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!!

- 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

- 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
Prospectivity in Mineral Exploration
What Defines Prospectivity?

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West Coast 9.5 M oz

Coromandel 11 M oz

Otago 12.3 M oz
New Mines: Macraes Gold Project, Otago

- 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
Genetic Models Based on University Research

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Exploration Activity

Exploration Permit Applications

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Exploration Expenditure

35 Million

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Land Access

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Environment

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Sovereign Risk

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Decisions Based On Full Picture Using All Facts
Prospectivity – Fundamental Driver For Exploration

- **Investment Criteria No. 1:**
  - geological potential and geological information

- **Investment Criteria No. 2:**
  - land access, sovereign risk – value of mineral rights
What Is The Exploration Value Chain?
Regional Assessments

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

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Satellite

Radiometrics
Interpretation And Exploration
Models = Ideas
Prospect Scale Exploration

- Geochemical Data – A Numbers Game
Detailed Geology

- 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

Resource Estimation And Preliminary Pit Optimisation
Reserve Estimation: Do We Mine?

Optimisation, Financial Risk Profile, Reserve Calculations
The Exploration Process Is All About Probability

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!!

Before

After
This is All About the Use of Spatial Data

- 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

- Historic Mines (training data)
- Geology
- Geochemistry
- Geophysics
- Simple Recipe
- Complex Mixture
Need To Be Able to Assess Datasets at International Scales

5 Million Data Points
14 Gb digital data
Measure Geological Variable Associations

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What is Geochemically Anomalous?

- 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
Integrating Data, Information, And Knowledge

Geological Data

Information

Knowledge of Process

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<th>Property-ID (PDVROL)</th>
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What Knowledge?
Genetic Models and Exploration Models
Known Deposit Studies

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

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

Fig. 8B. Cross section of the Golden Cross deposit (after Knall et al. 1993, Sampson et al. 2003).

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

Fig. 12A: Crostifem 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

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

Fig. 21: Deep geothermal fluid emerges from Champagne Pool Waiotapu to deposit a meter terrace containing up to 80 g/t gold and 175 g/t silver.
Genetic Model

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

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The Exploration Model

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- 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.

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Knowledge Of Process Allows Prediction

Concept Applies To All Users Of Spatial Data

Understanding
Integrating Data and Knowledge – How?
Single Variable Models

- Estimating New Points From Point Data
- Gridding
- Data Interpolation
3D Block Modelling

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Multi-variable Models

A weighted aggregation process

Resource Potential

Risk & Cost

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Weights Of Evidence

- 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

A weighted aggregation process

Risk & Cost

Mineralisation Potential
Fuzzy Logic and Neural Networks

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

\[ a = 10,000 \text{km} \]
\[ A = \text{Unit Cell} = 1 \text{km}^2 \text{ cell} \]
\[ n(d) = 10 \text{ total deposits} \]
\[ P\{D\} = 0.001 \]
\[ n(bd) = \text{dep in area} \]
\[ n(\overline{bd}) = \text{unit cells in area} - \text{dep} \]
\[ n(d) = \text{tot unit cells} - \text{tot dep} \]
\[ n(bd) = \text{dep not in area} \]
\[ n(\overline{bd}) = \text{u cells not in area} - \text{dep} \]

\[ W_+ = \log \left( \frac{n(\overline{bd})}{n(d)} \cdot \frac{n(\overline{bd})}{n(d)} \right) \]
\[ W_- = \log \left( \frac{n(\overline{bd})}{n(d)} \cdot \frac{n(\overline{bd})}{n(d)} \right) \]
\[ W_s = \frac{1}{n(\overline{bd})} + \frac{1}{n(bd)} \]
\[ C_s \approx \sqrt{W_+ + W_-} \]
\[ \text{StudC} = C/C_s \]
Spatial Analysis – Measuring Associations With Mineralisation

- 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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<thead>
<tr>
<th>Variable</th>
<th>Correlation Value</th>
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<td>Argillic Alteration</td>
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<td>Silicic Alteration</td>
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<td>Structural density of veins</td>
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<tr>
<td>Eruption breccias</td>
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<tr>
<td>Clay Alteration</td>
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<td>Silica-sulphide Alteration</td>
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<tr>
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<td>Structural density of faults excluding thrusts</td>
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<tr>
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<tr>
<td>Stream sediment Cu</td>
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<tr>
<td>Stream sediment Au</td>
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</tr>
<tr>
<td>Rock chip Hg</td>
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</tbody>
</table>
What You Can Do With Prospectivity Models

- Business Development
- Land Access
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
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

- 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
Test New Research Concepts

- 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

Exploring for Metals in Granite
Granite Gold Mineralisation

High Grade Au-ore

Tabular Ore-Zones

Low Grade Au-ore
Data And Information

• 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

Increasing Value

Projects

Propects

Drill Targets

Drill Assessment

Development

6 Au, Mo-Bi-Ag-Au, Sn-W

12 Au, Mo-Bi-Ag-Au, Sn-W

38 Au, Mo-Bi-Ag-Au, Sn-W

3 Projects NQ, NE and West Coast, containing 51 prospective areas
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:

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