Extended Abstract

Paleozoic Petroleum Systems on the NCS – Fake, Fiction or Reality?

What is presently Known & What Implications May such Source Rock Systems Have – Today - in terms of Exploration? SWOT

Prof. Dr. Dag A. Karlsen, Univ of Oslo

The Jurassic source rock systems continue to form the backbone for exploration on the Norwegian Continental Shelf NCS), with hitherto only 5 oil accumulations proven to be from Cretaceous source rocks, and with Triassic source rock contributions mainly occurring in the Barents Sea.

At the "other end of the stratigraphy" we have the Paleozoic rocks. Paleozoic source rocks were recognized early in Scandinavia, *e.g*. the Alum shale, which we today know to have generated petroleum during the Caledonian Orogeny (Foreland Basin), bitumen found now in odd-ball places in Sweden *e.g*. at Østerplane and at the Silje Crater Lake and also in Norway.

It took until 1995 until we could, via geochemical analytical work on migrated bitumen from the Helgeland Basin (6609/11-1), with some certainty point to migrated oil from a possible Devonian source (affinity to Beatrice & the Orkney shales).

Also around 1995, we could suggest bitumen from the 7120/2-1, later realized as one of the wells in the Alta Discovery v.200m dolomite Ørn/Falk Fm) to be of a non-Mesozoic origin, and possibly from a Paleozoic source, and geologist at RWE-Dea and later Lundin started to consider the Paleozoic reservoir systems at Loppa High and also the possibility of Triassic and Permian source rocks as a play model.

Why did it take the scientific and exploration environment in Norway so long time to consider source rock systems outside the Jurassic as important? Part of the reason is the great success of the Jurassic Plays on the NCS. Too much success in one play may partly "blind" alternative exploration, i.e. "Blinded by Success".

It is also the case that we did not have, until recently, age-specific" biomarkers which worked well for the Paleozoic system, and some issues still remain, in particular related to the Early Triassic. This in contrast to the fact that we have very good age specific biomarkers for the Tertiary since e.g. oleanane (*e.g.* 1985), and since the establishment of nordiacholestanes for the Upper Jurassic, Cretaceous and younger source rocks (since 1998).

Thus, before the use of aromatic steroids as age specific biomarkers in 2011 typing of Paleozoic oils would have to relay, to a large extent on facies parameters to infer SR age, like *e.g.* betacarotane for lacustrine systems *e.g*. the Devonian, gammacerane for hypersaline systems *e.g*. typically Permian or enhanced ratios of C29/C28 steranes for the Paleozoic systems.

With the recent progress in age specific biomarkers, and also increasing sensitivity of our analytical techniques, we have recently been able to find evidences for Paleozoic proto-sourcing in a series of fields offshore Norway.

Examples with Paleozoic signatures include migrated oil from the deep Embla, paleo-bitumen in Oseberg (Devonian signatures), bitumen extracted from the Statfjord Fm. units in a trap in the Agat/Gjøa region – with a clearly Paleozoic marine oil signatures, the 17/3-1 (Bark) – Stord B.), partly in 25/6-1 and recently was bitumen of clearly Domanik facies association (Timan-Pechora?) - one carbonate facies and one more distal shale type isolated from Ny-Friesland, Svalbard. Thus, these are a few examples in addition to the lacustrine 6609/11-1 (Helgeland B.) and the marine bitumen as part of the charge at Alta/Gohta. Other possible Paleozoic systems could include 15/5-1 and the "Russian oil" from Spitsbergen. On the UK-side, *e.g.* the Buchan and the Beatrice have been suggested as Paleozoic.

What does this imply in terms of the Petroleum System understanding?
Is this just of academic interest?
The following points are relatively clear:

SWOT
S: Old oil may have saturated migration path ways, making migration more effective for late generated charges (co-sourcing/multi SR systems), "old oil" may have helped to preserve porosity in part because they are often bio-degraded to a heavy bitumen "syrup". Assuming *e.g.* 50% residual "old" oil, even a previously dismigrated trap needs only 50% charge to be full. On the Barents Sea platform areas, Paleozoic source rocks may exist as the only matured, and in areas surrounding basins like the Olga B. and the Maud B. may co-sourcing from also Mesozoic SRs contribute to discoveries, while early charges could be Paleozoic. Paleozoic derived oil could open up Play scenarios in hitherto non explored regions.
W. An intrinsic problem with paleo-oil is the "Preservation Potential". Old SRs may mean early generation – hence along preservation towards the present time becomes a problem in normal faulted or uplifted basins. Still, generation may have occurred much more recently in, more recently matured and stable platform regions.
O: Huge upside for petroleum discoveries may exist in regions which today are shallow *e.g.* the Helgeland Basin, the Stord B and the Bjarmland Platform. Several proximal or "land-near" structural elements on the NCS may hold oil *e.g.* close to Finnmark and in the Helgeland B. It is in this concern important that "Platform regions" have intrinsically much higher "Preservation Potential" than normal faulted basins. Opportunities may include "sub-salt" prospects – virtually un-explored on the NCS.
T: Few. Only if generation occurred very early, then the "Preservation Potential" might be reduced. Recent uplift of the shelf has resulted in up-dip remigration. Still, dismigration (normally a negative) could imply - via the Gussow principles - that up dip re-migration in a proximal direction, has occurred where secondary traps could exist. This model is likely also for the Olga and Maud Basins and similar depressions, or margins along the western part of the Barents shelf. Up-lift provides kinetic energy for remigration and potential entrapment cf. onshore USA and The onshore Arabian Gulf regions. We do not, contrary to most, consider oil-stability a threat in deep hot basins with old SRs, and have suggested tentatively that sourcing from Carboniferous/Permian SRs may have occurred in *e.g.* the general Jade/Judy region where some utterly high maturity oils are known.

Extended Abstract

NPD Meeting Stavanger Oct 31-Nov 1, 2018

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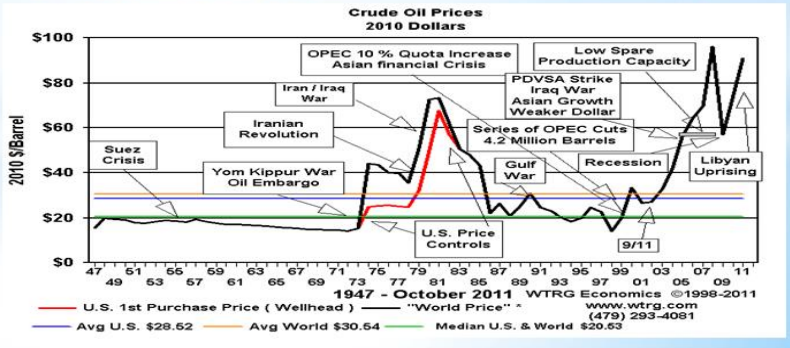
by
Prof. Dr. Dag A. Karlsen
University of Oslo

Lundin NORWAY · NORECO · RWE · wintershall · ConocoPhillips

HEADLINE PERSPECTIVE

OR **Déjà vu** *? Transient or Finale?*



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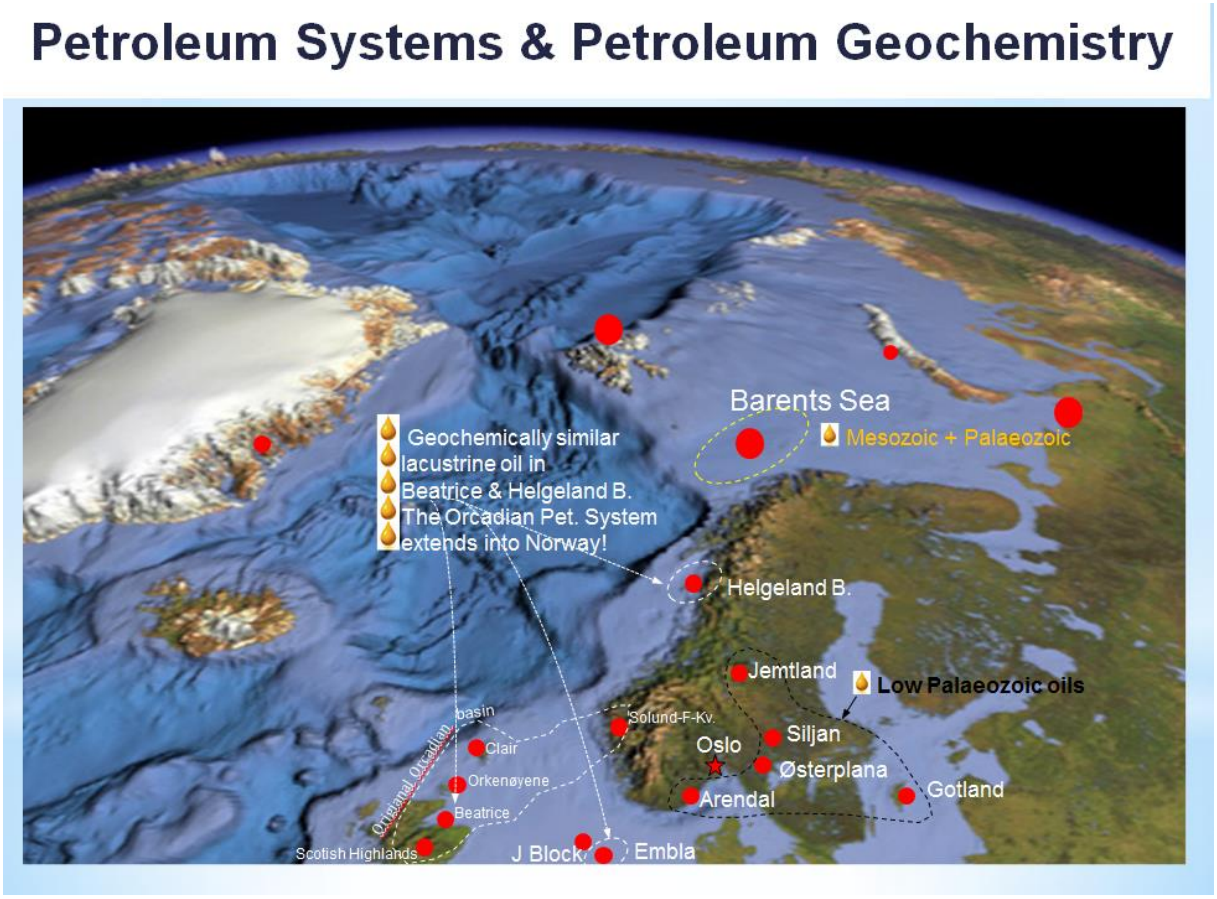

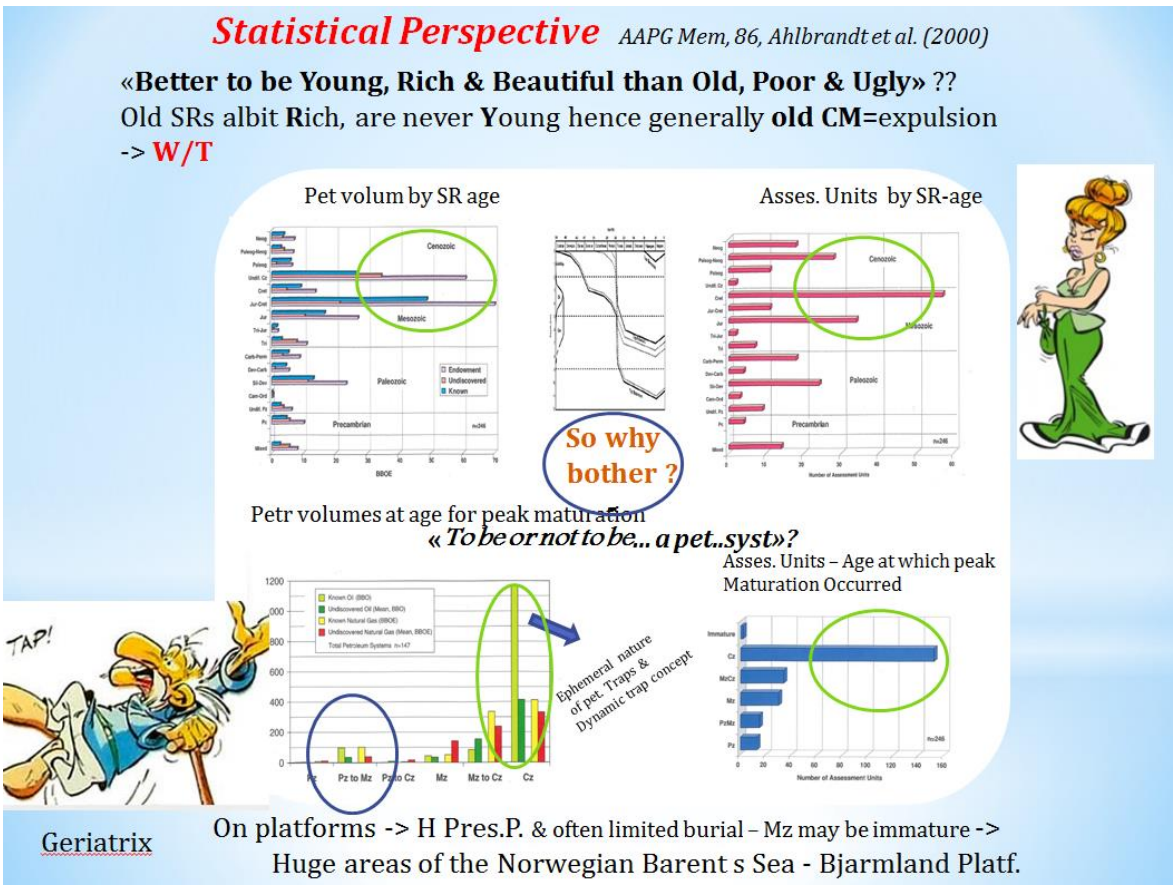

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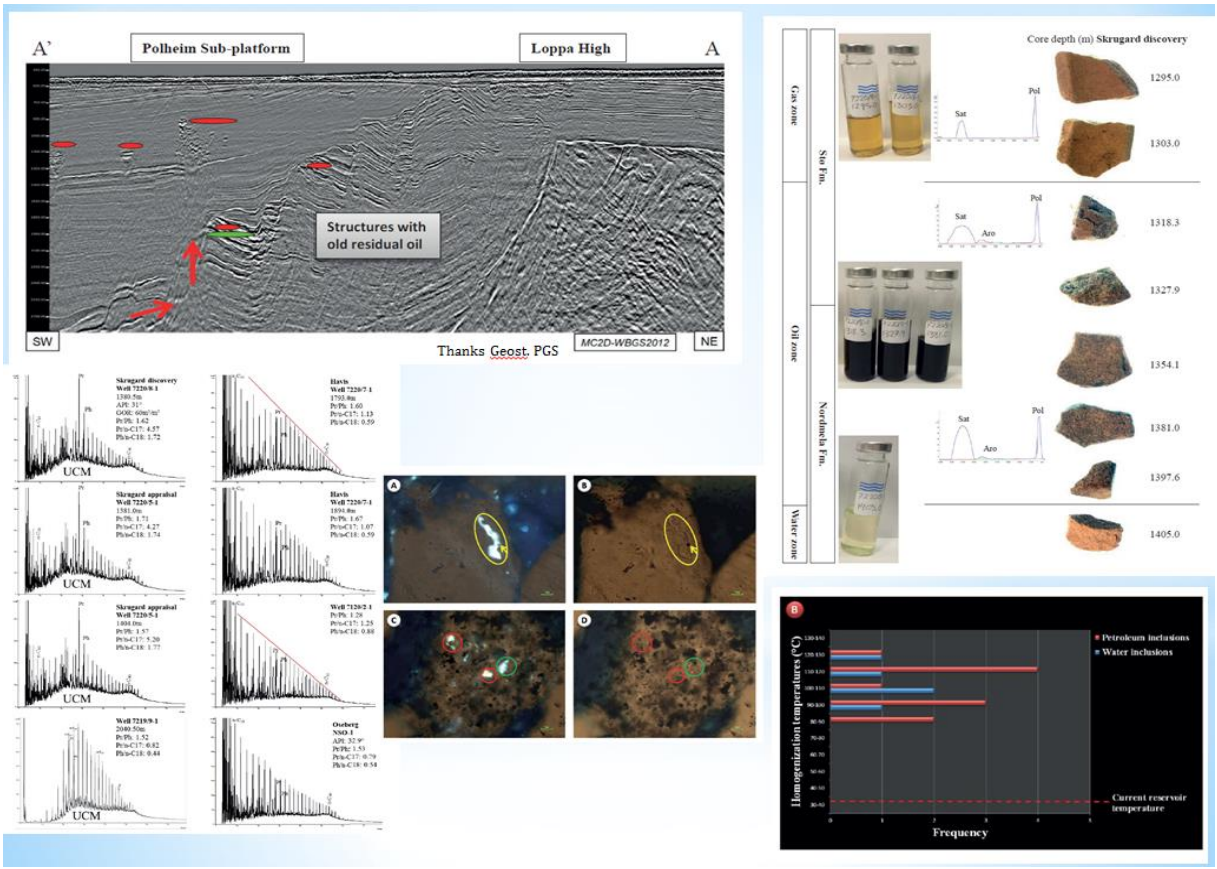
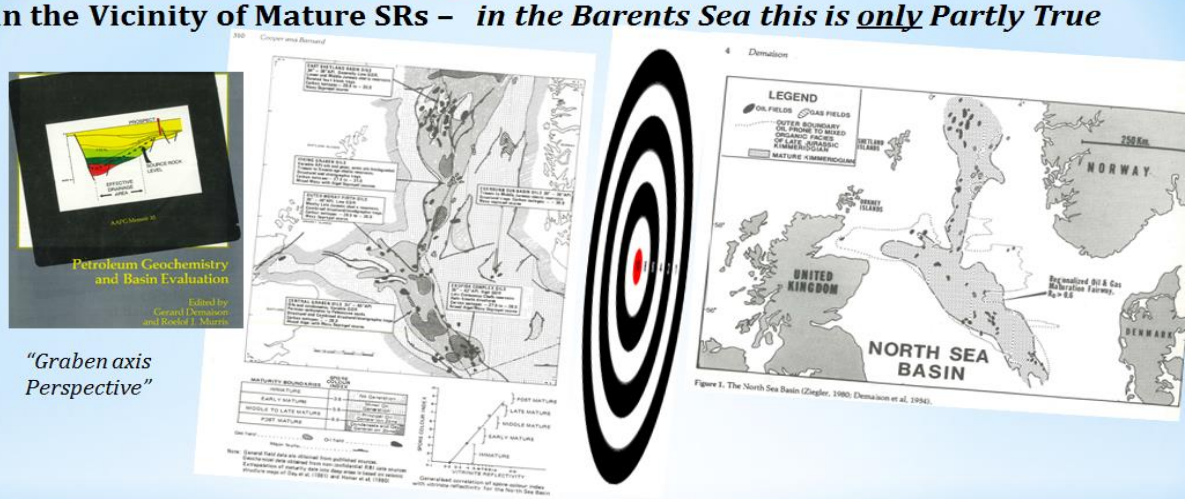


THE "WHERE TO DRILL" ASPECT 1970 – 2000 Emphasis – Oil occurs Directly in the Vicinity of Mature SRs – *in the Barents Sea this is only Partly True*



"Graben axis Perspective"

Still correct – but concepts are recently refined e.g. understanding the importance of Palaeo-Migration to saturate carrier avenues/migration channels - Porosity Preservation & Understanding Leak-& refill of traps e.g. like Ula, Skrugard (50% residual saturation + 40% new = NEW DISCOVERY as compared to 100% new)

1. We note the importance of GAME CHANGING –long-distance Migration onto Highs! e.g. Avaldsnes/J. Sverdrup – Utsira Høgda/Gohta-Loppa High & potentially Fedynsky High –including SR mega sequences - Jurassic & Triassic

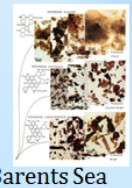
In fact "ONTO THE HIGHS may be the new codex for next decades! Why does this work? ***Proximal***

2. Thus if we consider UPLIFT and REMIGRATION we may have

AN ADDITIONAL PLAY TO UNDERSTAND, REFINE & DEVELOP ***Distal***

SOURCE ROCK ASPECT

45 Y OF SUCCESSFUL JURASSIC DOMINANCE CONCERNING SR & TRAPS



SR is silisiclastic Type II (distal e.g. Ekofisk) to more proximal Type II/III e.g. Viking G, Haltenbanken, Barents Sea

ARE THERE ALTERNATIVE SOURCE ROCK SYSTEMS ON THE NOCS?

1. **PALAEOZOIC SR SYSTEMS-**mostly palaeo-active – and hence more important than many think - but also occasionally active in proximal settings
   1. **CAMBRIAN/ORDOVIC/SILURIAN**-lots of migrated oil in Norway/Sweden
   2. **DEVONIAN** – Beatrice –Orkenøyene/Helgeland B/Barents/Tim.P
   3. **CARBONIFEROUS**- Finnmark P/Svalbard/Russian oil
   4. **Permian- Kupfersh/Marle Slate**-too thin? Buchan-UK 20/1 (Old Red ss/horst) – NOCS deep target
   5. Others – undifrentiated 17/3-1
2. MESOZOIC SR SYSTEMS NON-JURASSIC
   1. TRIASSIC-ubiquitous & world class top in the Barents Sea –e.g. Stockman. Disputed proximal Viking G. e.g. Frøy?
   2. **Jurassic non-silisiclastic** – more carbonate rich faceis e.g. 25/5-5, 2/2-5
   3. Jurassic coal – Åre source d – e.g. Idun –prox setting – paleo-sourcing

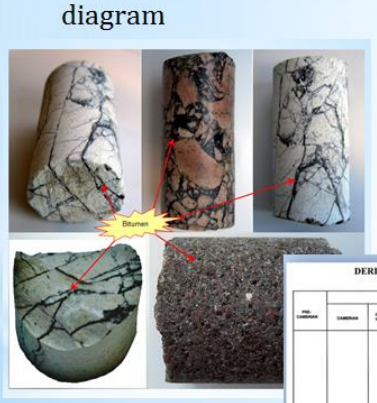
Cret. Enigma

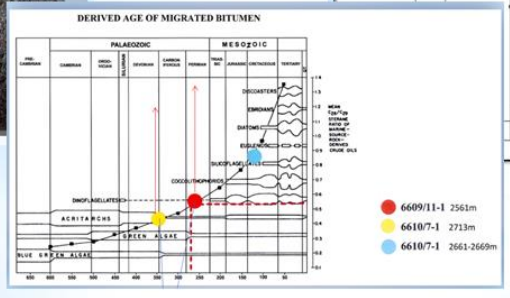
3. **CRETACEOUS SYSTEMS** – e.g. Marulk and Elida – large upside Potential e.g. Vøring
4. **TERTIARY** – certainly good TOC e.g. Vestbakken V.P. - but too diluted?
5. Special case: ONTO THE HIGHS & LONG DISTANCE MIGRATION EASTERN BARENTS SEA

How to Recognize Paleozoic Petroleum Systems?

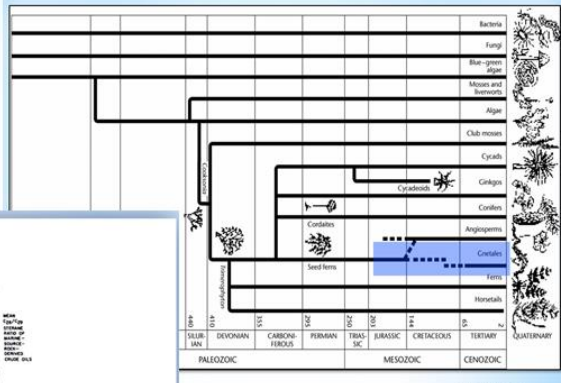
In the past – mainly possible by specific Organo Facies parameters e.g.
Devonian lacustrine – Helgeland 6609/11-1 Ni/V, very light C isotopes, betacarotane

BUT WHAT ABOUT NORMAL MARINE SR DERIVED OILS?
Most oils are from marine SRs – thus e.g. Alum shale derived oils is Boringly Normal
Still Phylogenetic evolution: e.g. cyanobacteria – rich in C29 steranes e.g. Grantham diagram

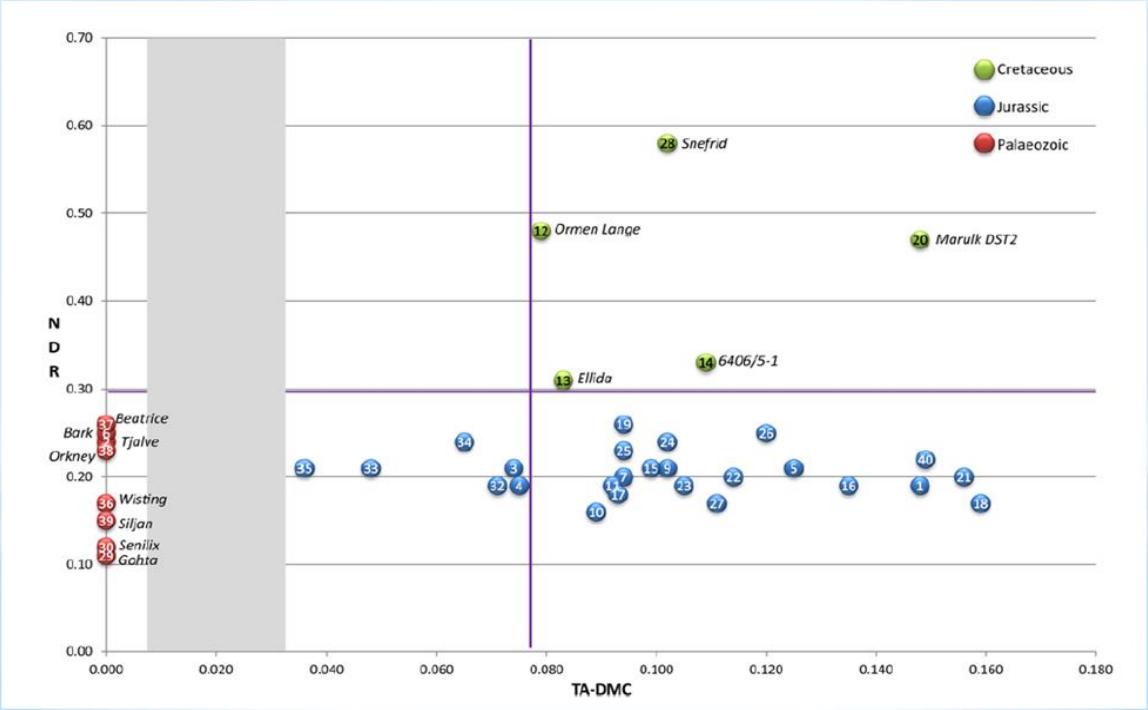




Biomass throughout geological time



Aromatic steroids – Lower Triassic + Paleozoic



Lower-Palaeozoic Pet. Systems – fossil only or still relevant ? Preservation potential?

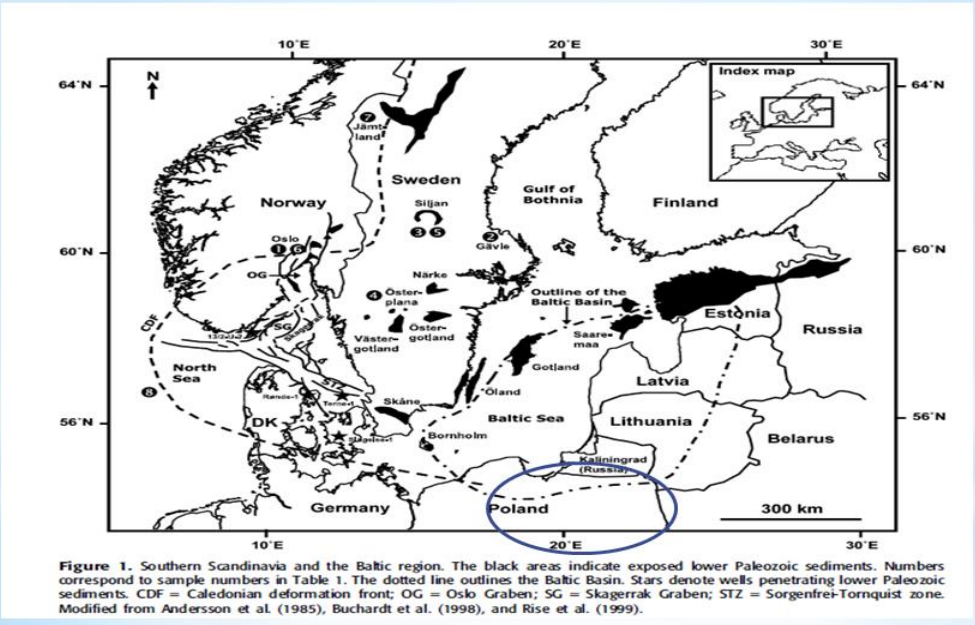


Figure 1. Southern Scandinavia and the Baltic region. The black areas indicate exposed lower Paleozoic sediments. Numbers correspond to sample numbers in Table 1. The dotted line outlines the Baltic Basin. Stars denote wells penetrating lower Paleozoic sediments. CDF = Caledonian deformation front; OG = Oslo Graben; SG = Skagerrak Graben; STZ = Sorgenfrei-Tornquist zone. Modified from Andersson et al. (1985), Buchardt et al. (1998), and Rise et al. (1999).

Lower Paleozoic petroleum from southern Scandinavia: Implications to a Paleozoic petroleum system offshore southern Norway

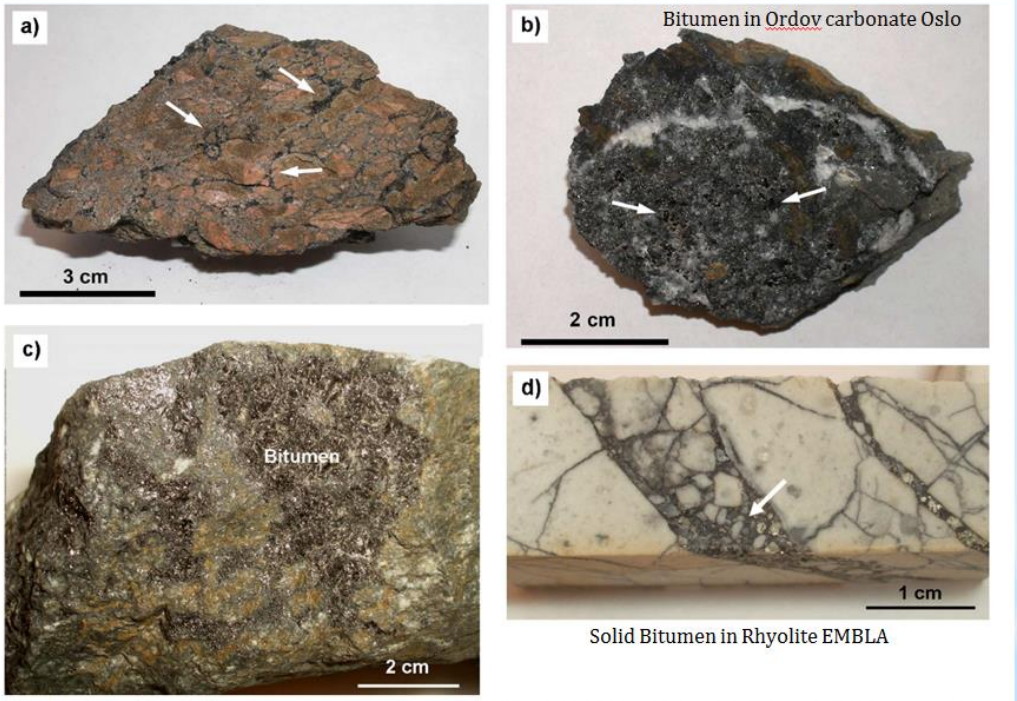
Jon H. Pedersen, Dag A. Karlsen, Nils Spjeldnæs, Kristian Backer-Owe, Jan E. Lie, and Harald Brunstad

AAPG Bulletin, v. 91, no. 8 (August 2007), pp. 1189–1212

All now lately found to function well with the new aromatic age specific biomarker

Extended Abstract

Bitumen In Oslo Permian Lava



Jemtland

Solid Bitumen in Rhyolite EMBLA

Figure 4. Different modes of bitumen occurrences from southern Scandinavia. (a) Bitumen in fractures (arrows) in a Lower Permian lava from the Oslo Graben, Norway; (b) bitumen dispersed in calcite in a Lower Ordovician limestone from the Oslo Graben; (c) bitumen in fractures in a granite from Jämtland, Sweden; (d) bitumen in fractures in an upper Paleozoic rock from Norwegian offshore well 2/7-21 S, the northern North Sea.

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Devonian Pet. System offshore Norway

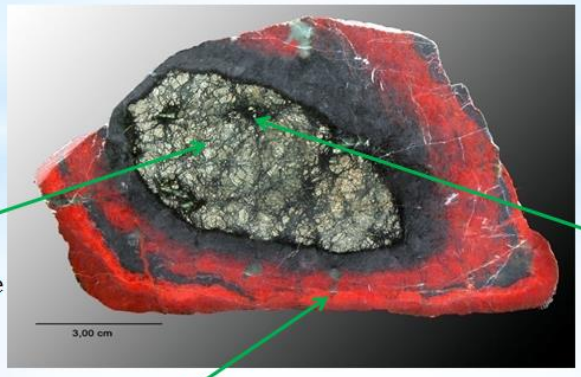
Oslo Graben Silur/Low.Devonian

Clues from possible traces of HC in serpentinized Ultramafic conglomerate from

Solun-Fensfjorden-Kvamshesten Devonian Intra-Montana basins

Lisbeth Helgesen
2008

AndersRønningen
2015 – with SRsamples from Orkneys plus
Helgeland bitumens



Fractured
Peridotite/olivine

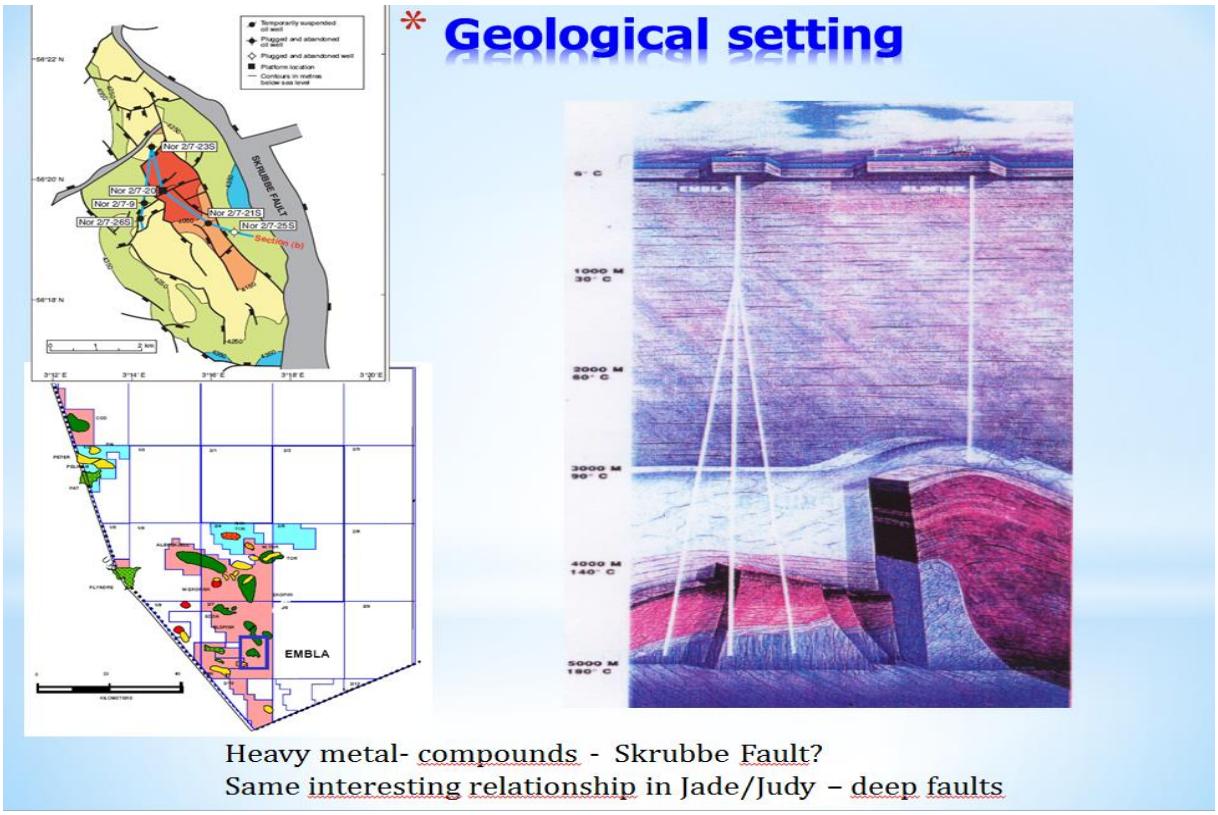
Carbon with
traces of methane

Oil probably invaded Fractured conglomerate

Oxidation zone - weathering

Later deep burial + uplift

Extended Abstract



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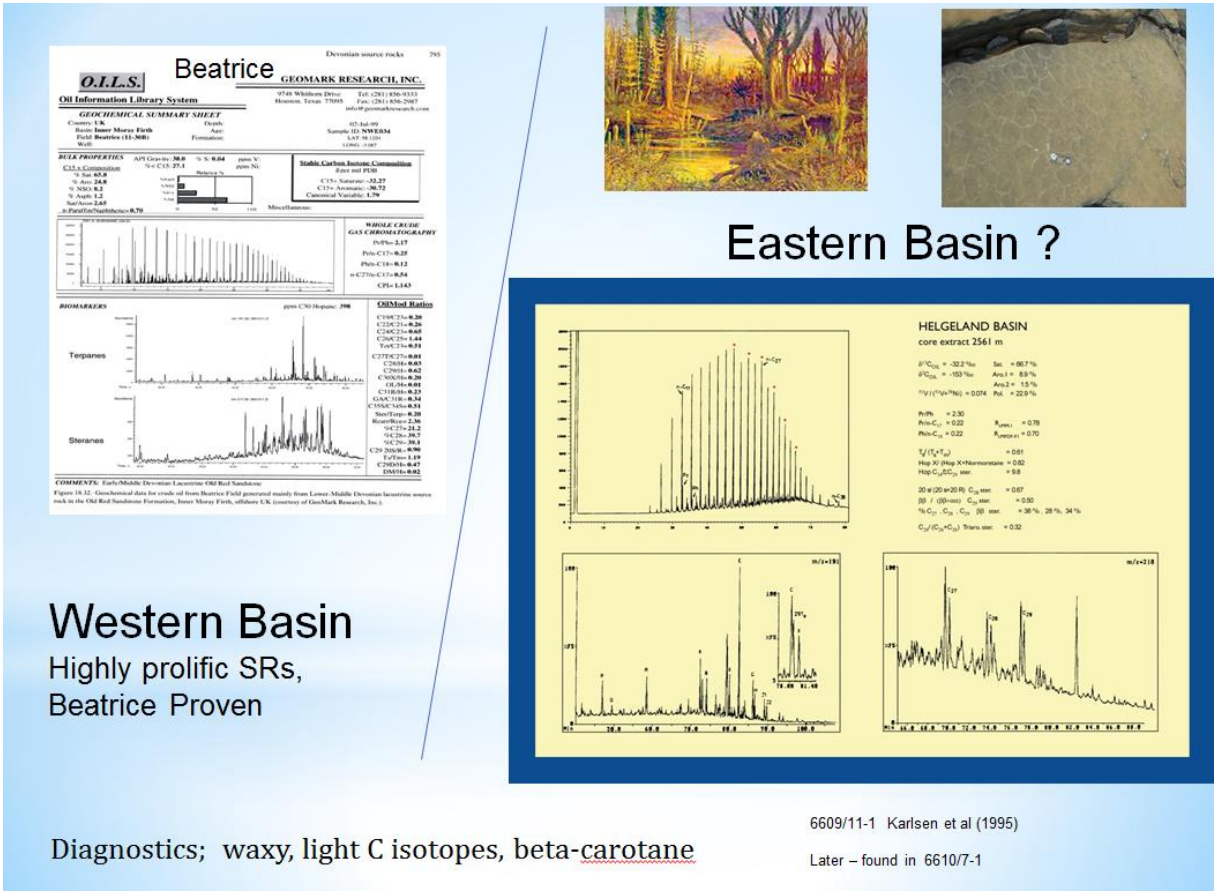


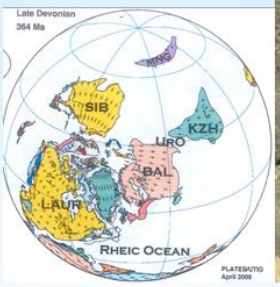
Extended Abstract

Lacustrine lakes

Stromatolites

Multiple
Repeated cycles -
Lunar/varv

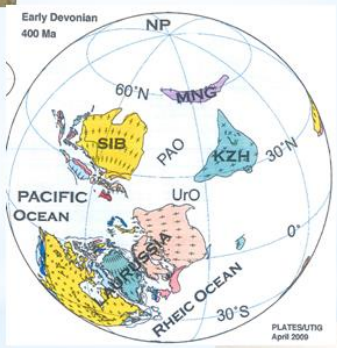
Wind blow
terrestrial dust
Into lakes



Lawver et al. 2011. Arctic Pet. Geology

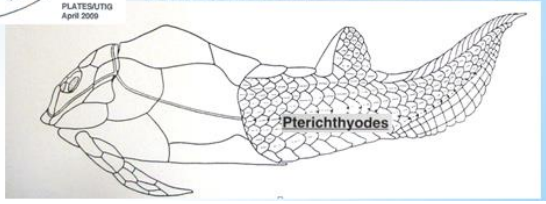
Aeolean mud-crack infill

Mud Cracks



Gypsum Pseudo-morphs

John Fleet Brown: Started as Orcadian Lake – inter-montana – later developed into lagonal – sea connection – sharks etc



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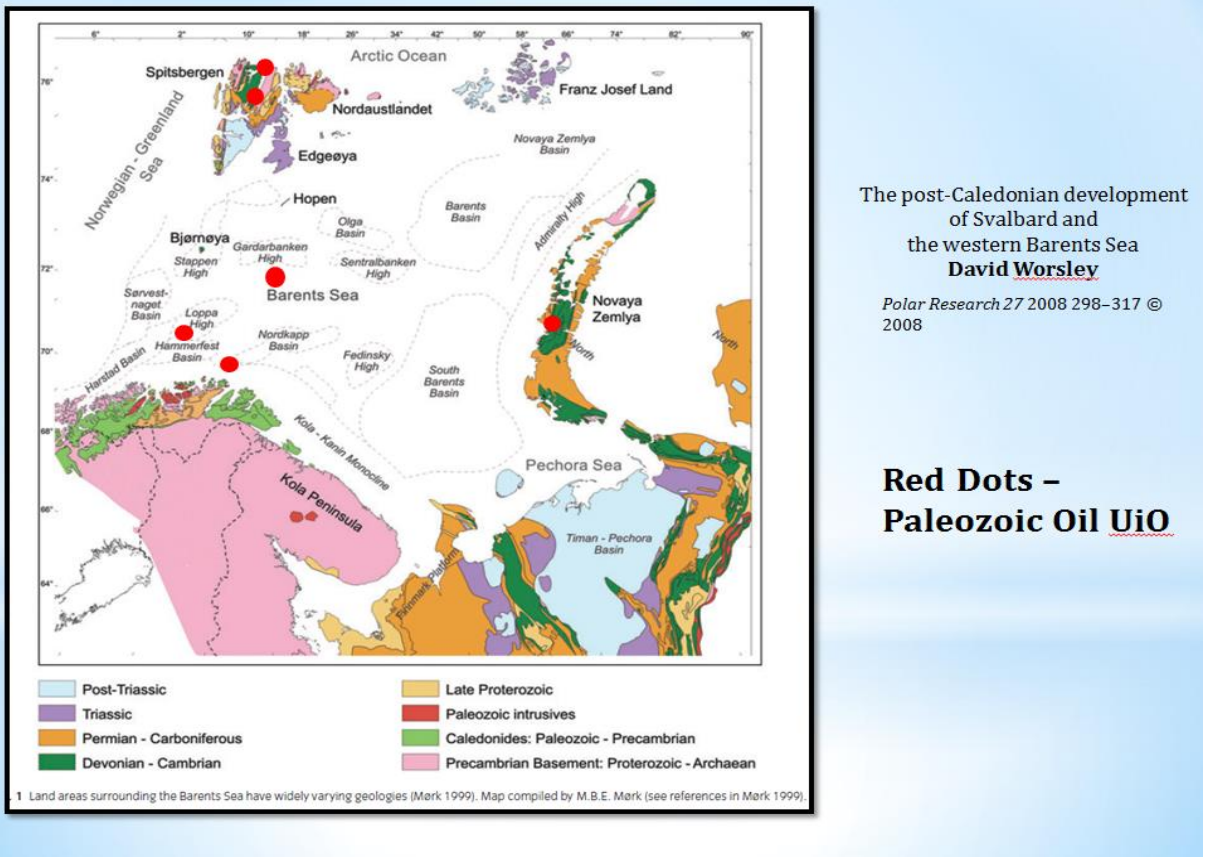


1 Land areas surrounding the Barents Sea have widely varying geologies (Mørk 1999). Map compiled by M.B.E. Mørk (see references in Mørk 1999).

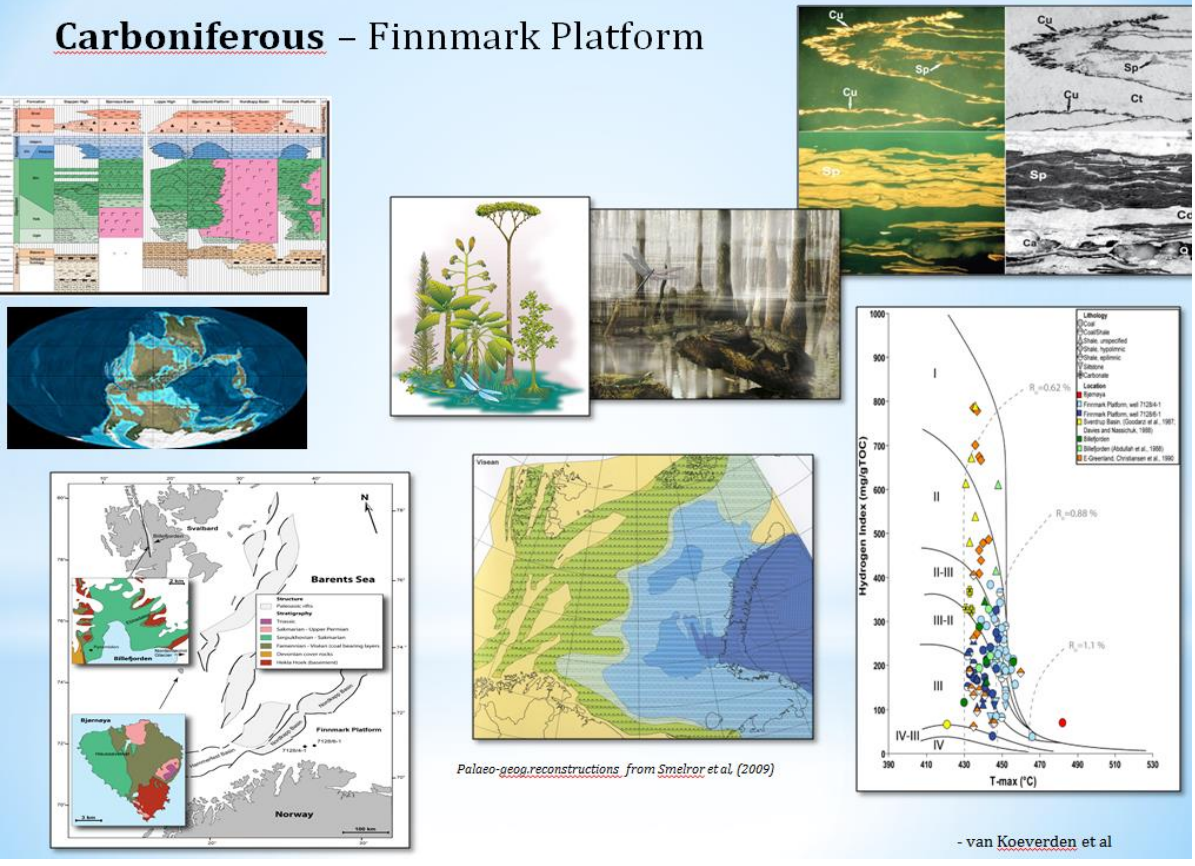
The post-Caledonian development of Svalbard and the western Barents Sea

David Worsley

Polar Research 27 2008 298–317 © 2008

Red Dots – Paleozoic Oil UiO

Carboniferous – Finnmark Platform



Palaeo-geog.reconstructions from Smelror et al. (2009)

- van Koeverden et al

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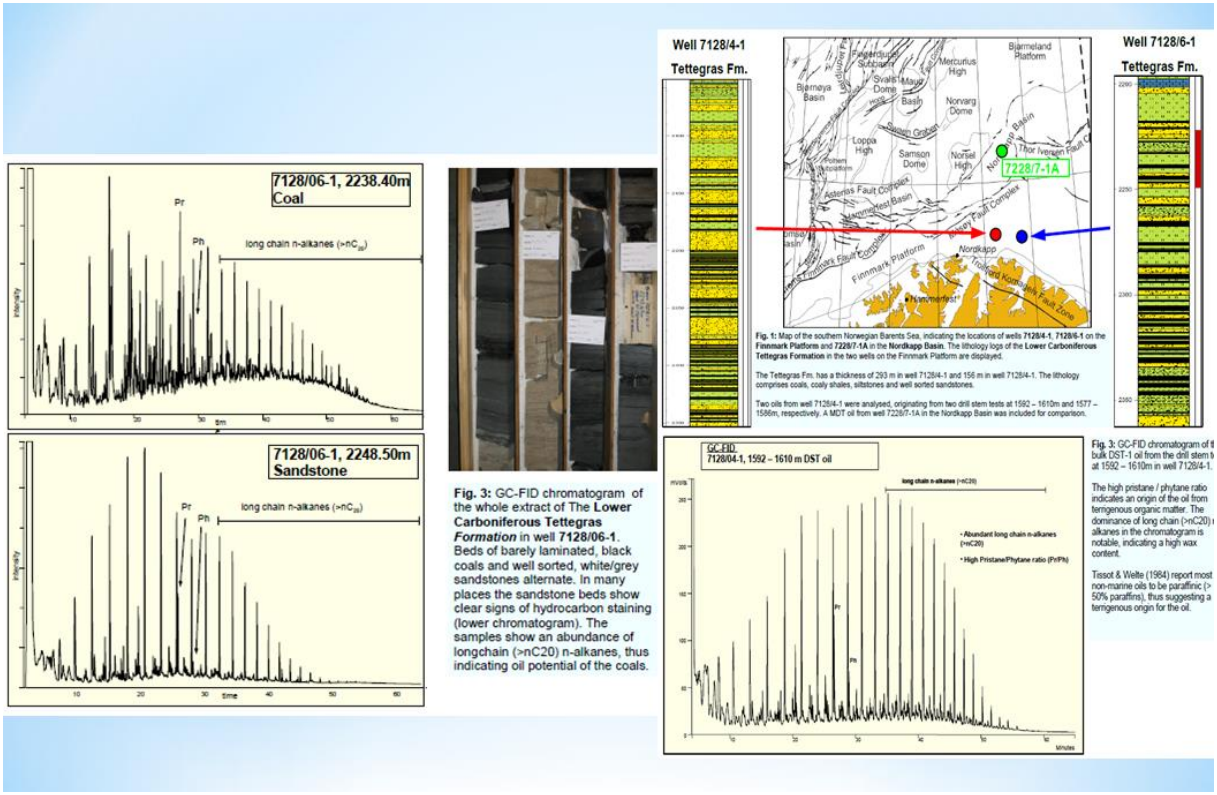

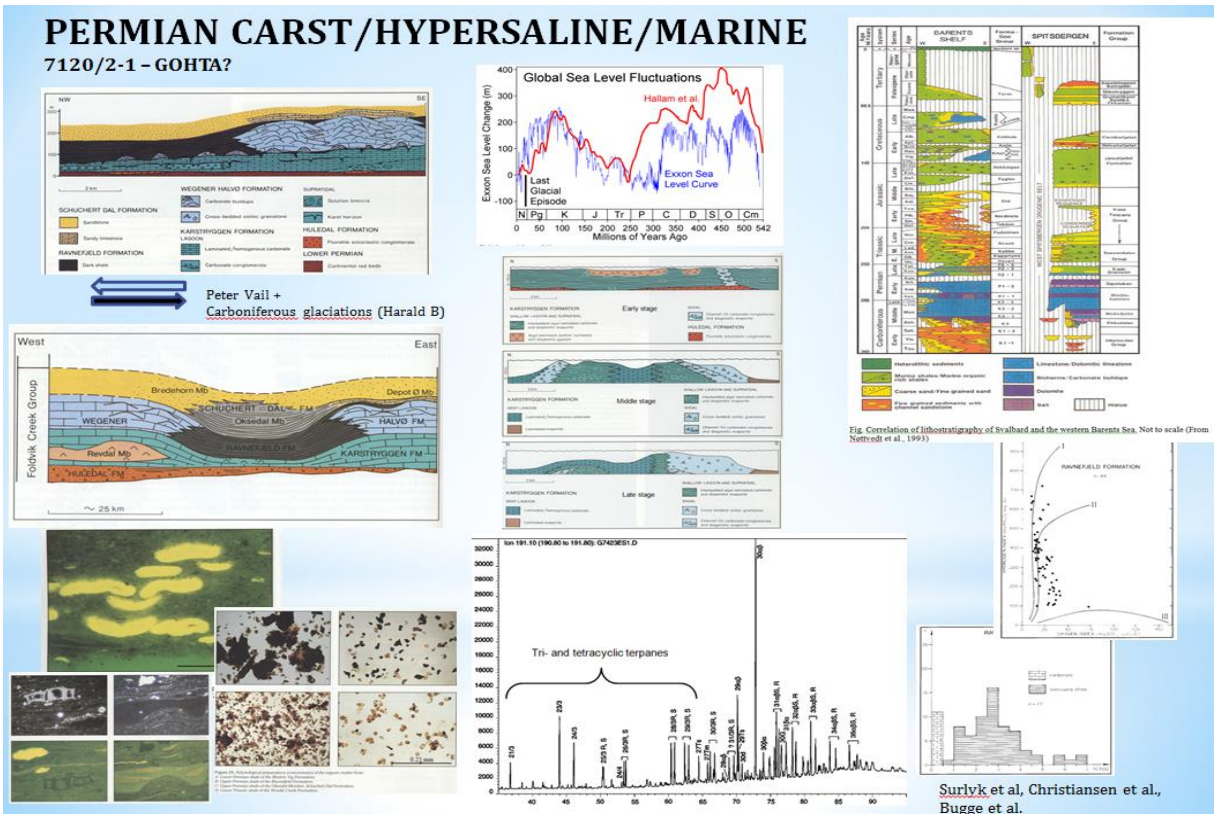

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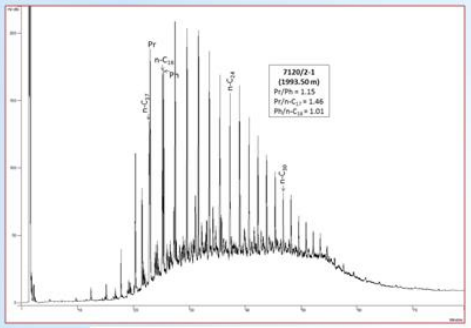
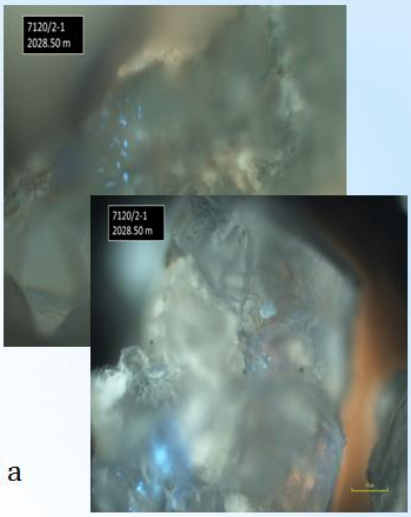
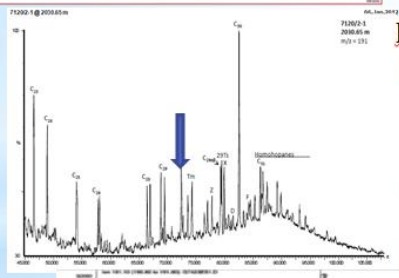
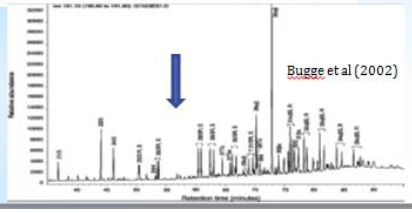
7120/2-1 Sales type III/IV
close to Gohta – now Alta disc.



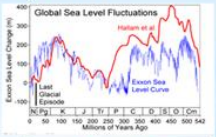




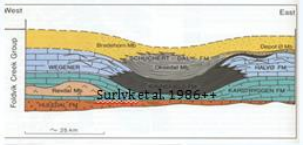
Received a top-up !

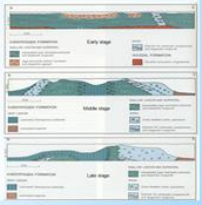


PERMIAN CARST/HYPERSALINE/MARINE
7120/2-1 – GOHTA?

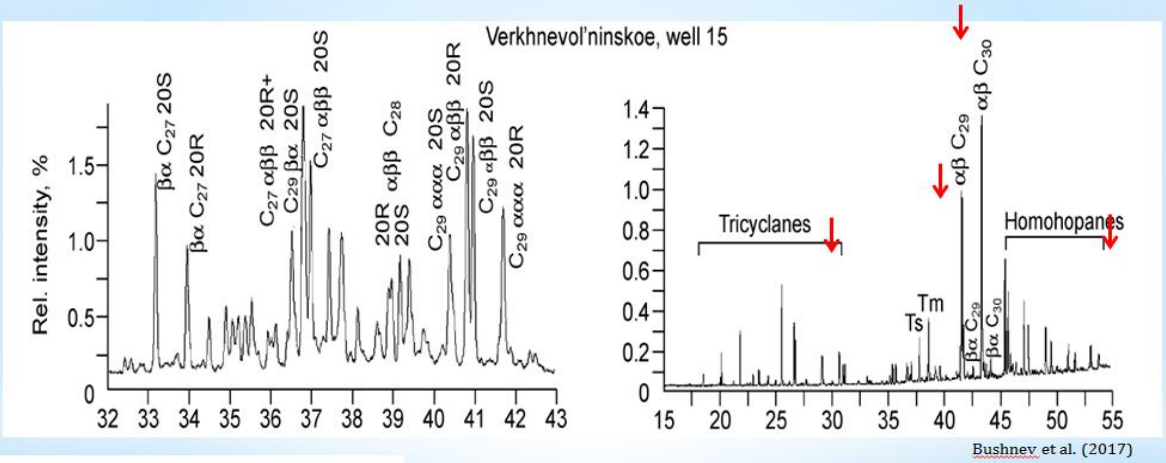


Peter Vail + Carboniferous glaciations (Harald B)

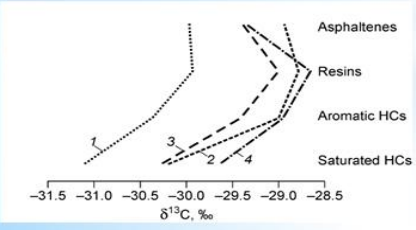




TIMAN-PECHORA – 5 different oil families



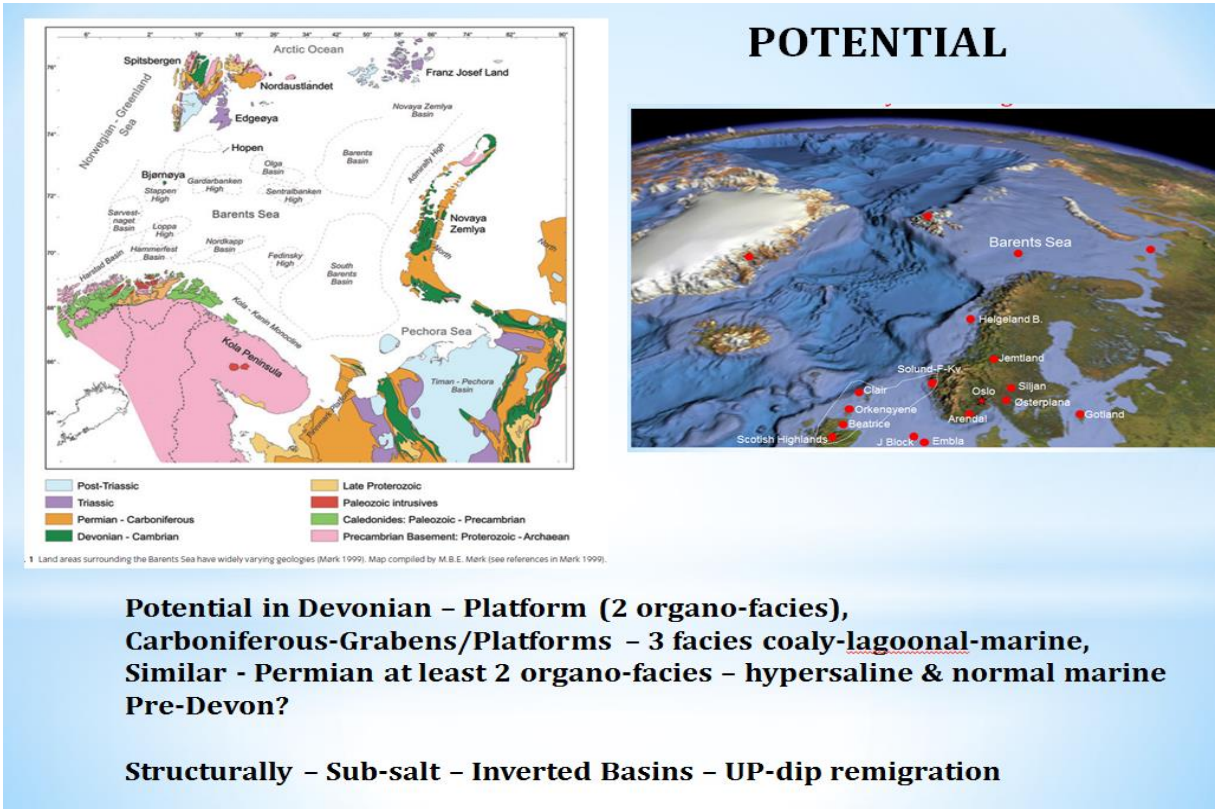
Bushnev et al. (2017)

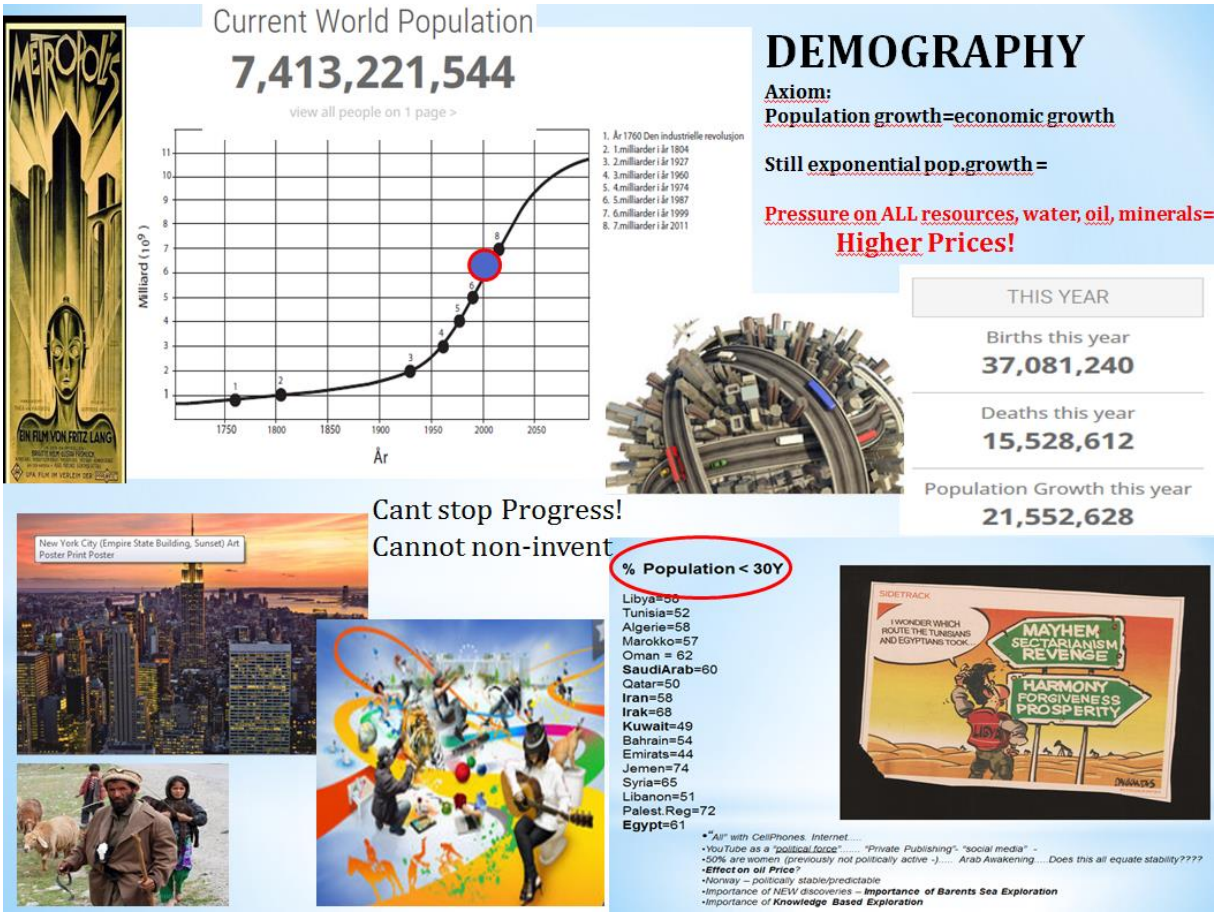


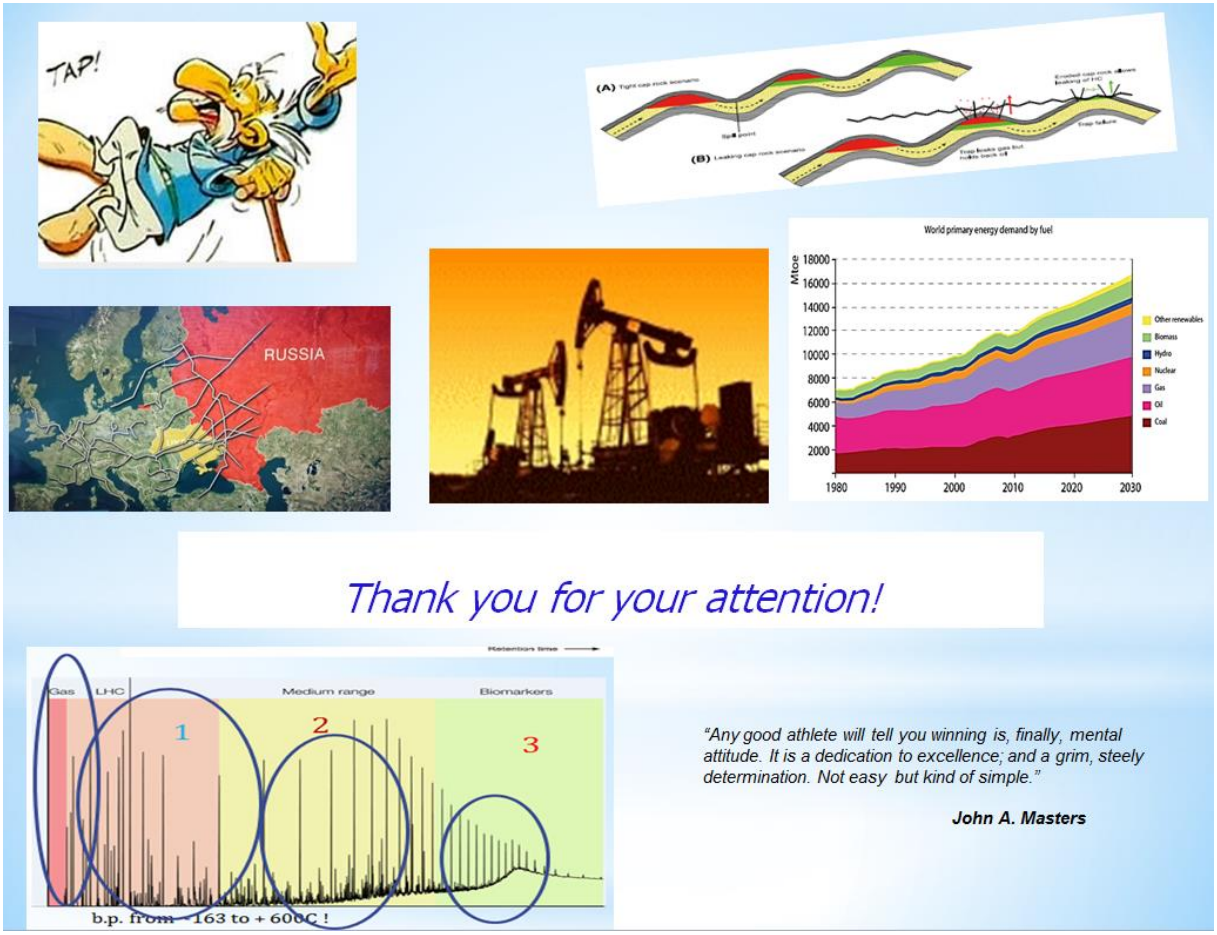
Fransinan
Pr/Ph generally 0.5-1 – 2.5
TOC 3-5%
Hop/Sterane 10 & Higher
Thickness c. 40m
Carbonate Platform, back-arch to silica-richer deep water

Gubikin, 1918; Ukhta Oil Bearing District;
-:- 1975 "The Doctrine of Oil"

Extended Abstract







EXTENDED REFERENCES –GENERIC LIST OF THE MOST RELEVANT PAPERS

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