Wismut's Mine Water Management and Treatment Approaches

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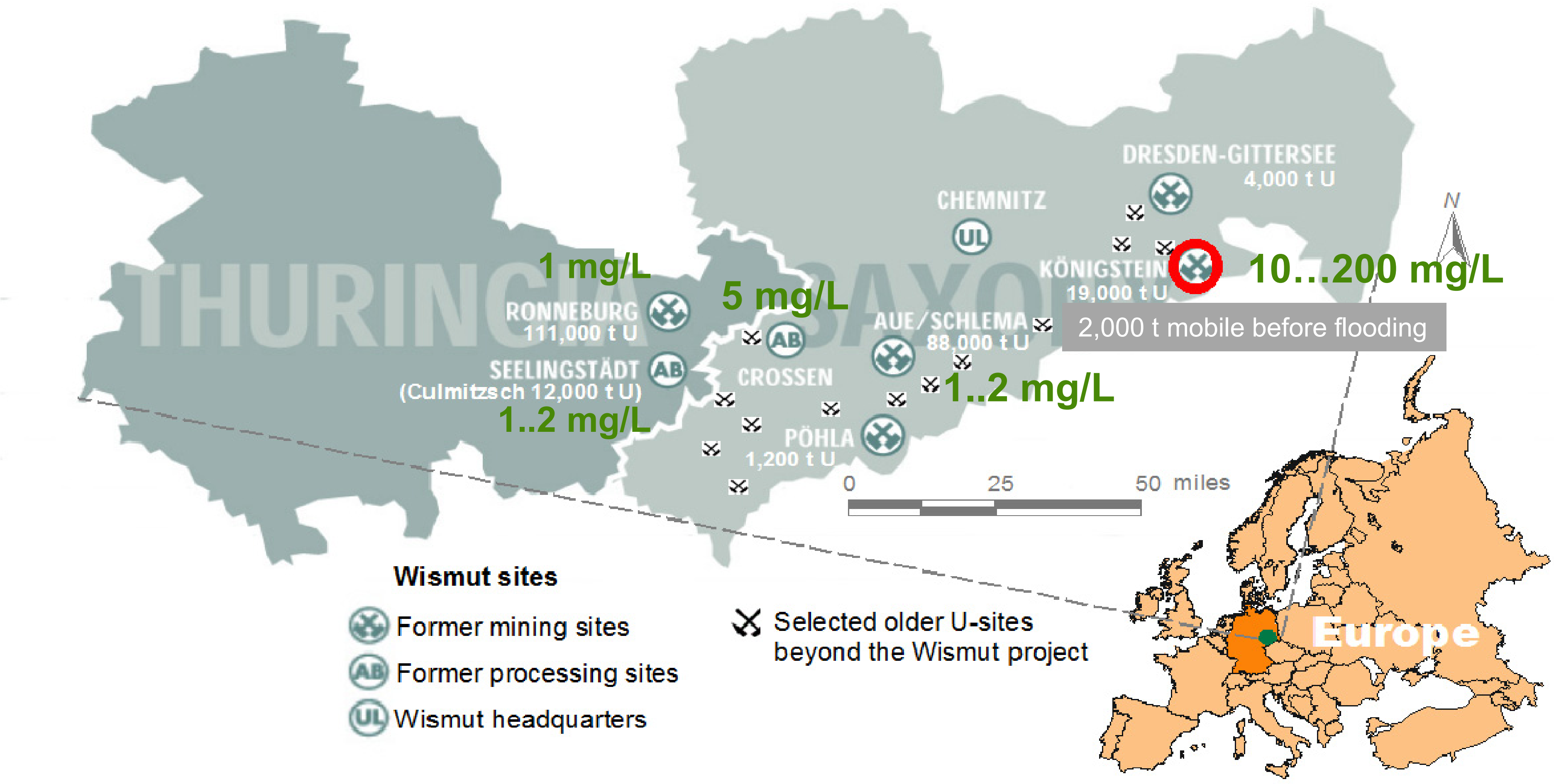
Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

Challenges and Best Practices in Metal Leaching and Acid Rock Drainage
BC MEND 2013, Vancouver, December 4 - 5, 2013

Contaminant Removal in Water Treatment Plants



total yearly Uranium removal in 2012: ~ 50 tonnes
maximum yearly Uranium removal: 200 tonnes (in 2002, Königstein site)

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Water Treatment Technology 1: Pretreatment

Ion exchange for uranium removal:

- -low pH
- -high U conc.
- -Königstein site
- -anion exchange resin
- -retention of uranylsulphato-complexes

CO_2 – stripping for TIC removal:

- -high pH / high TIC (~100 mg/L)
- -low U conc.
- -destruction of uranylcarbonato-complexes by lowering TIC (<4 mg/L)
- -HCl-addition (pH<4; ~1 kg/m^3) prior to stripping
- ~ 5 m^3 air / m^3 water

Water Treatment Technology 2: Precipitation

-airation (~ 5 m^3/m^3)
-$KMnO_4$ (~ 1 g/m^3)
-limewater (~ 0.05..0.9 kg/m^3; stepwise, pH ~ 9-10)
-$BaCl_2$ (~ 0.1 kg/m^3)
-$FeCl_3$ (~ 0.1 kg/m^3)
-flocculation aid
-HDS

- gas exchange, mixing
- oxidation of As, Fe, Mn
- precipitation of ironhydroxide sludges containing U, Ra, heavy metals

Water Treatment Technology 3: Sludge handling

Sludge separation and dewatering:
- sedimentation tanks
- sludge collectors
- decanter / chamber filter press

(30 – 50 % dry matter)

Sludge stabilization:
- cement / ash addition
- disposal in special storage sites

(total ~ 25,000 m^3 / a;
thereof U less than a thousandth)

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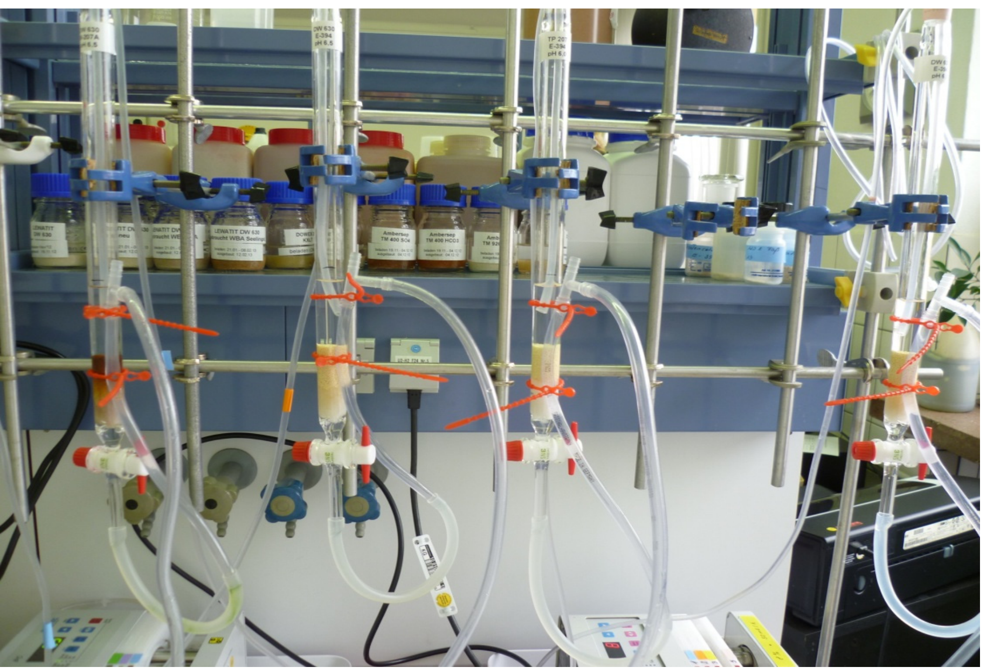
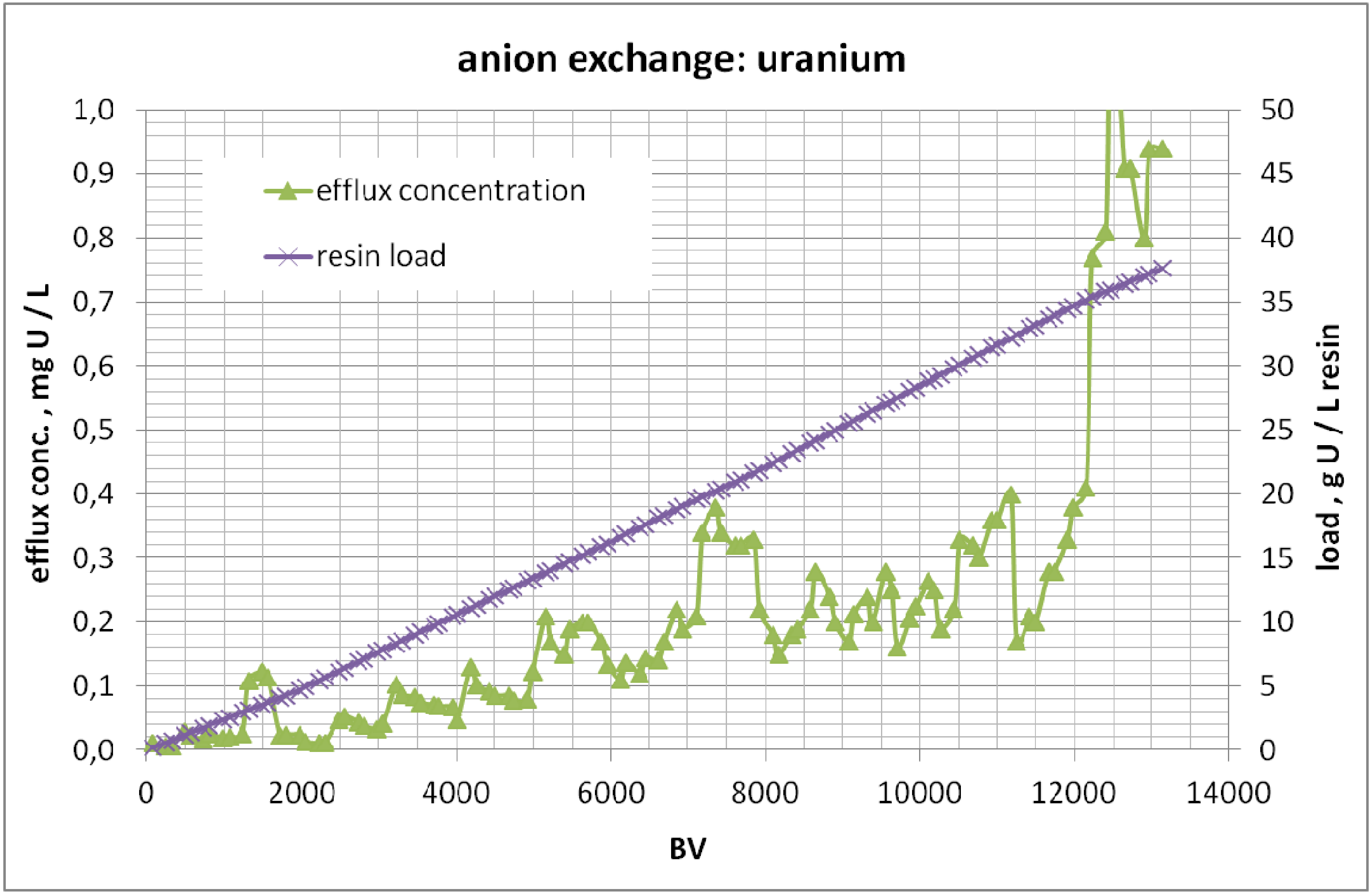
Water Treatment Optimization: Ion exchange

- Single contaminant (uranium) removal
- Seepage water from TMF:
  pH=7,5 TIC ~ 10 mg/L
  U ~ 3 mg/L Ca, Mg ~ 250 mg/L
  SO_4 ~ 3.5 g/L

- Retention of $UO_2(CO_3)_2^{2-}$, $(UO_2)_2CO_3OH_3^-$, $UO_2(CO_3)_3^{4-}$
- Anion exchange resin
- pH-adjustment
- Prevention of CO_2 - degassing



Water Treatment Technology: Ion exchange



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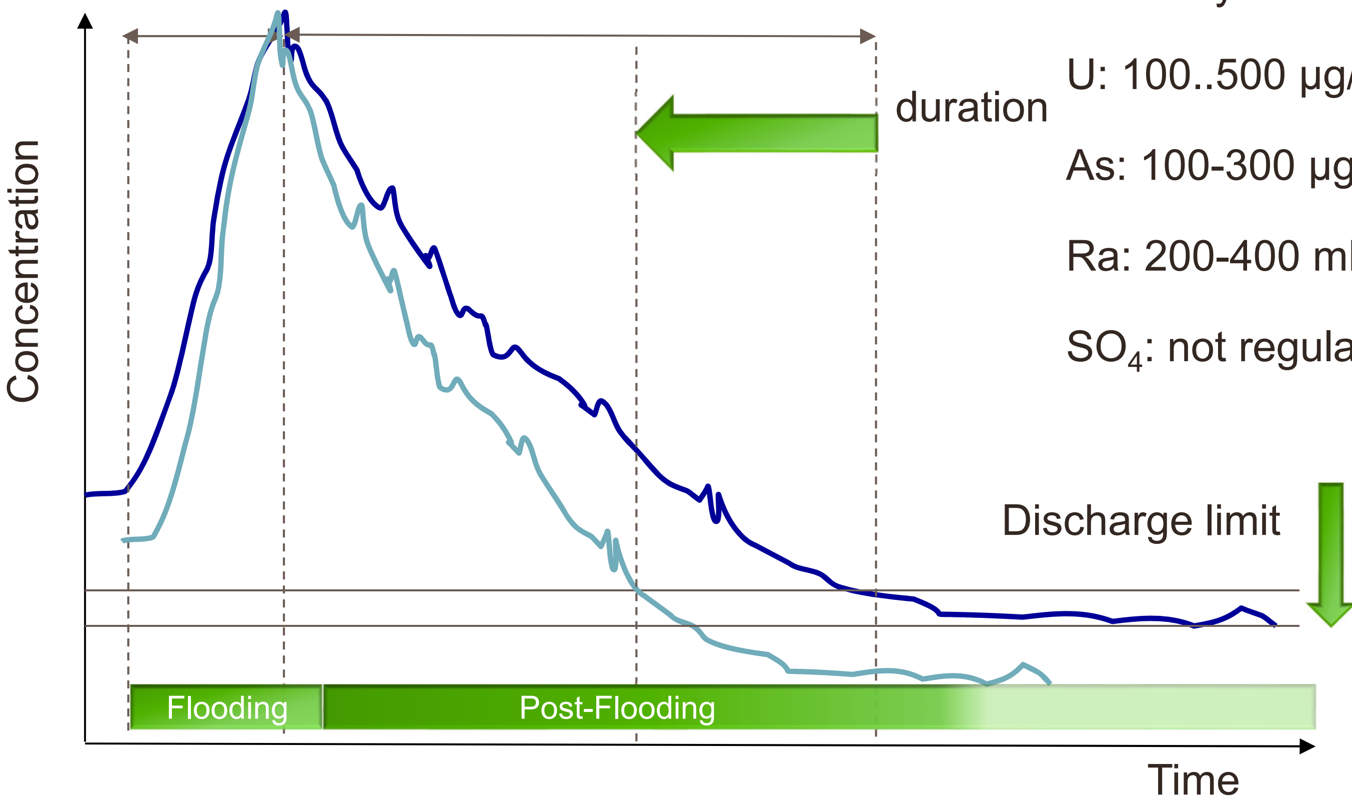
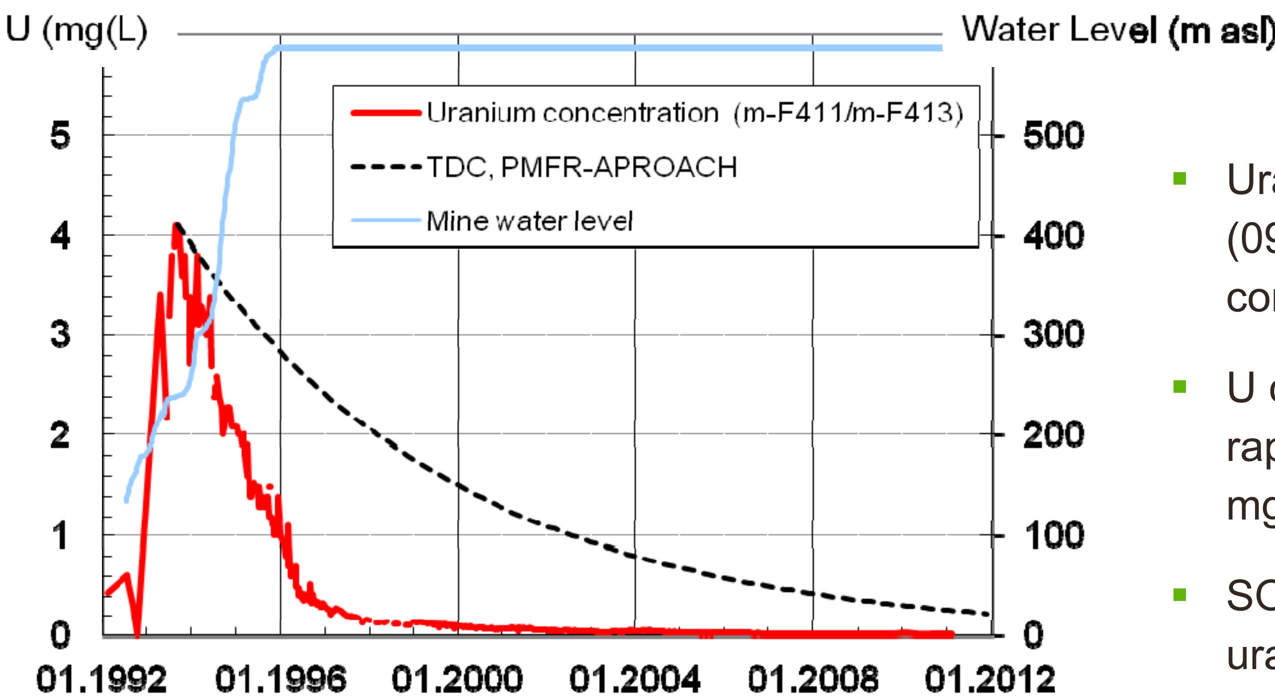
Water Treatment necessity



	Discharge limits Today	Discharge limits Future	mine water
U:	100..500 µg/L	20 µg/L	1-10 mg/L
As:	100-300 µg/L		<0.1-2 mg/L
Ra:	200-400 mBq/L		<0.1-6 Bq/L
SO_4:	not regulated	500 mg/L	0.5-4 g/L

Observed In-Situ immobilization of Uranium: Pöhla



- Uranium peak 4 mg/l (09/1993), steady state conditions since 1995
- U calc >> U measured, rapid decrease < 0.02 mg/L
- SO_4 decrease before uranium decrease
- pe 0.17 – 1.7
- Microbial induced reductive U precipitation

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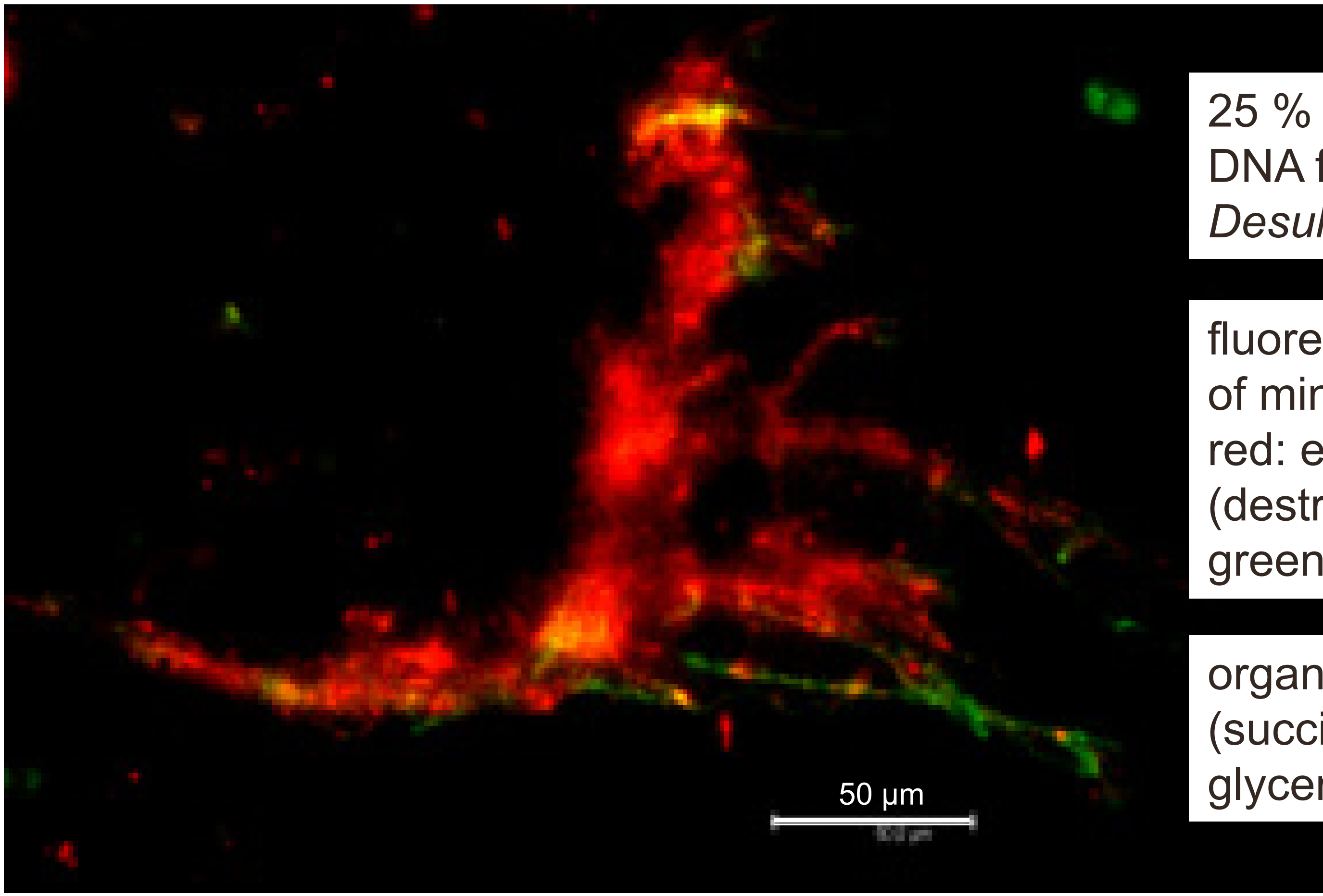
In-Situ immobilization of Uranium: Pöhla site



25 % of identified DNA from mine water: *Desulfobacterium sp.*

fluorescence microscopy of mine water foam:
red: extracellular DNA (destructed cell walls)
green: proteins (cell walls)

organic acids in mine water (succinic, malic, benzoic, glyceric acid)

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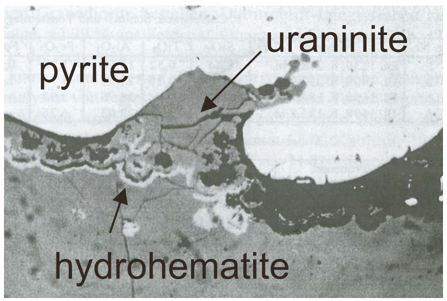
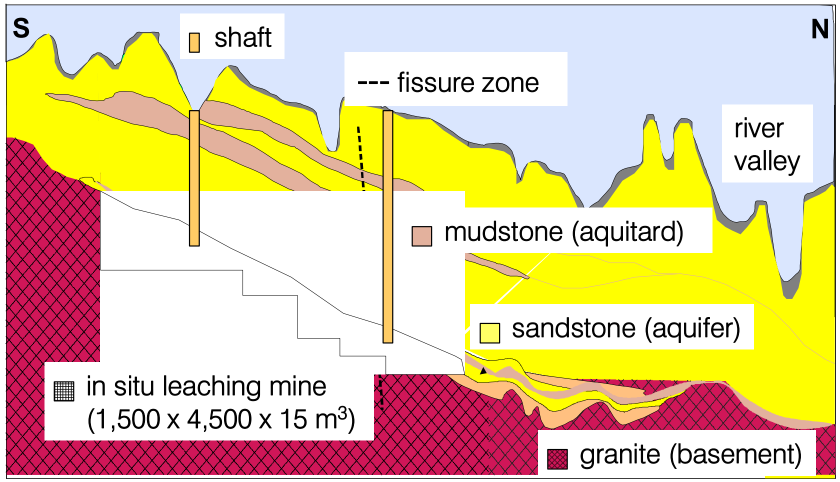
Activation of In-Situ immobilization: Königstein site

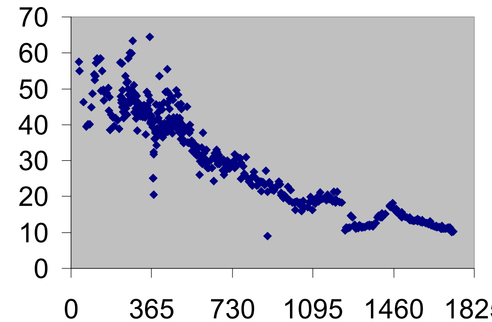
sedimentary uranium deposit



acidic in-situ leaching



acid mine drainage

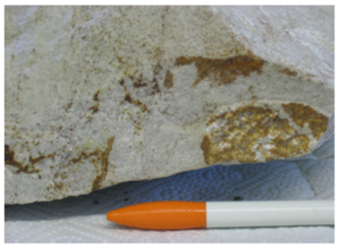


[U] ~ 5..50 mg/L
pH<3, pe~10
Zn, Pb, Cd, As

Activation of secondary ore formation for pollutant immobilization within the flooded mine:

- establishment of a reacitve, reducing zone for sulphide formation
- stimulation of authochthonous sulphate reducing bacteria
- precipitation of sulphidic minerals and uraninite
- encapsulation of reduced mineral phases by ironoxyhydroxide coatings

SRB's in former acidic ISL mine Königstein

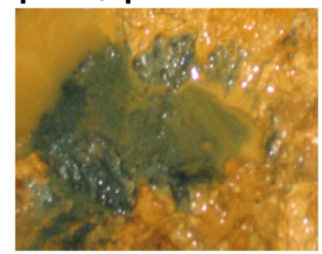


sandstone

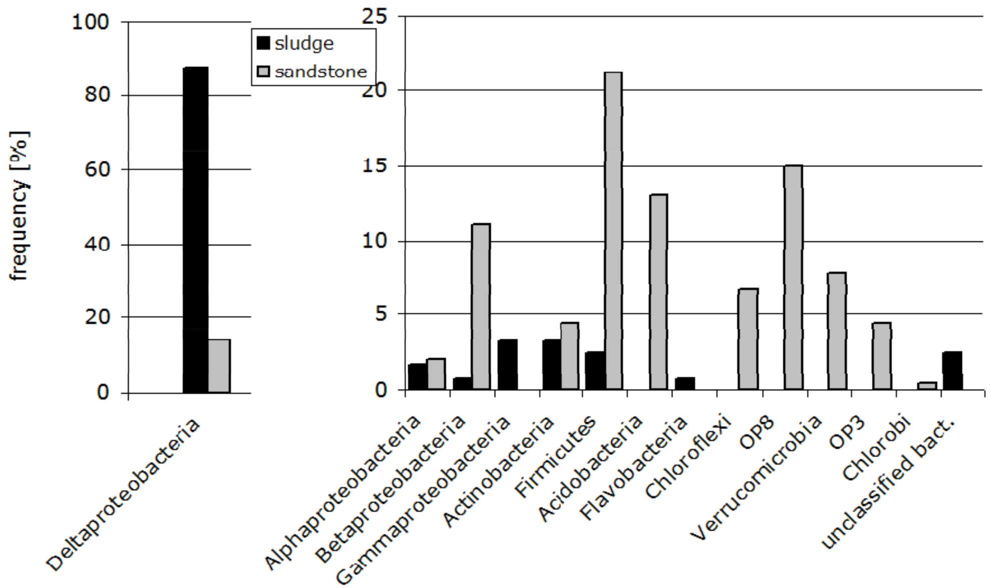
interbedded strata (organic rich)

pH=2.6, pe=14.5

pH=6, pe=4



Fe-hydroxide sludges



oxidized sludges:
Ferribacter polymyxa
Acidothiobacillus ferrioxidans

reduced sludges:
Desulfovibrio sp.
(~70% of Deltaproteobacteria)

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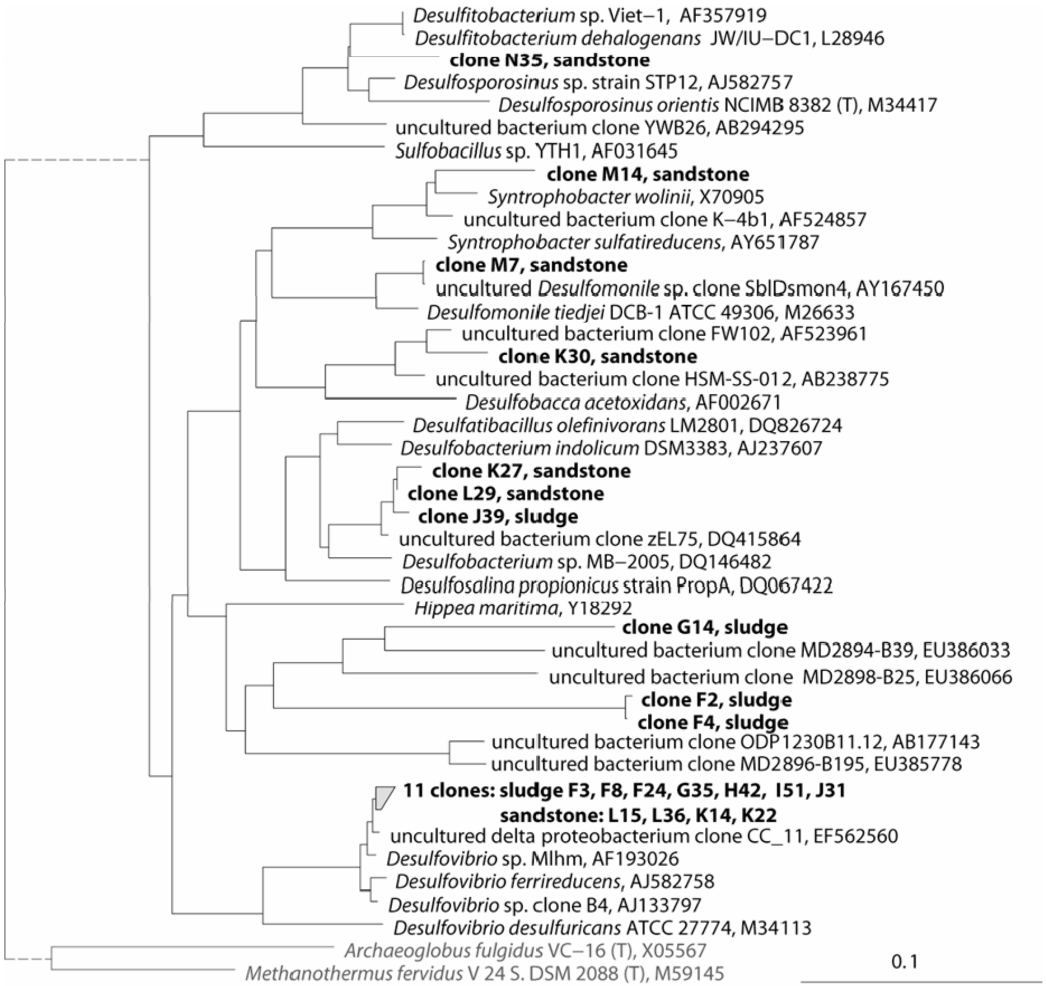
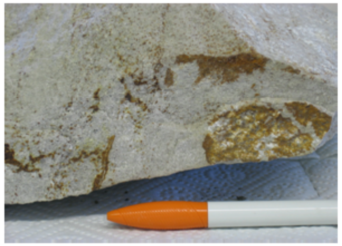
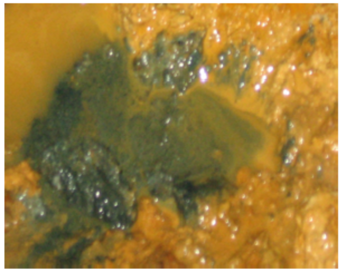
Deltaproteobacteria Königstein







cultivation autotrophes
- medium 63 DSMZ
- H_2 / CO_2
- sulphide formation
- 0.2 mg/L $S^{2-}_{aqu.}$
- 0.008 wt% S^{2-}_{solid}

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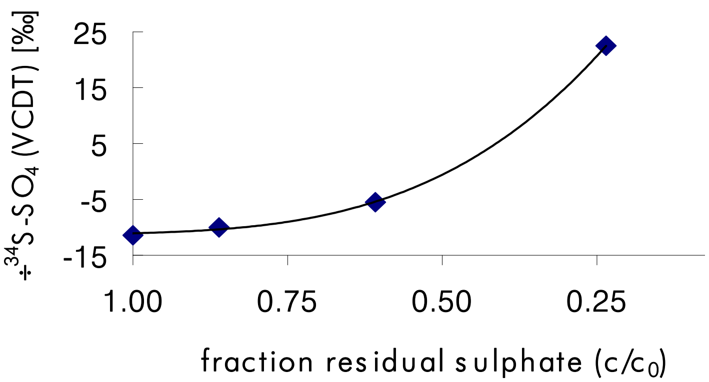
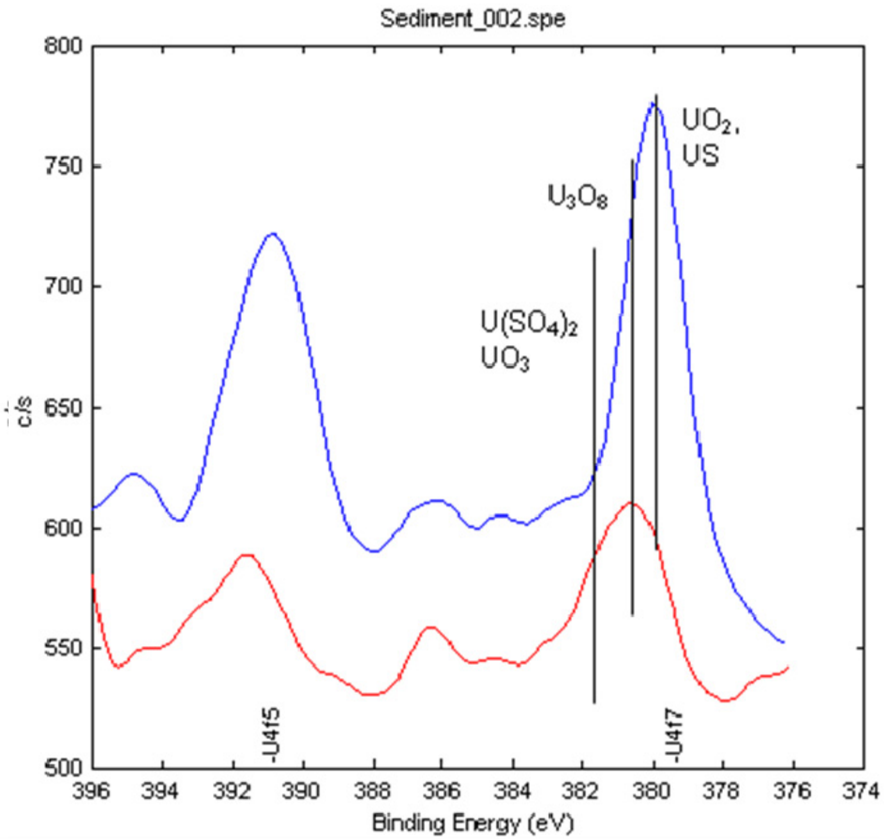
Batchexperiments SRB stimulation

•cultured sulphate reducers from lignite mine dump site

•H_2 from anaerobic cast iron oxidation
•milled rock and sludge material
•mine water, pH=3..6

^{34}S enrichment





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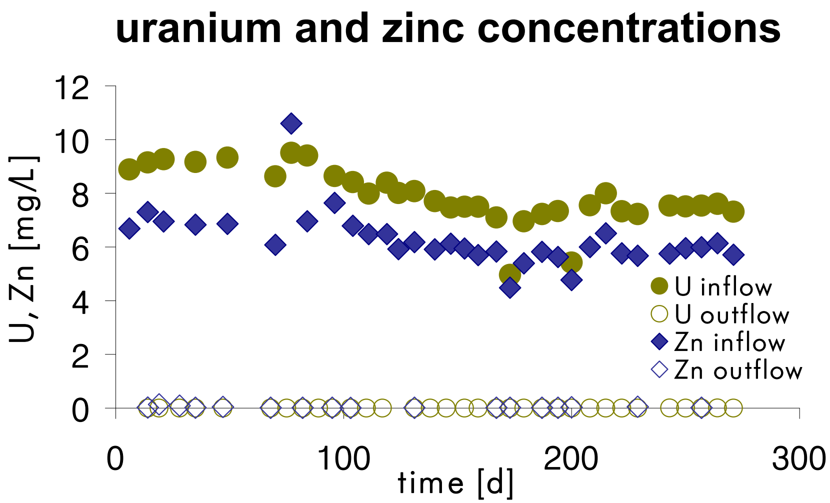
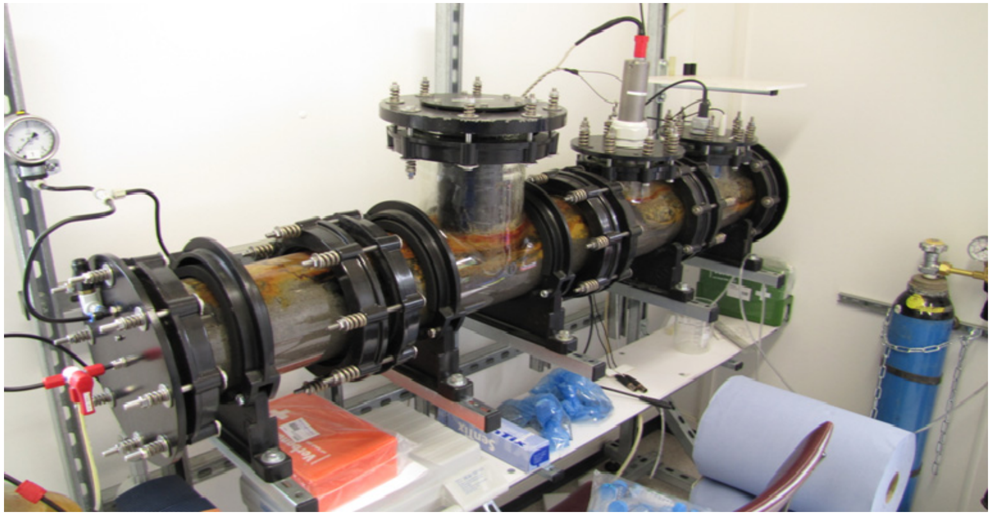
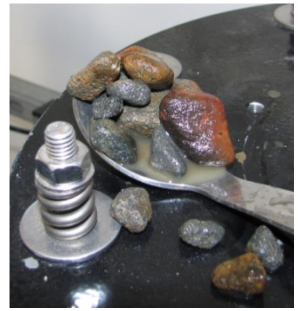
Bench scale experiments SRB stimulation

- 25 kg sandstone
- 2.5 kg foam glass (floating Fe^0)
- 4.5 kg iron-hydroxide sludge
- 8 L mine water
- Q=0.5 L/d
- 1 year flow through
- 1 year stand-by
- regularly gas and water monitoring





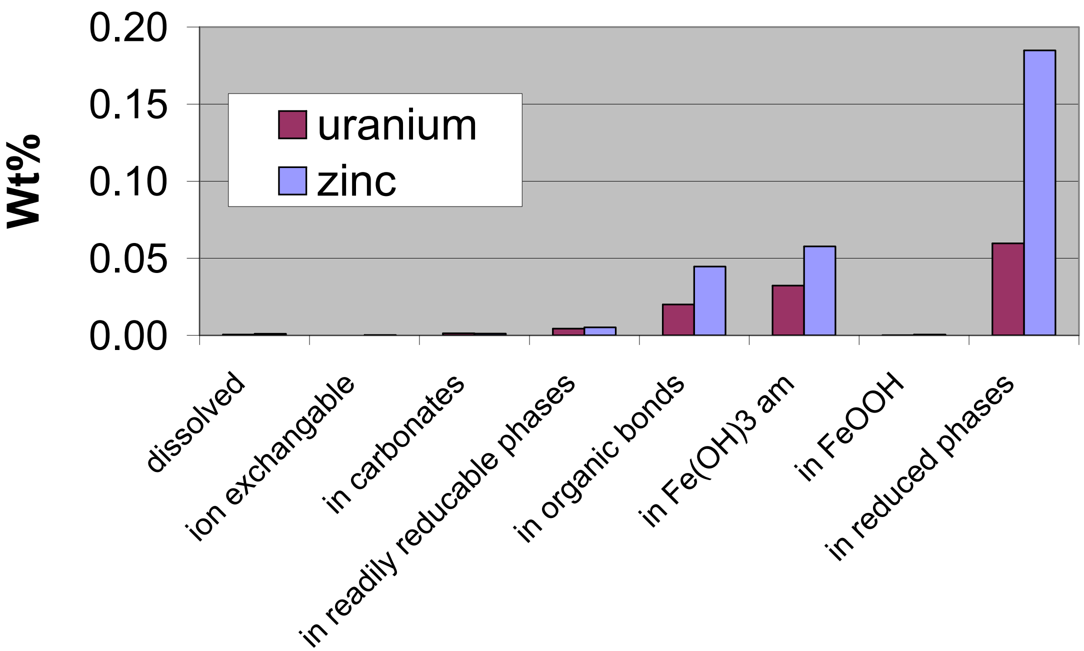
Bench scale experiments SRB stimulation

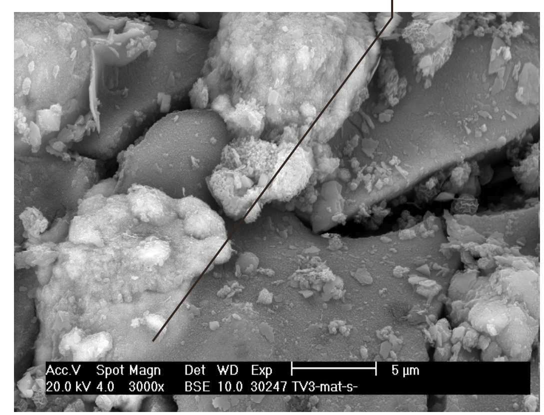


Total solid content:

-3.0 wt% U
-1.5 wt% As
-1.0 wt% Zn
-0.5 wt% Cd
-0.1 wt% Ni

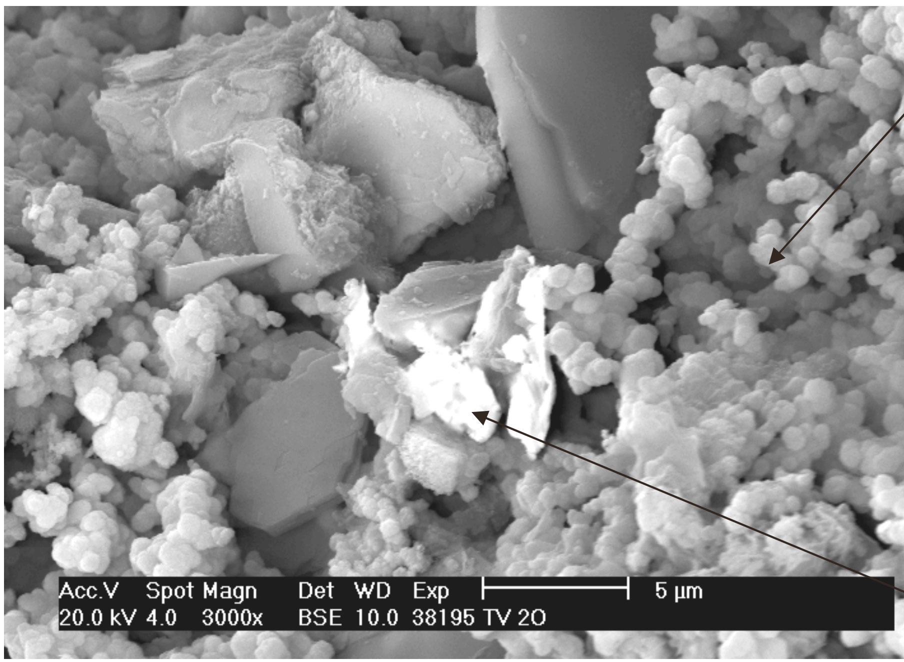
U and Zn bonds in mineral coatings

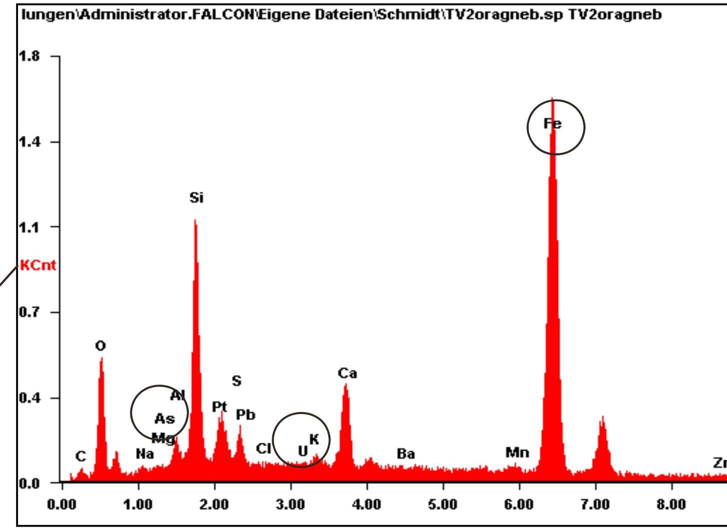


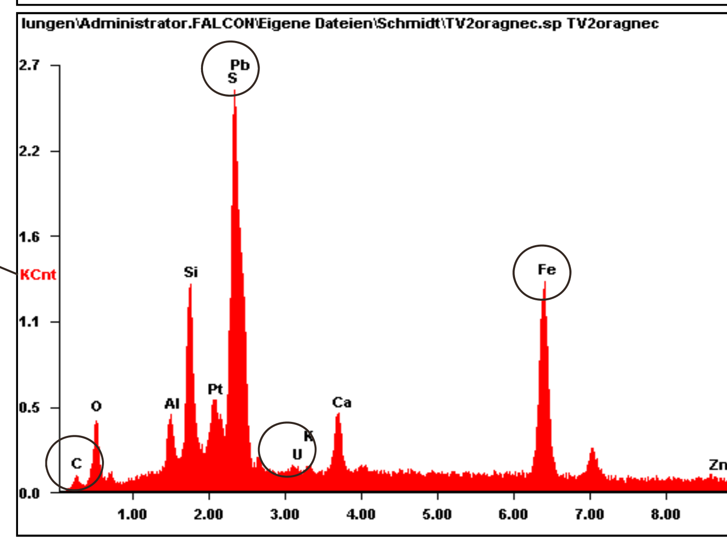


Bench scale experiments SRB stimulation

U, As, Fe, O





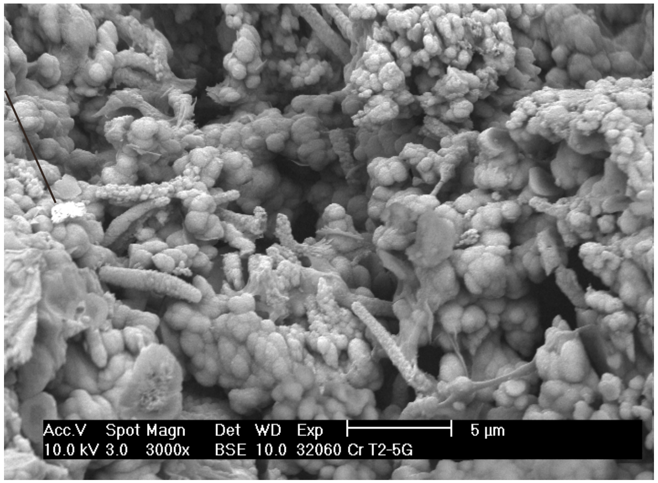


U, Pb, S, Fe, C

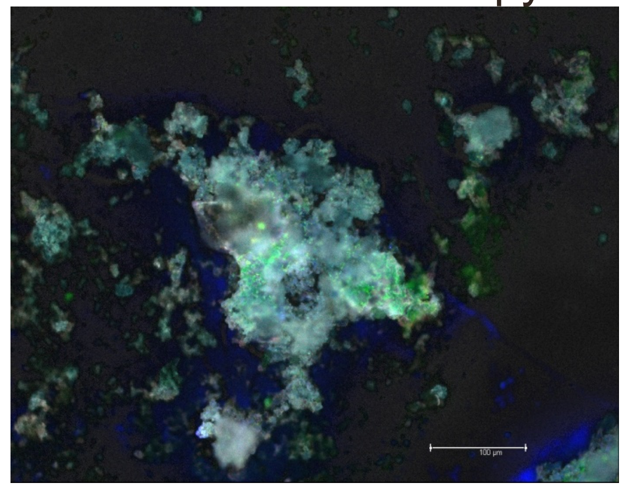
Bench scale experiments SRB stimulation

REM-EDX

biofilm, uranium



fluorescence microscopy

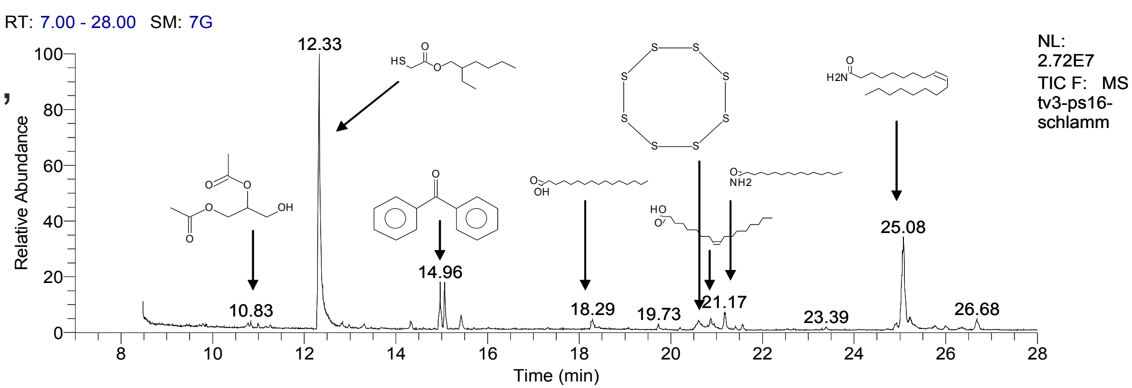


lipids (cyan)
proteins (green)

polysaccharides (blue)

GC-MS-Screening

elemental S,
organic S,
fatty acids



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Summary

- 7 WTP clean up ~ 20 million m^3 / a
- U removal ~ 50 tonnes / a, simultaneous removal of Ra, As, heavy metals
- Water treatment technology: modified / HDS lime precipitation
- Ion exchange at Königstein site for U recovery (~ 30 tonnes / a) prior to precipitation
- Ion exchange for single contaminant removal from TMF drainage
- Ongoing work on microbial induced mineral formation for in-situ immobilization

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