PS Impact of Depositional Environment on Reservoir Quality and Hydrocarbon Production*

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Abstract

It is a well-established fact that reservoir performance depends on reservoir quality. From alluvial fan deposits, aeolian dune deposits, fluvial channels to deep marine fan deposits, different reservoirs perform differently depending on a number of controlling factors. This project attempts to classify the different sedimentary depositional environments and sub-environments on the basis of hydrocarbon production performance. Other objectives are to establish a link between sedimentary environments and expected maximum well and field production rate. Overall reservoir recovery and recovery factor. To postulate best sedimentary environments in terms of overall hydrocarbon production performance. Primary data for this project is from the Norwegian North Sea, Norwegian continental shelf and the Barents Sea. These data were analysed to generate production curves, cumulative production and recovery factors.

Using wireline logs, cores and few seismic sections the fields were all classified into the different sedimentary environments and sub-environments used for the project. Other additional parameters derived which were useful for the project include trap type and geometry, prospect size, reservoir thickness, net-to-gross, number of production and injection wells, reservoir depth of burial, faults and compartmentalization. The reservoirs fall into three gross depositional environments: Paralic/shallow marine, Deep marine and Continental. Paralic/shallow marine oil maximum well rate ranges from 1800,000-143 Sm^3/day, highly varied recovery factor from 80-3% depending on architectural elements, the reservoirs were buried from 4,241-2,150 m. Deep marine reservoirs have oil maximum well rate from 1,404-134 Sm^3/day, recovery factor from 77-11% less varied within sub-environments, reservoir depths are from 4,000-1,700 m. Continental reservoirs oil maximum well rate ranges from 907-202 Sm^3/day, recovery factor is highly variable from 83-2% in some sub-environments, buried from 4,061-2,800 m. Paralic/shallow marine reservoirs have high oil discharge rates at initial phase of production, however recovery was not sustained, lower shoreface reservoirs have better recovery than backshore and foreshore. Deep marine reservoirs yield good volume, better recovery and good sweep. In continental reservoirs good initial well discharge is inconsistent with recovery, hence large volume discovered cannot be produced due to poor recovery.

IMPACT OF DEPOSITIONAL ENVIRONMENT ON RESERVOIR QUALITY AND HYDROCARBON PRODUCTION

SAFARI

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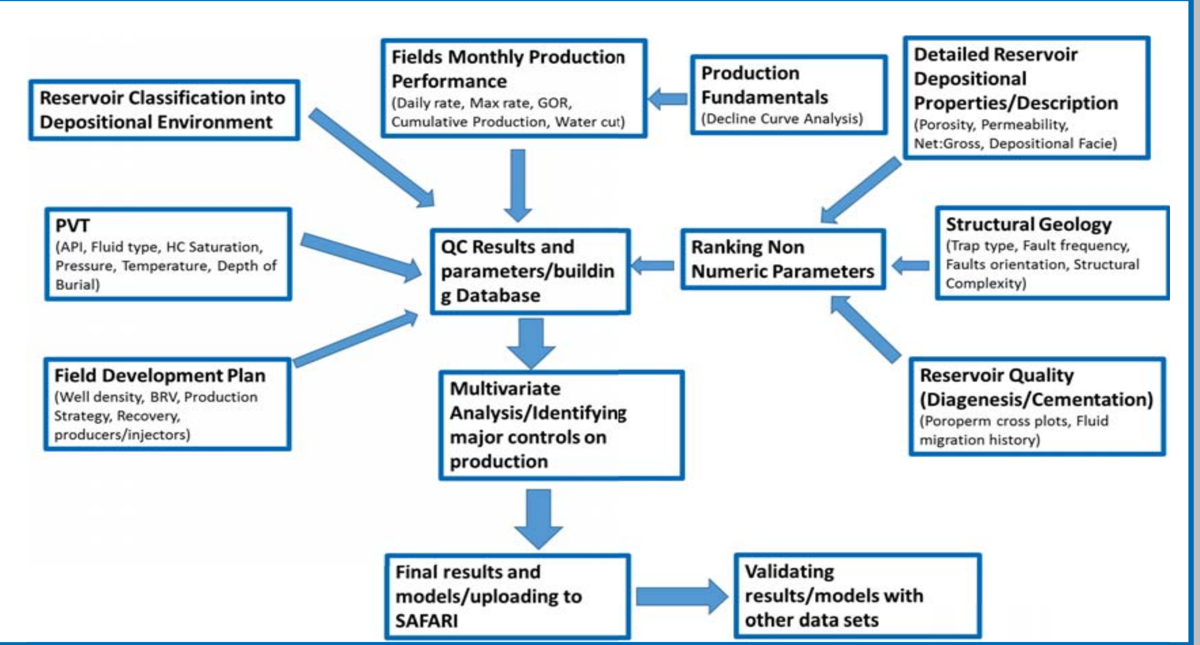
Aims

Reservoir performance is controlled by a number of factors both geological and engineering. Geological factors originate in the depositional environment and are modified by diagenetic and structural changes during burial. Engineering parameters include, the production mechanism, the number of wells, well completions etc.

The goal of this study is to examine the unique production database from the Norwegian Continental Shelf in order to attempt to unravel the importance of the various controls on reservoir performance with special reference to the impact of depositional environment and the primary facies architecture.

The work has been based on the monthly production data for 55 fields and analysed to try and determine which impacts production.

Workflow



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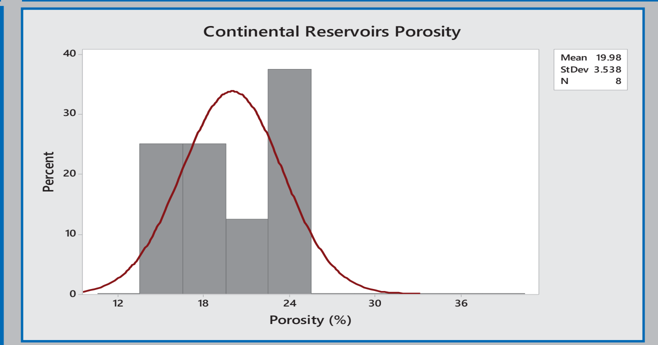

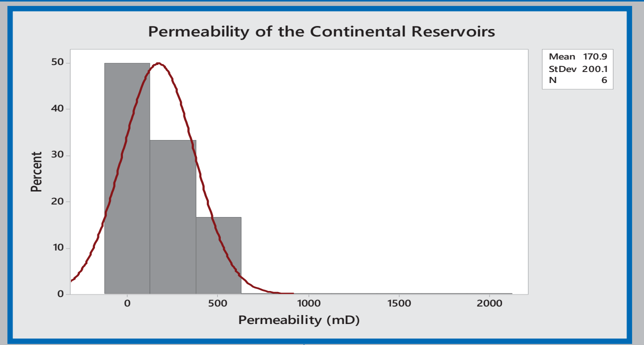

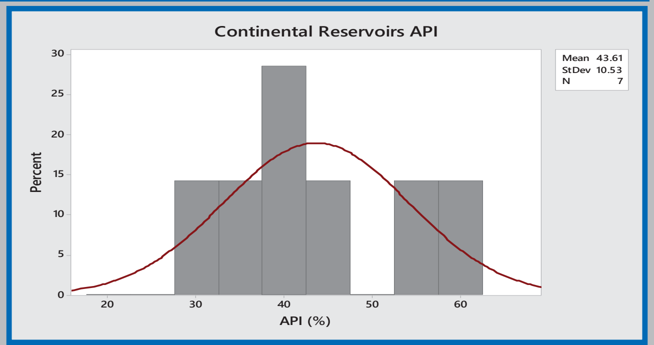

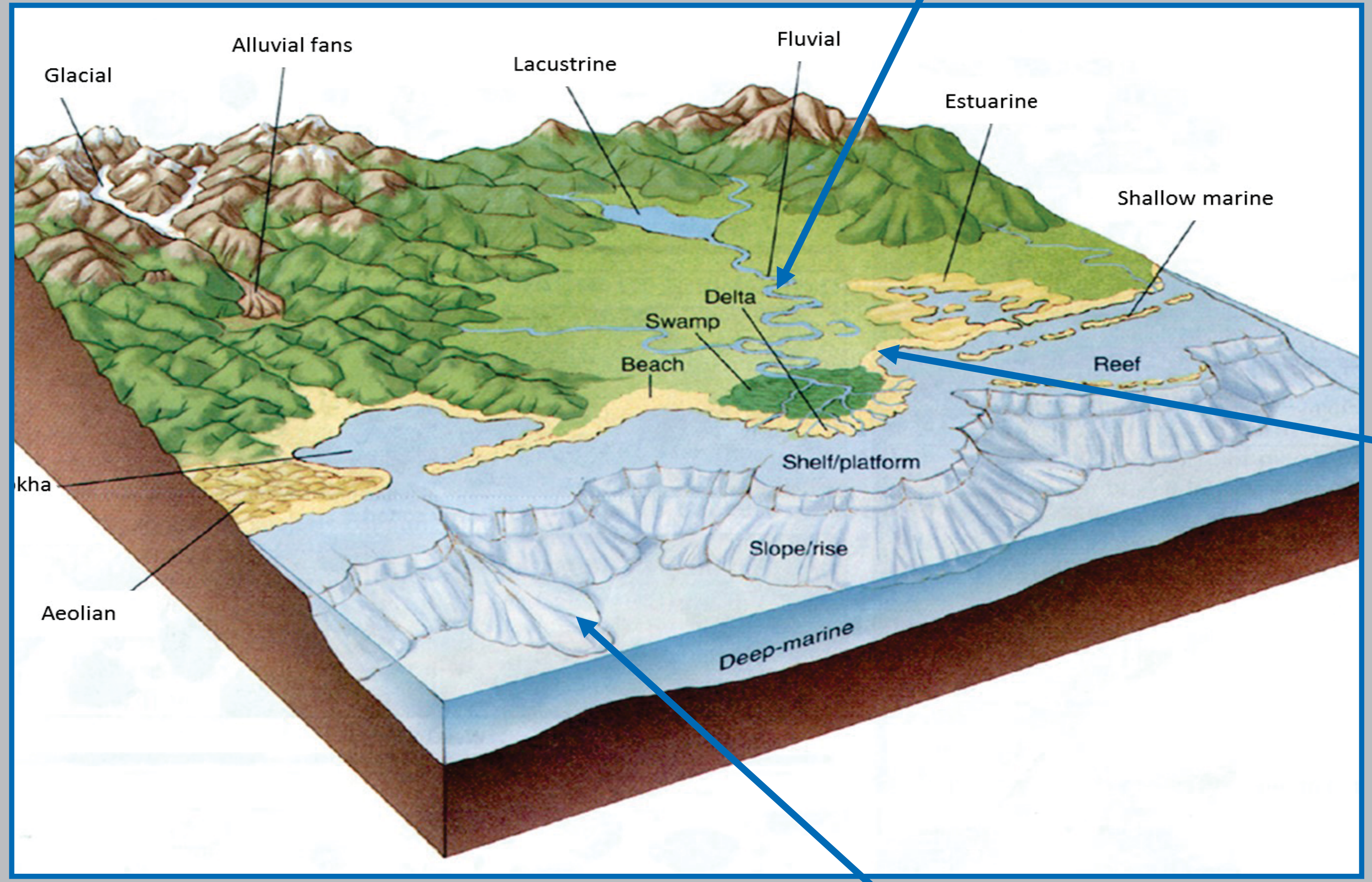

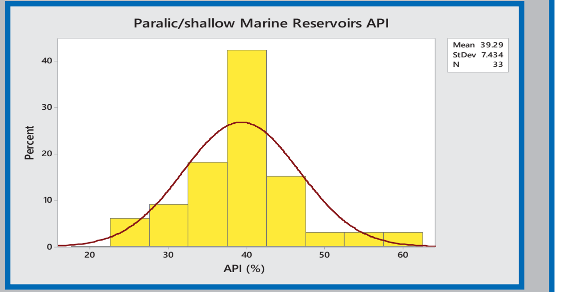

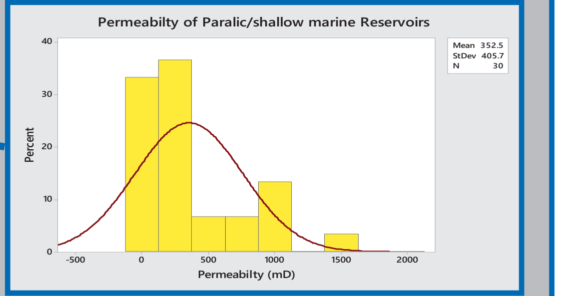

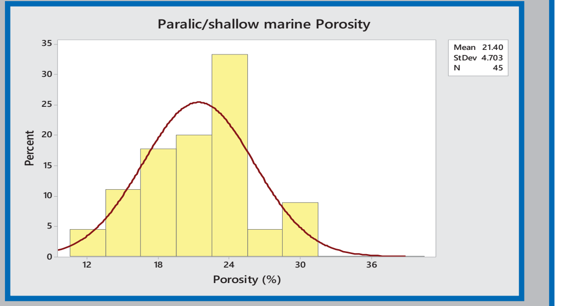

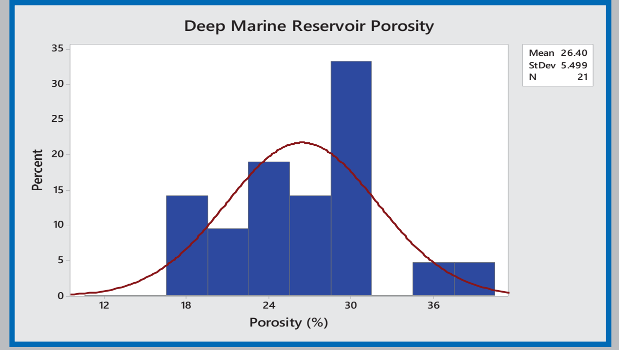

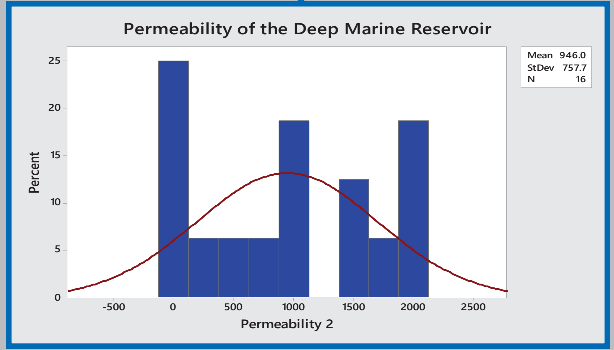

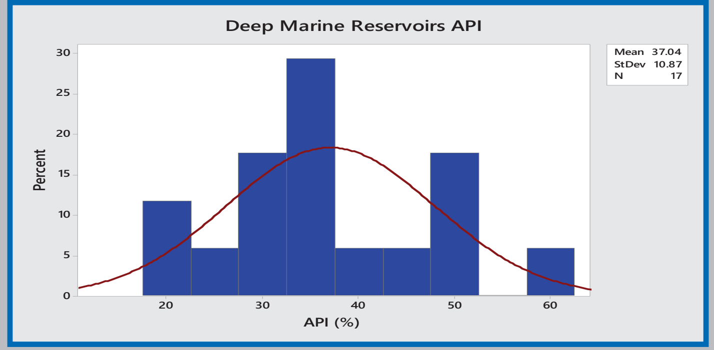

Data

This work considered production data from all the fields in the Norwegian North Sea, Norwegian Sea and the Barents Sea. Fifty-five of the 90 producing fields on the NCS were utilised. Fields were excluded because they were carbonate (9), lacked sufficient data (19) or had co-mingled production from multiple reservoir zones (7)

Parametres recorded for each field include:

Geological

- Depositional environment (with SAFARI Schema)
- Structural complexity Production profile
- Mean Porosity
- Average Permeability
- Reservoir Depth
- Reservoir Net:Gross
- Total reservoir volume

Fluids and Engineering

- Hydrocarbon API
- Drive mechanism
- Number of producing wells
- Wells per unit volume

Metrics

- Recovery Factor (estimated for end of field life)
- Initial well rates
- Maximum oil well rate

Table 1, 2, 3, 4 —List of fields included in the current study, also shown in the adjacent map. These are classified as continental, shallow marine or deep marine. Lithostratigraphy of the Norwegian North Sea and Norwegian Sea. Continental reservoirs are highlighted in brown, shallow marine in yellow and deep marine in green. The Cretaceous chalk reservoirs are in light blue. Most of the Continental reservoirs are Triassic. The Paralic/shallow Marine reservoirs are mostly Middle and Upper Jurassic. The Deep Marine reservoirs are mostly Palaeocene while a few are Cretaceous (NPD, 2016).

About SAFARI

SAFARI is an on-going Joint Industry Research Project at UniResearch CIPR and the University of Aberdeen supported by a consortium of currently 16 Oil Companies, the Research Council of Norway and the Norwegian Petroleum Directorate. The goal of the SAFARI project is to develop a fully searchable repository of geological outcrop data from clastic sedimentary systems for reservoir modelling and exploration.

The SAFARI project includes a fully searchable database that is accessed through the website www.safaridb.com The site includes:

Information from 350 outcrops, including descriptions, logs, photos, sections, reservoir models

Over 200 of these sections have photo realistic 3D models (Virtual Outcrops) that allow the user to fly around the outcrop in a purpose built web browser

A tool for identifying modern analogues to reservoirs in GoogleEarth

Over 6500 geometric measurements of reservoir elements from outcrops

Variograms and MPS training images extracted from outcrop analogues

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1

Field name (Reservoirs)	Age	Gross Depositional Environment
EMBLA	Lower Permian	
GULLFAKS SOR 2	Lower Jurassic	
GAUPE	Late Triassic	
GUNGNE	Upper Triassic	
SIGYN	Upper Triassic	
GULLFAKS 2	Lower Jurassic	
SNORE 1	Upper Triassic	
SNORE 2	Upper Triassic	Continental
HULDRA 1	Middle Jurassic	
HULDRA 2	Middle Jurassic	
TUNE 2	Upper Jurassic	
TUNE 1	Upper Jurassic	
VOLVE	Middle Jurassic	
MIKKEL	Middle Jurassic	
OSEBERG 1	Middle Jurassic	
OSEBERG 2	Middle Jurassic	
TRYM 2	Bojacian	
TRYM 1	Bojacian	
KRISTIN 2	Middle Jurassic	
KRISTIN 1	Middle Jurassic	
ALVE 2	Middle Jurassic	
ALVE 1	Middle Jurassic	
NORNE 2	Upper Jurassic	
NORNE 1	Middle Jurassic	
HEIDRUN 2	Lower Jurassic	
SNOHVIT	Upper Jurassic	
HEIDRUN 1	Middle Jurassic	
FROY	Middle Jurassic	
MIME	Lower Jurassic	
TAMBAR	Lower Jurassic	
GYDA	Lower Jurassic	
VALE	Middle Jurassic	
TYRIHANS	Middle Jurassic	
LILLE FRIGG	Early Bathonian	
ULA	Upper Jurassic	
BRYNHILD	Upper Jurassic	
YME	Upper Jurassic	
GULLFAKS SOR 1	Middle Jurassic	
VARG	Upper Jurassic	
FRAM 3	Middle Jurassic	
OSEBERG SOR 2	Middle Oxfordian	
OSEBERG SOR 1	Middle Bajocian	
STATFJORD OST	Middle Jurassic	
SKIRNE	Middle Jurassic	
GJOA 2	Middle Jurassic	
FRAM 2	Upper Callovian	
BRAGE 2	Upper Jurassic	
GJOA 1	Upper Jurassic	
BRAGE 1	Middle Kimmeridgian	
FRAM 1	Upper Jurassic	
GULLFAKS 1	Middle Jurassic	
DRAUGEN	Late Jurassic	
TROLL	Upper Jurassic	
SLEIPNER VEST	Middle Jurassic	Paralic/Shallow Marine
MARULK 2	Lower Turonian	
MARULK 1	Upper Turonian	
STATFJORD NORD	Upper Jurassic	
SLEIPNER OST	Paleocene	
GLITNE	Paleocene	
ALVHEIM	Paleocene	
HEIMDAL	Paleocene	
NORDOST FRIGG	Lower Eocene	
OST FRIGG	Lower Eocene	
SVALIN	Upper Paleocene	
GRANE	Paleocene	
BLANE	Upper Paleocene	
COD	Upper Paleocene	
FRIGG	Lower Eocene	
OSELVAR	Upper Paleocene	
JOTUN	Paleocene	
VOLUND 1	Upper Paleocene	
BALDER 1	Paleocene	
VOLUND 2	Eocene	
BALDER 3	Upper Paleocene	
BALDER 2	Eocene	Deep Marine

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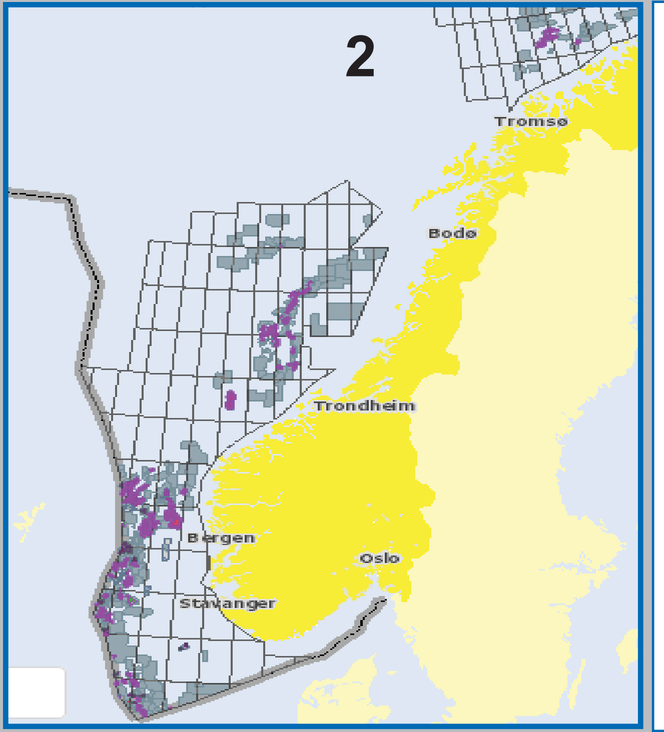

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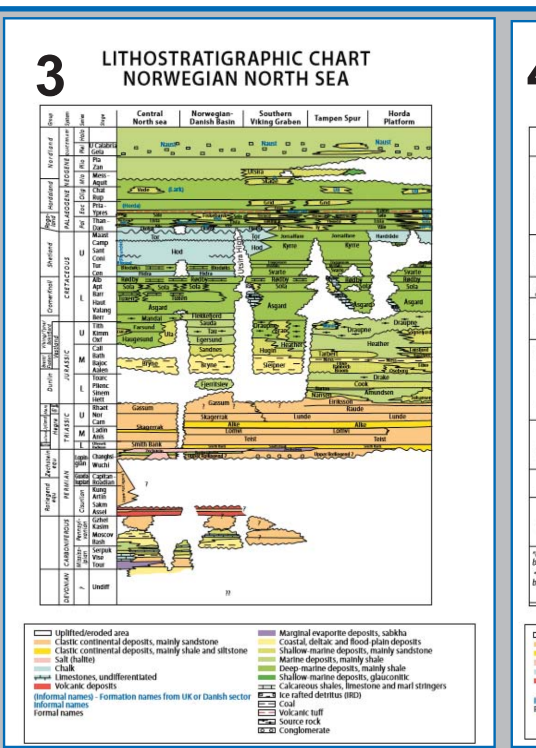

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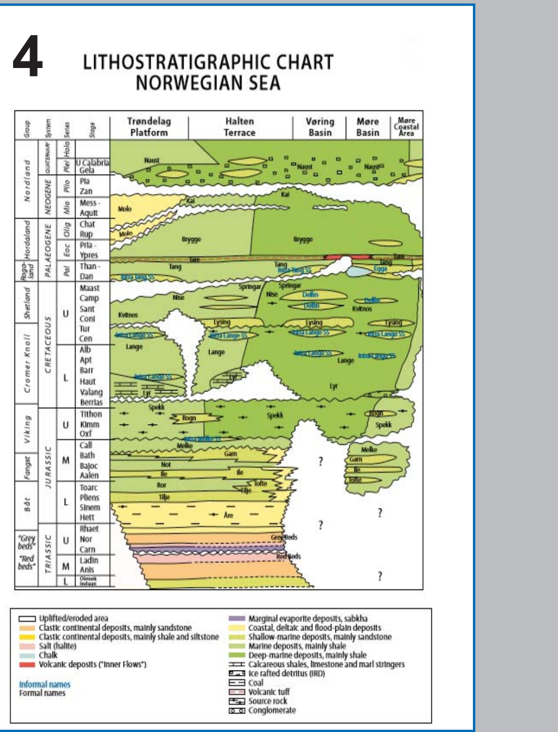
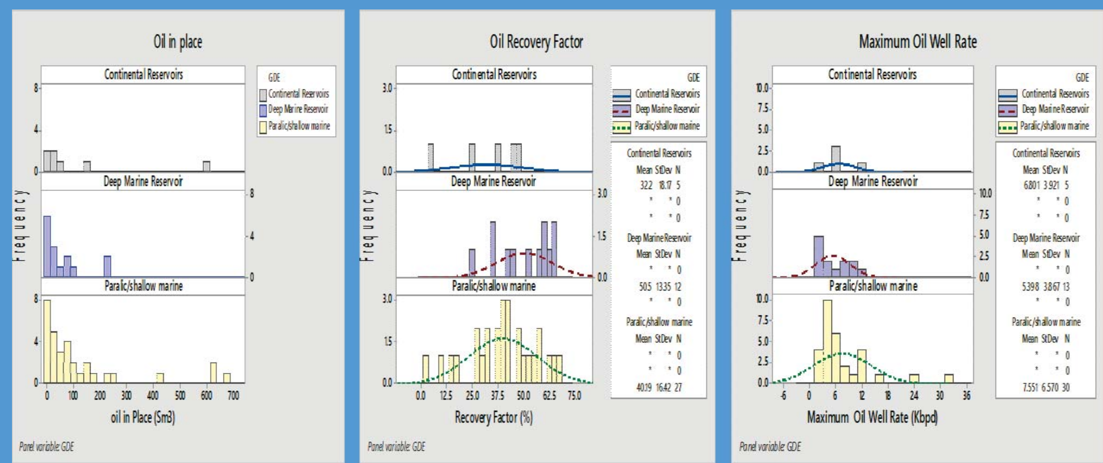
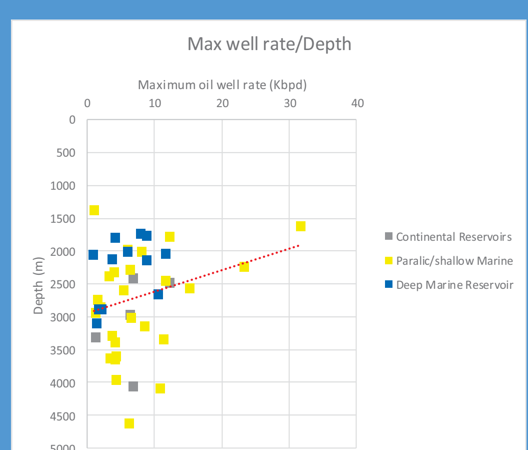


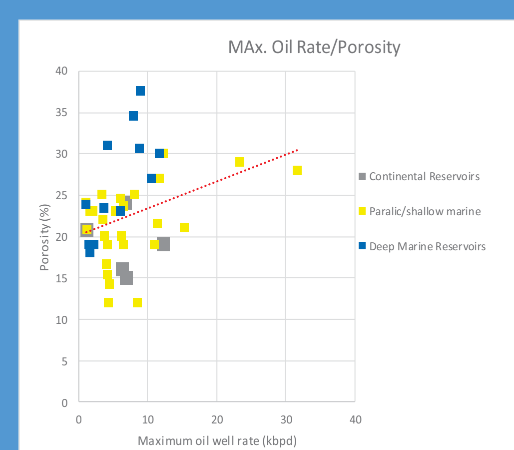
Depositional Controls on Production



Frequency Distribution Plots of the key metrics by depositional environment . The shallow marine reservoirs are typically the largest However Deep Marine have the best recovery factors. Individual well rates seem to be independent of depositional environment

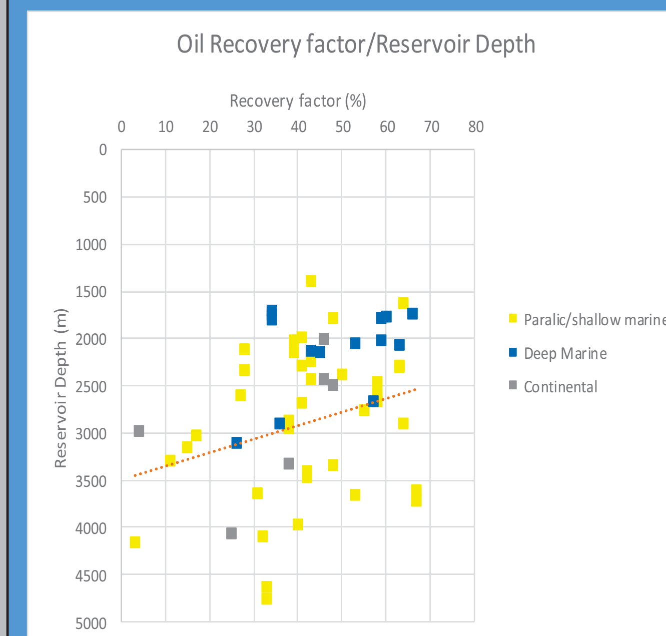
What controls Maximum well rate?



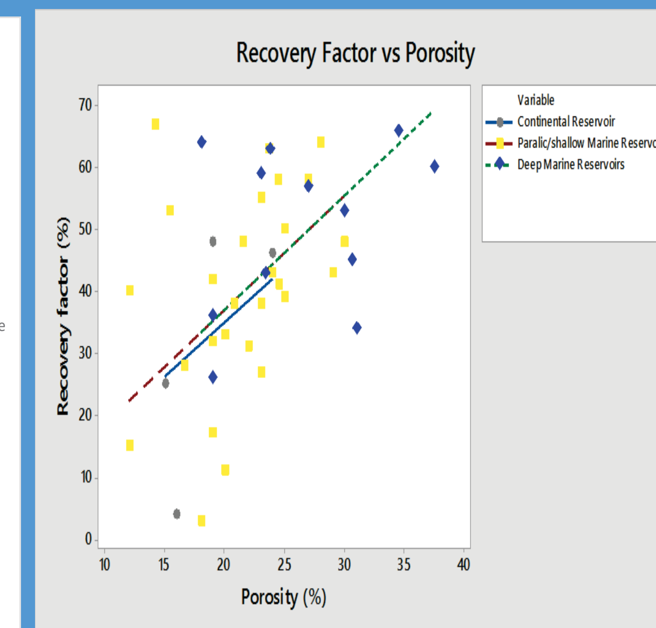


Maximum well rate is controlled by depositional environment. With shallow marine reservoirs performing better than fluvial or deep marine. This in turn is not clearly a function of depth or average field porosity, suggesting that facies architecture is also important

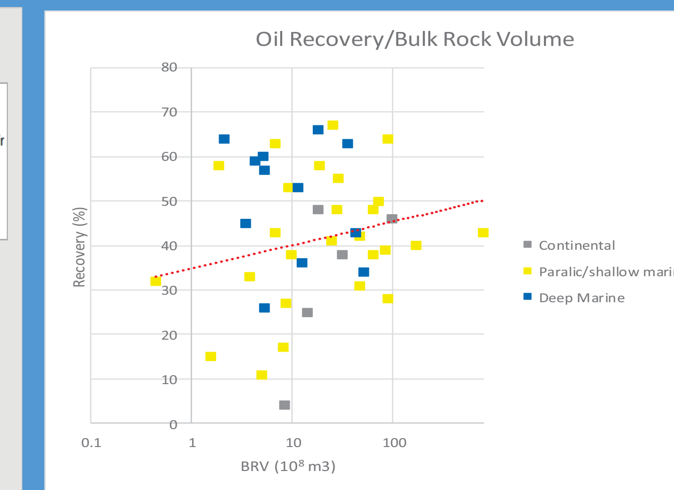
What controls recovery factor?



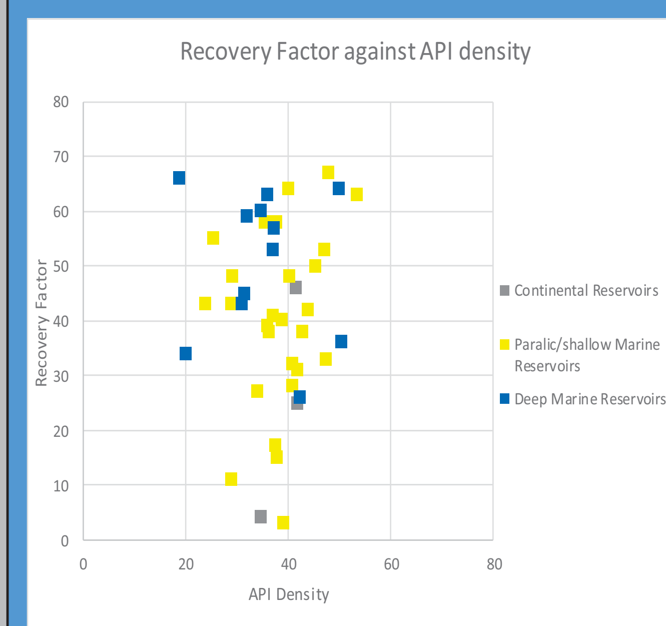
There is a relationship between RF and depth



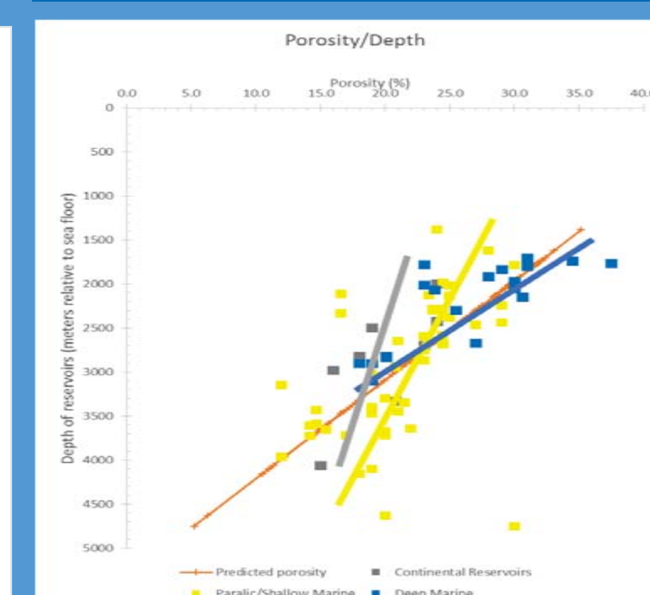
RF is related to average field porosity and reservoir depth



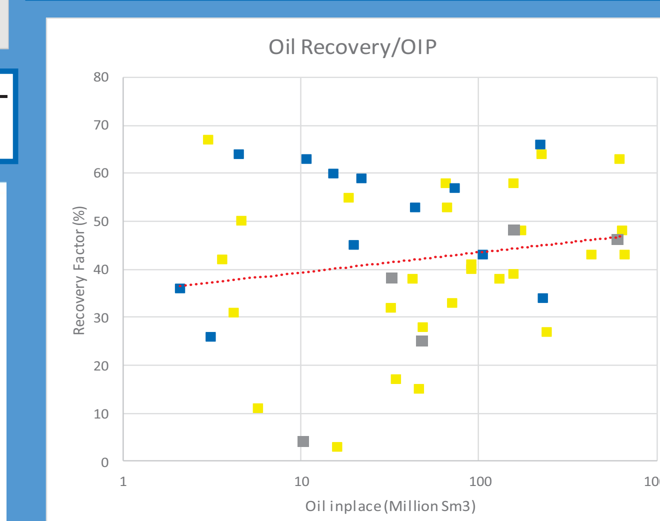
No relationship between RF and field size



The depth relationship is not a function of depth dependent API

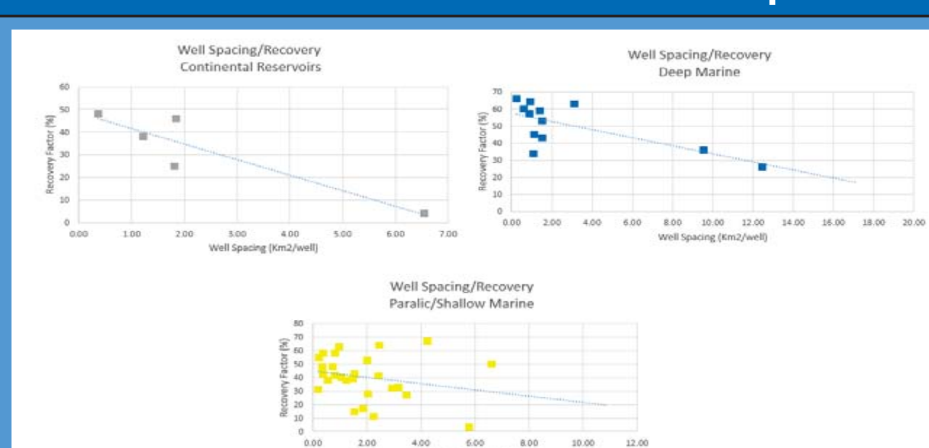


Average field porosity is a function of depth with different vertical trends for the different environments

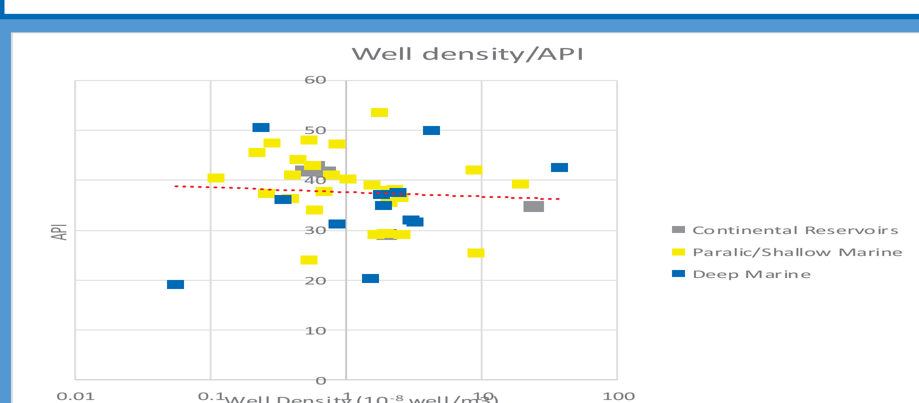


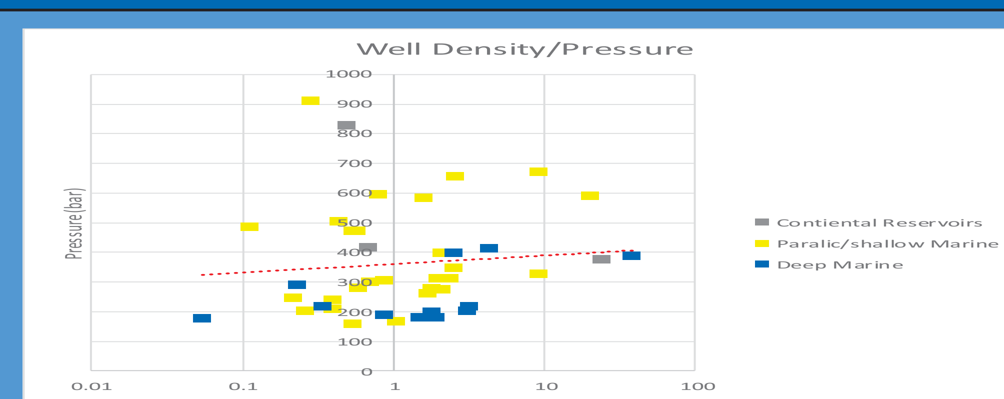
Recovery Factor is a function of porosity and depositional environment. It is not dependent upon field size, bulk rock volume or API. Deep marine reservoirs have better average recovery factor (50.5%) than Paralic/shallow marine (40.19%) and Continental Reservoirs (32.2%). Deep marine is blue, Paralic/shallow marine yellow and Continental reservoirs in

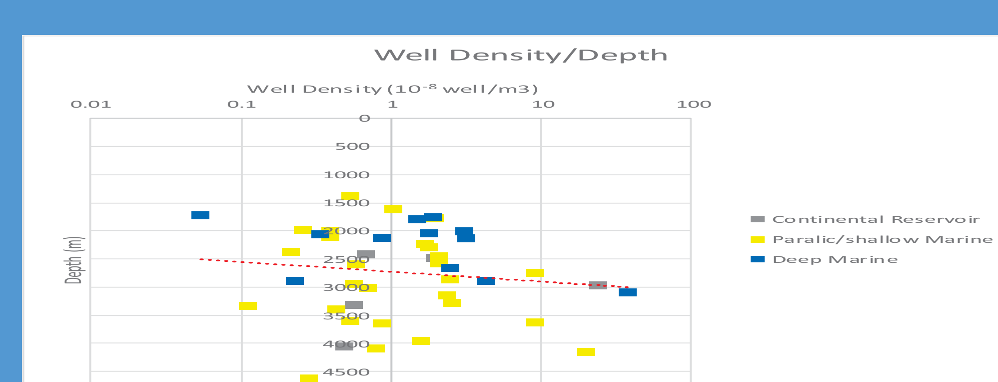
Importance of well density



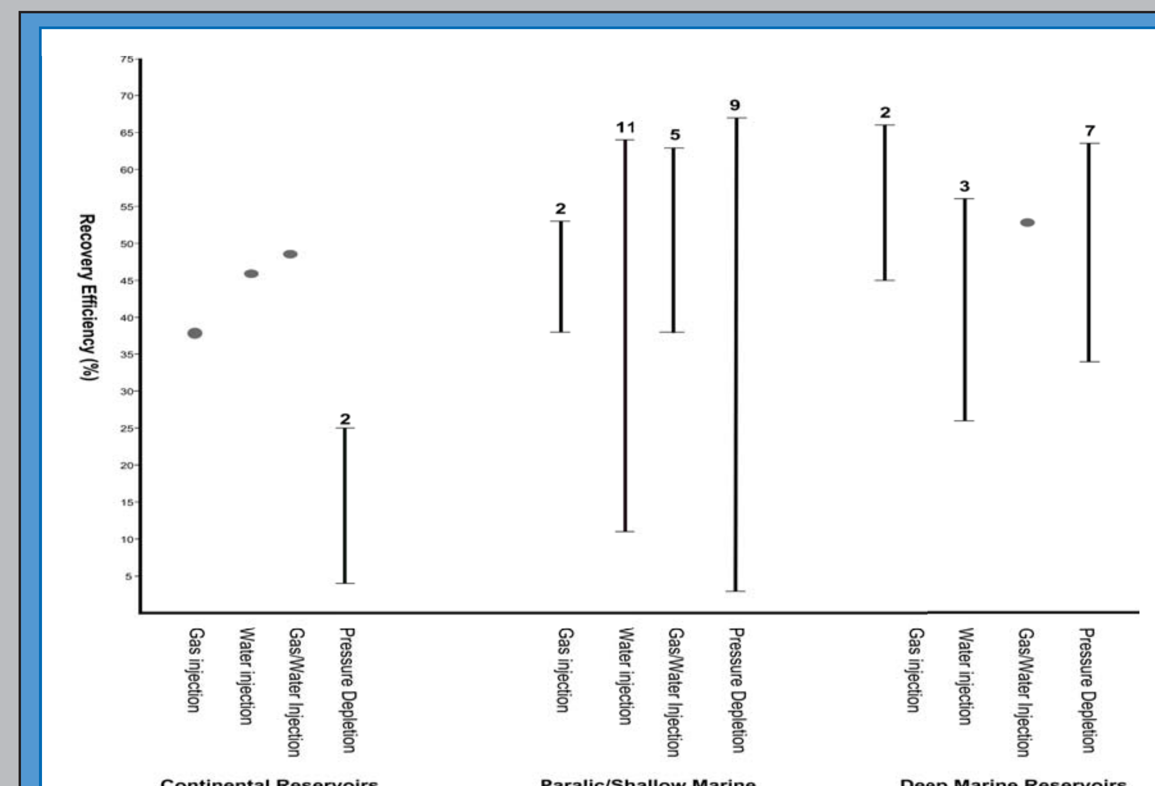
Well density vs recovery—there is no obvious link between well density and recovery however wells in the fluvial systems have a higher density and is fairly related to recovery.







There is no correlation between well density and API which is somewhat surprising. Lower APIs were anticipated to be associated with higher well density. There is also no relationship between well density and reservoir pressure or depth



Interestingly there is also very little correlation between recovery factor and drive mechanisms. This plot highlights the low recoveries in the fluvial reservoirs, the wide range in the shallow marine and the higher range in the deep water. The absence of a clear link between drive mechanism and recovery factor suggests that the individual fields are optimised in terms of structural complexity and fluid properties

Conclusion

- Reservoir performance is measured by field size, recovery factor, maximum well rate and well density (required to drain field)
- Performance of oil fields varies for the three gross depositional environment in the Norwegian continental shelf. Deep marine reservoirs have better recovery followed by paralic/shallow marine then continental reservoir. Shallow marine reservoir show the greatest spread.
- Depth of burial is a key factor, specifically its control on porosity and permeability. It is one of the underlying parameters controlling performance of the three GDE
- API is less important
- There is no clear link between RF and well density suggesting other aspects are also important
- Field size and field volume are not indicators of reservoir performance
- This work established the impact depositional environment have on oil field performance.

Selected Reference

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