



# Hyperspectral image analysis of Aguas Teñidas, Magdalena, Sotiel and Majada Drill-core scanning in the Iberian Pyrite Belt

Pedro Simões Teixeira **Mendes**

Barnabé P., Pons J.-M., Vazquez J.-C., Garcia C. & **Pirard E.**

# ANCORELOG

*Analytical Core Logger*

- Project leader



- Project partners

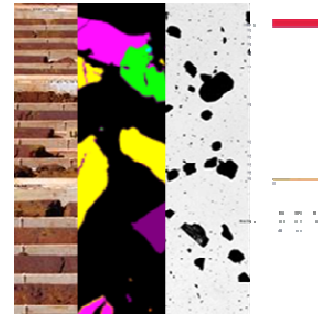


# Resourceful Engineers



## GEOMETALLURGICAL CHARACTERIZATION

Process oriented  
"mineralogical"  
mapping



## SMART SORTING

Advanced 3D  
imaging and  
hyperspectral sorting



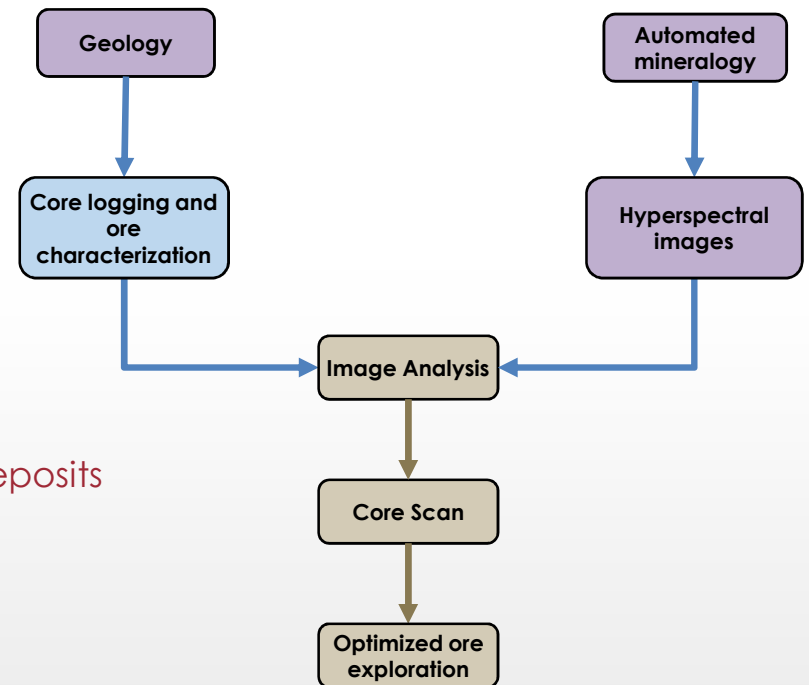
## MASTER IN GEORESOURCES ENGINEERING

Innovative Education  
in Geometallurgy



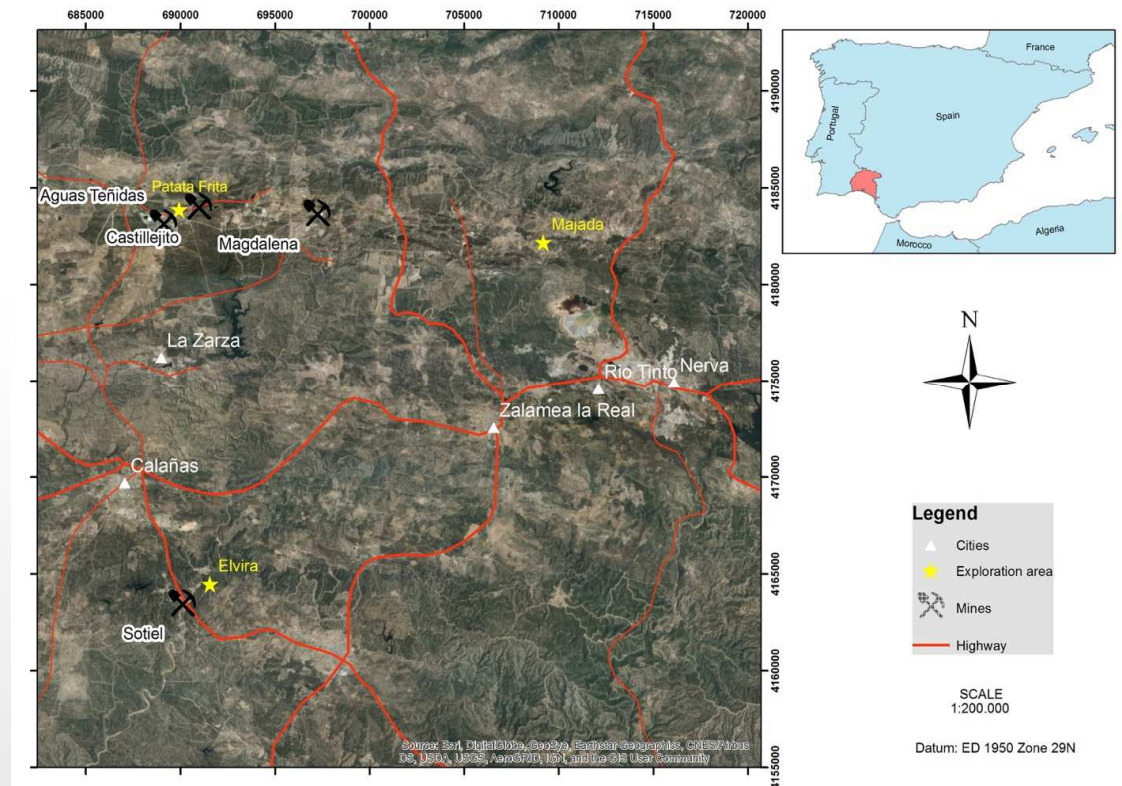
- **Resource**
  - Interest for both **MINING** and **URBAN MINING**
- **Efficiency**
  - Contribute to developing a more **CIRCULAR ECONOMY**
- **Engineering**
  - Focus on **TECHNOLOGICAL INNOVATION** embedded in education

- Project objectives :
  - Mobile drill core logging system
  - Real time multi-sensing
  - Fusion of chemical, physical and structural properties
  - Smart classification into geometallurgical domains
  - Increased productivity of logging
- Hyperspectral imaging objectives :
  - Integrate/calibrate hyperspectral imaging
  - Demonstrate potential for lithological classification in VMS deposits
  - Extend the methodology



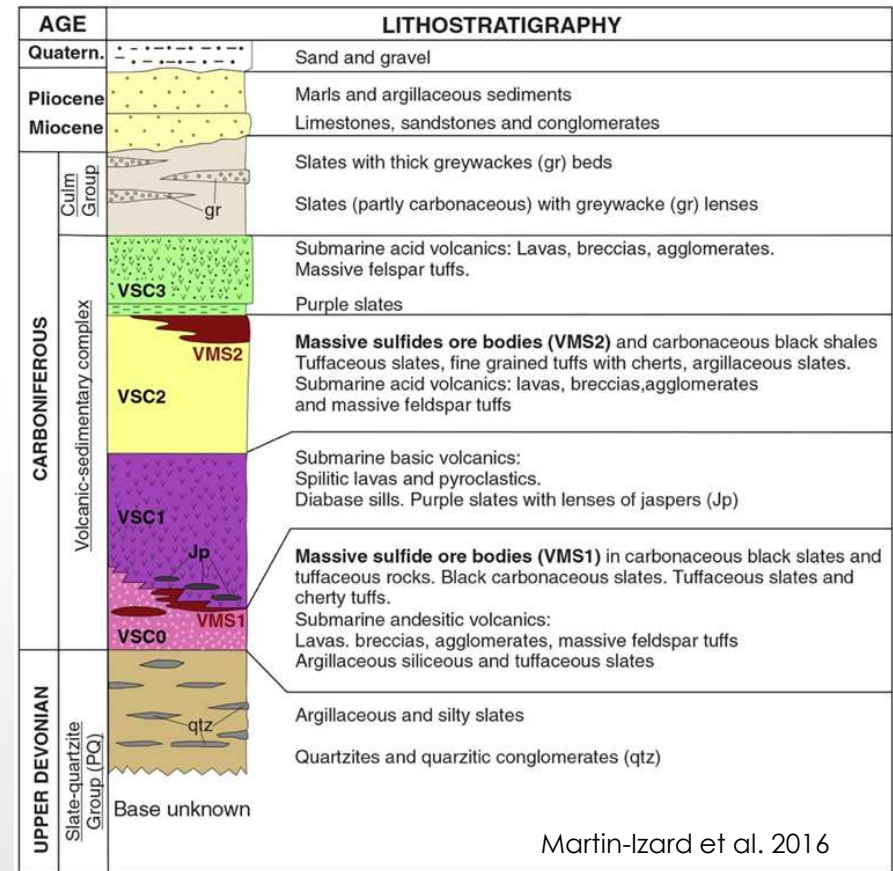
# Minas de Aguas Teñidas (MATSA)

- Iberian Pyrite Belt
  - Cupriferous (Cu)
  - Polymetallic (Pb,Zn,Cu)
- Deposit names
  1. Aguas Teñidas and Patata Frita
  2. Magdalena
  3. Sotiel and Elvira
  4. Majada



# Minas de Aguas Teñidas (MATSA)

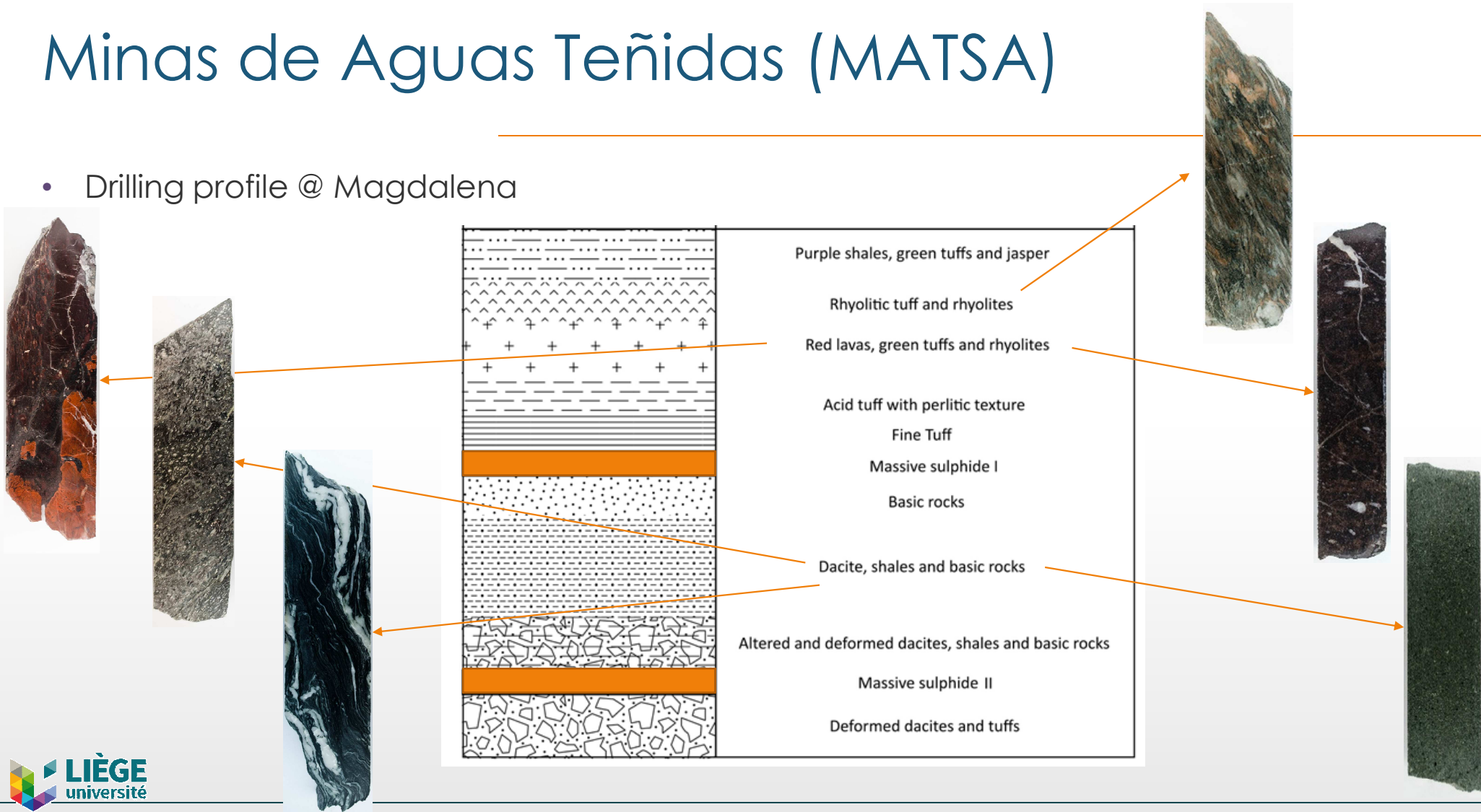
- Two types of deposits
  - EXHALATIVE : Shale-hosted (brine pools on seafloor)
    - Sotiel-Elvira
    - Majada
  - REPLACEMENT-STYLE : submarine dacites and rhyolites (well below seafloor, reducing environment)
    - Aguas Teñidas - Patata Frita
    - Magdalena



Martin-Izard et al. 2016

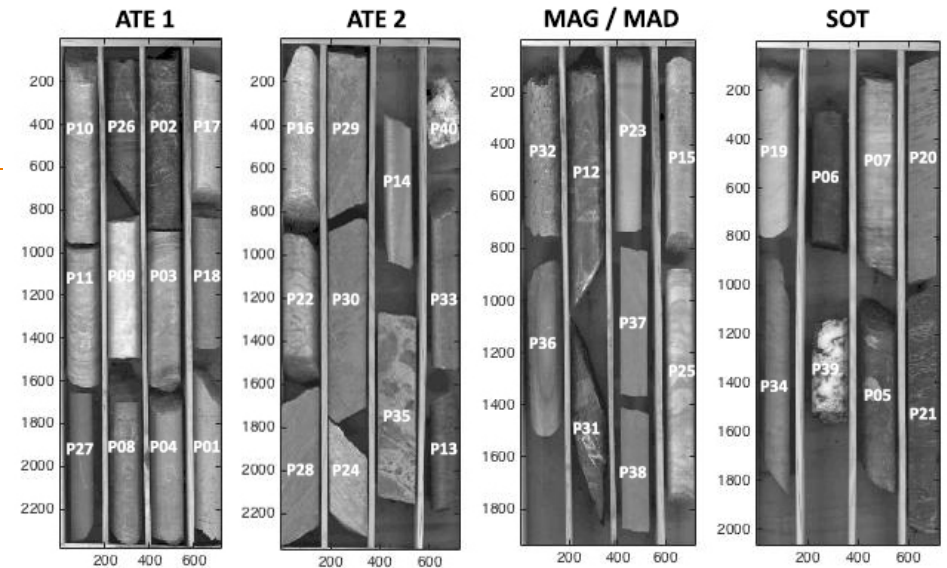
# Minas de Aguas Teñidas (MATSA)

- Drilling profile @ Magdalena

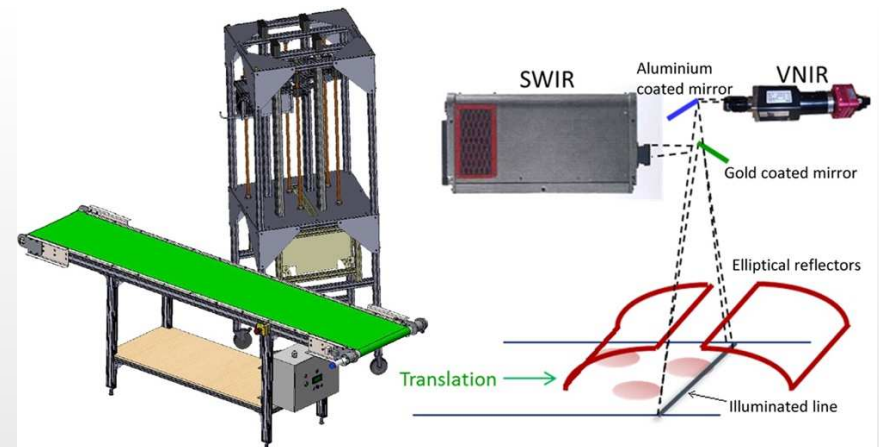


# Hyperspectral Imaging

- Material
  - 40 samples with representative lithologies
  - Full, half and ¼ cores
- Core-Scanning Prototype
  - Visible to Near Infrared: 400 - 1000 nm
  - Short Wave Infrared: 1000 - 2500 nm
  - Resolution VNIR: 30 pixels/cm (300 µm)
  - Resolution SWIR: 10 pixels/cm (100 µm)



Settings	VNIR	SWIR
Exposure time (ms)	10	0.1
Frame rate (mm/s)	11.7	5
Left/ right offsets (pixels)	438 / 153	-
Conveyor speed (mm/s)	5	
Image ratio (height/width)	3.3	
Power supply	56 V - 10.8 A	



(Barnabé et al. 2015)



# Hyperspectral Imaging

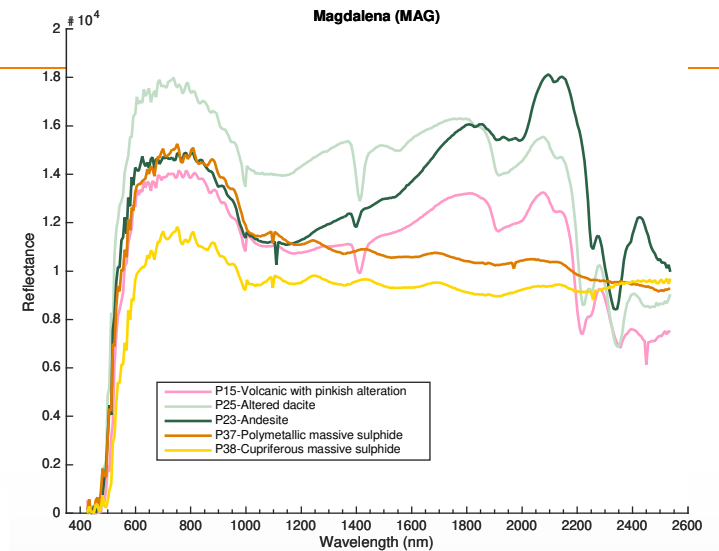
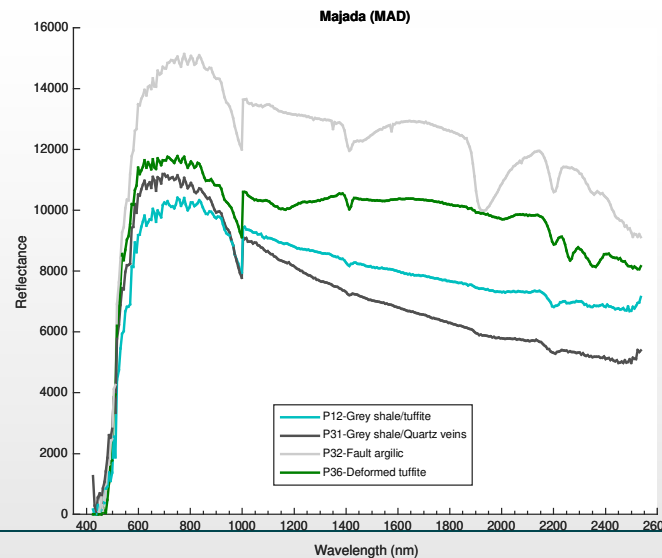
- Spectral Responses

- Clear Spectral Signatures

- Barren volcanic rocks (chlorite and white micas); ...; Calcite veins

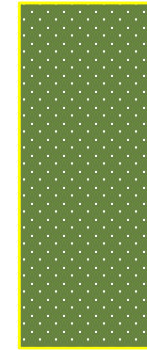
- Poor (A)spectral signatures

- Dark rocks (shales, black rhyolite,...), Sulphides, ...
    - Volcano-sedimentary packages














# Image Classification

- Full dataset
  - 323 bands



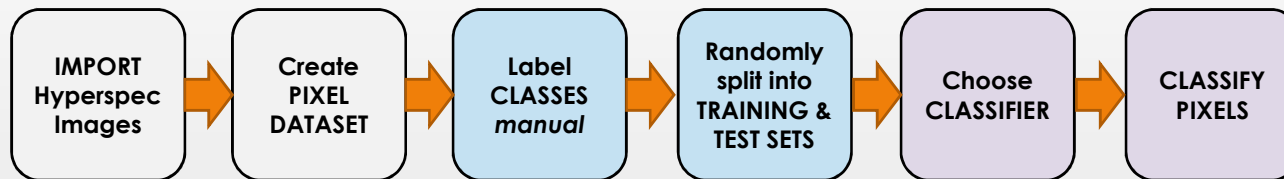
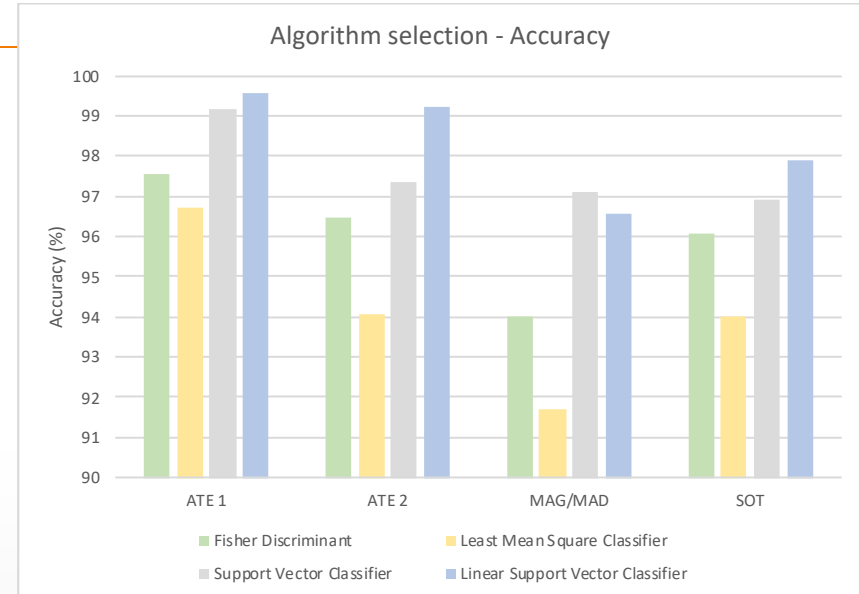
Region randomly sampled @ 0,2% (120px) for TRAINING



ATE 2	P28	Sulphide veins in volcanoclastic rock	219	187	70	
	P22	Brecciated tuff	25	90	23	
	P16	Sericitic Rhy	190	192	185	
	P24	Sericitic Rhy with Py	62	62	62	
	P30	Sericitic/Chloritic Rhy with Py	38	160	166	
	P29	Chloritic/Sericitic Rhy with Cpy	102	131	64	
	P35	Chloritic Rhy with Cpy	18	79	44	
	P14	Red shale	108	32	19	
	P13	Purple shale	105	0	109	
	P33	Red lava	163	10	29	
	P40	Calcite vein with Co	242	110	183	

# Image Classification

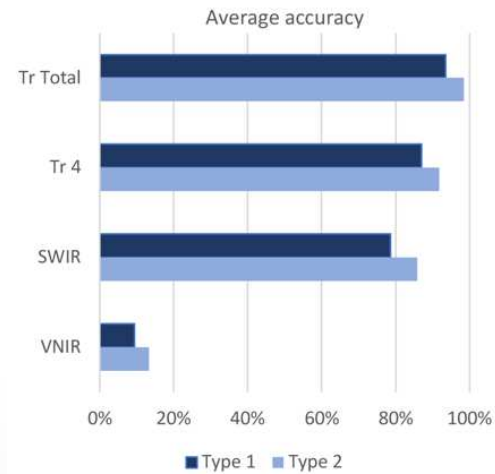
- Optimize Choice of Classifier (time vs. accuracy)
  - LINEAR SUPPORT VECTOR CLASSIFIER
    - Long, Accuracy > 99%
  - FISHER DISCRIMINANT ANALYSIS
    - Short, Accuracy > 97%



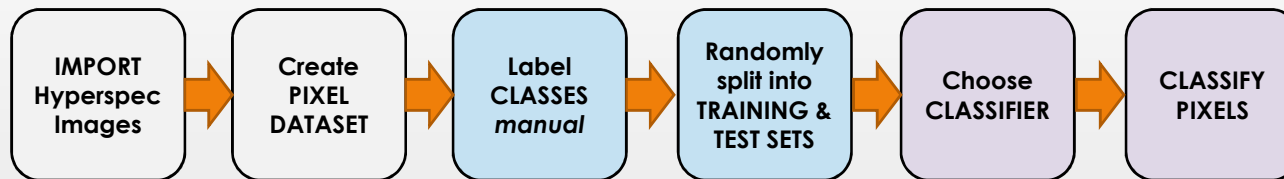
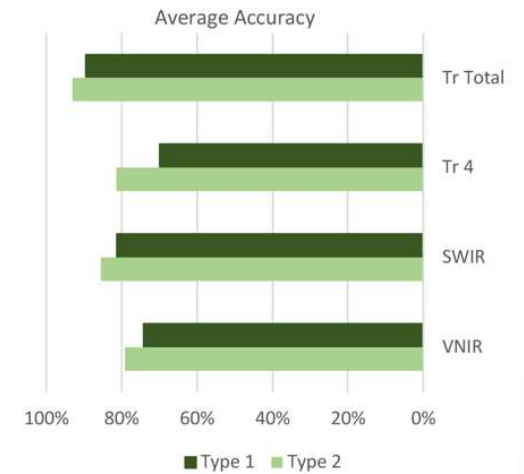
# Image Classification

- Test sub-selection of bands
  - VNIR alone
  - SWIR alone
  - VNIR + SWIR

Linear Support Vector Classifier

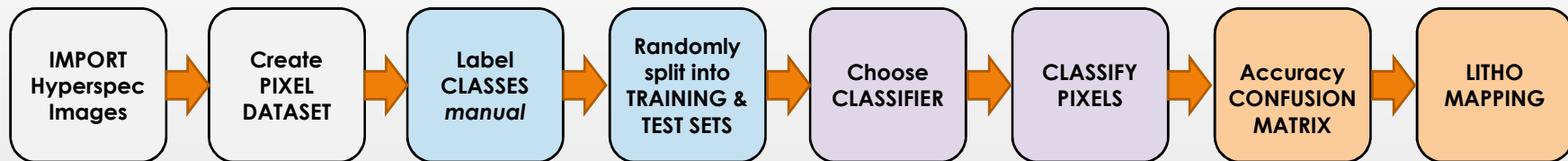
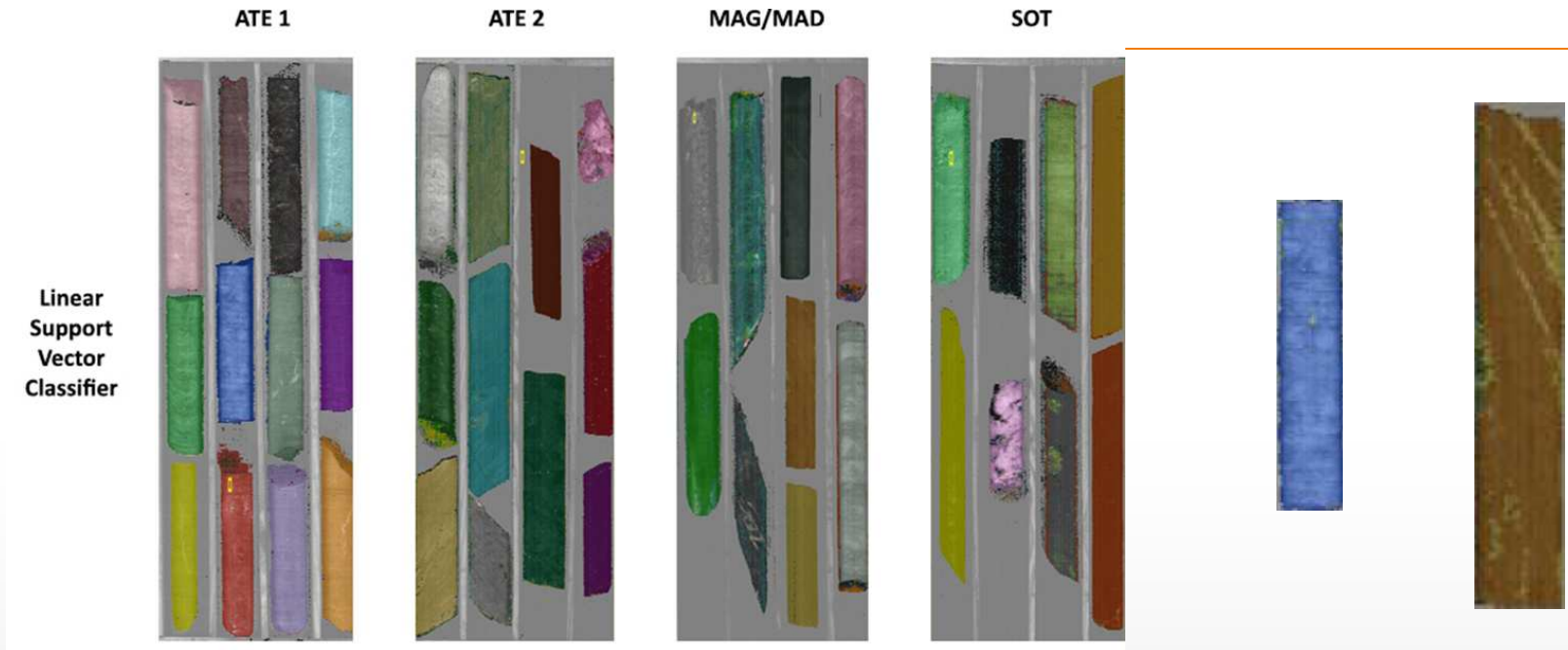


Fisher Discriminant



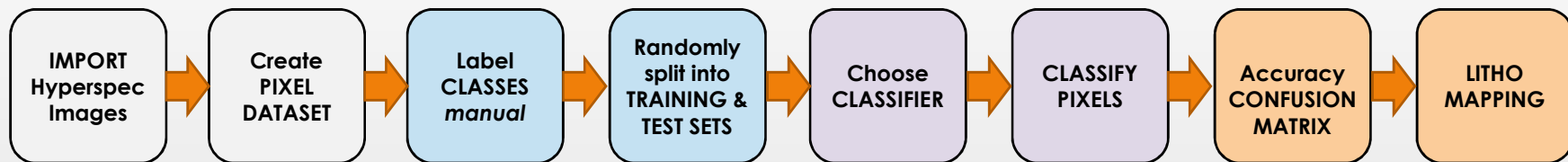
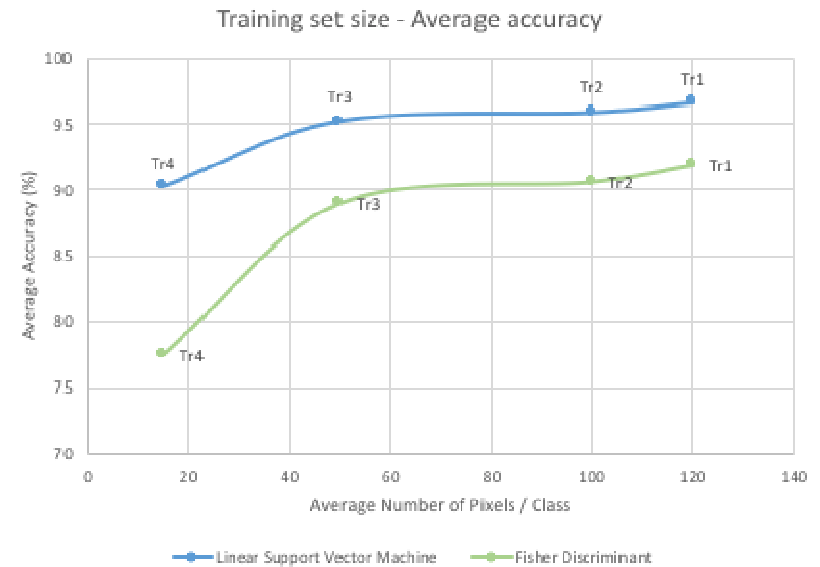
# Image Classification

- Validation



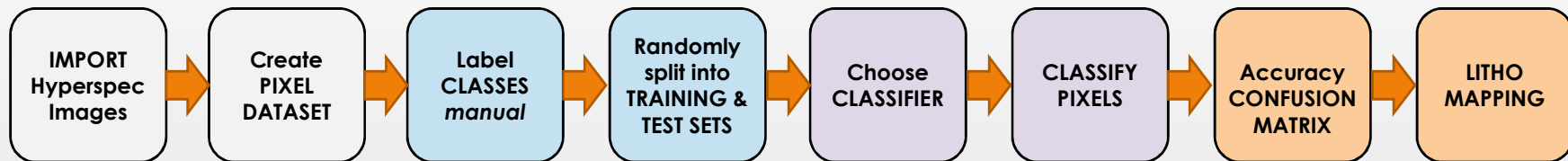
# Image Classification

- Accuracy vs. size of training sets
  - LSVC > FISCHER



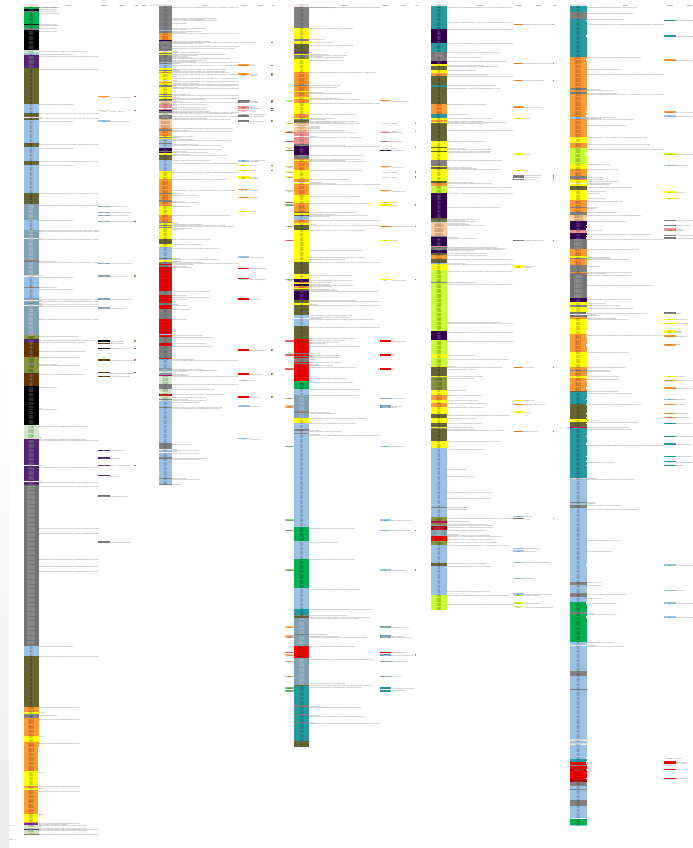
# Image Classification

- Size of training sets vs. time
  - FISCHER >> LSVC



# Ongoing Developments

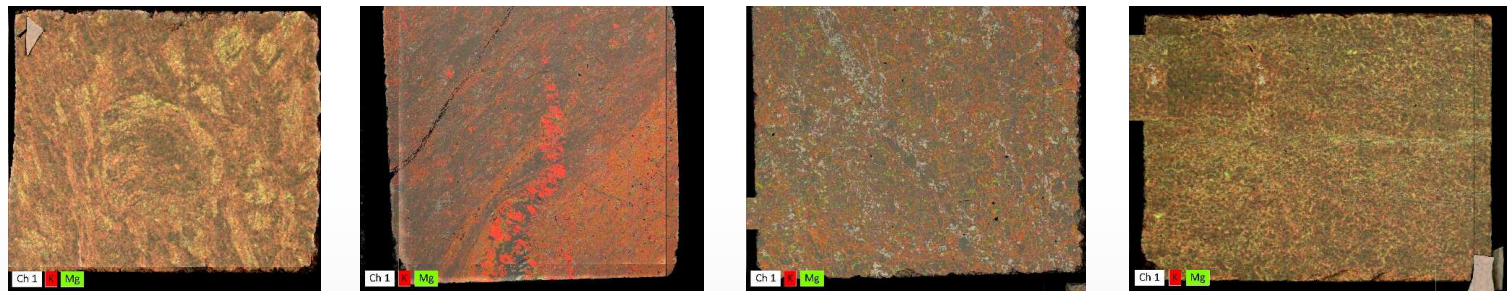
- Data Fusion SWIR + XRF
  - 200 m of cores scanned
  - Training on 6 to 14 lithologies
  - XRF acquisition on « blocks »





# Ongoing Developments

- Correlative Mapping
  - SEM EDX / Micro-XRF
  - SWIR Hyperspectral

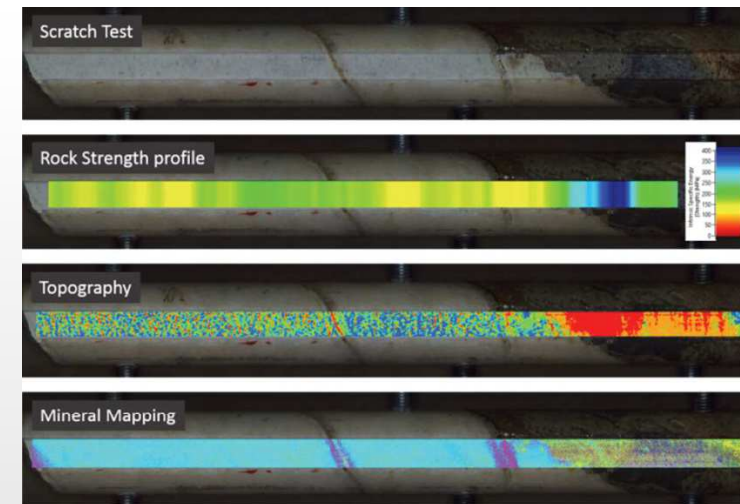


*Element to minerals  
Alteration regression model*

*Mg-Chlorite  
Fe-Chlorite  
Sericite / White mica*

# Conclusions

- Core-Scanning Technology
  - **MATURE** imaging technology
  - Proven results with **SIMPLE** classification tools
  - Restrict number of classes in **KNOWN** environments
- Future developments
  - Bring **COMPUTER ASSISTED LOGGING** instrument to the market
  - **MULTI-SENSOR** fusion technology
  - Include **TEXTURAL** recognition
  - Populate a large **DATABASE** of rock signatures
  - Implement **DEEP LEARNING** algorithms
  - Include **GEOMETALLURGICAL** data in domaining



Thank You!



**EMERALD**  
ERASMUS MUNDUS MASTER  
IN GEORESOURCES ENGINEERING

[www.em-georesources.eu](http://www.em-georesources.eu)

