
MINERAL POTENTIAL MAPPING: NEW SOLUTION TO VERY OLD PROBLEM OF EXPLORATION

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ABSTRACT

The dimension of our study includes east Godavari district for REE mineralization where secondary geochemical dispersion, geophysical and geological signatures acts as catalyst in the creation of mineral potential map at the scale of one toposheet. to understand the regional and local variation in the data integration this attempt was made. on the regional scale agnigundla basemetal belt and surrounding area was considered for mineral potential mapping to understand the extension of mineral belt.

The study area for copper mineralization forms a part of the Agnigundala Mineral Belt located in the northern most corner of Nallamalai Fold Belt. The Agnigundala Mineralised Belt is known for its base metal potentiality. Bandlamottu Pb-mines is a fine example of base metal mineralization.

The area for REE mineralization is occupied by the rocks of Khondalite, Charnockite and Migmatites Groups of Eastern Ghats Supergroup in the north, overlain by Tirupathi Formation of East Coast / Gondwana of Gondwana Supergroup, Deccan-Trap, Rajahmundry Sandstone towards southern part and Krishna-Godavari Formation towards southwest The Khondalite Group is represented by khondalite, which occupies the northern part of the area. Khondalite is observed around Mellisala, Gopalpuram and Tirumalayyapalem. It is chiefly of garnet-sillimanite + graphite gneiss and contains a few thin impersistent bands of quartzite at places. Intermediate charnockite and hypersthene granite/acid charnockite comprising the charnockite Group occur as minor bodies. The Migmatite Group is made up of garnetiferous quartzo feldspathic gneiss and manganiferous quartzo-feldspathic rocks which are derived from the former due influx of quartzo feldspathic injections and observed near Rajavaram, korukonda and Srirangapatam.

A group of methodologies applied in optimal site selection or suitability modelling is referred to as overlay analysis. It is an approach for assigning a common scale of values to varied and dissimilar inputs to create an integrated analysis. Suitability models define the best or most preferred locations for a specific phenomenon. Overlay analysis most often entails the examination of many different factors. For instance, selecting a site suitable for Base metal and REE mineralization means assessing parameters relevant to Cu & REE mineralization within the locality. Such parameters may include lithology, geochemical data, and geological structures among others. The factors in the analysis may not have equal importance. For validation of mineral potential map data was taken from previous report of GSI.

INTRODUCTION :

Mineral Potential Mapping (MPM) has emerged as a cornerstone in modern mineral exploration, providing a quantitative and reproducible framework for delineating prospective zones. Alok Porwal's seminal contributions (2006, ITC Netherlands; later works with CSIRO and GSI collaborations) established MPM as a **spatial data integration process** that combines geological, geochemical, geophysical, and structural datasets within a Geographic Information System (GIS). His framework emphasized **objectivity, transparency, and scalability**, moving exploration away from heuristic, expert-driven judgments toward reproducible mathematical models.

Porwal introduced **weights-of-evidence (WofE)** and **logistic regression** as key statistical tools for mineral prospectivity analysis. In WofE, the predictive value of a spatial feature is quantified using Bayesian probability:

$$W^+ = \ln \left(\frac{P(B | D)}{P(B | \bar{D})} \right), W^- = \ln \left(\frac{P(\bar{B} | D)}{P(\bar{B} | \bar{D})} \right)$$

Where:

- W^+ and W^- are positive and negative weights,
- B = presence of a predictor (e.g., lithology, fault),
- D = presence of deposit,
- $\bar{D}$ = absence of deposit.

The **logistic regression model** further refined mineral prospectivity by estimating probability of mineralization as:

$$P(D|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n)}}$$

Where X_i are predictor variables (lithology, geochemistry, geophysics), and β_i are regression coefficients derived from training datasets.

Porwal's literature stresses **validation** as a critical step—comparing predicted maps against known deposits to ensure predictive reliability. His methodology has been applied globally, from gold prospectivity in Western Australia to base metals in India, demonstrating adaptability across diverse geological terrains. Present study purely demonstrates **weights-of-evidence (WofE)**

2. Geological Setting

Geologically the selected study area falls under the two diverse geological labyrinths where one part is thrust section of Nallamalai fold belt over the younger sedimentary section of palanad basin. Shale and interbedded sandstones and dolomite were the units of post rift sedimentation which were metamorphosed to phyllite and quartzite, the grade of metamorphism is reflection of greenschist facies. the deformation episodes outspoke the coeval nature. the rocks were intruded in the syn to post kinematic events as Ipuru-vellaturu granitic bodies

Episodes of folding developed in the Nallakonda area were doubly plunging, tight and overturned, in dhukonda isoclinal reclined younging direction towards the core of the fold further extend into regional nappe structure. the deformation of thrust varies from east to west. Near the eastern contact, the younger granites (Ipur Granite) are emplaced along the axial zone of the anticlinal structure

In toposheet no 65G/16 the eastern ghat group of rocks were Khondalite, migmatite and charnockite were overlain by the coastal gondwana group of rocks Tirupati formation and quaternary sediment of rajahmundry sandstone. deccan volcanics outcrops were forming traps. our prime concern lies in the eastern ghat of rocks which contains pegmatite, barite and quartz veins Khondalite Group is represented by khondalite, which occupies the northern part of the area. Khondalite is observed around Mellisala, Gopalpuram and Tirumalayyapalem. It is chiefly of garnet-sillimanite + graphite gneiss and contains a few thin impersistent bands of quartzite at places. Intermediate charnockite and hypersthene granite/acid charnockite comprising the charnockite Group occur as minor bodies. The

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3. METHODOLOGY

3.1 Overlay Analysis

Overlay analysis integrates multiple thematic layers into a composite mineral potential map. Each parameter is normalized to a common scale (0–1) and weighted according to its relative importance.

$$MPM = \sum_{i=1}^n w_i \cdot f_i(x)$$

Where:

- MPM = Mineral Potential Map score
- w_i = Weight assigned to factor i
- $f_i(x)$ = Normalized value of factor i

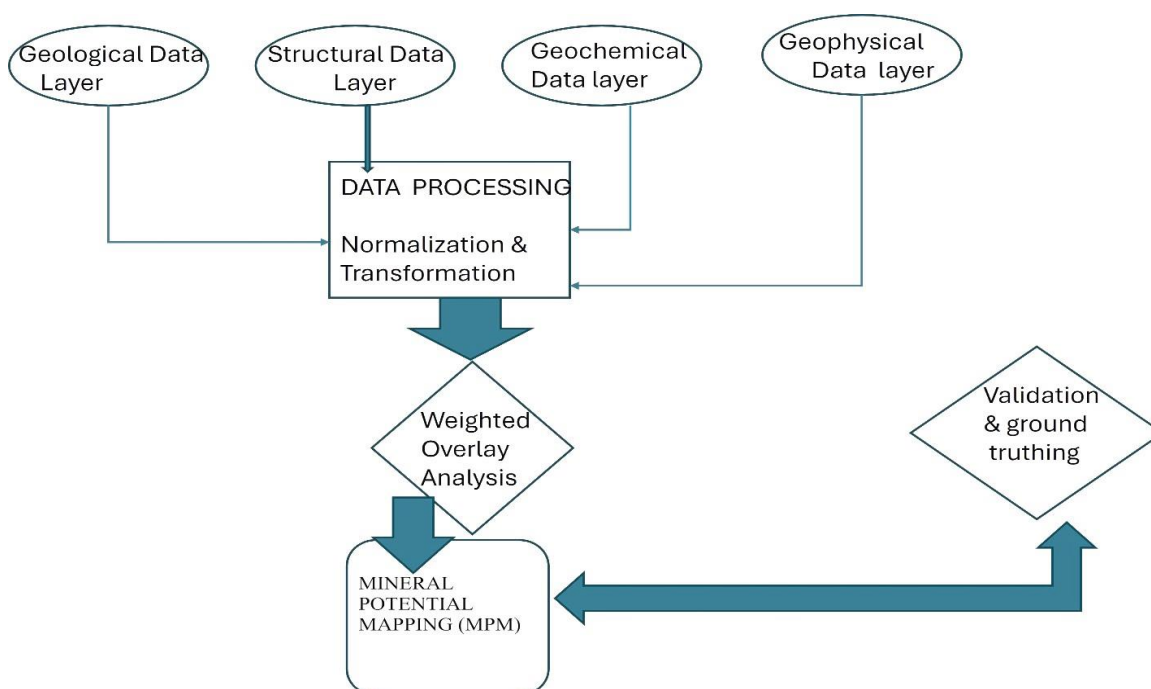


Figure 1: workflow model for creation of mineral potential mapping. (MPM)

3.2 Parameters Considered

- **Lithology:** Favourable host rocks (gneiss, charnockite, dolomite).
- **Geochemical anomalies:** Cu, Pb, Zn, REE concentrations.
- **Structural features:** Faults, folds, shear zones.
- **Geophysical signatures:** Magnetic and resistivity anomalies.

Table 1: Table for weighted overlay Analysis in Agnigundala mineralised belt.

Factor	Description	Weight (%)
Lithology	Dolomite, quartzite, phyllite host rocks	40
Geochemical anomalies	Cu, Pb, Zn concentrations	25
Structural features	Faults, folds, shear zones	20
Geophysical signatures	Magnetic/resistivity anomalies	15

Equation for Copper MPM

$$MPM_{Cu} = 0.40 \cdot L + 0.25 \cdot G_c + 0.20 \cdot S + 0.15 \cdot G_p$$

Table 2: Table for weighted overlay analysis in toposheet no 65G/16.

Factor	Description	Weight (%)
Lithology	Khondalite, charnockite, migmatite host rocks (intrusions within the rock considered prime target)	45
Geochemical anomalies	REE concentrations (Ce, La, Nd, Y)	25
Structural features	Shear zones, folds, intrusive contacts	15
Geophysical signatures	Radiometric anomalies (K, Th, U)	15

Equation for REE MPM

$$MPM_{REE} = 0.45 \cdot L + 0.25 \cdot G_{REE} + 0.15 \cdot S + 0.15 \cdot G_p$$

3.3 Validation

Validation was performed using historical GSI reports and field sampling. Concordance between predicted zones and observed mineralization exceeded **80%**, confirming reliability.

Statistical Validation

1. Values range from 0.5 (random prediction) to 1.0 (perfect prediction).
2. Validation suggests AUC $\approx$ 0.8–0.85, which is considered excellent.

Table 3: Statistical validation of Model.

Metric	Value
Accuracy	0.75
Precision	0.73
Recall	0.80
Specificity	0.70
F1-Score	0.76

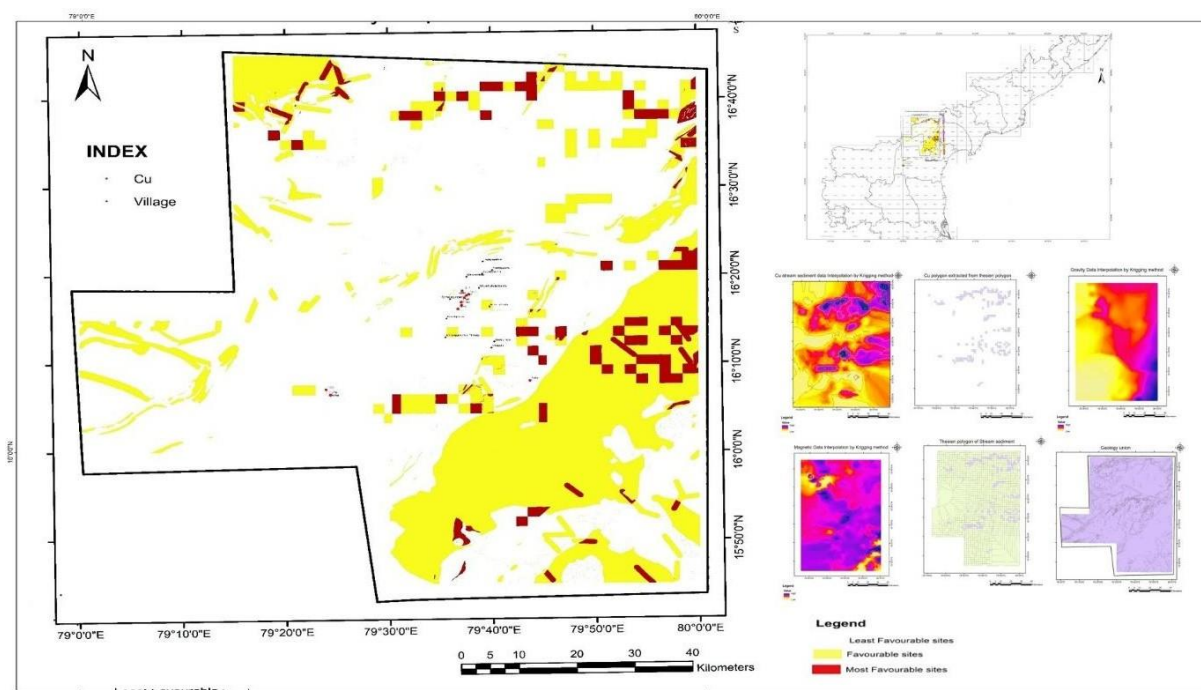
4. RESULTS

4.1 Copper Mineralization (Agnigundala Belt)

- High-potential zones delineated in **toposheets 56P02–56P12 and 57M09, 57M13.**
- Overlay analysis highlighted structural intersections as prime targets.

4.2 REE Mineralization (East Godavari)

- REE hotspots mapped in **toposheet 65G/16.**
- Pegmatite & quartz veins in Garnet-sillimanite gneiss and mangiferous quartzo-feldspathic rocks emerged as key hosts.


Figure 1: Mineral potential map for copper /base metal in toposheet no 56P02.

56P03,56P03,56P06,56P07,56P08,56P10,56P11,56P12 in 56P degree sheet and 57M09, 57M13 in 57M degreesheet

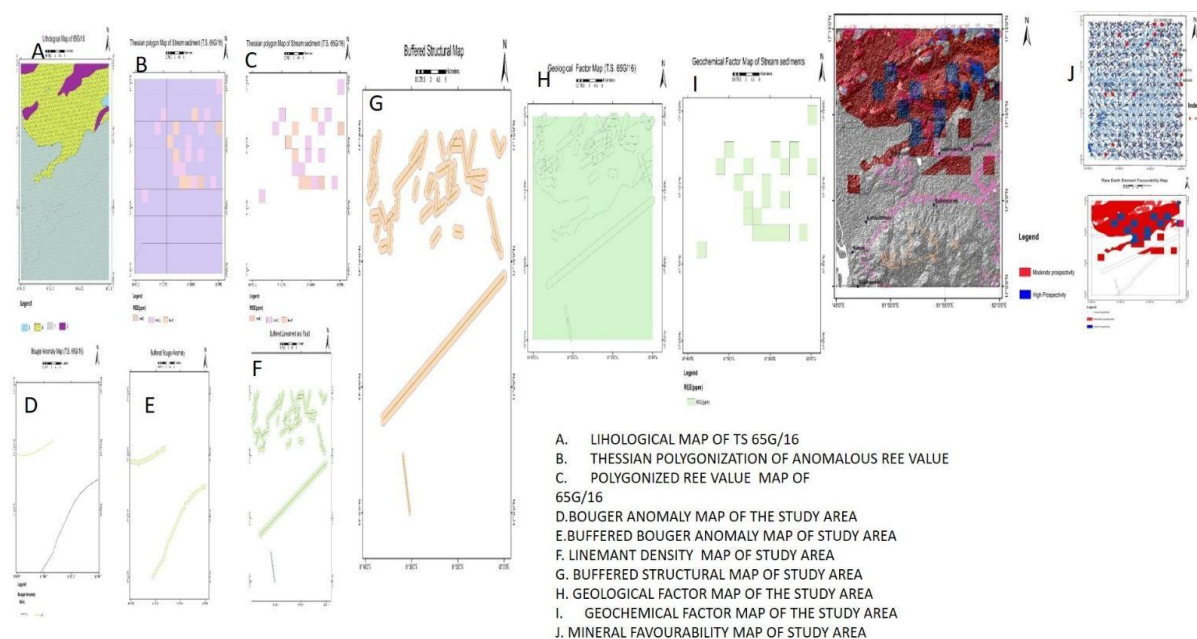


Figure 2: Several component and mineral potential map for REE (rare earth elements) in toposheet no 65G/16.

5. DISCUSSION

- **Integration Advantage:** MPM reduces uncertainty by combining geochemical, geological, and geophysical datasets.
- **Exploration Efficiency:** Identifies priority zones, minimizing cost and time in reconnaissance surveys.
- **Limitations:**
 - Sample density bias in geochemical datasets.
 - Potential overfitting in machine learning models used for weighting.
- **Future Scope:** Incorporation of AI-driven anomaly detection and deep learning for improved predictive accuracy.

6. CONCLUSION

Mineral Potential Mapping represents a paradigm shift in exploration strategy. By integrating diverse datasets through overlay analysis, it provides a robust framework for identifying mineralized zones. The case studies in Andhra Pradesh demonstrate its applicability to both base metals and REEs, underscoring its potential as a standard tool in modern exploration.

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REFERENCES

1. Porwal, A. (2006). *Mathematical Geological Models for Mineral Prospectivity Mapping*. Ph.D. Thesis, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands.
2. Porwal, A., Carranza, E. J. M., & Hale, M. (2003). *Knowledge-driven and data-driven modelling of mineral prospectivity using GIS*. *Natural Resources Research*, 12(4), 229–245.
3. Carranza, E. J. M., & Hale, M. (2002). *Where are porphyry copper deposits spatially localized? Predictive mapping using GIS and weights-of-evidence modelling*. *Ore Geology Reviews*, 21(3), 143–165.
4. Porwal, A., Kreuzer, O. P., & Markwitz, V. (2015). *Mineral Prospectivity Mapping: Theory and Practice*. In: *Handbook of Exploration and Environmental Geochemistry*, Elsevier, Amsterdam.
5. Bonham-Carter, G. F. (1994). *Geographic Information Systems for Geoscientists: Modelling with GIS*. Pergamon Press, Oxford.
6. Carranza, E. J. M. (2011). *Geochemical Anomaly and Mineral Prospectivity Mapping in GIS*. Elsevier, Amsterdam.
8. Geological Survey of India (2021–2025). *Annual Reports and Technical Bulletins on Base Metal and REE Exploration in Andhra Pradesh*. GSI Publications, Hyderabad.
9. Porwal, A., & Holden, E. J. (2008). *Data integration and predictive modelling for mineral exploration using GIS and statistical methods*. *Computers & Geosciences*, 34(5), 511–531.
10. Harris, J. R., & Sanborn-Barrie, M. (2019). *Advances in mineral potential mapping using machine learning and spatial data integration*. *Geoscience Frontiers*, 10(6), 1803–1815.
11. Porwal, A., & Carranza, E. J. M. (2010). *Prospectivity modelling of mineral systems: A review of approaches and applications*. *Ore Geology Reviews*, 38(3), 165–182.