Reducing geological risk in hydrocarbon exploration and exploitation operations

Ray Pratt – Geostart (UK) Ltd

Ray Pratt - Biography

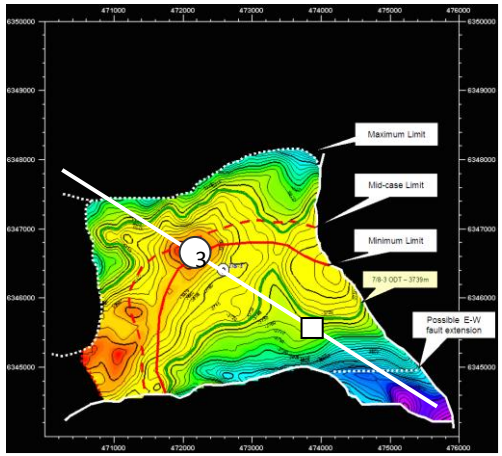
- Education.
  - BSc in Geology & Masters in Management. Thesis – Self Directed Teams in Oil and Gas
- Experience. 37 years in oil and gas exploration and exploitation.
  - For the first 10 years Ray worked mostly at the rig sites, initially as a mudlogger, then pore pressure engineer and finally as wellsite geologist. He then took up positions as operations geologist and petrophysicist.
  - He has worked around the world in all environments
  - He has successfully practised his learning's during his roles as Operations Geologist and Petrophysicist with a number of client companies where his ability to create effective teams, technical knowledge and mentoring skills were held in high regard.

Reducing geological risk in hydrocarbon exploration and exploitation operations

- **Introduce you to risks in exploring for oil**
- Talk will focus on planning a well
  - Geological Risks
  - Engineering risks
- Look at how we address those risks through a multi-disciplinary team approach
- Example high cost failures
- Summary

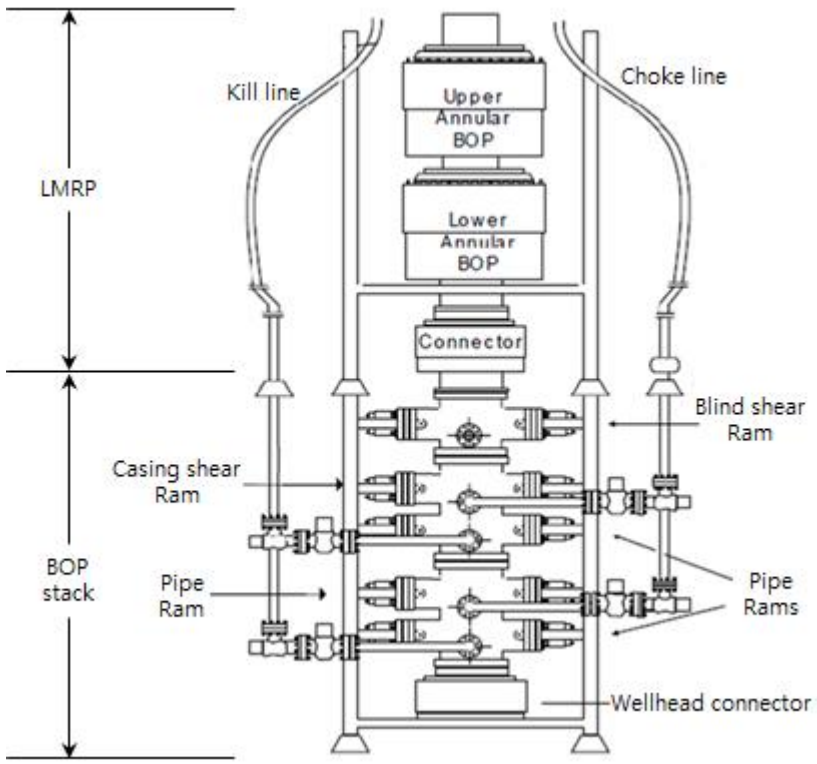
Exploration – The beginning

- Available data - none propriety seismic & studies
- Geological Model & Play Type
- Exploration Licence
  - shoot and interpret seismic,
  - build Geological Model
  - select potential drilling locations,
  - risk assess, (source and maturation, reservoir and trap, seal - top and lateral)
- Volumes, costs, sanction for drilling



Well Planning – Long Lead

- **Hire a rig**. Dependent on Terrain, Water depth , depth of well
- **BOP and Casing**. Dependent upon expected formation pressures and lithologies (Clay, salt, unconsolidated sand)
- **Location conditions**. Site survey – shallow hazards
  - sea floor conditions , wrecks, pipelines etc, shallow gas, relief well locations



Geo Risks and Data Acquisition

- **Well location.** Are we where we want to be ? Avoid sea floor & shallow hazards
- **Shallow Hazards**, boulders, shallow gas, water flows, glacial channels. (Pilot hole logging opportunities).
- **Overburden hazards**, Swelling clays, Gas chimneys, Salt or Tectonic dome induced fractures and their implications for drilling and evaluation
- Well **Pore Pressure** profile will dictate casing design and will impact data acquisition.
- Forecast **well temperature** – impacts logging and cementing
- MWD v Wireline
- Putting the **Data Acquisition plan** together (dry well v successful well).
- Data Acquisition **contingency** planning.

Engineering Risks

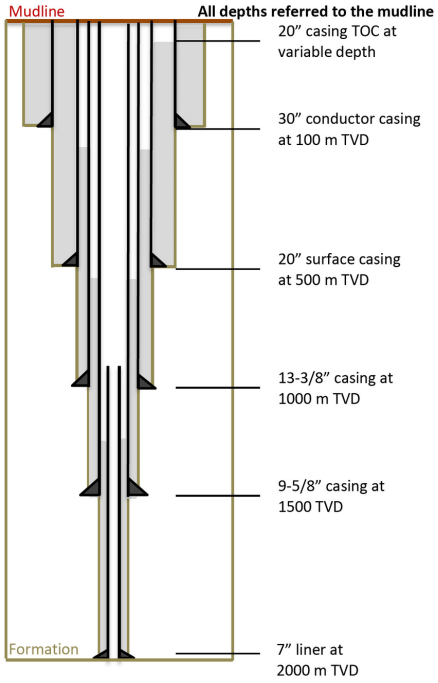
- **Commissioning the rig (weather)**
- **Sea floor Conditions** (pipelines, wrecks, reefs etc)
- **BOP** needs to be of sufficient rating for the **pore pressures** forecast
- **Casing design** needs to; prevent hole collapse, maintain sufficient kick tolerance, be of sufficient strength to prevent buckling e.g. salt tectonics.
- **Cement** chemistry to be in line with the downhole pressure and temperature (commonly a big risk of not being successful on first attempt)
- **Drilling fluid** to be sufficiently weighted to prevent influx of fluid but not overly weighted to cause differential sticking and other invasion issues. Additives to reduce chemical reaction with the formation and bridge any prognosed fractures. Must be harmonious with logging and coring requirements.
- **Bit, BHA selection** and planned drilling parameters to give acceptable ROP, quality geological samples, low vibration
- **Well trajectory** needs to be monitored closely and dog legs to be strictly avoided. Potential for walking needs to be considered based on prognosed bed dips.
- **Swab and surge** of trips to be limited. Hole volumes on trips to be tightly monitored.

Drilling hazards

Well 7/8-4 DRILLING HAZARDS		
Hazard Category	Formation / Issue	Hazard Description
Shallow Gas	Nordland Group	No shallow gas warning has been issued
Borehole Instability	Hordaland Group	"Gumbo" shales reported in 7/11-5 (1497m MDbrt) causing loss of mud over shakers, and in 7/11-10S (above 1269m MDbrt) requiring increased MW.. Potential for packoff
Formation Hardness	Lista, Ekofisk & Tor Formations	"Tight" formation resulting in slow drilling, tool damage, lost cones & stuck pipe recorded from chalks & limestones neaby wells. Potential Palaeocene (Forties) sandstones - possible but unlikely
Formation Hardness	Farsund, Ula Formations	"Tight" formation recorded from calc cemented siltstones in section immediately above reservoir in nearby wells.
Faults	Ula Formation Reservoir	The target boxes have been selected to avoid depth uncertainty due to faulting at top reservoir & minimise drilling or productivity risk. No reported well stability problems due to faulting.
Overbalance or Depletion	Ula Formation Reservoir	The Krabbe reservoir is overpressurted by ca. 3000 psi, more overpressured than Mime or Mimming. Higher overpressures and absolute pressures have been drilled in wells 7/11-9, 7/7-2 & 7/7-3. The Krabbe formation pressure is however well constrained by the 7/8-3 well pressures.
H_2S / CO_2	Ula Formation Reservoir	No H_2S reported from 7/8-3 DST. 4% CO_2

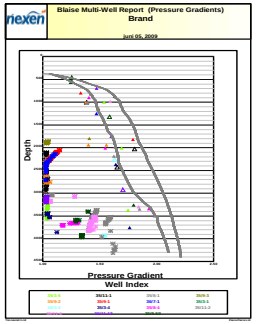
Well Design

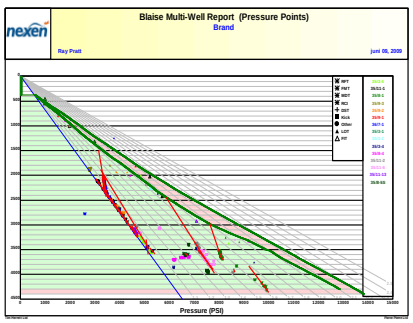
- Review available drilling records for offset wells for issues.
  - Shallow hazards (pre BOP installation)
    - Verticality of the well - Boulders,
    - Stability of the rig -glacial valleys, suitability for anchors or jack ups (punch through, scouring etc) ,
    - Safety of the rig and personnel - shallow gas
  - Lithology Challenges
    - Swelling clays, Coals, faults and fractures leading to wellbore instability, solubility e.g. salts, unconsolidated sands, temperature & pore pressure profile, formation hardness variations -severe variations
  - Lithology related drilling issues
    - potential for mud losses, differential sticking
    - ROP variations – bit selection and BHA design (including LWD tools)
    - hole cleaning, pack off
    - Hole washouts – issues for logging, re-entry after trip and casing
    - Vibration potential – BHA washouts, LWD tool failures
    - Geosteering (directional holes)
  - Data Evaluation Programme
    - Logs Wireline, LWD Logs,
    - Sampling. Cuttings, Core, Pressures, Fluid Samples
  - Offshore services
    - Mudlogging, Biostratigraphy, Pore Pressure
    - Core handling, core sampling, plugging, PVT Verification
    - MWD & Wireline
    - Testing
  - Contingency Planning
    - Additional casing
    - Extended logging programme in success case
    - Well Testing programme in success case
    - Sidetrack programme

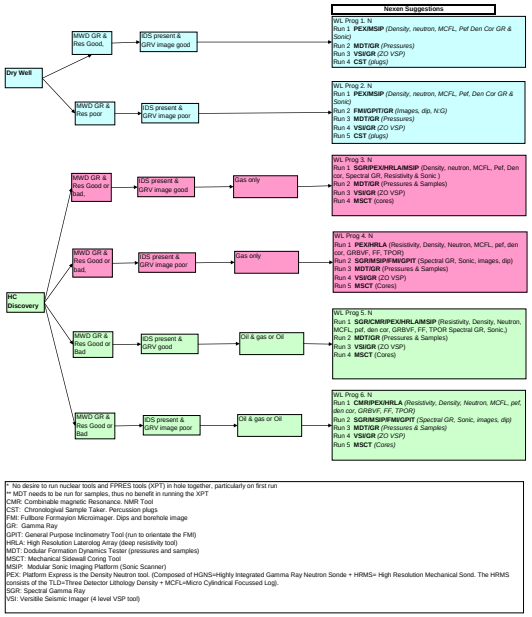


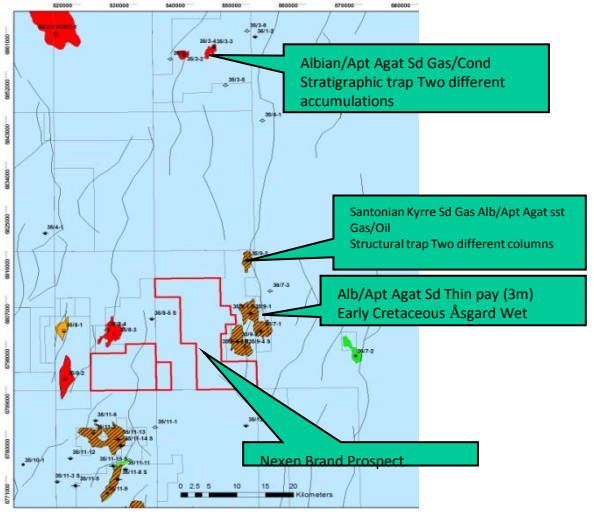
Communication - 35/9- 5 Geology Montage

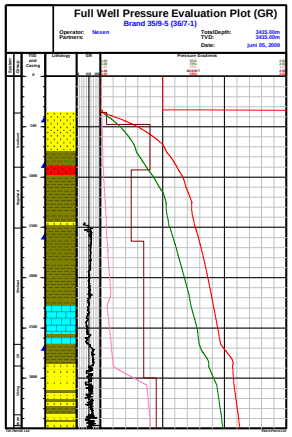
Surface Location	ED 50 Datum, Latitude Longitude UTM Zone 31N X: Y:	 61 19 28.90 N 03 48 45.19 E 543 499.7 E 6 799 386.6 N
Primary Reservoir Target (Vertical Hole)	Formation: Depth:	L Cretaceous Agat Fm . 2800m TVDSS
Target Tolerance		150m
Proposed Total Depth 50m below top Brent Sst	Formation: Depth: Includes 50m logging sump	Mid Jurassic Brent Fm 3415m TVDSS
Seismic Line Location	Survey: Mar09607 Reprocessed & merged 2007 (PGS) Line: 3088 Trace 8718	

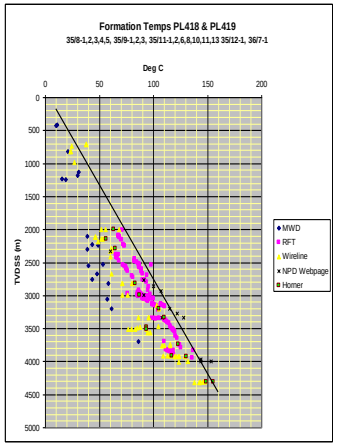


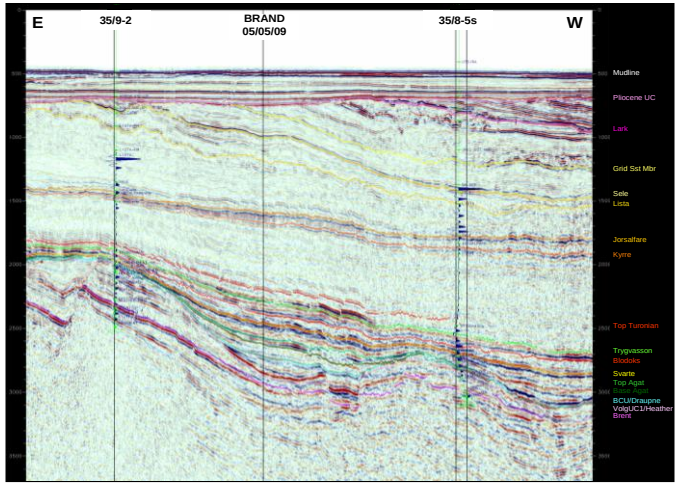












Stratigraphy		TWT ms	TVDSS m	TVDBRT m	Error Bar +/- M
Nordland Gp	Sea Floor	490	366	384	10
Hordland Gp	Grid Fm	738	680	698	20
	Gridd Sst	812	760	778	35
Rogaland Gp	Balder	982	900	918	25
	Sele	1004	950	968	25
	Lista	1182	1094	1112	35
	Våle	1596	1400	1418	40
Shetland Gp	Jorsalfare	1640	1505	1523	50
	Kyrre	1670	1610	1628	50
	Turonian	2192	2250	2268	50
	Trygvasson	2286	2320	2338	50
	Blodaks	2384	2594	2612	50
Comer Knoll Gp	Svarte	2454	2664	2682	50
	Agat	2576	2800	2818	50
	Base Agat	2622	2880	2898	50
Viking Gp	Draupne	2624	3090	3108	75
	Heather	2864	3307	3325	75
Brent Gp		2926	3365	3383	75
TD			3415	3433	75

WIRELINE LOGS

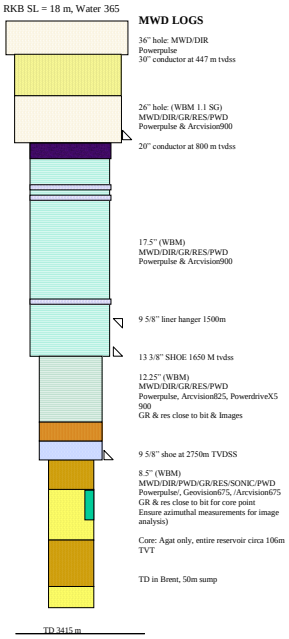
17.5" Hole Section
No open hole WL logs

First WL run
GR to be run to surface (Tie in)

12.25" Hole Section
No open hole WL logs

8.5" Hole Section
Firm:
PEX/MDT/ZO_VSI-4level/CST
MDT pressure and samples
MSIP
CONTINGENT ON Reservoir Characterisation needs
CMR/FMI/SGR

BU For MWD Tools & Core
HALS/MCFL/GR/MSCT



Communication and Decision Making

- Points of contact on in office and on wellsite.
- Roles and responsibilities
- RACI chart *(Responsible, Accountable, Consulted, Informed)*
- Use bite size diagram's where possible. A picture is worth a 1000 words
  - Real Time decision making aids
    - Wellsite pore pressure engineer – mud weight and casing point picks
    - Wellsite Palaeontologist - geosteering
    - Mobile Core laboratory – Plugging cores at wellsite for rapid evaluation of fluid properties and basic core analysis prior to wireline logging
    - Mobile Fluid Analysis lab to verify quality samples collected using wireline tools before ceasing operations.

Open Communication

- **Soft skills**. The importance of communication between the subsurface team and the project team
- Team Building, (trust, respect & co-operation)
- **Utilising the individual team member skill sets and experience**. The benefit of multi-disciplinary teams and knowledge management techniques for the achievement of successful drilling projects.
- Effective teams result in; “The sum of the whole being greater than the sum of the parts”
- Individual success is team success -

Drill Well on Paper

- Multi discipline teams (including rig personnel go over the geological model and the drilling program)
- Trade offs on mud types drill bits and downhole tools depending upon the need for specific petrophysical logs and geological data.
- MWD and wireline tradeoffs, MDT and testing tradeoffs
- Decision trees for the what if scenarios.
- Contingency plans

”If you think it's expensive to hire a professional to do the job, wait until you hire an amateur”. – Red Adair

What could possibly go wrong ?

- Salt Mine. https://www.youtube.com/watch?v=3cXnxGIDhOA 5.47

Lake Peigneur Salt Mine drilling accident.mp4

- 5 blowouts https://www.youtube.com/watch?v=BPIW8rXIYR4 10.03
- Spaghetti Tubing https://www.youtube.com/watch?v=lkqpEXy0frE 2.15
- Light Pipe https://www.youtube.com/watch?v=b9b_p0g77pE (2.37)
- Fug Ups https://www.youtube.com/watch?v=6d3c-HPIRHs (5.48)
- Shallow Gas blowout https://www.youtube.com/watch?v=NJiBS64RVVQ 3.47
- Shallow gas kick https://www.youtube.com/watch?v=UM_5EVkN6FU 0.47
- **Macondo blowout cost £30 bn**

Sidoarjo Mud Volcano (Lusi)- Java

The world's most destructive mud volcano was born near the town of Sidoarjo, on the island of Java, Indonesia, just over 11 years ago – and to this day it has not stopped erupting.

The debate is whether the eruption of Lusi was due to an **earthquake several days previously,** or down to a catastrophic failure of the Banjar Panji 1 gas exploration well that was being drilled nearby at the time.

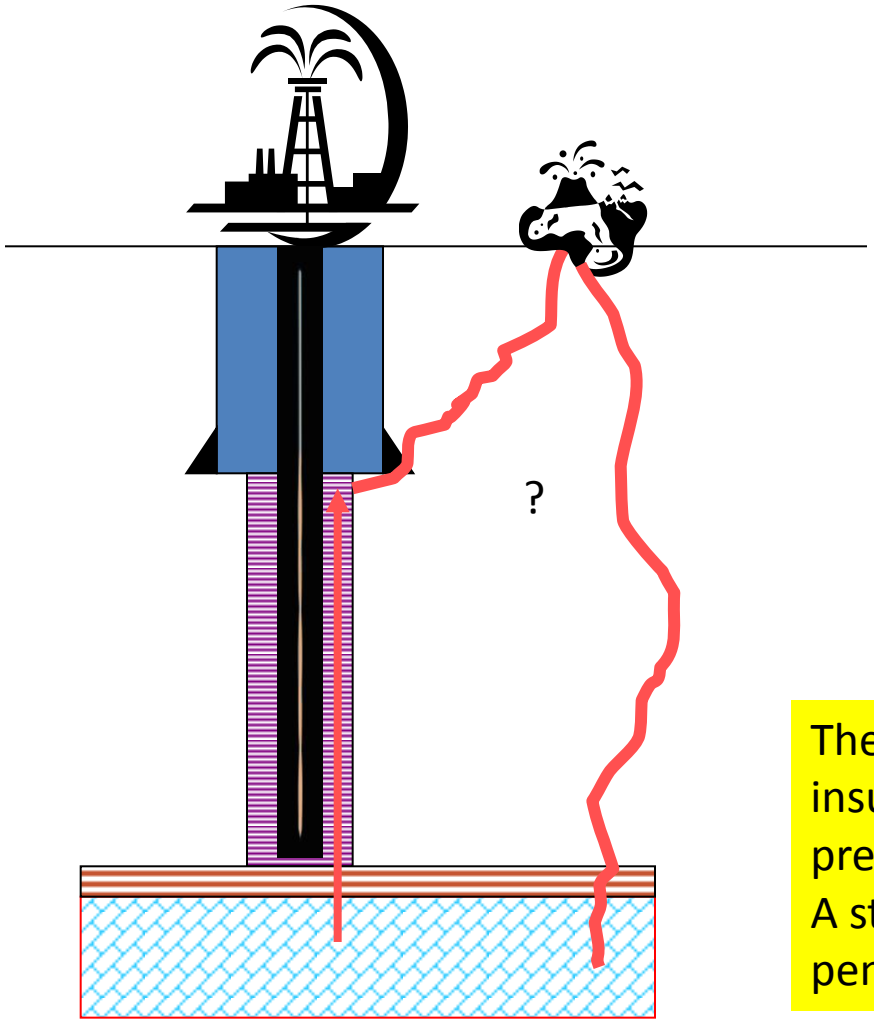
- The satellite images below show the area that is affected by the mud flow that started in May 2006. The top image was taken on 14 Aug 2005 while the bottom image was

  taken on 7 Aug 2006


steam from vent
bypass
mud flow
mud containment walls
1 km
N

More Images From AAPG Convention-Cape Town Oct 2008

Schematic of Lapindo Brantas well Banjar Panji 1



- Pressure release (water) from the reservoir moves up wellbore but wellhead shut in. Pressure builds up around the shoe and exceeds fracture pressure at shoe, creating a conduit to the surface 150m away from the rig. Water reacts and mobilises claystones creating a mud flow at surface sufficient to fill 50 Olympic size swimming pools daily.

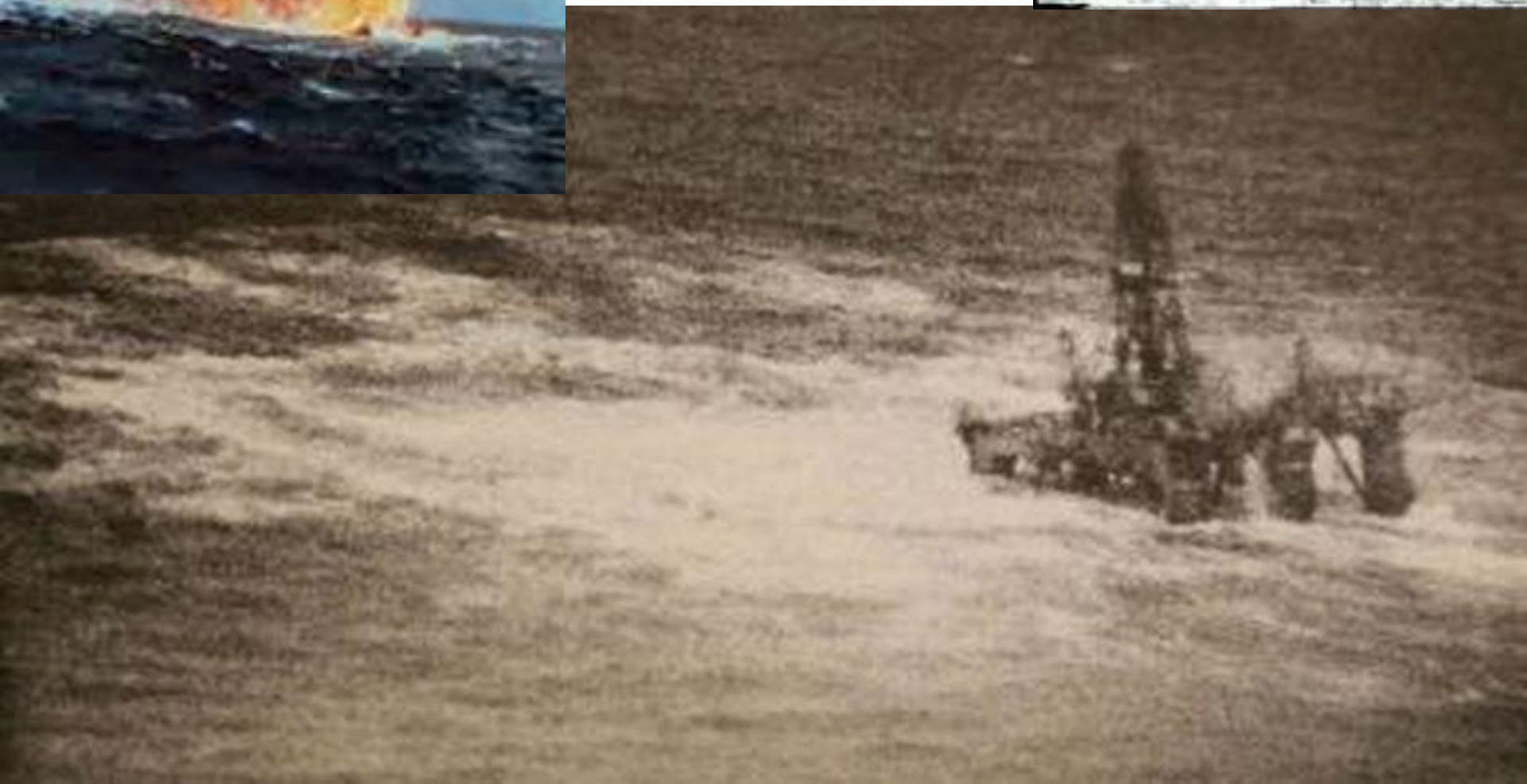
The casing shoe strength (LOT) was insufficient to cope with the kick pressure.
A string of casing was planned prior to penetrating the reservoir.

Shallow Gas Warning, NONE!

A shallow gas warning was not issued for Krabbe.

As a result of the influx taken at ~750m a series of investigations were undertaken.
The gas is thought to come from Iceberg Plough Marks, that were not considered a shallow gas threat.

Shallow Gas



Key Points – Planning

- Goal of the project must be clear
- The methodology can be applied to any geo related high cost investment project
- **Plan** to the n^{th} degree. Use all available records. Try to pre-empt potential problems.
- “Planning is everything, the plan is nothing” **Dwight Eisenhower**
- “Victory awaits him who has everything in order - luck, people call it”. “Adventure is just bad planning.” **Roald Amundsen**

Key Points – Team Building

- Individuals learn from experience, corporations do not. Therefore use all team members skills and knowledge in the planning and execution of the project. This will;
  - Instil ownership of the project
  - Encourage co-operation between colleagues
  - Create trust through effective team building
  - Ensure effective communication

Key Points - Drilling Phase

- Exact **well location** should be checked and double checked
- The well is drilled to evaluate the geological prospect. Success of the well will be determined by the successful completion of the **Data Acquisition Programme**.
- Follow the **well plan** and avoid “shooting from the hip”
  - Continuous monitoring the well at the wellsite and in the office.
- Real time data quality control and evaluation.
  - Data issues recorded on log headers.
  - Note and apply environmental corrections where required.
  - Depth control.
  - Coring, Core handling, Pressure data, Fluid samples, Testing. **Quality data analysis can be jeopardised by poor data acquisition practice at the wellsite (and during transport).**
- Continuously **review and learn**
  - Fully document work done, challenges faced, what went right, what went wrong, solutions adopted.

Post Drilling

- **Data Management** – Avoiding black holes. **Have a process** that ensures the specialists verify data received. Today's logging tools generate lots of measurements many of which make no sense other than to specialist users. Contractors do not always supply the full array of recorded measurements and this commonly does not come to light until many months after the well has been completed and the contractors have moved on.
- Review geological forecast and actual geological results and incorporate into the geological model.
- Review drilling results versus plan and capture lessons learned. What went right, what went wrong, how can we improve next time.
- Review contractor performances with contractors. Share learning's.
- Write end of well report (Geology & Drilling) to ensure everything is captured. Useful for future well planning, regional assessments and trade purposes.
- **A good team celebrates success**

Oil is cheap

Today Oil Price $71/bbl……

Oil (Brent Crude)	Milk	Water	Coca Cola	Premium Coffee	Wine	Chanel No. 5
$71 /bbl	$0.59 / pint	$1.69 / bottle	$1 / can	$3 / cup	$15 / bottle	$200 / bottle
$71 /bbl	**$198 / bbl**	**$269 / bbl**	**$480 / bbl**	**$806 / bbl**	**$3,180 / bbl**	**$1,075,200 / bbl**

Source: History – Argus; Forecast – Wood Mackenzie (2016)

Thanks to Malcolm Brown

Oil = $1.69 / gallon

Slides available from

https://geostart.co.uk/?page_id=162