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Gyro Wellbore Placement Using Advanced Solid-state Sensor Technology

Adrián Ledroz, John Weston, Gyrodata Inc. James Moisan, Apache Corp.

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Magnetic sensors

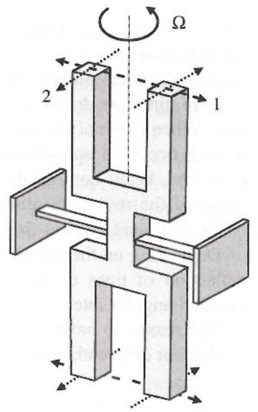
- Very rugged sensors
- Very stable sensors
- Minimally affected by movement
- Unstable reference
  - Not stable over time
  - Local anomalies (horizontal and vertical)
  - Affected by Magnetic Storms
- Affected by magnetic interference from
  - BHA
  - Nearby wells
  - Downhole ore deposits
  - Magnetized mud

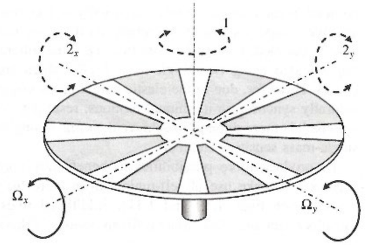
Gyroscopic sensors

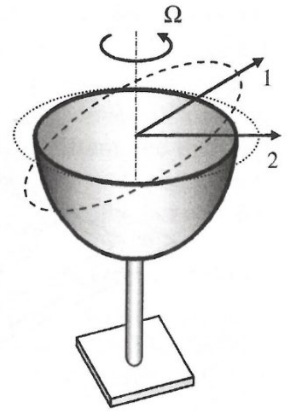
- Rugged sensors
- Stable sensors
- Greatly affected by movement
- Stable reference
- Not affected by magnetic material

Vibratory gyroscopes

- Technology incorporates vibrating element with piezo-electric driver circuits
- In the presence of device rotation, a Coriolis force is generated which modifies the motion of the vibrating element
- Coriolis motion detected using piezoelectric or capacitive pick-offs to provide measure of applied turn rate
- The vibrating element of such sensors can take various forms such as a string, a hollow cylinder, a rod, a tuning fork, a beam or a hemispherical dome
- Such devices are generally classified under the heading of Coriolis vibratory gyros (CVGs)
- High performance sensors with bias stability of hundredth's of a deg/hr – wellbore survey application



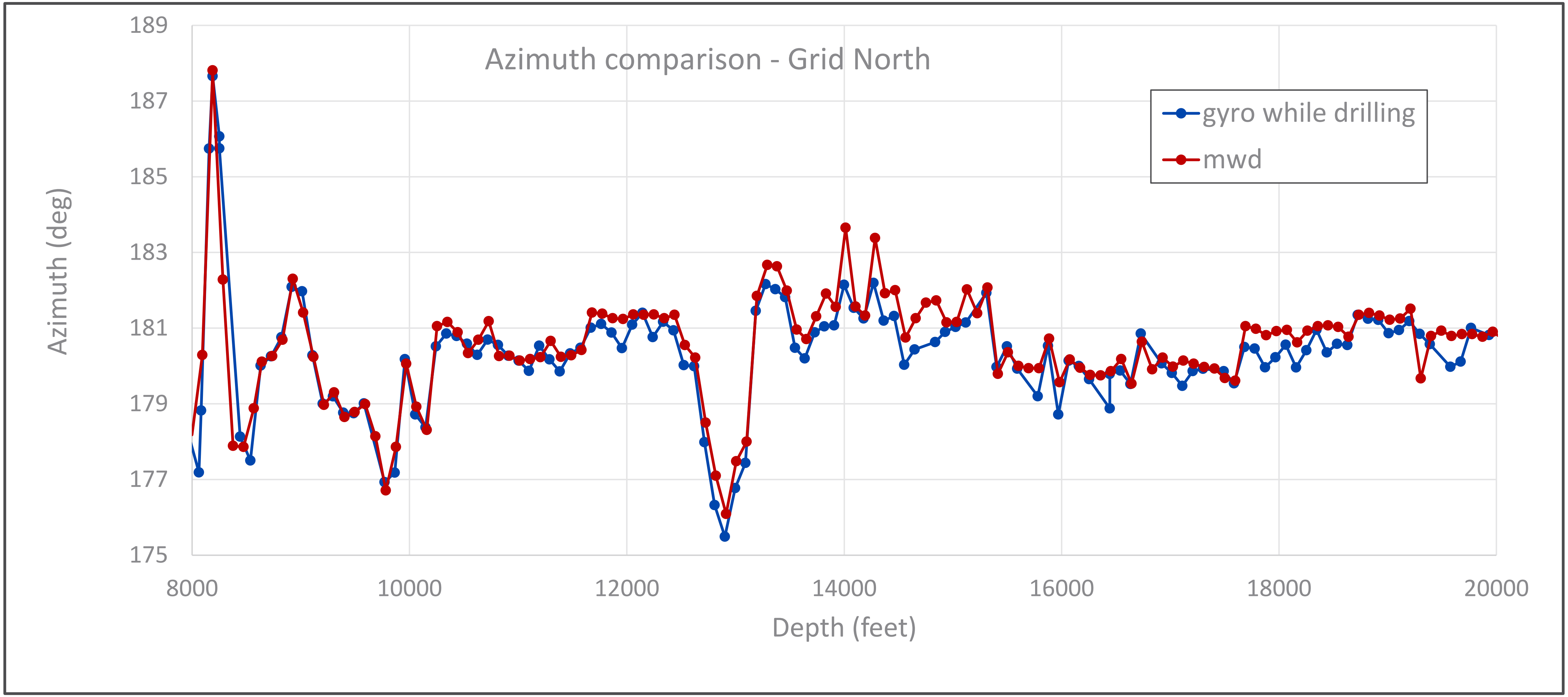




Solid-state gyroscope – development

- Initial laboratory tests and calibration 2012
- Initial deployment – memory tool for post-drilling survey
  - surveyed >1.5 million feet of wellbore trajectory to date
- Initial deployment of GWD tool 2018
  - ‘ghost mode’ run in BHA with dedicated battery and shock monitoring system
  - validated against the definitive survey
  - run in multiple wells in > 50,000 feet of wellbore
  - includes harsh drilling environment in the Bakken basin
- 2nd generation GWD tool
  - 15 runs in North American land drilling sites
  - 50,000 feet horizontal drilling

Ghost run - example

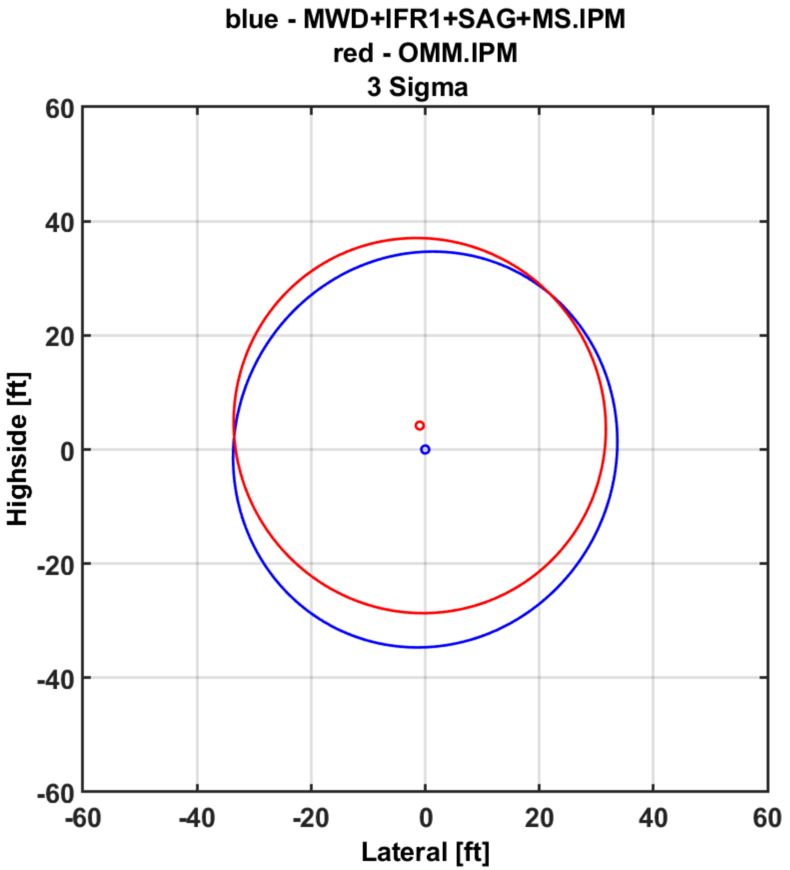


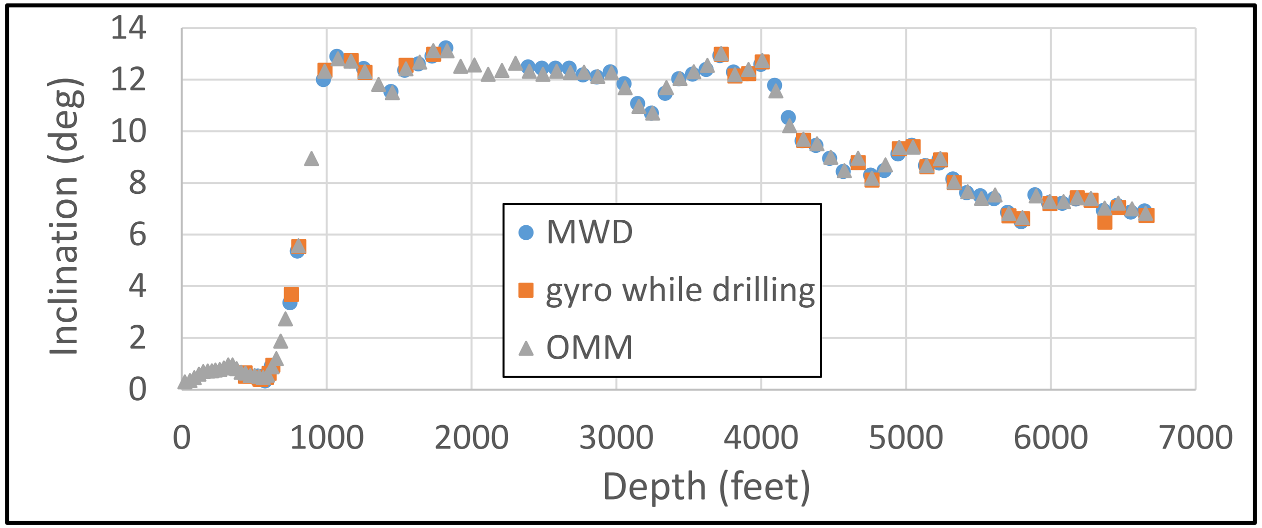
Case Study

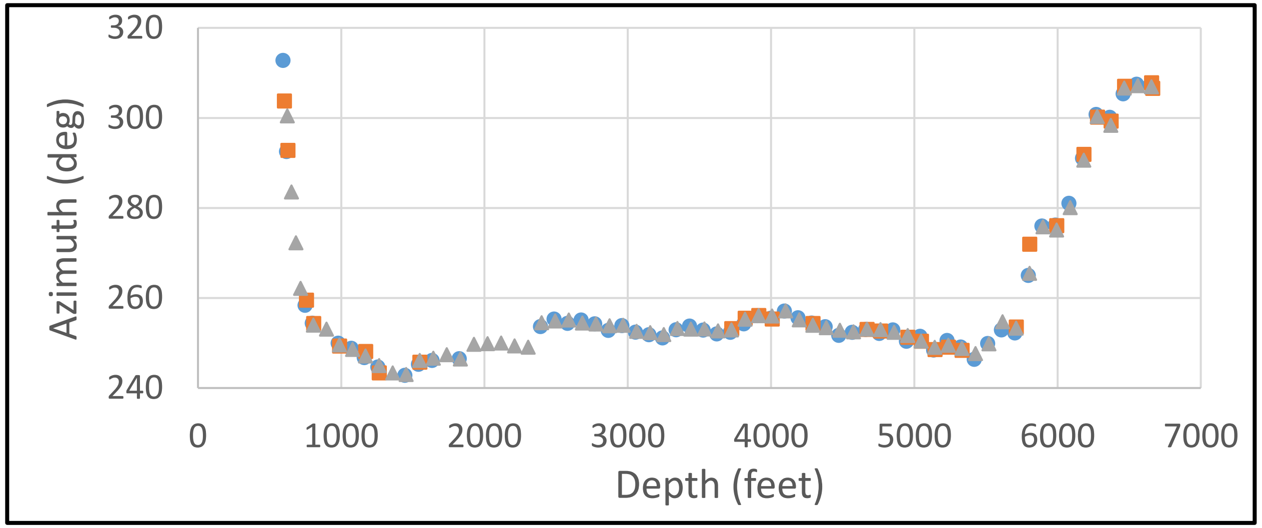
- Requirements
  - Accurate placement of well in Midland basin
  - Close proximity to another well
  - Lease-line constraints
  - Redundant information to reduce risk of NPT event
- Run MWD with IFR and MSA alongside Gyro while drilling tool
- 3 phases of drilling
  - Low inclination section
  - Build section
  - Lateral section

Case Study

Top hole section – Inclination and Azimuth

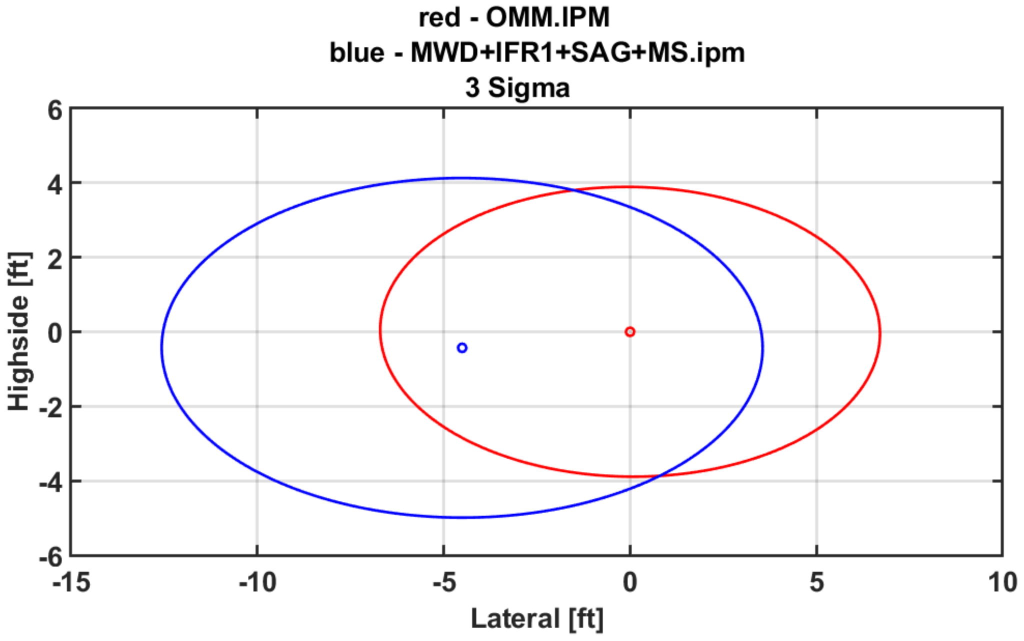


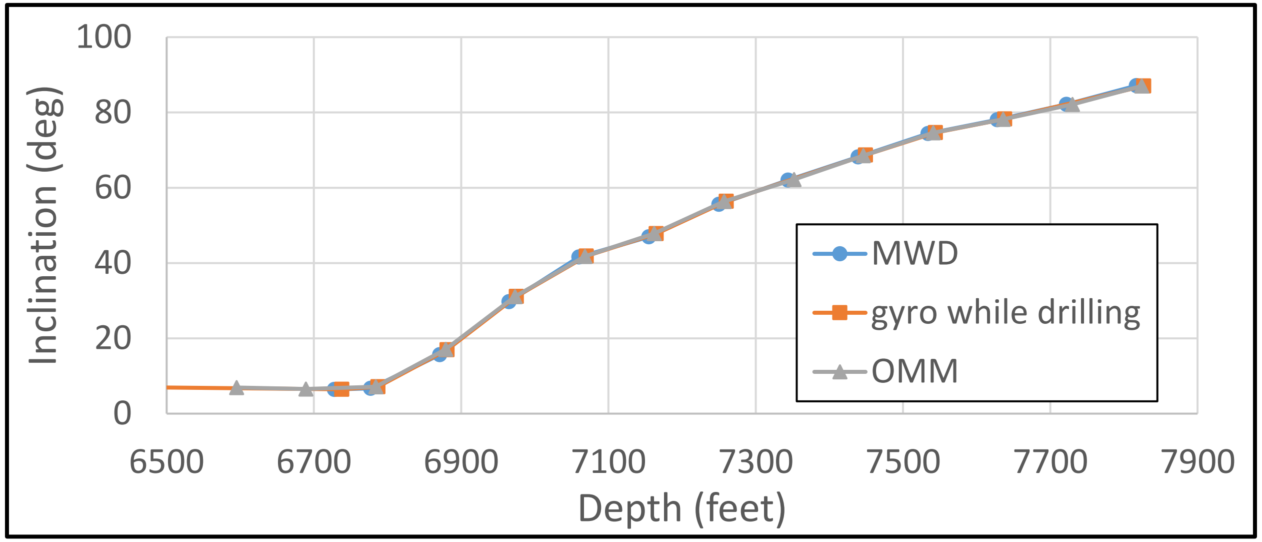


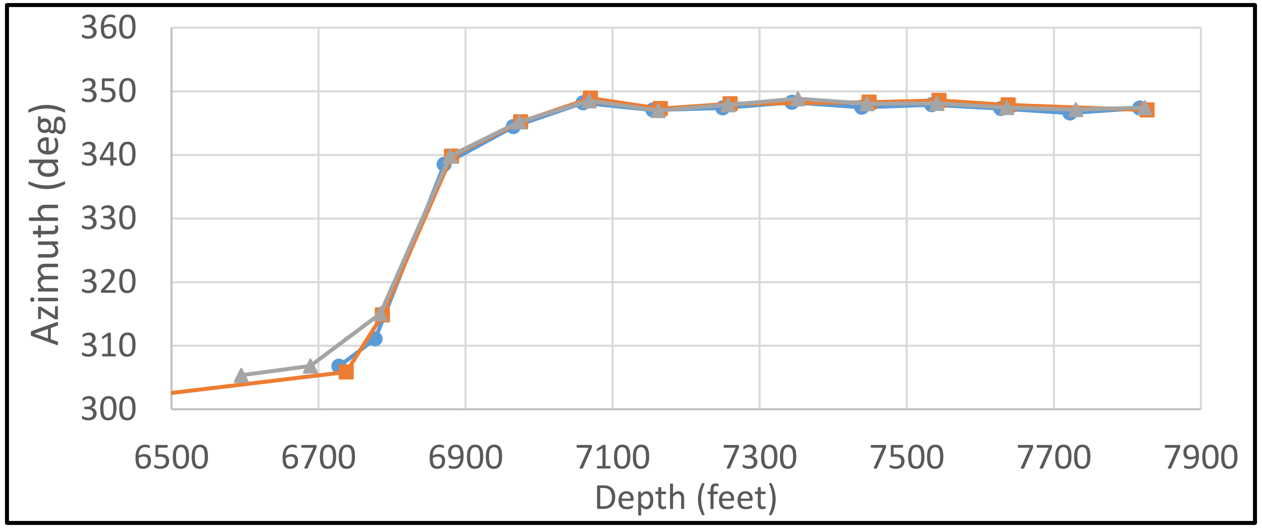


Case Study

Build section – Inclination and Azimuth





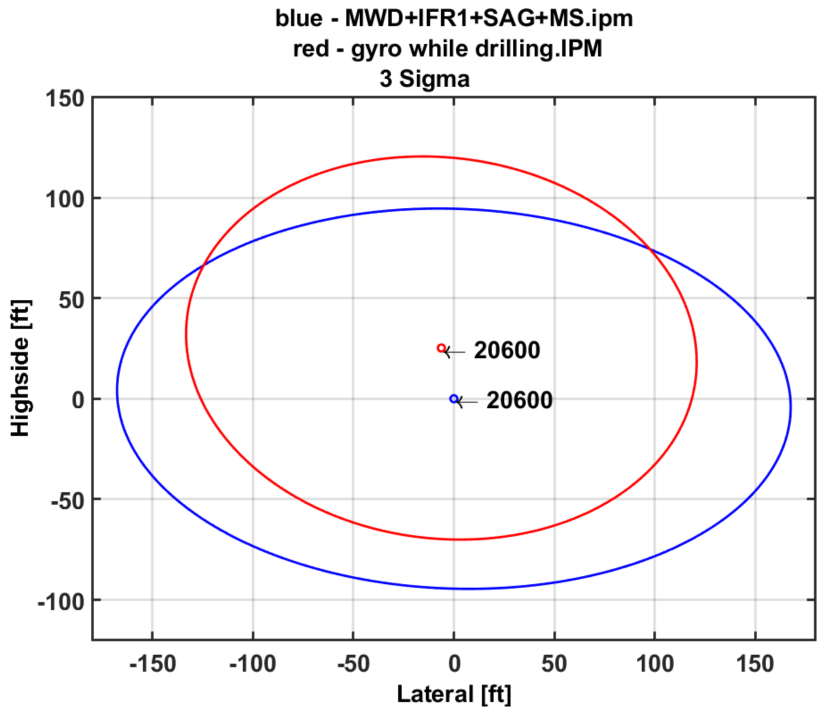


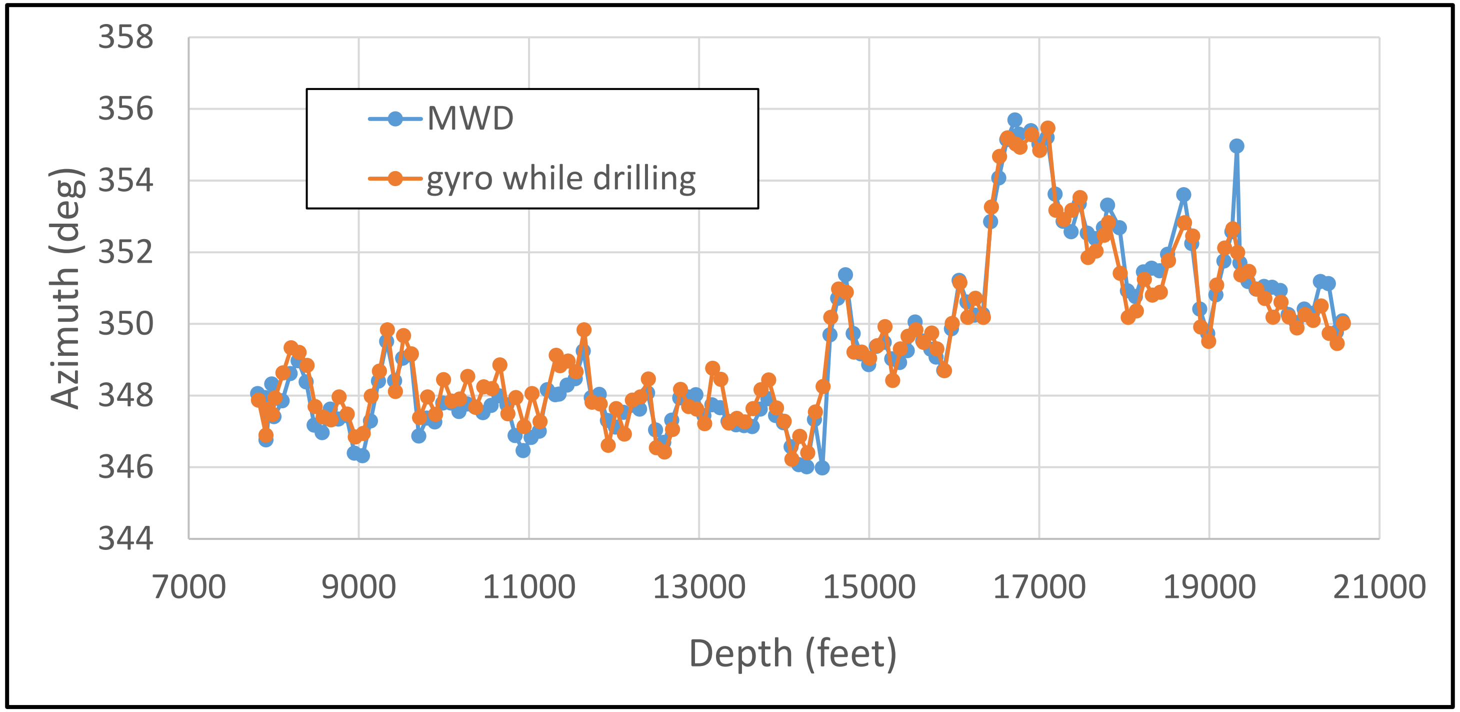
Case Study

Lateral section – Azimuth

Average difference between Gyro and MWD azimuth = 0.07 deg

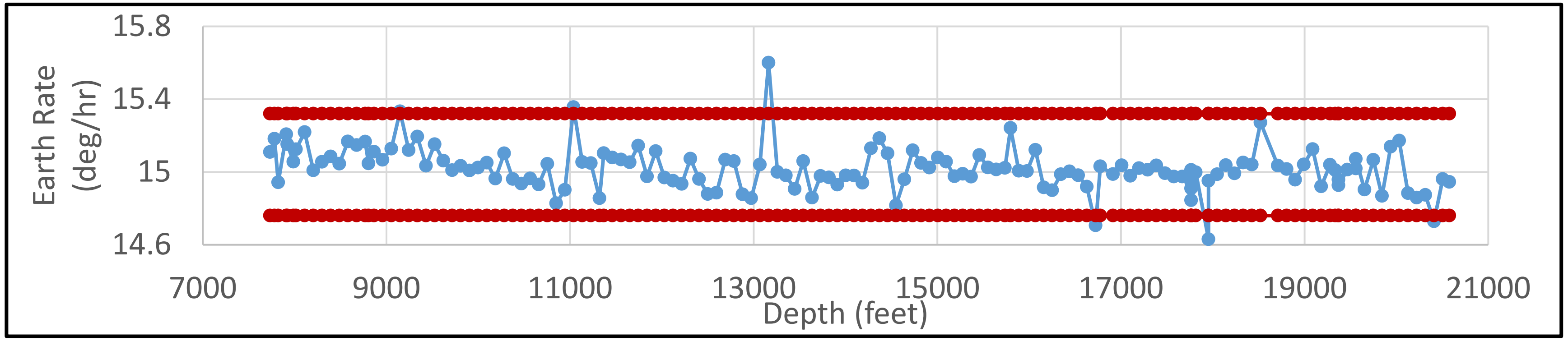
Standard deviation = 0.5 deg

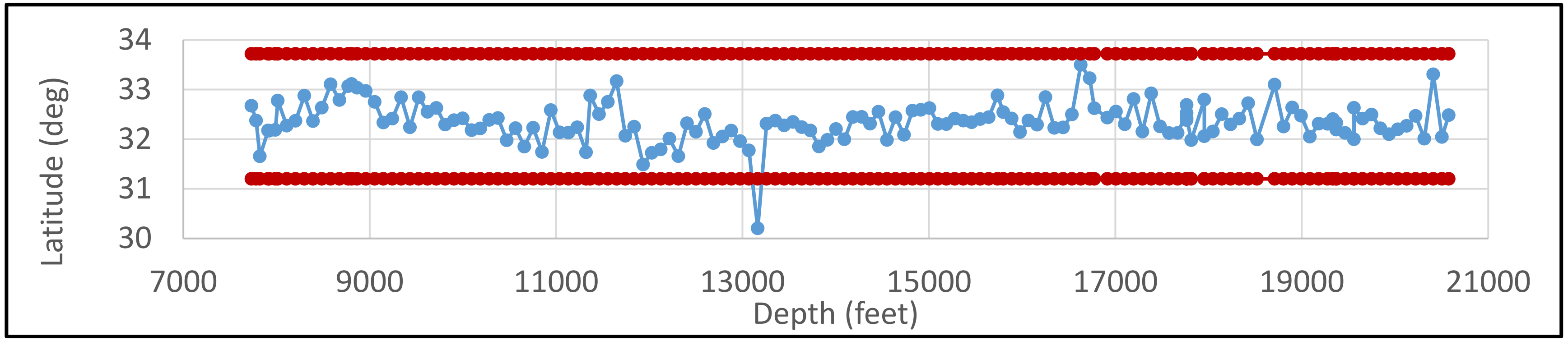


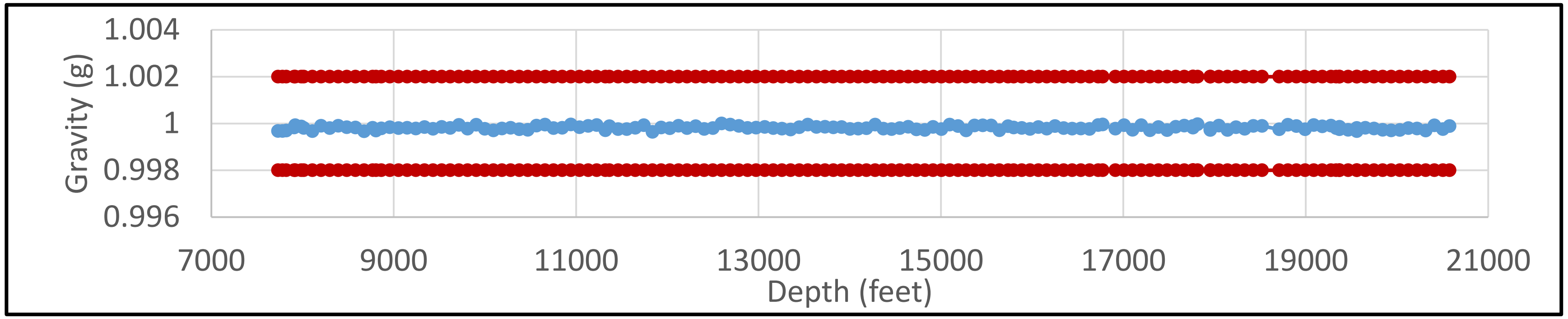


Case Study

Lateral section QC parameters



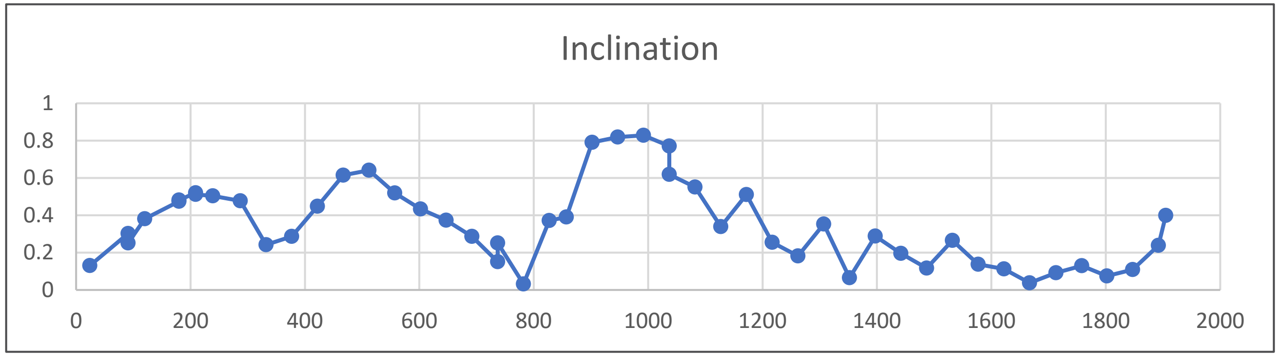


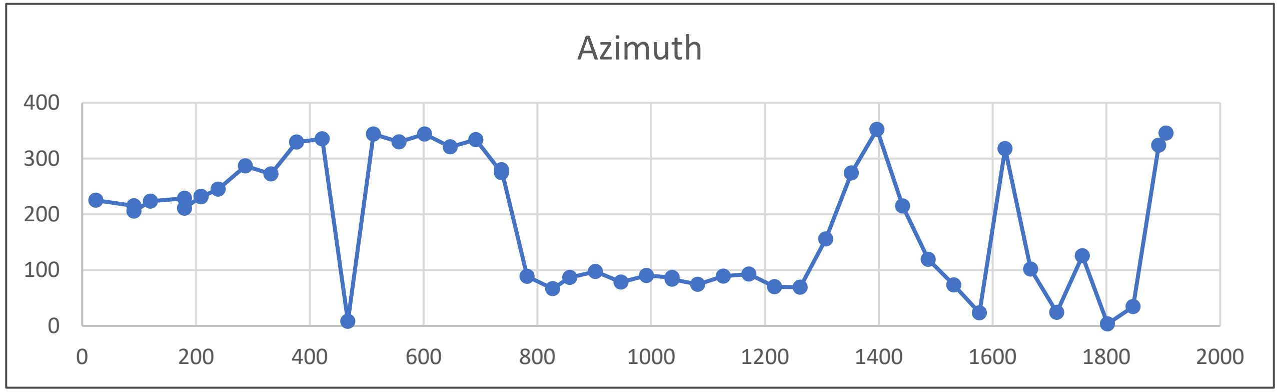


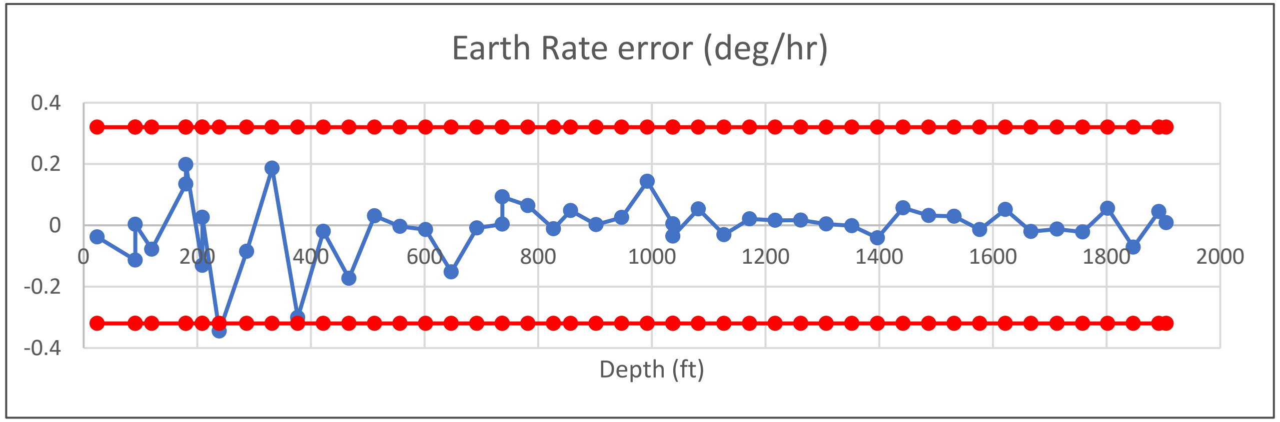
Additional Case Study – vertical well

No MWD present on the BHA

- It eliminates the need for Non-mag collars
- It eliminates the need of de-gaussing the BHA
- Azimuth, TF and QC are not affected by nearby casings/wells







Concluding remarks

- Survival in severe drilling environment demonstrated
- Good agreement between gyroscopic and magnetic measurement in all sections of the well
- Capability to detect noisy data and systematic changes related to the tool calibration demonstrated
- First time that a gyro while drilling tool has been utilized in every section of the well from surface to total depth
- Case study I involved:
  - More than 270 circulating hours
  - More than 400 hours below the rotary table
  - 20,000 ft of drilled wellbore
- Real-time gross error detection through comparison of MWD and gyro while drilling for all sections of the well is now a reality
- A reliable real-time alternative to MWD is available