SIDEROPHILE ELEMENTS IN THE PRIMITIVE UPPER MANTLE.
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The most primitive terrestrial rocks in terms of bulk chemistry are spinel and garnet lherzolite xenoliths from alkali basalts and kimberlites. These rocks were transported from the upper mantle to the surface of the Earth rather rapidly and thus have retained their original chemical composition. They are primitive i.e. reflect the composition of the primitive upper mantle more closely than any other rock type. Typical signatures are (a) high Mg/Fe-ratios (b) nearly unfractionated (i.e. chondritic ratios) of compatible refractory lithophile elements (Ca, Al, Sc, Yb, etc.) and (c) high contents of siderophile elements, such as Ni, Co, Ir. We have analysed 40 fertile spinel-lherzolites (>7% cpx) from 4 different continents for major and trace elements to extend an earlier data set [1]. All samples are xenoliths, except for some rocks from the Zabargad island. Here we will focus on siderophile elements.

Origin of siderophiles:
High siderophile element abundances in the upper mantle exclude equilibrium partitioning between core and mantle for such elements as Ni and Ir. Alternative explanations either invoke insufficient core formation, i.e. some metallic FeNi was retained in the upper mantle during core formation [2] or some type of inhomogeneous accretion, i.e. accretion of material that was not in equilibrium with the metal of the core because it was added after core formation [e.g. 3].

In both models Ni and a major fraction of Fe are derived from the same source. Therefore, the distribution of Ni in the upper mantle should closely follow that of Fe. In the inhomogeneous accretion model, accretion of a component with 2000 ppm Ni requires simultaneous accretion of some 3% Fe. A similar fraction of Fe is retained in the mantle in the insufficient core formation model. Since the upper mantle Fe content is certainly not higher than that of the lower mantle very effective mixing of Fe and Ni must have occurred after accretion and as a result a similarly high Ni content for the lower mantle should be expected. Fig. 1 demonstrates the uniform distribution of Fe, Ni and Co in the upper mantle beneath continents. Nevertheless there is some systematic variation in Ni content with MgO as indicated in Fig. 2. Variations of CaO are opposite to those of Ni, since during partial melting Ca will be enriched in the melt and Ni in the residuum. Estimates for primitive upper mantle composition range between 36 and 38% MgO [3-6] corresponding to a primitive upper mantle Ni-content of 1700 to 2000 ppm (Fig. 2).

Ni/Co-ratio:
It has been known for some time that the upper mantle Ni/Co ratio is approximately chondritic, as expected from the inhomogeneous accretion model. There are some systematic variations in this ratio in our suite of rocks (Fig. 3). Partial melts have lower and refractory residues higher Ni/Co ratios, reflecting the more incompatible behaviour of Co during melting processes. The trend extends into the field of komatites. The mineral data (Fig. 3) show that the trend is not produced by random mixing of minerals with variable Ni/Co-ratios. Fig. 4 indicates a Ni/Co ratio for the primitive upper mantle of about 19. This is 10-20% lower than ratios found in carbonaceous chondrites. The meteorite and the spinel lherzolite data were obtained with the same technique and using the same standards. The non-chondritic upper mantle Ni/Co-ratio may be a result of removal of some NiFe metal or sulfide into the core after accretion. Segregation of a small amount of metal and/or sulfide is necessary to extract highly siderophile elements (e.g. Ir) that have much lower upper mantle abundances than Ni [7]. Co is less affected by metal (or sulfide) extraction, leading to a lower than chondritic Ni/Co ratio in the residual mantle. Extraction of metal (sulfide) has the opposite effect on the upper mantle Ni/Co ratio as removal of partial melts. Before formation of partial melts the mantle must have been mixed extremely well to account for the uniformity in the Ni/Co ratio.

Ir-distribution:
The final addition of about 0.5% of a chondritic component also requires thorough mixing, since the distribution of Ir in upper mantle rocks is rather uniform (Fig. 1). Since Ir cannot be tied so well to Ni or Fe abundances nothing can be said on the depth of the Ir layer in the upper mantle. The rather homogeneous Ir distribution, however, suggests thorough mixing after any metal and/or sulfide segregated to the core. It is very likely that this mixing affected the whole mantle establishing a more or less uniform Ir level. Recent analyses of Antarctic spinel-lherzolites, however, (samples from L. Kogarko, Vernadsky Institute, Moscow) suggested the possibility that some areas in the mantle may be higher in Ir. Further analyses are performed to verify this trend. The Ir/Au ratio in upper mantle rocks is on the average higher than the CI-ratio perhaps reflecting admixture of C3 material as last accretional spike (Fig. 1).
