Mutual benefits from University-Oil Industry collaboration: The Norwegian experience

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"Oil & Gas Exploration in Greece – Challenges and Opportunities",
Conference at Chania Technical University, September 29th - 2011

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Outline

- Historical background
  - Offshore field development and need for R&D
  - Interplay oil companies - research institutes - universities
- University projects – petroleum related
  - Innovation
  - Fundamental research
  - Education
- Labs at UIS - cooperation with TUC
  - Geo
  - Reservoir
  - Drilling
  - Multiphase flow
  - Hydrates

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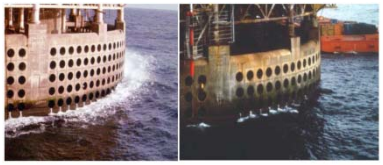
The start of norwegian oil – the "Ekofisk" field

Ekofisk discovered in 1969 - started production in 1971.
Contributed more than any norwegian field to economy and R&D :

- "Economy"
  - OOIP = 560 MSm^3, remaining 150 MSm^3

- Safety → Bravo accident 22 april 1977
  - Piper Alpha 1988; need for kick control methods

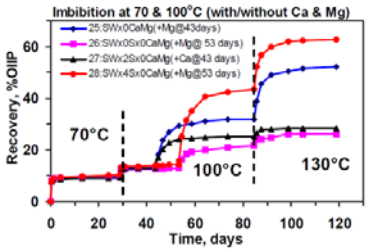
- Seafloor subsidence (0.4m / year)
  - Why - and with what effect



1973 1984

- IOR (→"Smart-waters"):

Wettability alteration by potential determining ions Ca^{2+}, Mg^{2+}, SO_4^{2-}



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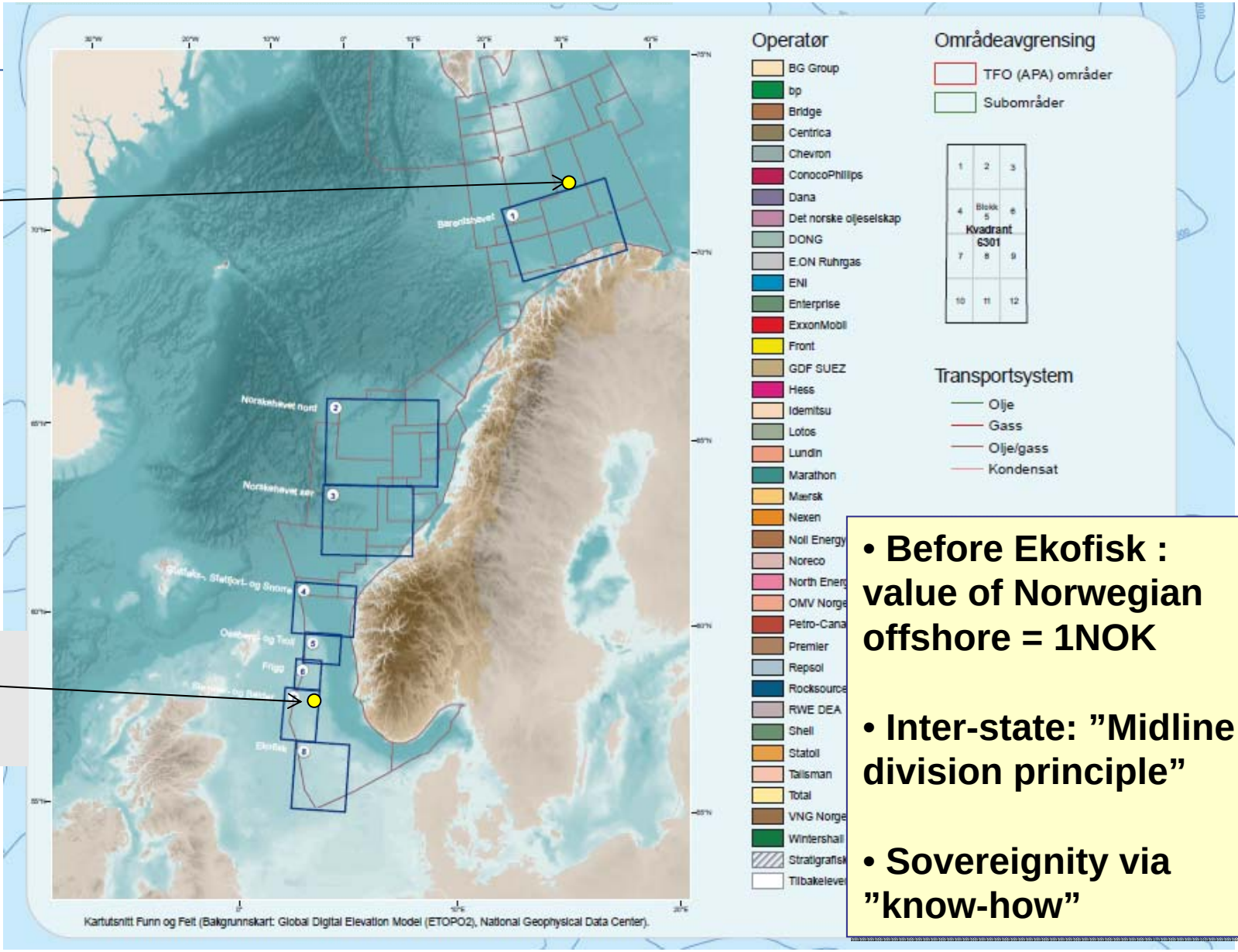
Oil companies operating Norwegian oil fields

April 2011: Skrugard field

August 2011: Aldous / Avaldsnes fields



- **Before Ekofisk : value of Norwegian offshore = 1NOK**
- **Inter-state: ”Midline division principle”**
- **Sovereignity via ”know-how”**

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Technology transfer ; "Technology Agreements" introduced by the Norwegian Parliament - 1973

a) 50% agreements: Mandatory to carry out at least 50% R&D with norwegian partners

a) "Offer" agreements: Companies would be given "concession" priority if they on beforehand agreed to do a certain R&D work in Norway

b) "Goodwill" agreements: Companies should on their own initiative contribute as much as possible to R&D in Norway

Agreements ended in 1992 with the EU-Norway Economical Cooperation Agreement (EØS)

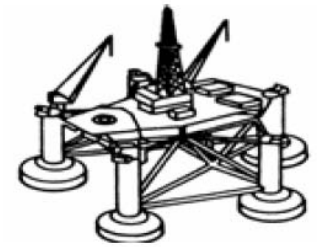
Why then still do R&D in Norway?

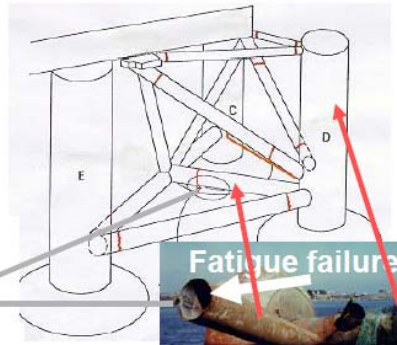
Norwegian tax level 78 % of company net income !

Why then stay in Norway ?

Accidents as driving force for research

The Alexander Kielland Accident (1980) Ekofisk





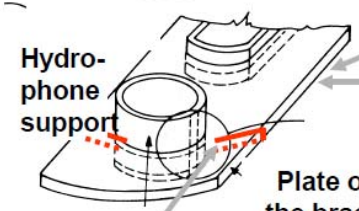
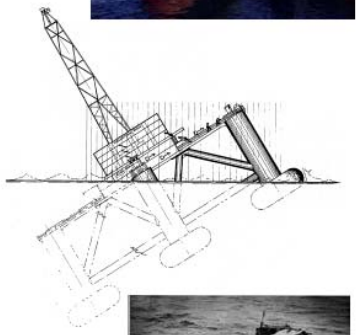
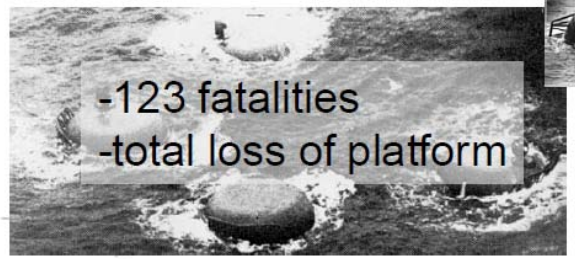


Plate of the brace





Technical-physical Causes-consequences

- fatigue/ fracture in brace D-6
- rupture/collapse in the other 5 braces
- loss of column D

↓listing
↓flooding
↓capsizing

↓evacuation
↓escape

http://www.ptil.no/getfile.php/PDF/Konstruksjonsseminar%20aug2010/Alexander%20L.%20Kielland%20ulykken%20%E2%80%93%2030%20%C3%A5r%20etter%20-%20%20Torgeir%20Moan%20(NTNU).pdf

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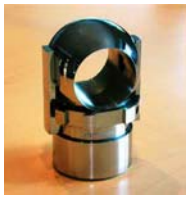
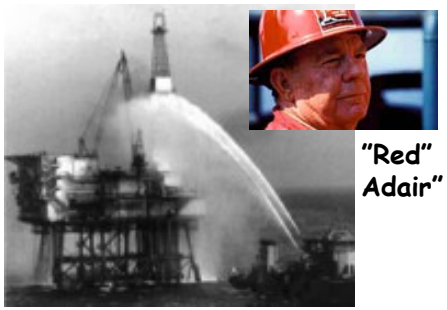
Other accidents as driving force



Bravo accident (22.april 1977):

- Education: petroleum MSc at UiS
- PiperAlpha accident 1988:
  Gas-kick simulator : IRIS (RF)
  → "Drillbench" simulator, PhD



"Red" Adair"

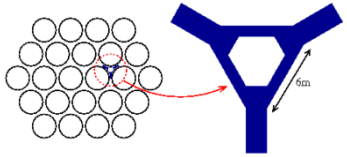
- Ekofisk 2/4 B producing 150.000 Bbl /day.
- 7.5 days outflow → 9500 ton oil spill

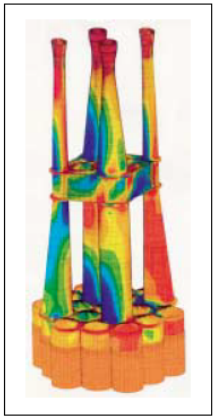
Sleipner A platform :

Sank during pressure testing
August 23rd 1991

"Earth quake": 3 Richter

- More focus on material & fatigue
- Critical view on numerical simulation
- Safety
- Environment





Trollplattformen konstruert i Sesam.

The post accident investigation traced the error to inaccurate finite element approximation of the linear elastic model of the tricell (using the popular finite element program NASTRAN). The shear stresses were underestimated by 47%, leading to insufficient design. In particular, certain concrete walls were not thick enough. More careful finite element analysis, made after the accident, predicted that failure would occur with this design at a depth of 62m, which matches well with the actual occurrence at 65m.

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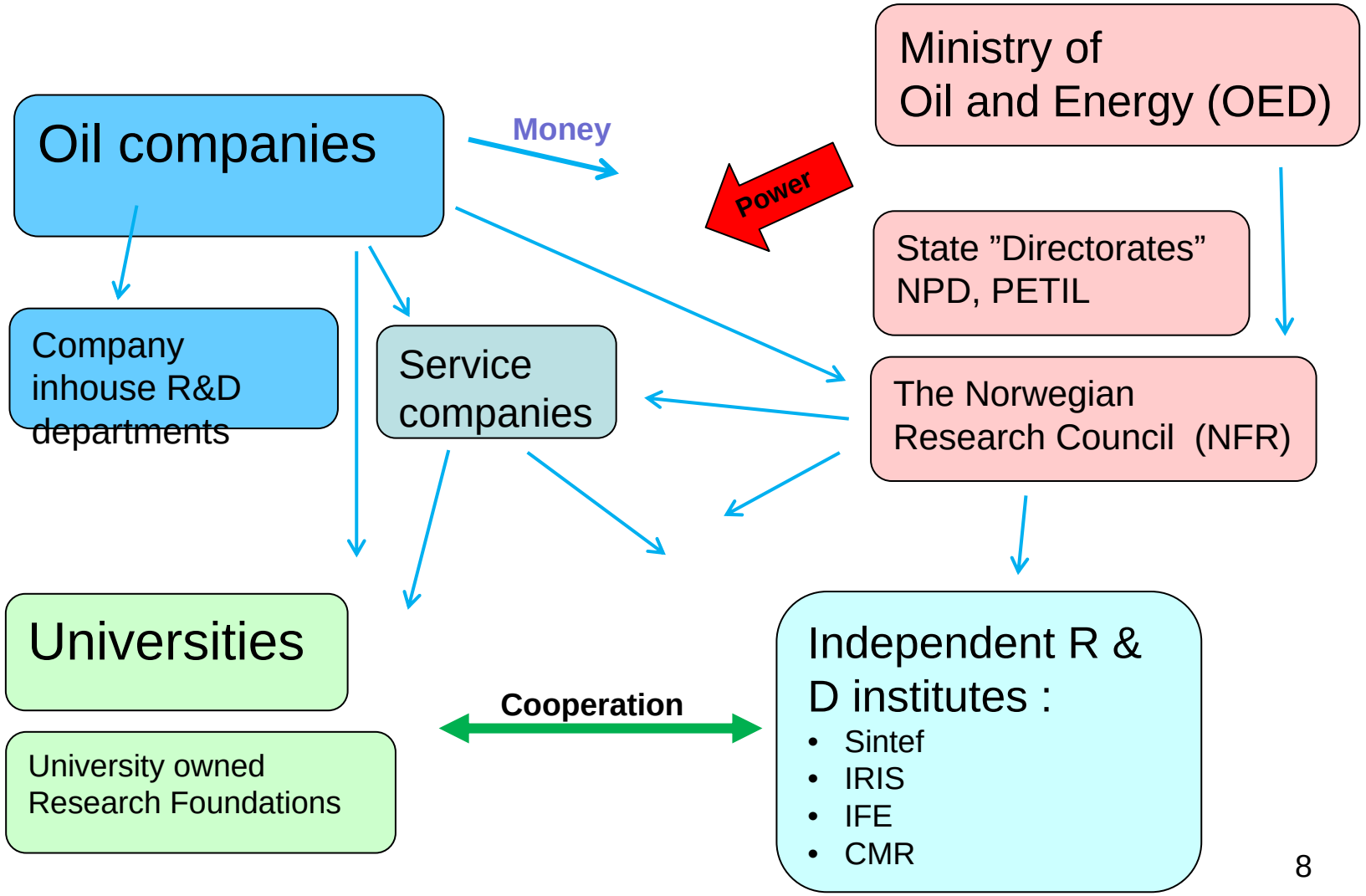
"Road map" - Norwegian petroleum research



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Major NFR financed research programs

Duality : Government - Industry

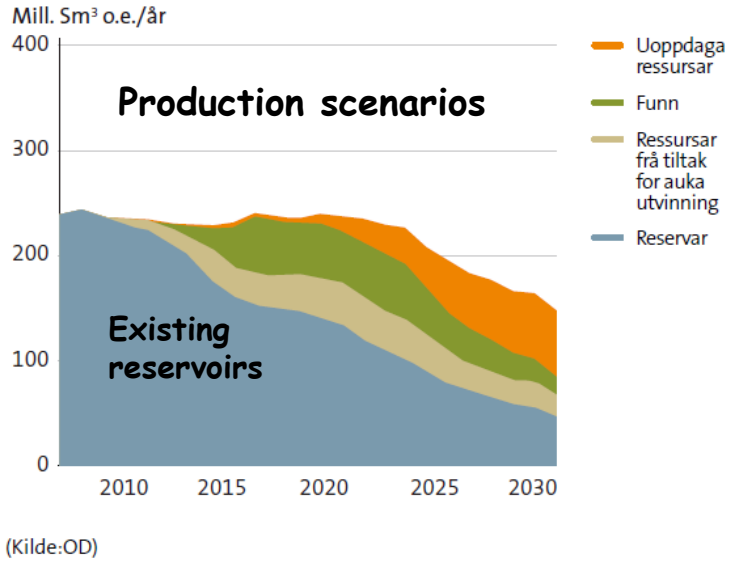
I) Previous national programs

Reservoir:

- SPOR, PROFIT, RUTH (→2002)

Natural gas:

- SPUNG (→1993)



(Kilde:OD)

II) University programs - Centres of Excellence :

- CIPR (Reservoir - UiB)

- FACE (Multiphase flow Sintef,IFE, NTNU)

Long transport: slugging, drag reducers, oil-water dispersion

III) PRESENT NFR (NRC) PROGRAMS (for 2010 - 430 Mill NOK):

- PETROMAKS
- DEMO 2000
- Gassmaks
- Petrosam
- OG21 (National strategy organ)

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Direct industry projects towards universities

Example case: Statoil

Before 2000:

- Statoil involved individually with each university partner, via licences
- VISTA program (with the Norwegian Academy of Science and Letters)

After 2000: Cooperation Agreement with the universities

- 5-10 Mill. NOK per institution per year.
- Planned 100 Mill NOK /year total…

Education: "Svalex" expeditions to Spitsbergen. Statoil "imperatives":

- Universities must change attitude: Learn from the real world
- "Experts in team"

"Akademia" program (2009 →) for the universities - (5-20 MNOK /year)

Research:

- Geology and Geophysics (NTNU, UIB, UIS, UiO, UiTø)
- Reservoir (NTNU, UIB, UIS)
- Drilling (UIS)
- Multiphase flow (Sintef, IFE, NTNU, UiO, UIS)

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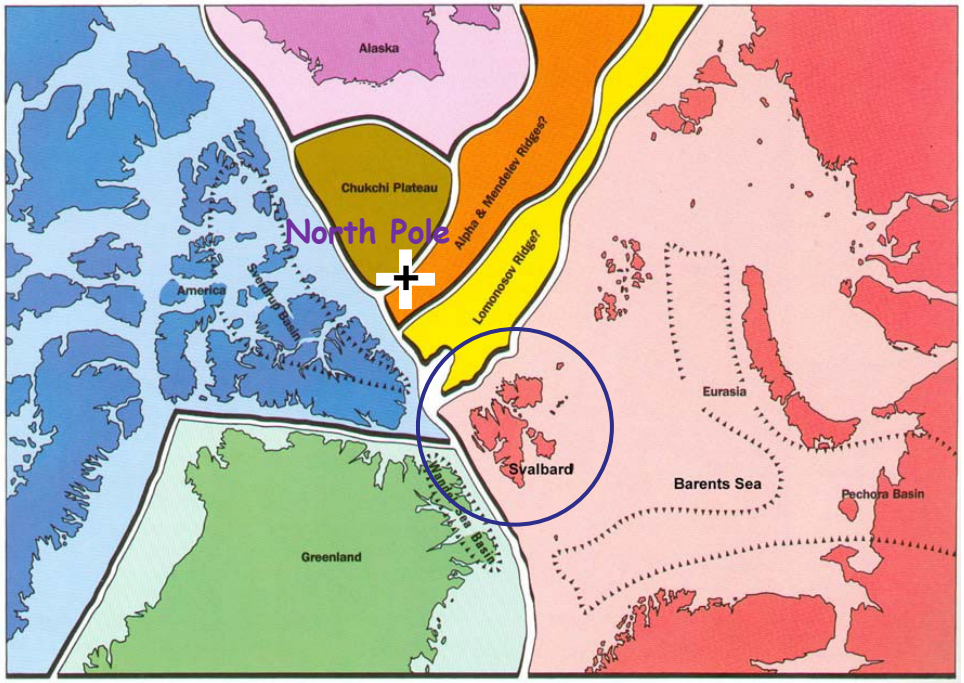
"SVALEX" expedition

STATOIL initiative for improved learning of petroleum sciences

All universities participate



Web page: http://www.svalex.net/

- Two week boat excursion from Longyearbyen, Spitsbergen
- 200 students and teachers
- Topics: Geology, Reservoir, Drilling, Production
- Projects in field development

Electronic Journal http://www.learninggeoscience.net/

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"COREC" program – Centre for Oil Recovery, established 2002

- **Cooperation: University of Stavanger - IRIS,**
- **Contributors: ConocoPhillips, and the other Ekofisk license companies: Total, ENI, Petoro, and Statoil.**

IOR
Sigmund Stokka (IRIS), Tor Austad (UiS), Bente Nyland (NPD

Water weaking of Chalk

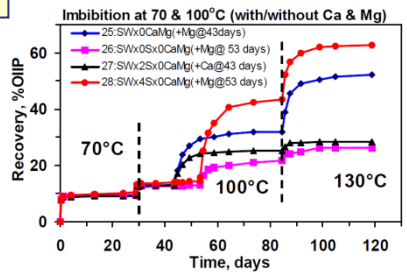
WORKSHOP: From left: Neal Nagel, Aksel Hiorth, Merete Vadla Madland, Larry Cathles.

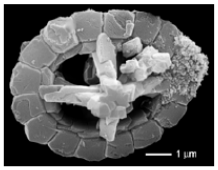
Why has sea water injection worked so well in Ekofisk? (ConocoPhillips, BP, NRC)

Why does Low-Salinity water improve recovery in sandstone and clay rich fields? (BP)

Does subsidence increase or decrease recovery? (ConocoPhillips)

Wettability alteration by potential determining ions Ca^{2+}, Mg^{2+}, SO_4^{2-}





Coccolites

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LABORATORIES

Petroleum Department, UIS

Appreciating further cooperation with TUC / Kreta

- Geology, geophysics (seismics)
- Reservoir
  - Core analysis (rel.perm, NMR , ..)
  - PVT analysis
  - Wetting alteration
- Drilling
  - Rock mechanics
  - Drilling Fluids
  - Pressure control, hydraulics
- Production
  - Multiphase flow in pipelines (metering and advanced instrumentation)
  - Flow assurance
  - Hydrate kinetics
  - Wax, asphaltenes, heavy oil

(+ laboratories at IRIS research institute)

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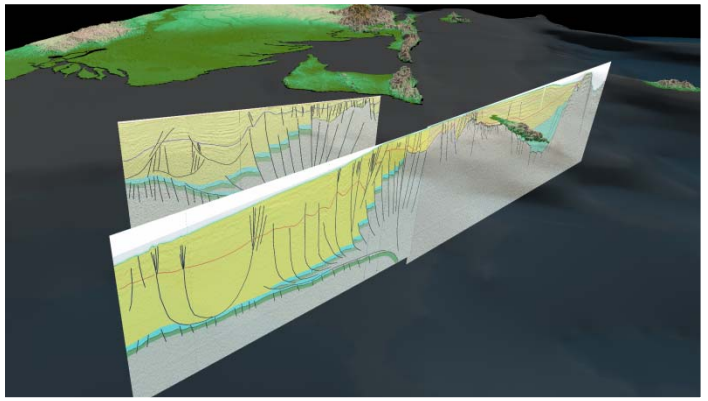
Geophysics - Subsurface interpretation lab

- 11 state of the art PC-workstations (768 MB videocard, 16 GB RAM) and 2 Linux servers with 24 TB of memory)
- Industry standard room and workstations
- Linux and Windows can be run simultaneously
- Programs: Landmark suite Kingdom Suite, Norsar suite, Move, TrapTester, ArcGIS, Fledermaus, RMS, Petrel, etc.
- Access to the Petrobank
- Perfect for exploration and reservoir characterization projects and industry training



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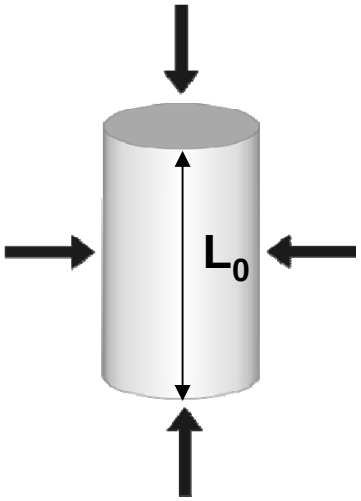
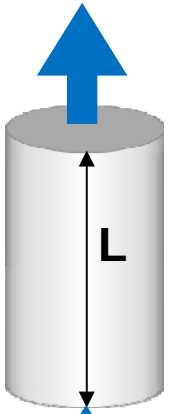
Rock mechanical testing at UiS
Water induced compaction



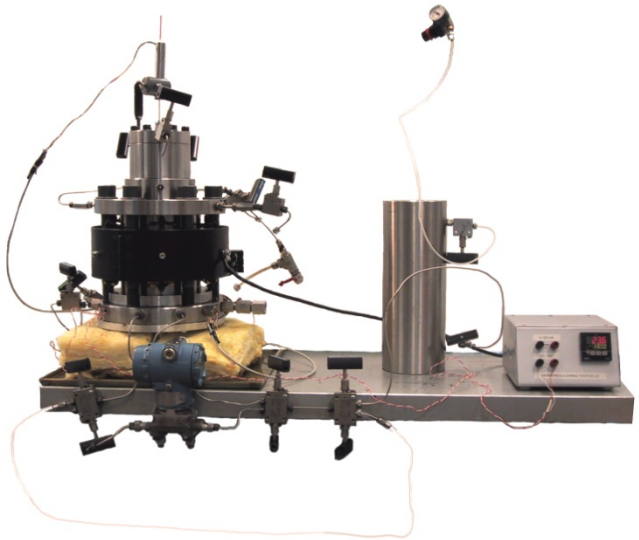
Stress

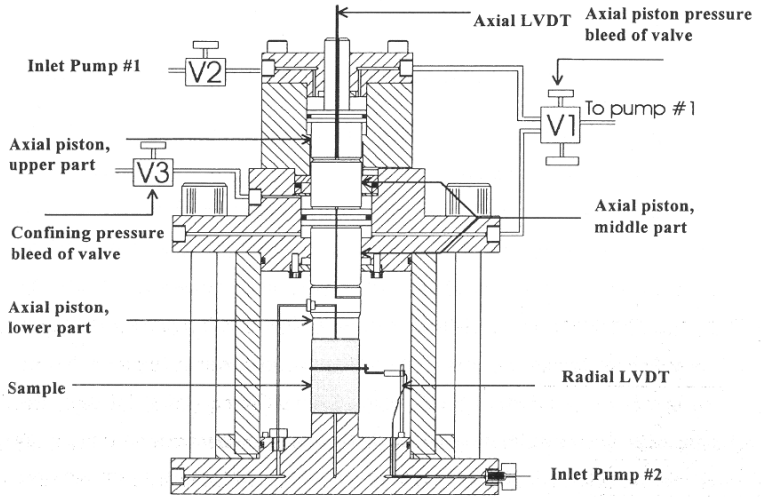
Strain:

$$\varepsilon = \frac{L_0 - L}{L_0}$$



Water injection





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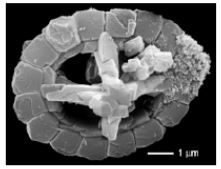
Rock-water interaction as revealed by SEM

- **Comparison of chalk cores prior to and after waterflooding experiments :**
  - Bulk chemical composition
  - Detection of possible secondary minerals

Zeiss Supra 35 VP @ UiS
- High resolution images
- Element analysis (EDS)

Coccolites



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Research direction – "Smart water"

- **Water based EOR by "smart" water**
  - Optimizing ion composition of injection water to promote wettability alteration → improve oil recovery by water flooding.
  - Detailed knowledge about the chemical mechanism → ability to evaluate actual field candidates for "smart" water.
  - Carbonates and Sandstones

- **Incorporate new chemical information into reservoir simulators**

Chromatographic separation between SCN^- and SO_4^{2-}

Surface reactivity of Ca^{2+}, Mg^{2+}, and SO_4^{2-}

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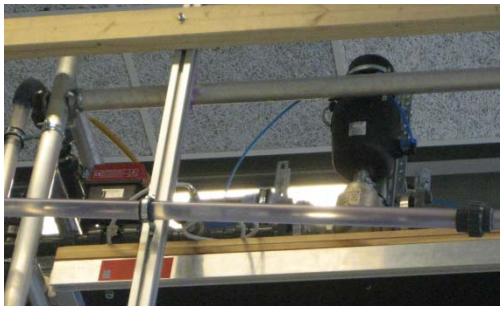
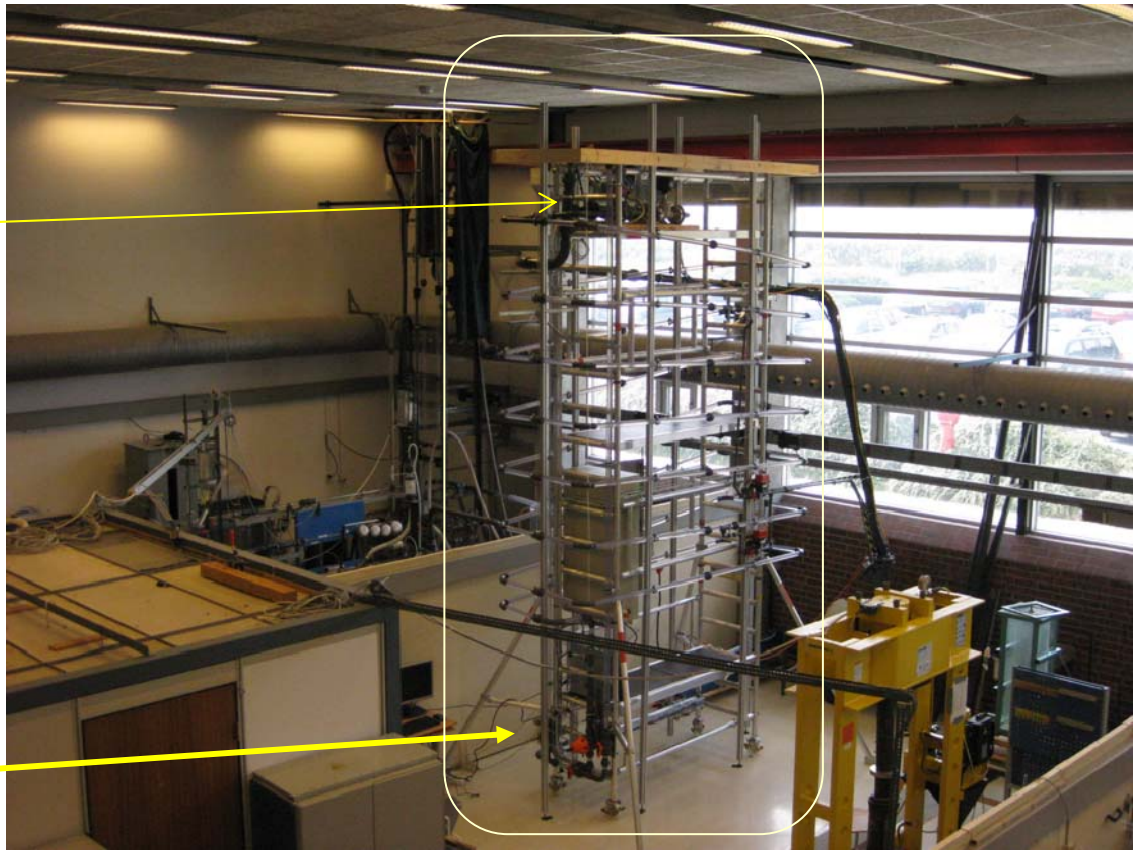
Flow rig for studies of hydraulic well control

Purpose:
Managed Pressure Drilling, Underbalanced Drilling and Gas-kicks

Valves and Coriolis flowmeter for BHP pressure control



Gas injector unit



Spiralled well flow loop - 50 m long, 5 m high

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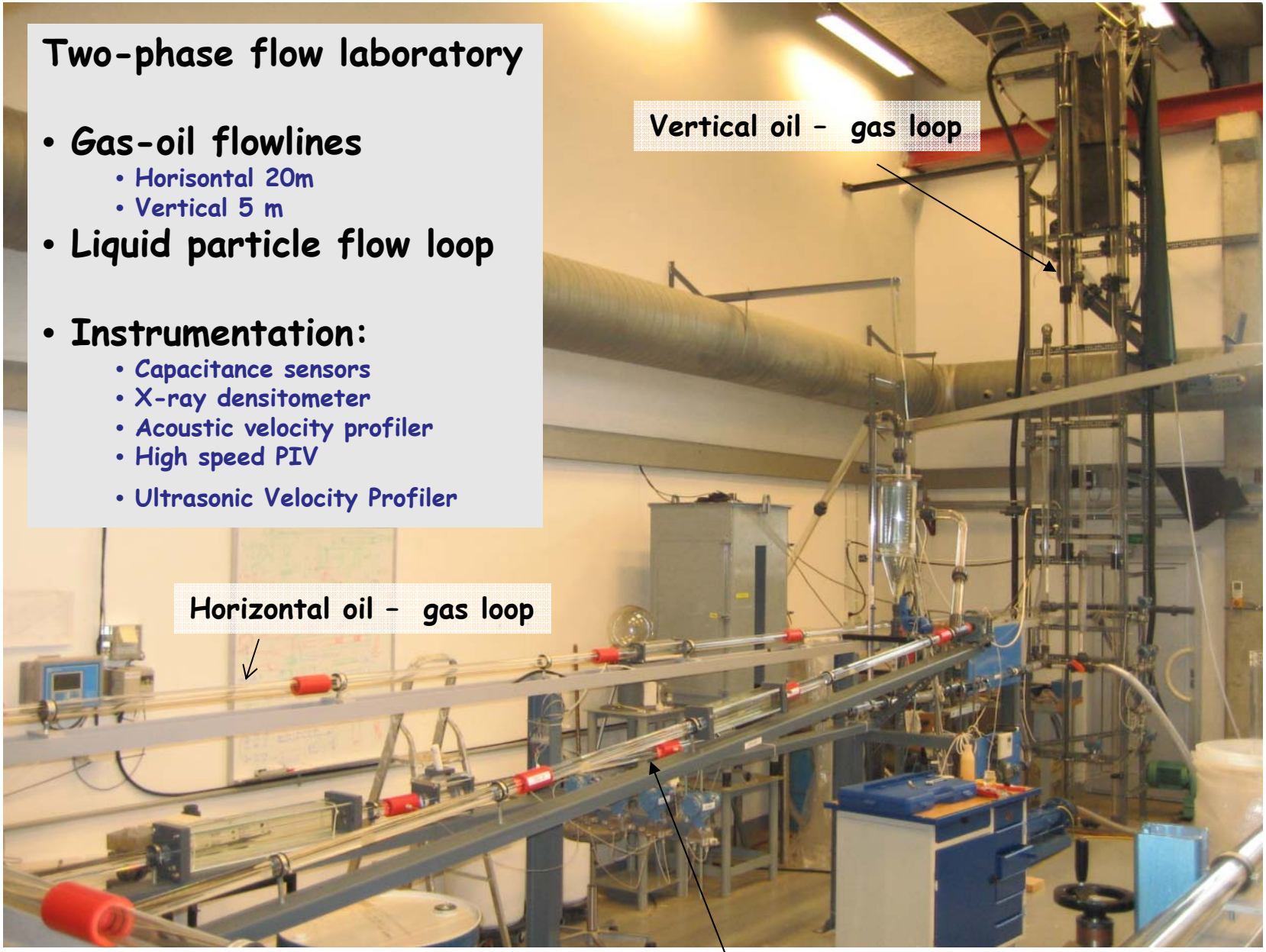
Two-phase flow laboratory

- **Gas-oil flowlines**
  - Horisontal 20m
  - Vertical 5 m
- **Liquid particle flow loop**
- **Instrumentation:**
  - Capacitance sensors
  - X-ray densitometer
  - Acoustic velocity profiler
  - High speed PIV
  - Ultrasonic Velocity Profiler



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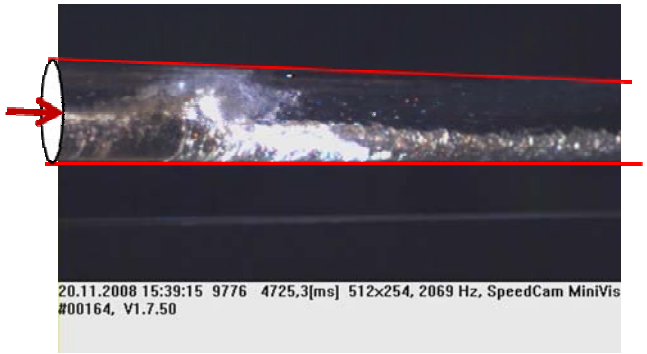
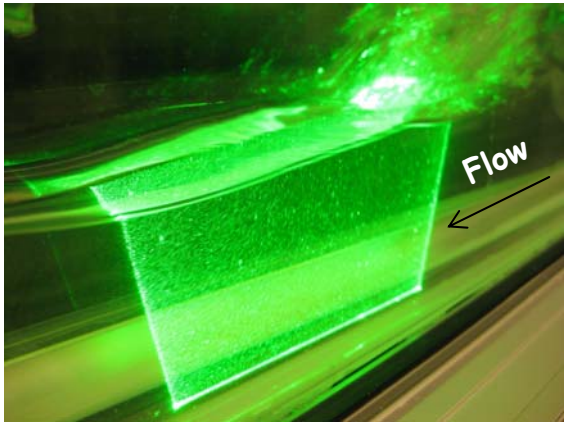
High speed optical methods for fluid dynamics PIV, LDA, high speed cameras

Slugging in circular horisontal pipes

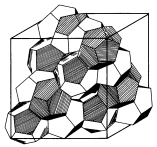


Catching the Kelvin-Helmholtz slugging instability in a rectangular channel with laser based hgh speed PIV (2000 frames/s)

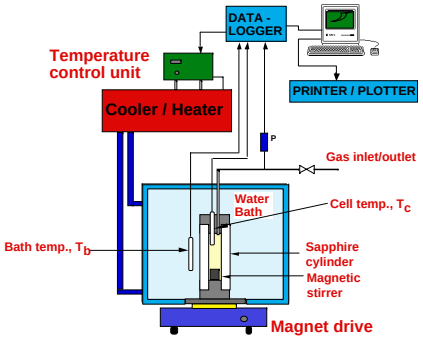


Taylor bubble diving up in a vertical well in non-Newtonian flow

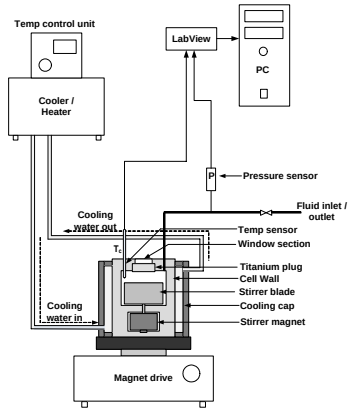
Lab facilities: Natural Gas Hydrates



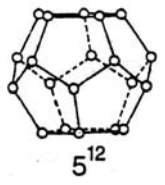
- **8 (9) cells with magnetic stirring**
  - **3 sapphire tube cells with stirring**
    - V = 23 cc
    - Operational temperature:
      - -30 to +40 °C.
    - Operational pressure: > 200 bar
    - Data sampled: Rpm, torque, P, T, time
    - One sapphire cell contains viscometer option

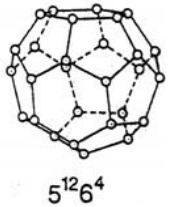


  - **4 titanium cells, stirring, 1 sapphire window**
    - V = 145 cc. Data sampled: P, T, time.
    - Operational pressure: 275 bar



  - **1 Stainless steel cell, stirring, 4 sapphire windows**
    - V = 258 cc. Data sampled: P, T, time. Operational pressure: 275 bar
- **Lab View data acquisition system**
- **Software:**
  - **PVTsim, CSMHYD, CSM Gem, CSM Plug**





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Conclusions

Norwegian R&D at research institutes and universities got substantial "vitamin pills" from offshore petroleum industry, caused by:

- Visionary politicians - at the right time, in a democratic system
- Oil companies that realized the advantage of involving R&D institutes and universities in joint programs
- Strong taxation regimes possible due to
  - high oil prices
  - large oil and gas reserves offshore Norway

Beyond national tax incomes, the outcome of industrial cooperation has lifted norwegian onshore - as well as offshore - industry. Improved quality standards, environment and safety!

Norwegian petroleum R&D top ranked in disciplines such as geophysical exploration, reservoir technology, deep and horisontal drilling, long distance multiphase transportation and flow assurance.

Being outside OPEC and EU, Norway is considered an "unbiased" partner for many countries who are in the process of building their own national oil and gas industry.

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Thank you for your attention