

The Bentley Field, UKCS Block 9/3b: Working with the reservoir and fluid properties to provide a cost effective development.

SPE Aberdeen Evening Meeting April 2016

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Agenda



- 1. Field Description how field parameters have influenced development
 - 2. Development Description how this delivers low cost heavy-oil
 - 3. Conclusions

North Sea Heavy Oil is of Strategic Importance



As North Sea production declines, heavy oil is growing in strategic importance

North Sea Heavy Oil Province



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9 billion barrels of estimated heavy oil resources-in-place⁽¹⁾ including:

- Bentley , discovered 1977, 10–12 °API, 2012 EWT, Development Ready
- Captain, discovered 1977, 19–21 °API, Producing, First Oil 1997
- Mariner, discovered 1981, 12–14 °API,, under development, first oil 2018
- Kraken, discovered 1985, 14 °API, under development, first oil 2017
- Bressay, discovered 1976, 10–12 °API, reviewing development

Bentley Field Summary

XCITE ENERG RESOURCE

- Four-way dip closed (15 km x 6 km) @ ~1.1km TVDss, in ~110m of water
- Field extent and depth means 2 drill centres required
- RAR PMean in-place of 885 MMstb
- Excellent reservoir , 90% N/G, 34% Porosity, in Upper Palaeocene, Lower Eocene Dornoch formation
- Oil-leg of 120 ft proven in wells, and up to 200 ft from seismic
- Underlying water-leg up to 400 ft
- Heavy oil 10-12 °API, 1500 cP
- Excellent effective horizontal permeability 47 D
- Oil mobility similar to other North Sea heavy-oil fields



- Proven sustainable commercial flow rates with downhole ESPs
- 2P Reserves of 267 MMstb plus 2C Contingent Resources of 9 MMstb

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Pre-Xcite Wells

Well Name	Completed	Operator	Hydrocarbons	Tests
9/3-1	1977	Amoco	Encountered 12° API oil – 81 ft oil column	Nitrogen evacuation. Oil too heavy to flow (no pump)
9/3-2A	1983	Conoco	92 ft oil column	ESP lifted DST. No flow due to pump failure
9/3-3	1986	Conoco	Dry hole on separate structure	
9/3-4	1986	Conoco	84 ft oil column	Not tested (commitment well, low oil price environment)

Xcite Wells

Well Name	Completed	Operator	Hydrocarbons	Tests
9/03b-5	2008	Xcite	87 ft oil column	ESP lifted, average 125 stb/day with high skin
9/03b-6	2010	Xcite	113 ft oil column	Logged and pressure tested
9/03b-6Z	2010	Xcite	1,821 ft oil section	ESP lifted, 36hr DST reaching stabilized 2,900 stb/day
9/03b-7	2012	Xcite	2,214 ft oil section	ESP lifted extended flow test, reaching 3,500 stb/day
9/03b-7Z	2012	Xcite	2,042 ft oil section	ESP lifted extended flow test

Xcite appraisal history described in SPE-172858

Top Reservoir Mapped with Confidence





- Top of Dornoch reservoir readily mapped on seismic due to hard layer in overlying Balder
- Interpretation further assisted through mapping seismic top-laps
- Shallow depth of burial and benign overburden gives confidence in depth mapping, with all wells lying close to a single velocity gradient



Oil-leg is Contained Within the Best Quality Reservoir Units





- Oil-leg is upper portion of overall reservoir
- Intra-reservoir sequences mapped on seismic
- Depositional model and facies defined, from cuttings, logs, seismic & analogues
- Oil-leg is within upper and lower shore-face facies of Upper Dornoch, proven to be excellent quality during appraisal drilling and testing



Reservoir Distribution is Favourable to Production





- Reservoir distribution predictable
- Reservoir well connected vertically to underlying aquifer, which means excellent pressure support and good vertical sweep
- Simple structure and high horizontal continuity of reservoir makes production bore placement more straightforward
- Excellent reservoir quality 90% N/G, 34% Porosity



Size Matters: Two Drill Centres Required but Low Overall \$/bbl



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RAR December 2015 Bentley (MMstb)				
	Mean	P90	P50	P10
PIIP	885.1	741.2	880.9	1033.9
Recoverable Reserves		235.9	267.3	298.0

- Tight range of PIIP results from confidence in mapping the structure and geology
 - Areal extent of field requires two drill centres and lends itself to a phased development (FPD then SPD)
- Approximately 2/3rds of 267.3
 MMstb 2P Reserves is from FPD
- Large Reserves helps reduce \$/bbl life of field development costs
- Good potential for incremental projects eg EOR

PIIP: Petroleum Initially In-Place FPD: First Phase Development SPD: Second Phase Development

Aquifer Provides Pressure Support and Drive (& Lots of Water)





The aquifer provides excellent pressure support and a widefronted natural water-drive, that results in good vertical sweep of oil-leg



- Bentley oil-leg is everywhere underlain by a well connected aquifer
- Flow tests show rapid pressure response and recovery
- Minimum aquifer size from EWT Material Balance is 10 Bbbl but shut-in pressures still building
- Reservoir mapping by Xcite shows potential 130 Bbbl aquifer
- Field produces nearly 6 Bbbl of water, all of which is reinjected back to aquifer
- Disposing of produced water is an easier problem to solve than provision of pressure support

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Bentley Has High Viscosity but This Can Be Managed







Bentley, at 1,500 Cp, will be amongst the highest viscosity offshore production however:

- Oil mobility, pressure support and drive mechanism are better indicators of flow potential – Bentley compares favourably to heavy oil peer group
- Naphthenic properties help with favourable relative permeabilities and with separation
- Crude is undersaturated in reservoir and can be flowed without evolving gas
- Crude viscoity responds well to heating and contains no wax, so flow assurance issues are minimised
- Blending with lighter crude improves dehydration time and net value in market



EWT Proved Sustainable Flow and Demonstrated Optimised Development



2012, 68 Day Extended Well Test:

- A scaled down version of development plan
- Multi-lateral well delivered with downhole controls and ESP
- 9/03b-7, placed 60 ft above OWC to monitor water breakthrough, comprised most of production
- 9/03b-7Z, placed approx. 10 ft from reservoir roof, flowed near end of EWT, to demonstrate control of laterals
- Resolved key subsurface uncertainties
- Demonstrated how development could be optimised







Wells drilled from jack-up, fluids degassed and transferred to DP shuttle tanker

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Water Movement from Aquifer to Production Bore Confirmed





- Average oil flow of 2,600 stb/day, over 57 days uptime, during 68 day test, reaching up to 3,500 stb/day, mostly from single 9/03b-7 lateral
- Water cut initiated at pre-well P50 expectation but trended towards P10 (better end of expectations) by the end of test
- Full wellbore contributing to flow, with most water-ingress at the heel
- History matching to EWT gave improved relative permeability curves and tighter range of production outcomes
- The EWT reservoir and flow data has resulted in higher certainty in the development production volumes and rates

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EWT Dehydration Performance Helps Optimise Development

- Bentley crude is hydrophobic and will separate naturally over time despite low API
- During EWT, brown emulsion exported from jack-up emerged at tanker as black-oil and water
- EWT demonstrated benefit of adding demulsifier to downhole below ESP to speed up separation process
- EWT wet crude was blended with lighter crude in tanker where it dehydrated to below 0.5% BS&W within 8 to 12 days
- Bentley development will benefit from a simplified, cost-effective, dehydration process that brings onshore heavy-oil techniques to the offshore environment



Onshore heavy oil fields use tankage for settling crude prior to export





Reservoir Drainage Optimised with EWT Calibrated Modelling





- Field and box models created to investigate production and optimise development
- Good vertical sweep results in high water-cut tent below production bore
- Effective horizontal sweep requires multiple closely spaced wellbores
- Horizontal production bore spacing of 80m computed as optimum
- 84 production bores at 80m spacing provides good drainage of FPD area
- Well costs kept to a minimum by embracing multi-lateral technology

Post EWT Development Improvements

XER XCITE ENERGY RESOURCES

The EWT has allowed the Field Development Concept, cost and schedule, to be substantially reduced and de-risked:

- Improved reservoir drilling parameters
- Optimise well completion design for improved flow performance
- Downhole injection strategy for improved flow performance
- Simplified dehydration process
- Optimised separation process confidently size equipment
- Optimise flow assurance uncontrolled shutdown and restart
- Enabled subsea completions to be considered
- Improved methodology of cooling produced fluids
- Accelerate the heavy oil EOR programme







Reservoir Characteristics Result in Good Production Certainty





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First Phase Development

- Platform (MOPU NPAI), with 24 well slots (21 producers, 3 injector wells)
- 7 year drilling, with jack-up rig positioned over platform
- De-gas fluids & bulk water knock-out on platform
- Oil and produced water pumped to FSO for dehydration separated produced water re-injected to flanks of aquifer for disposal
- 270,000 blpd capacity



MOPU: Mobile Offshore Production Unit NPAI: Note Permanently Attended Installation



Second Phase Development Plan

- Second Phase to start c.5 years after FPD first oil
- 20 slot platform (14 producers, 3 water injectors, 1 gas producer, 2 spare)
- 270,000 blpd capacity
- Linked to FPD with 200,000 blpd line
- Shared facilities further debottlenecks FPD & reduces FPD Capex requirements



Bentley First Phase Development





MOPU Provides Cost Effective Production Solution





Element	Length (m)	Width (m)	Height (m)	Weight (Tonnes)
Base	64	64	6	5,418
Jacket (inc. Wellbay)	34	34	152	10,511
Barge Deck	82	65	13	6,429
Topsides				6,166
TOTAL				28,524

- Mobile Offshore Production Unit is proven concept at Maari Field NZ (similar metocean conditions)
- Simple processing, based on fluid properties, allows reduced topside weight
- Simple steel structure reduces construction risk and allows competitive pricing from multiple yards, with potential to construct in same yard as FSO
- Self installing design reduces installation and decommissioning costs
- Allows for dry trees, enabling cheaper workovers and reduced operating costs
- Re-deployable unit allows the potential for asset financing / leasing

FSO Provides High Capacity Storage, Enabling High Throughput

- Proven concept and low complexity design, with no requirement for processing facilities on deck, simplifies construction and reduces schedule risk
- 1 MMbbl storage capacity, allows required throughput during peak production and tiein of area production in later years
- Favourable motion characteristics improve dehydration times
- Living Quarters on FSO with walk-to-work concept to MOPU via bridge, improves safety gradient and reduces Capex and Opex
- Cylindrical design removes the requirement for a swivel thereby reducing complexity
- MOPU to FSO jumper hose transfer lines, avoid requirement and cost of seabed pipeline installation and decommissioning





Cost Effective Drainage through use of Multi-Laterals





- Four bores per well reduces total drilling costs
- Best in class TAML 5 junctions provide high reliability, high repeatability systems
- Enables reduced MOPU size & costs as well requirement is 21 Producers and 3 injectors
- Reduces shallow anti-collision risk
- A total of 142 km of reservoir section is planned for FPD and SPD
- Significant learning potential over extended campaign



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Well Construction Strategy Evolves Over Time





- First ten producers constructed as Dual Laterals
- Reduces early construction risk as Dual Lateral proven by EWT
- Faster construction than Quad so pumps in ground quicker and peak oil reached earlier
- Double wellbore spacing for Dual Laterals, improves early production
- Remaining wells constructed as Quad Laterals as focus switches to reducing total cost and maximising economic recovery (MER)
- Dual Laterals later infilled with two extra laterals as part of MER
- Early wells of shorter length and into most certain areas further reduces risk

- Dual ESPs deployed during early years increases run-life & reduces production risk
- Single ESPs deployed in later years minimises Opex with minimal impact on production
- Selection of ESPs to cover wide operating envelope
- Focus on minimising friction losses below pump:
 - $dP = 3.84 \times 10^{-10} \times L \times Q \times \mu \times \frac{1}{D^4}$
 - Land pump deep
 - Minimise pump to reservoir length
 - Maximise internal diameters
 - Large diameter pump pod
- Introduction of small % base-oil below ESP acts as lubricant, significantly reduces friction losses, and boosts flow (observed in EWT and proven in flow-loop)
- Downhole lateral control valves optimise high oil-cut laterals and help keep ESP in optimum operating window









Life Cycle Development Cost of \$30/bbl



Unescalated Costs (\$MM)	1P	2P	3P
Dev Drill Capex	2,267	2,267	2,267
Facilities Capex	1,268	1,268	1,268
Total Capex	3,535	3,535	3,535
Unit CAPEX \$/bbl	15.0	13.2	11.9
Opex	4,279	4,253	4,233
Unit OPEX \$/bbl	18.14	15.91	14.20
Decommissioning	309	309	309
Unit ABEX \$/bbl	1.31	1.16	1.04
Total Cost	8,123	8,098	8,078
Unit COST \$/bbl	34.4	30.3	27.1
Reserves MMbbls	235.9	267.3	298.0

Assumes MOPU treated as Capex and FSO is leased

- Development choices have driven down Capex, Opex and Abex costs
- Bentley development plan delivers 267.3 MMstb Reserves at \$30/bbl on an unescalated full life cycle basis
 - Assumes MOPU treated as Capex and FSO as lease
- Option for MOPU lease reduces early Capex requirements
- SimOps enables early payback of capital

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Conclusions





- Bentley is a ready-to-go development project
- Systematic appraisal has led to a de-risked and optimised development plan
- Straightforward recovery mechanism provides good certainty on production volumes
- A total of 142 km of reservoir section and 540,000 blpd facilities capacity are key elements in delivering 267.3 MMstb 2P Reserves over FPD and SPD
- Simplification of the development concept and infield assets, coupled with use of multi-lateral wells delivers oil at \$30/bbl¹
- 1. Unescalated on full life cycle basis for 2P recovery



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