



Locating Volcanic Facies To Find Critical Minerals Through The Lens of Seismic Attributes and Machine Learning



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Introduction

Critical minerals (CM) such as Cobalt, Nickel, Copper play a pivotal role in sustainable resource development. Volcanic facies (VF) are one of the epicenters of CM exploration where CM accumulate and scatter due to hydrothermal processes. Seismic attributes provide a powerful tool for identifying VF by enhancing the interpretation of subsurface features. In this study seismic attributes were used to study an area in Otway basin in south Australia. Six (6) attributes were selected as the most successful in locating VF. The results were used to create machine learning (ML) models. Self Organizing Maps (SOM) , Independent Component Analysis (ICA), and Probabilistic Neural Networks (PNN) were developed. Results show that the SOM method is more helpful in discretizing between sills and lava. ICA and SOM resolved dykes and PNN managed to map VFs such as laccoliths and batholiths.

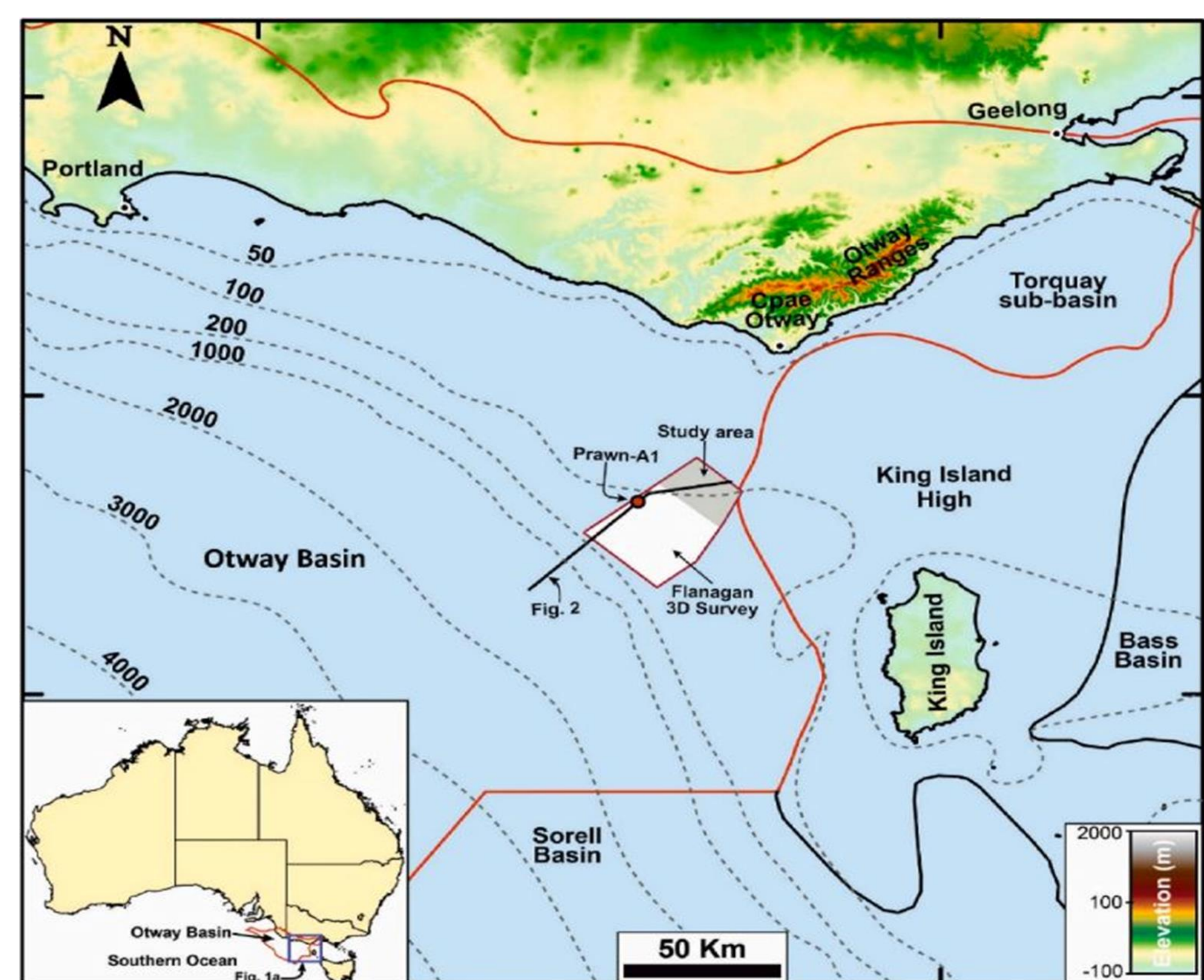


Figure 1- The Study Area, Flanagan survey south of Australian coast

Workflow

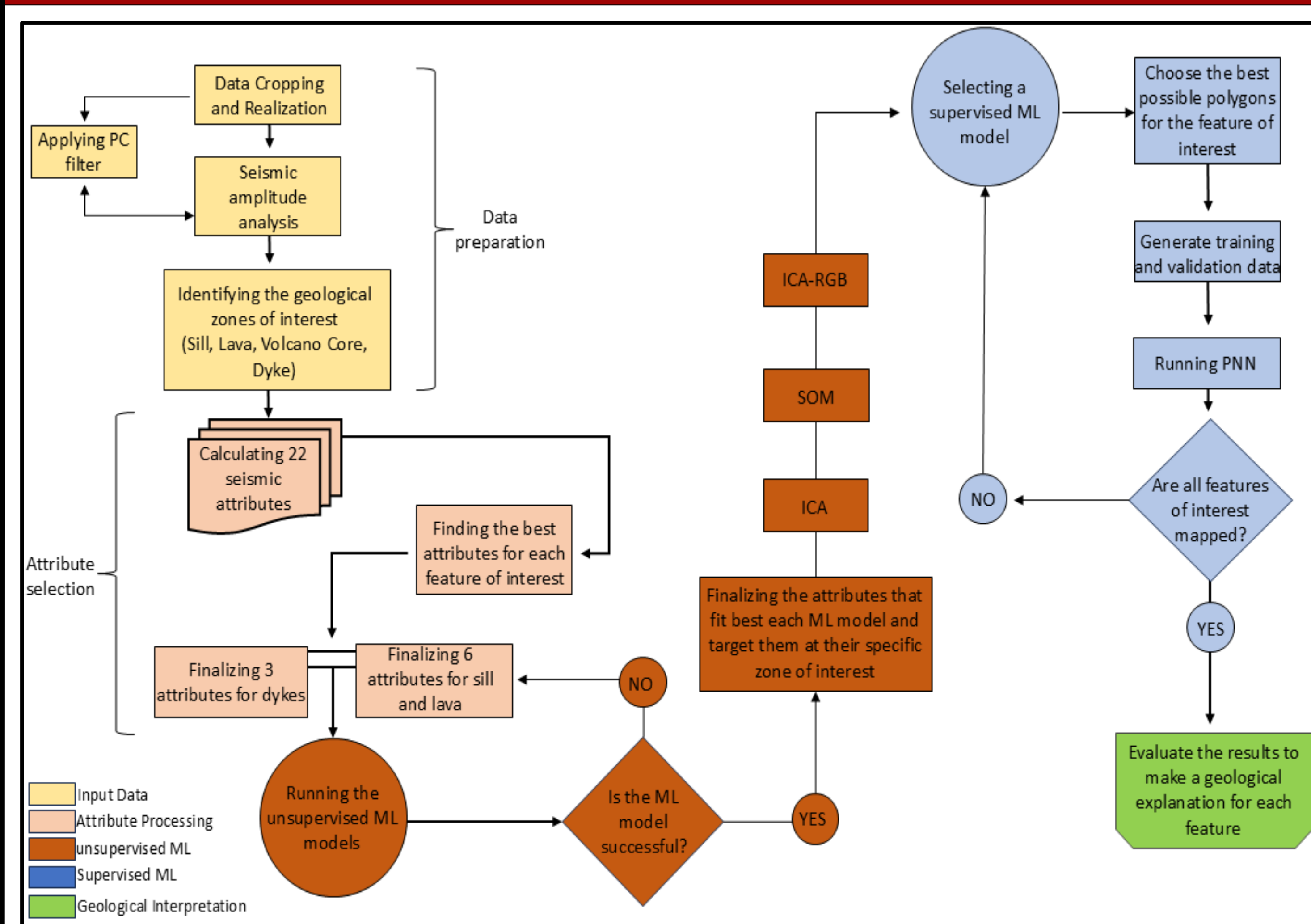


Figure 2- The Workflow of Attribute Analysis and Machine Learning

Attribute Results

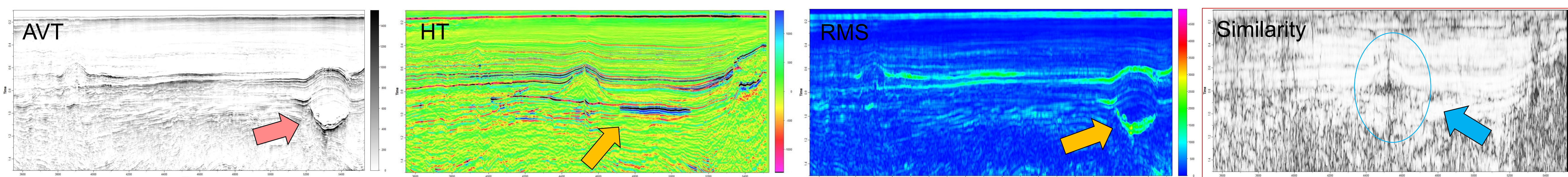


Figure 3- Seismic Attribute Results (Focus on Sills, Lava, and dyke Facies)

Unsupervised Machine Learning

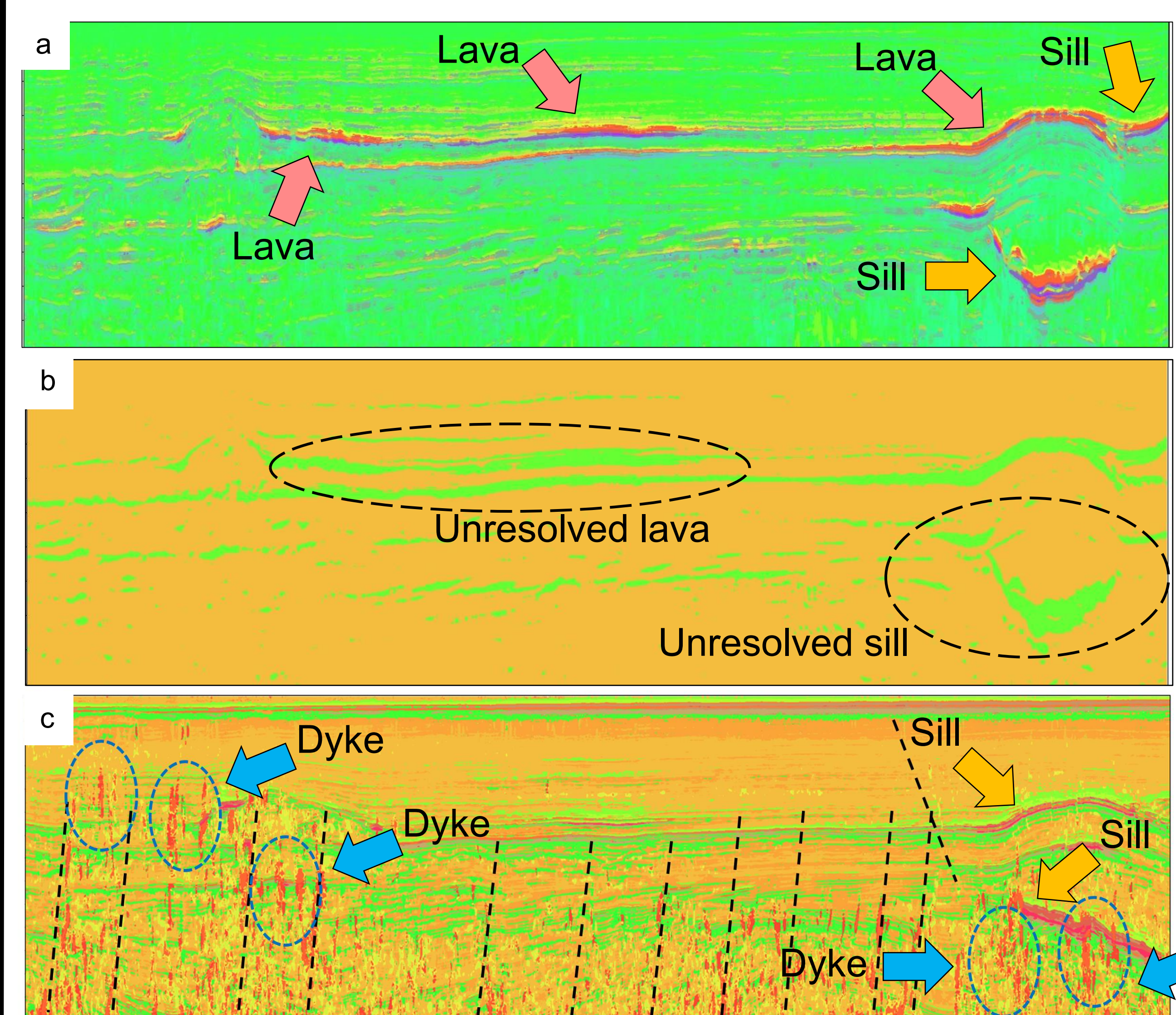


Figure 4 - Machine Learning Results (SOM)

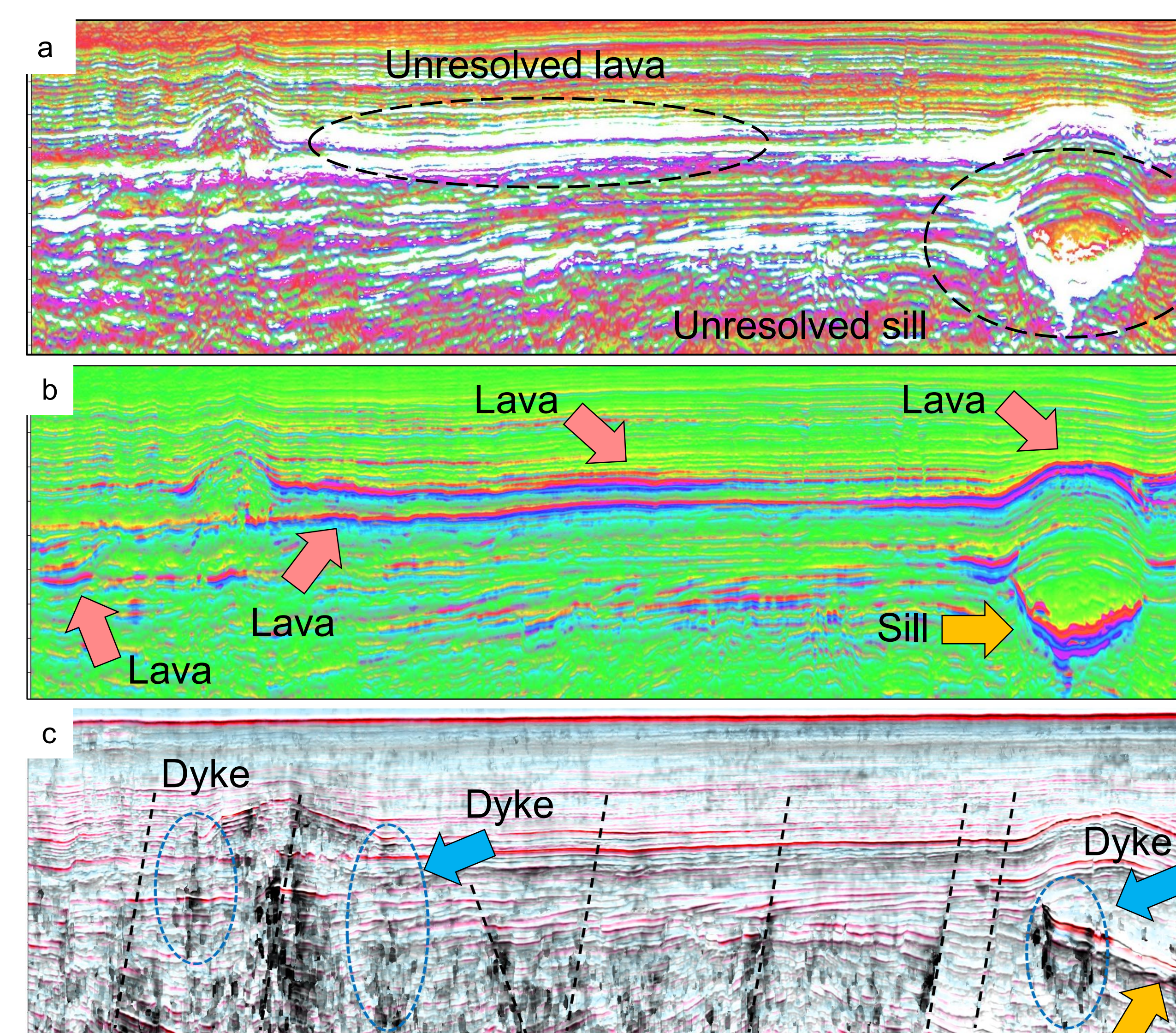


Figure 5 - Machine Learning Results (ICA)

Supervised Machine Learning

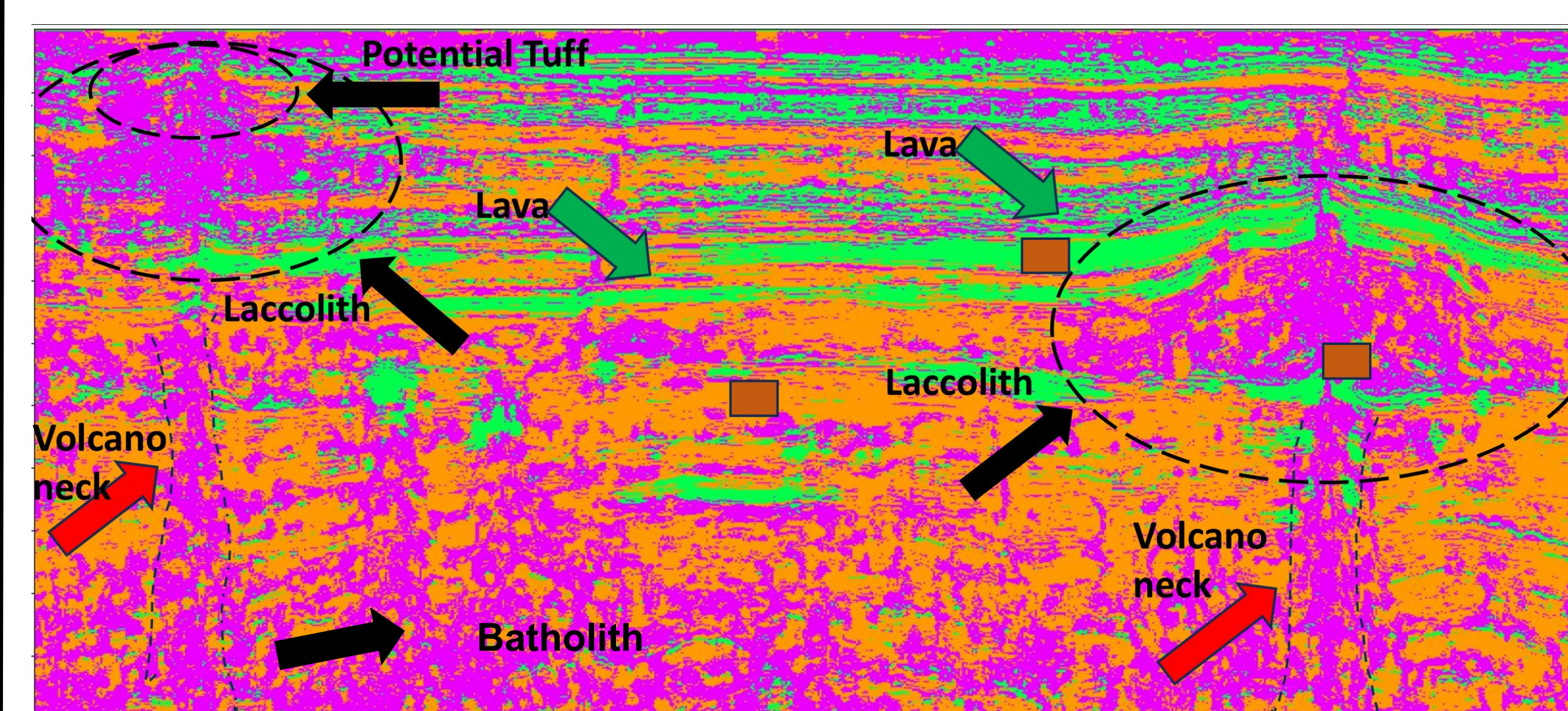


Figure 6 – Machine Learning Results (PNN)

- PNN was applied to resolve the unmapped VFs that were not found using SOM and ICA
- Using 3 sets of polygons, laccoliths, batholiths, volcanic mounds, and volcanic necks were found.

Interpretation

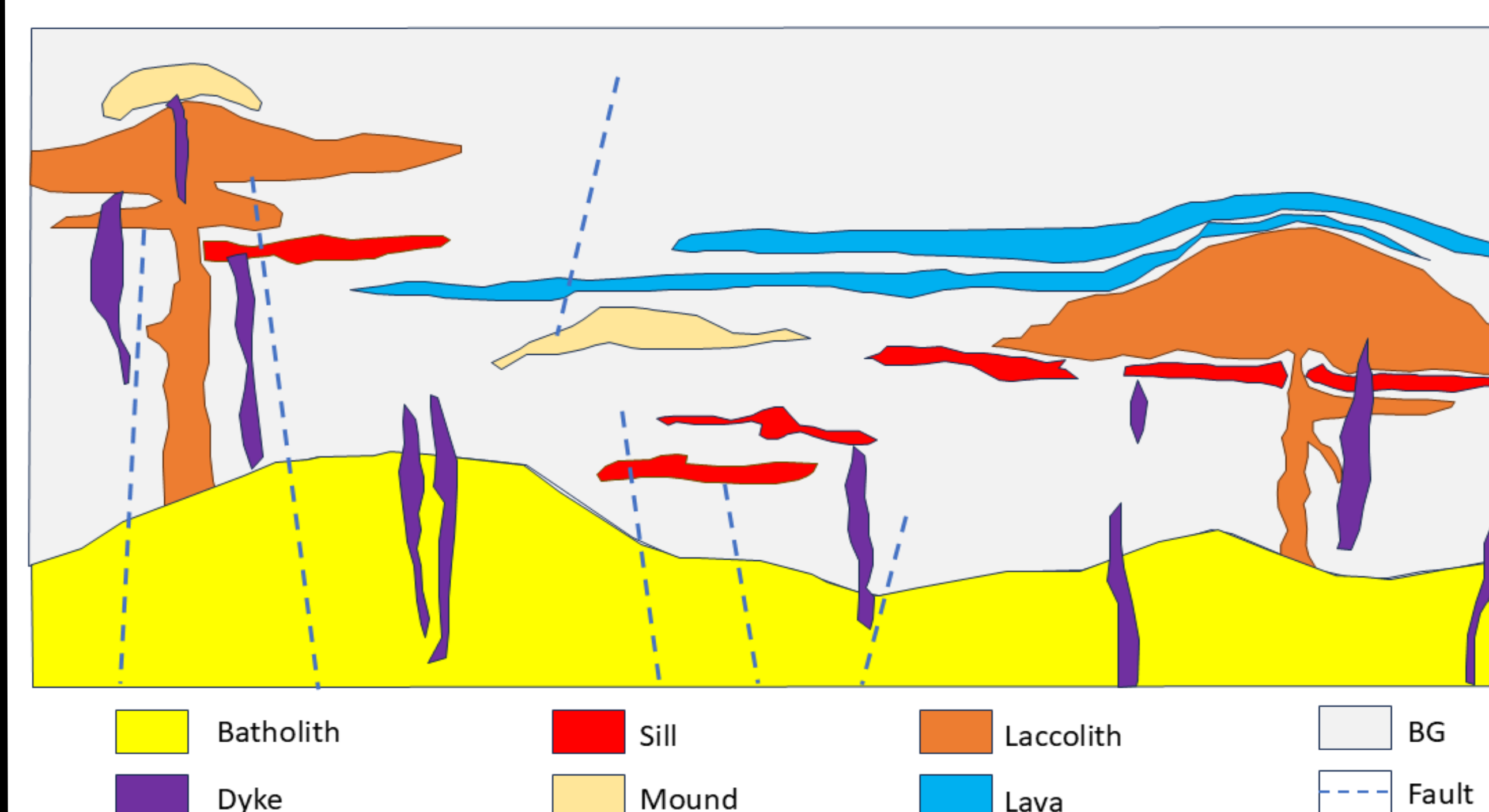


Figure 7 – Interpretation and rendering of the resolved volcanic facies

- All resolved VFs of this research were mapped on the same inline to represent the findings of the study using the combination of multiple attributes and ML models

Cases of Interpretation

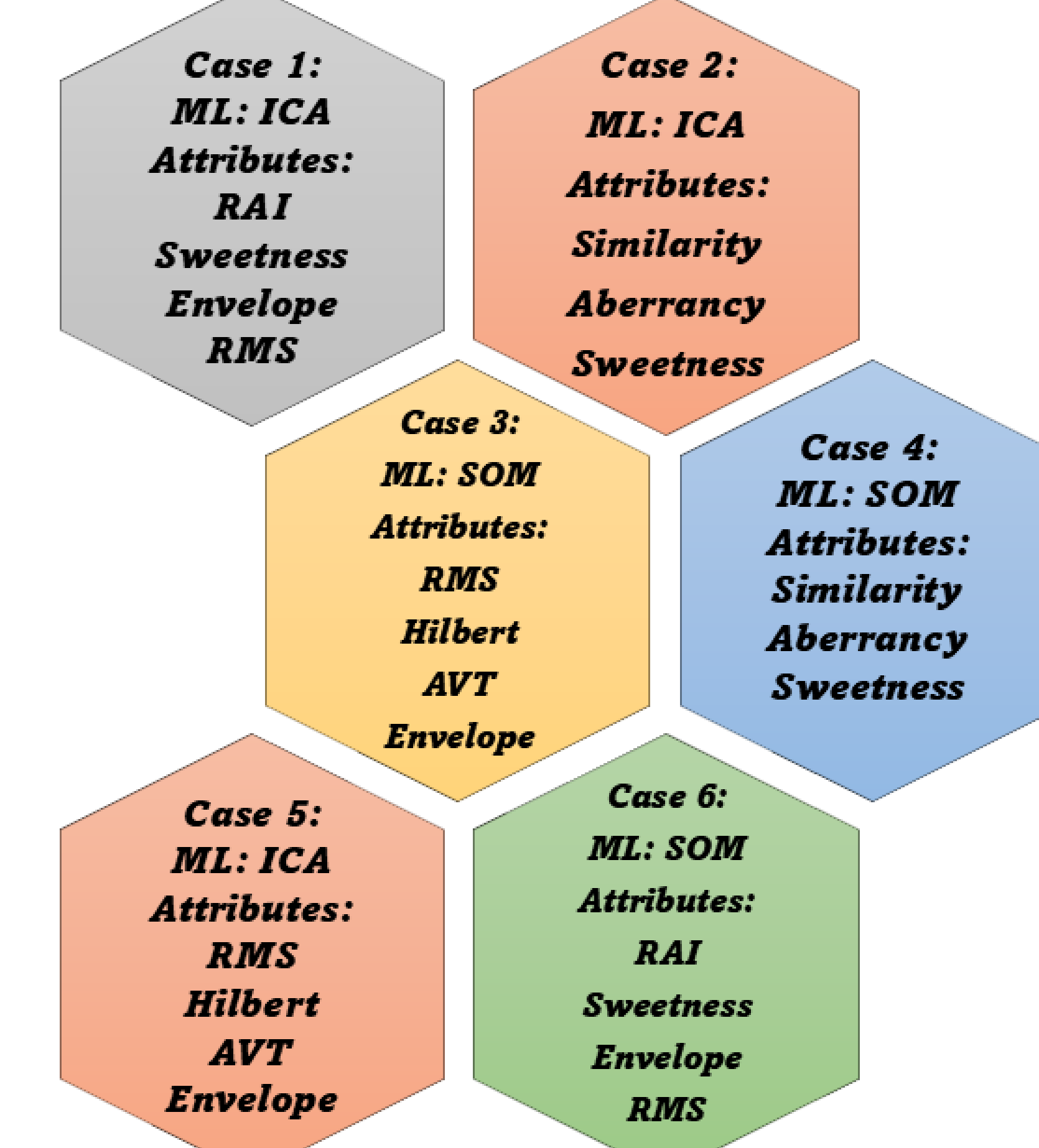


Figure 8 – Different cases applied to the study

Attribute Facies Depiction

Facies	Attributes	SOM	ICA	PNN	Overall Confidence Ranking	Potential Ambiguity
Sill	RMS, Hilbert, AVT, Envelope	Excellent	Fair	N/A	High (5)	Minimal ambiguity; strong amplitude and phase contrast, clear concordant geometry, consistent SOM separation
Lava	RAI, Sweetness, Envelope, RMS	Good	Fair	N/A	Fair to Moderate (3)	Partial overlap with sill amplitude responses; lower energy but similar lateral continuity
Dyke	Similarity, Aberrancy, Sweetness	Good	Good	N/A	Good (4)	Difficulty separating narrow dykes from steep faults due to seismic bandwidth and resolution limits
Laccolith Mound	Envelope, Sweetness, AVT, RMS, GLCM	N/A	N/A	Excellent	High (5)	Geometric similarity to volcanic mounds; dome-shaped morphology may overlap in seismic expression
Batholith	Envelope, Sweetness, AVT, RMS, GLCM	N/A	N/A	Fair to Good	Fair to Moderate (3)	Deep position, limited seismic signature, indirect interpretation as magmatic source

Discussion and Conclusion

- Seismic attributes help characterizing volcanic facies
- Functioning attributes in this study include: hilbert, envelope, RMS, similarity, impedance, GLCM, sweetness, AVT, aberrancy
- Best Attributes to distinguish between sills and lava are : RMS, hilbert transform and AVT
- Machine learning was helpful, SOM characterized sill, lava, and dykes. ICA was helpful with dykes.
- PNN resolved larger volcanic facies such as laccoliths

References

Niyazi, Y., Warne, M., & Ierodiakonou, D. (2022). Machine learning delineation of buried igneous features from the offshore Otway Basin in southeast Australia. *Interpretation*, 10(3), SE101-SE118.
Kumar, P. C., Niyazi, Y., Eruteya, O. E., Moscarillo, A., Warne, M., Ierodiakonou, D., & Sain, K. (2022). Anatomy of intrusion related forced fold in the Otway Basin, SE Australia. *Marine and Petroleum Geology*, 141, 105719.