VARIATIONS IN THE IRIDIUM CONTENT OF THE UPPER MANTLE OF THE EARTH

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It is well known that the concentrations of Ir and other noble metals in upper mantle rocks (spinel and garnet lherzolites) are higher than would be expected from metal-silicate partitioning during core formation. Either Ir and other noble metals were contained in a late accretionary component (about 0.5 % CI) which was never in equilibrium with the core (1,2,3,4) or the highly siderophile elements indicate the presence of a small fraction of metal left over from core formation (5). In the first case variations in Ir contents of upper mantle rocks would reflect incomplete mixing of the late accretionary component and Ir contents would be independent of the contents of other, more abundant, siderophile elements, such as Ni and Co. In the second case, the insufficient core formation model, Ir abundances would be connected with the concentrations of other siderophiles and uniform Co contents would imply similarly uniform Ir contents, since Ir and Co would be provided by the same component.

We have analysed 54 spinel and garnet lherzolites from 15 continental locations. Most samples are xenoliths in alkalic basaltic rocks, in addition 7 samples from Zabargad island and 3 samples from the Central Dinaric Ophiolite Belt in Yugoslavia were included. Most samples are rather fertile in terms of major elements (Ca, Al) and compatible trace elements (Sc, Yb, etc.). Analyses were performed by INAA on aliquots (typically 200 mg) of larger samples (at least several grams). Data for some lithophile and siderophile elements are presented in the Table. Some aspects of siderophile element chemistry in a subset of these samples were discussed earlier (6).

Significant regional variations in Ir concentrations are obvious from the Table. Eight samples from the Vitim area define a mean Ir content of 2.9 ± 0.14 ppb (standard deviation of the mean), while nine spinel lherzolite nodules from Antarctica have a mean Ir content of 4.92 ± 0.22 ppb, nearly a factor of two higher. The corresponding Co values are 101 ± 1.2 ppm for the Vitim samples and 101 ± 0.9 ppm for the Antarctic suite. Cobalt concentrations are surprisingly constant reflecting a partial melt/residue partition coefficient of approximately unity. Contents of Ni in spinel and garnet lherzolites are more variable, being positively correlated with Mg and negatively with Ca, Al, Sc etc. Within the error limits of the analyses (±10 %) Ir is not correlated with any other element. Therefore, we conclude that the difference in Ir between the Vitim samples and the Antarctic spinel lherzolites reflect real variations of Ir abundances in the upper mantle and that these variations indicate incomplete mixing of a late accretionary component.

The Antarctic spinel lherzolites have higher Au contents leading to Ir/Au ratio of 2.45 compared to 5.91 for the Vitim samples. The significance of this difference is unclear, since the Au data have comparatively high analytical uncertainties and Au is, in addition, a rather mobile element, which may be enriched by secondary processes. The suite of Antarctic spinel lherzolites is, on the average, less fertile than the Vitim samples, as reflected by their lower contents of lithophiles and their higher Ni abundances.

Most samples from other localities have similar Ir contents as the Vitim samples. The average Ir content of the Mongolian suite is, for example, 3.56 ± 0.24 ppb (107 ± 2.7 ppm Co). Rocks from the Zabargad island, however, define a higher Ir level of 4.43 ± 0.32 ppb (106 ± 1.9 ppm Co).

Conclusion: The final stage of accretion of the Earth probably occurred through impacts of large bodies. In a numerical simulation Wetherill (7) found that the last major impact occurred at 4.3 b. y. providing 0.3 % of the Earth's mass. The upper mantle Ir may be a signature of such an event. Variations in Ir would then reflect incomplete mixing of material provided by this last major impact contributing about to the accretion of the Earth.

Sources of samples: Vitim, D.A.Ionov; Antarctica, L.N.Kogarko; Jordan, S.Nasir, Yarmouk University, Irbid, Jordan; Saudi Arabia, F.Henjes-Kunst, Universität Karlsruhe; Mongolia, D.A.Ionov, H.-G.Stosch (8); Zabargad and Kapfenstein, G.Kurat, NHM Wien (9); Yugoslavia, B.Lugovic, Zagreb (10); All other samples from Mainz, E.Jagoutz (4).

Literature: (1) Kimura K. et al. (1974) GCA 38, 683; (2) Chou C.-L. (1978) Proc. Lunar. Planet. Sci. Conf. 9th, 219; (3) Morgan J. et al. (1981) Tectonophysics 75, 47; (4) Jagoutz et al. (1979) Proc. Lunar Planet. Sci. Conf. 10th, 2031; (5) Jones J. H. and Drake M. J. (1986) Nature 322, 221; (6) Spettel B. et al. (1990) Lunar. and Planet. Sci. XXI, 1184; (7) Wetherill G.(1990) Annual Rev. of Earth Sci. 18, 205; (8) Stosch H.-G. (1986) GCA 50, 2601; (9) Kurat G. et al. (1980) GCA 44, 45; (10) Lugovic B. et al. (1991) Contrib. Mineral. Petrol. (in press).

Lithophile and Siderophile Elements in Upper Mantle Rocks

		Ca %	Na ppm	Sc ppm	Sm ppm	Yb ppm	Hf ppm	Fe %	Ni ppm	Co ppm	Ir ppb	Au ppb
Vitim (USSR)												
313-54	g	1.98	2200	15.2	0.33	0.38	0.23	6.11	1980	100	3.2	0.6
313-110	g/s	1.82	1900	14.8	0.30	0.54	0.17	6.00	2070	103	2.4	0.4
313-74	g/s	1.38	1220	11.3	0.20	0.17	0.13	5.75	2220	102	2.8	0.5
314-59	s	2.29	2330	16.1	0.34	0.33	0.19	6.41	2280	108	3.1	0.6
313-105	g	1.75	1810	13.5	0.27	0.34	0.19	6.03	2100	100	2.4	0.6
313-8	g	2.36	2000	21.4	0.53	0.63	0.33	5.95	2480	95.1	3.2	<0.8
314-58	s	1.83	2000	14.3	0.27	0.37	0.20	5.96	2050	98.4	3.5	0.7
314-56	s	2.24	1990	16.1	0.39	0.45	0.25	6.53	1990	102	2.6	0.5
Antarctica												
ANA1	s	1.35	1250	15.8	0.27	0.36	0.17	5.92	2425	103	5.5	1.2
ANA2	s	1.40	1130	16.1	0.17	0.40	0.11	5.56	2340	102	5.1	2.2
ANA3	s	1.62	1380	13.6	0.26	0.32	0.15	5.88	2320	103	5.1	1.7
ANA4	s	1.62	1430	10.3	0.31	0.24	<0.8	5.84	2240	101	5.3	2.2
ANA5	s	0.98	900	8.79	0.27	0.12	0.21	6.18	2170	102	5.5	1.9
ANA6	s	1.89	1780	13.9	0.26	0.36	0.17	6.24	2200	101	5.0	3.0
ANA7	s	1.42	1220	10.2	0.46	0.26	0.17	6.06	2150	99.9	3.6	2.2
ANA8	s	1.40	1210	8.38	0.32	0.11	0.15	5.02	2170	93.9	5.3	2.3
ANA9	s	1.54	1320	12.6	0.33	0.31	0.25	6.48	2050	100	3.9	1.4
Jordan												
NAD1	s	1.20	1870	10.5	0.85	0.27	0.17	6.35	2340	108	2.3	<0.5
Saudi Arabia												
KAR1	s	2.08	1600	15.0	0.20	0.34	0.11	5.66	2595	97.2	3.1	0.8
KAR2	s	1.68	1420	13.5	0.17	0.29	0.11	6.44	2140	111	3.7	0.5
KAR3	s	2.19	1820	14.9	0.20	0.34	0.10	5.94	2370	103	3.3	1
KAR4	s	1.90	1650	13.5	0.17	0.29	0.10	5.62	2170	101	3.0	0.7
KAR5	s	2.28	1990	16.8	0.36	0.48	0.20	6.45	1880	102	3.5	1.3
Mongolia												
Mo105	s	2.68	3560	19.1	0.48	0.55	0.32	5.86	1910	92.6	4.7	0.4
MO103	s	1.02	900	10.5	0.15	0.13	<0.2	5.65	3020	109	3.9	<0.8
MOG1	s	2.62	2830	17.1	0.56	0.47	0.24	6.36	1840	102	2.9	0.6
MOG2	s	1.94	1860	13.9	0.20	0.31	0.15	6.22	2110	109	3.9	0.6
MOG3	s	2.10	1730	13.4	0.30	0.29	0.13	6.43	2350	116	2.8	0.4
MOG4	s	1.87	2010	14.5	0.23	0.33	0.51	6.36	2200	112	3.6	0.4
MOG5	s	2.49	2640	16.8	0.40	0.43	0.62	6.42	2140	106	3.1	<0.7
s.d. in %		10	3	3	5	10	10	3	5	3	10	20

		Ca %	Na ppm	Sc ppm	Sm ppm	Yb ppm	Hf ppm	Fe %	Ni ppm	Co ppm	Ir ppb	Au ppb
Dreiser Weiher (Germany)												
D1BN	s	1.85	1400	14.6	0.17	0.36		6.13	2400	114	4	0.4
Massif Centrale (France)												
FRA1N	s	2.60	2670	22.0	0.41	0.44	0.24	5.88	2000	102	5.6	0.5
Kapfenstein (Austria)												
KA111	s	1.79	2070	14.4	0.24	0.35	0.18	6.37	2360	113	3.7	1.4
KA155	s	1.40	1610	13.4	0.18	0.25		6.05	2400	114	4.0	
KA168	s	2.17	2110	14.7	0.27	0.37	0.15	6.33	2250	106	4.5	0.7
Kilbourn Hole (USA)												
KBH1B	s	2.45	2250	17.0	0.27	0.50	0.15	6.00	2120	104	3.2	0.4
KH5	s	2.27	1980	17.8	0.22	0.39	0.11	6.38	2110	109	3.7	1.4
Mojave (USA)												
MOJ4	s	1.97	1710	14.5	0.16	0.32	0.10	6.01	2325	105	2.6	<0.3
San Carlos (USA)												
SC1	s	2.72	2745	16.9	0.54	0.47	0.26	5.86	1890	98	3.2	0.5
SSC1	s	2.07	1950	15.6	0.25	0.38	0.17	6.57	2100	108	3.9	3.2
PM22	s	2.14	1900	14.3	0.23	0.42	0.17	6.25	2250	107	2.4	1
Potrillo (USA)												
PO1	s	2.54	2360	17.0	0.27	0.45	0.20	6.30	1990	105	3.2	0.3
PO5	s	1.67	1490	13.3	0.21	0.27	0.16	6.51	2340	110	3.4	1
Zabargad Island (peridodite massif, Red Sea)												
Z106	s	2.2	3740	17.7	0.23	0.39	0.13	5.89	2085	99.7	4.5	<4
Z118	s	2.11	1800	14.6	0.30	0.36	0.18	7.17	2320	111	3.0	1.6
Z13A	s	1.54	1310	13.8	0.18	0.25	0.11	6.49	2130	112	5.6	1.4
Z14	s	1.41	2130	16.1	0.21	0.34	0.10	6.18	2265	106	3.8	<1
Z15	s	2.08	1950	12.0	0.10	0.23	<0.1	5.80	2280	105	5.4	<1
Z34	s	2.01	1710	15.3	0.25	0.38	0.15	6.12	2220	108	4.1	<0.7
Z36	s	2.07	1635	10.9	4.00	0.57	<0.1	6.56	2390	97.8	4.6	1.1
Yugoslavia (peridodite massif)												
BI-15	s	2.91	1370	20.3	0.17	0.73	0.05	5.95	1710	85	3.5	1.1
87-63	s	2.30	1800	15.5	0.22	0.39	0.11	6.50	2080	101	5.3	1.9
87-122	s	2.50	2300	16.4	0.31	0.43	0.17	6.45	1760	99	3.9	1.2

all data by INAA; g - garnet lherzolite; s - spinel lherzolite; s. d. - representative standard deviation