Applied Deep Learning of Spatial Data

Why Do We Need Machine Learning?

We need machine learning for tasks that are too complex for humans to code directly. So instead, we collect lots of examples that specify the correct output for a given input. A machine learning algorithm then takes these examples and produces a program that does the job.

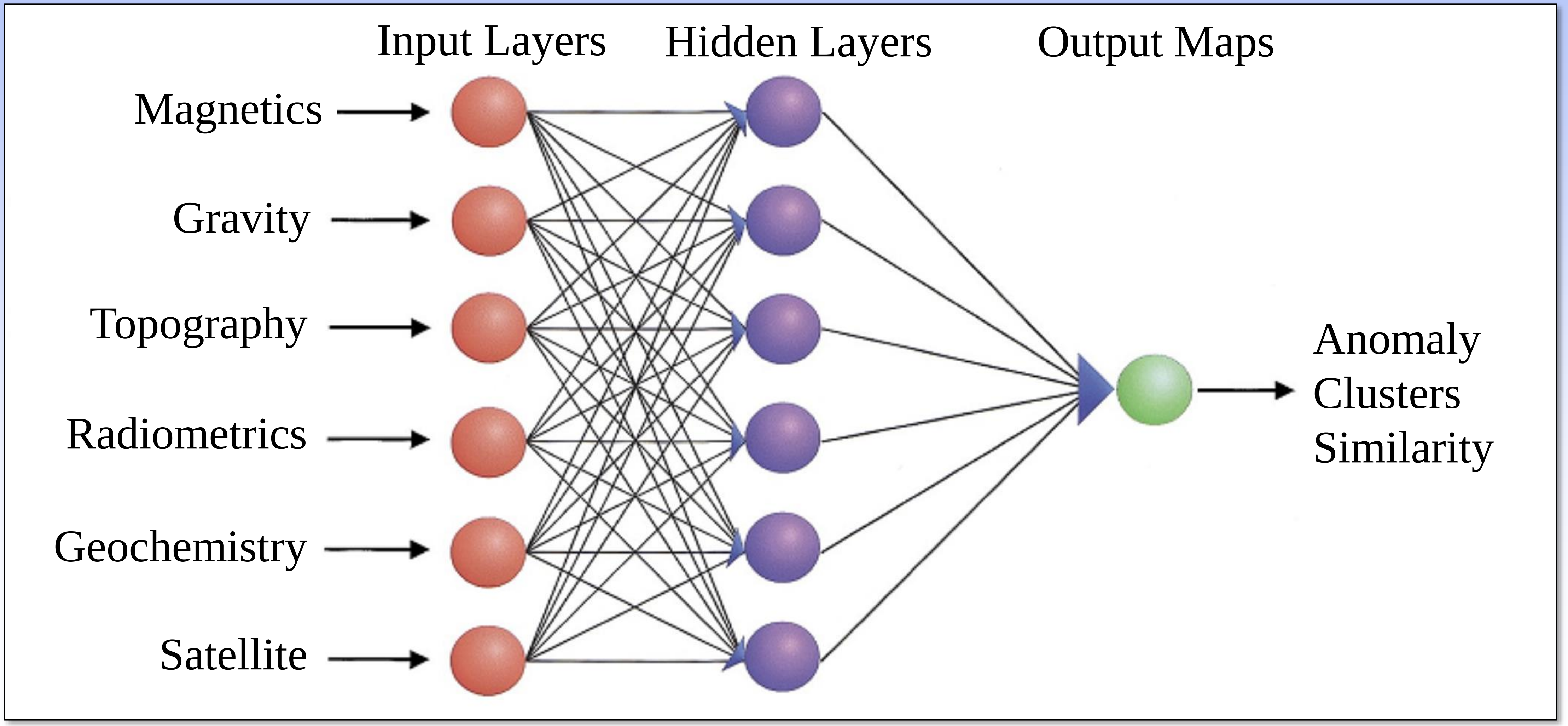
Some examples of tasks best solved by machine learning include:

- Recognizing patterns: objects in real scenes, facial identities or facial expressions, and/or spoken words
- Recognizing anomalies: unusual sequences of credit card transactions, unusual patterns of sensor readings in a nuclear power plant
- Prediction: future stock prices or currency exchange rates

Artificial Neural Networks (ANN)

- Inspired by the biological processes of the brain
- Learns by example
- Generalises from experience
- Automatically produce predictions

Artificial Neural Networks



Artificial Neural Network Analysis

- ANNs are one set of algorithms used in deep learning
- ANNs are good at:

  - Analysing large amounts of complex data

  - Identifying relationships between data layers

  - Recognising patterns and associations

  - Making predictions automatically
- Powerful analysis tool that can explore the complete set of data layers
- Decision support for the Geologist
- Orders of magnitude more time efficient than conventional methods

Types of Artificial Neural Networks

- **Unsupervised**:
  - Feedforward
  - The ANN model is only given input information and by learning, forms a structure representing the relationship between the input layer; this structure can then be analysed to find anomalies and clusters within the data
- **Supervised**:
  - Back propogation
  - An ANN model learns to predict specified target outputs based on input information. The model can than then be used to search for other targets eg. using a know mineral deposit to look for similarities within the data

ANN Analysis Techniques

Five types of neural analysis can be performed:

- Anomaly Detection
- Cluster Identification

UNSUPERVISED

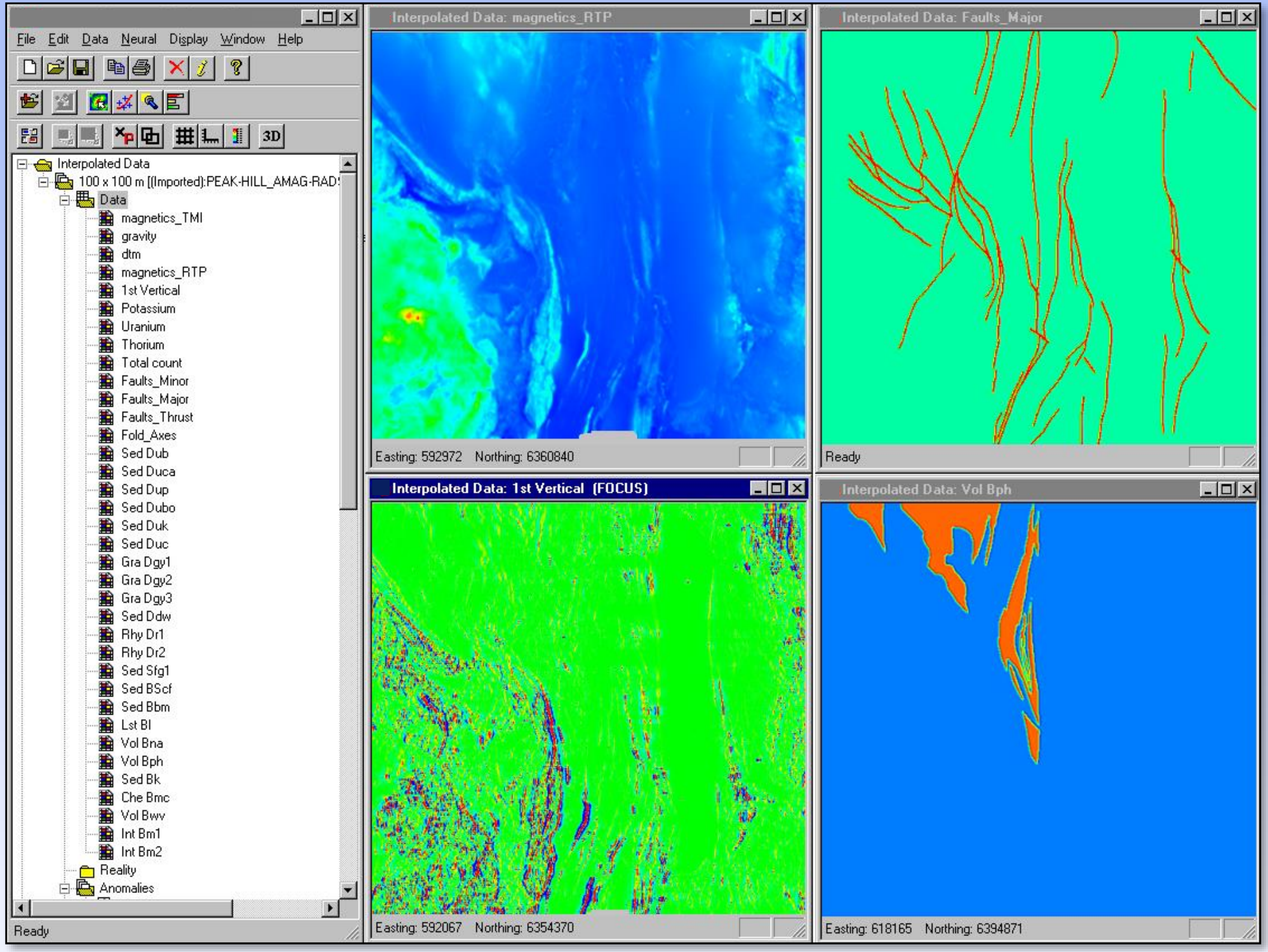
- Correlation Analysis
- Relationship Analysis
- Fuzzy Searching

SUPERVISED

Data Input & Output

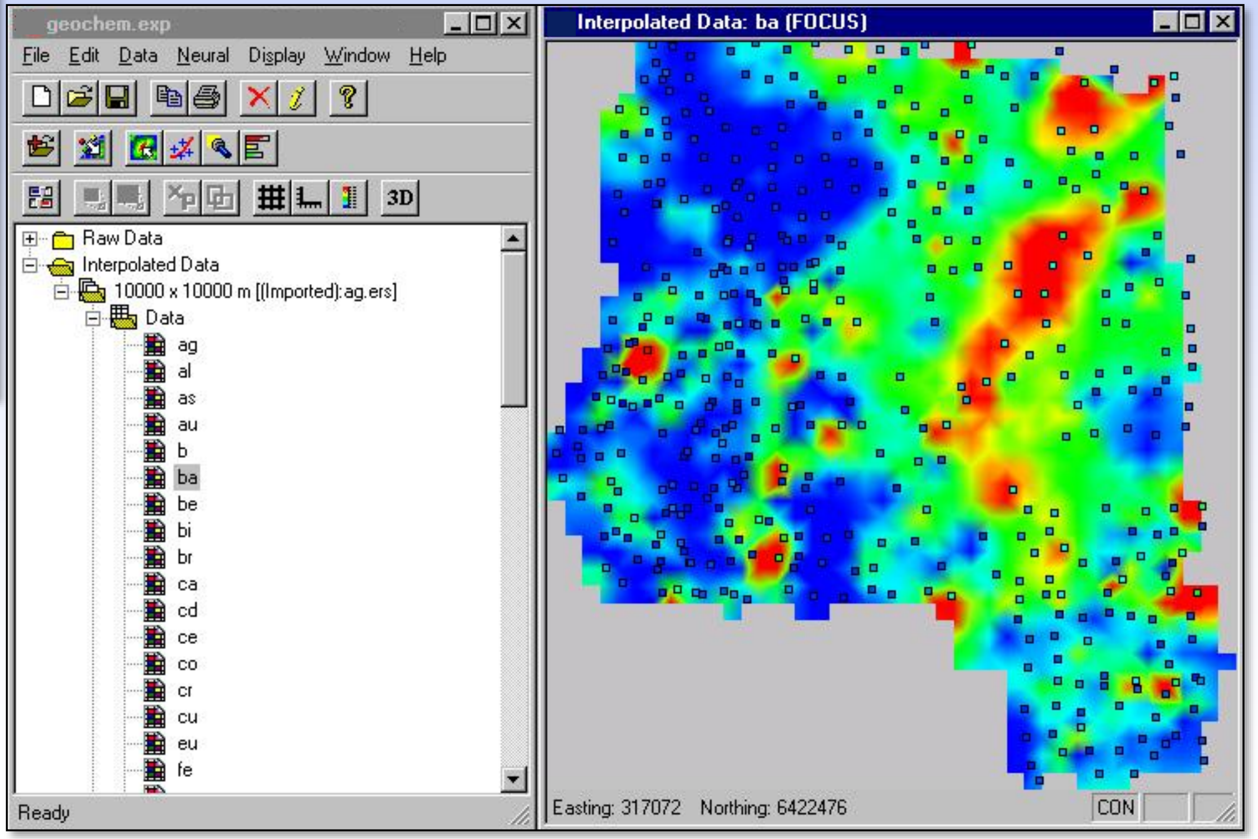
- Data Input
  - Gridded data – CSV, ER mapper, Geosoft, GIS
  - Geochemical, geological, geophysical, topographical, satellite etc.
  - Multiple DXF overlays

- Analysis Output
  - Image files
  - ER Mapper, Geosoft, MapInfio, ArcView



Prospect scale:

soil samples – 50 elements

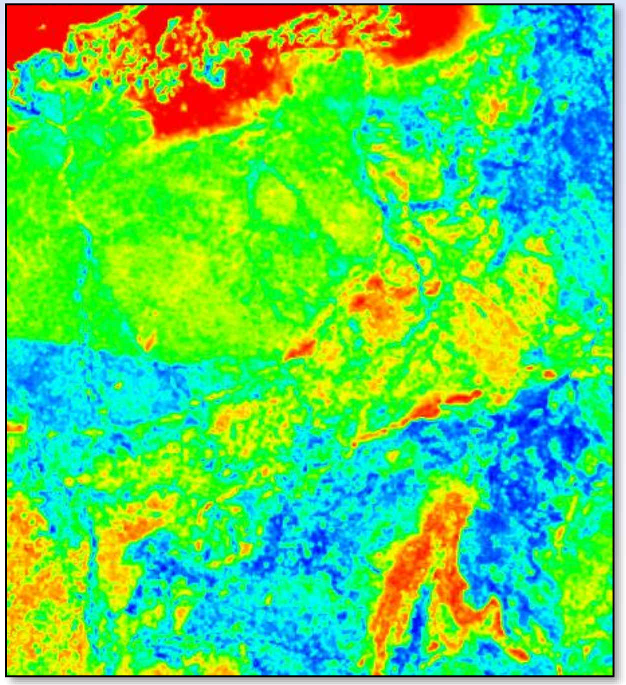


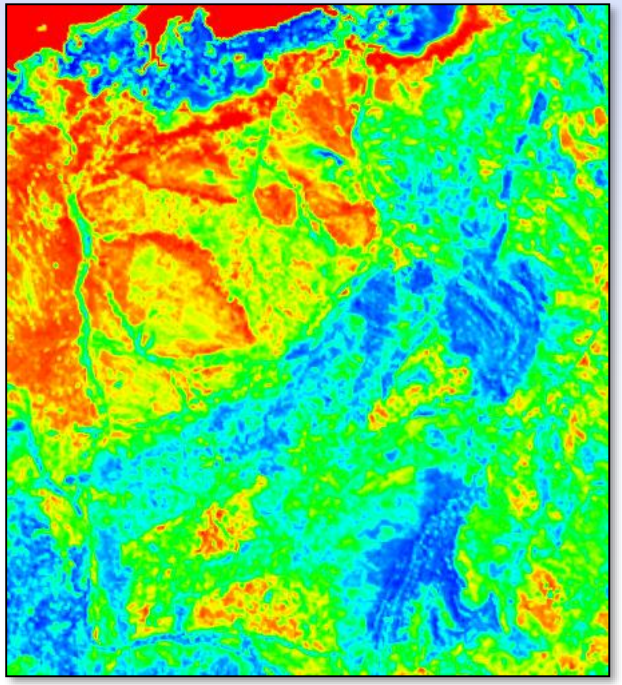
Regional scale data layers:

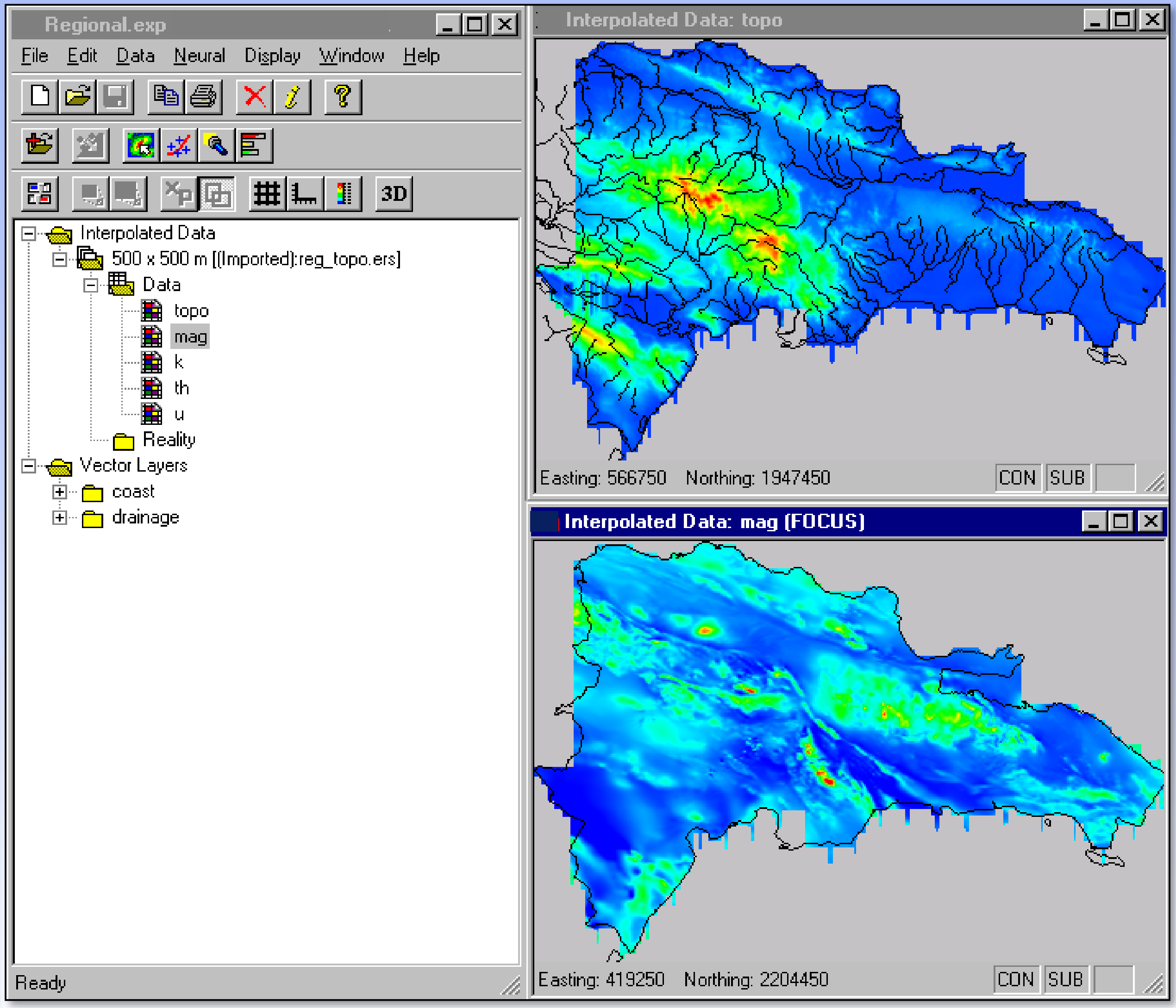
- Airborne magnetics
- Structural – 1st order faults,
- Processed magnetics - 1vd
- Geology layers

Regional scale hyperspectral data

- clay
- silica







Country scale data

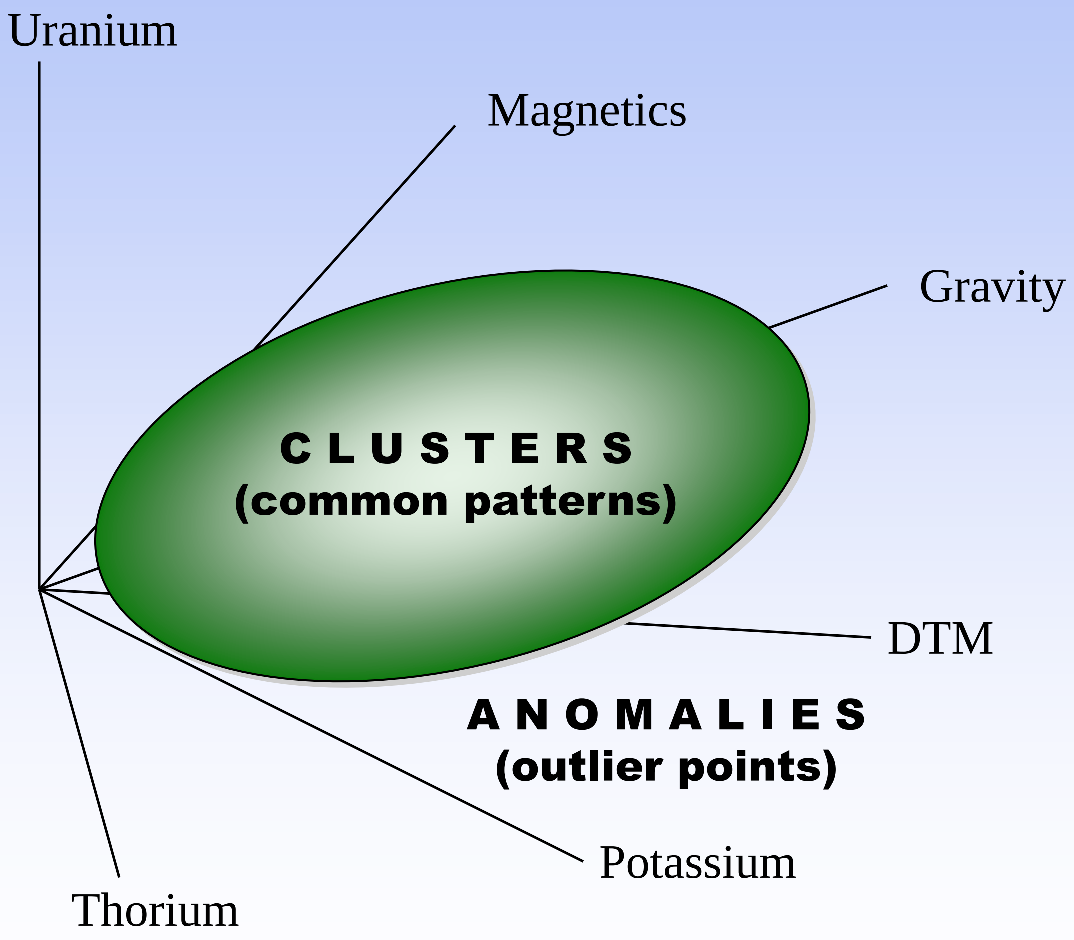
- Topography
- Airborne magnetics
- DXF overlays

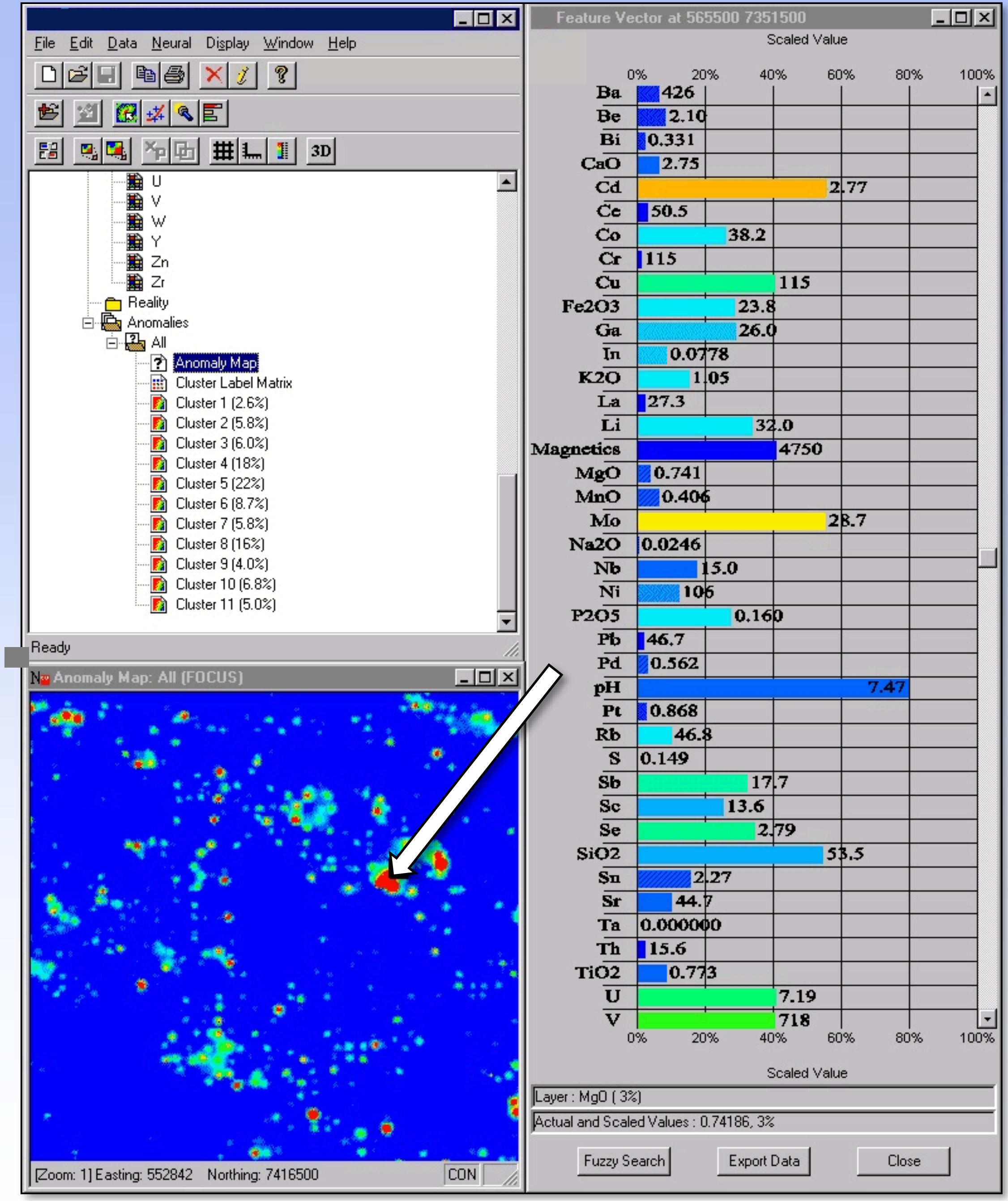
ANN Anomaly Analysis

- Features:
  - Identifies regions that are anomalous
  - Evaluates *how* anomalous these regions are
  - Relates anomalies back to the data with the ability to interrogate each anomaly
  - Fully automatic operation

- Control by:
  - Selection of survey layers
  - Region of interest
  - Training duration

Anomaly Detection





Anomaly analysis

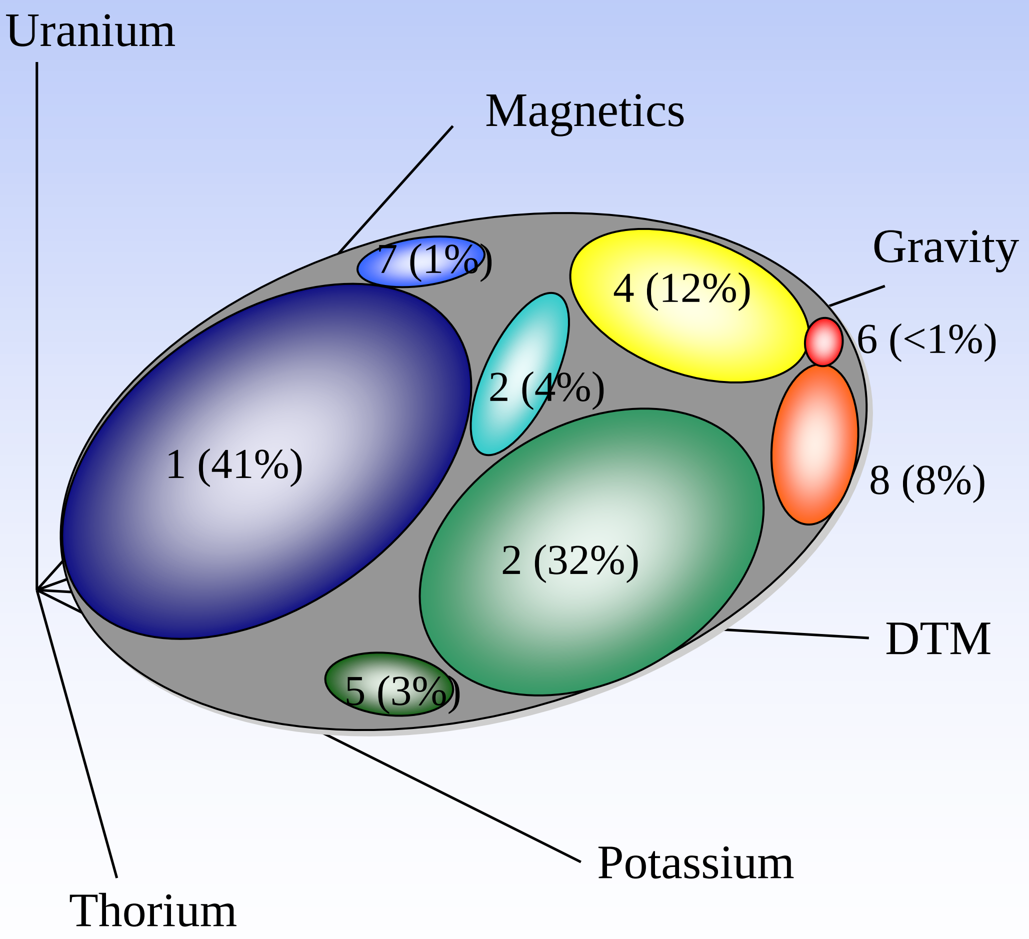
The Feature Vector Plot (FVP) shows the values at particular anomalies.

The colour of the histogram indicates which data layers are the most significant in determining the anomaly.

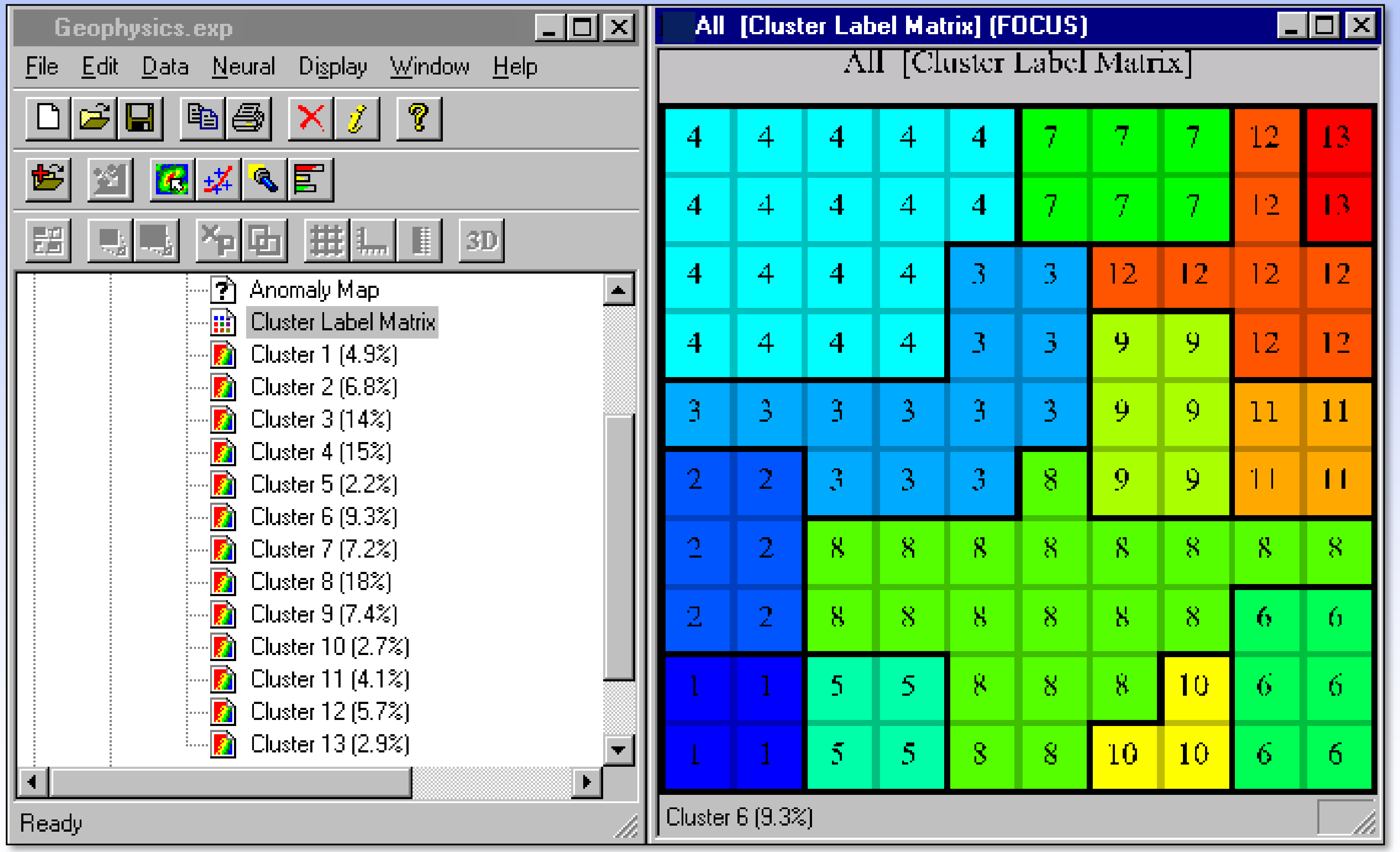
Cluster Analysis

- Extraction of pattern groups
  - common pattern types eg lithology
  - character of each cluster type
- Aids geoscientist:
  - Visualising geoscience data
  - Evaluating types of patterns within survey site
  - Geoscientist can interpret clusters according to the geological setting e.g. lithology and alteration zones

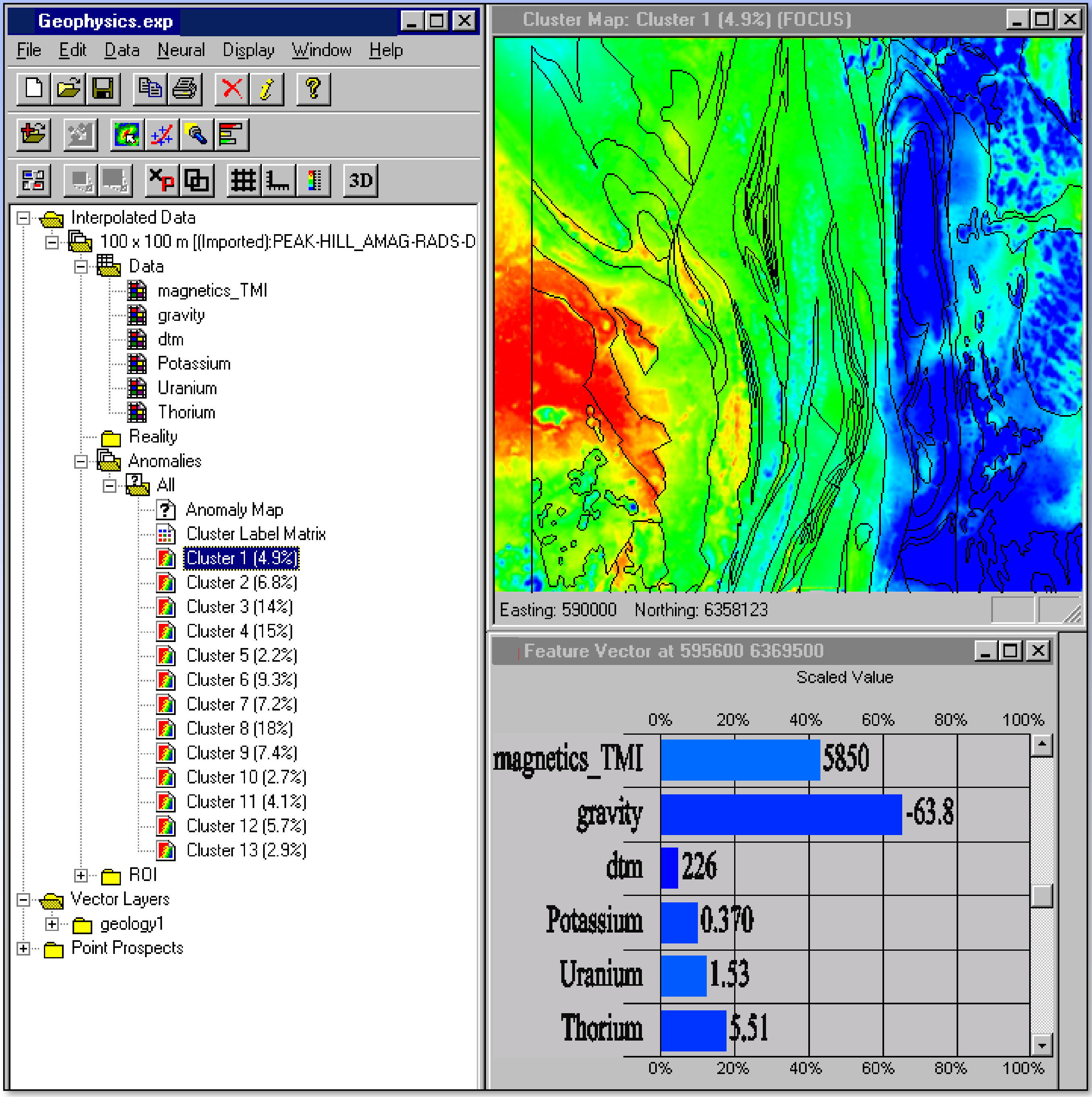
Cluster Identification



Cluster Label Matrix

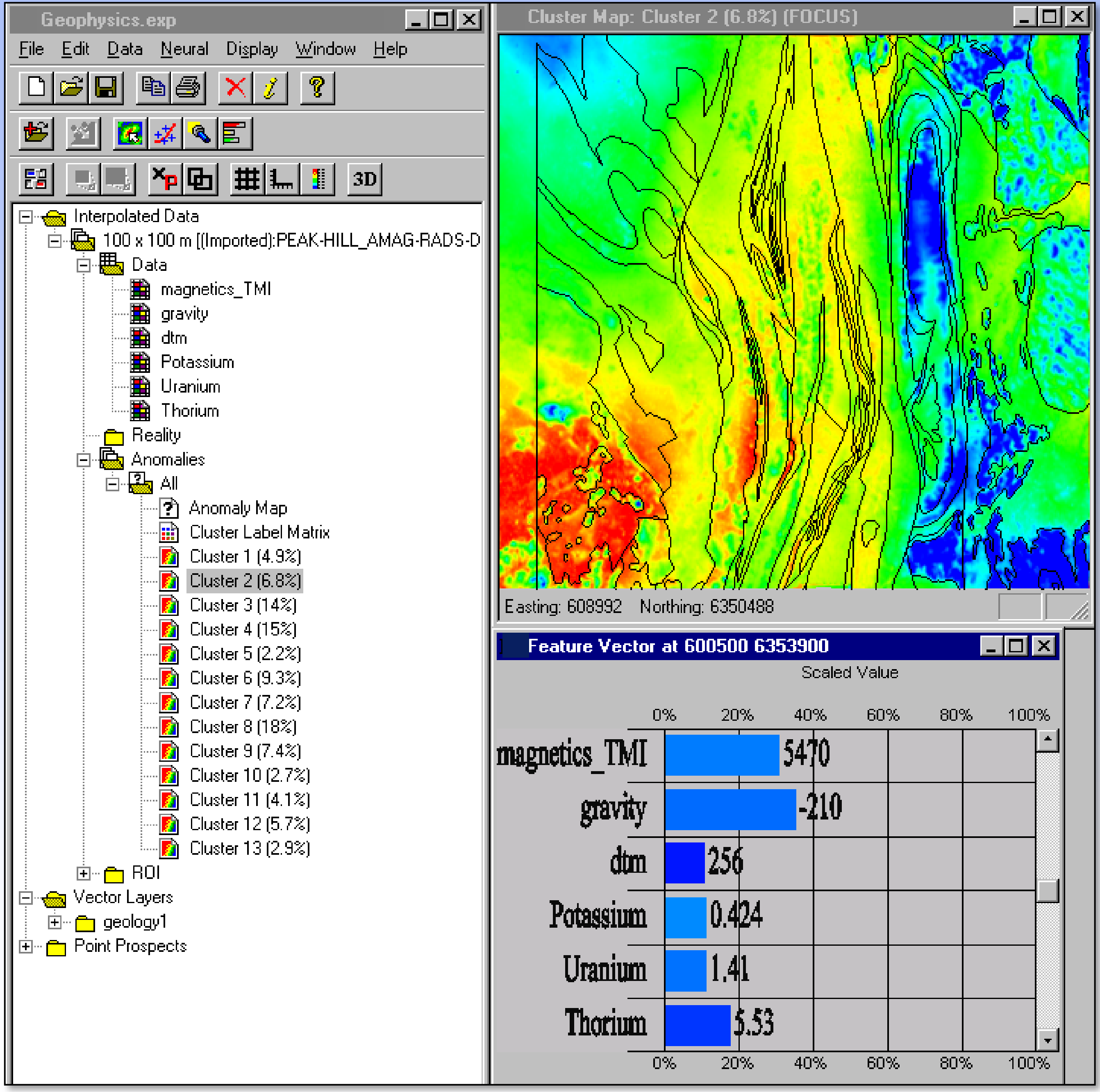


13 clusters identified in geophysical data

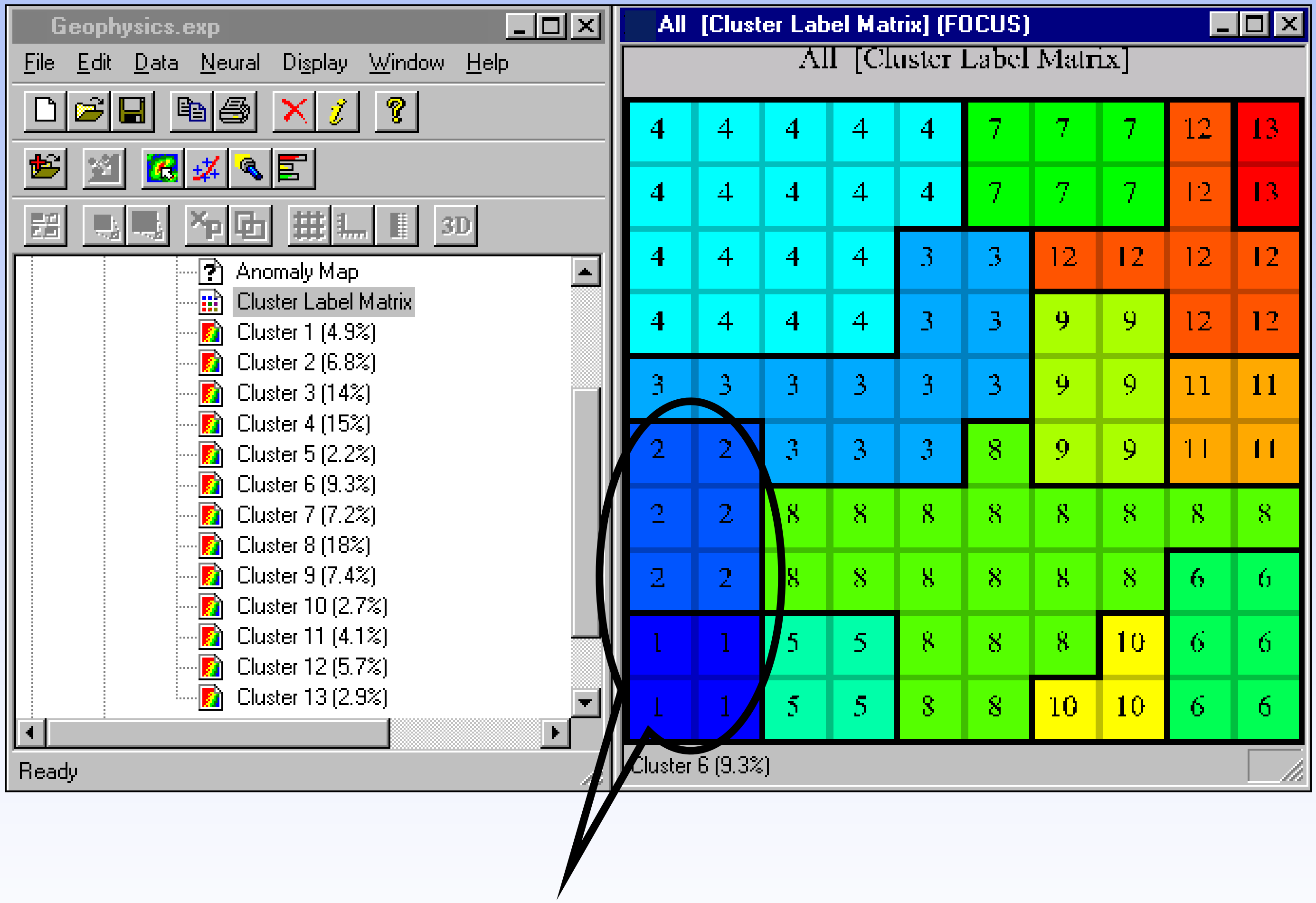


Cluster 1

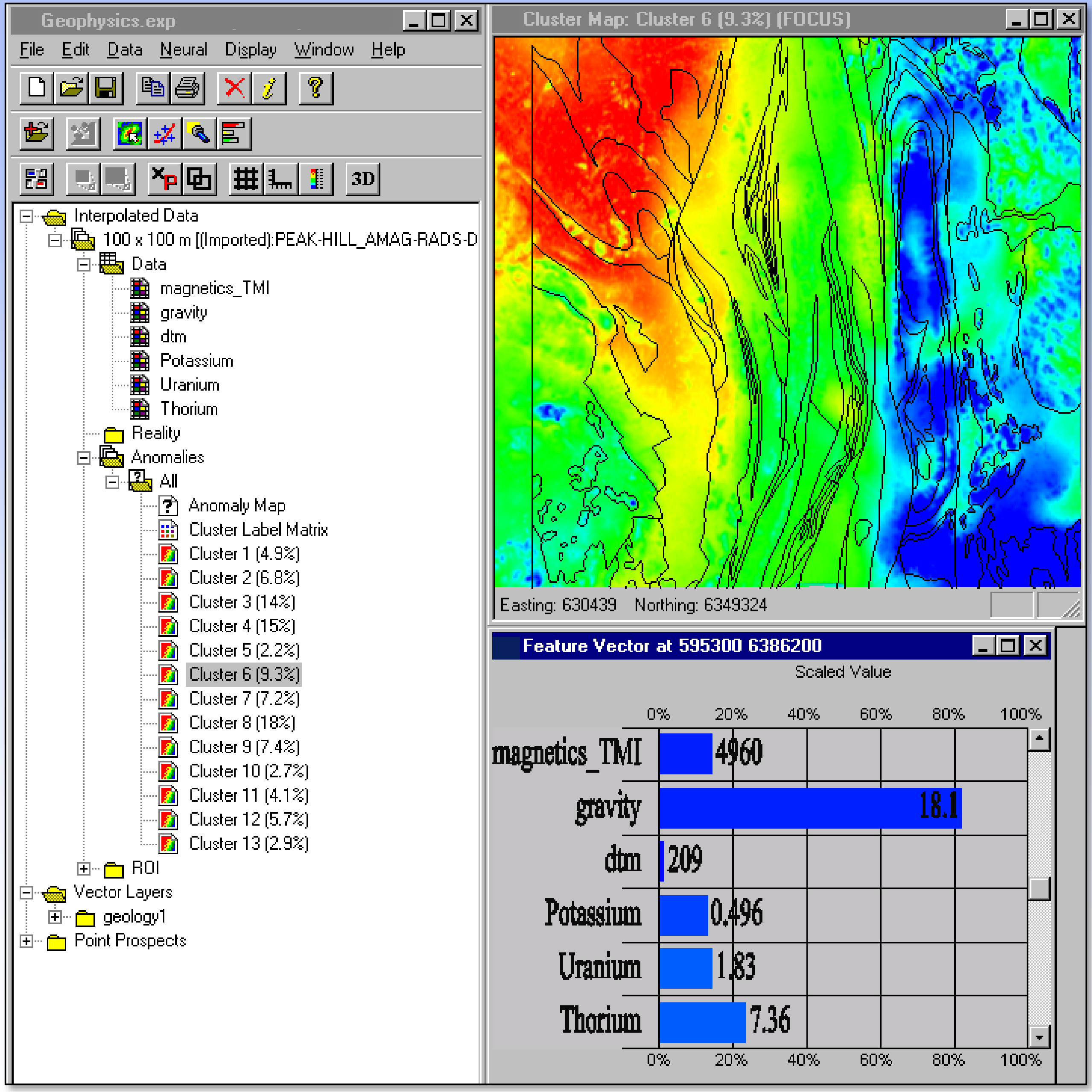
Feature Vector Plot shows the geochemical signature of this particular cluster. This may be mapping out a lithological boundary.


Geophysics.exp
File Edit Data Neural Display Window Help
3D
Interpolated Data
100 x 100 m [(Imported):PEAK-HILL_AMAG-RADS-D
Data
magnetics_TMI
gravity
dtm
Potassium
Uranium
Thorium
Reality
Anomalies
All
Anomaly Map
Cluster Label Matrix
Cluster 1 (4.9%)
Cluster 2 (6.8%)
Cluster 3 (14%)
Cluster 4 (15%)
Cluster 5 (2.2%)
Cluster 6 (9.3%)
Cluster 7 (7.2%)
Cluster 8 (18%)
Cluster 9 (7.4%)
Cluster 10 (2.7%)
Cluster 11 (4.1%)
Cluster 12 (5.7%)
Cluster 13 (2.9%)
ROI
Vector Layers
geology1
Point Prospects
Cluster Map: Cluster 2 (6.8%) (FOCUS)
Easting: 608992 Northing: 6350488
Feature Vector at 600500 6353900
Scaled Value
0% 20% 40% 60% 80% 100%
magnetics_TMI 5470
gravity -210
dtm 256
Potassium 0.424
Uranium 1.41
Thorium 5.53

Cluster 2



Cluster 1 and 2 are contain similar data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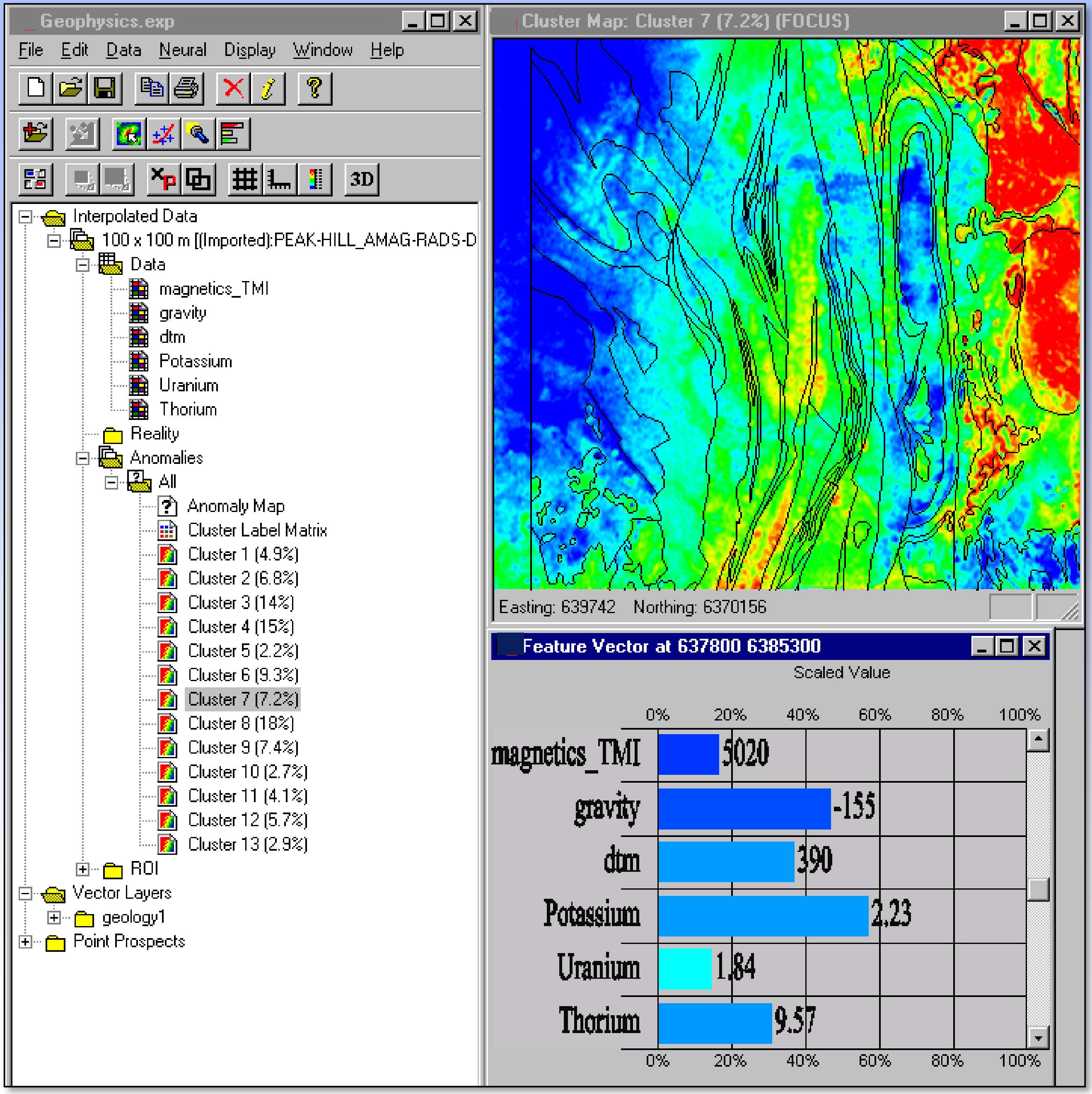
Cluster 7 (7.2%)
Cluster 8 (18%)
Cluster 9 (7.4%)
Cluster 10 (2.7%)
Cluster 11 (4.1%)
Cluster 12 (5.7%)
Cluster 13 (2.9%)
ROI
Vector Layers
geology1
Point Prospects
Cluster Map: Cluster 6 (9.3%) (FOCUS)
Easting: 630439 Northing: 6349324
Feature Vector at 595300 6386200
Scaled Value
0% 20% 40% 60% 80% 100%
magnetics_TMI 4960
gravity 18.1
dtm 209
Potassium 0.496
Uranium 1.83
Thorium 7.36
0% 20% 40% 60% 80% 100%

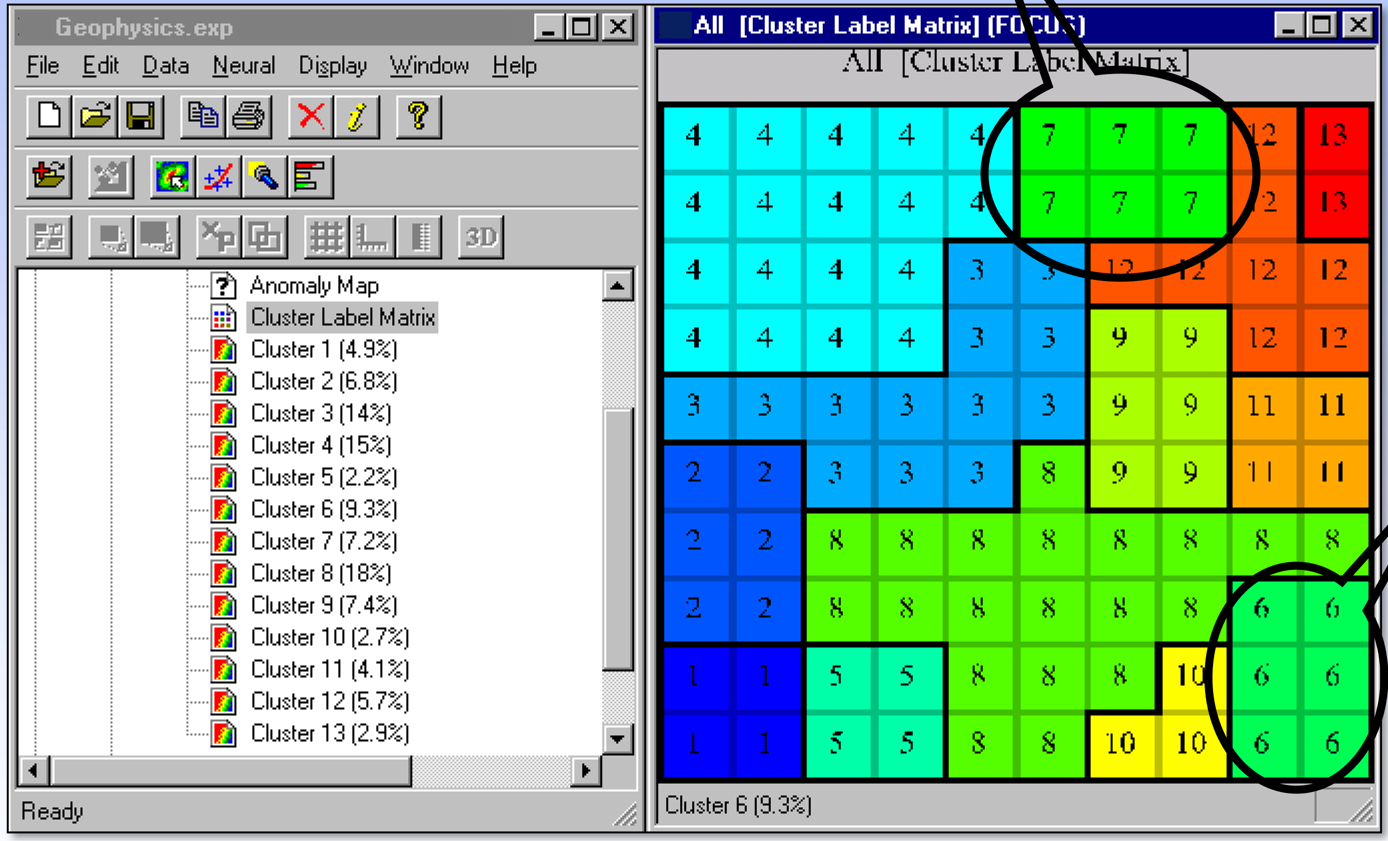
Cluster 6



Geophysics.exp
File Edit Data Neural Display Window Help
Interpolated Data
100 x 100 m [(Imported):PEAK-HILL_AMAG-RADS-D
Data
magnetics_TMI
gravity
dtm
Potassium
Uranium
Thorium
Reality
Anomalies
All
Anomaly Map
Cluster Label Matrix
Cluster 1 (4.9%)
Cluster 2 (6.8%)
Cluster 3 (14%)
Cluster 4 (15%)
Cluster 5 (2.2%)
Cluster 6 (9.3%)
Cluster 7 (7.2%)
Cluster 8 (18%)
Cluster 9 (7.4%)
Cluster 10 (2.7%)
Cluster 11 (4.1%)
Cluster 12 (5.7%)
Cluster 13 (2.9%)
ROI
Vector Layers
geology1
Point Prospects
Cluster Map: Cluster 7 (7.2%) (FOCUS)
Easting: 639742 Northing: 6370156
Feature Vector at 637800 6385300
Scaled Value
0% 20% 40% 60% 80% 100%
magnetics_TMI 5020
gravity -155
dtm 390
Potassium 2.23
Uranium 1.84
Thorium 9.57

Cluster 7

Cluster 7 - Granite Batholith



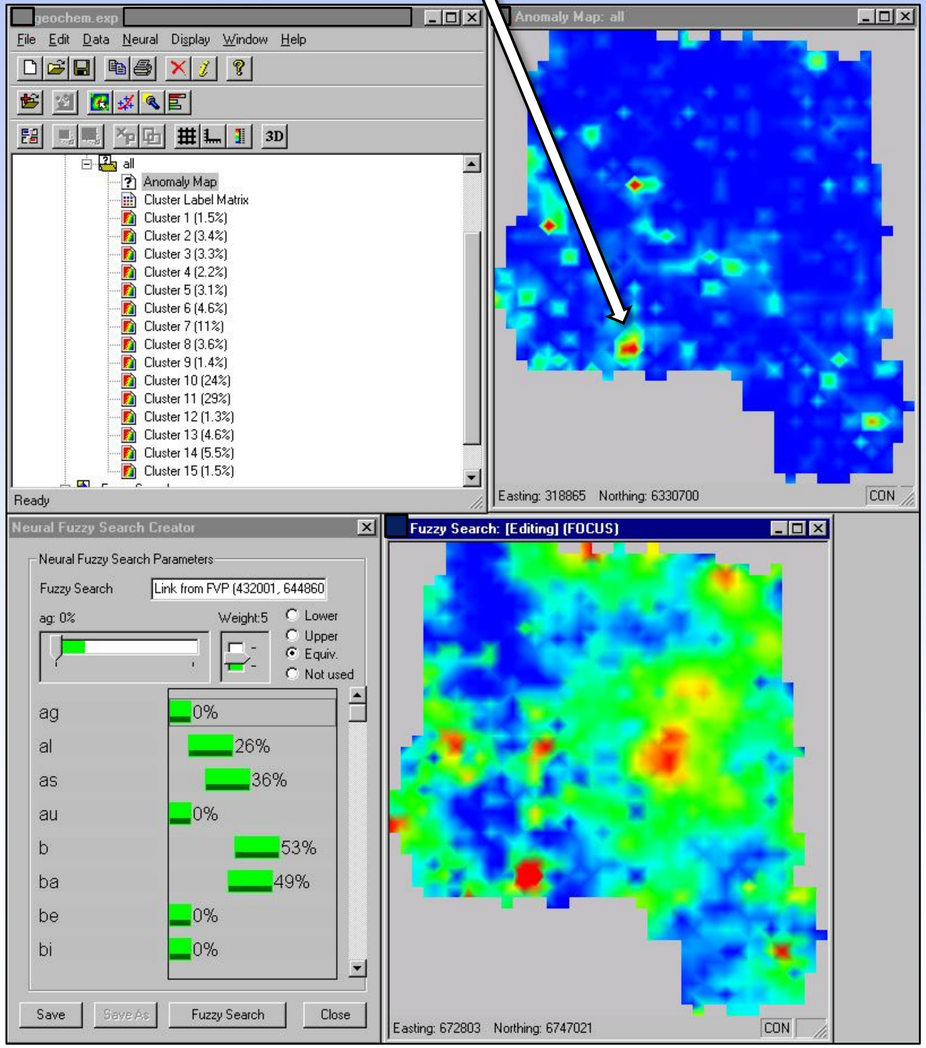
Cluster 6

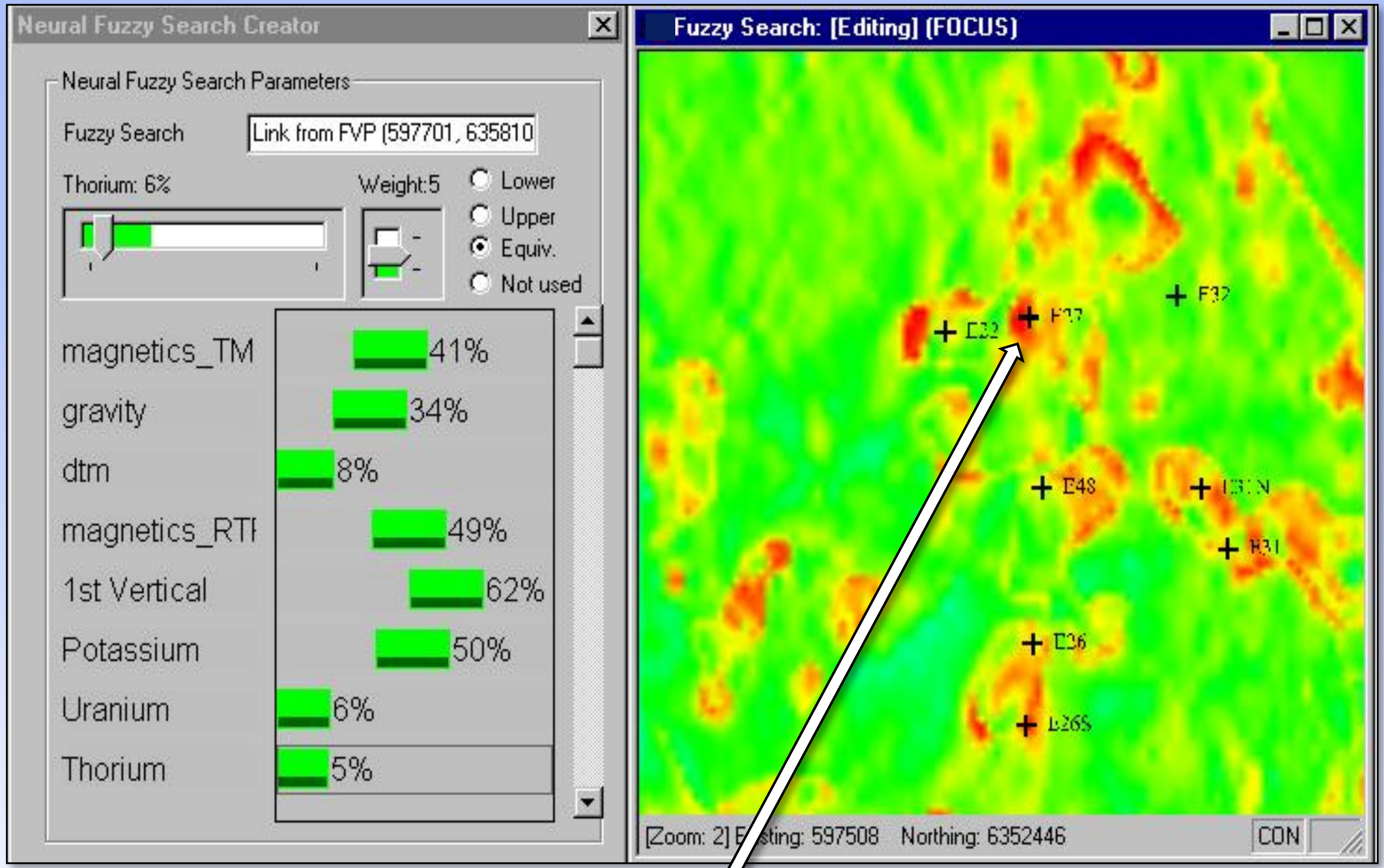
Sediments

Neural Fuzzy Search

- Specify search items
  - search a selected pattern eg. anomaly
  - search a particular location eg. known deposit
  - search for a “created” pattern - look for a particular deposit type signature
  - searches for a correlation signature
- Control by:
  - choose data layers to include
  - set the data threshold for each layer
  - control the weighting of each layer

Neural Fuzzy Search - link from known mineral deposit to look for areas with a similar geochemical signature

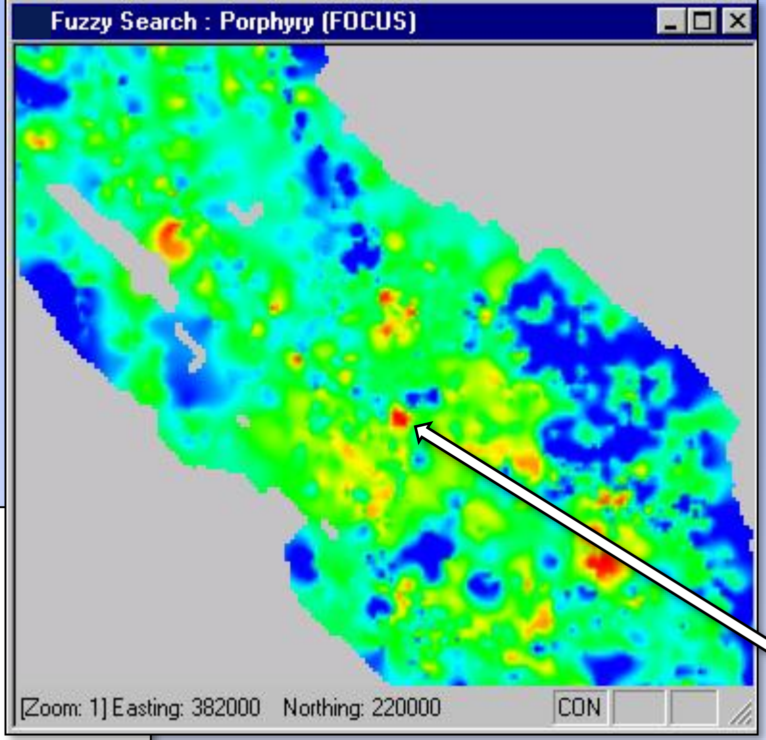


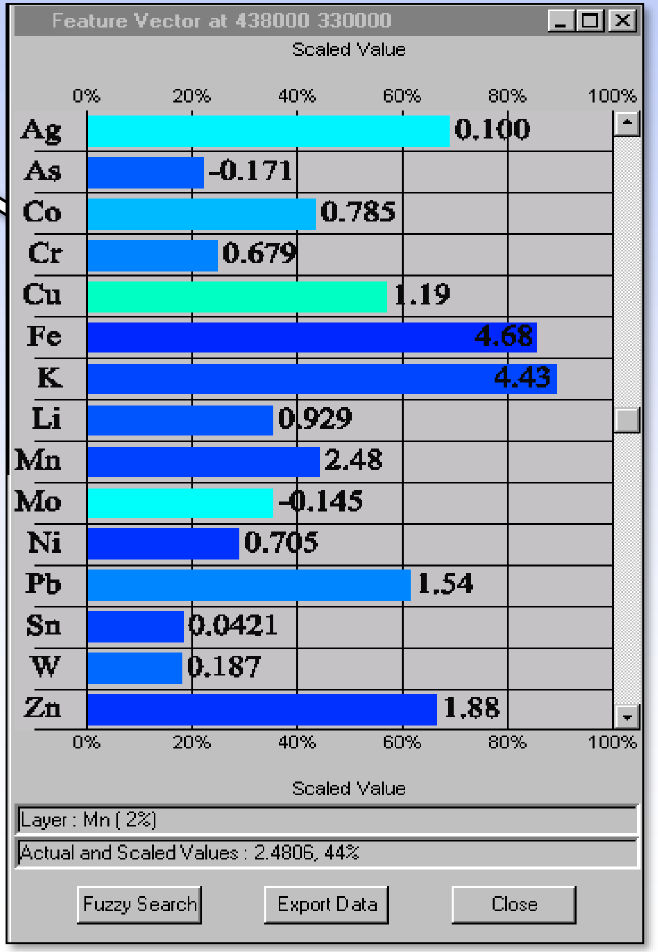


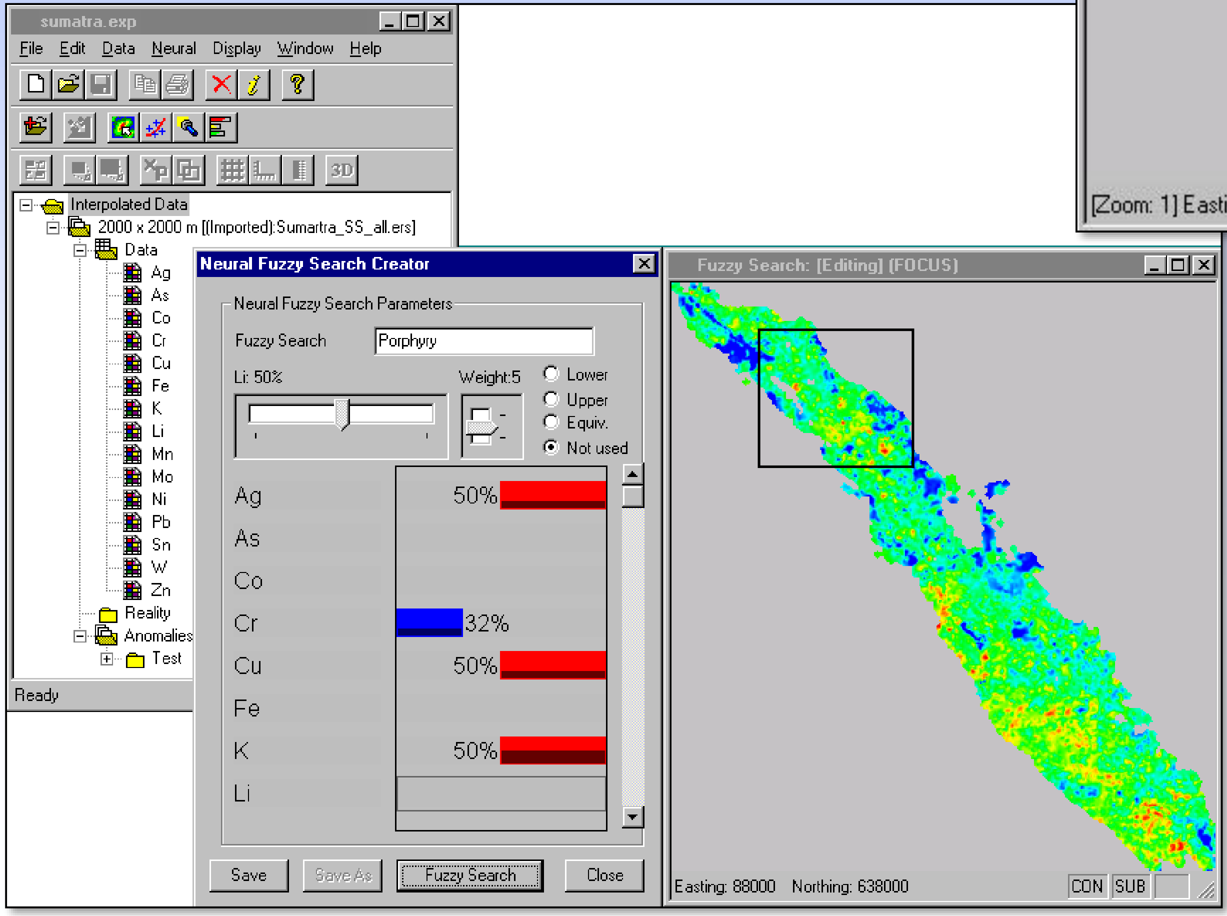
Neural Fuzzy Search using the North Parkes Endeavour 27 deposit as the search location

Porphyry *Fuzzy Search*

- elevated Ag, Au, Cu, K, Mo
- low Cr, Ni

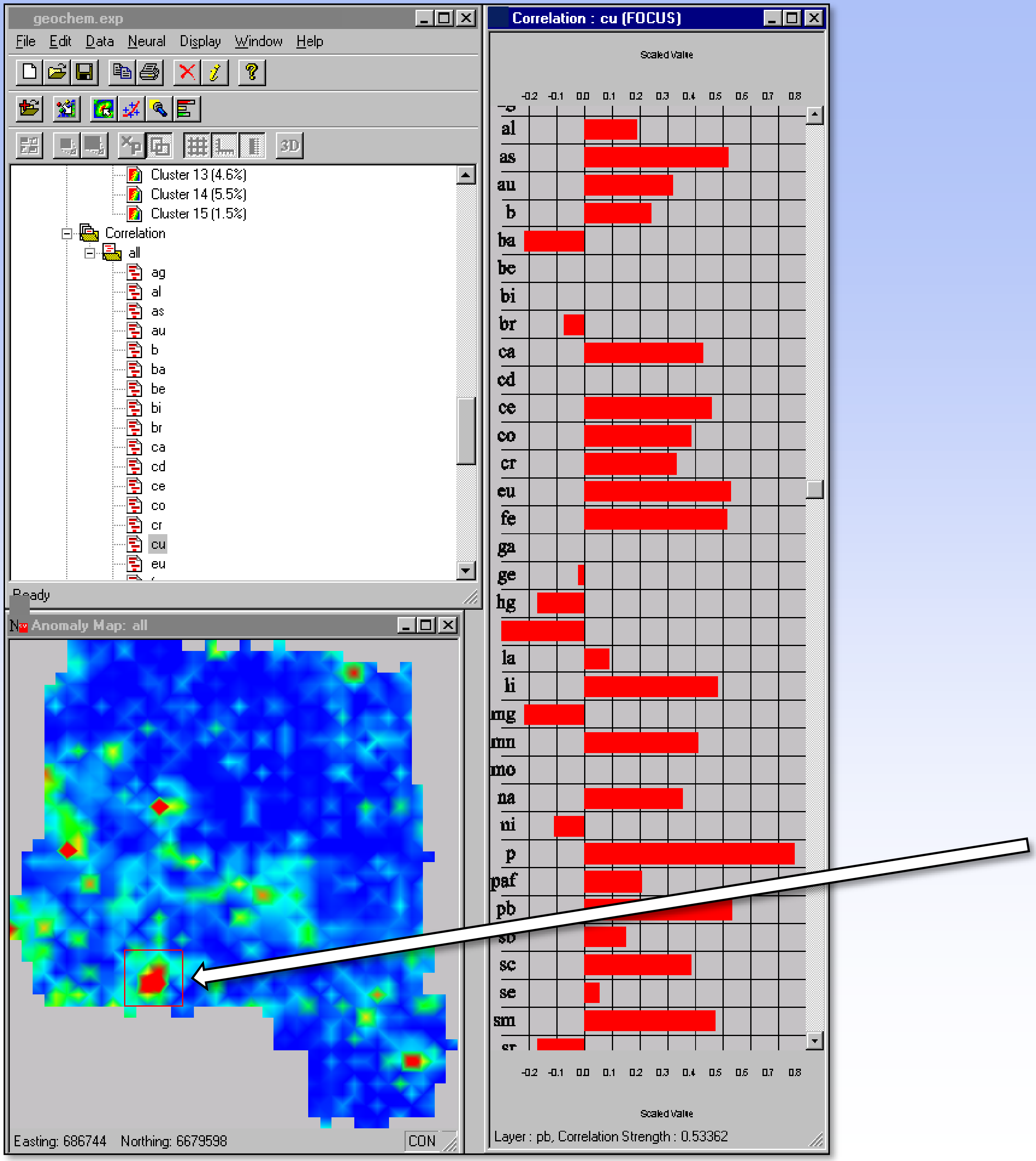




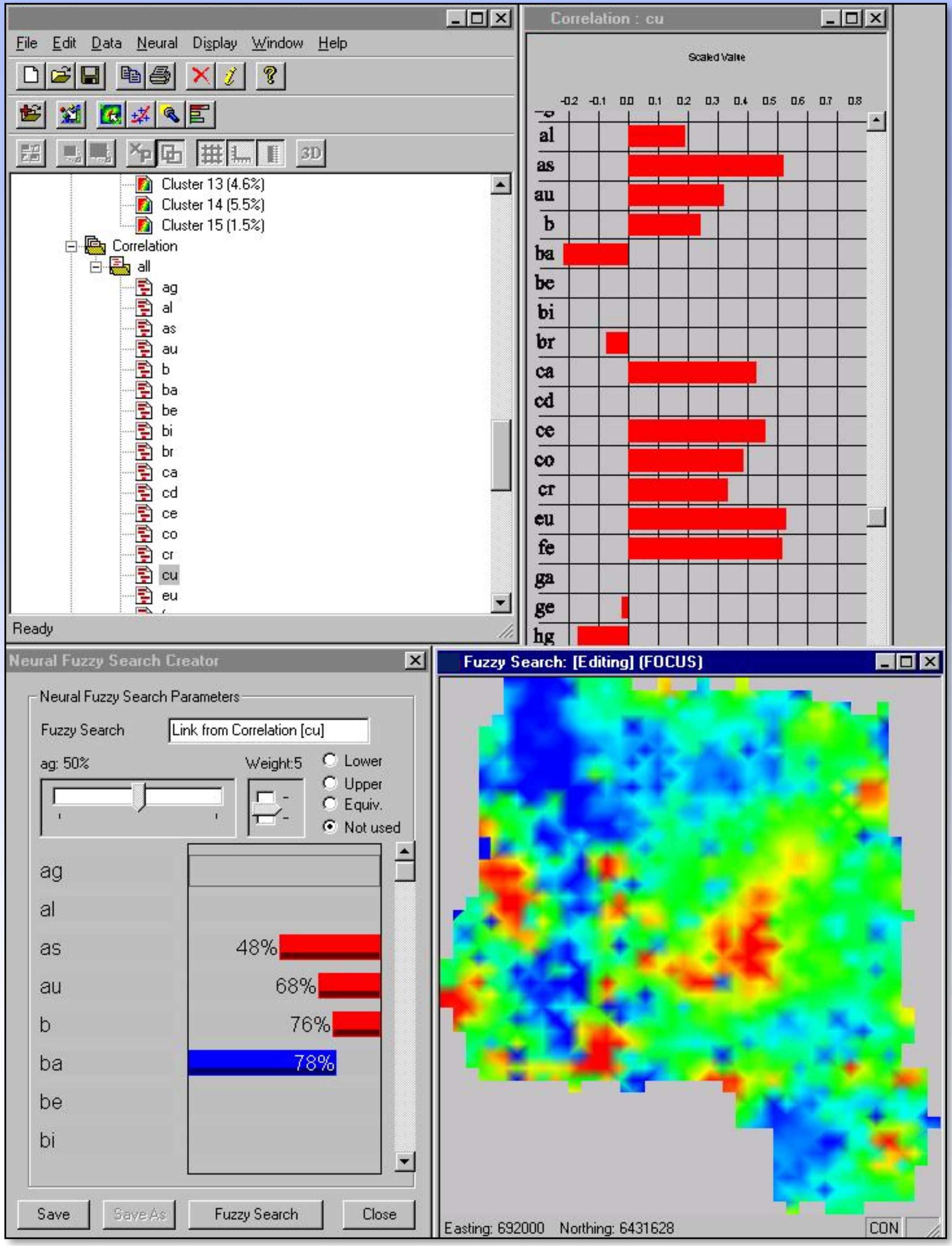


Correlation Analysis

- Relationships between survey results
- Relational Knowledge
- Correlation signatures can be determined
- Search for areas with similar correlation signature ie. search for similarities in relationships for population identification



Correlation of each element with respect to Cu within a specified region of interest

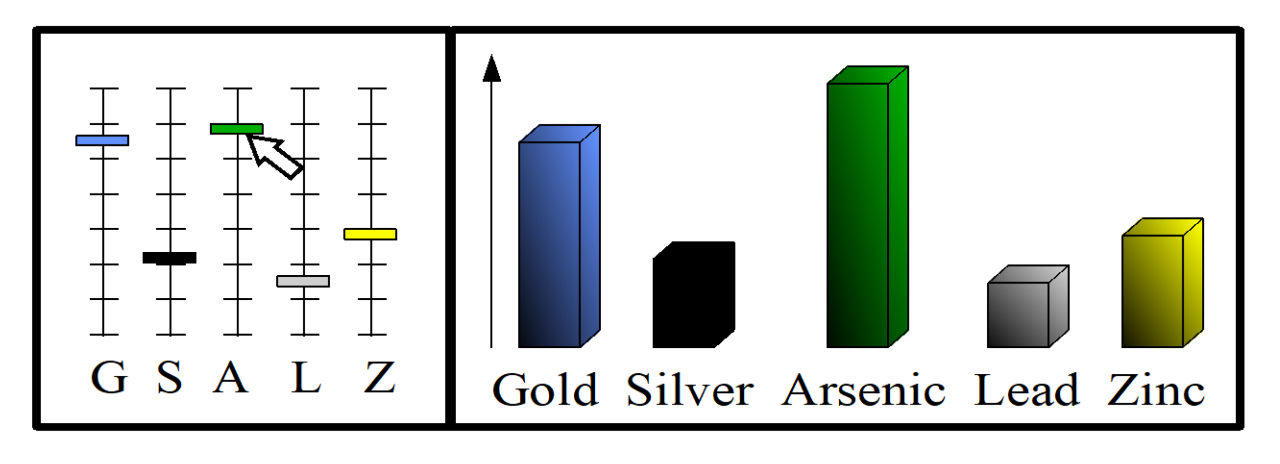


Correlation link to fuzzy search

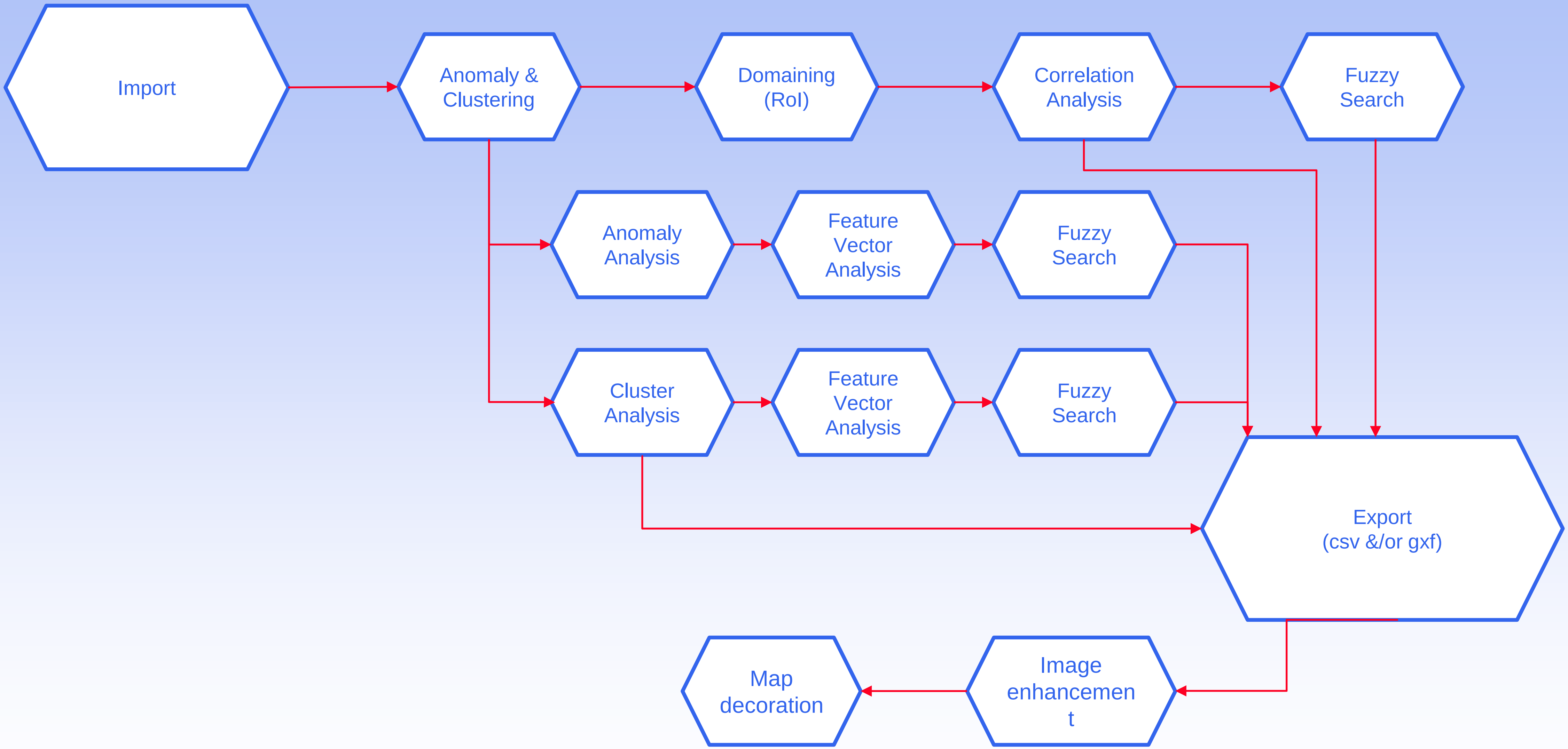
This searches for signatures of the relationships between layers, independent of the amplitude values of the layers and so may detect anomalies in areas where the raw values are close to the detection limit but the associations are the same as the higher values in the region of interest.

Relationship Explorer

- Visual "Graphic Equaliser"
  - enables analysis of inter-channel responses as one channel varies
  - ***allows more qualitative analysis of data***



WORK FLOW - Artificial neural network (ANN) Analysis



Oz Minerals Gawler Craton Challenge

- Northern Gawler IOCG Province
- 8 layers of geophysical and depth to basement data
- Regional analysis using publicly available data and a Prominent Hill analysis using data provided by Oz Minerals
- Anomaly detection, cluster analysis, fuzzy search and correlation analysis tools used

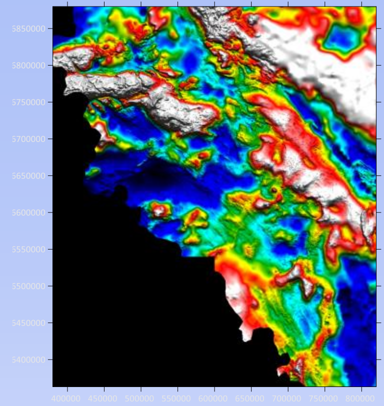
Regional study
Input Layers

North Eastern Gawler IOCG Province

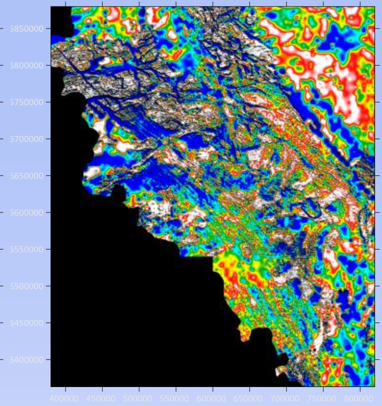
Neural Network Analysis Input layers

gravity

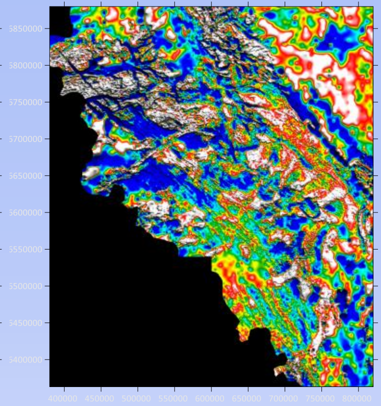
gravity



1VD

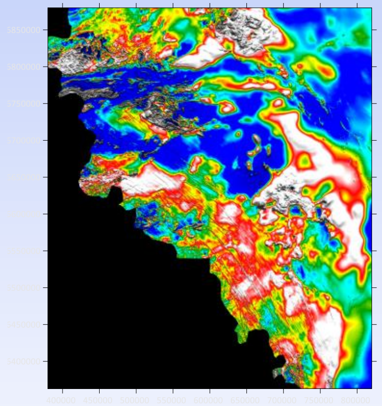


UC1000 residual

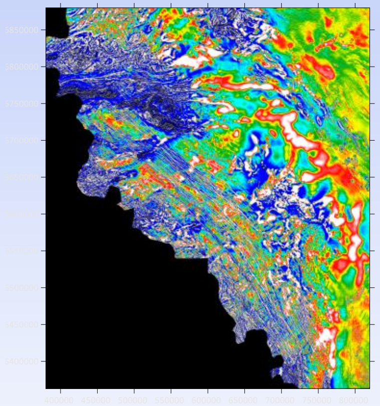


magnetics

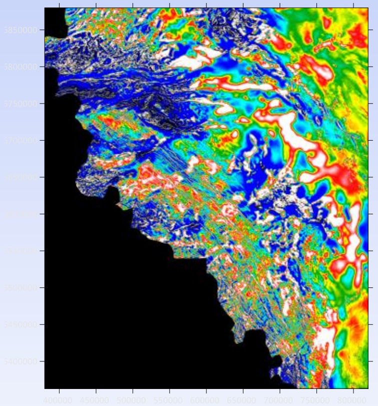
RTP



RTP 1VD

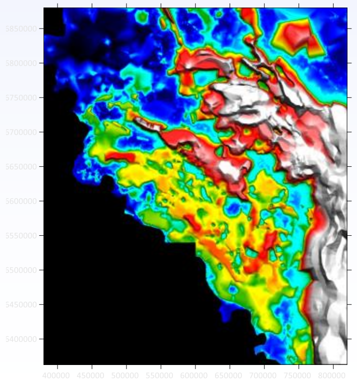


UC1000 residual

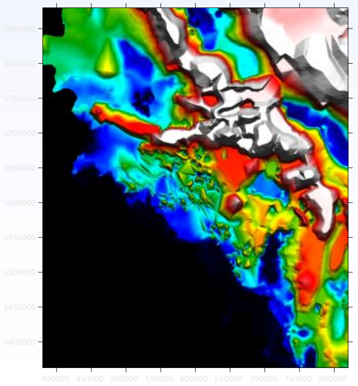


cover thickness

Neoproterozoic

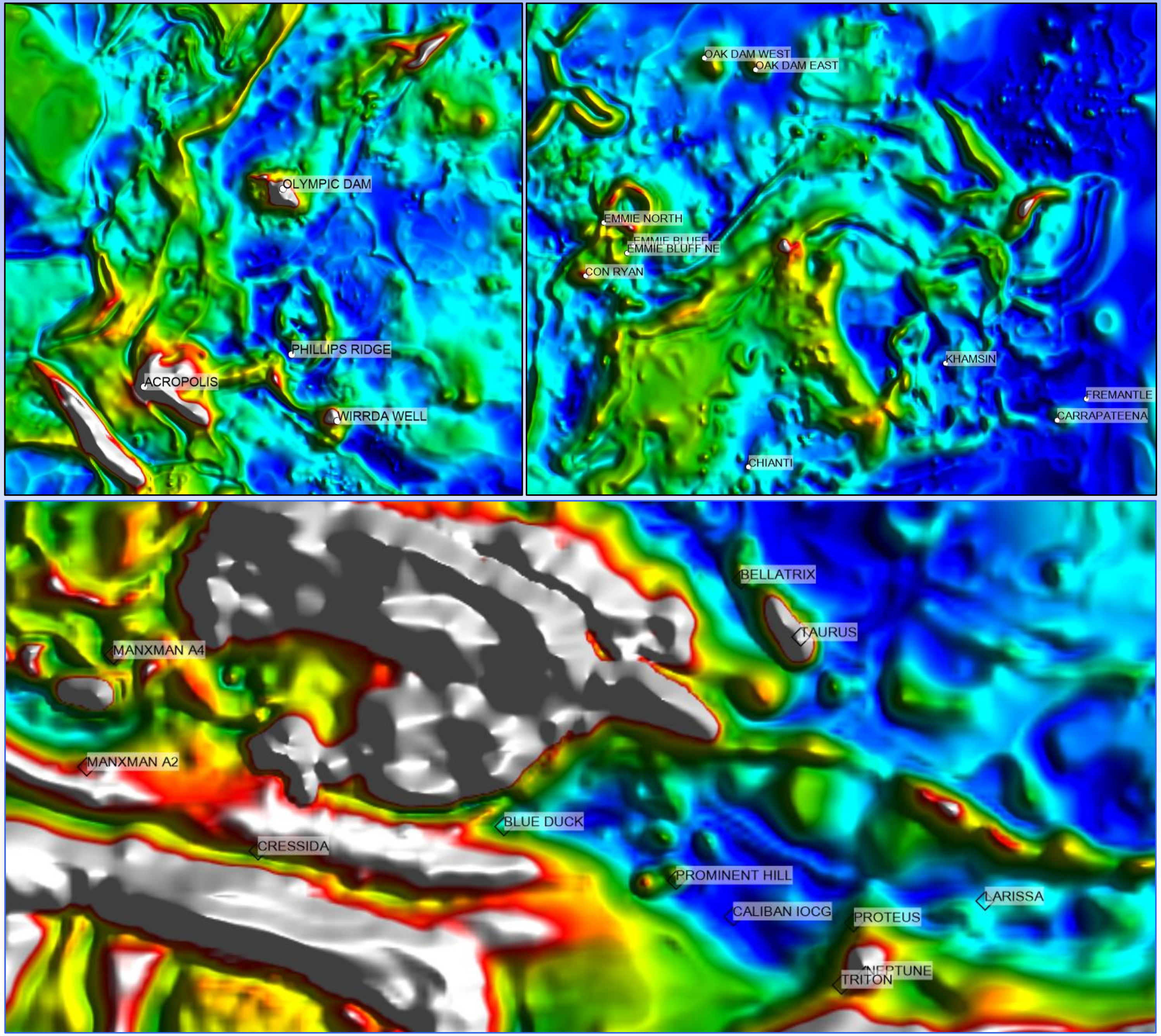


Phanerozoic



SARIG
South Australian
Resources Information Gateway
Delivering statewide geoscientific and geospatial data

DEEP EXPLORATION TECHNOLOGIES CRC
Uncovering the future



Regional studySearch Results

North Eastern Gawler IOCG Province

Unsupervised ANN

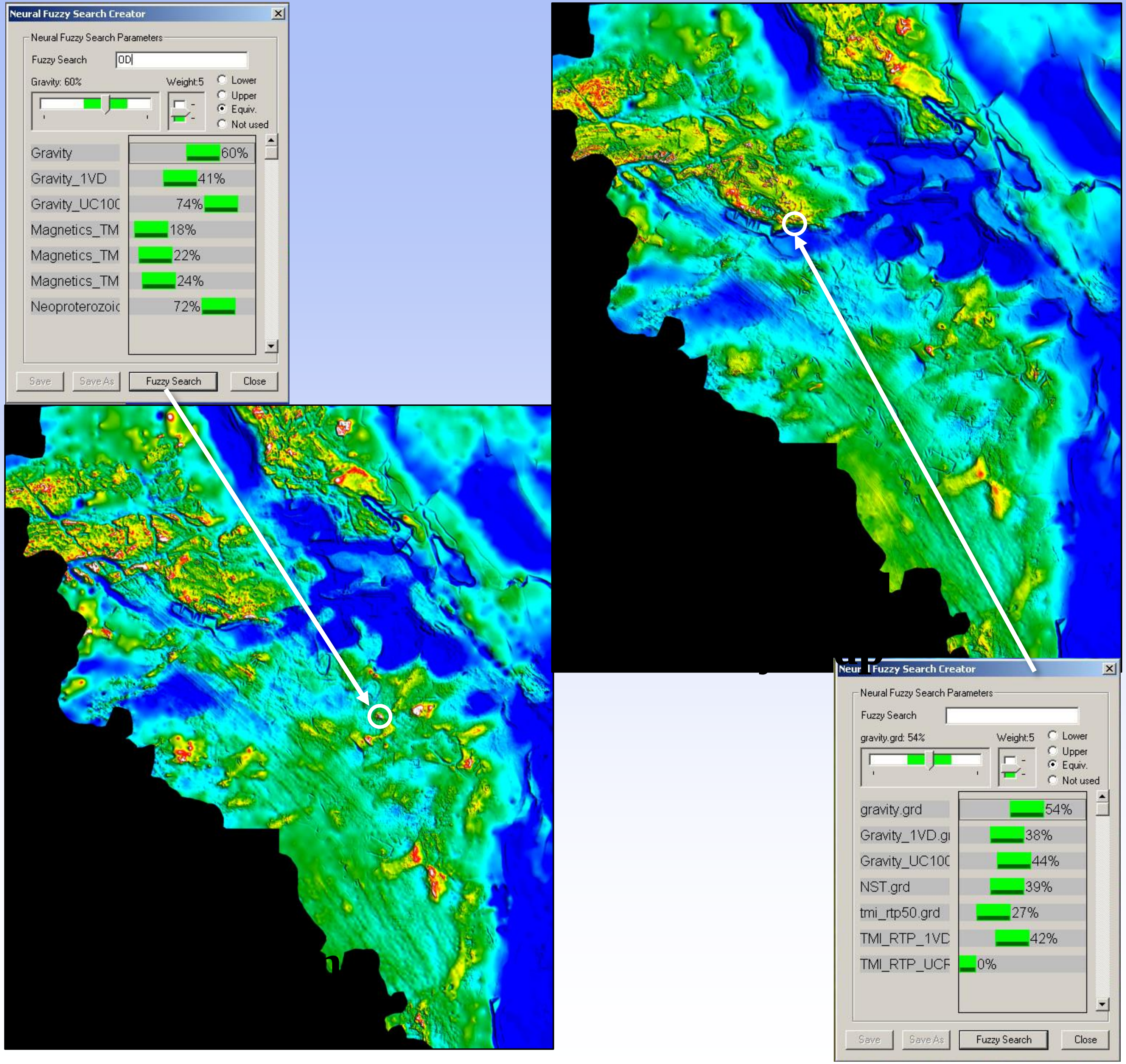
Detected relatively unique input-layer association (anomalies) over all major IOCG deposits and discoveries

Note:

warmer colours signify relative uniqueness and each feature is not unique for the same input-layer association

INNOVATIVE APPROACH JUSTIFIED

Regional study Search Results



North Eastern Gawler IOCG Province

Unsupervised ANN

Numerous features sharing similar input-layer associations for Olympic Dam (Left) and Prominent Hill (Right) as highlighted by the auto-generated fuzzy search creator parameters for each deposit

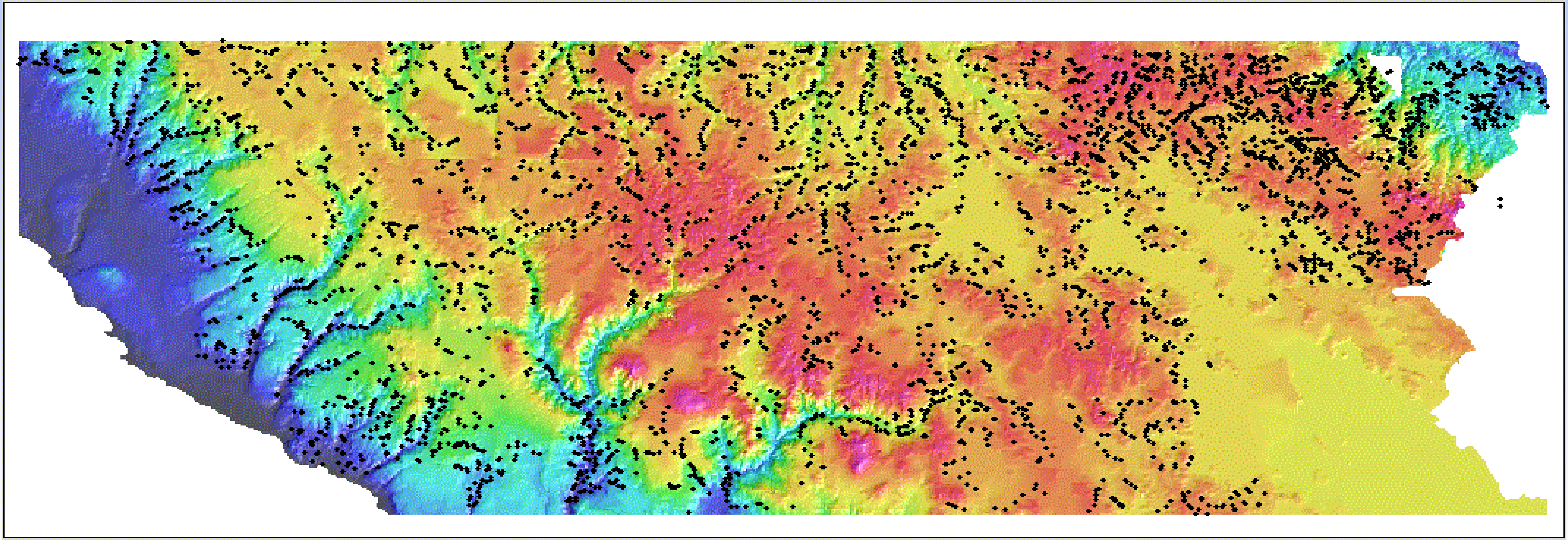
Note:

1. warmer colours signify relative similarity and each feature highlighted shares similar input-layer association
2. “character” of Olympic Dam is not the same as for Prominent Hill

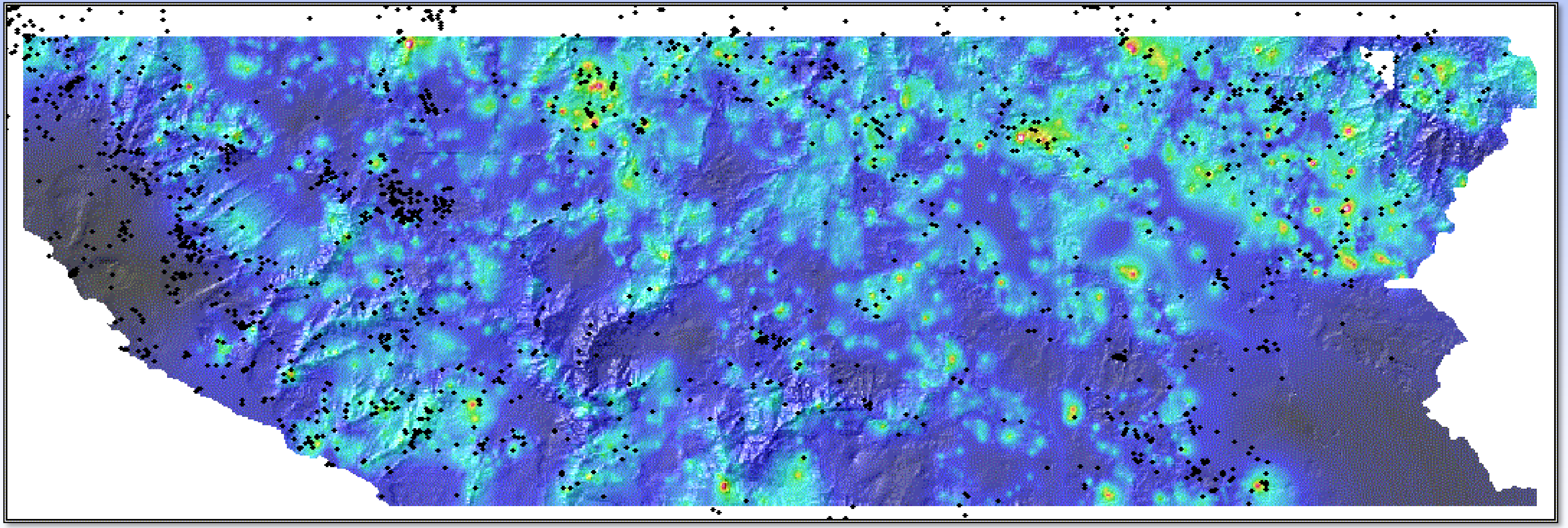
Rio Tinto Neural Analysis

- Ingemet Southern Peru Data Package
- Geochemistry - 30 layers of stream sediment geochem samples
- Mineral Occurences Database
- Anomaly detection, cluster analysis, fuzzy search and correlation analysis tools used

Stream Sediment Sample Points



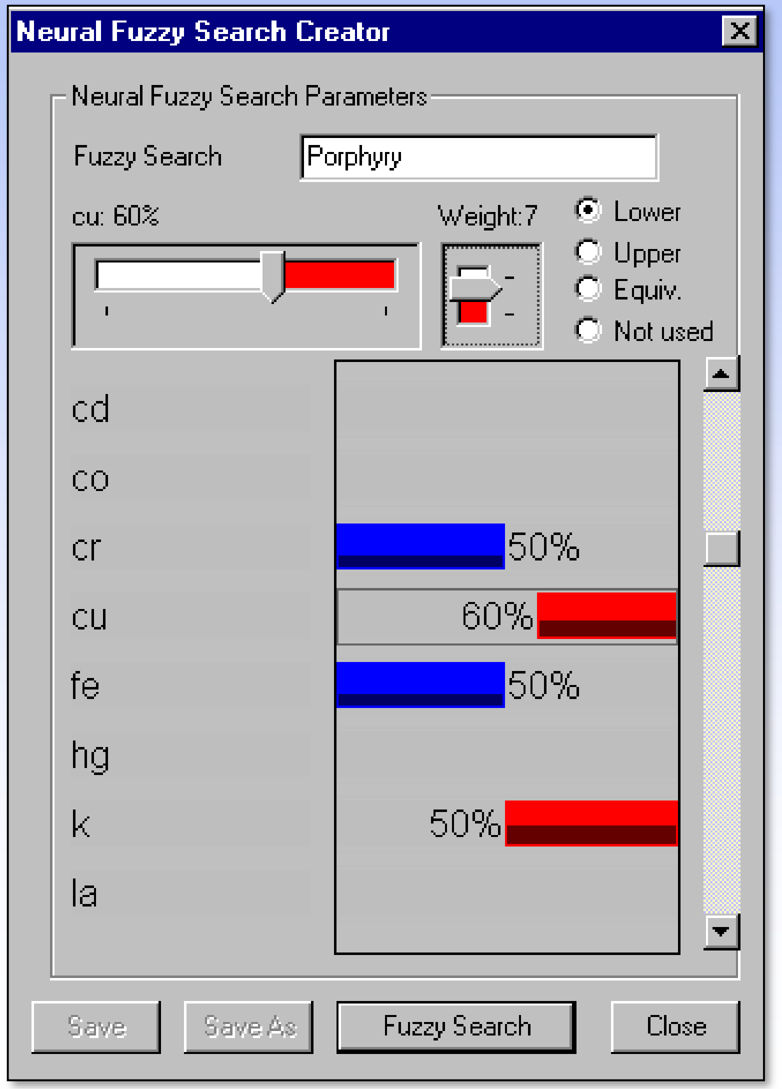
Anomaly Analysis



Unsupervised Anomaly Analysis

all elements used in search shown with known mineral occurrences

Fuzzy Search Creator



Porphyry search

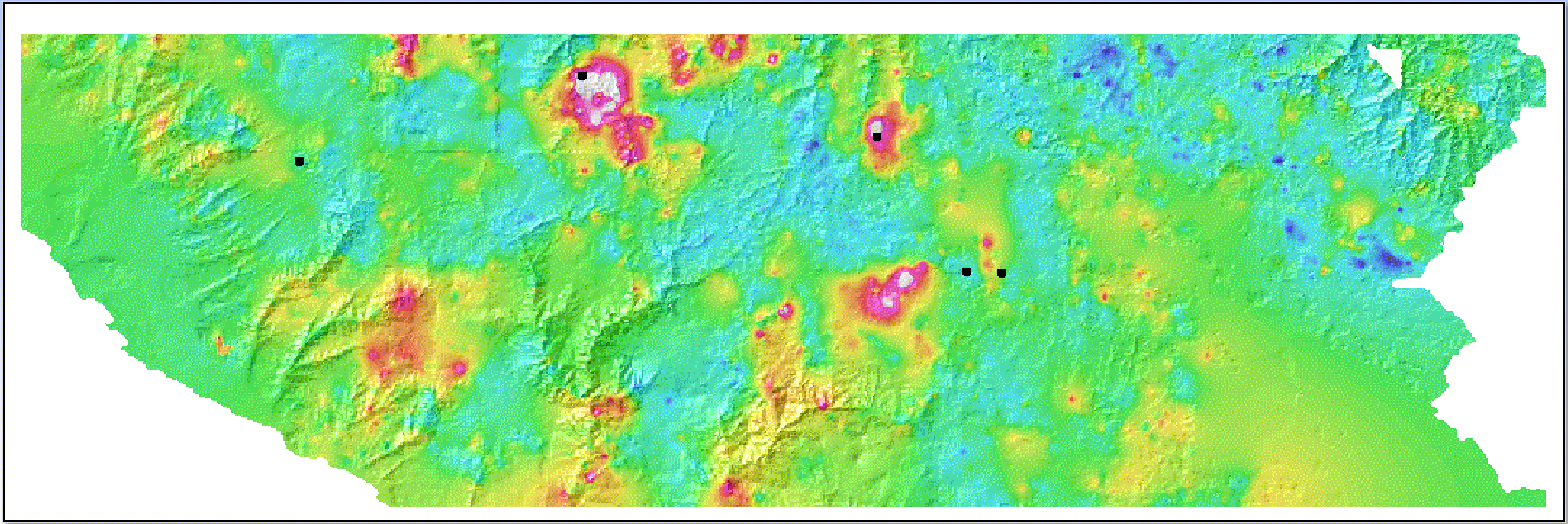
> 50% Ag-Au-Mo-Pb-Zn

> 60% high Cu weighting

> 50% high K weighting

< 50% low Cr-Fe-Ni

Fuzzy Search Results

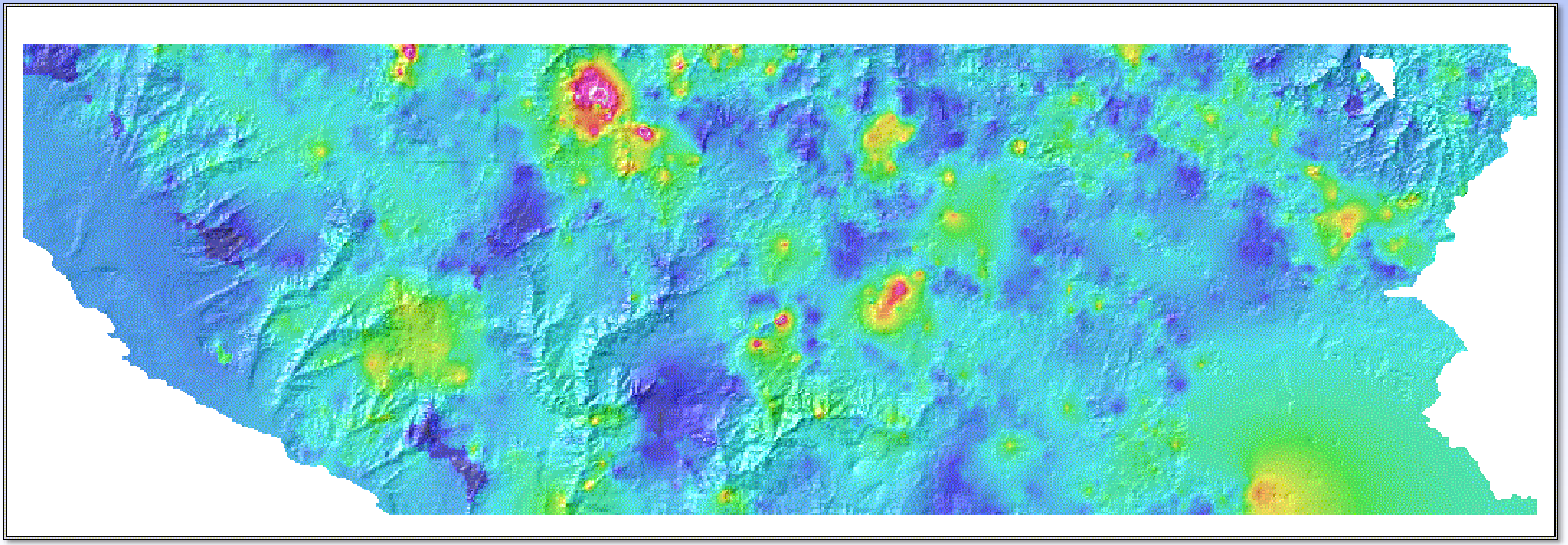


Porphyry search: > 50% Ag-Au-Cu-K-Mo-Pb-Zn

< 50% Cr-Fe-Ni

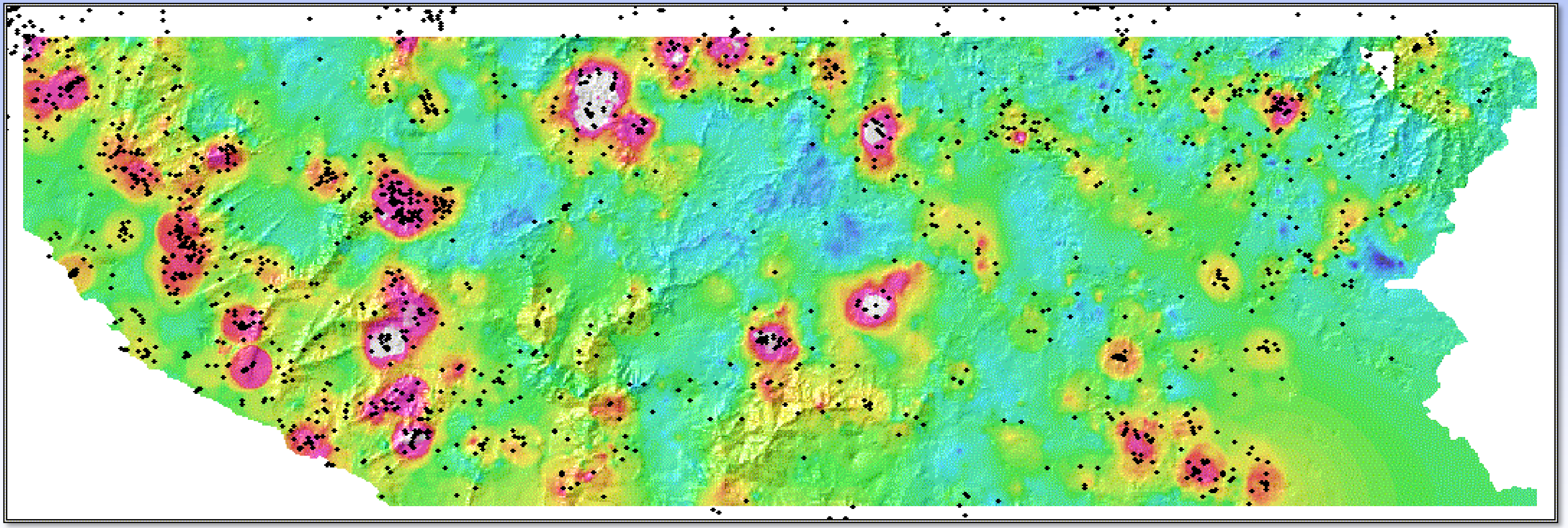
Known major porphyry mines and deposits

Fuzzy Search Results



Epithermal search: > 50% Ag-Au-As-Sb

Fuzzy Search Results



Mineralisation search: > 50% Ag-Au-Cu-K-Mo-Pb-Zn

> 50% mineral occurrences