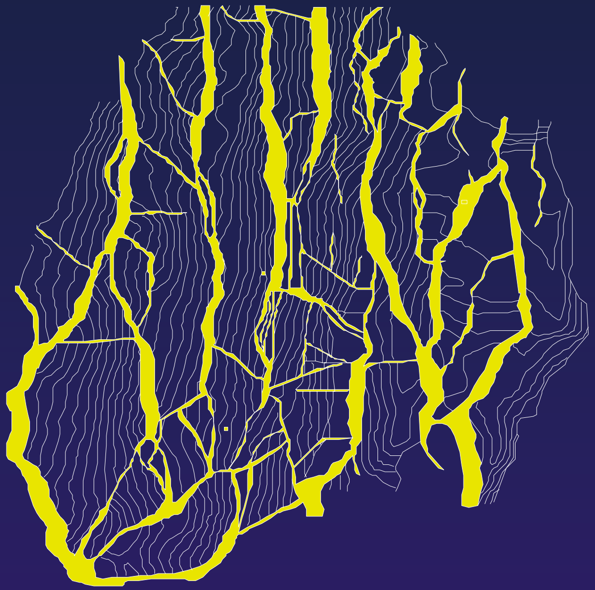
THE GULLFAKS FIELD



A MODELLING CHALLENGE

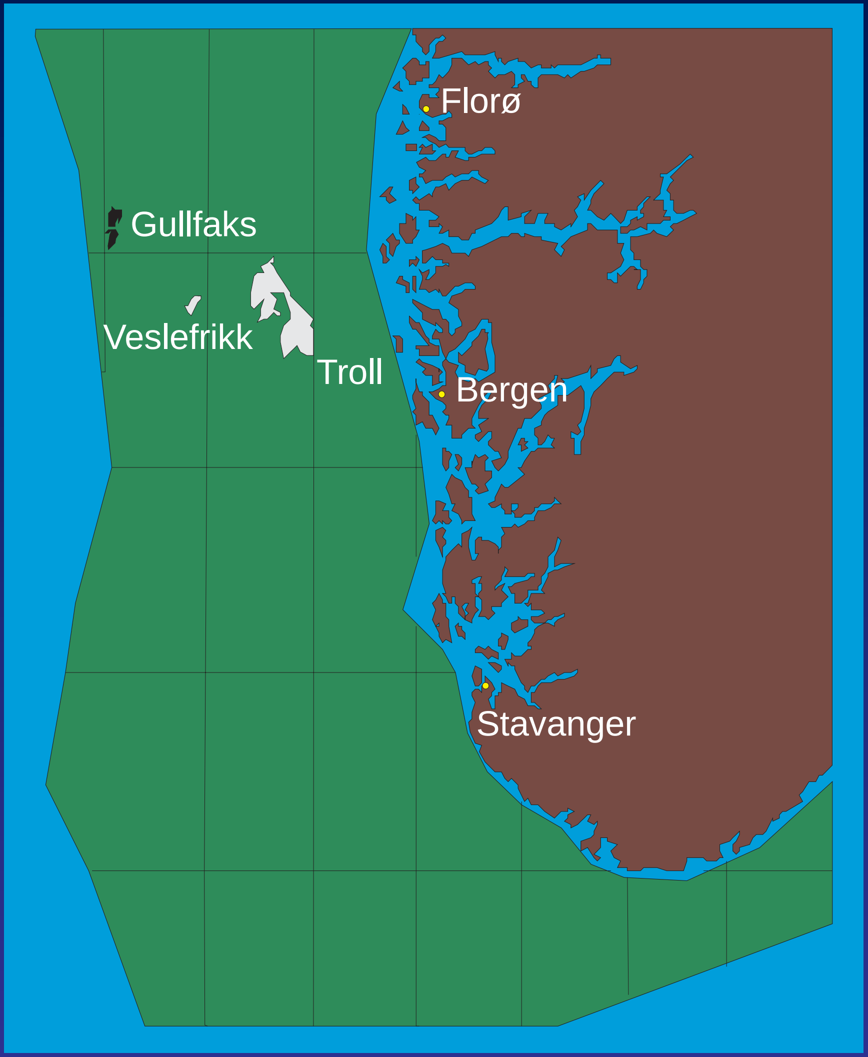
by
Øystein Pettersen

STATOIL

OUTLINE

* FIELD DESCRIPTION
* GENERAL MODELLING PROBLEMS
* CASE STUDY EXAMPLES

FIELDS OPERATED BY STATOIL DDB



SALZ03 | AUG92 | ØP

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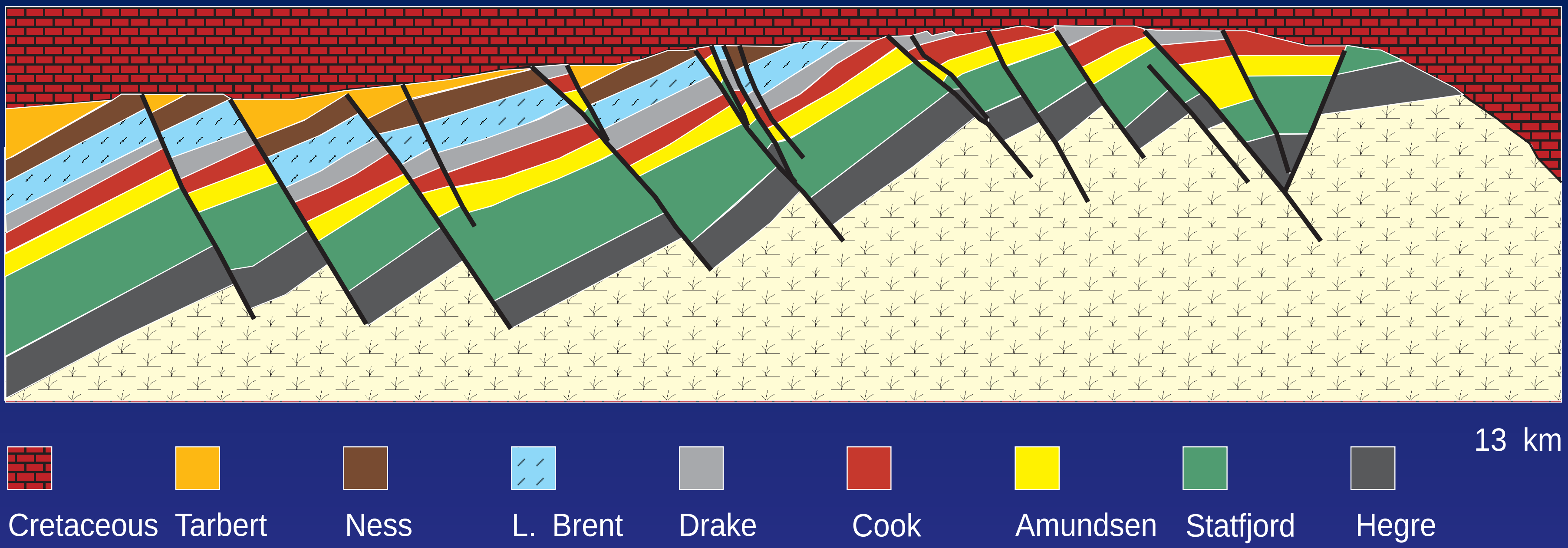
GULLFAKS WEST-EAST CROSS SECTION



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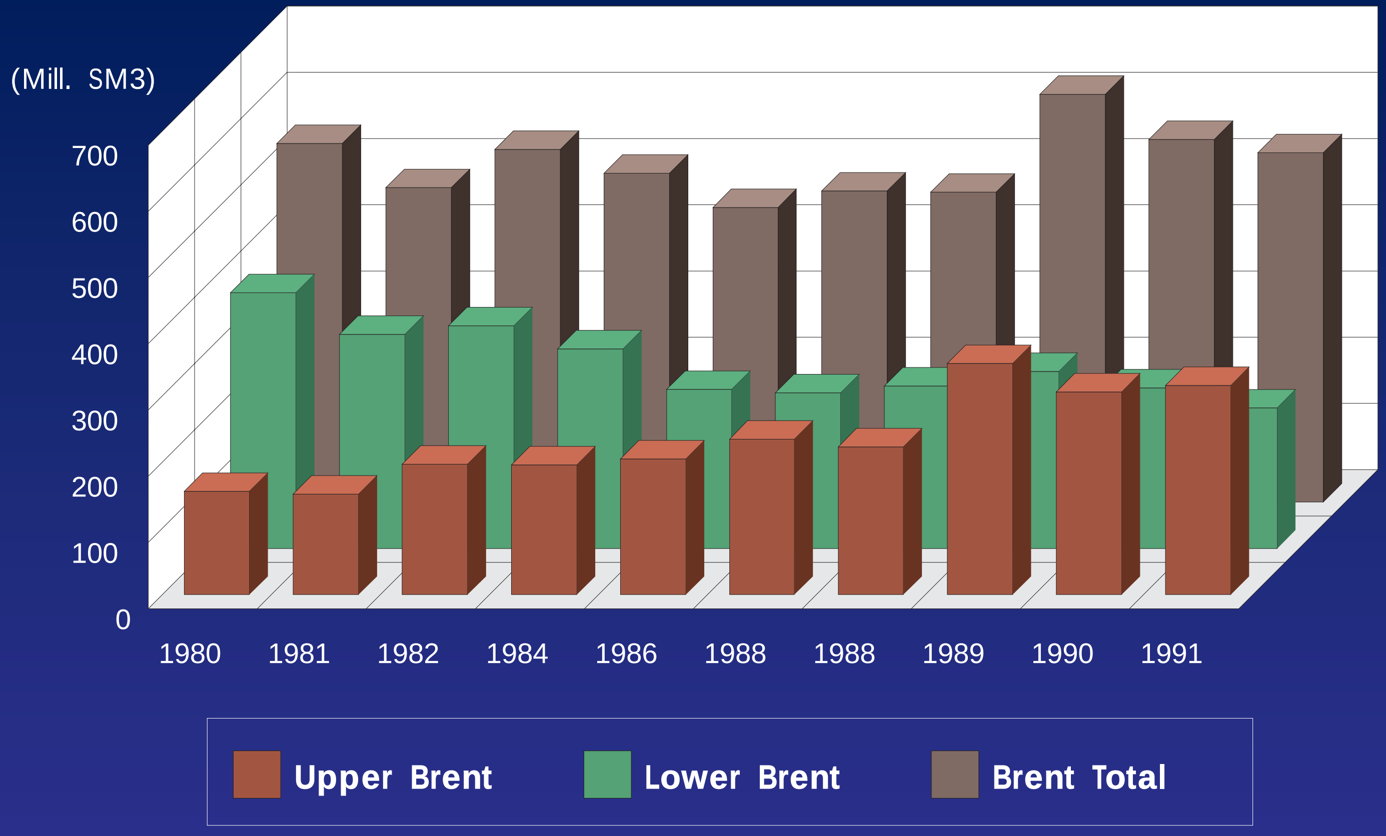
OFFICIAL HYDROCARBON PORE VOLUMES



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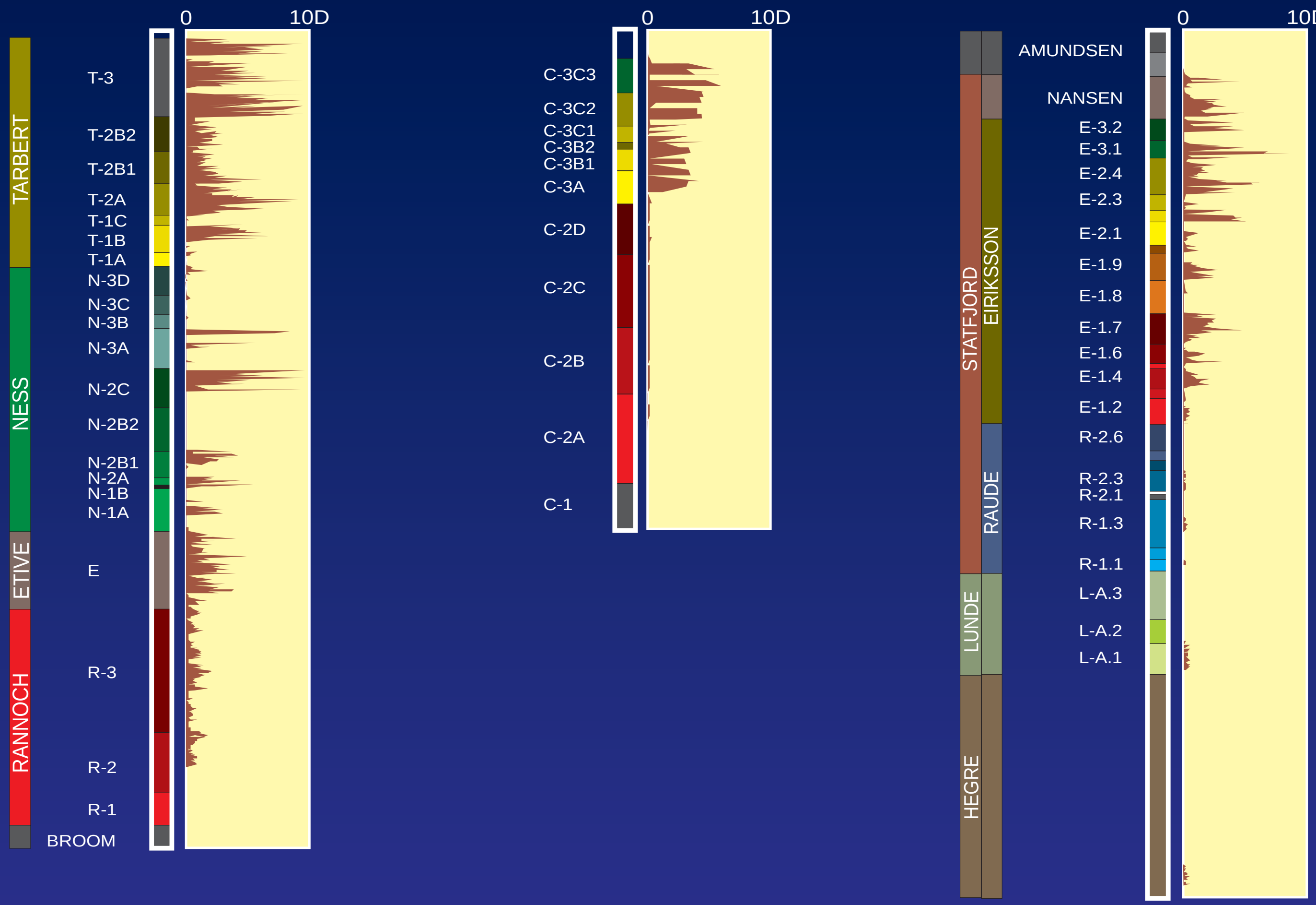
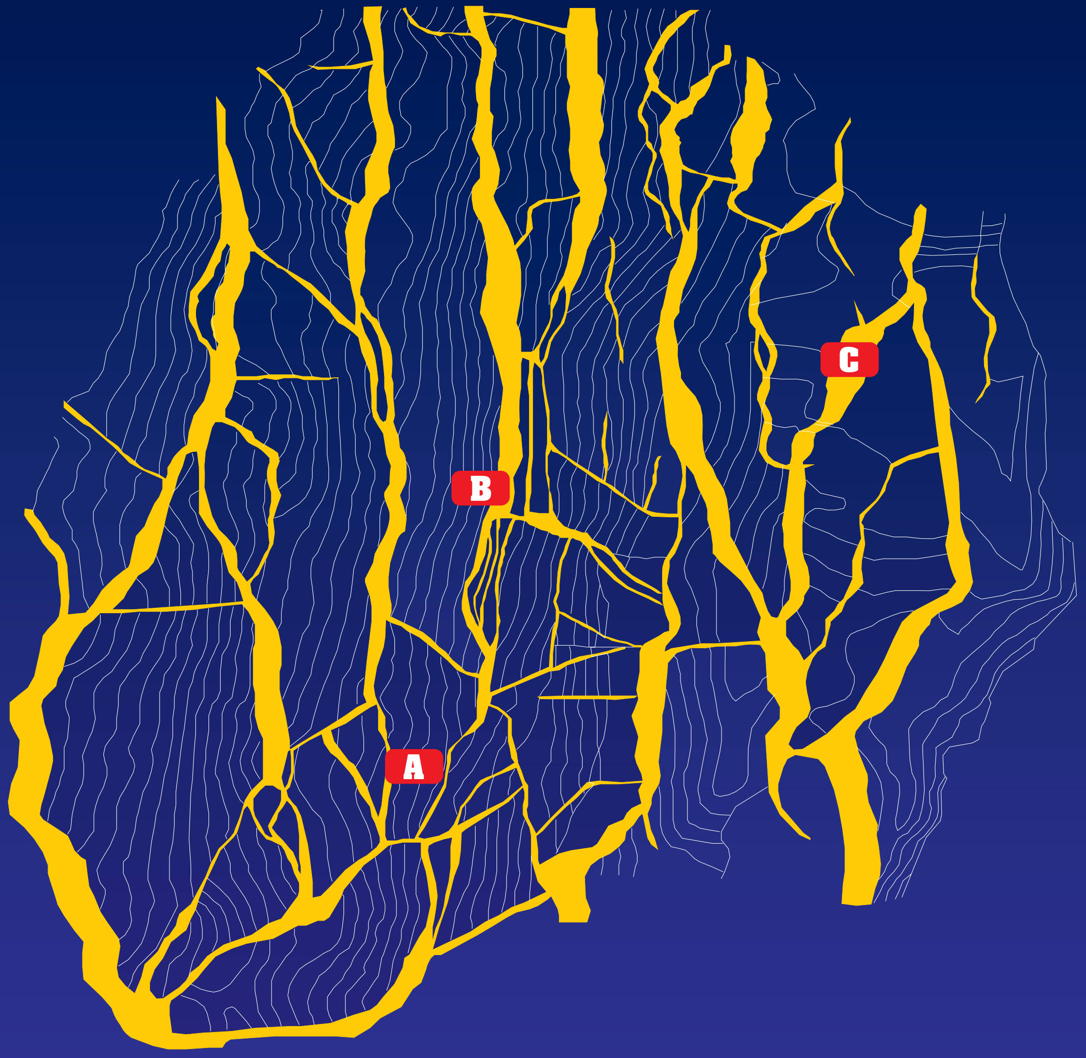
LITOSTRATIGRAPHIC ZONATION AND K_h



Brent Group | **Cook** | **Statfjord Group**

GULLFAKS FAULT MAP



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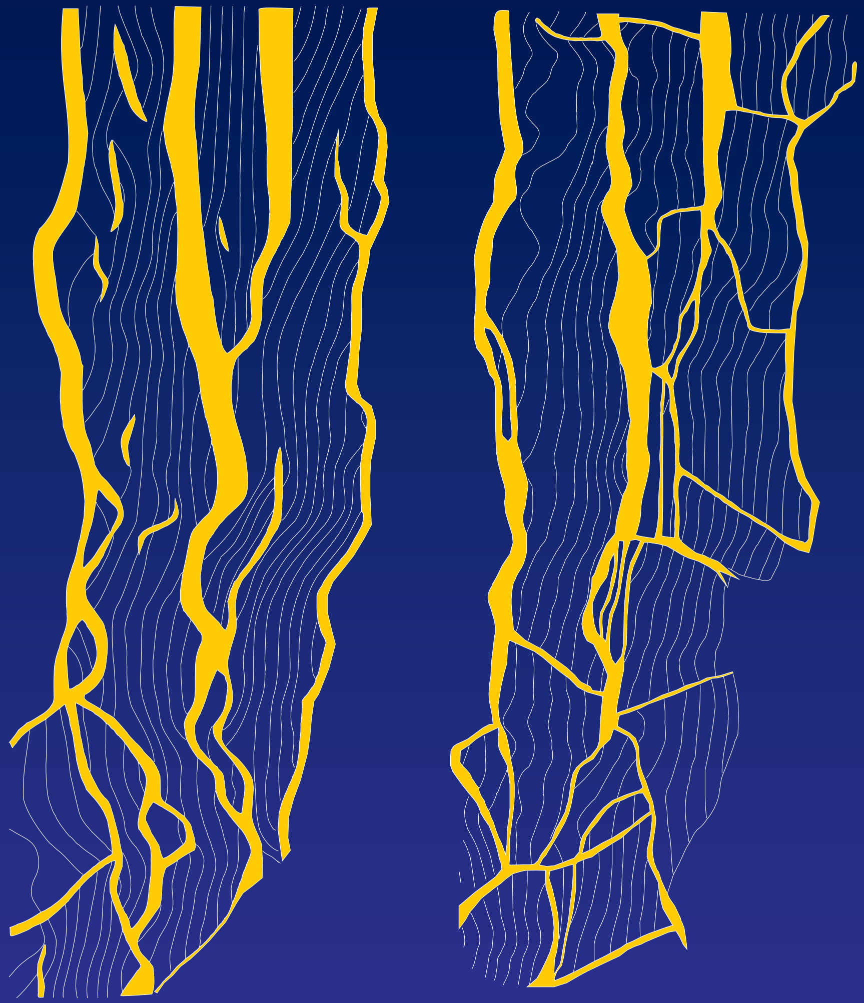
CENTRAL AREA BASE BRENT MAP



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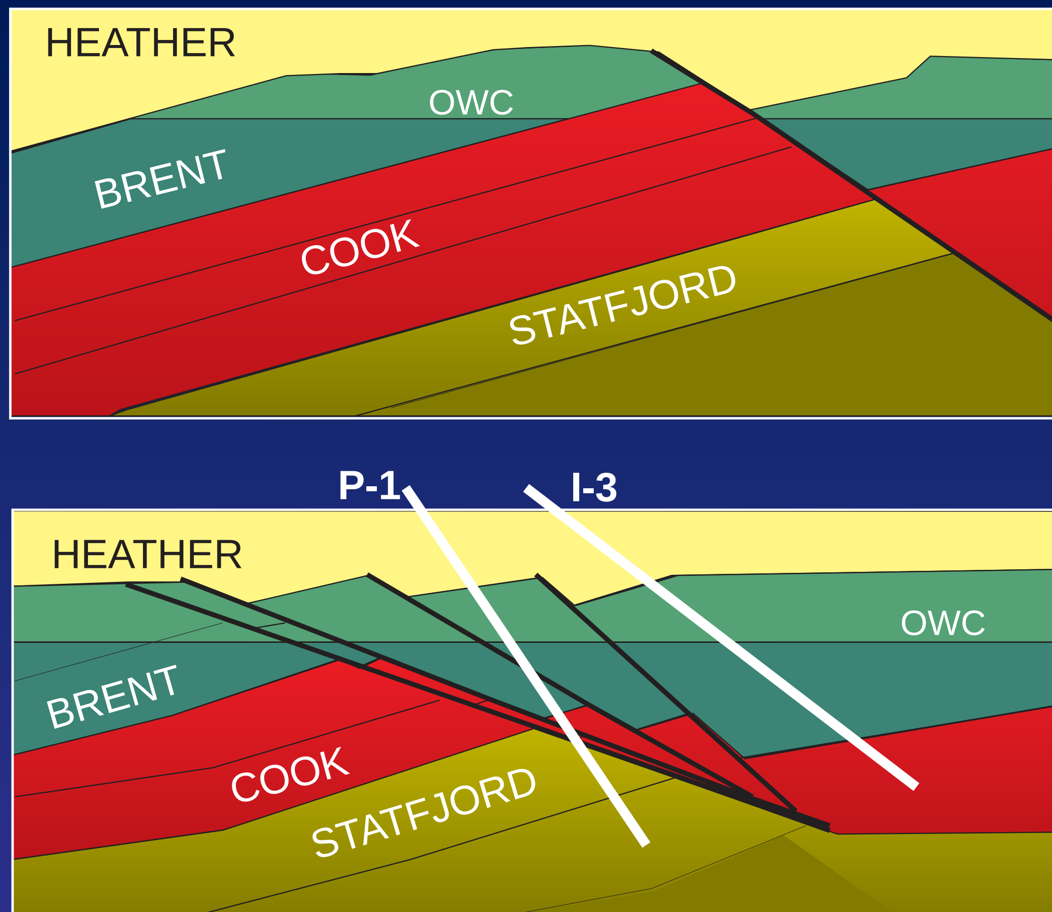
FAULT PATTERN BEFORE AND AFTER WELLS P-1 AND I-3



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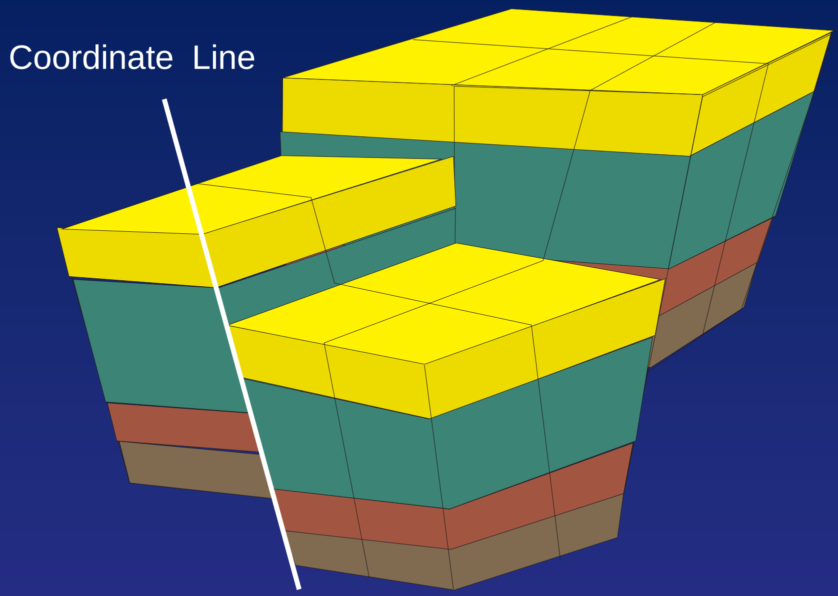
GRID BUILDING

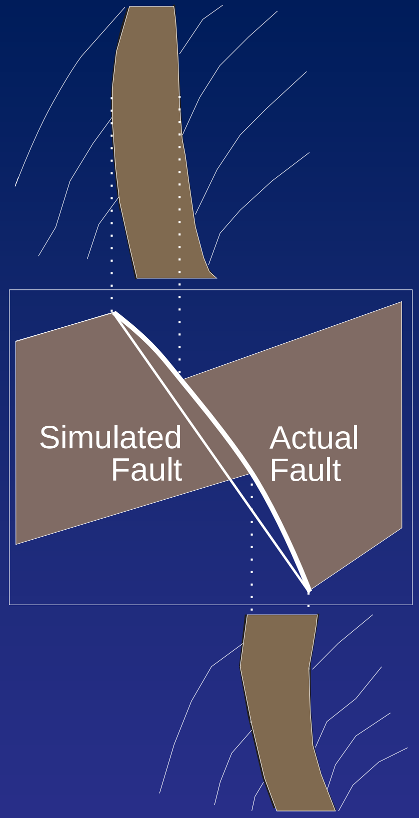
Corner Point Geometry

Sloping Faults

Non-Neighbour Connections

MODELLING SLOPING FAULTS





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SLOPING FAULTS

Moving of coordinate lines tricky

Frequent incompatibilties in conjunction with zig-zag faults

Interpolation less reliable

Node position calculation from isochores difficult (unsolved?)

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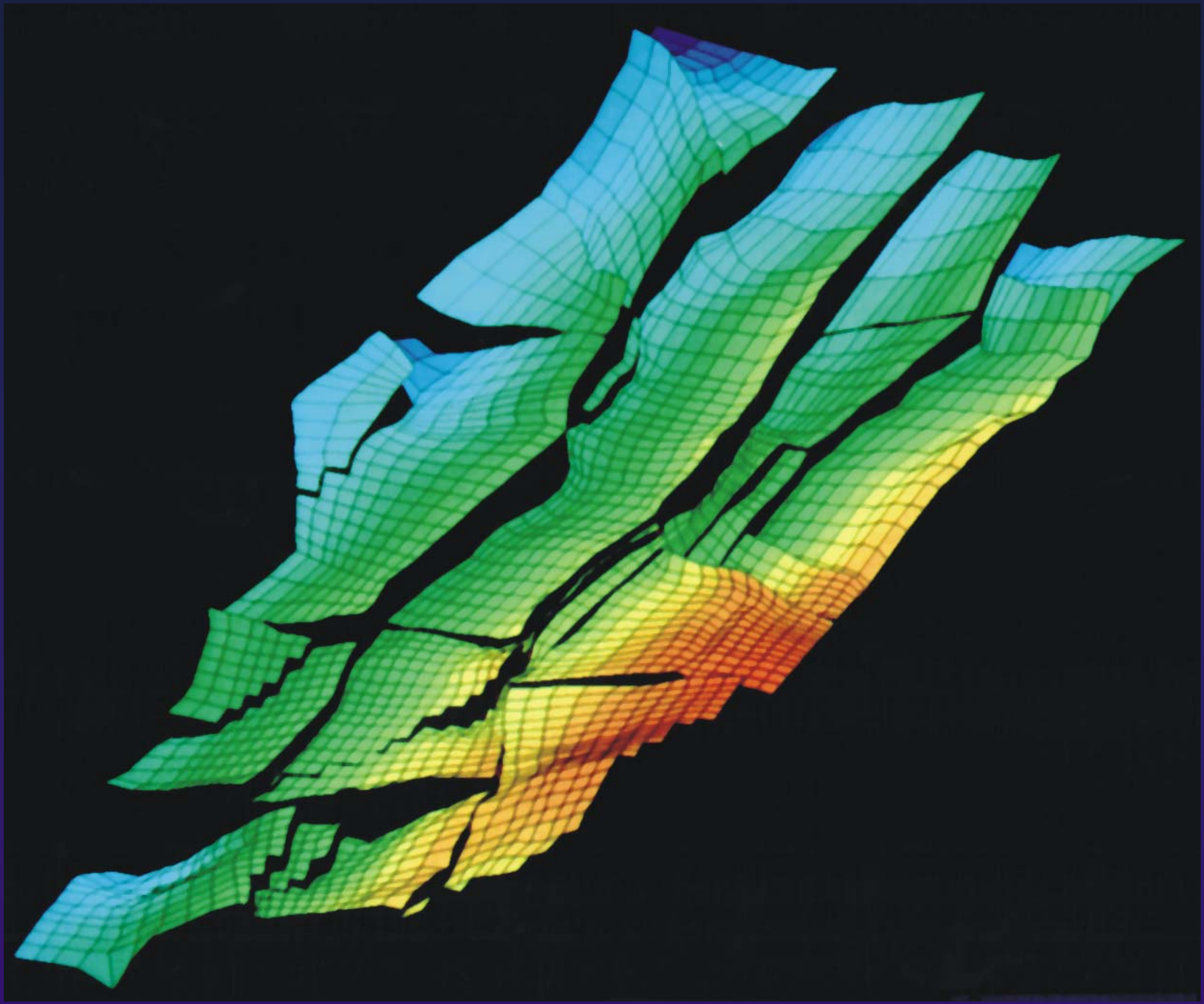
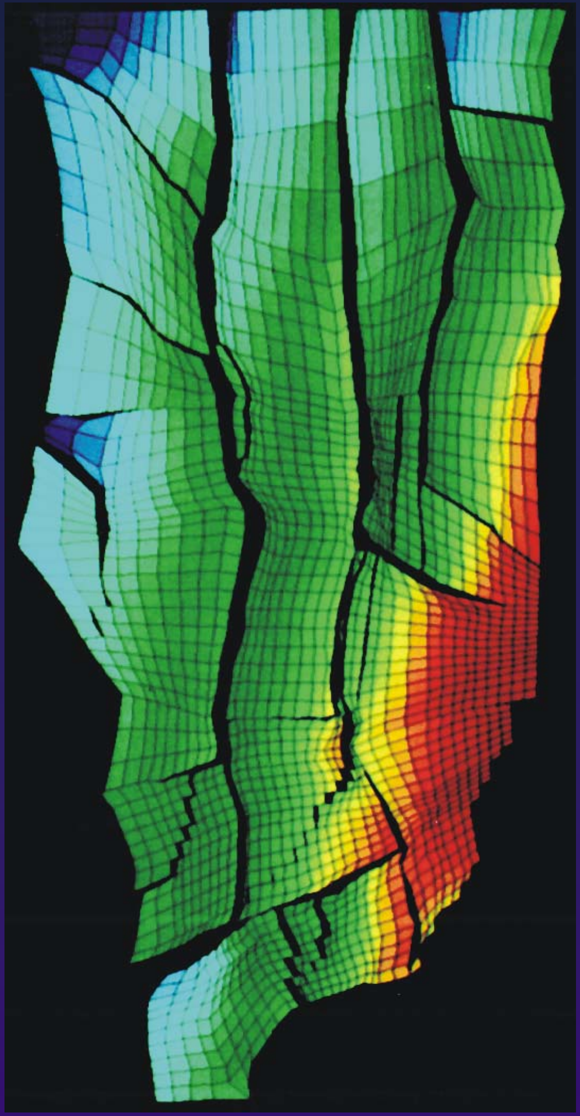
GULLFAKS SIMULATION MODEL

Isometric view



GULLFAKS SIMULATION MODEL

Topdown view



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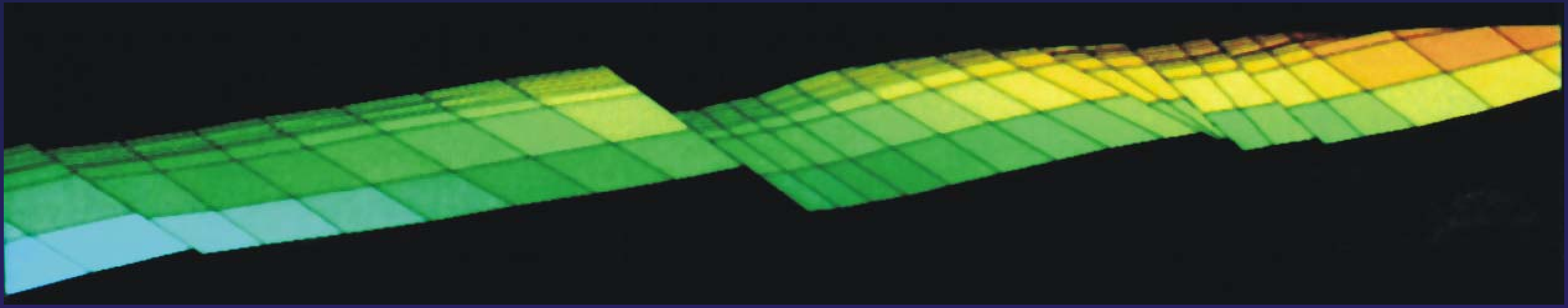
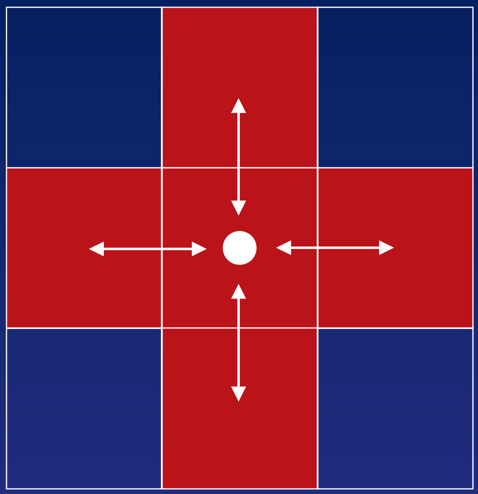
GULLFAKS SIMULATION MODEL

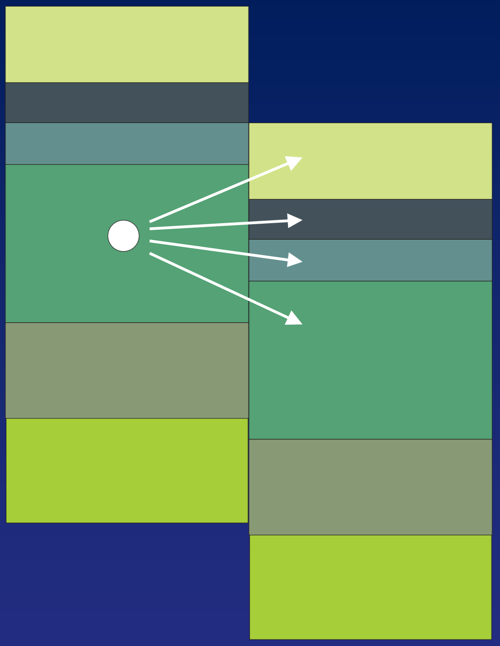


West - east cross section

NON-NEIGHBOUR CONNECTIONS

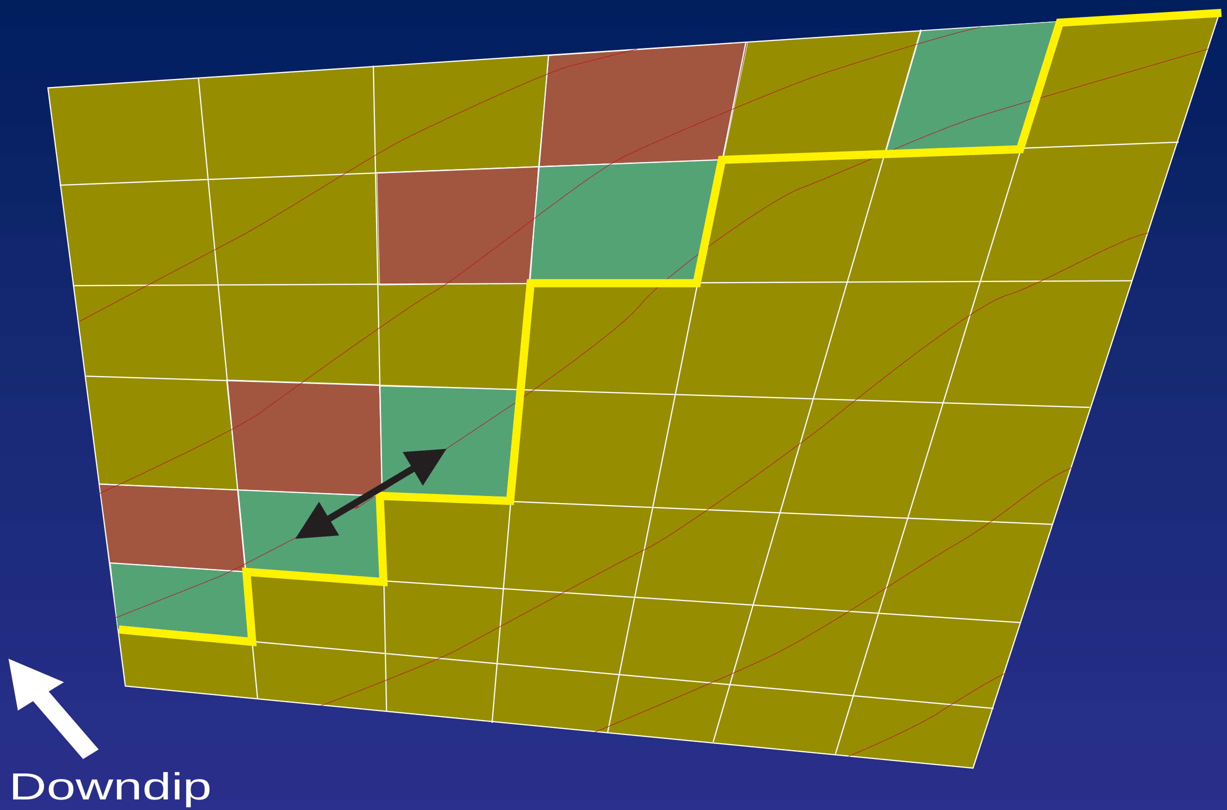


Flow restricted to neighbour blocks



"Normal" Non-Neighbour Flow

NNCs FORCE FLOW ALONG FAULT



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NON-NEIGHBOUR CONNECTIONS:

CONSEQUENCES

Coefficient Matrix Band Structure Destroyed
.... Many Solvers Fail

Typical: Less than 5% NNCs

Gullfaks: Often more than 50% NNCs

.... Requires robust solvers

POTENTIAL FOR INCREASED EFFICIENCY IN MODEL DEVELOPMENT?

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MODEL DEVELOPMENT PROCESS

GRID BUILDING	HISTORY MATCHING	PRED. RUNS
	6 mths	12 mths

6 mths 12 mths 15 mths

RESULT ANALYSIS	EDITING	MACHINE WORK HOURS
0800 – 1500	1500 – 1600	1600 – 2400

DIFFERING "MODUS OPERANDI"

	OIL COMPANY	RESEARCH INSTITUTION
Grid	Complex grid honouring geology, irregular top structure surface and fault pattern	Cartesian grid on rectangular reservoir, regular mesh, plane top surface
Layers	Thickness varies with (x,y,z)	Constant thickness for each layer
Perm., Porosity Net-to-gross	Sampled values, vary with (x,y,z)	Constant (global or per layer)
Well rates	Historical rates, e.g. weekly average for 60-100 wells	Constant rates for a few wells
Property tables	Each grid block, or a region of grid blocks associated with a separate table	Global tables

REQUEST FOR TECHNOLOGY

Interactive Phase (Preprocessing)	**Definitely**
Postprocessing	**Yes**
Integrated Systems	**Yes**
Accelerated Solvers	**Yes and No**
Improved Accuracy	**Not really**

SOME ASPECTS OF HISTORY MATCHING

PARAMETERS TO MATCH

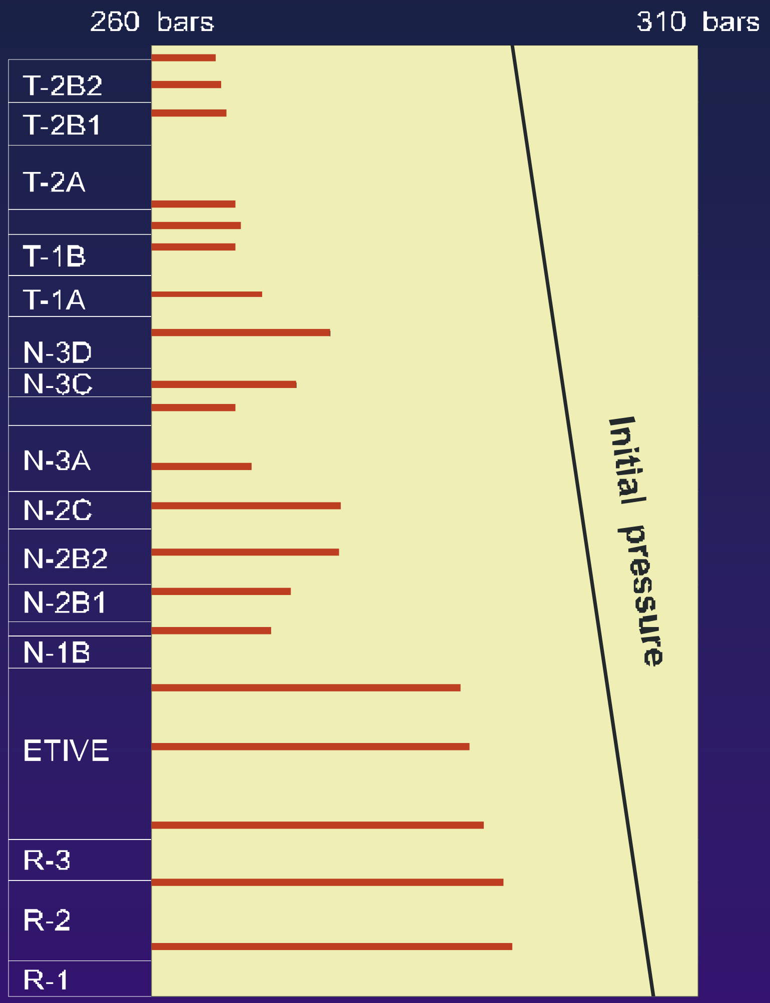
- Production/Injection rate History } Matched on Input
- Well Flow Profiles (PLTs)
- RFTs from more than 60 wells
- Watercut

DEGREES OF FREEDOM

- Interblock Transmissibilities across Faults
- Vertical Communication
- Rock Compaction
- Aquifer Support
- Relative Permeabilities

(Typically 30000 d.o.f.)

TYPICAL BRENT RFT PRESSURES



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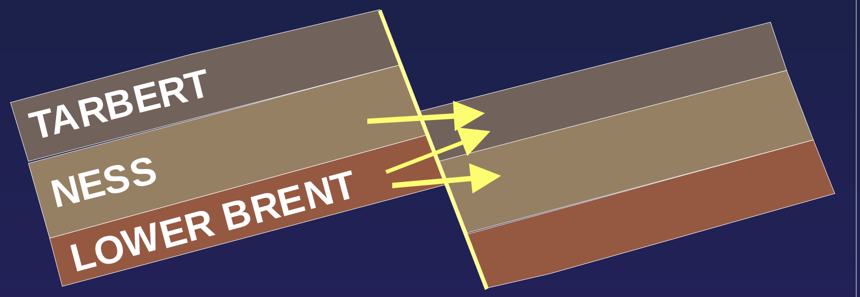
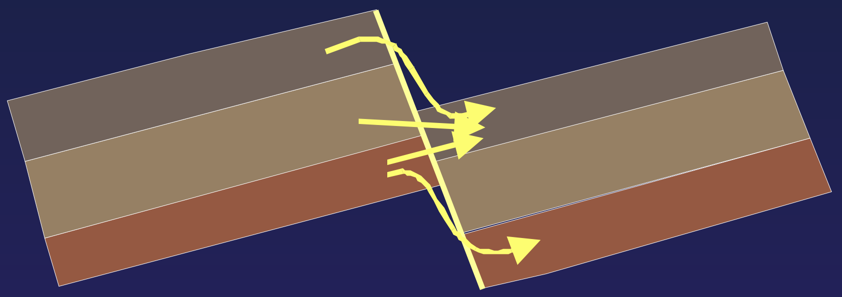
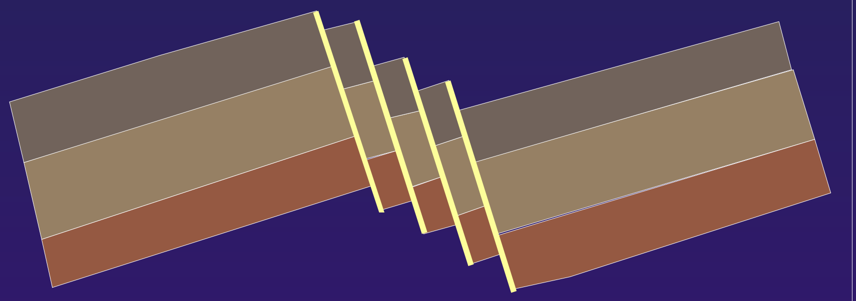
FAULT COMMUNICATION



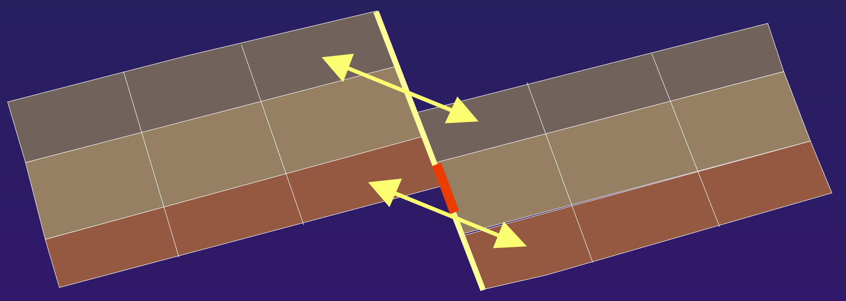
Expected Flow Pattern



Observed Flow Pattern



Revised Fault Interpretation



Adjustment by NNCs

THE PRAGMATIC APPROACH

An Acceptable History Match is a Combination of

Correct Modelling of known Field Properties

Incorrect Modelling of Insufficent Field Knowledge

Grid Approximations

Inaccuracies in the Simulator

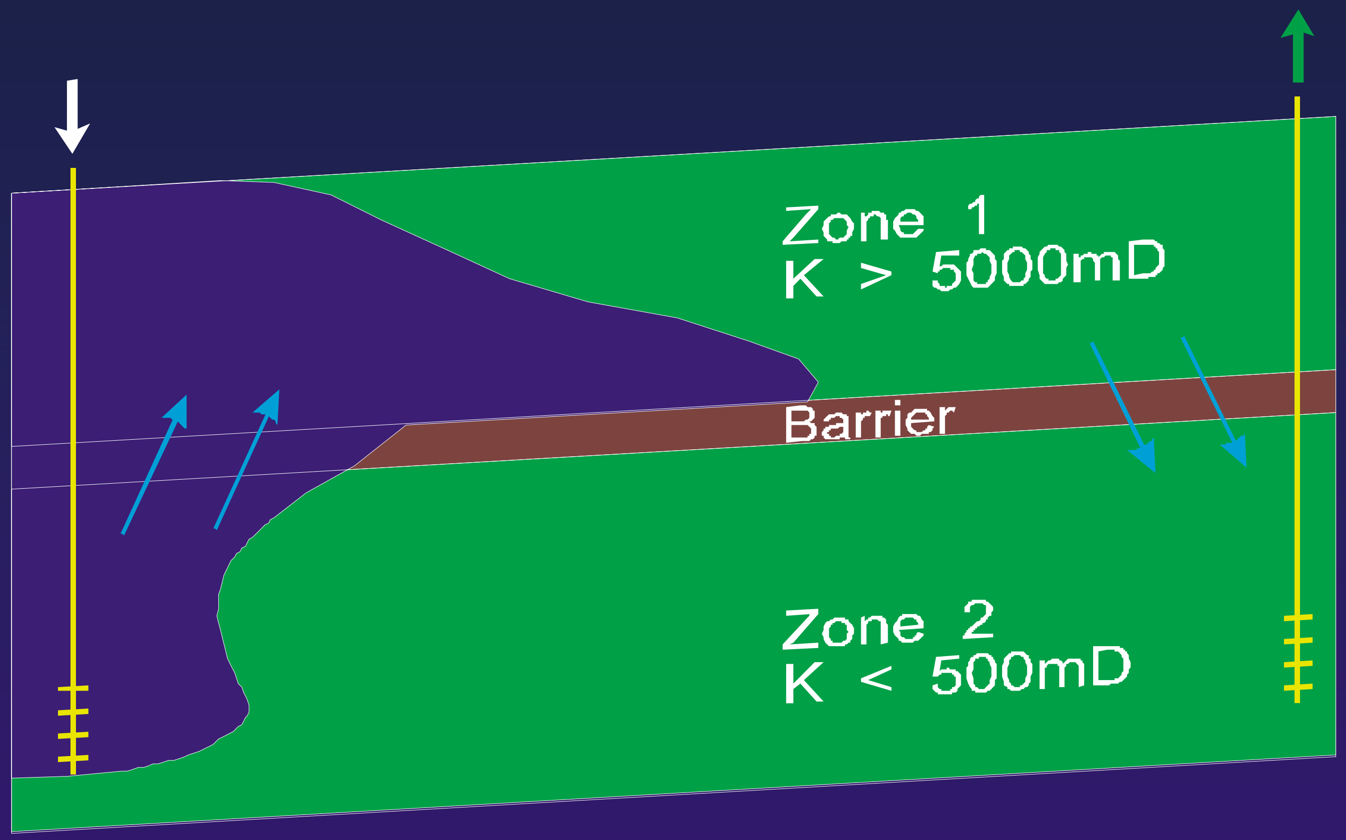
Simulator Characteristics

A History Matched Model is not Transferable to another Simulator

CASE STUDY EXAMPLES

LOWER BRENT OVERRIDE

OVERRIDE SCHEMATIC



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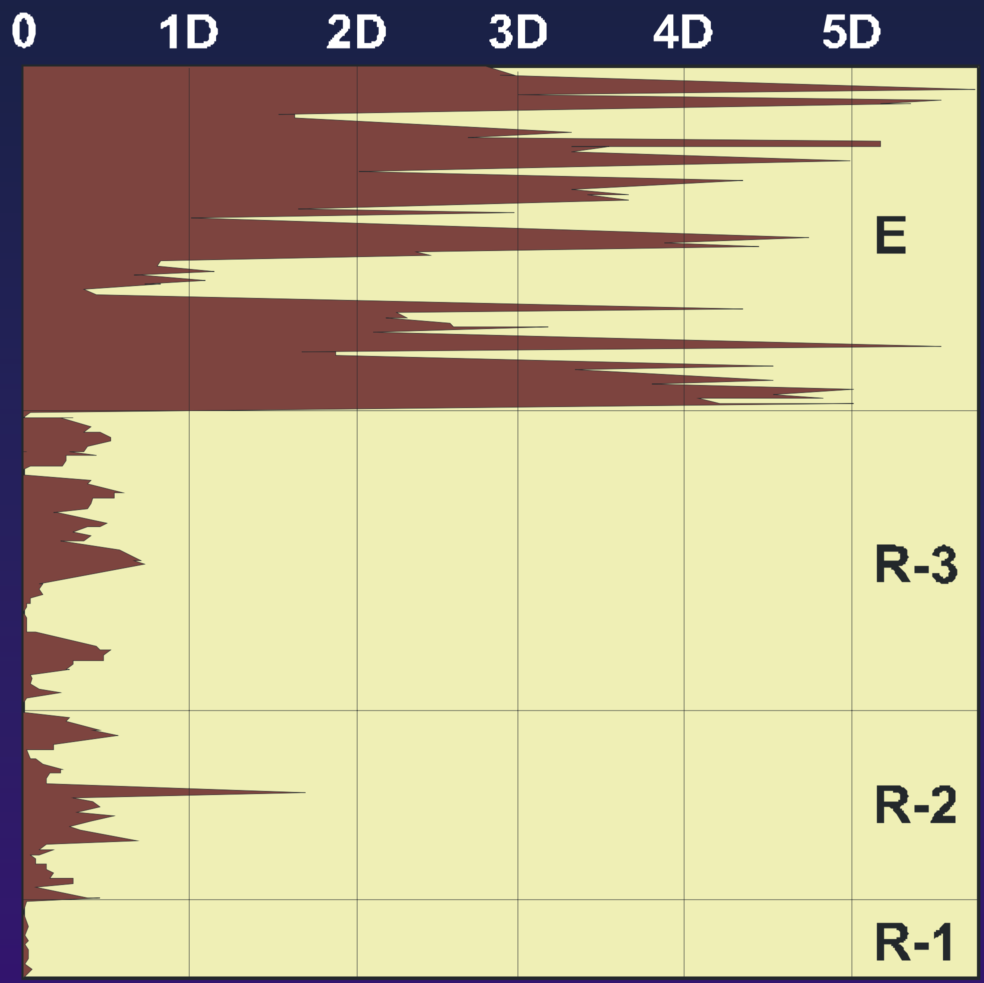
LOWER BRENT VERTICAL PERMEABILITY



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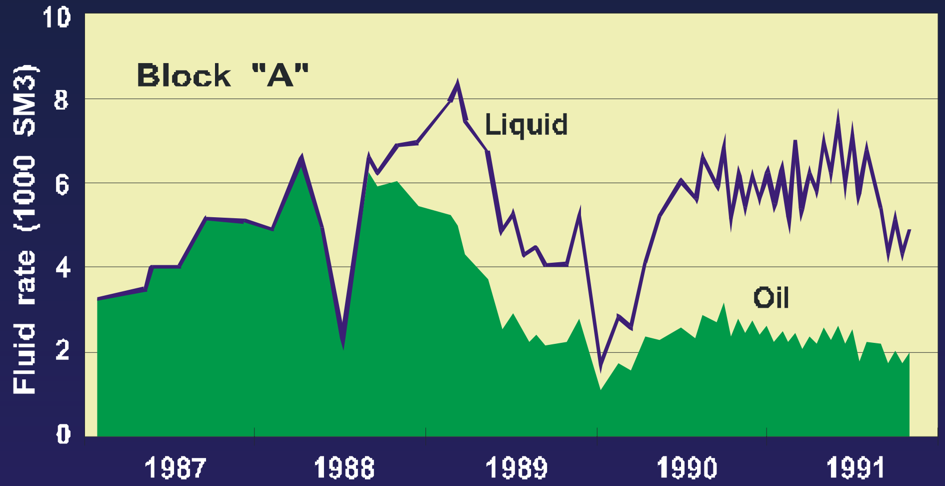
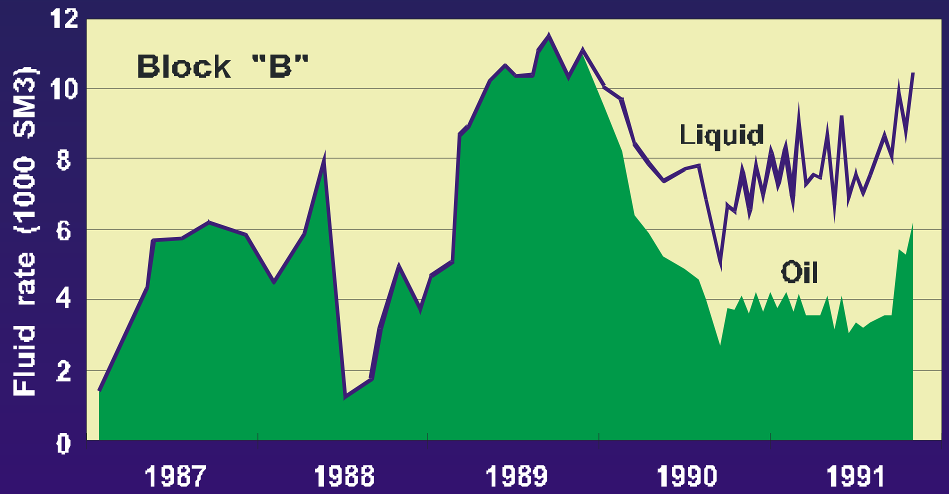
LOWER BRENT PRODUCTION





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LOWER BRENT PROJECT

SIMULATION RESULTS

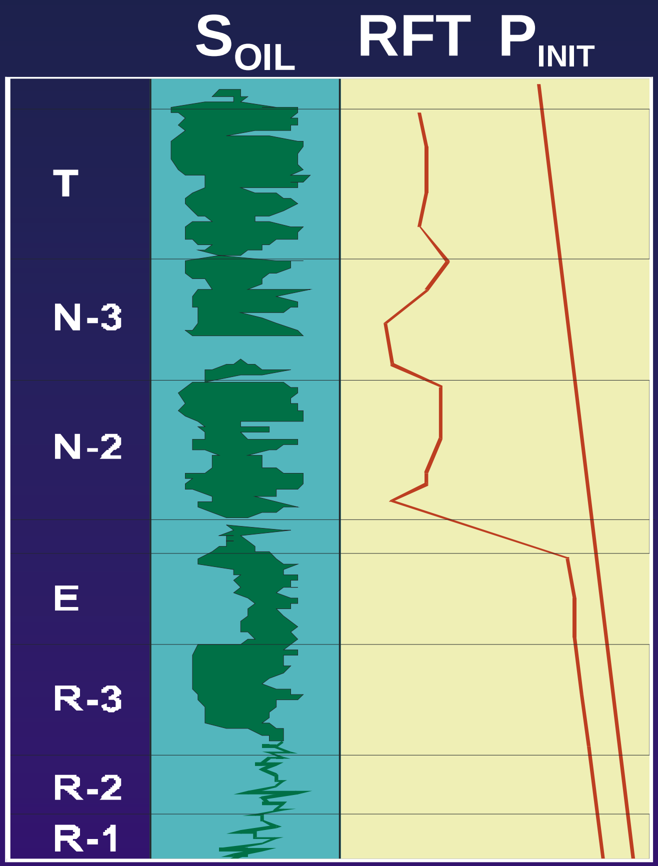
Watercut could only be matched by virtual injection into the Etive

Rannoch water was constrained to thin channels, resulting in very poor drainage

The Etive was almost completely drained

ETIVE OVERRIDE

CONFIRMATION BY SATURATION LOG



LOWER BRENT SIMULATION

REPRESENTATIVE X-SECTIONS (2-D and 3-D)

Early decisions based on 2-D X-sections

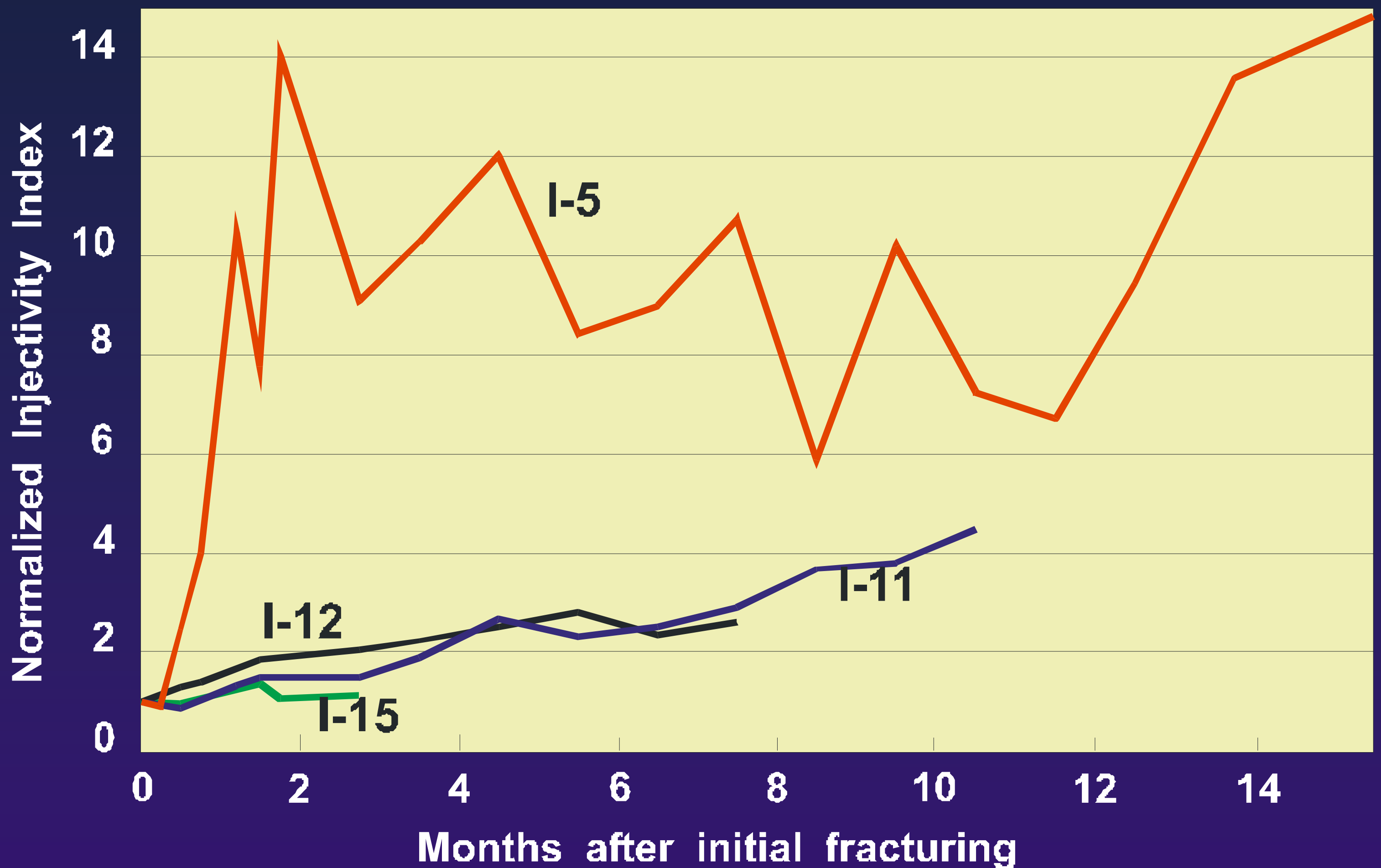
3-D X-section simulations DO NOT confirm override
(predicted in previous 2-D runs):

Either injection water stayed within the Rannoch,
Or it entered the Etive, but segregation would prevent override

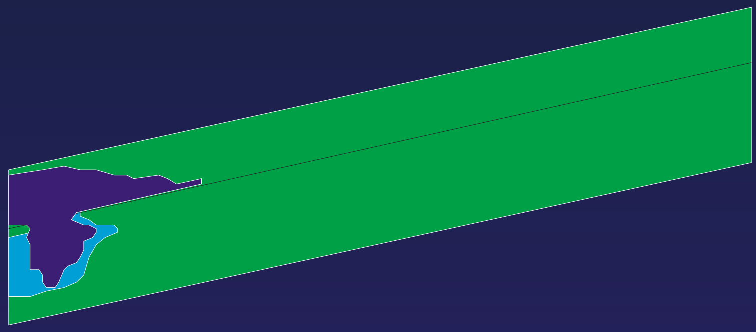
Critical Barrier Crossflow Transmissibility estimated too low in 2-D

2-D Models are of no value in override problems

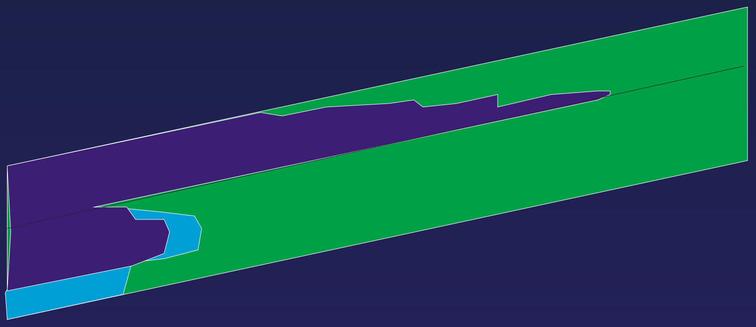
INJECTIVITY AND FRACTURING



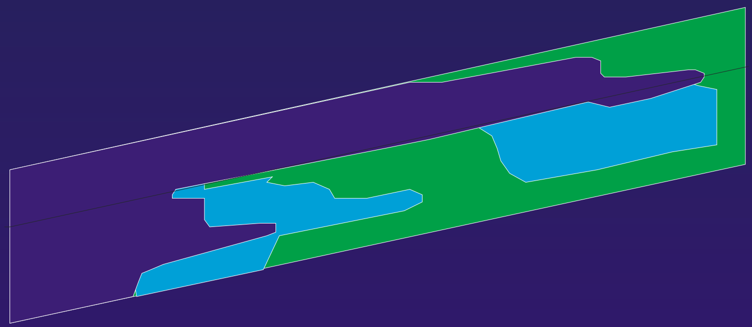
SIMULATED GEL BLOCKING



Shortly after Production Start



Prior to Polymer Injection



Some time after GEL blocking

Late in Production History

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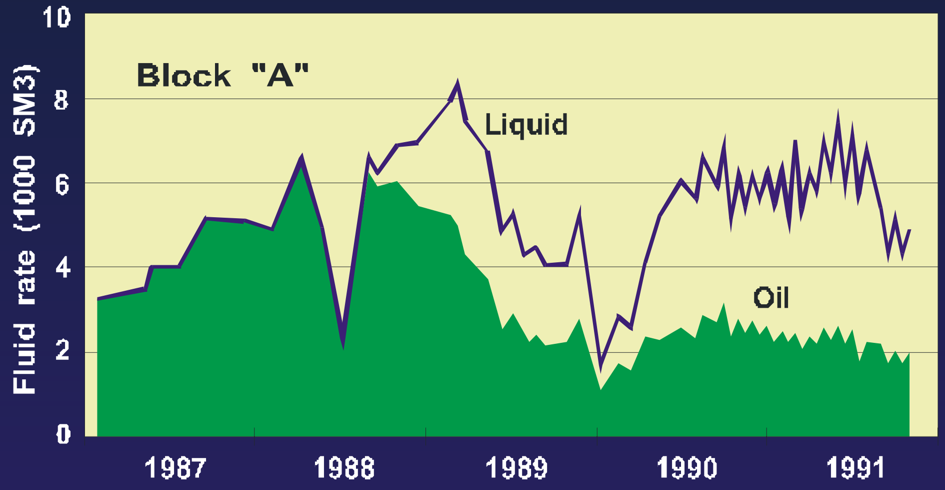
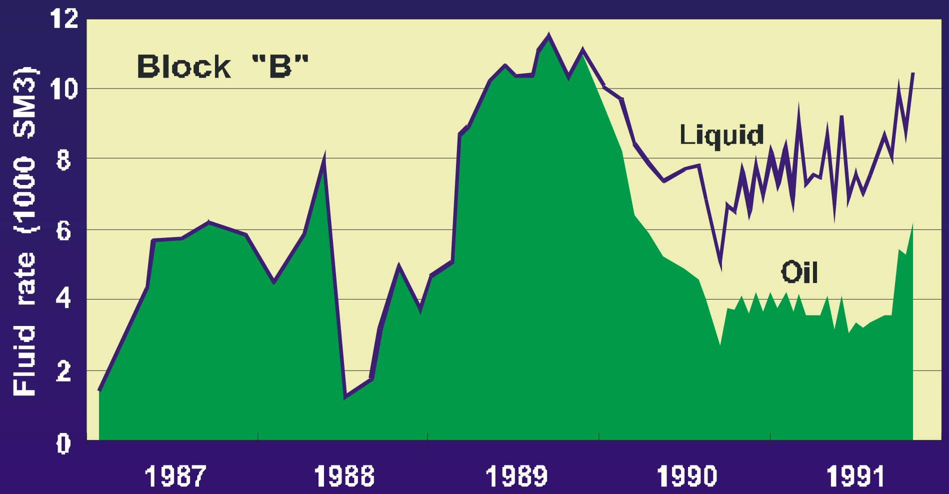
SAND PRODUCTION -- RATE LOSS





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CONCLUSION

Complex Geology

Continuously evolving Field Understanding

Unexpected Reservoir Behaviour

Imaginative Adaption of available techniques;

Models often more complex than Software was designed for

Far too much time has been spent in the process

IS GULLFAKS EXCEPTIONAL,

OR IS THERE A GENERAL INDUSTRY DEMAND

FOR A NEW GENERATION MODELLING TOOLS

?