Advanced technologies for sustainable exploitation of uranium-bearing mineral resources, SEXUM

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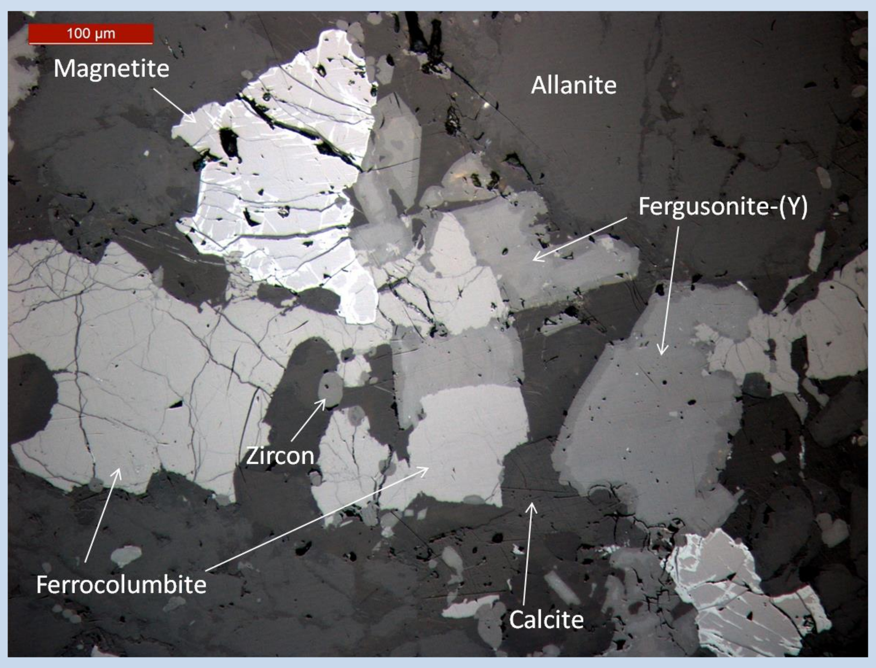
The global exploration and mining industry currently faces the challenges of discovering and extracting metals amid increasing expectations for community acceptance and compliance with principles of ecologically sustainable development. Particularly, the presence of uranium at low concentrations in polymetallic ore deposits is a challenge. This project is designed to demonstrate and integrate several novel techniques, including the use of bisphosphonates and bioelectrochemial processes for selective recovery and removal of uranium, either for secure sequestration and environmental remediation or for subsequent refinement as an additional metal commodity. The project is also intended to demonstrate the potential for recovery of a number of other critical metals, facilitating the beneficiation of low-grade or otherwise intractable mineral resources.

GTK: Deportment of uranium and beneficiation of polymetallic ore deposits

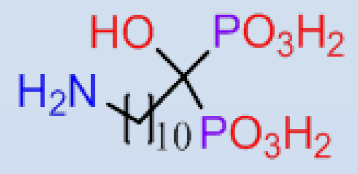
Several mine development and exploration projects in Finland are focused on polymetallic U-bearing mineral resources, the most important being the Talvivaara nickel mine in Sotkamo, the Juomasuo and Hangaslampi gold deposits in the Kuusamo region, the Sokli phosphorus mine project in eastern Lapland, the Katajakangas Nb-REE deposit in Otanmäki area, and the Rompas gold-uranium prospect in Ylitornio. Many of these mineral resources have complex, polymetallic assemblages, in which gold, base metals, rare earth elements, niobium or phosphates are associated with uranium.

Therefore, the SEXUM project includes evaluation of these resources from a mineralogical viewpoint, in order to understand the deportment of uranium during mining and mineral processing. The development of beneficiation methods will focus on how to control uranium during all processing stages in order to exploit the valuable metals in the ore in an economical and environmentally sustainable way. The study will also include a comprehensive environmental characterization of the waste materials created in the process to evaluate their chemical stability.

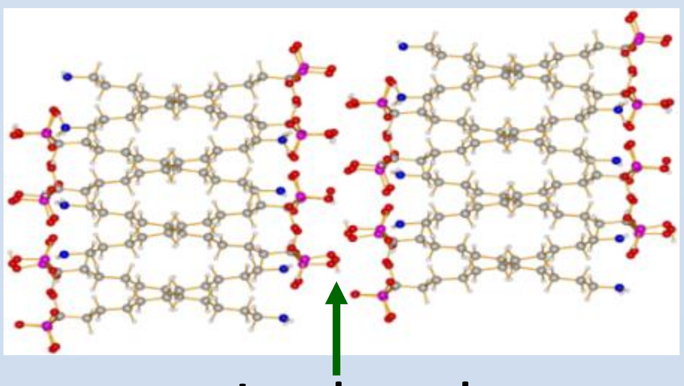
The main ore minerals of the Katajakangas Nb-REE ore under reflected light (drill hole Katajakangas 12, depth: 31.80 m).



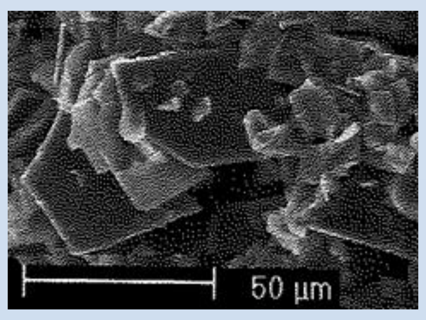
UEF (Prof. Vepsäläinen group): Novel possibilities for uranium removal include the recently discovered bisphosphorus (BP) material called N10O and nanoporous silicon carbide (PSiC) frameworks tailored with BPs (PSiC-BP). The main advantages with N10O and PSiC-BP are their ability to be re-used and the lack of precipitation step in the process, as the metal cations are absorbed directly into the ion channels located within these solid materials. Moreover, the collection efficiency is dependent on the speciation of the metal cation, pH and temperature, enabling selective cation removal.



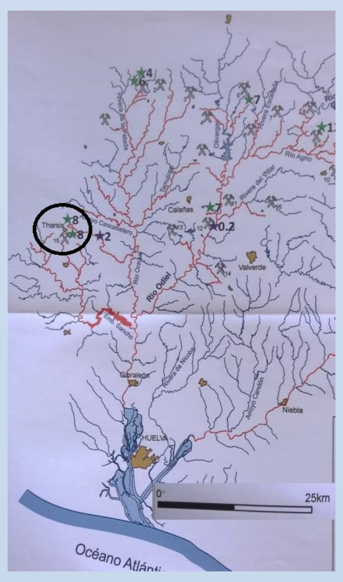
N10O

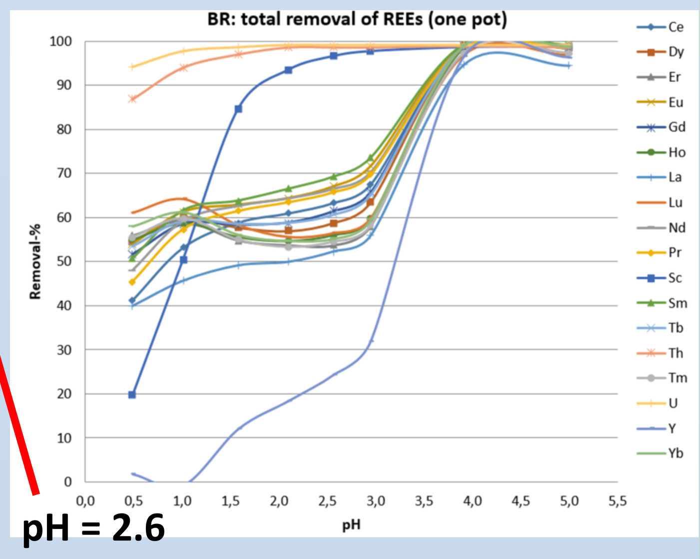


Ion channel



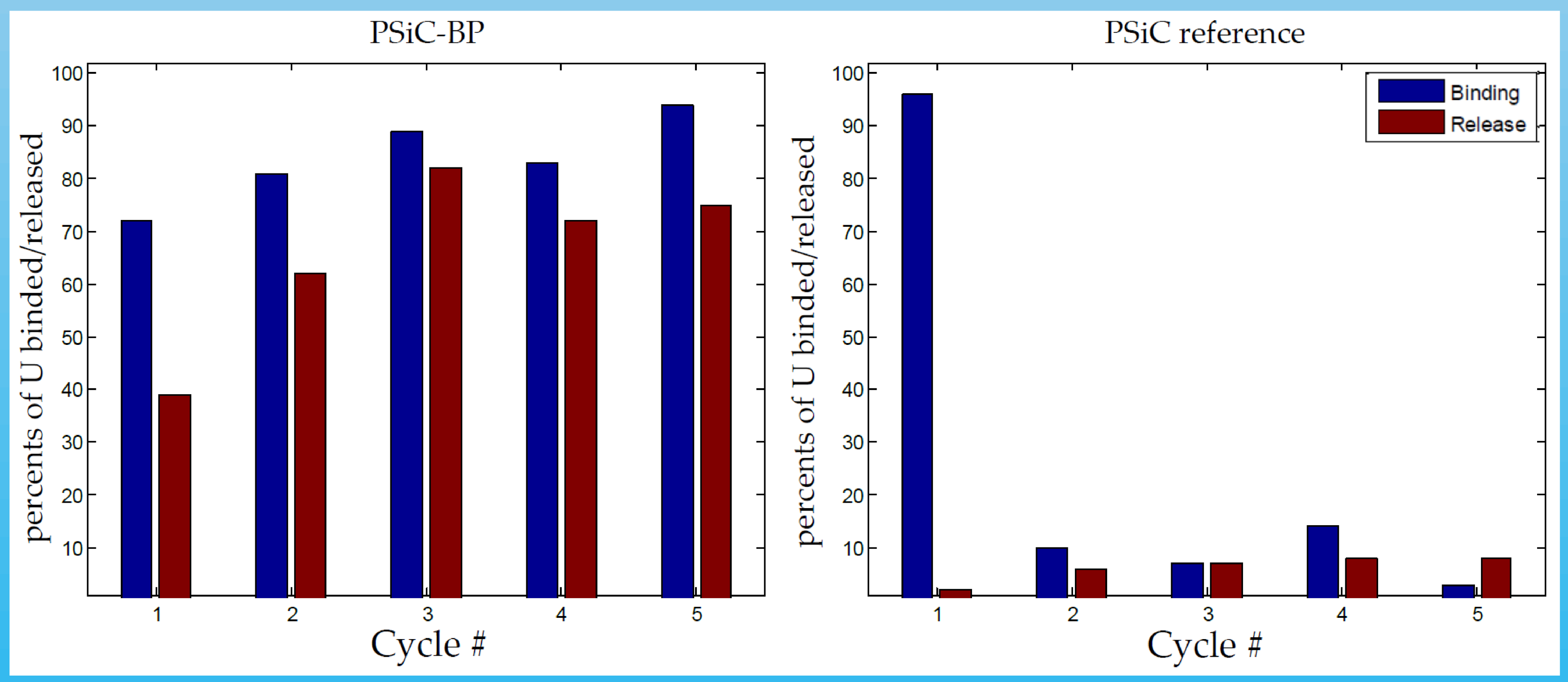
Some preliminary results with N10O are already obtained for samples collected from Spain, Huelva area.





pH = 2.6

UEF (Prof. Lehto group): The adsorption properties of the solid bisphosphonates (BPs) can be enhanced by conjugating BPs with terminal alkene (R=CH2) on the surface of a nanoporous silicon carbide (PSiC) framework. The particle size and porous structure of silicon carbide is tuned to optimize the metal adsorption process regarding the rate and quantity of the adsorption. The conjugation process is developed to maximize the surface coverage of bisphosphonates on the carbide surface. Preliminary results have shown that nanoporous PSiC-BP can indeed efficiently adsorb U(VI) from very dilute (ppm level concentrations) solutions in a flow through system and subsequently release them into acidic solution. The hybrid material is able to be re-used several tens of times without any loss in the adsorption/desorption performance.

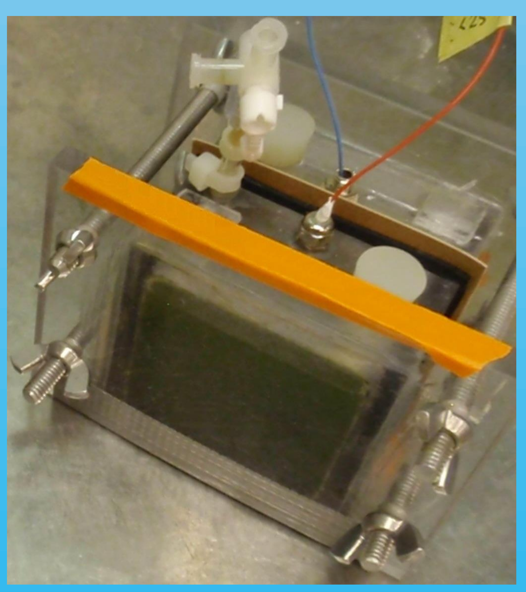


5 ml 1 ppm U ad/desorption for BP-functionalized PSiC and plain PSiC.

TUT (Dr. Lakaniemi group): Anaerobic uranium reduction enables uranium removal from water streams by the reduction of soluble U^{6+} to poorly soluble U^{4+}. Biological uranium reduction has been widely studied, but it has been shown to result in unstable uranium products that may later dissolve and return into the water phase.

The novel approach in the present project is to combine electrokinetic and biological processes in a bioelectrochemical system (BES), which based on previous research enables recovery of uranium as stable U^{4+} precipitates on the cathode electrode. There is only one previous research report on this topic demonstrating 87% uranium recovery for a uranium contaminated groundwater.[1] Optimization of the BES design and study of different microbial communities will likely lead to higher recovery while providing more fundamental understanding of the underlying electrochemical and microbiological phenomena.

The aim is also to compare efficiencies of biological and bioelectrochemical uranium reduction with each other and with biosorption and electrokinetic uranium reduction.



Photograph of a simple two-chamber bioelectrochemical system

References:

[1] Gregory KB, Lovley DR. 2005. Environ. Sci. Technol. 39: 8943-8947.