The Scratch Test
EPSLOG - Company ID

BELGIAN COMPANY
- Created in November 2005

KNOW-HOW
- 25 years of academic research
- 15 years experience in the oil and gas industry (drilling, scratch)

WOMBAT: last generation of scratch test
- High resolution log of uniaxial compressive strength (UCS)
- High resolution log of internal friction angle of geomaterials

DREAM - Interpretation and monitoring of drilling operations
- Analysis of down hole & surface data
Rock Cutting

Trace groove on surface of a rock specimen

\[ W = \varepsilon \times V \]

work performed by cutter

volume of rock cut

energy per unit volume to cut rock

strength

Wombat

measure

\[ \frac{W}{V} = \varepsilon \]

calculate

estimate
Wombat

Rock samples

![Rock samples diagram]

Deliverables

- Logs of strength ($\varepsilon$, $\mu$)
- Continuous high resolution picture

<table>
<thead>
<tr>
<th>L (mm)</th>
<th>D (mm)</th>
<th>H (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>20</td>
<td>1000</td>
<td>20</td>
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State of the art

High resolution
2 points per cm

High precision
1 MPa

Up to 20 m per 8 hours shift (full digital processed logs)
Experimental results

Sharp Cutter

\[ F_{cs} = \varepsilon wd \]
\[ F_{cn} = \xi \varepsilon wd \]

Blunt Cutter

\[ F_{bs} = \mu F_{bn} \]
\[ \mu = \tan \phi \]
High Resolution Continuous Profile

The scale of local heterogeneity is \textbf{centimetric}!

Homogeneous section \(1 \text{ cm}\)
One to One Correlations

**Strength**

5 INDEPENDENT LABORATORIES (1996 – 2012)
TOTAL (FRANCE), University of Minnesota (USA), University of Mons (BELGIUM), IKU-Sintef (NORWAY), EPSLOG (BELGIUM)

92 sandstones, 86 limestones, 19 shales, 6 dolomites, 4 chalks, 3 granites, 2 coals, 2 anhydrites, 6 artificial sandstones, 17 building materials, 3 refractories, 12 others

**Friction**

7 limestones, 5 sandstones, 3 shales, 1 chalk

Uniaxial Compressive Strength (MPa)

Specific Energy from scratch tests (MPa)

Friction angle from triaxial tests (°)

Friction angle from scratch tests (°)
Dispersion!

- **Highly repeatable**

- **Low dispersion**

- **Dispersion caused by UCS!**
Scratch Test

- shear failure (similar process)
- direct result of scratch test
- no calibration
- one to one correlation
- 0.5 to 250 MPa
- regardless of lithology, and origin
- “true” continuous profile
Correlation with porosity and permeability (plugs)
Plugs selection

Over-plugging

Missing the local extrema

“Misleading” plugs

High resolution scratch test results
Industry practice

Well logs

Lab Test (core)

Correlation

Mathematical relationships

Apply on non-core wells

Reservoir modelling

Geomechanics
Length scales

Well logs
- Resolution: 0.5/1 m

Lab Test (core)
- Resolution: 5 cm

~ 1 foot

Extensive Plugging (1 every foot at least)

Well log scale
- 12 MPa

Plug scale
- 1 < ? < 20 MPa

Statistical approach
Correlation Scratch – Porosity well Log

Scratch and porosity logs

Porosity log

Scratch

Porosity derived strength log

SANDSTONES

CARBONATES

Scratch and porosity logs

Porosity log

Scratch

Scratch and porosity logs

Porosity log

Scratch

Scratch and porosity logs

Porosity log

Scratch
Correlation Scratch – Well logs

- Porosity
- Density
- Sonic
- Permeability
- Density
- Shale content
A Coherent Additional Autonomous Source of Information

\[ \varepsilon = 96 - 273\phi \]

\[ \varepsilon = 76 - 18\log_{10}k \]
Coherence – Incoherence

\[ \varepsilon = 69 - 213 \phi_T \]

\[ \varepsilon = 122.5 - 0.95 DTC \]

\[ \varepsilon = 2 + 48 V_{\text{shale}} \]
Facies Identification
1. Simple, fast, robust, partially destructive test

2. Provides a direct continuous profile of strength with centimetric resolution
   Laboratory controlled well log
   Objective measure of the length scales of heterogeneities (layering)

3. Evidence of correlation between strength, porosity and permeability at the scale of plug (few cm)

4. Evidence of correlation with well logs: porosity, density, sonic, GR at the scale of well log (foot)
Summary - Applications

1. Optimize the core’s depth shift

2. Optimize location for plugs
   homogeneous vs heterogeneous sections, extremas

3. Correlation with well logs with large representative sets of data

4. Consolidate all measurements
   QC wells logs and plugs measurements
   Isolate inconsistency in logs-logs, logs-plugs,
   plugs-plugs relationships
Drilling Data

Surface Data

Data processing

Down hole values

Bit-rock interface model

Rock properties

Hook load
RPM
Torque
ROP
Sonic Derived Strength

\[ \varepsilon = 110 - 0.63 \text{DTC} \]
Alternative tests

Rebound Test (Leeb, Schmidt, Equotip)

- Rapid qualitative indicator of rock hardness
- Elasto/plastic response
- Non-linear correlation (function of the rock strength)
- Not recommended for weakly cemented rock
- Function of the rock type

Semi continuous – manufacturer recommendation 3 to 5 tests every 3 to 5 mm, minimum of 600 tests per meter up to 1650...