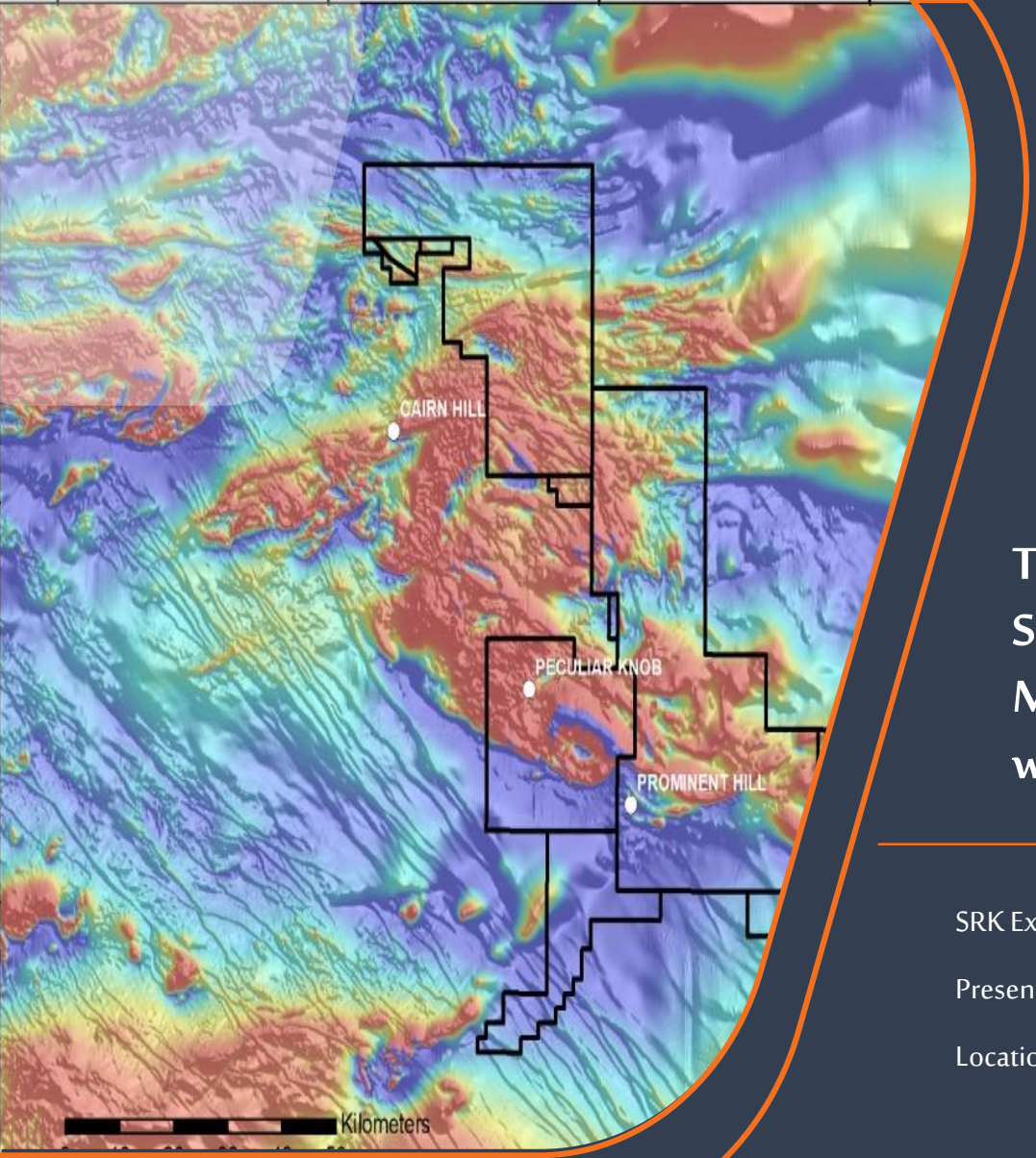


The merits and pitfalls of Data Science in Mineral Exploration, Does Machine Learning work and how can we improve upon it

SRK Exploration Services October 2020

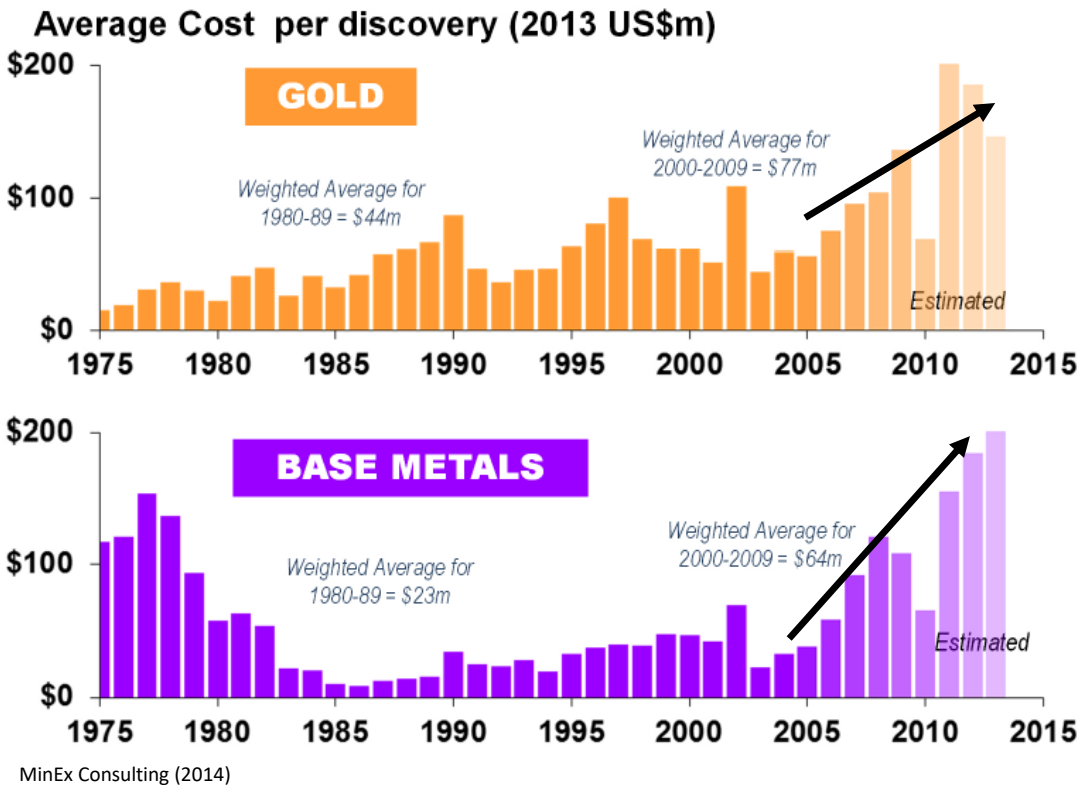
Presenter: James Gilbertson

Location: Minex 2020

srk exploration

Discovery Rates Have Been in Decline

- Poor value for the exploration dollar for most of this century to date
  - low hanging fruit taken
  - spend is transitioning to deeper/ under cover terranes
  - effectiveness of 'traditional exploration' deteriorates with depth
  - ➢ **need to adopt a different approach**

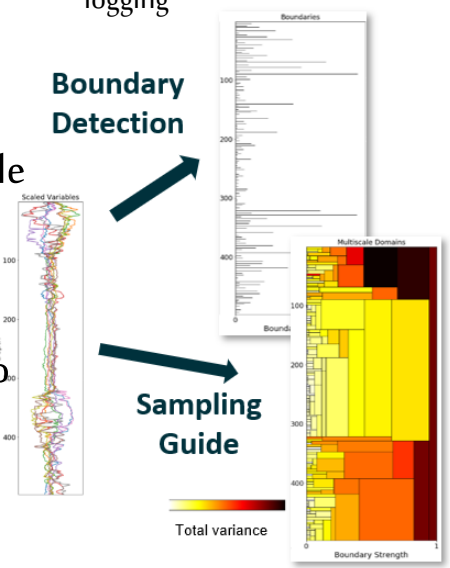


MinEx Consulting (2014)

Machine Learning and Data Science in Exploration

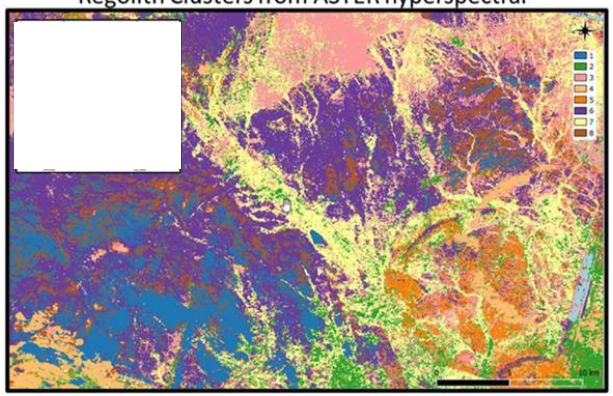
- Prospectivity analysis and mapping
- Analysis and prediction on remote sensing data such as satellite and geophysical data.
- Analysis and predictions on geochemical data (soil, lithogeochemical data along drillcore).
- Automated core logging can be done on any type of data: core images, geochemistry, spectral data and downhole rock physical properties measurements.
- CSIRO has developed recently a solution (Mosaic) using wavelet transformation to automate core logging. It is a nearly unsupervised approach.

Example of ML automated core logging



Satellite orthophoto

Regolith Clusters from ASTER hyperspectral



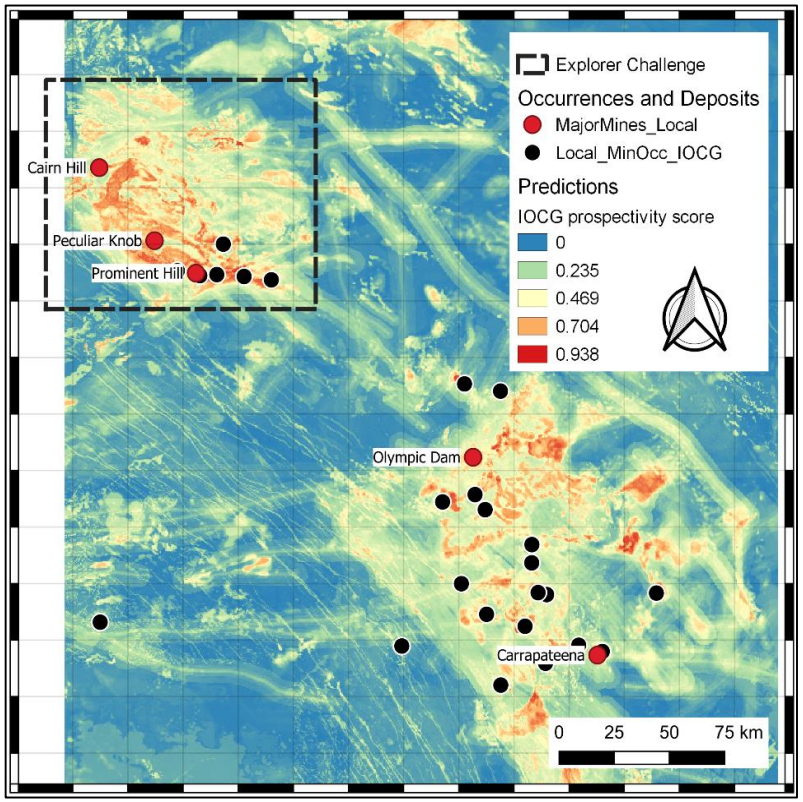
Example of ML analysis. Identification and mapping of regolith units

Prospectivity Targeting using Machine Learning

Growing usage in mineral exploration utilized to accept growing quantities of data.

Standard approach accepts satellite imagery, regional geology and geophysical data, available geochemical data.

Known occurrences (and non-occurrences) used to train algorithms



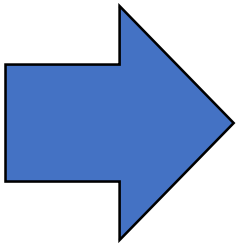
However, this approach is only as good as the data that it is provided.

It is limited by the available data set, if numerical data is not a good predictor, or if the area has poor prospectivity, targets will still be produced but these will be barren.

An integrated knowledge driven approach is more powerful

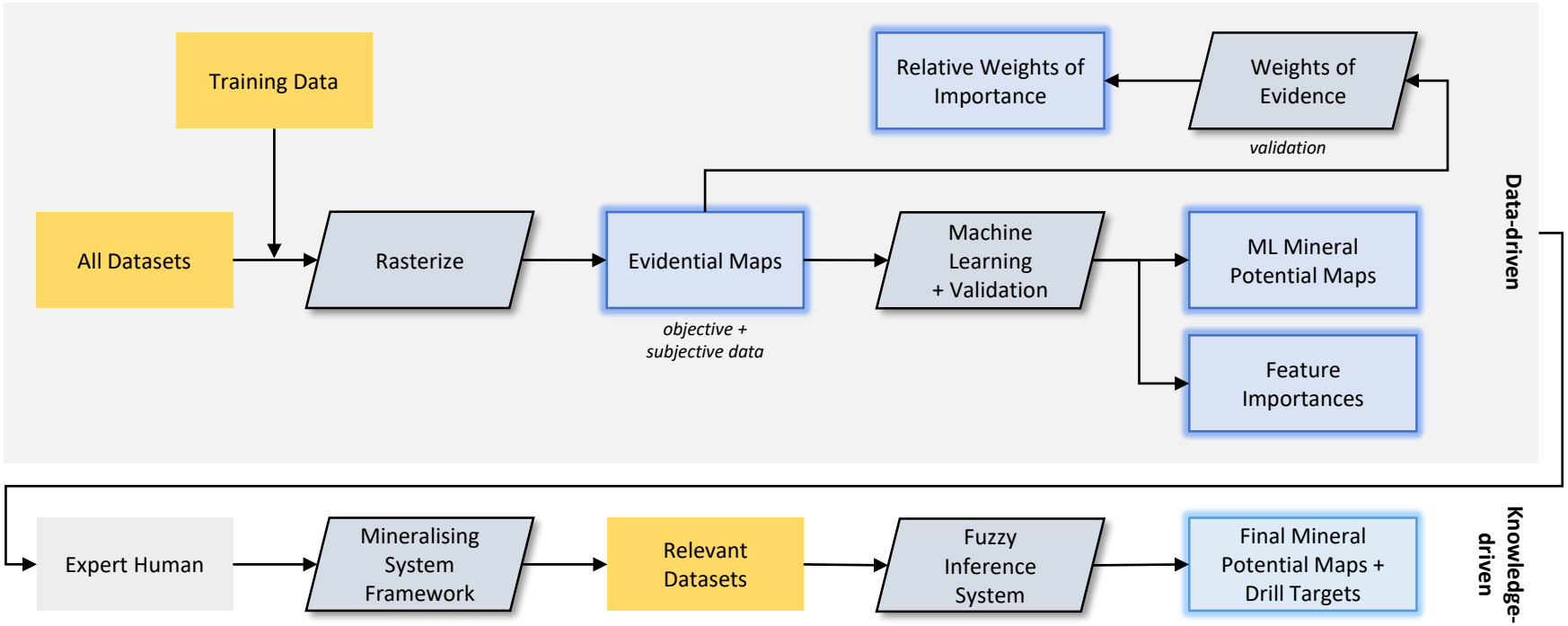
Prospectivity Targeting
- Data vs. Expert Knowledge

- More and more data becoming available
  - more drilling, more geophysics, geochron, isotopic maps, MT, seismic etc.
  - particularly true in brownfields or 'mature' terranes
- Greenfields
  - some terranes are still data poor!
  - 'knowledge' and 'experts' become even more important
  - limited pool of 'experts' however
  - ➢ which may limit diversity of ideas?
  - ➢ which may inadvertently lead to 'group think'?



Integrated Data-driven + Expert-Knowledge-driven approaches required

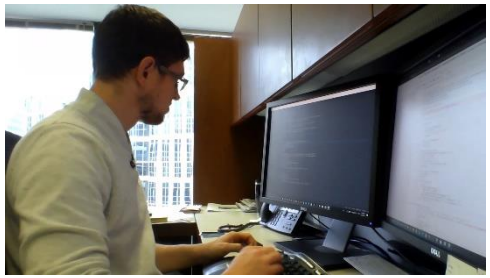
Integrated Targeting Workflow



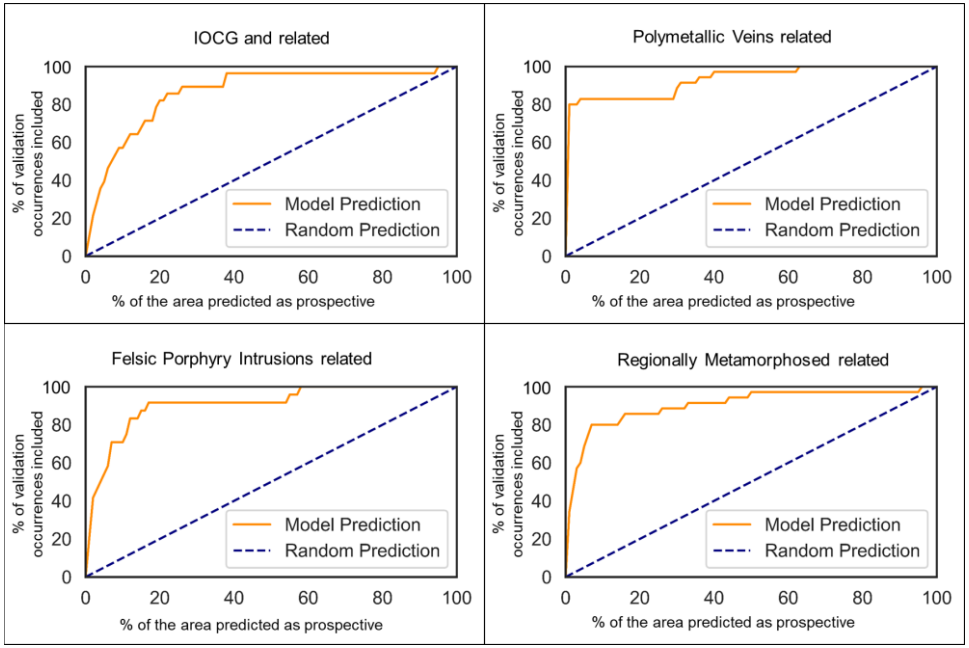
Can be run quickly – almost anywhere globally or at any depth slice

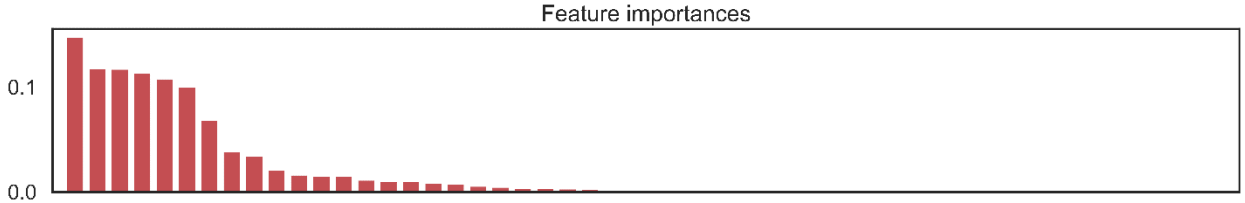
Data Driven Stage

Machine Learning



- Balanced Random Forest algorithm generates:
  - Success rate curves
  - **Feature Importances**
  - Mineral potential prediction map
- Uses training occurrences to estimate the relationship between the data and mineralisation
- Reveals unbiased data-driven controls and trends in the data
  - ➢ unconstrained from 'accepted wisdom'





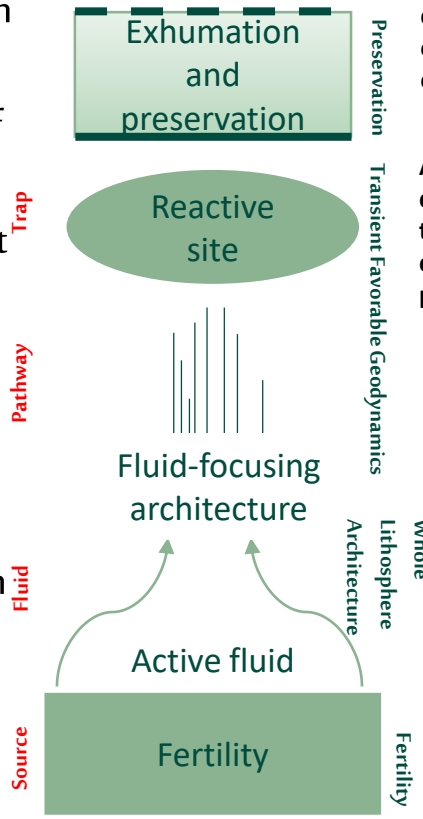
Expert Knowledge-driven Stage

Mineral System Framework

The main premise of predictive targeting using a organising framework, or the Mineral System Approach is that ore deposits are the outcomes of a much larger system, focusing energy and mass transfer at a range of nested scales and that ore forming systems show a diverse set of chemical processes but a fairly narrow set of physical phenomena.

These systems are complex, dynamic and exhibit self-organising behaviour.

The commonly listed key attributes to ore formation are Source, Fluid, Pathway, and Trap and can be integrated into a set of critical parameters of a mineral system including Whole Lithosphere Architecture, Transient Favourable Geodynamics, Fertility and Preservations. The interrelation between these parameters is the key to successful exploration targeting.



The concentration of minerals must have been brought close enough to the surface for discovery and exploitation, but not destroyed or dispersed by surface weathering or erosion.

A chemical or physiological difference (e.g. a drop in pressure, change in rheology or temperature) capable of destabilizing the dissolved mineral content and inducing precipitation at a particular depositional site.

A deep-rooted structure or framework of fluid pathways that can focus the mineral-carrying fluids into a conduit and/or over a long duration (or multiple phases).

A fluid (commonly sourced from magmas or metamorphic fluids at depth) capable of scavenging the relevant mineral and carrying it in solution or suspension.

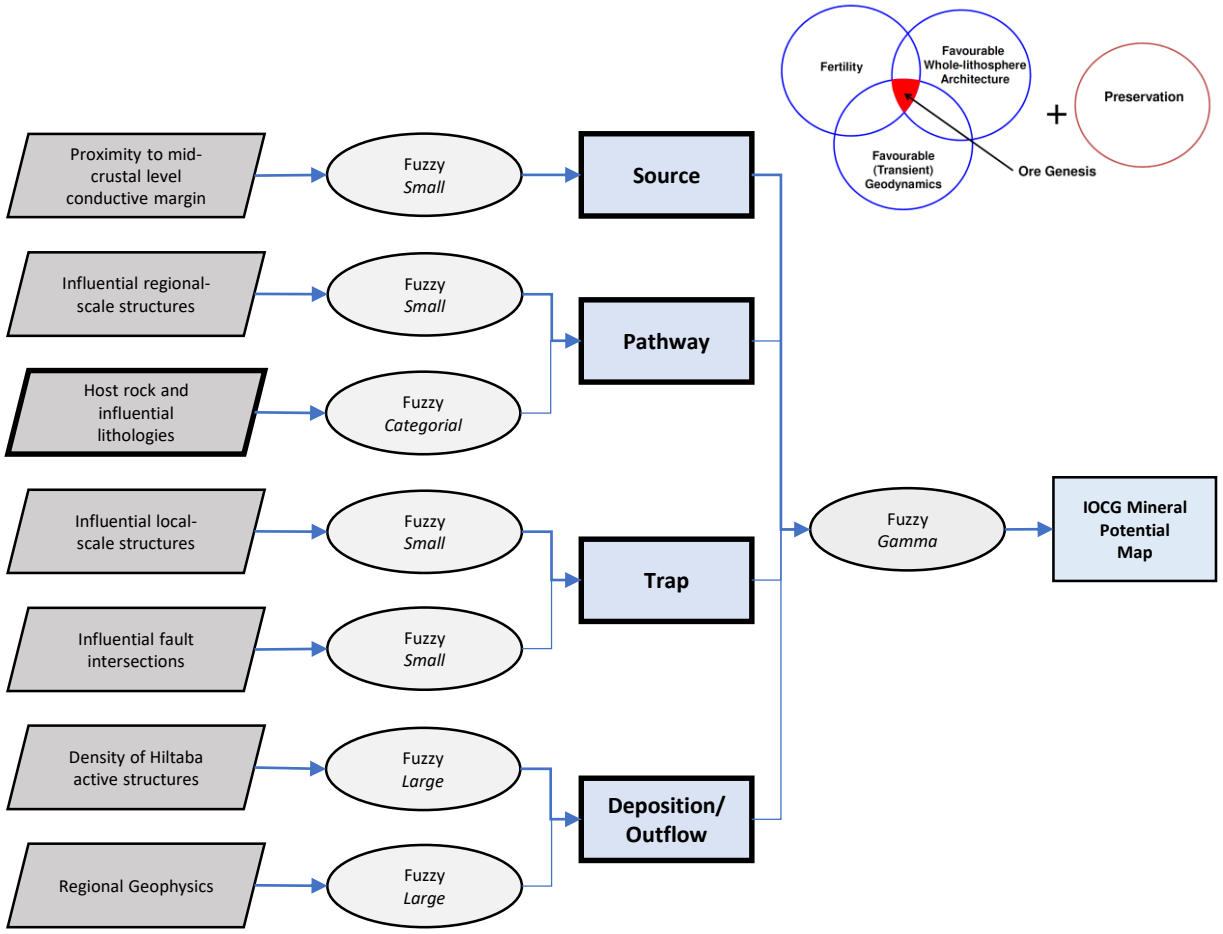
The presence of metal atoms contained within a volume of rock at depth that can be concentrated within fluids and transported.

Expert Knowledge-driven Stage

Fuzzy Inference Systems

- Uses outputs revealed from ML Feature Importances
  - validated by Weights of Evidence where differs from 'expected'

- If influential datasets are excluded, final outputs won't mean much
  - ➢ **the ML stage helps reduce this risk**



Integrated targeting workflow

An example of 'Augmented intelligence'

- e.g. Freestyle Chess Tournament, 2005:

  Weak human + machine + better process

  Defeats

  Strong human + machine + inferior process

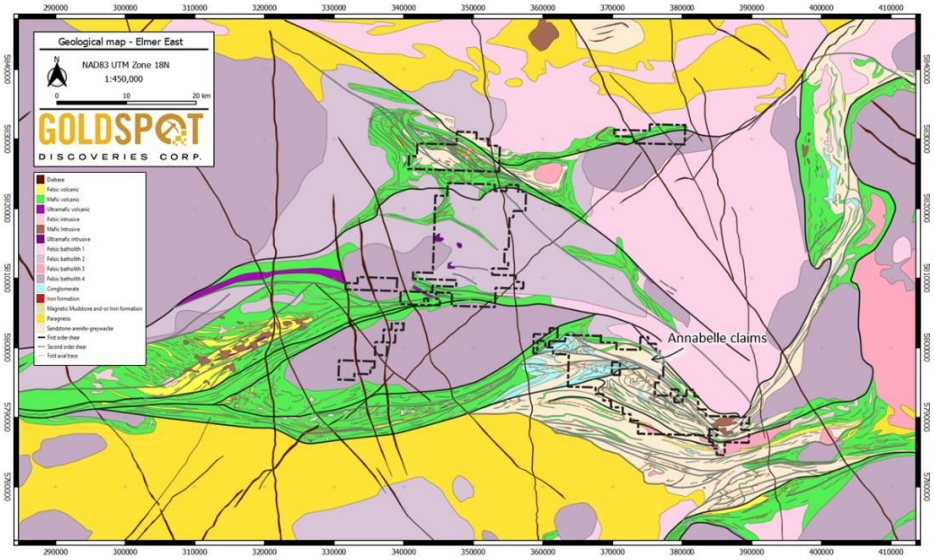
➢ **The next generation of mineral discoveries will not be made by strong humans alone**

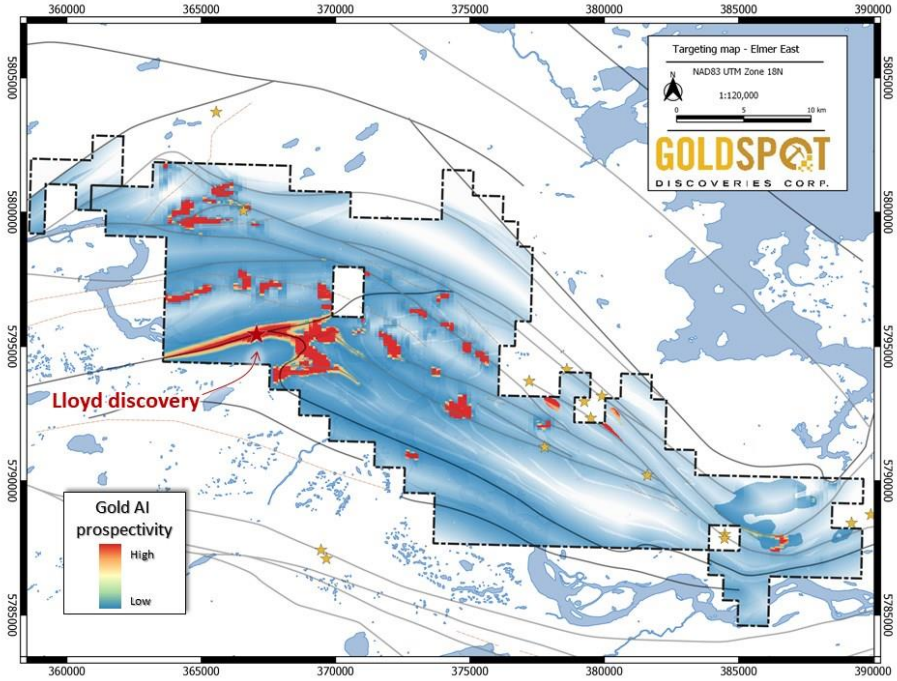
Chess grandmaster Gary Kasparov

- SRK integrated targeting workflow:
  - Strong humans + machine + better process … drill testing of targets to be the ultimate judge!
  - Can be applied to almost any terrain for almost any commodity style anywhere globally
  - ➢ **Scalable – from continental down to mine scale**

Success Stories

GoldSpot Discovers New Gold System at Quebec Precious Metals' Elmer East Gold Project Using Artificial Intelligence





Conclusions

Overall is important to recognise that:

- Machine learning used for prospectivity mapping and direct targeting is just a tool to integrate the data available. It is powerful but not 'magical'.
- It makes targeting more objective, more quantitative, and repeatable.
- It allows to better extract hidden patterns in the data.
- But it is not a magic wand. At the end of the day, if the proper exploration vectors are not in the data, machine learning will not be more successful than anyone.
- Integrating expert knowledge into the approach with an expert understanding of the full Mineralising System will provide much better results.

The potential of using machine learning for other applications such as pseudogeological mapping, remote sensing data integration, automated core logging or geological modelling is still in early development and not considered enough by exploration companies.

Further Development – integrating Mineral Systems Analysis with Mineral Endowment Modelling as a step towards and estimate of Absolute Prospectivity and a Unified Exploration Model – SRK Research Project – **Project Murchison**

Copyright and Disclaimer

version: Jan 2019