MICROANALYTICAL TECHNIQUES TO UNDERSTAND ELEMENT LEACHING FROM ORE MINERALS IN MINING WASTES

Sharon Diehl, William Benzel, Philip Hageman, Heather Lowers, Rhonda Driscoll, Robert Seal, II

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Purpose of USGS Geoenvironmental Assessment (Monomineral) Study:

Mineralogy in mining waste is complex—ore bodies host many minerals and these minerals host many individual elements. This study examines nearly pure zinc mineral phases knowing that they are not pure.

The bioavailability of a potentially toxic element is dependent on:

- element speciation in the mineral-host
- the mineral's physical properties
- the distribution, or residence of the element of interest in the mineral

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Objective of USGS Geoenvironmental Assessment (Monomineral) study:

To further understand the bioavailability of elements of concern such as As, Cd, Cu, Co, Fe, Hg, Mn, Ni, Pb, and Zn in complex mine-waste material by studies on monomineralic samples.

Demonstrate the importance of mineralogical characterization for better prediction of Acid Rock Drainage (ARD).

Direct characterization methods to identify mineralogy, locate residence of minor to trace elements, study weathering textures, and formation of secondary minerals:

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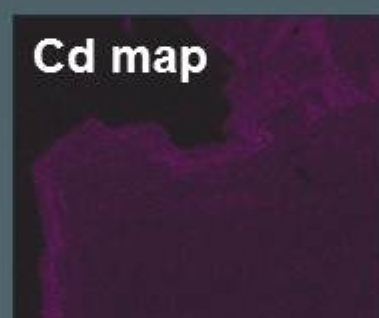
Microscopic Analytical Approach

Parameter:	Method:	Result:
Mineralogy	Petrographic Microscope	Mineral species; acid or non-acid generating
	Scanning Electron Microscope	Particle size, Mineral textures; cleavage, etching Structure Weathering features
	X-ray Diffraction	Mineral species
Trace Metals	Microprobe	Exact residence of trace metals Spatial distribution of trace metals



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Leaching Studies:

Importance:

Identify and characterize constituents that are mobilized from these minerals upon exposure to water.

The USGS Field Leach Test (FLT) provides specific answers to understand how minerals would act if leached in the natural environment.

- **Utilizes DI water, a short agitation period (5 minutes), and a 20:1 leaching ratio—this allows results to be compared to results of the EPA 1311 and 1312 methods.**
- **Resulting leachate identifies the constituents that would be mobilized due to leaching by natural precipitation (rain, snow)**

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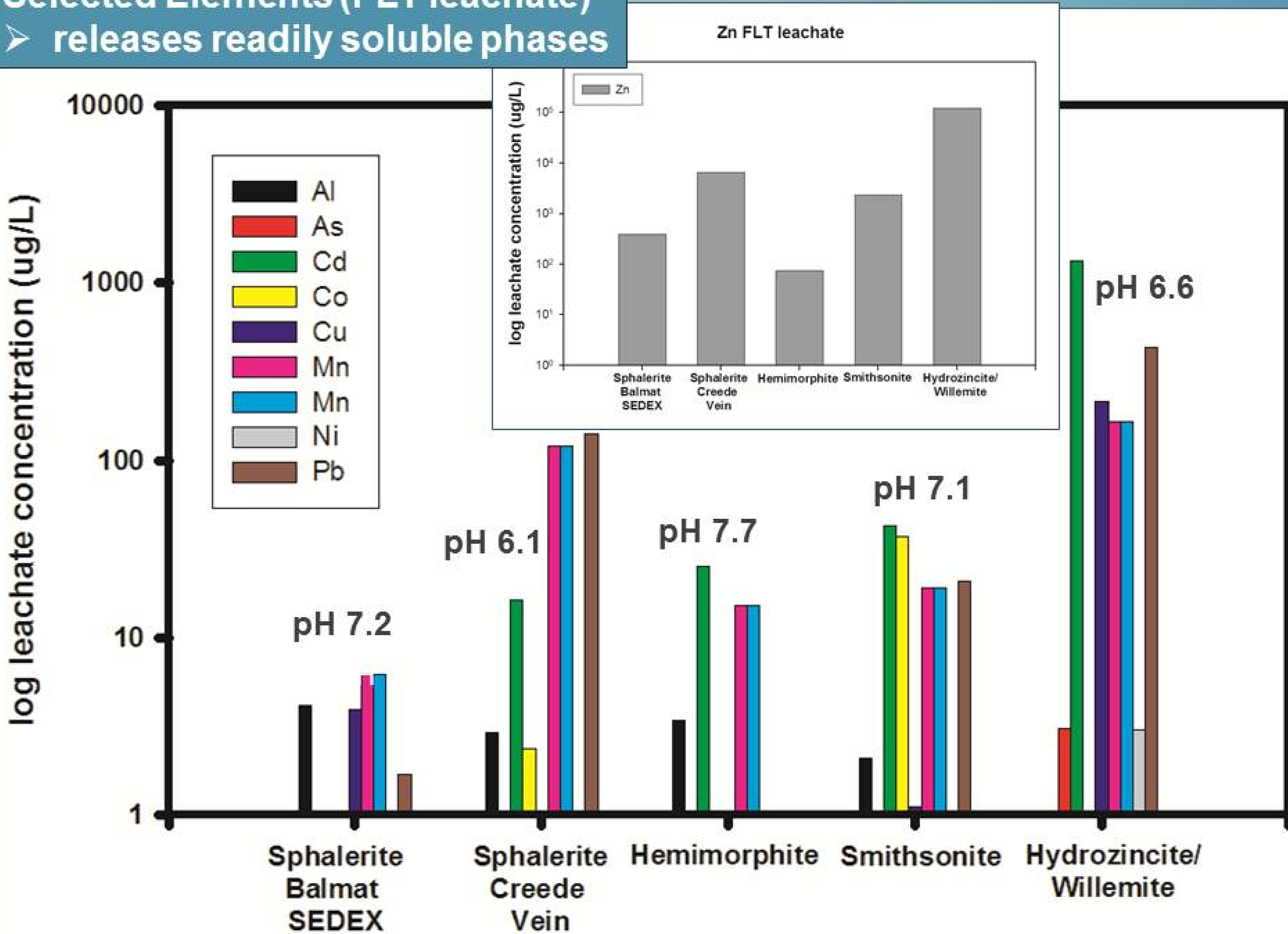
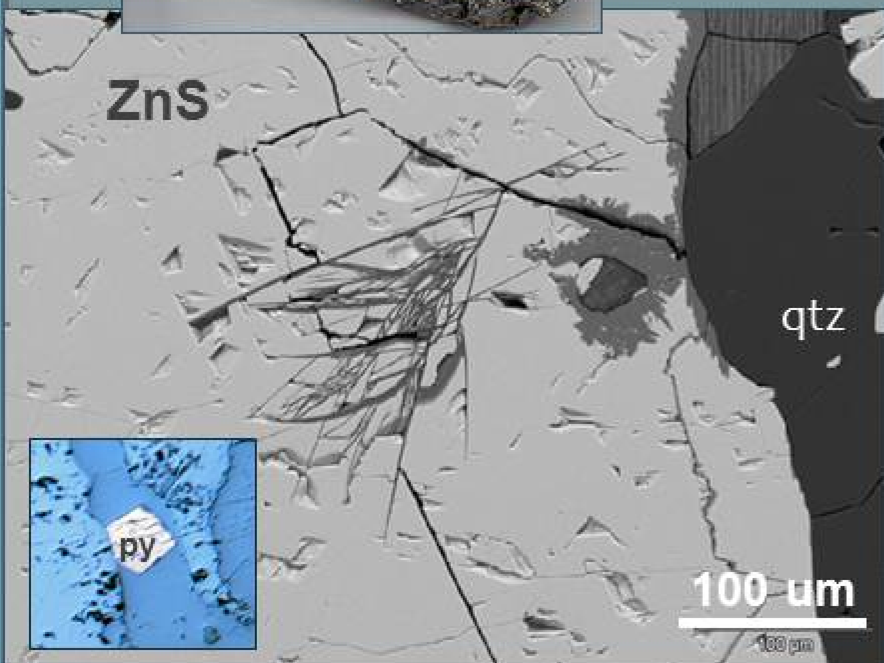
Selected Elements (FLT leachate)
➢ releases readily soluble phases



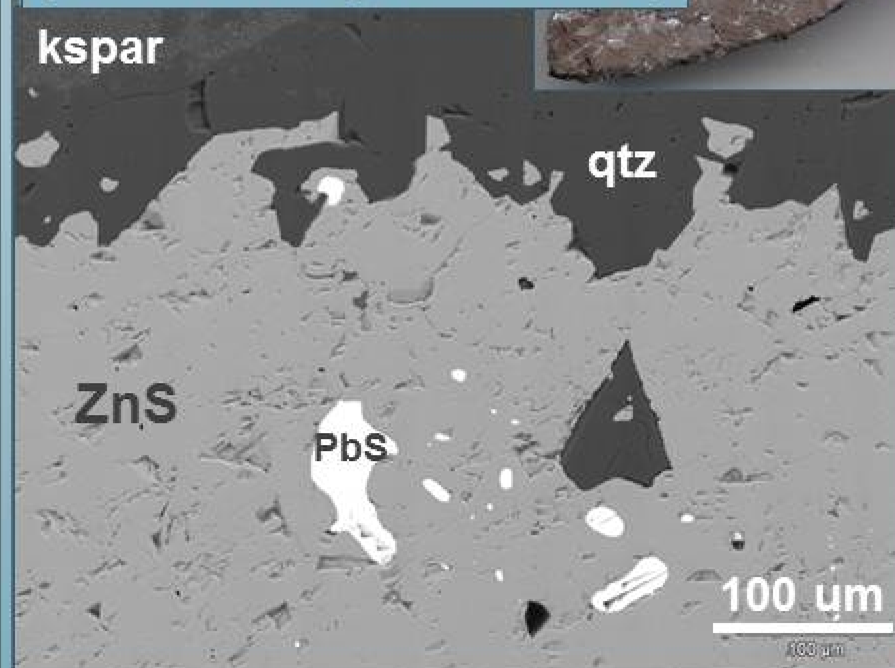
Sphalerite

Creede Vein



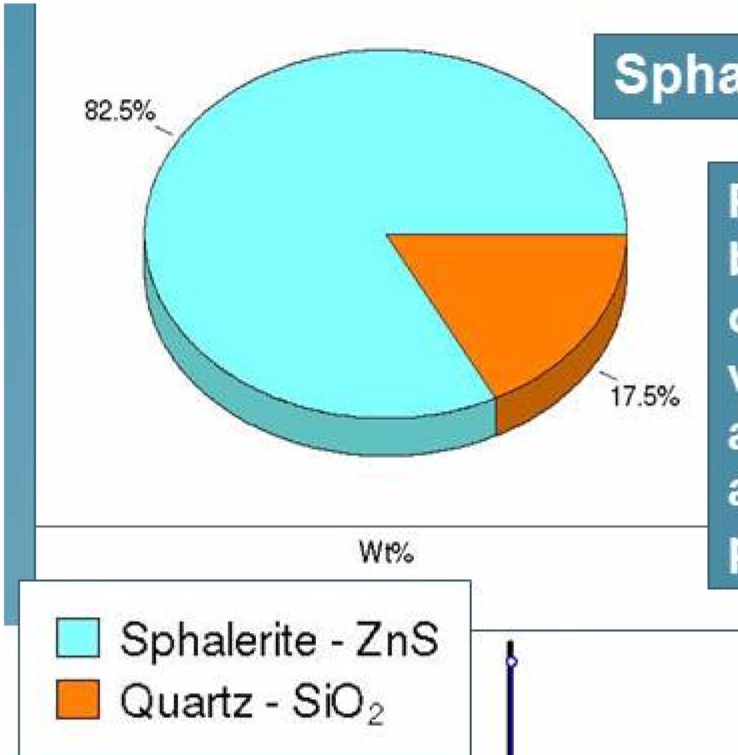
Note:
Alteration minerals along fractures.
Mineral inclusions such as pyrite.

Balmat SEDEX (sedimentary exhalative)

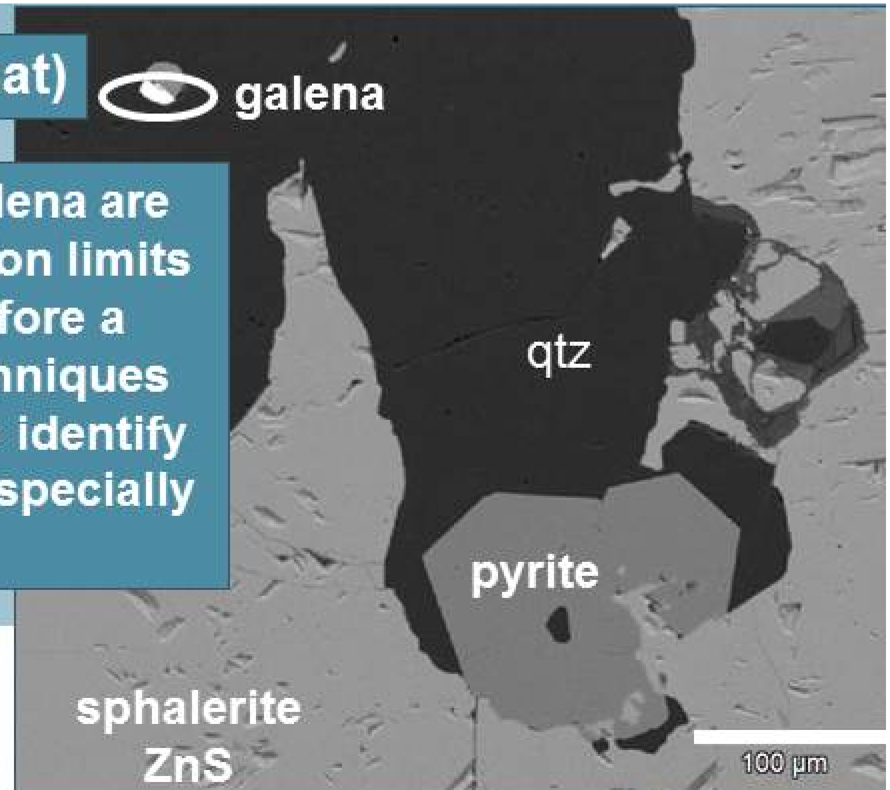


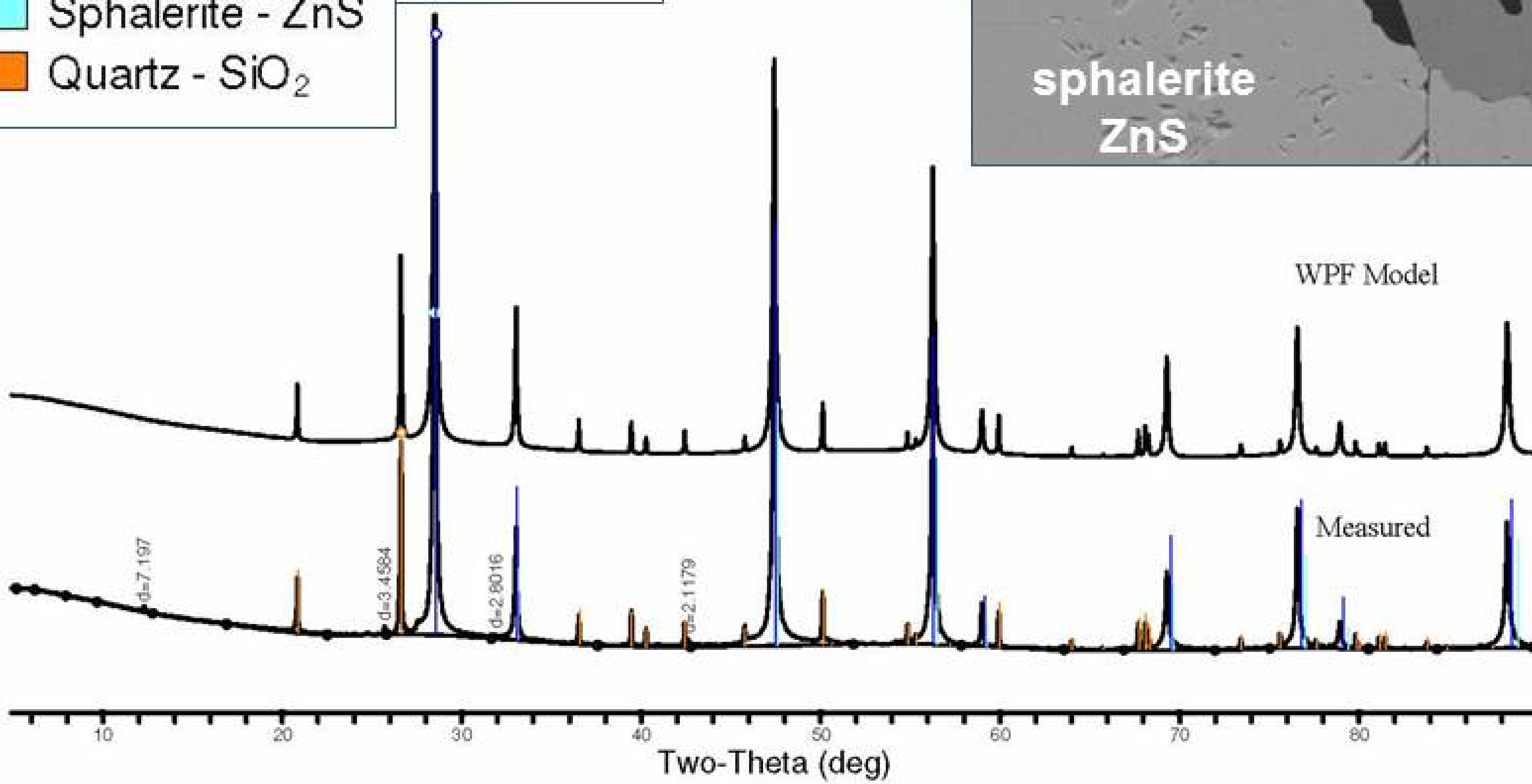
Note:
Mineral inclusions such as galena.

Sphalerite (Balmat)

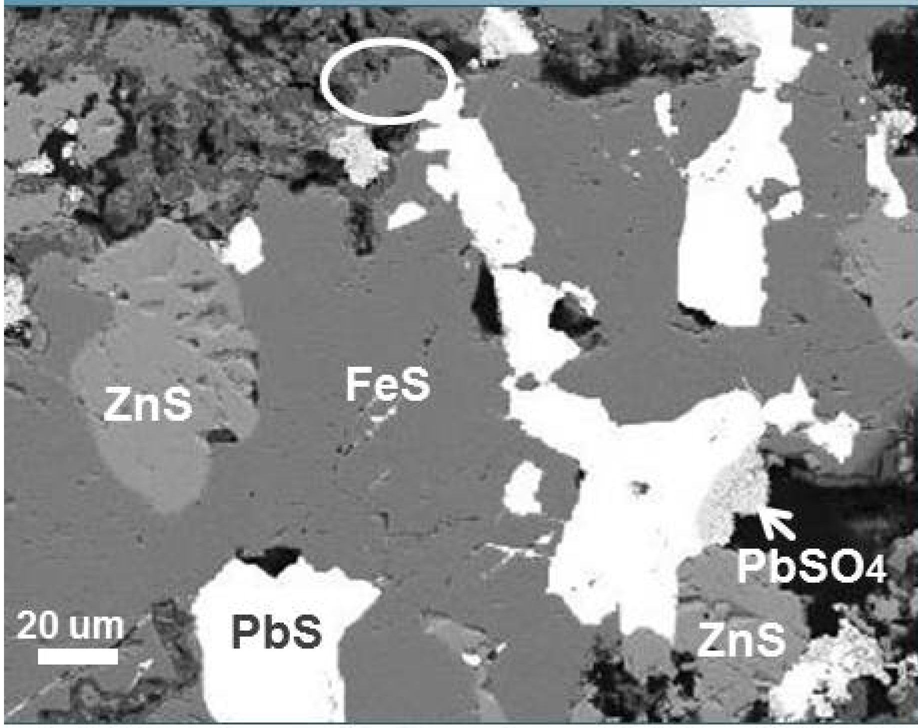


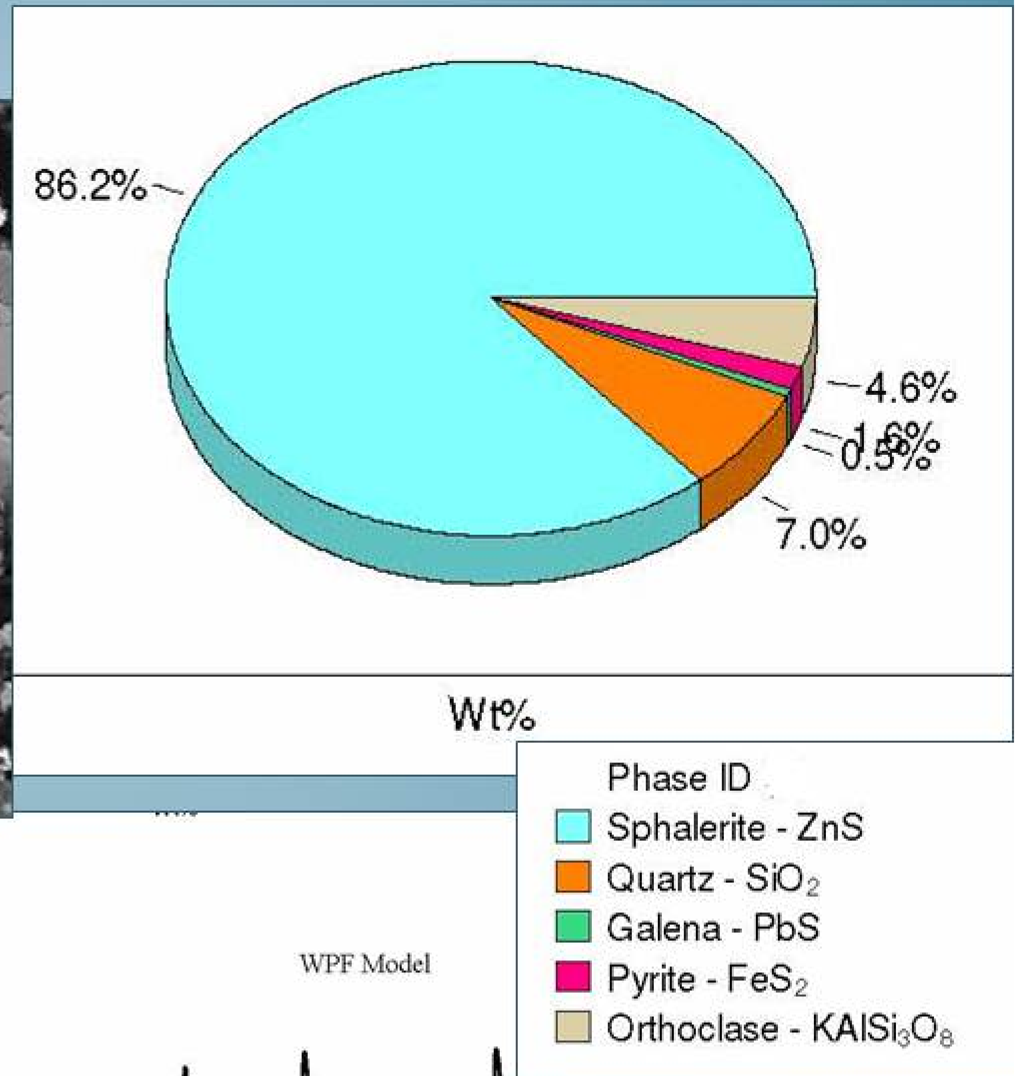
Pyrite and galena are below detection limits of XRD; therefore a variety of techniques are needed to identify all minerals-especially pyrite.

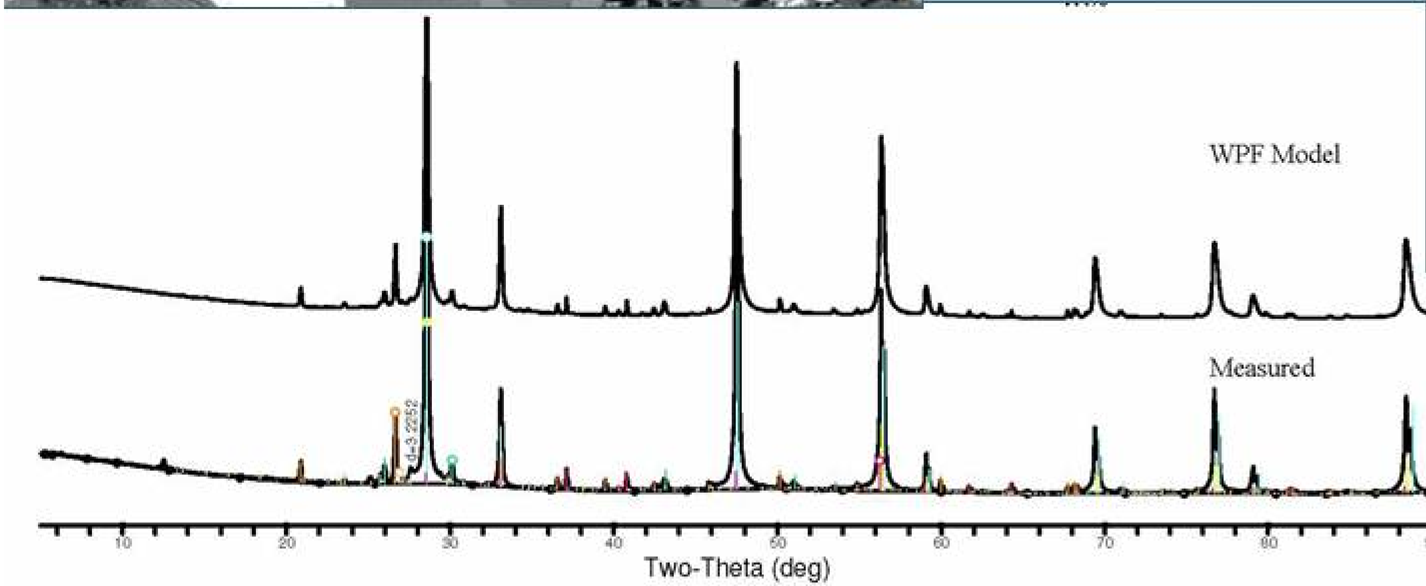




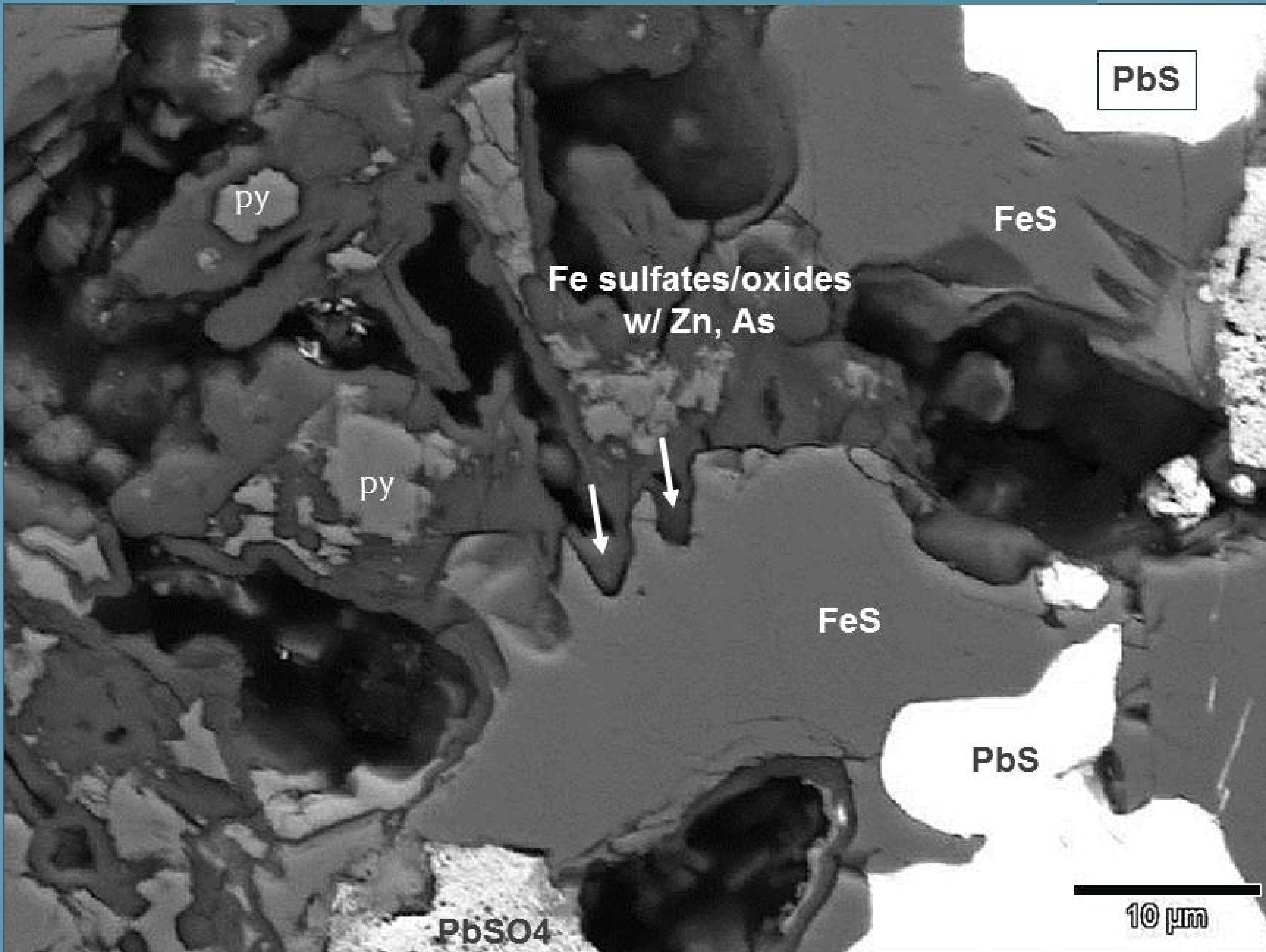
Sphalerite (Creede)



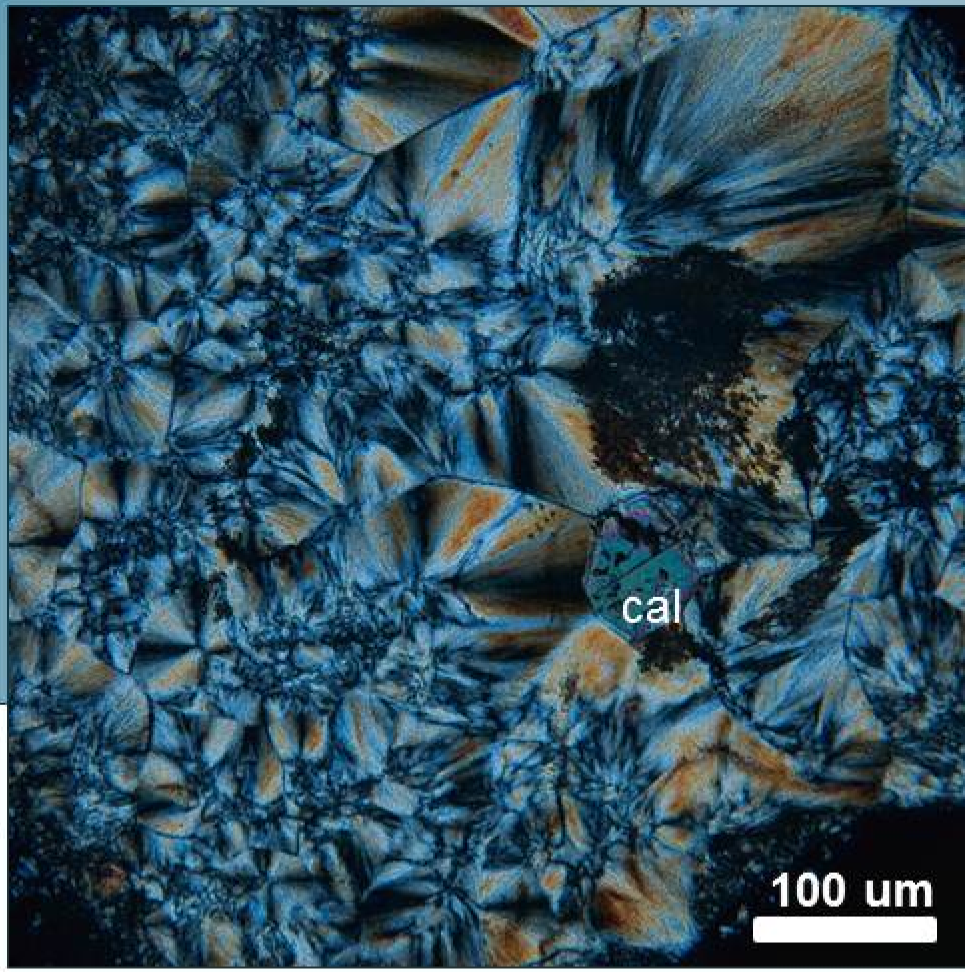


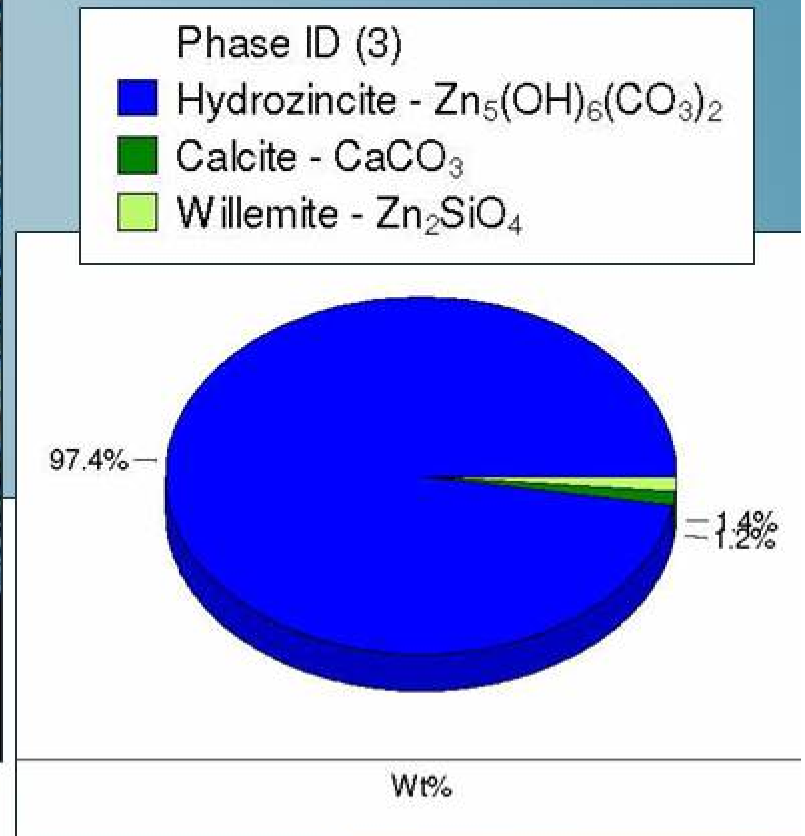


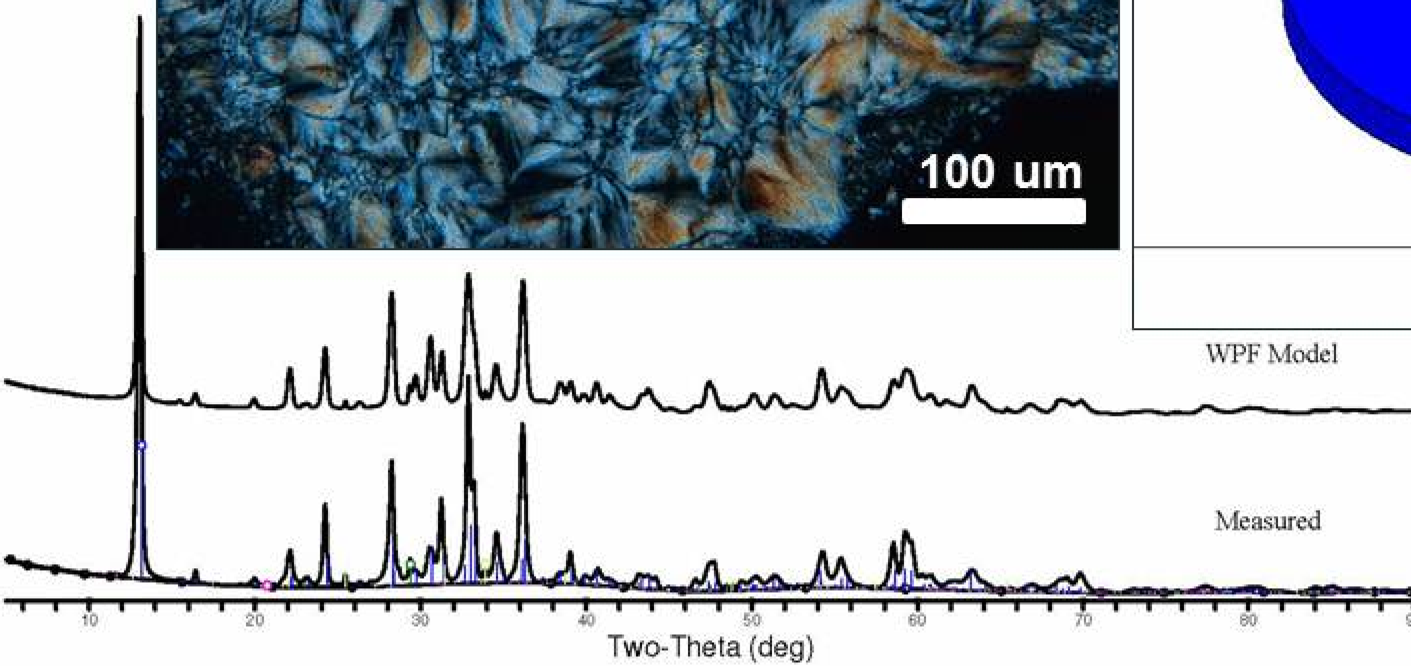
Secondary minerals and amorphous phases:

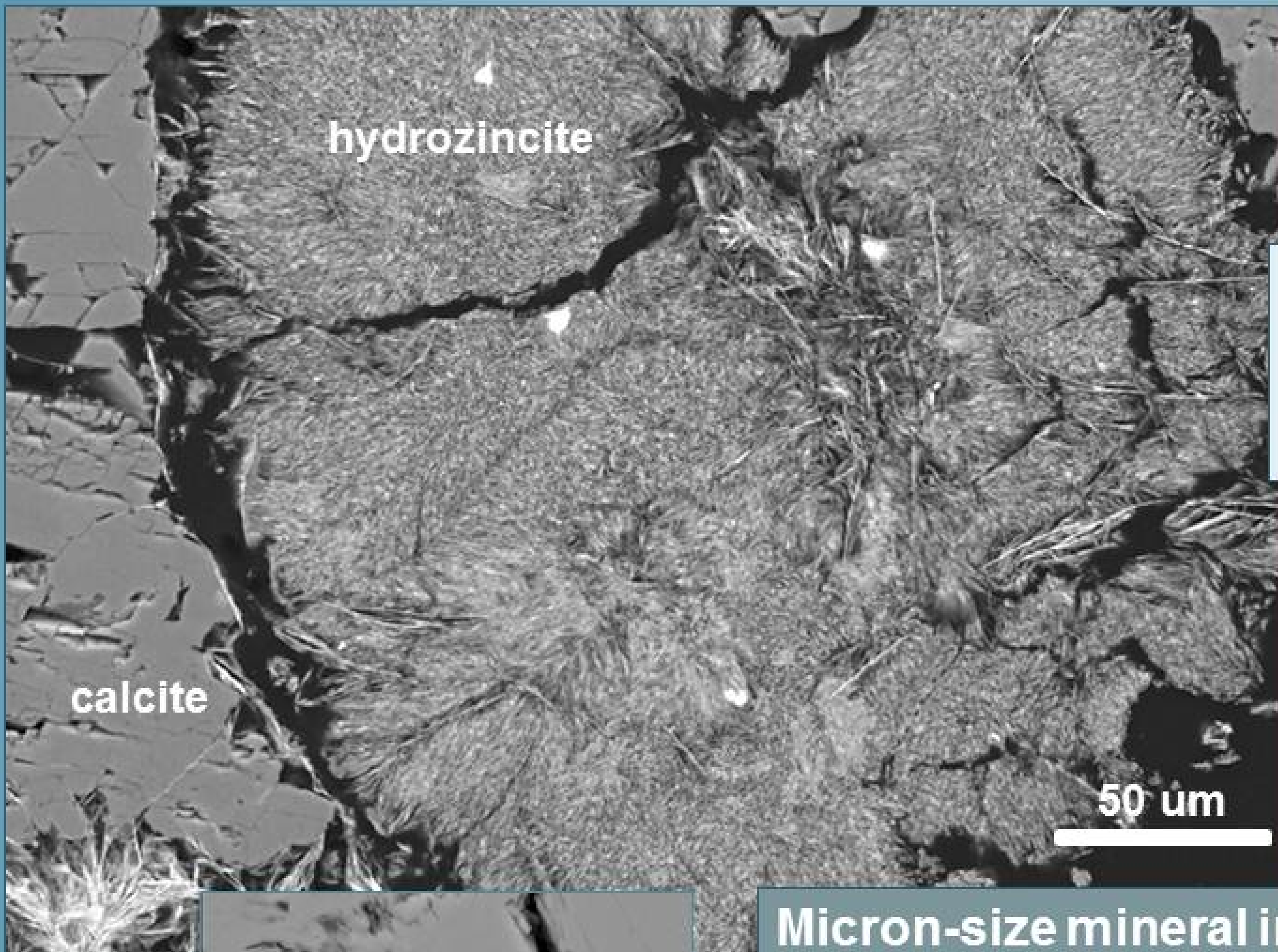


Hydrozincite/Willemite

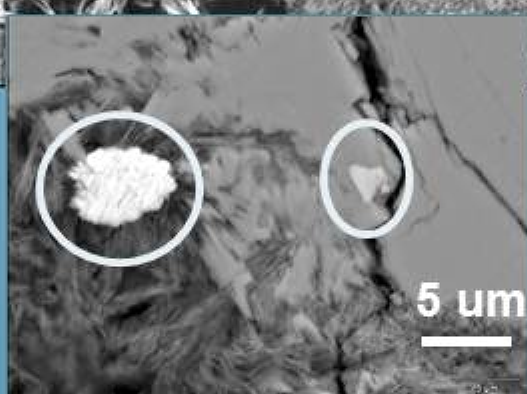








Hydrozincite adjacent to Cd-bearing calcite.



Micron-size mineral inclusions include:

- Cu, Zn mineralization
- Descloizite (Pb,Zn)$_2$(OH)VO_4)
- Ag, Sb mineralization

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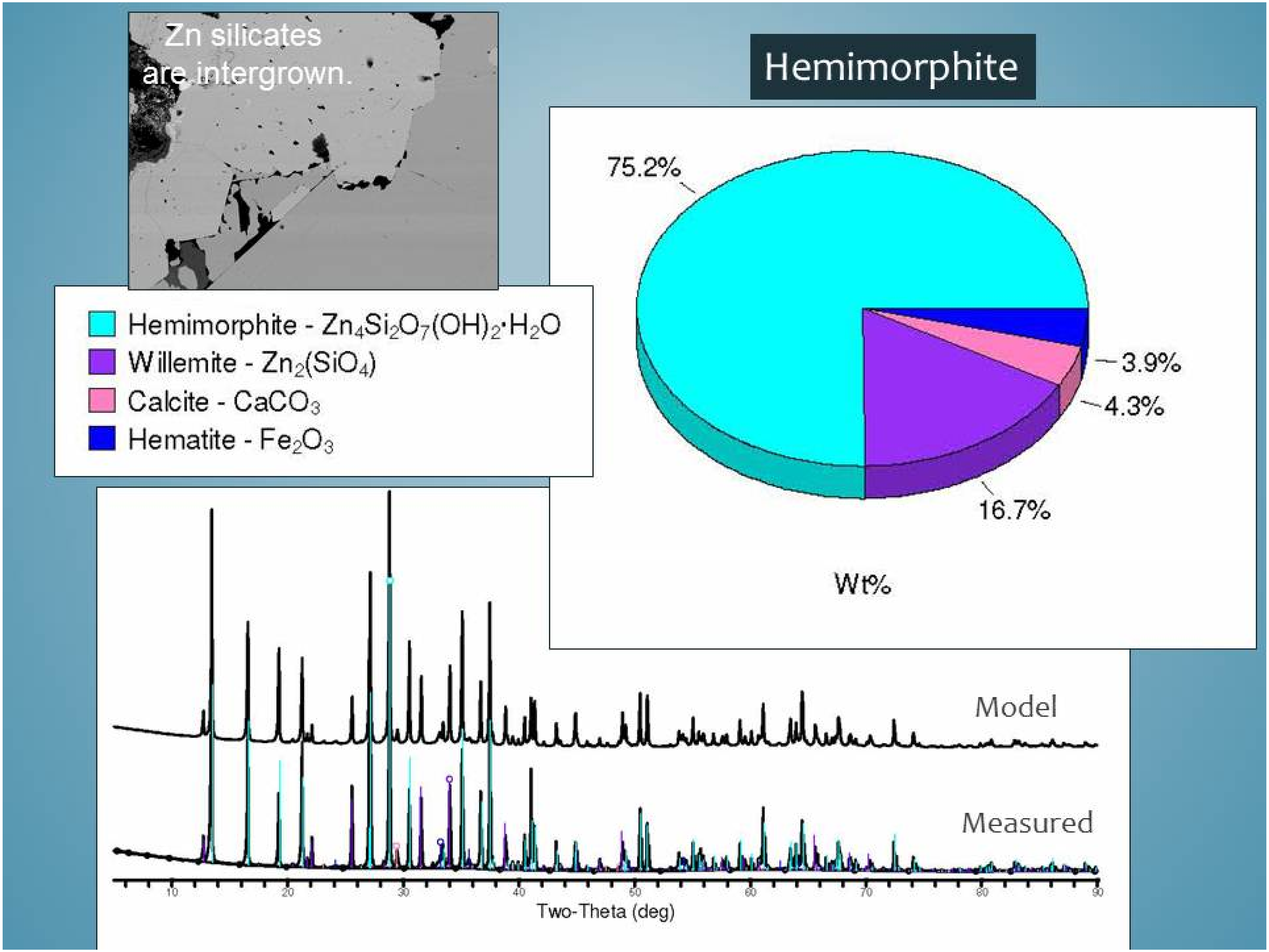
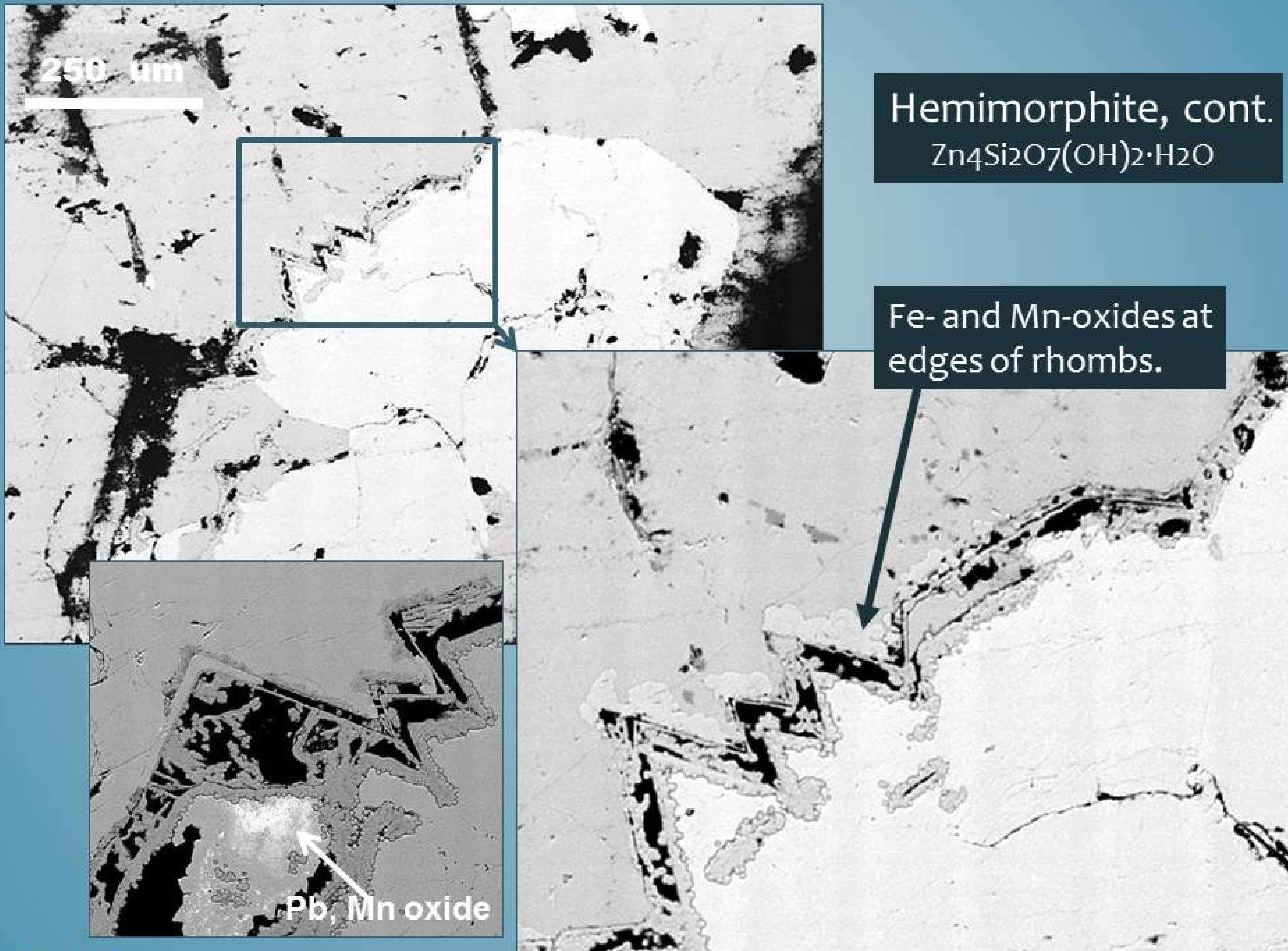
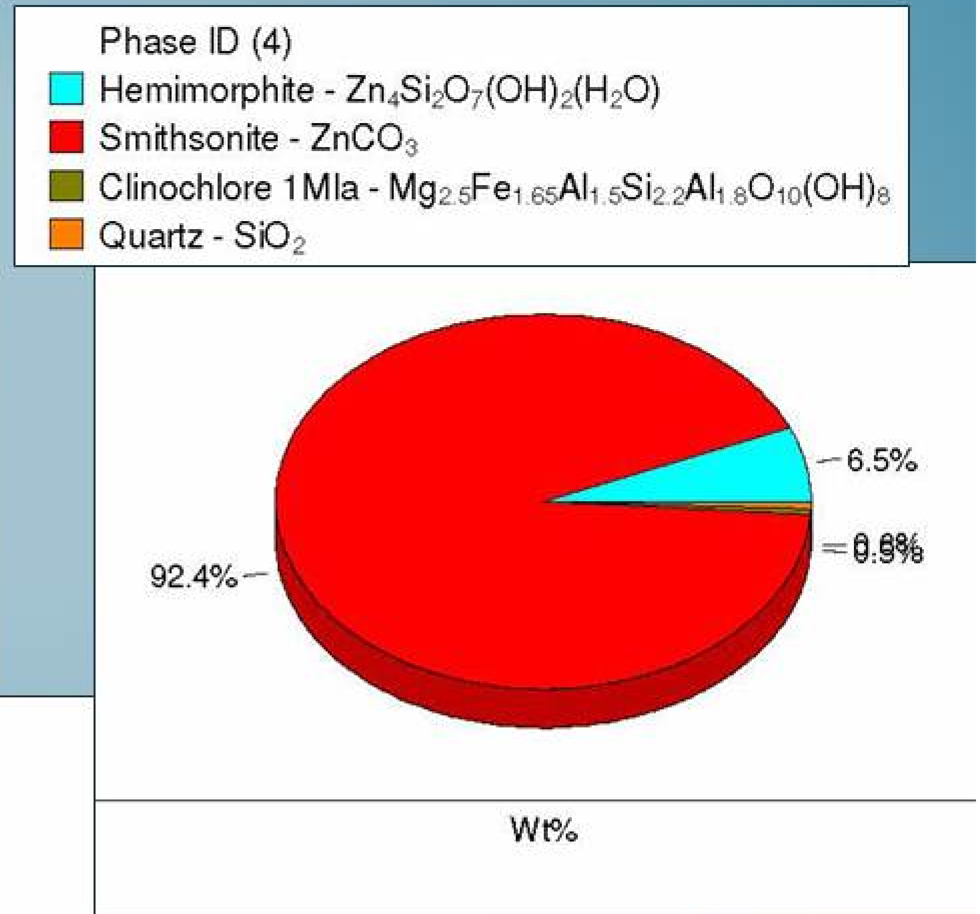


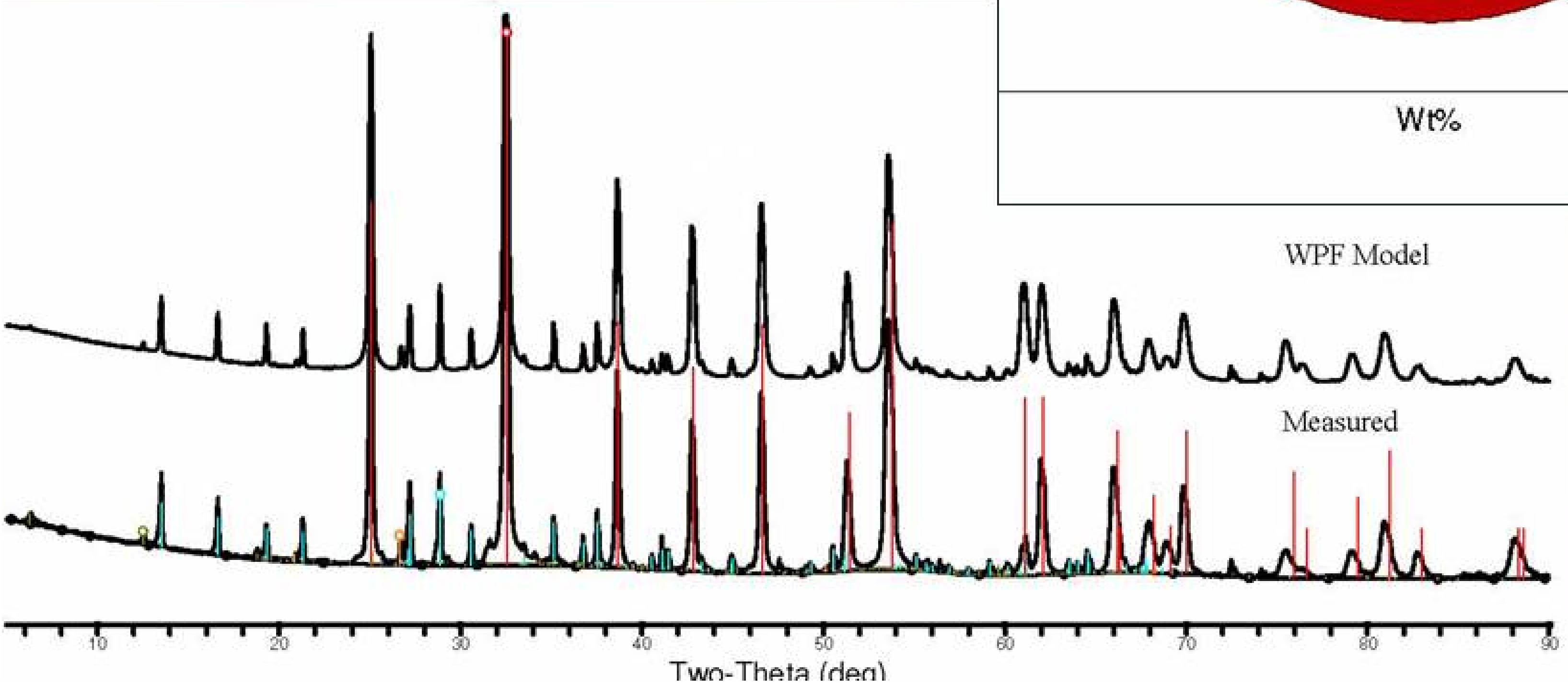
Hemimorphite
Zn silicates are intergrown.
Hemimorphite - $Zn_4Si_2O_7(OH)_2 \cdot H_2O$
Willemite - $Zn_2(SiO_4)$
Calcite - $CaCO_3$
Hematite - Fe_2O_3
75.2%
3.9%
4.3%
16.7%
Wt%
Model
Measured
10
20
30
40
50
60
70
80
90
Two-Theta (deg)

Hemimorphite, cont.
$Zn_4Si_2O_7(OH)_2 \cdot H_2O$




Smithsonite
ZnCO3
100 micron

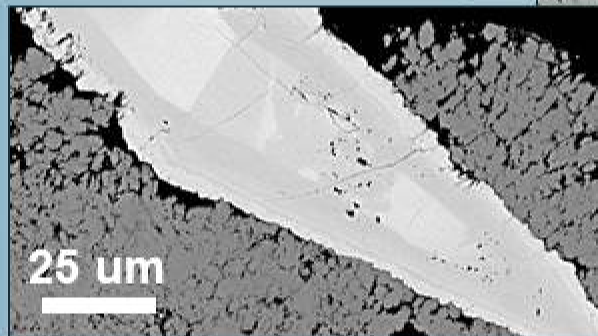

Phase ID (4)
Hemimorphite - $Zn_4Si_2O_7(OH)_2(H_2O)$
Smithsonite - $ZnCO_3$
Clinochlore 1MIa - $Mg_{2.5}Fe_{1.65}Al_{1.5}Si_{2.2}Al_{1.8}O_{10}(OH)_8$
Quartz - SiO_2
6.5%
92.4%
Wt%

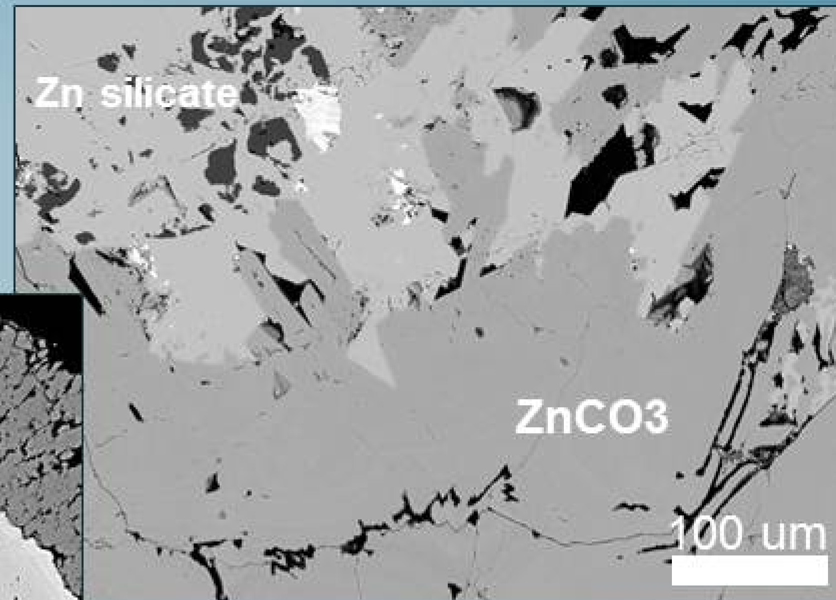

WPF Model
Measured
10
20
30
40
50
60
70
80
90
Two-Theta (deg)

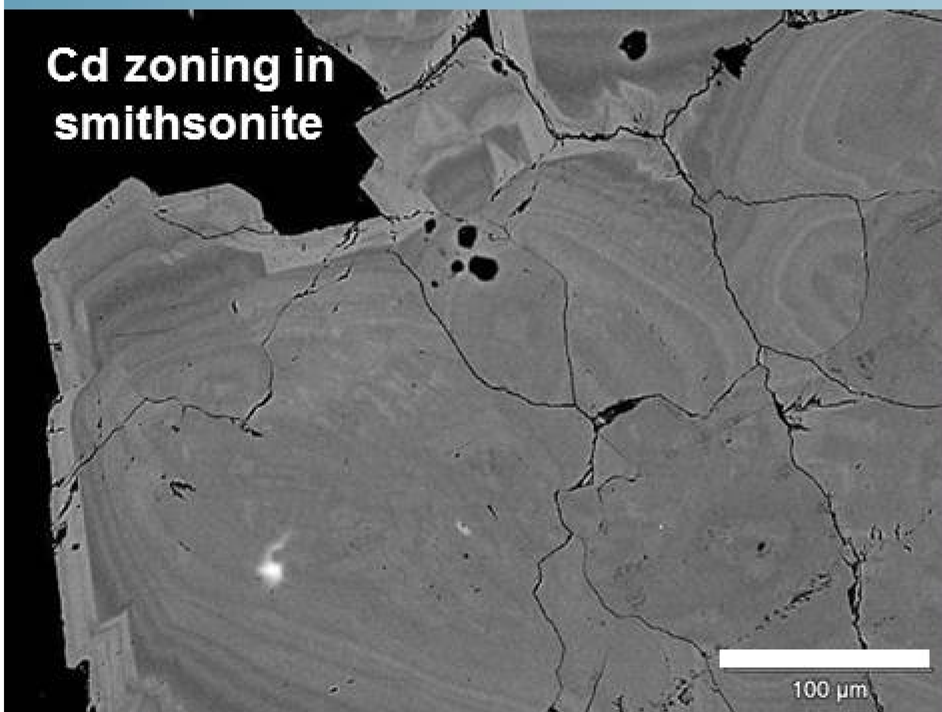
Smithsonite, cont.

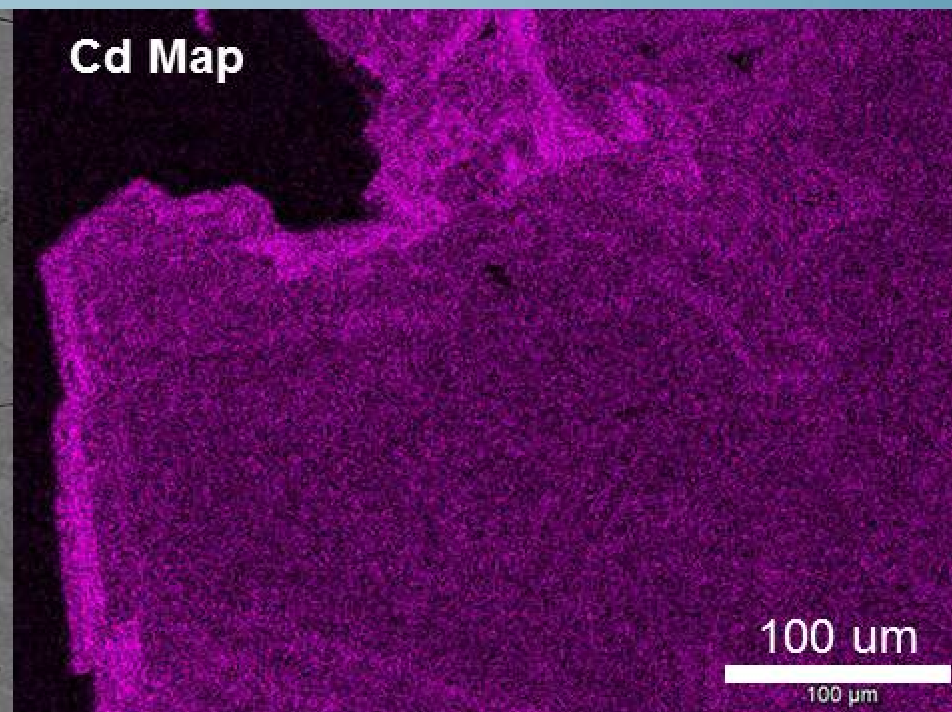
- •Zn silicates intergrown with smithsonite.
- •Smithsonite exhibits Ca and Cd zoning.

- Zn silicate exhibits Pb zoning.









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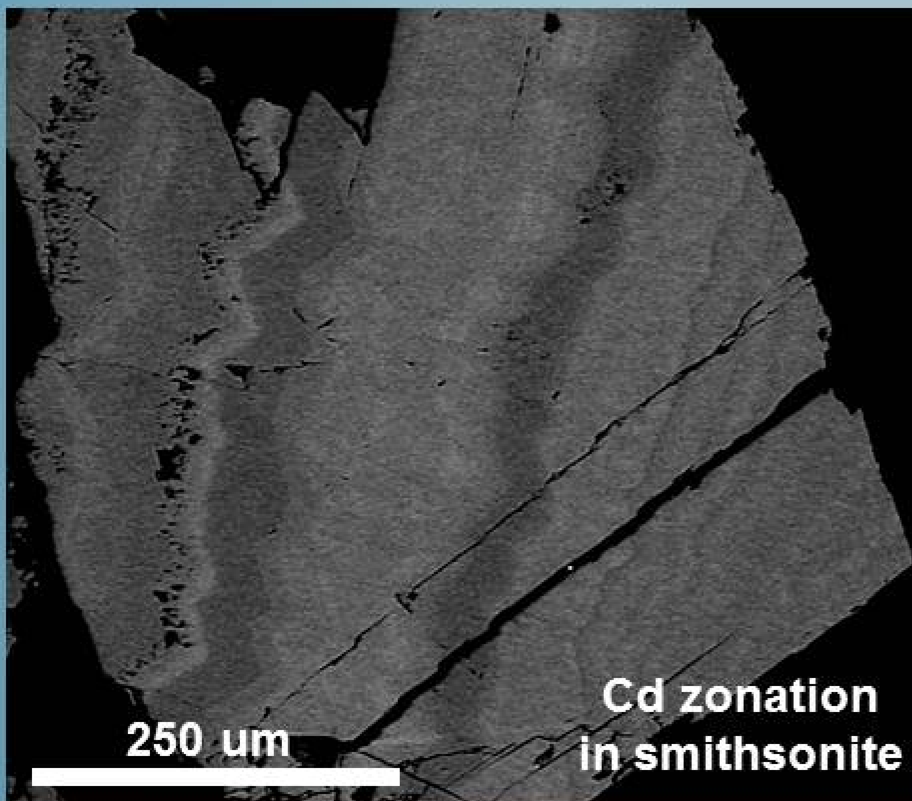
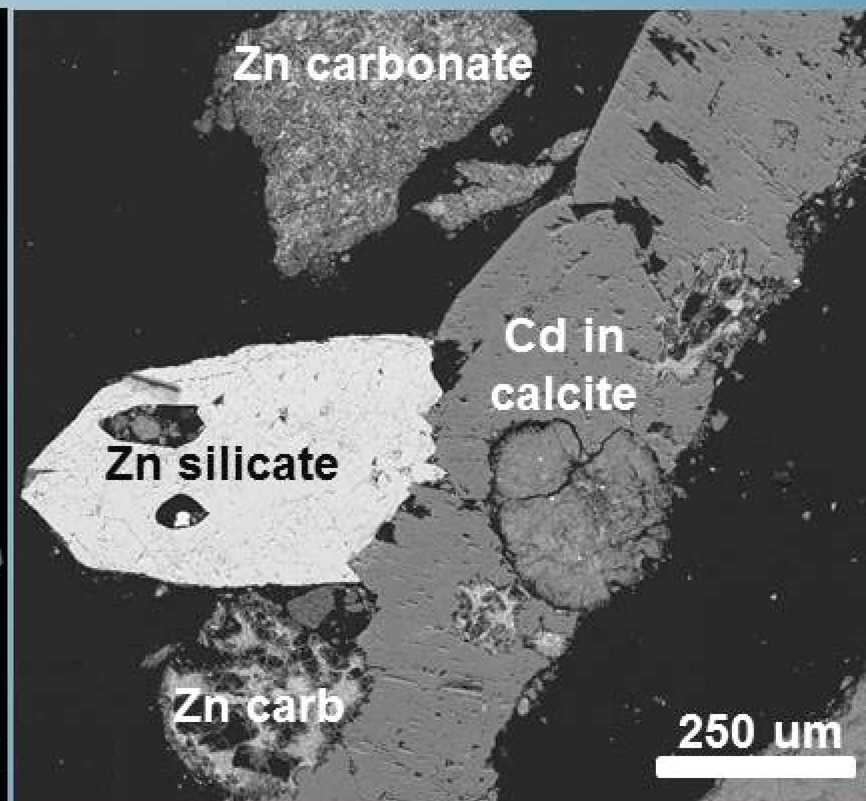
Two Zn carbonates with elevated Cd content in leachates:

- **Hydrozincite**
- **Smithsonite**

Different physical, chemical properties of Cd-bearing source material = different solubilities





$\geq$ 3 wt. % Cd in smithsonite

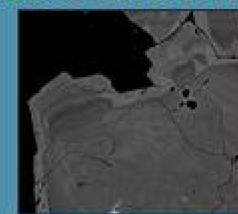
$\leq$ 3 wt. % Cd in calcite

Summary

In general:

- Trace metals are associated with characteristic geologic settings and their mineral assemblages.

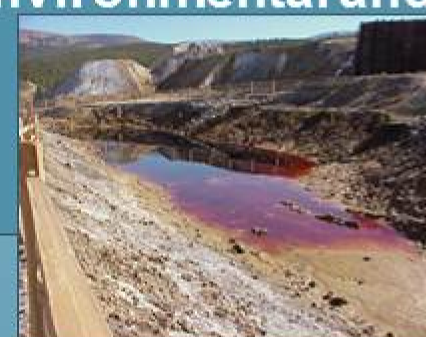
- Micromineralogic analysis is useful for better prediction of trace metal release and acid rock drainage from mine waste.



Monomineral Study:

- Water-based leach tests provide a more realistic indication of "naturally" leachable Zn concentrations in this 'monomineral' set.

- The data we acquire on the mobility of elements and degree of solubility of minerals will be assembled in a database for use in predictive acid rock drainage models and contribute to the broader understanding of minerals in natural systems and their importance in environmental and human health studies.



Future monomineral set/study: Pb and As

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Coming soon: “Techniques for Predicting Metal Mine Influenced Water

The Acid Drainage Technology Initiative (ADTI) and Society for Mining Metallurgy and Exploration (SME) developed a series of workbooks covering the generation and prevention of acid rock drainage.

Management Technologies for Metal Mining Influenced Water Volumes:

- Basics of Metal Mining Influenced Water
- Mitigation of Metal Mine Influenced Water
- Mine Pit Lakes: Characteristics, Predictive Modeling and Sustainability

The Prediction Volume (Dave Williams, BLM, senior editor):

“Techniques for Predicting Metal Mine Influenced Water” is next in this series and presents a summary of the various predictive technologies available, as well as establishing criteria for use in evaluating some of the most commonly used predictive tests.

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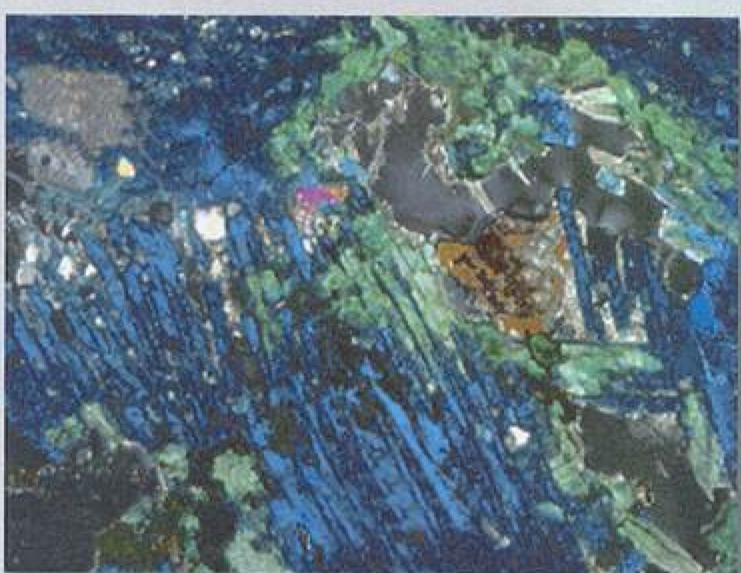
Assessment of the Geoavailability of Trace Elements from Minerals in Mine Wastes: Analytical Techniques and Assessment of Selected Copper Minerals



Scientific Investigations Report 2011–5211

U.S. Department of the Interior
U.S. Geological Survey

Contents:

Mineralogical Analyses

Bulk, Leachate, and Acid-Base Accounting

In Vitro Bioaccessibility Extractions
    ingestion, inhalation pathways

Procedure for Determination of Metal Toxicity Using MetPLATE

Acknowledgements:

Study funded by the USGS Mineral Resources Program