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Petrophysical, mineralogical, and geochemical investigations of a Li-Sn-W deposit – A contribution to develop a borehole probe for quantitative element determination in ores of natural deposits

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Introduction

- Many resources needed for key technologies originate from natural deposits that have to be explored and evaluated with regard to economic exploitation.

- Interest in exploration and exploitation of ore deposits has increased worldwide over the last years due to increasing prices of mineral commodities.

- EU critical raw materials 2014: Cr, Mg, Nb, W, REE, …
- DERA added Ta, Mo, V, and Sn.
- Costs of Li ores increased by 2-7 % since 2010 (BGR, 2015).

⇒ Efficient and universally applicable exploration technique to explore resources of low concentrations in situ.

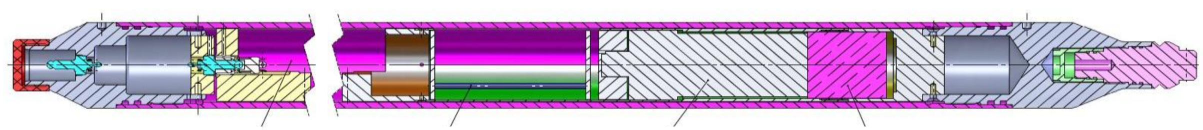
⇒ Use in low to medium-diameter exploration boreholes or during exploitation.

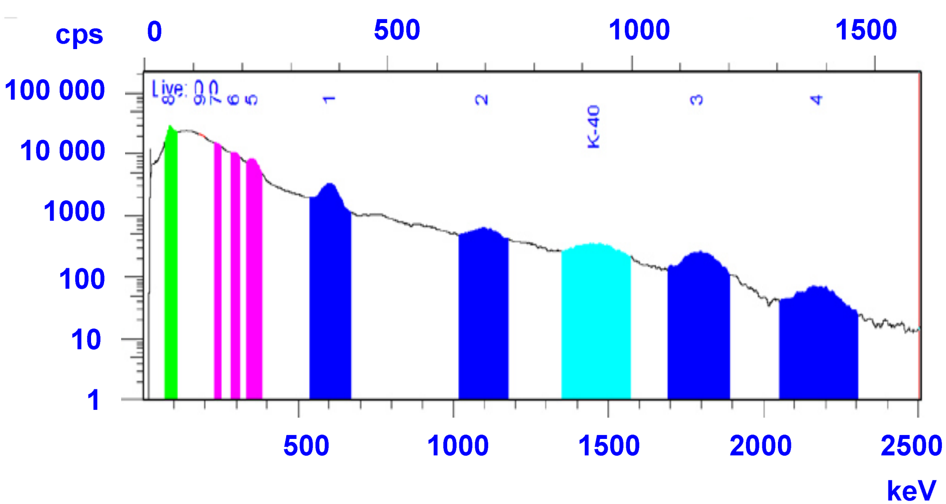
A novel borehole probe

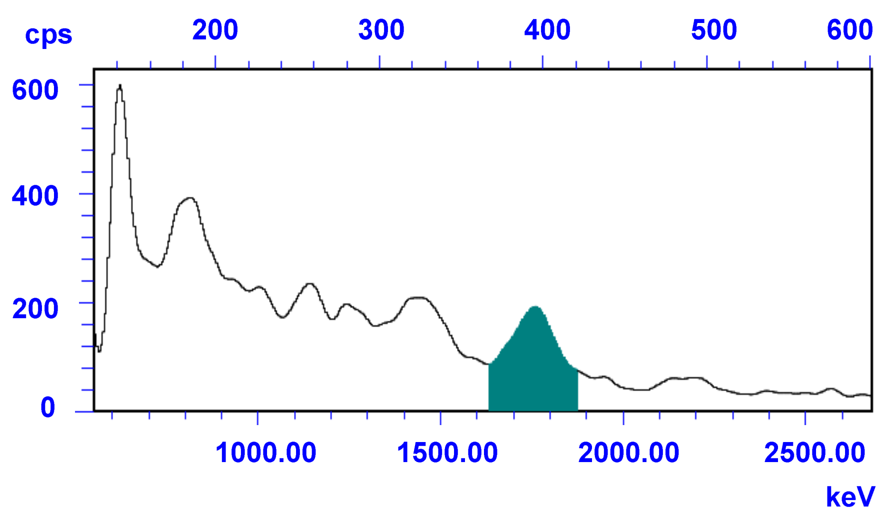
Multiactivation analysis

Element-specific detection and quantitative determination of element concentration based on:

- Gamma spectroscopy (natural gamma)
- Neutron activation analysis (Cf-252 source)
- Neutron-gamma spectroscopy
- Magnetic susceptibility







A novel borehole probe

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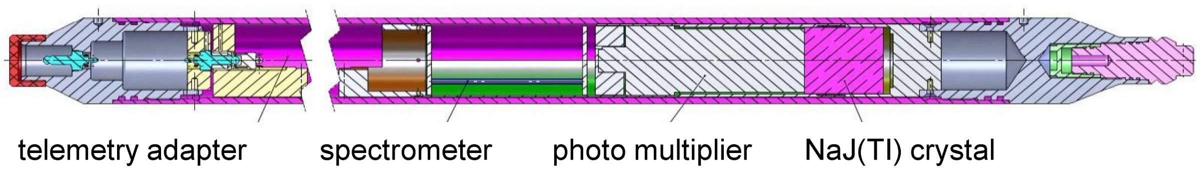
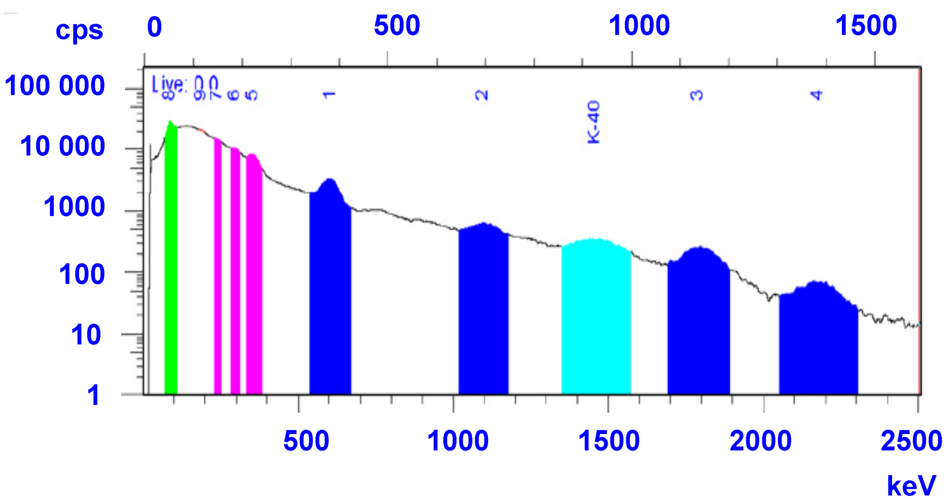
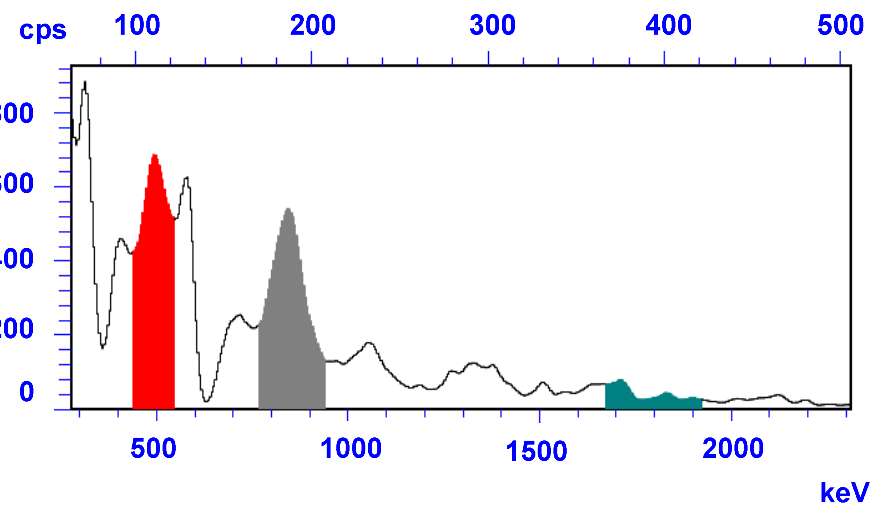
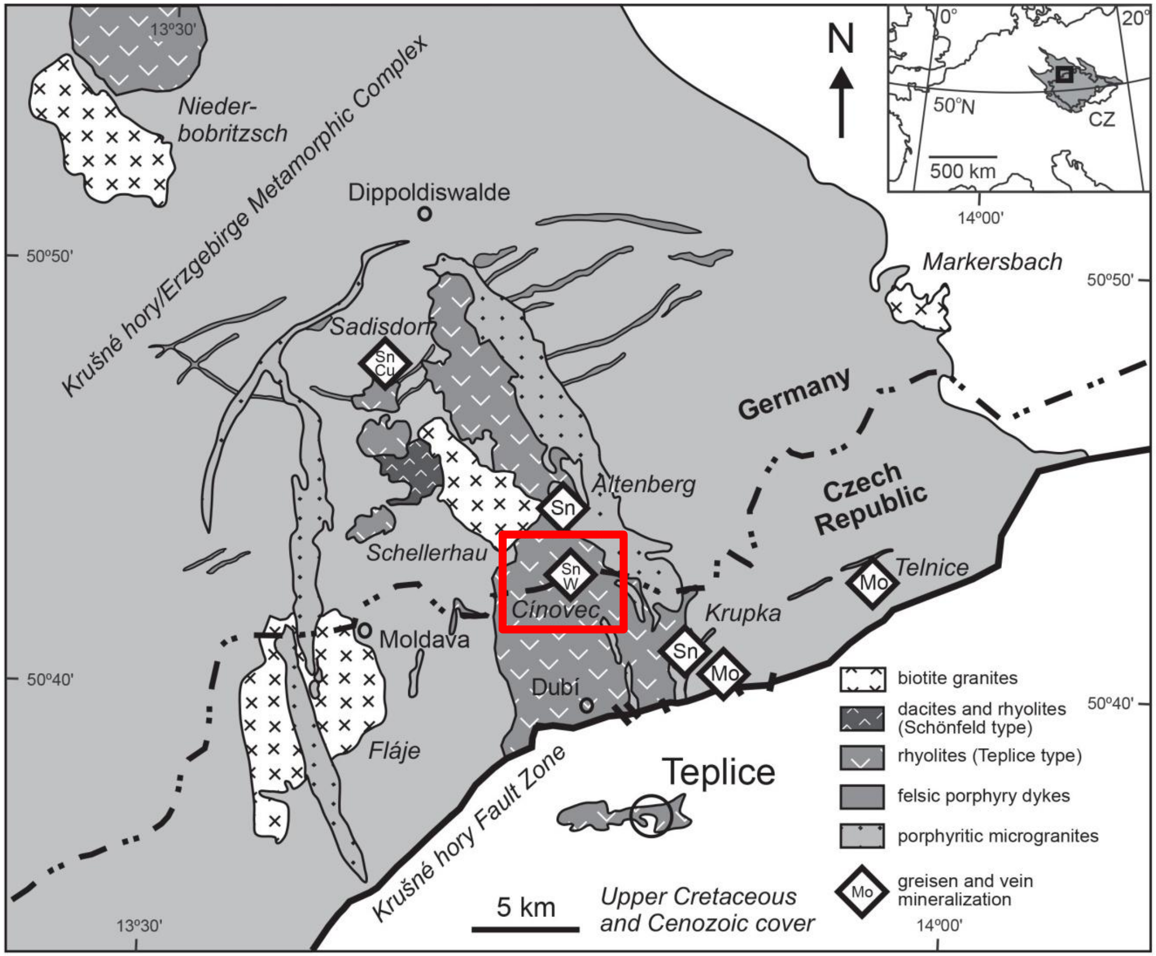






Rock material for calibration and testing

The greisen ore deposit of Zinnwald/Cínovec at the German-Czech border.

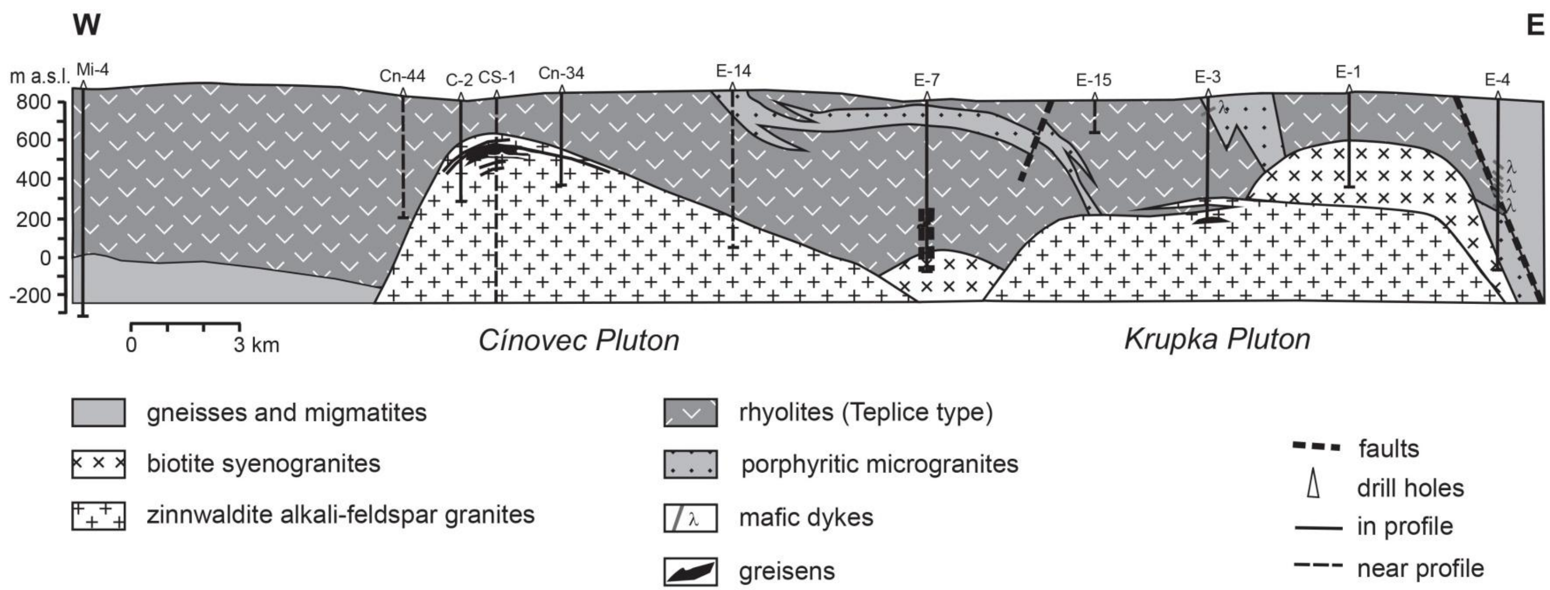


Štemprok et al., 2014

Rock material for calibration and testing

The greisen ore deposit of Zinnwald/Cínovec at the German-Czech border.

- Albite granite cupola located in rhyolite of the Teplice type.
- Postmagmatic alteration affected all granites and neighboring rocks.
- Replacement of feldspars by zinnwaldite, quartz, cassiterite, wolframite, fluorite or topaz.



Štemprok et al., 2014

Investigation methods

Petrophysical

- Sample dimensions, mass
- Bulk/Grain density
- Porosity (total, effective)
- Compressional wave velocity (axial: dry, saturated)
- Magnetic susceptibility
- Gamma spectroscopy (K, U, Th)
- Electrical resistivity (SIP)
- Magnetic resonance (NMR)

Sample geometry:

3.5 cm diameter; 5.5 cm length

Geochemical

- X-ray fluorescence
- ICP mass spectrometry (Li, Zn, W, Sn, Pb, Cu)

Mineralogical

- X-ray diffraction for identification of mineral phases
- Estimate of volumetric composition

⇒ In addition to distinct mineralogical/geochemical characteristics, mineralized rocks also possess typical ranges of petrophysical parameters distinguishing them from low- or unmineralized rocks.

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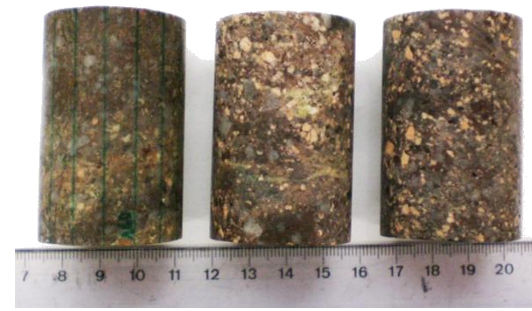
Investigated rock types

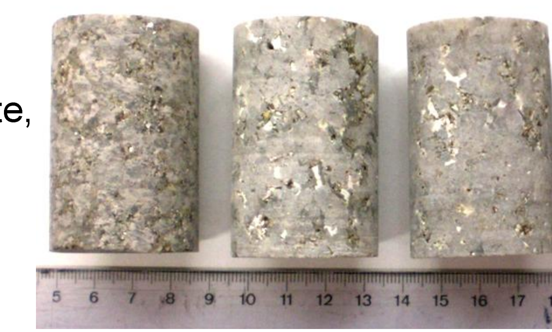


Teplice rhyolite

- Medium- to coarse-grained, porphyritic brown to violet
- Crystals: quartz, potassium feldspar (plagioclase, biotite)
- Matrix: potassium feldspar, quartz (biotite, muscovite)

Albite granite

- Medium-grained, greenish to greyish-white
- Quartz, potassium feldspar, albite and zinnwaldite
- Accessories: topaz, fluorite, …



Scale: cm

Greisen

- Grain size of original rock, grey to brown
- Quartz, zinnwaldite, muscovite, biotite, topaz, sericite, fluorite, epidote, cassiterite, wolframite, hematite, relics of original feldspars, …

Petrophysical characteristics

Grain density

Rhyolite, Albite granite

– 2,648-2,674 kg/m³ and 2,641-2,672 kg/m³

Greisen

– 2,669-2,862 kg/m³

– 2,646/2,986 kg/m³ for pure minerals

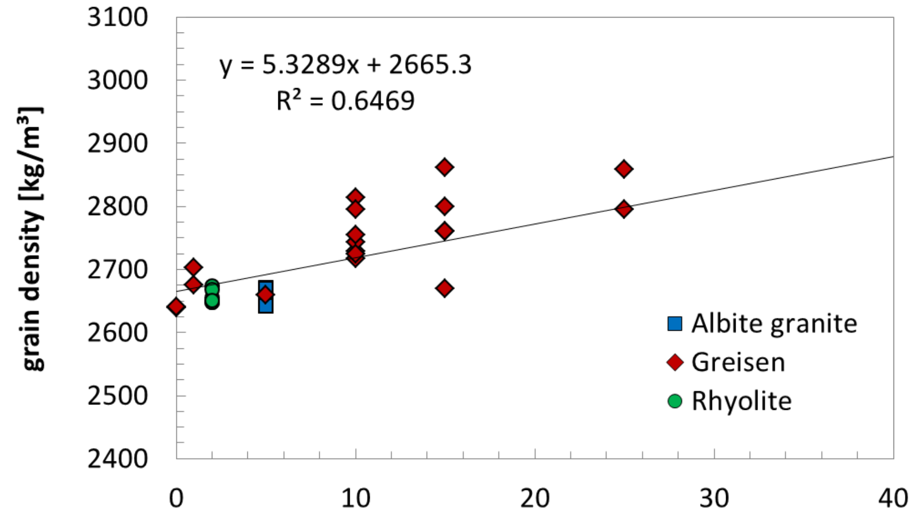
Magnetic susceptibility

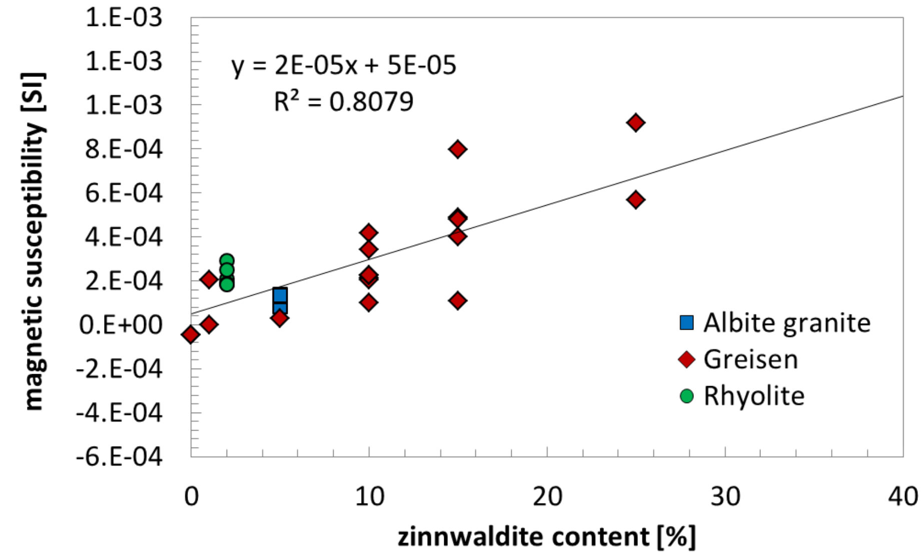
– $1.50*10^{-3}$ SI at 60% zinnwaldite content

– $2.05*10^{-4}$ SI at 95% quartz content

– $-4.70*10^{-5}$ SI at 99% quartz content

⇒ Indicators for high zinnwaldite content





Petrophysical characteristics

Gamma spectroscopy

- calculation of K, U, Th content
- based on standard material
- ranges in agreement with XRF analyses

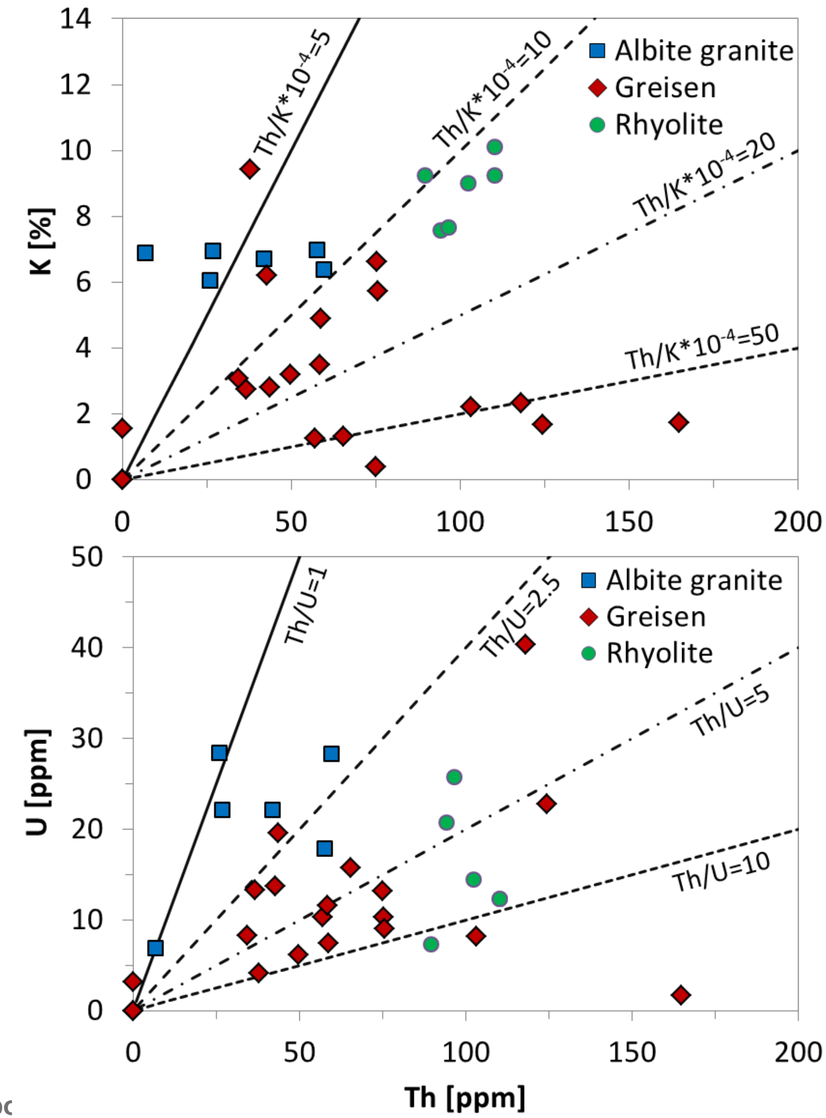
Rhyolite, Albite granite

- $Th/K*10^{-4}$ … <10-13
- Th/U … 1-12

Greisen

- $Th/K*10^{-4}$ … >10-200
- Th/U … 2-97

⇒ Indicators for high zinnwaldite content?



Petrophysical characteristics

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Electrical resistivity/SIP

Rhyolite, Albite granite
– Φ ~2.0-8.5%, ρ_0 … <1000 Ωm

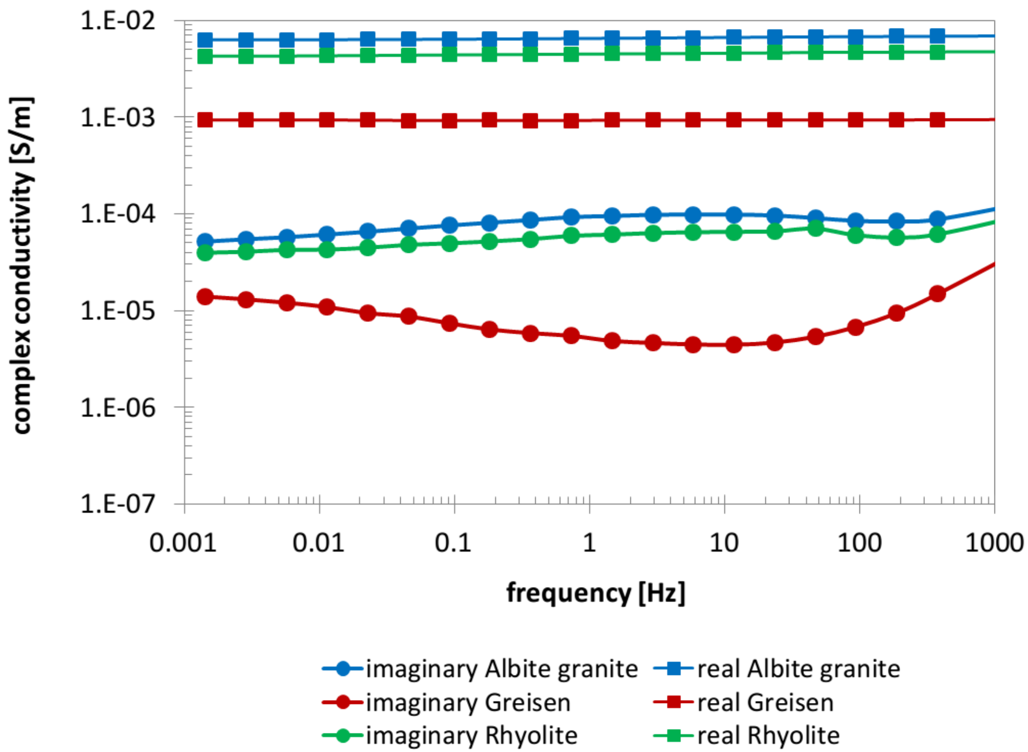
Greisen
– Φ ~1.7-5.0%, ρ_0 … >1000-7000 Ωm

Compressional wave velocity

Albite granite
– Φ ~4.0-7.0%, v_p … 2950-3860 m/s

Rhyolite
– Φ ~2.0-8.5%, v_p … 3970-5120 m/s

Greisen
– Φ ~1.7-5.0%, v_p … 1760-5250 m/s



⇒ Electrolytical + surface (+metallic?) conductivity

Geochemical characteristics

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Greisen

Characterized by

- Li … up to >5,000 ppm
- Sn … 50 to >100 ppm
- W … up to >1,000 ppm
- Rb … up to >3,000 ppm
- F … mostly >10,000 ppm

Element	Method	Range [ppm]	Mean [ppm]
As	XRF	7-65	46
F	XRF	4,820-32,555	20,210
La	XRF	11-24	17
Li	ICP-MS	162-8,500	3,045
Mn	XRF	138-7,896	2,142
Nb	XRF	28-137	63
Pb	ICP-MS	0.08-17	5
Rb	XRF	163-9,029	2,654
Sn	XRF	44-390	129
Th	XRF	20-86	44
W	ICP-MS	132-10,500	2,645
Zn	ICP-MS	11-601	191

Comparison of logging and experimental data

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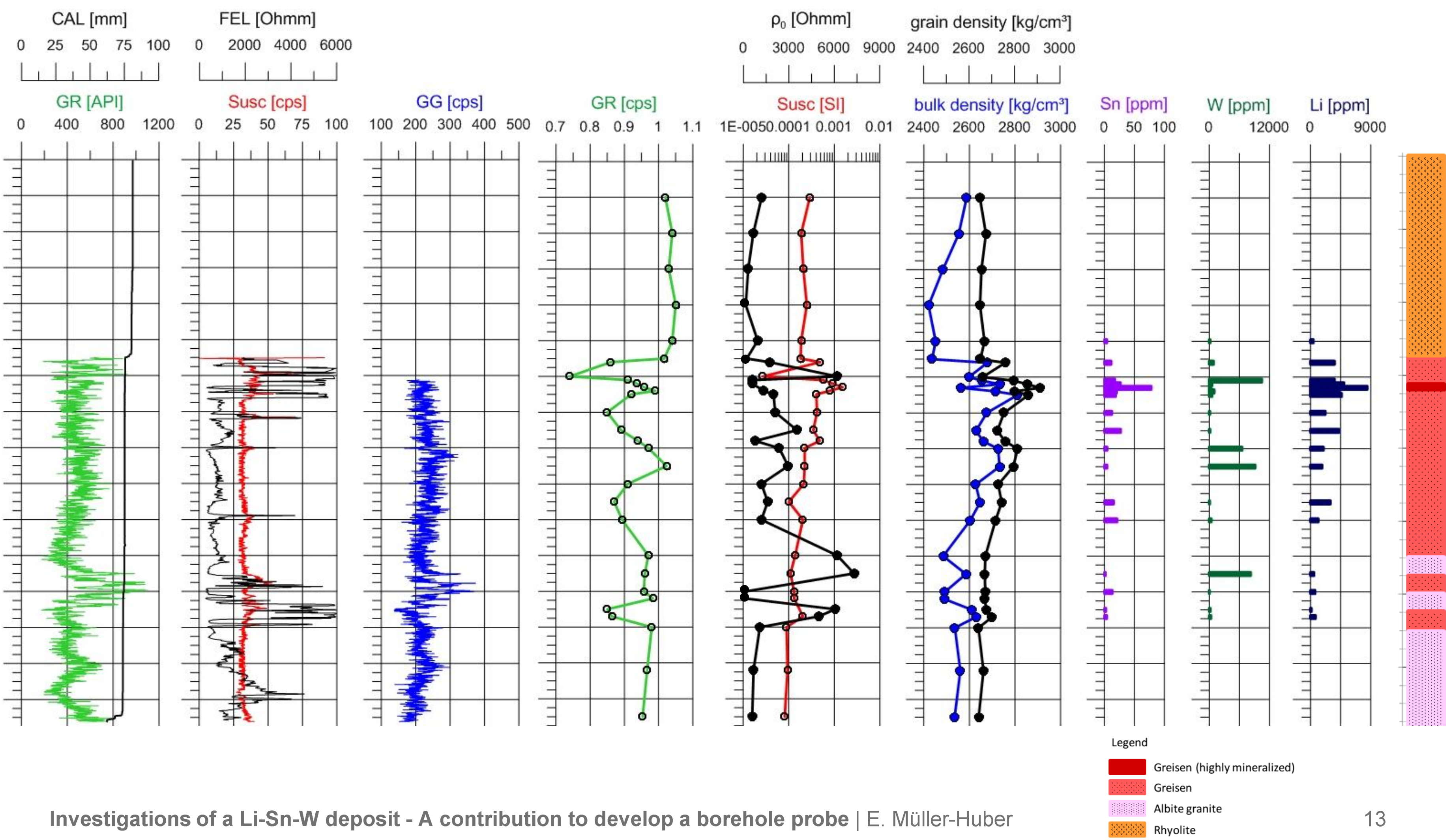

Conclusions/Outlook

The investigations confirmed that:

– Greisen, albite granite and rhyolite possess characteristic petrophysical properties (magnetic susceptibility, grain density, electrical resistivity/SIP, …) that can also be logged.
– There is good agreement between experimental laboratory data and logging data despite different measurement conditions.
– Calibration of the novel borehole probe with laboratory data is therefore possible.
– The investigated rock types are suitable for use as calibration material for the borehole probe.

Further steps will include:

– More detailed quantitative mineralogical analyses.
– Establishing correlations between petrophysical properties and mineral content for a compositional rock model based on petrophysical parameters.

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Thank you for your attention

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