

Contribution to the study of the “Terre de barre” of the coastal sedimentary basin of Togo (West Africa): chronostratigraphical and paleoclimatic implications

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Abstract

The emerged part of West African coastal basins is covered by a reddish continental formation generally called “Terre de barre”. In the coastal basin of Togo, this formation rests unconformable on the Mio-Pliocene deposits belonging to the Continental terminal *sensu stricto*. The age of the “Terre de barre” formation, often imprecise, is due to the difficulties involved in the investigation of continental sediments that are usually poorly fossiliferous and highly weathered. The discovery of pottery shards in the “Terre de barre” of this basin, makes it possible to date for the first time this formation in Togo. This study provides new stratigraphical, paleontological and paleoclimatic results that allow a better delimitation of the Neogene-Quaternary boundary in this basin.

Keywords: Coastal basin, Togo, “Terre de barre”, Prehistoric objects, Quaternary, Neogene-Quaternary boundary, Paleoclimates.

INTRODUCTION

The sedimentary cover of west-African basins highlights a Cretaceous to Tertiary marine series overlain by a post-Eocene, azoic, continental deposits called Continental terminal (Kilian, 1931; Lang et al., 1982, 1990; Yotoutouroufey, 1990). In southern Togo, the continental deposits outcrop on the Pan African metamorphic basement, and in the coastal basin where it overlies upper Cretaceous to Miocene marine series (Sylvain et al., 1986; Johnson, 1986; Johnson et al., 2000; Da Costa 2005; Da Costa et al., 2009) (Figure 1).

Recent works (Da Costa et al., 2006, 2011, 2012) done in the basin (Kpogamé quarry) has allowed subdividing the continental deposits into two units separated by an unconformable paleosurface considered as the Neogene-Quaternary boundary. The coarse grained lower unit, called Kpogame pebble bearing Formation (or Continental terminal *sensu stricto*) is of Mio-Pliocene age. The upper unit is a formation composed of fine and highly altered facies generally called “Terre de barre”. The advanced state of weathering and the azoic nature of the “Terre de barre” formation make it difficult to precisely date. Nevertheless, in the absence of accurate dating, former authors attribute this formation to the Quaternary because it rests unconformable on a terminal Pliocene paleosurface.

The aim of this study is to specify the age of the “Terre barre” formation based on lithological, petrographical, microscopic and paleontological data of two sections located respectively in the Tsévié quarry (north-east of the basin) and Kamina quarry (basement area) at 150 km from the North of Tsevié (Figure 2).

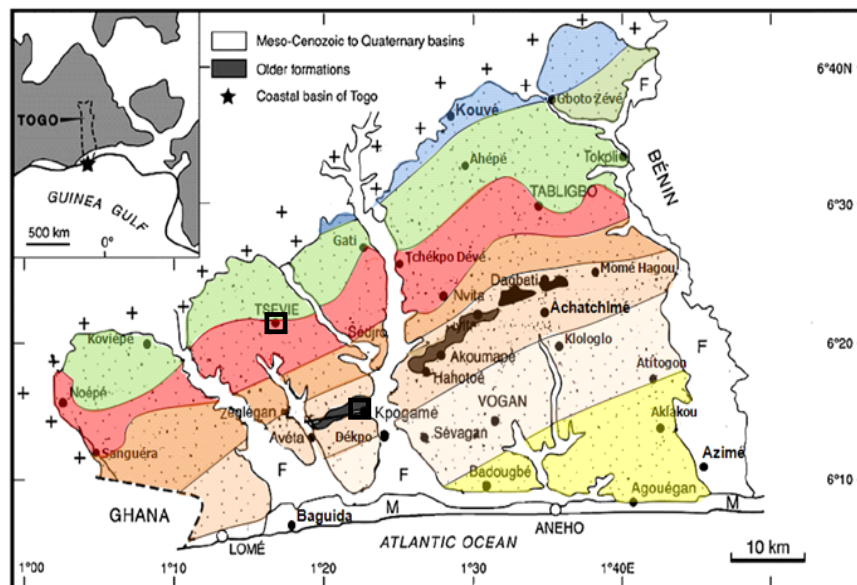


Figure 1. Simplified geological map of the Togolese coastal basin (Monciardini *et al.*, 1986, adapted). 1- Pan African basement; 2 – Continental terminal deposits (Terre de barre); 3 – Campanian/Maastrichtian; 4– Paleocene; 5- Lower Eocene; 6 – Middle Eocene (Lutetian) 7 – Middle Eocene (Bartonian); 8 – Oligo-Miocene; 9 – Fluvio-lacustrine deposits; 10 – Lagoonal to marine deposits; 11 – Hahotoé-Kpogamé phosphatic complex; 12 – Uncertain border. Investigated quarry.

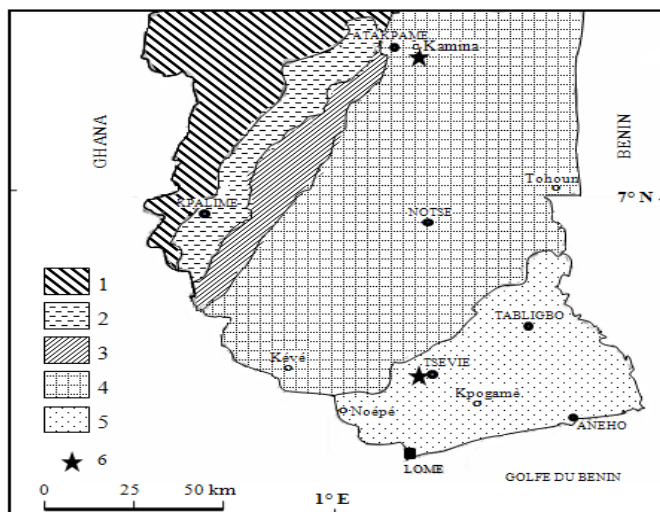


Figure 2. Location of investigated area. 1 - Structural unit of Atacora ; 2 – Kpalimé-Amlamé complex ; 3 – Ultrabasic to basic complex ; 4 – Pan African basement; 5 – Coastal sedimentary basin ; 6 – Investigated quarry.

Lithological and paleontological studies

Section of the Tsévié quarry

The section studied at the Tsévié quarry is a three(3) meter thick clayey sand series resting unconformably on the Pan African basement(Figures 3, 4). It shows prominent pedogenetic characteristics and is composed of two lithologic sets separated by an erosional unconformity.

The lower set is composed of reddish clayey sands; it is an approximately 2 meter thick layer rich in heterometric, mostly rounded quartz pebbles. It is unconformable on ferruginized, azoic conglomeratic sandstones (about 0.3 m). This

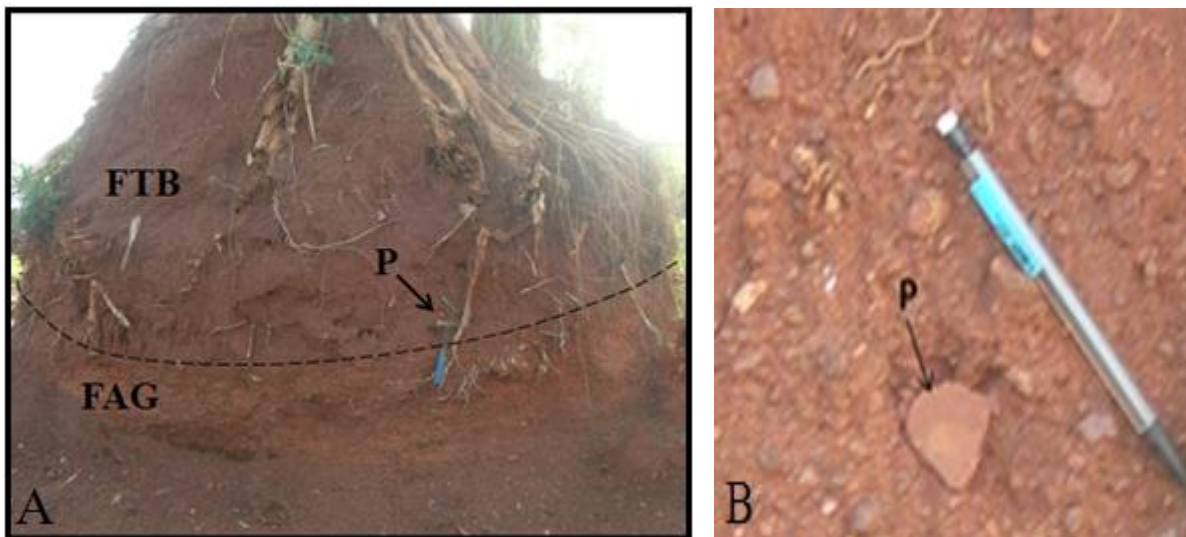
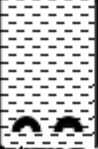




Figure 3. **A:** The view of the “sandy-argillaceous complex of Continental terminal in Tsévié quarry. FAG: Pebble Formation (or Continental terminal *sensu stricto*); FTB : Formation of the “Terre de barre”. **B:** Detail of the previous view showing the shard (P) of pottery fragment (prehistoric tools). --- Erosional unconformity

STRATIGR	FORMAT	LITHOLOGY	
QUATERNARY	“ TERRE DE BARRE”		Reddish clayey to silty sand bearing prehistoric objects
MIO -PLIOCENE	CONTINENTAL TERMINAL <i>SENSU STRICTO</i>	 DR	Reddish clayey sand with pebble of quartz
CAMP /MAASTR ?			Conglomeratic sandstone with pebble of quartz
PANAFRICAN	BASEMENT	+++	

0,50 m

Figure 4. Lithological section in the Tsévié quarry.

facies presents the same petrographic characteristics as the Kpogamé pebble bearing formation (Figures 10, 12) described in boreholes and at the Kpogamé quarry (Da Costa et al., 2006). The upper set lies on an erosional unconformity; it composed of reddish silty-clayey sands (about 1 m thick) bearing at its base pieces of broken decorated pottery (Figure 5).

The Kamina quarry section

The outcrop at the Kamina site also presents two unconformable lithological groups (Figures 6 and 7). The lower group is made of 1.5 m thick of an ochre to reddish lateritic crust rich in quartz pebbles of different shapes and sizes (millimetric to decimetric). This group reposes on basement rocks composed of altered metadiorites. The upper group in



Figure 5. Prehistoric objects discovered in Tsévié quarry

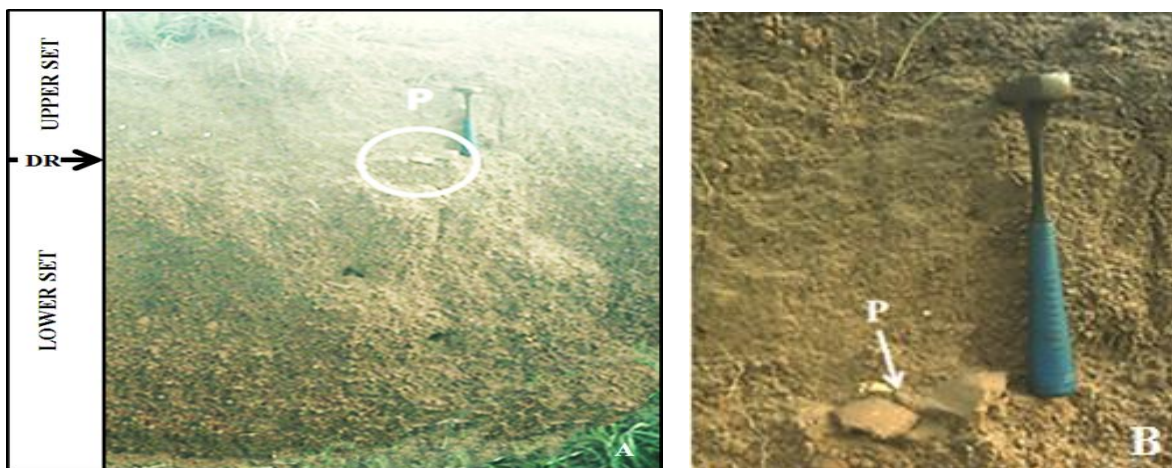


Figure 6. **A:** Position of the remains of prehistoric objects (shard of pottery). US: Upper set, LS: Lower set. DR: Erosional unconformity. **B:** Detail of remains of pottery (P).

STRATIGR.	LITHOLOGICAL SET	LITHOLGY
QUATERNARY	UPPER SET	Greyish soil Reddish clayey to silty sand bearing prehistoric objects
		DR
?	LOWER SET	Ochre lateritic cuirass with pebble of quartz 0.50 m
PANAFRICAN	BASEMENT	Althered metadiorites

Figure 7. Lithological section in the Kamina quarry

this section is made of approximately 1.5 m thick reddish silty-clayey sands containing at its base broken pieces of non-decorated pottery(Figure 8). Its undulating base suggests an erosional unconformity(Figure 11). It is covered by a grey soil about 0.2 m thick.



Figure 8. Prehistoric objects discovered in Kamina quarry

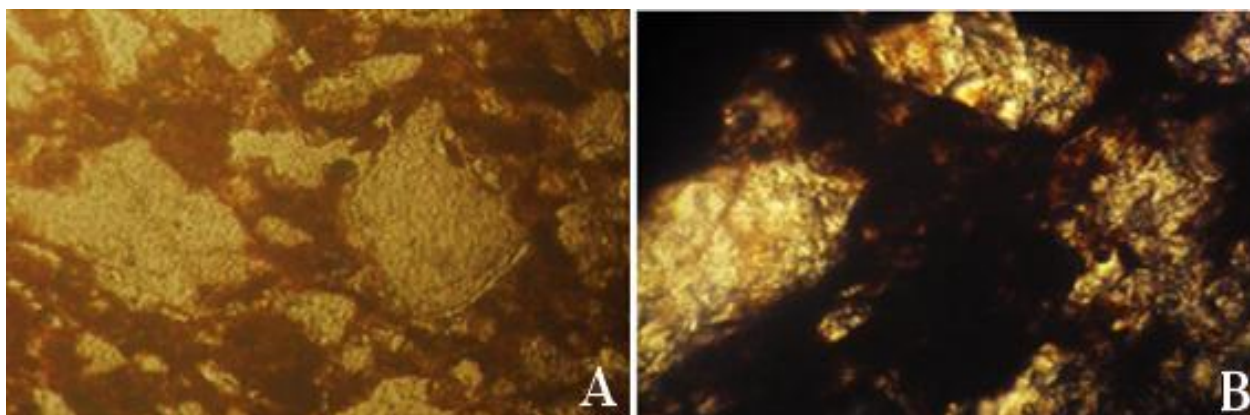


Figure 9. Microscopic analyses of remains of pottery. A : Pottery of Tsévié quarry; B : Pottery of Kamina quarry



Figure 10. Kpogamé quarry view showing the position of the Quaternary formation of “Terre de barre” (Da Costa, 2005)

Comparison of the sections studied with that of the Kpogamé quarry

The lithological data from the Tsévié site shows that the two groups in this section correspond to the two units defined in the sandy-clayey complex of the Continental terminal at the Kpogamé quarry (Da Costa et al., 2006, Figures 10, 12): the lower coarse grained unit represents the Kpogamé pebble bearing Formation and the upper fine grained unit corresponds to the “Terre de barre” Formation (which contains pottery remains). The two formations are separated by an unconformable paleosurface, equivalent to the unconformity D3. This complex (about 25 m thick) in Kpogamé quarry (center of basin), overlay an Upper Oligocene-Lower Miocene marine formations (Figure 12); but it reduced to a 3 m

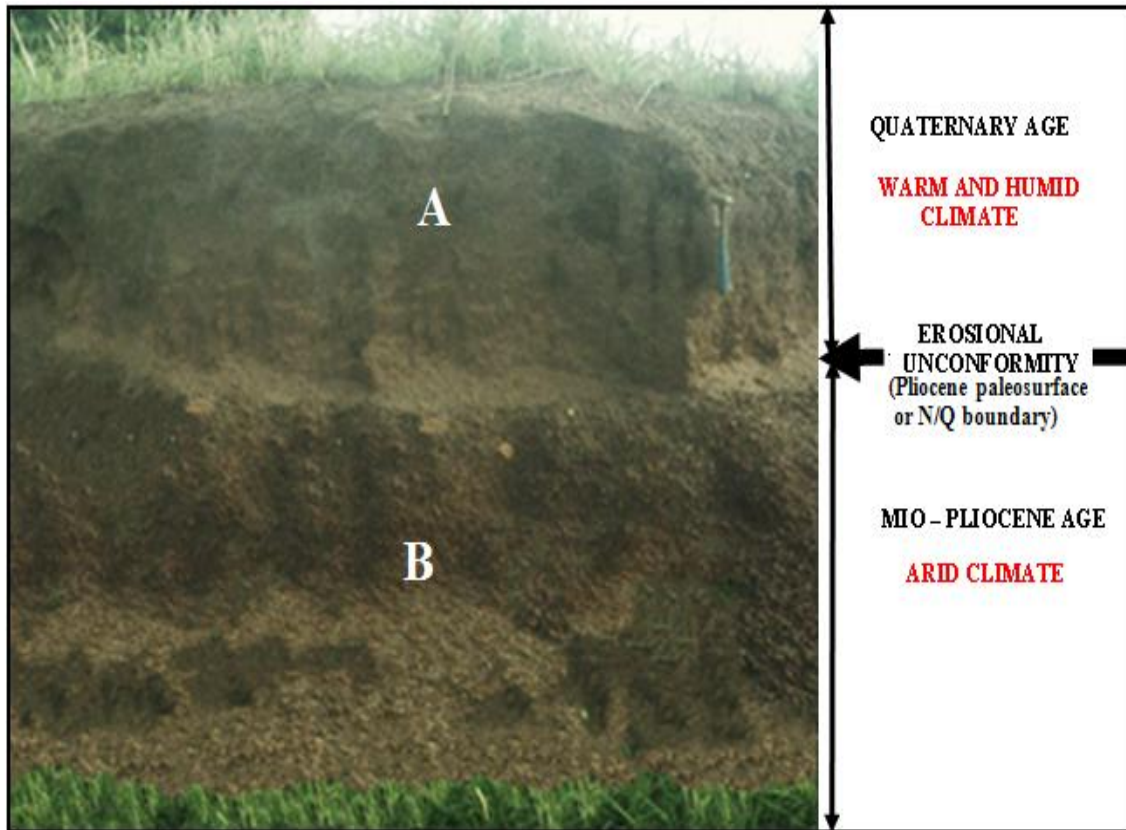


Figure 11. Kamina quarry outcrop showing the Pliocene cuirassed paleosurface of discordance, an evidence of climate changes during the Neogene/Quaternary transition. **A:** Clayey silty sand bearing remain potteries; **B:** ferruginous cuirass

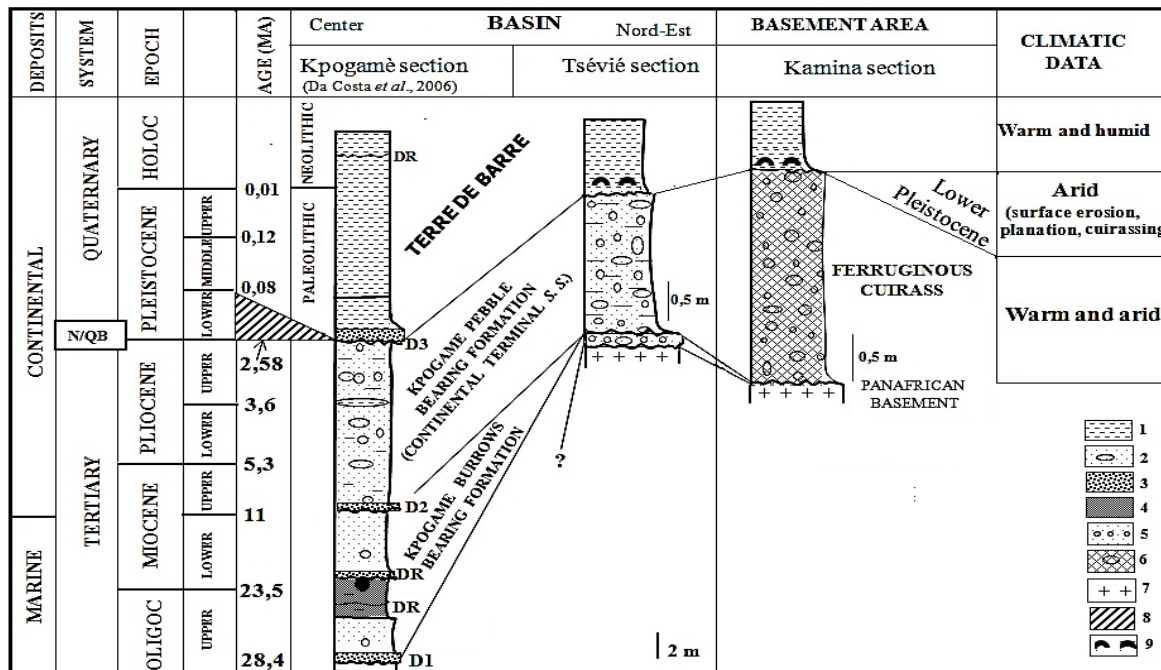


Figure 12. Stratigraphical correlation between the investigated field sections and the previous works (Kpogamè quarry). 1 – Clayey to silty sand ; 2- Conglomeratic clayey sand ; 3 - Ferruginous sandstone ; 4 – Siltstone bearing burrows ; 5 – Conglomeratic ferruginous sandstone; 6 – Ferruginous cuirass; 7 – Pan African basement; 8 – Lower Pleistocene gap; 10 – Remains of prehistoric objects.; D1, D2, D3, DR : Erosional unconformity.

thickness in the studied area where it rests unconformable on ferruginous conglomeratic sandstones. It should be noted that these sandstones which lie unconformably on the Pan African substratum, probably represent the first deposits in the basin and could be Campanian, the age of the oldest deposits known in the Togolese basin (Da Costa, 2005). All these deposits have undergone major post-sedimentary pedogenetic transformation.

A comparison of lithological and paleontological data shows that the Kamina section resembles the Tsévié section. The upper group reposes on paleosurface of discordance and presents a fine grained facies comparable to the 'Terre de barre'. This group also contains at its base similar pottery remains to those identified in the Tsévié section. The lower group of this section, which is a hardpan formation, is also rich in quartz pebbles like Kpogamé pebble bearing Formation. (Figure 12)

Description of pottery shards

The pottery shards collected from the two sites show different characteristics. At Kamina, the fragments are dark red in colour, very thick and present a coarse aspect. At Tsévié on the contrary, they are smooth, reddish and richly decorated. Microscopic analyse of thin sections of the pottery shards reveals a more or less advanced ferruginization depending on site. At Tsévié, the slides show a heterogranular groundmass, with a few geodes filled with iron oxides associated with the feldspar group minerals resembling albite (frequent plagioclase twin), flakes of altered biotite, granular heterometric quartz, oxy-hydroxy textures (goethite, hematite) and some opaque minerals.

At Kamina, analysis of the thin sections shows more or less advanced ferruginization. Some slides are less ferruginized, and show varied figurative elements in a crypto-crystalline quartzose groundmass. One identifies grains of heterometric angular quartz, rare plagioclases (with polysynthetic twinning), a few flakes of mica recognizable by their twinning, an intergrowth of iron oxy-hydroxides and opaque (subautomorphic) minerals. Other slides are in a more advanced state of ferruginization (abundant hematite and goethite minerals) and are impossible to describe.

One distinguishes a relatively coarser groundmass in which epidote and minerals whose properties allow them to be grouped either with calcite or ghemelite are found. Comparison of microscopic data from the two sites shows a difference in the nature of the original groundmass and the post-sedimentary evolution of the fragments. At Tsevié, the original material is more clayey, calcareous and less ferriferous than at Kamina. By contrary, at Kamina one notes the appearance of a cryptocrystalline groundmass, the presence of subautomorphic opaque minerals, and neogenic minerals (calcite, epidote, ghemelite), an alteration of most of the minerals and a significant ferruginization. This shows that the pottery remains at this site have undergone a more advanced alteration thus allowing the neof ormation of new minerals.

Discussion on the age of the formations studied, the 'Terre de barre' Formation

The lower group in the two sections studied at Tsevié and Kamina (Figure 12); has not produced any stratigraphic fossil that make it datable. Nevertheless, lithological and petrographical data obtained from the Tsévié site allows correlating this group with the Kpogamé pebble bearing formation describe in Kpogamé quarry where it was dated to Upper Miocene to Pliocene (Da Costa et al., 2006). This formation, often considered to be "Continental terminal *sensu strict*" is widely distributed in West African basins (Houessou and Lang, 1978; Kogbe and Sowunmi, 1975, in Lang et al., 1990; Kogbe and Burolet, 1990).

The upper group on the other hand has yielded pottery remains (prehistoric objects) which allow a discussion of its age. In the absence of any biostratigraphical marker, dating of the studied formations requires the choice of a dating method which is appropriate for the quaternary, one based on the use of prehistoric objects. The Quaternary often considered to be a period linked to the appearance of man, it was suggested that the "guide event" for locating its base should be related to the funding of the influence of man on biosphere, which is the appearance of the conceptual thinking documented in the deposits by the first man artefacts about 2,6 Ma ago (Odin et al., 2007). Thus, the decorated pottery shards recovered from the "Terre de barre" Formation at Tsévié and from the upper group in the Kamina section testify without doubt to the prehistoric man activities. So the deposits which contain these pottery remains are assigned to Quaternary age. This is corroborated by the presence of an unconformable paleosurface (unconformity D3; (Figure 12)) which marks the base of the "Terre de barre" Formation. According to Da Costa et al. (2011, 2012), such a basal unconformity corresponds to the Neogene-Quaternary boundary. Consequently, these prehistoric objects allowed the confirmation of the Quaternary age assigned to the "Terre de barre" Formation by former authors in neighbouring basins (Benin and Cote d'Ivoire) where similar prehistoric objects discovered allowed the dating of the 'Terre de barre' Formation (Paradis, 1980; Chernockian et al., 1982).

Archaeological studies carried out in the region, have produced numerous vestiges such as stone elaboration sites

(of decorated pottery) at Notsé, a town located at about 40 km from the North of Tsévié (figure 2). Dating of microlithic layers has yielded ages between 2600 and 2120 B.C. (Gayibor et al., 1997). These ages indicate the Neolithic period or the age of polished stone (8000 to 2000 BC). The decorated pottery shards of the Tsévié site could be of Neolithic age like those discovered at Notsé, because one of the characteristics of the Neolithic is the fabrication of pottery often richly decorated. Moreover, in the Kamina site the nature of the pottery shards and their highly altered character (high degree of ferruginization) leads one to think that the potteries of this site may probably be older than those found at the Tsévié. Subsequent dating based on thermoluminescence, OSL or phytoliths will allow a precise determination of the age of these pottery shards.

These results allow considering the upper group of the Kamina section (located in the basement area) as a probable equivalent of the "Terre de barre" Formation, since it also contains pottery shards (prehistoric objects). Similarly, the paleosurface of unconformity that separates the two groups in this site should be the equivalent of the one that separates the 'Terre de barre' Formation and the Continental Terminal *sensu stricto* in the Kpogame quarry (Figure 10, 12). It should be the equivalent of the extensive Pliocene paleosurface which is well known in West Africa (Vogt, 1959; Kogbe and Buroillet, 1990; Houessou and Lang, 1978, 1979; Lang et al., 1982, 1990; Lappartient, 1985; Guiraud et al., 1987; Da Costa et al., 2012).

Paleoclimatic data

The Kamina section is an alteration profile in a basement area with hardpan formation underlying quaternary silty-clayey sand (Figure 11). The presence of a thick layer of hardpan discovered at this site allows discussing climate during the ante-quaternary period. Hardpan formation requires a tropical climate with a harsh dry season (arid climate). Indeed, under such a climate, the savannah replaces the forest and the alteration processes are interrupted by the lack of water with the formation of ferruginous soils. Exposed to solar radiation and desiccation, these soils harden to form hardpans. The presence of an encrusted surface representing basal unconformity of the quaternary deposits (Unconformity D3; Figure 12) shows that the end of the Tertiary is characterized by a dry climatic phase. It is clear that the quaternary deposits studied here (the "Terre de barre" formation and the upper set of Kamina section) were emplaced after an arid climatic phase. The exclusive presence of kaolinite in the studied deposits (Da Costa et al., 2006) indicates a hot and humid climate in the Quaternary time. The data shows that the Neogene-Quaternary transition corresponds to a climate change. These results confirm previous works conclusions (Sittler et al., 1980; Lappartient, 1985; Lang et al., 1990; Da Costa et al., 2011, 2012). Indeed, works done in Ethiopia ("Homo Valley") shows that the beginning of the quaternary corresponds to the first arid climatic episode in Africa.

CONCLUSION

The results of this present work has provided new stratigraphic data on the "Terre de barre" formation and further information on the paleoclimatic evolution of the coastal basin of Togo during the end of Tertiary (Figure 12).

The lithostratigraphical analysis of the investigated sections reveals in the basin (Tsévié site) as well as the basement area (Kamina site) a sandy-clayey formation includes two unconformable lithological groups. An upper group, equivalent to the "Terre de barre" and a lower group or Continental terminal *sensu stricto* (Da Costa et al., 2006).

The decorated pottery shards (prehistoric objects) discovered in the studied deposits have allowed, for the first time, to assign a Quaternary age to the "Terre de barre" formation in the coastal basin of Togo. These results confirm former works done in neighbouring basins (Lang et al., 1982, 1990).

With regard to paleoclimate, a contrast has been shown between climate at the end of the Neogene and the beginning of the Quaternary: dry at the end of the Pliocene and, hot and humid in the Quaternary. The data confirm the major climatic change mentioned by several authors during the Neogene-Pleistocene boundary (Sittler et al., 1980; Chamley et al., 1980; Lappartient, 1985; Da Costa et al., 2012)

Finally, new paleontological evidences (pottery shards) combined with lithostratigraphical (paleosurface of unconformity) and paleoclimatic (encrustation) data constitute three criteria that allow a better delimitation of the Neogene-Quaternary boundary. These results complete the previous work (Da Costa et al., 2012) that helped define this boundary based solely on lithostratigraphical arguments

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