Tracking of critical minerals/elements using multispectral quantitative analysis: the case of Chelopech (Bulgaria)

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Europe consumes more than 20% of the global production of metals and produces only 3%
Periodic Table of the Elements
Production concentration of critical raw mineral materials

- Canada
  - Cobalt
- Russia
  - Platinum Group Metals
- USA
  - Beryllium
- Mexico
  - Fluorspar
- Brazil
  - Niobium
  - Tantalum
- South Africa
  - Platinum Group Metals
- Democratic Republic of Congo
  - Cobalt
  - Tantalum
- Rwanda
  - Tantalum
- India
  - Graphite
- Japan
  - Indium
- China
  - Antimony
  - Beryllium
  - Fluorspar
  - Gallium
  - Graphite
  - Germanium
  - Indium
  - Magnesium
  - Rare earths
  - Tungsten
1. Introduction

- Europe focus on its own resources/reserves
- Europe is largely under explored
- New prospections projets all over Europe
- Purpose: be less dependant of critical metal importation
1. Introduction

- Chelopech Mining: Cu/Au/Ag
- Presence of « critical elements »
- Quantitative mineralogy analysis»< Chemical analysis
- Link with ore processing
2. Location
3. Location

Popov and Popov 2000
3. Mineralization

- Chelopech ore composition made of
  - Cu, Fe, S, As and Ba (major elements)
  - Sb, Bi, Se, Te, Au, Ag, Pb, Zn, Sn, In, Ga, Ge, Ti, PGE (minor elements)

3. EDX analysis
3 EDX analysis

Rich Se-galena

8% to 14% Se in galena
4.3 Selenium

- **Main applications**
  - Glass production
  - Solar cells (Cu-In-Ga-Se)
  - Alloys (Pb-Se)

- **Price**: 42$/lb
4. Method

- 4.1 sampling points in the flotation plant
4.1 Samples

- Sieving of samples (38µm and 75µm)
- Creation of polished sections
- 38-75µm and +75µm
4.2 Qualitative analysis

Ore

Concentrate

Tailings
4.3 Quantitative analysis

- **After optical analysis**
  - 7 main minerals
    - Bornite (associate with Au, Te, Ge) *Arsenijevic 1958, Bonev et al. 2002*
    - Covellite
    - Pyrite
    - Chalcopyrite (associated with Au, Te, Bi) *Bonev et al. 2002, Kouzmanov 2001*
    - Galena (bearing Se)
    - Tetraedrite/Tennantite (bearing Sb, Ge, Bi) *Karamyan 1958, Kouzmanov 2001*
    - Enargite (bearing Ge, Au) *Vlassov 1964*

- **Multispectral analysis**

- **55 images/ polished section at 3 wavelengths**
Material
4.3 Quantitative analysis

Reflectance curves

- Bornite
- Chalcopyrite
- Covellite
- Covellite
- Enargite
- Enargite
- Galène
- Pyrite
- Tennantite
4.3 Quantitative analysis

<table>
<thead>
<tr>
<th>438nm</th>
<th>591nm</th>
<th>692nm</th>
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[Images of microstructures at 438nm, 591nm, and 692nm wavelengths]
4.3 Quantitative analysis

- Classification

Stacking of the "3 wavelengths images" (438nm+591nm+692nm)

Classification

- Pyrite
- Résine+gangue
- Covellite
- Enargite
- Chalcocite
- Chalcopyrite
- Galena
- Tennantite
- Bornite
Peripheral pixels

Blanc
Niveaux de gris
Noir
Pyrite
Chalcopyrite
Bornite
Covellite
Résine
5. Quantitative results

- Pixels of each class have been counted
- Surface percentage converts to weight %
- Allow to know the mineral proportions in each sample
5.1 Description of quantitative results
5.1 Description of quantitative results
5.2 Quantitative results >> chemical results

- Convert mineral proportions to Cu, As and S proportions

\[ \%Cu = \sum \%\text{mineral}(i) \times \text{proportion of Cu in mineral } i \]

Cu and As proportions of chemical and quantitative results are standardized with S
5.2 Quantitative results >> chemical results

Multispectral imaging base results

Quantitative results standardized with S

Chemical values standardized with S

Concentrate

Ore

T1

T2

TT

T1

T2

Cu

As
6. Conclusion

- Different kind of analysis on the samples
  - Qualitative analysis
  - Chemical analysis
  - EDX analysis
  - Quantitative analysis

- Quantitative results match qualitative and chemical results

- Mineral informations > Chemical analysis

- Information of mineral behavior in the process plant

- Tracking of minerals and elements in the process plant
Thank you for your attention