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WELLBORE POSITION, QUALITY CONTROL, GROSS ERRORS AND ERROR MODELS

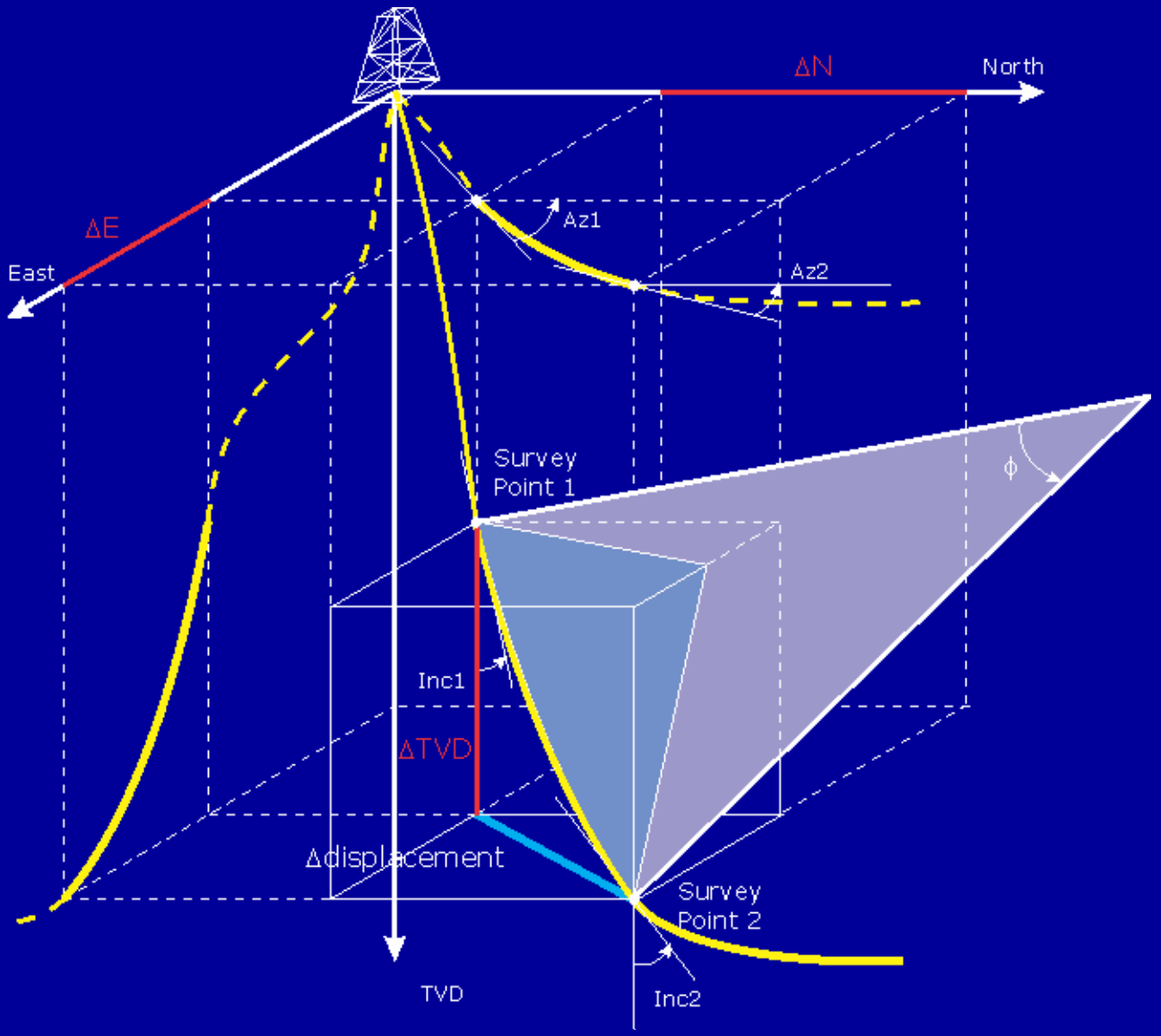
SPE 2014-2015 Distinguished Lecturer Series

Nestor Eduardo Ruiz
Gyrodata

OUTLINE

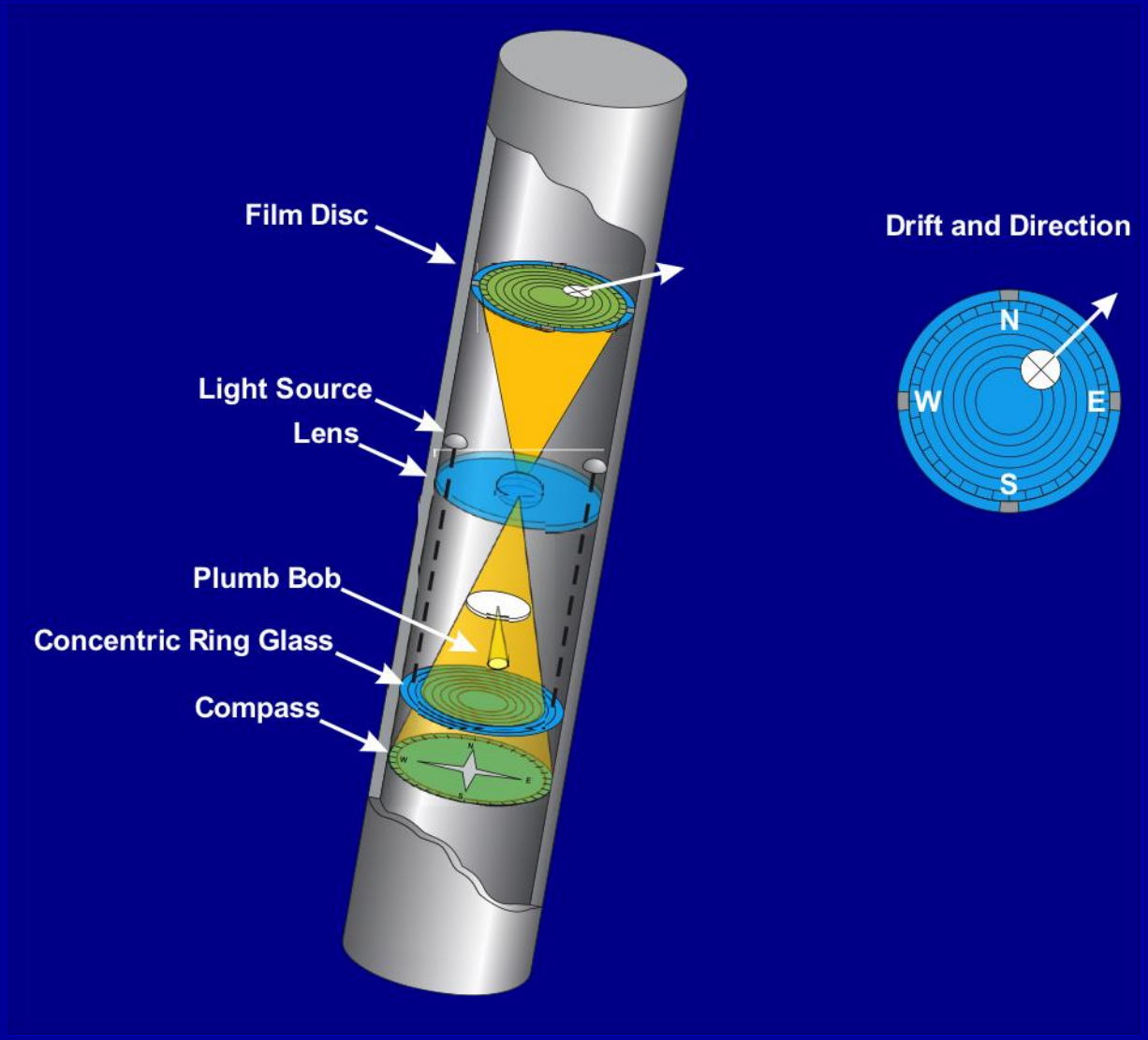
- Wellbore position
- Inclination measurements
- Azimuth measurements
- Error models for Magnetic tools
- Error models for Gyro tools
- Error models and gross errors
- Conclusions and Recommendations

WELLBORE POSITION

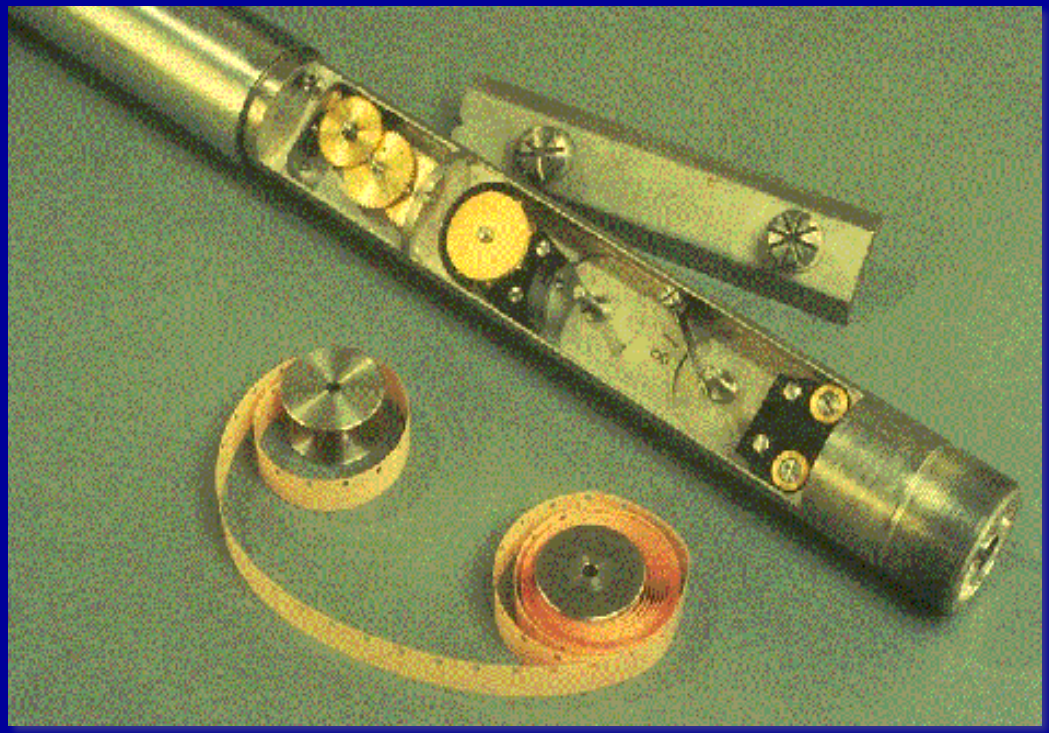


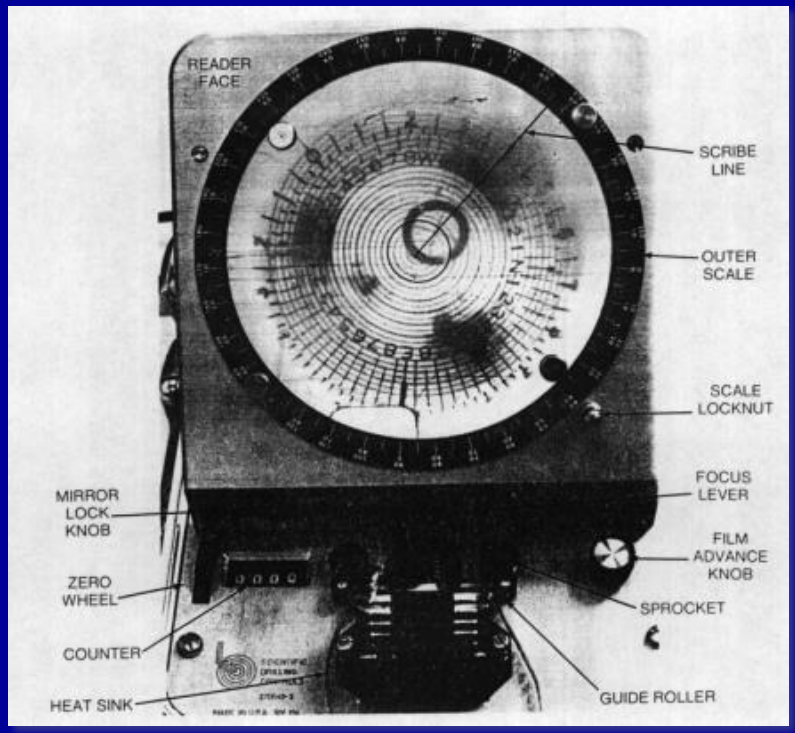
INCLINATION

AZIMUTH
OLD MAGNETIC TOOLS

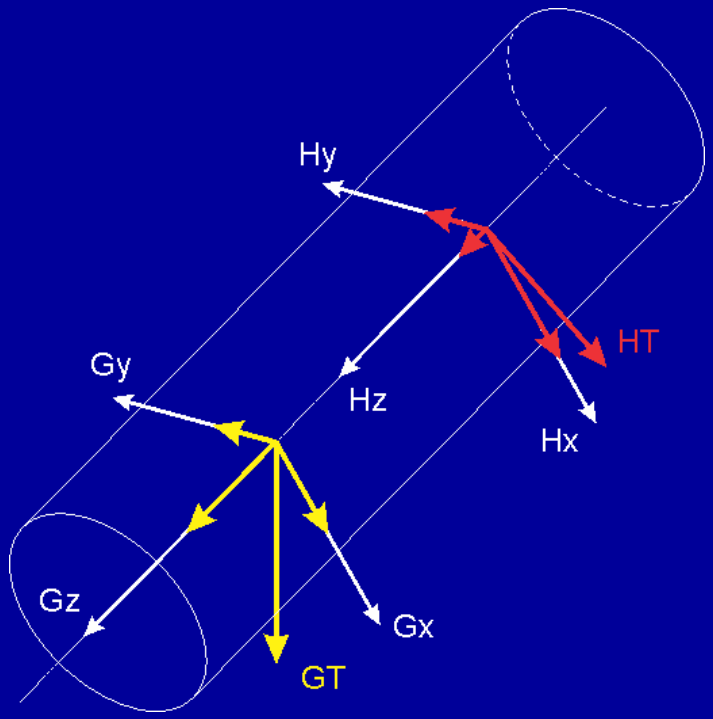


MULTISHOT MECHANISM





SOLID STATE MAGNETIC TOOLS



$$I = arctg \frac{\sqrt{Gx^2 + Gy^2}}{Gz}$$

$$\alpha = arctg \frac{Gx}{Gy}$$

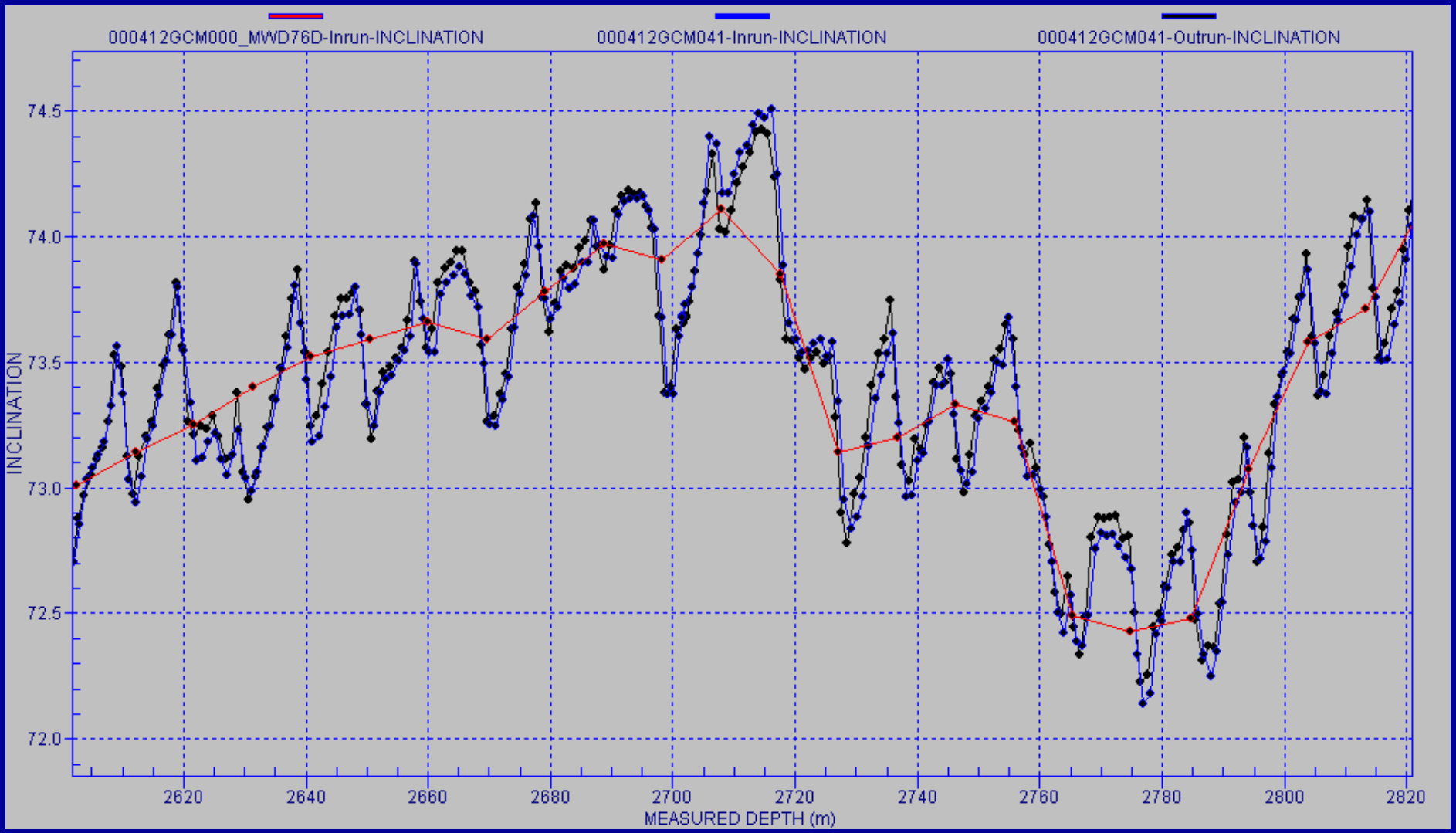
$$A = \partial + \tan^{-1}\left[\frac{Hx\cos\propto - Hy\sin\propto}{\cos I(Hx\sin\propto + Hy\cos\propto) + Hx\sin I}\right]$$

$$\text{Htotal} = \sqrt{\text{Hx}^2 + \text{Hy}^2 + \text{Hz}^2}$$

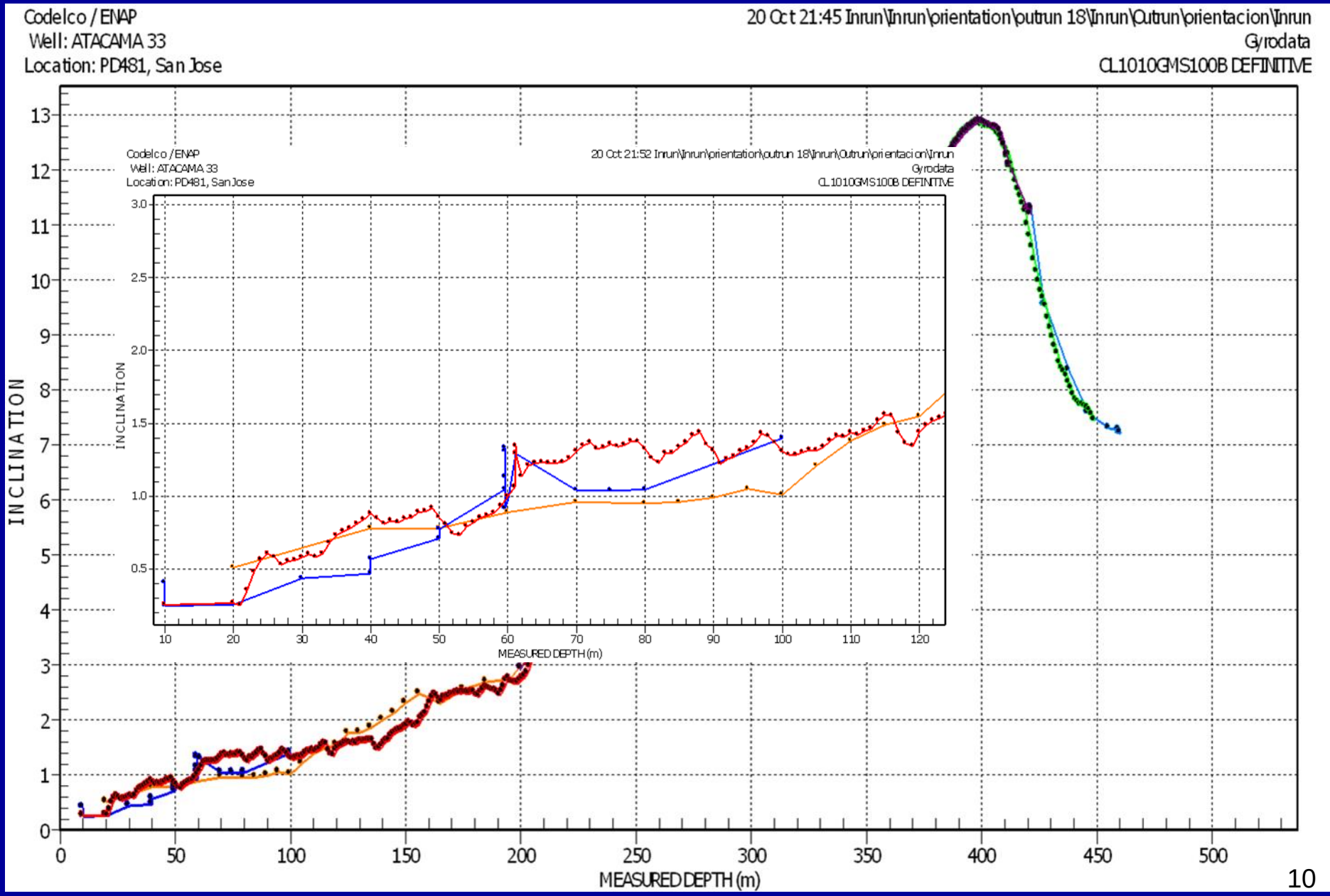
$$\text{G}total = \sqrt{Gx^2 + Gy^2 + Gz^2}$$

Dip Angle= f(Hx, Hy, Hz, Gx, Gy, Gz)

INCLINATION



INCLINATION



AZIMUTH

MAGNETIC REFERENCE

- **MAGNETIC TOOLS**
  - **Very stable sensors**
  - **Variable reference**

EARTH RATE REFERENCE

- **Rate Gyro tools**
  - **Very stable reference**
  - **Variable sensors**
  - **Self oriented with the Earth Rate.**

CONTINUOUS MODE

- **Rate gyro tools**
  - **Dependent of one initialization point**

QUALITY CONTROL FOR MAGNETIC TOOLS

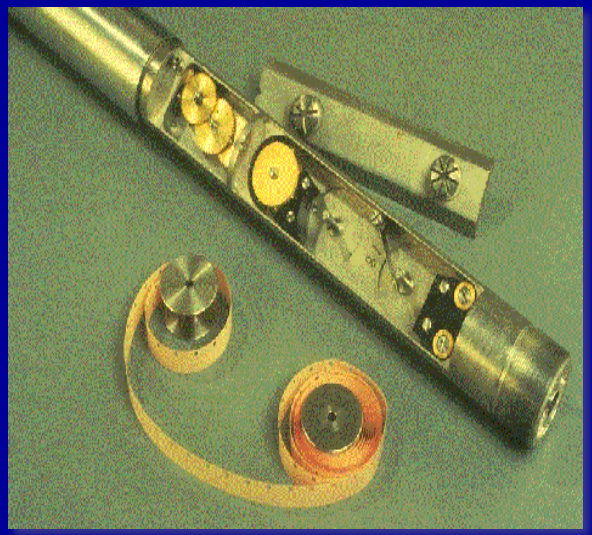
- **INTERNAL TEST in each shot**
  - **Total Magnetic Field (H Total)**
  - **Total Gravity (G Total)**
  - **Dip angle**

- **Additional tests**
  - Repeated measurements with additional down-hole sensors

- **Rotation Shot Misalignment Test**
  Tool misalignment components
  For BHA-fixed tool

(SPE PAPER 105558)

FREE GYRO



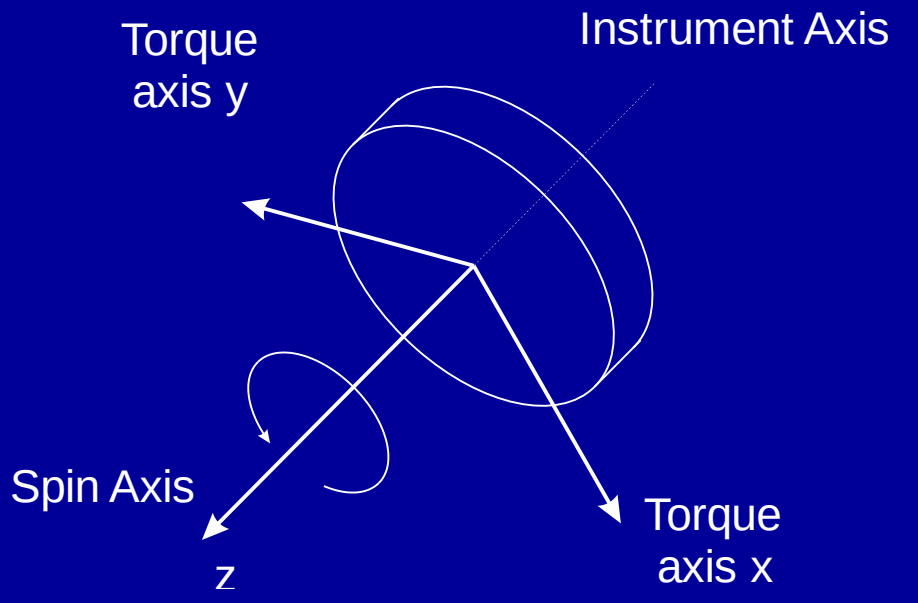
RATE GYRO
GYRO COMPASS MODE

Accelerometers provide

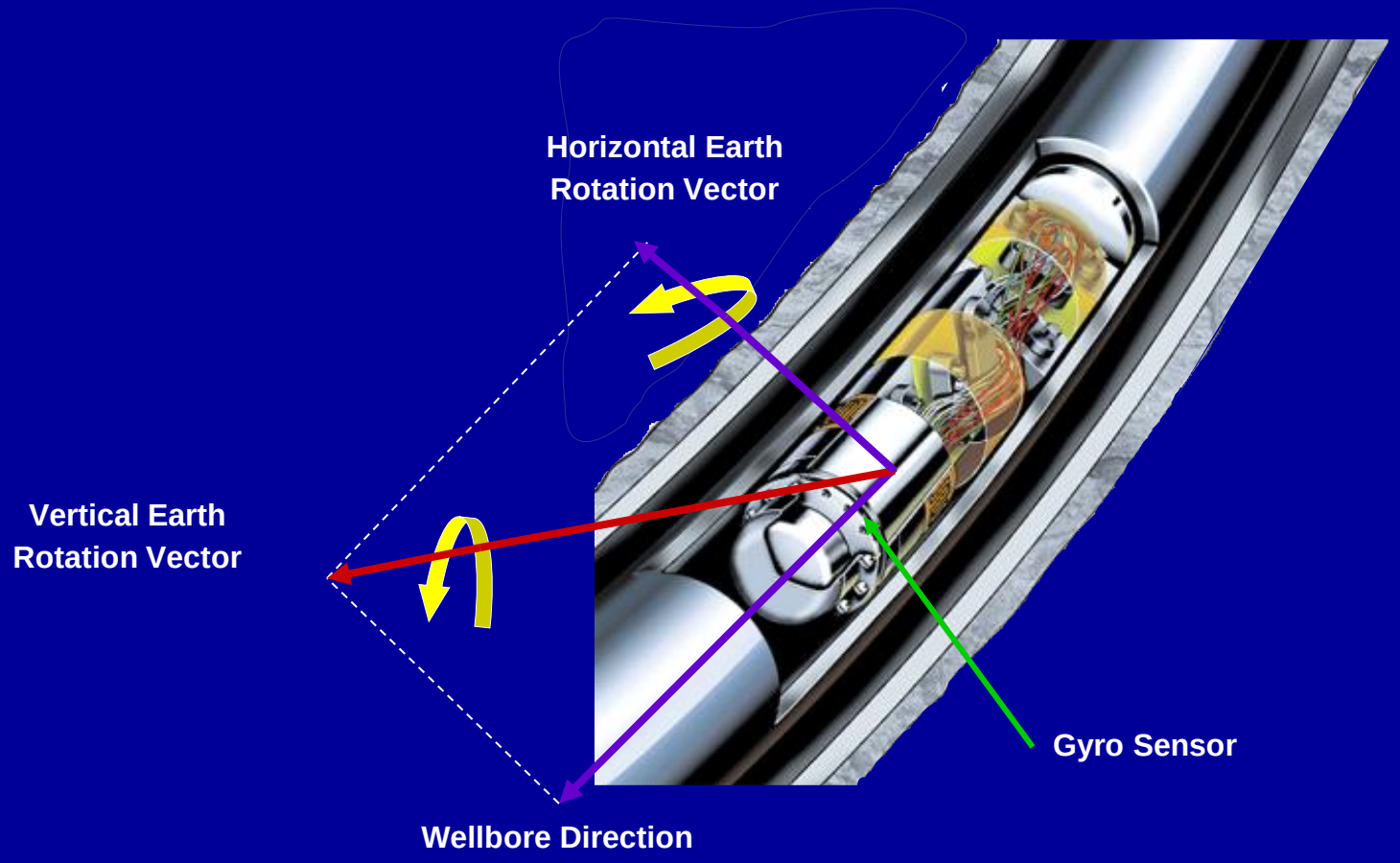
Inclination and Tool Face

Gyro provides the

direction to true North



RATE GYRO
CONTINOUS MODE



QUALITY CONTROL FOR RATE GYRO TOOLS

- For Gyro Compass mode
  - Horizontal Earth Rate Test for xy Gyro system
  - Total Gravity (G total)
- For Continuous mode
  - Quality Number
  - In run / Outrun comparison

ERROR MODEL FOR MAGNETIC TOOLS

- Wolff and De Wardt model in 1981

- Basic MWD ISCWSA model in 2000 (Williamson SPE 67616)
  - Assumptions
    - Errors in the calculated well position are caused exclusively by the presence of measurement errors at the wellbore survey stations

    - Three element measurement vectors
      - Depth
      - Inclination,
      - Azimuth.
      - Tool Face angle is required for the propagation of the error

ERROR MODEL FOR MAGNETIC TOOLS

- Error sources Statistically independent
- Linear relationship between the size of each measurement error and the position (or coordinate) error
- The combined effect on final position of any number of measurements at any number of survey stations is equal to the vector sum of the contribution of the individual error effects.

ERROR MODEL FOR MAGNETIC TOOLS ASSUMPTIONS

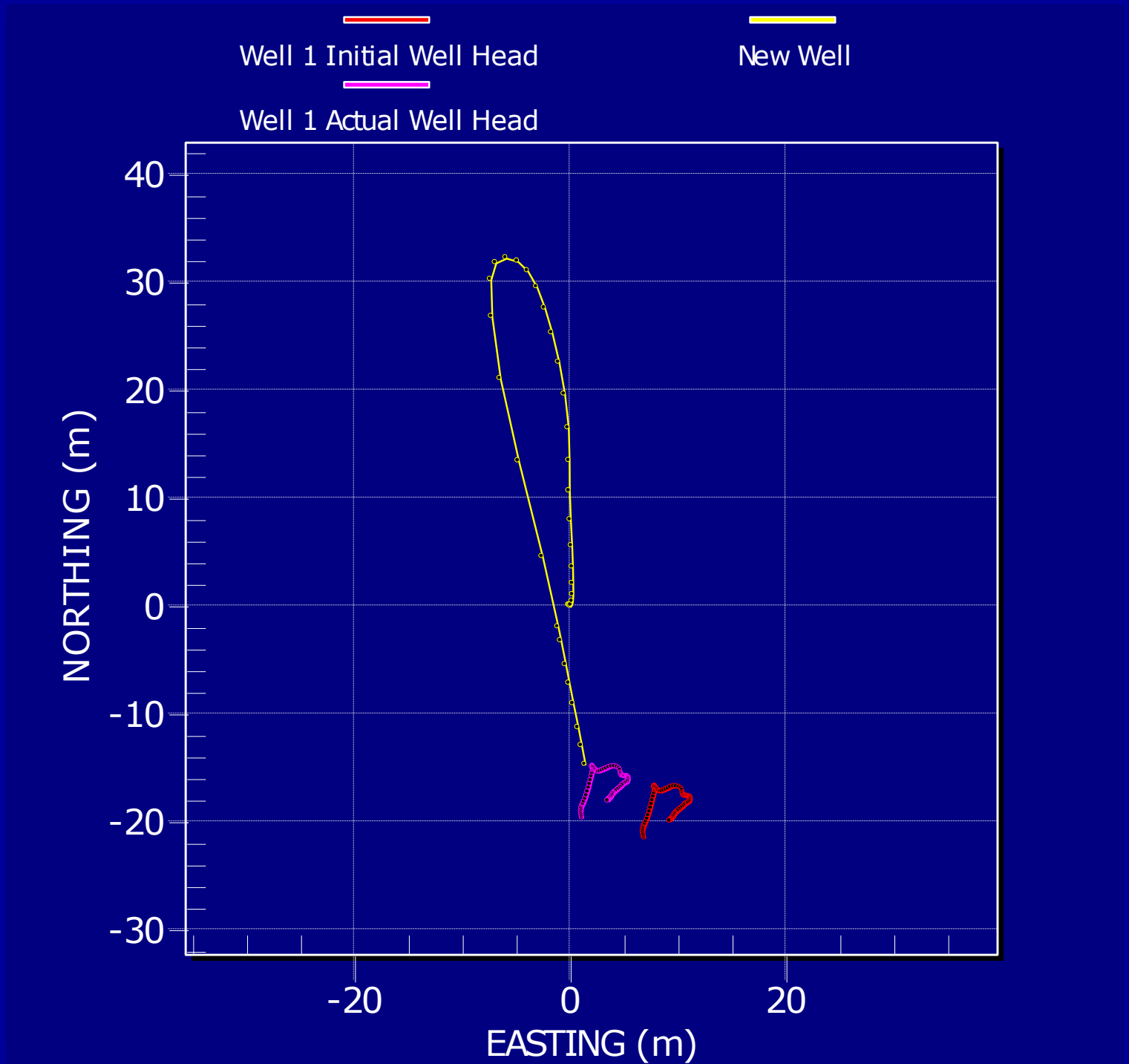
- Error propagation mode can be
  - Random
  - Systematic
  - Well by Well or
  - Global.

- MWD surveys run
  - following standard procedures
  - rigorous and regular tool calibration
  - survey interval no greater than 100ft
  - non-magnetic spacing according to standard charts
  - not surveying in close proximity to existing casing strings or other steel bodies

ERROR MODEL FOR GYRO TOOLS

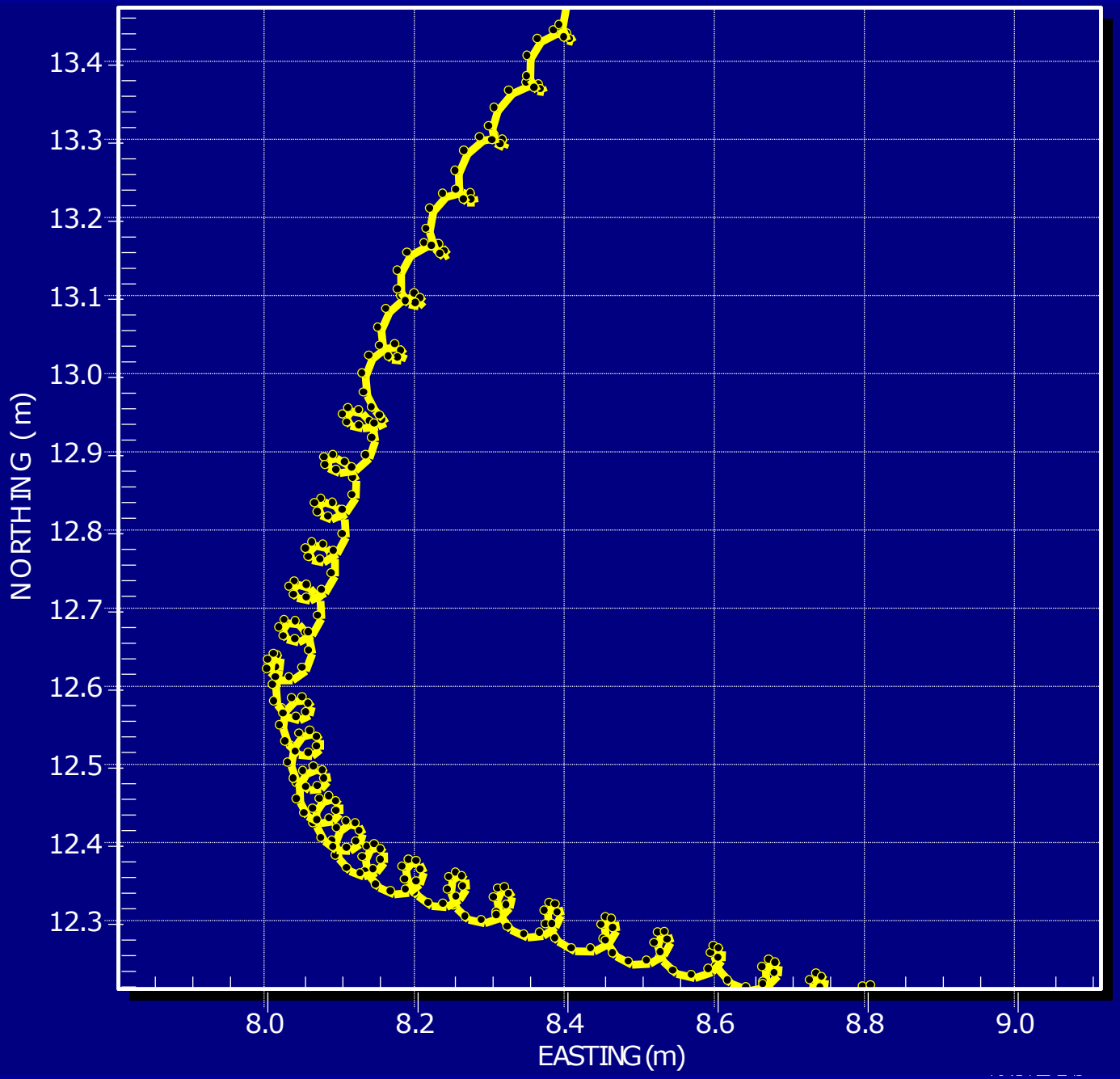
- Set of terms for the ISCWSA compatible model for Gyro compass mode
- Set of simplified terms for the continuous mode of operation
- All terms for the ISCWSA need to be provided for each gyro Company

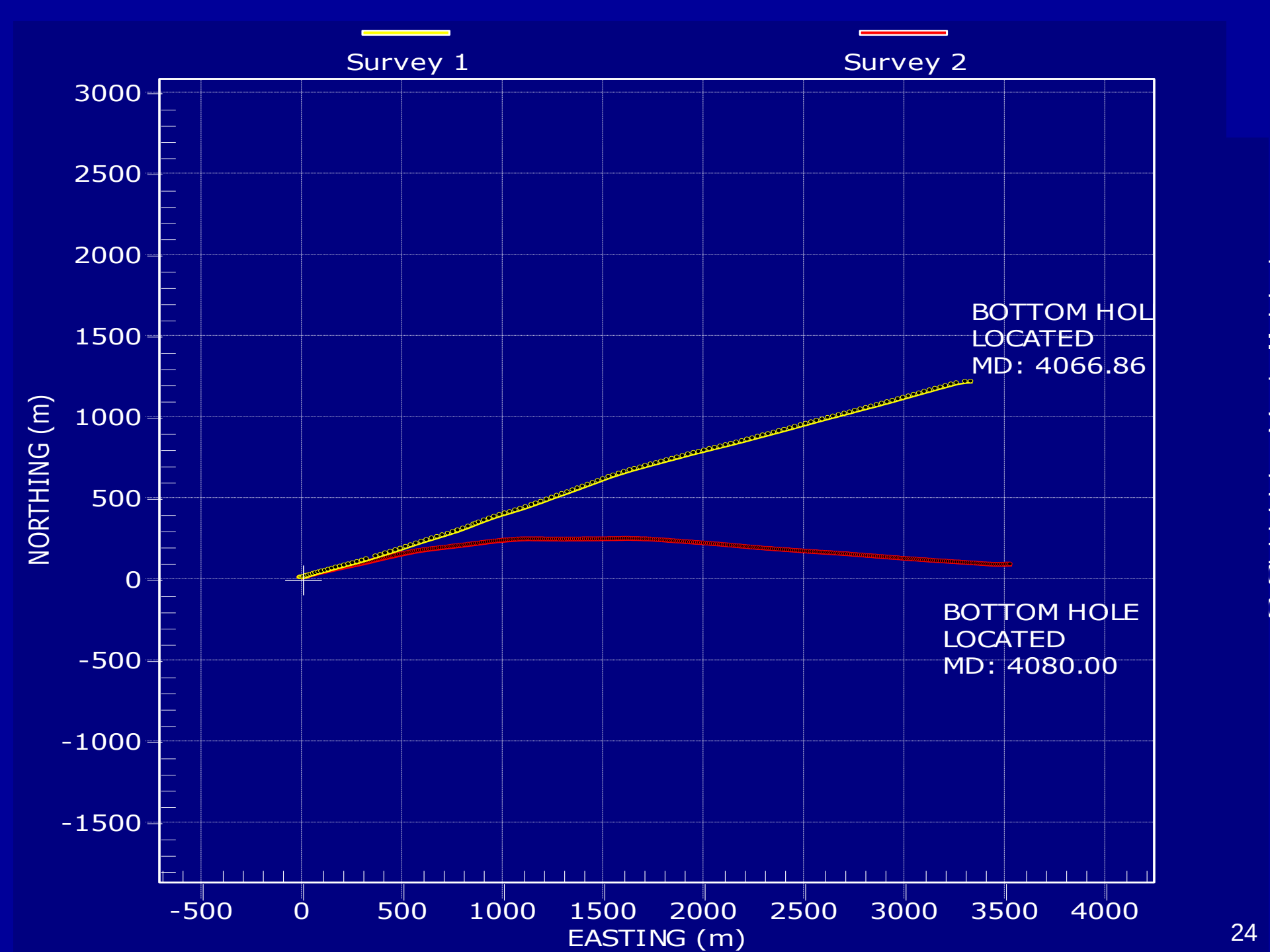
SPE 90408


Well 1 Initial Well Head
New Well
Well 1 Actual Well Head
40
30
20
10
0
-10
-20
-30
NORTHING (m)
-20
0
20
EASTING (m)

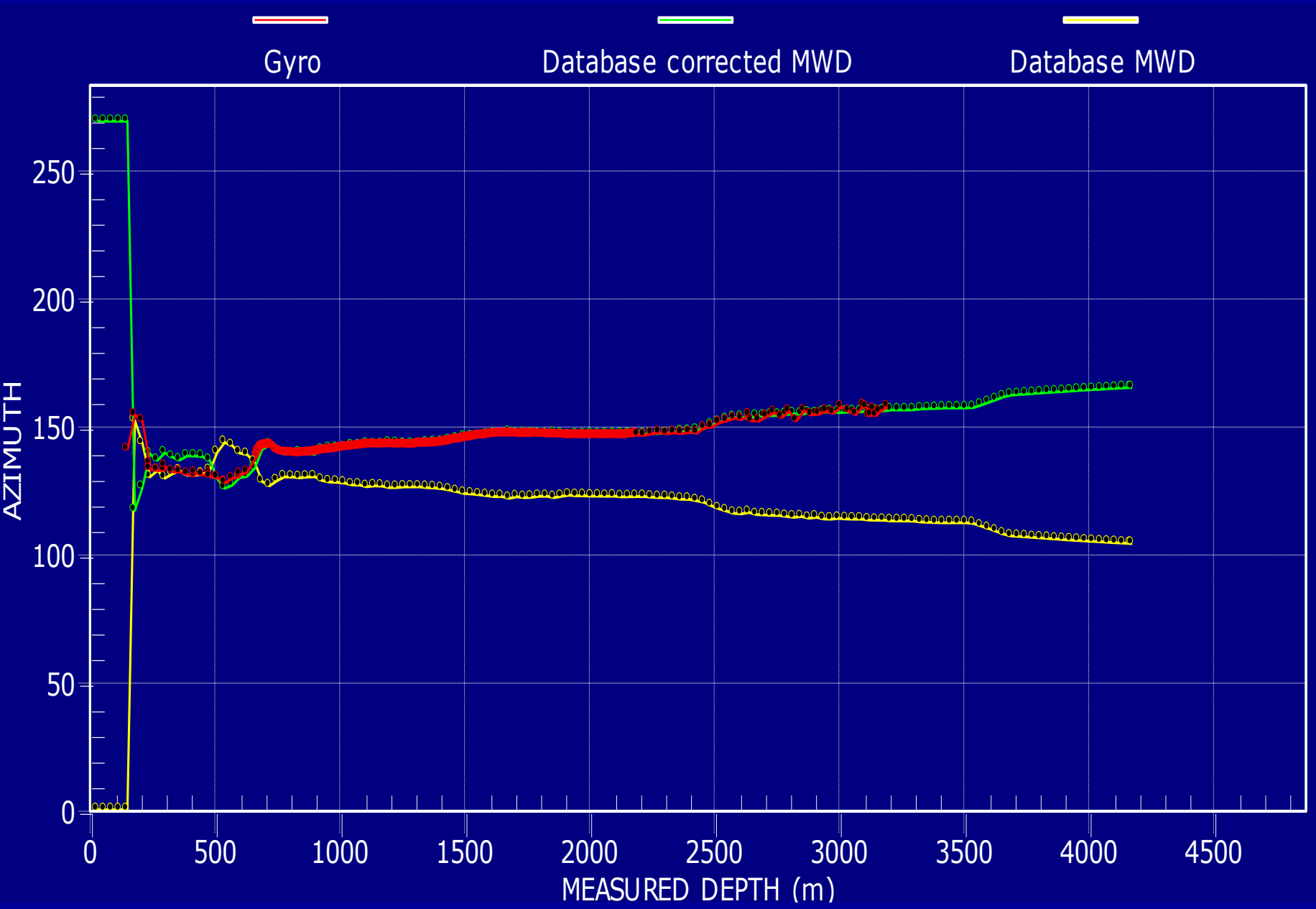
GROSS ERROR EXAMPLE

COMPLETION APLICATION EXAMPLE

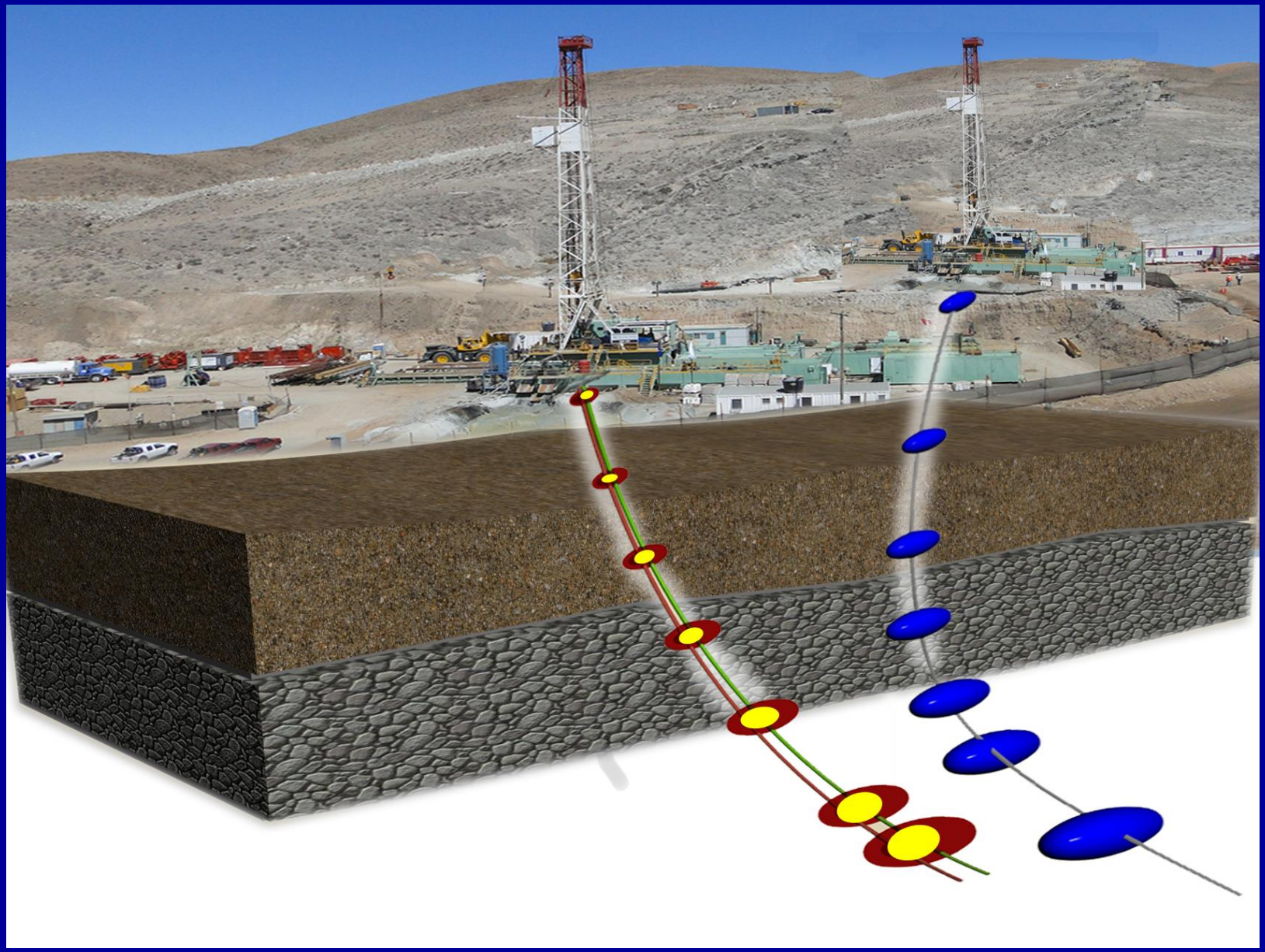



Survey 1
Survey 2
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
NORTHING (m)
-500
0
500
1000
1500
2000
2500
3000
3500
4000
EASTING (m)
BOTTOM HOL
LOCATED
MD: 4066.86
BOTTOM HOLE
LOCATED
MD: 4080.00

GROSS ERROR EXAMPLE



ERROR MODELS



BUSINESS CASE?

•A shorter gyro run	$10,000 +
•A proximity ‘shut in’	$100,000 +
•A plug back side-track	$1 million +
•A dry well or ‘Dead Zone’	$10 million +
•A deep landing	$100 million +
•A minor collision blowout	$1 billion +
•A major collision blowout	$10 billion +

Prof Angus Jamieson

CONCLUSIONS

- Survey planning is very important in the design of the well trajectory.
- Verify the wellhead position and the survey program to avoid gross errors.
- The survey data needs to be validated and screened for gross error before to use in the error model.
- Internal Quality Control measures after each shot are necessary but not enough.

CONCLUSIONS

- External Quality Control with an overlapping independent survey is the most reliable way to detect gross errors.

- Comparisons of Inclination, Azimuth and coordinates to an independent verification survey, is the most powerful Quality Control available.

- Each error model is validated by the service companies.

SURVEY RECOMMENDATION PRACTICES

- After each survey station
  - G-total-, H-total/dip- tests
    - Misalignments, Declination, Sag and Depth are not controlled

- At least once per survey section
  - Rotation shot tests
    - Misalignments are now controlled

- At the end of each survey section
  - Multi station corrections
    - Validity dependent on geometrical variation
    - No more terms controlled
    - Accuracy is improved

SURVEY RECOMMENDATION PRACTICES

- At an intermediate bit run
  - Independent verification survey tests
  - EMS - Declination is not controlled
  - Drop gyro - Depth is not controlled
  - Wire-line gyro - All error terms are controlled

- At TD if a definitive survey is necessary
  - Continuous gyro survey
  - Independent initialisation
  - Both in-run and out-run

- ISCWSA is a good source of information and is part of SPE please contact

- WWW.ISCWSA.NET

- Or inside the SPE web page:

http://connect.spe.org/WellborePositioning/home

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