SPWLA BHI SIG
Dip Data Delivery Standard

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2023 SPWLA Fall Topical Conference

Agenda

- Founding of the Borehole Imaging (BHI) SIG
- Motivation
- Several “What is …?” Questions
- The Dip Data Exchange Standard

Founding of the BHI SIG

- Two events took place…
  - September 2021 EAGE 4th Borehole Geology Workshop
  - October 2021 "Curry Friday"
    - Present: Peter Barrett, Bernd Ruehlicke and Tegwyn Perkins

Current Board

Chair: Christian Rambousek, NiMBUC Geoscience

Vice Chair: Chandramani Shrivastava, SLB

Secretary: Tegwyn Perkins, Geoactive Ltd

Treasurer: Peter Barrett, Halliburton

Contact them at: bhi_sig_comm@spwla.org

(as of 9-Nov-2023)

Borehole Imaging Special Interest Group

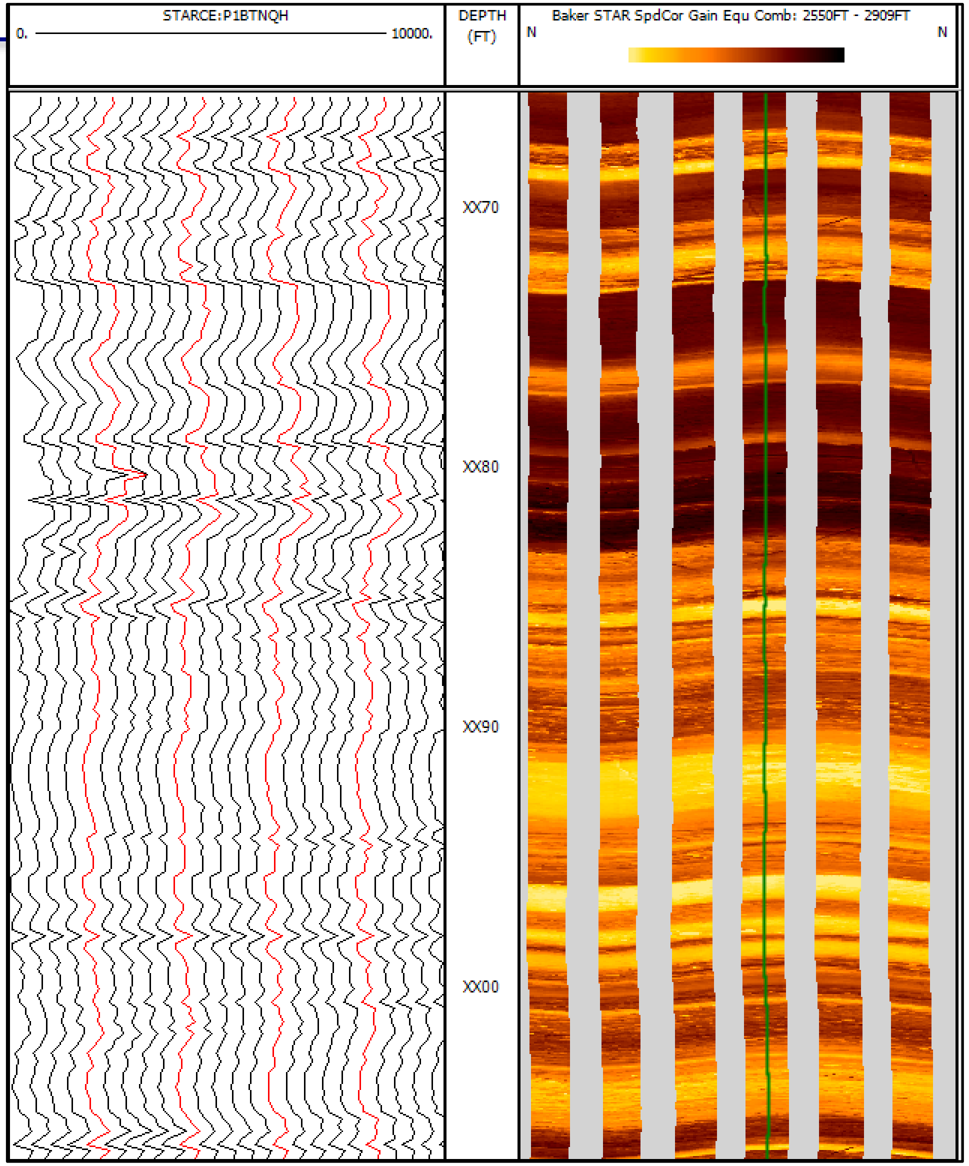
Motivation

- This initiative aims to provide a Human-Readable Dip Data Exchange format that enables all borehole imaging/dip software to utilize ALL available information related to an interpretation.

- The current work focuses on the following features:
  - Fracture and Bedding feature identification
    - Interpretation of Complete and Partial Sinewaves
  - Breakouts
  - Tensile Fractures
  - Truncations

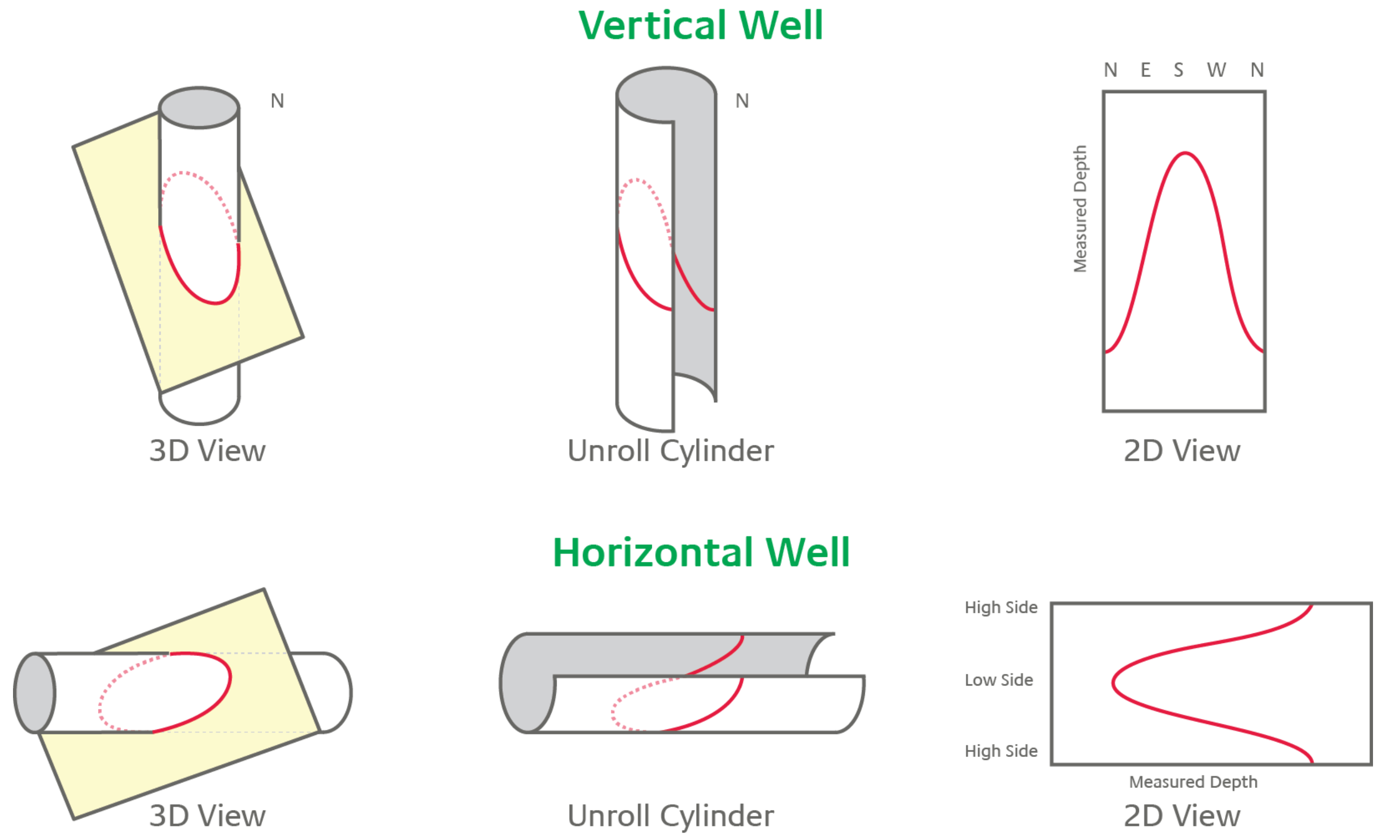
What is a Borehole Image?

- False colour pseudo-image of the borehole wall produced from high-resolution petrophysical measurements.
- Image data acquired by tools with sets of pads or rotating transducers and sondes/sensors.
- Conveyed by wireline, pipe or LWD.
- Oriented using accelerometers and/or magnetometers.
- Images are usually viewed unwrapped:
  - Features inclined to the borehole (i.e. planes) appear as sinewaves.



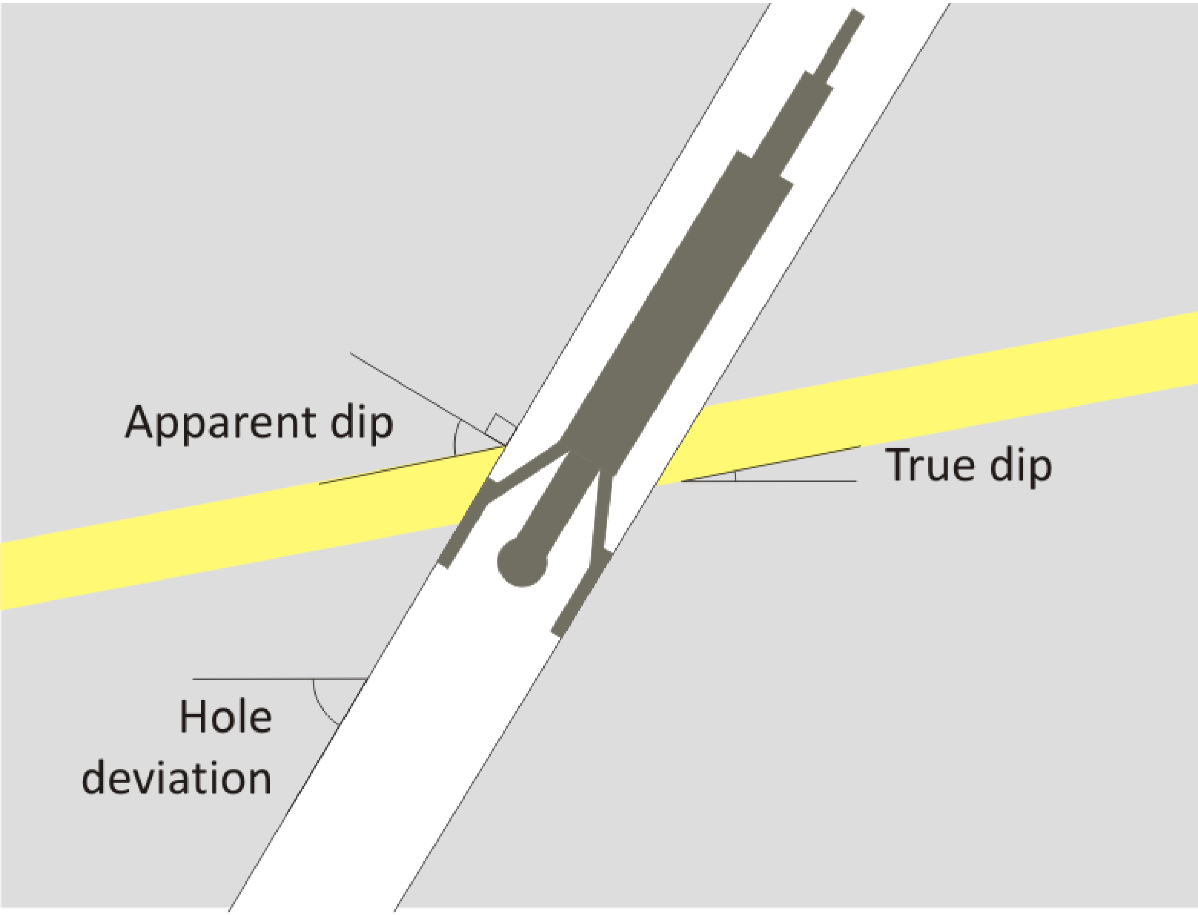
Viewing of unwrapped images

- Consider a plane intersecting a borehole.
- If we “unwrap” the borehole then the 3D plane is represented by a 2D sinewave.



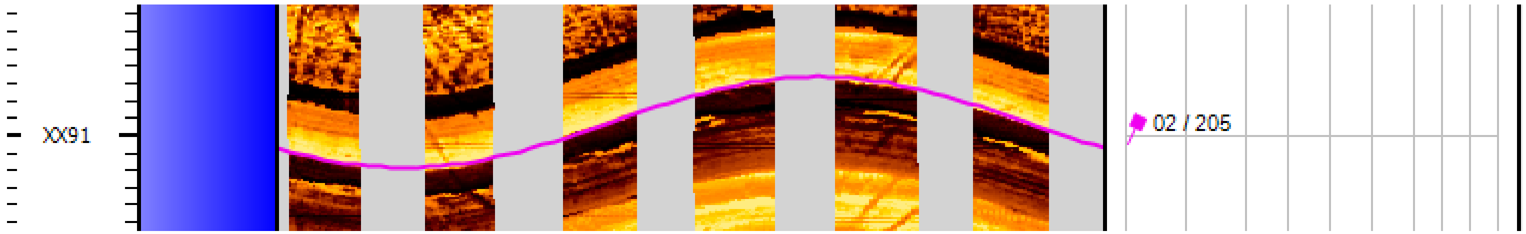
What are Apparent and True Dips?

- Apparent Dip refers to the angle at which rock layers or bedding planes are inclined within a borehole.
- True Dip is a measurement that indicates the actual angle at which rock layers or bedding planes are inclined beneath the Earth's surface.
- We determine Apparent Dip from Borehole Images and then use the position of the borehole and imaging tool to derive the True Dip.

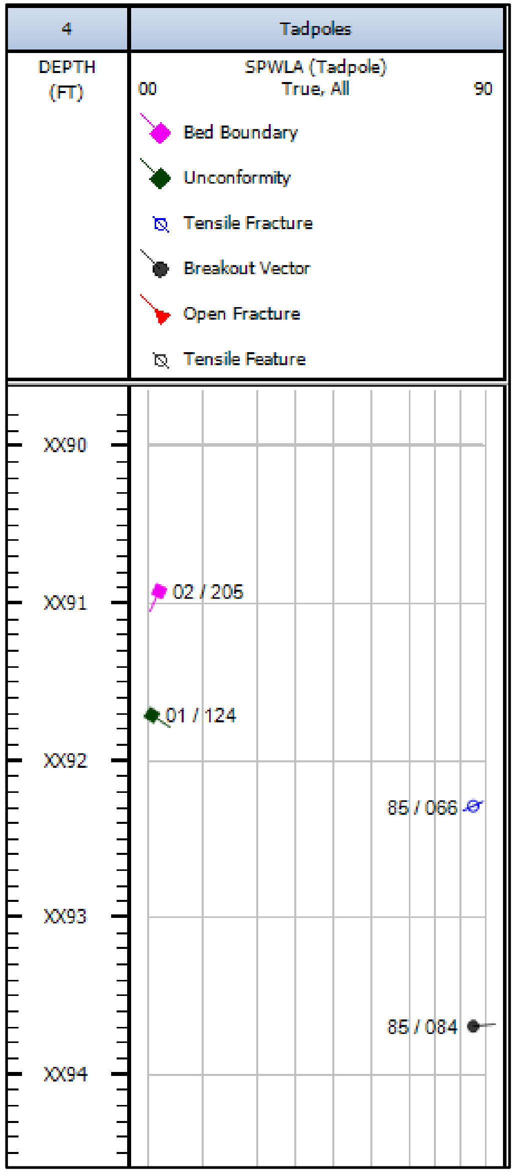


What is a Dip?

- A “Dip" is the normal vector to a 3D plane expressed in polar coordinates and is represented by Measured Depth and two angles: Dip Angle and Dip Azimuth:
    - Dip Angle is maximum angle measured from horizontal normal to Strike.
    - Dip Azimuth is direction of maximum dip.
- Dips are typically represented on a log plot by a “Tadpole” where the head is the Dip Angle and the tail points towards the Dip Azimuth or on a stereogram as a pole to the plane they represent.

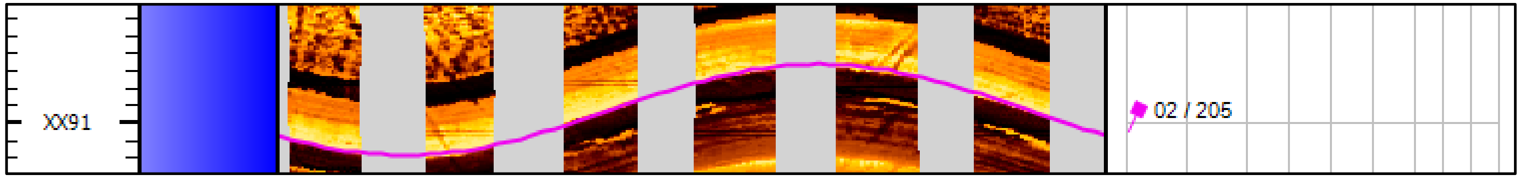


- NB: Strike refers to the azimuth of the horizontal line formed by the intersection of a geological feature with the Earth's surface.

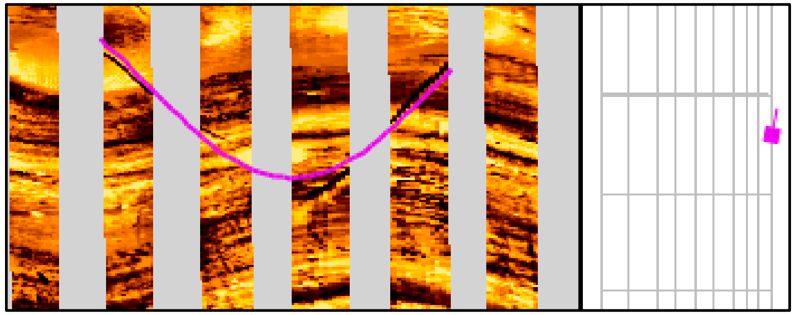


Planar Features

- Planar features are typically associated with beds, boundaries and fractures.

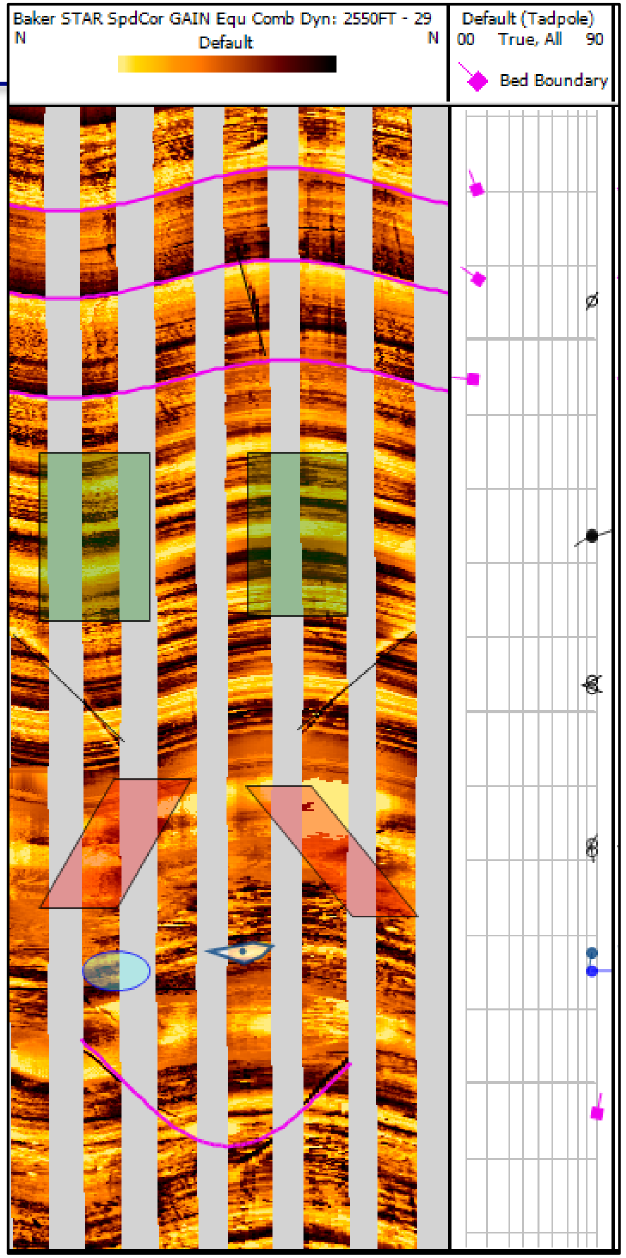


- Sometimes planar features are only visible over part of an image – we call these Partial Dips.



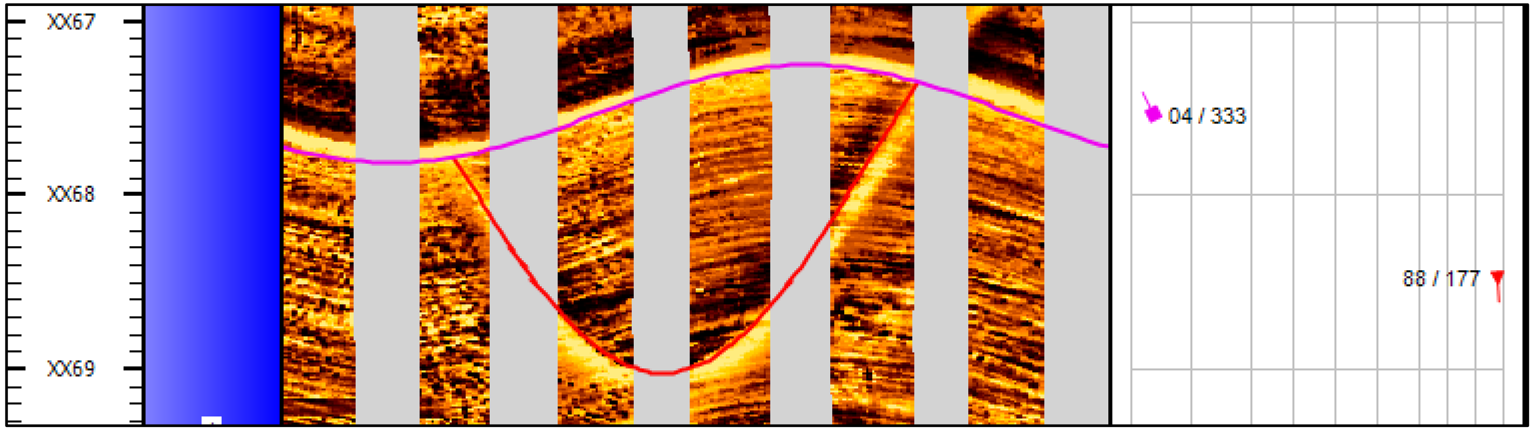
Not every feature is sinusoidal!

- Not every feature can be represented by a sinewave.
- Consequently, we employ different methods of picking and representing Breakouts, Tensile Fractures, Convex Fractures, Holes, Vugs, etc.
  - Breakouts = Rectangles
  - Tensile Fractures = Lines
  - Convex Fractures = Parallelograms
  - Holes = Ellipsoids
  - Vugs = Polygon
- Each of these are described by clearly defined mathematical properties.



Feature Relationships

- In addition to selecting individual features, it is possible to define relationships between them.
- Interpreters can identify truncation, abutting and containership relationships between data types.



- In this example, we have truncated a fracture into a bedding plane up-hole.

The Dip Data Delivery Standard

- This standard considers all the attributes that go into each pick so that a complete recreation of it can be made.
- In addition to the “dip data” there is specific header information required for accurate representation and we have listed that here.
- We employ the LAS 3.0 standard for data encapsulation:
  - Comma-delimited => Load as ASCII, if necessary.
  - LAS 2.0 does not (officially) support text strings.
  - Binary formats, such as DLIS, were discounted because not all dip interpretation software can read them.
  - We didn’t want to design “Yet another new file format” based on JSON/XML.
- NB: North is True North (not Magnetic or Grid or “Custom”).

LAS 3.0 Header Information

- This is the **minimum** information we would expect to include:

- Well Name
- UWI/API (for NAM)
- Field Name
- Country
- Company/Operator

- Latitude
  - Decimal; +/-
- Longitude
  - Decimal; +/-
- Date of Log Data Acquisition
  - YYYY-MM-DD format (- or /)

- Magnetic Field Intensity
- Magnetic Inclination
- Magnetic Declination
- Magnetic Model

- Datum and Elevations - all available
- Mud Type - useful for understanding fractures
- STRT, STOP, STEP=0.0 and NULL

LAS 3.0 Log Data - #1

- This is the **minimum** information we would expect to include:

- Measured Depth (i.e. depth along the borehole)
  - Units: feet or metres
- UID: a unique identification number for the pick. This can be an integer or NULL.
  - If NULL, then truncations cannot be included.

- True Dip Angle
  - Corrected for magnetic declination.
  - Units: degrees
  - Scaled 0-90 degrees
- True Dip Azimuth, corrected for magnetic declination.
  - Units: degrees
  - Scaled 0-360 degrees

- Dip Type
  - Units: None
  - Stored as a string
- Dip Quality
  - Indication of the quality of the auto-pick
  - Scaled 0 – 1; 1 is best
  - Units: None

- Apparent Dip Angle
  - Corrected for magnetic declination
  - Units: degrees
  - Scaled 0-90 degrees
- Apparent Dip Azimuth
  - Corrected for magnetic declination
  - Units: degrees
  - Scaled 0-360 degrees

LAS 3.0 Log Data - #2

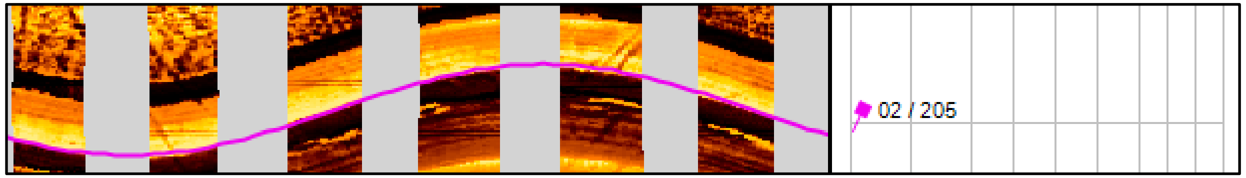
- This is the **minimum** information we would expect to include:

- Orientation Reference for Data Acquisition
  - This can be North, HighSide or LowSide
  - Units: None
  - No Abbreviations allowed.
  - NB: North is True North (not Magnetic or Grid)

- Inclinometry: DEVI, HAZI, RB and P1AZ/P1NO
  - Units: degrees
  - Corrected for Magnetic Declination

- Depth of Investigation
  - Stored w/ each pick
  - Units: inches

- Caliper
  - Units: inches
  - Diameter not Radius
  - Must NOT include Depth of Investigation

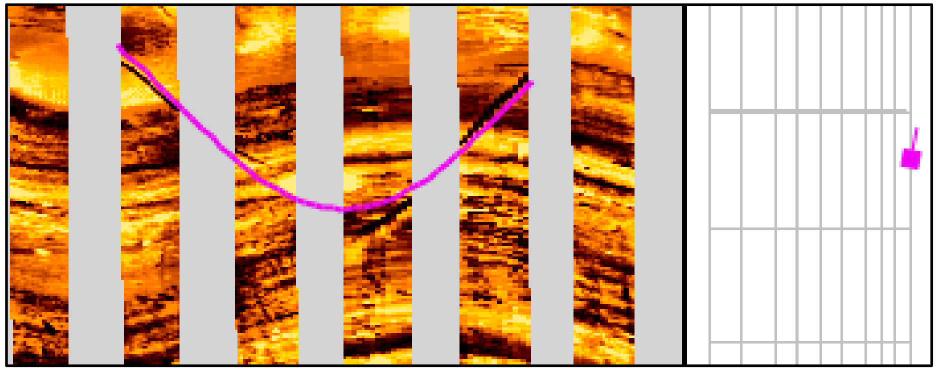


Partial Dips

- Partial Dip attributes will be stored as a pair of curves for the Apparent Dip Azimuth Start and Apparent Dip Azimuth End angles; otherwise use NULL.

- If multiple partial dips are to be specified for the same depth, then they will be specified by additional Apparent Dip Azimuth Start/End curves.

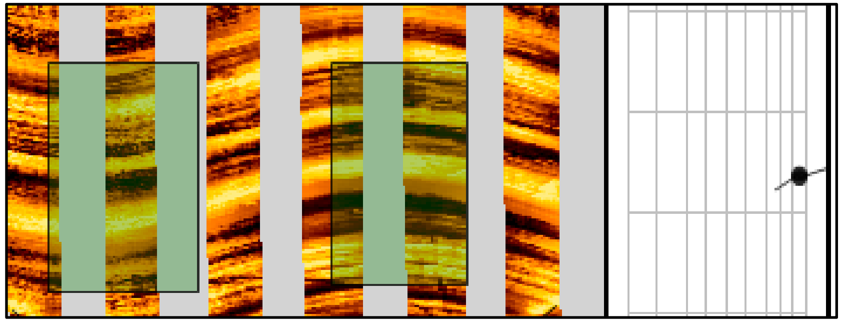
- Apparent Dip Azimuth Start
  - Units: degrees
  - Limited between 0 degrees and 360 degrees
- Apparent Dip Azimuth End
  - Units: degrees
  - Limited between 0 degrees and 360 degrees



Breakouts

- Breakouts will be characterized by the following information…
- Opposing breakouts do not have to have the same UID.

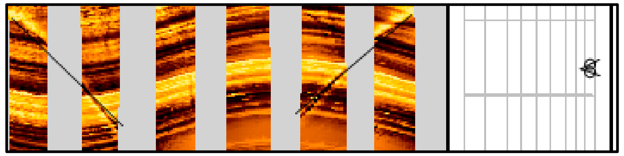
- Measured Depth (i.e. depth along the borehole) at mid-point of feature (i.e. Centered Depth)
  - Units: feet or metres
- Breakout Height along borehole axis
  - Units: feet or metres
- Breakout Width
  - Units: degrees
- Apparent Dip Azimuth, corrected for magnetic declination.



Tensile Fractures

- Tensile Fractures will be characterized by the following information…

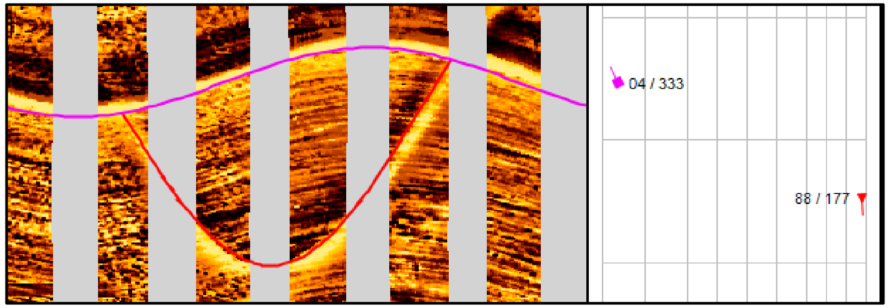
- Measured Depth (i.e. depth along the borehole) at mid-point of feature (i.e. Centered Depth)
    - Units: feet or metres
- Tensile Fracture Height along borehole axis
    - Units: feet or metres
- Omega Angle, angle measured from axis clockwise.
    - Units: degrees
    - Limited between -180 degrees to 180 degrees
- Apparent Dip Azimuth, corrected for Magnetic Declination.



Truncations

- Truncations will be characterized by the following information…
- Unique UID for each abutting feature for truncated sinewaves to distinguish between multiple picks at the same depth in case of truncation.
- We just need to have two additional attributes:

- Truncation Uphole UID
  - The unique UID for the uphole truncating dip
- Truncation Downhole UID
  - The unique UID for the downhole truncating dip



NB: Ask software companies to find a solution for getting the correct depth for truncation.

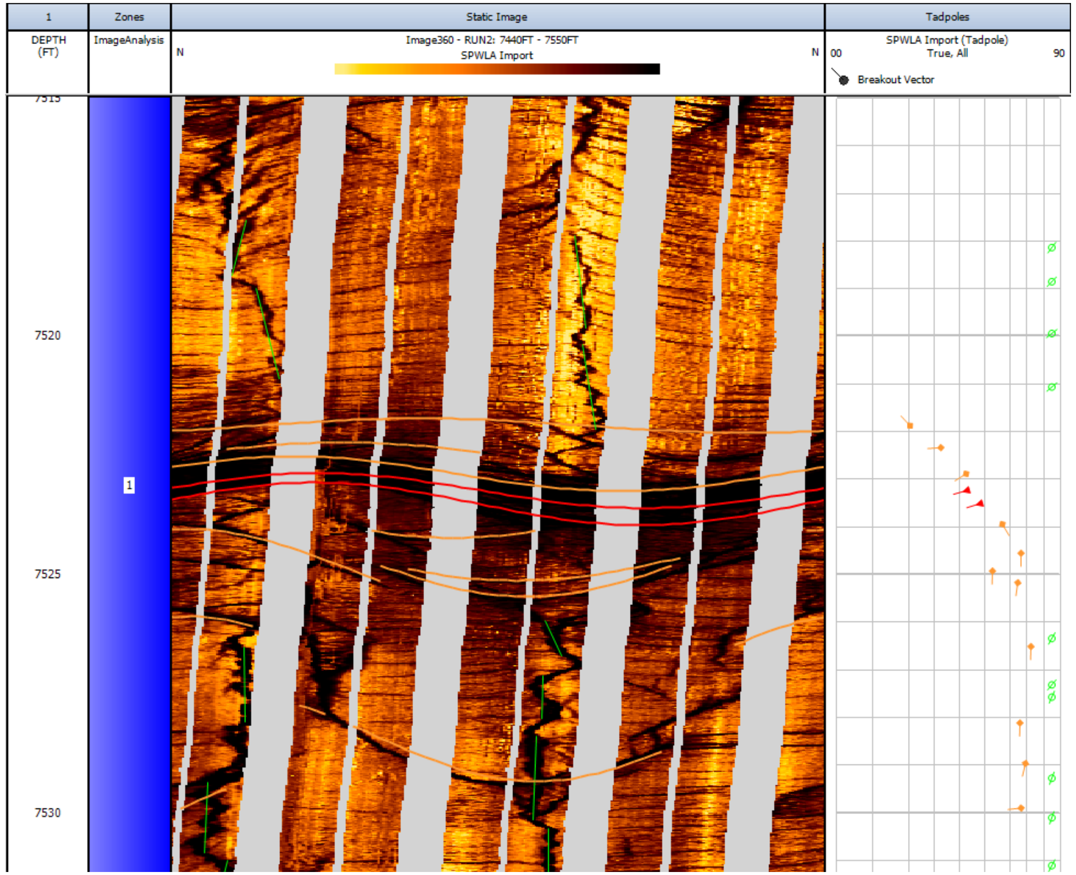
Example Data

- Our example is based on the Utah Forge dataset
- We have chosen Well: 58-32 (aka MU-ESW1); Run #2
- Image logs can be found here:
  - https://gdr.openei.org/submissions/1076
  - The file "Well 58-32 FMI Runs 1 and 2 Logs.zip" contains two FMI runs.
  - The page also links to a wealth of other data.
  - The file "58-32_logs.zip" contains the original Techlog dips stored in:
    - University_of_Utah_MU_ESW1_FMI_HD_7440_7550ft_Dip_Final_2ndRun.las

Energy and Geoscience Institute at the University of Utah. (2017). Utah FORGE: Well 58-32 Schlumberger FMI Logs DLIS and XML files [data set]. Retrieved from https://dx.doi.org/10.15121/1464529.

Example Data

- The example dataset provided is based on the original SLB Run#2 picks w/ the addition of bed/fracture combination to demonstrate the truncation feature.



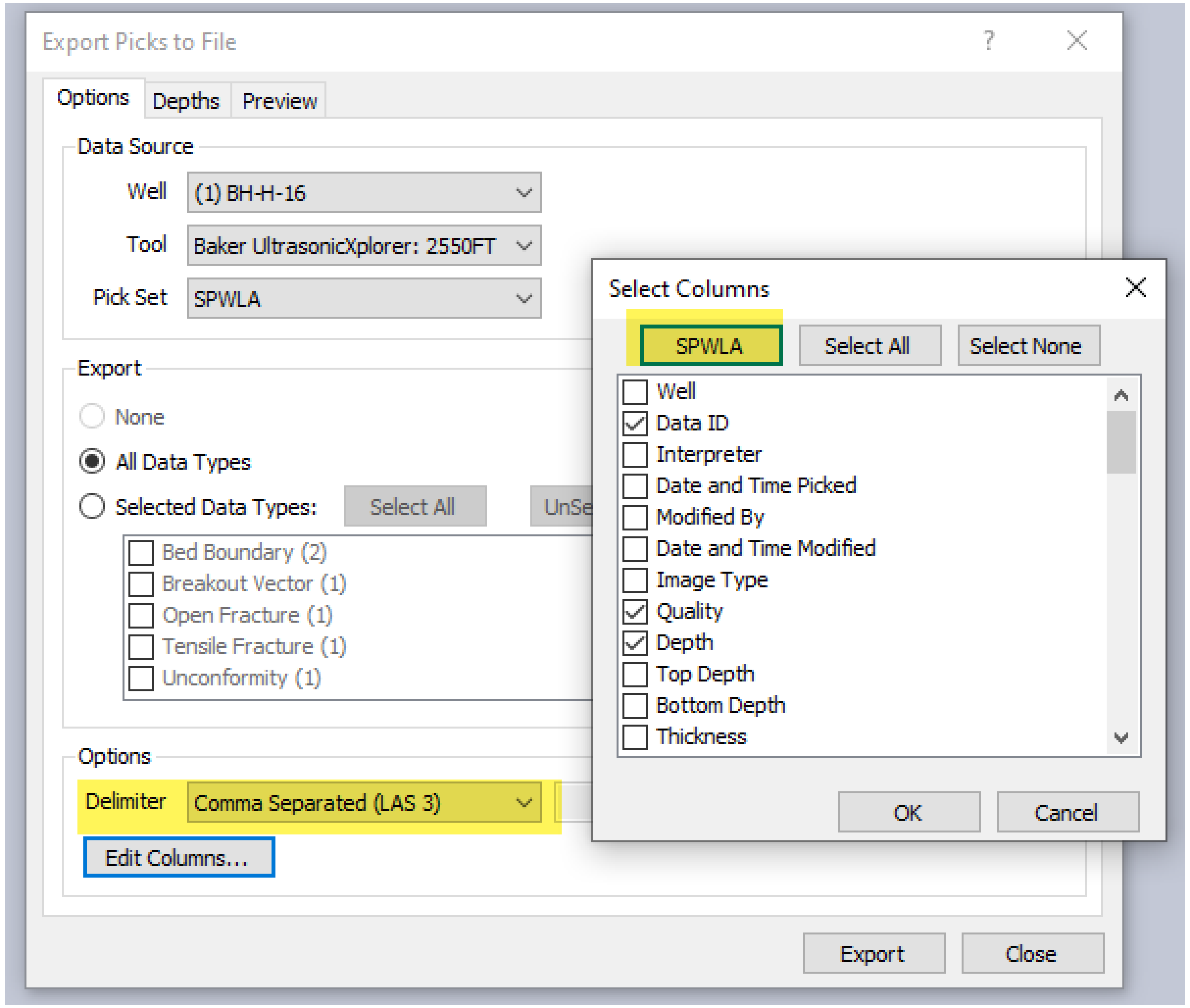
- The example LAS file can be downloaded from >>here<< Just click the link!

Commercial Software Implementation

- Whilst developing the standard, we incorporated it in Interactive Petrophysics.

- Please let the BHI SIG committee know if other software products have included it by contacting us at:

bhi_sig_comm@spwla.org



Suggested Header Mnemonics

- WELL — Well Name
- UWI/API — UWI/API
- FN — Field Name
- CTRY — Country
- COMP — Company/Operator
- LATD — Latitude: Decimal ; +/-
- LOND — Longitude: Decimal ; +/-
- DATE — Date of Log Data Acquisition: in YYYY-MM-DD format (- or /)
- MFIN — Magnetic Field Intensity
- MINC — Magnetic Inclination
- MDEC — Magnetic Declination
- MMOD — Magnetic Model
- DFT — Drilling Fluid Type
- LMF — Log Measured From (e.g. Drill Floor, Mean Sea Level, Ground Level, etc.)
- …

Suggested Curve Mnemonics

• DEPTH	Measured Depth
• UID	Unique Pick ID
• DPTR	True Dip Angle
• DPAZ	True Dip Azimuth
• ADIP	Apparent Dip Angle
• AAZI	Apparent Dip Azimuth
• DIPT	Dip Type
• DIPQ	Dip Quality
• OREF	Orientation Reference (North, HighSide or LowSide)
• DEVI	Hole Deviation
• HAZI	Hole Azimuth
• RB	Relative Bearing
• P1AZ/P1NO	Pad 1 Azimuth/North

• DOI	Depth of Investigation
• ACAL	Caliper
• AAS1	Apparent Azimuth Start 1
• AAE1	Apparent Azimuth End 1
• AAS2	Apparent Azimuth Start 2
• AAE2	Apparent Azimuth End 2, etc.
• BRKH	Breakout Height
• BRKW	Breakout Width
• TFRH	Tensile Fracture Height
• TFRW	Tensile Fracture Width
• TFRO	Omega Angle, angle measured from axis clockwise.

Thanks

- We would like to thank the team that helped define the standard:
    - Christian Rambousek, NiMBUC Geoscience
    - Chandramani Shrivastava, SLB
    - Bastian Roters, NiMBUC Geoscience
    - Bernd Ruehlicke, Eriksfiord
    - Peter Barrett, Halliburton
    - Tegwyn Perkins, Geoactive Ltd

And thanks to the BHI SIG…