

Rhenium-osmium isotopic systematics of an ancient laterite profile

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The objectives of this study were 1) to investigate the Re-Os isotopic systematics of a well-characterized laterite profile, including the unaltered bedrock, 2) to utilize the Re-Os isotopic data to address the issue of laterite genesis, and 3) to speculate on the extent to which Os derived from laterite soils may affect the Os budget of the oceans.

Approximately 80% of Os dissolved in the world oceans is derived from continental weathering, the rest being from hydrothermal alteration of oceanic crust and from dissolution of cosmic dust (Sharma *et al.*, 1997). At present, there is a large uncertainty in our understanding of the behaviour of Os during weathering and transport into deep oceans, which needs to be addressed to evaluate properly the marine Os isotopic record. Laterites cover more than one-third of the exposed continental surface with laterite-capped landforms occurring extensively in the humid tropical regions (30° N to 30° S). Outside the tropics, the laterite occurrences are thought to represent climate change and/or continental drift (e.g. Schwarz, 1997). Given that the tropics supply approximately 50% of the annual water input to the oceans, an understanding of the laterite genesis and evolution is important in evaluating the fluxes of elements from the continents into the oceans. In this study we are concerned with investigating the behaviour of Re and Os during tropical weathering of a granodiorite. Despite the potential of many laterites as sources of precious metals, high quality Re and Os concentration data on laterites are non-existent. We present Re-Os isotopic and concentration data on a laterite profile about 18 m deep developed on a Birrimian granodiorite in the Republic of Burkina Faso, West Africa. This profile is thought to have developed *in situ* in a tectonically stable and slowly eroding environment with possibly no relief inversion and no extensive lateral translocation of material. These observations make this profile especially suitable to study the vertical changes of elemental concentration, as a result of weathering.

Sample description

Re and Os concentrations and Os isotopic composition were determined on four bulk samples selected from well-characterized units of the laterite. Of the four samples taken from bottom of the profile to its top, the relatively unweathered bedrock granodiorite taken at 18 m, represents the reference material consisting mainly of feldspars, quartz and traces of hornblende. Most of these minerals disappear rapidly upwards: the amphiboles disappears within 1 m above the bedrock, the feldspars in the next 11 m and quartz in the upper 7 m. These minerals get replaced gradually by different types of clays and Fe-Al oxyhydroxides. Above the bedrock, a 'Pistachio Clay' sample taken at 15 m, contains a clay fraction made of 55% kaolinite, 35% smectite and 10% illite. The clay fraction of the 'Pink Clay' taken at 7 m, consists of 100% kaolinite with traces of smectite. The clay fraction of the indurated topsoil sample taken at 0.7 m, contains only kaolinite. Isovolumetric calculations for the major element composition for the bulk samples point to a systematic release of all elements from bottom to the top of the profile, except for the topsoil where Fe displays an inordinate increase and a small increase in Al₂O₃.

Results and discussion

The Re-Os isotopic and concentration data are given in Table 1. The results show an enormous increase in the Os isotopic concentration of the topsoil in comparison to the other horizons (about a factor of 75 over the Os content in the bedrock). Further, the ¹⁸⁷Re/¹⁸⁸Os ratio decreases upwards. But, there is no corresponding decrease in the ¹⁸⁷Os/¹⁸⁸Os ratio upwards indicating no simple control of ¹⁸⁷Re/¹⁸⁸Os on the ¹⁸⁷Os/¹⁸⁸Os ratio. Perhaps the most important observation is that, despite the old age of the bedrock, all samples and especially the topsoil do not yield highly radiogenic ¹⁸⁷Os/¹⁸⁸Os ratios.

TABLE 1. Re-Os concentration and isotopic data for the laterite profile

Sample	Sample wt. (g)	Re (pg/g)*	Os (pg/g)*	$^{187}\text{Re}/^{188}\text{Os}^*$	$^{187}\text{Os}/^{188}\text{Os}^\S$	$^{187}\text{Os}/^{188}\text{Os}^*$
Topsoil: 0.7 m	1.96	21.1	403	0.274	0.808	0.808
Pink Clay 7 m	3.33	6.73	6.43	6.140	1.790	1.813
Pistachio Clay 15m	3.11	14.2	2.71	29.86	1.542	1.588
Bedrock	1.25	94.8	5.38	107.1	2.125	2.229

* Blank corrected using the following values: Re = 10 picogram, Os = 417 femtogram and $^{187}\text{Os}/^{188}\text{Os} = 0.71$

§ Measured ratios. Typical uncertainty on the measured ratios is less than 1%.

From the data the following first order inferences may be drawn: 1) in contrast to Os, Re is mobile under oxidizing conditions and gets released during weathering; 2) the fact that the Pink Clay does not display Os enrichment suggests that the retention of Os in the duricrust is not related to kaolinization. Other factors such as precipitation of Fe-Mn-Al oxyhydroxides and interaction with organic acids may control Os enrichment in the topsoil; 3) depletion of Re and enrichment of Os in the topsoil may be an important feature of many lateritic soils developed in stable shield areas in the tropical belt. If true, this observation would indicate that on average the lateritic soils do not develop highly radiogenic $^{187}\text{Os}/^{188}\text{Os}$ ratios with time; 4) weathering and onset of Re leaching must have occurred very early.

If we assume that during the development of the soil profile: 1) there was no contribution from aerosols, which is possible as the topsoil is indurated, 2) Re loss occurred during the initial stages of weathering following which the system became closed for Re and Os, and 3) the bedrock has not lost any Re or Os subsequent to its formation, we can determine "model ages" of the three soil horizons by extrapolating their $^{187}\text{Os}/^{188}\text{Os}$ ratios back in time and projecting them on the evolving $^{187}\text{Os}/^{188}\text{Os}$ ratio of the bedrock:

This gives "model ages" of 812 Ma for the topsoil, 506 Ma for the Pistachio Clay and 251 Ma for Pink Clay. These ages are unreasonably high, suggesting that one or more of the above assumptions are not satisfied. Perhaps the simplest explanation for the high ages is that labile ^{187}Os was also removed in addition to Re during the weathering process (e.g. Peucker-Ehrenbrink and Blum, 1996). Another explanation is that the bedrock lost its Re before the onset of the weathering process while it was being exhumed.

If the data presented here can be generalized for

most soils, then it can be inferred that a relatively unradiogenic Os from the topsoils should control the isotopic composition of the dissolved load delivered currently (and for the last several million years) to the oceans. This is consistent with the direct measurements of the Os isotopic composition of some rivers (Sharma and Wasserburg, 1997). An additional pathway of delivering large amounts of Os from the continents to the oceans is through the dissolution of mineral aerosols in seawater. Clearly, the topsoils around the world are a major contributor to the mineral aerosols. An upper limit of Os contribution can be calculated from estimates of mineral aerosol flux to the oceans, assuming that the aerosols have the Os content of average continental crust. Taking a global aerosol flux of 9.1×10^{14} g/yr (Duce *et al.*, 1991) and Os content of 50 picogram/g (Esser and Turekian, 1993), we get 45500 g/yr of aerosol Os. The burial flux of continent derived Os is between 98000 g/yr to 430000 g/yr (see Sharma *et al.*, 1997). This suggests a 10 to 40% Os contribution from aerosols. The data presented here imply that the aerosols could potentially be a much more significant source of Os to the oceans than believed previously.

References

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