From Petrophysics To Geomodel:

Log Data QC, editing, splicing & interpolation

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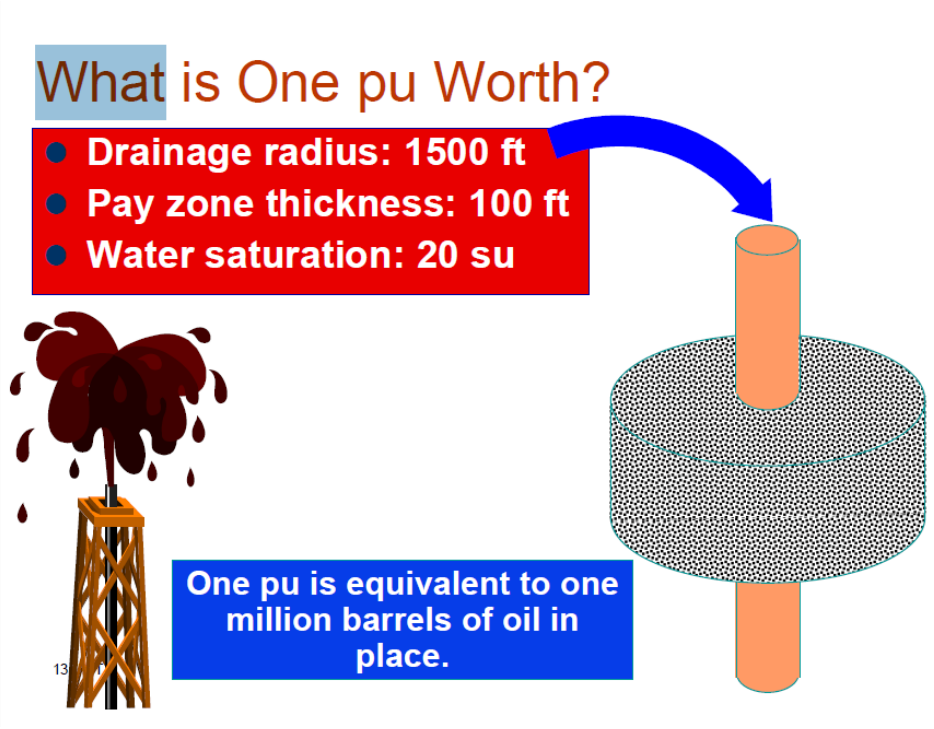
Purpose

- Why do we do it
  - Final logs to acurately represent the rock properties and contained fluids within
  - **Aquisition**: Normalise - remove environmental effects
  - **Editing**: Remove artifacts (casing effect, bad data)

Typical Uncertainties in HIP

- Mapping gross rock volume
- Fluid contacts
- Net thickness
- Porosity
- Saturation
- Driving mechanisms
- Recovery factor

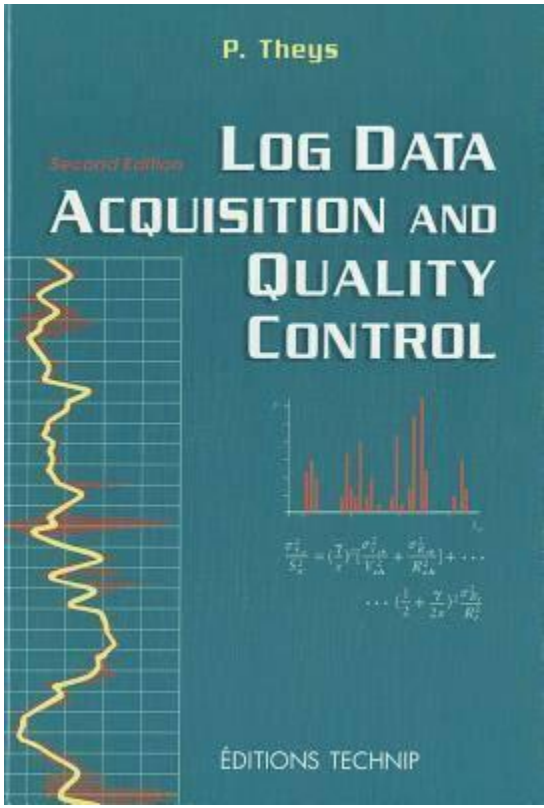


Log QC: Whys is it important

- Errors are expensive e.g.
  - Consequential well sidetracks
  - Incorrect well positioning (Co-Ordinates)
  - Incorrect well survey recording
  - Depth issues
- Blunders happen and are expensive

Log Data QC:

- Huge topic – 1 weeks course at least
  - Logging QC manuals in every company
  - recommend
    - **Log Data Acquisition and Quality Control:** Philippe Theys (otheys@aol.com), Second edition 1999



Briefly touch on Log QC for new wells, then discuss QC for data for purchased wells

Log Quality Control

- Data Integrity
- Log Calibration & Verification
- Log QC techniques & Environmental Corrections
- Tools run within limits
- Human Error & Ambiguities

Log QC: Data Integrity

- Original Data. Suppliers should not make shifts. Keep the original data otherwise loose data control
- Oil Field Standards: QHSE Standard 21 “Don’t mess with data”
- Acquisition record frozen as recorded (and Environmental Corrected)
- (Interpreted data can do what is required).
- Reduce tool error by calibration
- Correct for environment /HS, mud etc)
- Some environment errors we are unable to correct for e.g. hole shape and size, mud weight distribution in the hole e.g. barite sag.

Log QC: Calibration & Verification

- **Calibration**: Matching a measurement system to read a reference value. Density should be done regular e.g. every month Source is a key factor and reduces in strength with time. (Ensure noted on Header).
- **Verification**: Tool Check and quantification after check
- Flags do not detect bad calibrations.
- Calliper rings can be poor quality-will have a significant effect

LOG QC: Environmental Corrections

- Uncontrolled environmental corrections - Don't Guess inputs
- Big mistake if corrections not applied - BUT
- Don’t apply corrections twice
- Good idea to keep mud data with log data
- Double check potential ambiguities e.g. NaCl or Chlorides concentration (difference of 65%)

Log QC: QC Curves

- Clients: Always ask for QC curves
- 10-20 years on may need to review anomalies. Are they log problems or geological
- Intermittent failure: Occurs in the hole, but looks ok on surface.
- If suspect an issue look at each detector signal. If 1 of them out need to remove them from the averaging
- Get QC curves in plot format. (then will get the logs).
- Consistency between header, footer etc. Do cross checks on log and between other logs e.g. lithology type, stand-offs etc
- Every tool has a serial number - ensure logged
- Ensure comments on areas where tool outside parameters
- Check to ensure parameters not changed during logging and if are, ensure on log
- Use the remarks section of the log header more rather than less.

LOG QC: Data Quality

- Use a competent wellsite witness, a LQC form listing key log components
- **DEPTH**: A critical measurement –(later). Run GR from 1st WL run to surface.
- Do repeat section
- Limitations of tools: MW, Mud Type, Temp, Pressure, etc
- **Logging speed**. If vary changes precision. Better if slower. In cased hole may need station measurements. Check required sampling rates.
  - Pip marks in track 1 are logging speed. Each gap or tick is a minute
  - Increase SR for high res logs, increases VR, but reduces precision unless log more slowly
  - All logging curves **filtered** e.g. 3 level averaging. Improves precision.
  - When apply filtering loose on resolution, e.g. a 5 level filter may remove thin beds as well as noise. The more you filter the reduction in VR is greater.
  - Historically, when both precision and good VR required, several passes were run and data stacked.
- Data on **graphical files** not always the same as data on **digital file**. Always compare digital and graphical files.
- The logs will be used within the industry for years. Ensure they are **standardized** as best as possible.
- **Dry holes and overburden logs have a value**

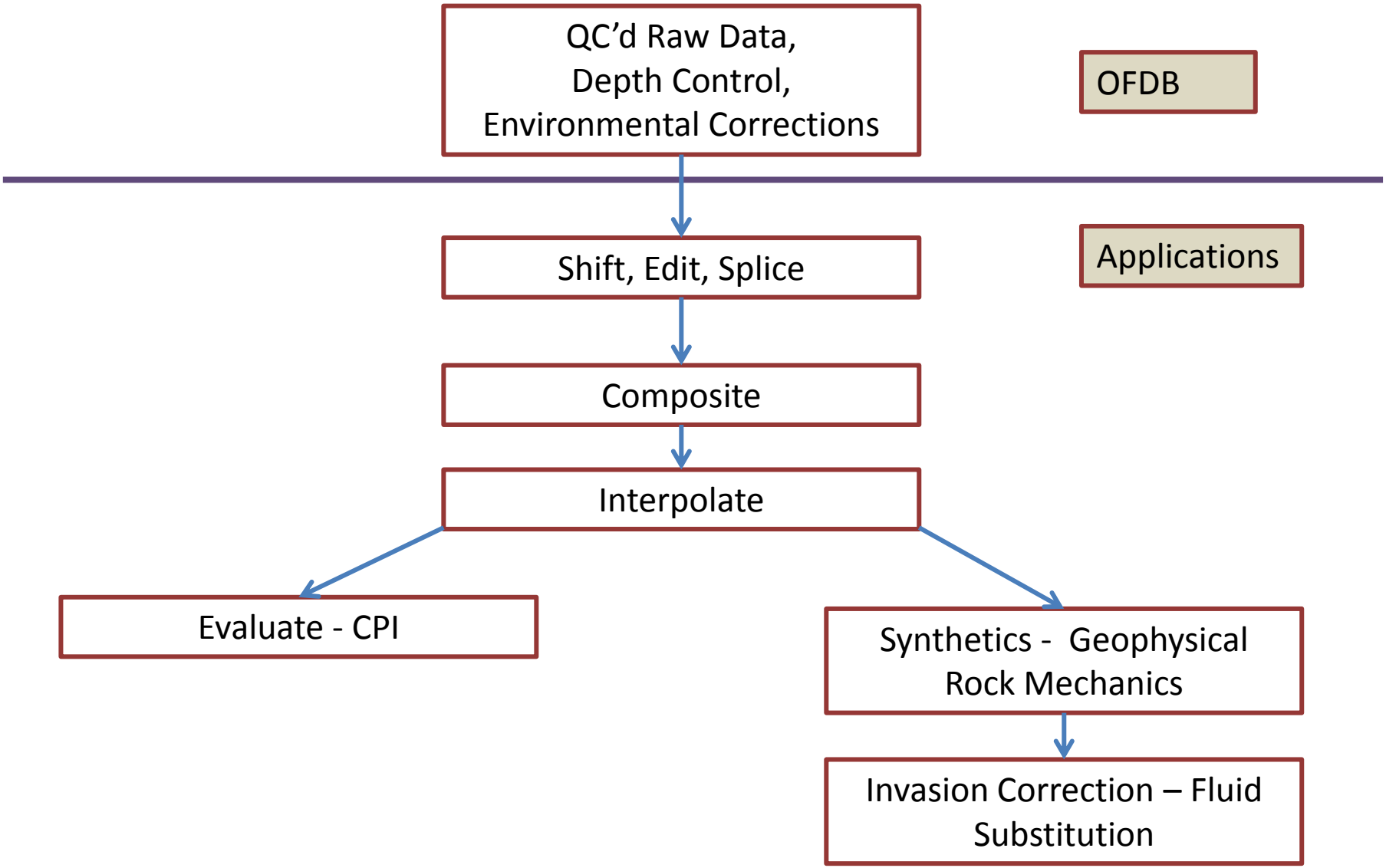
Log QC: Human Errors & Ambiguities

- Blunders happen and are expensive
  - Guessing parameters: e.g. standoff size, mix up of units, e.g. bars psi. m– ft.
  - Misunderstanding: Using a drillers depth reference for a wireline tie in reference, e.g. casing shoe. Does M represent 1000 or 1,000 000
  - Ambiguities: e.g. NaCl or Cl concentrations, % weight or % volume
  - Manual transfer of information:
  - Duplicating environmental corrections (adds porosity) , consequential effect on volumetrics

LOG QC: New Well Summation

- Plan your logging program and ensure the witness and logging engineers are fully involved and understand your goals.
- Have clear positions of contact on and offshore and ensure all the team involved are aware of their Roles (RACI)
- Ensure logs are run within specifications.
- Logs must be on depth. Off depth log data should not leave the rig.
- Ensure a strict file naming convention is followed. Inconsistent file naming causes havoc in databases
- Transfer of data from contractor to customer – black holes in database
- Rigorously QC all log header, footer and log data plots before accepting from the contractor. Establish and maintain a common Data Quality Control Process. *All petrophysical log data coming from a well operation should be checked and approved by the petrophysicist before it enters the company database.*
- Original logs and log plot files and other well data to be stored in an OFDB (Original Format Data Base). Keep metadata. Metadata is data about data. Data without metadata is of limited value.
- Ask for QC curves. These validate the data

Data: Work Flow



Log QC: Old Well Data

- The Completion Log (Composite Log) is supposedly the absolute record of the well.
- Check digital logs against the completion log to ensure the log character is the same. (Common problem to have logs from other wells or incorrectly named logs in the database.
- Check the log curves are on depth with the Completion Log
- If original field prints available compare the digital logs against these. Pay particular attention to the parameters used and environmental corrections made to the original data

Environmental Corrections establish what has been done

- GR: Hole size and mud weight.
  - Rarely done and result is large offsets in GR between hole sections making analysis by formation tops alone problematic.
  - GR should (normally) be the same above the casing point and below it as generally set in a claystone.
- Neutron Correction. Need to look at field print plot to see which log run and which corrections made. Need detailed mud data (mud salinity, filtrate salinity and MW). Usually correction is very minor.
- Res_Dep v Rt. Can make a difference in an invaded zone, particularly if resistivity not very high. Rule of thumb. If Res_Med == Res_dep then RT close to Res_Dep. Applicable for the older tools. The array tools are mathematically based and are supposed to give Rt and RXO as standard.

Log QC: Old Well Data What is available ?

Petrophysics Check List

Composite Log Data	Available
Hole Section Log Runs	
LWD	
Well Log Prints (Rmf etc)	
Well Header Information	
Remarks	
Shear Log	
Pef	
Bit Size	
Res_Mic	
NMR	
Diplog	
Directional (*Run wellpath TVD*)	
Tops_NPD/Operator	
Tops_Chrono	
Tops_Other	
Casing shoe	
Annotation	
HC flag	
CPI_Operator	
CPI_Other	
Lith	
RFT - FPRES	
RFT _ MOB	
RFT_Sample	
MUDLOG_GAS	
Shows	
Shows_Mudlog	
Shows_Core	
CORE_CCAL	
CORE_SWC_Symbol	
CORE_SWC_Annotation	
DST	
Checkshot	
Rock_Physics	
Geophysical	
Fluid_Substitution	

Wireline Logging Runs (Gathers data

Logging Runs	
Logging Tools	
Logging Depth	
Top of Logged interval	
Hole Size (“)	
Temperature	
Hrs since Circ Stopped	
Mud Type	
Mud weight (ppg)	
Viscosity	
OW	
Fluid Loss	
Mud salinity (ppm)	
Rm@T	
Rmf@T	
Rmc@T	
Resistivity tool – deep	
Resistivity tool – shallow	
Standoffs	
Neutron Tool	
Neutron Matrix	
(FSCO) Formation Salin Corr	
(MWCO) MW Corr	
(HSCO) Hole Size Corr	
(MCCO) Mudcake Corr	
(BSCO) Hole Salinity Corr	
(PTCO) Press - Temp Corr	
Density Tool	
Sonic Tool	
Comment	

Editing, Splicing, Interpolation (ESI)

- Petrophysical data used within applications kept separately.
- Have a company **standard mnemonics** list for all your petrophysical data
- The log data sampling rate should be consistent (0.1 or 0.1524 / m)
- What we do depends on the product we are creating
  - Composite log (& Rock Physics)
  - CPI
  - Geophysical & Rock Mechanics
  - Fluid Substitution

E.S.I: Composite Set

- An important processed output is the **COMPOSITE** set, which is designed to contain the most complete set of useful raw curves; **shifted as required, edit (de-spiked, etc)**, **splice** so as to cover the whole depth range logged. Curves from different runs are spliced and in some instances data from MWD/LWD will be spliced in with wireline data to give full depth coverage.
- **Do not interpolate nor use synthetic logs in this set.**
- COMPOSITED logs includes caliper, SP, gamma ray, density, density correction, neutron, shear and compressional sonic, spectral gamma ray, deep/medium/shallow/micro resistivity logs.
- A composite set treated in this manner will be suitable for **Rock Physics**

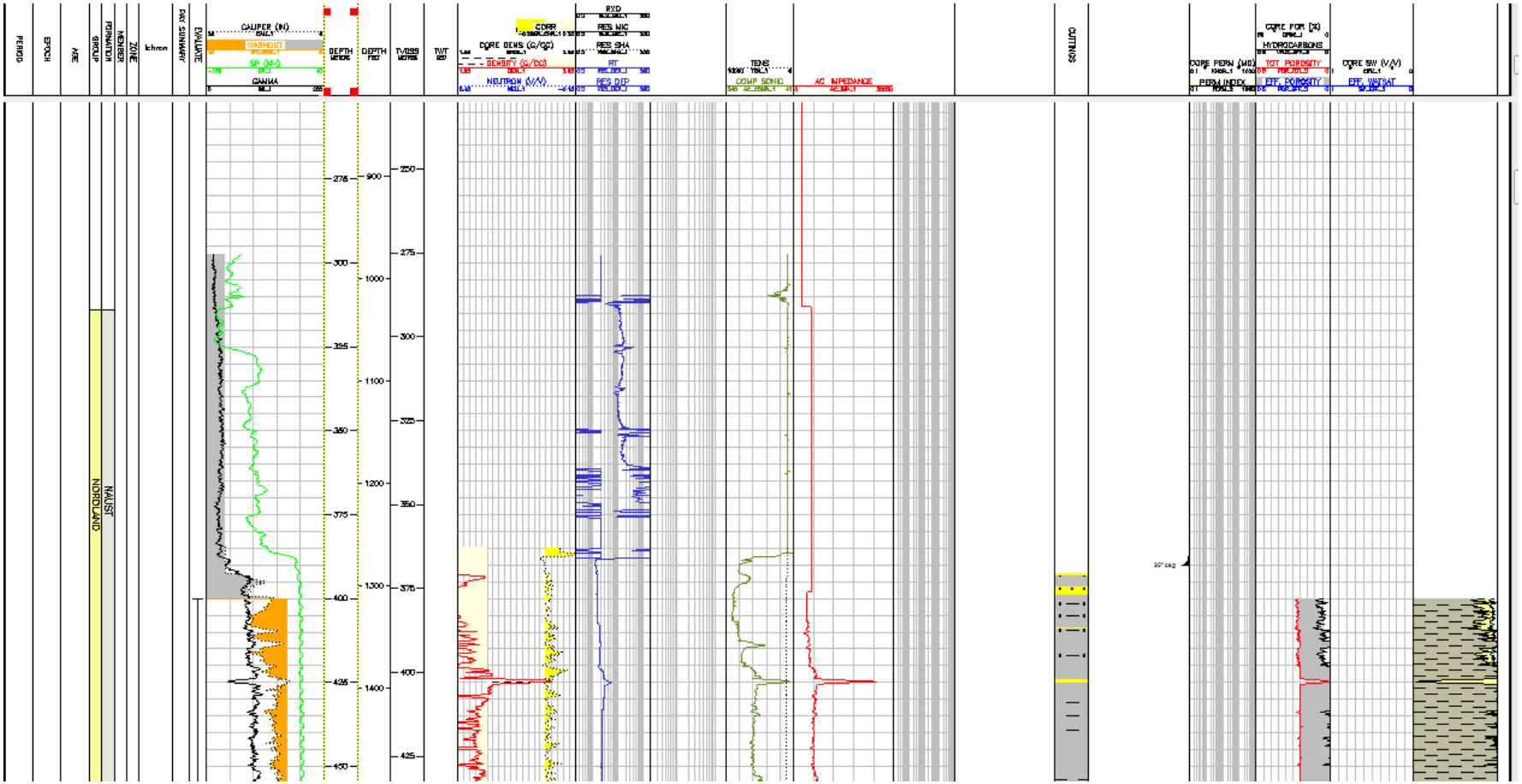
ESI: CPI

- The **CPI** log contains log interpretation results, including relevant input curve data used for analysis.
- The CPI is used for presentation of well results. There should only be one CPI for a well
- The CPI can be used as input to reservoir modeling and for most re-evaluations
- Customers, (Geologists & Geophysicsists), commonly want a CPI for the entire well
- The Composited log sets commonly form the inputs for the CPI. Gaps in the data need to be interpolated

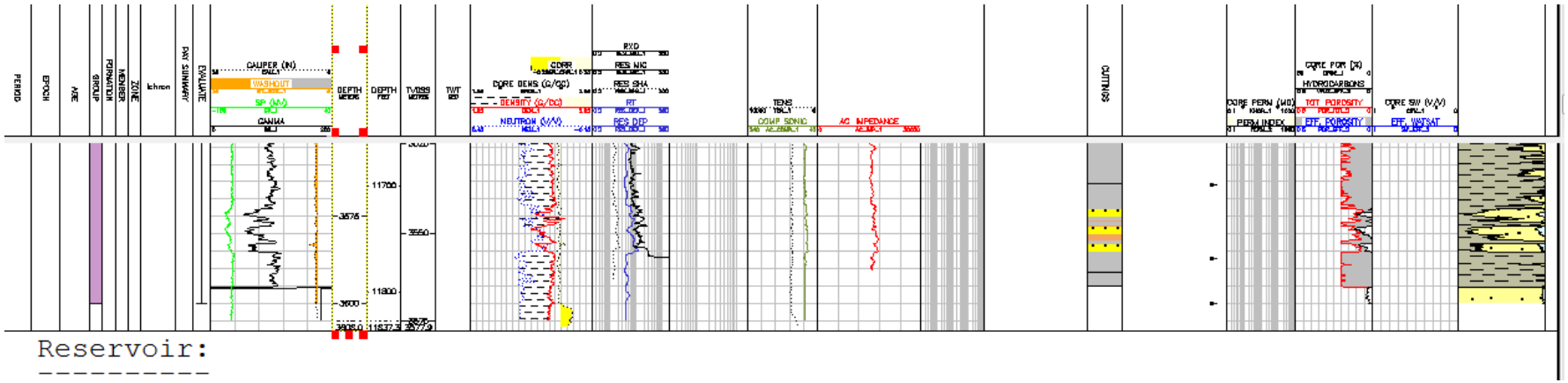
E.S.I: Geophysical Set

- The **GEOPHYSICAL** log contains edited and despiked density and sonic logs, possibly synthetic logs and geo-mechanical logs.
- For geophysical purposes, **it is important that neither the density nor the sonic log contains spurious readings or gaps.** Casing readings and straight-lining at tool pickup are removed. All data gaps are identified and interpolated, while avoiding steps in the data.
- The geophysicist needs data to generate a calibrated velocity log for synthetic seismograms and AVO analysis, using suitably edited and interpolated density and sonic logs from TD to top of the logged intervals
- **FLUID_SUBSTITUTION:** This uses GEOPHYSICAL and CPI as input, and it compliments GEOPHYSICAL data. Fluid substitution includes invasion correction of density and sonic data, and synthetic logs assuming different fluid combinations (gas, oil, water, irreducible water, residual oil, residual gas) in the pore space.

Editing: Casing effect – logs need topping

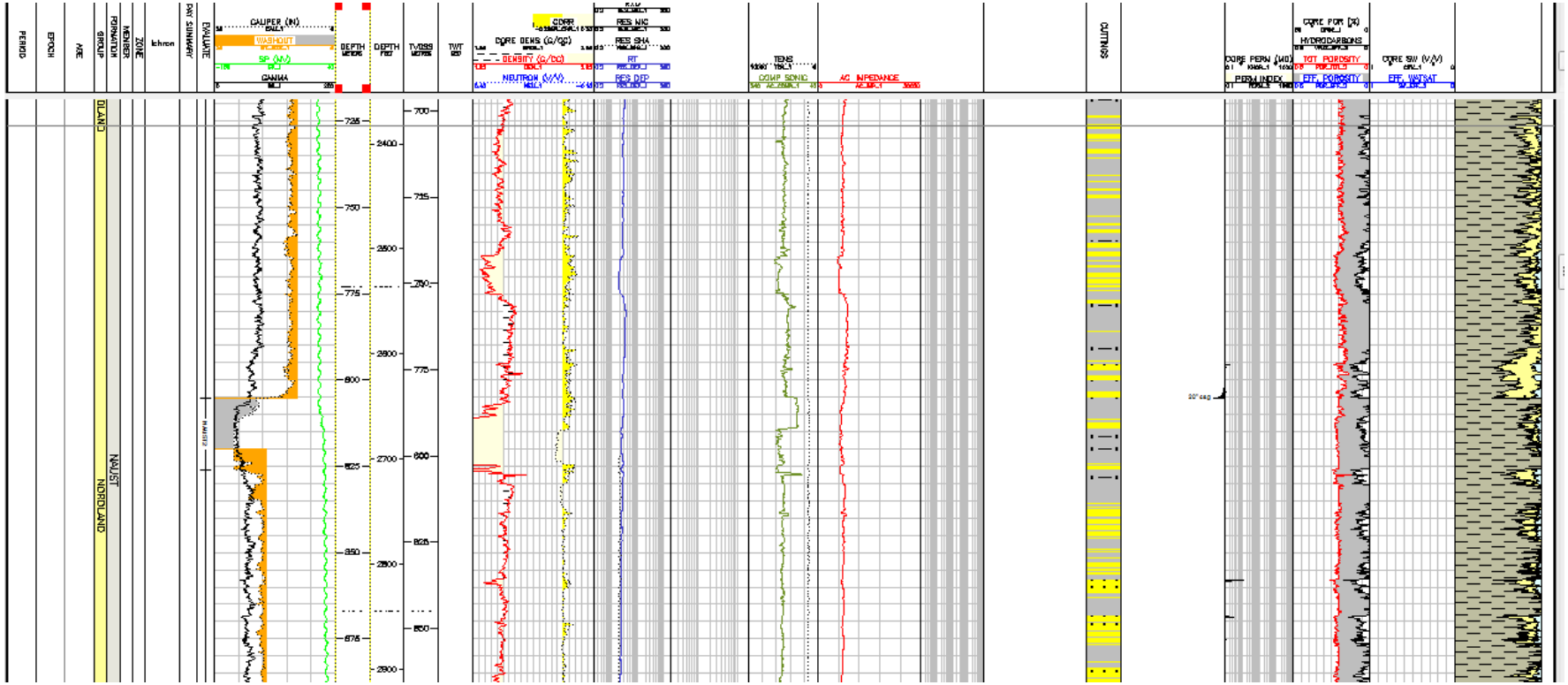


Editing: Tailing base of logs



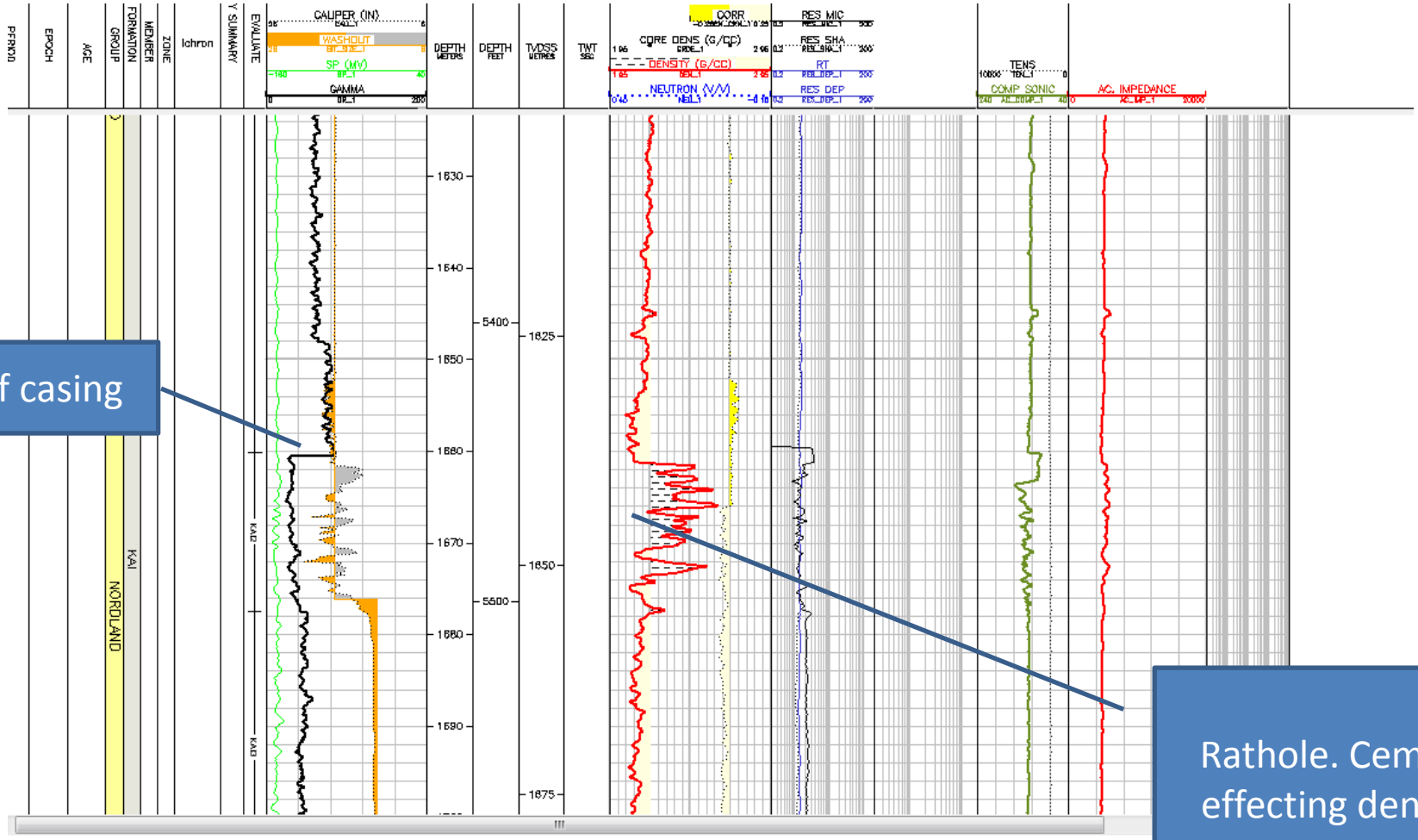
Use tension curve to establish point of pick up – if in doubt

Editing: – Casing effect



This splice is not okay

Editing: – Casing effect

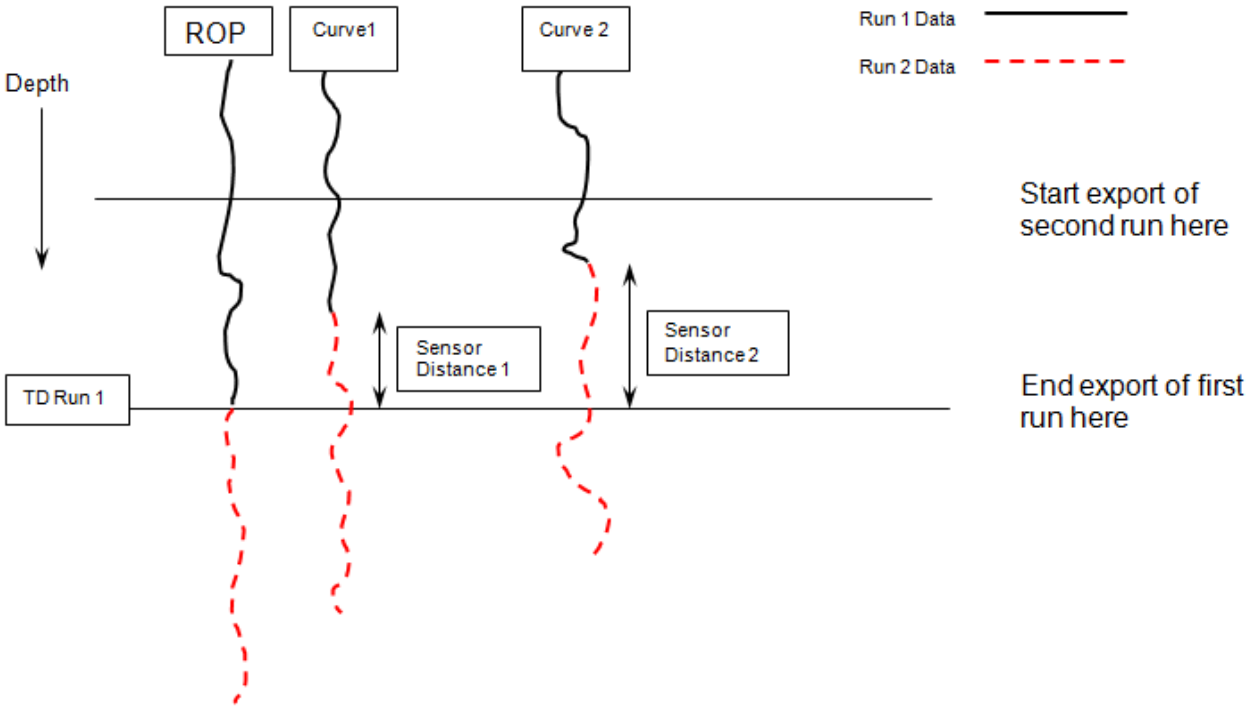


Top of casing

Rathole. Cement effecting density

Splicing

- During acquisition ensure overlap of log runs.
  - The depth range of the data export for the second run should start ABOVE the end of the first run, by at least as much as the largest sensor distance. This ensures that no data is missed from the second run (see figure below).



Before Splicing

- Do environmental corrections
- Edit logs
- Make sure logs being spliced are compatible and the units are the same

Splicing

- Avoid auto splicing routines
- Use Generic log names common to spliced logs
- Generally use open hole logs in preference to cased hole logs
- Use logs with the best VR & Log Character
- Mixing FEMWD logs with wireline logs over the same interval, (e.g within the Composite set), can be problematical due to stick slip and compression during acquisition. Could require very time consuming depth matching.

Interpolation

- Not required for Composite set or Rock Physics set
- Required for CPI, Geophysics & Rock Mechanics
- Straight Line (fill missing)
- Simple Regression
- Multiple Regression
- Established relationships e.g. Gardiner Equation. Can be used to fill gaps in both Density and Sonic logs

Synthetics - Density

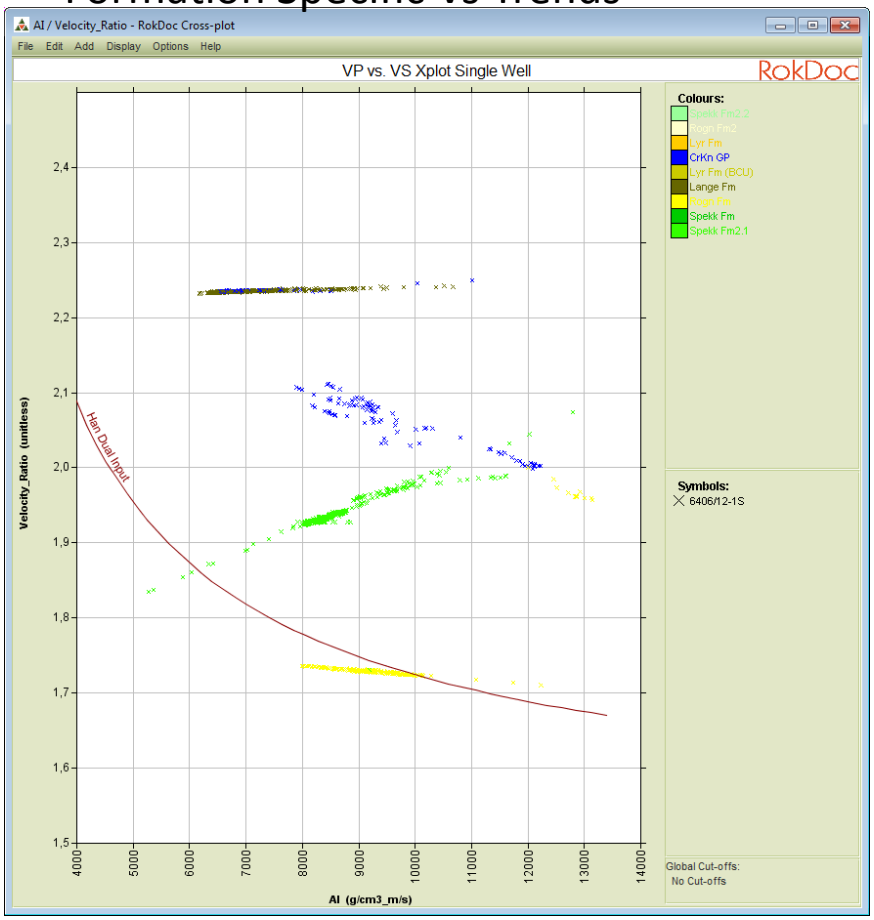
- Use the Gregory Gardner equation to create a synthetic density from sonic. Do initially where both logs are available.
- Use Gregory Gardner density as a check on log quality
- Can be used to fill gaps

Synthetics – Shear Sonic

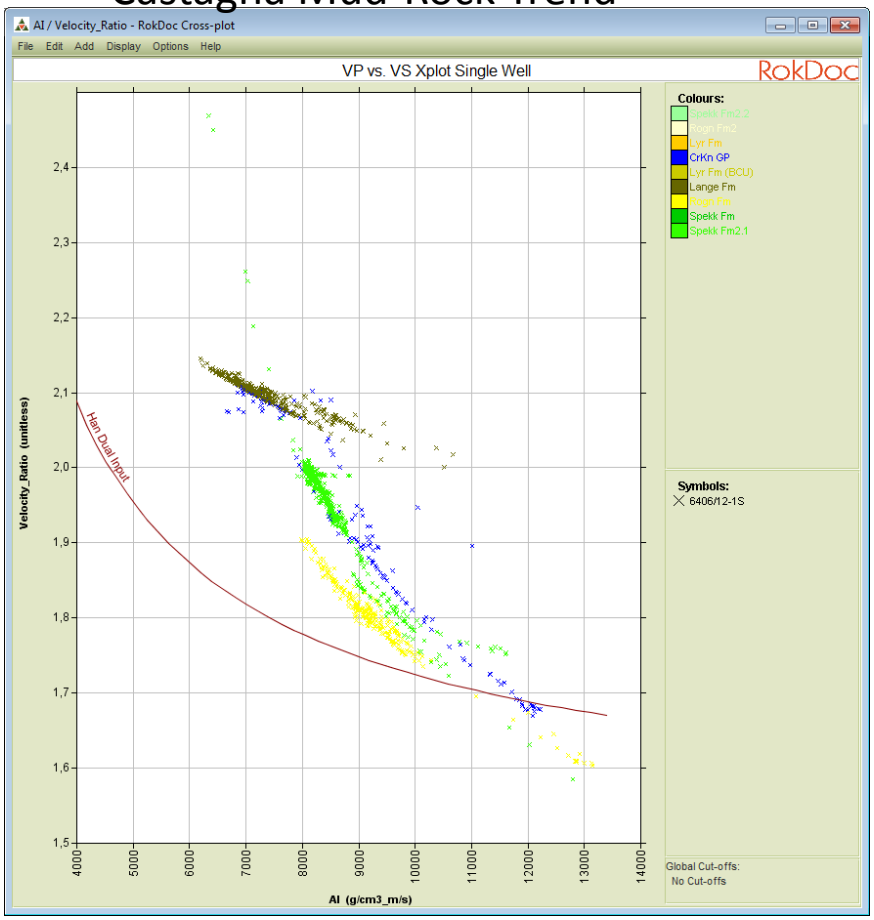
- First: Create a shear log based on DTC DTS relationships for each formation determined by simple regression from 1 or more offet wells
- Second: Run the Castanga and Kreif mudrock claculations within Petrophysics software. This tends to be a smoothed curve and should be used as a reference for the results from the next step
- Third : Compare results Castanga and Kreif to the regression curve.
- Finally Create a AC_SHR_GP from the 3 methods above. The Castanga method is usually good in deeper rocks, but can result in very slow estimates in shallower rocks. The Kreif method can be tweaked to generate results closer to the simple regression method and can be used for the upper sections of the well.
- Check your results.
- QC Check: If VP/VS < 1.5, Amber warning. If < 1.42 RED warning.
  - Generally the VPVS should not go below 1.5 Address before doing fluid sub work

Two different Synthetic Vs approaches

Formation Specific Vs Trends



Castagna Mud-Rock Trend



Different techniques can result in strikingly different results

Concluding Tips

- Understand the greater applications for the well data – well planning, basin appraisal, de-commissioning.
- Understand your in-house data management system, and the requirements of your colleagues, partners and authorities
- File Naming Convention (NPD, CDA, Recall)
- Petrophysical mnemonics
- Edit or remove all artefacts.
- Depth shift before splicing (paying to particular attention to MWD alongside wireline logs)
- Double check your interpolations – make sure they make geological sense