Improvements on 2D modelling with 3D spatial data: Tin prospectivity of Khartoum, Queensland, Australia

C. E. Payne, F. W. Cunningham,
A. J. Wilkins & G. A. Partington
Kenex Ltd.

Kenex
Creating opportunities in the spatial world

Outline

- Prospectivity modelling
- Weights of evidence modelling
- Background
- Data available
- Modelling Khartoum
- Conclusions

Prospectivity modelling

- Goal
  - To predict where there is a high probability of finding mineral deposition
- Basic method
  - Compile digital data into GIS and develop maps related to the mineral system being modelled
  - Use training data to weight mapped data (weights of evidence)
  - Or expert defined values to weight important mapped data (fuzzy logic)
  - Combine predictive maps using weights of evidence or fuzzy logic to produce prospectivity map

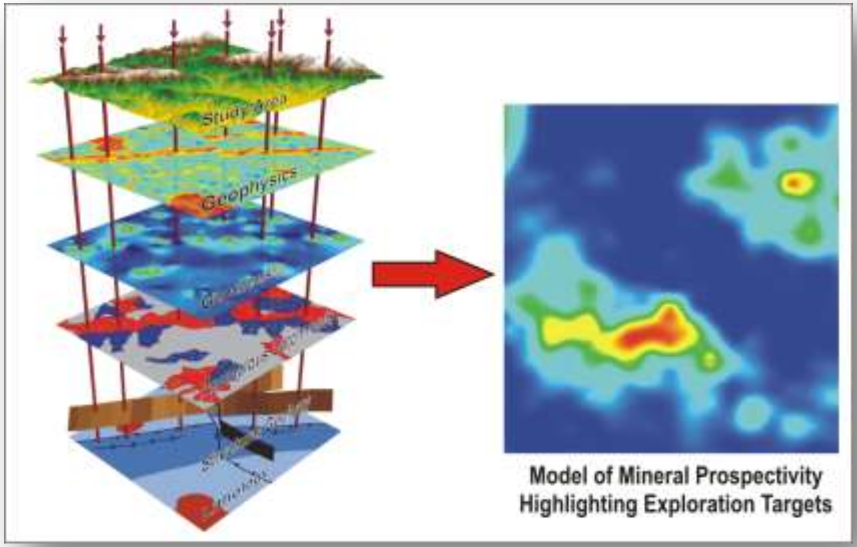
Weights of Evidence Modelling

- Pattern recognition approached developed for other industries
  - Graham Bonham-Carter adapted it for exploration
- WoE is a probability based method
  - Bayesian statistical approach
- Used WoE to create a prospectivity model for intrusion related Sn mineralisation in Khartoum, Queensland, Australia

Weights of Evidence Modelling

Basic Method

- Develop binary or multiclass predictive maps of data relevant to mineralisation style being modelled
- Use training data to test maps for spatial correlation
  - Points of known mineralisation
- Combine selected maps together using weights of evidence statistics producing a map of probabilities – the Prospectivity Map



Weights of Evidence Modelling

- Important Spatial Indicators

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

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

$W+ > 0$ indicates positive association with theme

$W- < 0$ indicates negative association with non-theme

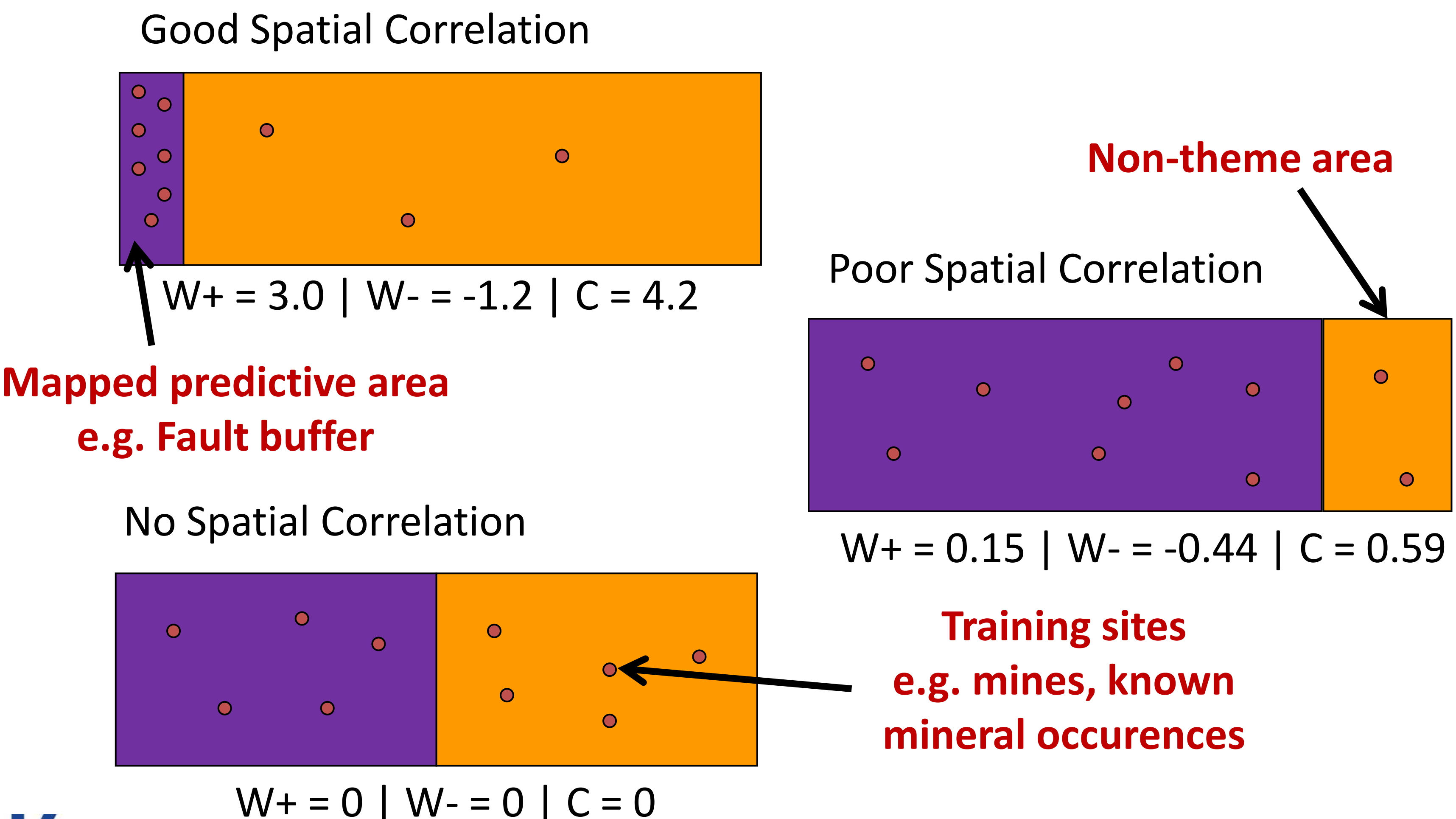
$C > 3.0$ Strong correlation

$1.0 < C < 3.0$ Moderate correlation

$C < 1.0$ Weak to poor correlation

Weights of Evidence Modelling

- Correlation of Themes



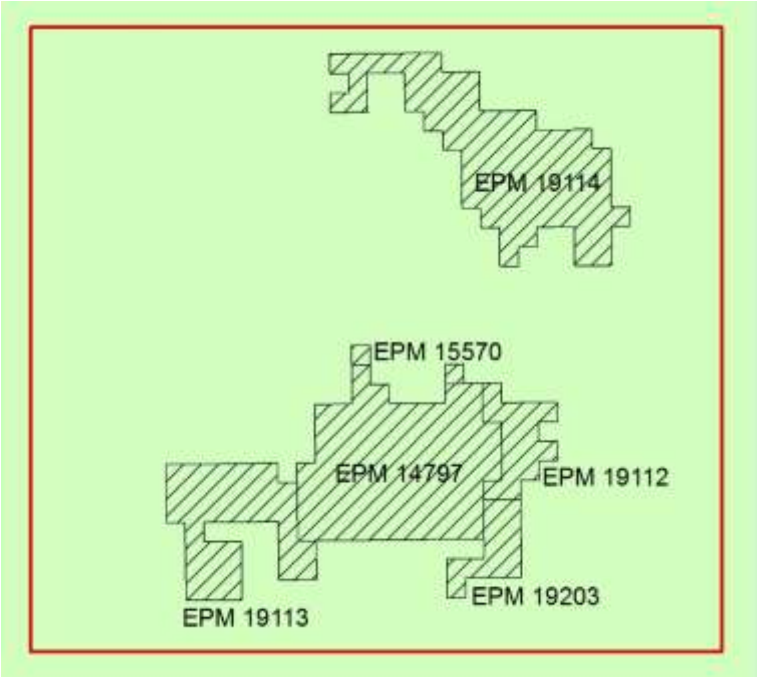
Kenex

Creating opportunities in the spatial world

Khartoum

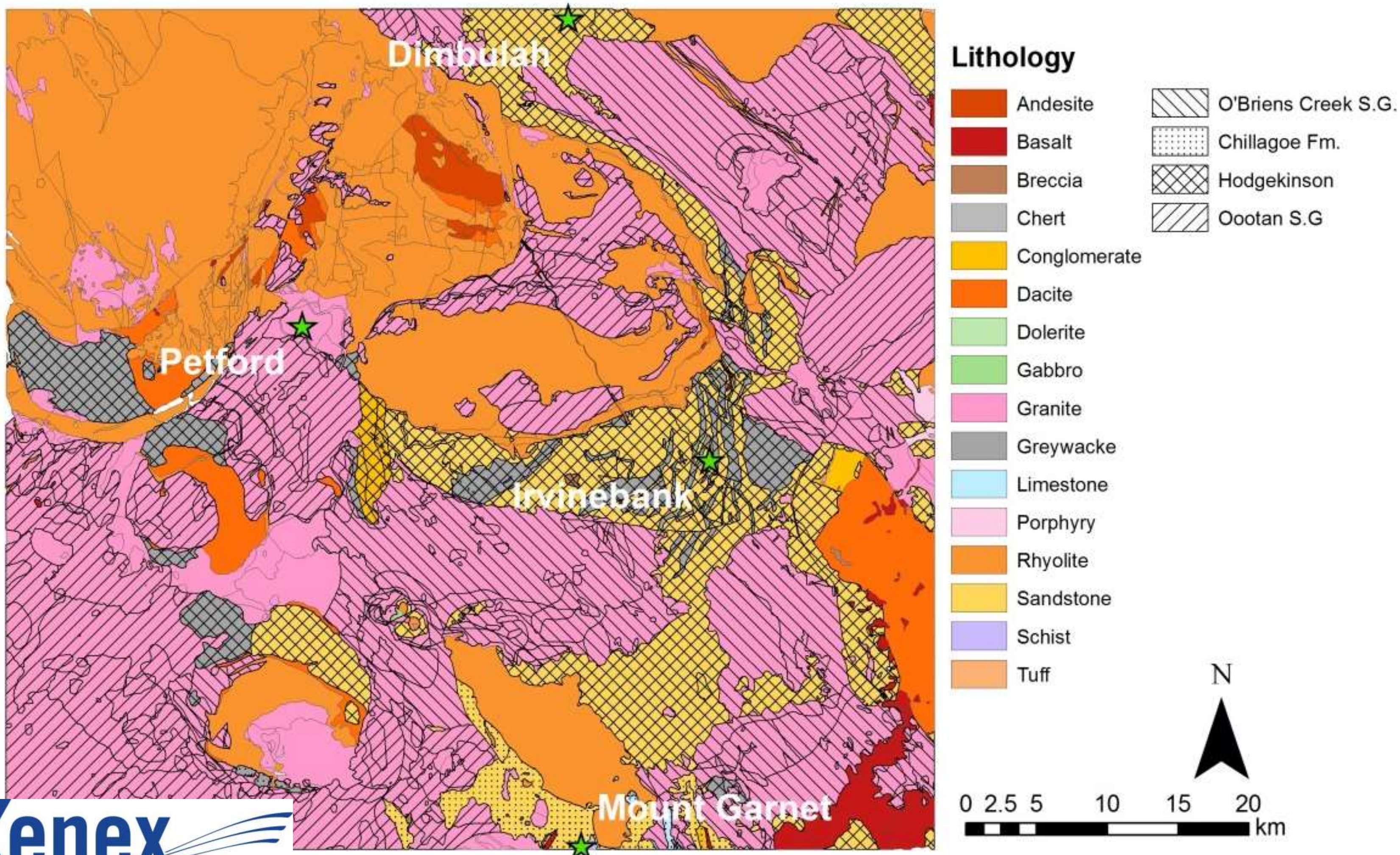
- Study Area

- The Khartoum region has been targeted for high grade tin veins mineralisation by AEL
- Used more than 50 known intrusion related Sn mineral occurrences as training points
- Historic production is estimated to be 15,000 tonnes tin
- New world class system >50km2 with conceptual tonnage 80-120 Mt



Kenex
Creating opportunities in the spatial world

Khartoum
- Geology

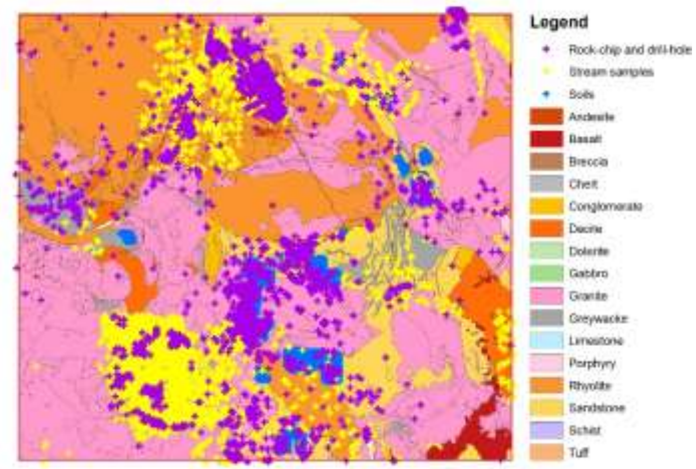


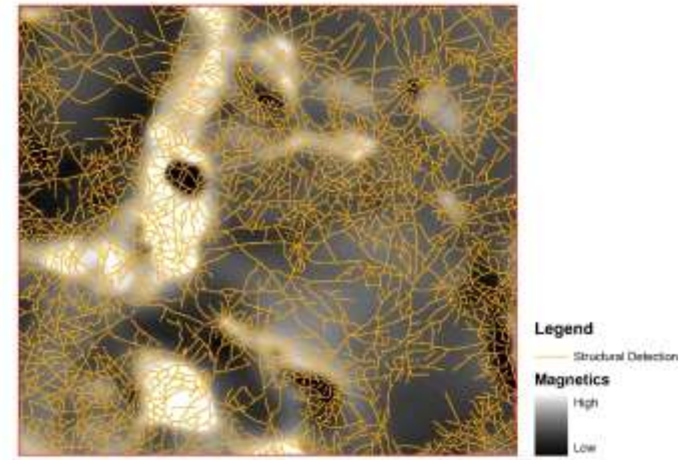
Kenex
Creating opportunities in the spatial world

Data Available

- Mineral occurrence data
- Geological mapping
  - Queensland Geological Survey
  - Detail outcrop mapping
- Geochemical data
  - Soil
  - Rock-chip
  - Drill-hole
- Geophysical data
  - Magnetics
  - Gravity
  - Radiometrics
  - Aeromagnetic structural interpretation
- ASTER data

Provided by AEL and Kenex Ltd.





Kenex
Creating opportunities in the spatial world

Modelling Khartoum

- Mineral Systems Model

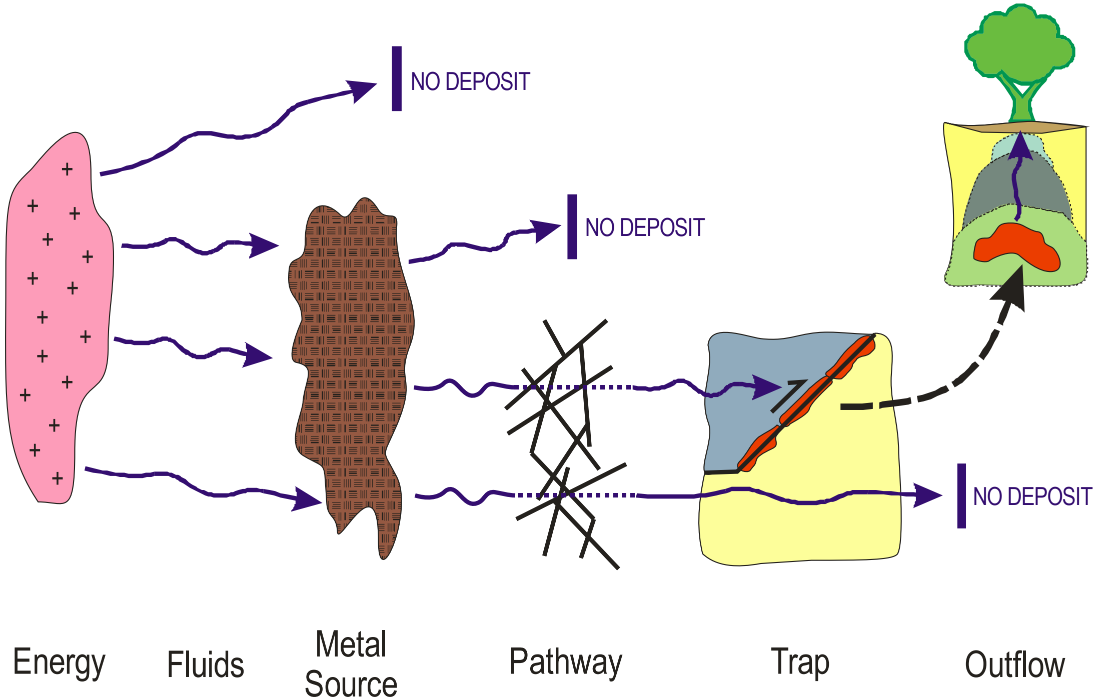


Figure demonstrates source of energy and fluids, migration pathways and the deposition of metal and outflow of fluids

Creating Predictive Maps

- Predictive maps were created using ArcGIS
- Use features from the data available that represent the mineral deposit model for the region
- Weighted using spatial correlation with training data
- Selected based on highest weights from each critical components of the mineral systems concept

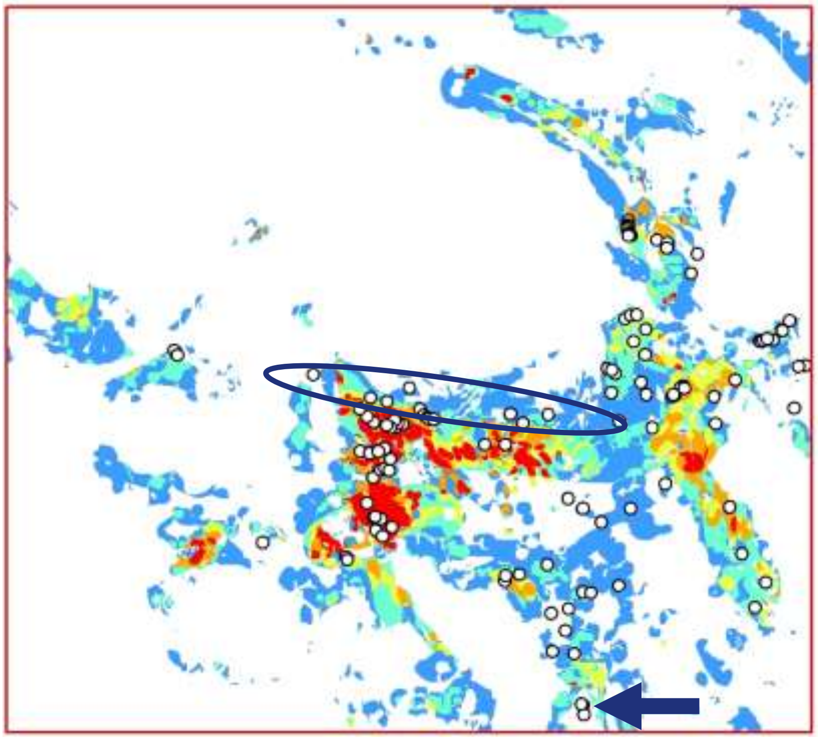
  i.e. Source, formation of and transport to trap, and concentration and deposition of metals

Layers Included in the Model

Mineral System	Variable		C	Stud C
Source of energy and fluids	Host lithology	Sandstone	1.6	8.7
		Greywacke	1.9	8.1
		Conglomerate	0.3	0.3
		Highly Fractionated Granites	0.4	2.0
	Proximity to dykes		1.1	5.5
Migration pathways	Proximity to crustal scale faults		1.6	7.3
	Centroids of radial fracture patterns		1.0	4.6
	Proximity to granite contacts		0.6	2.3
Deposition of metal and outflow of fluids	**Proximity to greisens**		**2.9**	**11.0**
	Association with anomalous Sn		3.8	3.7
	Association with anomalous W		2.6	4.2
	Association with high gravity slope		1.5	8.0
	Radiometric uranium highs		3.2	3.1

Kenex
Creating opportunities in the spatial world

Results



- Prospective areas in Hodgkinson Fm not highlighted
  - Contact zones don't extend far enough
- Misses key deposits
  - E.g. Pinnacles
    - Consolidated Tin Mines Ltd Jorc: 7,000,000 tonnes Sn @ 0.3% – part of the Mt Garnet Tin project

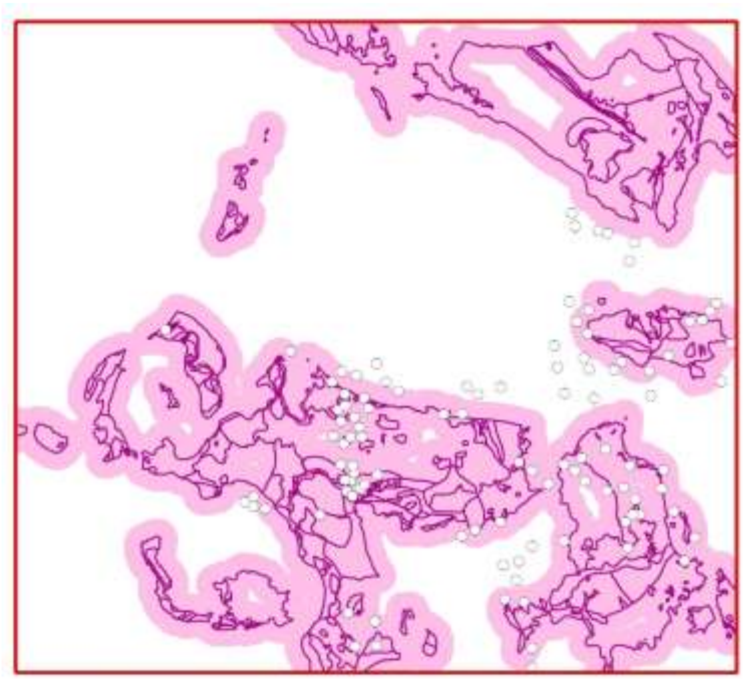
Kenex
Creating opportunities in the spatial world

Solution

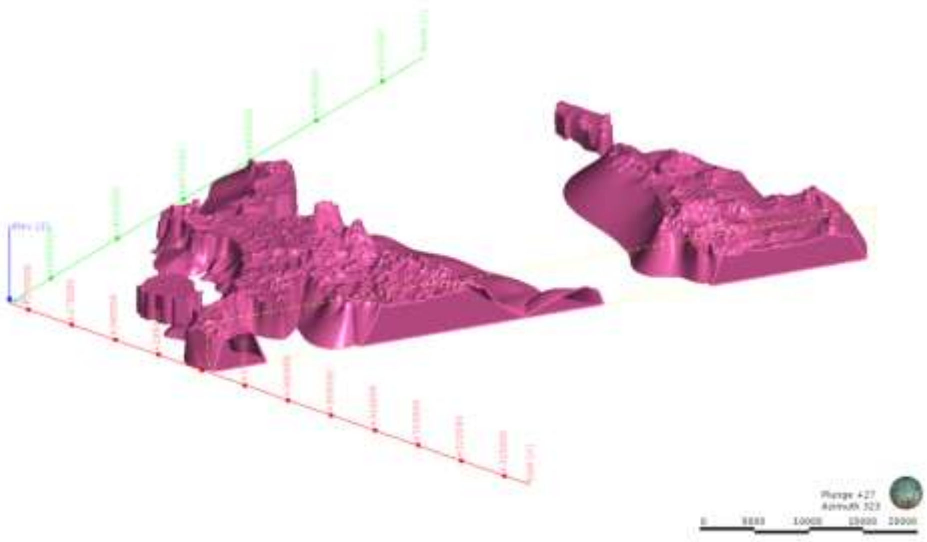
- Create better layers that are more representative of actual geology
  - Incorporate 3D geological layers
  - Created an interpretation of cooling fractures from DTM
- Retest all layers with new parameters

3D Data Incorporation

2D interpretation of highly fractionated granite extents



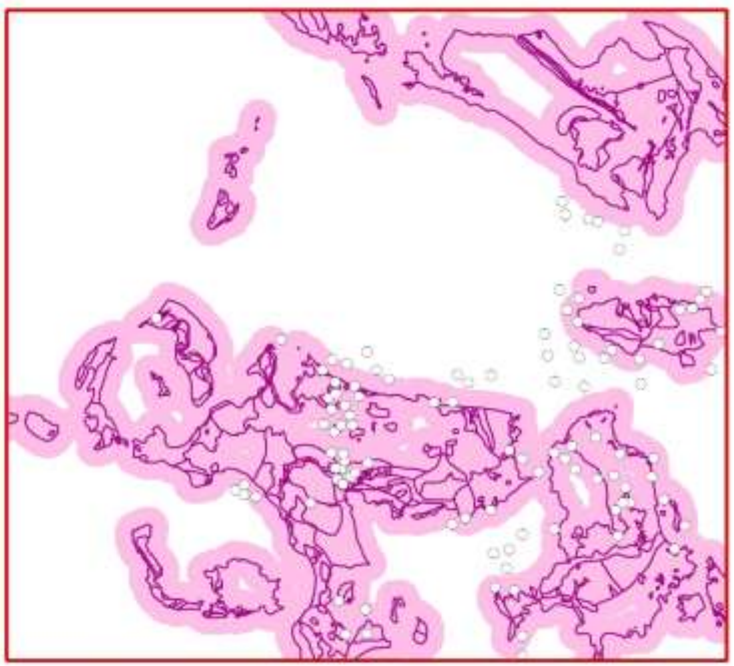
3D interpretation of highly fractionated granite extents



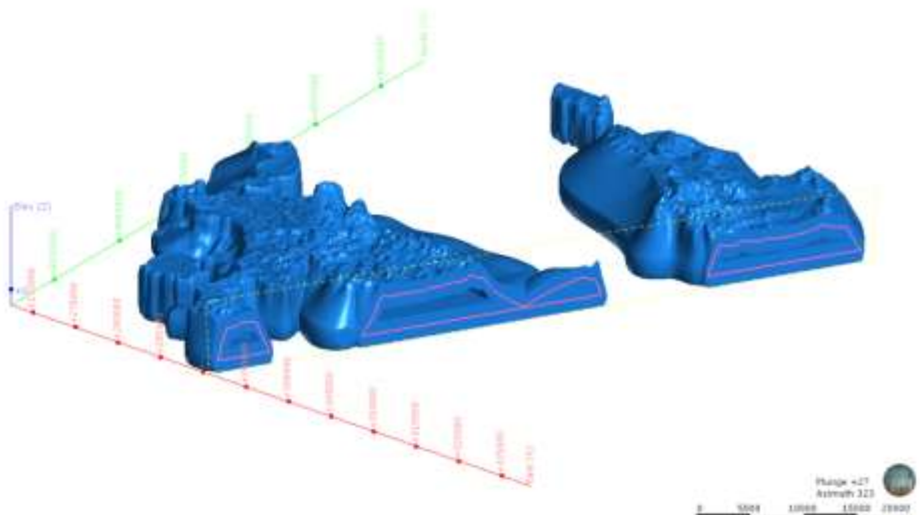
Kenex
Creating opportunities in the spatial world

3D Data Incorporation

2D interpretation of granite extents



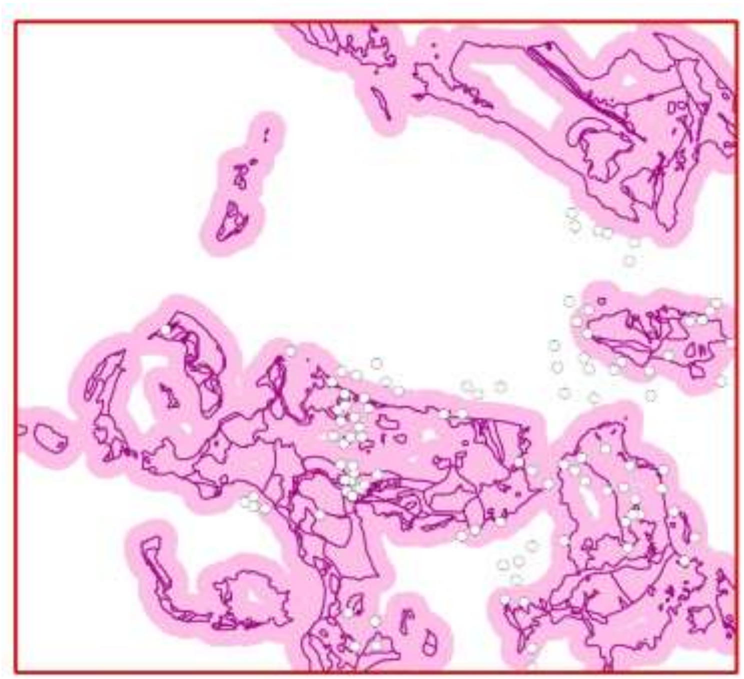
3D interpretation of granite extents



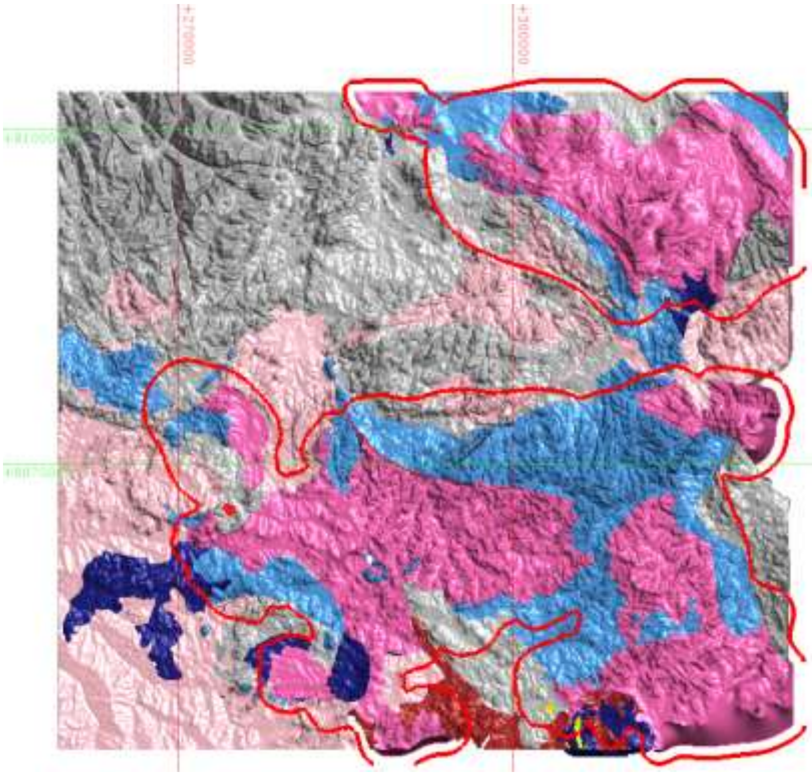
Kenex
Creating opportunities in the spatial world

3D Data Incorporation

2D interpretation of granite extents



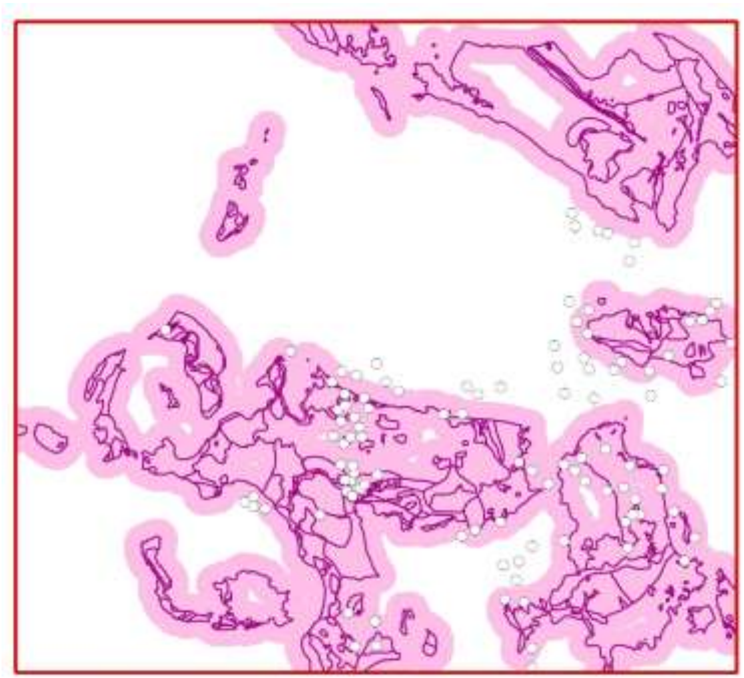
3D interpretation of granite extents



Kenex
Creating opportunities in the spatial world

3D Data Incorporation

2D interpretation of granite extents



3D interpretation of granite extents

Kenex
Creating opportunities in the spatial world

Layers Included in the Model

Mineral System	Variable		C	Stud C
Source of energy and fluids	**Host lithology**	Sandstone	0.2	4.6
		Greywacke	0.3	1.7
		Limestone	2.6	2.5
		Conglomerate	1.0	0.1
		Highly Fractionated Granites	0.2	3.0
	Association with highly fractionated granite		2.5	4.9
Migration pathways	**Proximity to linear cooling fractures**		0.7	2.5
	Proximity to faults older than 300 Ma		1.1	3.4
Formation of Trap	**Association with 3D granite contacts**		2.1	5.3
Deposition of metal and Outflow of fluids	Proximity to greisens		2.2	9.0
	Association with illite in granite		0.6	2.0
	Association with anomalous Sn		4.4	4.4
	Association with high sample density		3.3	9.0
	Association with high gravity slope		1.4	6.8

Redefined layer to include limestone

New! (Proximity to linear cooling fractures)

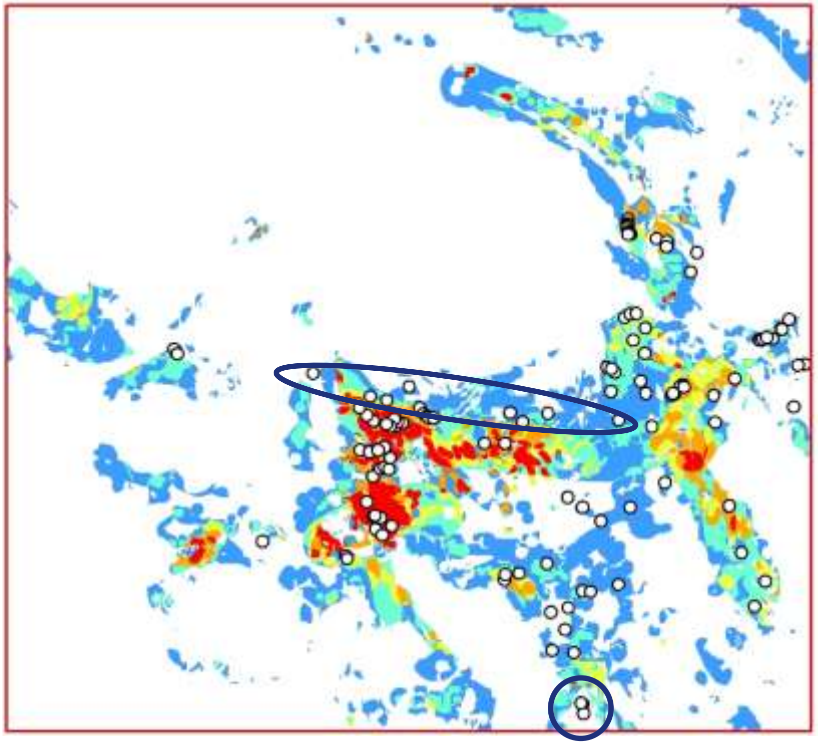
New! (Association with 3D granite contacts)

Lower weighting (Proximity to greisens)

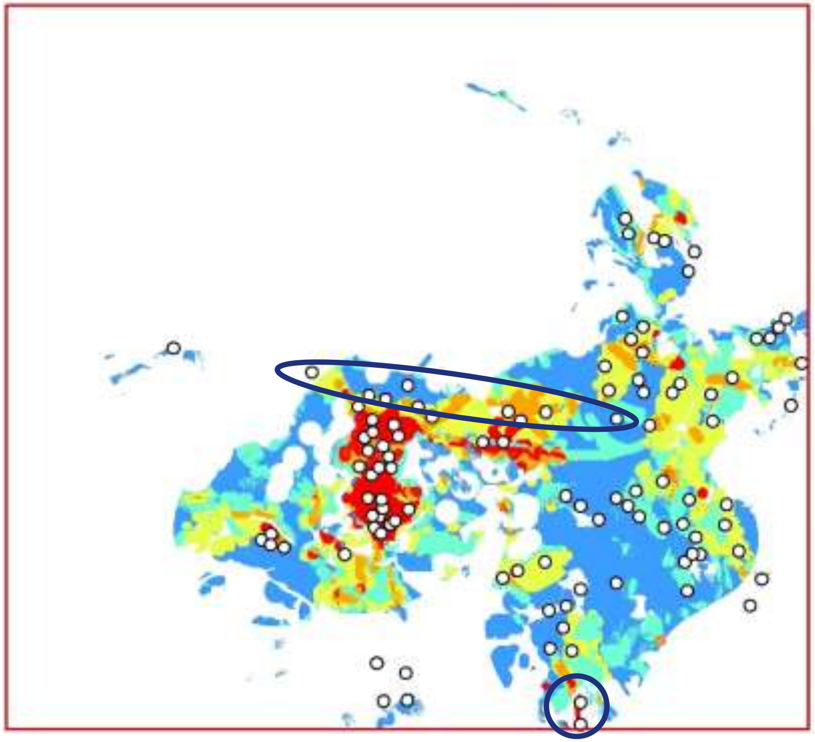
Kenex
Creating opportunities in the spatial world

Comparison

Initial prospectivity map



Final prospectivity map



Kenex
Creating opportunities in the spatial world

Results

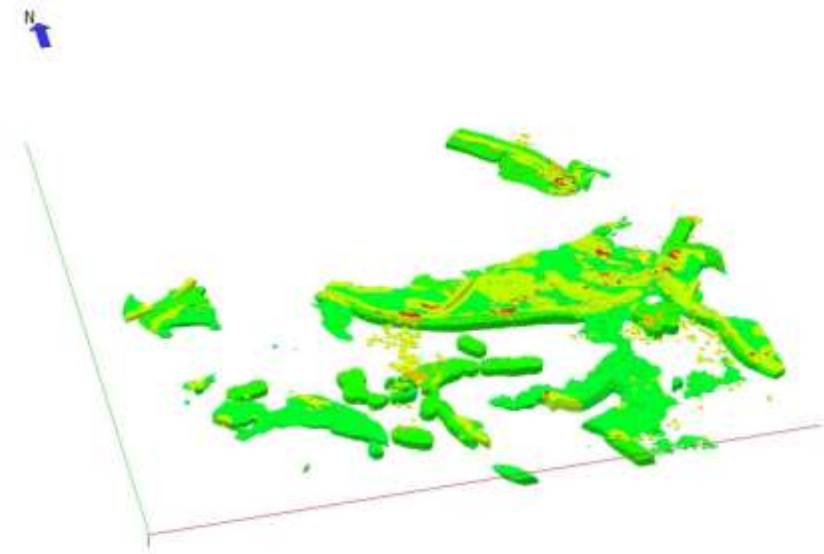
- Several important areas not highlighted initially but picked up in the updated model
- The most prospective areas are associated with highly fractionated granite and their contact zones
- Efficiency of prediction increased from 76.6% to 87.0%

Conclusions

- Model is statistically valid and is being used to objectively rank the prospectivity
- Including 3D geological data improved results
  - Resolved limitations of previous model
- Model is restricted in that there is no information at depth, only surface indication of likely mineralisation somewhere at unknown depth

From here?

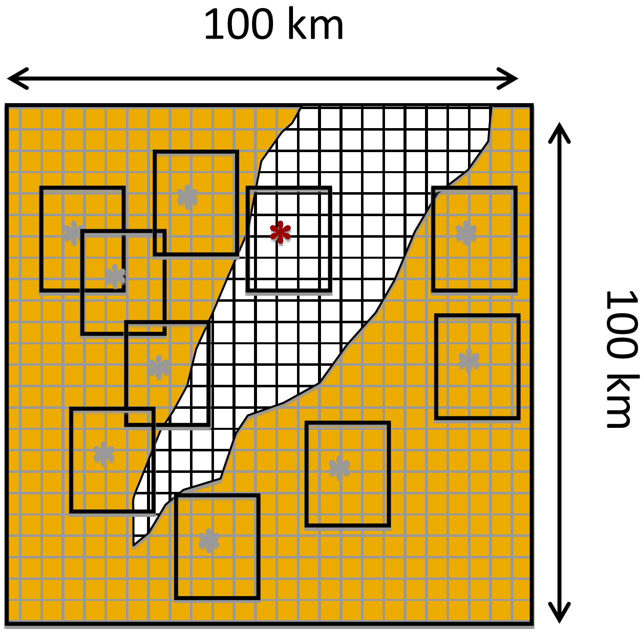
- Completed preliminary prospectivity modelling in 3D – Cunningham et al. poster
- Identify prospective targets to complete more detailed modelling of the target area in 3D



Kenex

Creating opportunities in the spatial world

www.kenex.co.nz



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(B) = area of binary theme not present
N(T) = N(B) + N(B) (as long as no missing data)

When unit cell inf. small

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

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

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

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

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

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

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

$$Cs = \sqrt{(Ws+) + (Ws-)}$$

$$StudC = C / Cs$$

Kenex
Creating opportunities in the spatial world

From: Bonham-Carter, G.F. (1994)
“Geographic information systems for geoscientists”.