Webinars

Welcome!

The program will begin soon.

You will not hear audio until we begin.

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Webinars

Why your wells may not be where you think they are

Prof Angus L Jamieson BSc FRICS

October 5th 2023

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H&P

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Don't be in the wrong place at the wrong time !!

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Why do we survey at all ?

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- Ensure a safe well path to the target
- Measure the progress and correct the path
- Ensure you hit target & maximise production
- Ensure you don’t hit another well
- Provide good log positions to G&G
- Provide good reserves estimates
- Report data to the government
- Conduct ‘forensics’ investigations afterwards
- To be prepared for a relief well if necessary

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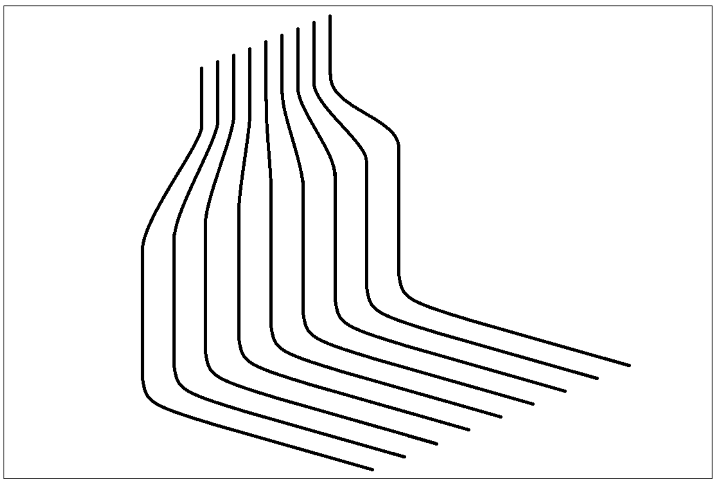
Good Surveying = Good Production



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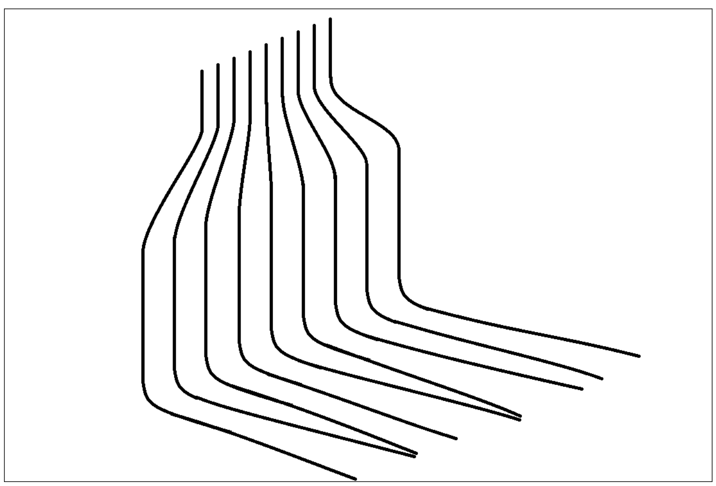
Good Surveying = Good Production



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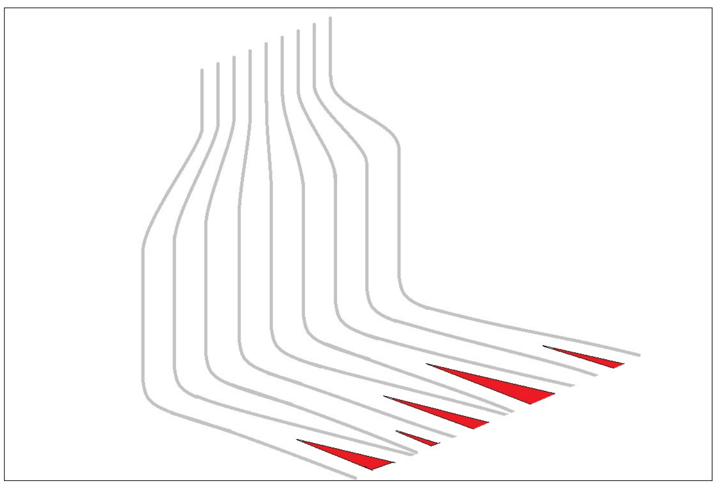
Good Surveying = Good Production



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Why do we survey at all ?

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Business Case ?

- ►A shorter gyro run $10,000 +
- ►A proximity 'shut in' $100,000 +
- ►A plug back sidetrack $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 +

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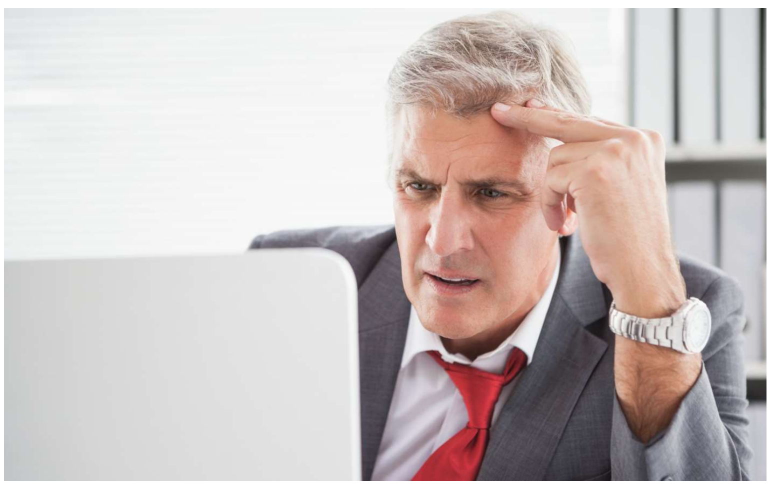
What happens if you do collide with another well or geo-hazard ?

Shutterstock Image



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Destruction of Assets


image courtesy of John Wright

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Environmental Damage

image courtesy of John Wright

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Atmospheric Pollution

image courtesy of John Wright

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Marine Pollution

image courtesy of John Wright

15

Reputational Damage

image courtesy of John Wright

16

Danger to Life

image courtesy of John Wright

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Fire is our worst enemy

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Low probability – High Impact

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In Summary

Saving money on surveying is a high stakes gamble which, if lost, will make you famous

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Is my survey reliable ?

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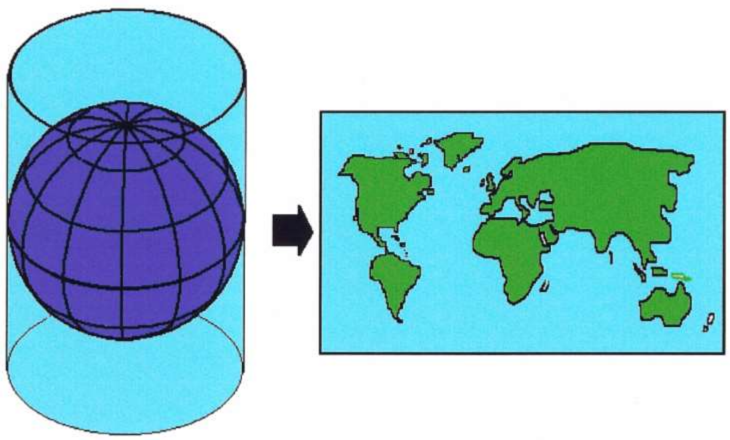
Mapping the World



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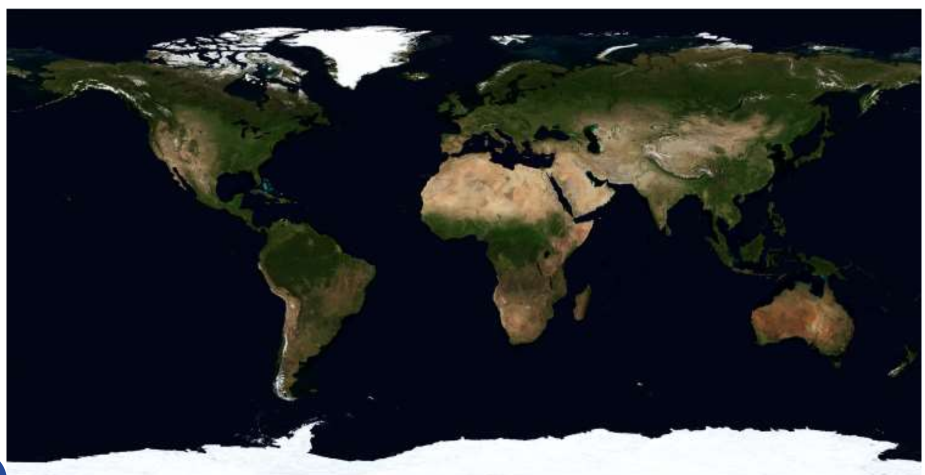
Any Projection distorts the World



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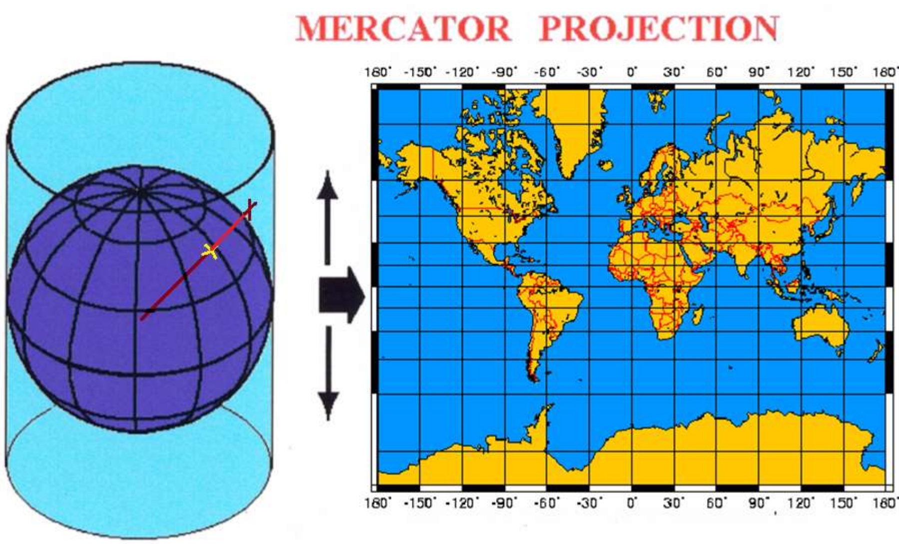
Project from the centre of the Earth



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Greenland is actually only 10% of the size of Africa

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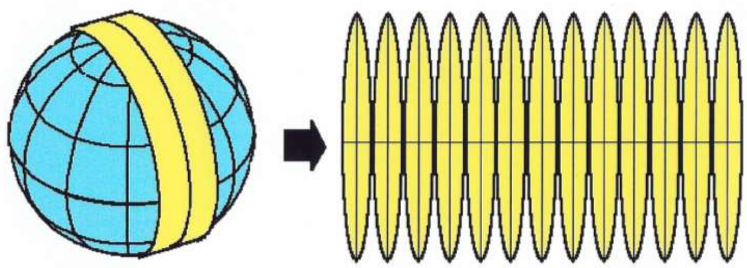
UNIVERSAL TRANSVERSE MERCATOR PROJECTION



Each of 60 cylinders maps a 6 degree wide 'Zone'

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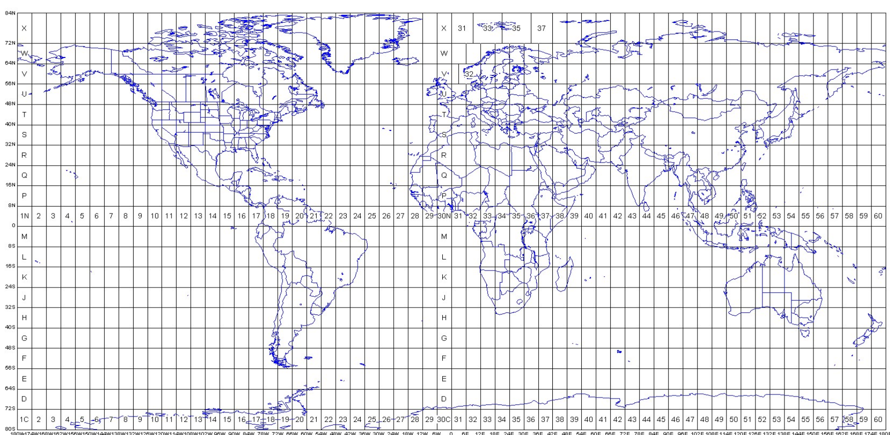
UTM Zones



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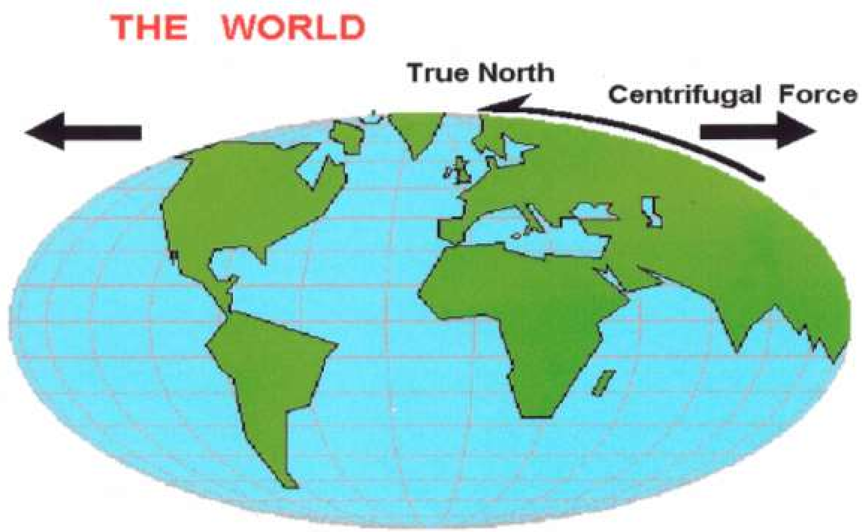

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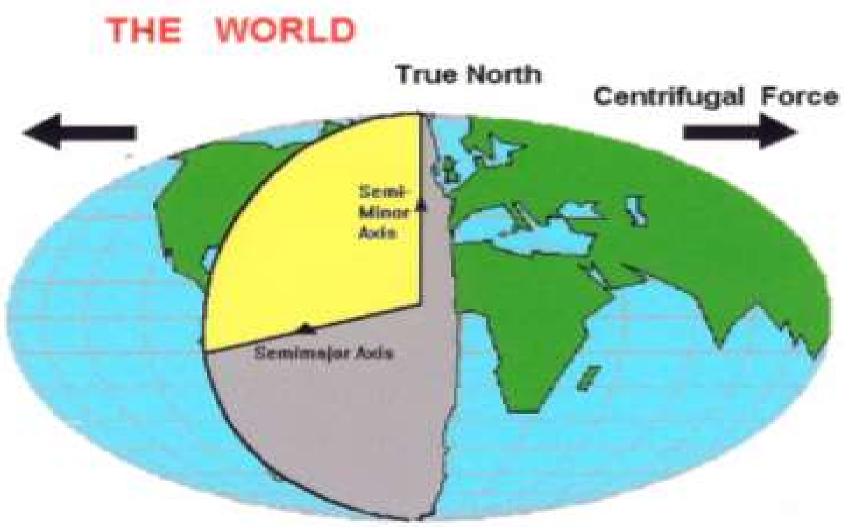

THE WORLD
True North
Centrifugal Force
Semi-
Minor
Axis
Semimajor Axis

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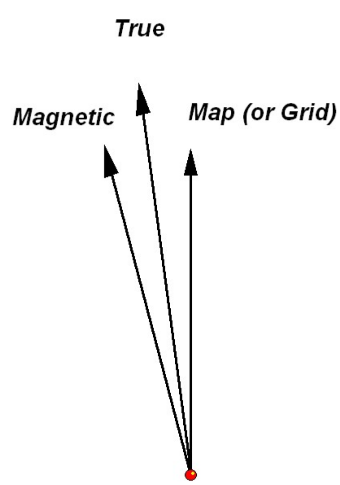
With three Norths it is easy to get confused



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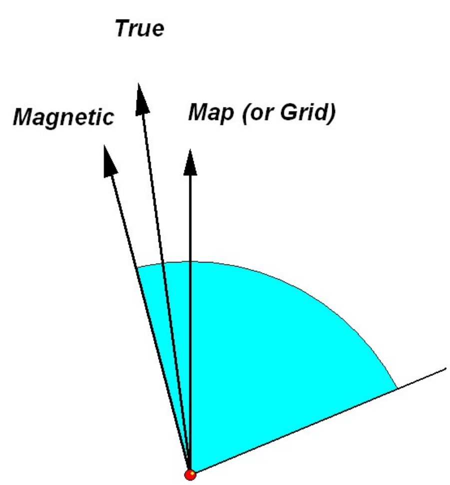
MWD measures from Magnetic North



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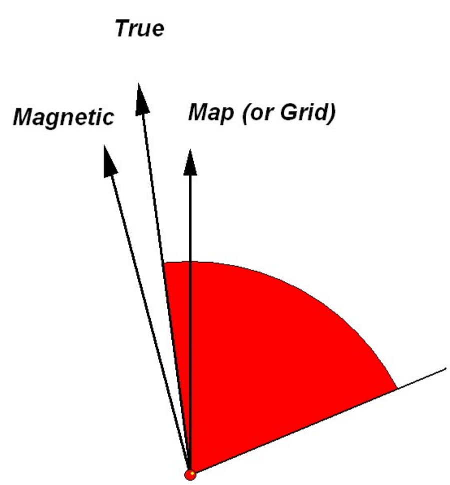
Gyros usually measure from True



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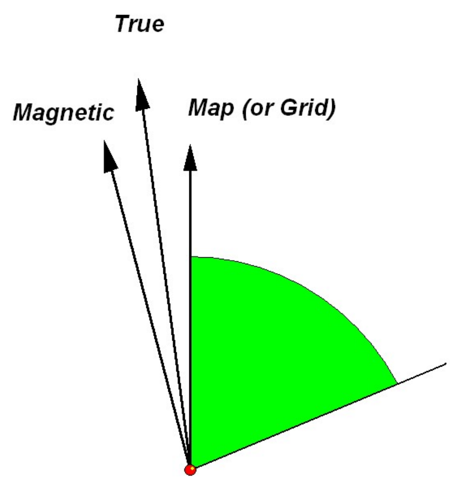
But most surveys are finally reported in Grid



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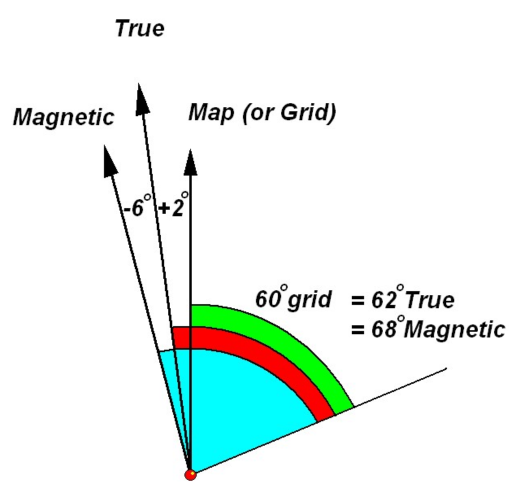
For Example if Declination was -6 degs and Convergence was +2 degs



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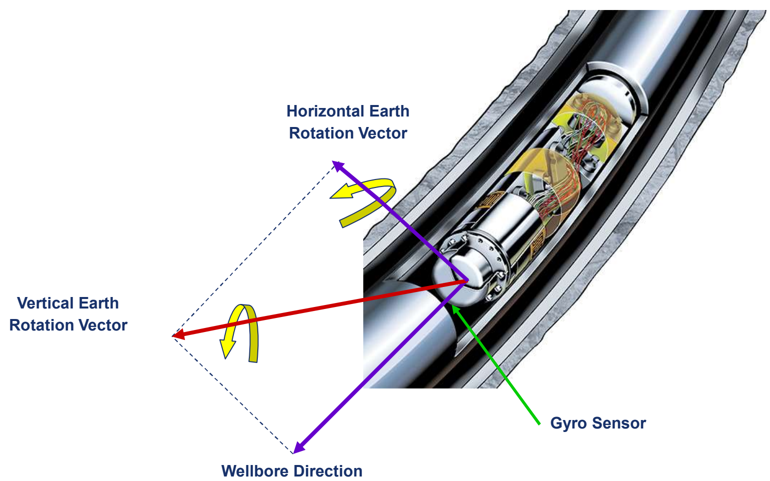
MWD

Continuous Gyro



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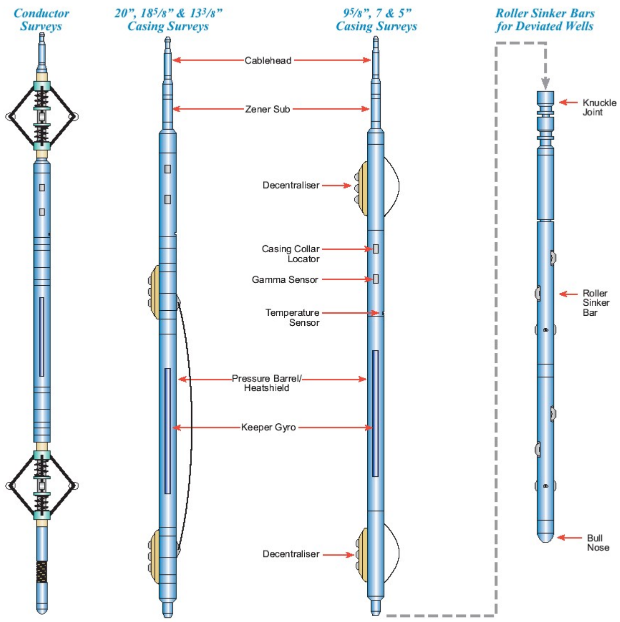
Gyroscopic Tools



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Survey Errors Form A Normal Distribution

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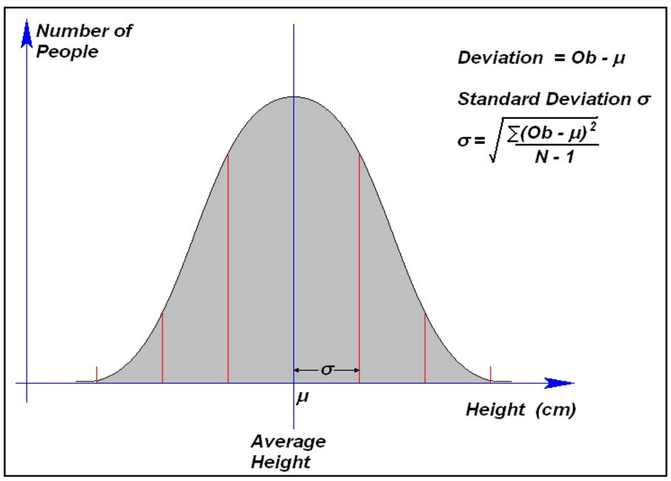

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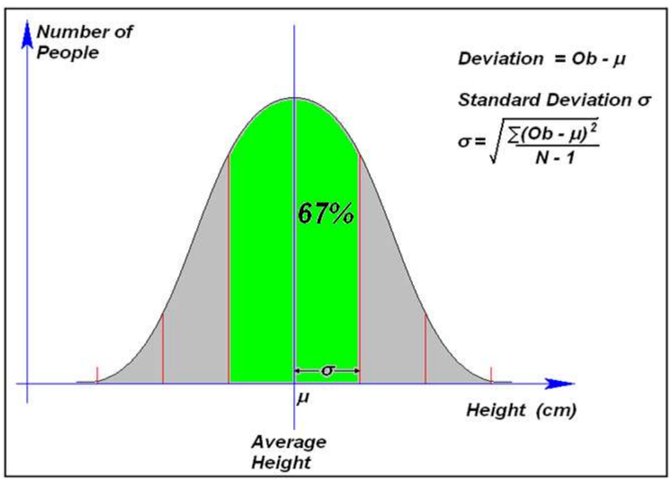
A Normal Distribution



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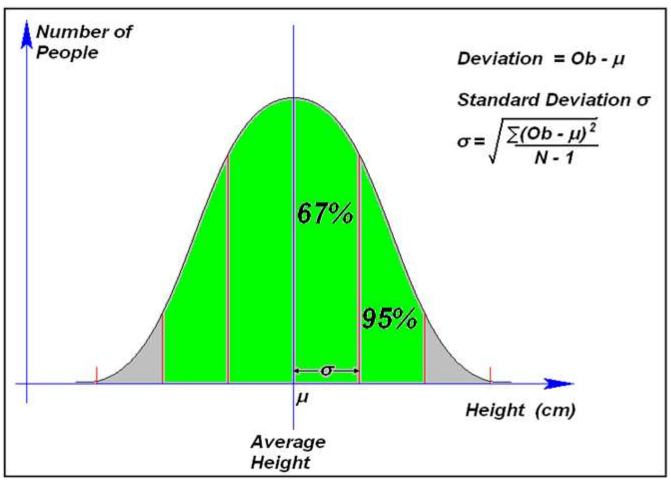
A Normal Distribution



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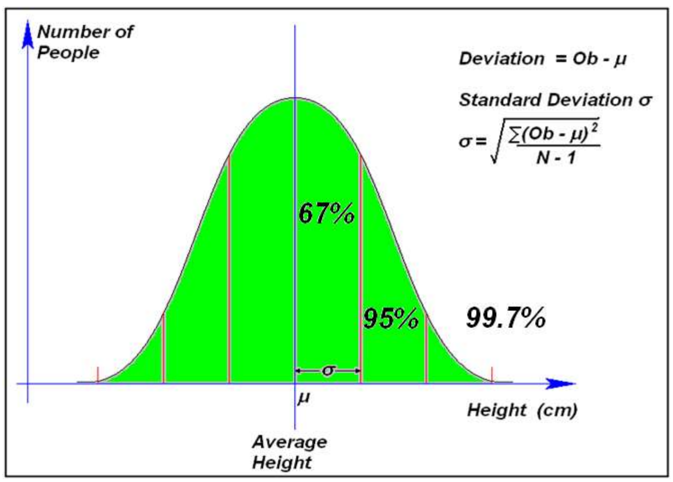
A Normal Distribution



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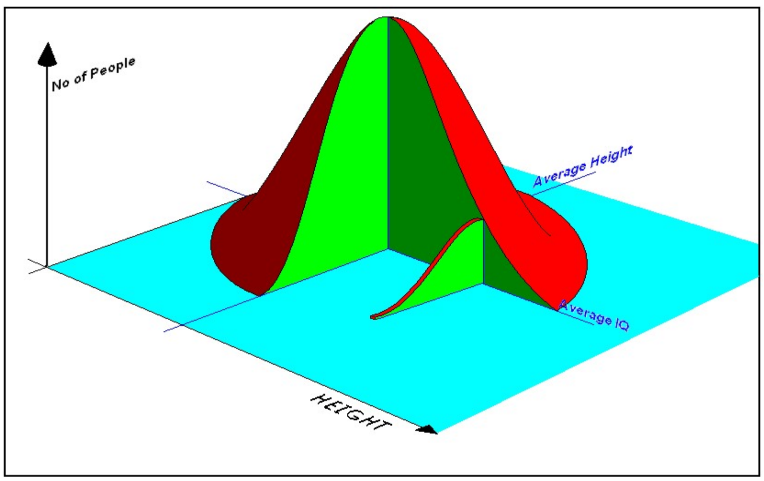
Normal distribution of 2 parameters



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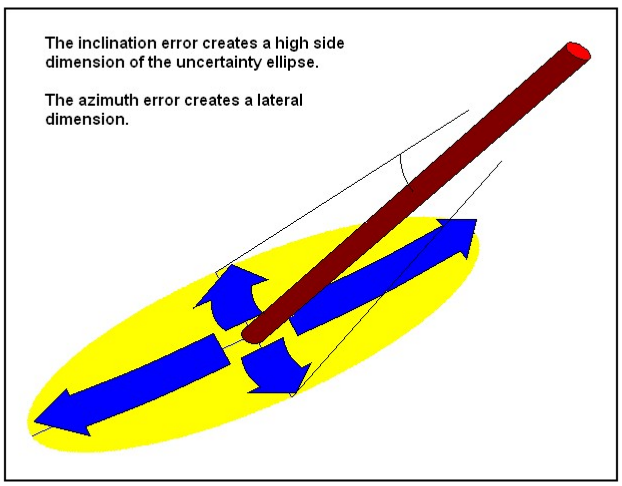
The inclination error creates a high side dimension of the uncertainty ellipse.
The azimuth error creates a lateral dimension.

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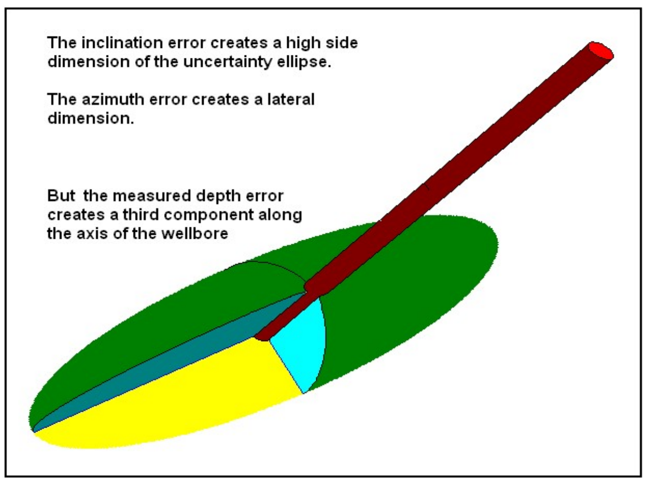
The inclination error creates a high side dimension of the uncertainty ellipse.
The azimuth error creates a lateral dimension.
But the measured depth error creates a third component along the axis of the wellbore

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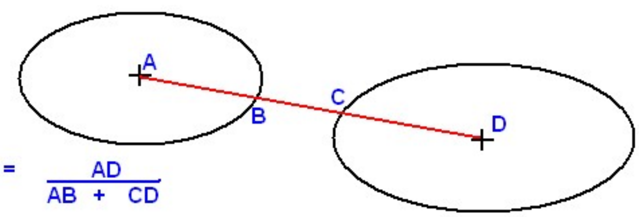
The ISCWSA MWD Model

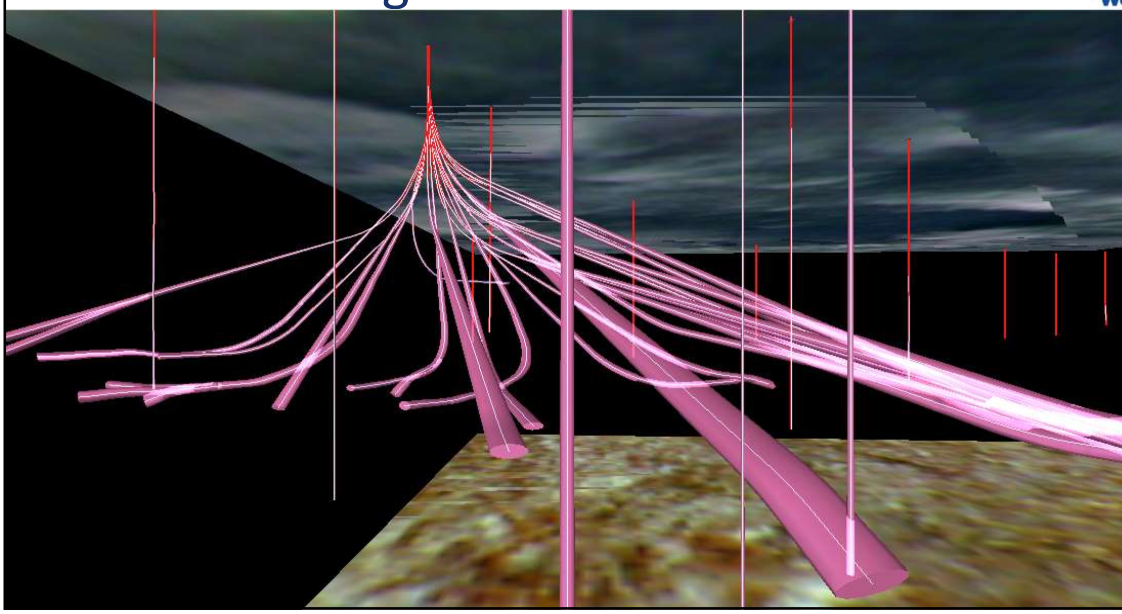
	Name	Vector	Tie-on	Value (1 sigma)	Units	Formula
1	dref	e	r	0.35000000	m	1.0
2	dsf	e	s	0.00024000	-	tmd
3	dsts	e	s	0.00000022	im	tmd*tvd
4	w_12	n	n	1.00000000	-	sin(inc)
5	w_34	n	n	1.00000000	-	sqrt(1-(w_12)^2)
6	mxy1	i	s	0.06000000	d	w_12
7	mxy2	l	s	0.06000000	d	w_12
8	mxy3	i	s	0.06000000	d	cos(azi)*w_34
9	mxy3	l	s	0.06000000	d	-sin(azi)*w_34
10	mxy4	i	s	0.06000000	d	sin(azi)*w_34
11	mxy4	l	s	0.06000000	d	cos(azi)*w_34
12	sag	i	s	0.20000000	d	(sin(inc))
13	azr	a	g	0.36000000	d	1.0
14	dbh	a	g	5000.00000000	dnt	1.0/(mtot*cos(dip))
15	azm	a	s	0.25000000	d	1.0
16	amid	a	s	0.60000000	d	sin(inc)*sin(azm)
17	abx	i	s	0.00400000	-	(-cos(inc)*sin(tfo))/gtot
18	abx	l	s	0.00400000	-	((cos(inc)*sin(azm)*sin(tfo)-cos(azm)*cos(tfo))*tan(dip)*sin(inc)+cos(tfo)*cos(inc))/
19	aby	i	s	0.00400000	-	(-cos(inc)*cos(tfo))/gtot
20	aby	l	s	0.00400000	-	((cos(inc)*sin(azm)*cos(tfo)+cos(azm)*sin(tfo))*tan(dip)*sin(inc)-sin(tfo)*cos(inc))/
21	abz	i	s	0.00400000	-	(-sin(inc))/gtot
22	abz	a	s	0.00400000	-	(tan(dip)*sin(inc)*sin(azm))/gtot
23	asx	i	s	0.00050000	-	(sin(inc)*cos(inc)*(sin(tfo))^2)
24	asx	a	s	0.00050000	-	(-(tan(dip)*sin(inc)*(cos(inc)*sin(azm)*sin(tfo)-cos(azm)*cos(tfo))+cos(inc)*cos(tfo)
25	asy	i	s	0.00050000	-	(sin(inc)*cos(inc)*(cos(tfo))^2)
26	asy	a	s	0.00050000	-	(-(tan(dip)*sin(inc)*(cos(inc)*sin(azm)*cos(tfo)+cos(azm)*sin(tfo))-cos(inc)*sin(tfo))
27	asz	i	s	0.00050000	-	(-sin(inc)*cos(inc))
28	asz	a	s	0.00050000	-	(tan(dip)*sin(inc)*cos(inc)*sin(azm))
29	mbx	a	s	70.00000000	nt	(cos(azm)*cos(tfo)-cos(inc)*sin(azm)*sin(tfo))/(mtot*cos(dip))
30	mby	a	s	70.00000000	nt	(-(cos(azm)*sin(tfo)+cos(inc)*sin(azm)*cos(tfo)))/(mtot*cos(dip))
31	mbz	a	s	70.00000000	nt	(-sin(inc)*sin(azm))/(mtot*cos(dip))
32	msx	a	s	0.00160000	-	(cos(inc)*cos(azm)*sin(tfo)-tan(dip)*sin(inc)*sin(tfo)+sin(azm)*cos(tfo))*(cos(azm)*
33	msy	a	s	0.00160000	-	(-(cos(inc)*cos(azm)*cos(tfo)-tan(dip)*sin(inc)*cos(tfo)-sin(azm)*sin(tfo))*(cos(azm)
34	msz	a	s	0.00160000	-	(-(sin(inc)*cos(azm)+tan(dip)*cos(inc))*sin(inc)*sin(azm))

Collision Risk



Separation Factor = $\frac{AD}{AB + CD}$

High Collision Risk



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Major Corrections to reduce Uncertainty

- **Depth Correction**
  - There are many sources of error affecting both drill pipe and wireline length downhole but depth correction will usually address the mechanical and thermal stretch. These account for the major depth errors and can be as much as 0.2%
- **Sag Correction**
  - This is an inclination correction to allow for the natural bending of the BHA under its own weight. It increases with inclination and can be 0.5 degrees or more.
- **IFR Correction**
  - This usually refers to the local correction of magnetic declination and is derived from an In-Field Referencing survey of the oilfield. This can be up to 1 degree in places
- **Magnetic Interference**
  - This applies to azimuth only and corrects for the magnetic influence of the BHA itself. It is particularly important when using short non-mag collars.

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Mechanical Stretch

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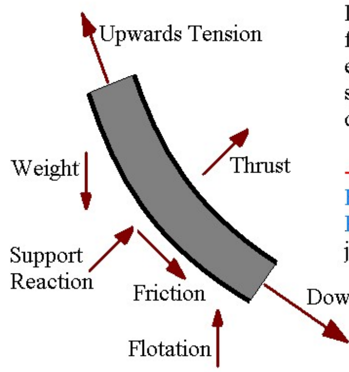

Integrate the effect of all forces acting on each finite element to determine the strain stretch at each survey depth and correct in the field

- requires
BHA weight   Mud Weight
Pipe Weight   Coeff Friction
just as for torque and drag

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Temperature Effects

- ▶Steel will stretch by

1.3m / 1000 / 100 degs C

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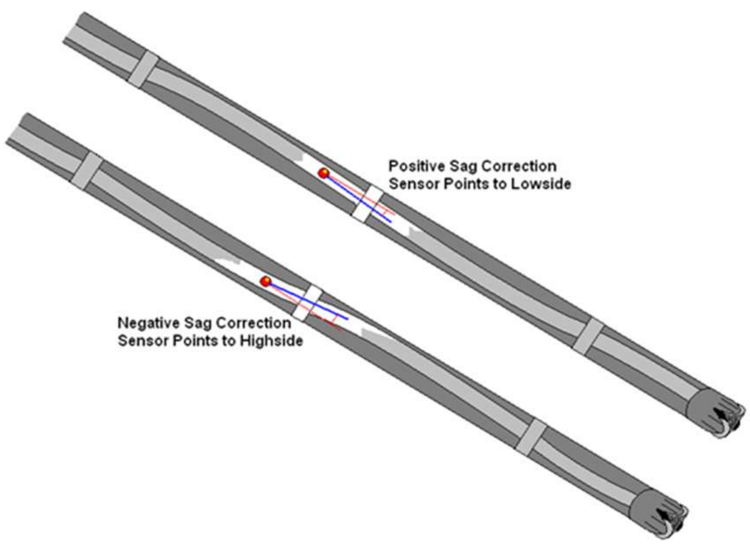
Sag Correction



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MWD Relies on the Earths Magnetic Field

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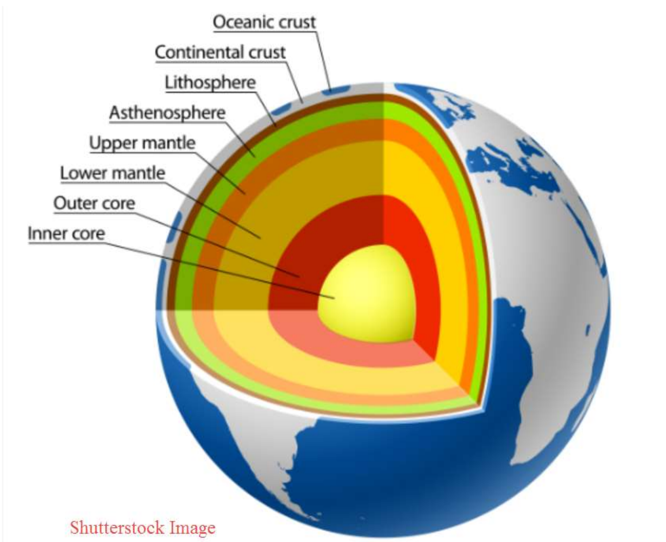
The Earth Has a Magnetic Core



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The Earth's Magnetic Vector

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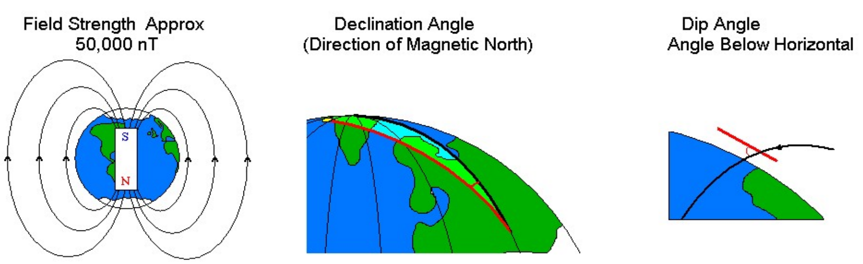

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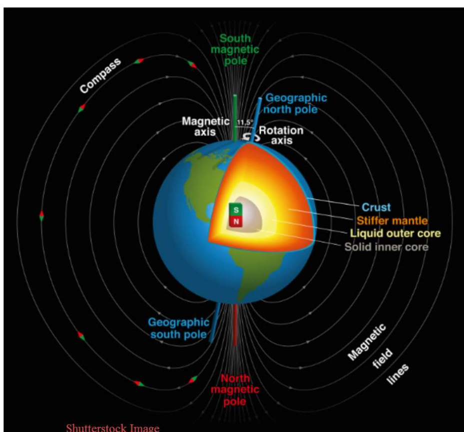
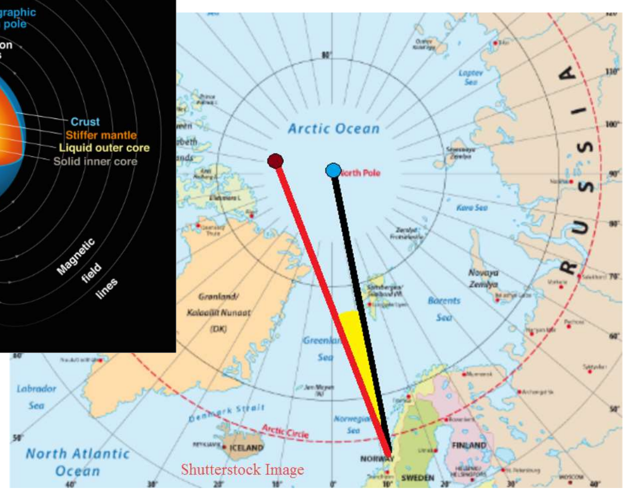
Declination





A Powerful Force but subject to three Variations

1. Secular Variation

Long slow changes in the earths magnetic core.
Typical Size: Fractions of a deg/year
Cured By: BGGM model

2. Diurnal Variation

Rapid daily variations caused by solar wind and earth rotation.
Typical Size: 0.2 degs (Randomized)
Cured By: Interpolated In Field Referencing (IIFR)

3. Crustal Variation

Permanent local effects caused by deep, magnetic basement rock
Typical Size: 1 degree
Cured By: In Field Referencing (described later) IFR

Shutterstock Image

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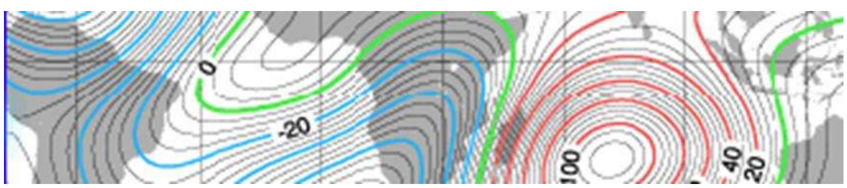
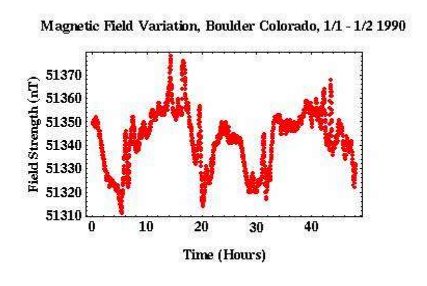
Secular Variation

- Observatories around the world provide data to the BGS in Edinburgh from which they make a prediction model called BGGM
- British Global Geomagnetic Model



Diurnal Variation

- The earth is constantly bombarded by ionised material from the solar wind creating a ripple effect in the magnetic field.
- The earth is also rotating creating a sine wave effect in the magnetic field.
- By observing distant land stations in real time, the diurnal effects can be interpolated locally.
- This is known as Interpolated In-Field Referencing or IIFR. (not to be confused with IFR)



Crustal Variation

- Caused by the magnetic effect of deep basement rock.
- Cannot be corrected with Global models
- Can be a degree or more in declination
- Must be measured in the field

Measuring the Earth Vector On Land

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Conditions are not always easy !

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Calibrating the Equipment on a Land Frame

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At sea, a Non-Magnetic Vessel carries the measuring frame

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Surveying is usually done in 10km x 10km grids at 2km spacing

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IFR by Air Land and Sea

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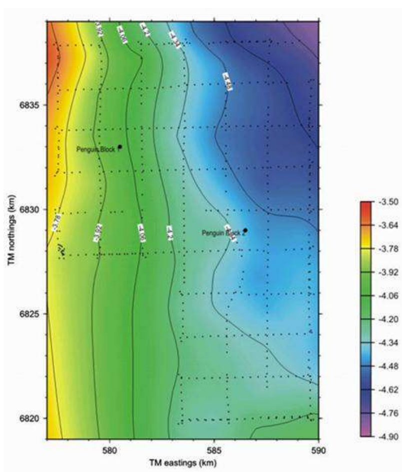
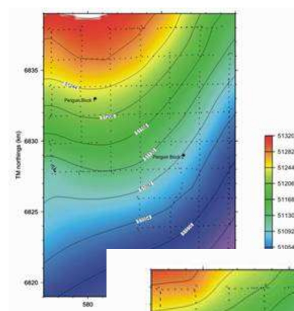
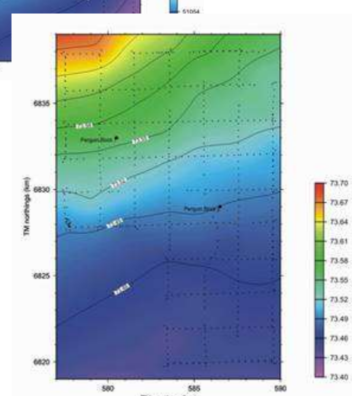
Results in graphical and software form

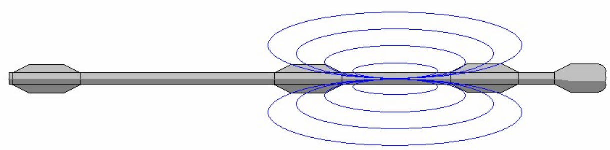






Magnetic Interference

- The interference created by the collars in the BHA can influence the observed azimuth by several degrees.



- Short Collar solutions only use the X and Y mags to calculate the azimuth
- Multi Station Analysis uses the fact that as the BHA changes toolface and attitude, the background magnetic field is unchanged but interference components rotate with the BHA. We can therefore back out the interference components over several survey stations

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Summary

- Reducing error is nearly always possible
- Sag is usually the biggest benefit in Vertical
- IFR is usually the biggest benefit in Horizontal
- Short Collar should only be used with caution
- MSA is only reliable in an accurate mag field
- SC and MSA do not work well when Bz small
- For high accuracy work nothing beats gyros

Conclusion

If we don't get the message out that wellbore positioning is worth spending money on, we will continue to waste reserves and occasionally risk lives.