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COMBINED FORAMINIFERAL AND PALYNOLOGICAL STUDY OF SOME AGBADA FORMATION DEPOSITS OF THE WESTERN NIGER DELTA BASIN, NIGERIA

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ABSTRACT

Well (ditch) cuttings from the GAB–1 Well from the Western Niger Delta basin were analyzed for foraminiferal and palynological study with the aim of determining the age of the sediments and to infer the environment of deposition. Four lithologic units were identified: shale, argillaceous sandstone, sandy mudstone and silt between 1250m and 2050m. Palynomorph distribution shows that there are more terrestrially derived miospores (dominated by *Zonocostites ramonae* (*Rhizophora* spp.), *Psilatricolporites crassus* (*Tabernaemontana crassa*), *Acrotichum aureum*, and *Laevigatosporites* sp.) than marine phytoplanktons. The recovered palynomorphs include; *Zonocostites ramonae, Corylus spp., Psilatricolporites crassus, Magnastriatites howardii, Pachydermites diederixi*, *Cyperaceaepollis* spp., *Monoporites annulatus, Acrostichum aureum, Laevigatosporites* spp., *Verrucatosporites* spp., *Pteris* spp., and *Verrucatosporites usmensis*. The recovered planktic foraminifera includes *Globigerinoides trilobus sacculiferus, Globigerinoides trilobus immaturus*, while the benthic foraminifera are *Planulina ariminensis, Quinqueloculina lamarckiana, Elphidium advenum, Ammonia inflata, Ammonia beccarii, Heterolepa floridana, Florilus* ex. gr. *Costiferum*. Integrated analysis of the microfossil assemblages puts the age of the studied sediments in GAB–1 well to be Miocene, while paleoenvironment of deposition assigned to the sediments is inner to middle neritic. Paucity of Planktonic foraminifera (abundance and diversity) compared to benthics suggests shallow marine depositional milieu or decrease in sea level.

Keywords: *Foraminifera, Planktics, Benthics, Palynomorphs, Miocene, Neritic*

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Introduction

The present day Niger Delta basin is situated on the Gulf of Guinea in the west coast of Africa. It originated during the episode of the separation of South American plate from the African plate in the Mesozoic break-up of the Gondwala land (Whiteman, 1982). The basin is most confined to the southern part of Nigeria. It merges with structural basin in Benue and Middle-Niger basins which holds thick marine, paralic and continental sequences southwards; it continues offshore into the Atlantic Ocean. Niger Delta basin is one of the most prominent basins in the West Africa and the largest delta in Africa. Niger Delta basin is a matured basin based on the exploration and exploitation of crude oil that have taken place over time. It's a prolific oil province within the West Africa subcontinent and is important because of its hydrocarbon resources which started to evolve during Eocene and still undergoing deposition in its offshore frontiers.

This study gives an account of Integrated foraminiferal and palynostratigraphy of GAB–1 Well, western Niger Delta basin (Fig. 1); to provide better information on the paleoenvironment of deposition and age of the formation, also to document the planktic and benthic foraminiferal and palynomorph assemblages.

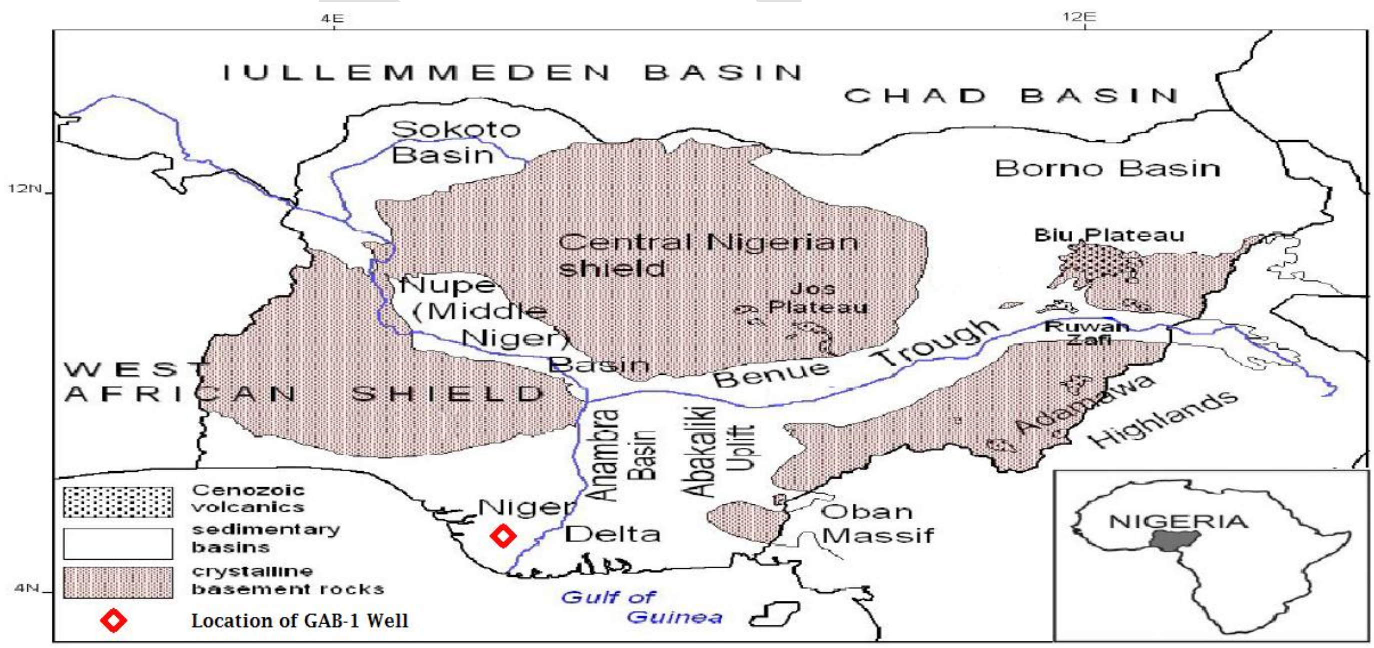

Figure 1. Location map of GAB–1 Well, Western Niger Delta (modified after Kurowska and Schoeneich, 2010).

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Geologic Setting and Stratigraphy

The tertiary Niger Delta is believed to be one of the world's largest deltas, it covers an area of about 300,000km^2 (Kulke, 1995) and reaches a maximum thickness of about 10km in the basin depocenter (Kaplan et al, 1994). As defined by Quaternary outcrop, the delta is about 670km long and 350km wide. It extends from longitude 3º – 9ºE and latitude 4º – 5ºN. Niger delta basin is one of the largest wet land basins, with sub-aerial portions covering about 75,000sqkm and extends more than 300km from the apex to the mouth, with regressive wedge of clastic sediment reaching maximum thickness of 12km in the central portion (Bustin, 1988; Doust and Omatsola, 1990). The Niger delta sedimentary basin is believed to have undergone three depositional cycles, which spanned from the Cretaceous to Recent (Short and Stauble, 1967).

However, Niger delta is a typical sedimentary basin which encompasses a larger region than the geographical extent of the modern delta. The wedge also contains major submarine part which contributes to complex continental margin intruding into the Gulf of Guinea. It has been shown that the Niger delta sedimentary wedge consist of a series of discrete depocenters, each characterized by an individual proximal distal facies trend within the Agbada formation (Murat 1972). Geological evolution and tectonic setting of the Niger delta goes beyond the post-Eocene regressive clastic wedge that is conventionally ascribed to the modern delta. The Niger delta basin occupies the coastal and ocean-ward part of a larger and older tectonic features, according to Murat (1972) and the Benue trough, a NE – SW trending, folded, halted rift basin that run obliquely across Nigeria. Cenozoic Niger delta marks a litho-genetic model that relates facies variation with a high energy wave dominated and arcuate – lobate tropical delta (Stacher 1995). These form the basis for the paleo-environmental, sedimentological and stratigraphical interpretation of the Cenozoic succession in the Niger delta.

Stacher (1995), using sequence stratigraphy, developed a hydrocarbon habitat model for Niger delta. The model was constructed for the central portion of the delta, including some of the oil-rich belt, and relates deposition of the Akata formation (the assumed source rock) and sand/shale units in the Agbada formation (the reservoir and seals) to sea level. Pre – Miocene Akata shale was deposited in deep water during low sands and is overlain by Miocene Agbada sequence system tracts. The Agbada formation in the central portion of the delta fits a shallow ramp model with mainly high sand (hydrocarbon-bearing sands) and transgressive (sealing shale) system tracts. Third order low sand

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system tracts were not formed. Faulting in the Agbada formation provided pathways for petroleum and formed structural traps that together with stratigraphic traps, accumulated petroleum. The shale in the transgressive system tracts provide an excellent sea above the sands as well as enhancing clay smearing within faults. Figure 2 is a simplified stratigraphy of the the Niger Delta basin.

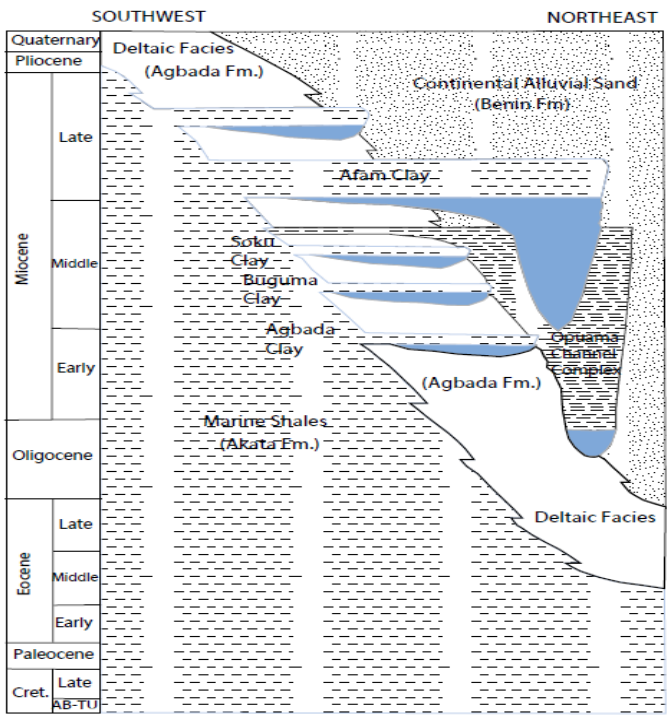

Figure 2. Stratigraphy of the Niger Delta (after Shannon & Naylon, 1989; Doust & Omatsola, 1990).

Materials and Method

Detailed palynological analysis was carried out on forty-four (44) ditch cuttings of GAB–1 Well between the interval of 1250 – 2050m. The samples were well preserved with fairly diverse pollen, spores and fungal spores. Lithologic description of the forty-four ditch cutting samples was also done carefully with the aid of a stereoscope binocular microscope.

Processing procedures

The samples were subjected to sedimentological analysis using visual inspection and a binocular microscope. Physical characteristics such as color, texture, hardness, fissility, and rock types were noted. Dilute (10%) HCl was added to identify the calcareous samples, fossil contents and presence of accessory minerals were determined.

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Foraminiferal preparation

Forty-four (44) ditch cutting samples within interval 1267 – 1633m were processed and analyzed for their foraminiferal and accessory microfaunal content. Twenty-five grams of each sample was processed for their foraminiferal content using the standard preparation techniques. The weighed samples were soaked in 10% hydrogen peroxide solution for 24 hours to dissolve the shale and isolate the foraminifera. The disaggregated samples were then wet-sieved under running tap water over a 63-µm mesh sieve. The washed residues were then dried over a hot electric plate and sieved (when cooled) into three main size fractions, namely coarse, medium, and fine (250-, 150-, and 63-µm meshes). Each fraction was examined under a binocular microscope. All the foraminifera, ostracodes, shell fragments, and other microfossils observed were picked and counted. Foraminifera identification was made to genus and species levels where possible using the taxonomic scheme of Loeblich and Tappan (1964) and other relevant foraminiferal literature such as the works of Fayose (1970), Postuma (1971), Petters (1979a, 1979b, 1982), Murray (1991), Okosun and Liebau (1999), Jones (1994) and Holbourn et al., (2013).

Palynological preparation

Ten grams of each dry sample were crushed into small fractions between 0.25 mm and 2.5 mm. Standard palynological preparation techniques were used (Faegri and Iversen, 1989; Wood et al., 1996). These included the digestion of the mineral matrix using dilute HCl for carbonates and concentrated HF for silicates. Removal of the fluoride gel formed during the HF treatment was achieved by using hot concentrated HCl and wet sieving the residue using a 10-µm polypropylene Estal Mono sieve. Residues were oxidized and inorganic $ZnCl_2$ of specific gravity 2.0. Slides were mounted using Norland adhesive mounting medium and dried under Ultra Violet light. One slide per sample was analyzed under the optical microscope and the photomicrographs of well preserved palynomorph specimens were taken using an Olympus CH-30 transmitted light microscope (Model CH-30 RF200) with an attached camera. Palynomorph identifications were done using the works of Germeraad et al. (1968) and Evamy et al. (1978) (i.e. Shell Oil Company Scheme, 1978). The data were plotted using StrataBugs software at 1:5000 scale with depth on the y-axis and the identified taxa on the x-axis.

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Results and Discussion

Sedimentological analysis

Lithologically, GAB–1 well comprises of silt, sandy-mudstone, argillaceous sandstone and shale (Fig. 3). The shales are light gray, fissile and slightly ferruginized while the sandy mudstone are light gray and ferruginous, few grains of glauconite were recovered. Quartz grains within the sediments vary from fine to medium, subangular to well-rounded and are moderately sorted.

Foraminiferal Assemblage

Thirty two (32) species of foramnifera were recovered in this study. Two (6%) of these were planktics while the remaining thirty (94%) were calcareous benthics. Twelve (12) species of calcareous benthic foraminifera and 2 species of planktic Foraminifera were recovered. The two planktic foraminifera are: *Globigerinoides trilobus sacculiferus* and *Globigerinoides trilobus immaturus* whereas the few important of the 12 species of calcareous benthic foraminifera include: *Planulina ariminensis, Quinqueloculina lamarckiana, Elphidium advenum, Ammonia inflata, Ammonia beccarii, Heterolepa floridana, Florilus ex. gr. Costiferum.* Other accessory fossils recovered include: Gastropod, Scaphopod, Sponges, Pelecypod, Echinoid remains, Ostracod and unidentified shell fragments.

Benthic Foraminifera ranged from most common to abundant in the shaly to sandy-mudstone sequence. However, both the shale and sandy-mudstone contains few numbers of Gastropod; other shell fragments are most abundant in the sandy-mudstone as indicated in the foraminiferal distribution chart. The samples within 1460 m – 1600 m interval of GAB–1 Well yielded highly diversified benthic foraminifera (fig. 4 and Plate 1). The benthic calcareous foraminifera account for the largest number of foraminifera recovered from the well. Also, it is evident that some depth intervals from 1700 m – 2050 m are barren (there is paucity of microfossils) in the lower part of the section and it is mainly dominated by Silt. This forms the basis for an integrated study of the well using foraminiferal and palynological analyses.

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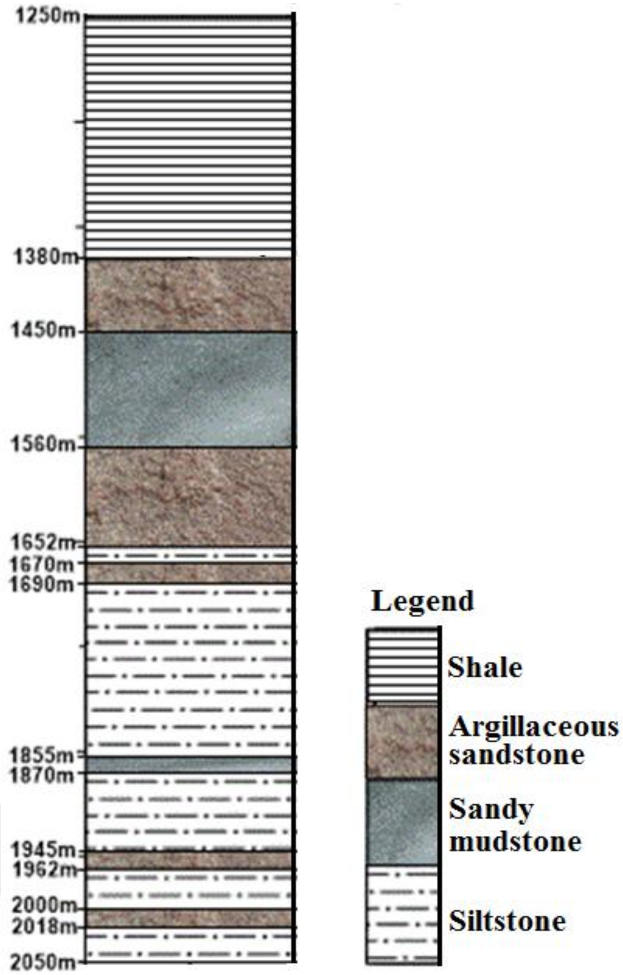

Figure 3. Graphic representation of the Lithology of GAB–1 Well

Palynomorph Assemblage

The Palynomorphs in the slides were observed under the palynological microscope and identified using relevant literatures including Evamy et al. (1978), Germeraad et al. (1968) and also based on the exine, sculpture and apertural characteristics of the palynomorphs (fig. 5 and Plate 2). The following pollen were recovered: *Zonocostites ramonae* (which is the most abundant*)*, *Corylus* spp., *Psilatricolporites crassus, Magnastriatites howardii, Pachydermites diederixi, Cyperaceaepollis* spp., *Monoporites annulatus, Proteacidites cooksoni, Stereisporites* spp., *Striatricolpites catatumbus, Sapotaceae, Retitricolpites irregularis, Gemmamonoporites* spp., *Psilamonocolpites marginatus, Marginipollis concinnus, Canthium* spp., *Proxapertites cursus* and a few others that could not be

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determined. The spores recovered are: *Acrostichum aureum*, *Laevigatosporites* spp., *Verrucatosporites* spp., *Pteris* spp., and *Verrucatosporites usmensis*. Other Palynomorphs present are *Pediastrum* spp., *Botryococcus braunii* and *cyst* which could not be determined. Figure 6 is a histogram of the relative abundance of palynomorphs in GAB–1 Well.

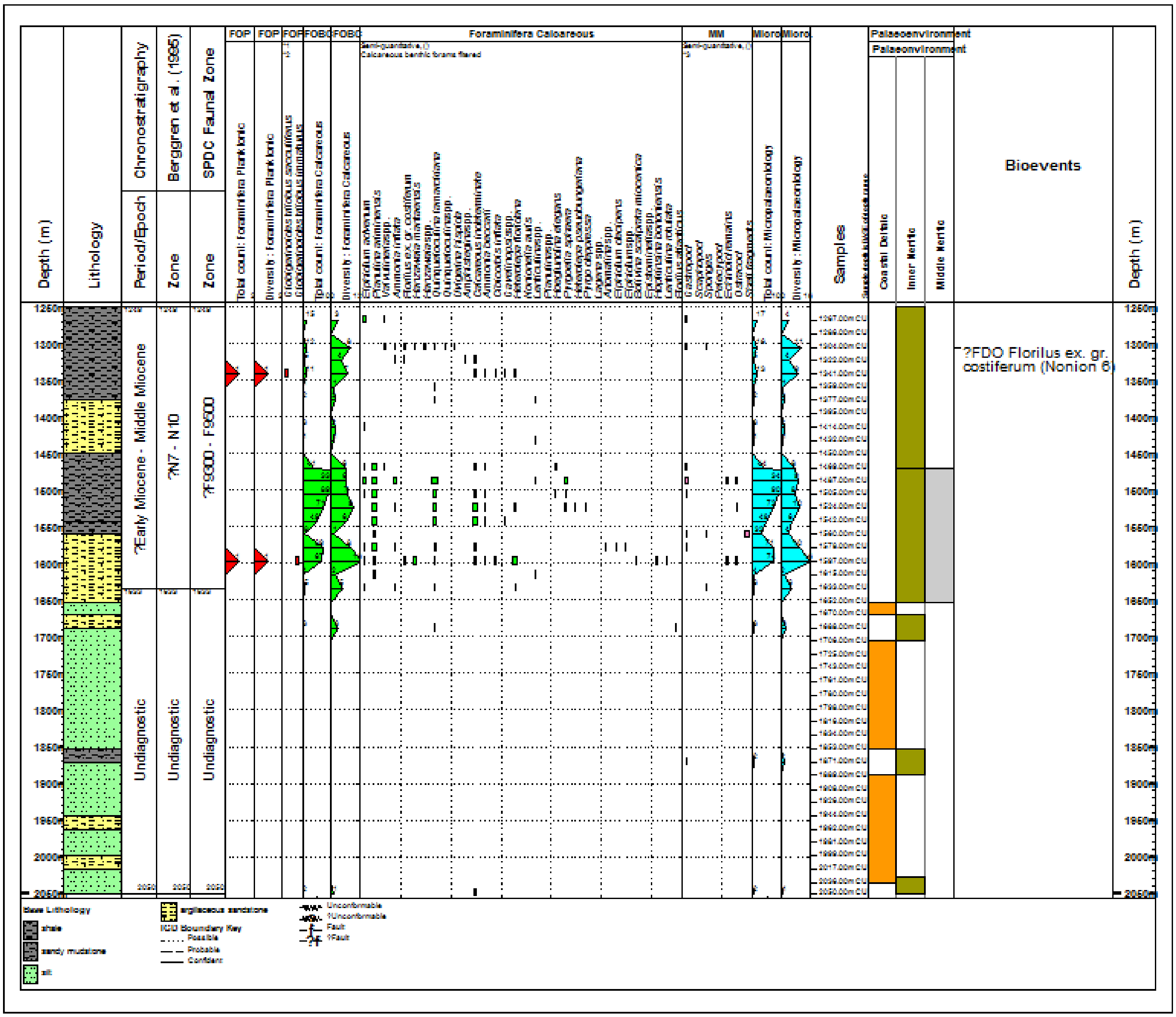

Figure 4. Foraminiferal distribution chart.

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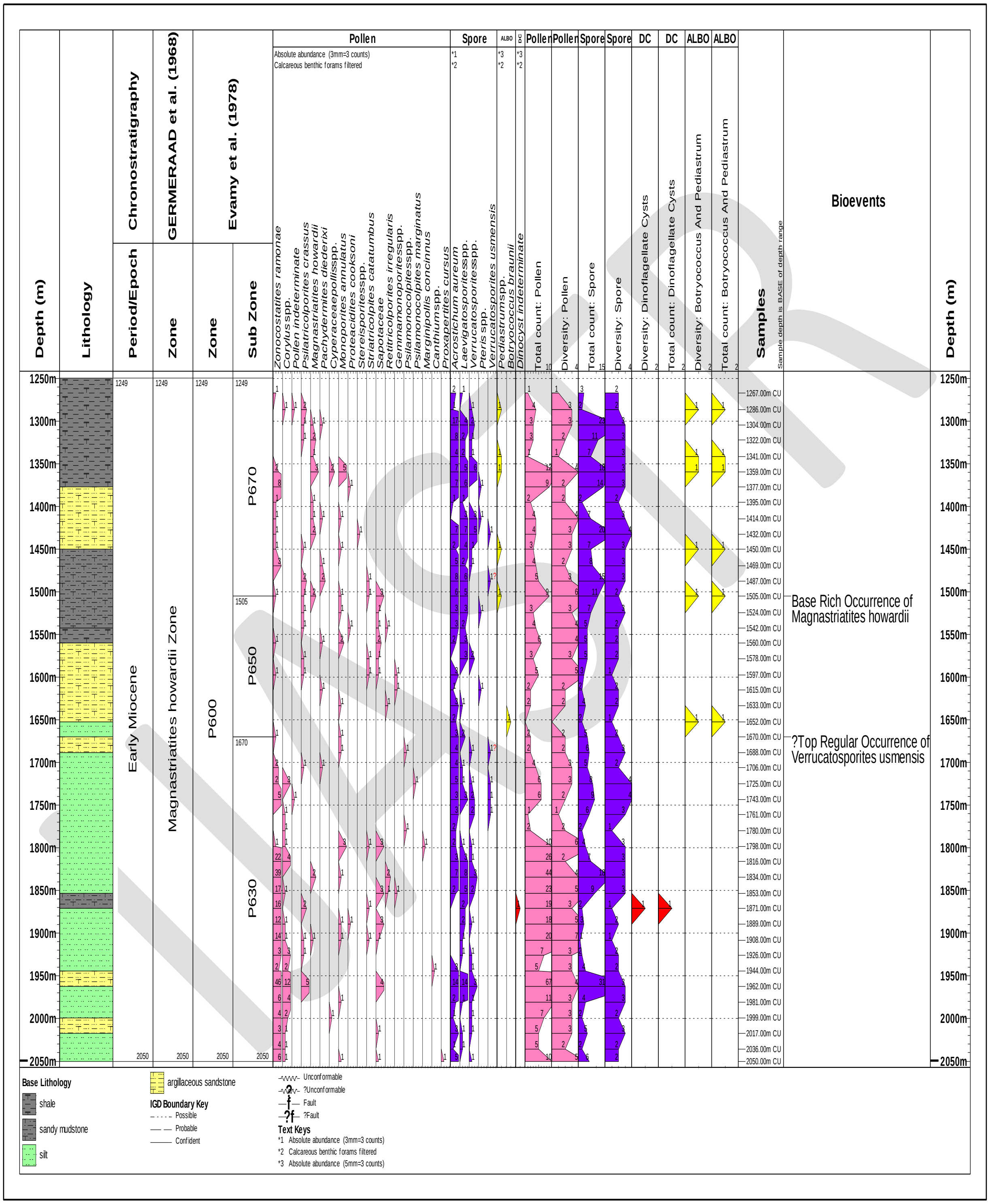

Figure 5. Palynomorphs distribution chart

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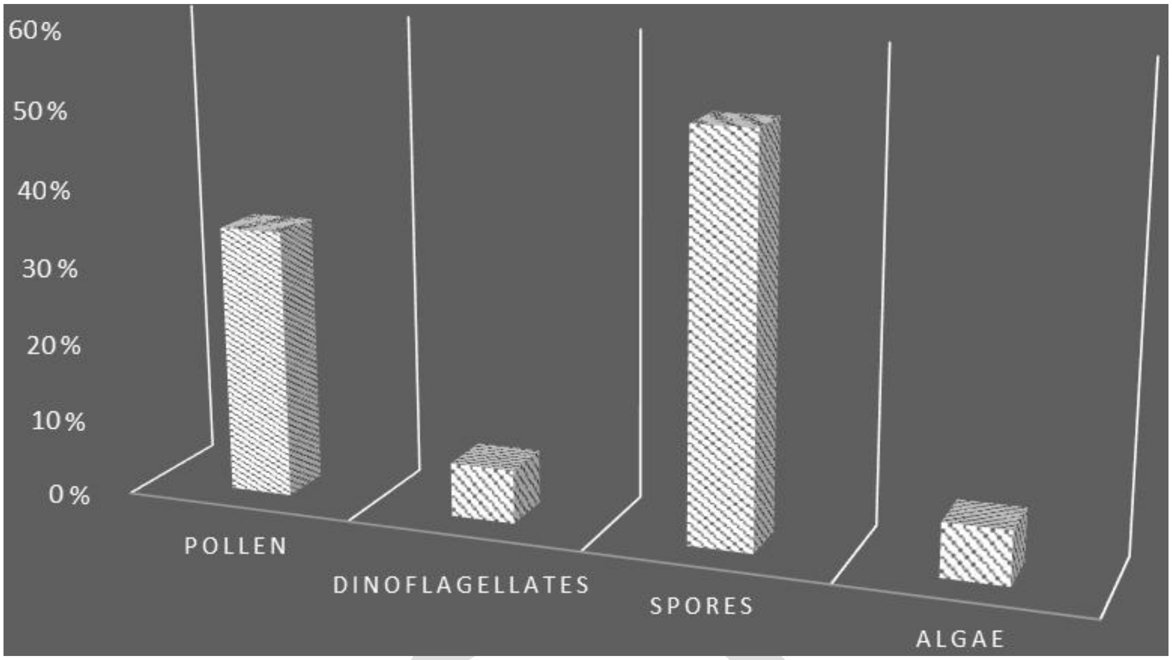

Figure 6. Histogram of the relative abundance of Palynomorphs in GAB–1 Well.

Total Count, diversity and its implications

Generally, the total count for all the foraminifera assemblages in GAB–1 well is at maximum at depth interval 1460m – 1490m, but the diversity is at maximum at the depth interval 1570m – 1600m (4). The total count and diversity below these depths range from low to barren at the lower part of the section. The total count of planktic foraminifera is two 2 specimens and of different diversity (fig. 4), whereas the total count of calcareous benthic foraminifera is 100 with 12 diverse forms. The total count of the planktic foraminifera occurred at depth intervals 1320m – 1360m and 1570m – 1610m. Therefore, we can infer that the greater number of foraminifera existed at the depth interval of 1460m – 1600m. The well is rich in palynomorphs (fig. 5) especially spores, which are present throughout the well, which is an indication that the sediments was deposited in a shallow marine environment. Also, intermixing of pollen and spores is evident as seen in the palynomorphs distribution chart. The total count of the pollen is maximum between the depth intervals of 1940m to about 1962m and this correspond with the maximum total count of the spores. The diversity varies throughout the depths of the well in that of spores but maximum between the depth intervals of 1910m – 1920m for the pollen. Therefore, it can be infered that GAB–1 well sediments are of shallow marine environment based on the abundance of palynomorphs and good distribution throughout the depth intervals of the well.

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Paleoenvironmental Deductions

The assemblage of the Foraminifera within interval 1267 – 1469m of the studied section consists of Inner neritic taxa such as *Elphidium advenum, Quinqueloculina lamarckiana* and *Florilus ex. gr. costiferum.* The occurrence of deeper environment dwellers such as *Epistominella* spp., *Pyrgo deppressa, Bolivina scalprata miocenica* and *Heterolepa pseudoungeriana* in association with *Quinqueloculina* spp., and *Q. lamarckiana* within interval 1469-1633m suggest sediment deposition in environment ranging between inner and middle neritic condition. Also, considering the palynomorphs assemblage, the depth interval 1249m – 2050m consist of common members of land derived palynomorphs particularly *Zonocostites ramonae*, *Monoporites annulatus, Psilatricolporites crassus*, and the presence of these fossils coupled with the presence of glauconite in the sandy shales suggest a marine environment of deposition. The presence of planktic foraminifera (i.e. *Globigerinoides trilobus sacculiferus* and *Globigerinoides trilobus immaturus*) indicates that the age of the sediment is of Miocene. The biostratigraphically important palynomorphs recovered from the well are: *Retitricolporites irregularis, Psilatricolporites crassus Pachydermites diederixi*, *Verrucatosporites usmensis*, *Monoporites annulatus* and *Zonocostites ramonae.* The palynomorph assemblage demonstrates robust links with those previously identified in the San Jorge Gulf Basin, Southern Patagonia, Argentina (Palamarczuk and Barreda, 1998), and especially those from the Mazarredo Subbasin (Barreda and Palamarczuk, 2000), dated as Early Miocene and also Late Oligocene-Early Miocene. Paleoenvironmental reconstruction of the studied well is based on some parameters such as floral assemblage, diversity, abundance and frequency distribution, as well as the relative abundance of *Zonocostites ramonae* to *Monoporites annulatus*, freshwater algae, organic wall microplanktons, lithologic characters and accessory mineral contents. These parameters suggests deposition in marine environment with open vegetation.

Conclusion

The lithologic description of the sediments within the studied interval reveals that the sediments were deposited in an inner to middle neritic environement (a quite low energy environment) which allows the fine sediments of similar sizes to accumulate. Due to the presence of planktic foramiminifera and important species of palynomorphs such as *Monoporites annulatus* and *Zonocostites ramonae*, in correspondence to Germeraad et al. (1968) and Ogbe (1982), the age of the sediment of GAB–1 Well was dated Miocene. The high abundance of benthic species at the depth interval between 1460m – 1490m and the few number of planktic foraminifera in the studied well indicates lack of nutrients and unstable environment. Also, paucity of planktonic foraminifera (abundance and diversity) compared to benthics might suggest sea level decrease. This is also supported by the intermixing of the pollen and spores (land derived) and dinoflagellates and algae (marine derived) suggesting a transgressive and regressive phases. This supports the previous work done by Germeraad (1968) and Ogbe (1982) on the palynological zonation of the tertiary sediment of the Niger delta.

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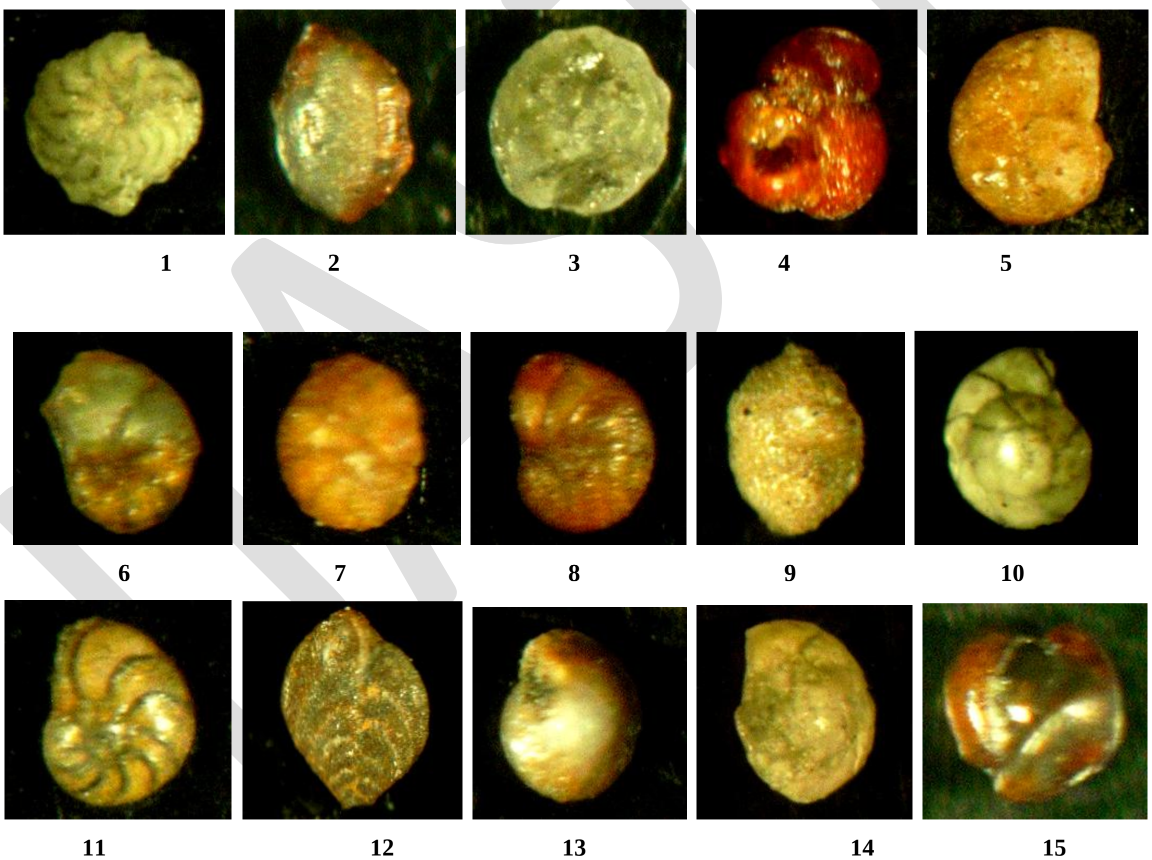

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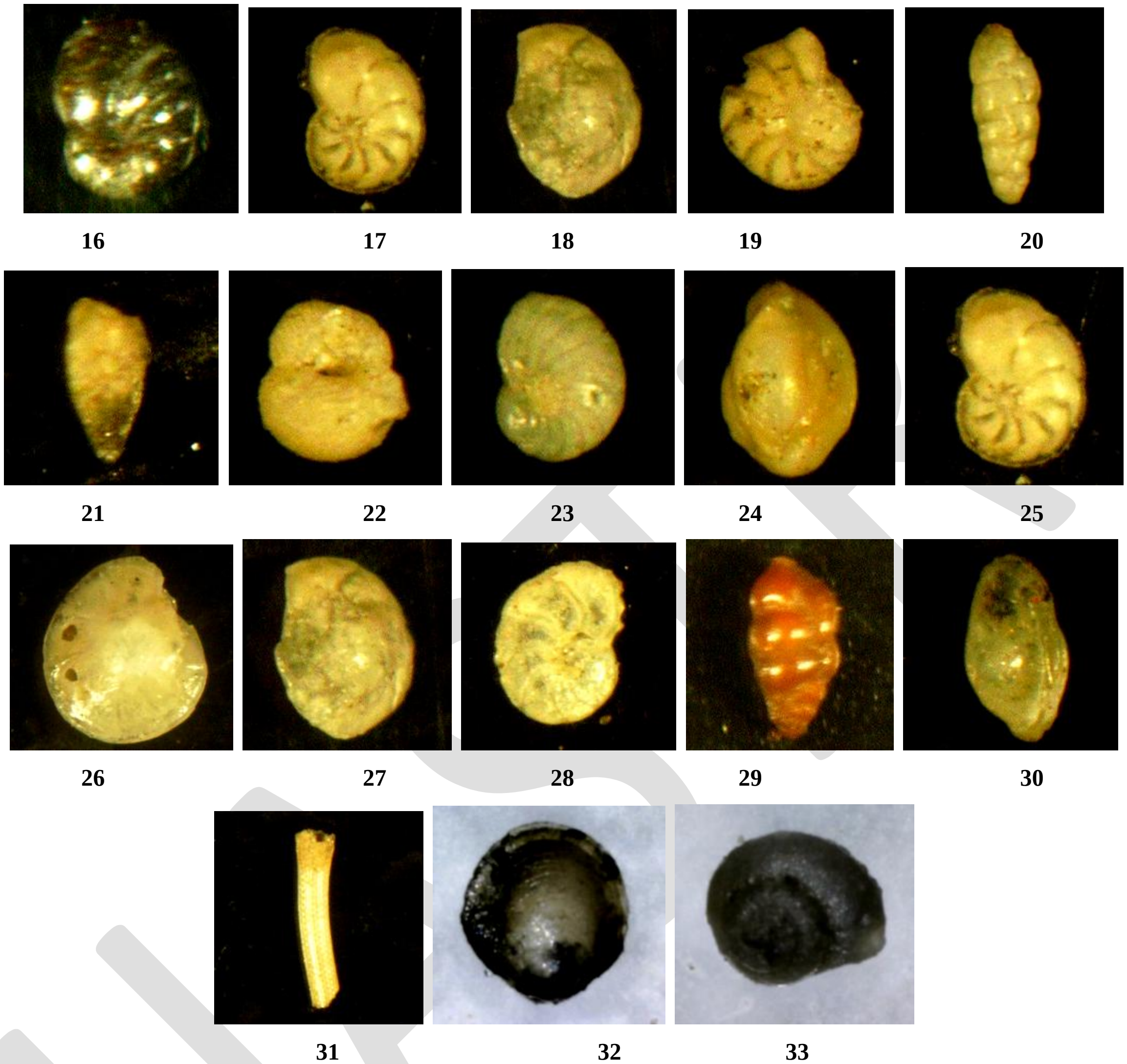

Plate 1. Photomicrographs of foraminifera and other fossils from the GAB-1 Well (1000x).

1. *Elphidium decipiens*; **2**. *Gavellinopsis* sp.; **3**. *Ammonia inflata* **4**. *Globigerinoides trilobus sacculiferus*; **5**. *Heterolepa floridana*; **6**. *Valvulineria* sp.; **7**. *Prygoella sphaera*; **8.** *Florilus ex gr costiferum*; **9.** *Uvigerina hispida*; **10.** *Ammonia beccarii;* **11.** *Hanzawaia mantaensis*; **12.** *Textullaria* spp.; **13**. *Heterolepa floridana*; **14.** *Lenticulina* spp.; **15**. *Quinqueloculina larmackiana*; **16.** *Nonionella auris*; **17**. *Hanzawaia* spp.; **18**. *Lenticulina* spp.; **19.** *Elphidium advenum*; **20.** *Hopkinsina bononiensis*; **21**. *Bolivina scalptrata miocenica*; **22**. *Globigerinoides trilobus immaturus*; **23.** *Florilus* ex.gr. *costiferum*; **24.** *Quinqueloculina larmackiana*; **25**. *Hanzawaia mantaensis*; **26.** *Heterolepa pseudoungeriana*; **27.** *Lenticulina rotulata*; **28**. *Planulina arinimensis*; **29.** *Hopkinsina bononiensis*; **30**. *Ostracod*; **31**. *Echinoid remains*; **32**. *Pelecypod*; **33.** *Gastropod*

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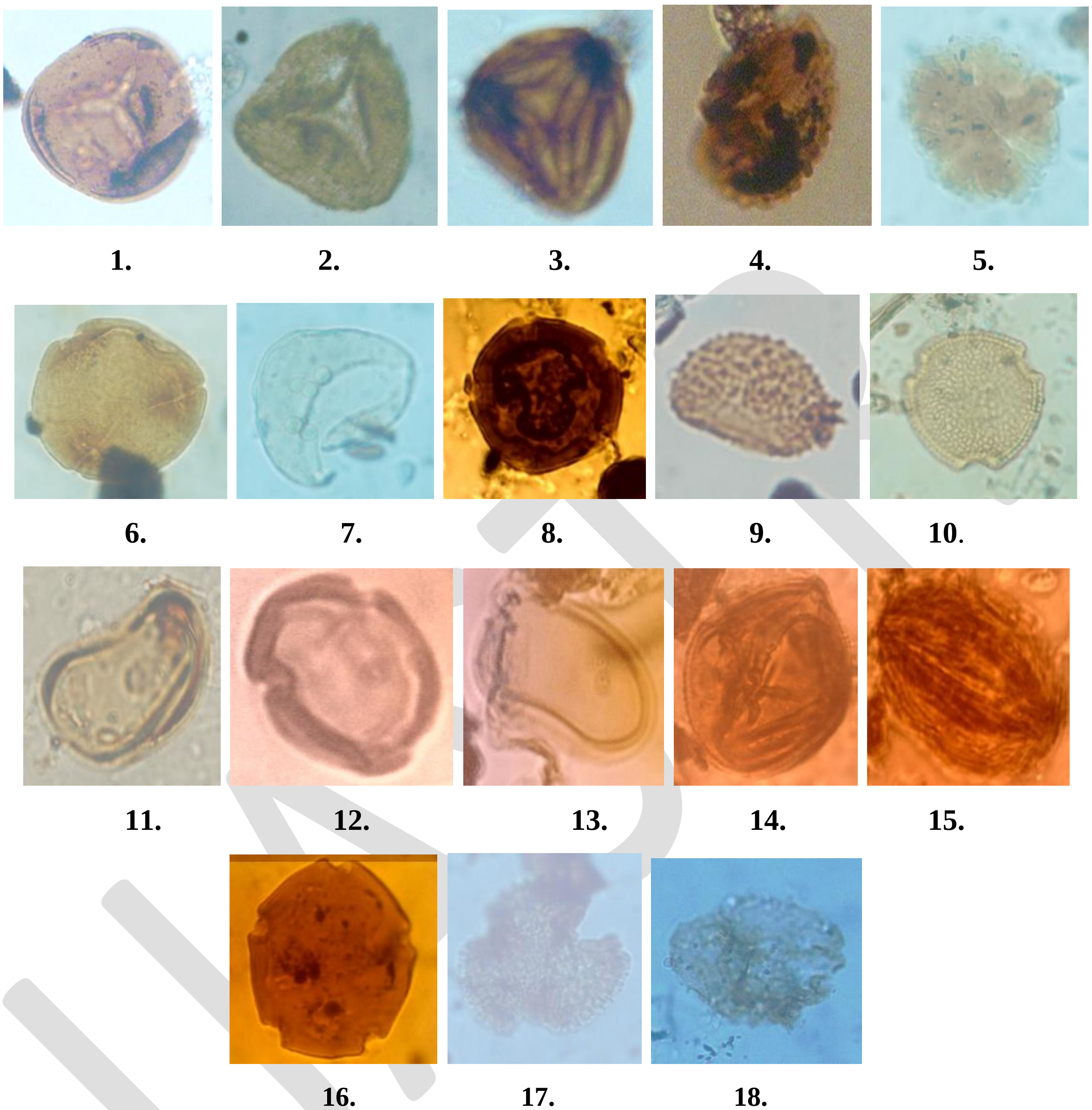

Plate 2: Photomicrographs of Palynomorphs from the the GAB-1 well

1. *Acrostichum aureum*; **2.** *Pteris* spp.*;* **3.** *Magnastriatites howardi;* **4.** *Verrucatosporites usmensis* **5.** *Botryococcus braunii*; **6.** *Psilatricolporites crasus*; **7.** *Gemmamonoporites* spp.; ***8*** *.Psilamonocolpites marginatus*; **9**. *Verrucatosporites* spp.; **10.** *Canthium* spp.*;* **11**. *Laevigatosporites* spp.; **12.** *Zonocostites ramonae*; **13**. *Cyperaceaepollis* spp.; **14.** *Monoporites annulatus*; **15.** *Striaticolpites catatumbus*; **16.** *Pachydermites diederixi*; **17** *Retitricolporites irregularis*; **18.** *Stereisporites* spp.