^{187}Os Enrichment in Some Plumes: Evidence for Core-Mantle Interaction?

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Re, Os geochemistry…

- Re and Os are highly siderophile elements; ca. 99% of the Earth's budget of Re and Os resides in the metallic core
- Re/Os and $^{187}Os/^{188}Os$ ratios of the bulk core similar to those of the bulk Earth and chondrites
- During partial melting/crystallization Re is partitioned preferentially into the melt while Os is retained by the residue

Decay equations

- $^{187}Re \rightarrow {}^{187}Os + \beta^-$ $t_{1/2}$ =42 billion years
- $^{190}Pt \rightarrow {}^{186}Os + {}^{4}He$ $t_{1/2}$ =666 billion years
- $^{187}Os/^{188}Os=(^{187}Os/^{188}Os)_i +^{187}Re/^{188}Os*(e^{\lambda t}-1)$
- $^{190}Pt/^{188}Os=(^{186}Os/^{188}Os)_i +^{190}Pt/^{188}Os*(e^{\lambda t}-1)$

^{187}Os enrichment in OIBs

- OIBs have elevated $^{187}Os/^{188}Os$ ratios compared with Chondrites and MORBs, indicating a long-term increase in the Re/Os ratio
- Recycling of oceanic crust can only explain some OIBs with ^{187}Os enrichment
- Incorporation of the outer core material into the plume -- An alternate hypothesis

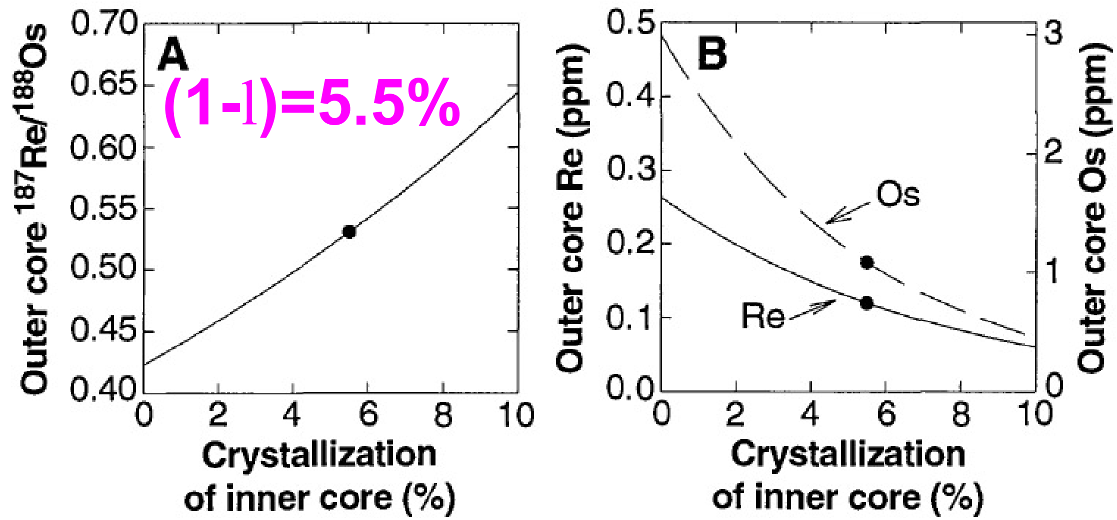
Keep in mind …

- There are several processes that can attribute to the enrichment (contaminated by aged oceanic crust..)
- But in this paper only discuss one potential process: chemical interaction between the outer core and lower mantle and plume derivation from CMB
- The crystallization trends in small asteroidal cores are analogs for the Earth Core

Crystallization of inner Core

- Assuming inner core formed very early
- $k^{Re}=15$, $k^{Os}=19$
- $(^{187}Os/^{188}Os)_i=0.096$ $(^{187}Os/^{188}Os)_t=0.1288$
- Upper mantle: $(^{187}Os/^{188}Os)_t=0.1271$
- $(^{187}Re/^{188}Os)_i$ $0.1288=0.096 + \mathbf{0.4224}*(e^{\lambda t}-1)$
- Re=0.263 ppm Os=3 ppm

Fig. 1. (**A**) $^{187}Re/^{188}Os$ of Earth's outer core versus the percent crystallization of the inner core. The plot shows that as the inner core crystallized, the $^{187}Re/^{188}Os$ ratio of the outer core increased from **0.4229** to 0.5303, assuming the modeling parameters described in the text. The solid circle indicates the resulting composition of the outer core. (**B**) Re and Os concentrations of the outer core (in parts per million) versus the percent crystallization of the inner core. The solid circles represent the concentrations of these elements in the outer core, assuming the modeling parameters described in the text.

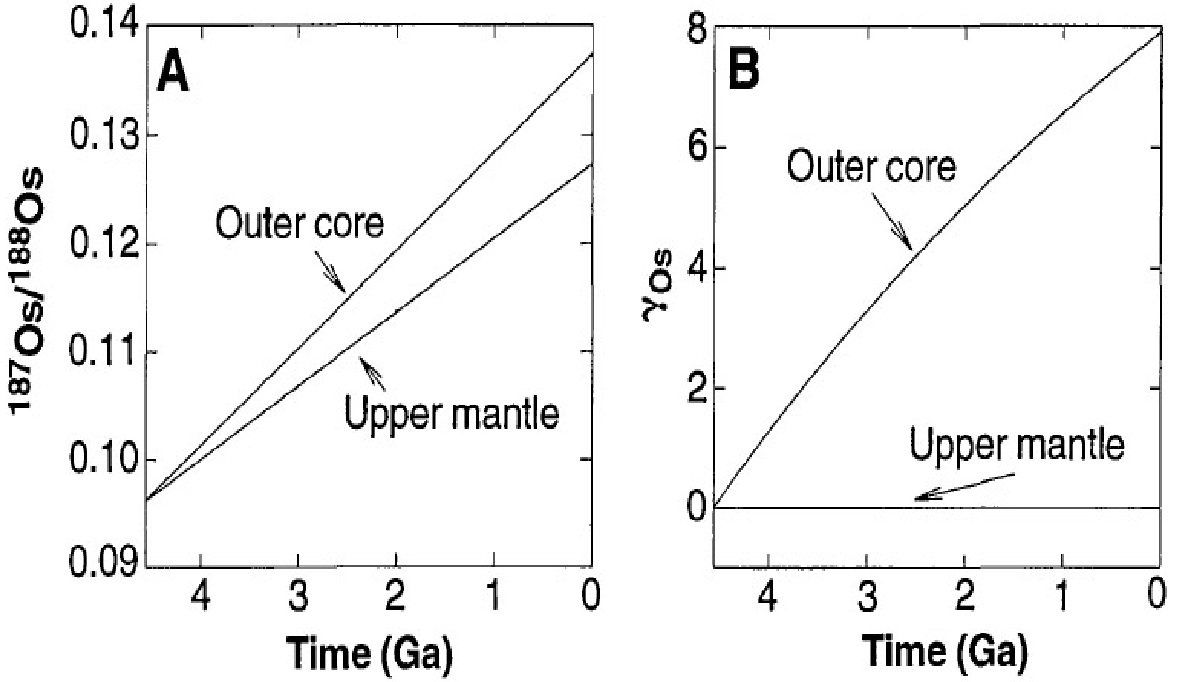


Increasing Re/Os ratio

$$\frac{C_l^{\mathrm{Re}}}{C_0^{\mathrm{Re}}} = l^{k^{Re}-1} \qquad \frac{C_l^{Re}}{C_l^{Os}} = \frac{C_0^{Re}}{C_0^{Os}} \times l^{k^{Re}-k^{Os}}$$

Re/Os=0.263/3=0.088 0.119/1.08=0.1098

Fig. 2. (**A**) $^{187}Os/^{188}Os$ versus time [in units of 10^9 years ago (Ga)] for the outer core and upper mantle with carbonaceous chondritic Os characteristics. (**B**) γ_{Os} versus time for the outer core and upper mantle with carbonaceous chondritic Os characteristics.



$$0.1372 = 0.096 + 0.5303 \times \left(e^{\lambda t} - 1\right)$$

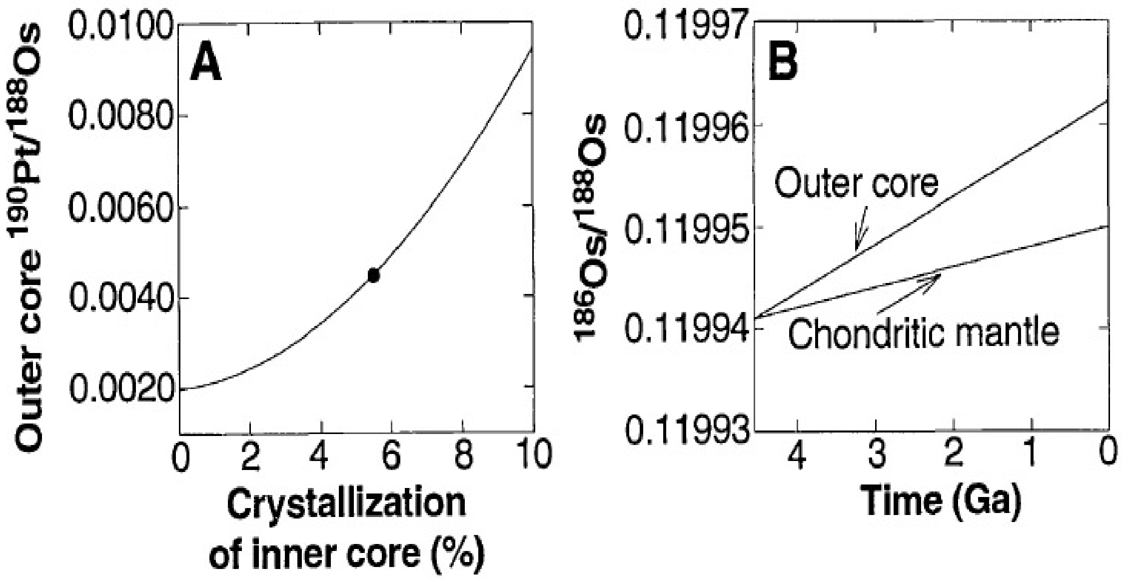
$t = 4.56 \times 10^9$ $\lambda = 1.64 \times 10^{-11}$

Crystallization of inner core increased Re/Os ratio (therefore $^{187}Os/^{188}Os$ ratio) and decreased Re, Os concentrations (but still hundreds times higher than lower mantle)

The outer core vs the mantle

- Outer core: Re=119 ppb Os=1080 ppb
- Upper Mantle: Re=0.25 ppb Os=3.3 ppb
- Even if only 1% of outer core material is added into plume, Os concentration is dominated by the core component

Fig. 3. (**A**) $^{190}Pt/^{188}Os$ of Earth's outer core versus the percent crystallization of the inner core. The plot shows that as the inner core crystallized, the $^{190}Pt/^{188}Os$ ratio of the outer core increased from 0.00183 to 0.00446, assuming the modeling parameters described in the text. The solid circle indicates the resulting composition of the outer core. (**B**) $^{186}Os/^{188}Os$ versus time (in Ga) for the outer core and upper mantle with carbonaceous chondritic Os characteristics.



Crystallization of inner core also increased Pt/Os ratio (therefore $^{186}Os/^{188}Os$ ratio)

Enrichment of ^{186}Os and ^{187}Os is expected if core material is involved in the plume

Conclusions

- The ascent of plume from the core-mantle boundary is a possible mechanism for ^{187}Os enrichment in some plumes

Pt-Os system ($^{186}Os/^{188}Os$)

- Pt-Os system can be used to distinguish core mantle interactions and mantle-crust mixing since Pt and Os are not as enriched as Re in the oceanic crust and most sediments relative to the mantle