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

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Introduction

- ***Europe consumes more than 20% of the global production of metals and produces only 3 %***

Periodic Table of the Elements

1 H 1.00794																1 H 1.00794	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		118 (293)

58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.03588	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

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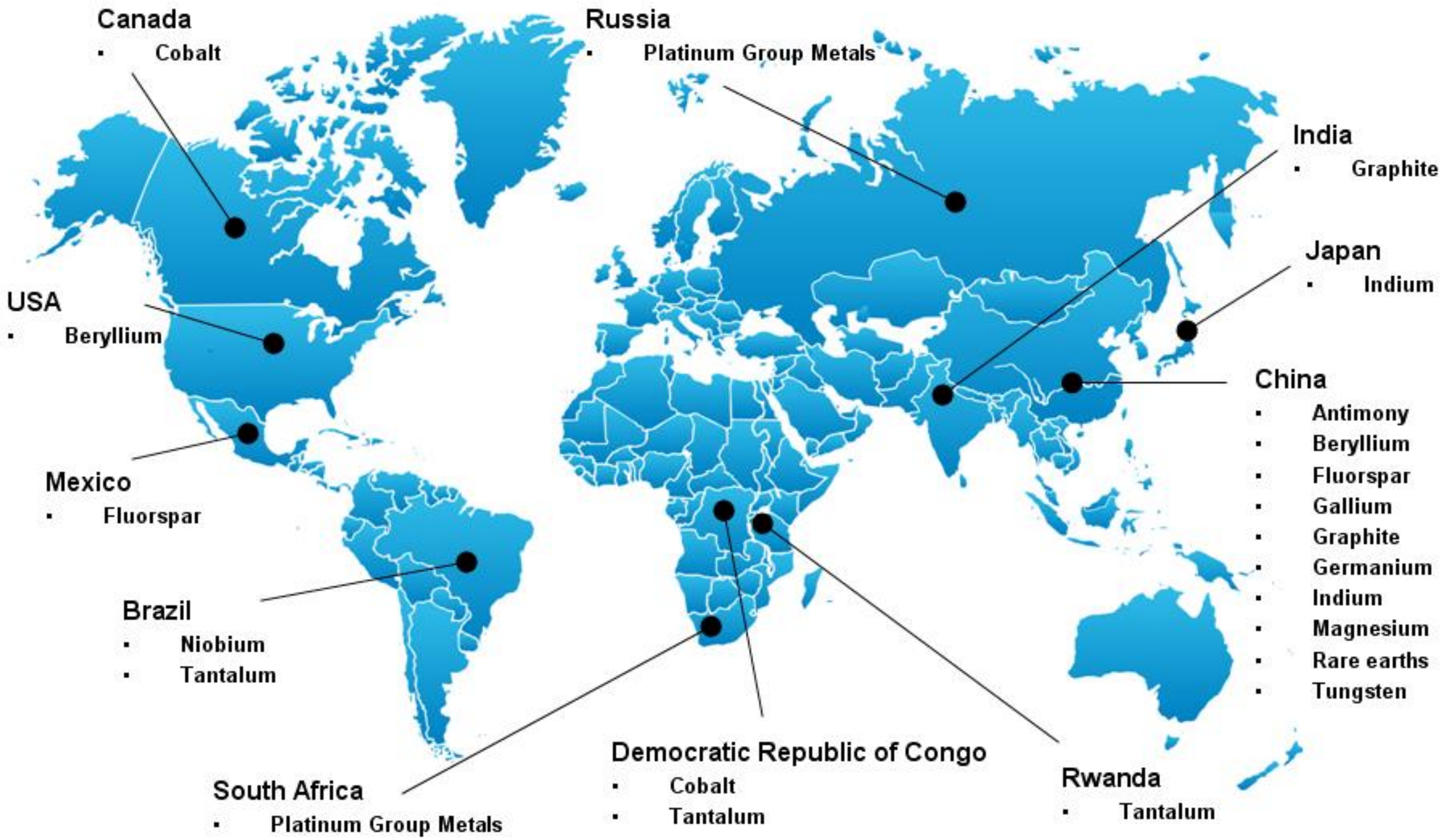
Production concentration of critical raw mineral materials



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

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2. Location

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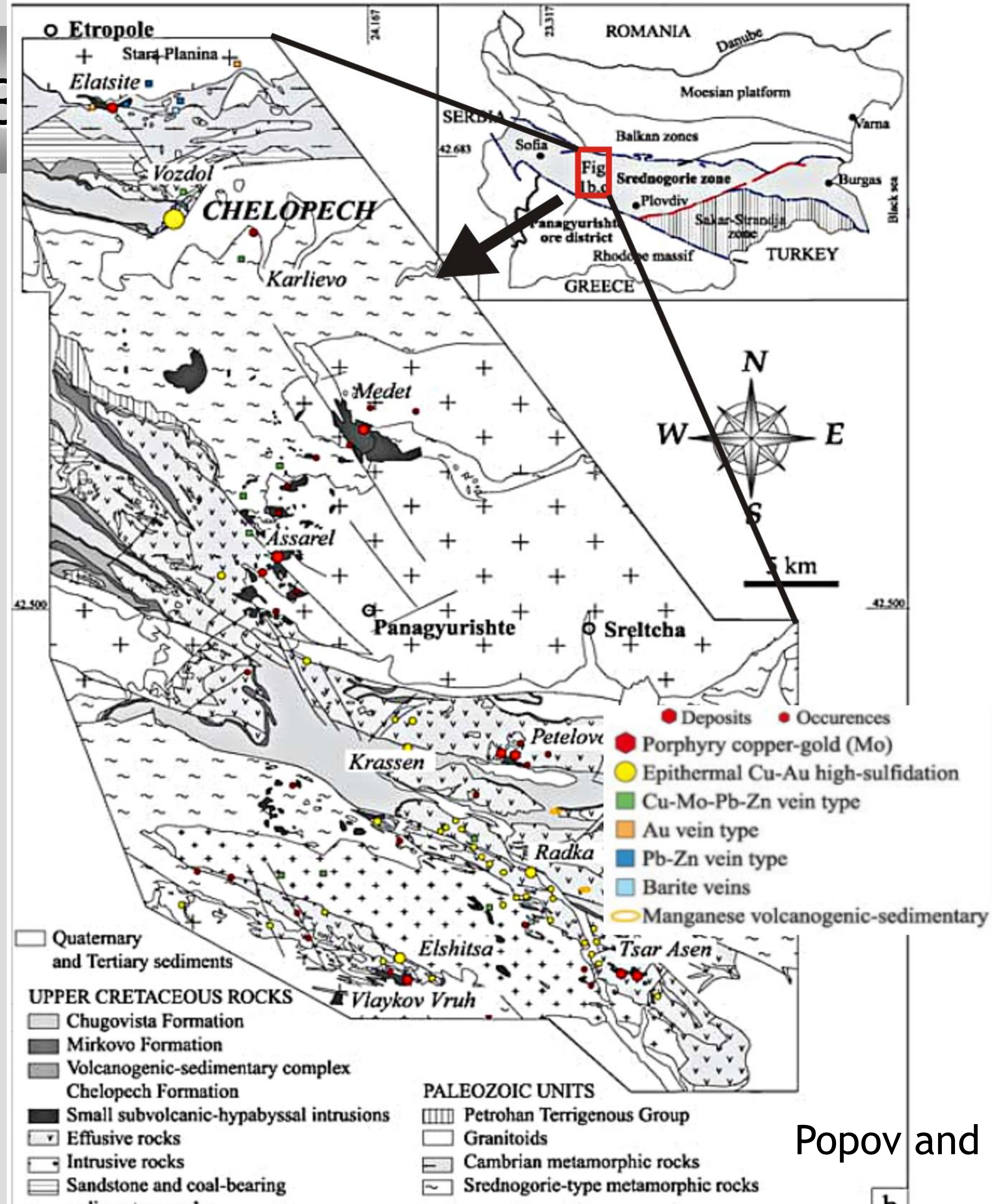


Popov and Popov 2000

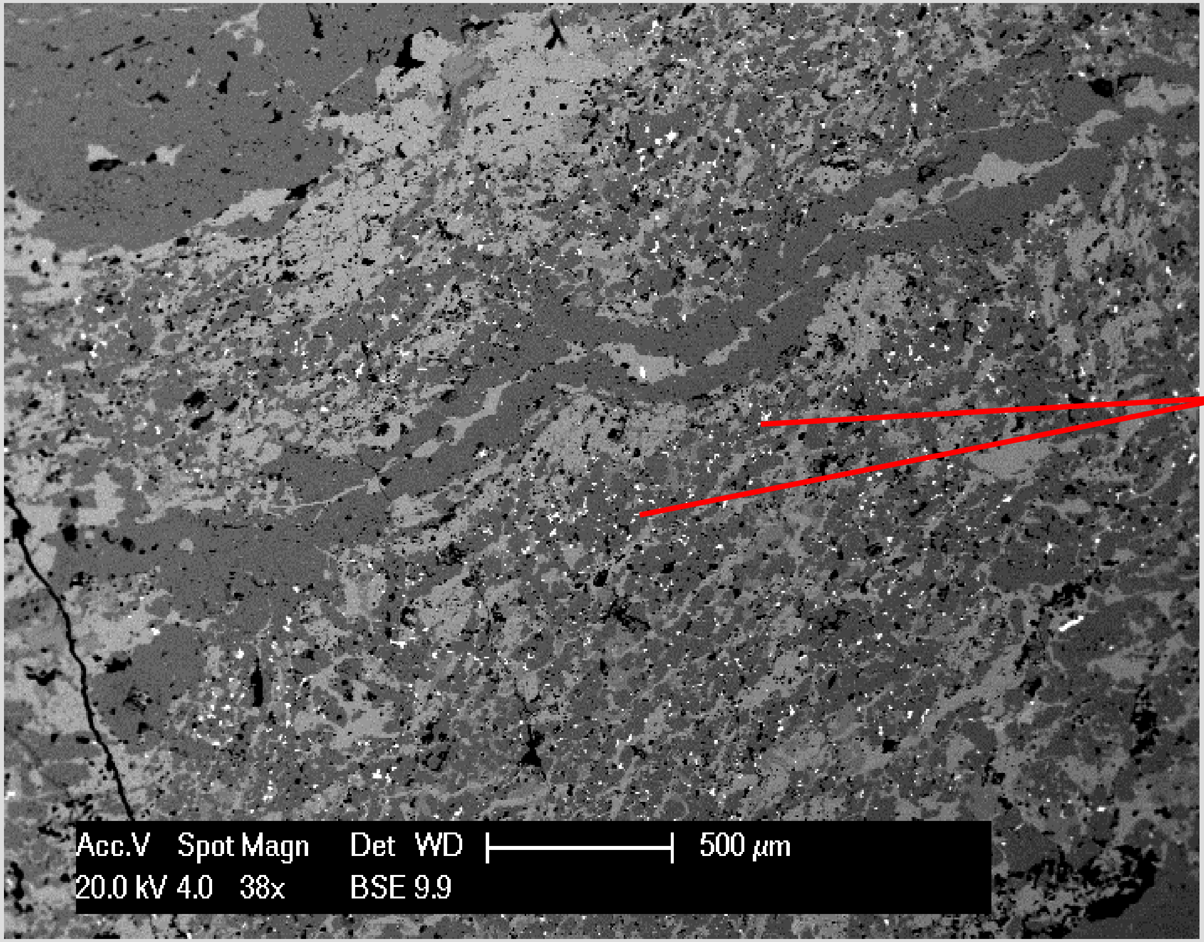
3. Mineralization

- 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)

(Bonev et al. 2002, Moritz et al. 2004, Chambefort 2005, Coffey Mining 2010)

3. EDX analysis

3 EDX analysis

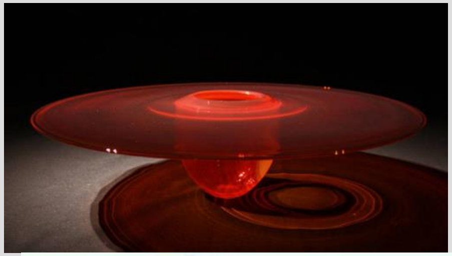


Rich Se-galena

8% to 14% Se
in galena

4.3 Selenium

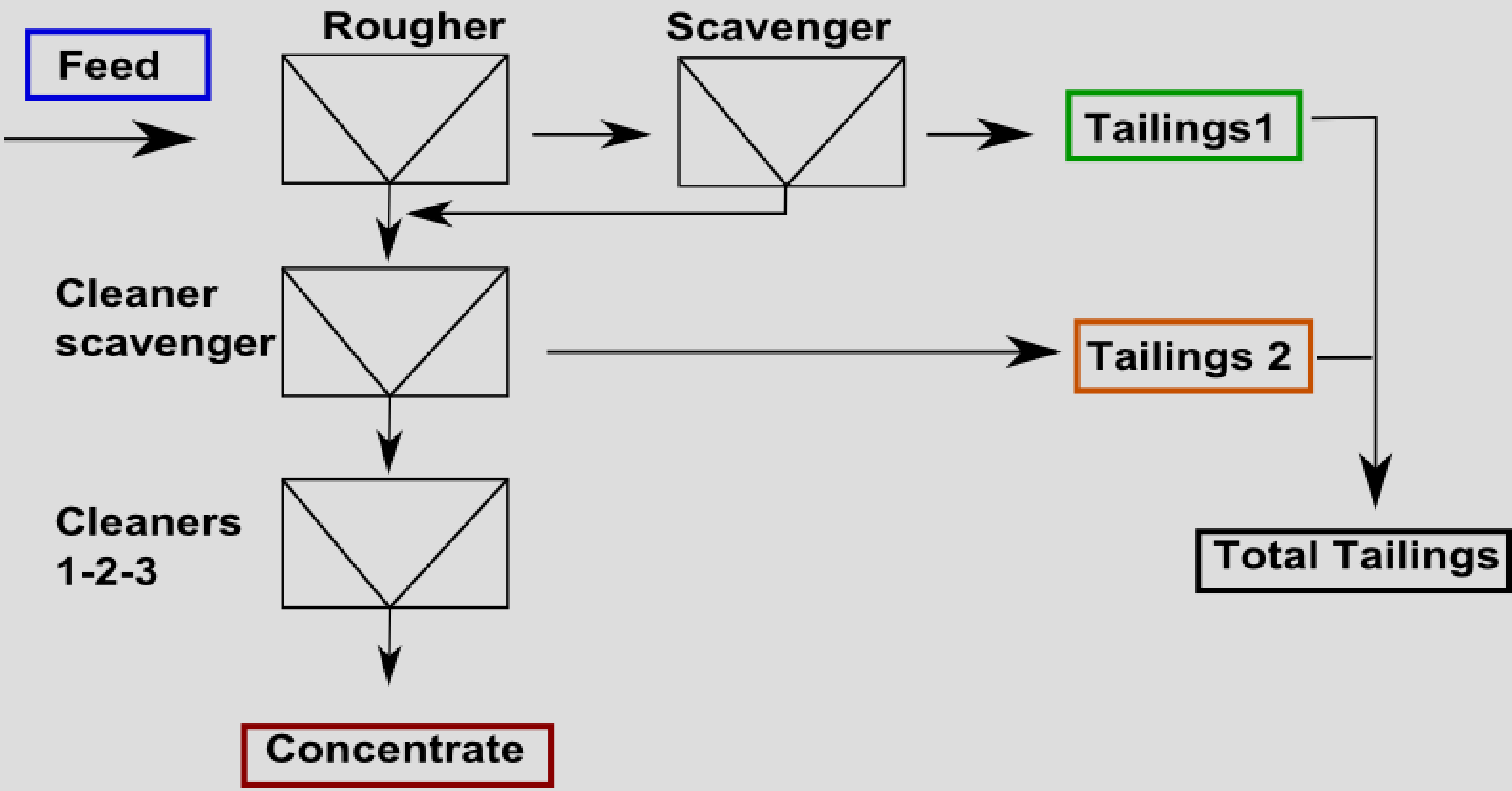
- Main applications
  - Glass production
  - Solar cells (Cu-In-Ga-Se)
  - Alloys (Pb-Se)



- Price: 42$/lb

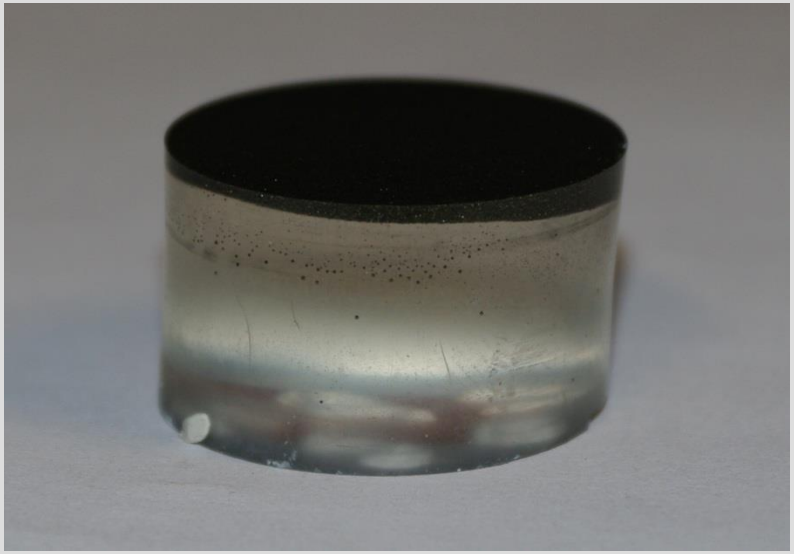
4. Method

- 4.1 sampling points in the flotation plant

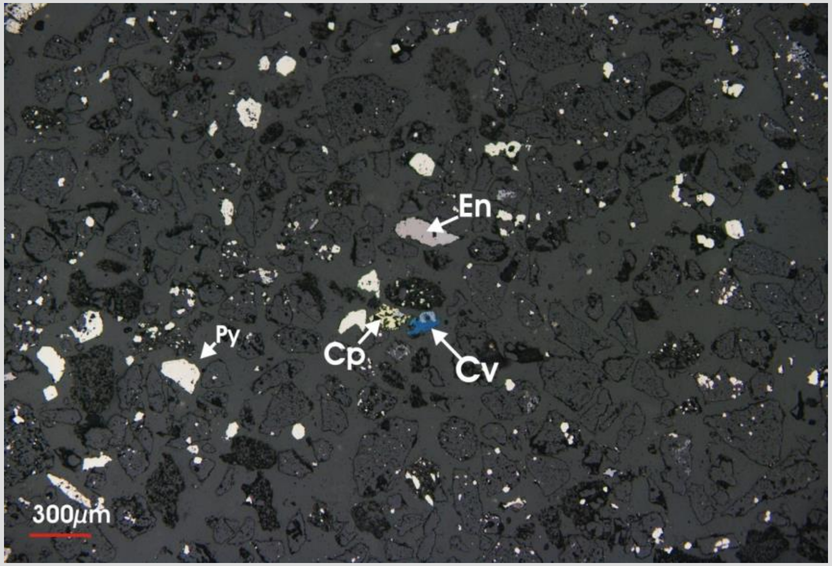


4.1 Samples

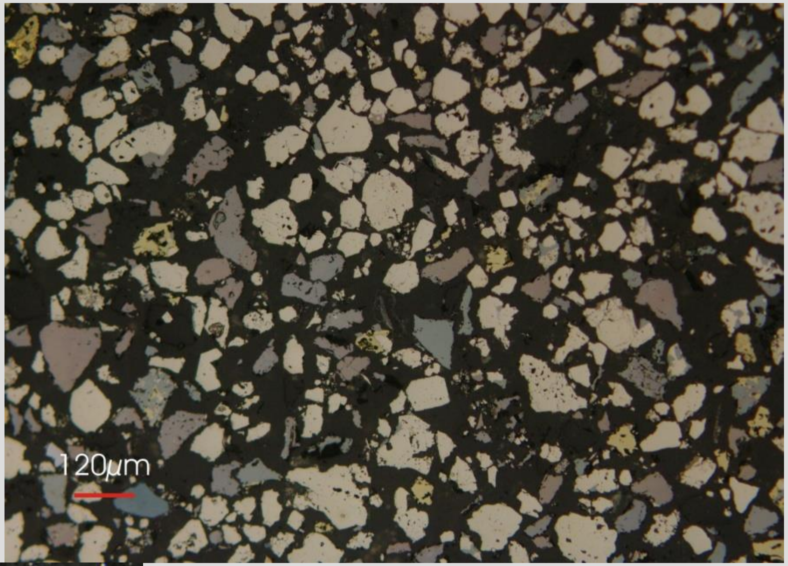
- Sieving of samples (38µm and 75µm)
- Creation of polished sections
- 38-75µm and +75µm



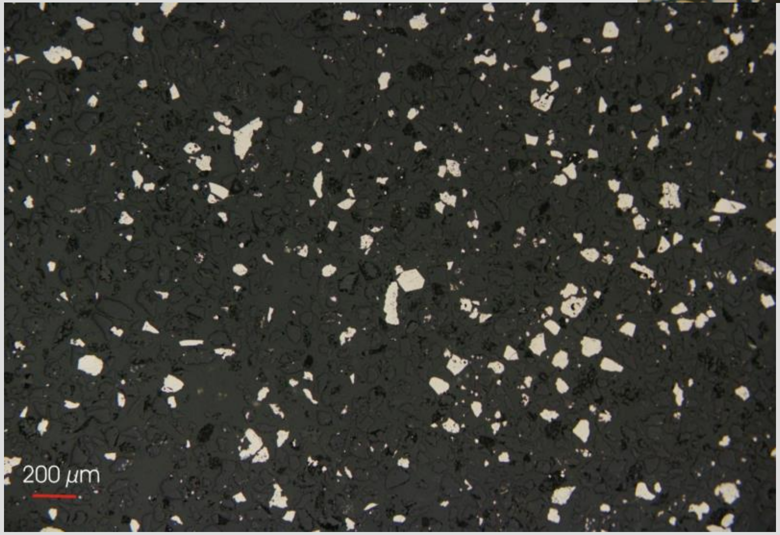
4.2 Qualitative analysis



Ore



Concentrate



Tailings

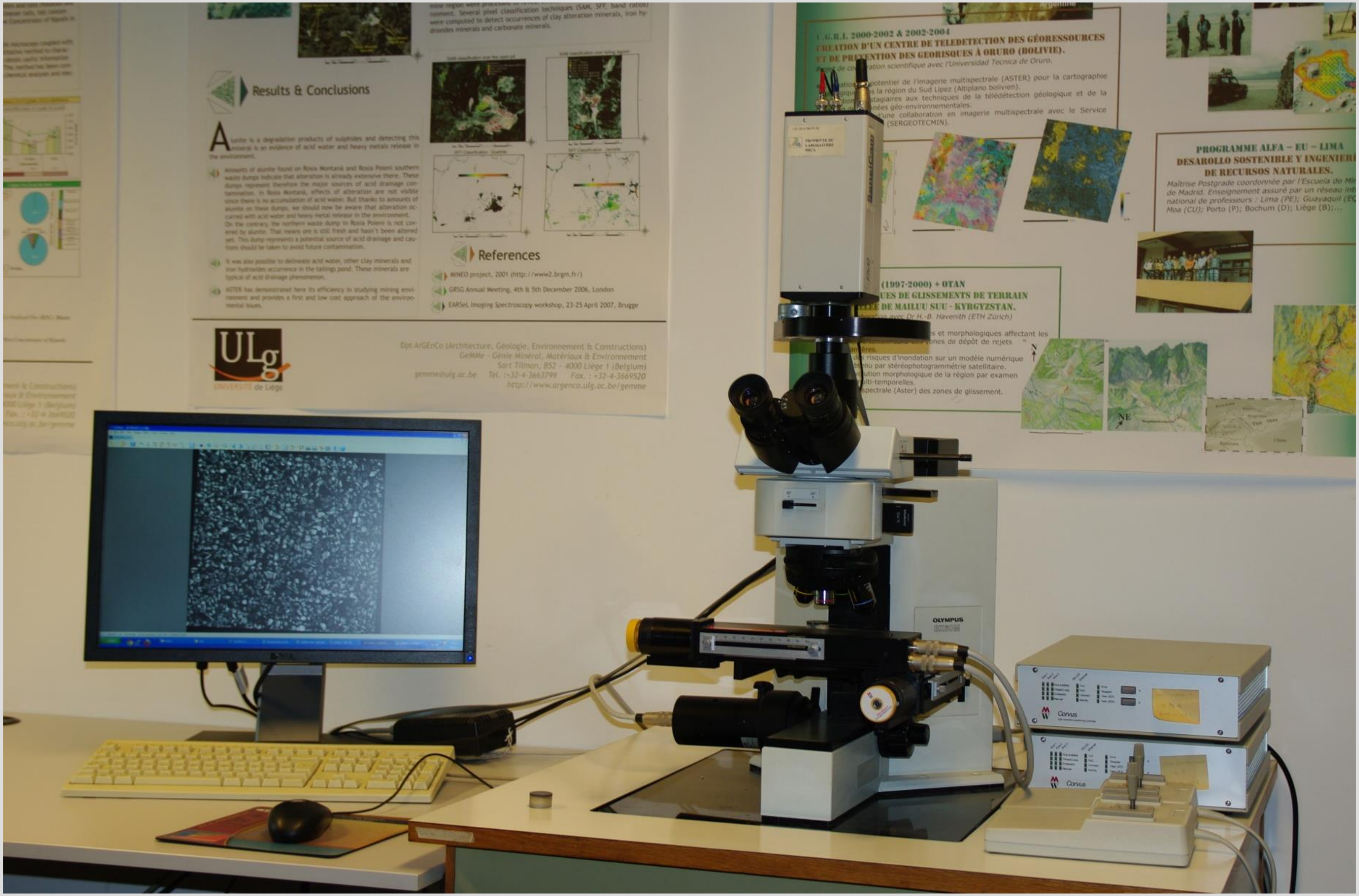
4.3 Quantitative analysis

- 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*

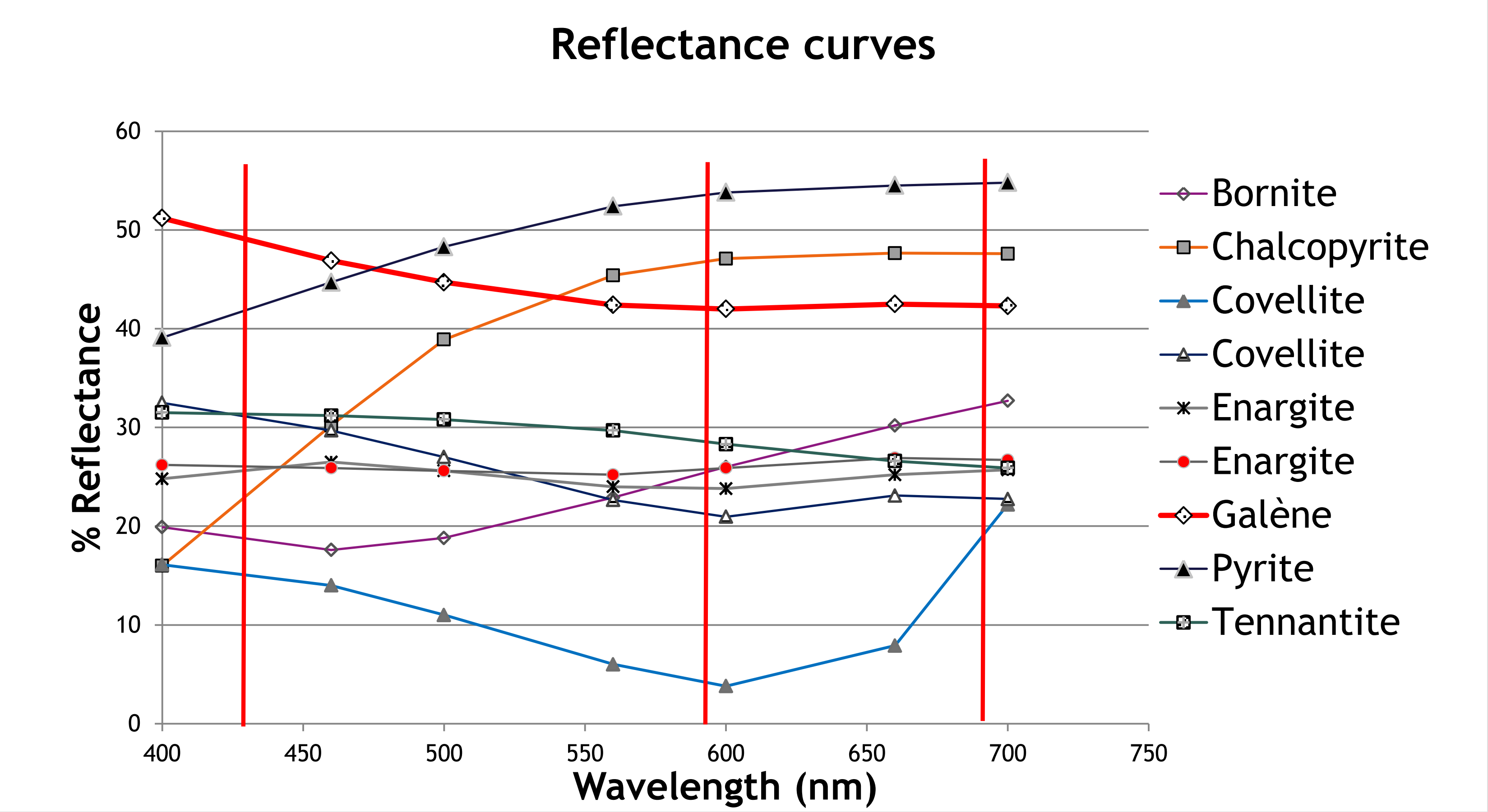
- Multispectral analysis

- 55 images/ polished section at 3 wavelengths

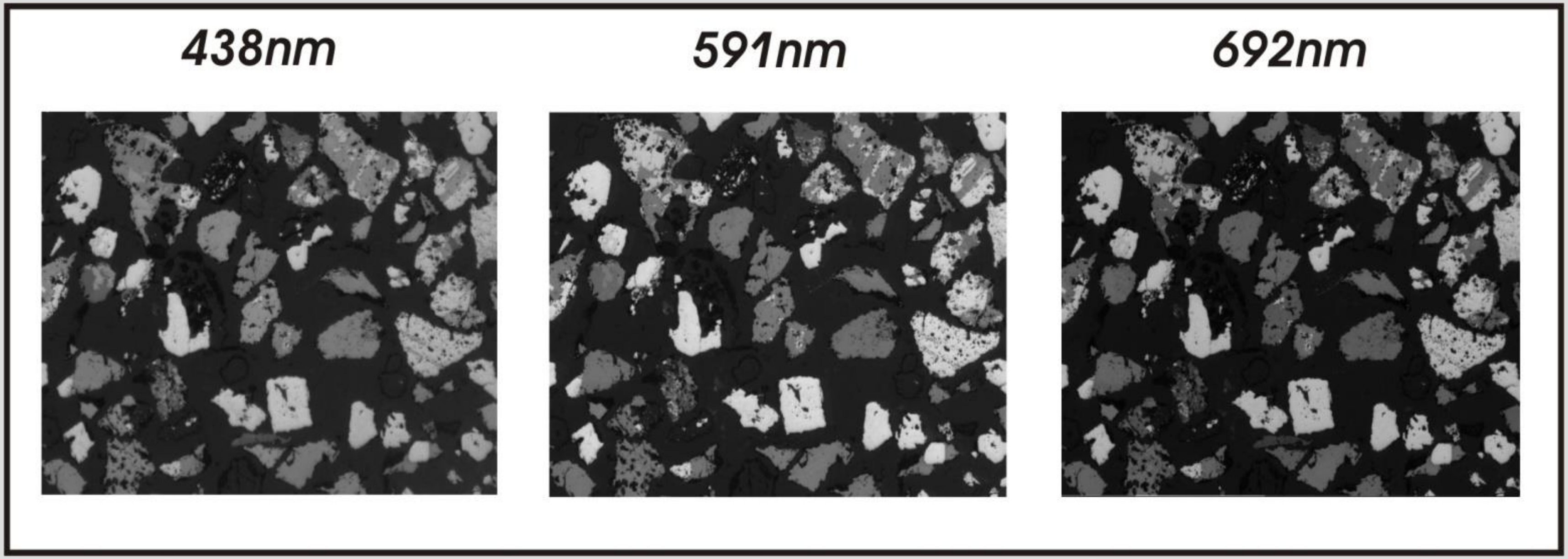
Material



4.3 Quantitative analysis

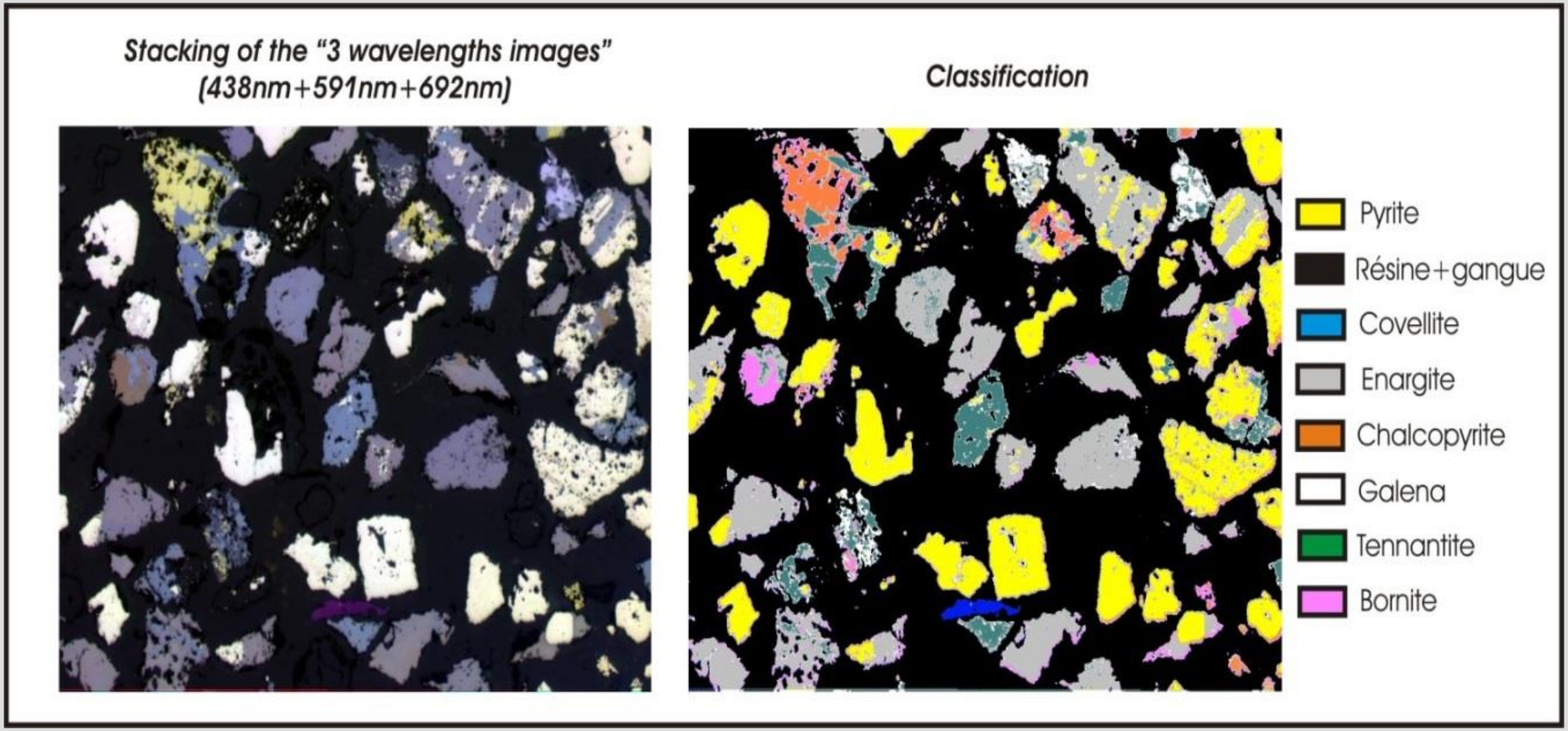


4.3 Quantitative analysis

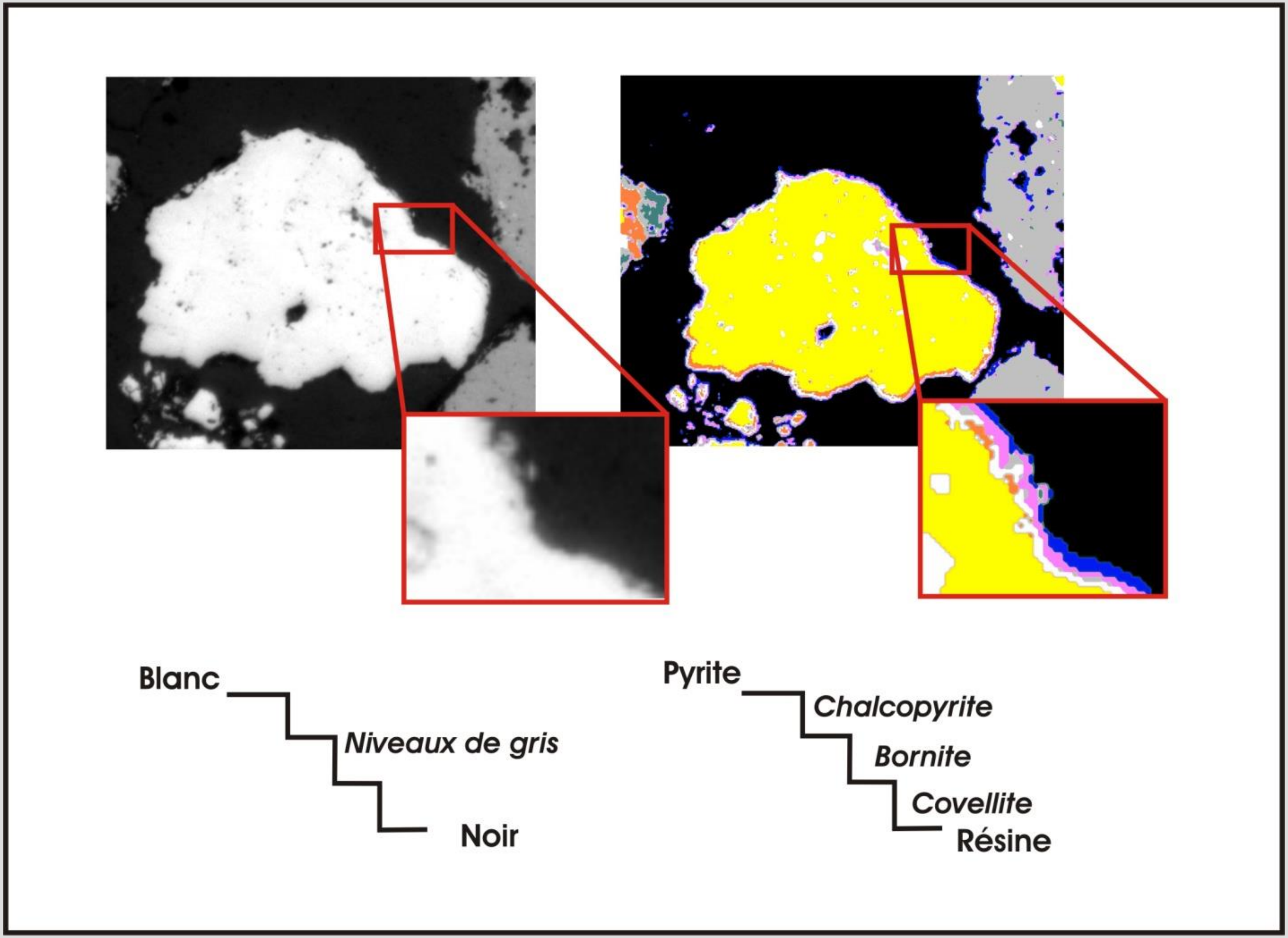


4.3 Quantitative analysis

- Classification



Peripheral pixels



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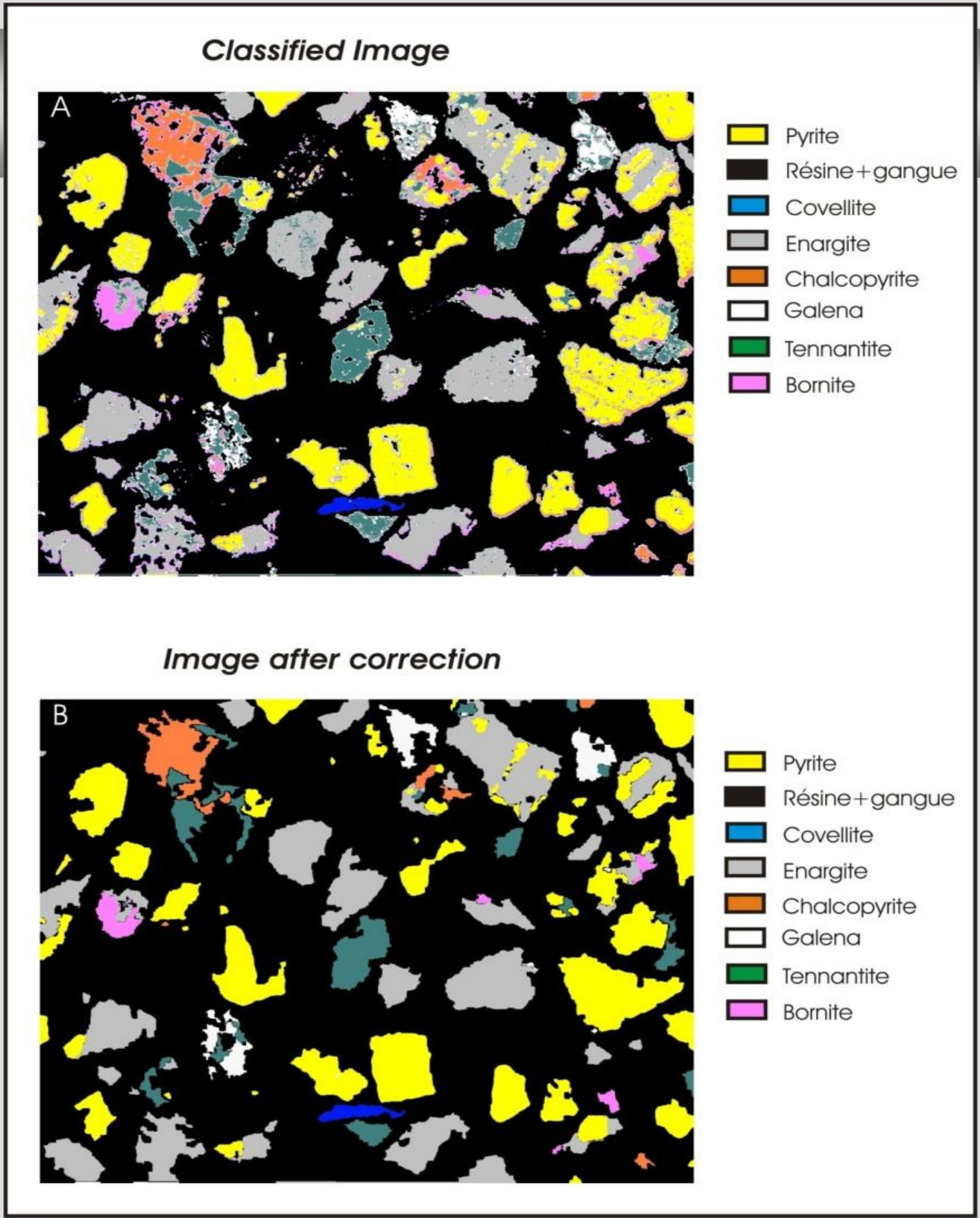
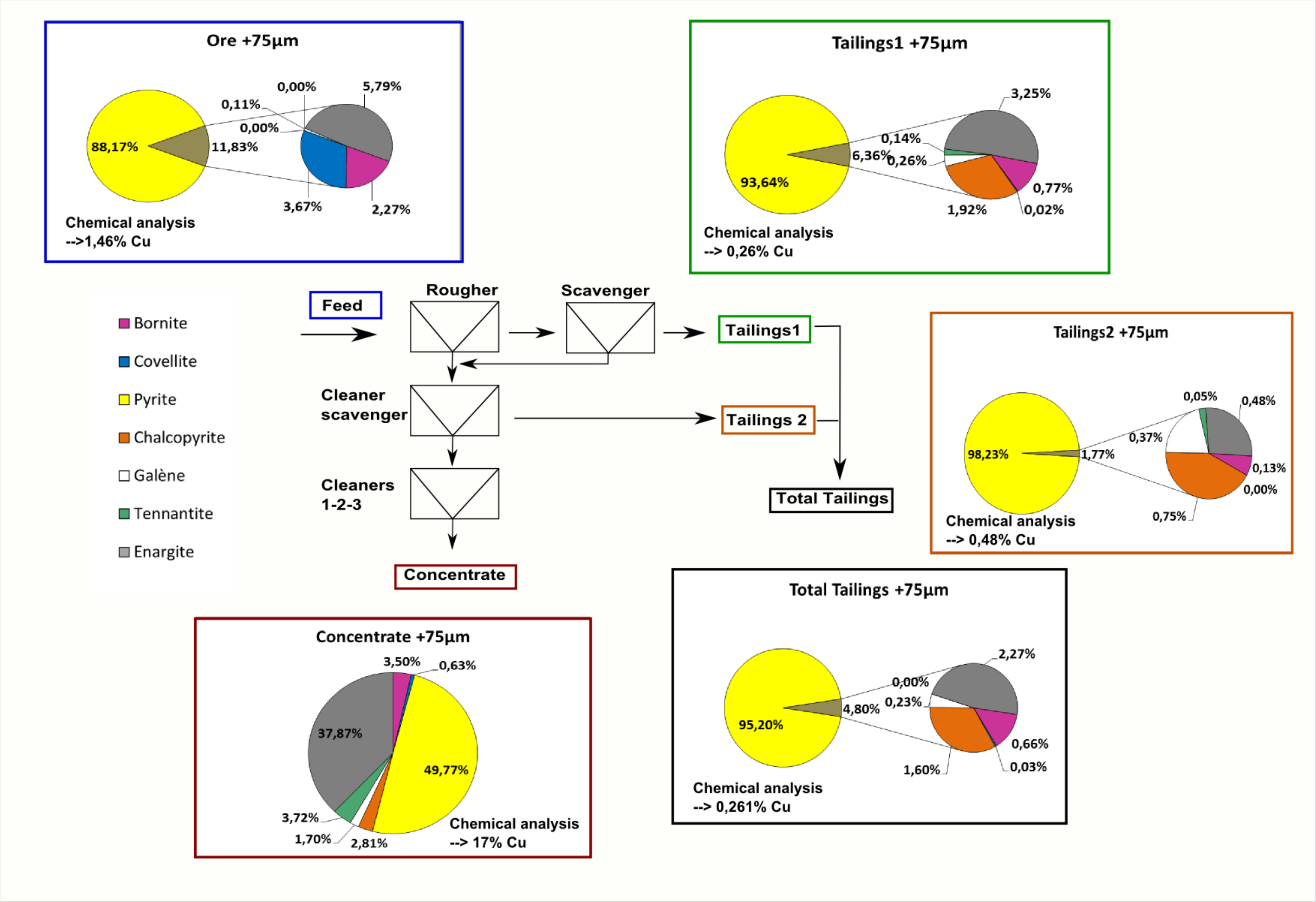


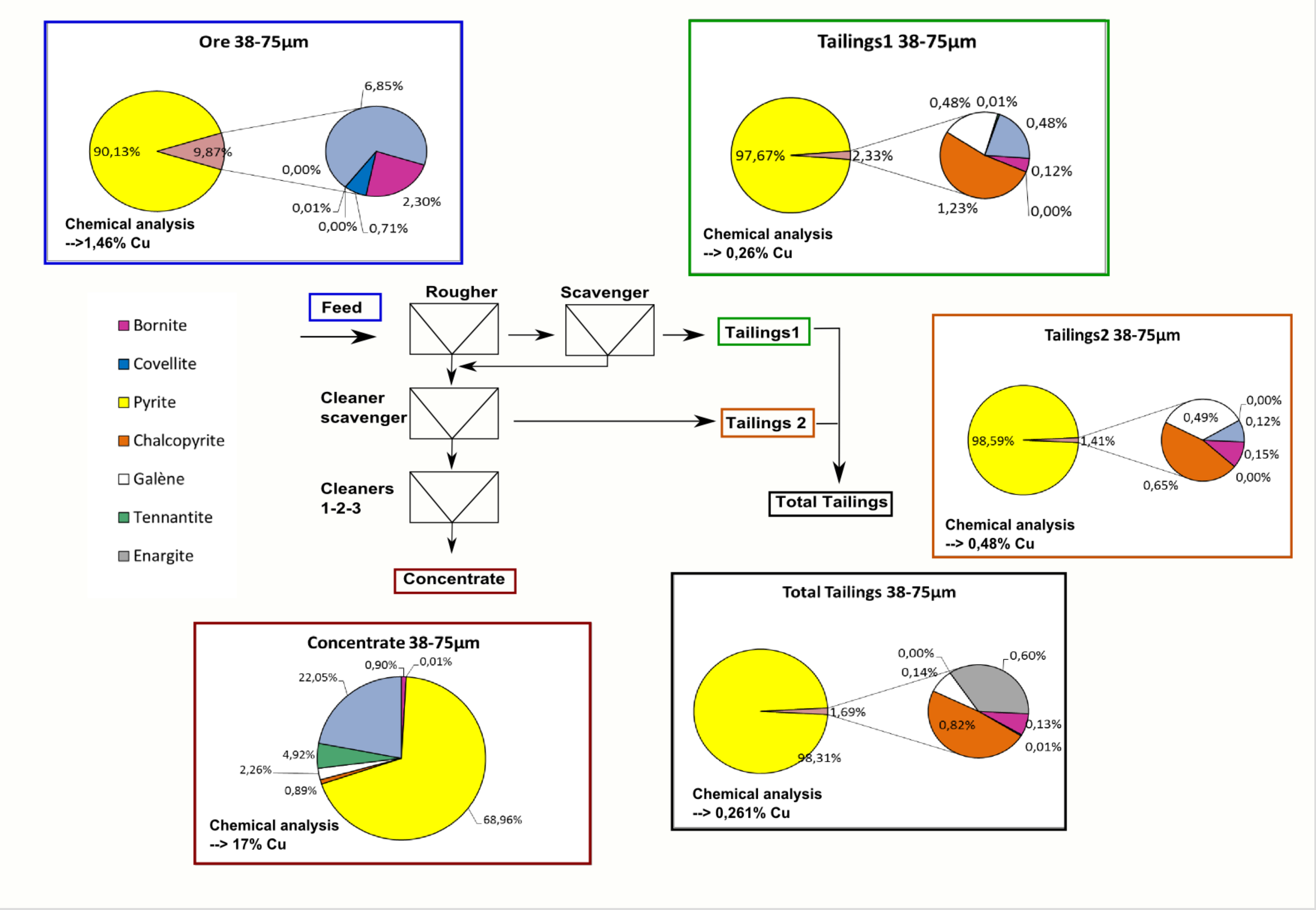
5. Quantitative results

- 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



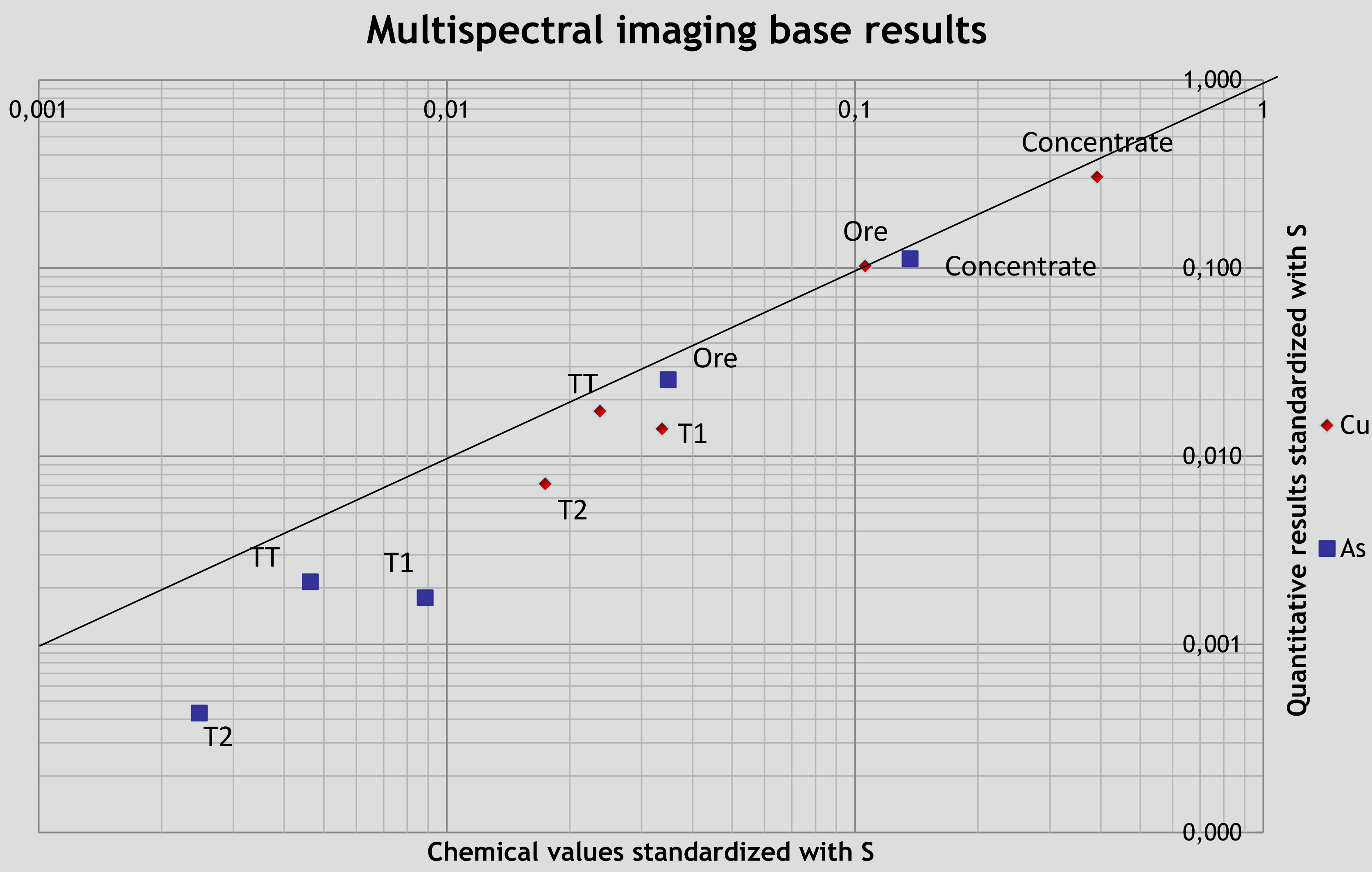
5.2 Quantitative results >< chemical results

- Convert mineral proportions to Cu, As and S proportions

%Cu = $\sum$ %mineral(i) * 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



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