Overview of optimal development choices depending on tight reservoir characteristics

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Development issues

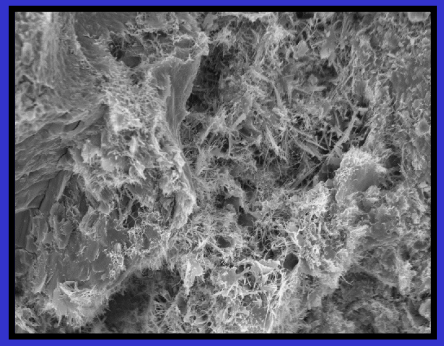
Tight gas means:

- Unattractive economics or a poor RF per well due to low connected GIIP or to poor well productivity

What can we do about it?

- Productivity Improvement (many existing techniques)
- Economic performance improvement :
  - Minimize technical risk by standardized designs and procedures, deploy existing (mature) technology, well organized planning of operations, cross-regional learning
  - Low-cost drilling and development

Tight Gas?



- Definition of ‘tight reservoir”
  - The definition of a “tight“ (very low permeability) reservoir is somewhat arbitrary
    - Generally formations which have a surface routine average absolute air permeability of <20 mD.
    - In-situ reservoir condition permeabilities in these types of reservoirs are generally <1 mD and can often range down into the low microDarcy range (10-e6 D)
  - Low pressure formations or gas fields with short length gas columns may fall into a ‘near tight’ category.
    - Most of these formations have 40 to 60% connate water saturation

Why Tight ?

- Varying reservoir quality can be due to several different combinations of factors:
  - Lithology / grainsize / sorting / clay content/ bedding type/ compaction
  - Exposure to various degrees of diagenetic alteration
- Poorly defined K/phi relationships are typical
- Key feature – generally not the entire reservoir is tight
  - significant heterogeneity is common
  - Higher porosity & permeability streaks (HPS) can be present
  - Fractures

A range of depositional settings

-Example Rotliegend

Alluvial fan

Wadi / floodplain

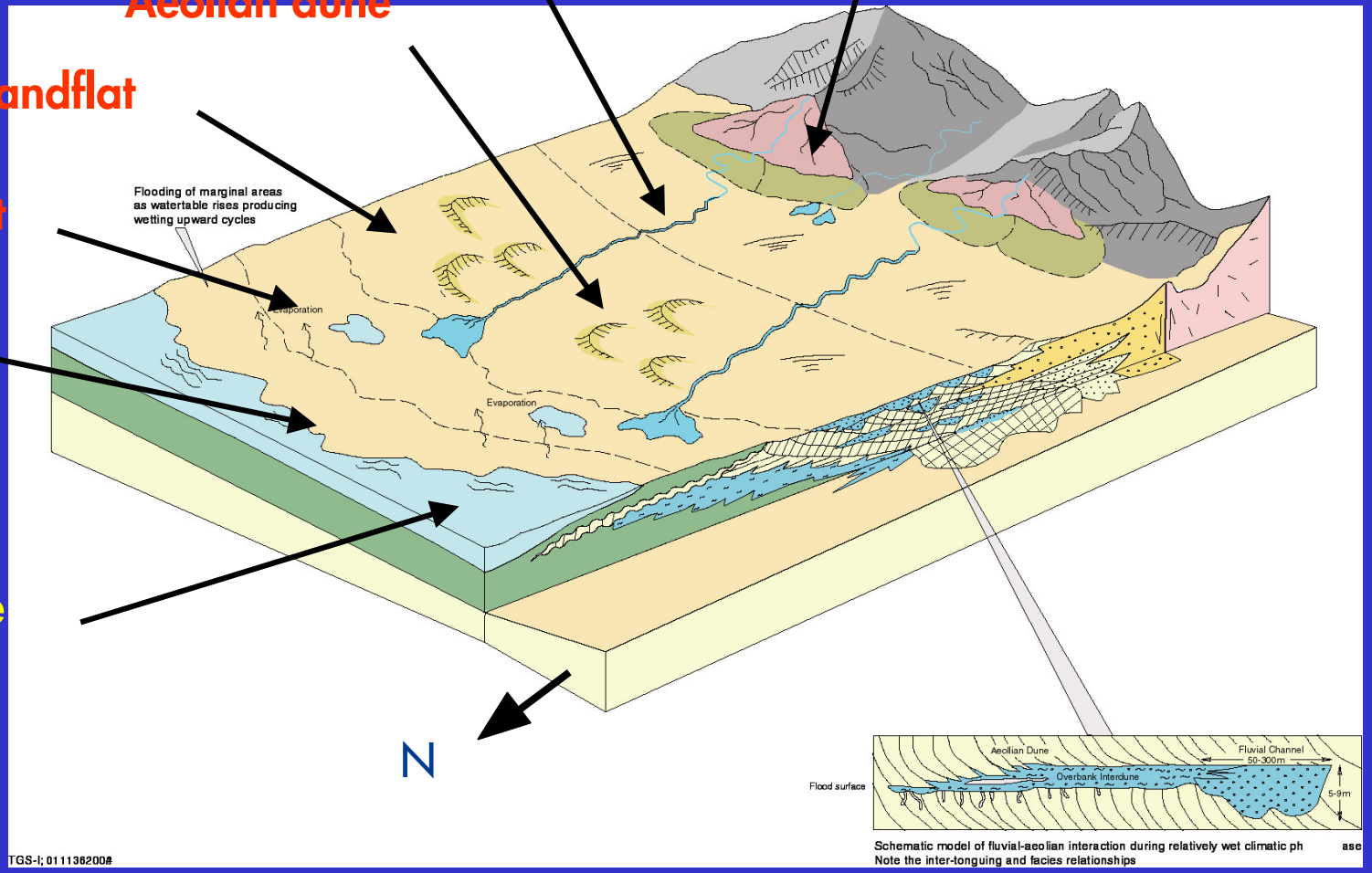
Aeolian dune

Dry sandflat

Damp sandflat

Wet sandflat

Playa lake



Key Development challenges

- TG Volume in NL is distributed over series of small fields with variable subsurface challenges
  - Requiring different toolbox solutions
  - Correct choice of development method critical for economic success. Typically will allow only 1-2 wells to develop the gas - a strong need to get it right first time !
  - Technical and operational de-risking essential

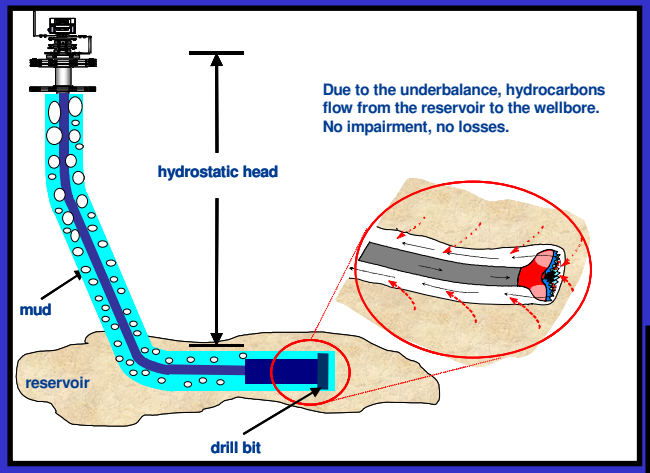
- Productivity improvement
  - **no silver bullets exist**
  - diversity of reservoir types/issues requires full toolbox: UBD, fraccing, CT/CT UBD drilling, enhanced perforation, ML/ultra short radius drilling

- Cost reduction
  - Focus on deployment and optimisation of already available techniques
  - operational efficiency, mob-demob costs

Development steps & elements

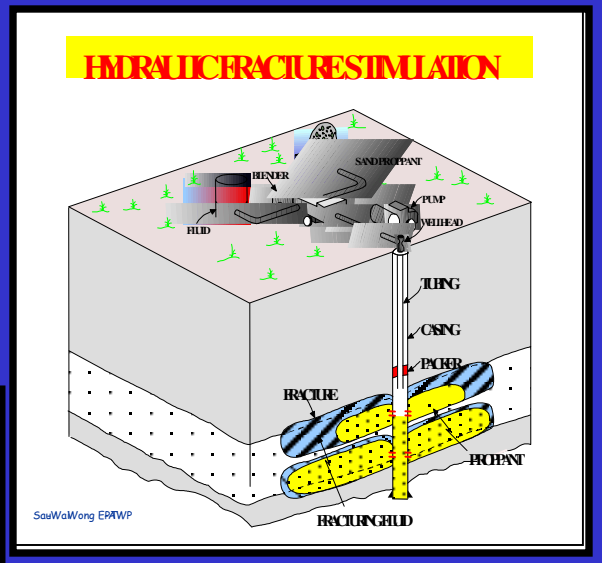
- Implementation staircase & Climbing of next steps
  - Stepwise de-risking of subsurface/surface risk elements by:
    - Enhanced data acquisition/knowledge of subsurface
      - » Reservoir description
      - » Reservoir productivity (prediction)
  - Technology elements (3D modelling/drilling/completion/stimulation)
    - Need to developed in parallel to build/maintain the necessary momentum and timing to climb each next step of staircase
  - Cost reduction

Overview TG Development methods used (TG Toolbox)



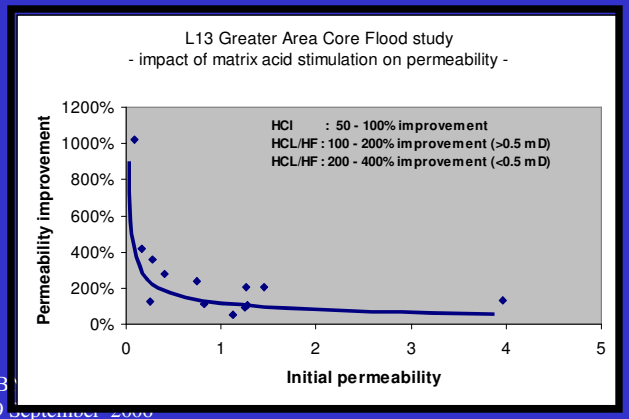
UBD

CT/CT UBD

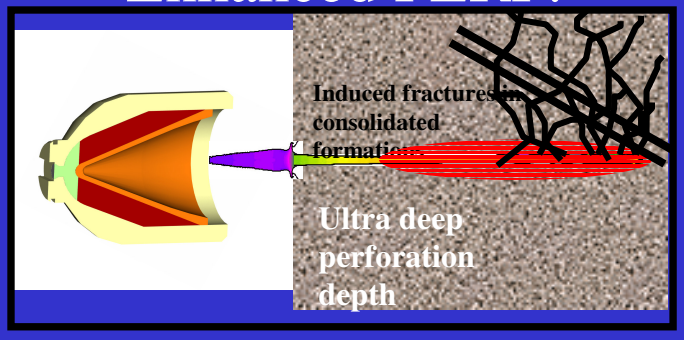


FRACCING

ACID



Enhanced PERF.



Development methods

Choice of development concept

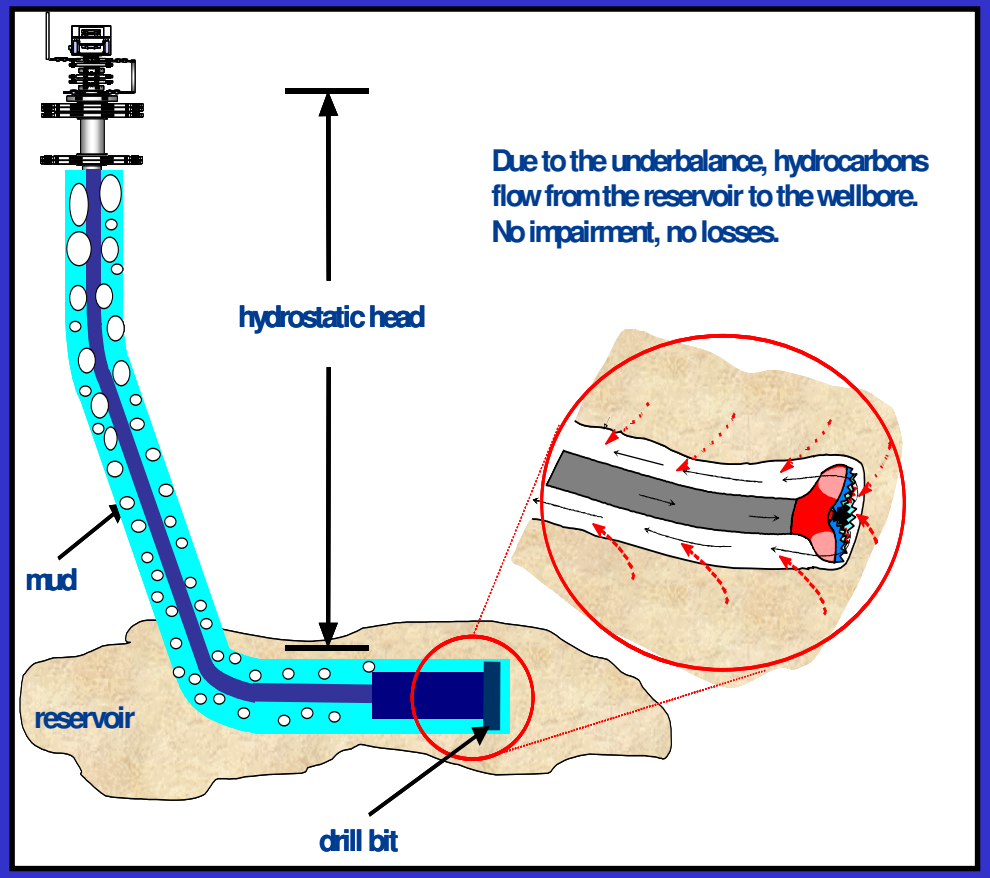
– is steered by the following factors:

- Borehole stability
- Presence of natural (open) fractures
- Fluid composition (sour/sweet gas)
- Height of HC column
- Compartmentalisation
- Vertical connectivity
- Permeability heterogeneity
- Cost vs. well productivity gain

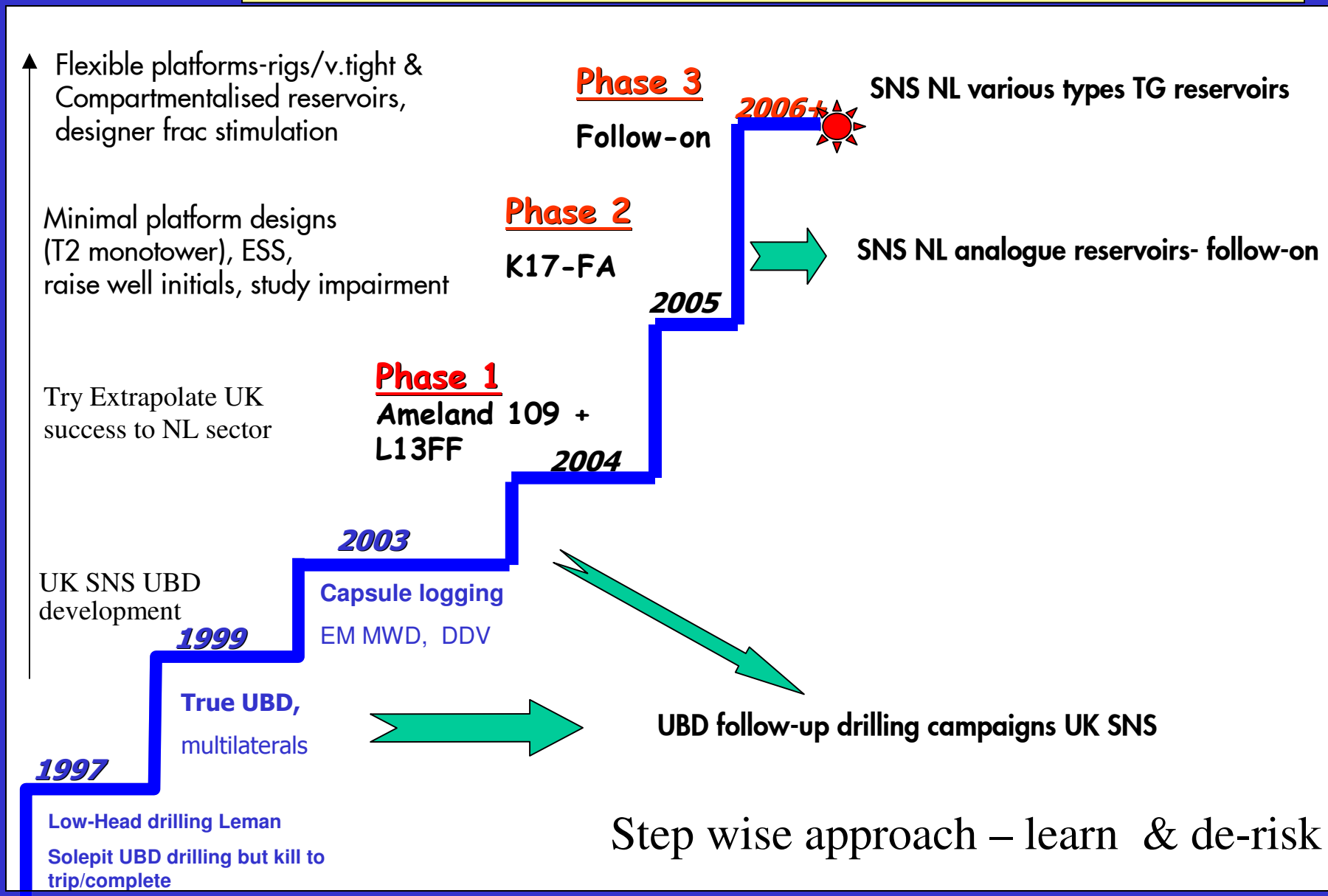
UBD

Issues

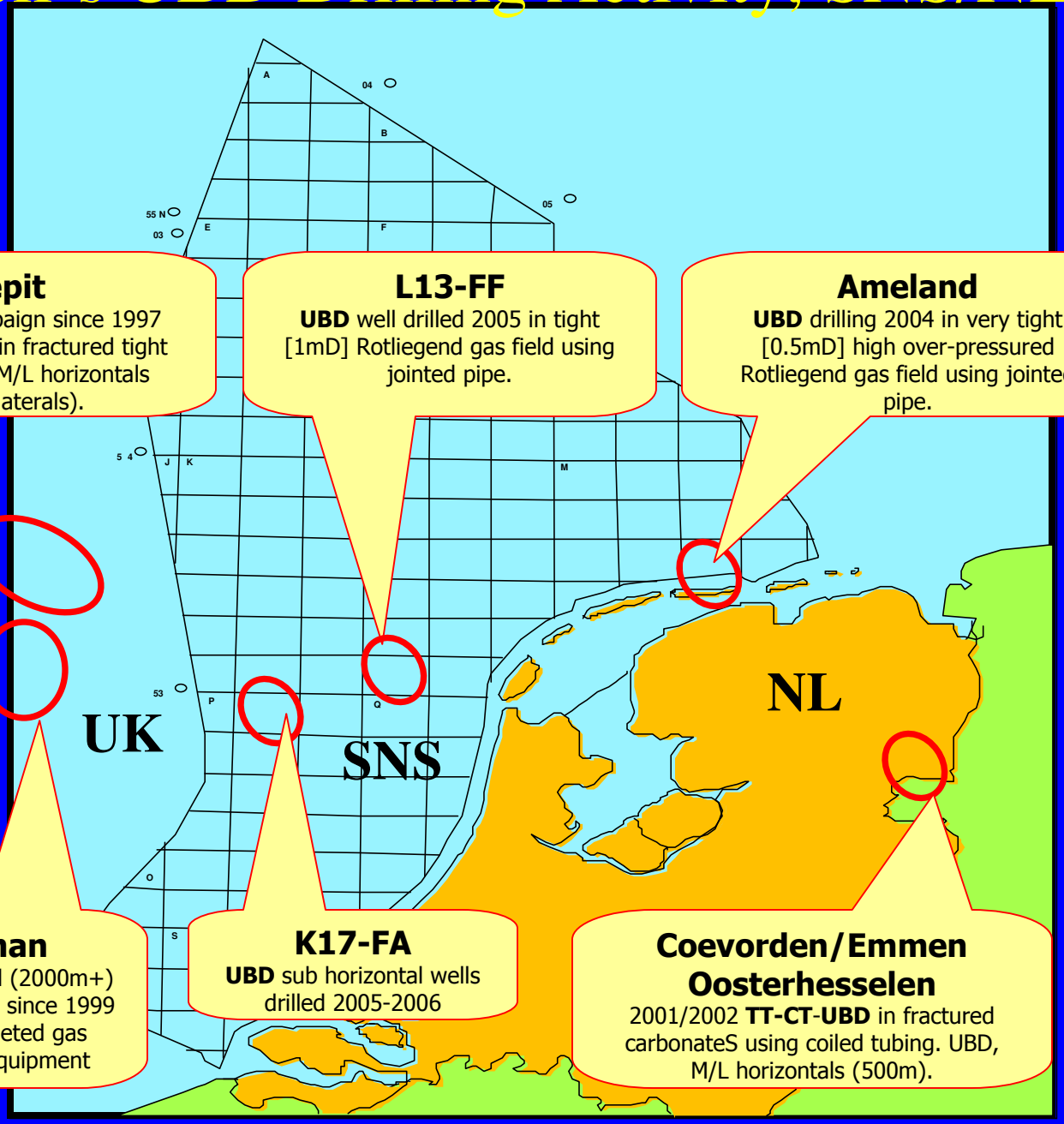
- Operational issues
  - Attention to detail is critical
- Costs
- Sequence continuity
- Borehole stability
  - shales
  - sand production/sand control
- Reservoir Characterization
  - Fractures
  - HPS
  - Focus on contra indicators
- Flaring



SNS tight gas staircase



Shell's UBD Drilling Activity, SNS/NL Land



Solepit
UBD drilling campaign since 1997 using jointed pipe in fractured tight gas fields. UBD, M/L horizontals (~1000m laterals).

L13-FF
UBD well drilled 2005 in tight [1mD] Rotliegend gas field using jointed pipe.

Ameland
UBD drilling 2004 in very tight [0.5mD] high over-pressured Rotliegend gas field using jointed pipe.

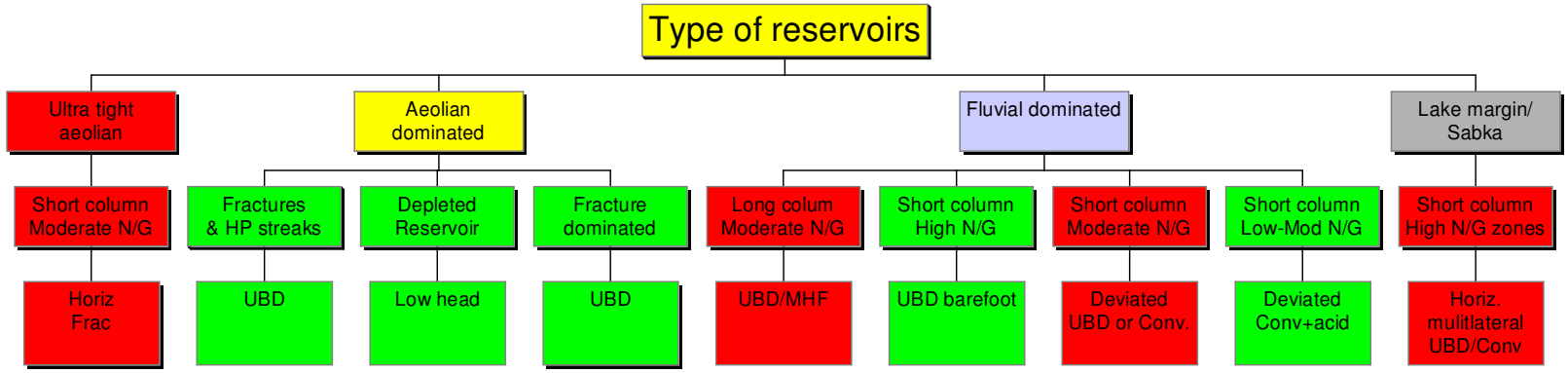
West Leman
Low-head horizontal (2000m+) well drilling campaign since 1999 to drill heavily depleted gas sands using UBD equipment

K17-FA
UBD sub horizontal wells drilled 2005-2006

Coevorden/Emmen Oosterhesselen
2001/2002 **TT-CT-UBD** in fractured carbonateS using coiled tubing. UBD, M/L horizontals (500m).

Type of reservoir steers TG wells development choice

Tight gas SNS



DE-RISKING	
Method specific	**Prospect specific**
Productivity matrix	GIIP
Nat. Fracture contribution	GWC
Hole stability	Compartmentalisation
ROP	K -distribution
Vertical transmissability	Facility cost
Rel perm	
well cost	

CT/CT UBD

Method used : through tubing coiled tubing drilling

Issues

- Rig/crew availability
- Sequence (mob/de-mob effort/costs)
- Limited hole length
- Borehole stability
- Fracture prediction

Successes

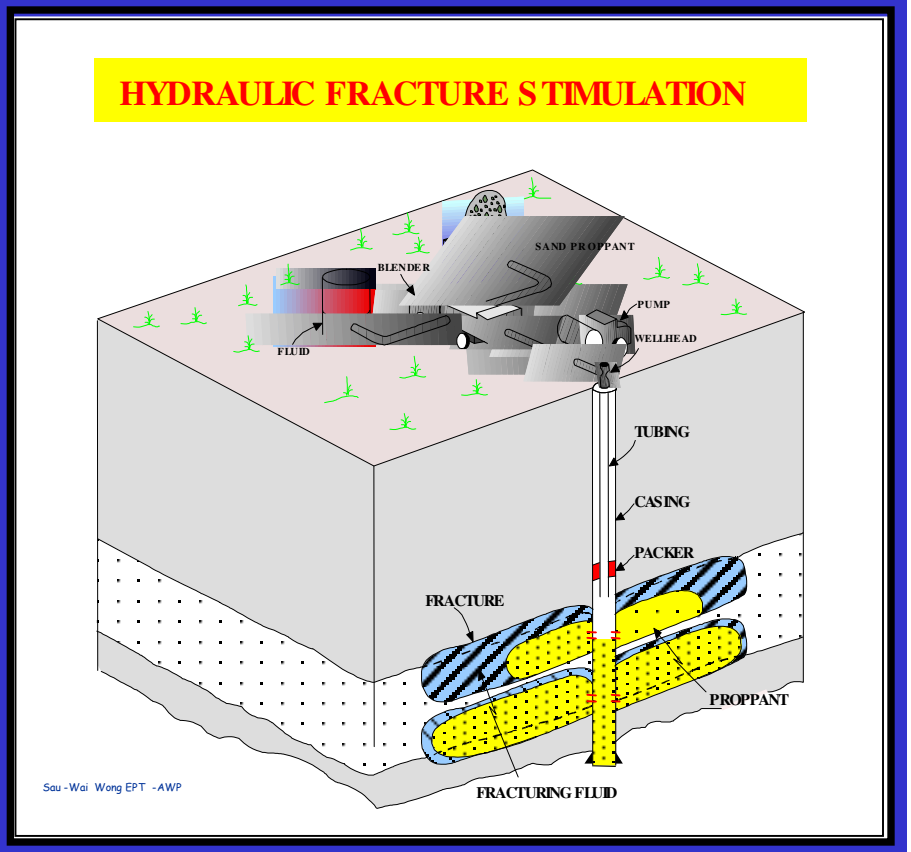
Netherlands land

- 4 wells drilled in fractured Zechstein carbonates (high H2S)
  - Emmen-8 /Coevorden 16 & 17 /Oosterhesselen-3
- Good cost reduction drive

Frac stimulation

Issues

- Crew/equipment availability
- Sequence
  - mob/de-mob effort/costs
  - discontinuous sequence
- Well to be designed for fraccing
- Frac fluids
- Placement control
- Proppant flowback
- Frac fluids recovery
- Thin columns (H2O influx)



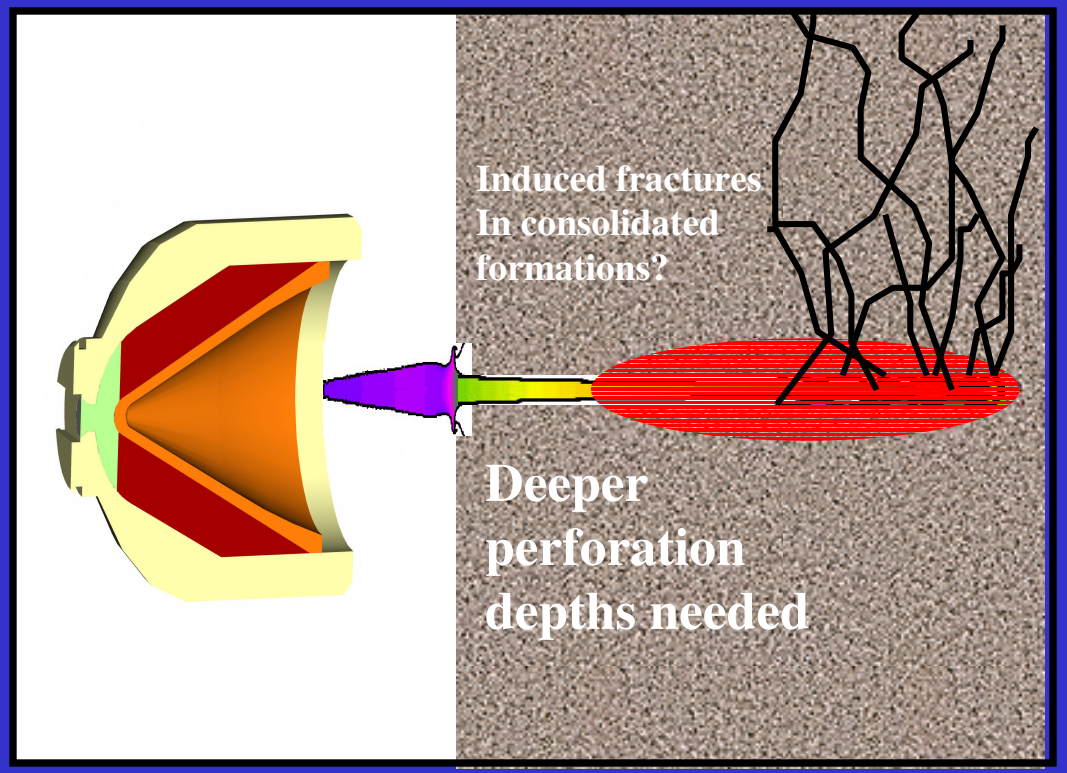
NL way forward

- Use experience gained by operators/service industry in N.America
  - Most used world wide method to develop TG reservoirs – 60000 wells/year
- Further study options for fraccing TG wells
  - long horizontal Rotliegend wells

Enhanced Perforation

Issues

- Hole size constraints
  - Choice needed on hole sizes
- Availability
  - Service industry working on enhanced depth guns
  - Late 2006/early 2007
- Unproven technology
  - Requires more testing



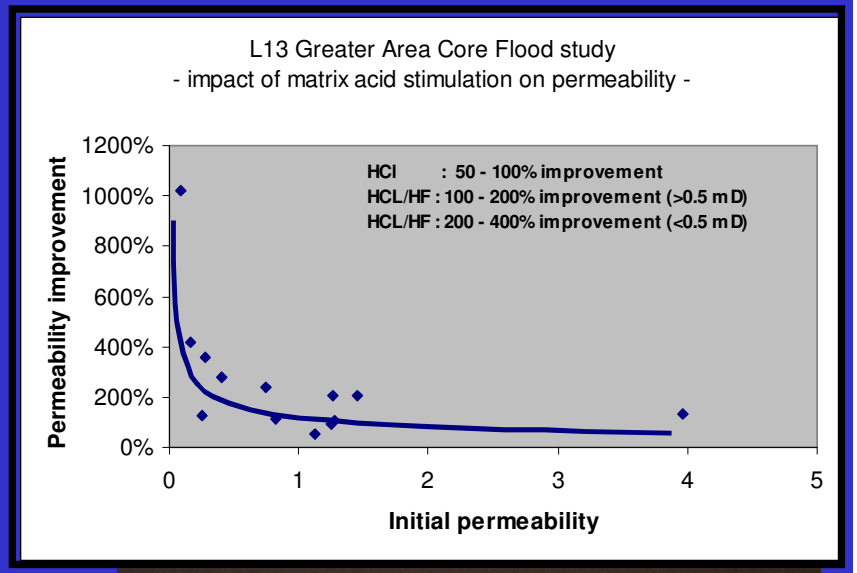
Acid

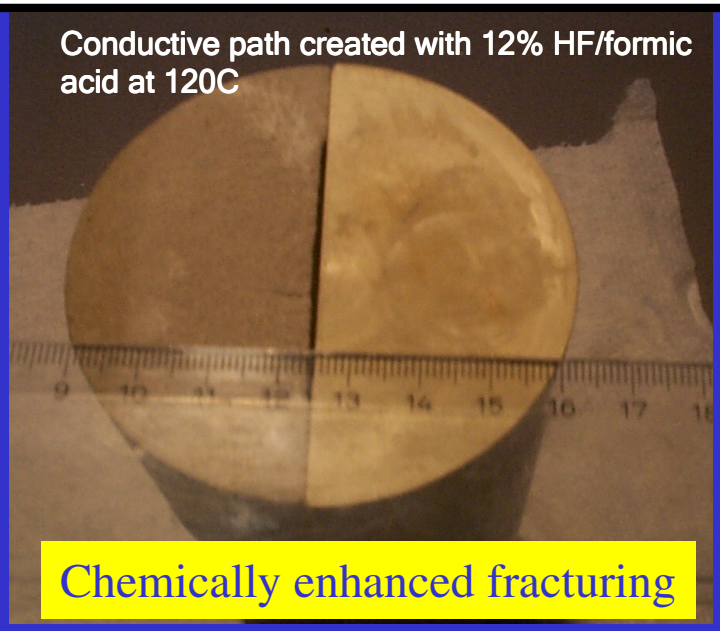
Issues

- Placement control
- Corrosion inhibition at higher temperatures
- Injectivity>
  - (min ~ 0.5 - 1 mD for gas wells)
- Disposal of spent acid

Successes

- NOV Denmark (Maersk)
  - Chalk TG fields acid frac and acid jetting
  - regularly applied in v. long offshore horizontal wells (15K-20K ft)
- SNS
  - Existing well treatments





Chemically enhanced fracturing

TG - Key Technology enablers

- Most of the technologies required for the development of tight gas reservoirs already exist but need to be tested/deployed and/or further refined.

Facilities

- Remotely operated minimal surface facilities
- Critical issues : Concurrent operations options, HSE (crew access/flaring)
- Moveable platforms/pipelines for initial development option (mitigate against low side risks)
- Wet gas compression at well head
- Modular facilities

Wells

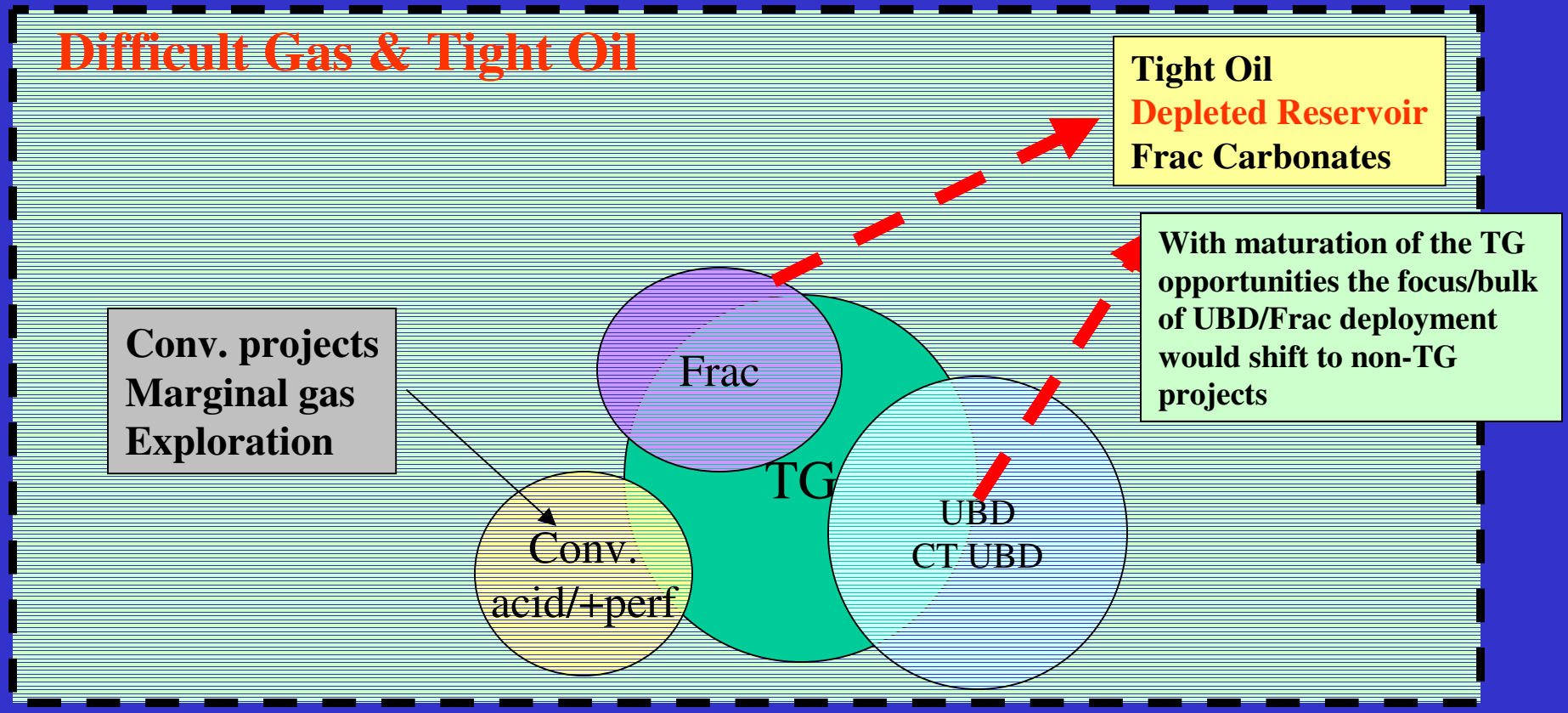
- High level multilateral wells
- Hydraulic multi-frac stimulation (wireline, frac fluids optimisation, precision fraccing, rock – fluid interactions)
- Underbalanced drilling
- Minimal footprint
- Casing drilling/expandables
- Enhanced perforation (propellant frac, enhanced/extreme deep perforators)

Data

- Improved data acquisition & enhanced LWD tool reliability
- Smart wells, reservoir monitoring

Way forward

Synergy with other opportunities??



Enabling technology will also progress development of marginal fields