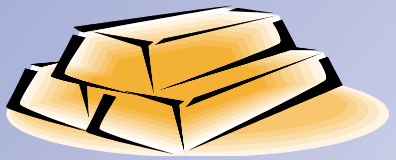
Spatial Data Modelling:

The Search For Gold In Otago



Presented By Matthew Hill
Kenex Knowledge Systems (NZ)

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Acknowledgements

Michelle Stokes & Greg Partington - Kenex Pty Ltd (Australia)

Paul Matthews, Charlene Wildman, & Lisa McCarthy
– Kenex Knowledge Systems (NZ)

New Zealand Minerals Ltd

HPD Exploration Plc

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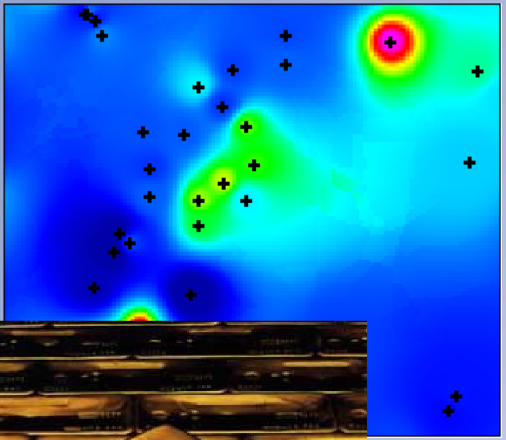
Outline



- What is spatial data modelling?
  - Why model?
  - Types of modelling
  - Probability modelling using WoE
- Prospectivity modelling for gold in Otago
  - The exploration model
  - The layers and testing
  - Running the model
  - The prospectivity map
  - The future…..
- Other examples:
  - Hawkes Bay Wine
  - West Coast *Powelliphanta* Land Snail

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Why undertake spatial modelling?

- Modelling can be a **non-bias view of data** which in some cases is an important process in moving forward and away from a companies preconceptions.
- Save time and money by putting resources into the most likely places the first time and **undertake value / risk assessment** of assets or facilities.
- You can create **predictive maps** from digital data and maximise the **knowledge** that can be obtained from spatial data sets.

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- Take advantage of the wealth of digital data available in the industry today, modern computer power and storage.
- Deals with **data overload** and quality issues
- Companies can combine their <u>spatial data</u> and <u>knowledge</u> in a way that allows them to manage more effectively.

Kenex company mantra:

“We don’t make maps“

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Spatial data modelling allows large scale analysis of data for scoping studies

Mineral Discoveries Are Typically Made By The 5th-7th Person / Company Covering The Ground

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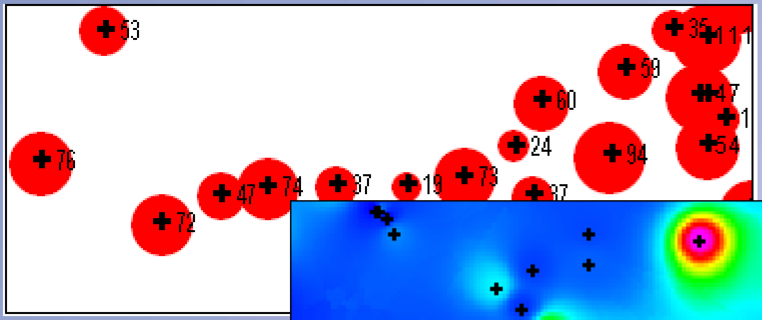
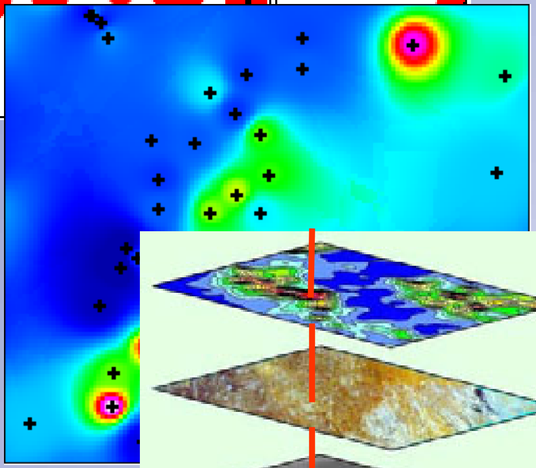
Types of modelling

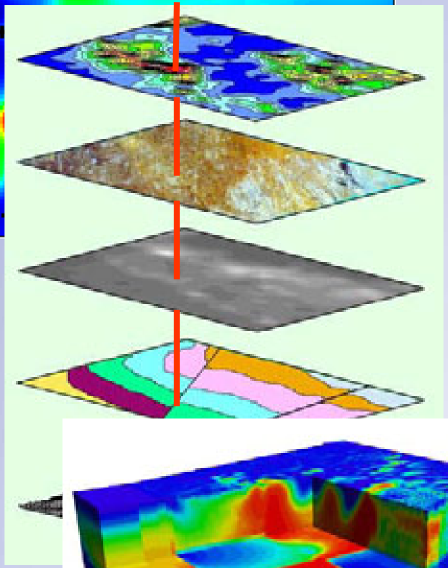
Illustrated maps that highlight important features or values.



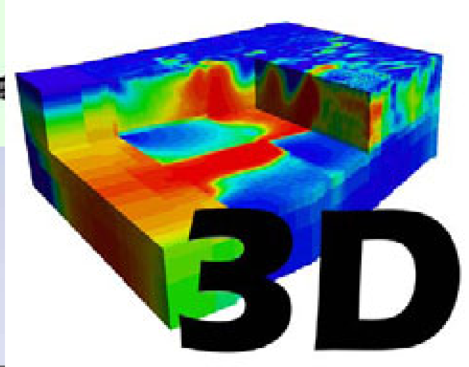
Basic single layer modelling using interpolation to estimate values between known point data.



Multi-variable models: Fuzzy logic, neural networking, and weights of evidence modelling.



3D modelling of underground structures or or 4D flow modelling of fluids & minerals.



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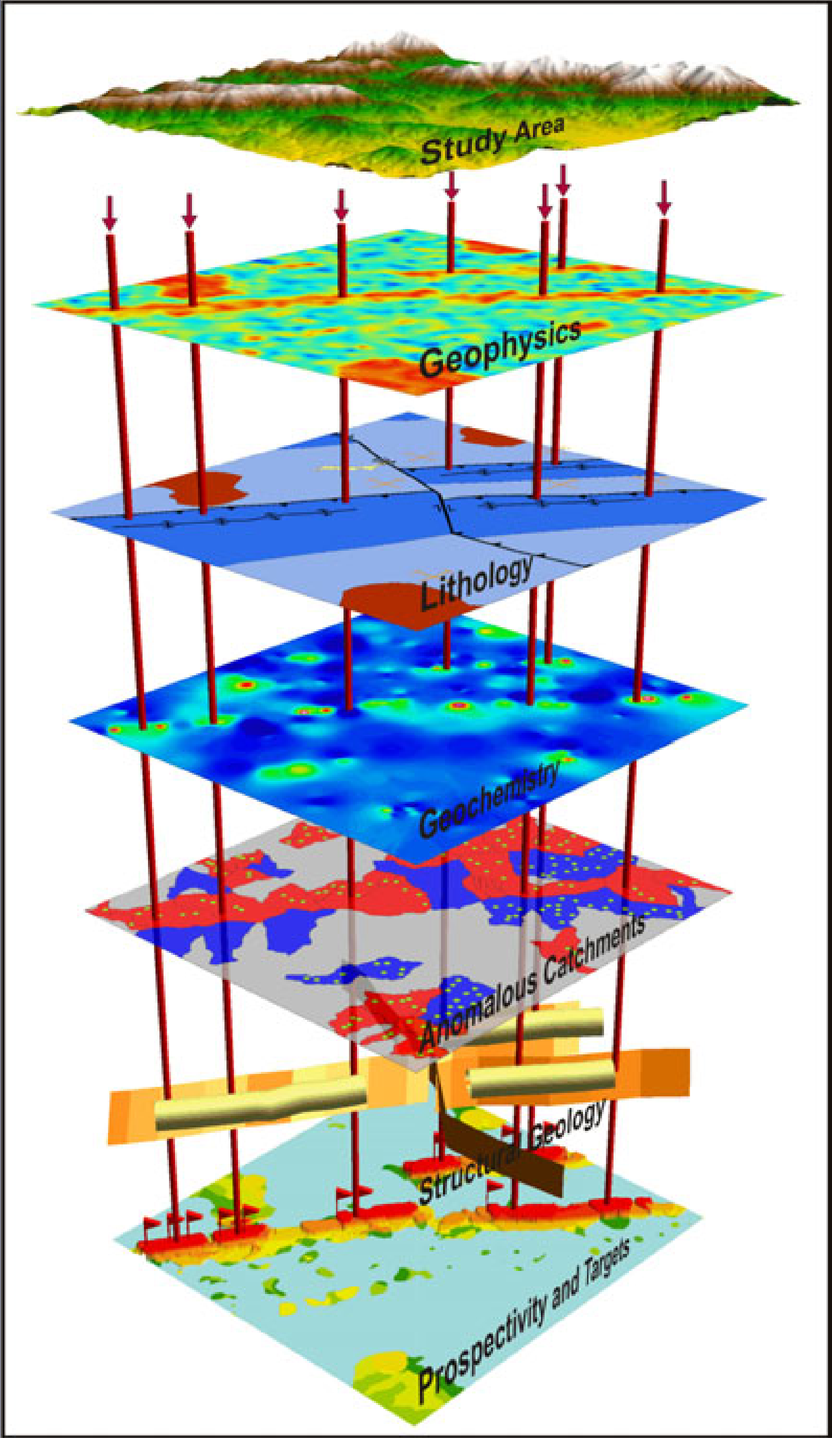
Weights of Evidence Modelling (WoE)

- Developed from the medical industry for use in mineral exploration by Graham Bonham-Carter at the Geological Survey of Canada.
- Prediction of a “disease” given a list of “symptoms”
- Can be applied spatially to may different types of industries, exploration, and data analyses.
  - E.g. Gold exploration, agriculture evaluation, environmental assessment, geotechnical risk etc.
- WoE is a probability based method that is a Bayesian statistical approach to predicting an occurrence.

GOAL: To predict locations where there is a high probability of an occurrence (e.g. a gold deposit or good place to grow grapes)

BASIC METHOD:

- Determine training points of locations where occurrences have been found in the past (e.g. known gold mines or good vineyards).
- Weight evidential themes in the model based on their spatial relationship to the training points.
- Combine evidential themes together to produce a “response theme” or predictive map.



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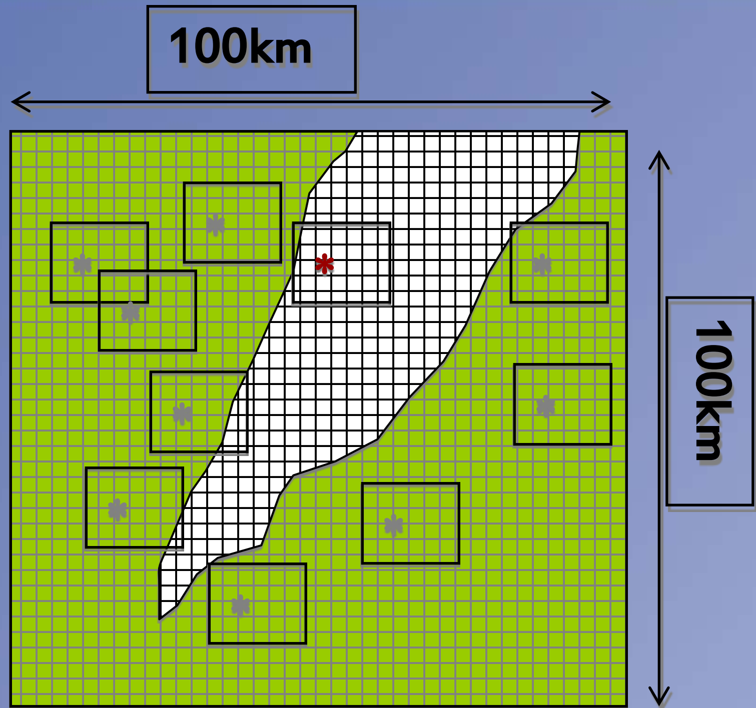

a = total study area (e.g. 10,000 km)

A = Unit Cell = 1 km^2 cell

N(D) = number of deposits

P(D) = prior probability

N(T) = total area of study region

N(B) = area of binary theme

$N(\bar{B})$ = area of binary theme not present

$N(T) = N(B) + N(\bar{B})$ (as long as no missing data)

When unit cell inf. small

$$W+ = \ln \frac{N(B \cap D) / N(D)}{N(B) / N(T)}$$

$$W- = \ln \frac{N(\bar{B} \cap D) / N(D)}{N(\bar{B}) / N(T)}$$

$$C = (W+) - (W-)$$

$$W+ = \ln \frac{P(B \mid D)}{P(B \mid \bar{D})} \qquad W- = \ln \frac{P(\bar{B} \mid D)}{P(\bar{B} \mid \bar{D})}$$

$$Ws+ = \frac{1}{N(B \cap D)} + \frac{1}{N(B)} \qquad Ws- = \frac{1}{N(\bar{B} \cap D)} + \frac{1}{N(\bar{B})}$$

$$Cs = \sqrt{(Ws+) + (Ws-)} \qquad StudC = C / Cs$$

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From: Bonham-Carter, G.F. (1994)

"Geographic information systems for geoscientists".

But basically….

Correlations / Layer Weights

$$W^{+} = \text{natural log} \frac{\text{Proportion of training points on theme}}{\text{Proportion of total area occupied by theme}}$$

$$W^{-} = \text{natural log} \frac{\text{Proportion of training points not on theme}}{\text{Proportion of total area not occupied by theme}}$$

$W^{+} > 0$ indicates positive association with theme

$W^{-} < 0$ indicates negative association with non-theme

Contrast

$$C = W^{+} - W^{-}$$

$C > 3.0$ Strong correlation

C 1.0 – 3.0 Moderate correlation

$C < 1.0$ Weak to poor correlation

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Example: Probability of a landslide

- Training points: 10 known landslide sites in study area
- Evidential themes:
  - Rock / soil type
  - Slope
  - Vegetation
  - Rain fall
  - Rabbit burrow density
  - Proximity to houses with value > $1M

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Probabilities

Results from students sent out to investigate the slip sites

1. Vegetation	➢ 9/10 were grass land
2. Rock / soil type	➢ 8/10 were mudstone
3. Rabbit burrows	➢ 8/10 areas of high burrow density
4. Slope	➢ 7/10 were high slope
5. Rain fall	➢ 5/10 area of high rain fall
6. Houses > $1M	➢ 3/10 near high priced houses

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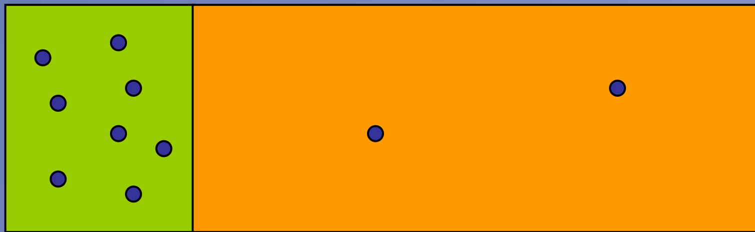
But what about the spatial effect?

Rock Type

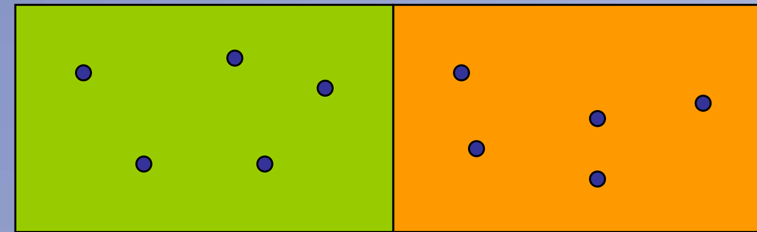
3



W+ = 1.4 | W- = -1.3 | C = 2.7

Rainfall

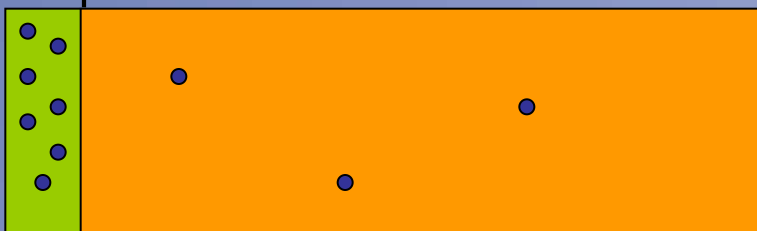
6



W+ = 0 | W- = 0 | C = 0

Slope

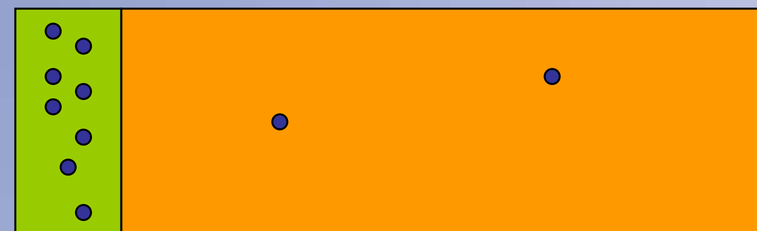
1



W+ = 3.0 | W- = -1.2 | C = 4.2

Rabbit burrows

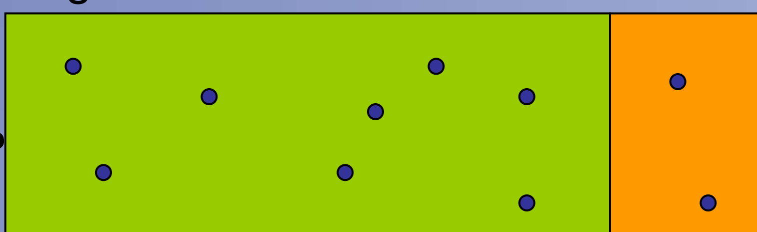
2



W+ = 2.3 | W- = -1.5 | C = 3.8

Vegetation

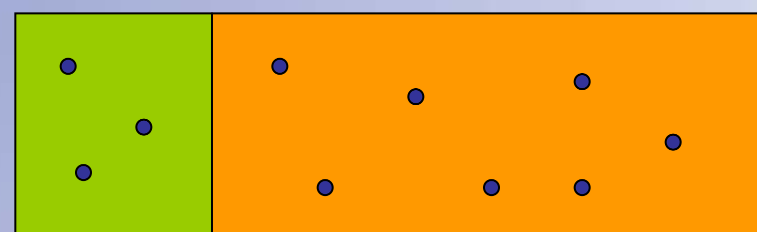
4



W+ = 0.15 | W- = -0.44 | C = 0.59

Houses > $1M

5



W+ = 0.2 | W- = -0.07 | C = 0.13

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The Modelling Software

MI-SDM from:

Arc-SDM from:

Free trial software from Avantra:
www.avantra.com.au

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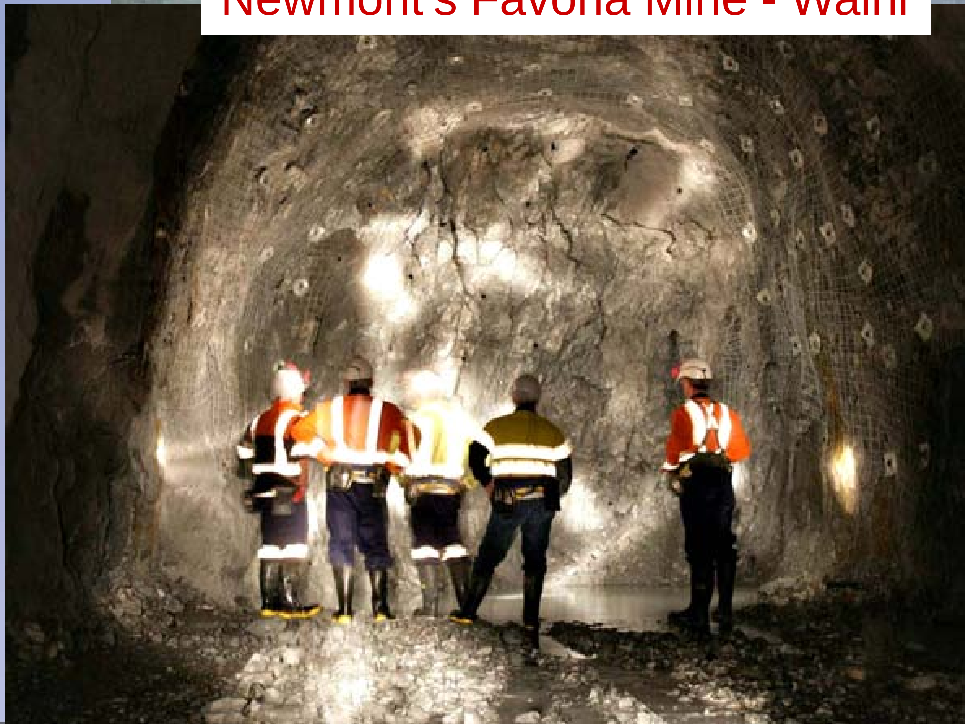
Gold in Otago

- We’re searching for another million ounce gold mine similar to Macraes Mine in Otago.
- The Otago Goldfield has so much potential and has undergone such little modern exploration.
- No new hard-rock discoveries have been made in the last 30 years!
- Potential remains to discover more big gold mines and significant alluvial deposits.
- Millions of dollars worth of exploration funding and mine development would be spent in the Otago region and throughout New Zealand.

Newmont’s Favona Mine - Waihi



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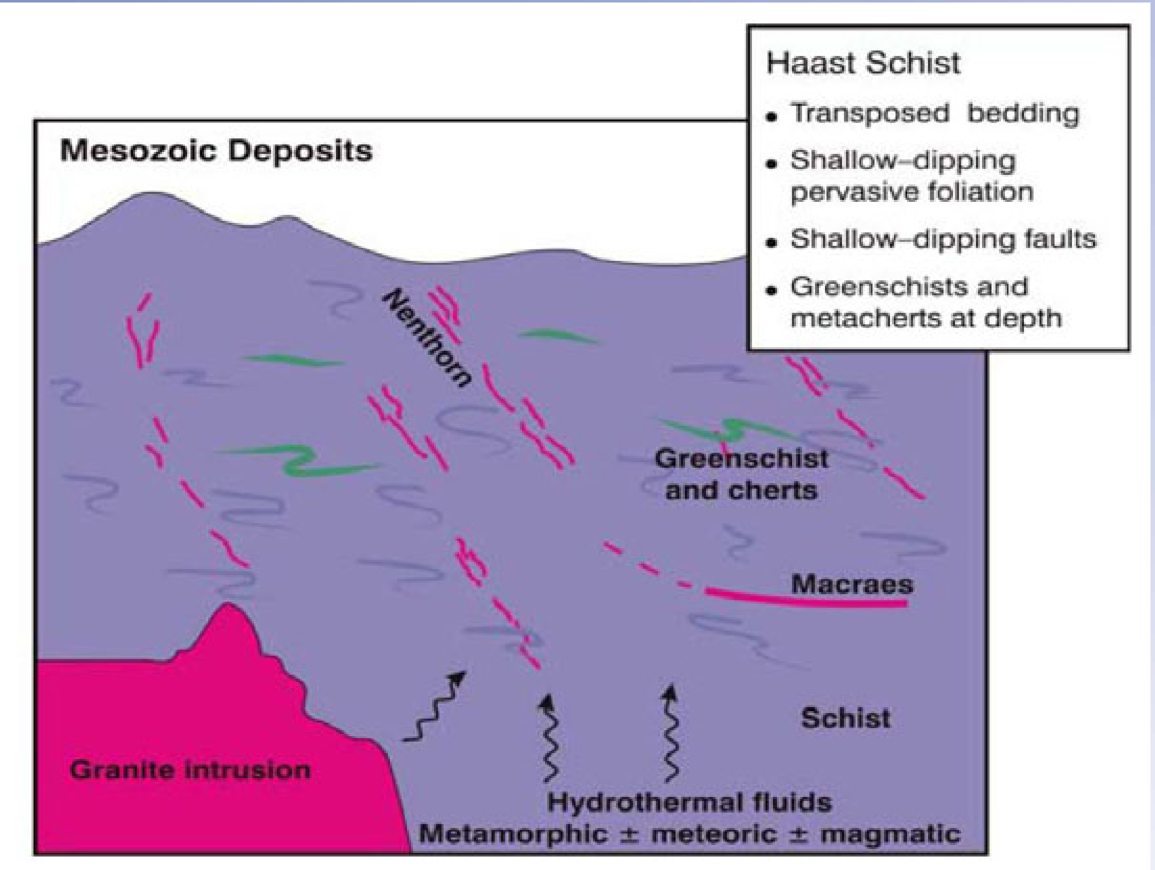
Exploration model

- Rock lithology
- Quartz veins
- Stream sediment geochemistry
  (As, Au, Pb, Ag and Cu)
- Rock chip geochemistry
  (Au, As, Pb, Zn, Ag, Sb and Cu)
- Soil geochemistry
  (Au, As, Ag, Sb and Cu)
- Faulting
  - Density
  - Jogs
  - Intersections
  - Orientation
  - Shear zones
- Folding
- Foliation style
- Textural grade
- Quartz reefs

Mesothermal Gold Mineralisation



From: Christie, A. (2002) GNS Science

35 layers were tested for correlation
9 were included in the final model

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Data sources

- GNS Science – QMAP geological mapping.
- Crown Minerals – Historical records of past exploration.
- Data entry – In-house at Kenex where possible.
- Experts – Research scientists, exploration managers.
- Company records and new work – e.g. mapping, sampling and drilling.

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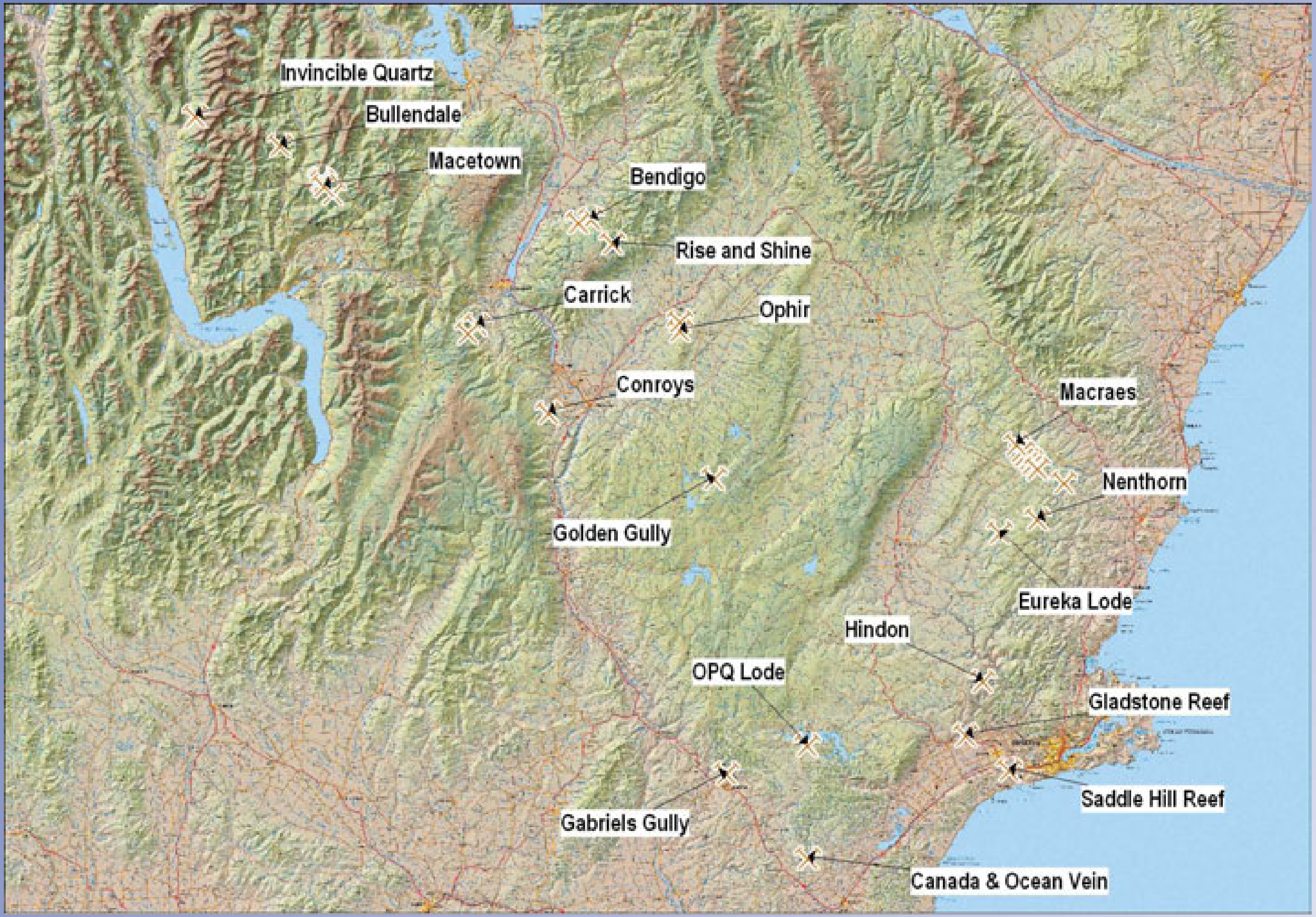
Training Points & Study Area



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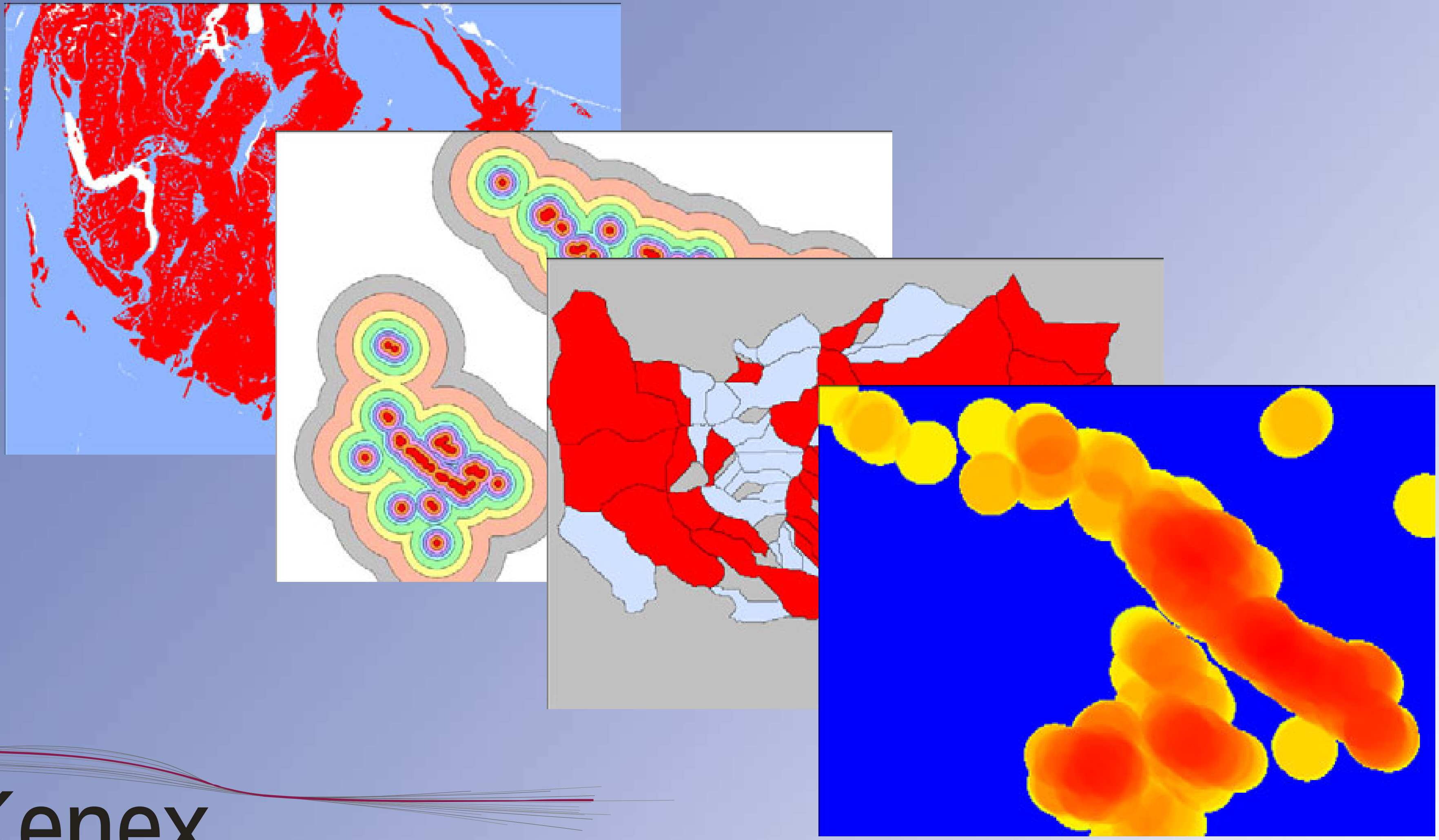
Four example layers……



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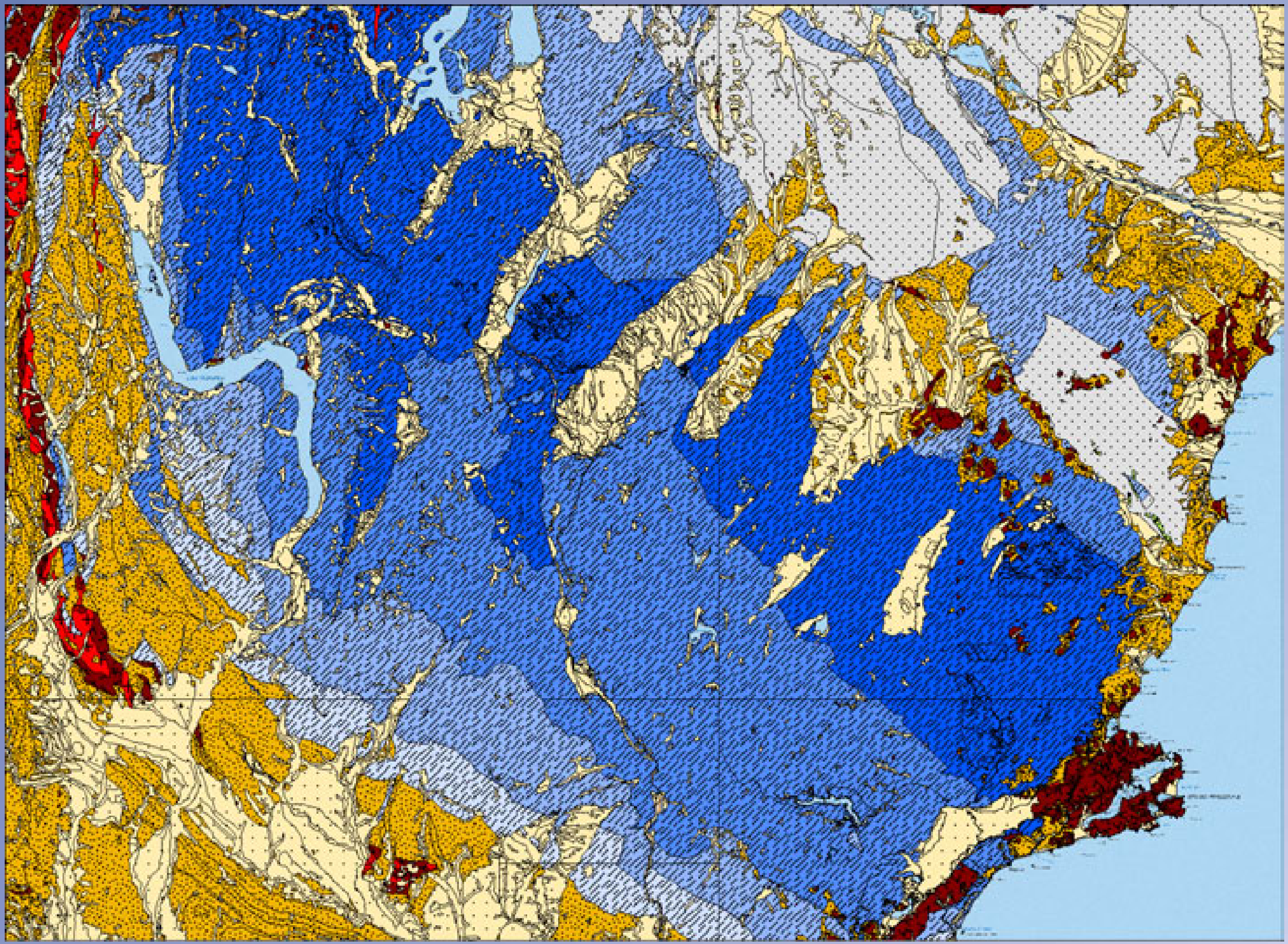
Lithology



Methods:

- Geology data is sourced from client or Kenex databases derived from publicly available maps, digitised from reports, or obtained from field mapping.
- Each geological unit is tested for correlation.
- Geological units are then combined into simplified themes and made into a grid.

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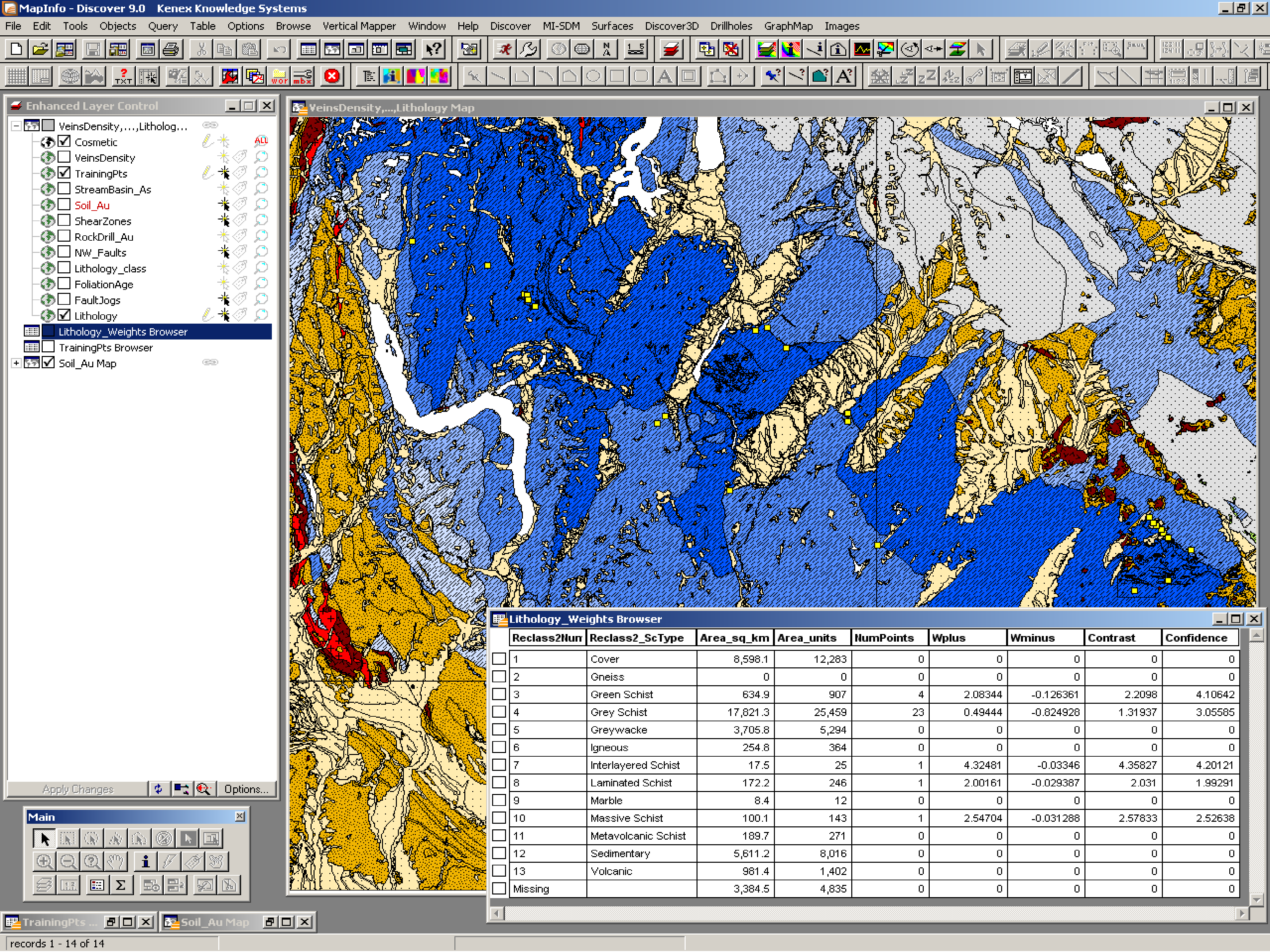
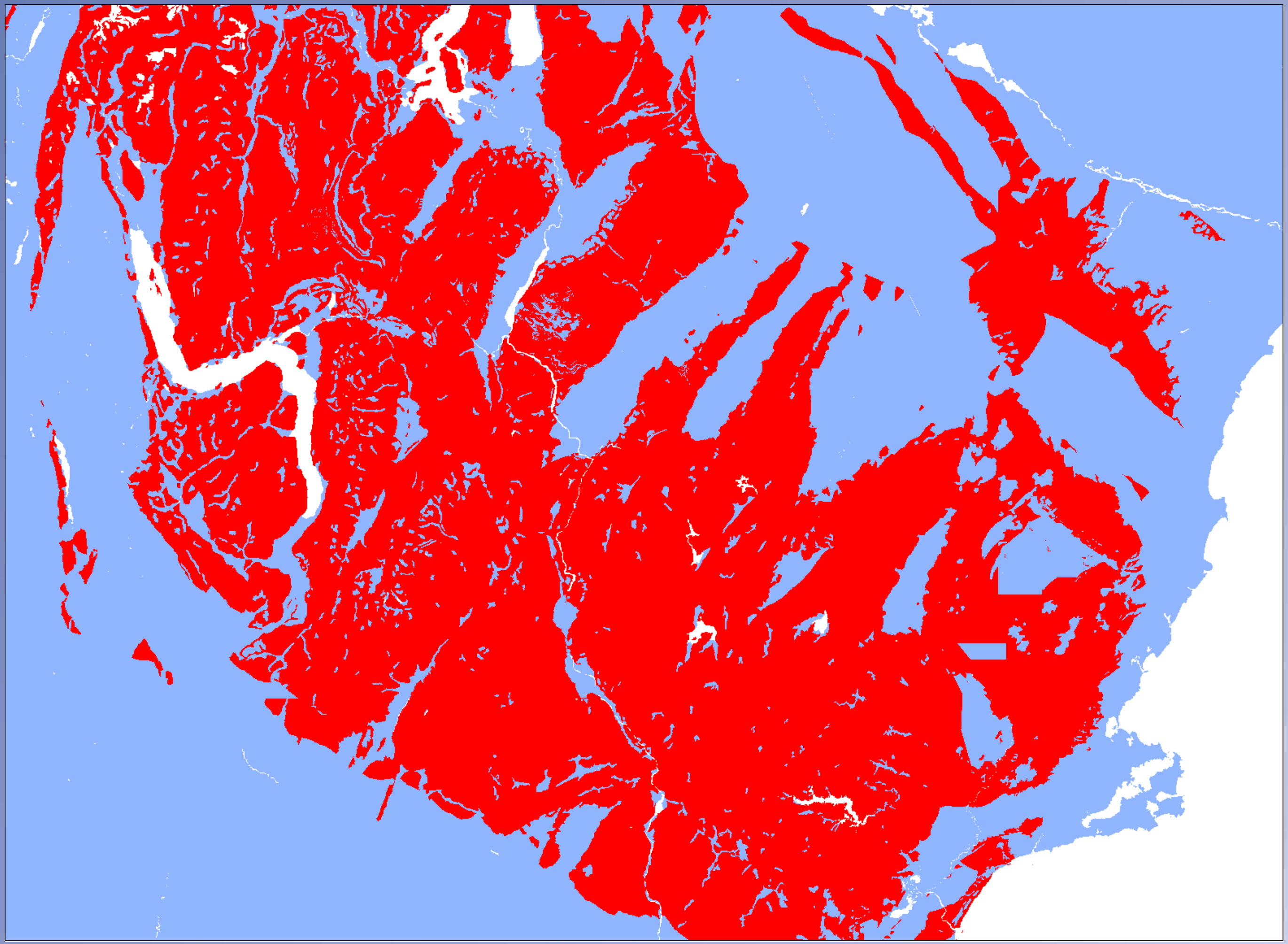
Data: QMAP Geologic data (sourced from Institute of Geological & Nuclear Sciences - Copyright Reserved)+ Kenex digitised prospect scale maps



Reclass2Nun	Reclass2_ScType	Area_sq_km	Area_units	NumPoints	Wplus	Wminus	Contrast	Confidence
1	Cover	8,598.1	12,283	0	0	0	0	0
2	Gneiss	0	0	0	0	0	0	0
3	Green Schist	634.9	907	4	2.08344	-0.126361	2.2098	4.10642
4	Grey Schist	17,821.3	25,459	23	0.49444	-0.824928	1.31937	3.05585
5	Greywacke	3,705.8	5,294	0	0	0	0	0
6	Igneous	254.8	364	0	0	0	0	0
7	Interlayered Schist	17.5	25	1	4.32481	-0.03346	4.35827	4.20121
8	Laminated Schist	172.2	246	1	2.00161	-0.029387	2.031	1.99291
9	Marble	8.4	12	0	0	0	0	0
10	Massive Schist	100.1	143	1	2.54704	-0.031288	2.57833	2.52638
11	Metavolcanic Schist	189.7	271	0	0	0	0	0
12	Sedimentary	5,611.2	8,016	0	0	0	0	0
13	Volcanic	981.4	1,402	0	0	0	0	0
Missing		3,384.5	4,835	0	0	0	0	0

Geology



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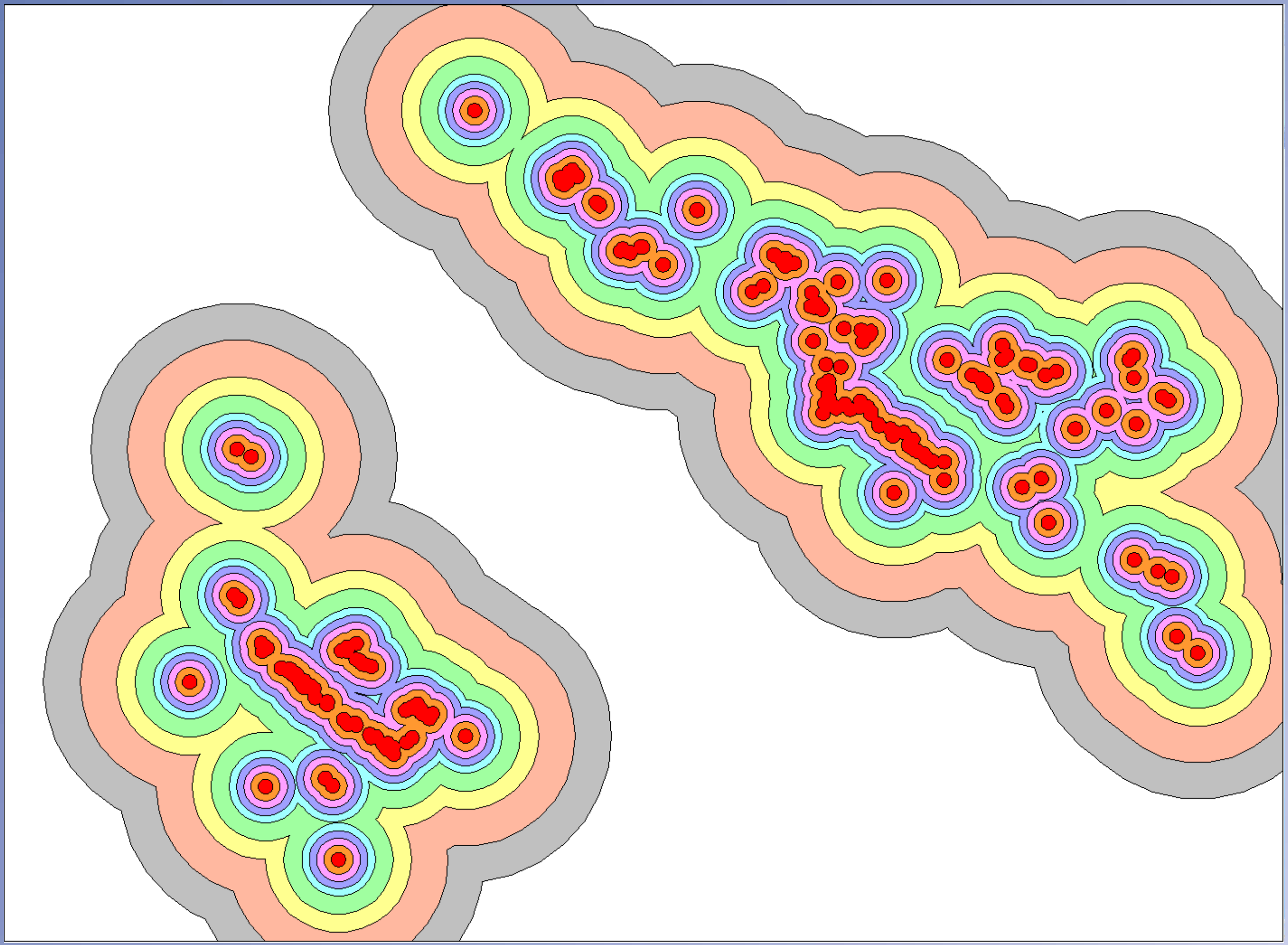
Au in Rock Chips



Methods:

- Rock chip geochemistry is analysed statistically for anomalous levels.
- Anomalous levels are then buffered or gridded.
- Buffer distances are then tested for correlations.
- A binary layer is then created based on anomalous and non-anomalous rock chips and made into grid.

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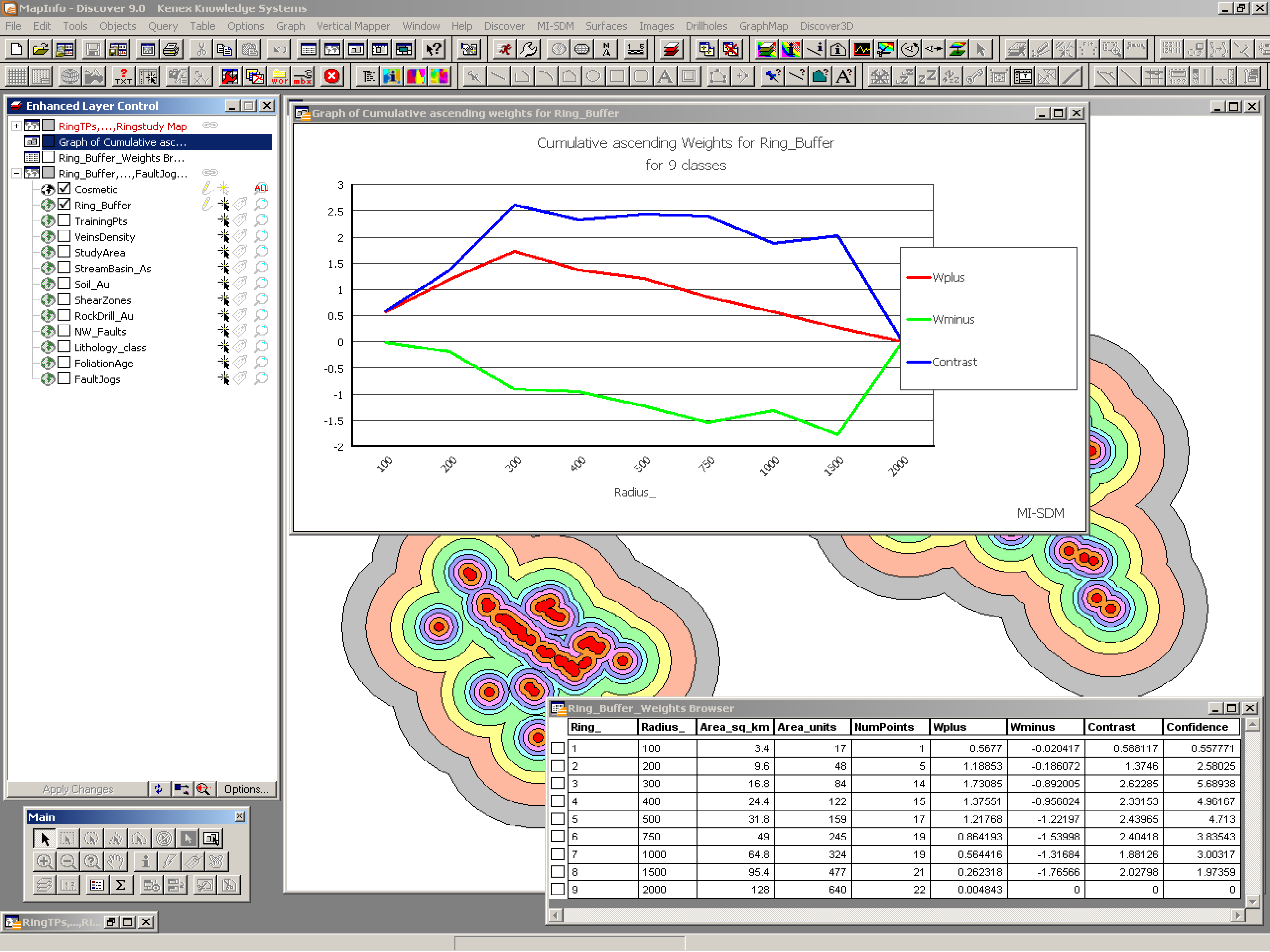

MapInfo - Discover 9.0 Kenex Knowledge Systems
File Edit Tools Objects Query Table Options Graph Vertical Mapper Window Help Discover MI-SDM Surfaces Images Drillholes GraphMap Discover3D
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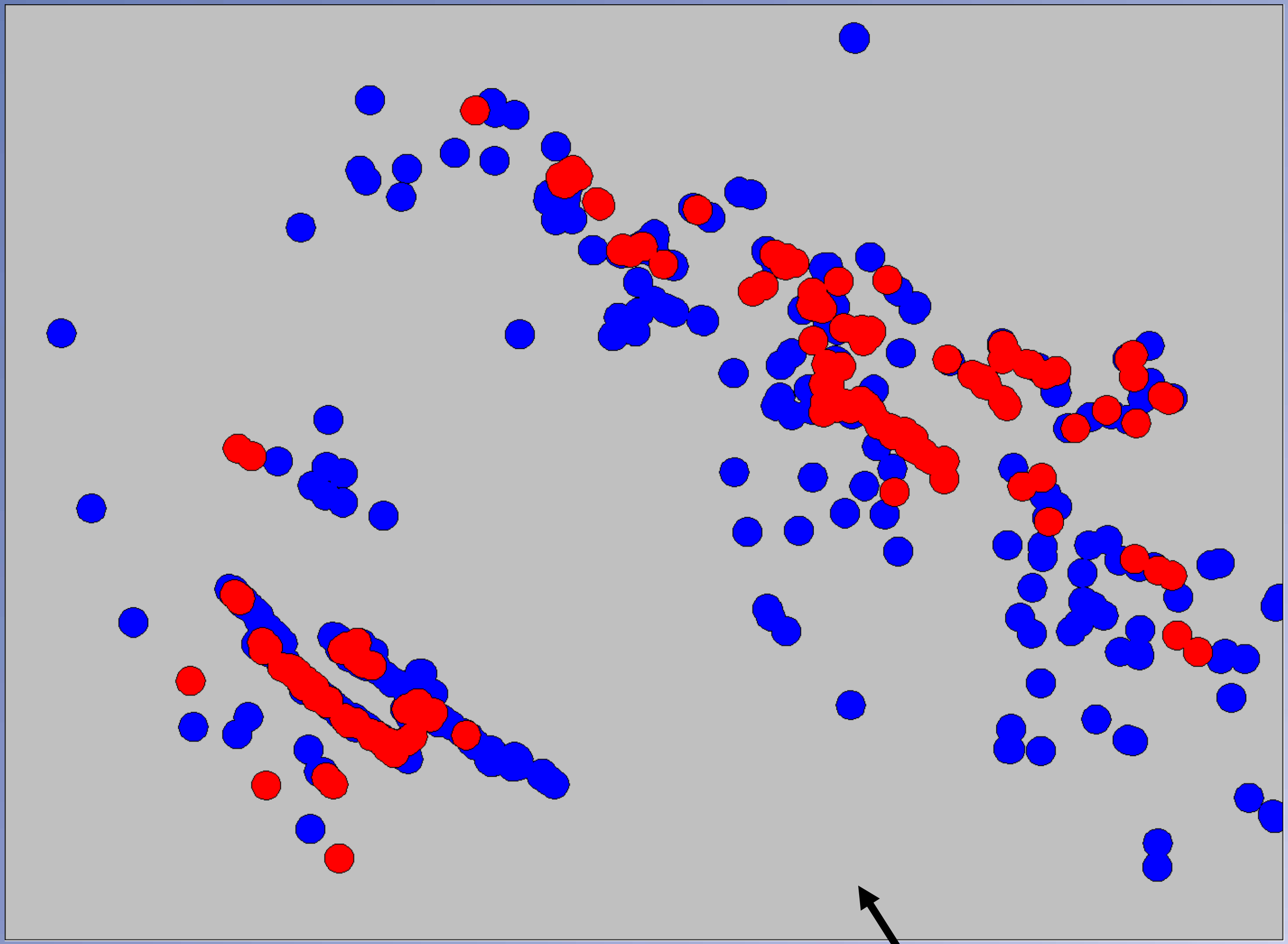
Graph of Cumulative asc...
Ring_Buffer_Weights Br...
Ring_Buffer,...,FaultJog...
Cosmetic
Ring_Buffer
TrainingPts
VeinsDensity
StudyArea
StreamBasin_As
Soil_Au
ShearZones
RockDrill_Au
NW_Faults
Lithology_class
FoliationAge
FaultJogs
Apply Changes
Options...
Main
Graph of Cumulative ascending weights for Ring_Buffer
Cumulative ascending Weights for Ring_Buffer
for 9 classes
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
100
200
300
400
500
750
1000
1500
2000
Radius_
Wplus
Wminus
Contrast
MI-SDM
Ring_Buffer_Weights Browser
Ring_ | Radius_ | Area_sq_km | Area_units | NumPoints | Wplus | Wminus | Contrast | Confidence
1 | 100 | 3.4 | 17 | 1 | 0.5677 | -0.020417 | 0.588117 | 0.557771
2 | 200 | 9.6 | 48 | 5 | 1.18853 | -0.186072 | 1.3746 | 2.58025
3 | 300 | 16.8 | 84 | 14 | 1.73085 | -0.892005 | 2.62285 | 5.68938
4 | 400 | 24.4 | 122 | 15 | 1.37551 | -0.956024 | 2.33153 | 4.96167
5 | 500 | 31.8 | 159 | 17 | 1.21768 | -1.22197 | 2.43965 | 4.713
6 | 750 | 49 | 245 | 19 | 0.864193 | -1.53998 | 2.40418 | 3.83543
7 | 1000 | 64.8 | 324 | 19 | 0.564416 | -1.31684 | 1.88126 | 3.00317
8 | 1500 | 95.4 | 477 | 21 | 0.262318 | -1.76566 | 2.02798 | 1.97359
9 | 2000 | 128 | 640 | 22 | 0.004843 | 0 | 0 | 0
RingTPs,...,Ri...

Au in Rock Chips



Methods:

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- Anomalous levels are then buffered or gridded.
- Buffer distances are then tested for correlations.
- A binary layer is then created based on anomalous and non-anomalous rock chips and made into grid.

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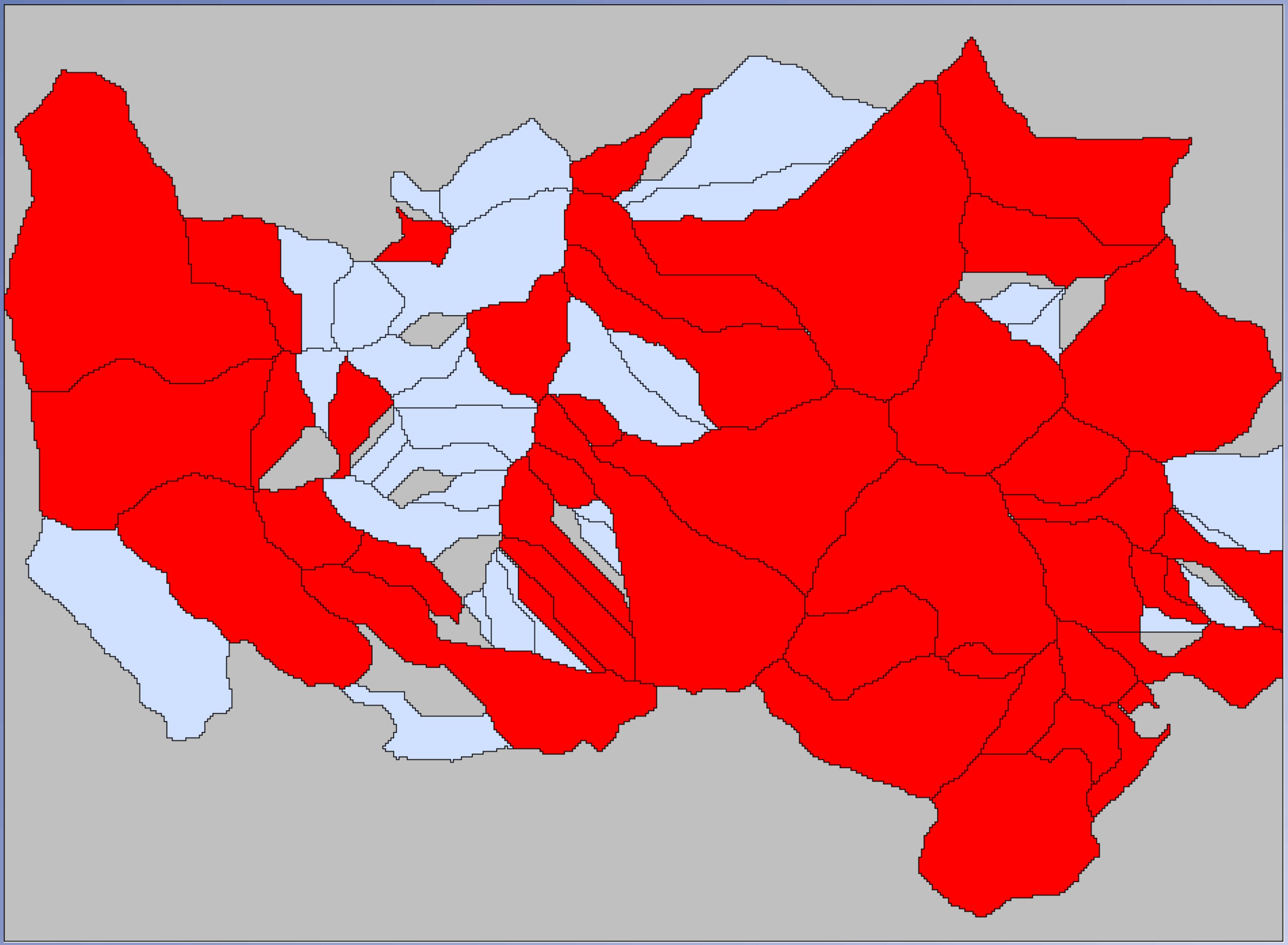
Areas of no data not included in the model

As in Stream Sediment



Methods:

- Locate and define anomalous stream sediment samples.
- Create basin boundaries from DTM using gridding tools.
- Apply maximum or average geochemistry to basins.
- Test basins for correlation with different geochemical anomalies.
- Create grid layer for basins with good geochemistry correlation.

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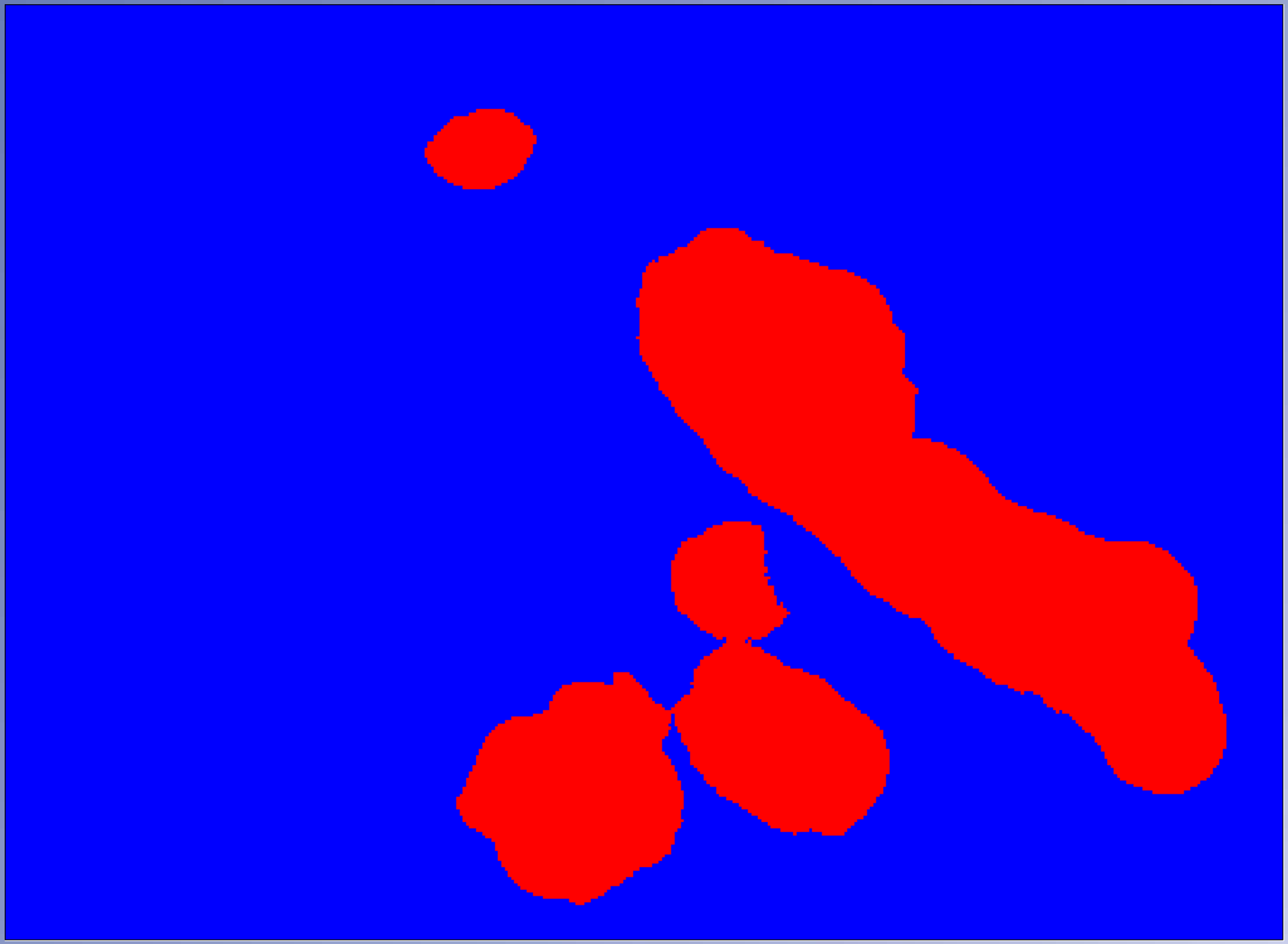
Quartz Vein Density



Methods:

- Create density grid of known quartz vein locations.
- Test different density ranges for correlations.
- Create grid layer for best correlation with vein density.

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Layers included in the model

Theme	Description	W+	W-	C
Lithology	Green and grey schists	0.62	-1.64	2.26
Faults	Distance from NW striking faults	3.78	-0.65	4.43
Fault Jogs	Distance from fault jogs	3.68	-0.21	3.89
Shear Zones	Distance from shear zones	4.37	-0.43	4.81
Rock Au	Anomalous Au	1.48	-2.70	4.19
Soil Au	Anomalous Au	2.08	-1.79	3.87
Stream As	Anomalous As	1.83	-1.10	2.94
Vein Density	Mod-high vein density	4.31	-1.03	5.34
Foliation Age	S2 developed foliation	0.95	-0.37	1.32

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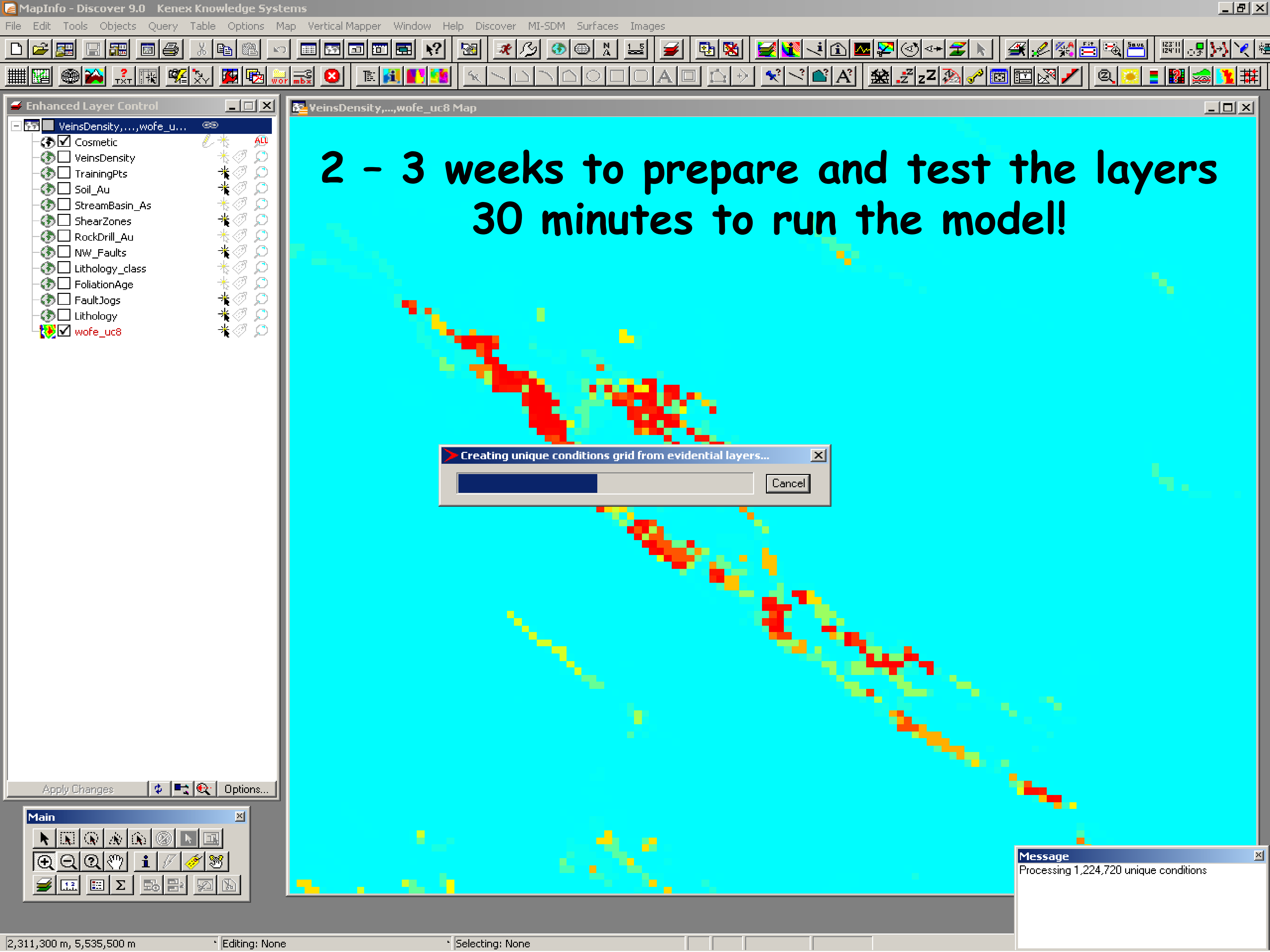
MapInfo - Discover 9.0 Kenex Knowledge Systems
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Enhanced Layer Control
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Cosmetic
VeinsDensity
TrainingPts
Soil_Au
StreamBasin_As
ShearZones
RockDrill_Au
NW_Faults
Lithology_class
FoliationAge
FaultJogs
Lithology
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Apply Changes
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Main
VeinsDensity,...,wofe_uc8 Map
2 - 3 weeks to prepare and test the layers
30 minutes to run the model!
Creating unique conditions grid from evidential layers...
Cancel
Message
Processing 1,224,720 unique conditions
2,311,300 m, 5,535,500 m
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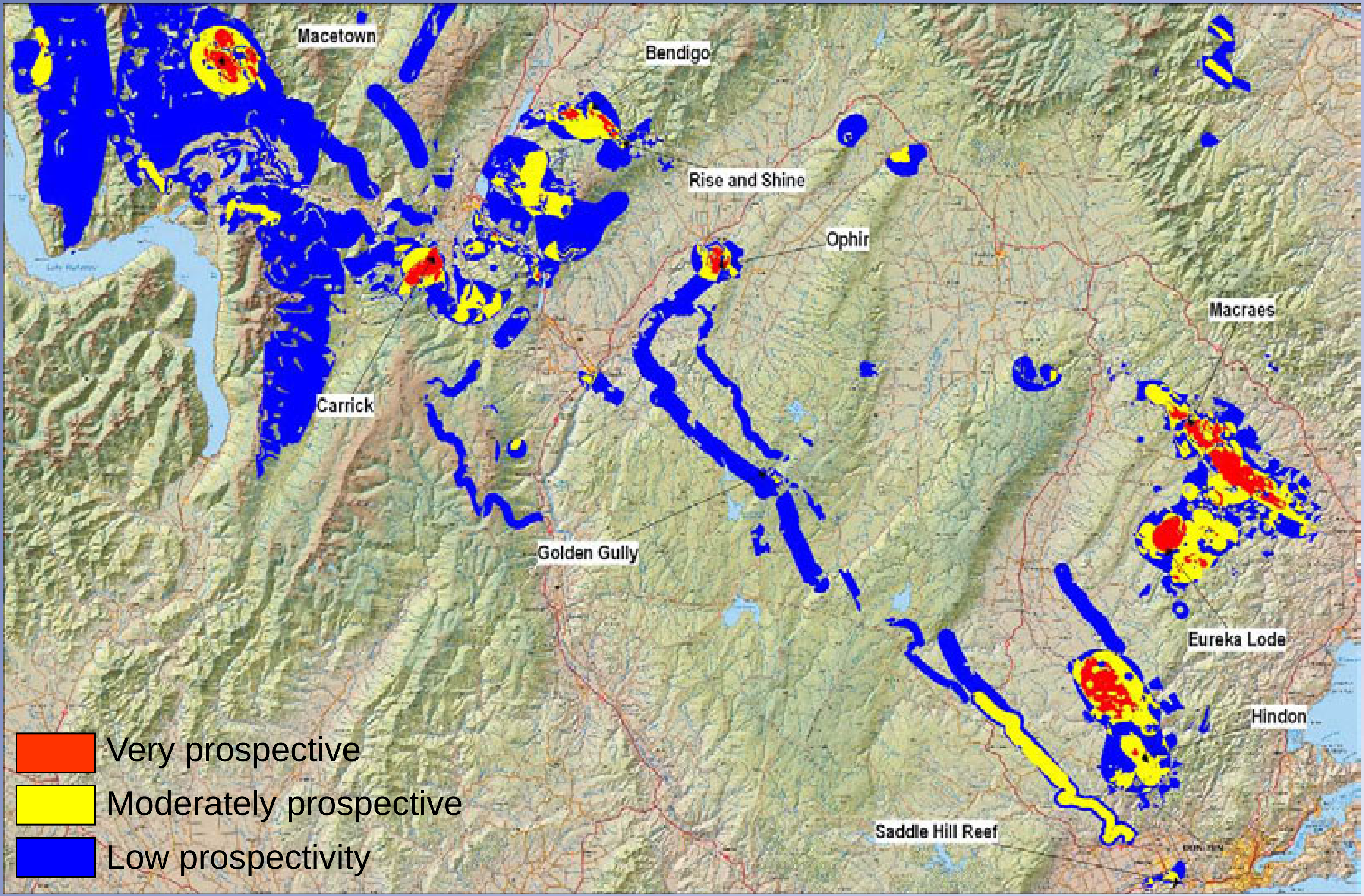
Prospectivity Map – Mesothermal Gold



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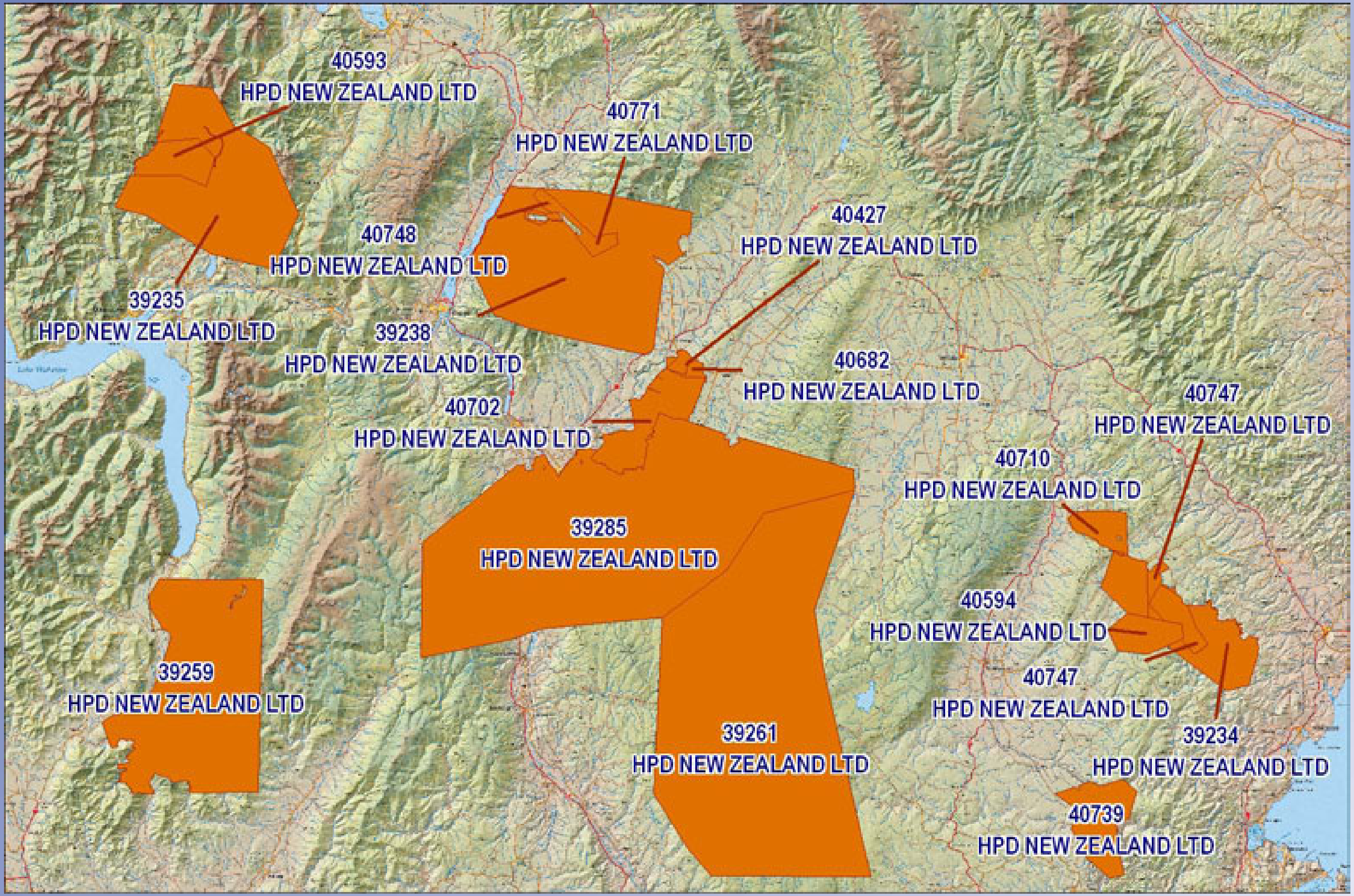
Data from Partington and Sale (2004)

Permitting / Pegging of Prospective Ground



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Follow-up Field Work

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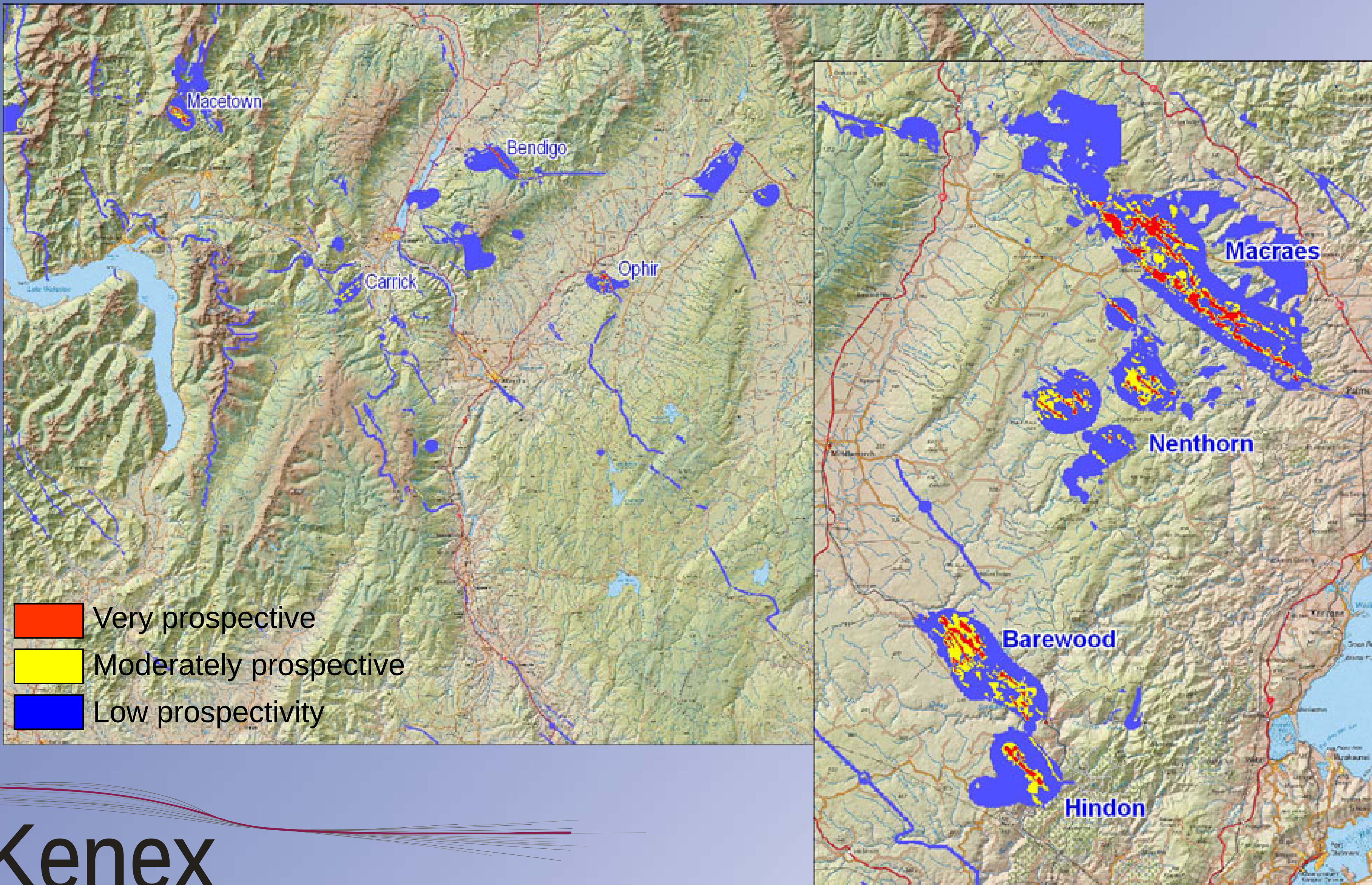
Remodelling with new data in 2006….



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The Future: Glass Earth (New Zealand) Limited

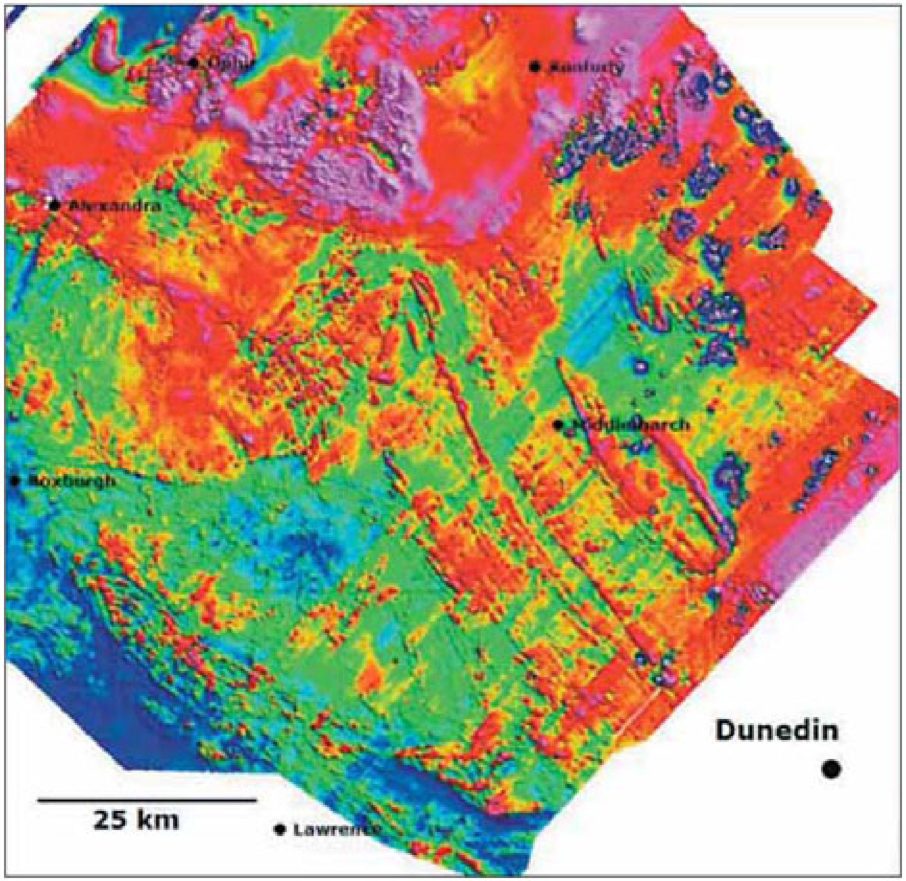

Fig. 3. Preliminary Total Magnetic Intensity

- Largest geophysical survey undertaken in Otago.
- Helicopter EM survey.
- Project cost: Over $NZ 4M!
- $NZ 1M invested into the project by Otago Regional Council in a bid to promote mineral exploration in the area.
- Will provide data on rock types, faults, shear zones, mineralisation.
- Allows geologists to see under the sediment that covers much of Otago and is limiting current exploration techniques.
- Preliminary results are looking to re-map the Otago schists and shear zones – Key indicators in the model shown today for mesothermal gold mineralisation.

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Figure and data from: Henderson, S. (2007) AusIMM Bulletin No. 4

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Creating opportunities in the spatial world