Artificial Intelligence Applied to Mineral Exploration Targeting

Inteligência Artificial Aplicada a Vetorização de Depósitos Minerais

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CURRENT CHALLENGES OF MINERAL EXPLORATION

High Global Demand

Reduction of Reserves

Restricted Labor Market

Preservation of Natural Resources

Simexmin X SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL X BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION

CURRENT CHALLENGES OF MINERAL EXPLORATION

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CURRENT CHALLENGES OF MINERAL EXPLORATION

High Global Demand

Reduction of Reserves

INDUSTRY 4.0

Restricted Labor Market

Preservation of Natural Resources

INDUSTRY 4.0

4th Industrial Revolution

1780s — Steam Engine

1870s — Electricity

1970s — Electronics

2000s — INDUSTRY 4.0

- Automation of process
- Real-time monitoring
- Decision-making based on big data

MINING 4.0

AI/Machine Learning

Systems and simulations capable of providing decisive geological information for exploration and mining

Robotics/Drones

Autonomous robots to perform repetitive and strenuous tasks. Loaders, excavators, drills, etc...

IoT/Sensors

Sensors that collect and transmit data during the extraction and processing of the ore

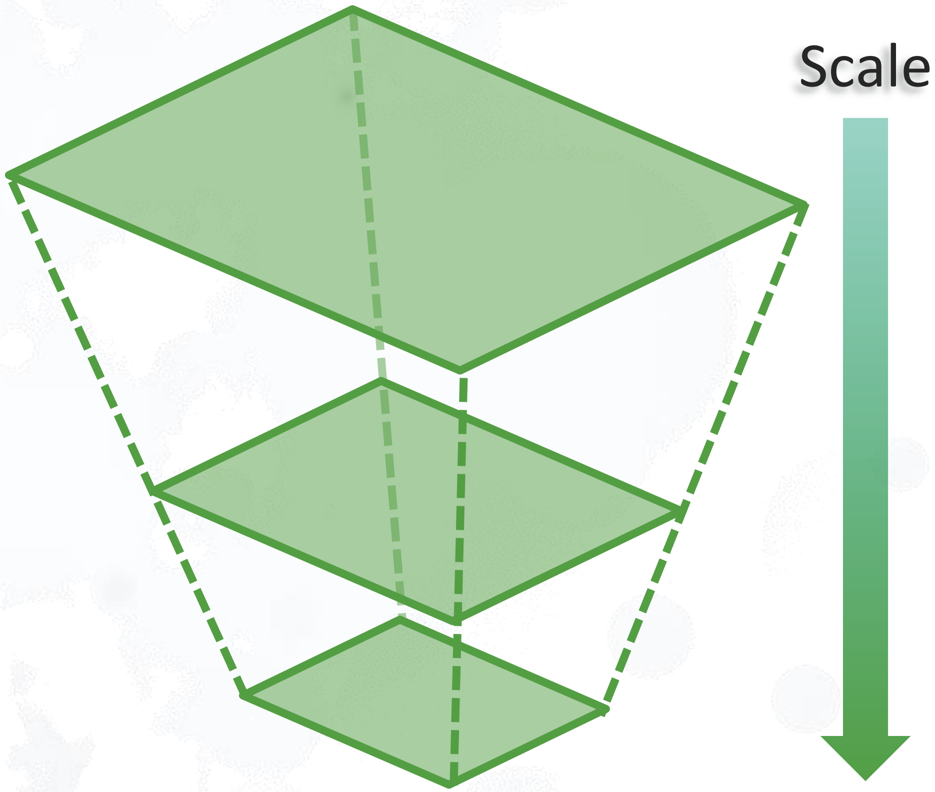
Virtual Reality

Simulations and training. Control, maintenance and inspection of equipment

MINING 4.0

MINERAL EXPLORATION TARGETTING

- **IA/Machine Learning**
  - **Mineral Prospectivity Mapping**
  - **Geochemical Exploration**
  - **Drill Core Data Integration**



AI Applications to Mineral Exploration Targeting

Mineral Prospectivity Mapping

Integrate **aerogeophysical**, **geological**, and **geochemical** data to generate **prospectivity maps**, assisting in target selection at the **province/district scale**.

Publications over the last years show that **ML models** produces **better** results **than traditional methods** as WofE. **XGBoost**, **SVM**, and **Random Forests** are among the best performing algorithms.

Important aspects:

- **Feature engineering** has a big impact on results
- **Data balancing** techniques should be used to increase the number of labeled samples
- **Explainable AI** algorithms can identify important relationships between the dataset and the mineralized zones

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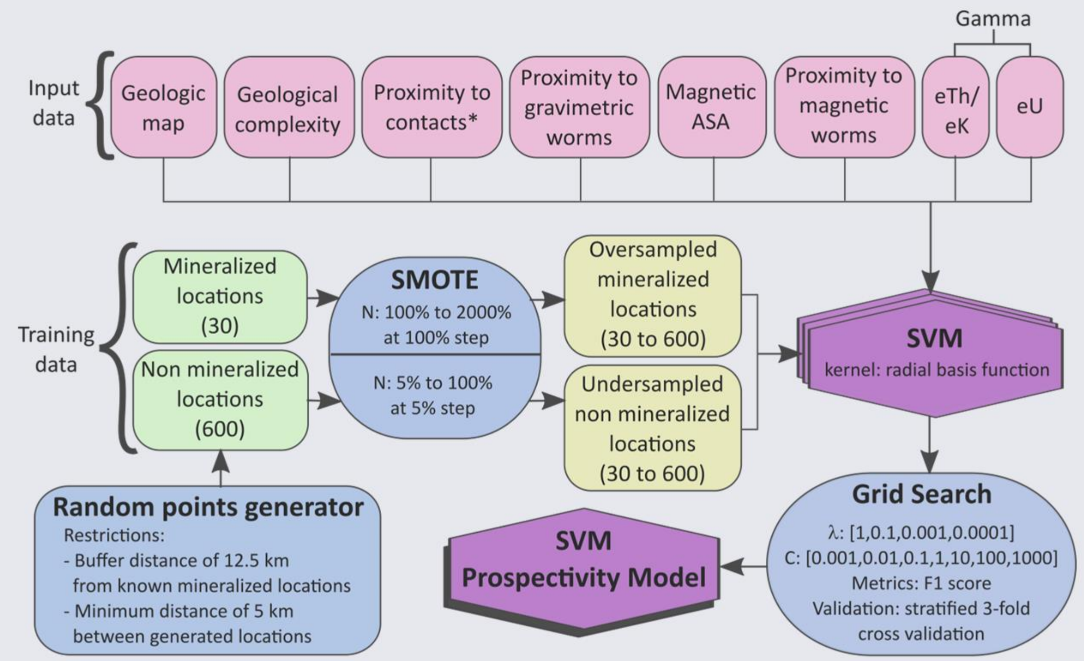
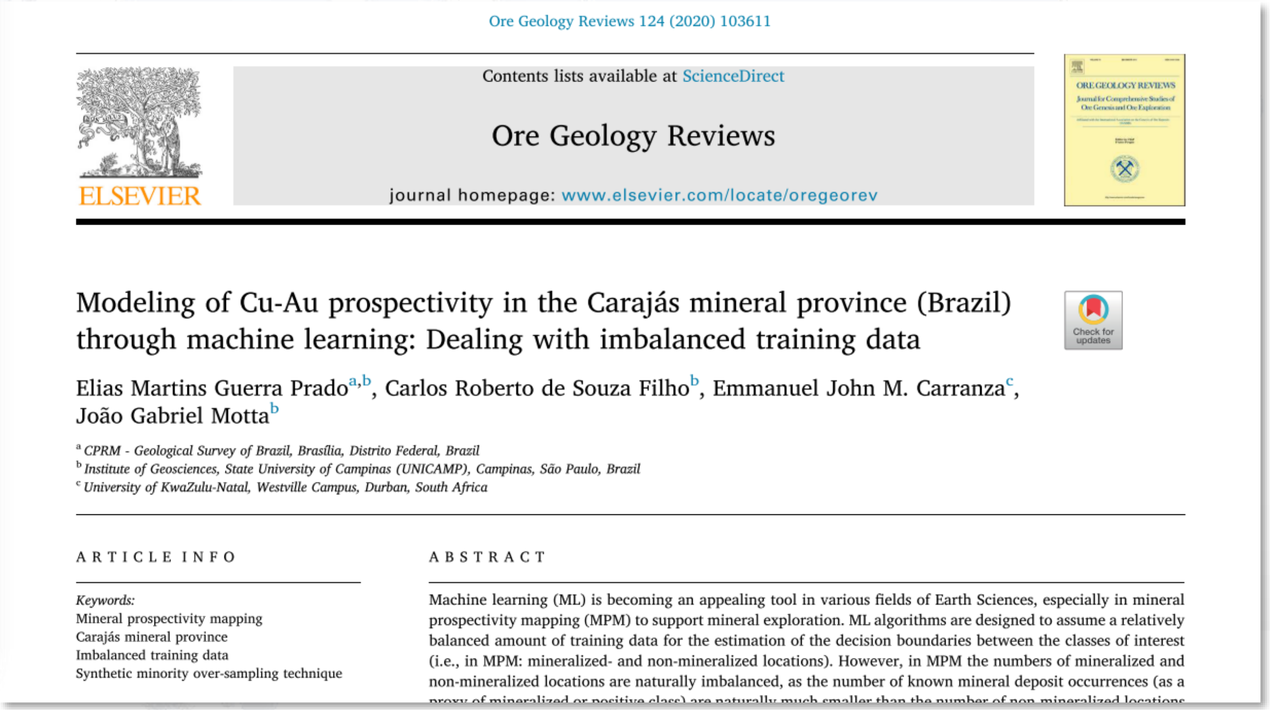
Mineral Prospectivity Mapping

MODELING OF CU-AU PROSPECTIVITY IN THE CARAJÁS MINERAL PROVINCE (BRAZIL) THROUGH MACHINE LEARNING: DEALING WITH IMBALANCED TRAINING DATA



*Proximity to contacts between Mesoarchean and Proterozoic stratigraphic units, Neoarchean and Proterozoic stratigraphic units, as well as contacts between Paleoproterozoic and Proterozoic stratigraphic units.



Ore Geology Reviews 124 (2020) 103611

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Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

ELSEVIER

Modeling of Cu-Au prospectivity in the Carajás mineral province (Brazil) through machine learning: Dealing with imbalanced training data

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[a] CPRM - Geological Survey of Brazil, Brasília, Distrito Federal, Brazil
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[c] University of KwaZulu-Natal, Westville Campus, Durban, South Africa

ARTICLE INFO

Keywords:
Mineral prospectivity mapping
Carajás mineral province
Imbalanced training data
Synthetic minority over-sampling technique

ABSTRACT

Machine learning (ML) is becoming an appealing tool in various fields of Earth Sciences, especially in mineral prospectivity mapping (MPM) to support mineral exploration. ML algorithms are designed to assume a relatively balanced amount of training data for the estimation of the decision boundaries between the classes of interest (i.e., in MPM: mineralized- and non-mineralized locations). However, in MPM the numbers of mineralized and non-mineralized locations are naturally imbalanced, as the number of known mineral deposit occurrences (as a

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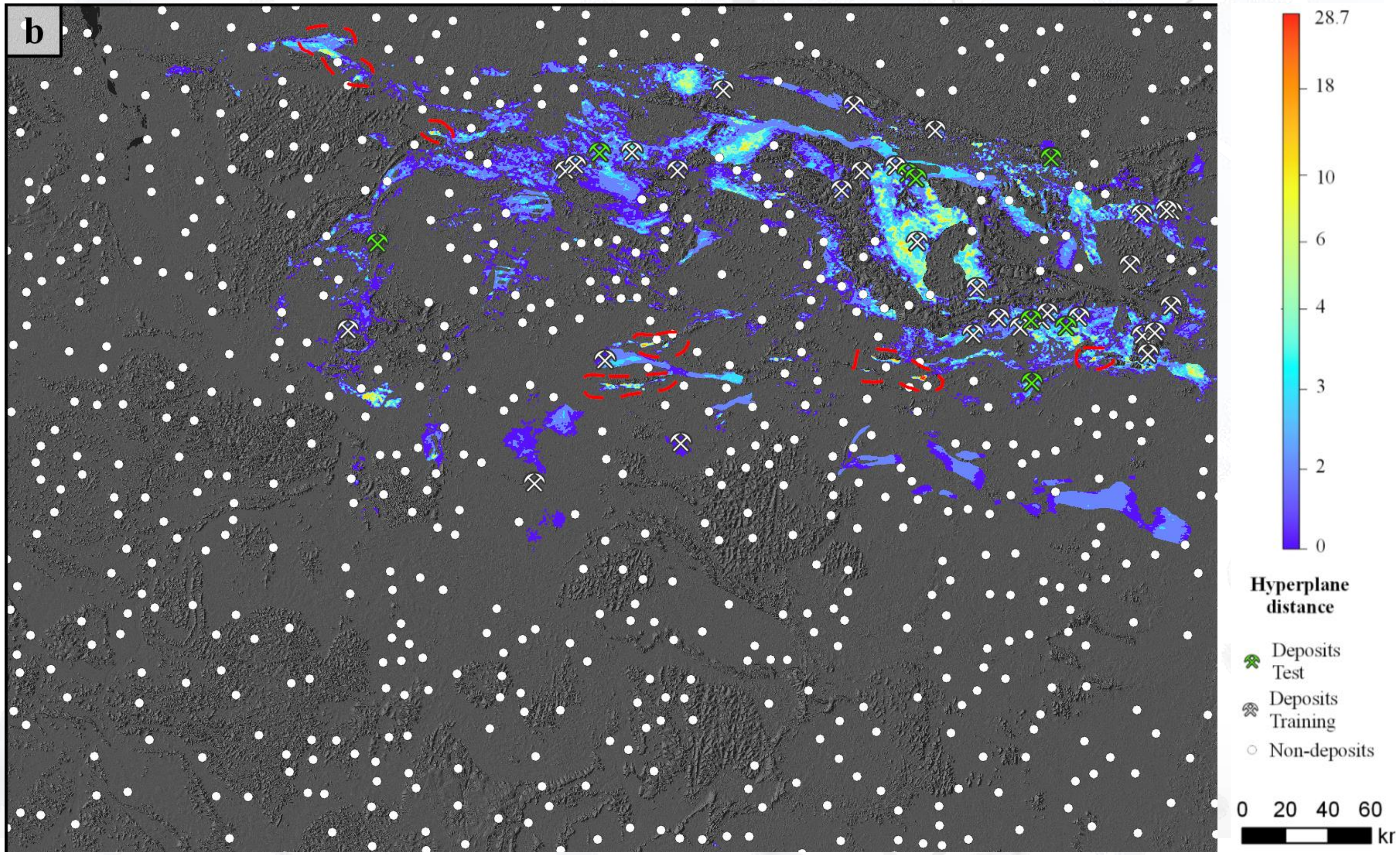
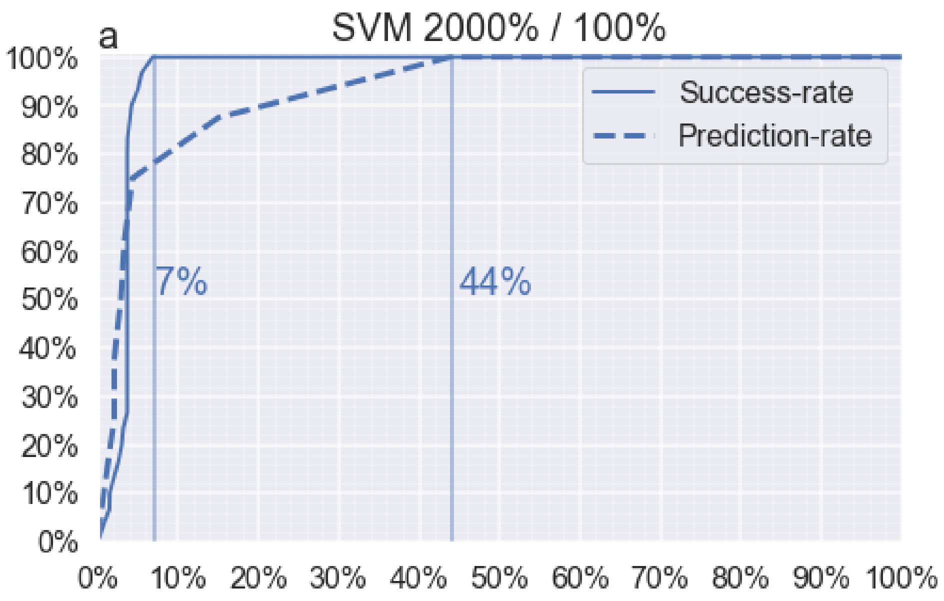
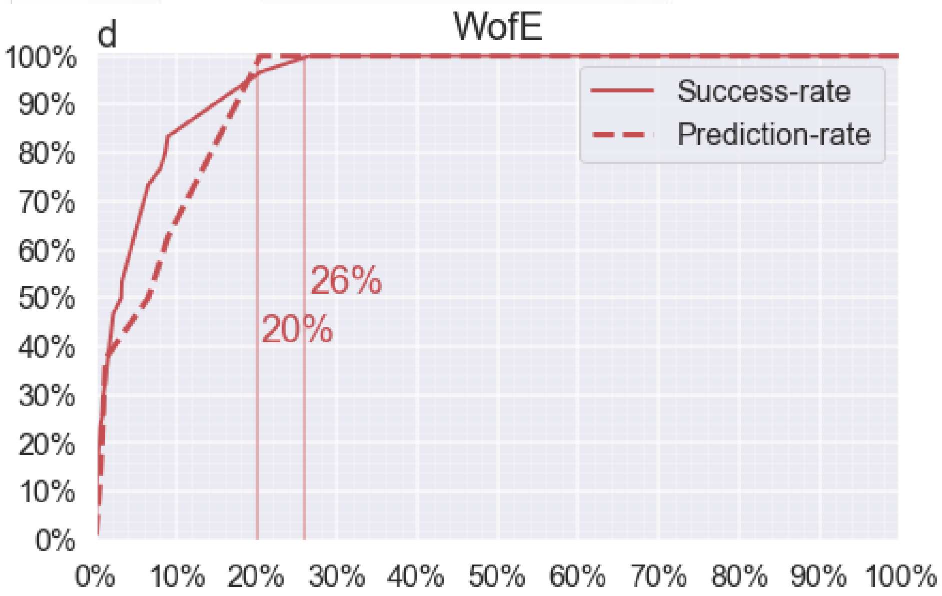
Mineral Prospectivity Mapping







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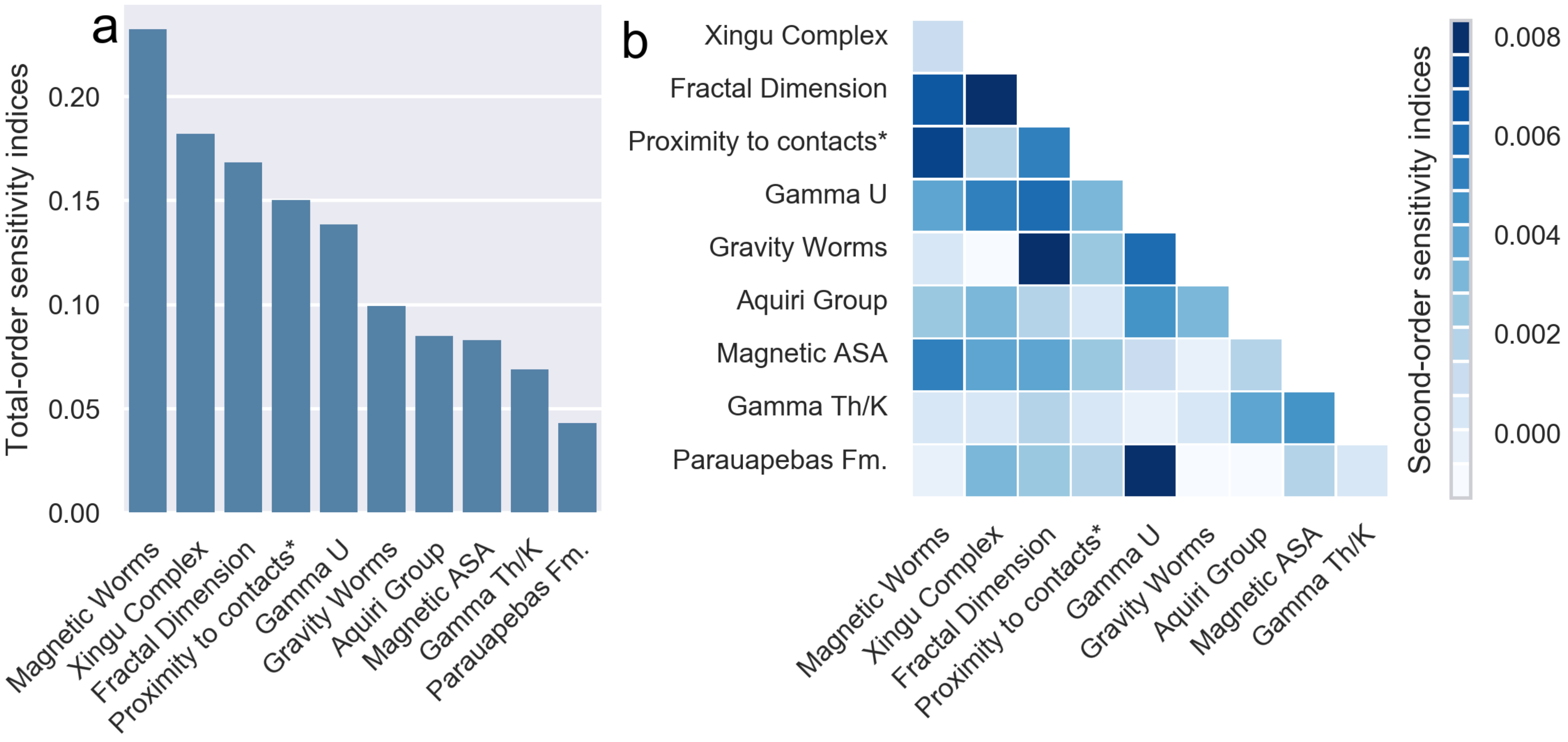
Mineral Prospectivity Mapping



AI Applications to Mineral Exploration Targeting

Geochemical Exploration

Use of **geochemical** data for **vectoring towards** the **mineralization**

ML models have shown **great potential** for the **processing** and **classifying geochemical datasets**

Important aspects:

- **Dataset organization** and **pre-processing** is usually time consuming
- **Specific normalization** techniques need to be applied (**BoxCox**, **CLR**)

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Geochemical Exploration

EXAMPLES:

- **Metallogenic fertility classification** of arc magmas (Nathwani et al., 2022)
- **Prediction** of rock **precursors** for **mass balance** calculation (Trépanier et al., 2016)
- **Prediction** of **unknown** elemental **concentrations** (Zhang et al., 2022)

Mineralium Deposita (2022) 57:1143–1166
https://doi.org/10.1007/s00126-021-01086-9

REGULAR ARTICLE

Check for updates

Machine learning for geochemical exploration: classifying metallogenic fertility in arc magmas and insights into porphyry copper deposit formation

Chetan L. Nathwani[1,2] · Jamie J. Wilkinson[1,2] · George Fry[3] · Robin N. Armstrong[1] · Daniel J. Smith[4] · Christian Ihlenfeld[3]

Computers & Geosciences 89 (2016) 32–43

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journal homepage: www.elsevier.com/locate/cageo

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Research paper

Precursors predicted by artificial neural networks for mass balance calculations: Quantifying hydrothermal alteration in volcanic rocks

CrossMark

Sylvain Trépanier[a,b], Lucie Mathieu[a], Réal Daigneault[c,*], Stéphane Faure[a]

Journal Pre-proof

1 **Advanced Geochemical Exploration Knowledge Using Machine Learning: Prediction of**
2 **Unknown Elemental Concentrations and Operational Prioritization of Re-analysis**
3 **Campaigns**

4 Steven E. Zhang[a,b], Julie E. Bourdeau[a,b], Glen T. Nwaila[b*], Yousef Ghorbani[c]

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Drill Core Data Integration

Integration of **dense** drill core **datasets** to extract information about the distribution of the mineralized zones

ML models can **identify complex patterns** which classical methods are not able to identify in such dense datasets

Important aspects:

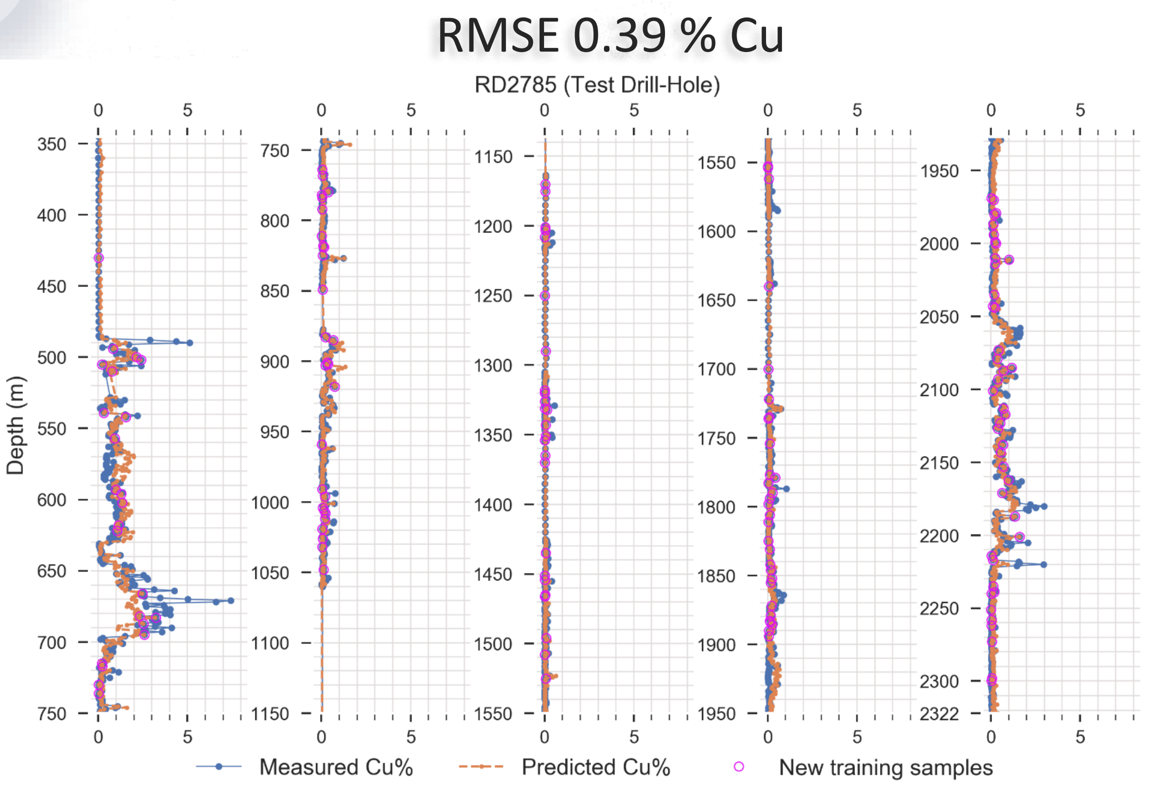
- **Deep Neural Networks** usually perform better
- **Core scanning system** enables the fast acquisition of training datasets
- **Models** can be used by **autonomous systems** to assist in **ore sorting** or **contaminant detection**

AI Applications to Mineral Exploration Targeting

Drill Core Data Integration

EXAMPLES:

- **Prediction** of **Cu grade** by means of **hyperspectral** data (Prado et al., 2022)



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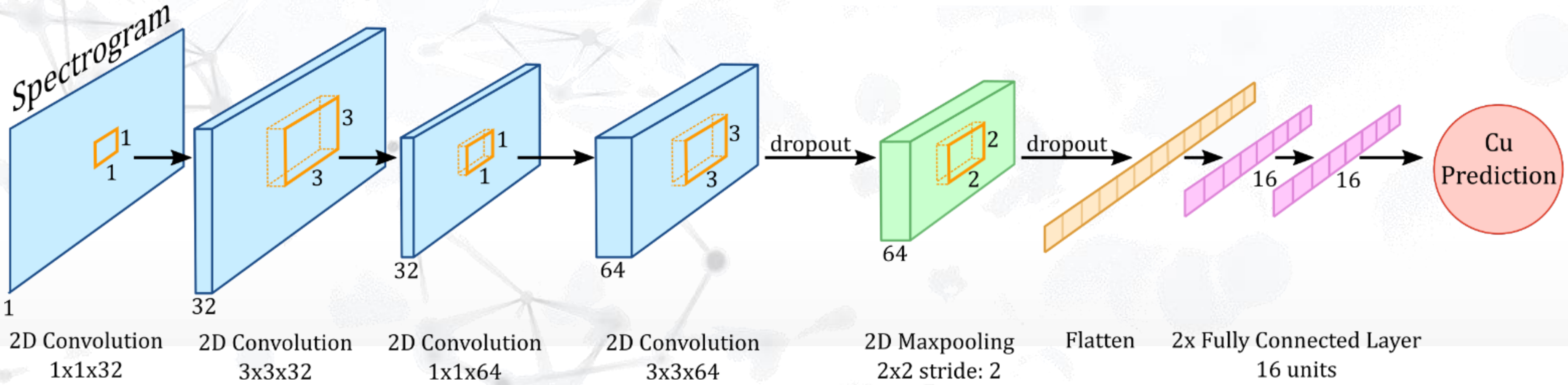

AI Applications to Mineral Exploration Targeting

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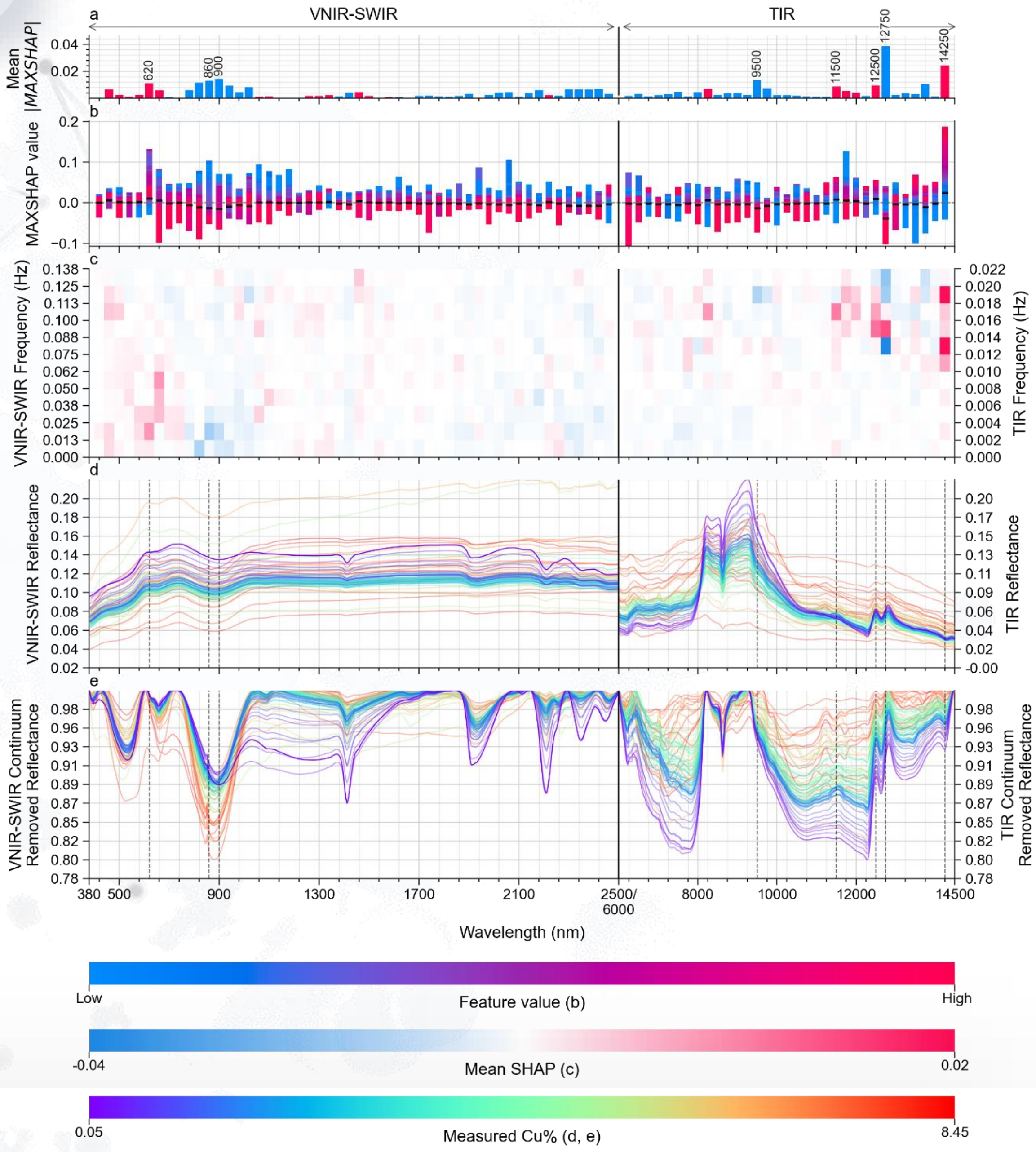
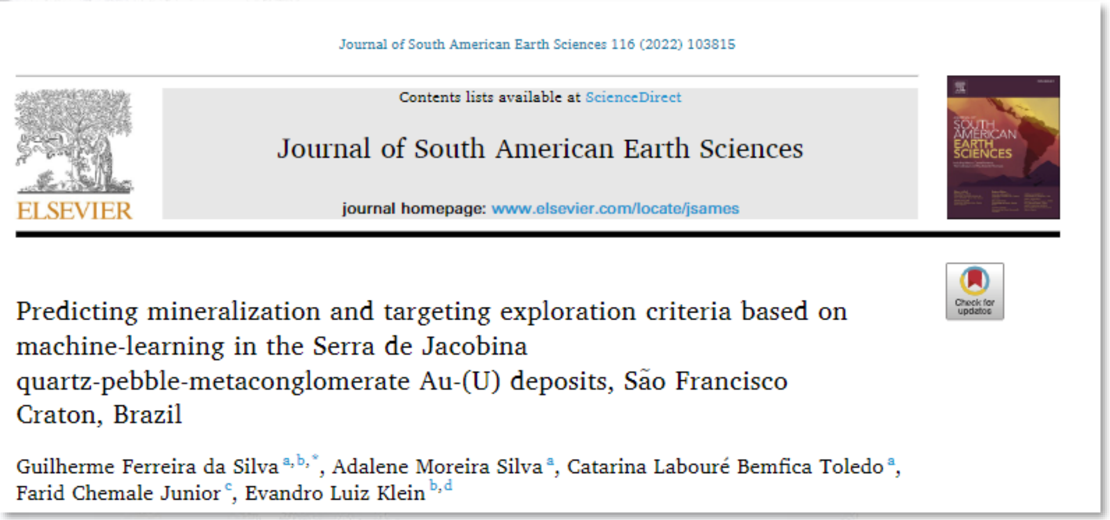


AI Applications to Mineral Exploration Targeting

Drill Core Data Integration

EXAMPLES:

- **Prediction** of **mineralization** by means of **geochemical** and **petrophysical** data (da Silva et al., 2022)



Journal of South American Earth Sciences 116 (2022) 103815

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Predicting mineralization and targeting exploration criteria based on machine-learning in the Serra de Jacobina quartz-pebble-metaconglomerate Au-(U) deposits, São Francisco Craton, Brazil

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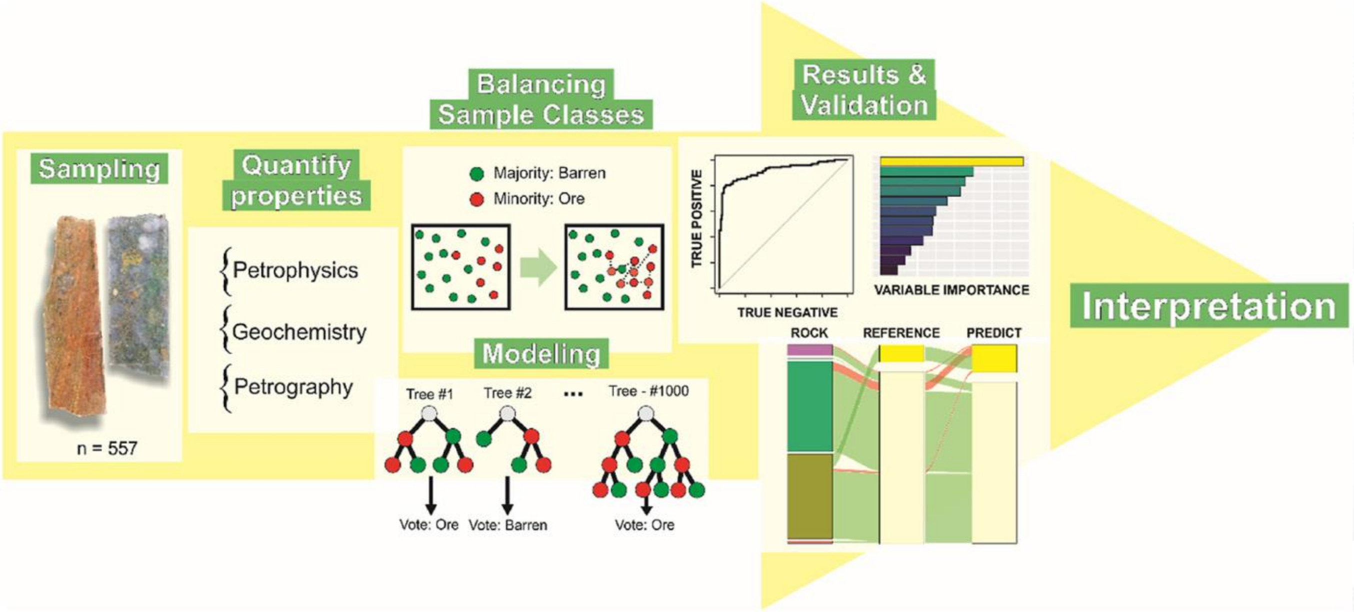

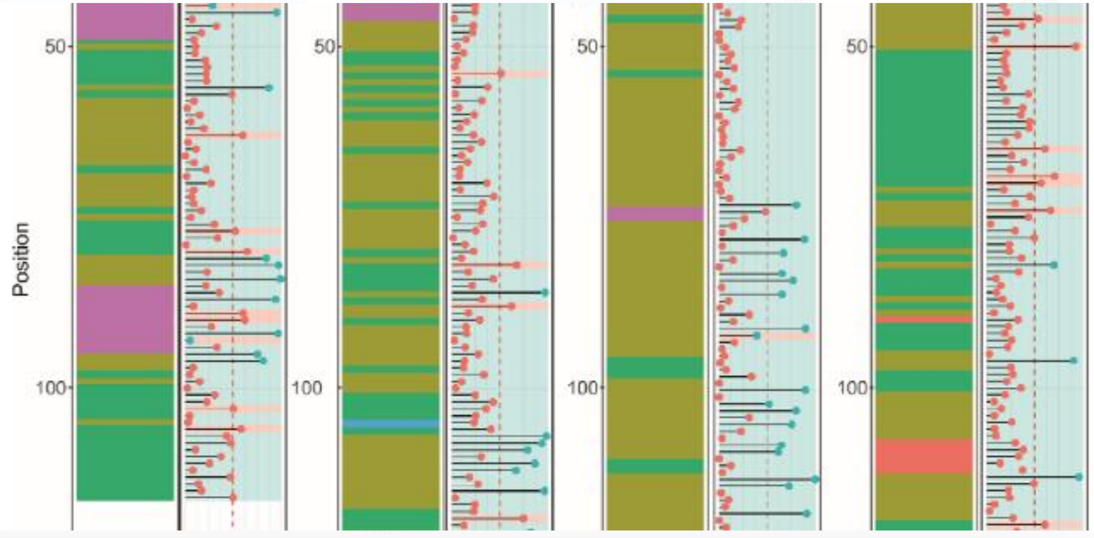

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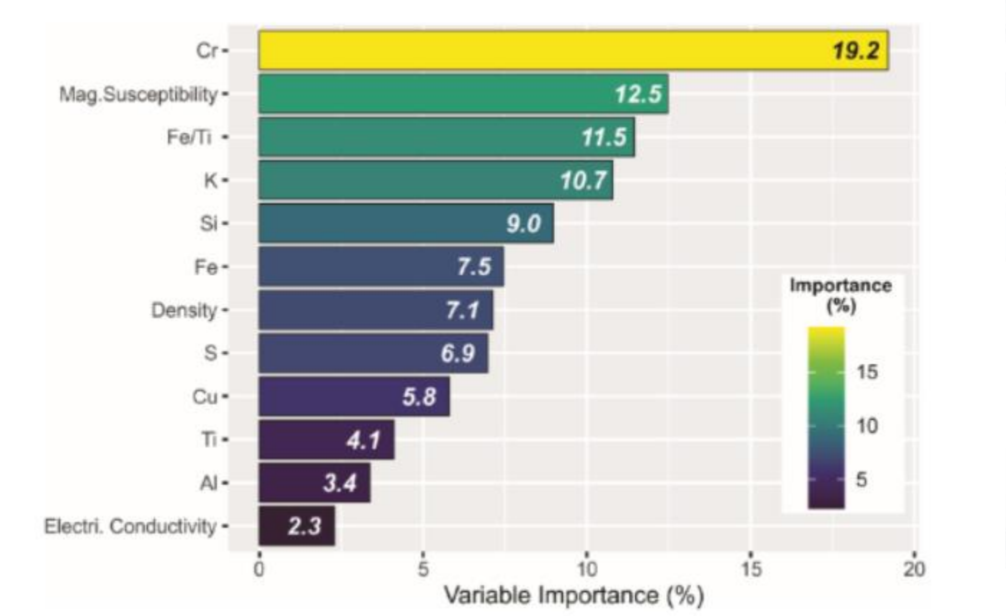

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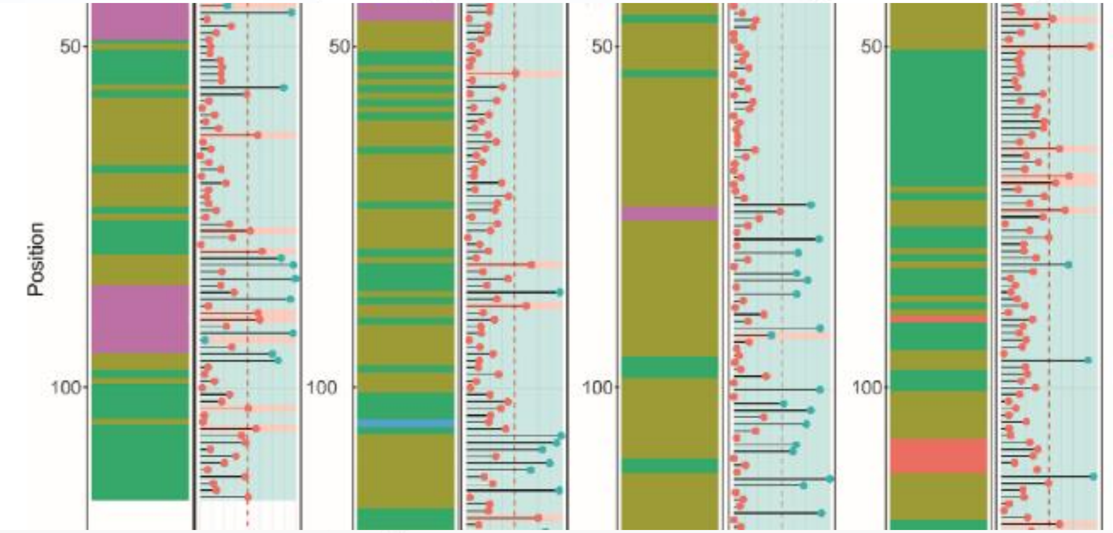

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Concluding Remarks

- **AI** and **ML** are becoming **indispensable tools** in **mineral exploration**
- **ML models** can be used to **extract** valuable **information** from datasets at **different scales**
- The **next step** is developing **generalized workflows** that **integrate all stages** of **mineral exploration** and **User Interfaces** (UI) that **allow** the **use** of **these methods** by **non-specialists**
- **Techniques** that can be **used** to **integrate Industry 4.0 technologies** with the **mineral industry contribute** to the **solid** and **sustainable development** of **mineral exploration**

Obrigado!

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