Geotechnica ME
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Wireline Logging Services

A powerful tool for ground investigation in traffic infrastructure projects

Wolfram Felfer
Fugro Wireline Logging Services
w.felfer@fugro.at

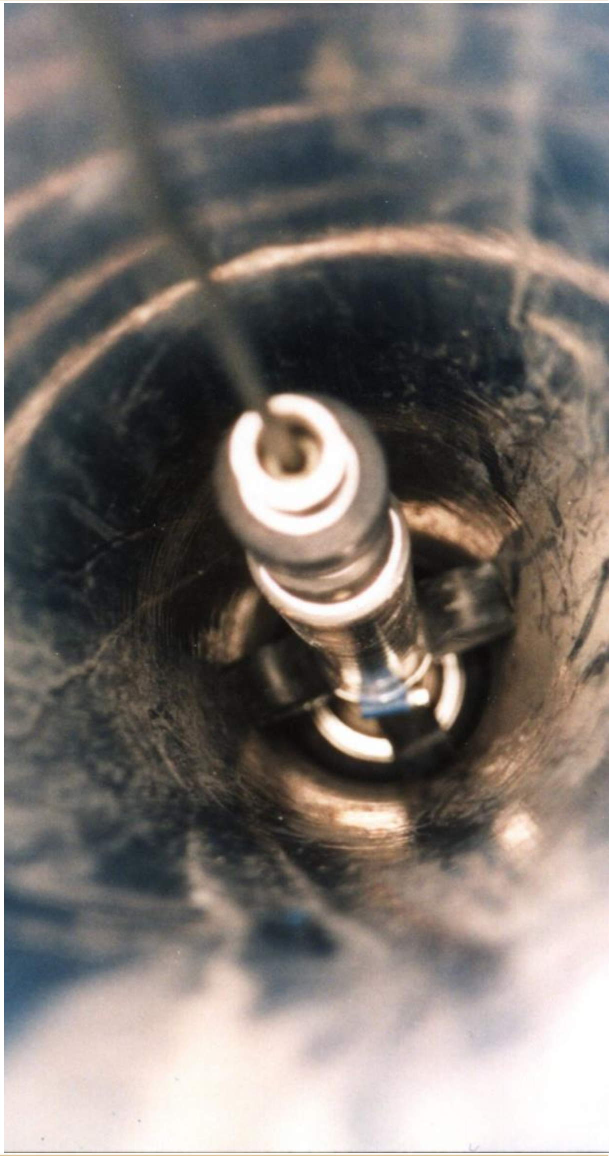
Overview

Wireline logging – general

Koralm railway tunnel

Wireline logging @ Koralm railway tunnel

Wireline logging – selected methods



Why spend money on it?

Wireline Logging provides…

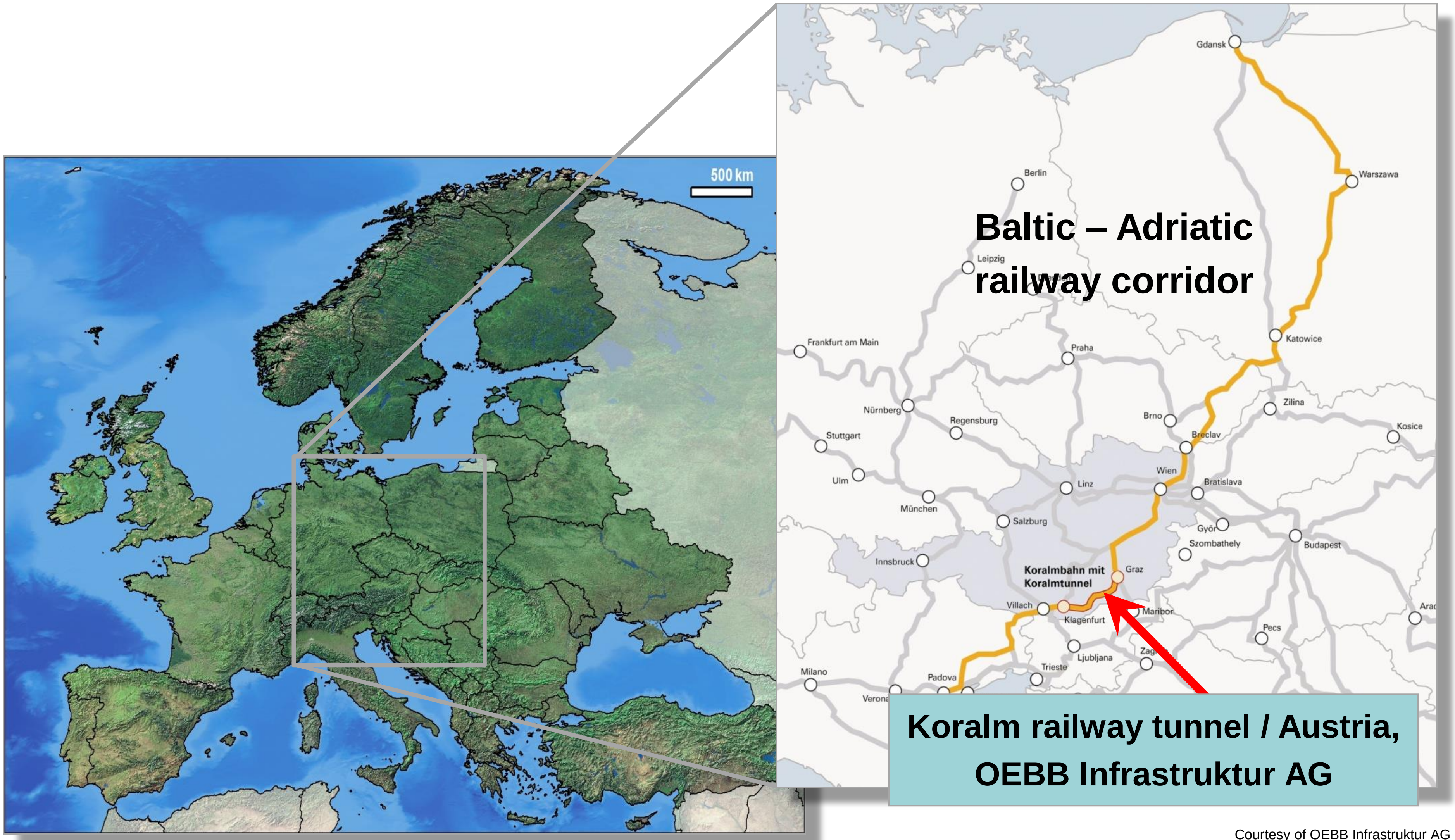
- …in-situ data of (nearly) undisturbed formation.
- …profiles with high depth sampling rate (“continuous”)
- …small integration volume but higher resolution compared to surface geophysics
- …data with exact depth information
- …data widely independent from the “human factor”
- ...cost-effective and reliable solutions that help to reduce construction risk

Why spend money on it?

But…

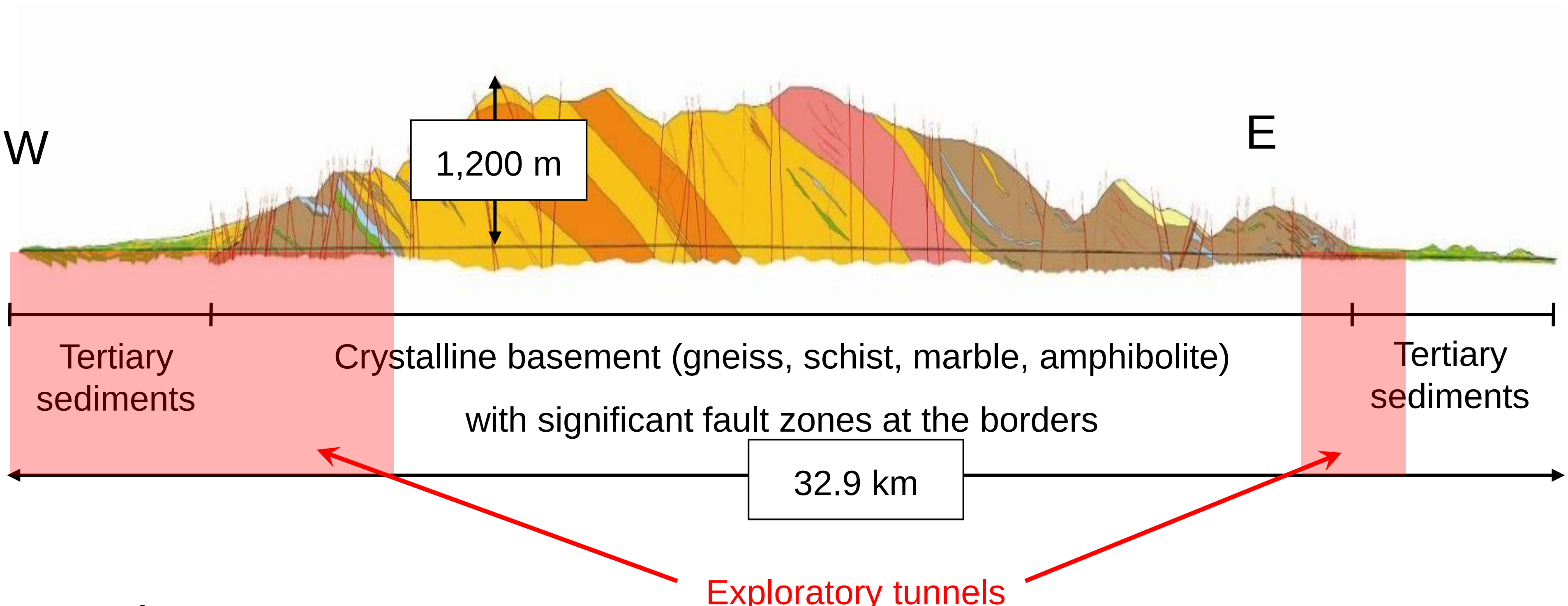
- …WL data are no substitute but complementary to drill records, geologist's logs or other available information
- …there must be a suitable borehole. Drilling diameter, drilling fluid, inclination, casing material influence the set of applicable methods
- …formation properties influence the set of applicable methods
- …the measurements have to be done by qualified field engineers with properly calibrated instruments
- …WL data have to be processed, interpreted and translated into the engineer's language by experienced geophysicists/geologists
- …this interpretation is partly based on models and assumptions

Koralm Railway Tunnel
The project



Courtesy of OEBB Infrastruktur AG

The project



Project status

- Start of ground investigation and groundwater monitoring in 1998
- Start of excavation in 2010, KAT1 finished (drill & blast), KAT2 active (2 TBM), KAT3 will start in 2014 (drill & blast + 1 TBM)
- Start of operation expected for 2023
- Target costs $ 2,500 mill

Courtesy of OEBB Infrastruktur AG

Wireline Logging @ Koralm Railway Tunnel
Ground investigation phase

>130 vertical or inclined boreholes
max. depth 1,300m
Total drill length 21,400 m, 100% cored

WLS methods

- Acoustic / Optical Borehole Imager
- Oriented 4-Arm Caliper
- Full Wave Sonic
- Gamma Gamma Density
- Cavity Scanners

Solutions

- Structure analysis (discontinuity planes)
- Evaluation of elastic rock parameters
- Cavity survey (carbonate karst)
- Evaluation of grondwater parameters for modelling (Transmissivity, yield, etc.)

Wireline Logging @ Koralm Railway Tunnel
Groundwater monitoring phase

120 vertical or inclined monitoring wells
Uncased / partly cased / fully cased
max. depth 1,300m

WLS methods

- Flowmeter
- Tracer Logs
- Qualitative water parameters (temperature, conductivity, oxygen, pH)
- Water Sampler

Solutions

- Monitoring of groundwater regime (gw-table, quality, quantity) before / during excavation of tunnel
- Temperature monitoring

Wireline Logging @ Koralm Railway Tunnel
Excavation phase of exploratory tunnels

20 horizontal boreholes ahead of the face of the exploration tunnels (max. length 240m)

WLS methods

- Acoustic / Optical Borehole Imager
- Borehole Deviation (open or metal cased hole)
- Natural Gamma Ray

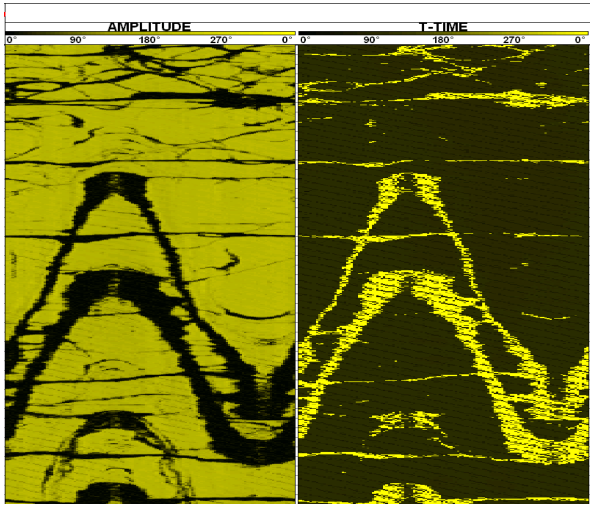
Solutions

- Structural and hydraulic investigation ahead of the tunnel face

Structure analysis of discontinuity planes

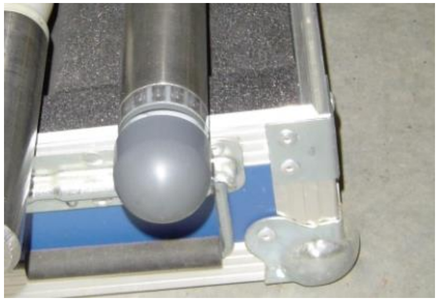
Acoustic Borehole Imager (ABI)

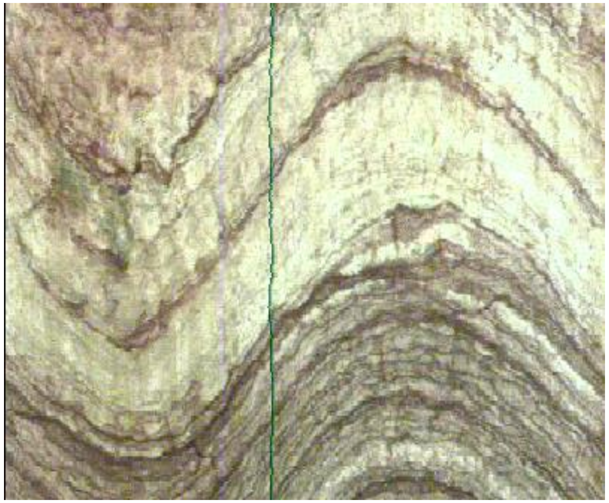
- Rotating ultrasonic device
- Fluid filled borehole
- Amplitude and traveltime



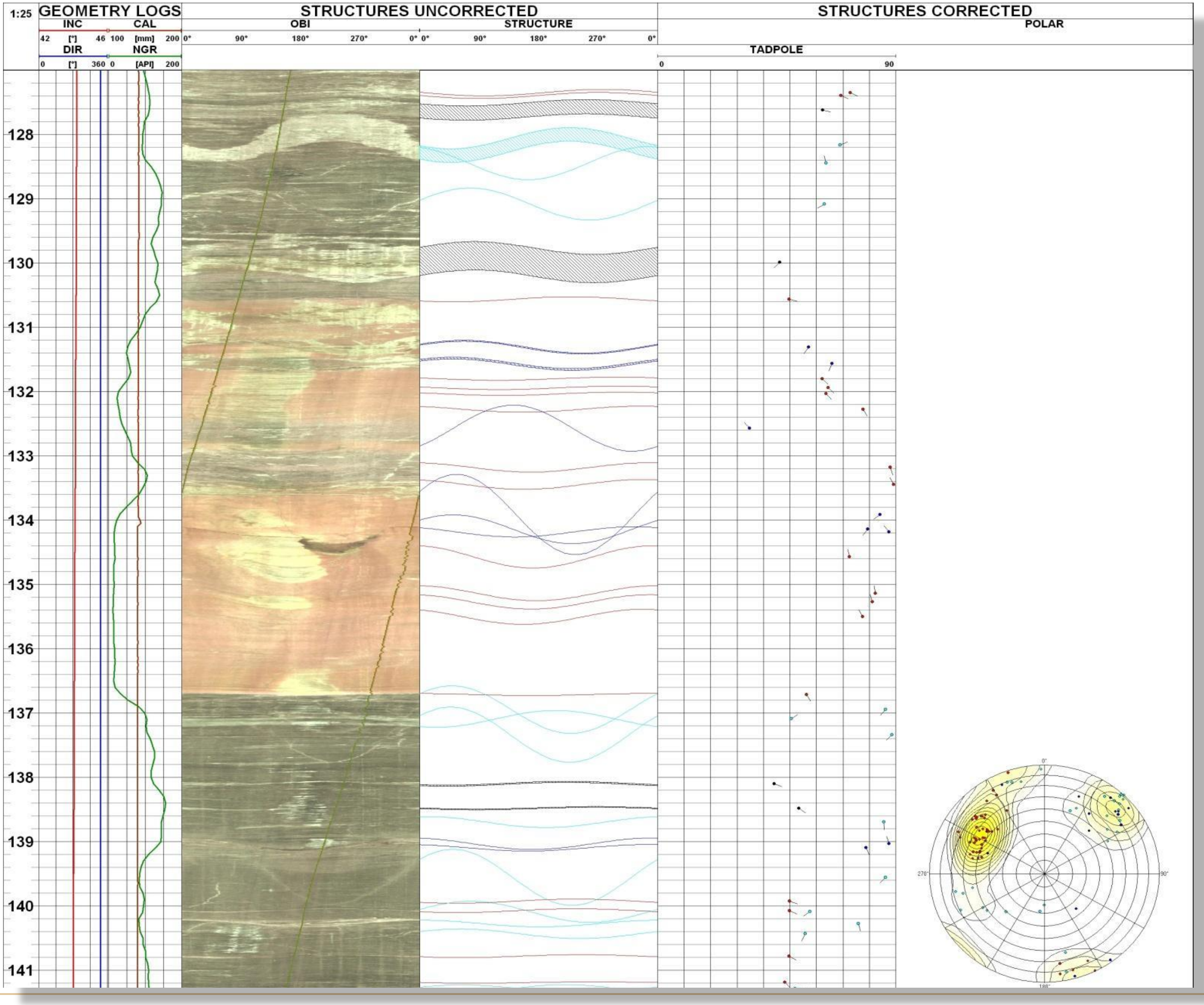
Optical Borehole Imager (OBI)

- Fixed camera + conical mirror
- Clear water or air
- Optical image





Structure analysis of discontinuity planes



Example of processed Optical Borehole Imager Log (OBI) in metamorphic rock (amphibolite, marble)

Evaluation of elastic rock parameters

Velocity of elastic waves

v_p, v_s

Formation density

ρ_b

Full Wave Sonic Log
or
PS Suspension Log
or
Borehole Seismic

Gamma-Gamma Density Log

Young's Modulus

$E_{dyn} = 2 * \rho * v_s^2 * (1 + \nu_{dyn})$

Poisson's Ratio

$\nu_{dyn} = [(v_p/v_s)^2 - 2]/[2*(v_p/v_s)^2 - 1]$

Shear Modulus

$G_{dyn} = \rho * v_s^2$

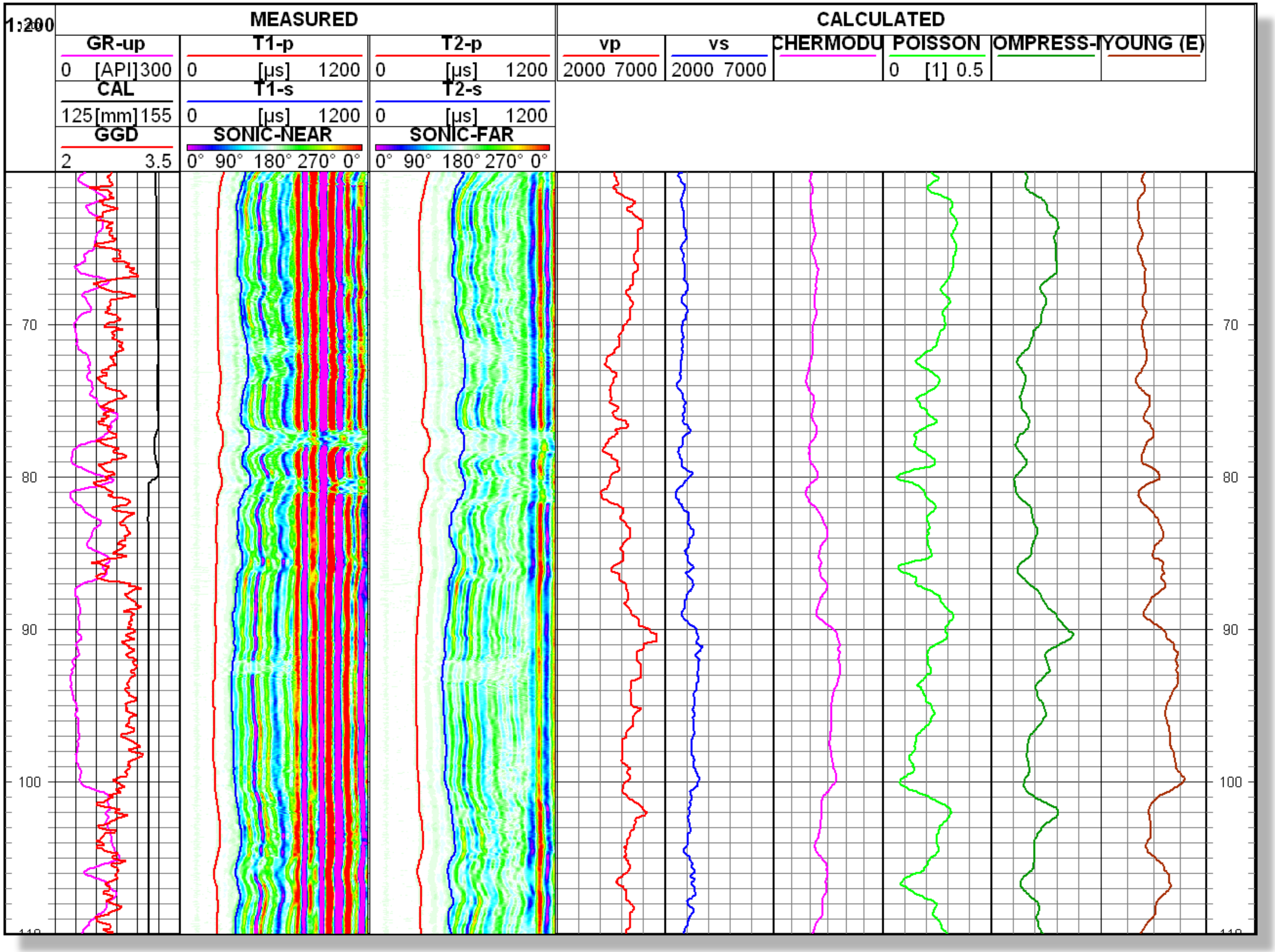
ρ … formation density [kg/m³]

v_p … velocity of compressional waves [m/s]

v_s … velocity of shear waves [m/s]

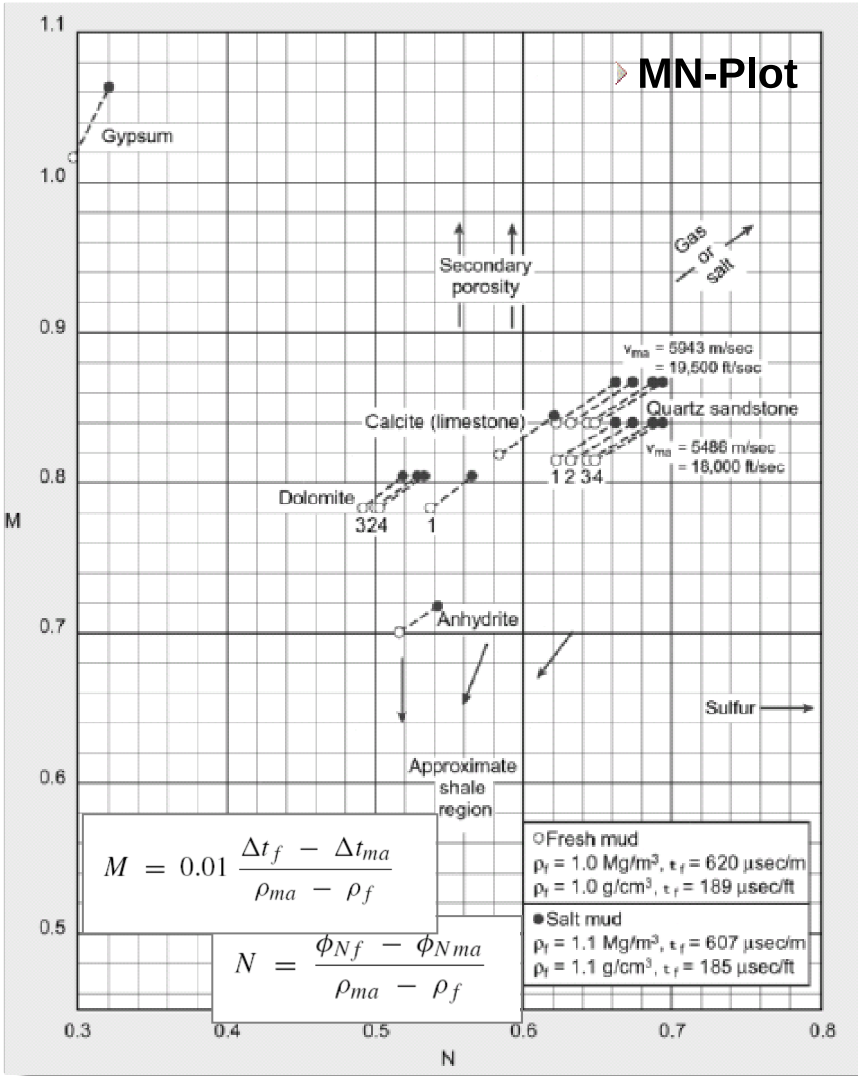
ν … Poisson's Ratio [1]

Evaluation of elastic rock parameters

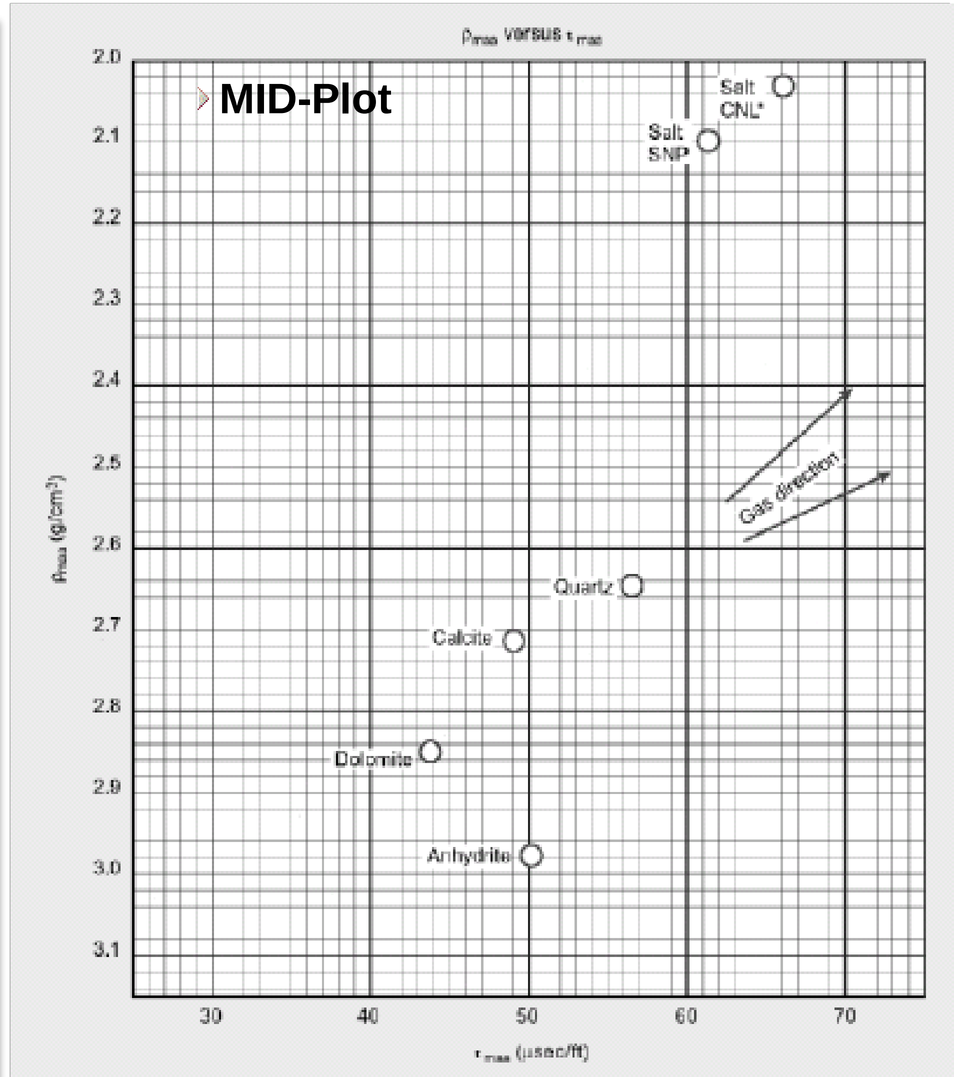


Elastic rock parameters from Full Wave Sonic and Gamma Gamma Density Log

Evaporite lithology evaluation



Schlumberger in Ellis 2006



Schlumberger in Ellis 2006

Cavity survey

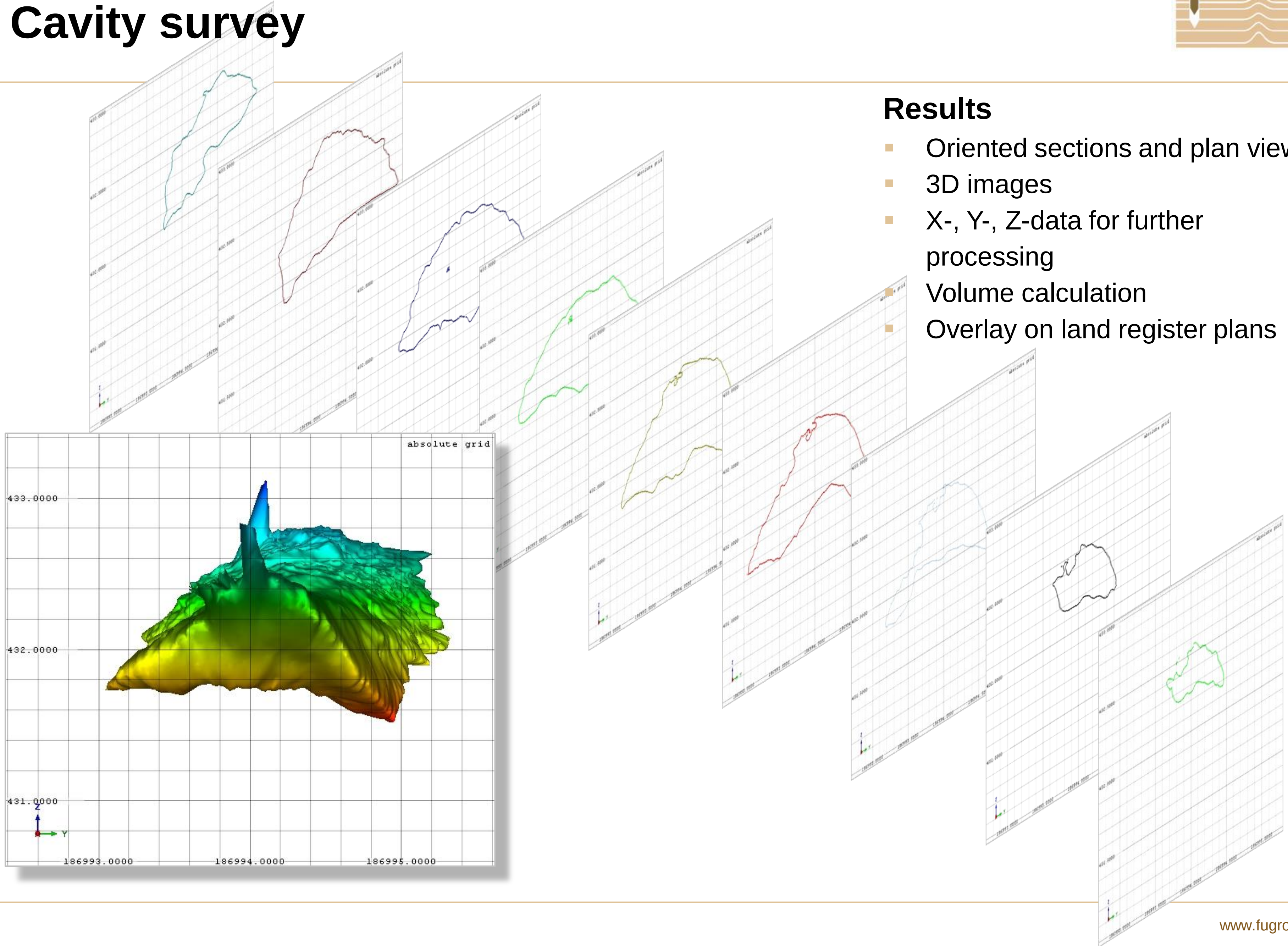
Tech Specs

- Cavities filled with air (**Cavity Laser Scanner CLS)** or water (**Cavity Sonar Scanner CSS)**
- Tool diameter 50mm (CLS) or 80mm (CSS)
- Distance range 0,50 m - approx. 50 m
- Orientation by magnetic compass module or torsion-free push-pull-rods

Limitations

- Dust / fine particles
- Roughness of reflecting surface
- Impinging angle of beam
- Shadow zone behind objects

Cavity survey



Results

- Oriented sections and plan views
- 3D images
- X-, Y-, Z-data for further processing
- Volume calculation
- Overlay on land register plans

Rock stress evaluation from borehole imaging

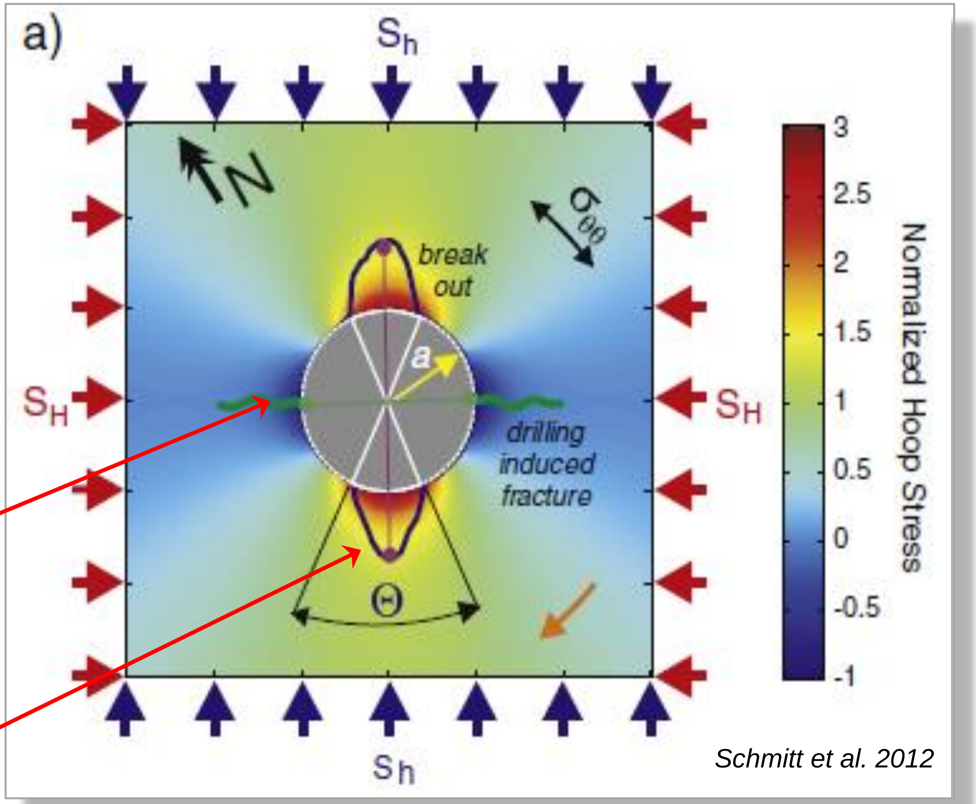
Theory

- The stress field is defined by

  S_H maximum horizontal stress

  S_h minimum horizontal stress

  S_V vertical stress
- Borehole is vertical, i.e. parallel to S_V



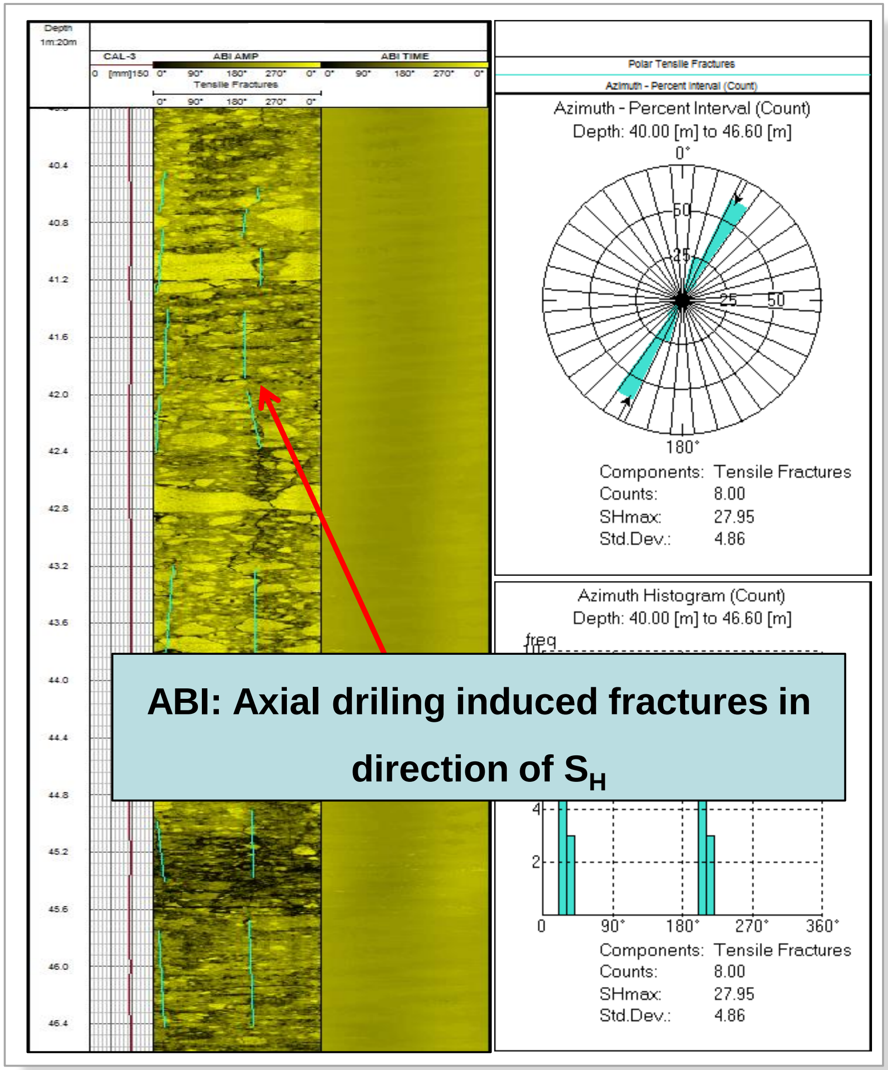
Schmitt et al. 2012

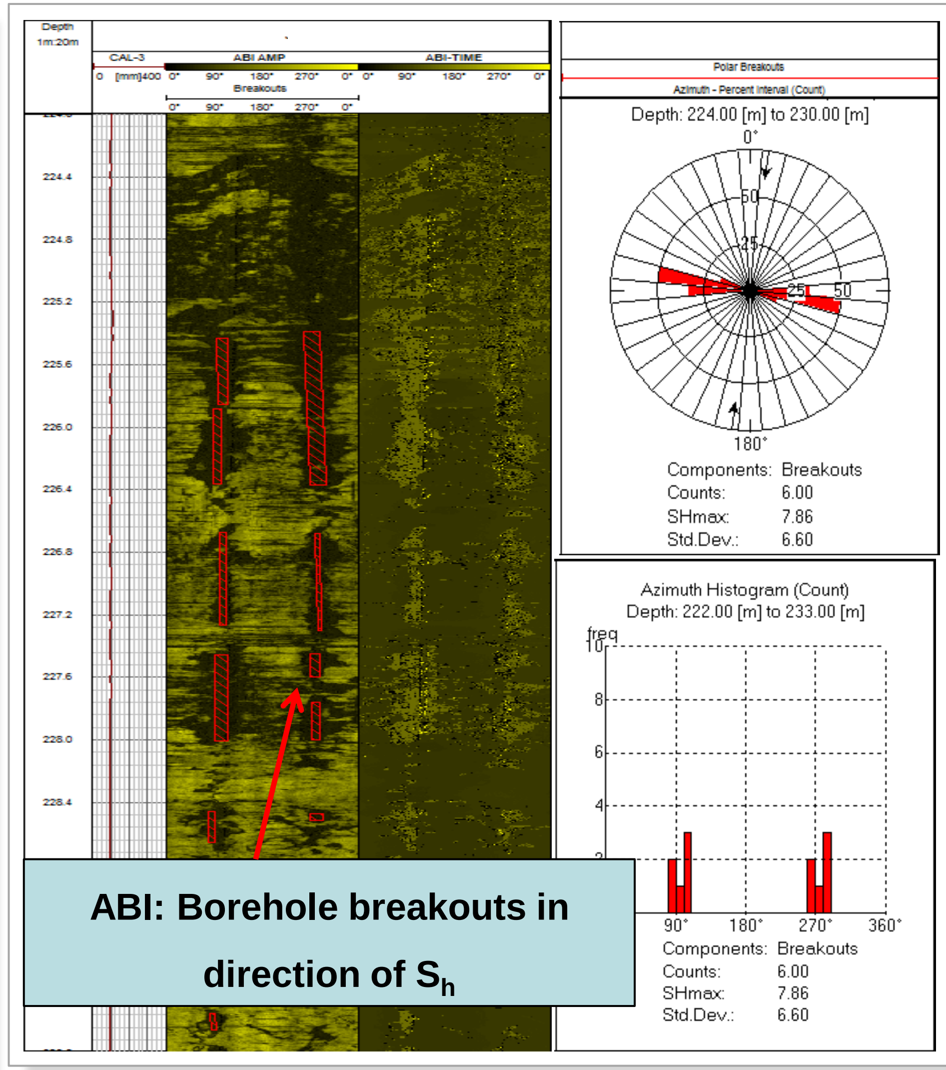
Signs of the stress field on image logs

- **Axial drilling induced tensile fractures** in direction of S_H

- **Axial borehole wall breakouts** in the direction of S_h

Rock stress evaluation from borehole imaging

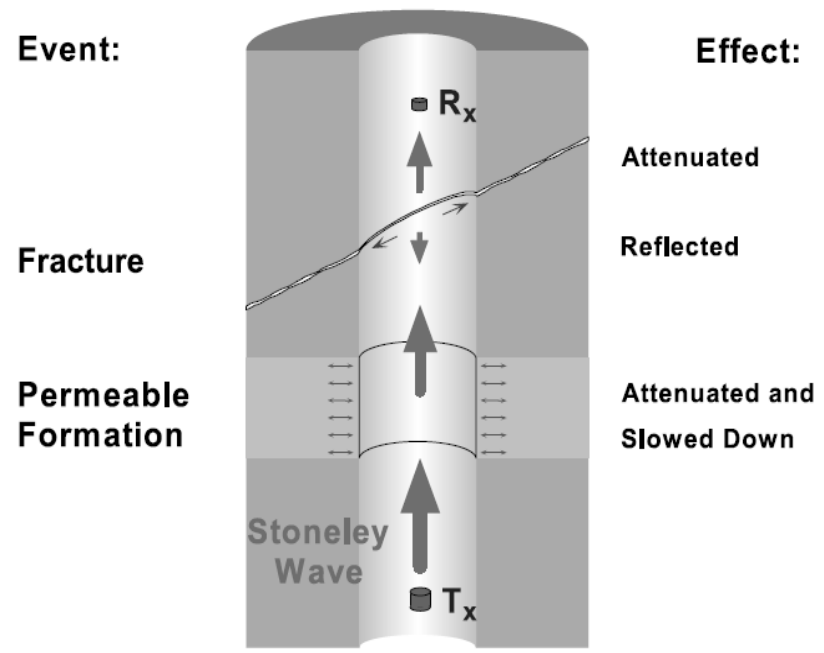




Hydraulics from reflected tube wave analysis

Principle

- Besides p- and s-waves Full Wave Sonic downhole tools generate also Stoneley Waves (=Tube Waves), travelling vertically along the wall at the speed of the borehole fluid.
- When a Stoneley Wave passes a **permeable formation**, the direct wave is slowed down and its amplitude is attenuated due to energy loss into the voids.
- When a Stoneley Wave passes a **distinct open fracture**, the direct wave is slowed down, its amplituide is attenuated and a reflected tube wave is generated.



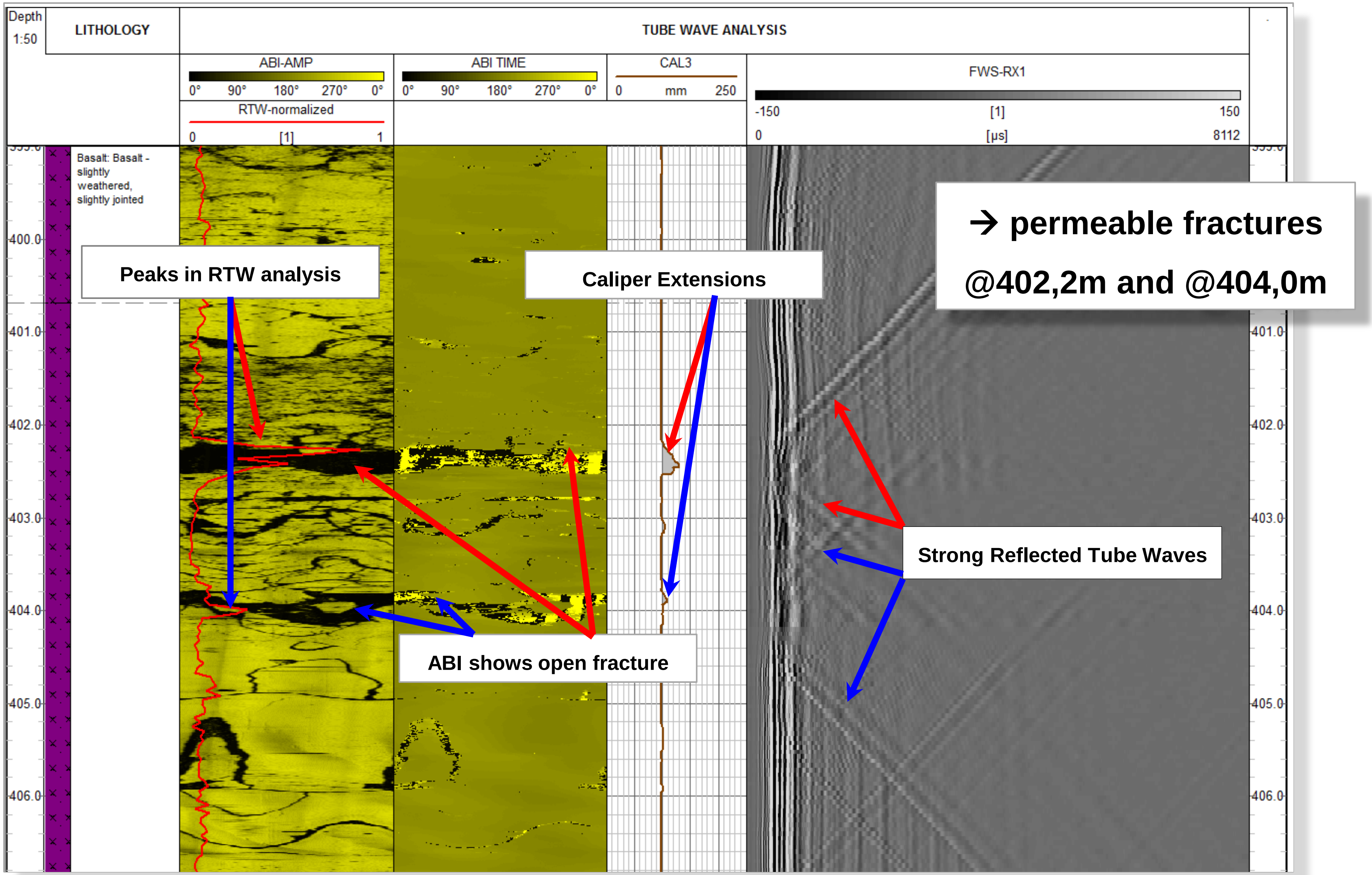
Endo, T. (2006)

Result

- Tube wave analysis gives qualitative information, if formations or single fractures are hydraulically permeable or not.

Wireline Logging – Selected Methods

Hydraulics from reflected tube wave analysis



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