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New Discoveries Using Spatial Analysis in GIS

Exploration in the Digital Age

Acknowledging: Kenex, Auzex Resources, Aurora Minerals, HPD New Zealand,
Garry Raines and Graeme Bonham-Carter

Talking About Passion!!

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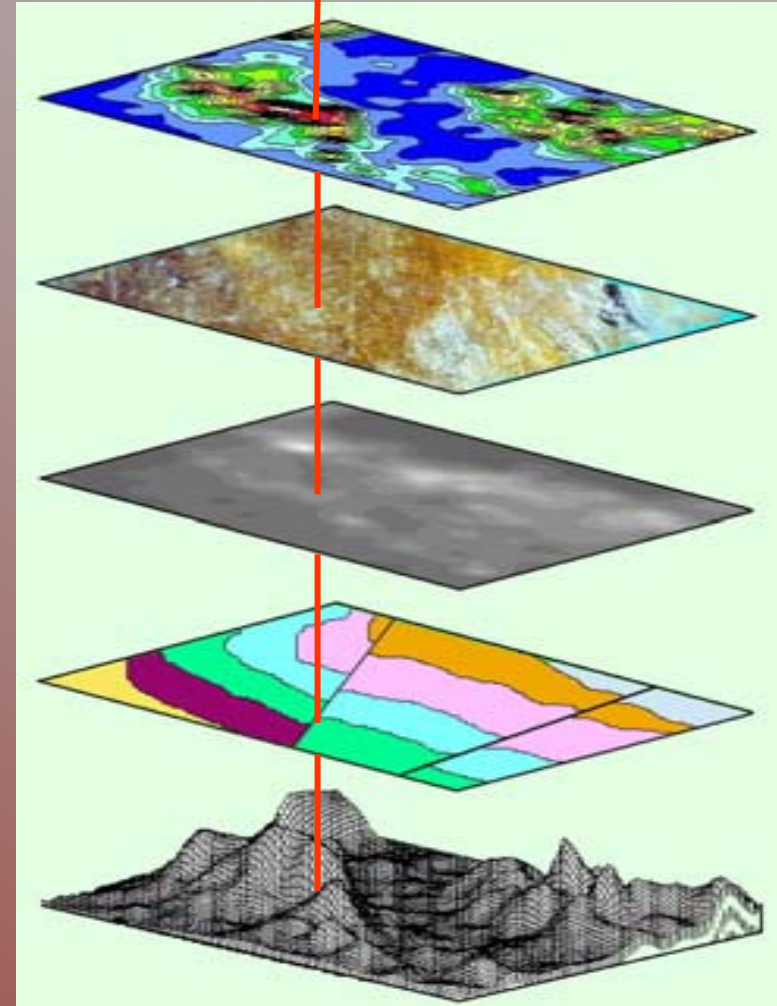




Finding New Deposits is Hard !!

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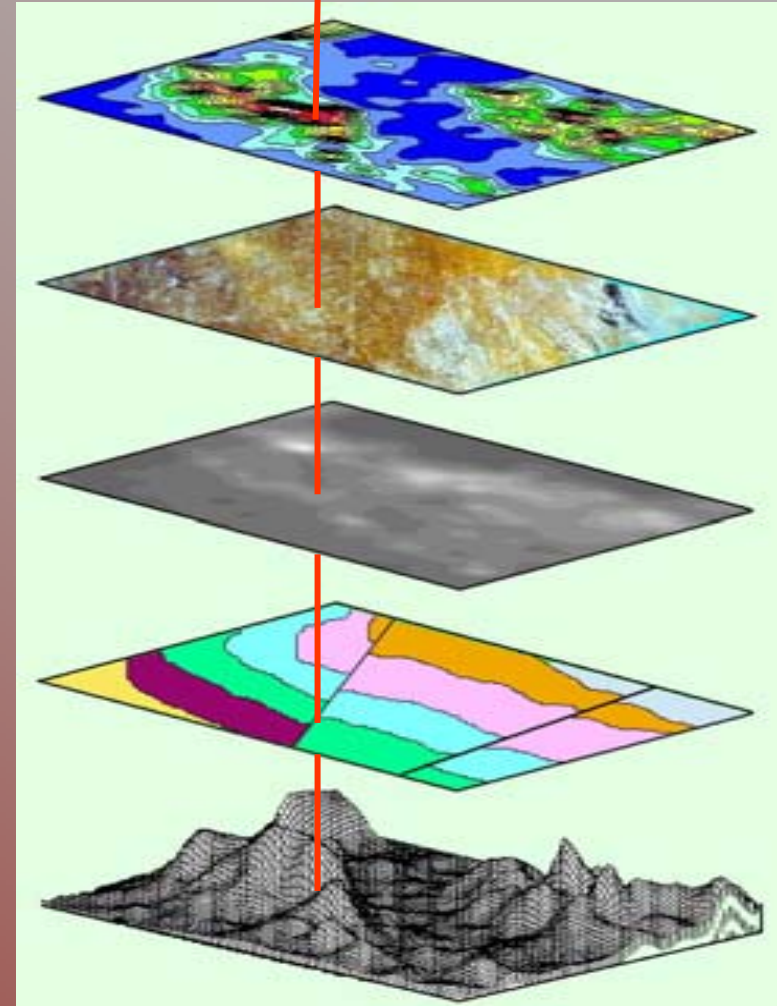
- Current Business Models Don't Work and Limit the Future
- Lack of Understanding of The Exploration Value Chain
- Mining is Often Not Where Value is Created
- Competitive Advantage – Ideas and People (Skills Shortage)



Requirements for Success

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- Data, Information, Knowledge, Technology and Management
- The Key is an Integrated Approach
- Prospectivity and Exploration Value Chain
- Research and Exploration
- Integrating Spatial Data
- Examples and Successes





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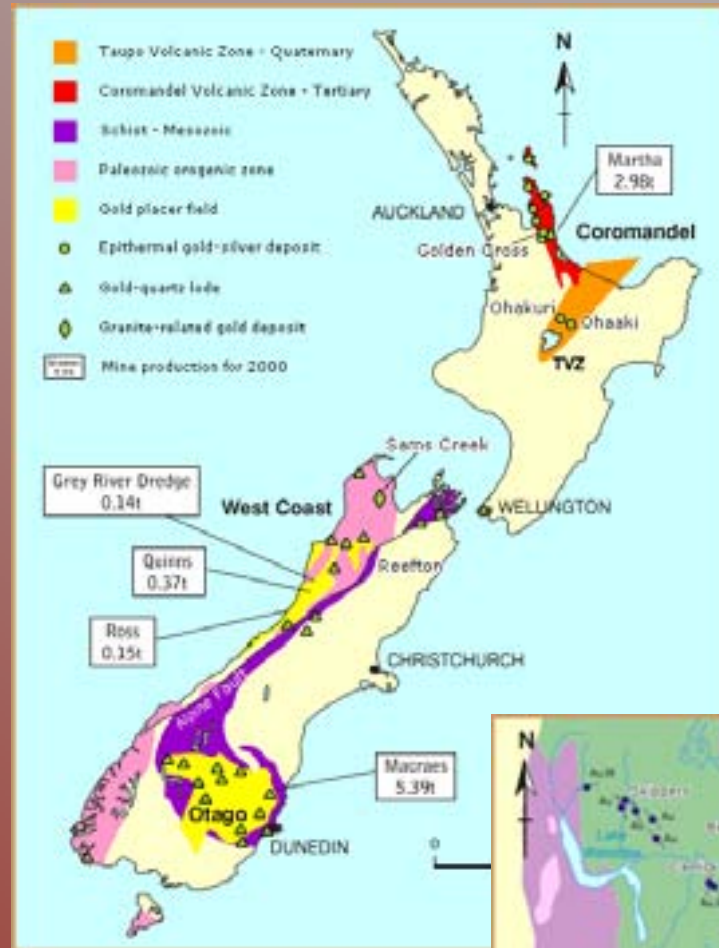
Prospectivity in Mineral Exploration

What Defines Prospectivity ?

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West Coast 9.5 M oz



Otago 12.3 M oz



Coromandel 11 M oz



New Mines: Macraes Gold Project, Otago

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- World Class Deposit
- 5 M oz Au
- Recent Discovery 1980s
- 160,000 oz Current Production
- Ten Year Mine Life



All this from a tiny portion
of Otago land ~ 5 x 3km during a ten
year period

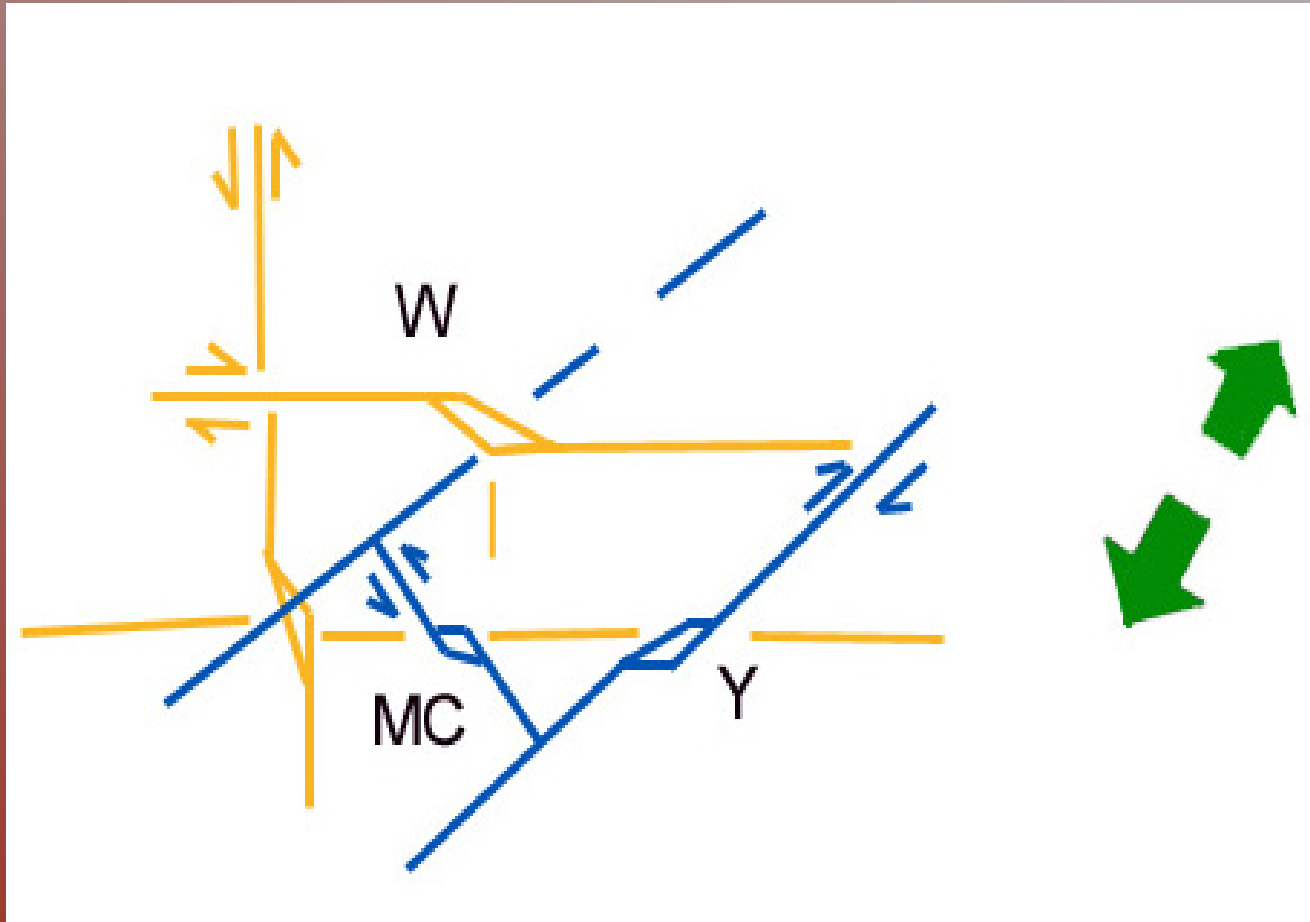


GOLD AND RESOURCE
DEVELOPMENTS
MACRAES GOLD PROJECT

Genetic Models Based on University Research



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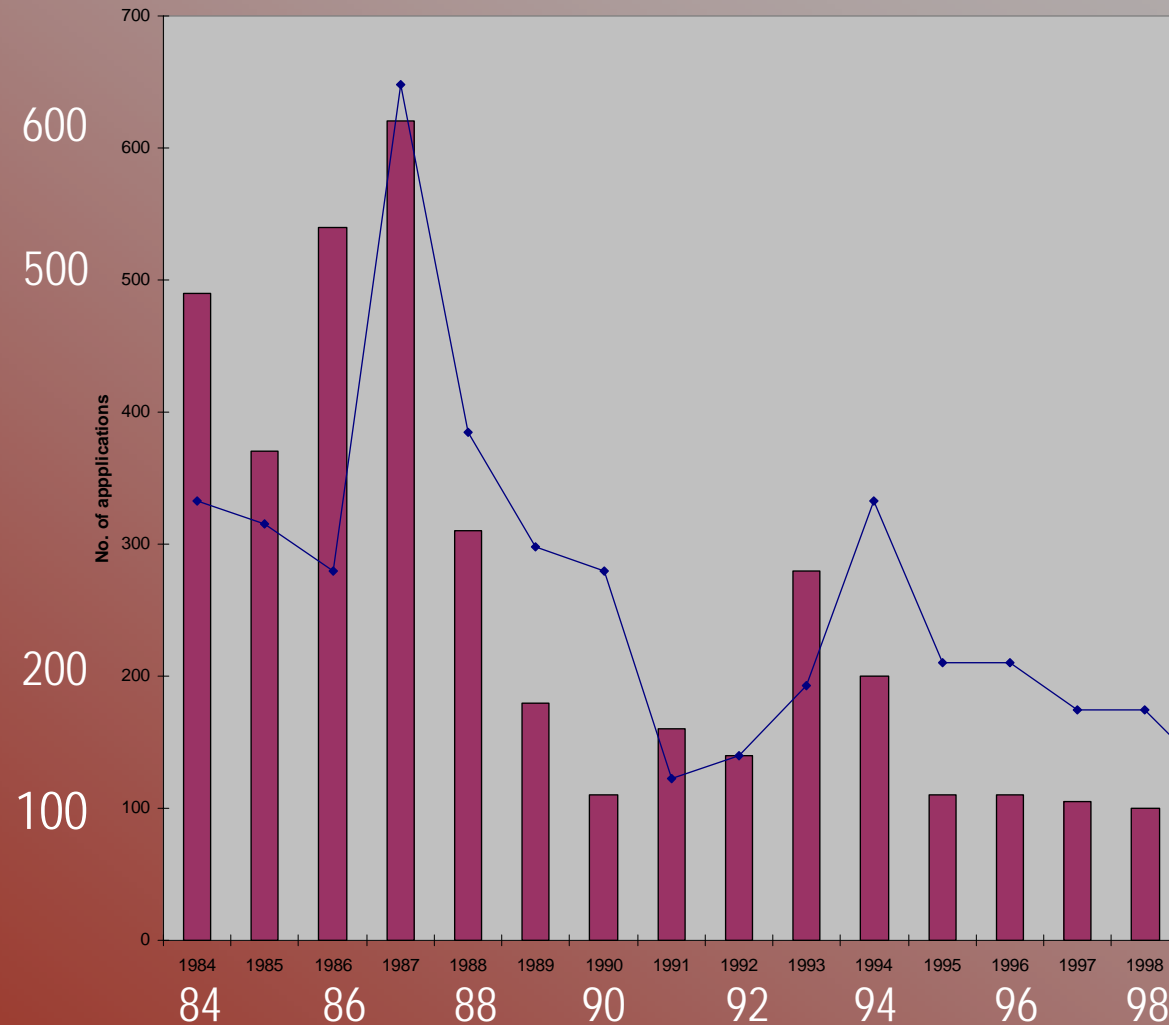




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Exploration Activity

Exploration
Permit
Applications



35 Million

Exploration
Expenditure

20

15

10

5

Land Access

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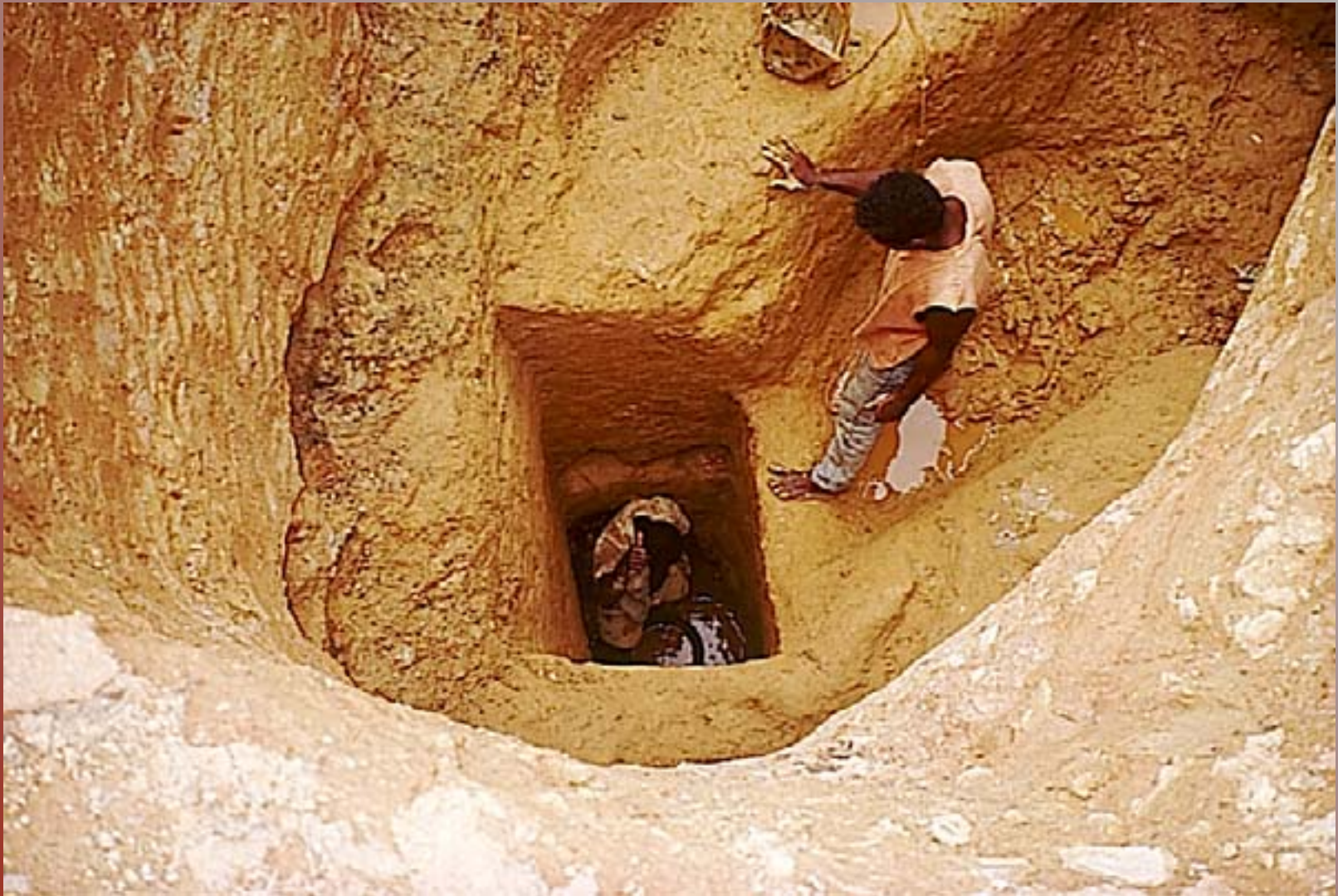
Environment

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Sovereign Risk

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Infrastructure

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Decisions Based On Full Picture Using All Facts

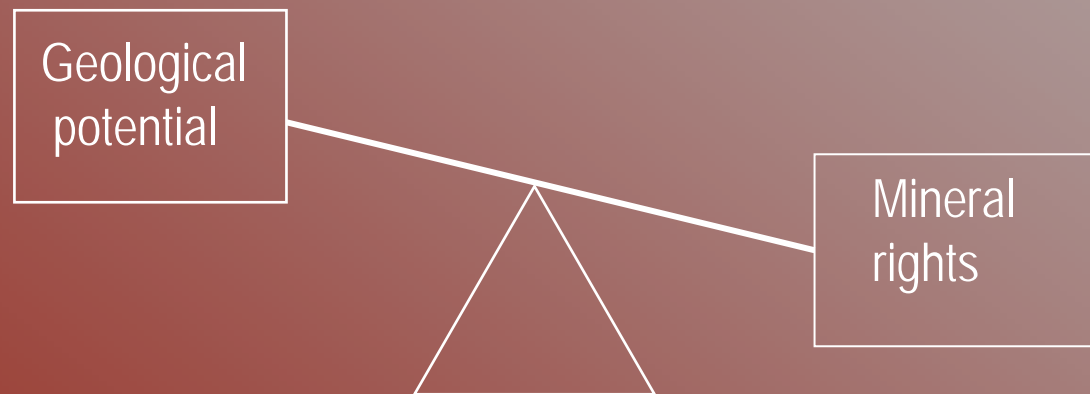
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Prospectivity – Fundamental Driver For Exploration

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- Investment Criteria No. 1:
 - *geological potential and geological information*
- Investment Criteria No. 2:
 - *land access, sovereign risk – value of mineral rights*



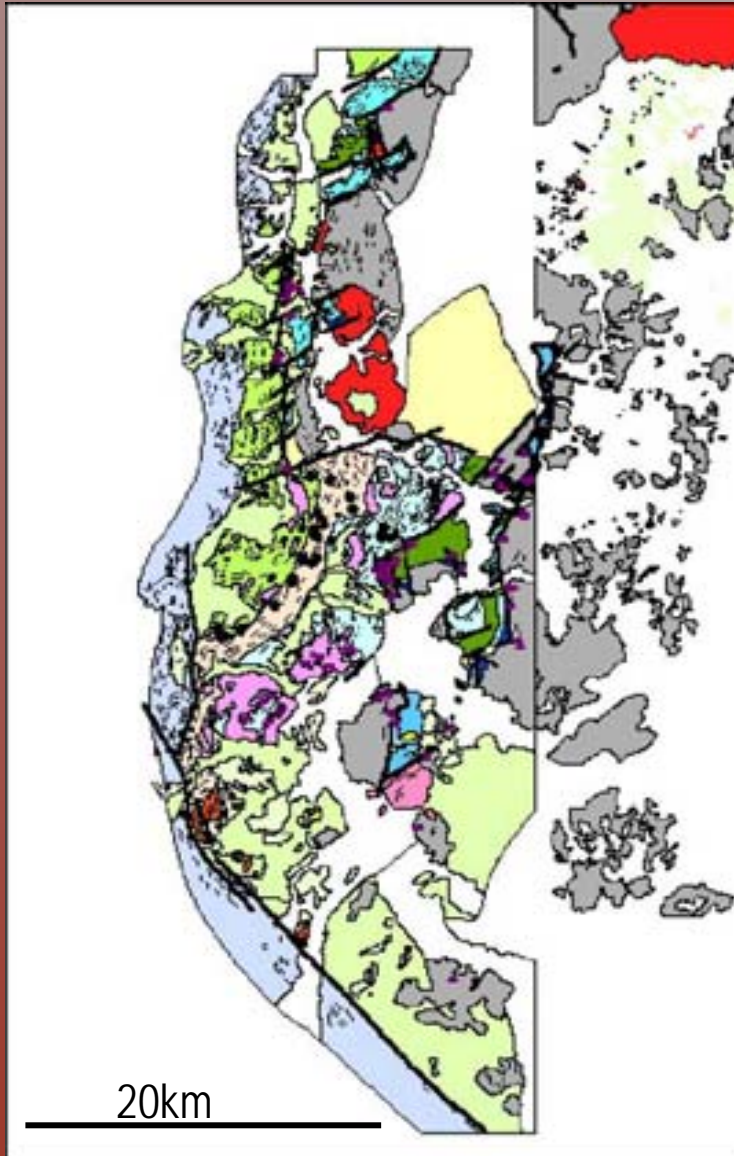


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What Is The Exploration Value Chain?

Regional Assessments

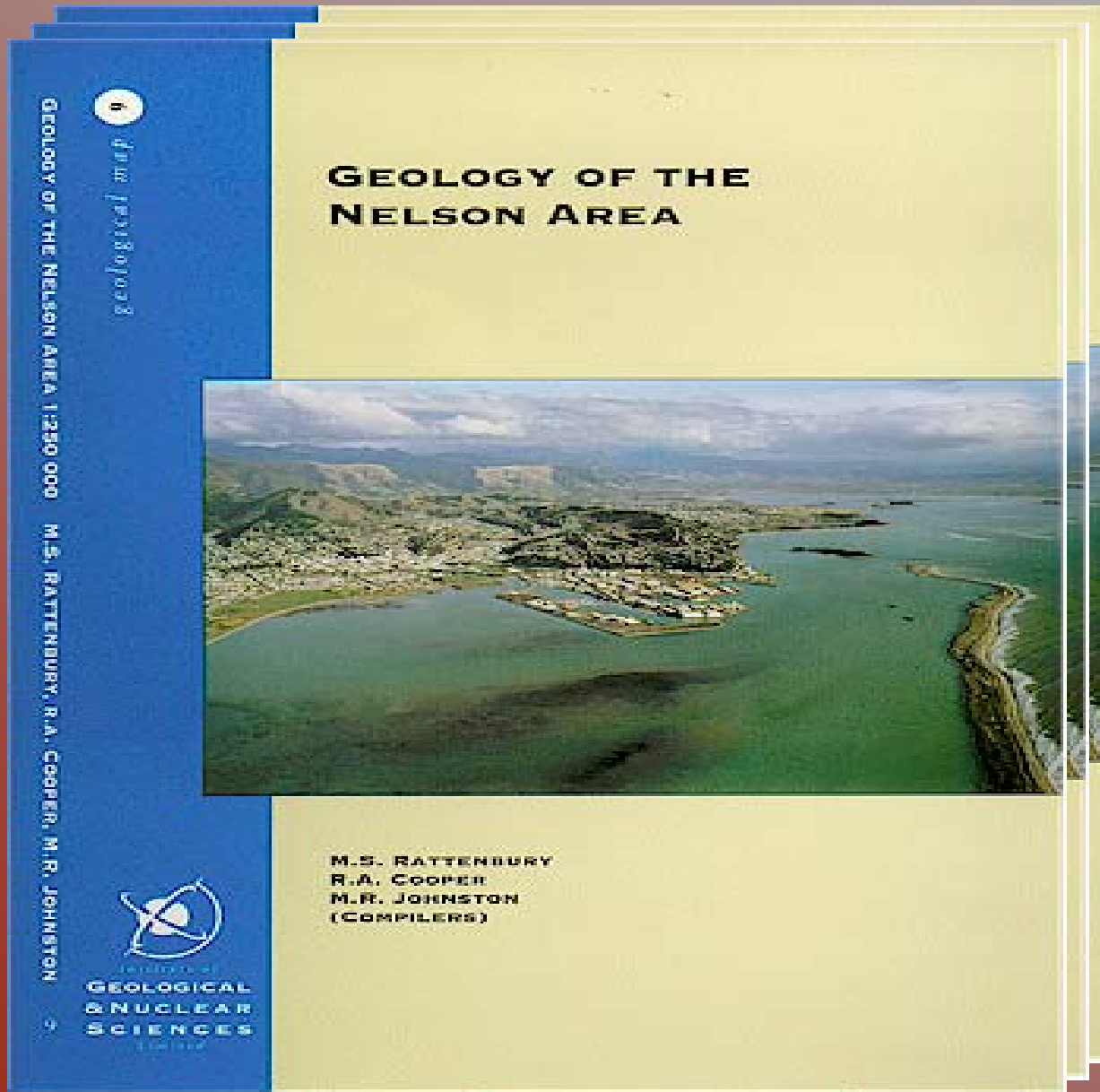
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- Exploration Value Chain.
- Critical Ingredients.
- Scale Dependent.
- Requirement to Get from Regional to Prospect Scale Quickly and Cheaply.

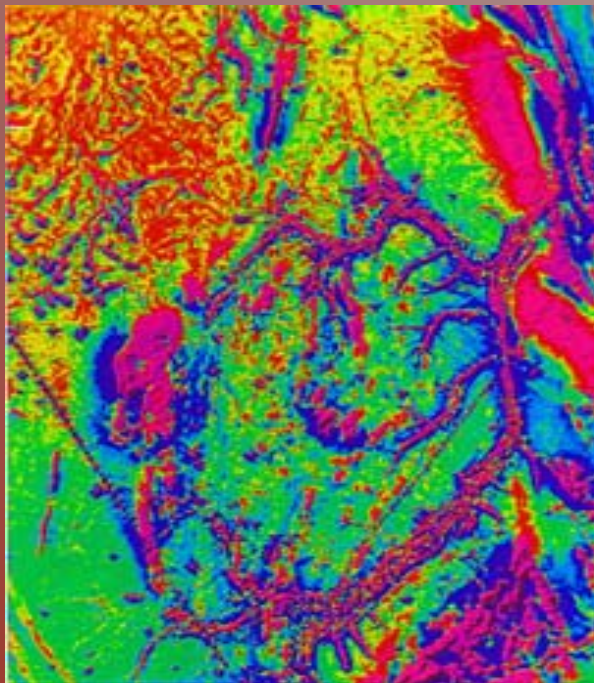
Digital Geology

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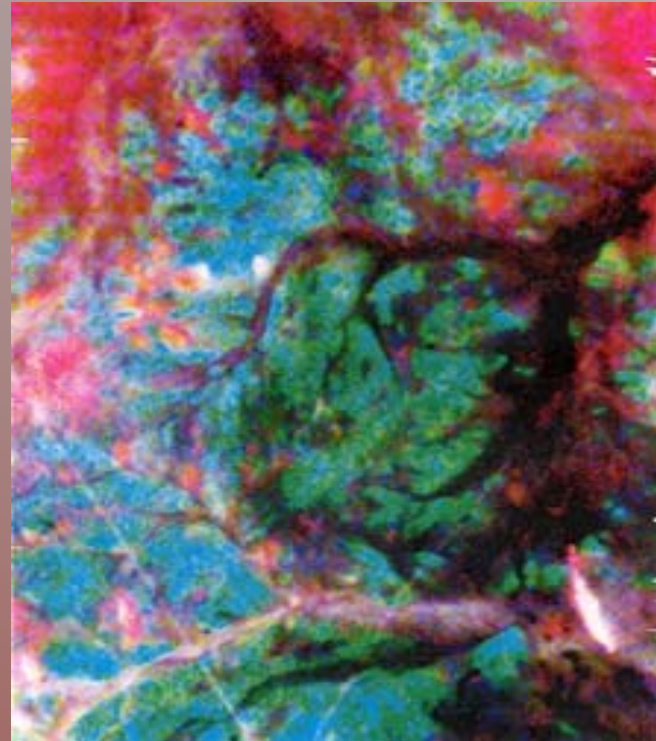


Other Data

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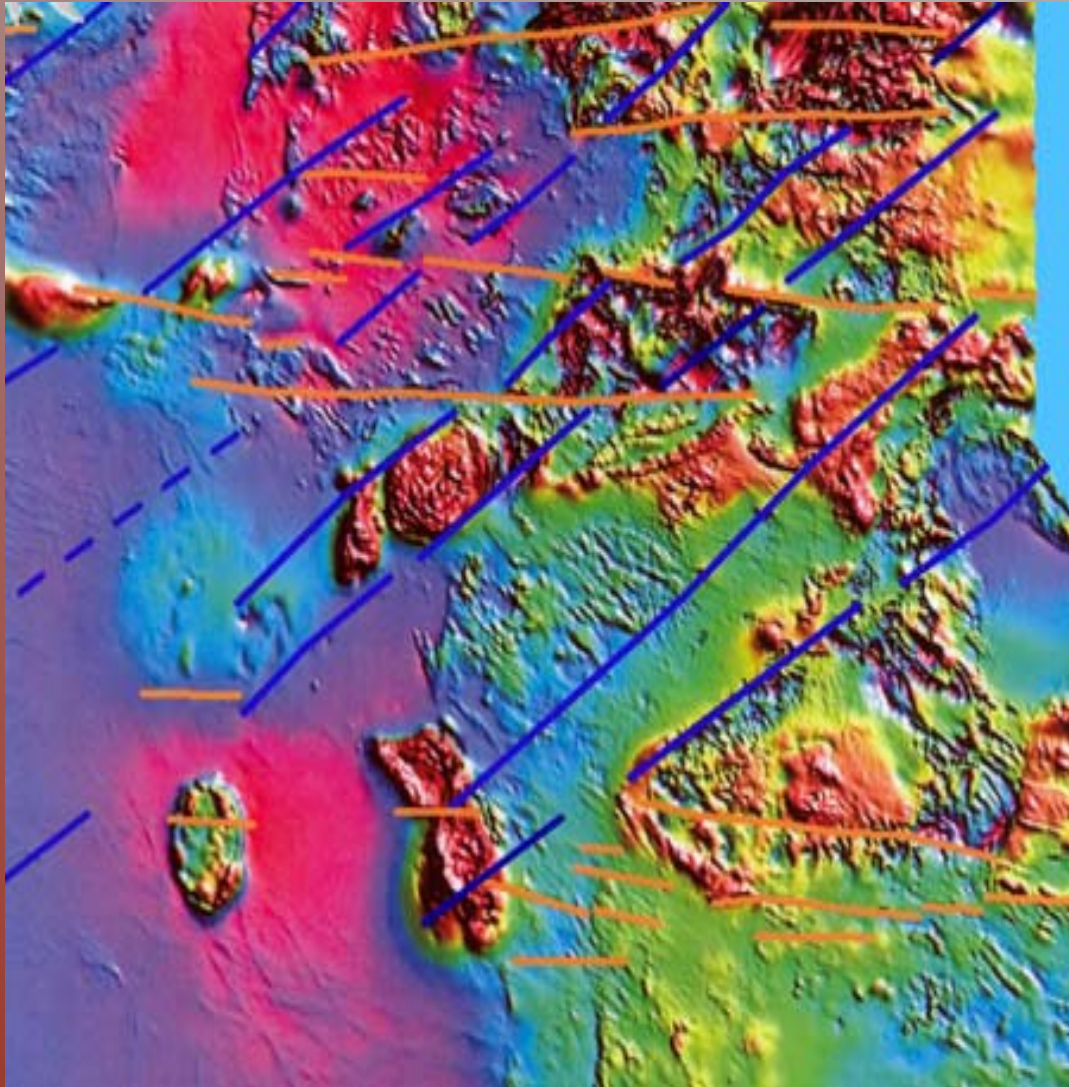
Satellite



Radiometrics

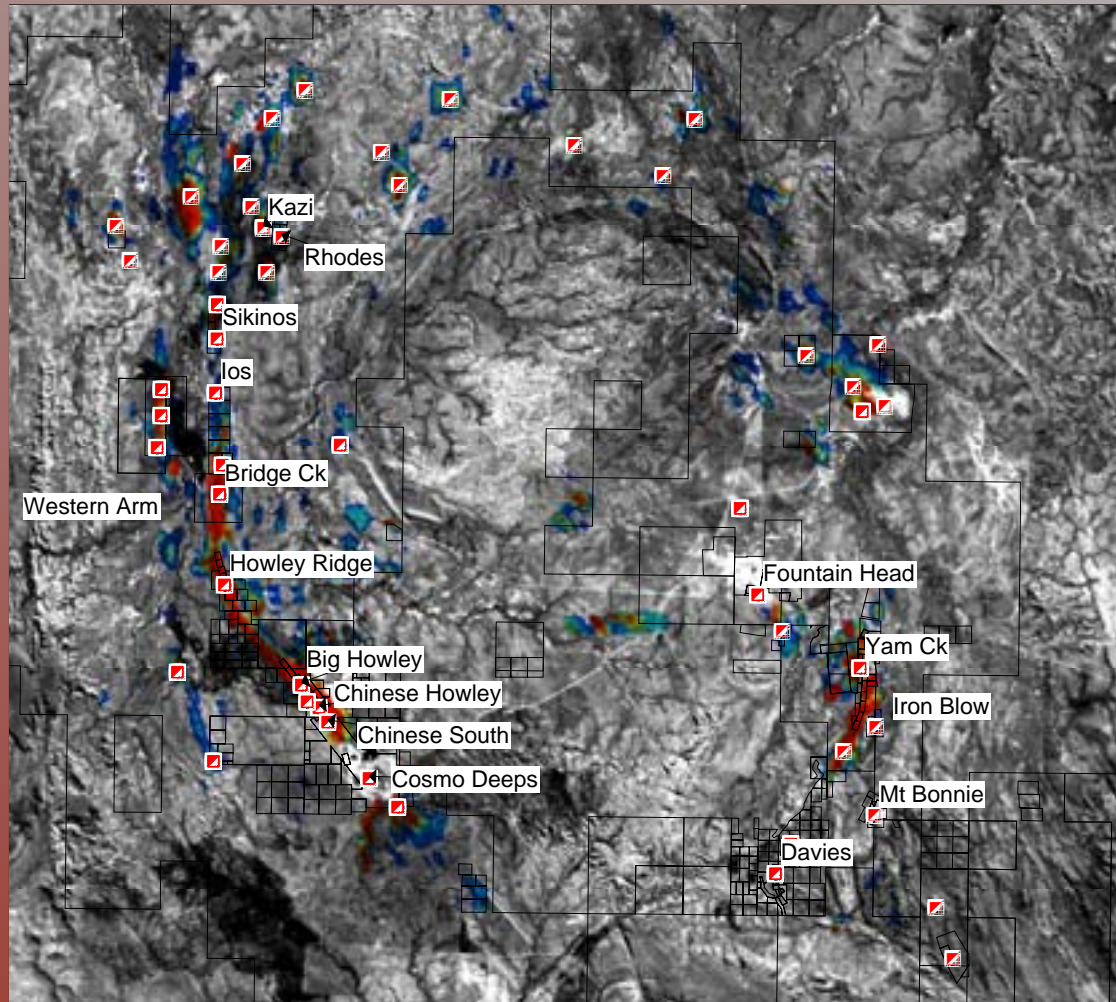
Interpretation And Exploration Models = Ideas

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Prospect Scale Exploration

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- Geochemical Data – A Numbers Game

Detailed Geology

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- Prospect Scale Geology Often Missing.
- Level of Detail Increasing.
- Prospect Scale to Orebody Scale.

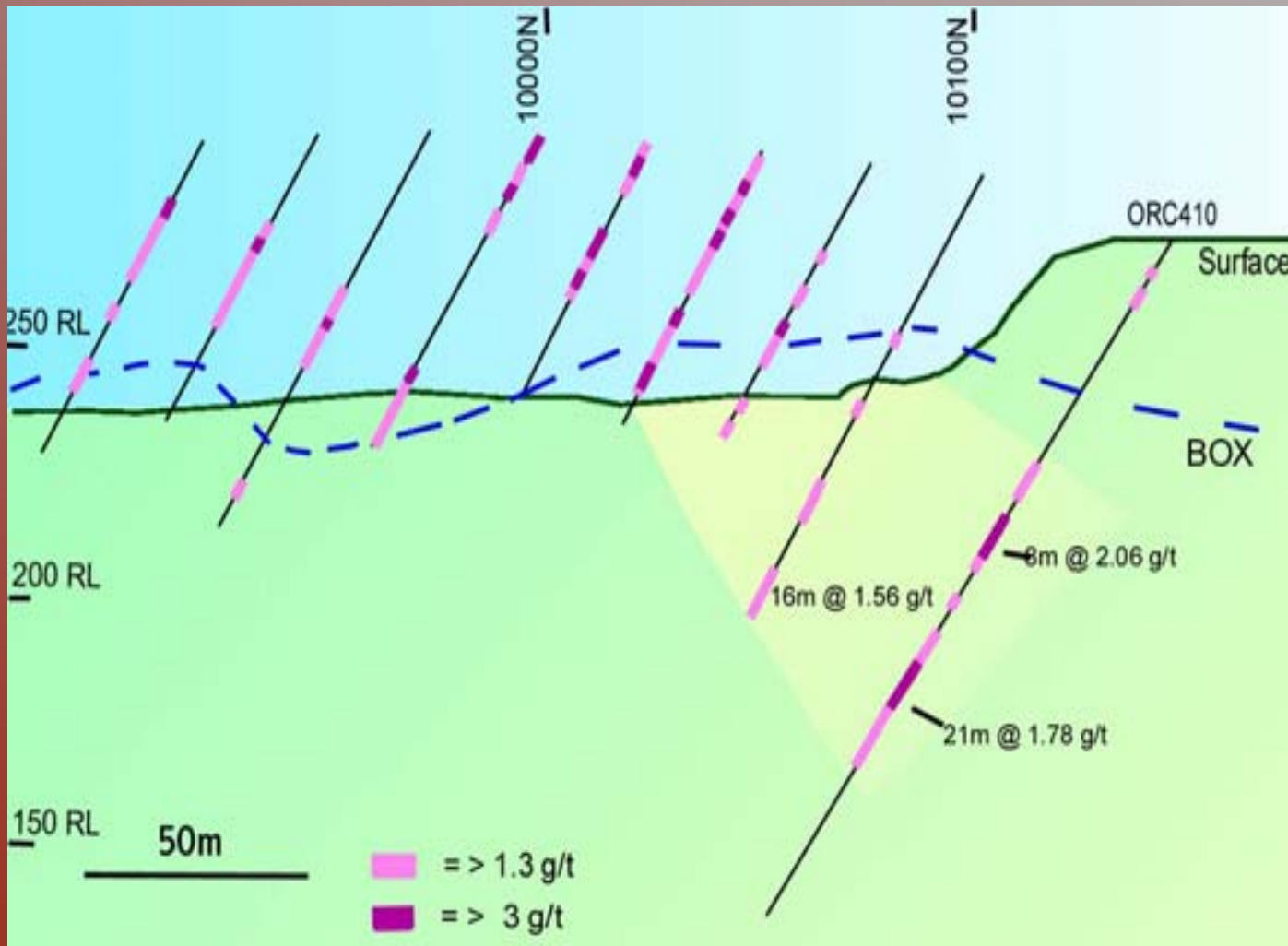
Discoveries Drilled

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Infill Drilling And Mineralisation Continuity

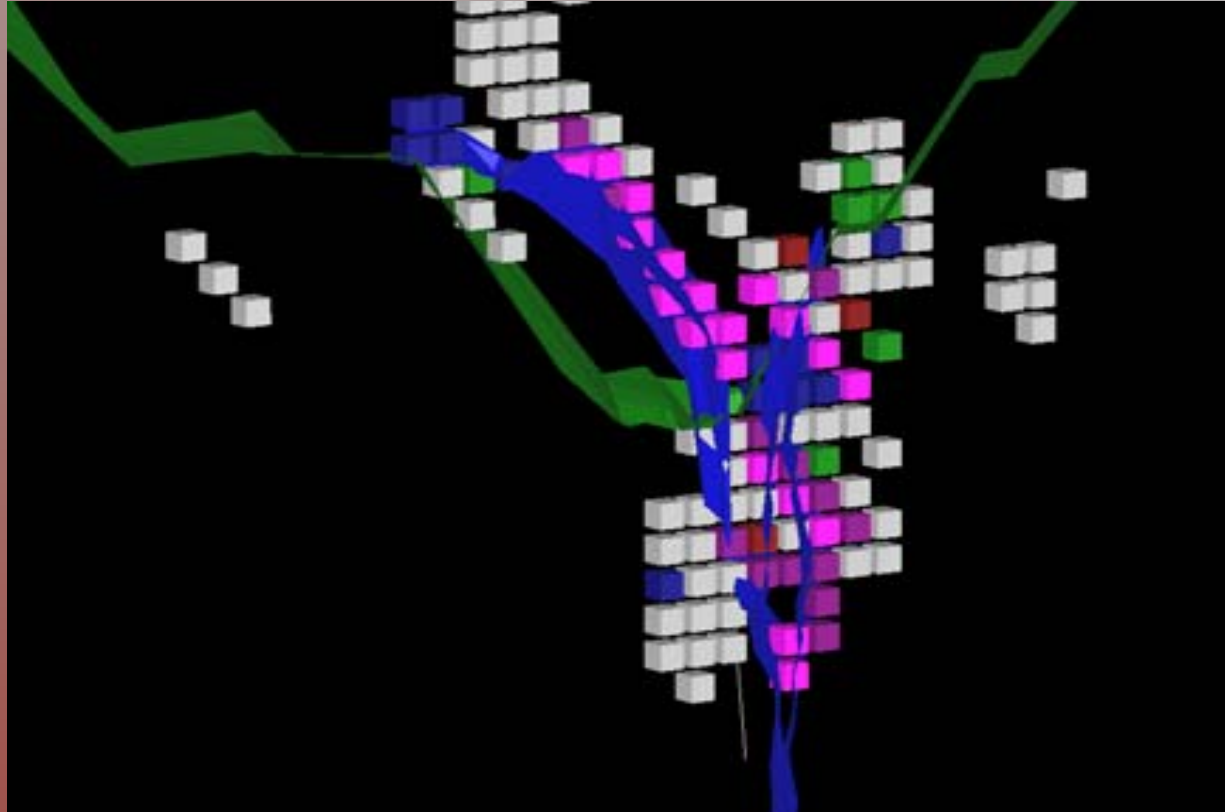
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Resource Definition



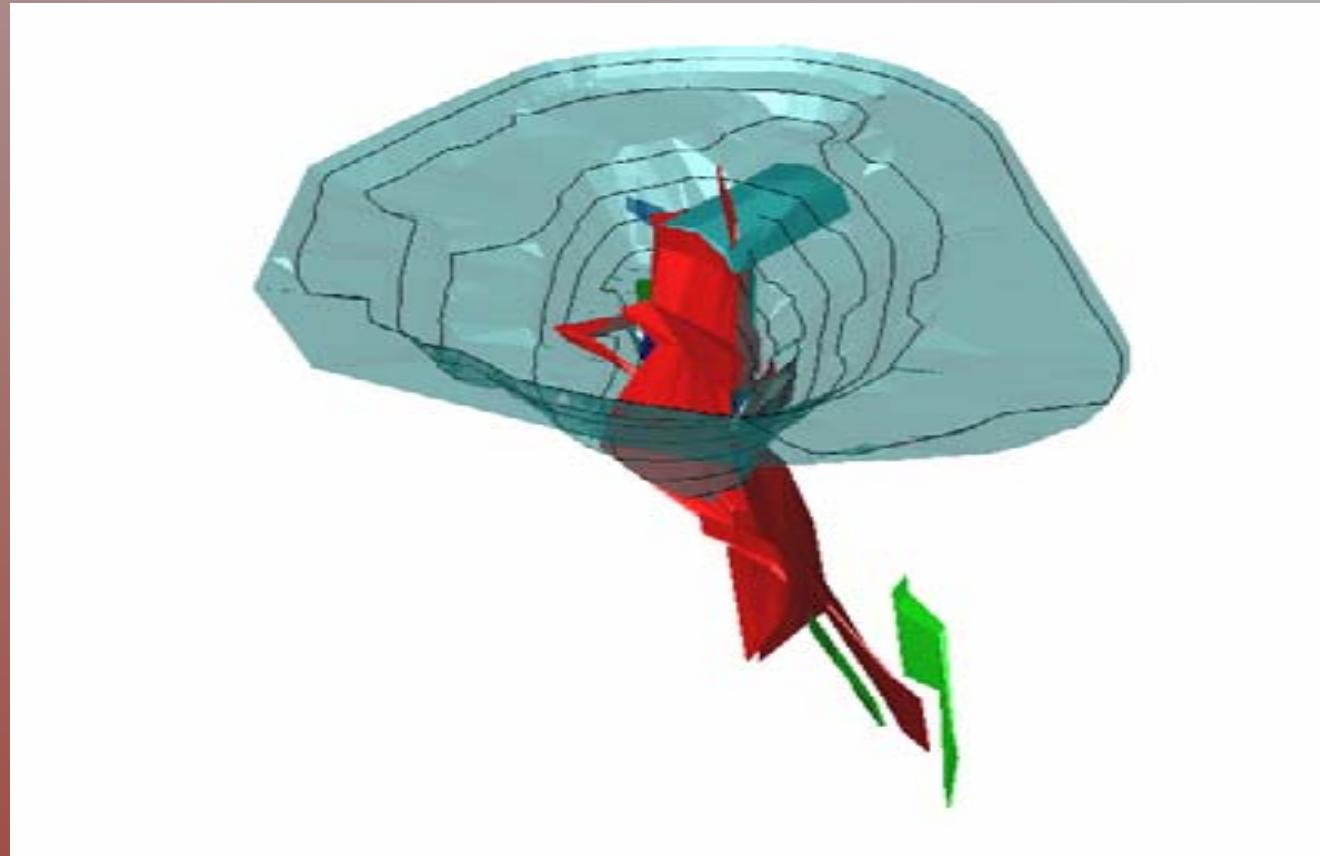
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Resource
Estimation And
Preliminary Pit
Optimisation

Reserve Estimation: Do We Mine?

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Optimisation,
Financial Risk
Profile, Reserve
Calculations

Data and Information - Critical Output From Exploration

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Prospectivity

DISCOVERY

explorer

information

explorer

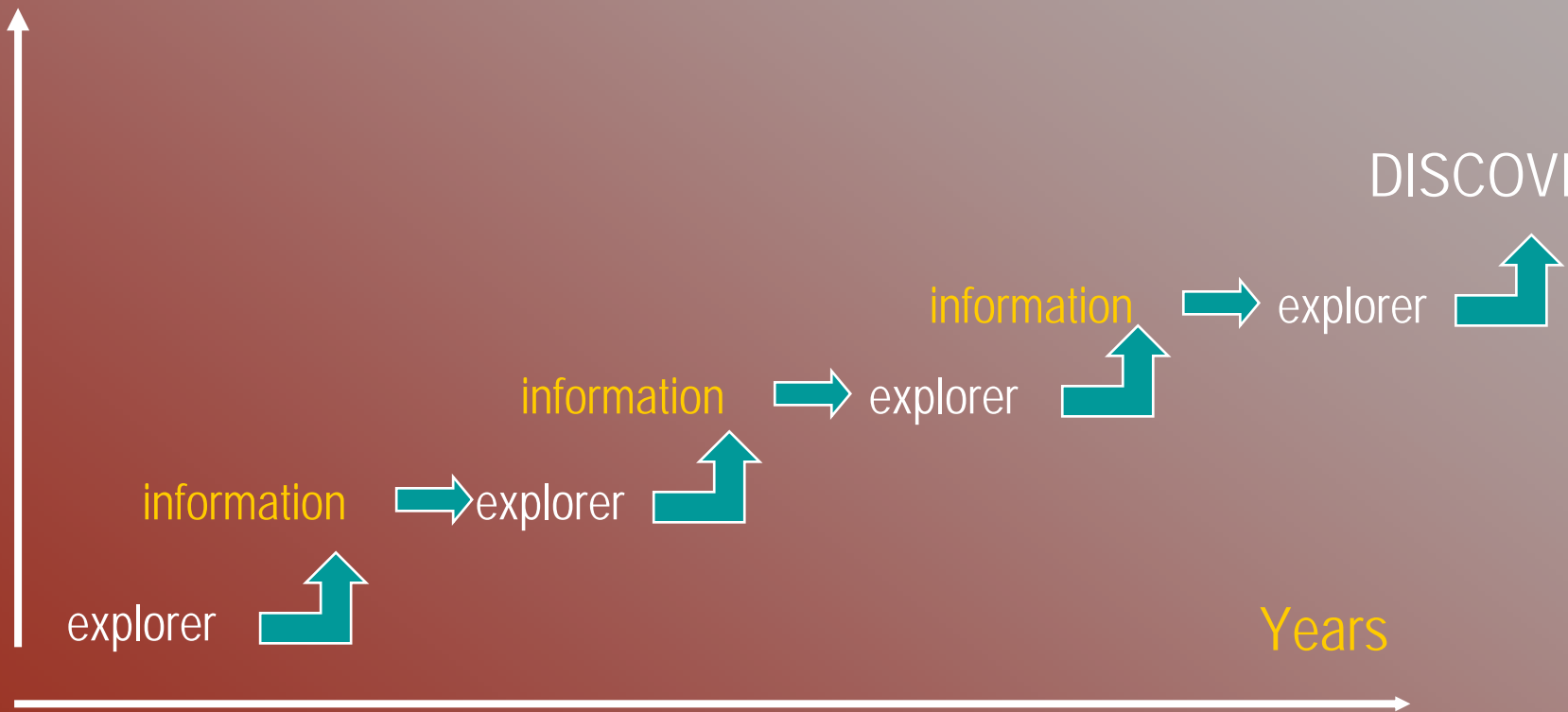
information

explorer

information

explorer

Years



The Exploration Process Is All About Probability

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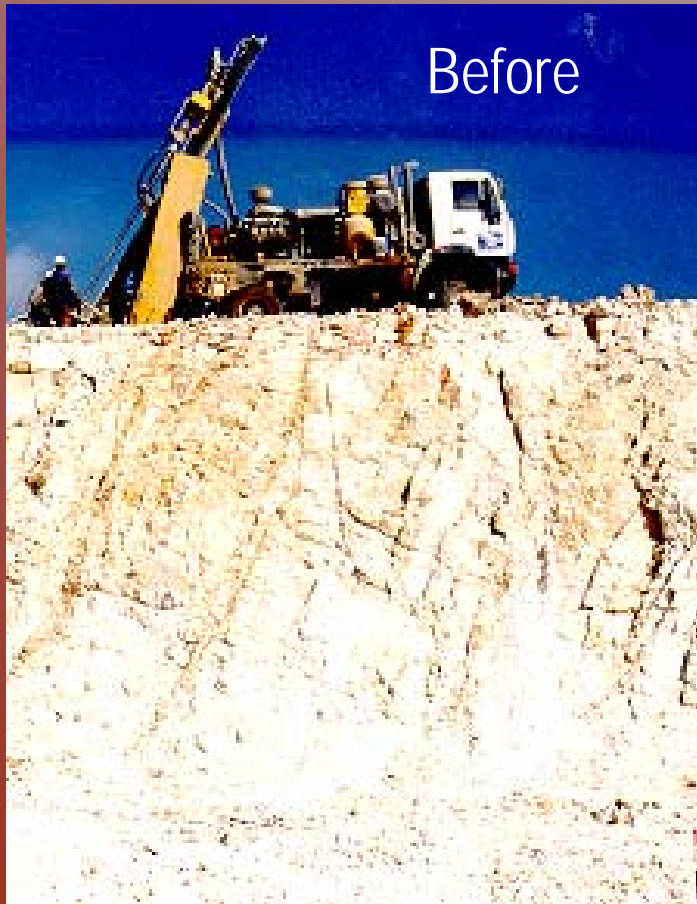
The Practical Implication Of High Discovery Risk For Strategic Planning & Exploration Budgeting Is A Large Difference Between The Average Cost Of Exploration Success And The Level Of Funding Required To Ensure Success (e.g. - "World Class" Deposits)

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

Geology is Fundamental!!

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Before



After



This is All About the Use of Spatial Data



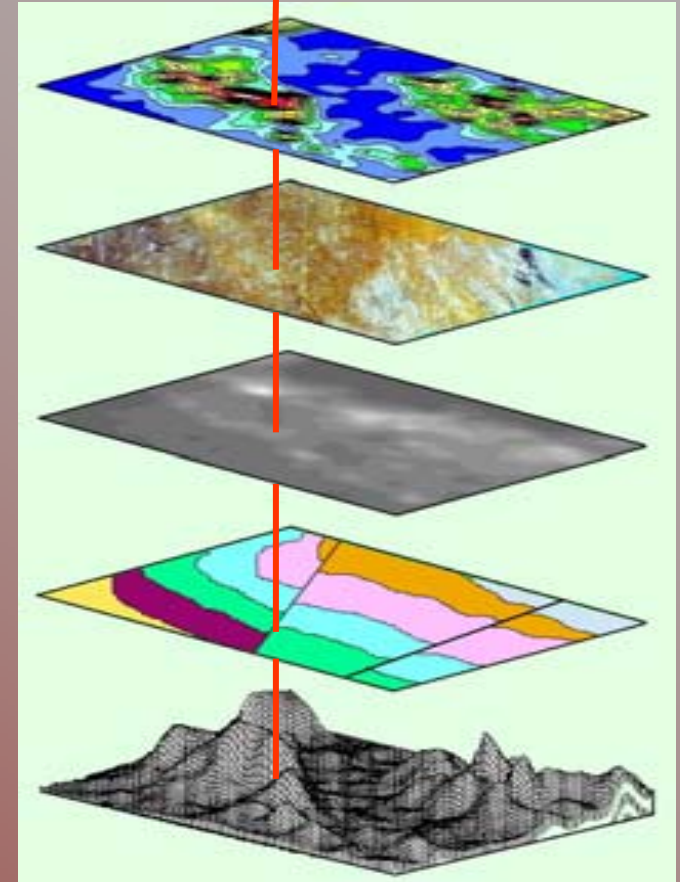
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- Data Were the Competitive Advantage
- Data Now a Commodity - Freely Available
- We Recognise a Problem for Organisations Due to Data Overload
- We Can Synthesise Available Spatial Data to Combine with and Add Value to Your Spatial Data
- Also Capture and Apply Your Knowledge to Your Data and Information

Need To Understand Patterns And Integrate Data

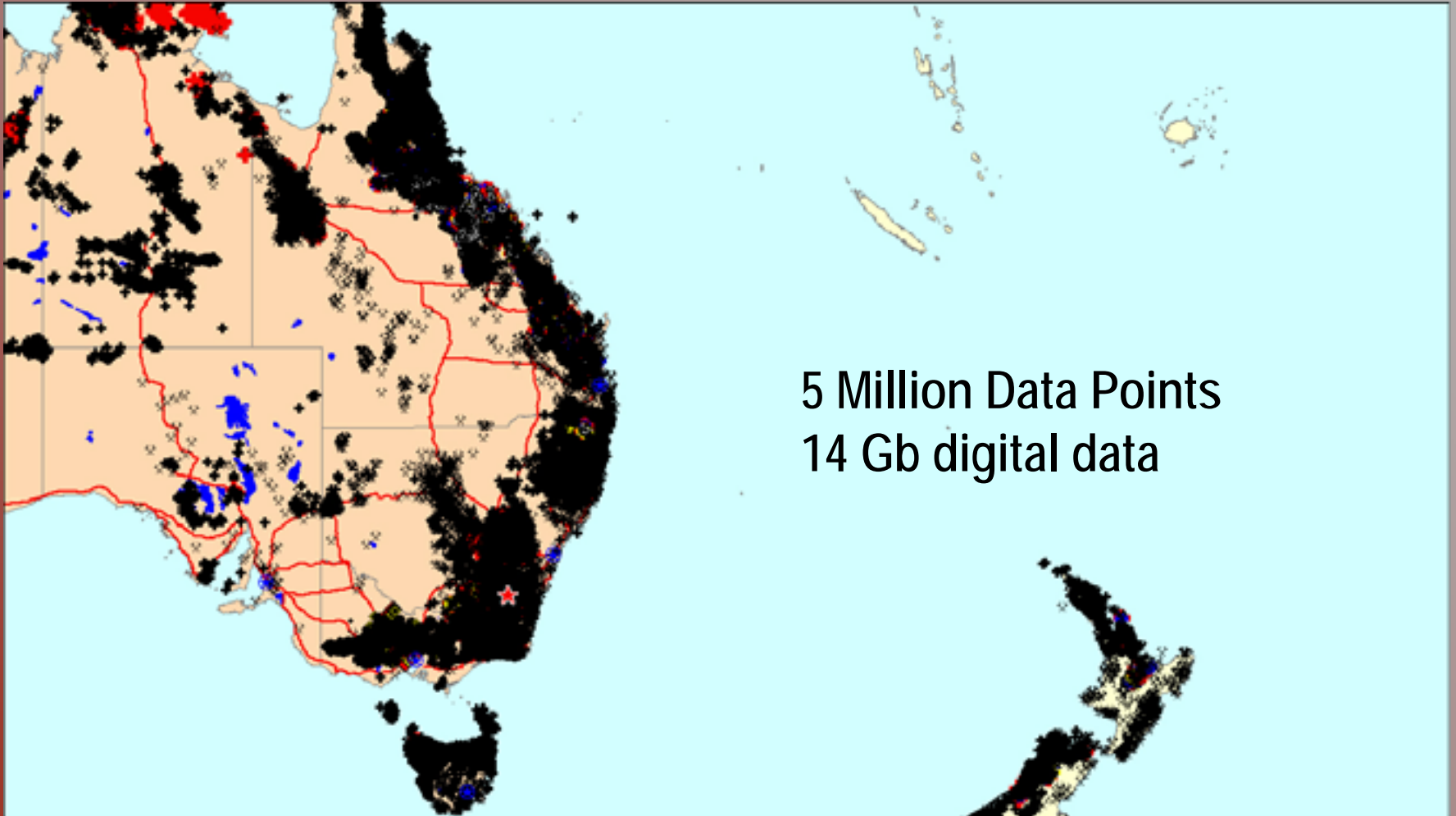
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- Historic Mines (training data)
- Geology
- Geochemistry
- Geophysics
- Simple Recipe
- Complex Mixture



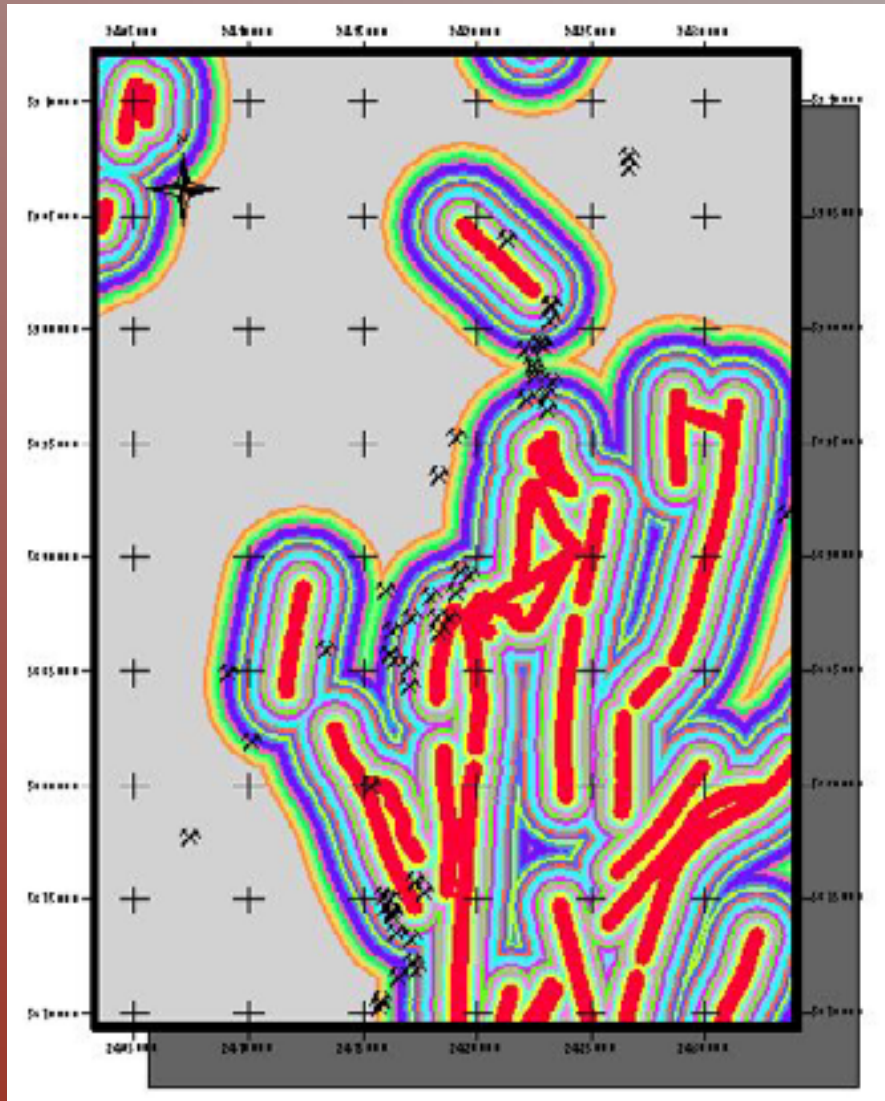
Need To Be Able to Assess Datasets at International Scales

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Measure Geological Variable Associations

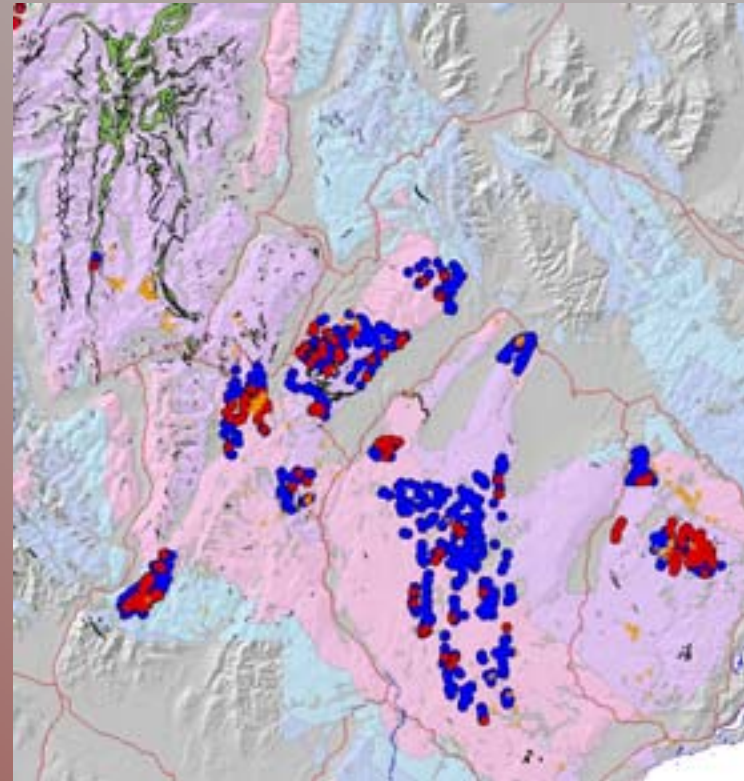
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What Is Geochemically Anomalous?

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- Stream Sediment Samples
- Rock Chip Samples
- Au, Ag, Cu, Pb, Zn, As Sb and W
- Defined Anomalies at National scale
- Defined Sphere of Influence for Each Sample for Each Element
- Created Buffers of Background and Anomalous Samples



Test Our Data Against Our Knowledge

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Integrating Data, Information And Knowledge

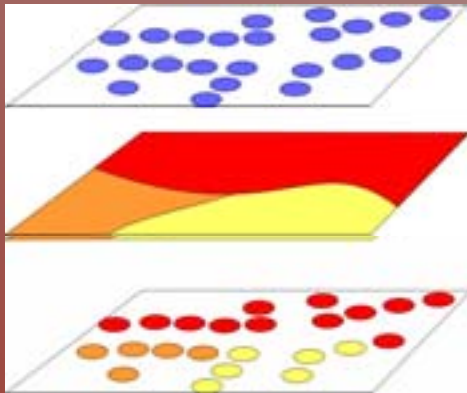
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... the power of GIS

Geological Data

Information

Knowledge of Process



Property-ID (PDVROL)	X-Coord (PDXCOO)	Y-Coord (PDYCOO)	Ground Condition (HZCGC)
11111	2953617	6953457	1
11112	2953634	6953463	2
11113	2953651	6953469	2
11114	2953668	6953475	3



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What Knowledge?- Genetic Models and Exploration Models

Known Deposit Studies

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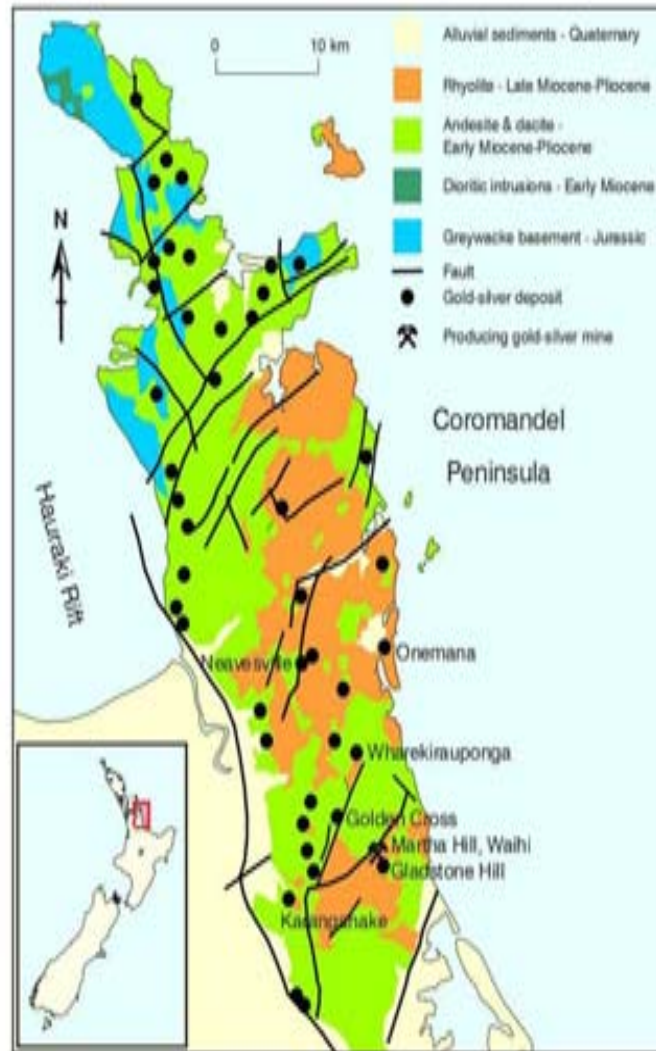


Fig. 5. Coromandel Volcanic Zone geology and epithermal gold-silver deposits.

Golden Cross

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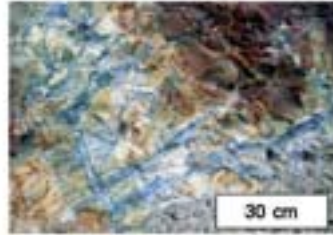


Fig. 8A: Stockwork veins in the open pit.

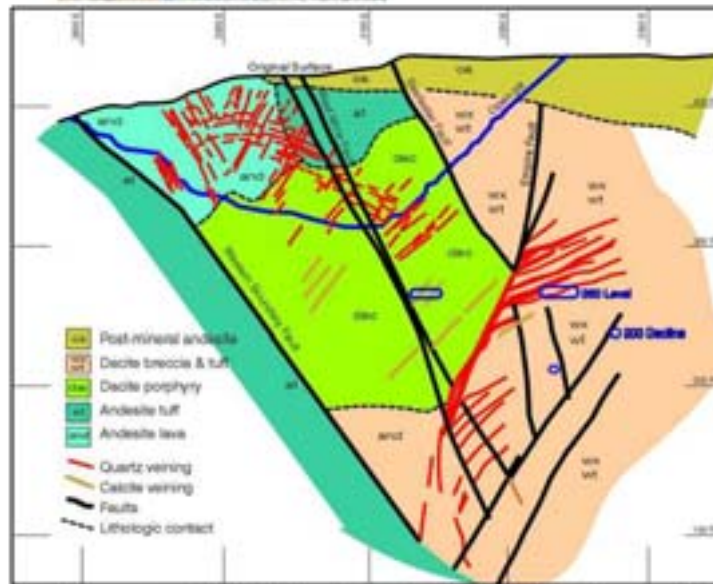
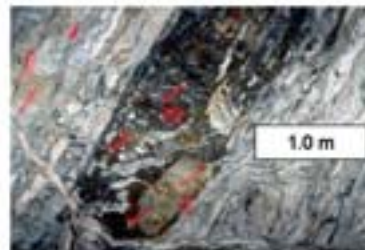


Fig. 8B: Cross section of the Golden Cross deposit (after Keall et al. 1993; Simpson et al. 2001)

Fig. 8C: Empire Vein Zone, showing laminated quartz-sulphide veins and quartz-sulphide breccia (dark colour)



The Understanding of Process

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Fig. 12A : Crustiform banded vein from Karangahake deposit, CVZ. Dark bands are composed of sphalerite, galena, chalcopyrite, pyrite and electrum (see Fig 12B)

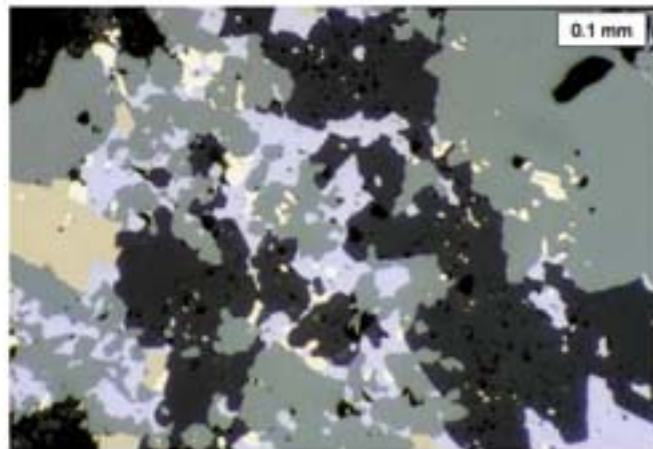


Fig. 12B: Photomicrograph of electrum, sphalerite, galena, chalcopyrite and pyrite from one of the dark bands of the specimen shown in Fig. 12A.

Present Processes To Understand the Past

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Fig. 20. Champagne Pool at Waotapu is a former hydrothermal eruption vent, surrounded by a silica sinter terrace. Photo: Lloyd Homer.



Fig. 21. Deep geothermal fluid emerges from Champagne Pool Waotapu to deposit a sinter terrace containing up to 80 g/t gold and 175 g/t silver.

Genetic Model

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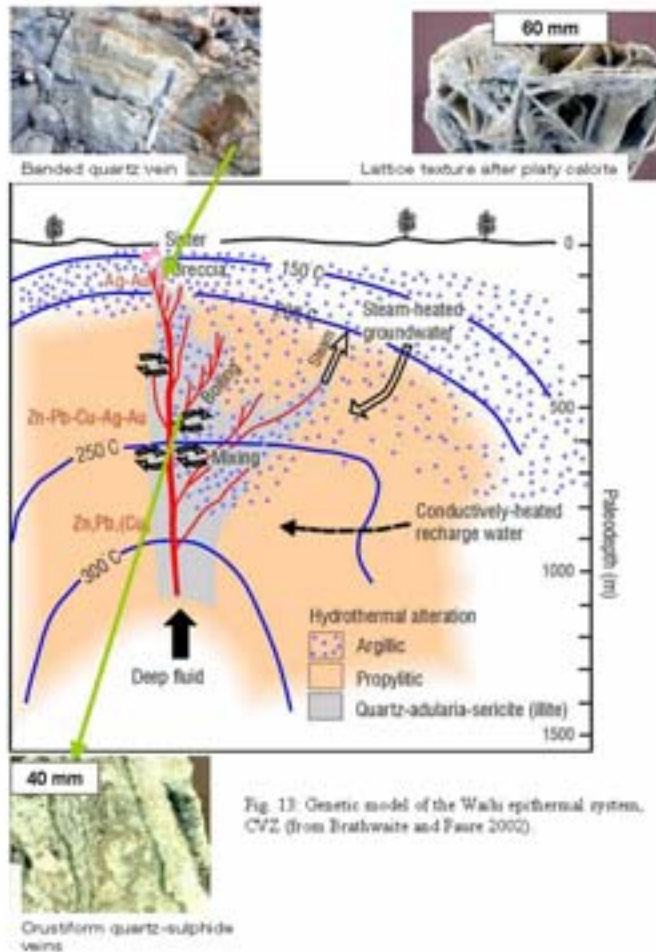


Fig. 13: Genetic model of the Walki epithermal system, CVZ (from Brathwaite and Faure 2002).

- Magmatic Input- Heat and Fluid.
- Metal Zonation.
- Mixing and Boiling.
- Sinters and Breccias.
- Alteration Zonation.
- Fluid Chemistry and Physics.

The Exploration Model

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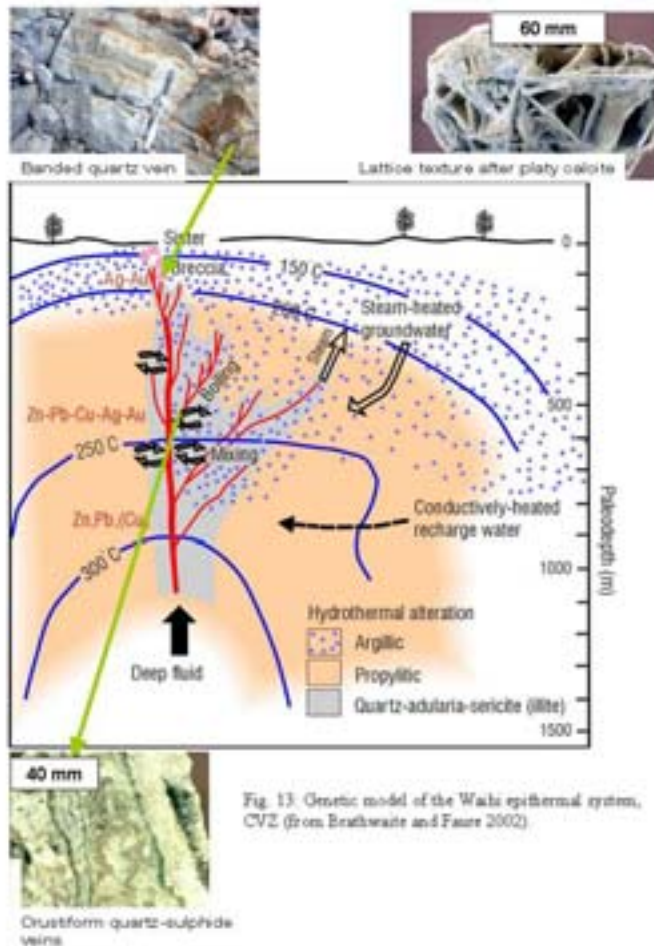


Fig. 13: Genetic model of the Wachi epithermal system, CVZ (from Brathwaite and Faure 2002).

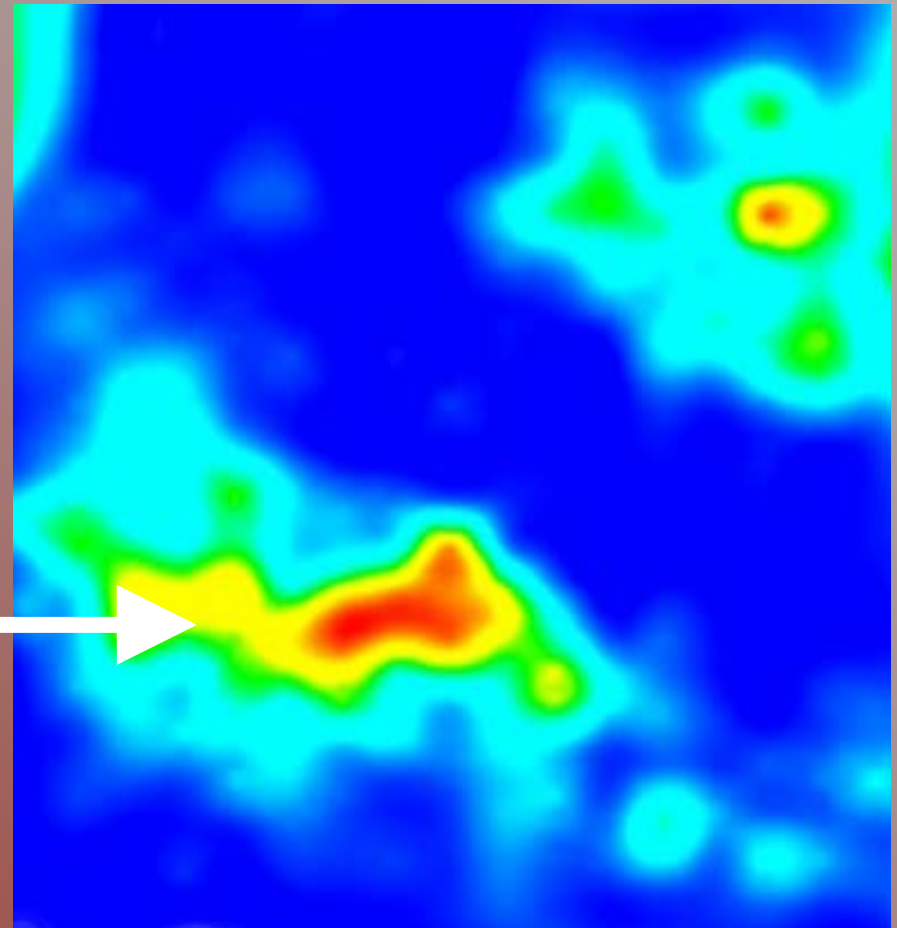
- Must Focus on Similarities.
- Data Limited.
- Budget Constrained.
- Time Delivery.
- It's The Combination of Variables That is Important.
- Testing Spatial Associations.
- Identifying Useful Features in Genetic Models.

Knowledge Of Process Allows Prediction

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Concept Applies
To All Users Of
Spatial Data

Understanding





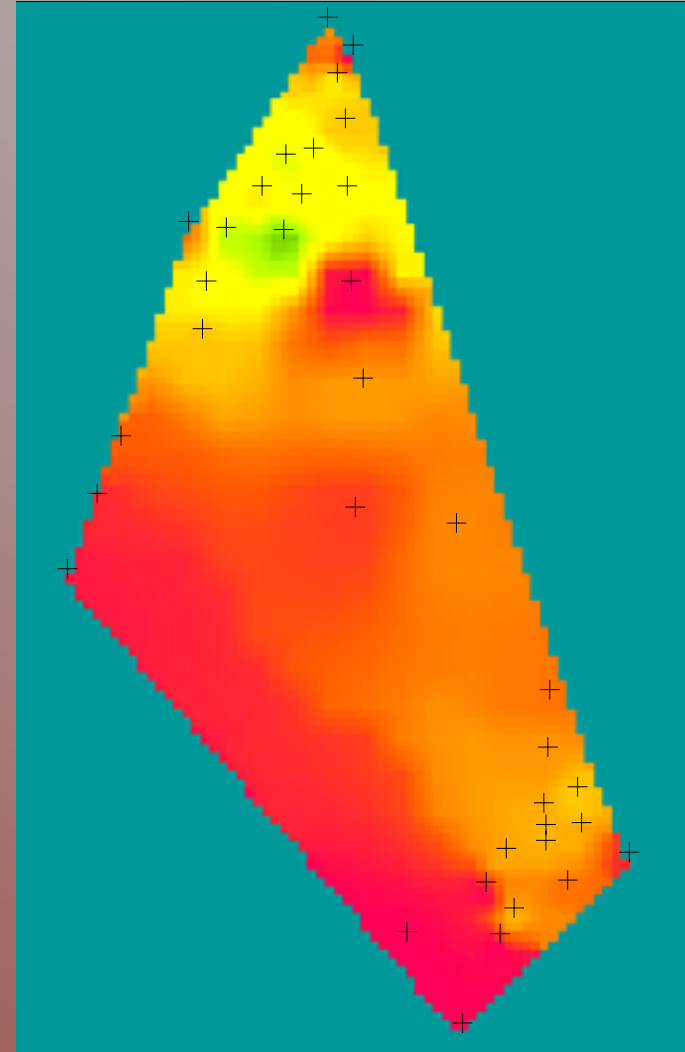
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Integrating Data and Knowledge – How?

Single Variable Models

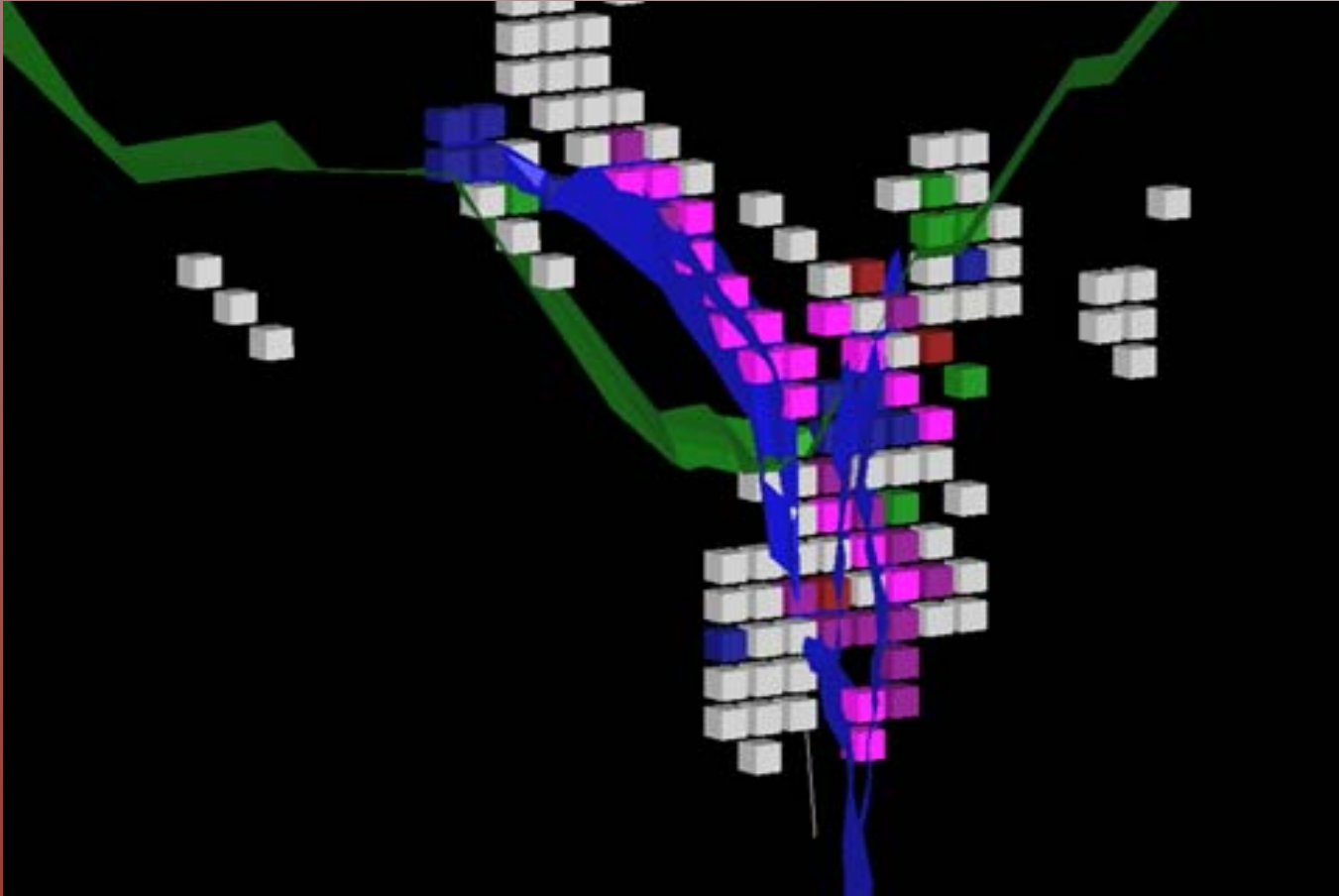
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- Estimating New Points From Point Data
- Gridding
- Data Interpolation



3D Block Modelling

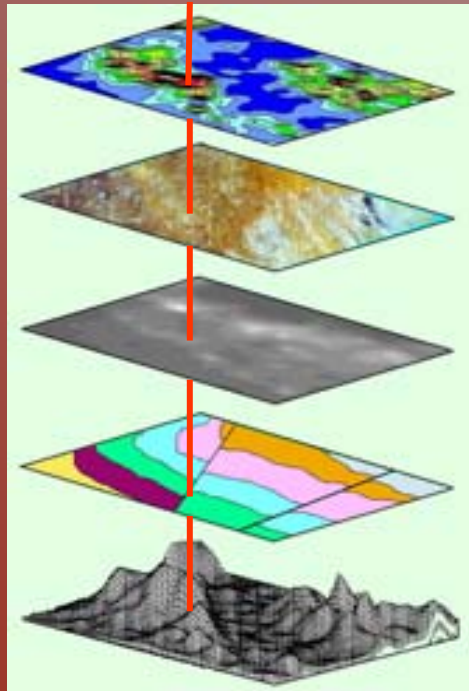
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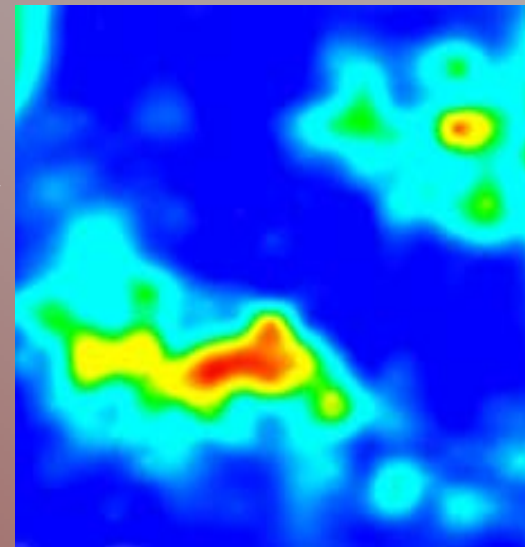
Multi-variable Models



A weighted
aggregation
process

Risk & Cost

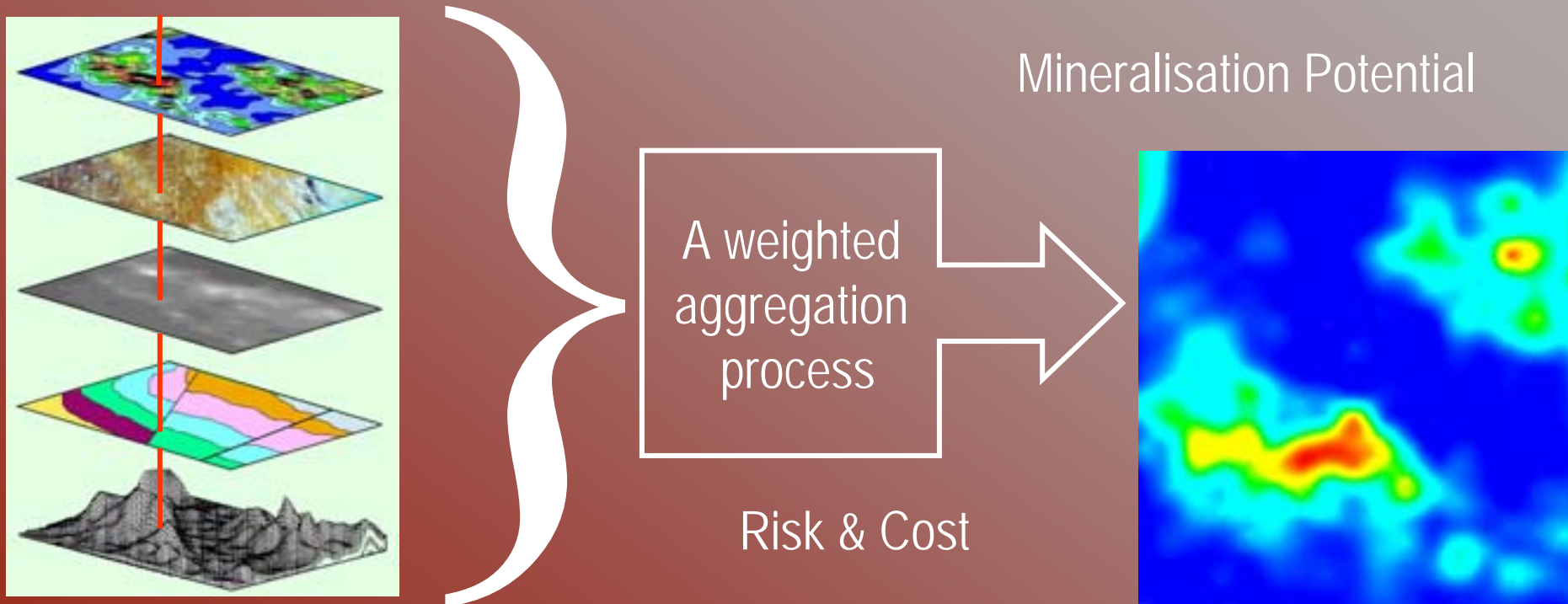
Resource Potential



Weights Of Evidence

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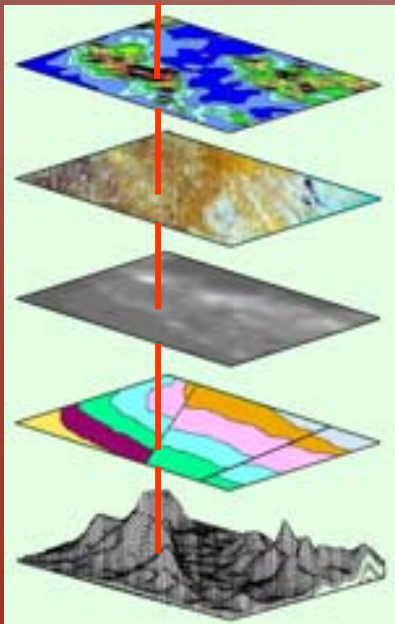
- Hypothesis is This Location is Favourable for Occurrence of Gold or Wine: Variables in Layers Weighted and Added
- Weights Estimated from Measured Associations
- Hypothesis is Repeatedly Evaluated for all Possible Locations on the Map, Producing a Mineral Potential Map



Fuzzy Logic and Neural Networks

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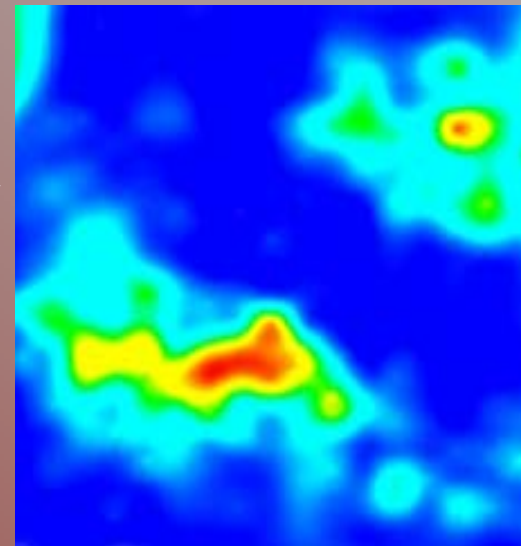
- Good for Poorly Explored Areas, Depends on Experts!!!
- Results Variable and Depends on Training Data



A weighted
aggregation
process
ArcView

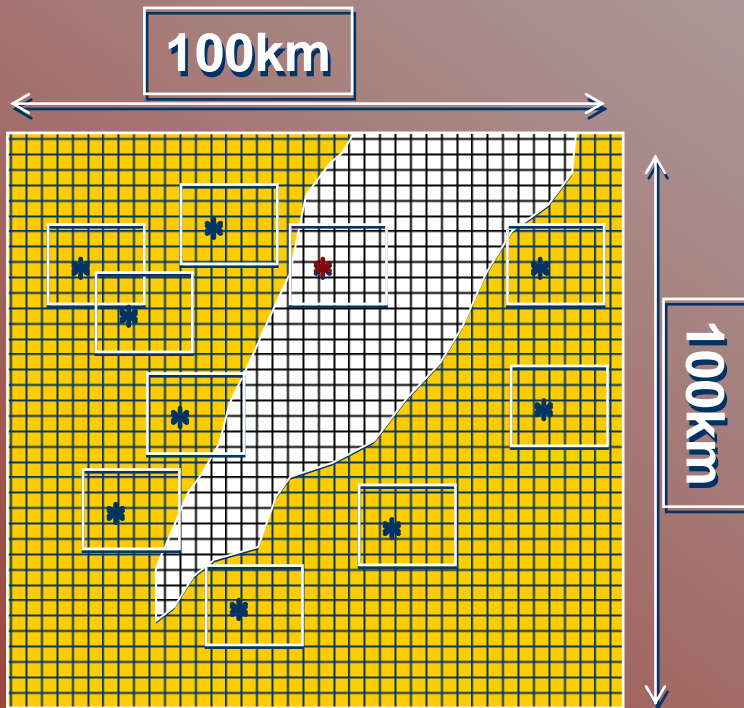
Risk & Cost

Mineralisation Potential



WofE Based On Probability

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$$a = 10,000\text{km}$$

$$A = \text{Unit Cell} = 1\text{km}^2 \text{ cell}$$

$$n(d) = 10 \text{ total deposits}$$

$$P\{D\} = 0.001$$

$$n(\underline{bd}) = \text{dep in area}$$

$$n(\underline{bd}) = \text{unit cells in area} - \text{dep}$$

$$n(\underline{d}) = \text{tot unit cells} - \text{tot dep}$$

$$n(\overline{bd}) = \text{dep not in area}$$

$$n(\overline{bd}) = \text{u cells not in area} - \text{dep}$$

$$W_+ = \text{Log}(n(\underline{bd})/n(\underline{d})/n(\overline{bd})/n(\overline{d}))$$

$$W_- = \text{Log}(n(\underline{bd})/n(\underline{d})/n(\overline{bd})/n(\overline{d}))$$

$$C = W_+ - W_-$$

$$W_{s+} = 1/n(\underline{bd}) + 1/n(\underline{bd})$$

$$W_{s-} = 1/n(\overline{bd}) + 1/n(\overline{bd})$$

$$C_s \sim \text{Sqrt } W_{s+} + W_{s-}$$

$$\text{StudC} = C/C_s$$

Spatial Analysis – Measuring Associations With Mineralisation



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- Proximity to Major Faults and to Fault Orientation
- Lithology (Basalt, Andesite, Dacite or Rhyolite; Flows Versus Pyroclastic Rocks) and Age of Host Rocks
- Proximity to Domes, Calderas and/or Ring Structures
- Correlation with Specific Geochemical Elements (Hg, Sb and As +ve; Cu, Pb and Zn –ve).
- New Measures, Fault Roughness, Fractals, Aftershocks

What Is Important?



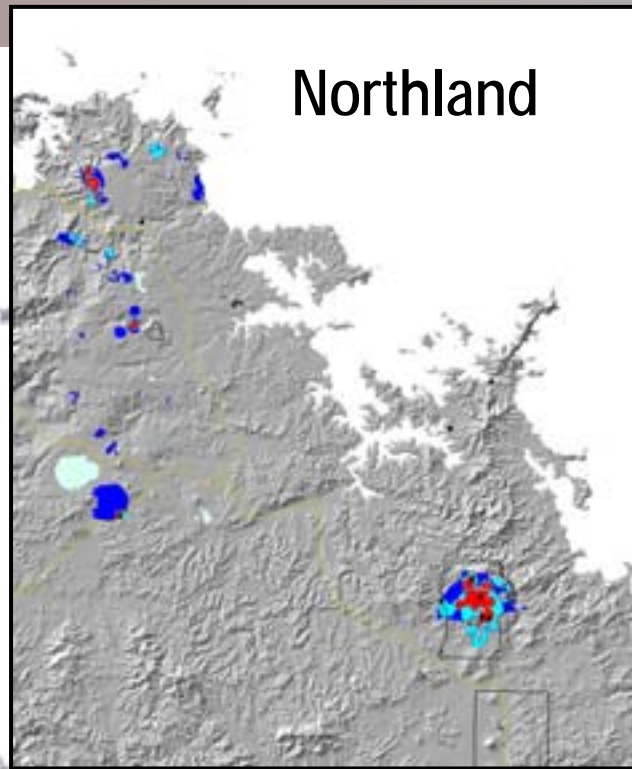
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Variable	Correlation Value
Argillic Alteration	5.2
Propylitic Alteration	5.0
Silicic Alteration	4.8
Structural density of veins	4.7
Eruption breccias	4.2
Host Rock Type	3.9
Clay Alteration	3.9
Silica-sulphide Alteration	3.3
Hg mineralisation	3.2
Stream sediment As	2.9
NE and ENE faults	2.7
Structural density of faults excluding thrusts	2.6
Rock chip Sb	2.2
Rock chip Au	2.1
Stream sediment Cu	2.1
Structural density of all faults	2.0
Rock chip As	1.9
Stream sediment Au	1.9
Rock chip Hg	1.7

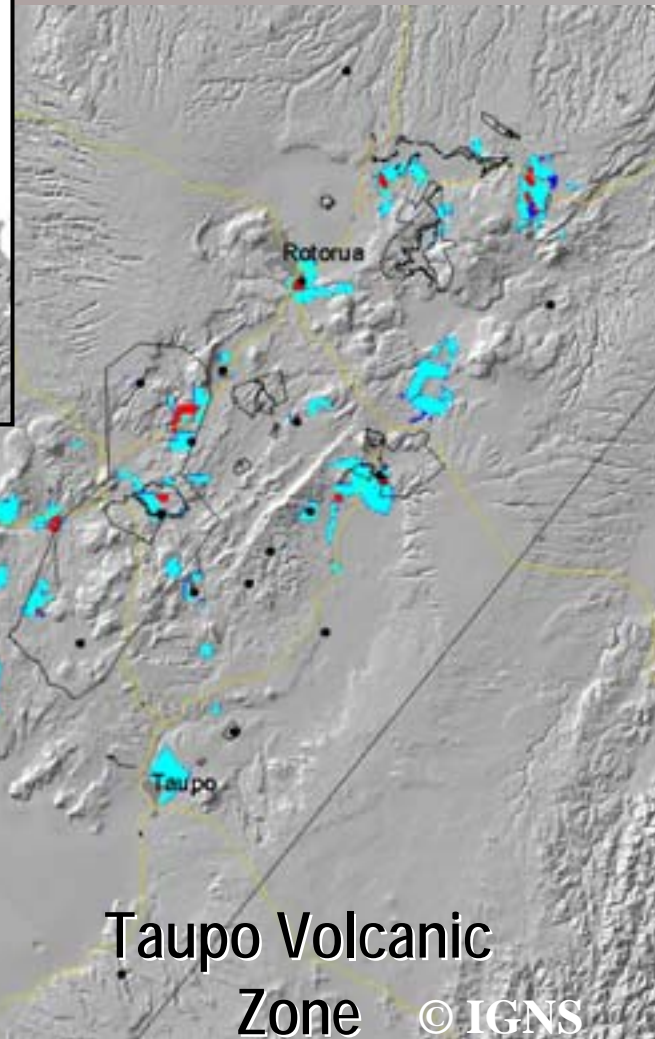
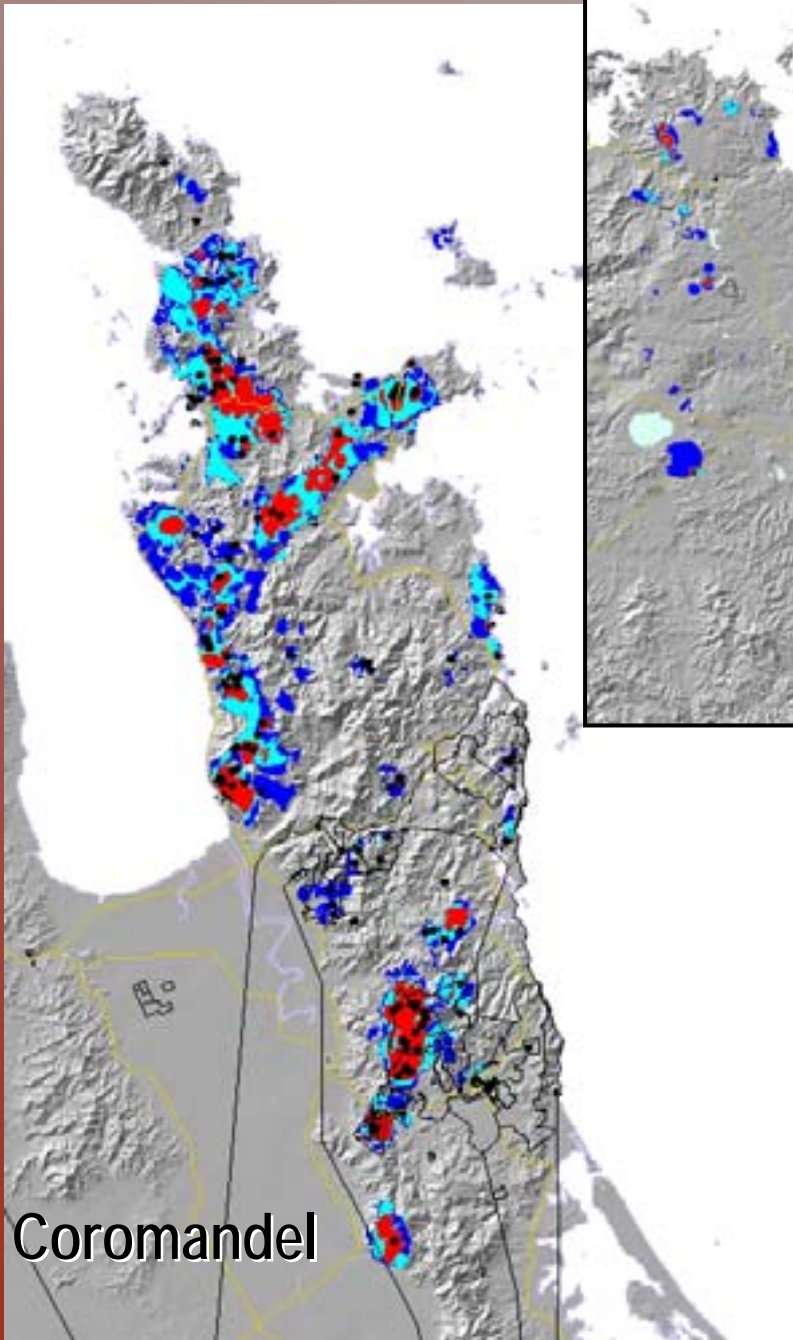


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Northland



Coromandel

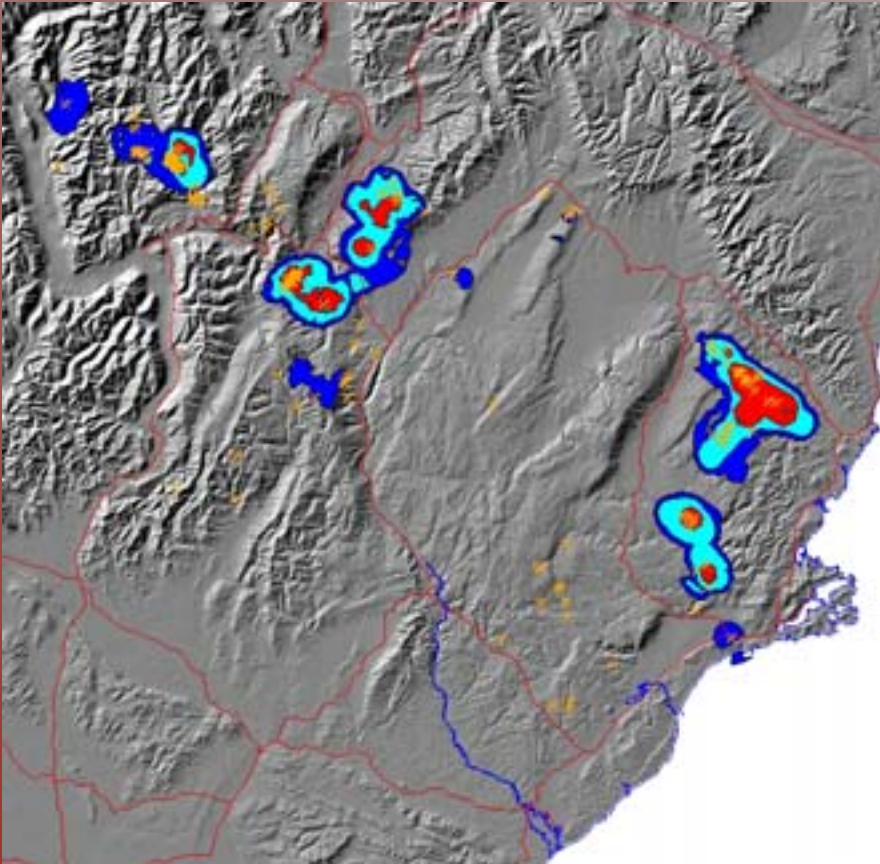


**Taupo Volcanic
Zone**

© IGNS

What You Can Do With Prospectivity Models

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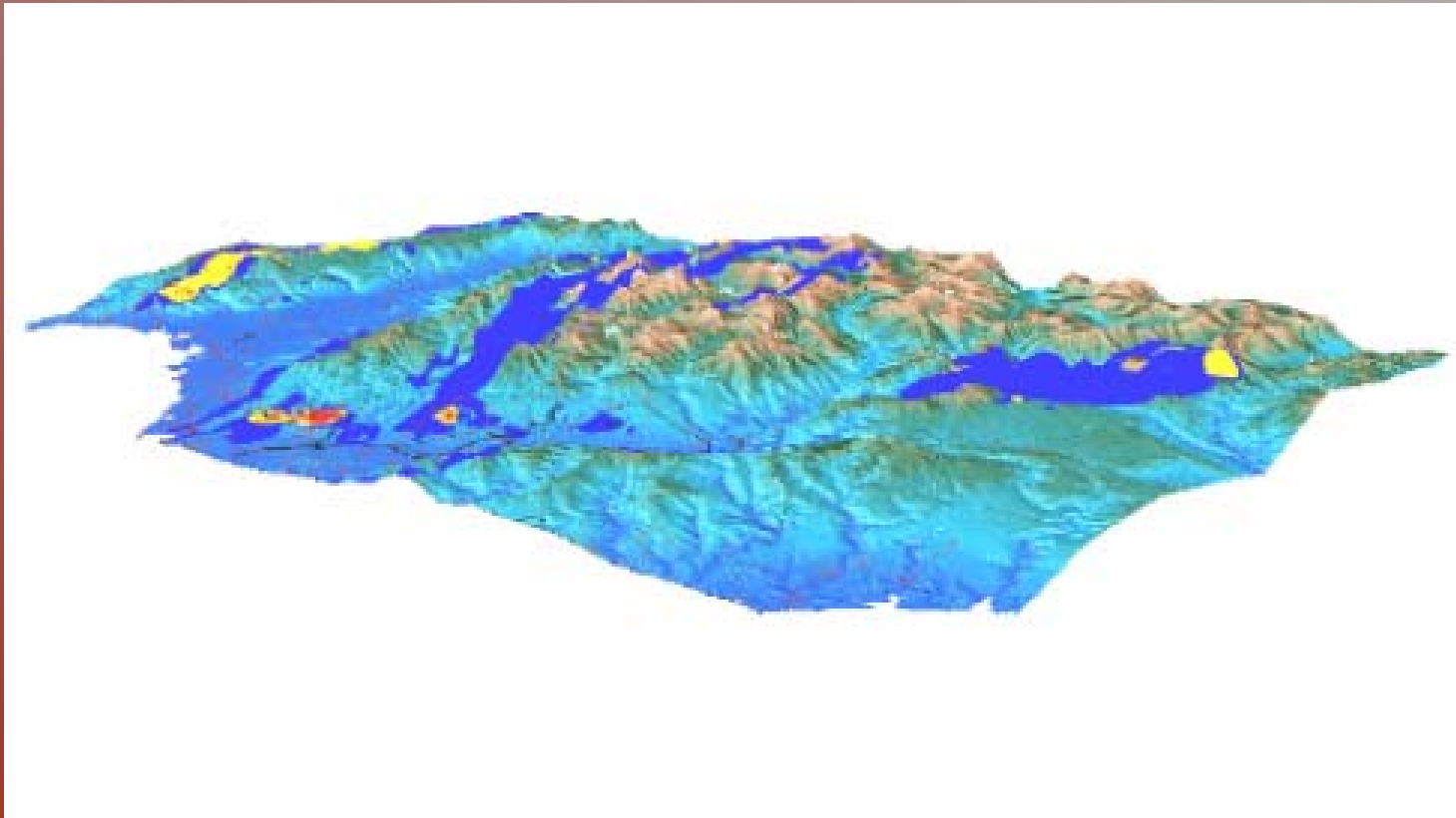


- Business Development
- Land Access



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Exploration Logistics





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Project Funding

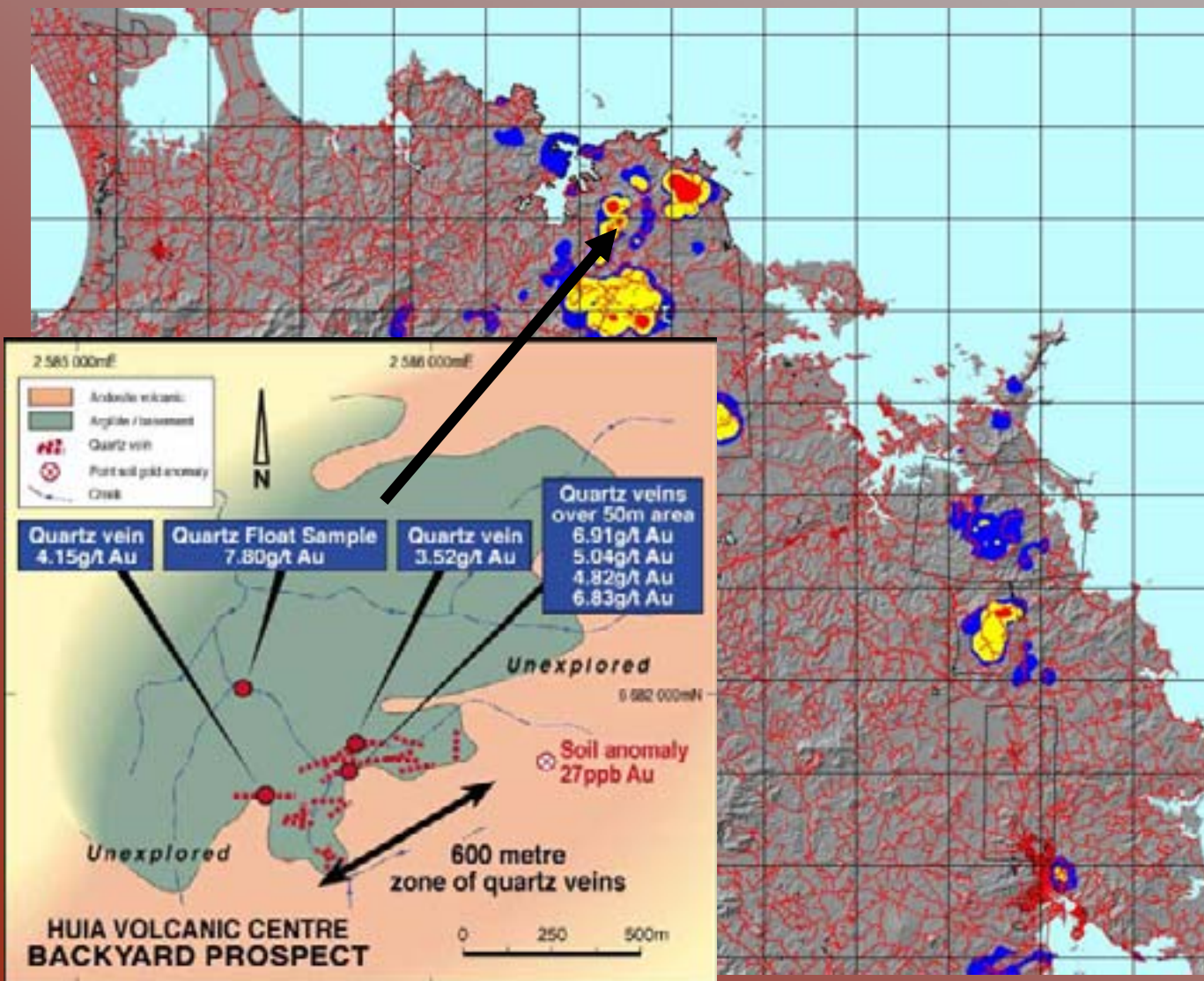
- Raising Capital
- Marketing to Project Funders
- Highlighting Prospectivity
- Convincing Non Geologists
- Simplifying Complex Concepts of an Exploration Model
- Cost Reduction and Risk Minimisation

Aurora Minerals Floated

2004 Raised A\$4.0M

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- Northland NZ
- Newly Discovered Gold Province
- Based on WoE Model
- First Area Checked Successful





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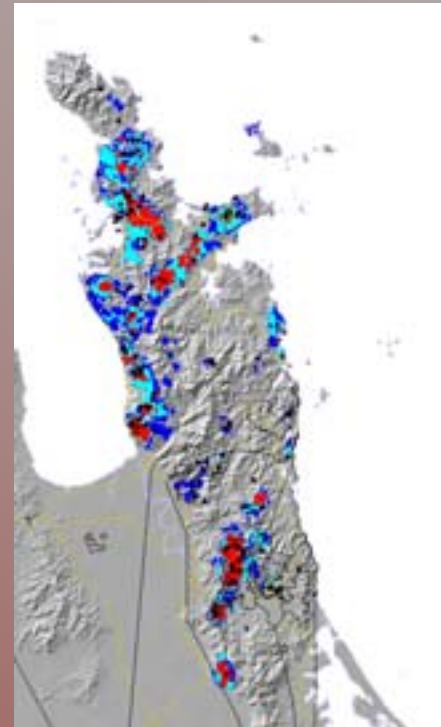
Exploration Work Planning

- Key Data and Exploration Model
- Which Data Contribute to The Model?
- Identify Areas of Missing Data
- Highlight Data that Will Add Value
- Prioritise Exploration
- We Lack Prospect-scale Geological Mapping

Exploration Management

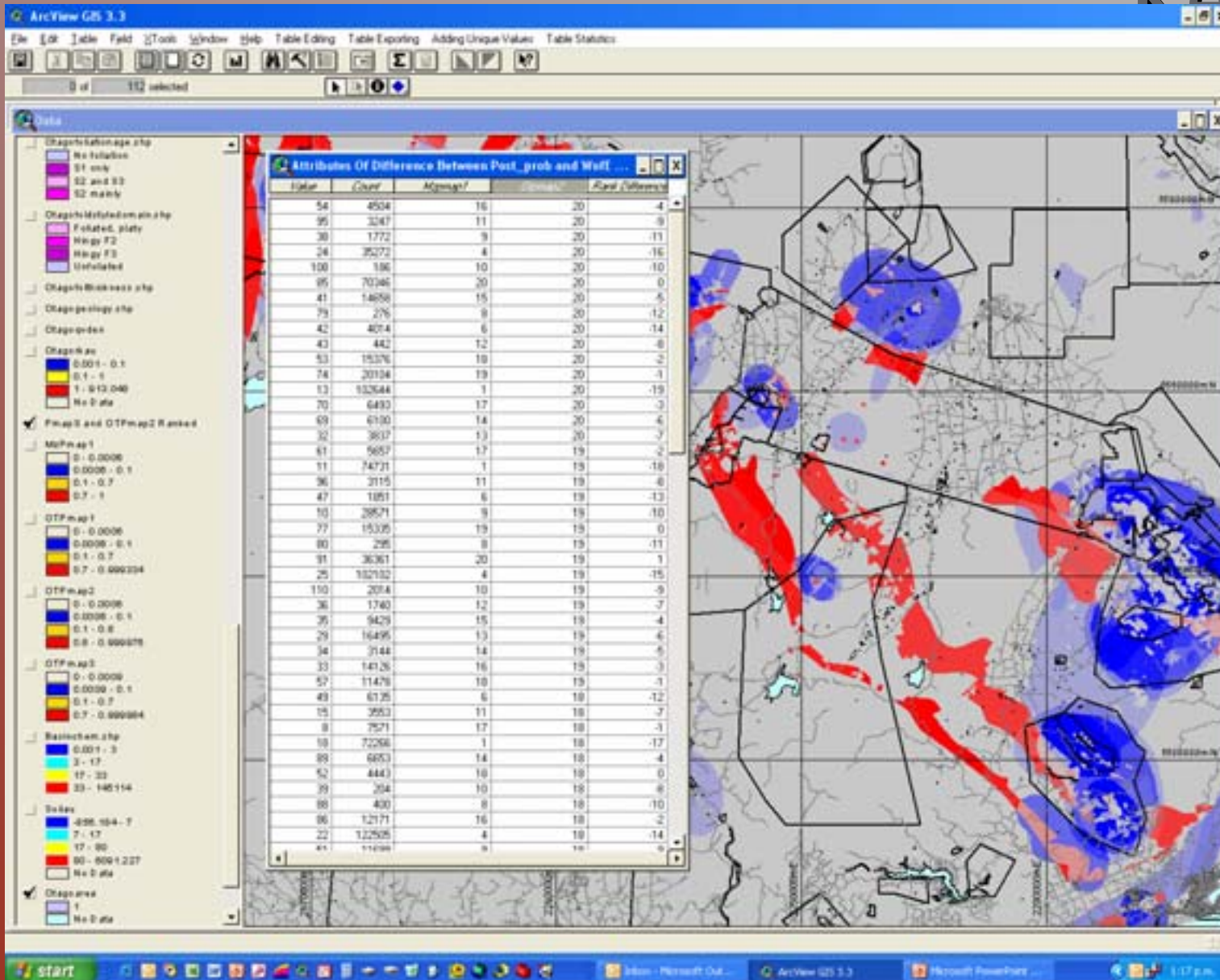
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- How Effective is Your Exploration?
- Has Your Data Added to the Prospectivity of Your Target?
- Is your Exploration Model Working?
- Re-prioritise Exploration Targets
- Cost Reduction and Risk Minimisation



Ranked Differences

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Test New Research Concepts **Kenex**

- Test Research Concepts
- Add Value to Historic Data and Knowledge
- Apply New Exploration Models to Old Data
- Make National-scale Comparisons
- Make International Scale Comparisons

Auzex Resources

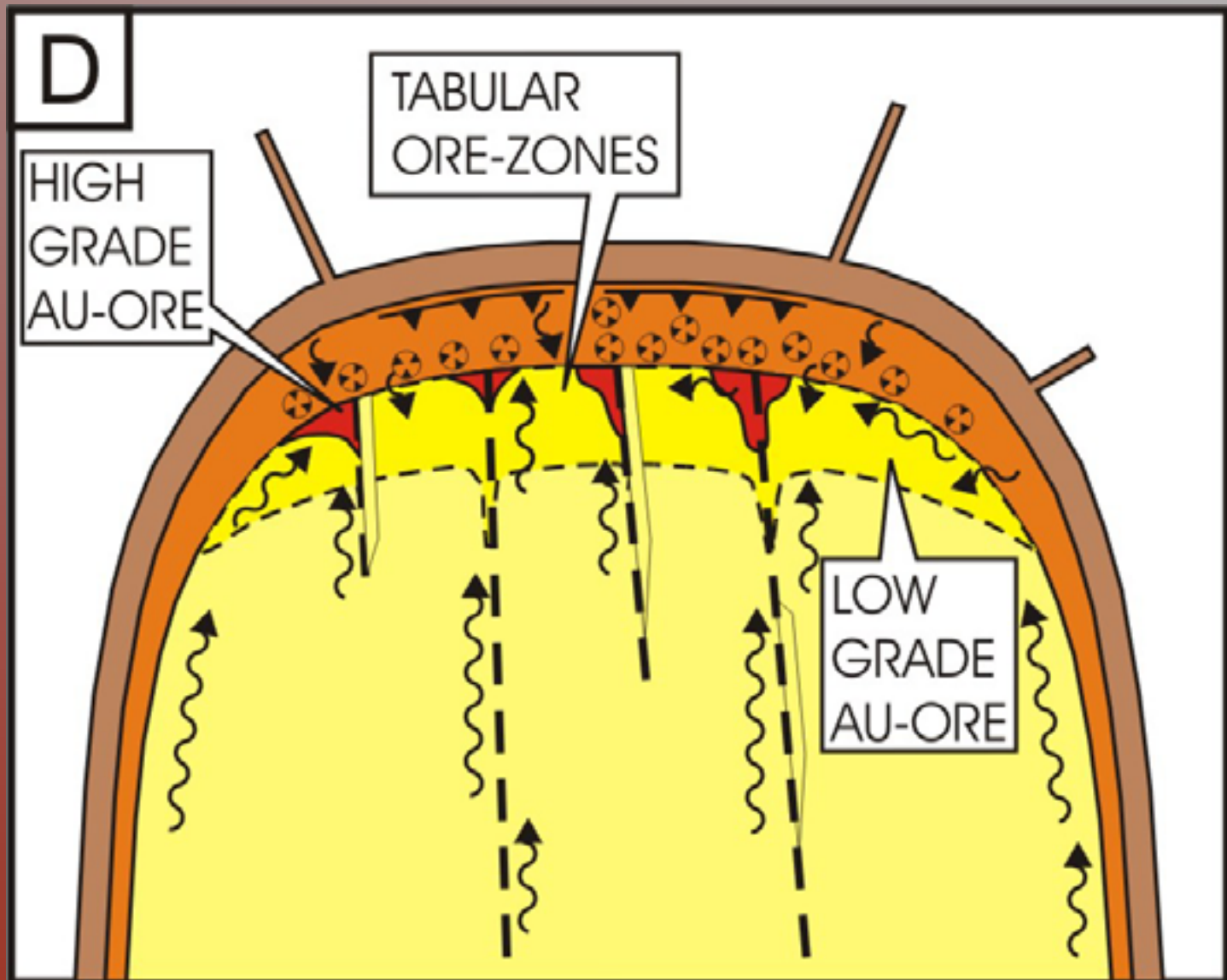
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Exploring for Metals in Granite

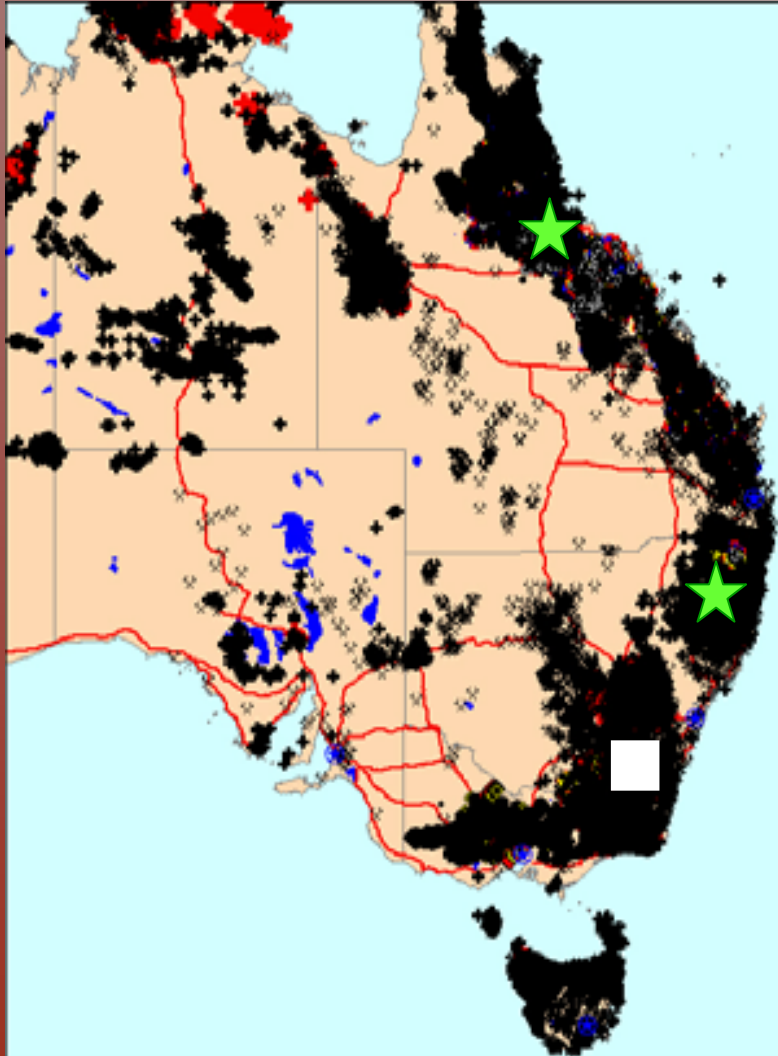
Granite Gold Mineralisation

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Data And Information

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- Integrated and assessed
- 79,000 mineral occurrences.
- 9,324,000 rock data.
- 21,912,000 SS data.
- 26,360,592 soil data.
- 109,000 drill holes.
- 2,537,522 km² of geological data.

International Scale Model – Search Area Reduced

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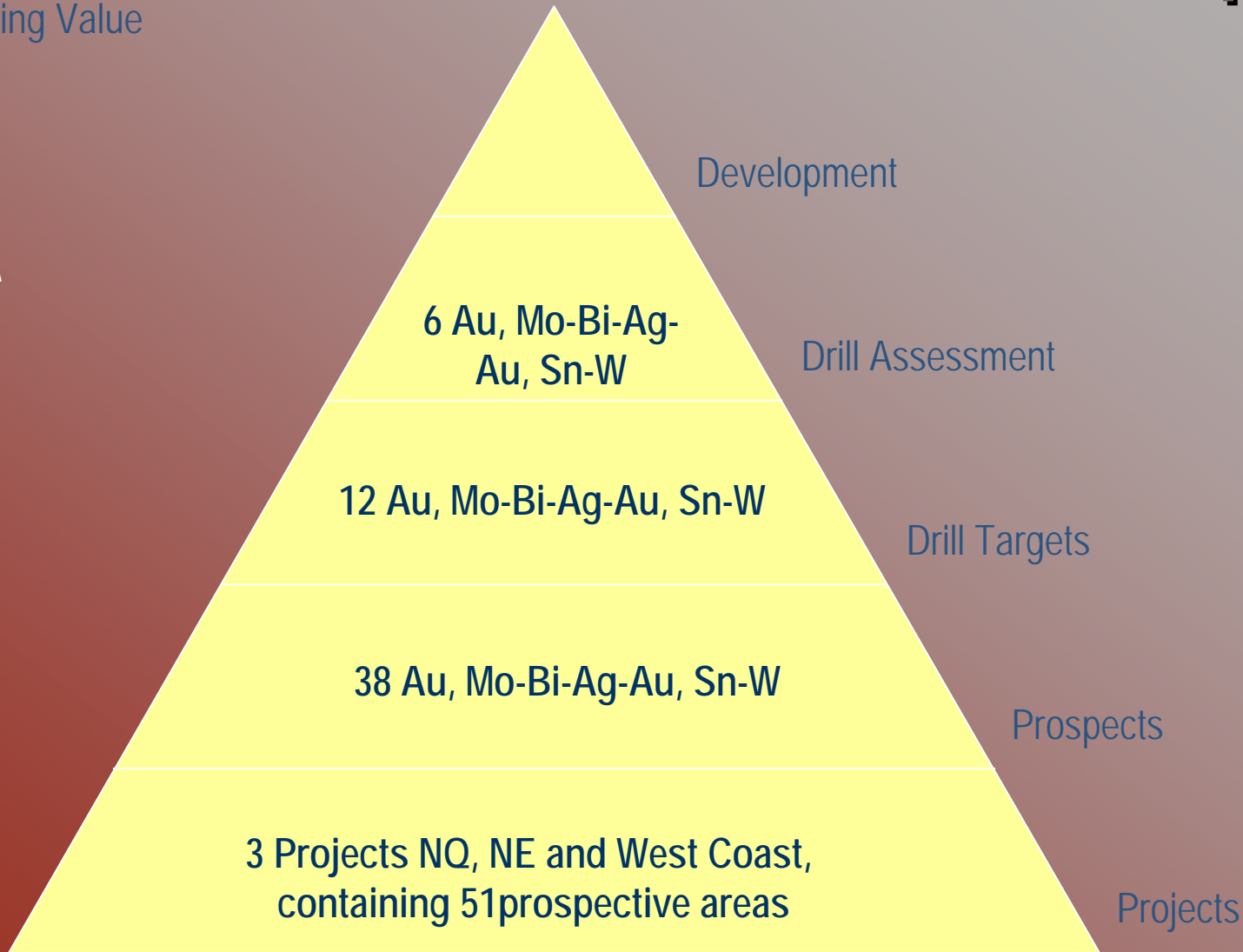


Portfolio Approach

Mineral Extraction

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Increasing Value



Probability And Risk Reduction Kenex



The Practical Implication Of High Discovery Risk For Strategic Planning & Exploration Budgeting Is A Large Difference Between The Average Cost Of Exploration Success And The Level Of Funding Required To Ensure Success (e.g. - "World Class" Deposits)

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

Finding New Deposits Is Hard! But:

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- Exploration is a Business.
- Geological Data are Key Predictors
- Opportunities Still Exist in Near Surface
- Data and Knowledge Must be Integrated.
- New Tools Available
- It Works

