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Drilling Optimization Simulation Reduces Drilling Cost

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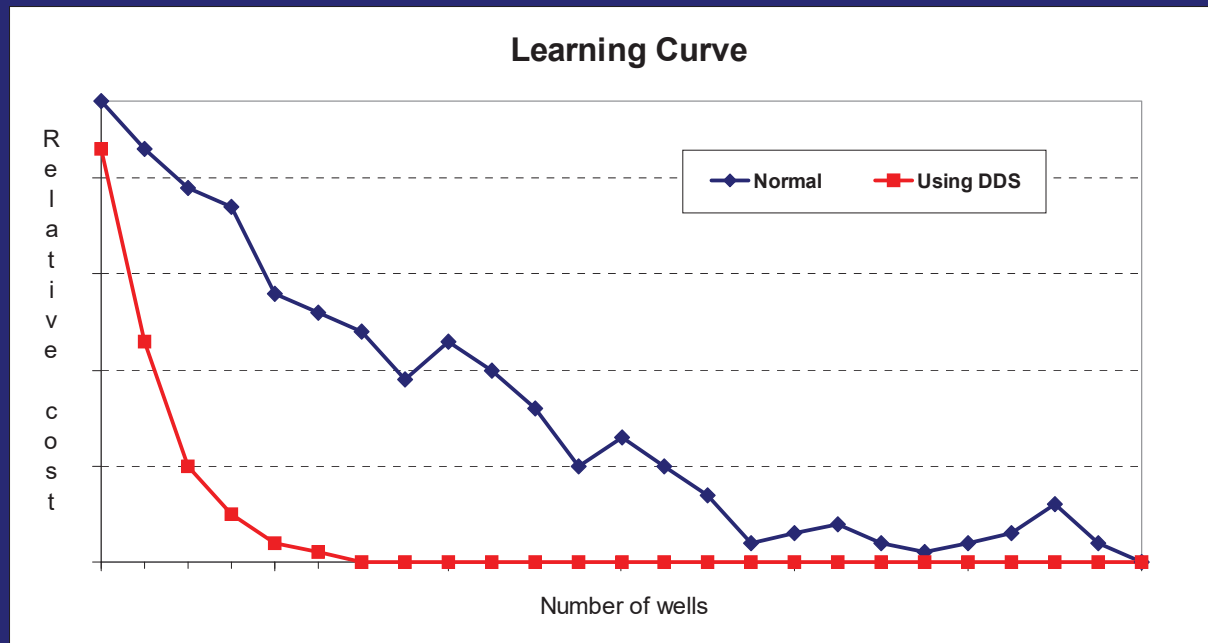


Simulation in Petroleum Engineering

- Simulation has existed in petroleum engineering for decades
- Simulators in reservoir, production and formation evaluation
- Main cost to deplete natural resources is the drilling and completion of the wells
- Drilling engineering simulation has been lacking simulation tools

The ROP Drilling Simulator Concept

- Simulate the **Learning Curve**
- Increase the leaning before the fact



The Drilling Simulator History

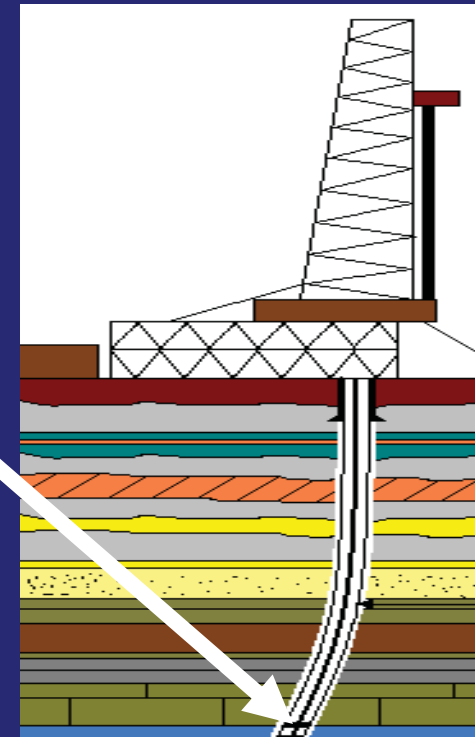
- Engineering Simulator for Drilling (ESD)
1983-1989
- ESD driver was rate of penetration (ROP) models
- The ROP models were used
 - To calculate ROP when rock strength was known
 - To calculate rock strength from offset data when ROP was known

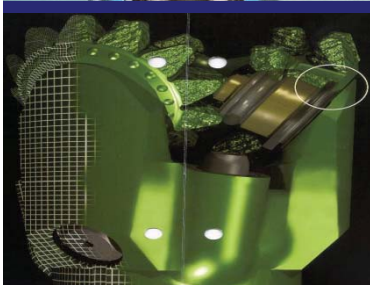
Drill Bit Costs

- Drill bits cost are about 3-5% of the total drilling budget
- The bits performance effect as much 60% of the drilling cost

Bit Optimization

Bit Type/Design
WOB
RPM
Flow rate/Nozzles





Courtesy
Northbasin Energy
Smith Bits

Drilling Simulator Development

- The ROP models were developed for different drill bits
 - Bit types and designs
 - Drilling Operation Parameters (WOB, RPM, Mud and Nozzles)
 - Rock Properties (Rock Strength, Pore Pressure and Abrasiveness)
 - Drill Bit Wear

Generic ROP formula

Rate of penetration (ROP) = function of

- Operational parameters
- Lithology
- Pore pressure
- Bit design
- Rock strength

or

Rock strength (ARS) = function of

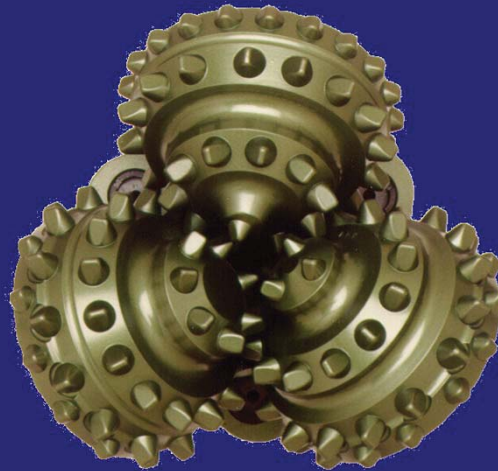
- Operational parameters
- Lithology
- Pore pressure
- Bit design
- ROP

Rollercone bits



135M

- soft formation milled tooth bit;
- motor application



447X

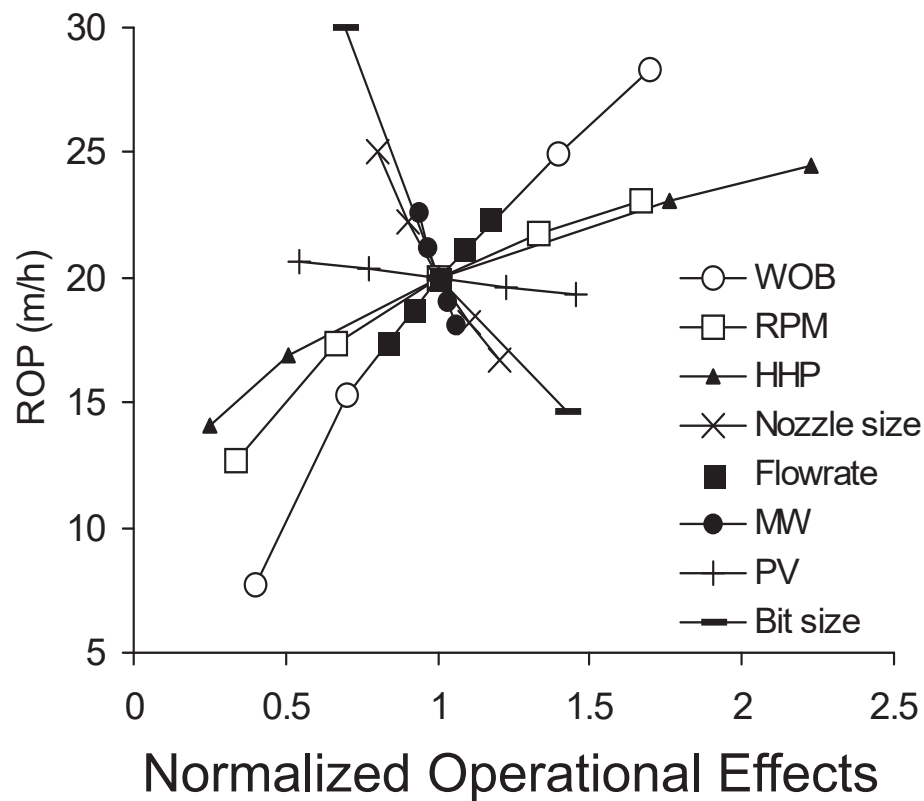
- soft formation insert bit;
- chisel inserts



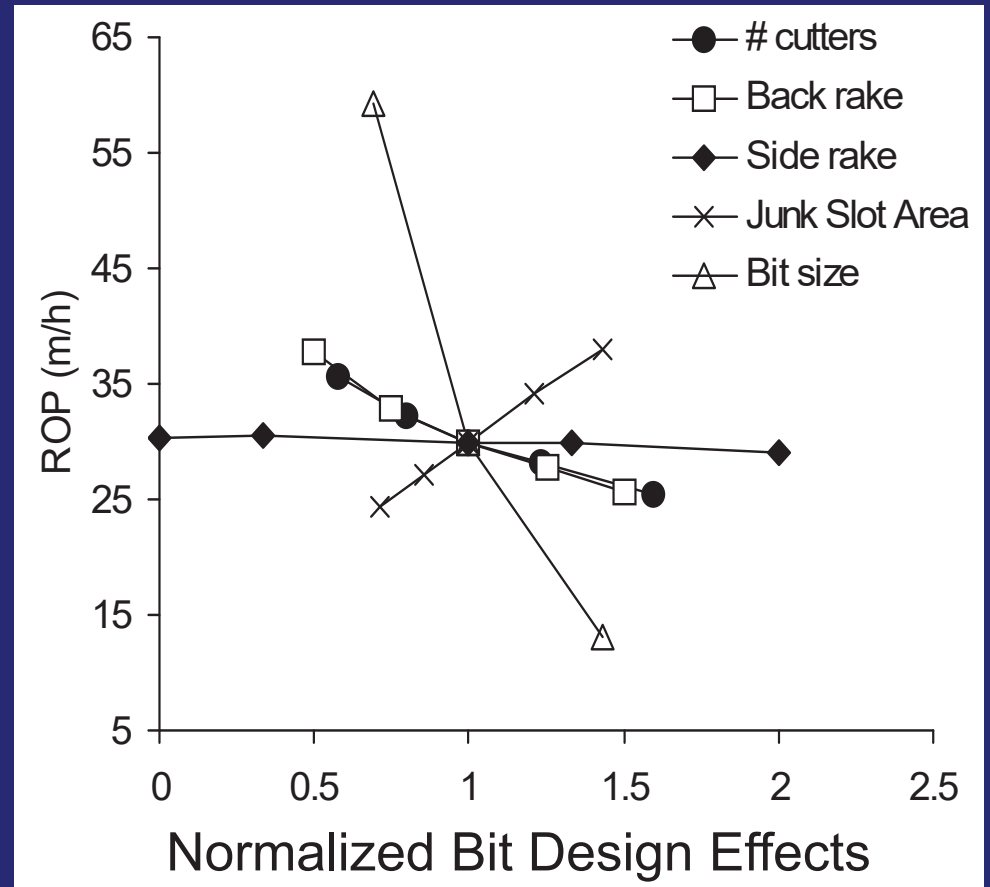
637Y

- medium-hard insert bit;
- conical inserts

Development of a rollercone bit ROP model



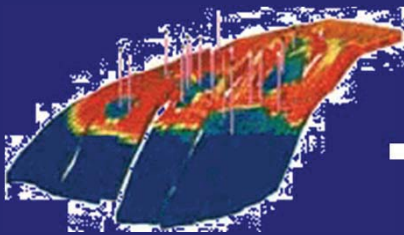
Development of a PDC bit ROP model



Drilling Simulator Application

- Software simulator tool used to:
 - Analyze offset wells
 - Predict target well ROP to minimize drilling cost
- Goal: Develop a set of drilling parameters to optimize ROP and bit life for lowest overall \$/m
 - WOB, RPM, Flow Rate
 - Bit Types, Run Lengths

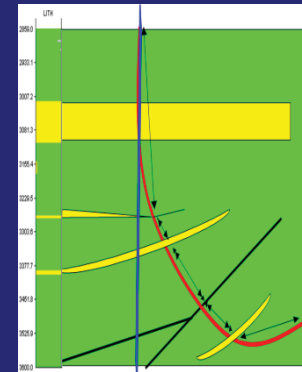
Drilling Simulator Application



Drilled Well
Data



ARS log



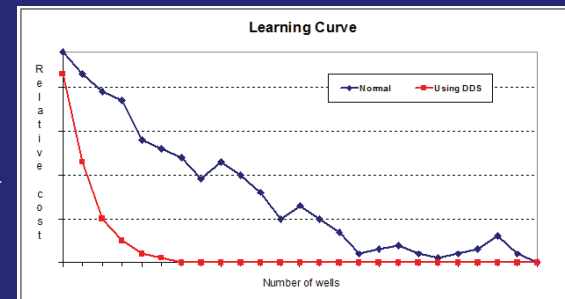
Correlate ARS
log to new tops



Drilling Simulation
\$/m



Follow Up Rig



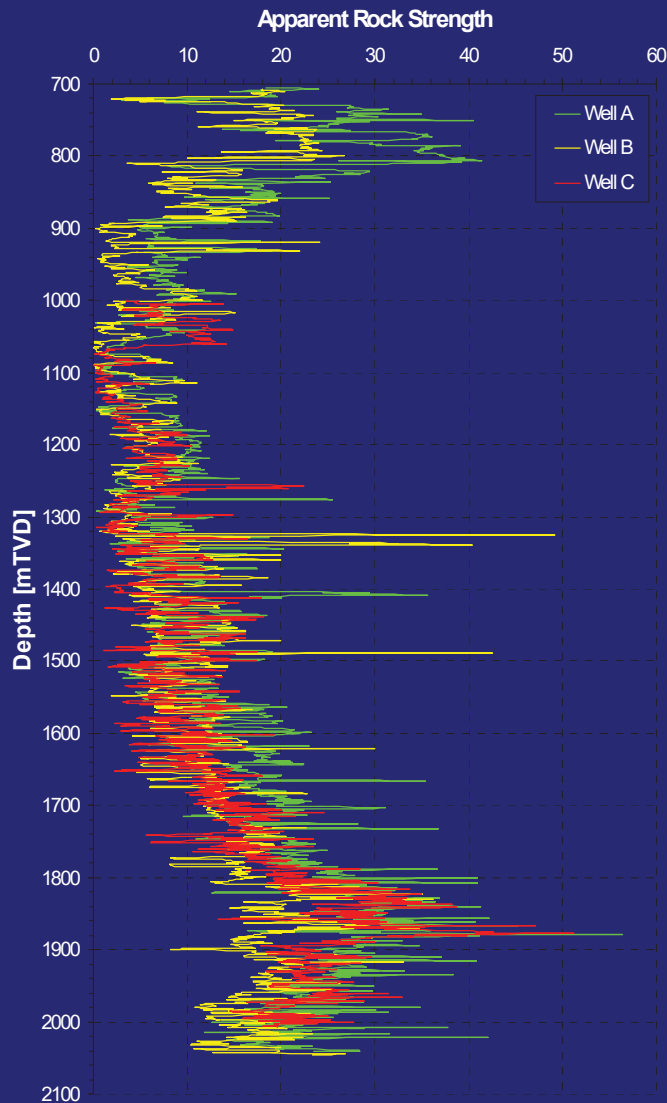
Accelerated Learning
Knowledge Transfer
\$/m

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Drilling Simulator: Required Data to Generate the ARS Log

- **Required Drilling Data:**
 - ROP, WOB, RPM, Flow Rate
 - MW, PV, mud type
 - Surveys
 - Formation tops
 - Drive System: Rotary or PDM, if PDM need rev/L.
 - Bit Record: make, size, type, depth in/out, dull grade, nozzles
 - Bit Specs: IADC code for tricones, design specs for PDC

Drilling Simulator: Procedure to Generate the ARS Log



- For each bit run:**
- Initially assume little bit wear
 - ARS is a function of bit wear
 - Iterate and convergence when field reported bit wear the same

What and How do we optimize ?

- Know the limitations of your equipment
- Number of bits and trips
- Different pull depths
- Bit types and designs within types
- Different WOB/RPM combinations
- Bit hydraulics
- Evaluate and compare performance for the entire section
- Change operating conditions as a function of ARSL variations

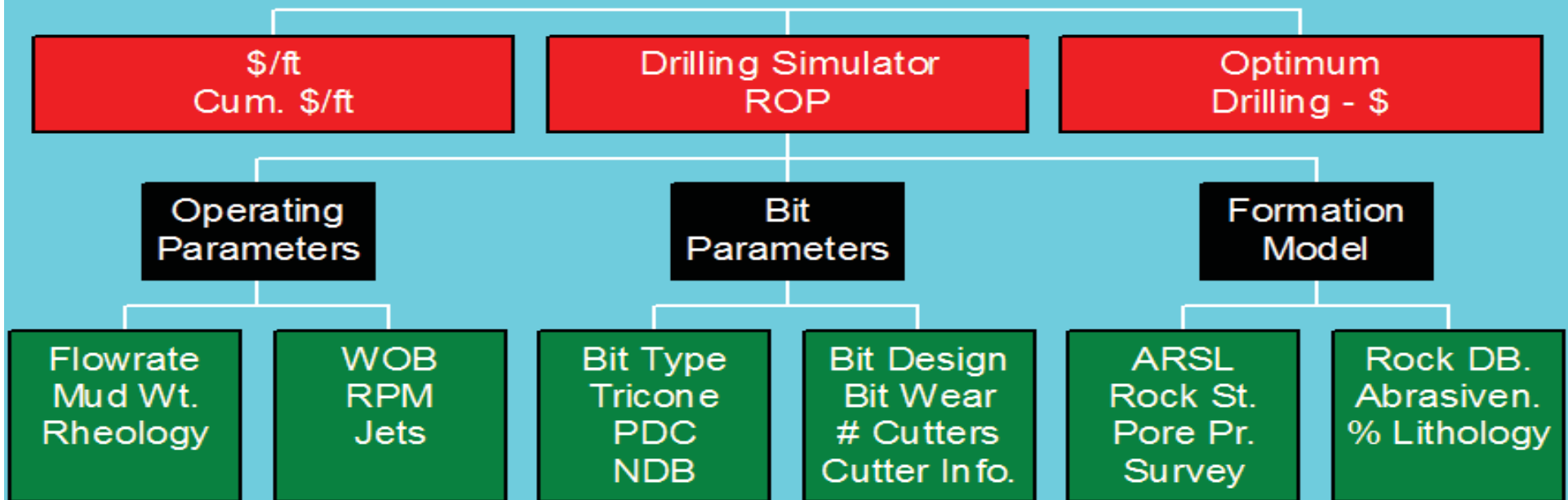


\$/m

Cost Equation and Evaluation

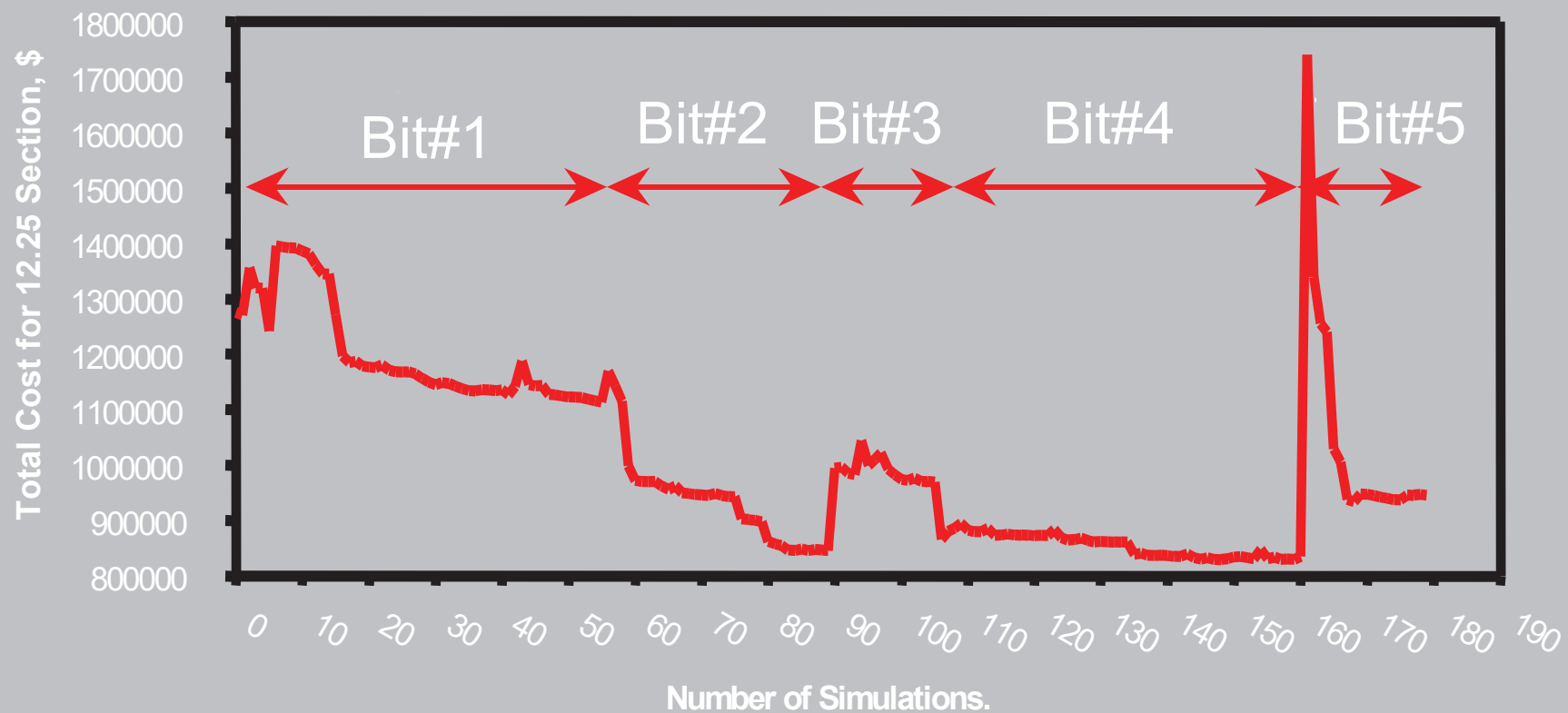
- Costs are bit, rig rate, motor and other costs
- The simulator calculates rotating time (from ROP), connection time and trip time
- The individual bit run cost pr. meter and the cumulative cost pr. meter are used to evaluate the optimum economics

Drilling Simulator Functionality



Typical Simulation Learning Curve for One Bit for One Well Section

Learning Curve for 12.25 Section Using One Bit.

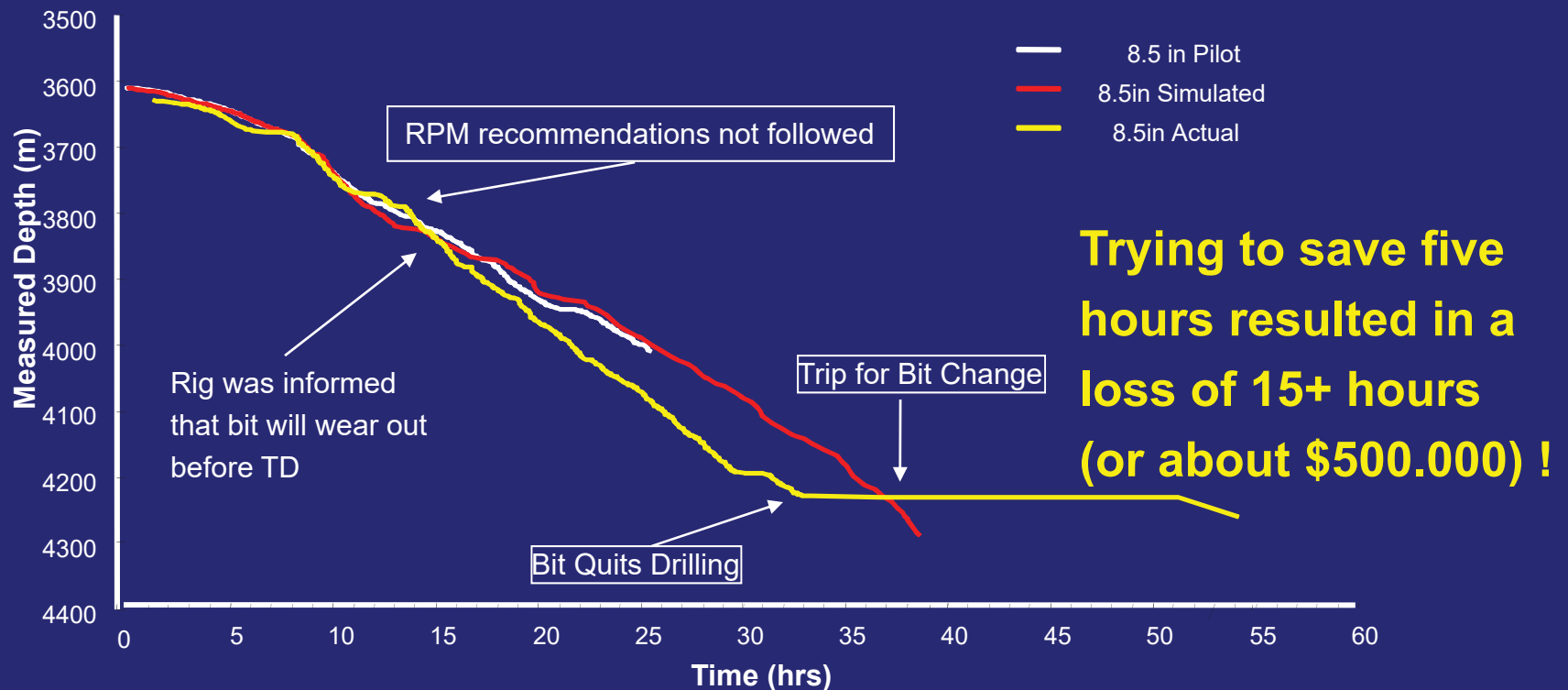


Comparison of Optimized Simulations and Drilling Results

- 150+ wells over 10 years with average depth about 3000 meter
- Alberta, British Colombia in Canada, US, China and North Sea
- Pre-planning plans to the field and follow-up daily at morning meetings

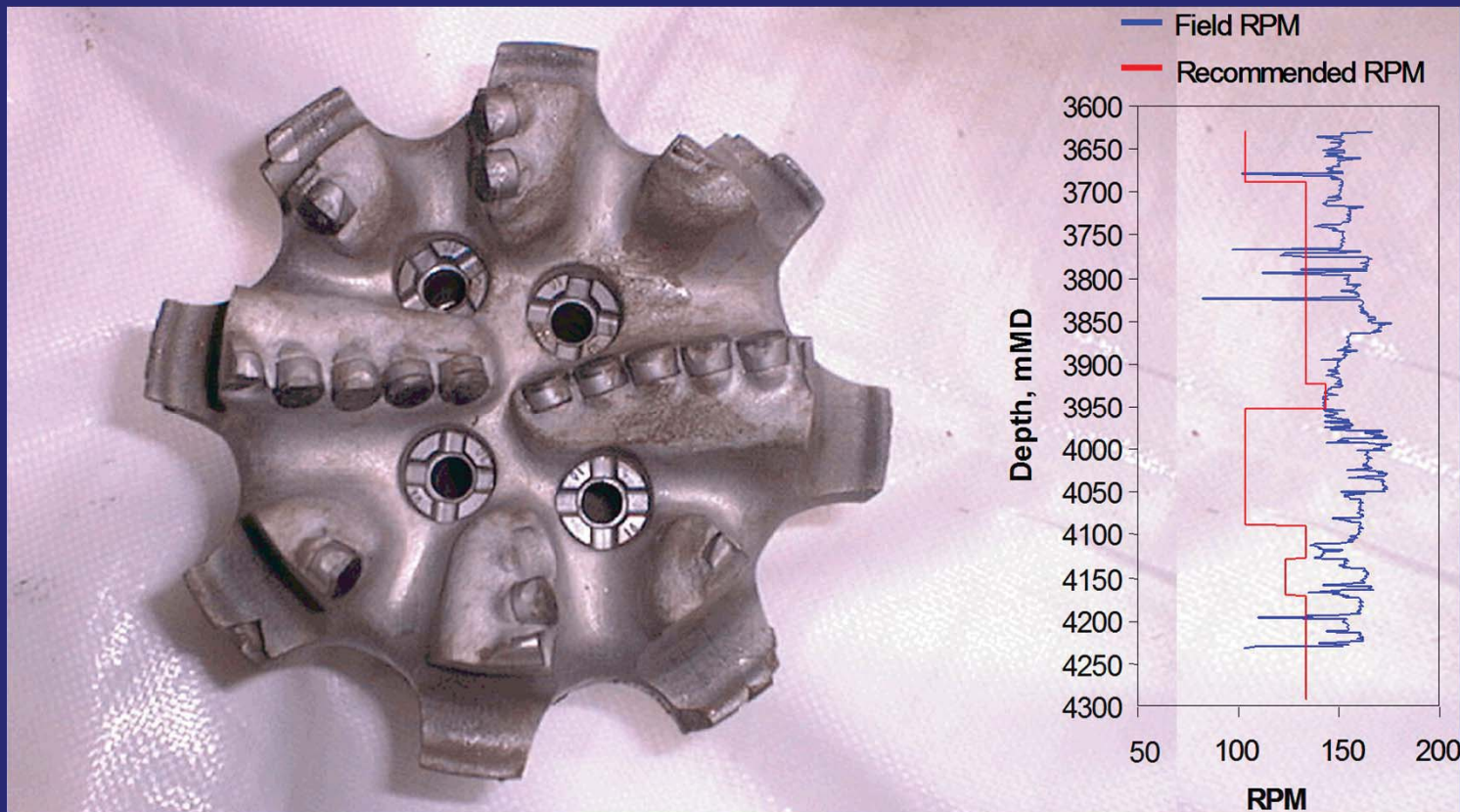
Example #1: Simulation follow up

- 8 1/2" Section Time-Depth Curve North Sea



Example #1: Simulation follow up

- Re-simulations showed that if recommendations had been followed the bit would have made TD
- Recommendations and follow-up proves its value

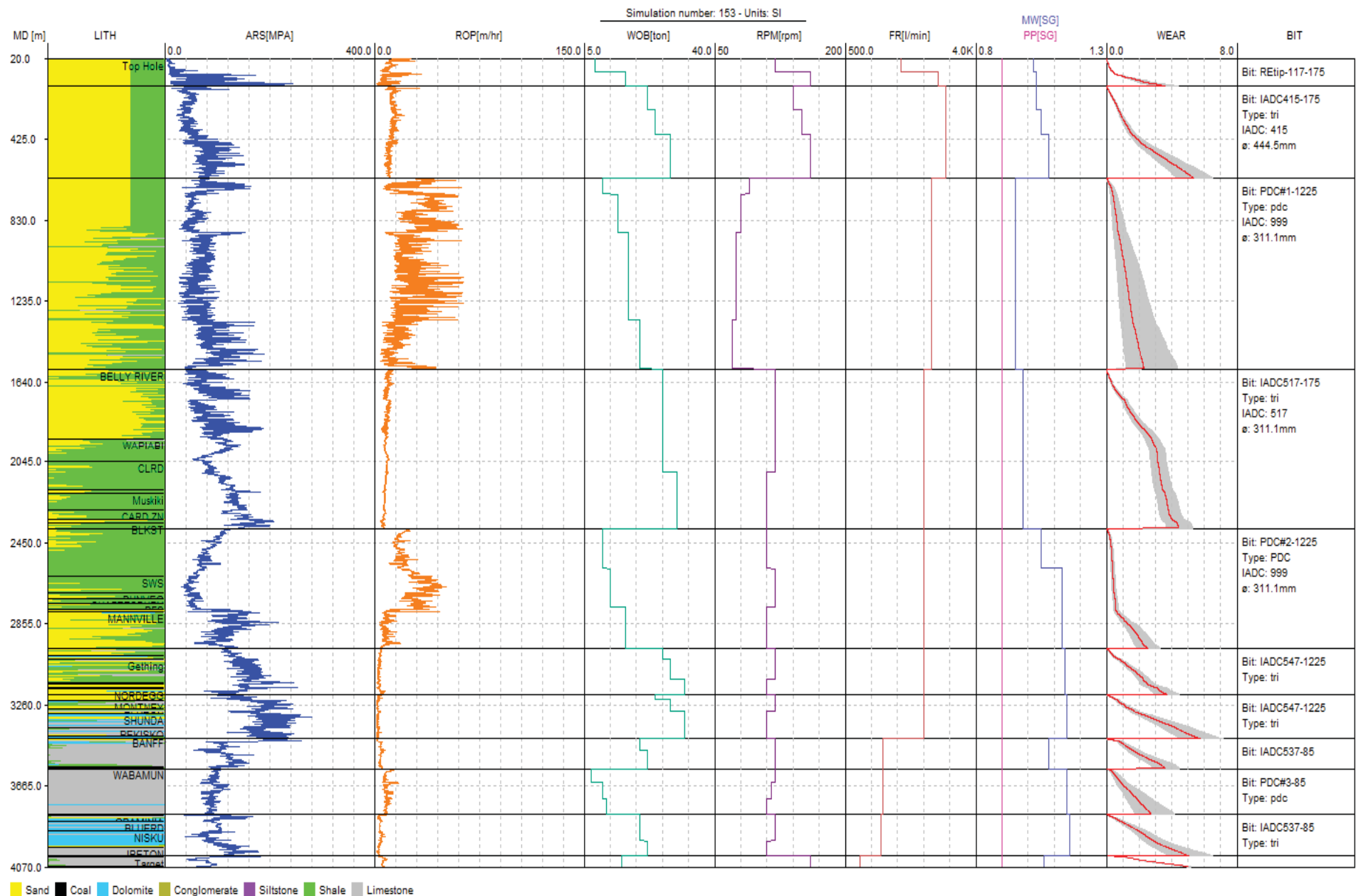


Example #2: Optimized Simulation for Well In Western Canada

- Simulate the best bit performers
- Maximize the bit runs by balancing bit wear and operating parameters for optimal performance
 - ARS profile variations
 - 3 to 5 sections with parameters variations

\$/m

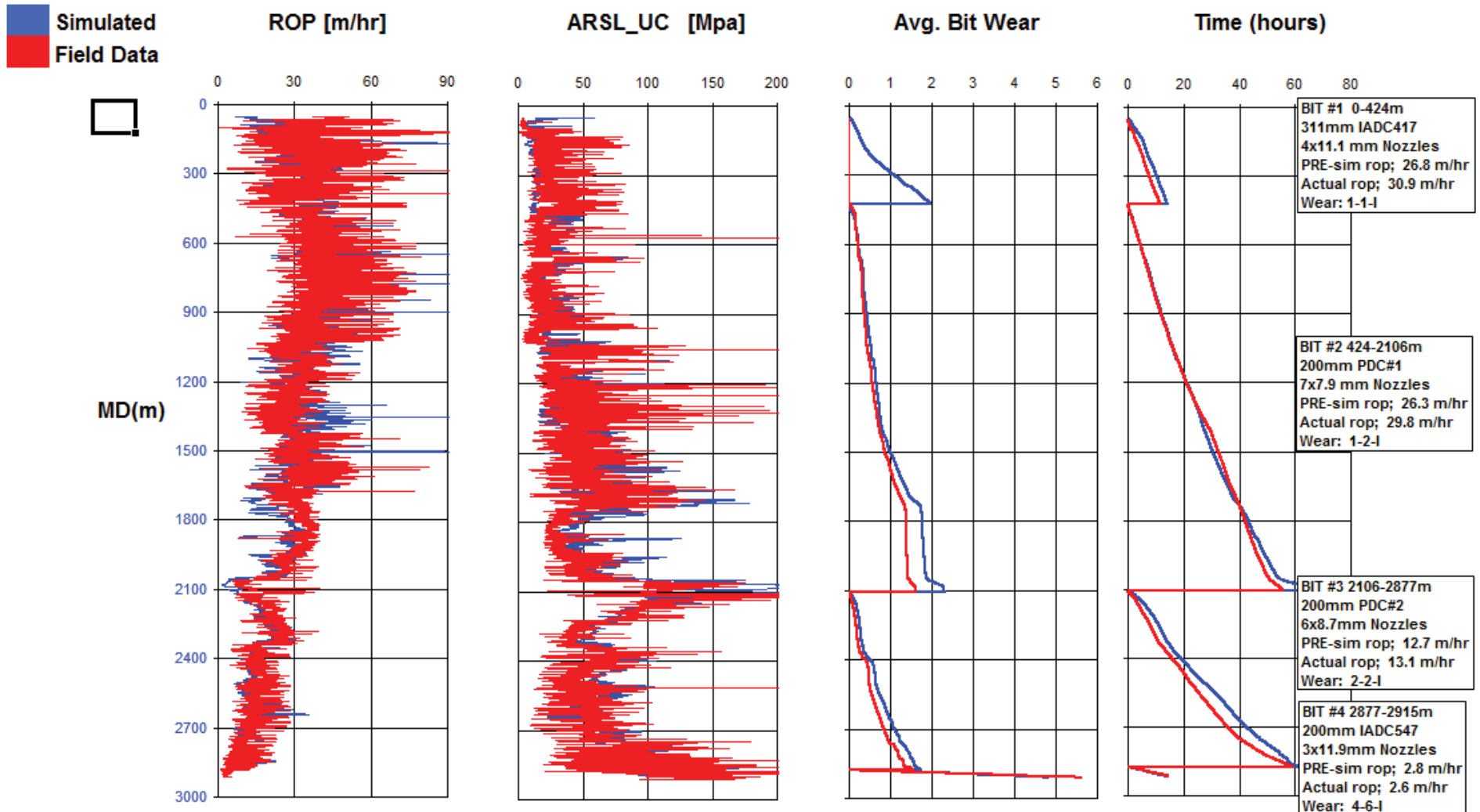
Example #2: Optimized Well



Example 2: Well Follow-Up

□ Done Daily

□ Overlaid ROP, ARSL, time and bit wear



Example#3

Field Case - China

- Exploration well in Sichuan Basin, China
- Second part of 2010 with two operators
- Drill to 4045m
- Previous pacesetter used 144 days to TD
- Typical time to TD wells in the area is between 200 and 300 days
- Same Procedure as in Western Canada (Example #2)

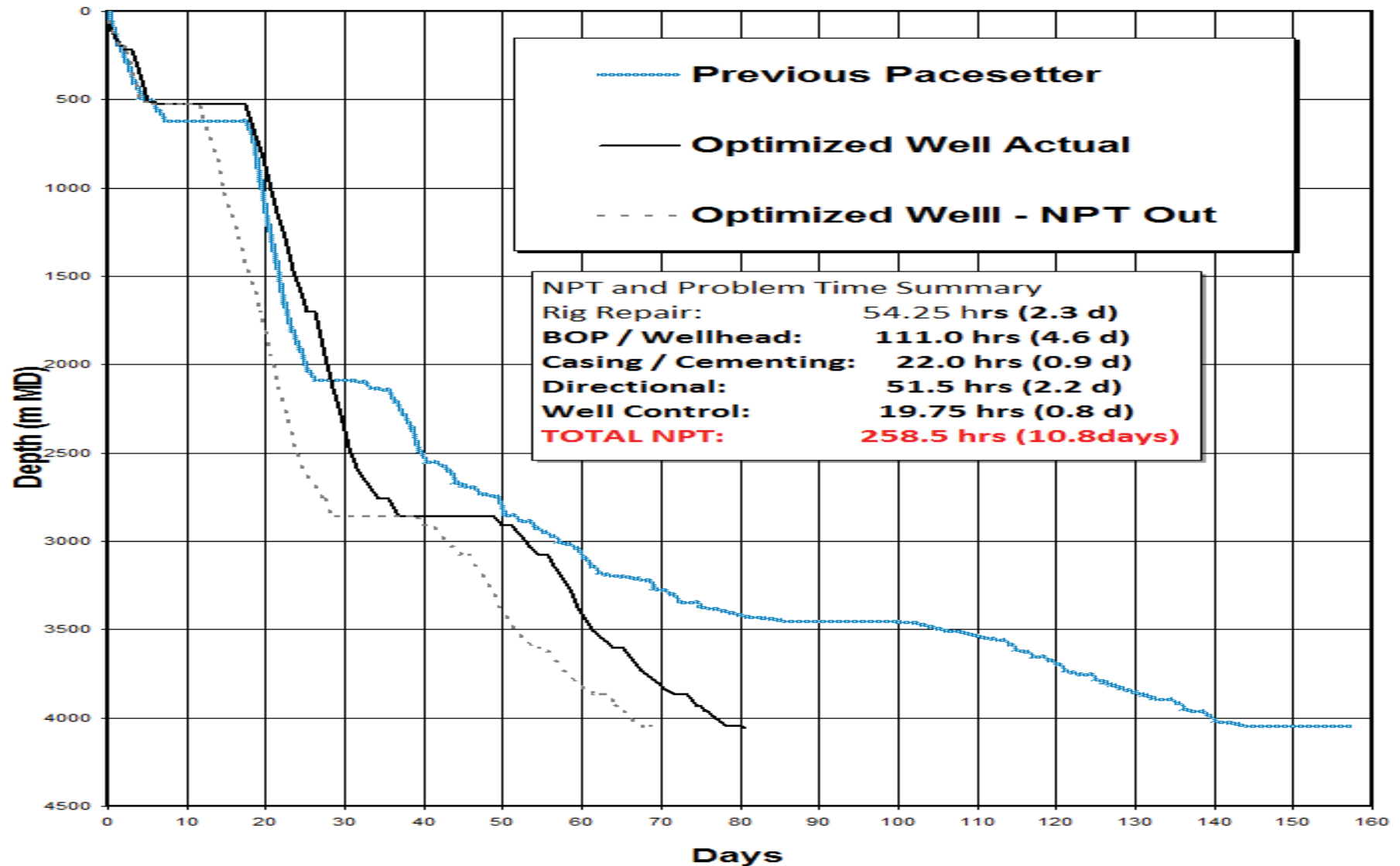
China, Sichuan Location



Sichuan Time-Depth Curve

Sichuan Well Results

Days vs Depth



Example#3 -Results - Savings

- The use of the drilling simulation technology was a success
- Previous Pacesetter drilled in 144 days and simulated well drilled in 80 days including 11 days of NPT
- 14 bits were simulated and 14 bits were used (Previous Pacesetter used 22 bits)
- Total rotating hours was 870 versus 1450 on previous pacesetter (~740 Simulated)
- Estimated savings at least \$3MM (Rig Rate \$50K/day)

Summary and Conclusions

ROP Models

- The simulator history, development and application
- Used on 200+ wells
- Predictions to actual drilling data
- Pacesetter performance is constantly pushed
- Knowledge transfer

Summary and Conclusions

ROP Models

- 15-20 % reduction in total drilling time in mature fields (+30 wells)
- Up to 50 % reduction in total drilling time in less mature fields (1-5 wells)
- Follow up results in better communication
- Drilling data is an unused resource!

Questions?



Thank You!

