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The use of Machine Learning in Exploration

From greenfield to near mine

Tom Carmichael + Datarock Team

Outline

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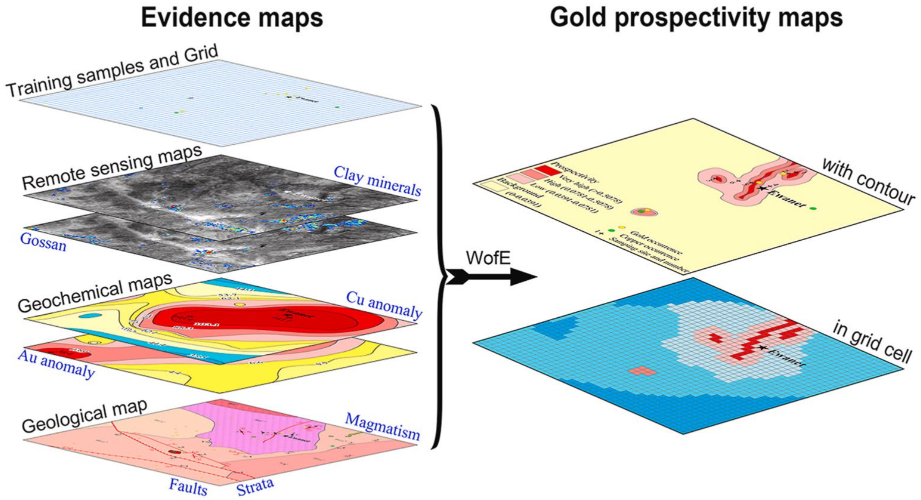
- Why Data Science and Machine Learning in Exploration?
- Where should we use ML (and maybe where we shouldn't use it)
- What can I do at the regional scale?
- What can I do at a camp scale?
- What can I do at a near-mine scale?
- *(How) can we move beyond the prospectivity map to provide concrete value in exploration and mining?*



WOE (weights of Evidence) diagram from Fu et al 2021

Beyond the prospectivity map: Tackling the growth challenges facing the mineral industry with the application of mineral systems - Nicole Januszczak, 2021.

Why Data Science and ML in Exploration?

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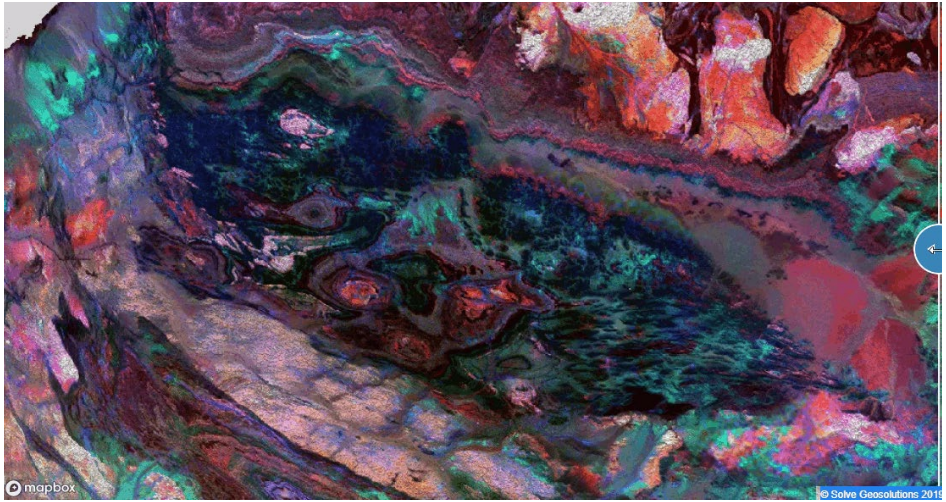
- We collect a *lot* of data as an industry.
- The value of this data isn't always realised with traditional methods of geological analysis.
- Understanding of where ML provides value can add new techniques to the Exploration geologists toolkit



Geological data that is suited for geological interpretation often needs to be manipulated to be more appropriate for ML purposes , particularly in the imagery space

Where should we use ML?

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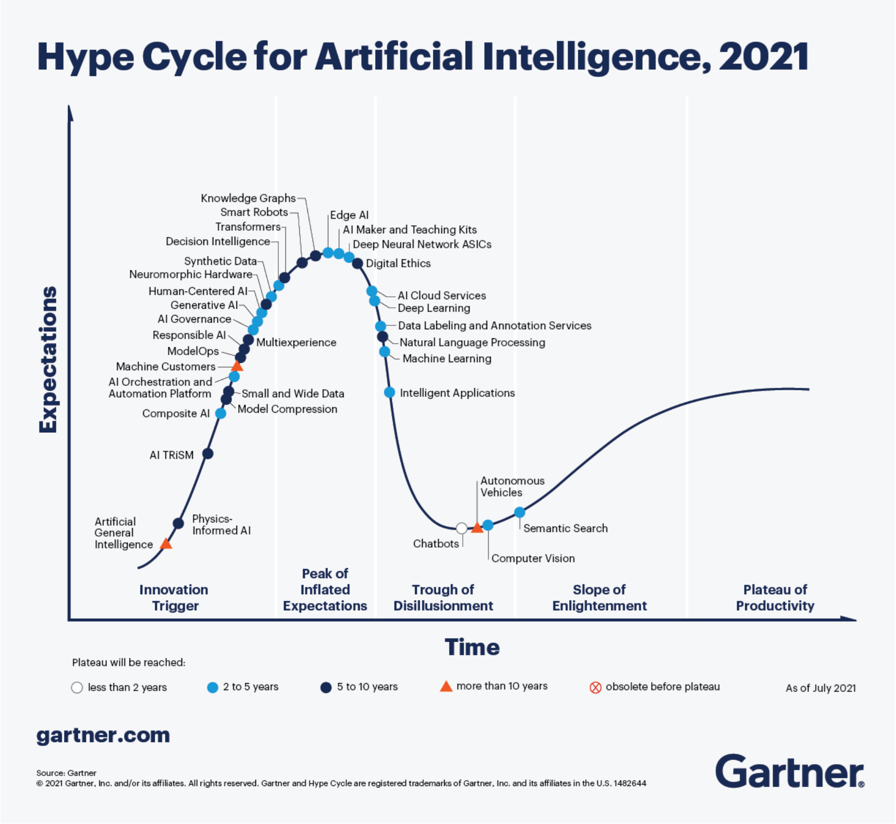
- ML (and all techniques!) aren't a silver bullet - and applying them where they're not appropriate harms both side of this work.
- *'When rules depend on too many factors and many of these rules overlap or need to be tuned very finely, it soon becomes difficult for a human to accurately code the rules. You can use ML to effectively solve this problem.'*



https://docs.aws.amazon.com/machine-learning/latest/dg/when-to-use-machine-learning.html

Different exploration phases - Different requirements

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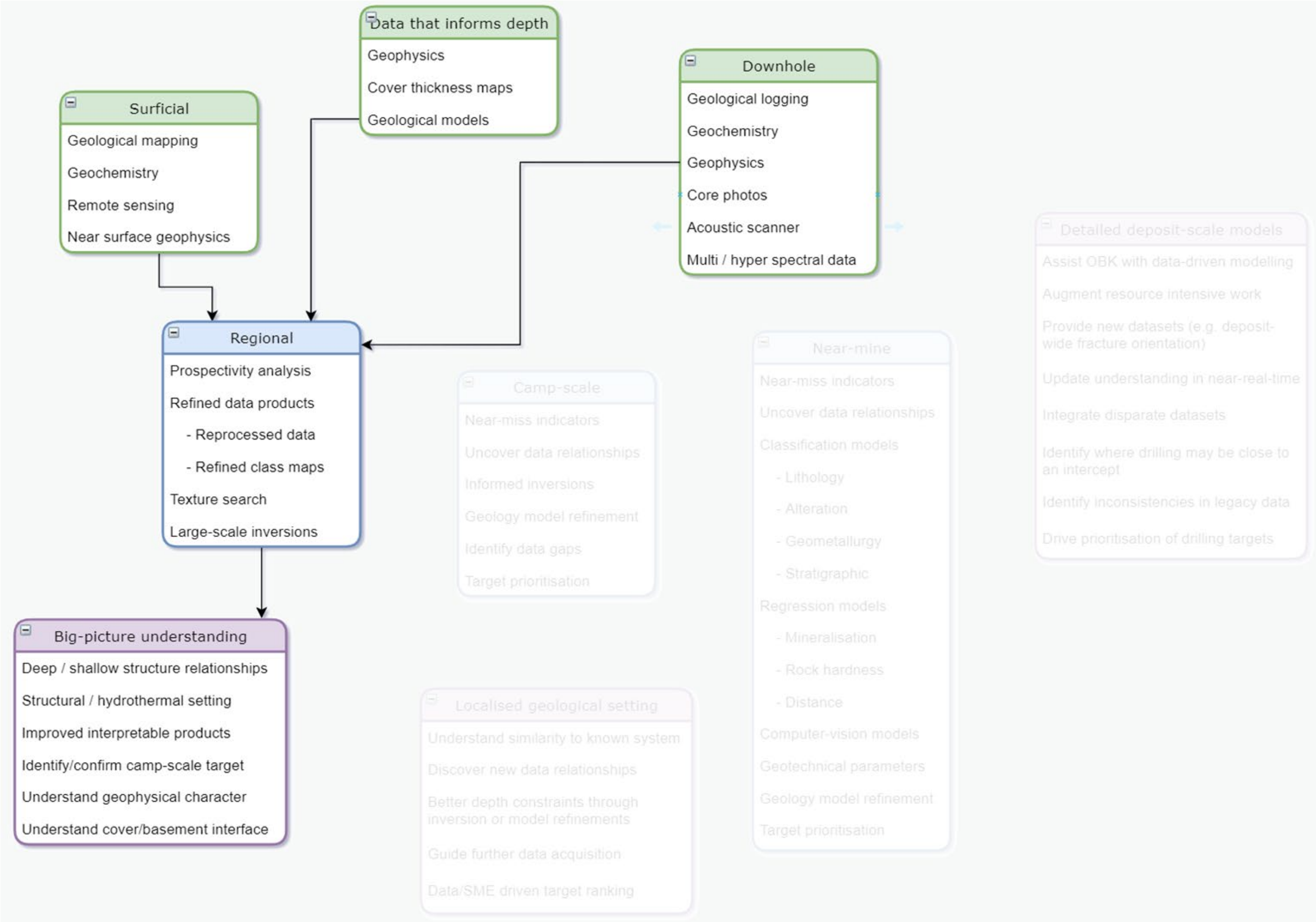

Greenfields Exploration

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- There are two broad approaches towards prospectivity - Knowledge Driven (*mineral Systems approach*) and Data Driven.
- A *minerals systems approach* works by combining theories of mineral formation are defined, then numerically and spatially quantified. (McCuaig et al 2010)
- The data driven approach maps a set of quantified features to known deposits and represents spatial areas relative to those known points
- Is a hybrid approach possible? (Januszczak 2021)

Processes	Sub processes	Mappable ingredient	Predictor maps
Fluids, Metals And ligands	Magmatic-hydrothermal fluids	Geochemistry of rocks	**Proximity and elemental map**
	Magmatic	The presence of iron-rich intrusive/ extrusive rocks	**Proximity of granitoid/ rhyolitoid rocks**
	Country rocks	The presence of iron-rich metal sedimentary rocks	**Proximity of limestone/ sedimentary rocks**
Energy	Intrusive-volcanic complex	The presence of iron-rich intrusive/extrusive rocks	**Proximity and airborne magnetic anomalies**
	Hydrostatic head for oxidised fluid	Geochemistry of felsic rocks	**Elemental map /**

Examples of geological process and predictor relevant to some prospectivity maps from Sadeghi 2019.

Regional Exploration

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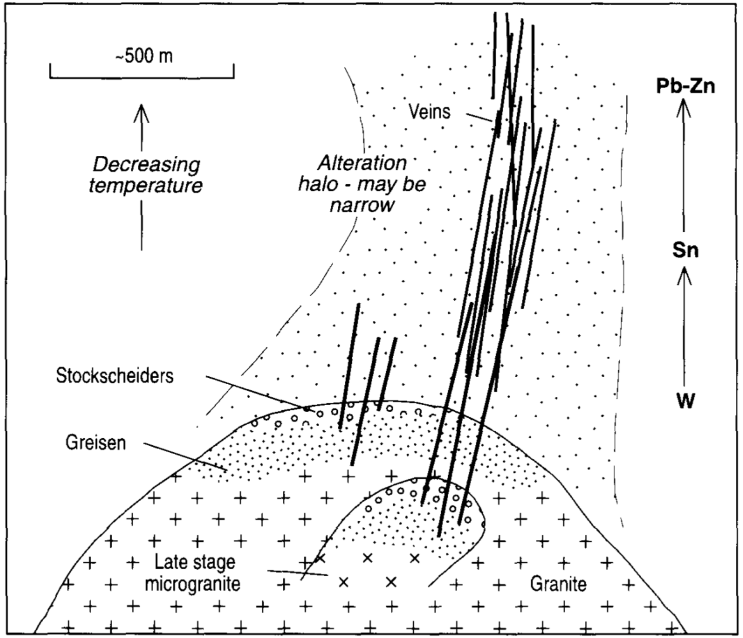
- Tin-tungsten deposits (in NW Tasmania) are typically associated with upper parts of evolved Devonian granite plutons where fluids from cooling granites have ponded and/or concentrated.
- Geophysical characteristics of the mineral system
  - Upper parts of low density granite bodies manifest as gravity lows
  - Low Fe-Ti oxide evolved granites tend to be magnetically 'quiet'
  - When exposed at surface, evolved prospective granites will give rise to strong radiometric responses due to high K, U and Th content



Source: [Blevin (1998)]

Regional Exploration

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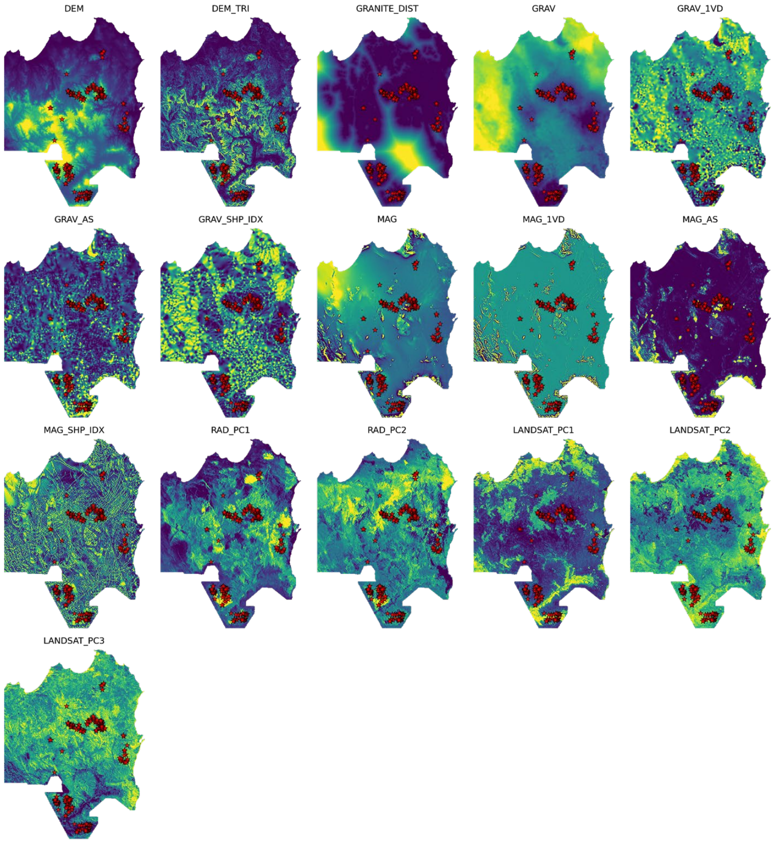

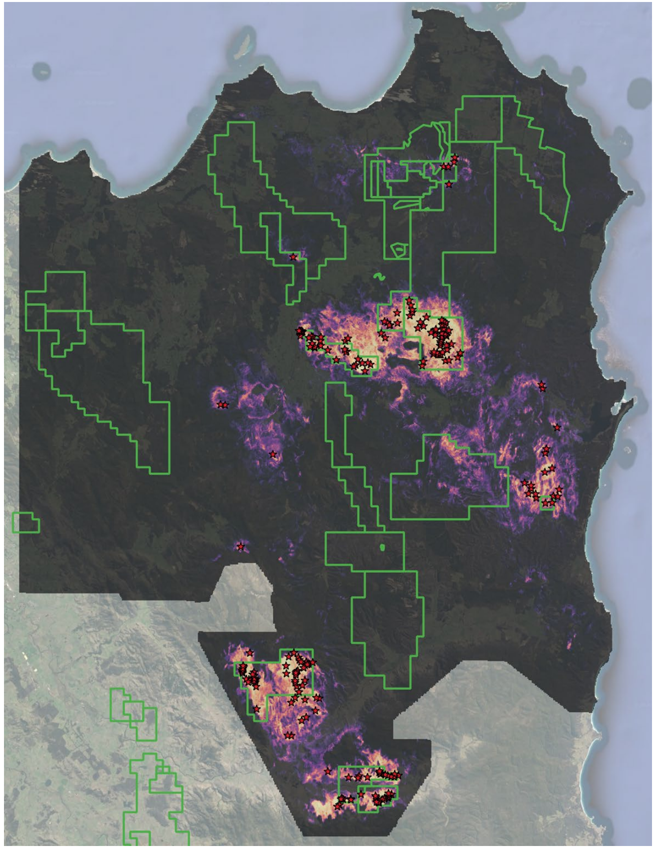

Greenfields Exploration

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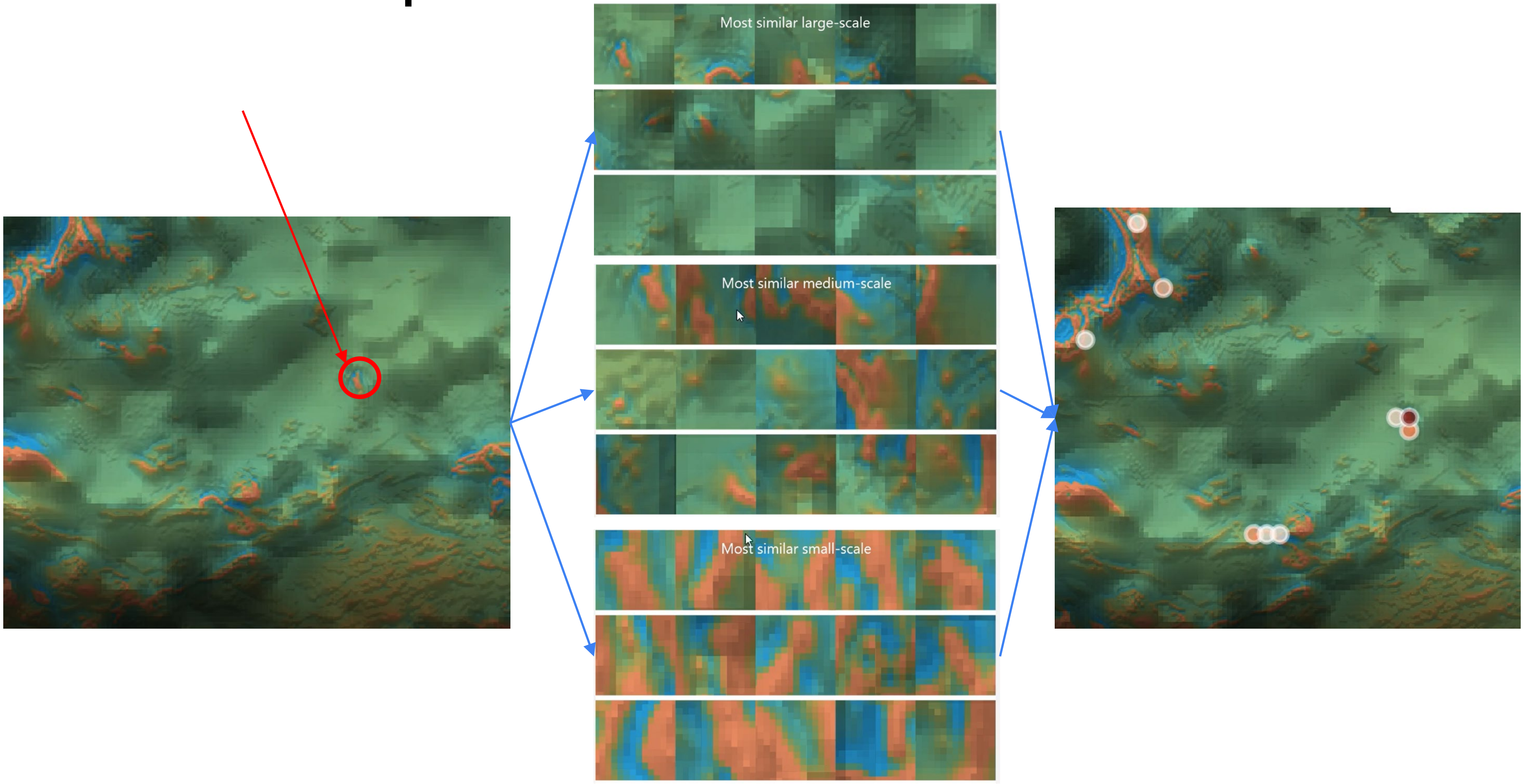

Different exploration phases - Different requirements

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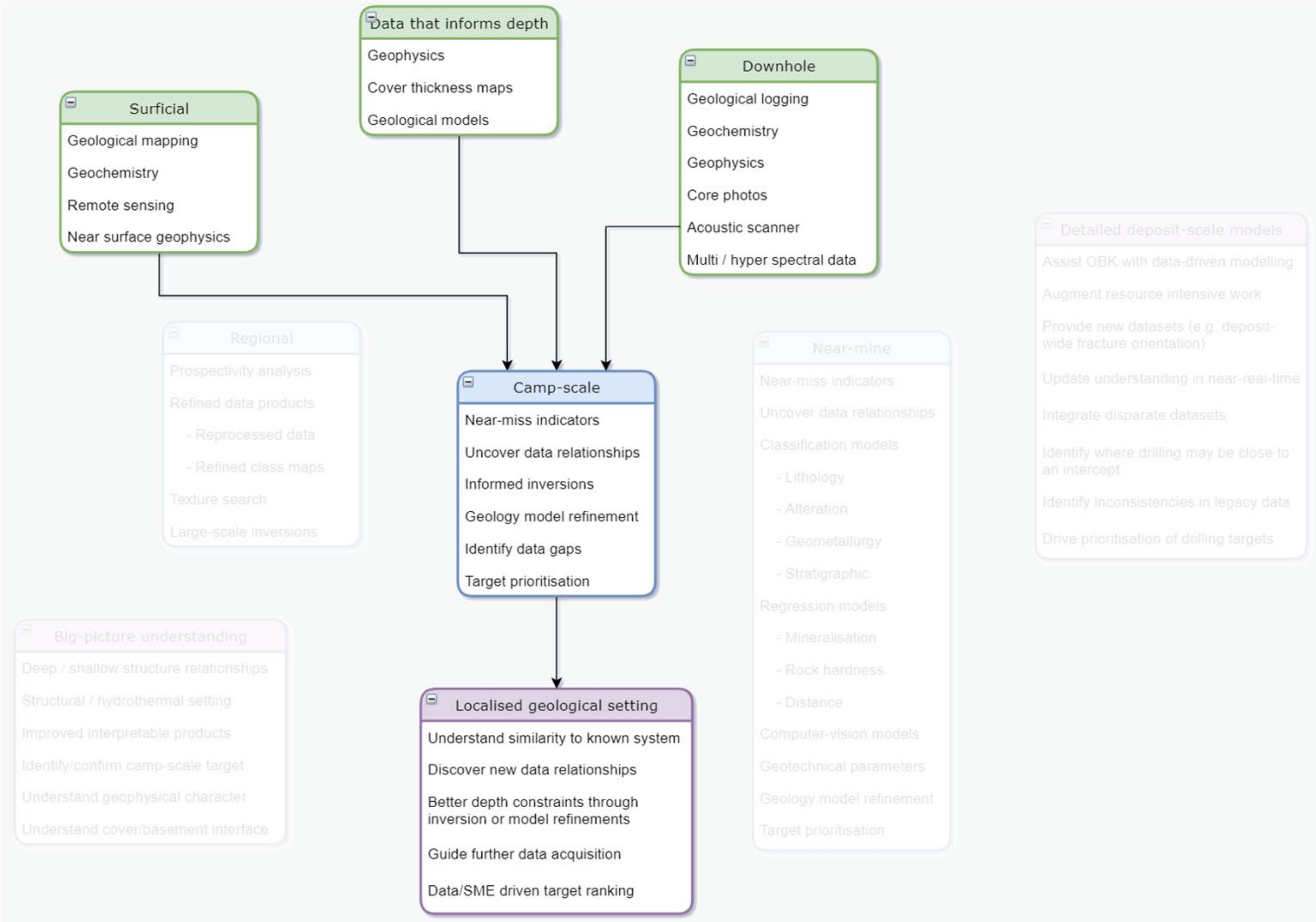

Camp Scale Exploration

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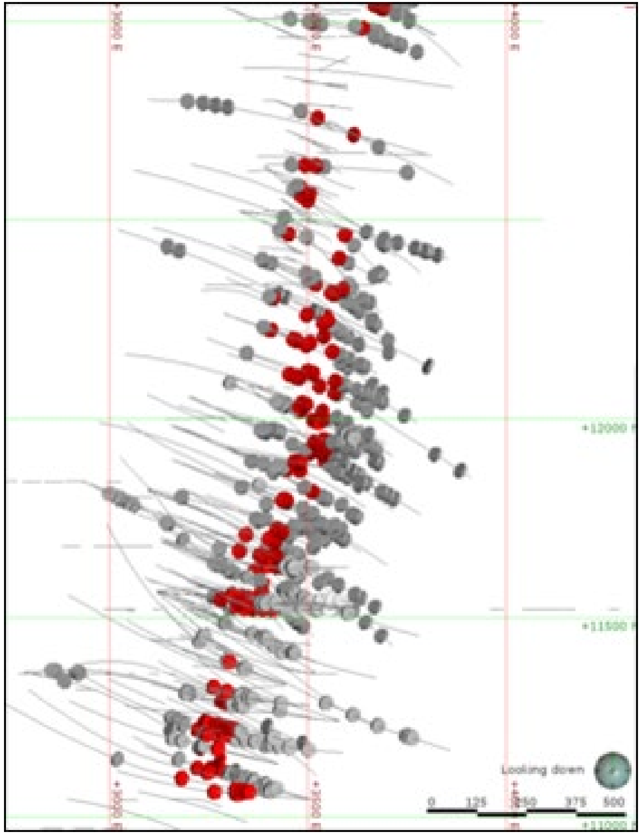
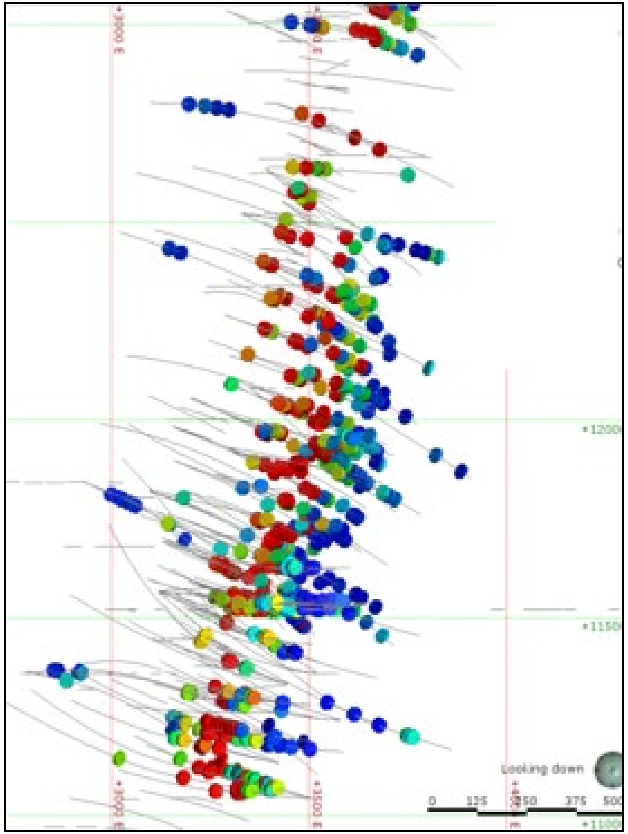


Classification of ore bearing unit



Probability of ore bearing unit

Camp Scale Exploration

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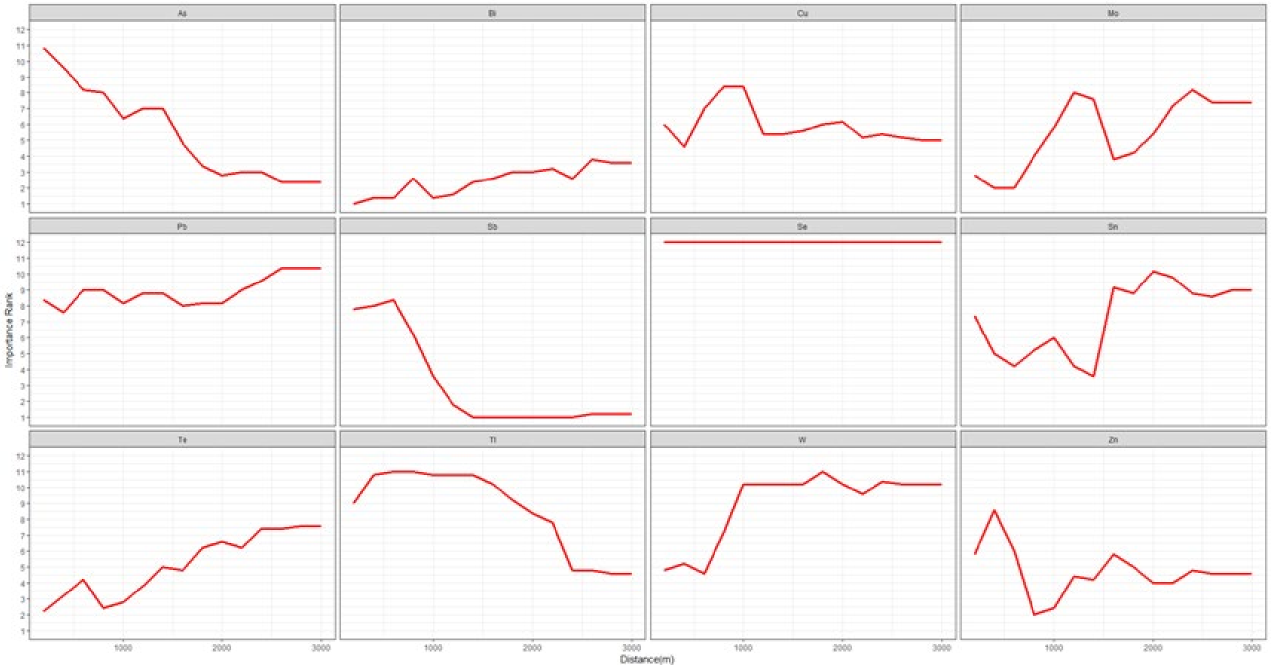

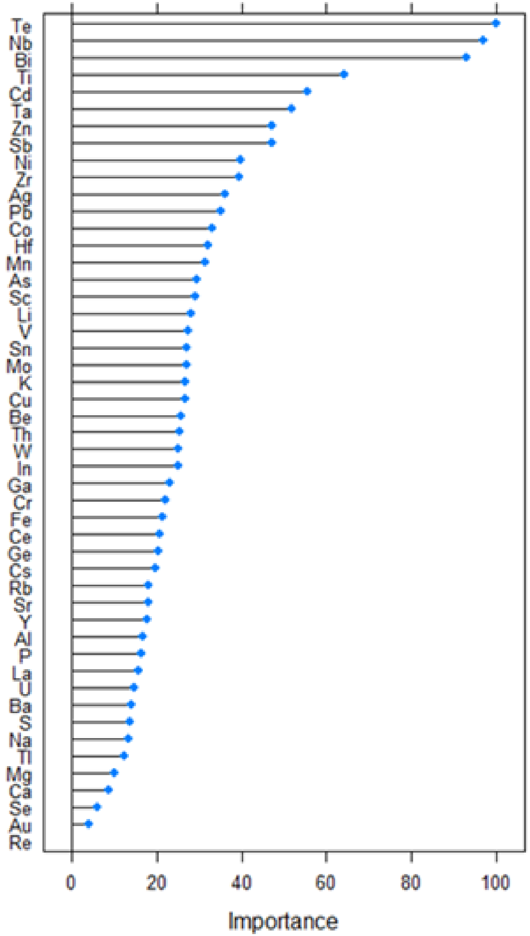

Different exploration phases - Different requirements

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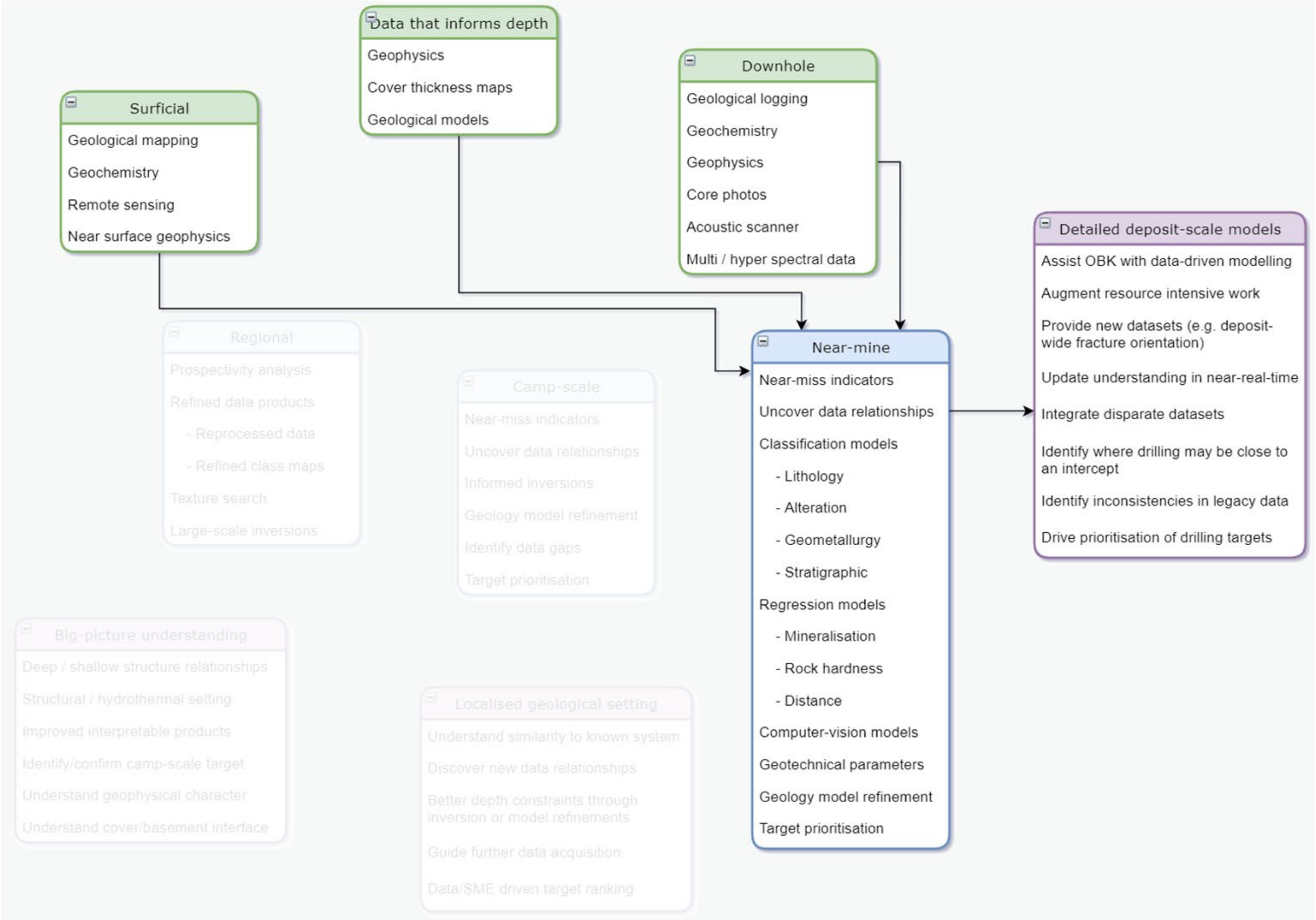

Near Mine Exploration

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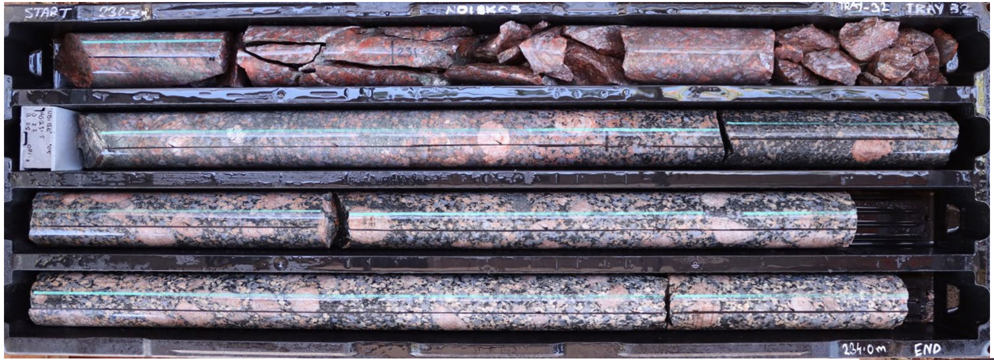
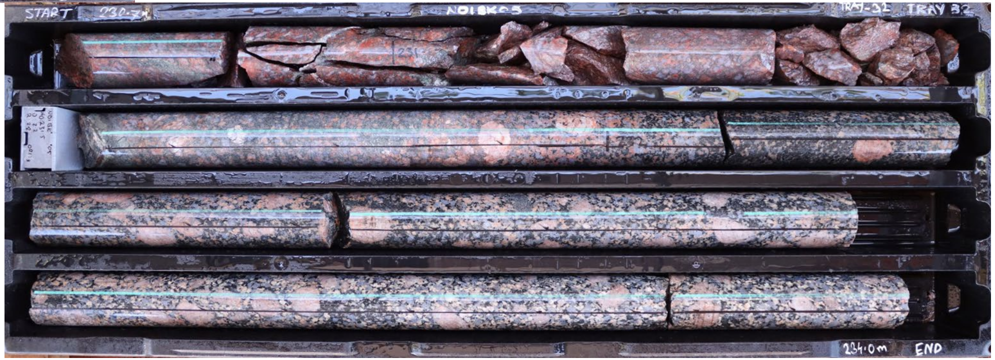
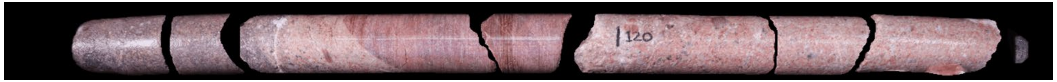
- Photo dewarping + identifying corebox location + masking
- Identify + mask the sections of the corebox that don't contain core.
- Identify + mask the section of the corebox that has coherent core.
- Identify + mask the section of the corebox that has *in*coherent core.







- Use OCR to identify writing on the core and use this in an intelligent way to determine the depth on the core.
- Depth register the image.
- Export + post process the required dataset (remove artefacts from writing, poor lighting in coresheds, etc)

Near Mine Exploration

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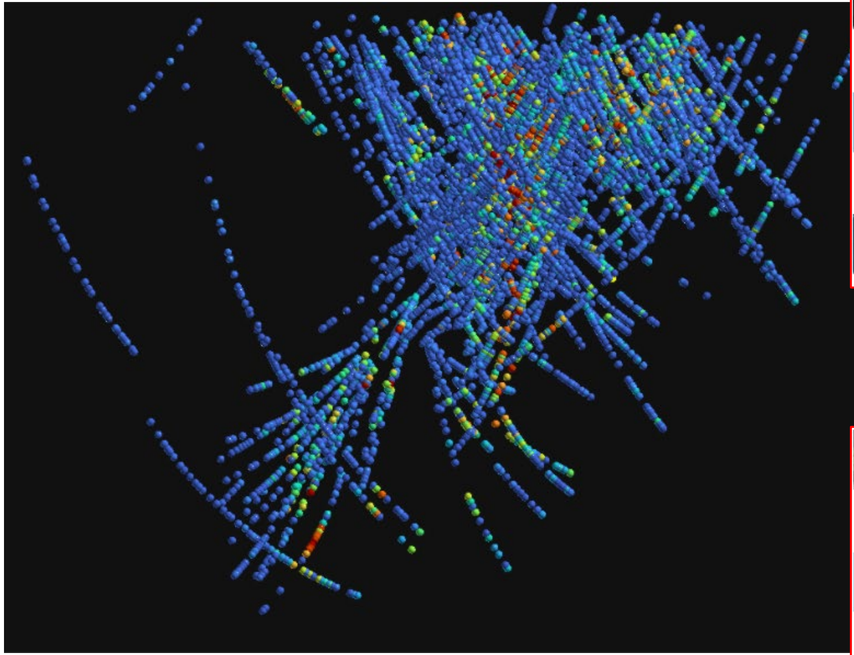

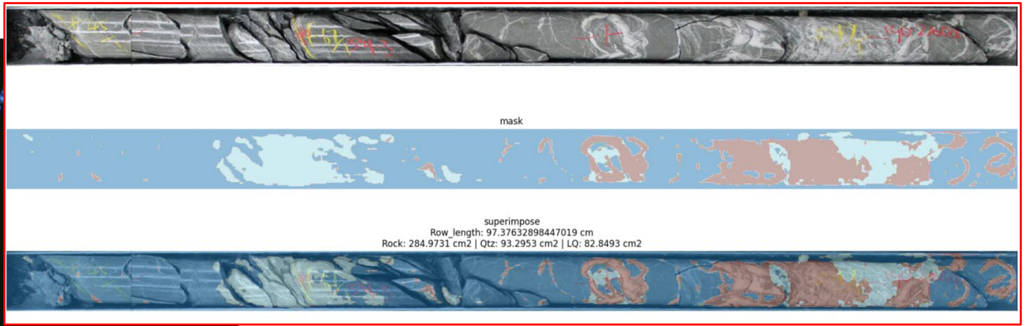

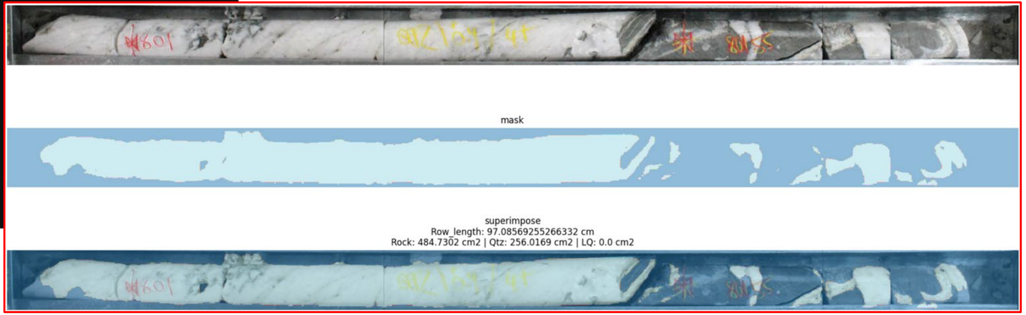

Vein area per metre

Near Mine Exploration

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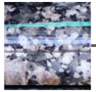

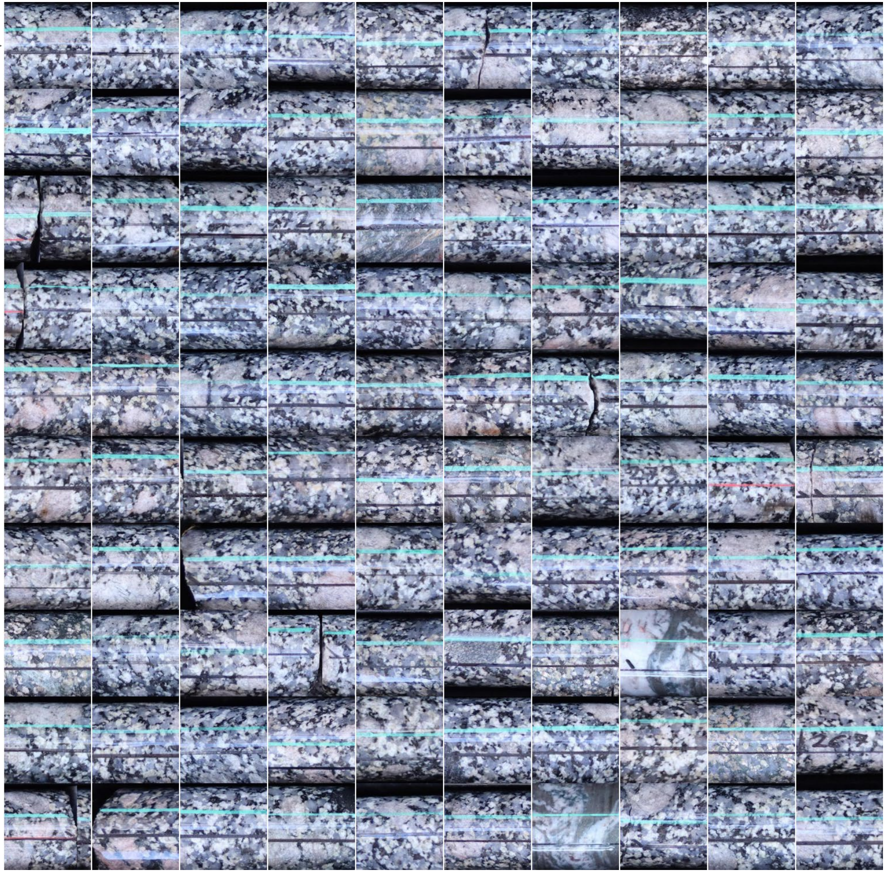

- Textural characteristics can be difficult to identify easily due to the vast amount of data available.
- Finding one or two examples can be easy (?) - then use ML to identify potential candidates of that texture in the remainder of the available dataset.

Near Mine Exploration

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Data driven domains