# Reply to the comment by Dominique Schwartz on the paper "Geochronological arguments for a close relationship between surficial formation profiles and environmental crisis (c. 3000–2000BP) in Gabon (Central Africa)"

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Reply

# Reply to the comment by Dominique Schwartz on the paper "Geochronological arguments for a close relationship between surficial formation profiles and environmental crisis (c. 3000–2000 BP) in Gabon (Central Africa)", by D. Thiéblemont et al., 2013 [C.R. Geoscience 345, 272–283]

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Our paper and another by Thiéblemont (2013) detail the arguments that led us to propose an aeolian origin as being the most probable for the Cover Horizon.

This interpretation is denied by D. Schwartz, but he and us (as well as most authors) agree on two key-points of the profiles of surficial formations in western central Africa:

- the Cover Horizon is an almost continuous unit blanketing the landscape;
- this unit is generally superimposed on a more or less polygenic coarse-grained unit (stone line) carrying a frequent lithic industry.

This organization may be explained in three different ways (Vogt and Vincent, 1966):

- the stone line has sunk into the Cover Horizon;
- the Cover Horizon came from above and was deposited over the stone line;
- the Cover Horizon came from below and was spread over the stone line.

This latter solution is the one put forward by the many "authors highlighting the role of bioturbation as a major process of soil dynamics" cited by D. Schwartz (including Schwartz, 1996), the second being the one we favor.

As noted by Schwartz (1996), the occurrence of a lithic industry within the Stone line is a key-point for the origin of this unit and that of the overlying Cover Horizon. Schwartz (1996) argued that this industry could be of Sangoan age, which corresponds to an age of c. 70,000 to 40,000 years. This indicates an age younger than 40,000 years for the Cover Horizon. Thus, 40,000 years is the larger time-interval that we can assume for the formation of the Cover Horizon. In this time-interval, the "biogenic" model (*e.g.*, Schwartz, 1996) postulates that:

- all the matter was transported by termites from the altered rocks-basement to the surface through the Stone line;
- this matter was spread by colluvial processes over the landscape;
- this colluvium was converted into a homogeneous 1- to 2-m-thick layer covering the landscape.

As the Cover Horizon is commonly observed as lying directly on an unaltered basement (see Fig. 3 in

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Thiéblemont, 2013 or p. 11 in Vogt and Vincent, 1966), sometimes at a regional scale, it must also be postulated that the colluvial process would have been so intense that the material accumulated by termites could have been transported far away from its source.

D. Schwartz mentions the work of Vogt and Vincent (1966) (note that these authors provided strong arguments against the above "biologenic" model) who reported the existence of a strong analogy of mineralogical compositions between the Cover Horizon and the underlying altered basement in some (not all) places where the two units were observed on a single outcrop. Thiéblemont (2013) and Thiéblemont et al. (2012) have demonstrated that the trace element and Nd-isotopic signatures of the fine-grained fraction of the Cover Horizon are almost constant, irrespective of the geological basement on which the Cover Horizon rests.

In our opinion, too many counterexamples exist against the hypothesis of a biological origin of the Cover Horizon. This leads us to envisage and evaluate an alternative model, and as mentioned above, deposition of particles brought by wind appears to us as the most likely.

D. Schwartz presents his own set of counterexamples to this hypothesis.

## 1. Lack of aeolian dune structures

Away from the recent sandy formations of the eastern (Batéké sands) and western (Cirques series) parts of Gabon, the Cover Horizon is mainly composed of clay and silt. This makes it similar to a loess that is a type of aeolian deposit with no associated dune structures. Possible dune structures are however observed in the southwestern part of Gabon, where the Cover Horizon passes to a 10- to 30-m-thick sandy-clayey material. The radar image (SRTM survey) of these structures is reported in the explanatory note of the third edition of the Geological map of Gabon at a scale of 1:1,000,000 (zone D on Fig. 52, p. 235) (Thiéblemont et al., 2009; Thiéblemont, 2009).

## 2. Lack of typical impacts on sand particles

The only work on this topic is from Giresse and Le Ribault (1981), who studied two samples collected in the surface cover close to the Atlantic in SW-Congo. The authors concluded that the material was deposited by aeolian processes during the Holocene, but they noted that because of its fast duration this aeolian event did not produce impact structures on quartz grains.

## 3. Lack of lacustrine silt deposits

As far as Gabon (Giresse et al., 2009) and Congo (Vincens et al., 1998) are concerned, the most recent sections (upper 2 m with ages of less than 2500 BP) of cores collected in lakes sediment are described as organic-rich "muds" or "clays" with a large predominance of fine-grained particles ($< 50\ \mu m$).

## 4. Poor–sorting of the Cover Horizon

No data or reference is provided by D. Schwartz in support to the assumption that the Cover Horizon would be poorly sorted. From our own data, this is especially untrue for the western parts of Gabon and Congo, where the Cover Horizon overlying the Cirques Series shows the sigmoid-shaped cumulative curve frequently considered as typical of aeolian deposits. It is worth noting that the exoscopic study of Giresse and Le Ribault (1981) mentioned earlier was performed on samples collected in western Congo. Nevertheless, recent studies on aeolian sediment (see Muhs, 2013 for a synthesis) no longer consider sorting as a necessary and sufficient condition to state the aeolian origin of sediment. Most aeolian materials are in fact a combination of different grain-size fractions of more or less distal/proximal origin (McTainsh et al., 1997; Yvard, 1968). Well-documented examples of unsorted aeolian sediments in Africa are provided by Brunotte and Sander (2000) and Brunotte et al. (2009) in the Kaokoland of northern Namibia.

## 5. Archeological constraints

As mentioned above, the stone line displays an abundant lithic industry of old-stone to middle-stone age and different new sites were indeed recovered during our geological mapping in Gabon (Thiéblemont et al., 2009). As mentioned by Locko (1991), in Gabon the artifacts appear as dispersed elements within the stone line. D. Schwartz mentions sites where "it was sometimes possible to recognize structures such as knapping sites, which demonstrate that the artifacts are strictly in position and that the soil profiles were not disturbed since burial." From the references given by the author, the mentioned site should be the Mokeko site, located near Ouesso in the Sangha region of Congo. In this site, Lanfranchi and Schwartz (1990) first described the artifacts as being "perfectly in place at the top of stone lines" but later, Lanfranchi (1991) considered that the site had been reworked, "as most the sites of old-stone to middle-stone ages (MSA) reported in central Africa". This is a good indication that the emplacement of the Cover Horizon took place after c. 12,000 BP, which is the age postulated for the end of the MSA in Gabon (Locko, 1991). We may thus conclude that the about 2 m of sandy to clayey materials forming the Cover Horizon was accumulated in less than 12,000 years. A detailed discussion of the geochronological constraints related to the timing of the deposit of the Cover Horizon is included in our paper.

## 6. $\delta^{13}C$ constraints

D. Schwartz argues that the progressive change of the $\delta^{13}C$ of SOM with depth in savannah soils should be incompatible with the emplacement of this soil by aeolian sedimentation, because such a process would result from distinct episodes. A striking feature of the Cover Horizon is its vertical homogeneity. This characteristic being common to many aeolian deposits and especially loess, thus we see no contradiction between the continuity of the $\delta^{13}C$ variation (whatever its cause) and the aeolian hypothesis.

The hypothesis of an aeolian origin of the Cover Horizon is not strictly new (see ref. in Vogt and Vincent, 1966), but was apparently considered as ''unreasonable'' in the second part of the 20th century. This hypothesis is now founded on a large set of new analytical data, as well as on classical field observations. As noted earlier, a large agreement exists amongst scientists on the organization of the profiles of surficial formation in western central Africa. New analyses provide strong arguments for their largely allochthonous nature and abundant geochronological data clearly demonstrate that their formation (and especially that of the Cover Horizon) was a very fast process. These are two key-points that have to be taken into account by any future research.

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