PHARIS ENERGY

PILOT: AN UNDEVELOPED HEAVY OIL FIELD OFFSHORE STEAM FLOODING

GWL

21 June 2018

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AGENDA

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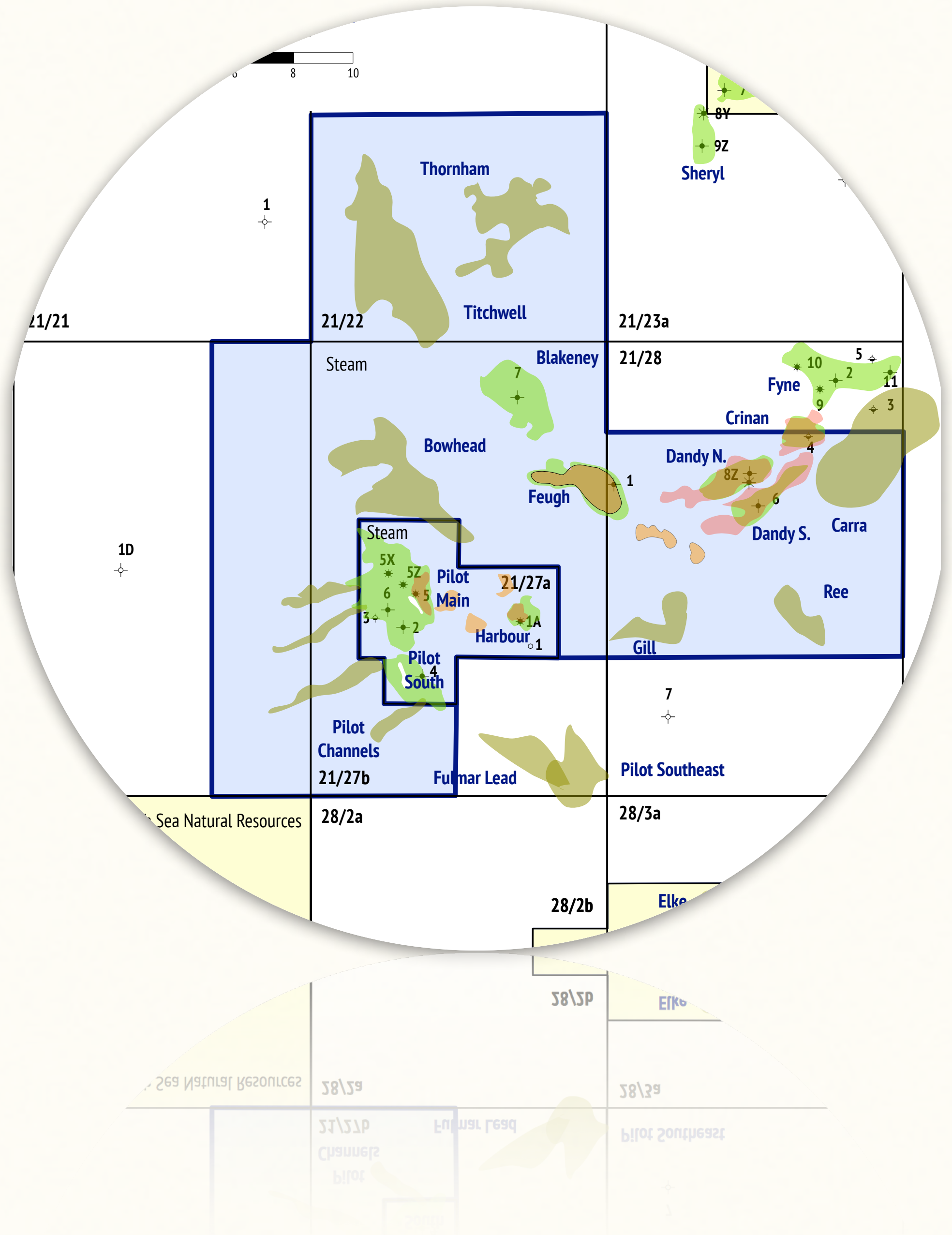
- **Who are Steam Oil**
- Pilot Geoscience
- North Sea Heavy Oil
- The case for Steam Injection, the Offshore, & Pilot
- Pilot Development scheme



MANAGEMENT TEAM

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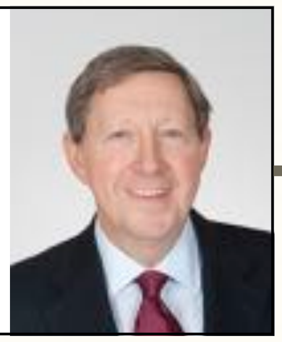
Prof Jon Gluyas
Greg Harding
Julia Cane-Honeysett
Joe Darby
Alan Hume

Pharis Board

Joe Darby
Non-Executive Director



Steve Brown
CEO

Alan Hume
CFO

Greg Harding
Technical Dir.

Maurice Bamford
Exploration Adv.

Simon Bradbury
Projects Advisor

- Formed as The Steam Oil Production Company Ltd, in 2014 to apply for the Pilot discovery in the 28th Round
- Core of team had worked together in Setanta Energy
- Significant UKCS development experience
  - Harding
  - Alba
  - Andrew

ASSET PORTFOLIO

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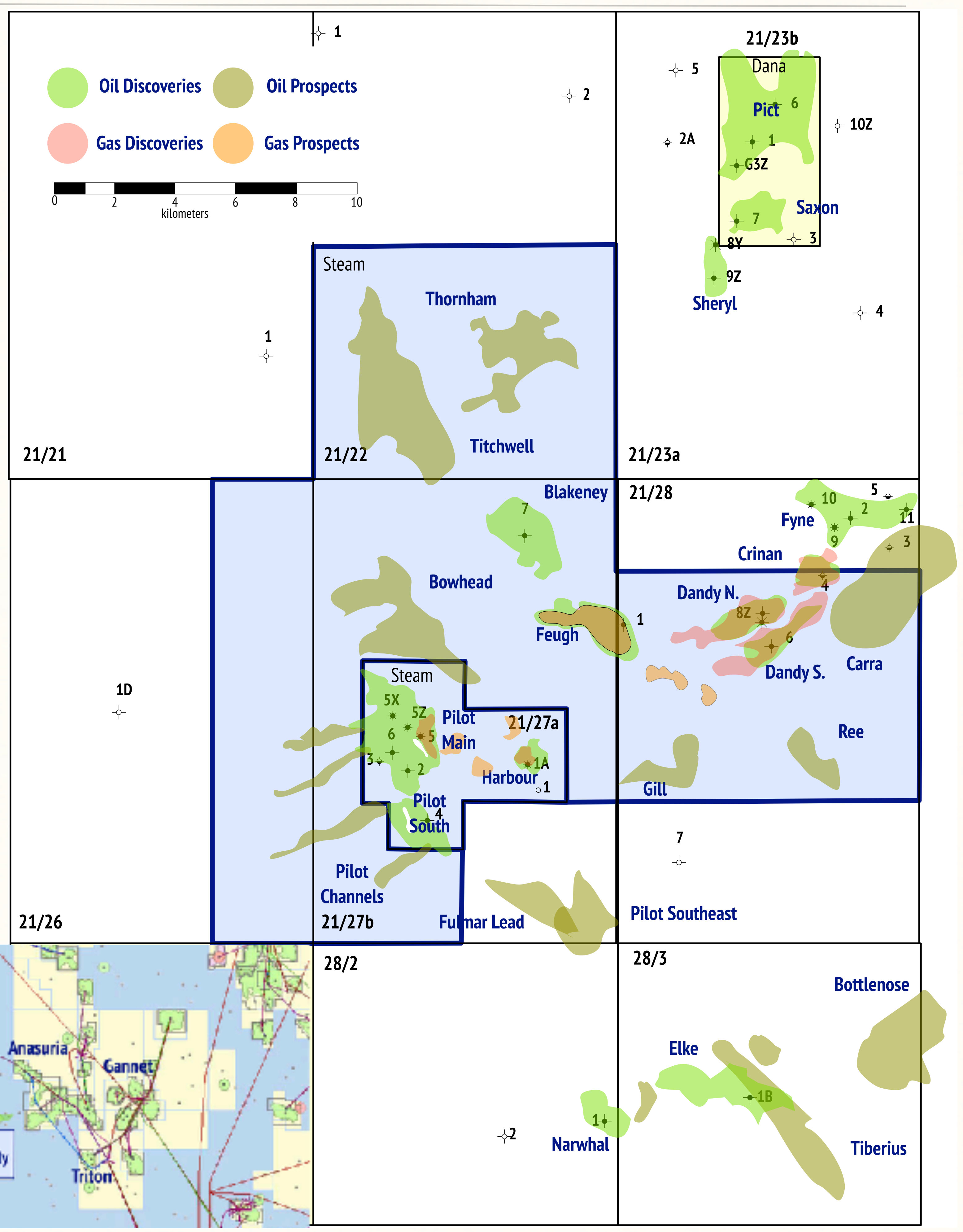
- **28th round:** Pilot & Harbour, over 270 mmbbls of STOIIP in very well appraised discoveries
- **29th round:** Blakeney, Dandy & Feugh c. 150 mmbbls of discovered STOIIP; Bowhead & Titchwell prospects with STOIIP of c. 300 mmbbls
- Hot waterflood recovers over 70 mmbbls from Pharis's discovered fields, steam injection can enable recovery of over 160 mmbbls
- Exploration success on low risk prospects, could increase Pharis's recoverable resources to over 300 mmbbls.



All licences are held 100% by Pharis

PILOT LICENCE HISTORY

- Fina was the original operator and drilled most of the wells on the block from 1989 to 1998
- After the merger with Total, the licence was marketed by TotalFina in 2000, and acquired by Venture in 2001
- By 2007 Venture had developed a plan to exploit the field based upon an elegant geochemical model which predicted a pool of 100 cP oil; this was tested and found wanting by the 21/27a-6 well; Venture then relinquished the licence prior to being taken over by Centrica
- EnQuest applied for and won a traditional licence over the field in the 26th Round, acquired the Western Geco reprocessed seismic over the block and undertook comprehensive G&G studies, but relinquished the block in 2013 as the water flood development plan was not sufficiently attractive
- Pharis Energy Ltd applied for and won a promote licence over the field in the 28th round

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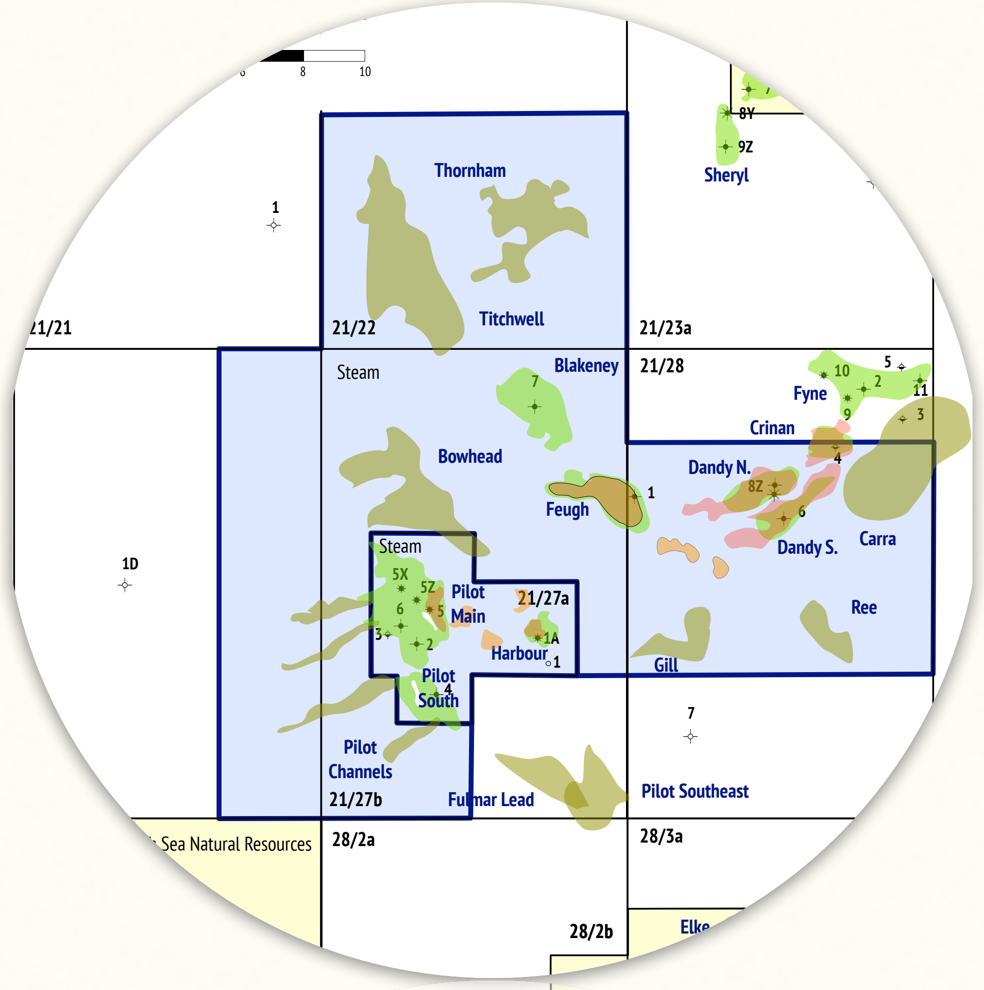

GEOLOGICAL SETTING

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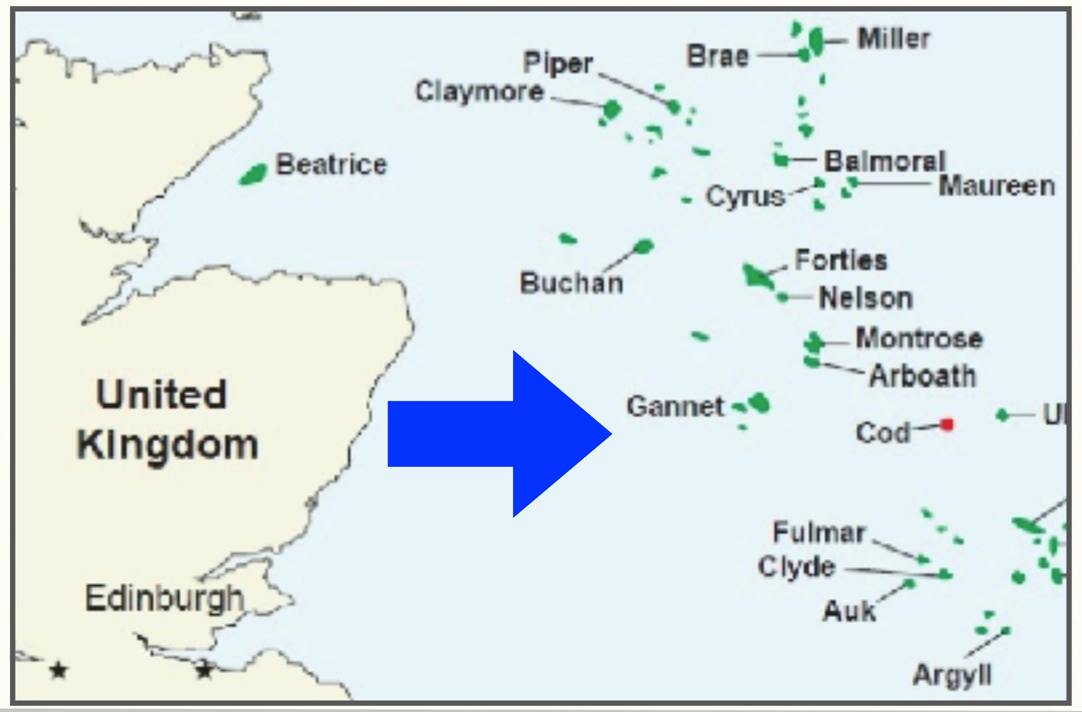
- Pilot Field sits on the Western platform
- Positioned outside of the Central Graben hydrocarbon kitchen; at the end of a migration route
- Migration of hydrocarbons in shallowly buried reservoirs has resulted in biodegradation and thus heavy oil



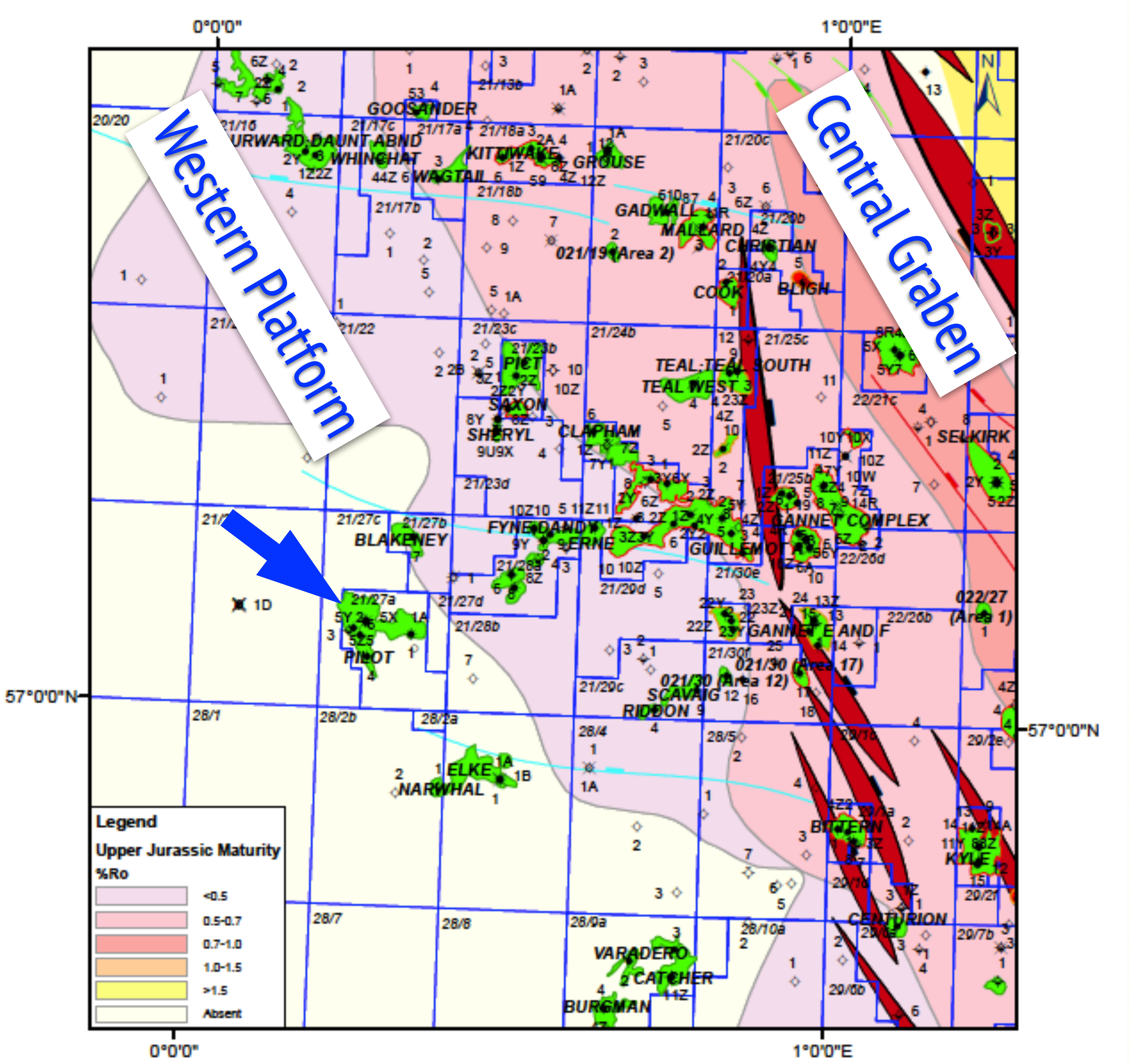


Figure 3-10 Upper Jurassic Maturity map

THE TAY FAIRWAY

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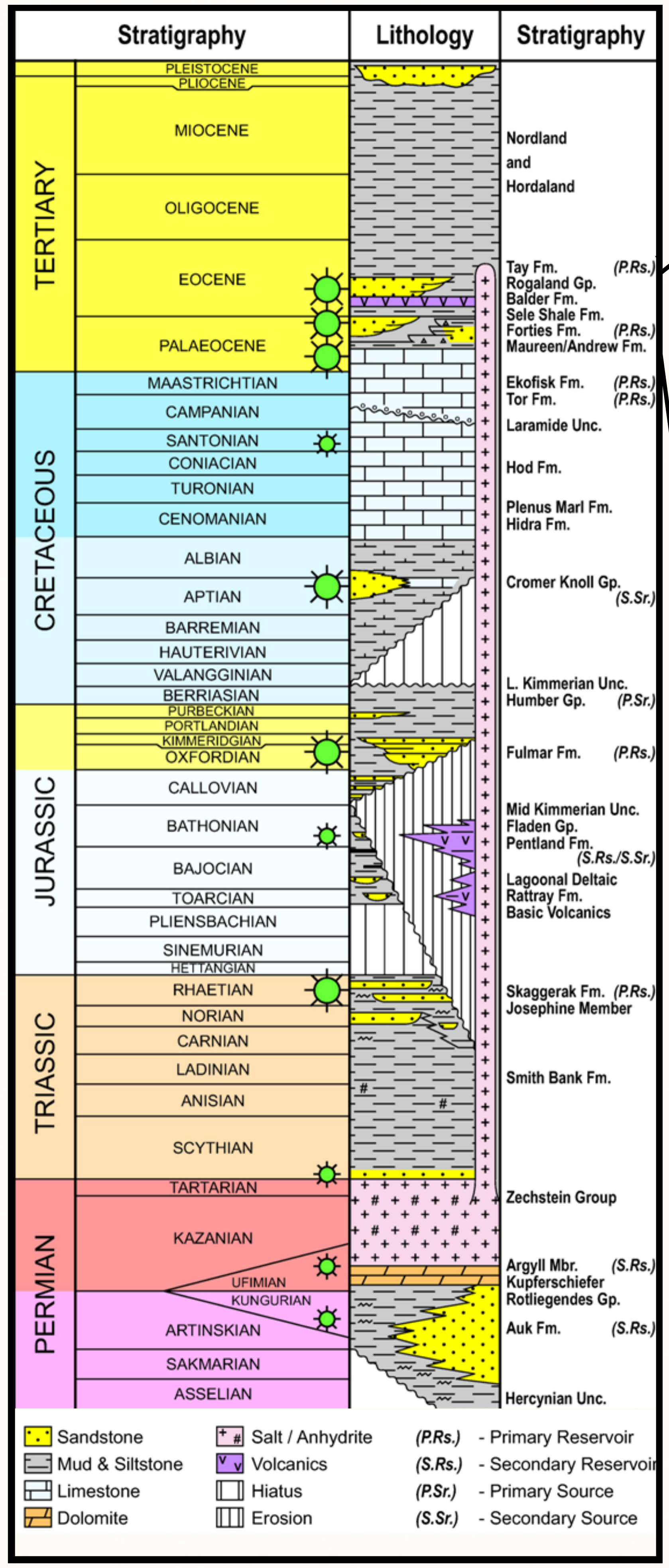

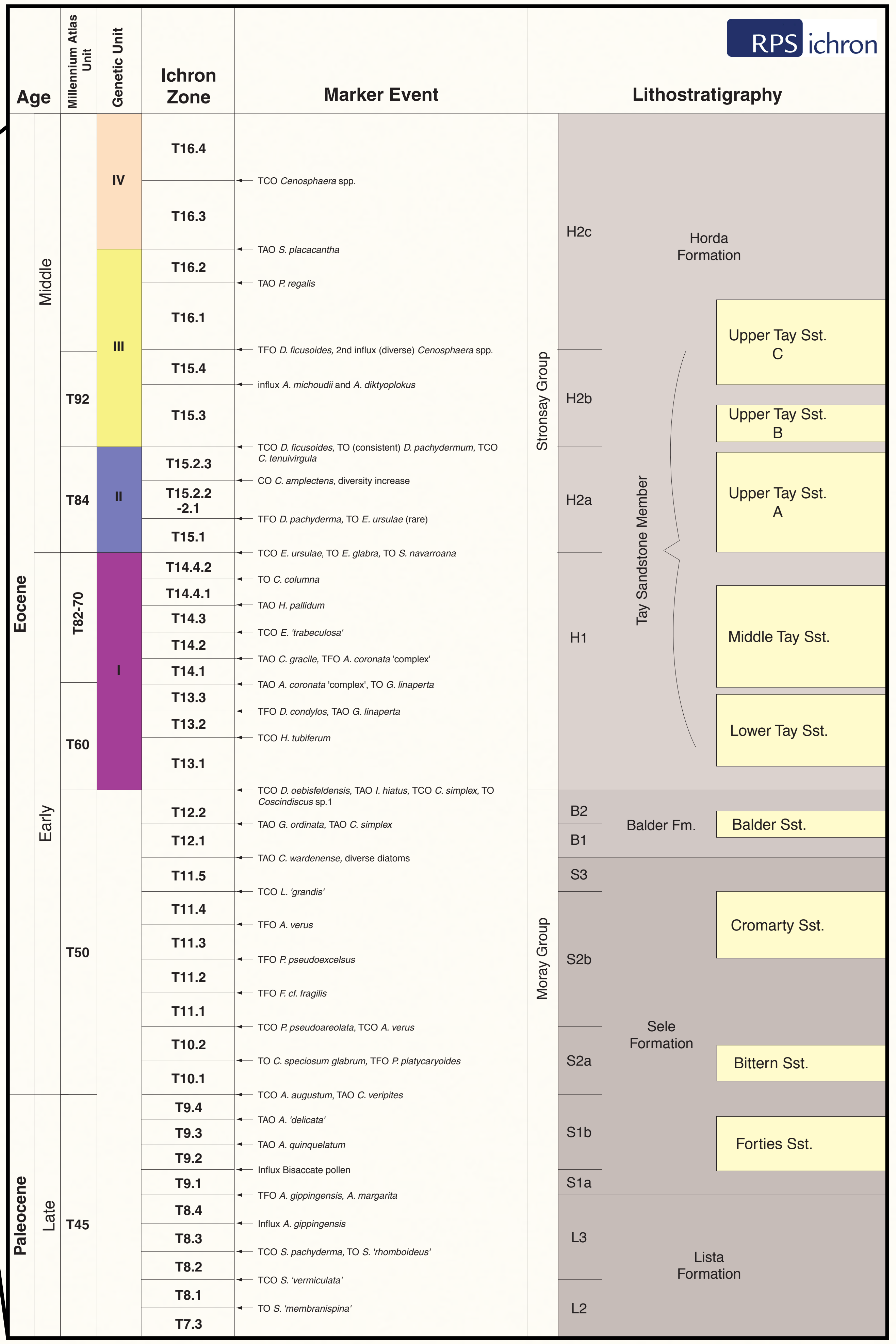

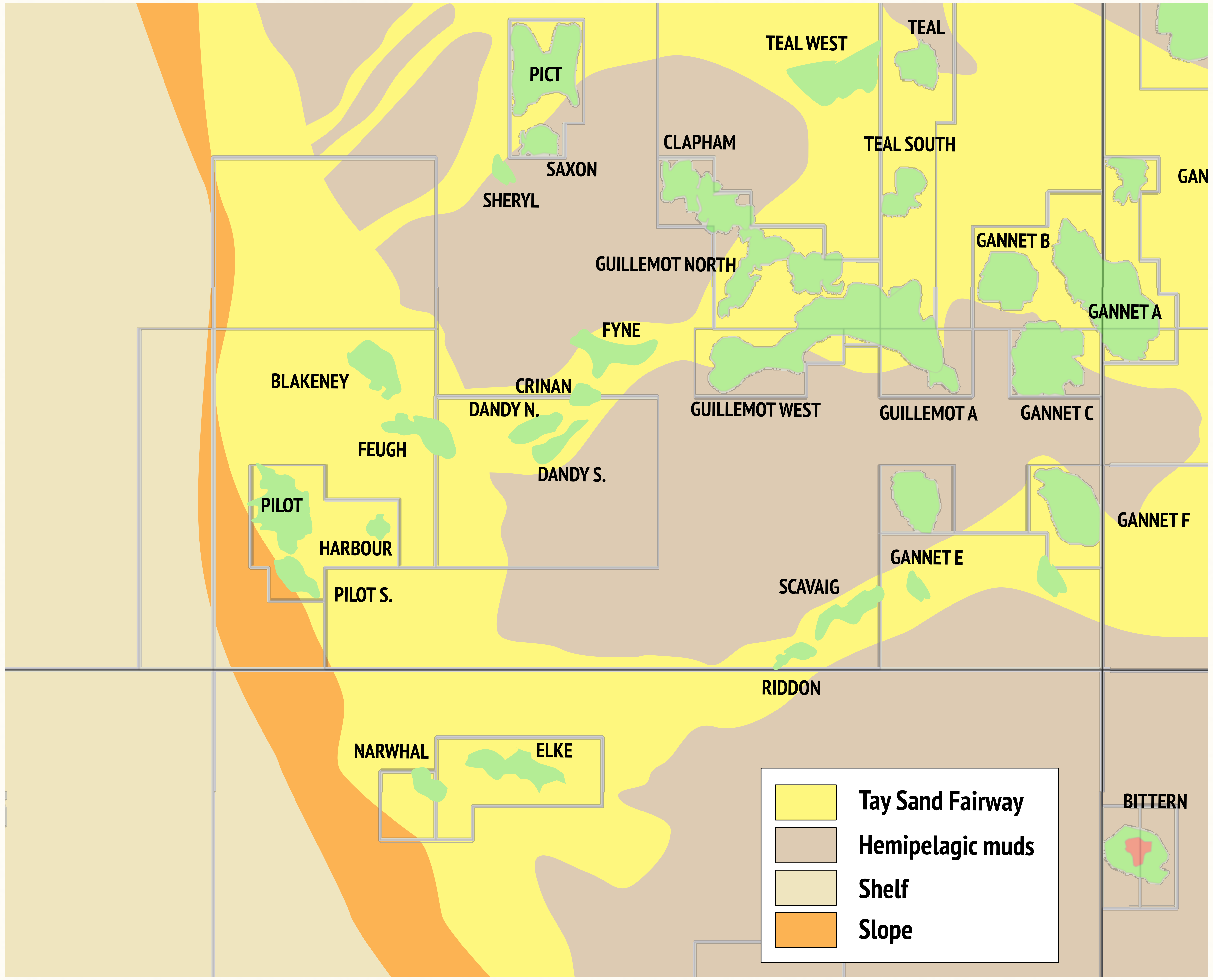

THE PILOT FIELD
A WELL APPRAISED DISCOVERY

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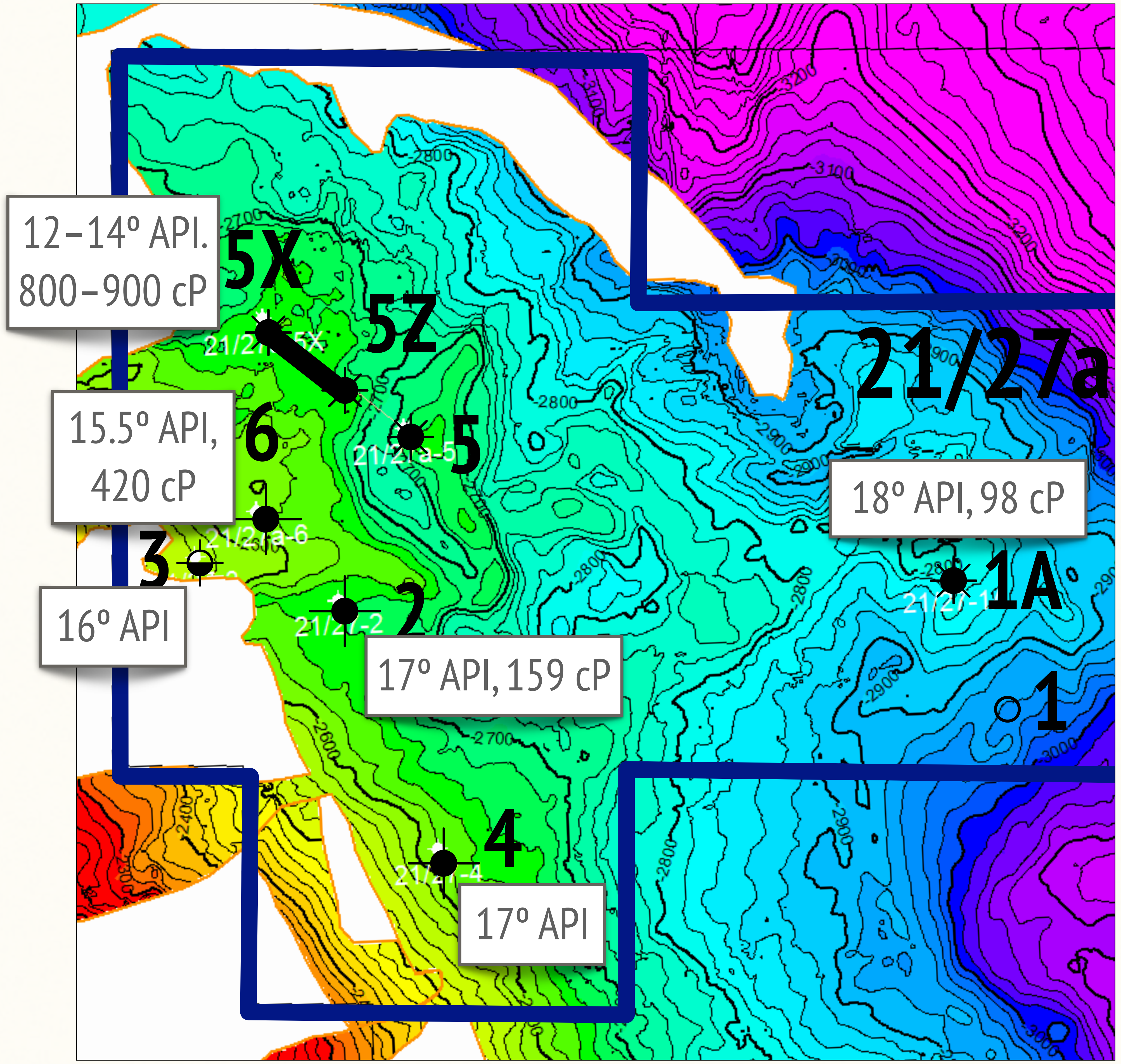
- Harbour & Pilot discovered by Fina in 1989 by the 21/27-1 and 21/27-2 wells
- 1990 saw the drilling of 21/27-3 (delineated the up dip pinch out) and 21/27-4 (discovery of Pilot South)
- 21/27a5, 5Z & 5X (a 680m horizontal) were drilled in 1998. 5X tested at rates over 1,800 bopd (using an ESP) despite being in the most viscous part of the field
- Venture drilled 21/27a-6 in 2007 and obtained an excellent oil sample, but this derailed their low well intensity waterflood development plan
- In total six wells were cored, and three wells were tested including the horizontal well



NORTH - PILOT MAIN

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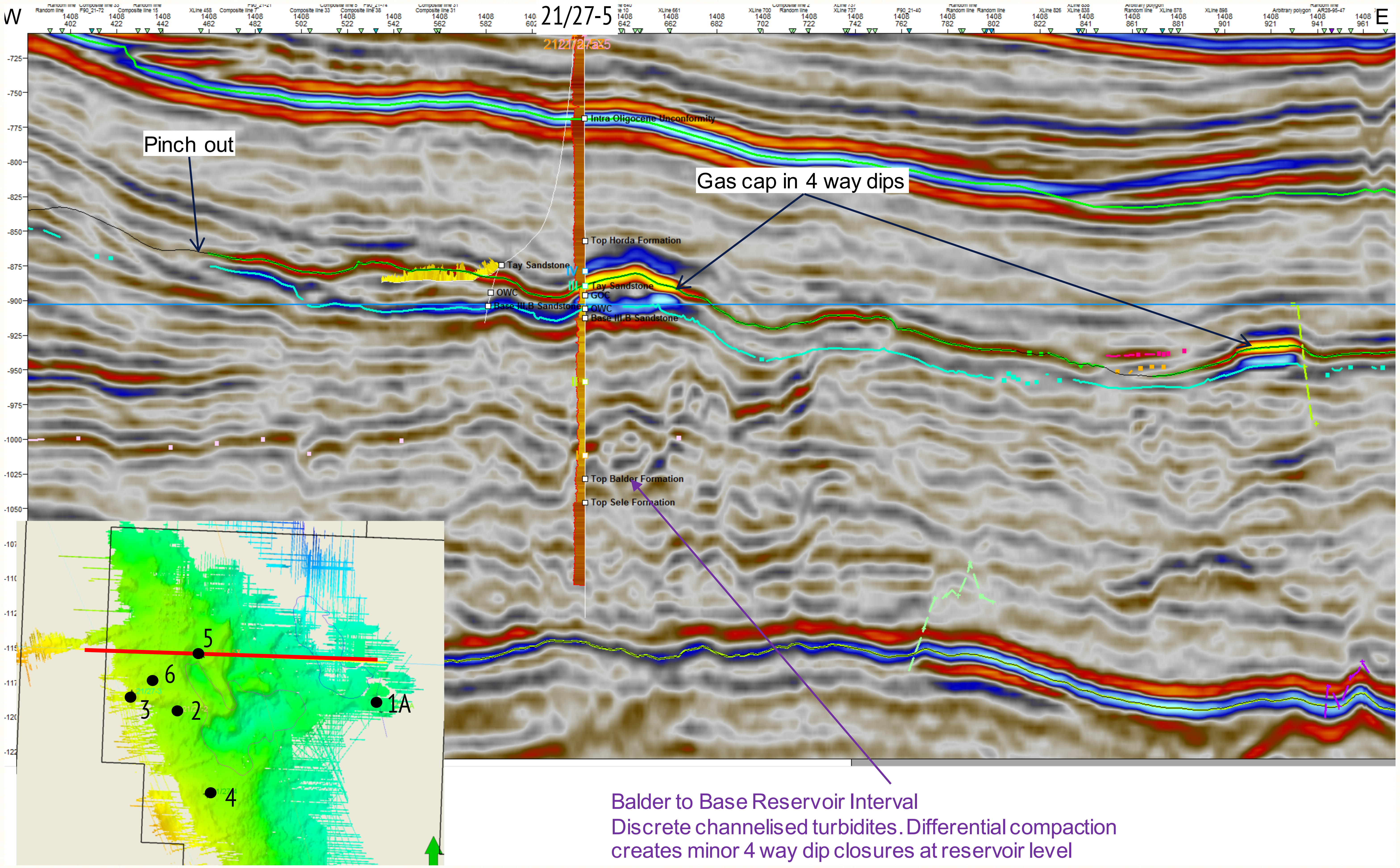
- Seismic line through 5 well with horizontal sidetrack
- Gas caps occur in small 4-way dip closures
- Gas cap is lacking at pinch-out edge
- Interpreted to be a result of a weaker lateral seal allowing gas to escape
- Deeper palaeo-column below OWC suggesting some oil leakage as well



PILOT - COLOURED INVERSION

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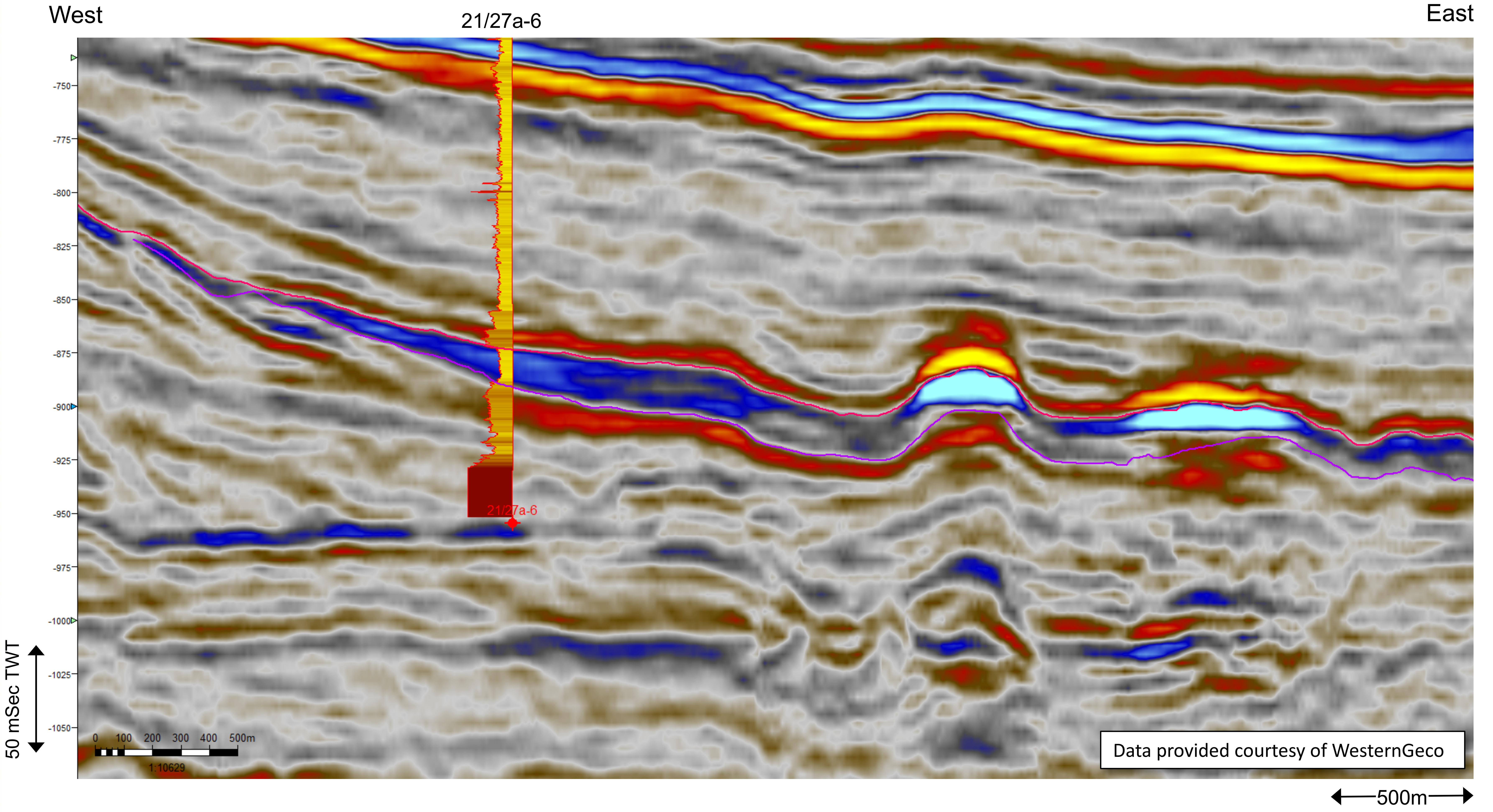

- Seismic line through the 21/27a-6 well
- Coloured inversion display
- Demonstrates how seismic effectively images the pinch-out of sands to the East
- Gas cap over East Pilot and undrilled small 4-way dip structure also apparent

STRIKE LINE - PILOT

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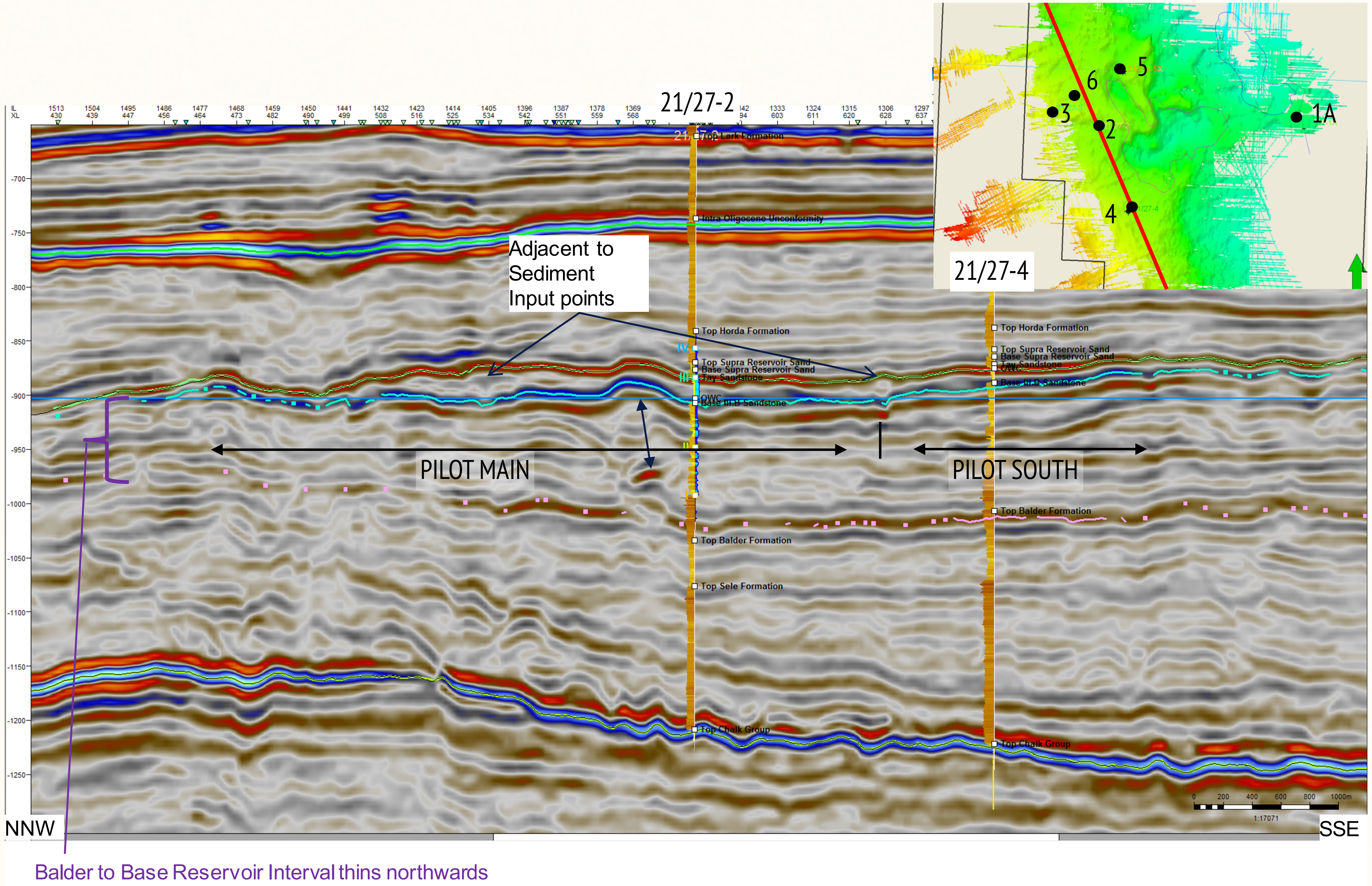
- Strike line from across Pilot Main and Pilot South
- Localised thickening of Tay reservoir package associated with updip input channels observed
- Top reservoir dims in area between Pilot South and Pilot Main indicative of facies change and/or absence of oil charge



SEPARATION OF PILOT MAIN & SOUTH (4 WELL)

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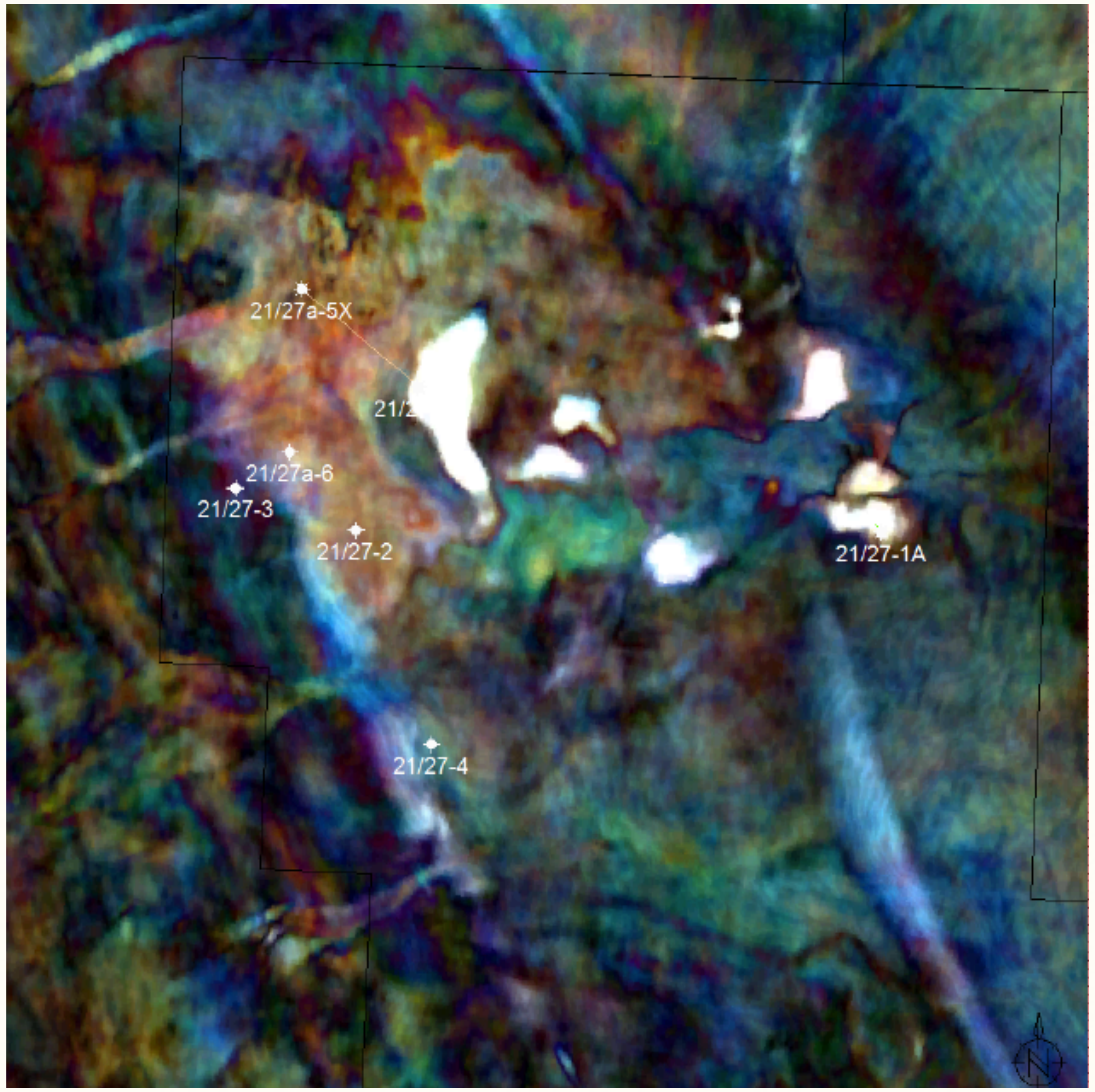
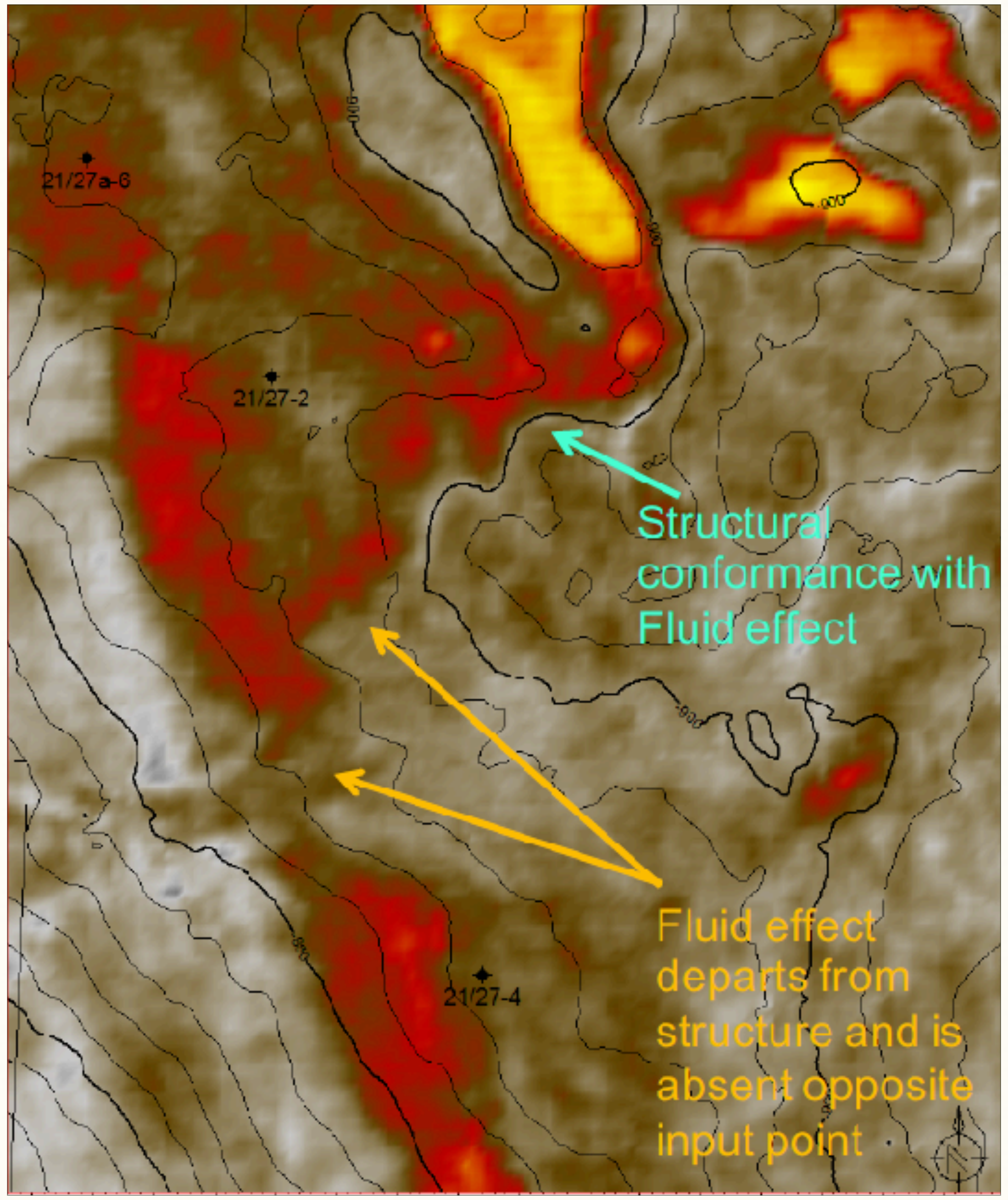
Attribute Map - Top Reservoir Spectral Decompostion
Colour blend (20/28/45 Hz)



- Separate OWC seen in Pilot South (4 well) - 93 ft shallower
- Interpreted to be a result of channelised erosion and subsequent localised argillaceous fill within multi-cut and fill system
- Seen on Spectral Decompostion map as incision with different fill; and also on Far Stack Amplitude map where OWC structural conformance is lost in the area of the channel cut
- Also seen on Colour Inversion map

Attribute Map - Far Stack Amplitude



TOP TAY DEPTH MAP & FLUID AREAS

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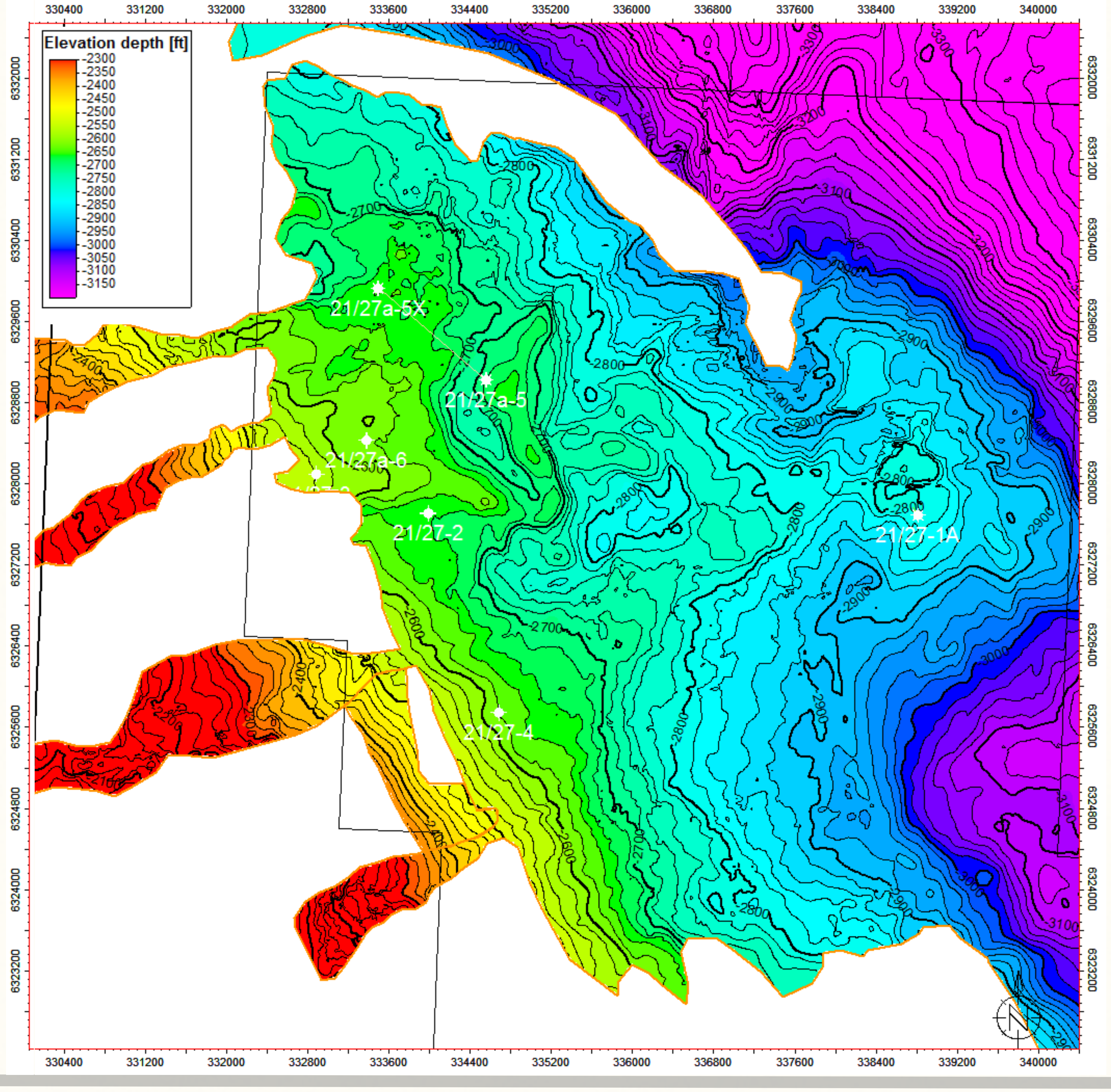

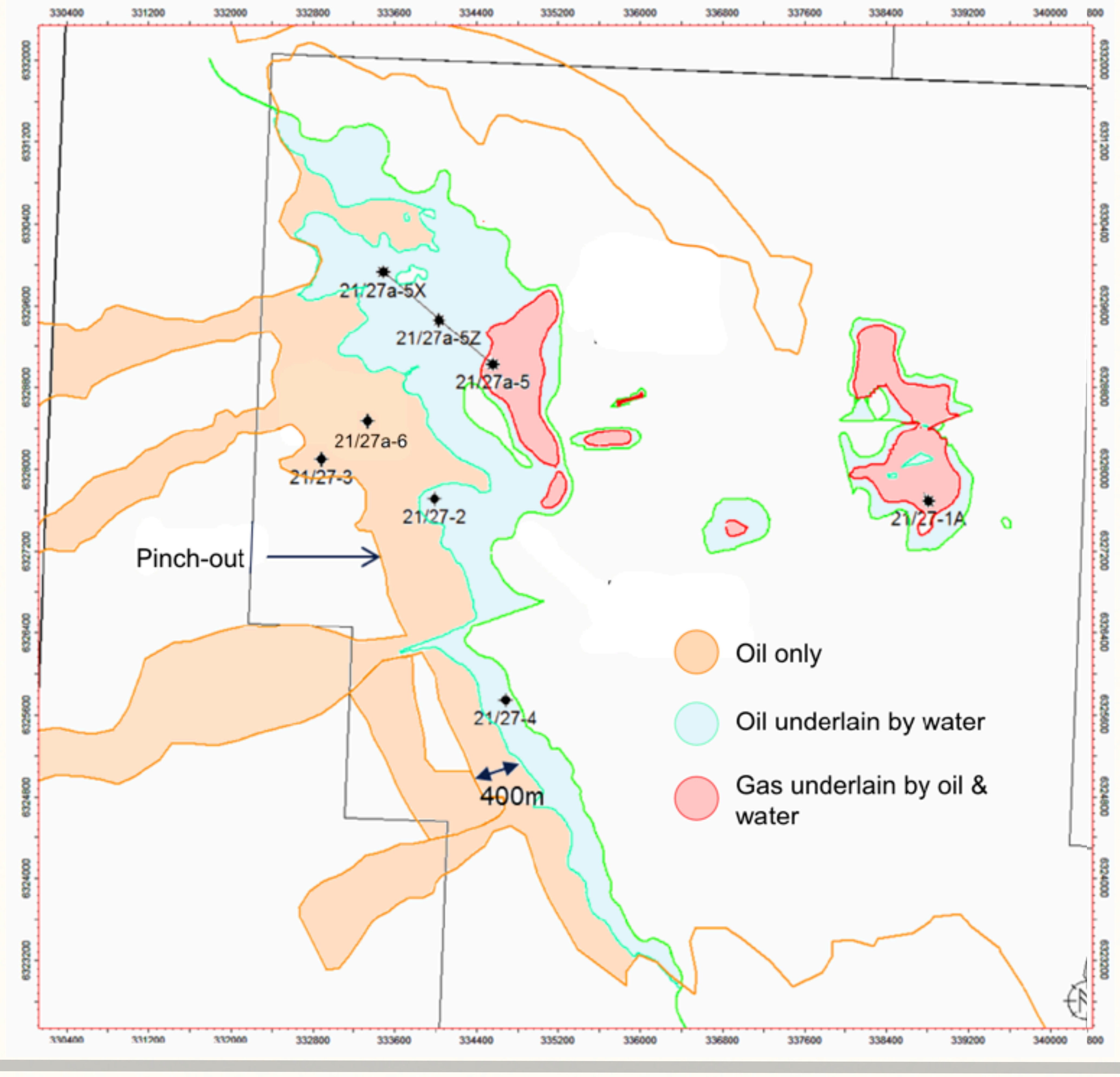

DEPOSITIONAL MODEL – PONDED TURBIDITE

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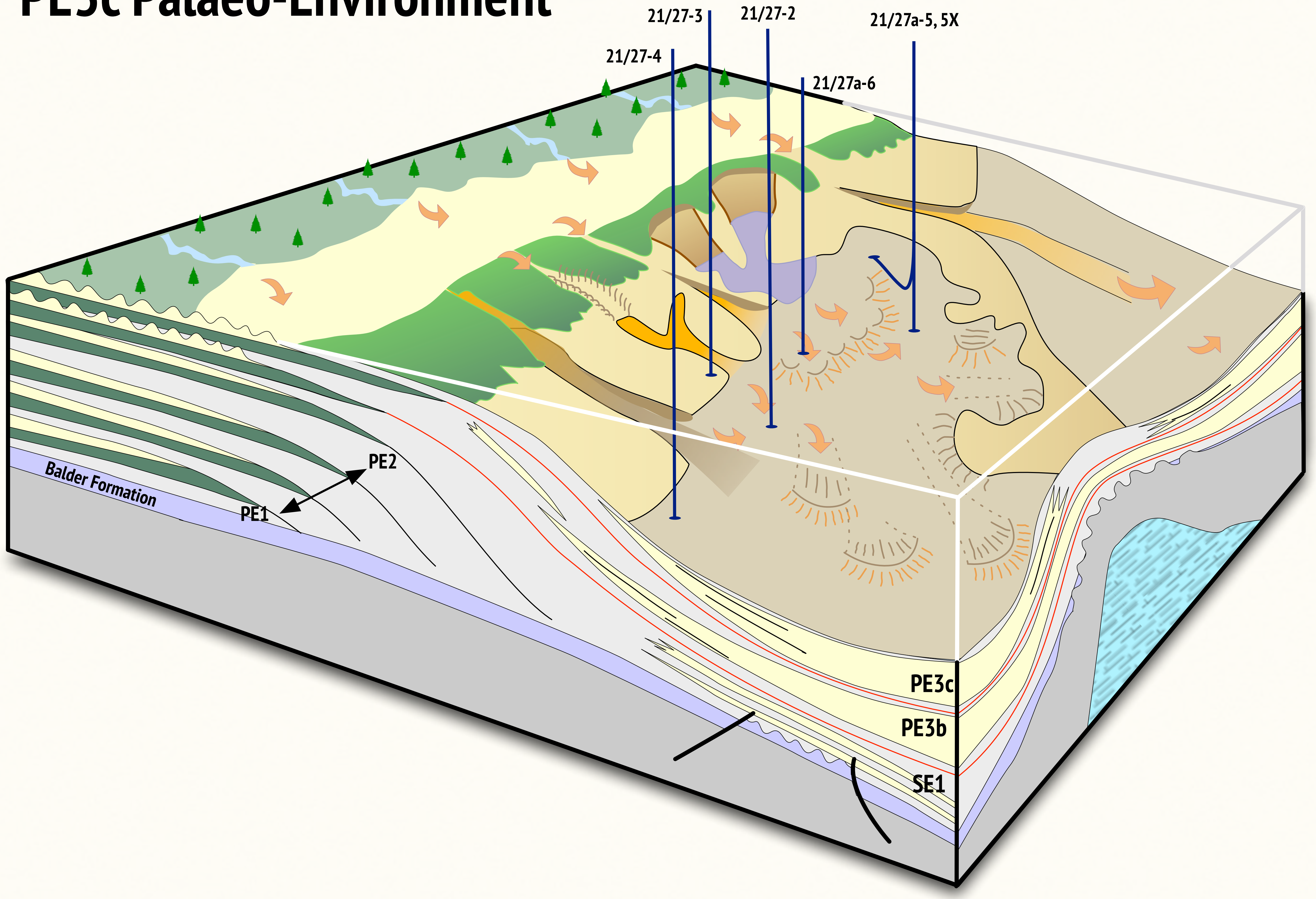
PE3c Palaeo-Environment



Bio-stratigraphic Zonation

Middle Eocene: PE3c & PE3b

Lower Eocene: PE1, PE2, SE1

Processes Key

- Sand reservoir with interbedding
- Coherent Slide
- Channel Lobe Complex
- Sand Transport Direction
- Sequenece Boundary

Lithology Key

- Sand
- Silt
- Mud or Claystone
- Tuffaceous Claystone
- Paleocence Claystone
- Cretaceous Chalk

Facies Key

- Shelfal sands
- Shelf edge mixed sands & silt
- Slope silts & argillaceous sands
- Basin floor fan

- Ponded turbidite model developed by Fina with sedimentological input from Badley Ashton

PETROPHYSICS

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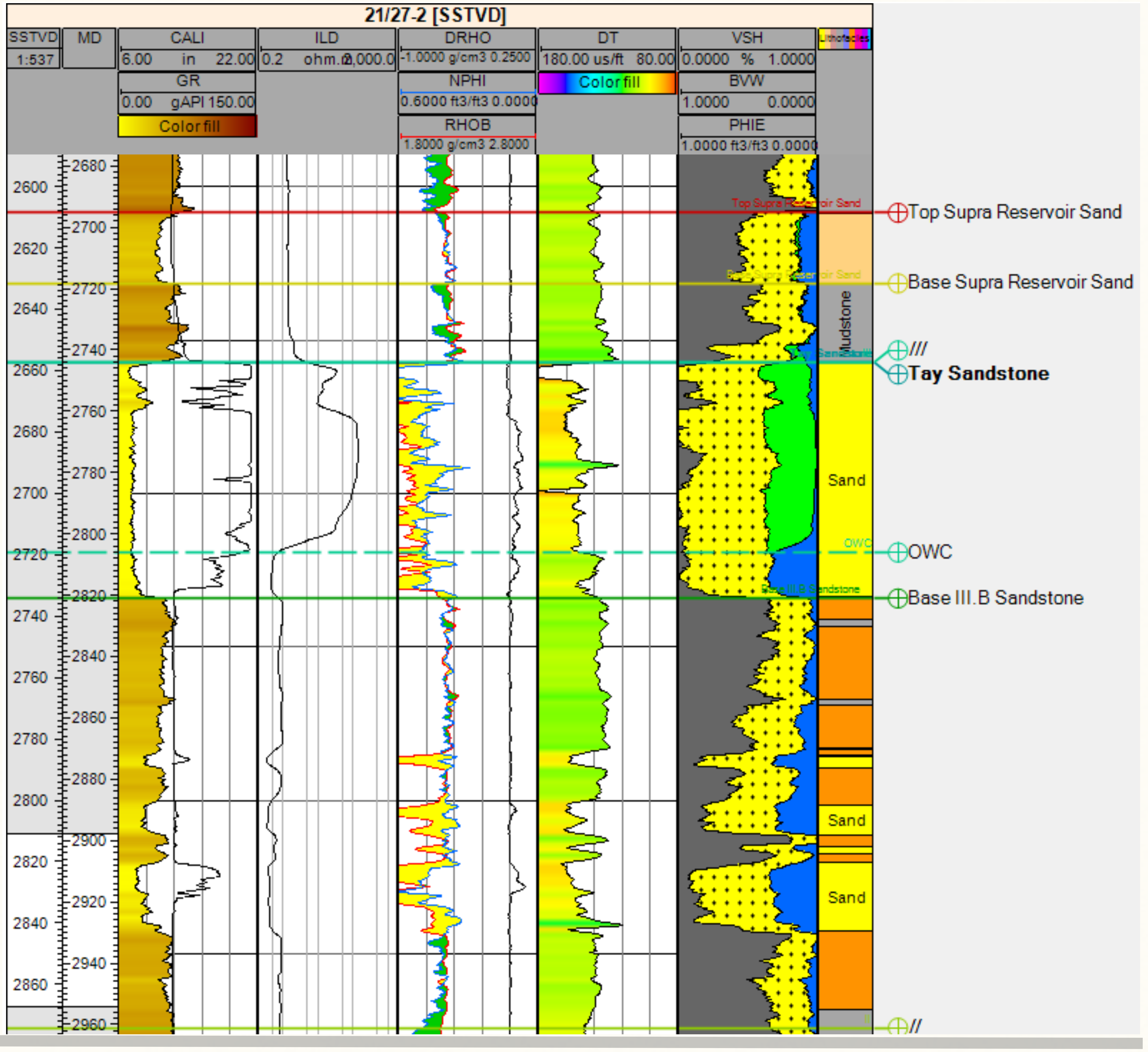
- EnQuest review and re-interpretation of all Pilot wells
- Consistent methodology
- No significant differences from previous interpretations
- High porosities: above 35% in parts
- Reservoir sand is clean, zero to very low clay content, but presence of glauconitic and pyrite sands appear as argillaceous sands on log analysis
- Low S_w, with clearly resolved transition zone



WELL CORRELATION

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FACIES DESCRIPTION

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- Lithofacies description:
  4 Components

Massive Sandstone

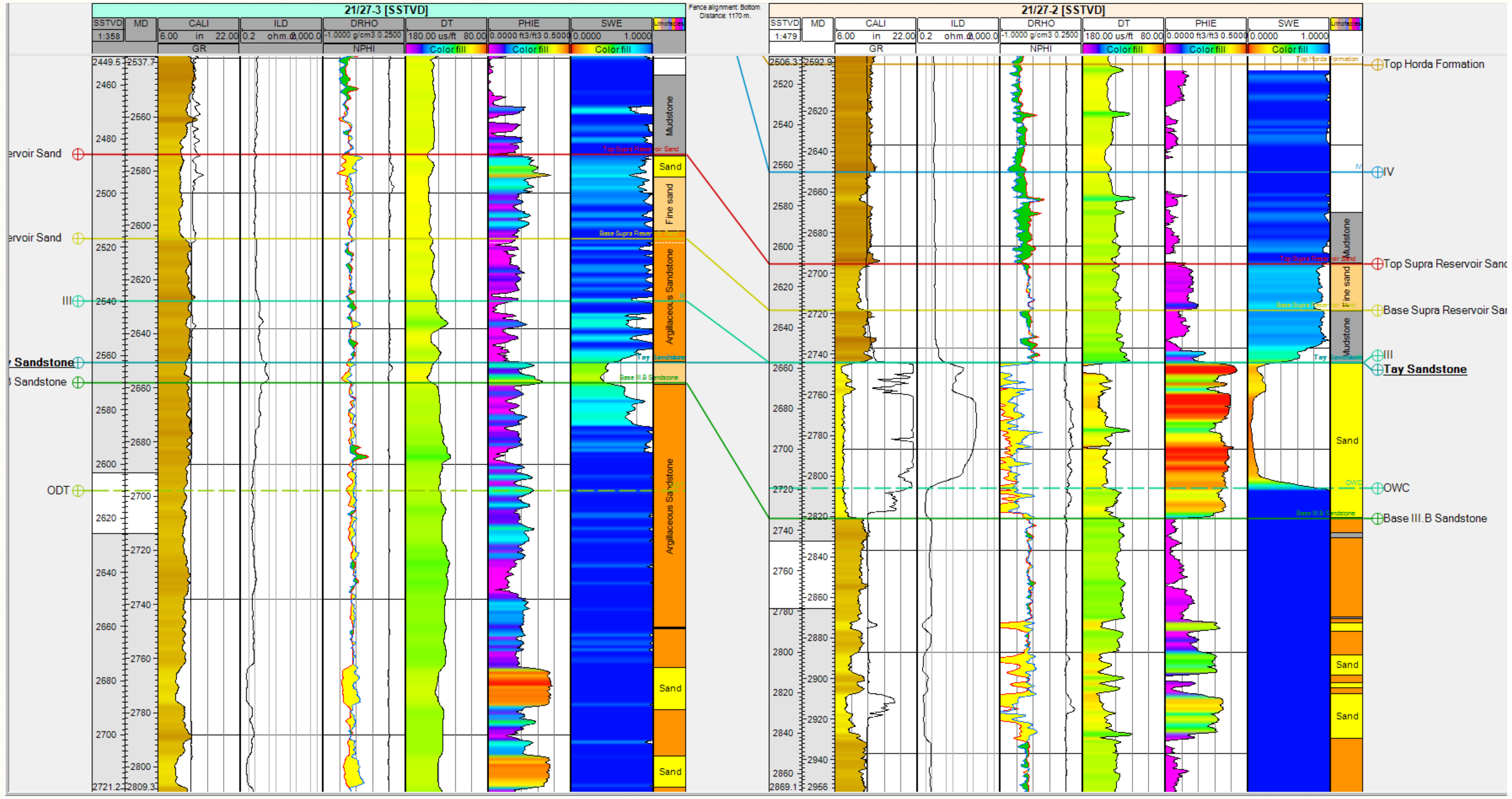
Fine Sandstone, locally very fine, argillaceous in places (seen in 21/27-3 pinch-out well)

Argillaceous Sands/Sandy Claystones. Glauconitic. Non-Reservoir for heavy oil - forms base seal

Mudstone

21/27-3

21/27-2



FACIES MAPS

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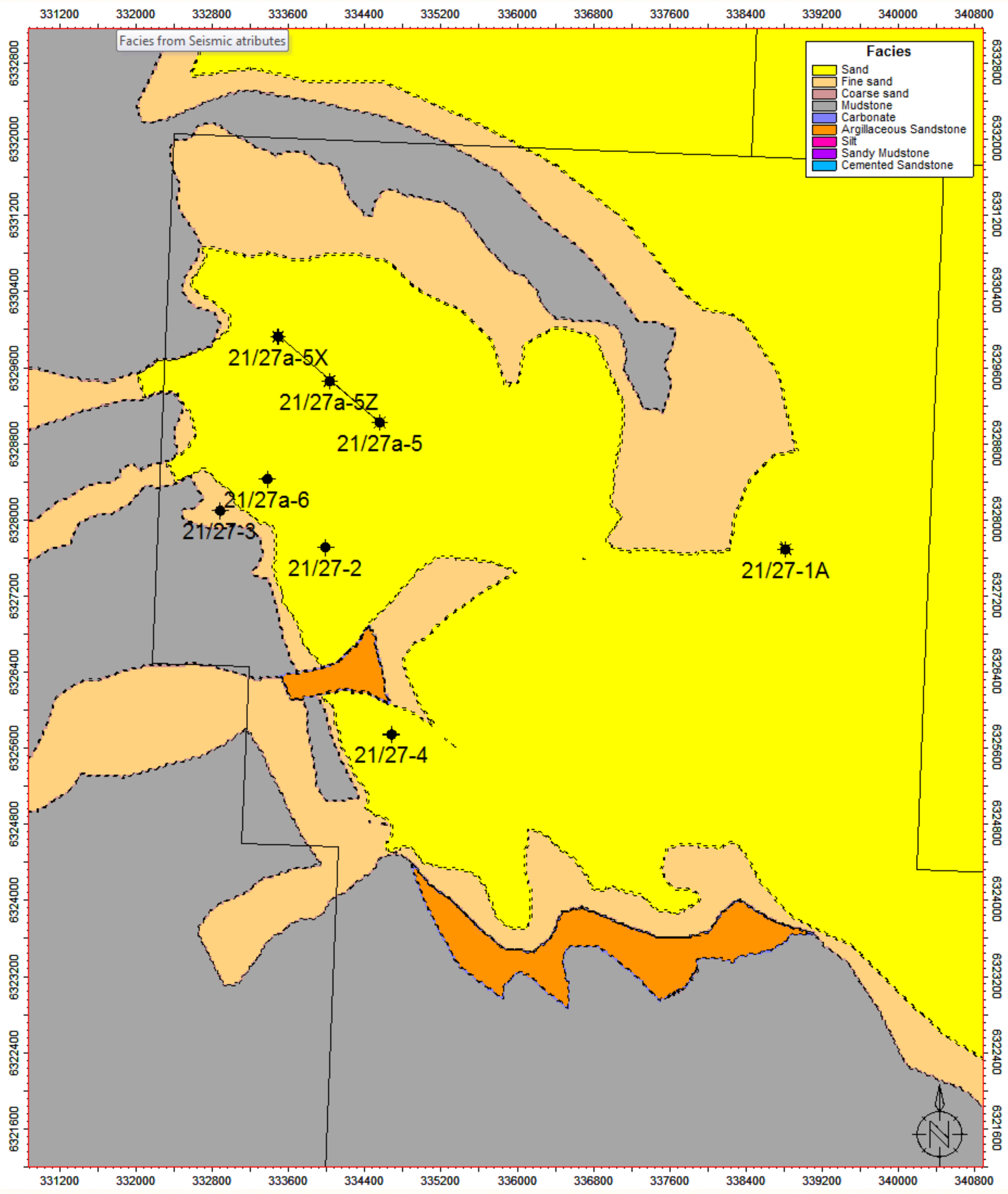
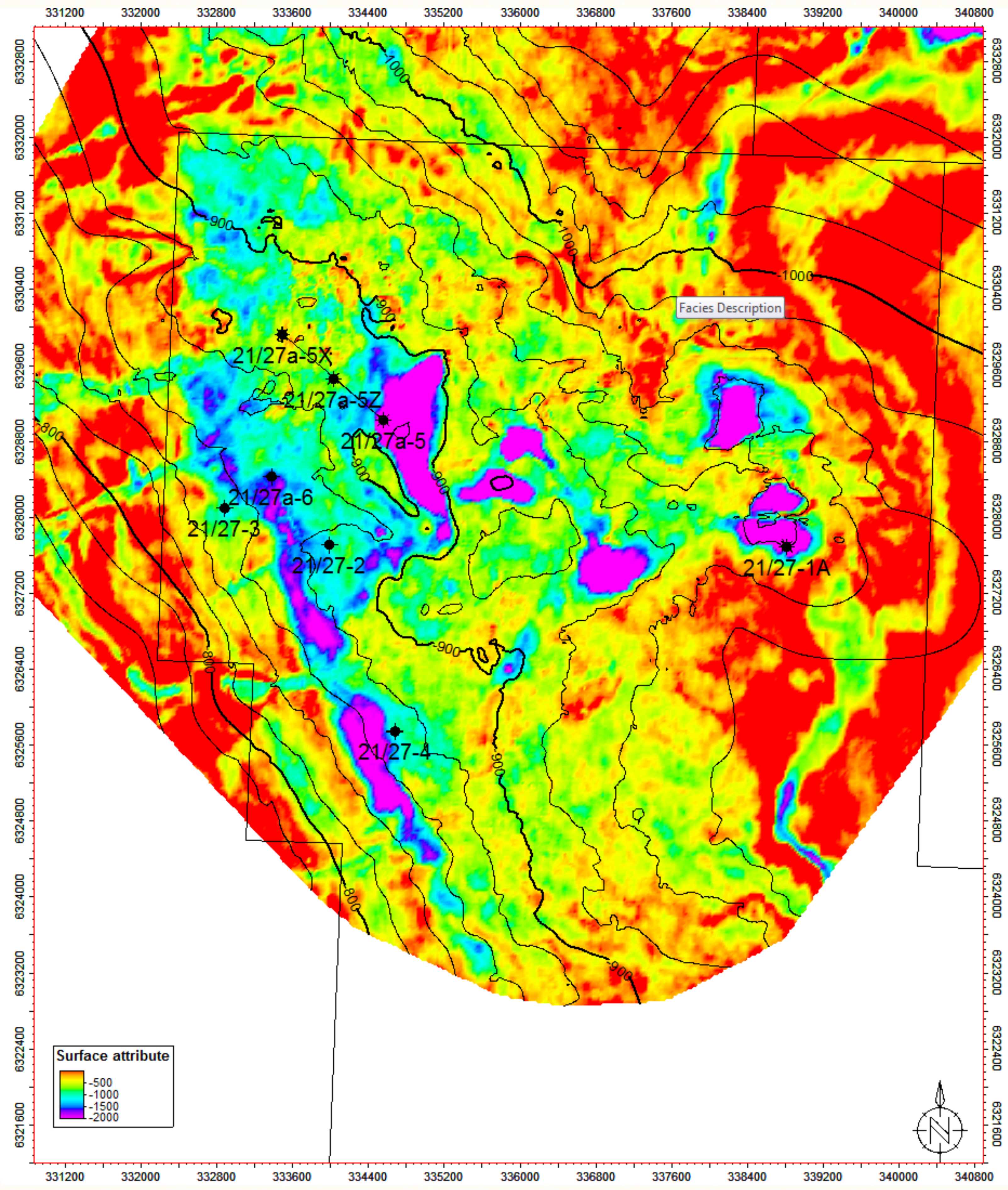
- Descriptions based on fairly abundant core material, and logs. Hand digitised into Petrel
- Main reservoir constant Massive Sandstone; apart from 21/27-3 which is in Fine sand facies
- Mud channel separates South from Main, explaining the different OWC's
- Mapped from well data, isochron and attributes





MINERALOGICAL AND TEXTURAL DATA PILOT FIELD - 5 WELL

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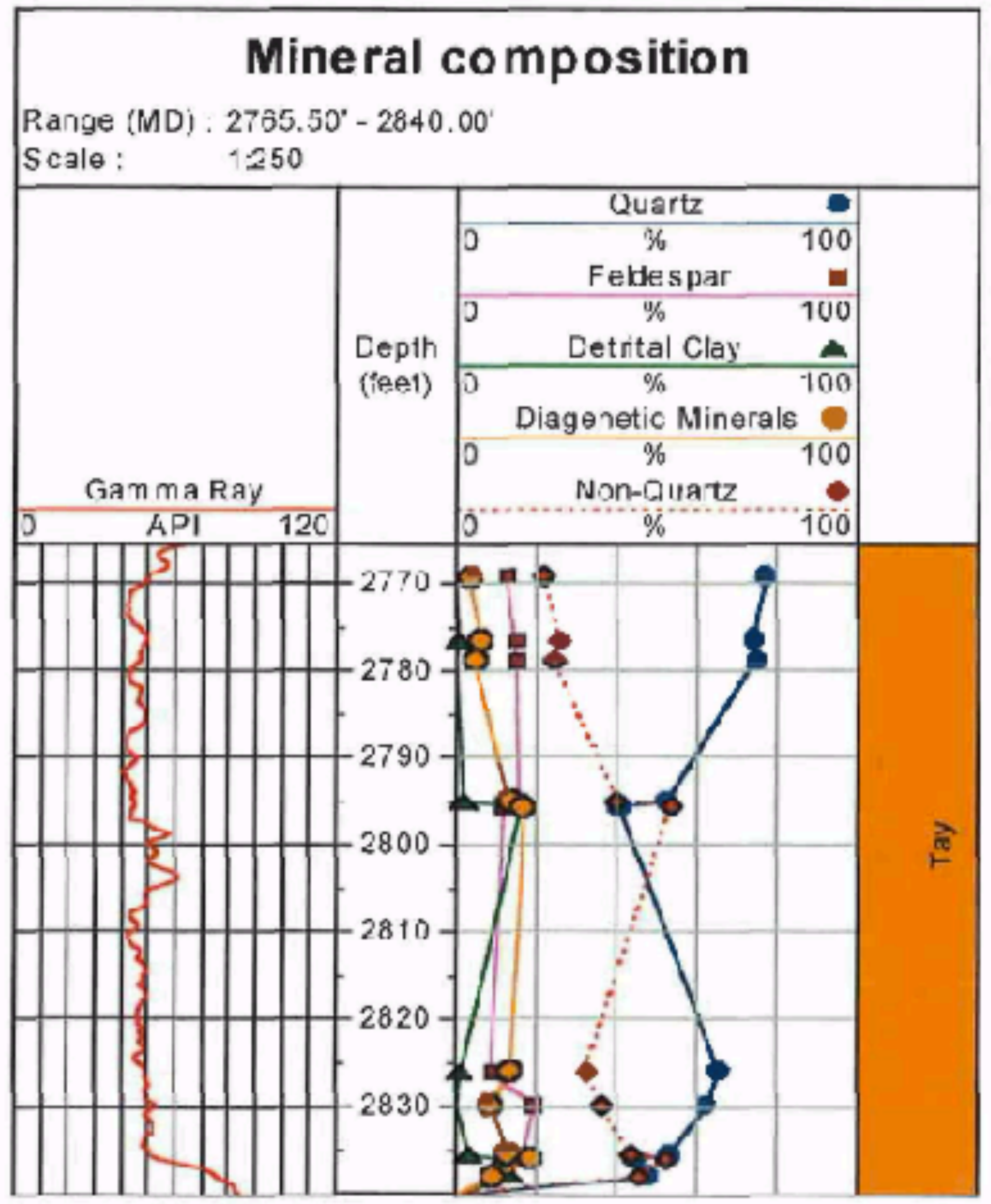

Figure 3.1 – Tay sandstone mineral composition

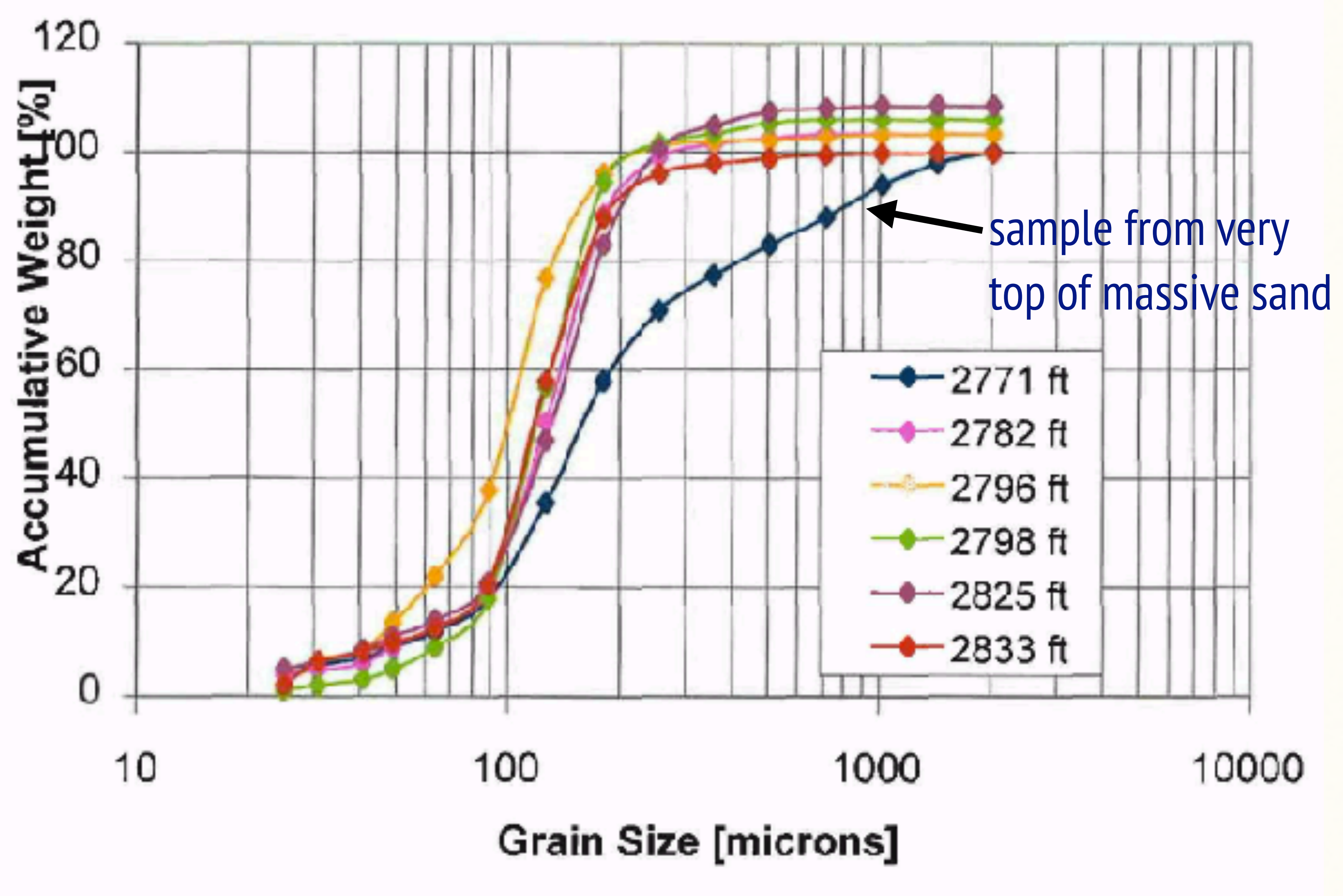

Figure 3.2 – PSD results – Well 5

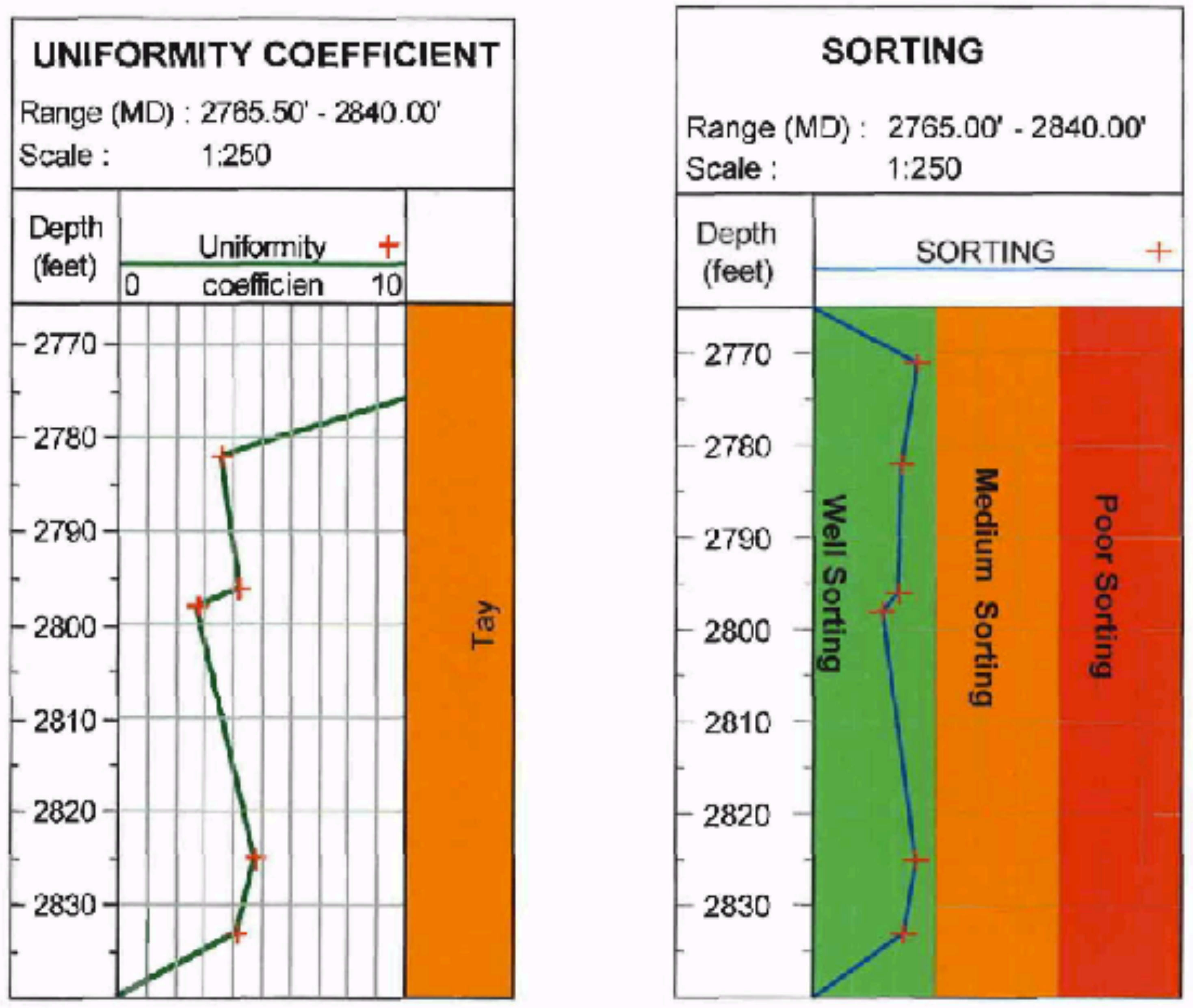

Figure 3.4 – Sand grains sorting and uniformity – Tay sand

- Shallow , immature sand with quartz content of 45% to 78%
- Well to fair sorted, uniform sand; with the very top not as uniform
- Given low quartz the sand content is well sorted and uniform
- Minor detrital clay present; typically over estimated in log analysis due to presence of pyrite and glauconite
- Some diagenetic minerals present - surprising given high average porosity

PERMEABILITY

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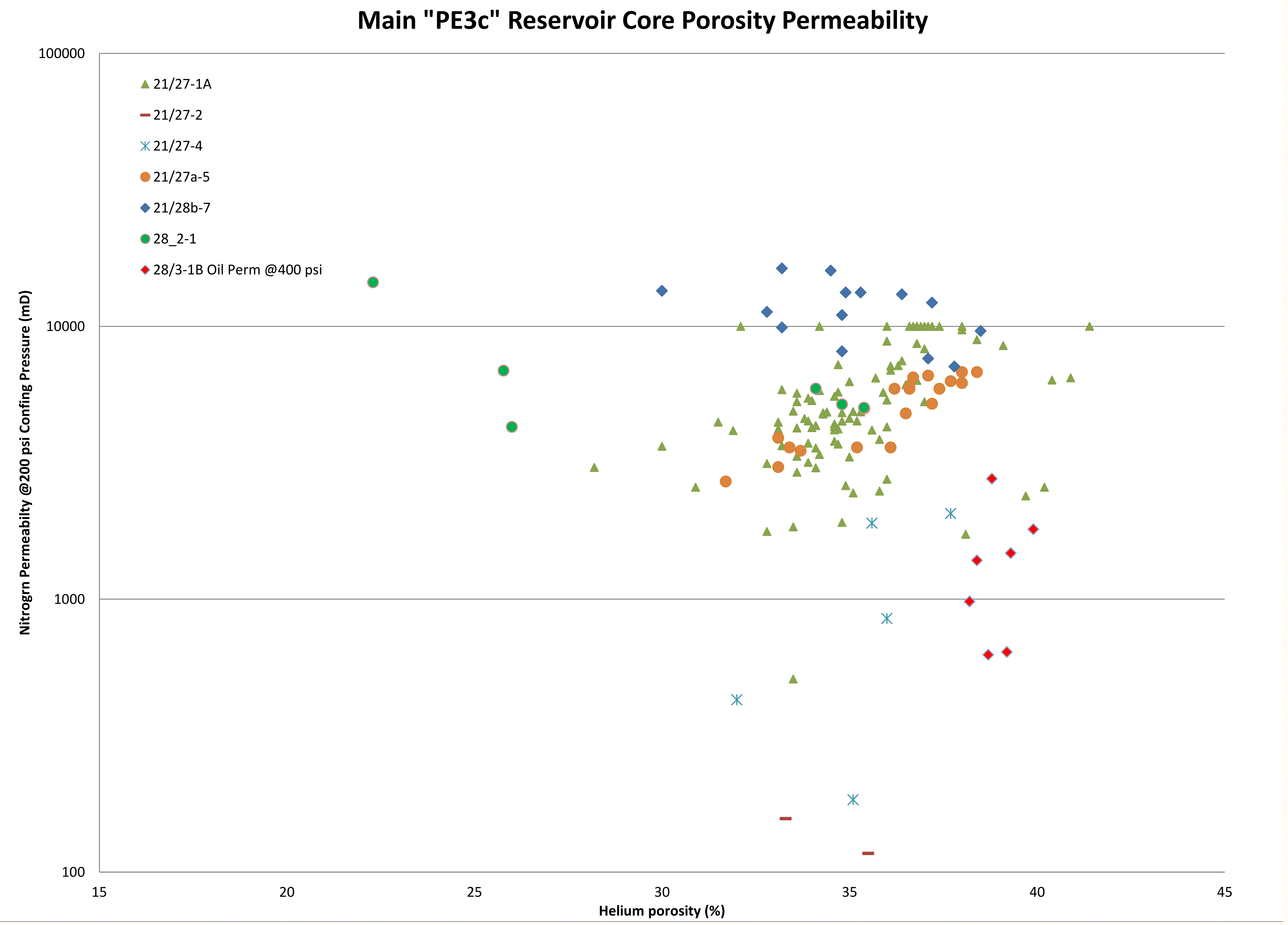

Source	Perm. Estimate	Comments
DST	multi-darcy	2 well test analysis indicates 1.5 to 10D depending on how the test is interpreted
Core data	3 to 7 darcies	Not compaction corrected, very unconsolidated sand, very few measurements (if any) from the oil leg
WFT mobilities	400-1000 md/cP	Filtrate viscosity uncertain (maybe 10 - 20 cP), but mobilities fairly consistent and high

- A number of data sources indicate that the system is of uniformly high permeability
- Difficult to get reliable quantitative permeability estimates
- Core poro-perm lacks any significant trend and validity of measurements in these high unconsolidated sands is questionable
- Using a 3 darcy value in the model, likely to be conservative

LOG DERIVED POROSITY

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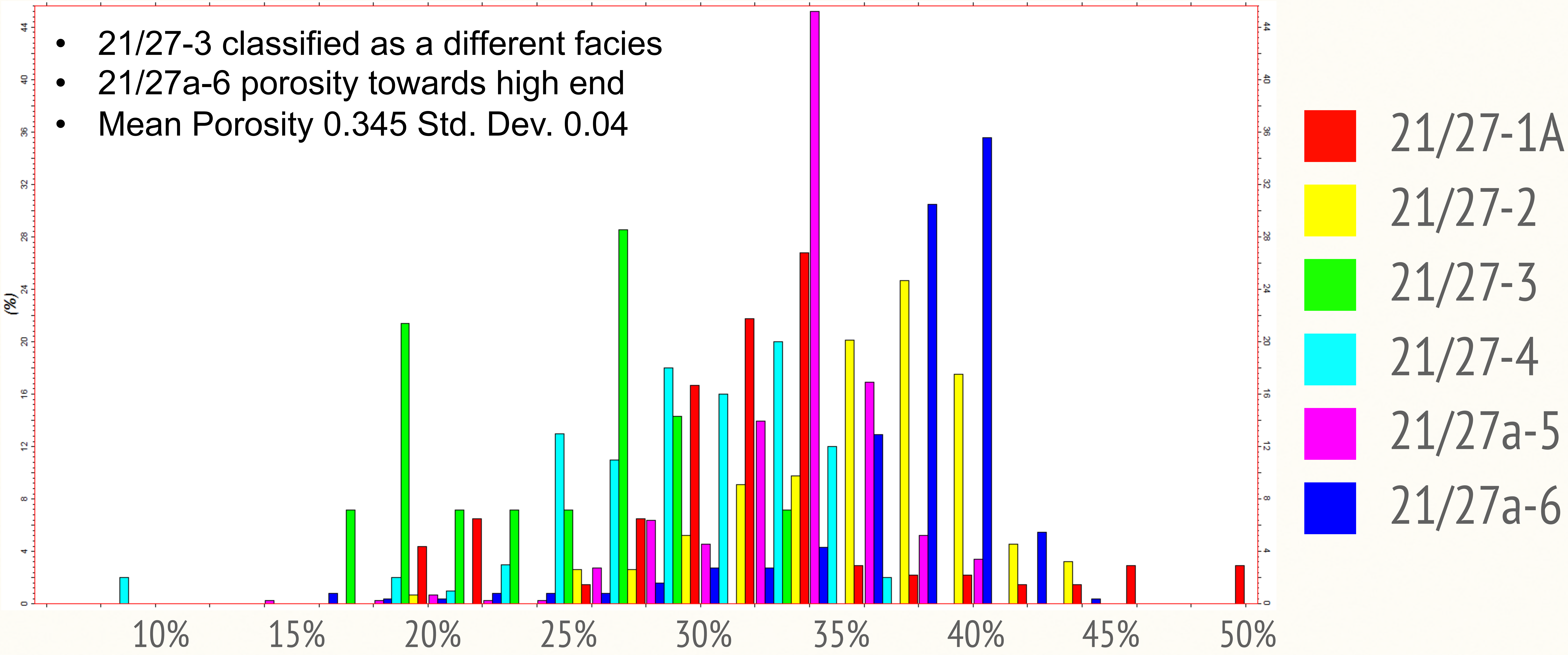
- 21/27-3 classified as a different facies
- 21/27a-6 porosity towards high end
- Mean Porosity 0.345 Std. Dev. 0.04



WATER SATURATION

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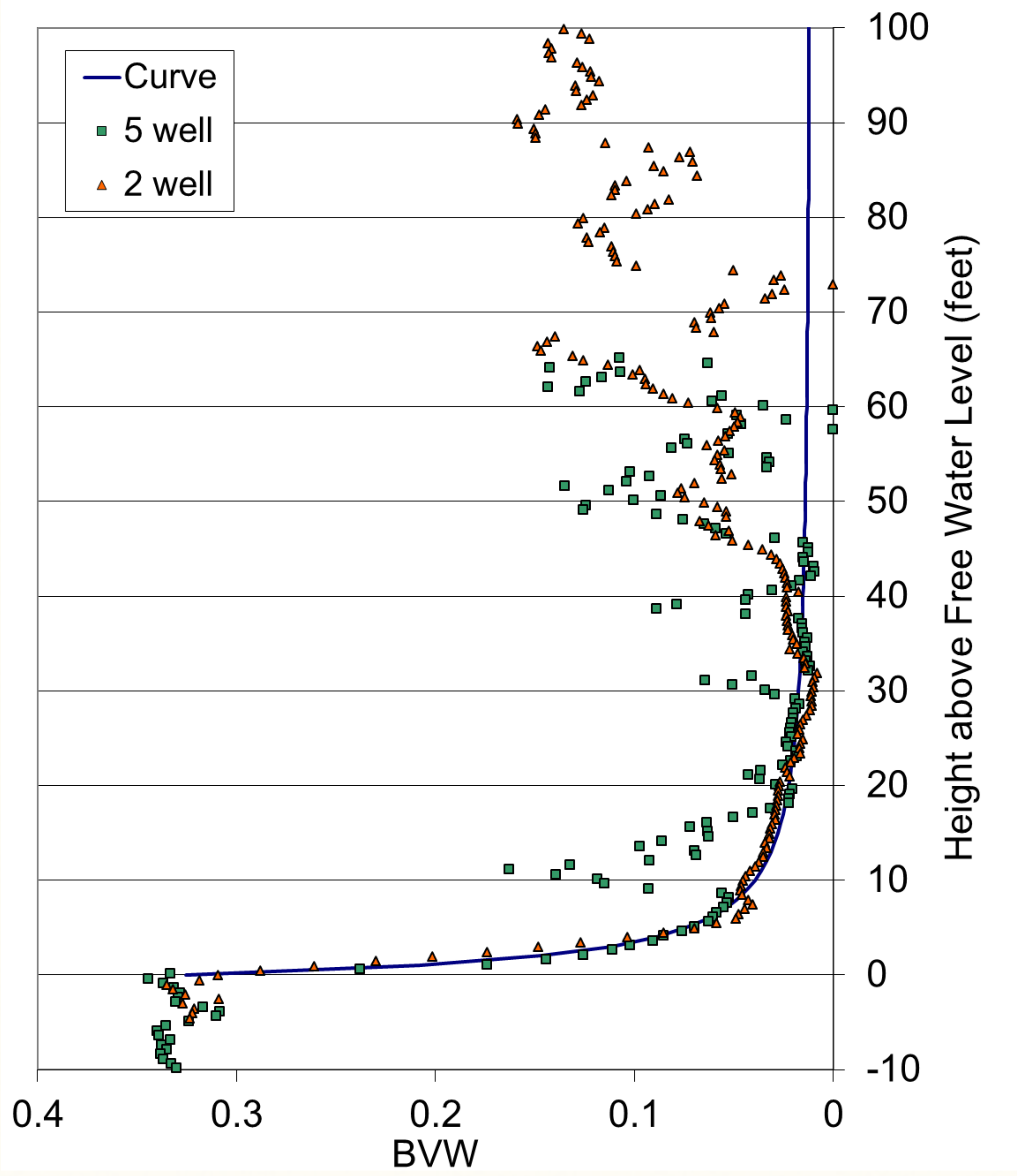
- Saturation Height function estimated using 21/27-2 and 21/27a-5
- Similar fluid density but high permeability have opposing effects
- Sharp saturation change in first few feet, then fairly low order change
- “Irreducible” Sw fairly low, around 3- 4%
- Possibility of being oil-wet, but well site wettability tests implied the reservoir is water wet assuming the tests are valid



VISCOSITY CORRECTIONS FOR ENQUEST BY NIGEL BREALEY

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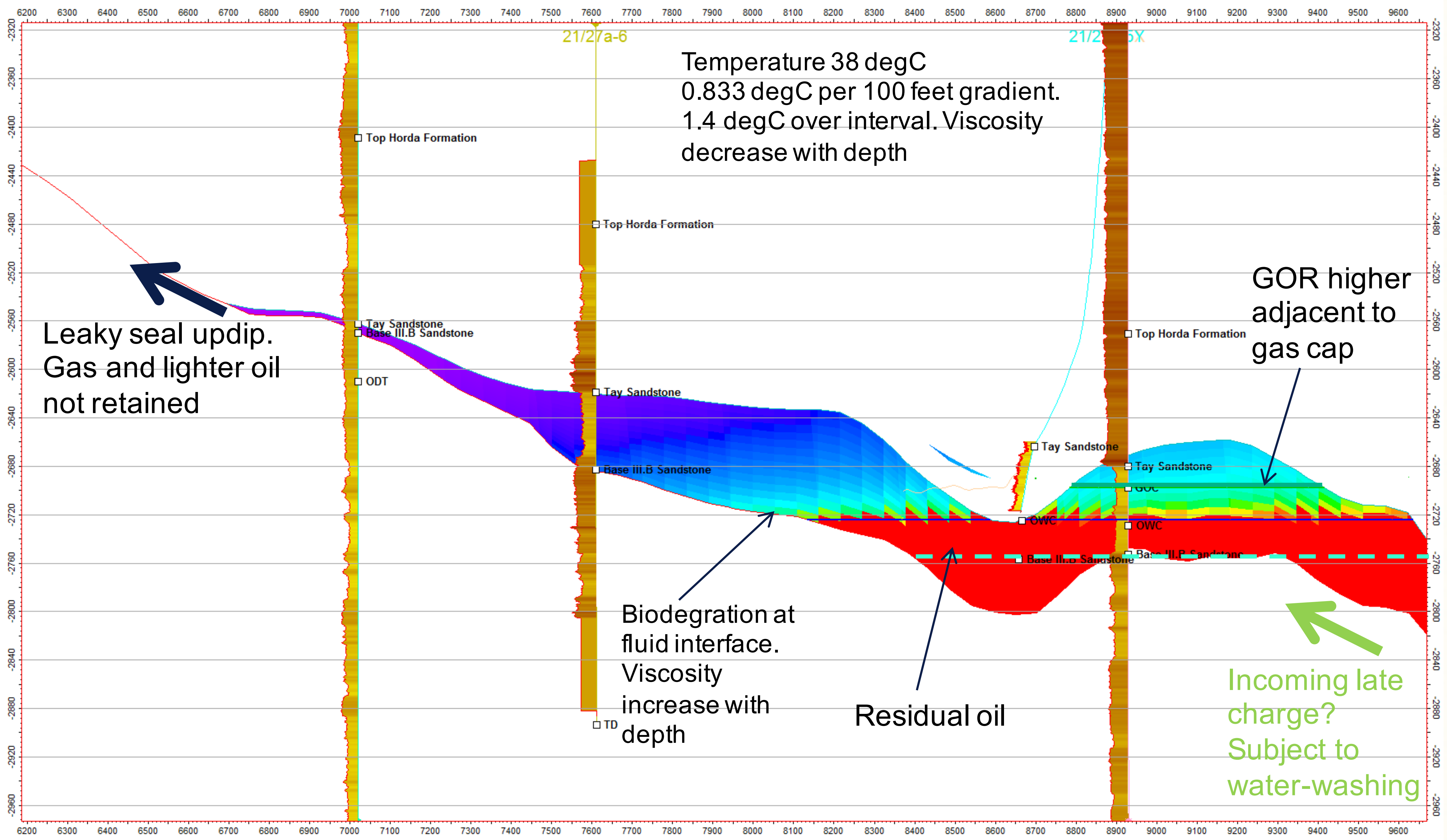
- Previously oils assumed to be at bubble point due to #5 gas cap – probably optimistic
- Experiment to add methane back to #5x sample > ~550 cP
- GOR/Pb uncertain e.g. #5x flowed below Pb
- Most reliable sample from #6 – Pb = 793, Rs = 83
- Correlations used to adjust live oil viscosities for other samples on the basis of constant Pb & Rs
- Some adjustments also made to API Gravity



Well	MD	TVDSS	Sample Viscosity (cp)	Density (API)	Nigel's Corrected Viscosities @ Pres (cp)	Corrected to 21/27a-6 sample depth assuming 2.5cp/ft (cp)
21/27a-6	2751	-2645	409.4	15.8	405	405
21/27a-5X	4360	-2680	1870	13.8	895	807.5
21/27-2	2747	-2660	159	17.5	190	152.5
21/27-3	2656	-2568		15.8		
21/27-4	2715.5	-2629.5		17.1	248	

PILOT FIELD SUMMARY

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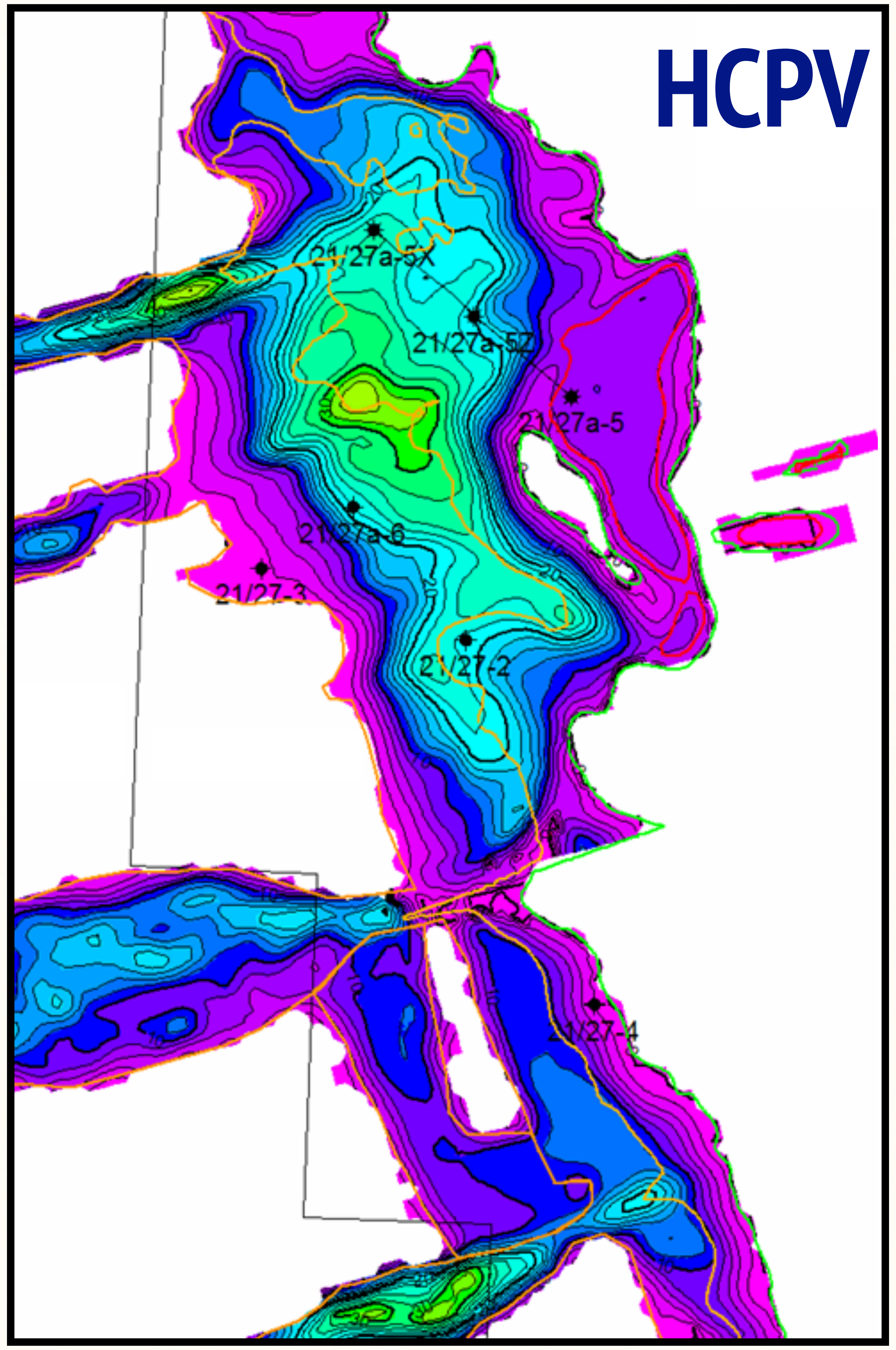
- Very well appraised, detailed and thorough G&G evaluation: full Petrel model available
- Very high quality reservoir, 35% porosity, 2 to 8 darcies of permeability
- Significant proven oil in place, about 263 mmbbls
- Variable quality oil from 12° to 17° API, 160 cp to 1,200 cP



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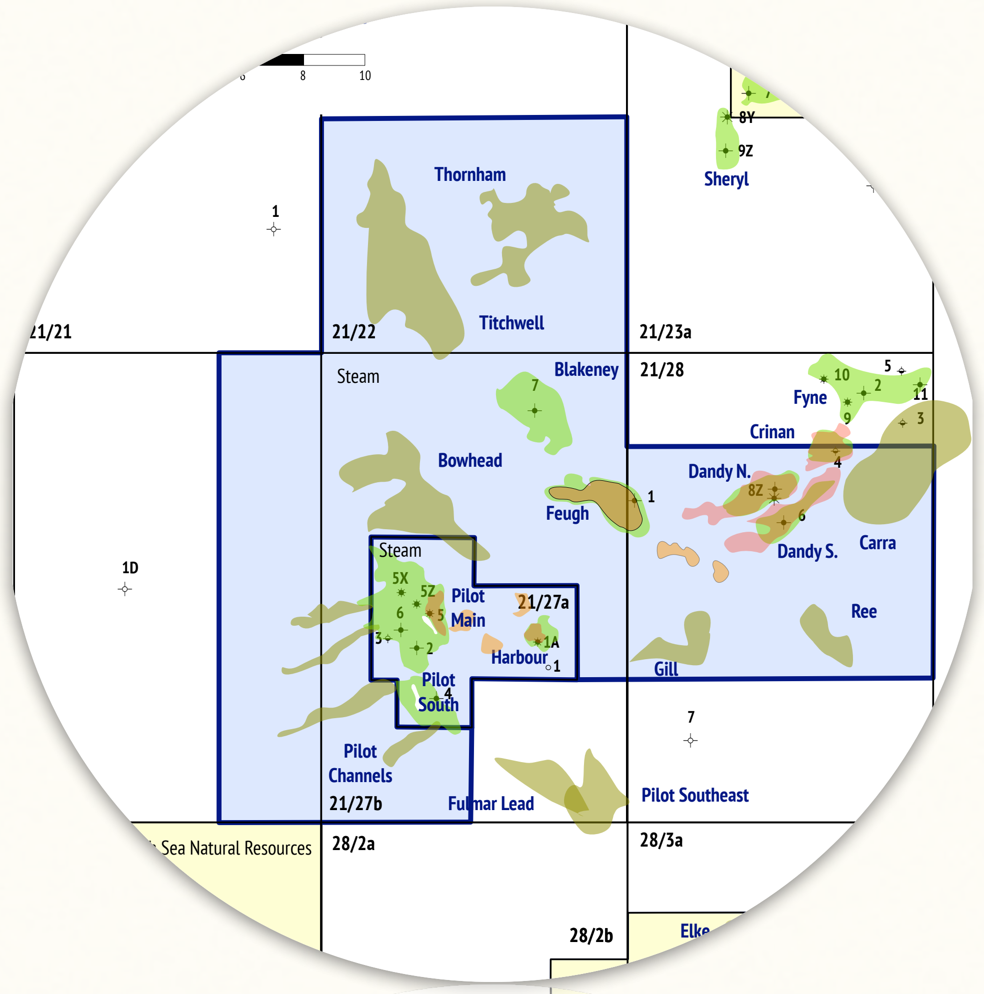

NORTH SEA HEAVY OILFIELDS

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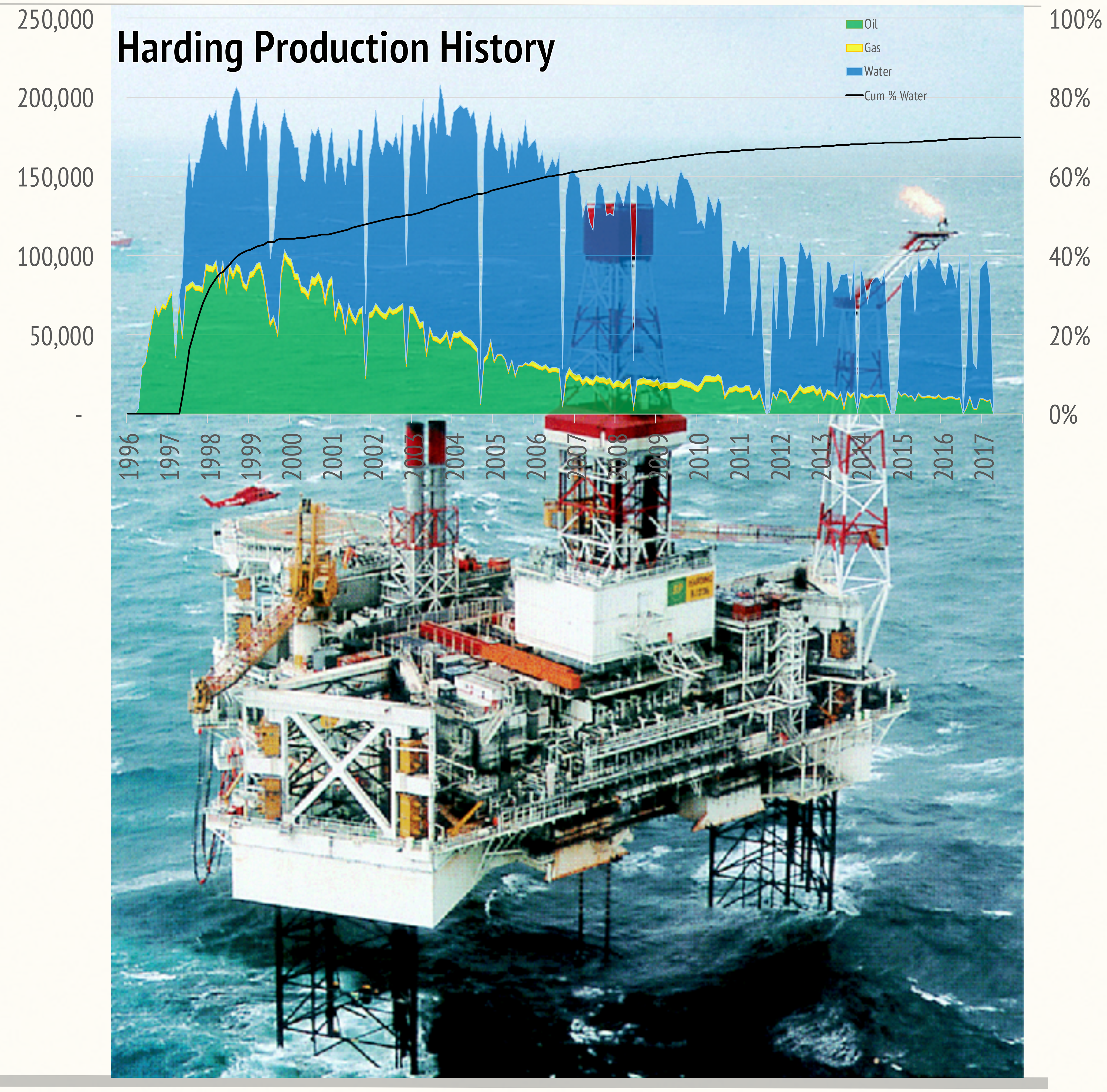
- Two phases, but essentially one approach to heavy oil
  - 1990's: Harding, Alba, Gryphon, Captain
  - 2010's: Mariner, Kraken; (2020's Pilot, Bentley & Bressay)
- Long horizontal producers, high volumes of water injection
  - Recovery factors a function of the pore volumes produced, mobility ratio and well spacing
  - Mariner is being developed with hot water injection (60º to 70ºC)
- Pilot and Blakeney have similar oil qualities to Mariner & Kraken so waterflood will work well



OIL VISCOSITY

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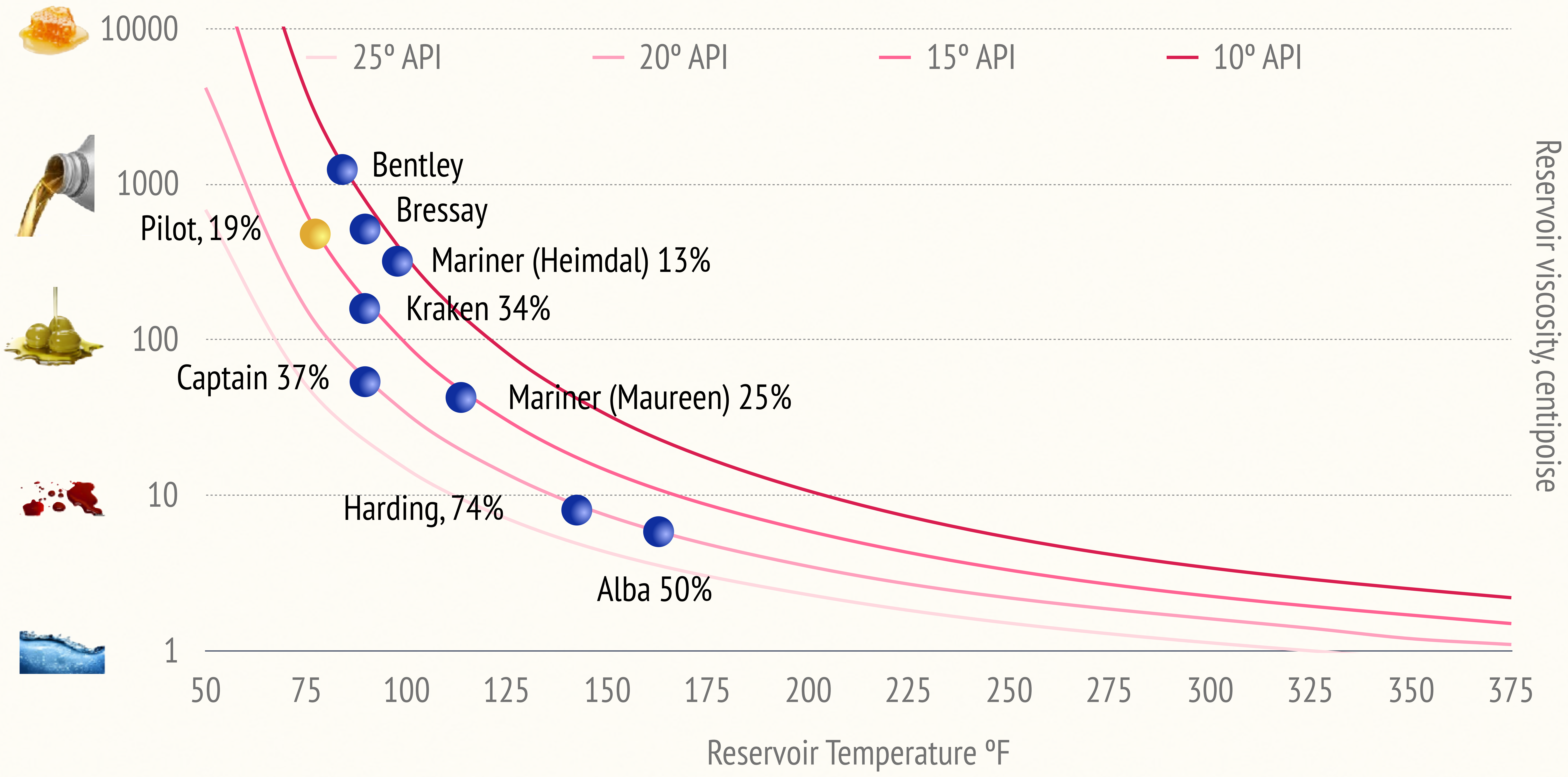

- Viscosity shown as a function of API gravity and temperature
- North Sea fields plotted at reservoir temperature

Viscosity correlation derived from the Excel Macro PVTProps.xla based upon the Petroleum Fluids Pack developed by Hewlett Packard for use in their HP-41 series programmable hand-held calculators. GOR = 100 scf/bbl, Pressure = 1500 psi, bubble point = 1500 psi

OIL VISCOSITY

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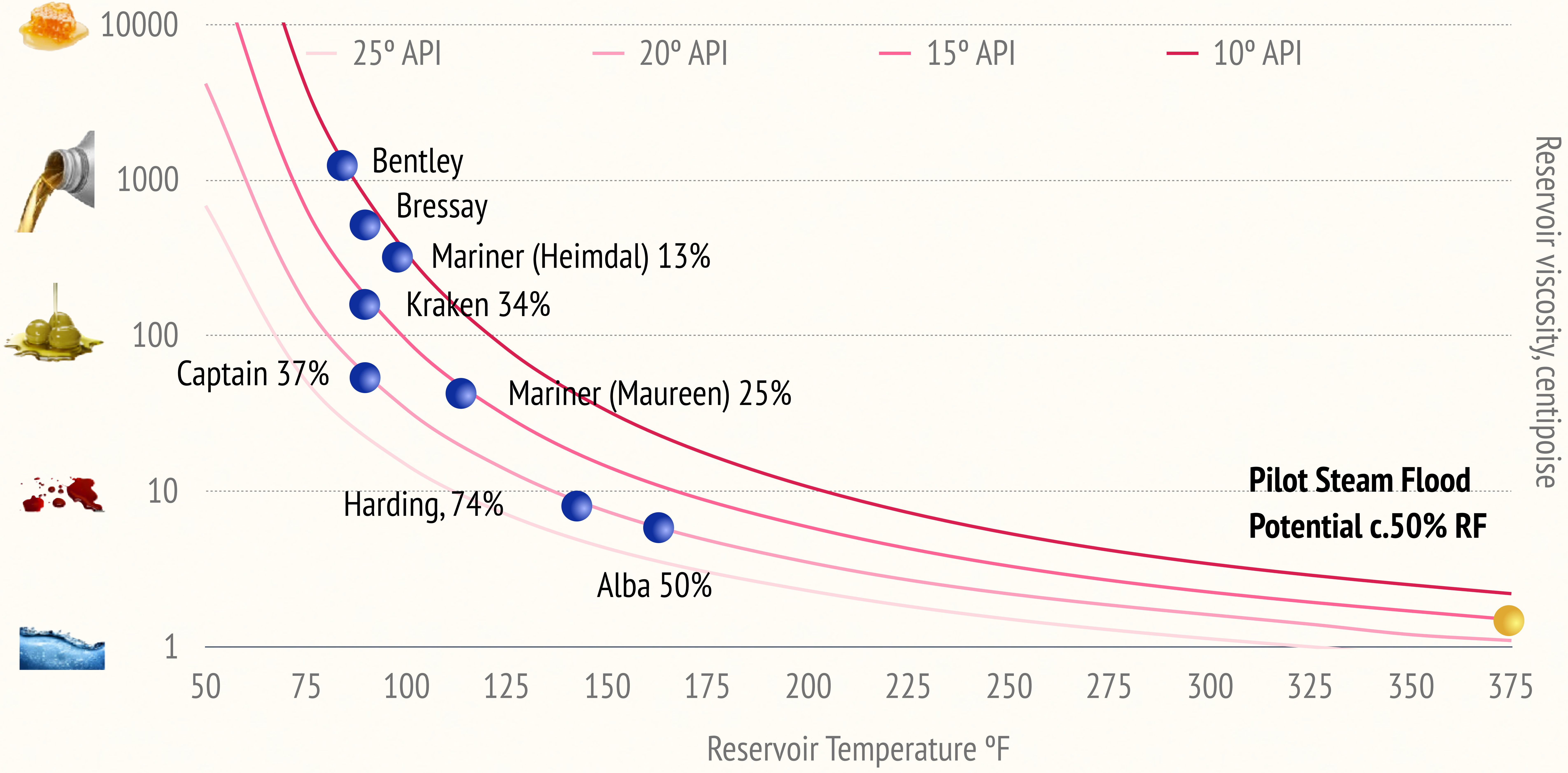

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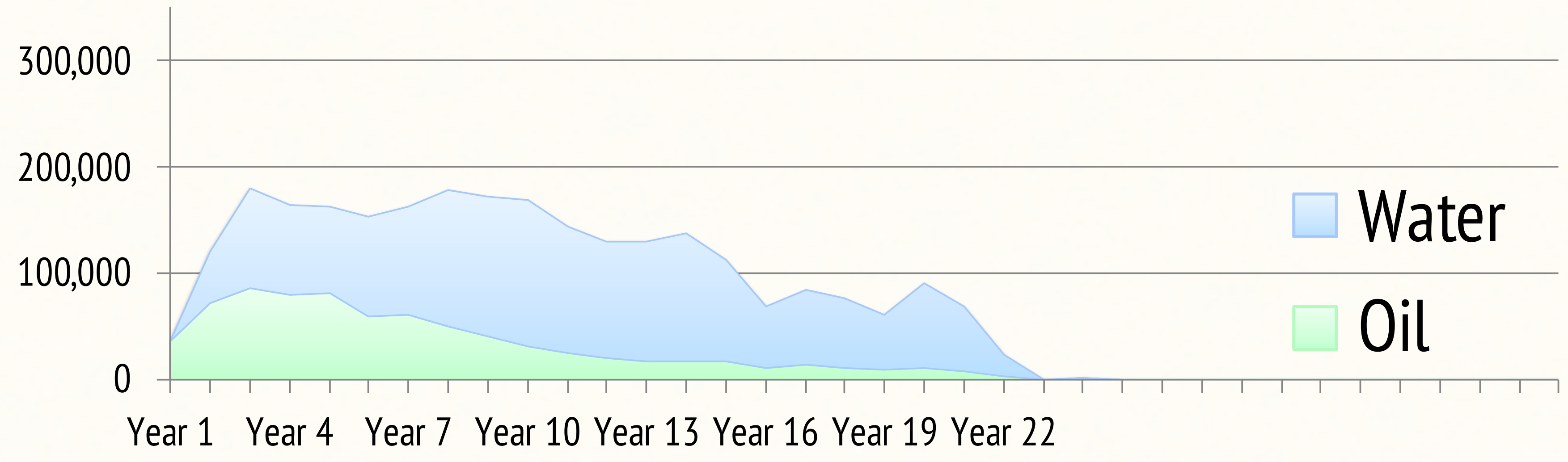
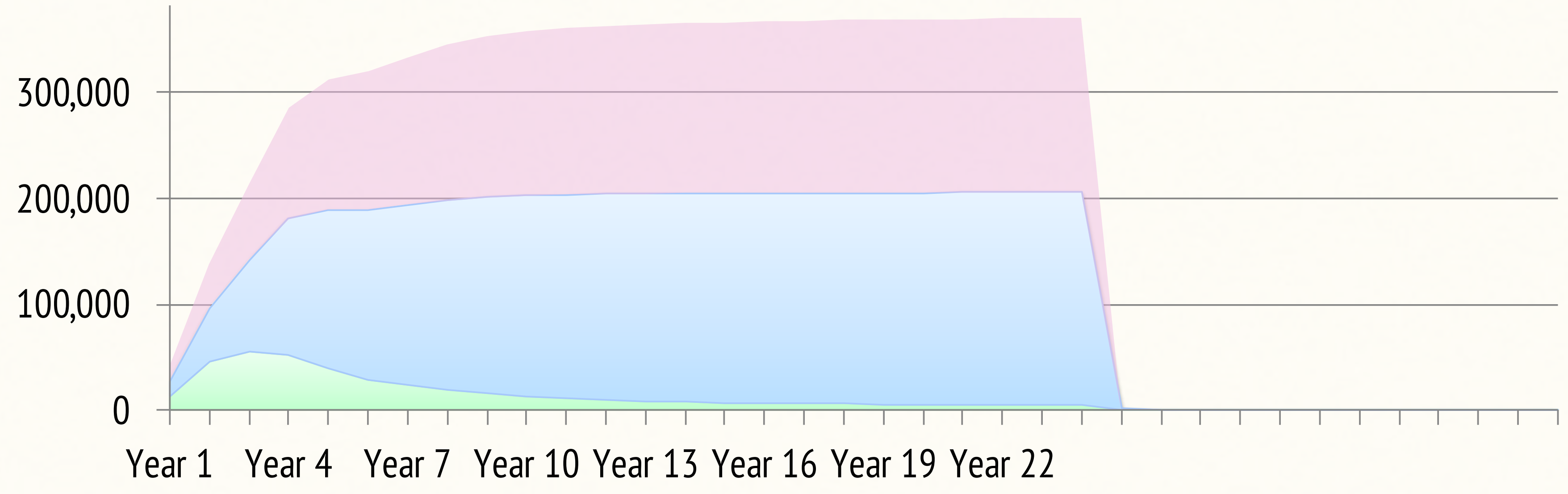
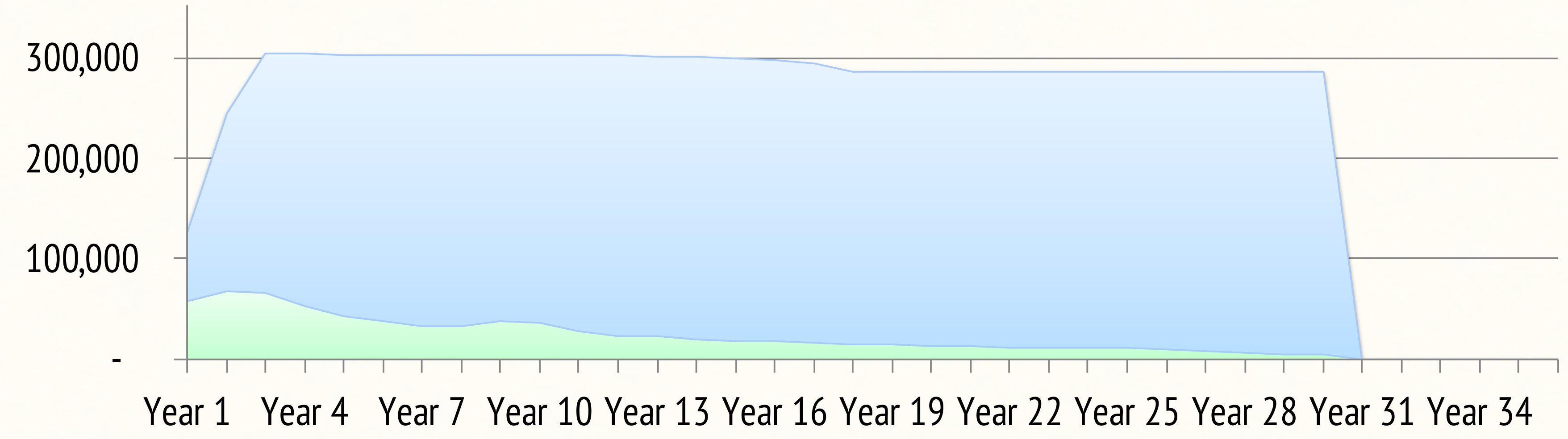
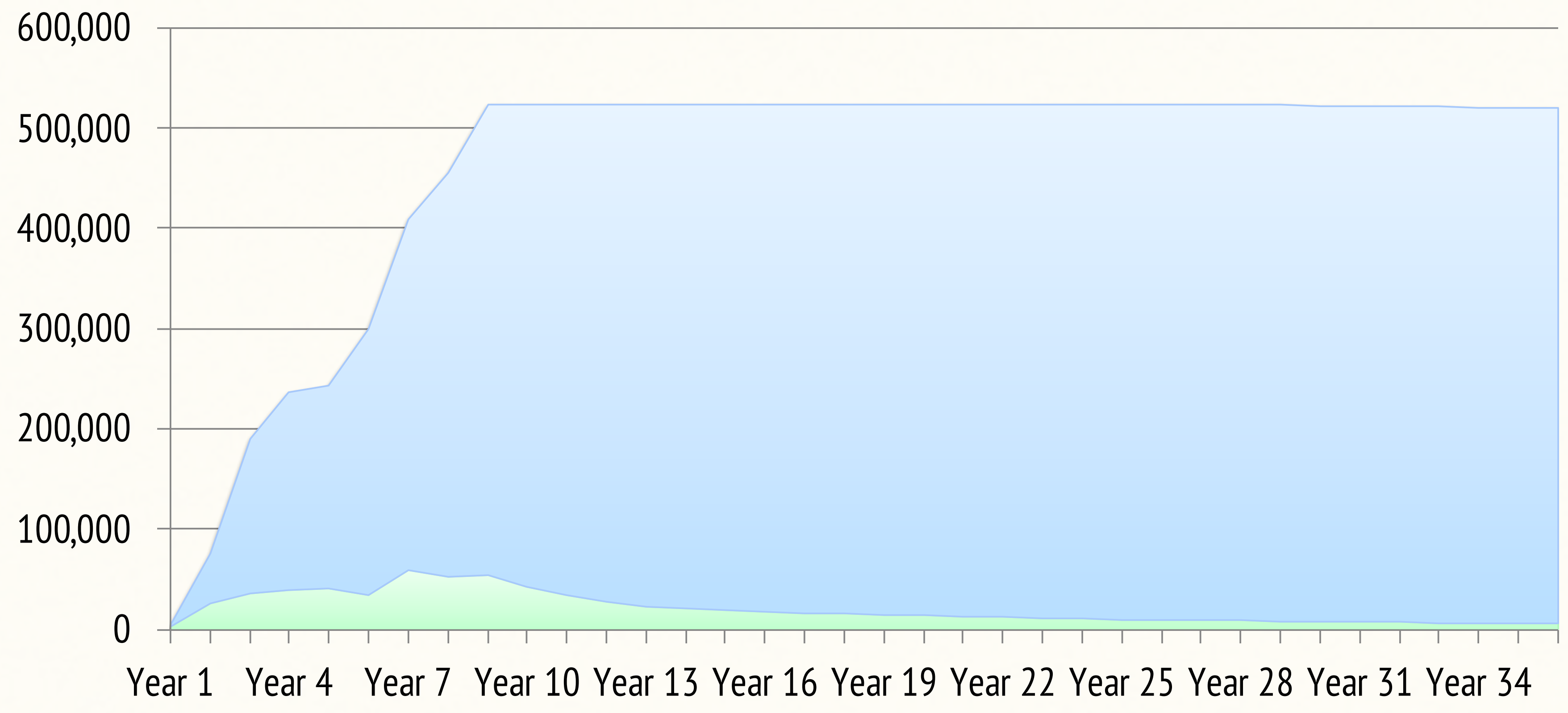








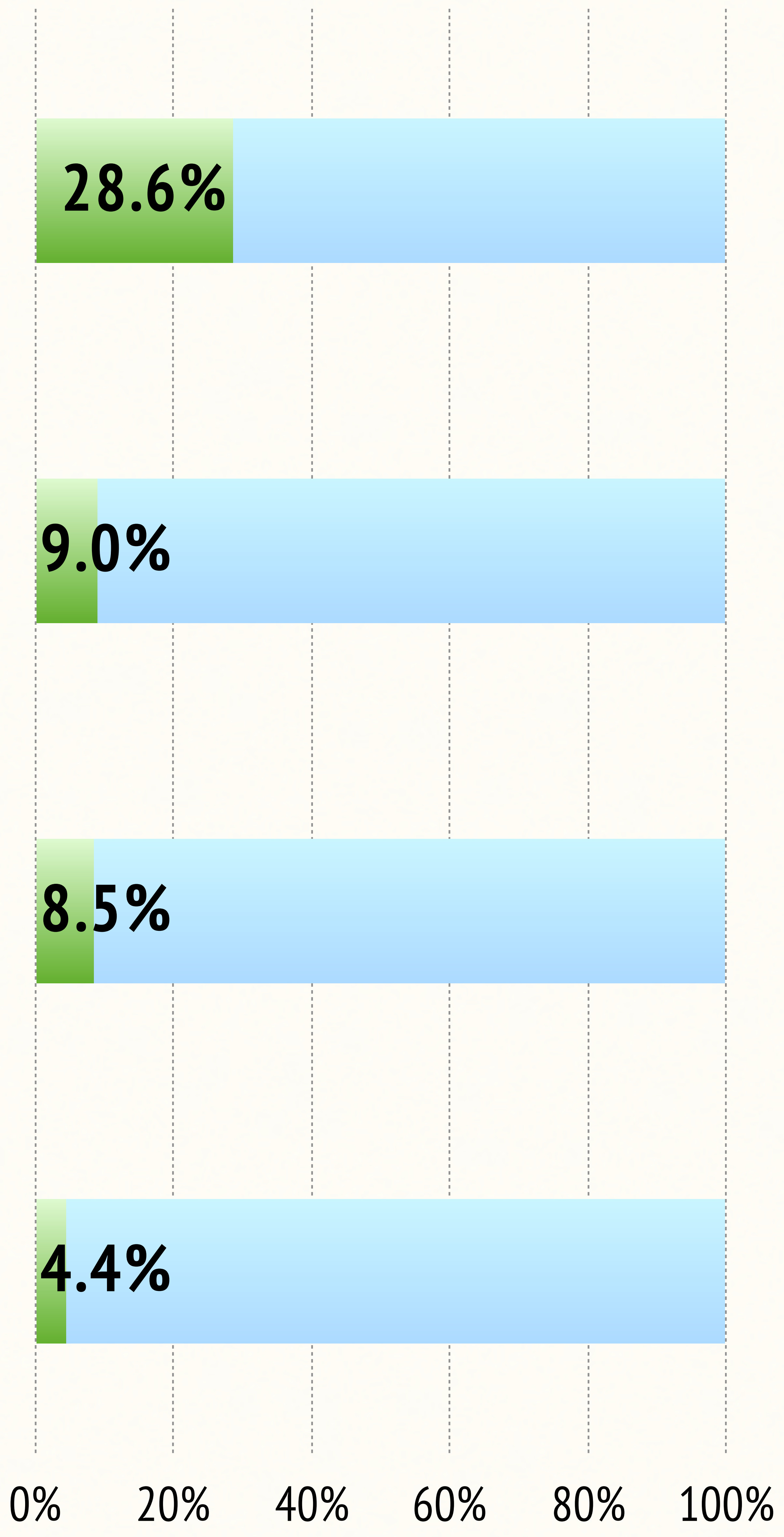
HARDING
19º-21º API, 10 cP
270 mmbbls of oil
657 mmbbls of water

KRAKEN
14ºAPI, 160 cP
147 mmbbls of oil
1,492 mmbbls of water

MARINER
12º-14º API, 60 - 500 cP
251 mmbbls of oil
2,876 mmbbls of water

BENTLEY
10º-12º API, 1500 cP
265 mmbbls of oil
5,778 mmbbls of water

Proportion of oil in produced fluids



Recovery Factors

	Recovery Factors
HARDING	>70%
KRAKEN	35%
MARINER	13-25%
BENTLEY	30%

Kraken profiles EnQuest Capital Markets Day November 2013, capex from 4Q2015 results; Bentley estimates Reserves Assessment Report as at 31/12/14; Mariner estimates, oil production profile from SPE presentation 25/9/13, water profile Environmental statement; Capex 3Q 2015 results

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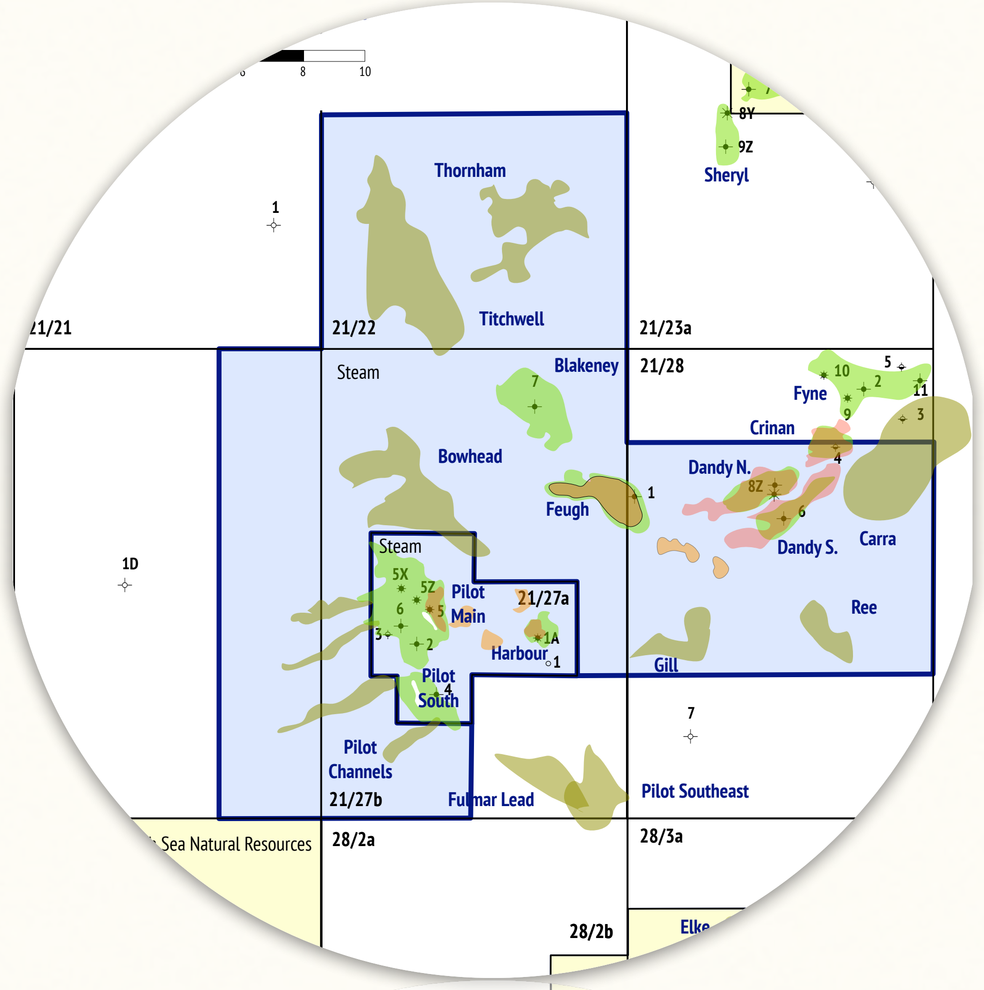
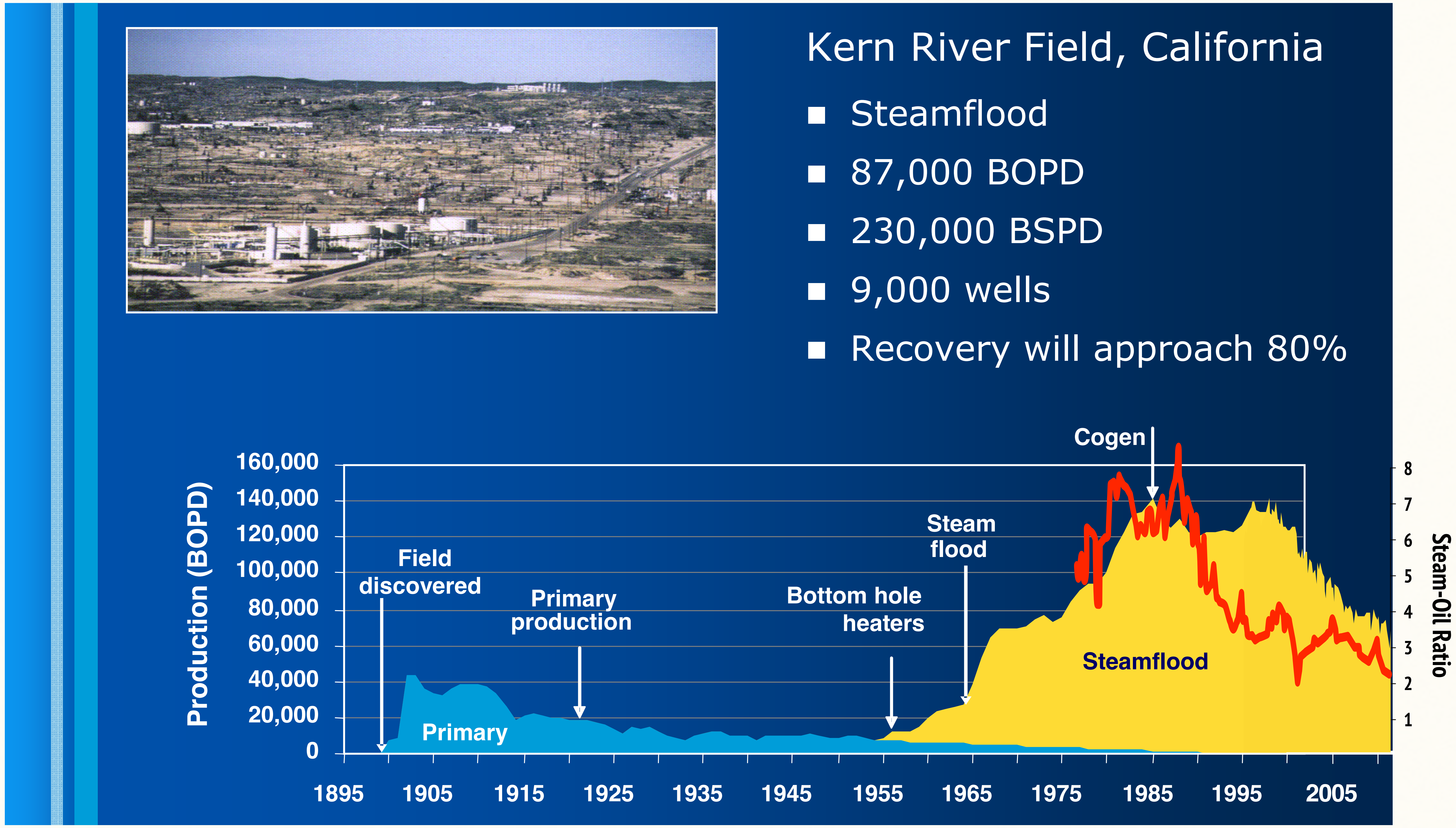
- **The case for Steam Injection, the Offshore, & Pilot**
- Pilot Development scheme





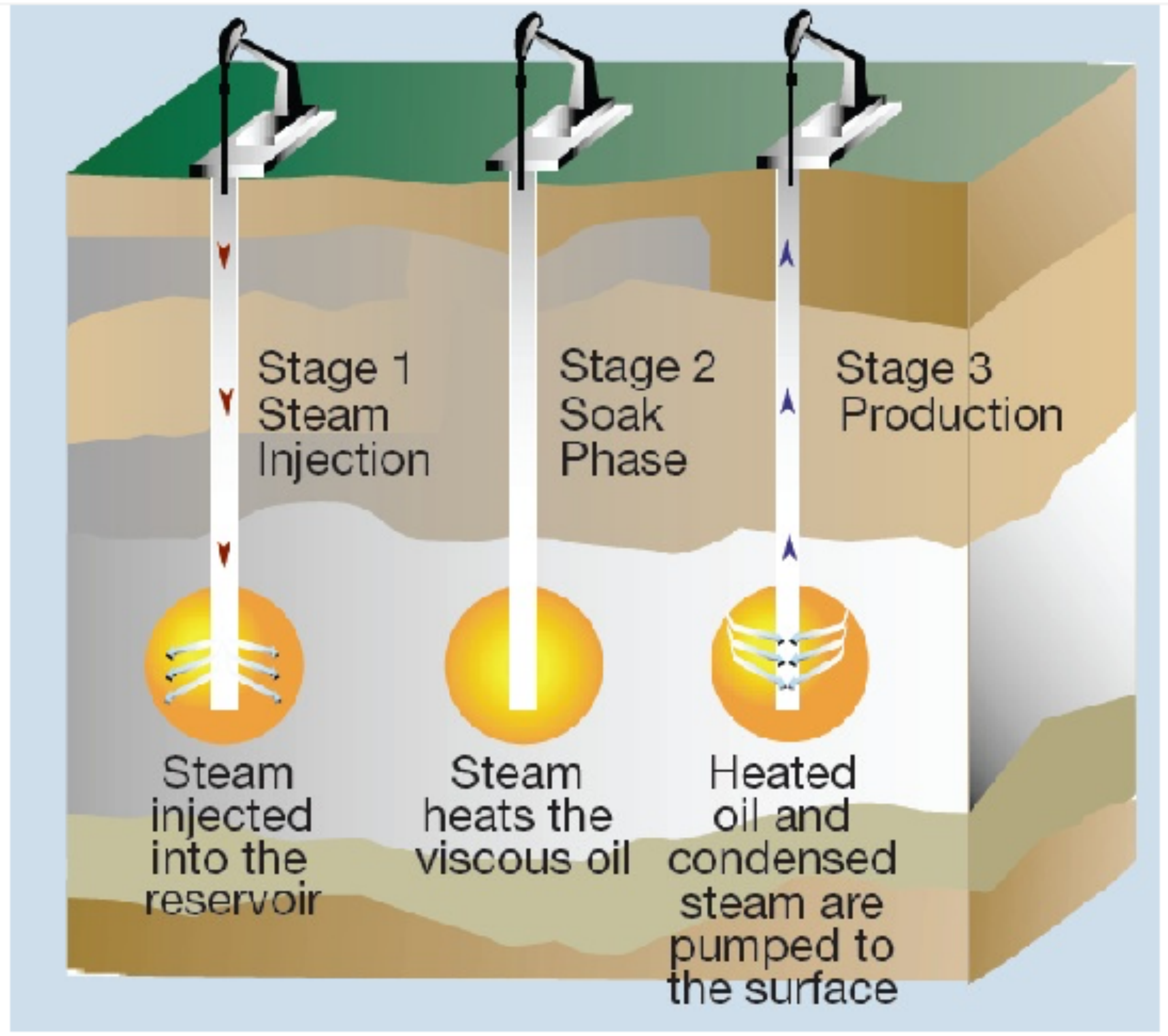
KERN RIVER

Chevron Corporation

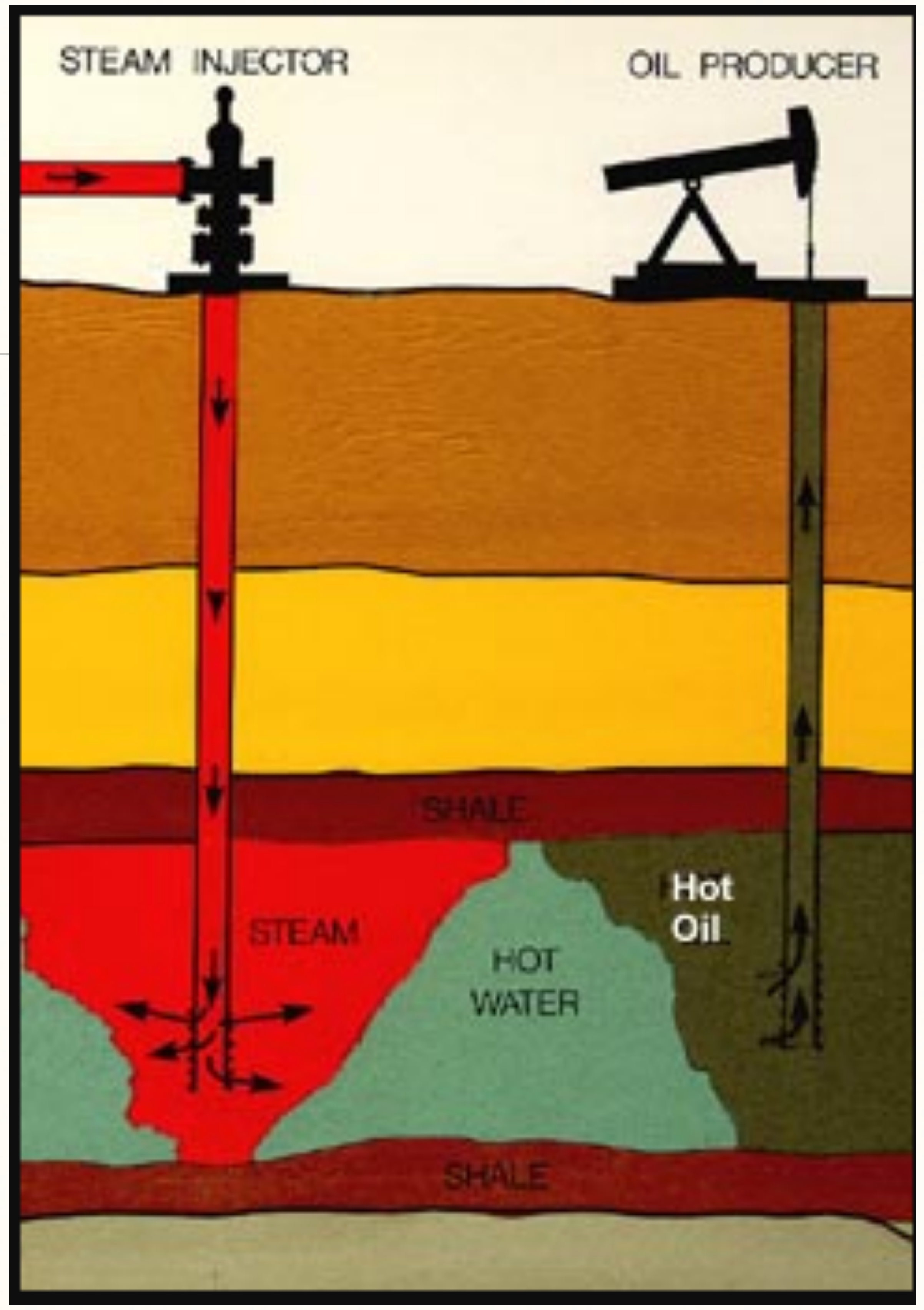
Original Chevron plot extended with production and steam oil ratio data from Chevron paper from June 2011: http://www.greencarcongress.com/2011/06/chevron-20110623.html

HEAVY OIL: THERMAL EOR METHODS

- Hot Water Flooding (HWF)
- Steam Flooding
  - Cyclic Steam Injection or Soak (Huff-and-Puff)
  - Continuous Steam Injection
- Steam Assisted Gravity Drainage (SAGD)
- Electric Beam Heating
- Combustion in Situ (CIS or Fire Flood)



https://oilfieldteam.com/en/a/learning/stages-220118



https://en.wikipedia.org/wiki/Steam_injection_(oil_industry)#/media/File:Steam_eor1.jpg

Alternative to Thermal techniques:

- VAPEX - Solvent based vapour extraction
- Hybrid model: addition of solvent to any steam injection scheme

HEAVY OIL: THERMAL EOR METHODS

PHARIS ENERGY

- Hot Water Flooding (HWF)
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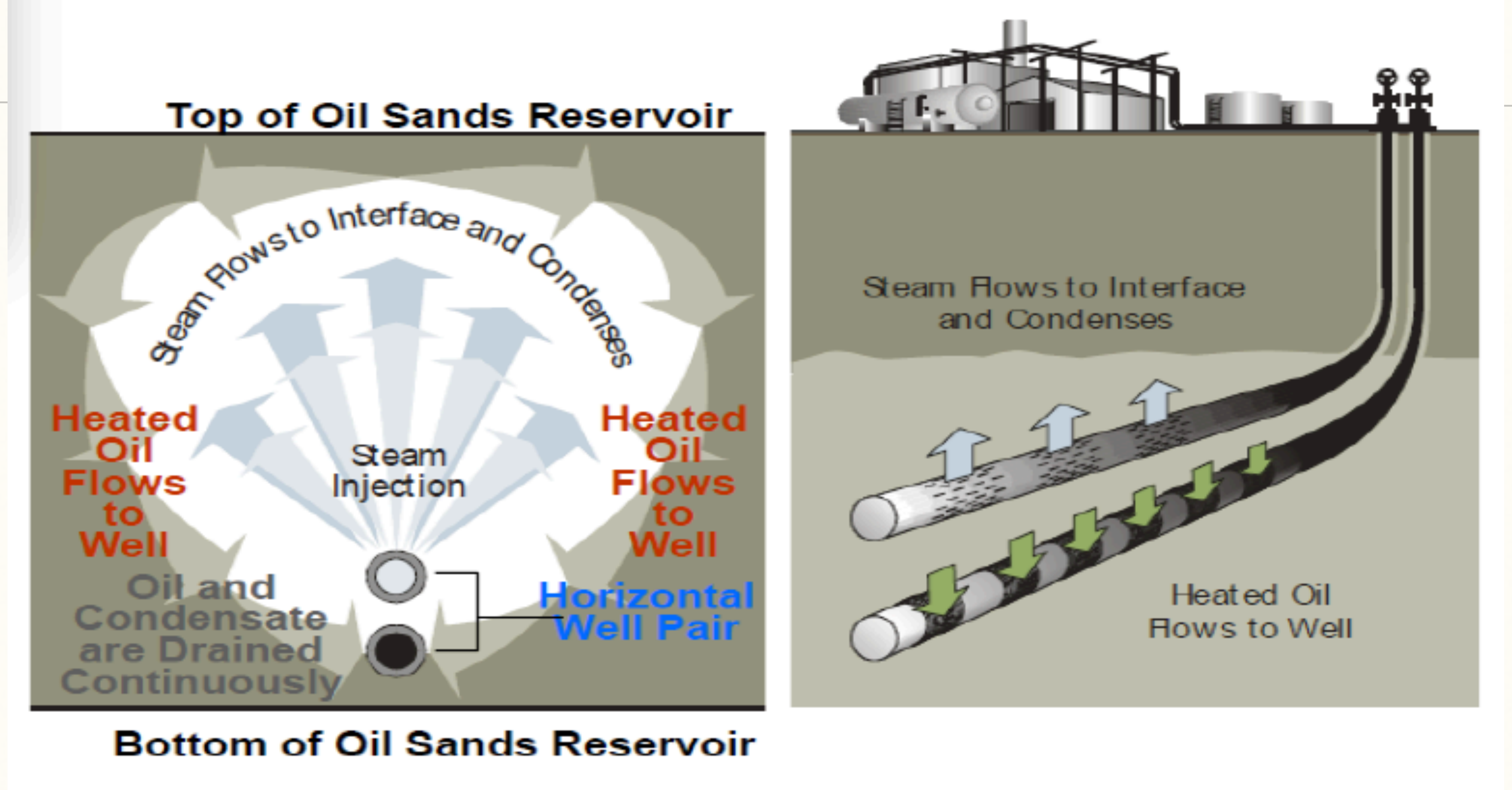
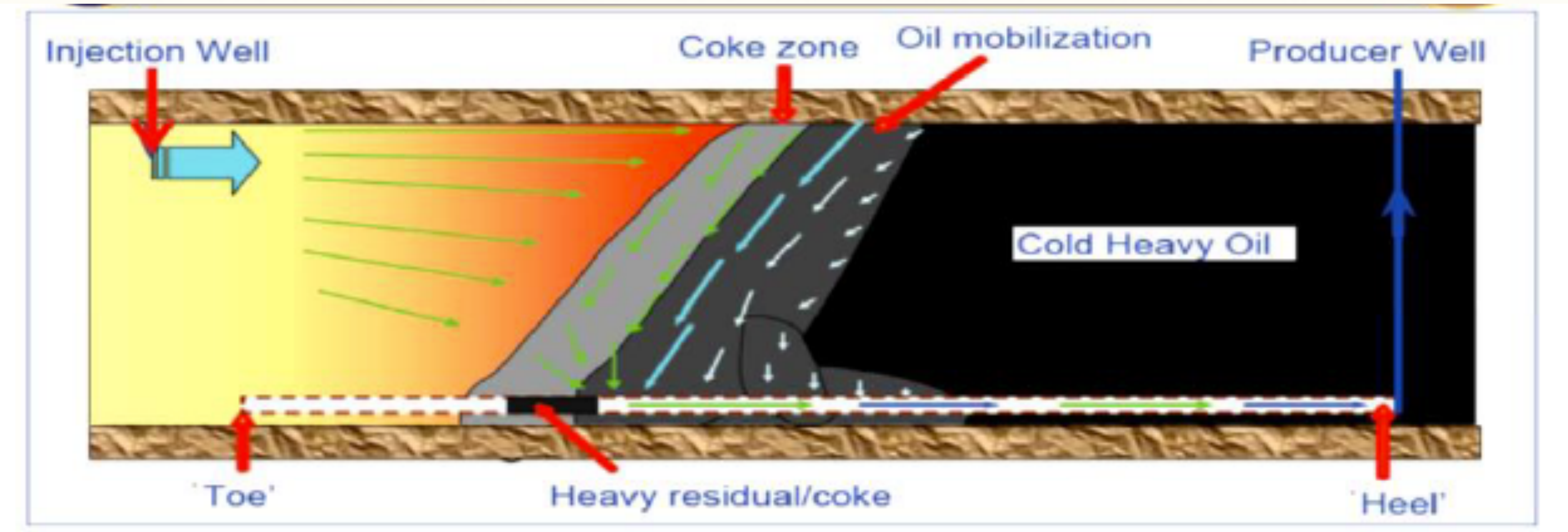
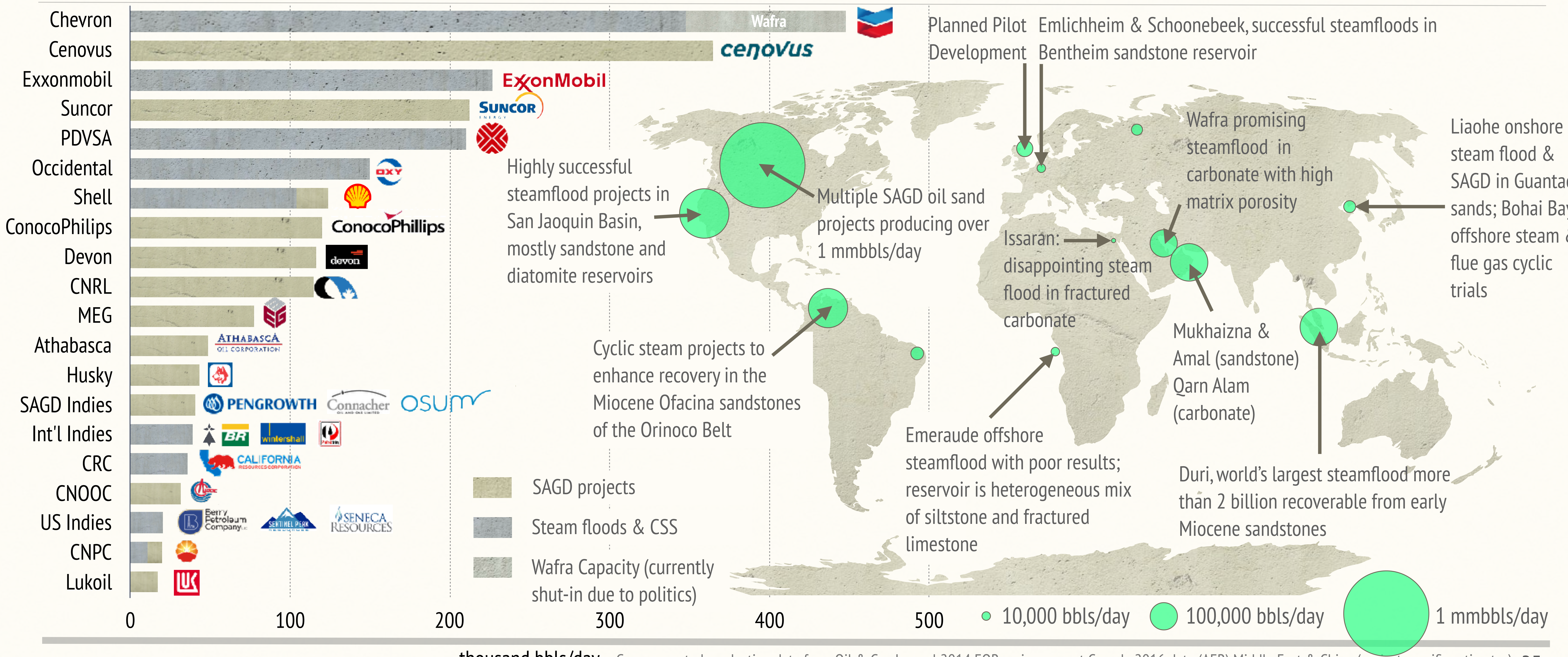




Figures after Canadian Heavy Oil Association. : "Recovery process-Thermal Heavy Oil (Heavy Oil 101)".

STEAM BASED PRODUCTION
c. 2.5MMBBLS PER DAY WORLDWIDE

PHARIS
ENERGY



Gross operated production data from Oil & Gas Journal 2014 EOR review, except Canada 2016 data (AER) Middle East & China (project specific estimates)

WHY STEAM?
AND ITS DEPTH LIMITATIONS

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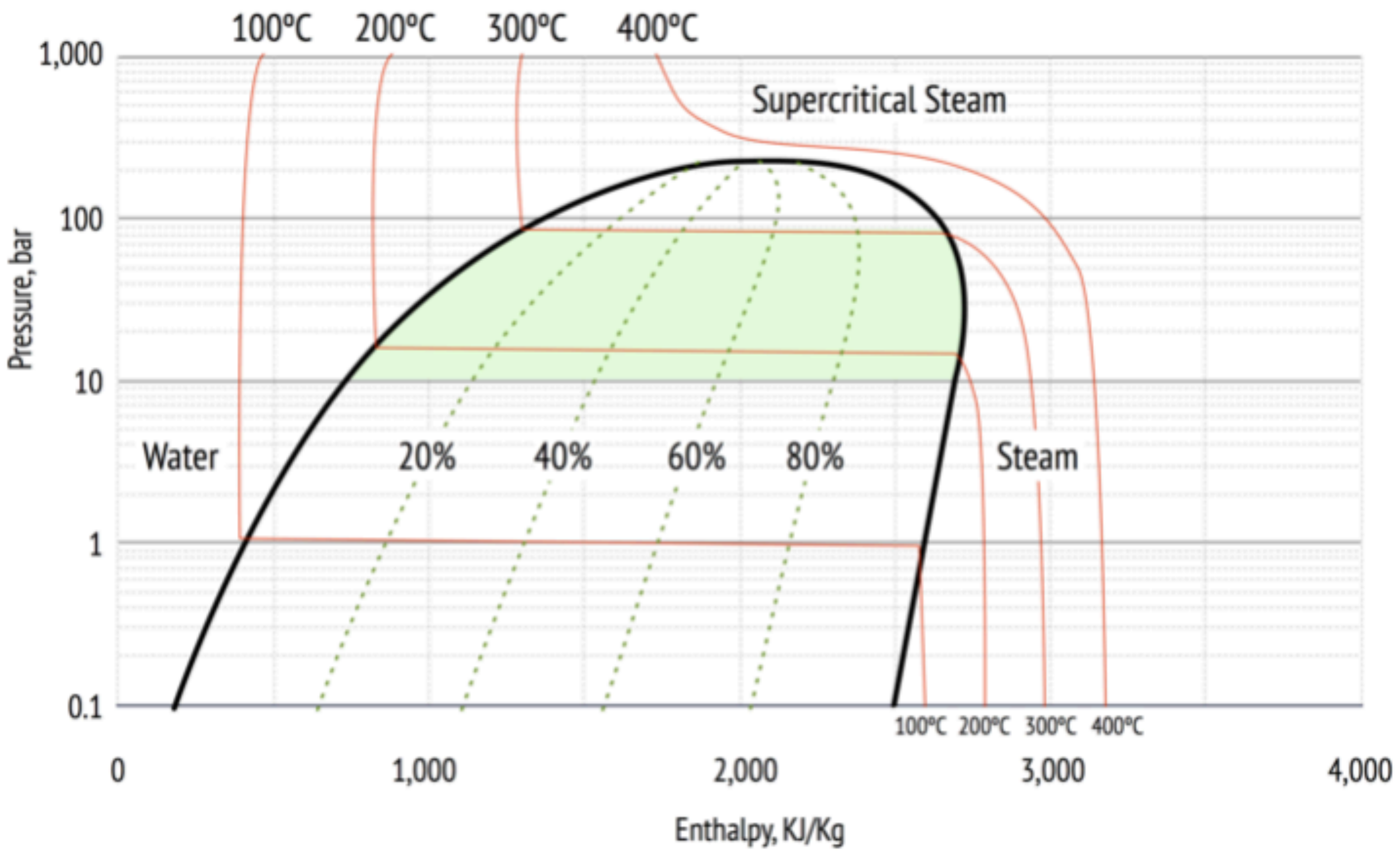
ENERGY



Pressure vs Enthalpy for water, showing phase, steam quality and temperatures as isotherms

- Enthalpy (measure of heat transfer at constant pressure in closed system) - at low pressures it requires an large amount of energy to turn water to steam
- At higher pressures the enthalpy of condensation reduces, until at 200 bar there is no difference between steam and water
- Conventional limit of steam flood is ca. 3,000 ft (top green zone) - steam is at ca 300deg C (600 deg F) - few components rated above this
- Wellbore heat loss also increases with distance from heat source

WHY CAN'T STEAM INJECTION GO OFFSHORE ?!
WELLBORE HEAT LOSS

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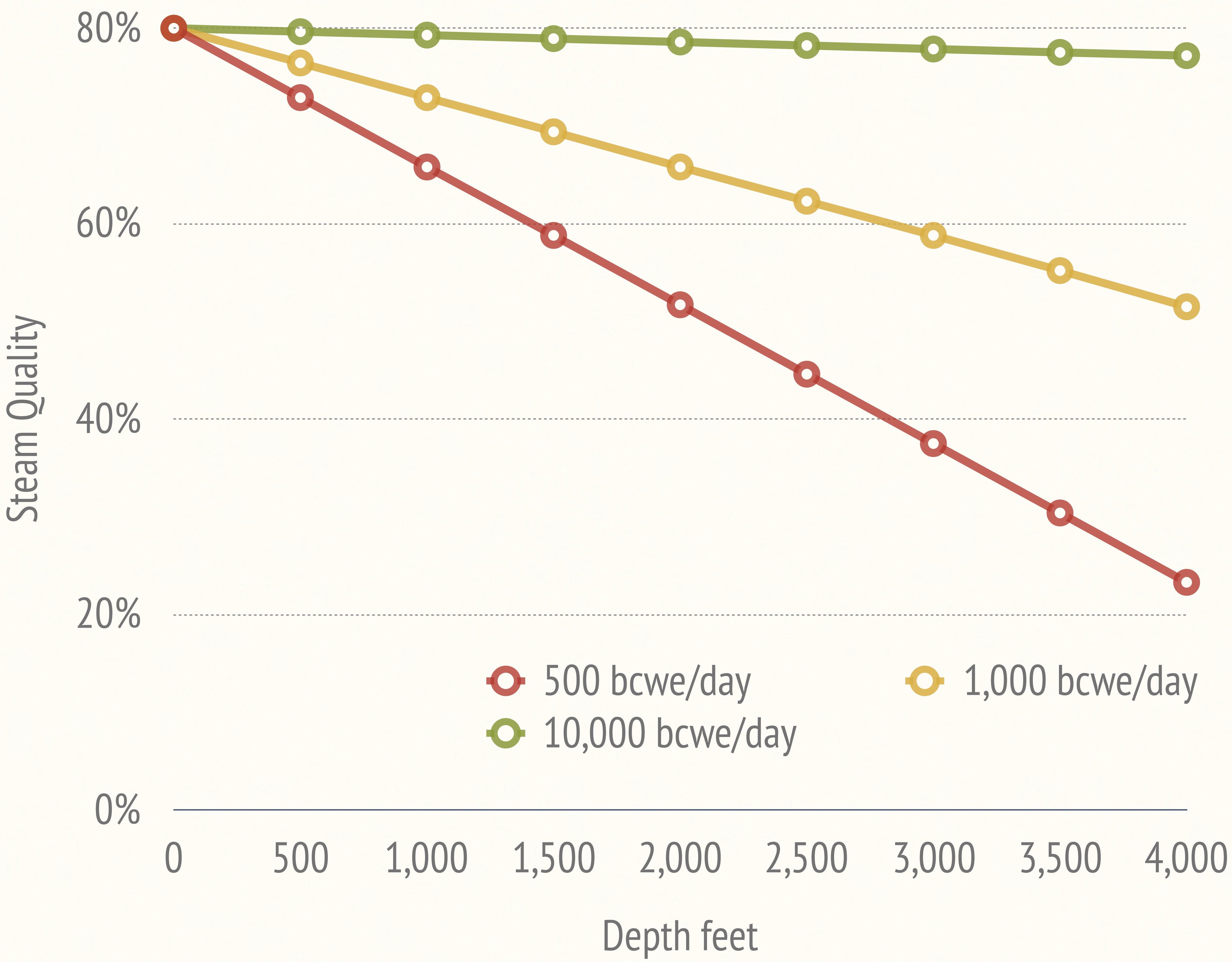
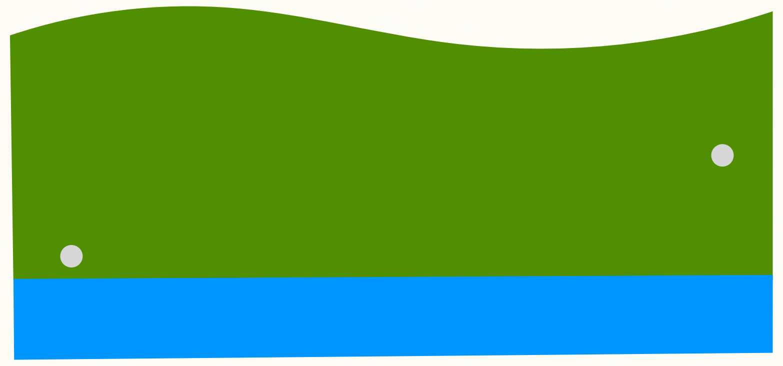


- Initial steam quality of 80%
- At 500 bcwe/day steam quality is reduced to 23.3% at 4,000'
- At 1,000 bcwe/day steam quality is reduced to 51.5% at 4,000'
- Steam condensed is 285 bcwe/day in each case
- So, at 10,000 bcwe/day steam quality would reduce by about 3%

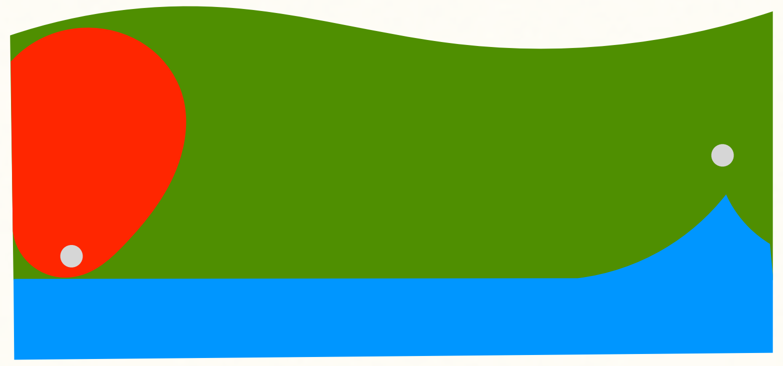
cwe = Cold water equivalent. Data for 500, and 1,000 bcwe/day cases, New Advances and a Historical Review of Insulated Steam Injection Tubing - SPE-113981, 500' and 4,000' data points calculated by extrapolation

RECOVERY MECHANISM: GASD
GRAVITY ASSISTED STEAM DRIVE

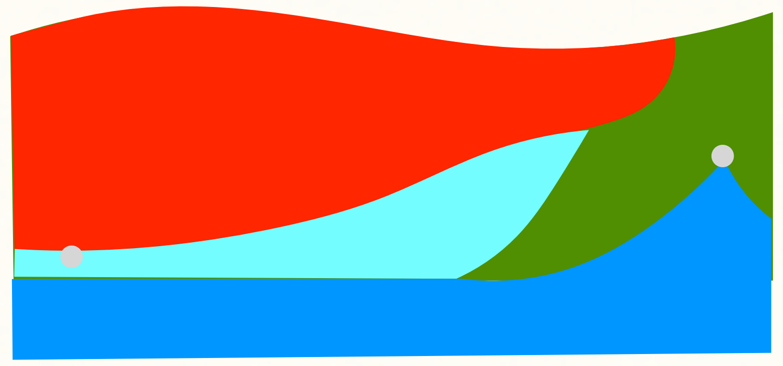
PHARIS ENERGY



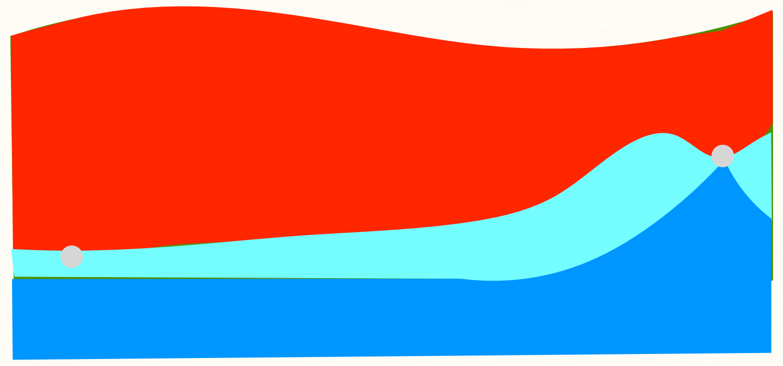
Cross-section view at initial conditions, injection well low in section, production well mid way in oil leg



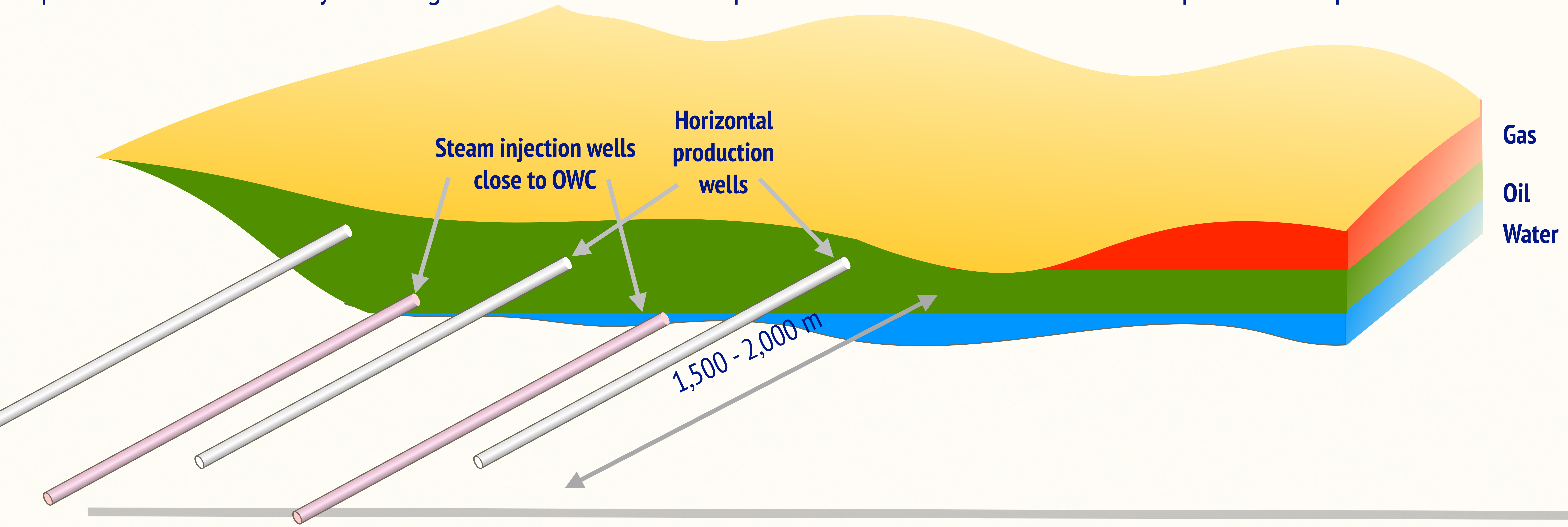
Steam chamber forms above injector and water cone forms below production well



Steam chamber sweeps top of reservoir and bank of condensed water sweeps the lower part of the reservoir



As steam breaks through the affected section of the production well is closed in to force steam to sweep the whole length of the well



SIMULATION SHOWING THE FRACTION OF WATER THAT IS IN THE FORM OF STEAM

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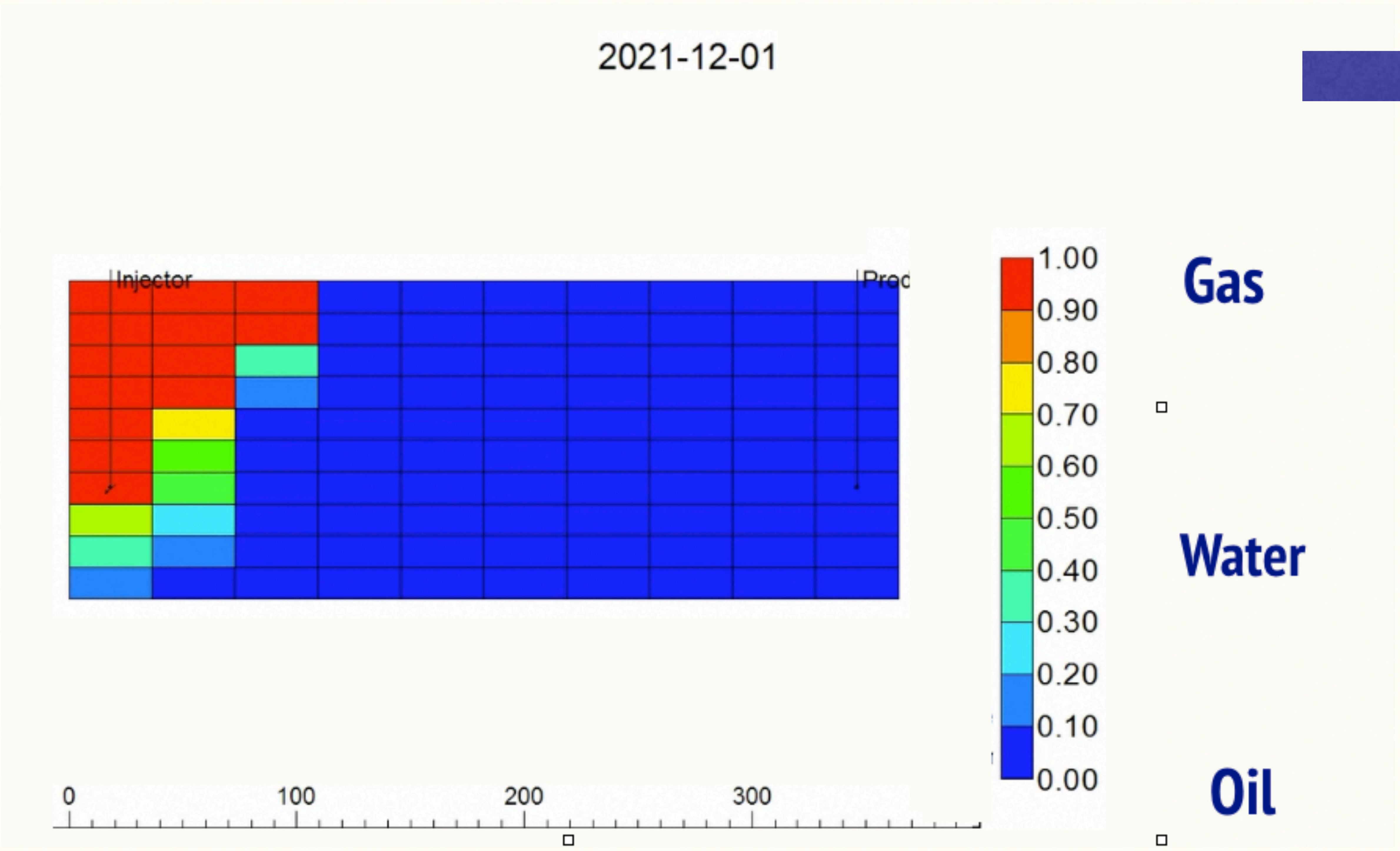
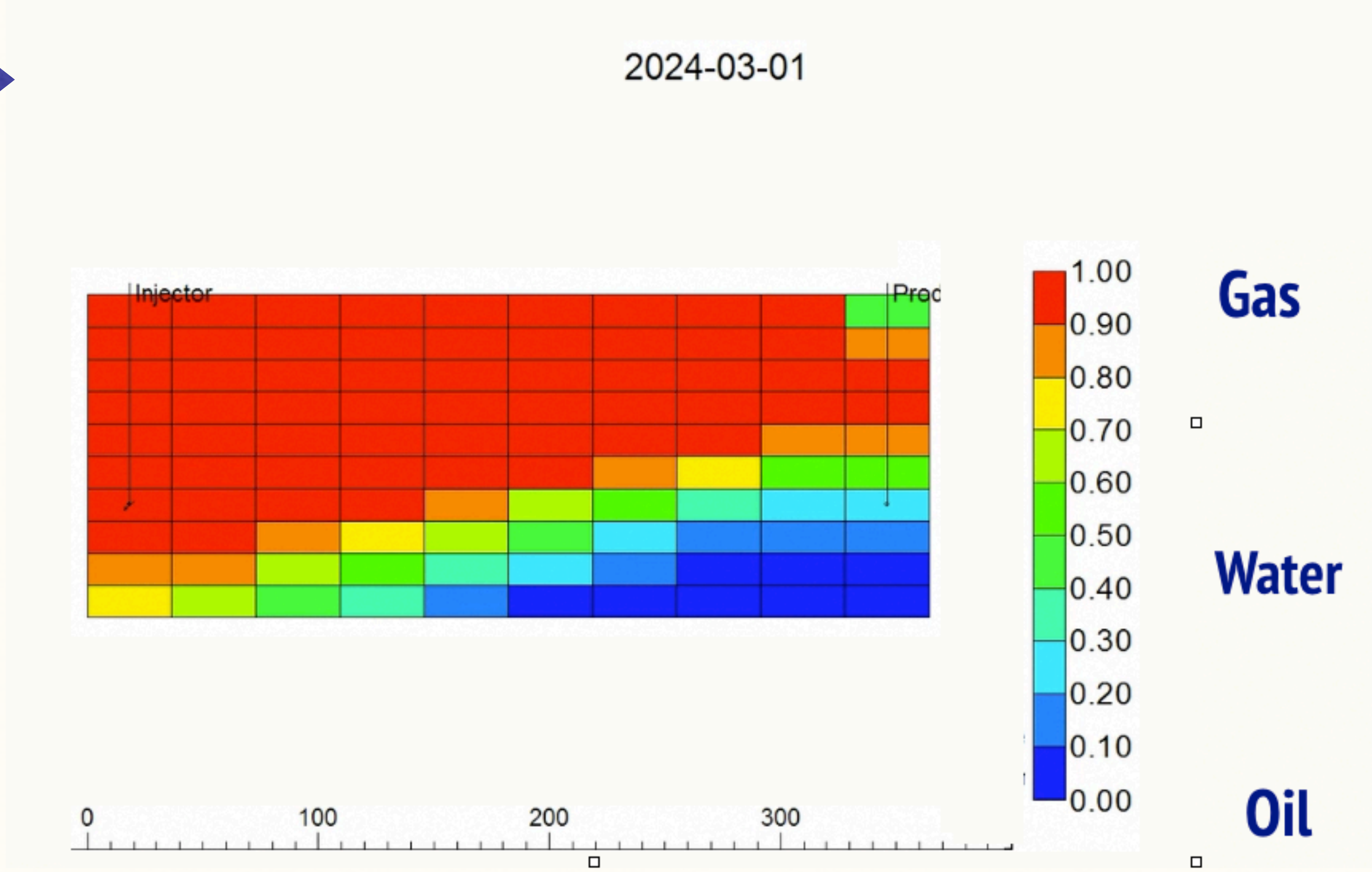
ENERGY





GASD vs SAGD
STEAM ASSISTED GRAVITY DRAINAGE

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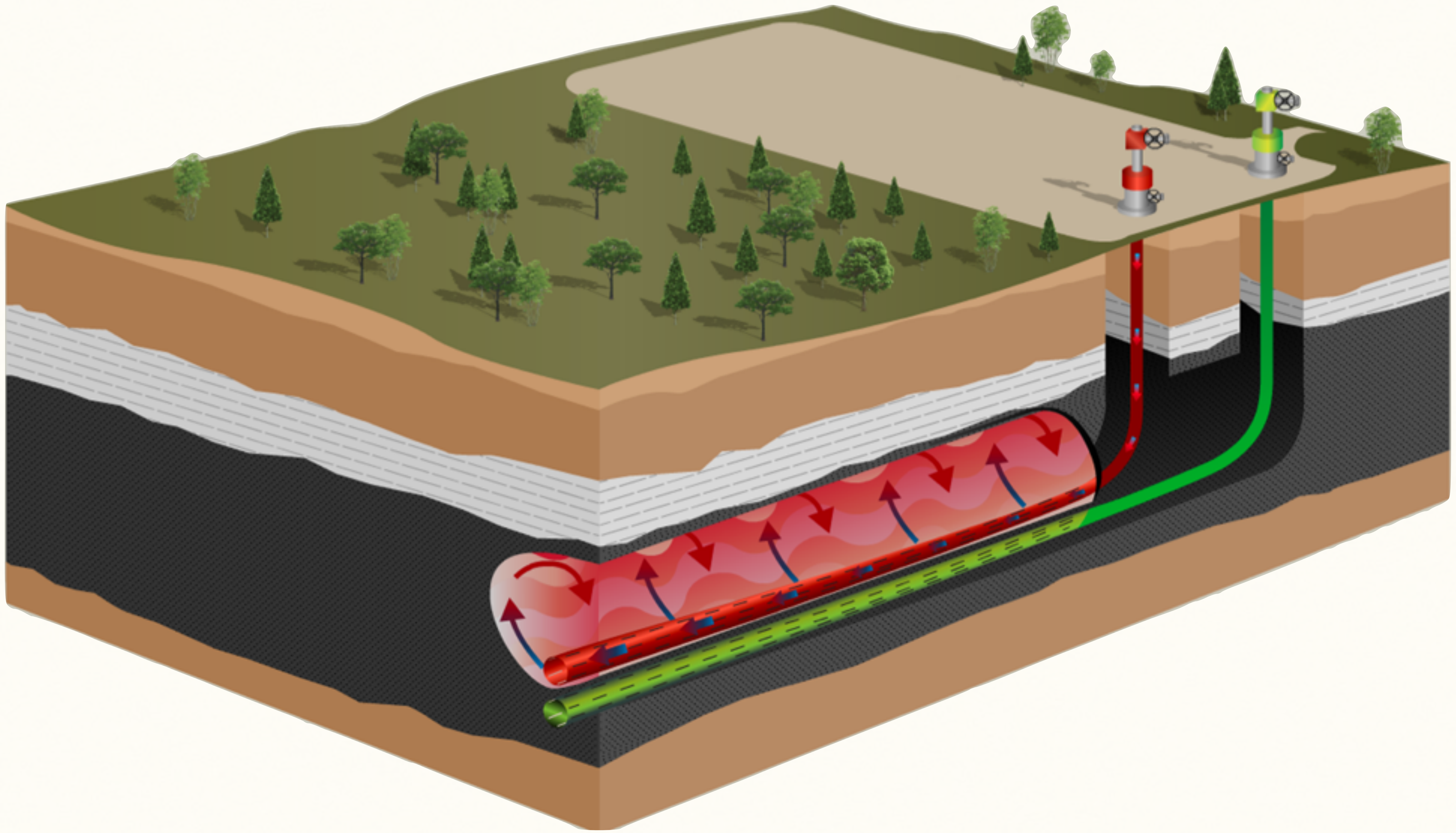
- GASD needs oil that flows cold, whereas SAGD works for 1,000,000 cP oil
- Well positioning is different but both techniques create a steam chamber and either rely on gravity or are helped by gravity to drain oil into the producer
- SAGD works very well in high quality sandstones (no matter how viscous the oil) and delivers very high recovery factors >70%



SAGD: A 21ST CENTURY PRODUCTION TECHNOLOGY

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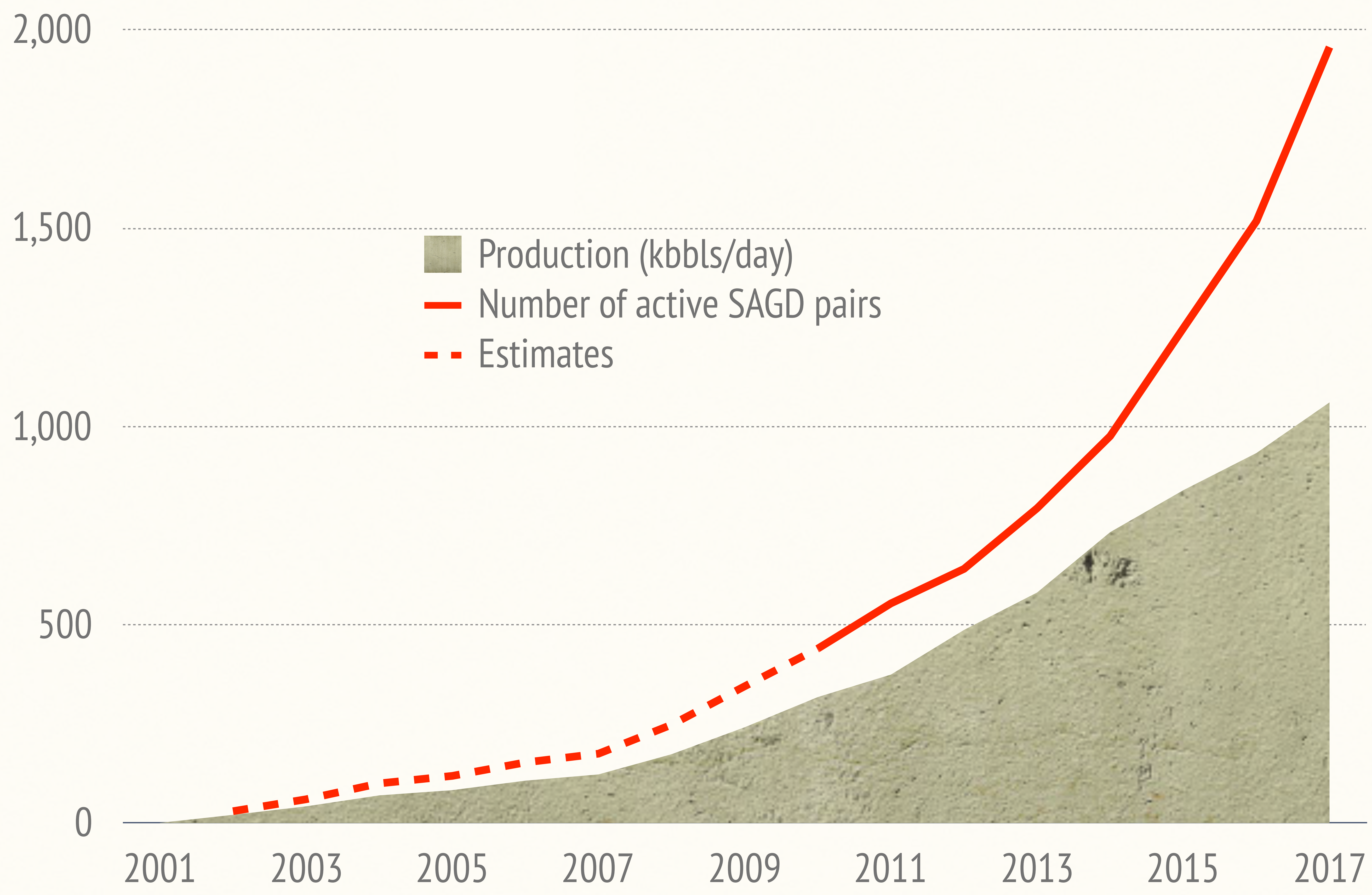

- SAGD production in Alberta from 2001
- Experimental work started in 1984 at AOSTRA, Cenovus' Foster Creek became the first commercial SAGD project in 2001
- Now producing over a million bbls/day
- Over 1,900 SAGD well pairs drilled
- Horizontal well lengths now extended to over 1600m*

Alberta Energy Regulator - Report ST98 https://www.aer.ca/data-and-publications/statistical-reports/st98 and archives. *https://www.cenovus.com/news/our-stories/cenovus-reaches-new-SAGD-drilling-measured-depth-record.html

WHY WE LIKE STEAM FLOOD

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- Very high recovery factor potential (50%-80%)
- Dramatic increase in plateau production rates compared to primary production (c. 3 times)
- Shorter field lives significantly reduce non-fuel opex
- Very well proven onshore especially in high permeability sandstones – California, Indonesia, Oman etc.
- Undepleted reservoirs which can flow cold (just like Pilot) are the very best targets

Mechanism	Heavy Oil Recovery
Primary	5 - 15%
Steam Flood	50 - 80%

Typical oil saturated core in Duri Field, Indonesia

COMPARING WATER & STEAM

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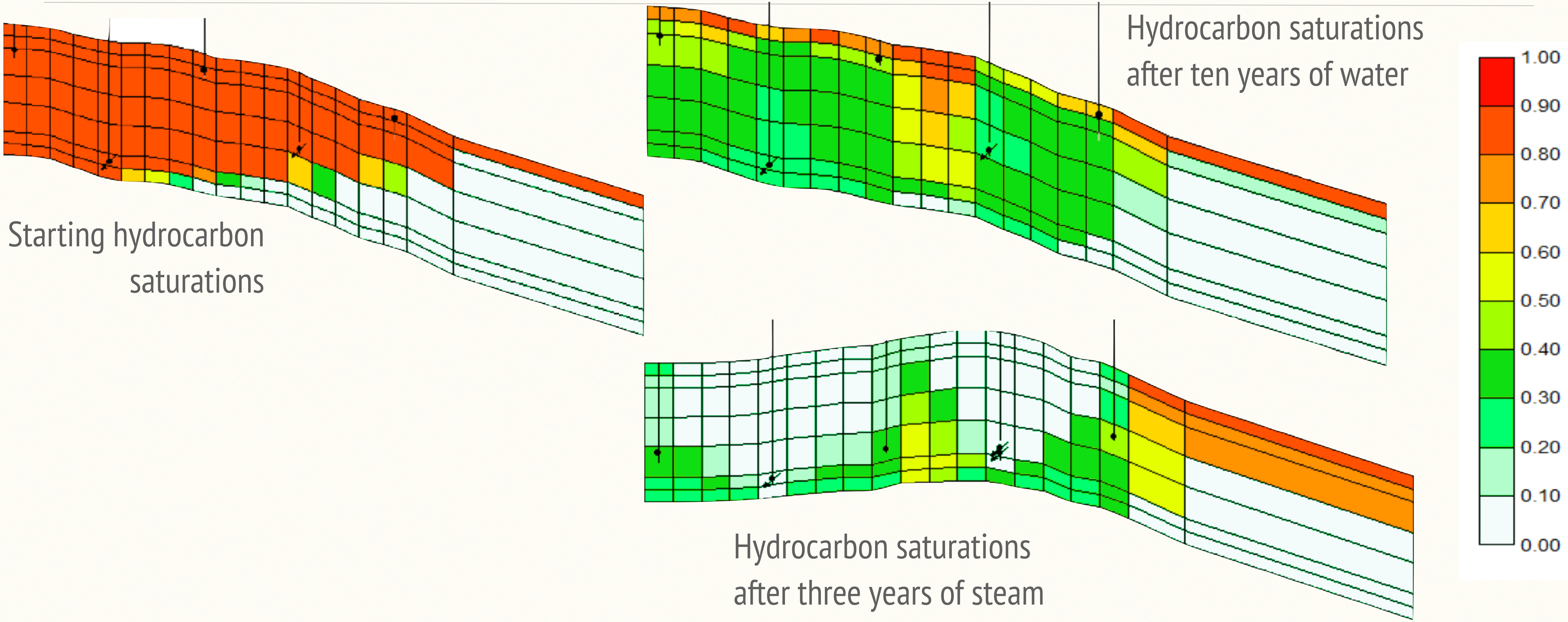

SAGD PROJECT STEAM OIL RATIOS

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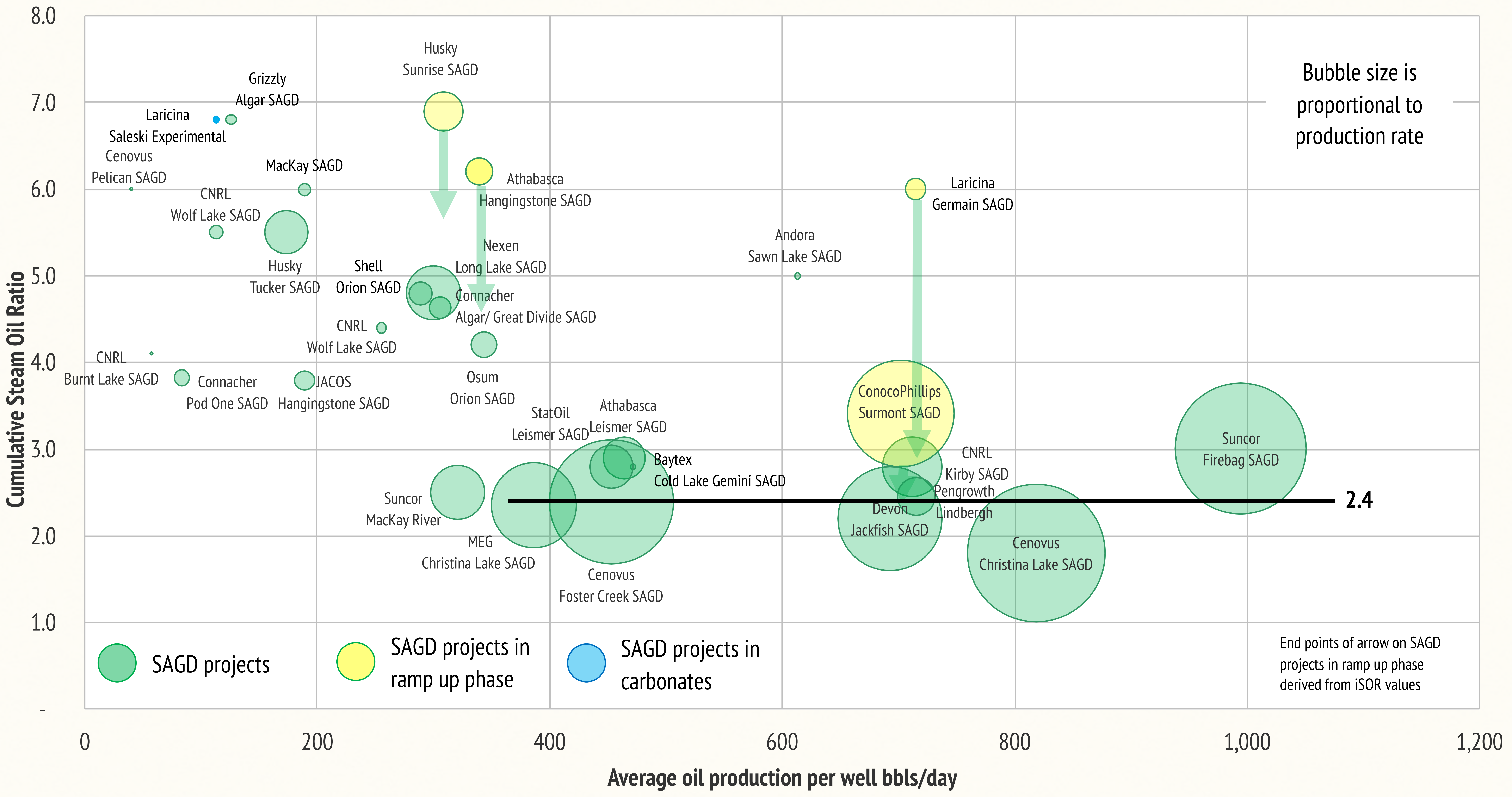

- Data extracted in 2017 from most recent in-situ performance presentations to the Alberta Energy Regulator
- Over 1.3 mmbbls/day of heavy oil production
- Setting aside projects ramping up the average cSOR for projects with well rates > 350 bopd is 2.4
- Best performance is Cenovus' Christina Lake with an SOR of 1.8

CHRISTINA LAKE: STEAM INJECTOR COMPLETIONS

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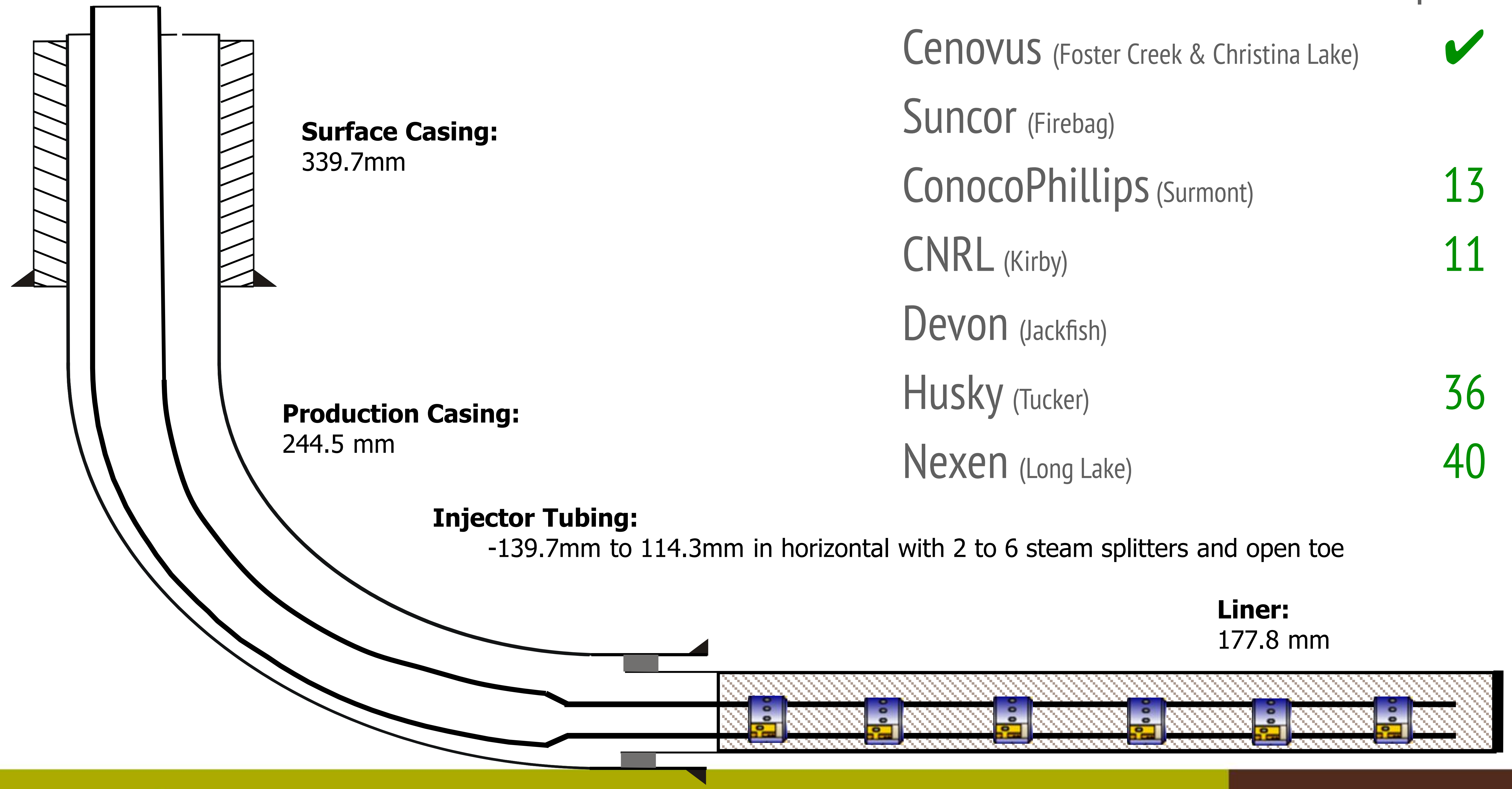
Sample injector completion



	Splitters	Long/Short
Cenovus (Foster Creek & Christina Lake)	✔	
Suncor (Firebag)		✔
ConocoPhillips (Surmont)	13	158
CNRL (Kirby)	11	42
Devon (Jackfish)		✔
Husky (Tucker)	36	73
Nexen (Long Lake)	40	65

cenovus ENERGY

June 6, 2017
37

- Cenovus one of the few operators to use steam splitters widely
- Other operators mostly use a long string/short string approach
- Highly likely to improve conformance in the injection wells and hence SOR

HANDLING STEAM BREAK-THROUGH: INFLOW CONTROL VALVES

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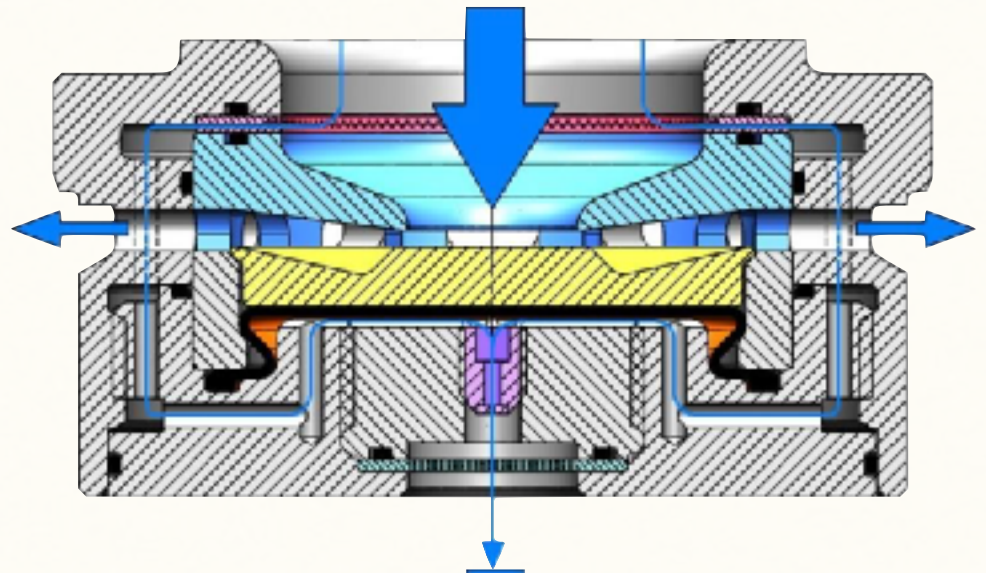
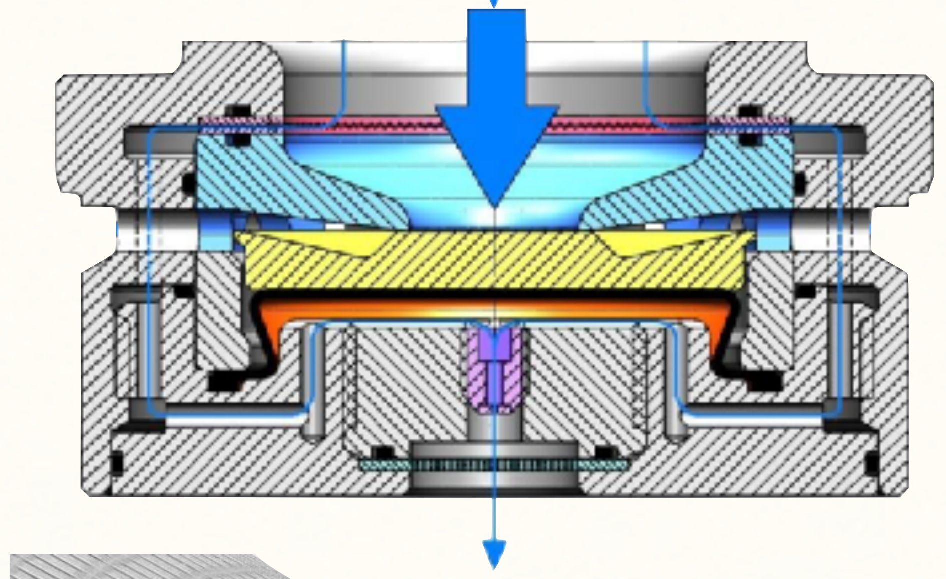
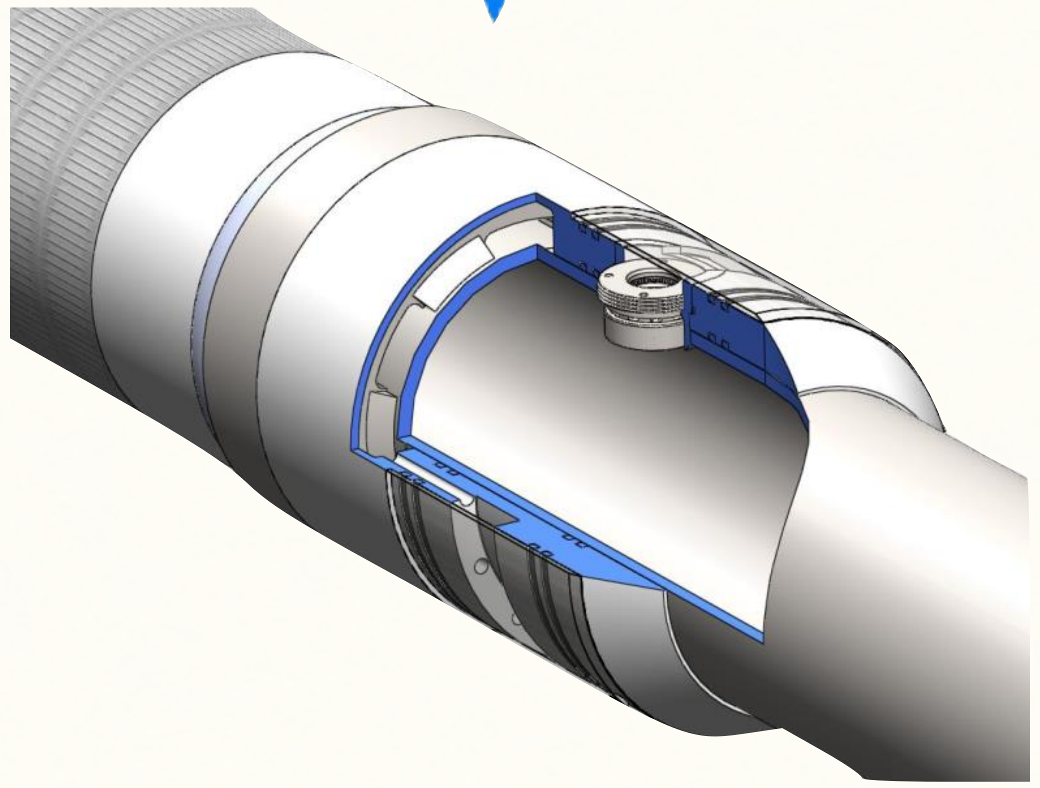
- Autonomous Inflow Control Valves (AICV®) from Inflow Control of Norway
- Valve has two flow pathways, one always open (1%-5% of combined flow) one open or closed (95%-99%)
- Pilot flow pathway has two flow restrictors a laminar flow restrictor and a turbulent flow restrictor, pressure between the restrictors is determined by the viscosity of the fluid
- Status of main flow pathway depends on pressure within the pilot flow pathway ∴
- Valve can shut off low viscosity fluids (e.g. steam, gas or water)
- Installed in each joint of sand screen with swellable packers at every fifth joint or so







Illustrated valve is available in a high temperature version from Inflow Control of Norway http://www.inflowcontrol.no

WHY STEAM FROM THE START

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Different strategies trialled in one sector model, the latter strategy describes virtually all onshore steam flood projects

STEAM SUCCESS FACTORS

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Key Characteristic	Significance	Pilot	More Successful ⟵⟶ Less Successful					
			Kern River	Duri	Mukhaizna	Schoonebeek	Emeraude	Issaran (CSS)
Areal Communication	Allows steam to sweep oil laterally from injectors to producers					Extensive faulting	Siltstone interbedded with fractured limestones	Complex carbonate
Well & Reservoir Productivity	Producers flow cold Pressure sink at producer establishes flow and injectivity Rapid sweep reduces heat loss time				300-600 mD		100-500 mD	3-300 mD
Oil Intensity & Concentration	Unit Thickness, Porosity, Oil Saturation Sufficient recoverable STOIIP per acre to justify heat losses above and below		Previously depleted	Previously depleted		Previously depleted		Low Porosity
Homogenous Reservoir	No barriers to vertical gravity-dominated flow sweeping attic above horizontal wells No high perm streaks or fractures bypassing oil						Siltstone interbedded with fractured limestones	Impermeable stringers

AGENDA

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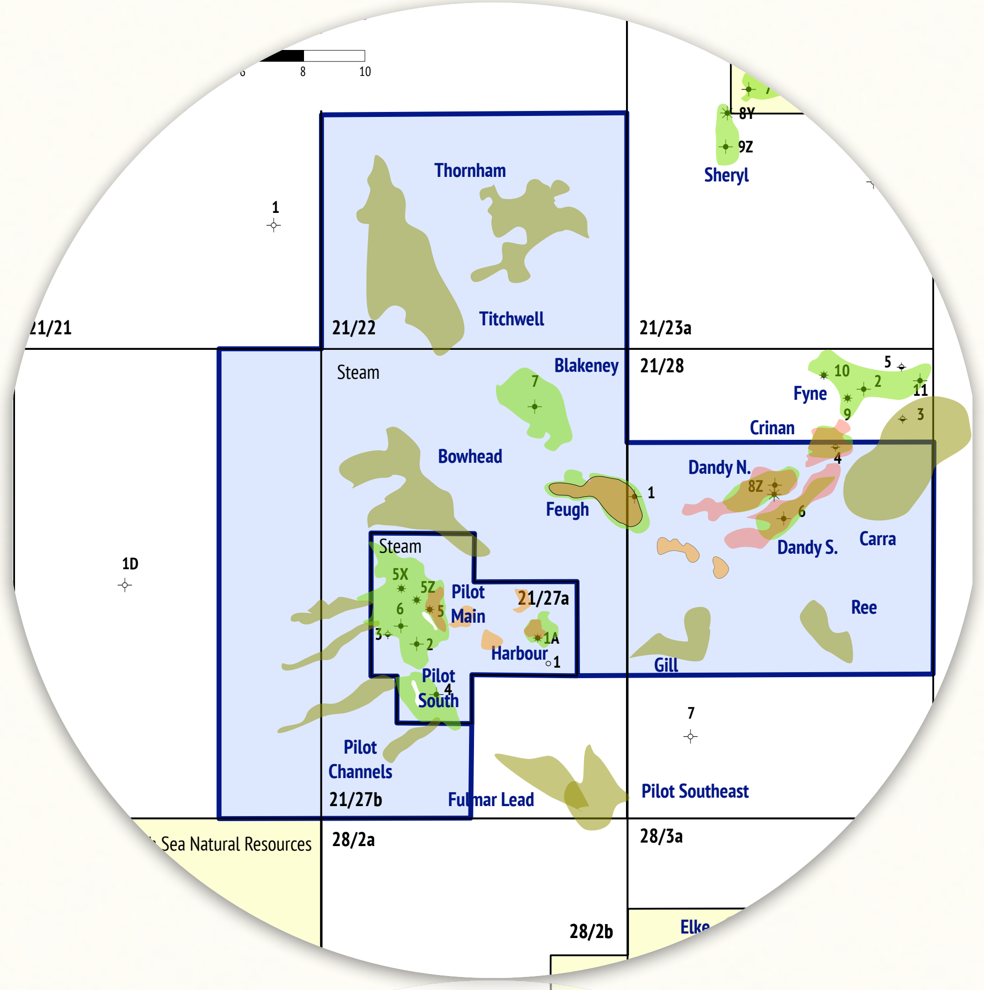
- Who are Steam Oil
- Pilot Geoscience
- North Sea Heavy Oil
- The case for Steam Injection, the Offshore, & Pilot
- **Pilot Development scheme**



DEVELOPMENT CONCEPT

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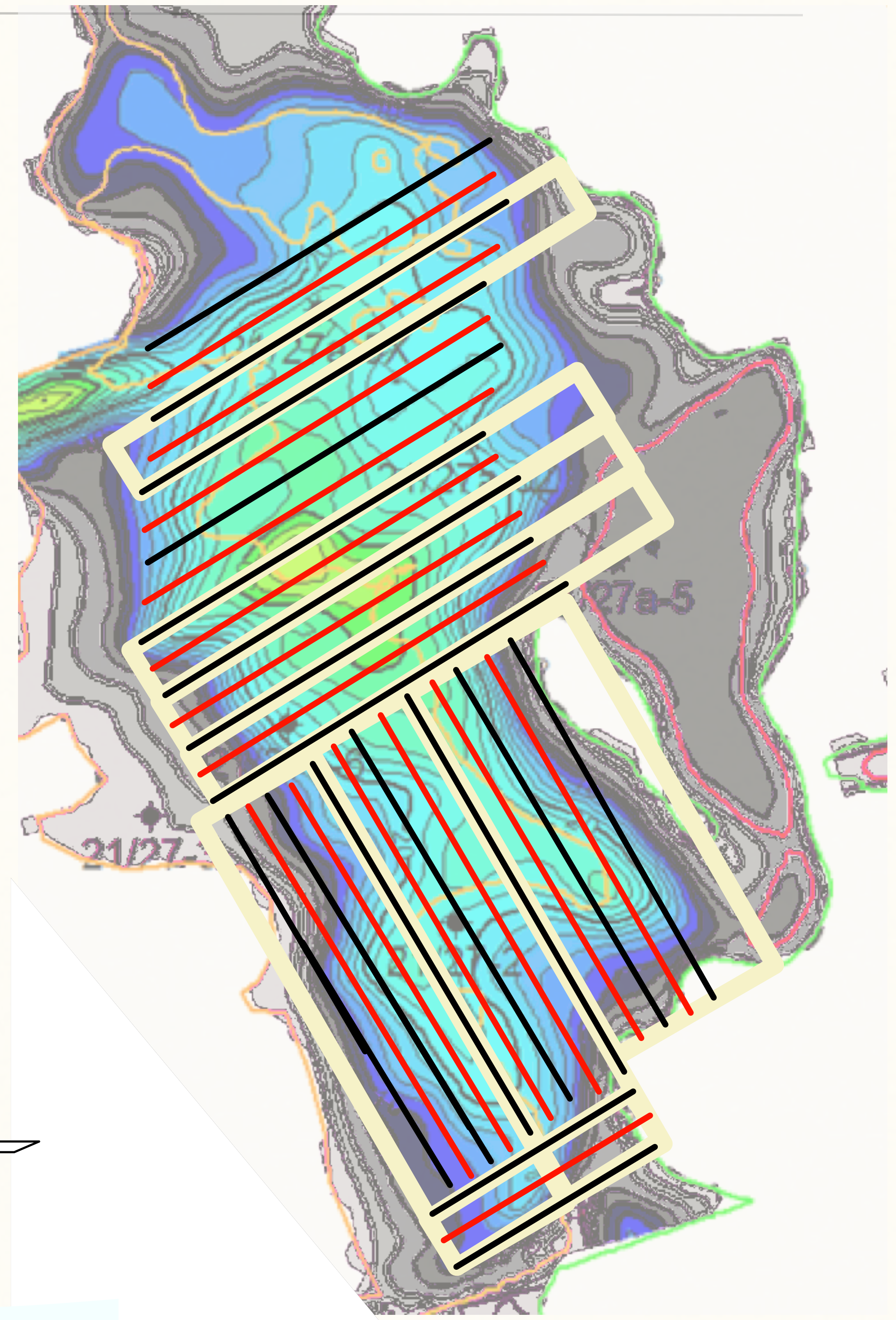
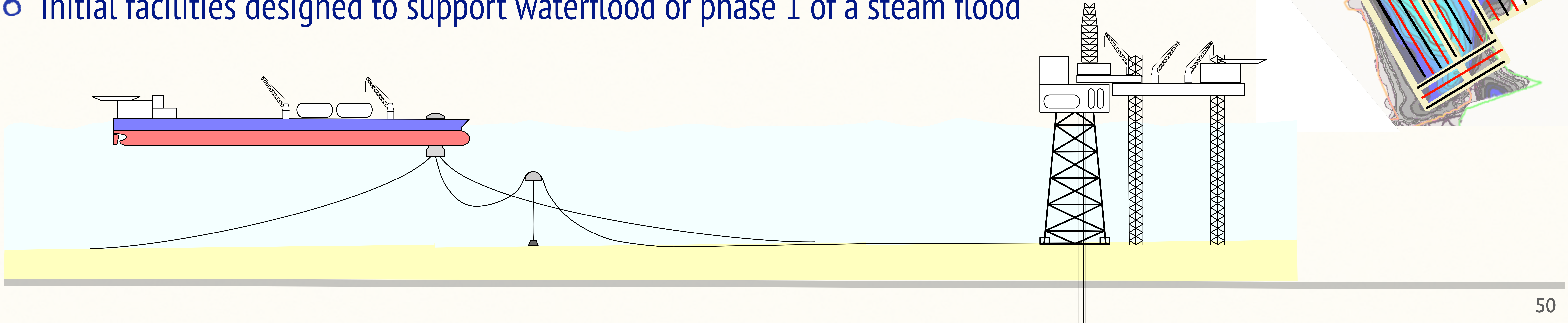


- A wellhead platform with ca. twenty slots, degassing facilities, water treatment and a boiler
- Utilities, drilling and accommodation to be provided by a jack-up rig (minimal modifications required)
- Oil water separation in wash tanks on the FSO as well as water treatment either overboard or returned to the platform for water injection
- Initial facilities designed to support waterflood or phase 1 of a steam flood



PILOT WATERFLOOD PRODUCTION PROFILE

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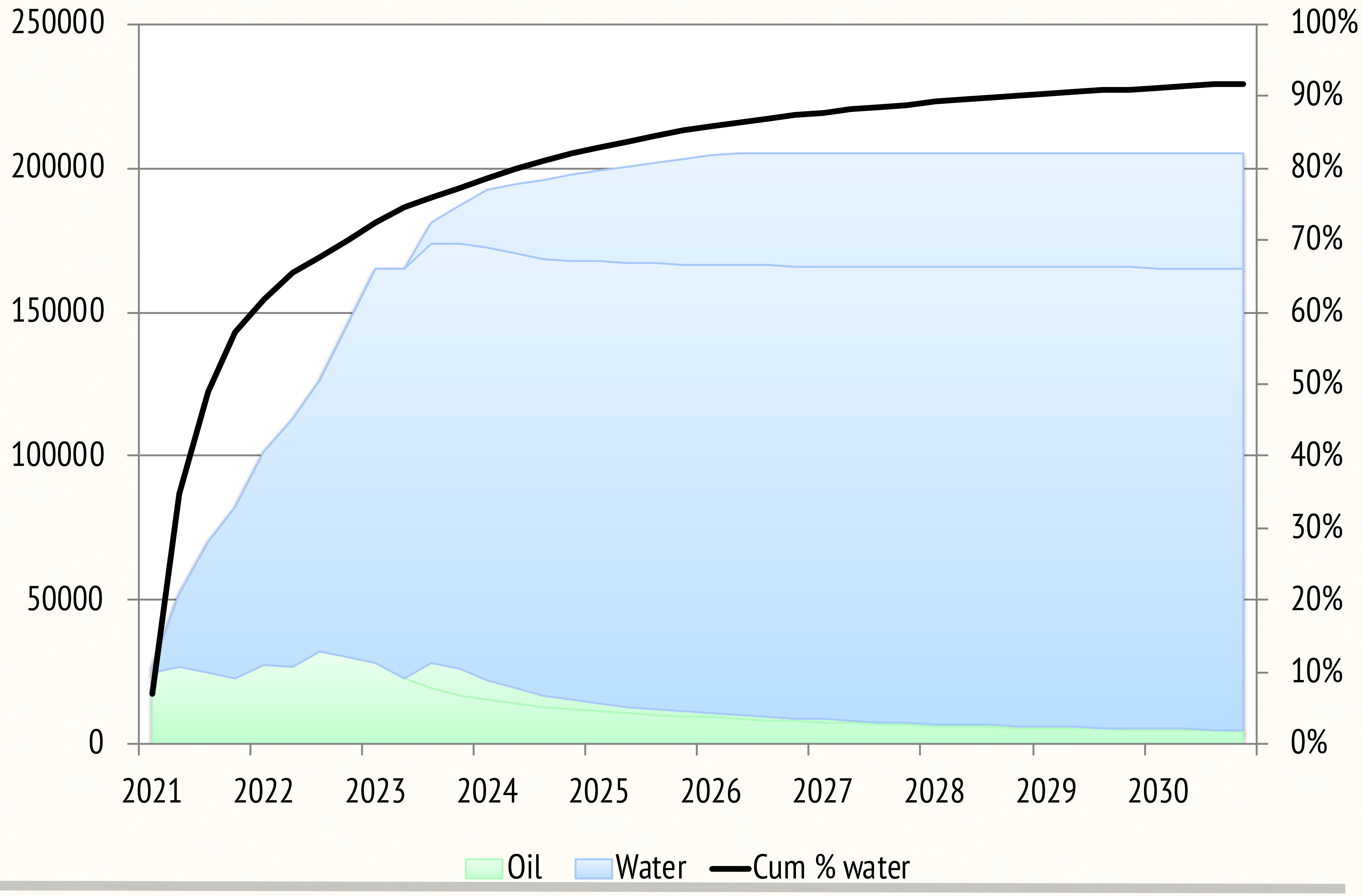
- Based on hot (65ºC) water injection
  (as implemented by Statoil on Mariner)
- 46 mmbbls recoverable from twenty wells on Pilot Main
- 5 mmbbls recoverable from three wells on Pilot South
- Overall recovery factor of 19%
  (Mariner 16%, Kraken 34%)



Volumes produced economically using the January McDaniel price forecast

PILOT FULL FIELD PRODUCTION PROFILE

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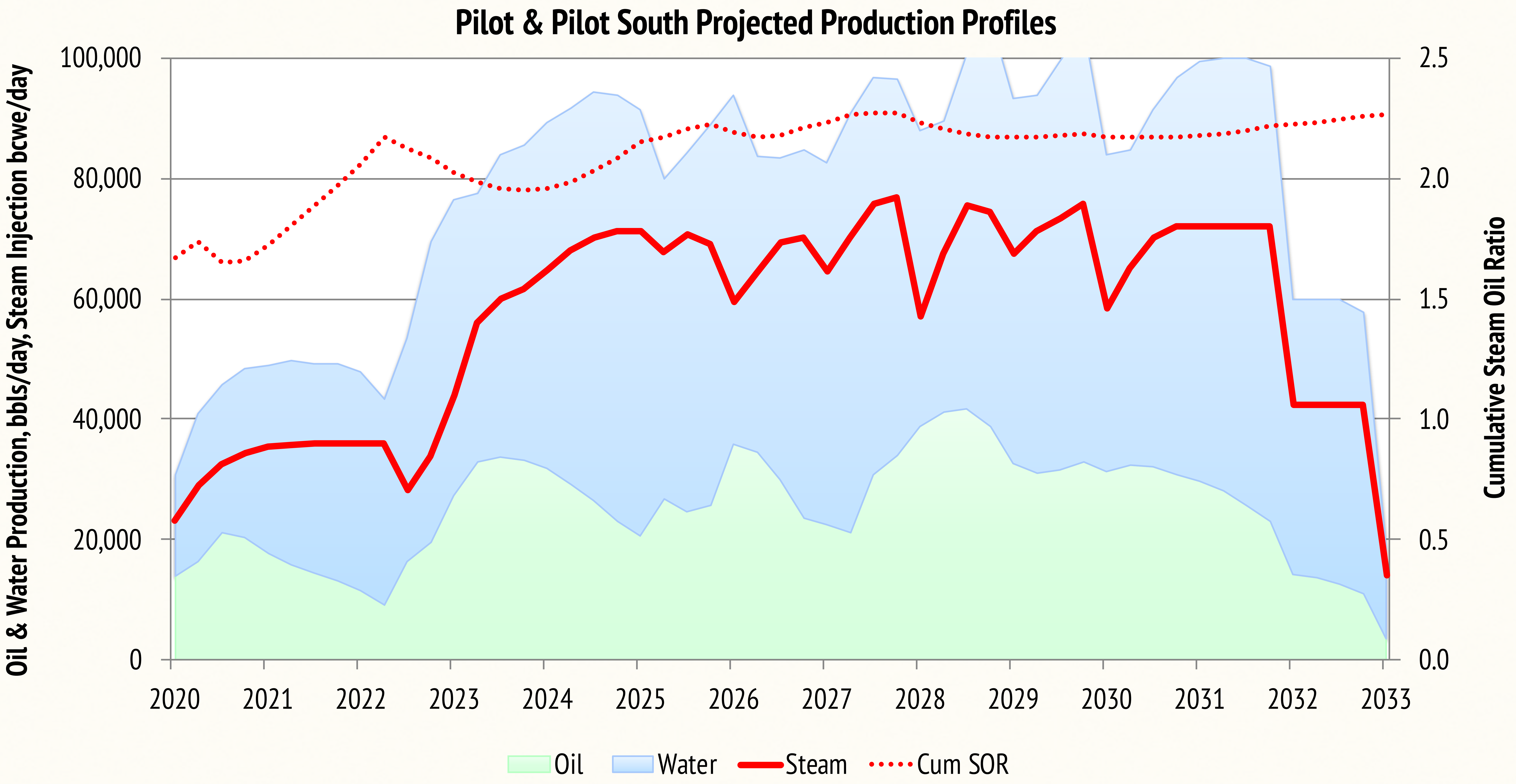
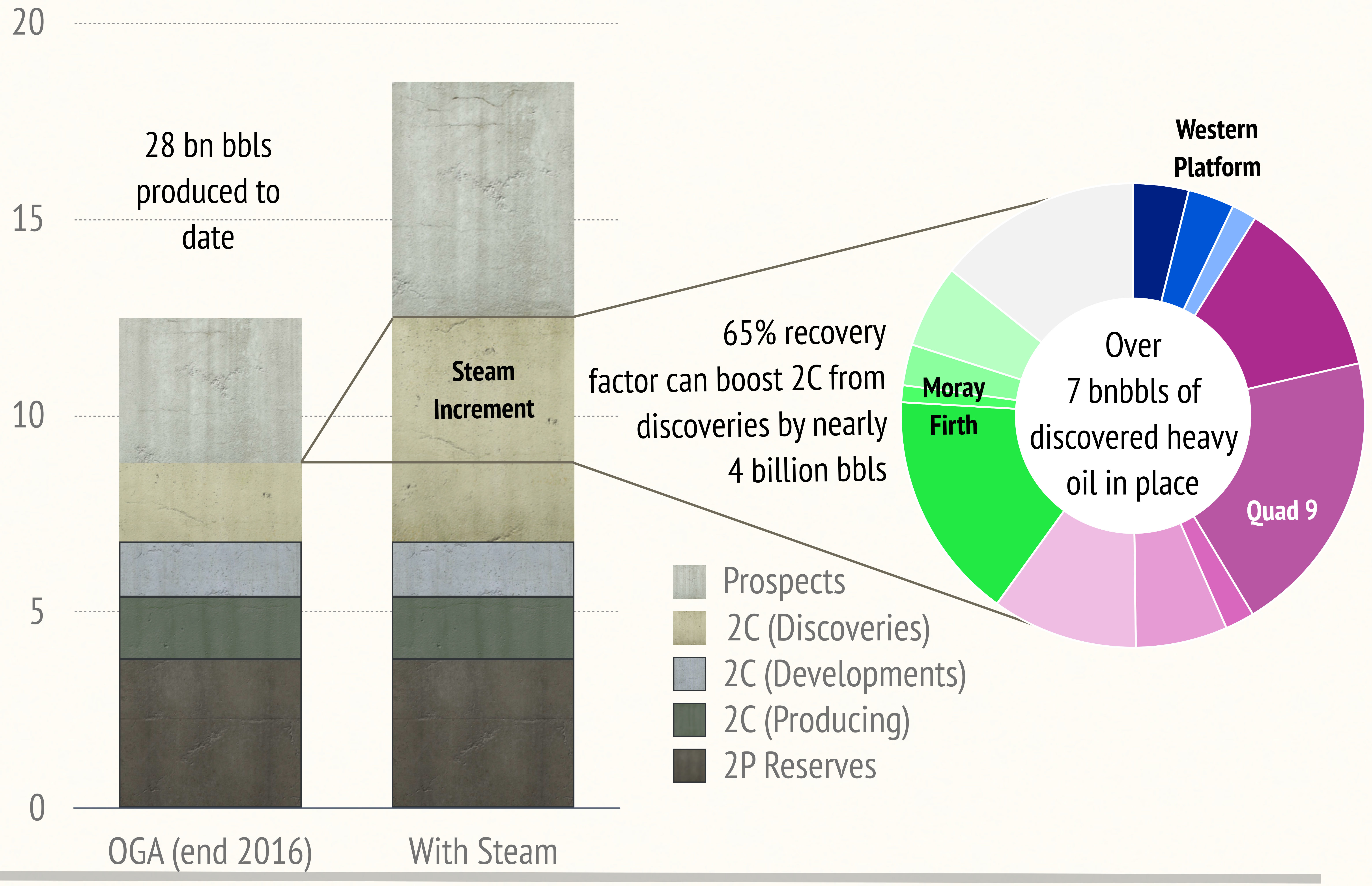


- 36,000 bcwe/day steam injection per platform
- Second platform (doubling steam capacity) installed to come on stream in 2023
- Pilot South developed using extended reach wells
- 122 mmbbls recoverable, 46% recovery factor, Steam Oil Ratio of 2.3

STEAM INJECTION CAN BOOST UKCS OIL RECOVERY BY c. 5 BILLION BBLS

PHARIS ENERGY

- Offshore steam injection is feasible and profitable
- It works best in shallow high quality sands, where most discovered heavy oil lies
- Steam injection techniques can boost recovery from discoveries on the UKCS by nearly 4 billion bbls
- There is even more to find



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