Journal of Geology and Mining Research Vol. 2(6), pp. 159-169, November 2010
Available online http://www.academicjournals.org/jgmr
ISSN 2006 – 9766 ©2010 Academic Journals

Full Length Research Paper

Existence of “late continental” deposits in the Mbere and Djerem sedimentary basins (North Cameroon): Palynologic and stratigraphic evidence

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Accepted 12 October, 2010

Current palynologic and stratigraphic data presented in this paper, show the existence of Upper Tertiary to Lower Quaternary deposits in the Mbere and Djerem basins. The upper part, so called “Late Continental” deposits encounters different palynomorphs with angiosperms (Gramineae, Chenopodiaceae, Malvaceae and Compositeae), spores, fungi, gymnosperm and freshwater algae, which are of Late Tertiary/Quaternary aspect. No marine palynomorph is reported. The border faults might have reworked at several occasions during post-cretaceous periods, probably during the Oligocene/Miocene as indicated by the Oligo-Miocene volcanic products associated with the “Late Continental” sedimentary series. Three periods of sedimentation can be distinguished, interbeded by erosional and volcanic phases.

Key words: “Late continental” deposits, sedimentology, terrestrial palynology, stratigraphy, Mbere and Djerem basins, Cameroon.

INTRODUCTION

The Mbere and Djerem basins, which are part of the Central Domain of the North Equatorial fold belt, are situated along the Central Cameroon Shear Zone (C.C.S.Z.) in the Southern Adamawa Highlands (Figure 1). These basins, like the other small Northern Cameroonian basins, were thought as rift filling during the cretaceous. These sediments are mostly continental (agglomerates, sandstones, sands, sandy clays, clays and travertines). The Mbere and Djerem basins are separated by Tertiary volcanic deposit of the Adamawa plateau (Lasserre, 1961). Near Southern Adamawa highlands in North Central Cameroon they settled as an intracontinental NE-SW trough in the Precambrian basement. The initial rift developed within the Cameroonian Shear Zone (Ngako et al., 1991) and extends along the main orientations of the major structural trends, through the cretaceous reworking of some N70°E Precambrian faults, which are considered the main tectonic features of the North equatorial Pan-African Chain. The opening and infilling of these basins have been occurred in several and different phases of deformation (Ngangom, 1983; Dumont, 1984, 1987), certainly through the lower cretaceous during the opening of the Gulf of Guinea (Njiké-Ngaha, 2005).

Time stratigraphy of these basins was a matter of controversy (Bresson et al., 1952; Roch, 1953; Guiraudie, 1955; Lasserre, 1961; Le Maréchal and Vincent, 1971) and is poorly known. Palaeontologic data are also fragmentary due to the unfossiliferous nature of these sediments. However, unpublished results on some remains of silicified woods were collected in the Djerem stream sediments by Koeniguer (Le Maréchal and Vincent, 1971) and in the Mbere Basin by Fritel and

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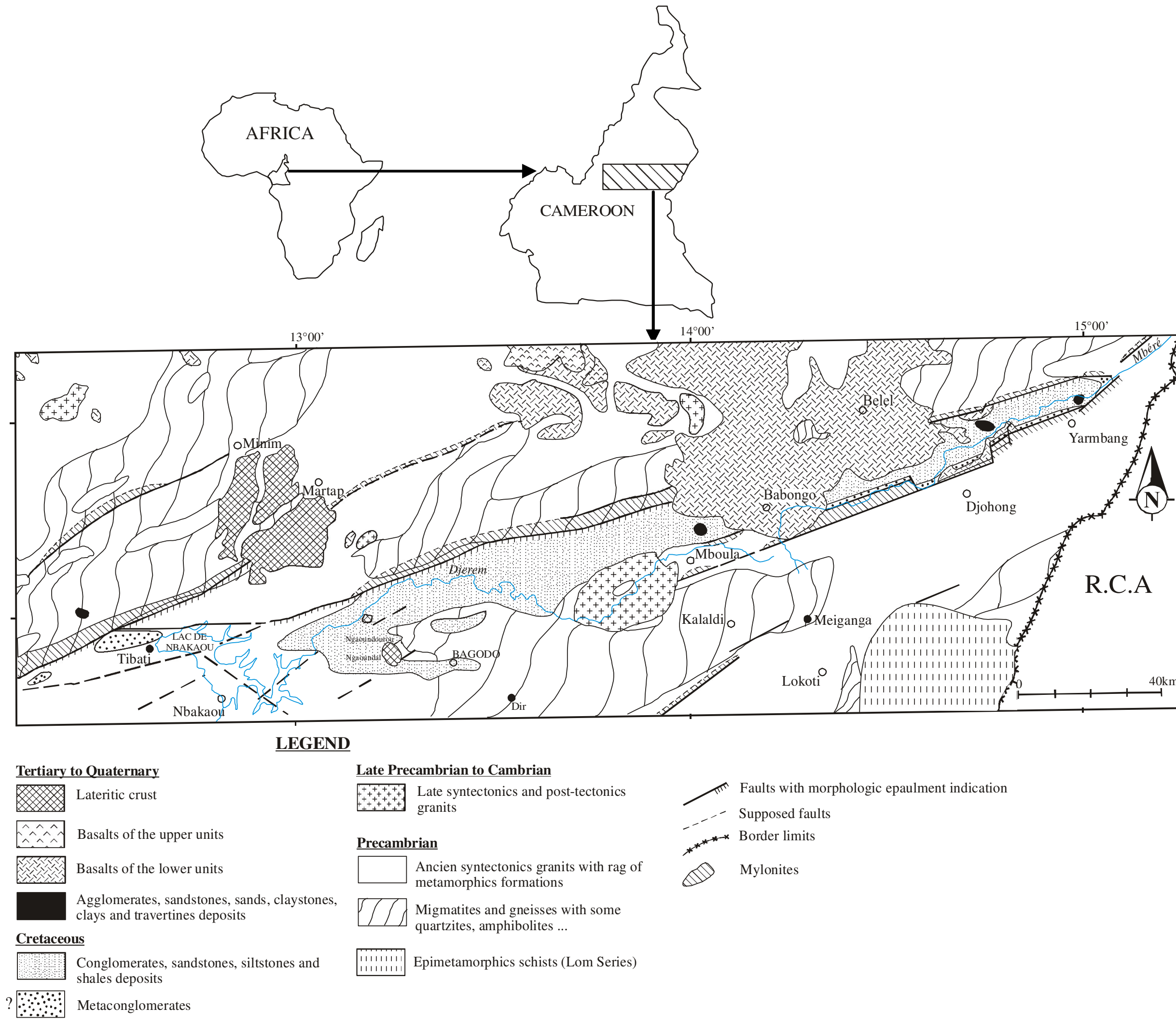

Figure 1. Geologic map of Mbere-Djerem basin (modified from Le Marechal, 1976).

Chudeau (Eno-Belinga, 1983). Based on these findings a cretaceous age was suggested for these sediments and generally for the “Late Continental” deposits in the Adamawa Region (Eno-Belinga and Ndjeng, 1976). The generalized term “Late Continental” was introduced by Kilian (1931) to indicate tertiary saharian continental deposits of similar lithofacies in African geological context. Faure et al. (1956) considered that such term is applicable for the whole Cenozoic. Furon and Daumain (1959) extended this nomenclature to the quaternary to encounter several basins in West Africa, where fossil fishes, reptiles and silicified woods were recorded. However, this extension was later refused by Didier de Saint-Amand (1969). In contrast, older Triassic to lower cretaceous detrital deposits were referred to as the “Continental Intercalaire” by Kilian (1931) and encounter fish and dinosaur remains (Lapparent, 1960). These sediments were not considered part of the Mbere and Djerem biostratigraphic features although their lithostratigraphies are very similar.

GEOLOGICAL AND STRATIGRAPHIC SETTING

The Mbere Basin shows the morphological characteristic of a rift. It is a dissymmetrical tectonic trough with Northern shoulder (Collignon, 1970). In the Djerem Basin the southern denivelation do not exist. The two basins display roughly the same basal petrographic facies. Nevertheless, in the Djerem Basin, there is a scarcity of conglomeratic facies outcrops, a remoteness of metaconglomerates from others sedimentary rocks and particularly a relatively thinner deposits according to geophysical data (Collignon, 1970; Essissima, 2001; Noutchogwé, 2004, 2006; Kandé-Houétchak L, 2008). From bottom to top Precambrian basement, cretaceous and

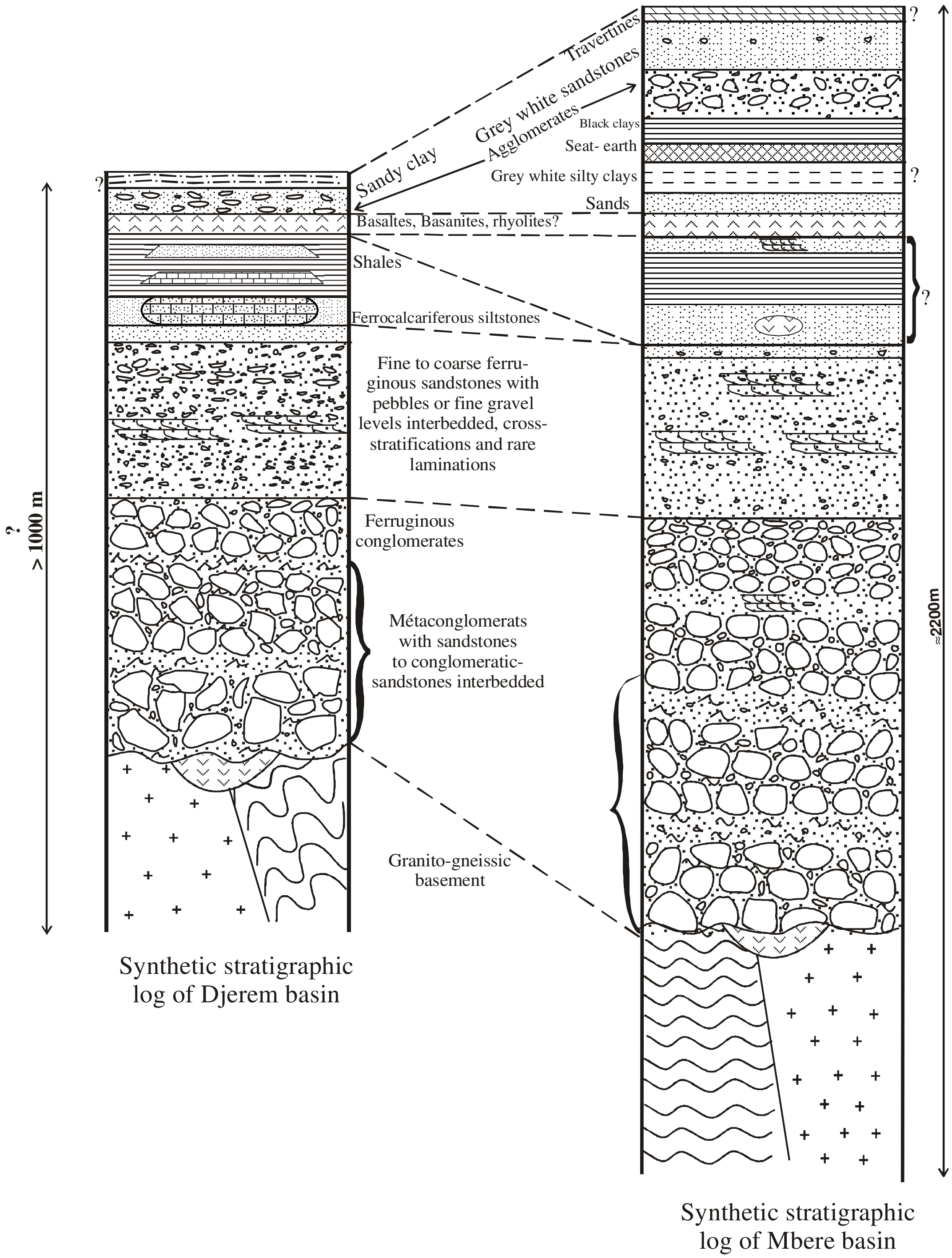

Figure 2. Correlation between Djerem and Mbere deposits.

Tertiary/Quaternary deposits crop out. These rock units are displayed by geophysical records except of the “Late Continental” and other cretaceous clastics. The basement outcrops both at the borders and inside the basins and exhibit many deformation features such as, faults, folds or fissures.

The lithostratigraphy of the Mbere and Djerem basins (Figures 2 and 3) from the bottom to the top is composed of cretaceous deposits, probably Eocene deposits and Upper Tertiary to Pleistocene deposits. The lower part probably belongs to the “Continental Intercalaire”. It lies disconformably over the metamorphic and granitic

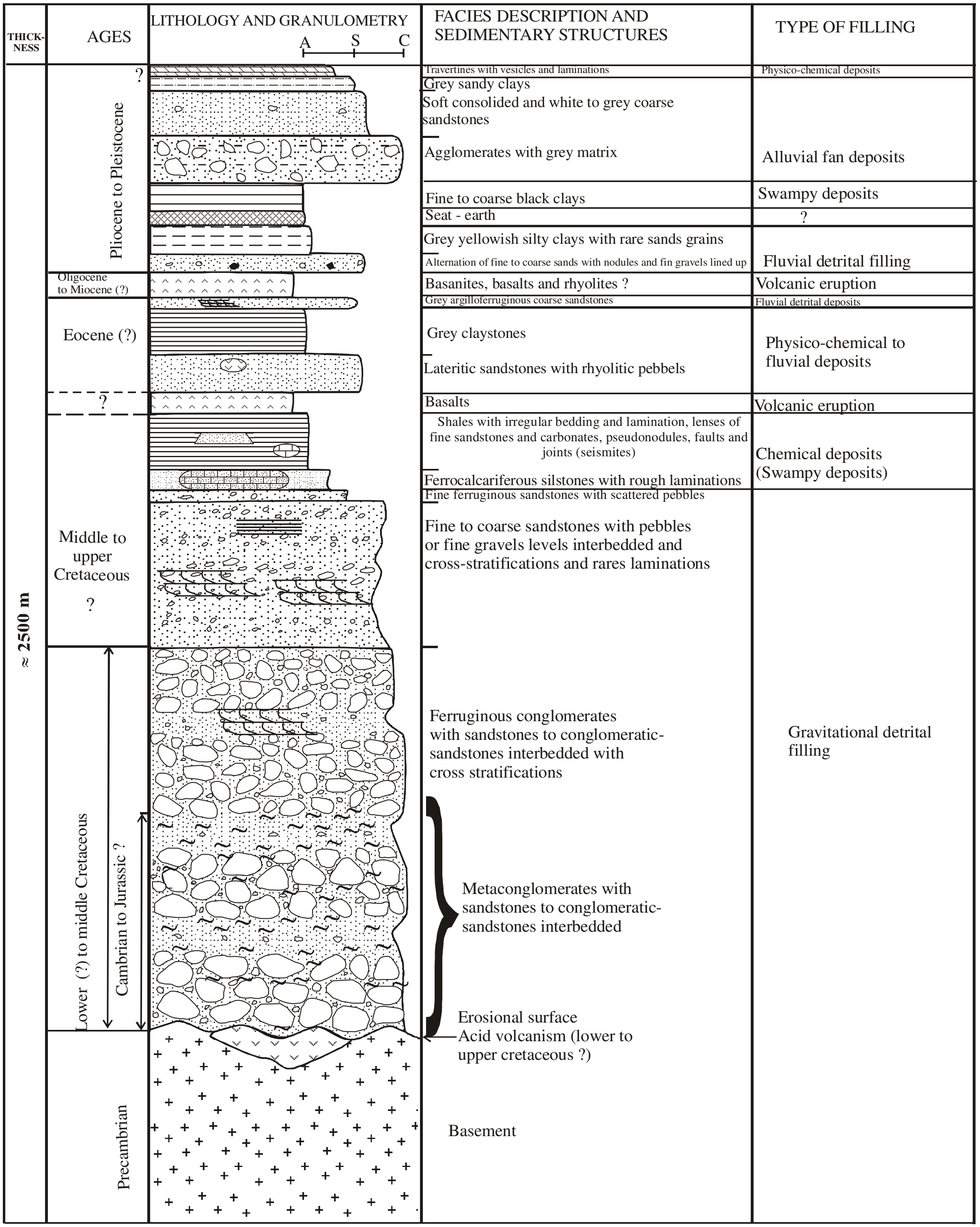

Figure 3. Synthetic stratigraphic log of Mbere-Djerem basin.

Precambrian basement cretaceous deposits are represented probably by metaconglomerates, ferruginous conglomerates, ferruginous sandstones, ferrocalcariferous siltstones and shales. The metaconglomerates are generally located near the border faults and very often they follow different dips in angles and trends.

Metamorphism affects only the cement which shows new phases of mineral recrystallization. In the Djerem Basin, these metaconglomerates crop out in a discontinuous manner at Tibati (Guiraudie, 1955). Their dip values are low to moderate (23 to 45°). In the Mbere Basin, occurs metaconglomerates of the Borogop stream, which were formerly referred to as "Borogounous conglomerates" (Bresson et al., 1952; Roch, 1953). They are exposed also at Sanyaoué, along the Bah stream, near the Lebou stream, in the Ka-Borogop hills and in numerous isolated points at the Eastern extremity of the basin (Le Maréchal and Vincent, 1971). In the Djerem, the conglomeratic facies are scarce; they outcrop at the west of Mbong-Betara Congo village near the Djerem stream and in the bed of the latter where the sizes of pebbles are reduced. An exceptional outcrop has revealed typical characteristics of metaconglomerates and conglomerates (ferruginous cement), initially unmetamorphosed, with ferruginous cement that has been affected by a later metamorphism. The ferruginous sandstones are fine to coarse and frequently marked by gravely or pebbly levels and cross bedding, with rare laminations. Their dip varies between 10 to 30°. This facies overlies conformably or unconformably the ferruginous conglomerates. Ferrocalcariferous siltstones outcrop in Djerem basin and their dip is approximately 12° towards NE. Shales are exposed in the Djerem basin, in a point bar zone of the Djerem stream with approximately 7 m of thickness with regard to water level in the dry season and showing differential weathering and platy parting. They show many sedimentary structures like parallel, wavy to convolute laminations pseudonodules with peel-onion structure and fine sandstones lenses. There are numerous faults and joints. Their dip is parallel to subparallel, approximately 10°SE, with a local dip of 25°SW (fault). This facies overlies unconformably the ferruginous sandstones or the ferrocalcariferous siltstones.

Deposits of probable Eocene age are represented by lateritic sandstones, grey claystones and grey argiloferruginous sandstones. These deposits constituted a cyclic sequential unit (Yarmbang sequence). The lateritic sandstones, the basal deposit, show numerous particularities such as, decimetric pebble of rhyolitic tuff. The grey claystones, with about 5 m of thickness, seem to overlie conformably lateritic sandstones. This facies show numerous burrows.

Upper Tertiary to Quaternary deposits are represented by sands, clays, agglomerates, clayey sandstones and travertines. The Dor stream sands show alternation of fine to coarse grained layers with intercalations of gravely layers and clayey sandy nodules. Its observable thickness is few centimetres. This facies pinches out towards the East and overlies unconformably on the basal ferruginous conglomerates. The clayey deposits have maximum thickness of about 3 m. The clays crop out at several places. The agglomeratic deposits are exposed at Njoya (Djerem) and Dor (Mbere) streams, with thicknesses approximately between 1.5 to 4 m.

Volcanic products are variable in nature (olivine basalts, andesitic basalts, basanites and probably rhyolites). The basanites are exposed near the Southern border of the Mbere basin and lie unconformably on the consolidated sedimentary formations (ferruginous sandstones and metaconglomerates). Basalts are generally derived from the Adamawa plateau and constitute the paleogeographic limit between the Djerem and Mbere basins. A major problem is posed on the episodic nature of the volcanic products. The flows exhibit advanced degree of weathering at certain places; this is the case of the Ngaoundourou region (Djerem) where deeply weathered basalts cover the ferruginous and conglomeratic sandstones. Moreover, they show remarkably a degree of freshness. The presence of rhyolitic pebbles in the conglomerates (Mbere and Djerem) and the metaconglomerates of the Tibati explains the existence of acid volcanism, probable episodic, prior to basalts.

MATERIALS AND METHODS

Palynology

Eight surface samples were analyzed according to standard palynological methods, six were found suitable for the present work and contain well-preserved and abundant palynomorphs. Samples were digested by acids 35% HCl for approximately 24 h to dissolve the carbonate and 40% HF for approximate by 72 h to remove the silicates. No centrifugation and heavy liquid separation were performed. The residues were not subjected to oxidation or alkali treatments. Ultrasonic procedure was carried out for one clay sample (sample S4). The acid-digested residues were sieved using 10 µm polyamide nylon sieves. Two to seven permanent slides for each sample were prepared using glycerin jelly as a mounting medium. The semi-quantitative study was based on counting at least 200 grains of different palynomorphs in each sample. The slides were examined using a Leica DM LB 2 light microscope equipped with a Leica DFC 280 digital Camera.

Petrography and heavy minerals

The technique used by Duplaix (1958) and Parfenoff et al. (1970) are used. The heavy liquid used for the separations of minerals is the bromoform with a density of 2.89. The heavy minerals belong to the 100 - 200 µm fraction of each sample. Their determination and estimation of their numerical percentages were carried out under the polarized microscope, which was also used to study thin sections mounted according to the modern standard method for sedimentological characteristics.

RESULTS

Distribution of the palynomorphs from samples studies

Representatives of four major palynomorph groups

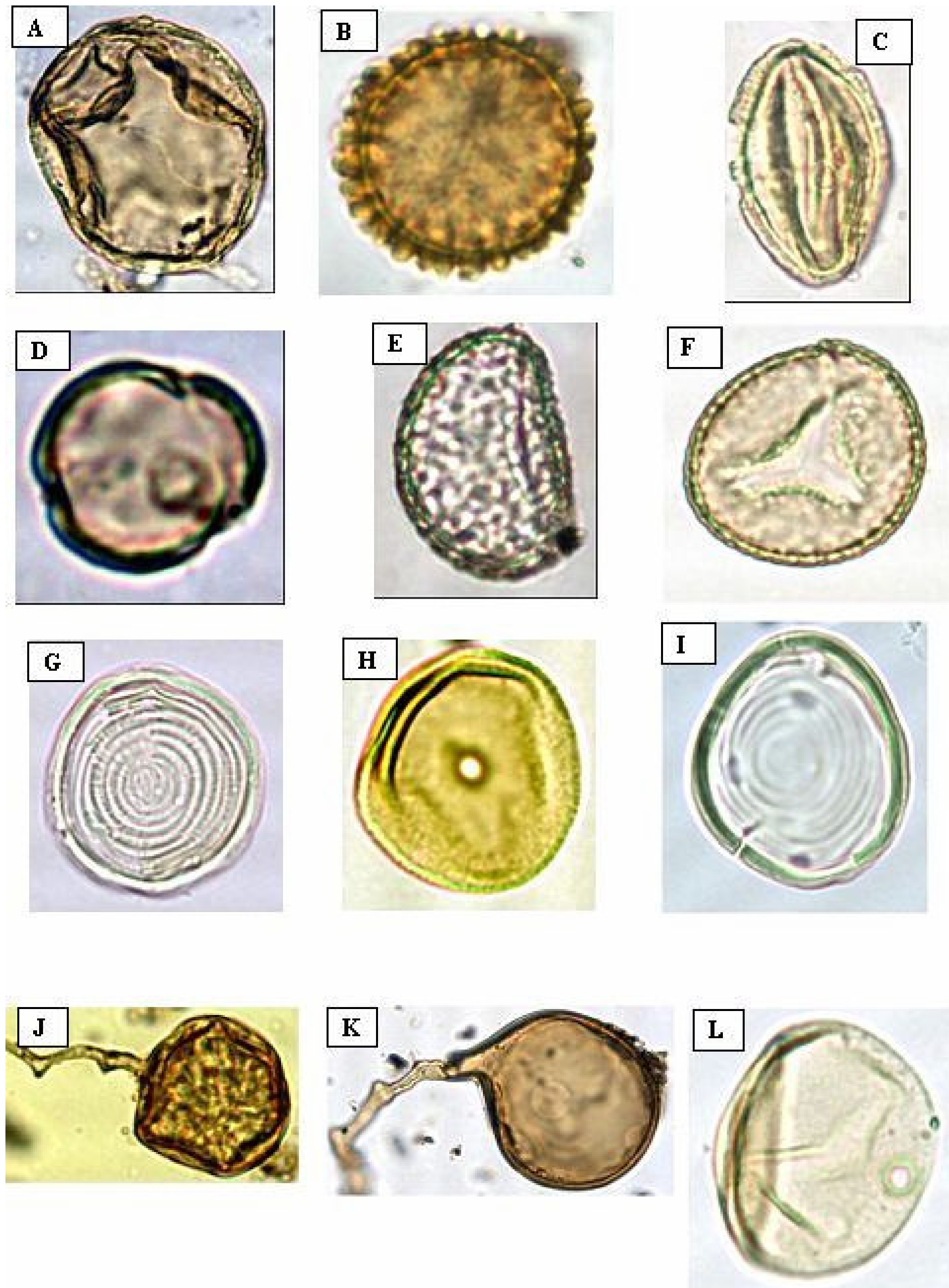

Plate 1. Palynomorphs. A, J, K: Rhizophagites sp. A- Sample S8, slide S8B (G27-3), diameter 60 µm. J- Sample S2, slide S2B (Q22-3), diameter 35 µm. K- Sample S2, slide S2A (U34-2), diameter 50 µm. B: Fungal Conidia aseptate, sample S2, slide S2A (C39-3), diameter 32 µm. C: Tricolporopollenites sp., sample S6, slide S6A (J39-3), diameter 40 µm. D: Tricolporate sp., sample S8, slide S8A (G28-4), diameter 17.5 µm. E: Polypodiisporonites sp., sample S7, slide S7D (D45-3), length 60 µm. F: Triletes, sample S4, slide S4C (N46), diameter 22 µm. G, I: Chomotriletes minor (kedves) Pockock, Mahmoud, 2000. G- Sample S4, slide S4D (M42-1), diameter 40 µm. I- Sample S4, slide S4A (T32-1), diameter 38 µm. H, L: Gramineae. H- Sample S4, slide S4B (L25-3), diameter 33 µm. L- Sample S4, slide S4D (V54-3), diameter 37.5 µm.

(Plates 1 and 2) were recognized: angiosperms, spores, freshwater algae and fungi. Gymnosperms are rare or absent. The distribution of the palynomorphs (Figure 4) in the samples studied is generally similar with different

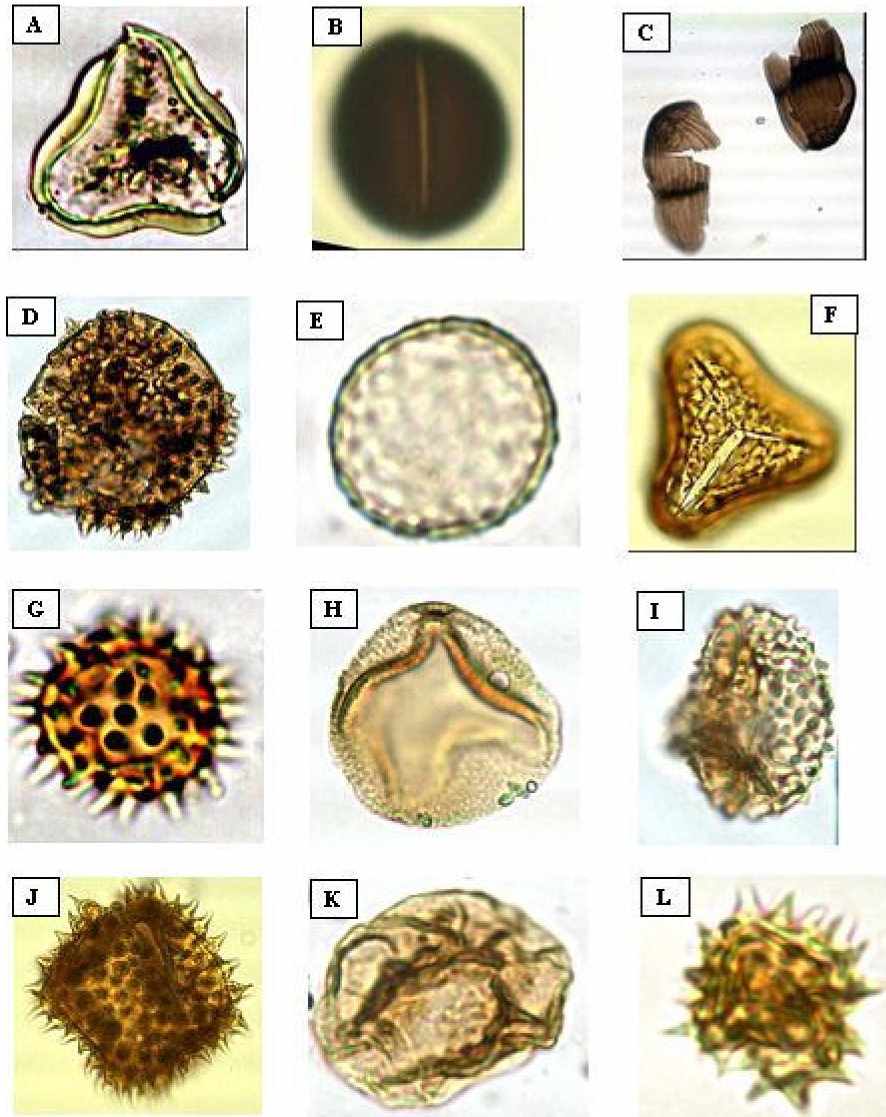

Plate 2. Palynomorphs. A: (?) Espora triletes (Guerstein, 1990), sample S7, slide S7C (V33-3), diameter 32 µm. B: Monoporisporites sp., sample S8, slide S8A (F43-4), diameter 20 µm. C: Fusiformisporites sp., sample S6, slide S6A (A51), diameter 6.25 µm. D, J: Malvaceae. D- Sample S4, slide S4D (V47-2), diameter 53 µm. J- Sample S4, slide S4A (G29-2), diameter 50 µm. E, I: Chenopodiaceae – Amaranthaceae E- Sample S2, slide S2A (J48-2), diameter 29 µm. I- Sample S4, slide S4D (Q24-2), diameter 35 µm. F: (?) Polypodiceoisporites sp., sample S4, slide S4A (J57-4), diameter 50 µm. G, L: Compositeae. G- Sample S4, slide S4C (F25), diameter 37.5 µm. L- Sample S4, slide S4A (M40-4), diameter 18 µm. H: (?) Araucariates australis (Takahashi and Jux, 1989a), sample S4, slide S4D (G50-4), diameter 40 µm. K: Inaperturopollenites sp., sample S2, slide S2B (N17-3), diameter 35 µm.

proportions. The most striking aspect of the palynoflora in the travertines (S8) is the dominance of various fungal palynomorphs, where pollen in the sandy clays (S6 and S7) and dark clay (S4) occur in great numbers. This means that many microenvironments could have existed during almost the same periods (Upper Tertiary to Pleistocene).

Petrographic study and analysis of heavy minerals

The petrographic study was dedicated to the indurate sediments such as, clays (S1, S2, S4 and S7), agglomerates matrix (S5) travertines (S8) and clayed sandstones (S10). The study of heavy minerals was instead based on S1, S2, S3 (sands), S4 and S6 (sandy

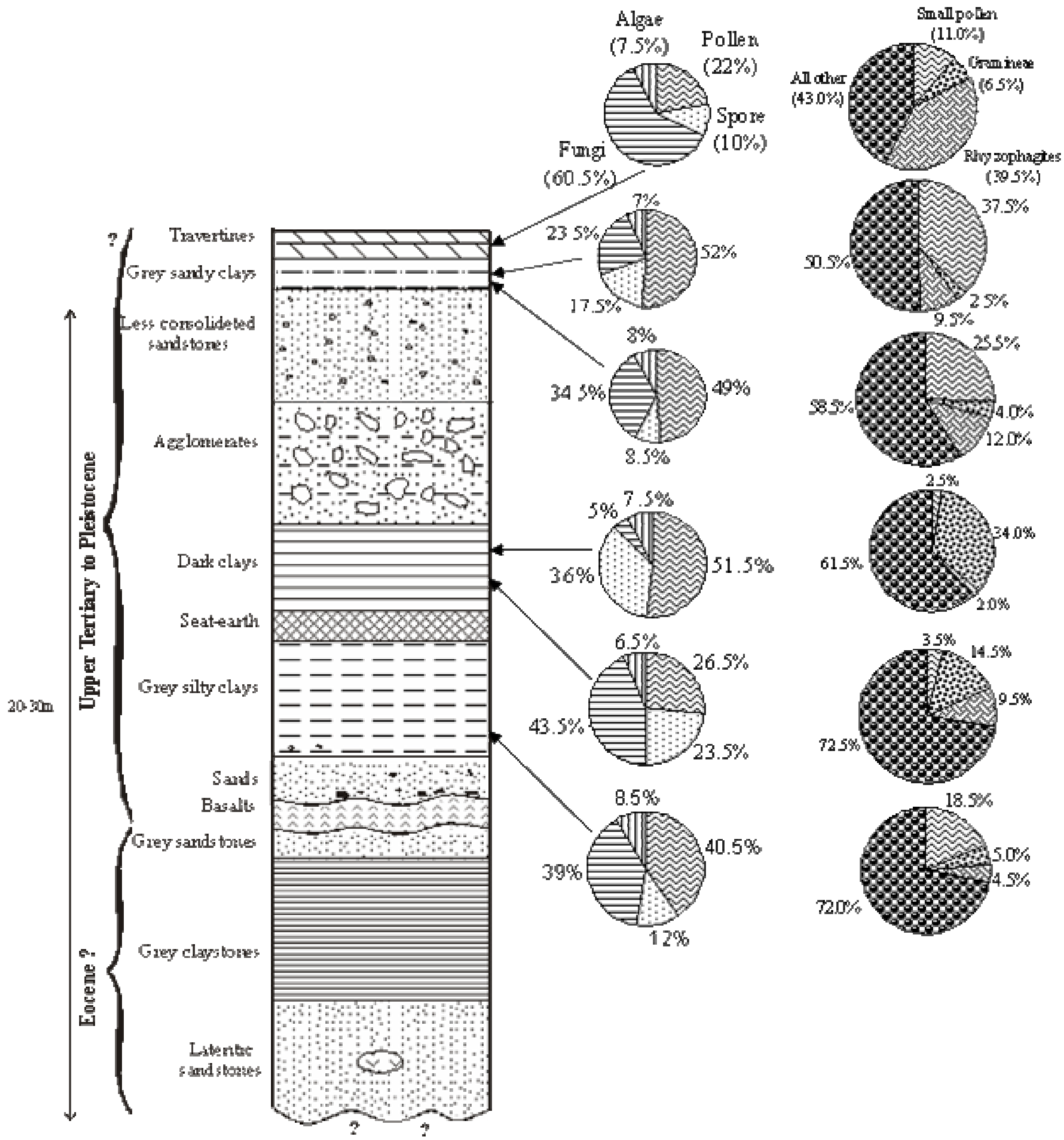

Figure 4. Synthetic stratigraphic log of Tertiary-Quaternary deposit of Mbere-Djerem showing the distribution of palynomorphs.

clays). All those deposits show a volcanogenic source of supply (olivine and associated minerals or accessory bipyramidal quartz). In effect, those sediments, on one hand, are posterior to the basaltic, trachyphonolitic and undoubtedly rhyolitic volcanism and on the other hand, originate from diverse nourishing sources, according to the Table 1. The study of heavy minerals has enabled the identification of several mineral species for which the most frequent and most represented, in decreasing order, are opaque oxides (15 - 62%), olivine (1 - 50%), garnet (2 - 17%) and zircun (1 - 30%). Other minerals included chlorite, serpentine, epidote, aegyrine, aegyrine-augite, zoïsite, augite, hornblende, apatite, muscovite, tourmaline and monazite. Chlorite, serpentine and a great proportion of the oxides are derived from the weathering of olivine. The petrographic data reveals that the deposits are immature to sub-mature and rich in quartz grains (50 - 88%). These deposits are very poorly to poorly sorted

Table 1. Sources supply of the deposits.

Supply source	Corresponding constituents
Basaltic volcanic source	Olivine, small fragments and microfragments of basalt
Acide volcanic source (rhyolite)	bipyramidal quartz
Plutonic source	Monazite, granites microfragment and others
Metamorphic source	Staurotide, sillimanite, kyanite, gneiss microfragments and others
Sedimentary source	Fine sandstone fragments

(S5, S7 and S10), poorly sorted (S2 and S8) or poorly to moderated sorted (S4); the grains are irregular with some rare rounded outline (S5, S7, S8); fine texture (S2 and S4), fine to medium texture (S7 and S8), fine to coarse texture (S3 and S5) or medium to coarse texture (S10).

INTERPRETATION AND DISCUSSION

Cretaceous deposits

Bresson et al. (1952), Roch (1953) and Lasserre (1961), have attributed a Precambrian age to the metaconglomerates of Borogop basing arguments on the subvertical dip and their metamorphism. Vincent (1968, 1970) and Le Maréchal and Vincent (1971) dated those metaconglomerates at the cretaceous just as the unmetamorphosed conglomerates; their proximity, their petrographic analogy and particularly the occurrence of transition members between the two support the hypothesis of an original continuity of the two materials.

Le Maréchal and Vincent (1971) have attributed the upper cretaceous age to the most recent deposits in the Djerem Basin, by assimilation to the Lamé Basin (Chad, mid cretaceous), because of the presence of numerous silicified wood debris collected in the Djerem stream sediments near Nbakaou (Tibati) [Koeniguer (Unpublished)]; this corresponds to the heteroxylated wood where five different structures have been identified; one of them corresponds precisely to a leguminous dated at the Upper cretaceous-Tertiary. By another way, Fritel and Chudeau (Eno-Belinga, 1983) have pointed out a coniferous wood remembering those of Sahara, probably a Protopodocarpoxylon dated of Wealdian to mid Cetaceous. It is admitted that the coarse conglomerates (piedmont molassic facies) in the basins resulted from vertical movements that were responsible for the primary uplifting of the Adamawa Horst (Le Maréchal and Vincent, 1971). Supposing that those vertical movements are contemporaneous to the opening of the Golf of Guinea and those having given rise to the synclines in the Fali Land of North Cameroon during the Lower cretaceous such as, the Babouri-Figuil and Mayo Oulo-Lere basins (Ndjeng, 1992), those molassic deposits might be Lower cretaceous of the “Continental Intercalaire”, at most, for the basal part. If in contrary, those vertical movements are contemporaneous and responsible for the Cenomanian marine transgression observed both at the West Coast of Africa; Gabon (Boltenhagen and Salard-Cheboldaeff, 1985), Cameroon (Njiké-Ngaha, 2005) as well as in the continental part, the Benue Basin (Allix and Popoff, 1983) and Lame Basin (Le Maréchal and Vincent, 1971), hence, those deposits do not belong to the “Continental Intercalaire” but rather to the zone included between the lower limit of the “Late Continental” and the upper limit of the “Continental Intercalaire” (Cenomanian-Maastrichtian).

Eocene deposits

It is known that a wide alteration of laterite type has supplied the chemical sedimentation in Africa dated from Eocene (Eno-Belinga, 1972). The lateritic sandstones and doubles, the grey claystones and grey sandstones might be of continental alteration during the Eocene but following the varied conditions of sedimentation. That is the case of Niger, where it is initially established that the Senonian end previous formations have been subjected to intensive lateritic alteration of Eocene (Faure, 1962).

Volcanics

The volcanic products are not dated with precision but rather by analogy. Nevertheless, geochronological data of lavas of the ancient series from the Ngaoundere region (Adamawa) indicate an age that corresponds to the Miocene (Gouhier et al., 1974), while the chronological data of the felsic and mafic lavas in the Tchabal Gangdaba region (Adamawa plateau) indicate an age that corresponds to the Oligocene (Itiga, 2007). The deeply weathered basalts of the Ngaoundourou have been attributed the upper cretaceous age (Eno-Belinga, 1970), which seems doubtful, although the first basaltic manifestation in the Lame Basin were observed in Middle cretaceous (Cornacchia and Dars, 1983); It is at times admitted that the Lava flows of almost the same age might be weathered at very different rates. Therefore, a more recent age for the Ngaoundourou basalts seems evident. The unique cretaceous volcanic activity (Lower to Middle cretaceous or before cretaceous?) is mainly rhyolitic as indicated by the presence of the rhyolitic pebbles in the basal conglomerates.

Upper tertiary to quaternary deposits

The different assemblages and species of palynomorphs studies reveals an upper Tertiary to Pleistocene age of the lightly to unconsolided deposits and thus are of the “Late Continental”.

Pollen of Chenopodiaceae (in association with Gramineae) are recorded from the Upper Member of the Reindeer Formation of the Caribou Hills (Arctic Canada), by Doerenkamp et al. (????) (Mahmoud, 1996), which is probably dated as Miocene to Pleistocene age (?).

Rhizophagites were recorded in the Plio-Pleistocene sediment (Zaklinskaya, 1978). Rhizophagites cerasiformis were recorded in the Pliocene and probably Paleogene sediments (Norris, 1986; Head, 1993), in the Pliocene to Pleistocene sediments (Mahmoud, 1996, 2000).

Fusiformisporites sp. and *Multicellaesporites* sp. were recorded in the Rudeis and Kareem formations, in the Gulf of Suez, of Miocene age (El Beialy et al., 2005).

Malvaceae (*Malvacipollis subtilis*, in Stover and Partridge, 1972 and other *Malvacipollis* sp.) are known from Early Eocene – Late Miocene of Australia (Stover and Partridge, 1973), Eocene of Queensland (Foster, 1982), Tertiary of Argentina (Mahmoud, 2000) and Plio-Pleistocene of West Assiut, Egypt (Mahmoud, 2000).

Chenopodiaceae-Amaranthaceae was recorded in the West Assiut, Egypt (Mahmoud, 2000). Their distribution is Late Miocene, Spain (Mahmoud, 2000), Maastrichtian(?)-Palaeocene, Argentina (Mahmoud, 2000), Pliocene or Plio-Pleistocene (as *Chenopodiipollis krutzschii*), Yemen (Mahmoud, 2000), Late Miocene (*Chenopodiipollis multicavatus*), Argentina (Mahmoud, 2000) and Plio-Pleistocene, Egypt (Mahmoud, 2000).

Conclusion

The palynogical data have showed the evidence of Tertiary deposits (“Late Continental”) in the Mbere and Djerem basins. These deposits are lacking in macrofossils. The “Late Continental” deposits, unknown in Cameroon, exist in many regions in Africa, especially to the eastern and western of Assiut in Egypt (Mahmoud, 1996, 2000, 2004). The “Late Continental” forms the upper series of the Mbere and Djerem basins and are the products of the erosion of all other former formations such as, basement, cretaceous to lower tertiary sedimentary deposits and mainly volcanic rocks. The Mbere and Djerem sedimentary basins seam to be characterized by three main phases of sedimentation the first phase extends probably from the lower cretaceous to upper cretaceous, the second is probably eocene-miocene and the third from the upper miocene or pliocene to lower pleistocene. Between those three sedimentations episodes, erosional and volcanic activities dominated. An intensive erosional phase seems conspicuous between the Miocene and Pliocene and another erosional phase during the Palaeocene-Eocene (Eno-Belinga, 1972). If surface bauxite formations of Minim-Martap or those of Ngaoundourou and Ngaoundal are dated Lower Tertiary (Eocene) according to Eno-Belinga (1972), therefore, it is evident that it is a volcanism of Upper cretaceous to Lower Palaeocene.

The original continuity between the metaconglomerates and the conglomerates seems very evident. The metamorphism affecting the basal part of the deposits and partially at certain places might be related to the replay of the bordering faults (strike-slip fault or transpression) if one considers their positions and their very variable dips. The sub-vertical dip of the “Borogounou Conglomerates” seems to be related to folding, as seems to reveal the dip and their strike trends of the stratifications plane, having being affected the deposits due to a syn- to post-sedimentary more or less localised land sinking. Meanwhile, considering the Tibati and Borogop metaconglomerates as have been affected during the same metamorphic event, it is nevertheless possible that those of the Borogounous are older: the rhyolitic pebbles are very abundant at Tibati and present in the conglomerates of the Mbere but not reported at “Borogounous”.

ACKNOWLEDGMENTS

The authors are grateful to the authorities of the Assiut University (Egypt), Prof. Dr. Ahmed Y. Abdel-Malek, Dean of the Faculty of Science; Prof. Dr. Mervat A. Elhaddad, Head of Geology Department and particularly Prof. Dr. Magdy S. Mahmoud, Head of Palynology Laboratory and co-author of this paper for providing the laboratory facilities. The remarks of anonymous reviewers are substantially improving the quality of this work.

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