Predicting Magma Fertility in Porphyry Copper Deposits Using Machine Learning

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ABSTRACT

This study investigates the application of linear regression, SVM, and random forest to predict magma fertility in porphyry copper deposits. Each model was trained and validated on four dataset variations and tested using two independent datasets. The objective is to illustrate the potential of machine learning to improve the discovery and extraction of copper, a vital resource for the renewable energy transition.

INTRODUCTION

The energy transition offers significant advantages for people, the environment, and the economy by reducing climate change impacts, mitigating pollution, and conserving biodiversity. A successful transition relies on critical minerals such as copper, lithium, nickel, and cobalt, with copper being essential for powering solar, wind, and bioenergy technologies. This study aims to use machine learning to improve the accuracy and efficiency of copper deposit fertility prediction by analyzing large datasets of magma and zircon indicators.

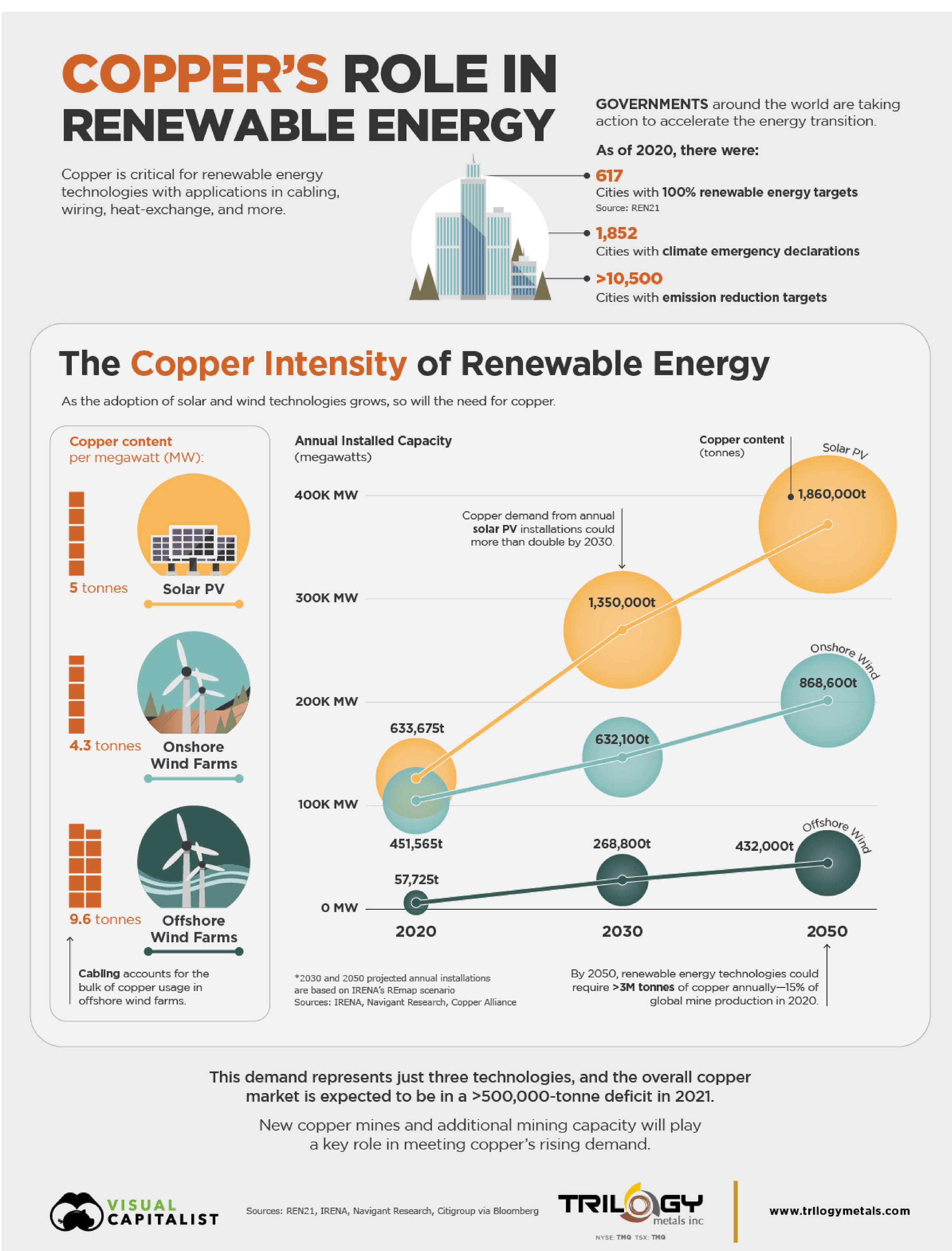

Figure 1. *Importance of Copper in renewable energy.*

Methodology

Preprocessing
- Imputing Missing Data
- Extracting Complete Data Cases

Splitting Data
- Training (80%)
- Validation (20%)

Training & Validating Models
- Logisitic Regression
- Random Forest
- SVM

Testing Datasets
- Predicted on regional datasets from Canada and China.

Predictions
- Calculated Magma Fertility Index (MFI) from predictions by group:
  - Rock Type (Canada)
  - Rock Sample (China)

Test Plots
- Plotted MFI values against groups.
- Compared to plots from previous studies.

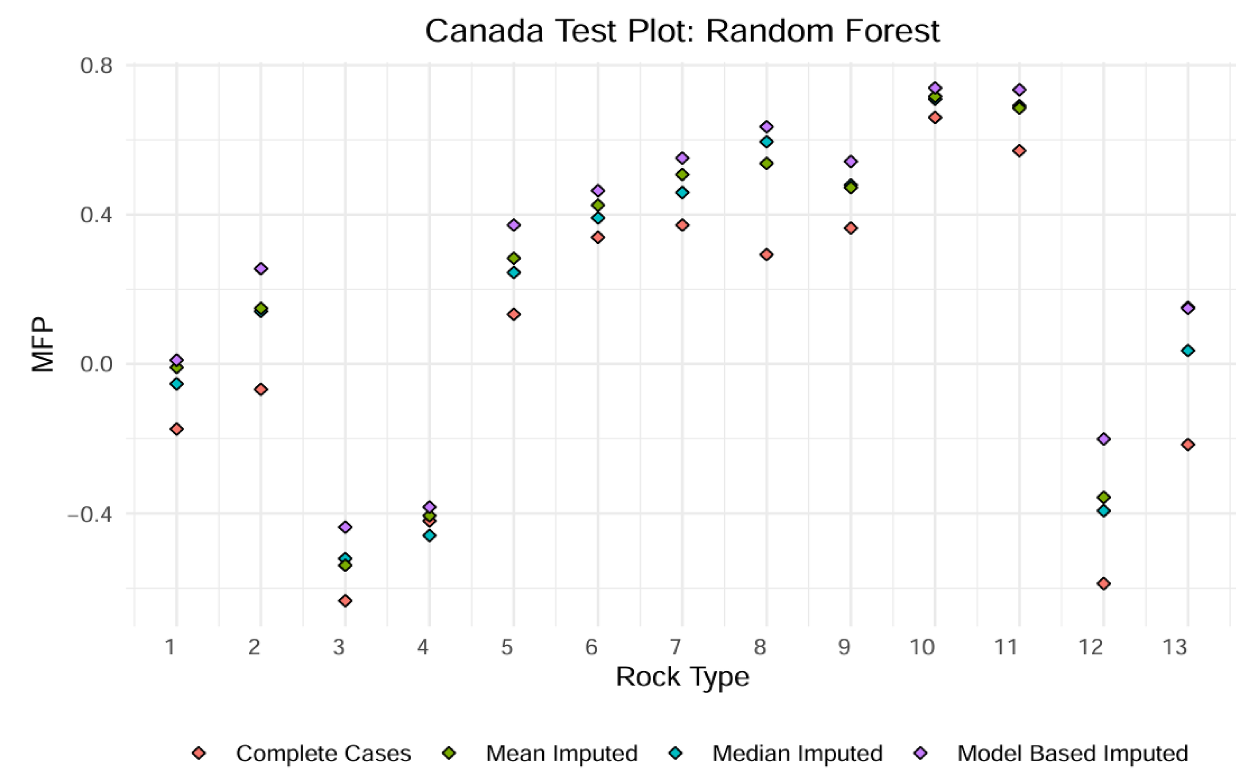

Figure 2. *The predictions of magma fertility from the Random Forest model based on zircon measurements on rock samples from Canada.*

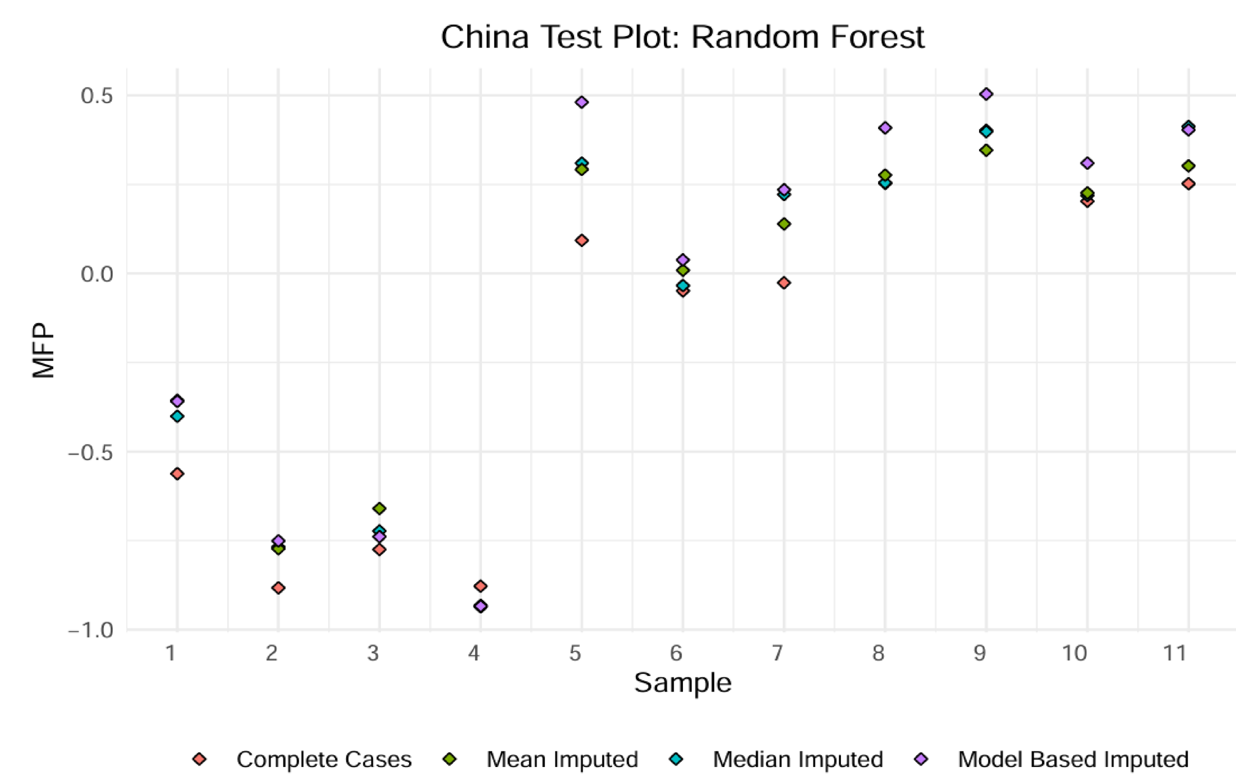

Figure 3. *The predictions of magma fertility from the Random Forest model based on zircon measurements on rock samples from China.*

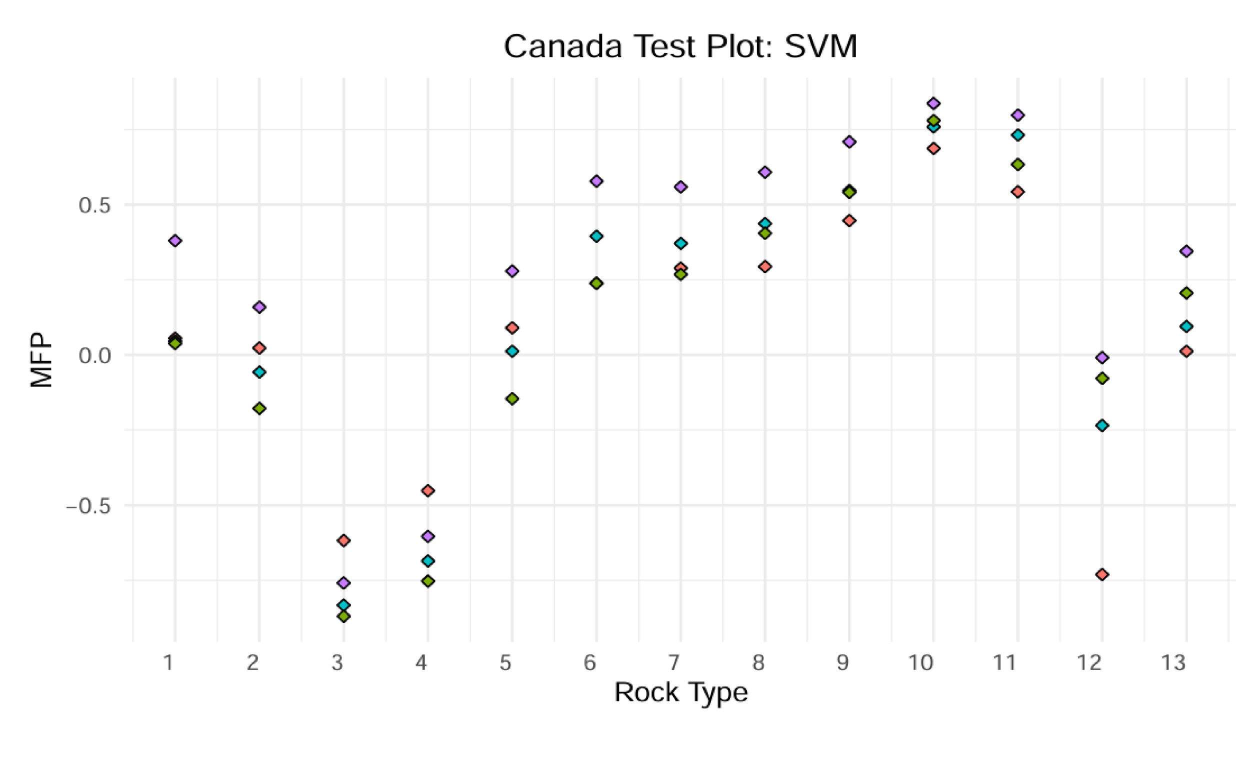

Figure 4. *The predictions of magma fertility from the SVM model based on zircon measurements on rock samples from Canada*

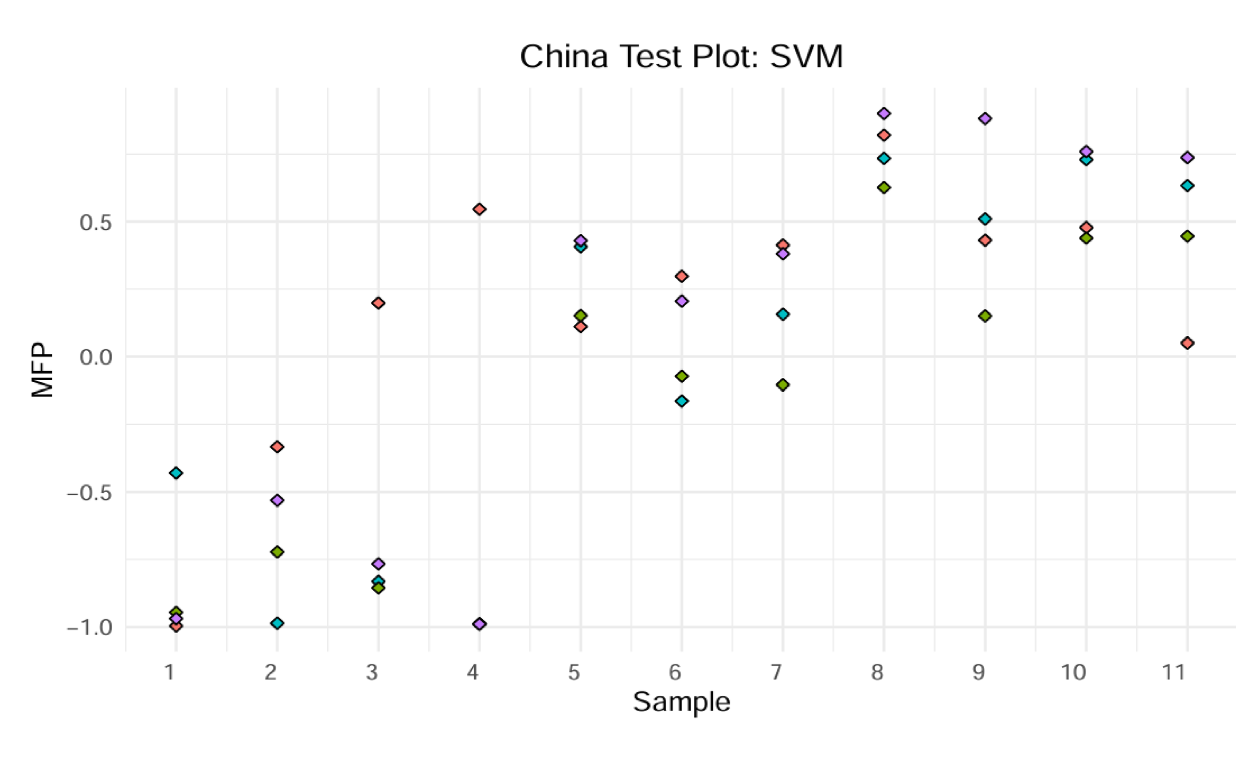

Figure 5. *The predictions of magma fertility from the SVM model based on zircon measurements on rock samples from China.*

Legend for **Figures 2-5**.

	1	2	3	4	5	6	7
Canada: Rock Type	Gump Lake stock	Border facies	Guichon sub-facies	Gui-Chat sub-facies	Chataway sub-facies	Bethlehem facies	Bethlehem porphyry
China: Rock Sample	Gurong (WR-12-11)	Quxu (QS-11)	Nanmu (NM11-01)	Kangmaqie (KMQ-12-2)	Jiama (JM11-36)	Xigaze (PZ11-03)	Pagu (PG11-03)
	8	9	10	11	12	13	
Canada: Rock Type	Jersey Stock	FQPC	Skeena facies	Bethsaida facies	S&P Bethsaida	QFPQ	
China: Rock Sample	Jiru (JR-2)	Jiru (JR-5)	Jiru (JR11-06)	Pagu (PG11-06)			

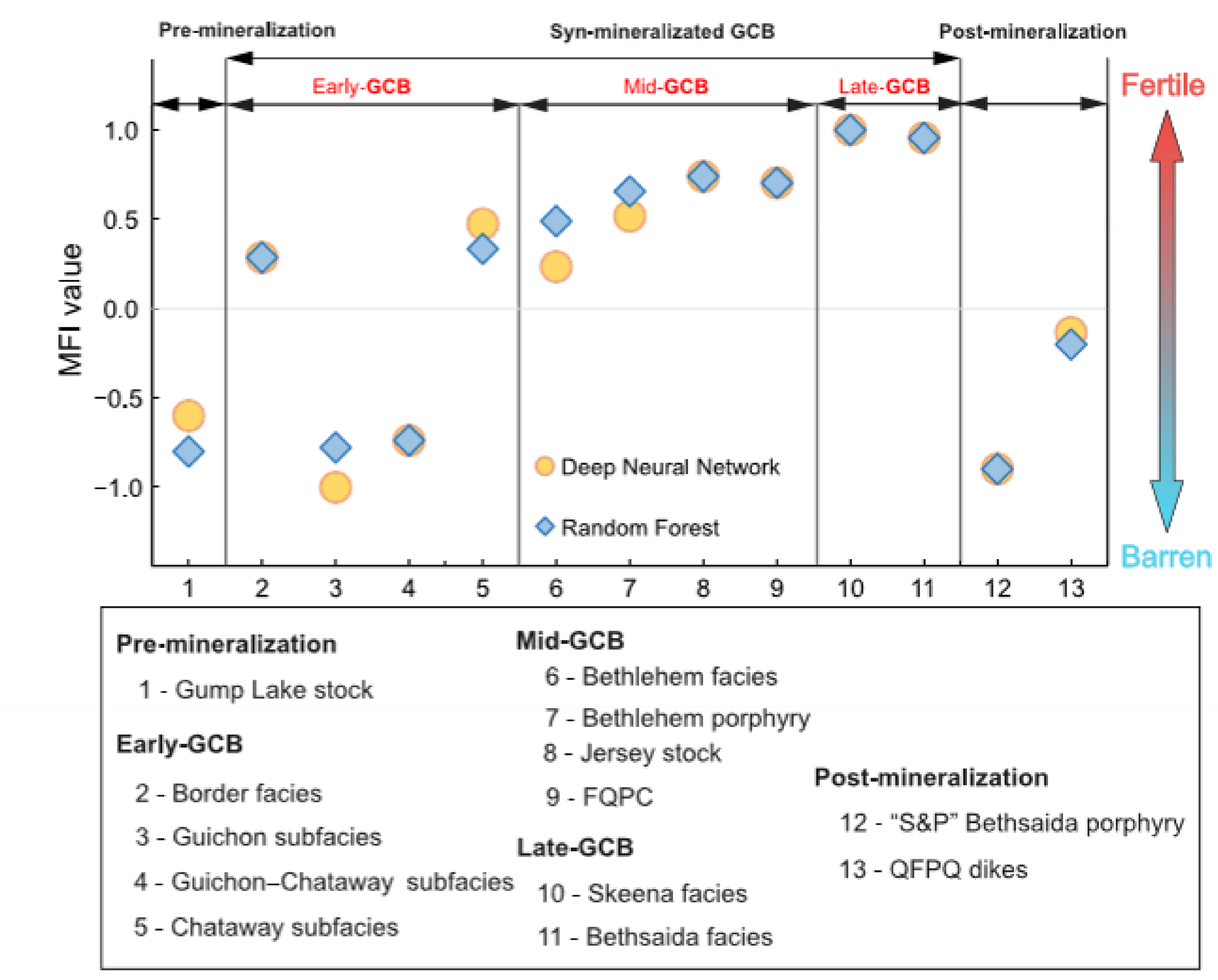

Figure 6. *The predictions of magma fertility from Zou et al. (2022) based on zircon measurements on rock samples from Canada.*

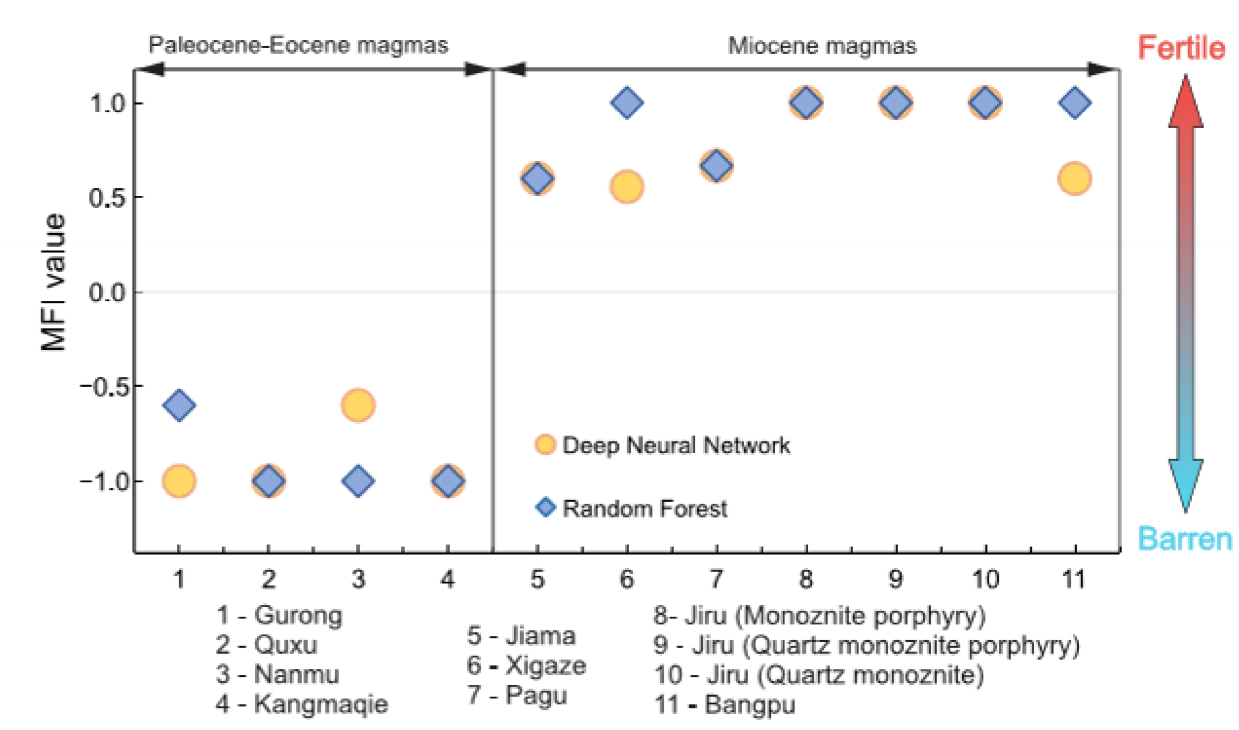

Figure 7. *The predictions of magma fertility from Zou et al. (2022) based on zircon measurements on rock samples from China.*

DISCUSSION

The machine learning models (Logistic Regression, Random Forest, SVM) were validated against magma fertility trends established in previous studies, which utilized Deep Neural Network and Random Forest analyses. Despite some prediction variability due to imputation methods, the models' predicted fertility patterns showed a general consistency with these prior findings, indicating their potential to effectively capture the various geological factors that influence magma fertility relevant to copper exploration.

CONCLUSION

In summary, this research demonstrates the potential of machine learning models (Logistic Regression, Random Forest, SVM) for predicting magma fertility, a significant factor in copper exploration that can be informed by zircon measurements. Validation against previous studies utilizing Deep Neural Network and Random Forest analyses confirmed that the models, despite some imputation-related variability, reliably captured magma fertility trends. This highlights the value of machine learning in enhancing the efficiency and accuracy of copper exploration efforts.

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