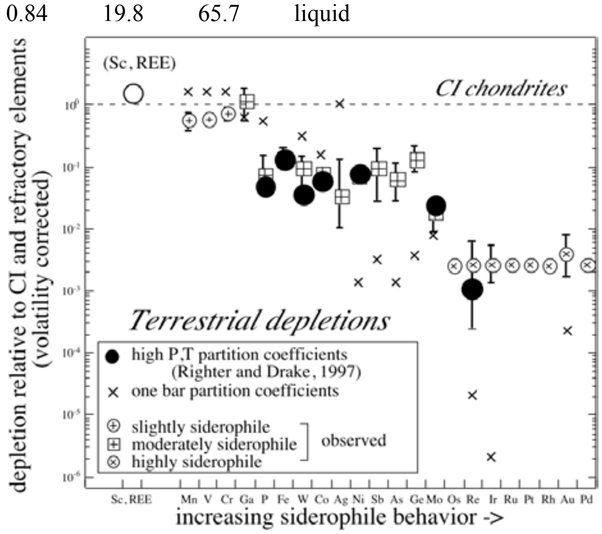

Figure 2. Depletions of elements, including V and Cr in Earth's mantle after core formation [after 10]. Silicon is at CI value.

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