Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Terre, 2012, n° 34, p. 41-43. *SHORT NOTE*

$^{13}C/^{12}C$ ratios of soil organic matter as indicators of vegetation changes in the Okondja basin (Gabon)

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$\delta^{13}C$ de la matière organique de sol comme indicateur de changements de végétation dans le bassin d'Okondja (Gabon).

Résumé étendu. Huit échantillons de matière organique ont été prélevés le long du profil pédologique Oss de 80 cm de profondeur, localisée dans le Sud du bassin d'Okondja[Fig. 1]. L'étude de ces échantillons (précédemment décarbonatés) par la méthode du carbone 13 associée à une ^{14}C datation obtenue par AMS montre des changements significatifs de la végétation qui s'organisent en deux principaux épisodes [Fig . 2]. Le premier épisode, antérieur à 2870 ans B.P., est caractérisé par des valeurs de $\delta^{13}C$ qui augmentent régulièrement de la base du profil à 2870 ans B.P. puisque ces valeurs passent respectivement de –6,9 à –24,07 ‰. Cette évolution correspond à une ouverture progressive de la végétation qui, initialement forestière, devient une mosaïque forêt-savane. La dynamique de la végétation ainsi observée est liée à la péjoration climatique que l'Afrique centrale atlantique a connue autour de 2500 ans B.P. Cette histoire de la végétation du bassin d'Okondja est globalement parallèle (si nous ne prenons pas en compte l'aspect chronologique) à celle du bassin voisin de Franceville [Fig. 2] qui se fait également en deux épisodes climatiquement identiques.

Mots clés: $\delta^{13}C$, matière organique, sols, végétation, Bassin d'Okondja, Gabon.

INTRODUCTION

For more than one decade, the ^{13}C carbon isotope in soil organic matter (SOM) has been used as an indicator of vegetation changes in the tropical ecosystems (Schwartz *et al*. 1986, Schwartz 1991, Mariotti & Balesdent 1990). Indeed, the ^{13}C is one of the three carbon isotopes, and contrary to ^{14}C, ^{13}C is a stable isotope as ^{12}C. These two isotopes are absorbed by plants according to their photosynthetic pathways. Thus, the forest plants using C3 photosynthesis (Calvin cycle) incorporate less ^{13}C than Graminae using C4 photosynthesis (Hatch-Slack cycle). This carbon isotope fractionation, noted $\delta^{13}C$ (expressed in ‰) that takes place in the plant chloropyll is transferred without considerable change into the SOM. The processes of humification and mineralization undergone by SOMs, induce very weak variations of $\delta^{13}C$ (Mariotti 1996). Thus, the SOM $\delta^{13}C$ of C3 plants (forest vegetation) varies from –28‰ to –26‰ while that of C4 plants (savanna vegetation) varies from –18‰ to –12‰. The intermediate values correspond to mixed vegetation of forest savanna mosaics that systematically characterizes vegetation changes. The replacement of a forest by a savanna, or the opposite case, can be therefore determined in tropical zones thanks to the $\delta^{13}C$ proxy.

In the present note, we expose the results of the study of the vegetation evolution in the Okondja Proterozoic basin from the carbon isotope abundance ratios of soil organic matter that derive from this basin. This study is age-constrained by to a ^{14}C dating.

SETTING

The Okondja basin is a Proterozoic sedimentary basin situated in the southeast of Gabon (Fig. 1), north of the Franceville basin (Webber 1968). Two types of vegetation are found in the Okondja basin: a forest vegetation exclusively in the north of the basin and a forest-savanna mosaic in the southern part. The forest vegetation is composed of various species such as *Maranthes gabunensis, Murianthus arboreus, Musanga cecropioides,…* In the forest-savanna mosaic, where the forest areas are wider than those of the savannas which are often reduced, one meets a specific vegetation of savanna including tree species (*Crossepteryx febrifuga, Nauclea latifolia, Hymenocardia acida*, etc), herbaceous species (*Hyparrhenia diplandra* and *Pobeguinea arrecta*, etc.) and a typically forest vegetation formed of Caesalpinioideae and Moraceae. These different vegetation types are maintained by a hot and humid equatorial climate characterized by two rainy seasons and two dry seasons with an annual rainfall about of 1800 mm, a temperature that varies from 22 to 32°C and a humidity rate of 85%.

Pedologically, the Okondja basin generally ferrallitic soils are the result of the rock weathering (sandstones, ampelites, jaspers etc.).

MATERIAL AND METHOD

This study deals with the organic matter of the pedogenic profile Oss. The profile was achieved under

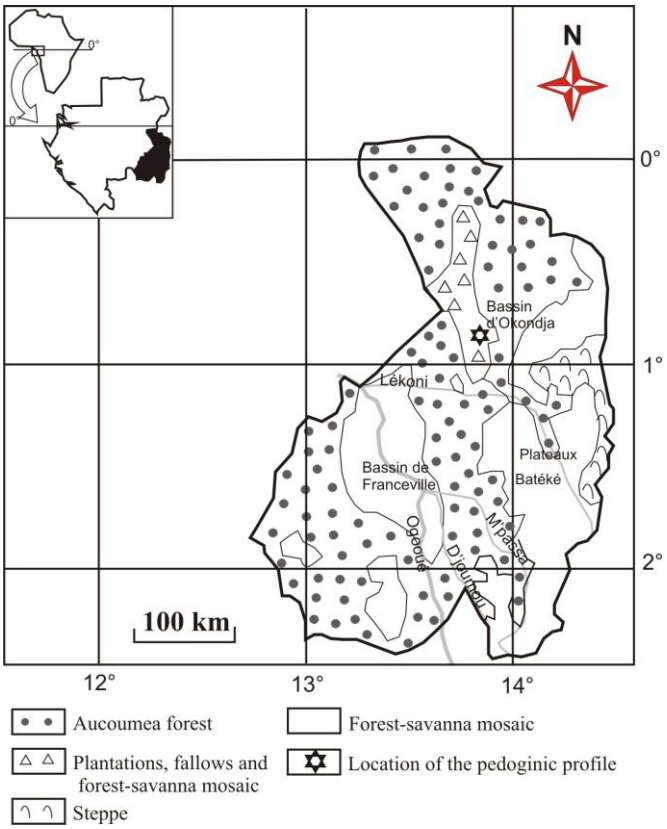

Figure 1: Vegetation map of Haut Ogooué region southeast of Gabon (from Caballé 1983) and location of the pedogenic profile.

forest using a mechanical auger in the south of the Okondja basin. This profile reaches 80 cm depth and its horizons have not been identified because the technic used did not allow it. Eight samples were taken each 10 cm.

The samples were initially decarbonated with diluted HCl in an agitated ultrasonic bath. Measurements were achieved in the ISEM Laboratory of the University of Montpellier using a mass spectrometer GILSON XL 222. The results are expressed in ‰ with respect to the N.B.S 19 standard (National Bureau of Standard 19), an international standard which has some stationary values with the P.D.B. It is delivered by International Atomic Energy Agency. The used method is the one of the $\delta^{13}C$. It permitted to measure the $^{13}C/^{12}C$ ratios of the total soil organic matter of eight samples taken.

RESULTS AND DISCUSSION

The $\delta^{13}C$ values of soil organic matter of the profile Oss associated to a ^{14}C dating are presented in figure 2. The evolution of this curve shows two distinct episodes.

The first episode is characterized by $\delta^{13}C$ values increasing from –26.9 at the profile base to –24.07 ‰ at the level dated at 2,870 yr B.P. This evolution shows a progressive opening of the landscape because $\delta^{13}C$ value (–26.9 ‰) at the profile bottom is typical of a forest vegetation and the one at 2870 yr B.P. is typical of a forest-savanna mosaic. This evolution is globally identical to the one observed in several sites (Cameroon, Gabon, Congo) of Atlantic Central Africa (Vincens *et al.* 2000, Makaya 2005). It is due to the climatic worsening that occurred in the region around 2,500 yr B.P (Maley 1992). However, our results show that in the south Okondja basin, the consequences of this climatic deterioration ended toward 2,870 yr B.P. This is not the case in other sites as Sinnda lake in Congo (Vincens *et al.* 1994) where they ended toward 600 yr B.P with a total savanisation of the site. The observed difference could be due to a difference in the precipitations on the two sites: 1,800 mm/yr in the Okondja basin and 1,100 mm/yr in the Sinnda lake.

The second episode, from the level dated at 2,870 yr BP to the profile top, shows $\delta^{13}C$ values that vary from –24,07 to –27,4 ‰ respectively. This $\delta^{13}C$ evolution corresponds to the progressive replacement of the previous mosaic forest-savanna by the present-day forest vegetation. This forest vegetation is colonizing the entire studied area because some arboreal savannas are now observed. The presence of these savannas would be due to the metallurgic activities that took place in the region 2,350 – 1,850 years B.P. (Digombé *et al.* 1985). Indeed, these activities require important quantity of wood for the reduction of iron, resulting in the destruction of thousands of trees. Therefore, these savannas show that the forest renewal in the second episode seems to have been interrupted by human metal lurgic type activities, in spite of the climatic humidification

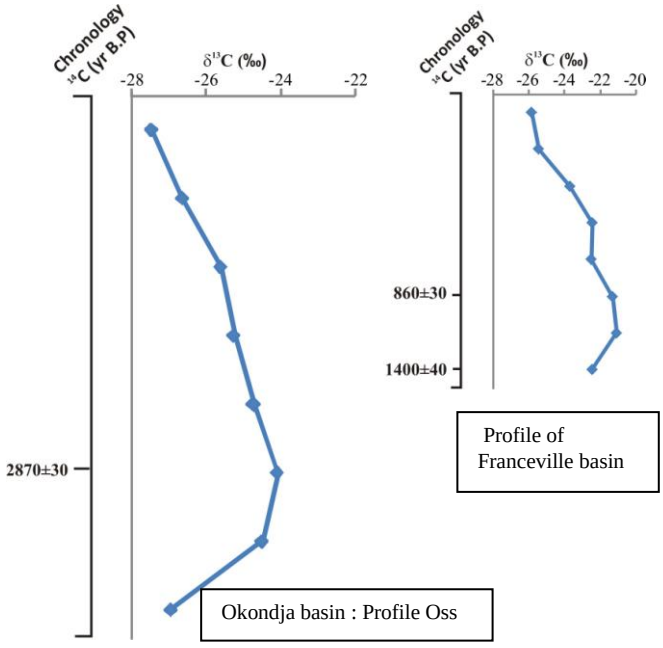

Figure 2. Vertical evolution of the $\delta^{13}C$ values of soils organic matter associated with ^{14}C dating (conventional age) along the pedogenic profile Oss (left), compared to those of the Franceville basin (right) taken from Makaya *et al.* (2012).

that characterized all the Atlantic Central Africa after the dry phase.

This vegetation evolution is also globally parallel to that of the Franceville basin (Makaya *et al.* 2012) as shown in figure 2. The evolution of the vegetation in the two sites (distant at about 100 km) took place in two episodes. The first episode corresponds to a climatic deterioration (a weakly humid phase) that resulted in the transition of a strongly arboreal mosaic forest-savanna toward a less arboreal mosaic forest-savanna. The second episode, controlled by a more humid phase, results in a progressive densification of vegetation that is more marked in the South of Okondja basin than in Franceville basin.

Chronologically, these vegetation evolutions reveal a diachrony concerning the end of the climatic deterioration in the two sites (2,870±30 years B.P in the Okondja basin and 860±30 years B.P in the Franceville basin) as in all other Central Africa sites. This diachrony is due to the climatic and edaphic conditions at each site (Makaya, 2005, Giresse et *al.* 2009) that influence the forest dynamics when the conditions become more humid.

CONCLUSION

The study of $\delta^{13}C$ soil organic matter of Oss profile in the south of Okondja basin indicates that the vegetation history in this part of Gabon took place in two main episodes. The first episode, previous to 2,870 yr B.P., corresponds to a progressive opening of vegetation, initially forest that becomes a forest-savanna mosaic. This vegetation degradation is related to the climatic deterioration that occurred in the region around 2,500 yr B.P. (Maley 1992). The second episode, from the level at 2,870 yr BP to the profile top shows a forest renewal following a climatic humidification that succeeded to the climatic deterioration. The current existence of savannas seems to indicate that this forest renewal has been interrupted by the metallurgic activities in the southeast of Gabon between 2,350 and 1,850 yr B.P.

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