ESTIMATED MASS OF IRON METEORITES CONTRIBUTING TO HIGHLY SIDEROPHILE ELEMENT AND NI INVENTORY OF THE EARTH CRUST

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Introduction: The highly siderophile element (HSE) and Ni composition is a key issue for understanding its origin and the influence of impactors on the chemical composition of the Earth crust and mantle.

The HSE systematics of the Earth upper mantle shows decreasing solar system normalized abundances with increasing condensation temperatures (Fig. 1), consistent with high-temperature fractionations in the solar nebula, suggesting that these elements were added to the accreting Earth by a late bombardment after core formation. However, the mantle Ru/Ir ratio of exactly 2 [1] in comparison of 1.51 ± 0.04 of the known different chondrite groups is still enigmatical (Fig.1). This feature of the primitive upper mantle (PUM) has been observed by other groups as well [2,3]. In fact, the HSE in PUM are even more fractionated than the enstatite chondrites - an indication that some inner solar system materials were more highly fractionated than the latter.

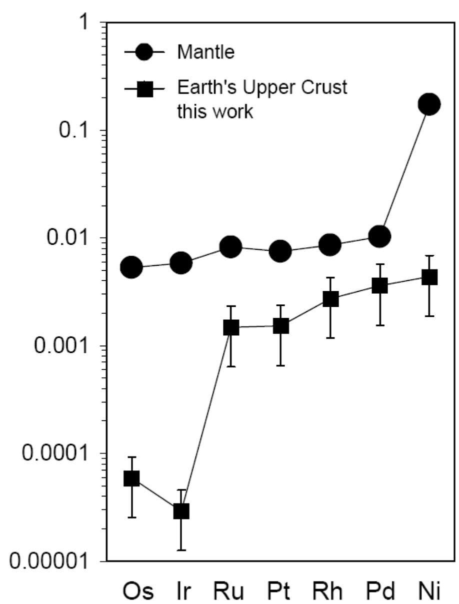


Fig. 1

In contrast to the mantle, the HSE and Ni pattern of the Earth's upper continental crust (UCC) is strongly fractionated (Fig. 1) with low Os and Ir and relatively high Ru, Pt, Rh, Pd, and Ni. The highly fractionated Ru/Ir ratio preserved in the Earth's UCC is unparalleled in terrestrial magmatic systems. Sulfide/silicate partition coefficients for Os are very similar to those of Ir, Ru, Pd, and Pt. Thus similar abundances of these elements would be expected which is not observed (Fig.1). The difference between the crustal abundances of HSE suggests that during crust formation by partial melting mantle sulfides were not involved. The HSE UCC composition is difficult to explain if the crust is generated by single-stage melting of peridotitic mantle since Ir and Os together with Ru retained in residual mantle phases during manle melting. The coherence of fractionation of the siderophile elements between two groups suggests a cosmochemical effect. In fact, the HSE and Ni systematics of the UCC closely resembles IIIAB iron meteorites and pallasites (Figs. 2,3, data for Earth's crust multiplied by a factor of 2.5 x 10^3, error-bars are represented by the size of the symbols if no error-bars indicated), probably an indication that the UCC preserves an imprint of some of the major fractionation processes which have occurred in magmatic iron meteorites or pallasites.

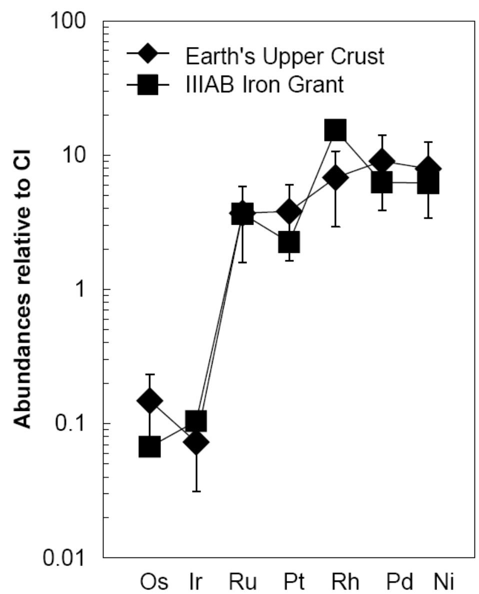
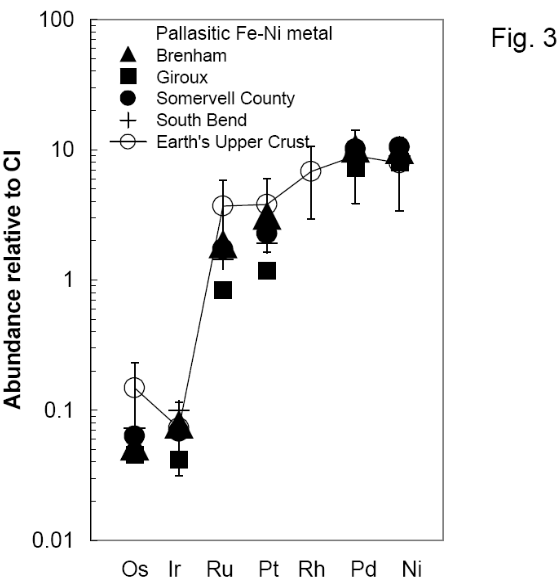


Fig. 2

The deep continental crust is far less accessible than the upper continental crust. Therefore average HSE composition of middle, lower, and bulk continental crust carry a much greater uncertainty. Examination of HSE abundances must be conducted to get more specific information on the early evolution of the Earth deep crust.

Chemical Fractionation of HSE and Ni in IIIAB Iron Meteorites and Pallasitic Metal

IIIAB iron meteorites cover a wide range of Ni/Ir ratios and trace-element variations span more than three orders of magnitude within group IIIAB irons. Trace element trends observed in several iron meteorite groups could be explained by fractional crystallization of cores with approximately cosmic bulk trace element/Ni ratios and that the outside edges of such cores should be strongly depleted in Os and Ir, moderately depleted in Ru and Pt, and slightly enriched in Pd, relative to Ni-normalized Cl chondrite abundances [4].



Chemical similarities between pallasitic metal and high-nickel IIIAB irons has been mentioned by Scott and Wasson [5]. Trace element composition of metal from pallasites is characterized by strong depletions in Os and Ir, moderate depletions in Ru and Pt, and a slight enrichment in Pd, relative to Ni-normalized Cl chondrite abundances [6].

The IIIAB iron meteorite Grant (Fig. 2), the pallasites Brenham, Giroux, Sommervell County, and South Bend (Fig. 3), and the UCC generally show similar fractionated element patterns with low Os and Ir, and high Ru, Pt, Rh, and Pd. Additionally, the observed Ni/Ir ratio of about 2.4×10^6 in the UCC is not distinguishable from the Ni/Ir ratios found in magmatic iron meteorites and pallasites. The similarity in HSE ratios and the very systematic compatible-incompatible element behaviour of IIIAB irons, pallasitic metal and the UCC strongly supports a genetic link between these type of meteorites and the HSE and Ni component in the UCC. A possible interpretation is that the HSE in the Earth's UCC have been introduced by impacts of magmatic iron meteorites and/or pallasites.

Estimated Mass of Iron Meteorites Contributing to HSE and Ni Inventory of Earth Continental Crust

Iron and stony-iron meteorites constitute about 6% of the meteorite falls (cf. [7,8]). However IIIAB Iron is a common iron meteorite type and many of the small impact craters on Earth are produced by this type of iron meteorite projectiles (cf. [9] and references therein).

An average density of 2.8 g cm^{-3} for the Earth crust gives a total crustal mass of 2.06×10^{25} g (± 7%) [10]. The Ni content of the crust is 59 µg/g [11]. The meteoritic mass (magmatic irons or pallasites, for example Grant with 92.4 mg/g Ni [12]) is thus estimated to be 1.32×10^{22} g, which could account for the abundances of Ni and HSE in the Earth continental crust. This is about 0.06 % of the bulk crustal mass. Assuming a mean density of 8 g cm^{-3} for magmatic iron meteorites [14], this corresponds to a volume of 1.65×10^{21} cm^3 and thus a sphere with a radius of 73 km as an upper limit. Since the mass of the upper continental crust is about half the mass of the total crust [13] and the Ni content of the UCC is 47 ± 11 µg/g (cf. [11]) the addition of less than 0.03 % of a meteoritic (magmatic irons or pallasites) component is required. Assuming that (1) bulk Ni in the upper crust is extraterrestrial in origin and (2) the mass of the upper continental crust is about half the mass of the total crust, this corresponds to a volume of 6.55×10^{20} cm^3 and thus a sphere with a radius of about 54 ± 4 km as an upper limit [15]. Of course these estimates are very rough but not unlikely assuming that more than a single projectile may have hit the Earth UCC since its formation.

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