Low abundances of highly siderophile elements in the lunar mantle: evidence for prolonged late accretion

Walker, Horan, Shearer and Papike

EPSL, 2004

Sabine, Maureen, Scott and Karin

Lunar timeline

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Please see:

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Earth HSE ~0.008xCI, .1-.5% HSE added after last interaction between core and mantle Most likely the silicate portion of the moon was stripped of HSE prior to and during coalescence of the moon. Early lower lunar mantle probably low in HSE

Apollo samples

green glasses

- Mare basalt
- 3.4 Ga
- 15-19% MgO
- near primary precursors to very low TiO_2 basalts.

orange glasses

- Mare basalt
- 3.3 Ga
- 14-15% MgO
- near primary precursors to high TiO_2 basalts.

dunite

- cumulate
- 4.45 Ga
- 43.6% MgO
- highlands magnesian suite

→ melting of magma ocean cumulate assemblages @ >400 km depth, leaving behind ol and opx residuum

→ cumulate from a pre-mare basaltic melt

How do you get at the lunar mantle composition?

Glasses most diagnostic of lunar mantle with respect to HSE

Dunite serves as comparison to high MgO terrestrial rock

Exp method

- spherule sample
- spike with known isotopic composition
- etchate: digest 5-30% of sample
- remove spike from residual solids
- ground and respike
- residue: digest 10-50% rela to initial sample masses
- Uncertainties in Os concentration and isotopic composition were typically much less than for the other HSE.

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Pd removed during leaching of samples low concentrations of HSE, dominated by blanks, great uncertainties in the concentrations. more reliable

Summary of results

Often…

- residues have higher 187Os/188Os ratios (are more radiogenic) than etchates (green and orange)
- residues are more fractionated than etchates (green)
- residues are depleted in HSE relative to etchates (green)
- orange etchates are more fractionated than green etchates
- finer fractions have higher Os abundances than coarser fractions (green and orange)

- The initial 187Os/188Os ratio for the dunite is within uncertainty of chondritic average at time of formation

Preferential post-eruption additions of micrometeorites to the surfaces of the finer fractions

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Lunar glasses and dunite are depleted in Os relative to terrestrial rocks with similar MgO.

Green glasses show contamination from meteoritic component with chondritic composition

Less meteoritic contamination in orange glasses

Two indigeneous components and meteoritic component

Discussion

Possible reasons for low HSE abundances in the lunar mantle:

1. Lunar mantle assembled largely from the silicate portion of a differentiated impactor (already stripped of HSE).
2. Segregation of the small lunar core stripped the silicate mantle of HSE.

Possible reasons for high HSE abundances in the lunar mantle:

3. Late veneer was added mostly before the formation of permanent crust.

1. And 2. new lunar max estimates are 40 x higher than estimated from 1 and 2.
2. If Os/Os chondritic suggested by dunite – little core participation.
3. Would expect more mass to accrete to the earth.

Earth 0.1 % of Earth's mass added to account for HSE abundance in upper mantle.
If homogeneous then .4% Earth's mass added to the earth.

Earth/Moon mass influx ratio is 35 suggests .8%moon mass added. Would create similar abundances to the Earth.
Earth/Moon influx ratio may have been much higher than 35.

HSE in the Earth may not be distributed homogeneously in the mantle.

Conclusions

- HSE in the lunar samples ~1/20 terrestrial mantle
- Lunar crust 10 ng/g Os
- Lunar mantle .15 ng/g Os

→ *75% HSE in crust*

This suggests late accretion post 4.4 Ga

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low HSE and high HSE/Pd → no metal
subchondritic Os/Os
Re/Os and relative abundances of the other HSE were not highly fractionated from chondritic in the mantle source of its parental melt