ANALYSIS OF MINING SAMPLES USING INFRARED SPECTROSCOPY AND MACHINE LEARNING

MATLAB CONFERENCE
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BUREAU VERITAS MINERALS SERVICES
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**
- Scoping samples
- Field analysis
- Routine Laboratory
- Target samples
- Routine laboratory
- Project samples
- Research analysis
- Proxies
- On site lab
- Fast turn around
- High accuracy (trade)

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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

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SPECTRA OF IRON ORE SAMPLES

Examples by dominant mineral

Hematite
Quartz
Kaolinite

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EXAMPLE SPECTRA

1200 – 2500 Datapoints per sample
SPECTRAL INTERPRETATION

- Spectral Library
- Analyse Features for
  - DEPTH
  - LOCATION
  - SHAPE
- Major Minerals Only

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MACHINE LEARNING AND MATLAB
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

**Spectral Process Overview – Value Proposition**

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
RESULTS

Matrix/dominant minerals – Fe ore

**Hematite**

**Goethite**
RESULTS

Matrix/dominant minerals – Fe ore

Kaolinite

Quartz
RESULTS

Substitution Analyte – Fe ore
RESULTS

Element – Ni laterite

![Graph showing the relationship between Ni by FTIR model and Laboratory Data (Ni by XRF).](Image)
RESULTS

Element speciation – $\text{Fe}^{2+}$

$$y = 1.0079x - 0.14$$

$$R^2 = 0.9886$$
RESULTS

Physical property - Density

Pulp Density by Gas Pycnometer

- Data
- Fit
- Confidence bounds
RESULTS

Ore Processing Properties

Bond Work Index (BWI)

FTIR model (kWh/t) vs. Laboratory Data (kWh/t)
► 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.
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™, 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.
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