Advanced Horizontal Technologies Improve Drilling Performance in the Barnett Shale*

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Abstract

The Barnett Shale is the producing reservoir in the most productive and fastest growing natural gas field in North America. It has a multi-trillion cubic feet equivalent upside potential but poses several drilling and completion challenges. A precise evaluation of the bedding planes, natural and induced fractures is critical to maximize the shale gas recovery. The initial LWD tool-runs generated images of low resolution and penetration rates had to be controlled below 50 ft/hr to ensure good image quality. To overcome this challenge state-of-the art resistivity imaging LWD tools were developed and run. The high resolution images generated from these LWD tools while drilling up to 180 ft/hr have yielded an unprecedented quantity and quality of geological data. This has tremendously aided in reservoir evaluation and will substantially improve recovery of natural gas. To address drilling challenges, bottom hole assemblies were re-designed and drilling parameters optimized. A new directional drilling system with an automated rib-steering closed loop system was utilized. Real time downhole drilling data was acquired and utilized for early detection of drilling problems. A precise evaluation of bed boundaries and formation dips was crucial for precise placement of the well. Real time gamma imaging LWD tools were run; the high resolution images developed from azimuthal gamma ray measurements were utilized to precisely detect bed boundaries and estimate formation dips accurately. These advanced technologies have been implemented to drill several wells in the Barnett Shale with excellent results. Drilling performance has significantly improved and precise placement of the wellbores has been achieved. The rotating hours have been reduced from 330 to 165 hours per well. A 48.39% reduction in days required (31.2 to 16.1 days per well) from spud to rig release has been realized.

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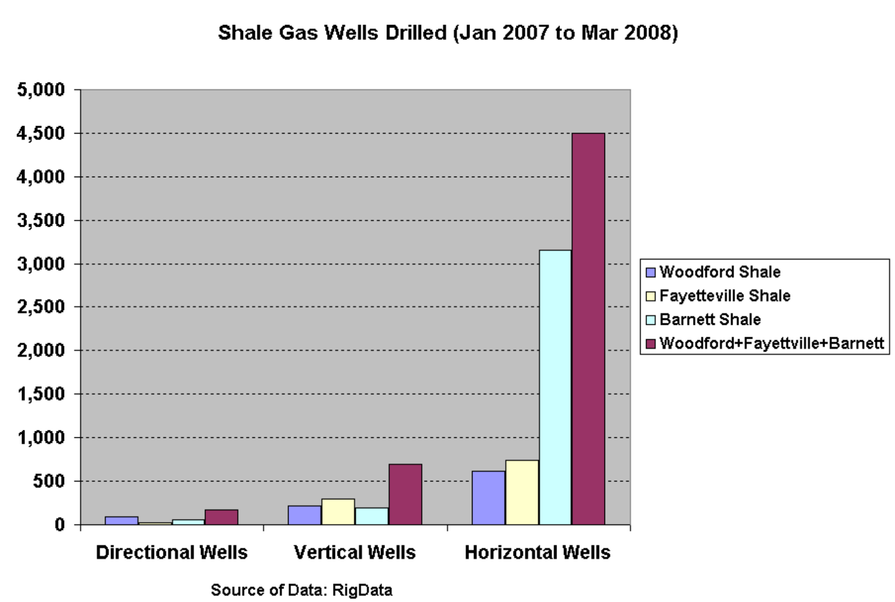
Presentation Outline

An optimization project aimed at specific but key drilling and completion challenges in an unconventional play

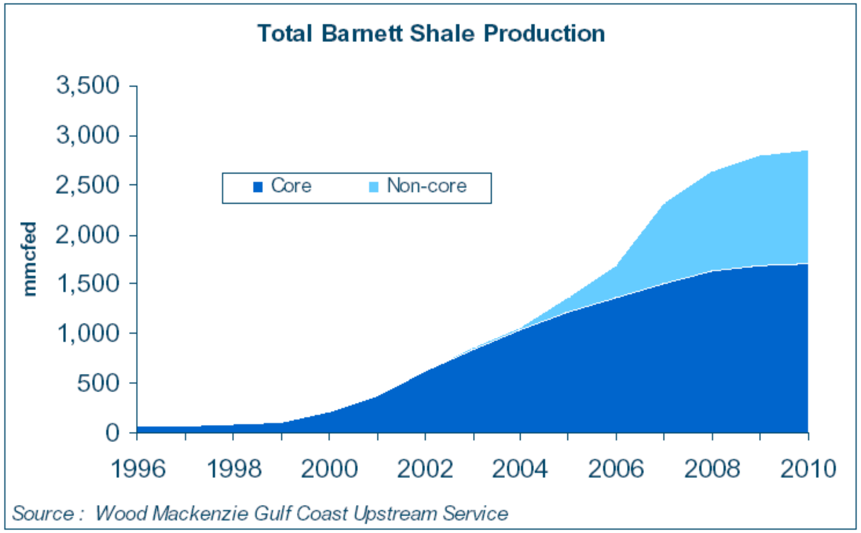
- **Barnett Shale - Growing Need for New Technology**
  - Rapidly Growing Unconventional Resource
  - Challenges and Evolution of Well Design

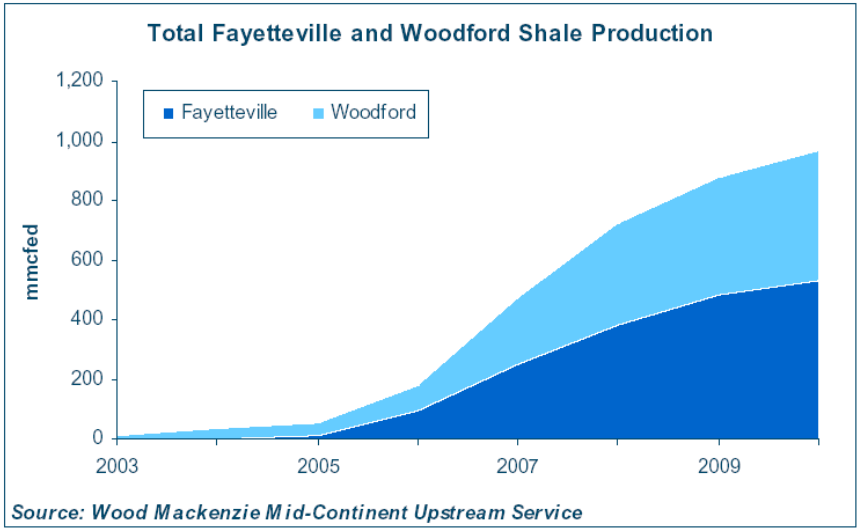
- **Barnett Shale Drilling/Completion Challenges**
  - Logging While Drilling
    - Resistivity Imaging
  - MWD Tool with Imaging Capabilities
    - Real Time Gamma Imaging
    - Real Time ECD Monitoring

Evolution of Shale Gas Well Design to Optimize Production



- Hydraulic Fracturing Due to Low Porosity
- Horizontal Drilling to Maximize Production





Answers While Drilling™

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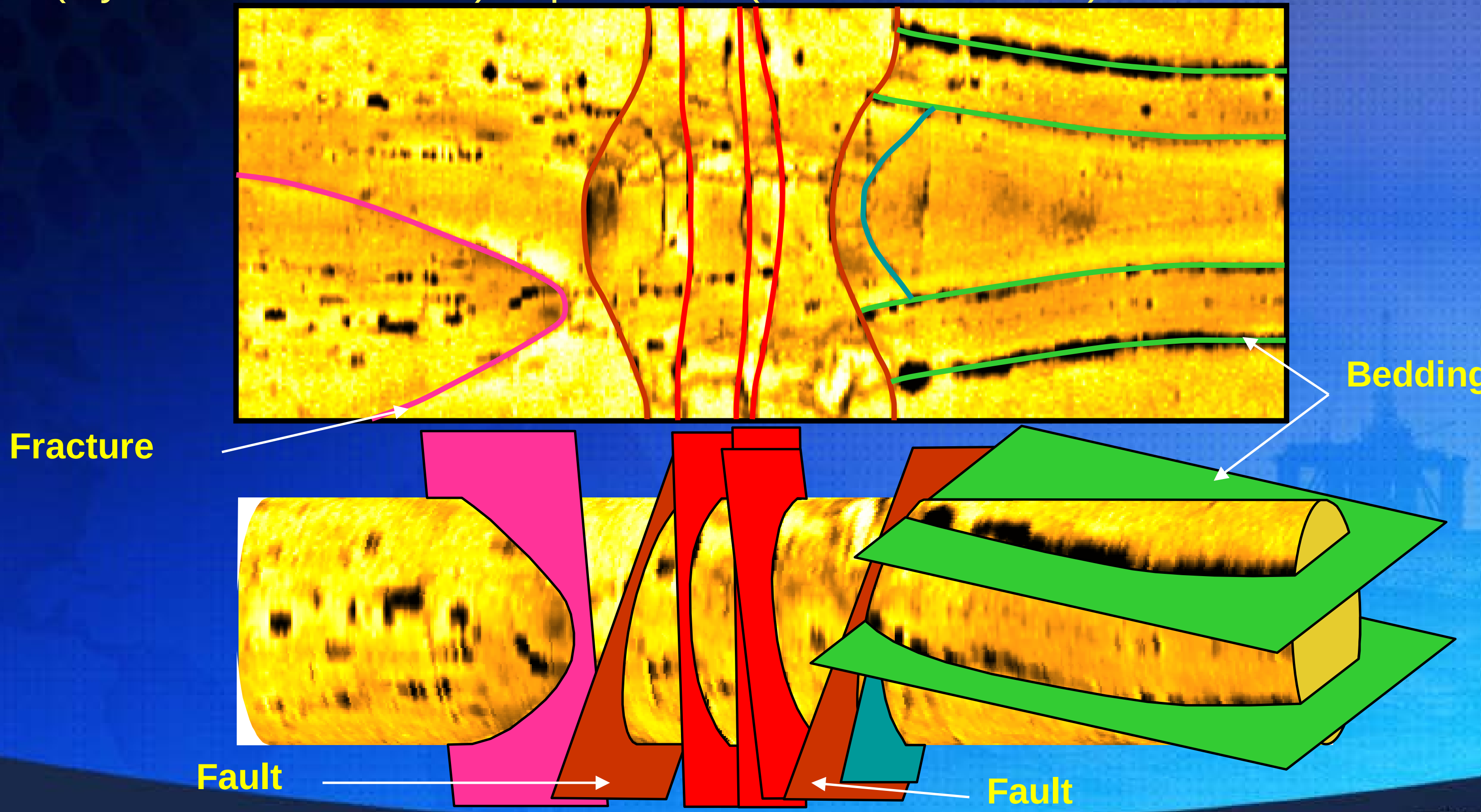
Drilling & Completion Challenges - Significance of Images

- High Quality LWD Images While Drilling
- LWD Data Acquisition Without Compromising Drilling Performance
- Interpretation of Geo-mechanical Features
- Visualization of Distribution, Orientation and Spatial Density of Fracture Sets
- Identification and Interpretation of Faults
- Steer the Well to Stay in Payzone
- Apparent Dip Calculation

Borehole Images in Horizontal Wells

- Images used to visualize the orientation of bedding, indicating well trajectory (up or down section)
- Relationships of fractures to bedding and other fractures, including containment (layer-bound fractures) or pervasive (fracture corridors)



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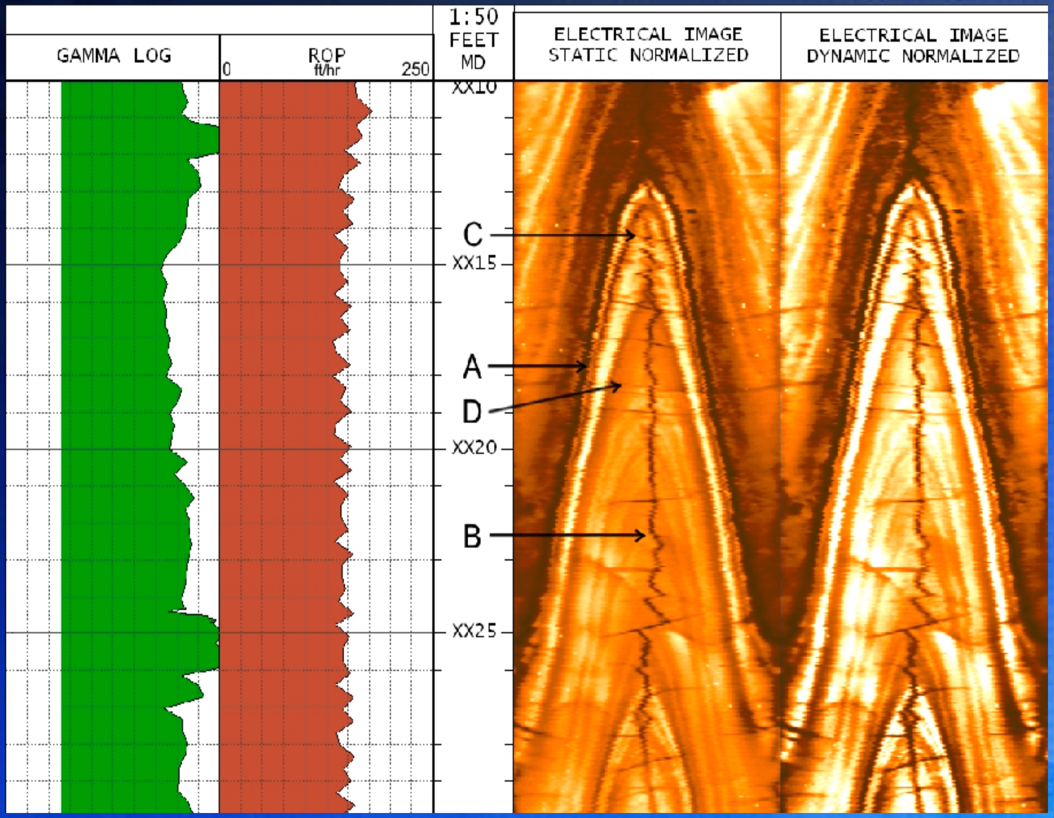
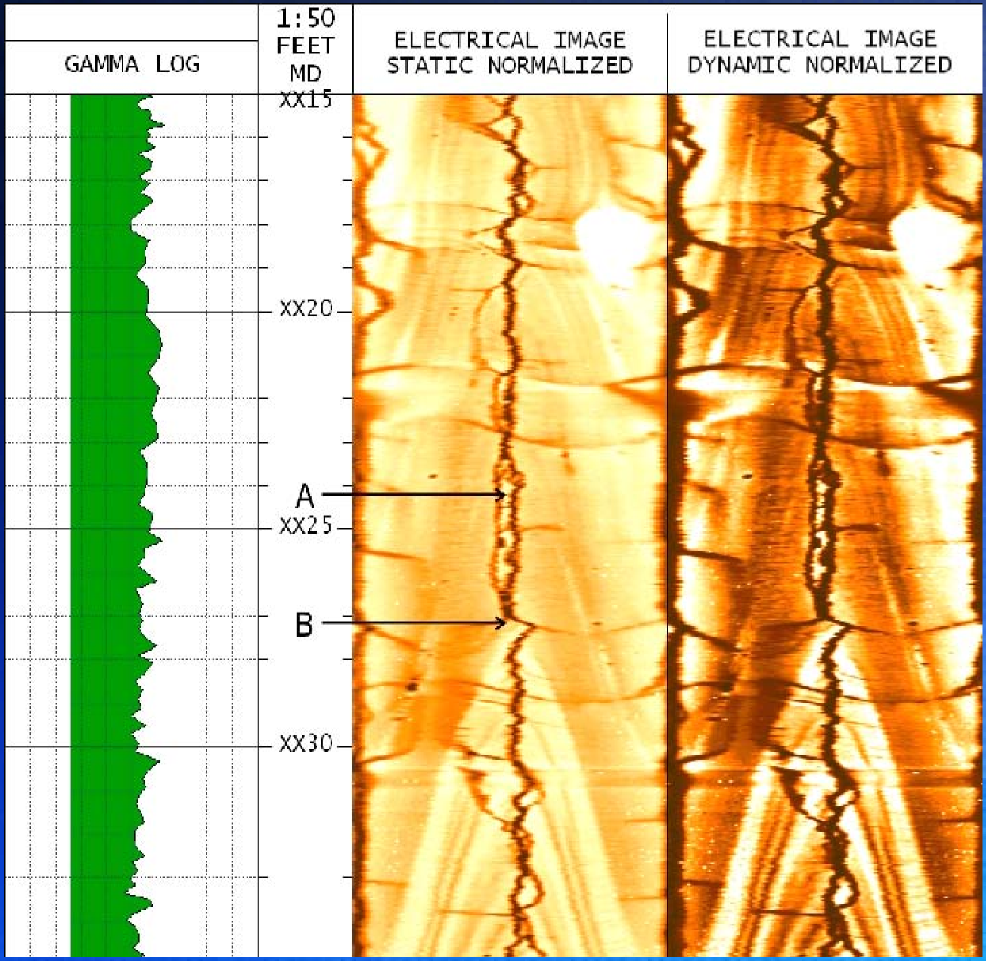
Resistivity Image Quality at High ROP

Average rate of penetration in lateral interval @ 150 ft/hr



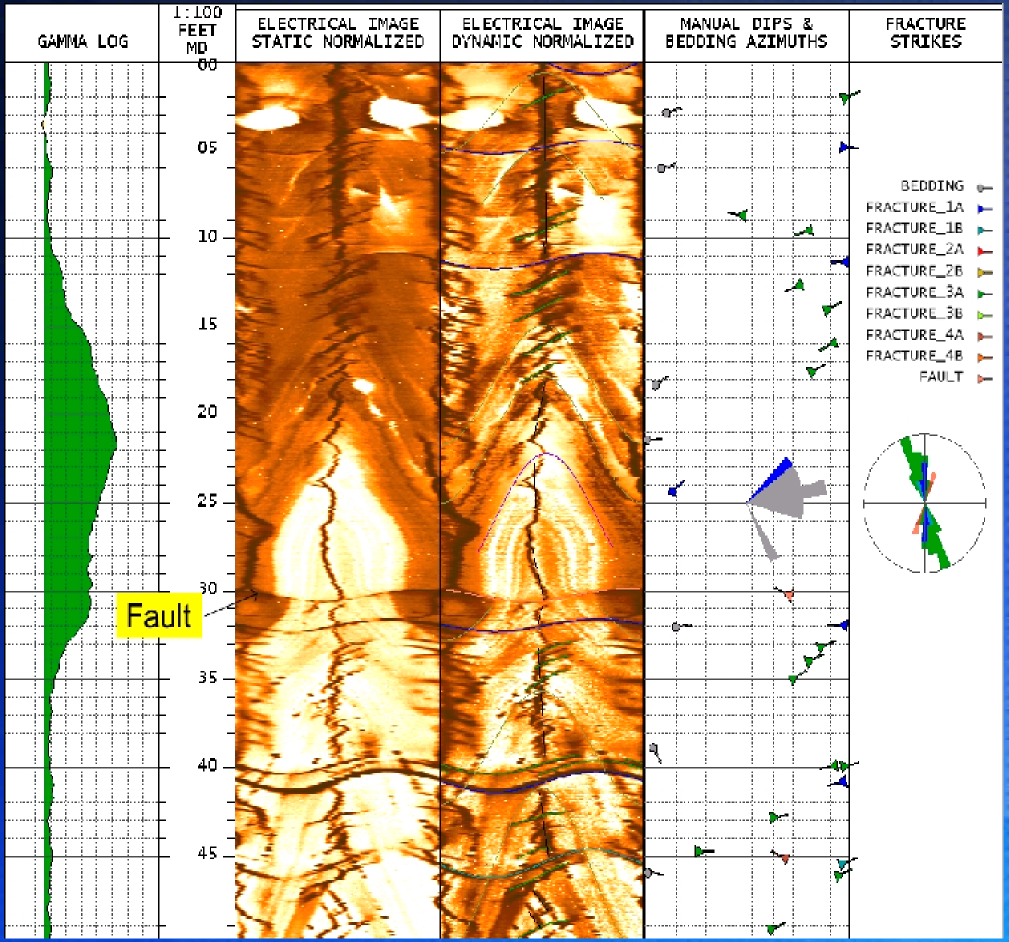
A. Internal bedding
B. DITF at bottom of borehole and three orientation sets of natural and enhanced fractures
C. Fracture orientations confined by lithology
D. Fractures continuous around the borehole wall

Resistivity Imaging:Geo-mechanical Application for Successful Well Bore Integrity



A. Fracture bifurcates in several places
B. Intersection of DITF's with fractures and the small offset

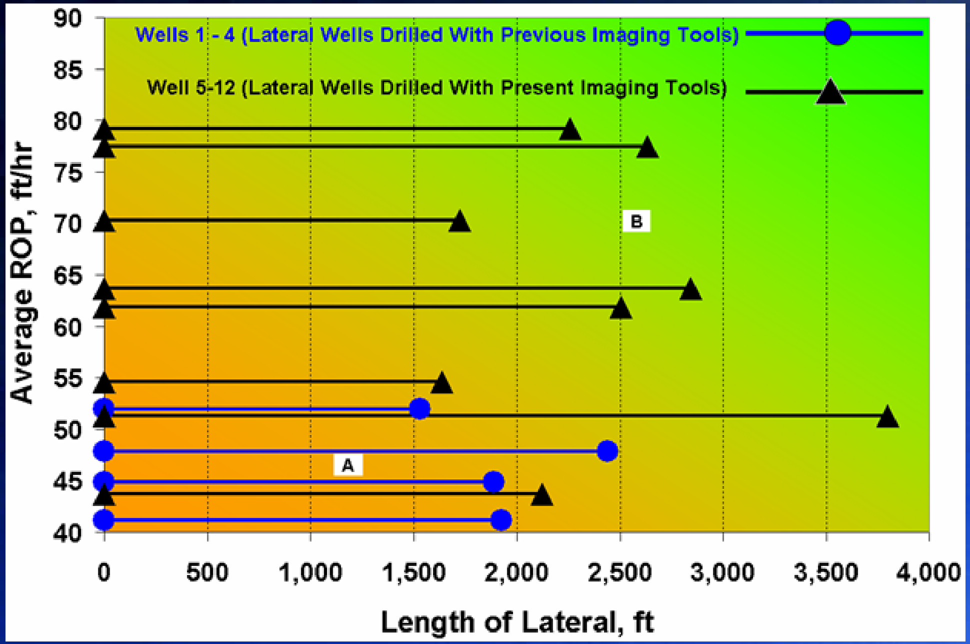
Resistivity Imaging-Fracture Characterization

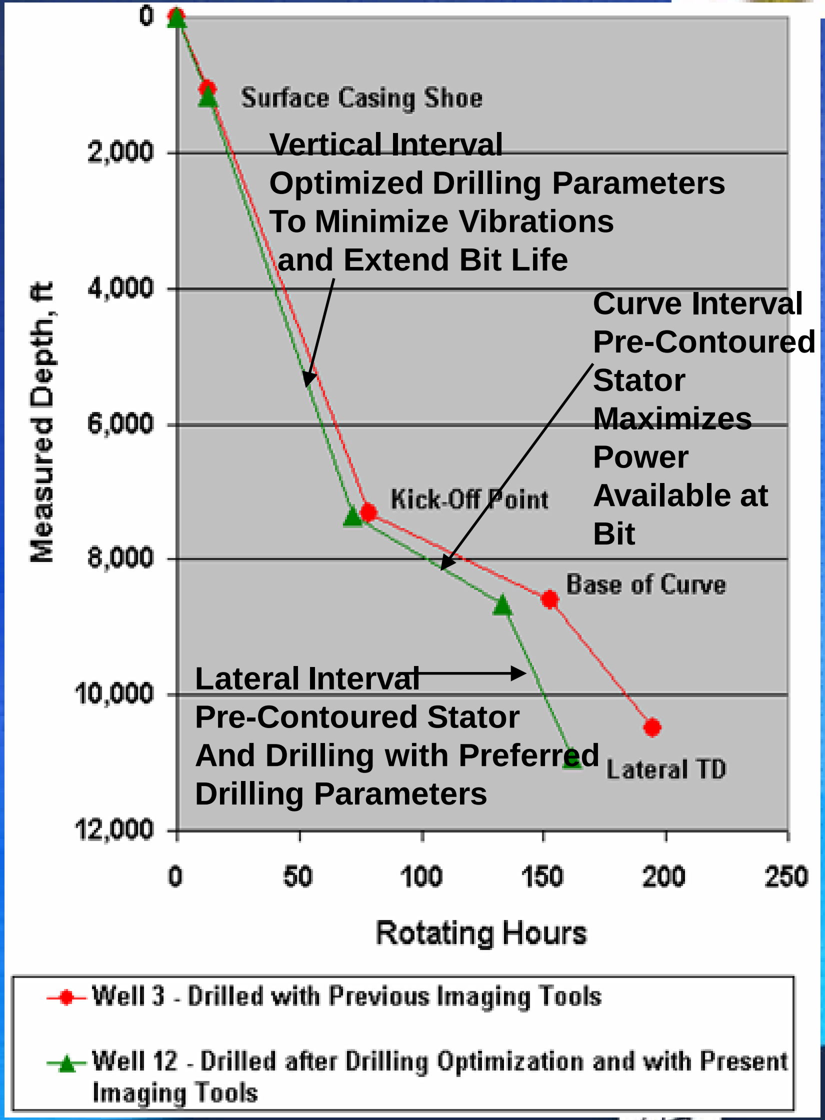


Fracture analysis used for:

- Fracture characterization
- Fracture density, geometry, intersections and continuity
- Location of areas to use for fracture stimulation

Performance Improvements by Utilizing Advanced Resistivity Imaging Technology





- Average ROP in lateral up to 80 ft/hr
- Instantaneous ROP in lateral up to 180 ft/hr
- Length of lateral interval up to 3,800 ft

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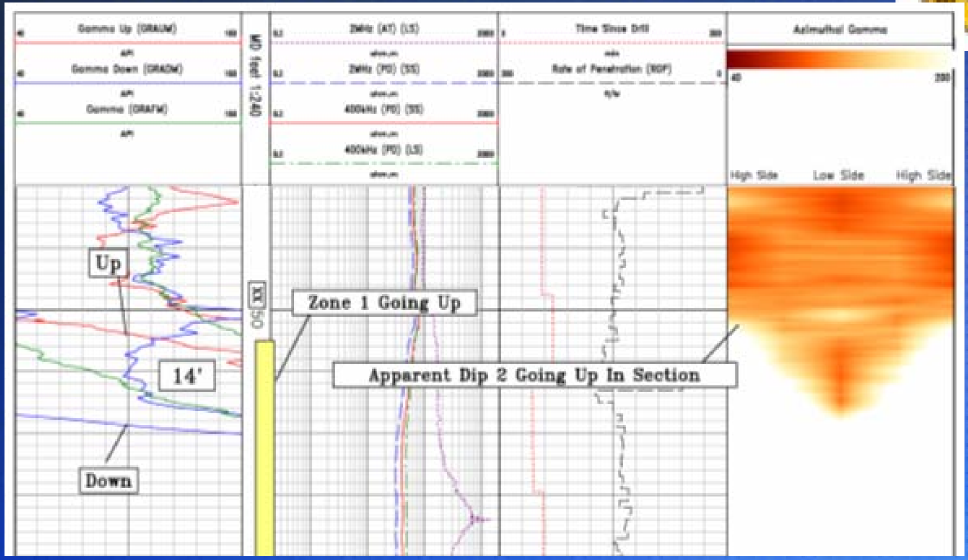
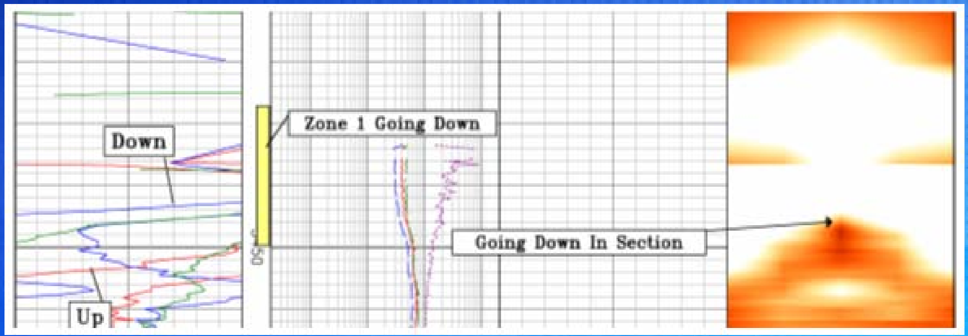
MWD with Real Time Gamma Imaging and Real Time ECD Measurements

Measurements

- Vibration / Stick-Slip
- Directional
- Resistivity
- Dual Azimuthal Rotating Gamma
- Bore & Annular Pressure

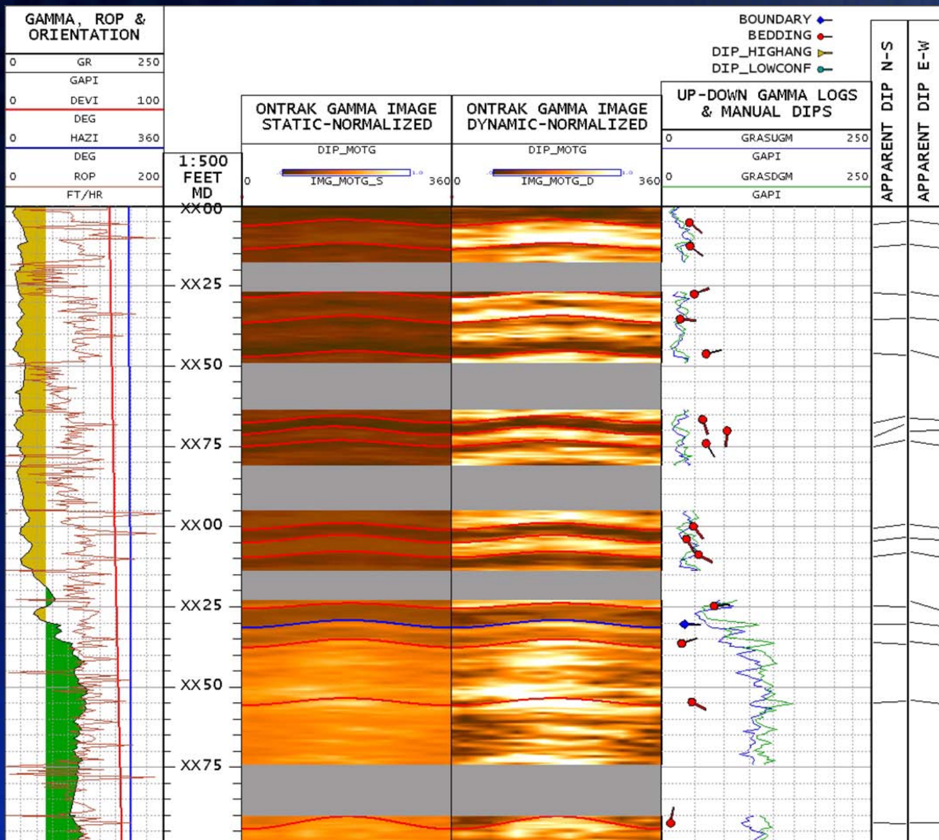
  (flow on & off)

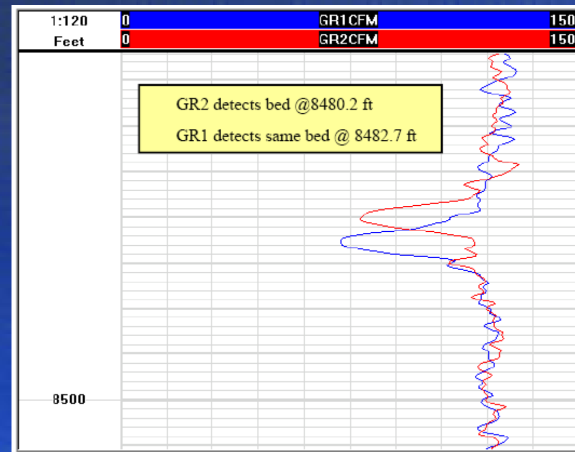


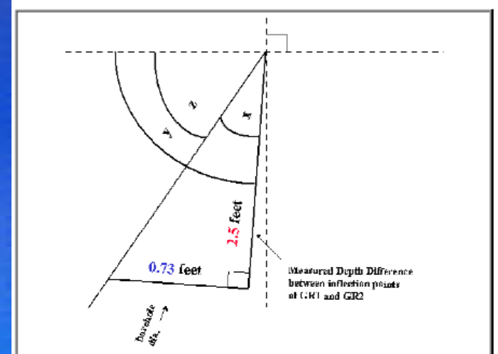


- Indicates bed entry from above or below
- Real time apparent dip calculation
- Real time fault indication from gamma image

Apparent Dip Calculation - Gamma Images







Tan x = 0.73/2.5
x = 16.2

y = 90 - well inc
= 90 - 1.8
y = 88.2

z = y - x
= 88.2 - 16.2
z = 72.0

Procedure utilized to calculate apparent dip

- High density of dips
- Build section with several sliding intervals
- Dips picked in high & low gamma response lithologies
- Boundary orientation can also been seen

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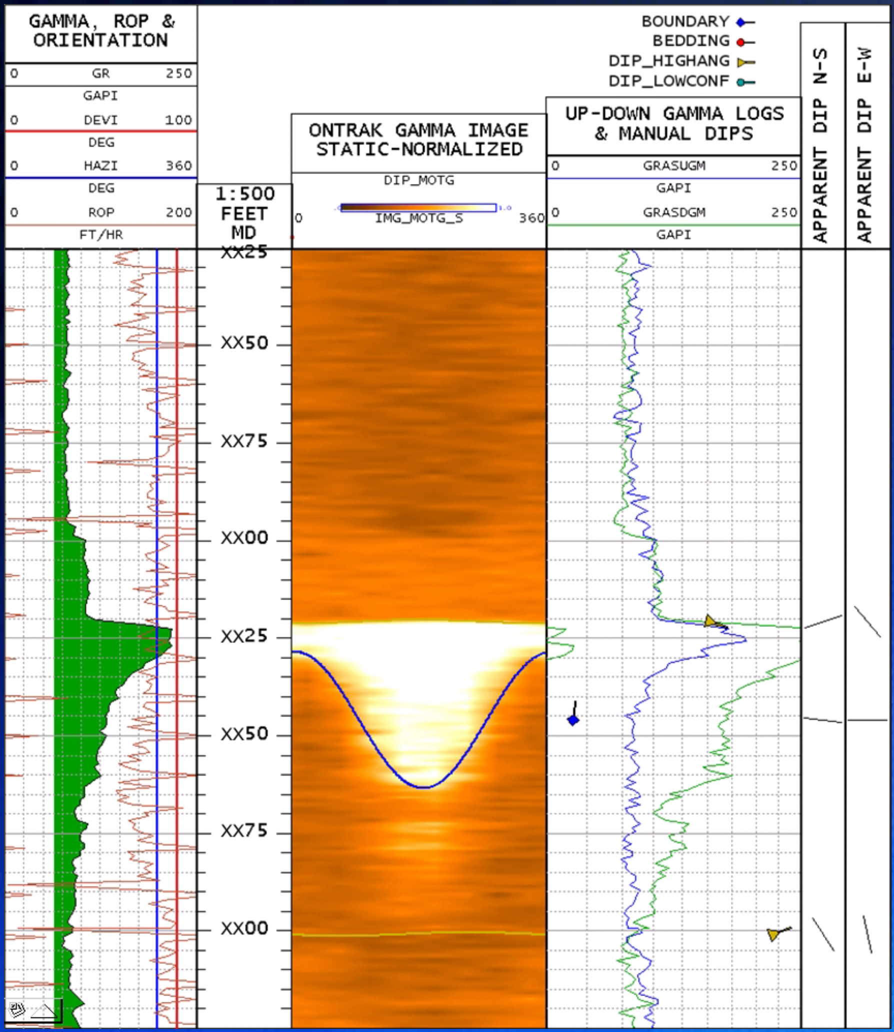
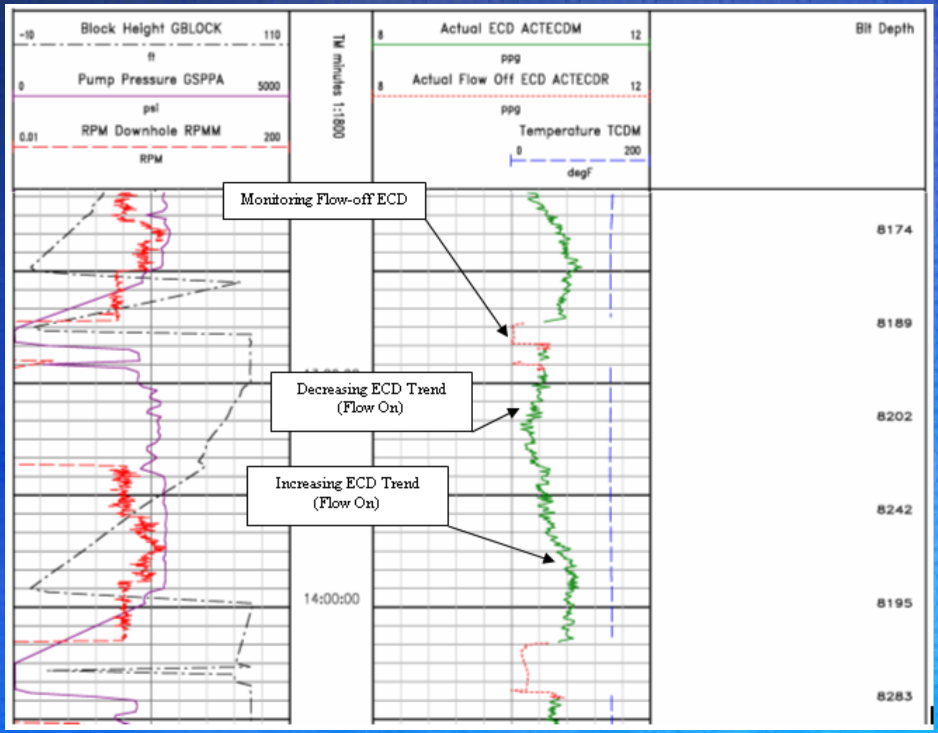
Benefits of Real Time Gamma Imaging and Real Time ECD Data

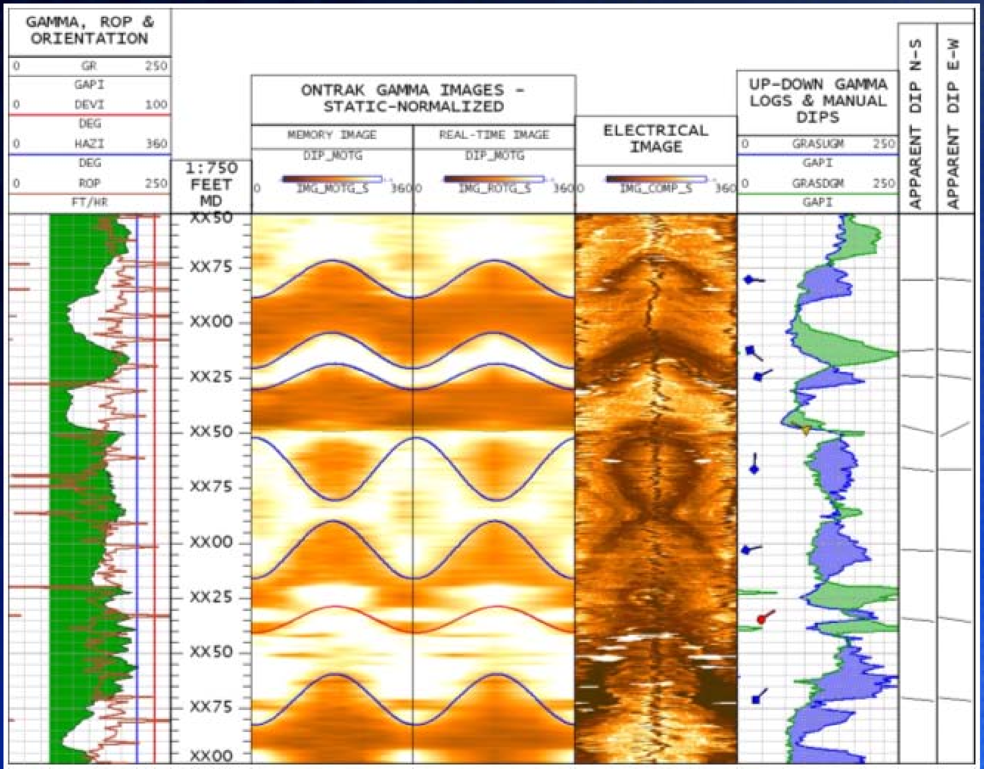


Gamma Image Showing Major Fault



Monitoring of Real Time ECD Data

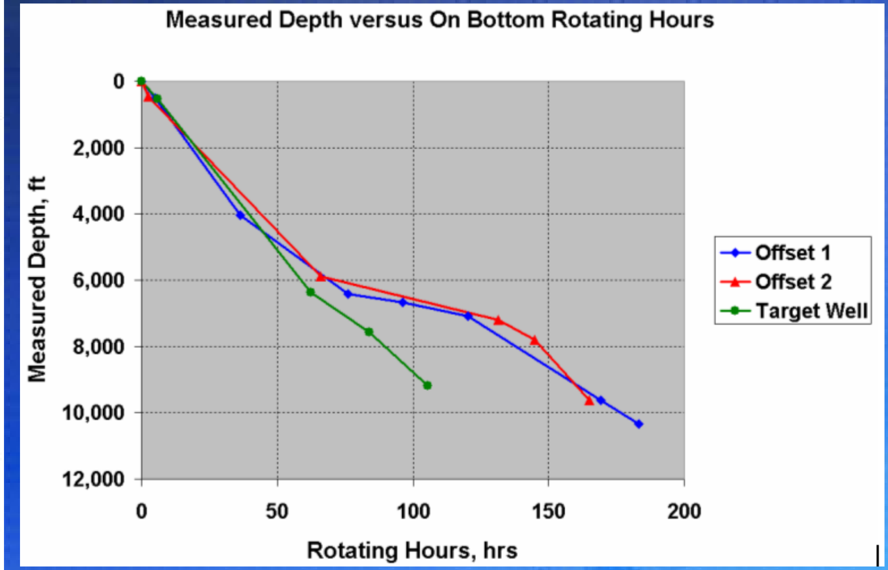
Real Time Gamma Image Quality and Drilling Performance Improvements



Gamma Image Memory

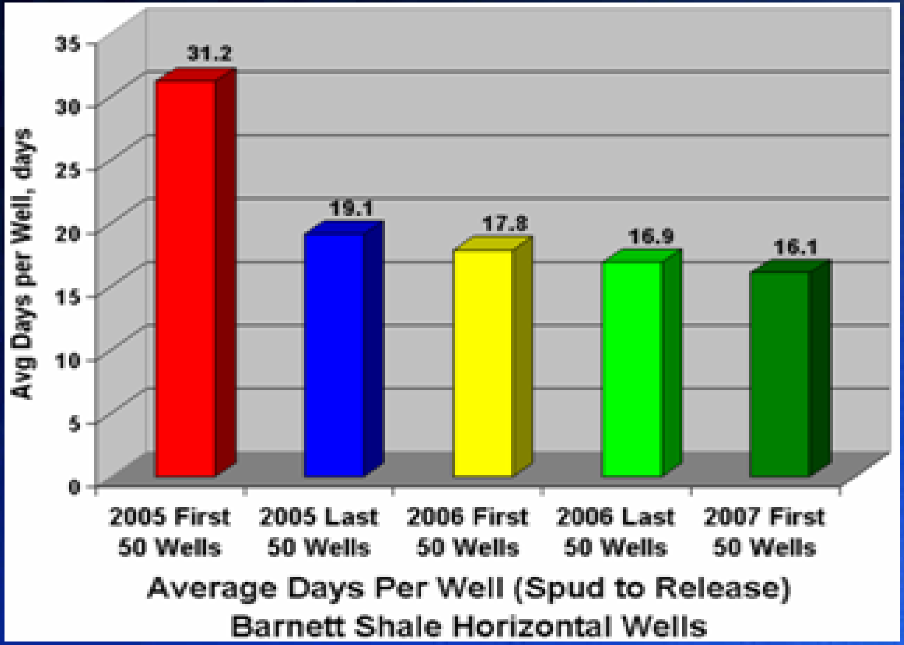
Gamma Image Real Time

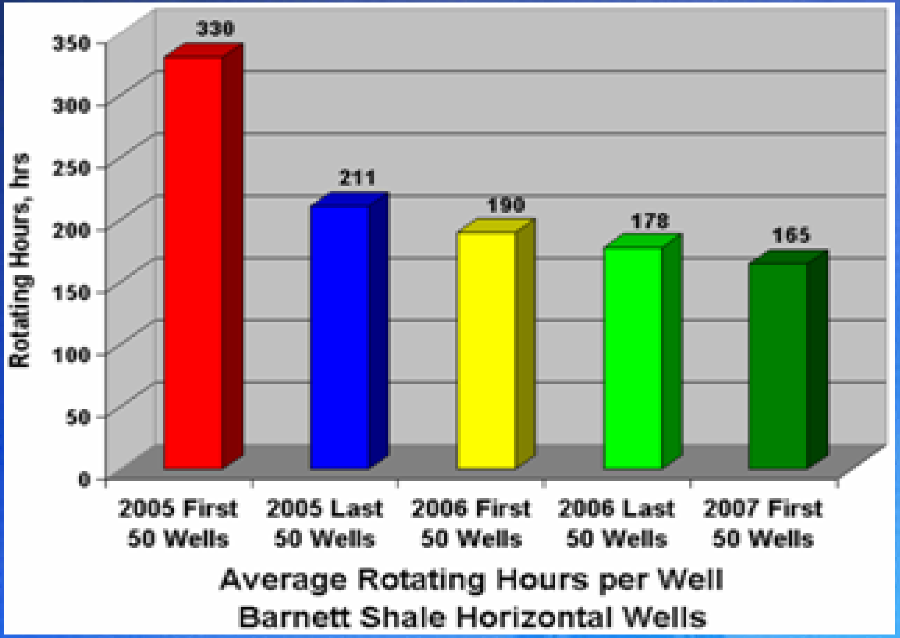
Resistivity Image Memory



Performance Improvements

Drilling Performance Improvements 2005 to 2007





Average days per well reduced from 31.2 to 16.1 days

Average rotating hours per well reduced from 330 to 165 hours

Conclusions

- Reduced Drilling Days by:
  - Drilling lateral interval with preferred drilling parameters
  - Minimized slide drilling by steering the lateral interval with real time gamma images
  - Geo-mechanical analysis from high quality resistivity images
  - Real time monitoring of ECD data

- Optimized Completion by:
  - Fracture characterization from high quality resistivity images without compromising ROP
  - Identifying faults from images
  - Better placement of wells by steering with real time gamma images

Thank You!

Questions?