Palynology and its use in Hydrocarbon Exploration

Leeds Microscopical Society.

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November 2011

Talk outline

Part 1: Palynology -
* A sub discipline of Micropalaeontology.
* The stratigraphically important palynomorphs.

Part 2: Hydrocarbon Exploration –
* The role of palynology in oil and gas production.
* How do we use Palynology to find oil and gas?

Micropalaeontology

- Palaeopalynology
  - Organic walled microfossils
- Micropalaeontology
  - Calcareous and siliceous microfossils
- Nanopalaeontology
  - Nanoplankton.

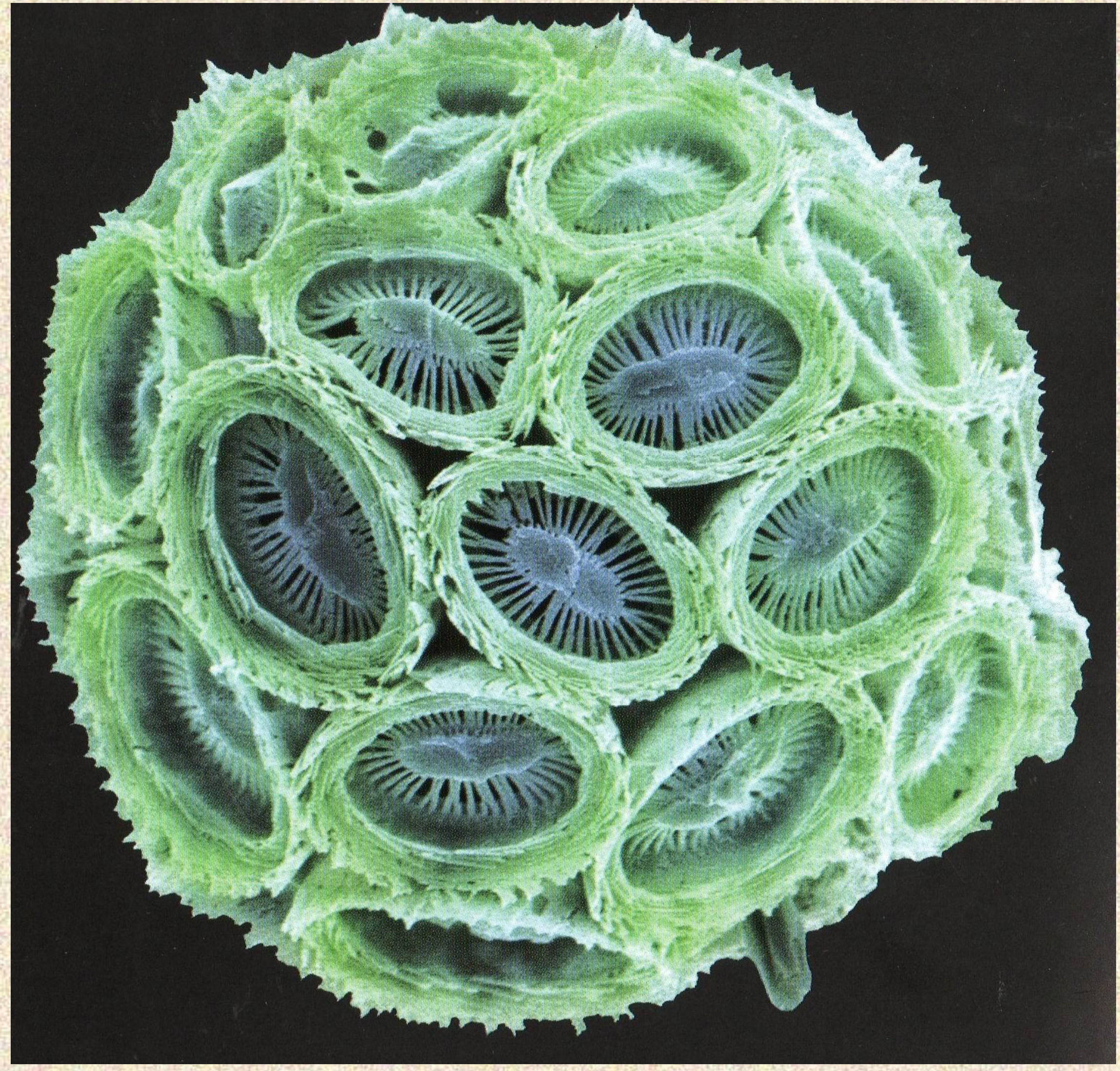
Micropalaeontology

- Foraminifera
- Ostracods
- Radiolaria
- Charophytes
- Diatoms
- Conodonts

Foraminifera

Coccolithophores

Coronosphaera mediterranea



Palynology

- Coined by Hyde and Williams (1944).
- Derived from the Greek verb ‘*palunein*’.

  = to sprinkle, strew or dust.
- Also the Latin word ‘*pollen*’ = fine flour.
- Organic-walled, acid resistant microflora and microfossils.

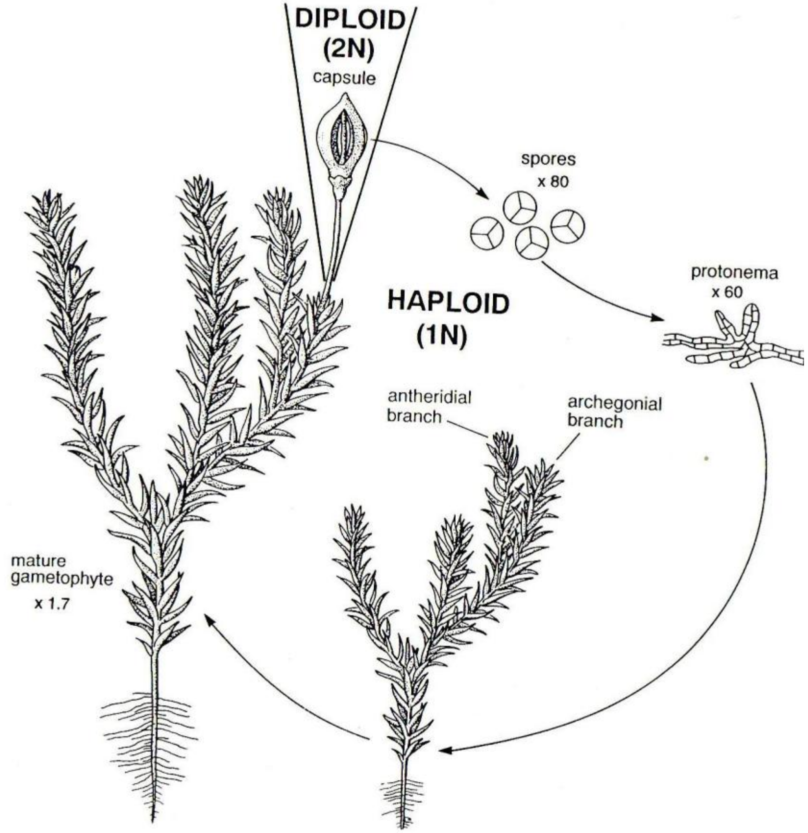
Palynological Applications

- Stratigraphical palynology
- Palynofacies
- Archaeological palynology
- Medical palynology
- Forensic palynology
- Melissopalynology
- Entomopalynology

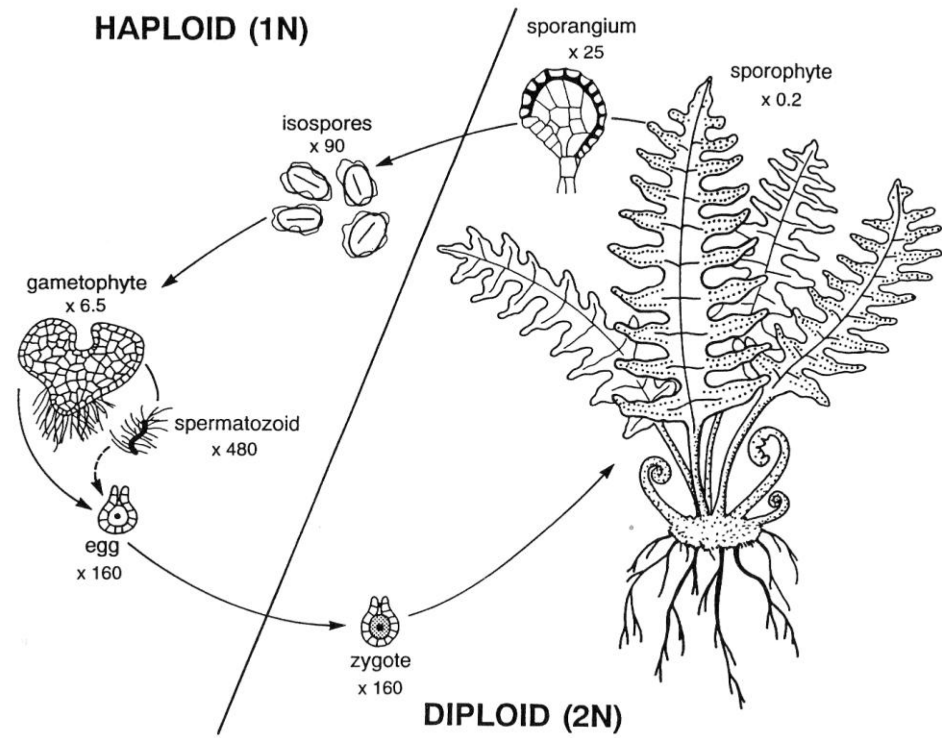
Palynomorphs

- Spores and Pollen
- Prasinophycean algae
- Scolecodonts , Microforam test linings
- Chitinozoa
- Dinoflagellates cysts and Acritarchs
- Fungi

Spore Life Cycle



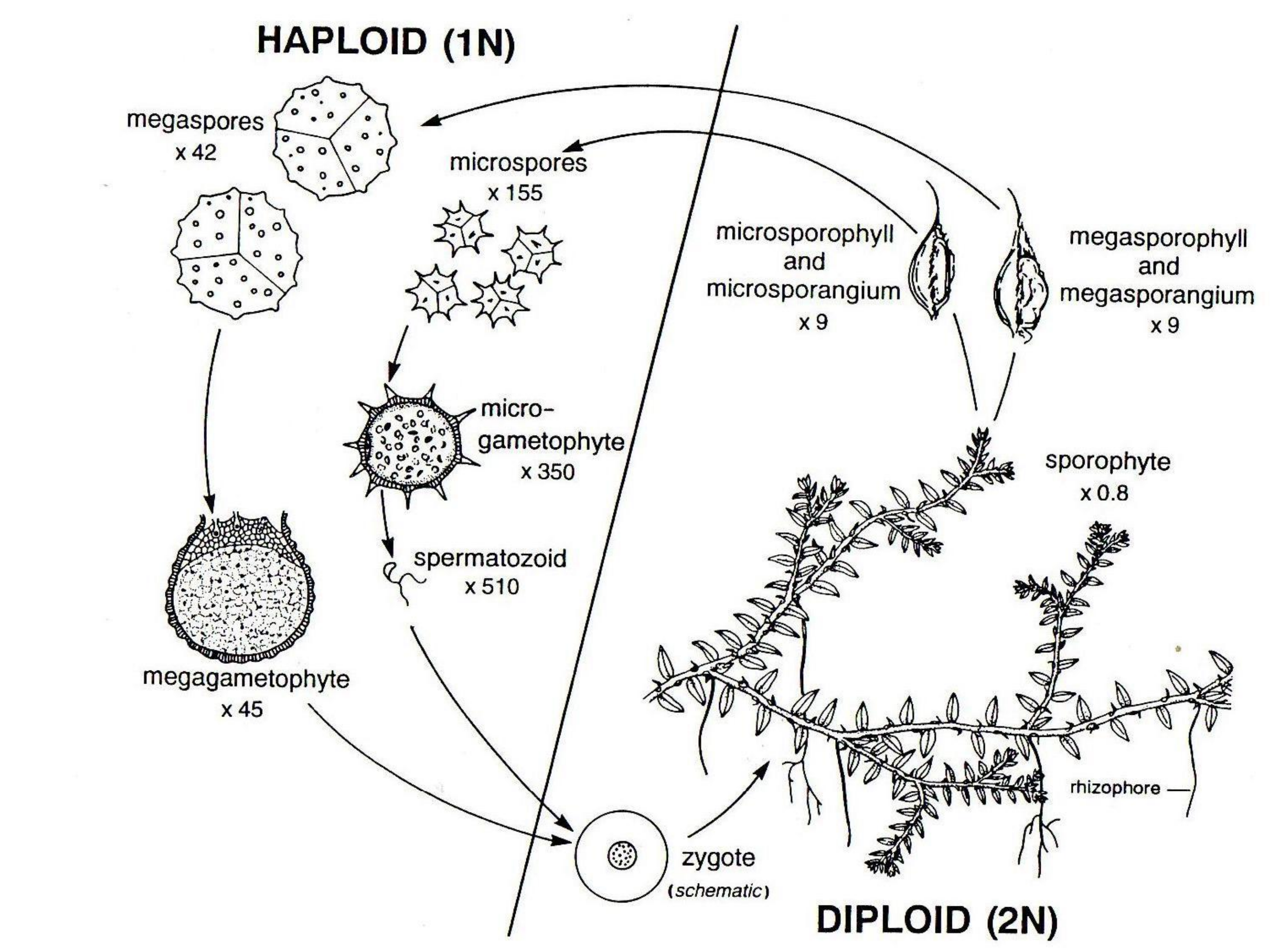
Life cycle of a moss plant (Division Bryophyta).



Life cycle of a homosporous fern (Division Pterophyta).

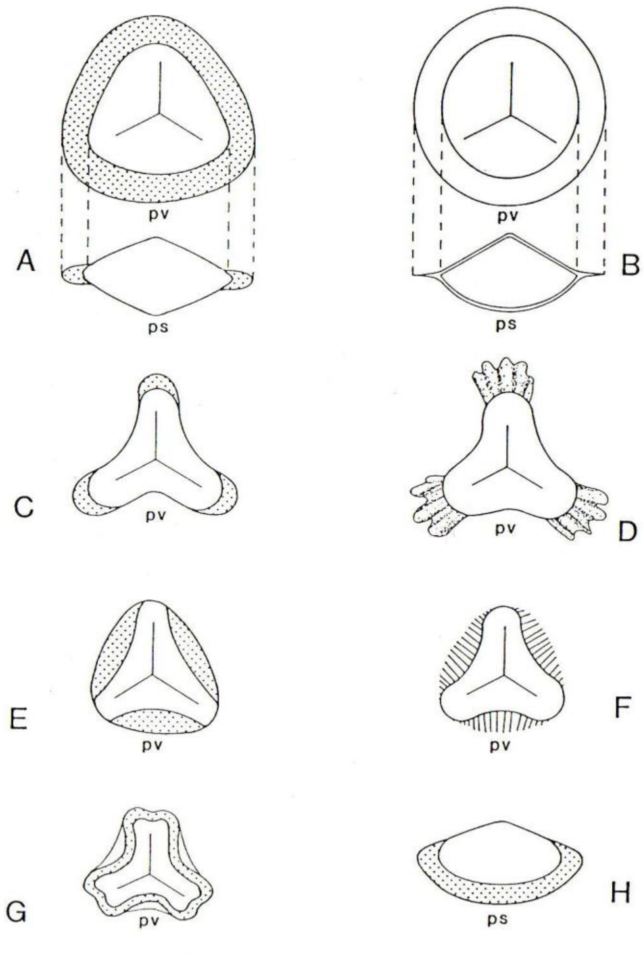
Spores

Lycopod life cycle

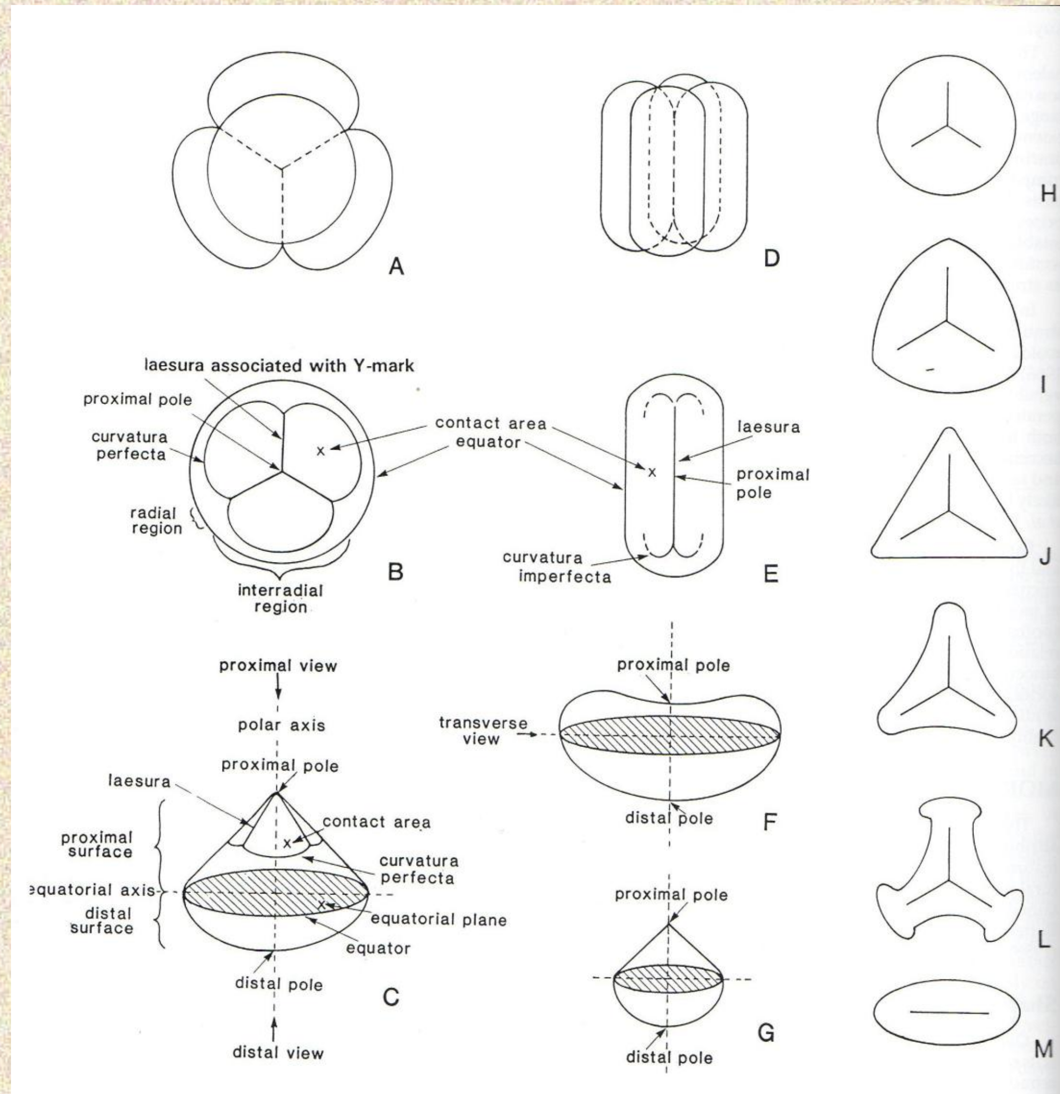


Life cycle of a heterosporous selaginellid lycopod (Division Lycopodophyta).

Miospores

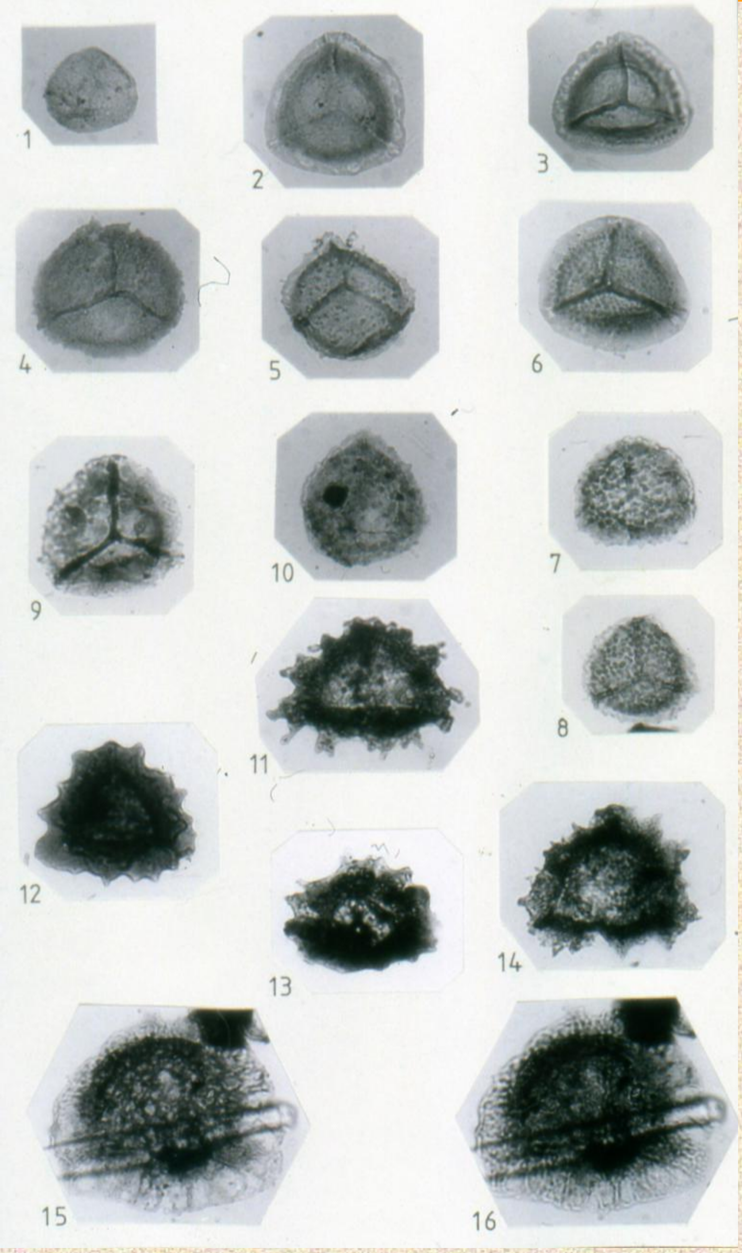


Text-Figure 9. Structural modifications of spore walls. **A**, cingulum. **B**, zona. **C**, valvae. **D**, auriculae. **E**, interradial crassitude. **F**, corona. **G**, kyrtome. **H**, patina (equatorial/ distal). pv, polar view; ps, polar section.

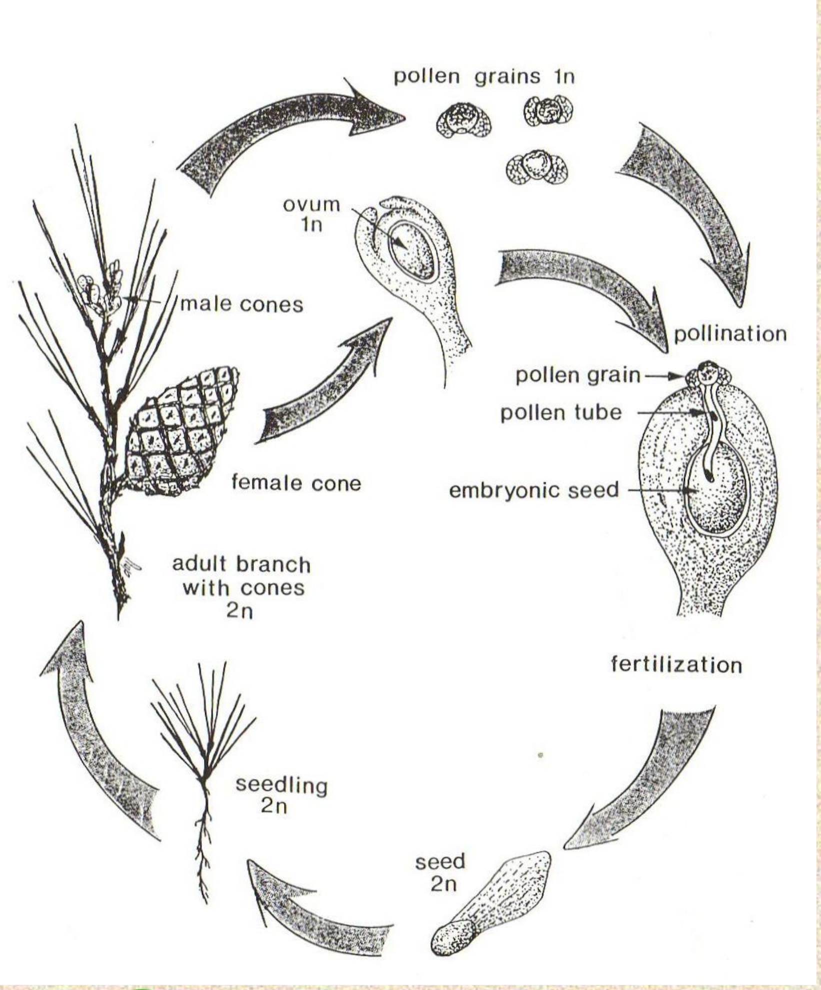


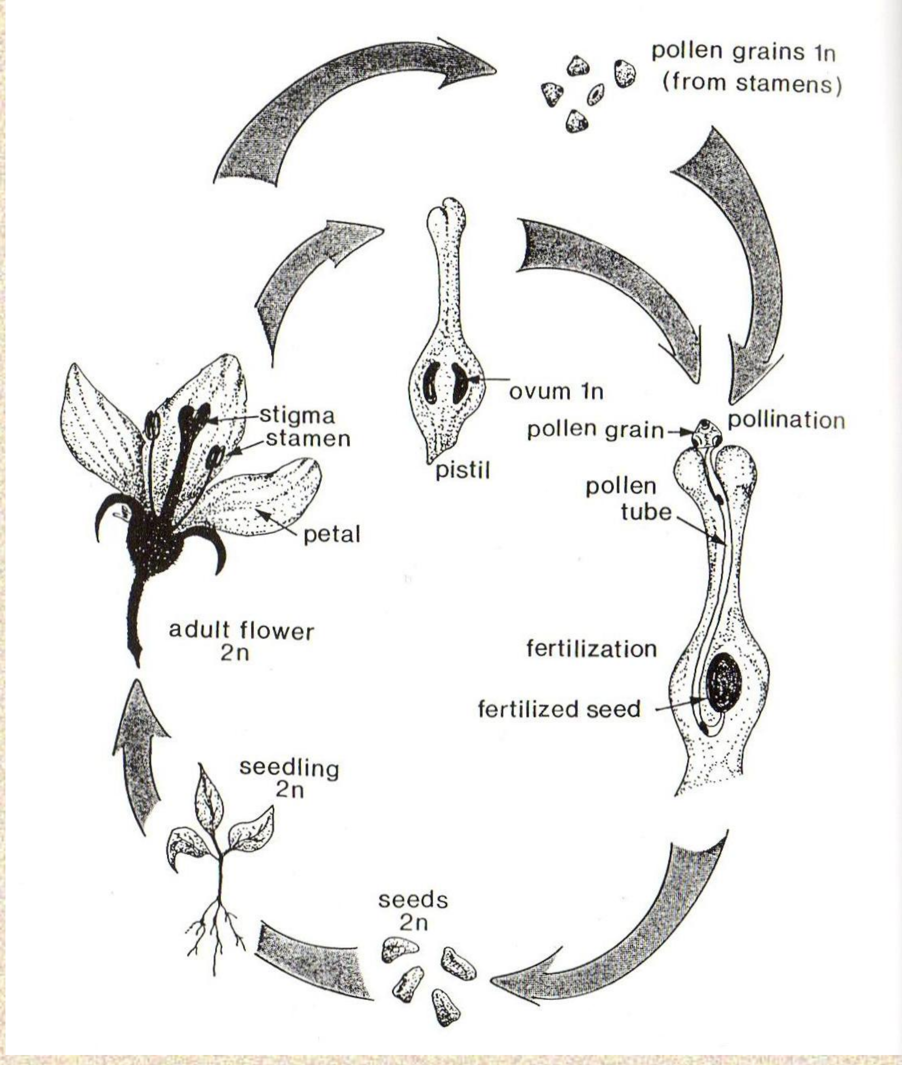
Carboniferous Miospores

1 – 10	Lycospora spp.
11– 14	Cristatisporites spp.
15-16	Radiizonates spp.



Pollen Life Cycle



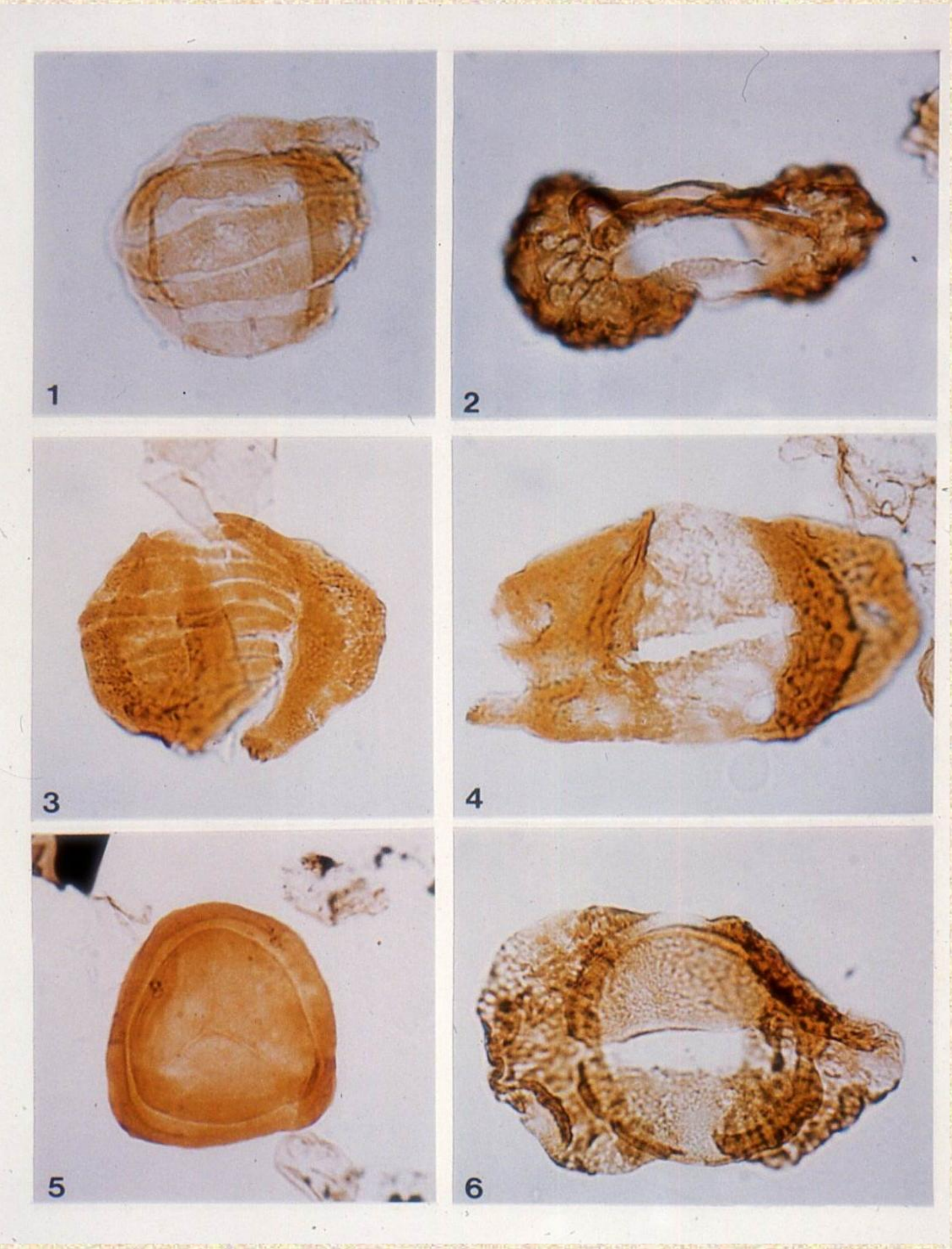


Fossil Spores and Pollen

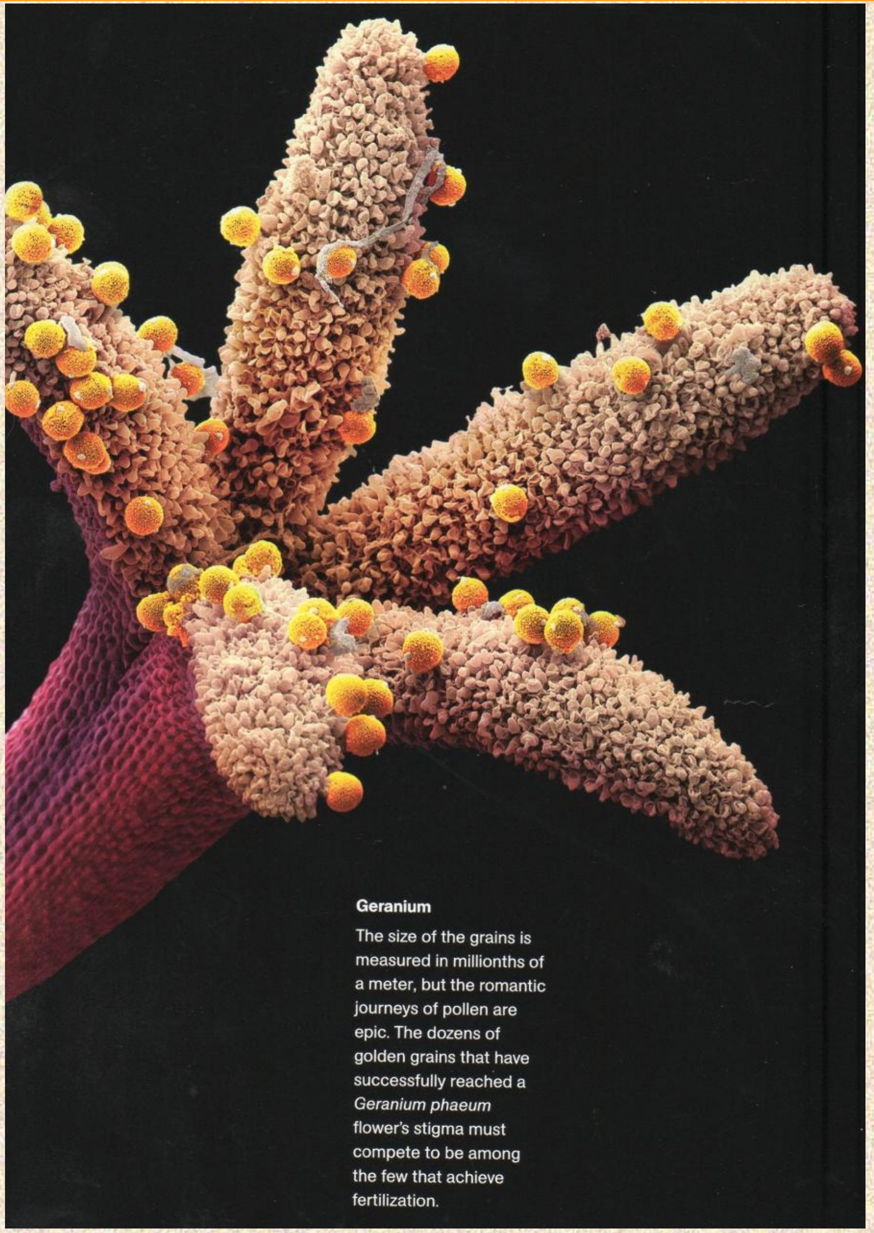
1- 4. Permian Taeniate pollen

5. Densoisporites velatus
(Jurassic)

6. Lueckiisporites virkkiae
(Permian)

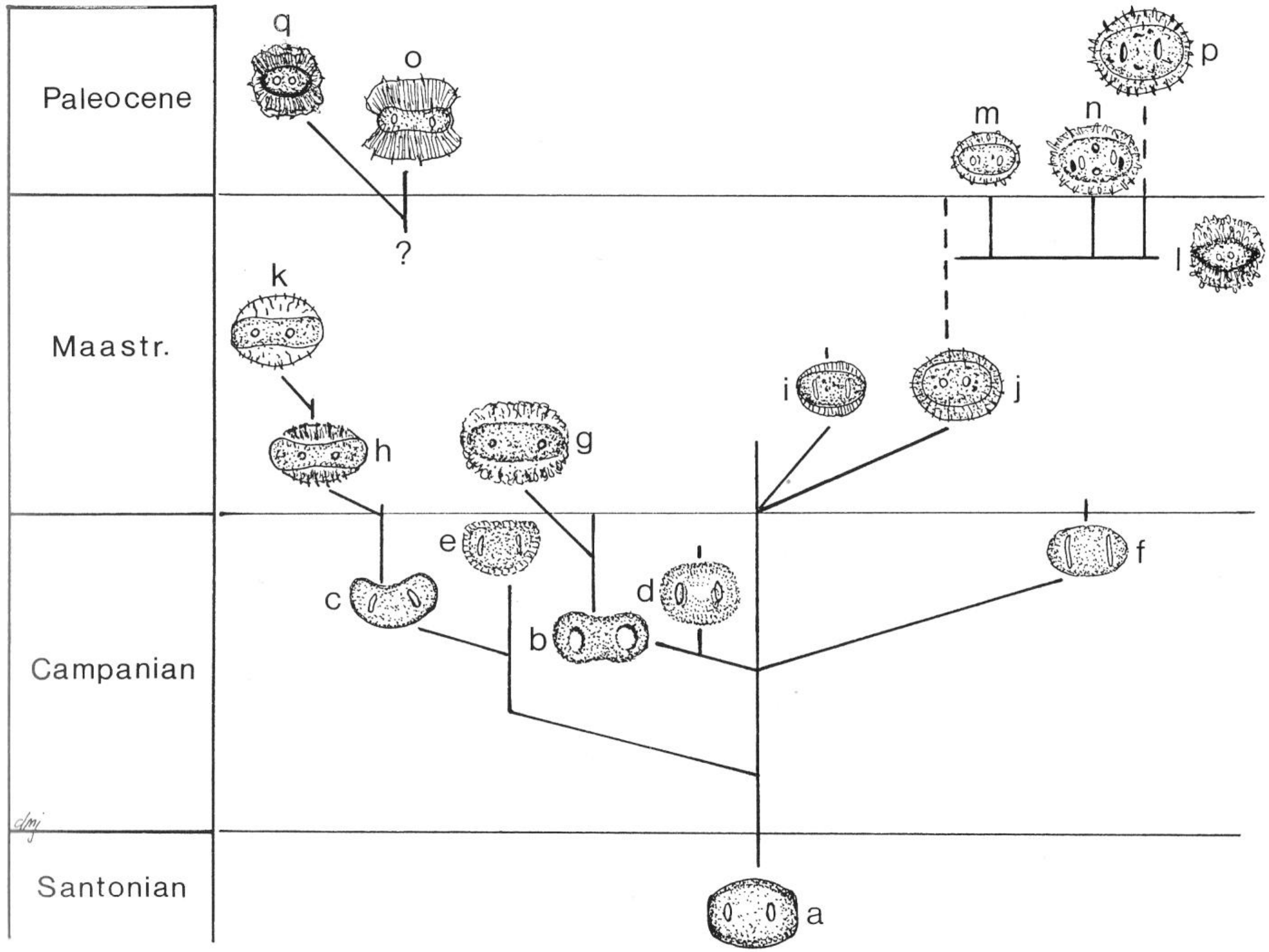


YOUR PLANET EARTH



Geranium
The size of the grains is measured in millionths of a meter, but the romantic journeys of pollen are epic. The dozens of golden grains that have successfully reached a *Geranium phaeum* flower's stigma must compete to be among the few that achieve fertilization.

Pollen



Text-Figure 14. Evolutionary radiation of Alaskan Oculata pollen. **a** – *Azonia pulchella*; **b** – *A. recta*; **c** – *A. fabacea*; **d** – *A. sufflata*; **e** – *A. parva*; **f** – *A. cribrata*; **g** – *A. calvata*; **h** – *Wodehouseia avita*; **i** – *W. edmontonicola*; **j** – *W. stanleyi*; **k** – *W. capillata*; **l** – *W. vestivirgata*; **m** – *W. quadrispina*; **n** – *W. octospina*; **o** – *W. fimbriata* subsp. *constricta*; **p** – *W. spinata*; **q** – *Wodehouseia bella*. Modified from Wiggins (1976); used with permission.

Prasinophycean Algae

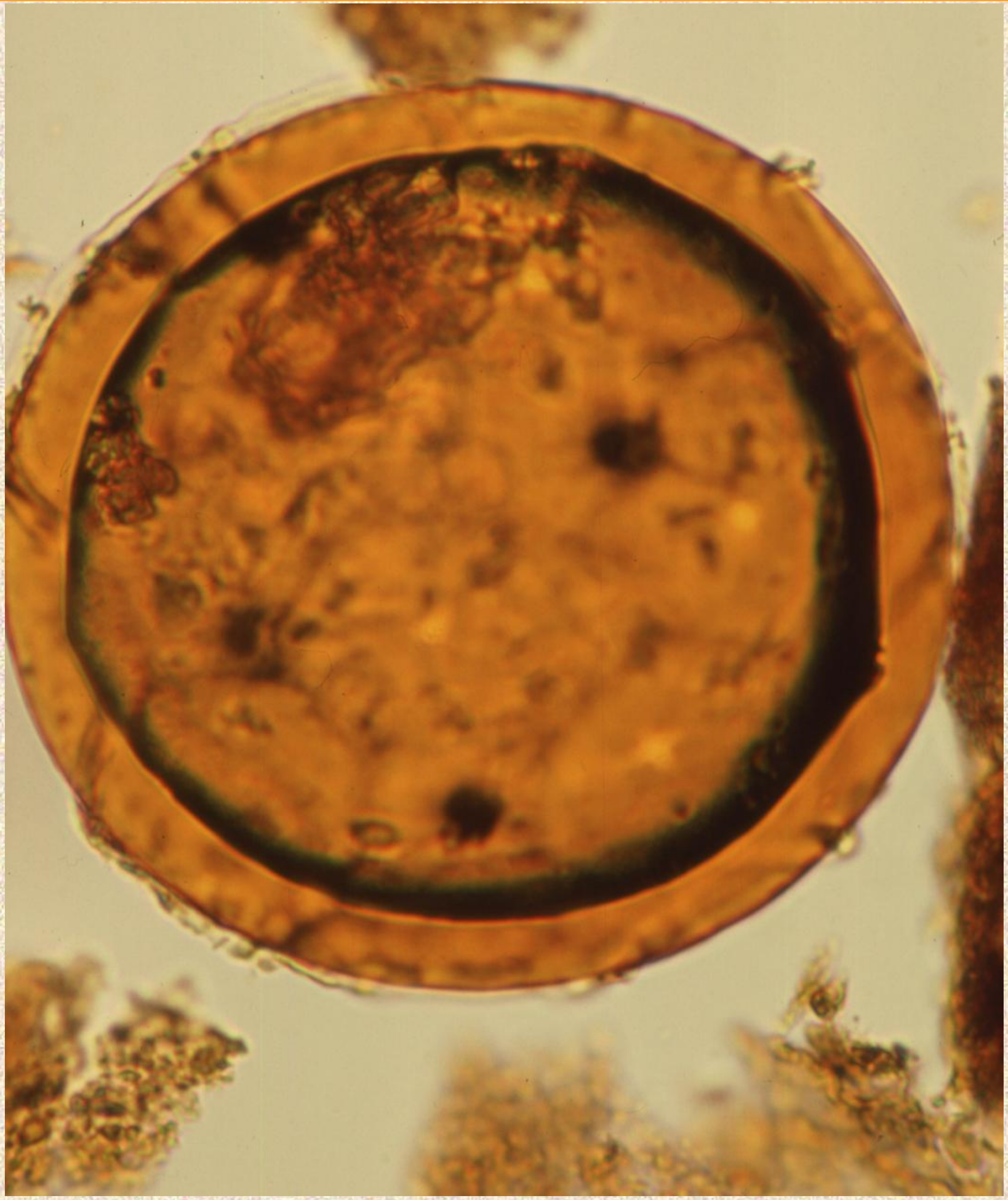
Common forms include :-

Pterospermella spp.

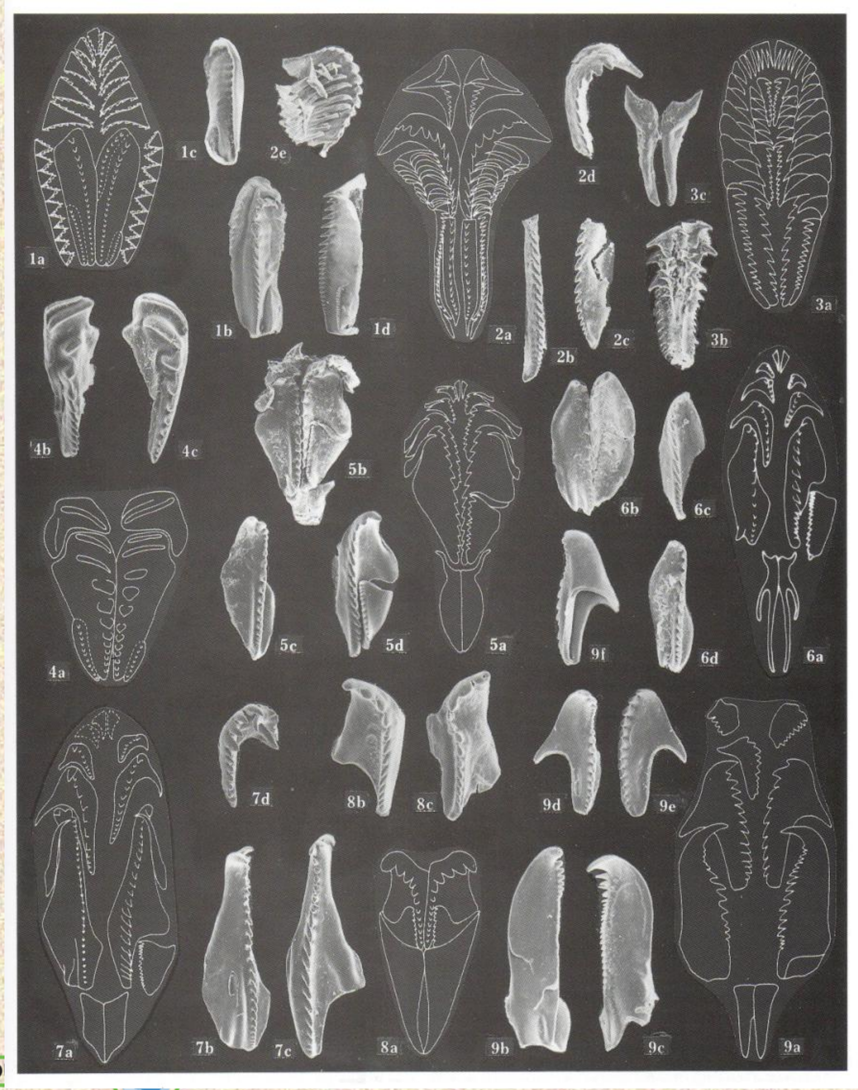
Tasmanites spp.

Crassosphaera spp.

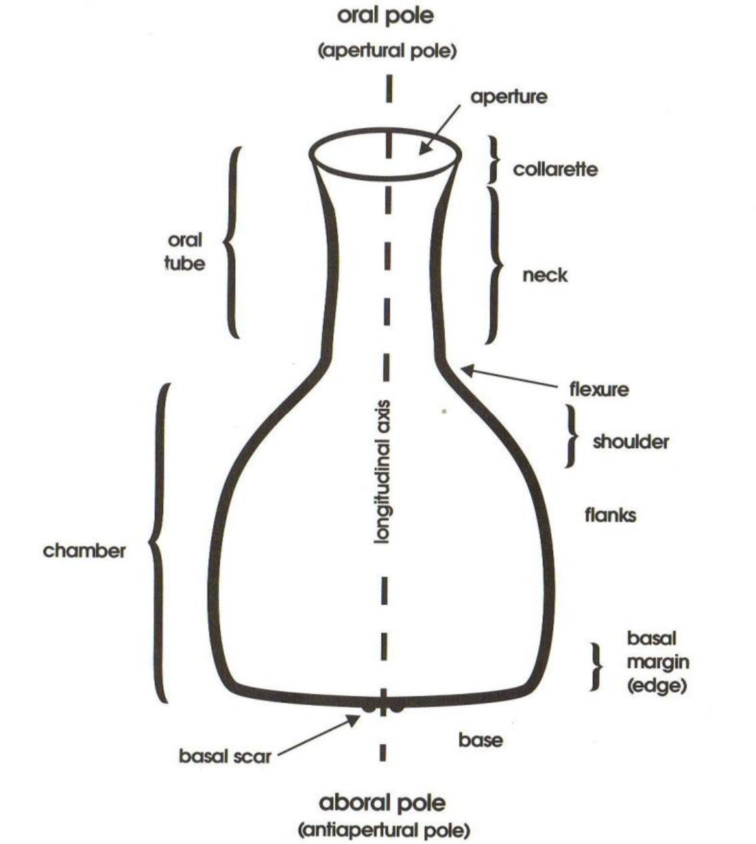
Cymatiosphaera spp.
(Illustrated)



Scolecodonts



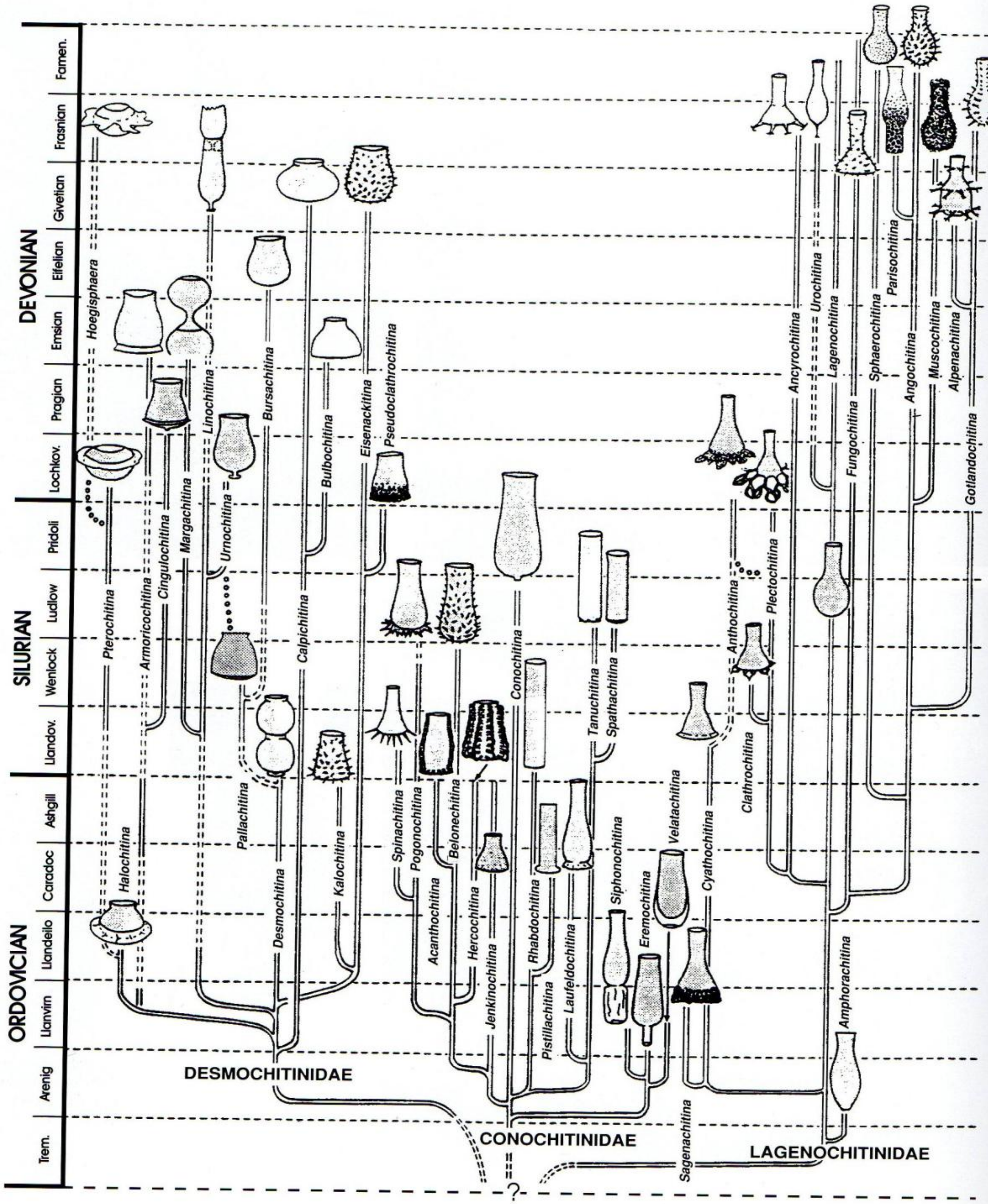
Chitinozoa



Text-Figure 1. Diagrammatic lateral view of chitinozoan vesicle with terminology of the major structural features. Internal structures of the oral tube are detailed in Text-Figure 5.

Chitinozoa

Stratigraphic Ranges



Dinoflagellate lineage

Division

Pyrrhophyta Pascher 1914

Class

Dinophyceae Fritsch 1929

Order

Prorocentrales
Lemmermann 1910

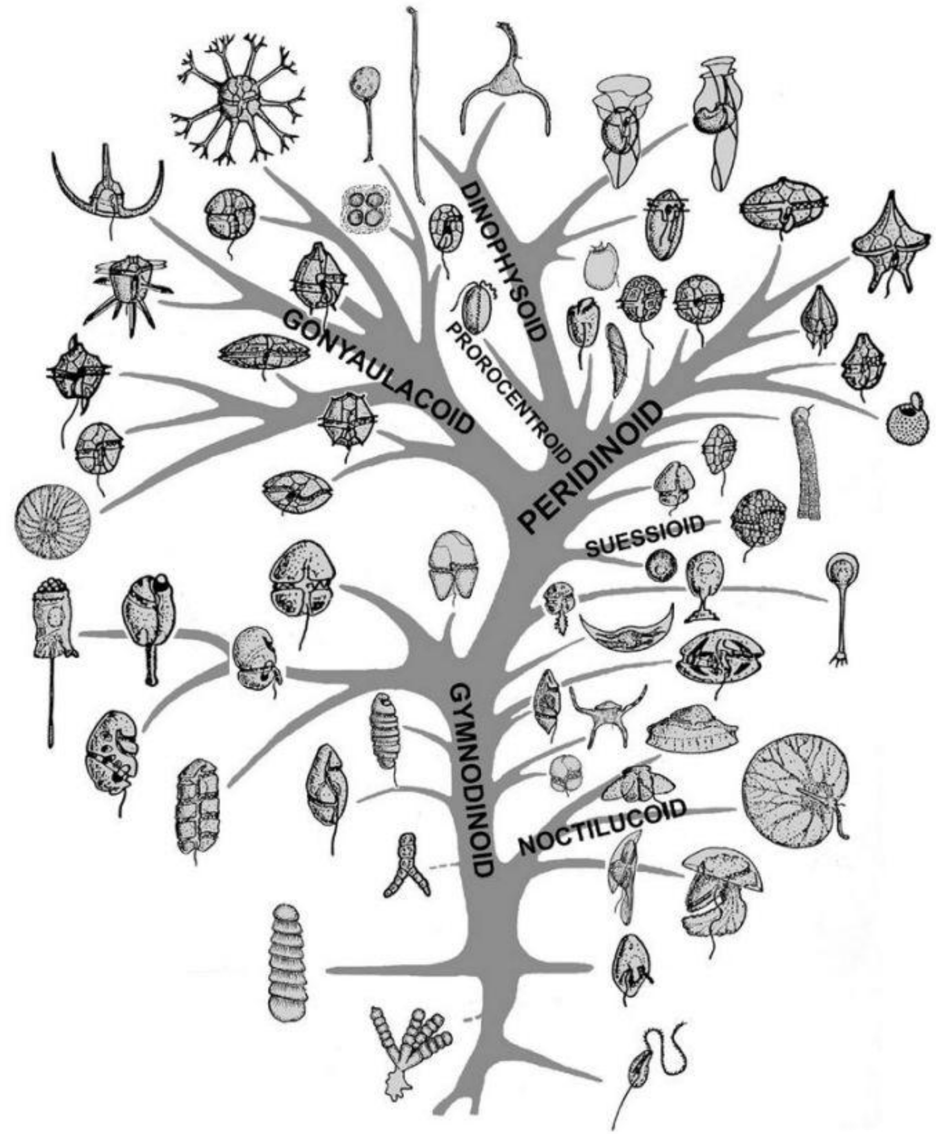
Dinophysiales
Lindeman 1928

Peridinales
Haeckel 1894

Gonyaulacales
Taylor 1979

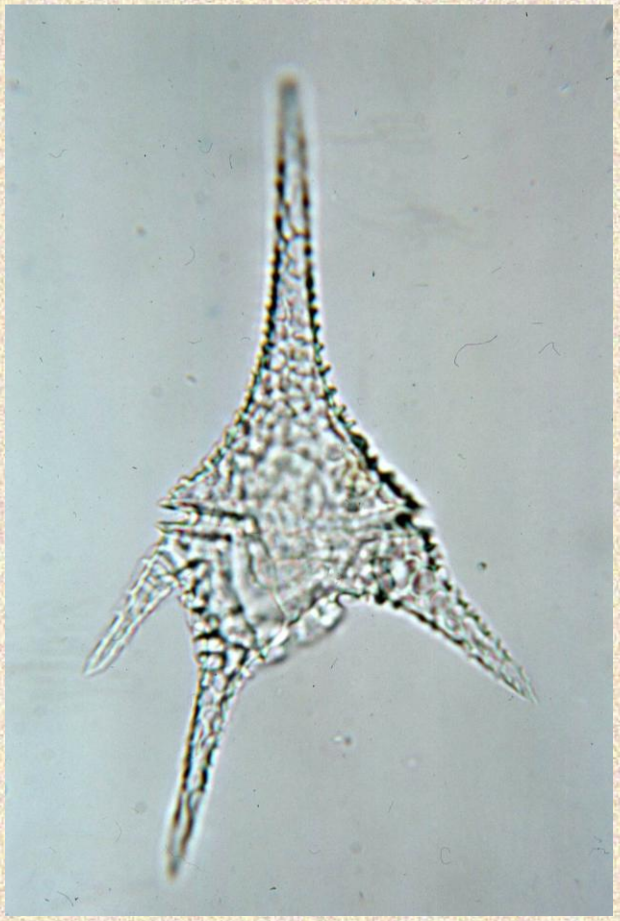
Gymnodiniales
Lemmermann 1910

Nannoceratopsiales
Peil and Evitt 1980



Taylor, Hoppenrath & Saldarriaga (2008) Bidiv. Cons.

Present Day Phytoplankton 1



Present Day Phytoplankton 2

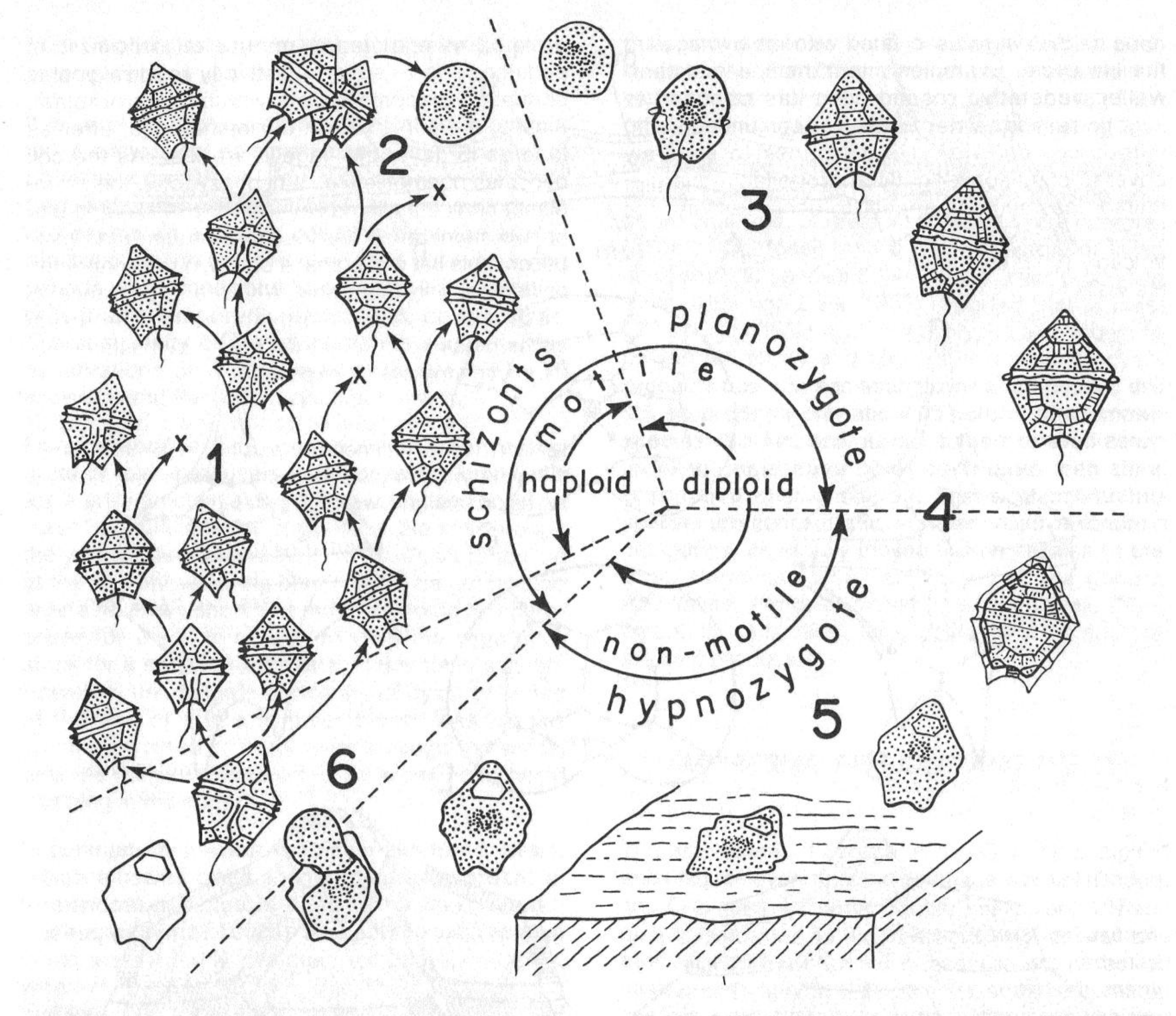
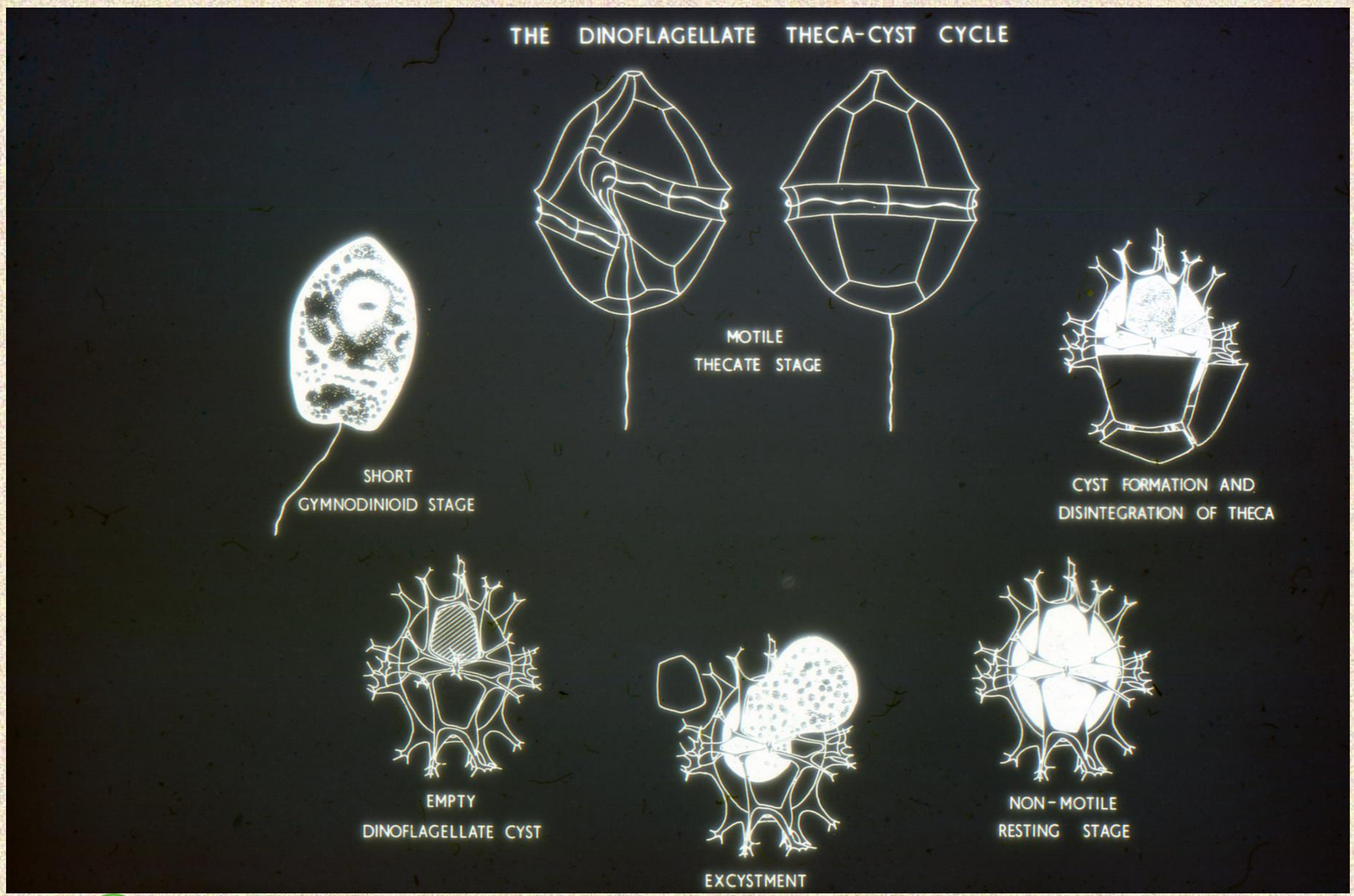


Figure 1.3 - SCHEMATIC LIFE CYCLE OF CYST-PRODUCING DINOFLAGELLATE


THE DINOFLAGELLATE THECA-CYST CYCLE
MOTILE
THECATE STAGE
SHORT
GYMNODINIOID STAGE
CYST FORMATION AND
DISINTEGRATION OF THECA
EMPTY
DINOFLAGELLATE CYST
EXCYSTMENT
NON-MOTILE
RESTING STAGE

Encystment

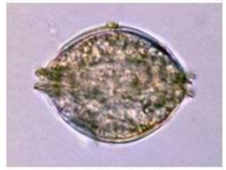
- Cysts are produced in the dinoflagellate's life cycle.
- These are very resistant, durable and easily fossilised.
- Sporopollenin.
  - A complex biopolymer derived by oxidative polymerization of carotenoids or carotenoid esters.

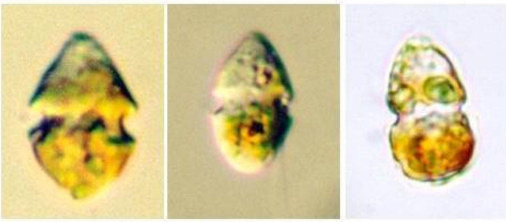
Blooms

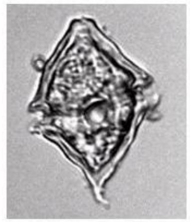
Dinoflagellate bloom

- Today, most plankton can be found where deep ocean currents rise to the surface
- This upwelling water is rich in nutrients and causes the plankton to bloom
- Blooms of certain plankton called dinoflagellates may give the water a red tinge

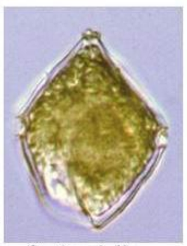
Peridiniales

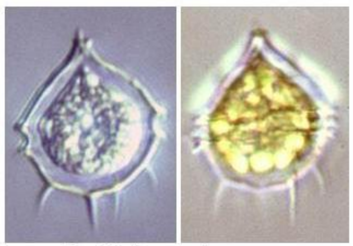

Zygabikodinium lenticula


Heterocapsa circularisquama

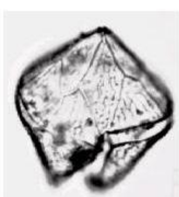

Heterocapsa triquetra

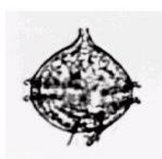

Scrippsiella trochoidea

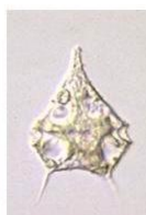

Scrippsiella spinifera


Peridinium quinquecorne


Protoperidinium claudicans

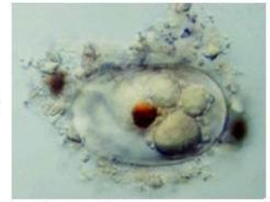

Protoperidinium leonis

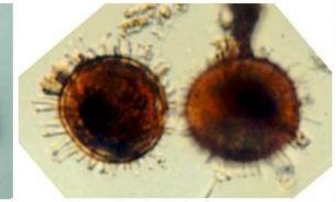

Protoperidinium pellucidum

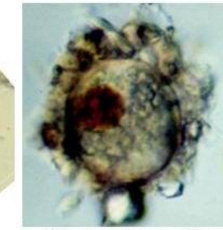

Protoperidinium bipes

Cyst

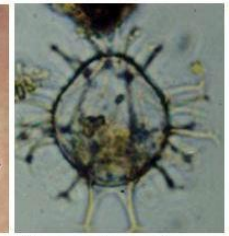
Gonyaulacales

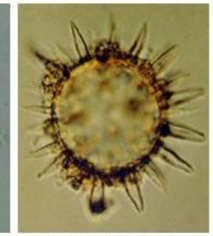

Alexandrium tamarense

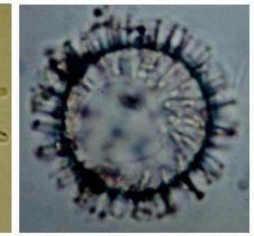

Pyrodinium bahamense

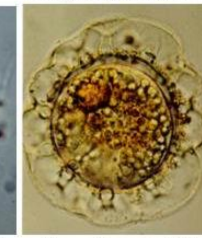

Gonyaulax verior


Gonyaulax

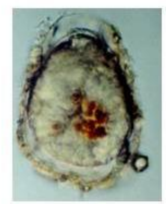

Gonyaulax scrippsae


Lingulodinium polyedrum

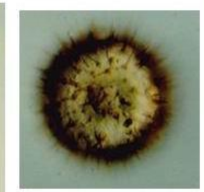

Protoceratium reticulatum

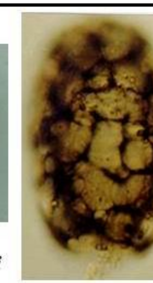

Pyrophacus steinii

Gymnodiniales


Gyrodinium instriatum

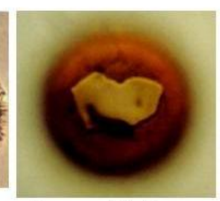

Cochlodinium polykrikoides

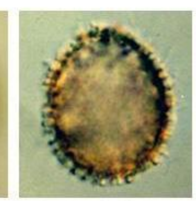

Pheopolykrikos hartmannii

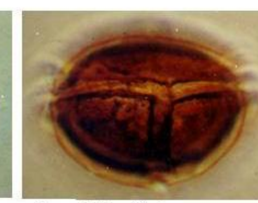

Polykrikos kofoidii

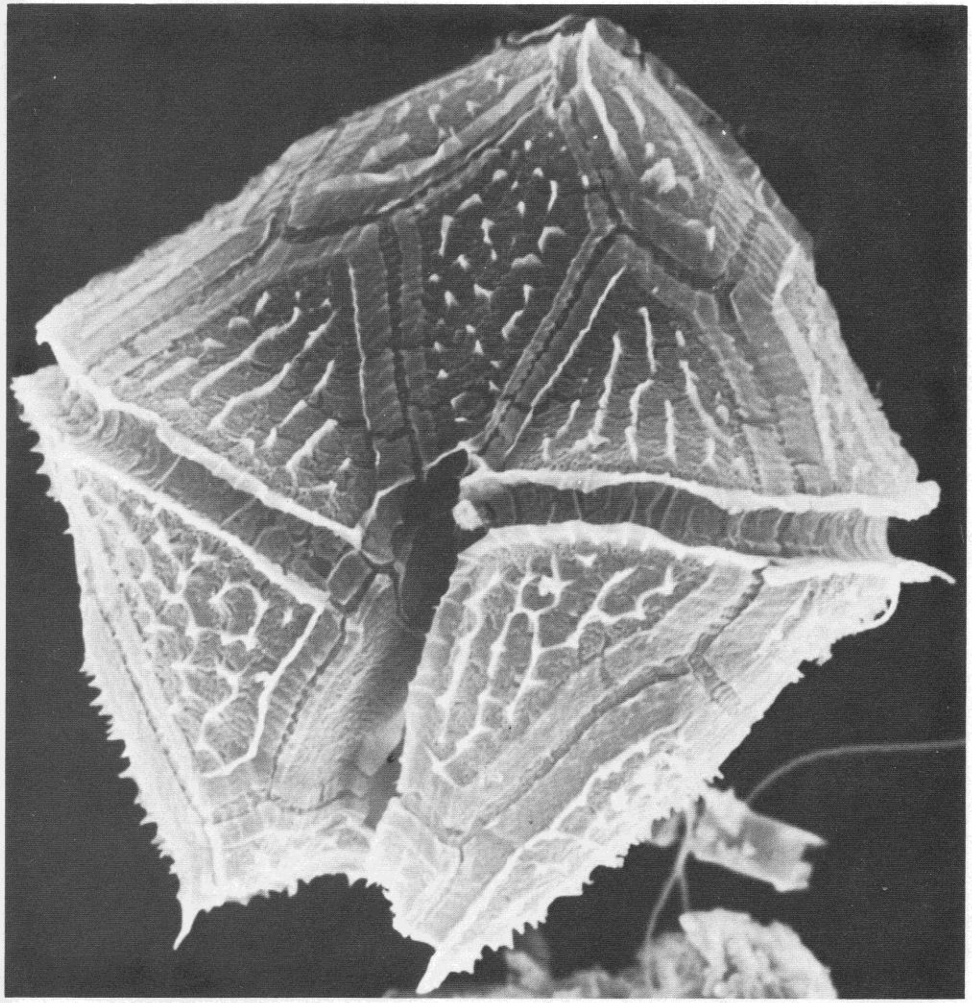
Peridiniales


Protoperidinium claudicans

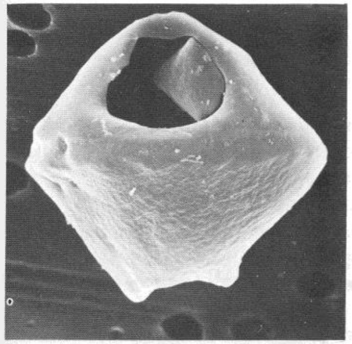

Protoperidinium thorianum


Scrippsiella trochoidea


Zygabikodinium lenticulatum



Gonyaulax spinifera (Claparédè & Lachmann) Diesing
The type species of the genus but a real problem regarding its correct identification since it has been confused with *G. digitale* and other species. It has a fairly delicate theca with several spines at the posterior end and a very big displacement of the girdle. Several types of cyst are reported and one, *Spiniferites mirabilis* is shown.
North Sea. 52 μm l, 44 μm w.



Protoperidinium leonis (Pavillard) Balech
A distinctively straight-sided species with a slightly offset median girdle. The ornamentation of the plates is somewhat varied, but often involves longitudinal ridges as here. The cyst (small picture) has a clearly peridinoid shape, is smooth, and has a four-sided archeopyle.
North Sea. 70 μm l, 65 μm w.

Dinocyst variety

Shape

Proximate

Chorate

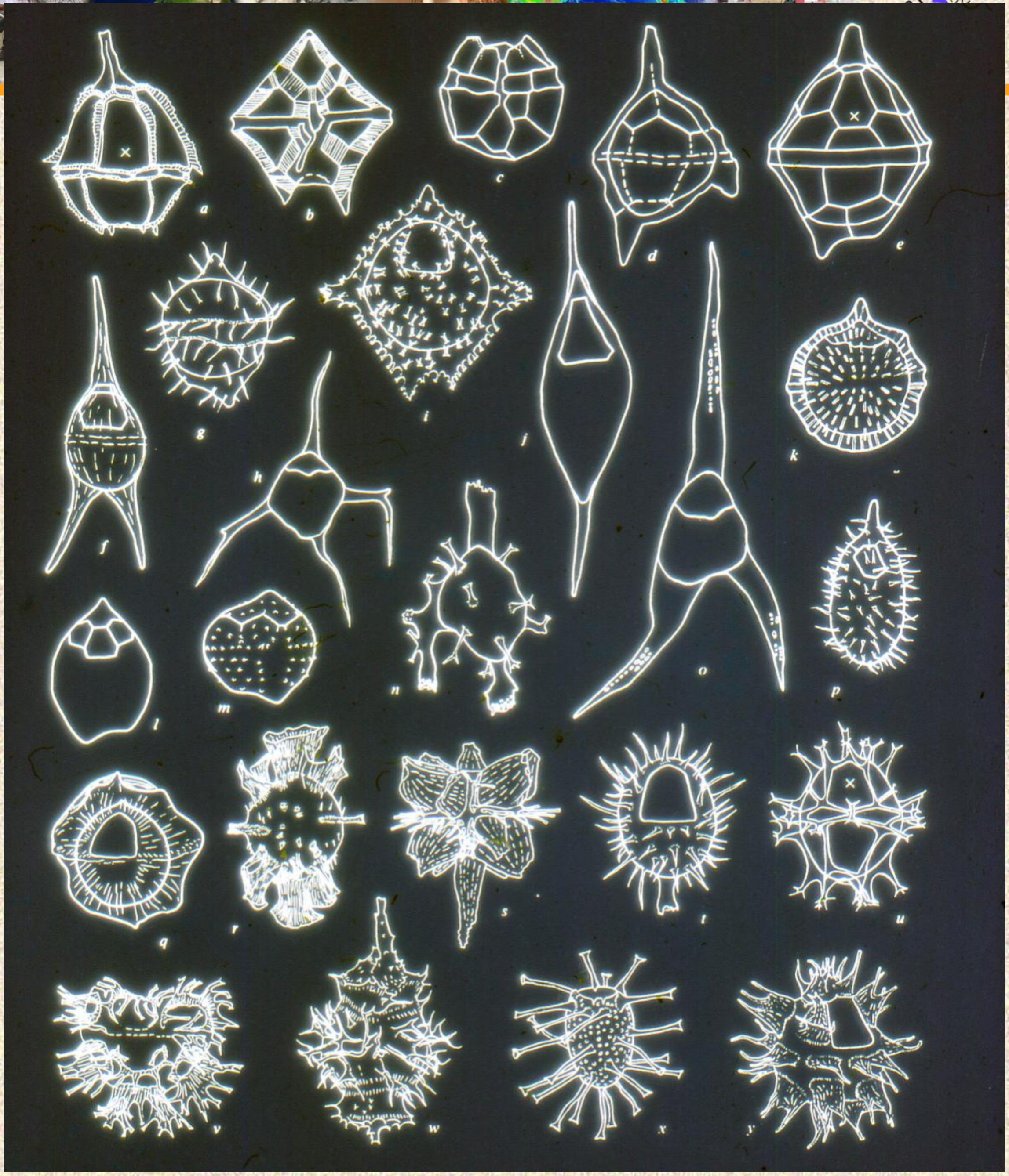
Cavate

Cyst wall

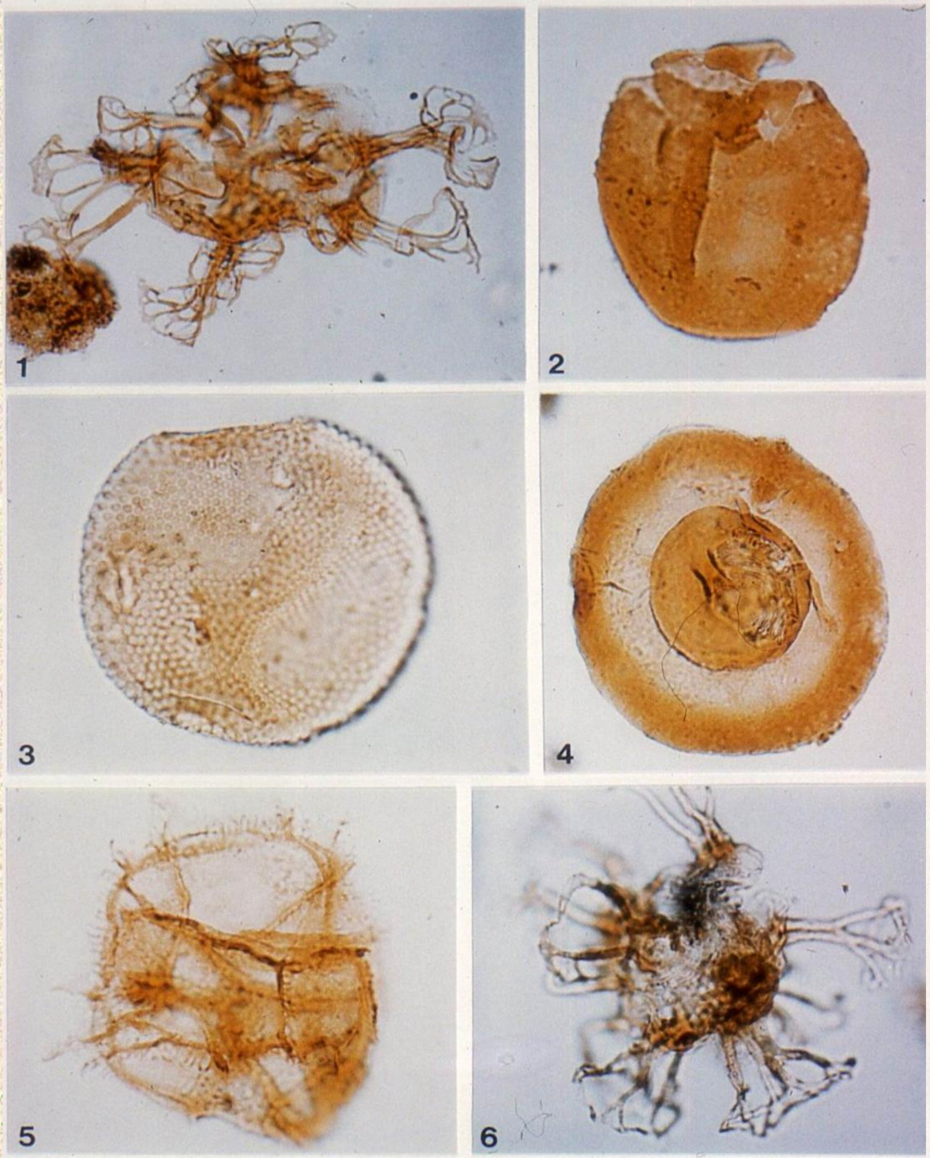
Paratabulation

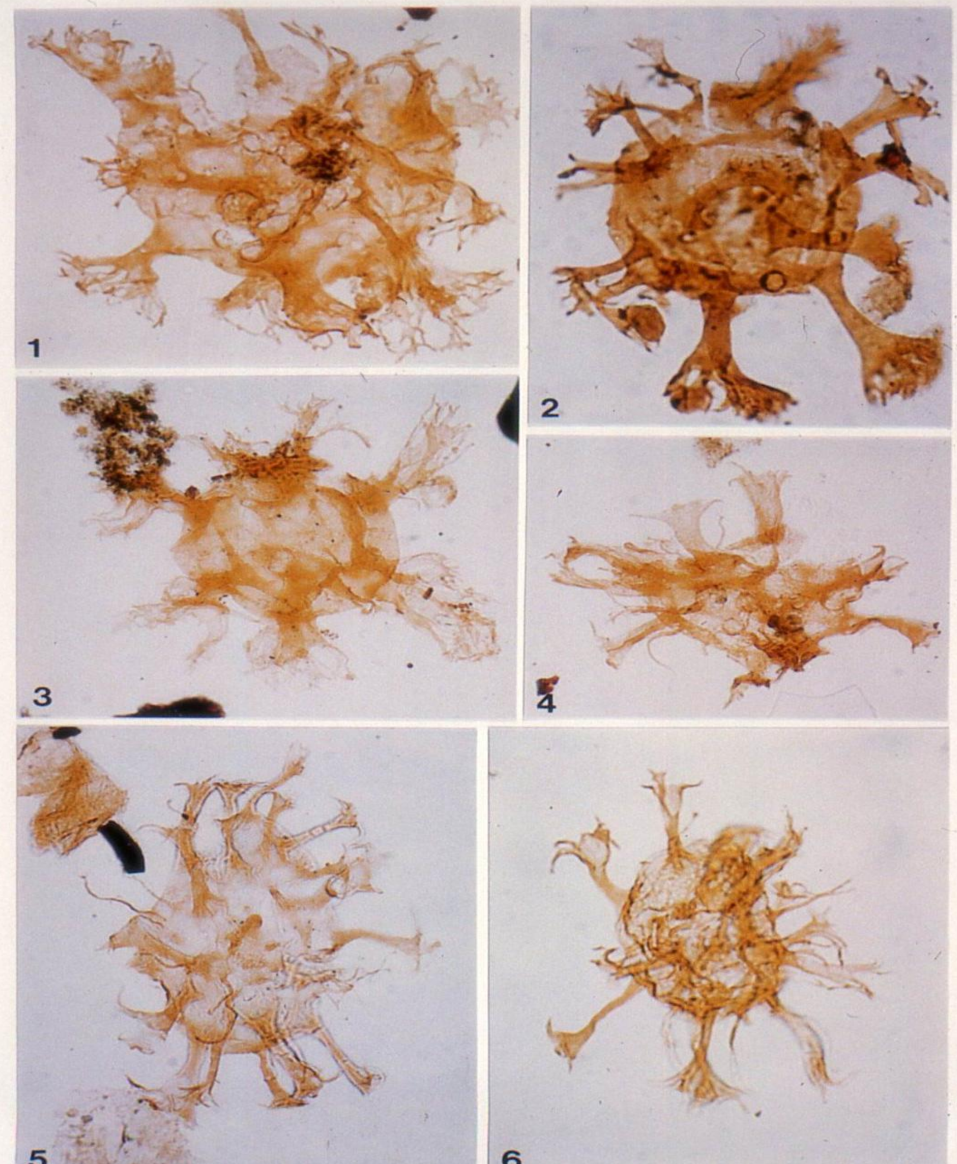
Archeopyle style

Ornamentation

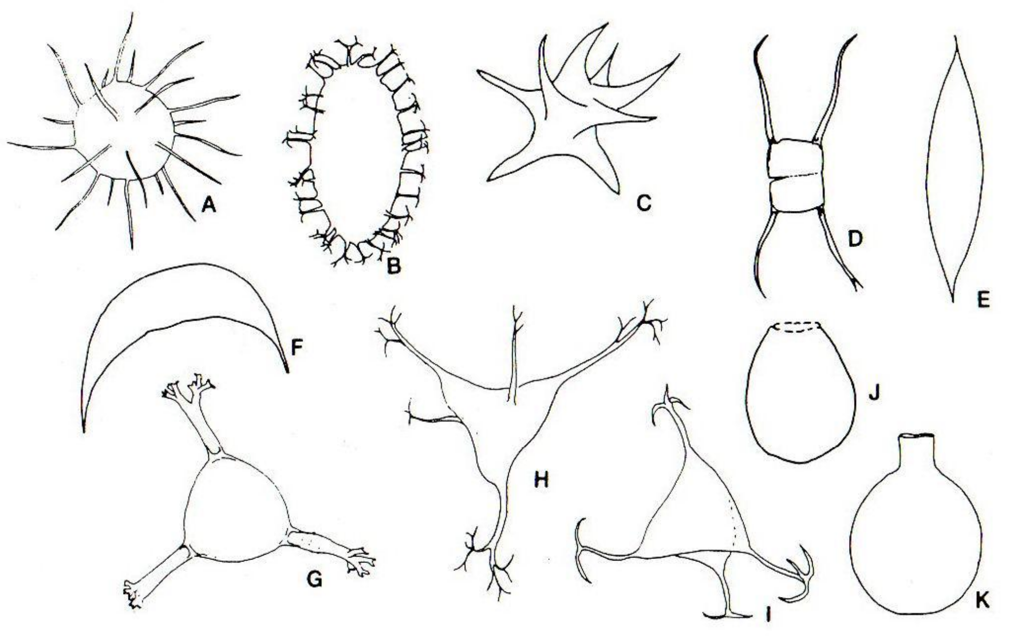


Fossil Dinoflagellate Cysts

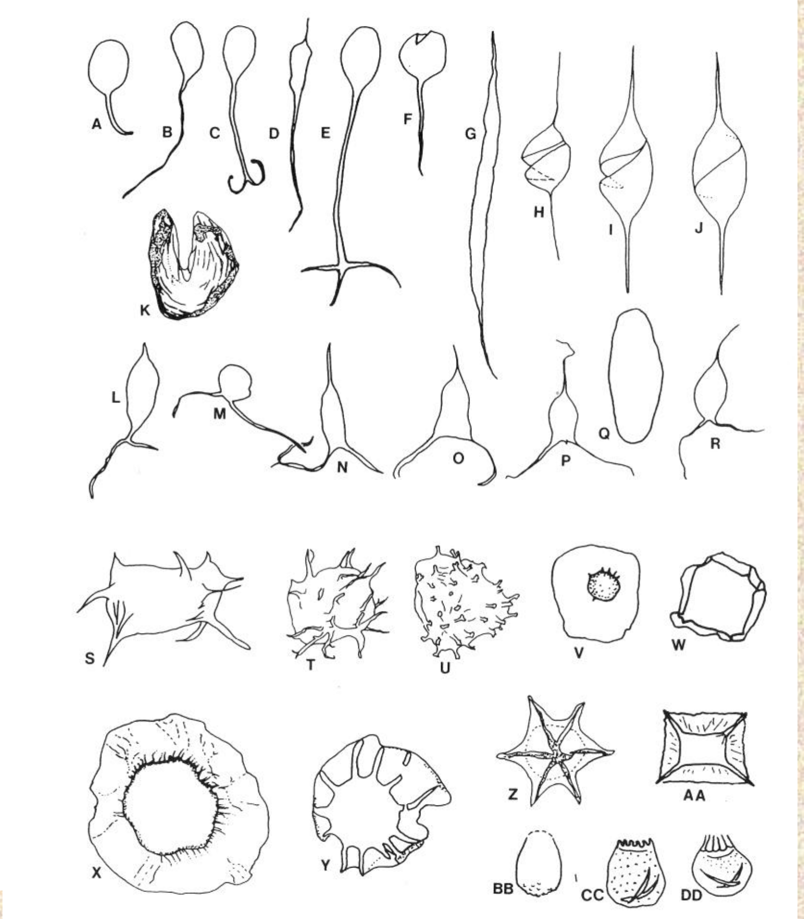




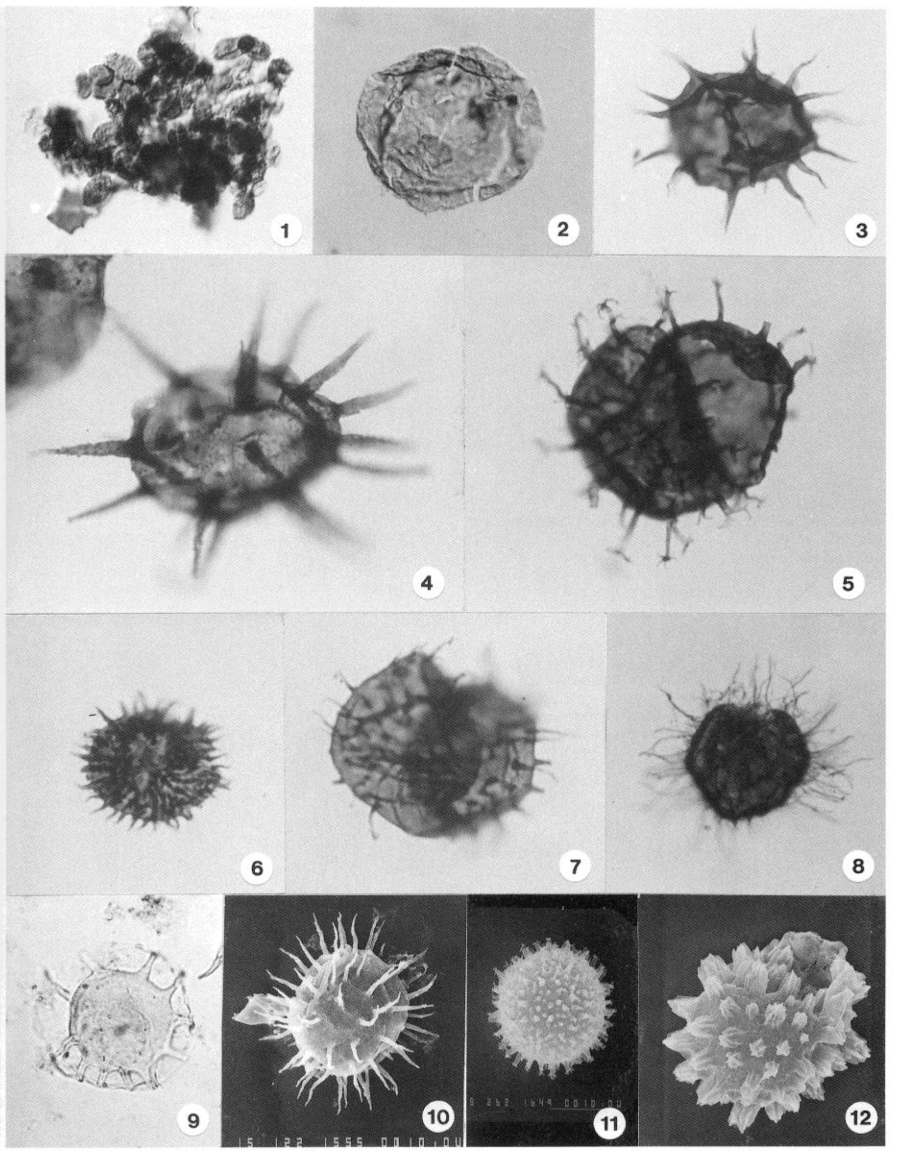
Acritarch morphologies

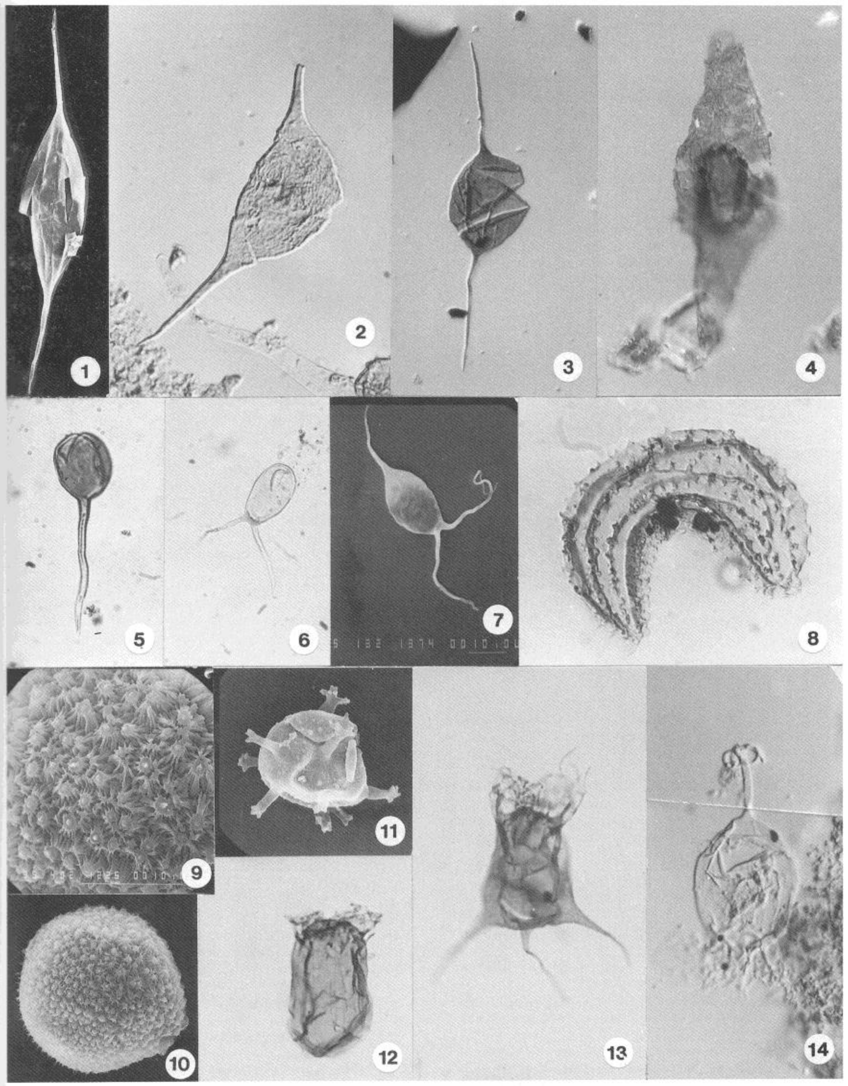


Text-Figure 2. Basic acritarch shapes. **A**, spheroidal; **B**, ellipsoidal; **C**, stellate; **D**, rectangular; **E**, fusiform; **F**, crescentic; **G**, triapsidate; **H**, triquitrate; **I**, tetrahedral; **J**, ovoid; **K**, flask-shaped.



Palaeozoic Acritarchs



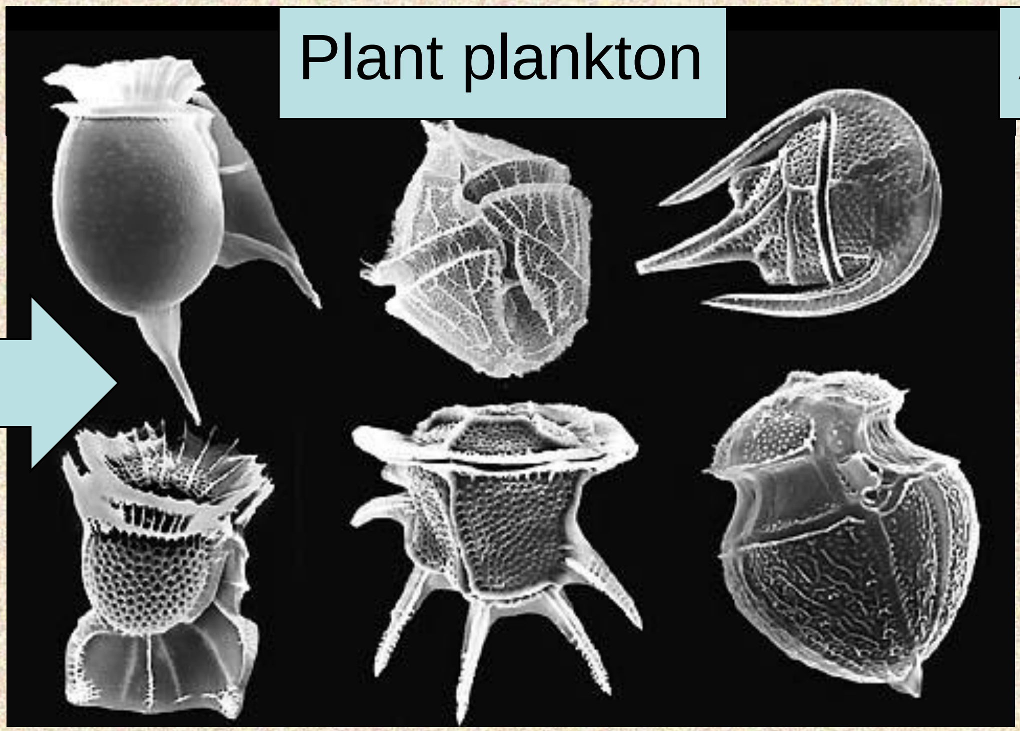


Oil and Gas – Black Gold!

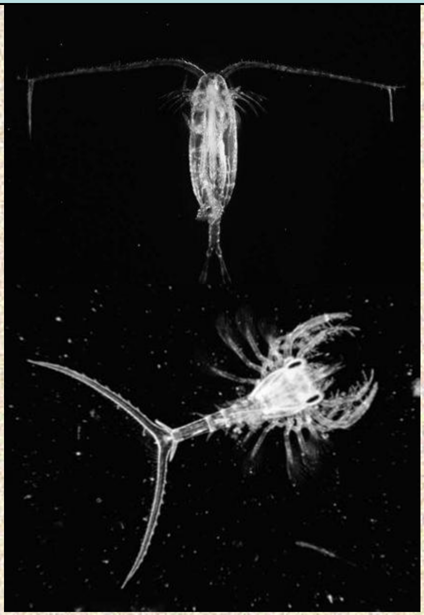
Plankton

10,000 of these bugs would fit on a pinhead!

Plant plankton

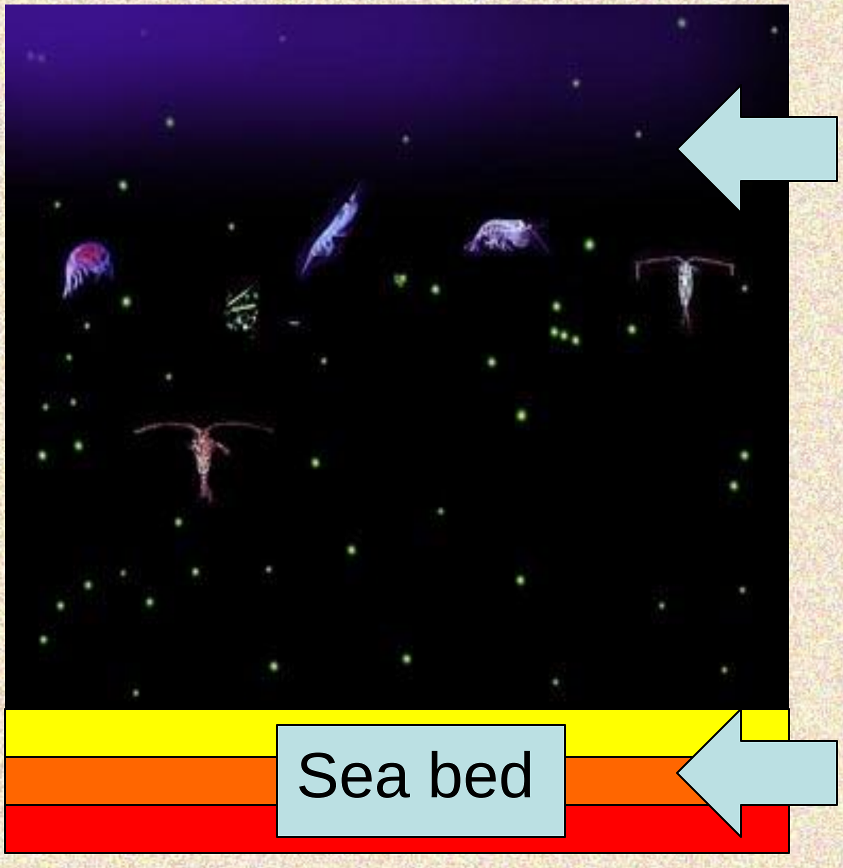


Animal plankton



- Most oil and gas starts life as microscopic plants and animals that live in the ocean.

On the sea bed



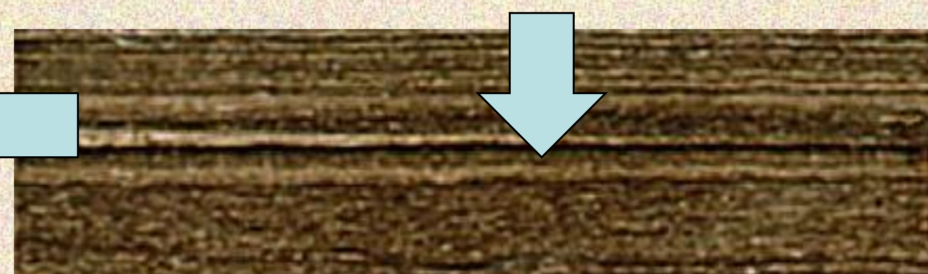
When the plankton dies it rains down on sea bed to form an organic mush

If there are any animals on the sea bed these will feed on the organic particles

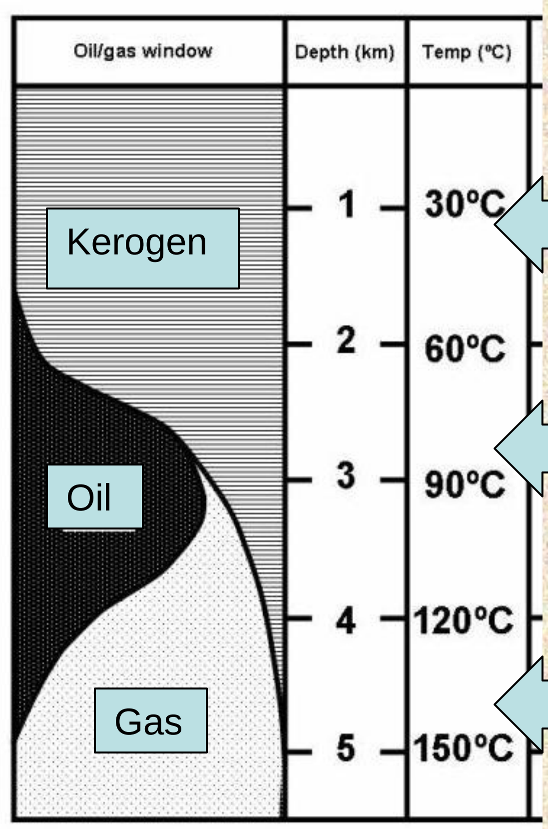
Black Shale

- However, if there is little or no oxygen in the water then animals can't survive and the organic mush accumulates

- Where sediment contains more than 5% organic matter, it eventually forms a rock known as a Black Shale



Cooking



As Black Shale is buried, it is heated.

Organic matter is first changed by the increase in temperature into kerogen, which is a solid form of hydrocarbon

Around 90° C, it is changed into a liquid state, which we call oil

Around 150° C, it is changed into a gas

A rock that has produced oil and gas in this way is known as a Source Rock

Kerogen Maturity

1 . Level 2. Middle Volgian , N.Sea.

2. Level 2-3. Tertiary, N.Sea.

3. Level 2-3. E.Cretaceous, N.Sea.

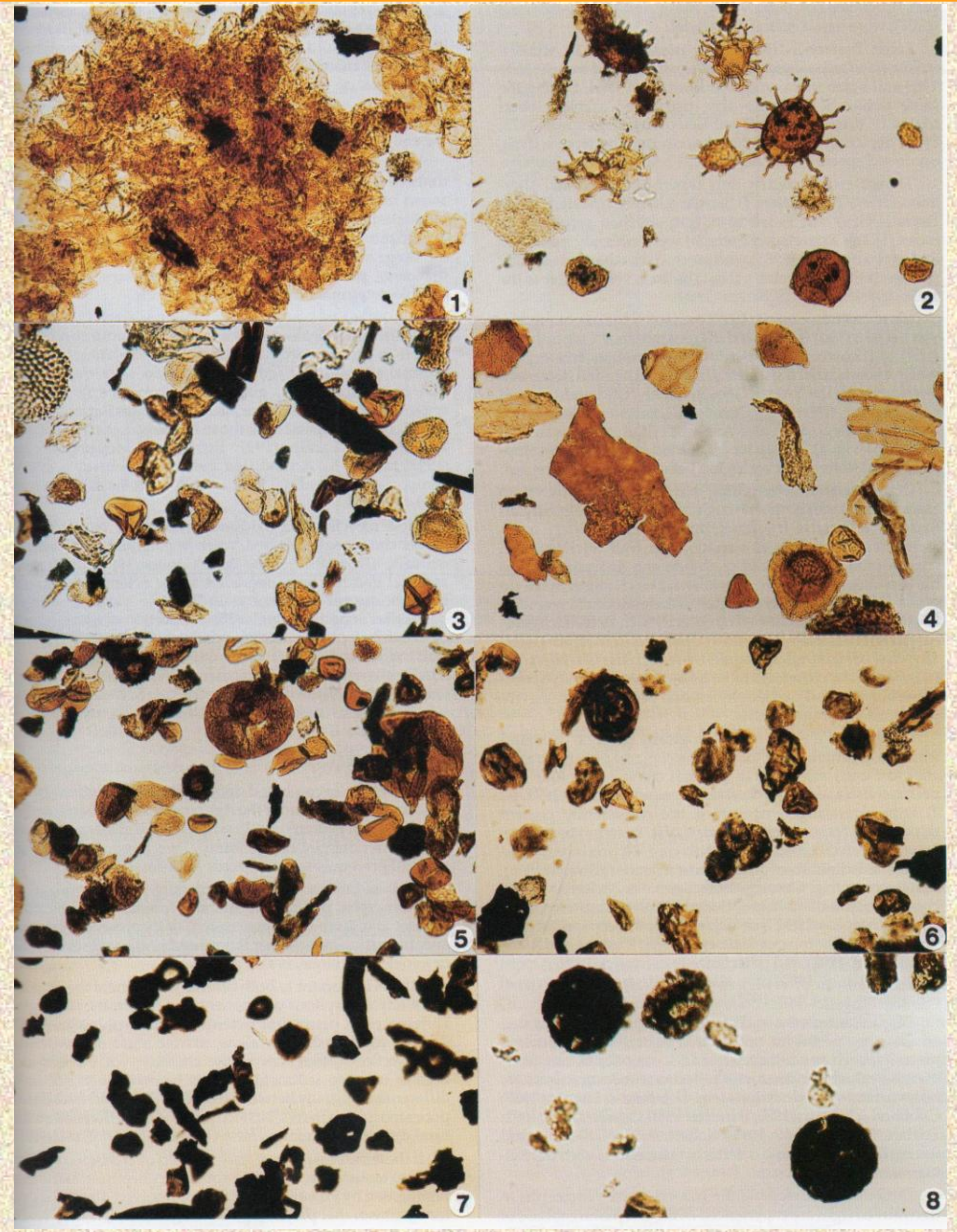
4. Level 3. Devonian, Brazil.

5. Level 3-4. Carboniferous, Yorks.

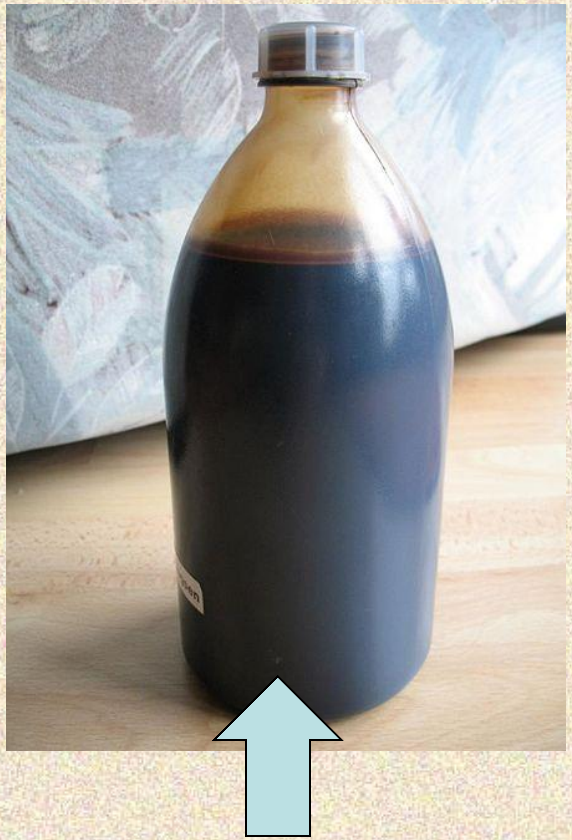
6. Level 5. Triassic , E Midlands.

7. Level 6. Carboniferous, Ireland.

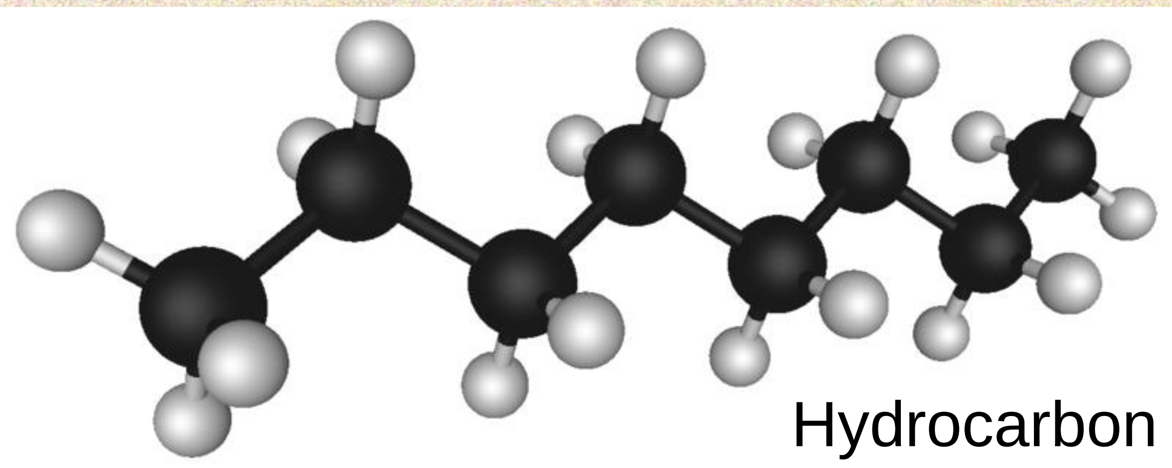
8. Level 6-7 Devonian. Australia.



Chemistry



Crude Oil



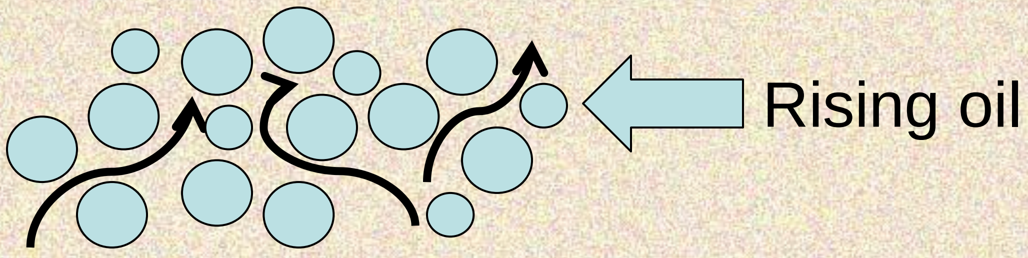
Hydrocarbon

- Oil and gas are made of a mixture of different hydrocarbons.
- As the name suggests these are large molecules made up of hydrogen atoms attached to a backbone of carbon.

Migration

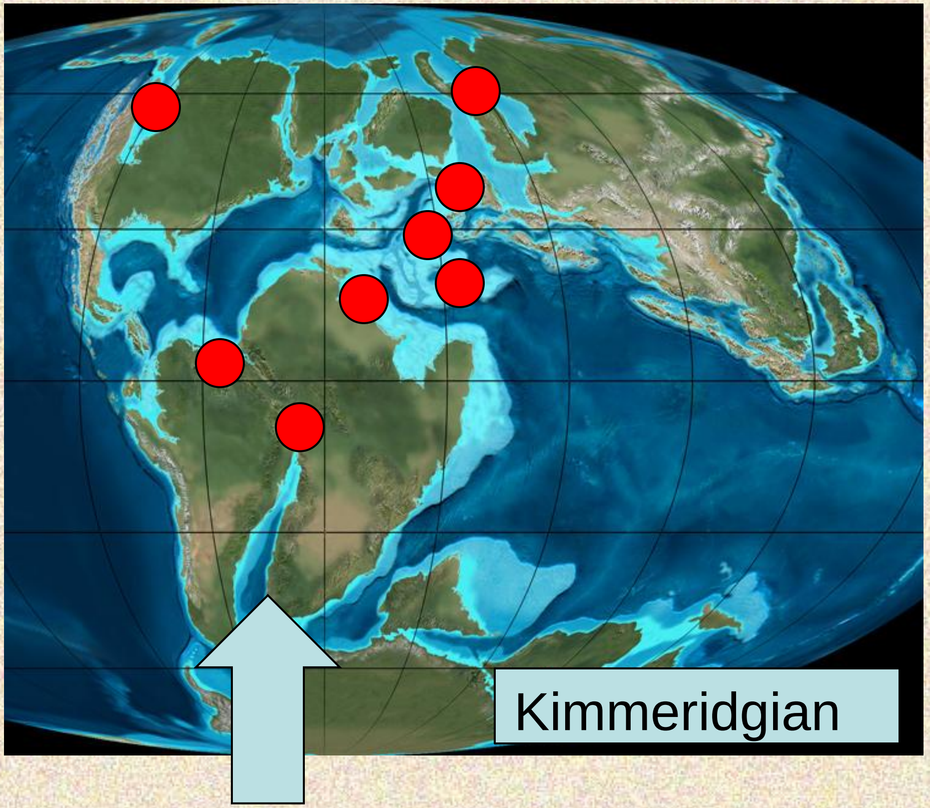
- Hot oil and gas is less dense than the source rock in which it occurs

- Oil and gas migrate upwards up through the rock in much the same way that the air bubbles of an underwater diver rise to the surface



- The rising oil and gas eventually gets trapped in pockets in the rock called reservoirs

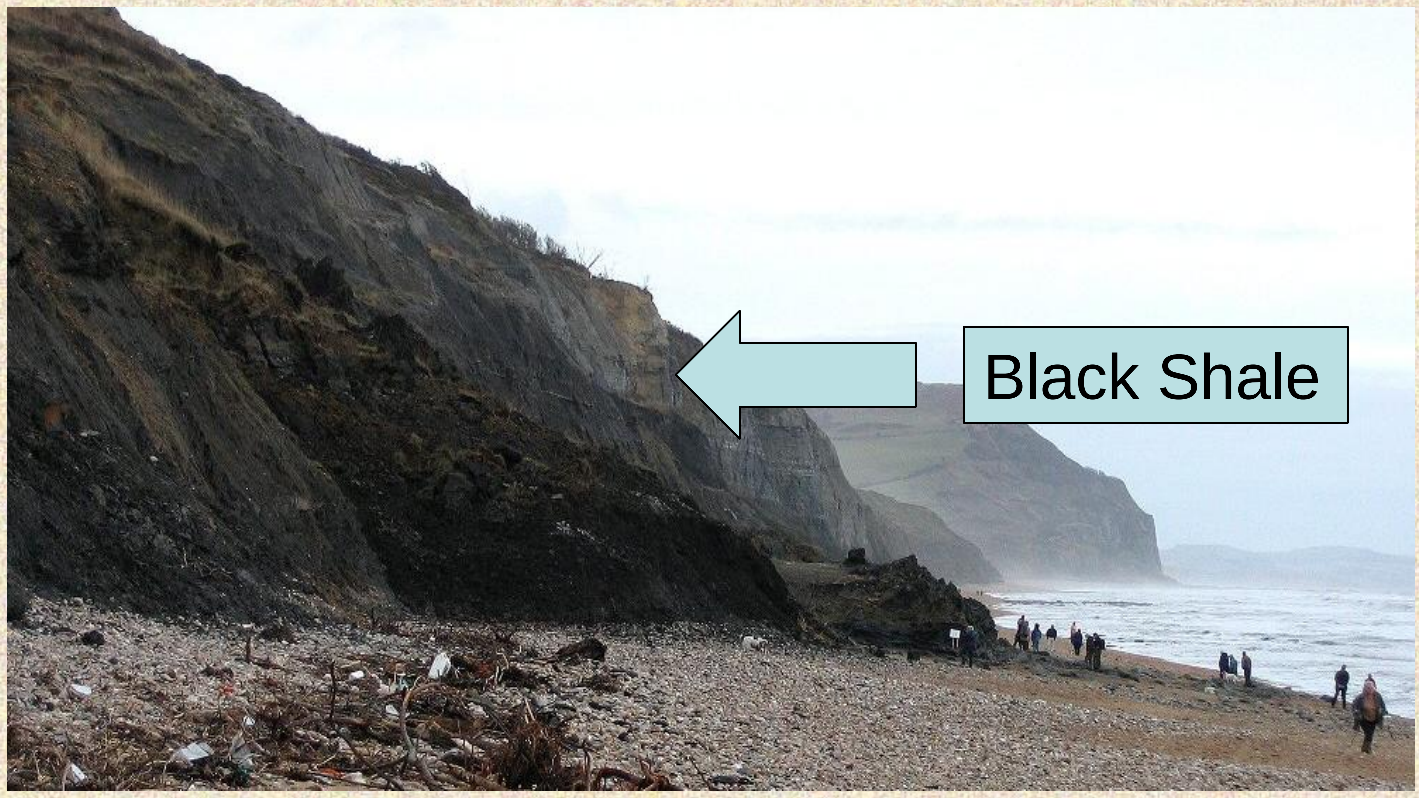
Kimmeridgian



- During mid-Mesozoic times around 150 million years ago, conditions were just right to build up huge thicknesses of Black Shale source rocks

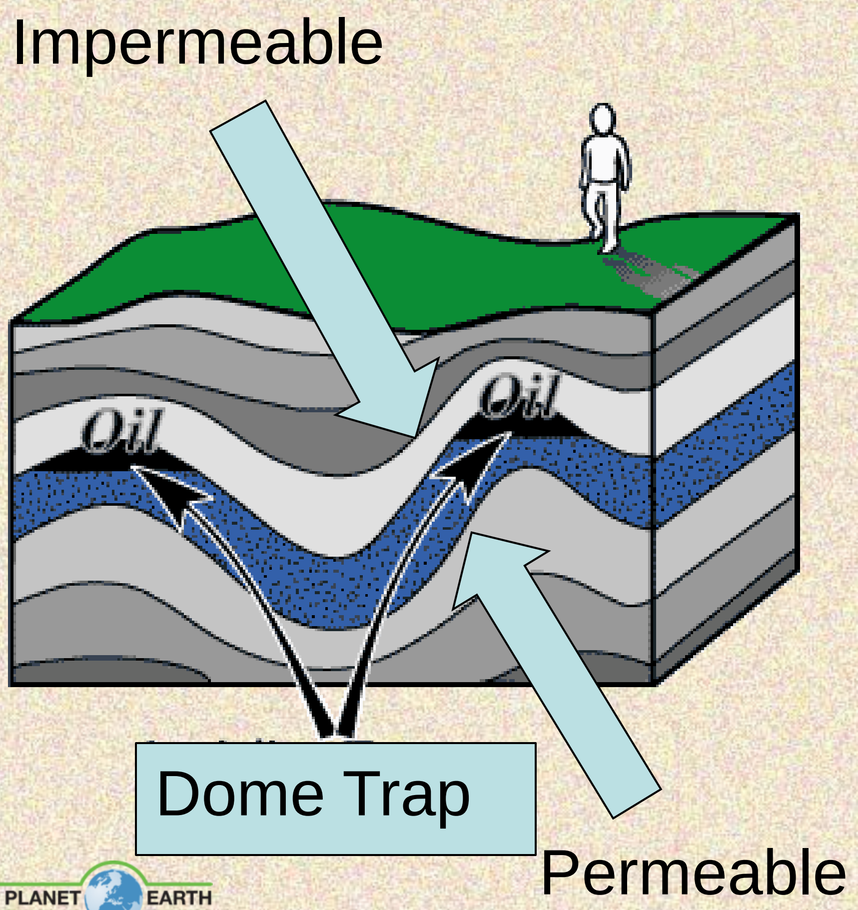
The world's main oil deposits all formed in warm shallow seas where plankton bloomed but bottom waters were deoxygenated

Source of North Sea Oil



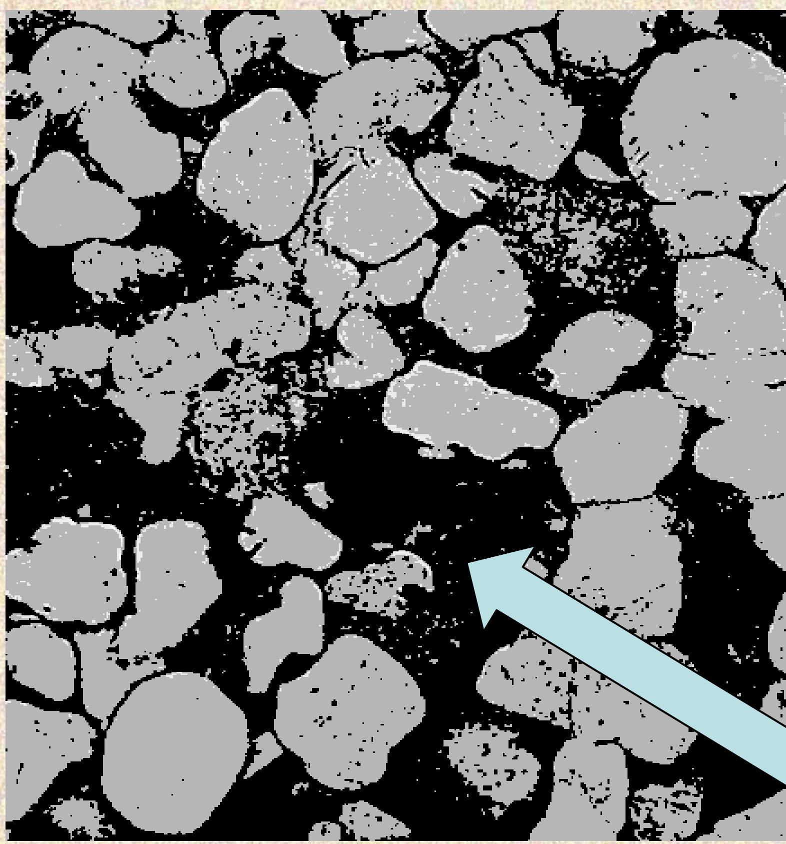
The Kimmeridge Clay is a Black Shale with up to 50% organic matter. It is the main source rock for the North Sea Oil Field

Oil Traps



- Some rocks are permeable and allow oil and gas to freely pass through them
- Other rocks are impermeable and block the upward passage of oil and gas
- Where oil and gas rises up into a dome (or anticline) capped by impermeable rocks it can't escape. This is one type of an Oil Trap.

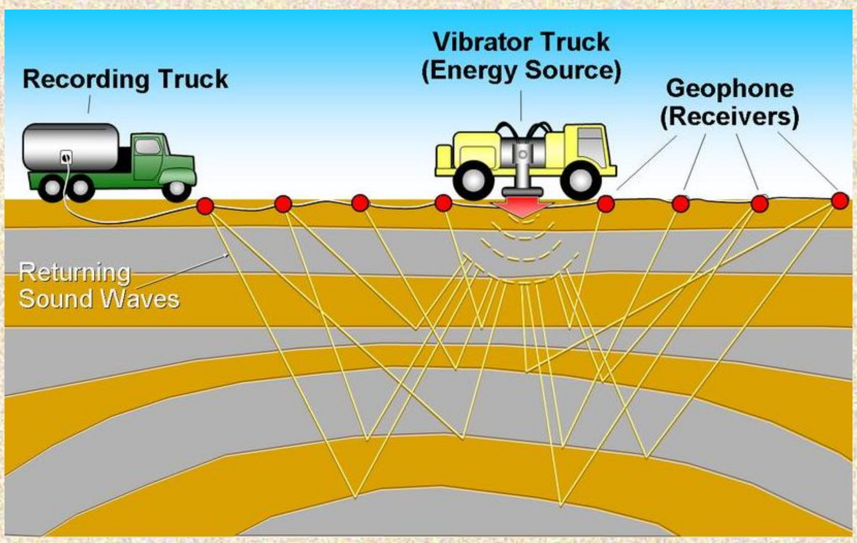
Reservoir Rocks



- The permeable strata in an oil trap is known as the Reservoir Rock
- Reservoir rocks have lots of interconnected holes called pores. These absorb the oil and gas like a sponge

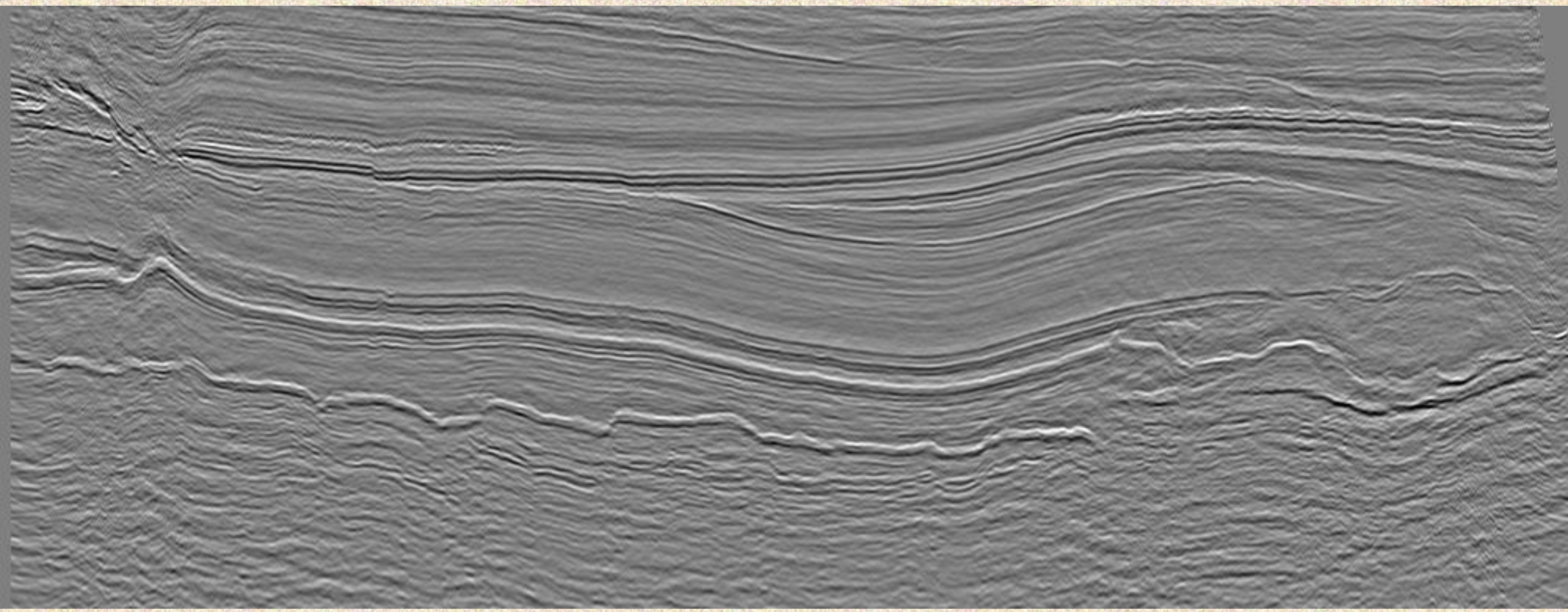
As oil migrates it fills up the pores (oil-filled pores shown in black)

Seismic Surveys

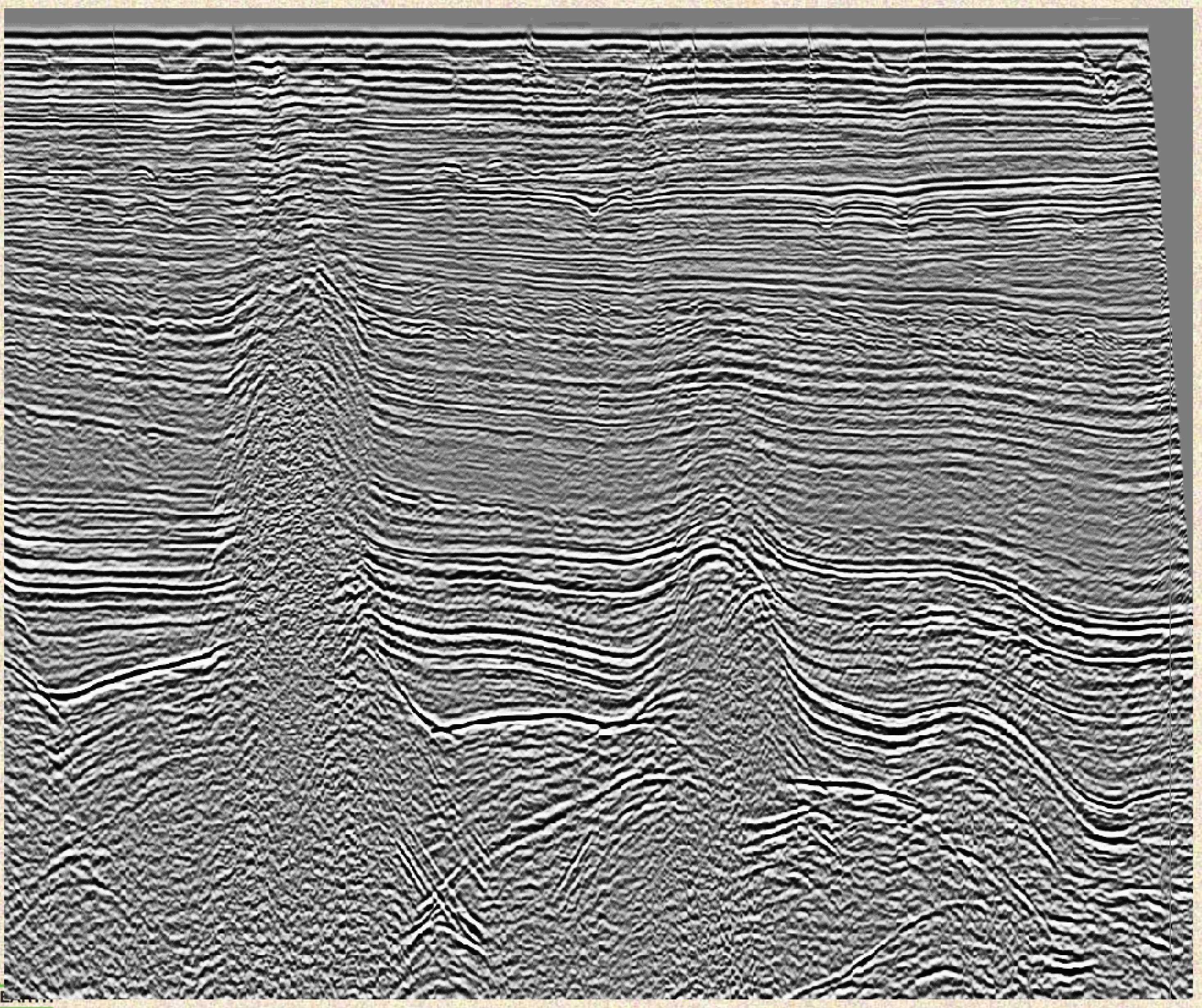


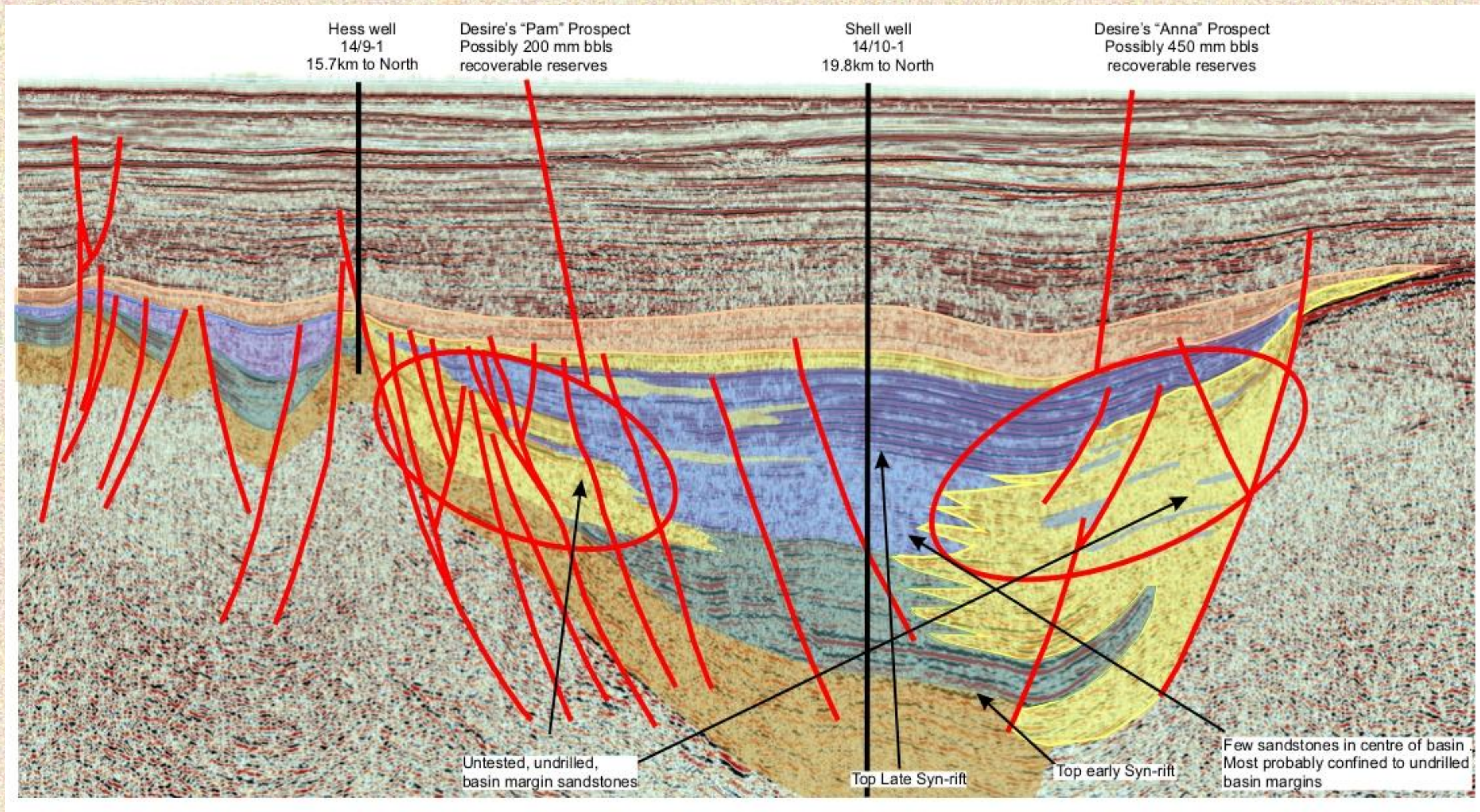
- Seismic surveys are used to locate likely rock structures underground in which oil and gas might be found
- Shock waves are fired into the ground. These bounce off layers of rock and reveal any structural domes that might contain oil

Southern North Sea Seismic Section



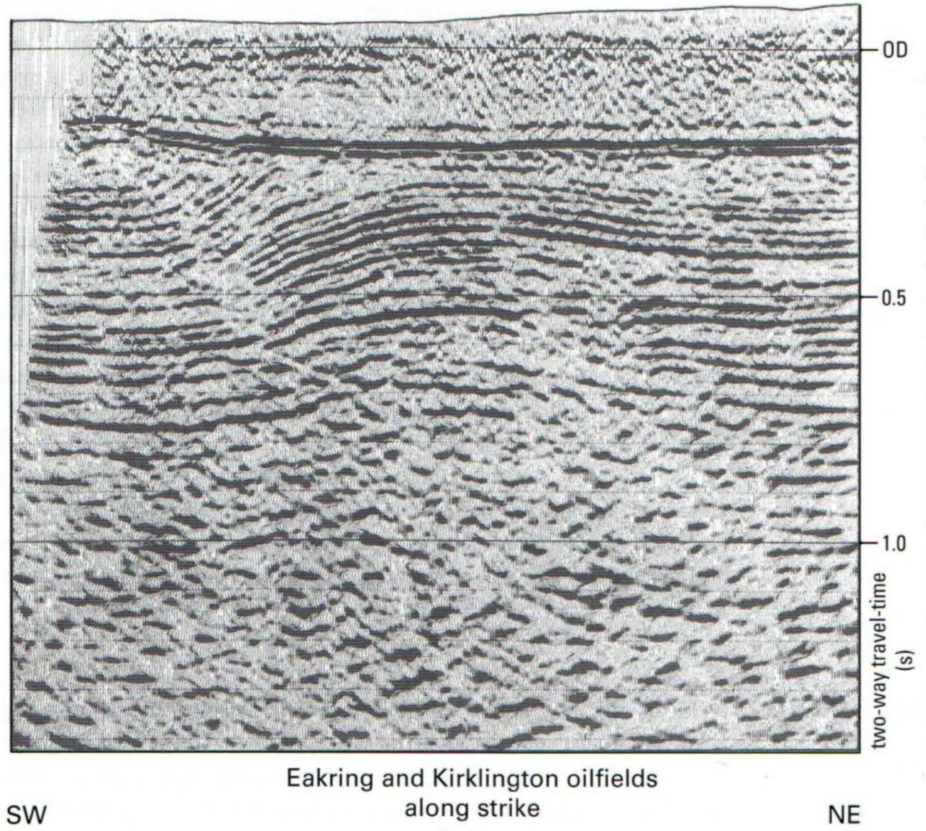
- Carboniferous Fault Blocks with Permian and Mesozoic Meagasequences



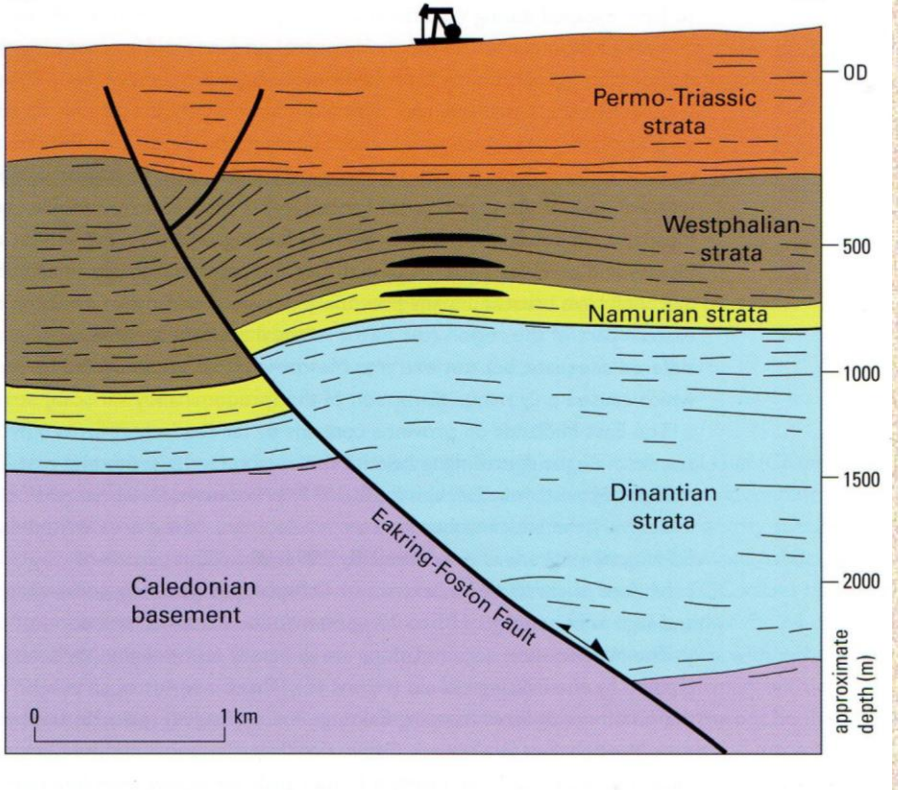


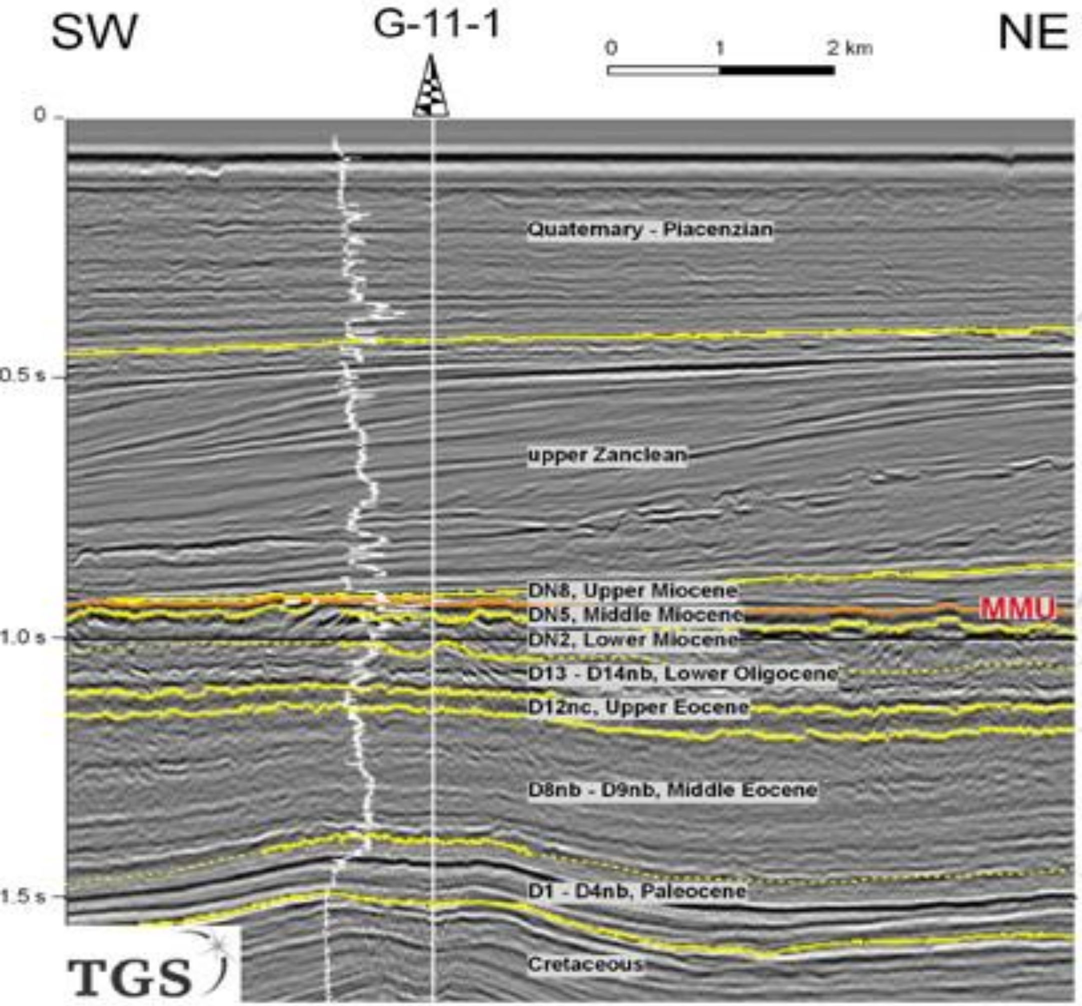
Hess well
14/9-1
15.7km to North
Desire's "Pam" Prospect
Possibly 200 mm bbls
recoverable reserves
Shell well
14/10-1
19.8km to North
Desire's "Anna" Prospect
Possibly 450 mm bbls
recoverable reserves
Untested, undrilled,
basin margin sandstones
Top Late Syn-rift
Top early Syn-rift
Few sandstones in centre of basin .
Most probably confined to undrilled
basin margins

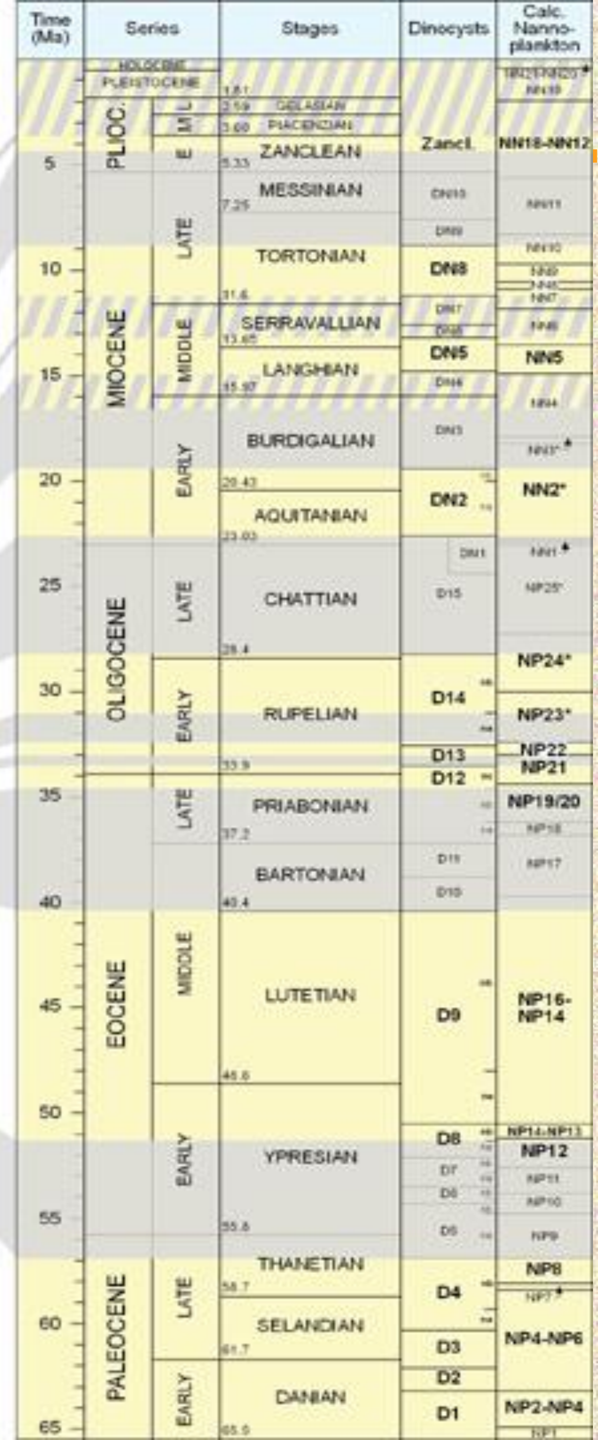
Eakring Oil Field



Eakring and Kirklington oilfields along strike







Time migrated seismic line (normal polarity), gamma-ray log and the ages of the sediments

Source: BGR

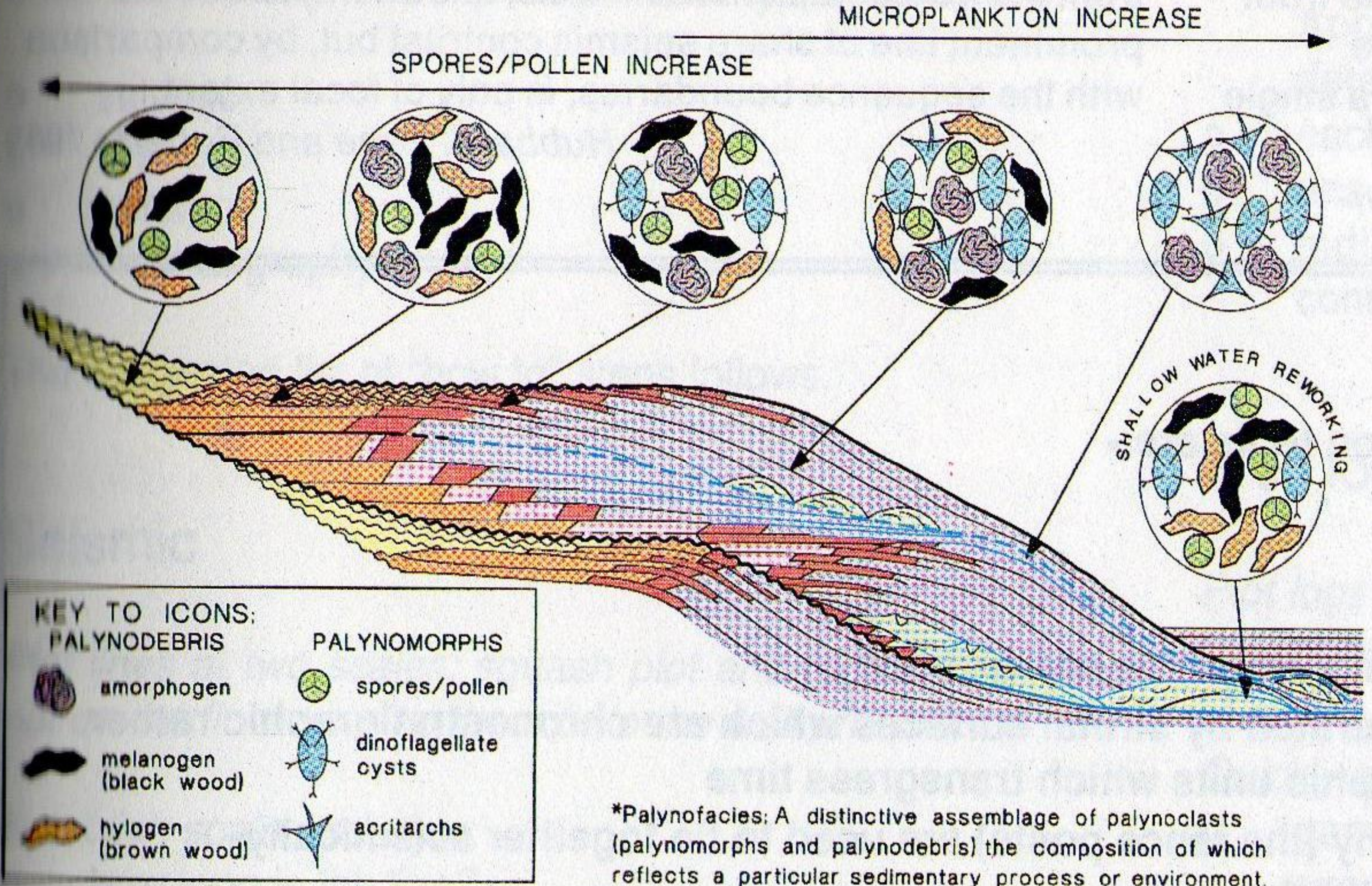
Drilling the well

- Once an oil prospect has been identified, a hole is drilled into the top of the trap
- The cost of drilling is very great. On an offshore rig, it may cost £1 million for each metre drilled.
- A company incurs vast losses for every “dry hole” drilled

Well Correllation

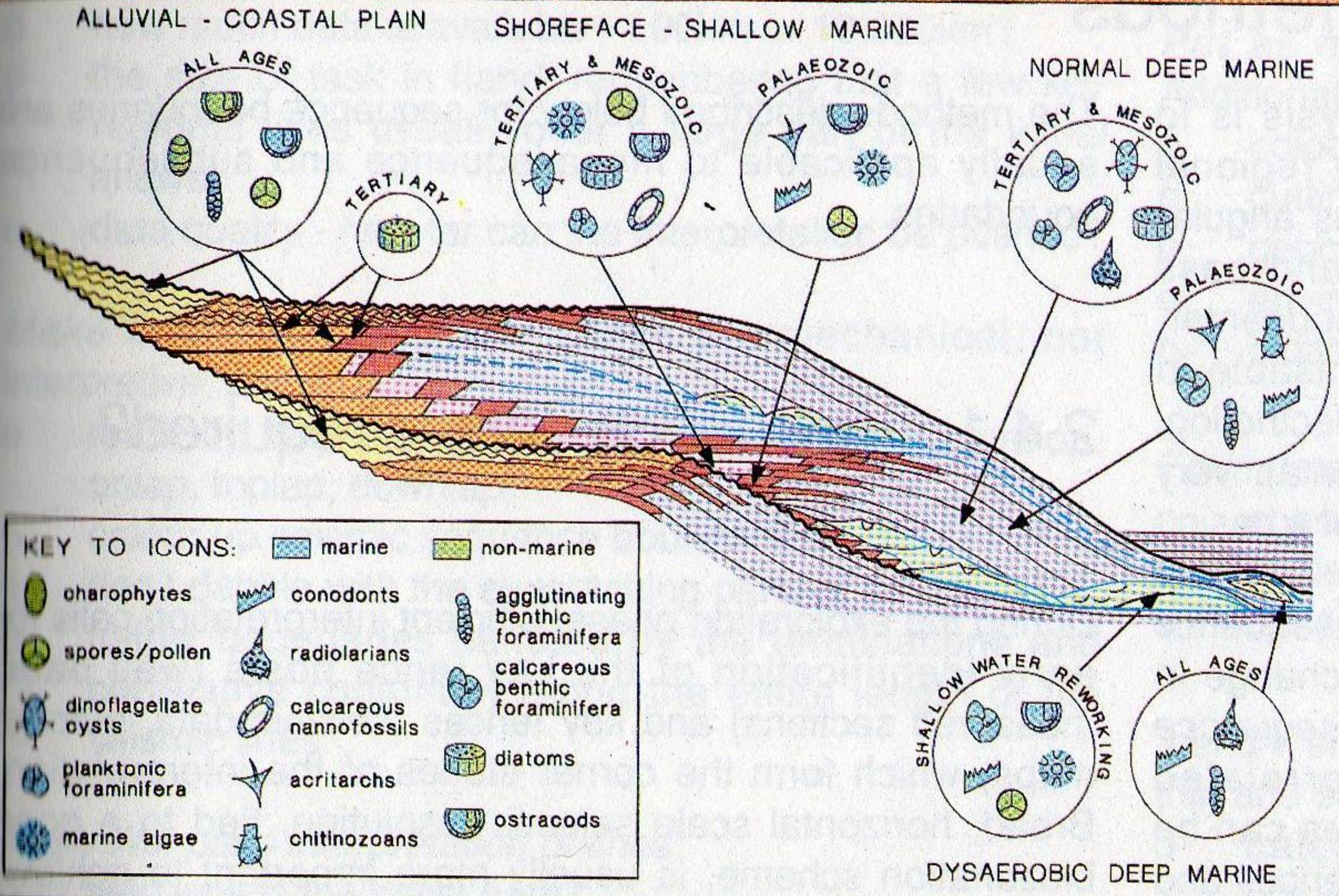
- To reduce the high costs of drilling it is important to know exactly where the well has reached in the oil and gas bearing rock formations.
- Microfossils can provide this information because they are good zone fossils and very small and are not destroyed by the action of the bit in the drilling process.

PALYNOFACIES*: GENERALISED SPATIAL AND TEMPORAL DISTRIBUTION OF THE MAIN PALYNOCLASTS



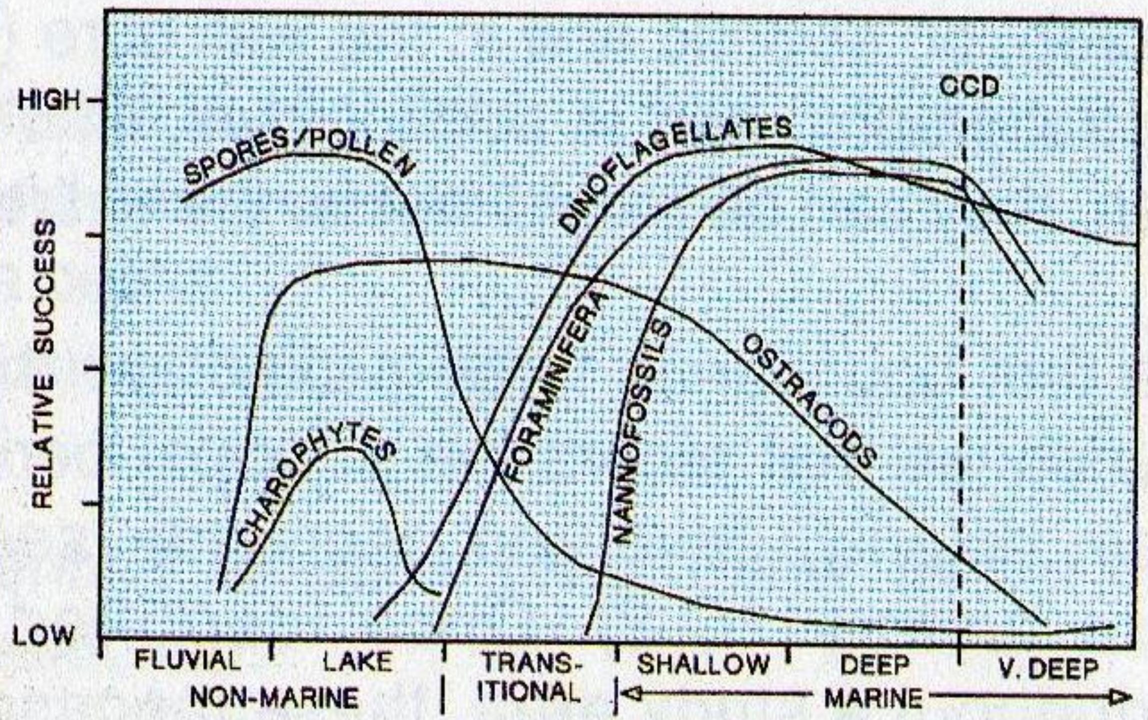
*Palynofacies: A distinctive assemblage of palynoclasts (palynomorphs and palynodebris) the composition of which reflects a particular sedimentary process or environment.

GENERALISED SPATIAL AND TEMPORAL DISTRIBUTION OF THE MAIN MICROFOSSIL GROUPS



Environment and the Microfossil Groups

These graphs represent the success likely in dating and correlating using different microfossil groups in various environments. Note that some groups tend to be restricted to a single environment.



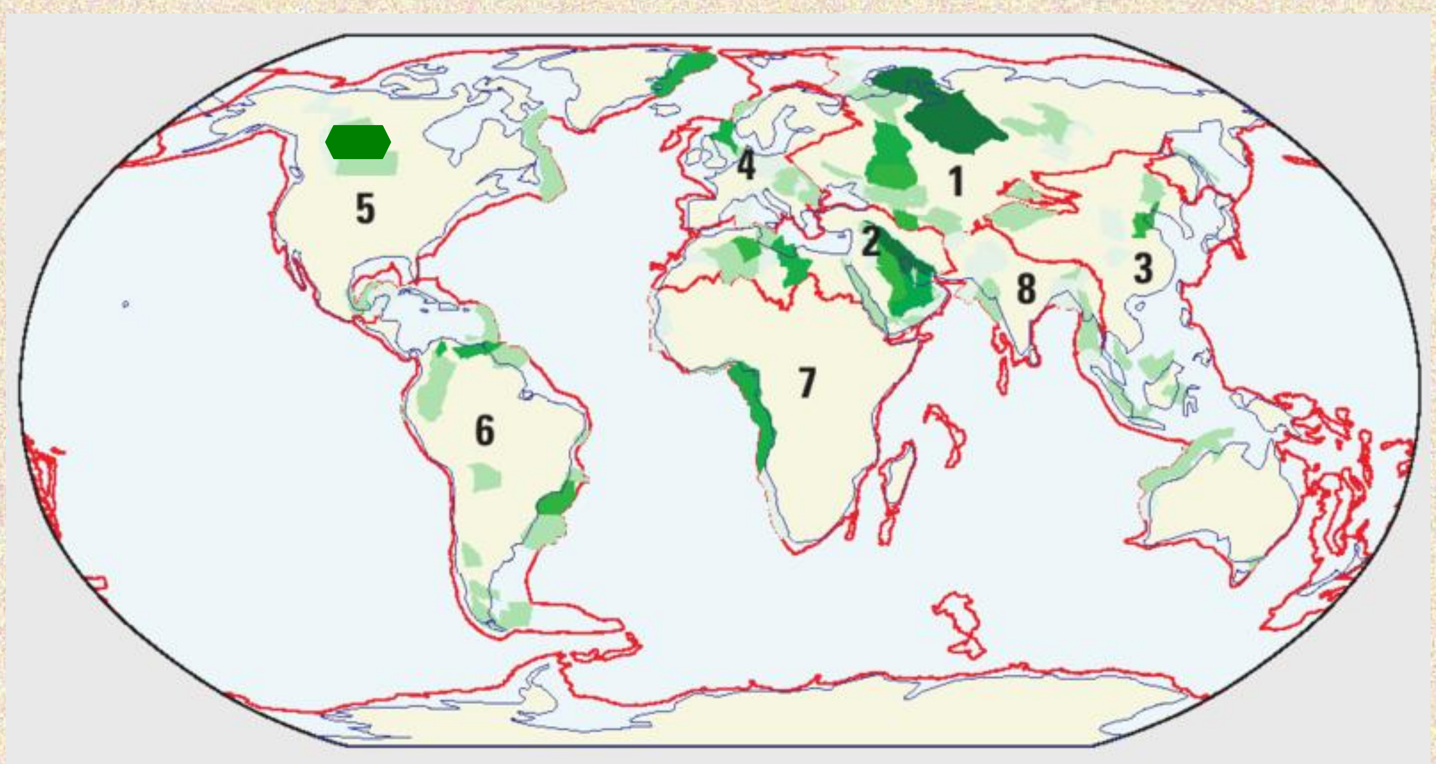
Geosteering

- Modern drilling techniques allow the bit to be guided in all directions.
- Drilling is made possible by the use of specialised drilling mud.
- Rock fragments are brought to the surface well head and analysed for oil and gas content , rock formation properties and microfossil content.

Oil Field Development

- The size and volume of the oil field is determined and a PRT fence drawn
- The oil field is then developed.
- A detailed biostratigraphic zonation is use to correlate each development well.
- Biostratigrapher can work at well site or in office in development phase.

The Situation Today



Global oil and gas occurrences are now well understood (fields shown in green). Only Antarctica and the Arctic remain unexplored.

Oil and Gas