Conventional Logging - geothermal wells

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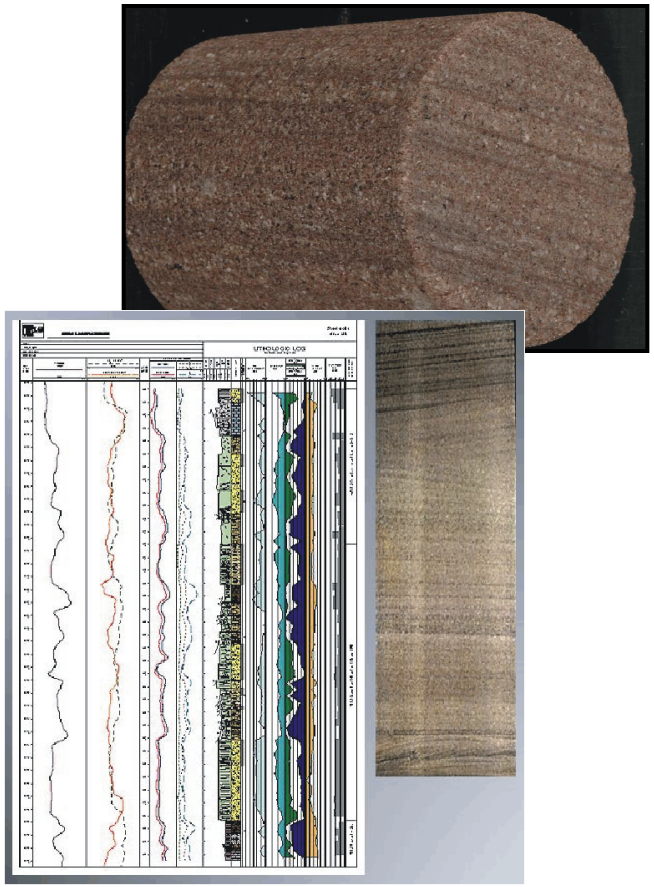
Drilling cost effectiveness and feasibility of high-temperature drilling - Reykjavik, Iceland, ÉNGINE Workshop4

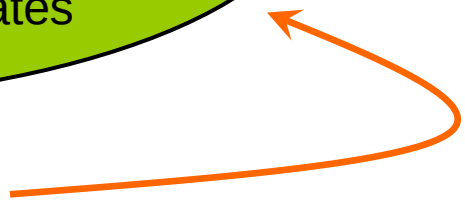
Content

- Key questions
- Tools and purposes
  - sedimentary environment
    - hard rock environment
- Logging in typical EGS systems
- Economics
- Conclusions



Key questions – EGS project feasibility

Temperature
Pressure
Brine chemistry & gas content
Potential production rates



Reservoir

Lithology	
Porosity	primary / secondary ?
Permeability	primary / secondary?
	secondary - joints, open or sealed?
Saturand	water / steam ?
Structure	where are we ? - geosteering

EGS project classes & poro/perm type

Evaluation procedures

Degree of complexity

Structural features

km

Lithology

Φm

kf

Φf

deep	deep sediments	matrix & fractures
	granites	fractures
shallow	volcanics	
	metamorphics	

Standardisation

Structural features

kf

Φf

Lithology

EGS project classes & poro/perm type

„New Area“

„Exploration well“

Logging effort

„Development well“

Reservoir complexity

Granites	Volcanics	Metamor-phics	Sediments

Classical wireline tools

Tool Types	Schlum.	B.-Atlas
Induction and/or Resistivity devices	DIL / DLL / ES	DIFL / DLL / EL
Micro resistivity	MSFL	ML
Litho-density and Neutron porosity	LDT/CNL	CDL/CNL
Acoustic monopole / dipole	LSS / DSI	ACL / DAC
Caliper	CAL	CAL
Natural Gamma / Spectral Gamma	GR / NGS	GR / SPL
Spontaneous Potential	SP	SP
Dipmeter	SHDT	HRDIP
Pressure and Temperature	RFT / HRT	FMT / TEMP
Rock and fluid sampling device	CST	SWC
Acoustic and electric image device	UBI / FMI	CBIL / HDIP

Detection of fractures

CAL	› borehole rugosity and breakouts can indicate a fractured zone.
DT, RHOB, NPHI	› makes use of the difference between total porosity and matrix porosity.
GR	› may detect clay filled fractures.
SN,LN	› can indicate fluid filled fractures.
DSI	› attenuation of stoneley waves.
IMMAGE LOGS	› Direct fracture detection.

Logging volcanics - Iceland

Schlumberger	Baker Atlas	
HRT / CAL / GR / CNL / ES / CBL	TEMP / CAL / GR / EL / CNLog ACBL	@ casing
HRT / CAL / GR / CNL / ES / RFT	TEMP/ CAL / GR / EL / CNLog / FMT	@ total depth
HRT / CAL / CDR	TEMP / CAL / GYRO	@ drilling

Kuster	
KTP / KPG	@ recovery

- Lithological discrimaination necessary, but relative homogenious volcanic deposits, no complex lithology
- no great attention needed for existing fracture networks << fractures exclusively induced by thermal fracturing!

Data source:
Steingrimsson et. al. & Thorhalsson et. al. 2003

Logging metamorphics - Larderello & Travale

Schlumberger	Baker Atlas
CAL / GR / NGS / CNL / LSS	CAL / GR / SPL/ CNL / ACL
FMI / FMS	CBIL

- Lithological discrimaination and stratigraphic reconstruction
- Structural reconstruction - breakout analysis
- Calibration of seismic and gravimetric surveys
- Evaluation of elastic parameters for fracture identification
- Detailed fracture analysis

Data source:
Batini, F., et. al. 2002

Logging garnites - Soultz-sous-Forêts

Schlumberger	Baker Atlas
GR / CAL / NGS / LDT / BHC	GR / CAL / SPL / CDL / ACL

› lithological / petrographical discrimination

Schlumberger	Baker Atlas
UBI / FMI	CBIL / HDIP

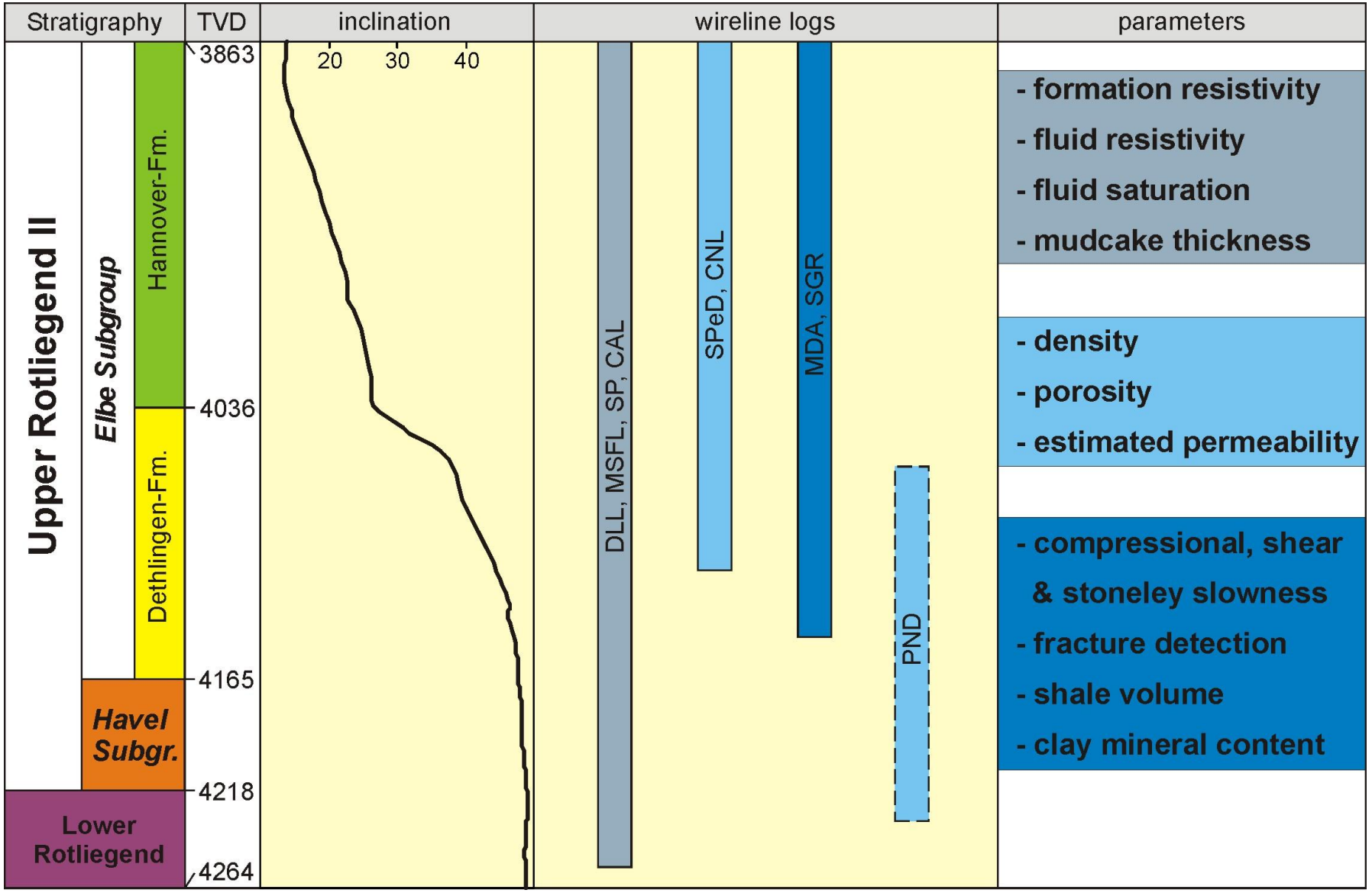
› fracture (network) identification and description

Schlumberger	Baker Atlas
CFS / HCFS / HCFT	FMCS

› identification of flow zones

Data source:
Sausse J. et.al, 2006

Logging program – Groß Schönebeck



Logging - economics

- 5 % - 15 % of overall drilling costs

  Data source:
  Tracs logging taining Manual

- 3 % of overall drilling costs

  Data source:
  Legarth, B. 2003

- 2,5 % - 5 % of overall drilling costs

  Data source: GrSk 4
  Holl

- Production Test
- 30 % - 70 % of logging costs

  Data source:
  Brandt

Conclusions

- Clear need for further Standardisation
- Make use of all available data
  - Production data
  - drilling data,
  - core information
  - mudlug data
- Target oriented logging program
  - as simple as possible as complicated as necessary
- Take an interdisciplinary approach
- Further research should be directed into economics of acquiring wireline data
  - wireline vs. MWD/LWD
  - wireline vs. Pipe conveyed / shuttle
  - wireline vs. well tests

Thank you very much

for your attention!!