AFRICA ACCELERATING 2018
LOGISTIC FOR INNOVATION & DIGITAL OPPORTUNITIES IN MINING DAY

APPLICATION OF MACHINE LEARNING IN MINERAL EXPLORATION

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Global Project Geologist

October 25, 2018

WHEN YOU NEED TO BE SURE

SGS

ABOUT SGS

>95,000

EMPLOYEES

>2,400

OFFICES & LABORATORIES

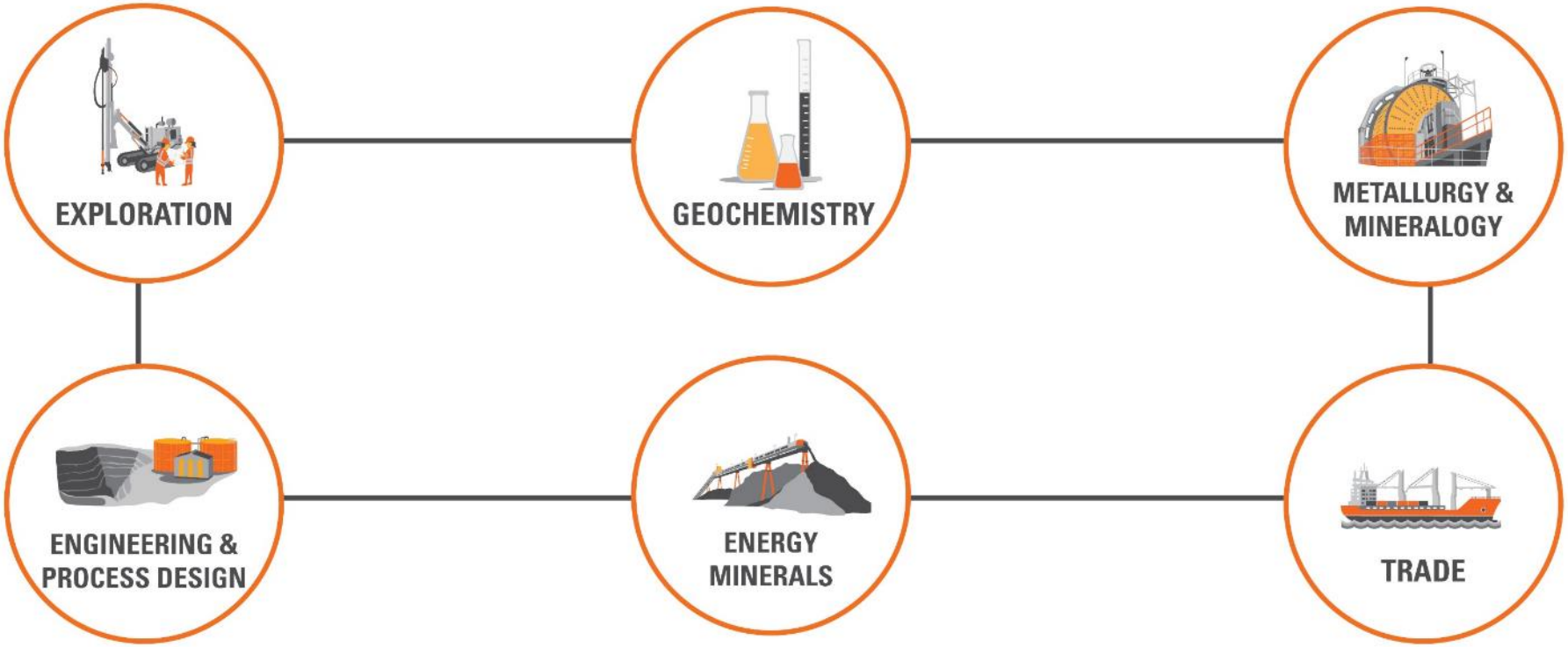
1

GLOBAL NETWORK

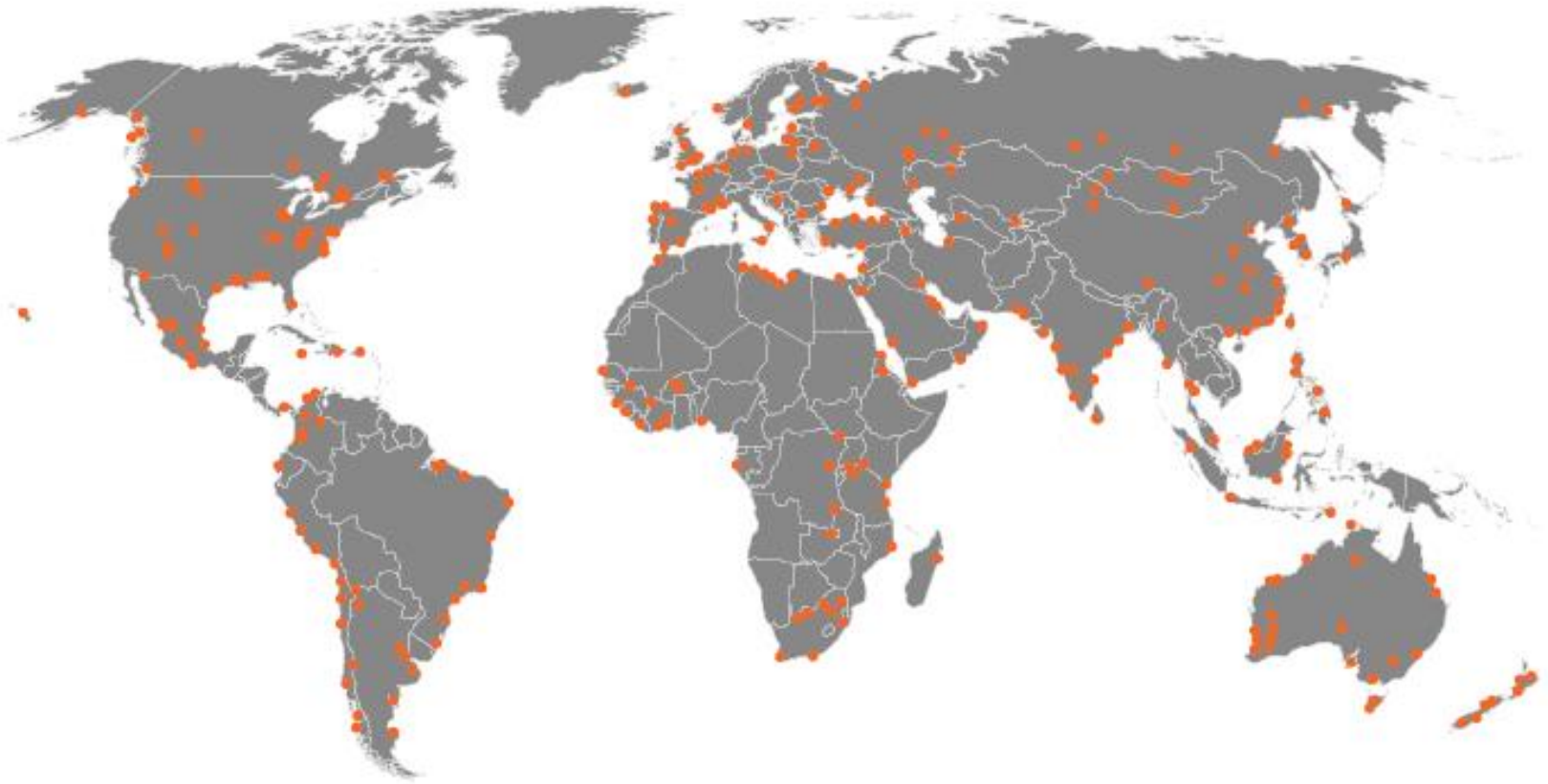
SGS IS THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY

PROVIDING LEADERSHIP AND INNOVATION ACROSS 11 MAJOR INDUSTRIES SINCE 1878

ABOUT MINERALS SERVICES



YOUR GLOBAL PARTNER



WHO IS SGS GEOLOGICAL SERVICES

- Since 2009, SGS Geological Services is SGS's independent geological and mining consultancy firm and has been operating for over 35 years providing geological and mining consultancy services to the minerals industry.
- SGS Geological Services is known globally as an expert in providing 3D mineral resource geological modeling and mineral resource / reserve estimation and geostatistical services.
- SGS Geological Services brings the disciplines of geology, geostatistics, and mining engineering together to provide its clients with accurate and timely mineral project evaluation solutions.
- Since 1987, SGS Geological Services has completed over 1,000 projects in more than 30 countries.

CURRENT CONSULTING SERVICES - COMMODITIES

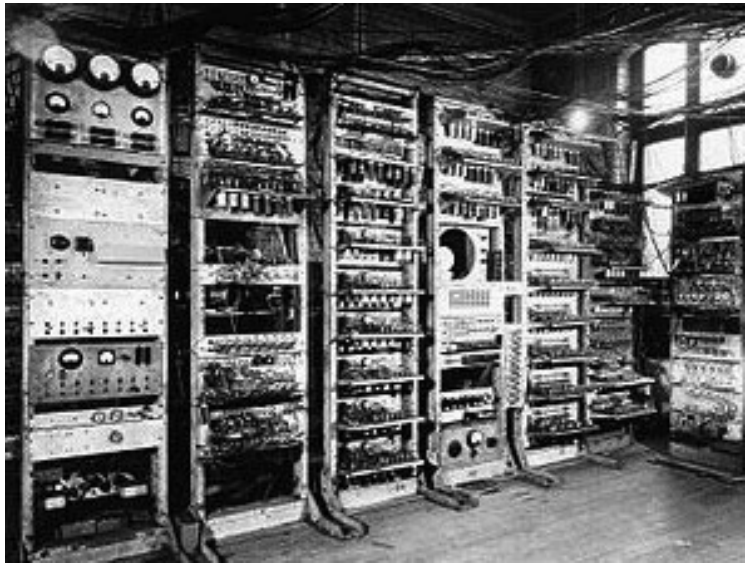
- Precious metals (Au, Ag, PGE)
- Base metals (Cu, Pb-Zn, Ni)
- Iron ore
- Rare Earth Elements, Niobium, Tantalum, Lithium
- Uranium, Coal
- Industrial minerals (bauxite, barite, limestone for cement and lime, salt, sands with titanium bearing minerals etc.)
- Diamonds and Coloured Gemstones (emerald, ruby, tourmaline, etc.)
- As part of the larger SGS Minerals Group, we can draw upon our massive network of laboratories, metallurgists, process engineers and other professionals to help bring our clients mineral project to the next level.

A brief history of AI

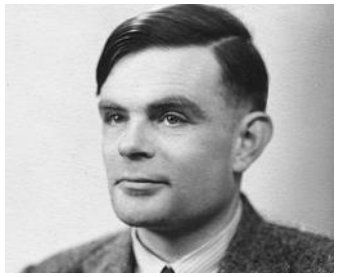
1940 — 1960 — 2018

- With the development of the first computers in the 40s, the idea of creating an artificial intelligence became a possible future prospect.

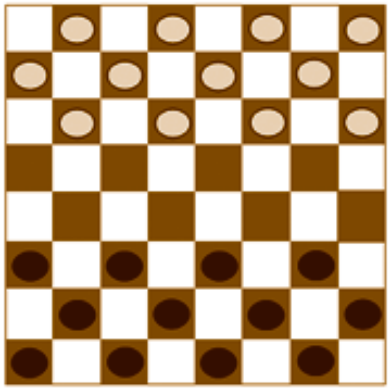
1941



1950 — 1960 — 2018



1950: Turing test



1956: Computer game

Arthur Samuel checkers program

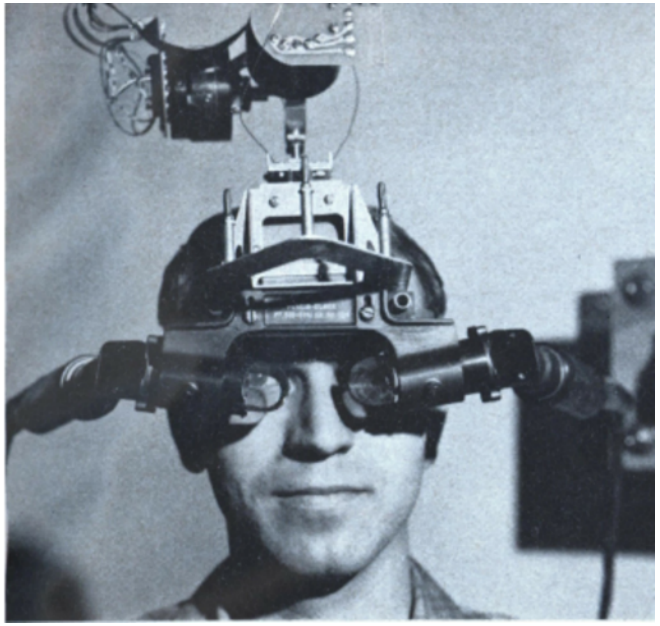
1956: Dartmouth conference

1950 1960 2000 2018

1950: Turing test

1951: Computer game

1956: Dartmouth conference



- 1968: Ivan Sutherland develop the first virtual reality system called Sword of Damocles
- Following decades recorded its ups and downs in the interest for the field of artificial intelligence. Developments evolved from a philosophical “human-mind” replication mindset to a more problem solving one.

A brief history of AI

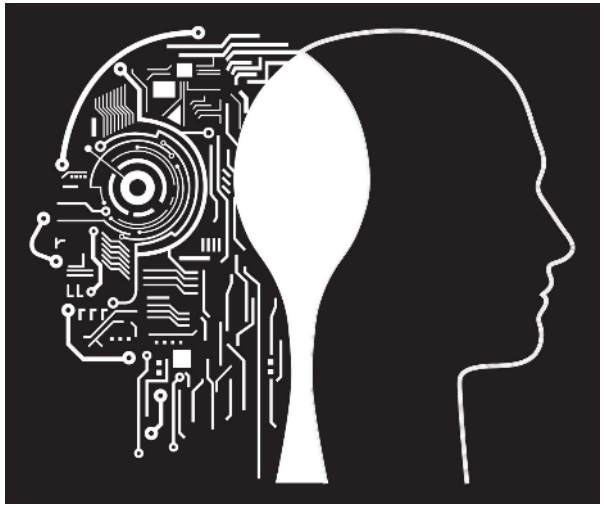
1950

1950: Turing test

1951: Computer game

1956: Dartmouth conference

1960



1987: Widespread use of expert systems

2000

1997: Deep blue beats Kasparov at chess

2018

- Improvement in computation power brought us closer to the dream of an AI. Integration of a wide array of data is now possible, leading the way to new AI enhanced analytical methods.

1950
- 1950: Turing test
- 1951: Computer game
- 1956: Dartmouth conference

1960
- 1987: Widespread use of expert systems
- 1997: Deep blue beats Kasparov at chess

2000

2018

2005: First DARPA Challenge in Nevada for autonomous vehicle

1950 1960 2000 2018

1950: Turing test

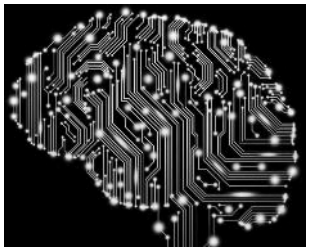
1951: Computer game

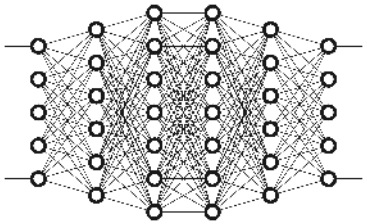
1956: Dartmouth conference

1987: Widespread use of expert systems

1997: Deep blue beats Kasparov at chess

2000s: Progress in machine learning and deep learning…



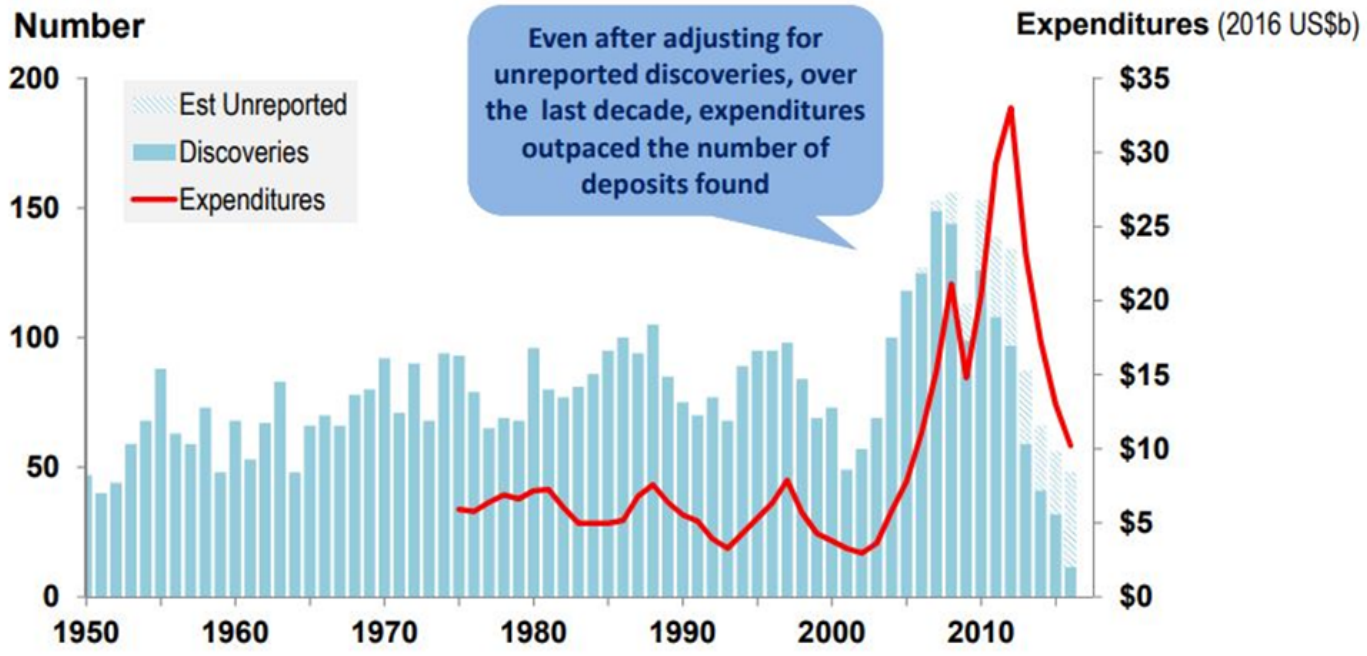


IBM Watson System won Jeopardy in 2011

Exploration in the era of AI

Number of discoveries versus expenditures

Mineral discoveries in the World : All Commodities : 1950-2016



Note: Discoveries based on deposits >="Moderate" in size
i.e. >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt U_3O_8 , > 10Mt Fe, >20Mt Thermal Coal

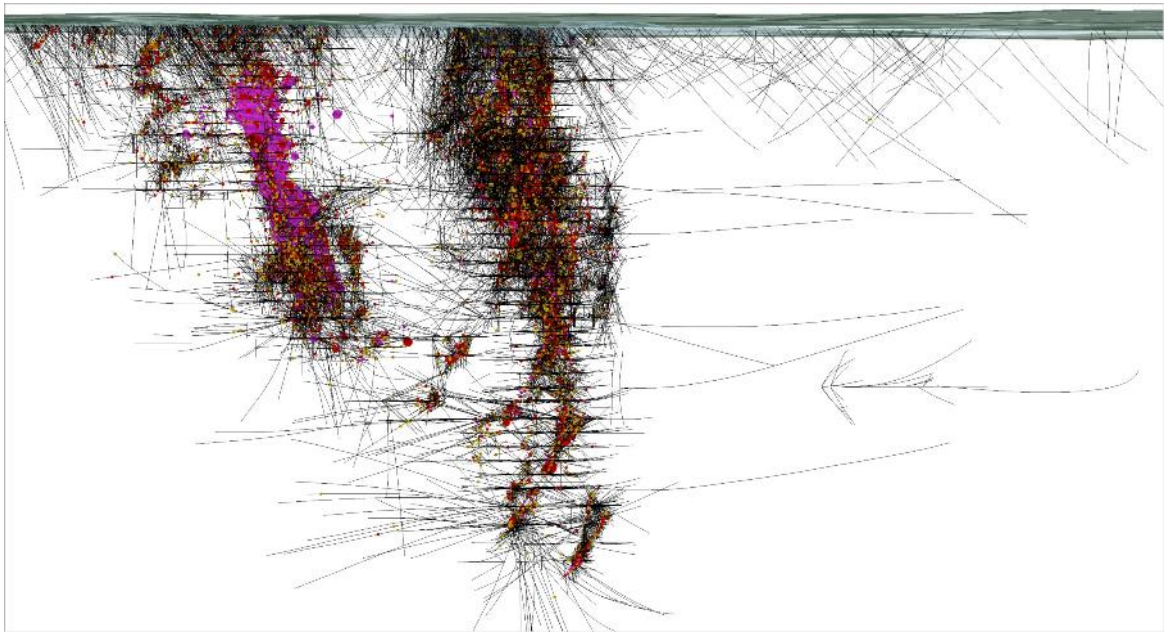
No World exploration data prior to 1975

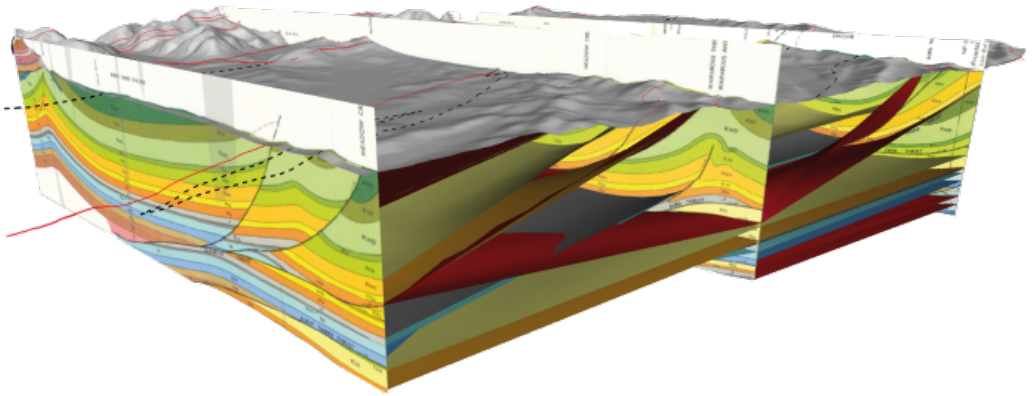
Source: MinEx Consulting © March 2017

Exploration in the era of AI

- Mining and exploration companies have now a wide spectrum a data acquisition capabilities ranging from structural, lithological, geochemical and geophysical information.

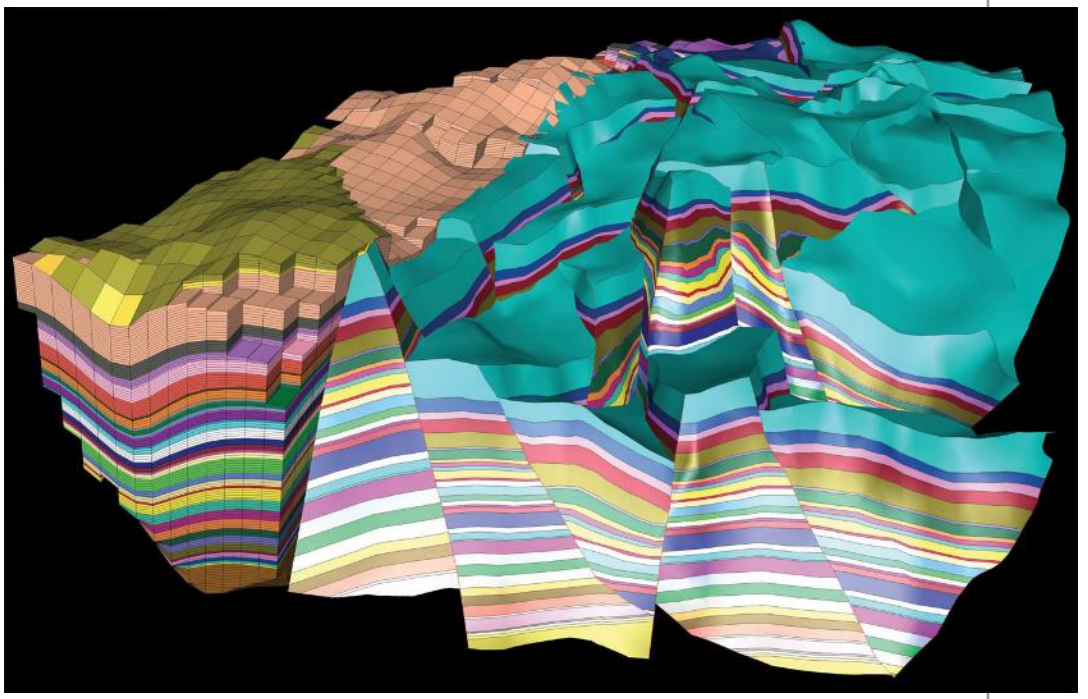
- Mature mining site have hundreds of thousand meters of core logged and legacy information that is no longer realistically be analysed by human alone





Geological Models

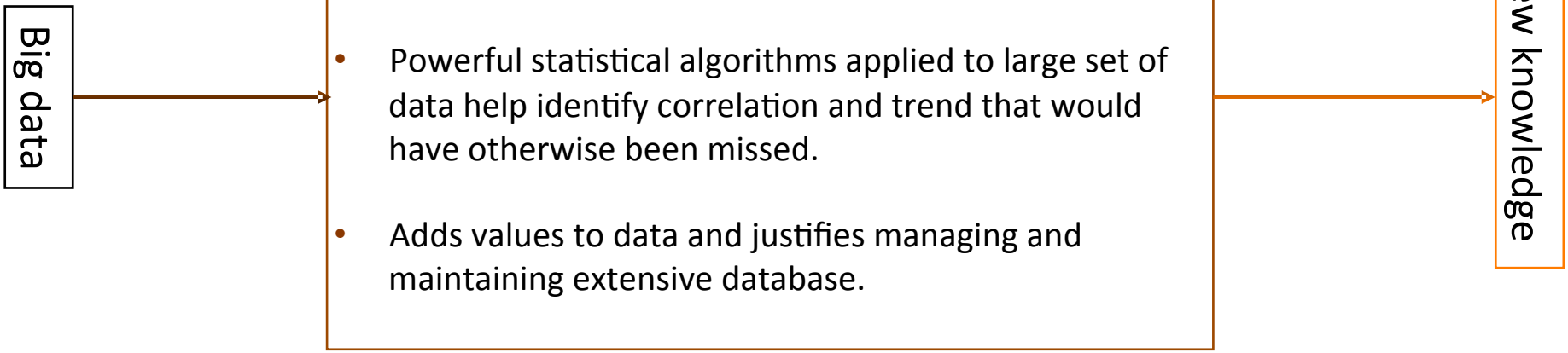
- Transforming this huge amount of data into new knowledge through the traditional interpretation methods is hard and ineffective.
- This is a common problem in our big data era. However, tools exist to manage this vast amount of information.



Exploration in the era of AI

Big data → Machine learning → New knowledge

Exploration in the era of AI



Conceptual Approach

- The first step towards machine learning targeting is to generalized the predictors over the study area, and then to classify the targeted feature in two classes: positive learning nodes and negative learning nodes.

- Since the targeted feature is frequently available as a grade value, the positive and negative nodes differentiation is based on a threshold of economic importance.

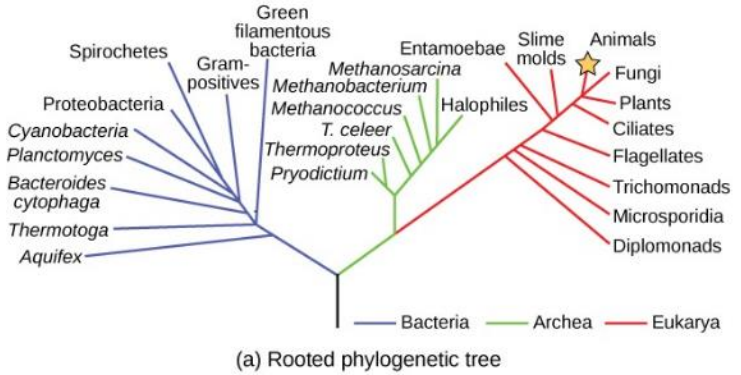
Conceptual Approach

- The machine learning algorithms have been developed to identify correlations between a set of data, the predictors, and a single targeted feature.
  - This means that an actual set of the targeted feature must exist in the study area so that the algorithm can identify the correlation between this set and the predictors.
  - This also suppose that the relation between the target feature and the predictors is somewhat constant over the study area.

Conceptual Approach

- Many algorithms have been tested but three are currently used in Genesis software and Microsoft Azure:
    - Specialized phylogenetic algorithm
    - Boosted classification trees algorithm
    - Bayesian Gaussian process latent variable

Specialized phylogenetic algorithm



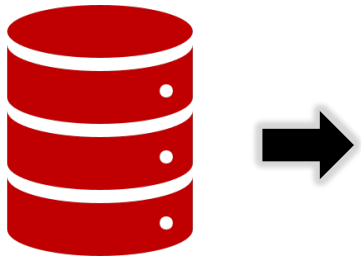
(a) Rooted phylogenetic tree

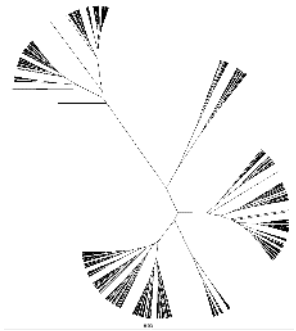
- Developed as a tool to map species differentiation and evolution based on their genes.
- Adapted by SGS Geological Services to work on the same principle with rock geochemical and mineralogical components.
- Used during interpretation to identify rock families and create lithological groups which serve as a starting point for modelization.

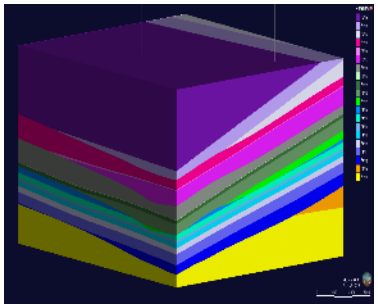
Specialized phylogenetic algorithm

Data
- Qemscan
- XRF
- ICP

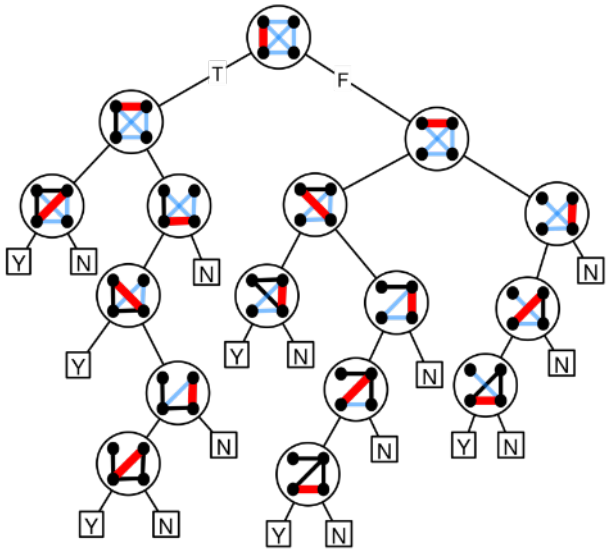
→ Phylogenetic classification → Rock grouping → Modelization



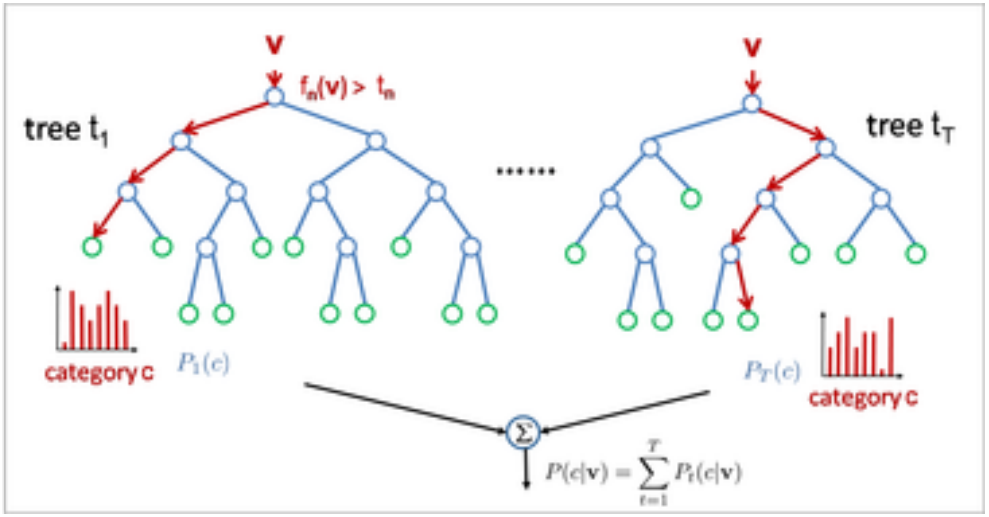


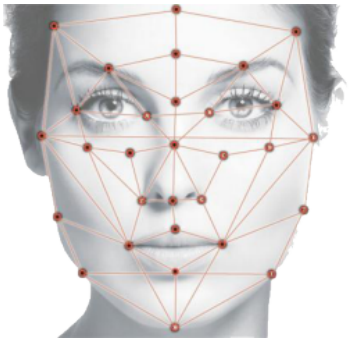


Boosted classification trees algorithm



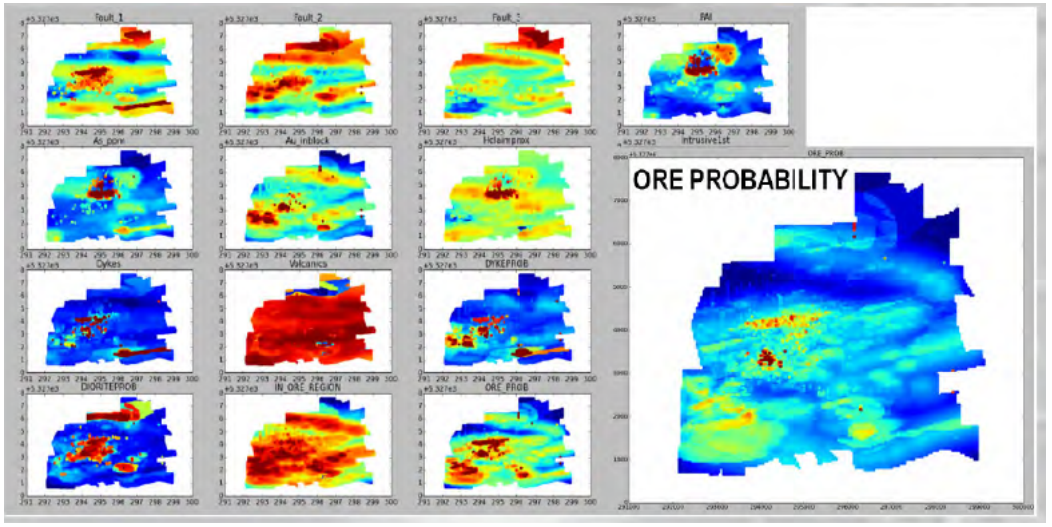
- Boosting build an ensemble of classifier from the different variables and combined simple classifier into a robust classifier
- The algorithm is adaptive and aim at lowering the prediction error to the lowest
- Decision trees are good for non linear correlation





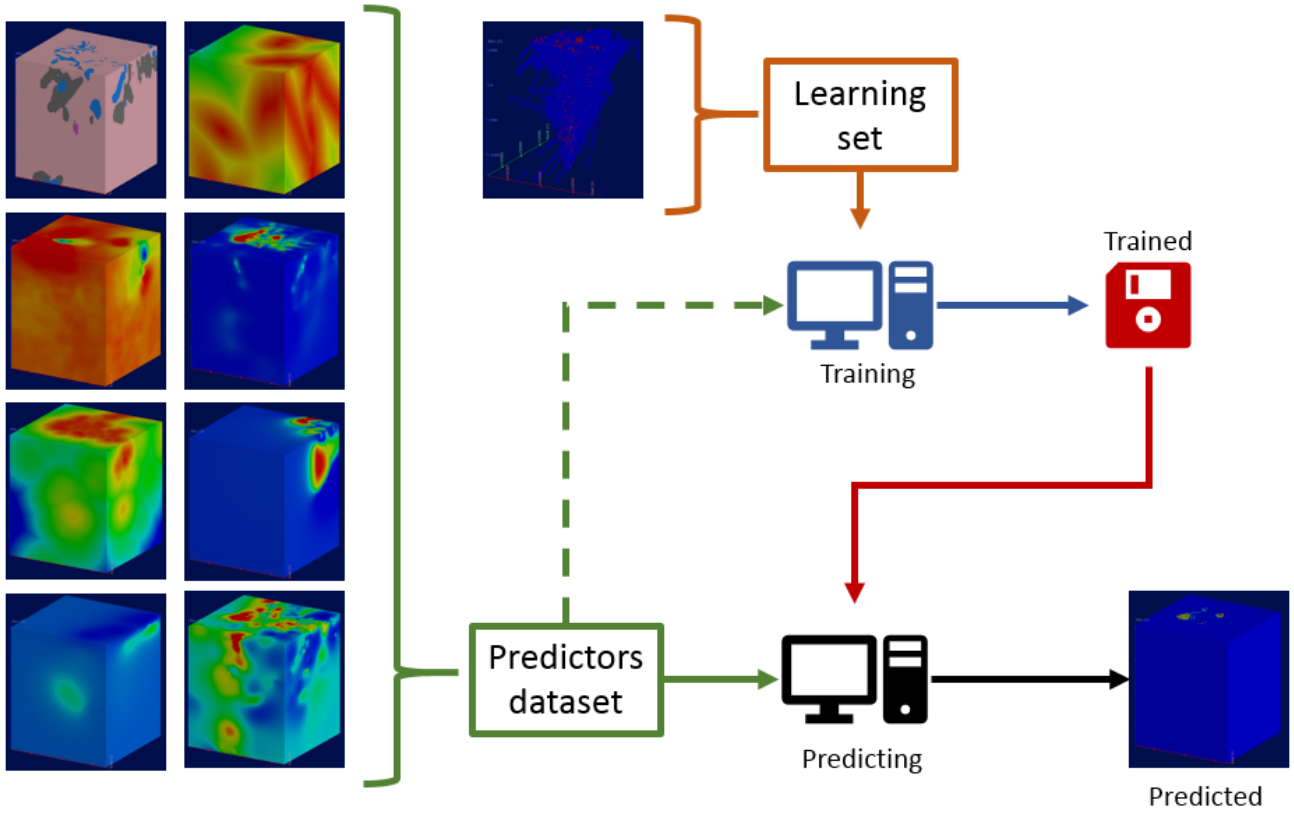
Bayesian Gaussian algorithm

- Brings the variable in a Bayesian distribution
- Predict the variable in a latent space and vet the variable with the best impact on the predictor
- The algorithm was design for non linear correlation of variable to predictors
- Good to handle missing data

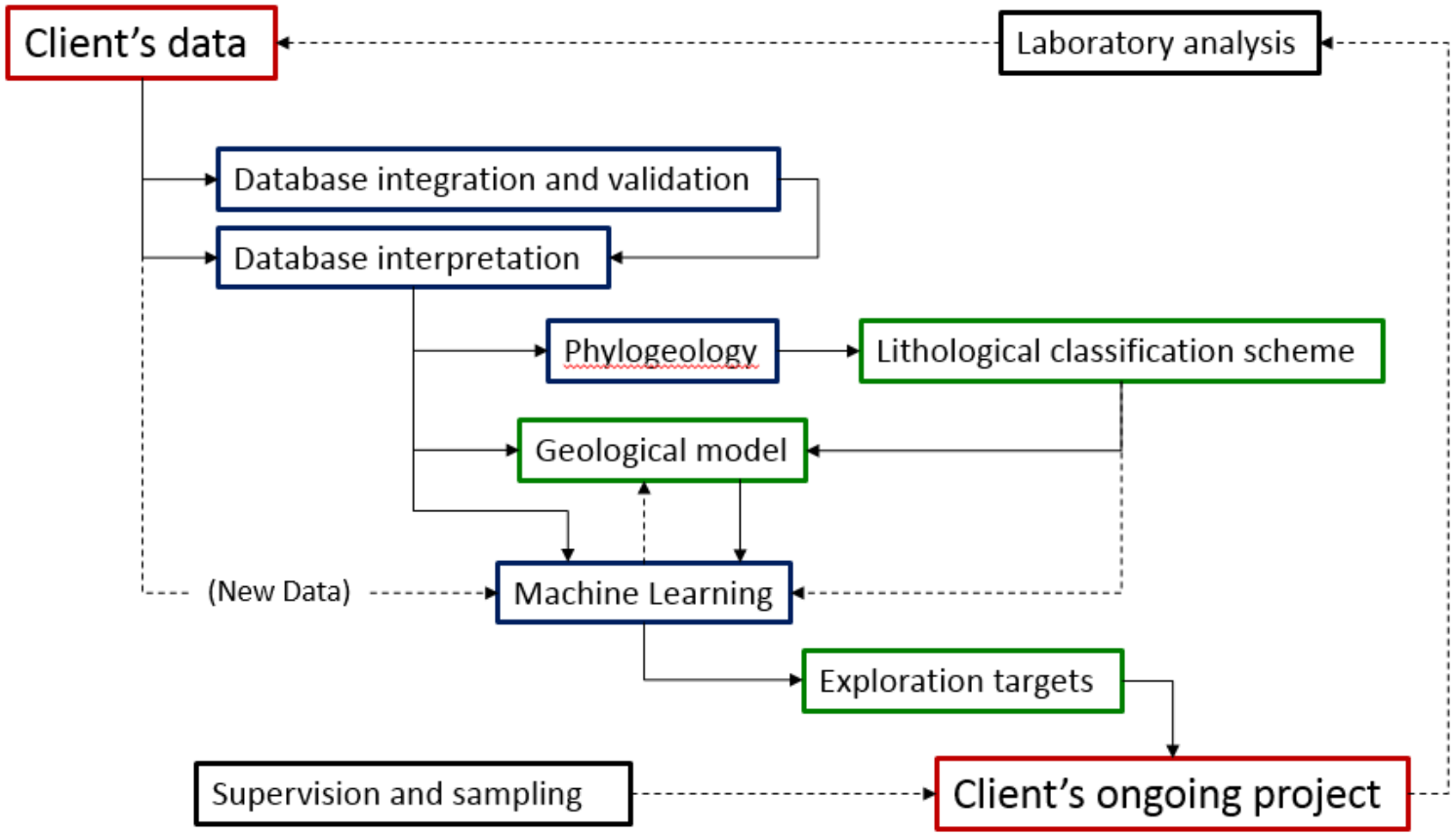


SGS Machine Learning Workflow

Boosted classification trees algorithm

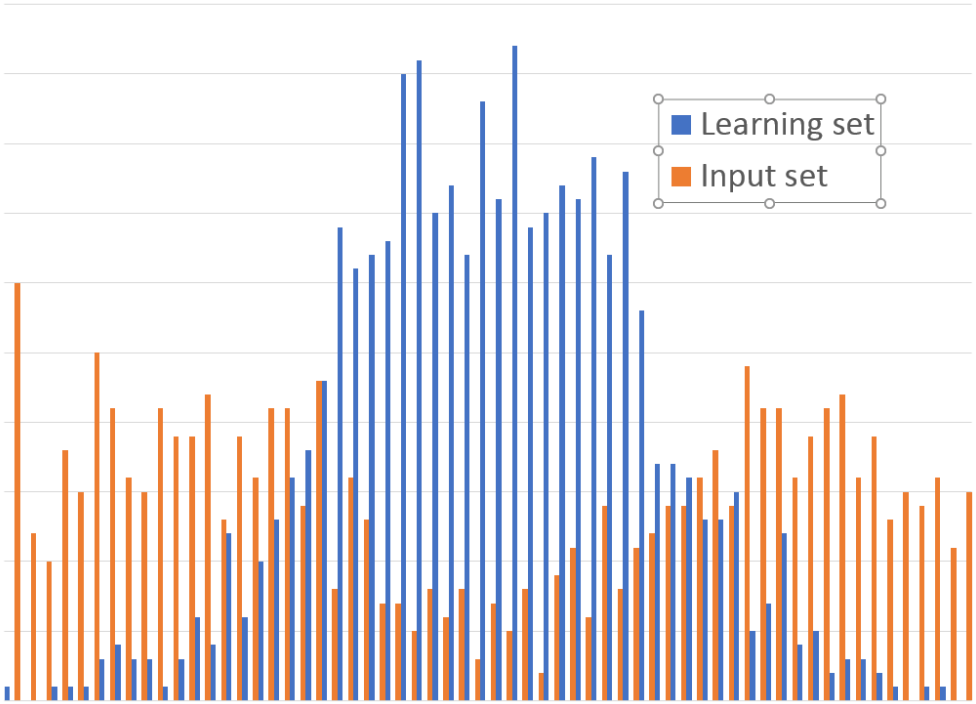


General Machine Learning Worflow



Machine Learning Target Validation

- However, those algorithms need to be used with caution. The quality of the data is what determines the new knowledge generated.
- Mismatch in the data distribution between the learning set and the input data can lead to incorrect classification.
- The use of correlation matrix help to evaluate the quality of ML targeting.
- Can be compare the classical weight of evidence (WoE)

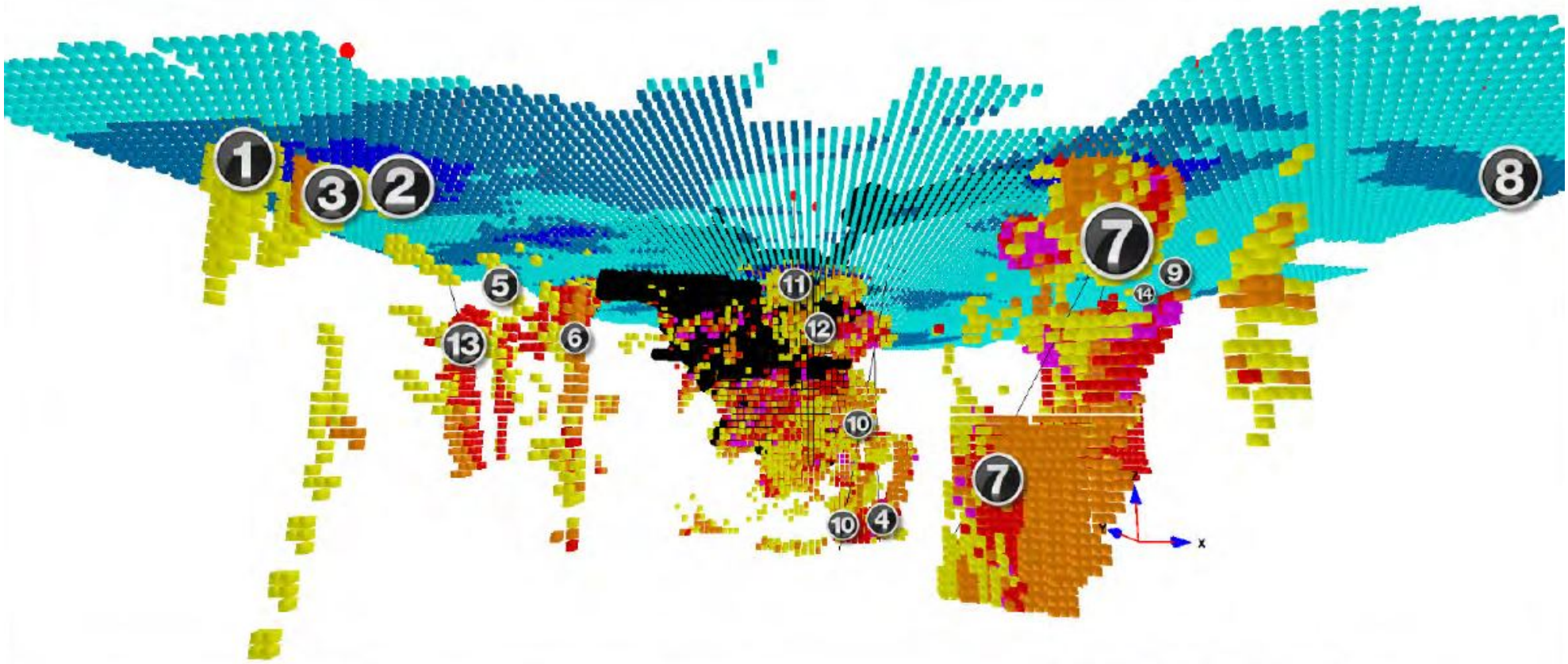


Our Recent and Current Projects

Integra Gold Corp.

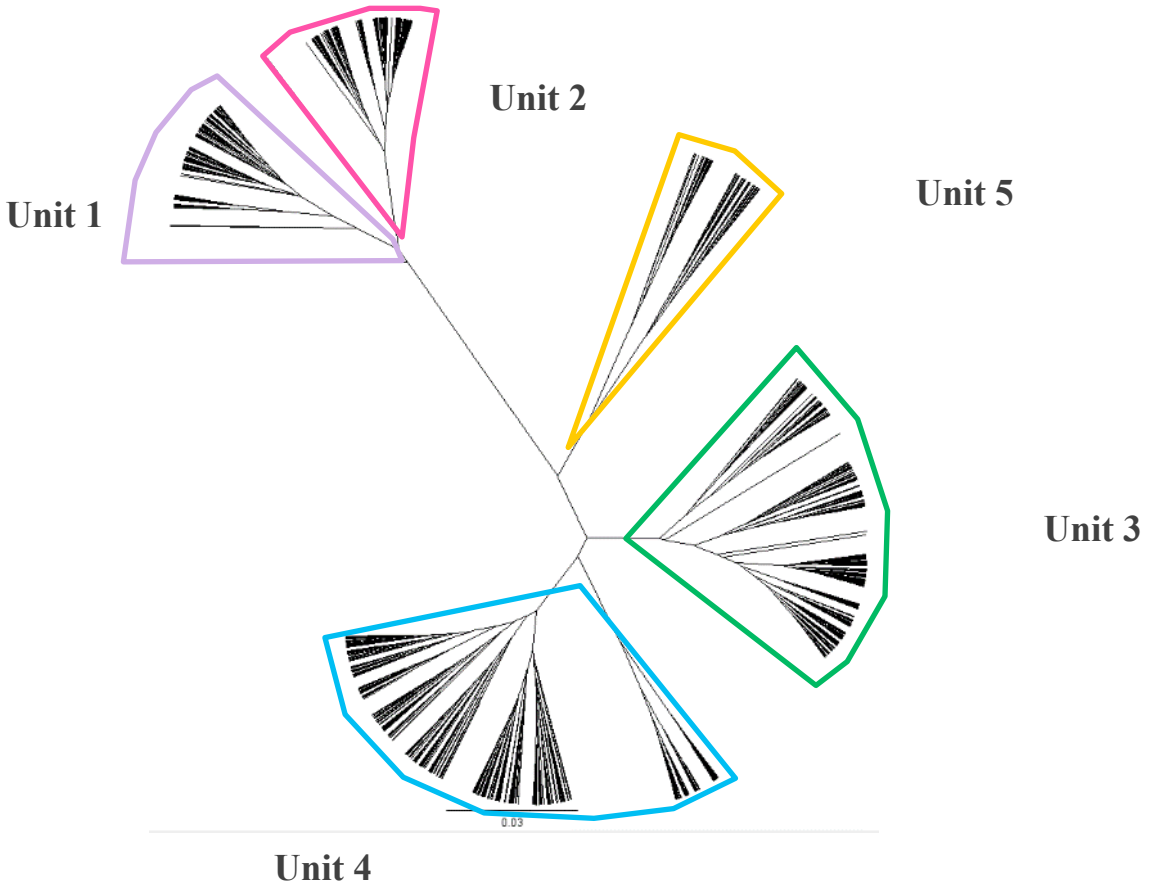
Gold Rush 2016 Targeting challenge – First Prize 500,000$, 1300 teams from 80 countries

Integra Gold Targeting Results

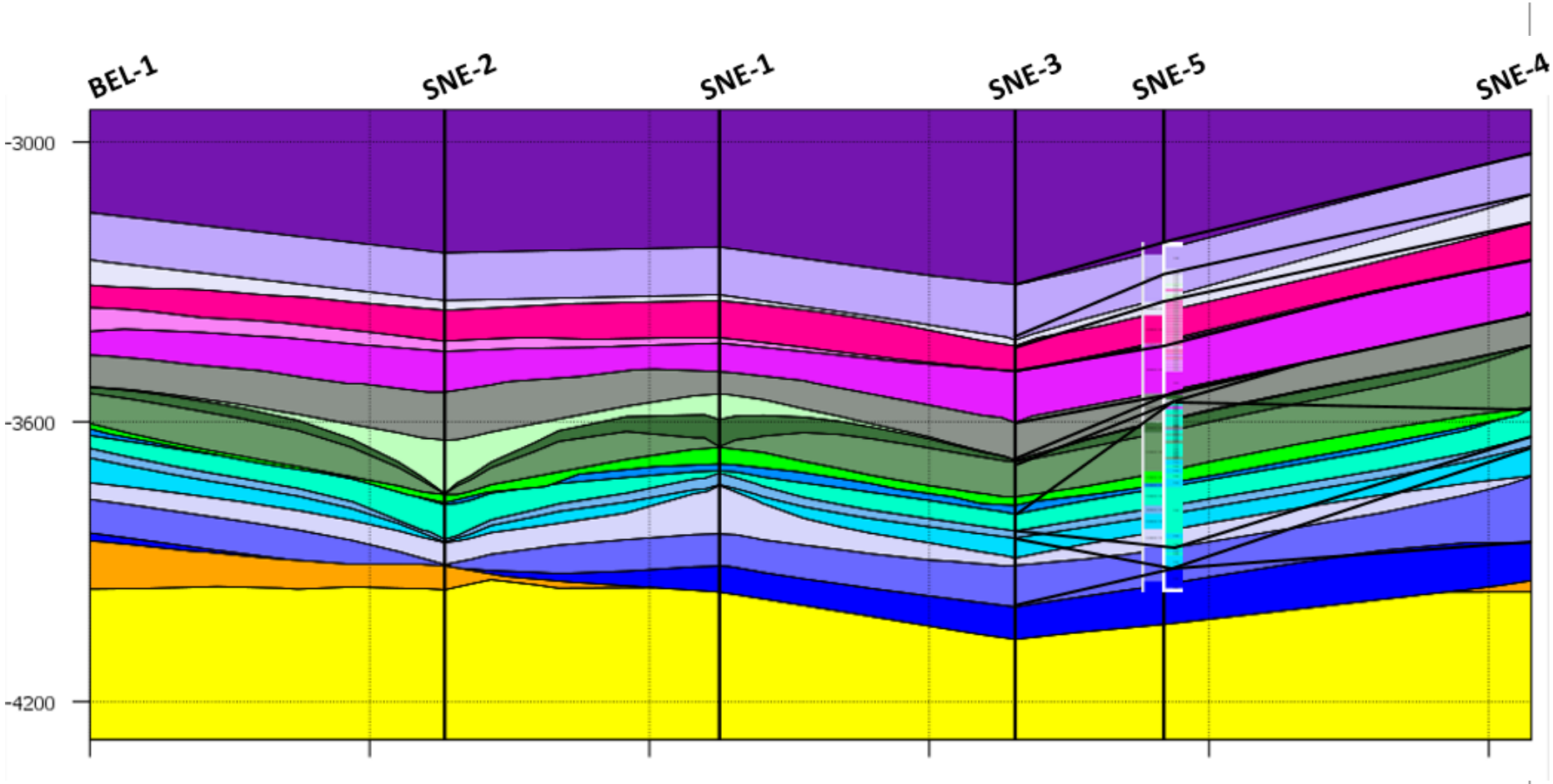


Phylogenetic: Mineralogy Data

The mineralogy data with x, y and z position of each sample was submitted to the classification algorithm with the following classification tree.

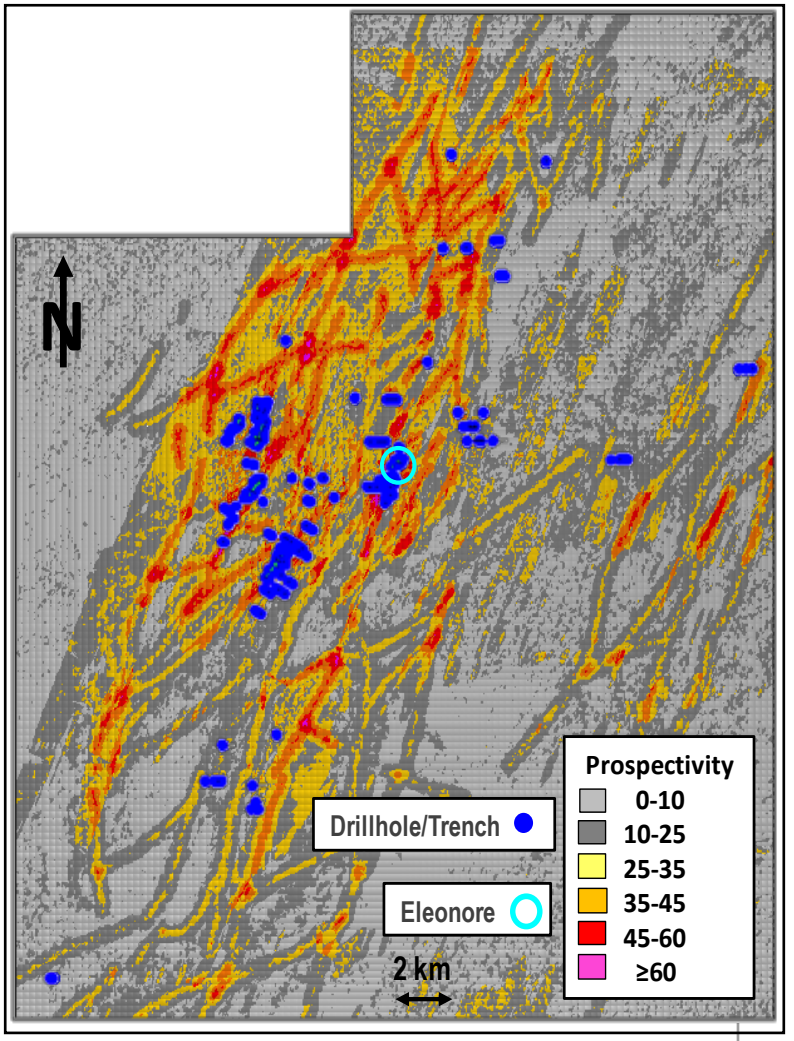


Phylogenetic in the Oil Industry

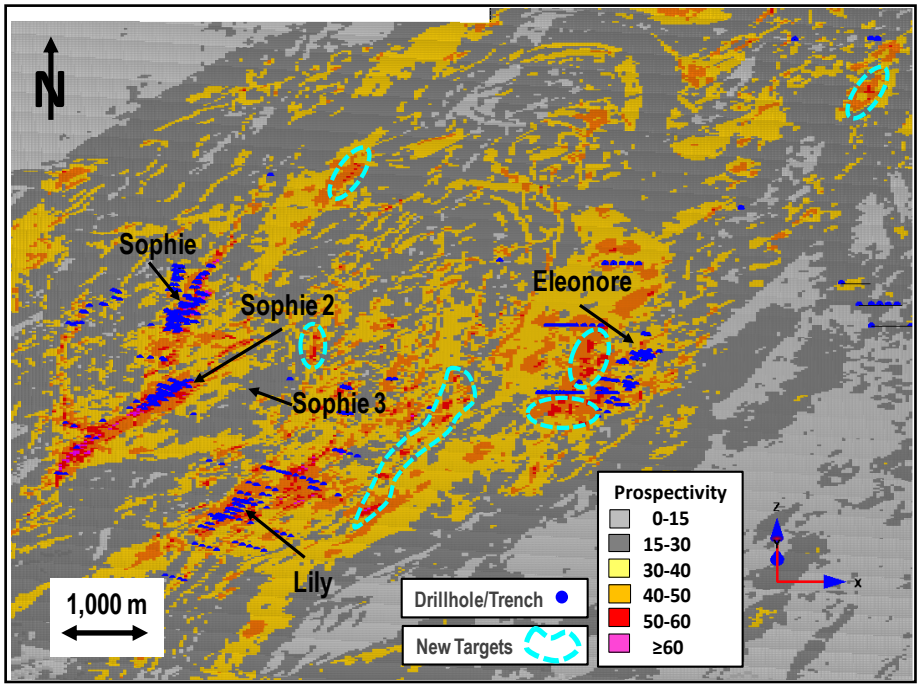


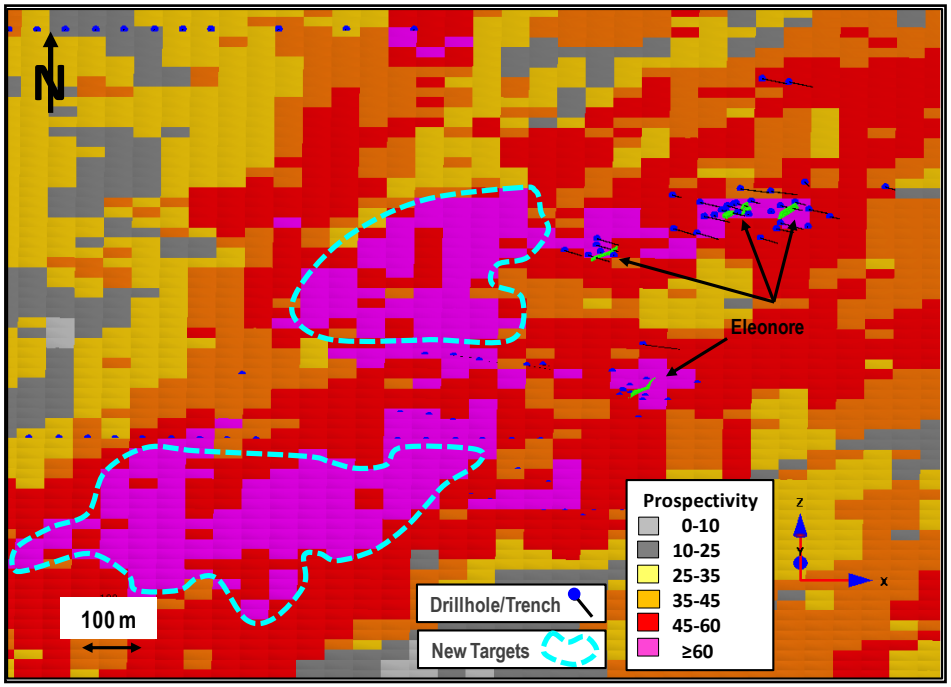
West African Gold Project

- Current project involve the integration of a vast database on a well developed mining camp.
- Identification of targets for open pit as well as underground mining for Au-PGE-Cu-Zn and Ag.
- Use of conditional simulation to quantify the risk in order to be more efficient on drilling.



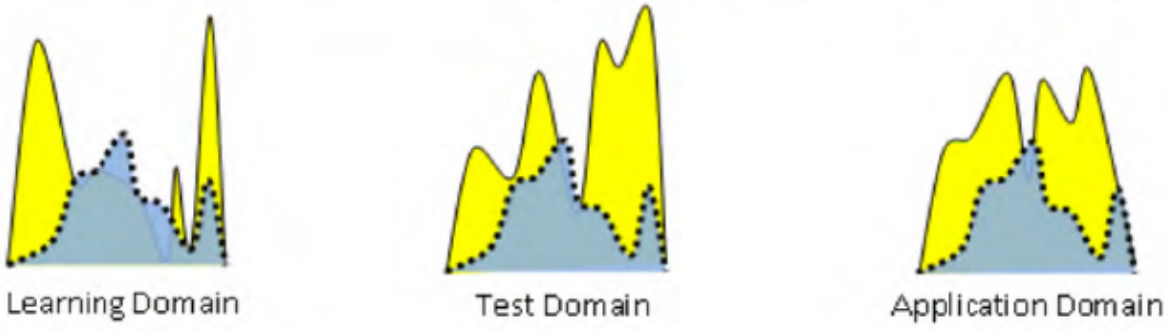
West African Gold Project





Limitation Machine Learning in Exploration

- The geology world is al about domains… Can we learn from a domain an applied it the another?
- At the moment, the statistical probability distributions between the learning, test and application domains are too different and optimisation of the error is difficult
- Not all variable can be threshold for interpretation purposes
- The mineralisation model may not be as simple as we think
- Need large amount of data to generate reliable targets
- Target are size and block model volume must be realistic or multiple targeting exercise will be needed



Future development

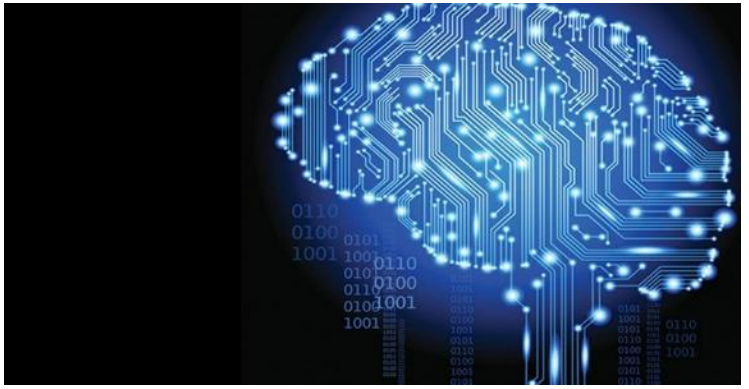
- Future development are in the optimization of the methodology and the improvement of the statistical predictive power of the algorithm used.
- Ongoing process aiming at sampling a wide range of algorithm all fitted for specific purposes. Be more efficient by trying to solve specific problems.
- Work is also being done on reducing the amount of prior interpretation necessary before being able to run the algorithms.
- Iintegration of more information in the current model to lower the predictive error

Conclusion

- The versatile capabilities of machine learning assisted classification makes it a powerful tools for geological interpretation and to generated new correlation

- Main application for exploration is still targeting, but is not limited to and can be apply to geometallurgical sampling, rock classification and more…

- At the moment, all option are possible and the future success will drive the ML forward for the mining industry



Questions