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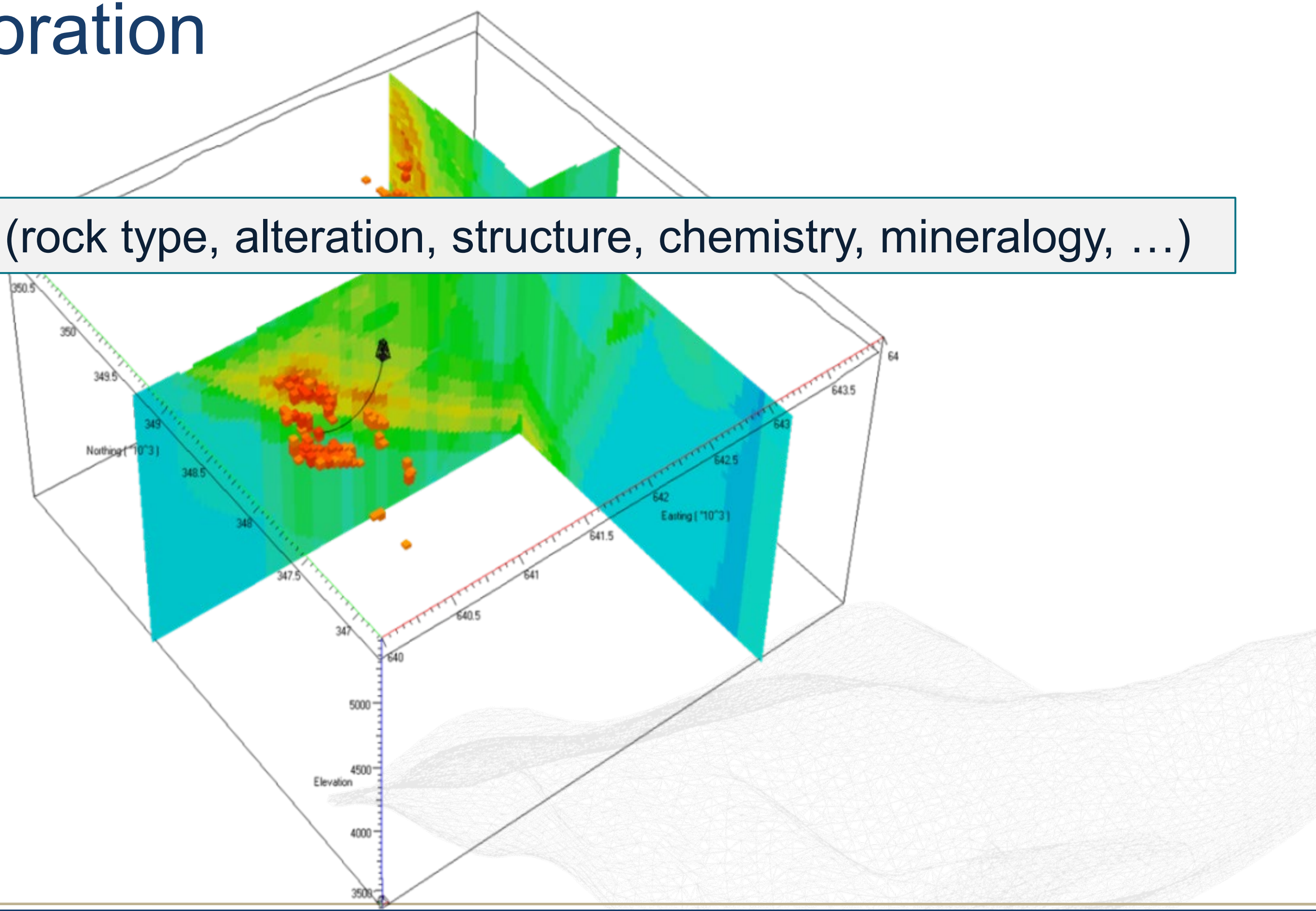
20 years of modelling the earth

Advances and opportunities for AI in mining and geotechnical engineering

NATIONAL ACADEMY OF SCIENCES
SUBSURFACE DATA AND MACHINE LEARNING MEETING – JUNE 2019

John McGaughey

Mineral exploration



target (x, y, z) = *f* (rock type, alteration, structure, chemistry, mineralogy, …)

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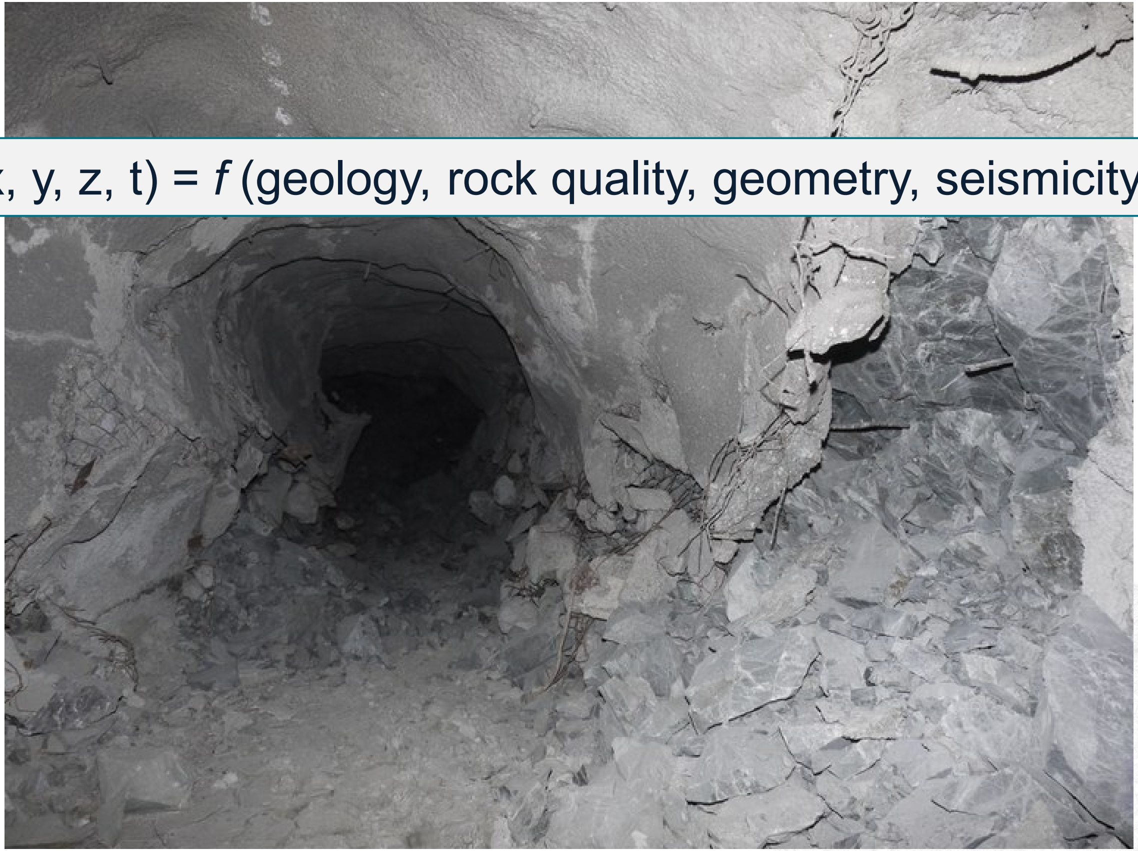
Geohazard



hazard (x, y, z, t) = *f* (geology, rock quality, geometry, seismicity, stress, …)

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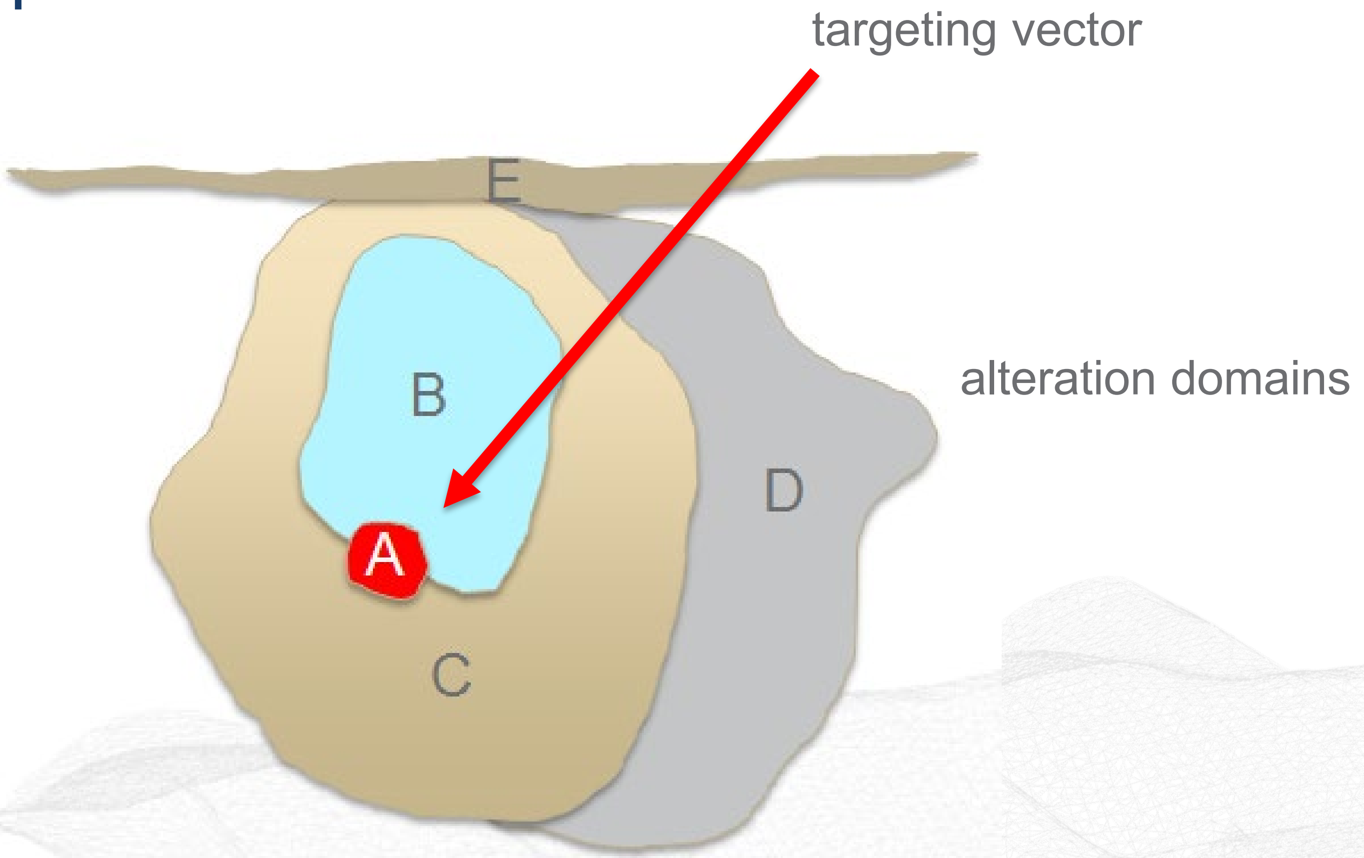
The AI challenge in mineral exploration

- potential benefits of AI in mineral exploration may be immense, yet its application is far from simple
- we must identify the location of an ore deposit at the core of a very complex, natural system—the result of millions of years of structural and hydrothermal alteration
- evidence of the deposit must be assembled from interpretation of subtle alteration effects extending kilometres from the target
- the challenge is in the problem set up, not the machine learning

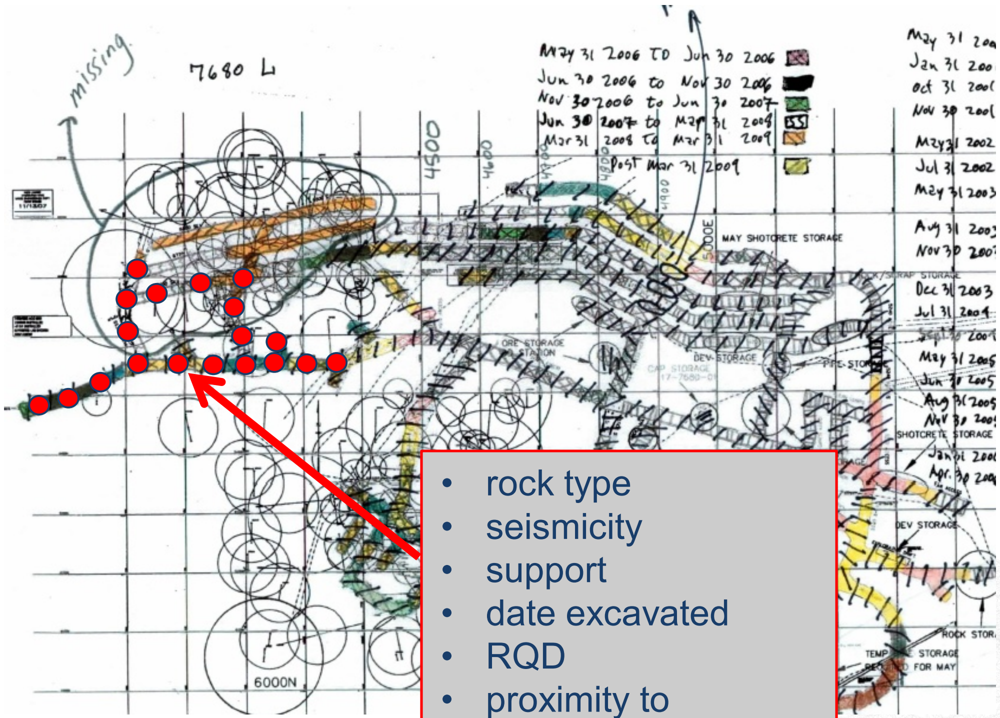
Conceptual framework



The AI challenge in geohazard assessment

- potential benefits of AI in geohazard assessment may be immense, yet its application is far from simple
- we must identify the probable location and time of a geohazard resulting from a very complex system with natural and engineered components
- evidence of the geohazard must be assembled from interpretation of numerous sparse, heterogeneous, time-dependent non-collocated data
- again, the challenge is in the problem set-up, not the machine learning

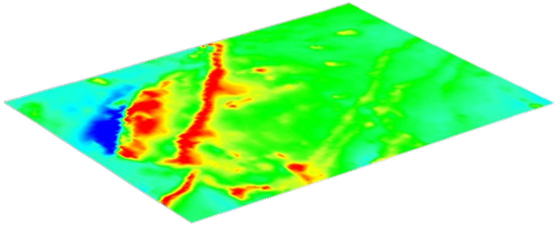
Conceptual framework



- rock type
- seismicity
- support
- date excavated
- RQD
- proximity to structure
- etc…

Data and models

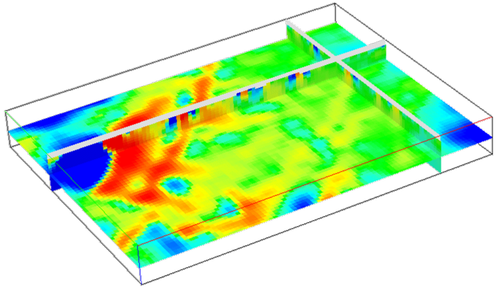
geophysical data



$$\phi_m(m) = \alpha_s \int_V w_s \Big[w_r(z)(m - \ldots$$

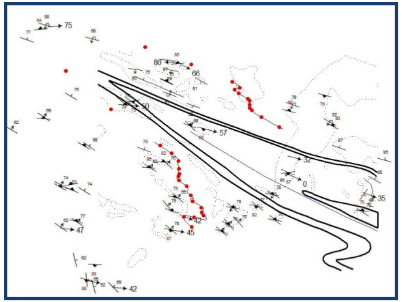
$$\alpha_x \int_V w_x \Big[\frac{\partial}{\partial x}\big(w_r(z)(\ldots$$

geophysical model



inconsistent assumptions

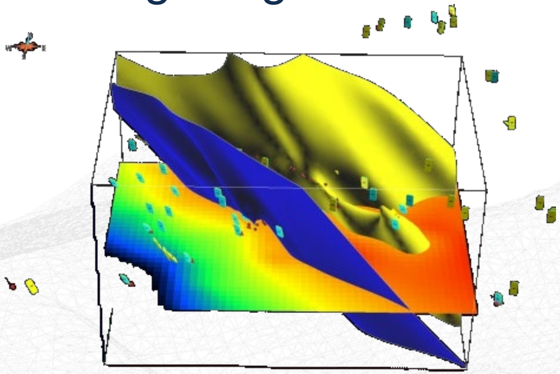
geological data



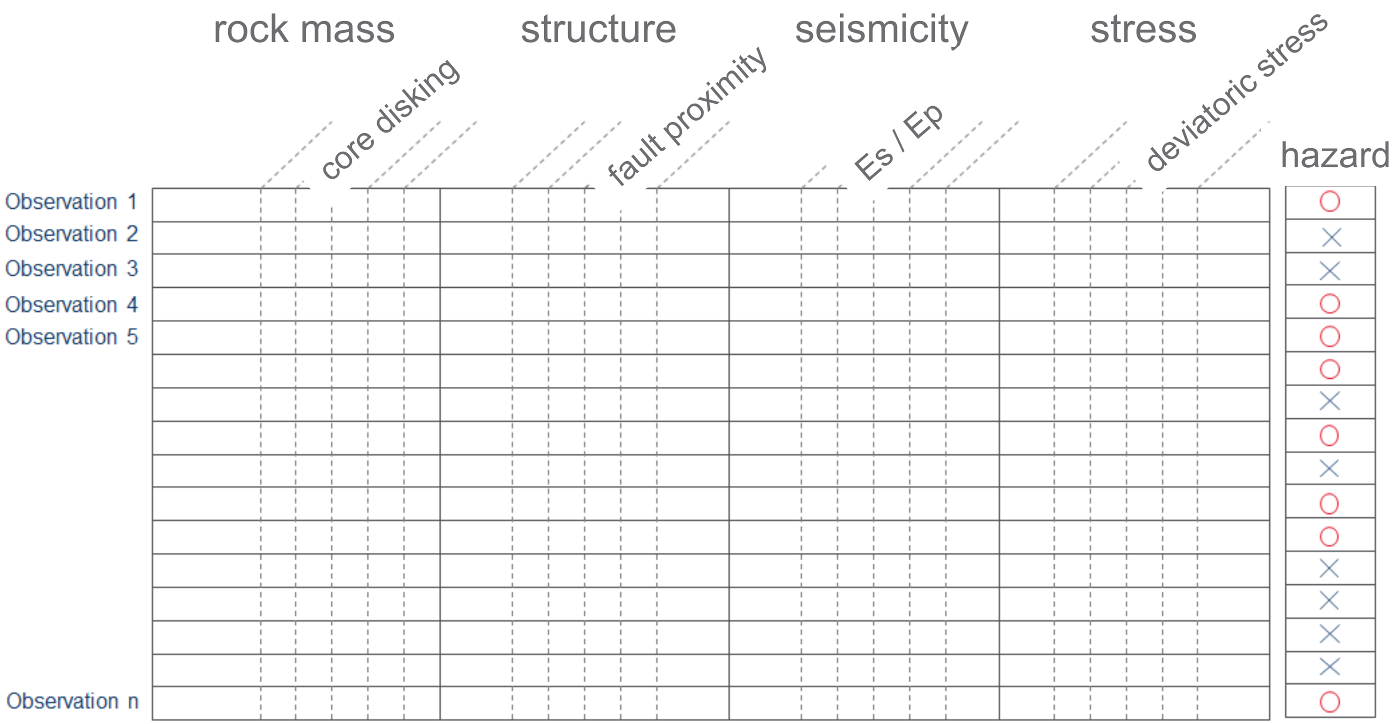
$$s(\boldsymbol{x}) = \sum_{j=1}^{\mu} a_j K(\boldsymbol{x}, \boldsymbol{x}_j) + \sum_{k=1}^{\sigma} \ldots$$

$$+ \sum_{l=1}^{\tau} e_l \Big\{ t_{\mu+\sigma+l,x} \frac{\partial K(\boldsymbol{x}, \ldots}{\partial \ldots}$$

geological model



Data fusion table



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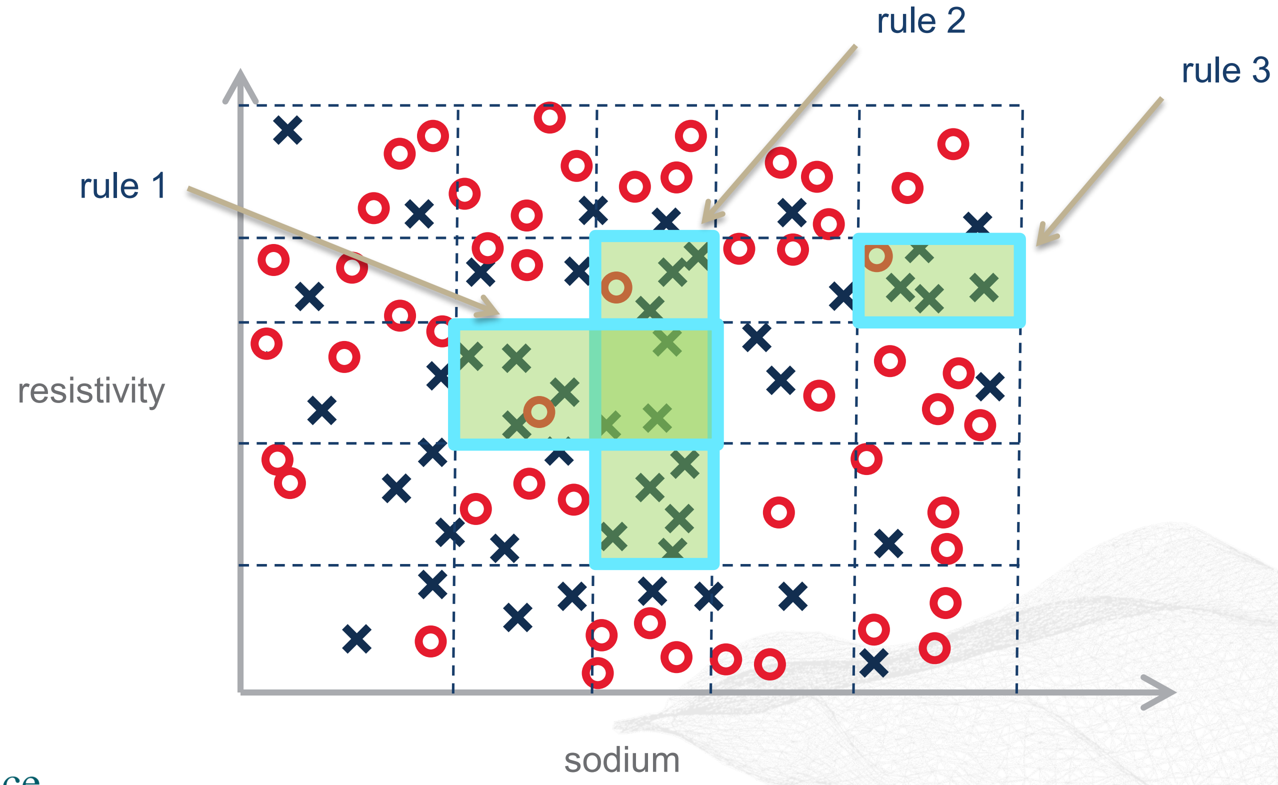
Machine learning



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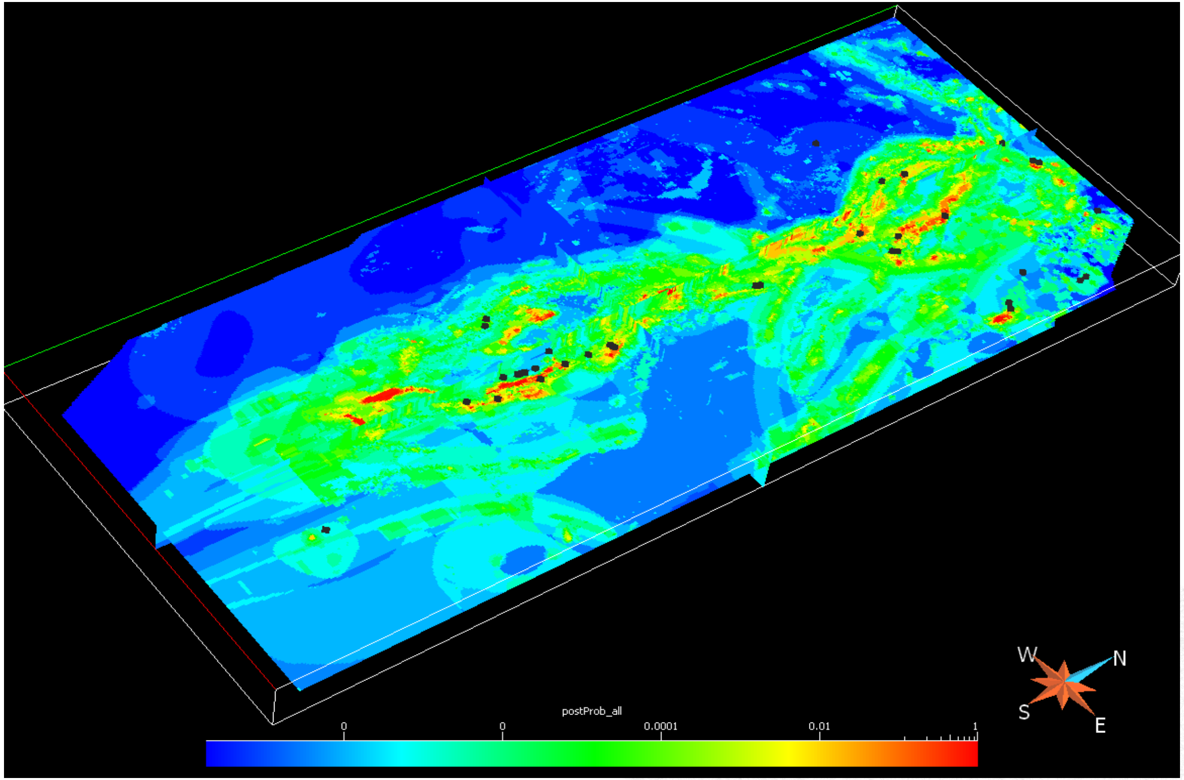
Exploration target probability model



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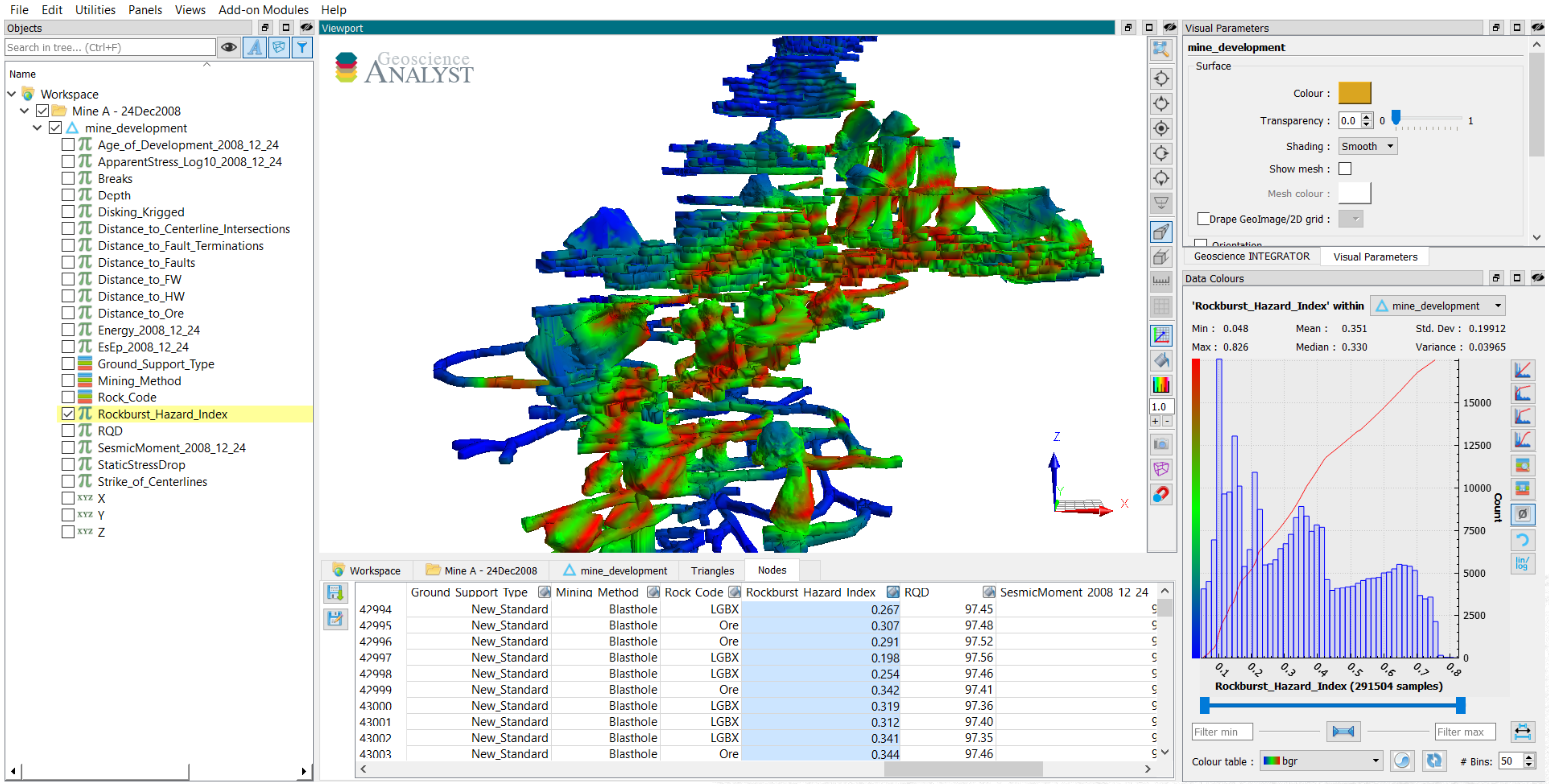
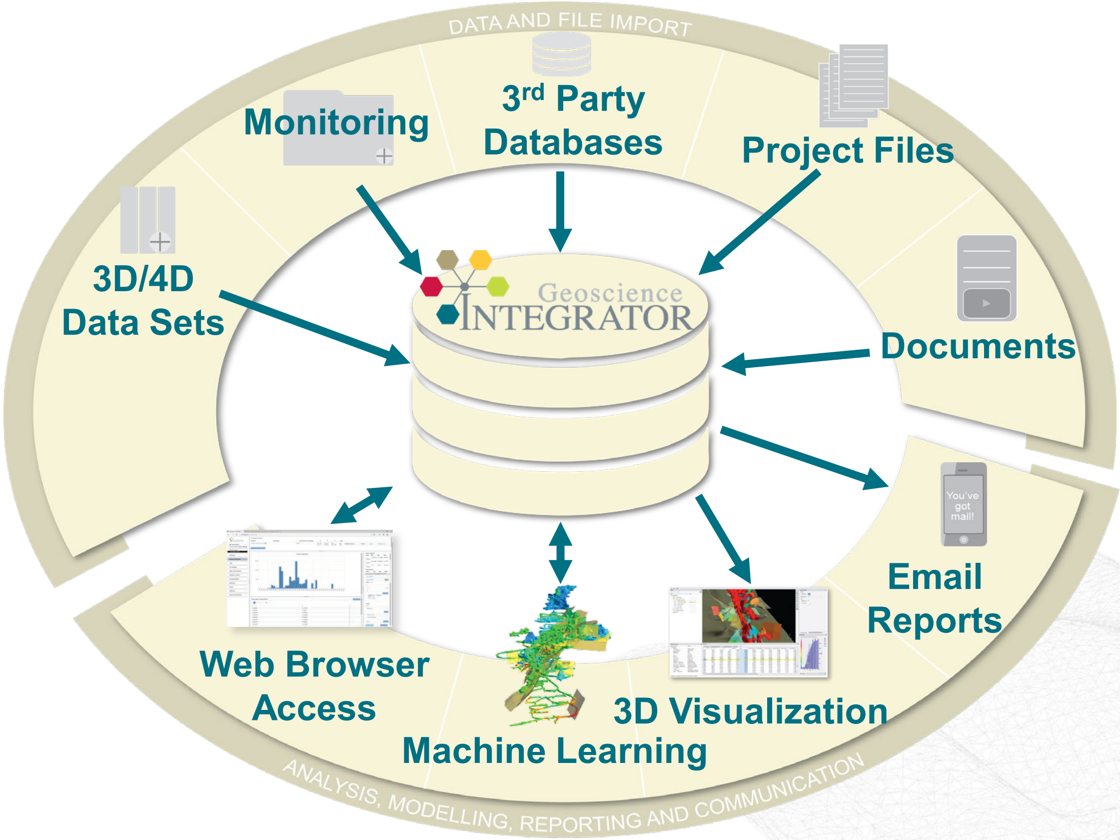
Geohazard probability model



Solution requirements

- take the focus off the methods of AI as a discipline unto itself and put the focus on how the geoscience problem is set up for AI
- this is where deep domain knowledge and a domain-specific, supporting computational framework is required

Geoscience INTEGRATOR



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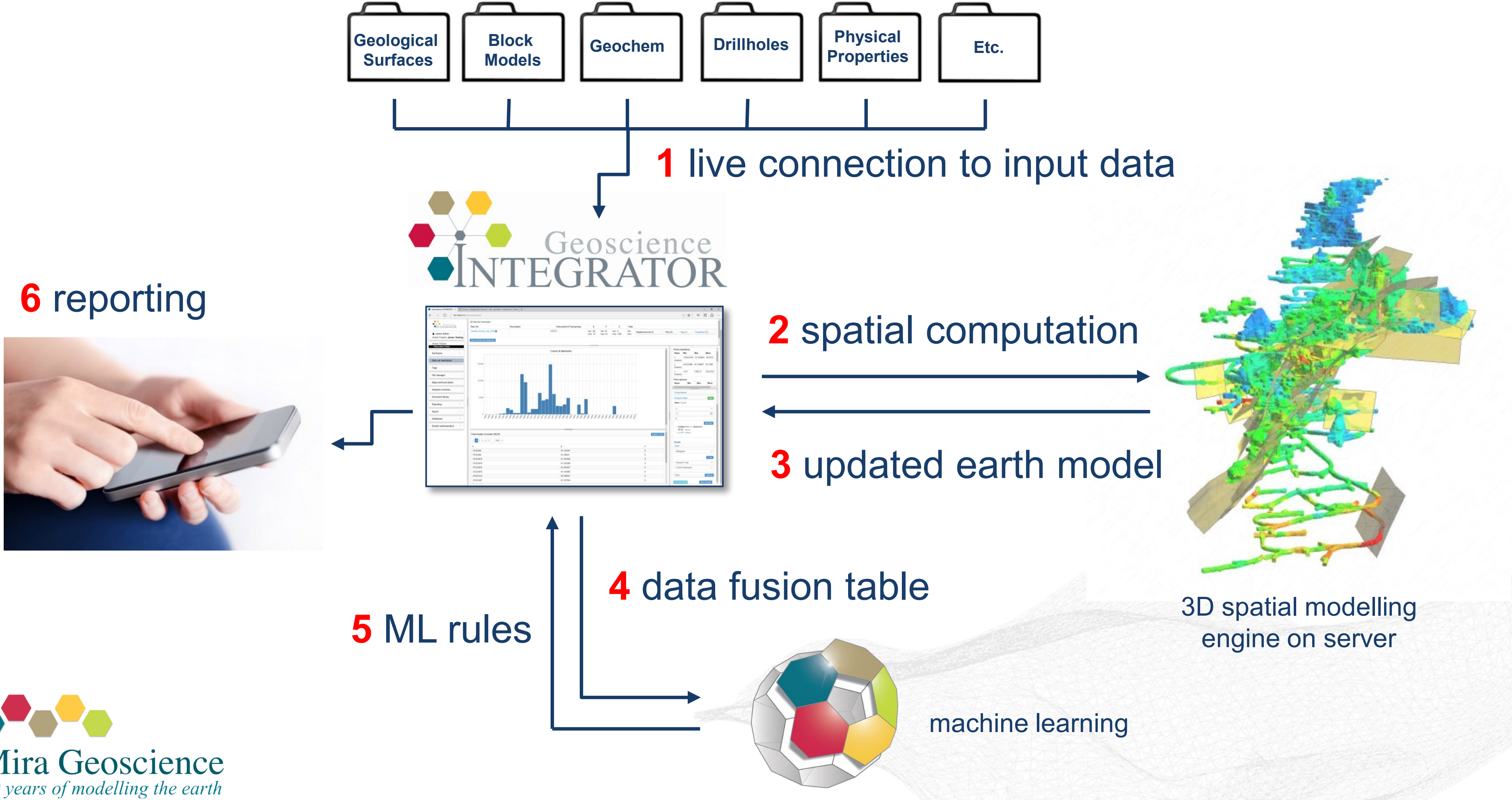

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Conclusion

target (x, y, z, t) = *f* (rock type, alteration, structure, chemistry, mineralogy, …)

- The targeting equation can be solved; practical application requires:
  - integrated multi-disciplinary 3D and 4D modelling
  - compilation of data and model into a “data fusion table”
  - connection to statistical and machine learning applications
  - integrated data management, model update, and analysis