EARTH SCIENCES

PALYNOFACIES AND THERMAL MATURITY ANALYSIS OF BZ-1 AND BZ-2 WELLS, NIGER DELTA BASIN, NIGERIA.

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ABSTRACT

The palynofacies and thermal maturity analysis have been carried out on one hundred and twenty composited ditch cuttings samples from BZ-1 and BZ-2 wells, offshore Niger Delta, Nigeria. The hydrocarbon potential of these sediments recovered from both wells were estimated on the basis of palynofacies analysis and thermal alteration index (TAI) values based on the palynomorphs (spore or pollen) colouration.The palynofacies analysis of the two wells reveals rich organic matter preservation, with amorphous organic matter and phytoclasts constituting the bulk of the total organic matter and low palynomorphs. The relative ratio and distribution of the palynofacies across the wells shows that the formation is gas laden and very little oil prospect. The thermal maturity deduced from the optical examination of the organic matter revealed that well BZ-1 sediments are immature while those of well BZ-2 are immature to slightly mature (TAI between - 2 and + 2 and SCI between 3 and 5).The lithological description of the analyzed sections of both wells revealed a clastic sequence composed of alternating sand and shale sequences with accessory shell fragments, carbonaceous detritus, ferruginous materials, mica flakes, pyrites and rare glauconite.

Keywords: *Palynofacies, Thermal maturity, hydrocarbon potential and Niger Delta.*

INTRODUCTION

The Niger Delta is a major hydrocarbon producing basin in Nigeria where intensive exploration and exploitation activities have been on since early 1960's owing to the discovery of commercial oil in Oloibiri-1well in 1956 (Reijers *et al., 1*996). Since then, exploration and production activities have moved from the near shore into the shallow-water offshore and presently into the deep-water.This region has been described as the seat of oil and gas production in the country and placing the country as one of the top ten leading oil producing nation in the world is no longer news (Egberongbe *et al*., 2006). The tremendous increase in the world population over the last two decades and high industrial development has led to increase demand of petroleum products. The increasing demand of these products has significantly affected the pricing in the world market. Although, the recent shale oil discovery coupled with the economy recession have drastically reduced the price of the petroleum products. With the reduced price, the cheaper way of hydrocarbon assessment and discovery in ageing field and new frontier basin has preoccupied the geologist and engineers.Thermal maturity and paleoenvironment of deposition are very important parameters in evaluating the hydrocarbon potentials of source.Among the multi-tools used in assessing these parameters, palynofacies analysis is a very cheap and effective method of optical screening and semi qualitative control for geochemical bulk rock parameters.Hence, this study isaimed atevaluating the hydrocarbon potentials of the studied sections (BZ-1 and BZ-2)using palynofacies and to establish the paleoenvironment of deposition.The study area fall within the shallow offshore Niger Delta (Fig 1), the coordinate and the name of the wells were not made available for confidential reasons by the oil companies.

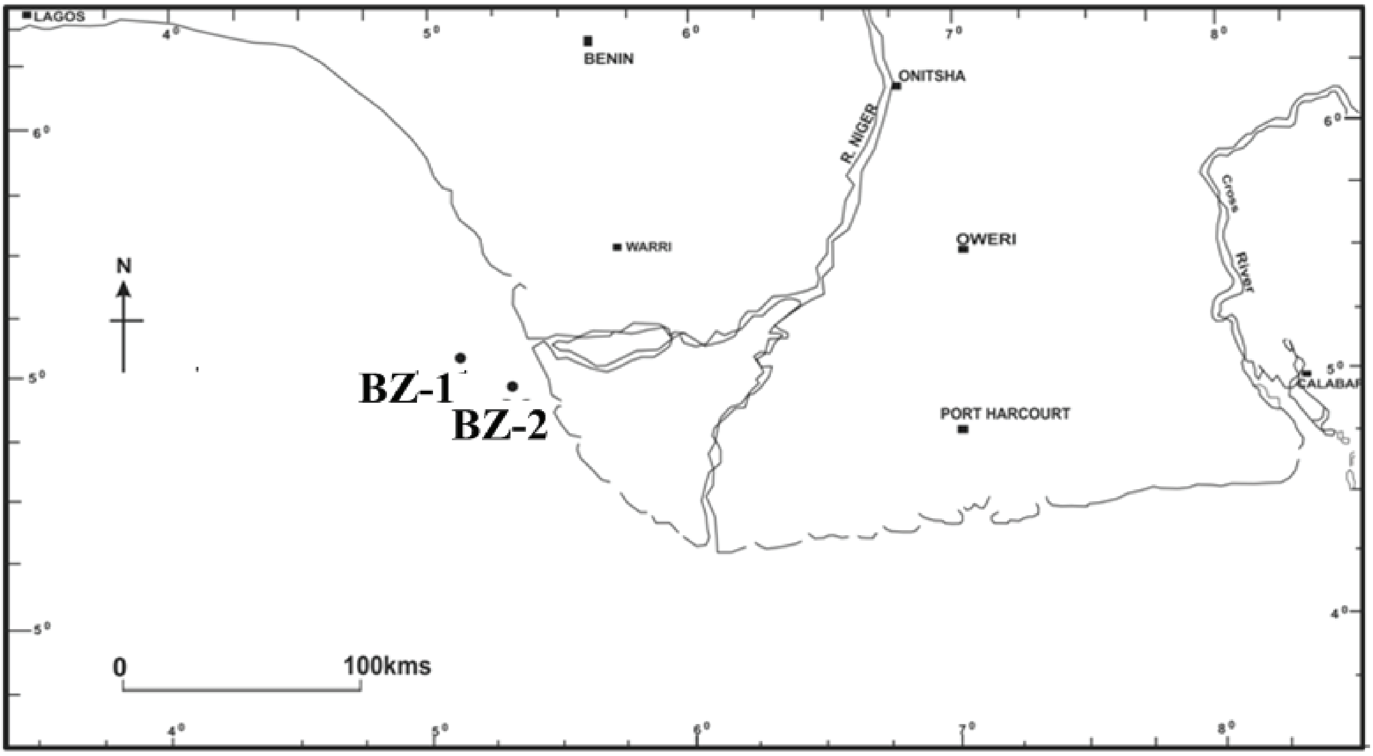

Fig. 1: Map showing the location of well BZ-1 and BZ-2 offshore Niger Delta.

MATERIALS AND METHODS

The present studies is based on one hundred and twenty (120) ditch cuttings ranging in depth from 2105m to 3305m and 1000m to 2220m samples from BZ-1 and BZ-2 wells, shallow offshore, Niger Delta. About fifty grams of each sample were washed with soap and water through 63 micron mesh sieve and oven dried at about 80^0C. Lithologic descriptions were undertaken by observation of the samples under the Olympus stereoscopic microscope and by considering the textural parameters. The textural parameters been considered are grain size, sorting, colour, lithology, post depositional effects such as ferruginization, presence of accessory minerals and fossils contents. The samples were tested with 10% hydrochloric acid to determine the presence of calcareous materials.

For the palynofacies preparation, twenty five grams of each sample were subjected to maceration and dissolved with hydrochloric acid (HCl) and hydrofluoric acid (HF). The organic matter was separated in heavy mineral ($ZnBr_2$) solution(Faegri and Iversen1989). The organic residue were not oxidized or sieved in order to preserve the organic matters present. A slide per sample was scanned withtransmitted light LeitzOrtholux II microscopeunder various magnifications (X250, X400 and X1000) and compared with the standard spore comparator (Traverse, 2007).In this work,three main groups of morphological constituents can be recognized within the organic assemblages: Phytoclasts, Palynomorphs, (sporomorph and phytoplankton) and Amorphous Organic Matter - AOM (Tyson 1993, 1995).

RESULTS AND DISCUSSION

The Lithology of Well BZ-1 was sampled from 2105 m to its total depth of 3300 m. Three lithologic units were found which are shale, sandy shale, shaly sand and sand. The well is dominated with thick shales at 2225 – 2305m, 2765 – 2825m and 2905 – 3005m which are synonymous to the Lower Agbada Formation. The sands were milky white, pinkish and light brown in colour. They are moderately sorted, medium grained and subangular to subrounded in shape. The shale shows alternation of light grey to grey and black. The shale is moderately hard, bulky and fissile to sub fissile. The formation has some accessories minerals like glauconite, pyrite, mica specs, ferruginized and carbonaceous materials. The depths 2605 – 2665m, 2765 – 2825m, 2905 – 3025m and 3125 – 3165m were characterized with the presence of shell fragment, pyrite and spec of mica which suggest a deposition in a relatively low energy environment, partially oxygenated (inner to middle shelf). The basal part of the formation was characterized by ferruginised and carbonaceous material, pyrite and few glauconite which suggest a partially oxygenated to oxygenated environment and (proximal coastal to inner shelf). Also, when the shale was tested with 10 % hydrochloric acid it shows effervesce which confirm the presence of calcium carbonate ($CaCo_3$) in the shale at 2325 – 2345 m, 2705 – 2725 m, 2665 – 2685 m and 2365 – 2385 m.

Lithology of Well BZ-2 was sampled from 1000m to its total depth of 2220m. Four lithologic units were found which are shale, sandy shale, shaly sand and sand. The alternation of shale and sandstone was conspicuous in the well. The upper section of the formation in the well BZ-2 is dominated by shaly sand and shale. Distinct sand formations were found at interval 1560m to 1600m. The sand units of the upper section were mostly white to locally pinkish in colour. The sands are medium grained, subrounded to round in shape and moderately sorted. The shale shows alternation of light grey to grey and dark grey. The shale is moderately hard and fissile to sub fissile. The shale is dominated with accessories minerals like pyrite, glauconite, mica specs, carbonaceous materials and ferruginized materials. The upper section of the formation from 1000 – 1260m has a persistence of accessory minerals like pyrite, carbonaceous and few occurrence of shell fragment, $CaCo_3$, ferruginious material. This is probably a quiet, low energy and partially oxygenated environment (inner to middle shelf). The middle to lower section of the formation from 1260 –1920mhas persistence of occurrence of ferruginious material, carbonaceous material and few pyrite and glauconite. This is probably a low energy, oxygenated environment (proximal (fluvial) to marginal). The calcium carbonate was also found at 1020 – 1040m, 1060 – 1080m and 1440 – 1460m.

Palynofacies analysis involves the identification of Palynomorphs, plant debris and amorphous particles, their absolute and relative proportion, size spectra and state of preservation (Combaz 1964, 1980). Palynofacies can help not only to establish the depositional environment but also to determinate the hydrocarbon source potential and assessment of thermal maturity of the host sediments.In this work, three main groups of morphological constituents can be recognized within kerogen assemblages: phytoclasts, Palynomorphs, (sporomorph and phytoplankton) and Amorphous Organic Matter - AOM (Tyson 1993, 1995).The different types of organic matter and their frequency variation patterns as revealed in the studied section of Agbada Formation is depicted in the Fig. 2 and 3.

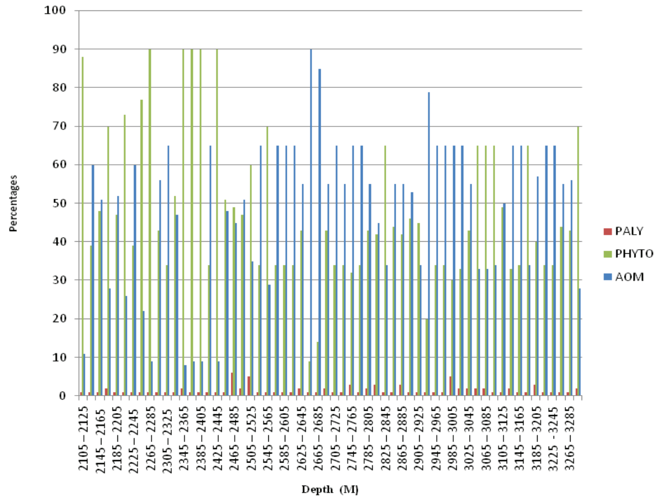

Fig. 2: Percentage relative abundance of Amorphous organic matter (A%)Phytoclasts (PHYTO%) and Palynomorph (PALY%) in well BZ-1.

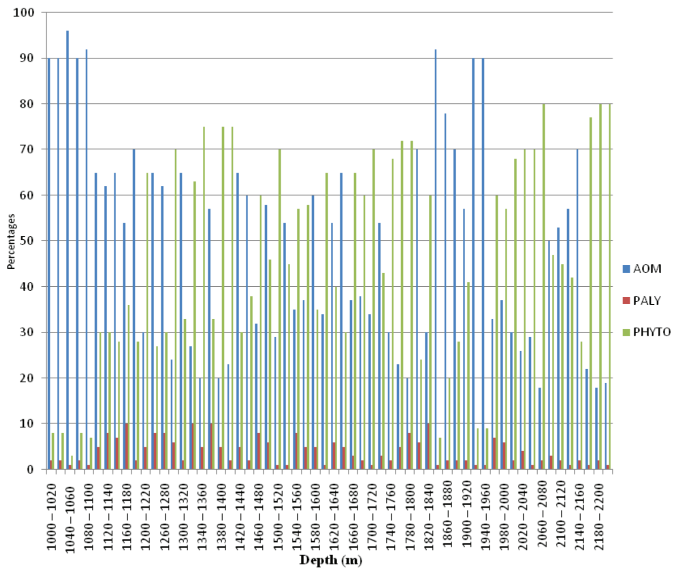

Fig.3: Percentage relative abundance of Amorphous organic matter (A%)Phytoclasts (PHYTO%) and Palynomorph (PALY%) in well BZ-2.

Phytoclasts are pieces of plant derived and structured organic material (Tyson, 1993). In this research, they are divided into three categories: opaque organic material (charcoal), brown translucent material and cuticles. Opaque organic material is made up of either charcoal or biochemically oxidized wood. It originates from the oxidation of organic material, either during forest fires, repeated degradation or thermal maturation. This is represented between average to high percentage of the total organic matter in the both wells (BZ-1 and BZ-2) studied, i.e. 45-70% (Fig.2 and Fig.3). It mainly contributes forgaseous hydrocarbons.

Amorphous Organic Matter (AOM) can have either a terrestrial or aquatic origin. Terrestrially, higher plants can secrete AOM as intra-/extra-cellular resins or decomposition of higher plants (Tyson, 1993). Aquatically, faecal pellets from zooplankton, aggregates of flocculated dead organic matter (DOM) or bacteria can form AOM (Tyson, 1993). AOM is recognizable by its unstructured appearance. It is usually grey, translucent and can have a bubbly texture. The frequency of this organic matter is quite high in the studied sections of the wells and the range varies from 18–80% (Fig.2 and Fig.3). Amorphous organic matter is considered to be anexcellent source for liquid hydrocarbons.

Palynomorphs are all organic microfossils, either plant or animal derived. They include spores and pollen; acritarchs and algae remains, including dinoflagellate cysts. Spores and pollen are the terrestrial component of this category and knownto be rich in lipids, which contribute mostly to liquid hydrocarbon.The frequency of spores and pollen is quite low and the range varies from 1-10%in the studied wells (Fig.2 and Fig.3).

Hydrocarbon Source Rock Evaluation

The optical assessment of the studied samples was done by observing the colour change of the palynomorphs due to the effect of temperature and the maturity stage of the studied wells was determined from the colouration. To access the Thermal Alteration Index (TAI) and the Spore Colour Index (SCI) of the studied samples,the colour of spores and pollen grains appearance has been chosen to show the result of temperature effect on its colour changes.Also cuticles, phytoplankton and amorphous organic matters were used in the present study for determining TAI values in the absence of palynomorphs. The TAI and SCI values for the studied slides have been determined using transmitted light microscopy and according to the TAI and SCI scale proposed by Traverse (2007).

Hydrocarbon Potential and thermal Maturity of Wells

The different types of palynofacies (Organic Matter) and their frequency variation patterns at various depths of the well sections were used to reveal the hydrocarbon potentials of the sediments.

Well BZ-1

2105m – 2425mrepresents the top most part of the section in the well and shows a very high percentage of phytoclast (between 45 – 90%), average AOM (11 – 55%) and a very low palynomorphs (0 – 5%). According to Tyson (1993), this palynofacies distribution is synonymous to marginal dysoxic - anoxicpaleoenvironment and the organic matter composition (Kerogen III type) are prone to gas production.

2425 – 3265 mrepresents the mid to base of the section studied in the well and shows average percentage of phytoclast (14 – 65%), AOM (20 – 55%) and very low palynomorphs (0 – 5%). According to Tyson (1993), this palynofacies distribution is synonymous to proximal suboxic – anoxic basin paleoenvironment and the organic matter composition (Kerogen II type) are prone to gas production.

Well BZ-2

1000 – 1320m represents the top most part of the section studied in the well and shows high AOM (24 – 90%), low phytoclasts (3 – 33%) and very low palynomorphs (1 – 10%). This palynofacies distribution signifies the distal suboxic-anoxic basinpaleoenvironment and the organic matter composition (Kerogen II>I type) are prone to oil production (Tyson 1993).

1320 – 1840m falls within the mid section of the section studied in the well and shows averagely equal percentage of phytoclasts (20 – 55%) and AOM (30 – 60%) but very low palynomorphs (1 – 8%). This palynofacies distribution is synonymous to proximal suboxic – anoxic basin paleoenvironment and the organic matter composition (Kerogen II type) are prone to oil production (Tyson, 1993).

1840 – 1960m is depth is close to the base of the section studied in the well and shows high percentage of AOM (20 – 90%), low phytoclasts(2 – 30%) and very low palynomorphs(1 – 8%). This palynofacies distribution signifies the distal suboxic – anoxic basinpaleoenvironment and the organic matter composition (Kerogen II>I type) are prone to oil production (Tyson 1993).

1960 – 2200mcorrespond to the base of the section and shows moderate percentage of phytoclasts (65 – 80%), moderately high AOM (18 – 38%) and low palynomorphs (1 – 10%). This facies distribution is equivalent to Tyson (1993) organic matter for marginal dysoxic-anoxic basin paleoenvironment and the organic matter composition (Kerogen III type) are prone to gas production.

Age of the wells

On the basis of the stratigraphic distribution of diagnostic species and palynomorph assemblage recorded which *irregularis, Crassoretitriletesvanraadshooveni, Echiperiporitesestelae* and *Nympheaepollisclarus*.) The studied sections were been subdivided into zones based on the biozonationscheme of Germeraad *et al.,* (1968) and Evamy *et al*.,(1978) and later dated Late Miocene.

Thermal Maturity of BZ-1

The palynomorphs found in the well BZ-1 shows two different colours when compared with the standard colour chart of Traverse *et al.,* (2007). The lemon yellow colouration (TAI = -2 and SCI = 3) were found at interval 2105 – 2885m in the well (Fig.5). The golden yellow colouration (TAI = 2 and SCI = 4) were found at interval 2885– 3305 m in the well BZ-1 (Fig.5). The palynomorphscolouration at these intervals indicates that the organic matters were immature. The samples with palynomorphscolour lemon yellow (TAI = -2 and SCI = 3) and golden yellow (TAI = 2 and SCI= 4) means that the organic matter in the sediments is thermally immature. It indicates the sediments have been through the later stages of diagenesis and only into the early stage of the "oil window".

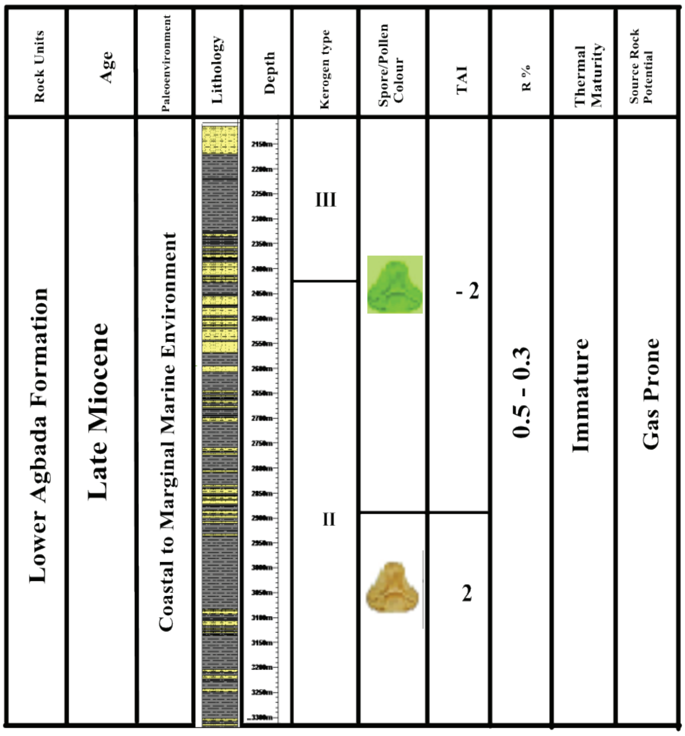

Fig.5: Lithology, Age, paleoenvironment and thermal maturity for well BZ-1 (Modified from WEPCO, 1971).

Thermal Maturity of Well BZ-2

The palynomorphs found in well BZ-2 shows variations three colours when compared with the standard chart of Traverse *et al.*, (2007). The lemon yellow colouration (TAI = -2 and SCI = 4) were found at interval 1000 – 1560m (Fig.6). The golden yellow colouration (TAI = 2 and SCI= 4) were found at interval 1560 – 1980m.The yellow orange colouration was found at interval 1980– 2220m in well BZ-2 (Fig.6). The samples with palynomorphscolour yellow orange (TAI= +2 and SCI= 5) means that the organic matter in the sediment is thermally mature. It indicate the sediment have passed the oil window and in the first oilbirth.

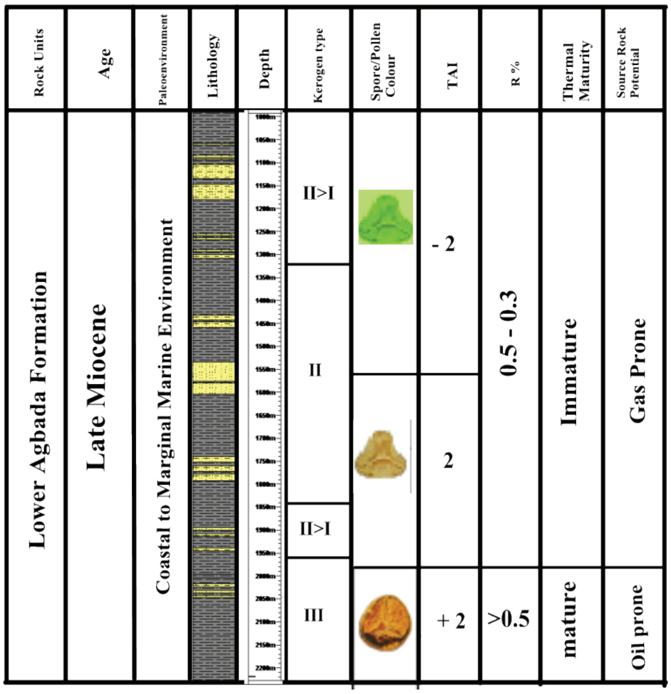

Fig. 6: Lithology, Age, paleoenvironment and thermal maturity for well BZ-1 (Modified from WEPCO, 1971).

CONCLUSION

The study integrated palynofacies and sedimentology analysis to ascertain the paleoenvironment of deposition, thermal maturity and hydrocarbon potential of the studied sections of the wells. Based on the result obtained from the lithofacies and log data interpretation, the sequence penetrated by the two studied wells was established. It was concluded that the studied intervals within the two wells 2105 – 3305m and 1000 – 2220m for well X and well Y correspond to lower units of Agbada Formation with thick shale and intercalation of sands. On the basis of the above lithofacies, coastal to marginal marine environment was proposed for the sequence penetrated by the two wells and this was supported by Short and Stauble (1967) for Niger Delta Basin.

The colour of the palynomorphs was used to determine the organic thermal maturation for both wells.

Colours were compared with Transverse (2007) scale of palynomorphcolours to determine the numerical thermal alteration index (TAI) and spore colour index (SCI) of sequence penetrated by both wells. The thermal alteration index and spore colour index of the recovered palynomorphs shows the sediment were between immature and mature (sediment have passed the oil window and in the first oil birth).

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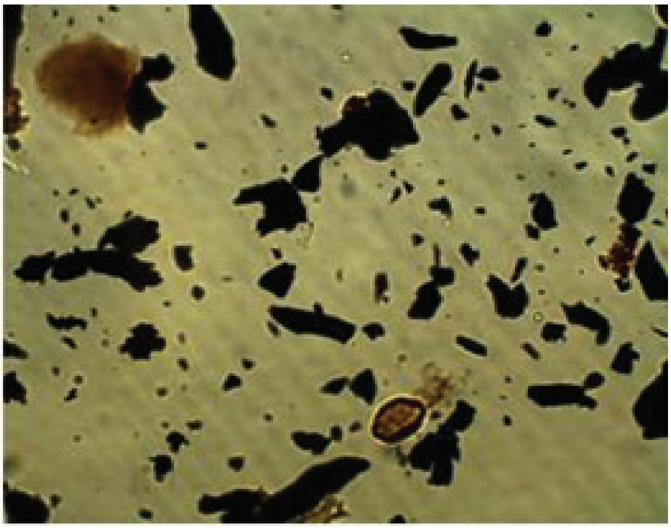
Plate 1: Phytoclast

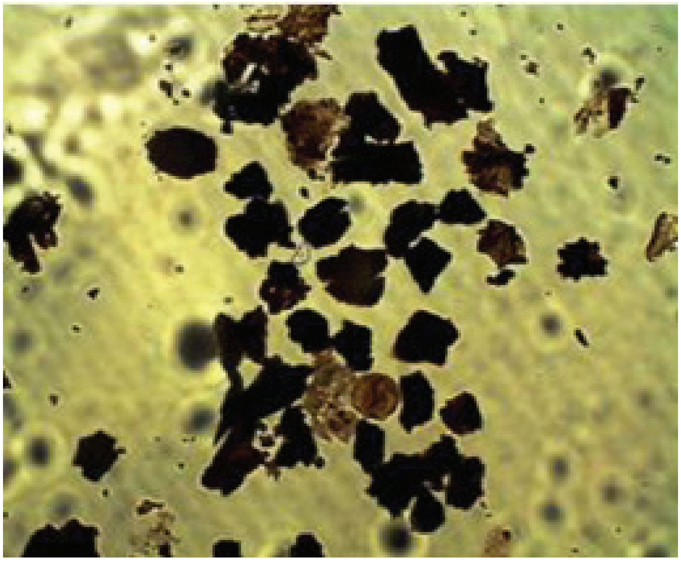
Plate 2: Phytoclasts

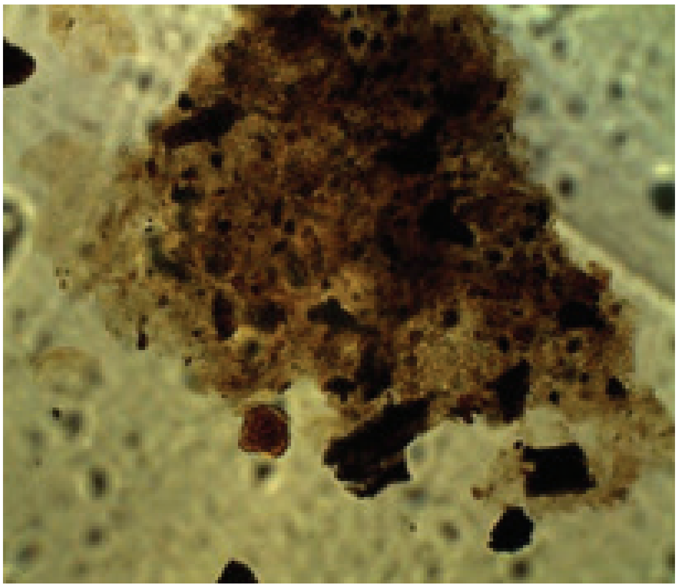
Plate 3: Amorphous Organic Matter

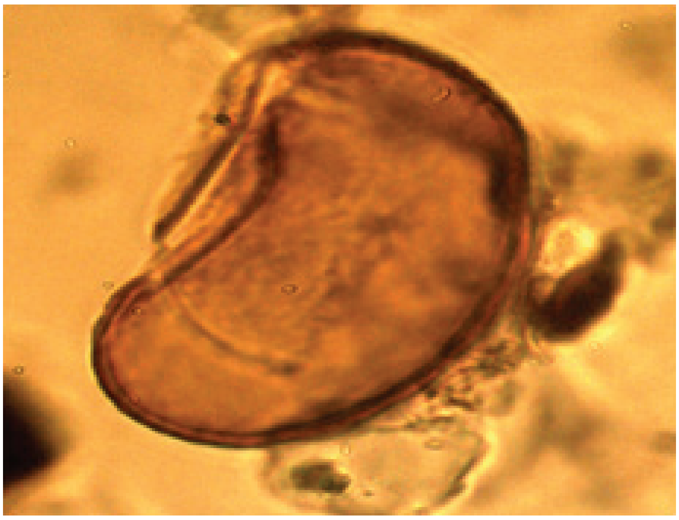
Plate 4: Palynomorphs

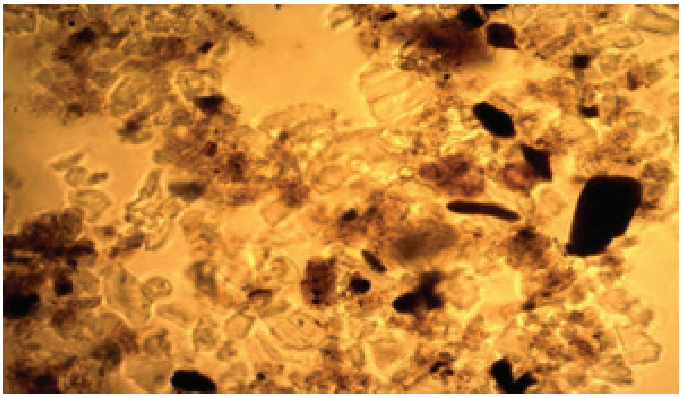
Plate 5: Palynofacies I.

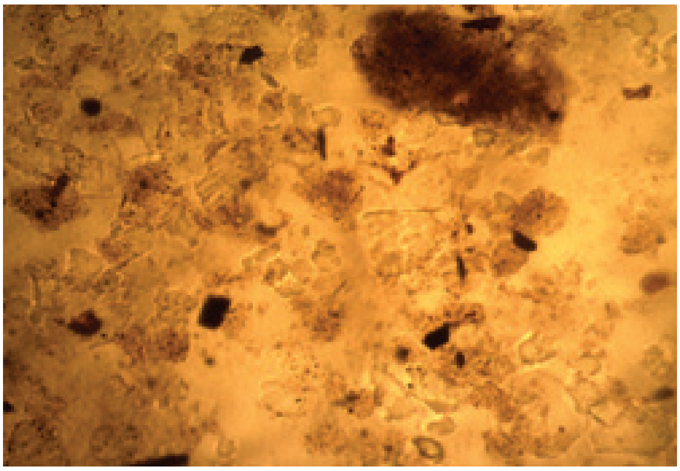
Plate 6: Palynofacies II

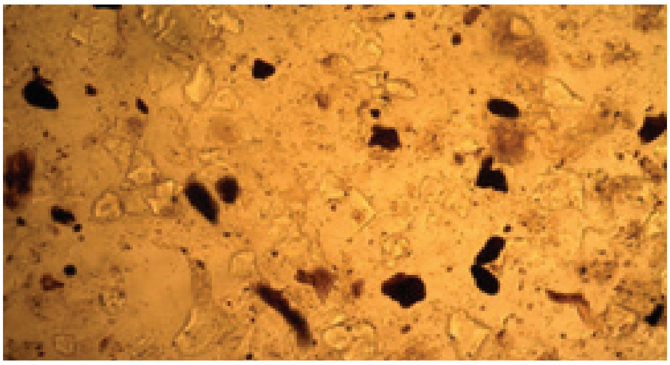
Plate 7: Palynofacies III