IN SITU ION PROBE MEASUREMENTS OF PGEs AND THEIR DISTRIBUTIONS BETWEEN METALLIC PHASES OF IRONS.

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We have developed an ion-probe technique that permits *in situ* determination of the abundances of Os, Ir, Pt, and Au in iron meteorites. This technique allows us to examine the microdistributions and partitioning of heavy PGEs and Au within and among the metallic phases of iron meteorites. This information is important for the further development of the Re-Os chronometer, for understanding the behavior of PGEs during solid-state segregation of Fe,Ni phases, and perhaps for refining estimates of cooling histories of iron meteorites. We have applied this technique to kamacite and taenite in the Cape York (IIIA), Canyon Diablo (IAB), and Colomera (IIE) iron meteorites.

Experimental: Data were collected using a Cs^+ primary beam (spatial resolution ~20 µm) to sputter negative secondary ions of Fe, Co, Ni, Os, Ir, Pt, and Au from sample surfaces. An energy offset of 40 eV was used to suppress complex molecular ions, and a mass resolution of ~1600 resolved the remaining signals from various Cs-Fe or Cs-Ni molecules. Isotopic ratios ($^{188}Os/^{189}Os$, $^{191}Ir/^{193}Ir$, and $^{194}Pt/^{195}Pt$) were monitored to assure that only PGE ions were being counted. Sensitivity factors were determined from the Santa Clara ataxite, which has high PGE abundances and for which abundances of Os, Ir, and Au are available[1-3]. The abundance of Pt was inferred by assuming a cosmic Pt/Ir ratio in Santa Clara, an assumption supported by the measured cosmic Os/Ir ratio in Santa Clara. Ion yields for Fe, Ni, and Co co-vary by up to a factor of 5 over the course of a measurement, while those for Os, Ir, Pt, and Au remain approximately constant. Since the Fe, Ni, and Co count-rate patterns are not reproducible from spot to spot, we normalized our PGE count rates to the beam current and ran all samples and standards using a 10 nA ion beam. Drifts in ion-beam current limit our reproducibility to 20% from spot to spot, but differences larger than this are considered to be real. The absolute calibration of the abundances is more uncertain due to real variation in PGE abundance in Santa Clara. A suite of 31 independent measurements of Santa Clara gave a range of 50%, so our absolute abundance determinations are uncertain by about a factor of two. We had hoped to measure Re and the light PGEs with the same procedure, but ion yields were too low for meaningful results.

Results: Cape York (IIIA) has well exsolved taenite lamellae (Ni ~ 15wt%), ~500 µm in width. Six PGE profiles were measured across taenite lamellae (Fig. 1). Ni/Fe exhibits an M-shaped profile, while Co/Fe exhibits a subdued W-shaped profile, consistent with previous work [e.g., 4]. Os, Ir, Pt, and Au abundances are higher in taenite than in kamacite (Fig. 1b-d). Distribution coefficients ($D_{Taenite/Kamacite}$), estimated from the points closest to grain boundaries, are ~2.4 for Os, ~1.5 for Ir, ~1.4 for Pt, and ~2.3 for Au. Although PGEs and Au are enriched in taenite relative to kamacite, Os/Ni, Ir/Ni, Pt/Ni and Au/Ni are *lower* in taenite than in kamacite (Fig. 1f). Cape York appears to exhibit evidence of a relative fractionation of Os, Ir, and Au between kamacite and taenite. Os/Ir and Au/Ir both tend to be slightly lower in kamacite than in taenite (Fig. 1e). The high relative abundance of Pt in both phases is not understood. Average bulk abundances for Cape York, estimated from the measured data and the modal abundances of kamacite and taenite are: Os = 5 ppm, Ir = 6 ppm, Pt = 24 ppm, Au = 1.5 ppm. Our Os, Ir, and Au values are slightly higher than, but within a factor of 2 of, previously reported bulk values determined by INAA and isotope dilution [4-6]. Os/Fe, Ir/Fe, and Au/Fe are higher in Cape York than the cosmic abundances by factors of 2-4x in kamacite and 3-6x in taenite, with Pt enrichments slightly higher.

Colomera (IIE) contains small (~ 50 µm) rounded taenite grains (~45 wt% Ni) surrounded by kamacite. Taenite in Colomera is enriched in Os, Ir, Pt, and Au relative to kamacite. The inferred $D_{T/K}$ values are: ~2.5 for Os, ~1.8 for Ir, ~1.5 for Pt, and ~3.3 for Au, similar to the Cape York values. Os/Ni, Ir/Ni, Pt/Ni, and Au/Ni are all lower in taenite than in kamacite, with the ratios in taenite 25-50% of the cosmic ratios. PGEs and Au were fractionated with respect to one another during partitioning in Colomera. In taenite, the relative abundances of Os, Ir, and Pt are approximately cosmic, while Au is depleted by about a factor of 2. In kamacite, Os/Ir is only about half of cosmic and Pt/Au is about 2.5x cosmic (Fig. 1e). The relative abundances of the bulk meteorite are controlled by kamacite, and PGEs/Fe are higher than cosmic by factors of 1.5-3.

Canyon Diablo (IAB) exhibits discontinuous taenite lamellae that are locally up to ~500 µm across. M-shaped profiles were obtained for Ni/Fe and Au abundance, but Os, Ir, and Pt abundances showed no clear pattern. As in Cape York and Colomera, Os/Ni, Ir/Ni, and Pt/Ni are lower in taenite than in kamacite, while Au/Ni is approximately constant. There are hints of relative fractionations among PGEs between kamacite and taenite (e.g., Au/Pt may be higher in taenite), but the data are not clear-cut. Bulk-meteorite Os/Fe and Ir/Fe are ~1.5x cosmic, while Pt/Fe and Au/Fe are ~3x cosmic.

Discussion: Abundances of Os, Ir, Pt, and Au tend to be higher in taenite than in kamacite, but Os/Ni, Ir/Ni, Pt/Ni, and Au/Ni are lower in taenite than in kamacite. These data show that Os, Ir, Pt, and Au are fractionated from Ni during solid-state redistribution in iron meteorites. The M-shaped profiles exhibited by Au and to a lesser extent by Pt, Os, and Ir (Fig. 1), indicate that partitioning between taenite and kamacite is a function of exsolution history. PGEs were fractionated relative to one another by factors of between 1.2 and 3.3 as they partitioned between kamacite and taenite (Fig. 1e). These relatively low distribution coefficients contrast dramatically with the extreme values (0.02 to ~50) reported by previous workers [4, 7].

Relative fractionations of PGEs between kamacite and taenite indicate that there are very likely to be fractionations between Re and Os as well. Subsolidus redistribution must be considered in Re-Os chronology. Fractionation of Re from Os has already been shown to occur in metal in the vicinity of schreibersite [8]. Similarly fractionations between metal phases may explain why very small samples of iron meteorites, which do not adequately sample all phases, shows small deviations from the iron meteorite isochron [11]. Further work will have to be done to address this issue and we hope to expand our element list in the near future to include Re.

This study demonstrates the capability of *in situ* ion probe measurements of Os, Ir, Pt, and Au in iron meteorites. This capability provides a new tool with which to investigate the distribution of these elements on a micro scale in a variety of samples that have previously been extremely difficult or impossible to analyze. In addition to cosmochemical applications such as those discussed here and in [9] and [10], the ability to measure PGEs in metal with the ion probe may have important industrial applications, such as investigating the siting and distribution of PGEs in commercial materials.

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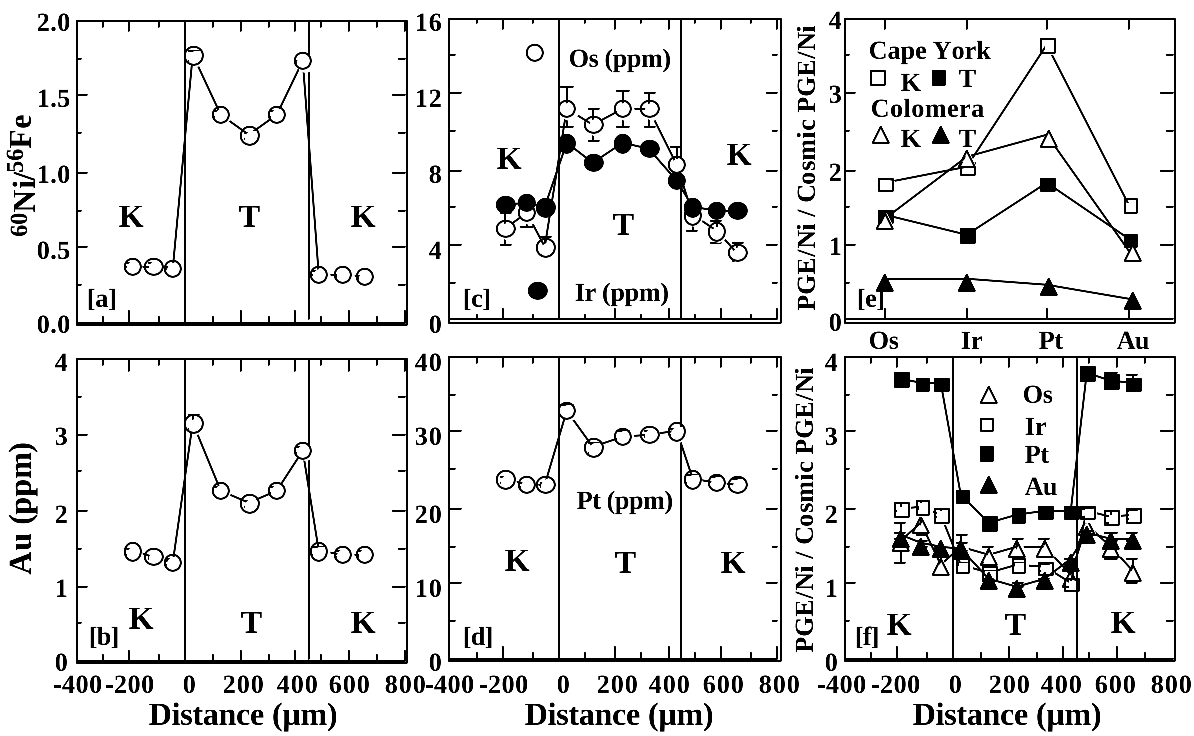

Fig. 1 Ni/Fe (ion count ratios), and Os, Ir, Pt, and Au concentration profiles across a single taenite (T) lamella within kamacite (K) host of Cape York.