Highly siderophile elements in Earth's upper mantle: Composition of the late influx

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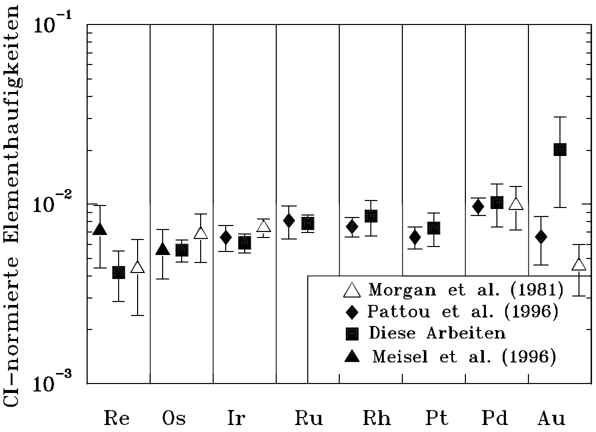
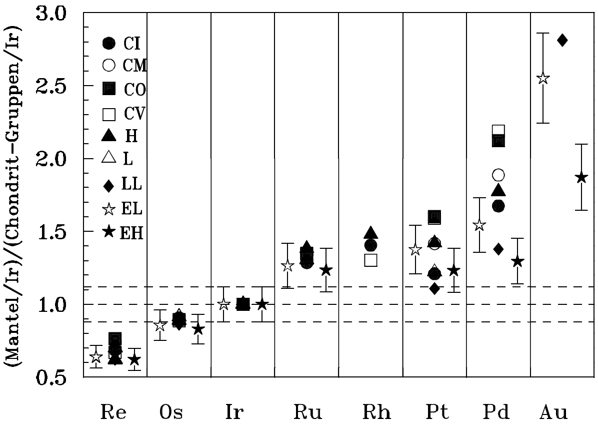
The relative "high" abundances of highly siderophile elements (HSE) and their approximately chondritic proportions in the Earth's undepleted primitive upper mantle (PUM) have been used to argue for the addition of a late chondritic veneer after core formation [1-6]. Recent Re-Os and Pt-Os isotope systematics in upper mantle rocks have shown that the late veneer more closely resembles ordinary or enstatite chondrites than carbonaceous chondrites [7-9]. Many recent studies of mantle samples, including samples from massive peridotites, abyssal peridotites and xenoliths, have documented significant regional variations in absolute PGE abundances and inter-element ratios [10-16]. Such variations may have been caused by complex geochemical processes such as partial melting, melt percolation and aqueous metasomatism in the subcontinental lithosphere. For a better characterisation of the late veneer component(s) of the Earth I review here selected instrumental neutron activation data from our own studies for orogenic spinel lherzolites [14-15] (Tab. 1) that have suffered only slight melt depletion (Ca/Si>0.086) and compare this data with selected data from the literature ([4], [7], [10]).

	Ca/Si	Re ng/g	Os ng/g	Ir ng/g	Ru ng/g	Rh ng/g	Pt ng/g	Pd ng/g	Au ng/g
L92	0.098	0.10	3.35	3.52	6.61	1.31		7.80	1.93
L66	0.108	0.09	2.57	2.51	5.11	1.15		6.01	1.32
L732A	0.097	0.20	3.13	3.00	5.31	1.50		8.16	2.76
L79	0.086	0.15	3.23	3.18	6.53	1.26		6.99	1.68
ERN1/2	0.109	0.19	2.26	2.30	5.13	1.05	6.18	5.30	2.84
ERN1/4	0.102	0.17	2.56	2.72	5.56	0.87	6.53	4.11	2.96
ERN1/5	0.104	0.23	2.61	2.56	5.50	1.21	8.06	6.75	2.07
ERN2/16	0.113	0.10	2.47	2.40	4.71	1.14	8.32	4.73	6.38
ERN2/18	0.099	0.15	2.22	2.64	5.20	0.78	6.18	4.14	2.34
ERR3/3	0.090	0.17	2.86	3.02	6.19	1.31	10.90	6.43	3.34
ERS2/2	0.116	0.19	2.39	2.84	5.86	1.84	6.87	5.56	6.40
ERS2/4	0.087	0.12	2.93	3.00	6.17	1.14	6.38	3.05	3.32
ERSP4	0.103	0.20	2.34	2.70	4.98	1.04	6.58	4.81	2.41
Average		0.16	2.69	2.80	5.60	1.20	7.33	5.68	3.06
S.D.		0.05	0.38	0.34	0.61	0.27	1.55	1.52	1.60
S.D. (%)		29	14	12	11	22	21	27	52
CI		38.3	486	459	714	140	994	556	152
Mantle x	10-3 CI	4.1	5.5	6.1	7.8	8.6	7.4	10.2	20.1
S.D.		1.2	0.8	0.7	0.9	1.9	1.6	2.7	10.5

In Fig. 1 the HSE data are plotted normalized to CI-abundances [17]. In a large number of fertile lherzolites from the studies by Pattou et al. [10], Lorand et al. [14], Snow et al. [15], and mantle-derived samples from Morgan [4] and Meisel et al. [7] the abundance distribution of the HSE is remarkably uniform with slightly increasing abundances with decreasing refractory character of the elements from Re to Pd, except Pt. The variously depleted incompatible elements Re and Au may be due to above mentioned secondary effects. Abundances of HSE in PUM sampled by lherzolites from our studies [14-15] are as follows; 0.16±0.05 ng/g Re; 2.69±0.38 ng/g Os, 2.80±0.34 ng/g Ir, 5.60±0.61 ng/g Ru, 1.20±0.27 ng/g Rh, 7.33±1.55 ng/g Pt, 5.68±1.52 ng/g Pd and 3.06±1.60 ng/g Au (Tab. 1). From a large number of mantle derived peridotites Morgan et al. [6] have found that Ir is normally distributed with a mean of 3.2±0.2 ng/g or (6.7±0.5) x 10^{-3} CI. The worldwide distribution of Ir agrees reasonably well with the mean Ir value of 2.80±0.34 ng/g Ir estimated from our studies (Fig. 1).



In Fig. 2 the HSE data from this work are plotted normalized to Ir and various chondrite groups (chondrite data are from [18-20]). The Pd/Ir-, Pt/Ir-, Ru/Ir- and Os/Ir inter-element ratios of E-chondrites agree reasonably well in comparison to the averaged mantle HSE abundances of the Earth's upper mantle. Probably the small-sized samples from our meteorite collections are unlikely to be exact samples of the material that enriched the Earth's upper mantle in HSE and the identity of the late veneer object(s) can be found only in the ancient lunar breccias created at that time [6].



[1] Kimura K., Lewis R. S., Anders E. (1974) GCA 38, 683-701. [2] Chou C.L. (1978) Proc. LPSC 9, 219-230. [3] Jagoutz E. et al. (1979) Proc. LPSC 10, 2031-2050. [4] Morgan J.W. et al. (1981). Tectonophysics 75, 47-67. [5] Spettel B. et al. (1991) LPSC XXII, 1301-1302. [6] Morgan J.W. et al. (2001) Met. Planet. Sci. 36, 1257-1275. [7] Meisel T., Walker R.J., Morgan J.W. (1996) Nature 383, 517-520. [8] Meisel et al. (2001) GCA 65, 1311-1323. [9] Brandon A.D. et al. (2000) EPSL 177, 319-335. [10] Pattou L., Lorand J.P., Gros M. (1996) Nature 379, 712-715. [11] Rehkämper M. et al. (1997) Science 278, 1595-1598. [12] Snow J.E., Schmidt G. (1998) Nature 391, 166-169. [13] Schmidt G. et al. (2000) Chem. Geol. 163, 167-188. [14] Lorand J.P., Schmidt G., Palme H., Kratz, K.-L. (2000) Lithos 53, 149-164. [15] Snow J.E., Schmidt G., Rampone E. (2000) EPSL 175, 119-132. [16] Schmidt G. et al. (2003) Chem. Geol., in press. [17] Palme H., Beer, H. (1993) In: Voigt H.H. (Ed.), Landolt-Börnstein, Springer-Verlag, 196-206. [18] Hertogen J. et al. (1983) GCA 47, 2241-2255. [19] Wasson J.T., Kallemeyn G.W. (1988) Philos. Trans. R. Soc. 325, 535-544. [20] Jochum K.P. (1996) GCA 60, 3353-3357.