PSLocate the Remaining Oil (LTRO) and Predictive Analytics: Application for Development Decisions on Marmul GNR Field, The Sultanate of Oman*

Cristian Masini¹, Sergey Ryzhov², Dmitry Kuzmichev³, Rina Bouy³, Saeed Majidaie³, and Denis Malakhov²

Search and Discovery Article #42191 (2018)**
Posted March 26, 2018

Key Notes and Outline

Some Major Features of Marmul GNR Field

- More than 30 years of production from hundreds of horizontal wells and tens of vertical wells from two main reservoirs
- 20° API oil, with viscosity of 100-1000cP; water-cut greater than 96%

Key Uncertainties

- Production allocation uncertainties
- Subsurface uncertainties
- Permeability, facies distribution, initial oil saturation, viscosity

Fast Track vs. Traditional Workflow

- Opportunity
- Operator's dilemma

Marmul Full Cycle LTRO and Forecast

- Poseidon (production engineering software) deck definition
- Production allocation
- ROCM (Remaining Oil-Compliant Mapping)
- Handling Poseidon ROCM uncertainty
- Poseidon remaining oil

^{*}Adapted from poster presentation at AAPG Middle East Region Geosciences Technology Workshop, "Decision Based Integrated Reservoir Modeling Middle," Muscat, Oman, October 30-November 1, 2017. Please refer to very similar article by same authors, <u>Search and Discovery Article #42190 (2018)</u>.

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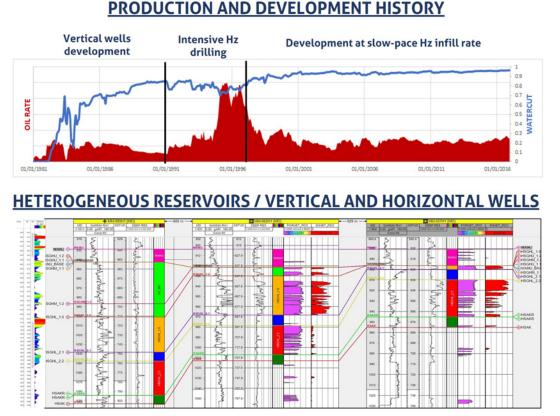
- Infill opportunity framing
- Predictive analytics history machine learning
- Machine learning full field forecast
- Development scenarios forecast

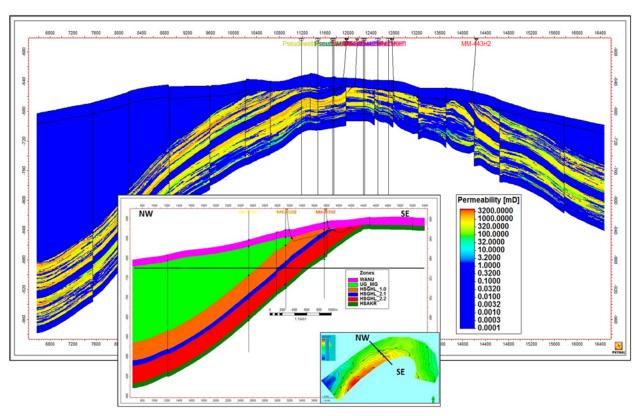
LOCATE-THE-REMAINING-OIL (LTRO) AND PREDICTIVE ANALYTICS APPLICATION FOR DEVELOPMENT DECISIONS ON MARMUL GNR FIELD, THE SULTANATE OF OMAN

Cristian Masini¹, Sergey Ryzhov², Dmitry Kuzmichev³, Rina Bouy³, Saeed Majidaie³, Denis Malakhov² ¹ Petroleum Development Oman, ² Target Oilfield Services, ³ Leap Energy

MARMUL GNR

- 30+ years of production
- 100's horizontal
- + 10's vertical wells
- Two main producing reservoirs
- Recent WI implementation
- Heavy Oil with API = 20
- Viscosity = 100-1000 cP
- Water cut > 96%

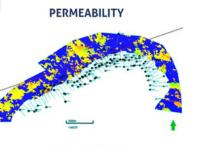




KEY UNCERTAINTIES

PRODUCTION ALLOCATION **UNCERTAINTIES**

- ~30% of the total production is comingled
- Both vertical and horizontal wells are commingled
- Limited PLT dataset and pressure data
- Other uncertainties on reservoir pressure, oil API/viscosity distribution and permeability estimation in wellbore



Limited and/or unreliable core data hence poro-perm uncertainty **SCAL** dataset incomplete

LOW | MID | HIGH

LOW | MID | HIGH **Limited constraining of** facies and reservoir quality distribution seismic due to

old vintage & low

resolution

maps, MBAL)

Complex facies assemblage resulting in difficulty in estimating initial oil saturation (wells drilled post-production, and Hz) Poor coverage from early vertical wells (log vintage)

Study

initiation

LOW | MID | HIGH

Evidence from sampling that API & viscosity varies, both areal and depthtrends present; significant fluid PVT uncertainty

LOW | MID | HIGH

LIMITED TIME AND RESOURCES AVAILABLE

SIGNIFICANT CHALLENGES TO ADDRESS

Study

Completion

DEVELOPMENT

locations and

locations at

Screen 100's of well

generate forecasts

for infill drilling

different spacing

SCENARIOS

FORECAST

FAST TRACK VS TRADITIONAL WORKFLOW

THE OPPORTUNITY: A mature field with low recovery factor and potentially significant undrained volumes; can more be economically recovered?

OPERATOR'S DILEMMA: The long road of reservoir simulation with uncertain results vs. traditional analytical methods with limited quantitative capability



Alternative

Fit-for-purpose

geologically consistent

Physically /

Straight into full field static & dynamic modelling Long process (8-12 months), Large resource loading; History-matching unlikely to be fully well-compliant... problematic for infill decisions

SUBSURFACE UNCERTAINTIES

Simpler and faster, but historically proven not to be sufficiently quantitative: how to estimate confidently and consistently incremental reserves from infill wells?

Revert to 'simple' traditional analytical workflows (OFM

The LTRO workflow: 3 months end-to-end comprehensive assessment Delivered high-graded infill locations, risk assessment,

EUR/ well and production forecast for each well location with uncertainty assessment (P90/P50/P10). Predictions validated by full physics simulation sector model

PRODUCTION ALLOCATION Data QA/QC, commingling analysis, Alternative reservoir allocation

REMAINING OIL SENSITIVITY CASES Testing impact of subsurface uncertainties on by-passed oil

scenarios

SECTOR MODEL BENCHMARK Validation of ROCM maps to sector models

REMAINING OIL MAPPING ANALYSIS By passed oil analysis and identification of Water shutoff and Infill Opportunities

REMAINING OIL RISKING Incorporation of subsurface uncertainties into a set of combined scenarios and delivery of

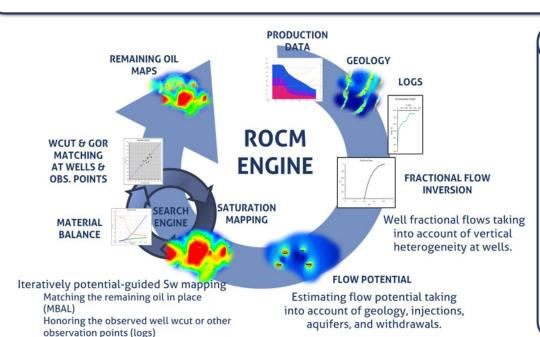
P10/50/90 remaining

oil maps with risk map

associated

SECTOR MODEL BENCHMARK Benchmarked machine learning outcomes to sector models

MARMUL FULL CYCLE LTRO & FORECAST



aguifers, and withdrawals.

- POSEIDON DECK DEFINITION Low | Mid | High • Static properties definition using
- direct export from Petrel as maps
- General properties import PVT, Rel. Perms, Reservoir Pressure, etc.
- Low / Mid / High realisations to capture subsurface uncertainties

Commingling analysis per well /

PRODUCTION ALLOCATION

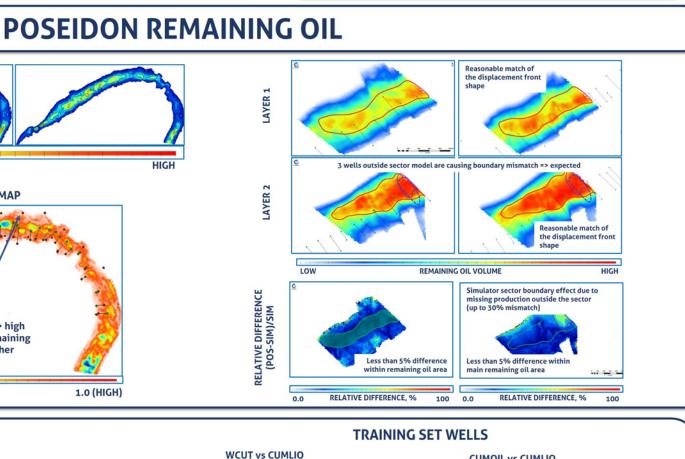
- production volume
- Generating alternative allocation cases (LOW / MID / HIGH) to capture allocation uncertainty
- (ROCM)

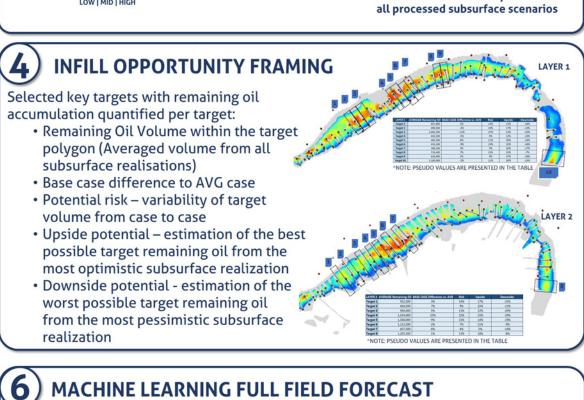
REMAINING OIL COMPLIANT MAPPING

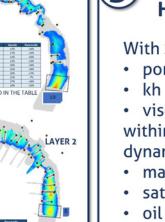
- SENSITIVITY cases runs (varying one uncertainty parameter) - to classify key parameters for further runs
- COMBINED cases runs (varying few selected) uncertainty parameters) - basis for opportunities screening and risking criteria

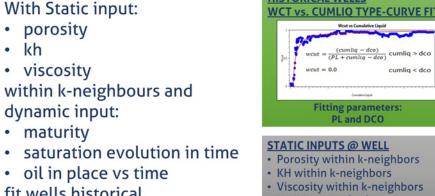
HANDLING POSEIDON ROCM UNCERTAINTY **REMAINING OIL MAPS** SUBSURFACE UNCERTAINTIES **SENSITIVITY COMBINED** Each gridcell on the map is a probabilistic remaining oil lume out of all processed subsurface scenarios **ALLOCATION UNCERTAINTIES REMAINING OIL CONFIDENCE MAP** بالماللين بيابلالا لمهيناها Standard deviations map based on

REMAINING OIL CONFIDENCE MAP High confidence => low uncertainty of remaining oil in the area, potential Low confidence => high uncertainty of remaining oil in the area, higher **CONFIDENCE LEVEL PREDICTIVE ANALYTICS**









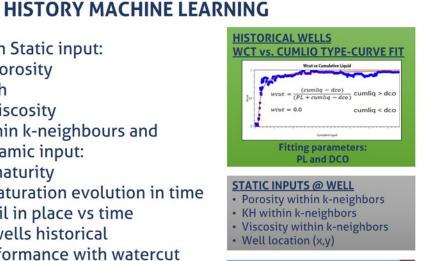
 maturity saturation evolution in time oil in place vs time fit wells historical performance with watercut and cumulative oil type curves for a further POSEIDON APACHE neural network "learning".

50m

Predicted well performance has been validated using dynamic

sector modelling

DEVELOPMENT SCENARIOS FORECAST



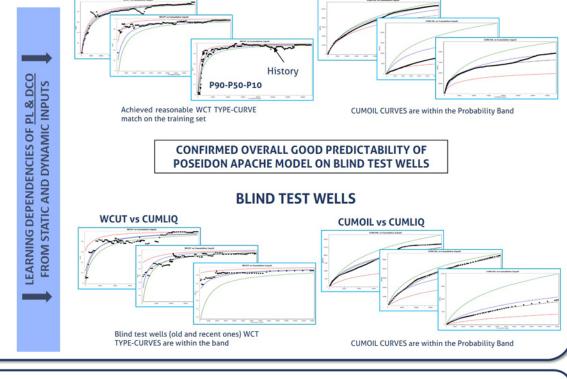
DYNAMIC INPUTS @ WELL ΔSw(t) within k-neighbors Sw(t) within k-neighbors OIP(t) within k-neighbors **AVAILABLE VIA ROCM POSEIDON**

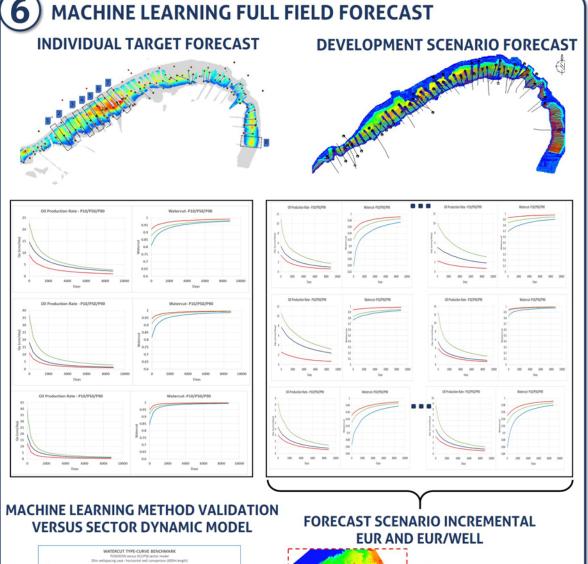
NUMBER OF INFILL WELLS

LAYER 1

LAYER 2

DEV.SC.





SELECTED HISTORY-

SIMULATION RESULT

DEVELOPMENT CASES GENERATED 150m Alternative infill spacing 75m Sequencing alternatives 50m Uncertainty analysis P90-P50-P10 profiles LAYER 1 LAYER 2 **EUR DISTRIBUTIONS (P10/50/90)** 50m LAYER 1 LAYER 2 5m **INFILL WELLS** LAYER 1 LAYER 2

