



*Canadian  
Light  
Source*

*Centre canadien  
de rayonnement  
synchrotron*

***The Canadian Light Source:  
A New Tool for Mining and  
Environmental Headaches***



**J.N. Cutler**  
**Canadian Light Source Inc.**



# Light lets you see!

Interaction of light with matter is very simple, that's why scientists use it.

The energy of light determines what it lets you "see"

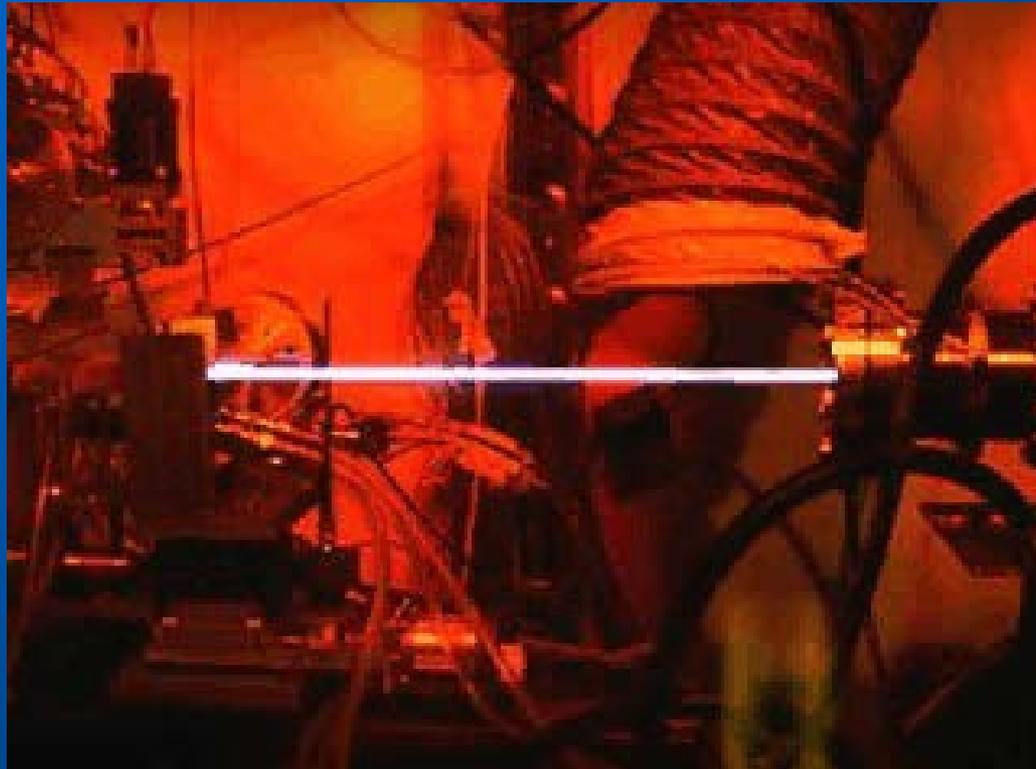
- Visible light let you see "large" things
- X-rays let you see "through" things



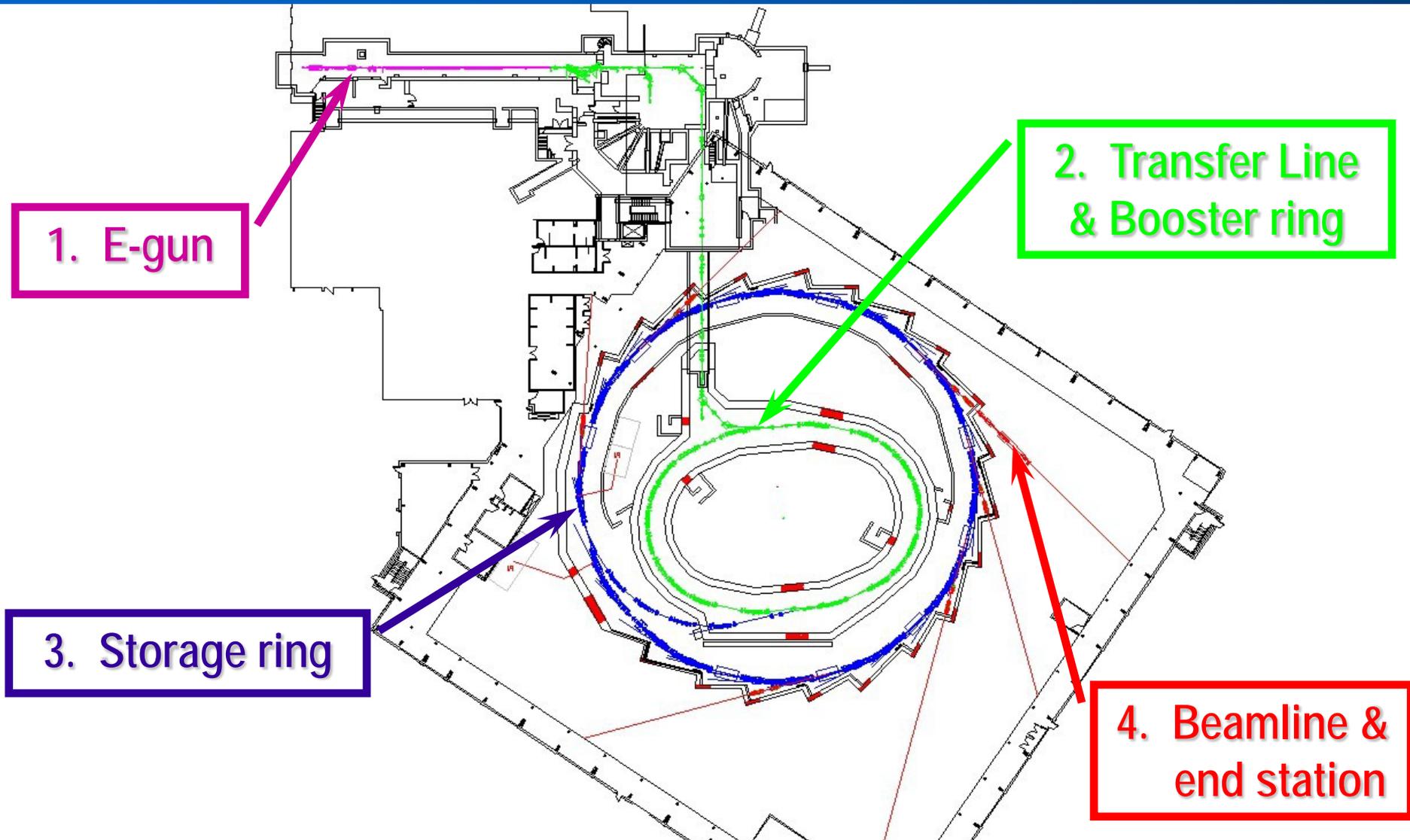
# The Construction Site



# ESRF Animation



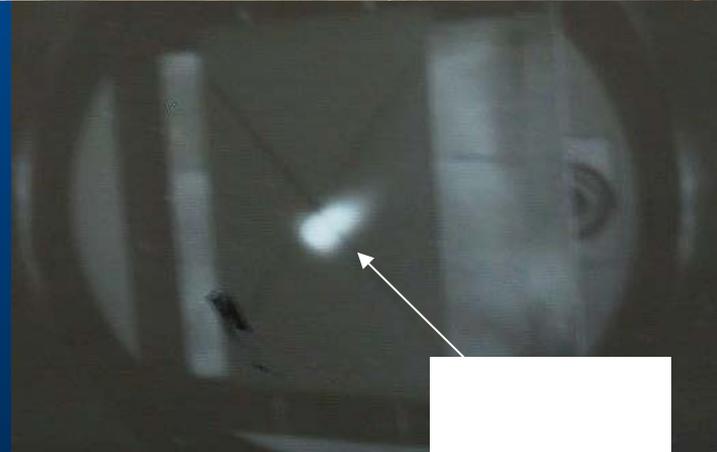
# Synchrotron Facility Components



# Booster Ring

First injection in June  
> 10 mA ramped to 2.9  
GeV and extracted.

Commissioning  
complete



# Synchrotron Hall, Main Floor



# Electromagnetic Spectrum

millimetre

$10^{-3}$

$10^{-4}$

$10^{-5}$

micron

$10^{-6}$

$10^{-7}$

$10^{-8}$

$10^{-9}$

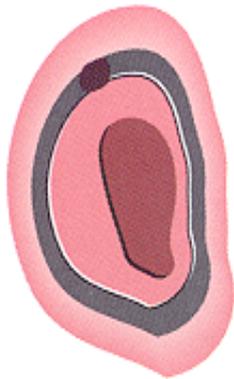
angstrom

$10^{-10}$

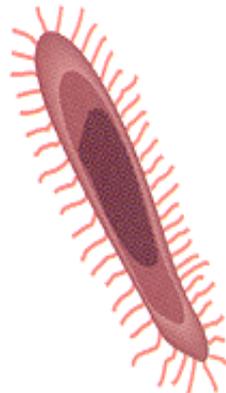
$10^{-11}$

This dot

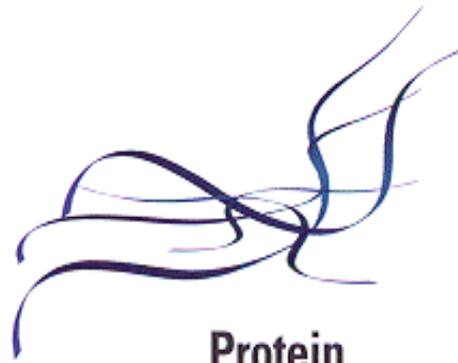
Cell



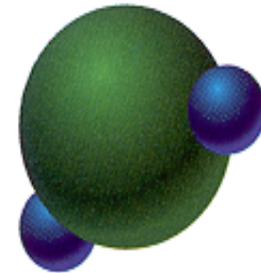
Bacterium



Protein



Water Molecule



INFRARED

ULTRAVIOLET

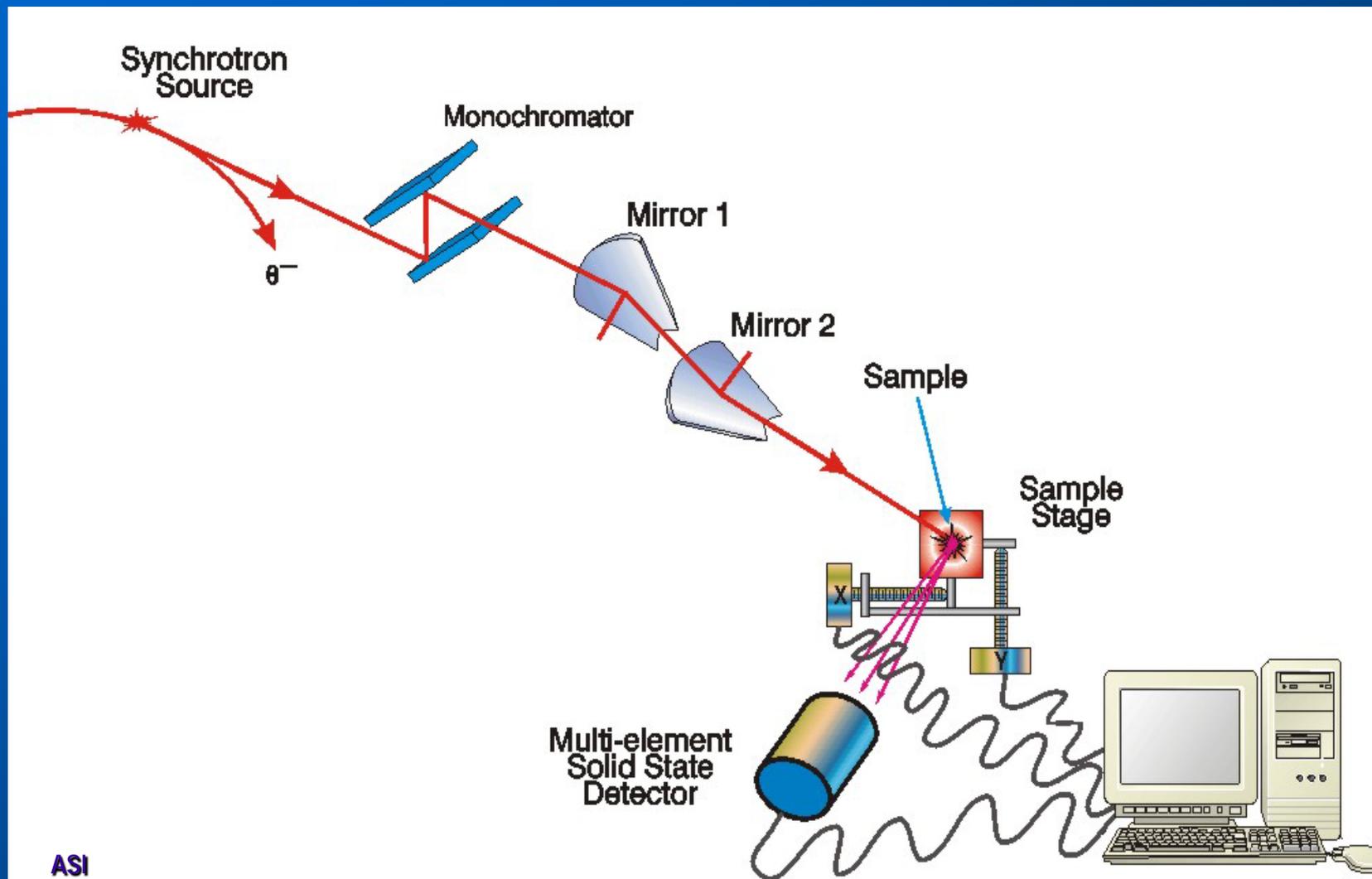
"HARD" X RAYS

VISIBLE

"SOFT" X RAYS



# Sample Microprobe Beamline Layout



# Canadian Light Source Inc. Vision

To advance Canadian scientific and industrial capabilities by operating the Canadian Light Source facility as the national synchrotron research and development centre of excellence.



# Multi-disciplinary Opportunities

## Advanced materials – hybrid materials, stress, transistors, foams

- Metals/ceramics, coatings, fibers, polymers, pulp/paper, welding
- Information technologies (IT), storage, semi-conductors, sensors
- MEMS (micro-electrical-mechanical systems); Nano-technologies

## Health & Life Sciences – biotech (human, animal, plant)

- Designer pharmaceuticals, medical imaging (cell chemistry)
- Genome & proteomics (protein functionality)
- Viruses; treatment therapies; diagnostics; implantable devices

## Earth Sciences – geology, mining, industrial processing

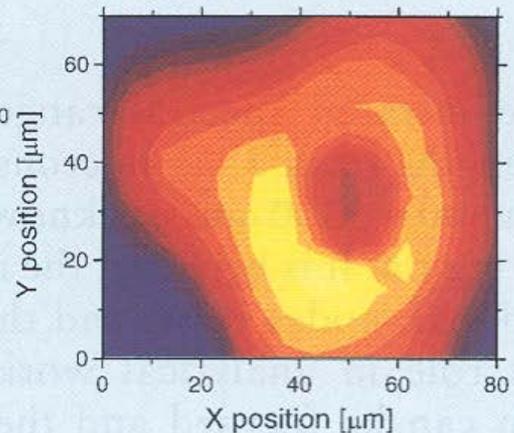
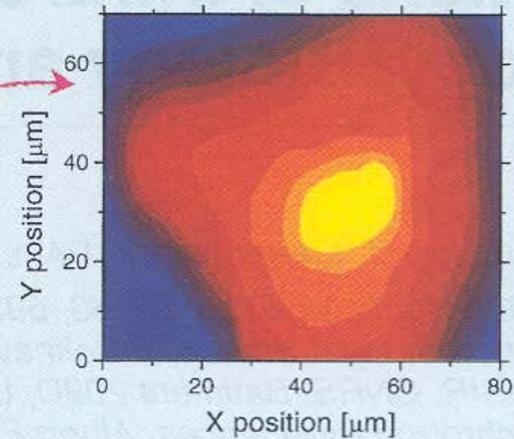
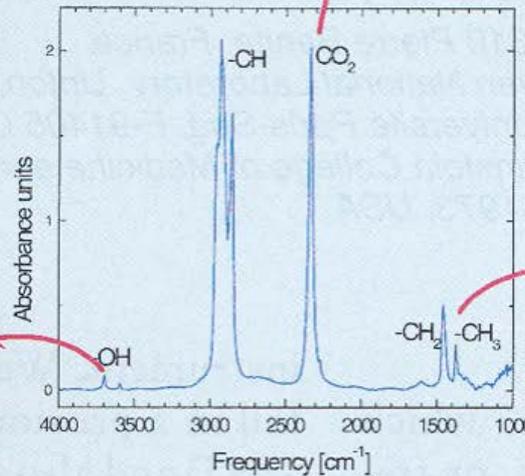
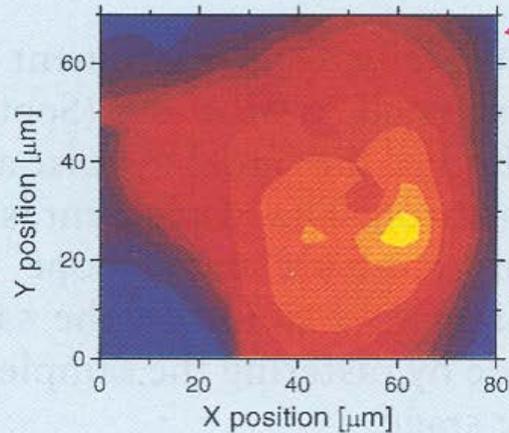
- Environmental geo-chemistry, bio-active stability analysis
- Oil tribology, fingerprinting, soils in situ, corrosion
- Remediation assessments, waste management



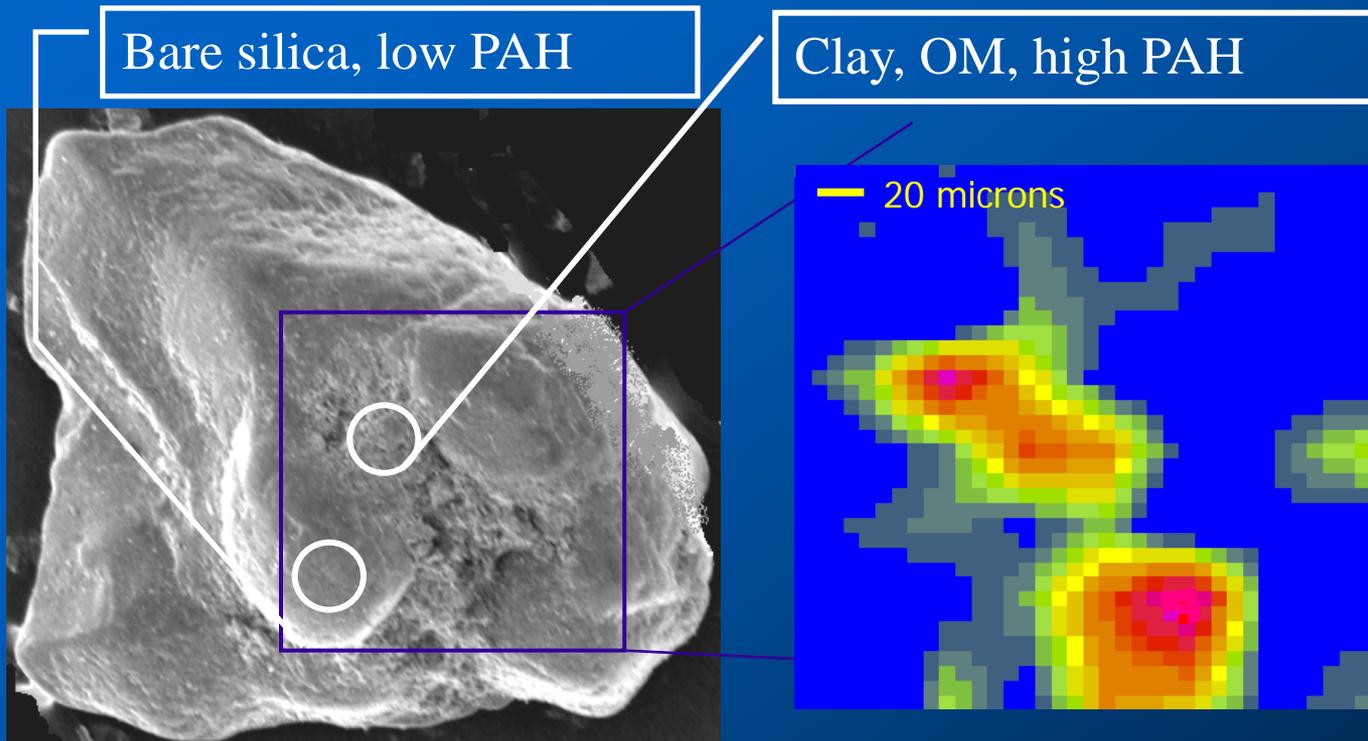
# IR Microscopy of a fluid inclusion



Visible Image



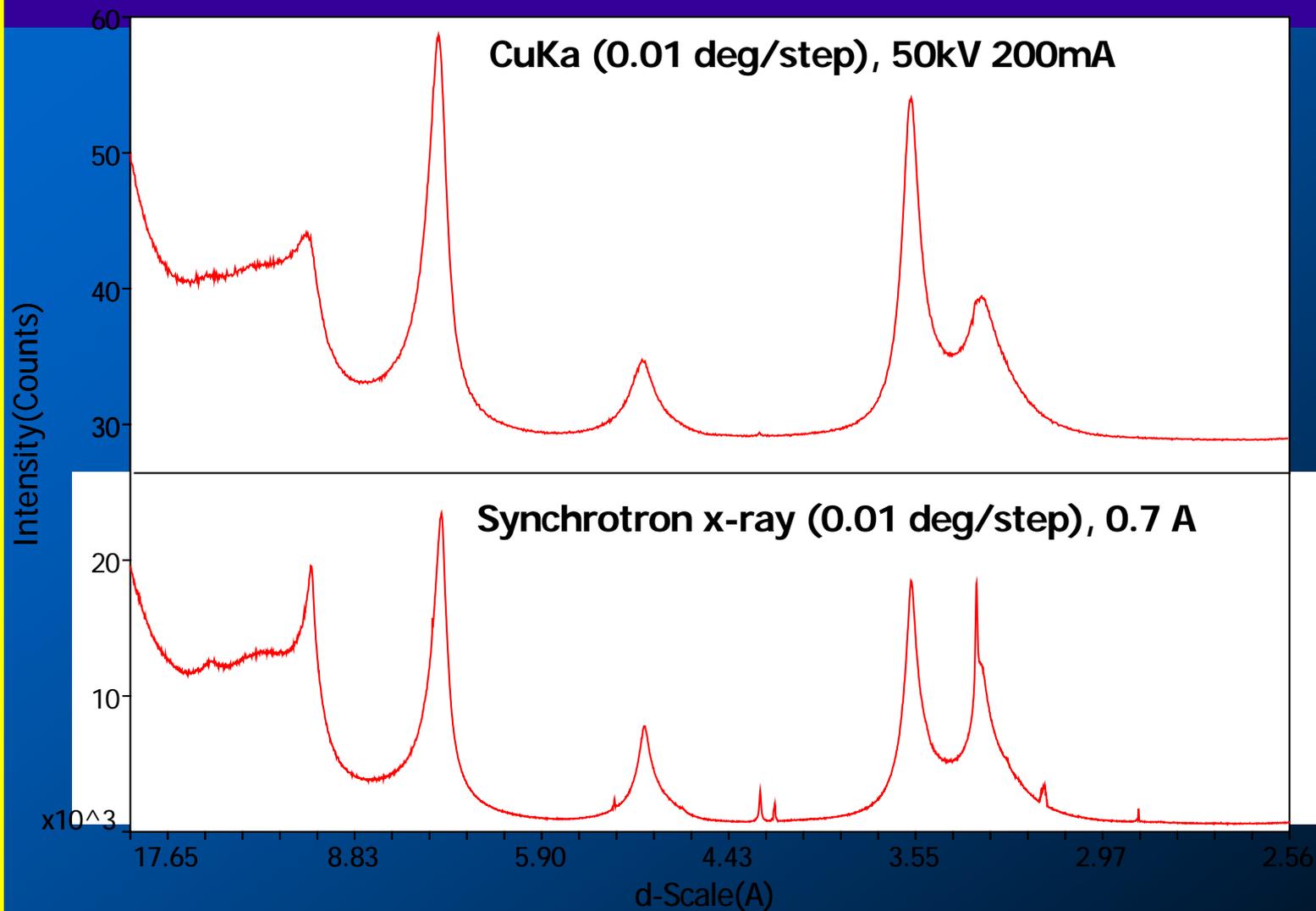
# Infrared Study of Organic Material on Marine Sediment



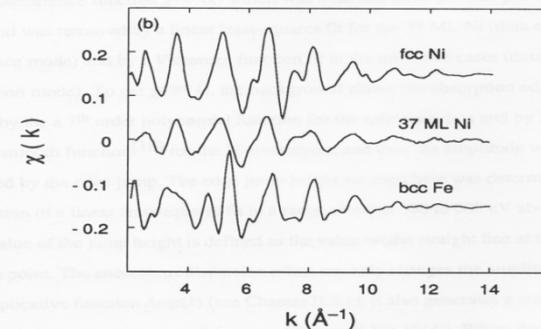
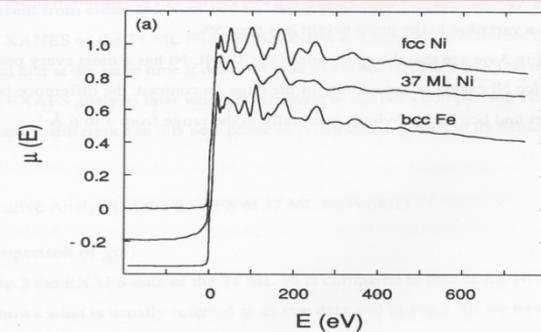
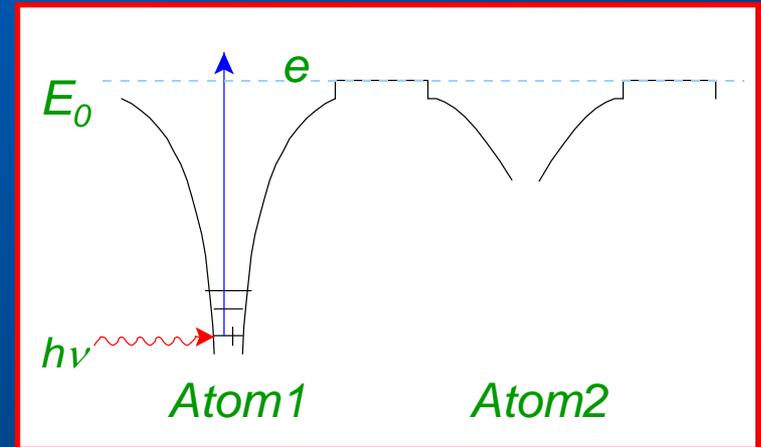
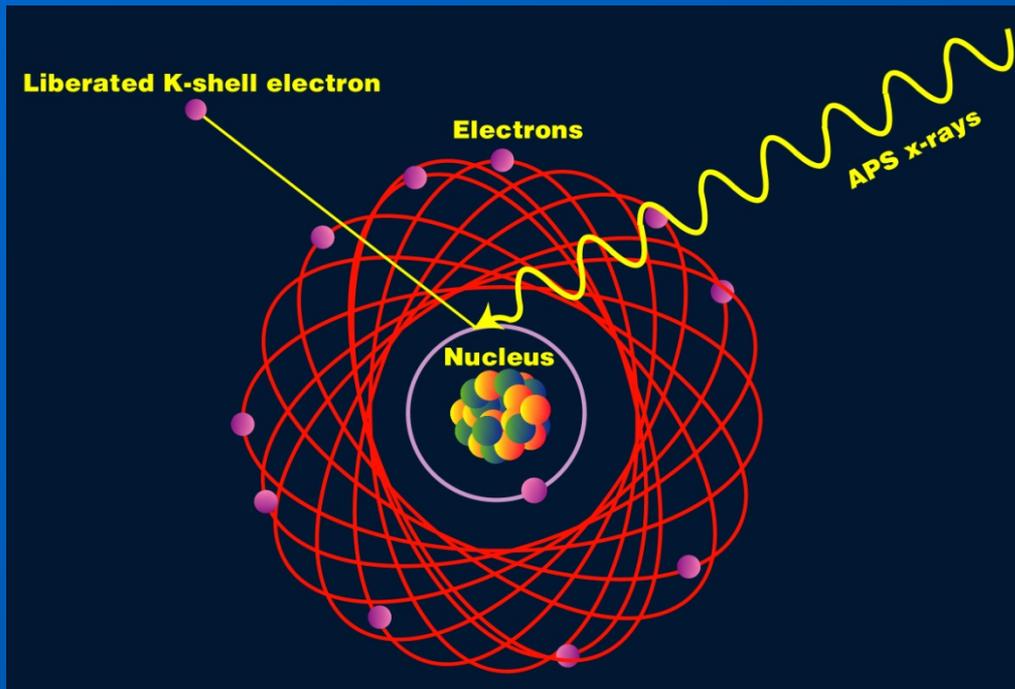
SEM image of a silica particle. (Right) IR image of organic material on the silica particles. Red and yellow areas indicate high PAH concentration.

- PAHs present on silica particles were found associated with organic carbon locations. These organic matter regions containing PAHs are colonized by bacteria during biodegradation studies.

# Comparing synchrotron & lab results



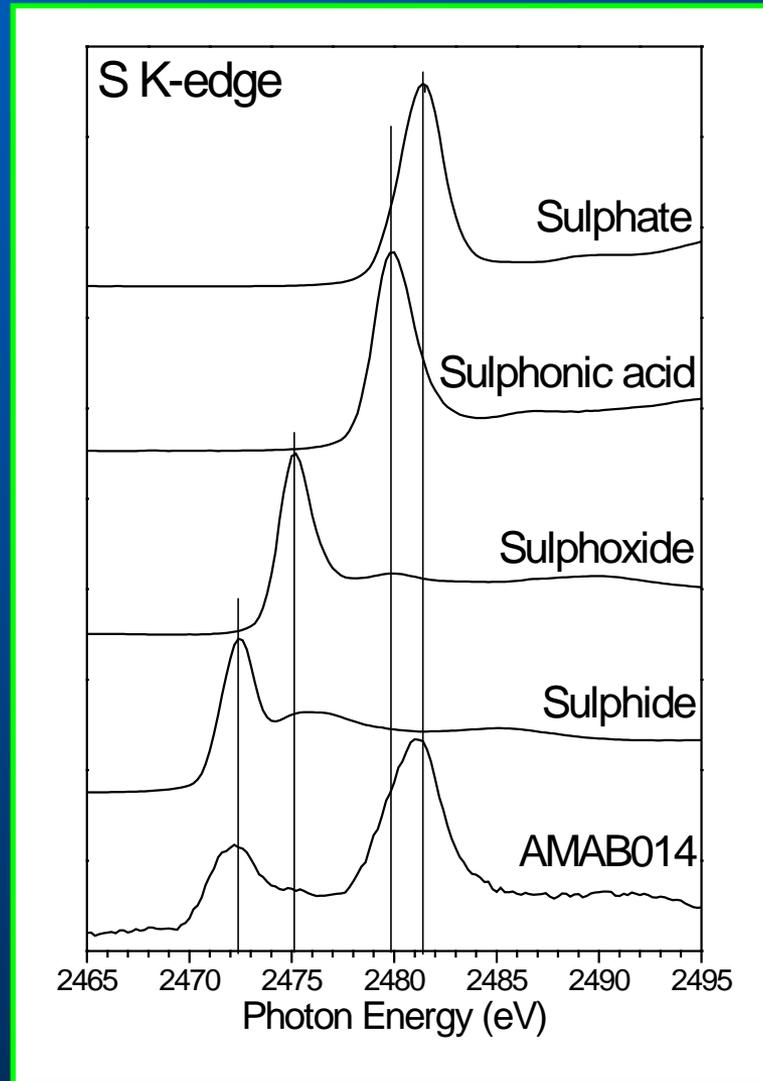
# X-ray Absorption Spectroscopy (XAS) using Synchrotron Light



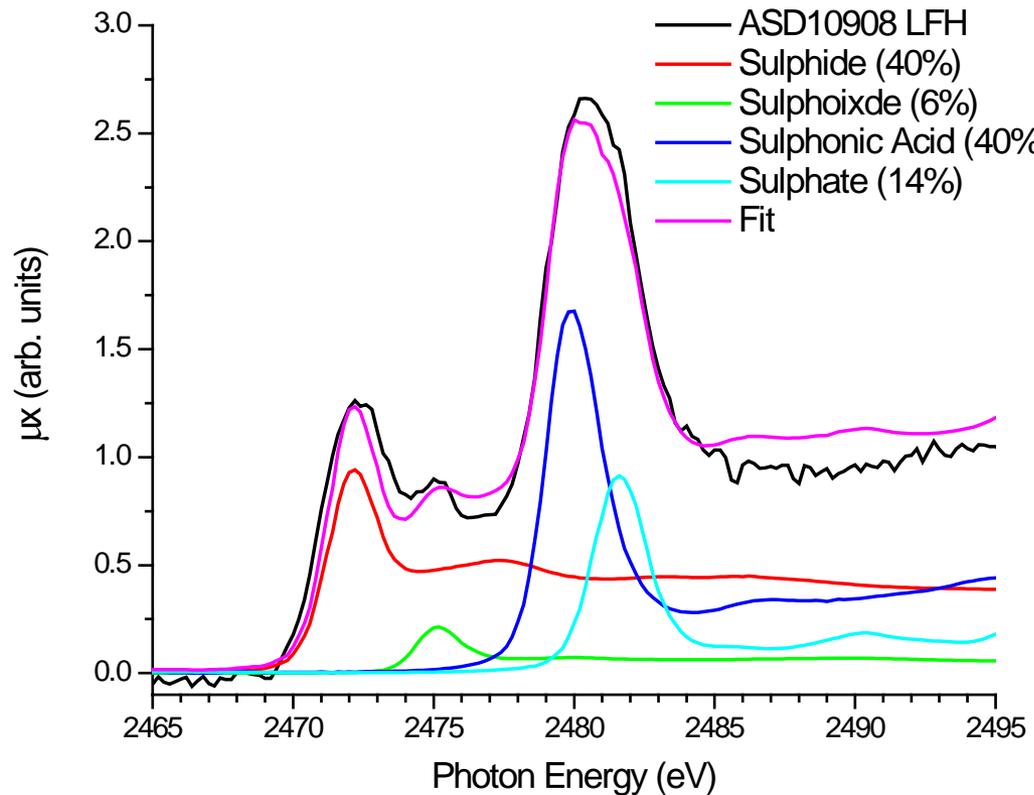
$$\chi(E) \equiv \frac{\mu(E) - \mu_0(E)}{\mu_0(E)}$$



# Soil Chemistry

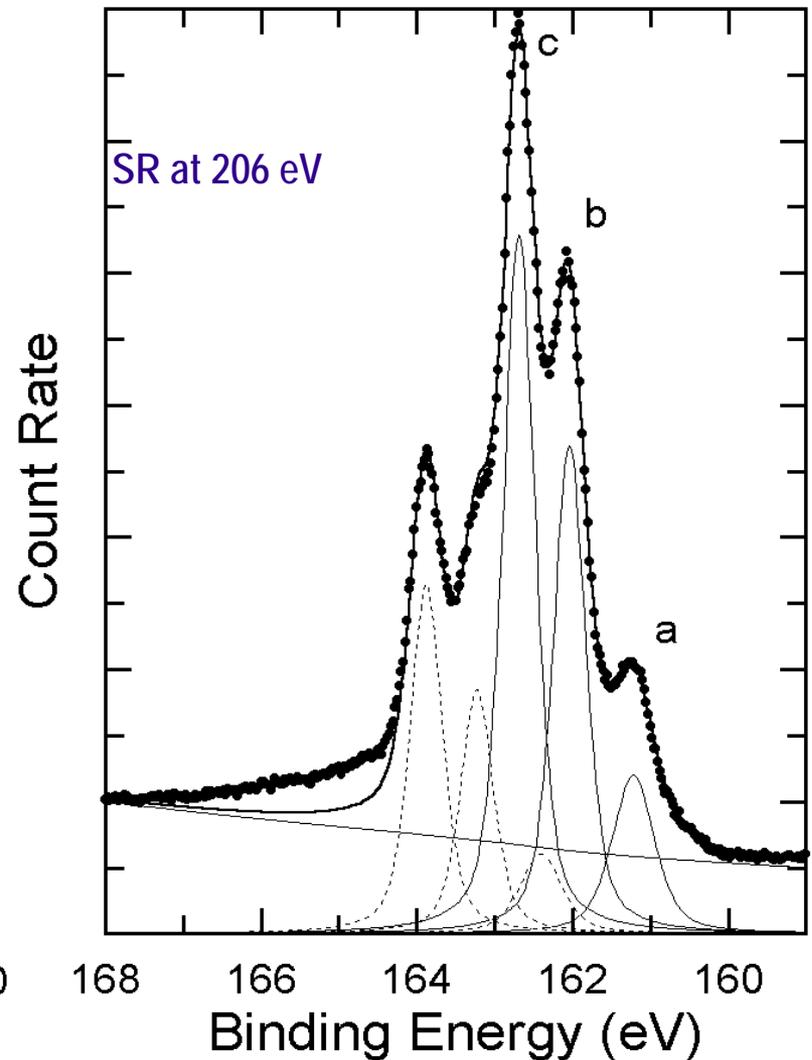
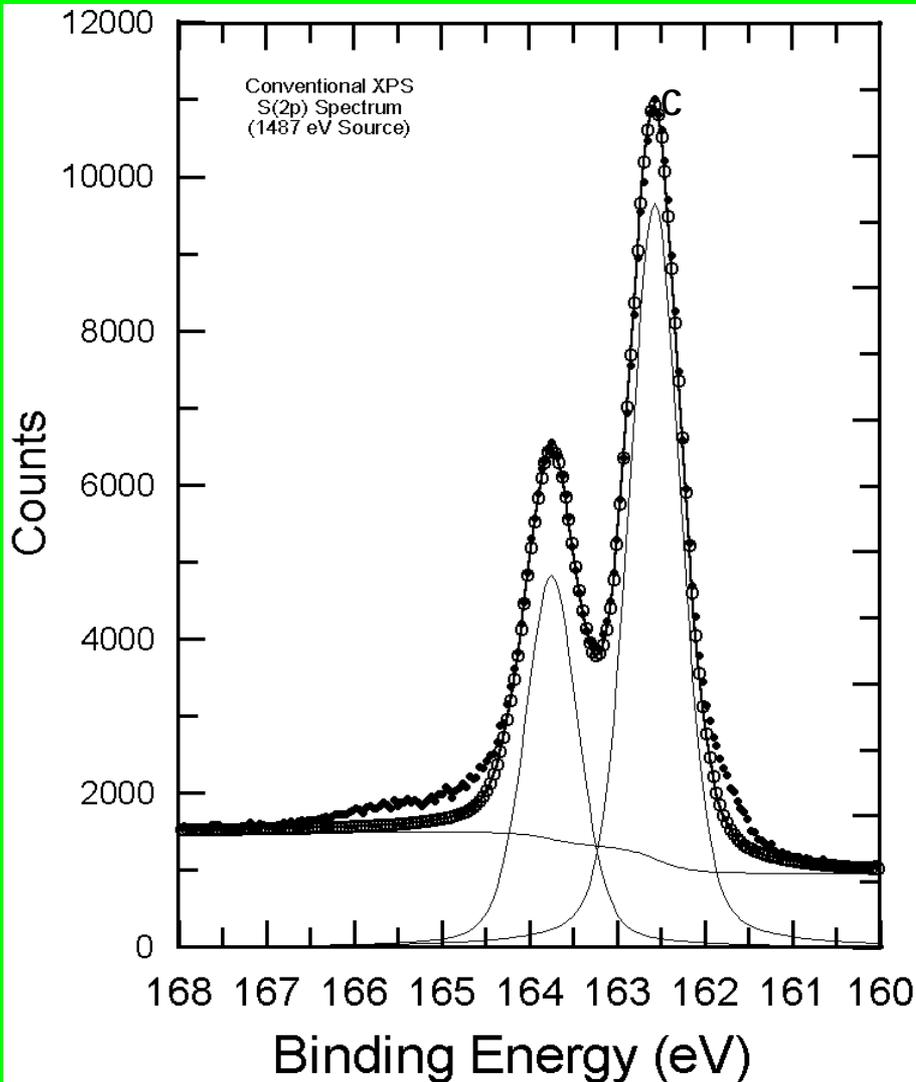


# Determination of Sulphur in Soil

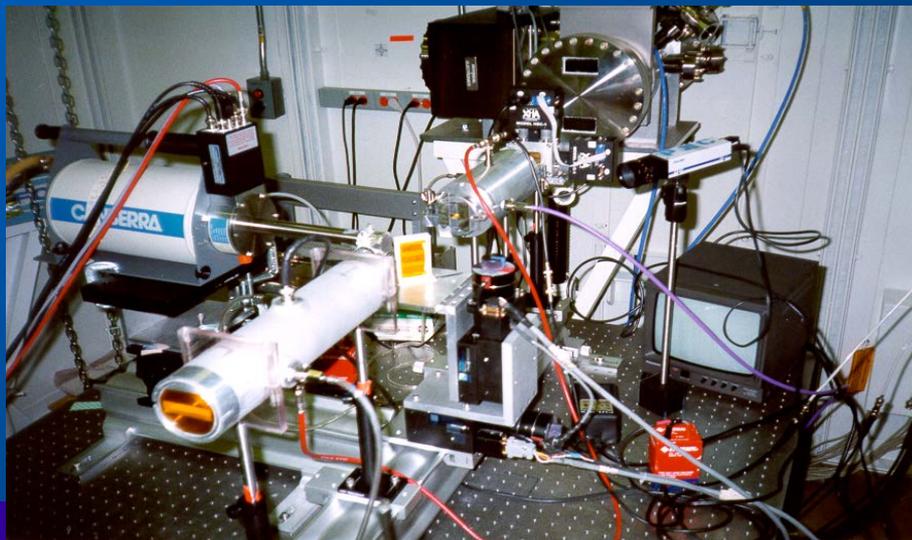
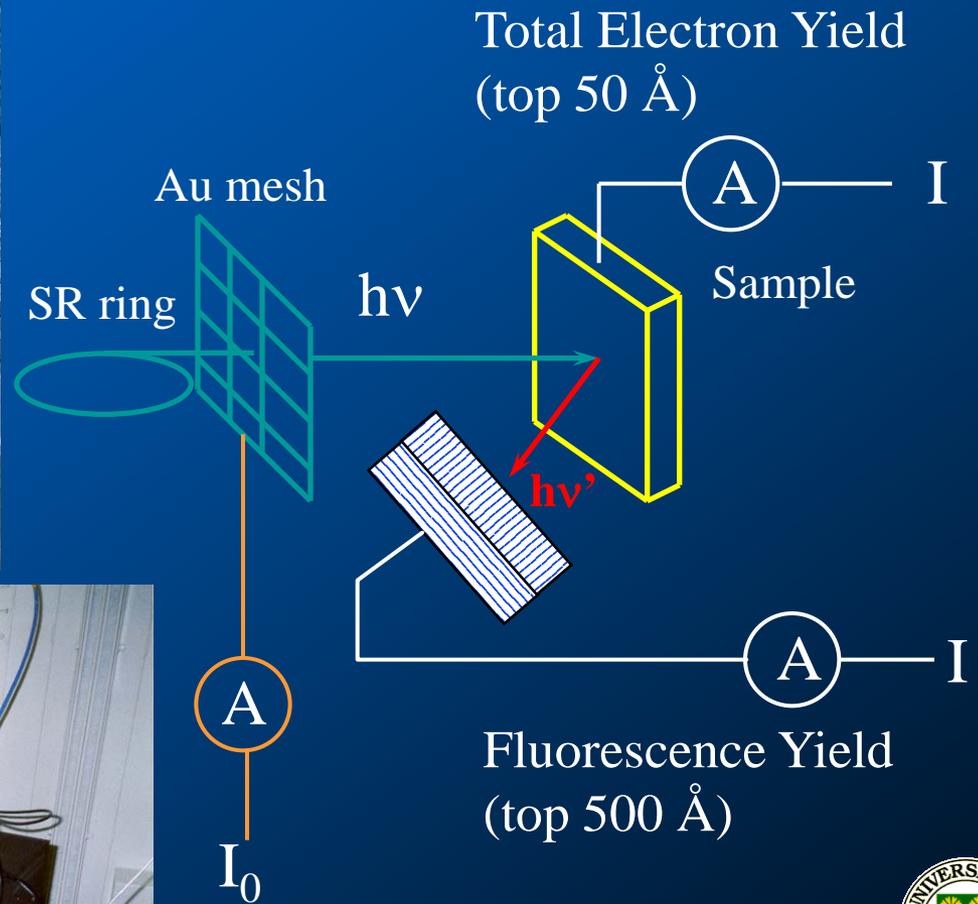


- quantification of sulphur in soil

# XPS of S 2p of FeS<sub>2</sub>



# Synchrotron Experimental Set-up

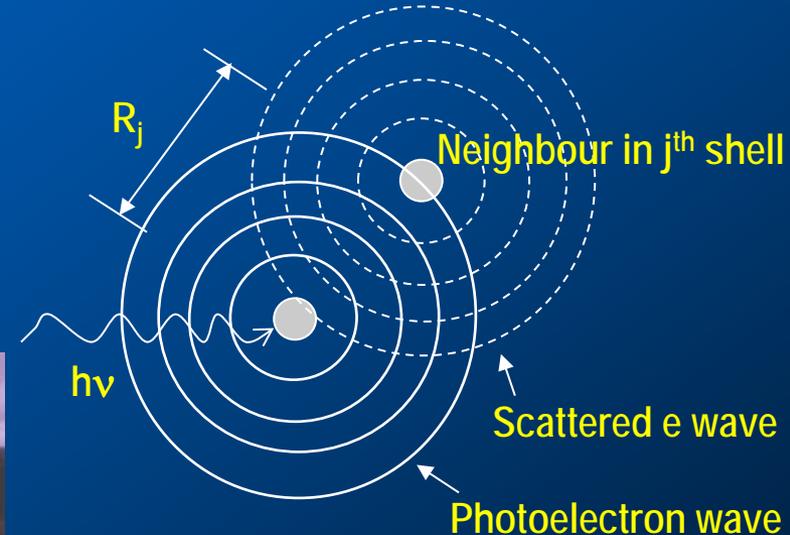


$$\mu x = \log(I_0/I)$$



# Environmental; Mine Tailings

Nature & bio-availability of heavy metals in mine waste



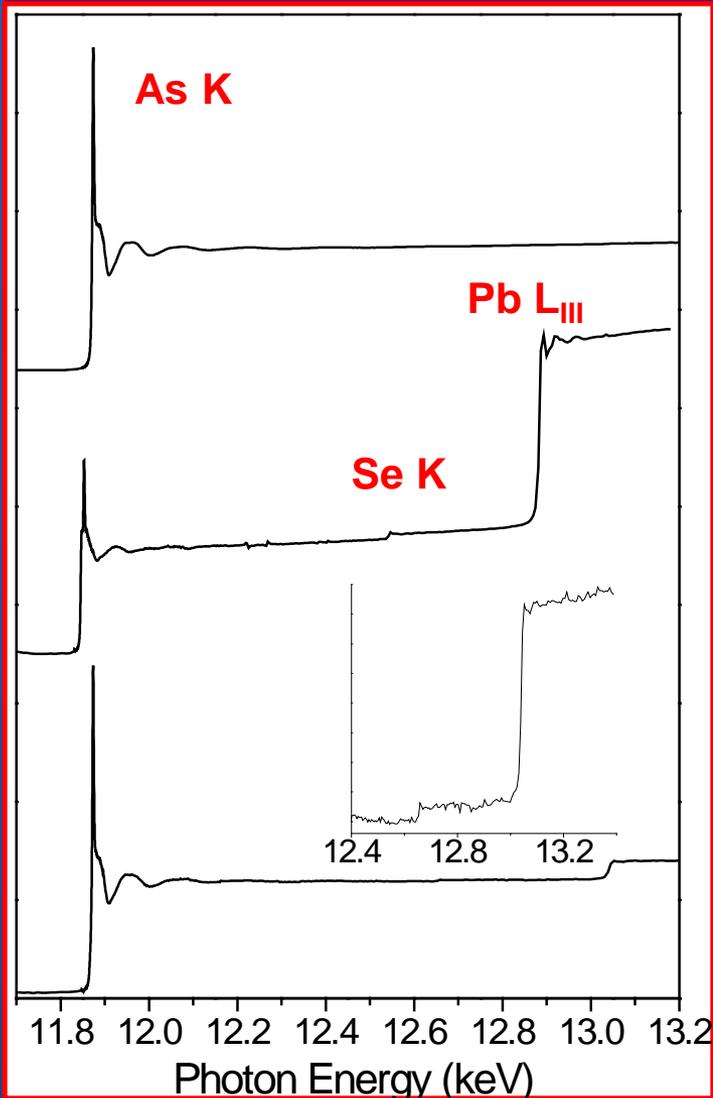
Examine diffusion of materials into surrounding eco-system



COGEMA  
Resources Inc.



# Characteristic X-ray Absorption Spectra from Raffinate, Leach Residue and Tailings



Raffinate  
Fe/As 3.5

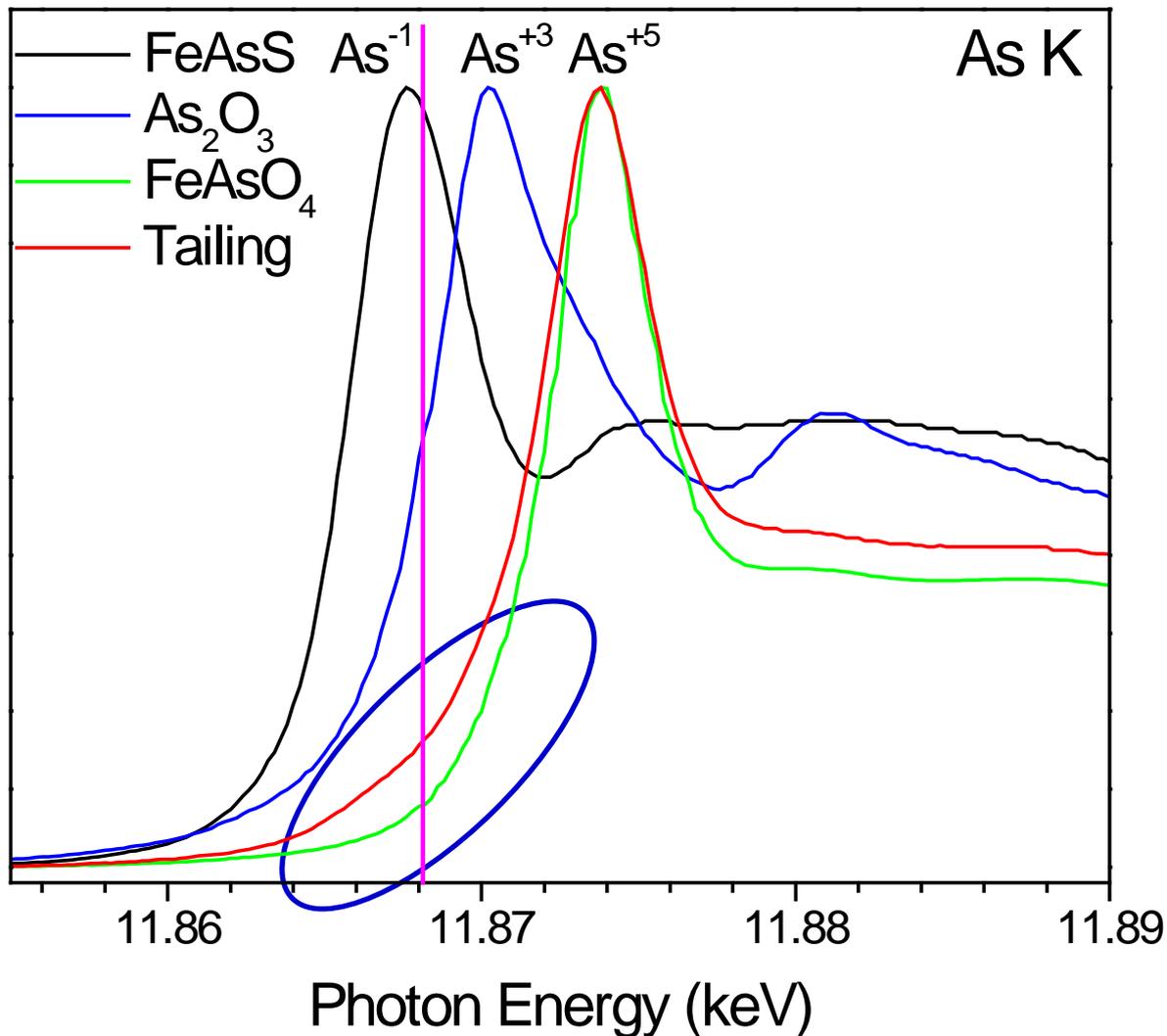
Leach Residue

Tailing Sample  
Gypsum dissolution

- Element specific
- Sensitive to local structure
- Non-invasive
- Applicable to all sample physical states
- *In Situ*



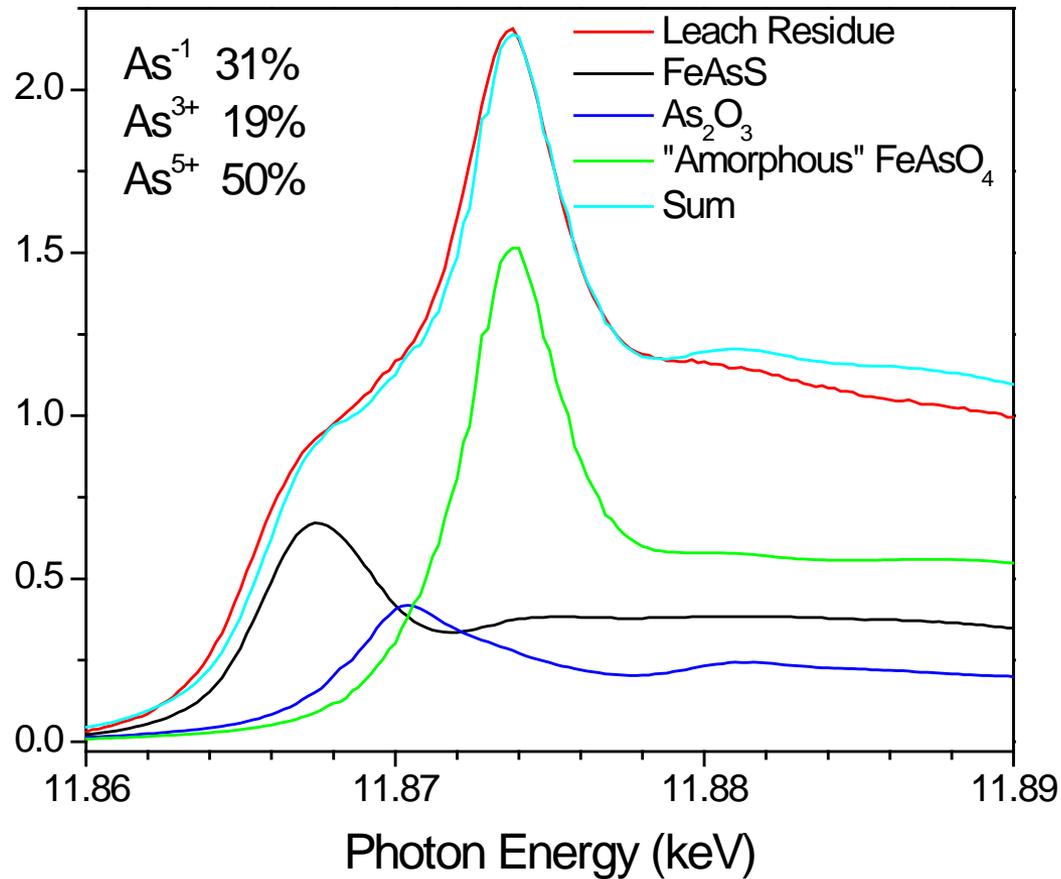
# Determination of Chemical States Using Arsenic X-ray Absorption Spectroscopy



- Position of maximum absorption is related to oxidation state of arsenic
- Tailing samples show a broadening due to a mixture of oxidation states



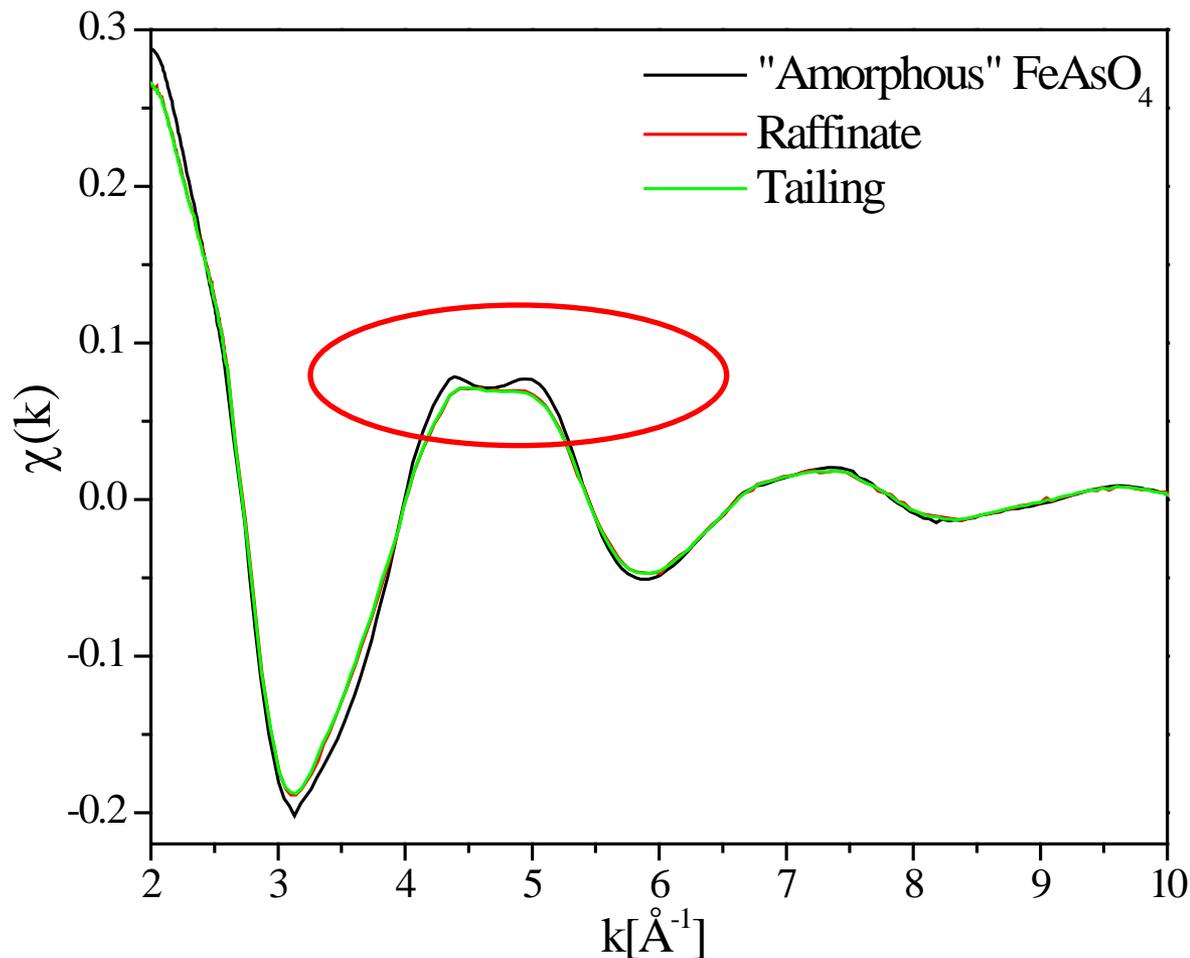
# Characterization of Chemical States within Leach Residue



- XANES spectroscopy can be used to determine oxidation states within a sample
- Leach residue is a mixture of at least 3 different oxidation states

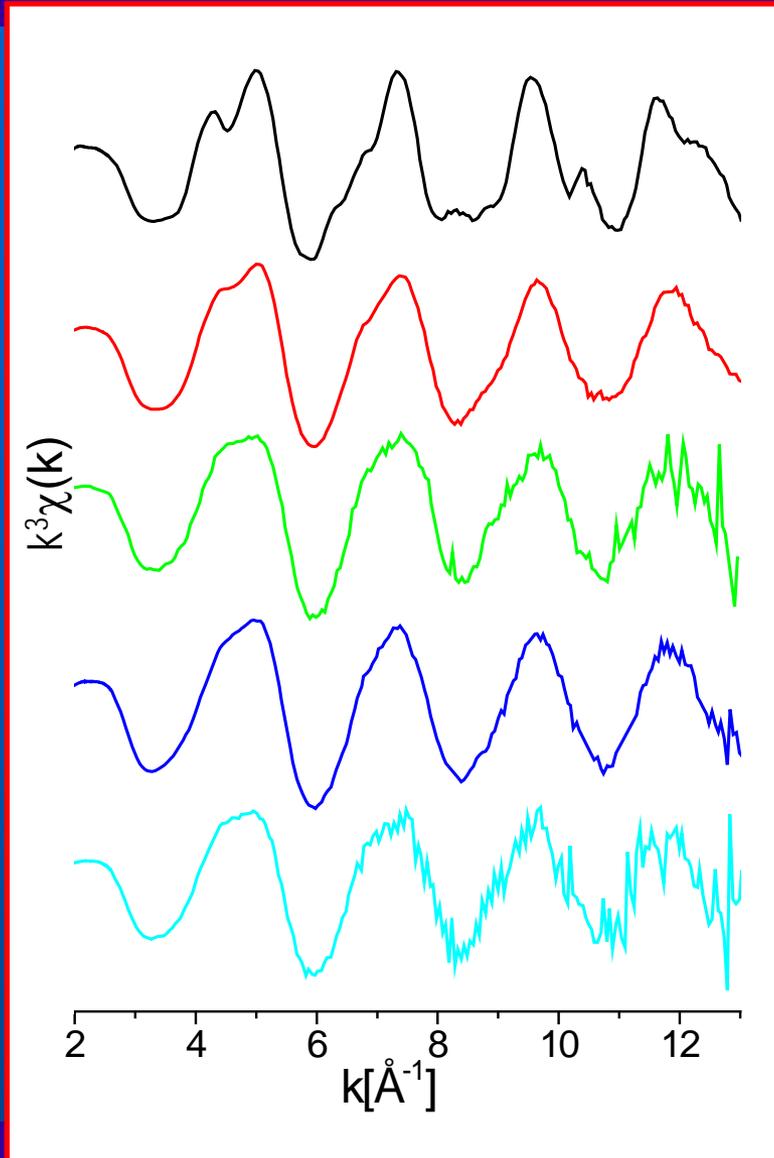


# XAFS Comparison of Reference Compound to Raffinate and Tailing Samples



- Raffinate and tailings are different than "amorphous"  $\text{FeAsO}_4$

# XAFS Comparison of Reference Compounds to Raffinate and Tailings



Crystalline FeAsO<sub>4</sub>

FeAsO<sub>4</sub>

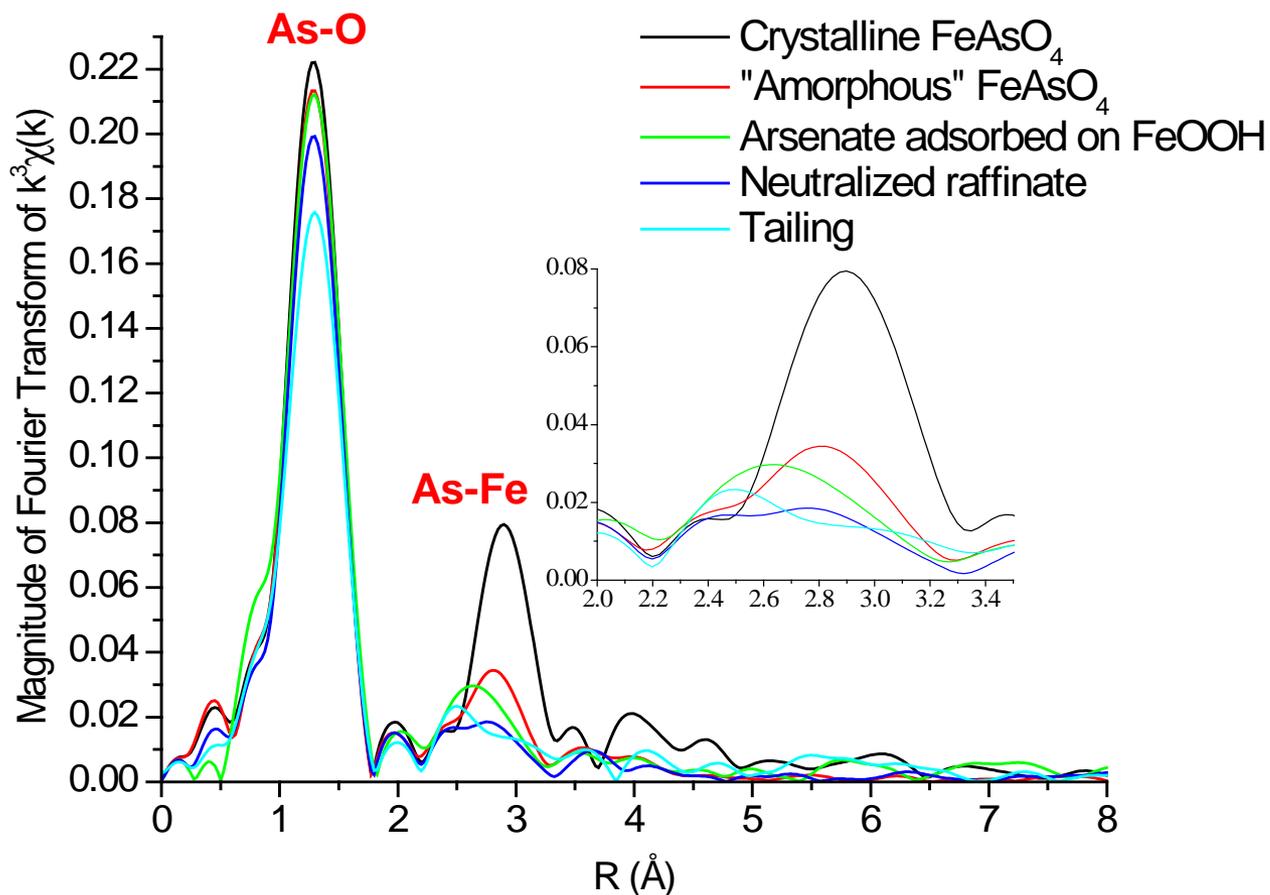
Arsenate adsorbed on FeOOH

Raffinate

Tailing



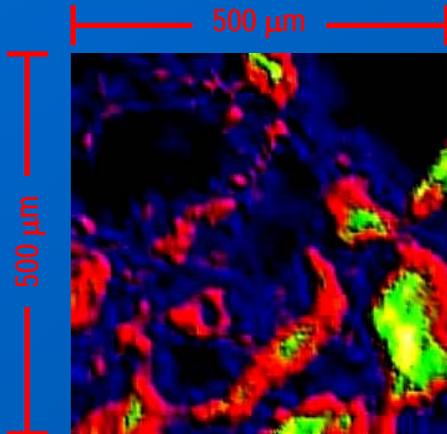
# Structural Environment around Arsenic within a Raffinate & Tailing Sample



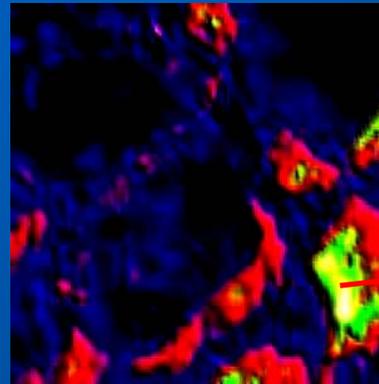
- Tailings & raffinate are different
- Raffinate appears to contain some "amorphous"  $\text{FeAsO}_4$



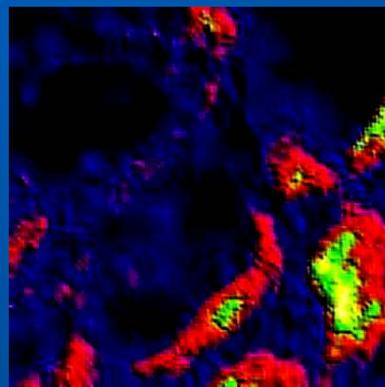
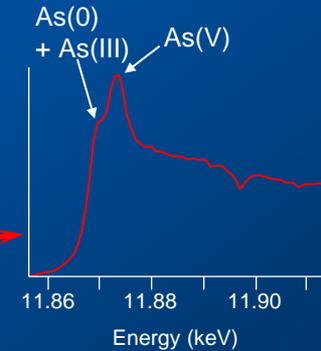
# Microprobe Study of Mine Tailings



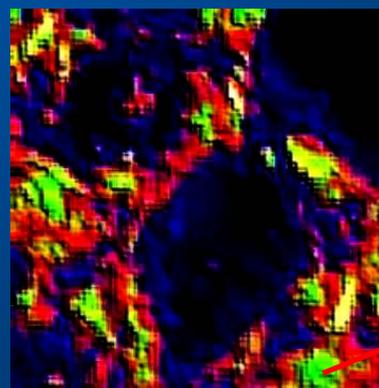
Nickel Map



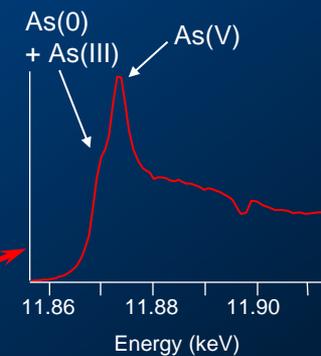
Arsenic Map



Iron Map



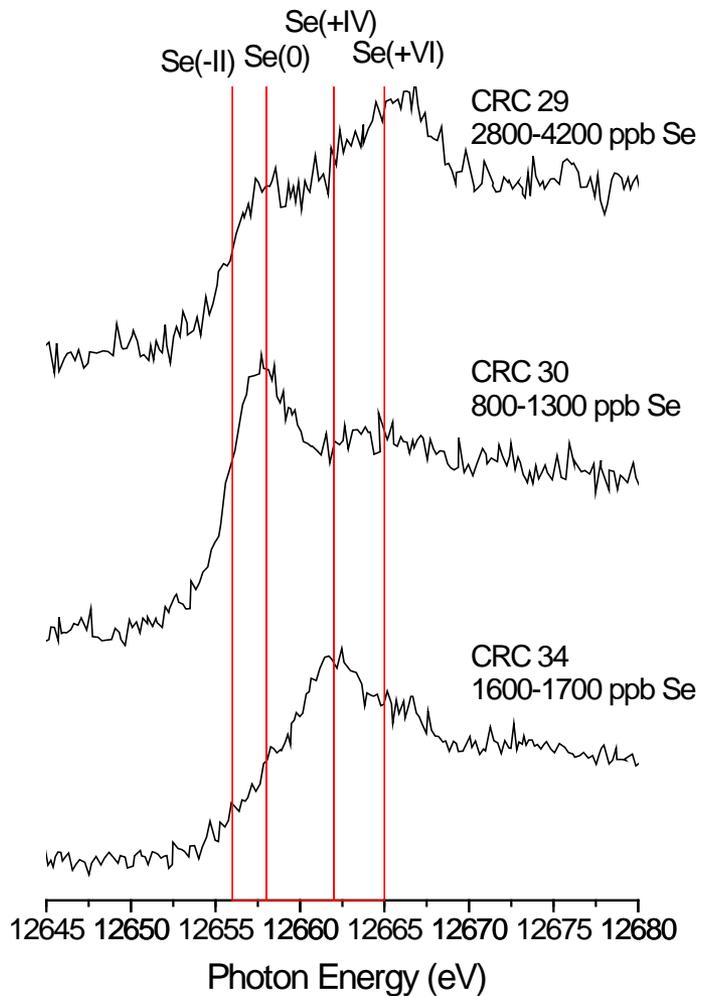
Calcium Map



Photon Energy: 12 keV  
Spot size: 5  $\mu\text{m}$

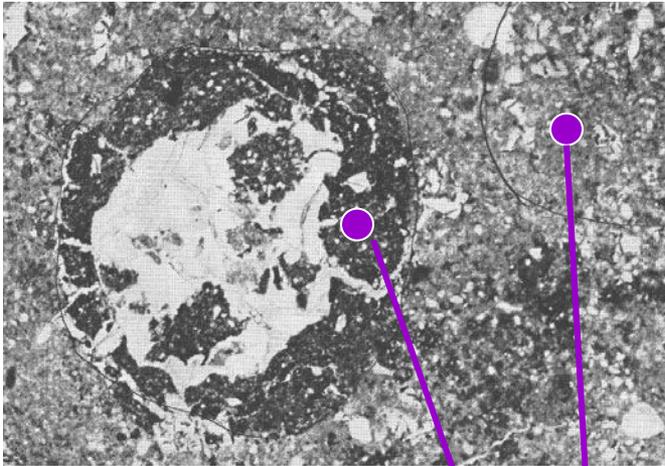


# Selenium in the Environment

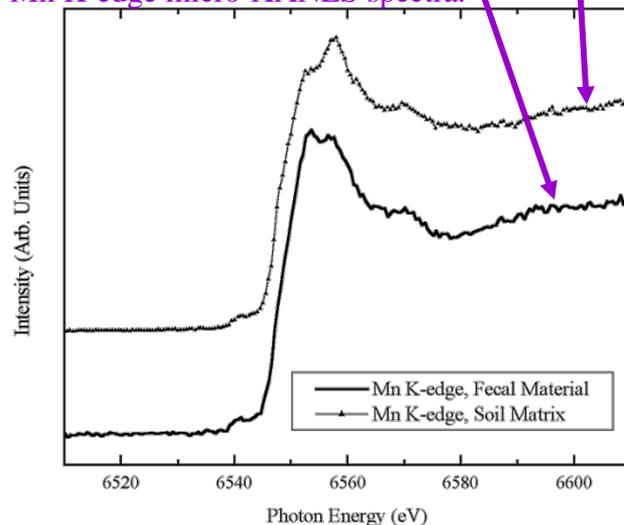


# Effects of Earthworms on Soil Manganese

Picture of the studied worm burrow.

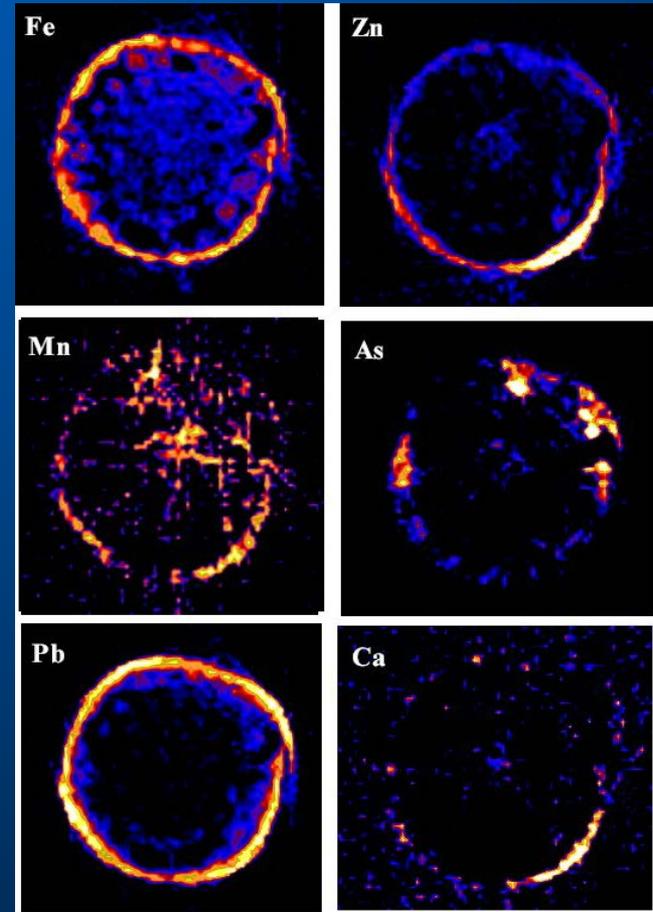
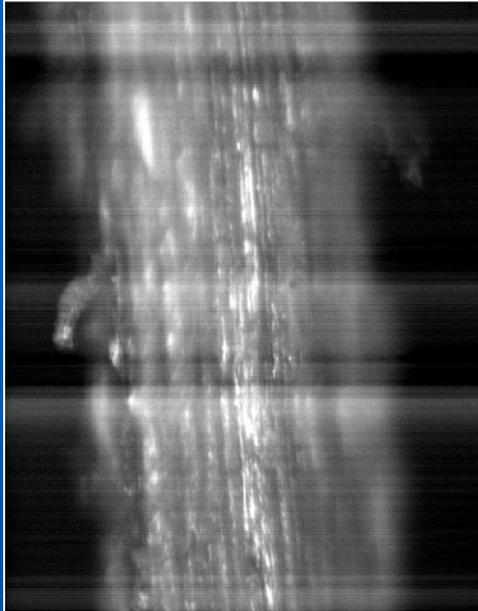


Mn K-edge micro-XANES spectra.



- Earthworms move materials through soils
- Fecal matter often contains higher levels of metals than surrounding soil
- Not only do worms move material but they change the speciation of the metals

# Toxic Metal Attenuation by Root-borne Carbonate Nodules

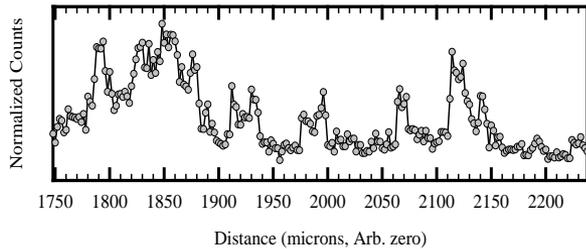
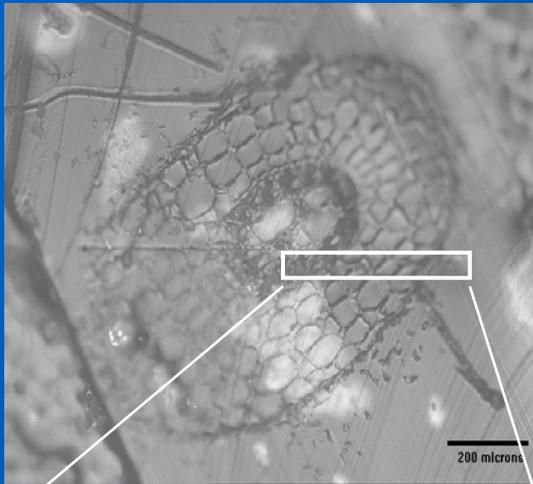


- Zn and Mn correlate with nodules
- Fe and Pb are fairly uniformly distributed
- As is heterogenous and poorly correlated with epidermis

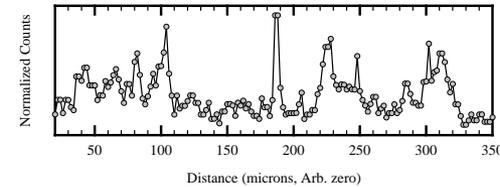
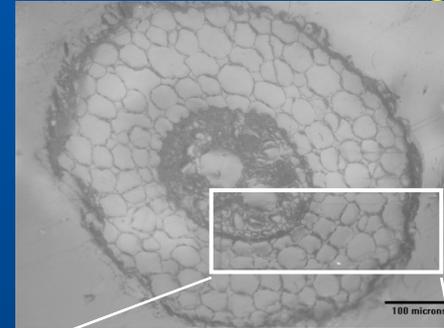


# Cadmium-Challenged Corn Roots

Control



Cadmium-Challenged



Ca maps

Cu map

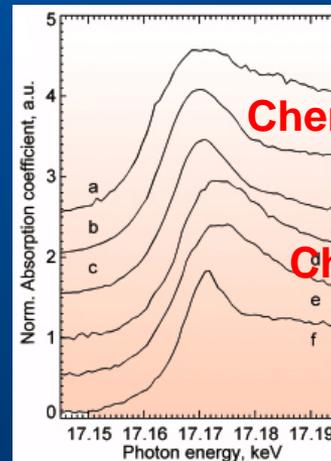
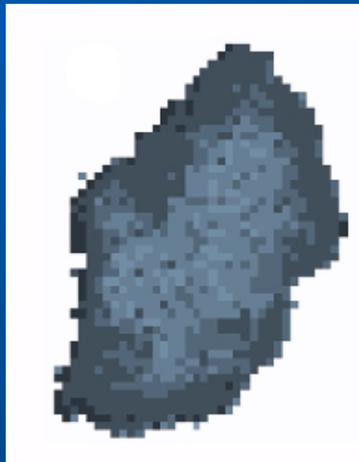
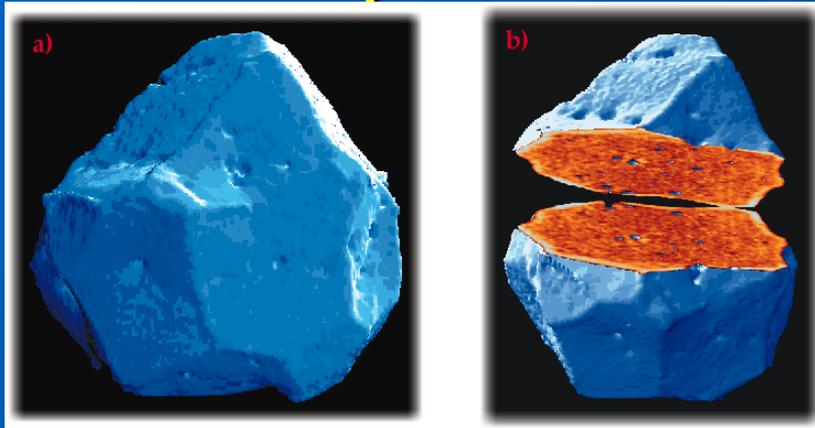


Naftel *et al.*



# Micro-Imaging and Tomography

## Uranium fuel particle from Chernobyl



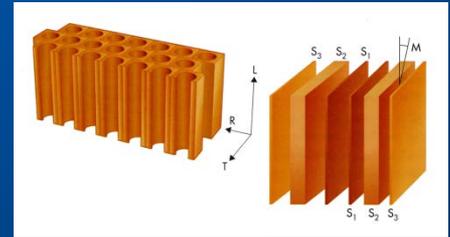
B. Salbu, K. Janssens, T. Krekling, A. Simionovici, M. Drakopoulos, C. Raven, I. Snigireva, A. Snigirev, O. C. Lind, D. H. Oughton, F. Adams, V.a. Kashparov

ESRF



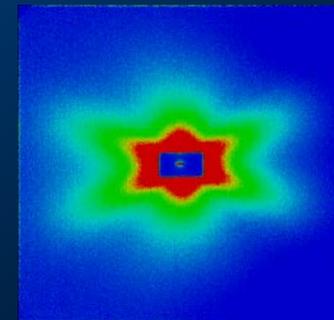
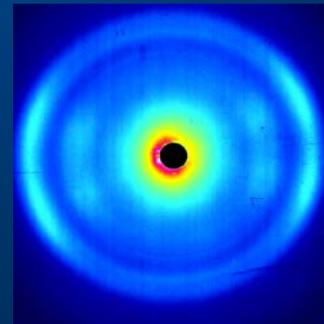
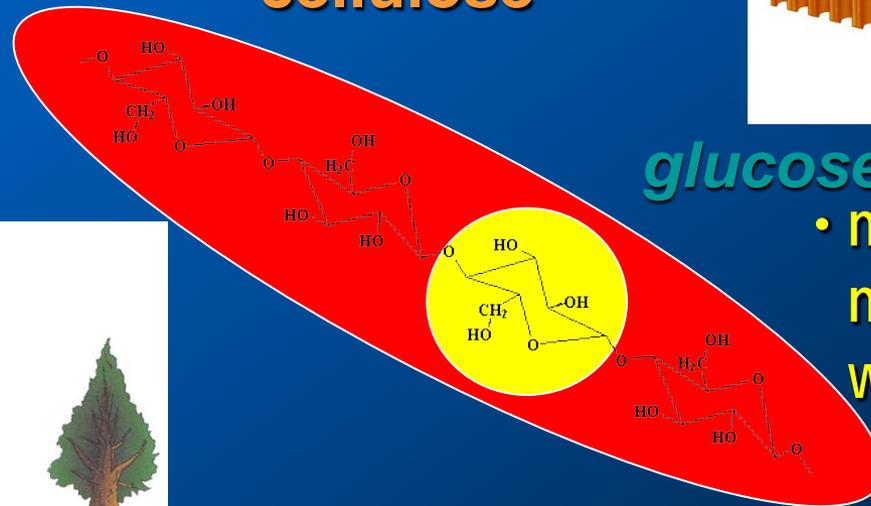
# Using SR to see the wood from the trees

cellulose



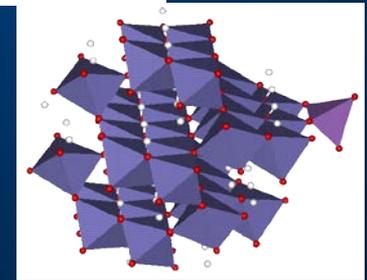
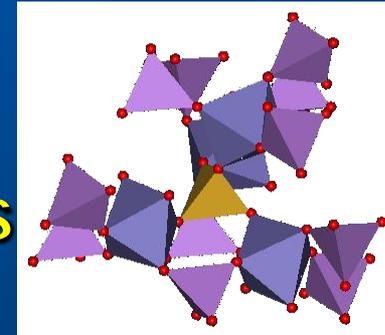
glucose

- measurement of microfibril angle within wood



# Opportunities

- Characterization (oxidation states and mineralogy) of metals in solids
  - tailings
  - sludges from water treatment plants
  - sediments from limnocorrals
  - wetland uptake
- sulphur associated with ARD
- biochemistry of SRBs and bioreactors



# Conclusion

The uses of synchrotron light are as limitless as your imagination is!





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*"Field of Beams"*

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