Application of Machine Learning to Resource Modelling of a Marble Quarry with DomainMCF

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GREEK MARBLE INDUSTRY

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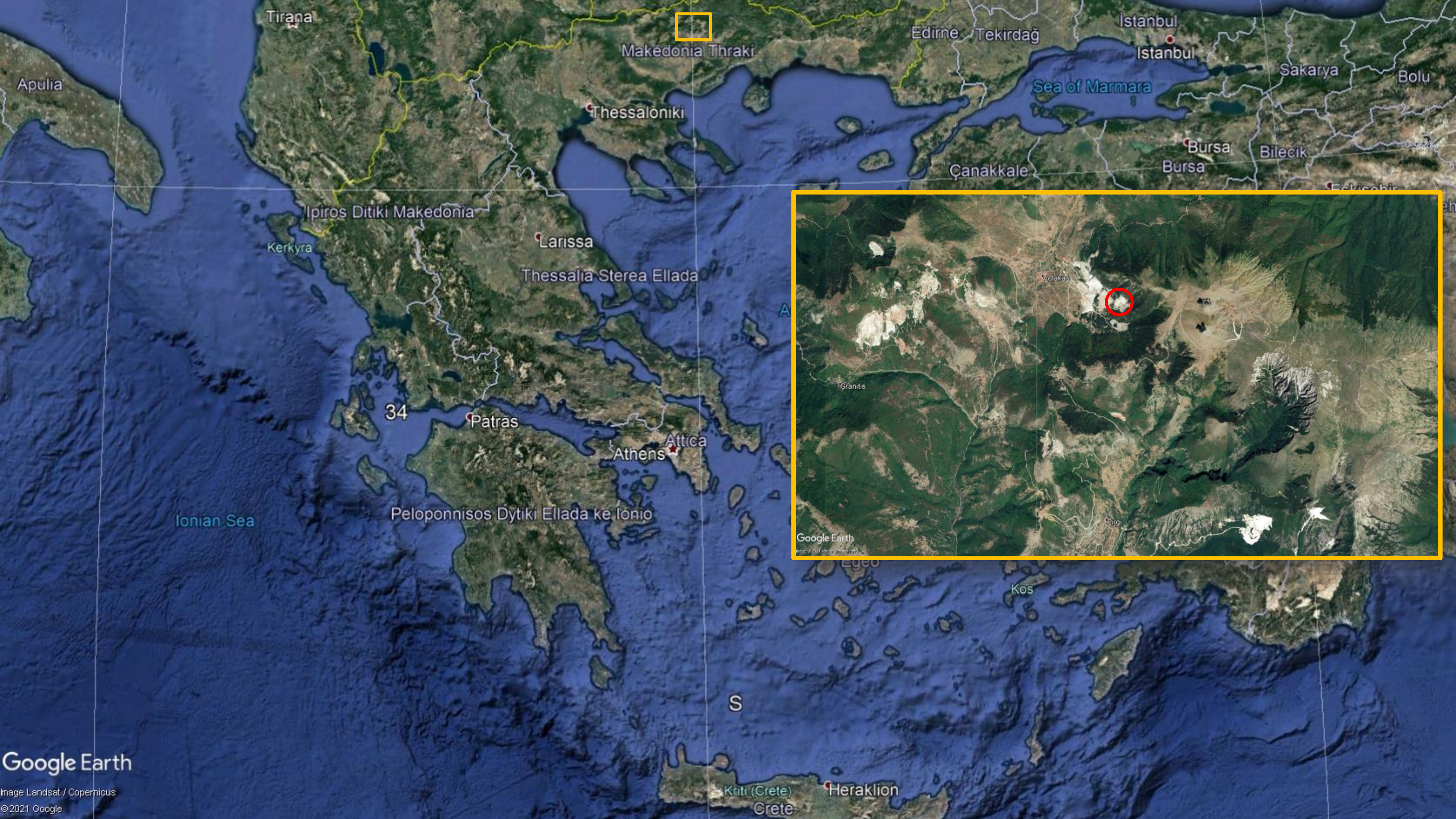
About this presentation

> Marble quality classification - description of the modelling problem
> Conventional classification method using inverse distance interpolation
> Some words on machine learning and artificial neural networks
> Application of DomainMCF to marble quality classification
> Conclusions

The Case of the Iktinos Hellas Volakas Quarry

- Iktinos Hellas SA has various marble quarries, mostly located in the Eastern Macedonia & Thrace area in NE Greece.
- The Volakas quarry is located NW of the city of Drama.
- Mount Volakas hosts a number of marble quarries.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Marble Quality Parameters

In the case of the Volakas marble, the following parameters were identified and used to characterise the marble features that are significant to its quality classification:

- Lithology (dolomitic or calcite)
- Type (flower-like or diagonal-vein features)
- Background (presence of visible defects)
- Tectonic features

Marble Type – Main Categories

Type L – flower like features

Type D – diagonal features

There are 4 more categories of marble type

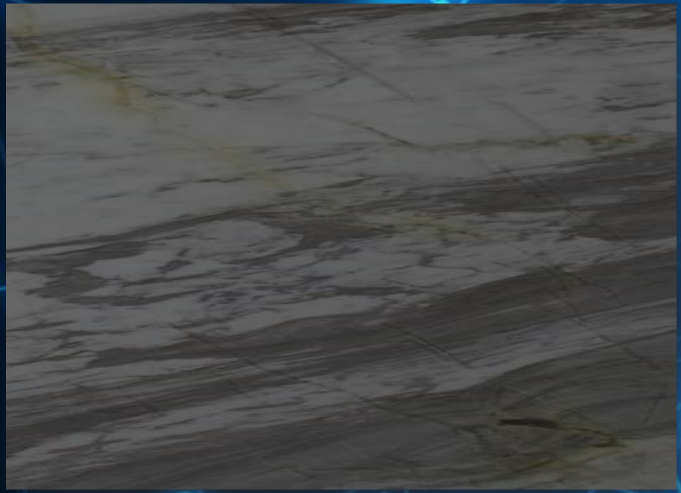
Marble Background

Background 1: White background with homogenously distributed thin veins or flowers with no presence of calcite crystals and steins (yellow or red lines)

Background 2: Slightly darker background with veins or flowers of varying thickness with some calcite crystals (glass)

Background 3: Dark background with veins or flowers of varying thickness and many calcite crystals (glass) and steins (yellow or red lines)

Background 4: Very dark background with veins or flowers of varying thickness with dense calcite crystals (glass) and steins (yellow or red lines)



Marble Tectonism

The presence of discontinuities in marble mass is measured in different orientations, leads to four parameters called TECTO1, 2, 3, 4.

Parameter	TECTO1	TECTO2	TECTO3	TECTO4
Dip direction/dip	40/40	210/70	320/55	20/80

Parameter value	1	2	3	4
Discontinuities	0	1	2	3 or more

Conventional Method of Classification

- As the available information is categorical, conventional estimation methods include the use of indicator kriging or some other interpolator of indicator values.
- Iktinos Hellas has been using Maptek Vulcan Quarry Modeller since 2014 and has implemented a methodology based on inverse distance interpolation of indicator values for the various marble parameters.
- In this process, each of the marble parameter values is associated with an indicator field that can be either 0 or 1, depending on whether the sample is classified to have the particular parameter value, e.g. if a sample is considered to be TYPE L, then the field L_PR = 1 and field D_PR = 0.

Conventional Classification Method – Final Marble Quality Classification

- Interpolation of marble parameter indicator field values is normally performed using the inverse distance squared method as implemented by Maptek Vulcan Quarry Modeller software on the basis of a block model.
- The estimated volume is divided in blocks of the same size.
- Block dimensions are configured based on the marble volumes that are extracted separately at the given quarry.
- Samples are selected around each block using search ellipsoids which are oriented according to the geological features of the particular deposit.
- Each block receives a final marble classification by consolidating the interpolated indicator field values using a block model script.

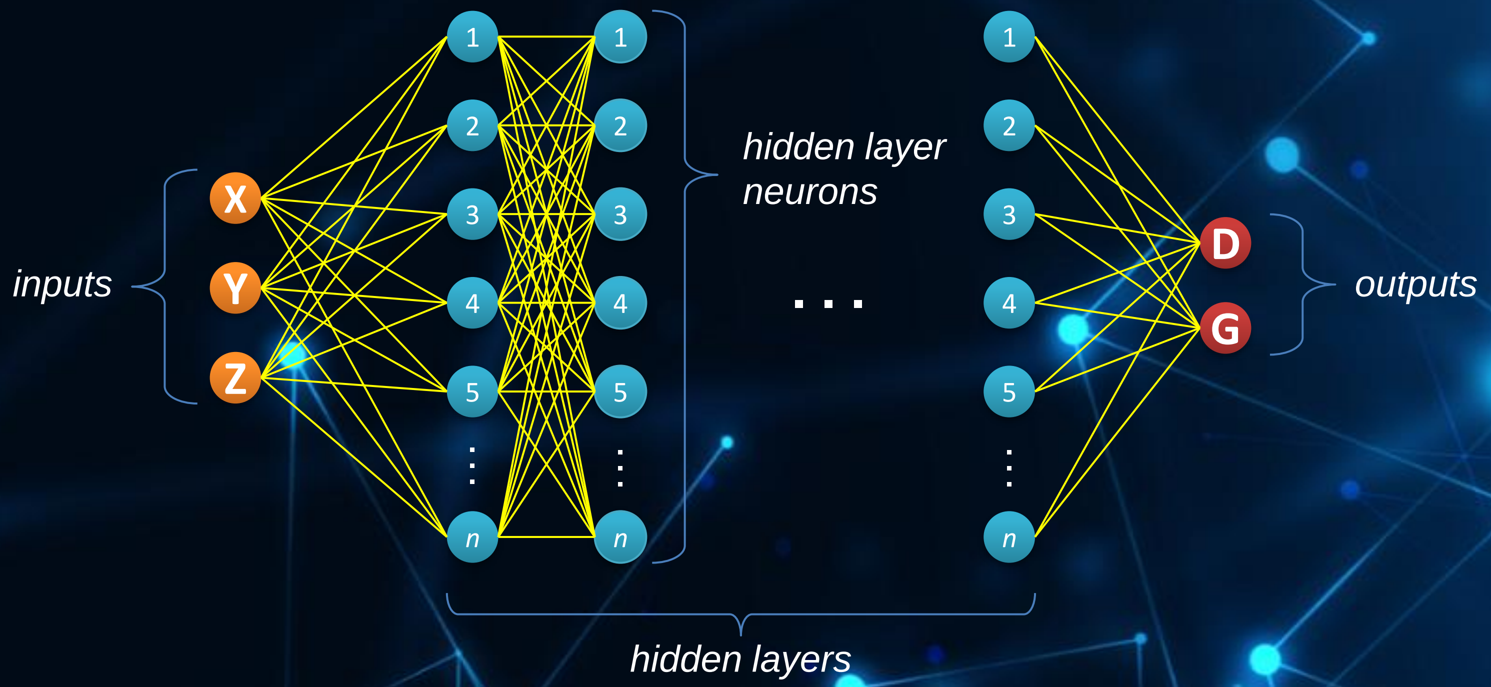
DomainMCF

> DomainMCF, a machine learning based system developed by Maptek, was used to model the spatial distribution of marble quality characterisation parameters, and the resulting values were combined to produce a final marble quality classification.

> DomainMCF was made available as a cloud processing service through an early access program for individuals or companies who are interested in testing its capabilities and suitability in various modelling scenarios and geological settings.

> DomainMCF is based on artificial neural network (ANN) technology to model the spatial distribution of discrete domain values from a set of samples.

Architecture of an Artificial Neural Network used for Domain Modelling



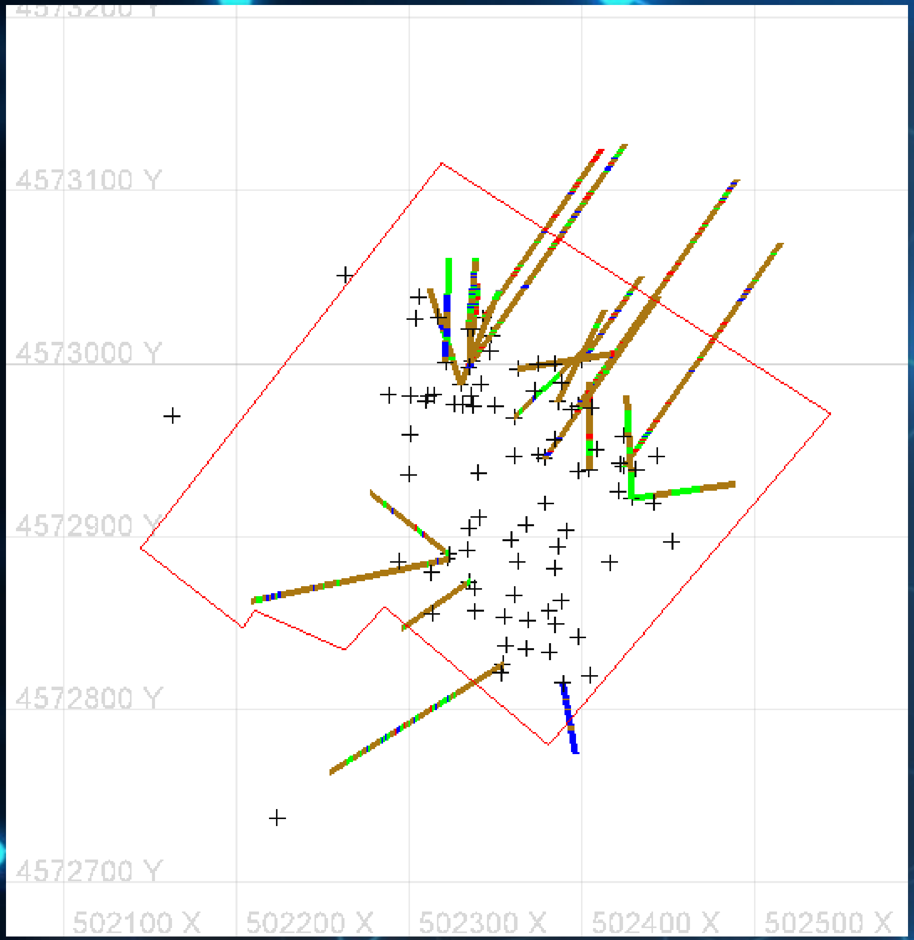
Data Requirements and Related Issues

- ANN development is data driven and thus largely dependent on the quantity of data.
- In the case of domain modelling, more samples will be required to produce a representative model in a more geologically complex scenario.
- A more complex ANN architecture with more PEs and hidden layers, allows a more complicated model to be generated (through development) but also requires more data.
- After development, the ANN can be used to get output values for any set of X, Y, Z coordinates presented at its input layer (e.g. block centroid coordinates), even outside of the sample coordinates range.
- However, outputs produced in areas outside of the range of examples introduced to the ANN during development, should be treated with caution and examined carefully as to their validity, as in any case of extrapolation by more conventional methods.

Case Study Data

> The quarry data used in this study consists of 95 drillholes and quarry face analyses, giving a total of 3570 1m samples.

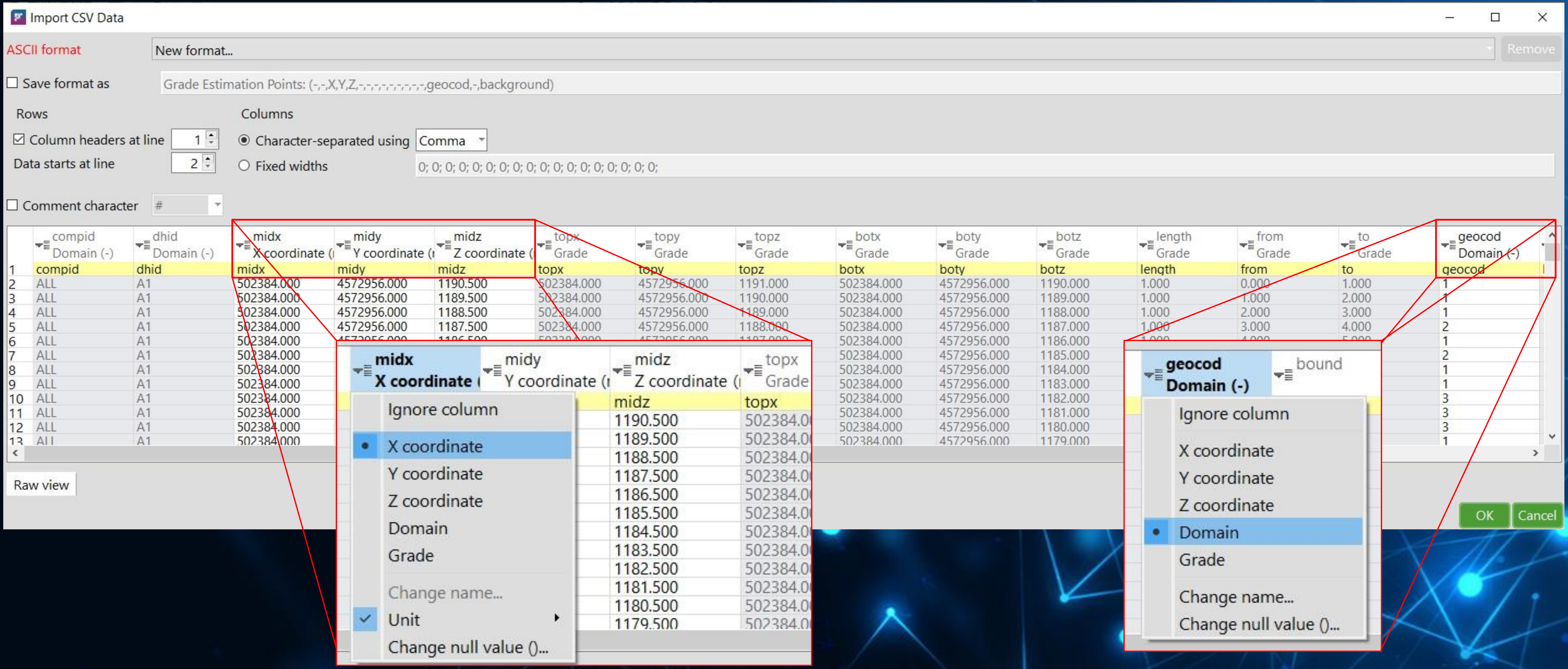
> Most of the drillholes are vertical, but some are horizontal and intersect areas where underground quarrying is carried out or operations are planned for the near future.



Selection of Inputs and Outputs

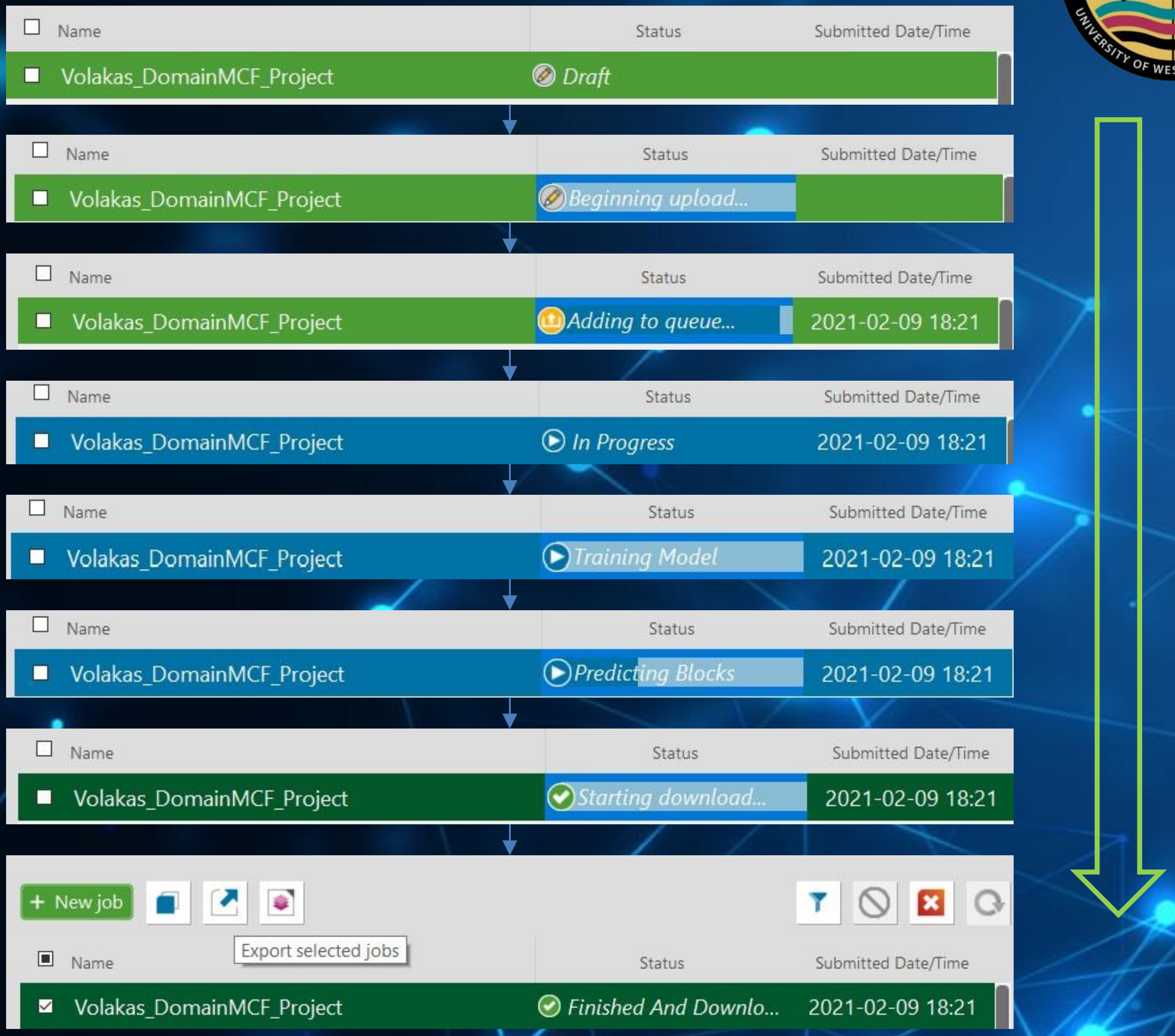
> For each CSV file containing the training samples, the network inputs and output fields were selected.

> DomainMCF would be trained to map the input values to the corresponding output(s).

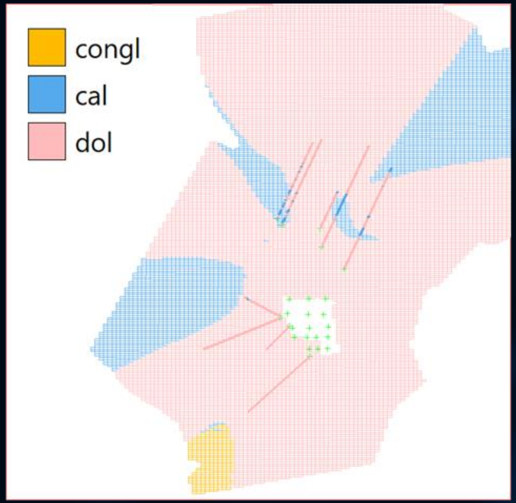


Running DomainMCF

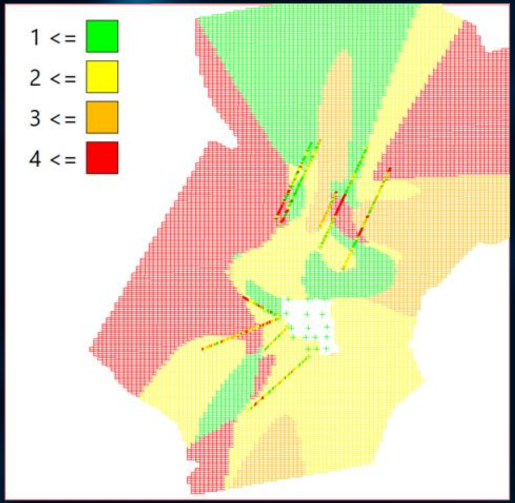
- Once the setup was complete, DomainMCF was run.
- Running included uploading of the data, training using the sample data, application on the block model, and downloading of the block model.
- As the data and block model were limited (3570 samples and 2 million blocks), the whole process took less than 2 minutes for each run.
- The predicted values from the produced block models were exported and imported to a single block model that also contained classifications from the conventional system.



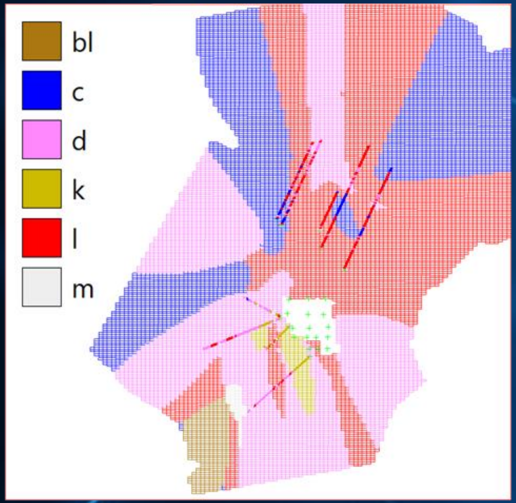
DomainMCF Marble Parameters Predictions



LITHO



BACKGROUND



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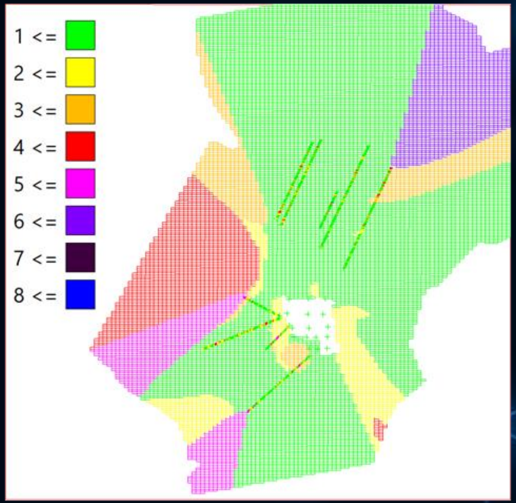
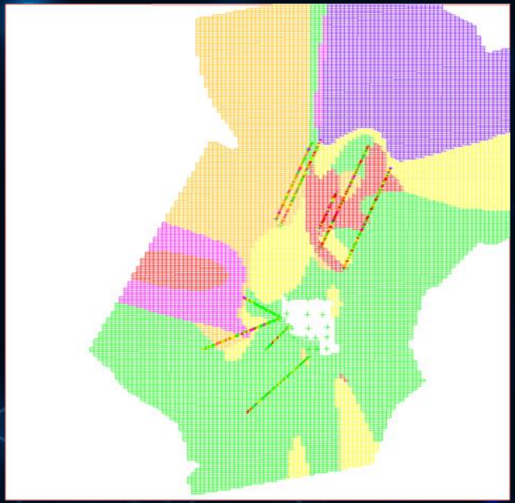
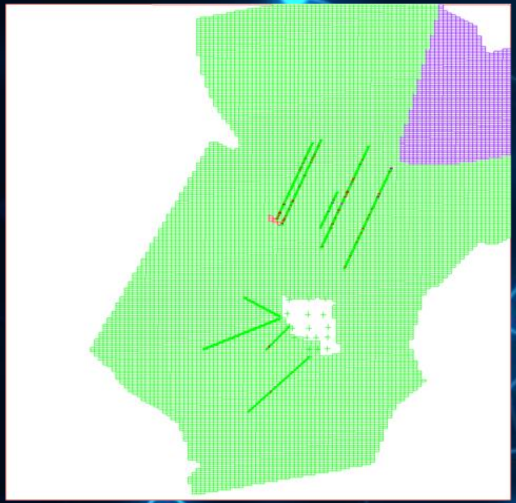


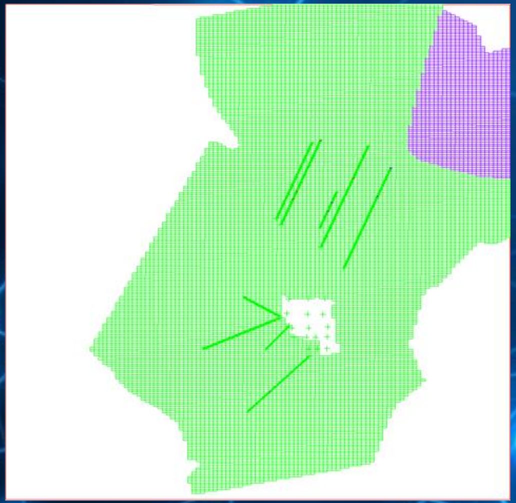
TECTO1



TECTO2



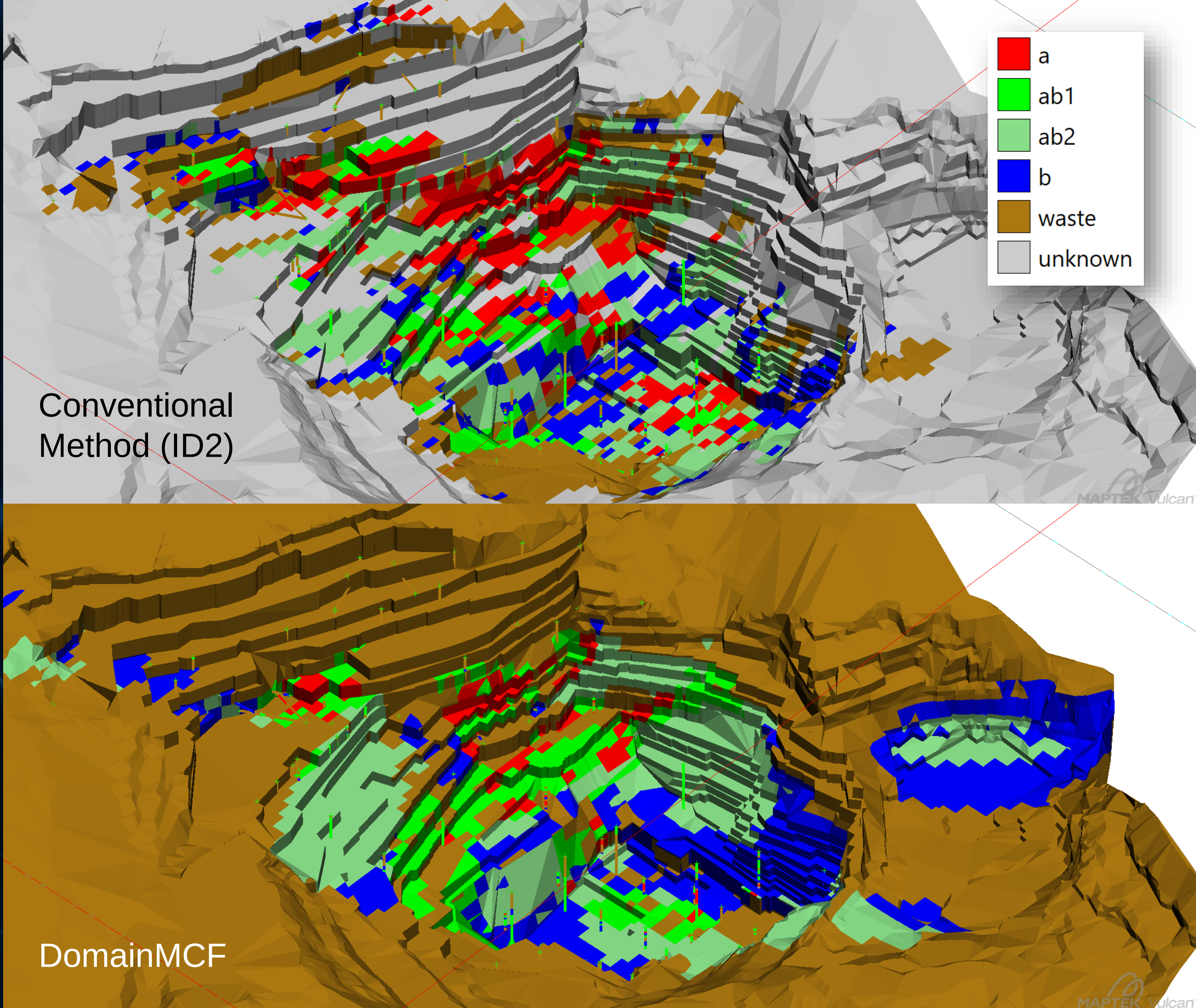
TECTO3



TECTO4

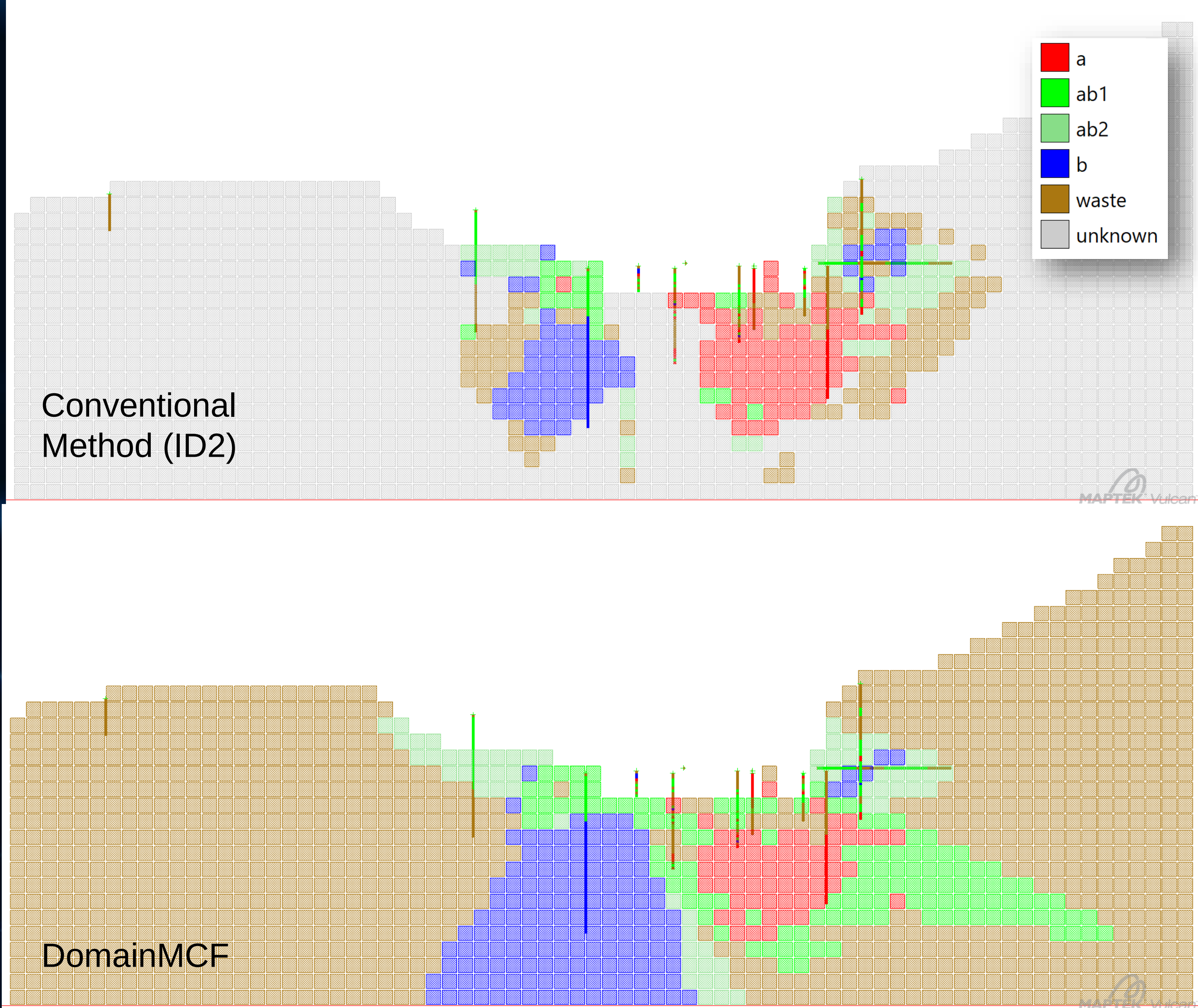
Comparison of Final Marble Quality Classifications

- A final marble quality classification was produced using the predicted marble parameters from DomainMCF and the same script used in the conventional method.
- DomainMCF classifications appear more uniform than those of the conventional method.



Comparison of Final Marble Quality Classifications

The conventional method classifications were limited by search ellipsoids and minimum sample limits and so the comparison was focused only in blocks that were predicted by both methods.

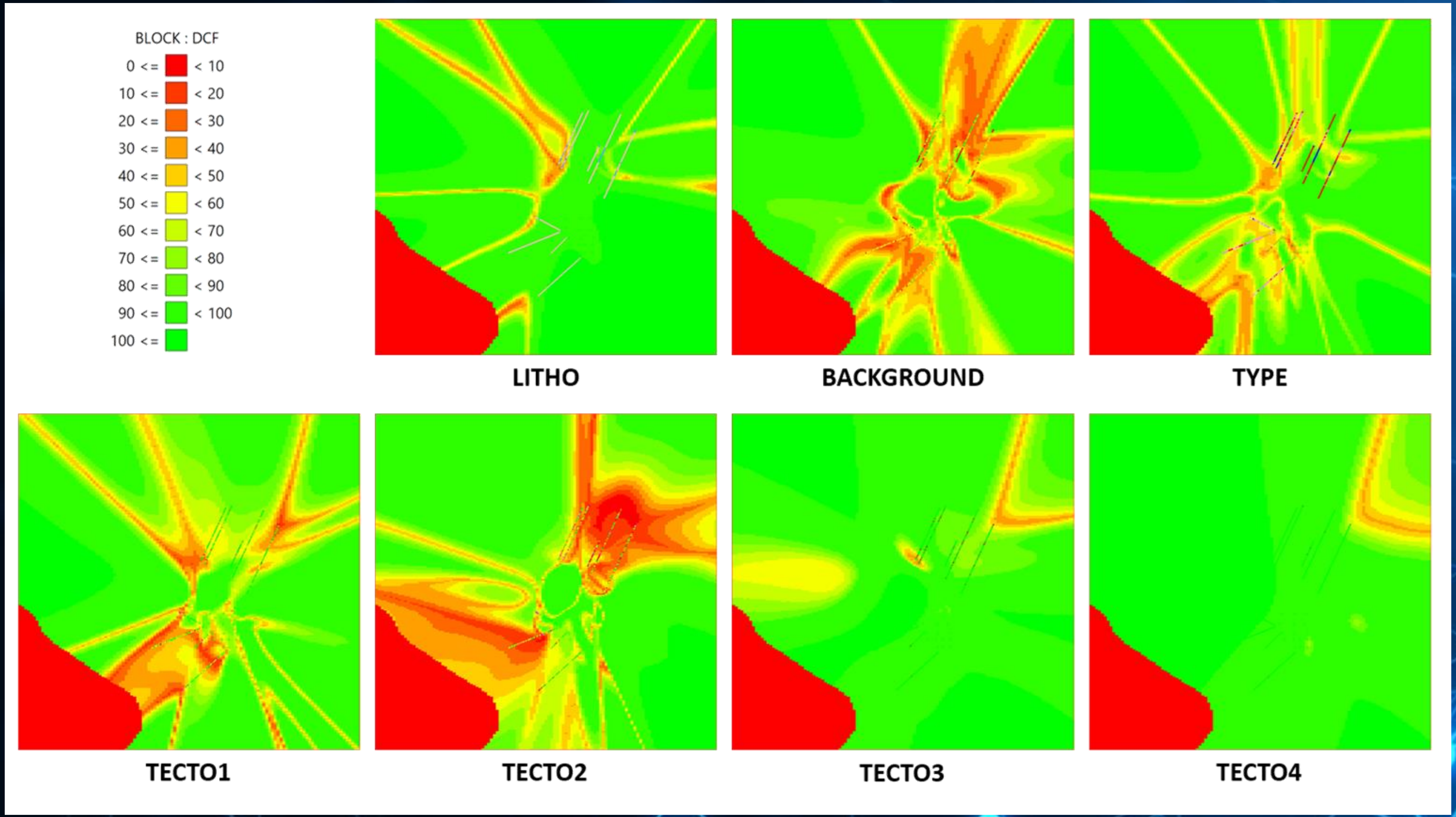


DomainMCF Confidence Levels

- In addition to the required outputs (domain, grade) in each of the block centroids presented to it, DomainMCF also produces a domain confidence value
- This is calculated during ANN development and gives some measure of the system's certainty on the produced domain value at each location.
- Domain confidence can be used to identify areas where it is more difficult to be certain about the predicted domain value, for example, areas where more sampling is required, or existing samples have higher local variability.
- As any other estimation or classification system, it is necessary to have tools to measure the local confidence of the results.

DomainMCF Confidence Levels

Horizontal section of DomainMCF confidence levels for each of the modelled marble parameters



Conclusions

DomainMCF Advantages

- Extremely quick way to produce marble classifications based on drillhole and other data.
- Produces more uniform marble classifications that are more reasonably distributed.
- Requires no structural analysis of the categorical parameters.
- Sampling pattern has no effect on the difficulty of the process.
- Reads from and writes to standard Vulcan file formats.

Future Work

- Ability to use anisotropy in predicting different marble parameters.
- Better understanding of confidence level values produced and how they can be associated to resource categories.
- More testing to investigate the influence of the grade field (when included as output) to domain predictions and vice versa.

Thank you for your attention