6.4.14

Re-Os isotope and PGE constraints on the timing and origin of gold mineralisation in the Witwatersrand basin

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Analyses of the Re-Os isotope system and PGE abundances have been used to constrain the timing and origin of mineralisation in the Vaal Reefs section of the Witwatersrand Basin, the world's largest gold deposit. Consistent interelement PGE fractionation in both organic and sulphide phases intimately associated with gold mineralisation suggests that the Re-Os isotope system was fractionated during gold deposition and has remained essentially undisturbed since mineralisation.

The Re-Os isotope data on organic separates intimately associated with the gold in this part of the basin indicate a preferred mineralisation age of 2.26±0.19 Ga (2σ), at least 300 Myr younger than the minimum age of sedimentation. The overlying Ventersdorp volcanics preserve a Re-Os isochron age of 2.43±0.21 Ga, ~250 Ma younger than their U-Pb zircon emplacement age. This is strongly indicative of substantial post-depositional noble metal mobility within large parts of the Witwatersrand Basin.

Re-Os model age calculations on Os-rich fractions suggest that noble metals were derived from a 3.0-3.1 Ga terrain of granite-greenstone affinities, significantly younger than the Barberton Greenstone Belt. These data support a hybrid model involving post-depositional mobilisation of ancient noble metals for the origin of mineralisation in this part of the Witwatersrand basin. This model is applicable to other areas of gold mineralisation in the basin that display similar textural characteristics and geochemistry.

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Gold: A Re-Os geochronometer?

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Re-Os systematics in gold could be an invaluable tool for determining the age and origin of ores and applying metallogenic constraints to tectonic processes and the earth's early history. Analyses to date suggest that initial $^{187}Os/^{188}Os$ ratios used for tracer studies may be obtained in some cases, but that gold by itself is unlikely to be a good chronometer.

We first tested methods by analyzing samples from gold wire from two different lots. Samples from both lots yield low Os (37 to 48 ppt) and consistent $^{187}Os/^{188}Os$ ratios (~0.16 and 0.26) in triplicate analyses. Cleaning the gold in hot HNO_3 or molten NaOH had no effect on the results. Concentrations are consistent with those reported by Kirk et al. [1] for two lots of gold powder (43-91 ppt). In all cases, in both labs, Re concentrations were below detection limits.

Preliminary analyses of late Archean gold samples from deposits in the Yilgarn craton (Australia) and Abitibi belt (Canada) give similar results. Because sample sizes were very small, Os concentrations were at or below blank levels, but constrained to <25 and <50 ppt, respectively. Again, Re concentrations were at blank levels. Analysis of gold from a 145 Ma epithermal vein yielded a surprising 2.3 ppb Os, but only 0.119 ppb Re (too low to change the initial $^{187}Os/^{188}Os$ ratio of 0.534 within uncertainty). Thus, some samples may have measurable Os for determination of initial $^{187}Os/^{188}Os$, but very low $^{187}Re/^{188}Os$ may preclude age determinations.

The announcement of a Re-Os isochron for Witwatersrand gold has fueled interest and sparked debate over use of Re-Os in gold for geochronology [2]. Os concentrations in five gold separates from a single hand sample from the Vaal Reef range from 4 to >4000 ppb, while Re concentrations range from 2.5 to 11.4 ppb [2]. Given the wildly varying Os concentrations in these separates and the near absence of Os in other samples analyzed by us and by Kirk et al. [1], it seems plausible that the Os resides in placer-derived Os-rich inclusions rather than in the gold itself. Similarly, Os concentrations in hand-picked "gold" from a mill concentrate range from 220 to 1400 ppb, an order of magnitude less than the Os concentrations reported for uncleaned concentrate [1]. This suggests micro-inclusions of an Os-rich mineral phase in the gold, undetected during hand-picking. Further study of Re-Os in native gold is warranted.

References

[1] Kirk, J. et al. (2001) *GCA* **65,** 2149-2159.
[2] Kirk, J. et al. (2002) *Science* **297**, 1856-1858.