Downhole Physical Properties Measurements Supporting Iron-oxide Deep Exploration and Mining in Blötberget, Sweden

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Motivation

- **Blötberget (Bergslagen)** – one of the most important mineral districts in south-central Sweden
- Iron-oxide deposits → magnetite and hematite mineralization (several boreholes)
- Delineate the mineralization at depth and understand the relationship between the host rocks and the ore body
- Analyze physical properties and provide better control for surface measurements
- Part of extensive studies for future exploration and mining!
Study Area & Surveys

- Vulcano-sedimentary rocks (Svecokarelian orogen)
- Iron-oxide mineralization: found between 350 to 600 m depth (down to at least 700 m), dipping southeast
- Host rocks: metavolcanics

**Measurements:**
- **Downhole geophysical logging:**
  - magnetic susceptibility
  - natural gamma
  - formation resistivity
  - fluid temperature and conductivity
  - full-waveform triple sonic
- **Laboratory measurements:**
  - density
  - magnetic susceptibility
  - magnetite content
Downhole logging data

BB14002
Downhole logging data

BB14004

MAG

PEG
Downhole logging data

BB14004
Downhole logging data

BB14004
Downhole logging data

BB14005
Downhole logging data

BB14005

Graphs showing various parameters such as natural gamma, magnetic susceptibility, magnetite content, resistivity, fluid temperature, fluid conductivity, P-wave velocity, S-wave velocity, RQD, and far receiver data. Reflection series and synthetic seismogram data are also presented.
- Sonic waveform and RQD analysis:
  - poor RQD and decreased amplitude zones correlate (washed-up amplitude in the waveform logs)
  - There is potential to extract indirect rock quality information from sonic logging

- Next step: extract amplitude information from all three receivers (near, mid, far) and calculate the attenuation factor
- **Sonic waveform and RQD analysis:**
  - Poor RQD and decreased amplitude zones correlate (washed-up amplitude in the waveform logs)
  - There is potential to extract indirect rock quality information from sonic logging
- **Next step:** extract amplitude information from all three receivers (near, mid, far) and calculate the attenuation factor
Downhole logging data

BB14008
Downhole logging data

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Downhole logging data

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[Graphs showing various logging data parameters such as natural gamma, magnetic susceptibility, magnetite content, resistivity-long, fluid temperature, fluid conductivity, P-wave velocity, S-wave velocity, RQD, far receiver, and density. The graphs are color-coded with labels for different materials such as MAG, FEO, JASP, HEM, GRA, PEG, BMV, SAR, and SARH.]
Downhole log

BB14008
Results

1) Physical properties and expected seismic response

- **Observations**
  - Magnetite and hematite show a significantly higher contrast compared to the other rock types, but primarily due to density.
  - Velocities overlap a wide range over all rock types.
2) Physical properties (from the mineralized zone)

- **Hematite vs magnetite**
  - Far less samples of hematite mineralization but their paramagnetic character is illustrated
  - Most mineralized rocks show high conductivity but not all
  - Mineralized rocks show lowest gamma radiation
3) Physical properties (all depths)

- **Observations**
  - Granite and pegmatite intrusions show highest gamma radiation
  - Magnetic susceptibility increases with density (some pegmatite shows increased mag. susceptibility)
  - Most mineralized rocks show high conductivity but not all (depending on magnetite content primarily)
  - Density controls the response of the mineralized zone rather than velocity
Surface measurements
Seismic reflection profile

- **Pilot seismic reflection profile (September 2015)**
  - Uppsala University broadband seismic landstreamer (200 sensors) and wireless sensors (52 sensors) connected to 10 Hz geophones
  - 4 m shot spacing, Bobcat mounted drop hammer as source (also explosives)
  - Total length: 3km (only part of it shown here)
Results

- Ore body model extending down to 700 m
- The 6 measured boreholes intersect the ore body at depths with increased density
- Logs show increased density and a strong response in the synthetic seismograms at the ore body zone
- Matched with a reflection event in the preliminary seismic section
Overview so far

- Seismic data shows a strong response from the ore body!
According to the density and downhole velocity measurements, a strong seismic response can be expected from the mineralized zone (confirmed by the test seismic reflection survey).

A good correlation was observed between RQD and amplitude response in the sonic logs.

Full-waveform sonic data could be used for rock quality estimations (very important for mine planning).

Sonic data can be used for studying the amplitude attenuation in the 3 receivers and ultimately within the mineralized zone.
Thank you!

Old ironworks in Blötberget area