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On the Absence of Oligocene in Onshore Part of Cote D'ivoire Sedimentary Basin. Preliminary Results of Clays Study of Samo Area, South-East of Cote D'ivoire, West Africa

Bruno Zeli Digbehi
Université de Cocody: UFR des Sciences de la Terre et des Ressources Minières
22 BP 582 Abidjan 22, Côte d'Ivoire
E-mail: digbehizelib@yahoo.fr
Tél. 00 225 09 35 67 39

Silvina Marfil
Departemento de Geología, Universidad Nacional del Sur
San Juan 670, 8000 Bahía Blanca, Argentina
E-mail: smarfil@uns.edu.ar

Pedro Maiza
Departemento de Geología, Universidad Nacional del Sur
San Juan 670, 8000 Bahía Blanca, Argentina

Bie Goah
Université de Cocody: UFR des Sciences de la Terre et des Ressources Minières
22 BP 582 Abidjan 22, Côte d'Ivoire

Sylvain Mondé
Université de Cocody: UFR des Sciences de la Terre et des Ressources Minières
22 BP 582 Abidjan 22, Côte d'Ivoire

Célestin Boko Sombo
Université de Cocody: UFR des Sciences de la Terre et des Ressources Minières
22 BP 582 Abidjan 22, Côte d'Ivoire

Ama Valérie Wognin
Université de Cocody: UFR des Sciences de la Terre et des Ressources Minières
22 BP 582 Abidjan 22, Côte d'Ivoire

Abstract

We studied the argillaceous fractions of three wells carried out in Samo area, located in the South-Eastern part of Côte d'Ivoire sedimentary basin. Preliminary works whose results are presented in this paper related to the mineralogical studies of clays of the levels crossed by these wells. They precede the study aiming at establishing the palynostratigraphy as well as the variation of the depositional environments in connection with the eustatic episodes which occurred in this sector of the Northern Gulf of Guinea.

The results indicate that analyzed samples are mainly made up of quartz and kaolinite with a small proportion of illite. In the upper part sequence identified like the Continental terminal, the deposits are primarily made up of quartz and kaolinite. In bituminous gray clays of the lower section, the samples are dominated by quartz and illite. These results lead to distinguish two lithostratigraphical sequences: the variegated clays of Continental terminal Mio-Pliocene age are provided by Quaternary lateritic continental detritus; the Lower sequence of bituminous clays is mainly marine origin.

Keywords: Shales, Tertiary, Samo, Côte d'Ivoire.

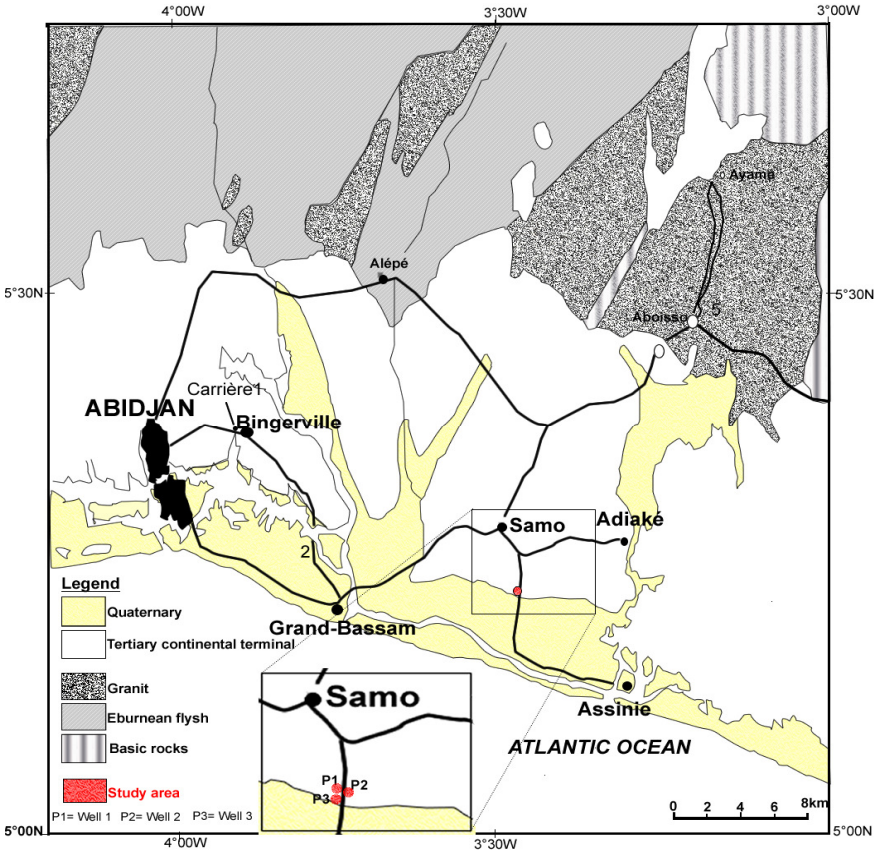
1. Context and Objectives of the Study

The study area is a very faded outcrop of Tertiary and Quaternary formations located on Samo to Assinie road (Fig.1). One of the rare palynological studies of this outcrop has been undertaken in 1983 by Simon and others and showed a rich palynoflora dominated by dinocysts. Palynofloral associations identified and described revealed the Upper Eocene within the bituminous dark clays. These dark levels are covered (in discordance) by variegated Mio-Pliocene clays deposits of the so called <<Continental Terminal>> series (Tessier et al, 1975).

Since a few years, this outcrop is periodically described in lithostratigraphical point of view by students of Marine Geology and Sedimentology Laboratory of University of Cocody.

But the very strong deterioration of the outcrops during these last twenty years, led us to dig in the beginning of 2008, three wells P1, P2 and P3 on and in proximity of this outcrop, in order to follow in subsurface, lithological variations, become impossible on the surface.

Figure 1: Location map of the studied perimeter in Samo area



The coordinates of these three wells of 11 m maximum final depth are indicated on table I.

Table I: Geographical coordinates, diameters and final depth of the wells P1, P2 and P3

Well	Longitude W	Latitude N	Altitude (m)	Diameter (m)	Final depth
P1	03°28'32''	05°13'38''	44	1.5	5.3
P2	03°28'37''	05°13'38''	41	1.5	6.3
P3	03°28'39''	05°13'28''	43	1.5	7.5

The main objective of the study of this outcrop is the revision of this former palynological analysis realized only on outcrops in 1983 by Simon and others, by considering levels deeper in continuity downstairs with those outcrops. This study would, in the long term, confirm or not the existence of a stratigraphical hiatus between the bituminous black deposits and the levels of Mio-Pliocene age consisting of multi-coloured clays. These palynological analyses are in the course of execution.

These present preliminary results relate to mineralogical studies of the argillaceous fractions of various layers crossed by the three wells. They aim to better characterizing these clays whose lithology, colors and nature vary quickly.

After a short presentation of the geological settings of Côte d'Ivoire sedimentary basin, materials and adopted analytical methods, so that the results of the analyses are exposed. Then the sedimentary context of the analyzed deposits is discussed.

2. Geological Settings

The geological history of Côte d'Ivoire sedimentary basin is related to the opening and expansion of the South Atlantic, was formed following the intracratonic divergence of Benue rift, during Lower Cretaceous (Digbehi, 1987; Aka, 1991; Chierici, 1996; Benkhelil et al, 1998; Pickett and Allerton, 1998; Marcano et al, 1998). The sedimentary evolution of the basin of Côte d'Ivoire proceeded according to four principal phases described by Digbehi (1987) then by Chierici (1996). The stratigraphy of this basin, generally well-known starting from drillings, is established using the microfaunas (Lys, 1961; Dufaure and Tastet, 1984; Digbehi et al, 1994; N'da et al, 1995; St-Marc and N'da, 1997; Goua, 1997; Digbehi et al, 1997; Bellier, 1998; Holbourn and Moullade, 1998; Moullade et al, 1998).

The palynological studies date from 1960 and continue (Jardiné and Magloire, 1965; Reyre and Tea-Yassi, 1981; Simon et al, 1983; Medus and Paradis, 1987; Masure et al, 1996, 1998; Digbehi et al, 1996; Goua 1997; Digbehi et al, 1997; Tea-yassi et al, 1999).

In the plan purely sedimenttological, data are not very frequent (Charpy and Nahon, 1978;Digbehi, 1987; Aka, 1991; Klasz and Klasz, 1992; Mondé, 1997; 2004; Strand, 1998).

3. Materials and Analytical Methods

The samples studied in this work result from cuttings yield by three wells carried out with the PK 8.5 km on Samo-Assinie road. Two aspects of the sedimentological study are approached in this work related to 50 samples of cuttings taken along three wells:

3.1. Lithological Study

On the field, missions carried out on the perimeter of study made it possible to raise and describe the various facies of deterioration of the outcrop of the clayey sand extraction career studied. Many photographs taken in this career are commented. Then the three wells whose samples are analyzed in this work are dug. In the second time, at the laboratory, after a visual lithological description of the samples taken on the fields, approximately 40 grams of each one is washed through four sieves of

meshes 500, 250, 125 and 63 microns. The refusal of each sieve are dried and sorted with the binocular microscope, for a finer description of the residues (illustrated elements, dominant and accessory minerals) which will specify visual lithological description.

3.2. Mineralogical Study

Difractograms were done to the mineralogical study in 54 natural samples with a Rigaku D-max IIIC, X-ray diffractometer with Cu Kα radiation and a graphite monochromator operated at 35 kV and 15 mA were used. The results were compared with the ICDD files and the database.

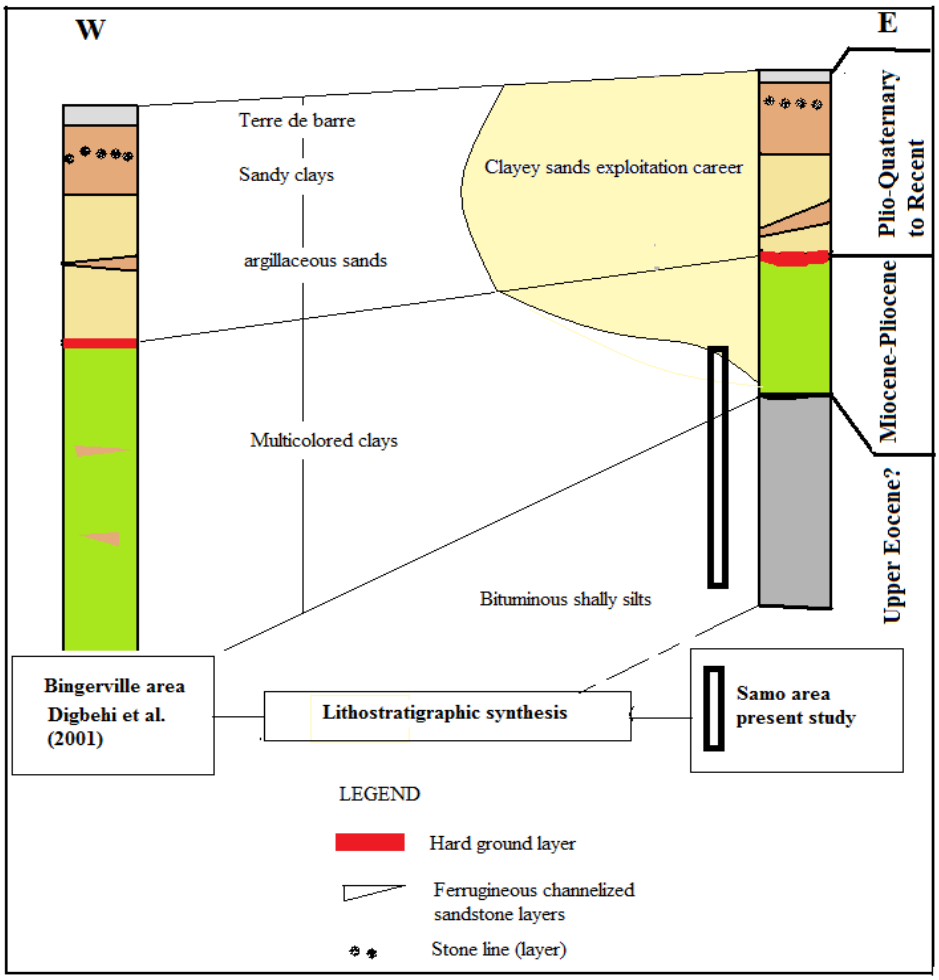
4. Results

4.1. Lithology

The lithotologic column of the deposits of Mio-Plio-Quaternary age, outcroping in the terrestrial part of the Côte d'Ivoire basin, had been described by Digbehi et al, (2001) in Bingerville area, around Abidjan (Fig.2).

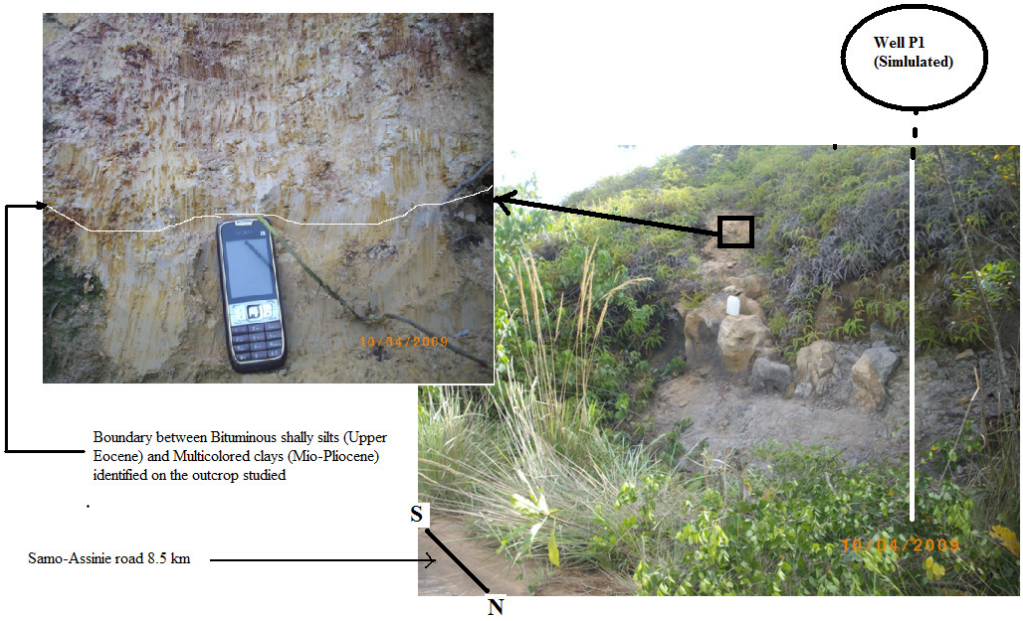
In the present career of extraction of ochres clayey sand (located at 8,5k of Samo), the sequence of the deposit was reconstituted (Fig.2) and then described some facies even for levels not studied in this work. But only have been studied in mineralogical point of view the sections crossed by wells.

Figure 2: A compared lithostratigraphic synthesis of Bingerville area (Digbehi et al, 2001) and Samo area (present study) showing the possible stratigraphic hiatus between Mio-Pliocene and Upper Eocene?.



Photograph 1 indicates the narrowness of the outcrop of the bituminous shally silts (main object of this study). The need for drilling the P1 well (and the two others) lies in impossibility of finding on the surface, of the healthy and nonfaded sediments.

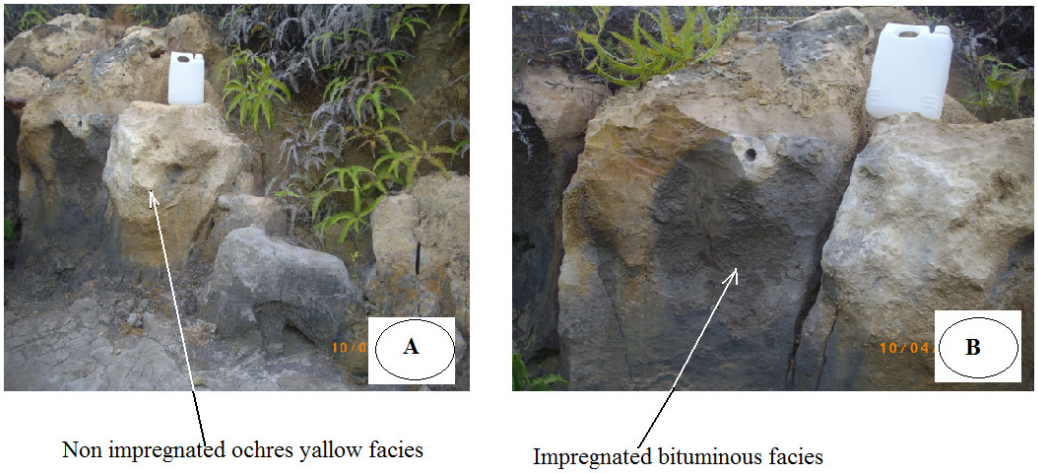
Photograph 1: The outcrop Pk 8.5 km on Samo-Assinie road and stimulated well P1. It shows the boundaray between the Upper Eocene bituminous shally silts and the Mio-Pliocene multicolored clays.



This limit would mean that there exists on this outcrop, a stratigraphic discordance between the bituminous shally silts deposits of the Upper Eocene and the subjacent multi-coloured layers, suggesting therefore the lack of Oligocene.

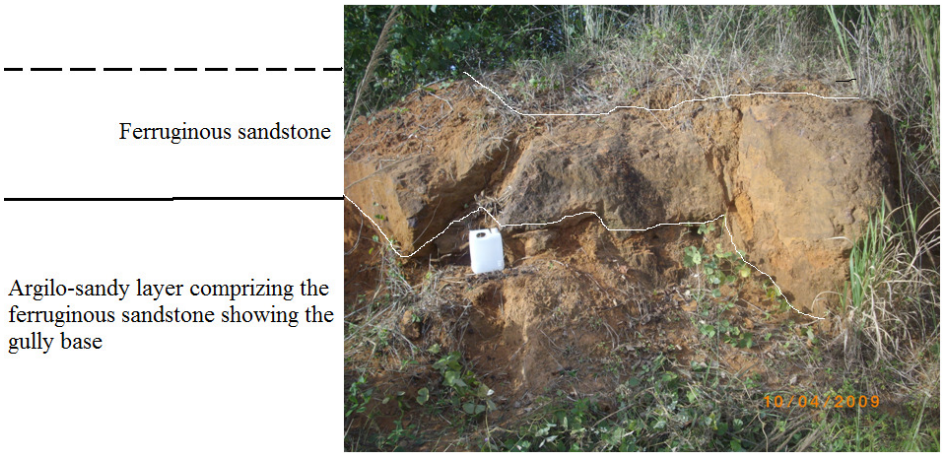
The bituminous impregnations observed on the outcrop (Photo 2A) clearly slice with the ochres yellow facies of these silteous clays of which the blocks show signs of a vigorous deterioration (Photo 2B)

Photograph 2: Outcrops showing impregnated and non impregnated shally silts vigorously deterioted, on Pk 8.5 km Samo-Assinie road.



In the ochres argilo-sandy facies of Mio-Pliocene-Quaternary age, the ferruginous sandstone pluricentimetric layers of fluvial origin (Digbehi et al, 2001) are sometimes strongly channelized, wilth gully base (photo 3).

Photograph 3: Outcrop of the argilo-sandy layers showing the ferruginous sandstone with gully base.

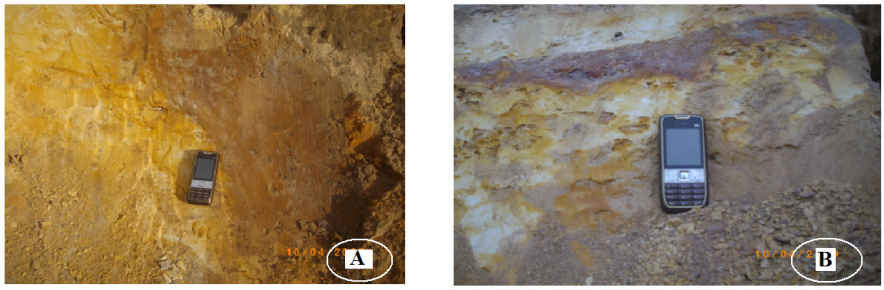


The granulometric facies of these sandy levels are also variable according to the places (Photo 4).

Photograph 4: Variabiliy of color and structure in ferruginous sandstones in the outcrop studied on Pk 8.5 km on Samo-Assinie road

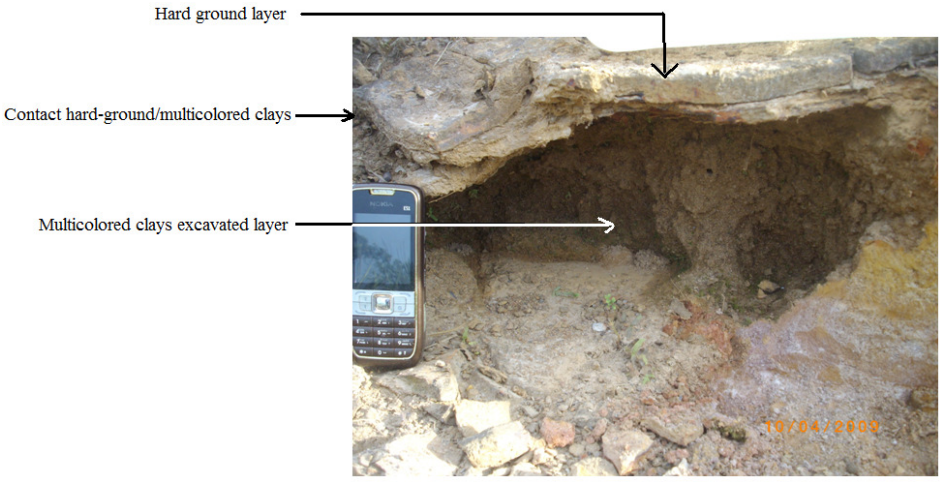
The faded facies of Mio-Pliocene are variable in the career of exploitation of the ochres clayey sands. They are sometimes marked by ferruginous dominance (iron hydroxide and iron oxides photo 5A), but sometimes in frank alternation of purplished levels (iron, photo 5B), white color (kaolinite or leaching of de iron?, 5B) and/or yellow color (alumina, 5B)

Photograph 5: Variability of color through the Mio-Pliocene deposits on the outcrop studied on Samo-Assinie road Pk 8.5km



At the top of the multicolored clays levels, hardened surfaces (hard ground) made up of centimetric levels of ferruginized clays (Photography 6) traduce a temporary suspension of sedimentation at the end of Mio-Pliocene.

Photograph 6: One sector of the outcrop showing the overlying hard-ground and the mostly excavated multicolored Mio-Pliocene layer.



Three lithological units are described in each well.

4.1.1. Well P1

Upper unit (0 - 2.40m). It corresponds to the lateritic sandy and argillaceous cover, containing frequent ferruginous concretions. The grains of sand are very fine to rarely coarse, angular to rounded shape and translucent. It comprises fine centimetric ferruginous sandstone layers with very fine grains.

Mediun unit (2.40 - 3.30m). It consists of ochres clayey sands, with fine layers of sandstone and multi-coloured clays. The quartz grains are translucent, fine to medium, moderately sorted. Argillaceous layers are sometimes impregnated of bitumen and comprises carbon remains.

Lower unit (3.30 - 5.30m). It is mainly composed of bituminous shally silts, rich in pyrite and carbon remains. The sandy fraction comprises some angular coarse quartz grains with round-offs.

4.1.2. Well P2

Upper unit (0-2.05m). It consists of lateritic clayey sands with ferruginous concretions. Sand grains are fine, angular to round shaped and translucent.

Medium unit (2.05-3.55m). It is composed of ochre clayey sands comprising fine multi-coloured clay and ferruginous sandstone layers. The grains of sand are fine to medium size, angular to rounded shape and translucent.

Lower unit (3.55-6.3m). It is composed of bituminous silts rich in pyrite, carbon remains and glauconite (?) are fine to coarse size, angular to rounded shape and translucent.

4.1.3. Well 3

Upper unit (0-2.05m). It consists of lateritic clayey sands with ferruginous concretions. The grains of sand are fine, angular to rounded shape and translucent.

Medium unit (2.05-4.50m). It is composed of ochre clayey sands comprising fine multi-coloured clay and ferruginous sandstone layers. The grains of sand are fine to coarse, angular to rounded and translucent. Carbon remains and pyrite are rare.

Lower unit (4.50-7.5m). It is composed of argillaceous bituminous silts rich in pyrite, carbon remains and glauconite. Sands are fine to coarse, angular to rounded and translucent.

In total, each well comprised the three units. Only the presence of the glauconite(?) and the pyrite in the Lower unit of wells P2 and P3 constitutes the notable difference in the sedimentological plan.

Figure 3 summarizes the lithological correlation between the three wells. This profile indicates the identity of three different unties from one to another well.The main difference being the presence of pyrite and glauconite within the third lower layers in P2 and P3.

4.2. Mineralogical Study

Difractograms were done between 3 and 60º (2θ). The database was used to identify the clay minerals. A relative quantitative analysis was done using the reflexions intensities of the principal minerals presents. The results were compared with the software.

In the figure 4 the results of samples of the 3 well at the same levels are compared.

According to the interpretations of the various diffractograms of the three wells, the samples are constituted principally by quartz with kaolinite and in same cases minor amount of illite.

Figure 3: Lithological correlation profile between the three wells (P1, P2 and P3) studied on Samo-Assinie road PS.

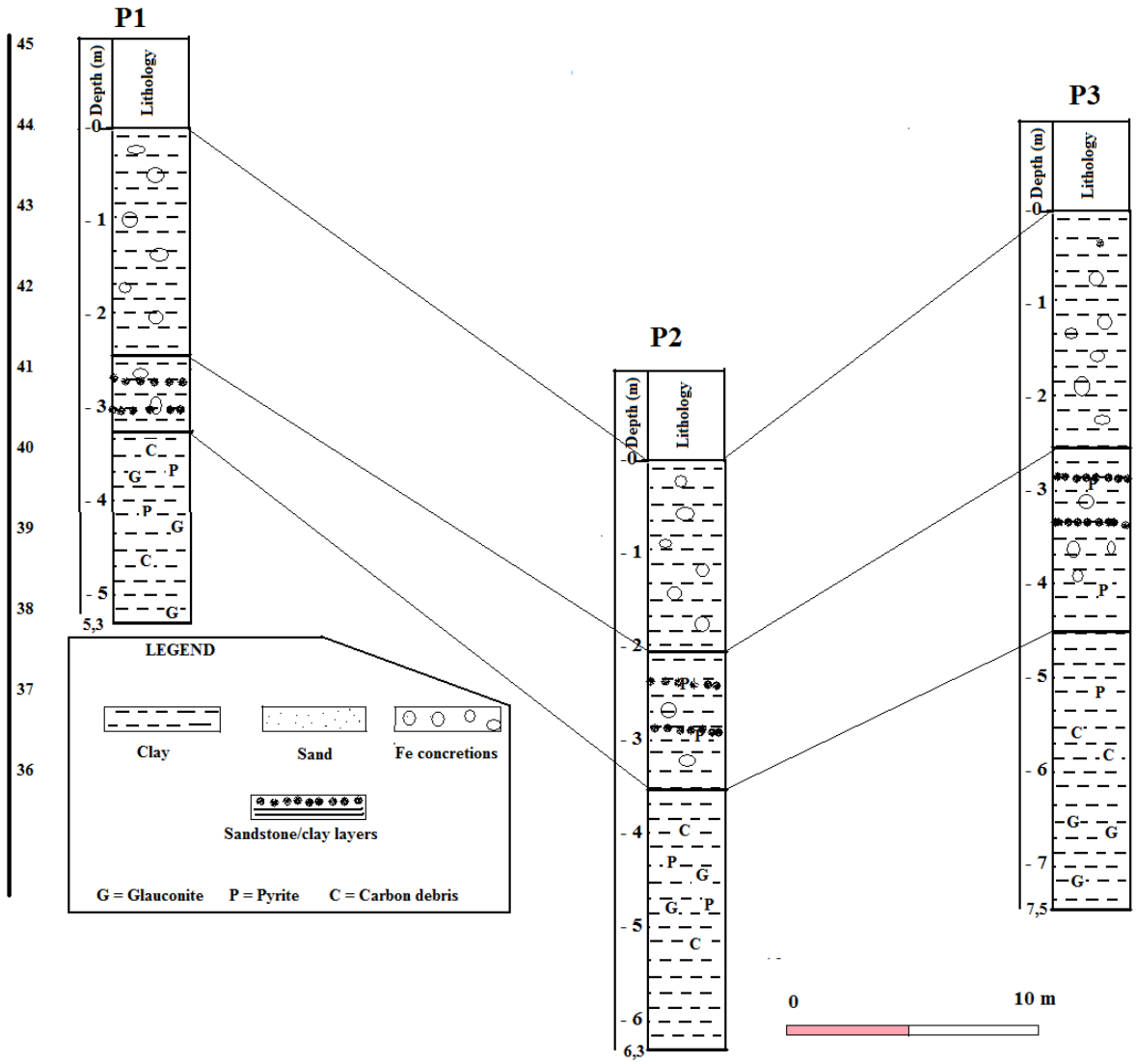
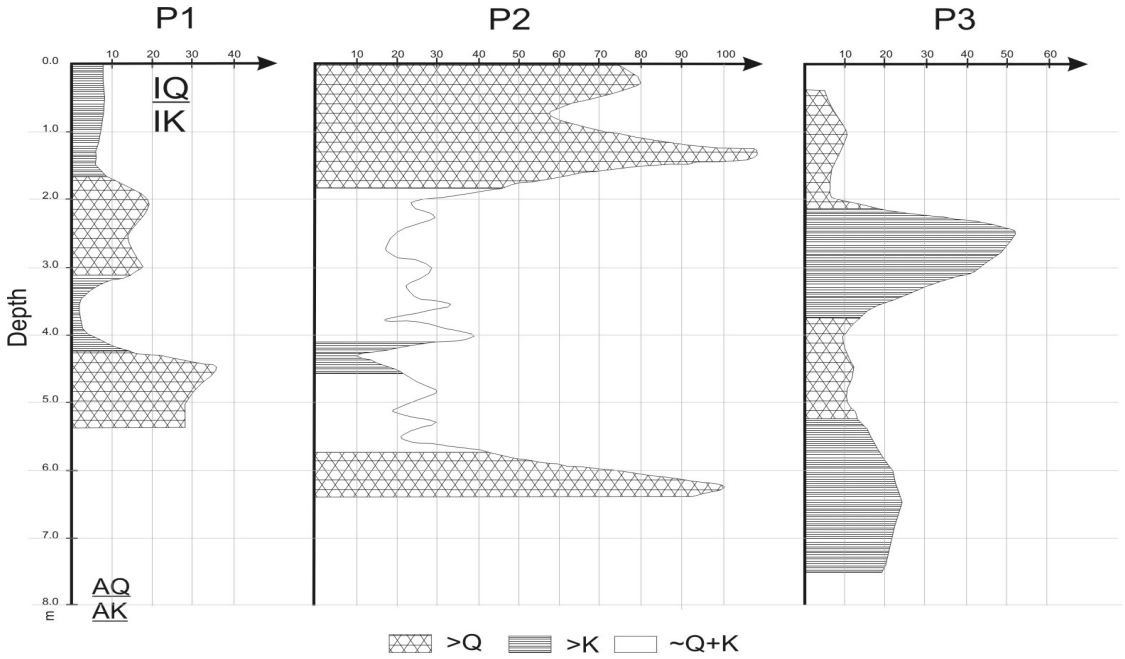


Figure 4 indicates a graphic with the results of the interpretation of the mineralogical composition of the samples determined by XRD. The graphic was drawn using the ratio in the intensity of the reflexions and the area between kaolin and quartz in the difractograms.

The main criteria are the use of the ratio between the intensity of the peaks. The mica present is illite 1M.

Figure 4: Comments of data of the three wells



In the well P1, the amount of hematite is high between 0.2 to 1.5 meters. This content is increased in the sample 3.0 and at the end of the well. The goethite has elevated concentration until the 4.0 meters. And their presence is near 0 from 4.25 to the end of the well. In the well P2, hematite was identify only between 4.05 and 5.15 meters. Goethite couldn't be identifying in any sample.

At 4.05 m kalinite ($KAl(SO_4)_2.11H_2O$ and/or mendocite $NaAl(SO_4)_2.11H_2O$ were identified. In the well P3, hematite and goethite are identifying only in the upper levels (until 3.0 m). From 5.0 meters to the end of the well it was identified pyrite.

P1 and P3 are comparable. They have two zones with more kaolin and two zones principally with quartz. P2 only has a zone with kaolin predominant and two with quartz principally. Illite is in practically all the samples. In the yhree wells between approximated the central zone and the end, there are organic mater.

5. Discussions

The discussion of the results obtained in this work concerns as well the mineralogy as depositional environment of studied sediments. All the minerals described here already were subject of many works. They are mainly kaolinite and quartz and incidentally illite (*1M*). In the same way, the iron rich silicate minerals met are primarily hematite (frequent) and goethite. The pyrite, an iron sulphide is only met in well (P3). Kaolinite $[Si_2O_5]$ Al_2 $(OH)_4$ comes from partial hydrolysis of k-feldspar and more generally from the alteration of acid rocks rich in feldspar (Plagioclases). It appears almost at the end of the Alterites chain, the ultimate stage is then, under more thirst producing climate, the release of free alumina of gibbsite form (Al (OH) 3), mineral constitutive of bauxite. But the absence of mica spangles in the washed residues shows that this kaolinite would have been redeposited starting from a relatively distant primary education layer.

The illite KAl_2 [Si_4Al 0_{10}] (OH) 2.is the argillaceous mineral most widespread belongs to the mica group and which contains a little less potassium but more water than muscovite. Illite testifies depositional environment less washed than those where kaolinite develops. In the chain of the altrites, its place is thus before kaolinite. The glauconite ((K, Na) 2 (Fe^{3+}, Fe^{2+}, Al, Mg)$_4$ [Si_6 (Si, Al) $_2O_{20}$] $(OH)_4$) is a illite rich in iron. It is the weak presence of the illite in these deposits which probably induces that of the glauconite

Some works evoke detrital or authigenic origin of these clay minerals in particular kaolinite (Cagatay et al, 1996; Hart et al, 2002; Wilson, 2004; Wilson et al, 2006; Sandler et al, 2006; Balan et al, 2007; Bauluz et al, 2008). Other authors indicate the mechanisms of their formation (Eberl, 1984; Marfil et al, 2005; Fritsch et al, 2005) and finally, others describe mineral associations characteristic of various depositional environments (Angelica et al, 2001). This origin seems sometimes controversial (Meunier and Abderrazak, 2004).

The mineralogical analysis did not reveal any glauconite peaks, whereas small granules of greenish color observed within washed residues, were assimilated to glauconite in lithological plan, in particular in the third lower part of wells P2 and P3. These granules generally described as glauconite in other works were interpreted as indicators of more or less deeper and badly oxygenated marine conditions either in Côte d'Ivoire (Digbehi et al, 1994; 1996) or elsewhere (Pratt, 1962; Hugget and Gale, 1997; Lim et al, 2000; Hesselbo and Hugget, 2001; Hassan and El-Shall, 2004; Rousset et al, 2004; Abderrazak et al, 2005). Some rare exceptions described in litterature (Porrenga, 1968) indicate glauconites formed under non marine conditions. But the non identification glauconite peaks leads to compare these green grains described in our samples to the verdine facies of authigenic origin, highlighted in basins of the world (RAO, 1990; Rao et al.1993; Ku and Walter, 2003) and even off Côte d'Ivoire (Odin et al, 1987). These verdine facies develop, according to these authors, on the continent-ocean boundary, close to an iron rich source, with depths ranging between 5 and 60m.

We conclude that these green granules met within the third lower part of studied wells, could be regarded as deposited under shallow marine conditions. Illite is represented by its polytype *1M*, that, according to rare consulted works (Grathoff and Moore, 2002; Aldega and Eberl, 2005) is of possibly diagenetic origin. In addition, some of iron rich silicate minerals such as hematite and goethite are identified. The first is relatively abundant in the upper part (Mio-Plio-Quaternary) and sporadic while the second is rare and concentrated in the third lower part of well P3 (Upper Eocene?). However, according to work of Schwertmann et al. (1977), hematite and goethite develop in tropical and subtropical zone. For other authors (Weibel and Grobety, 1999; **Gualtieri** and Venturella, 1999), a pseudomorphous transformation of goethite (α-FeO (OH)) into hematite (Fe_2O_3) must have taken place during increased burial phase. It is the probable reason which explains this staging of these two minerals within the sequences studied.

The constant presence of the organic matter of probably algal origin represented by a rich dinocyst palynoflora (SIMON et al, 1983) associated with pyrite towards the base of P3 (Upper Eocene?), evokes a depositional environment relatively confined and badly oxygenated. The preponderance of sub-rangular quartz grains traduces a relatively proximal origin of studied sediments, probably of the inland rocks.

6. Conclusion

The argillaceous fractions of 54 samples **prov**ided by three wells carried out in Samo area, related to the mineralogical studies of clays of the levels crossed by these wells. The Mio-Pliocene-Quaternary faded deposits outcropped have only been described under their purely petrographic and structural aspects.

The results indicate that analyzed samples are mainly made up of quartz and kaolinite with a small proportion of illite. In the upper part sequence identified like the Continental terminal, the

deposits are primarily made up of quartz and kaolinite. In bituminous gray clays of the lower section, the samples are dominated by quartz and the illite.

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