



COMPETENCE CLUSTER FOR EFFICIENT RAW MATERIALS PROCESSING

# CONTENTS

## Contents

Welcome to Freiberg	3
Service Range	4
Our Strengths	5
Infrastructure	6
Laboratories	8
Geobiological Technologies	10
Modeling and Evaluation	12
Case Study	13
Pilot Plants	14
Case Study	16
Education	17
Strong Alliance	18





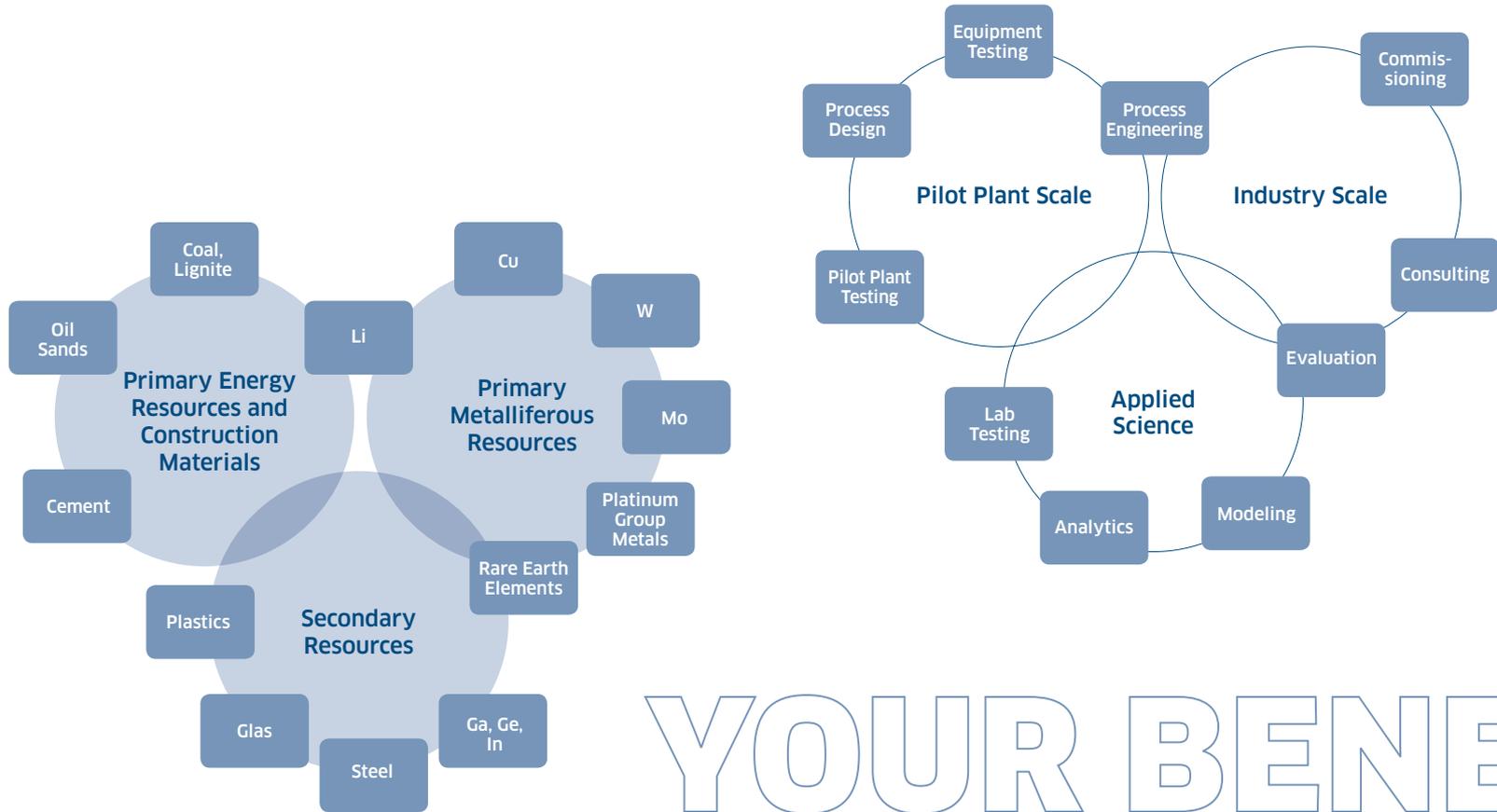
# WELCOME TO FREIBERG

## A UNIQUE COMPETENCE CLUSTER FOR MINERAL PROCESSING TECHNOLOGIES

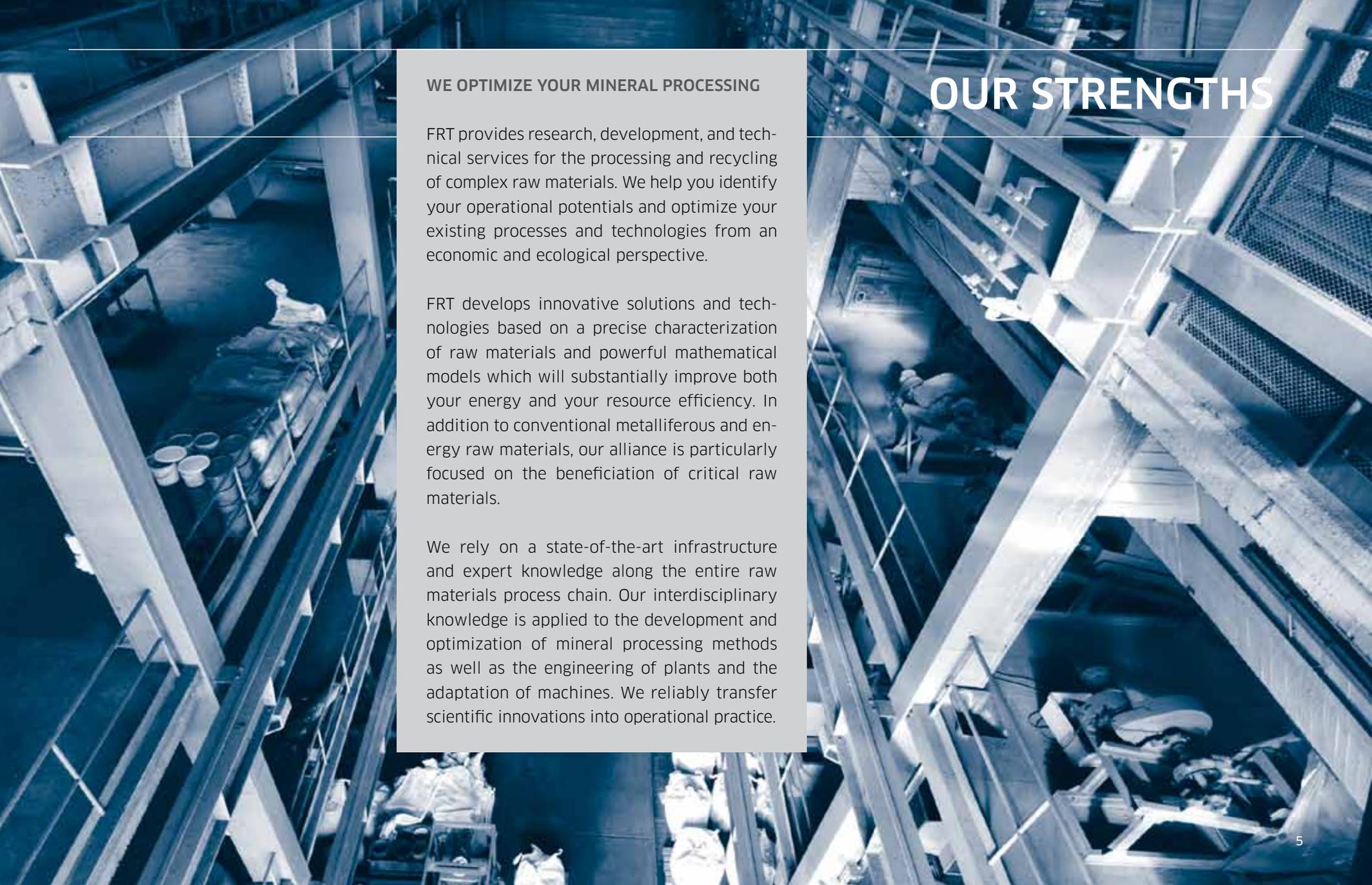
Three internationally renowned partners from research, education, and industry - the TU Bergakademie Freiberg, the Helmholtz Institute Freiberg for Resource Technology (HIF), and the UVR FIA GmbH corporation - have joined forces in the strategic alliance Freiberg Resource Technologies (FRT). Together, we have created a competence cluster for the processing of complex primary and secondary raw materials. Our research infrastructure and our combined expertise which are based on 850 years of mining tradition are one of a kind throughout Europe. We conduct applied research and development for the global raw materials industry. We provide comprehensive services, equip students, and professionals with the skills required for a career in industry or academia. We employ our competences and knowledge to boost the efficiency of your raw materials processing.

WHAT WE DO

# SERVICE RANGE



# YOUR BENEFITS



# OUR STRENGTHS

## WE OPTIMIZE YOUR MINERAL PROCESSING

FRT provides research, development, and technical services for the processing and recycling of complex raw materials. We help you identify your operational potentials and optimize your existing processes and technologies from an economic and ecological perspective.

FRT develops innovative solutions and technologies based on a precise characterization of raw materials and powerful mathematical models which will substantially improve both your energy and your resource efficiency. In addition to conventional metalliferous and energy raw materials, our alliance is particularly focused on the beneficiation of critical raw materials.

We rely on a state-of-the-art infrastructure and expert knowledge along the entire raw materials process chain. Our interdisciplinary knowledge is applied to the development and optimization of mineral processing methods as well as the engineering of plants and the adaptation of machines. We reliably transfer scientific innovations into operational practice.

# INFRASTRUCTURE

## WORLD-CLASS FACILITIES FOR RESEARCH AND DEVELOPMENT

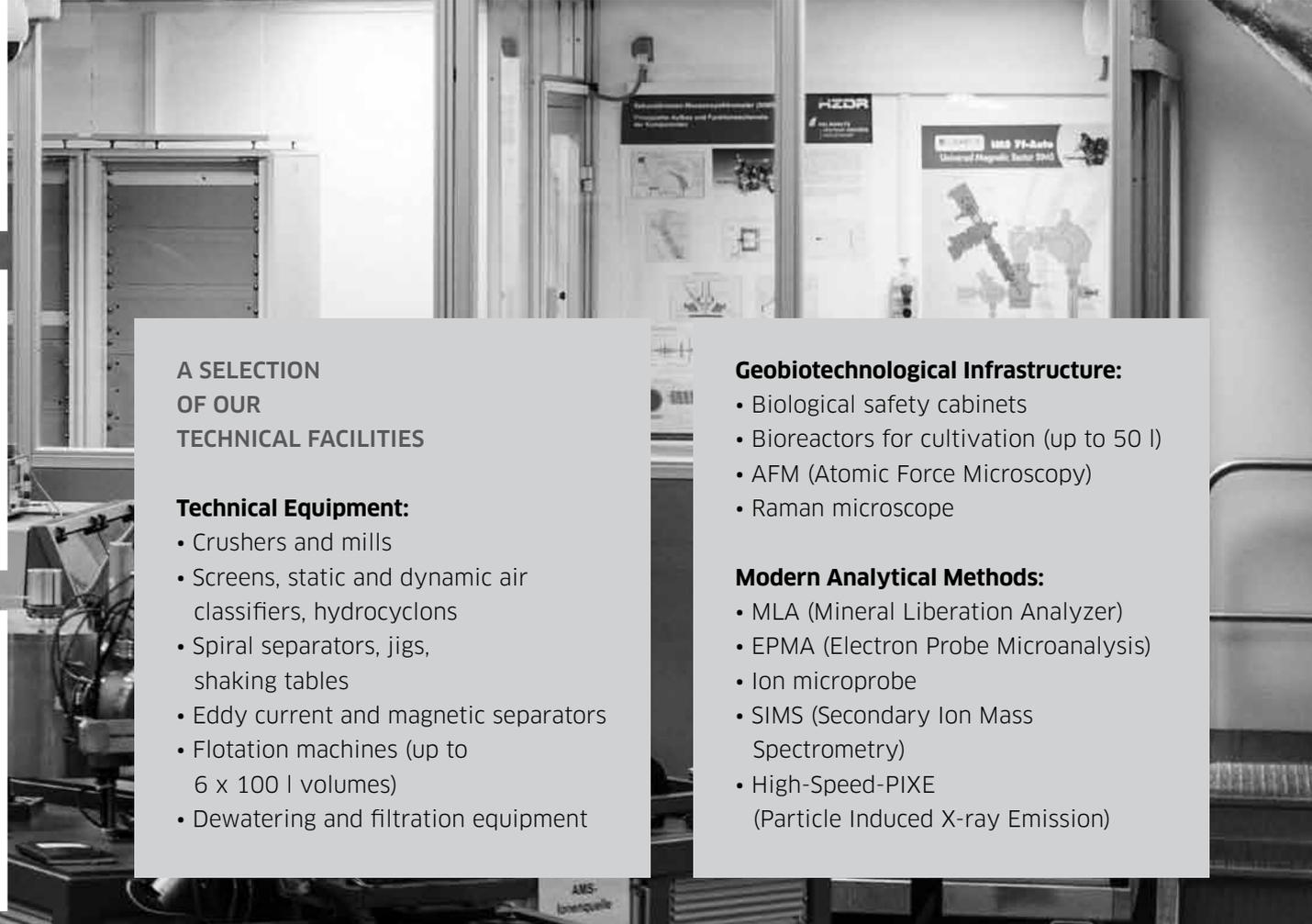
The infrastructure available to our partners is unique in many ways. We draw on the latest standards in resource analytics. These include, above all, highly specialized analytical methods based on x-ray, ion, or electron beam technology. FRT's clients benefit from labs and technical facilities which cover the entire range of applications used for characterizing and processing raw materials. They are designed for both fundamental and applied research.

As a result, we are able to develop and optimize highly innovative approaches in minerals processing. Furthermore, we have the ability to test processes at lab and pilot plant scale in order to define suitable mineral processing strategies to be applied on an industrial scale.



# WORLD-CLASS

# INFRASTRUCTURE



## A SELECTION OF OUR TECHNICAL FACILITIES

### **Technical Equipment:**

- Crushers and mills
- Screens, static and dynamic air classifiers, hydrocyclons
- Spiral separators, jigs, shaking tables
- Eddy current and magnetic separators
- Flotation machines (up to 6 x 100 l volumes)
- Dewatering and filtration equipment

### **Geobiotechnological Infrastructure:**

- Biological safety cabinets
- Bioreactors for cultivation (up to 50 l)
- AFM (Atomic Force Microscopy)
- Raman microscope

### **Modern Analytical Methods:**

- MLA (Mineral Liberation Analyzer)
- EPMA (Electron Probe Microanalysis)
- Ion microprobe
- SIMS (Secondary Ion Mass Spectrometry)
- High-Speed-PIXE (Particle Induced X-ray Emission)

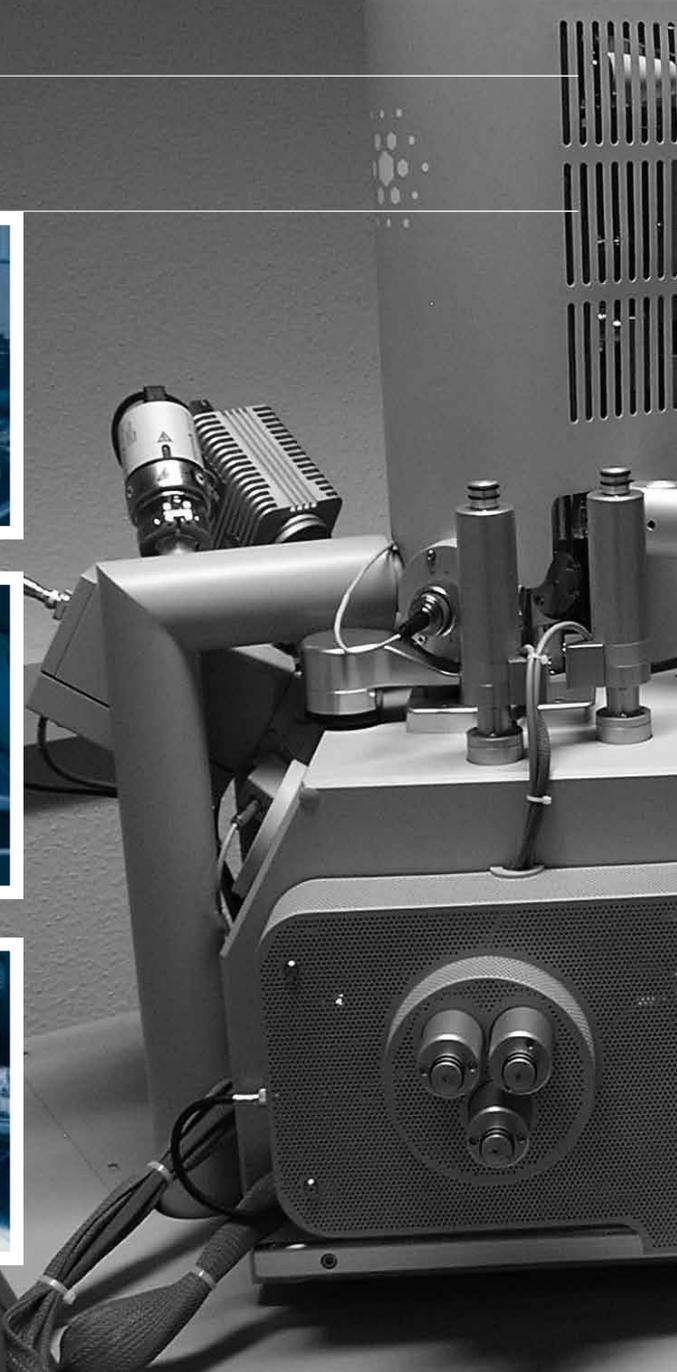
# LABORATORIES

## EFFICIENCY THROUGH INNOVATIVE TECHNOLOGIES AND OPTIMIZED PROCESSES

Superb infrastructure at our facilities allows for physical as well as chemical analyses of primary and secondary raw materials.

Relevant separation processes can be assessed for their efficiency at lab scale. New analytical methods coupled with innovative methodological competences will give you the opportunity to significantly increase the economic viability of your mineral processing.

Our equipment for the quantitative characterization of raw materials is a global benchmark. With electron and ion beam analyses we offer state-of-the-art insights into the composition of raw materials.



# LABORATORIES



## OUR LABS ARE EQUIPPED FOR

- Comminution down to submicron scale
- Dry and wet classification (90 mm to 2  $\mu\text{m}$ )
- Analysis of suspensions and their processing, e.g. filtration, centrifugation, flotation, dispersion
- Separation technologies, e.g. froth and two-liquid flotation; magnetic, electrostatic, gravity and solid-liquid separation; filter cake washing
- Particle and bulk characterization methods, e.g. size and surface analysis, chemical analysis, bulk mechanics and rheology

- Grindability tests (BOND, ZEISEL, HARDGROVE, etc.)

## Selected Applications

- Selective comminution and separation of complex raw materials
- Development of absorption materials for rare earth elements
- Grinding to devarnish tinned sheet iron or cryomilling of oil sands
- Flow behavior of bulk materials, e.g. prediction of silo vibrations, measuring the lateral stress ratios
- Development of analytical methods to characterize unconventional, fine grained and polymetallic raw materials

# GEOBIOLOGICAL TECHNOLOGIES



## NEW OPPORTUNITIES IN BIOMINING

We are breaking new ground in process engineering in order to improve the cost effectiveness of beneficiating complex and fine grained raw materials. One of our core research fields is the application of microbiology-based mineral beneficiation.

Microorganisms are used to extract and concentrate finely dispersed raw materials from ores, residues or other materials. Bioleaching enables the extraction of important metals and industrial minerals with the help of bacteria. Today, this method is used primarily for the extraction of copper. We test conventional, but also completely new bacteria and bacterial strains for their use in biological processing.

A further research focus is the selective concentration of metals from dilute solutions by so-called biosorption. Moreover, we “design” suitable biomolecules such as proteins or DNA for the selective bonding of metals and rare earth elements.

# BIOMINING

# GEOBIOLOGICAL TECHNOLOGIES



## RESEARCHING NOVEL BIOTECHNOLOGIES

- Biosorption: developing biocomposites to concentrate metals
- Biologically inspired mineralization: designing surface layers of proteins as a substrate for selective mineralization
- Bioleaching: extracting metals of strategic economic relevance using bacteria
- Biosensors: developing S-layer-based biosensors to detect metals
- Surface functionalization with bacterial proteins
- Bioflotation

# MODELING AND EVALUATION

## INNOVATIVE APPROACHES AND VALID ASSESSMENTS

Our alliance partners are specialized in both spatial and process modeling. These skills are applied during the exploration of ore deposits and are equally suitable for the economic assessment of raw material process chains. The objective is to organize and optimize process chains in raw materials extraction and processing according to the latest standards, particularly when it comes to economic and ecological impacts. FRT delivers mathematical models designed to maximize the efficiency of processes based on the exact analysis of materials and enables you to adjust your strategies well in advance. For that reason, you will save material, time, energy, and unnecessary investments.

Some of our successful projects include mathematical modeling of steel filtra-

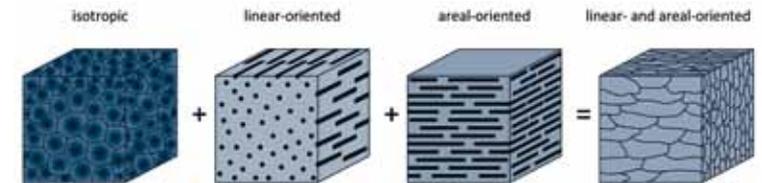
tion processes, economic assessment of rare earth element mining projects, and consultation services for the largest German consortium for the procurement of mineral raw materials.

Our competences are in demand not only in industry and research, but also in Germany and the European Union.

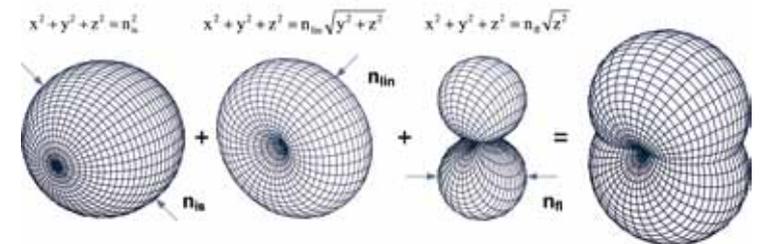
### Broad Service Range Combining Expert Knowledge and Technology:

- Geometallurgical modeling of ore deposits
- Optimizing geometallurgical process chains
- Process modeling, e.g. comminution, flotation, bioleaching
- Assessment of projects and technologies with regard to their resource efficiency
- Statistical consultation and method development

### Addition of elemental boundary surface systems



### Addition of the spatial roses of intersections



## CONSULTATION FOR THE DEVELOPMENT OF A RARE EARTH DEPOSIT

Quest Rare Minerals Ltd. (Quest) is a Canadian company which is active in the extraction of raw materials primarily from the Strange Lake deposit. Strange Lake, located in northeastern Québec, is currently one of the largest known deposits of heavy rare earth elements in the world.

In 2013, we were commissioned by Quest to review and assess the front-end engineering design that had been proposed within the scope of the feasibility study for Strange Lake. After having completed the review, we developed a comprehensive and detailed proposal

for improvements of the front end process including ore sorting, flotation, and magnetic separation. This significantly improved the economics of the project. A follow-up project examines the processing, acid leaching, and chemical separation processes on a full pilot plant scale. Jointly with Quest, we are developing a pilot plant that will continue to operate as a demonstration plant.

“We’re very pleased with the results of this pre-feasibility study. Our FRT consultants made a valuable contribution with their proposals, and we can expect a very healthy return on investments. This is decisive for any such capital intense project.”

Peter Cashin, President and CEO of Quest



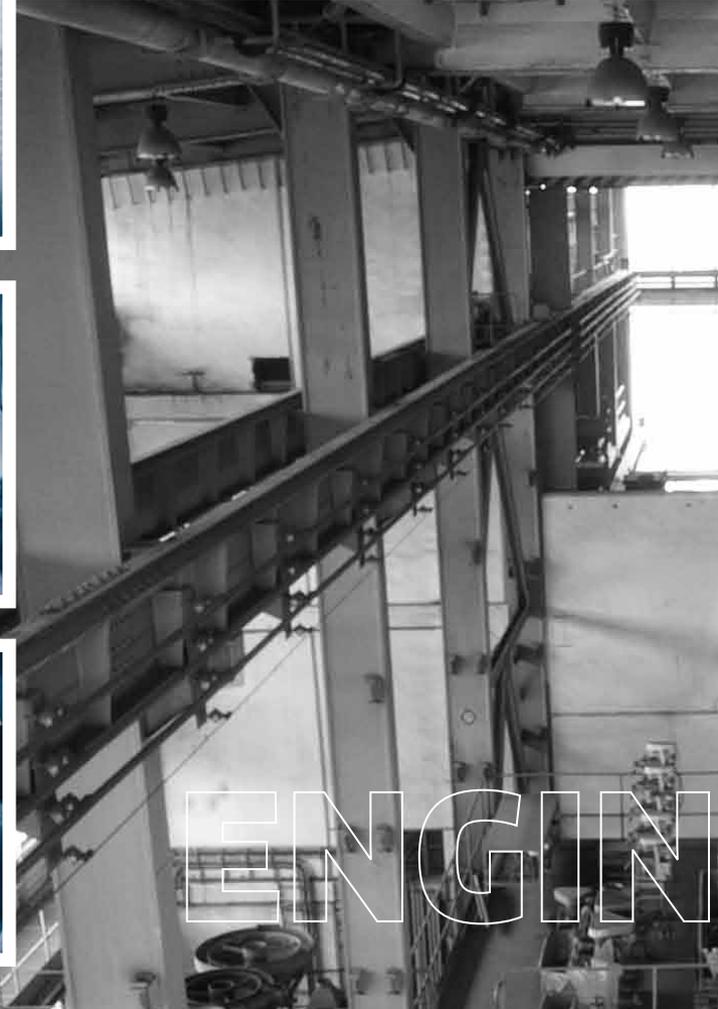
# RARE EARTH ELEMENTS

# PILOT PLANTS

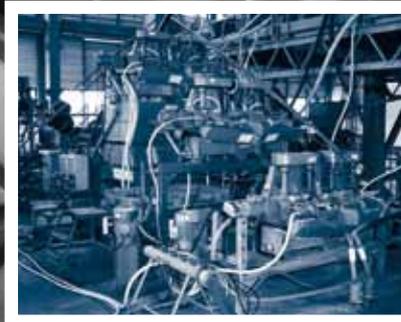
## PRACTICAL EXPERTISE AND LARGE-SCALE CAPACITIES IN PROCESSING TECHNOLOGIES

With our large-scale experimental facilities, we are able to apply all standard technologies for the mechanical processing of complex ores at both the pilot and the semi-industrial scale. Machinery for comminution, classification, sorting, mixing, dewatering, and filtration are available on a total floor space of about 3,000 square meters. In our facilities, material quantities of up to one ton per hour can be processed.

Our technical center provides the opportunity for testing your mineral processing procedures and/or available raw materials either at the pilot plant or at the semi-technical scale. Additionally, there is the possibility to use our related services. You save on investment costs for the requisite infrastructure and benefit from our expert knowledge.



# PILOT PLANTS



## SELECTED APPLICATIONS

- Comminution tests, e.g. optimized liberation of lithium-bearing mica
- Flotation tests, e.g. for sulfides, oxides and other complex raw materials such as rare earth ores
- Silo design, e.g. caking behavior of glass batches in raw materials silos
- Processing concepts, e.g. recycling of Li-ion batteries and carbon composites, process design for rare earth elements
- Grinding cycles, e.g. extraction of fillers, optimized grinding of ores

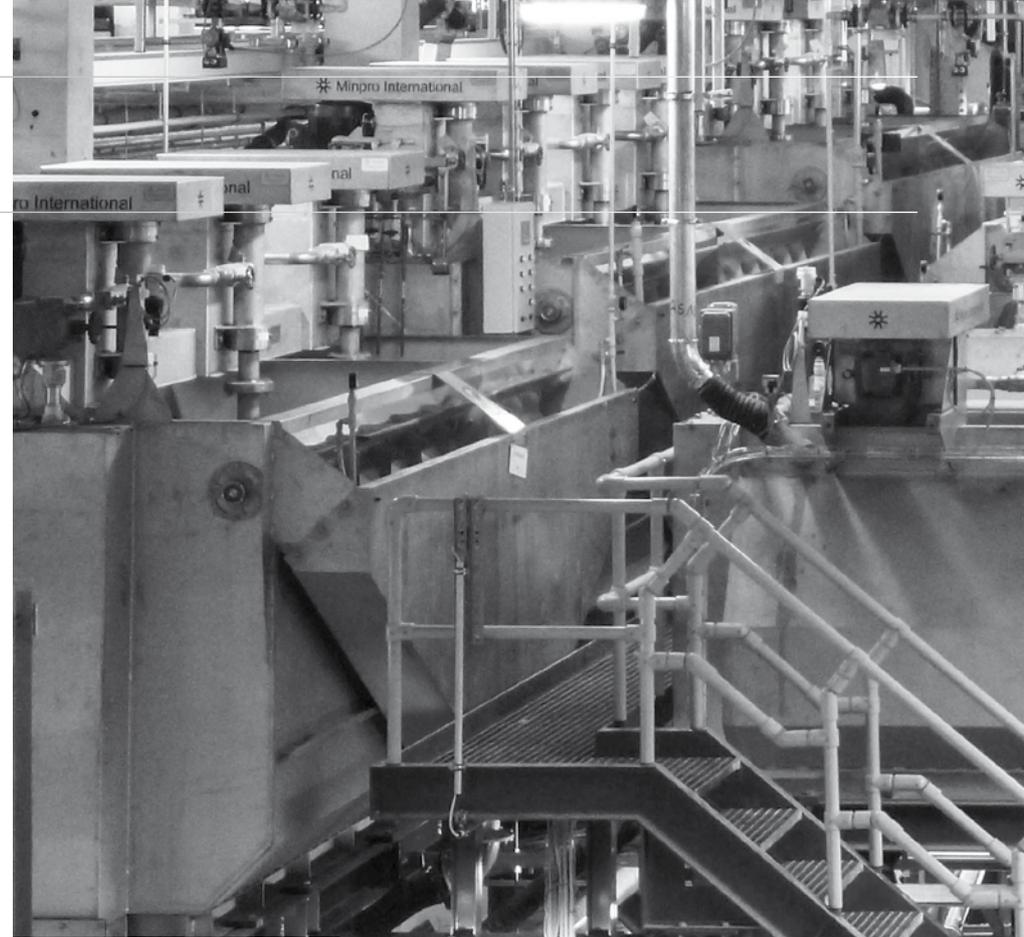
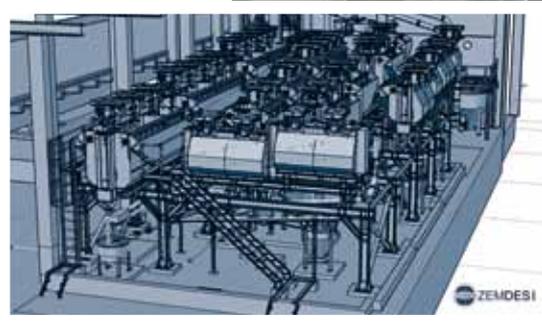
EERING

# CASE STUDY

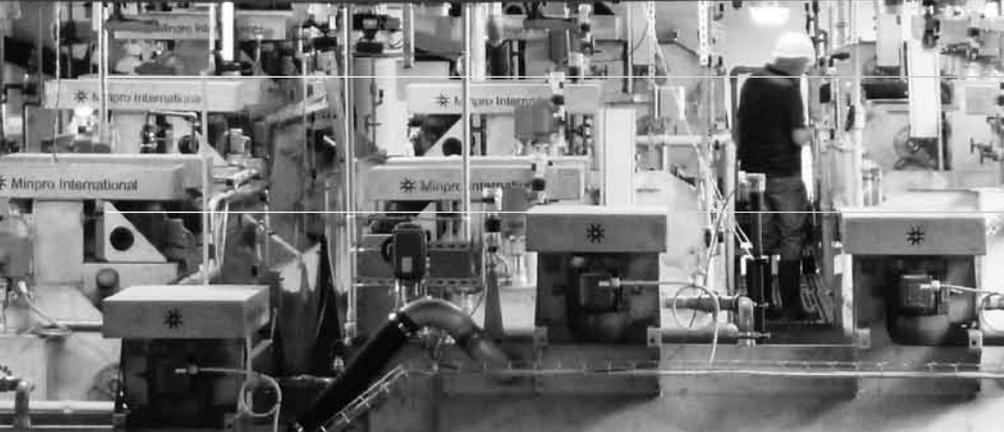
## PROCESS DESIGN AND PLANT DEVELOPMENT FOR THE PROCESSING OF FLUORITE

Between 2010 and 2013, the FRT partners carried out a large-scale project for the owner of a fluorite and barite deposit in the Erzgebirge, Saxony. Based on the executed laboratory and pilot tests, we developed a processing route suitable to separate fluorite, barite, and sulfides.

This, in turn, allowed us to deliver the basic engineering and plant design. We also supported the construction and commissioning of the plant. The work carried out focused in particular on the flotation section of the processing plant. Here, we not only reviewed and tested the various reagent systems in order to achieve an optimized flotation process, but we also administered the design and engineering. This resulted in a flotation process that includes sulfide flotation, spar (fluorite + barite) flotation, barite cleaning flotation, and five-step fluorite flotation.



# EDUCATION



## IMPARTING EXPERT KNOWLEDGE IN THE RAW MATERIALS SECTOR

New technological and economic solutions are required to assure the sustained supply of raw materials. This translates into secure jobs for specialists with a background in minerals engineering and resource technology. Freiberg is one of the leading international locations for education and further training in this field. Various qualification opportunities are not only provided by the TU Bergakademie Freiberg (TUBAF) or the Helmholtz Institute Freiberg for Resource Technology (HIF) but can also be found in the local business community.

TUBAF stands for superb academic education in all fields of minerals en-

gineering and resource technology as well as innovative training in the energy resource sector. The participating TUBAF institutes and HIF also offer tailor-made courses for the continuous education of specialists and/or special courses designed to meet the needs and requirements of interested parties, for example, “Basics of Mineral Processing” or “Machines for Crushing, Grinding, and Milling.” Furthermore, instruction and training at all state-of-the-art mineral processing machines are also possible at the UVR FIA GmbH corporation.

The Career Center of the Bergakademie offers students access to the job market and helps companies to find the right student for an internship or full time employment.

# STRONG ALLIANCE

Freiberg Resource Technologies is an alliance of three partners who cooperate closely with one another.

Helmholtz Institute Freiberg for Resource Technology



## Helmholtz Institute Freiberg for Resource Technology (HIF)

HIF researches and develops innovative resource technologies for the business community. These technologies are engineered to provide minerals and metalliferous raw materials more efficiently and to recycle them in an environmentally friendly manner. The focus is on primary and secondary raw material sources from domestic or international sources. The institute, founded in 2011, is part of the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and closely cooperates with the TU Bergakademie Freiberg.

## Technische Universität Bergakademie Freiberg (TUBAF)

Four core fields – geo, material, energy, and environment – contribute to TUBAF's unique profile as a resource university. Research and instruction are conducted along the entire raw materials process chain. More than 5,000 students are educated in geosciences, geotechnology and mining, mechanical and process engineering, and energy technology. The Institute of Mechanical Process Engineering and Mineral Processing Technology, and the Institute of Mineral Processing Machines are core members of the FRT alliance.

## UVR FIA GmbH corporation

The UVR FIA GmbH corporation is the successor of the former Research Institute for Mineral Processing. The corporation benefits from decades of experience in the field of mechanical process engineering for comminution, concentration and recycling of raw materials. The focal points of the UVR FIA GmbH corporation's activities are: the task-related characterization of materials, the analysis of experimental processing technology with an assessment of the required economic viability, process modelling, and the testing of processes in pilot plants prior to their transfer into operational practice.

# IMPRINT

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## **CONTACT**

contact@freiberg-resource-tech.com  
Phone: +49 351/260 -4430

## **EDITOR**

Tina Schulz  
Communication and Media Relations  
Helmholtz Institute Freiberg for  
Resource Technology, HZDR  
t.schulz@hzdr.de  
Phone: +49 351/260 -4427

## **DESIGN AND LAYOUT**

Mario Bengs Werbung und Marketing  
MBWM, info@mbwm.de

## **TEXT**

Inge Gerdes  
www.igtext.de

## **PICTURE CREDITS**

HZDR: Frank Bierstedt, Oliver Killig  
TU Bergakademie Freiberg: Detlev  
Müller, Mario Köhler, Waltraut Rabich,  
Wolfgang Thieme  
UVR-FIA GmbH, MBWM

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WHO  
WE ARE



#### CONTACT

[www.freiberg-resource-tech.com](http://www.freiberg-resource-tech.com)  
[contact@freiberg-resource-tech.com](mailto:contact@freiberg-resource-tech.com)