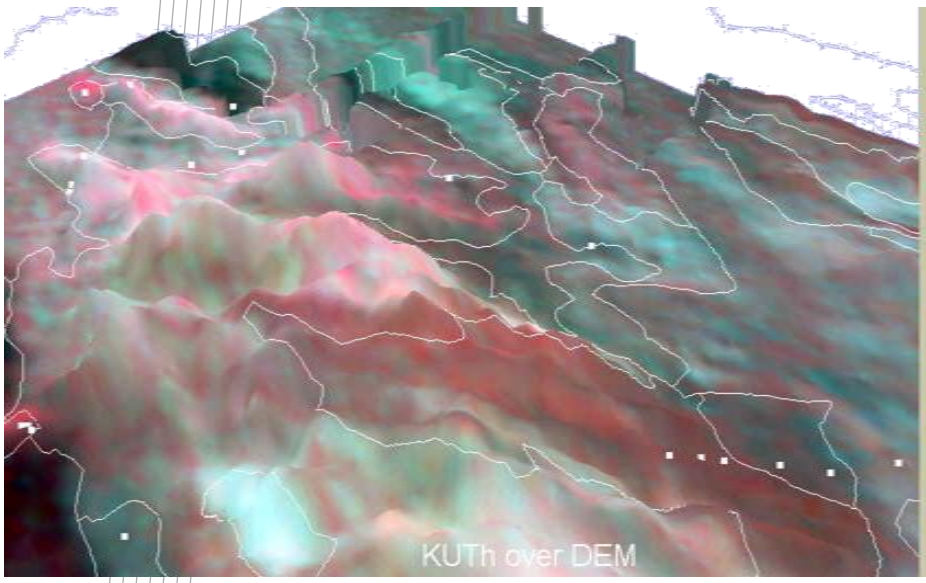
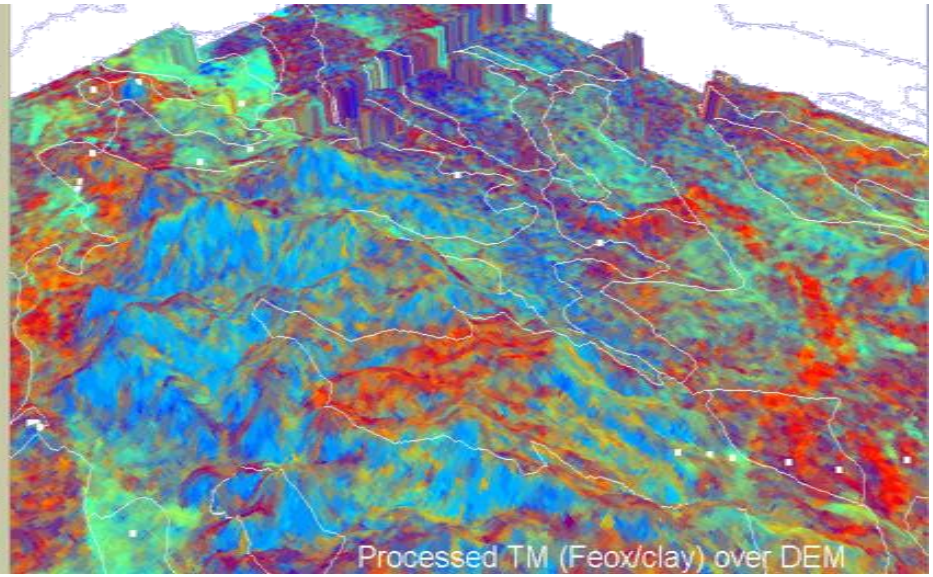




Radiometrics

Processed Landsat TM

www.csiro.au

Self Organizing Maps

A New Approach for Integrated Analysis of Geological Data.

"We are drowning in information and starving for knowledge."

Rutherford D. Roger

National Research FLAGSHIPS

Minerals Down Under

CSIRO

Stephen.Fraser@csiro.au

Background #1

- Explorationists/Geoscientists/Miners now gather data faster than it can be interpreted.
- Traditional multivariate statistical methods are confused by:
  - ***Non-linear relationships***
  - ***Non-normal data distributions (non-Gaussian)***
  - ***Missing or censored data (nulls)***
  - ***Need to analyze disparate or complex data types***
    - ***Categorical (text), continuous, and discontinuous types***

Background #2

- GIS/Mine Planning Packages enable data storage and display; but do not solve the problem of,

"How do we intelligently analyze and interpret the volumes of data we collect?"

Clustering & Data Analysis: A brief history

- **Classical Statistical – Fisher's Discriminate Analysis, Least-Squares, Principal Components Analysis, Factor Analysis.**

- **Modern Statistical - more flexible methods, that estimate within, and between class probabilities: Nearest Neighbour, Projection Pursuit, Causal Networks, CART (Classification & Regression Trees), MARS (Multivariate Adaptive Regression Splines)**

- **Machine Learning – automatic or logical systems based on logical or binary systems: Artificial Intelligence, Expert Systems, Decision Trees, Neural Nets (most ML is supervised!)**

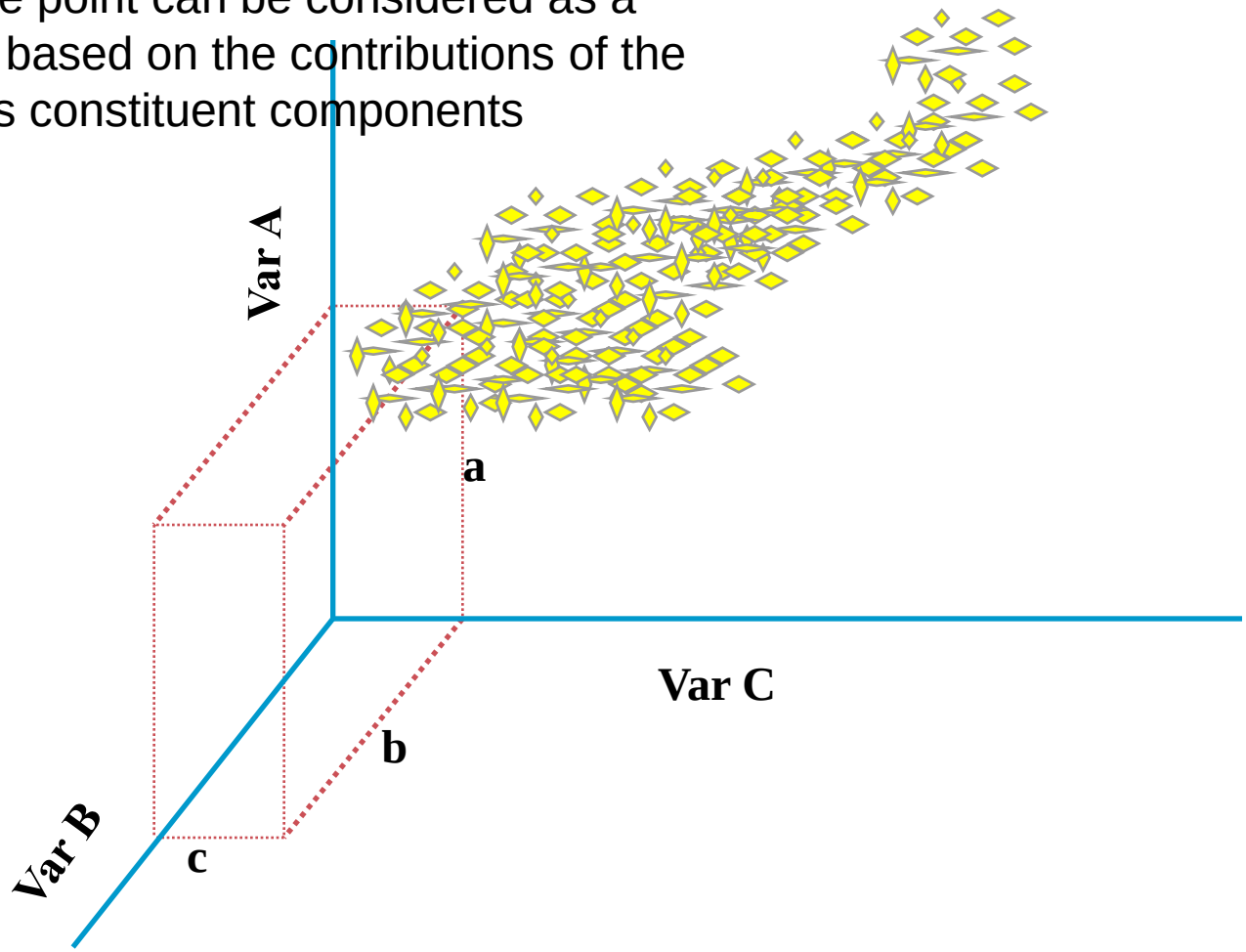
- **Kohonen Nets - (Teuvo Kohonen, 1985) Self Organizing Maps (SOM) - A non-traditional, method of data analysis based on principles of vector quantization and measures of vector similarity. Developed as a computational method to counter neural nets.**

-
  - **"Ordered Vector Quantization"** (Kohonen's preferred name)

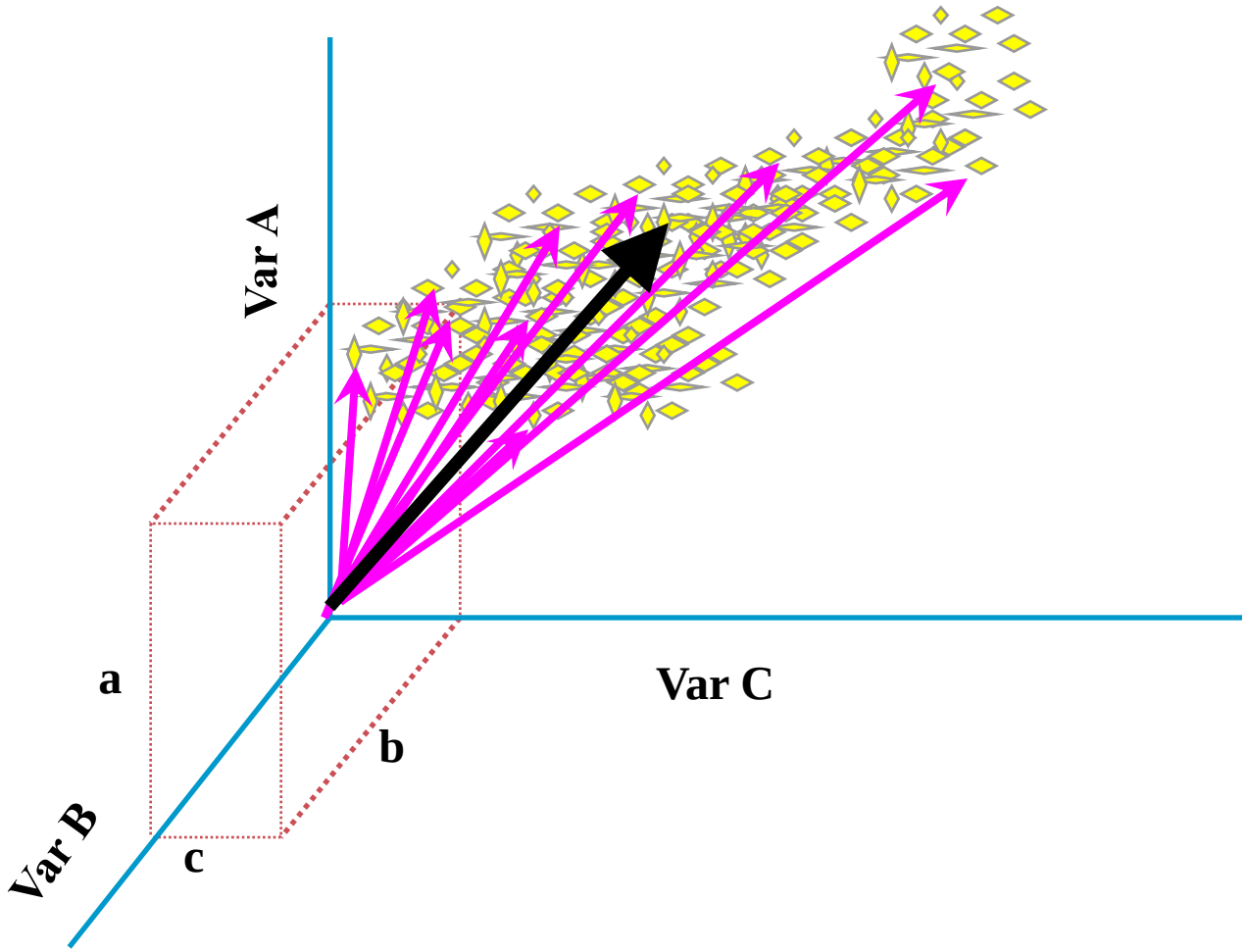
Scatter Plots: An Effective Tool for Conceptualizing Data Processing methods

Consider a grouping of similar/related samples in n-D space

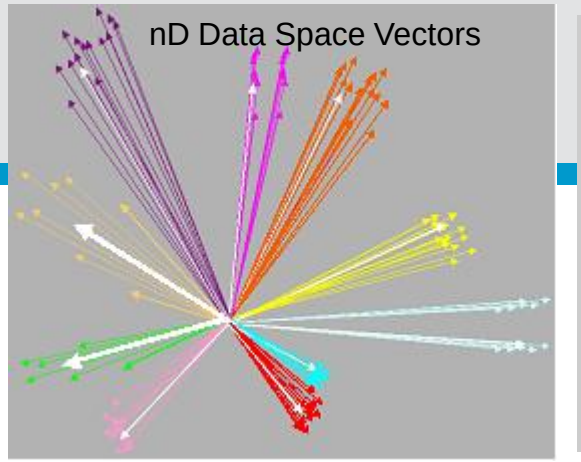
Sample point can be considered as a vector based on the contributions of the various constituent components

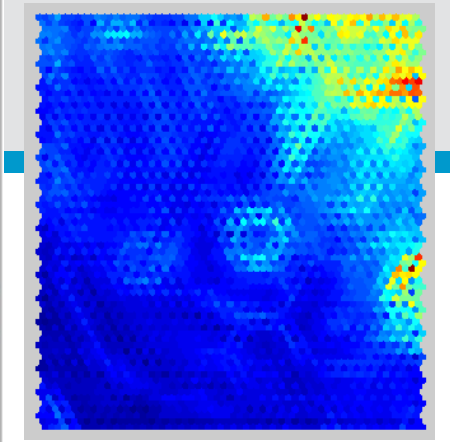


Scatter Plots: An Effective Tool for Conceptualizing Data Processing methods



Background: Self Organizing Maps

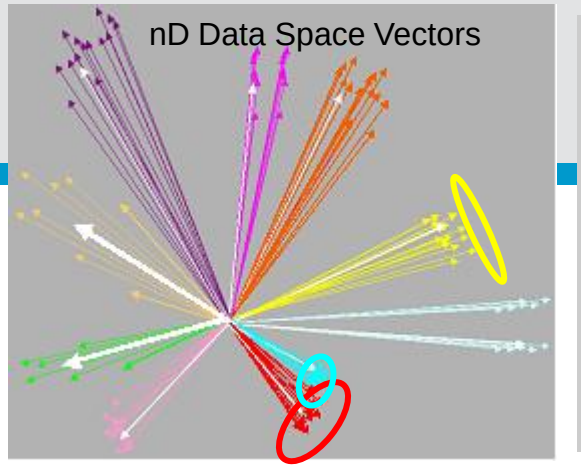


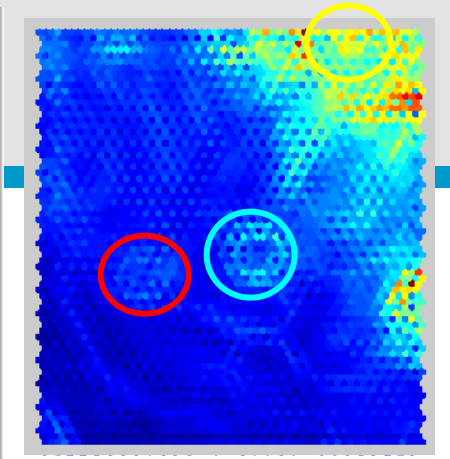


2D Self Organized "Map" Representation of Samples: Colours indicate similarity or dissimilarity of adjacent nodes

- A segmentation and visualization technique to explore relationships between diverse data types:
  - Based on principles of vector quantization and measures of vector similarity;
  - Can handle Non-linear relationships and Non-Gaussian data distributions;
  - Can handle categorical (nominal) data and "labels";
  - Can handle Nulls, hence sparse data, can be accommodated.
  - Outputs 2D "orderly-maps" that represent the nD data structure and maintains the relationships between inputs.

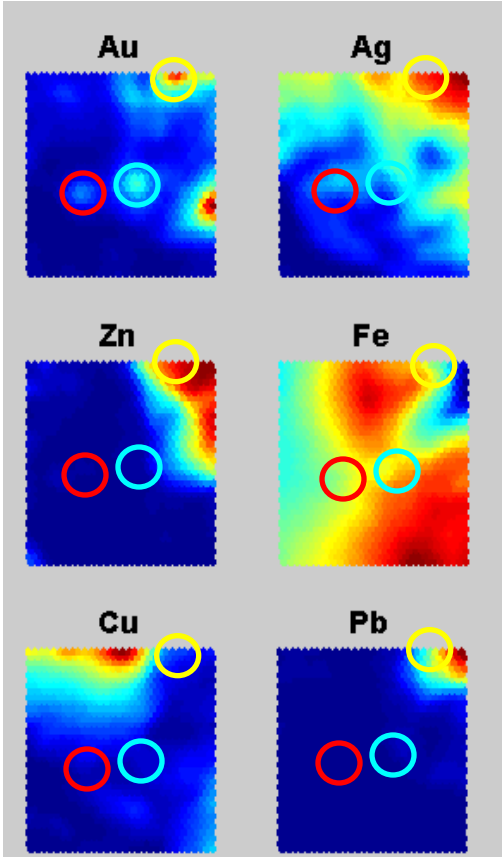
Background: Self Organizing Maps





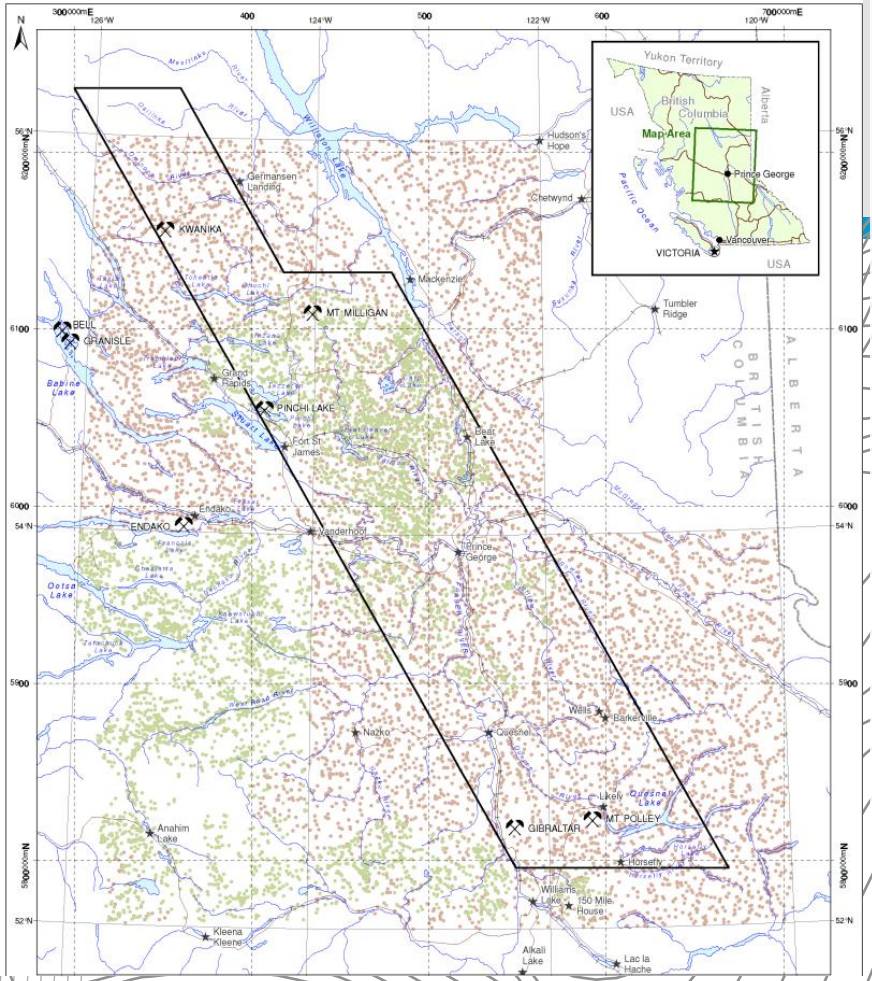
2D Self Organized "Map" Representation of Samples: Colours indicate similarity or dissimilarity of adjacent nodes

- A segmentation and visualization technique to explore relationships between diverse data types:
  - Based on principles of vector quantization and measures of vector similarity;
  - Can handle Non-linear relationships and Non-Gaussian data distributions;
  - Can handle categorical (nominal) data and "labels";
  - Can handle Nulls, hence sparse data, can be accommodated.
  - Outputs 2D "orderly-maps" that represent the nD data structure and maintains the relationships between inputs.



Variable Contributions for samples shown on the "Map" - "Component Plots": colours indicate spread of values across range of input values.

National Research FLAGSHIPS Minerals Down Under CSIRO



Analysis of Geoscience BC's QUEST Stream & Lake Sediment Geochemical Database

Stephen Fraser, Peter Kowalczyk & Jane Hodgkinson

Input Samples "levelled" "gridded" and "log-transformed" geochemistry.

15020 samples x 42 elements: (over ~150,000 km^2)

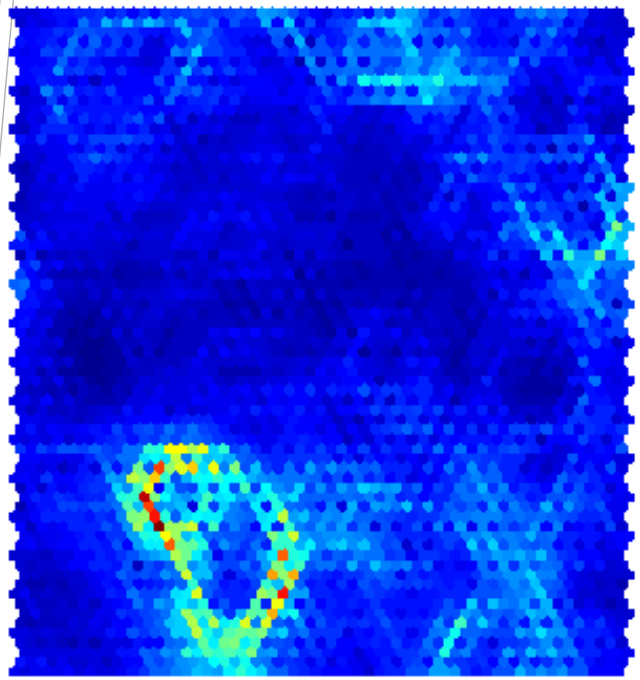
Geoscience BC

National Research FLAGSHIPS Minerals Down Under

CSIRO

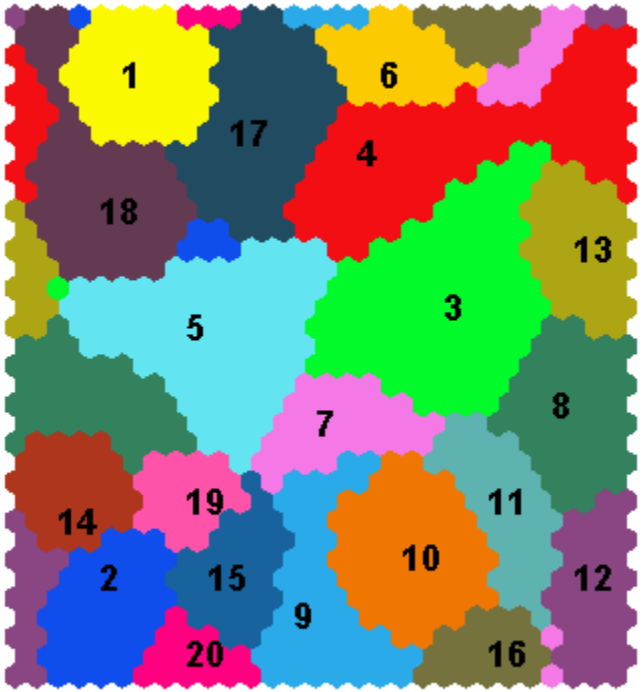
U-Matrix & K-means2 20 clusters

U-matrix



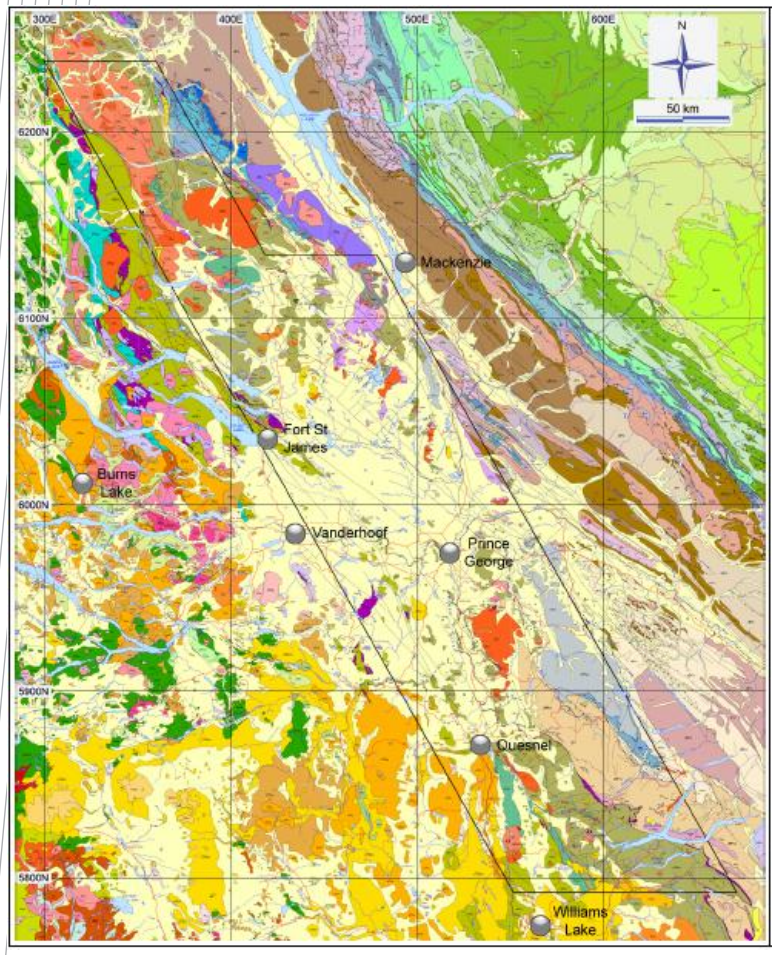
U-matrix with selected components only

Color code

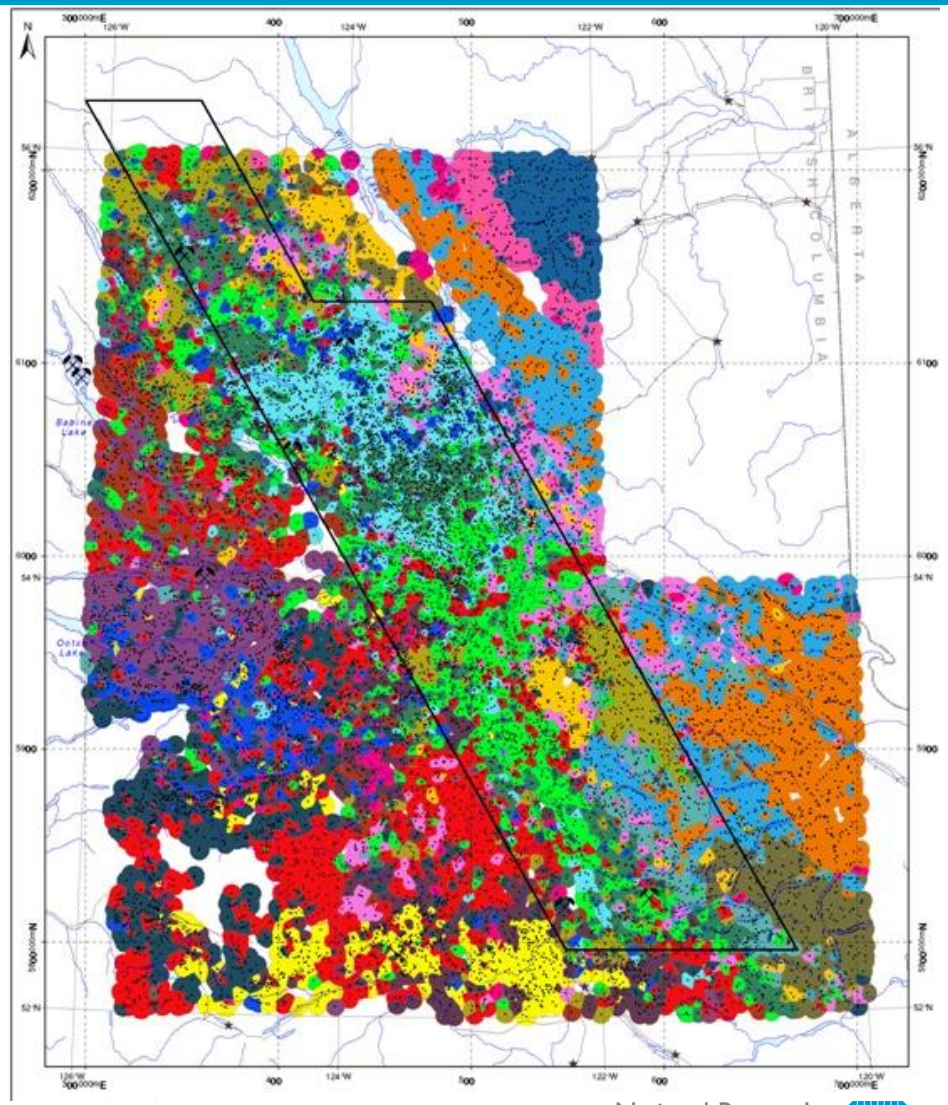


SOM 19-Apr-2009

Surficial Geology vs Samples Coded by SOM-derived K-means (20 clusters)



Surficial Geology



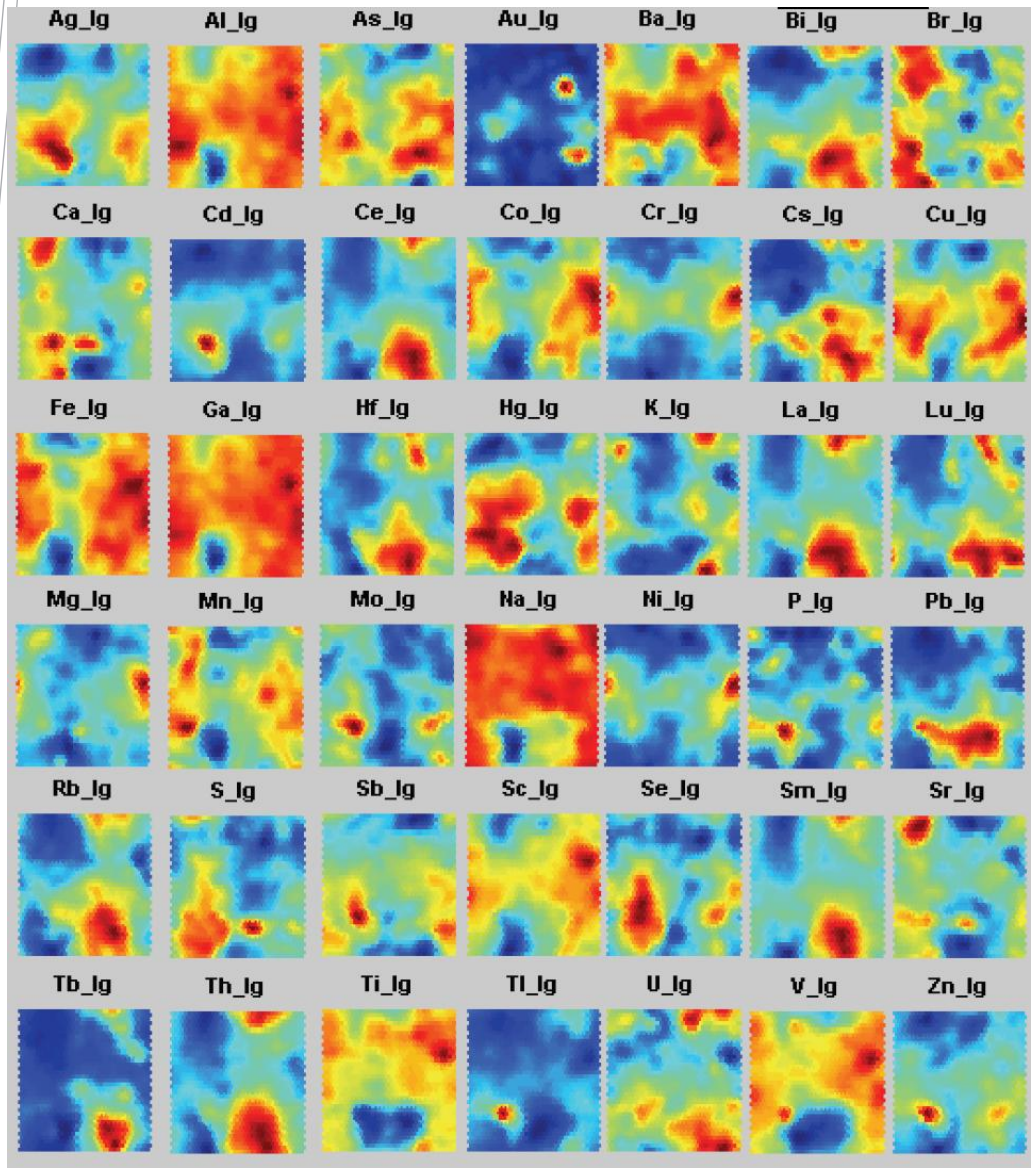
SOM-derived K-means

National Research FLAGSHIPS Minerals Down Under

CSIRO

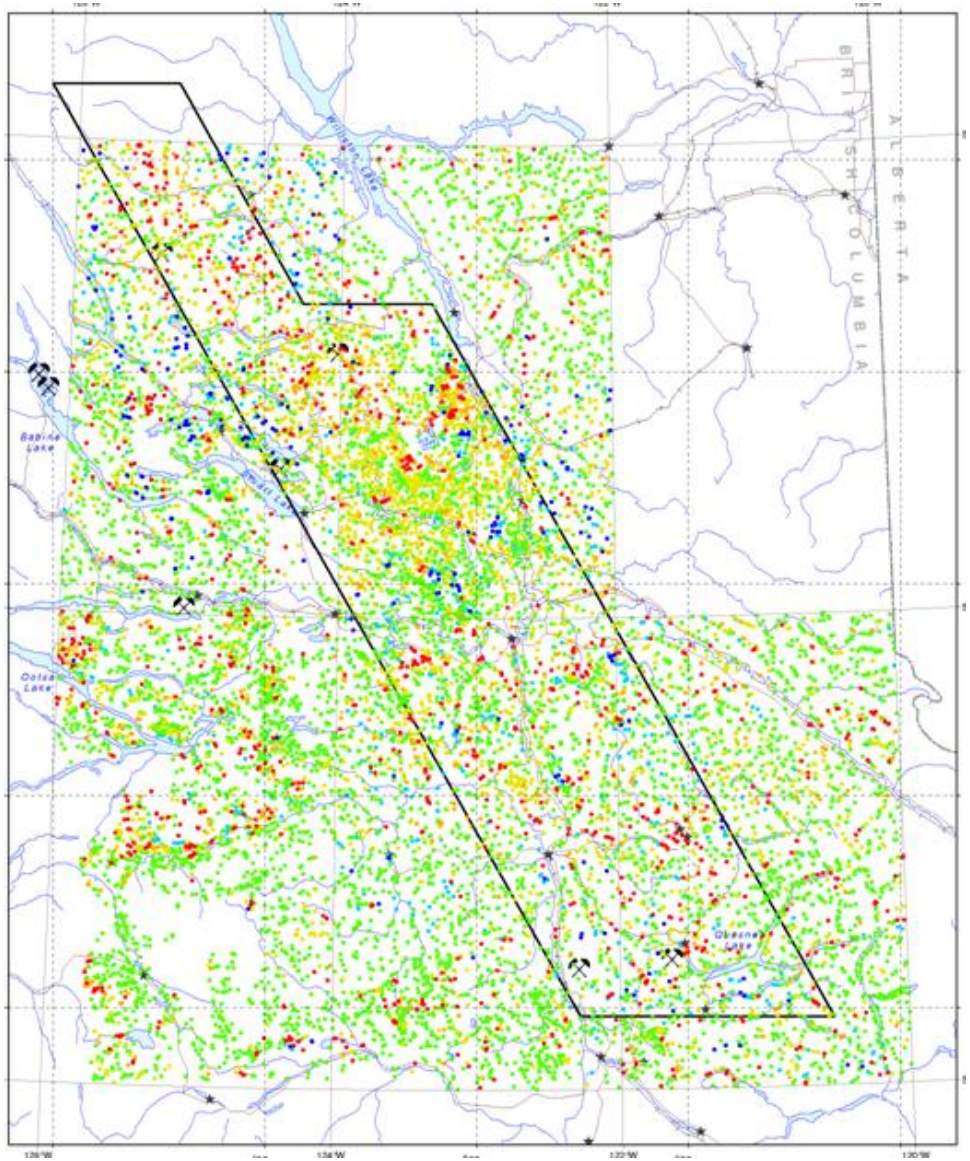
K-means Cluster Normalized Elemental Maps

Component Plots for each of the 42 elements



National Research FLAGSHIPS
Minerals Down Under
CSIRO

Cluster-Normalized Elemental Maps – Au – example

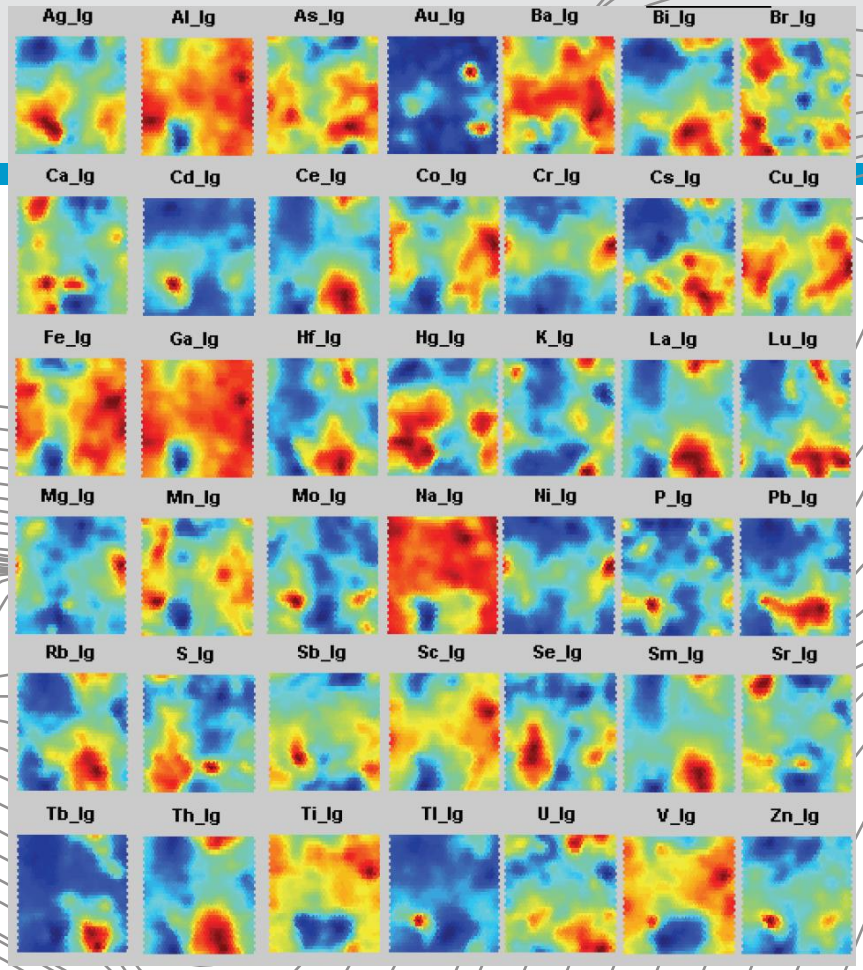


Normalized Gold Anomaly Value Breakdown

	>	1.5
1	to	1.5
0	to	1
-1	to	0
-1.5	to	-1
	<	-1.5

Maps for each element available from GBC web site

National Research FLAGSHIPS Minerals Down Under CSIRO



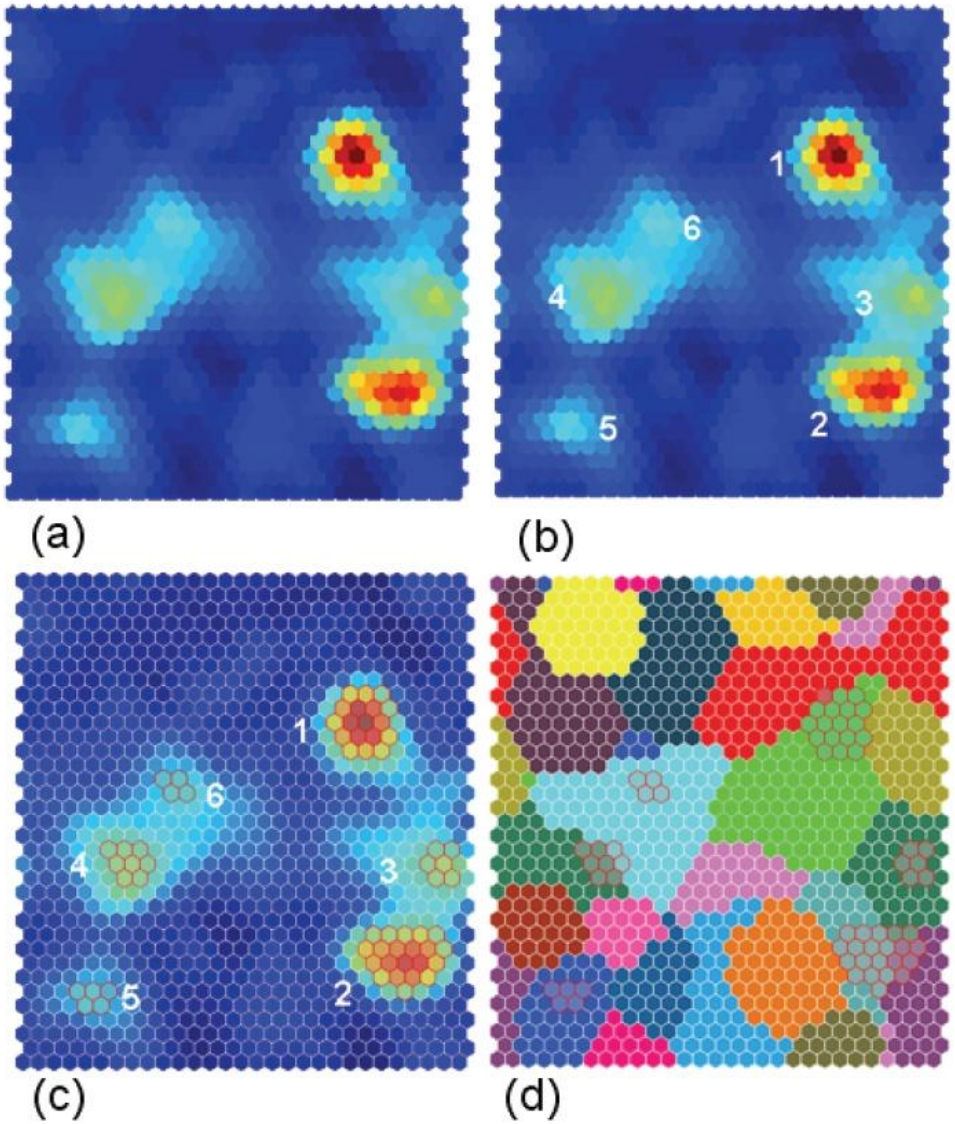
Component Plot - Element Distributions

Geoscience BC

National Research FLAGSHIPS Minerals Down Under

CSIRO

Au Component Plot



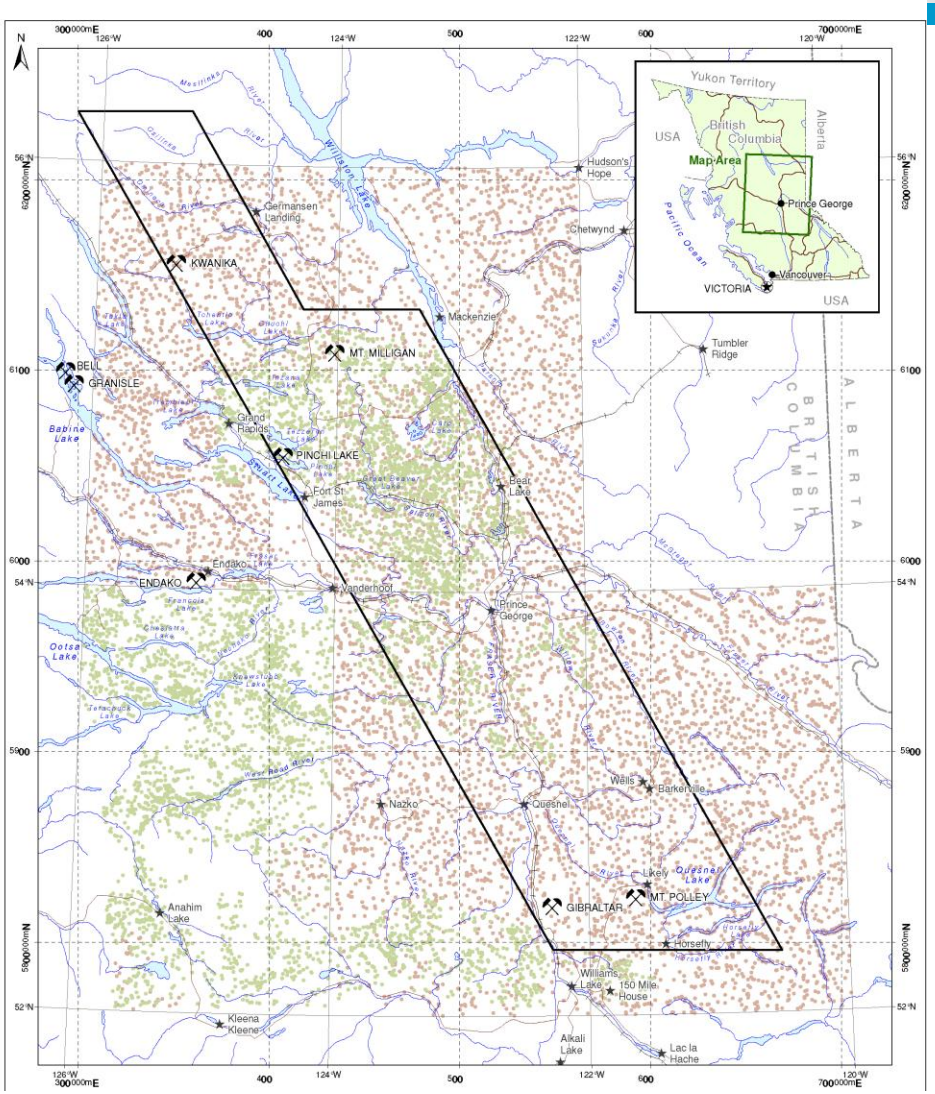
Six groups of BMU's are identified as anomalous in gold

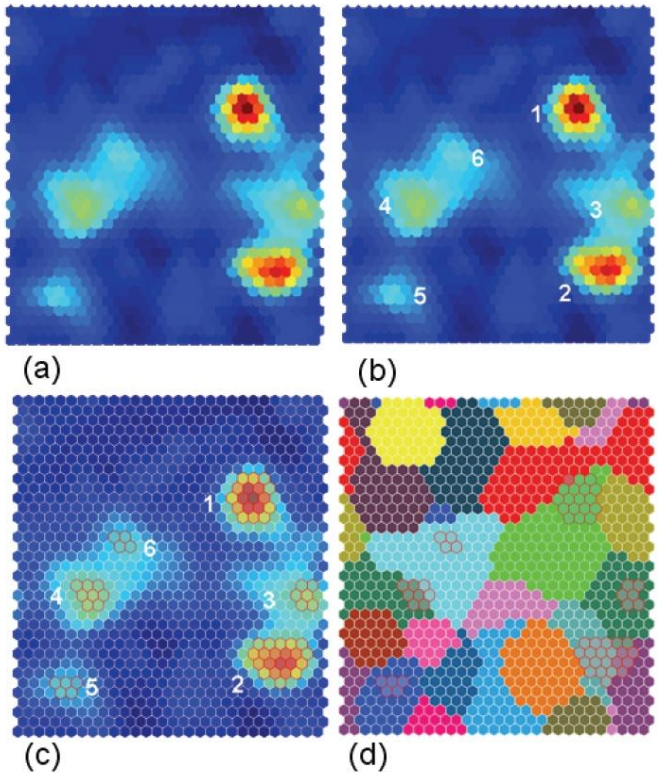
These BMU's are selected, and then samples from that BMU are plotted on a map.

National Research FLAGSHIPS Minerals Down Under CSIRO

Sample Sites & Au Component Plot

Between Prince George and Quesnel & Mt Polley /Gibraltar

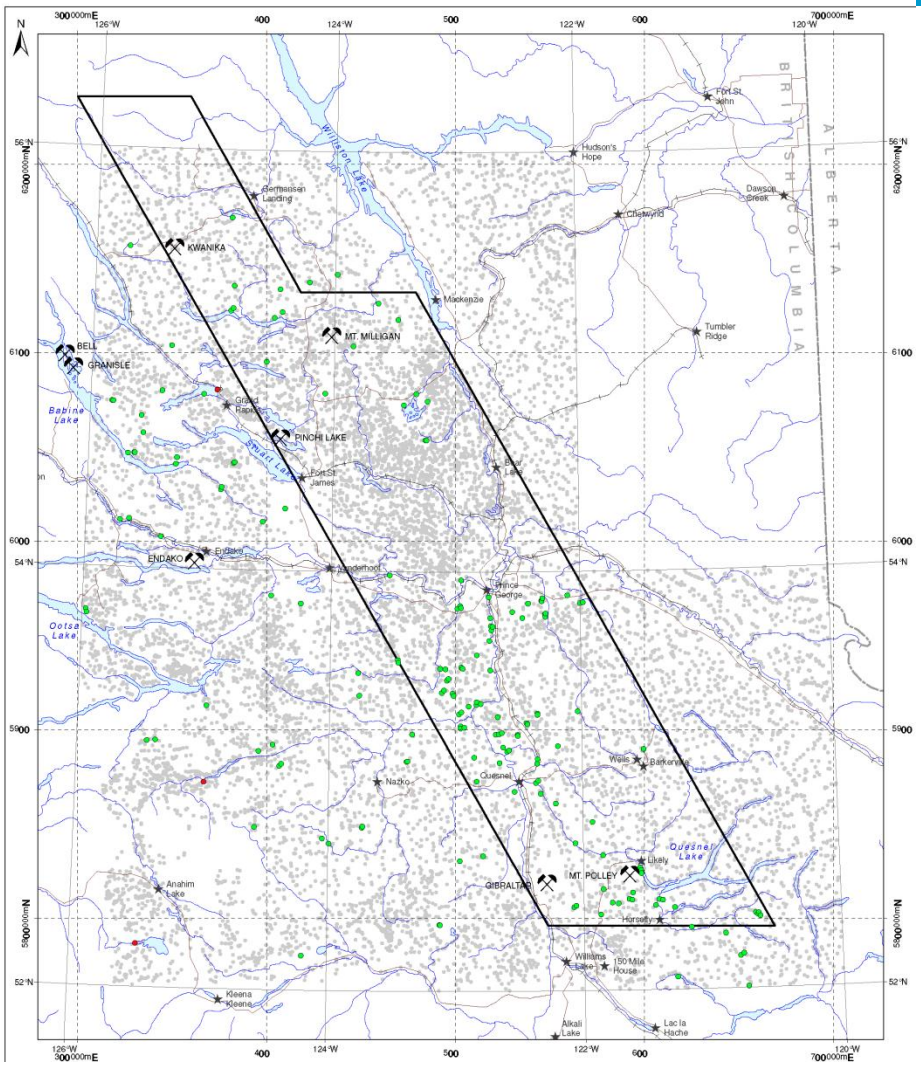


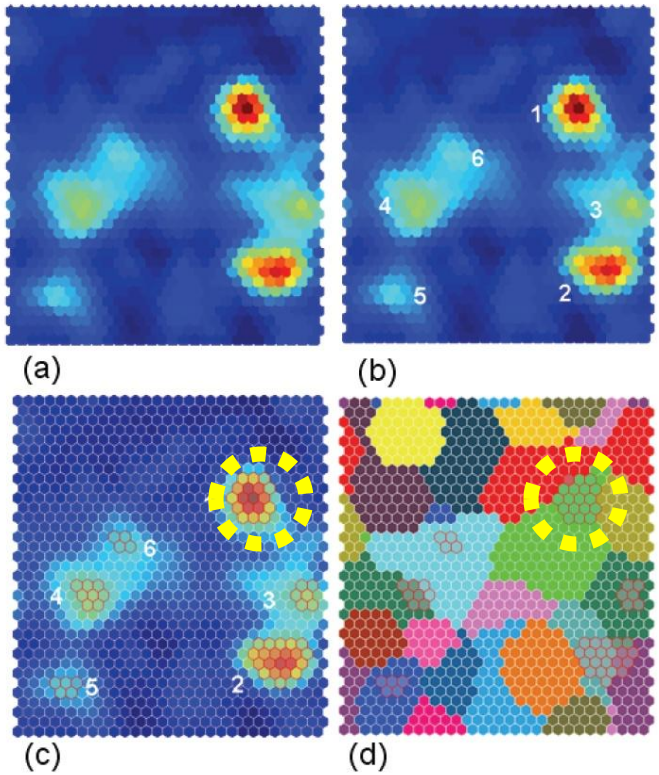


National Research FLAGSHIPS Minerals Down Under

CSIRO

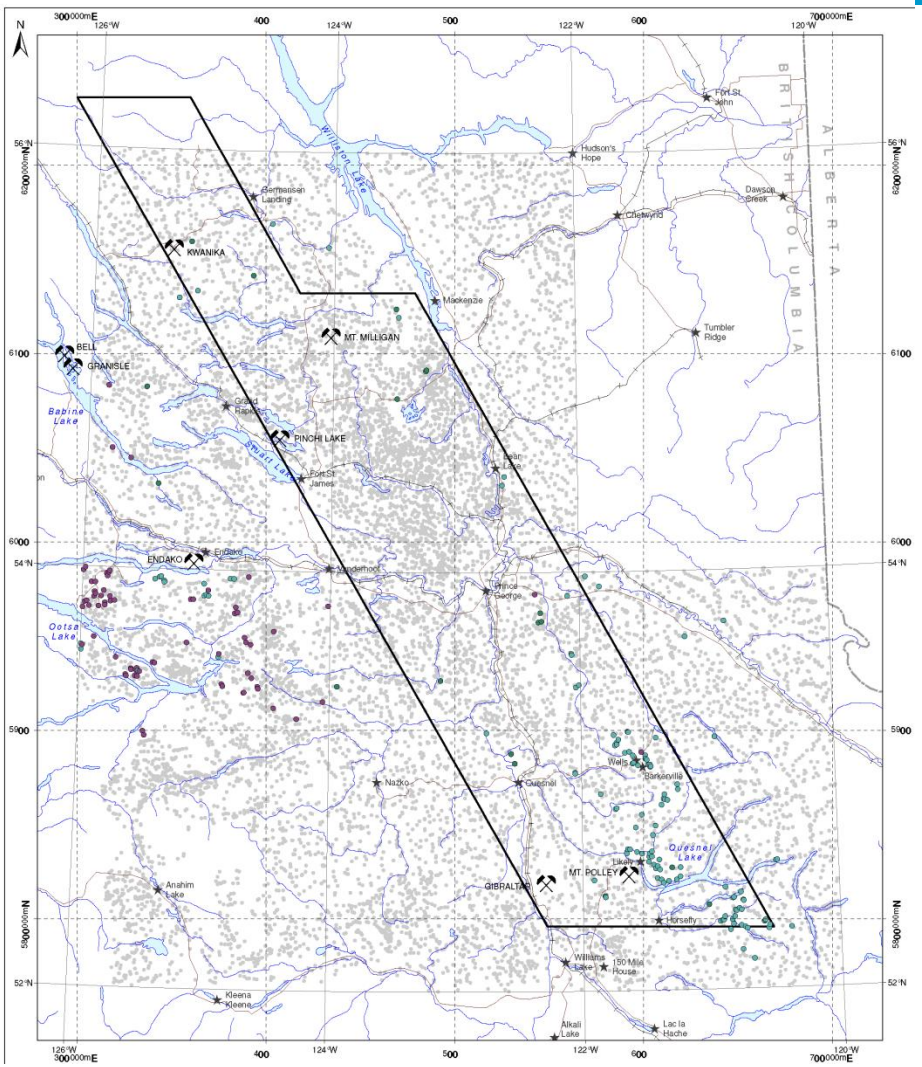
Group 1 of the Anomalous Au BMUs spatially plot between Prince George and Quesnel & Mt Polley /Gibraltar

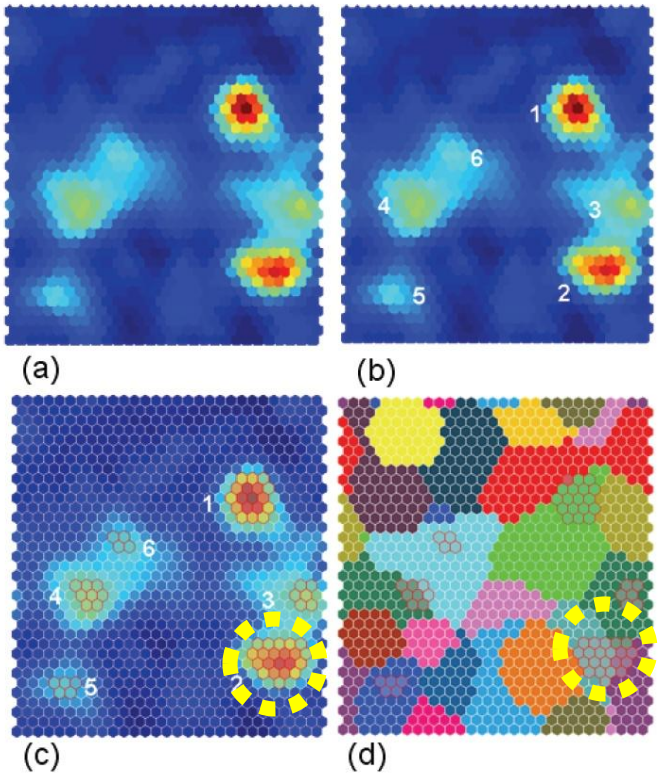




National Research FLAGSHIPS Minerals Down Under CSIRO

Group 2 of the Anomalous Au BMUs

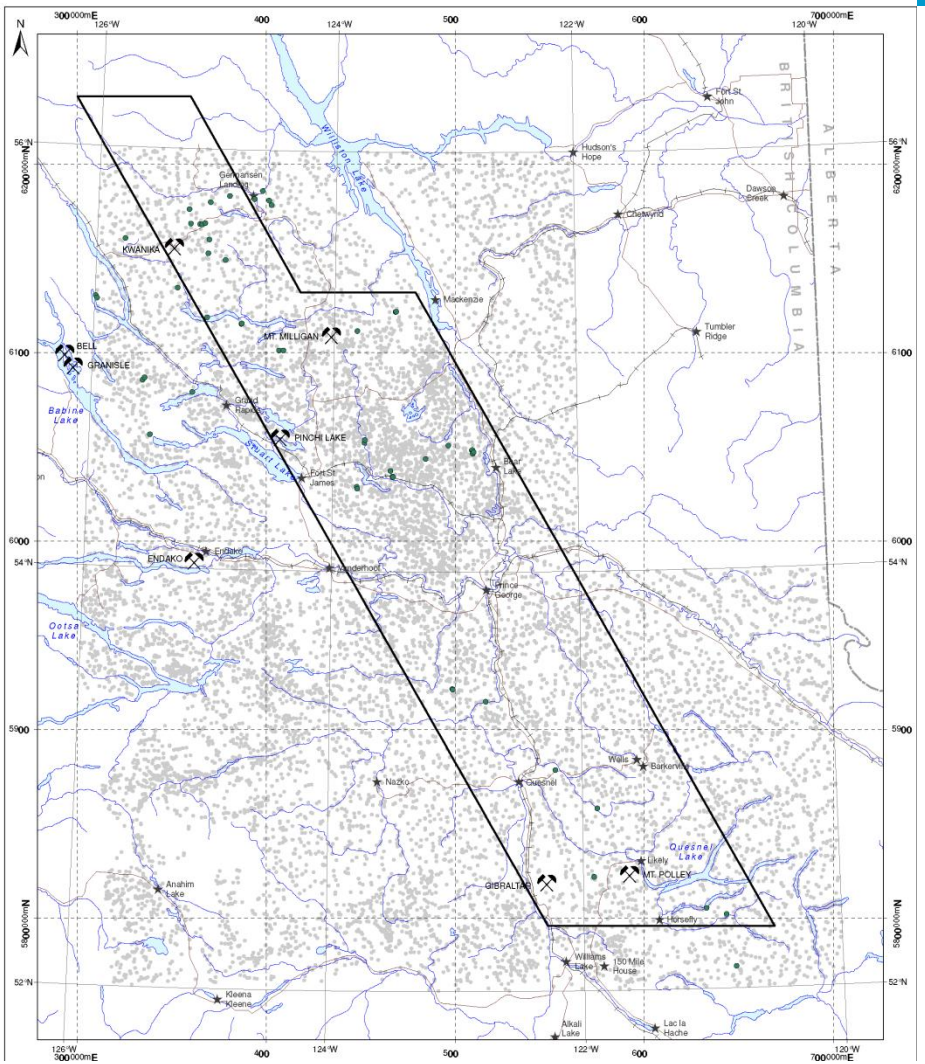


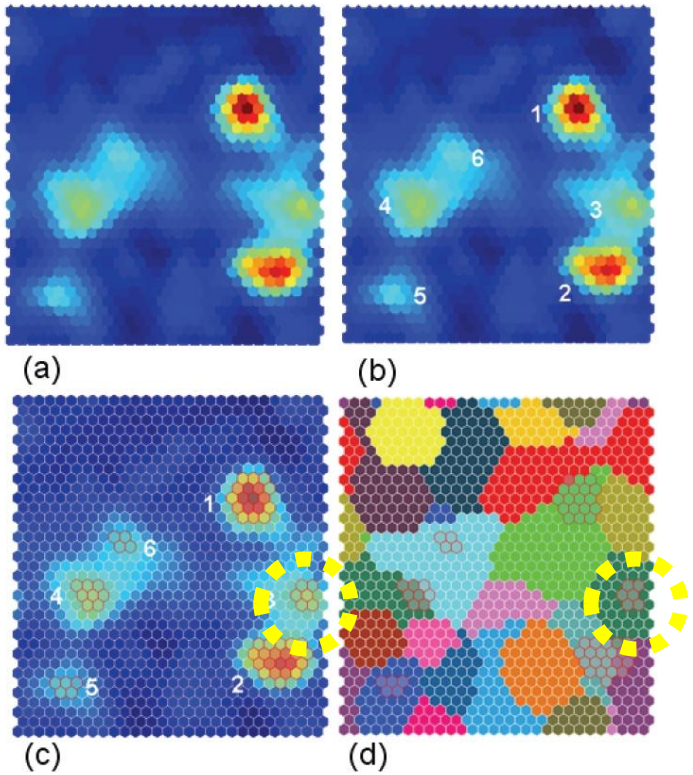


National Research FLAGSHIPS Minerals Down Under

CSIRO

Group 3 of the Anomalous Au BMUs

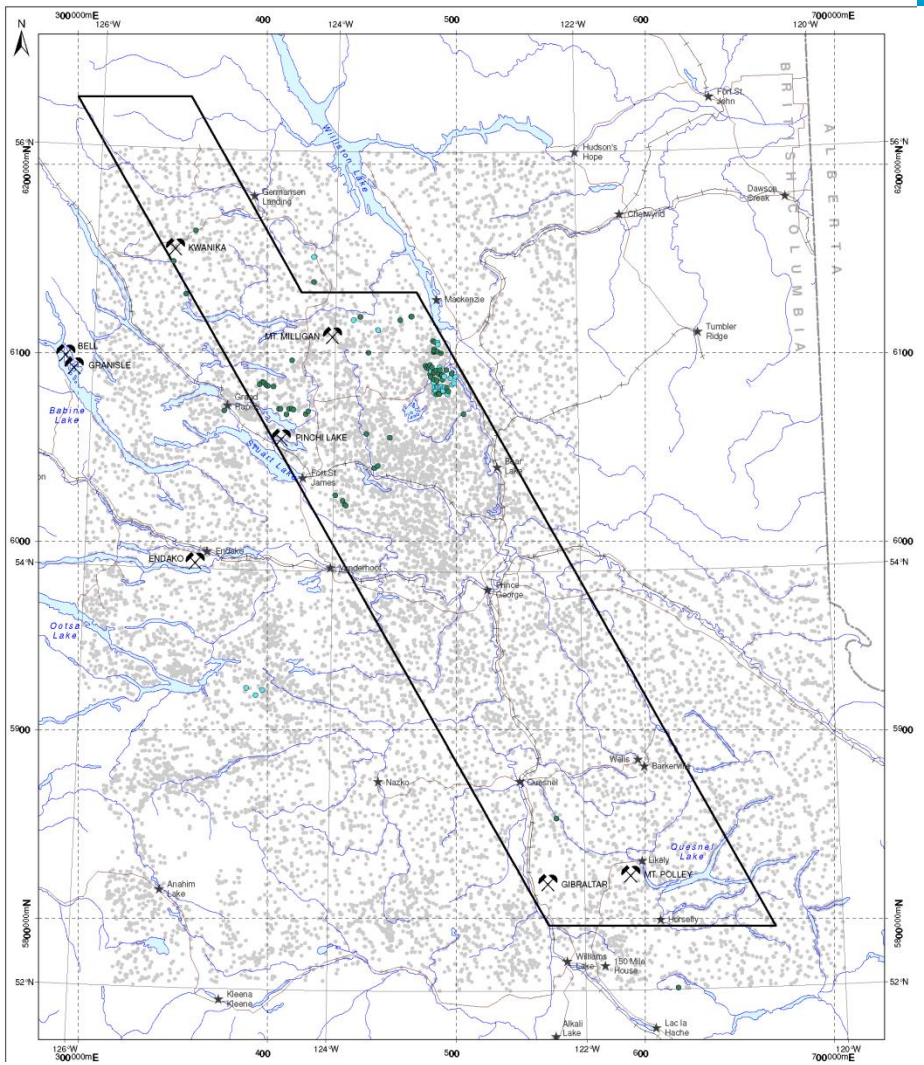


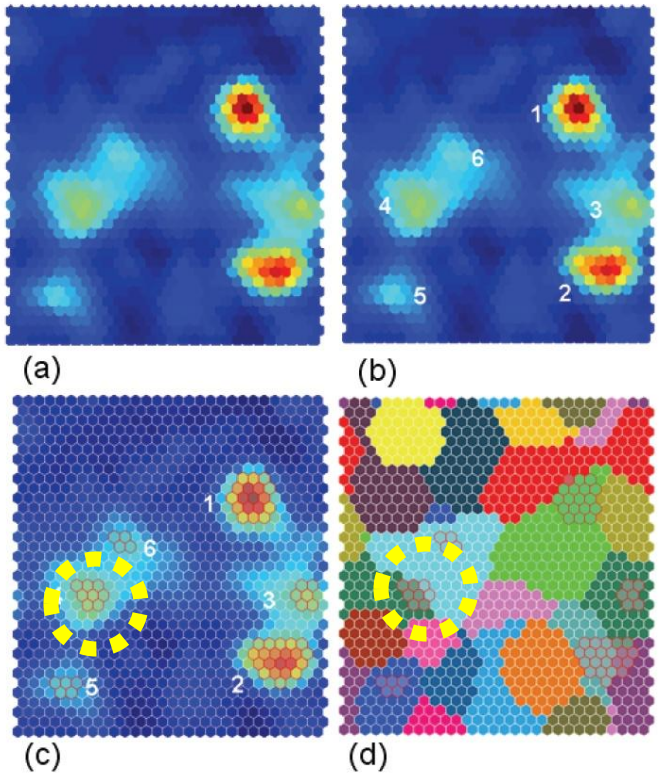


National Research FLAGSHIPS Minerals Down Under

CSIRO

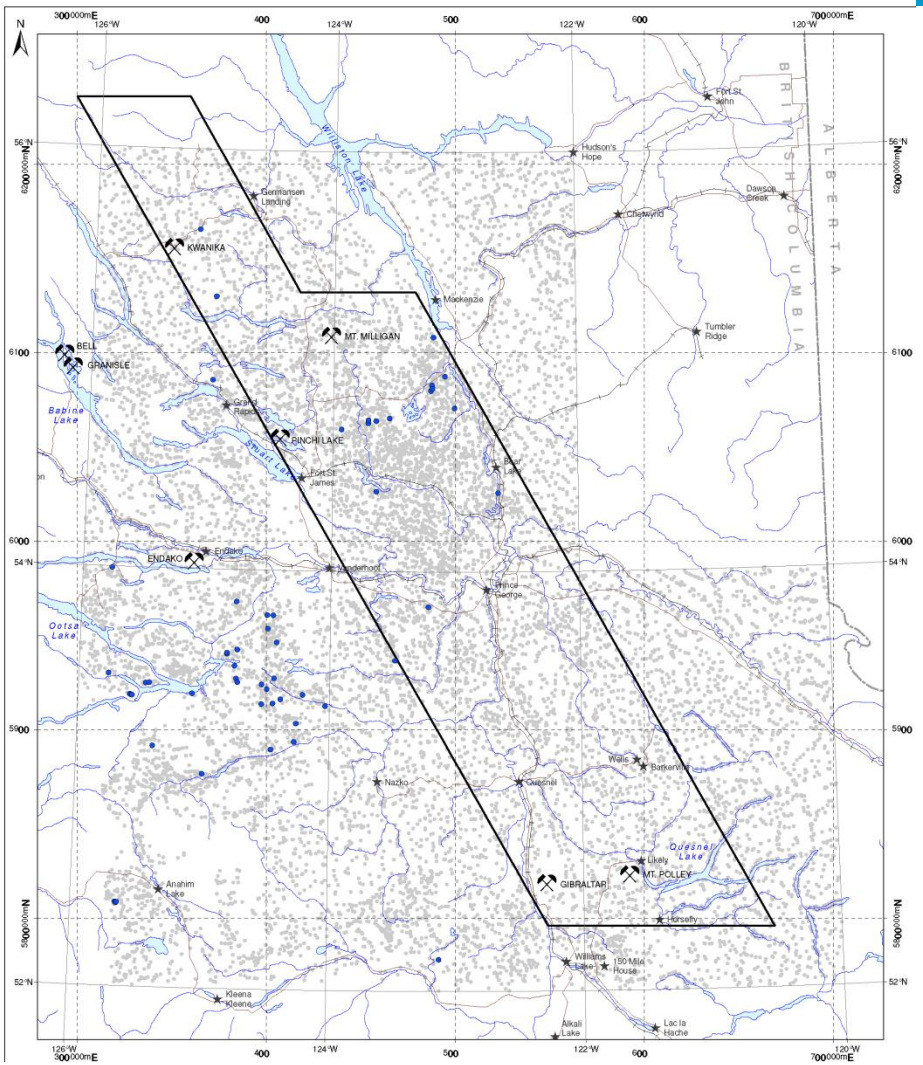
Group 4 of the Anomalous Au BMUs

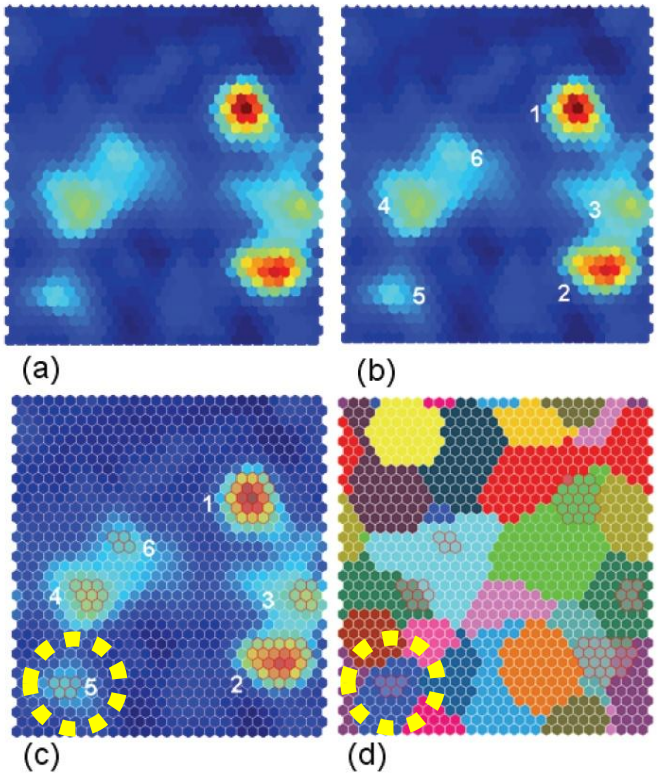




National Research FLAGSHIPS
Minerals Down Under
CSIRO

Group 5 of the Anomalous Au BMUs

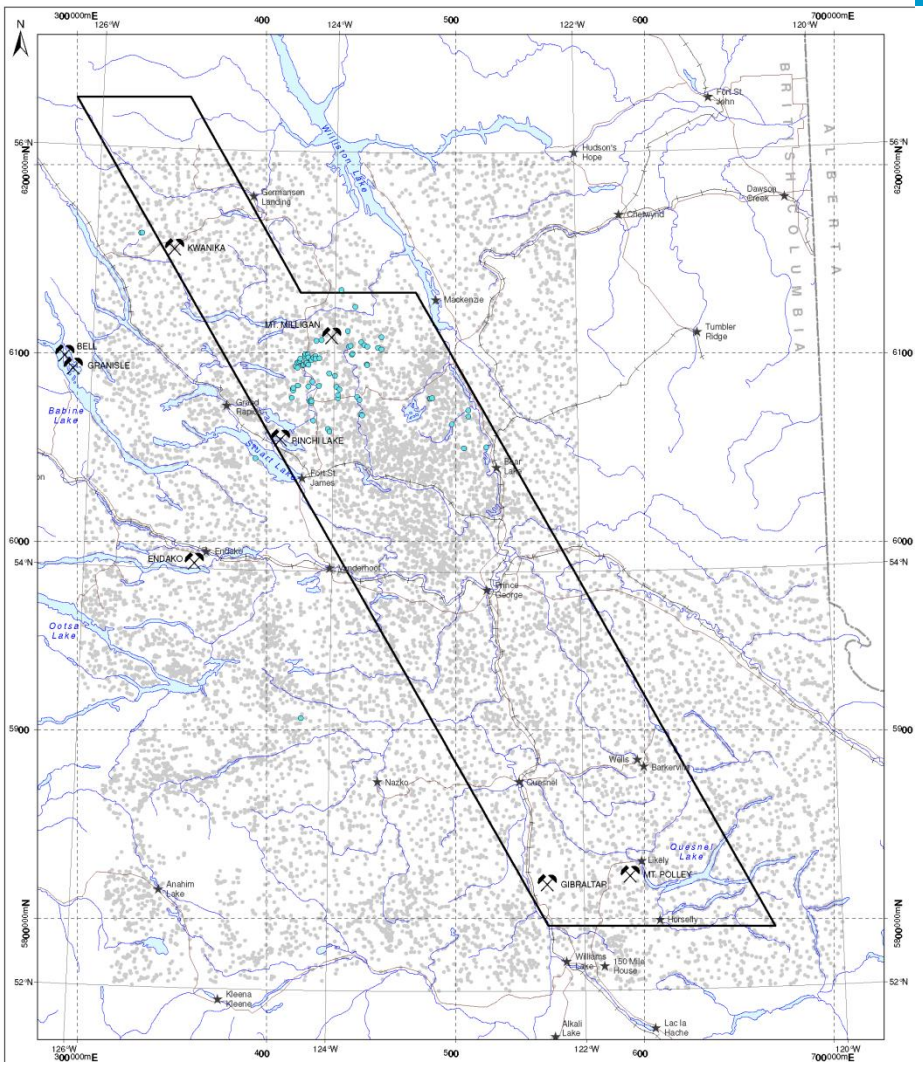


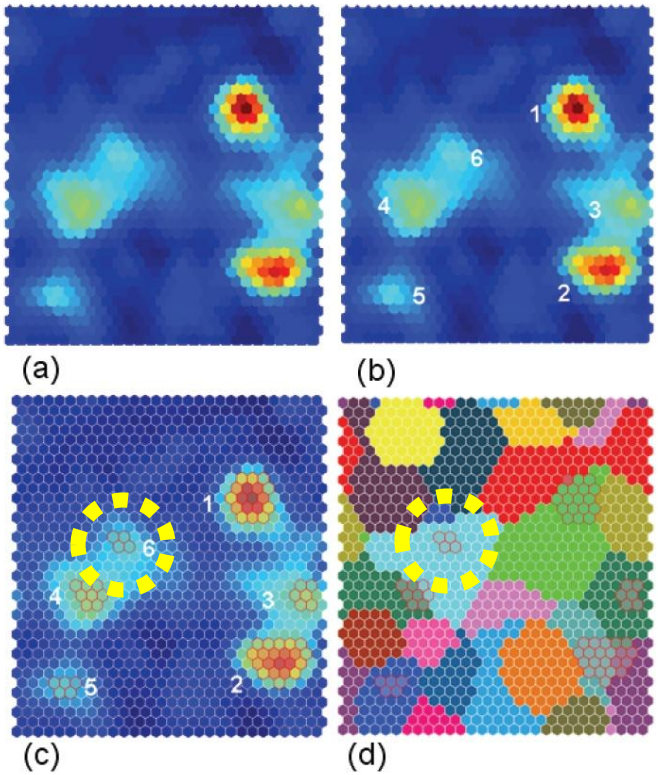


National Research FLAGSHIPS Minerals Down Under

CSIRO

Group 6 of the Anomalous Au BMUs
Plots around Mt. Milligan

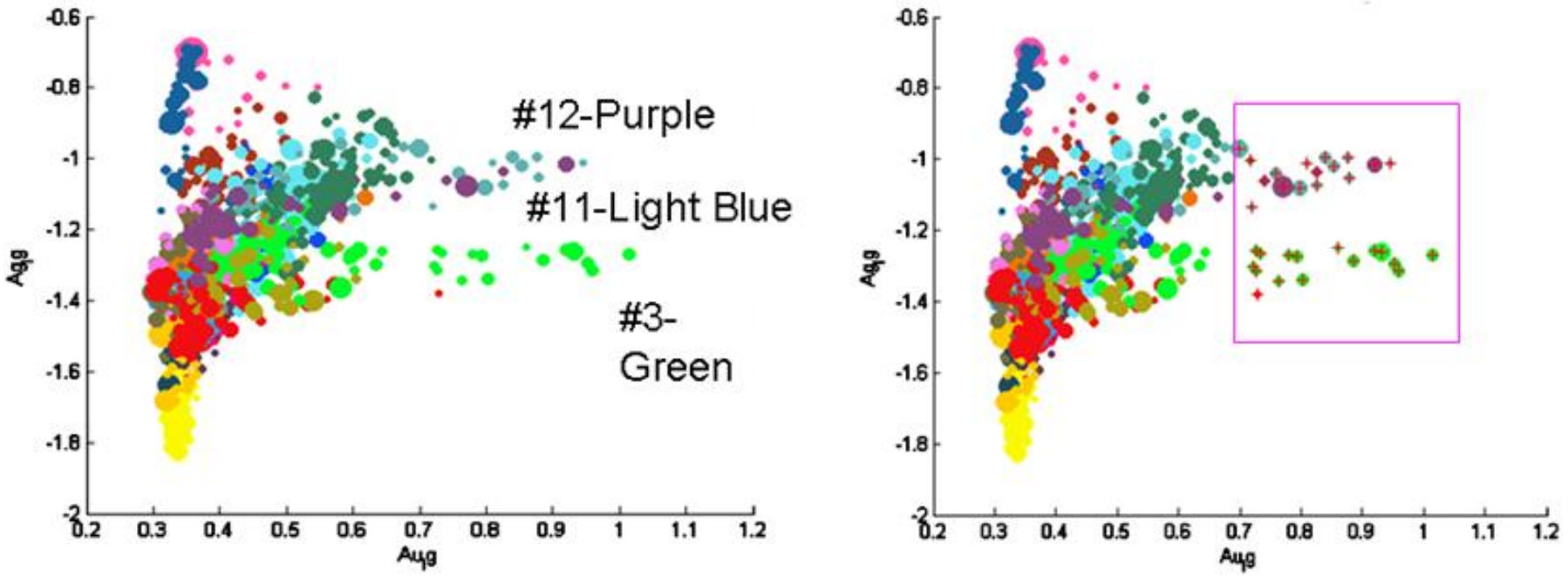




National Research FLAGSHIPS
Minerals Down Under
CSIRO

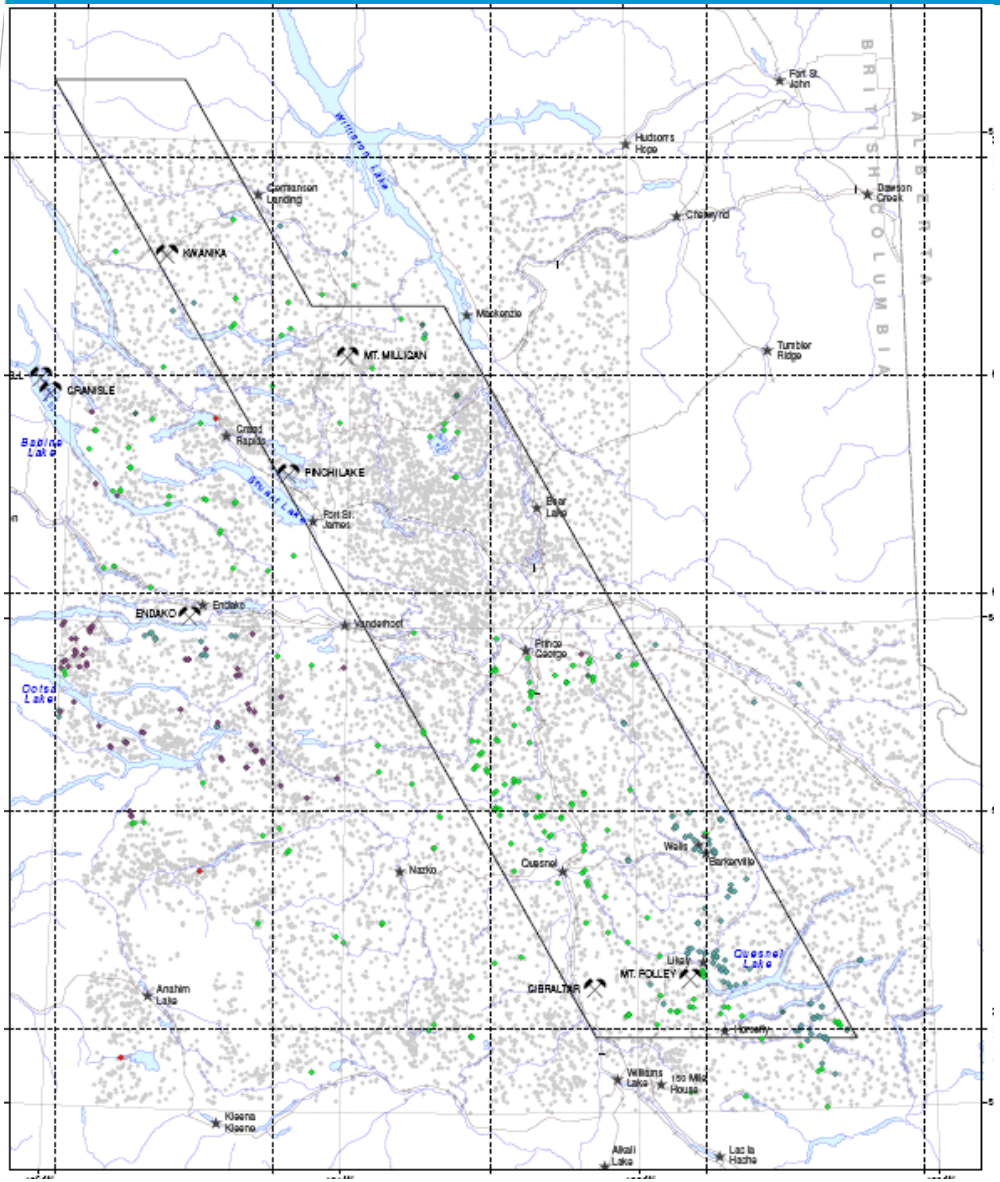
Cross-plots of Selected Elements

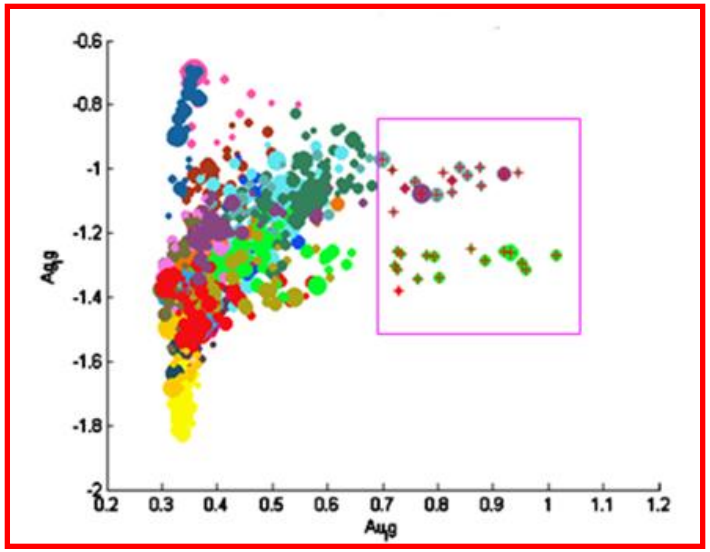
Cross-Plot of Au vs Ag SOM Node values

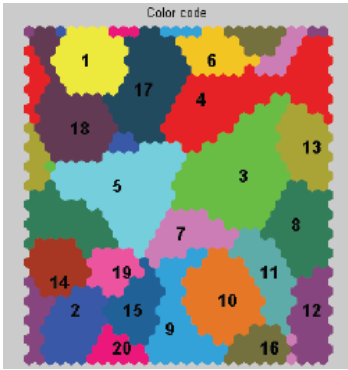


Three elevated Au “associations” evident

Spatial Distribution of Selected Ag vs Au Samples –High Au







National Research FLAGSHIPS
Minerals Down Under
CSIRO

Brownfields Regional Geochemical Database -Osborne

- **SOM used to identify populations related to “processes”**
- **SOM used to identify prospective “targets”**

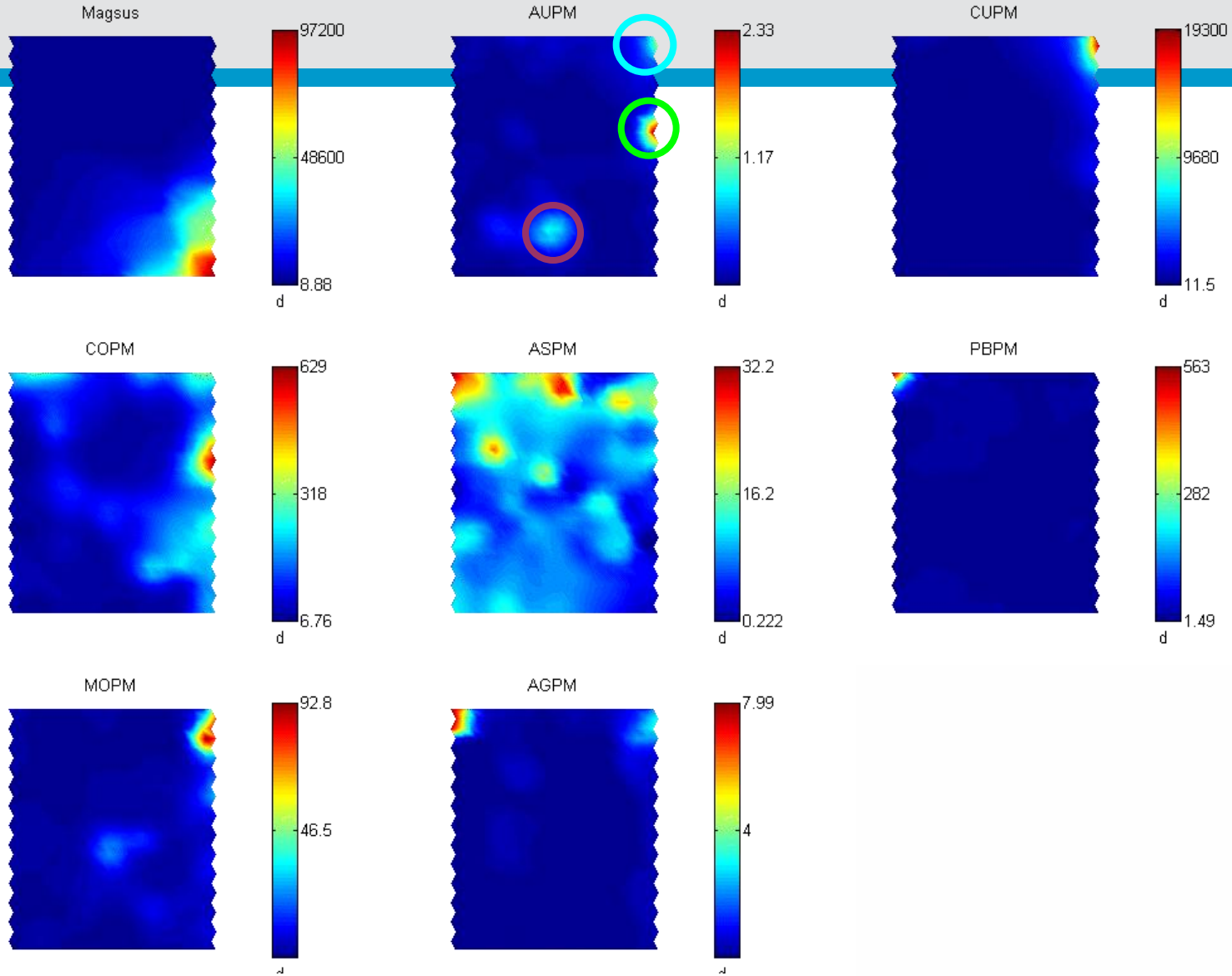
Bruce Dickson, Peter Kowalczyk, Gary Sparks

~ 40,000 located (XYZ) geochemical samples with up to 13 elements assayed:
~ 60% of data base is “empty”

Exploration around the Osborne Cu-Au Deposit, Queensland, Australia.

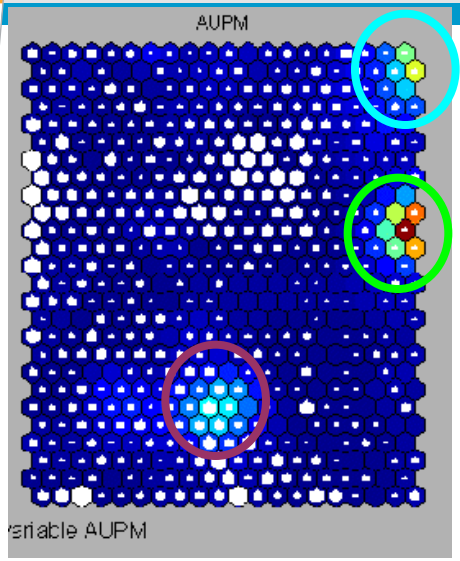
A Demonstration of SOM where a large fraction (60%) of data is “missing”.

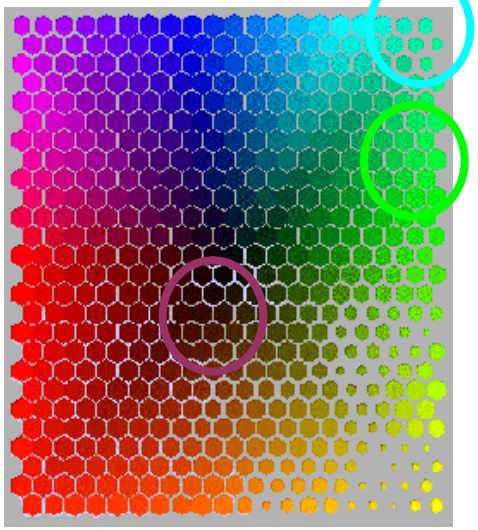
Component Plots

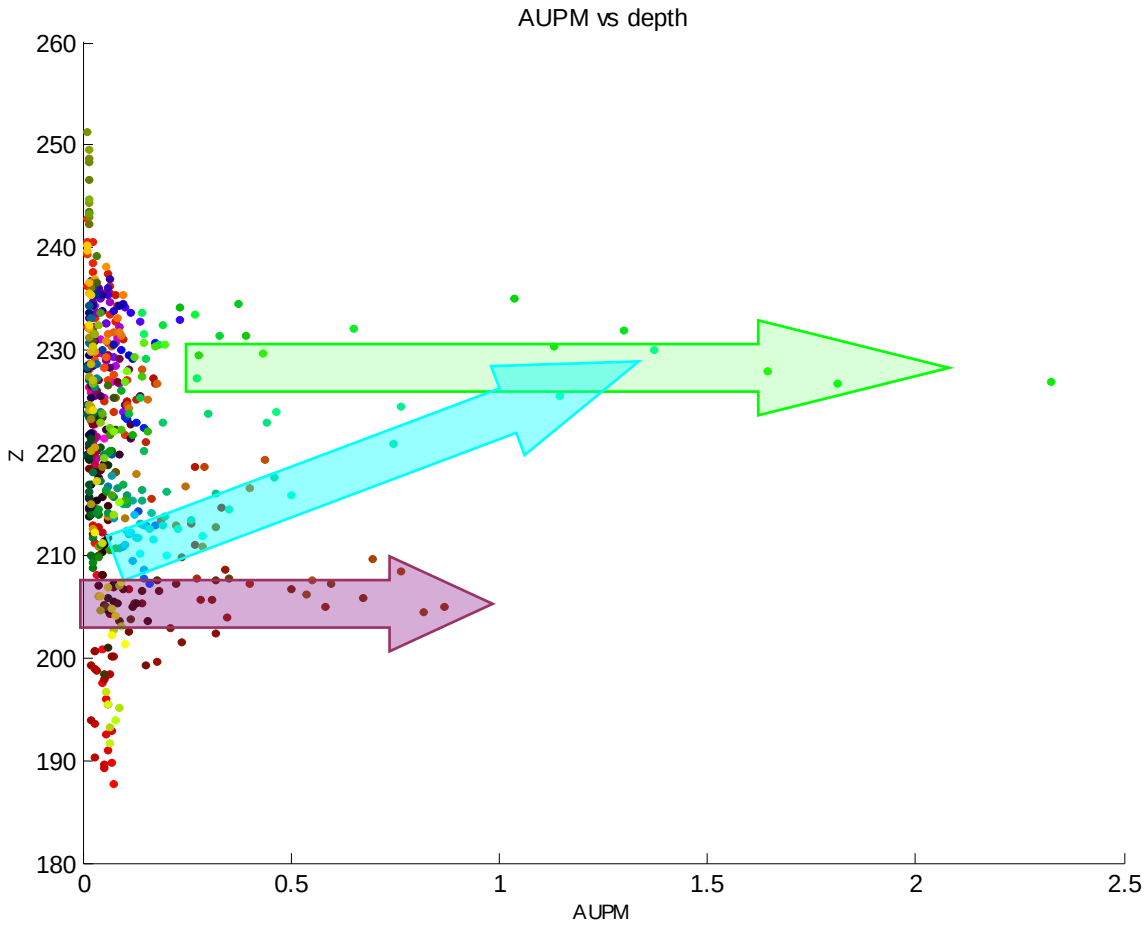


Component Plots #1

SOM Node - Depth Plot



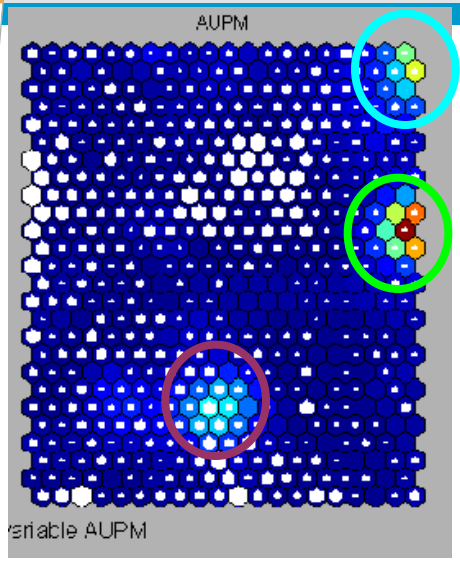


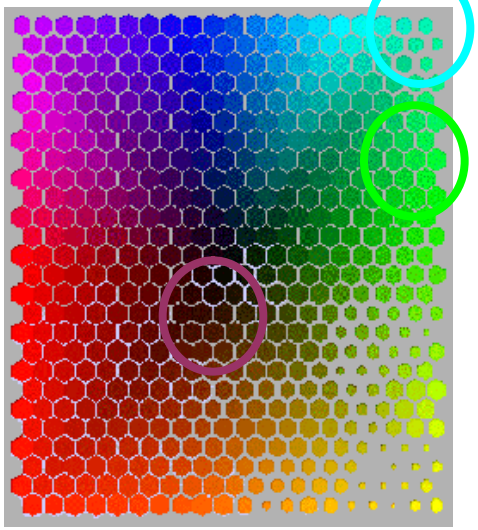


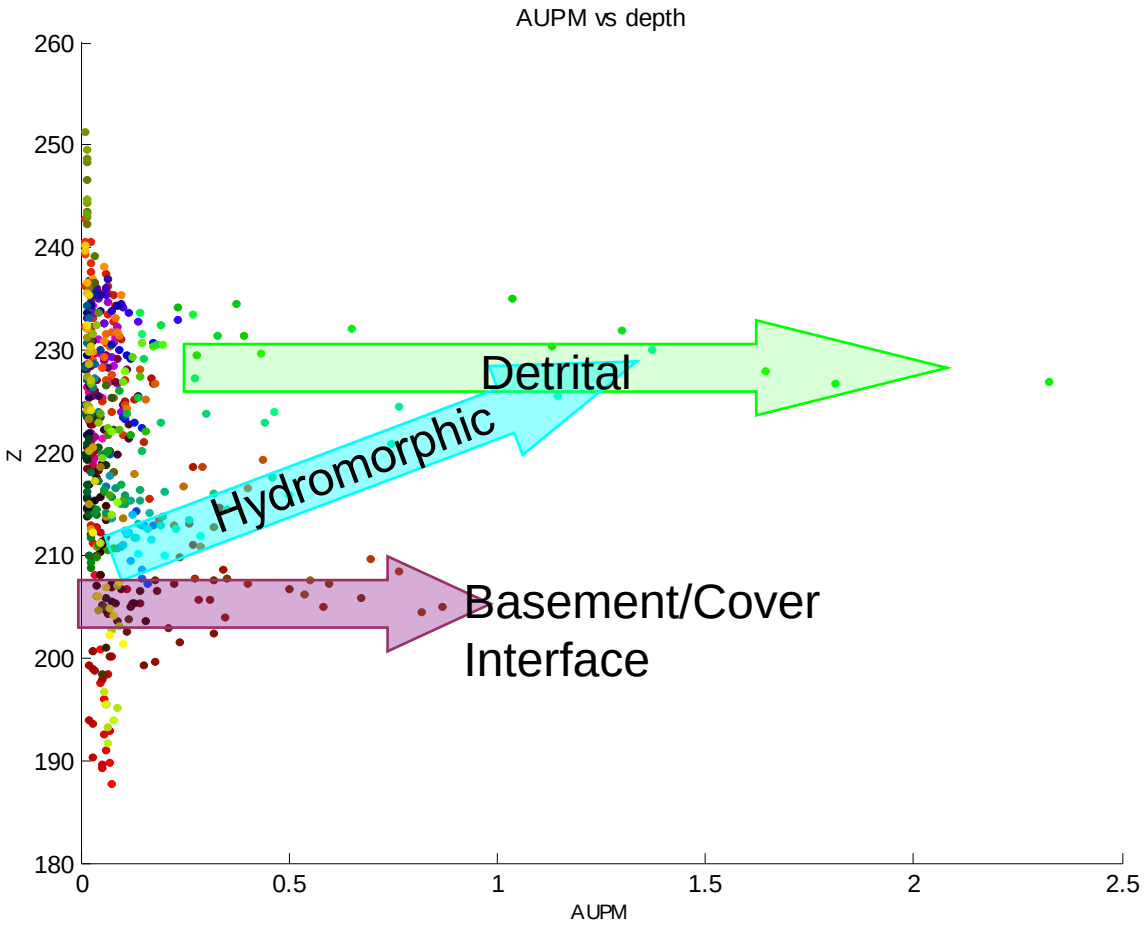
Au Vs Depth

National Research FLAGSHIPS Minerals Down Under CSIRO

SOM Node - Depth Plot



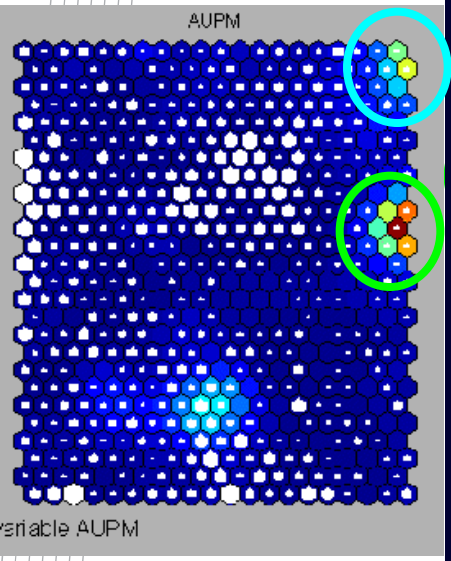


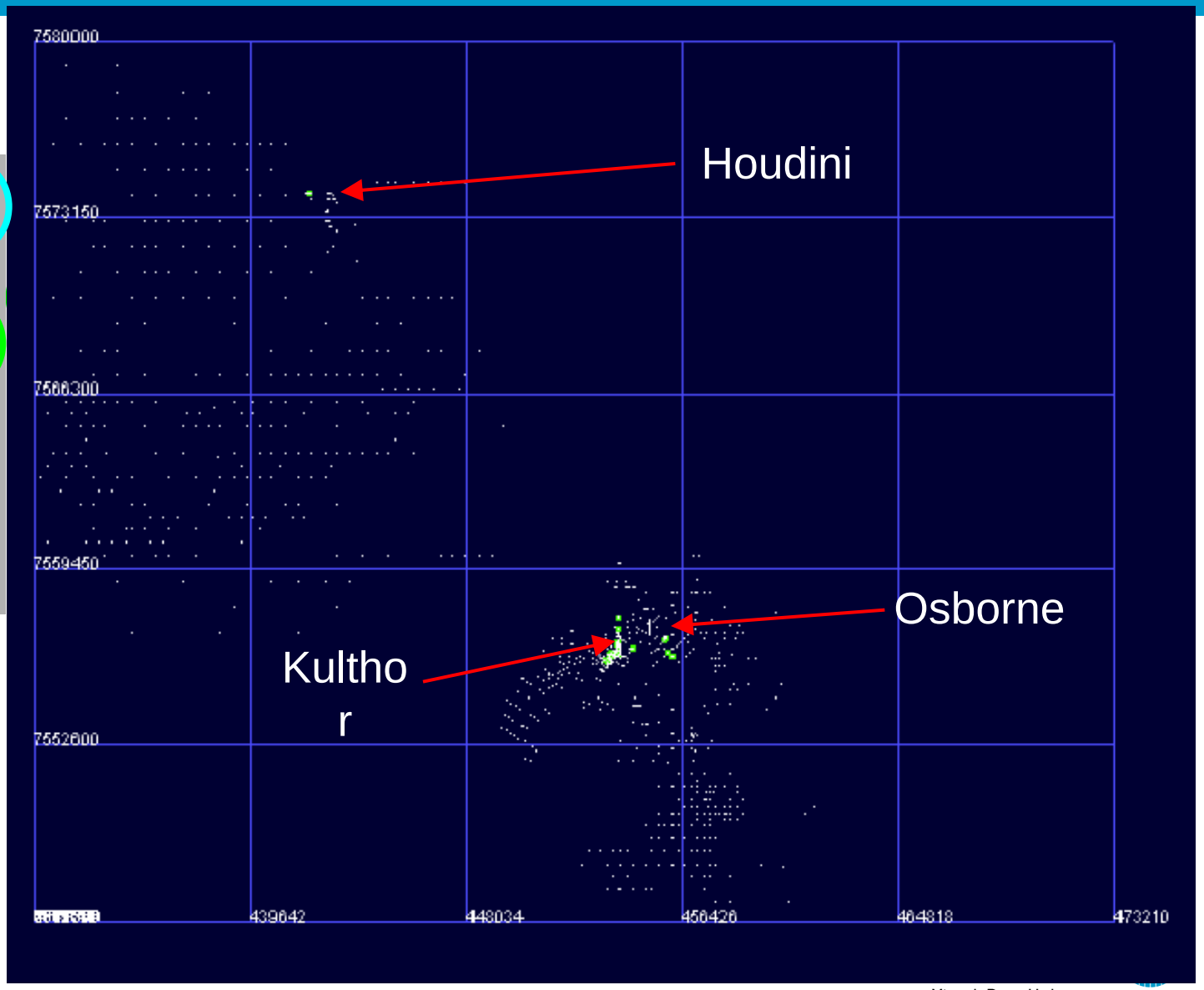


Au Vs Depth

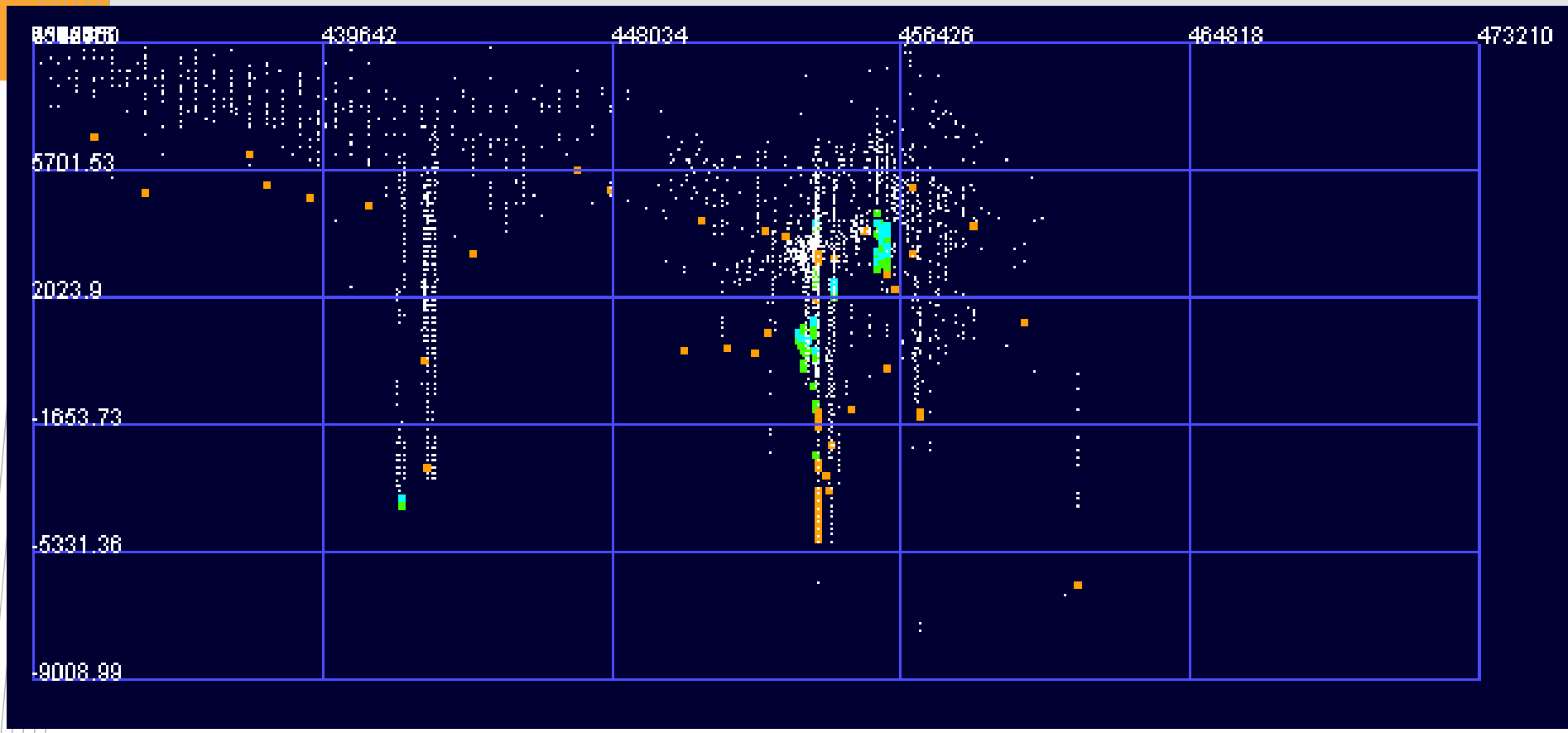
SOM can assist in the identification of "process"

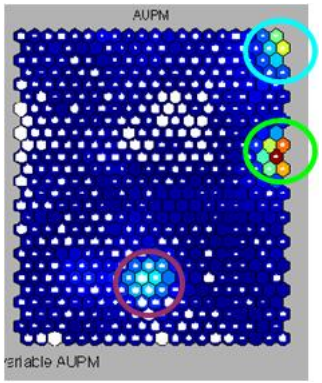
Au group I: Detrital





Au All Looking ---- North





SOM on Voxel Volumes of Petrophysical Data resulting from "Unconstrained Geophysical Inversion"

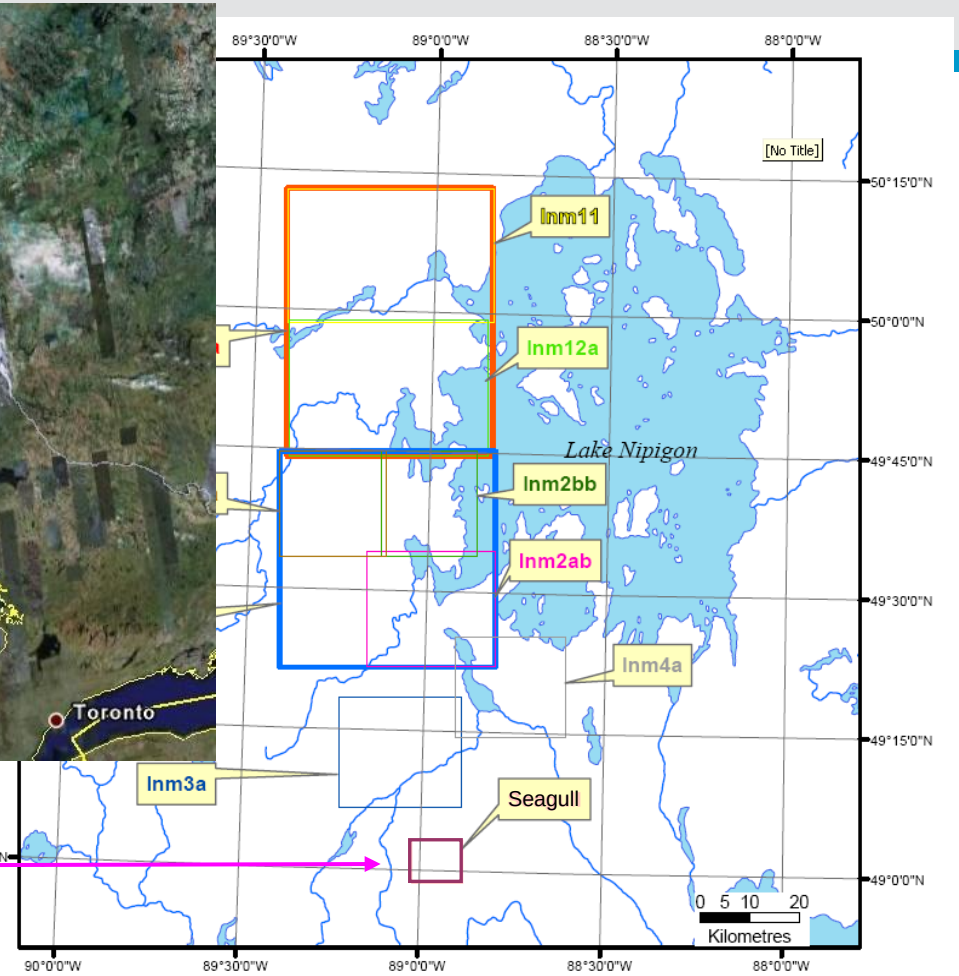
Seagull (PGE-Ni-Cu) Geophysical Model

Data from:

Magnetic and Gravity Three-Dimensional (3D) Modelling: Lake Nipigon Region Geoscience Initiative L.E. Reed, D.R.B. Rainsford

Ontario Ministry of Northern Development and Mines, Ontario Geological Survey
MRD report 193 2006

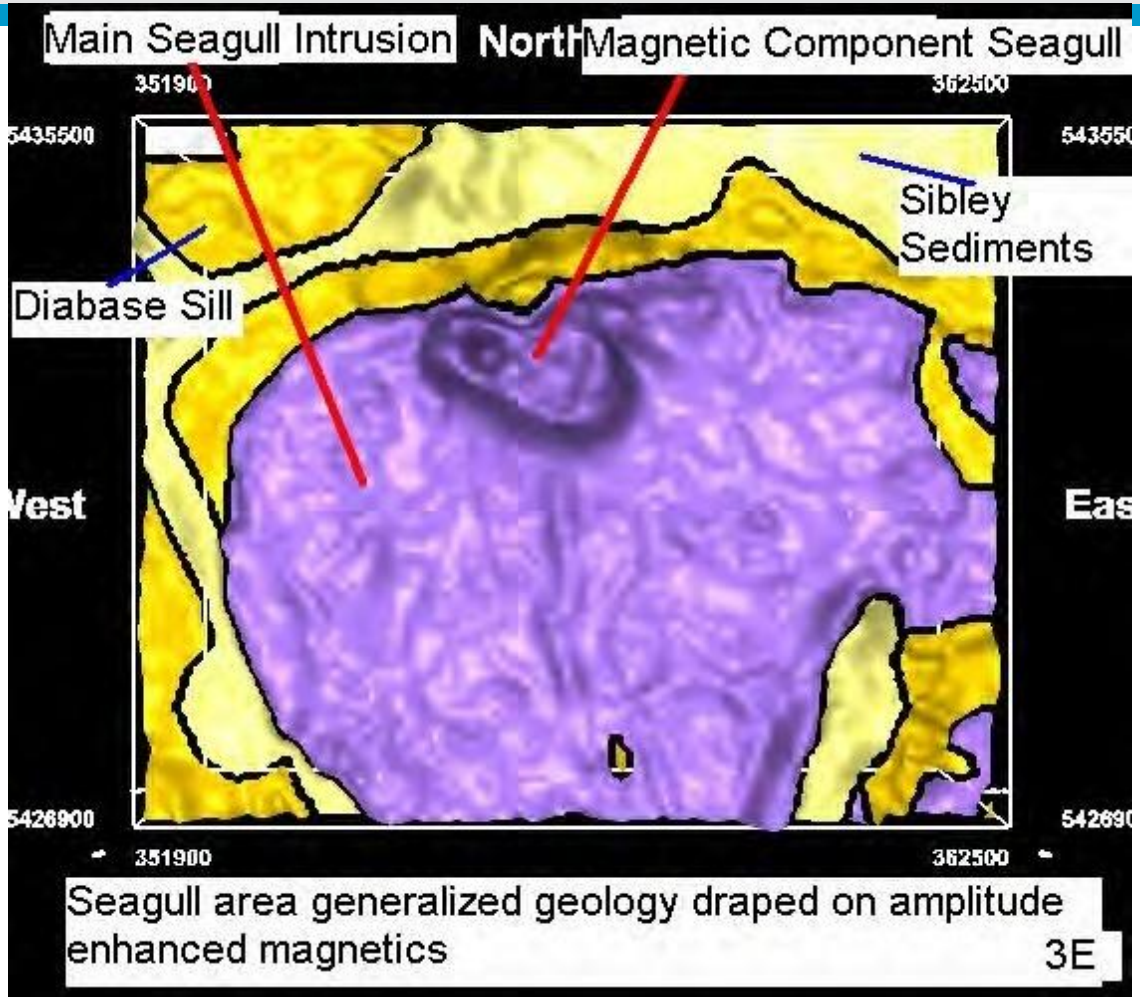
Seagull Location



Seagull

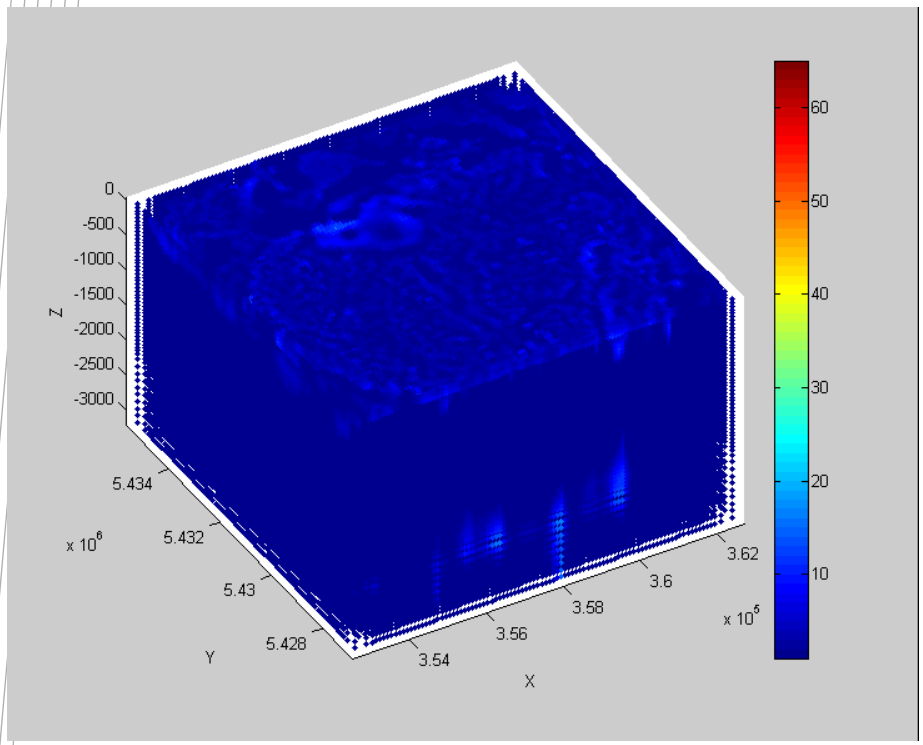
Location of Seagull and other magnetic models in area [*from* Magnetic and Gravity Three-Dimensional (3D) Modelling: Lake Nipigon, Region Geoscience Initiative, L.E. Reed, D.R.B. Rainsford, Ontario, Ministry of Northern Development and Mines, Ontario Geological Survey, MRD report 193, 2006]

Geology draped over Magnetics TMI

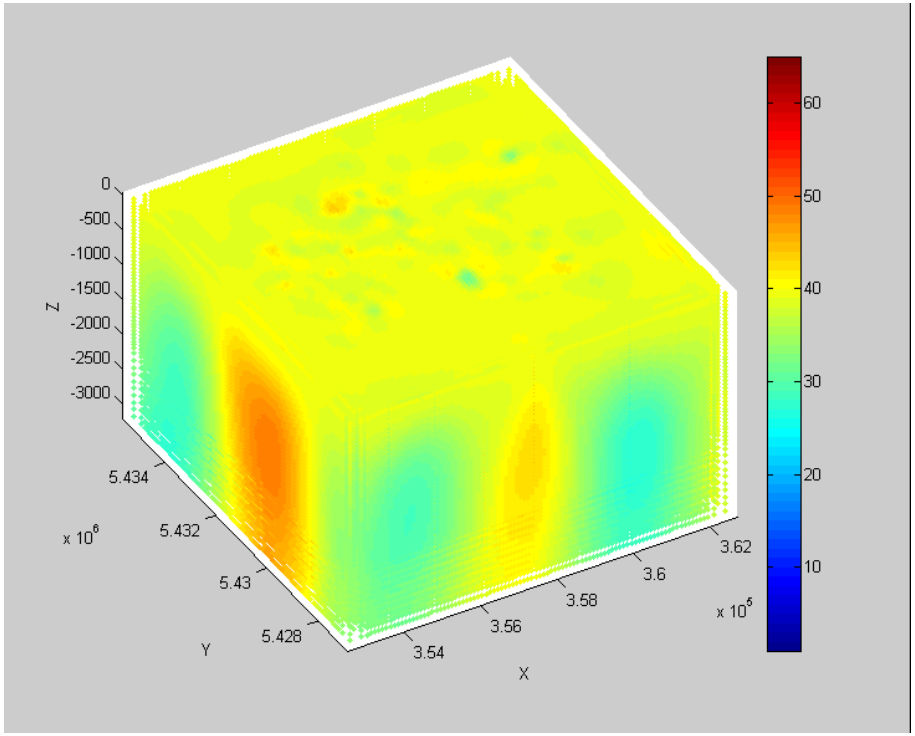


Magnetic model for Seagull. Overhead view of geology draped on amplitude enhanced total field magnetics. [*from* Magnetic and Gravity Three-Dimensional (3D) Modelling: Lake Nipigon, Region Geoscience Initiative, L.E. Reed, D.R.B. Rainsford, Ontario, Ministry of Northern Development and Mines, Ontario Geological Survey, MRD report 193, 2006]

Raw Data

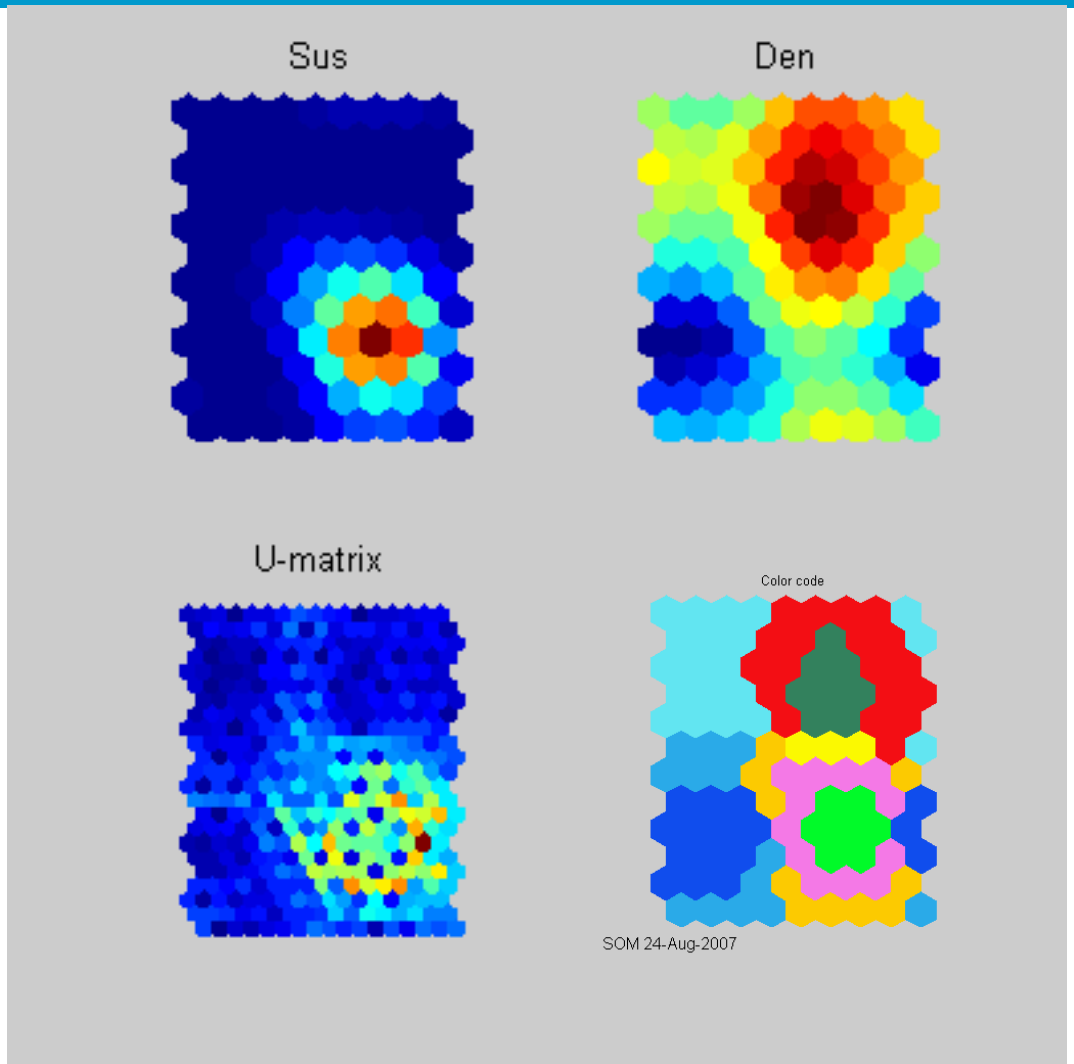


Magnetic Susceptibility



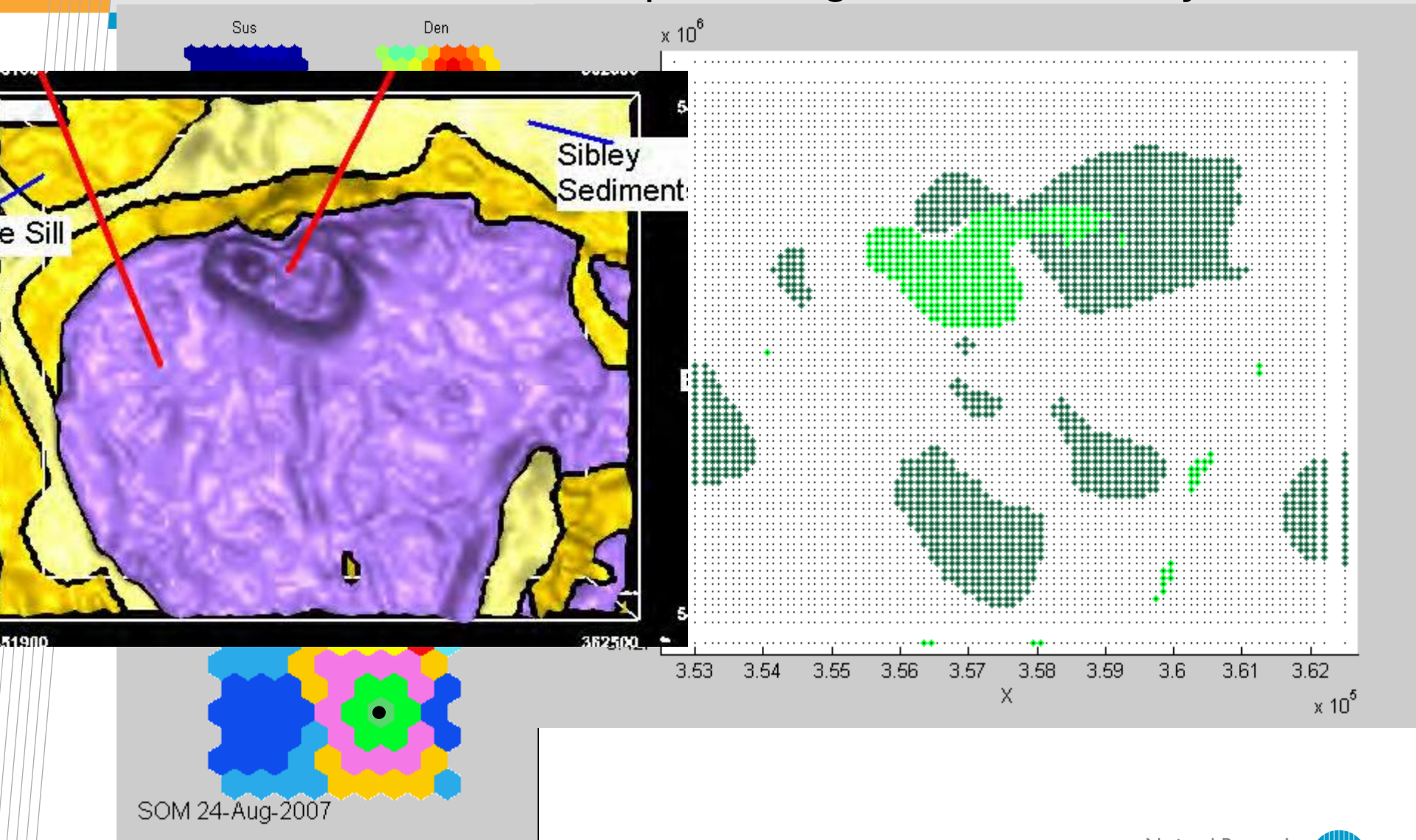
Density

SOM on 411,156 samples each: MagSus and Density

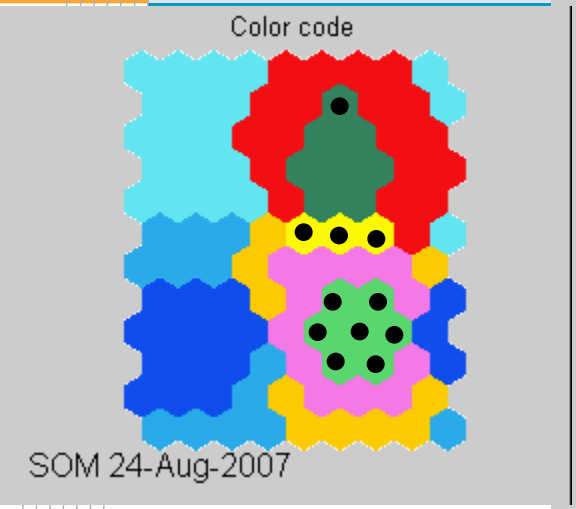


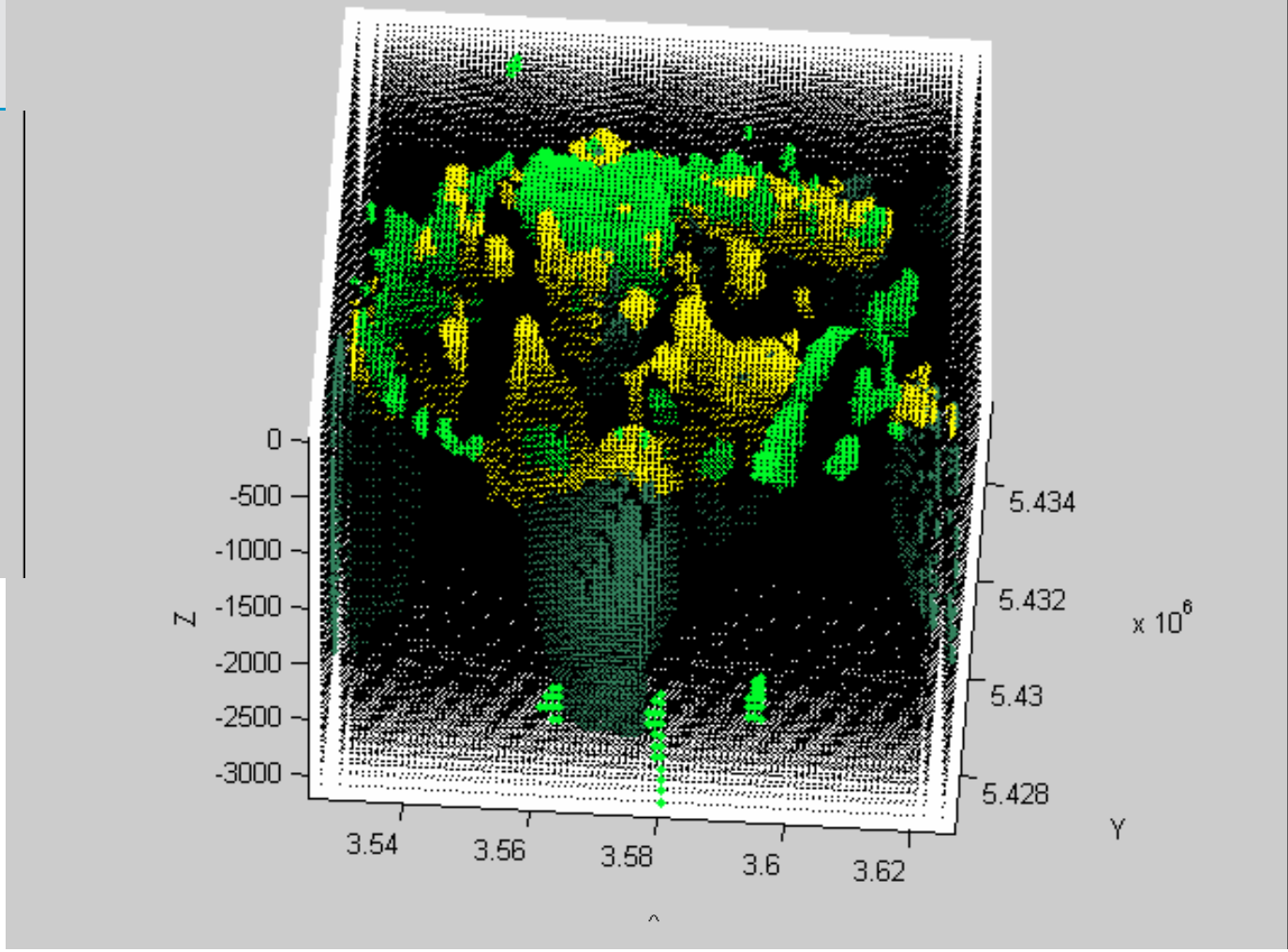
sf10k_sus_den_12x9_toroid_2_Km2_9

SOM on 411,156 samples: MagSus and Density



sf10k_sus_den_12x9_toroid_2_Km2_9

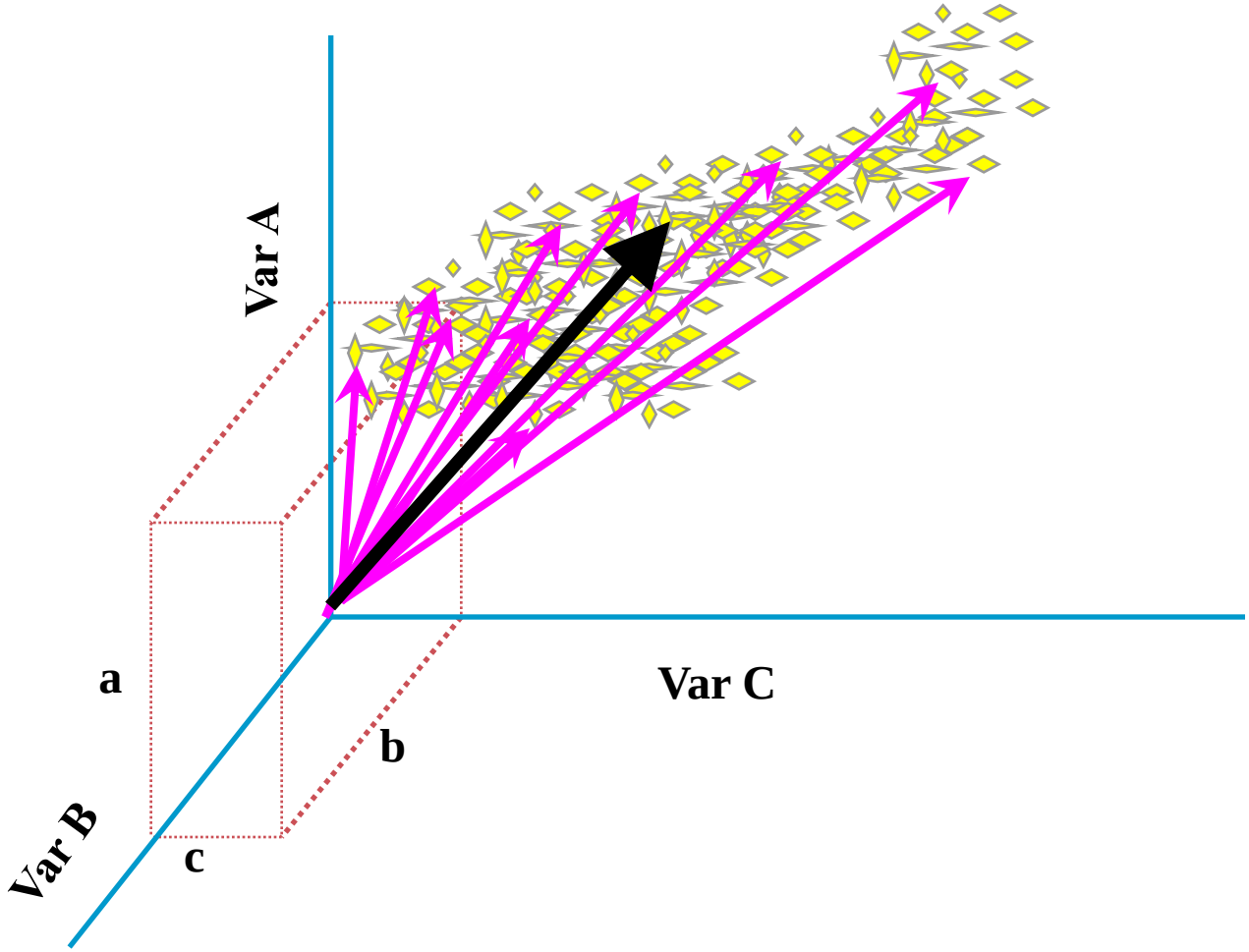




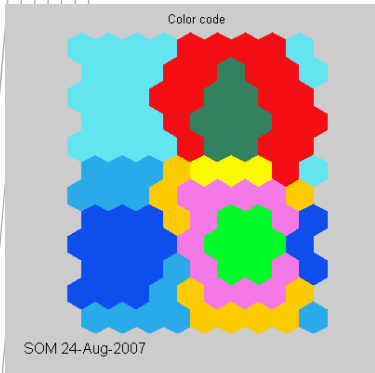
sf10k_sus_den_12x9_toroid_2_Km2_9

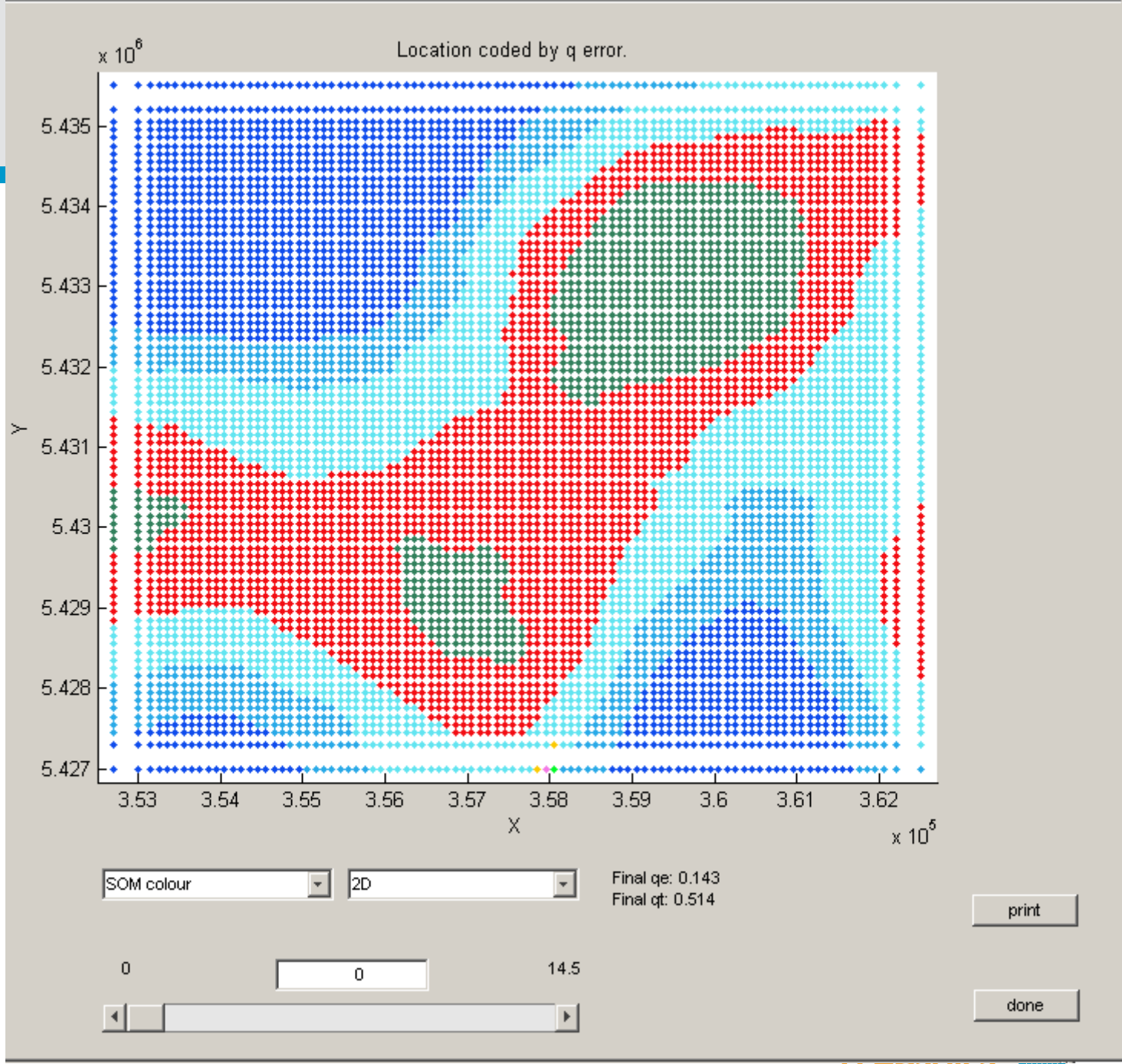
Outlier Analysis

- Based on measures of how far away a sample is from its SOM Code Vector - QER

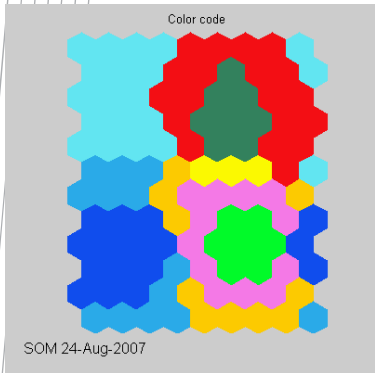


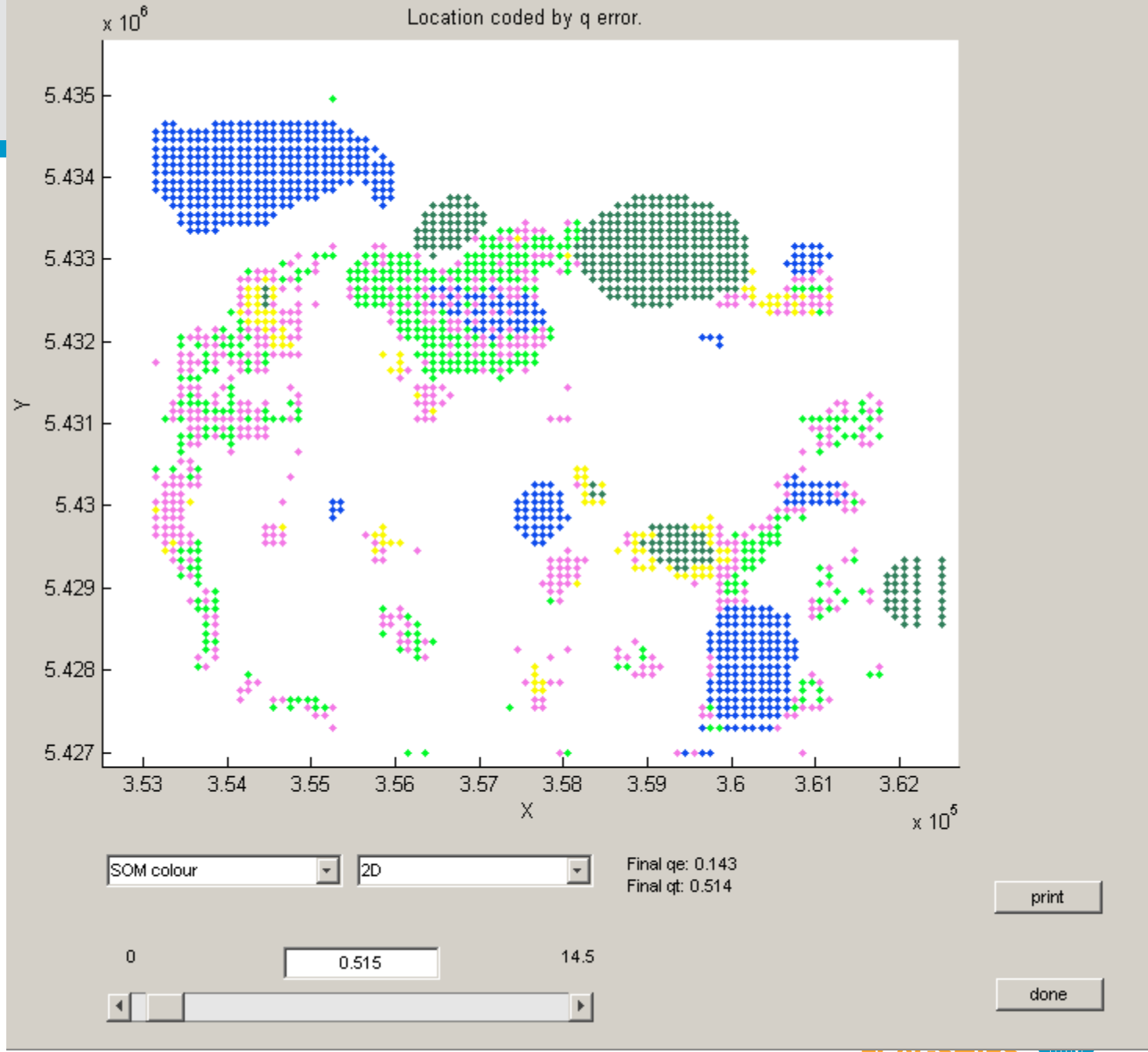
X-Y Plot Quantization Errors



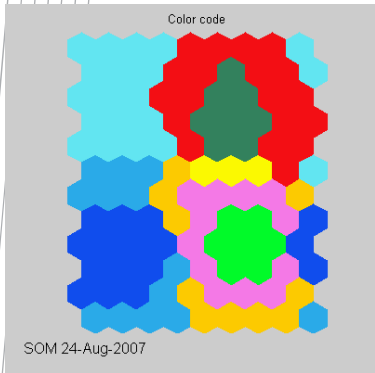


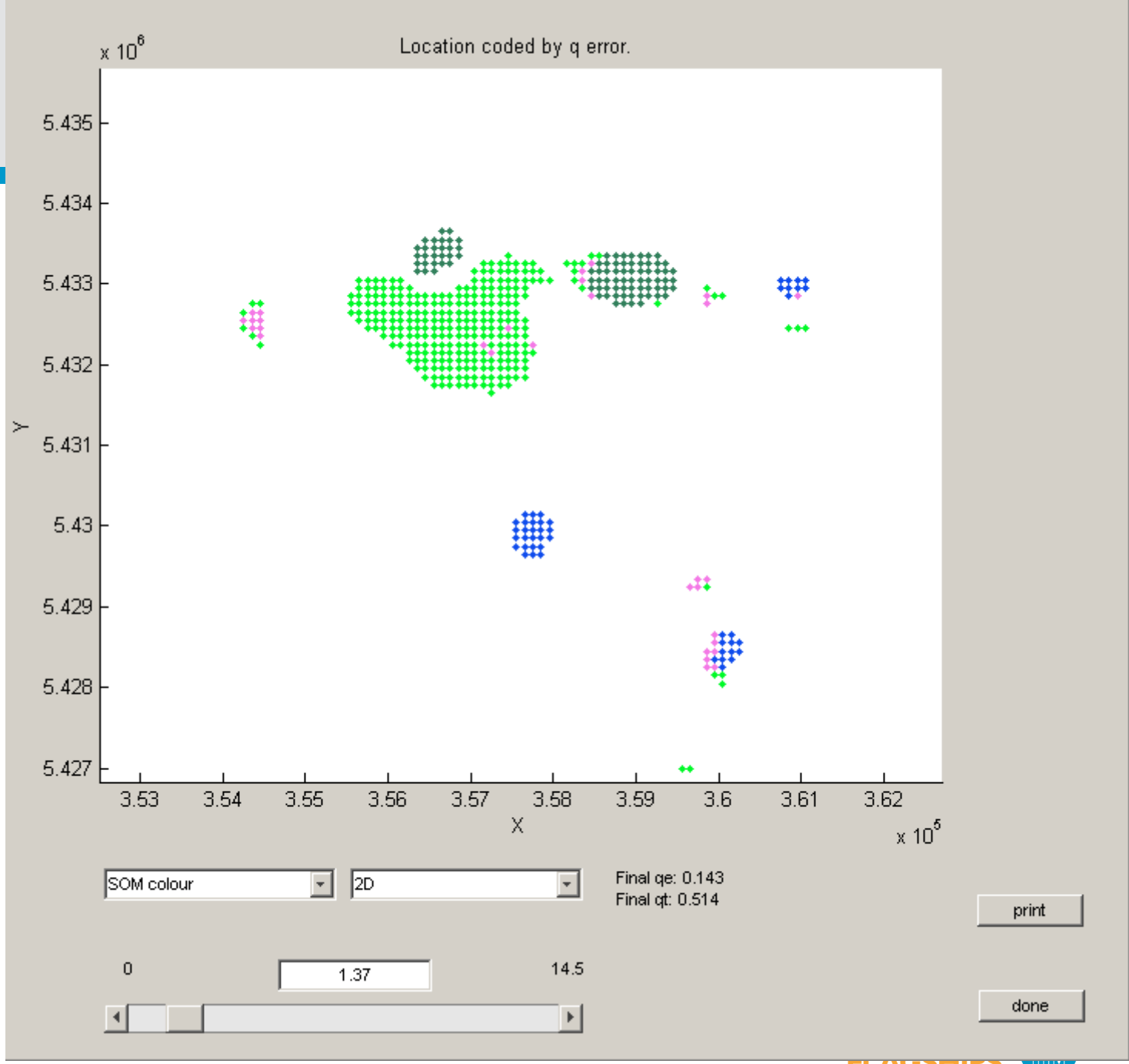
X-Y Plot Quantization Errors



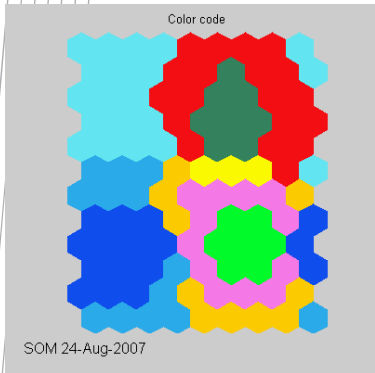


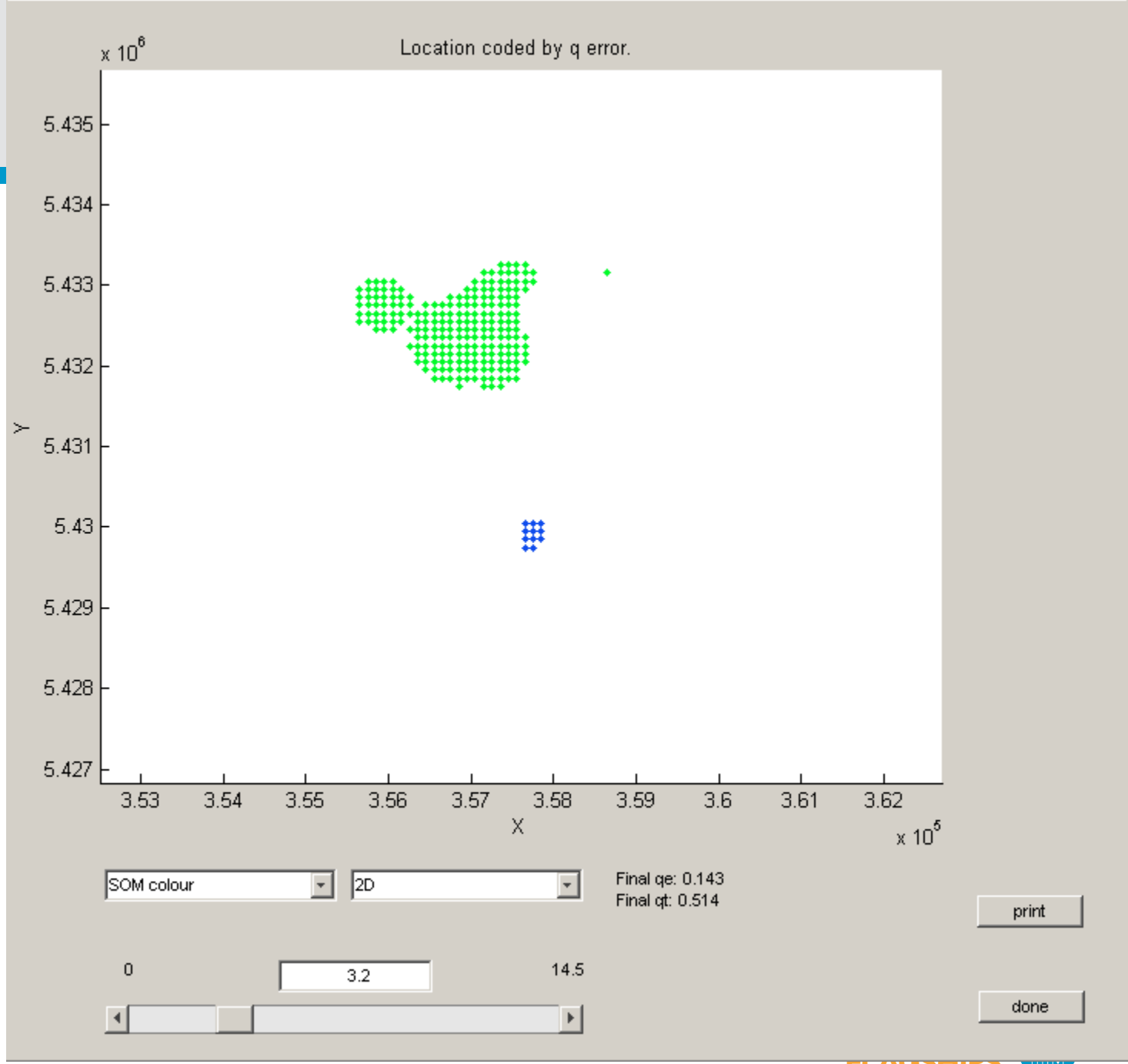
X-Y Plot Quantization Errors



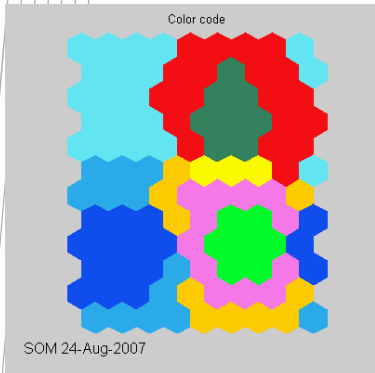


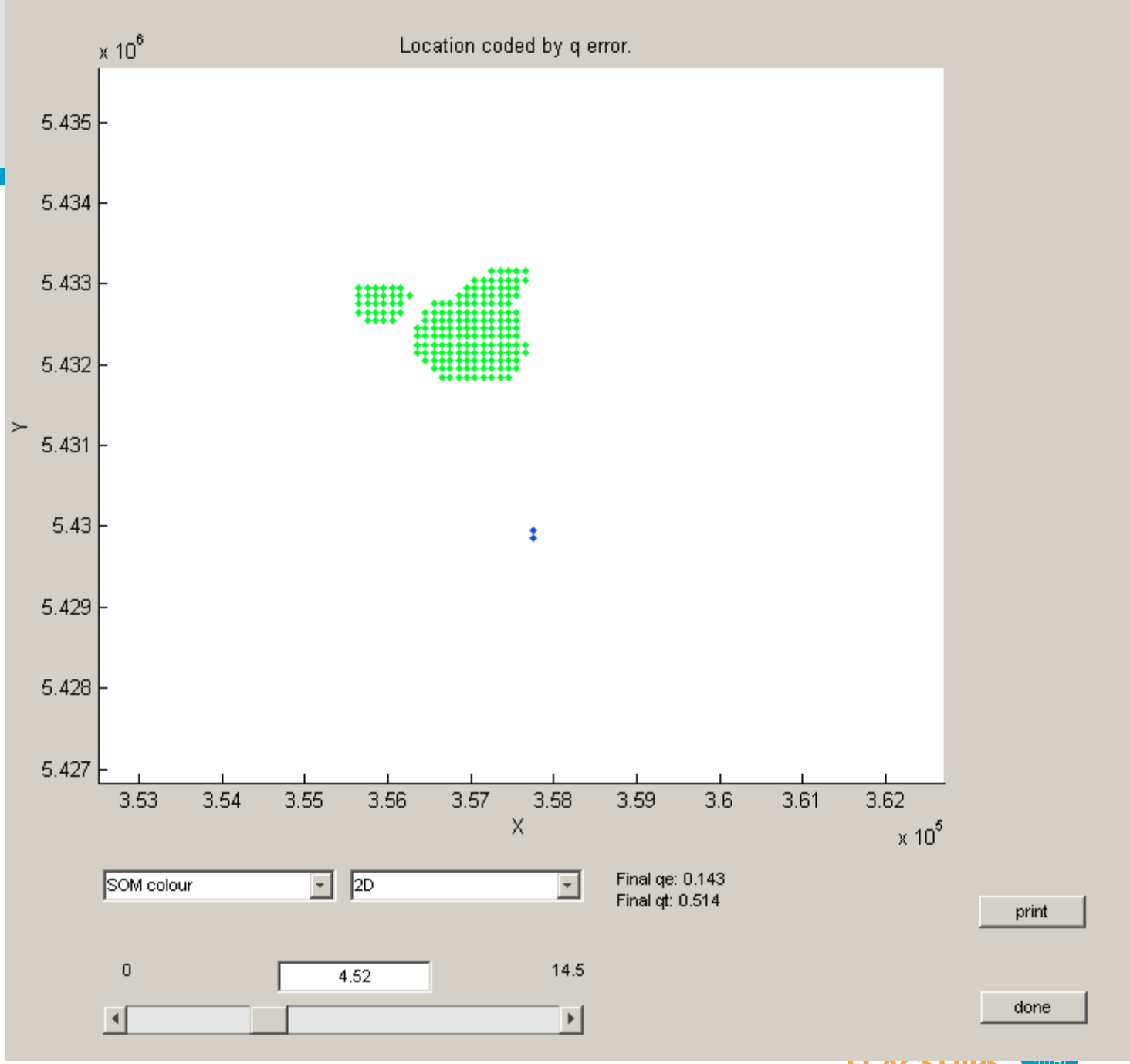
X-Y Plot Quantization Errors



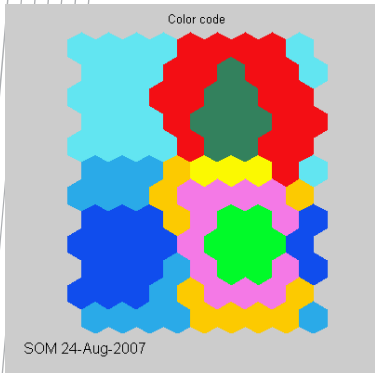


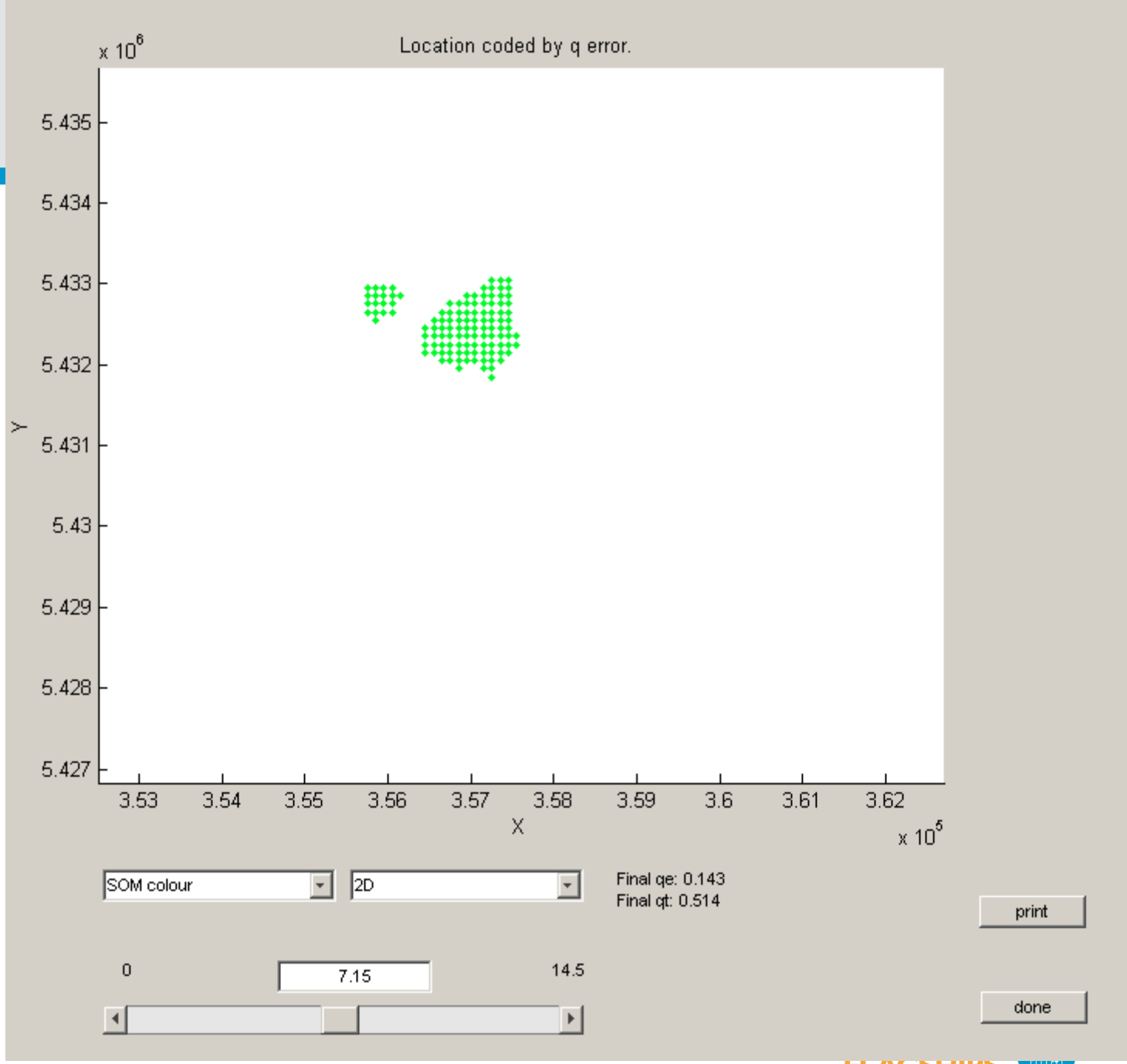
X-Y Plot Quantization Errors



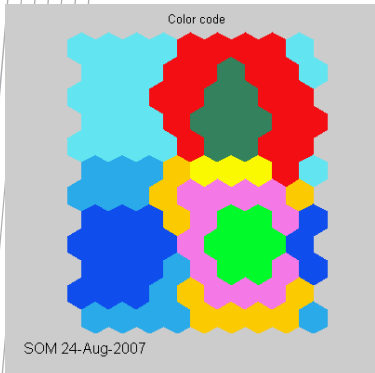


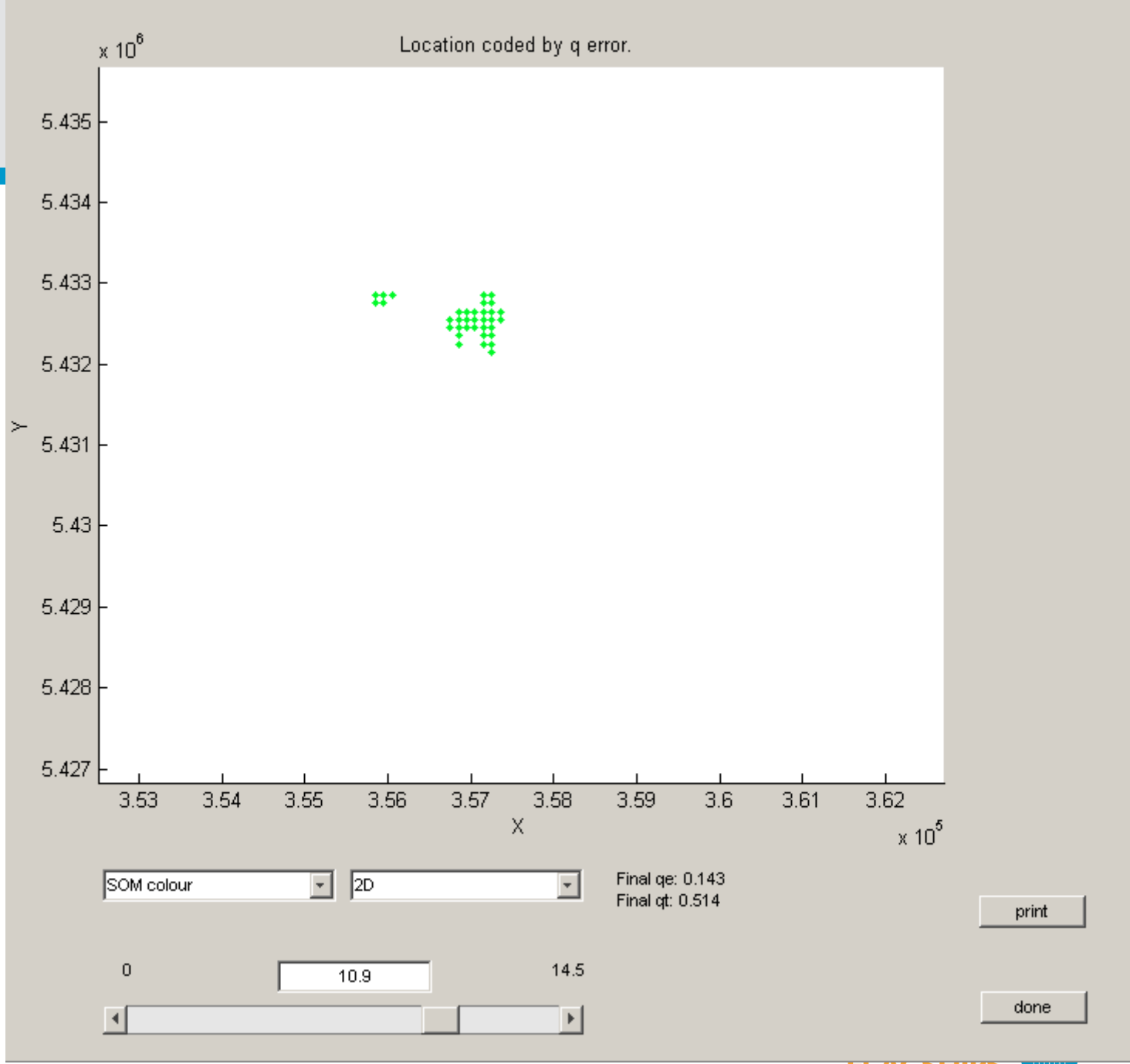
X-Y Plot Quantization Errors



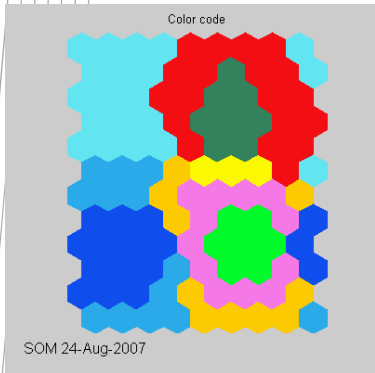


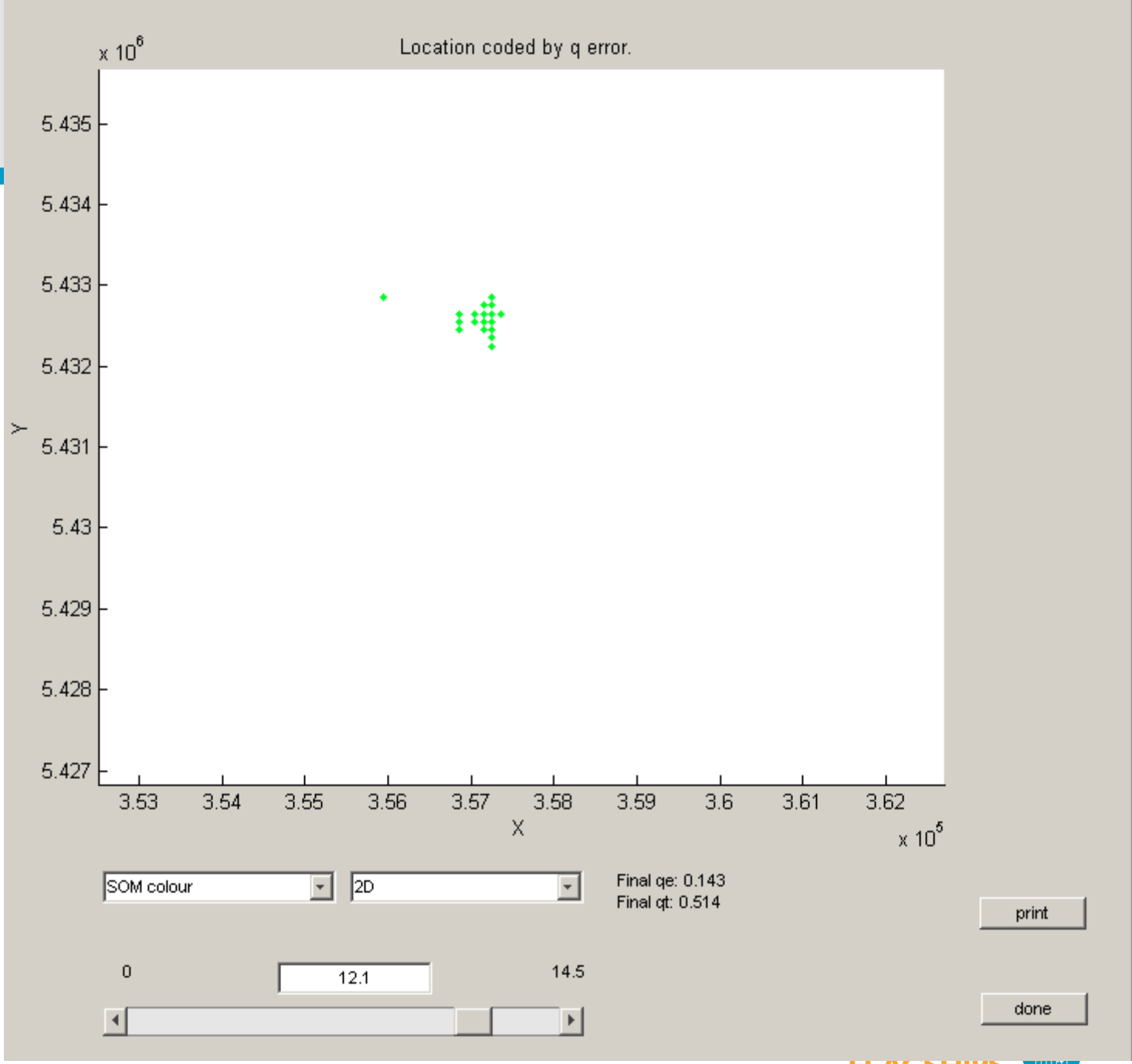
X-Y Plot Quantization Errors



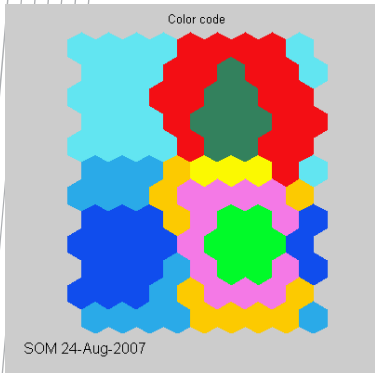


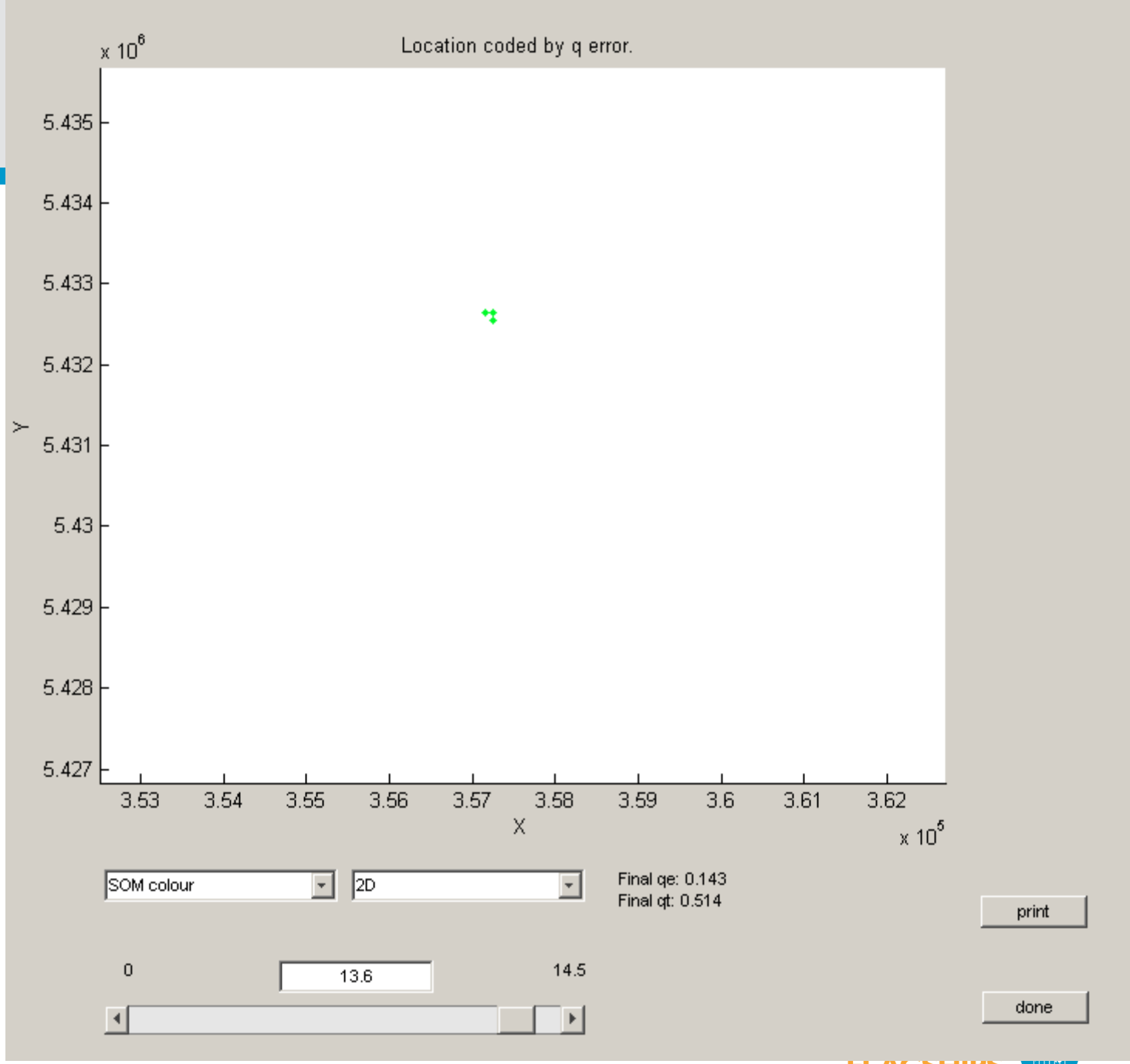
X-Y Plot Quantization Errors



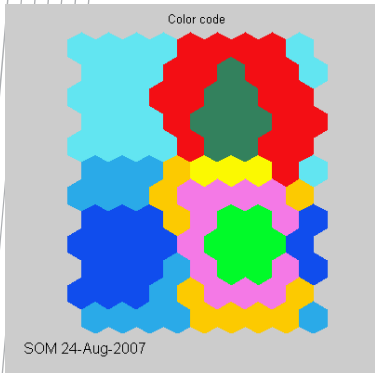


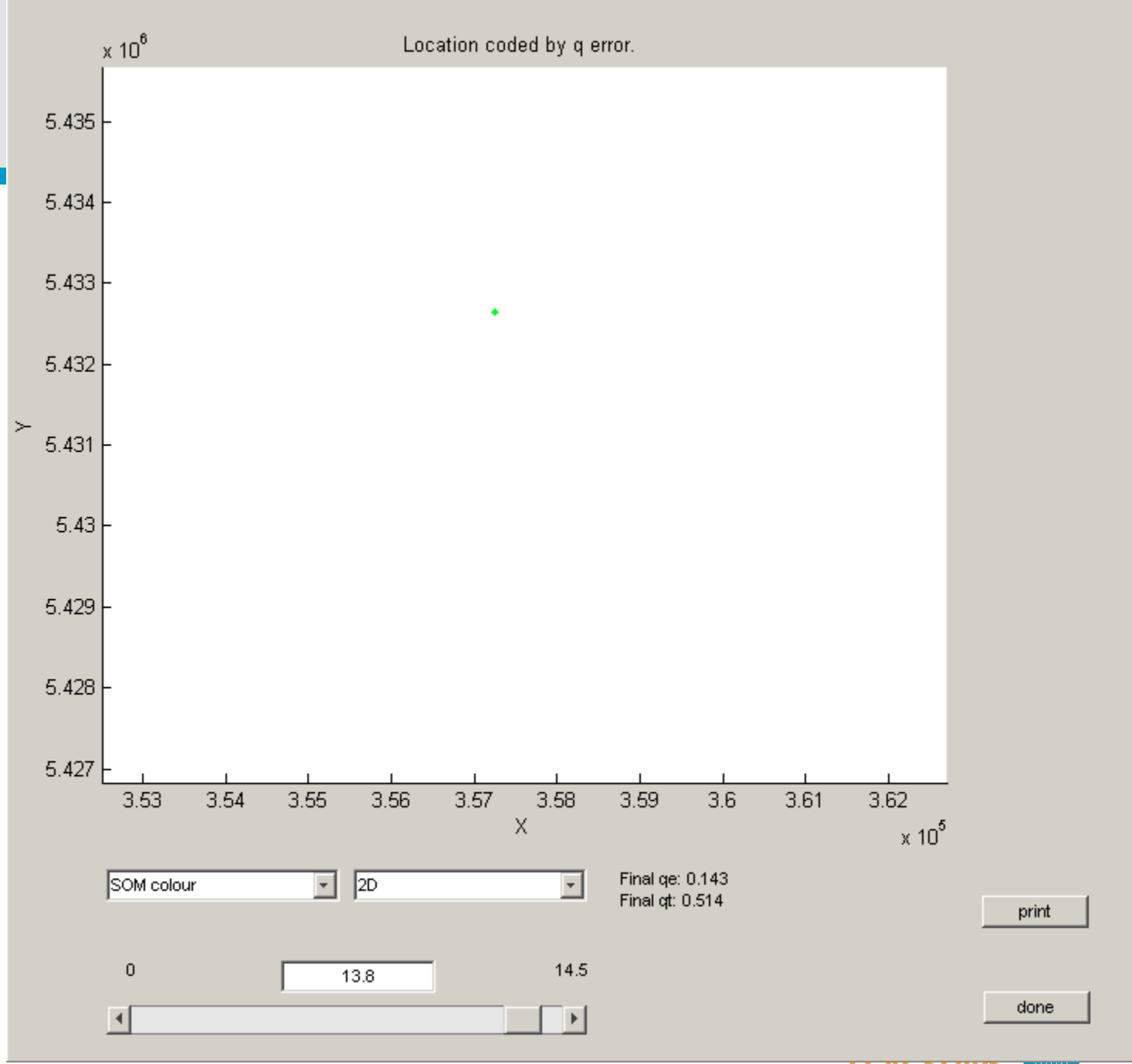
X-Y Plot Quantization Errors



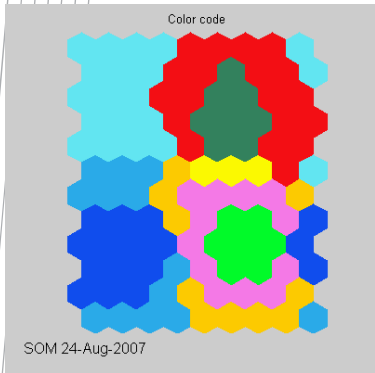


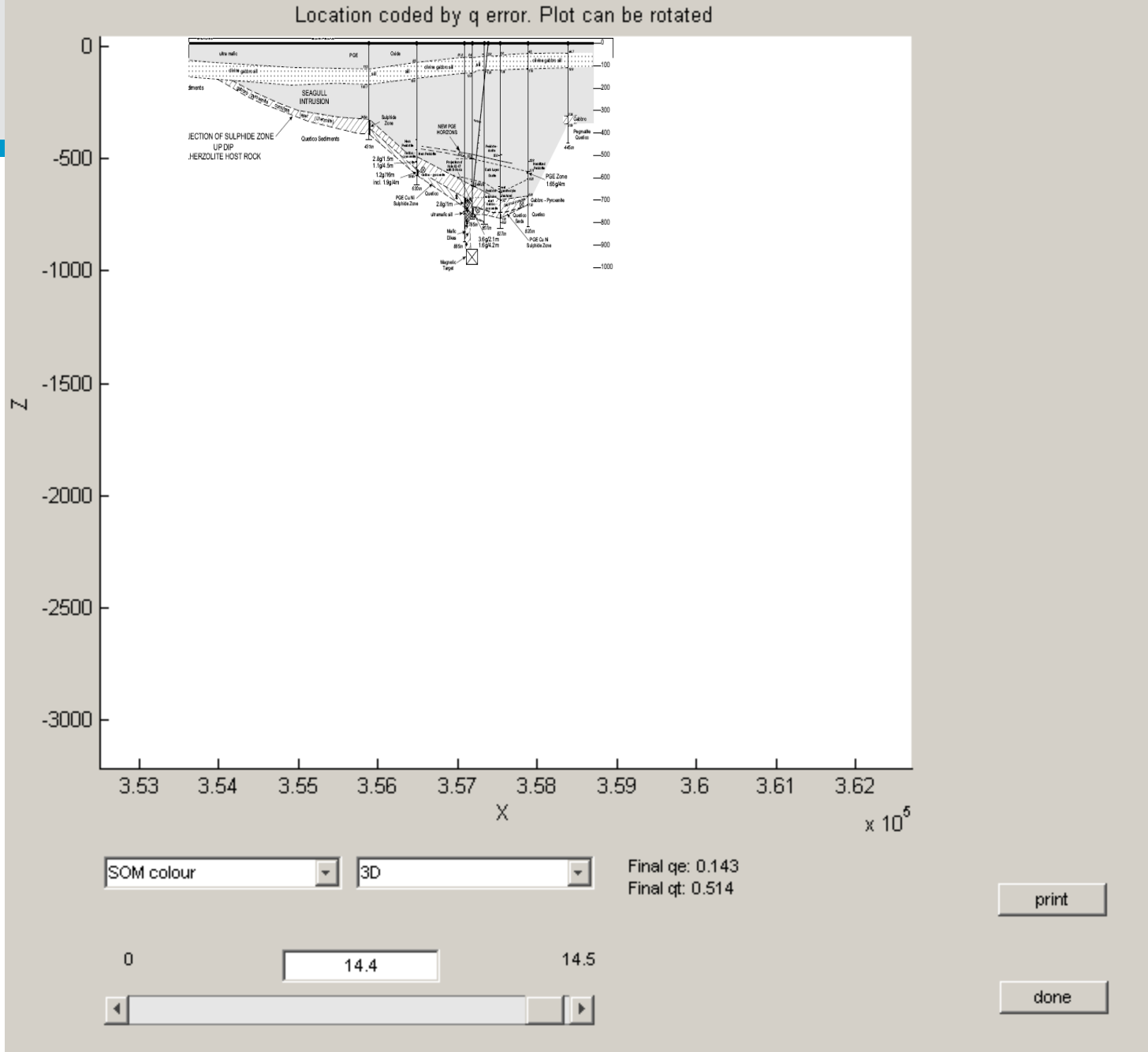
X-Y Plot Quantization Errors





X-Z Plot Quantization Errors





SOM on Voxel Volumes of Petrophysical Data resulting from "Unconstrained Geophysical Inversion"

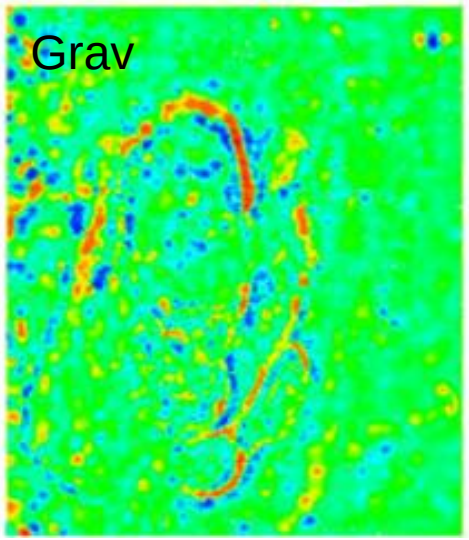
SiroSOM Analysis of UBC-Inverted Geophysical Voxel Data in the Mt Isa Region for Geological Survey of Queensland.

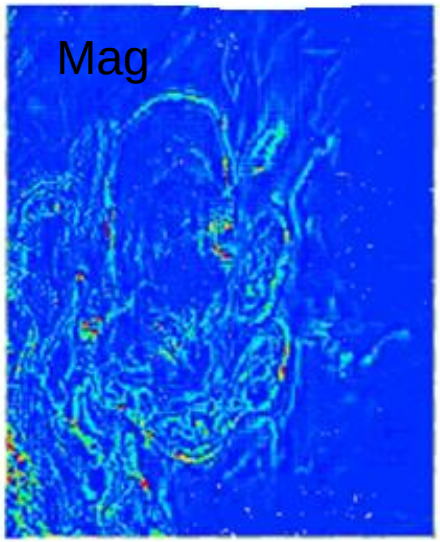
- Jane H Hodgkinson, Stephen J Fraser

- January-February 2009
- gravGrd to mag list no negs_35x30_toroidkm2_5

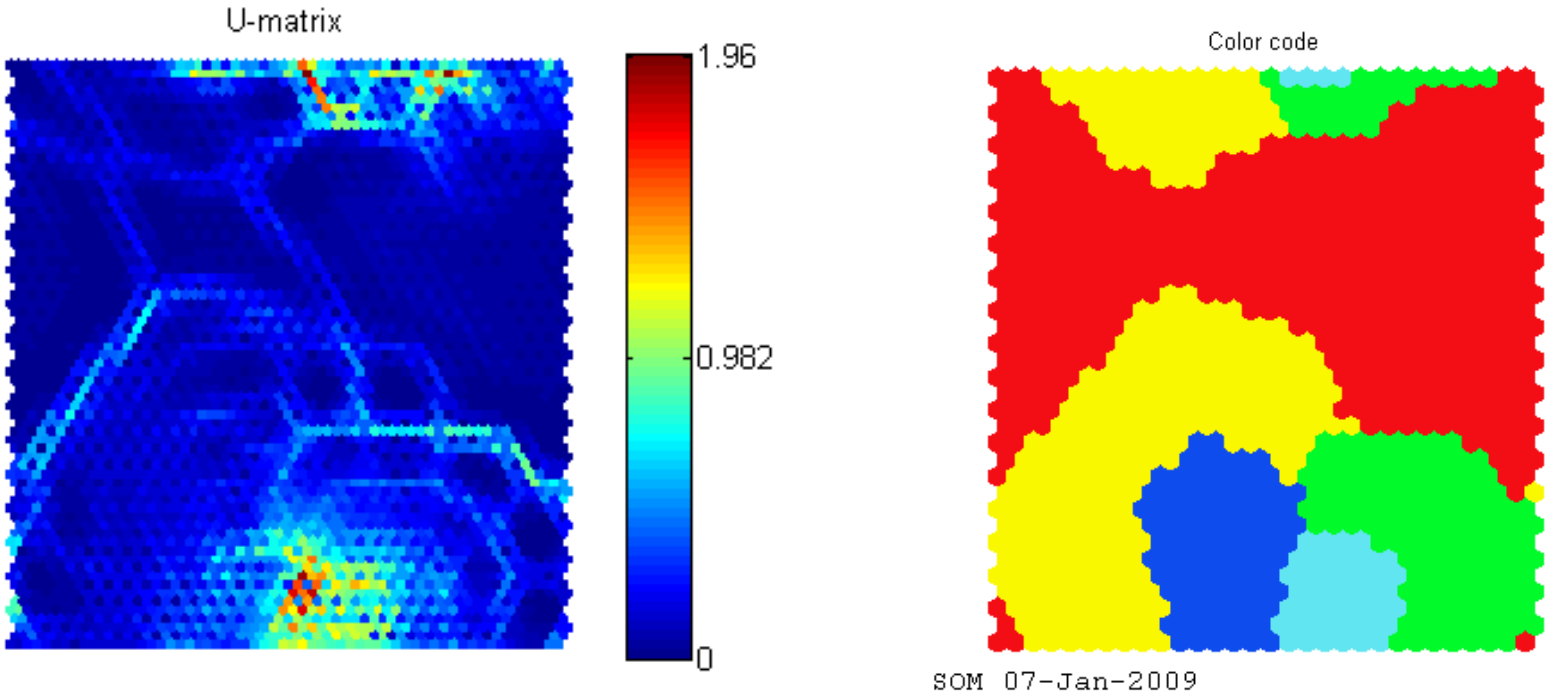
National Research FLAGSHIPS Minerals Down Under CSIRO

Location and Input Data Sets

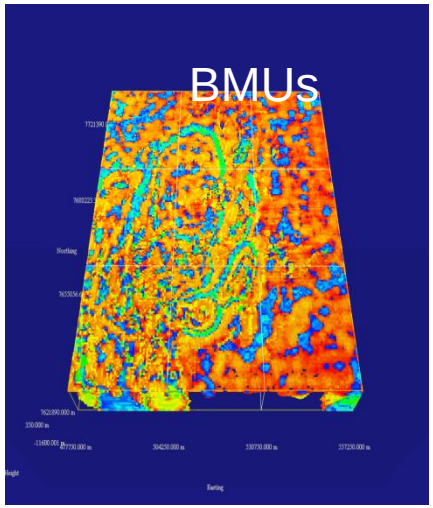


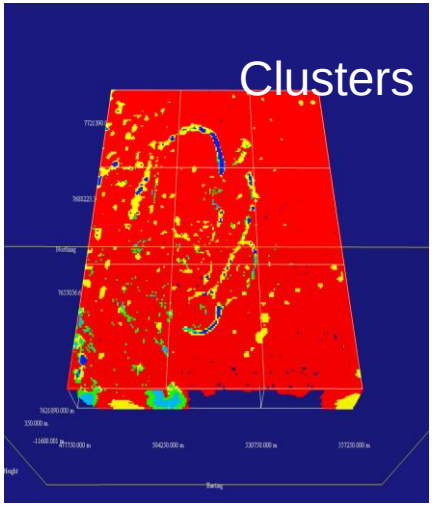


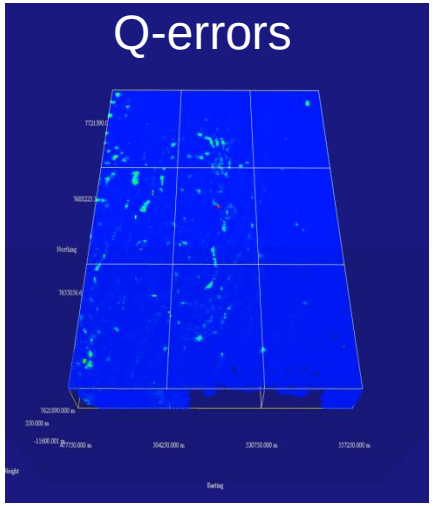
U-Matrix and K-means – 5 Classes

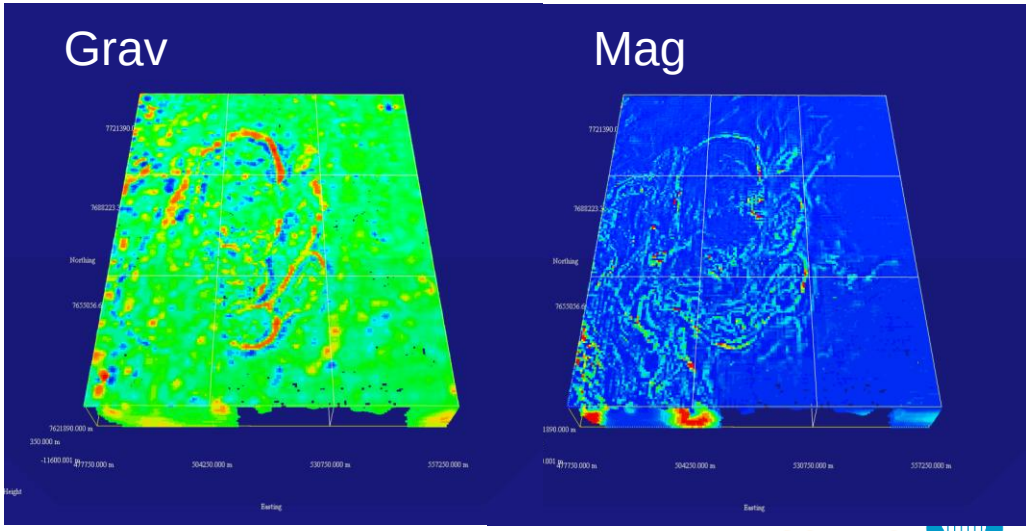


Block Perspectives looking towards North

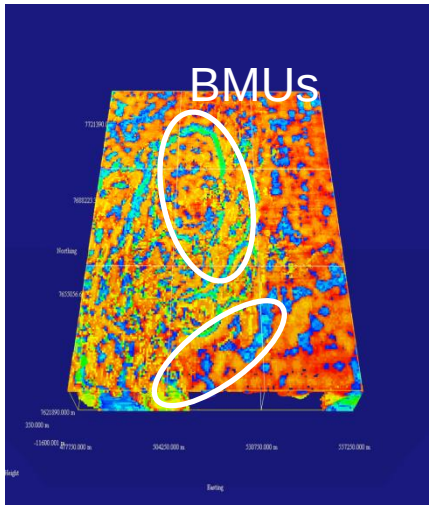


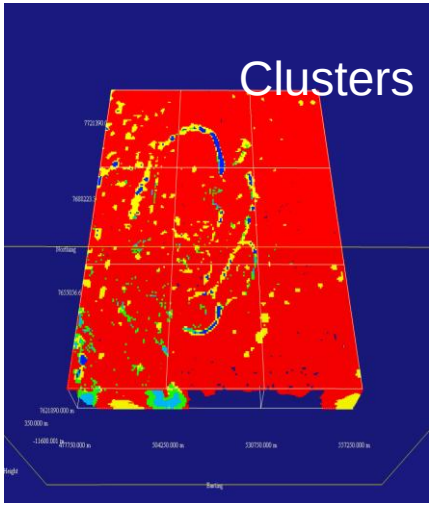


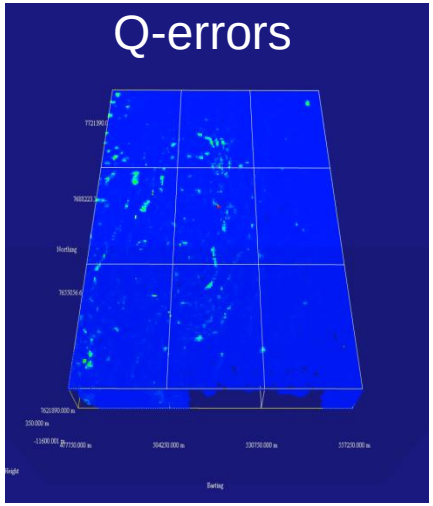


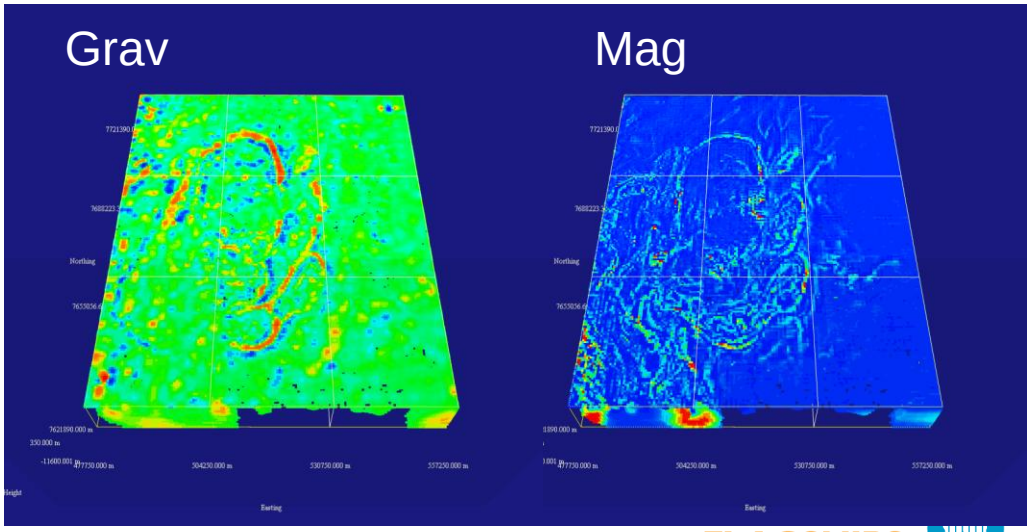


Block Perspectives looking towards North

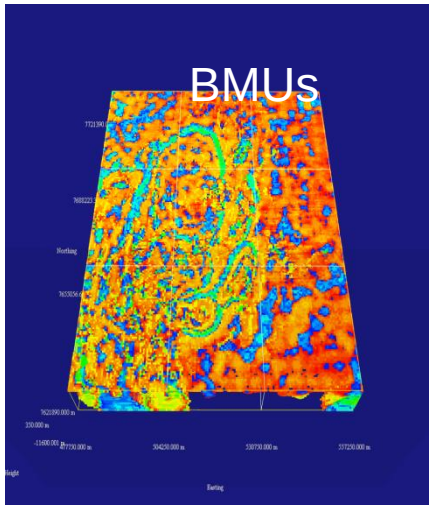


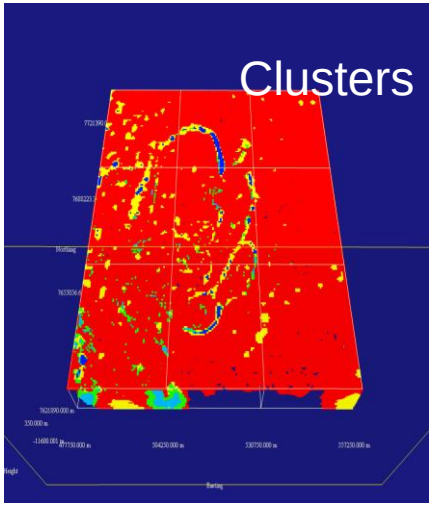


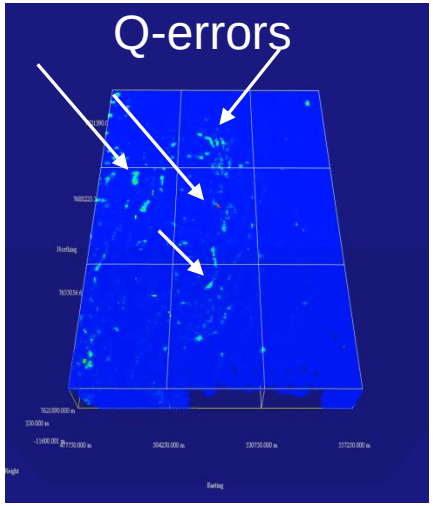


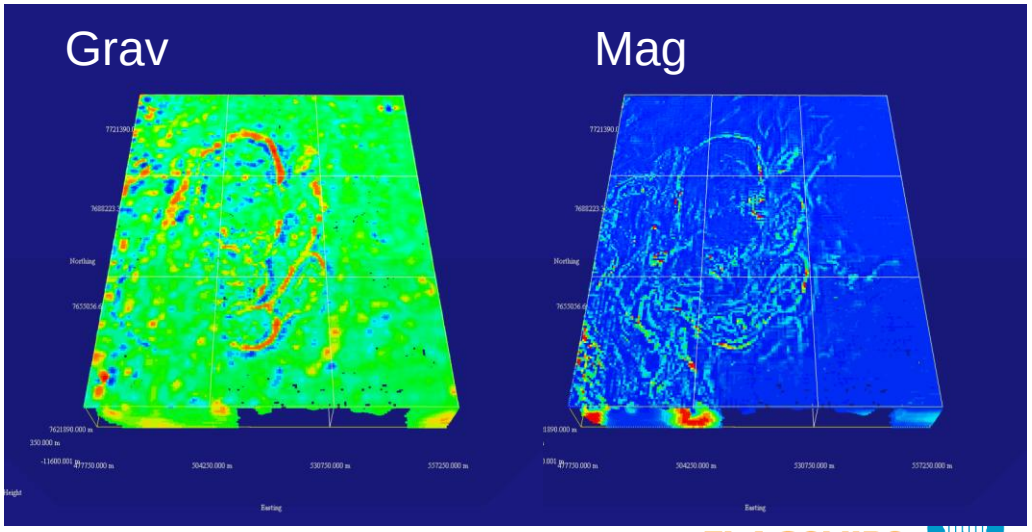


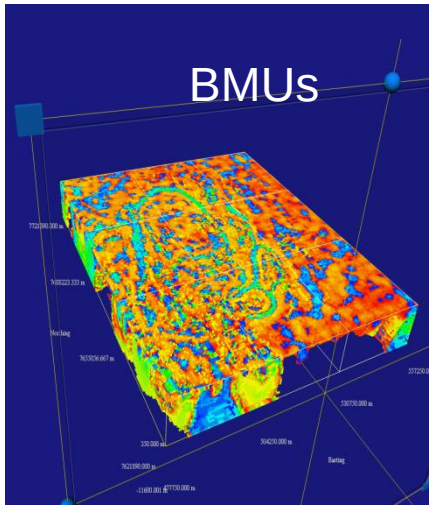
Block Perspectives looking towards North

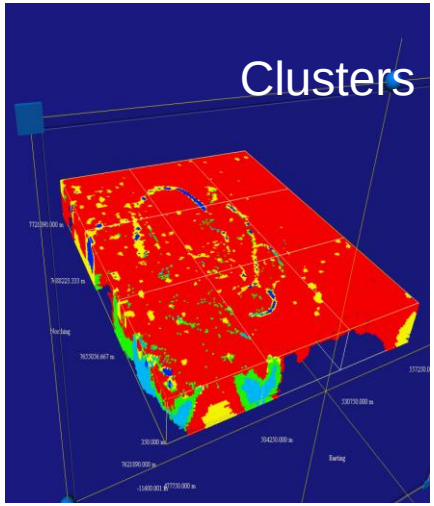


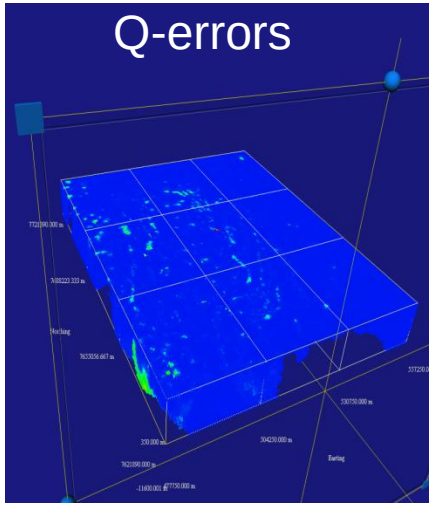


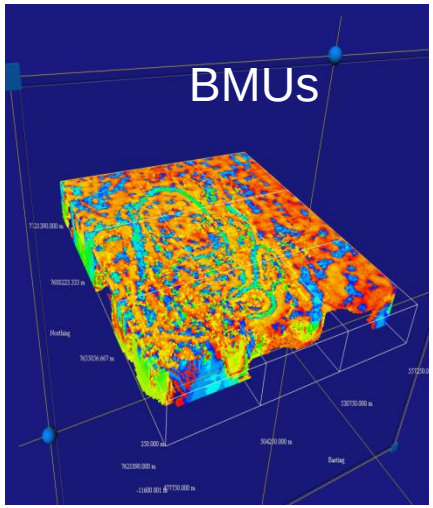


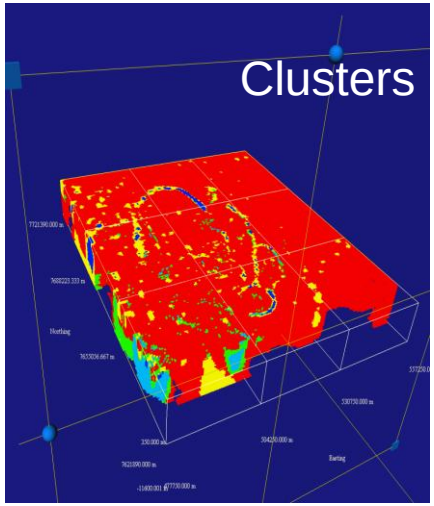


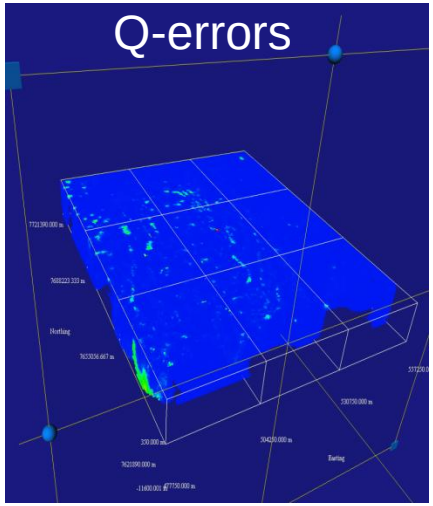

BMUs

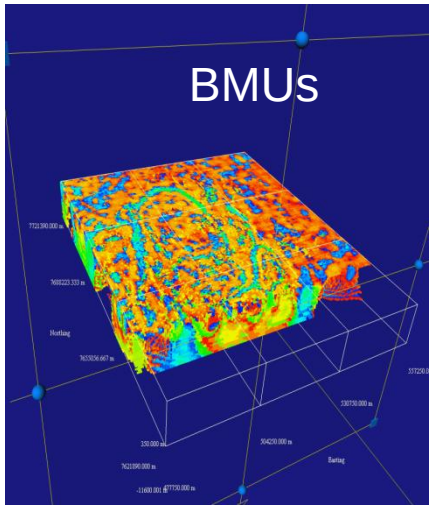

Clusters

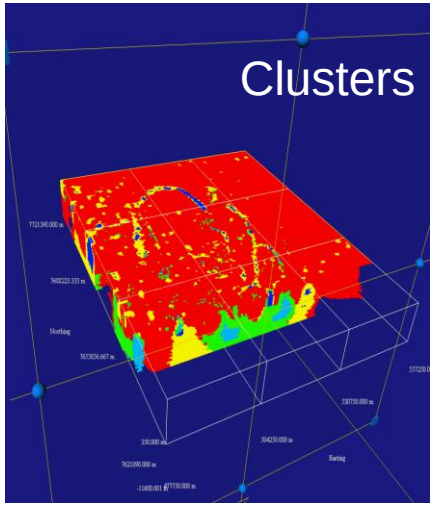

Q-errors

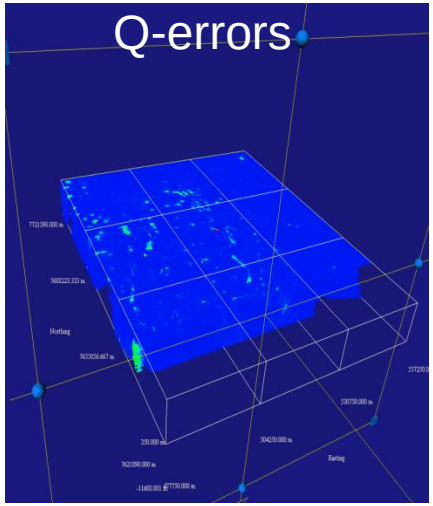

BMUs

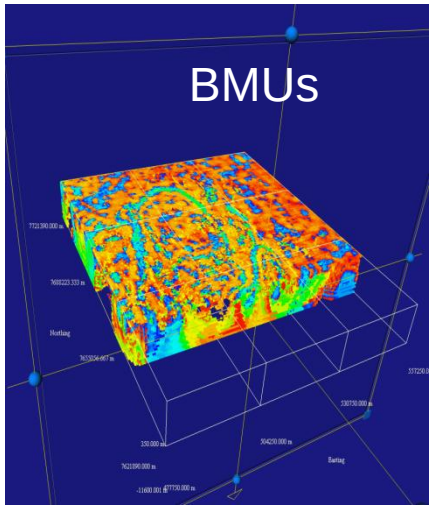

Clusters

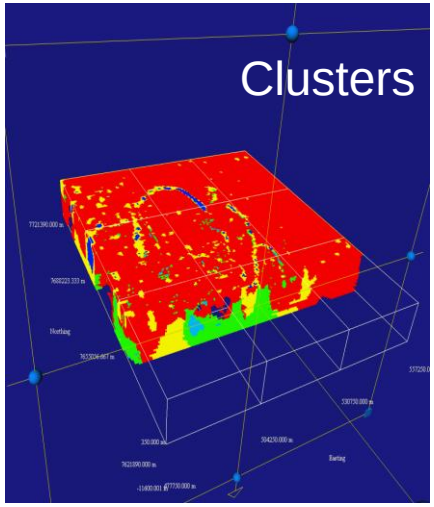

Q-errors

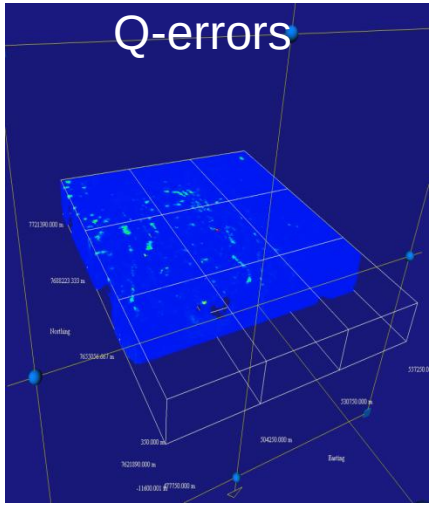


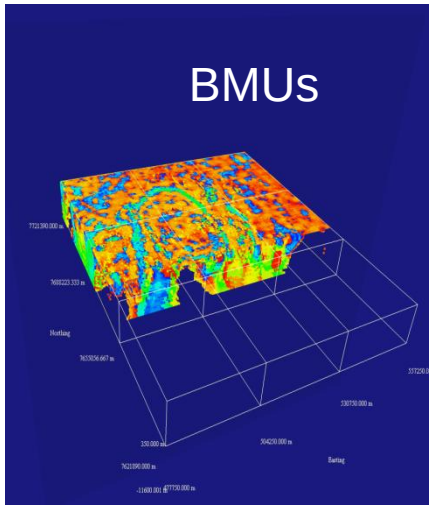


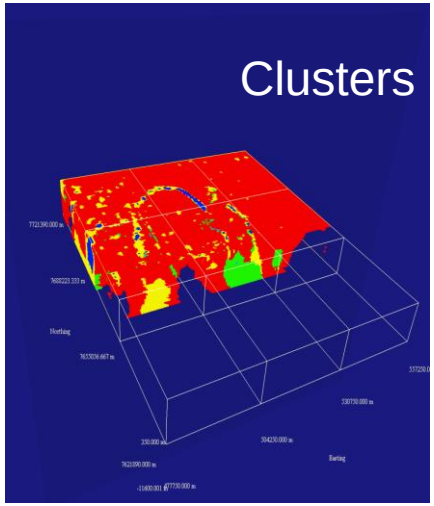


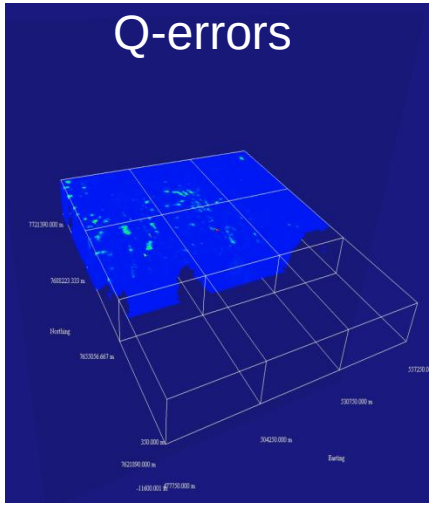

BMUs

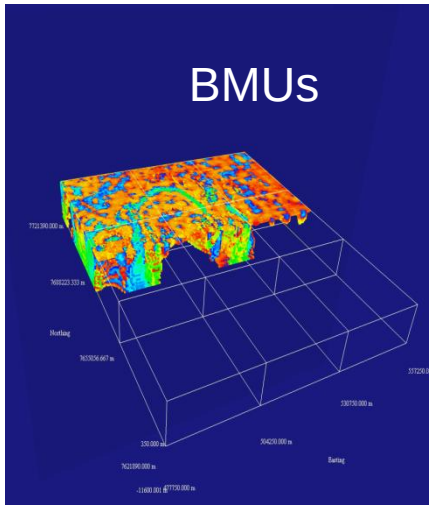

Clusters

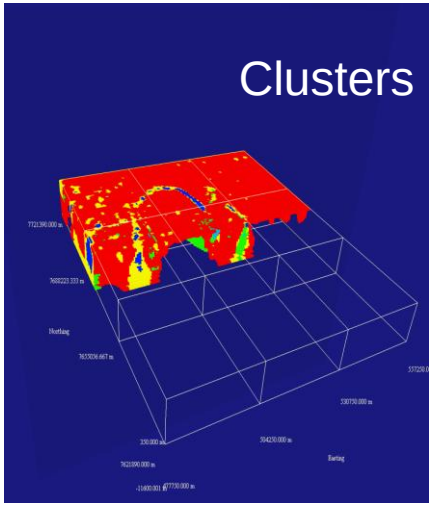

Q-errors

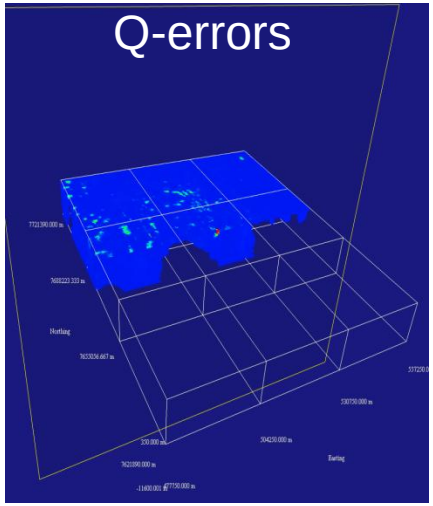

BMUs

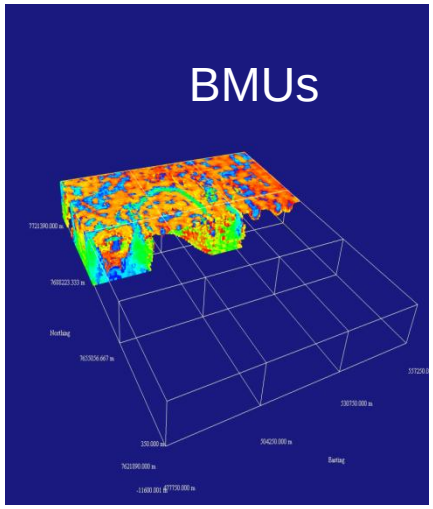

Clusters

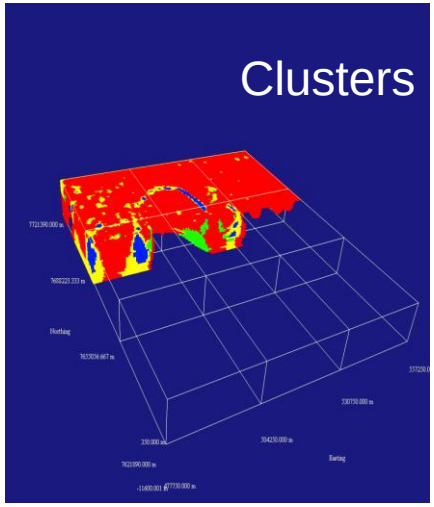

Q-errors

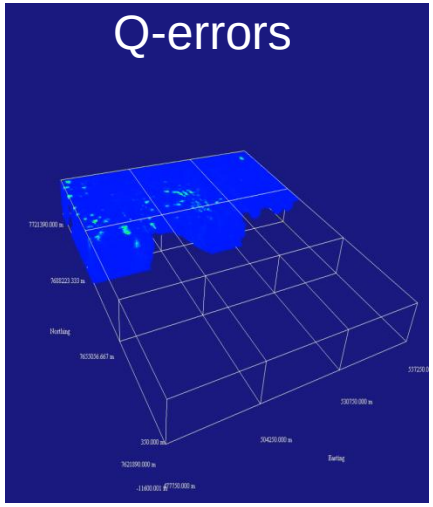

BMUs

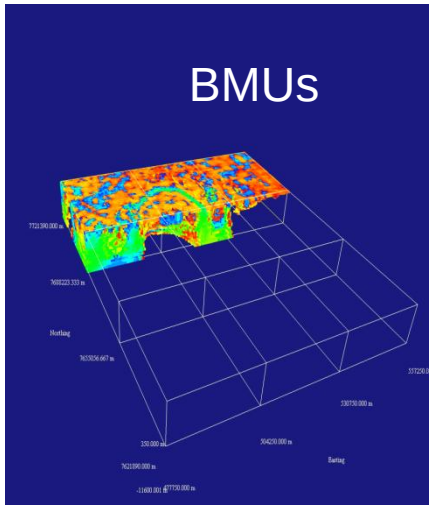

Clusters

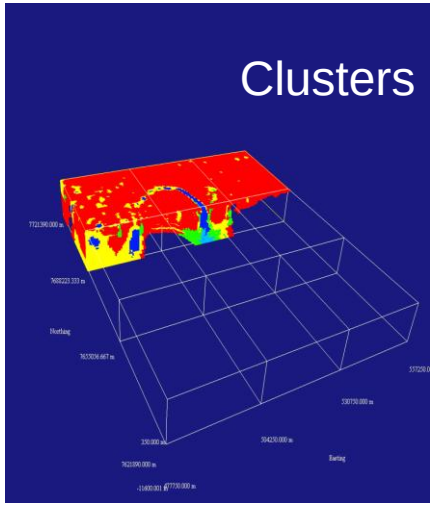

Q-errors

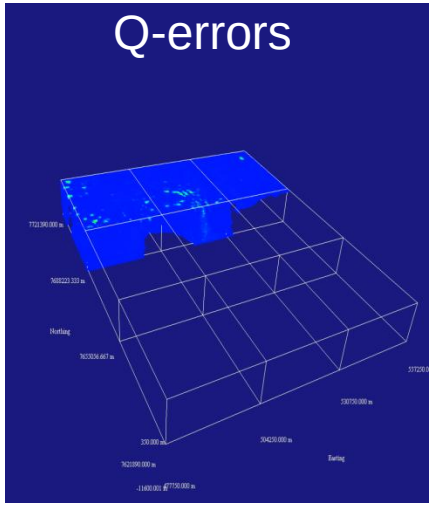

BMUs

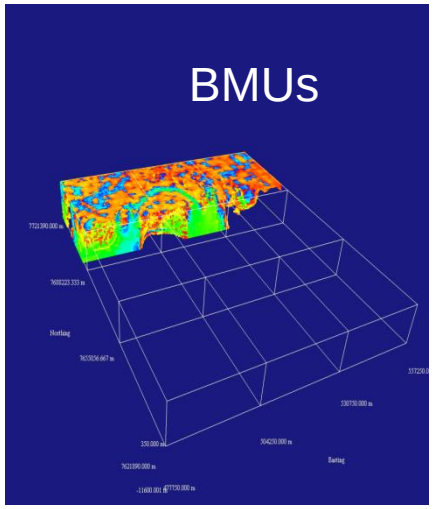

Clusters

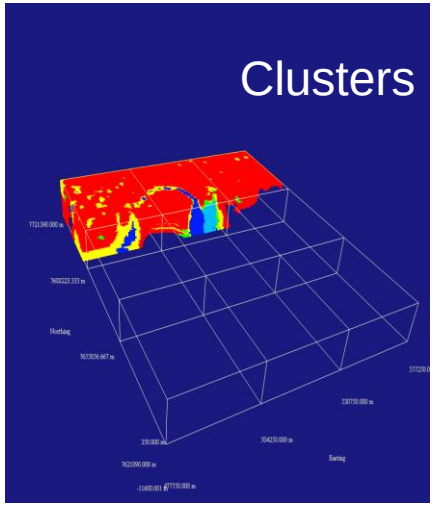

Q-errors

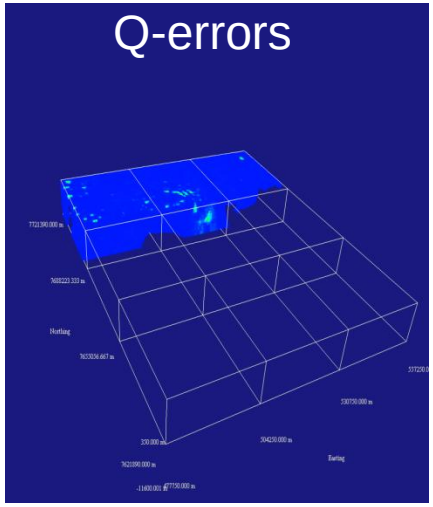

BMUs

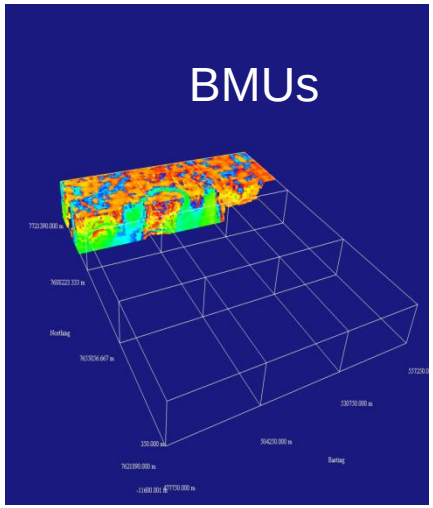

Clusters

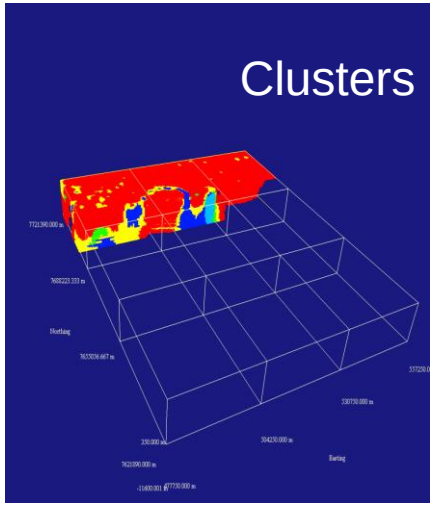

Q-errors

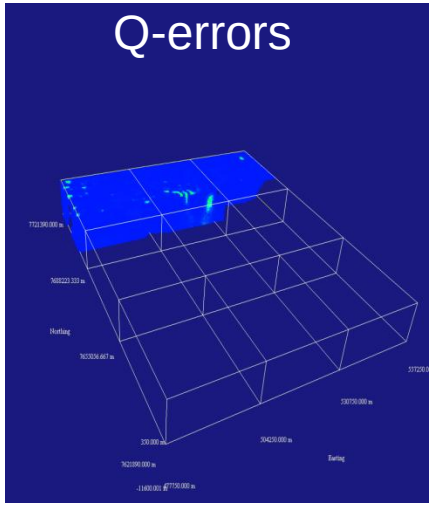

BMUs

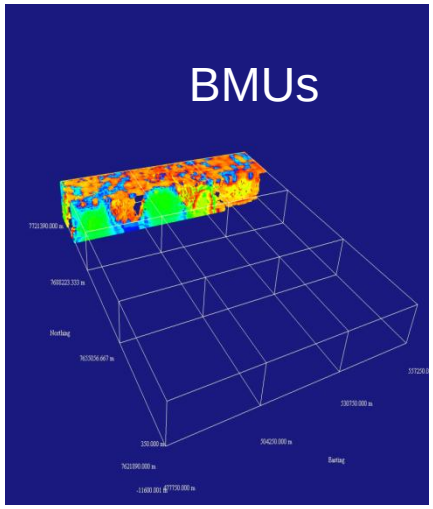

Clusters

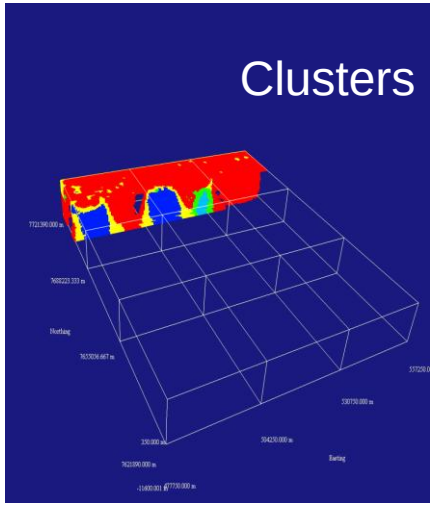

Q-errors

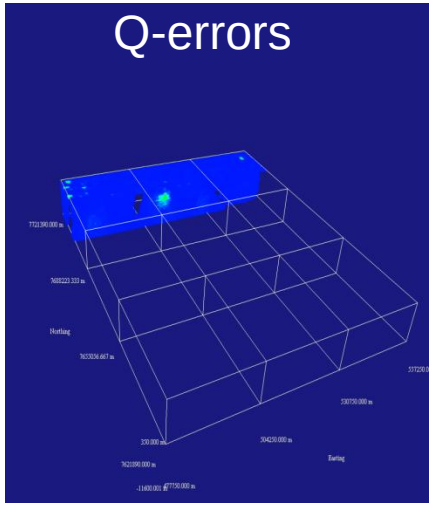

BMUs

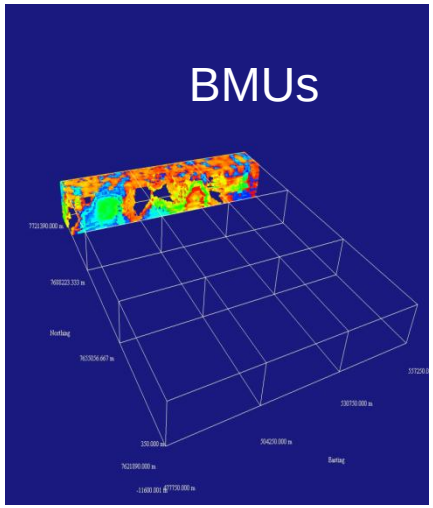

Clusters

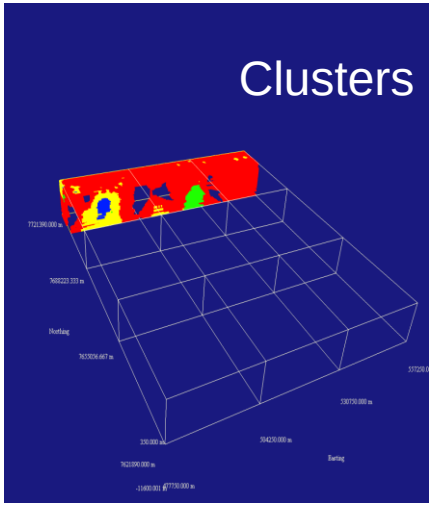

Q-errors

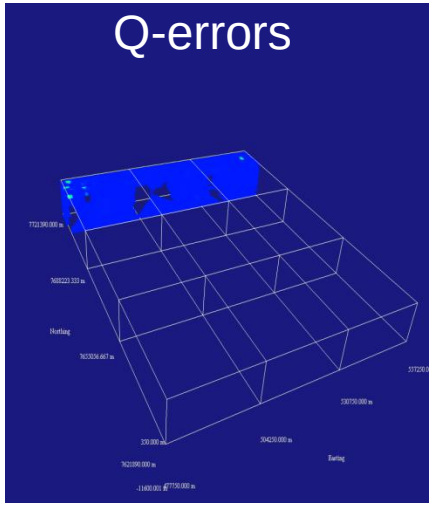


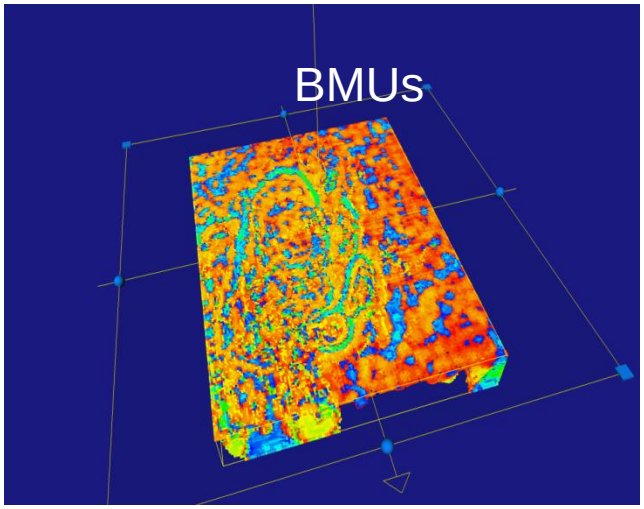


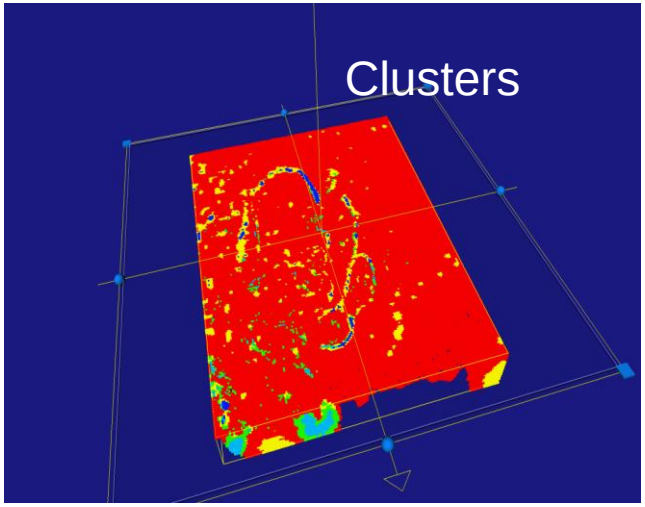


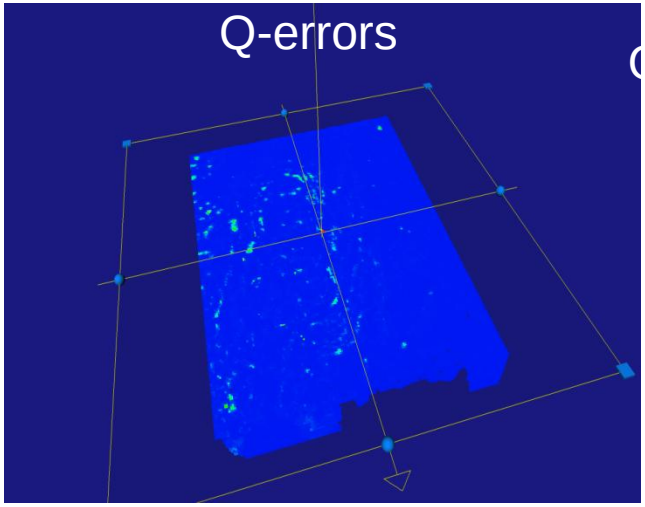

BMUs

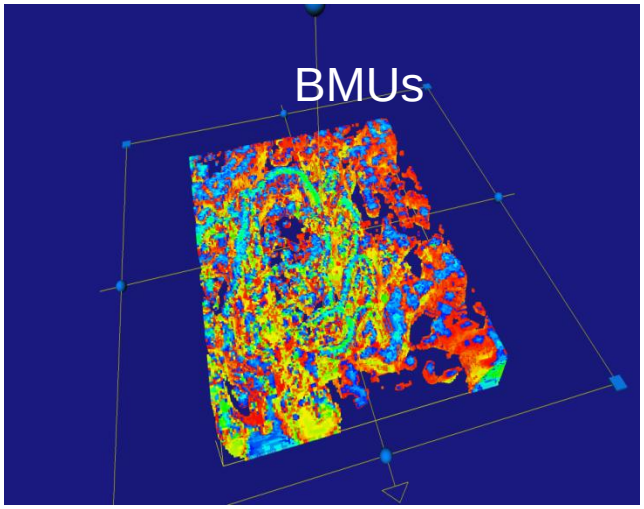

Clusters

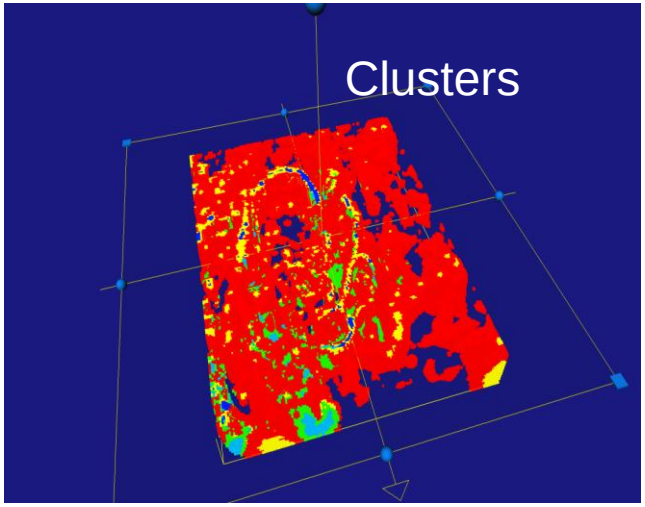

Q-errors

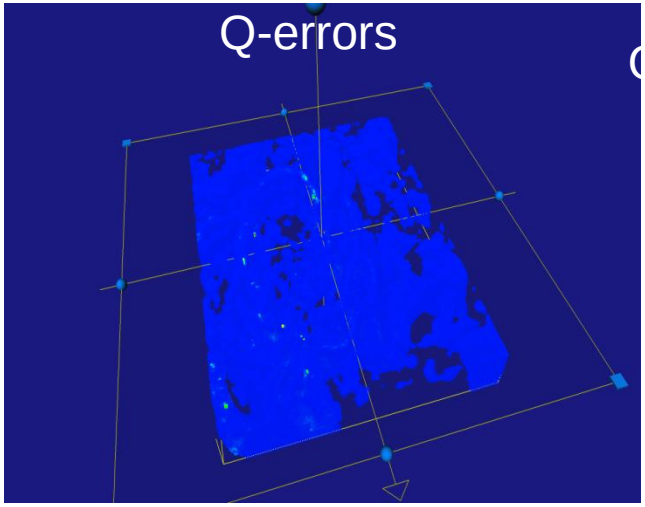


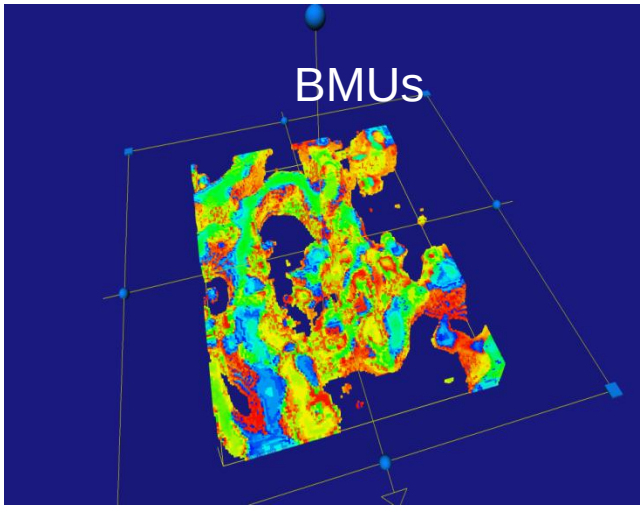


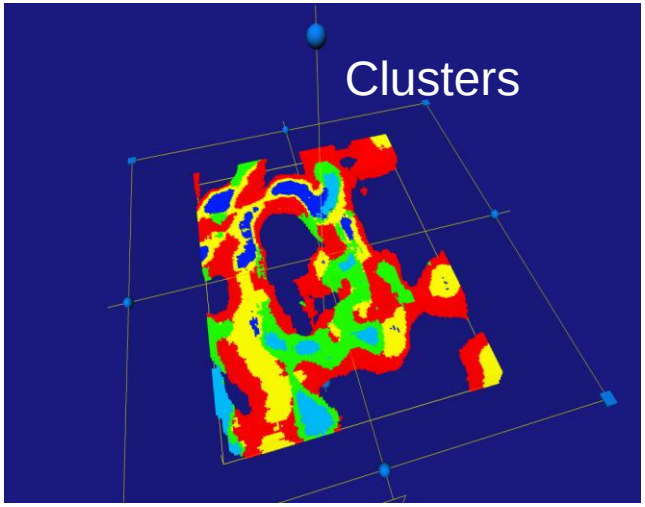


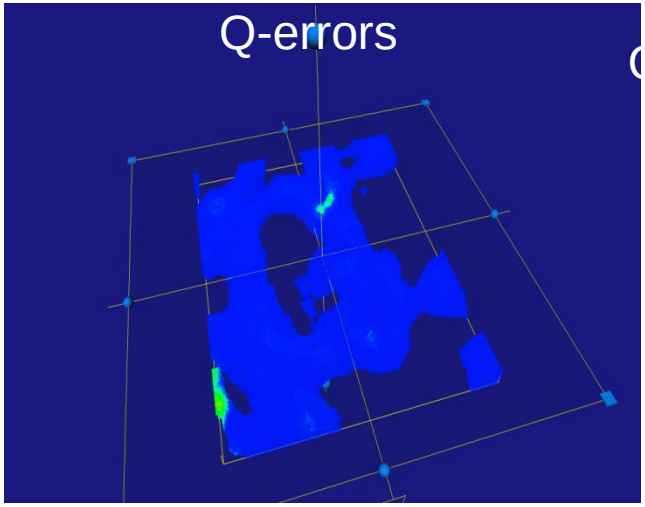


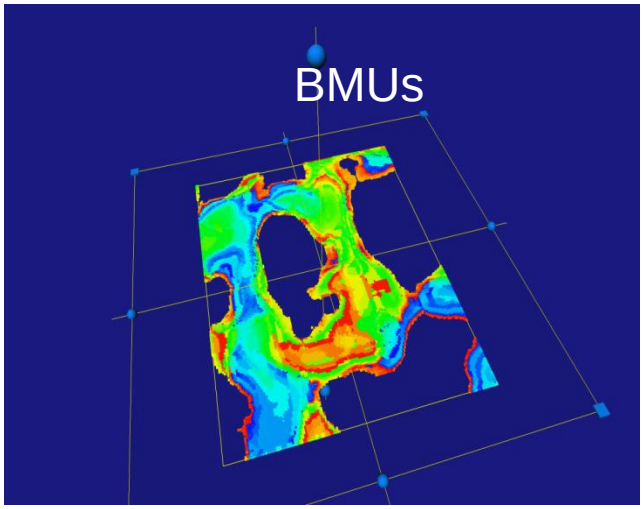


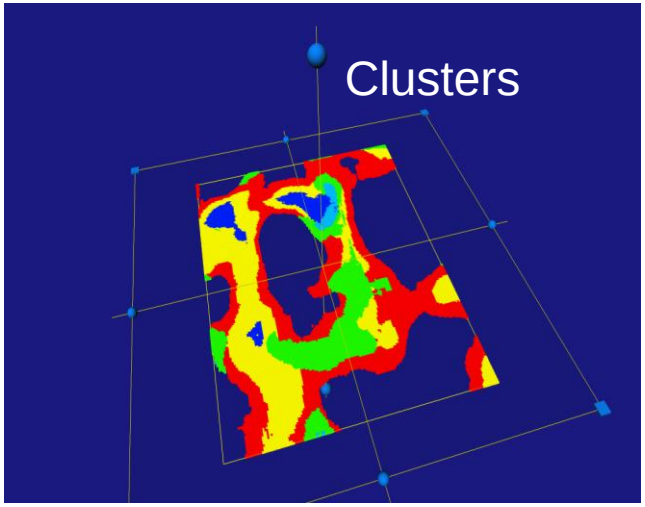


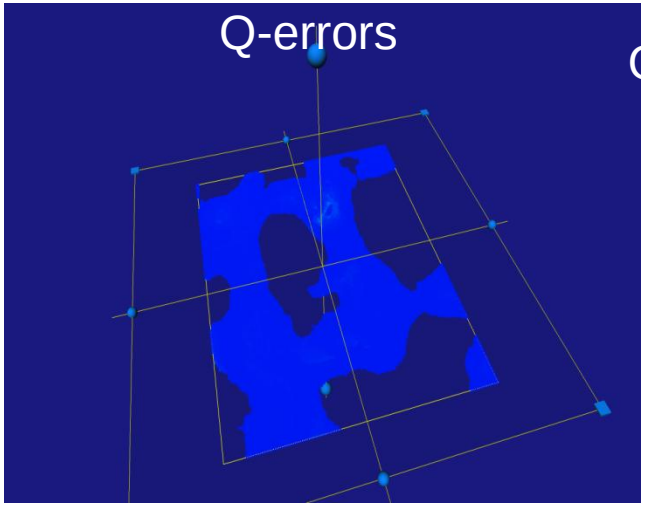












Conclusions

- SOM sub-populations can show “process” or allow targeting of samples with specific characteristics; SOM can assist in identifying:
  - stream and lake sediment geochemical targets;
  - targets and domains in petrophysical volumes.

- Complex and diverse data types can be analyzed using SOM;
  - Geochemical, Geophysical, Mineralogical (Geotechnical, Geo-metallurgical …….)
  - Any spatial data with complex or disparate inputs