PALEOECOLOGY OF THE NEOGENE AGBADA FORMATION, NIGER DELTA, NIGERIA

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ABSTRACT

Abundant and well preserved assemblages of pollen, spores, dinoflagellates, freshwater algae and fungal remains had been encountered and documented from three selected wells within the onshore Central II and Coastal I and II depobelts in the Niger Delta. The encountered assemblages indicated a preponderance of forms belonging to terrestrial origin which include: the pteridophytic and bryophytic spores, gymnosperm and angiosperm pollen. The retrieved angiosperm pollens were those typical of Neogene tropical areas. In addition, marine indices (dinoflagellates), freshwater algae and other indeterminate groups were also abundantly recovered from the investigated sediments. The ecologically significant taxa yielded five main phytoecological groups namely mangrove, freshwater, coastal-swamp, savanna, montane and tropical rainforest groups.

Keywords: Dinoflagellates, Pollen, Spores, Agbada Formation, Niger Delta, Nigeria

INTRODUCTION

The Niger Delta Basin of Nigeria is located at the tip of the failed arm of a triple junction, the fracture zone that initiated the separation of Africa Continent from that of South America plate (Fig. 1) between the Late Jurassic and the Cretaceous (Weber and Daukoru, 1975). The southeastern boundary of the Niger Delta is delineated by the Calabar flank with the Late Cretaceous Abakaliki Anticlinorium (Abakaliki Fold Belt) defining the northeastern limit (Figs. 1-2). To the west, the Niger Delta Basin is bounded by the Late Cretaceous Dahomey Basin. The Anambra Basin marks its northern boundary; to the south and offshore is the Gulf of Guinea. The evolutionary history of the basin has been extensively researched and documented in the works of: Hospers, 1965; Short and Stäuble, 1967; Weber and Daukoru, 1975; Lehner and De Ruiter, 1977; Evamy *et al.*, 1978.

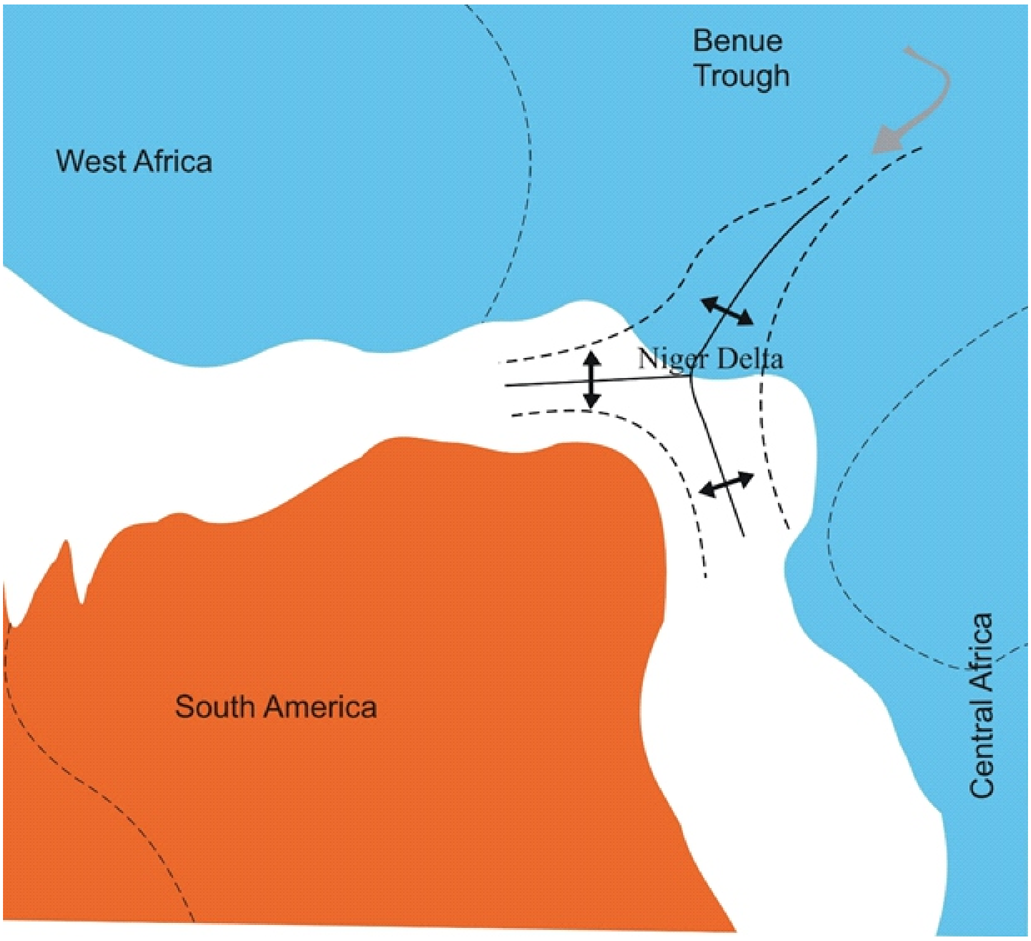


Fig. 1. Sketch Map of the Separation of the African and South American Plates in the Cretaceous. (Note the position of the Niger Delta)

The palynology of the Neogene Agbada sedimentary unit of the Niger Delta has also attracted the attention of several workers. Among the workers are: Germeraad *et al.* (1968), Jan du Chêne *et al.* (1978), Oboh *et al.* (1992), Morley and Richards (1993), Oboh (1995), Armentrout *et al.* (1999), Van Der Zwan and Brugman (1999), Ige (2009) and Bankole *et al.* (2014) among many others.

The present paper presents the ecological significance of some of the palynomorphs recovered from the analysis of 407 ditch cutting samples from three wells (Wells 4, 6 and 8) selected from three different depositional belts namely Coastal Swamps I & II and Central Swamp I (Fig. 2). The primary aim of this work, therefore, is to reconstruct the phytoecology of the flora which inhabited the Niger Delta province during the Paleogene using their pollen and spore record.

Stratigraphy The sedimentary sequence of the Niger Delta is divided into three formations namely Akata, Agbada and Benin from base to the top (Short and Stäuble, 1967). The Akata Formation is a holomarine sequence characterized by uniform shale deposit (Fig. 3). The shales of this formation are largely under-compacted (Akpoyovbike, 1978) despite its stratigraphic position. This results in the over-pressure of the Akata Formation. Lying on top of the Akata Formation is the paralic Agbada Formation. This formation consists of fine to medium-grained sand/sandstones and mudstones. Several fairly clean coarse-grained sands have also been encountered in the lithologic units. They are also locally calcareous, shelly, and contain pyrite (Bankole *et al.*, 2014). Capping the sequence is the continental Benin Formation. The Benin Formation is characteristically medium to coarse-grained sands/sandstones. The sands are generally fairly clean but evidence of organic remnants (wood fragments) have been found in the formation (Bankole *et al.*, 2014).

MATERIALS AND METHODS

Four hundred and seven (407) ditch cutting samples from three wells (Well 4, 6 and 8) with their corresponding electronic gamma ray logs were used for the present investigation. The materials were provided by Shell Petroleum Development Company of Nigeria. The geological formations penetrated by the wells are: the Agbada and the Benin Formations. The lithological sections of the three wells were produced by feeding the Gamma Ray raw data into Petrel Software. This generated a log based on Gamma Ray principle of discriminating between shale and sand or radioactive elemental composition of materials. The ditch cutting samples were analyzed following standard palynological preparation method which included sample treatment with 10% HCl and 35% HF. It is important to point out that no oxidation was conducted on the samples because of the selective destructive effect this can have on some of the palynomorphs, especially on the dinoflagellates.

Microscopic scanning of the palynomorphs was carried out using a Leitz Diaplan Microscope (Leitz Wetzlar; Type 307-148.001). Photographic work was done using Olympus Digital Camera DP 12. All slides, sieved and unsieved residues were stored at the Institut für Angewandte Geowissenschaften, Technische Universität Berlin, Germany.

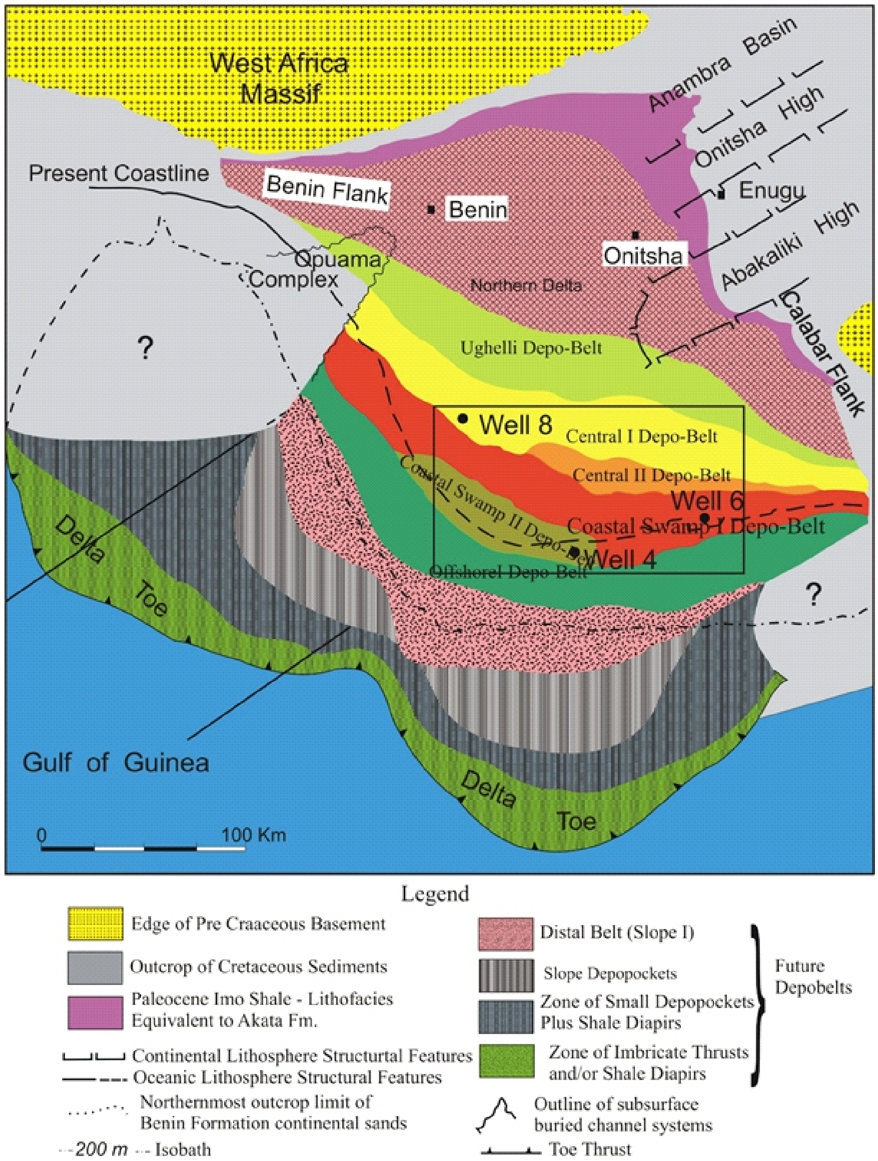


Fig. 2. Regional Structural Elements and Depobelts of the Niger Delta (Modified after Doust and Omatsola, 1990; the box indicates the Location of the Study Area).

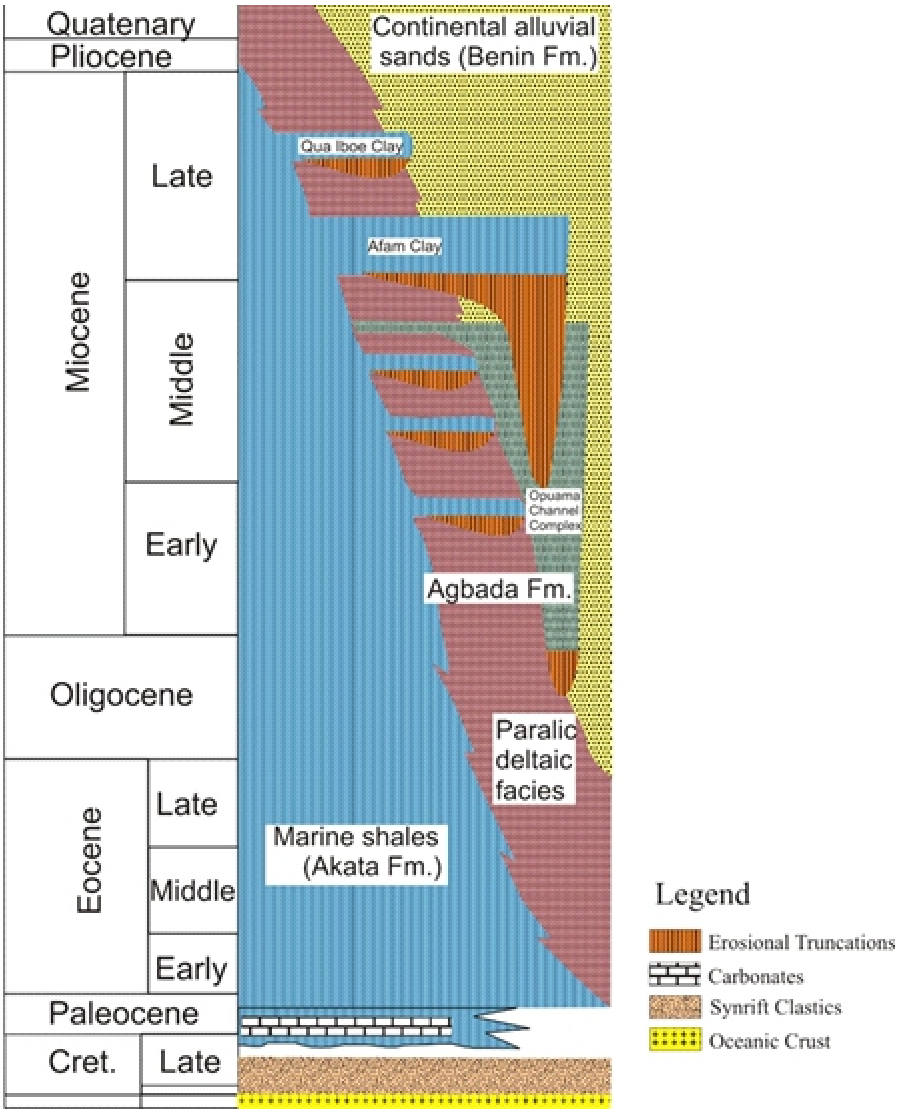


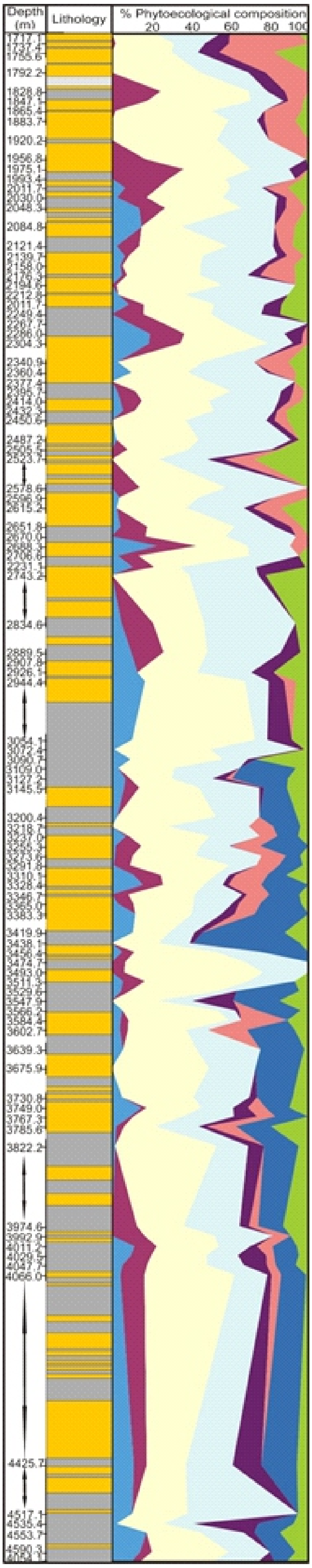
Fig. 3. Schematic Representation of Diachronous Nature of Major Lithofacies Units and Stratigraphic Relationships of Clay-filled Channels on the Delta Flanks (Modified after Doust and Omatsola, 1990 and Lawrence *et al.*, 2002).

RESULTS AND DISCUSSIONS

Palaeoecological Consideration of the Palynomorph Groups

The palynomorphs encountered in the three wells (Wells 4, 6 and 8) spread across five main ecological groups namely mangrove, coastal plain, savanna, montane and the rainforest groups (Figs. 4-6; Plates 1-2). Other ecological groups include marine and freshwater groups. These groupings were based on the botanical affinities of the fossil pollen and spores recovered from the wells

Well 4 (Coastal Swamp II)



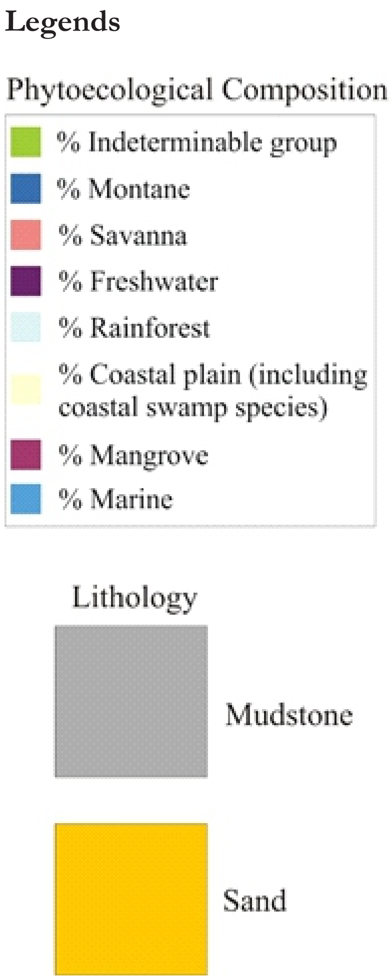


Fig. 4: Phytoecological Composition of the Palynomorph Assemblages in Well 4. (Note: Arrows indicate large sample intervals resulting from barrenness or non-availability of samples).

Well 6 (Coastal swamp I)

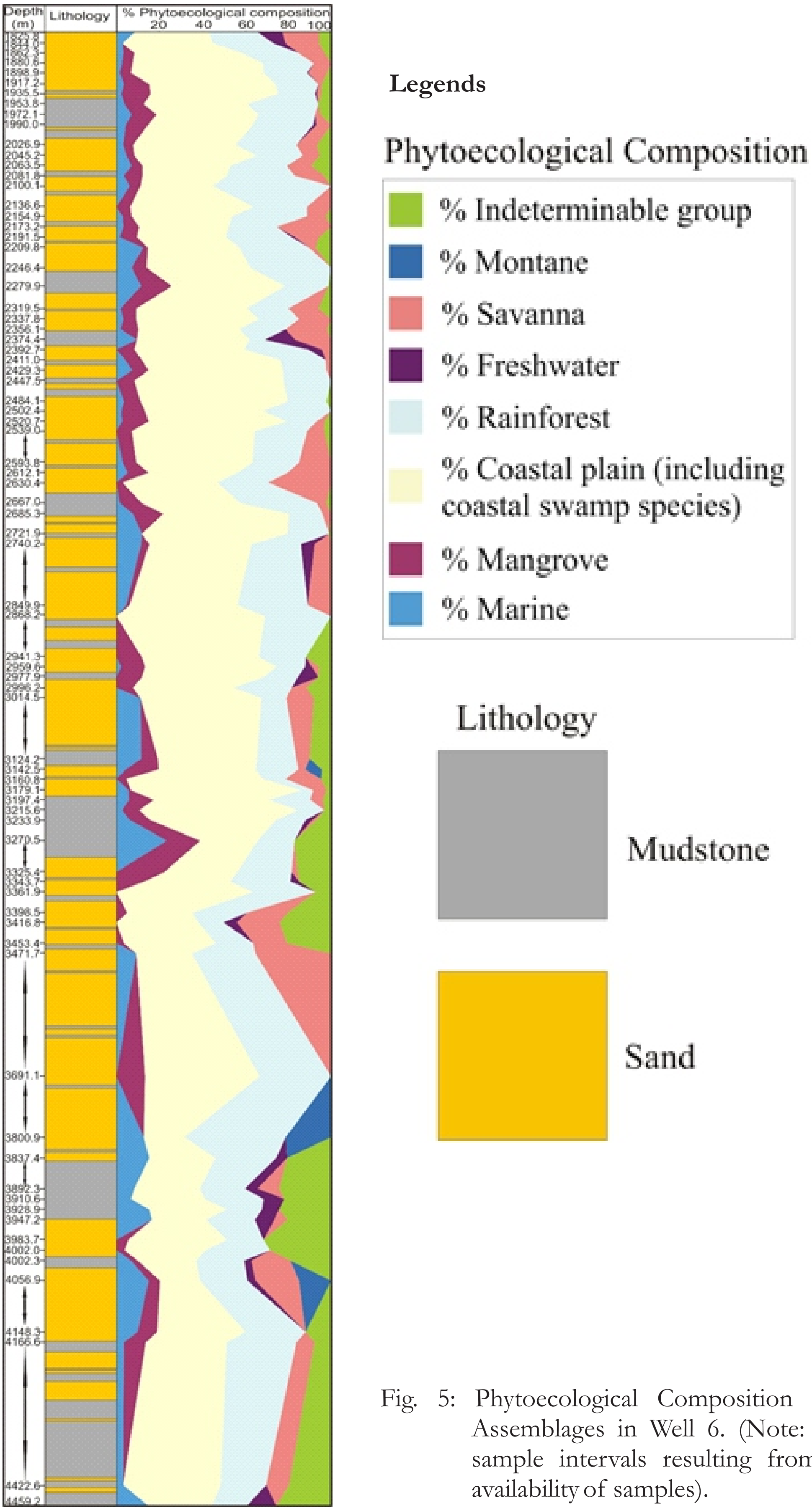


Fig. 5: Phytoecological Composition of the Palynomorph Assemblages in Well 6. (Note: Arrows indicate large sample intervals resulting from barrenness or non-availability of samples).

Well 8 (Central Swamp I)

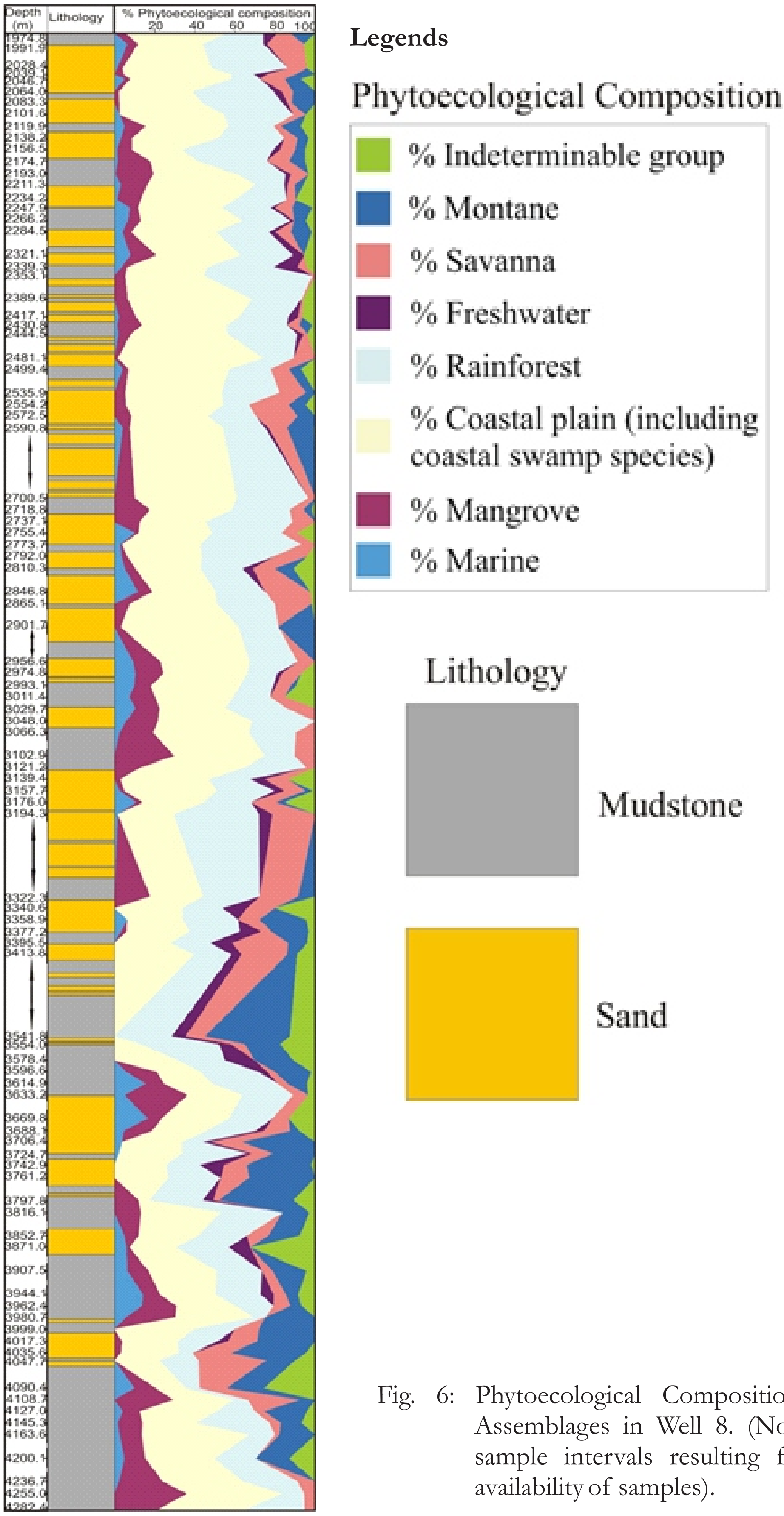


Fig. 6: Phytoecological Composition of the Palynomorph Assemblages in Well 8. (Note: Arrows indicate large sample intervals resulting from barrenness or non-availability of samples).

Mangrove Group

The principal mangrove elements recovered from the investigated sections include the genera *Acrostichumsporites*, *Psilatricolporites* and *Zonocostites*. The genus, *Acrostichumsporites* is morphologically similar to the spores of *Acrostichum aureum* which has been identified as a principal fern presently growing within mangrove vegetation (Kar, 1992 with references therein; Graham, 1995; Ramcharan and McAndrews, 2006; Massini *et al*., 2006). The above mentioned authors have indicated the adaptation of *Acrostichum* to coastal areas associated with mangrove vegetation, areas inundated with saline waters, open salt marshes, coastal swamps and areas along estuarine rivers (Massini *et al*., 2006).

The pollen of *Zonocostites ramonae* botanically belongs to the *Rhizophoraceae* (Van der Hammen and Wymstra, 1964; Germeraad *et al*., 1968). *Rhizophora* is an important member of mangrove community in southern America (Graham, 1995; Germeraad *et al*., 1968; Graham and Jarzen, 1969); in the Gulf of Guinea (Germeraad *et al*., 1968; Poumot, 1989) and across the low latitudes of NW Borneo (Osterloff, pers. comm., 2010). *Psilatricolporites crassus* is another important component of the mangrove community widespread across tropical Africa (Germeraad *et al*., 1968) and South America (Van der Hammen and Wymstra, 1964; Graham, 1977; Rull, 2001). The pollen *Psilatricolporites crassus* is believed to be derived from the mangrove plant *Pelliceria* (Graham, 1995; Rull, 2001).

Coastal Plain Group (including Swamp Species)

Taxa characteristic of this assemblage as recovered from the present work include: *Pachydermites diederixi*, *Retitricolporites* cf. *irregularis, Retitricolporites* sp., *Crassoretitriletes vanraadshooveni*, *Magnastriatites howardi*, *Polypodiaceoisporites* genus, *Perimonoletes* sp. and *Cyathidites congoensis*. *Magnastriatites howardi* is associated with alluvial plain and coastal swamps, especially in shallow water where the parent plant grows (Germeraad *et al*., 1968; Rull, 2001). Graham (1988b) also reported the occurrence of the spore in aquatic ditches, lagoons, river/lake margins and brackish waters of southern and northern America. *Crassoretitriletes vanraadshooveni* which is a climbing fern spore is reported to be inhabitant of humid marshes and coastal swamp forests in West Africa and in the Indo-Malaysian area (Germeraad *et al*., 1968).

The genus *Polypodiaceoisporites* has been referred to as *Pteris* in many of Graham's works (Graham, 1988a, b and 1989). It is the spore of a fern inhabiting coastal wet and humid environments (Graham, 1991). *Pachydermites diederixi* which is related to *Symphonia globulifera* (Germeraad *et al*., 1968) displays constant occurrence in the three wells investigated. The *Symphonia globulifera* plant is known to be a dominant species in the coastal swamps of Africa, including Nigeria (Germerad *et al*., 1968). *Retitricolporites* cf. *irregularis*, a taxon of sustained presence in this study has also been identified with coastal swamp (especially creek) environments (Germeraad *et al*., 1968). Armentrout *et al.* (1999) attributed the same pollen to an open freshwater swamp forest index species. The tree ferns such as Cyathea (*Cyathidites*) and *Pteris* (*Polypodiaceoisporites*) indicate thick and closed tropical forest (Samant and Phadtare, 1997; Graham, 1988b).

Savanna Group

This assemblage is defined by the abundance occurrence of *Graminidites annulatus*. The pollen botanically belongs to the Gramineae (Poaceae) confined basically to more open vegetation, coastal savannas and river valleys (Germeraad *et al*., 1968). Morley and Richards (1993) in their work on charred Gramineae cuticles from the Cenozoic sediment in the Niger Delta also associated Gramineae to savanna and freshwater swamp environments. *Graminidites annulatus* is mostly associated with dry environments. The following taxa: *Monocolpites marginatus*, *Psilamonocolpites* cf. *medius*, *Racemonocolpites hians*, and *Striatopollis* genus also occupy freshwater to upper coastal plain environments. The pollen of the Palmae, ?Liliaceae and ?Arecaceae groups which include *Monocolpites marginatus, Psilamonocolpites* cf. *medius* and *Racemonocolpites hians* have all been identified as inhabitants of upper coastal plain forests (Van der Hammen, 1957; Van der Hammen and Wymstra, 1964; Morley and Richards, 1993; Mahmoud and Schrank, 2007).

Montane Group

The bissacate pollen group represented by the single genus *Podocarpidites* is considered an important member of tropical montane/highland flora. Their morphology (presence of air-sacs) enables far and wide dispersal through wind and water flotation. They might have been transported by wind from far away in the continent, probably from mountainous areas of Cameroun before finally been incorporated into marine sediments through the Niger-Benue Rivers. If this hypothesis holds, the tree must be a prolific pollen producer due to their very high frequency of abundance in Wells 4 and 8 (Figs. 4 and 6).

Rainforest Group

Large amounts of fossil pollen (mostly Angiosperms) with botanical affinities assigned to tropical rain forest plants were recovered from the three wells (Wells 4, 6 and 8). Notable among these pollen are *Bombacacidites* cf. *africanus, Bombacacidites* sp. cf. *clarus, Brevitricolporites molinae, Caprifoliipites superbus, Polyadopollenites indecorus*, *Psilastephanocolporites laevigatus* (*Sapotaceae*), *Psilastephanocolporites* cf. *perforatus,* and *Psilastephanocolporites* spp..

Marine Group

Marine-derived elements such as dinoflagellates and foraminifera test linings have also been commonly associated with the mangrove pollen/spore component of this setting. The dinoflagellates identified range from those typical of shallow to open marine environments, i.e. *Lejeunecysta*, *Lingulodinium* and *Paleocystodinium* for shallow marine and *Adnatosphaeridium*, *Cordosphaeridium*, *Homotryblium*, *Polysphaeridium*, *Spiniferites* and *Tuberculodinium* for the relatively open marine settings.

Freshwater Algal Group

Fossilised remains of freshwater green algae including *Chomotriletes minor*, *Ovoidites parvus* and *Pediastrum* spp. show significant representations in the three wells investigated (Figs. 4-6). *Chomotriletes minor* and *Ovoidites parvus* belong to the freshwater green algae family Zygnemataceae. A few specimens of *Botryococcus* are also sporadically represented in the sections. Though the presence of *Botryococcus* may suggest the inclusion of a freshwater or lacustrine environment but they are not more definitive as *Chomotrilete minor*, *Ovoidites parvus* or *Pediastrum* which show greater preference for freshwater or lake environments than *Botryococcus*. Fossil records of *Botryococcus* range from lacustrine, fluvial, to lagoonal facies (Batten & Lister, 1988) and even in shallow marine settings of the Niger Delta.

Fungal Elements

Fungal remains and inaperturate components of the recovered palynomorphs which could not be specifically assigned to any ecological group are referred herein to the Indeterminate group (Figs. 4-6). They are abundantly represented in all the sections investigated. The fungal components of this group include: *Callimothallus pertusus, Callimothalus* spp.*, Fusiformisporites crabii, Microthyriacites* spp. and *Parmathyrites* spp.. They are often associated with rapidly degrading woody tissue under aerobic condition (Van Der Zwan and Brugman, 1999) reported to be abundant in deltaic environments.

CONCLUSIONS

The main ecological groups (mangrove, coastal swamp forest, savanna to upper coastal forests and montane to rainforest) identified in the study largely belong to the humid tropical ecosystem which might have persisted in the Niger Delta of Nigeria since the Neogene. Majority of the species encountered (*Acrostichumsporites*, *Psilatricolporites*, *Zonocostites*, *Pachydermites* and *Polypodiaceoisporites* etc.) have been reported in other parts of the world such as South America, Indonesia, Malaysia and India making them highly cosmopolitan. The implication of this is that the mentioned parts of the world share the same ecosystem with the Niger Delta in the Neogene.

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PLATE 1

Well name, sample number, slide number and coordinates are given for each of the illustrated specimen. Scale bar equals 20 µm.

Fig. 1. *Perinomonoletes* sp. 1 6-9890-2, coord., 46/94.1

Fig. 2. *Cyathidites congoensis* Sah, 1967 4-12540-2, coord., 36.8/99.2

Fig. 3. *Acrostichumsporites meghalayaensis* Kar, 1991 6-6470-2, coord., 46/110

Fig. 4. *Acrostichumsporites* sp. 1 6-7190-2, coord., 30.6/103

Fig. 5. *Magnastriatites howardi* Germeraad et al. 1968 4-10620-2, coord. 55.1/105

Fig. 6. *Crassoretitriletes vanraadshooveni* Germeraad et al., 1968 8- 6530-1, coord. 46/107

Fig. 7. *Polypodiaceoisporites* sp. cf. *congoensis* Sah, 1967 4-6180-1, coord. 38.7/107.4

Fig. 8. *Podocarpidites clarus* Sah, 1967 4-10500-2, coord. 41/106.

Fig. 9. *Podocarpidtes* sp. 3 4-11040-2, coord. 40.8/110.6

Fig. 10. *Polyadopollenites indecorus* Takahashi & Jux, 1989 4-6840-2, coord. 45.8/104.4

Fig. 11. *Graminidites annulatus* (Van der Hammen) Potonié, 1960 6-7130-2, coord. 38.2/110.7

Fig. 12. *Longapertites marginatus* Van Hoeken-Klinkenberg, 1964 6-8690-, coord. 36.7/105.7.

Fig. 13. *Psilastephanocolporites laevigatus* Salard-Cheboldaeff, 1978 6-10730-1, coord. 28/110.2

Fig. 14. *Pachydermites diederixi* Germeraad, Hopping & Muller, 1968 4-7920-1, coord. 37.3/107.1

Fig. 15. *Retitricolporites irregularis* Van der Hammen & Wymstra, 1964 6-13070-2, coord. 39.1/107

Fig. 16. *Annutriporites iversenii* González Guzmán, 1967 6-10370-1, coord. 23/93.1.

Fig. 17. *Polygalacidites* sp. Takahashi & Jux, 1989 6-10910-1,coord. 42.2/94.8.

Fig. 18. *Caprifoliipites superbus* Sah, 1967 6-6230-1, coord. 35.3/108.9.

Fig. 19. *Zonocostites* cf. *ramonae* Germeraad, Hopping and Muller, 1968 4-6420-1, coord. 60.2/96.1

PLATE 1

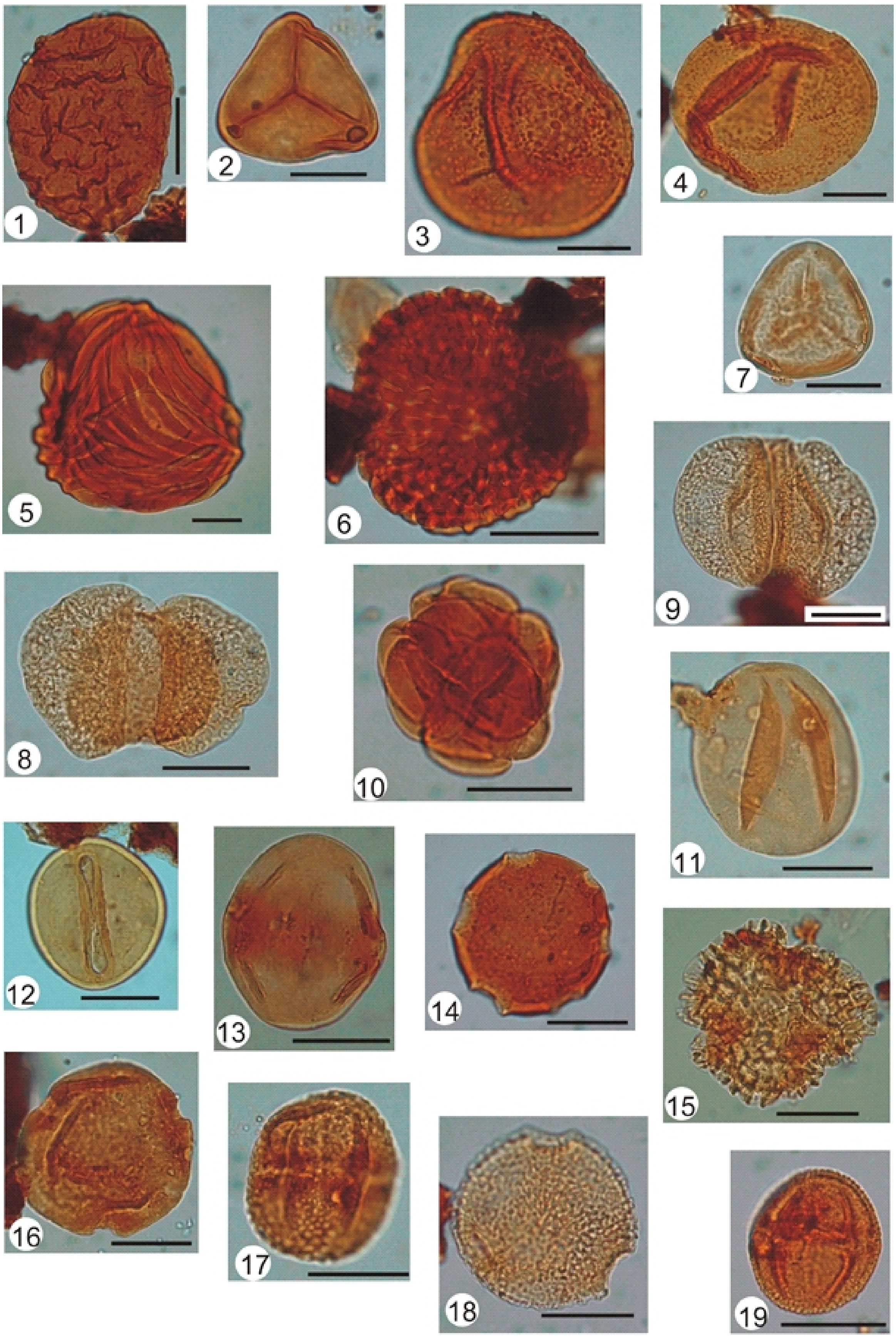


PLATE 2

Well name, sample number, slide number and coordinates are given for each of the illustrated specimen. Scale bar equals 20 µm.

Fig. 1. *Psilatricolporites crassus* Van der Hammen & Wymstra, 1964
6-6650-1, coord. 36.1/108.4

Fig. 2. *Bombacacidites* cf. *africanus* Takahashi & Jux, 1989
8-9880-2, coord. 40/108.9.

Fig. 3. *Racemonocolpites racematus* (Van der Hammen, 1954a) González Guzmán, 1967
6-12950-1, coord. 43.8/93.3

Fig. 4. *Lejeunecysta lata* Biffi & Grignani, 1983
4-10320-1, coord. 47.9/112.4

Fig. 5. *Lejeunecysta cinctoria* Bujak, 1980
4-10320-1, coord. 52.5/111.4.

Fig. 6. *Lejeunecysta* sp. 1
4-9600-2, coord. 29/105.6.

Fig. 7. *Palaeocystodinium* cf. *golzowense* Alberti, 1961
4-7740-2, coord. 33.2/91.7.

Fig. 8. *Cordosphaeridium fibrospinosum* Davey & Williams, 1966
6-10730-2, coord. 32/105.8.

Fig. 9. *Lingulodinium* sp. cf. *sicula* (Drugg, 1970) Wall & Dale in Wall et al., 1973
6-10250-1, coord. 51/101.6

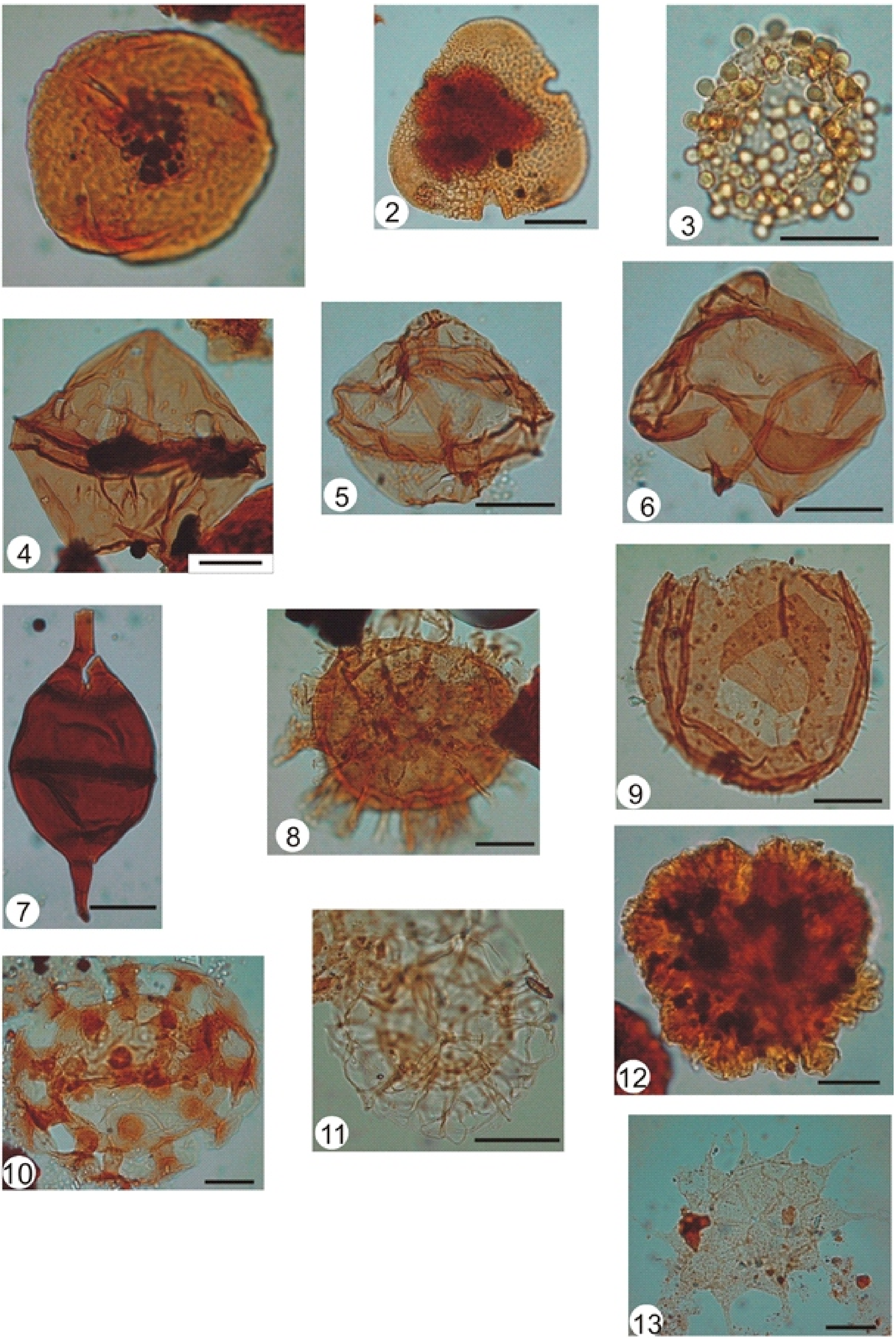
Fig. 10. *Tuberculodinium vancampoae* Rossignol, 1962
4-9480-1, coord. 43.3/98.3.

Fig. 11. *Adnatosphaeridium* sp.,
6-7250-1, coord. 30/105.1.

Fig. 12. *Brotyococcus* spp.,
4-6600-1, coord. 40.3/102.

Fig. 13. *Pediastrum* spp.,
4-13220-1, coord. 51.7/103.5

PLATE 2



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