NSEP 239

PALYNOLOGICAL RESULTS

OF

WELL 6407/9-1

EPXT/2

MICHAEL F. WHITAKER

DECEMBER 1984

A/S Norske Shell

Exploration and Production

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SUMMARY OF RESULTS

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SUMMARY

A palynological analysis of 18 core, 132 sidewall cores and 3 ditchcutting samples was made of the Jurassic interval for stratigraphical and environmental interpretation.

Results indicate the upper part of the sequence is comprised of a "hot shale" interval of Late Jurassic age (Berriasian-Kimmeridgian) enclosing a marine sand (Frøya Formation) characterised by abundant reworked dinocysts of Early and Middle Jurassic age.

A major stratigraphic hiatus, between 1675 and 1702,0 m, separates the above sequence from an underlying interval of Middle and Early Jurassic age. A precise age for the upper part of this sequence is as yet not determined but there are indications for an earliest Bathonian age. The remaining interval is represented by a fairly complete Early Jurassic sequence and includes palynological events that provide a basis for correlation with their equivalent formations to the south of Haltenbanken.

At 2264,0 m Late Triassic sediments of Rhaetian age can be demonstrated, down to 2391,5 m, which is close to the total depth of the well.

DISCUSSION OF RESULTS

A stratigraphic subdivision of the Jurassic interval of well 6407/9-1 is presented together with supporting microfloral distribution chart (Enclosure 1). Resulting age interpretations are summarized and discussed further together with a synopsis of the observed palynofacies.

As a reference and guide, illustrations summarizing the distribution of the various palynofacies types in coastal plain and offshore sediments are included (Figs. 1. - 7.).

1591.5 - 1600.5 m (SWS)

EARLY BERRIASIAN

Top : Presence of abundant structureless (sapropelic) organic matter (SOM). Absence of later Cretaceous forms.

Base: Lower limit of Broomea ramosa and Egmontodinium torynum.

Discussion

Dinocysts occur infrequently. Associated forms include Hystrichodinium pulchrum, Endoscrinium pharo, Cyclonephelium distinctum and Cassiculosphaeridia magna.

Palynofacies

Interval characterised by palynofacies type II indicating an offshore lower depositional setting in which the bottom conditions were relatively stagnant.

Employing ultra-violet light characteristics the S.O.M. shows virtually no fluorescence indicating the hydrogen content may have been lowered by oxidation. Such a feature may be the results of dysaerobic conditions existing at the sea bottom. Normal light characteristics also indicate a significant proportion of woody debris occurs together with the SOM.

Depositional Environment

Ofshore lower; restricted circulation at sea bottom; some terrestrial influence.

1603.0 - 1609.0 m (SWS)

MIDDLE/LATE PORTLANDIAN

Top : Upper limit of commonly occuring Gonyaulacysta longicornis (sensu lato).

Base: Lower limit of Gochteodinia villosa.

Discussion

Dinocysts can be moderately frequent in occurrence. Associated forms include Tanyosphaeridium sp., Cyclonephelium distinctum, Hystrichodinium pulchrum and at 1609.0 (SWS) Egmontodinium polyplacophorum.

Palynofacies

As above.

1613.0 - 1620.0 m (SWS)

PORTLANDIAN (possibly EARLY)/LATE KIMMERIDGIAN

Top : Immediately below base occurrence of Gochteodinia villosa. Upper limit of Gonyaulacysta longicornis (sensu stricto) indicates an age not younger than Early Portlandian.

Base: Immediately above top occurrence of Perisseiasphaeridium sp.1 (Davey 1982) and Hystrichogonyaulax cladophora, together with the common occurrence of Gonyaulacysta longicornis (s.l.).

Palynofacies

As above.

1640.0 - 1669.1 m (Core and SWS)

MIDDLE/LATE KIMMERIDGIAN

Top : Upper limit of Perisseiasphaeridium sp.1 (Davey 1982) at 1645.0 m (SWS) and Hystrichogonyaulax cladophora at 1640.0 m (SWS).

Base: Lower limit of Egmontodinium sp.A (Davey).

This interval coincides with that of the Frøya Formation and can be subdivided into two units on the basis of its contained palynofacies and dinocyst content.

UNIT 1

1640.0 - 1659.0 m (SWS)

Discussion

Dinocysts are moderately frequent and include associated forms Gonyaulacysta longicornis (s.l.) Glossodinium dimorphum and Chlamydophorella sp. A single occurrence of Gonyaulacysta jurassica may indicate a Kimmeridgian age, if not reworked.

Palynofacies

The palynofacies (dinocyst and debris association) from the interval 1621.0 - 1646.0 m bear characteristics of both type III and IX. This interval also corresponds to the upper coarser part of the Frøya Formation. The palynofacies characteristics suggest deposition in an offshore setting, relatively distal to any major terrestrial influence. The virtual absence of blade shaped inertinitic material (palynomaceral 4) suggests winnowing activity was at a minimum, both regionally and locally. Reworked dinocysts are virtually absent.

These latter two features (ie. blade inertinite and lack of reworked dinocysts) serve to distinguish this interval from the lower part of the Frøya sandstone. Palynofacies from the overlying "hot shale" interval are more comparable in their general appearance in that they lack blade shaped palynomaceral 4, reworked dinocysts and present a similiar colour and preservation to their constituents.

Intermediate palynofacies types, containing material comparable to small fragments of S.O.M., were obtained from sidewall cores at 1620.0 m. and 1621.0 m.

Depositional Environment

Offshore lower.

UNIT 2

1660.4 - 1669.1 m (core and SWS)

Discussion

This interval is characterised by commonly occuring dinocysts of Early, Middle and Late Jurassic age. Diagnostic forms include:-

Bajocian - Middle Toarcian (reworked)	:	Nannoceratopsis gracilis, Parvocysta nasuta, Scriniocassis weberi, Fromea sp., Mancodinium semitabulatum.
Early Callovian /Bathonian (reworked)	:	Lunatodinium sp., Dichadogonyaulax sp. (D.99), Gonglyodinium hochneratum D.32).
Oxfordian (reworked)	:	Gonyaulacysta scarburghensis, Wanaea fimbriata, Adnatosphaeridium aemulum, Endoscrinium galeritum, Scriniodinium crystallinum.
Kimmeridgian (autochtohonous):	:	Egmontodinium sp. A (Davey), Gonyaulacysta sp. 4/8 (Morgenroth) Pareodinia tabulata (M.S.) Gonyaulacysta sp. (thick walled)

The forms indicating a Kimmeridgian age (ie. lower limit of Egmontodinium sp. A), although not commonly occuring in the lower part of the interval, are considered autochthonous. The remainder are thus believed to be reworked.

Palynofacies

The types IV BLT and V BLT predominate in this interval. They are characterised by a high proportion of blade shaped palynomaceral 4 and degraded (darkened, bleached and frayed) palynomacerals 1-3. This type of palynofacies has been commonly observed in the Troll Field area, and

is believed (in this area) to represent the early stages of transgressive activity where sediments have been reworked and redeposited. In this case, the abundant occurrence of Early and Middle Jurassic dinocysts, suggests marine sediments of this age have been reworked.

Depositional Setting

Offshore (reworked marine).

1670.3 - 1675.0 m (Core and SWS)

OXFORDIAN/KIMMERIDGIAN

Discussion

Dinocysts are generally infrequent, and in some samples virtually absent. Assemblages include Hystrichogonyaulax cladophora, Endoscrinium galeritum, Gonyaulacysta jurassica and Gonyaulacysta scarburghensis. The types indicating an Oxfordian age are most likely reworked. No forms indicating this interval to be of undoubted Kimmeridgian age have been observed, as yet. However, the co-occurence of abundant S.O.M. is only rarely observed in Late Oxfordian sediments and more usually associated with Kimmeridgian and later intervals.

Palynofacies

Type II B characterised this interval. In normal transmitted light, woody material together with large sized bisaccate and trilete sporomorphs, can be seen associated with the S.O.M. In ultra-violet light the S.O.M. does not fluoresce.

Depositional Setting

This interval is represented by the lower "hot-shale" sequence. The depositional setting appears to have been offshore but with a strong terrestrial influence. Sea bottom conditions were anoxic/dysaerobic.

1675.4 - 1676.2 (core)

?OXFORDIAN/KIMMERIDGIAN?

Discussion

No dinocysts were observed.

Palynofacies

The two core samples were taken from a 1.5 meter interval of light grey shales. The grain size of this interval is similar to the thin overlying "hot shale". The volume of organic residue was very thin, and was characterised by darkened constituents, some of which appeared to be degraded S.O.M. Included palynomaceral 1, displayed worm-like burrows which have been observed previously only from "hot shale" intervals. Thus genetically this interval may form part of the overlying darker shales. The evidence however is tenuous.

Depositional Environment

Winnowed crestal area, in an offshore marine environment. Sea bottom conditions may have been more restricted in surrounding areas away from the crest. (N.B. This interpretation assumes the interval to be Kimmeridgian age).

1702.0 - 1727.0 (SWS)

EARLY BATHONIAN/LATEST BAJOCIAN

Top and Base : Total range of Sentusidinium pelionense together with the absence of forms indicating an earlier or later age.

Discussion

S. pelionense occurs in abundance in a sample at 1702.0 m (SWS).

Palynofacies

Characterised by palynofacies type VII^{ET}, and occasionally high numbers of a dinocyst (S. pelionense) suggesting high energy, low salinity conditions in proximity to terrestrial influence. It is possible that sediments from this interval were laid down in a shallow water, coastal setting.

Depositional Environment

Possibly middle shoreface; setting-transgressive.

1749.5 - 1780.0 m (SWS)

Probably BAJOCIAN

Top : Upper limit of Tasmanitid type.

Base: Immediately above top certain occurrence of Scriniocassis weberi. Presence of Tasmanitid type.

Discussion

The occurrence of this particular Tasmanitid type is associated with the Rannoch Formation in the East Shetland Basin area.

Palynofacies

As above.

1788.0 - 1904.5 m (SWS)

AALENIAN/MIDDLE-LATE TOARCIAN

Top : Upper limit of Scriniocassis weberi.

Base: Lower limit of abundant blade-shaped palynomaceral 4.

Discussion

Dinocysts were infrequent and occurred only in the upper finer grained part of the interval. Associated forms included Nannoceratopsis gracilis (angular variety).

Palynofacies

All palynofacies were characterised by abundant blade-shaped palynomaceral 4. Interval 1792.0 - 1807.0 was characterised by type IV^{T} indicating an offshore lower setting on a high energy marine shelf. Interval 1815.0 - 1904.5 m is characterised by types VII^{ET}, V^{T}, and $V^{(T)}$, indicating perhaps a more coastal shallower water setting.

The palynofacies from this interval contrast with those below, and represent a correlatable palynological event recorded from within Drake (or equivalent) Formation across the northern North sea. The palynofacies indicate a regional (basin wide) increase of sea bottom energy conditions due to the opening up of a previously enclosed sea and the formation of an open seaway. A high energy shelf is established on which coastal shore sands, during shoreface retreat, are sometimes reworked and redeposited as coastal marine sands. Sediments from the present interval may well have resulted from such processes.

Depositional Environment

Interval	1792,0 - 1807,0 m	Offshore lower; transgressive, high energy shelf.
"	1815,0 - 1904,5 m	Coastal (shoreface and coastal marine sands).

1921.0 - 1967.5 m (SWS)

Probably EARLY TOARCIAN

Top : Upper limit of well preserved palynofacies types indicating very low energy sea bottom conditions. Upper limit of commonly occuring Nannoceratopsis senex, Chasmatosporites magnoloides and small clusters of sphaeromorphs.

Base: Lower limit of the above palynofacies and sphaeromorph clusters.

Palynofacies

Characterised by types intermediate to IV, V^B and II, containing well preserved constituents (rare palynomaceral 4) including minor proportions of S.O.M. Sea bottom conditions were very low and at times dysaerobic.

The palynofacies from this interval represent a correlatable palynological event recorded at the base of the Drake (or equivalent) Formations and across the northern North Sea.

Depositional Environment

Offshore lower with dysaerobic seabottom conditions; setting - low energy shelf.

1971.5 - 1991.0 m (SWS)

Probably LATE PLIENSBACHIAN

Top : Immediately belows distinctive palynofacies of above interval.

Base: Lower limit of Nannoceratopsis spp.

Discussion

Dinocysts occur infrequently. Chasmatosporites magnoloides is occasionally common.

Palynofacies

Type IV^T and VII^T characterise this interval.

Depositional Environment

Offshore high energy shelf setting.

2016.0 - 2112,0 m (SWS) EARLY PLIENSBACHIAN/SINEMURIAN

Top : Immediately below lower limit of Nannoceratopsis spp. and the upper limit of Microreticulatisporites sp. (cf. fuscus) together with commonly occuring Chasmatosporites thiergartii.

Base: Lower limit of forms comparable to Ceratosportes spinosus.

Discussion

A precise age for this interval is difficult to establish for lack clear diagnostic palynomorphs. However ceratosporites spinosus does not usually occur in strata older than Pliensbachian.

Palynofacies

Interval 2028.0 - 2061.0 m includes types V (X) and IV. Acritarchs and tasmanitids occur infrequently. Palynofacies indicate a marine offshore environment in a relatively enclosed sea with low energy sea bottom conditions. The distinctive character of the palynological constituents, particularly their well preserved nature and the type of palynomacerals 2 and 3, suggest comparison with palynofacies obtained from intervals referred to the Upper Amundsen Formation of the East Shetland Basin and Troll Field areas. At 2099.5 palynofacies type IX R suggests proximity to a reworked horizon, possibly associated with a period slower deposition rates related to transgressive activity. This type of depositional setting is frequently observed in the Johansen Formation.

At 2112.0 m type X indicates marine influence (acritarchs) in a low energy, strongly terrestrial influenced setting. Such palynofacies have been observed from interdistributary bay settings.

Depositional Environment

Interval	2028,0 - 2061,0 m	Offshore upper and lower; setting - relatively enclosed low energy shelf sea.
	2099,5 m	Reworked horizon - non deposition possibly related to transgression.
	2112,0 m	Interdistributary bay.

2134.0 - 2253.0 m (SWS)

SINEMURIAN/HETTANGIAN

Top : Immediately below lower limit of Ceratosporites spinosus.

Base: Immediately above forms indicating a Late Triassic age.

Discussion

Few samples yielded palynomorphs in this interval, and those observed were not very age diagnostic. The age of this interval is thus not clearly defined.

Palynofacies

Microplankton are absent. Palynofacies type XIV at 2134.0 m may well indicate this sediment resulted from crevasse-splay deposition. Interval 2167.5 - 2290.0 m are characterised by palynofacies with darkened and opaque constituents (types IX, XI^{LD}), indicating severe oxidation, possibly the result of a subaerial setting.

Depositional Environment

Coastal plain setting, mixed subaqueous and subaerial settings.

2264.5 - 2391.5 m (SWS)

RHAETIAN

Top & Base: Association of Cinqulizonates rhaeticus Limbosporites lundbladii, Riccisporites tuberculatus, Striomonosaccates microcorpus and Ovalipollis sp.

Palynofacies

Interval:	2264.5 - 2392.0 m:	Characterised by palynofacies types XII^{T}, XV, XI and XI^{T}.
Interval:	2408.0 - 2485.0 m:	Characterised by palynofacies type IX, containing only very small dark constituents.

Depositional Environment

Interval:	2264.5 - 2392.0 m:	Coastal plain, subaqueous setting.
" :	2408.0 - 2485.0 m:	Alluvial plain.

DEPOSITIONAL HISTORY OF FRØYA FORMATION

(A TENTATIVE SUGGESTION)

Based on the lithological characteristics and the organic content of the sediments, a possible model is suggested, which may indicate the depositional events surrounding the origin of the Frøya (Sand) Formation. This model however must be considered only as highly speculative at this early stage of drilling.

The Frøya Formation is situated close to a plane of unconformity where sediments of Kimmeridgian age immediately overlie strata of earliest Bathonian age. It could, therefore, be hypothesised that during middle Bathonian-Oxfordian times the site of well 6407/9-1 represented a relatively shallow, perhaps emergent area.

During Late Jurassic times the surrounding Haltenbanken areas were being gradually drowned by a series of transgressions (as observed in other northern North Sea areas), at first creating a shallow high energy marine shelf but later by a less energetic, perhaps deeper sea, with lower energy conditions at the sea bottom. It was only during this later phase that on the site of 6407/9-1 (? and immediate surrounding areas?), which had remained relatively shallow until this time, sedimentation was resumed.

Sedimentation was immediately characterised by finer grained organic rich shales containing abundant structureless organic (palynofacies type II B). The oxic/anoxic interface, however, was most likely very close to the sea bottom and in the early stages resulted in oxidation and degradation of this material as possibly represented by the sediments of interval 1675.4 - 1676.2 m. Further increase in the sea depth, however, eventually allowed preservation in sediments immediately overlying, represented by interval 1670.3 - 1675.0 m. Periodic oxidation was still probably occurring, since the S.O.M. displays no fluorescence under ultra-violet light. Included woody palynodebris and trilete sporomorphs suggest proximity to a terrestrial influence.

Energy conditions at the sea bottom at this time must have been very low. The overlying Frøya Formation, however, clearly displays features which suggest deposition involving high energy processes. ie) a gradually coarsening upwards sequence; the very coarse nature of the sandstone in its upper parts; the palynofacies types IV BLT and V BLT indicate oxic and winnowed sea bottom conditions. The return of oxic, higher energy sea bottom conditions may have resulted from a relative drop in sea-level, thus creating a shallower marine setting OR further structural movement or transgression temporarily connecting this marine basin with another (eg Boreal northern North Sea with Arctic (Triassic) sea) creating an open seaway and thus a higher energy marine shelf.

The above siltstones and coarser sandstones are in some ways difficult to interpret with certainty. They are in their upper coarser parts distinctly bimodal in sediment grain size and display little evidence of bioturbation (although it may exist) or structure. Such features might in some ways suggest very rapid deposition, perhaps by turbiditic or mass-flow mechanism. The latter processes, however, normally result in a fining upward sequence, even in their most proximal parts, with a rapid change to coarser sandstones at their base. The absence of these features in the Frøya Formation therefore casts doubt on this interpretation.

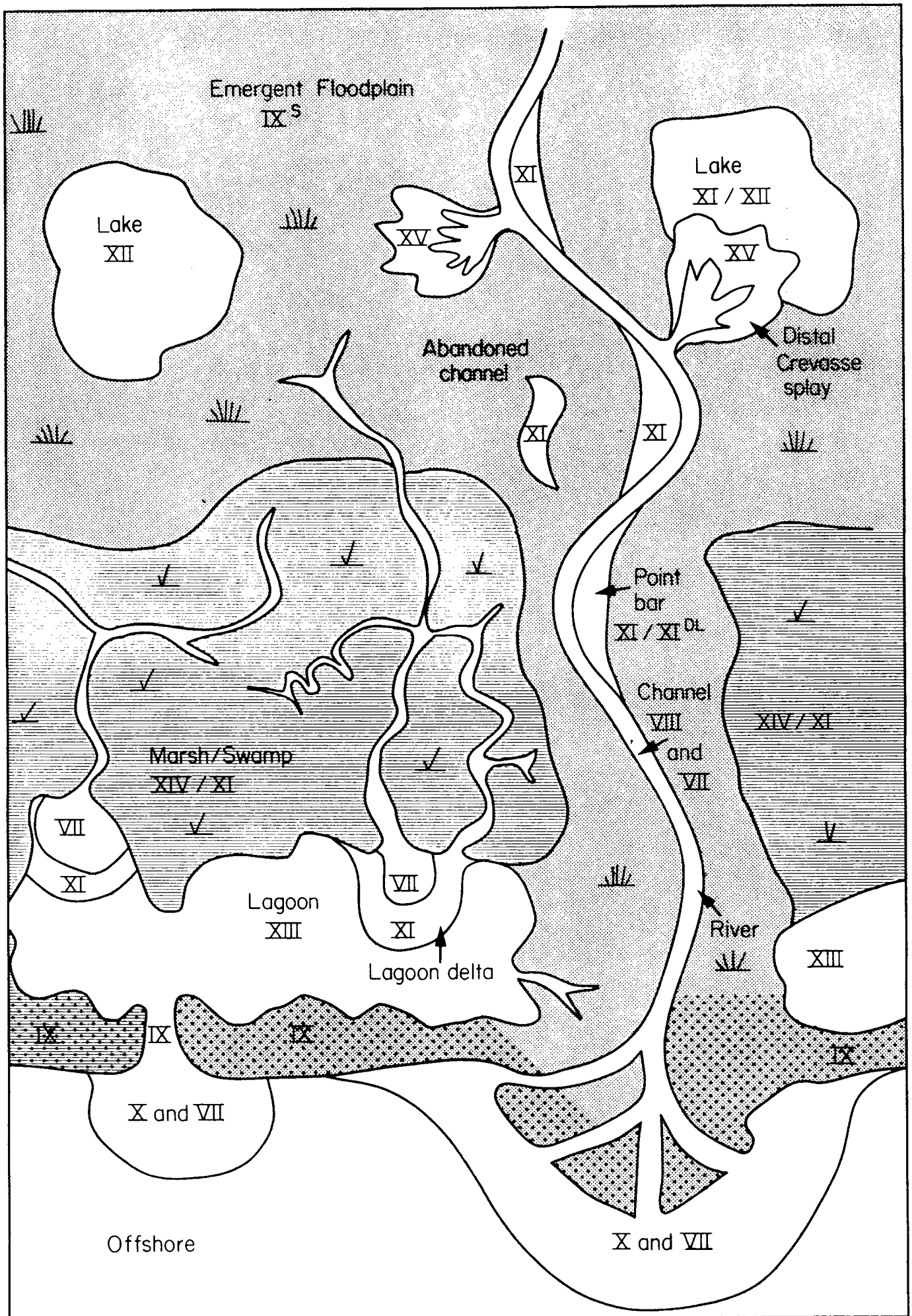
The palynological characteristics also lend little support to the above hypothesis. Instead, palynofacies studies tend to suggest a mechanism related to offshore bar formation closely involving the underlying siltstones. These features can be described as follows.

As a result of increasing energy conditions at the sea bottom, previously deposited Early, Middle and Late Jurassic marine sediments in the shallowest areas become eroded and transported further offshore. This period of activity may be represented in the winnowed siltstones occurring in interval 1660.4 - 1669.1 m characterised by degraded palynodebris. Rare dinocysts indicating a Kimmeridgian age suggest there is also a relatively autochthonous component present.

The subsequently deposited coarser sediments overlying these siltstones would have required more energy in their early stages of transport and

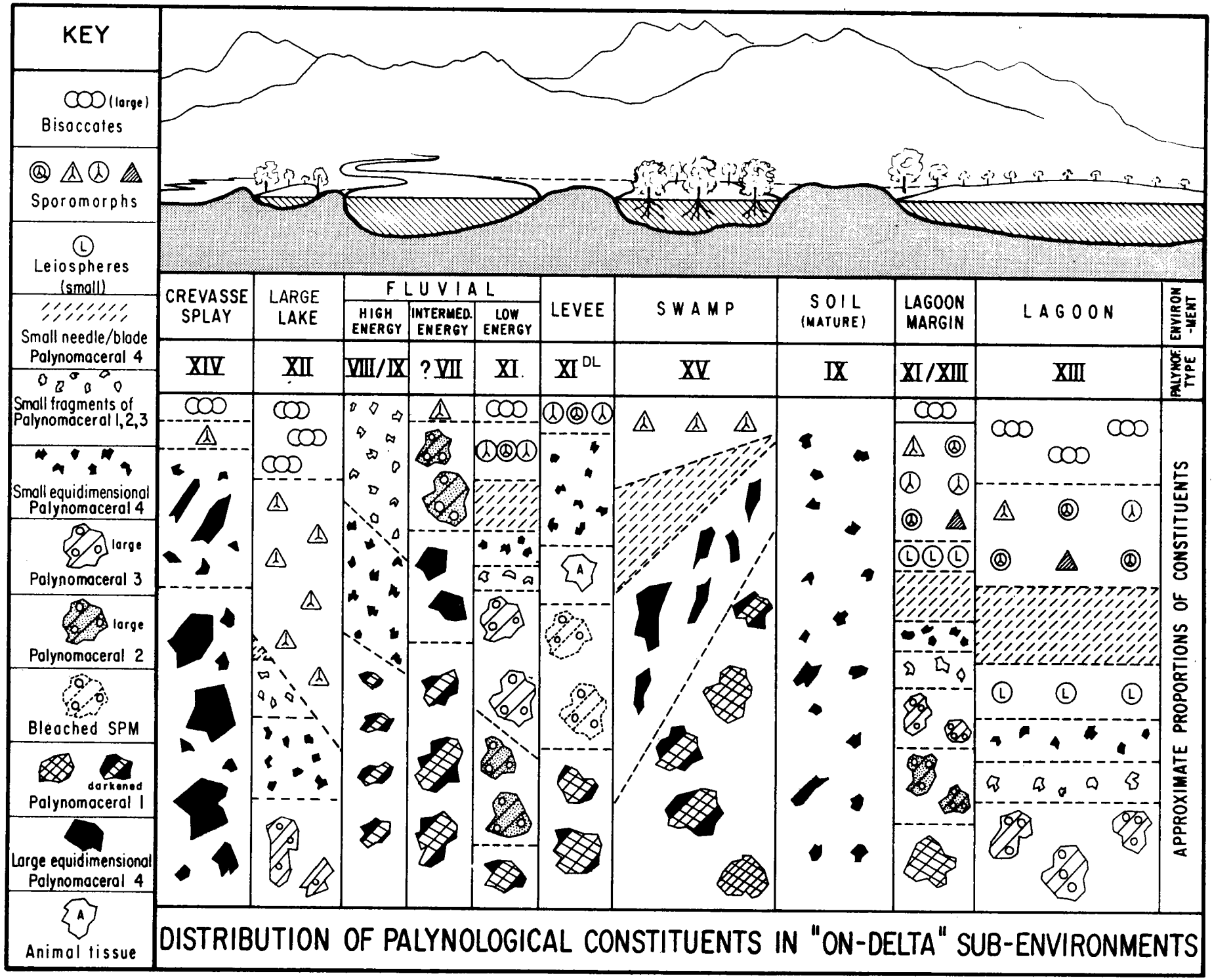
may have been consequently more thoroughly oxidised. Any included reworked organic material would most likely have been destroyed. This may explain the rarity/absence of reworked dinocysts in the organic content of the upper part of the sands. However, during final deposition, (the transport of these sands by storms being periodically halted by deeper and lower energy conditions), some organic constituents (autochthonous dinocysts and bisaccate sporomorphs) from the floatation load may have been incorporated, together with finer grained sediment.

The absence of abundant palynomaceral 4 in the uppermost parts of the sands may suggest energy conditions were not regionally very high at this stage, and that there was in fact a gradual return to lower energy dysaerobic sea bottom conditions, (despite the sharp change in the wireline log) eventually characterised only by fine grained deposition containing abundant but periodically oxidised S.O.M. (palynofacies type II A). This return to lower energy conditions may have been the result of a relative increase in water depth, or a restriction of circulation caused by the temporarily opened seaway being closed off again. These conditions continued uniformly throughout the remaining Jurassic and earliest Cretaceous (Berriasian) times.



EVISAGED DISTRIBUTION OF PALYNOFACIES TYPES IN COASTAL AND FLOODPLAIN DEPOSITIONAL ENVIROMENTS

FIG. 1
G1810/1



DISTRIBUTION OF PALYNOLOGICAL CONSTITUENTS IN "ON-DELTA" SUB-ENVIRONMENTS

FIG. 2
G1810/2

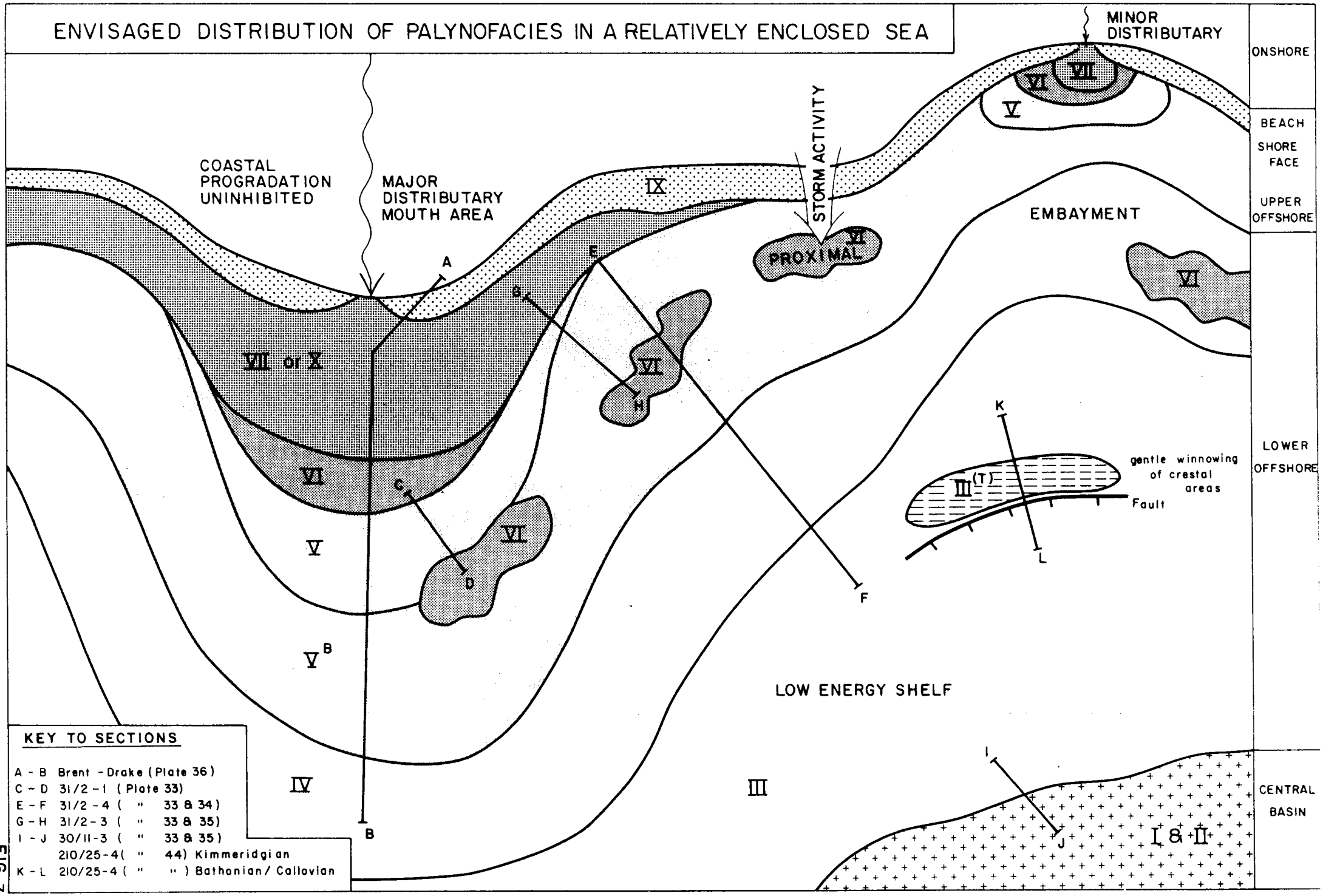
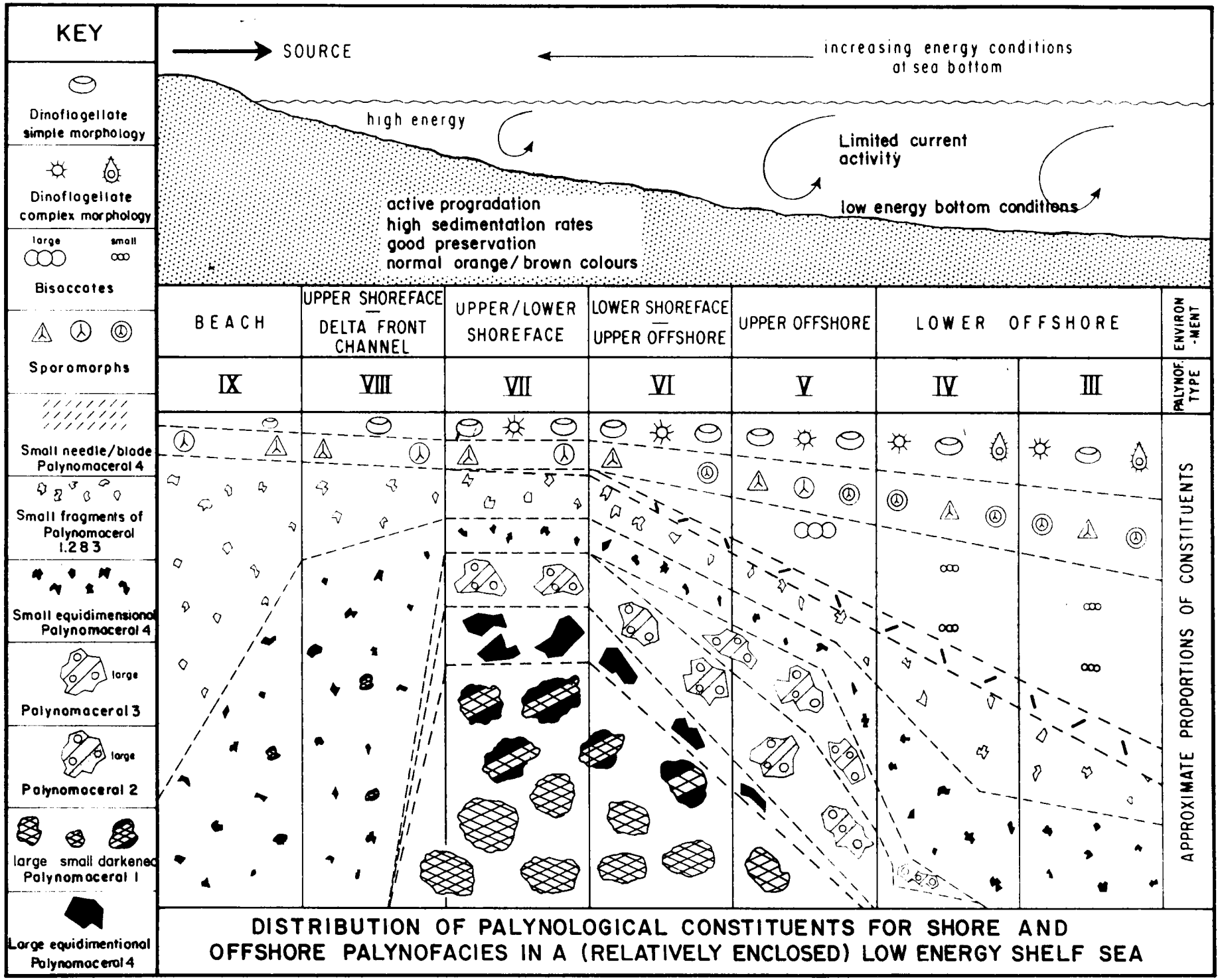

ENVISAGED DISTRIBUTION OF PALYNOFACIES IN A RELATIVELY ENCLOSED SEA
MINOR DISTRIBUTARY
ONSHORE
BEACH
SHORE FACE
UPPER OFFSHORE
LOWER OFFSHORE
CENTRAL BASIN
COASTAL PROGRADATION UNINHIBITED
MAJOR DISTRIBUTARY MOUTH AREA
STORM ACTIVITY
EMBAYMENT
PROXIMAL
VII or X
IX
VI
V
IV
III
V^B
III(T)
gentle winnowing of crestal areas
Fault
LOW ENERGY SHELF
I & II
A
B
C
D
E
F
G
H
I
J
K
L
KEY TO SECTIONS
A - B Brent - Drake (Plate 36)
C - D 31/2-1 (Plate 33)
E - F 31/2-4 (" 33 & 34)
G - H 31/2-3 (" 33 & 35)
I - J 30/11-3 (" 33 & 35)
210/25-4(" 44) Kimmeridgian
K - L 210/25-4 (" ") Bathonian/ Callovian

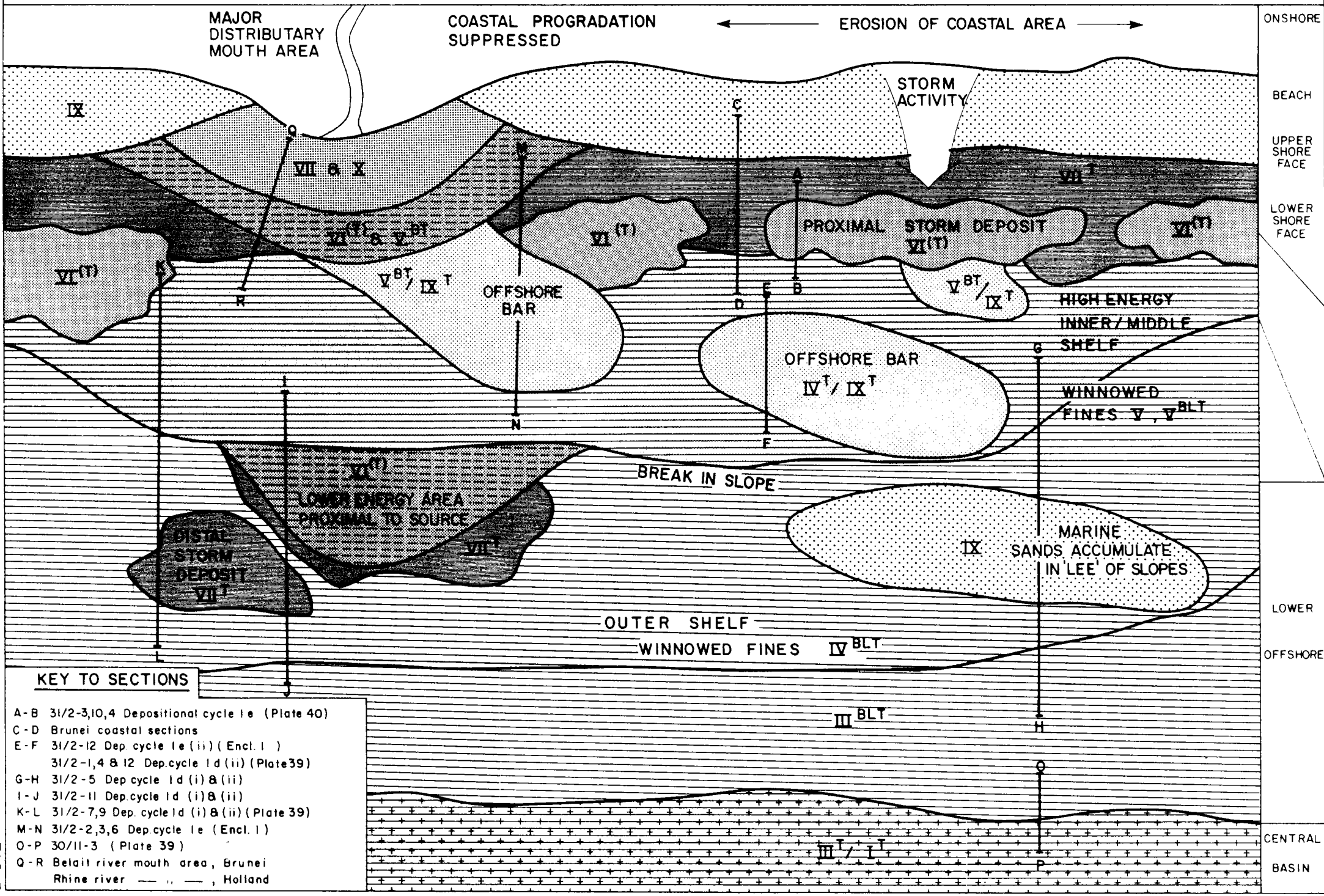
FIG 7

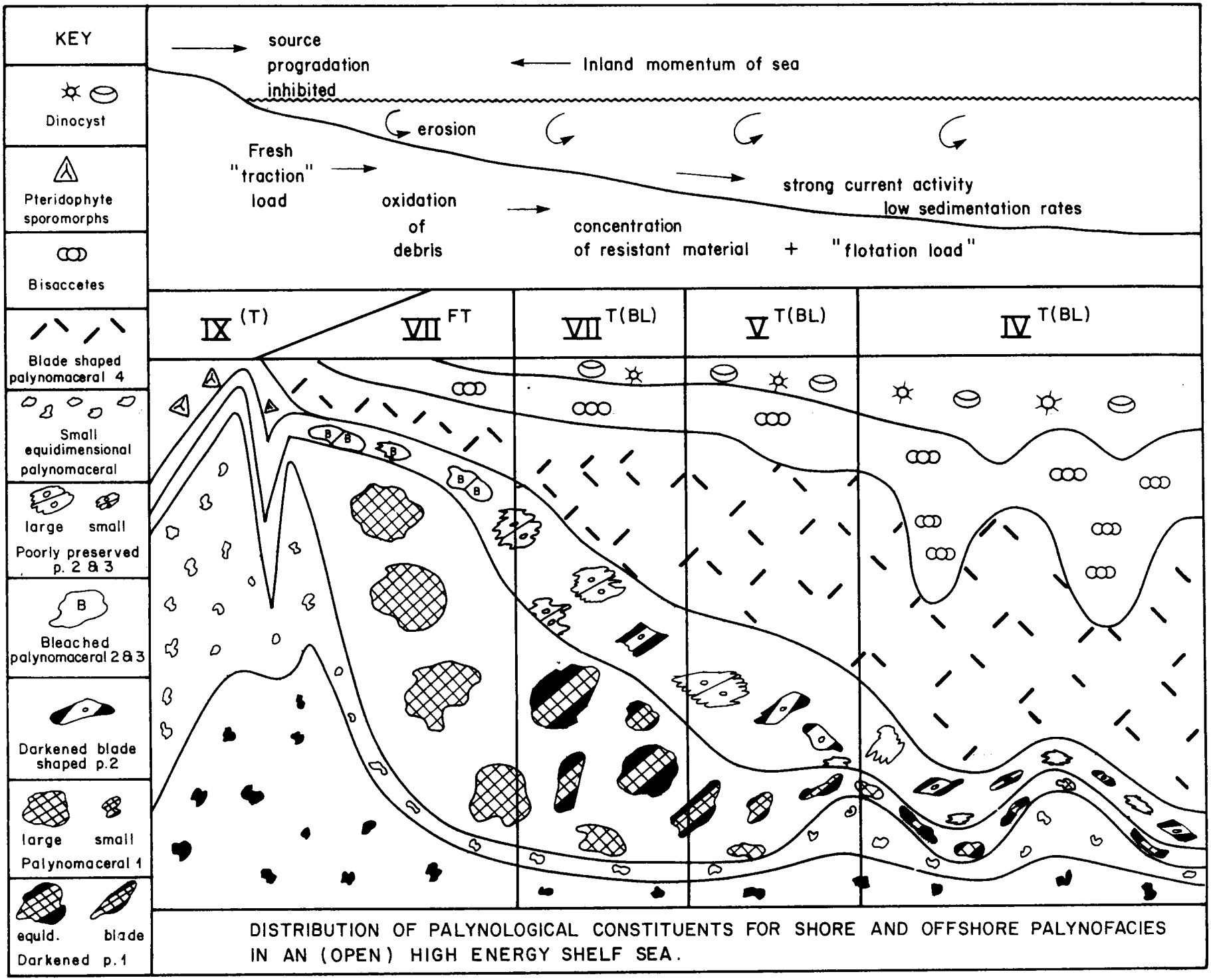


DISTRIBUTION OF PALYNOLOGICAL CONSTITUENTS FOR SHORE AND OFFSHORE PALYNOFACIES IN A (RELATIVELY ENCLOSED) LOW ENERGY SHELF SEA

FIG. 4
G 1810/4

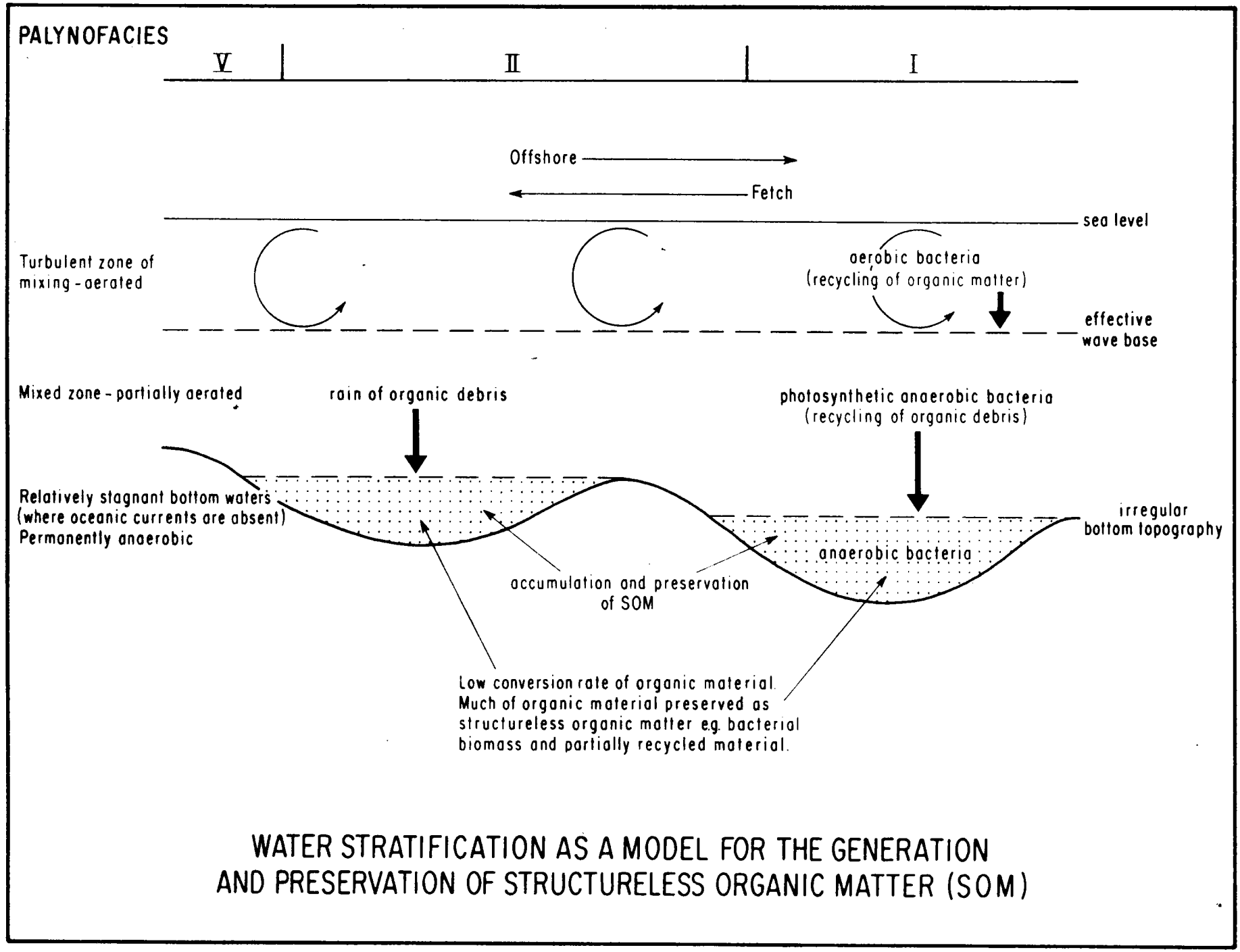
ENVISAGED DISTRIBUTION OF PALYNOFACIES TYPES IN AN OPEN HIGH ENERGY SHELF SEA (TRANSGRESSIVE)





DISTRIBUTION OF PALYNOLOGICAL CONSTITUENTS FOR SHORE AND OFFSHORE PALYNOFACIES IN AN (OPEN) HIGH ENERGY SHELF SEA.

FIG. 6
G.1810/6



WATER STRATIFICATION AS A MODEL FOR THE GENERATION AND PRESERVATION OF STRUCTURELESS ORGANIC MATTER (SOM)

FIG. 7
6181D/7

WELL 6407/9-1
GAMMA RAY
ENVIRONMENTAL INTERPRETATION
AGE
COMMENTS
SAMPLE TYPE
CORE
SWS
DITCHCUTTING
DEPTH (IN METERS)
PALYNOFACIES TYPE
ALLUVIAL PLAIN
COASTAL PLAIN
OFFSHORE UPPER/LOWER
Relatively enclosed low energy shelf
OFFSHORE LOWER
Dysaerobic sea bottom conditions
COASTAL
Shoreface and marine coastal sands
High energy shelf, ?shallow water?
Possibly MIDDLE SHOREFACE
RHAETIAN
HETTANGIAN/SINEMURIAN
SINEMURIAN / EARLY PLIENSBACHIAN
Probably EARLY TOARCIAN
MIDDLE - LATE TOARCIAN / AALENIAN
Possibly BAJOCIAN
LATEST BAJOCIAN
EARLY BATHONIAN
MIDDLE/LATE KIMMERIDGIAN
MICROPLANKTON
SPOROMORPHS