

High Angle GWD90™ Experience

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March, 2013

Gyro While Drilling (GWD™)

- » North Seeking gyro sensors located in the BHA
- » Utilizes mud pulse, E.M. telemetry or wired pipe to transmit survey information to surface
- » Initially run to replace wireline gyro single shot, orientations and steering services
- » Originally limited to about 20° inc.



GWD™ Evolution



2002
GWD™

2008
GWD with EM
Telemetry

2011

GWD40™

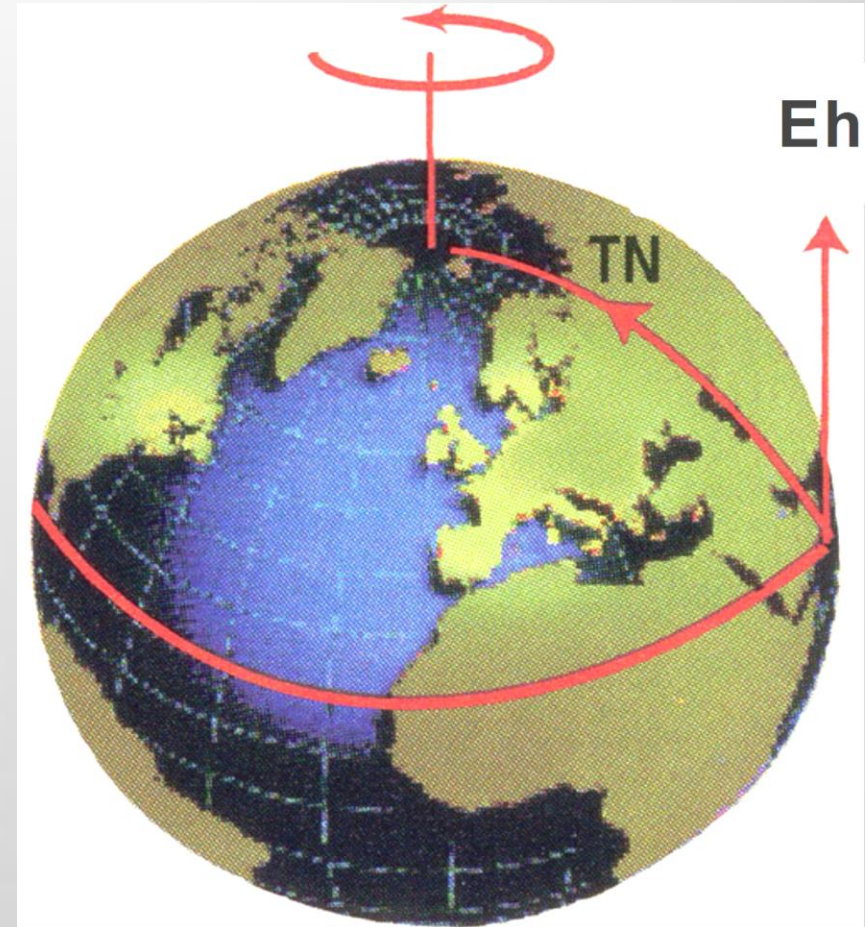
MXY™ Gyro

GWD70™

2013
GWD90™

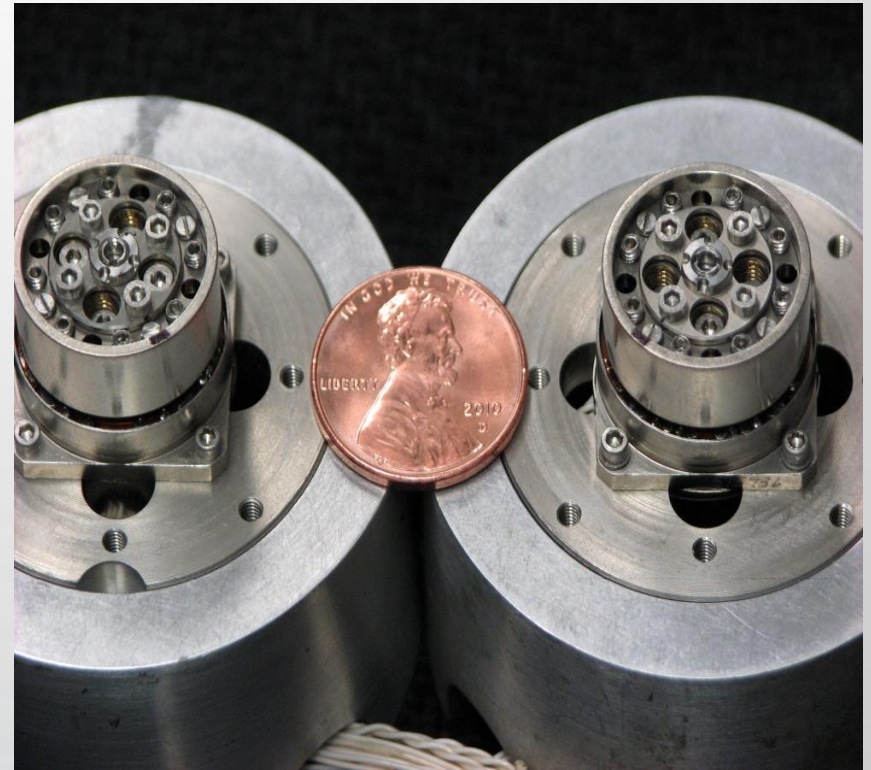
GWD™ – Initially inclination limited

- » Increasing inclination moves the sensitive gyro axes away from horizontal component of Earth rate
- » Gravity sensitive error terms effect on azimuth measurement becomes more significant as inclination increases



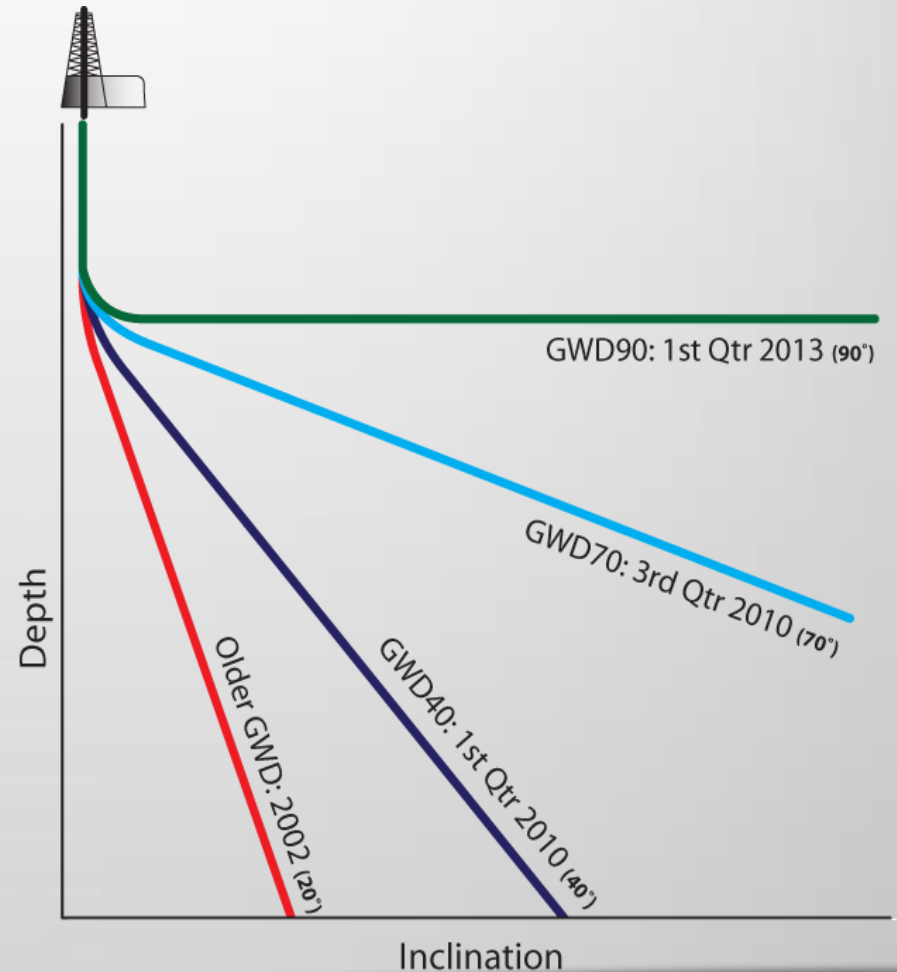
MXY™ Gyro Sensors

- » First gyro developed and optimized specifically for oilfield applications
- » Larger mass and higher spinning speed resulting in increased sensitivity
- » Improved signal to noise ratio
- » Better bias stability
- » Increased shock tolerance
- » Complete control of system design, manufacture, calibration, deployment and operation



Benefits of High Angle GWD™

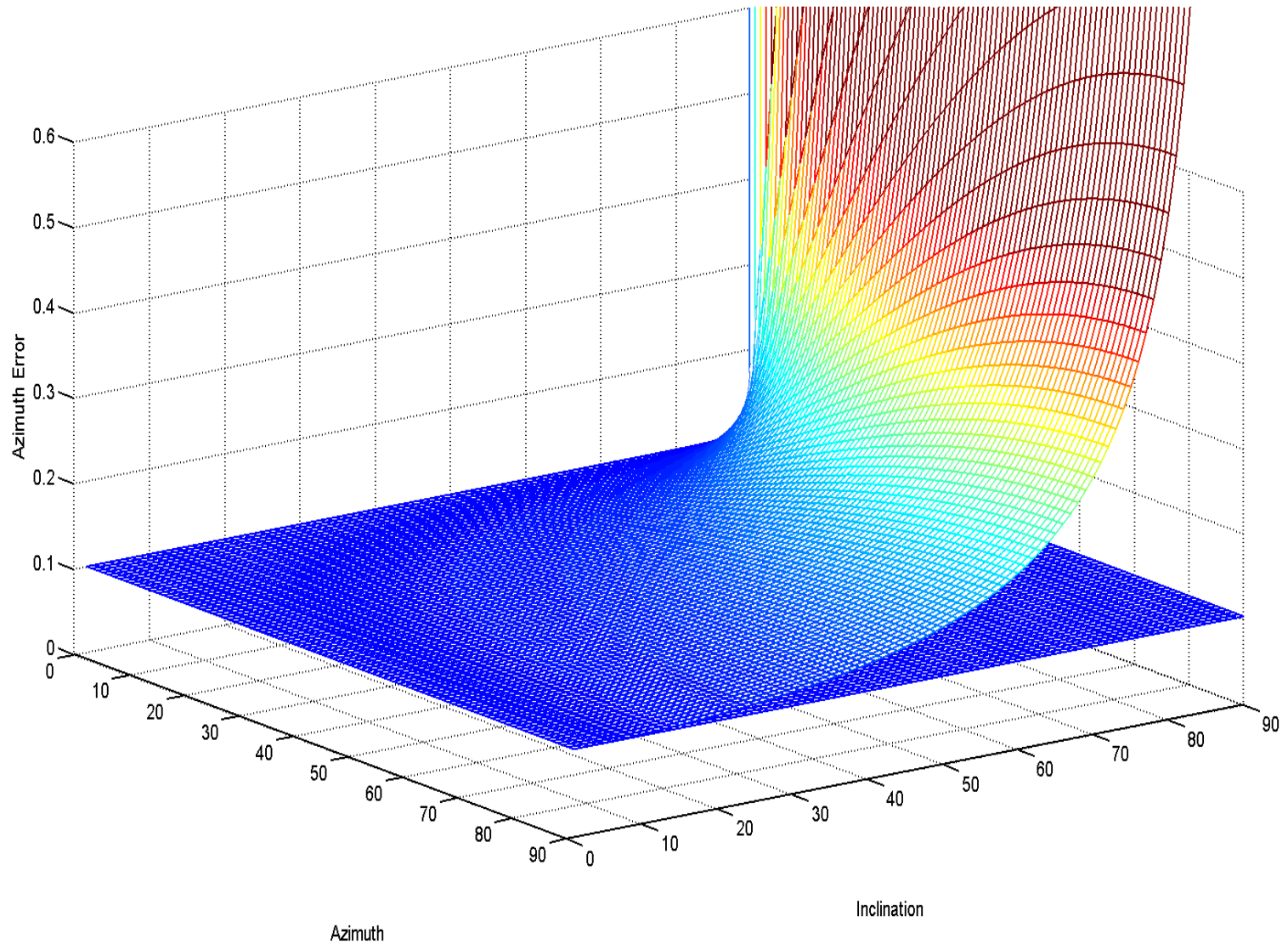
- » Positional uncertainty reduced by combined data sets - real time definitive surveying
- » Real-time gross error detection
- » High inclination close approach drilling
- » Assurance of error models
- » In-hole referencing of magnetic sensors, reducing need for magnetic field monitoring and referencing
- » Multi-shot survey on trip out at section TD



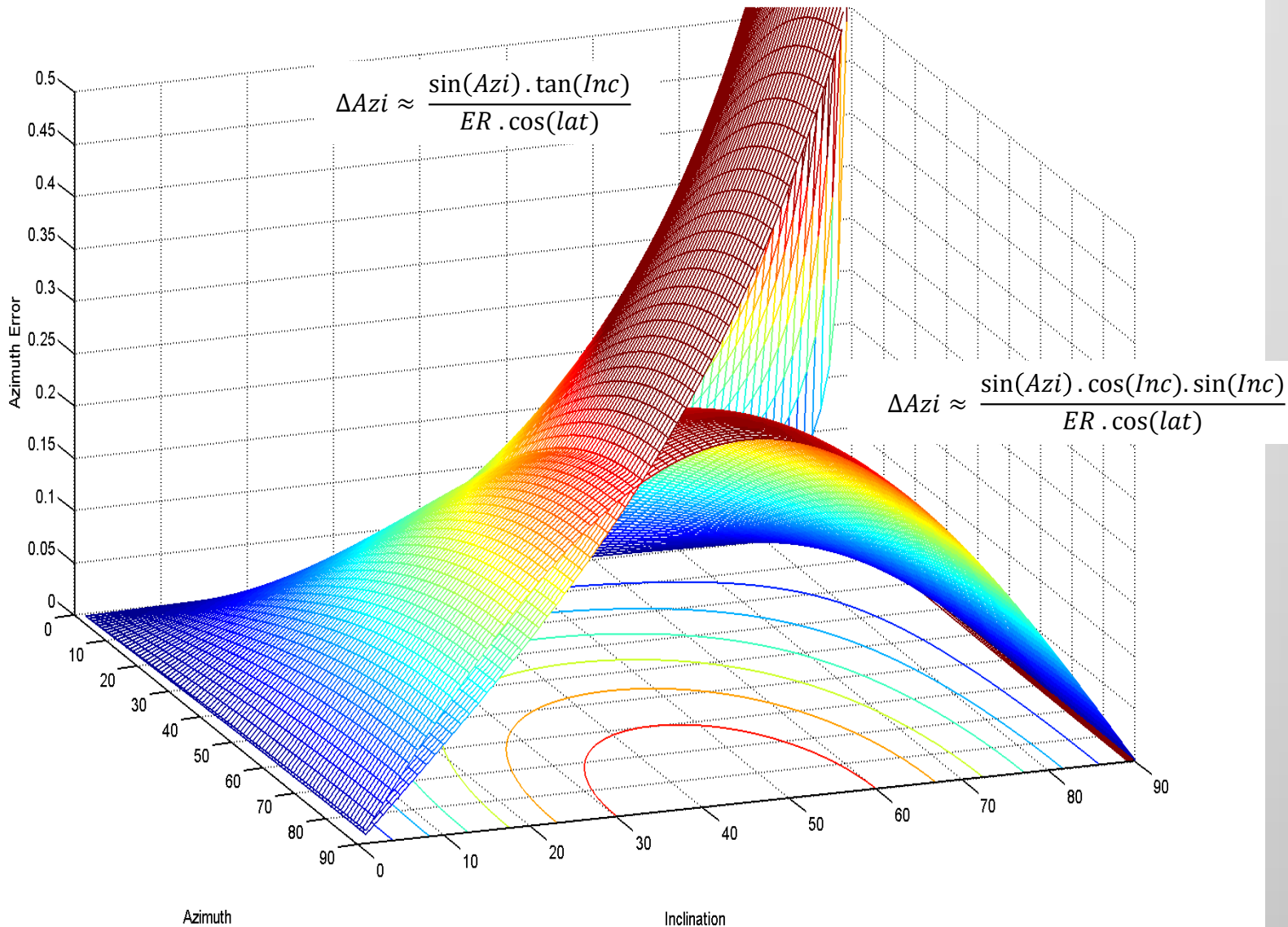
Going Beyond 70 deg Inc

- » Use of a dual MXY™ sensor array
- » 3 orthogonal axes measuring Earth Rate
- » New mechanization controlling bias in all 3 axes
- » CAP™ system correcting g-sensitive errors in 3 axes
- » Significant reduction in azimuth errors related to high inclination and East/West direction
- » Very robust quality control

Random Noise Error



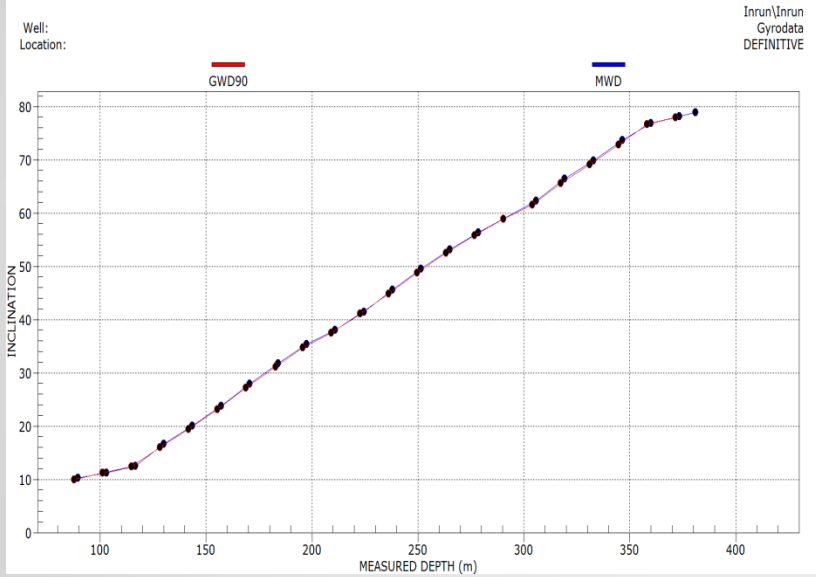
Mass Unbalance Error



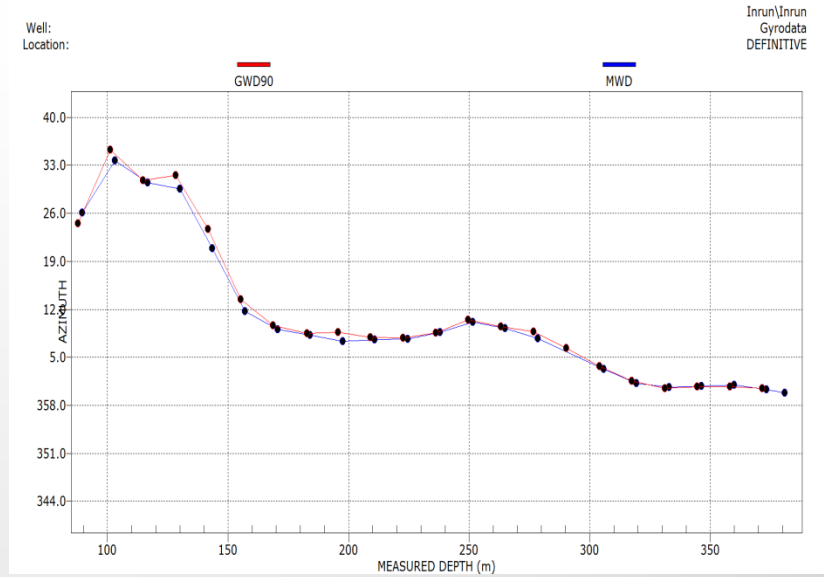
GWD90™ Run History

- Most wells drilled starting from vertical to 78 degrees of inclination
- Several over 90 degrees inclination
- Well profiles varied from due North/South to due East
- Varying latitudes up to 60 degrees

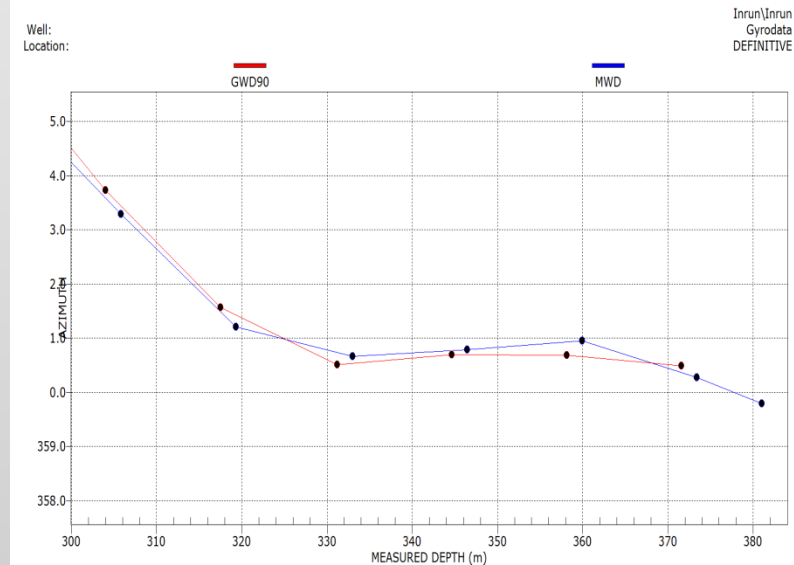
GWD90 vs MWD Inclination



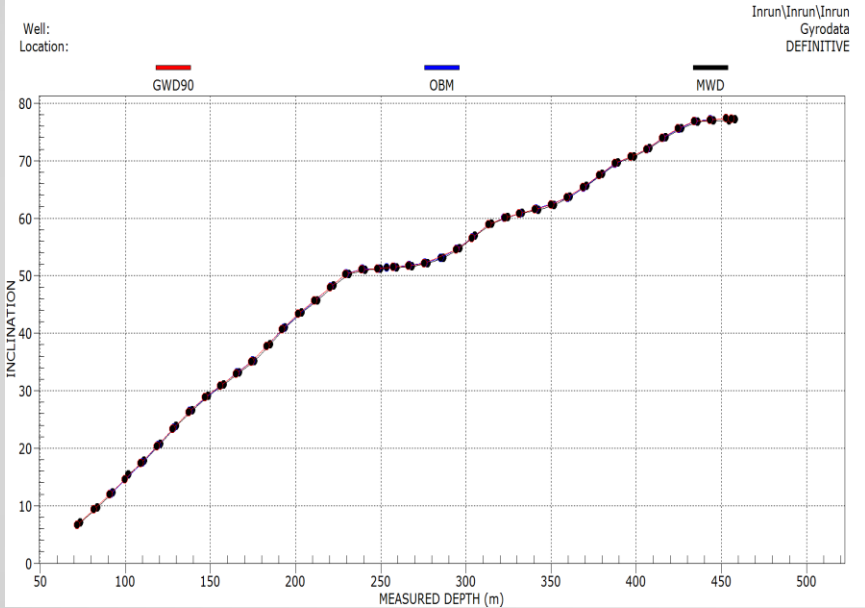
GWD90 vs MWD Azimuth



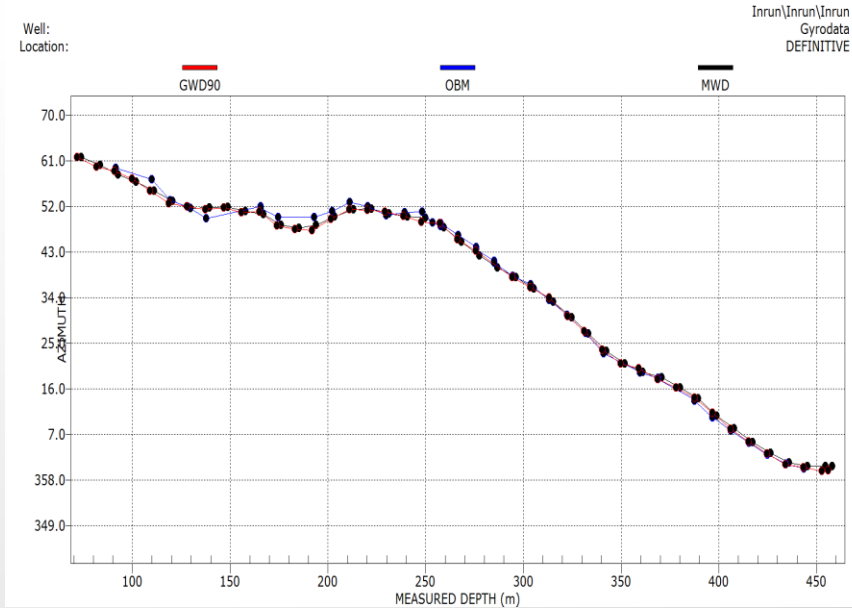
GWD90 vs MWD Azimuth



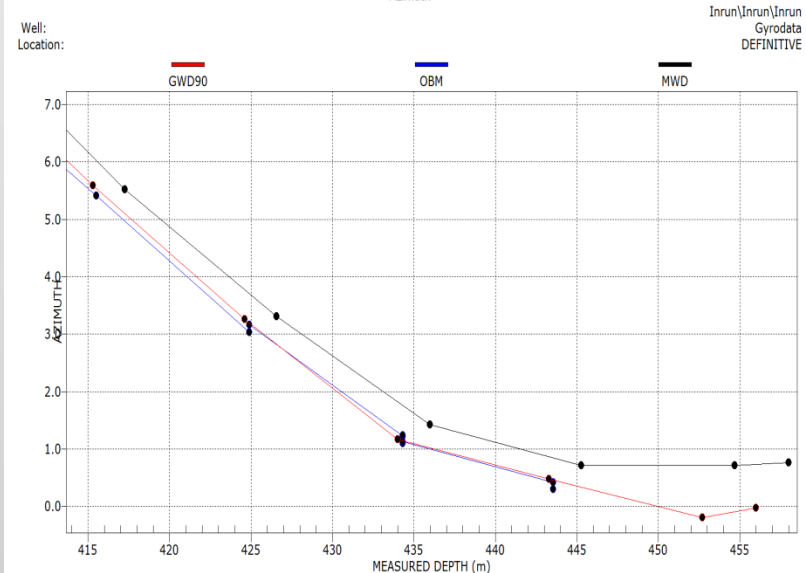
GWD90 vs OBM vs MWD
Inclination

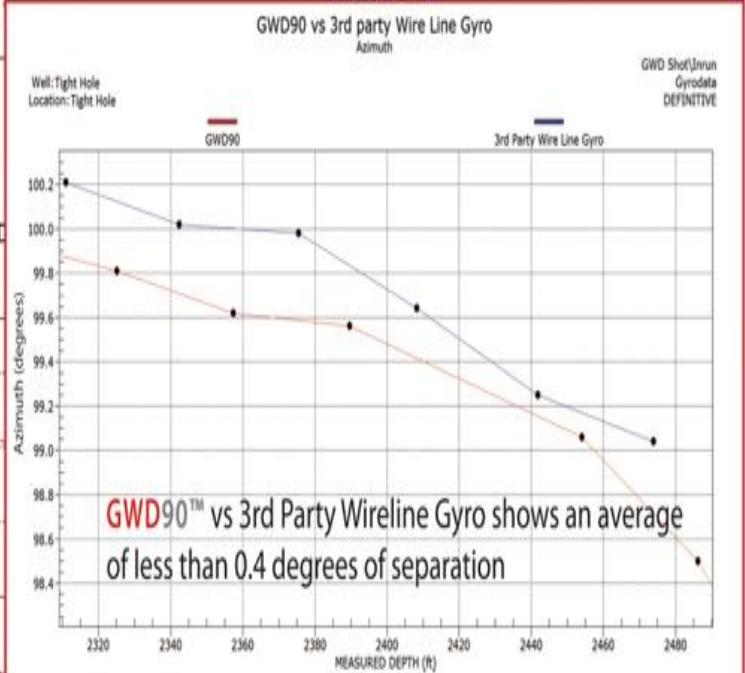
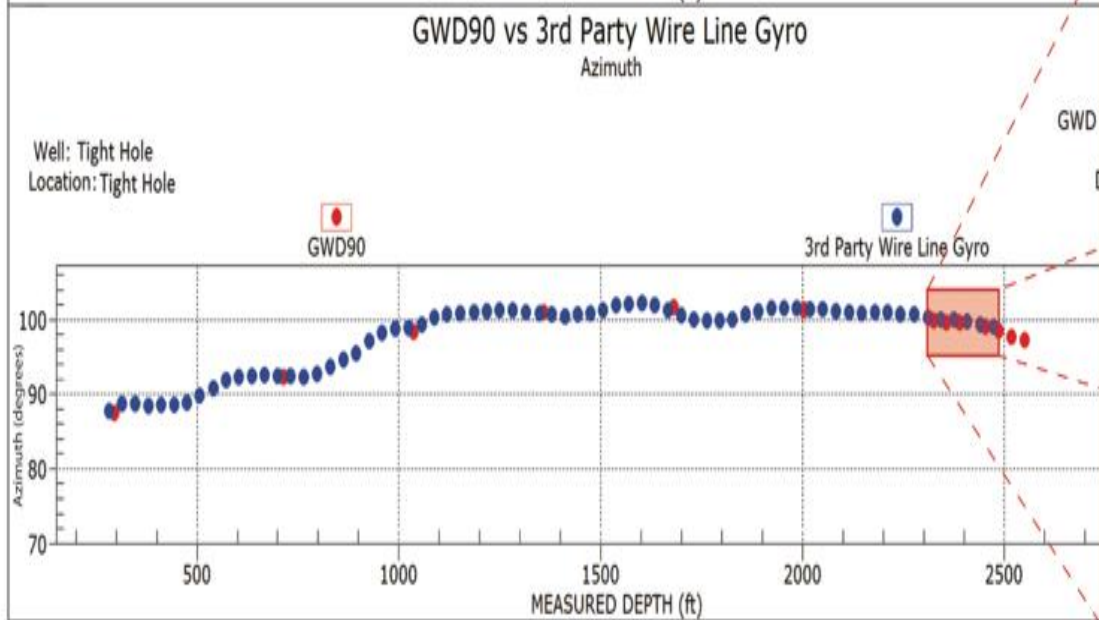
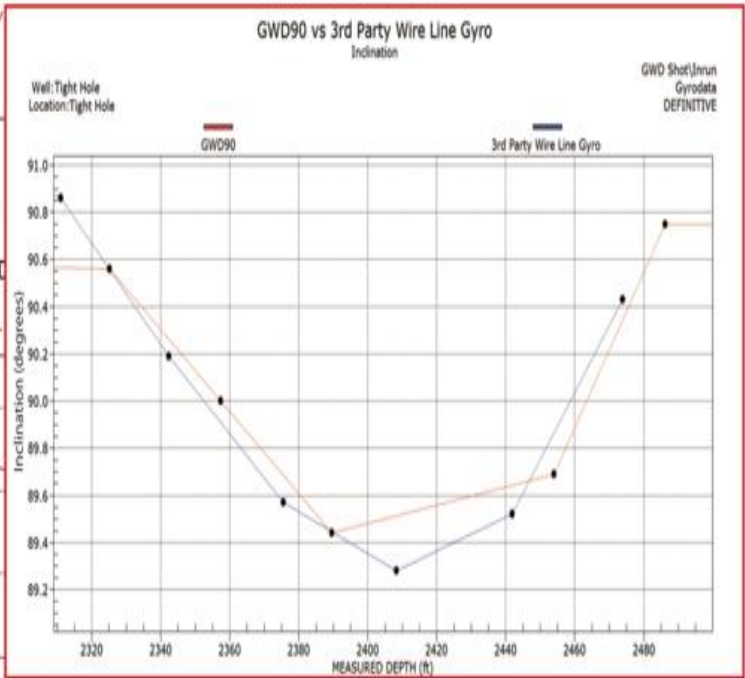
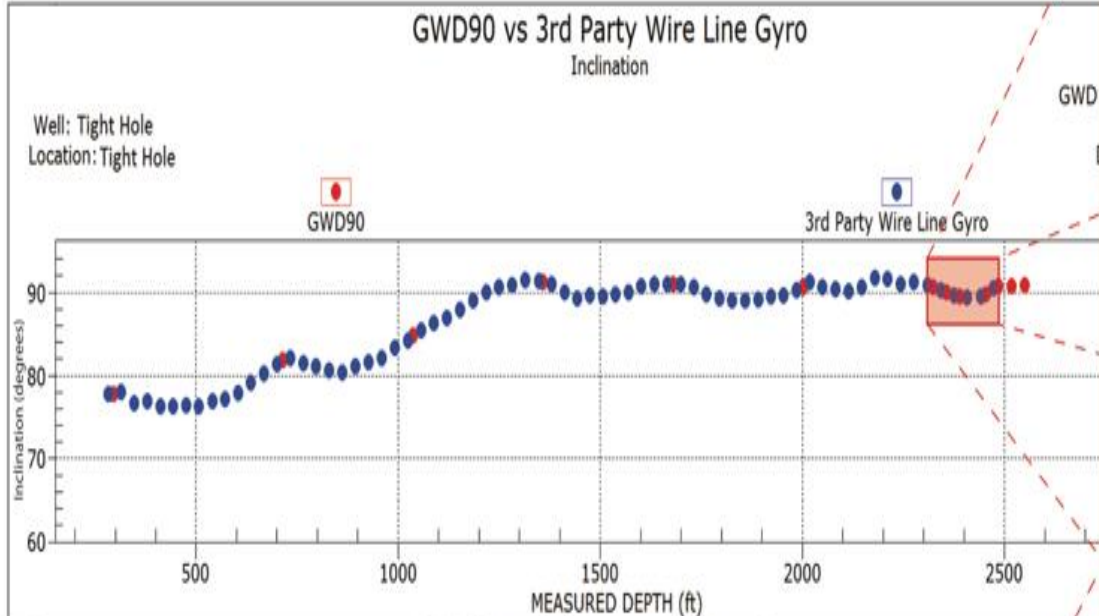


GWD90 vs OBM vs MWD
Azimuth



GWD90 vs OBM vs MWD
Azimuth







GWD90 vs 3rd Party Wire Line Gyro

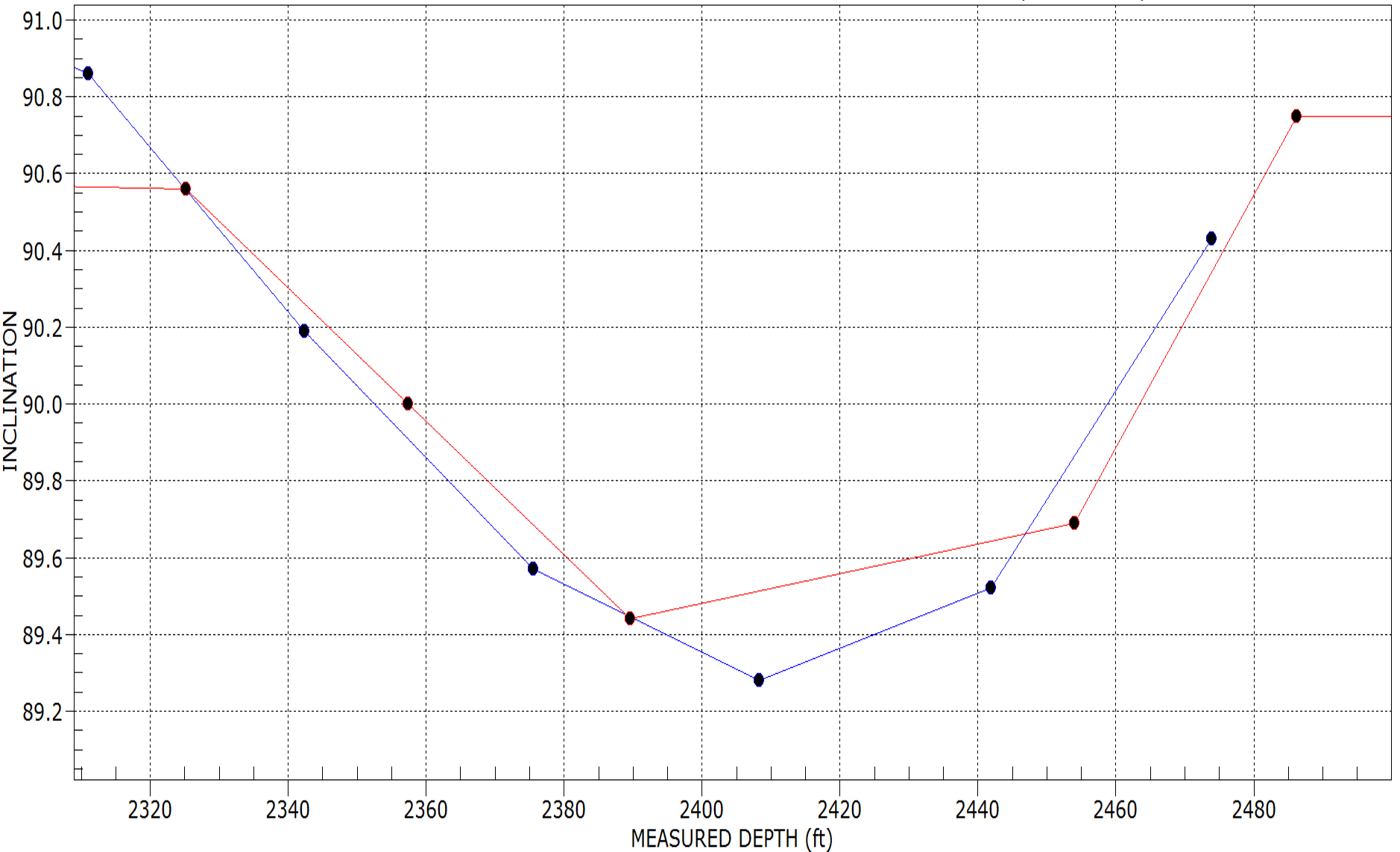
Inclination

Well:Tight Hole
Location:Tight Hole

GWD Shot\Inrun
Gyrodata
DEFINITIVE

 GWD90

 3rd Party Wire Line Gyro





GWD90 vs 3rd party Wire Line Gyro

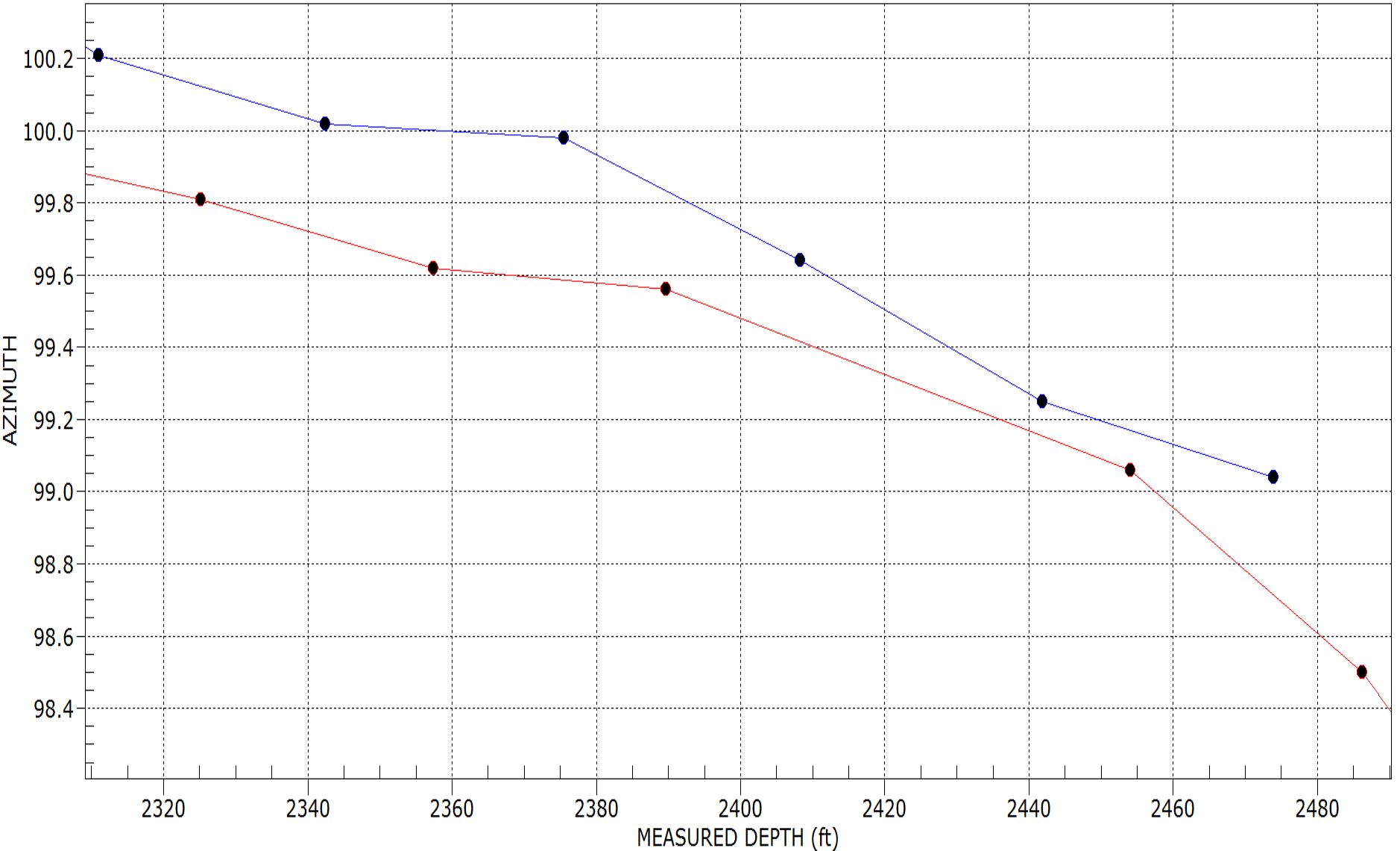
Azimuth

Well: Tight Hole
Location: Tight Hole

GWD Shot\Inrun
Gyrodata
DEFINITIVE


GWD90


3rd Party Wire Line Gyro



High Angle GWD™ Conclusions

- Azimuth uncertainty reduced at high inclination and E/W directions
- Gross error detection
- Outrun multi-shot data provides definitive surveying information
- In-hole referencing of magnetics
- **Field data confirms GWD90™ successful for horizontal applications**

Thank You