Discovery of dinosaur footprints in the Stanley Pool Formation of Gabon

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ABSTRACT
Stanley Pool is a Cretaceous continental formation which outcrops Southeast of Gabon to Congo. The current investigations performed in this continental formation in Gabon just revealed seven dinosaur footprints on pieces of argillites flags. The analysis of these more or less well preserved footprints highlights three morphotypes. Morphotype 1 comprises footprints 1, 2, 3 and 4 of the same shape but of different sizes. These footprints belong to tridactylous dinosaurs. Morphotype 2 comprises footprints 5 and 6 whose shape is oval. They would correspond to sauropods. Finally morphotype 3 only represented by the footprint 7 consists of four fingers. This well-preserved footprint would belong to a tetradactylous dinosaur. This major discovery is the first record of dinosaurs in Gabon. It strengthens the knowledge of dinosaurs palaeoichnology in Africa.

KEY WORDS
Footprints, morphotype, dinosaur, Cretaceous, Stanley Pool, Gabon.

RÉSUMÉ
Découverte d'empreintes de dinosaures dans la Formation Stanley Pool, au Gabon.
Le Stanley Pool est une formation continentale crétacée qui affleure du sud-est du Gabon jusqu'au Congo. Les recherches en cours au sein de cette formation continentale viennent de révéler au Gabon sept empreintes de dinosaures présentes sur des morceaux de dalles d'argilites. L'analyse de ces empreintes plus ou moins bien conservées met évidence trois morphotypes. Le morphotype 1 regroupe les empreintes 1, 2, 3 et 4, de forme identique mais de tailles différentes. Ces empreintes appartiennent à des dinosaures tridactyles. Le morphotype 2 est représenté par les empreintes 5 et 6 dont la forme est ovale. Ces empreintes correspondraient aux sauropodes. Enfin, le morphotype 3, représenté seulement par l'empreinte 7, est constitué de quatre doigts. Cette empreinte très bien conservée appartiendrait à un dinosaure tétradactyle. Cette découverte majeure constitue le premier signalement de dinosaures au Gabon. Elle vient renforcer les connaissances de la paléoichnologie des dinosaures en Afrique.

MOTS CLÉS
Empreintes, morphotypes, dinosaures, Crétacé, Stanley Pool, Gabon.

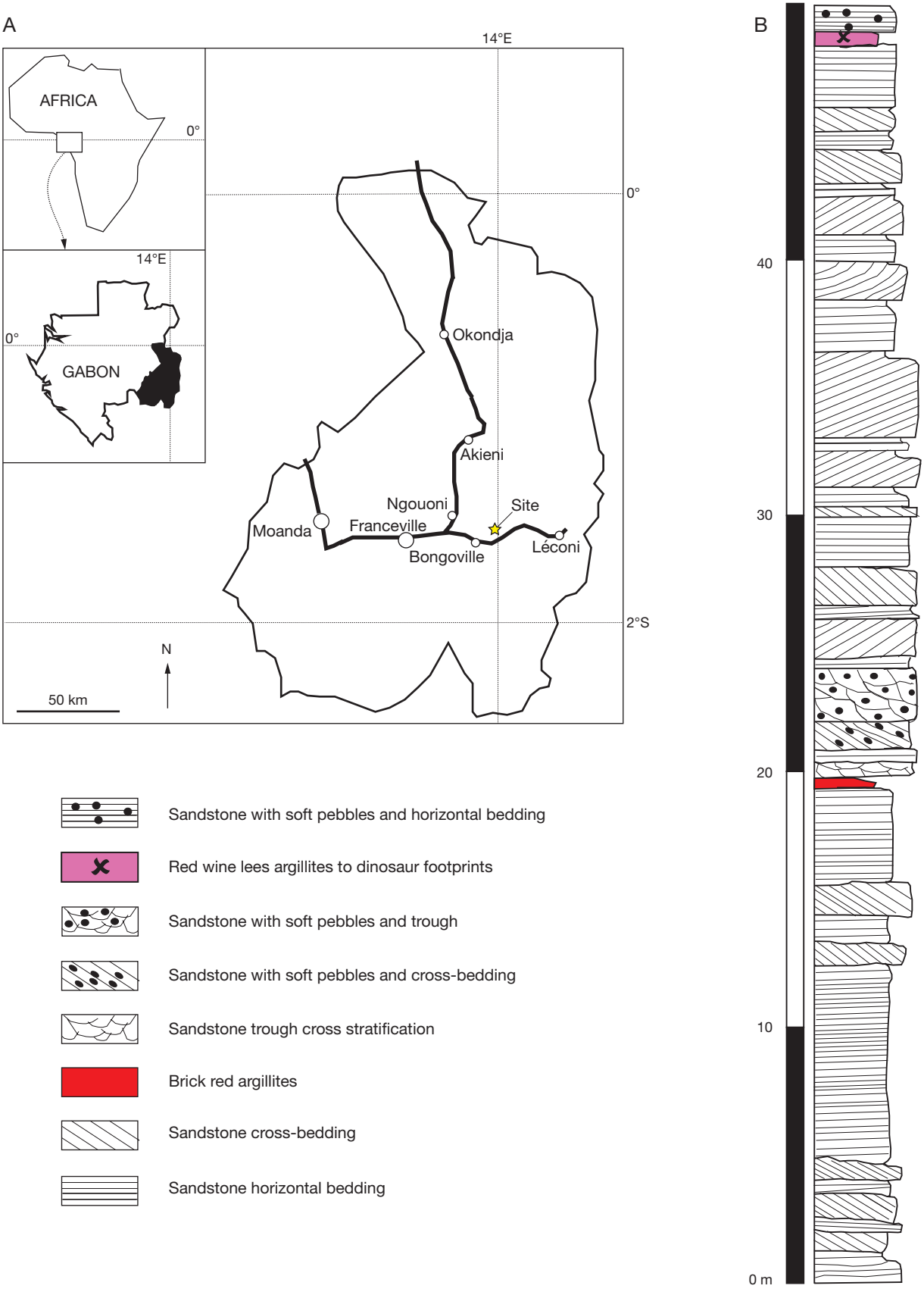

Fig. 1. — Location of the site (Stanley Pool Formation, Gabon): **A**, footprints; **B**, geological section corresponding to the studied outcrop.

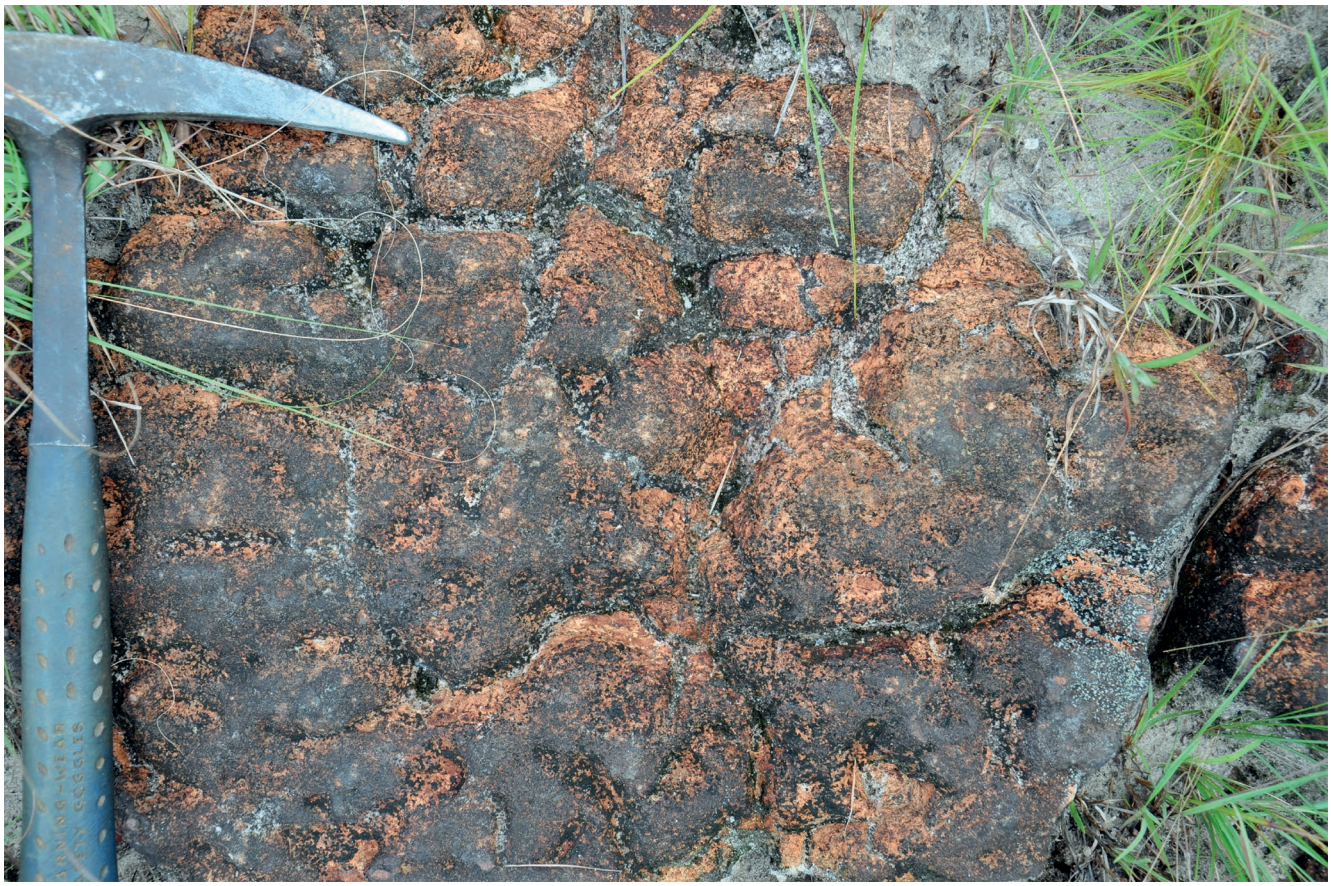

Fig. 2. — Mud cracks from the Stanley Pool Formation (Gabon) attesting of arid climate.

INTRODUCTION

The african palaeoichnology is well known thanks to the dinosaur footprints discoveries made in the Maghreb (Mahboubi *et al.* 2007; Bessedik *et al.* 2008; Gierlinski *et al.* 2009) and in Southern Africa (Ellenberger *et al.* 1970). It has been almost non-existent in central Africa where only dinosaur footprints were found in Cameroon (Jacobs *et al.* 1996).

The dinosaur footprints that we present in this article were discovered in 2015 during a fieldtrip in the Stanley Pool, cretaceous formation which outcrops in southeastern Gabon. Four footprints were discovered during this fieldtrip. The excavation schedule set up enabled us to discover three others footprints. Thus, currently seven footprints were found on pieces of red argillites belonging to two different stratigraphic levels. The current excavations give further hope to find new footprints and tracks eventually. This discovery will therefore help to expand knowledges on the palaeoichnology of Central Africa.

The purpose of this work is to describe and identify in the morphotype point of view the seven footprints discovered in southeastern Gabon.

GEOLOGICAL SETTING

Stanley Pool is a cretaceous continental formation which outcrops in the eastern basin of Gabon (Weber 1968). It extends to the Congo where he has been particularly well studied (Cosson 1955; Giresse 1982, 1990). In Gabon, the Stanley Pool rests with strong unconformably on the formations of Francevillien or on the archaean basement (Chevallier *et al.* 2002). But it still remains relatively unknown despite numerous studies (Donnot & Weber 1968-1969; Makaya *et al.* 2013). By analogy to the Stanley Pool defined in Congo (Donnot & Weber 1968-1969), three members of this formation have been described in Gabon:

– a basal conglomerate containing sandstone, quartzite and jasper pebbles up to 20 cm. This member is overlain by fine-grained sandstone of various colours (red, maroon, purple, etc.);
– a middle member which is composed of a chaotic deposit made up of large blocks of white to yellow, hard and compact chalcedonous quartzitic sandstone with vugs filled by kaolinite;
– an upper member of white fine-grained sandstone rich in kaolinite.

MATERIAL AND METHODS

These seven footprints found on flags of argillites are from the dismantling of the section shown in Figure 1B. These flags are so scattered that footprints do not form obvious tracks like in some african (Bessedik *et al.* 2008; Haddoumi *et al.* 2010); french (Bernier *et al.* 1984; Mazin *et al.* 1997) or brazilian (Carvalho 2000; Da Silva *et al.* 2007) sites.

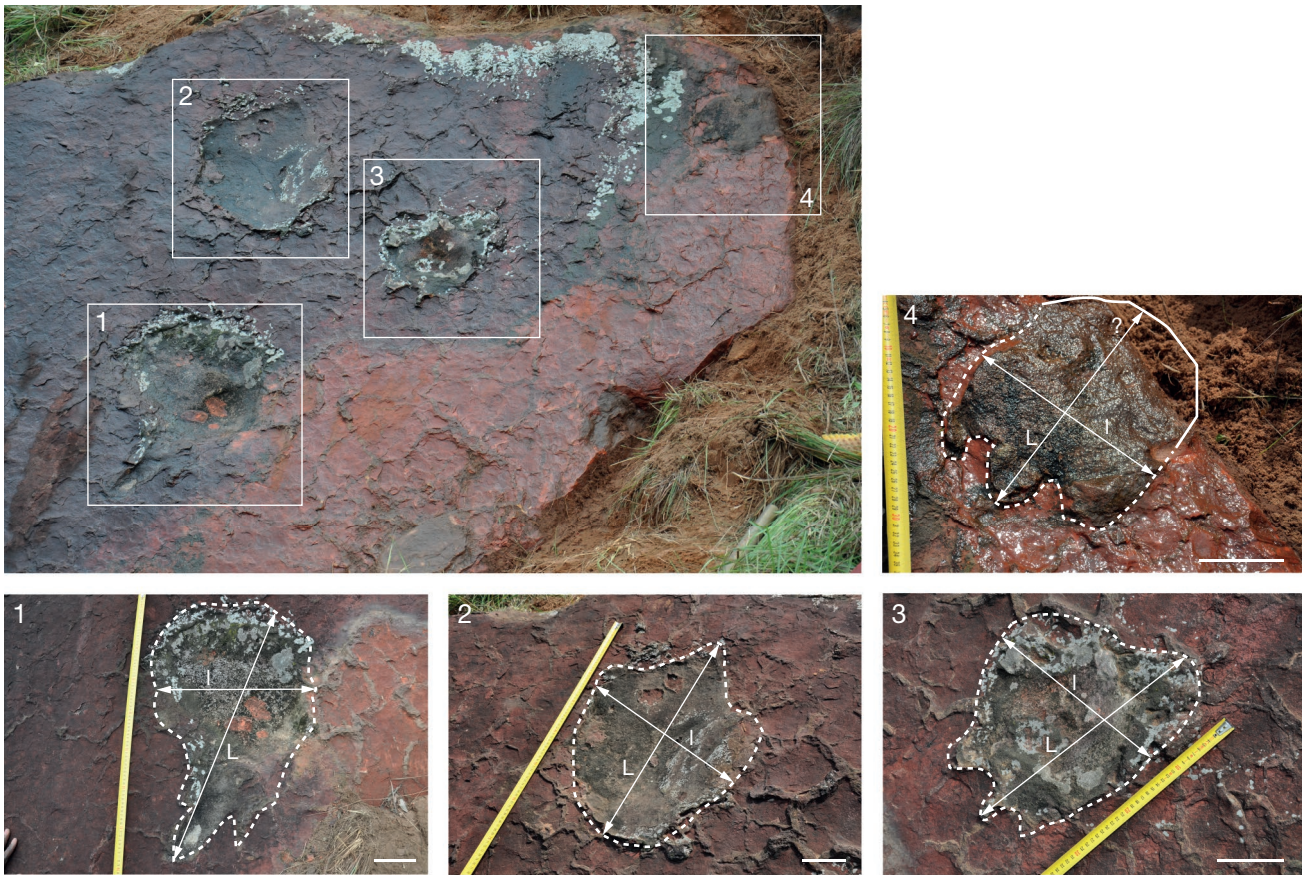

Fig. 3. — Dinosaur footprints (nos 1 to 4, morphotype 1) on piece of red argillites (Stanley Pool Formation, Gabon). Scale bars: 10 cm.

Table 1. — Measurements of the length (**L**) and width (**l**) of footprints. Abbreviation: **M**, morphotype.

	Morph. 1				Morph. 2		M 3
Empreintes	1	2	3	4	5	6	7
L (cm)	80	67.5	38.75	?	?	42.78	20
l (cm)	47.5	50	28.75	25	48	39.65	16.8

The section that revealed the seven footprints is located in south-east of Gabon precisely 15 km after Bongoville going towards Léconi, in the Plateaux department (Fig.1A). This section is composed mainly of sandstone and argillite facies (Fig. 1B). The sandstone facies is characterized by horizontal bedding, cross-bedding and trough cross stratification that reflect a fluvial or river-lake continental deposit. However, the argillite facies contains mud cracks (Fig. 2) attesting to the immersion of the deposit. Bioturbations are also observed. On the section, this fine facies is represented by two layers of very low thicknesses and varying colors. The first layer of bricks is red and is between 17 and 20 meters of depth while the second one is red wine lees and is between 46 and 50 meters of depth (Fig. 1B). The seven footprints were found on the two argillite layers. In the sandstone beds located immediately above argillites the red bricks, there are soft pebbles attesting of the reworking of these argillites. This section, never described before, corresponds to the upper member of the Stanley Pool Formation.

The study of the seven footprints is based on the description of their shape and size. Measurements of the greatest length and width of these footprints was made directly in the field using a meter. Photographs were also taken to clearly illustrate the footprints.

RESULTS

The footprints found are illustrated in Figures 3, 4 and 5. The measurements (length: L and width: l) performed on these footprints are summarized in Table 1.

Footprints description

On the Figure 3, there are four remarkable footprints thanks to their expulsion beads despite their poor conservation. The footprint 1 is hallow and has a length of 69.47 cm and a width of 42.10 cm. Its back is quite round, proving that it perfectly touched the flag. In contrast, the front part of this footprint is narrower than the back and is composed of three fingers. The median finger is well preserved and is longer than the two others. The footprint 2 forms a millimeter depression like the footprint 1. The length and width are respectively 67.5 and 52.5 cm. It is rounded in its back part while the front also

Fig. 4. — Dinosaur footprints (nos 5 and 6, morphotype 2) on piece of red argillites (Stanley Pool Formation, Gabon). Scale bar: 10 cm.

contains three fingers. While both fingers at the extremities are barely recognizable, the remarkable median finger is relatively sharp. Unlike the two first footprints, the footprint 3 is quite prominent and more or less rounded in the back. The front part consists of three fingers of roughly equivalent length. The length of this footprint 3 is 40 cm while the width is 30 cm. The footprint 4 forms a small dome like the footprint 3. Within the break of the flag, the back part of footprint 4 seemed rounded though difficult to describe. For this reason, the length of the footprint was not measured. However, its width is 27 cm. The front part of this footprint also includes three fingers, but of almost the same length.

Figure 4 includes footprints 5 and 6 which are clearly better preserved than the footprints 1, 2, 3 and 4 because of their clear dynamic structures. The footprint 5 although within the flags break forms a one-centimeter depression. Its shape is difficult to determine because it is only partially fossilized. However, the width, only measured dimension done 48 cm. The footprint 6 also forms a one centimeter deep depression. The latter footprint has an oval shape has 42.8 cm of long and 39.6 cm of wide. It contains no finger.

Finally, the Figure 5 reveals the footprint 7 which is well preserved. This footprint shows a clearly visible dynamic structure. It contains in its front part four fingers. The back part is very narrow and rounded. The length and width of this footprint 7 are respectively 20 and 16.8 cm.

DISCUSSION AND CONCLUSIONS

Knowing that the seven footprints have been found in the Stanley Pool which is a cretaceous formation, we may think that these ichnofacies belong to dinosaurs. The poor conservation of these footprints allows to make a morphotypic identification only. So there are three morphotypes:

– the morphotype 1 which includes the footprints 1, 2, 3 and 4 whose back part is rounded and the front composed of three fingers. These footprints could be those of tridactylous dinosaurs. The measurements made on the four prints give a length and a width respectively between 38.75 and 80 cm and between 25 and 50 cm. These values are apparent because they were obtained from visible outlines of the expulsion beads and not dynamic structures that give the real dimensions of footprints. In addition, these outlines of the expulsion beads have been altered by their permanent subaerial exposure;

– the morphotype 2 is represented by the footprints 5 and 6 that have an oval shape and no finger. These footprints would belong to sauropods. The length of 42.78 cm and the width of 39.65 cm appeared to be real values from footprint 6. Indeed, the footprint 6 contains a depression that clearly corresponds to a well-preserved dynamic structure;

– the morphotype 3 corresponds to the footprint 7 which is characterized by four fingers. As the footprint 6, the length and width were respectively 20 and 16.8 cm providing real

Fig. 5. — Dinosaur footprint (no. 7, morphotype 3) on piece of red argillites (Stanley Pool Formation, Gabon). Scale bar: 4 cm.

values because of the well preserved footprint 7 dynamic structure. This footprint would be a tetradactylous dinosaur.

In a paleoenvironment point of view, the presence of footprints associated with mud cracks indicates that the climate of the time was hot. Indeed mud cracks are present in most dinosaur footprints sites (Carvalho 2004).

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