# Optimal Exploration Target Zones

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# Outline

# OVERVIEW OF HYPERSPECTRAL REMOTE SENSING



Hyperspectral sensors

- record the reflectance in many narrow contiguous bands
- various parts of the electromagnetic spectrum (visible - near infrared - short wave infrared)
- at each part of the electromagnetic spectrum results in an image

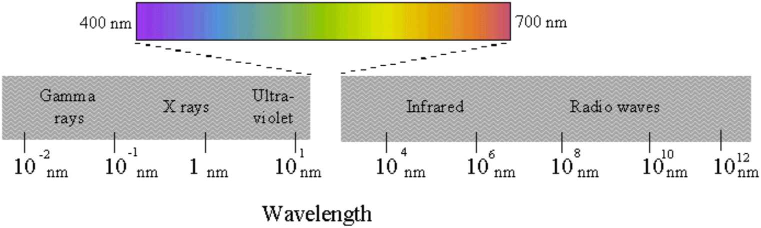


Figure: Spectral Range

# OVERVIEW OF HYPERSPECTRAL REMOTE SENSING (cont. . . )

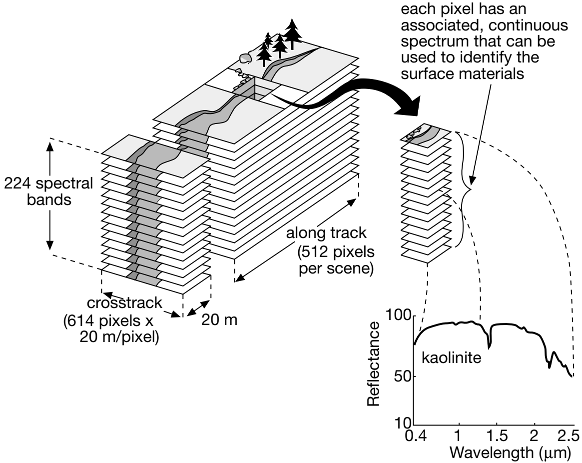


Figure: Hyperspectral cube

# OVERVIEW OF HYPERSPECTRAL REMOTE SENSING (cont. . . )



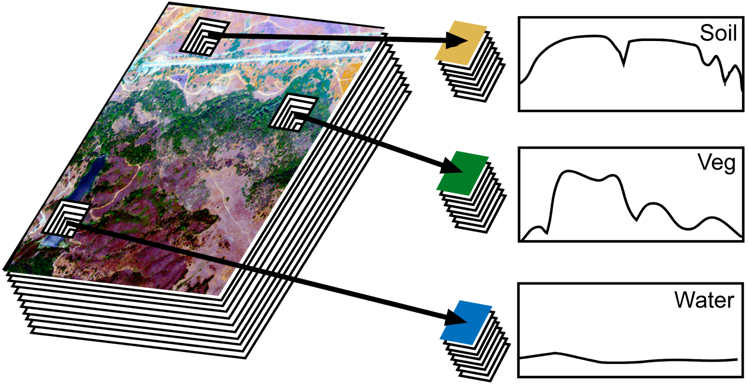


Figure: Pixels in hyperspectral image

# OVERVIEW OF HYPERSPECTRAL REMOTE SENSING (cont. . . )

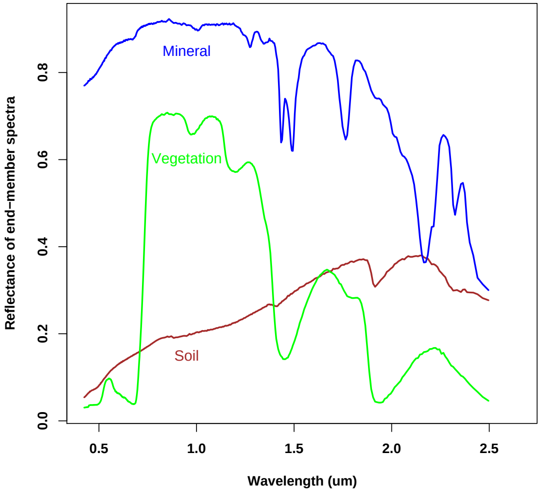


Figure: Example of 3 different spectral signatures

# BACKGROUND AND OBJECTIVE OF STUDY

The location of known mineral occurrences (mines/prospects) are used for training in data-driven predictive mapping of prospective ground. Particular methods for obtaining a mineral prospective map are

- the weights-of-evidence (WofE) method
- logistic regression
- canonical favorability analysis
- neural networks
- evidential belief functions

# BACKGROUND AND OBJECTIVE OF STUDY (cont. . . )

Mineral prospectivity maps are then usually used to guide further mineral exploration. A logical question regarding efficacy of mineral prospectivity maps is: “Where should targets of exploration for undiscovered mineral occurrences be focussed?”

The objective of this study is to demonstrate a methodology that we have developed in order to provide a plausible answer to the above question in a district-scale case study.

# STUDY SITE



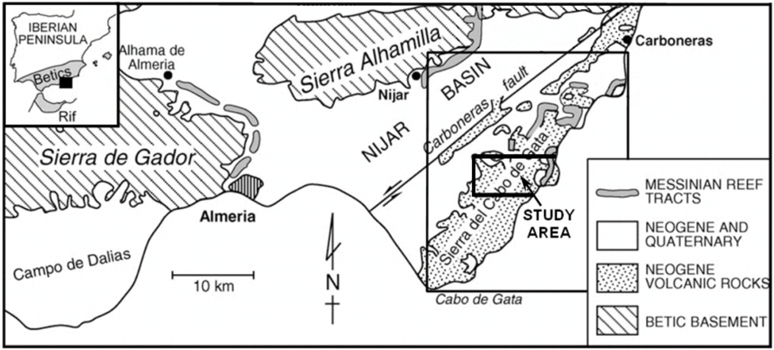


Figure: A generalized geological map of the Rodalquilar area mineral district.

# DATA USED

- Two sets of locations of mineral deposit occurrences, from different sources, were used in WofE modeling.
- Set 1: 14 epithermal deposits and set 2: 36 epithermal deposits.
- Set 2: Training set for WofE and designing optimal exploration target zones.
- Set 1: Validation of WofE and optimal exploration target zones.
- HyMap: 126 bands – 0.4–2.5 $\mu$m
- Geology: 30 bands – 1.95–2.48 $\mu$m
- Distinctive absorption features at wavelengths near 2.2 $\mu$m

# DATA USED (cont. . . ): CREATION OF BAND RATIO AS EVIDENCES



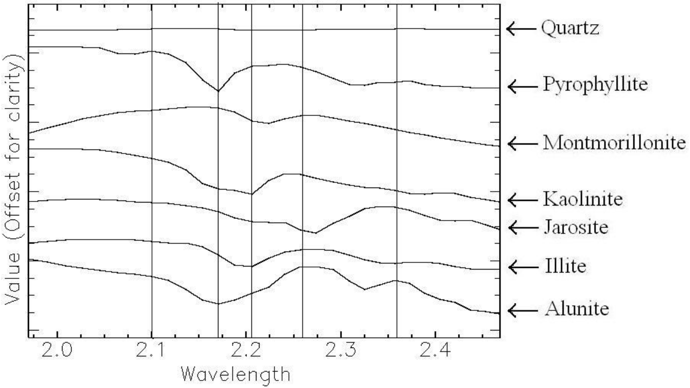


Figure: Plot of seven endmembers from USGS spectral library in the spectral range 1.95–2.48 $\mu$m. Vertical lines indicate the band centers used to obtain band ratio images (see text for further information).

# DATA USED (cont. . . ): CREATION OF BAND RATIO AS EVIDENCES



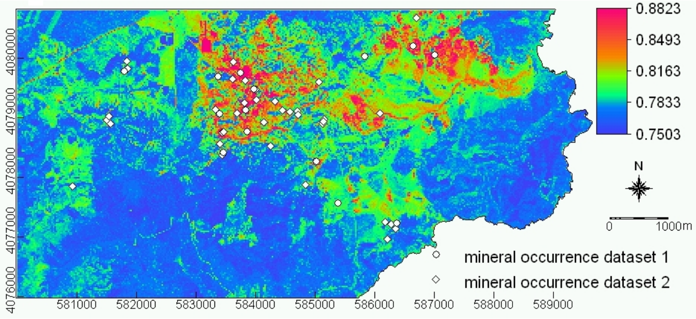


Figure: Band Ratio 1: arctan transformation on bands 103/107 (2.100/2.171 $\mu$m).

# DATA USED (cont. . . ): CREATION OF BAND RATIO AS EVIDENCES



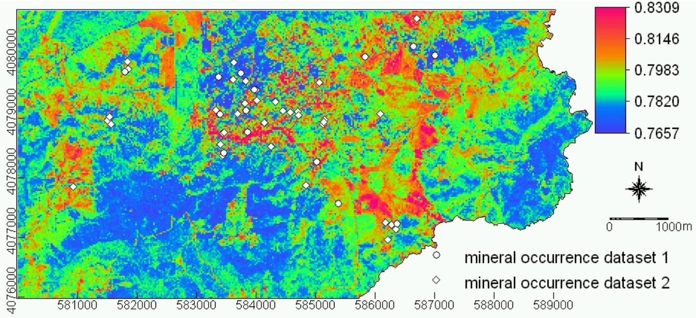


Figure: Band Ratio 2: arctan transformation on bands 107/109 (2.171/2.205 $\mu$m).

# DATA USED (cont. . . ): CREATION OF BAND RATIO AS EVIDENCES



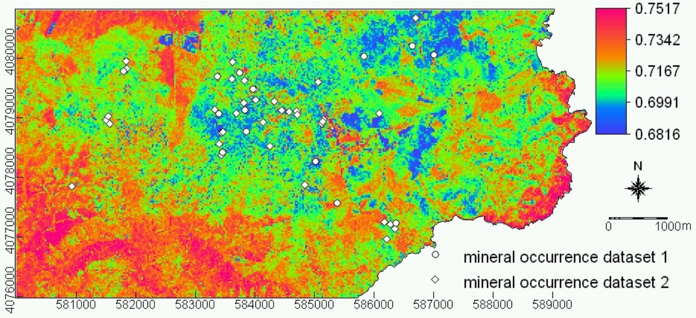


Figure: Band Ratio 3: arctan transformation on bands 118/112 (2.357/2.258 $\mu$m).

# DATA USED (cont. . . ): CREATION OF STRUCTURAL EVIDENCE



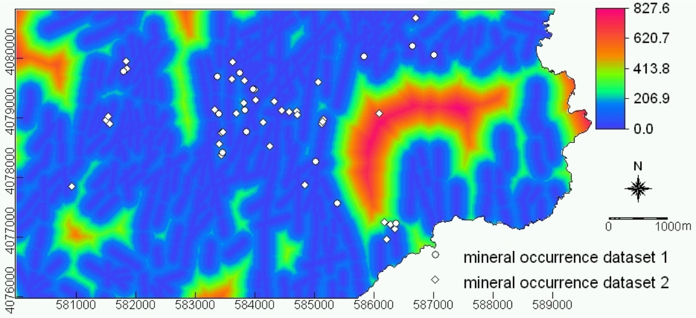


Figure: Distance to fault and fracture. Increasing pixel brightness in this image indicates increasing distance from a fault or fracture.

# METHODS



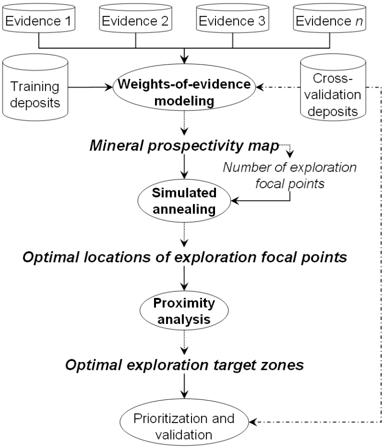


Figure: Flow diagram describing the process.

# METHODS (cont. . . ): ESTIMATION OF THE NUMBER OF EXPLORATION FOCAL POINTS



To estimate the number of exploration focal points, we used the binomial distribution – mineral deposit occurrence is a binary variable, being either present or absent.

Thus, estimation of $n$ exploration focal points so as to yield (or discover) at least $r$ mineral deposit occurrences, with a probability of success $p$, at a 95% confidence, requires a solution for the following equation:

$$\sum_{i=r}^{n} \binom{n}{i} p^i (1-p)^{n-i} = 0.95\,. \tag{1}$$

$$\phi_{\mathrm{WMSD+V}}(\mathbf{S}^n) = \frac{\lambda}{N(A)} \sum_{\vec{\mathbf{x}} \in A} P(\vec{\mathbf{x}}) \left|\left| \vec{\mathbf{x}} - Q_{\mathbf{S}^n}(\vec{\mathbf{x}}) \right|\right| + (1-\lambda) s^2(O_{\mathbf{S}^n}) \,, \qquad (2)$$

where $Q_{\mathbf{S}^n}(\vec{\mathbf{x}})$ is the location vector of an optimal exploration focal point in $\mathbf{S}^n$ nearest to $\vec{\mathbf{x}}$, and $s^2(O_{\mathbf{S}^n})$ is the variance of the posterior odds.

# RESULTS: ESTIMATION OF THE NUMBER OF EXPLORATION FOCAL POINTS



Assume

- $r = 9$ based on the nine predicted out of 14 undiscovered epithermal occurrences in training set 1
- $p = 0.0025$ based on the average posterior probabilities of prospective pixels in the input WofE prospectivity model

With these assumptions we derive $n = 6280$.
Instead of $p = 0.0025$, we used $p = 0.6$ based on the approximate prediction rate of the input WofE model.
Accordingly, $n = 22$

# RESULTS (cont. . . ): OPTIMIZED TARGET ZONES



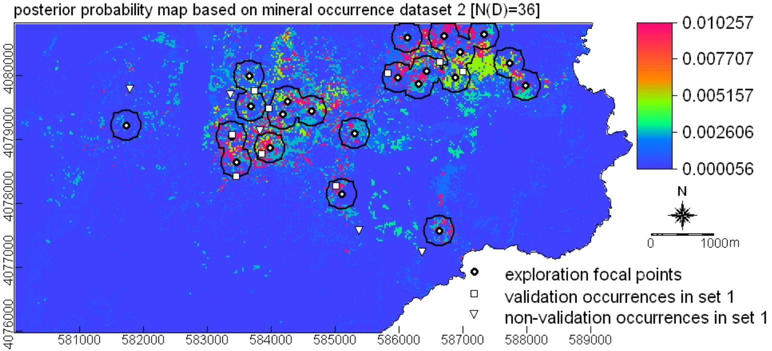


Figure: Optimal exploration target zones defined by buffering to 238 m each of the optimal exploration focal points.

# RESULTS (cont. . . ): OPTIMIZED TARGET ZONES



- Total area represented by the 6280 unit cells is approximately $6280 \times 25^2 = 3925000\,\text{m}^2$.
- Delineated sub-area of $3925000/22 = 178409\,\text{m}^2$
- If assumed undiscovered deposit is within a radius of $\sqrt{178409/\pi} = 238\,\text{m}$ (area of circle $= \pi \times \text{radius}^2$) around a derived optimal exploration focal point – then close.
- Each of the 22 allocated focal points of exploration targets was thus buffered to a radius of 238 m to delineate exploration zones.

# RESULTS (cont. . . ): OPTIMIZED TARGET ZONES



- Seven of the nine (assumed) undiscovered occurrences, delineated by the WofE model out of the 14 cross-validation undiscovered occurrences, are within the 238 m buffered exploration target zones.
- The result of this analysis indicates that allocated focal points of exploration targets are proximal to undiscovered epithermal occurrences.