Sedimentology, Geochemistry and Palynofacies of Onshore Formations in Côte d'Ivoire: Case of the Dabou and Abidjan Sectors

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***Abstract*—** Twelve (12) samples of cuttings from two wells in the Ivorian onshore sedimentary basin were used in the present work. These samples were subjected to sedimentological, geochemical and palynofacies studies in order to understand the effect of the variation of the rate of chemical elements and the nature of sediments on the depositional environments. The sedimentological results show that these lutites are predominantly silty in nature with a low clay content in the well SAN1F4. Organic geochemistry of these sediments revealed a very low organic matter (OM) content in the SAN1F4 deposits (7%). Geochemistry shows an enrichment of trace elements, markers of anoxic conditions (As, Cu, Mo, U, Zn), these deposits rich in organic matter characterize anoxic deposit environments. At the palynofacies level, the presence of both inertinites and dinokysts in wells SAN1F4 indicates a marine environment under continental influence. Spores, pollen grains, and phytoclasts identified a continental environment in the well SAN2P5. Sediments with little clay (SAN1F4) are less favorable for the preservation of organic matter. On the other hand, sediments with high silt content (SAN2P5) are favorable for the preservation of organic matter.

***Keywords*—** Geochemistry, Palynofacies, palynology, sedimentology.

I. INTRODUCTION

The onshore basin has also been the subject of several studies, the most recent of which are those of Akobé(2010), Gbangbot (2012), Yao (2012), Assalé (2013), Bié (2013) and Guédé (2016). These works, although few in number, have nevertheless made it possible to characterize the onshore basin at the sedimentological, biostratigraphic and geochemical levels.

In addition, recent hydraulic drilling work in the Bingerville sectors should help to understand better the sedimentary cover of this onshore basin. Indeed one could wonder about their lithological nature and their concentration in organic matter in this recent cover.

In addition, be able to correlate biostratigraphic, geochemical and sedimentological levels with other levels of a similar nature observed in outcrop in certain parts of the onshore basin.

The objective of this work is to characterize the fine sediments of dark color in terms of sedimentology, geochemistry and palynofaciology of the formations in the sectors of Dabou and Abidjan (Attécoubé).

II. MATERIALS AND METHODS

A. Presentation of the study zone

The study area is located in the onshore part of the Ivorian sedimentary basin, precisely in the cities of Dabou and Abidjan (Attécoubé). The SAN1F4 well has been positioned in the city of Dabou and the SAN2P5 well is located in the city of Abidjan precisely in Attécoubé (Figure 1).

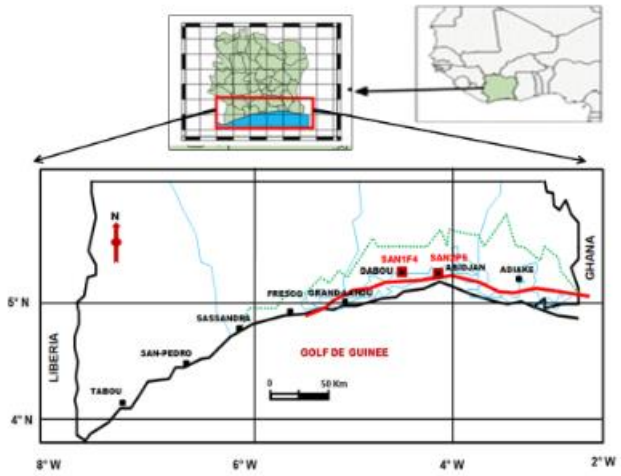

Figure 1: *Localisation Card of studies wells*

B. Material and method of palynological study

Twelve (12) samples from the cuttings of two sites (Dabou and Attécoubé) are used for the palynological and sedimentological analyses.

Twenty grammes (20g) of samples are treated with concentrated acids (hydrochloric and hydrofluoric) under an extractor hood and then filtered using a 15µm cloth filter.

The washed material is stored in aqueous phase in pillboxes. Then they are placed between blade and coverslip.

A light microscope coupled with a camera (brand Motic 300) and a reference slide, the England graticule, were used to study the palynological slides.

C. Material and method of geochemical study and the rate of organic matter

For this study, the samples are analyzed with XRF. This analysis consists of establishing relationships between the different chemical elements (major and trace elements) in order to determine the lithology (Si, Ca, Al) and the sediment deposition environment (Mo, U, Cu, Se, Zn)

The samples undergo a treatment that takes place in several steps: sampling, washing, drying-sieving, grinding, making pellets and XRF analysis. Making pellets consists of using aluminum cartridges in which 4g of powdered samples are mixed with 1g of a binder powder of CEREOX type.

This mixture is compressed under a pressure of up to 15 tonnes to form pellets 33 millimeters of diameter which will be used for a complete XRF analysis. After checking the stability of the XRF, the pellets are deposited one after the other in a specific order inside the device for chemical analysis.

III. RESULTS

A. Sedimentology

- Well SAN1F4 (120-121m et 182- 184m)

Figure 2 presents the lithology of the SAN1F4 well. It is composed mainly of clay, of moderately dark gray color, blackish gray.

They are firm, massive, slightly silty, slightly micromicaceous, with traces of glauconite. Accessory, carbonaceous micro-debris and mica flakes are observed.

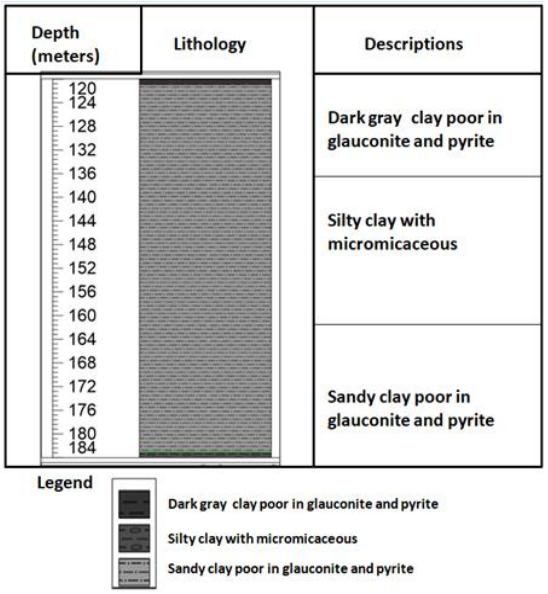

Figure 2: *Lithologic log of the SAN1F4 well*

- Well SAN2P5 (29m ; 32m ; 79m et 80m)

This well is made up of clay and siltstone: The clays are in low proportions. They are gray, slightly brownish, dark gray. They are slightly, silty, micromicaceous. Siltstones are in significant proportions. They are light gray, dark gray and present carbonaceous micro-debris with traces of pyrites (Figure 3).

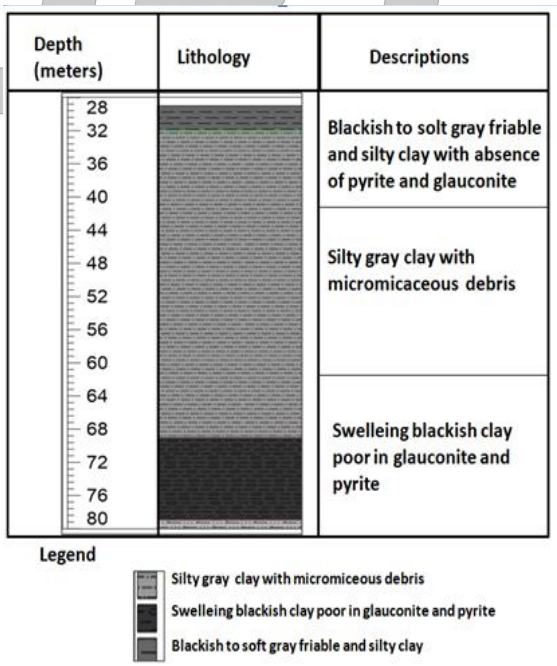

Figure 3: *Lithologic log of the SAN2P5 well*

B. Fine fraction analysis (figure 4)

The objective of this step is to know the nature or the composition of the lutites. The SAN1F4 well is composed of a high proportion of clays (41.5%). The

samples with the lowest clay content are observed in the SAN2P5 well. These proportions are 13% at most.

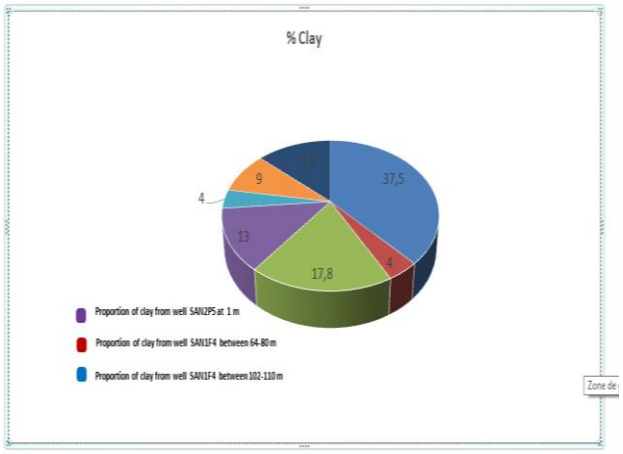

Figure 4: *Proportion of the clay fraction in the SAN1F4 and SAN2P5 wells according to the depth*

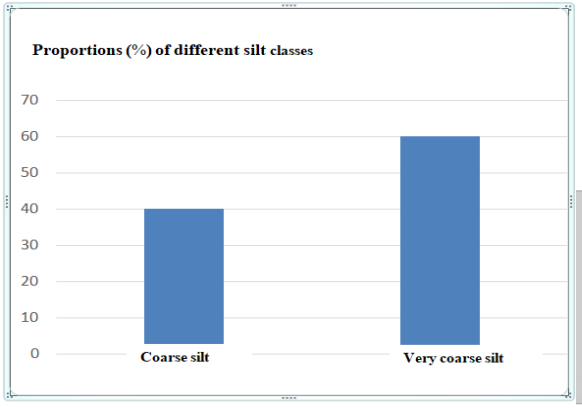

Figure 5: *Composition of silts in the SAN2P5 well*

We obtain the high proportion of clays in the SAN1F4 well, the SAN2P5 well contains a high concentration of

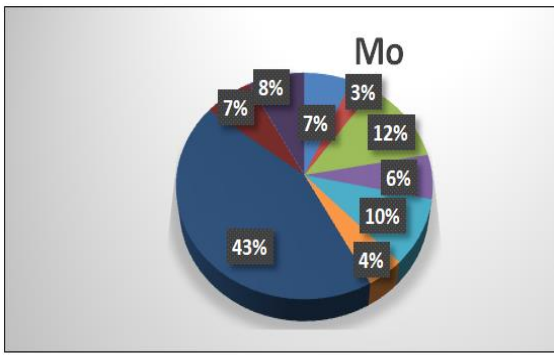

Figure 6: *Molybdenum (Mo) rate in the sediments of the SAN1F4 and SAN2P5 wells*

- The samples from the SAN1F4 well are low in Zinc (Zn) with a rate of 7%; those of the SAN2P5 well recorded the highest concentrations (38%).

silts. The variation in grain size of this fraction makes it possible to distinguish two subclasses, namely coarse silts and very coarse silts (Figure 5). Coarse silts are present at 40% and very coarse silts have a proportion of 60%.

Three subclasses of lutites have been highlighted indicating a sedimentation dominated by silty formations:

- subfissile gray clays, abundant in the SAN1F4 well;
- very coarse silts observed in all wells ;
- coarse silts recorded in the SAN2P5 well.

The analysis of the fine fraction highlights two subclasses of lutites, the second of which is subdivided into two other subclasses, which reflect the different deposit environments. The first subclass, dominated by clays, is rich in organic matter. It is mainly observed in the SAN1F4 well. This lithology reflects a calm deposition environment, locally disturbed by turbid currents (bottom current or nepheloid) allowing the deposition of coarser sediments.

C. Geochimical characterization

Variable proportions of chemical elements are recorded in the two wells SAN1F4 (Dabou) and SAN2P5 (Attécoubé). They are: Molubden (Mo), Zinc (Zn), Calcium (Ca), Uranium (U), Copper (Cu), Lead (Pb), Arsenic (As), Chromium (Cr), Vanadium (V) and Sulfur (S). The geochemical analysis shows that the samples from the SAN1F4 well are low in Molubden (Mo), i.e. 10% of the total concentration rate of the samples. The highest rate is recorded in the SAN2P5 well with 43% concentration at 80m (Figure 6).

- For calcium (Ca), the geochemical analysis reveals a concentration of 5% of Ca in the SAN1F4 well and 24% for the SAN2P5 well (Figure 7).

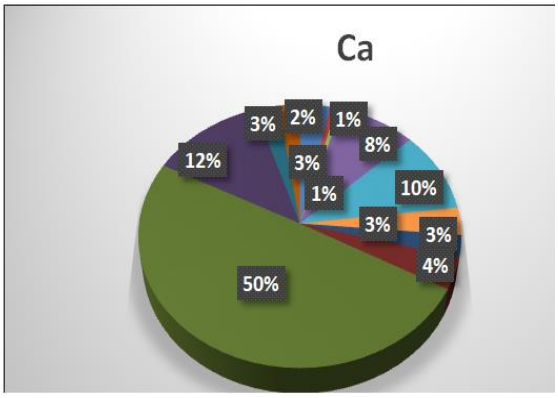

Figure 7: *Calcium (Ca) rate in the sediments of the SAN1F4 and SAN2P5 wells*

The results of the analyzes give a concentration of 31% Uranium (U) in the sediments of the SAN1F4 well. The highest rate is observed in the SAN2P5 well (43%).

- In the SAN1F4 well, the copper (Cu) concentration is 35% while the SAN2P5 well samples give 27% Cu.
- The lead (Pb) content in the SAN1F4 well is 23%. That of the SAN2P5 well is 32%.
- The results of the analysis show an average level of Arsenic (As) of 16% in the SAN1F4 well. The SAN2P5 well records a higher content of Arsenic which is 54%.
- For Chromium (Cr), the SAN1F4 well records 22% Cr. Well SAN2P5 contains a high rate of 33%.
- The analyzes indicate 23% Vanadium (V) for the samples from the SAN1F4 well. For the samples from the SAN2P5 well, the analysis gives higher proportions of 39%.
- The analyzes reveal a high concentration of Sulfur (S). The samples from the SAN1F4 well recorded a sulfur concentration of 24% and those from the SAN2P5 well 48%.

There is an enrichment in Ca reflecting the presence of carbonates (CaCo3) in certain levels. The Ca levels are high in the sediments of the SAN2P5 wells, however the content is lower in the SAN1F4 well. The presence of calcium carbonate in the SAN2P5 well indicates a calm, warm and shallow depositional environment. The high contents of U and V and the low presence of Mo reflect a suboxic to anoxic environment. This is the case of the SAN1F4 well. The high rate of U, V and Mo would reflect an euxinic environment at the water-sediment interface, as observed in the SAN2P5 well which records the highest rate of these elements.

The SAN2P5 well has higher levels of trace elements (U, Cu, As, Zn, Pb, Mo) than the SAN1F4 well. The significant presence of these elements suggests a deposition in an anoxic environment. These anoxic conditions are verified by the high rate of undegraded organic matter (OM) in this well. In the SAN1F4 well, the low concentration of trace elements and the presence of black clays, soft and poor in accessory minerals (pyrites and glauconites) indicate a shallow and calm marine deposit environment.

D. Rate of Organic Matter (Figure 8)

The analysis of the OM rate of the SAN2P5 well shows that these have the highest concentrations (75%) while the SAN1F4 well records a low OM concentration (2%).

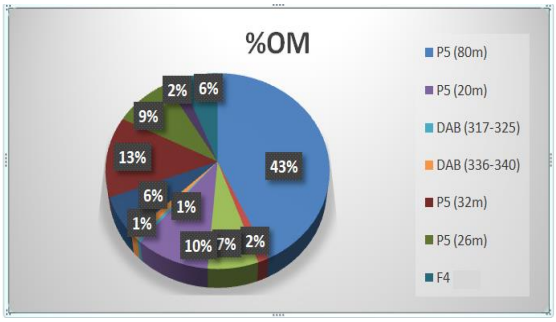

Figure 8: *Level of organic matter (OM) in the sediments of wells SAN1F4 and SAN2P5*

There are two types of organic matter, including the Exinite-Liptinite group and the Inertinite group. Two groups of macerals (coals) were observed. The samples from the SAN1F4 well indicate an abundance of AOM (Amorphous Organic Matter), weakly preserved in proportions of 60 to 100%, with low levels of humic OM (vitrinite and inertinite) generally carbonized. We find palynomorphs of marine and continental origin (Dinocyst, spores and pollen grains) indicating a modified environment.

In the SAN2P5 well, 50 to 70% of the total OM are essentially Exinite-Liptinites made up of palynomorphs of continental origin (spores, pollen grains), leaf cuticles and other plant secretions. The organic matter is well preserved and the high concentration of trace elements suggests an anoxic environment.

E. Palynofacies

F. Palynofacies of well SAN1F4

The organic matter observed is abundant and is dominated by inertinites, i.e. carbonized organic matter (Figure 9). Palynomorphs are mostly dinocysts (gonyaulacoids) and these palynomorphs are poorly preserved. The proportion of phytoclasts is very low at these depths. The presence of figured organic matter, dinocysts and the low rate of phytoclasts in the sediments suggests an environment of anoxic marine deposition. The presence of chitinoid basals of foraminifera and acritarchs confirm the marine conditions during sedimentation.

G. Palynofacies of well SAN2P5

In this well, the inertinite is in very low proportion (Figure 10), which indicates that the organic matter was deposited in an oxygenated environment. Organic matter is very rich in vitrinite; this vitrinite is essentially composed of weakly carbonized amorphous organic matter, massive in shape, pink-brown in color and represents about 70% of the vitrinite. This amorphous organic matter is humiferous in nature, and confirms its terrestrial origin.

The phytoclasts present have small size, automorphic and of medium proportion (about 30%). The concentration of this organic matter in translucent phytoclasts and low content in carbonized matter indicates an oxygen-rich (oxic) depositional environment. The palynomorphs observed are essentially made up of spores and pollen grains (about 99%) and 1% of dinocysts. The predominance of spores and pollen grains and phytoclasts reflects a continental environment.

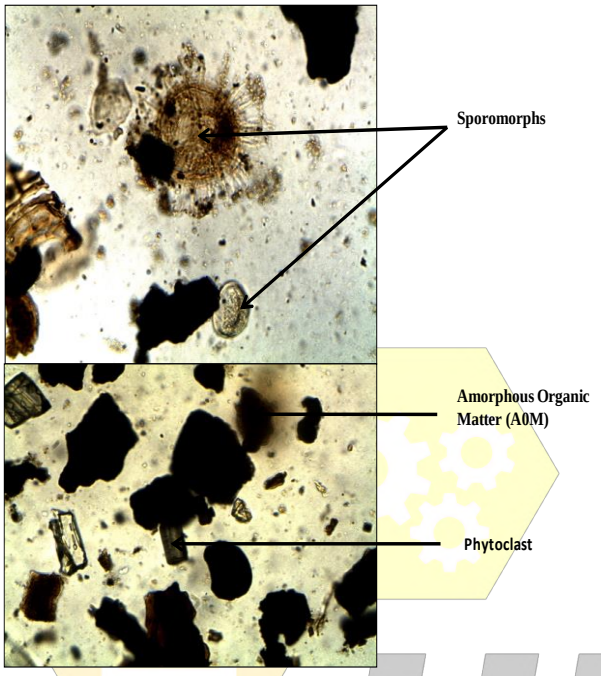

Figure 9: *Palynofacies of well SAN1F4*

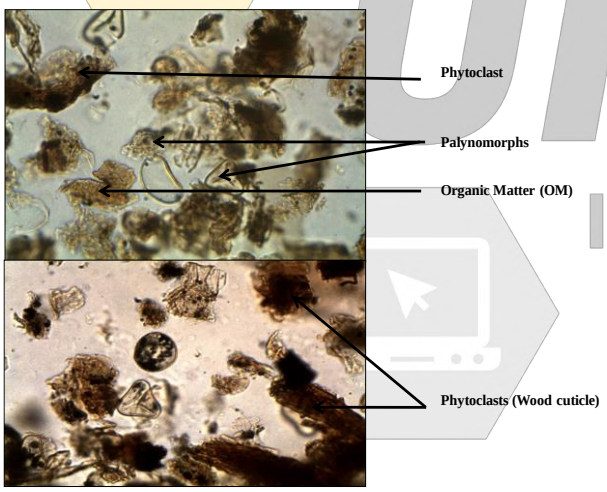

Figure 10: *Palynofacies of well SAN2P5*

IV. DISCUSSION

The sedimentological study made it possible to distinguish two lithologies. The SAN1F4 well is essentially composed of clays with a small proportion of siltstone. This gives a silty-clay lithology. However, the sediments of the SAN2P5 well are dominated by silts (coarse and very coarse silts), which characterize a low-energy environment. These results agree with those of Sombo (2002) who had described, west of Abidjan, the presence of clay, silt, shale or carbonate type sediments, deposited in a stable low-energy environment. These deposits contain very low proportions of glauconite and pyrite, suggesting a relatively deep and anoxic marine environment and notably outer platform deposits. These results are in agreement with those of Bamba et al. (2011).

The geochemical study reveals a high concentration of trace elements in the SAN2P5 well with a high level of group 1 organic matter. This reflects an anoxic marine environment in accordance with the work of Tribovillard, (2006), for whom these levels would reflect a suboxic to anoxic environment. These analyzes reveal low proportions of chemical elements in the sediments of the SAN1F4 well with low levels of carbonized amorphous organic matter. According to Ouattara, 2018, this could be due to the type of OM deposited which would be poor in hydrogen responsible for the fluorescence.

The palynofacies study of the fine fractions made it possible to highlight two types of palynofacies: a marine palynofacies and a continental palynofacies. The abundance of organic matter rich in vitrinites, phytoclasts, palynomorphs of continental origin (spores and pollen grains) and the absence of dinocysts in the SAN2P5 well suggests a continental depositional environment. According to Gbangbot (2012), an organic matter rich in translucent phytoclasts and poor in carbonized matter indicates an environment of oxic deposition generally reflecting an open marine environment. However, when the rate of spores and pollen grains is much higher than the rate of marine microplanktons, this indicates a continental or estuarine type deposit environment.

At the SAN1F4 well, the sediments are characterized by a high rate of amorphous organic matter (AOM) and carbonized phytoclasts. The observed palynomorphs are dominated by dinocysts. These indices suggest an oxygen-poor marine environment. These results agree with those of Bié (2013) for whom the formations of the Abidjan margin presenting these same characteristics are found in oxic to anoxic marginal marine environments.

V. CONCLUSION

At the end of this work, we have at the sedimentological level two subclasses of lutite: The subclass of silts which are more abundant in the SAN2P5 well in Attécoubé and the subclass of silty-clay sediments dominant in the

SAN1F4 well in Dabou. Geochemically, the samples from the SAN2P5 well are richer in trace elements sensitive to redox conditions with organic matter dominated by exinite-liptinites characterizing an anoxic continental deposit environment. The sediments from the SAN1F4 well are poor in trace elements. The organic matter observed in these wells is dominated by inertinites, thus indicating a marine deposition environment under continental influence.

From a palynofaciological point of view, the high concentration of amorphous organic matter (AOM) of marine origin and the high proportion of dinocysts in the SAN1F4 well indicate a marine deposit environment. However, the SAN2P5 well presents organic matter dominated by phytoclasts and palynomorphs (spores and pollen grains) of continental origin, thus characterizing a continental environment. Finally, we note that clayey sediments that are not very rich in trace elements are unfavorable to the conservation of organic matter and palynomorphs, while silty deposits very rich in trace elements are more favorable to the conservation of organic matter and palynomorphs.

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