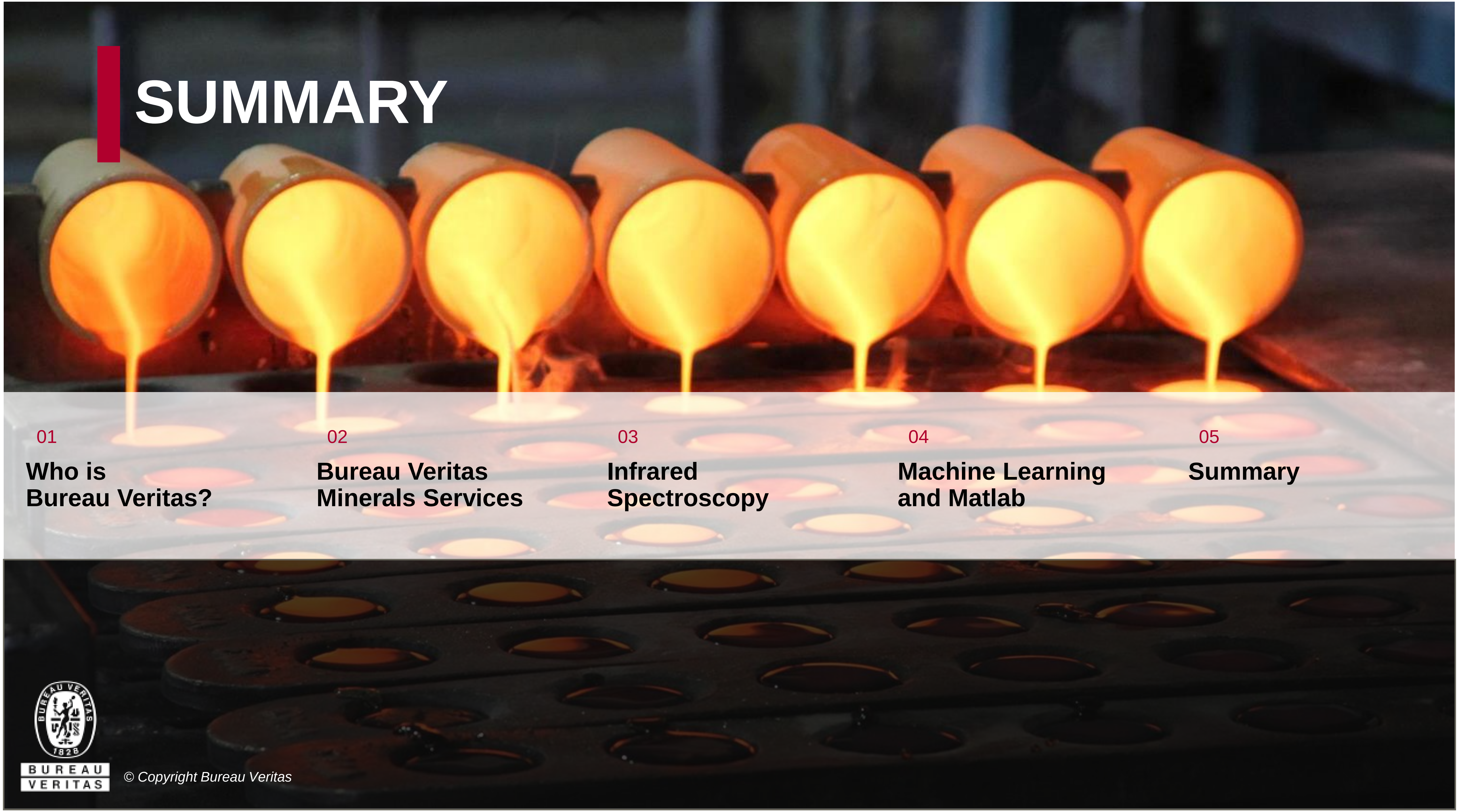
ANALYSIS OF MINING SAMPLES USING INFRARED SPECTROSCOPY AND MACHINE LEARNING

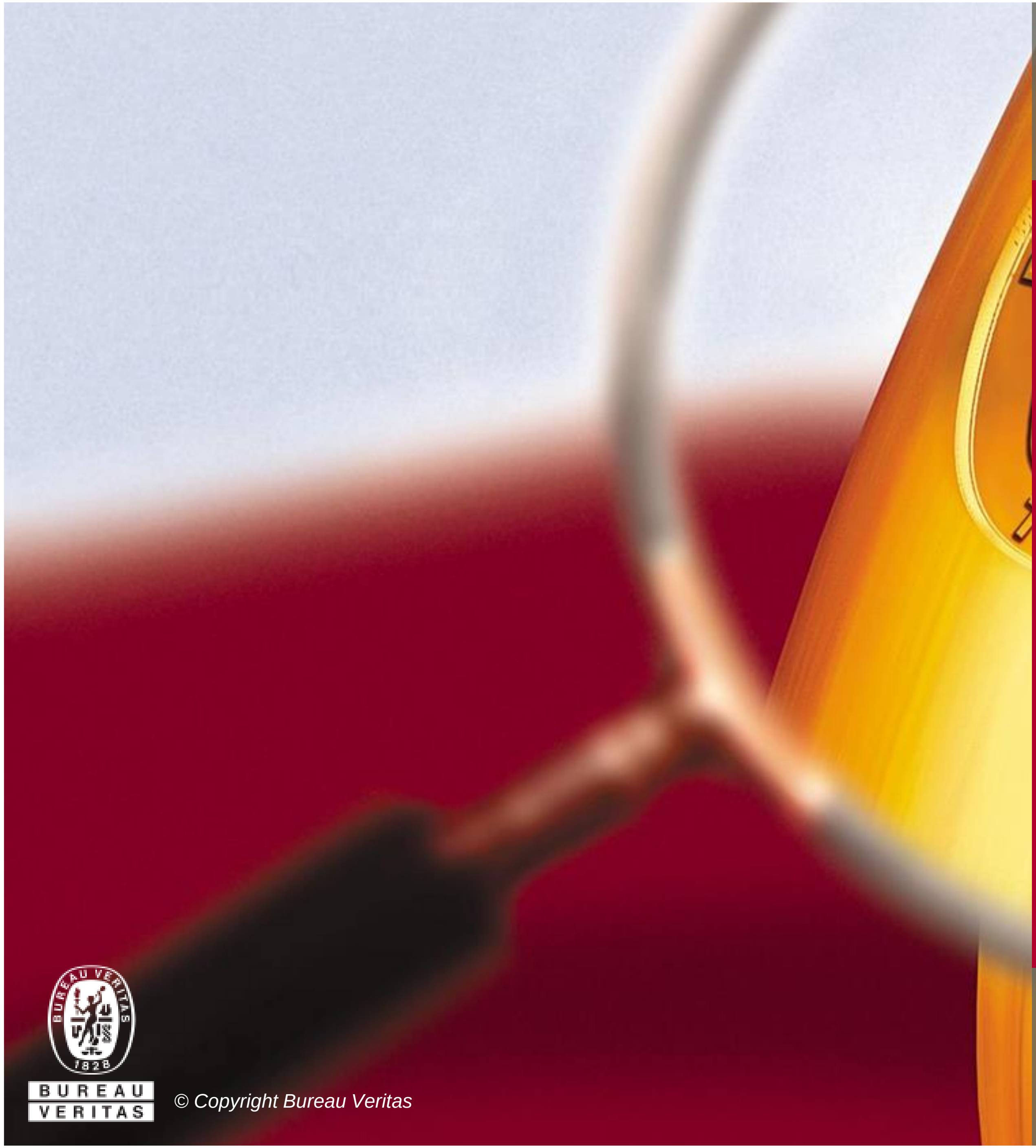
MATLAB CONFERENCE

PERTH, MAY 2017



SUMMARY

BUREAU VERITAS



01 WHO IS BUREAU VERITAS

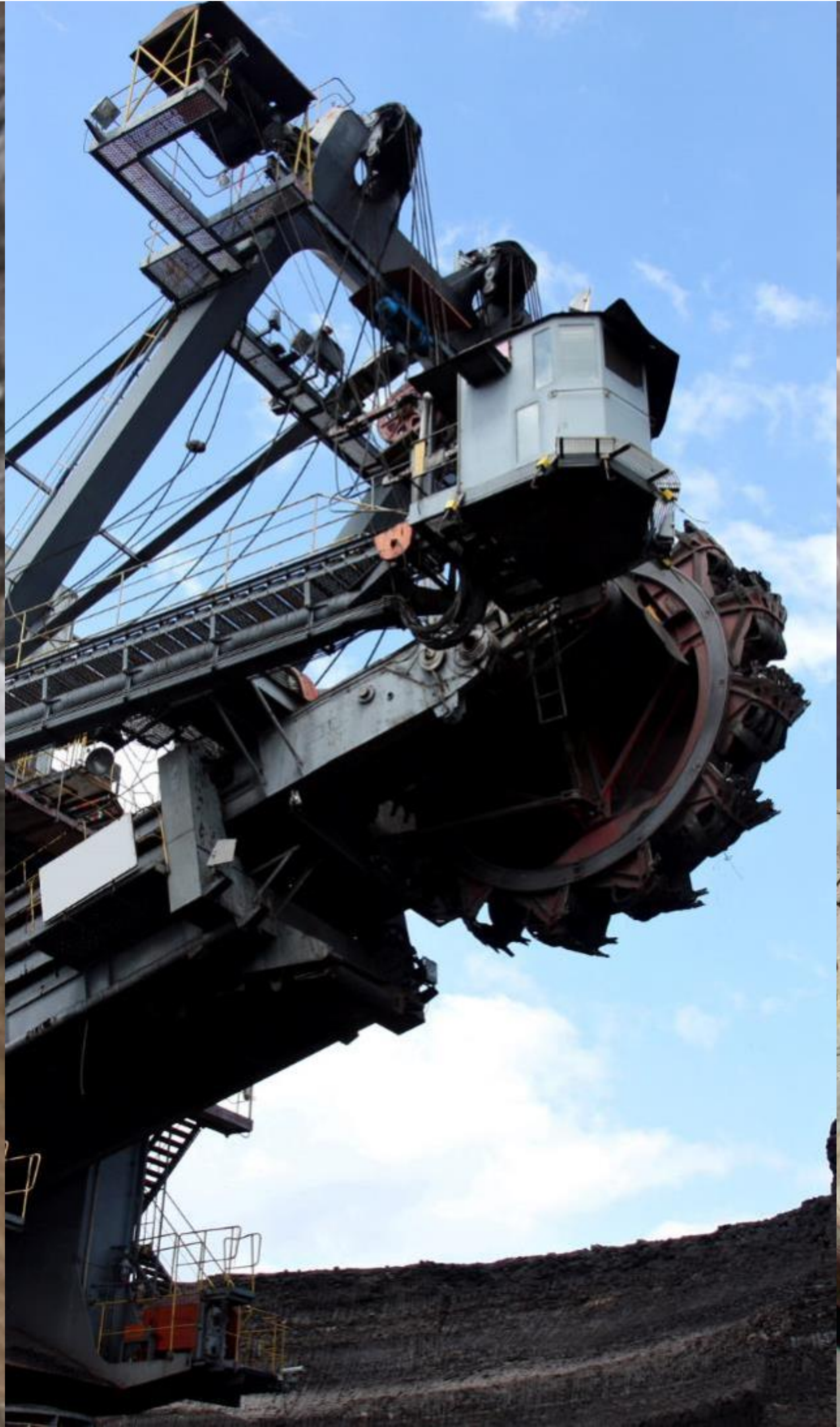
Established in 1828, Bureau Veritas is a global leader in Testing, Inspection & Certification services in the areas of Quality, Health & Safety, Environment and Social Responsibility across eight global businesses.

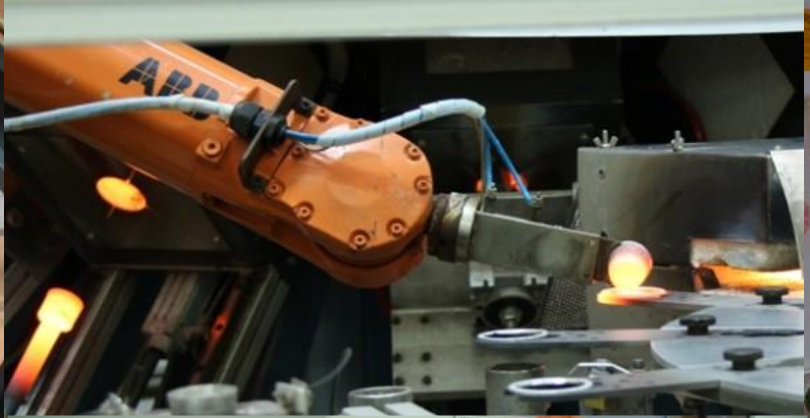
8 GLOBAL BUSINESSES
2015 REVENUE: €4.6 BILLION

Global network comprising of 66,500 employees in 1400 offices and laboratories across 140 countries.

- 8% — Marine & Offshore
- 17% — Commodities
- 14% — Consumer Products
- 6% — Government Services & International Trade
- 23% — Industry
- 13% — In-Service Inspection & Verification
- 11% — Construction
- 8% — Certification

02
BUREAU VERITAS MINERALS SERVICES

ABB

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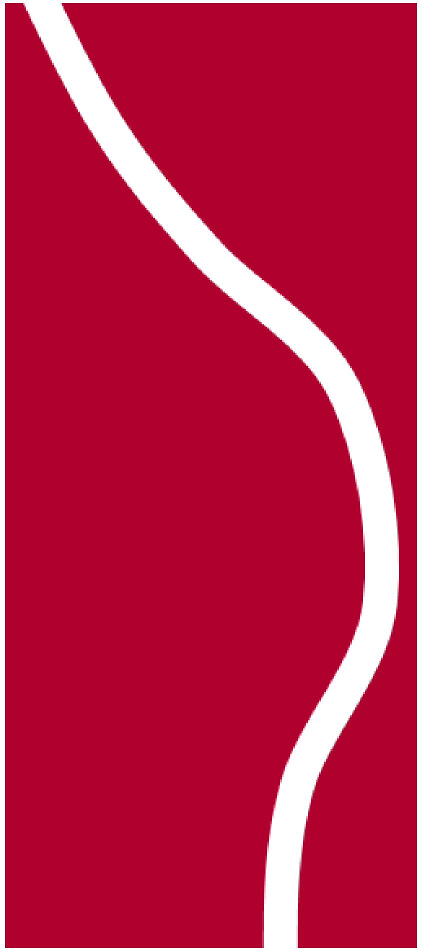
X RAYS ON
RAYONS X

MINING DEVELOPMENT

Cycle
Exploration
⇩
Resource Development
⇩
Process and Mine Development
⇩
Production

Scope of Work
Geo Assay
Mineralogy
Ore Characterisation
⇩
Geo Assay
Process Scoping
Geomet Studies
⇩
Feasibility Studies
Pilot Plant
Product testing
⇩
Process Optimisation
Product Quality
Grade Control
Geomet Programs

Analysis Type
Low detection levels
Pathfinders
⇩
Accurate
Quantitative analysis
JORC reporting
⇩
Mineralogy
Recovery
Concentrates
⇩
Tailored methods for operations
Metal accounting
Transactions

Analysis Cost


Analysis Volumes
Scoping samples
Field analysis
Routine Laboratory
⇩
Target samples
Routine laboratory
⇩
Project samples
Research analysis
Proxies
⇩
On site lab
Fast turn around
High accuracy (trade)

03
INFRARED SPECTROSCOPY

INFRARED SPECTROSCOPY

Sample is presented to a light source. – No special preparation

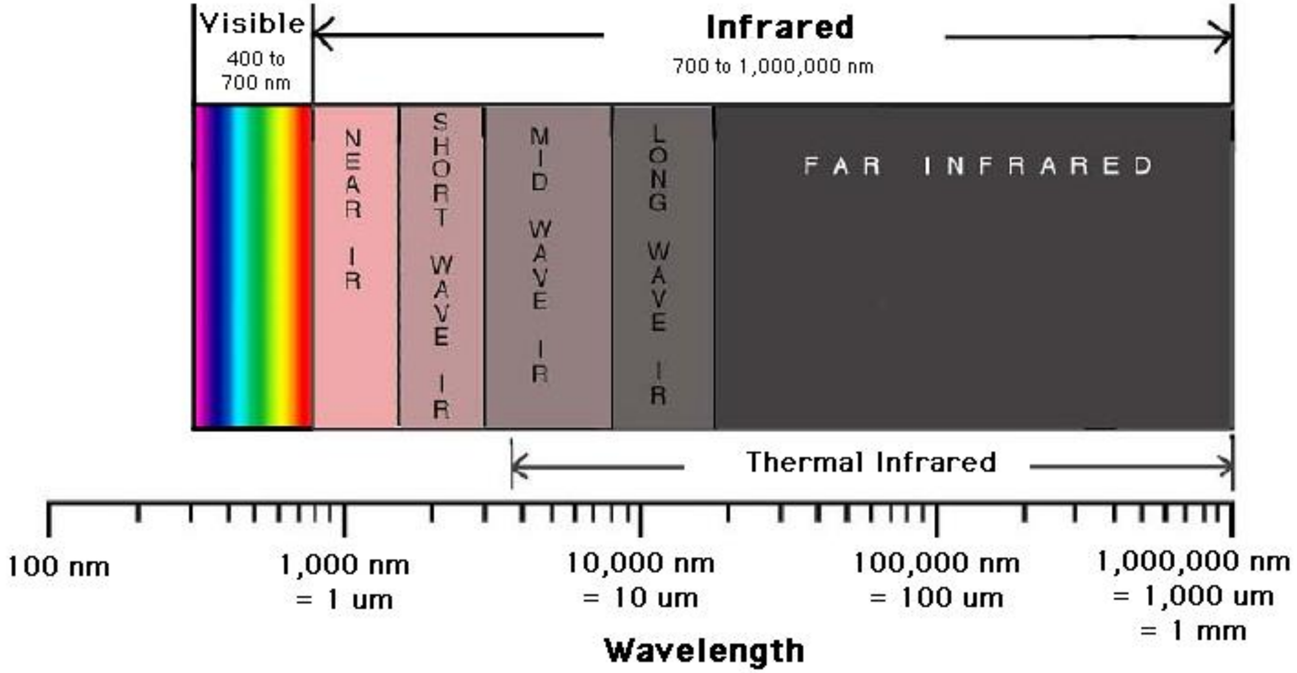
The response from the sample is measured by a detector.

- Near Infrared, Short Wave Infrared
- FTIR – Fourier Transform Infrared Spectroscopy – Mid to Thermal Infrared

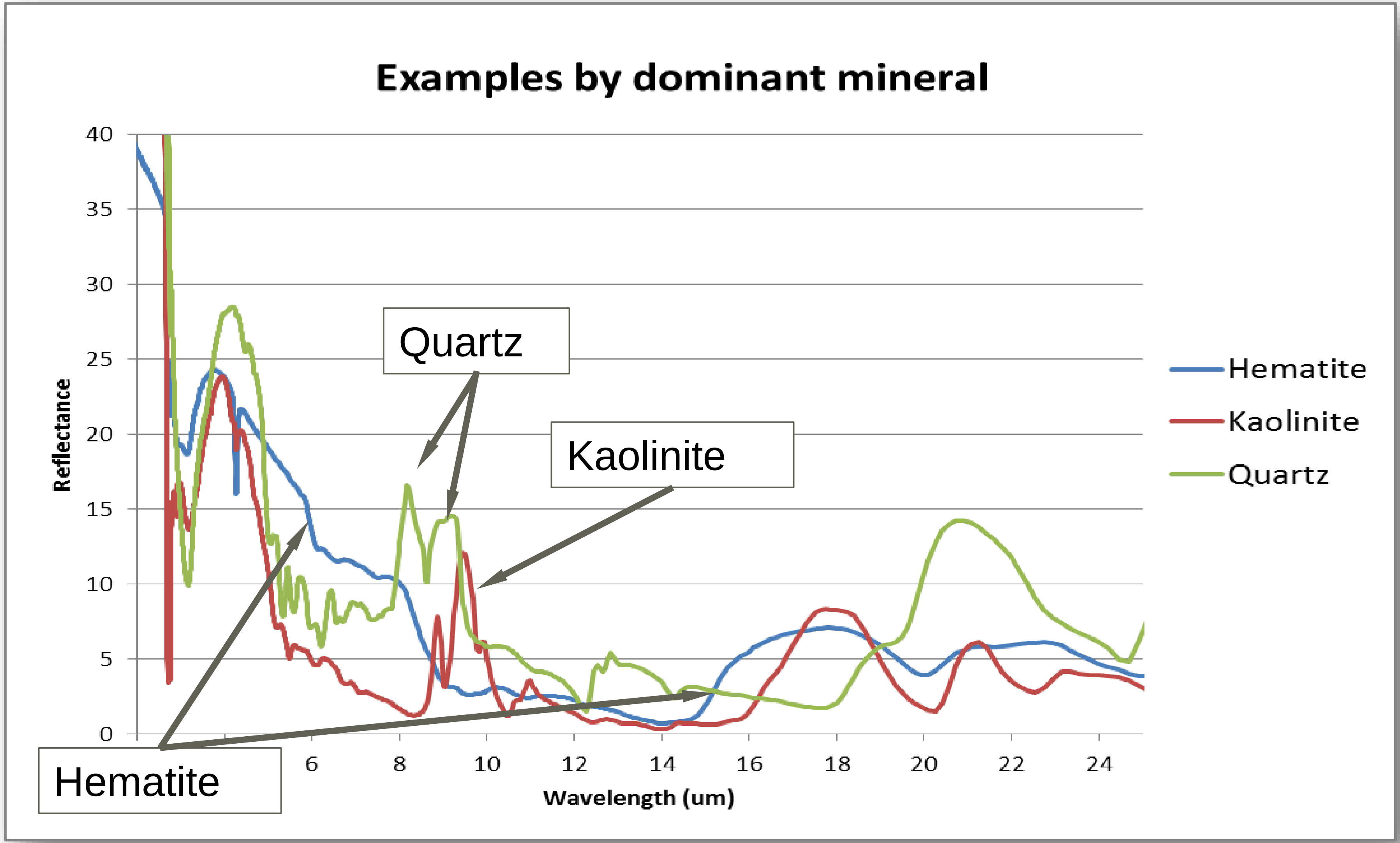
Spectra is representative of the molecular bonding in the sample

Absorption of incident light at specific characteristic wavelengths

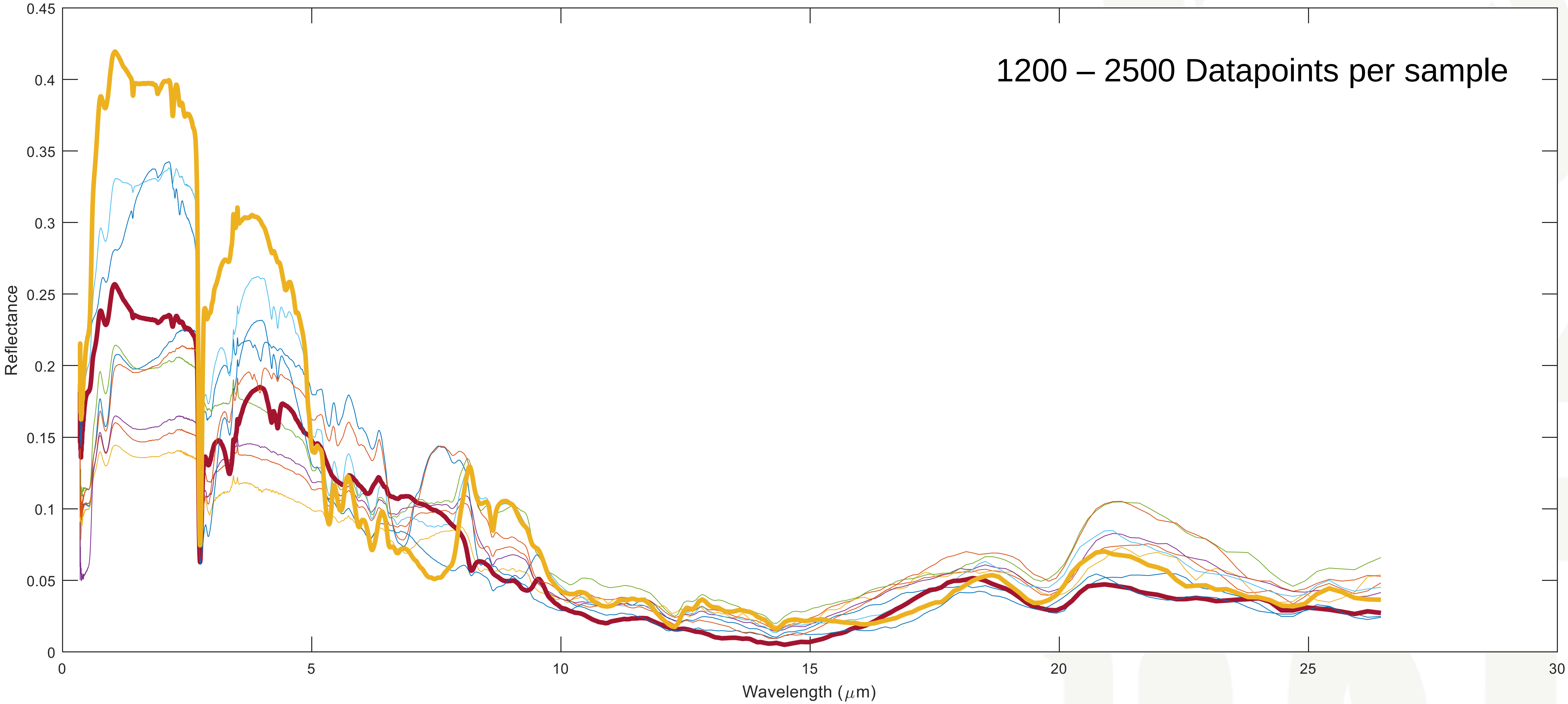
Bond vibration, bending and stretching



SPECTRA OF IRON ORE SAMPLES



EXAMPLE SPECTRA

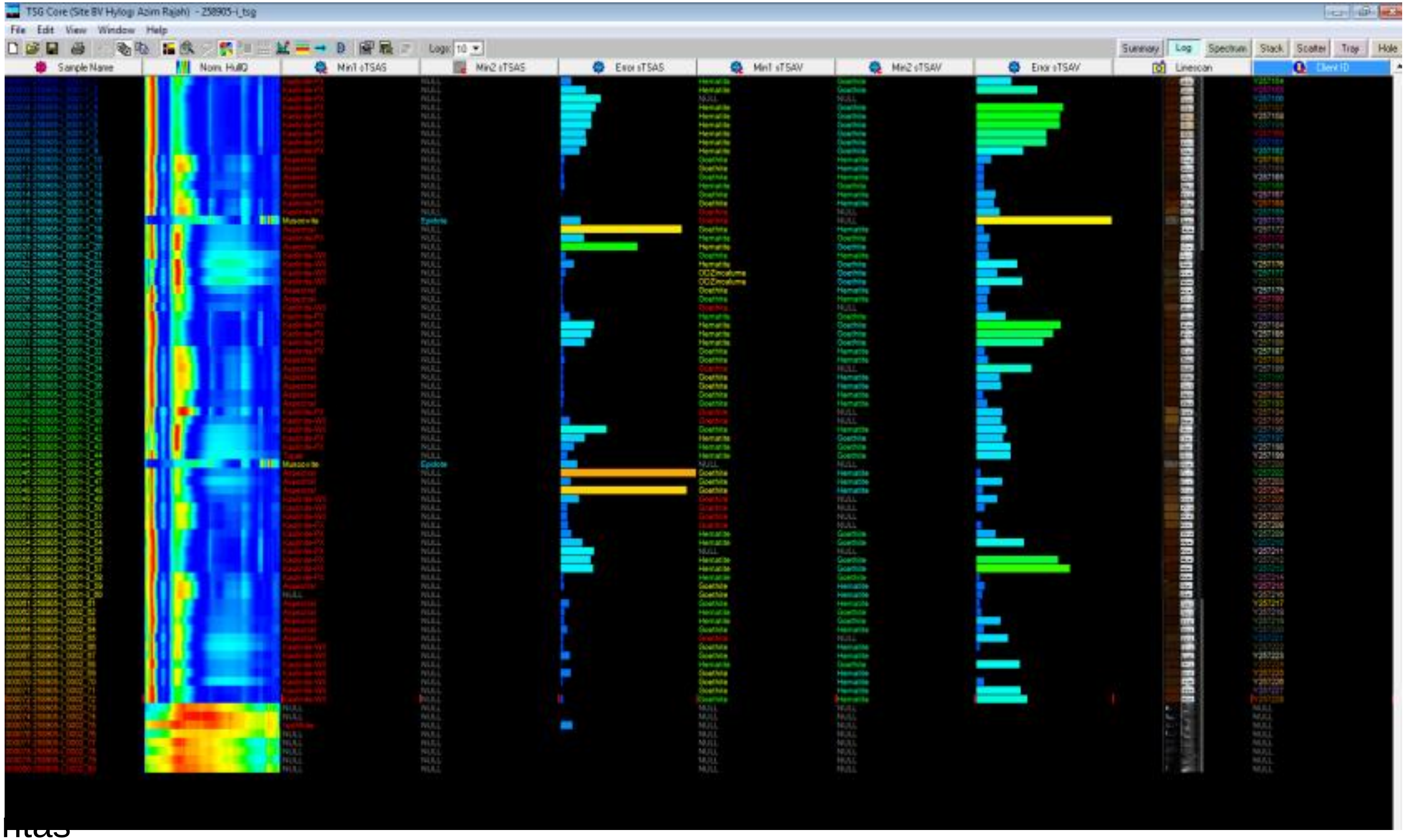


SPECTRAL INTERPRETATION

- Spectral Library
- Analyse Features for

  DEPTH
  LOCATION
  SHAPE

- Major Minerals Only



04
MACHINE LEARNING AND MATLAB

Spectral Process Overview – Value Proposition

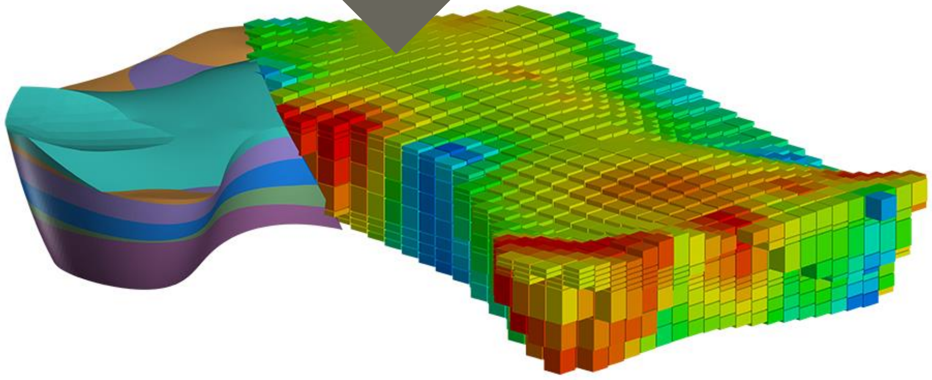
1. *Mineralogy and Proxies*

- Mineralogy drives block model design
- Metallurgical testing is expensive
- Proxies are unreliable

2. *Infrared Red Spectra*

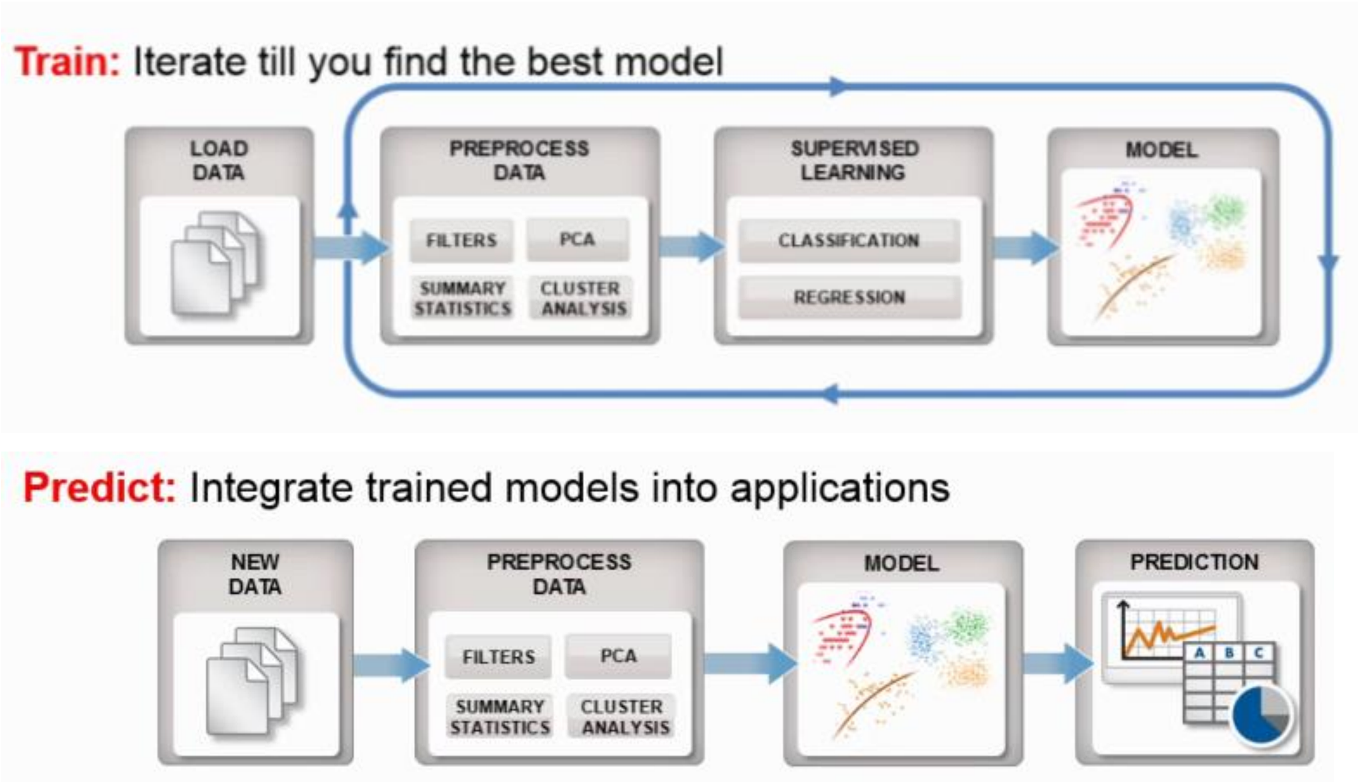
- Simple and low cost
- Laboratory Workflow
- Spectral fingerprint

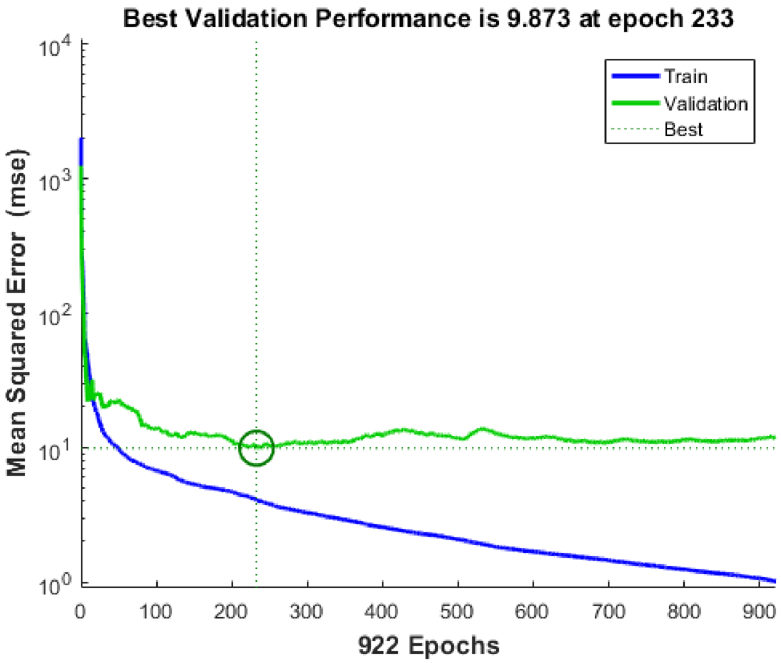
Machine Learning



How do we use this data for routine analysis?

Two step process:





▶ Mineralogy

- Hematite, Goethite, Gibbsite, Kaolinite, Talc, Mica, Quartz

▶ Physical properties

- LOI, SG, Bulk Density

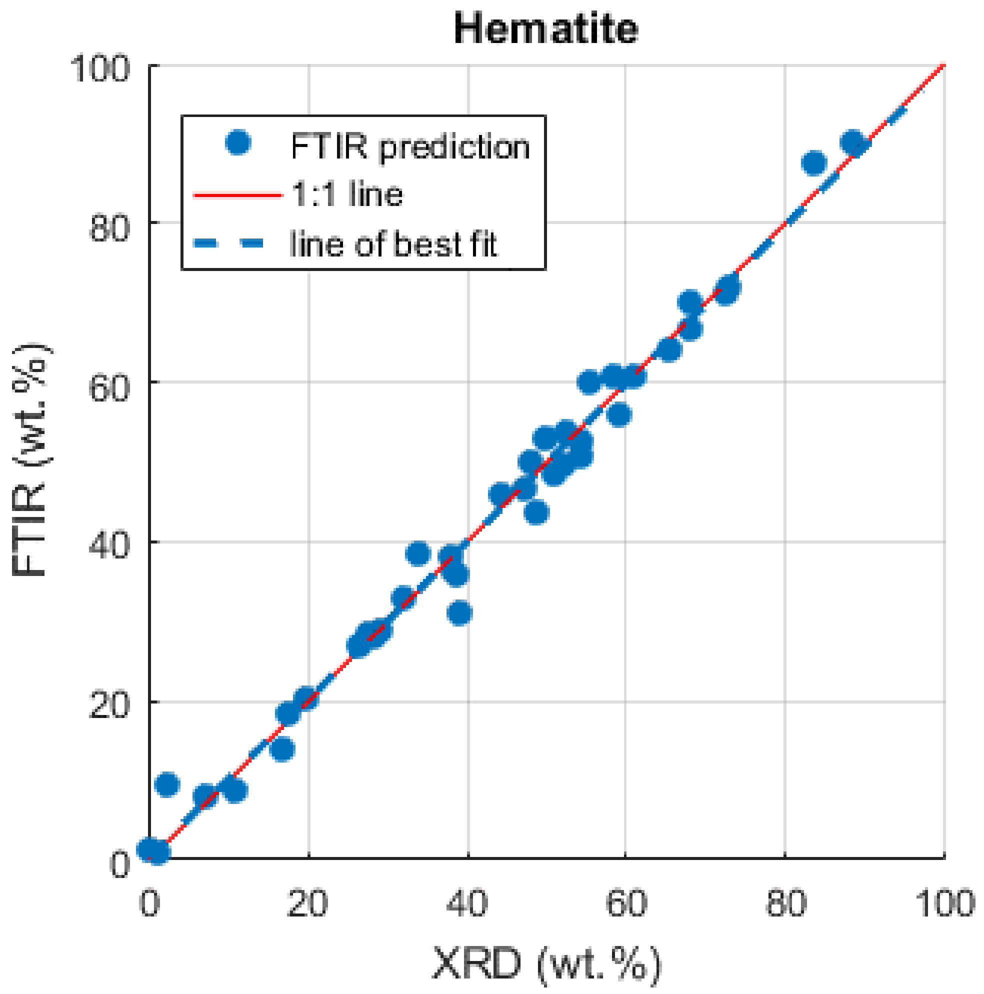
▶ Ore processing properties

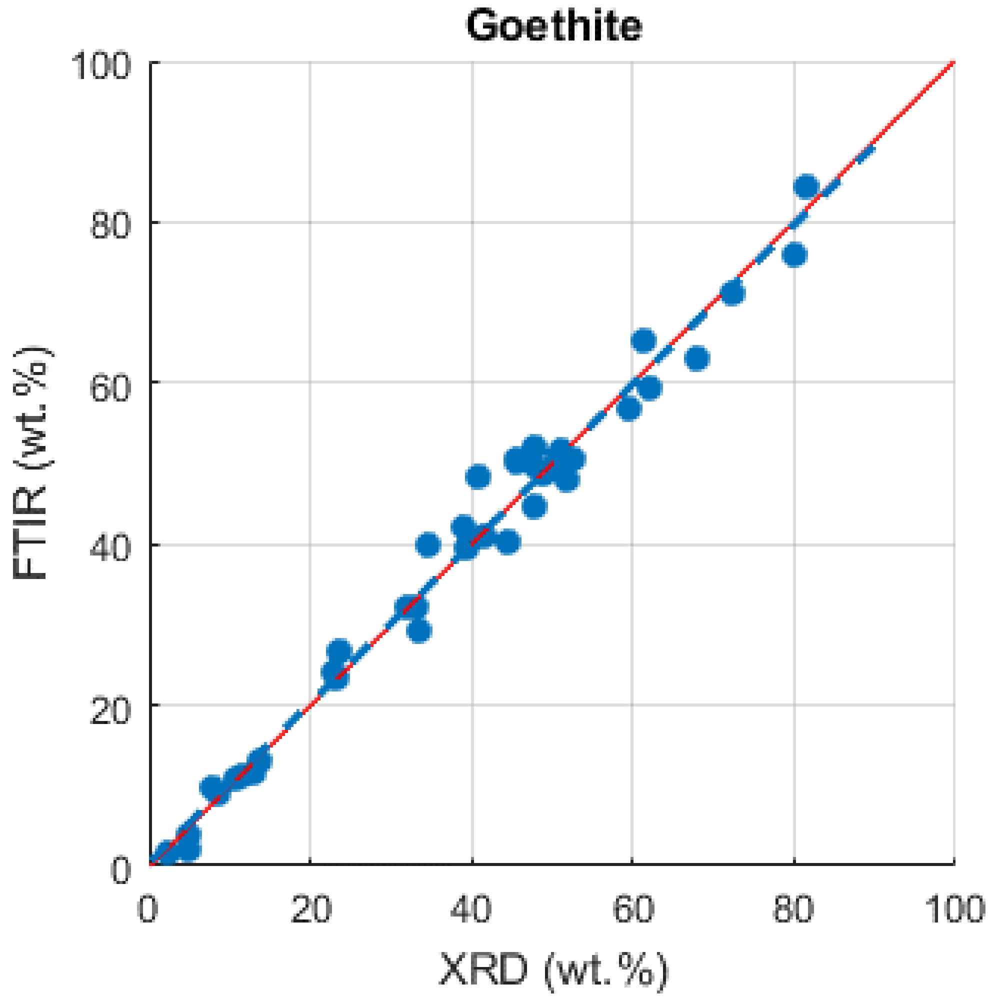
- Comminution energy, recovery, acid consumption

▶ Chemistry

- Fe, Al, Si for laterites and Cu, Ni, Pb, Zn for base metal ores

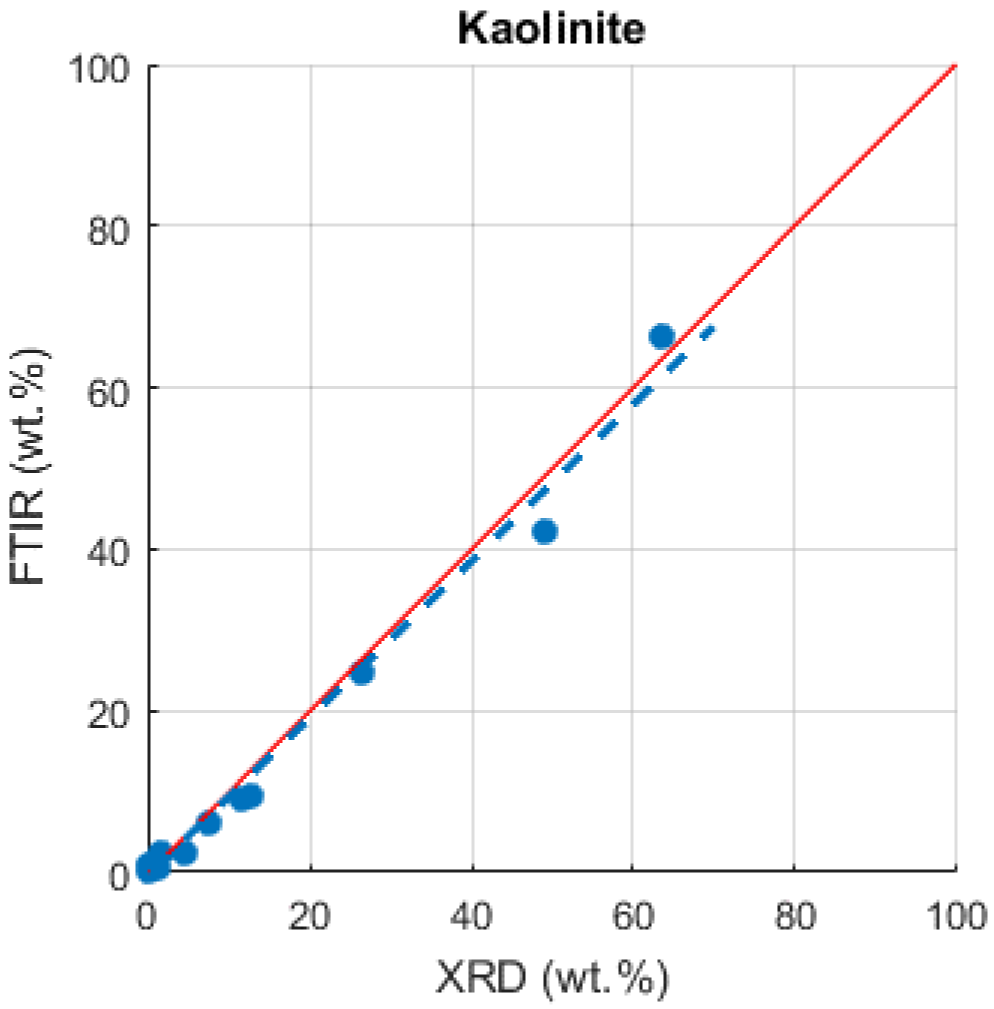
Matrix/dominant minerals – Fe ore

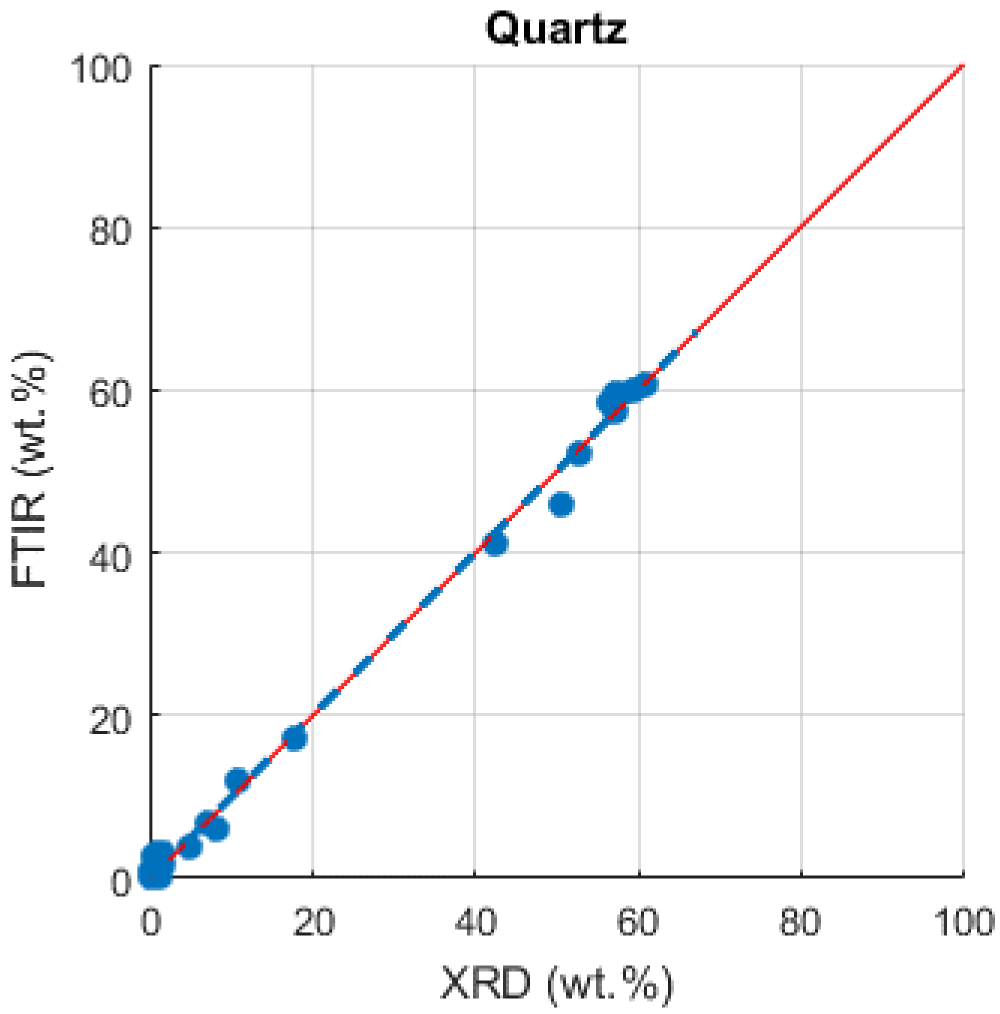




RESULTS

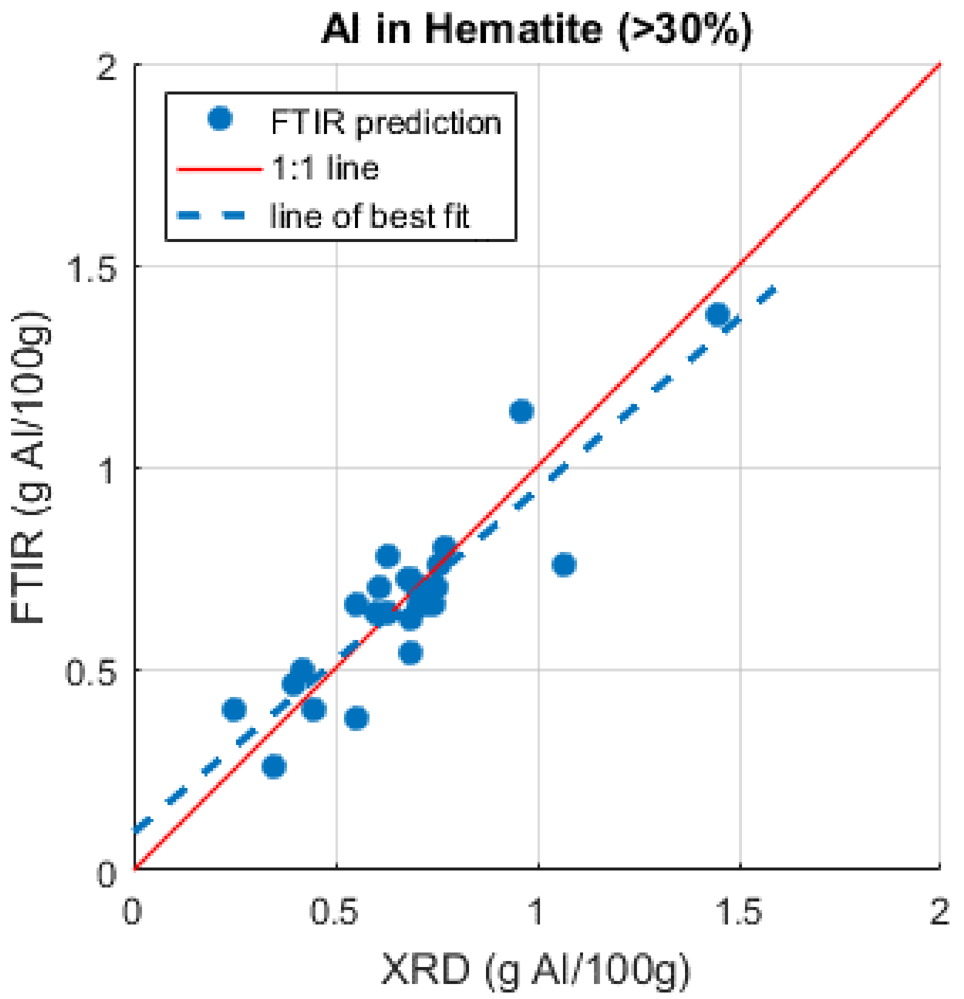
Matrix/dominant minerals – Fe ore

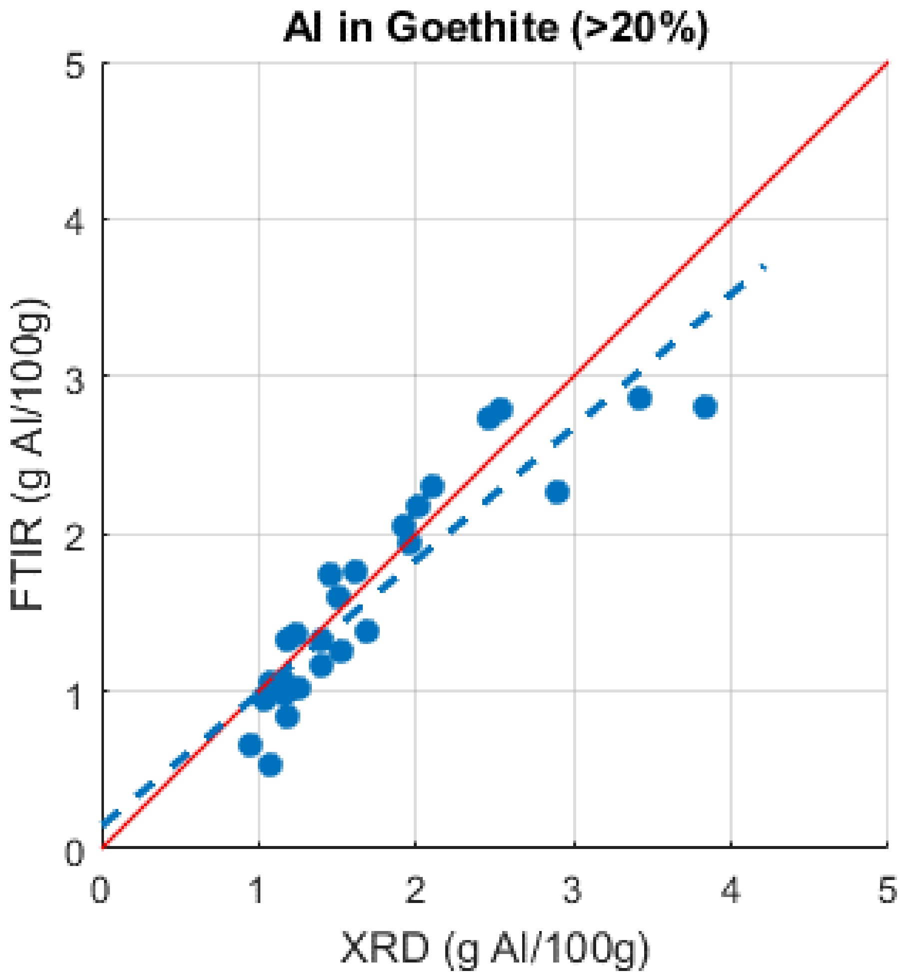




RESULTS

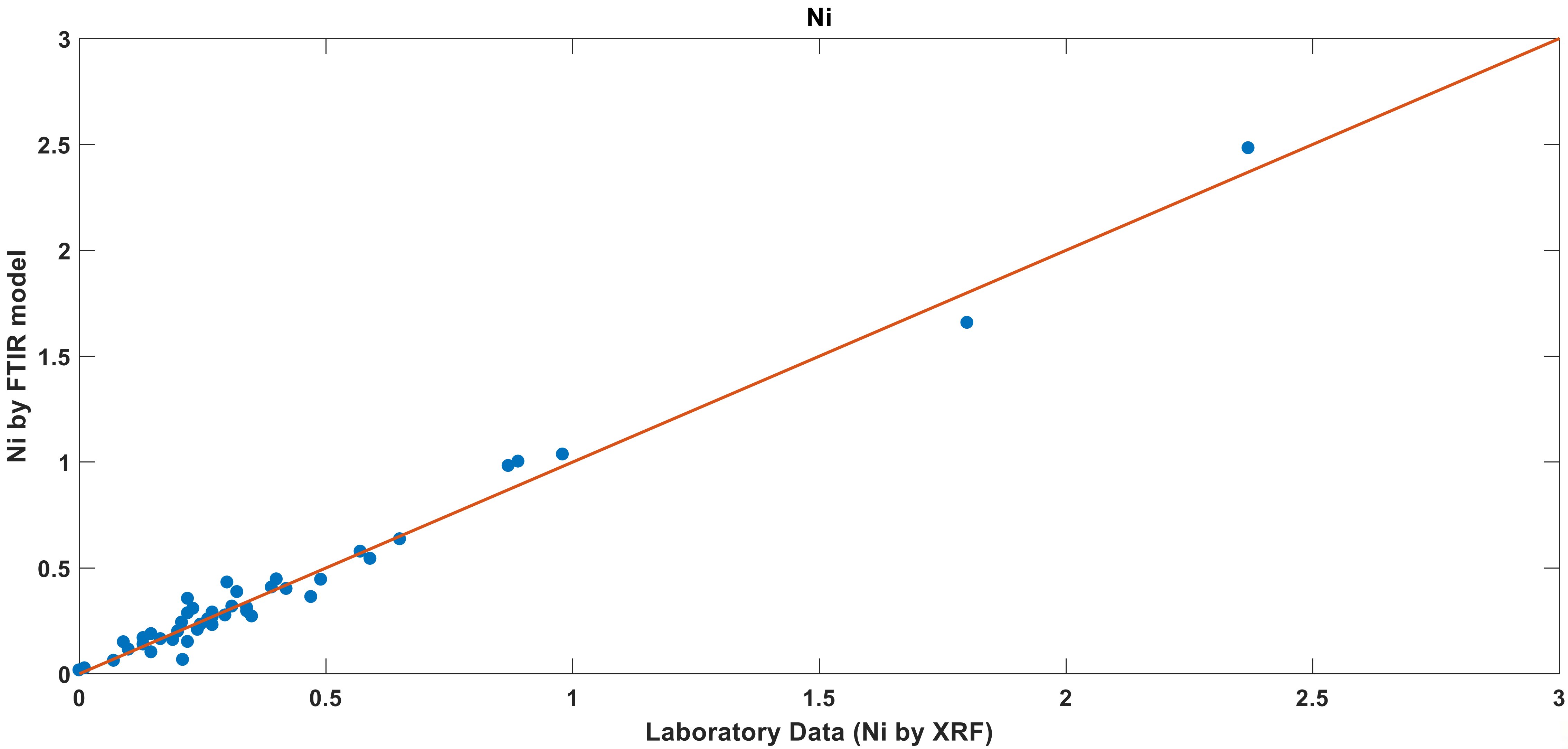
Substitution Analyte – Fe ore





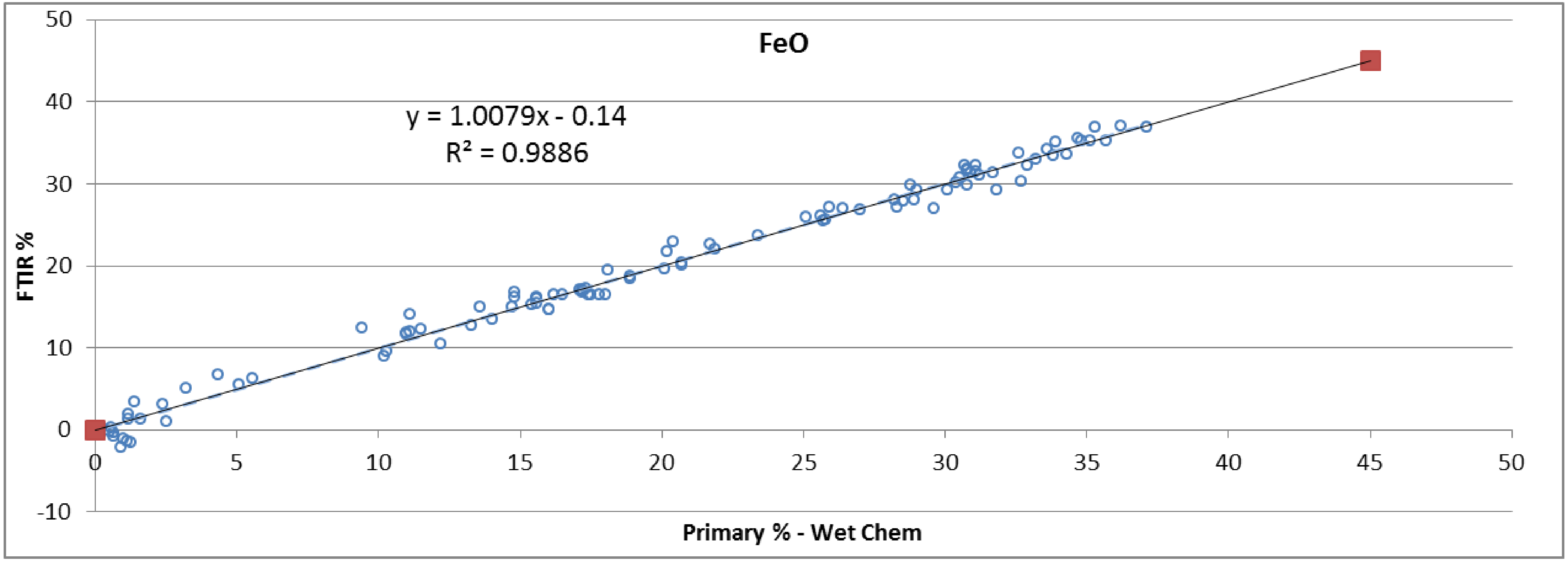
RESULTS

Element – Ni laterite



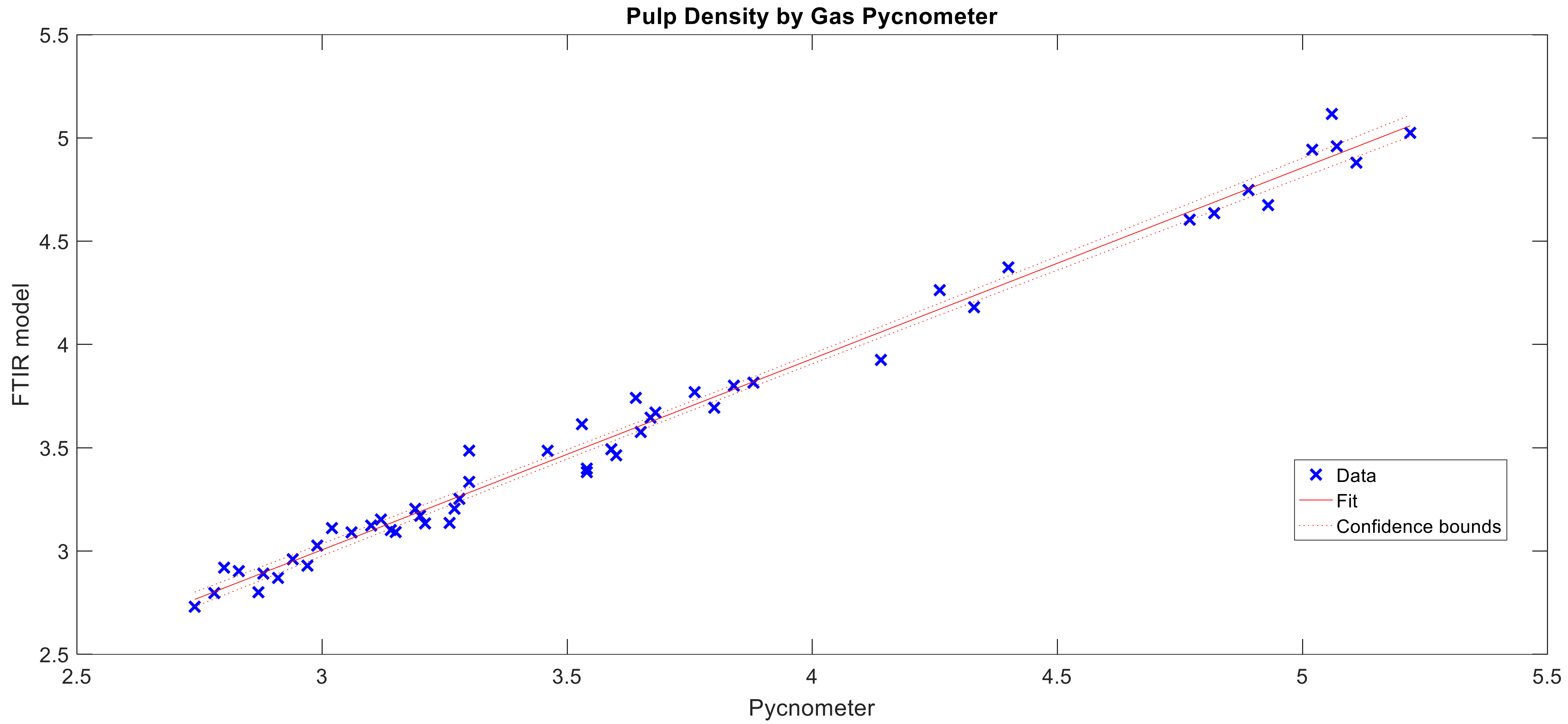
RESULTS

Element speciation – Fe^{2+}



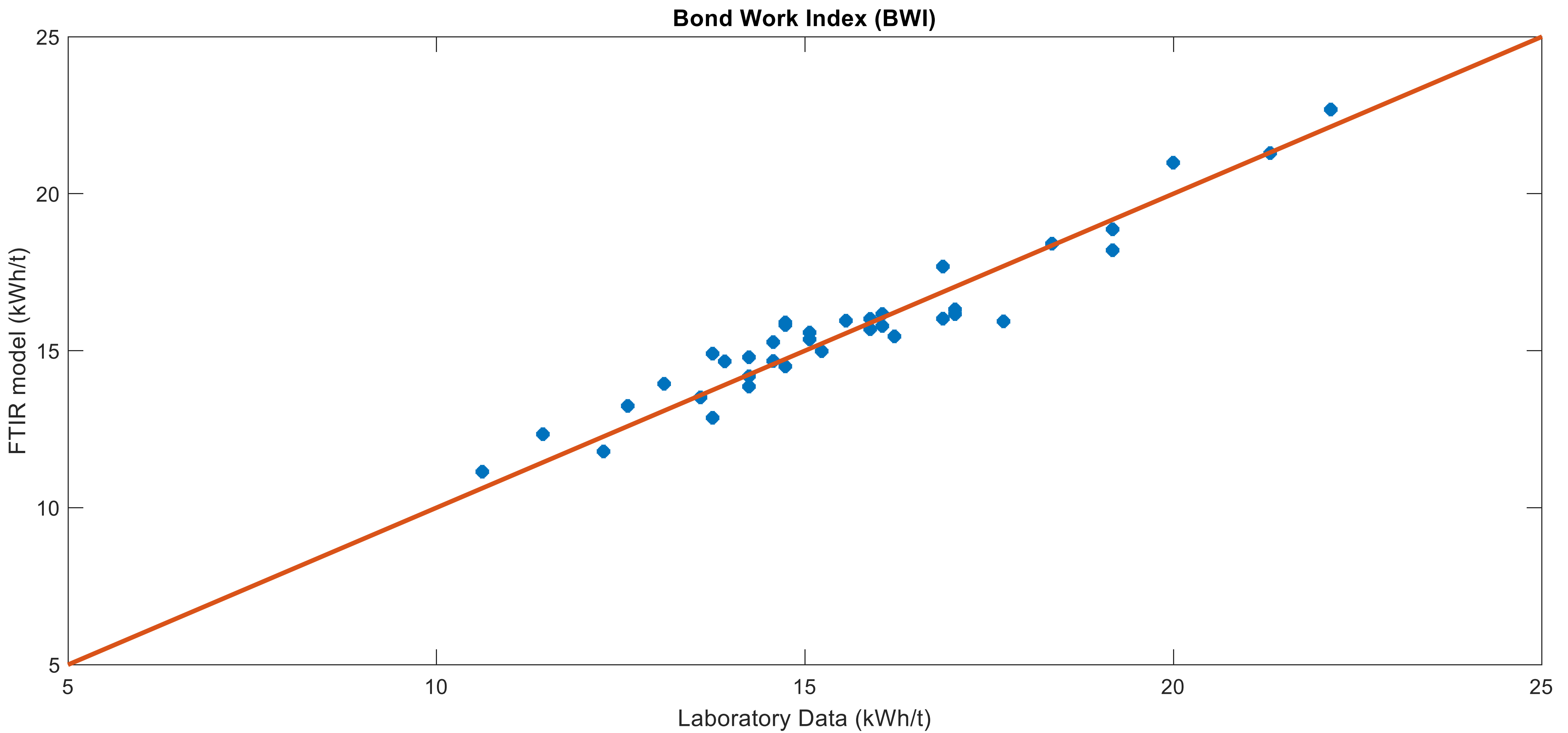
RESULTS

Physical property - Density

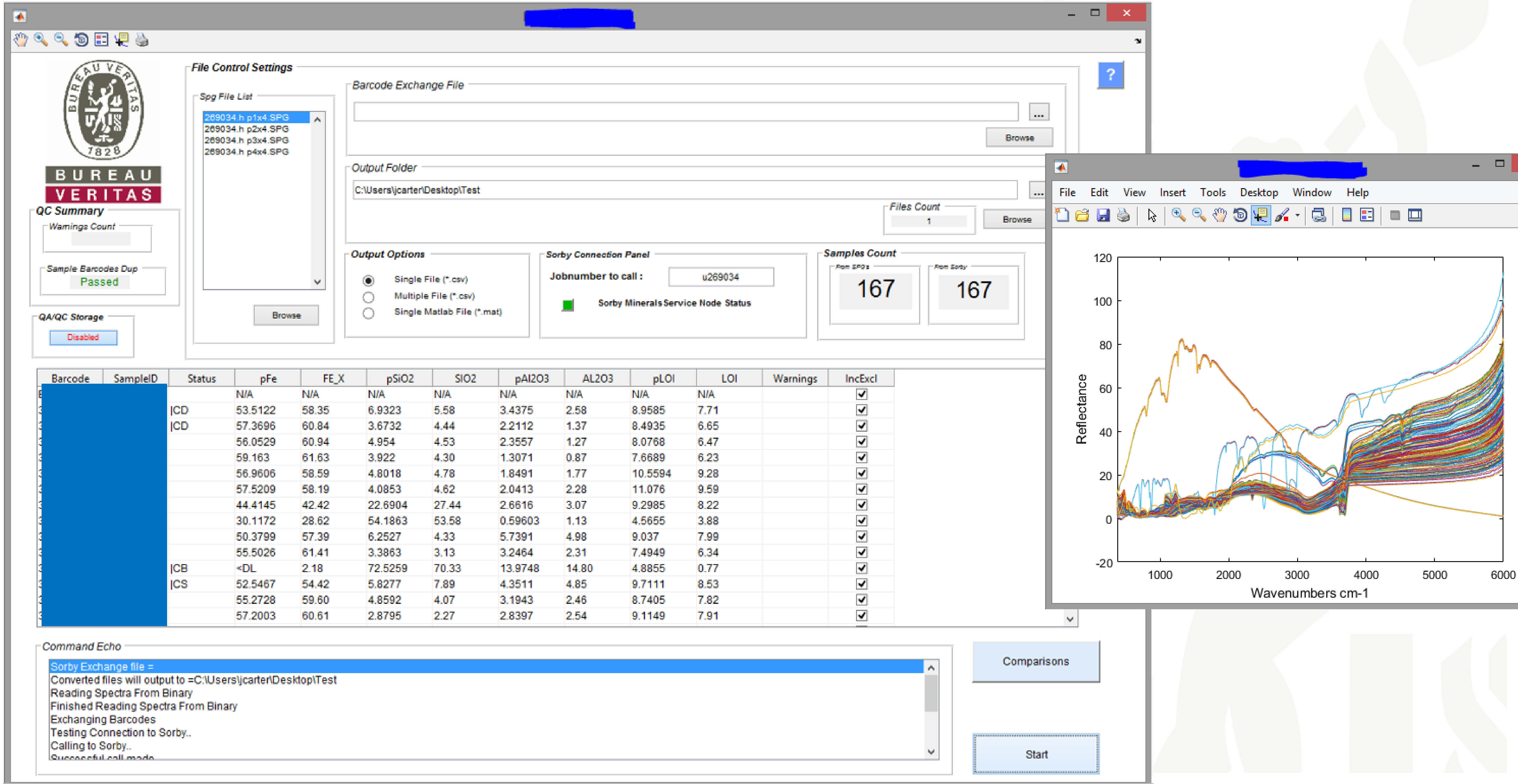


RESULTS

Ore Processing Properties

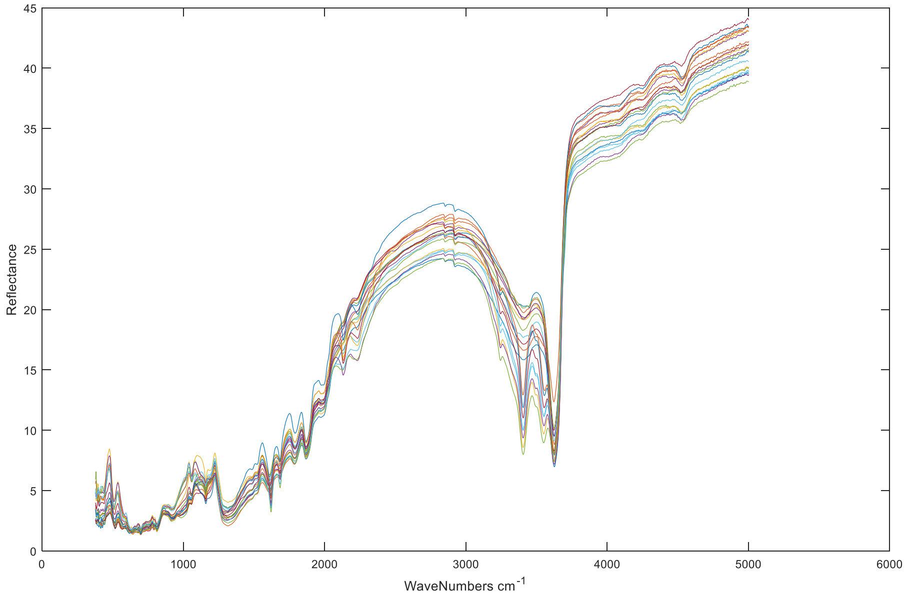


APPLICATION DEPLOYMENT - OPERATIONS



05
SUMMARY

SUMMARY



10.66	2.97	0.138	0.017	0.013	0.011
11.54	2.71	0.187	0.021	0.016	0.008
21.63	1.60	0.035	0.019	0.015	0.006
21.68	1.59	0.035	0.020	0.015	0.005
21.51	1.58	0.034	0.018	0.014	0.054
28.42	1.65	0.063	0.021	0.016	0.008
69.40	14.33	0.336	0.050	0.039	1.640
4.64	0.13	0.050	0.020	0.015	0.015
4.66	0.14	0.049	0.020	0.015	0.015

- Low cost analysis (Spectral <$10 per sample vs XRD >$100 per sample)
- Obtain complete mine picture from a routine laboratory workflow
- Predict future processing conditions – high value data !!
- Create a digital mine record.

Bi-Annual premier iron ore conference – July 2017

Determination of Iron Ore Mineralogy using Fourier Transform Infrared Spectroscopy: a Chemometric Approach.

J Carter, K Auyong and L Dixon

Fourier Transform Infrared (FTIR) spectroscopy and other NIR tools have been used in the bauxite industry for many years. Infrared spectroscopy exploits the differences in chemical composition and lattice structure to produce a characteristic response. Spectral devices, such as those from ASD Inc. and the Hylogger^{TM}, provide qualitative mineralogical data targeted towards hydrated minerals detected in the near and short wave infrared region. The FTIR spectrum extends into the mid and thermal infrared range and can therefore respond to the presence of silicates and oxides, in addition to hydrates and carbonates.

The key to successful utilisation of infrared spectra, however, is the interpretation methodology. In this study, FTIR spectra were calibrated against quantitative x-ray diffraction data for the determination of the mineralogy of iron ore. A full pattern machine learning technique was utilised for the calibration, and the assessment of the regressions determined from an independent validation set. The abundance of key minerals - hematite, goethite, kaolinite and quartz - were determined and the results correlated against X-ray fluorescence assays and loss on ignition data. The results of the study indicate that spectral techniques using a full pattern machine learning approach and artificial neural networks can be used successfully to obtain objective and quantitative mineralogical data to support field observations and analytical results for iron ore resource modelling. A comparison of this technique to the cost, quality and timeliness of other quantitative mineralogy tools is also made.

BUREAU VERITAS

Move Forward with Confidence