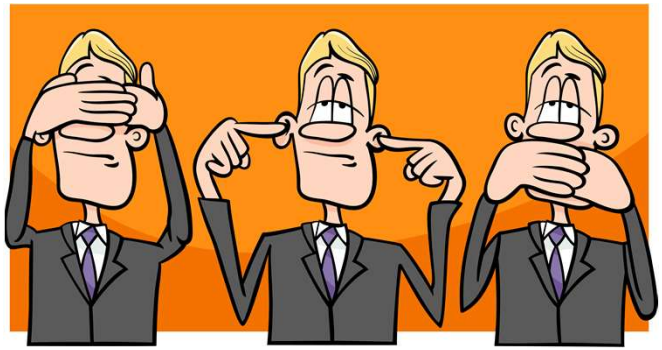
What is the actual depth and why do we ignore it ?

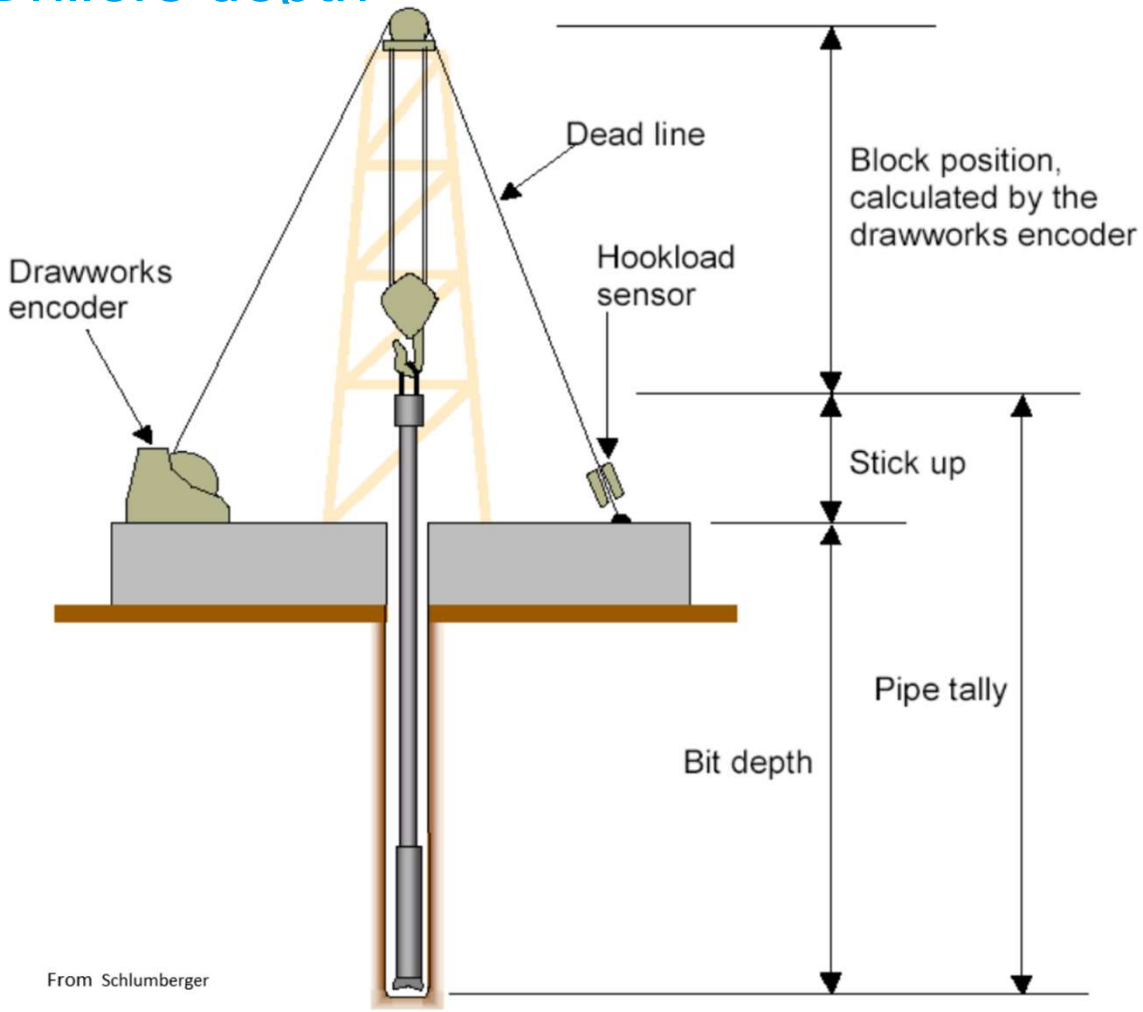
Russell Gray

DEPTH the basics

- DEPTH is **THE** most fundamental measurement acquired – all well data and field data is referenced to depth.
- Drillers Depth (DD) is applied while the well is being drilled and remains the reference depth in well records, Final Well Report, casing and completion reports.
- Drillers Depth is used for final survey and well position (critical for anti-collision and well paths) TVD and TVDSS.
- **Depth is also the most ignored measurement**



Drillers depth



Pipe tally = drillers depth

- Drill pipe comes in around 10 to15m lengths
- Lengths connected to make one stand – 30m

- Each pipe length is measured usually with a strap or tape measure

Uncertainty in each pipe length +/- 0.05% to 0.2% (1.5 cm to 6 cm per 30m)

- Pipe length can also be measured using a laser

Uncertainty+/- 0.015% to 0.02% (0.45 cm to 0.6 cm per 30m)

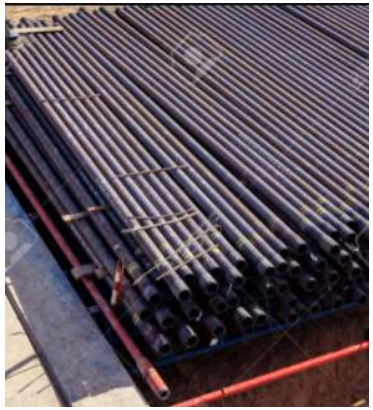
Both methods measure lengths in pipe yard, length will vary due to pipe bowing, temperature, care and attention.

Courtesy of Weatherford

Pipe tally

- Pipe yard tally
- Check offload tally at rig site
- Keep record of pipe lengths while run in hole
- Cumulative Tally = Drillers Depth

Bundle number (on tags)	Tally number (Centre) on pipe	Overall length (painted 6ft from pin end) meters	Cumulative length meters
5	1	11.651	137.441
	2	12.711	150.152
	3	13.001	163.153
6	4	12.903	176.056
	5	13.032	189.088
	6	11.932	201.020
7	7	13.177	214.197
	8	13.188	227.385
	9	12.824	240.209
8	10	12.880	253.089
	11	11.884	264.973
	12	12.824	277.797
9	13	12.778	290.575
	14	11.801	302.376
	15	12.043	314.419
10	16	10.723	325.142
	17	13.141	338.283
	18	13.602	351.885
11	19	13.845	365.730
	20	13.113	378.843
	21	13.099	391.942
12	22	13.421	405.363
	23	13.624	418.987
	24	13.227	432.214
13	25	13.506	445.720
	26	13.832	459.552
	27	13.745	473.297
14	28	13.082	486.379
	29	13.765	500.144
	30	13.787	513.931
15	31	13.811	527.742
	32	13.870	541.612
	33	13.505	555.117
16	34	13.595	568.712
	35	13.743	582.455
	36	13.599	596.054
17	37	13.892	609.946
	38	13.681	623.627
	39	13.447	637.074

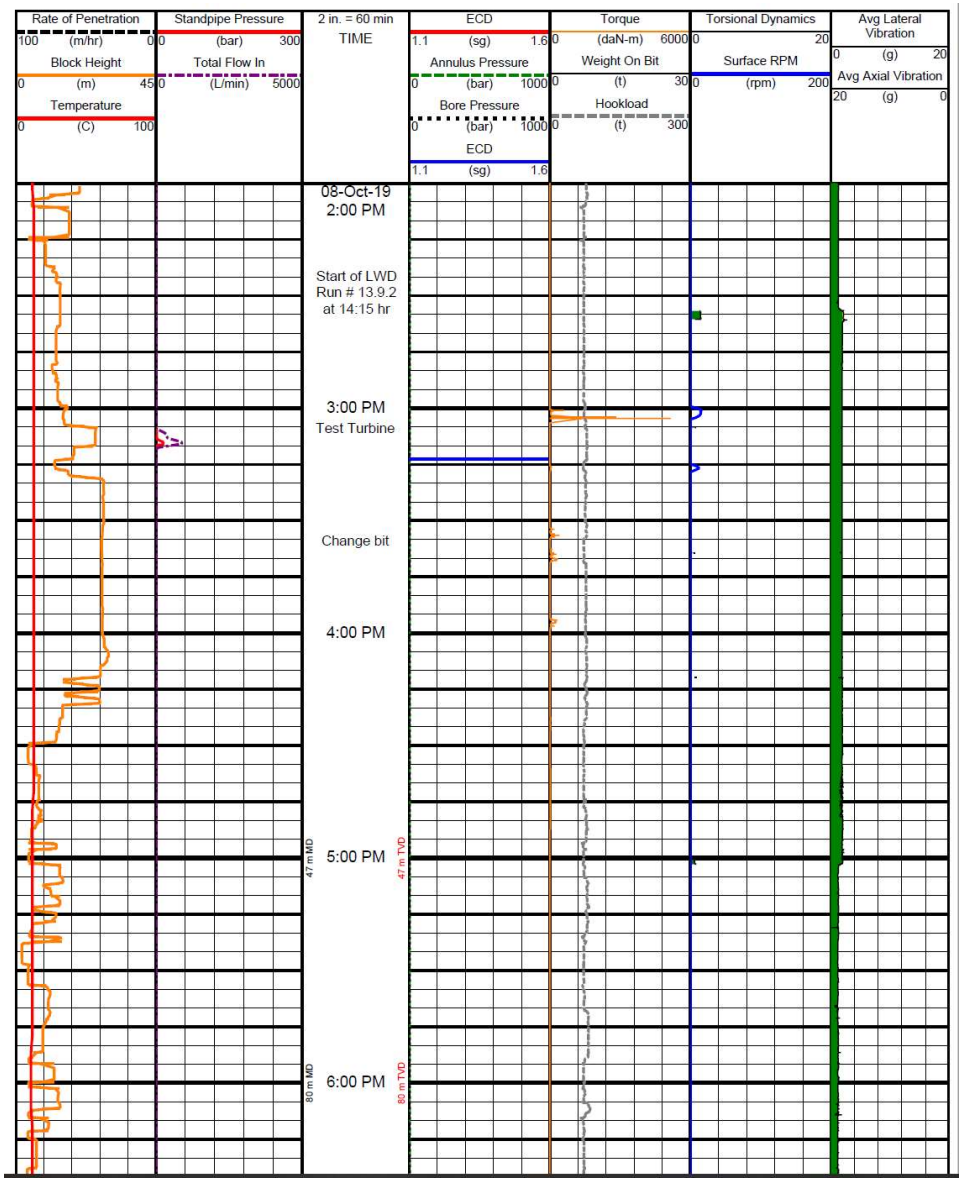


Drillers depth uncertainty

- Pipe lengths measured in yard with no load and ambient temperatures
- Tally errors
- Incremental depths based on hook height (Drawwork encoder)
- Pipe stick up at connection variation
- Real Time depth ‘adjustments’ are common
- Often rely on one encoder for the depth on drawworks – independent encoder from mudlogging unit or LWD unit not always installed

Time depth log

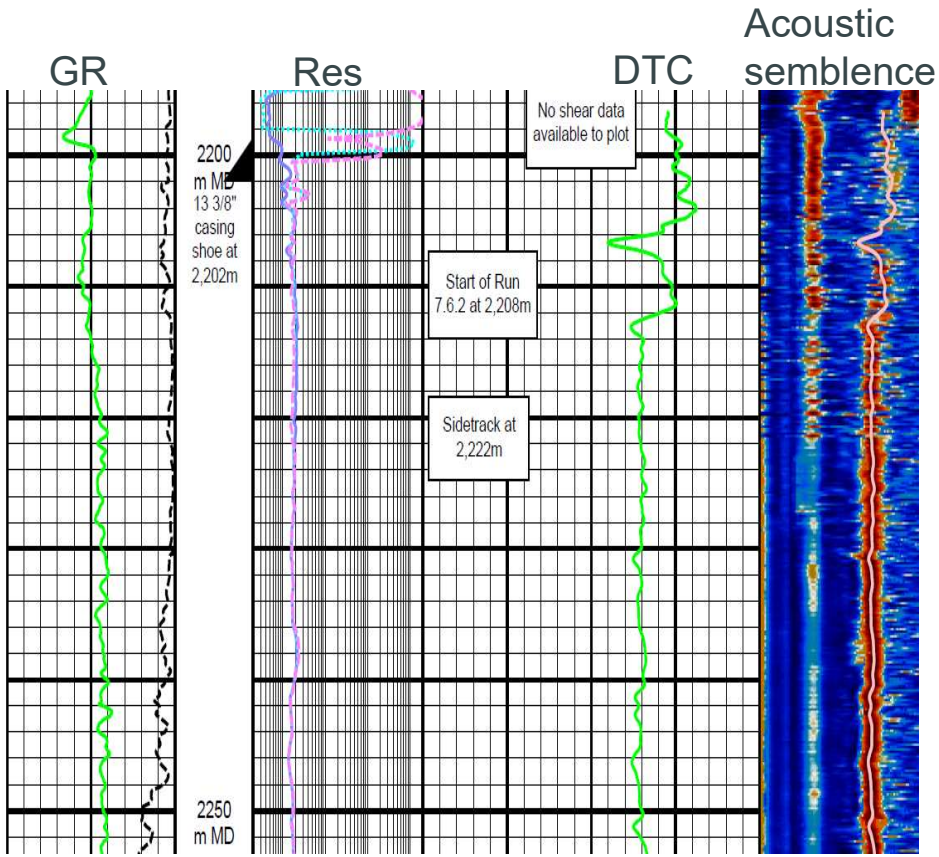
- Block height variation
- How consistently is the block height being recorded
- M/LWD engineer on the fly adjustments to fix any gaps or overlap



LWD depth

- Real time and memory final data based on drillers depth

- Very often when compare to wireline have to apply stretch and squeeze in LWD due to the adjustments in time to depth and load variation in drill pipes.

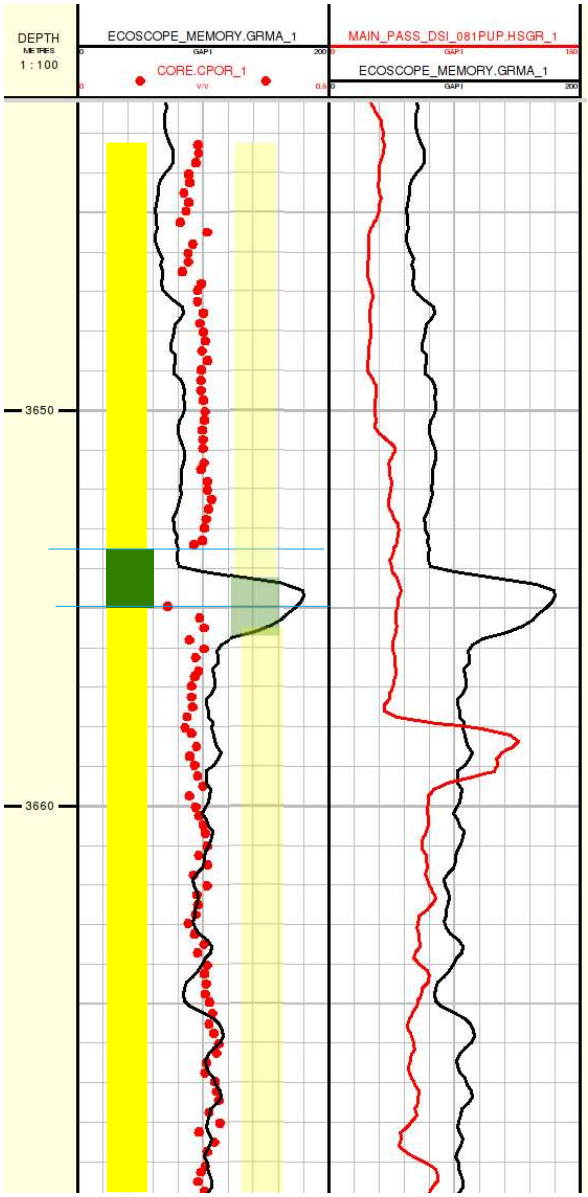


CORE DEPTH

Core depth is based on drillers depth

Core depth should match LWD logs – both are drillers depth

In this case can see the core data (red circles sampled in sands only) is 1m shallow to the GR



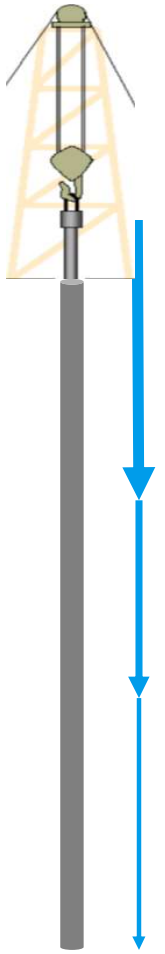
Black curve is LWD depth

Red curve is wireline log and is 3.8m deeper than the LWD depth

Which curve is the core to be matched to – was the core depth assumed to be the same as the LWD ?

Post well drillers depth correction

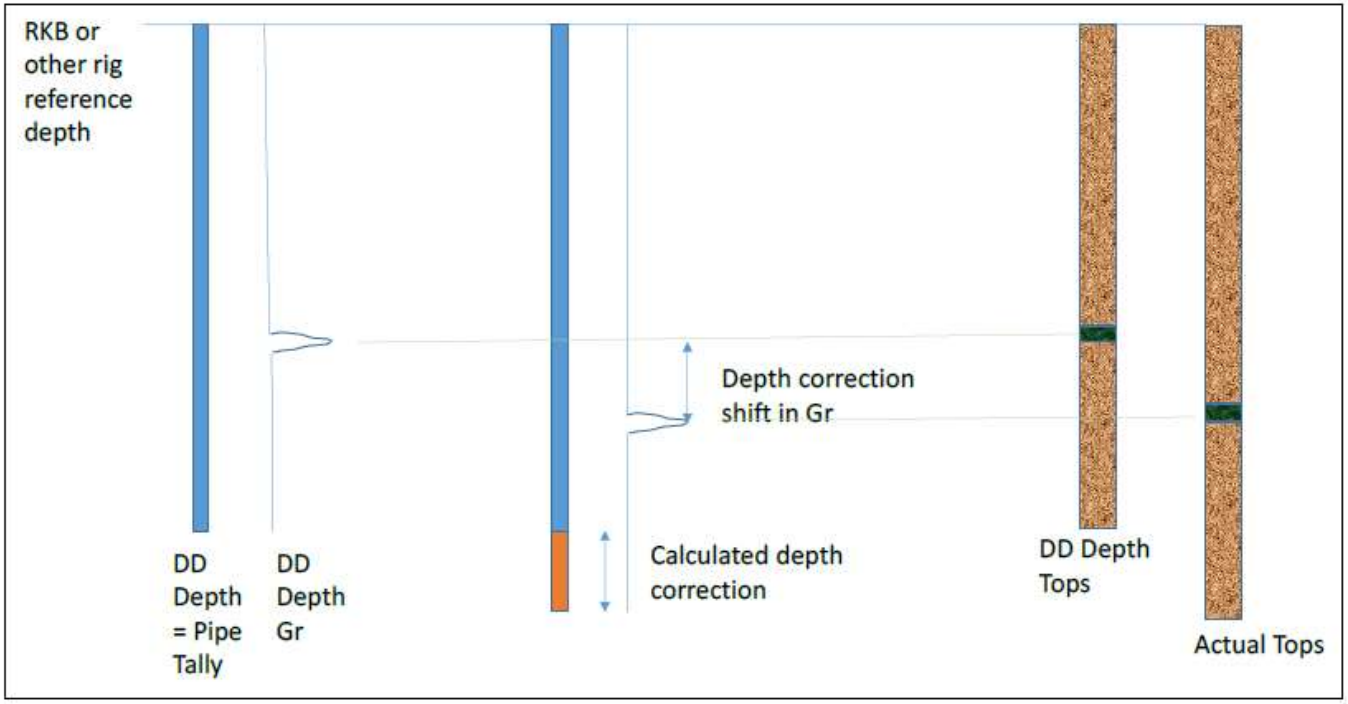
- We all know Drillers Depth is not ‘true depth’
- Pipe length measured with no load and surface temperature
- During drilling the pipe is in tension due to weight of connected pipes
  - Hook load increases with depth
  - Weight on bit is controlled by reducing the hook load transfering the weight of the pipe to the bit
- Pipe expands with increases in temperature
- Drilling dynamics; drag / bouyancy with mud and cuttings, pump rates, torque, WOB variation make for complex corrections



High tensional strain

Low tensional strain

Drillers Depth is **shallow** to true depth

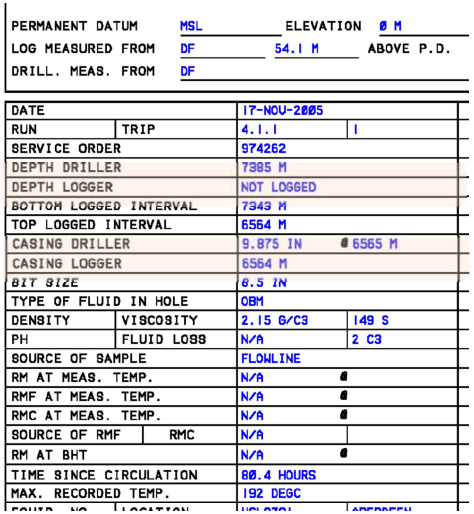


Drillers depth correction

- LWD is nearly always shallow to ‘true depth’
- Typically around 1 m per 1000 m depending on trajectory and temperature
- Correction possible using contractor in-house correction models with drilling and mud parameters applied
- Correction possible using Along Hole Depth corrections (Harald Bolt publications)
- VERY rarely is any correction applied – so we are at least consistently wrong!

Wireline depth

- First wireline run usually used as **PRIMARY DEPTH CONTROL**
- Wireline is the second measurement of depth in a well, in open hole or with in the casing.
- The wireline depth must be **INDEPENDENT of Drillers Depth**
  - NOT TIED TO CASING SHOE DEPTH - Logging crews can be requested to tie their depth to drillers. Results in no disagreement with drillers depth so drillers are happy.
    Need to go to field prints to read remarks to know if this is the case.
- Wireline depth should be deeper than drillers depth.



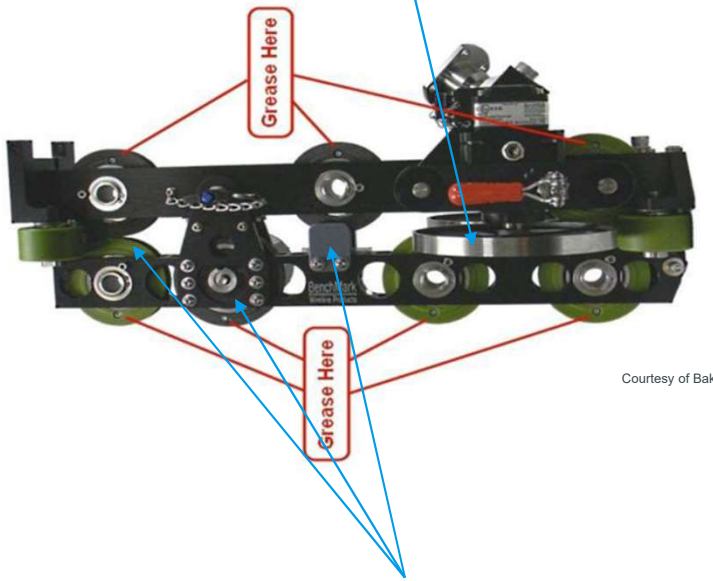
PERMANENT DATUM		MSL	ELEVATION	0 M
LOG MEASURED FROM		DF	54.1 M	ABOVE P.D.
DRILL. MEAS. FROM		DF		

DATE		17-NOV-2005	
RUN	TRIP	4.1.1	1
SERVICE ORDER		974262	
DEPTH DRILLER		7385 M	
DEPTH LOGGER		NOT LOGGED	
BOTTOM LOGGED INTERVAL		7343 M	
TOP LOGGED INTERVAL		6564 M	
CASING DRILLER		9.875 IN @ 6565 M	
CASING LOGGER		6564 M	
BIT SIZE		8.5 IN	
TYPE OF FLUID IN HOLE		OBM	
DENSITY	VISCOSITY	2.15 G/C3	149 S
PH	FLUID LOSS	N/A	2 C3
SOURCE OF SAMPLE		FLOWLINE	
RM AT MEAS. TEMP.		N/A @	
RMF AT MEAS. TEMP.		N/A @	
RMC AT MEAS. TEMP.		N/A @	
SOURCE OF RMF	RMC	N/A	
RM AT BHT		N/A @	
TIME SINCE CIRCULATION		80.4 HOURS	
MAX. RECORDED TEMP.		192 DEGC	

Wireline depth

- Cable passes through a measuring head
- Cable contacts precise measuring wheels which rotate as the cable passes
- One revolution of the measuring wheel results in a linear distance equaling the circumference of the wheel
- Depth is recorded through an Encoder

Measure wheels, horizontal to cable



Courtesy of Baker Hughes

Tension is measured by the amount the cable bends between offset wheels

Wireline depth – magnetic marked cables

- During the spooling of a cable onto a drum magnetic marks are applied onto the cable at fixed intervals of 25m or 50m with the cable pre tensioned to a fixed value (usually 1000 lbf).
- The depth mark is recorded at a reference point close to surface and the calibrated depth derived from the number of marks from the reference.
- Between marks the measurehead wheel encoder provide incremental depths.
- The use of a magnetically marked cable allows correction for measurehead wheel errors.
- By logging up over a recognised marker such as a casing shoe the magnetic mark depth compared to the wheel only values provide the correction in the measurehead wheel depth.

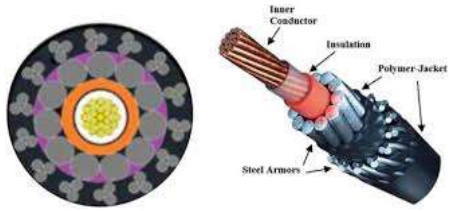
Wireline uncertainty

- To correct for possible cable slip on either measure wheel a fastest wheel algorithm is applied.
- The accuracy for measurement wheels is 0.03% to 0.05% (0.3m to 0.5m /1000m assuming zero slippage)
- The accuracy for magnetic marked cable is 0.01% to 0.015% (0.1 to 0.15m /1000m).

- Measure wheel only depth cannot be corrected for any errors – you have but one depth measurement

- If the tool zero point depth when RIH is > 50cm than return to zero tool depth on POOH - indicates issues with measure wheel depths (slippage, accuracy).

- Cables stretch – as tension increases the stretch of the cable increases – each cable has it own stretch co-efficient, The age (seasoning) and condition of the cables are not constant so the stretch coefficient has some uncertainty.



Courtesy of Camesa

Depth Uncertainty

Depth measurement will be closer to actual depth if a well is:

- Shallow
- Low temperature
- Large Hole Size
- Truly Vertical
- Using a seasoned cable
- Logging centralized tools
- In gauge borehole with low rugosity

- **These borehole conditions are very rare !**

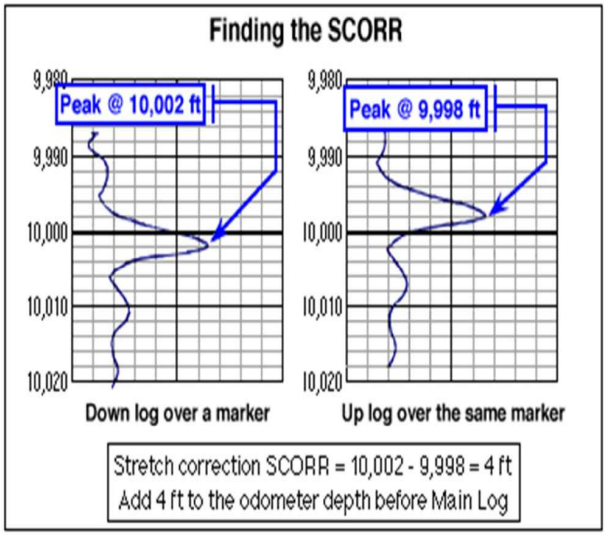
Log down Depth as primary reference

- **Schlumberger Standard Operating Procedures state the log down depth reference should only apply in vertical wells, where the well inclination is not vertical or where hold ups occur during RIH the wireline RIH depth should be corrected for calculated stretch.**

- The log down depth reference is applied in all wells regardless of trajectory / hold ups. **The RIH stretch is not applied unless specifically requested before logging.**

- It assumes any cable stretch is accounted for in the approximately 1.5m of cable between the drum and measurewheel
- It assumes the cable tension on the drum is the same as the previous well / run in hole i.e. all runs have the same tension versus depth profile.
- Assumes no loss in RIH tension due to hold ups, tool floating i.e tension continuously increasing.
- Is a Measurewheel only depth record (Schlumberger stopped using magnetic marked cable) so assumes no measurewheel error.

- The SCORR (Stretch Correction) is the depth shift between the RIH depth which is taken as the correct and primary depth versus the main up log.
- A **bulk shift** of the SCORR is applied to the up log depth. (Note this would mean the zero depth for Gr to surface will now be below the rig floor by same amount of shift applied at TD as will the seabed and all formation tops !)



Engineer real time adds the depth to the main up log at single point towards base of the logged interval

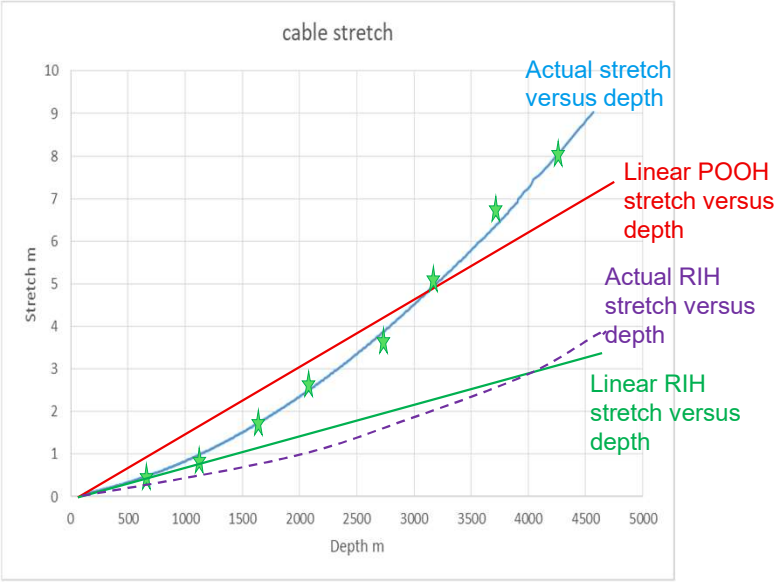
Cable Stretch

- Cable tension and thus the cable stretch is a **non linear** relationship
- Changes in well bore rugosity, mud properties, trajectory all influence the wireline tension
- Standard procedures to perform Pick up tensions while RIH allow modelling of non linear behaviour and allow cable stretch to be calculated along the well
- The stretch corrections applied by the logging contractor are provided in the remarks on the log header (hopefully !!). Either as a calculated stretch or as a bulk shift of up log to down log.

- Linear tension and stretch in ideal vertical well during POOH shown in red
- True stretch during POOH shown in blue as tension is non linear (actual pick up tensions while RIH in green stars)

- Note even in a vertical well the cable stretches while RIH (Green) not accounted for by measurewheels.

  If do not account for this stretch the down log will be shallow to true depth

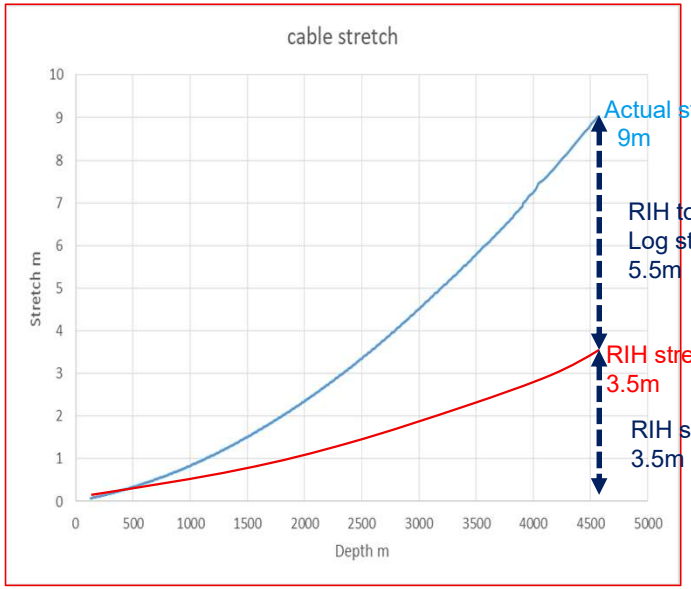


Cable Stretch

- In this example:

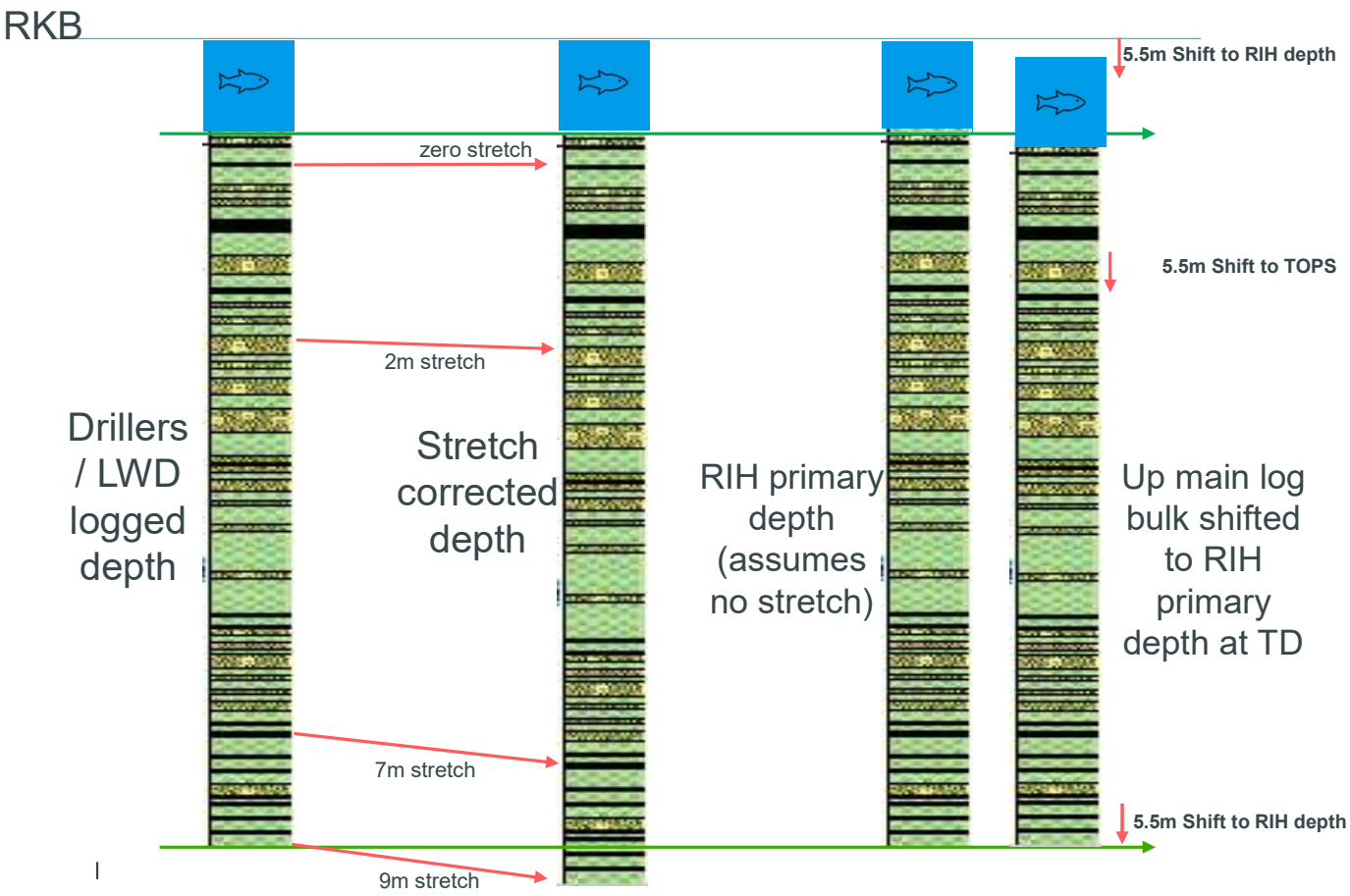
- Main Up Log cable stretch is 9m
- RIH cable stretch is 3.5m

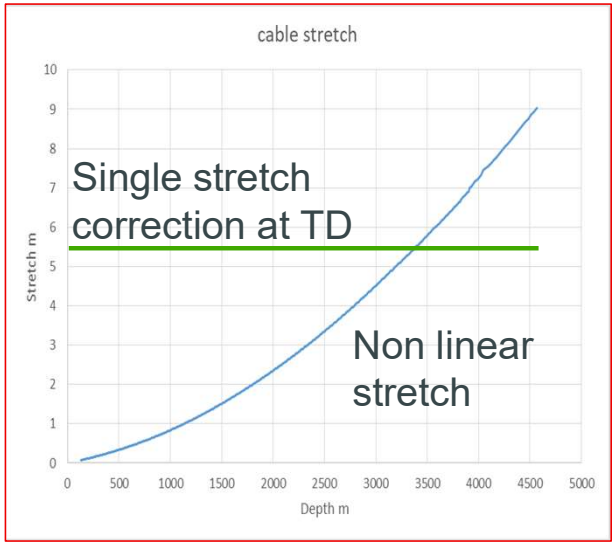
- If logging contractor uses a cable stretch correction then logs are 9m deeper
- If logging contractor uses RIH as primary depth then only account for difference in RIH to main up log. No RIH accounted for so logs 3.5m shallow to actual depth



Cable Stretch – varies with depth

- To apply stretch must use a non linear correction – not a bulk shift





As the stretch is calculated at TD is maximum stretch which is then applied over full well

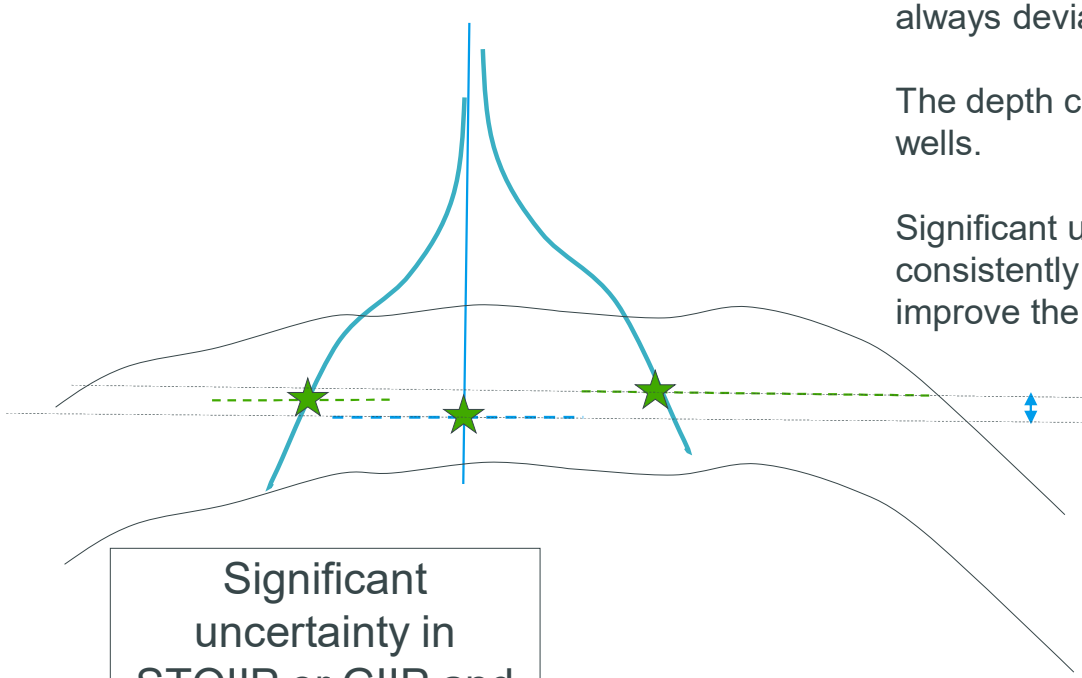
Drillers /LWD or Wireline Depth

- **What depth do you use for your well reference?**
- **The Drillers and Wireline depths are not the same**
- **A)** Use drillers depth and tie Wireline to this e.g. at casing shoe – very common in USA
- **B)** Use Wireline depth and shift drillers depth to the wireline
- **C)** Hybrid of A & B based on which trust the best
- **D)** No idea just take the given depth and input into model
- With A, B or C can we say we know what the uncertainty in depth is ?
- How does this impact formation tops, seismic ties and correlations
- Who looks at this – is the data base consistent. Remember the well TVDSS is most likely based on drillers depth with LWD survey. Is this the same depth used for fluid contacts from wireline pressure data ?

Understanding Depth

- We can apply corrections to the Drillers (LWD) Depth after well TD.
- We can validate and apply (as required) wireline stretch corrections. Compare values to the corrected Drillers Depth
- We can apply uncertainties to both corrected depths to get closer to the true depth (and understand our uncertainties in the well depth)
- Why not let sleeping dogs lie?
- The reservoir model is depth referenced for reservoir tops, fluid contacts and seismic volumes. A 5m, 10m, 15m depth error in each well or mixing of drillers and wireline depths can significantly impact on STOIIP / GIIP

Important to know depth correct ?



Significant uncertainty in STOIIP or GIIP and connectivity

Exploration wells are usually vertical
Appraisal and development wells are nearly always deviated.

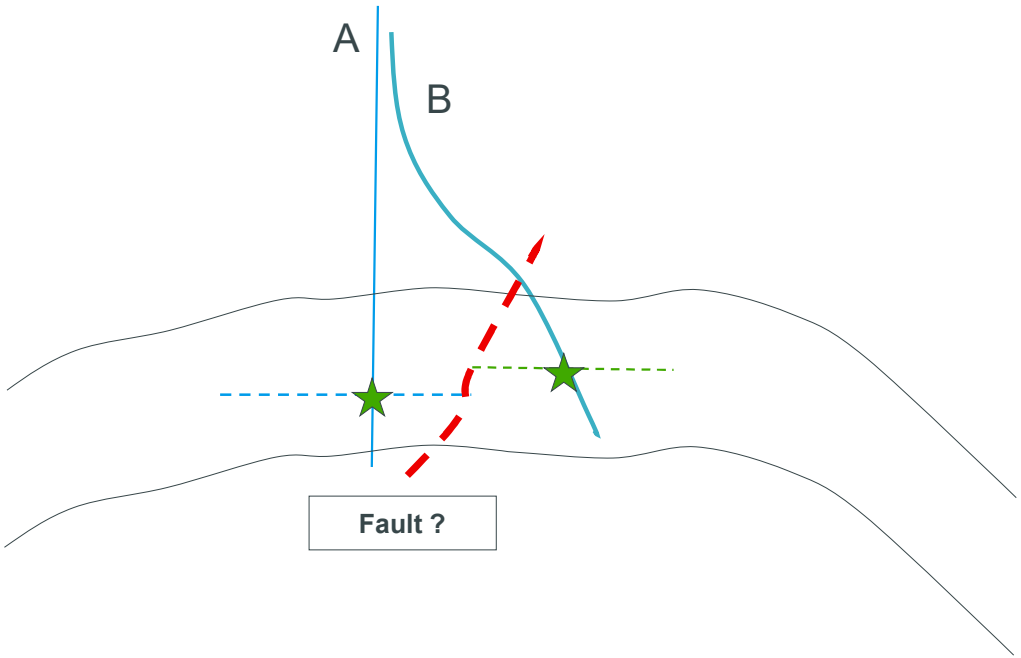
The depth corrections will not be uniform across all wells.

Significant uncertainty in the actual depth must be consistently corrected for and understood, to improve the reservoir model.

Pragmatically this is a concern for newer fields, older fields close to end of life - the horse has bolted !.

In smaller fields economic volumes are more critical and thus a consistent reference depth (with uncertainties) is mandatory.

Recent case



In the exploration well A the log response indicated a OWC.

The appraisal well B found logged OWC 25m (82ft) shallower.

Model required a fault for offset (no indication on seismic) and possible compartmentalisation.

In well B, LWD calculated TVDSS was 1.5m shallow to a wireline calculated gyro run. This is the TVDSS uncertainty associated with well trajectory.

LWD and wireline depth in well B in agreement (<1m) – thus the WL was tied to Drillers Depth.

The wireline stretch was calculated based on trajectory, cable type and tool weight in well B. A stretch of 18.5m was derived.

Thus well B was 18.5m shallow and with 1.5m increase in TVDSS the “true depth” of well B is 20m deeper.

5m difference in OWC can be due to baffle rather than need for a fault and disconnect between wells

Conclusions

- **Depth is the reference for all well and reservoir data sets**.

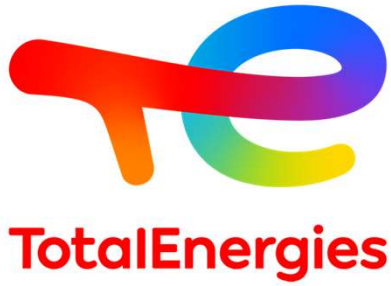
- Drillers Depth = is non corrected pipe tally and is shallow to actual depth
- Wireline depth is more complicated with an elastic cable to account for.

- Historically no corrections to driller depth are applied

- Operators rely on wireline vendors to apply any cable stretch corrections real time and report corrections in remarks on field prints (hopefully !)
  - Contractor methods differ – best method is to account for stretch and do not bulk shift any corrections

- We can chose which depth to use as the well reference and to populate the reservoir models.
- **Do we reference depth consistently with the uncertainties or assume someone has done it ?**

- Applying depth corrections is a way to normalise and understand depth uncertainty within and between wells and improve the reservoir model – it depends where your field and reservoir models are in the field life whether it is worth having the courage to open Pandoras box for depth



Thank you & any questions