Visual Kerogen Analogues and Palynofacies Applications to Hydrocarbon Exploration in New Zealand*

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Abstract

Visual kerogen and palynofacies analyses are useful tools for determining the origin, composition and petroleum generative potential of organic-rich sedimentary rocks and the depositional conditions for a wide range of sedimentary rocks.

Here, we present recent studies that utilize visual kerogen and palynofacies analyses. Firstly, we provide an example of analogues in a northern high-latitude setting. This study aims to test an existing fossil kerogen-based palynofacies model, through applying the model to quantitative palynofacies and environmental data from sediments deposited over the last 1500 years. Secondly, we use the palynofacies model to interpret the depositional environment for the Tartan Formation, a potential Paleocene source rock in the Great South Basin, New Zealand. Thirdly, we introduce preliminary findings from a recent project that aims to develop a standard palynofacies methodology, including laboratory processing and a standardised approach to data collection.

Results from the analogue study show that the distribution of particulate organic matter in environments ranging from near-shore to deep-sea is correlated with distance from the shore. Phytoclasts and amorphous organic matter represent the major components of the total assemblage in coastal and shelfal settings; phytoclasts are rare to absent in the distal, deep-water sediments. In deep-water, palynomorphs consist of a selection of organic material, which could result from transport and/or sorting.

In the Great South Basin, visual kerogen analysis of the Tartan Formation (late Middle to early Late Paleocene) (10% average TOC) indicates that it was deposited in a marginally marine environment with a strong influx of terrestrial plant detritus. Analysis of the underlying and overlying units indicates that they were deposited under more distal conditions. The changes observed are best explained by a base-level fall and short-lived regression, including deposition of the Tartan Formation, followed by latest Paleocene–Eocene transgression.

However, recent comparisons of palynofacies results from several GNS Science palynologists has shown that occasionally different researchers can produce different results from the same sample, mainly due to an absence of a standardised approach, a reference set of morphologic types for categories of particulate organic matter (analogous to taxonomic type specimens), and criteria for laboratory extraction techniques. A detailed study is presently being carried out in order to resolve this matter. As a result, processing costs for new palynofacies samples may be significantly reduced if we are able to isolate the aspects of the assemblage unaffected by variation in laboratory extraction technique. Moreover, this will allow data to be extracted from the large existing resource of >25,000 palynological preparations that already exist in the GNS Science collections.

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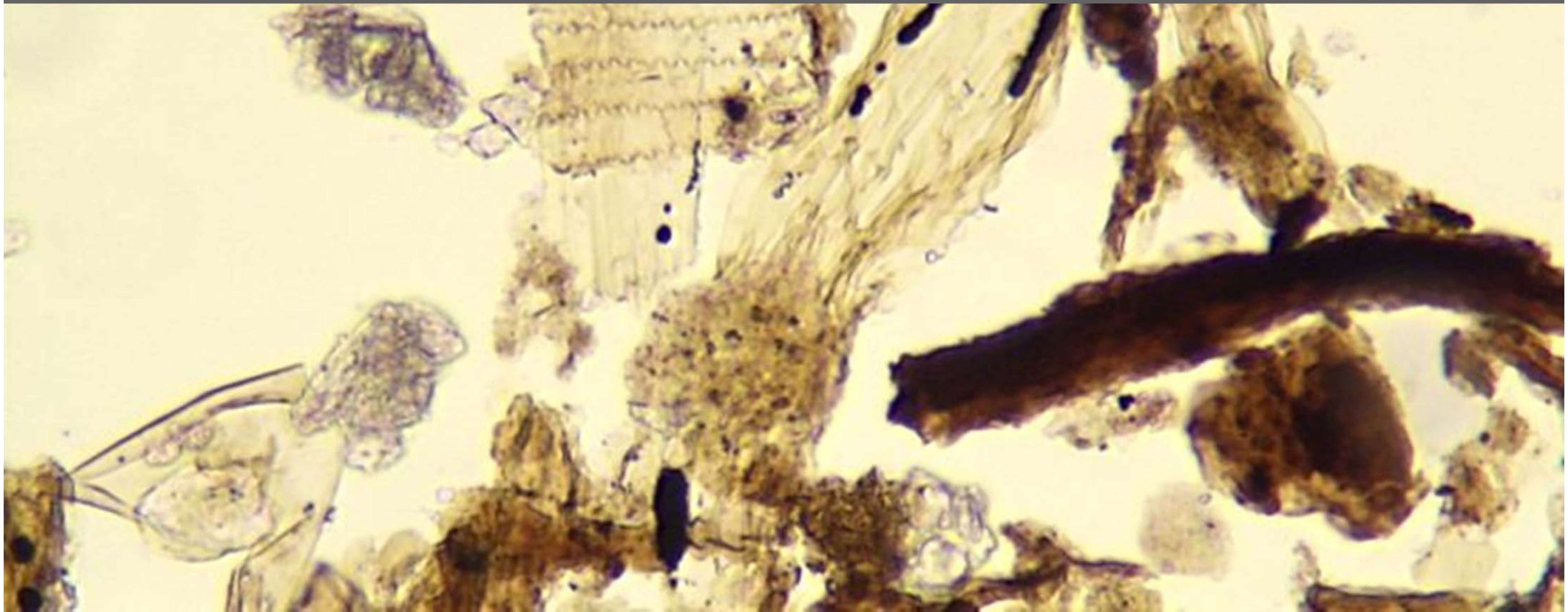
Visual kerogen analogues and palynofacies applications to hydrocarbon exploration in New Zealand



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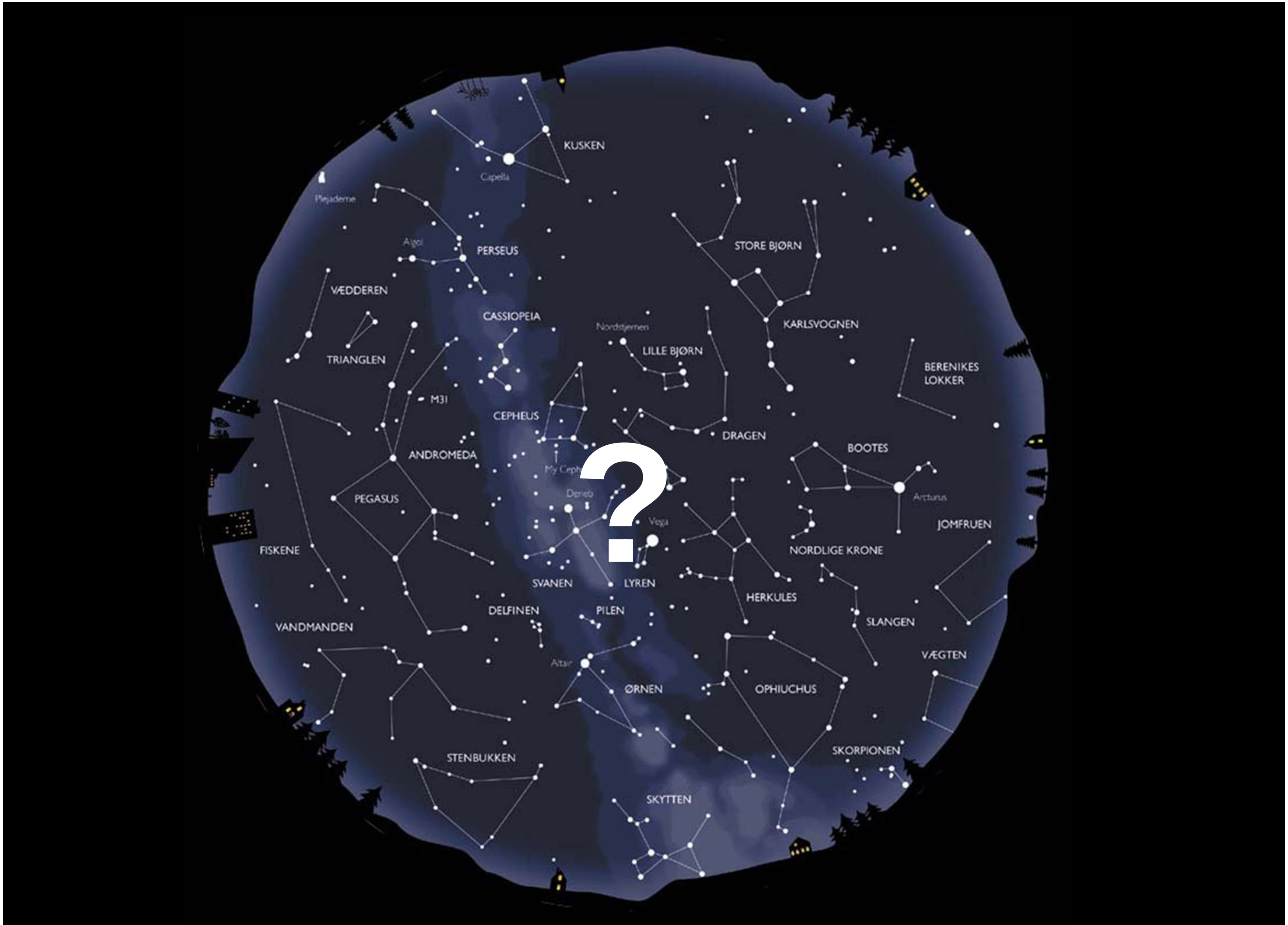
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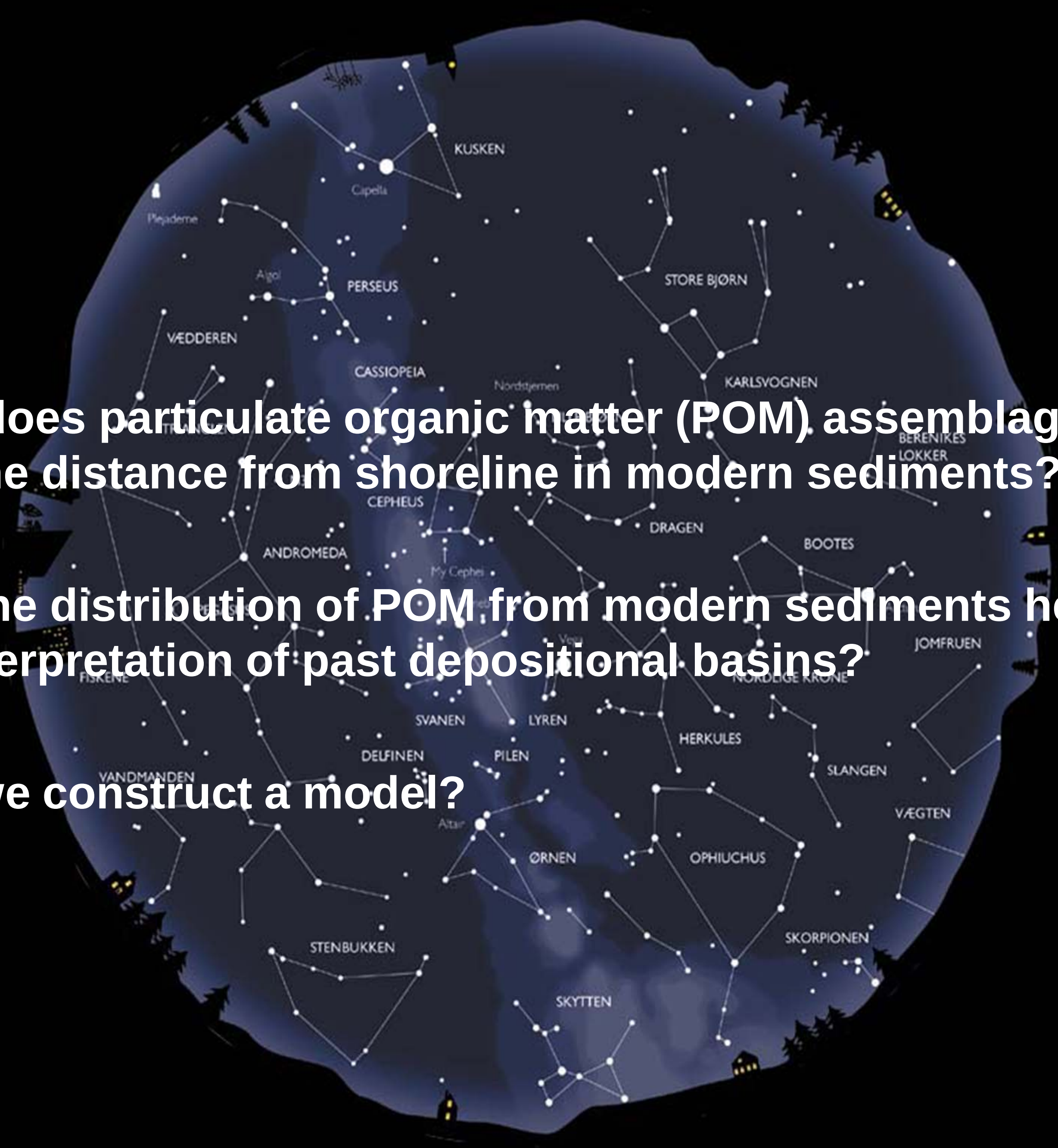


- **How does particulate organic matter (POM) assemblage change with the distance from shoreline in modern sediments?**
- **Can the distribution of POM from modern sediments help us in the interpretation of past depositional basins?**
- **Can we construct a model?**

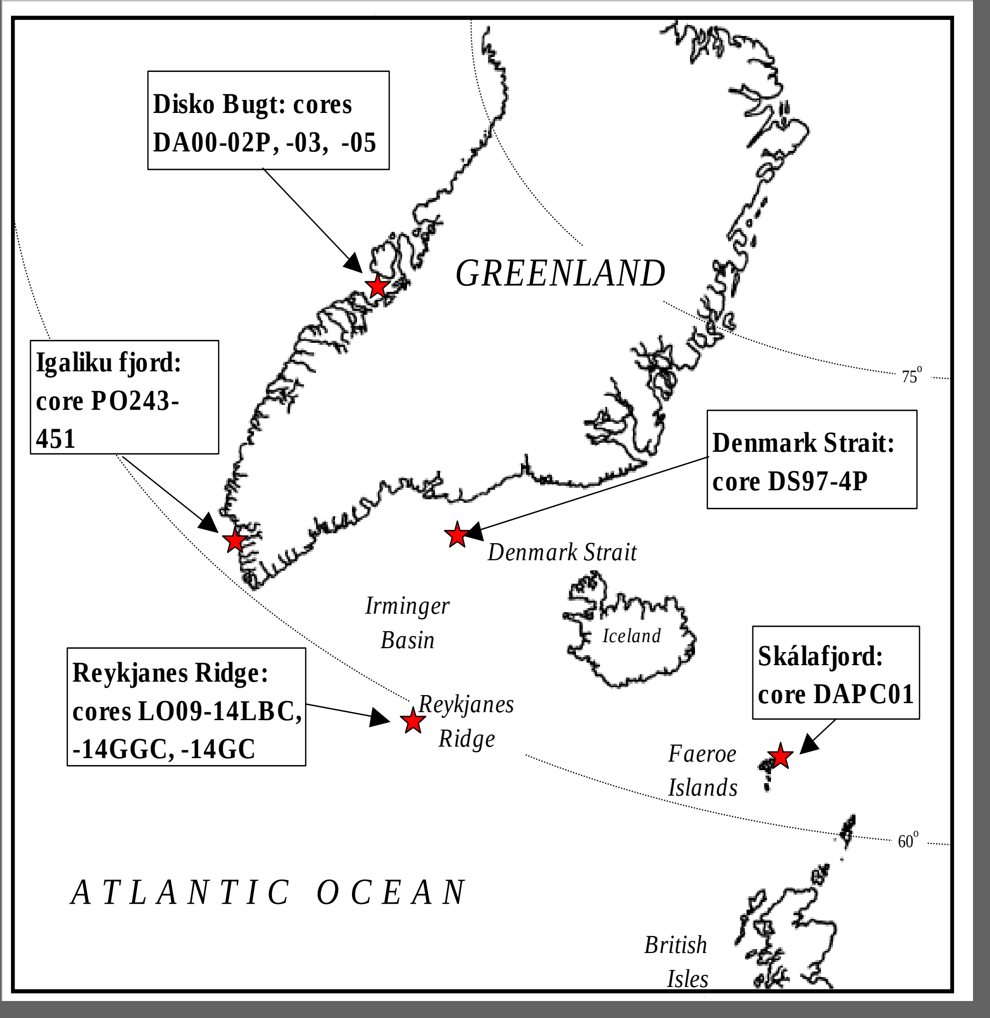
Outline

1. Analogue study, modern sediments, high latitudes

2. Application to Late Paleocene-Eocene sediments, Great South Basin, New Zealand

3. Implications for the hydrocarbon exploration

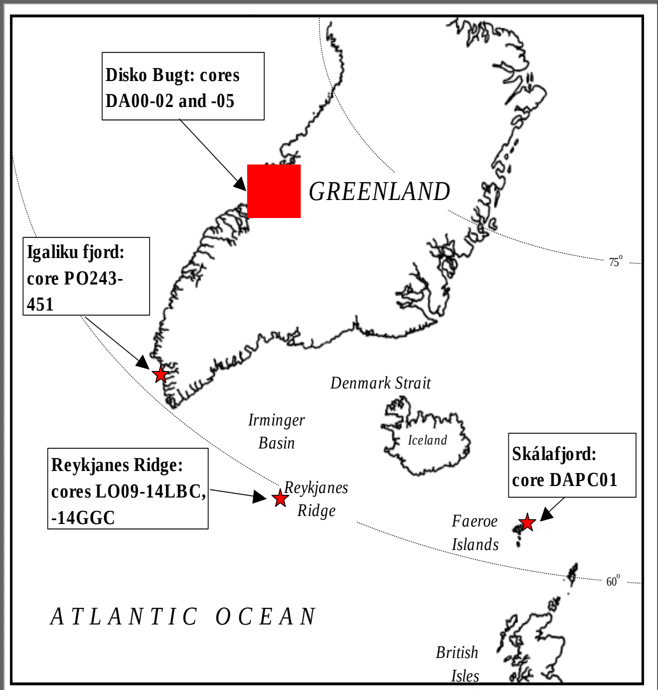
Aims

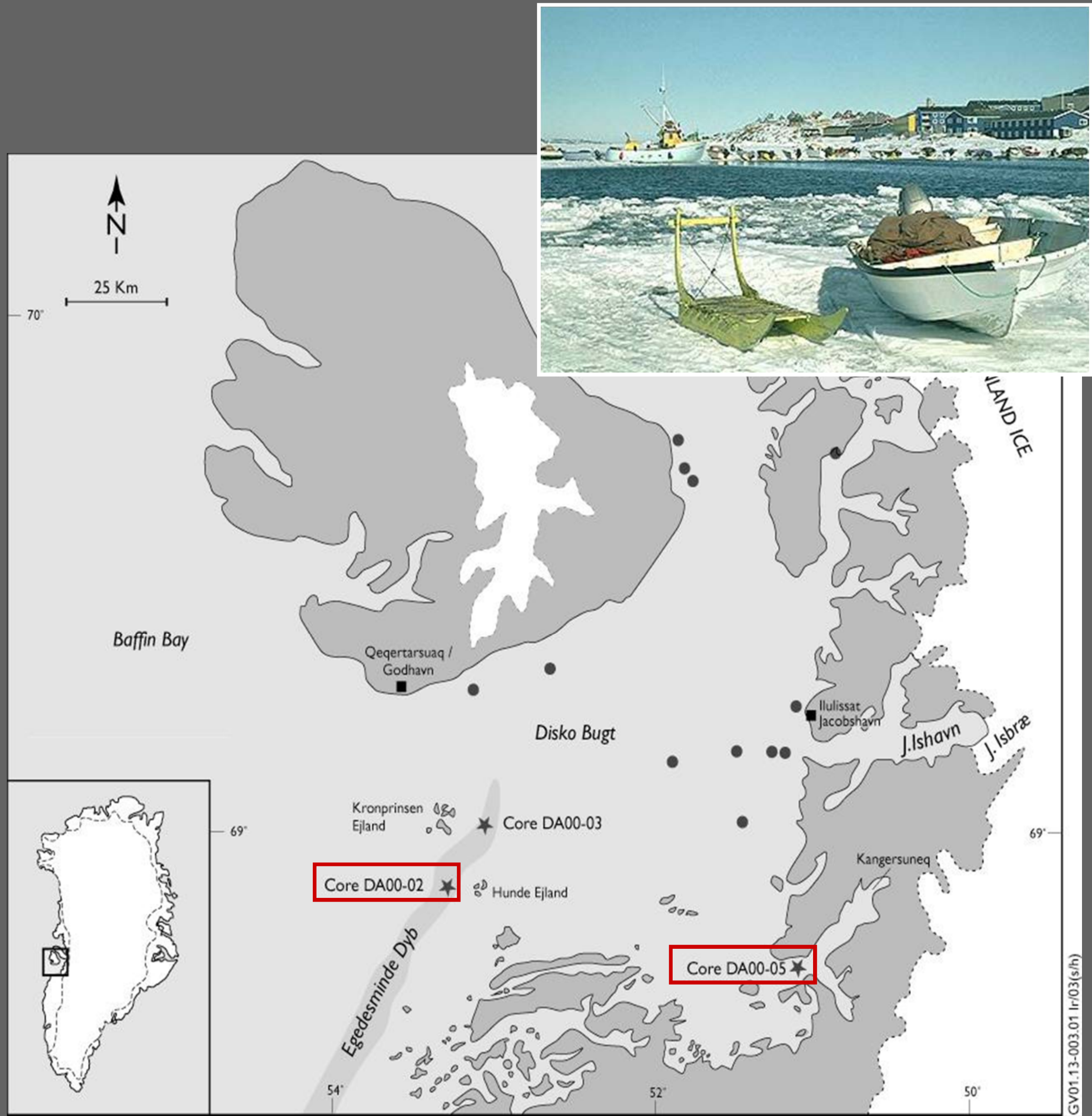


- **Document the composition of org. matter assemblages in top-core sediments from the North Atlantic Ocean during last 1500 cal. yr BP**
- **Provide information about variations in the org. matter distribution with increasing distance from shoreline and water depth**
- **Construct a sedimentological model - based on quantitative palynofacies analysis - for assessing marine depositional facies in the geological past**

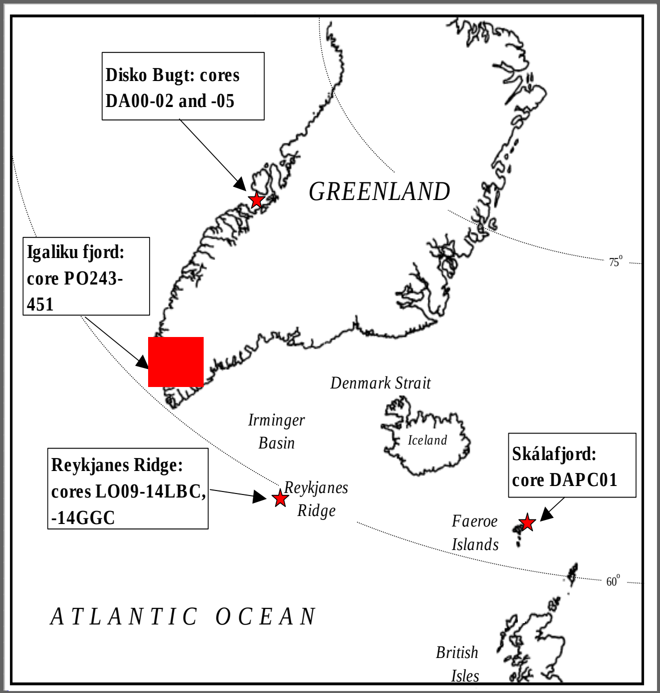
Location of the sites

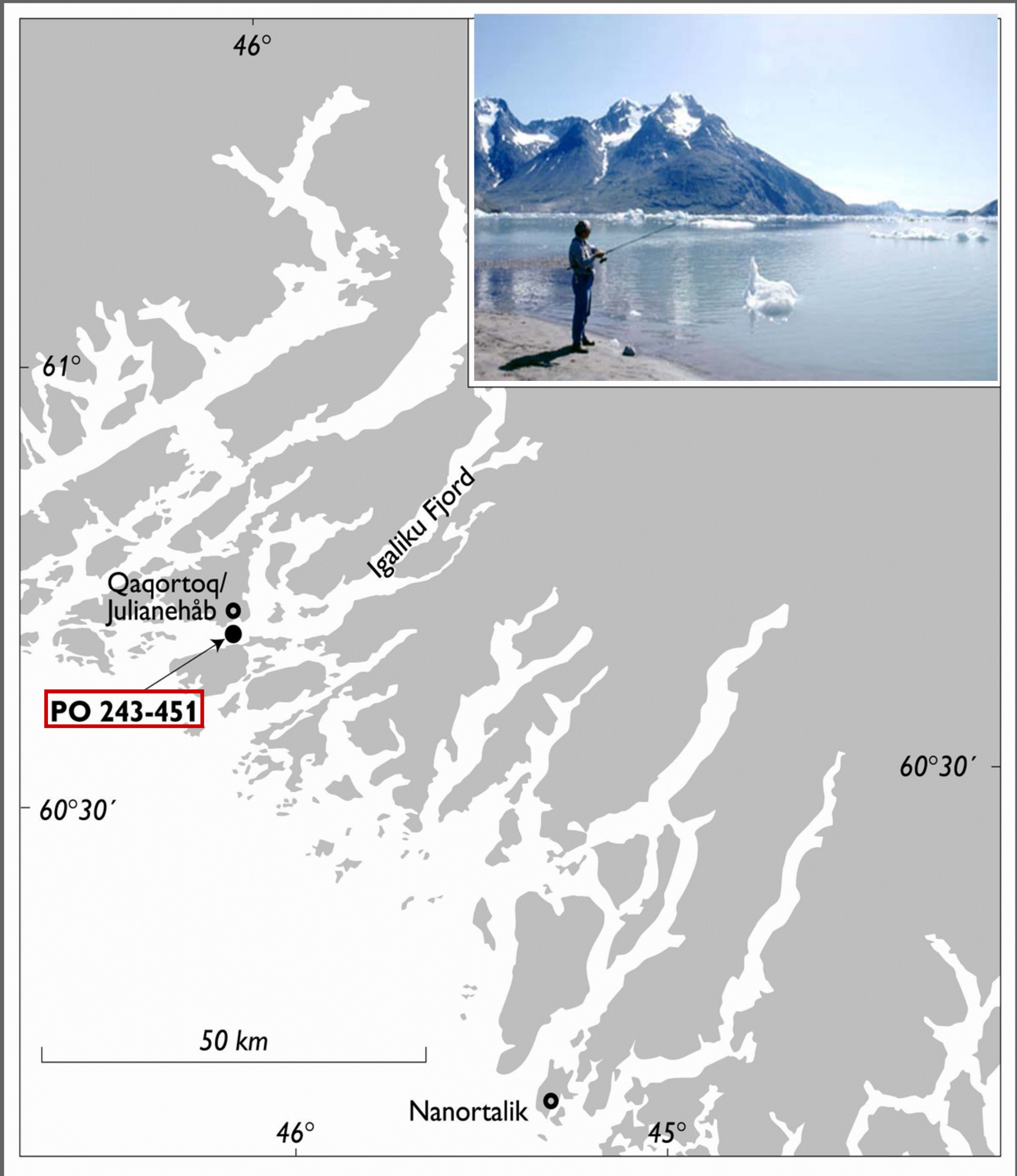
Location of sites: Disko Bay, central W Greenland



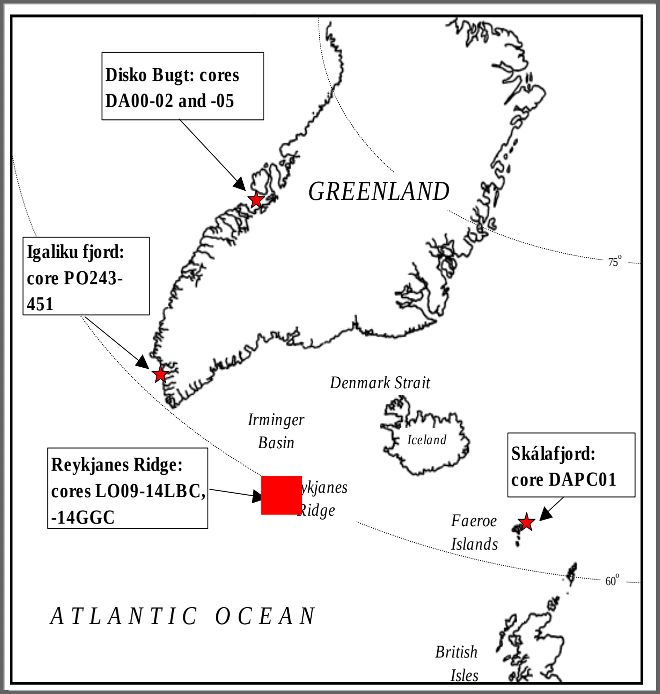


Location of sites: Igaliku Fjord, SW Greenland

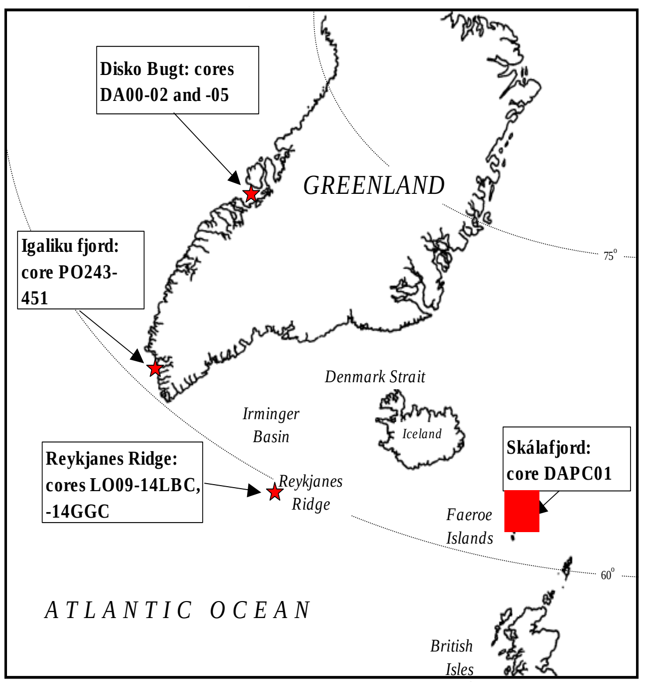


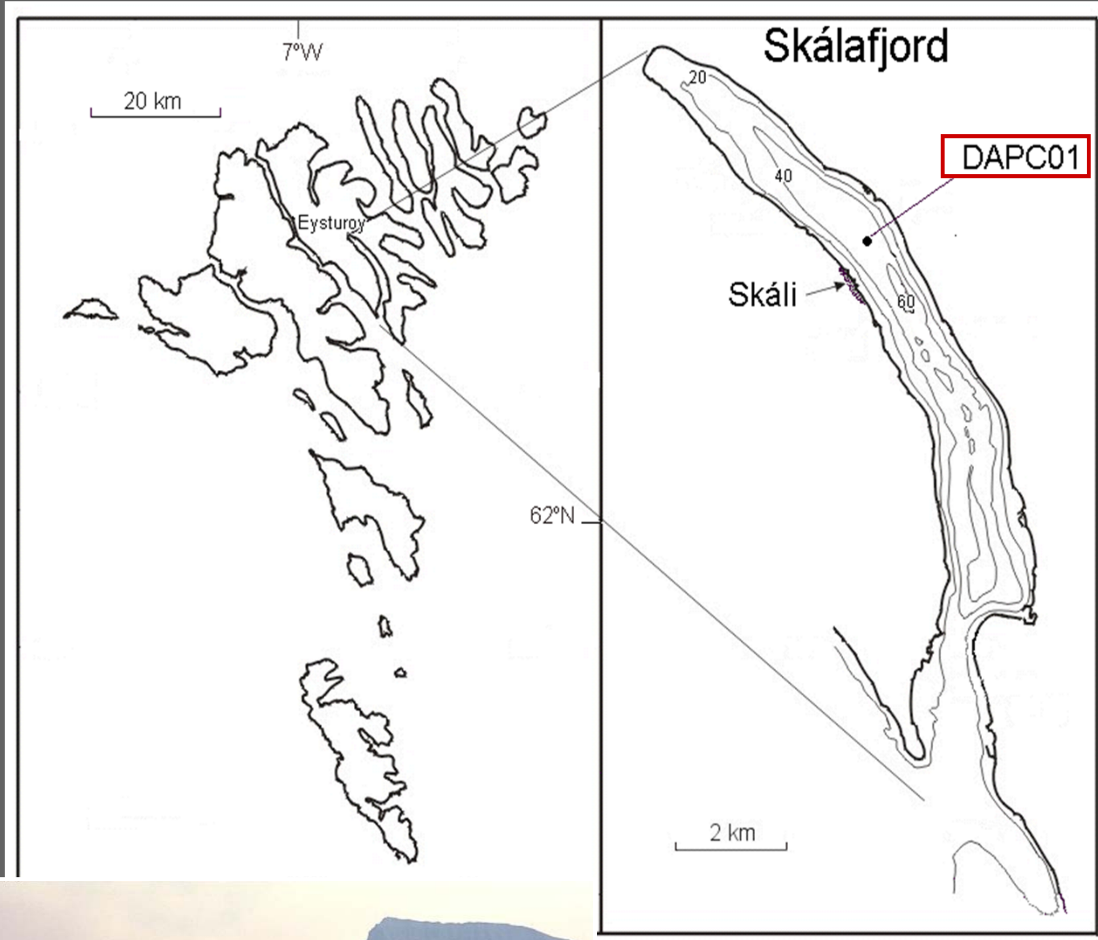


Location of sites: Reykjanes Ridge, North Atlantic Ocean



Location of sites: Skálafjord, Faroe Islands





Depositional settings

Core	Location	Water depth (m)	Distance from the shore (km)	Setting	Position	Year of collection	Research vessel name
PO243-451	60° 41.96´ N 46° 02.00´ W	304	1.5	fjord	Igaliku Fjord South Greenland	1998	Poseidon
DAPC01	62° 10.54´ N 6° 47.94´ W	50	0.5	fjord	Skálafjord, southern Eysturoy Faroe Islands	1997	Dana
DA00-05	68° 42.92´ N 51° 06.42´ W	335	1.6	fjord	Kangersuneq Fjord south east margin of Disko Bugt	2000	Dana
DA00-02	68° 51.88´ N 53° 19.72´ W	840	24	shelf valley	Egedesminde Dyb, Disko Bugt	2000	Dana
LO09-14LBC	58° 56.33´ N 30° 24.53´ W	1719	600	open ocean	southeastern Reykjanes Ridge flank, Mid Atlantic Ocean	1997	Prof. Logachev

Material

Material

The upper 50-54 cm of sediments from the five North Atlantic cores was investigated for palynology

- The sediments consisted of olive grey to brown muddy silt
- Occasionally the sediments were mottled and faintly laminated
- Black specks, shell frangments and macroalgae plant debris were observed in fjord and shelf sediments

Despite the different location of the sites, the sedimentology of the upper part of the cores was very alike

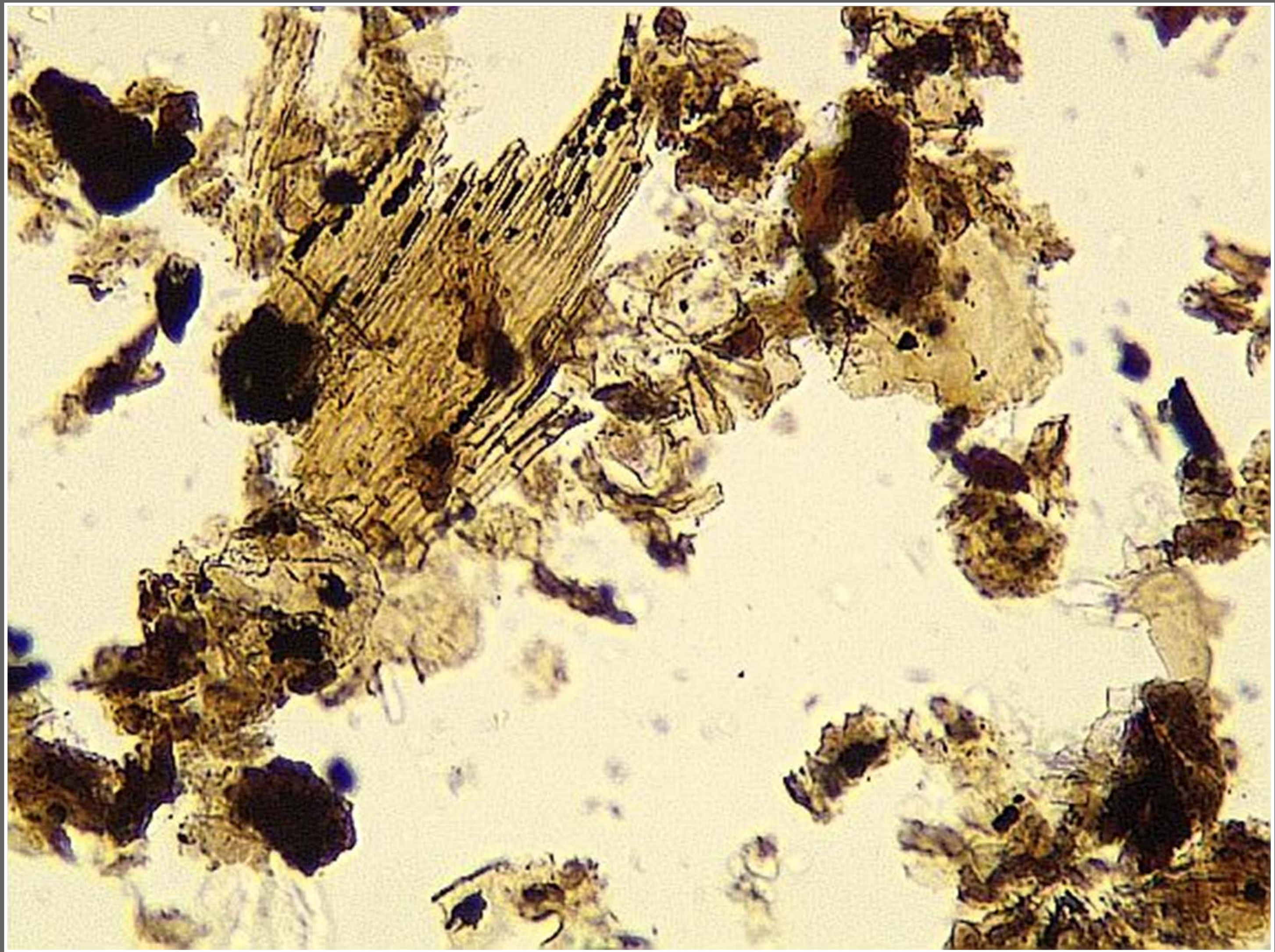
Results

Chronology

Core	Sample depth (cm)	Lab. no.	Sample type	^{14}C uncorrected age (rad. yr BP)	^{14}C res. corrected age (rad. yr BP)	Calibrated age AD (cal. yr)
PO243-451						
	1	450A-00*				1994
	2	450A-01*				1983
	3	450A-02*				1961
	4	450A-03*				1924
	5	450A-04*				1875
	6	450A-05*				1812
	20	AAR-5937	marine plant	1120 ± 40	720 ± 40	1285
	37	AAR-5938	shell	1425 ± 40	1025 ± 40	1015
	57	AAR-5939	shell	1830 ± 40	1430 ± 40	640
DAPC01						
	130	AAR-6566	shell	2105 ± 60	1705 ± 60	340
DA00-05						
	50	AAR-7509	marine plant	1705 ± 38	1305	685
DA00-02						
	256	AAR-7512	shell	1810 ± 47	1410 ± 47	645
LO09-14LBC						
	1	AAR-5555	shell	705 ± 40	305 ± 40	1630
	40	AAR-5556	shell	1530 ± 40	1130 ± 40	882
	53	AAR-5557	shell	1520 ± 40	1120 ± 40	830

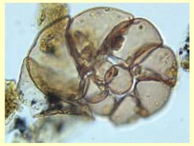
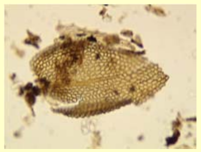
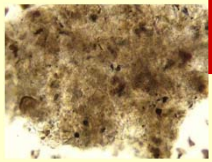
* ^{210}Pb and ^{137}Cs measurements

Total Particulate Organic Matter (TPOM)



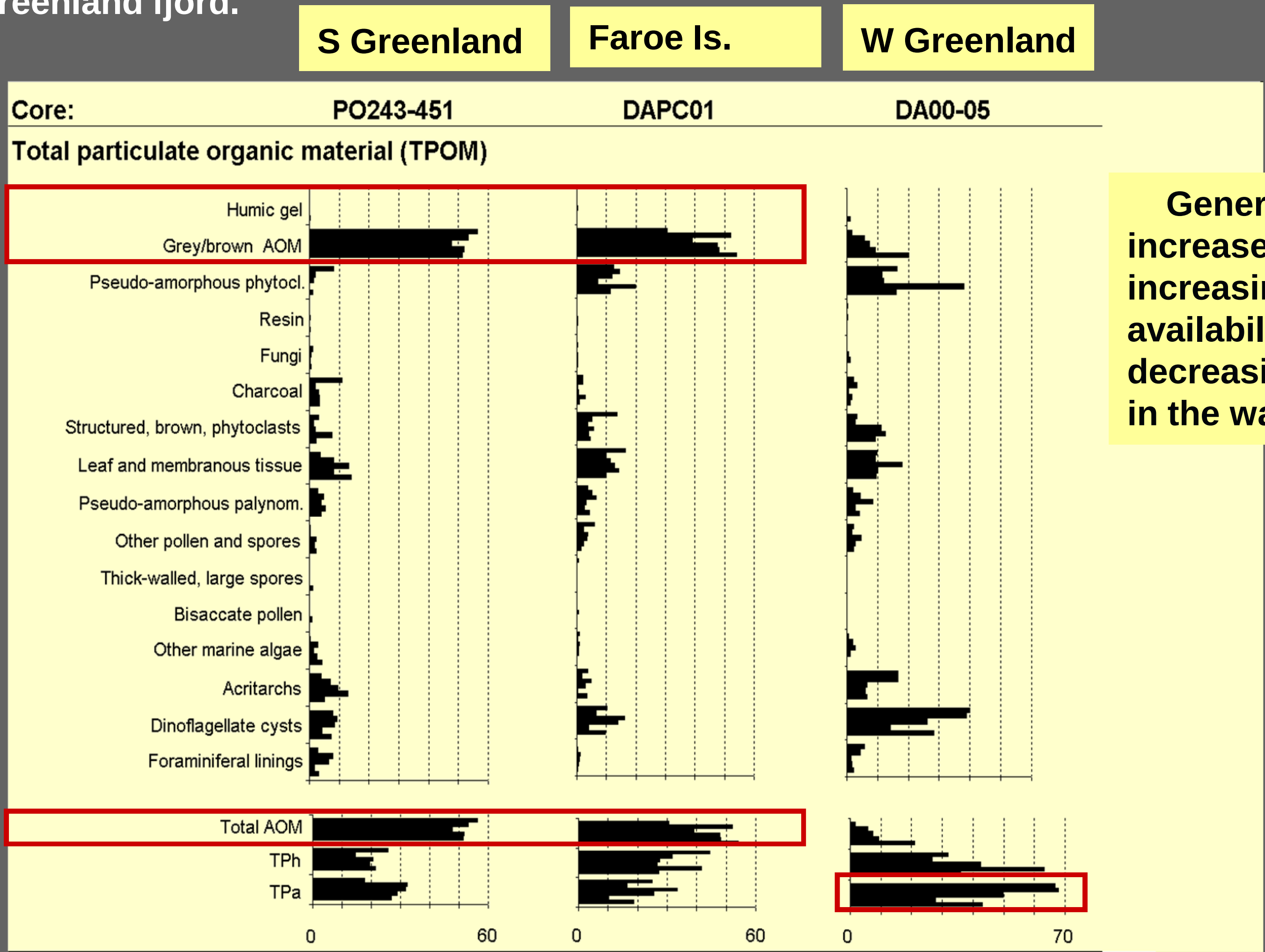
Total Particulate Organic Matter (TPOM)

modified after Tyson (1995)

Group		Source	Category	Constituent
Structured	Palynomorphs	Zoomorphs 	**foraminiferal linings**	benthonic and planktonic foraminifera
		Organic-walled phytoplankton	**dinoflagellate cysts** **acritarchs** **other marine algae**	sensu Williams et al. (1998) sensu Fensome et al. (1990) Prasinophyte phycomata, Chroo- and Chloro-coccales
		Sporomorphs	**bisaccate pollen** **thick-walled, large sporomorphs** **other pollen and spores**	pollen Megaspores Miospores: microspores and pollen
			pseudo-amorphous palynomorphs	<50% of surface intact
	Phytoclasts	Macrophyte plant debris	**leaf and membranous tissue** **structured, brown phytoclasts** **charcoal** **pseudo-amorphous phytoclasts**	cuticle and epidermal tissue cortex and secondary xylem (wood) biochemically oxidized wood <50% of surface intact
		Fungal debris	**fungi**	hyphae
Unstructured		Higher plant secretions	**resin**	
	Amorphous organic matter	Flocs, phytoplankton, bacteria	**grey/brown AOM**	aggregates, faecal ribbons and pellets
		Higher plant decompositional products	**humic gel**	cell-filling and extracellular precipitates

Fjords: abundant, well-preserved POM characterised the sediments

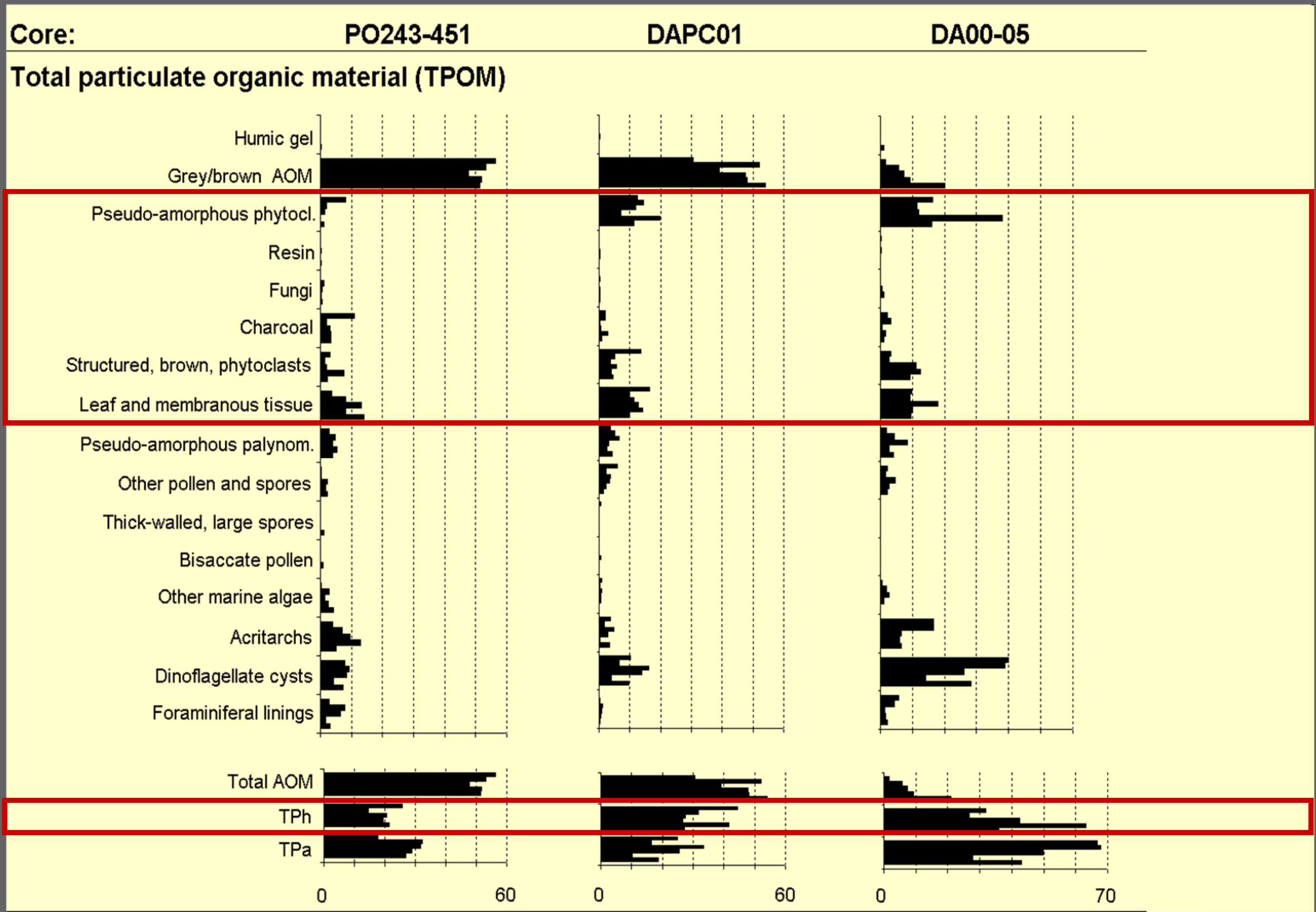
- AOM dominates the assemblage in S Greenland and Faroe Islands;
- Palynomorphs dominate in W Greenland;
- The assemblage reflects higher oxygen and lower nutrients availability which occurs in the waters of the W Greenland fjord.



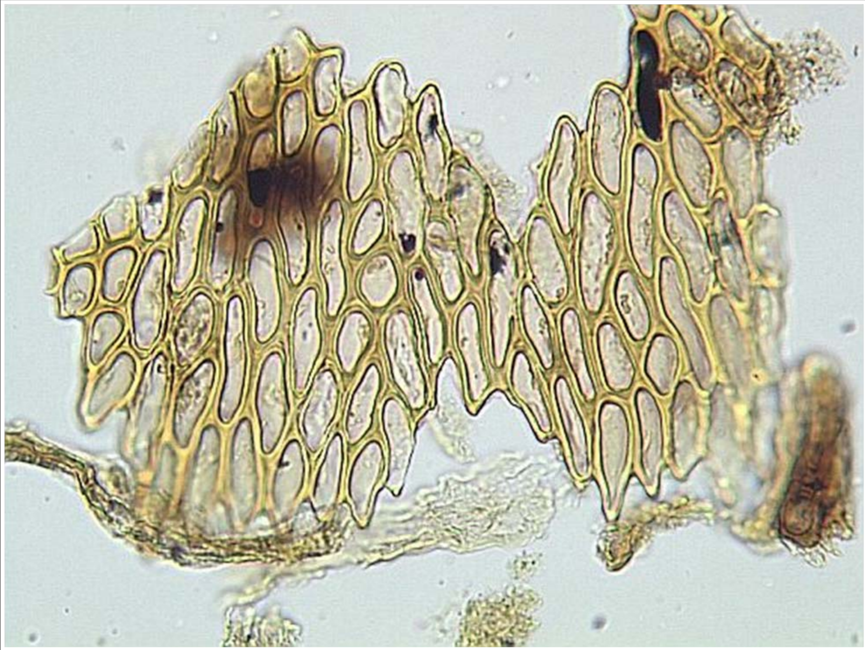
Generally, AOM increases with increasing nutrients availability and decreasing oxygen in the waters

Fjords

- Phytoclasts are very abundant and dominated by leaf and membranous tissue (up to 65 % of TPh);
- The former consist of large (25-400 microns) clasts and represent >4% of the total assemblage;



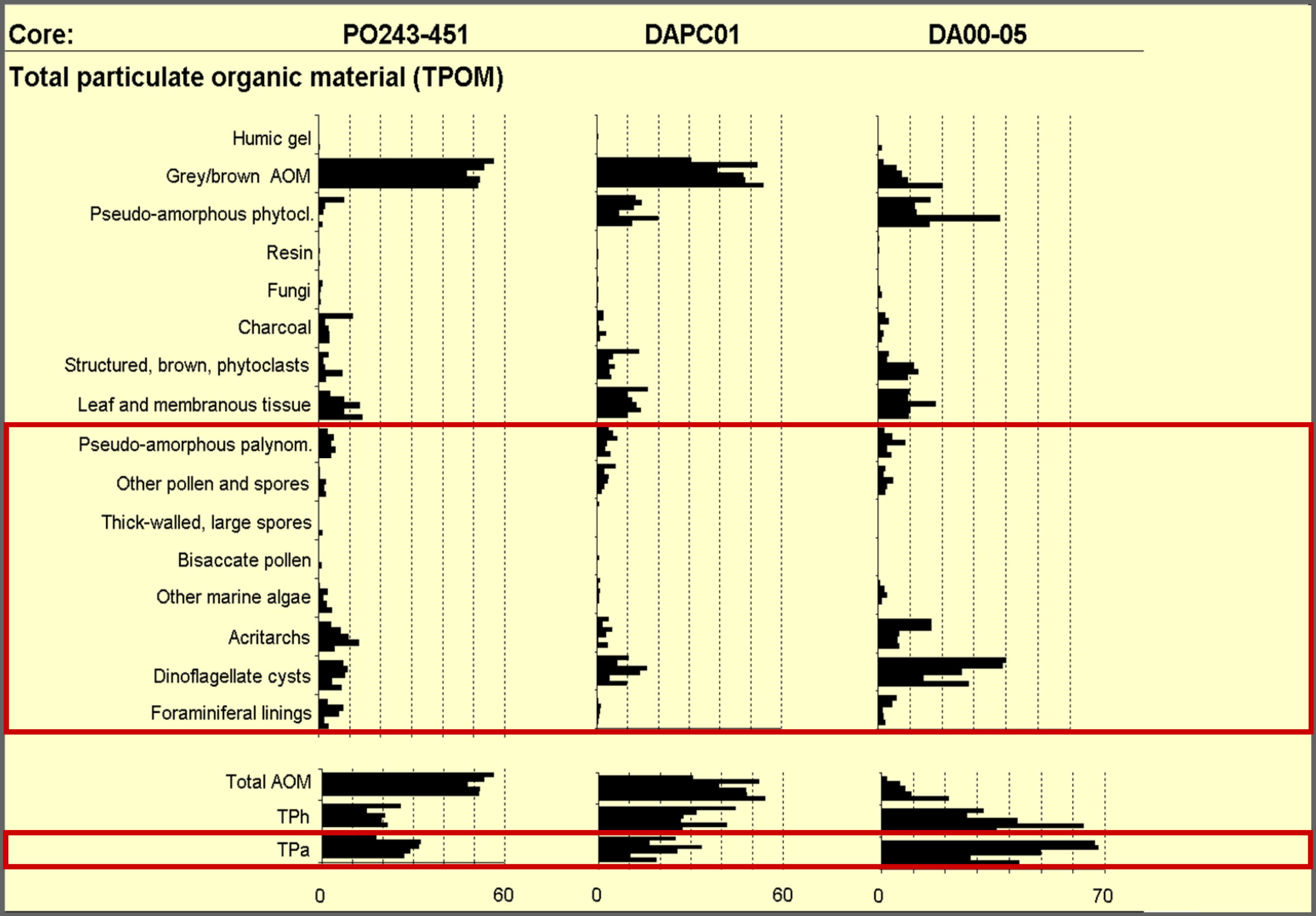
Leaf and membranous tissue in the fjords



Palynomorphs

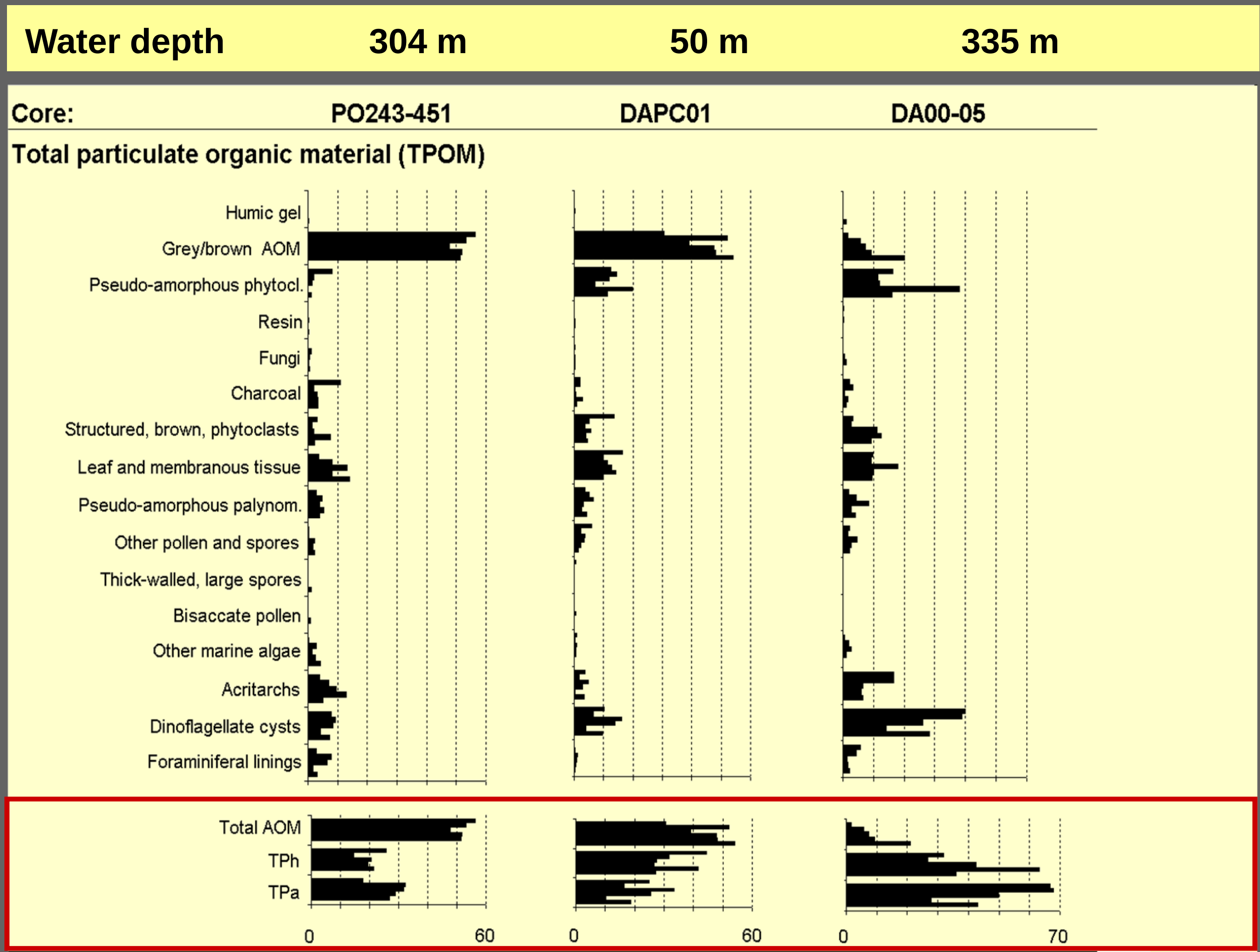
Fjords

- The palynomorph assemblage is dominated by dinoflagellates and acritarchs (up to 40% of the total POM);
- Inner lining of benthic and planktic forams are common in fjords in Greenland; they are absent in the Faroe Islands fjord reflecting the low oxygen availability which occurs in the bottom waters;



Fjords

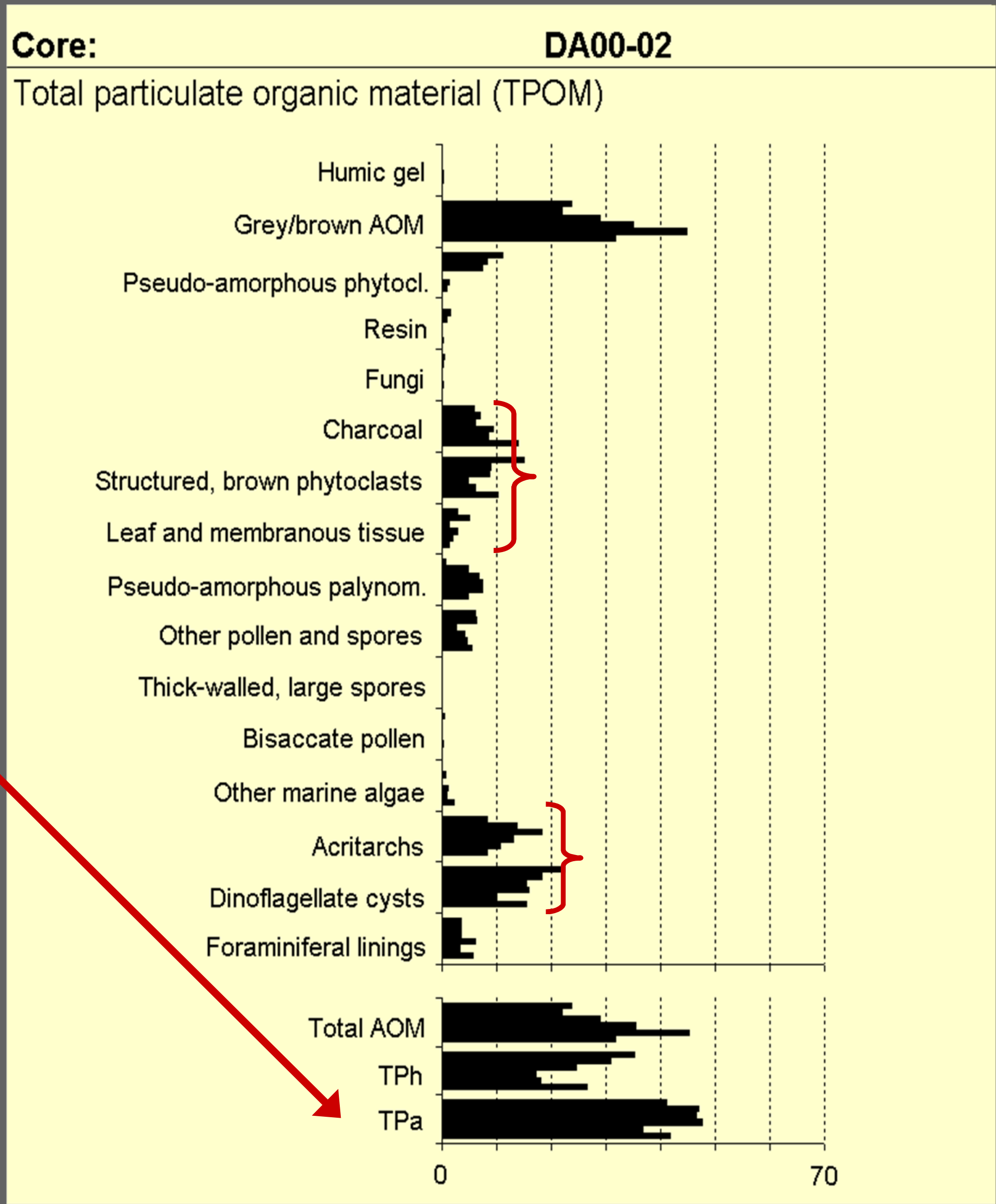
- The oxygen is an important parameter influencing the POM distribution;
- Changes in water depth within the fjords do not affect the POM distribution.




Shelf valley

Shelf valley

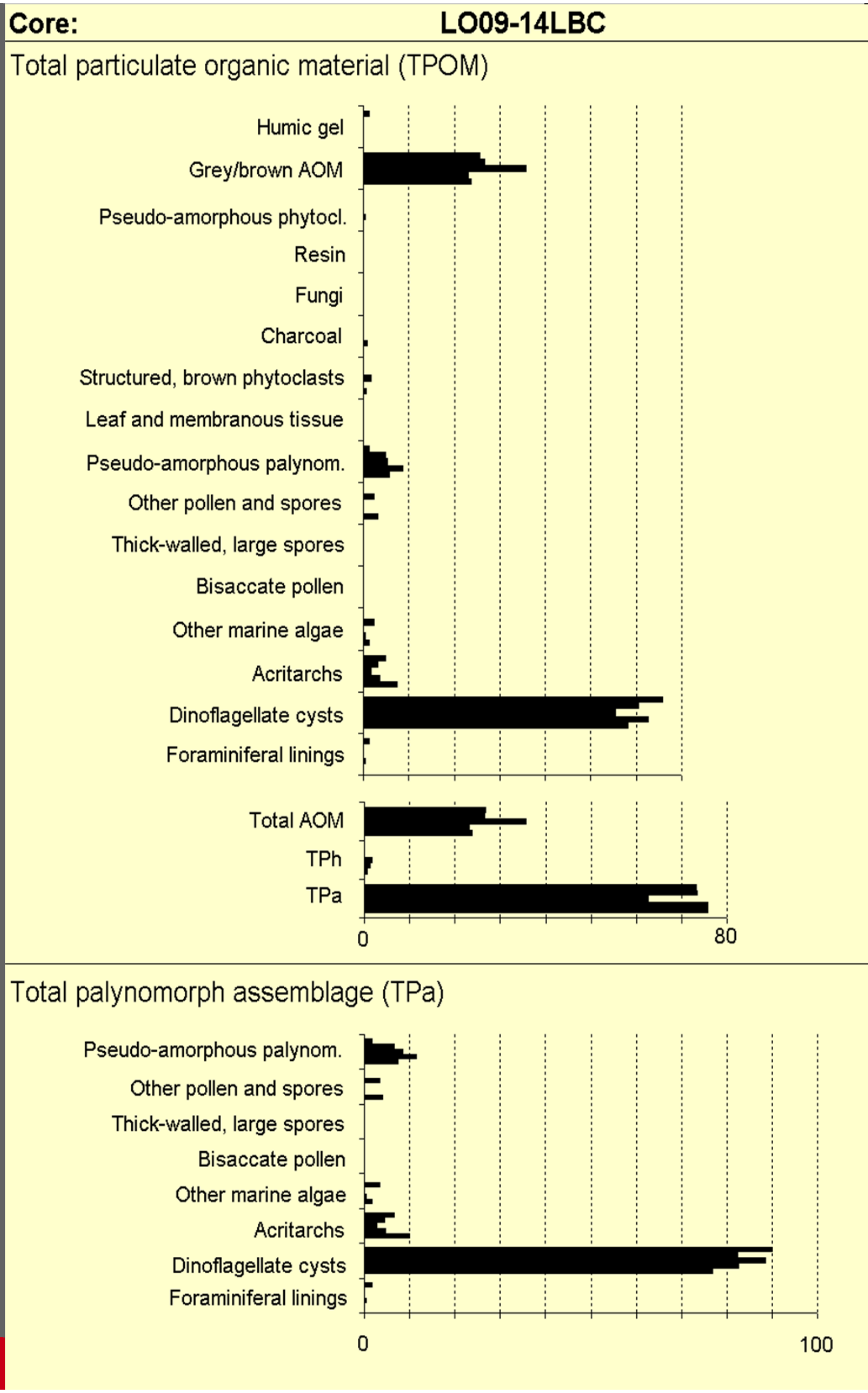
- Abundant, highly diversified and relatively well-preserved POM
- Palynomorphs dominate the total assemblage (36-47%); AOM and phytoclasts are common



- Wood dominate the phytoclast assemblage
- Leaf and mem. tissue (small clasts) represent a minor component of the assemblage


Open ocean

Open ocean



- Large (2-5 mm in diameter) flocs of org. mat. were observed in the sediments

↑

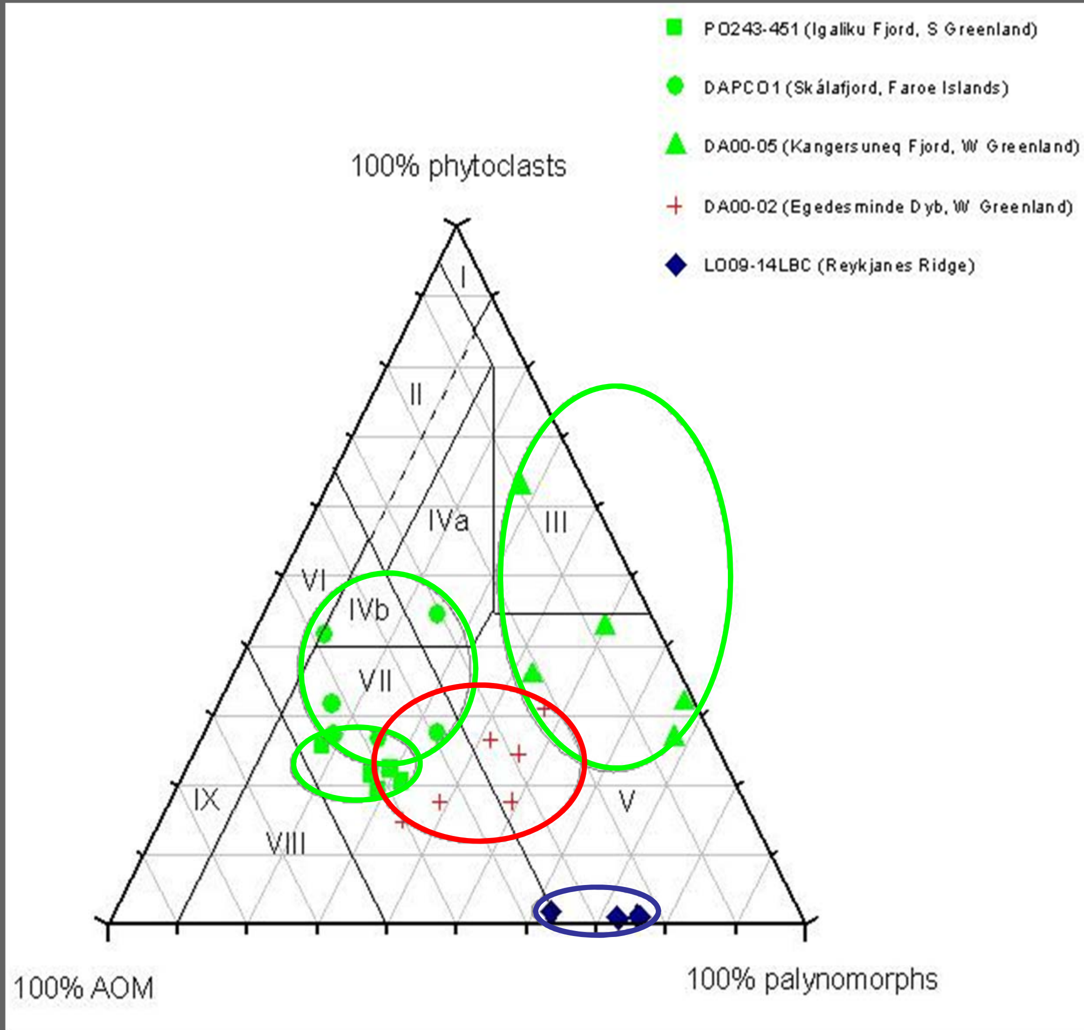
mechanical agglomeration or fecal pellets ?

- POM sparse and poorly diversified
- The assemblage is dominated by palynomorphs (in particular dinoflagellates)
- AOM ranged 25-35%
- Phytoclasts very rare to absent

The model of Tyson (1993)

This ternary diagram plots the relative numerical particle frequency of phytoclasts, AOM and palynomorphs given as % of a total POM assemblage

- the plot aims to pick the difference in relative proximity to the shore and the redox status of the depositional settings
- eleven fields are identified



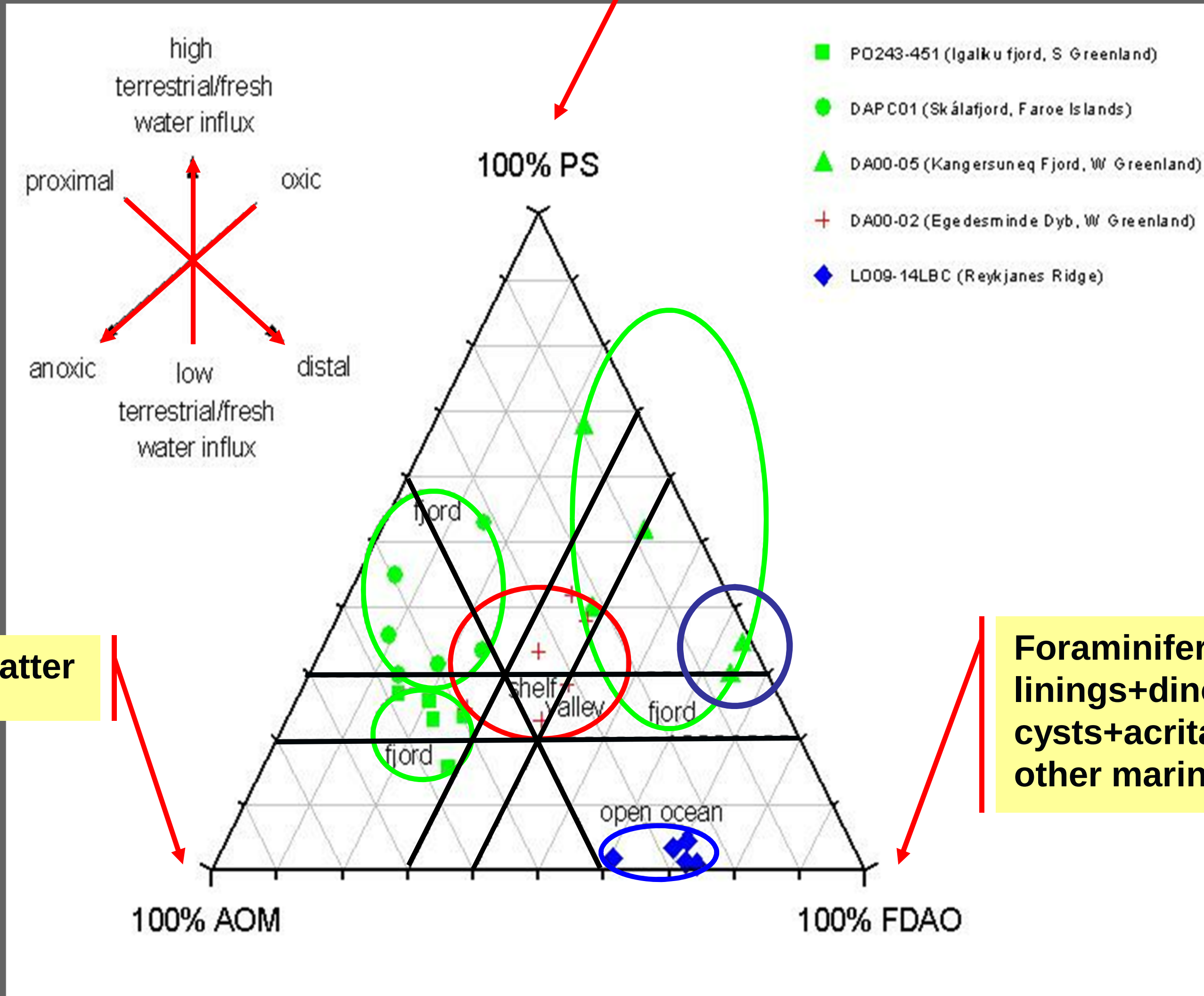
- most residues from the study sites enter fields V and VII which correlate with facies deposited distally on the shelf
- only three samples from the fjords entered fields III & IV which correlate with facies deposited proximally on the shelf

The model is satisfactory for sediments from the shelf and open ocean but inadequate for sediments from the fjords

One alternative…

Modified model

Phytoclasts and sporomorphs



Amorphous org. matter

Foraminiferal linings+dinoflagellate cysts+acritarchs+ other marine algae

Summary

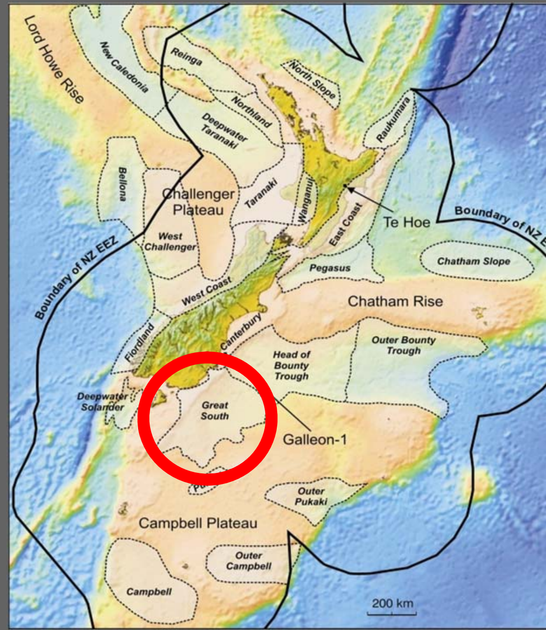
The composition of the phytoclast assemblage on the shelf provides indication of distance from the shore:

- in the fjords, leaf and membranous tissue dominate and are characterised by well-preserved, large clasts;
- at the shelf site, black and brown phytoclasts dominate whereas leaf and membranous tissue (small clasts only) represent a minor component;
- in open ocean, the phytoclasts are absent.

In fjord settings, oxygen plays an important role whereas changes in water depth do not affect the POM assemblages.

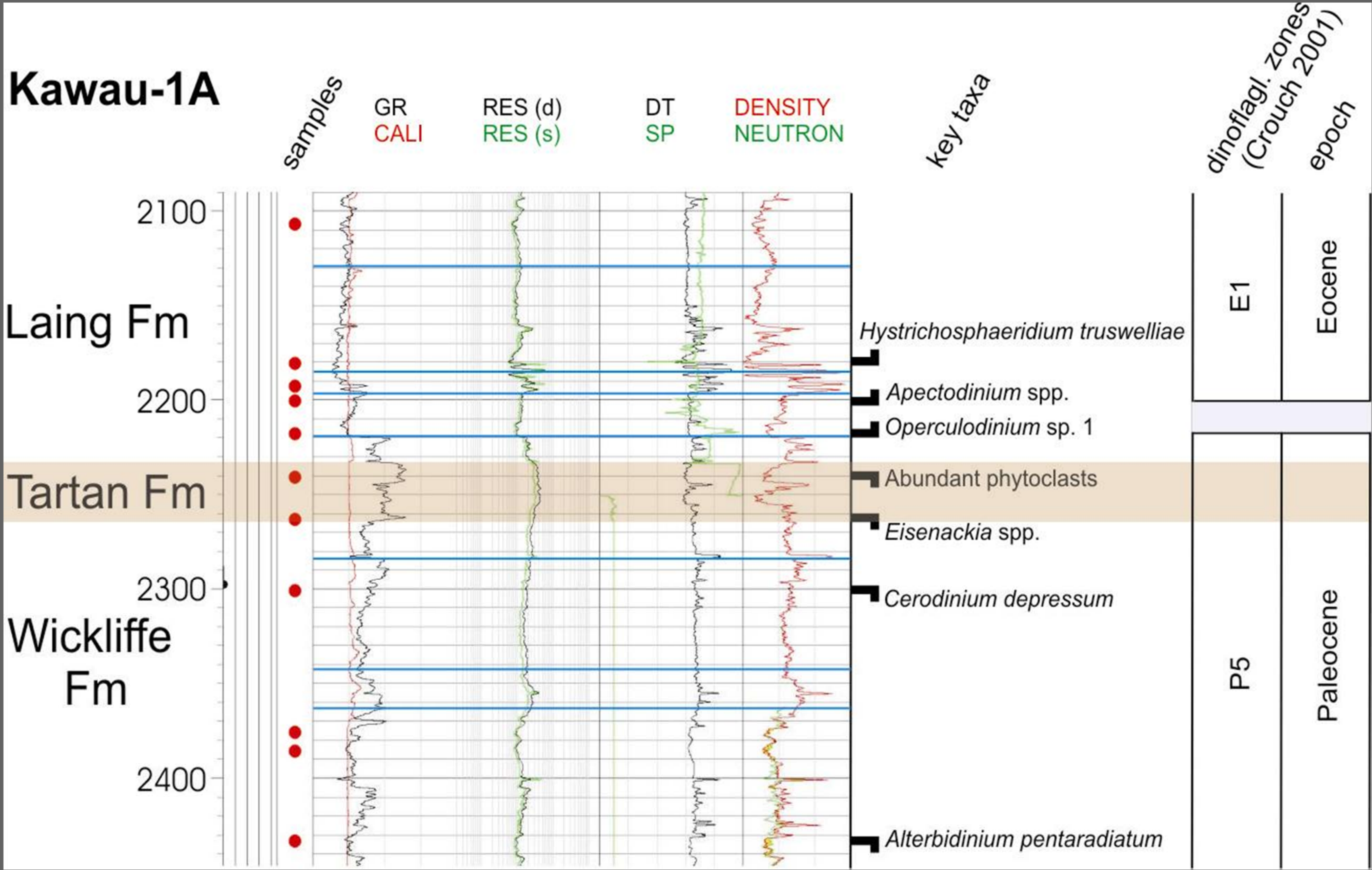
Based on integration of quantitative palynofacies data, the validity of the sedimentological model of Tyson (1993) is confirmed and slightly modified as ternary plot constructed for the interpretation of depositional facies in the geological past.

The Great South Basin (GSB)



The Tartan Formation as a marine source rock

Biostratigraphy around the Tartan Formation



Suggested depositional model:

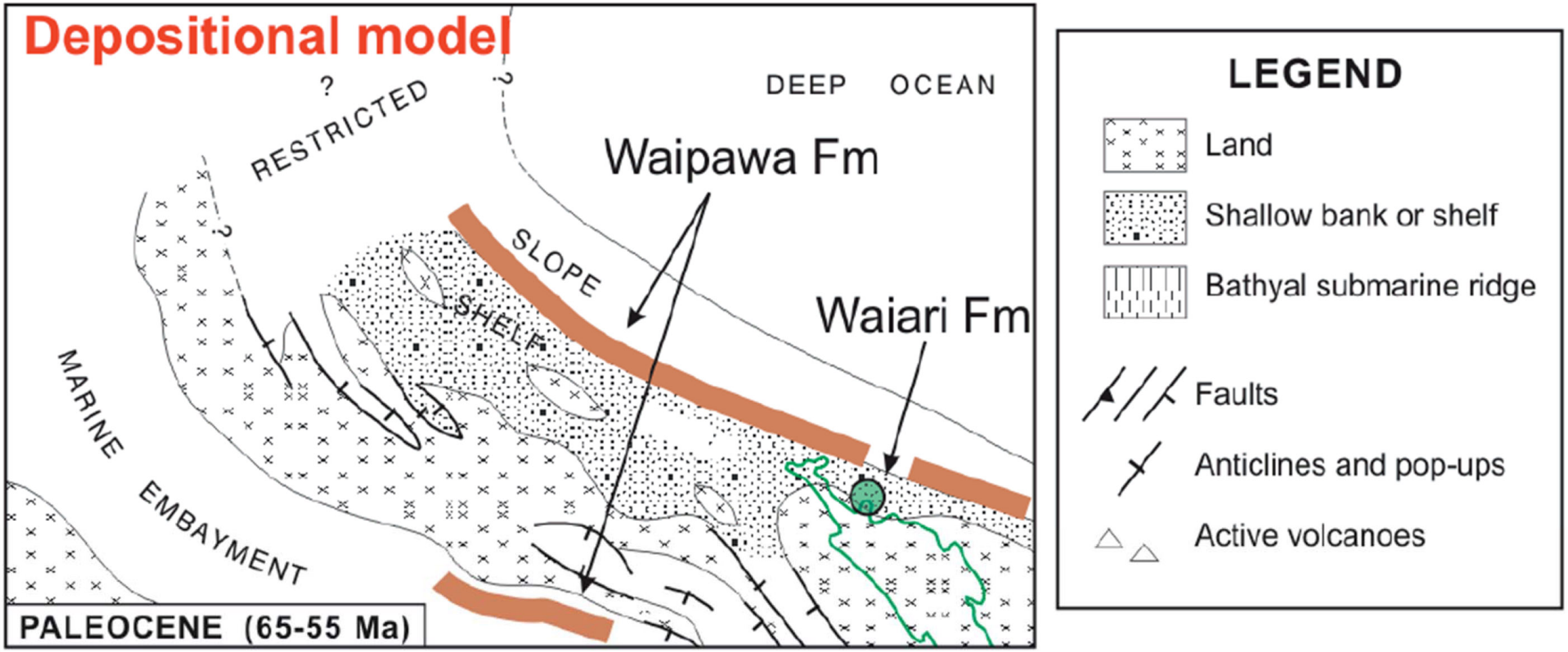


Figure 5. Paleogeography of the North Slope Basin during Paleocene deposition of Waipawa facies and in the early Miocene following the emplacement of the Northland Allochthon (after Herzer et al., 1997).

from Hollis et al., 2006

Upwelling?

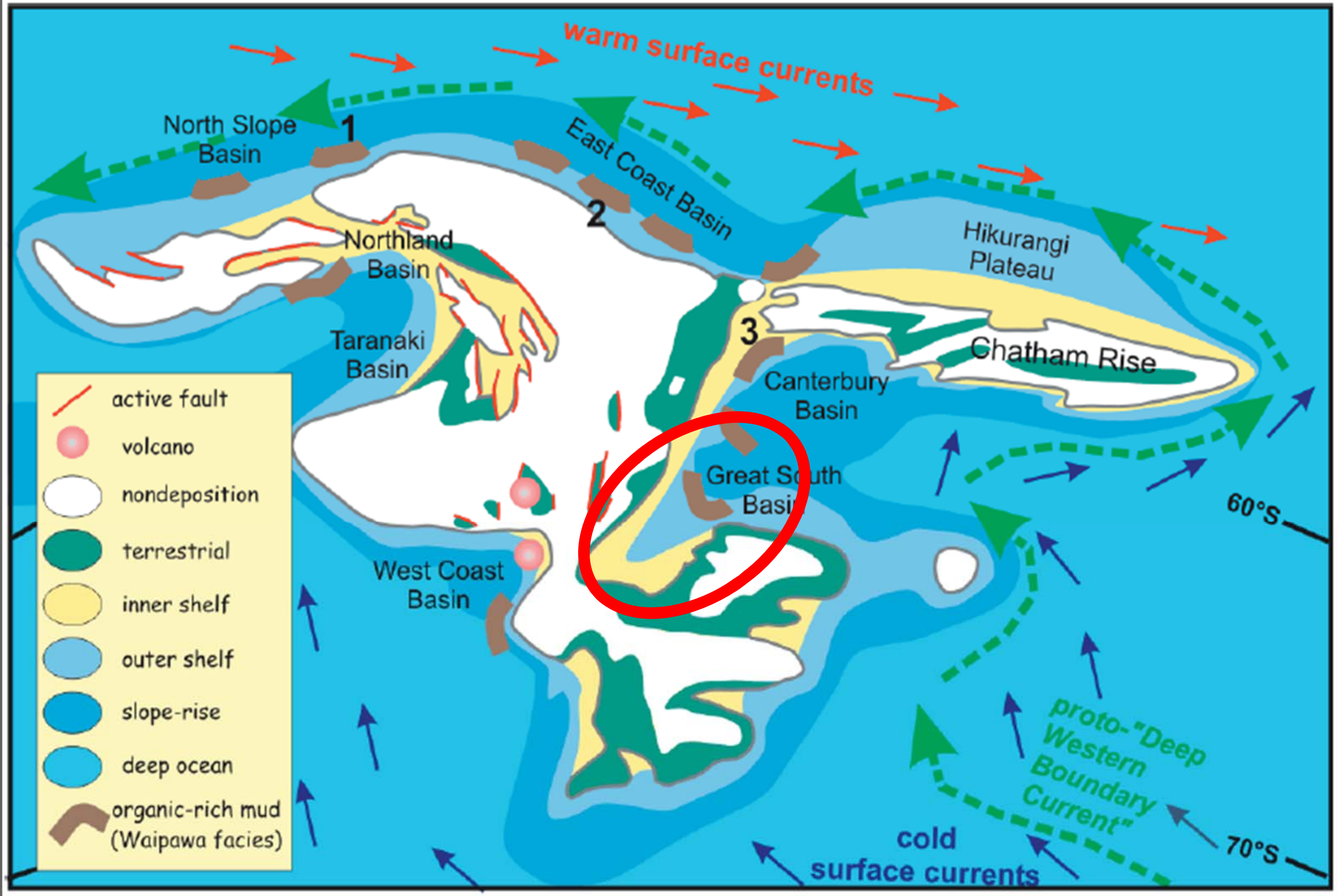
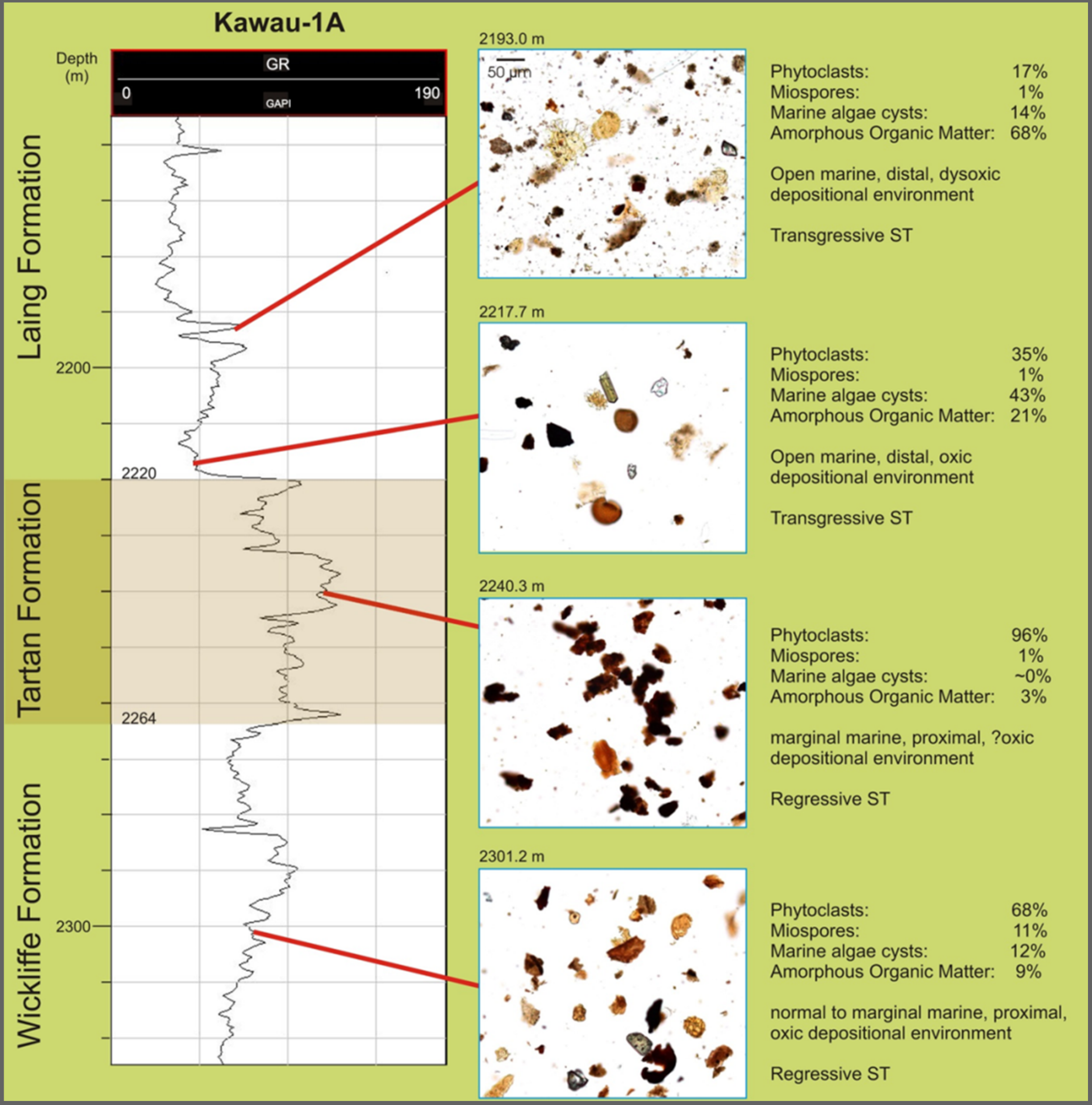


Figure 6. Paleogeographic reconstruction for New Zealand subcontinent in the Paleocene (65-55 Ma). From Hollis (2003); after King et al. (1999). Distribution of Waipawa Formation based on Killops et al. (2000), Hollis et al. (2005) and Crouch et al. (2005).

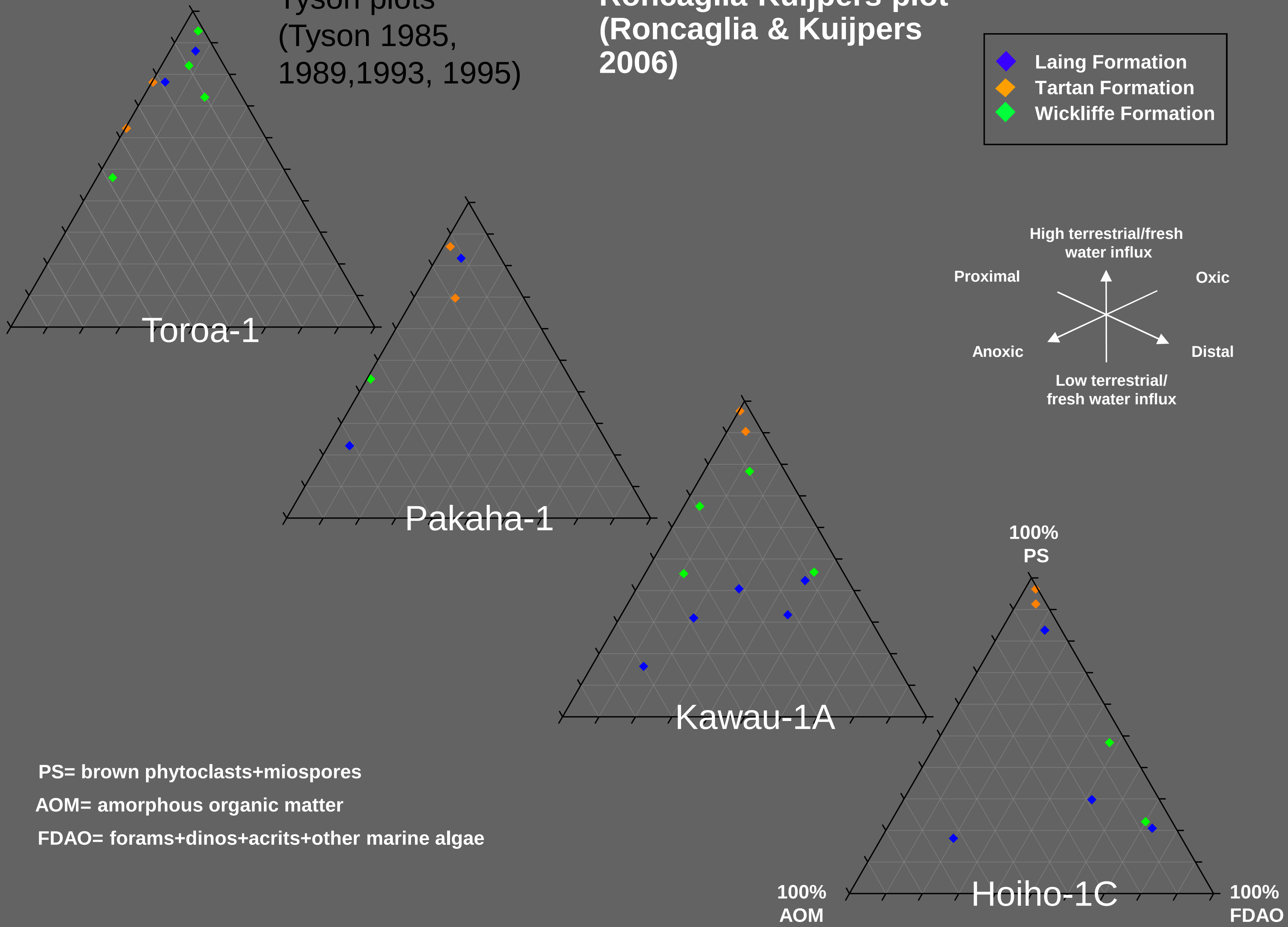
from Hollis et al., 2006

Palynofacies in the Tartan Fm



Tyson plots (Tyson 1985, 1989,1993, 1995)

Roncaglia-Kuijpers plot (Roncaglia & Kuijpers 2006)



PS= brown phytoclasts+miospores

AOM= amorphous organic matter

FDAO= forams+dinos+acrits+other marine algae

Palynofacies in the GSB

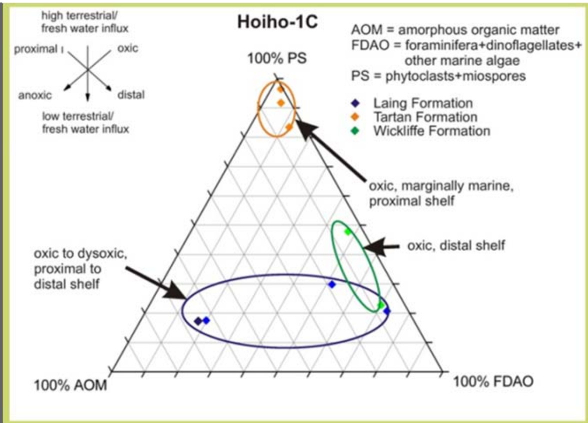
Observation 1:

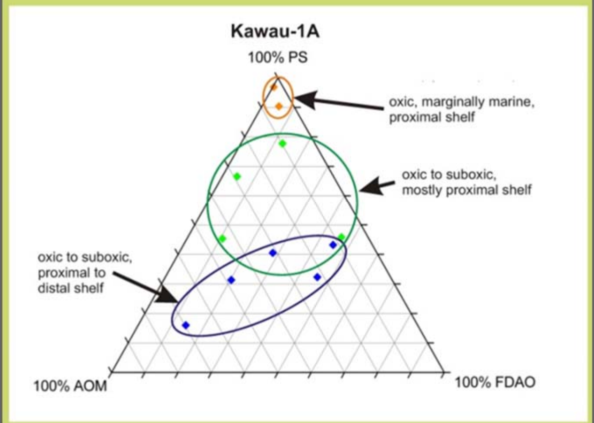
- **Tartan Fm. plots as oxic to dysoxic, very proximal basin**

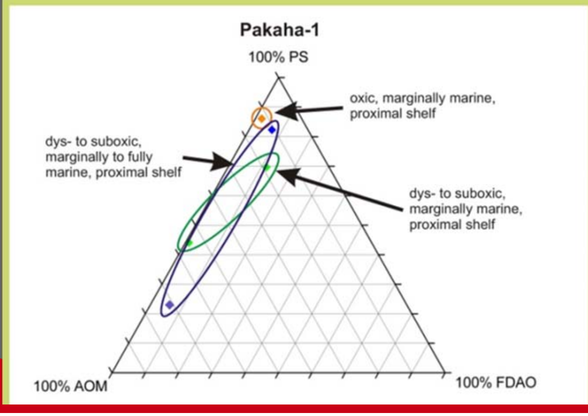
Observation 2:

- **Laing and Wickliffe Fms in distal wells: oxic to dysoxic mud-dominated distal shelf or basin**

The changes observed through this sequence are explained as a result of base-level changes in a relatively shallow water sea, with the Tartan Formation deposited at the time of peak regression in the Late Paleocene.







Implications for the hydrocarbon exploration in NZ

- With its kerogen dominated by non marine woody matter and high (mean 8%) TOC and Corg values, the Tartan Formation display good generative hydrocarbon (gas-prone) potential.
- The Tartan Fm (and Waipawa Fm to the north) may have larger and possibly more continuous offshore distribution area than previously thought.
- Care should be taken when interpreting sequence stratigraphy from well logs: a GR maximum may reflect peak regression rather than maximum transgression.
- It is wise to always apply palynofacies analysis when doing basin studies

Thank you