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PETROBRAS

A Methodology to Design Exploratory Wells

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Topics

- Introduction
- Well Management Process
  - Matrix of Criticality
  - Processes
    - Engineering
    - Operation
    - Safety
- Case Study
- Conclusions

Introduction

Depletion of old field

New opportunities

New frontiers

High cost of the drilling rigs

Cost Reduction

Underestimate the well design

Loss of the well

Reconstruct a new well

Expensive Wells

Unexpected Increase in Cost

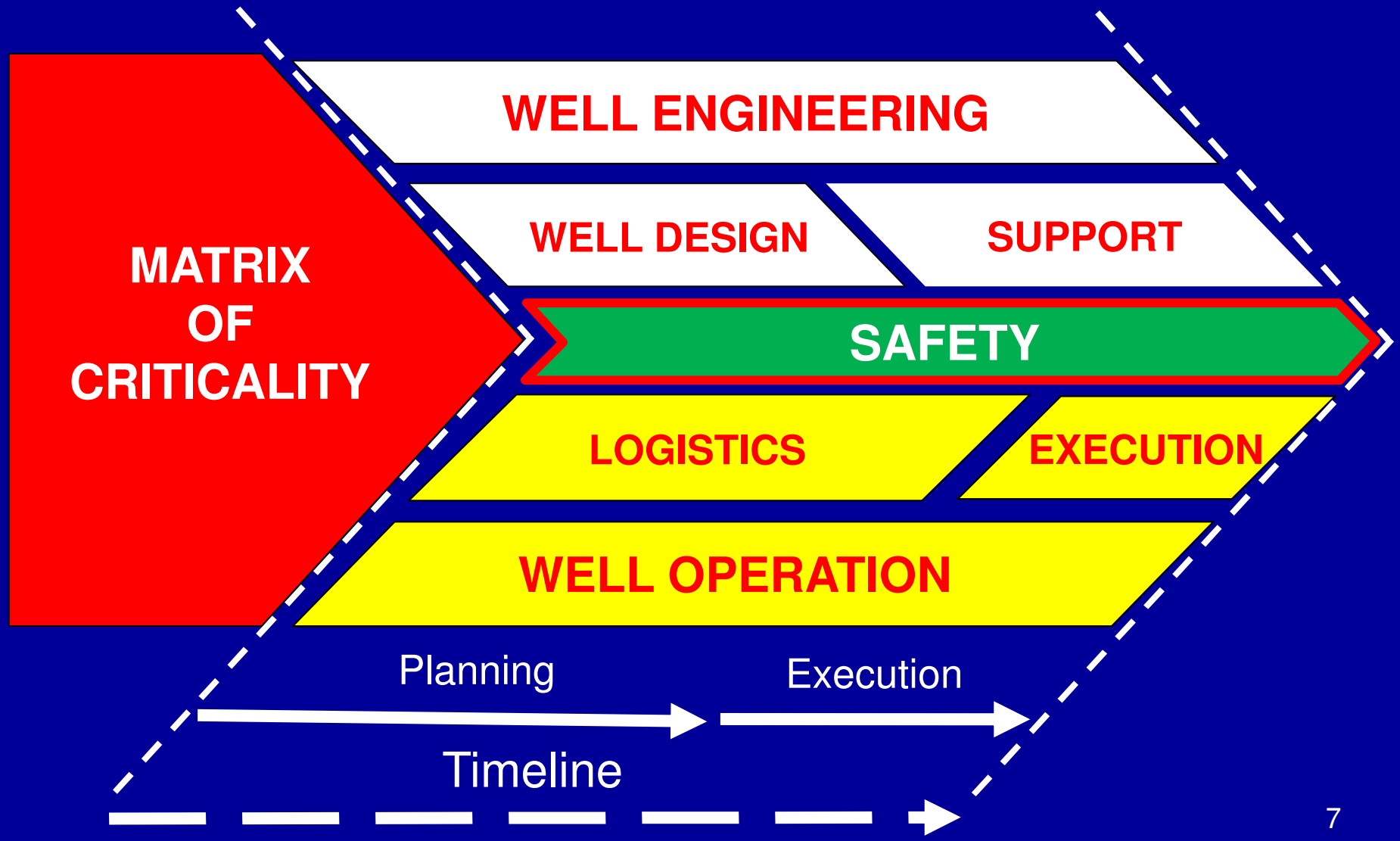
Wild Cat Wells / Country	Year	Safety Related Problems
Well-1 (Country 1) Shallow Water	1	Actual pore pressure higher than predicted pore pressure ➔ kick Rig and well design considered inappropriate Well reach TD but time and cost much higher than forecast **Lack of methodology and "well robustness" was low**
Well-2 (Country 1) Shallow Water	2	**Kick. No barite during the well control operation.** Rig and well design considered inappropriate Well did not reach TD **Lack of methodology and "well robustness" was considered low**
Well-3 (Country 2) Deepwater	2	Lithology: predicted and actual did not match. Temperature much higher than expected. No pore pressure specialist at the rig site. Well did not reach TD **"Well robustness" was considered low**
Well-4 (Country 3) Deepwater	3	**New systematic for designing wells** **Great emphasis on reducing geopressure uncertainties** Three independent geopressure studies were performed **Well reached TD within the forecasted time and cost**

Objective

Well Management Process (WMP) based on Petrobras Best Practices

The final goal of the WMP is to construct the well that safely reaches its targets within the expected time and cost

Well Management Process



Matrix of Criticality

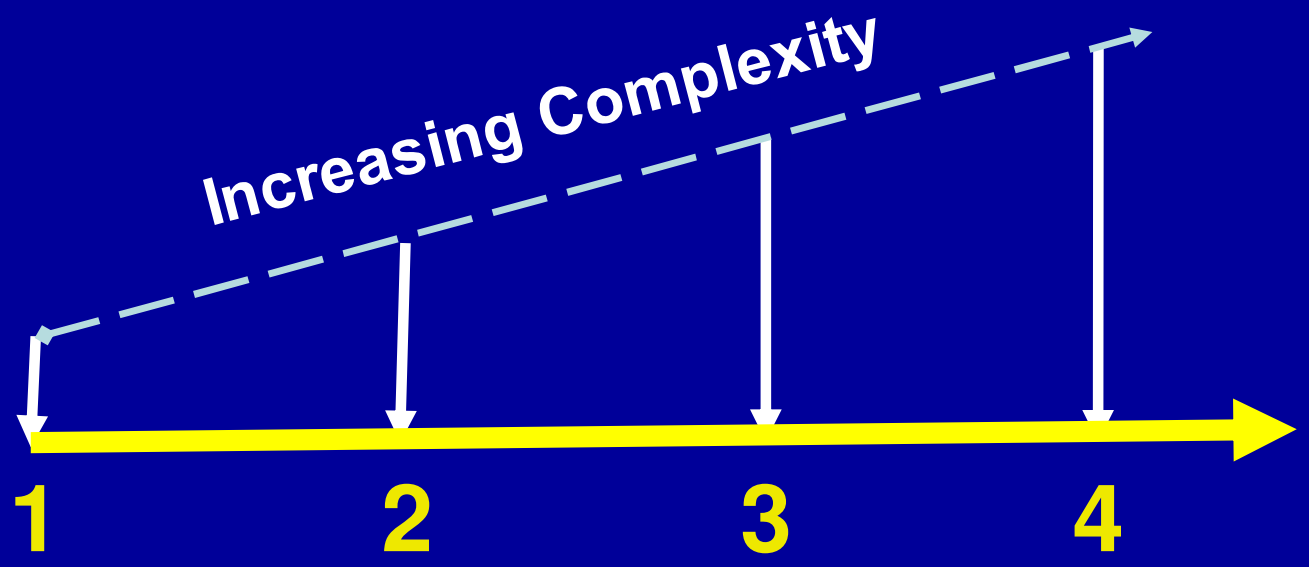
Matrix of Criticality

Matrix of Criticality

- Well Complexity Index
- Well Robustness
  - Extra Casings
  - Mitigating Actions

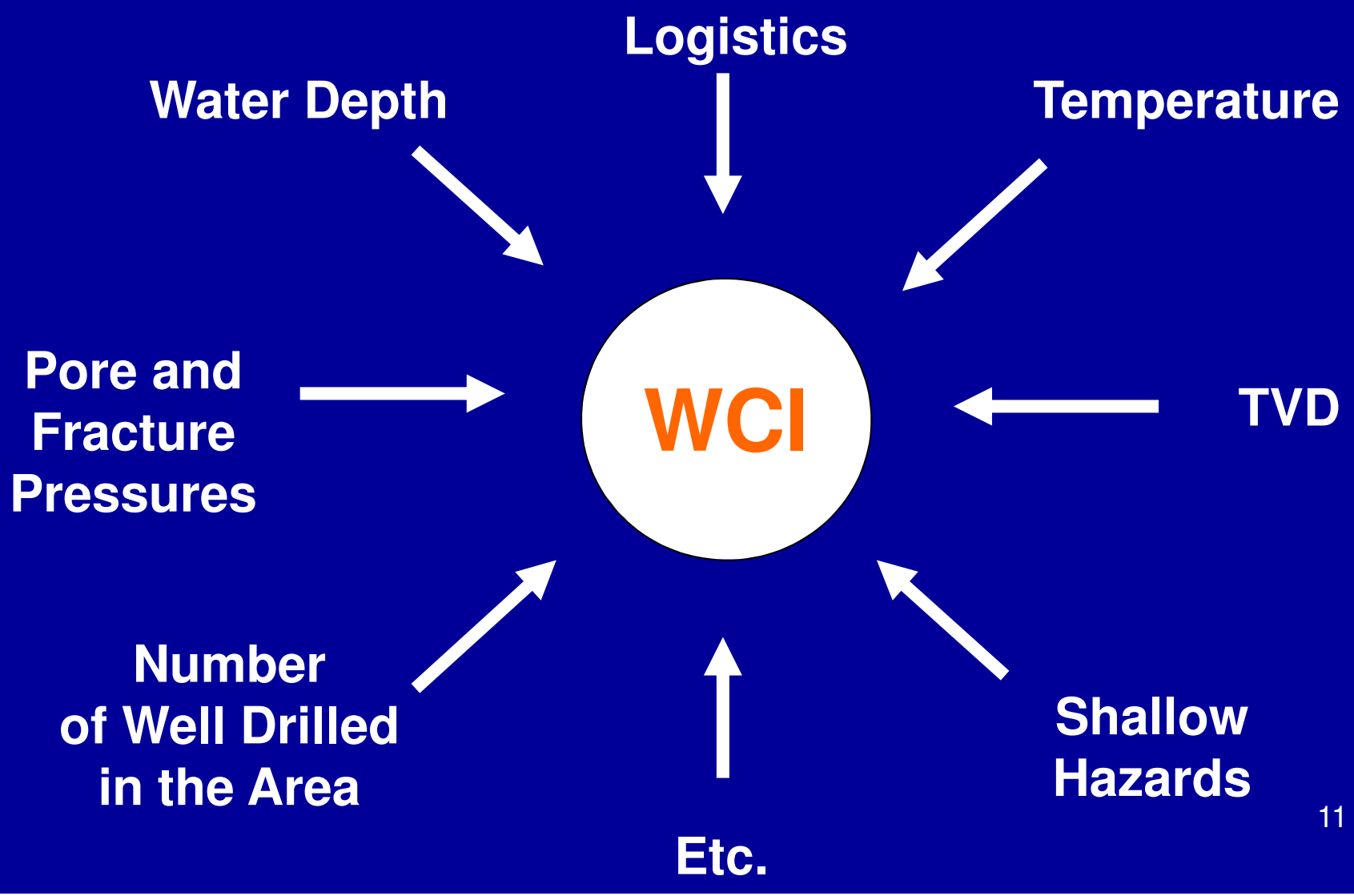
Well Complexity

The **Well Complexity Index** (**WCI**) is used to quantify the geological, operational and logistics risks associated to the drilling of a well.



Well Complexity Index

Well Complexity Index (WCI)



Well Robustness

Well Robustness (**WR**) is the combination of the number of casing strings and the mitigating actions that the company must follow to guarantee the success of the well.

More Robust

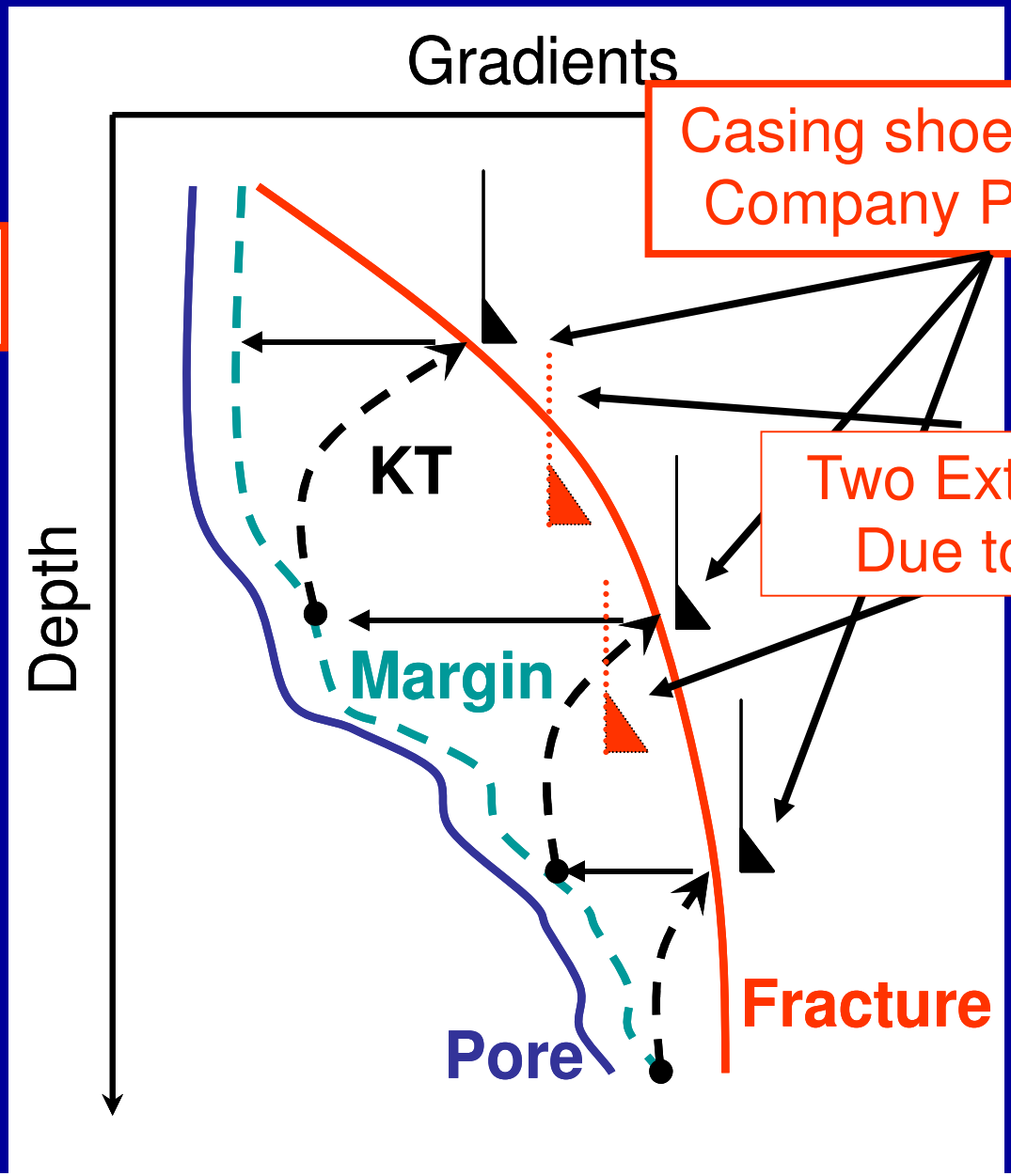
Well Robustness	Number of Extra Casings
A	0
B	1
C	2
D	3

Well Robustness versus Extra Casings

Example

WR = C

Two Extra Casing Strings



Casing shoes based on Company Procedures

Two Extra Casings Due to WR = C

Well Robustness versus Mitigating Actions

Mitigating Actions for Different Well Robustness				
Item	A	B	C	D
Seismic for GP	No	No	Yes	Yes
GP Models	1	1	2	3
Real Time GP	-	-	24 / 7	24 / 7
Company Man Experience	5 years	5 years	15 years	20 years

GP - Geopressure

WR = C

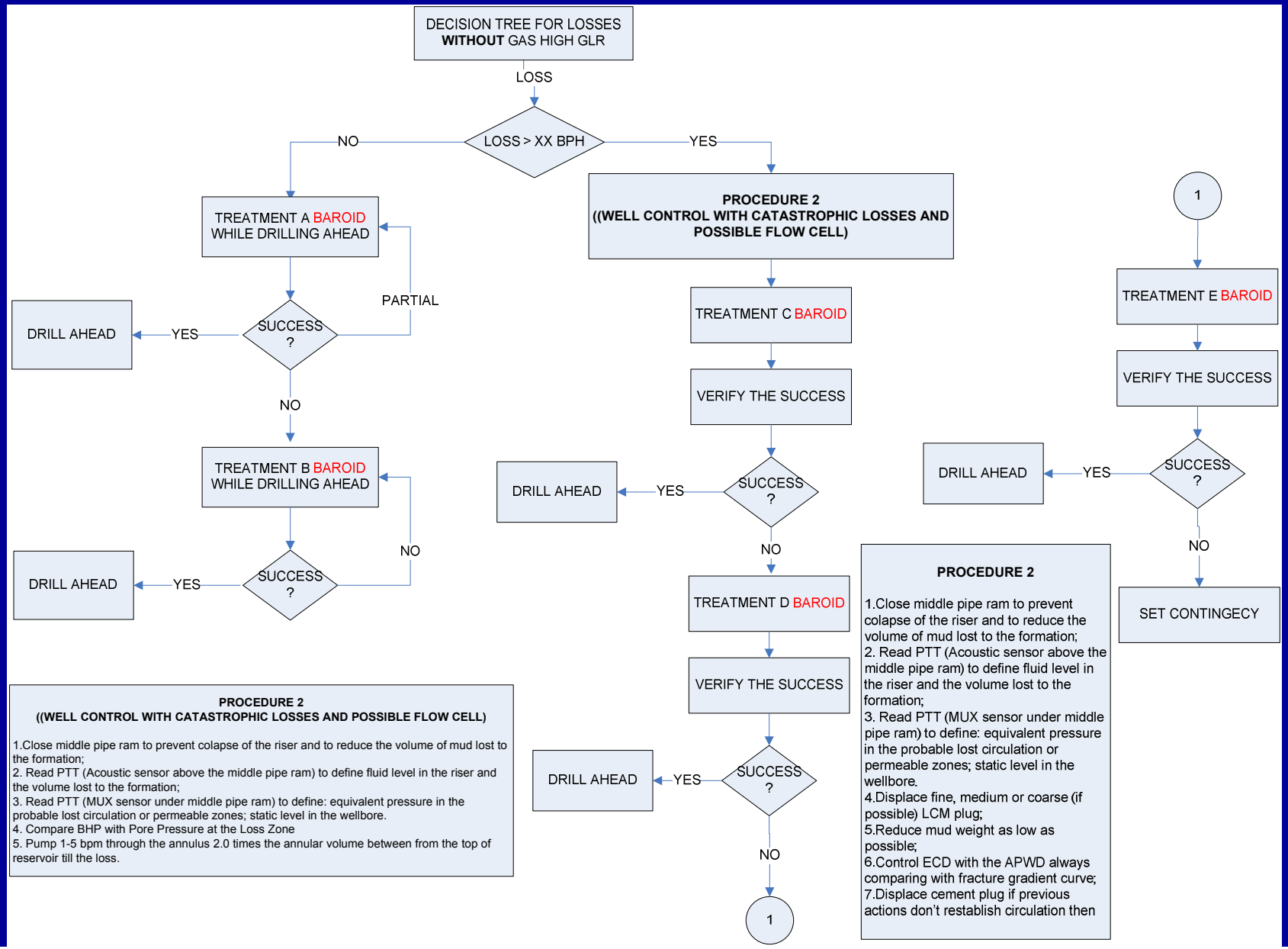
Well Robustness versus Mitigating Actions

Mitigating Actions for Different Well Robustness				
Item	A	B	C	D
Lost Circulation	-	-	Specific DT prepared	Specific DT prepared

DT – Decision Tree

WR = C

Example of Decision Tree



Decision Tree

MUD TREATEMENT TO COMBAT LOSSES (FROM LOW TO HIGH SEVERITY)

LOST CIRCULATION SEVERITY

TREATMENT A (NO PBL)

50 ppb Calcium Carbonate Fine in drilling fluid as sweeps.

OR

Spot 25 bbls of pill

Calcium Carbonate F 10 ppb
SAFE CARB 20 20 ppb
SAFE CARB 40 20 ppb

OR

Mica F 5 ppb
Mix II Fine 7 ppb
SAFE CARB 250 7 ppb
Nut Plug F 7 ppb

TREATMENT B

NO PBL
SAFECARB 40 5 ppb
SAFECARB 250 20ppb
SAFECARB 500 20 ppb
SAFECARB 1000 20 ppb

NEED PBL
Mica M 10 ppb
Mix II Med. 10 ppb
Mix II C 10 ppb
SAFE CARB 2000 20 ppb
Nut Plug F 10 ppb

BROWN – RESERVOIR FRIEND
BLACK – NOT RESERVOIR FRIEND

TREATMENT C

NO PBL FOR CONCENTRATION 1-4 PBB
CEM-NET (MUST BE IN FRONT OF THE LOSS ZONE)

OR

NO PBL
FORM – A- SQUEEZE (Calcium Carbonate)

OR

DISCUSS WITH SCHLUMBERGER ABOUT THE USE OF PBL
FORM – A- SET

OR

DISCUSS WITH SCHLUMBERGER ABOUT THE USE OF PBL
FORM – A- PLUG II

TREATMENT D

DISCUSS WITH SCHLUMBERGER ABOUT THE USE OF PBL
SODIUM SILICATE/ Calcium Chloride/ Cement

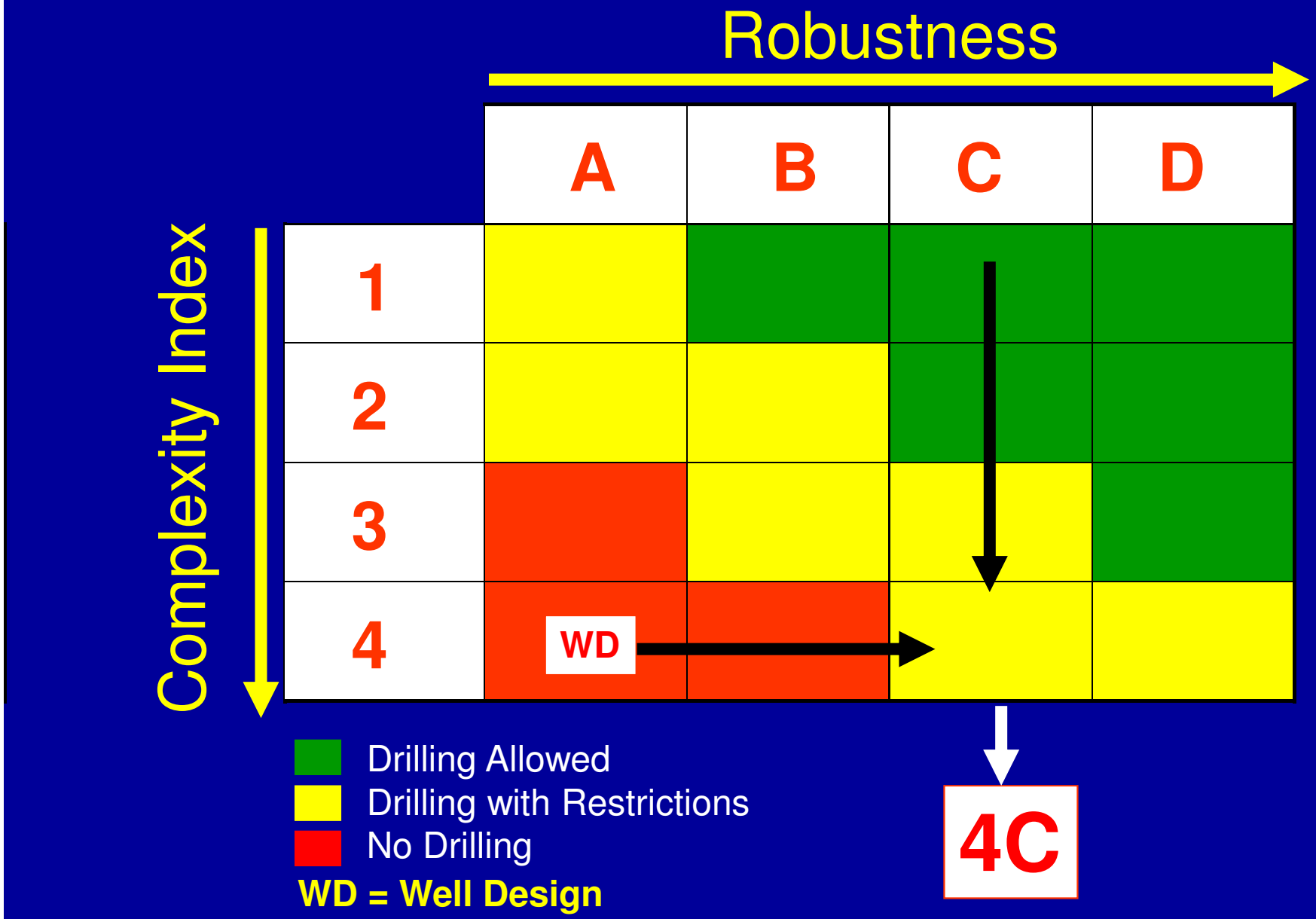
OR

NEED PBL
BARITE PLUG

TREATMENT E

NEED PBL
GUNK SQEEZE

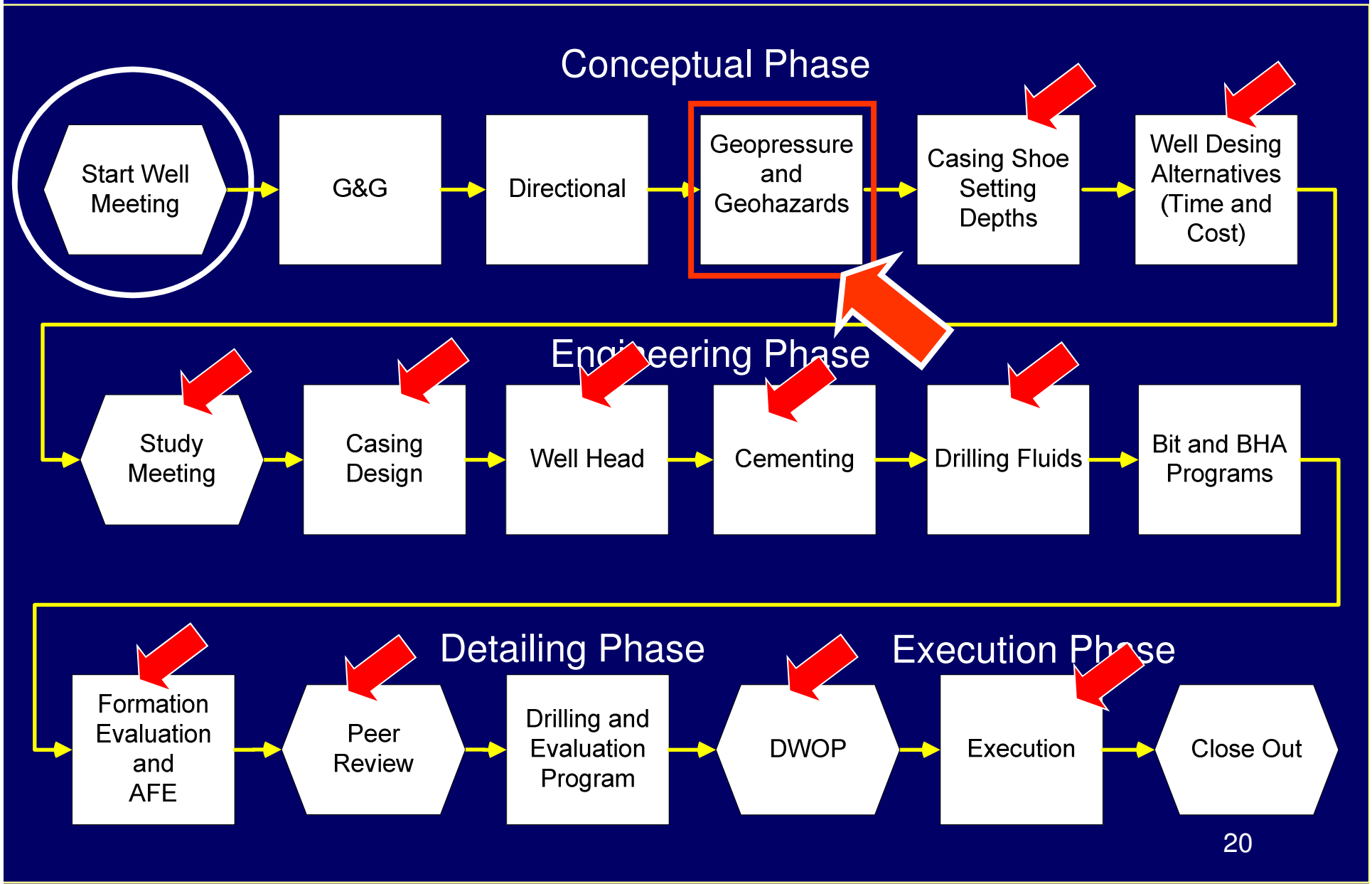
Matrix of Criticality



Well Engineering Process

Well Design and Engineering Support

Well Engineering Process



Well Safety Process (WSP)

The main goal of the WSP is to guarantee that all Company Safety Requirements are implemented in all phases of the project.

(from planning to execution)

Well Safety Process

- Operator Standards and Best Practices
- Well Control Specialists
- Prevention and Response
- **Well Control Emergency Response Plan**
  - Implemented to guarantee that the entire drilling team is well trained

Well Control Emergency Response Plan
(WCERP)

Small Kicks ……Large Kicks……..Blowout

Level 1 …….. Level 2 …….…. Level 3

Simple well control situation requiring only the use of the Drillers Method

Complex well control situation requiring actions such as direct intervention, relief well or capping

The Operator Must Be Prepared for Any of These Situations ...

Well Control Emergency Response Plan
(Blowout Control)

(Level 3 Situation)

- Simple small water kick

- Direct Intervention
- Relief Well
- Capping

The Operator Must Be Prepared for This ...

Relief Well

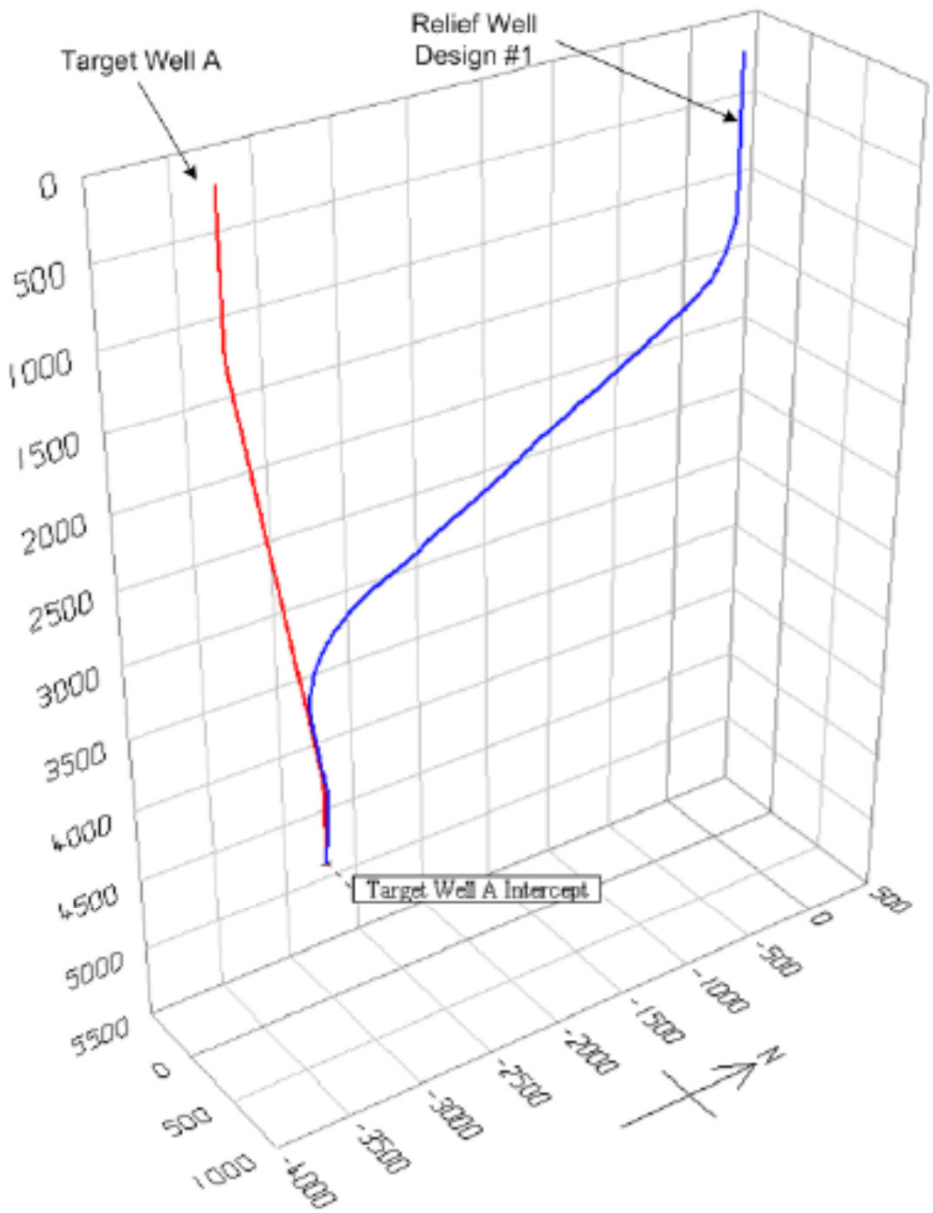
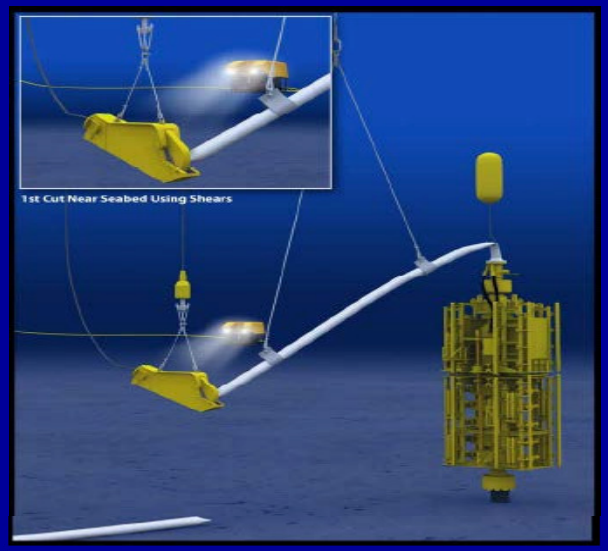
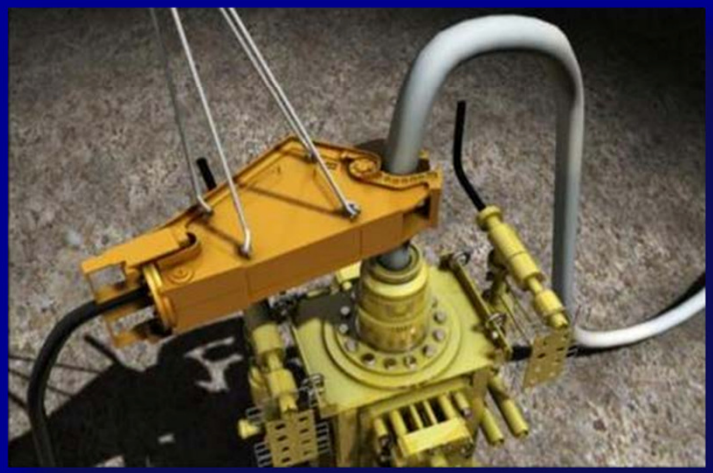


Figure 5 – Sample directional and intercept design for a relief well.

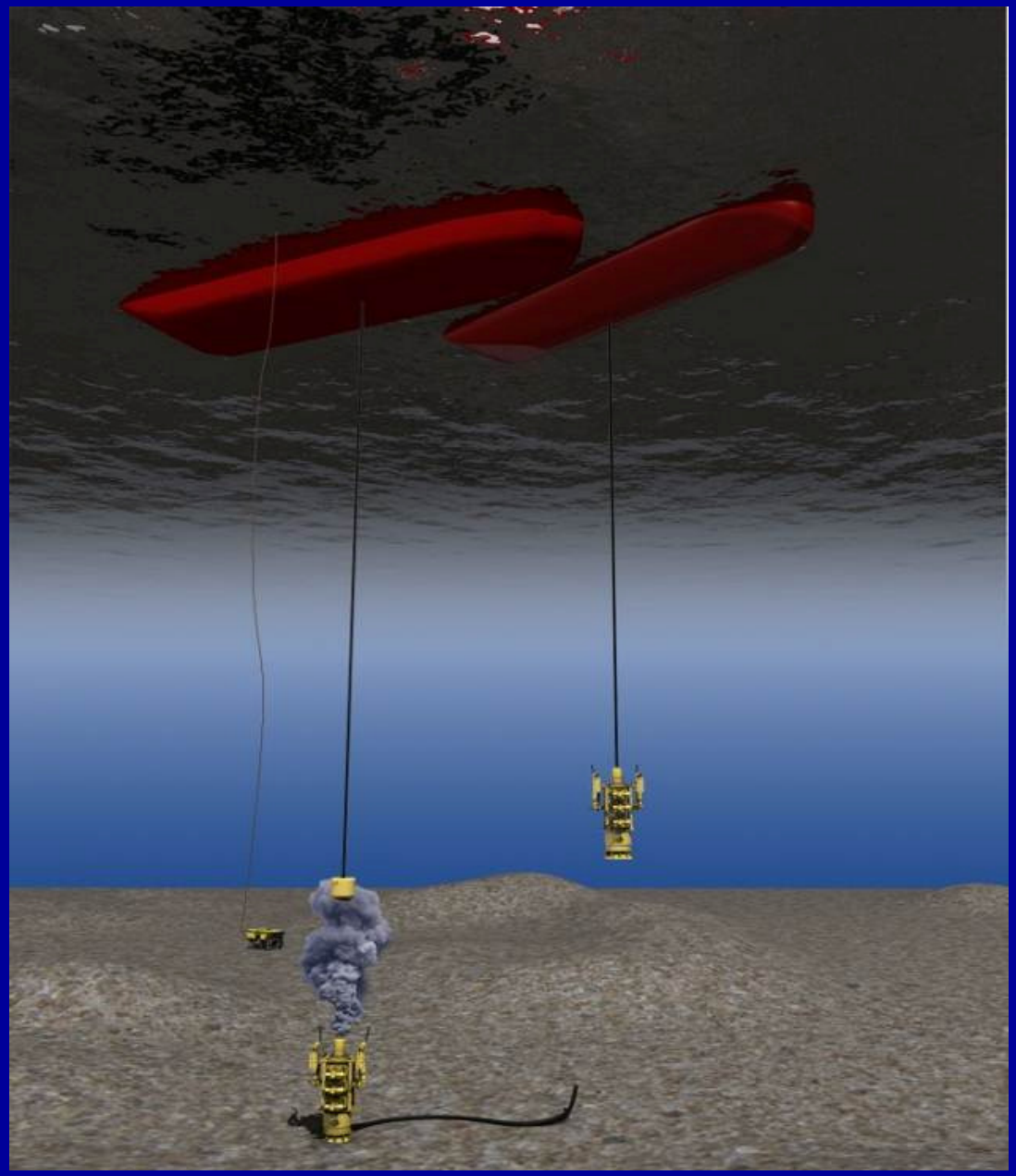
Capping

Capping





Capping



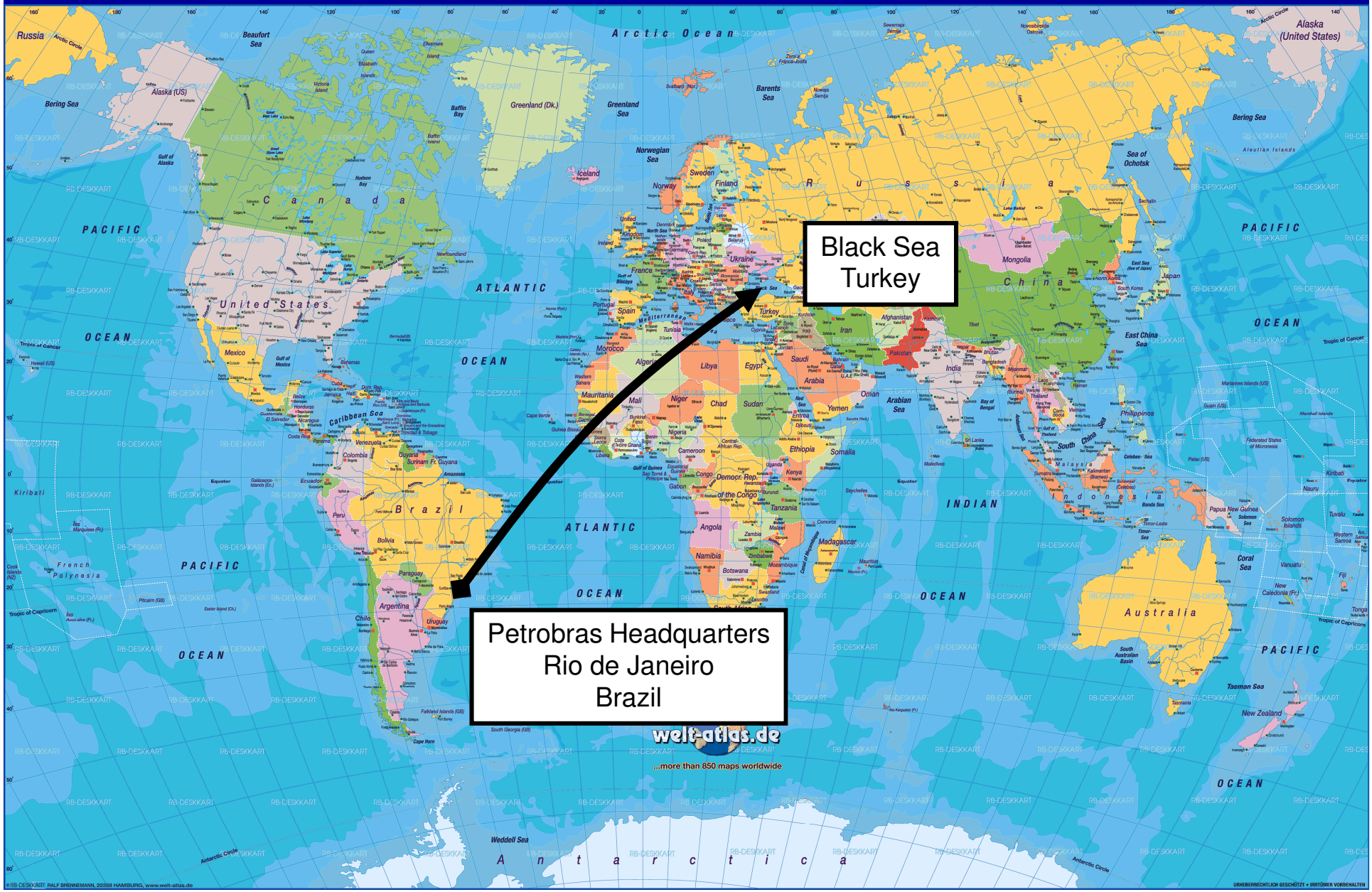
The Black Sea Project

4 C

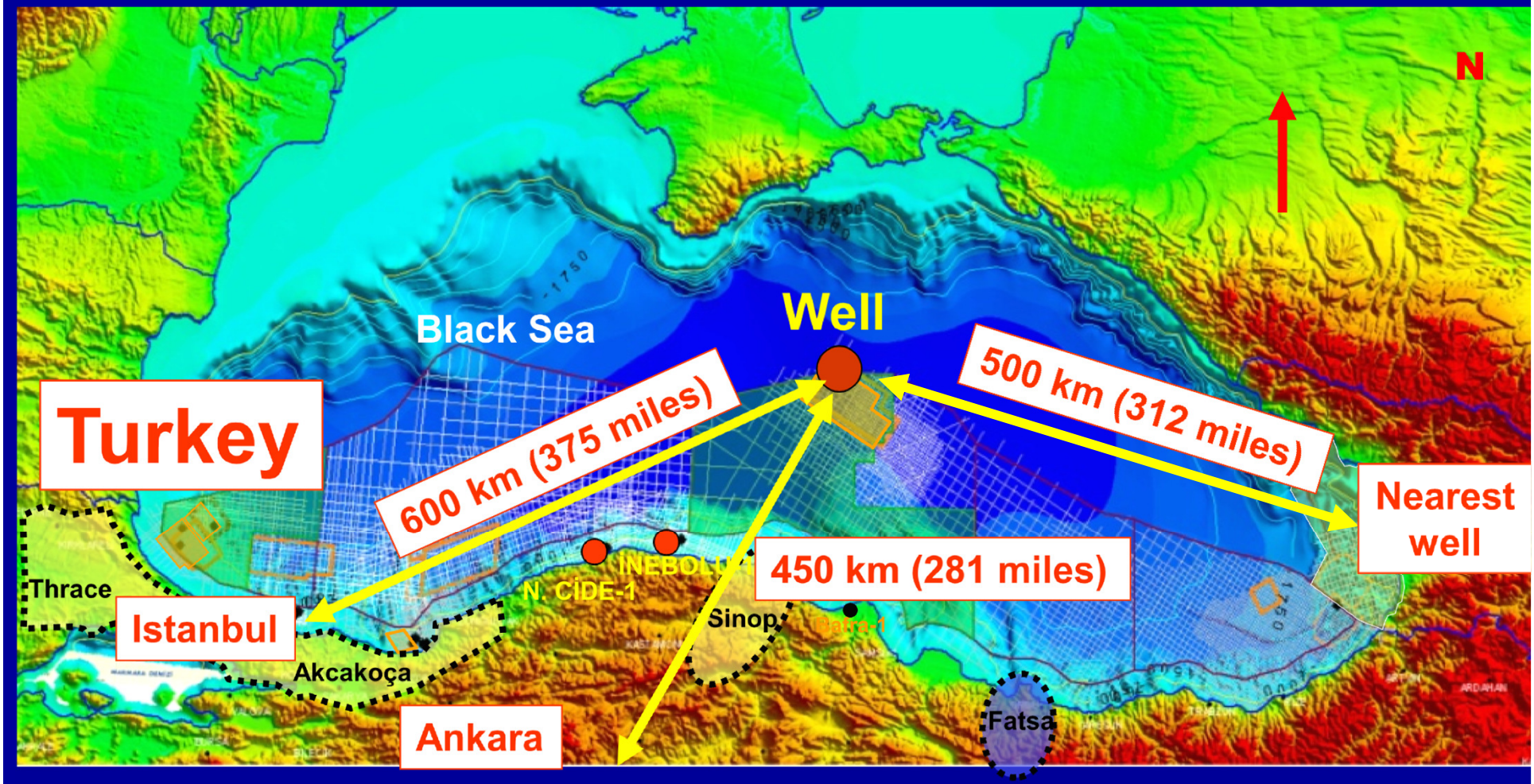
Well Complexity Index

Well Robustness

The Black Sea Project



The Black Sea Project



Water Depth = 2200 meters (7 218 ft)

Ultra Deepwater Well

Characteristics of Ultra Deepwater Wells of Complexity 4

- Small operational window (pore and fracture pressures very close)
- High rate of penetration (ROP)
- Long time for tripping
- Tendency to display high non productive time (NPT)
- Generally NPT higher than 40% (GoM)

Black Sea Challenges

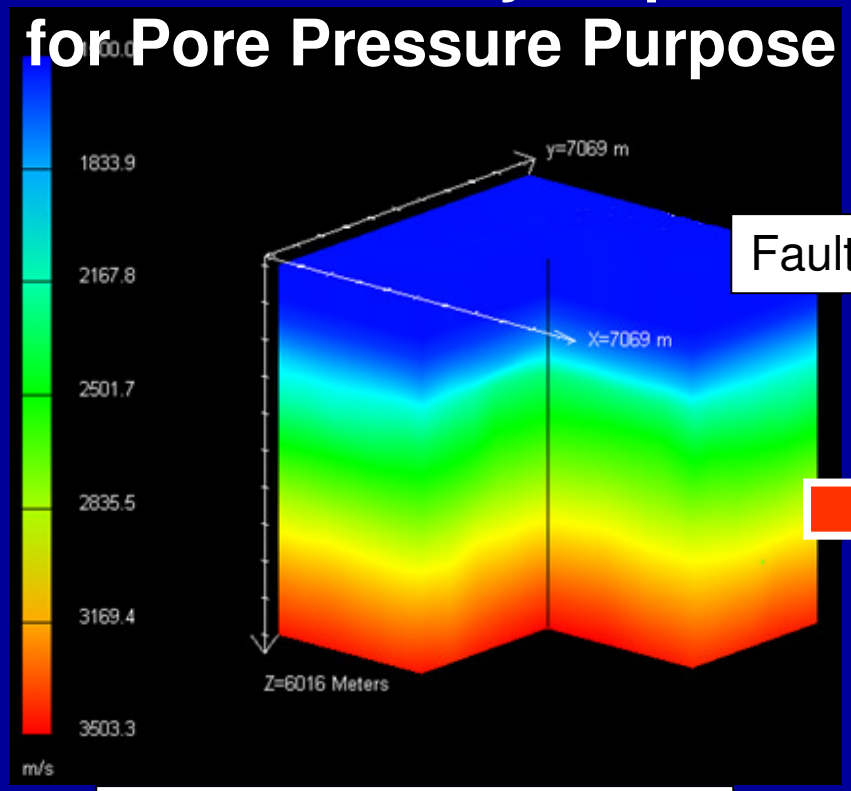
- Drilling
  - Expected shallow gas intervals
  - Long abnormally pressurized intervals
  - Low fracture pressure gradients
  - Expected severe lost circulation zones
  - Great potential for false kicks
  - Risk of gas migration through the riser

Well Engineering Process

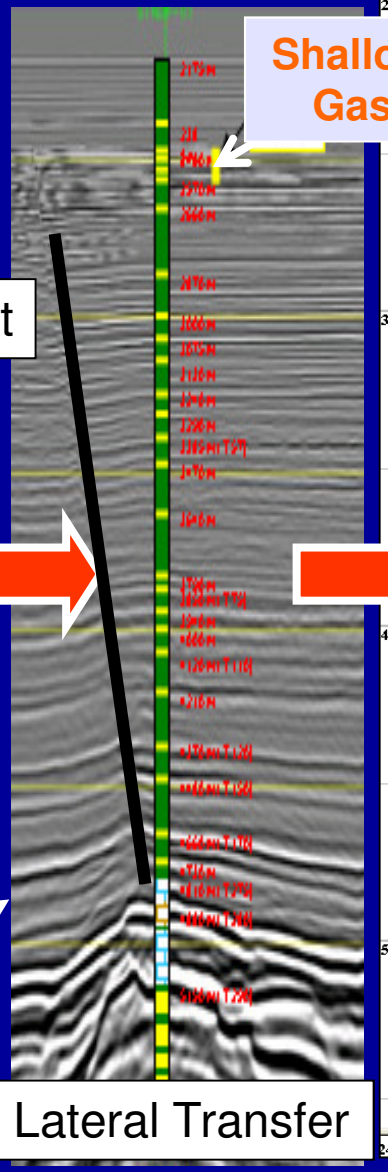
Well Design

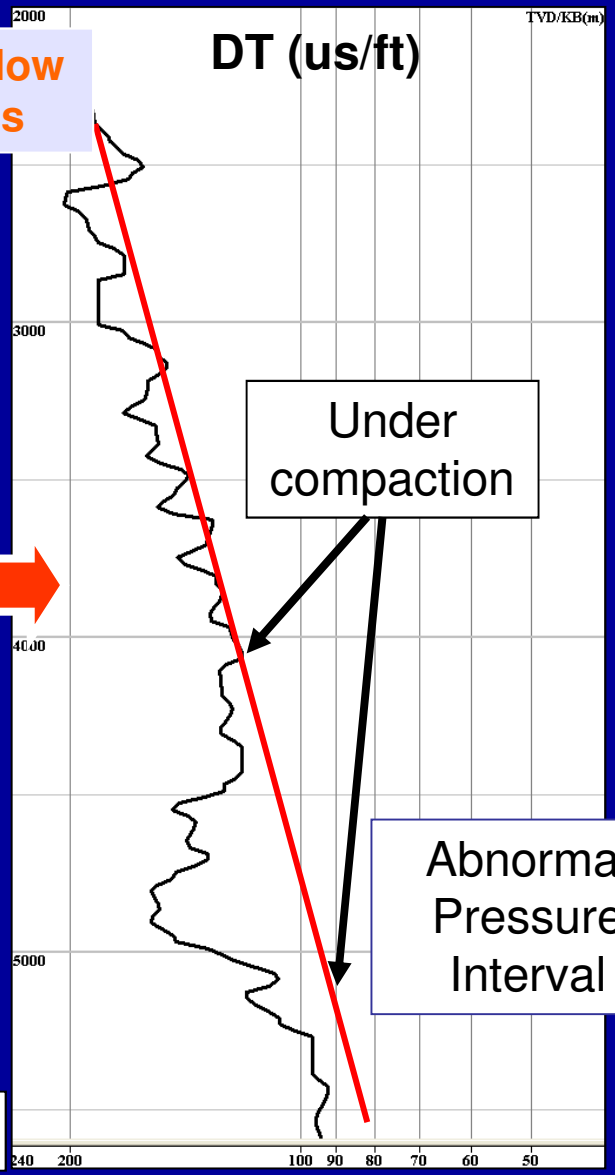
Geopressure: The Black Sea Well

Interval Velocity acquired for Pore Pressure Purpose



Abnormal Pore Pressure Mechanisms

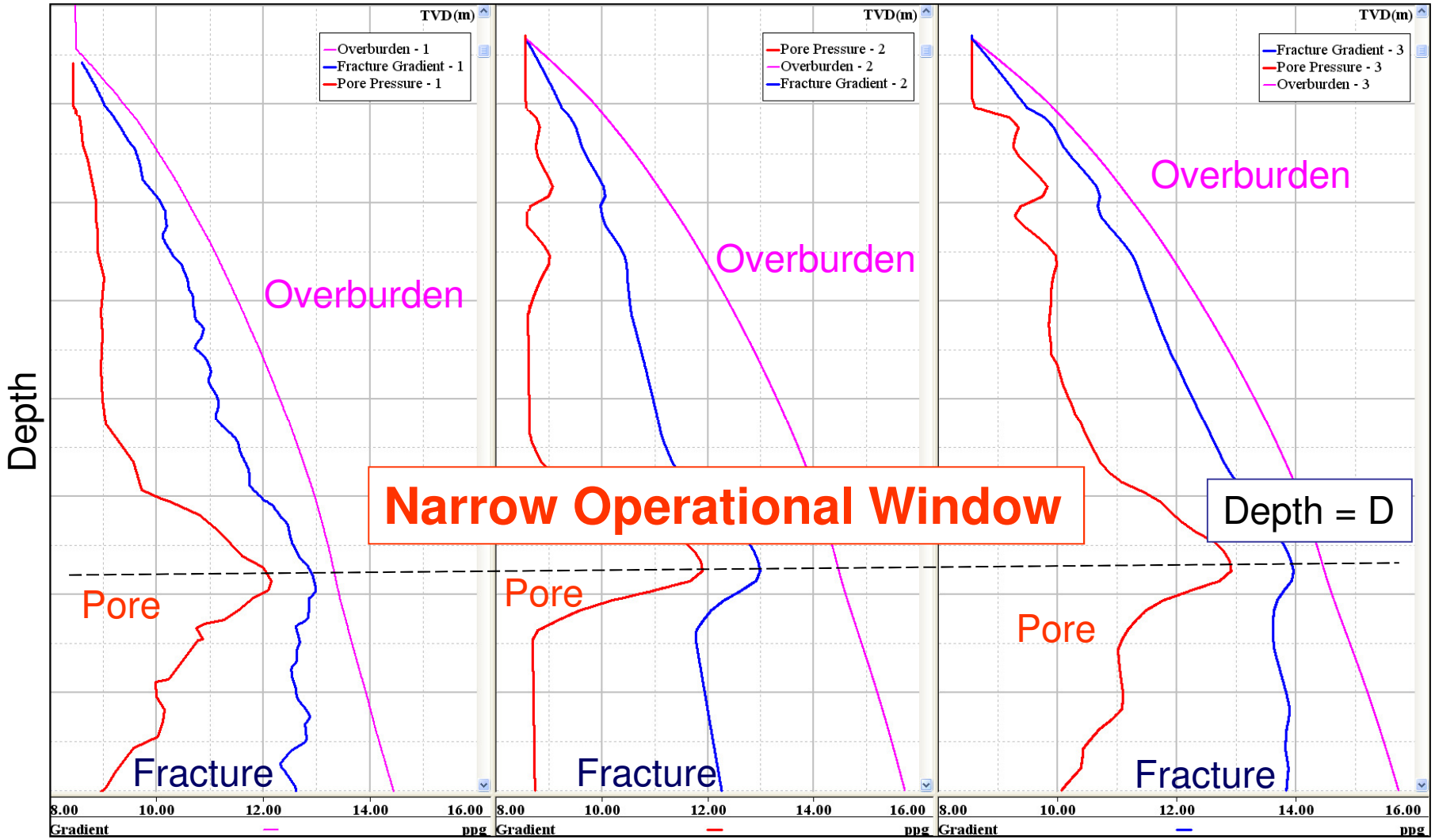


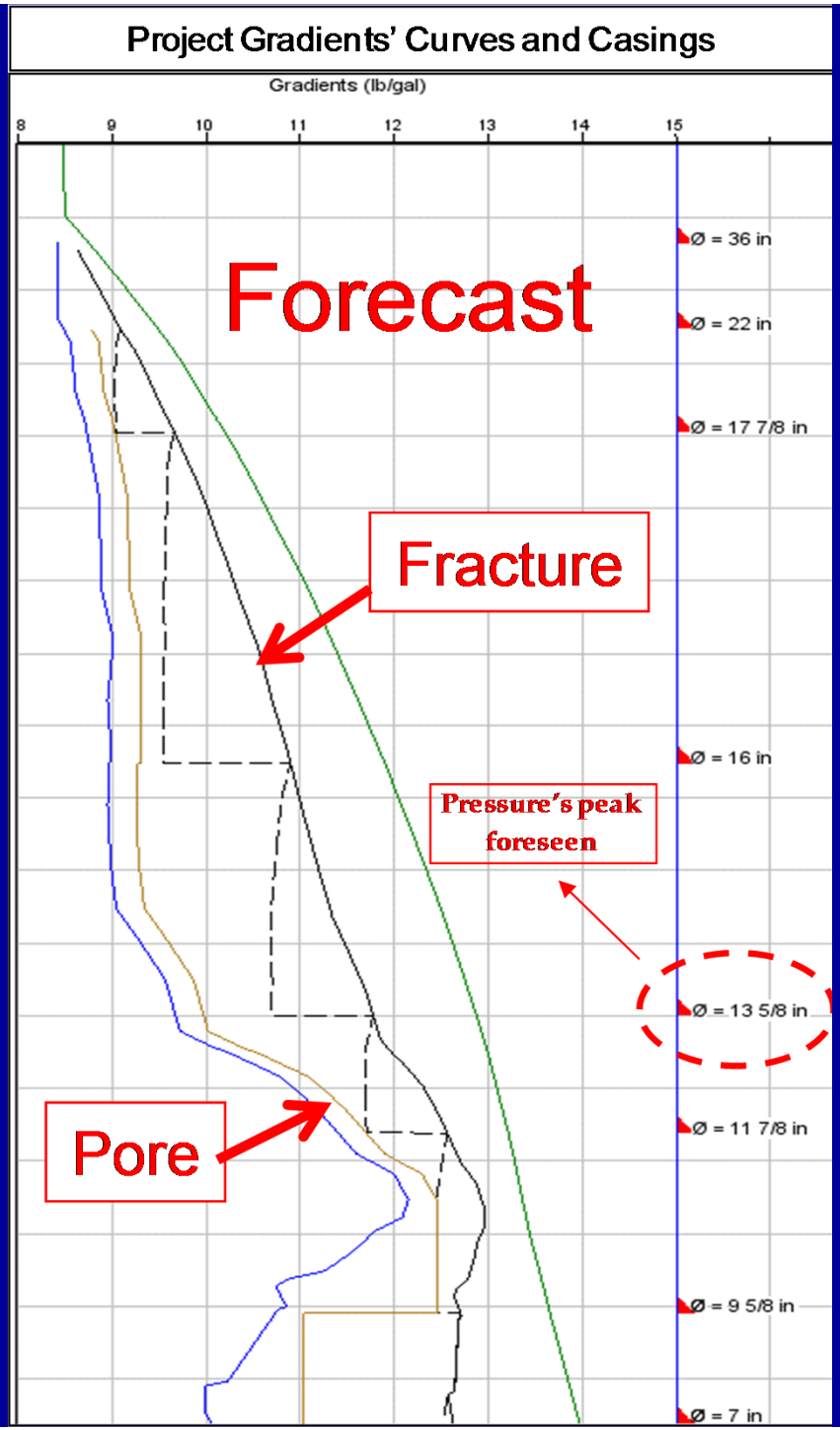


Mitigating Actions to Reduce Geopressure Related NPT

- Shallow Intervals (above surface casing)
  - Conduct Shallow Hazard Study
- Deeper Intervals (below surface casing)
  - Use seismic velocity adjusted for pore pressure purpose only
  - Identify abnormal pore pressure mechanisms
  - Conduct independent estimates
  - Create scenarios using different interpretations

Geopressure: Independent Studies





Well Design Considerations

- Shallow Gas Interval
- Kick Tolerance
- Lithology
- Loss Circulation
- Differential Pressure
- Targets

WCI = 4
WR = C

Well Operation Process

Logistics

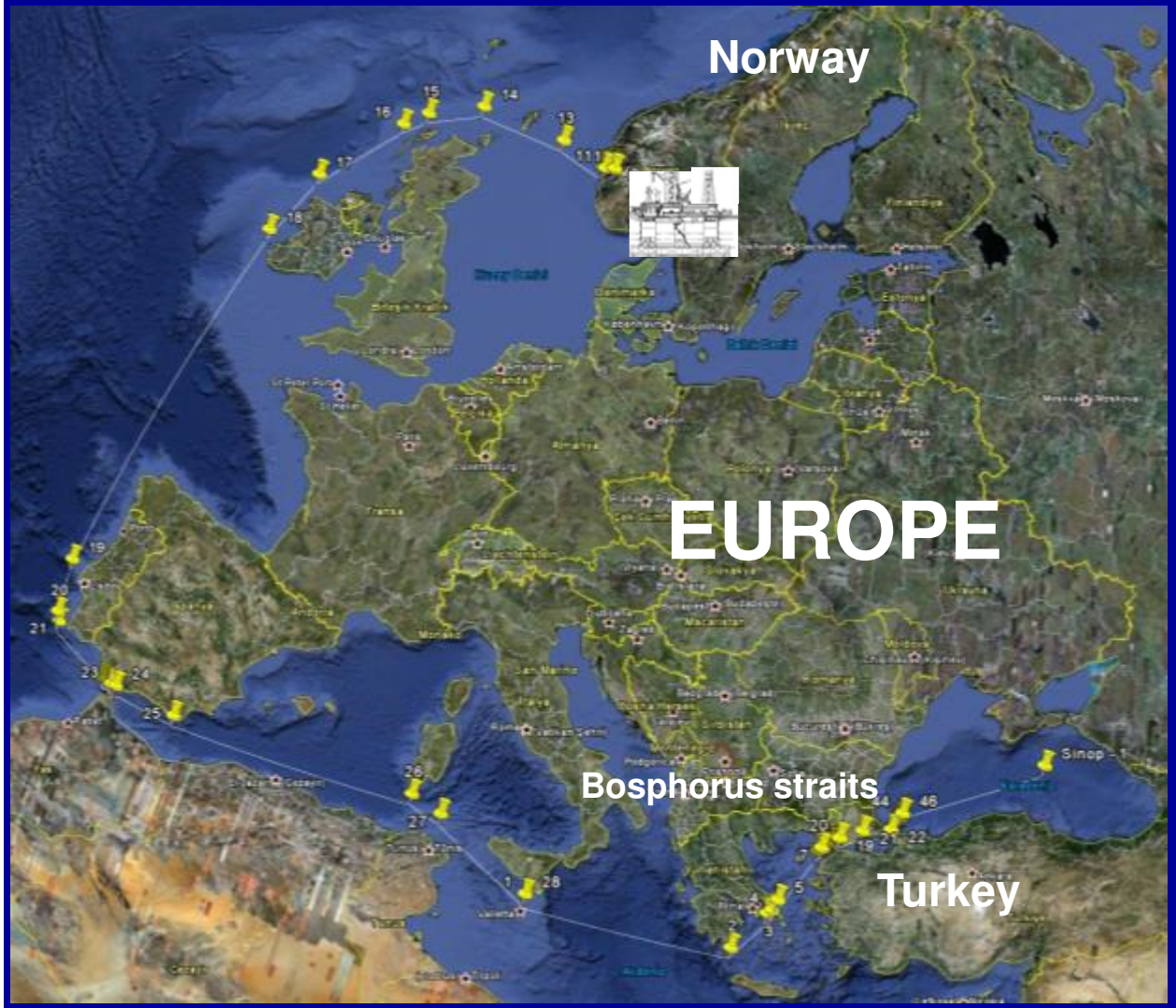
Well Operation: Logistics

- Plays primary role in well operation
- Frontier area with no offshore infrastructure
- Mobilization of the drilling rig to the Black Sea
  - **Challenge**: Pass the rig below the existing bridges of the Bosphorus Straits, Turkey

Drilling Rig - Mobilization

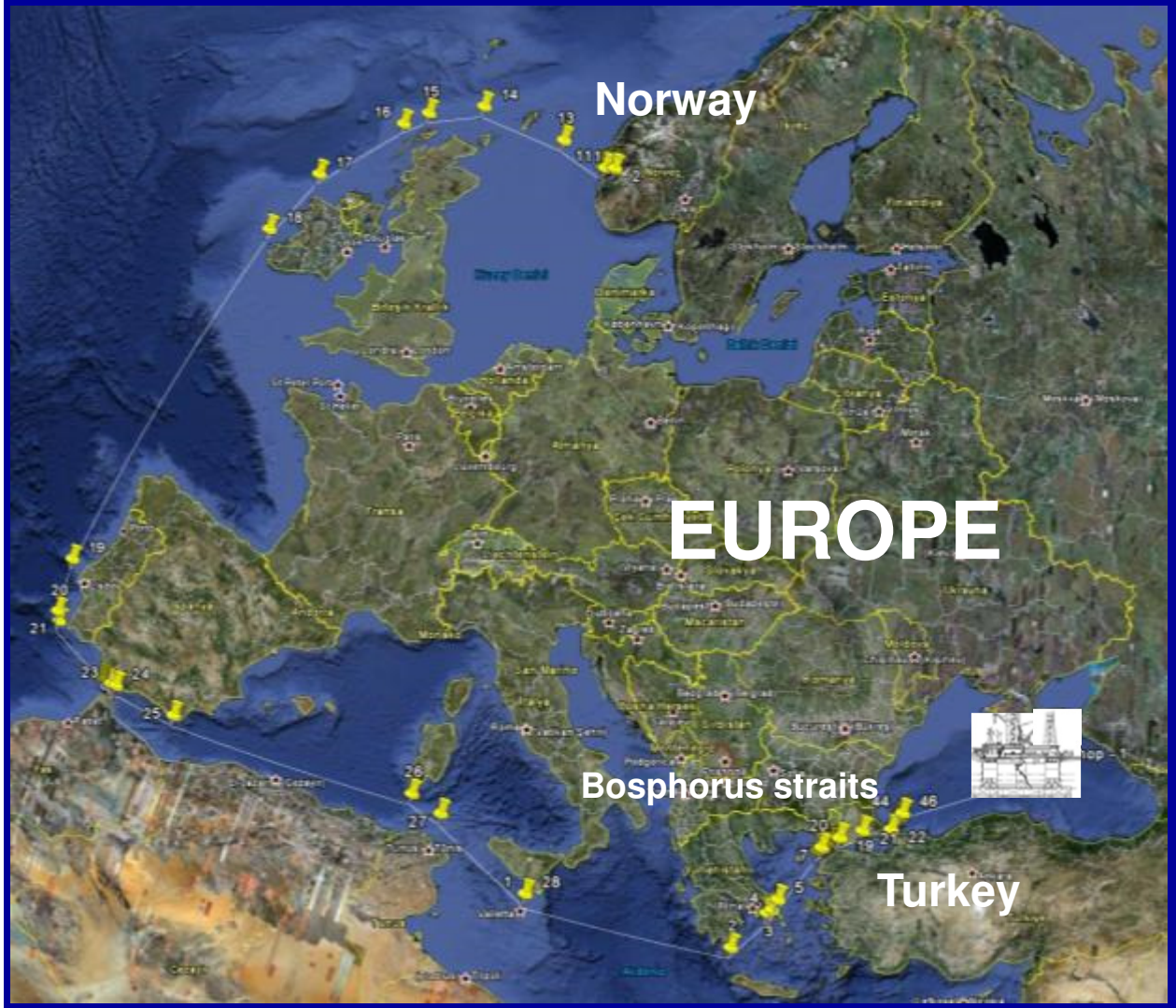
- Rig received and derrick disassembled in Olen, Norway;

Drilling Rig - Mobilization



- Rig received and derrick disassembled in Olen, Norway;
- Rig navigated more than 4,000 nm to the Black Sea;

Drilling Rig - Mobilization



- Rig received and derrick disassembled in Olen, Norway;
- Rig navigated 4,130 nm to the Black Sea;
- Rig passed underneath the existing bridges of the Bosphorus Straits;
- Derrick reassembled in the Black Sea, Turkey.
- Rig Mobilization = 117 days

Well Operation: Logistics

Drilling Rig Mobilization

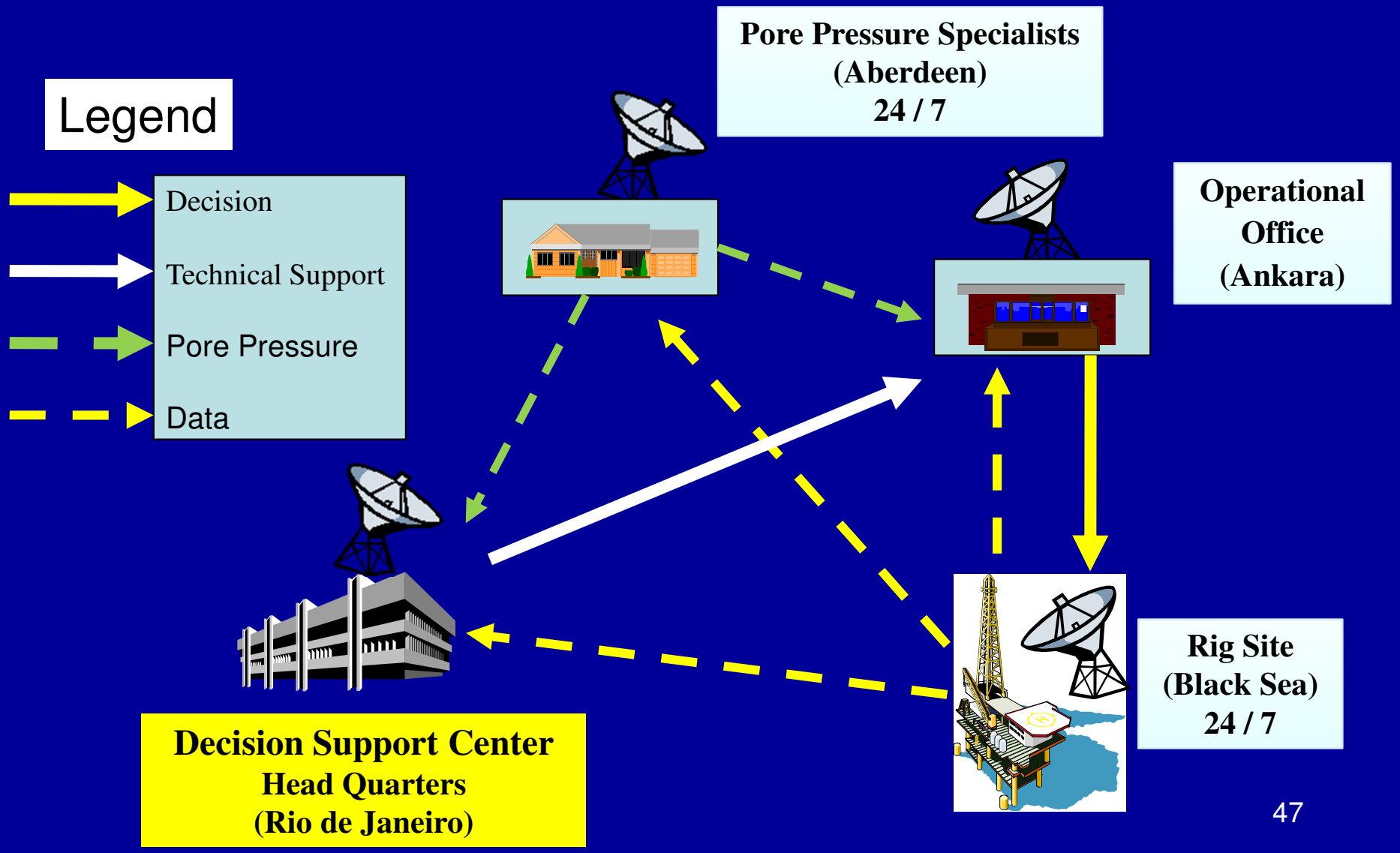
Well Operation and Engineering Processes

Execution and Engineering Support

Execution and Engineering Support

- Mitigating Actions
  - Special procedure created to drill the shallow gas interval
  - All operation planned in Advance
  - Decision Trees developed to mitigate problems for each operation
  - Robust Real Time Surveillance System implemented to increase safety and reduce NPT

Robust Real Time Surveillance



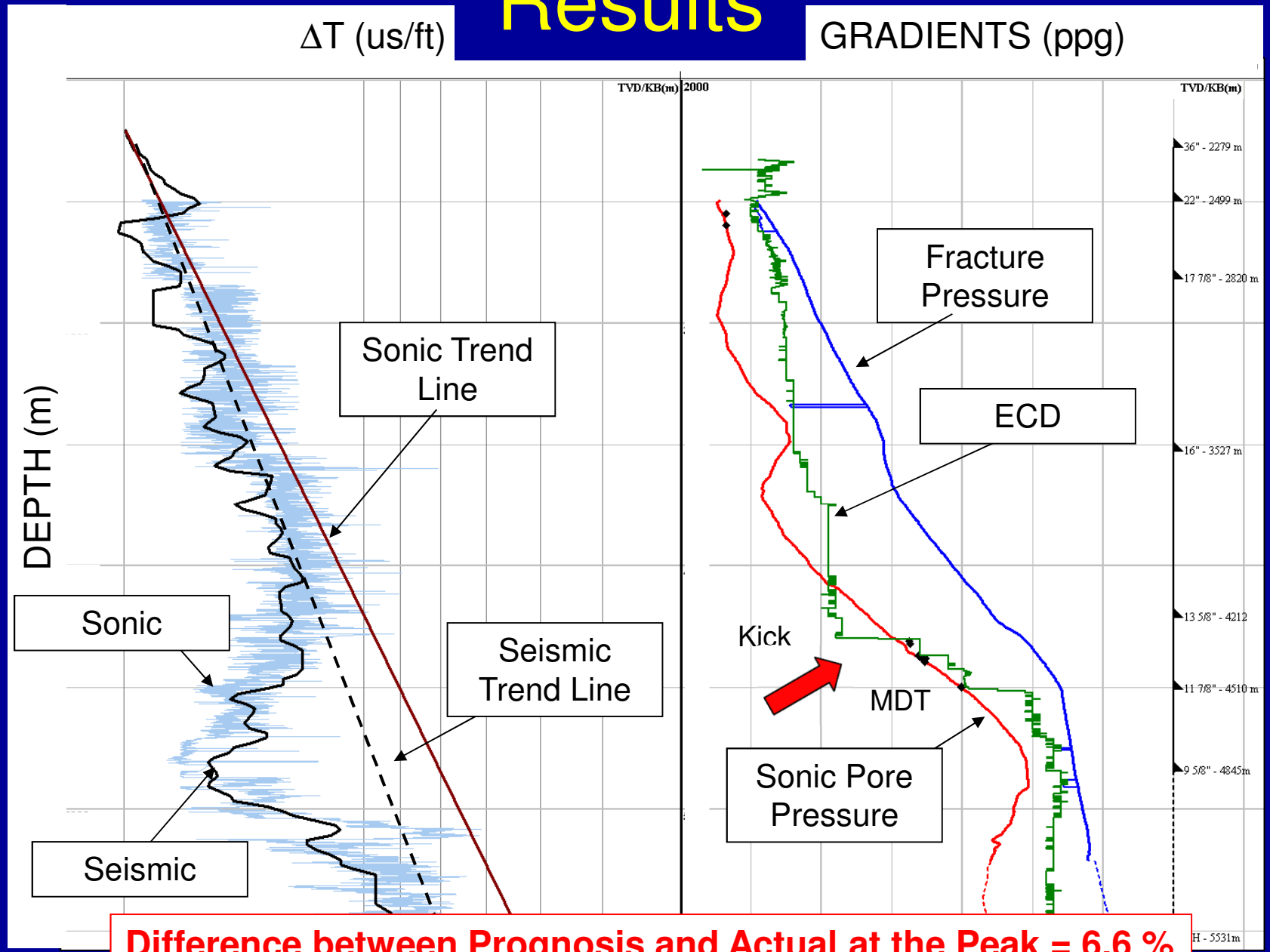
Robust Real Time Surveillance

Results

Results

Fact / Incidents	Observation	Lesson Learned
Shallow gas zone drilled without incidents	Good well planning.	Adequate Well Robustness
Most of the expected problems (kicks, losses, etc.) were successfully controlled.	Mitigating actions, such as the use of Decision Trees, were effective	Adequate Well Robustness
All planned casing were run due to well conditions	Extra casing available as needed	Adequate Well Robustness
Kick occurred while drilling a fault zone	Geological issue	Improve geologic prognosis for drilling purpose. **Improve well control response.**

Results



Difference between Prognosis and Actual at the Peak = 6.6 %

More Results

Project in Numbers	Planned	Actual
Total depth (meters)	5,525 / (18,127 ft)	5,531 / (18147 ft) *
Duration (days)	152	162
NPT (%)	40	35
Number of casing strings	8	7
PPGI = 1.066 (at the peak)		

*** Considered unplanned operations (VSP, MDT, etc.)**

PPGI = Pore Pressure Gradient Index = Actual PP / Expected PP

More Results

The Well Management Process was applied in other three wells drilled in three different countries

All wells were drilled without major incidents, safely reaching their targets within the expected time and cost

Conclusions

- Petrobras Well Management Process has proved to be effective as a management methodology
- Quantifying the right well complexity and well robustness helped define the required resources to effectively reach the objective of the well (safety, time and cost)
- Mitigating actions used during the planning and the execution phases were also valuable

The End

Questions?