

Origin of Abundant Palaeocene Oil Prone Type III Kerogen Deposits, Spitsbergen*

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Abstract

Oil-prone perhydrous (>5.6% H dmmf basis) coals are economically important as source rocks. Abundant oil-prone coal (Type III Kerogen) deposits are preserved within the high latitude, middle Palaeocene, Todalen Member of the Central Tertiary Basin, Svalbard. These coals provide a significant opportunity to understand the processes which control Arctic oil-prone Type III kerogen production. This paper presents initial findings from the Svea and Longyear coals and four coals sampled from borehole 05/2009 in the Longyearbyen region. Samples were separated into kerogen, free maltene, and asphaltene fractions by solvent extraction and n-hexane precipitation. Hydropyrolysis-GCMS was then used to compare the source, maturity, and biodegradation parameters for the free, kerogen, and asphaltene-bound biomarkers to determine the origins of the perhydrous coal and associated bitumen. The principal findings of this study are:

- Coals in the Longyearbyen region are of high volatile bituminous rank (% Ro 0.65-0.69) and contain significant amounts of fluorescent vitrinite and detrovitrinite peaking in the upper Todalen member coals and low liptinite content (3-6%).
- Coals from the Svea region are more mature (% Ro 0.77) and exhibit variable maceral compositions.
- Generally, the Svea coals contain increased inertinite content (50-70%) at the expense of oil-prone macerals (perhydrous vitrinite and liptinite) limiting oil potential.

- Extracts from the Longyear and Svea coals produce significant bitumen with ca. 10% and 5% extracted bitumen respectively.
- Bitumen is composed mostly of maltene fractions (57.5% and 60-68% of extract respectively) with bound asphaltenes making up the remainder of the bitumen.

Comparison of hopane, sterane, n-alkane, and tricyclic diterpane source and maturity biomarker ratios for the asphaltene and kerogen phases indicates a terrestrial source for the bitumen with no evidence of in-migration from elsewhere within the basin. The Pr/nC17 ratio of the maltene fraction is higher than that of the bound asphaltene fraction (4.5 vs. 0.1 in the Longyear seam) which is a general trend for coals reflecting the weaker covalent bonding of the iso-prenoids compared to the n-alkanes. A key feature of the Svalbard coals and bitumen is the extremely high concentrations of hopanes (up to 72 µg/g C). Examination of the m/z 177 mass chromatogram indicates the absence of norhopanes, which suggests that the hopanes are derived from the coal kerogen rather than from the mixing of bitumen generated in situ with more degraded bitumen from elsewhere in the basin. Consequently, high hopane concentrations are attributed to rapid microbial biodegradation rates during peatland deposition caused by the unique climatic position of Svalbard in the Palaeocene and preservation of hydrogen rich organic matter by organo-sulphur compound formation.

Selected References

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Lundegard, P.D., and J.R. Knott, 2001, Polar organics in crude oil and their potential impacts on water quality, *in* Petroleum Hydrocarbons and Organic Chemical in Ground Water Prevention, Detection, and Remediation, National Ground Water Association (NGWA) Conference, Houston, Texas, Proceedings, p.138-144.

Lüthje, C. J. 2008. Transgressive Development of Coal-Bearing Coastal Plain to Shallow Marine Setting in a Flexural Compressional Basin, Paleocene, Svalbard, Arctic Norway: Department of Arctic Geology, UNIS/Department of Earth Science, UiB, University of Bergen, Bergen, Norway, 181 p.

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Acknowledging

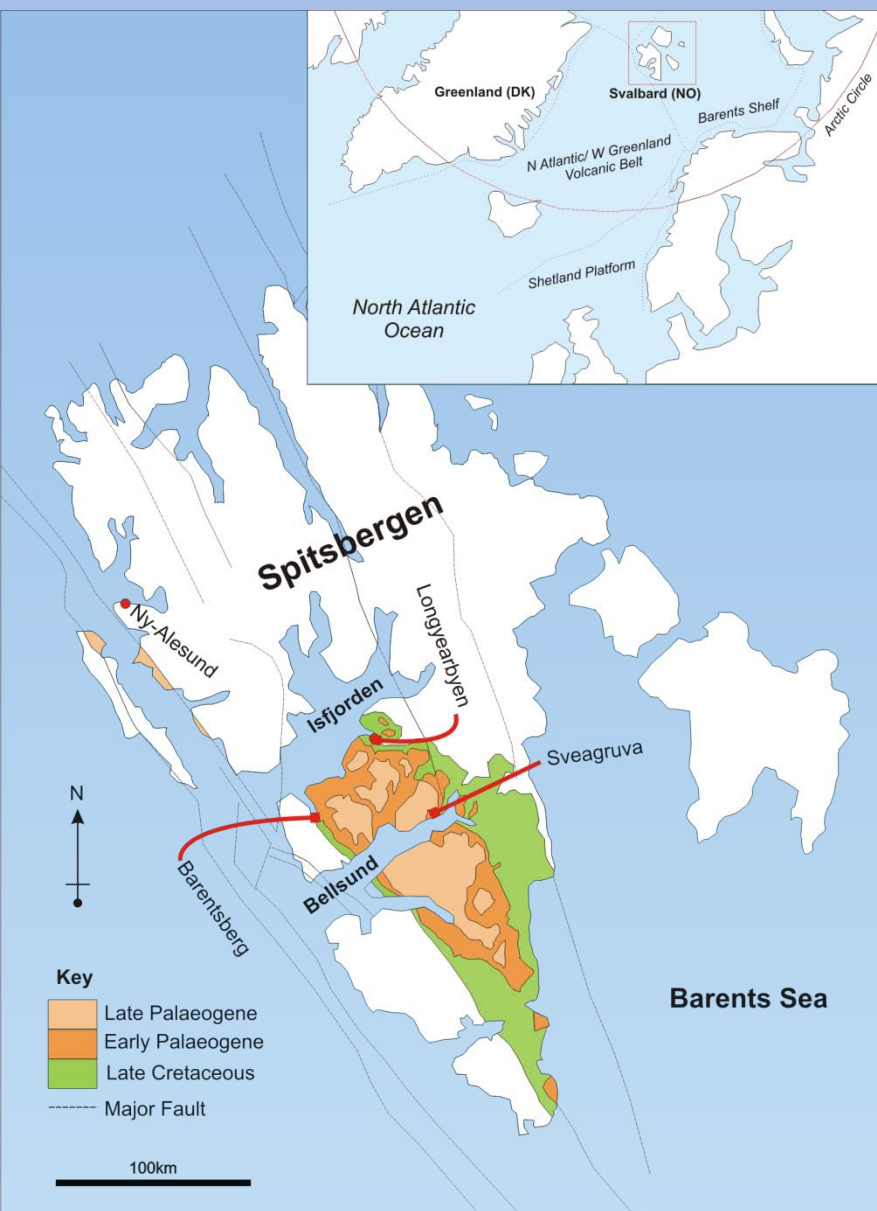
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Palaeocene Stratigraphy



- 5 Seams found within the Palaeocene Todalen Member

- 4 seams have HI values exceeding 300 which are named (oldest-youngest)

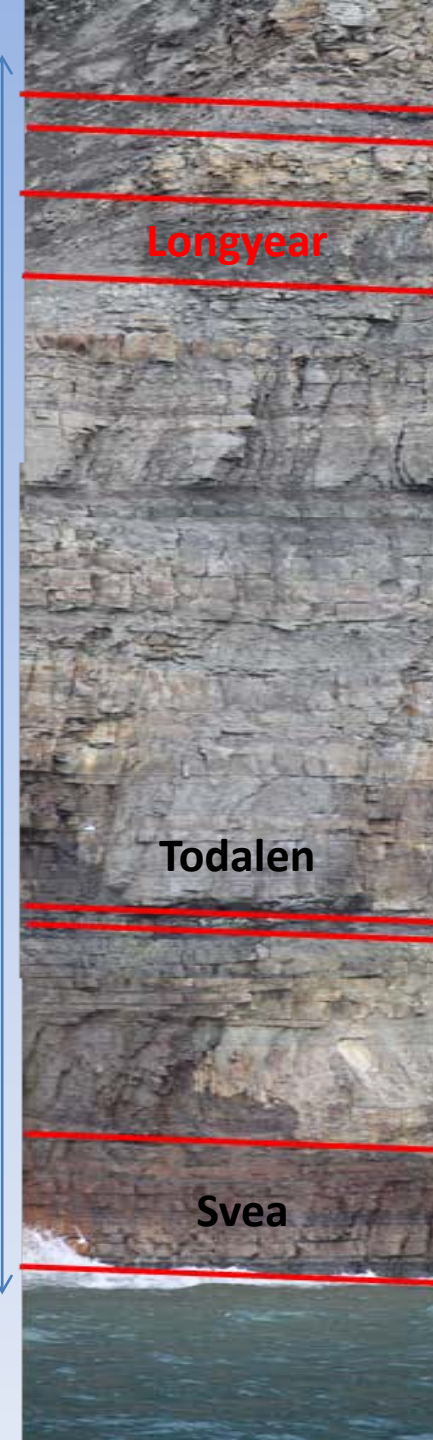
- Todalen
- Longyear
- Svarteper
- Askeladden

- Total resource size up to 61 million tonnes (SNSK)

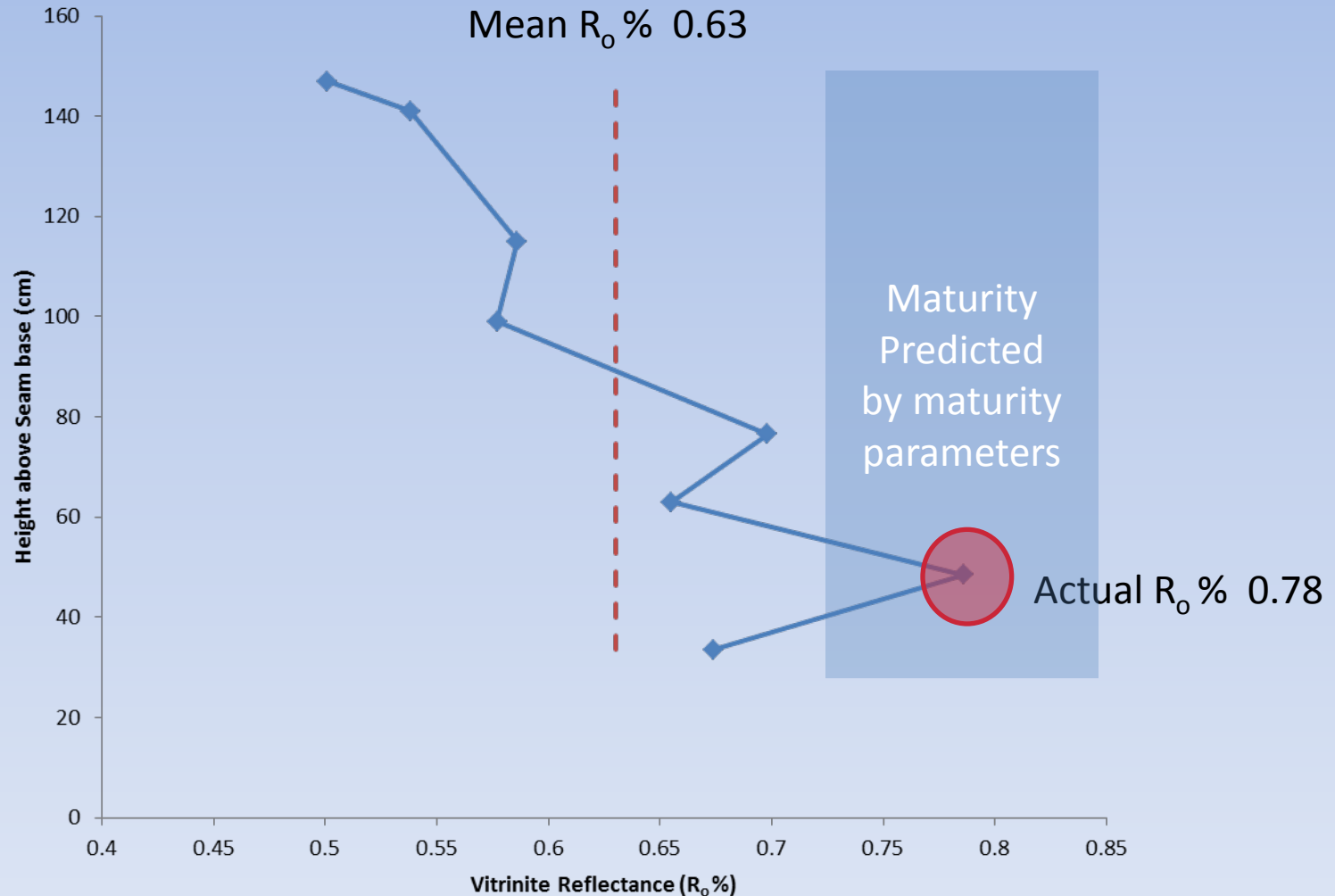
- Longyear seam is a high volatile bituminous coal

- C = 78%
- S = 0.5 – 8%

50m

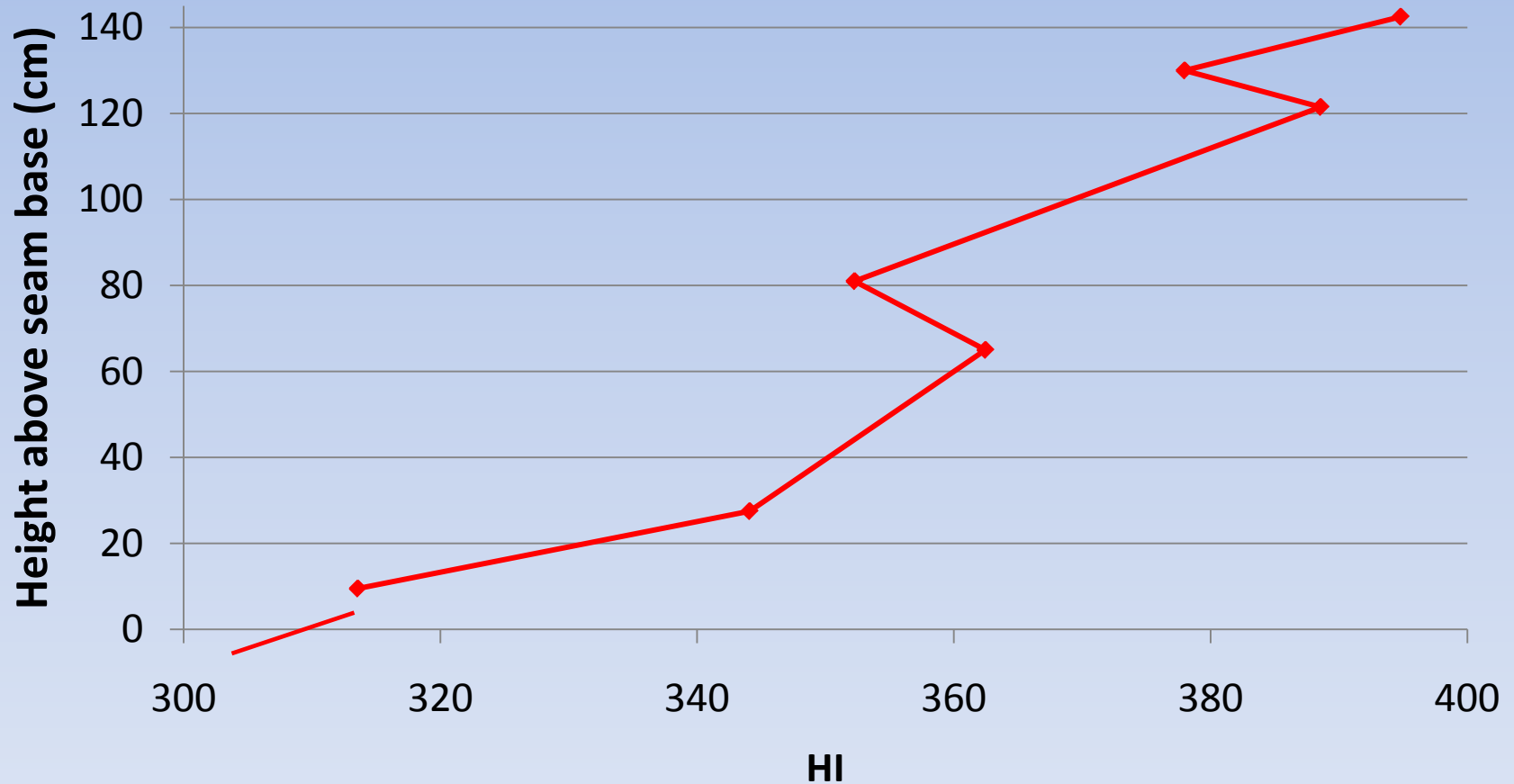


Maturity of the Longyear Seam



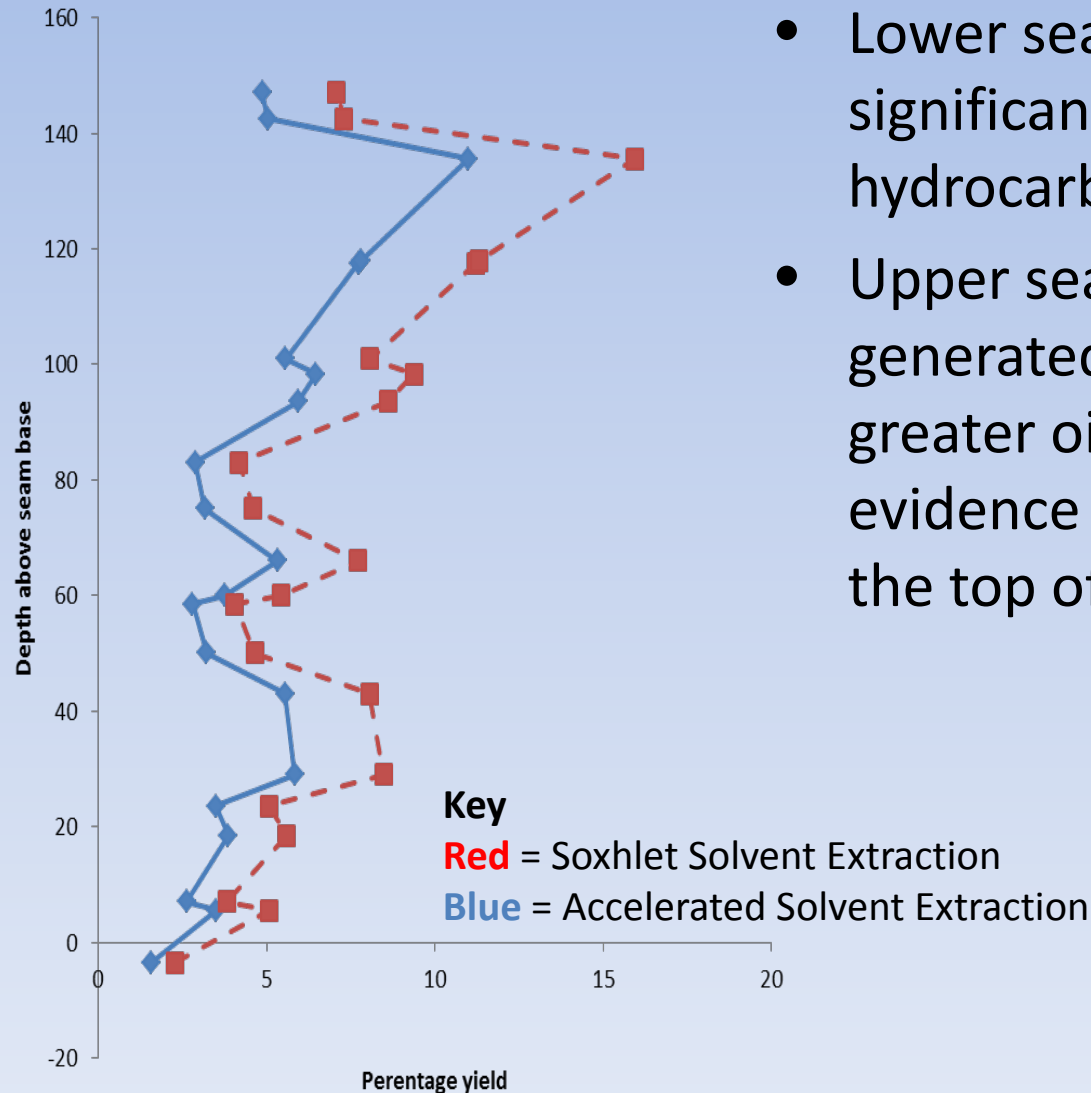
20% Suppression between mean and actual R_0 %

Oil Potential of the Longyear seam



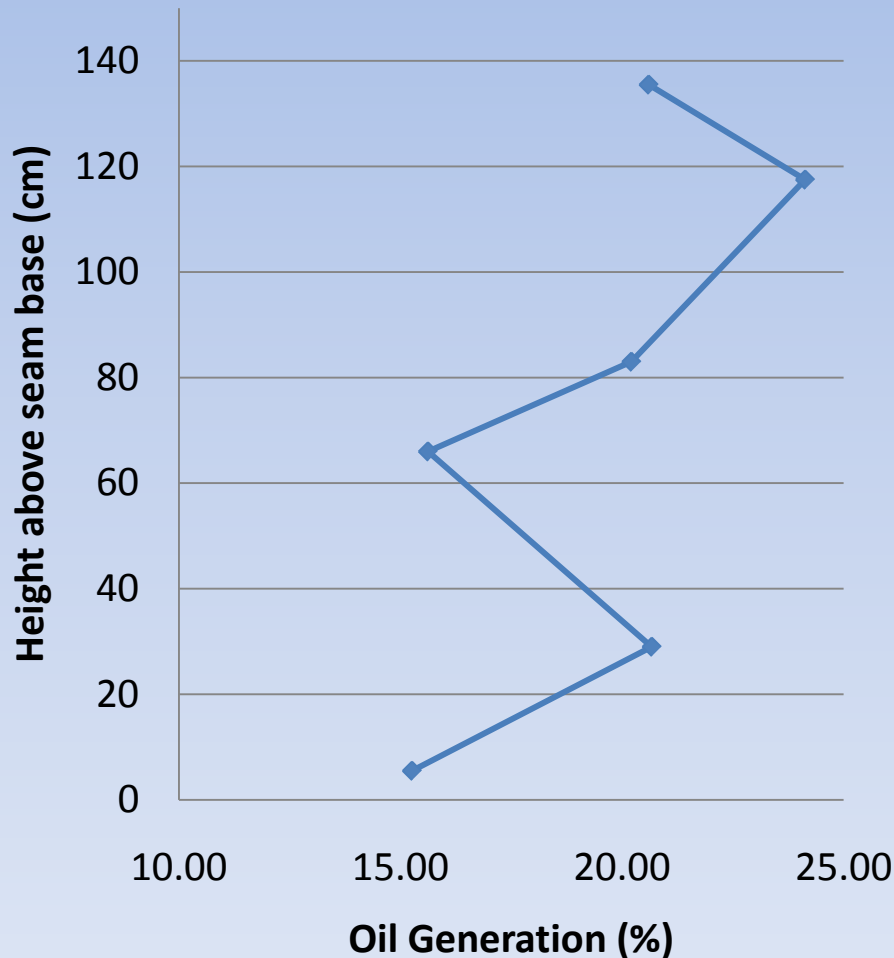
Values >300 indicate significant oil potential

Degree of in-situ oil generation (S_1)



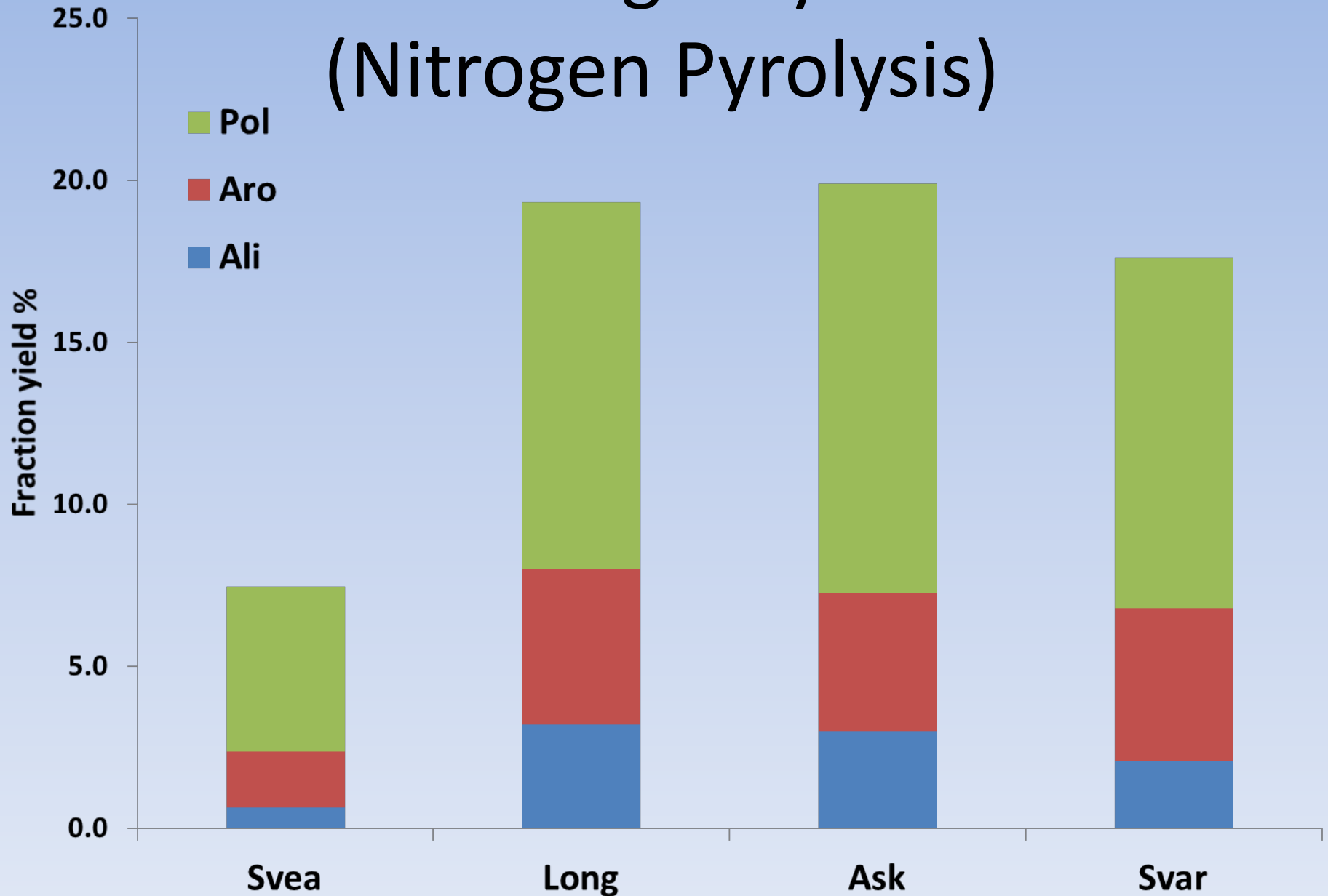
- Lower seam has not generated significant amounts of hydrocarbons
- Upper seam has greater yields of generated hydrocarbons due to greater oil potential and also some evidence of limited migration to the top of the seam

Residual Oil Potential (S_2)

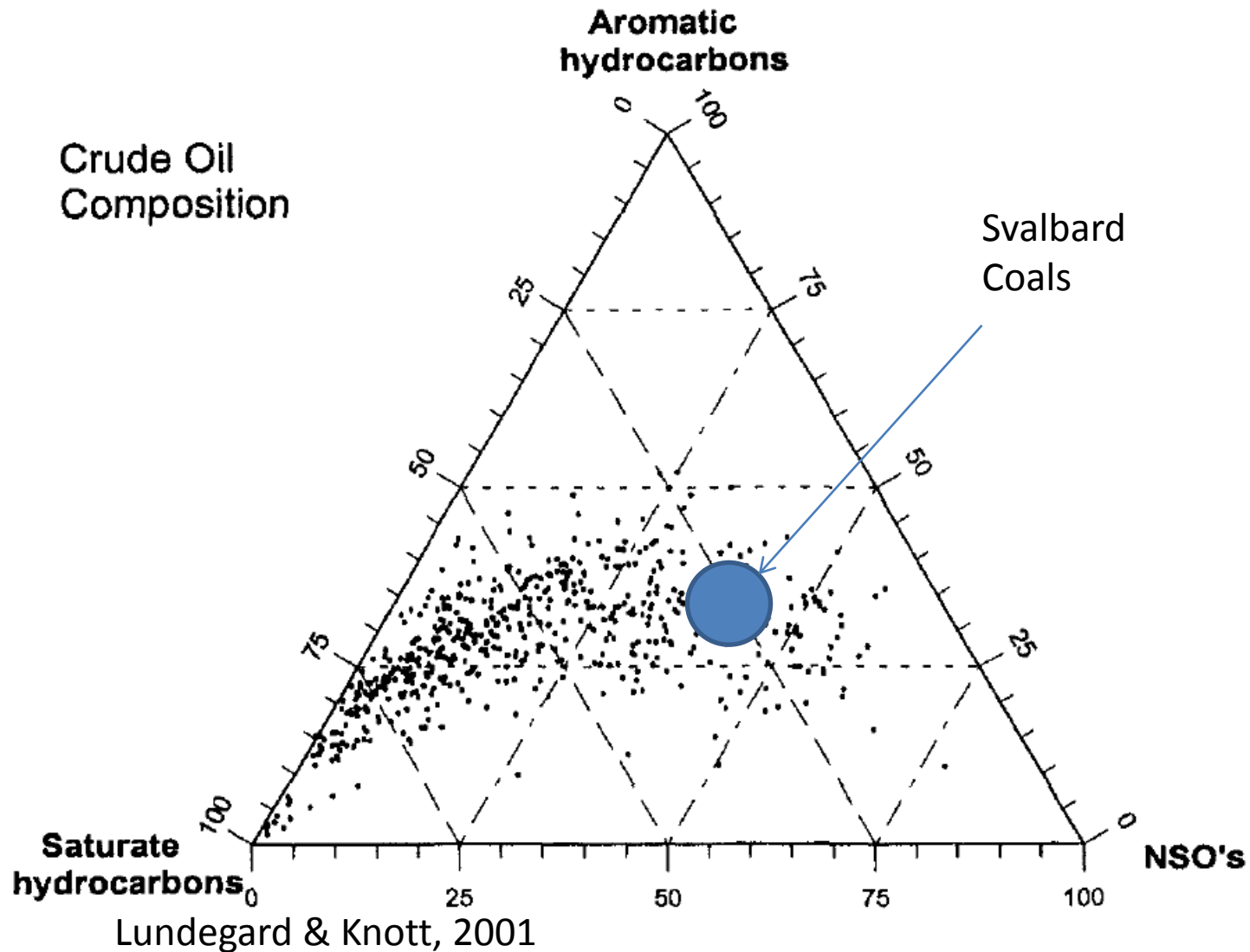


- Hydrous pyrolysis used to simulate geological yields of hydrocarbons after further burial
- Indicates that around 60-85% of hydrocarbons yet to be generated

Retorting oil yields (Nitrogen Pyrolysis)



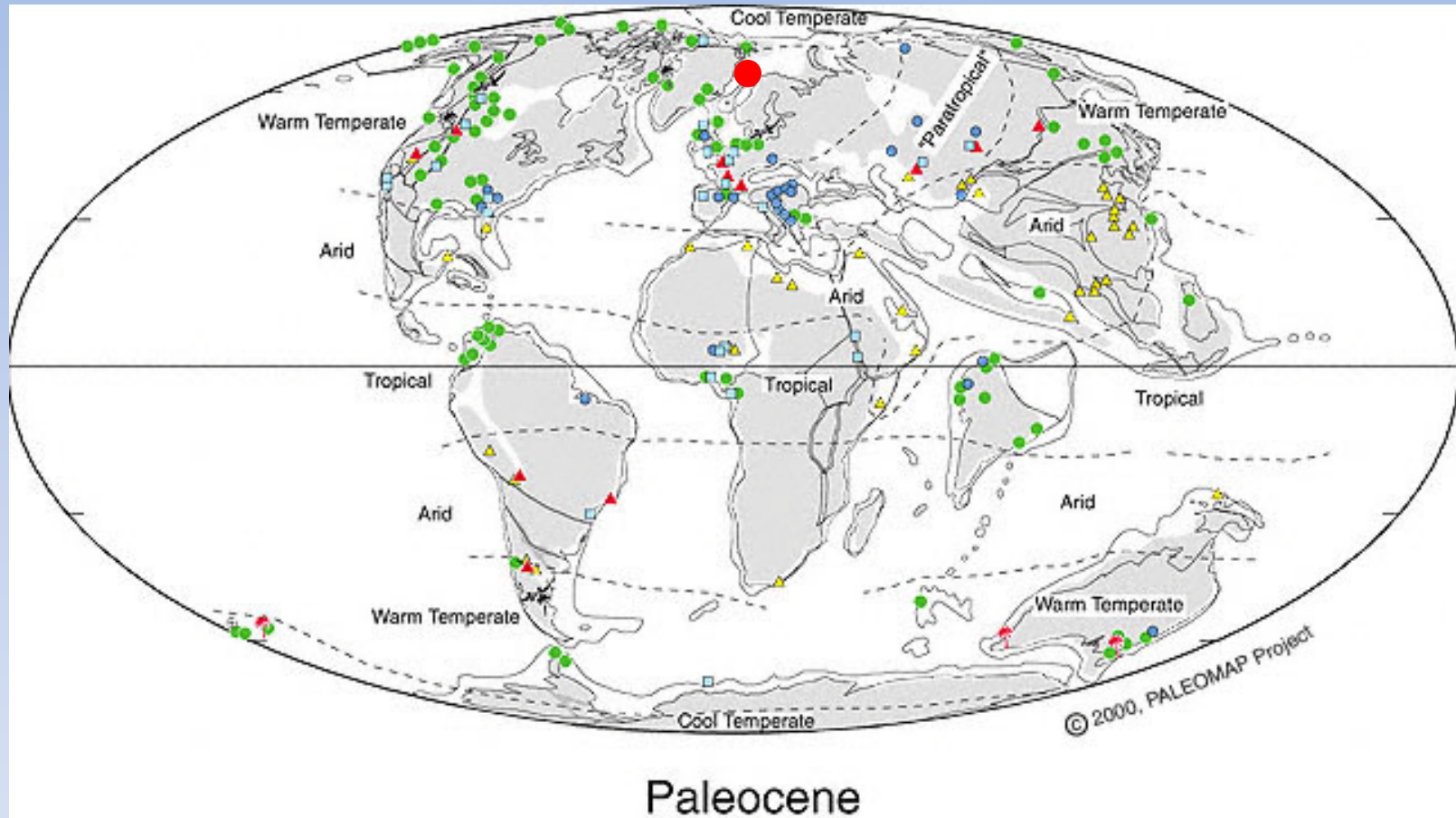
Comparison with Global Crude Oils



Why are these Coals Oil-Prone?

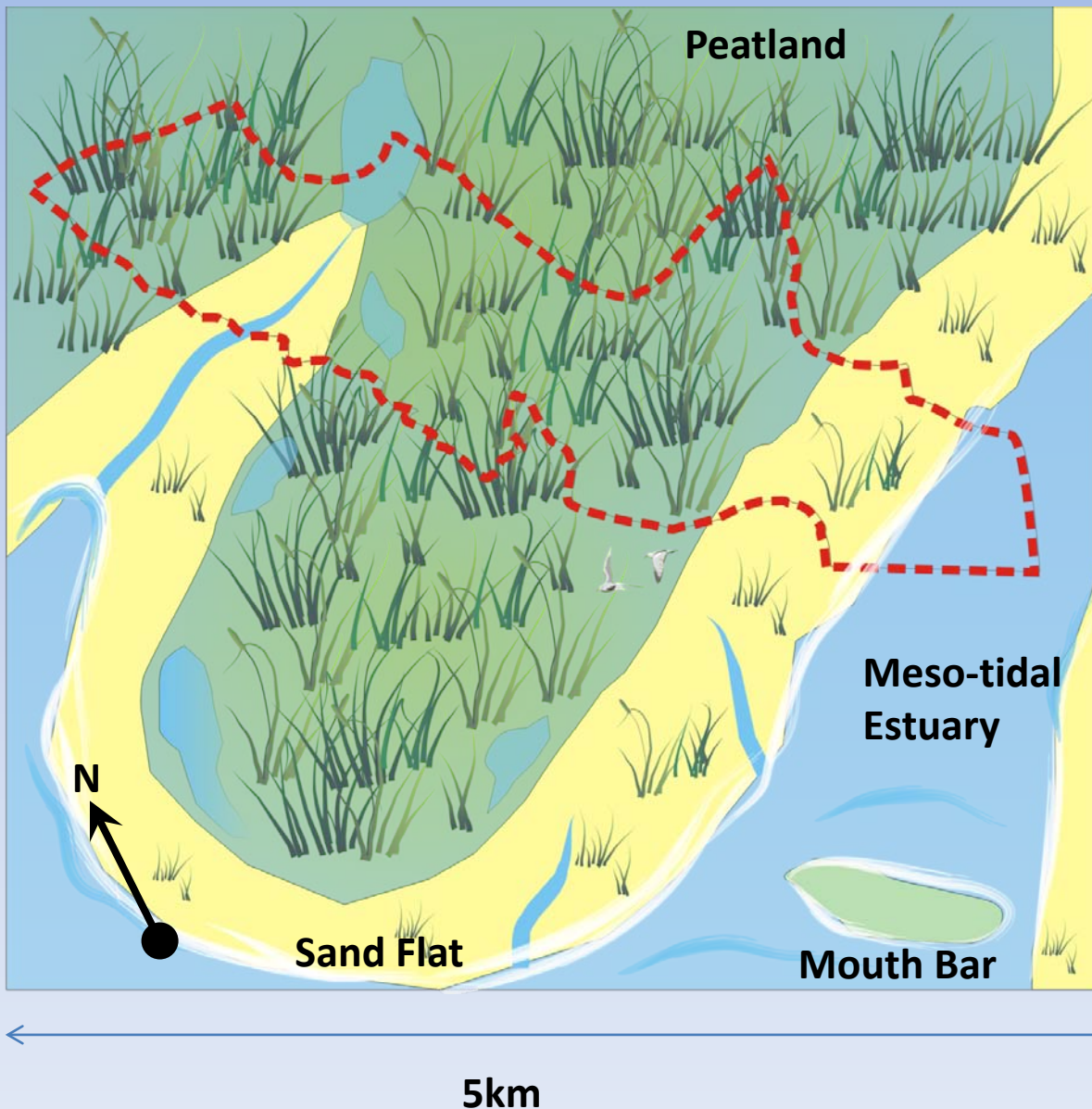
- Key conditions for oil prone coal formation are
 - High biodegradation rates
 - High sulfur and alkalinity
- This is a function of the peatland environment in which coal formed
 - Palaeoclimate
 - Depositional Setting
 - Organic Source material
 - Hydrological stability

Palaeoclimatology Arctic ~ 60Ma



Svalbard in the Palaeocene was situated ~68N (Lüthje, 2008) and winter temperatures are thought to have rarely fallen below zero (Greenwood et al, 2010)

Depositional Setting

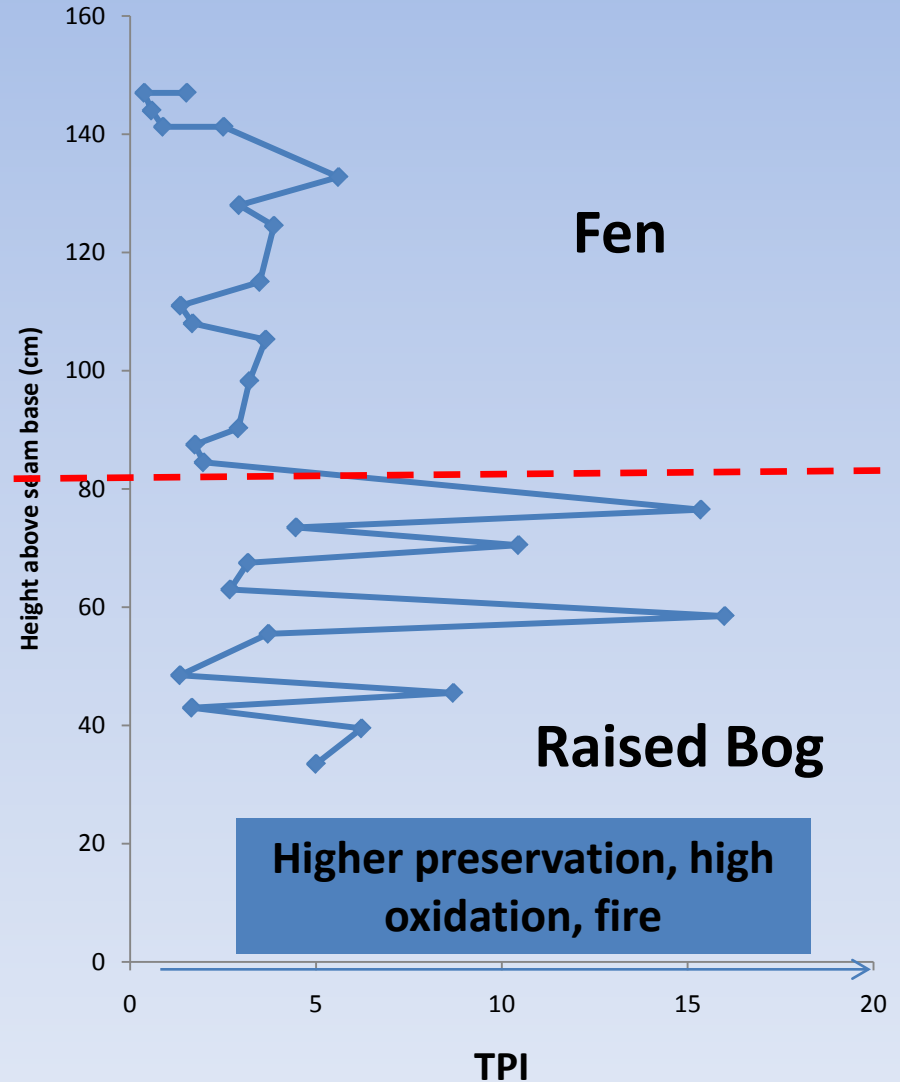
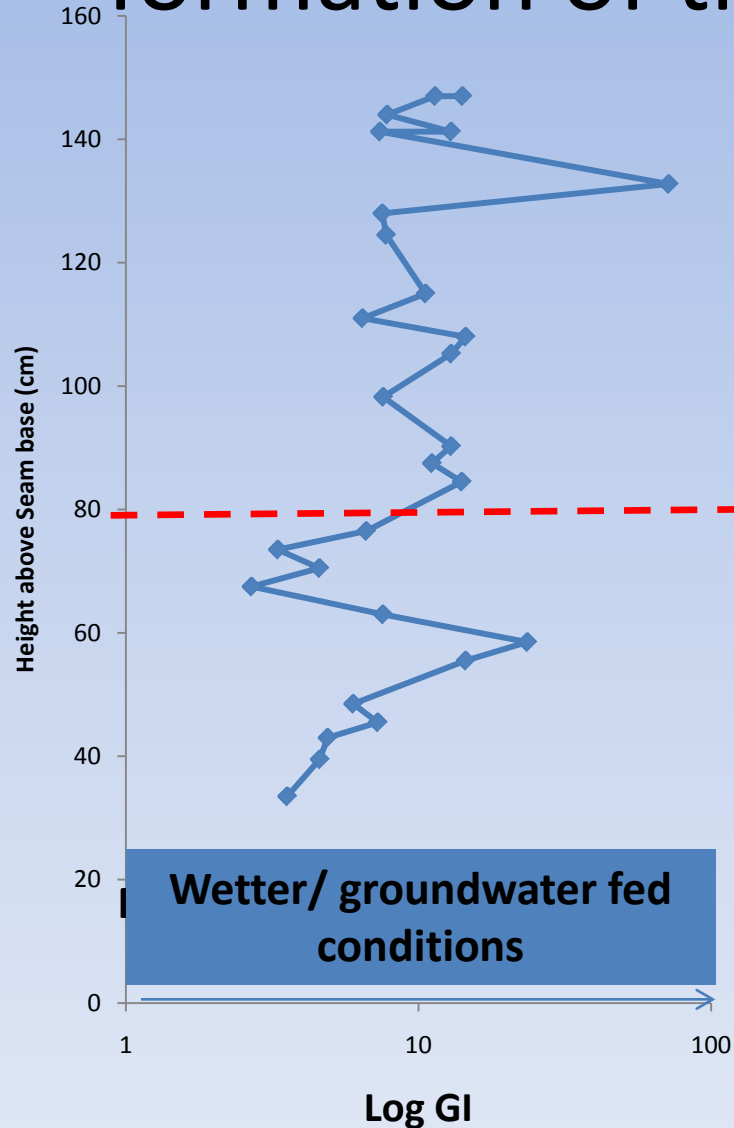


- Estuarine setting - with peatland forming between channels
- Marine Influence – supply of S and alkalinity decreases away from the channels

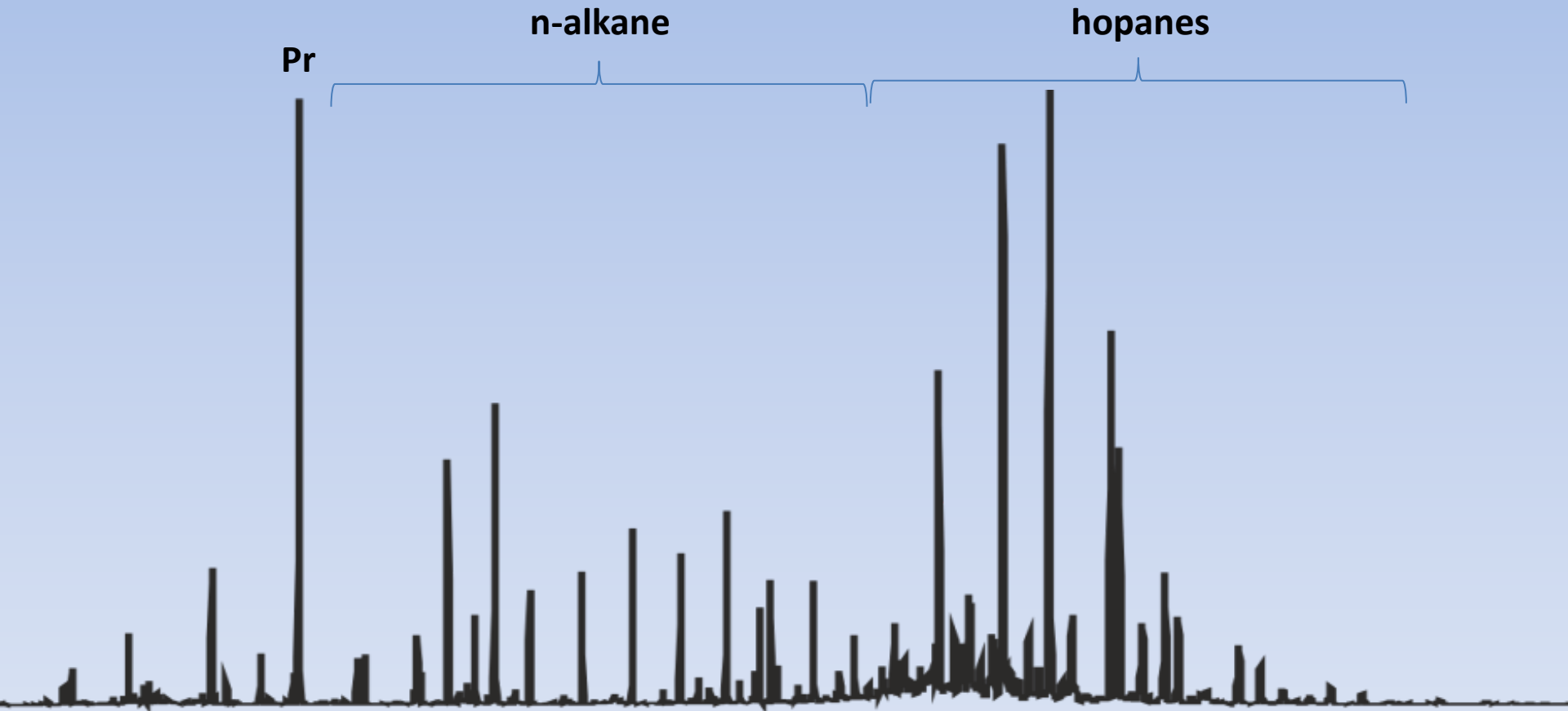
Key

- Longyear seam outline at Lunckefjellet

Peatland Conditions during the formation of the Longyear Seam

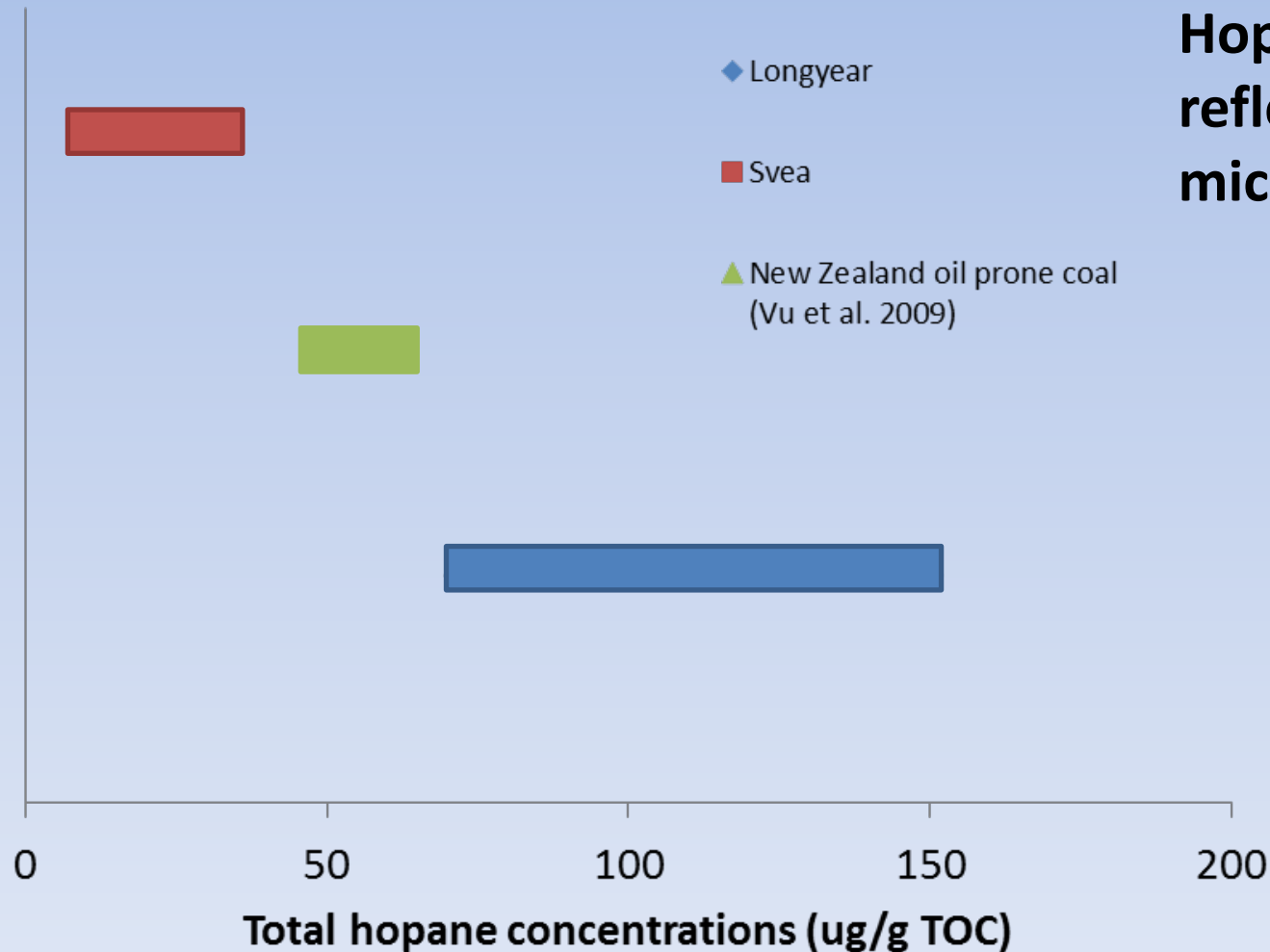


Total Bacterial input to Palaeocene Arctic Peatland



Total Ion Chromatogram Longyear Seam
Evidence of high bacterial biodegradation

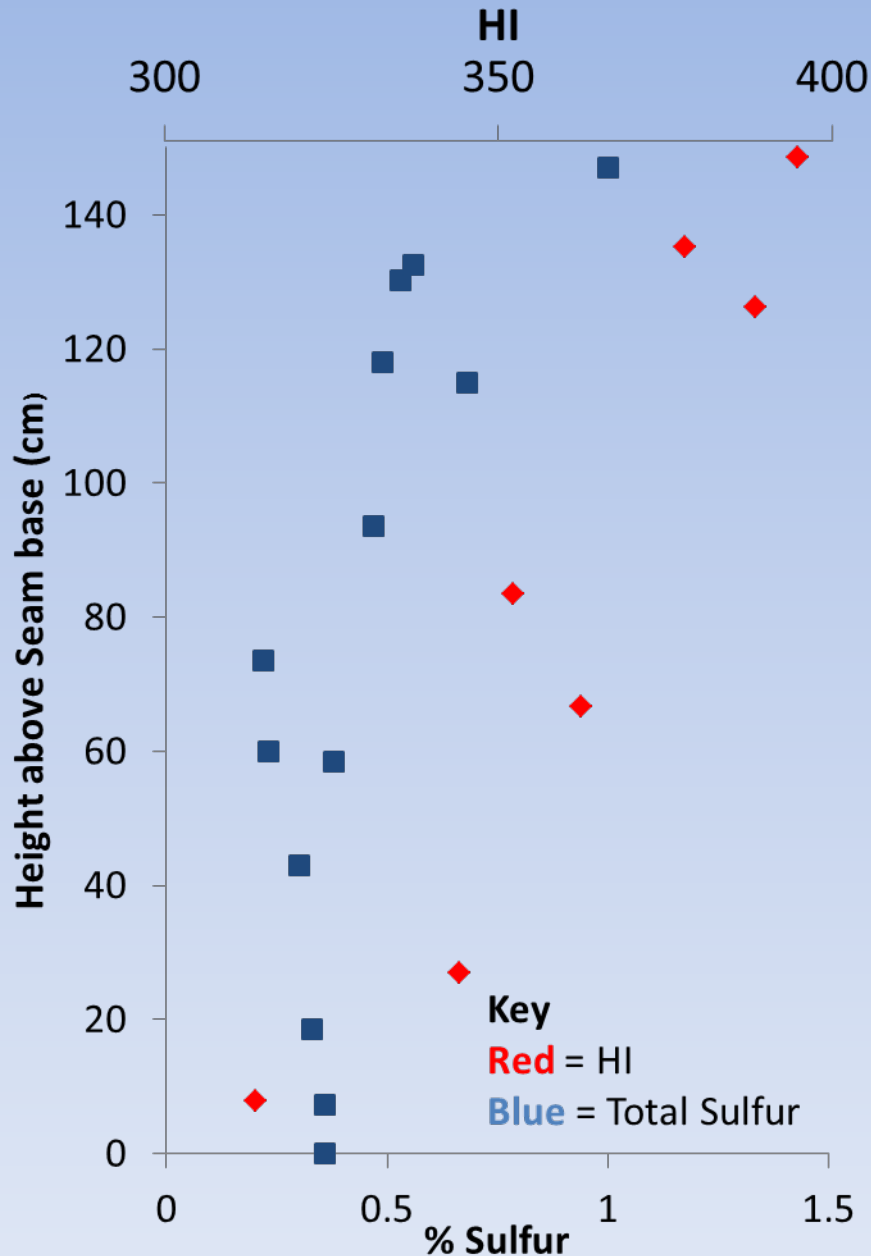
Total Bacterial input to Palaeocene Arctic Peatland



Hopanes thought to reflect primary microbial activity

- **Biodegradation indicators such as norhopanes and methylsteranes absent**
- **High absolute concentrations of hopanes**

Sulfur and Oil Potential



- Hydrogen Index and Total Sulfur follow similar trends, increasing upwards
- Sulfur related to increased preservation of oil-prone source material liberated by biodegradation
- Allows formation of organo-sulfur molecules
- Also indicative of coastal influence and degree of pH regulation by sea spray

Conclusions

Longyear coals are significantly oil-prone with nitrogen pyrolysis indicating significant economic potential using retortion.

Oil prone coal formation on Spitsbergen is favoured by

- 1) Intense aerobic decay processes both bacterial
- 2) High Productivity compared to modern high latitudes
- 3) Formation in a coastal environment providing alkalinity and S
- 4) Stable hydrological conditions

These conditions help to liberate and preserve hydrogen rich oil-prone plant material during subsequent burial and diagenesis



Gjelder hele
Svalbard