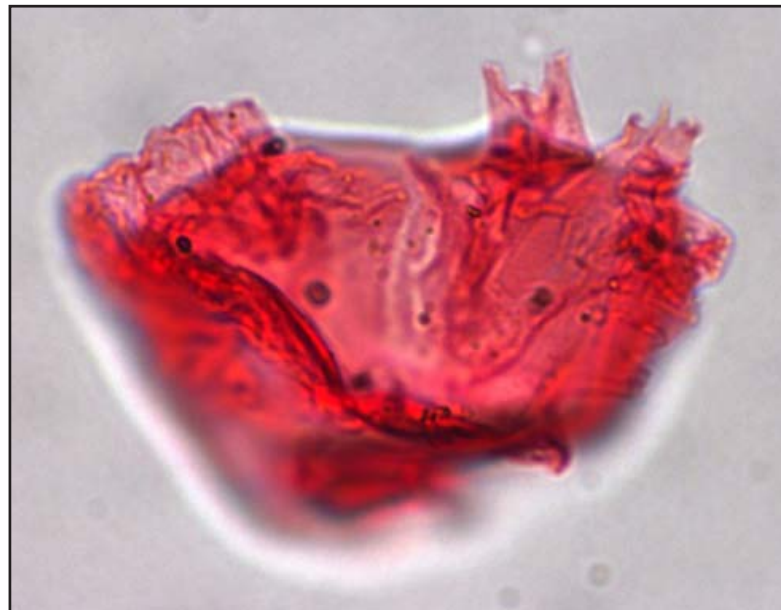


**Oligocene to middle Miocene
sediments from ODP leg 159, site
959 offshore Ivory Coast,
equatorial West Africa.**

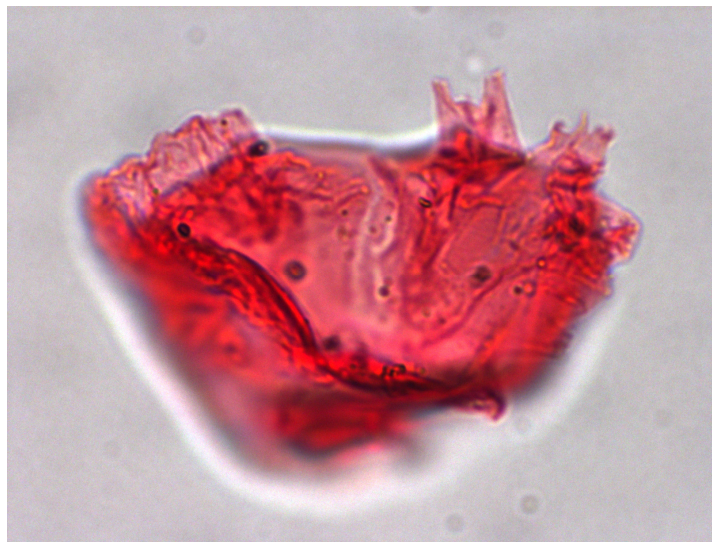
Elin Hulth

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Geologiska institutionen
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**Palynology of Oligocene to middle
Miocene sediments from ODP leg
159, site 959 offshore
Ivory Coast, equatorial West Africa.**



Bachelor Thesis
Elin Hulth

Department of Geology
Lund University
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Abstract: The Oligocene and Miocene are characterized by a number of climate oscillations, following the primary Milankovitch cycles but varying in magnitude. Dinoflagellates are sensitive environmental indicators as well as biostratigraphic markers, but their use as the former has mainly been restricted to higher latitudes. This palynological study is made on samples belonging to the Oligocene-Miocene interval from the Ocean Drilling Project leg 159, site 959, outside the west coast of equatorial Africa. The sediments comprise two units: The lower dominated by silica and the upper by chalk. The palynological assemblages have been set in two main groups; dinoflagellates and terrestrial pollen and spores, and additionally *Pediastrum*, acritarchs, fungi and “bags” (unidentified), in order to make a palaeoenvironmental interpretation. The palynomorph assemblages vary in diversity and relative abundance, but the terrestrial microfossils are predominantly the richest in number.

It is evident that there were changes in the environmental conditions during time of deposition of the investigated sequence, with the effect of fluctuating terrestrial/nearshore and oceanic influences, as well as indications of shifting water chemistry.

Keywords: Palynomorphs, Oligocene, Miocene, ODP leg 159 site 959, Ivory Coast, palaeoenvironment, climate.

Elin Hulth, Department of Geology, GeoBiosphere Science Centre, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden. E-mail: albatrots@hotmail.com

Palynologi i Oligocena till mellersta Miocena sediment från ODP leg 159, site 959 utanför Elfenbenskusten, ekvatoriala Västafrika.

ELIN HULTH

Hulth, E., 2009: Palynologi i Oligocena till mellersta Miocena sediment från ODP leg 159, site 959 utanför Elfenbenskusten, ekvatoriala Västafrika. *Examensarbeten i geologi vid Lunds universitet*, Nr. xxx, 18 sid. 15 poäng.

Sammanfattning: Oligocen och Miocen karaktäriseras av flera klimatoscillationer som följer de primära Milankovitchcyklerna men varierar i magnitud. Dinoflagellater är känsliga miljöindikatorer såväl som biostratigrafimarkörer, men deras användning som det föregående har i huvudsak varit begränsat till högre latituder. Denna palynologiska studie är gjord på prover tillhörande ett Oligocen-Miocen – intervall från the Ocean Drilling Project leg 159, site 959, utanför ekvatorialafrikas västkust. Sedimenten består av två enheter: Den lägre dominerad av kisel och den övre av kalk. De palynologiska fynden har organiserats i två huvudsakliga grupper; dinoflagellater och terrestriska pollen och sporer, och därutöver *Pediastrum*, achritarker, fungi och ”säckar” (oidentifierade), för att möjliggöra en miljötolkning. Palynomorferna varierar i diversitet och relativt antal mellan proverna, men de terrestriska mikrofossilerna är företrädesvis flest.

Det framgår tydligt att förändringar i miljöfaktorerna har förekommit vid tiden för avsättning av den undersökta sekvensen, med fluktuerande terrestriska/strandnära och oceaniska influenser som resultat, såväl som indikationer av skiftande kemiska förutsättningar i vattnet.

Nyckelord: Palynomorfer, Oligocen, Miocen, ODP leg 159 site 959, Elfenbenskusten, palaeomiljö, klimat

Elin Hulth,, Geologiska Institutionen, Centrum för GeoBiosfärvetenskap, Lunds Universitet, Sölvegatan 12, 223 62 Lund, Sverige. E-post: albatrots@hotmail.com

1 Introduction

Dinoflagellates are motile planktonic protists that form a main part of the primary producers of present day's oceans and fill an important role in the global carbon cycle. Presently, interest is partly focussed on the fact that dinoflagellates can cause harmful algal blooms or disruptions for the world's economy. However, about 15% of the dinoflagellate species have lifecycles during which an organic resting cyst is produced, and such fossil cysts are also found in the sedimentary record as far back as to the Triassic. There is an increased interest for dinocysts as dating and paleoenvironmental tools, as they are sensitive environmental indicators and have many short-ranging species, providing a detailed biostratigraphy (Williams et al. 2004; Sluijs et al. 2005).

The focus of this report is marine sediments that span the Oligocene- Miocene boundary. In Zachos et al. (1997), it is demonstrated that the time periods Oligocene and Miocene were characterized by climate oscillations related to orbital frequencies, and different authors have since been able to make detailed astronomical calibrations as well as correlations with isotope records of $\delta^{18}O$ and $\delta^{13}C$ (e.g. Billups et al. 2004). In the sedimentary record, the isotope values through the Oligocene and Miocene have been identified as following all primary Milankovitch frequency bands, with a prominent excursion of both positive $\delta^{18}O$ and $\delta^{13}C$ values at the boundary (Zachos et al. 2001b). General consensus is that in the beginning of Oligocene, a sudden rapid cooling and increase in seasonal-

ity took place, until the climate once again changed for the warmer in the late Oligocene, to reach a temperature peak. The Oligocene/Miocene (O/M) boundary at 23.03 Ma is characterized by an isotope event - called the Mi-1, which is interpreted as new ice growth taking place due to global cooling. A stepwise warming culminated during the mid-Miocene climatic optimum. The end of this warm-period marked the onset of Miocene cooling, likewise interrupted by periods of increased temperatures (Zachos et al., 2001; Hirohiko & Shikazono 2003 Mosbrugger et al. 2005; Akgun et al., 2007.)

The aim of this study is to give a brief summary of the climatic changes associated with the Oligocene-Miocene boundary interval in eastern equatorial Atlantic, offshore of the Ivory Coast, focusing mainly on marine ecosystems and the dinoflagellate assemblages. Another aim is to gain practical experience of palynological procedures and learn about the identification of palynomorphs, dinocysts primarily, and the routine of count study through the use of light microscopy. Furthermore, the intent of this study is to attempt a paleoenvironmental and climate interpretation from the identified specimens and assemblages of sediments spanning the Oligocene-Miocene boundary from an ODP drill core at site 959, offshore Ivory coast.

2 Geological setting and Background

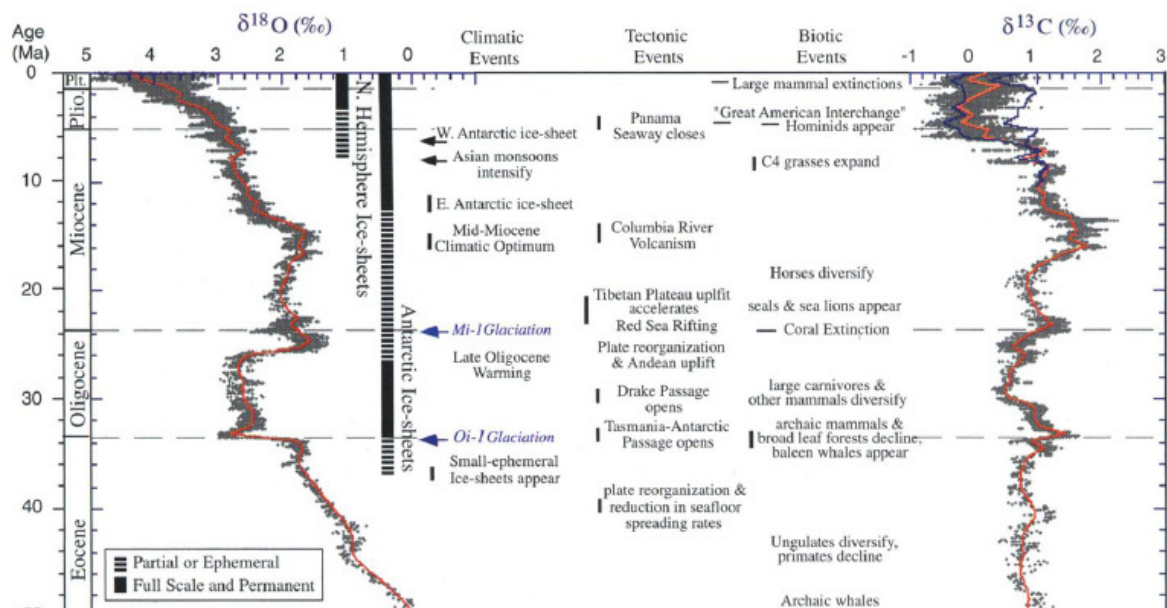


Fig. 1. "Global deep-sea oxygen and carbon isotope records based on data compiled from more than 40 DSDP and ODP sites", modified from Zachos et al. (2001a).

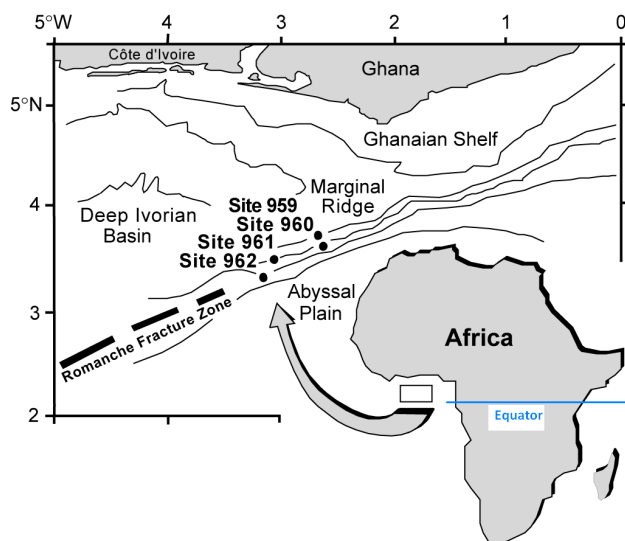


Fig. 2. Location of Côte d'Ivoire-Ghana Marginal ridge and position of Leg 159 drill sites. Modified from Strand (1998).

The Côte d'Ivoire-Ghana Marginal Ridge (hereafter referred to as CIGMR) is situated south of the western lobe of Africa, and can be followed westward to the Romanche Fracture Zone (Fig. 2). Between the CIGMR and the coast towards the northwest lies the Deep Ivorian Basin and Site 959 is located on the shoulder of this, adjacent to the Marginal ridge (e.g. Schellpeper and Watkins 1998). The Ridge is a passive transform margin marking the boundary of the African continent, and the formation of the Deep Ivorian Basin most likely began during the Early Cretaceous when Africa rifted away from South America (e.g. Basile et al. 1996; Basile et al. 1998). The final separation between the two continents occurred in the Santonian, and an active continental transform margin stage commenced. It continued until Paleocene, whereafter tectonic movements ceased and the margin became passive. Hence, there was no active tectonism during the Oligocene-Miocene. At site 959, the sediments of this period are dominated by mainly siliceous sedimentation with some occasional, more clay rich intrusions in the Oligocene, changing to nannofossil/foraminiferal ooze and chalk with the addition of clayey deposits and diatomite sediments during the early Miocene. The diatomite only occurs from early Oligocene to early Miocene (Fig. 3.). Higher up in the Miocene sedimentary record, nannofossil, foraminiferal ooze and chalk dominate. This has been interpreted to be a shift from pelagic sediments in the Oligocene, changing to hemipelagic sediments in the Miocene (Obboh-Ikuenobe & Yepes 1997; Strand 1998).

3 Previous works

The Ocean Drilling Program (ODP) Leg 159, undertaken in 1995, carried out a detailed study of the CIGMR. The cruise and its resulting reports mainly focused on the tectonic history of the area and on the evolution of the transform margin. Other geological articles dealing with sediments offshore the Ivory Coast derive data from ODP material, since the ODP cores present the best and most complete access to the sedimentary record from this area (Masclé et al. 1998 p.10).

Previous works have focused mainly on Cretaceous to Paleocene sedimentary successions, but for instance Schellpeper & Watkins (1998), Norris (1998) and Obboh-Ikuenobe & Yepes (1997) deal with the palynology across the Miocene/Oligocene boundary transition. Dinoflagellates were not examined in detail in their studies, but a more extensive examination has been made by Obboh-Ikuenobe et al. (1998). This was, however, restricted to older sediments. It follows that the papers used in this article are from 1995 or later but there are nevertheless several studies preceding the ODP: The regional scale surveys (Equamarge I and II) were carried out during the 1980:s but initiated already in the 1970:s Géoguinée, Bénin and Walda cruises, where both seismic profiles and some samples were collected. The 1990:s saw Equasis, Equaref, and C. Darwin before the final cruise preceding the ODP: Equanaute, investigating the CIGMR slope, in 1992 (Basile et al. 1996 p. 47).

4 Material and methods

For this palynological study, six samples from ODP Leg 159, site 959A, spanning an interval from 193.25m to 388.81m, were examined. The samples were processed according to standard palynological processing methods (Vidal 1988), first treated with dilute hydrochloric acid (HCl) to remove calcium carbonate, and subsequently macerated by leaving the sample in hydrofluoric acid (HF) of a concentration of 75% over night. The organic residue was afterwards sieved through a 10 μ m mesh and mounted in epoxy on strew slides. The slides were studied through the use of light microscopy. A total of 250 palynomorphs belonging to dinoflagellates and mioflora (pollen and spores of land plants, see Appendix 1) were counted. The mioflora was divided into pollen and spores; with separate groups for saccates solely, monoporate and colpate pollen, as well as one group for those pollen not belonging to either. Additionally, the groups *Pediastrum*, acritarchs, fungi and unidentifiable "bags" were counted alongside the count of dinocysts and mioflora. Identification of taxa of interest was done

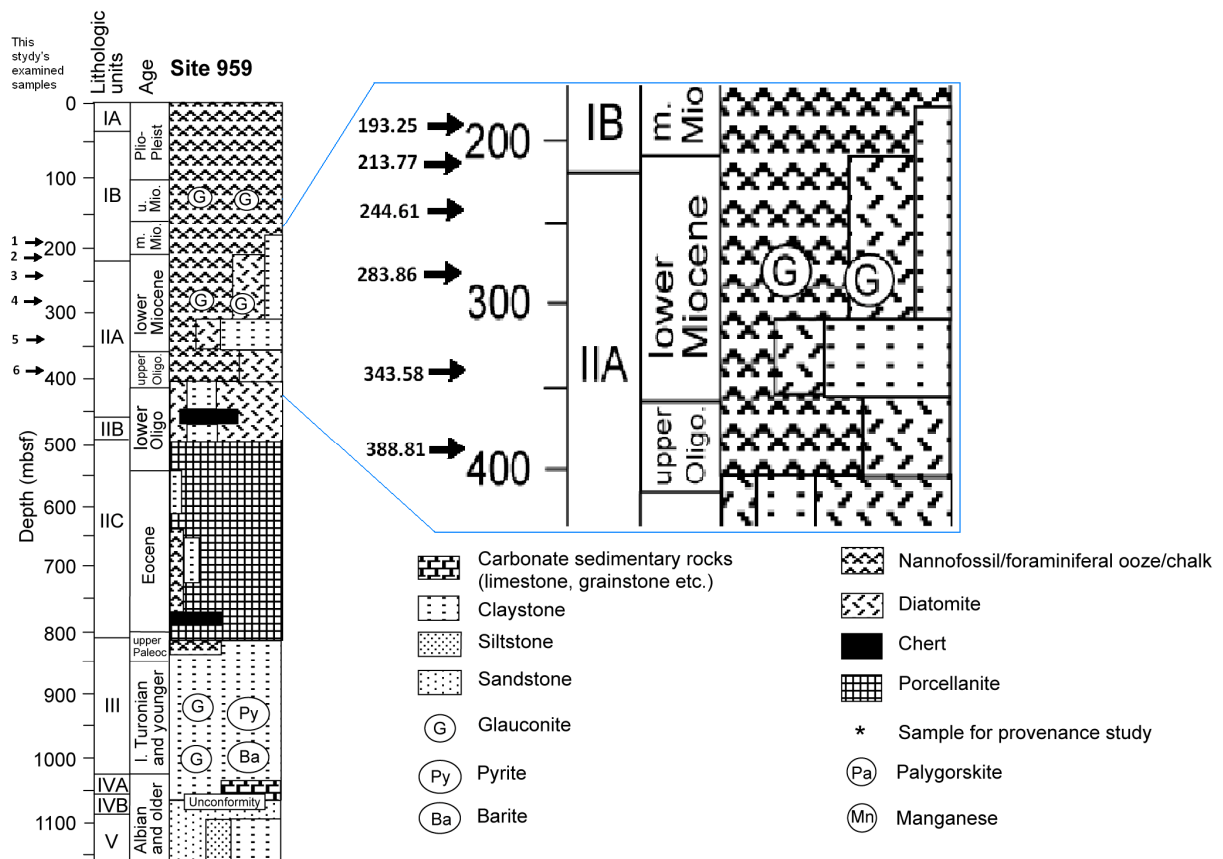


Fig. 3. Schematic log illustrating the stratigraphy of site 959 from ODP leg 159, with arrows to mark the depths from which the samples in this study are taken. Modified from Strand (1998).

using literature, previous works and instructive course material, as well as direct tutelage from Dr. Pi Willumsen. Distinction between dinoflagellate species within groups was not within the scope of this project, but as can be seen in Appendix 1, some groups consist of one single species.

5 Results

This investigation of sediments spanning the Oligocene-Miocene boundary from an ODP drillcore from the Ivory Coast, West Africa yielded well preserved palynological assemblages including dinoflagellates, pollen, spores, acritarchs, colonial algae, and foraminiferal inner linings. The results of the studied palynological slides are shown in Appendix 1. In total, 24 dinoflagellate groups have been identified, while also unidentifiable dinoflagellates as well as those clearly belonging to either *Achomosphaera* or *Spiniferites* though uncertain which, have been counted. Terrestrial groups, i.e. pollen and spores from land plants, generally dominate, but relative percentages of the different groups within each sample and also between samples will be discussed fur-

ther on. Some further explanation for some of the groups is warranted: "Unidentifiable dinoflagellates" contains specimens that could not be assigned to any group due to preservation, folding or obscuring of any kind. "Other pollen" are any pollen not belonging to the previously outlined three groups and also includes species which could not be identified. Colpate and saccate pollen are easily distinguishable even while poorly preserved, which is not true for monoporates. Thus, monoporate pollen are likely to be overrepresented in this group. "Bags" is a group used solely for comparison between different samples, as it comprises any thin-walled object with sack-like morphology, open or closed, of uncertain affinity. Thereby, amongst "bags" there might possibly be both dinocysts and mioflora (probably monoporates), albeit the relative number is expected to be fairly small. However, the classification was kept as it has significance for the palaeoenvironmental interpretation as the "bag" group was declining as amorphous matter increased, thus being indicative of change in lithology and thereby environment. In a similar manner, "fungi" was noted since its presence was seen to vary greatly over the interval.

5.1 Summary of the content of the paly-

nological slides:

No 1: 013/COR, depth 193.25m:

Good-excellent preservation with some reworked dinoflagellate specimens. Fungi dominates over all other palynomorph groups.

No 2: 015/COR, depth 213.77m:

Good-excellent preservation. Excellently preserved specimens of *Spiniferites*, and dominance of dinocysts. However, dinocysts are usually caught in clusters obscured by amorphous organic matter (AOM), which makes identification difficult.

No 3: 017/COR, depth 244.61m:

Good preservation. The lowest amount of marine palynomorphs (less than 10% of the palynomorphs) over the interval, and a specimen of the pollen *Praedopollis*. Fungi are abundant.

No 4: 020/COR, depth 283.86m:

Good-excellent preservation. No major differences from previous slide, though presenting a markedly more complete fragment of *Pediastrum* than in previous slide, the first distinct striate pollen counted and otherwise unusually good mioflora specimens. Pollen and spores still dominate, but only with the ratio 2:1.

No 5: 023/COR, depth 343.58m:

Excellent preservation, but again the palynomorphs occur in clusters and accordingly causes an increase in unidentified specimens. This slide holds a fair number of rather minute cysts similar in size to acritarchs, however, with reference to Schiøler (2005): Plate 9:15 and 17:6, 14, 15, they have been determined as *Impagidinium* (plate 2:6 in this article) and *Microdinium*. Having about the same proportion of dinocysts and mioflora, this slide shows a discrepancy from the previous and following ones. Furthermore, it displays a relatively high amount of tricolpate pollen, and a specimen of *Spirosyncolpites*.

No 6: 024/COR, depth 388.81m:

Poor-medium preservation. AOM is abundant, though mostly finely dispersed. Foraminifera inner linings observed. Pollen and spores dominate, while fungi are notably rare.

5.2 Biostratigraphy

Following the first occurrence (FO) and last occurrence (LO) as outlined in Williams et al. (2004), the species *Chiropteridium galea* ranges from 31.0 Ma to 23.98 Ma at the equator, however *Ectosphaeropsis burdigalensis* has its FO at 23.7 Ma. As both species

are present in sample no. 1, see Appendix 1, this discrepancy presents a problem. Nevertheless, as all specimens of *C. galea* are very badly preserved (for the best specimen, see Plate 1:10), whilst the specimen of *E. burdigalensis* is well preserved and almost perfectly compares to the example given in p.54 of Williams et al. (2004); it is reasonable to interpret *C. galea* as reworked. *Reticulosphaera actinocoronata* is present in equatorial waters from the late Eocene until early Pliocene, and is therefore not very valuable as a biostratigraphic tool in this study, but the presence of *E. burdigalensis* (LO equator: 13.8 Ma) confirms the age of the sample to Miocene; middle Miocene at the youngest. This is in agreement with the age given from sample depth in the logs (Figs. 3, 4). As few dinocyst groups were identified to species level, detailed biostratigraphy is difficult to perform. An occurrence of *Distatodinium apennicum* would provide us with an age between 22.57 and 21.73 Ma. Similarly, specific species of the other groups would have provided a limited time span for the samples in this study. As is, the age interpretation shown in the log of Fig. 3 will be adopted.

5.3 Environment

Figure 4 shows the reconstructed paleobathymetric curve from Oboh-Ikuenobe et al. (1997). The tables in Fig. 5 list and describe studied particles in her report, providing a comparison to the relative abundance of the palynomorphs recorded as a part of my study (Appendix 1). Appendix 2 and Fig. 7 therein accounts for the interpretations that follow below:

The two basal samples examined; no. 6 and 5 (from 388.81 m and 343.50 m depth, respectively), both contain the oceanic genus *Impagidinium*, which would indicate an oceanic influence. This is supported in sample 6 by the presence of foraminiferal inner linings and in sample 5 with the occurrence of *Nematosphaeropsis*. Among the dominating groups in sample 6 are *Achomosphaera*, *Operculodinium* and *Spiniferites*, which together belong to a neritic open marine setting, however. These are also present, and dominating, in sample 5, but the relative amount of *Spiniferites* and *Achomosphaera* is much greater than in the previous sample, while the number of *Operculodinium centrocarpum* specimens has diminished. *Thalassiphora* numbers are similar in both samples, but environmental factors have not been distinguished on group level. However, it has been suggested that certain species in the genus *Thalassiphora* relate to salinity and/or water oxygen levels (Sluijs et al. 2005). A further difference is the amount of mioflora and fungi. The number of mioflora is higher in the older compared to the younger sample, while sample 5 carries more colpate pollen and a saccate pollen grain, and also more fungi. The difference in the relative

PALEOBATHYMETRY

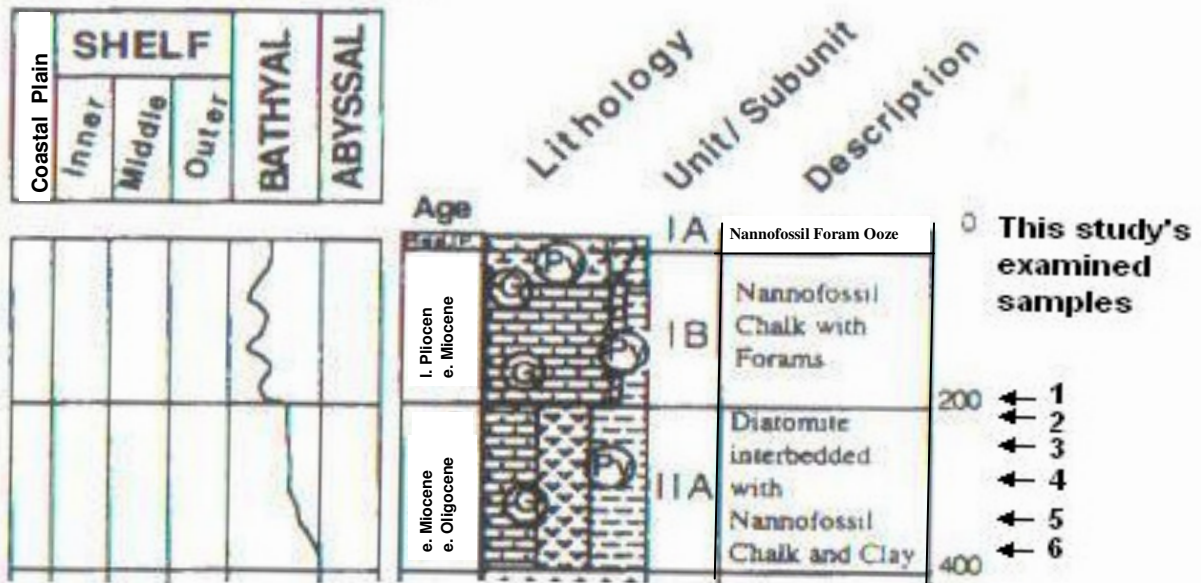


Fig. 4. Reconstructed paleobathymetric curve, lithofacies, lithological units, and description, along with depth (m) and arrows to mark level of samples in this study to the far right. Modified from Oboh-Ikuenobe et al. (1997).

Point count data (%) for organic particles and mean TAI values for samples from Site 959

Sample, hole-core-section, interval (cm)	Depth (m b.s.f.)	Aom	Mar	Algae	Resins	Bdb	Y-b	B-b	Cut	Plant	Wood	Sporom	Fungi	Mean TAI	Lith. unit
Site 959															
159-959A-21X-3, 115-117	193.25	30.70	9.30	0.00	0.70	1.30	9.00	16.70	6.00	7.70	14.00	1.30	3.00	1.00	IB
159-959A-22X-2, 40-43	200.50	34.70	7.30	0.00	0.70	1.00	7.70	16.00	6.70	5.00	12.70	4.70	3.70	1.47	IB
159-959A-23X-5, 17-21	213.70	62.70	3.30	0.00	0.00	0.70	4.70	8.00	4.70	4.00	7.70	1.30	3.00	1.67	IIA
159-959A-25X-7, 44-48	235.24	44.70	5.00	0.00	0.00	1.00	9.30	14.00	6.00	5.00	10.30	2.30	2.30	1.13	IIA
159-959A-26X-7, 11-15	244.61	55.00	4.30	0.00	0.00	0.60	6.70	10.70	7.30	4.30	7.70	1.00	2.00	1.29	IIA
159-959A-28X-1, 118-123	255.98	76.00	4.30	0.00	0.00	0.70	2.00	3.70	3.00	2.00	6.00	0.70	1.70	1.28	IIA
159-959A-29X-5, 41-45	270.81	73.30	4.00	0.00	0.00	0.70	3.00	5.30	3.70	2.70	3.70	1.30	1.30	1.62	IIA
159-959A-31X-1, 16-18	283.86	53.70	2.70	0.00	0.00	1.30	5.30	14.70	3.30	4.70	11.30	1.30	1.70	1.62	IIA
159-959A-33X-2, 143-146	305.93	66.70	4.00	0.30	0.00	0.30	4.30	11.70	2.70	4.00	7.70	1.00	1.30	1.26	IIA
159-959A-34X-4, 84-89	317.94	70.70	4.00	0.00	0.00	0.00	3.30	6.70	2.30	3.00	5.70	1.30	3.00	1.89	IIA
159-959A-37X-2, 58-61	343.58	72.70	3.00	0.00	0.00	0.00	3.70	5.30	2.70	2.30	7.00	1.70	1.70	1.15	IIA
159-959A-41X-6, 111-115	388.81	73.30	4.00	0.00	0.00	0.00	4.00	6.30	2.70	1.70	4.70	1.30	2.00	1.50	IIA

Descriptions of dispersed organic matter in the samples

Palynodebris	Characteristics	Size(µm)
Amorphous organic matter	Structureless, irregularly shaped, yellowish-amber to brown masses; usually gel like	variable
Marine palynomorphs	Dinoflagellates, acritarchs and chitinous inner linings of foraminiferal tests	30-90
Algae	Aquatic algal remains, mainly <i>Pediastrum</i>	20-70
Resins	Unstructured amber-coloured fragments from stem tissues	variable
Black debris	Opaque particles with sharp angular outlines; lath-shaped, sometimes more equidimensional	20->200
Yellow-brown fragments	Structureless particles of yellow to light brown color; attributable to highly degraded herbaceous material	5-80
Black-brown fragments	Unstructured dark brown to nearly black particles; attributable to highly degraded woody material	variable
Cuticle fragments	Platy epidermal fragments of leaves, roots, etc.; pale yellow to light brown in color	30->200
Plant tissue	All other herbaceous material including parenchyma	variable
Wood	Light to dark brown particles with sharp angular edges and/or discernible cellular structure; mainly lath-shaped	30->200
Sporomorphs	Land plant spores and pollen dispersed by water and wind into continental and marine environments	10-80
Fungi	Fungal remains such as spores, hyphae and mycelia	5->100

Fig. 5. Point count data spanning sampled interval used in this study, and explanatory description. Modified from Oboh-Ikuenobe et al. (1997).

abundance of the dinoflagellate species *Polysphaeridium zoharyi*, is the most prominent discrepancy between samples 5 and 6. *Polysphaeridium zoharyi* is mostly related to high salinity, and thus often interpreted as belonging to a restricted neritic environment. There are, however, studies suggesting salinity stratification in the upper water column that may under rare conditions permit *P. zoharyi* to prevail in more distal settings. The drastic change indicates a significant alteration in salinity, if not bathyal conditions, but it should be noted, given the high amount of terrestrial palynomorphs, that transport is a factor to consider. That said, the drop in terrestrial influx is in relative terms very small compared to the change in *P. zoharyi* abundance.

In sample 4, diversity has dropped and main groups have shifted. *Polysphaeridium zoharyi* is again abundant and dominates the dinocyst group, followed by *Lingulodinium*, that suggests nearshore euryhaline conditions (Jaramillo & Oboh-Ikuenobe 1999), though a specimen of *Nematosphaeropsis* is found. More importantly, fragments of *Pediastrum* have appeared, proving the influence of fresh water – again, this might be due to transportation along with *Lingulodinium*. Changes in terrestrial input are otherwise not very notable. There is a slight increase in mioflora abundance (mostly monoporates) and a larger increase of fungi, whereas the drop in dinocyst relative abundance is more prominent. As a whole, sample 4 indicates a stronger terrestrial influence, with little input from oceanic or outer neritic settings.

This is much more pronounced in sample 3, where dinocyst numbers are less than a tenth of the mioflora numbers. Mioflora on the other hand, together with acritarchs, is at its highest abundance among the samples. Diversity of dinocysts is low, and altogether it seems to have been relatively unfavorable conditions for dinoflagellates during this period. From *Pediastrum* and the dinocyst groups present it would appear to have been in a middle to inner shelf setting, but that is not coherent with the study of Oboh-Ikuenobe et al (1997), though non-fluorescence AOM (see Fig. 6) does have a peak about this level. Depth 244 m is around the latest early Miocene, where, according to Schellpeper & Watkins (1998), there was also a pulse of abundance of silicoflagellates. There might be some significance to this, as there are arguments of dinoflagellate blooms often succeeding diatom blooms, and dinoflagellate abundance increasing in lithological unit IB, above the siliceous sediments of subunit IIA (Oboh-Ikuenobe et al. 1997).

Despite this statement, there is a major change of dinocyst abundance already in sample 2, which belongs to subunit IIA. Here terrestrial influence is at its lowest, acritarch numbers have dropped and the relative dinocyst diversity is high. The group in absolute dominance is *Spiniferites*. As *Spiniferites* and *Achomosphaera*, which is also among the dominant groups,

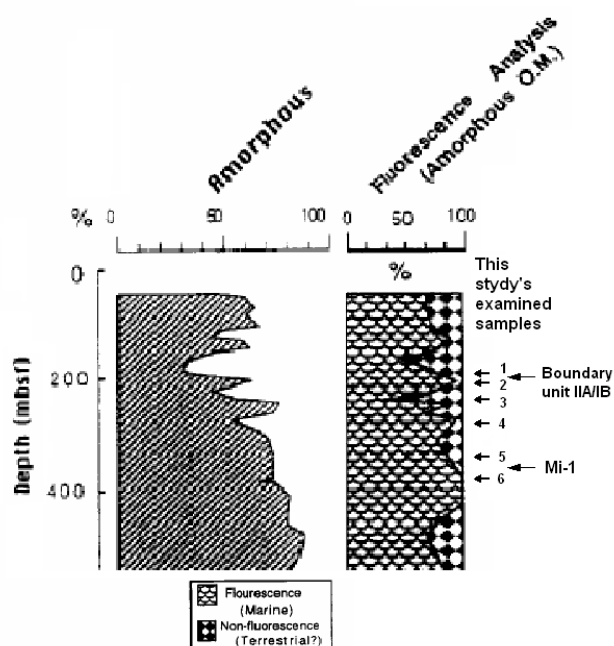


Fig. 6. Relation marine/nonmarine AOM. Arrows mark depth of the samples in this study. Modified from Oboh-Ikuenobe et al. (1997).

are associated with highest abundance during transgression and in deeper, open water, the relatively high percent of *Lingulodinium* relative to *Operculodinium* might promote the idea of a transgression from near shore to deeper neritic settings. Also, the sudden starvation of mioflora as well as fungi, and the absence of monoporates, would be in line with an increased distance to the shoreline, i.e. transgression. The AOM of Fig. 6 supports the notion, however there are no such indications in Fig. 4. Given that it is not in the scope of this study to include or investigate productivity, chemistry, currents, winds and other factors that might have instigated the result, they cannot be disregarded either.

The sample with youngest sediments, taken from subunit IB, is indeed rather different from the previous: Almost 60% of the dinocysts are *Polysphaeridium zoharyi*, the second largest group being *Nematosphaeropsis* followed by *Distatodinium*. *Polysphaeridium zoharyi* would, as previously discussed, most often indicate shallow water with high salinity, but *Nematosphaeropsis* is most abundant here relative the other five samples and so is a sign of at least outer neritic influence. Mioflora numbers are again higher than those of dinocysts. Spores and fungi are more abundant than in any of the other samples. Without further clues to relative water depth, it is difficult to determine. Oboh-Ikuenobe et al. (1997) interpret it as a minor regression during this time interval, though still a bathyal setting, and the marine AOM appears to be in a decline. There lacks an explanation for the high amount of *P. zoharyi* though. An examination of the pollen might be rewarding in this aspect,

since monoporates in particular display drastic differences.

5.4 Summary

To summarize: Sample 6 is the only sample of Oligocene age, the rest belong to Miocene (see Fig. 3). A regression can be interpreted in the interval from sample 5 until sample 3, which would correspond to the upper part of lower Miocene. Sample 2 (upper lower Miocene) is instead interpreted as an interval of transgression, while the sediments of sample 1 (middle Miocene) show characteristics of outer neritic influences in a high salinity environment. The presence of *Spiniferites* and *Achomosphaera* in sample 5 could also be interpreted to indicate as a transgression, but the difference in relative depth between sample 5 and 6 is hard to determine. Nevertheless, such a notion could be fitted with the isotope curve of Fig. 1; the Mi-1 event with a short regression and then transgression occurring in the interval between samples 6 and 5. The interpretations for the other samples can be fitted with the result of Zachos et al. (2001a) as well (see Fig 1).

However, comparing with the interpretation of Oboh-Ikuenobe et al. (1997), their study shows only regression at different rates or stable states until after the shift into lithological subunit IB (see Fig. 4). From fig. 5, it would also seem that our point count data do not entirely agree with each other.

6 Conclusion

It is confirmed that the sediments examined herein range from late Oligocene to middle Miocene in age. Even with the limited data acquired from species in this study, a timeframe based solely on this information would have a lower limit within the Oligocene, and upper limit in middle Miocene. Should more species within groups have been identified, age of the samples could have been narrowed down to a few million years. There are evident differences between every sample, the most drastic mainly addressed to the marine assemblages. It is possible to make an interpretation indicating fluctuating sea levels, but other factors (e.g. productivity, chemistry, currents, winds, reworking) could well be dominant, and there is no confirmation of sea level change in this study. It would require more thorough and detailed, multidisciplinary investigation to obtain a detailed reconstruction of the environment at this place and time.

7 Acknowledgements

I would like to sincerely thank, above all, my supervisors Pi Willumsen and Vivi Vajda for their great patience and help with this project: Use and mending of microscope, literature, photography and every other aspect. Without their tutelage and encouragement, I would not have been able to embark on this subject. I would also like to express gratitude towards Elin Löfroth for all her aid and advice, as well as to Francisca Oboh-Ikuenobe for gracefully allowing me the use of her samples. Lastly, I would like to thank the various individuals at the Geological Department, Lund University that have in every small way helped me on my way, whether it be practical or just making me smile.

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Appendix 2

Interpretation

The following is a summary from the articles of Jaramillo & Oboh-Ikuenobe (1999), Helenes & Cabrera (2003) and Sluijs et al (2005) on the marine palynomorphs in this study. Interpretations based on specific species are not included in general groups.

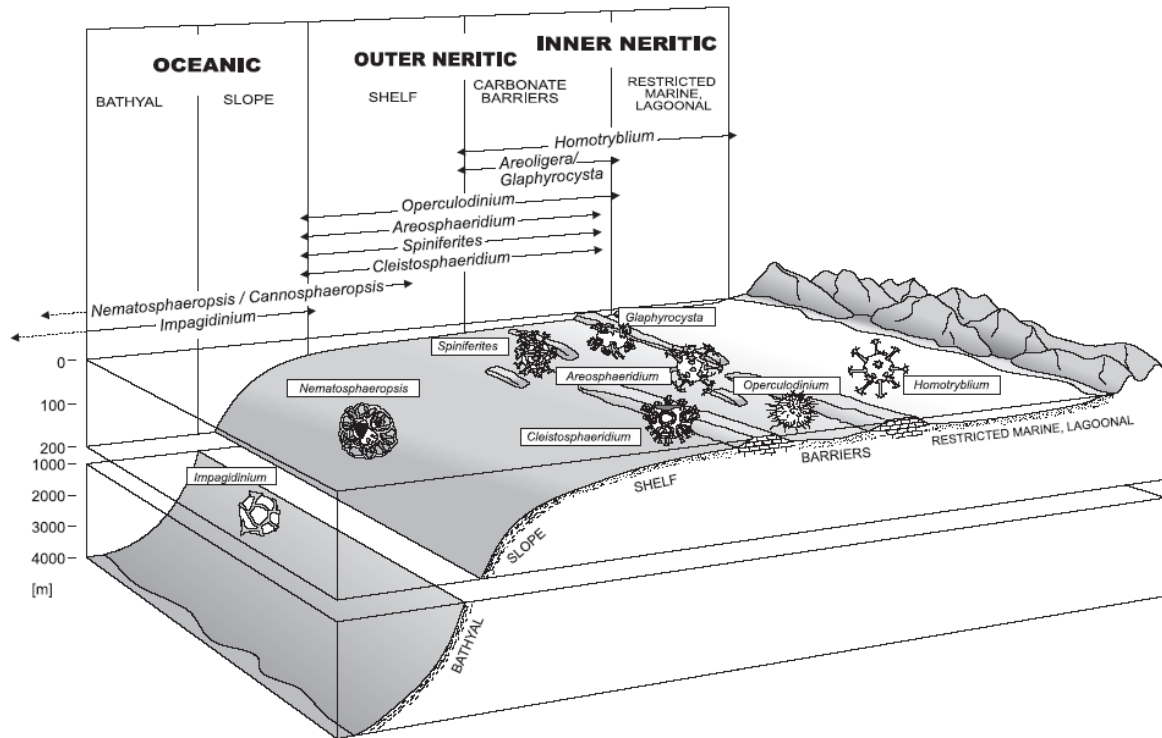


Fig. 7. “Schematic model for the distribution of dinocyst associations along a proximal-distal transect during the late Eocene and early Oligocene in central Italy.” From Sluijs et al. (2005).

<u>GROUPS</u>	<u>PREFERRED ENVIRONMENT</u>
<u><i>Achomosphaera</i></u>	Lower paleolatitudes
	Middle to outer neritic
	Open marine neritic or its influence by offshore transport
	Nearshore shallow water
	Transgressive tendency, higher % deeper water
	Open marine, most abundant during transgressions

<u><i>Impagidinium</i></u>	Oceanic, 1-2% in neritic/oceanic boundary, stable salinity 35% Oceanic Outer neritic-oceanic Warm
<u><i>Lingulodinium</i></u>	Nearshore Eurohaline
<u><i>Nematosphaeropsis</i></u>	neritic-oceanic, dominate oceanic assemblage temperate
<u><i>Operculodinium</i></u>	overlapping/slightly landward of <i>Spiniferites</i> Neritic Indicative of the shelf
<u><i>Polysphaeridium zoharyi</i></u>	high salinity, inner neritic Shallow water Tropical, subtropical
<u><i>Spiniferites</i></u>	Middle to outer neritic Open marine neritic or its influence by offshore transport Abundance peak in upper shelf Nearshore shallow water Transgressive tendency, higher % in deeper water Open marine, most abundant during transgressions Estuarine Estuarine, low cyst diversity Neritic Marginal marine Landward of <i>Nematosphaeropsis</i> (Sluijs et al)
<u><i>Systematophora placacantha</i></u>	Marginal marine Open marine, warm water

All marine environments, global

Cosmopolitan in estuarine and neritic (Beialy)

Pediastrum

Fresh-water algae

Plate 1

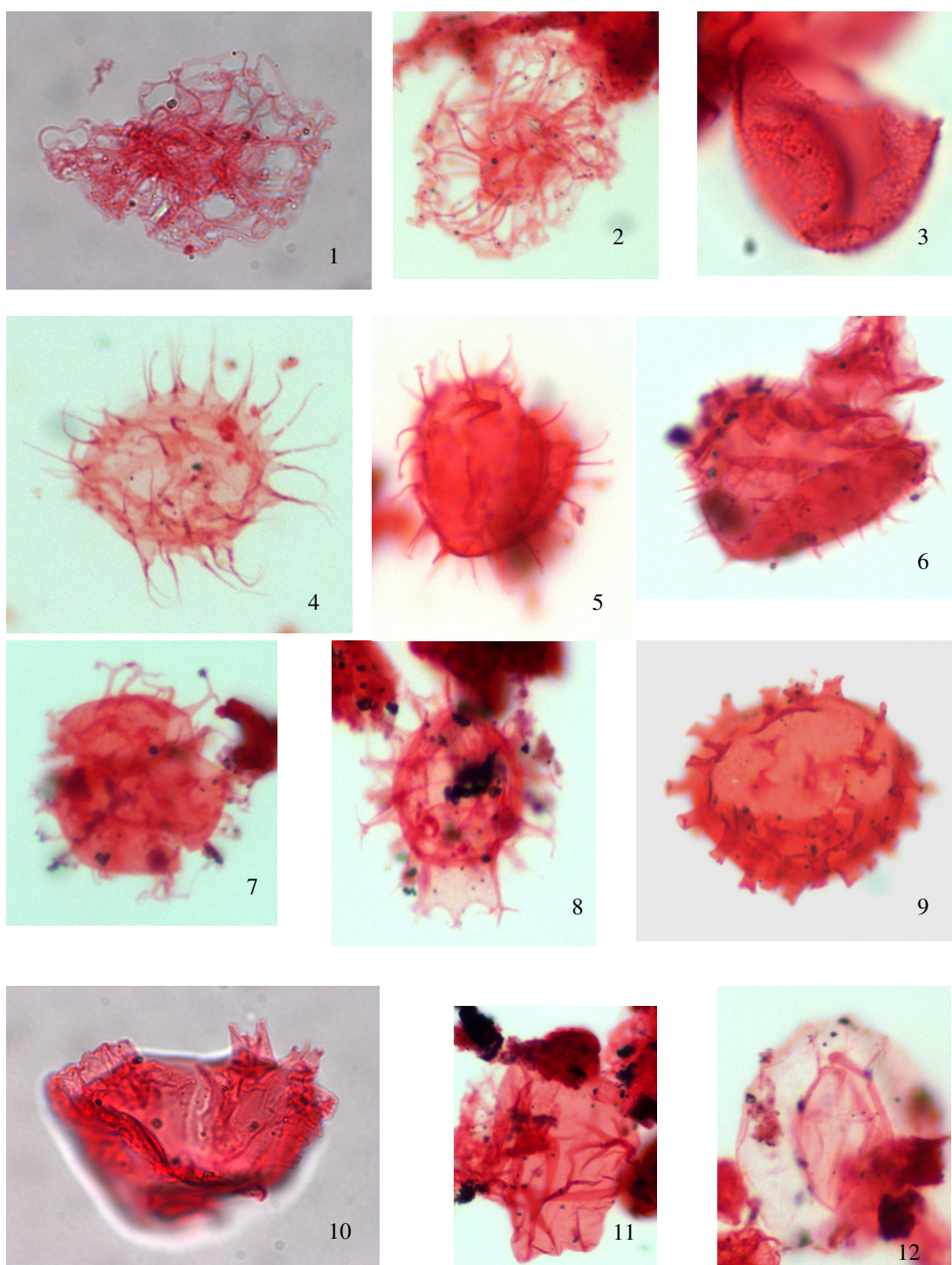


Plate 1

1. *Ectosphaeropsis burdigalensis*, 100x, sample 013/COR. **2.** *Nematosphaeropsis* sp., 40x, sample 013/COR. **3.** *Habibacysta* sp., 100x, sample 023/COR. **4.** *Selenopemphix* sp., 40x, sample 024/COR. **5.** *Operculodinium centrocarpum*, 40x, sample 020/COR. **6.** *Lingulodinium* sp., 40x, sample 015/COR. **7.** *Achomosphaera* sp., 40x, sample 023/COR. **8.** *Spiniferites* sp., 40x, sample 015/COR. **9.** *Polysphaeridium zoharyi*, 40x, sample 013/COR. **10.** *Chiropteridium galea*, 100x, sample 013/COR. **11.** *Lejeunecysta* sp., 40x, sample 015/COR. **12.** *Thalassiphora* sp., 40x, sample 023/COR.

Plate 2

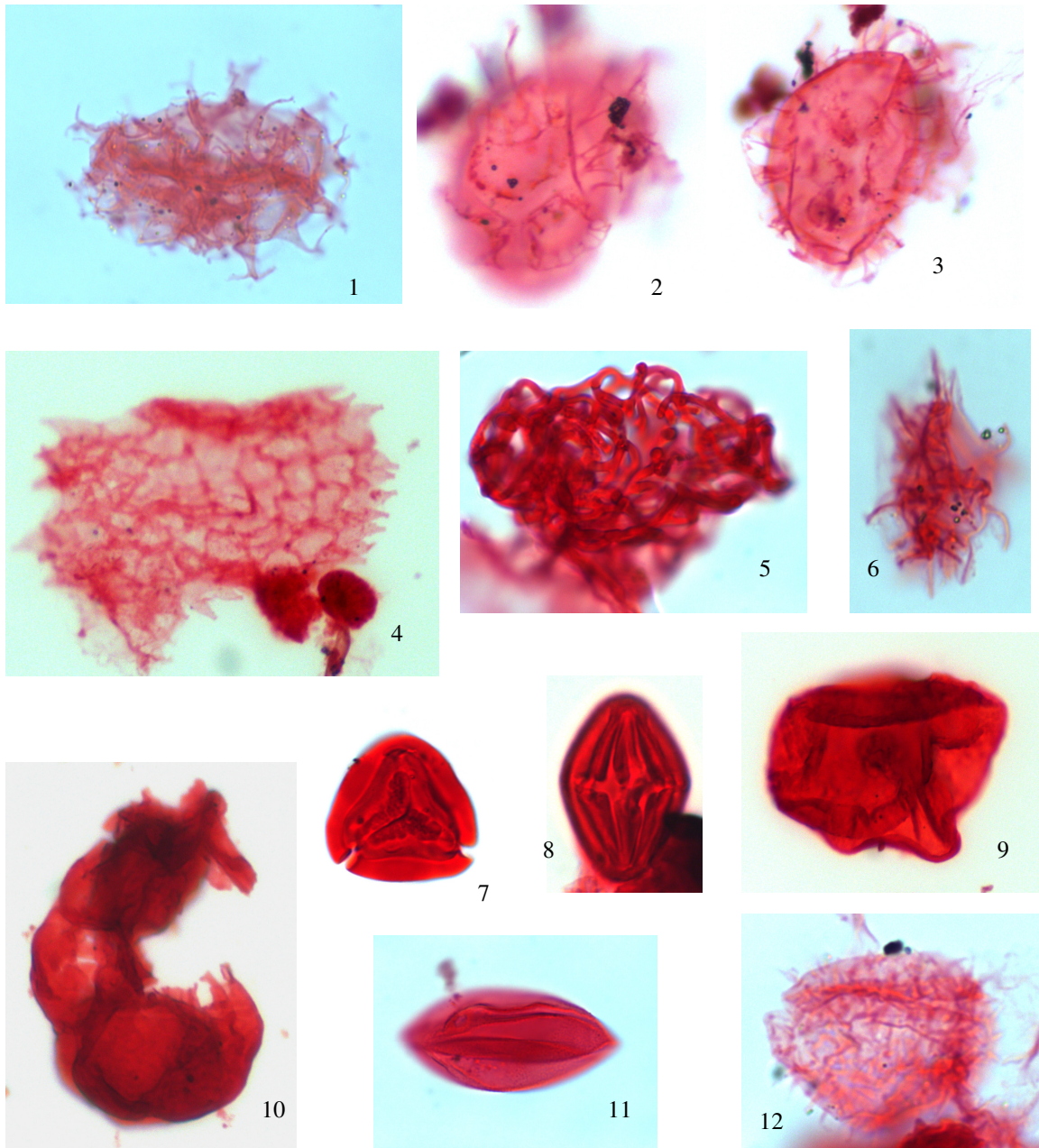


Plate 2

1. *Distatodinium* sp., 100x, sample 013/COR. **2.** *Systematophora* sp., 40x, sample 015/COR. **3.** Same specimen as 2. **4.** *Pediastrum*, 40x, sample 020/COR. **5.** *Praedopollis*, 100x, sample 017/COR. **6.** *Impagidinium* sp., 100x, sample 023/COR. **7.** Trilete spore, 100x, sample 013/COR. **8.** Colpate pollen, 100x, sample 017/COR. **9.** Saccate pollen, 40x, sample 020/COR. **10.** Foraminiferal inner lining, 40x, sample 024/COR. **11.** Monoporate pollen, 100x, sample 017/COR. **12.** Acritarch, 100x, sample 017/COR.

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