# Hyperspectral UAV-Sensing for Monitoring Tailing Ponds: Towards Responsible Resource Repurposing

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Technische Hochschule Georg Agricola

# Research Center of Post-Mining


Perpetual tasks and mine water management

Geomonitoring in post-mining

Material sciences for the preservation of Industrial Heritage

Reactivation and Transition

# Agenda

**Motivation**

Review on current and future supply (primary and secondary) of metals for reaching climate neutral economy

**Background**

The critical importance of mine waste in a circular economy

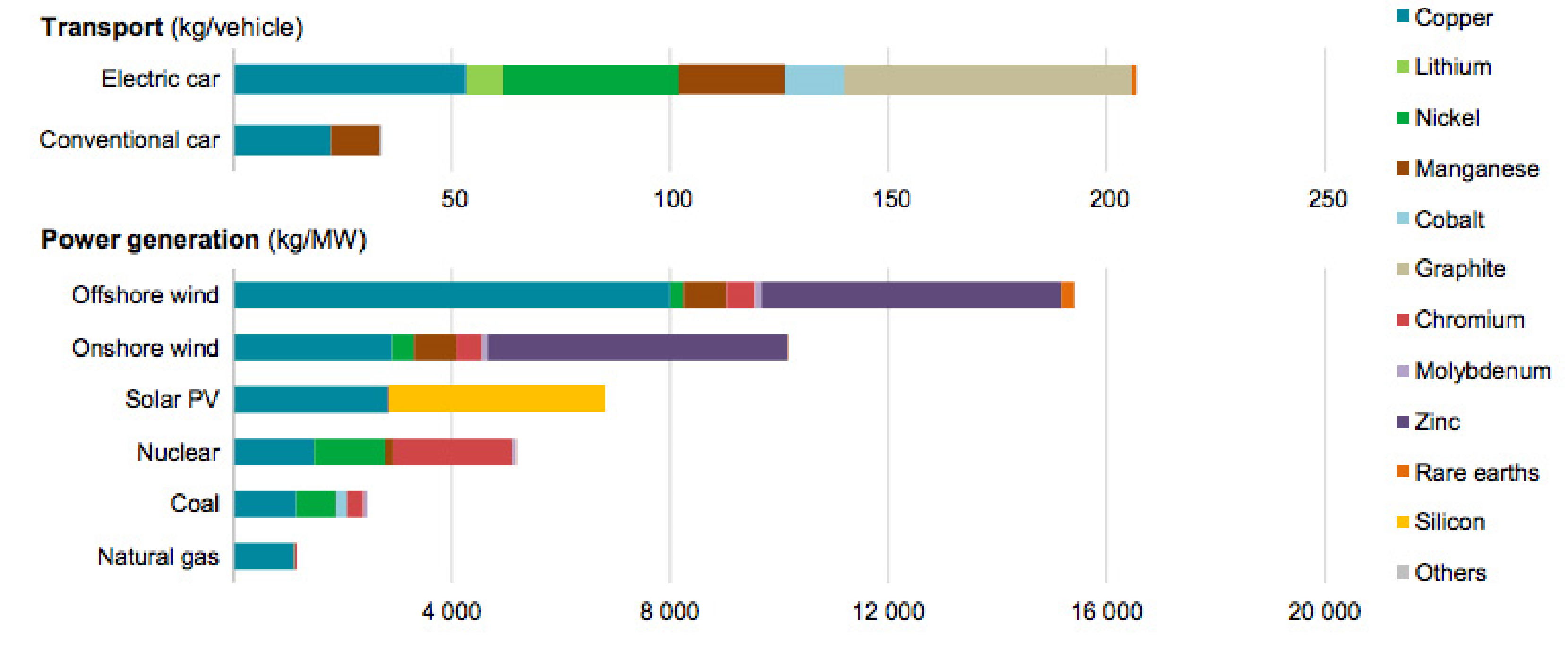
**Methodology** | **Case Study**

Innovative tools for characterization and monitoring mine waste constellations

**Results** | **Outlook**

Research and development, multi-scale applications

# Clean energy transitions are driving a significant increase in mineral demand




*Electric vehicles use close* ***to ten times*** *the material of conventional cars*

*Reaching net zero by 2050 will require about* ***six times today's*** *critical mineral use in 2040.*

Source: International Energy Agency (IEA).

# We can't have sustainable mines, but we can have responsible mines

## Technology & Environment

- Safer Tailings Management
- Water Recycling
- Acid Mine Drainage
- Site Remediation
- Clean Energy Sources
- Digitalization, Robotics

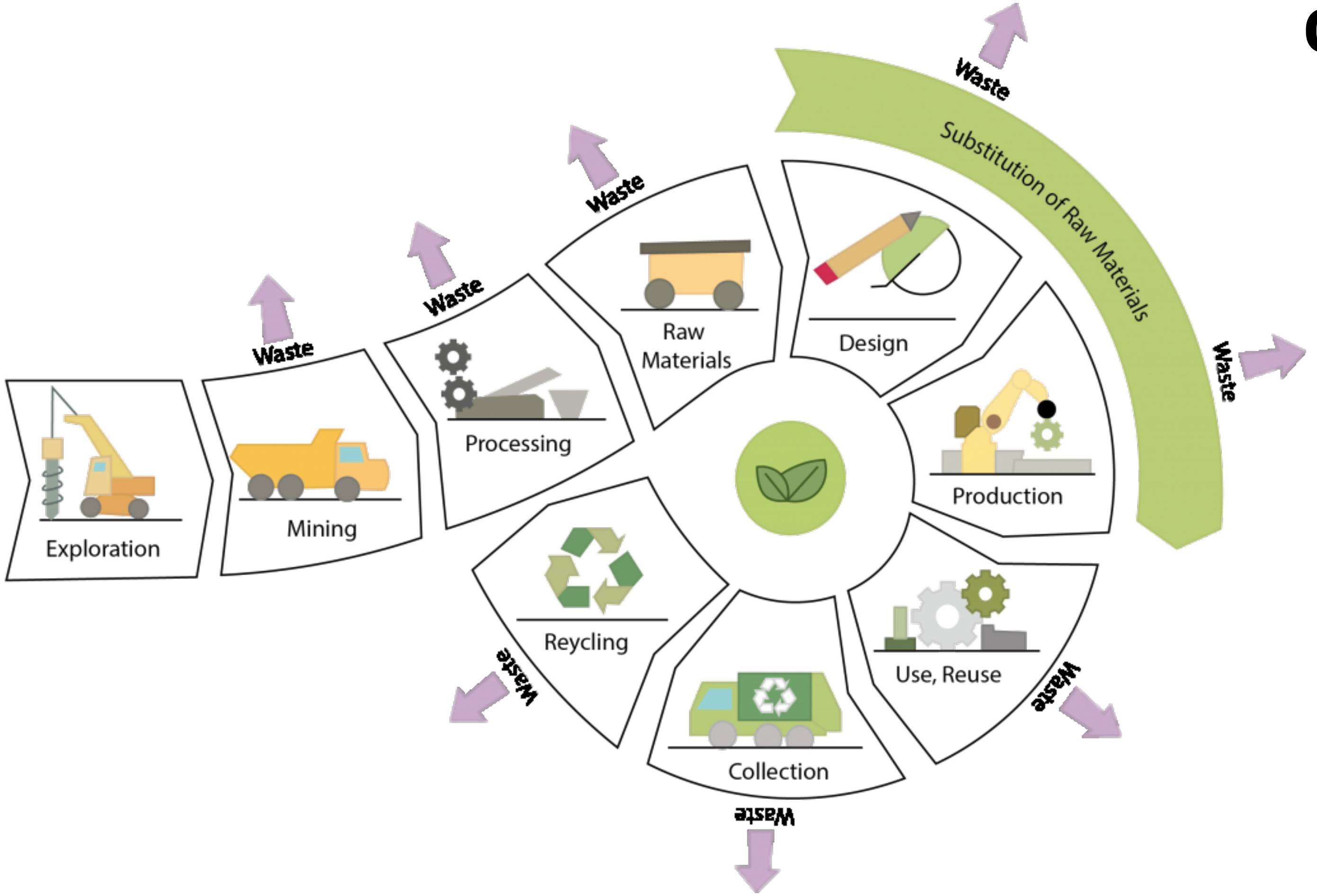
## Social Responsibility

- Corporate Governance
- Social Responsibility
- Transparency
- Due Diligence of Supply Chains

Source: Adopted from Pirard, 2023

Bauxite tailings upstream dam, located next to the Aluminio municipality in countryside of São Paulo (Source: NGI), 2023

# Responsible mining and circular economy



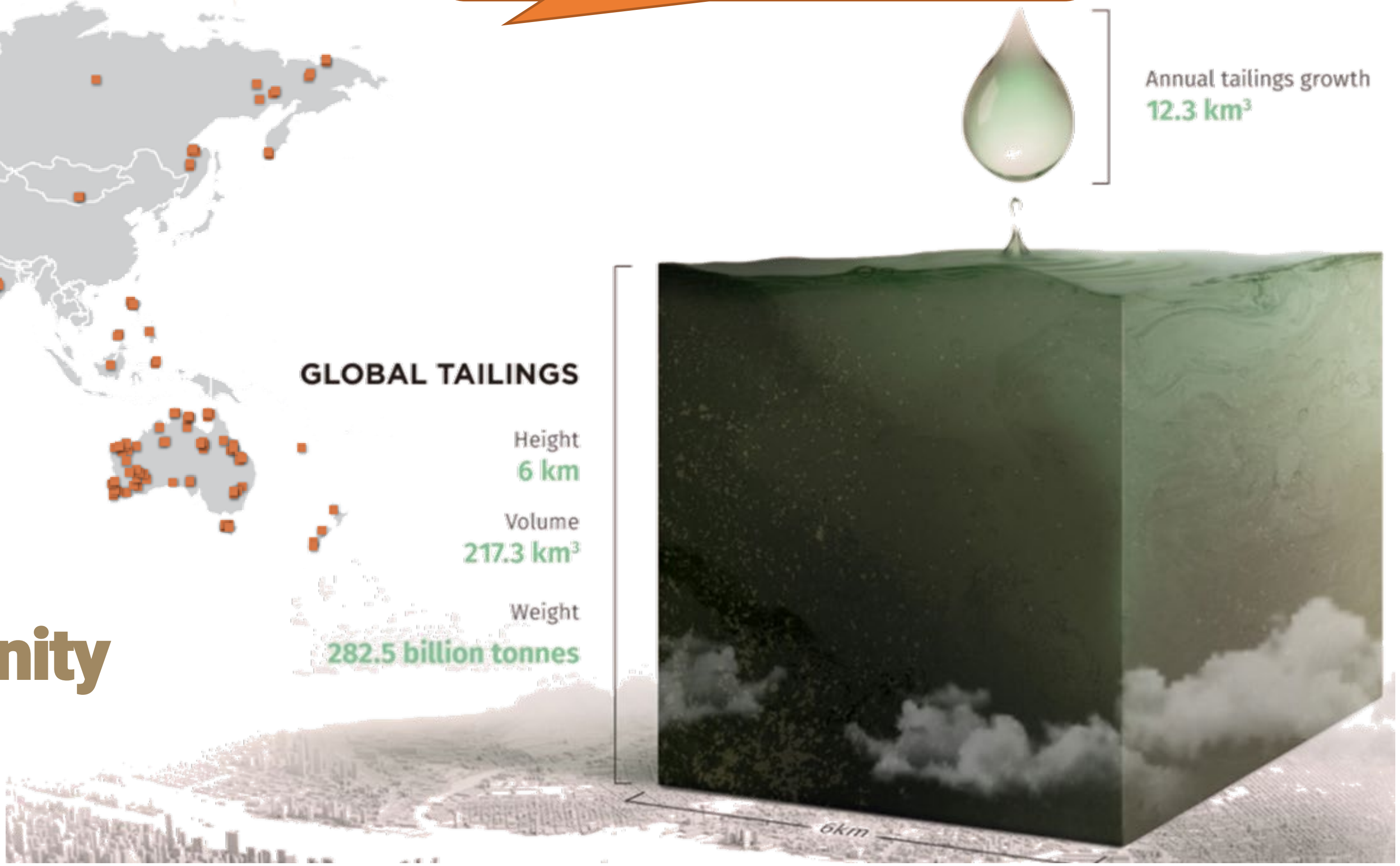

**Globally, 30 Gt of waste material per annum is removed, handled and placed into final repositories or landforms**

**Several types of waste are generated in a mine, but three types stand out with the largest volume:**
**waste rock,**
**tailings**
**and mine water.**

Source: Novotek Group, 2022

# Environmental threat or blessing?

>1000 waste rock dumps and tailing storage facilities categorized




## Mining Mine Waste Opportunity

**Critical Raw Materials (CRM) and Rare Earths (REEs)**

Source: Safety First. Guidelines for Responsible Mine Tailings Management Earthworks, 2022

Source: USGS, 2016; Mudd, 2020, Global Tailings Review, Elements Visual Capitalist, 2021

# Take-make-dispose to make-use-return

## Waste rock

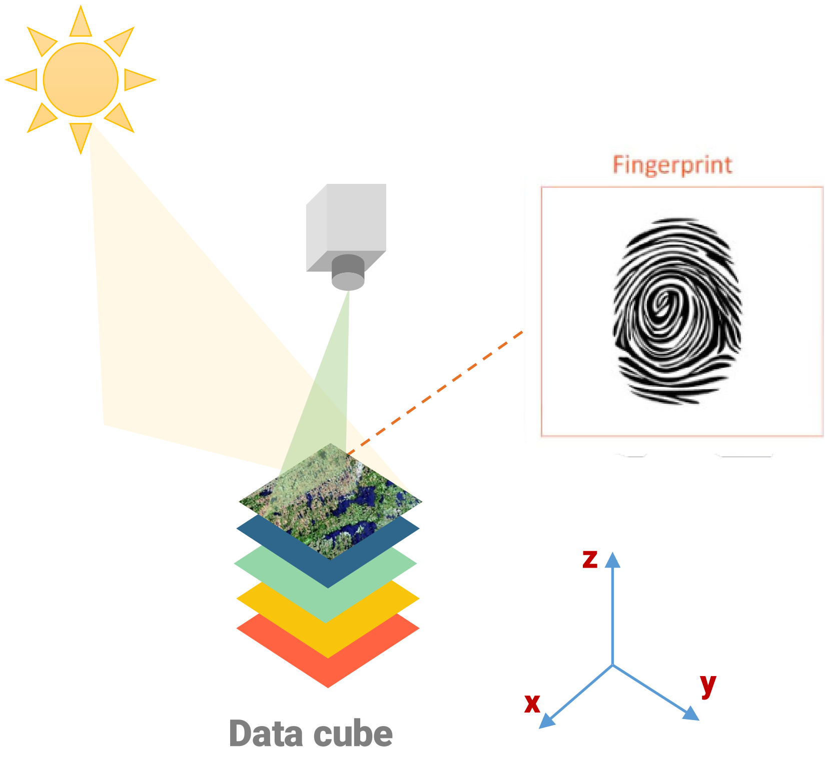
## Tailings

## Mine Water

**Improving methodologies for predicting the behavior of future mine wastes, in order to protect communities, reduce liabilities and realize potential economic benefits.**

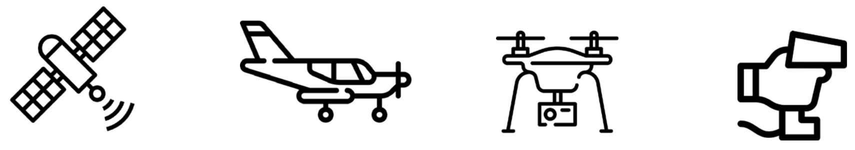
# Non-invasive environmental monitoring tools

# Spectral-sensor technology



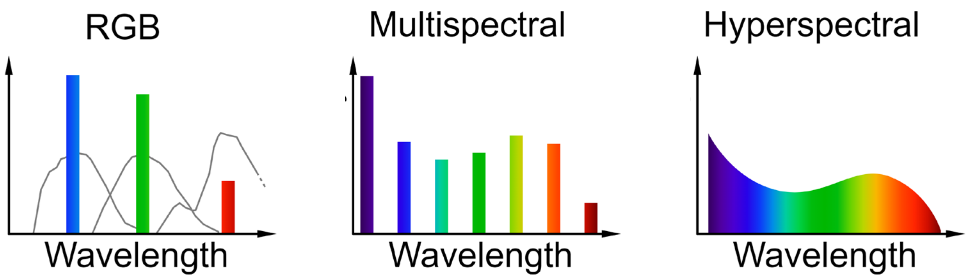

## Spatial

++ resolution -- resolution

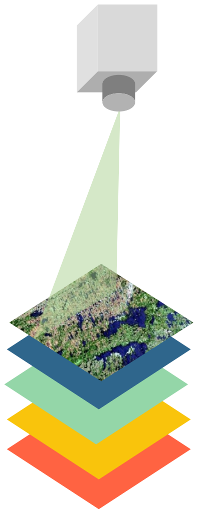


## Spectral

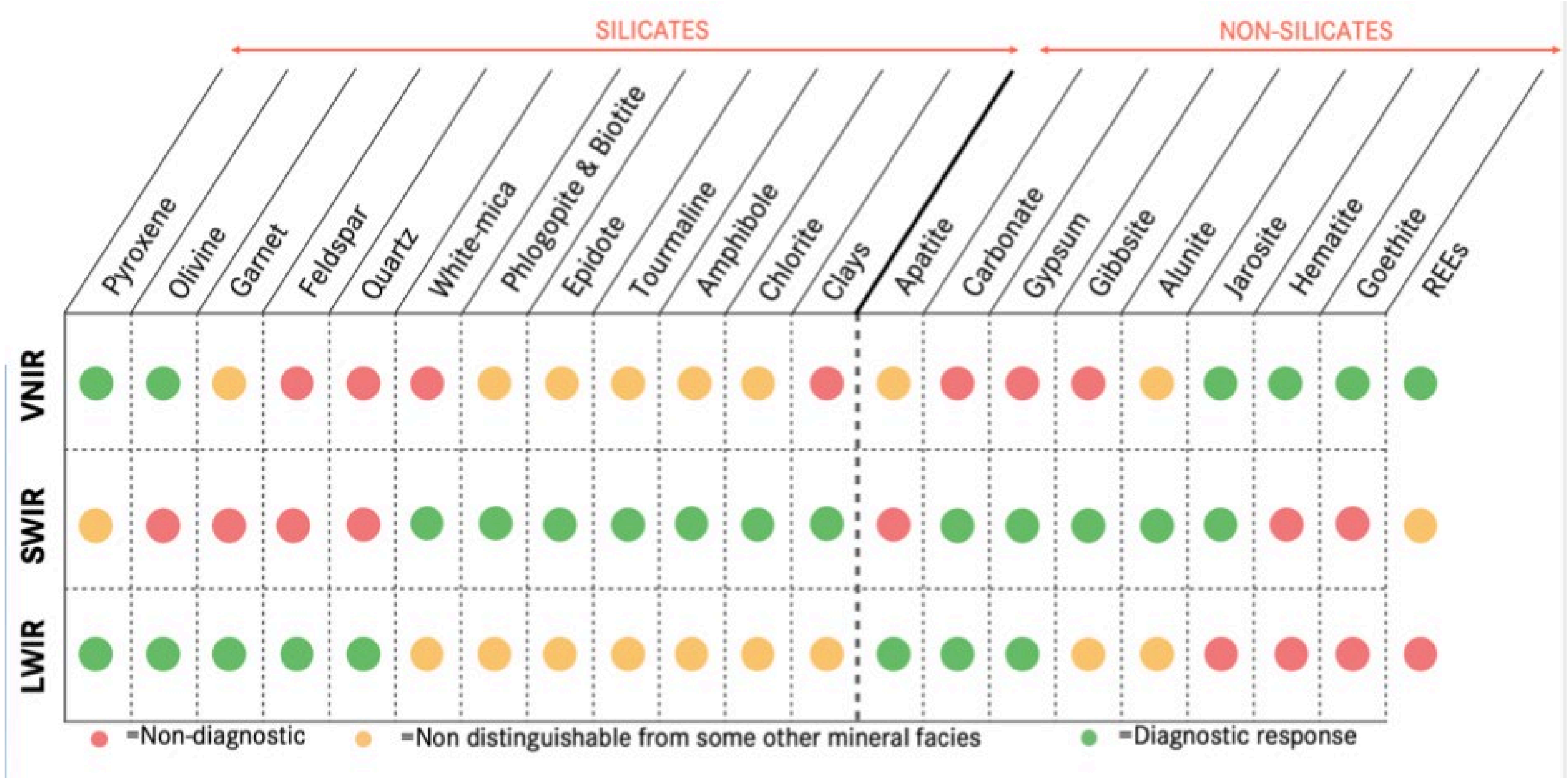
-- resolution ++ resolution



# Hyperspectral mineral detection



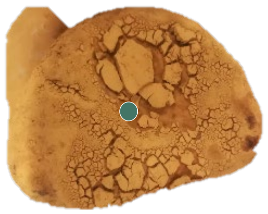
Data cube




Source: Adopted to Booysen, R. et al, 2020

# Spectral imaging as a tool for AMD mineral detection

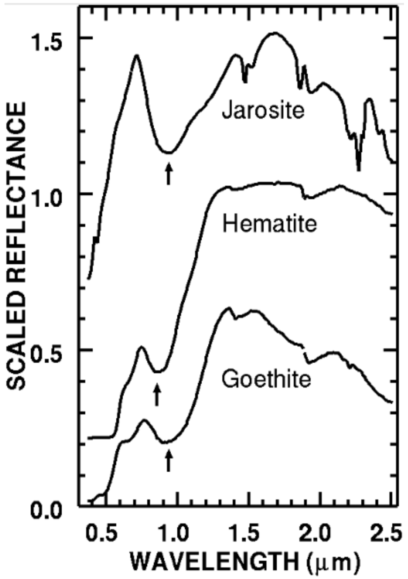
## Common AMD proxy minerals Spectra

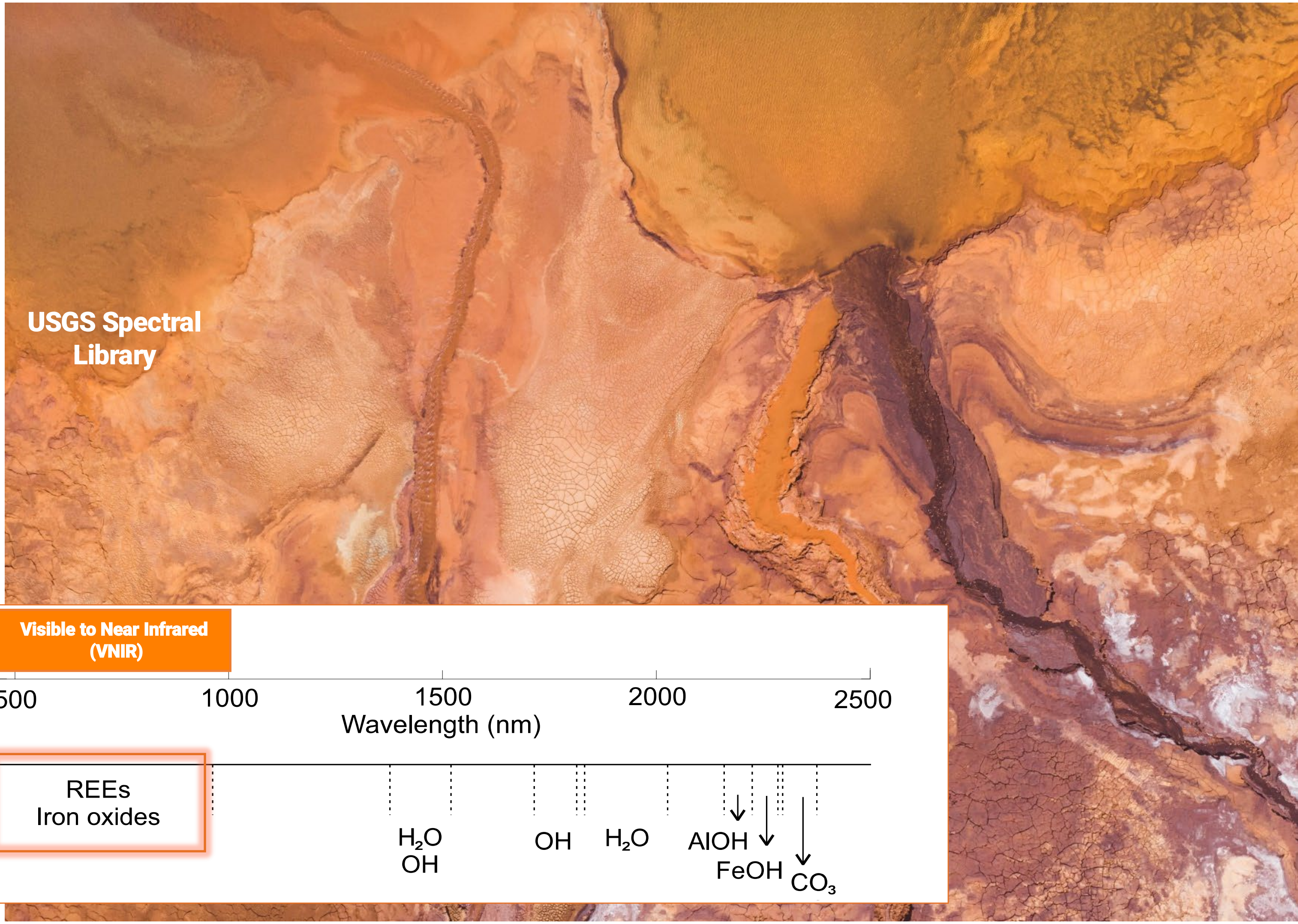

Jarosite


Hematite


Goethite

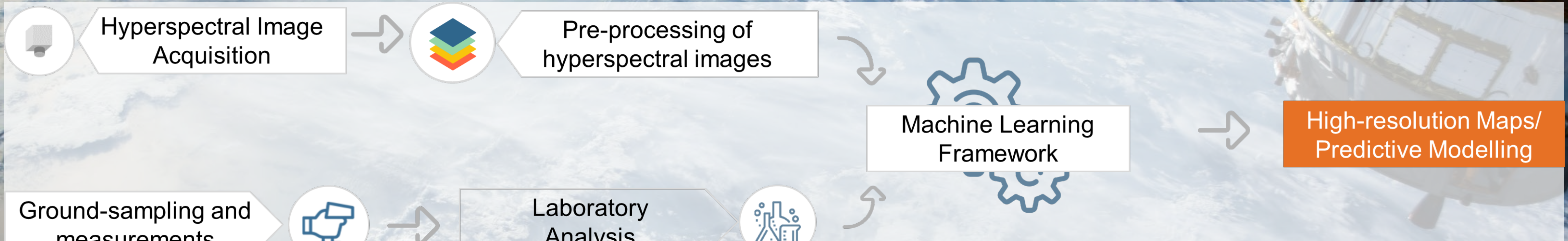
5 cm




Hunt, 1977, Clark, 1999, Crowley, 2003

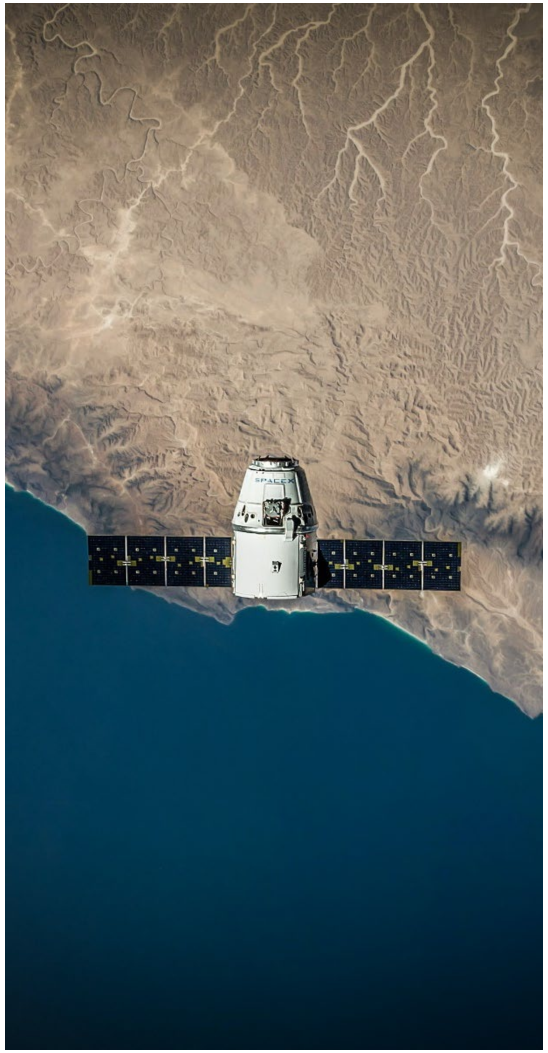
# Multi-scale workflow



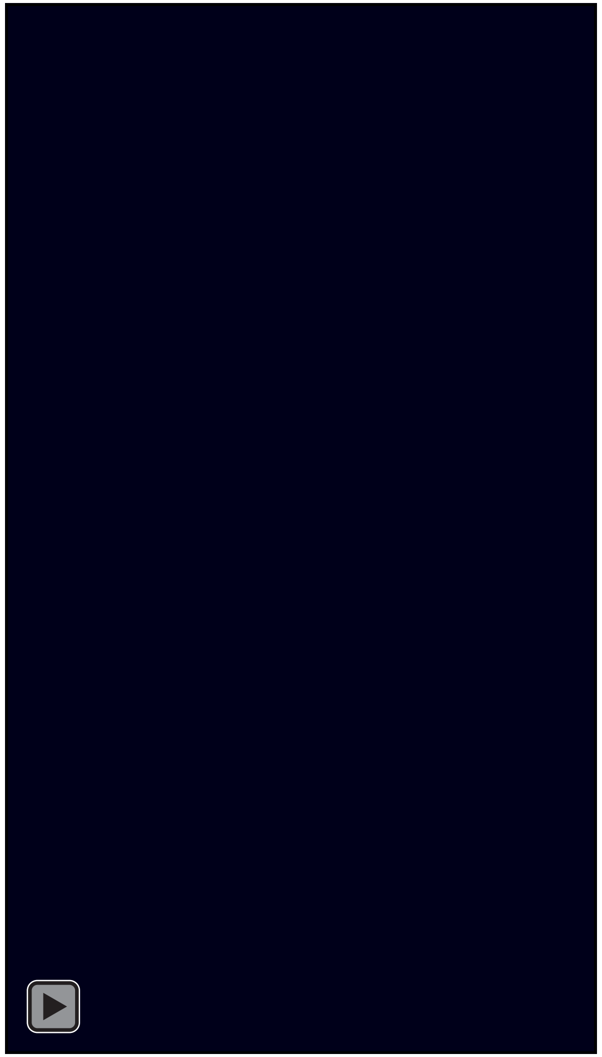

Source: Flores et al, 2021, Flores et al 2023

**Regardless the scale of acquisition, this methodology involves the integration of two main datasets, spectral data cubes and state-of-the-art geochemical analyses over specific samples as training data using machine-learning techniques.**

# From satellite to laboratory




THGA-FZN, 2023



TUBAF, 2022

# Tailing ponds application

Forschungszentrum Nachbergbau

Technische Hochschule Georg Agricola

RAG STIFTUNG

## Project

## IAW3³

*( Innovative processing technologies and their potential for extracting valuable materials from mine water, precipitation products and processing residues in the Ruhr, Saar and Ibbenbüren with special consideration of critical metal resources)*

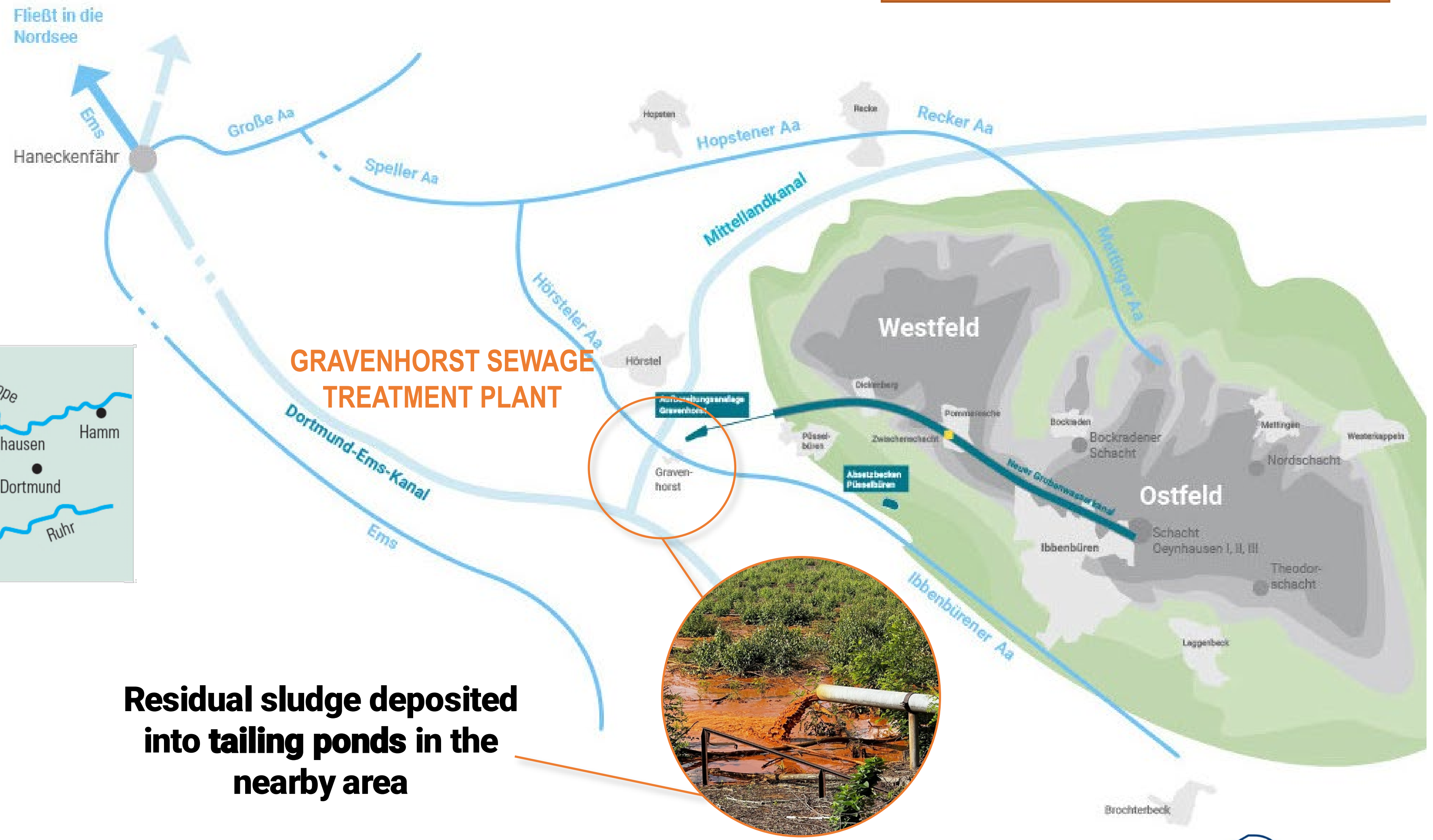
Obtaining new valuable materials from mine water

# Ibbenbüren coalfield in Germany

**Last hard-coal mines in Germany**

- **Saar Region – 2012**
- **Ruhr Region – 2018**
- **Ibbenbüren Region – 2018**

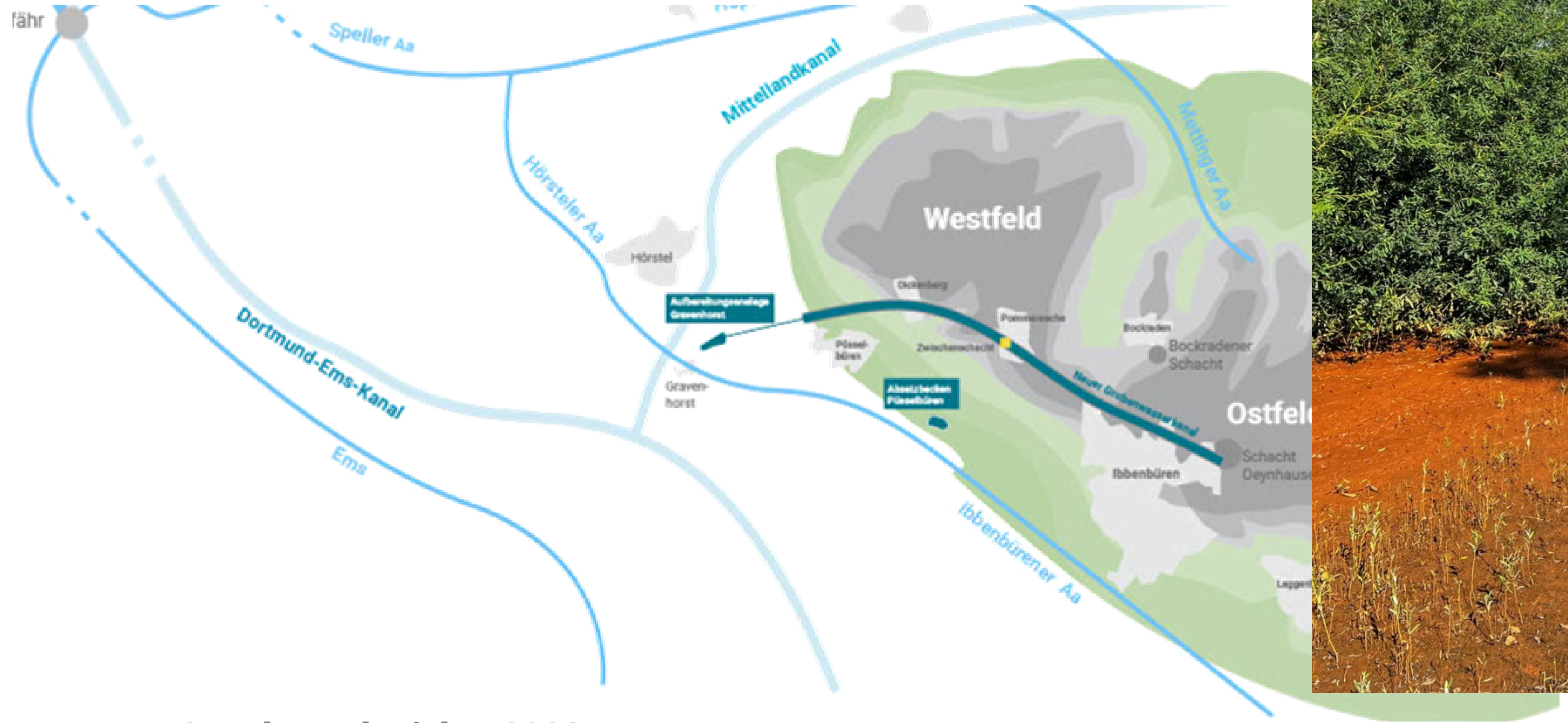

**Mine water management plan**




**Residual sludge deposited into tailing ponds in the nearby area**

# Tailing ponds from treatment plant

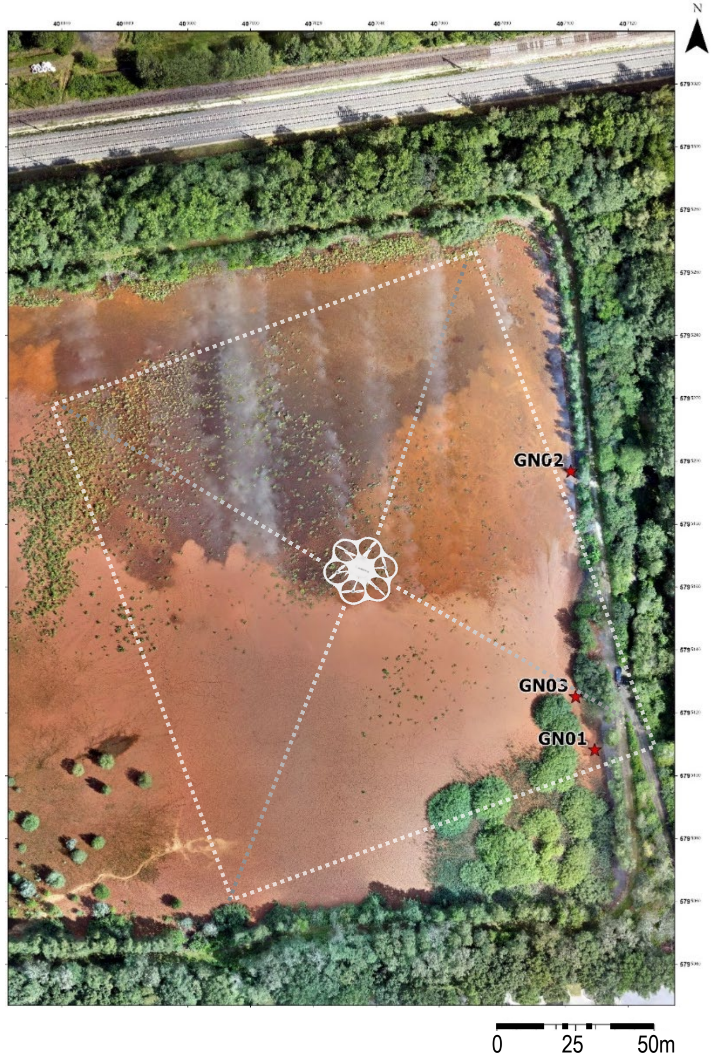
**Previous studies have found that certain critical raw materials (Al, B, Li, Mg, Sr, and Zn) were detected in the mine water from the Dickenberger adit (West field), which flows out without pressure**




Stemke and Wieber 2022

Picture: Flores 2024

# UAS (Drone) approach




The BlackBird V2 from HAIP manufacturer, mounted on the Matrice M300


VNIR from 500 nm to 1000 nm

# Validation survey and laboratory

# Water and sediment characterization


| Parameter | Value |
|---|---|
| pH | 8.2 |
| Eh (redox) | 277,5 mV |
| Temperature | 19.9°C |
| EC | 3.15 mS/cm |
| Fe Concentration | 0.25 mg/L |

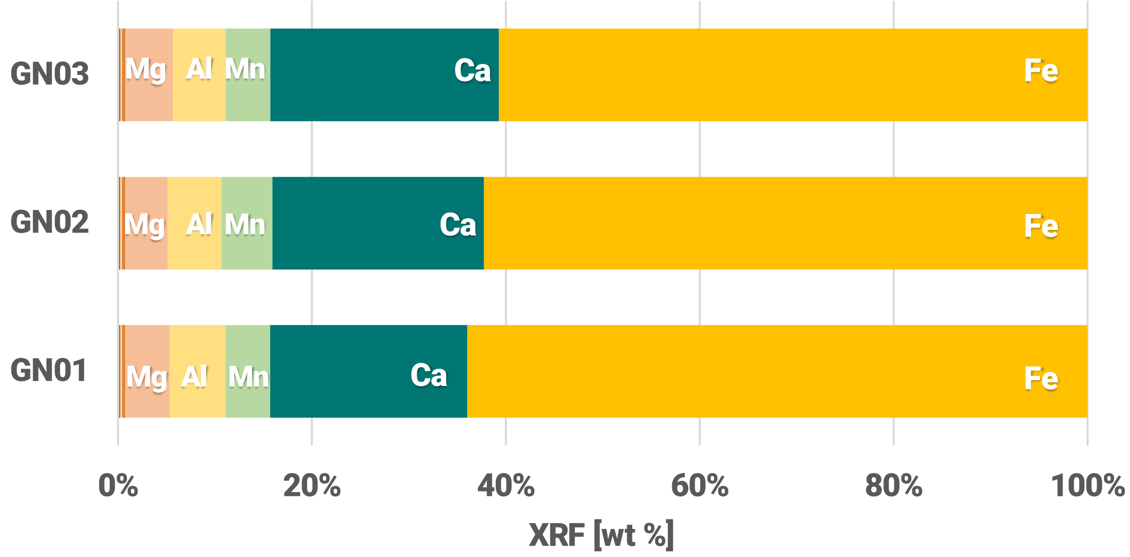
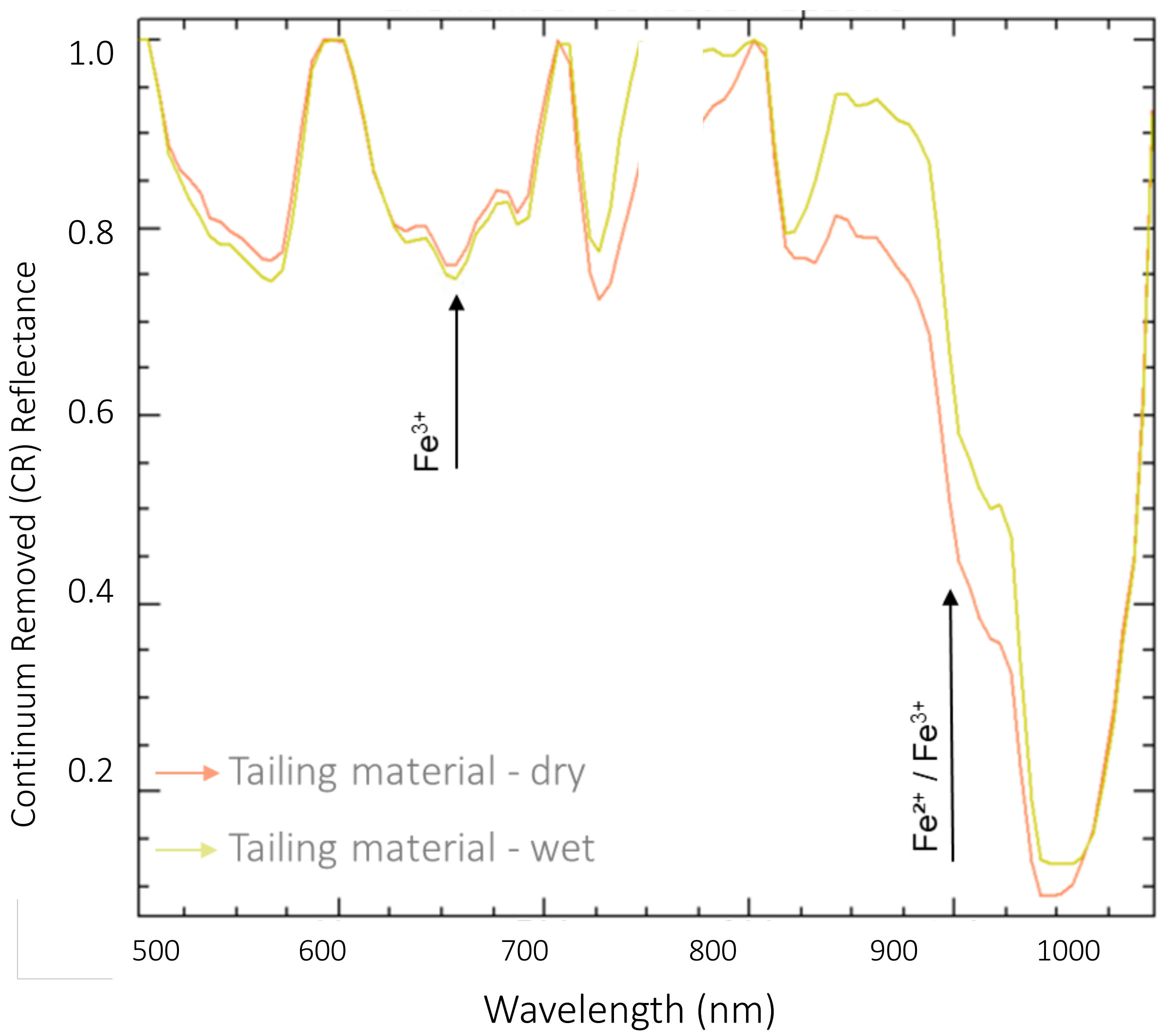


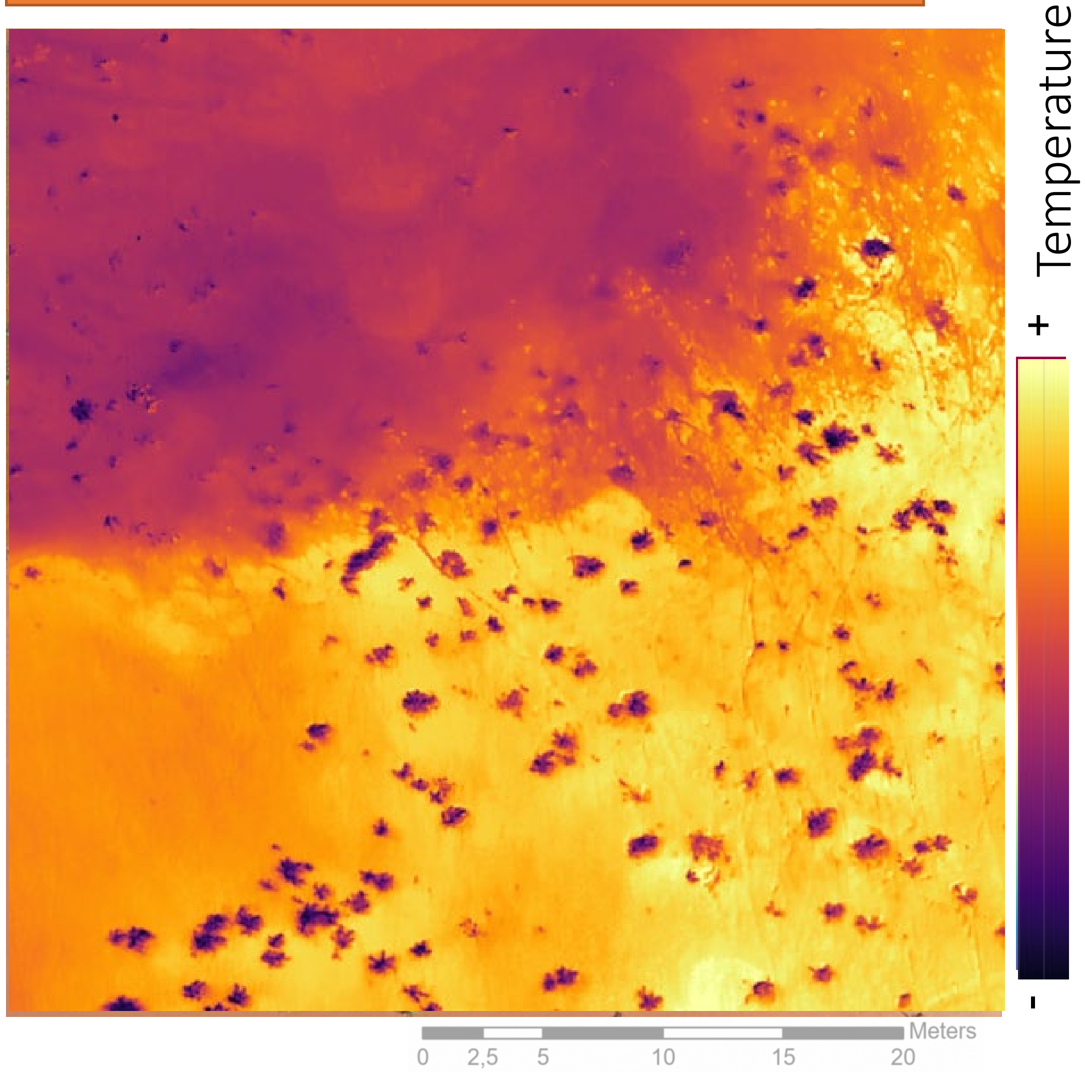

Chart of the main element fractions of three sludge samples determined by the **XRF** analysis.

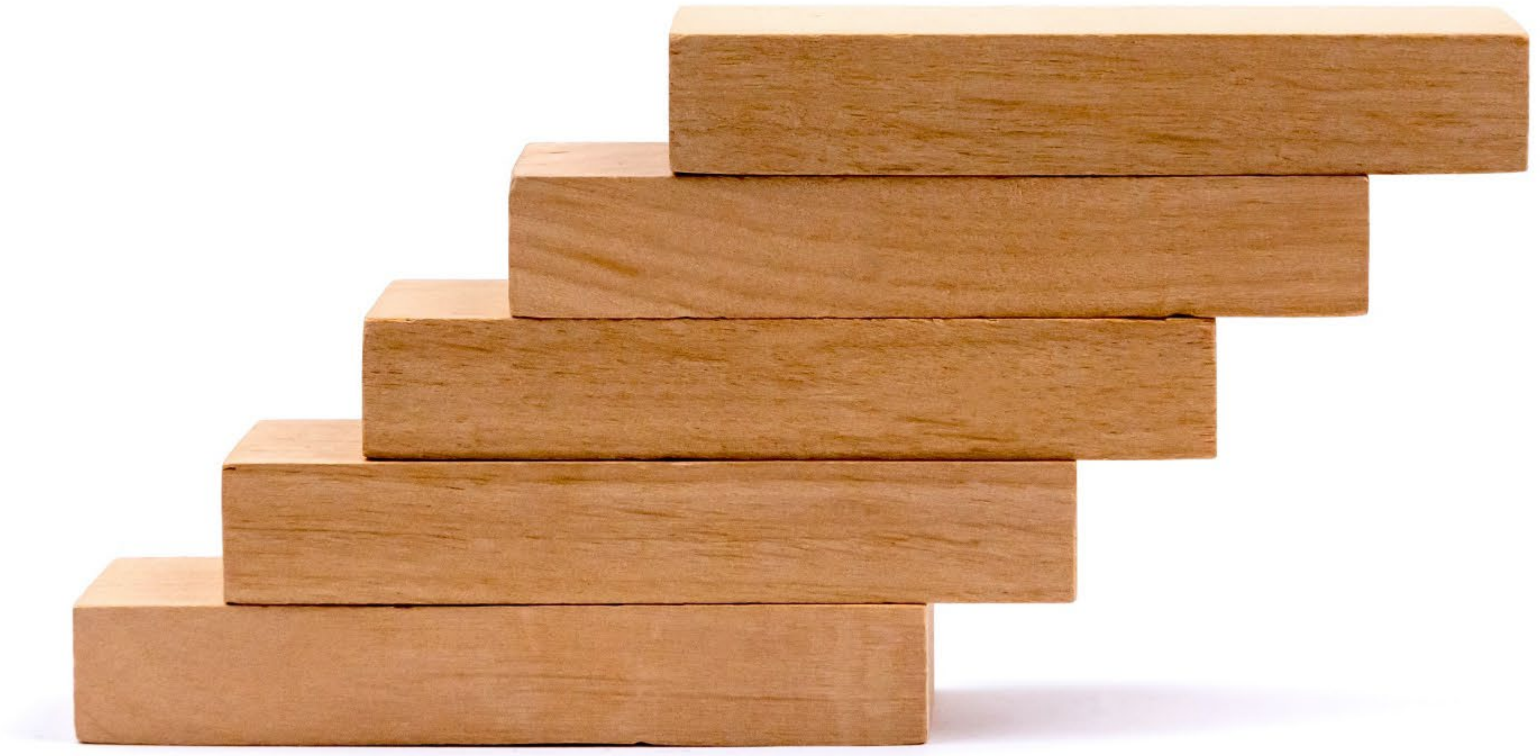
XRF performed at German Mining Museum, Dr. Michael Bode, and Mr. Till Genth

# High-resolution mapping




**Fe band ratio (650/735 nm) and Temperature**





# Research and Development

# Water monitoring solution

**RPAS- survey**

**Rikola HS Frame Based Camera**

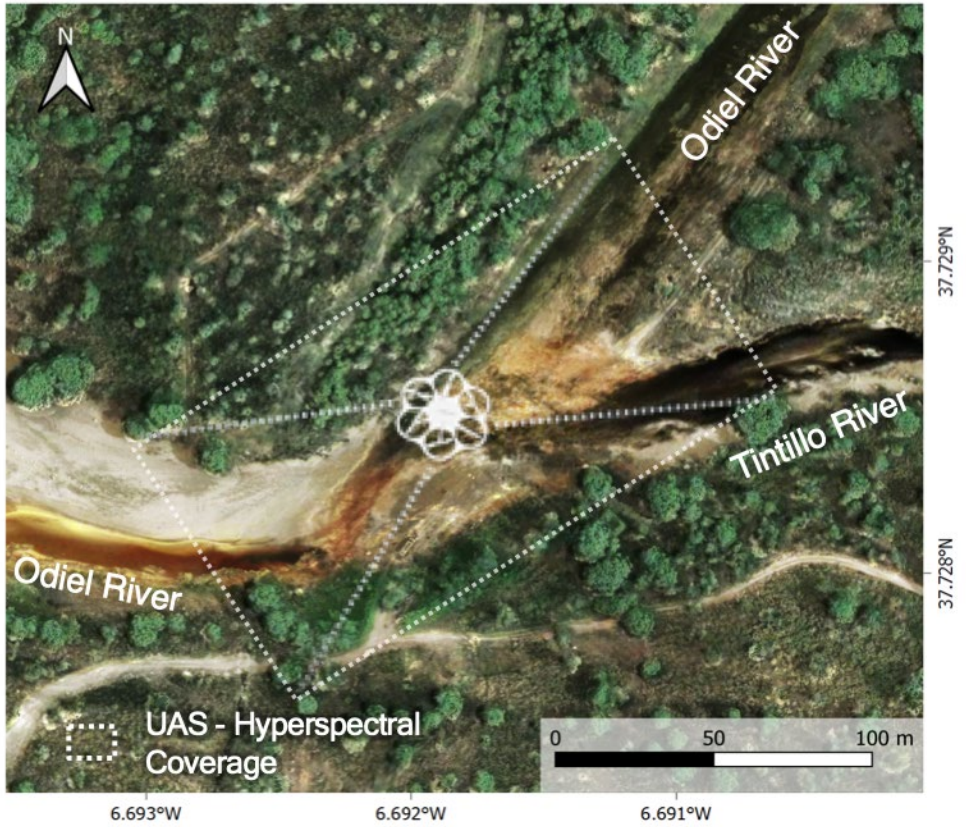
**In-situ measurements and spectral validation**

**Water samples for analysis**

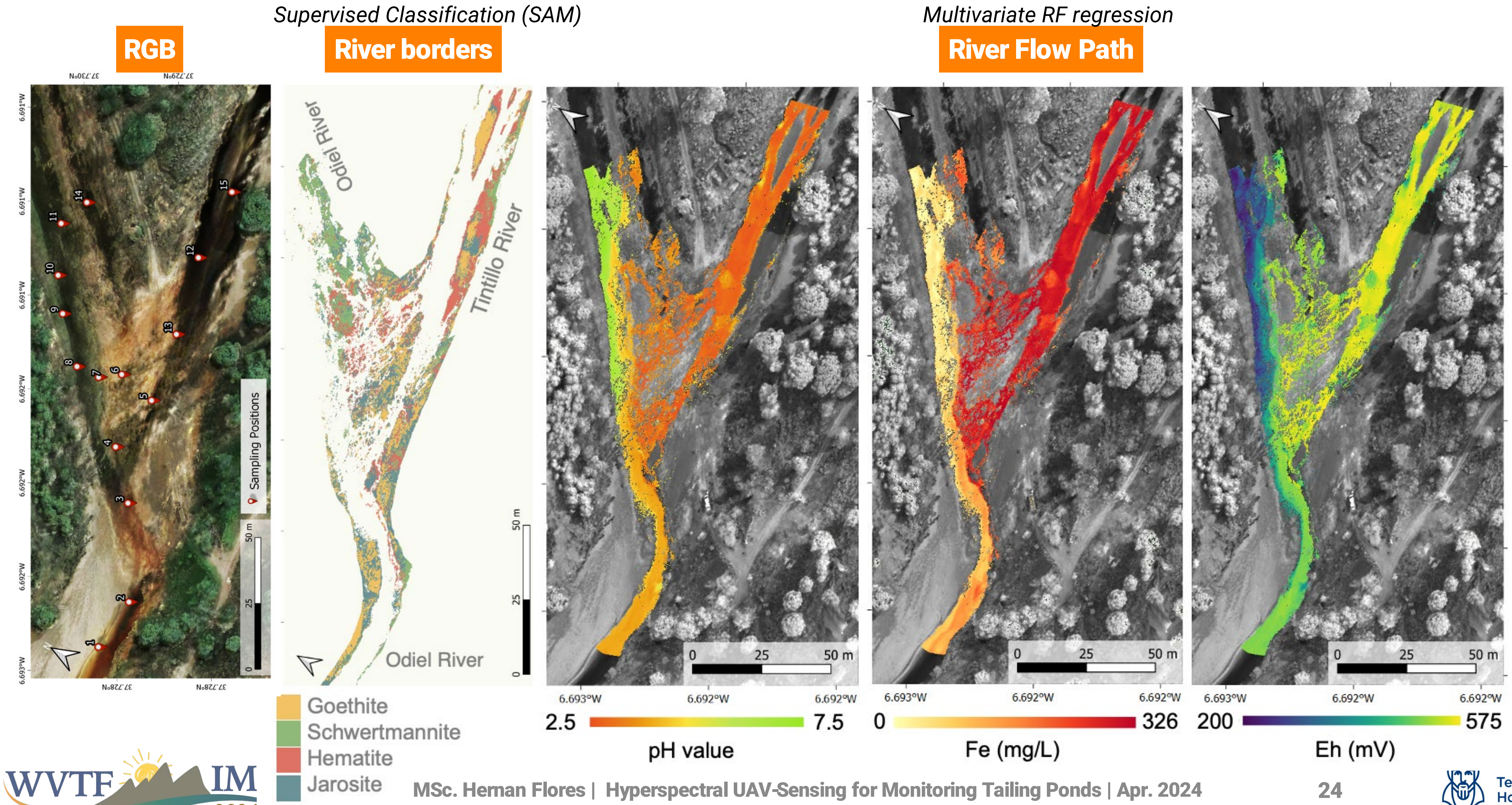
**Test site**

**Tintillo and Odiel River confluence, Huelva**


**Interaction of very acidic water (pH 2.5 – 3.0) with neutral water (pH 7.0 – 8.0).**



# Map catalogue for interpretations and decision making



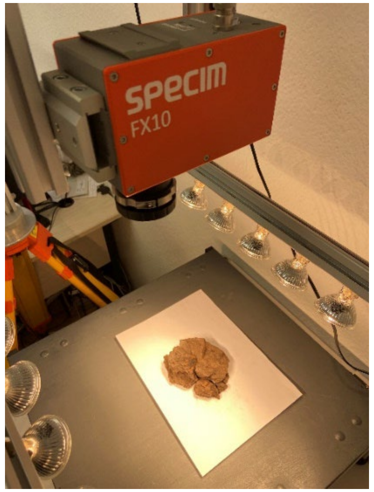
# Micro-scale characterization

## Spectral, chemical and mineralogical characterization of waste via innovative sensors

Spectral, 2022

Laser induced breakdown spectroscopy (LIBS)

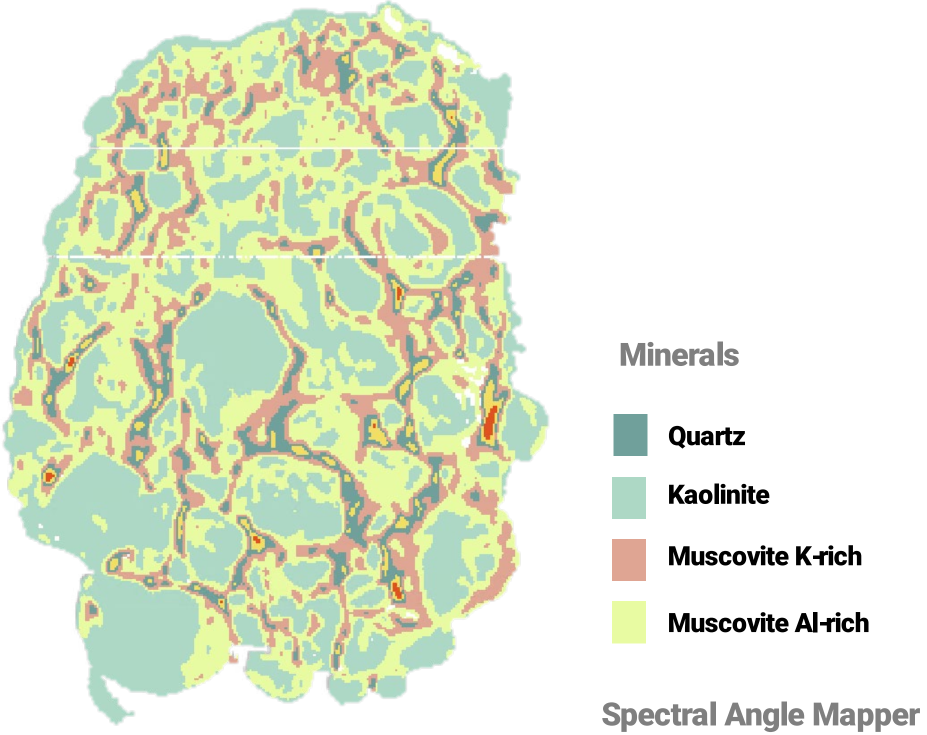
TUBAF, 2022




Hyperspectral Imaging (HSI)

TUDELFT, 2022

Fourier-transform infrared Spectroscopy (FTIR)

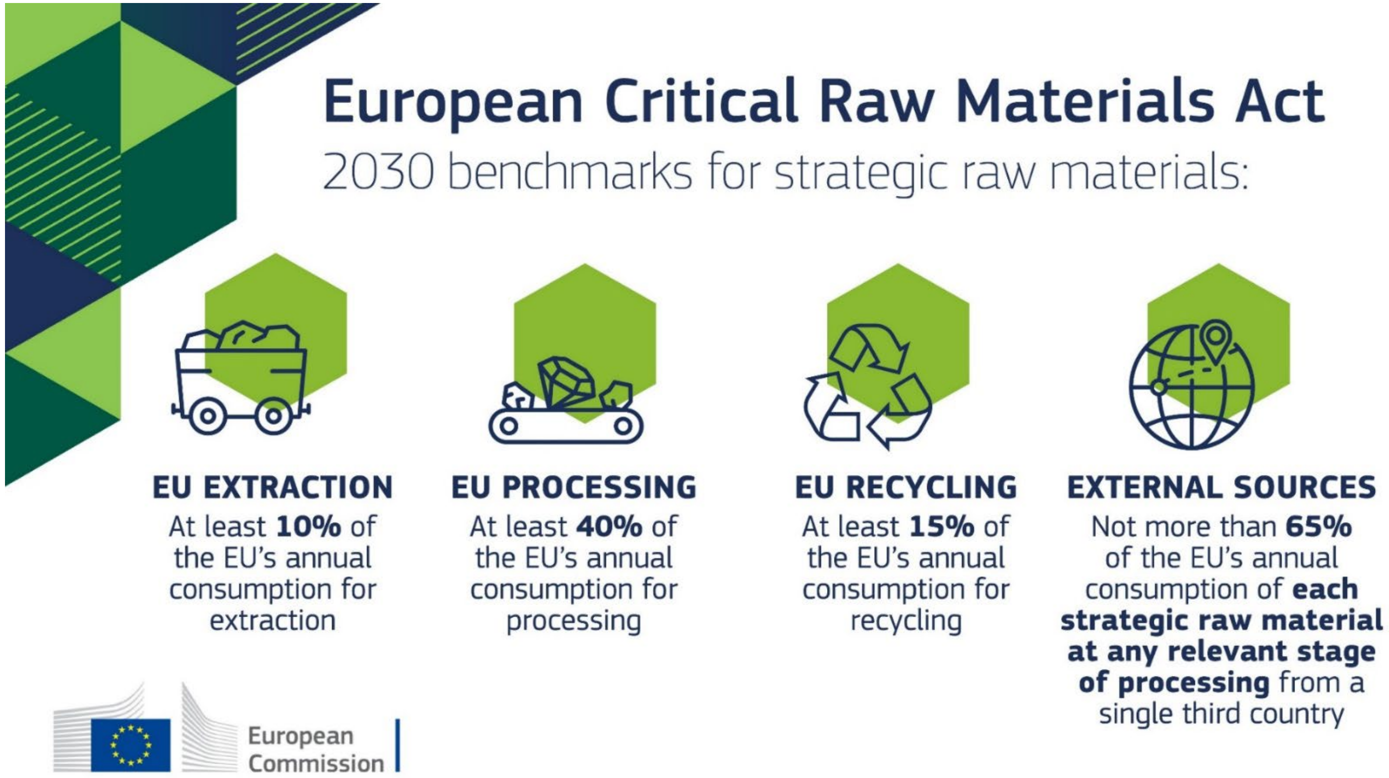



Flores, H., et al. (2023, June). TRIM4Post-Mining: Mine Waste Management and Risk Monitoring–A lignite mine case. In *84th EAGE Annual Conference & Exhibition* (Vol. 2023, No. 1, pp. 1-5). European Association of Geoscientists & Engineers.

**Spectral signature and mineralogy**

# Take away messages

## Without energy-transition (critical/strategic) metals, there is no transition to green economy




**So what?**

- **Relocation of the whole value chain**
- **Recycling can only contribute between 10% -30% of needs**
- **Opportunities for reindustrialization**
- **Waste at all stages**

*"We need to open new CRM mines, responsibly!"*

*Peter Tom Jones Director KU Leuven Institute for Sustainable Metals and Minerals*

# Take away messages

## While tailings are waste, they are not useless

**REUSE**

... there are examples of **repurposing** the mining areas into tourist attractions or science education sites...

**RECYCLE**

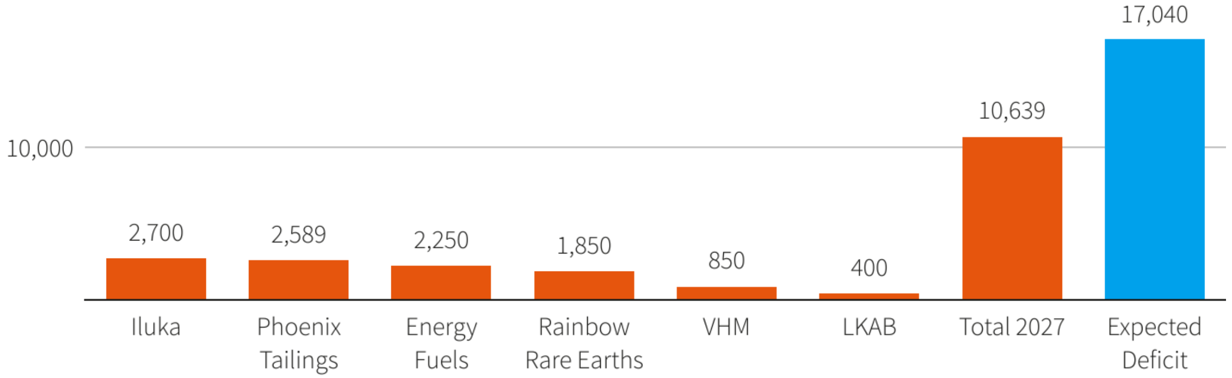
... estimations around **$10B in total metal value** in Canadian gold mining waste...

**RETHINK**

.... research on a process in which tailings **naturally draws $CO_2$** from the air and traps it in tailings

**Rare Earth Output to Jump from Discarded Mine Waste**

Six advanced global projects plan to extract rare earths from mine tailings and by-products in coming years, helping to ease expected shortages of the minerals used in electric vehicles and wind turbines

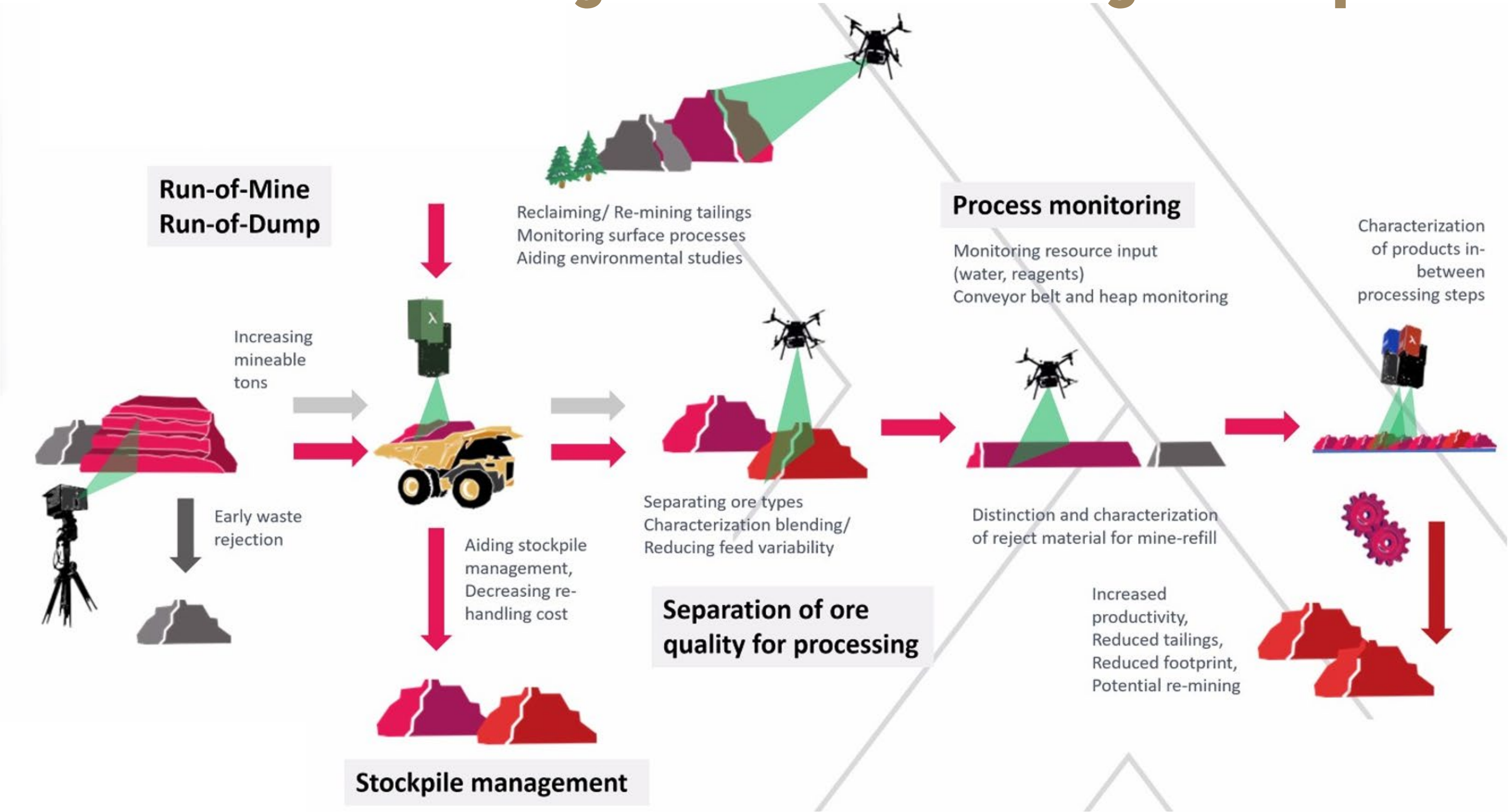



Note: Yearly production in tonnes of neodymium and praseodymium (NdPr) oxide in 2027. LKAB output of total rare earths is 2,000 T, NdPr is estimated by Adamas. Phoenix to produce 2,200 T of NdPr metal, Adamas calculated equivalent in oxides. Energy Fuels figure is midpoint of projected output of 1,500-3,000 T.

Source: Companies and Adamas Intelligence

# Take away messages

## The trend towards innovative sensors development can enhance traditional routines in mine waste management and monitoring at multiple scales




Source: HySpex, 2022

# Thank you!

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