Development of an XRF Borehole Probe for Depths up to 500 m

Jan Bachmann
Claus Bachmann
Markus Reich
Ulrich Harms
Helge Wurst
Why Borehole Probe Development?

- Exploration is done by borehole drilling
  - Core Drilling
    - Cores can be analyzed with hand held XRF devices
    - Later analysis in laboratory
    - Time consuming
    - Very expensive
    - Very precise
Why Borehole Probe Development?

- Exploration is done by borehole drilling
  - Conventional Drilling
    - Drill debris is collected as sample
    - Evaluation of subsamples is done in laboratory
    - Analysis in laboratory is time consuming and costly
    - Samples represent average of certain part of the drilled hole (e.g. 20 m)
    - Poor depth resolution
- Conventional methods do not allow fast action according to results
X-Ray Fluorescence

• Suitable for Elemental Analysis

• Present Status:
  - XRF measuring devices in operation under various conditions
    • On-belt measurement
    • Slurry measurement
    • Hand held devices for sample investigation
  - Logical step: Use of XRF for Borehole Logging
X-Ray Fluorescence

• Basic Measurement Principle
XRF Probe: Feasibility

• Prototype Development:
  – Borehole Probe
    • Depth up to 30 m
    • Not pressure proof
    • Width 90 mm
    • Cable based real-time data transmission to surface
    • Designed for blasthole logging
XRF Probe: Feasibility

• Prototype Development:
  – Based on standard XRF Analyzer
  – Big drum
  – Electronics included inside drum
  – Purpose:
    feasibility testing
XRF Probe: Feasibility

• Prototype Development:
  – Sensor length 600 mm
  – Standard X ray tube
  – Standard X ray sensor
  – No center alignment
  – No adaption to changing borehole diameters
XRF Probe: Feasibility

- Prototype Development:
  - Control of measurement is done with a laptop using WLAN
XRF Probe: Development

- Development of Industrial Version:
  - Borehole Probe
    - Joint development with GFZ, Potsdam, Germany
XRF Probe: Development

- Development of Industrial Version:
  - Borehole Probe
    - Depth up to 500 m
    - Widthstands pressure up to 5 MPa
    - Width 53 mm
    - Length approx. 2.000 mm
    - Cable based real-time data transmission to surface
XRF Probe: Development

- Borehole log
  - Logging speed variable
    - Accuracy increases with decreasing speed
  - Raw Sensor Data acquisition
- Simultaneous logging of different elements
- Density log
## Borehole Probe

### Challenges of high depth

<table>
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<th>Prototype</th>
<th>Final Development</th>
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<tbody>
<tr>
<td><strong>Depth</strong></td>
<td>30 m</td>
<td>500 m</td>
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<tr>
<td><strong>Temperature</strong></td>
<td>Up to 40 °C</td>
<td>Up to 70 °C</td>
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<tr>
<td><strong>Borehole Width</strong></td>
<td>90 mm</td>
<td>53 mm</td>
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<tr>
<td><strong>X-Ray Power Supply</strong></td>
<td>Ground Level</td>
<td>Inside of Probe</td>
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<td><strong>Data Transmission</strong></td>
<td>Ethernet</td>
<td>DSL</td>
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<tr>
<td><strong>Data Transmission Range</strong></td>
<td>30 m</td>
<td>500 m</td>
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<tr>
<td><strong>Scan Speed</strong></td>
<td>10-200 mm/s</td>
<td>10-200 mm/s</td>
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XRF Probe: Width

- All components must fit into the probe
  - Restriction
    - Available space: 43 mm inner diameter
  - Requirements
    - Development of a special power supply for voltages up to 50 kV
    - Development of an adapted X-ray sensor
    - Use of a miniaturized X-ray tube
    - Development of a high speed data transfer using standard winch cables
XRF Probe: Depth

• Increasing outside temperature with depth
  – Restriction:
    • All components must withstand increased temperature range
  – Requirements:
    • Excess heat has to be absorbed or exchanged to the environment
      – Heat pipes
      – Peltier cooling for sensor and electronics
      – Intelligent energy management
XRF Probe: Electronics

- All electronic components had to be adapted
  - Sensor
    - Adaption of an industrial available sensor
    - Sensor module with new supply board
XRF Probe: Electronics

• All electronic components had to be adapted
  - X-ray power supply
    • Commercially available power supplies (50 kV, 50 W) do not fit into tube
    • Complete new development required
XRF Probe: Electronics

- All electronic components had to be adapted
  - Data transmission
    - Adaption of existing ADSL techniques
    - Commercially available modules do not fit into tube
XRF Probe: Physics

- Probe must be tight, heat resistant and transparent for low energy X-rays
  - Requirements:
    - Thin window
    - Low Z window material
    - Pressure resistant
    - Temperature resistant
  - Solution:
    - High sensor sensitivity (10 Mio cps)
    - High X-ray intensity
Borehole Probe

- Power Supply
- Sensor
- Sensor Electronics
- Communication
- Probe Alignment
Borehole Probe

- Sensor Design
Borehole Probe

- Power Supply
- Sensor
- Sensor Electronics
- Communication
- Probe Alignment
Borehole Probe

- Power Supply
- Sensor
- Sensor Electronics
- Communication
- Probe Alignment
XRF Borehole Probe

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ZIM

impulse für wachstum
Zentrales Innovationsprogramm Mittelstand

Bachmann
Thank you for your attention!