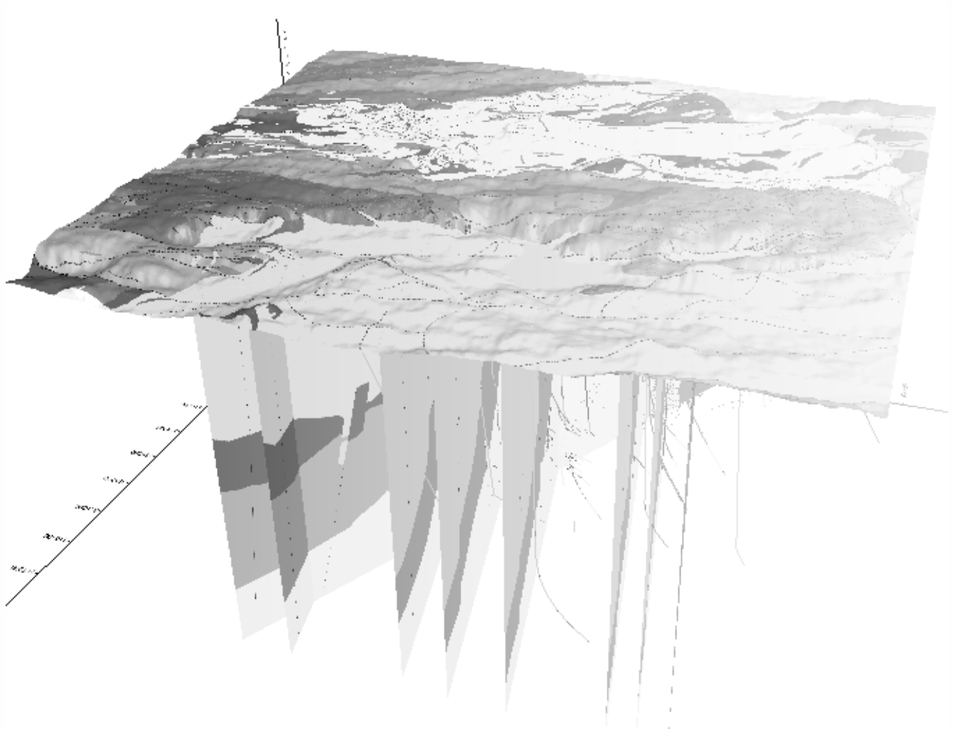

PRO245: A Machine Learning framework with Ensemble Learning for 2D Predictive Modelling of Mineral Deposits: A case study in South Rajasthan

by Rock Lens Team

Advisor :

Group Members

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Geologist

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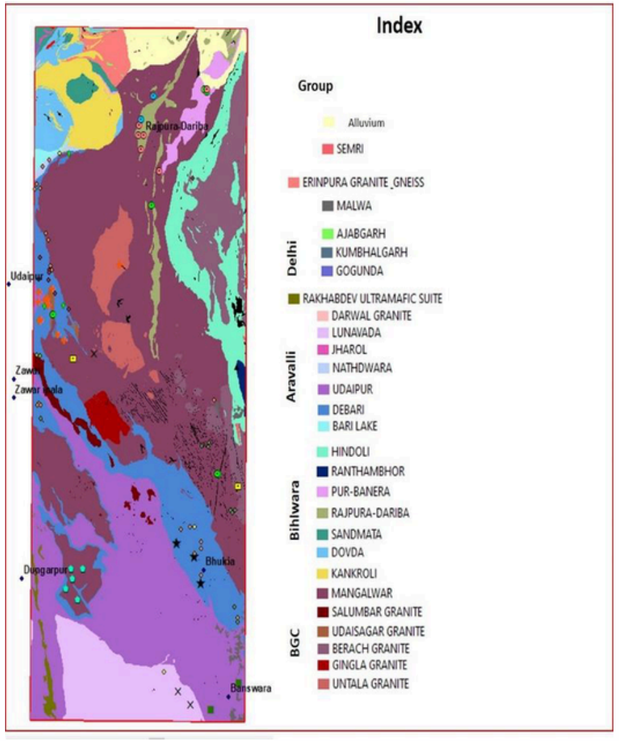
Founder, AI Engineer & Geoscientist

Affan Aji Wiwitama

Junior Geologist

CONTENTS

Geological Background



Primarily the area exposes the rocks of Archean basement and Proterozoic supracrustals along with intrusive granites and ultramafics. Eastern and central part of the area consists of Bhilwara Supergroup primarily consisting of gneiss and migmatites of the Mangalwar Complex and low-grade rocks with volcanics of the Hindoli group. The southern and south-western part contains rocks of the Aravalli Supergroup, basal part of which exposes metavolcanics overlain by thick pile of metasediments.

Aravalli sequence is juxtaposed with Archean Bhilwara Supergroup having ductile shear zone separating the two.

In the Aravalli Supergroup of rocks, copper and gold occurrences are reported at number of places along 150 km long strip from Nathadwara in the north to Ghatol in the south. Berach granite and related quartz reefs with N-S strike occupy central part of the area.

The area exhibits different metallogenic belts like, Salumbar Bhukia Ghatol, Rajpura-Dariba-Bethumbi, Pur-Banera, Zawar, Jhamarkotra, Banswara related to copper, gold, silver, lead-zinc, chromium, nickel, manganese, PGE, iron, graphite and other important commodities like phosphorite, baryte etc. Moreover, significant geologic features like Phulad Ophiolite Suite, Rikhabdev Ultramafic Suite and Berach Granite are also present in this segment.

OBJECTIVE DATA

1. Demonstration of methodology and application of techniques, classical as well as emerging technologies, in finding exploration blocks using baseline (regional scale) geoscience data
2. Identification of new potential areas for exploration of gold, base metal, within a pre-defined 14780 sq. km area in the state of Rajasthan, India.
3. Deriving suitable ML codes for different mineral systems in the area and its validation with data not included in training set.
4. Proposed new well based on the probability map of AOI (Area of Interest)

OBJECTIVE DATA

Specific Area of Interest Objectives

South Rajashtan. The proposed area of 14780 sq. km. Hackathon covers part of south Rajasthan.
Multi-metal / element deposits of different ages.

The objective of the regional assessment in South Rajasthan, as summarized from the provided information, is to evaluate the economic mineral potential of a geologically diverse region.

The area covers Archean to Proterozoic formations and is known for hosting a variety of metal and non-metal deposits.

Specific objectives include:

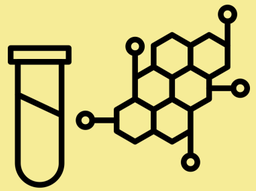
1. Identify potential metallic deposits: The area is prospective for economically valuable metals such as copper, gold, lead, zinc, and nickel, with known mineral belts (e.g., Rajpura-Dariba, Salumbar Bhukia Ghatol) that require further exploration to confirm economic viability.
    a. Potential Deposits: Porphyry, Epithermal, and Orogenic Gold
2. Assess rare earth element (REE): Given the presence of ultramafic rocks and Proterozoic supracrustals, exploration for rare earth elements (REE)

DATA

Geology

Lithology and Structural Data

- Lithology (shapefile)
- Structure (shapefile)
- Geomorphology(shapefile)
- Mineralization (shapefile)
- Exploration report (PDF)



Geochemistry

Soil Sampling Data

Geophysic

Gravity and Aero-Magnetic Data

Remote Sensing

ASTER Data

- Iron Index
- Clay
- Advance Argillic-Kandite
- Argilic-sericite-smectite
- Carbonate Propylitic
- Hydrous Silica-Jarosite-Sericite
- NDVI
- Fault

RESOURCED USED

SOFTWARE

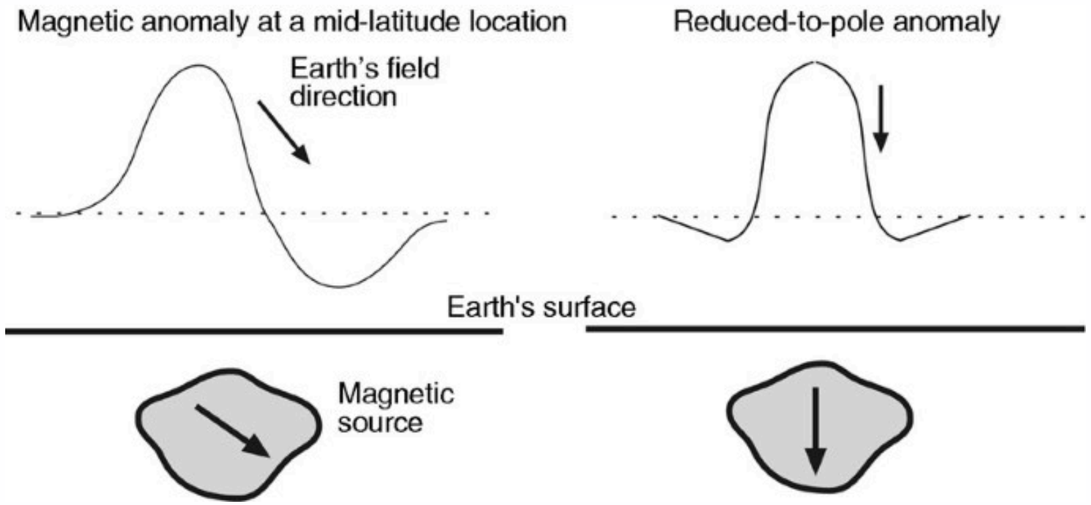
- *QGIS*
- *OaSIS Montaj*
- *ioGAS*
- *Phyton*
- *Microsoft Excel*
- *Visual studio code*

HARDWARE

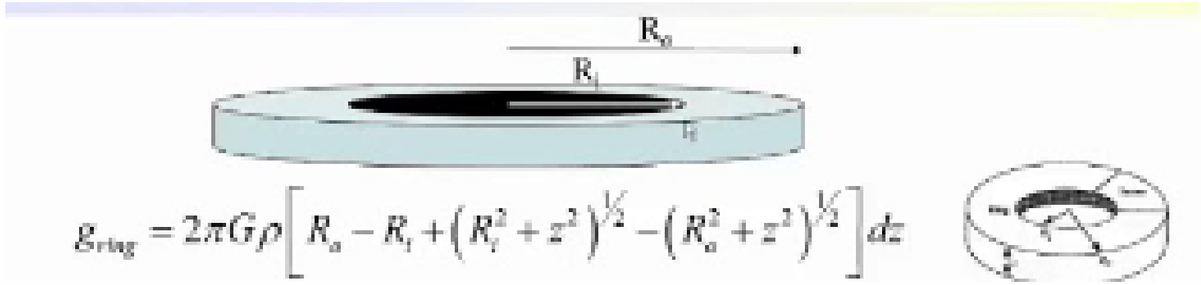
- *Laptop*

GEOPHYSICS

Reduce to Pole for Magnetic

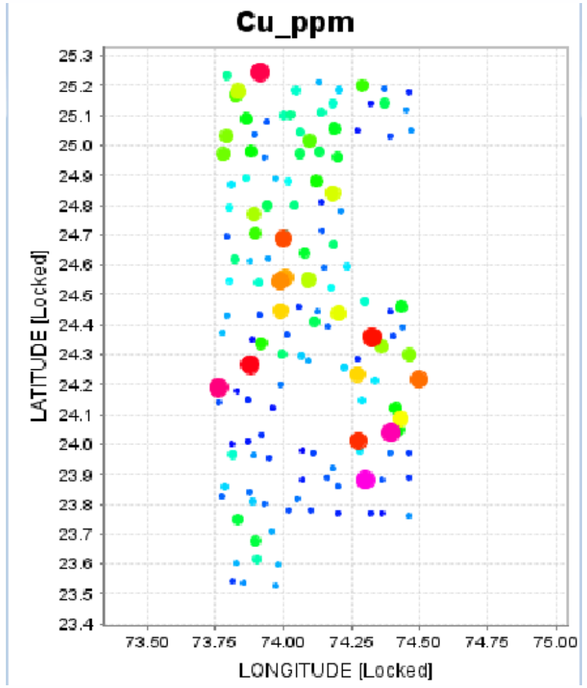


Terrain Correction for Gravity

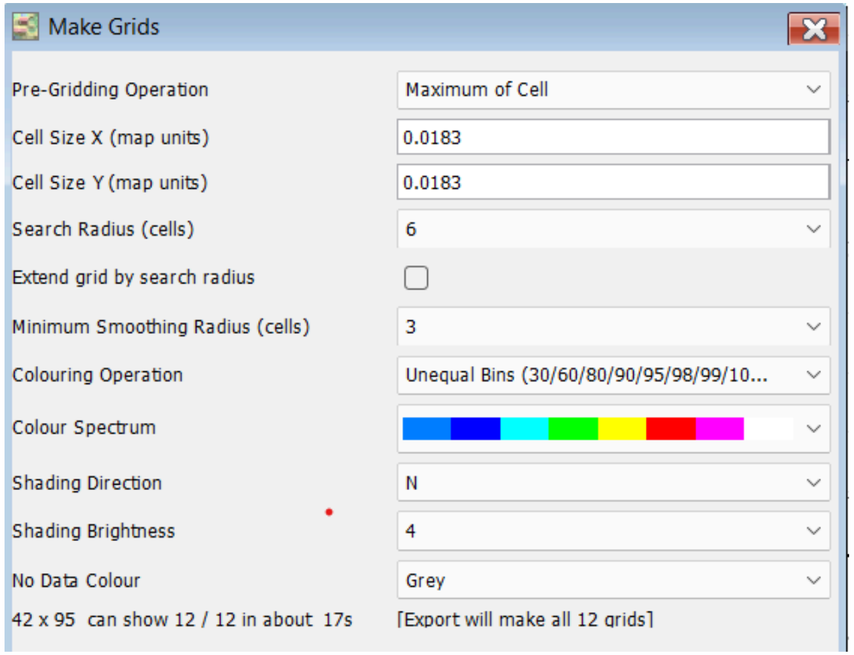


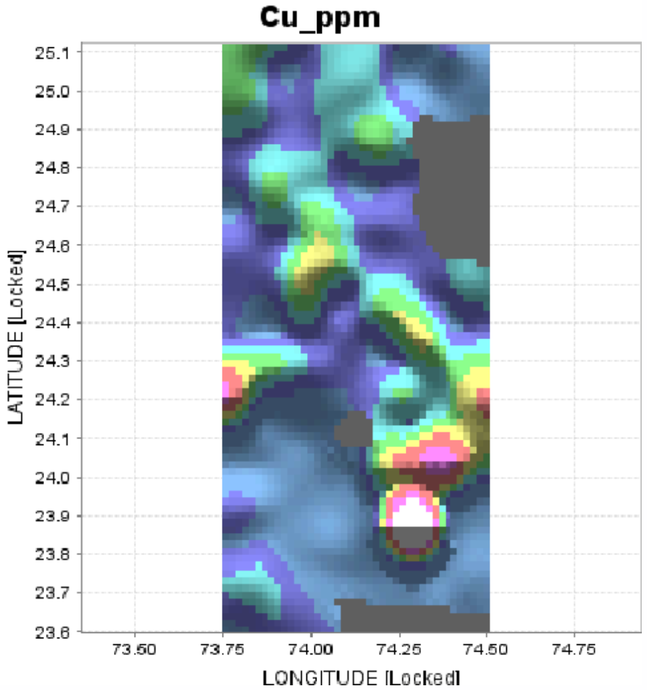
METHODOLOGY

GEOCHEMISTRY



Variable Map



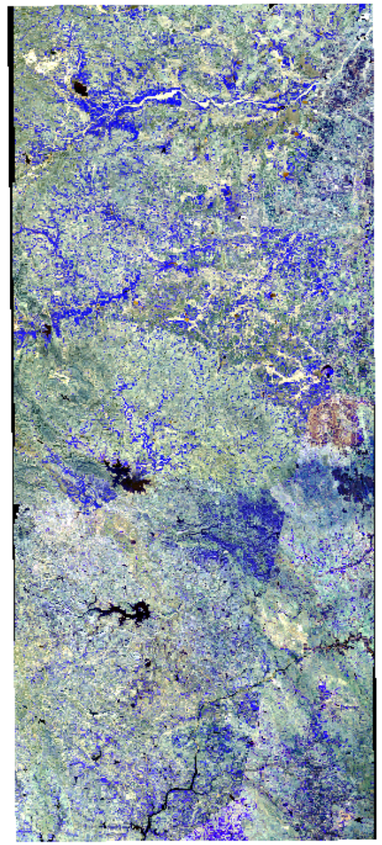


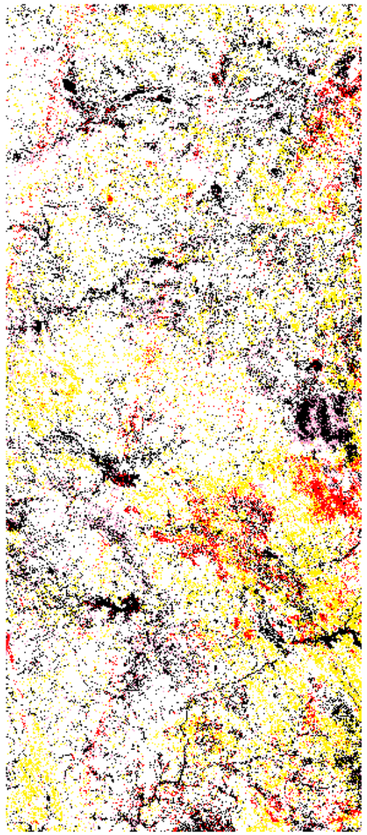
Gridding

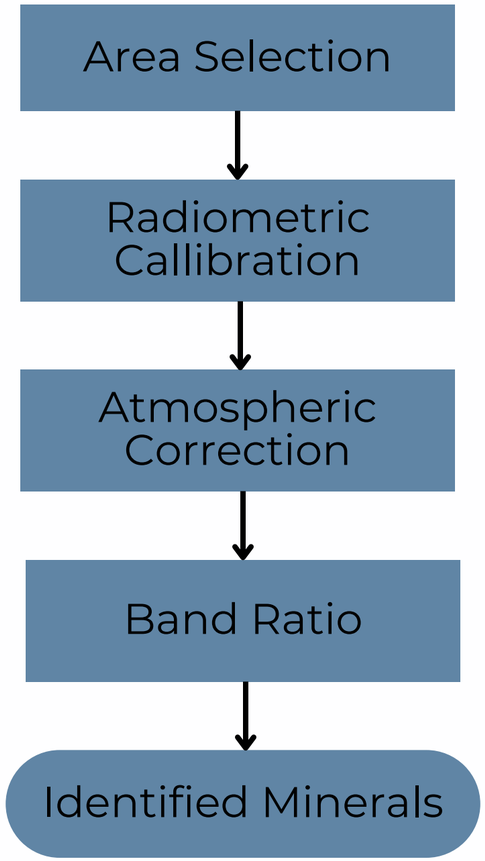
Geochem Statistic > Data Cleaning > Select Variable for Each Deposits > Variable Map > Gridding

METHODOLOGY

REMOTE SENSING







Using Band Ratio Method to identified the type of minerals

Band Ratio of each mineral/material

- *Iron Index (2/1)*
- *Clay Index ((5x7)/6^2)*
- *Advance Argillic-Kandite Index((4+7)/5)*
- *Argilic-sericite-smectite Index((5+7)/5)*
- *Carbonate Propylitic index ((6+9)/(7+8))*
- *Hydrous Silica-Jarosite-Sericite index ((5+8)/(6+7))*
- *NDVI Index((1+3)/2)*

METHODOLOGY

BLOCK AREA PROSPECTS

Characteristics	Location	Geology	Structure	Geochemistry
Porphyry deposits are large, low to moderate-grade ore bodies commonly associated with magmatic arcs in convergent tectonic settings. They are typically found in granitoid intrusions and are characterized by stockwork veining and widespread hydrothermal alteration.	The central part of the area with the Berach granite and related quartz reefs could be a potential site for porphyry copper-gold systems.	The presence of granites (Untala-Gingla Granite, Berach Granite) and basic/ultramafic intrusions in the region suggests a potential for porphyry copper-gold mineralization, especially where magmatic activity and hydrothermal fluids interact with host rocks. The area has Proterozoic granitoids, which might indicate older porphyry systems	Usually near structure	**AOI : Cu-Au-As-Pb-Zn-W-Sb-Zn-Bi**
Epithermal deposits form at shallow crustal levels from hydrothermal fluids, typically associated with volcanic activity. They often occur in subvolcanic settings and are commonly linked to porphyry systems at depth. These deposits can be high-grade in terms of gold, silver, and sometimes copper.	Areas where **volcanic rocks** of the Aravalli Supergroup are present could host epithermal gold-copper systems, though these would likely be linked to deeper magmatic intrusions.	The Aravalli Supergroup contains metavolcanics and metasediments, which could provide a suitable environment for epithermal systems. However, the region's known volcanic activity is relatively ancient (Proterozoic), which might limit epithermal potential unless there has been later tectonic reactivation.	Usually near structure	**AOI (Possibly Northeast area) : Au-Ag-As-Cu-Pb-Zn-Sb-Hg-S-W high**
Characteristics	**Location**	**Geology**	**Structure**	**Geochemistry**
Orogenic deposits (also known as mesothermal) are typically found in greenstone belts or ancient metamorphic belts within compressional or transpressional tectonic settings. These deposits are associated with regional-scale shear zones and typically contain gold, sometimes with copper. They form at moderate to deep crustal levels.	The copper-gold occurrences along the 150 km strip from Nathadwara to Ghatol strongly suggest an orogenic system. The ductile shear zones and juxtaposition of Archean and Proterozoic rocks further support this.	The area's ductile shear zonesseparating Archean basement from Proterozoic rocks, along with metavolcanics, metasediments, gneiss, and migmatites in the Bhilwara and Aravalli Supergroups, are classic settings for orogenic gold systems. These zones may provide fluid conduits for orogenic gold mineralization.	Always with structure	**AOI** **Au-Ag-As-W-Sb+/-Cu+/-Pb+/-W**
1. REE deposits can sometimes be associated with granite-related systems (especially alkaline or peralkaline granites and pegmatites), which are also potential sources of tin. In these settings, REEs are commonly hosted in pegmatites, greisens, or alkaline intrusions, which may also contain cassiterite (the primary ore of tin).	o The Berach granite with its quartz reefs and magmatic activity might be particularly significant in this context.	1. REEs would be associated with granitic intrusions that could also host tinmineralization (similar to Sn-REE pegmatites).		**La-Ce-Pr-Nd-Sm-Eu-Gd-Tb-Dy-Ho-Er-Tm-Yb-Lu**

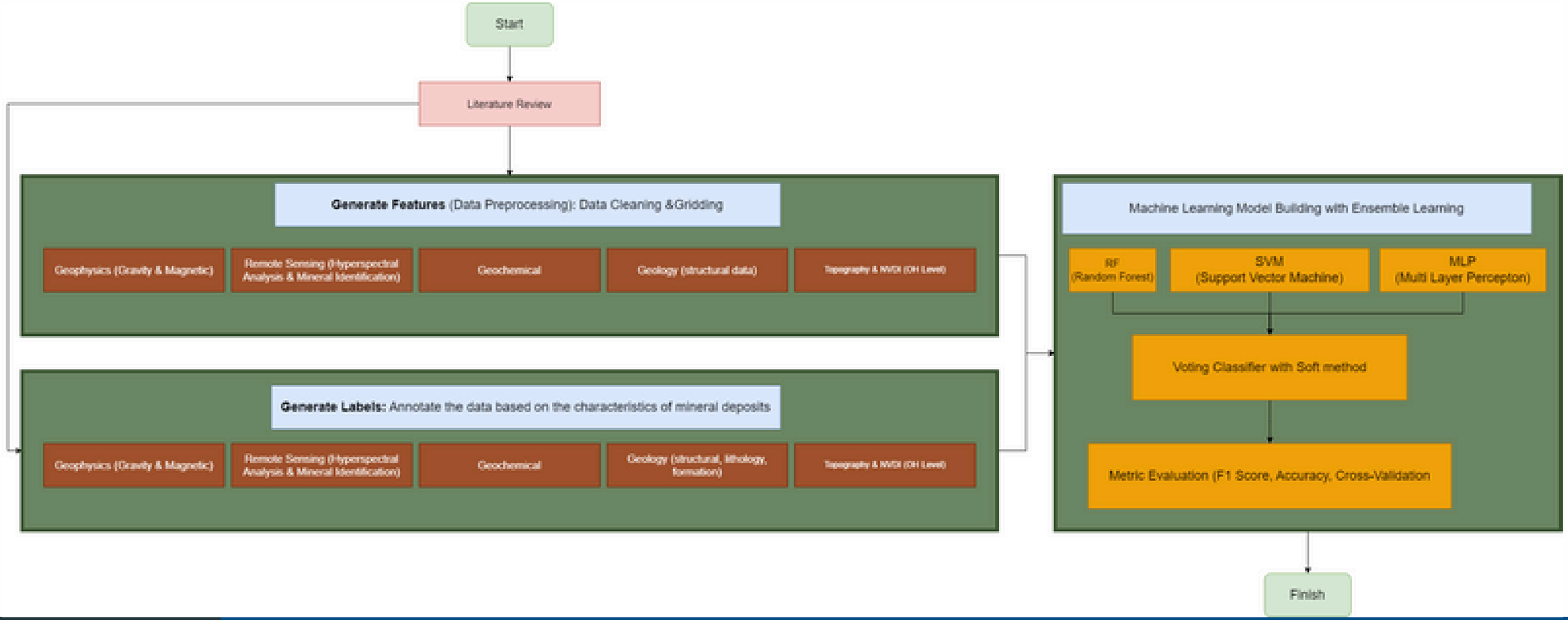
METHODOLOGY

BLOCK AREA PROSPECTS

Type of Deposit	Drilling	Spectral	Geophysics	Supergroup
Porphyry		AOI: Muscovite, Advance Argilic Kandite, Argilic Serisite-smectite (2)	High gravity, but could be low if there is correlated with AA High magnetic	Bhilwara dan Aravalli
Epithermal		AOI: Advance Argilic Kandite, Argilic Serisite-smectite (2)	Low Gravity, High Magnetic	Bhilwara
Orogenic	Cu - Au - Zn deposit in Delwara and Guralli Formation	AOI: Muscovite, Amphibole, Carbonate-Propilitik (2)	High gravity, High magnetic	-Arawalli Supergroup -Mangalwar Complex dari Bhilwara Group (untuk Archean Greenstone belt), -other untuk Archean Granitoid
REE-Granite		AOI: Advance Argilic Kandite, Carbonate-Propilitik, Argilic Serisite-smectite (2)	High gravity, Low Magnetic	Lithology Quartzite : Arawali Lithology Granite: Bhilwara Supergroup)

METHODOLOGY

Flowchart



METHODOLOGY

Flowchart

- Feature Generation:

We analyze the dataset to be used for training the model based on the parameters and characteristics of each deposit. The data undergoes preprocessing, including grayscale conversion and flattening. The features are extracted from the pixel values of each grid cell in the dataset.

- Labels Generation:

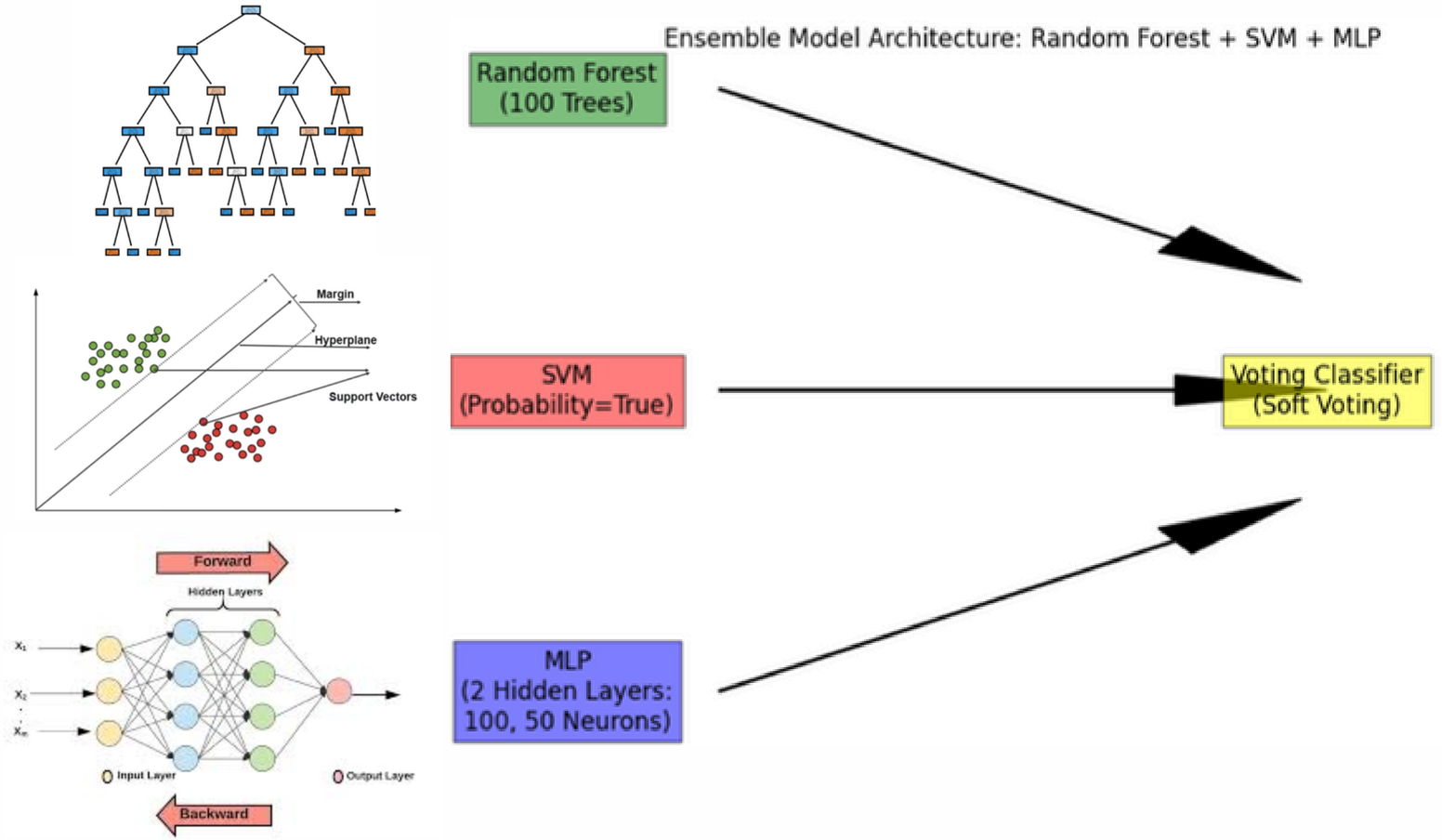
We annotated the points of mineral occurrences to be used for training the model, based on the parameters and characteristics of each deposit presented in the previous slide. We generated a new TIFF file that contains pixel values of 1 for AOI (Area of Interest) and 0 for non-AOI.

- ML Model:

We created four machine learning (ML) models for each possible deposit using Random Forest, Support Vector Machine (SVM), and Multi-Layer Perceptron (MLP) to calculate the probability of areas with low-contrast anomalies.
In this study, we propose several algorithms to obtain the best model that can accurately represent our data. The optimal model is achieved using the voting classifier method with soft voting, which provides probability-based outputs by averaging the predictions from all individual models. This approach aims to reduce uncertainty and prevent overfitting.
For training each model, the labeled dataset is split into 60% for training and 40% for testing, ensuring that the model learns effectively and generalizes well to unseen data.

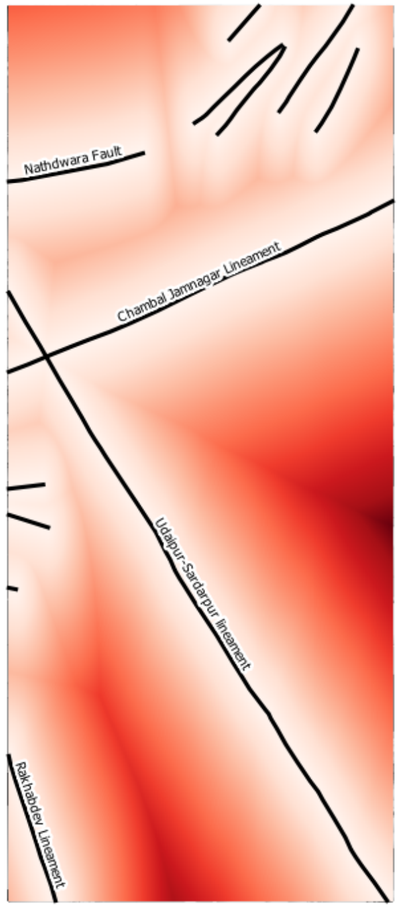
METHODOLOGY

PRO245: Machine Learning Architecture



RESULT

Structural Data



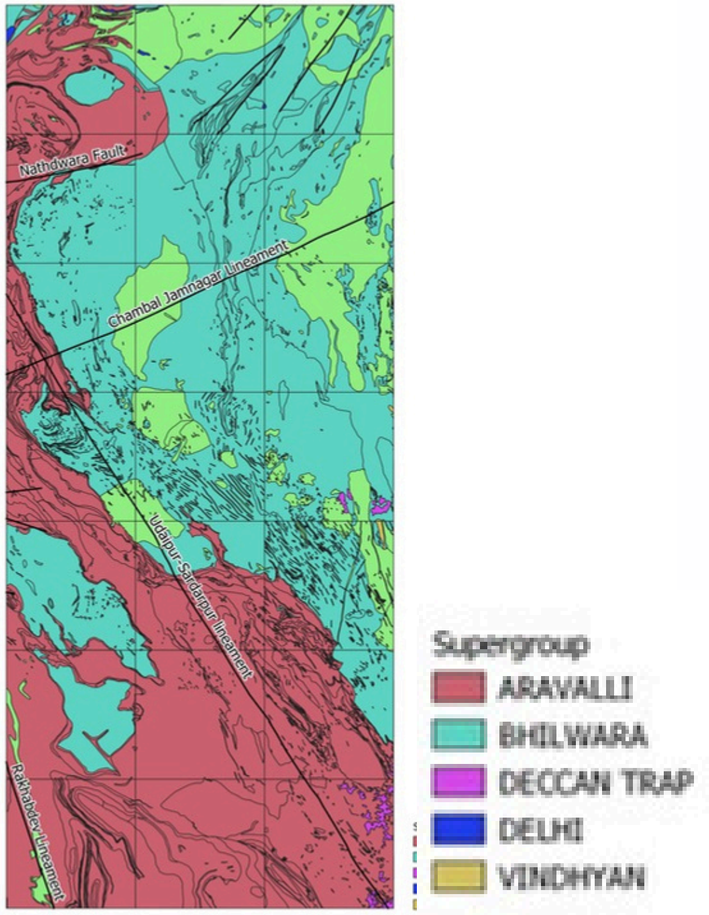
Using buffer system

Buffer zone has relatively 30 km lenght from fault tectonic

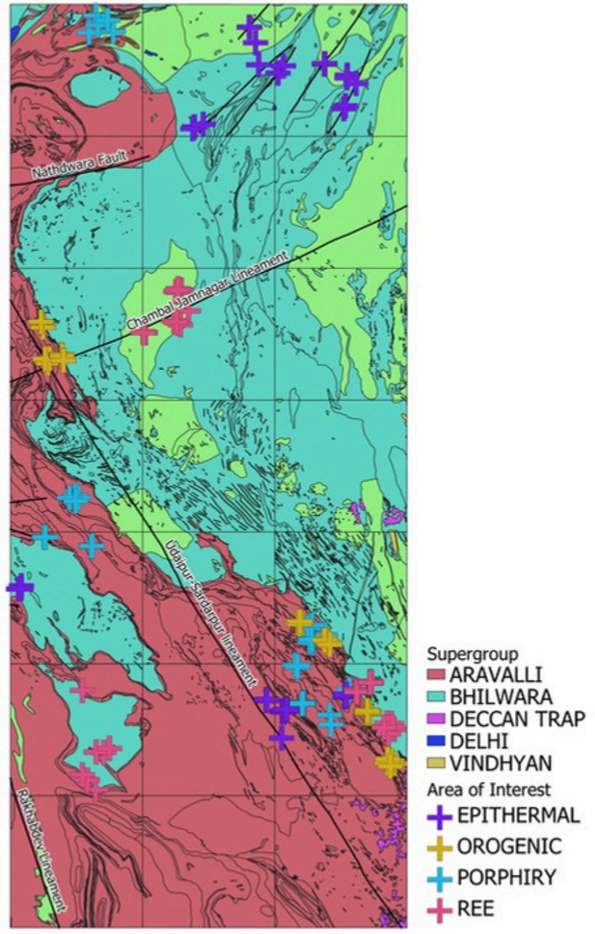
0 km

30 km

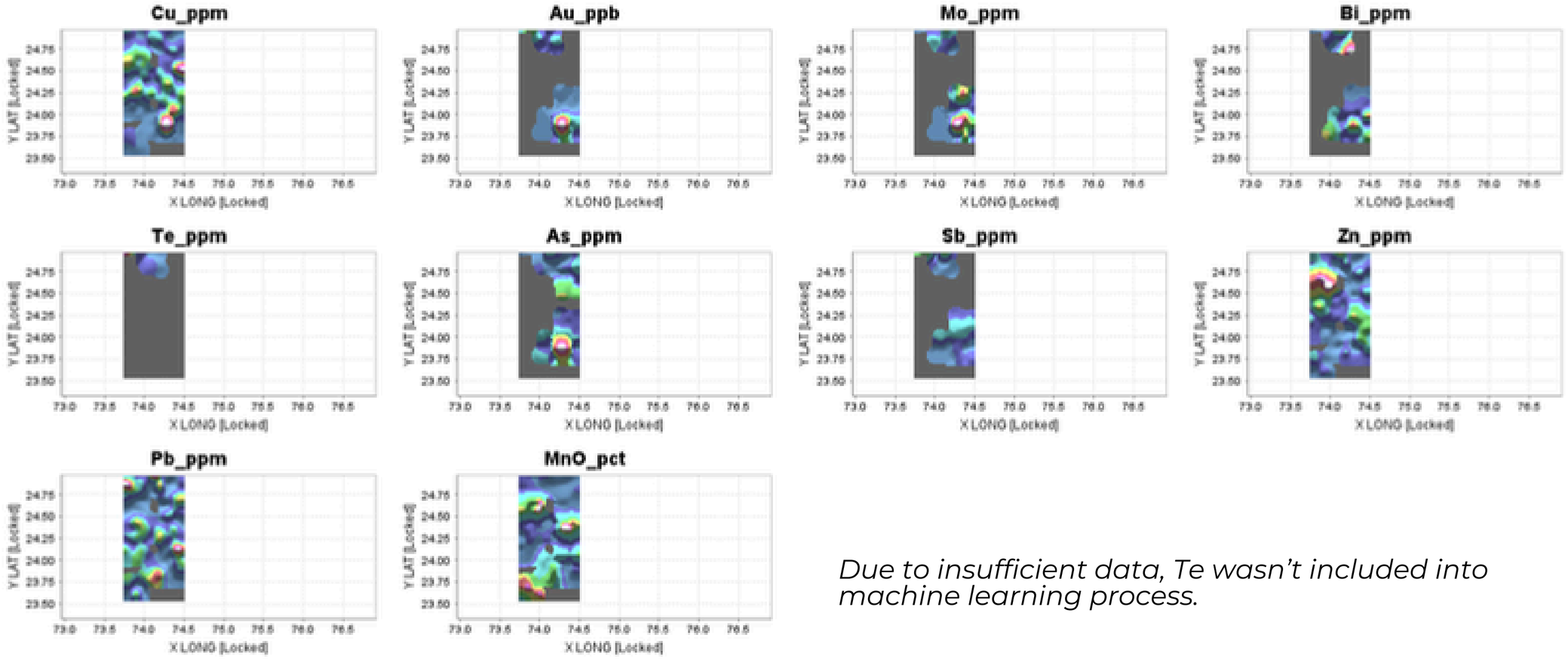
Supergroup Map



Prospectivity Map

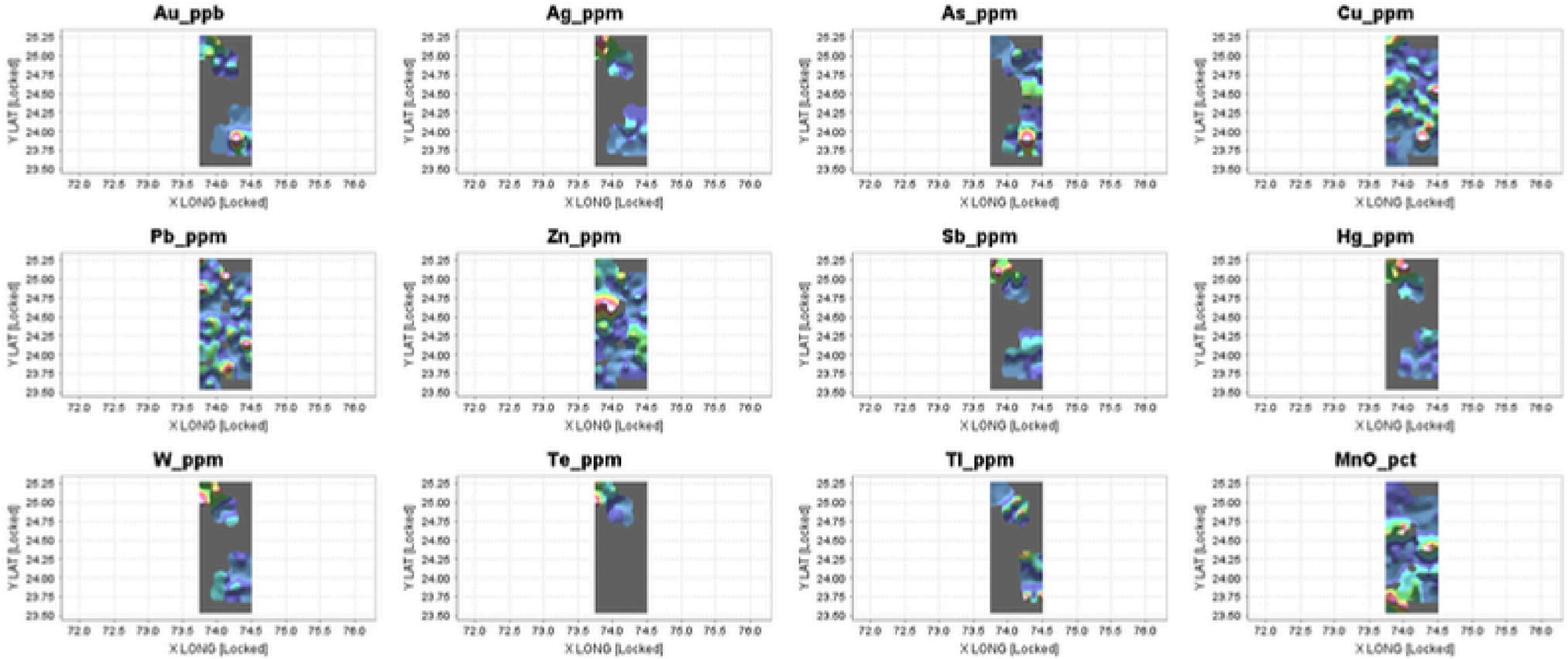


Geochemistry - Porphyry



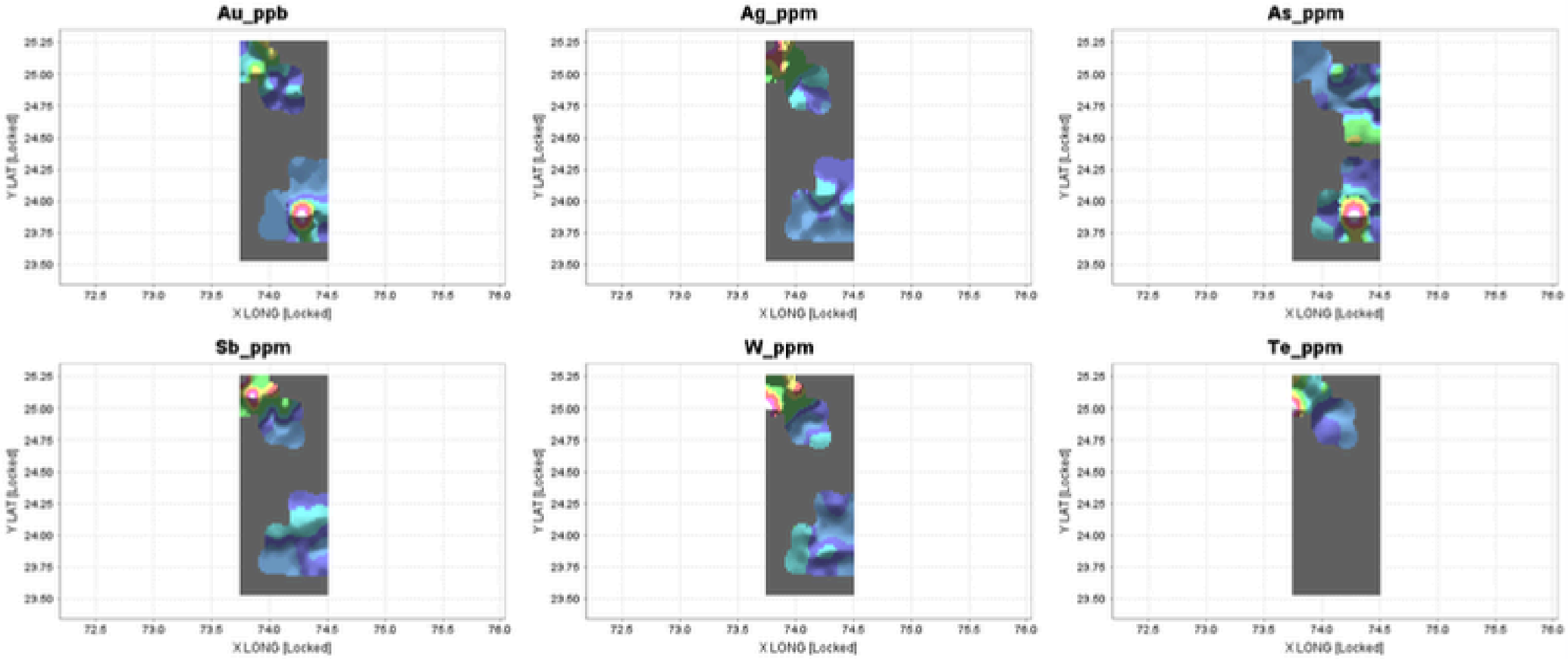
Due to insufficient data, Te wasn't included into machine learning process.

Geochemistry - Epithermal



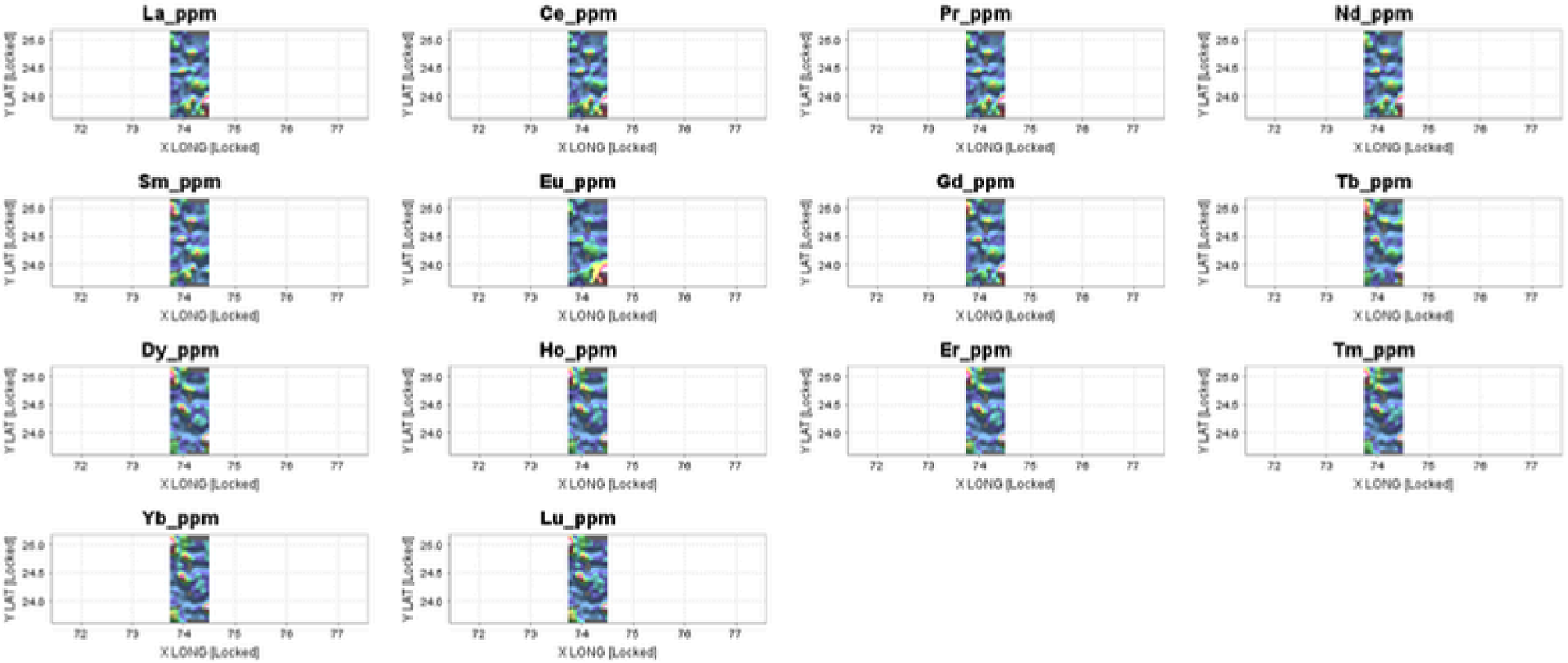
Due to insufficient data, Te and Ti were not included into machine learning process.

Geochemistry - Orogenic

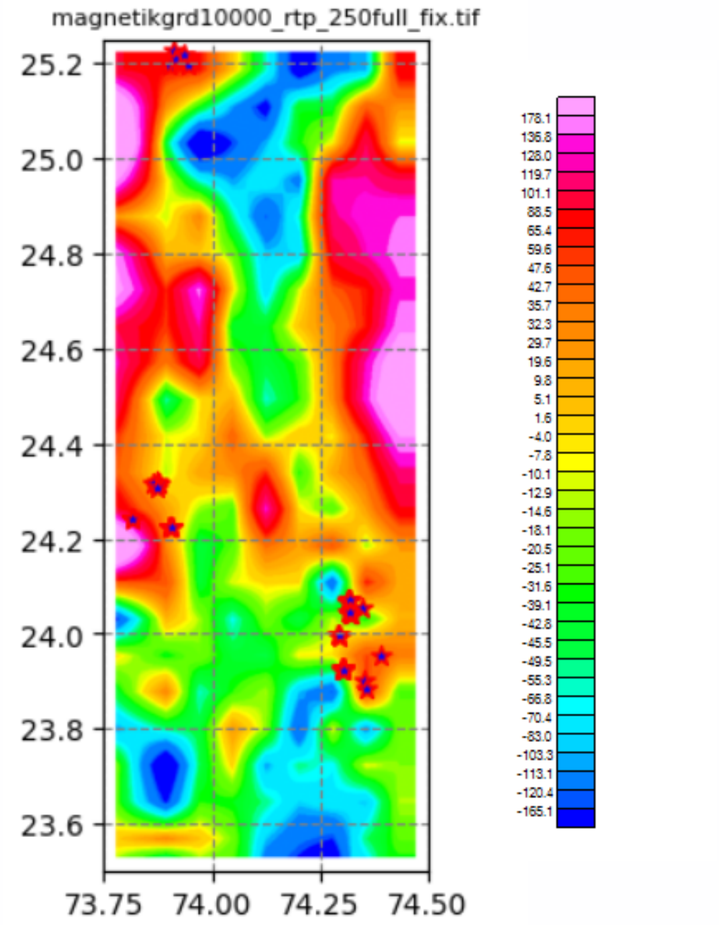


Due to insufficient data, Te wasn't included into machine learning process.

Geochemistry - REE



Geophysics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74.00
74.25
74.50
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136.8
128.0
119.7
101.1
88.5
65.4
59.6
47.6
42.7
35.7
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19.6
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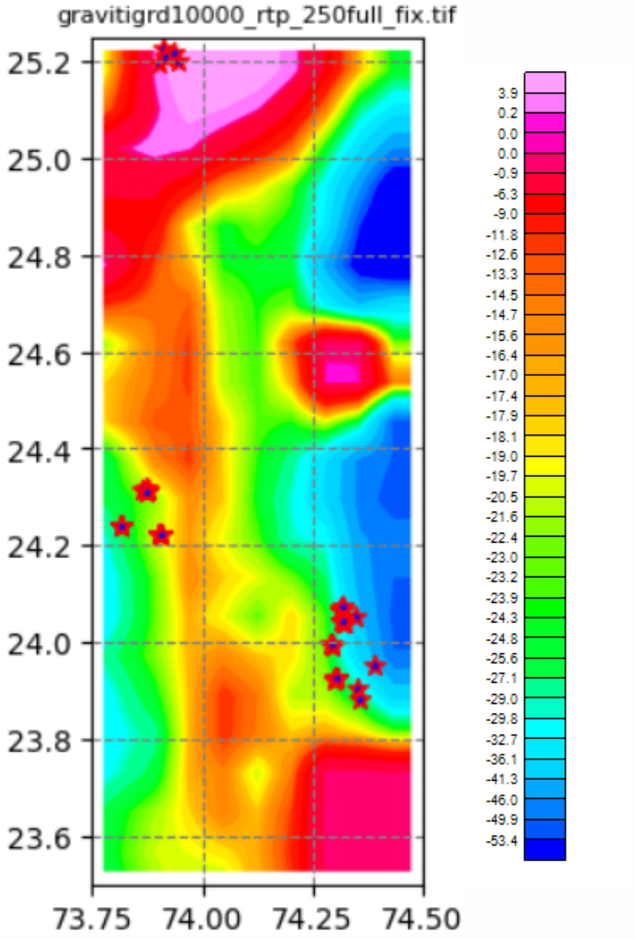
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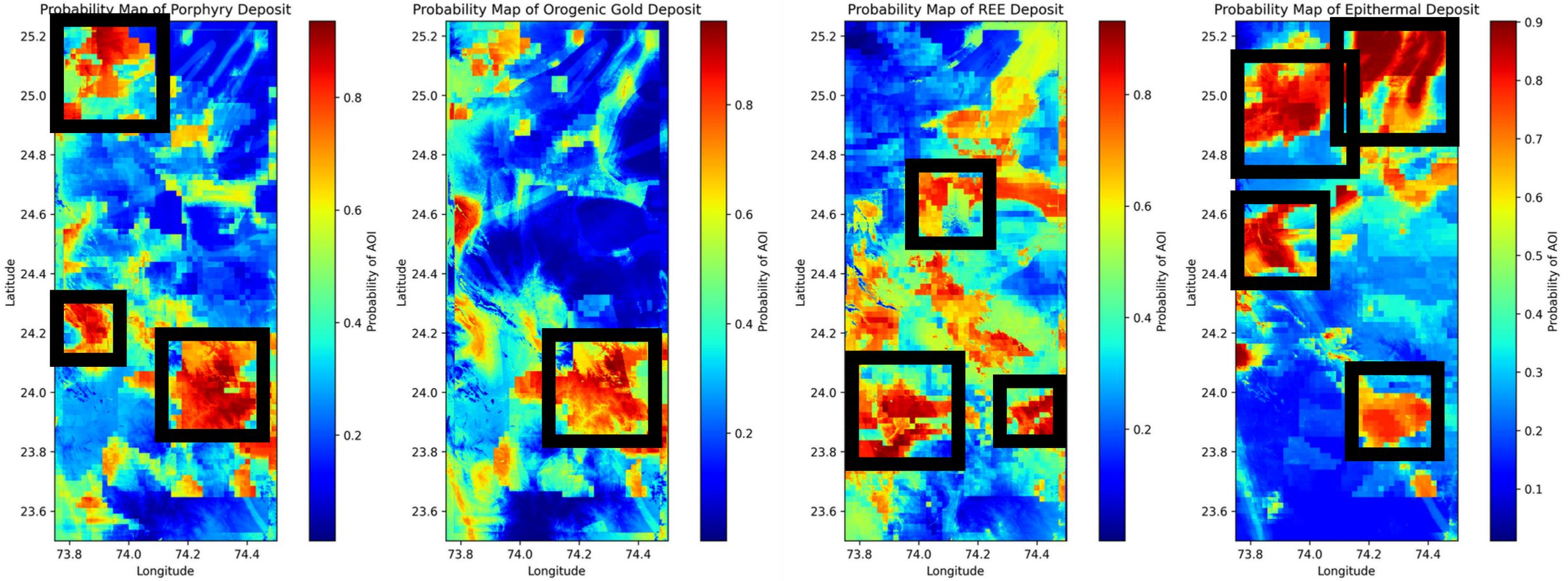
-53.4

Machine Learning for 2D Predictive Modelling of Deposits Distribution



Evaluation Metrics for Each Deposit Using F1 Score, Accuracy, and Cross-Validation

Porphyry Deposit

```
Cross-Validation Accuracy: 99.64%
Test Accuracy: 99.92%
F1 Score: 1.00

Classification Report:
              precision    recall  f1-score   support

         0.0       1.00      1.00      1.00      2780
         1.0       1.00      1.00      1.00      3462

    accuracy                           1.00      6242
   macro avg       1.00      1.00      1.00      6242
weighted avg       1.00      1.00      1.00      6242


Confusion Matrix:
 [[2780    0]
 [   5 3457]]
```

Orogenic Deposit

```
Cross-Validation Accuracy: 99.69%
Test Accuracy: 100.00%
F1 Score: 1.00

Classification Report:
              precision    recall  f1-score   support

         0.0       1.00      1.00      1.00      2320
         1.0       1.00      1.00      1.00      1970

    accuracy                           1.00      4290
   macro avg       1.00      1.00      1.00      4290
weighted avg       1.00      1.00      1.00      4290


Confusion Matrix:
 [[2320    0]
 [   0 1970]]
```

Evaluation Metrics for Each Deposit Using F1 Score, Accuracy, and Cross-Validation

REE-Granite Deposit

```
Cross-Validation Accuracy: 97.84%
Test Accuracy: 100.00%
F1 Score: 1.00

Classification Report:
              precision    recall  f1-score   support

         0.0       1.00      1.00      1.00      2295
         1.0       1.00      1.00      1.00      2772

    accuracy                           1.00      5067
   macro avg       1.00      1.00      1.00      5067
weighted avg       1.00      1.00      1.00      5067


Confusion Matrix:
 [[2295    0]
 [   0 2772]]
```

Epithermal Deposit

```
Cross-Validation Accuracy: 100.00%
Test Accuracy: 100.00%
F1 Score: 1.00

Classification Report:
              precision    recall  f1-score   support

         0.0       1.00      1.00      1.00      2296
         1.0       1.00      1.00      1.00      2768

    accuracy                           1.00      5064
   macro avg       1.00      1.00      1.00      5064
weighted avg       1.00      1.00      1.00      5064


Confusion Matrix:
 [[2296    0]
 [   0 2768]]
```

CONCLUSIONS

1. In this research, we were focusing on 4 areas of interest which are divided into 4 deposits (porphyry, epithermal, orogenic gold, and REE) that has economic mineral potential in the South Rajasthan region. The economic valuable metals such as copper, gold, lead, zinc, and rare earth elements were analyzed using a geoscience point of view (remote sensing, geochemistry, geology. geophysics, and structural). Furthermore, we applied advanced steps using machine learning to recognize areas of interest by new approach.
2. Machine learning uses 3 algorithms, Random Forest, MLP, and SVM.
3. The results of machine learning approach were

Porphyry:
Minimum 3 potential area (North, West, and Southeast)
Mostly in Southeast area
Epithermal
Minimum 3 potential area (North, West, and Southeast)
Mostly in North area
Orogenic:
Mostly in East area
REE:
Minimum potential area: West, East, and North east
4. Propose 10 well for each rectangular

DELIVERABLES

The solution has to be submitted online in a structured manner. There will be two components:

1. Outcome / Result as 2D / 3D visualization, and
2. Documentation with following sections
3. Name and details of Participant / Company etc
4. Resources used (Hardware, Software, Manpower etc)
5. Data used in details (List of Geological, Geophysical, Geochemical, Petrological, Drill, Remote Sensing, any other datasets)
6. List of derived data layer / extracted feature, if any, from primary data
7. Description and significance of those derivative layers or extracted features vis-à-vis mineral targeting
8. Methodology in details including data preparation / cleaning / transformation operations, statistical analysis, flow chart of steps etc.
9. AI/ML algorithms and other codes written by the contestant (s)
10. Supportive documents and information related to degree of confidence, relative contribution of input layers in the final output, etc.
11. All processed data sets (outcome / result) should be in the form of grid, tiff, jpeg, doc, xls etc. The dataset should be visualized in open source/ nonproprietary software. Only soft copy/ digital form will be accepted.

Thank You