(^{234}U/^{238}U) disequilibria and Sr isotopic variations in a laterite: dating or tracing U mobility?

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Isotopic dating of laterites remains problematic and controversial. Comparison of the available data shows contradictory ages. The Rb-Sr, K-Ar and ^{40}Ar/^{39}Ar chronometers provide ages of several tens of millions years ([1], [2], [3]), while (^{234}U/^{238}U) disequilibria ([4], [5]) and ^{10}Be analyses ([6]) lead to recent ages. In fact, the different chronometers were not applied strictly to the same soil fractions (whole rock, clay fraction, pure mineral phase), which could partly explain the contradictory results. Actually, any analysed fraction may consist of inherited, altered and weathering mineral phases. This study was thought to analyse the same soil fractions with two different chronometers, the Rb-Sr and the (^{234}U/^{238}U) disequilibria methods. They were applied on < 0.2 μm fraction from the Goyoum laterite (Cameroon) consisting of three petrologic units : a saprolite at the base, a intermediate nodular zone, and a soft topsoil. The < 0.2 μm fraction was extracted from two profiles, it contains essentially kaolinite and Fe-oxyhydroxides. The Rb and Sr concentrations and the Sr and U isotope ratios were determined by thermo-ionisation mass spectrometry.

The data reveal complex and wide variations of the ^{87}Sr/^{86}Sr and ^{87}Rb/^{86}Sr ratios with depth, with different patterns in each profile. No isochron line can be drawn in an ^{87}Sr/^{86}Sr vs ^{87}Rb/^{86}Sr diagram. The data scatters in the mixing and in the isochron diagrams suggest a Sr isotopic heterogeneity which could represent either an initial Sr isotopic variability of the analysed fractions, or a secondary process disturbing a previously homogeneous system.

The (^{234}U/^{238}U) activity ratio varies from 0.85 to 1.20 in each profile (see Fig. 1). No correlation appears with the ^{87}Sr/^{86}Sr ratio. The variations of the (^{234}U/^{238}U) activity ratio with depth are similar in both profiles. An important disequilibrium is visible at the base of the saprolite with a (^{234}U/^{238}U) ratio significantly below unity. Above, the values tend progressively towards equilibrium. A second impor-

tant (^{234}U/^{238}U) disequilibrium occurs at the base of the nodular zone with values below and above unity. Like in the saprolite, the values tend towards equilibrium in the nodular zone. A third similar sequence could possibly exist in the topsoil.

The fact that the (^{234}U/^{238}U) variations are similar in both studied profiles inclines us to believe that these variations are characteristic of the whole lateritic profile. The lateritic formation would then contain two horizons of U fractionation with progressive return to secular equilibrium above them. The lower horizon at the base of the saprolite, shows an enrichment of ^{238}U which could result from leaching of the bedrock initially in secular equilibrium, inducing preferential loss of ^{234}U and crystallisation of residual minerals depleted in ^{234}U. The progressive trend to secular equilibrium suggests no further fractionation in the saprolite The intermediate horizon at the base of the nodular zone could record perturbation of the kaolinite + Fe-oxyhydroxides mixture that could be either a recrystallisation of the pre-existing minerals or an addition of one or several new mineral phases. The fact that (^{234}U/^{238}U) activity ratios are again below unity suggest another episode of mineral leaching with formation of ^{234}U-enriched fluids. However, migration of these fluids over only short distances could explain crystallisation of minerals enriched in ^{234}U. Return to the secular equilibrium of the mineral fractions suggests a confinement of the process in the transition zone. For each fractionation front, a migration rate of 6 to 8 m/Ma may be calculated.

The occurrence of (^{234}U/^{238}U) disequilibria in the Goyoum laterite emphasises that this laterite is presently affected by geochemical fractionations. The location of the fractionation zones at the lower parts of the petrographical units, allows to consider that the fractionation of U mirrors the pedological history of the laterite. It may also be considered that the
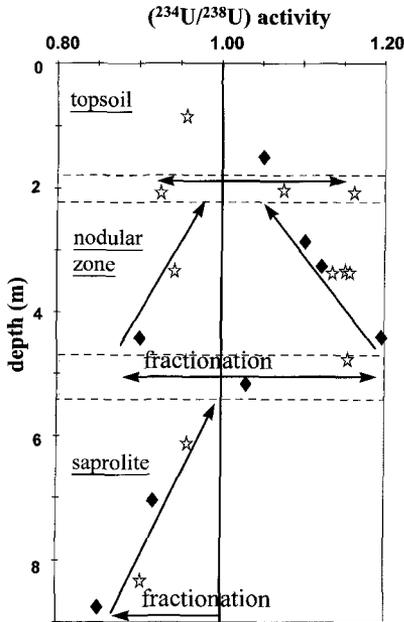
FIG. 1. $(^{234}U/^{238}U)$ activity ratio variations with depth. The symbols differentiate the two studied profiles.

FIG. 2. First results from the leaching experiments.

$(^{234}U/^{238}U)$ disequilibrium at the base of the saprolite records a present-day weathering of the bedrock with subsequent authigenesis of minerals depleted in ^{234}U. Fractionation at the lower part of the other units could then indicate reorganisation processes of the mineral fractions that have yet to be identified, in relation with the pedological evolution of the laterite. The use of the $(^{234}U/^{238}U)$ radioactive decay in each petrologic unit for datation purpose provides an age estimate for the whole profile which could be of about 1.5 Ma. This simple model based on the fact that each petrographical unit records a fractionation process located at its base and evolves as a closed system, implies that the $^{87}Sr/^{86}Sr$ ratios of the constitutive minerals of the analysed fractions were different at their formation time. A possible explanation for this is that the Sr isotope ratios may reflect the isotopic signatures of the precursor minerals from which the authigenic minerals formed. This interpretation is, however, not univocal : the whole U and Sr data could also be interpreted as resulting from a recent perturbation of an old lateritic formation. In this case, the samples and data would be representative of both old and recent events, which needs a finer separation of the constitutive mineral phases to distinguish them.

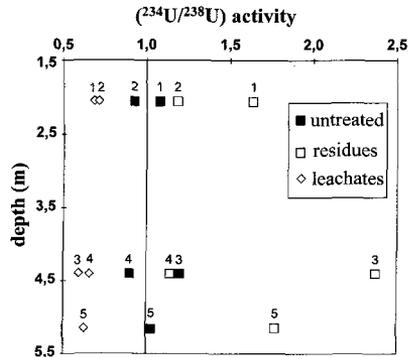In this respect, gentle leaching experiments with 1N HCl were performed on some < 0.2 µm fractions in order to remove part of the Fe-oxyhydroxides. The preliminary $(^{234}U/^{238}U)$ results show that the obtained leachates have $(^{234}U/^{238}U)$ activity ratios below unity and that the residues yield wide disequilibria variations above unity. The studied fractions consist therefore partly of ^{234}U-depleted mineral phases, and partly of more or less ^{234}U-enriched counterparts. Unlike to the data from the untreated < 0.2 µm fractions, no progressive trend towards equilibrium is observed to the data from leaching experiments. The $(^{234}U/^{238}U)$ disequilibria obtained reveal that recent U fractionations affect the mineral mixtures, whatever the position in the profiles. This outlines an apparent contradiction with the chronometric interpretation of the data using the untreated fraction. A possible resolution of this contradiction would be to consider that the recent U fractionations affecting the mineral phases, occurred at a submineralogical scale without disturbing the U system at the scale of the < 0.2 µm fractions. If this is true, the data from the < 0.2 µm fractions would provide dating information, while the leaching experiments would provide information about the U carriers and the fractionation processes.

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