DMEC workshop series:

Risk in Exploration: Measuring it and How to Avoid Ruin

Wednesday, March 5, 2014
DMEC workshop series: Risk in exploration: Measuring it and how to avoid ruin

Chairs - Ken Witherly, Condor Consulting, Inc.
Charles Beaudry, Gold Crossing Inc.

Introduction

Decennial Minerals Exploration Conferences (DMEC) was created in 2007 as the legal entity responsible for managing the Exploration 07 conference and is the corporation that now holds the copyright for the proceedings of the conference. The Exploration 07 conference, held in September 2007, was the fifth and most successful of a series of conferences which have been held every 10 years since 1967. These meetings have been designed to summarize the advancements in the different fields of mineral exploration science and technology over the previous decade through a focused series of technology reviews and case studies given by world leaders in various aspects of geophysics, geochemistry, remote sensing and information processing and data management.

The fundamental objectives of DMEC are to promote the science and business of mineral exploration and the advancement of the geosciences. The board of directors and organizing committee of the corporation are all volunteers working actively in the mineral exploration industry and most are based in Toronto.

Although the next Decennial International conference is three years away (ie 2017), the DMEC organizing committee decided that it should undertake an activity at a modest scale but on a recurring basis to advance exploration during the intervening years. To this end this workshop, organized under the auspices of the PDAC annual convention, is an excellent way to advance these objectives. This is the fourth half-day workshop that is organized by DMEC and each of the previous events were sold out.

In the first workshop, we focused on exploration issues related to a major VMS exploration program in the Abitibi and then in the second workshop, we examined the challenges of exploration undercover in the search for Cu-Au porphyry deposits in the Quesnel terrain, east central B.C. In 2013 we looked at exploration undercover in the northern copper belt of Chile. Presentations examined the geological, geochemical and geophysical methodologies being used to search for new deposits particularly in the pediment-covered areas of the Atacama fault zone.

For this year we have chosen to focus on risk in exploration and as the name of the workshop implies the objective is to measure it in order to avoid failure.
The field of risk management has been developed to a high degree in the oil and gas industry (see various publications of AAPG at http://bookstore.aapg.org/). However in the minerals industry, progress has been much slower. Earlier work by Brian Mackenzie of Queen’s University looked at the problem from the perspective of cost of discovering a mineral occurrence in the Abitibi and the odds that the discovery would be economic (1 in 50 or 2%) to argue that 10 years was required on average and an investment of $44M (in current dollars) to ensure a 90% chance of discovering and defining an economic deposit in the Abitibi.

In spite of this there is little work that is being done on the quantification and management of risk in on-going early-stage exploration, before a resource has been defined and even before a discovery is made. This type of risk assessment is now routine in the oil and gas business and there is no theoretical reason why this could not be done in the mineral exploration industry.

The conferences we have selected for presentation cover the range of issues affecting risk in mineral exploration, from the human element (Ken Witherly), to the organizational (John Gingerich), to the financial (Michael Doggett), to the evaluation of technical information (Michel Rheault and Eric Grunsky) to the resource itself (Graham Davis). We hope that you will find in these papers some food for thought that you will participate actively in the panel discussion at the end.
## Program Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>14:00-14:10</td>
<td>Introduction - Ken Witherly, Charles Beaudry</td>
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<tr>
<td>14:10-14:40</td>
<td>The human factors in risk assessment and management; Ken Witherly, Condor Consulting Inc.</td>
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<tr>
<td>14:40-15:10</td>
<td>The prospector myth - coming to terms with risk management in mineral exploration (10 years later); John Gingerich, Advanced Exploration Inc.</td>
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<tr>
<td>15:10-15:40</td>
<td>The Challenge of creating value through exploration; Michael Doggett, Doggett and Associates</td>
</tr>
<tr>
<td>15:40-16:00</td>
<td>Break</td>
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<tr>
<td>16:00-16:30</td>
<td>Risk assessment contribution from remote sensing and GIS within the mine lifecycle; Michel Rheault, Effigis Geosolutions</td>
</tr>
<tr>
<td>16:30-17:00</td>
<td>A probability-based approach to predictive geological mapping and mineral resource potential using regional geochemical data; Eric Grunsky, Geological Survey of Canada</td>
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<tr>
<td>17:00 - 17:30</td>
<td>The Upside and Downside of Resource Uncertainty; Graham Davis, Colorado School of Mines</td>
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<tr>
<td>17:30 – 18:00</td>
<td>Panel discussion</td>
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<tr>
<td>18:00</td>
<td>End of Workshop</td>
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Short Biographical Notes

Charles Beaudry

Charles Beaudry is a Professional Geologist with over 30 years experience in project generation, business development, exploration geochemistry and hands-on project management. Charles was previously President and CEO of Xmet Inc., a Junior focused on advanced gold projects in the Abitibi region of Quebec. He held the position of General Manager of new business opportunities with IAMGOLD Corporation from 2008 to 2009, after having spent nearly 17 years in various positions for Noranda-Falconbridge-Xstrata. His newest venture is called Gold Crossing, just launched and focusing on gold and base metal exploration in the Timmins region of Ontario. Charles holds a Bachelors of Science in Geology from the University of Ottawa and a Masters of Geology from McGill University. Charles is also a QAQC specialist, having spent several years in Six Sigma and Quality Systems training, and gives a 3-day short course on Quality in Mineral Exploration and QAQC. He is also a Qualified Person as defined in NI43-101.

Graham Davis

Graham A. Davis is Professor of Economics and Business at the Colorado School of Mines, where he has taught and researched mineral economics for 20 years. He holds a B.S. in Metallurgical Engineering from Queen’s University, an MBA from the University of Cape Town, and a Ph.D. in Mineral Economics from the Pennsylvania State University. Prior to joining academia Graham worked as a metallurgical engineer at mines in Canada and Namibia. His research focuses on the valuation of mineral and energy assets under uncertainty, and on the impacts of mining on economic and human development. Graham has been a member of the Society for Mining, Metallurgy, and Exploration for over 30 years, where he is a Registered Member. He is also a Fellow of the Australasian Institute of Mining & Metallurgy.

Michael Doggett

Dr. Michael Doggett is a mineral economics consultant based in Vancouver. He has 25 years of experience in the field of mineral economics advising mining companies, governments and international agencies. He has delivered professional development programs in mineral project evaluation to more than 1,800 people in a dozen countries. Dr. Doggett is an Adjunct Professor at Queen’s University, Canada where he served as Director of the Mineral Exploration Master’s Program from 1997 to 2007. In 2002 he was the recipient of the Robert Elver Mineral Economics Award of the Canadian Institute of Mining (CIM). He has served as the Society of Economic Geologists International Exchange lecturer in 2005 and as a CIM Distinguished Lecturer in 2010-2011. He currently serves on the Board of Directors of four exploration and mining companies as well as the Mineral Deposits Research Unit at the University of British Columbia.
John Gingerich

John C. Gingerich, P. Geo. is a professional geophysicist (APGO) with 35 years experience in exploration, mining and related technology industries. In a career that spanned 15 years within Noranda’s Exploration group, he served as Chief Geophysicist and Director of Research and Technical Innovation. John’s exploration career as a geophysicist began with Eldorado Nuclear Ltd (merged with SMDC in 1988 to become CAMECO). In 2002, John left Noranda and founded Geotechnical Business Solutions (GBS), a company dedicated to the development and financing of exploration opportunities and related technology. GBS also provides consulting services to First Nation Communities. As a recognized leader within the mining and technology communities, John has served as a member of several industry and government boards and committees including the previous Ontario Geological Survey Advisory Board (Chairman) and Exploration Division of the Canadian Mining Industry Research Organization. Mr. Gingerich currently serves as Advanced Explorations Inc, CEO and Chairman of Bactech Environmental Corporation.

Eric Grunsky

Dr. Grunsky is a research scientist at the Geological Survey of Canada (GSC), Natural Resources Canada, Ottawa, Ontario. Since 2002, he has worked at the GSC carrying out research in the discovery of geochemical and geological processes from the evaluation of geochemical survey data. Dr. Grunsky makes use of multivariate statistical methods and spatial statistics as the basis of his research. In 2005, he received the Felix Chayes Medal for Excellence in Research in Statistical Petrology, by the International Association for Mathematical Geosciences (IAMG) and served as Editor-in-Chief for the International Journal, Computers & Geosciences from 2006-2011. In 2012, he was received the Krumbein Medal IAMG, the highest award given by the IAMG, to senior scientists, for career achievement. He was recently named the 2014 Distinguished Lecturer for the IAMG. Dr. Grunsky’s career has included field mapping and research at the Division of Exploration and Mining, CSIRO, Australia and the Alberta, British Columbia and Ontario provincial geological surveys. He holds B.Sc and M.Sc degrees from the University of Toronto and a Ph.D. from the University of Ottawa.
Michel Rheault

Michel Rheault holds a master in remote sensing from the Laval University and a bachelor degree in geology from the University of Montreal. He is a member of the Ordre des Géologues du Québec (OGQ #259). He has realized numerous geological studies mandates for the mining and the oil and gas industry, and he has directed several projects on geological applications development for the Canadian Space Agency and the European Space Agency. At Effigis, he is developing Remote Sensing and GIS projects applied to exploration geology and to environmental geology. With over 30 years of experience, he is recognized for his expertise at the national and international level.

Ken Witherly

Ken graduated from UBC (Vancouver Canada) with a BSc in geophysics and physics in 1971. He spent 27 years with Utah/BHP Mineral Company during which time as Chief Geophysicist, he championed BHP’s programs in airborne geophysics, which resulted in the development of the MegaTEM and Falcon technologies. In 1999, Ken helped form a technology-focused service company that specializes in the application of innovative processing and data analysis to help drive the discovery of new mineral deposits.
Decennial Mineral Exploration Conferences Organization

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Canada Revenue Agency Business Number 85158 8756

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Presentation agenda

- Exploration as an economic activity
- The impacts of resource uncertainty on exploration value
- Final comments
Exploration as an economic activity

The impacts of resource uncertainty on exploration value

Final comments

Exploration is a value-creating economic activity

- Money is spent only where there is some expectation of an eventual economic return.
- Evidence
  - economic returns are higher when prices are higher.
  - more exploration activity when metal/energy prices are higher.
  - there is an upward-sloping supply curve for exploration just as there is for any economic activity.

![Diagram showing the relationship between metal price and exploration activity](image)
What makes exploration hard to evaluate as an economic activity?

- High uncertainty as to what is there, if it will be mined, when it will be mined, and what prices will be when it will be mined.
- For major precious and base metal deposits, 28 years from spending first $1 on exploration to receipt of first $1 of income.
- Traditional discounted cash flow evaluation of exploration dollars will usually yield a negative NPV.
- Exploration is actually compound option on information. Options are not easily valued using standard discounted cash flow techniques.
- Need Integrated Valuation and Risk Modeling (IVRM) techniques
The first step in value creation modeling - model the resource uncertainty

- Consider greenfield/brownfields resource uncertainty
  - There is some initial estimate about the amount of economically recoverable material
  - Probably a lognormally distributed density function with very high standard deviation
- Exploration does two things:
  - Updates the mean (Bayesian)
  - Reduces the standard deviation around that mean
- The economic decision: should we spend $X for the next stage of exploration?
  - Only if it is a value-creating proposition!

Example: Valuing late-stage exploration, 5 years, 6 stages, exploration cost increasing in current resource estimate, no discounting for risk.
The first step in value creation modeling - model the resource uncertainty

- Is initial resource uncertainty good or bad?
  - Would you rather have a play that you are certain has 10,000 ounces of recoverable gold on it (an uneconomic property), or a play that has a 99% probability of having nothing and a 1% probability of having 1 million ounces?
  - Would you rather have a play that has a guaranteed 2 million ounces of recoverable gold, or a play that has a 50% chance of nothing and a 50% chance of 4 million ounces?
  - More uncertainty is good in some situations, bad in others.

How does the value in our example change with twice the initial resource uncertainty?
Final Comments

- IVRM methods can take resource uncertainty into account.
- They often treat uncertainty as a good thing rather than a bad thing, showing value in exploration activities where standard Discounted Cash Flow techniques do not.
- IVRM justifies the aggressive decisions that exploration managers take in the face of contrary economic evidence.
- IVRM may help exploration managers make better value-creation decisions re: when to explore, when to defer, when to walk away.
Remote Predictive Lithologic Mapping
and Prediction of Potential Mineral Resources using a Probabilistic Approach with Multivariate Methods

Eric Grunsky
Geological Survey of Canada

Outline

- The use of multi-element geochemistry of rocks, soils, stream/lake sediments, regolith and weathered materials can be very effective in the prediction of mineral resources and underlying bedrock lithologies.
- The application of multivariate data analysis and statistical methods on geochemical data, patterns are revealed that describe geochemical/geological processes that related to underlying lithologies and potential ore mineralization.
- These patterns can be expressed in qualitative and quantitative terms at regional (> 1:250 000) and mineral camp (< 1:25 000) scales.
- The integration of the results of multi-element statistical analysis and spatial analysis assists in rendering interpretable results. The results can be presented in a probabilistic framework thereby assigning levels of confidence/risk in predictive mapping and resource identification.
- A sequential approach is described in how these methods are applied, interpreted and visualized.
- Examples include:
  - Melville Peninsula, Nunavut, Canada
  - Nueltin Lake area, Nunavut, Canada
  - Kimberlite ore-grade phase discrimination is demonstrated using lithogeochemistry from the Star kimberlite field in Saskatchewan, Canada
  - Camp-scale studies of lithogeochemistry that identify mineralization are shown from the Abitibi Greenstone Belt in Ontario/Quebec, Canada
Identifying risk in geochemical data

- How much risk is involved in the assessment of geochemical data?
  - Incorrect methods of sampling, sample preparation and instrumentation.
  - Misinterpretation of geochemical signatures.
  - Lack of validation of interpretation.

Geochemical Sample Media

- Choice of sample media (soil, lake/stream sediments, till, lithologies) reflects different processes.
- Method of sample preparation affects analytical results.
- Method of instrumentation affects analytical results.
- Spatial density (support) affects the ability to detect various processes.
Goals of Geochemical Data Analysis

• Detect inter-element relationships of geochemical data reflect that mineralogy or chemical species interactions and describe or infer geological processes.
• Isolate atypical observations or groups of observations that are potentially identified with processes of interest (mineral deposit, hazardous environment).

Geochemical Data Processing & Visualization

Evaluation of Geochemical Data

• Variable Space
  – Statistics and Data visualization. Numerous graphical and statistical methods characterize and describe the variables.

• Geographic Space
  – Geographic representation of data using Geographic Information Systems (GIS) or Image Analysis Systems
  – Geostatistical Analysis – spatial processes.
Approaches to investigate and visualize geochemical data

- **Exploratory Approach (Process Discovery)**
  - investigate and characterize data
  - few assumptions
  - Scatter plot matrix, principal component analysis, cluster analysis

- **Modelled Approach (Process Validation)**
  - test groups of samples with known parameters and determines the probability of unknown samples belonging to none, one or more of the groups.
  - Discriminant analysis, neural networks, logistic regression
  - Through the estimates of probability, a measure of risk can be defined.

The Challenges [Risks] in Evaluating Geochemical Data

<table>
<thead>
<tr>
<th>Different</th>
<th>Level the data where appropriate</th>
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<tbody>
<tr>
<td>- methods of digestion,</td>
<td></td>
</tr>
<tr>
<td>- limits of detection,</td>
<td></td>
</tr>
<tr>
<td>- instrumentation</td>
<td></td>
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</tbody>
</table>

| Censoring- | Adjustment using simple/statistical methods |
| samples < | > detection limit | |

| Missing values and zeros | Suitable replacement values that depend on objectives. |

| Constant sum (closure) problem | Application of ratios and logratios |
| Adequate Spatial Sample Design | Spatial schemes & Geostatistical evaluation |
Process Discovery
Empirical Approaches

• Employ the use of empirical methods to explore the data.
  • Methods that make few assumptions.
  • Multivariate methods group elements that are stoichiometrically related.
  • Visualization of patterns/trends from which models can be built and tested.

• Risks:
  • Correct selection of sample media.
  • Correct method of sample preparation.
  • Correct method of analytical instrumentation.
  • Spatial sampling scheme.
  • Adequate sample population for statistical methods and validation of processes.

Process Validation
Classification Approaches

• Analysis of variance permits the selection of the most useful elements or PC’s that best discriminate between groups.
• Methods such as linear discriminant analysis, random forests, neural networks, logistic regression are commonly used in classifying geochemical data.
• These methods assign class membership through the estimates of probability, which represents a measure of risk.

• Risk:
  • Correct selection of training sets
  • Adequate population of samples for the training sets of interest.
  • Adjustments for inhomogeneity of covariance structures in the data.
Examples of Process Discovery and Validation

Kimberlite Classification using Lithogeochemistry

Fort a la Corne Kimberlite, Saskatchewan, Canada

\(^1\) with Bruce Kjarsgaard, Geological Survey of Canada
Kimberlite Classification using Lithogeochemistry

- Lithogeochemical sampling program of drill core from a series of kimberlite eruptions.
- Kimberlite mineralogy varies from olivine bearing magmas to fractionated magmas contaminated by crust.
- Historically, the lithogeochemistry of kimberlites have not been considered to be useful as an indicator for diamond content.
- Kimberlites analyzed the following 22 oxides/elements: SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, P₂O₅, Rb, Nb, Zr, Th, V, Cr, Co, Ni, La, Er, Yb, Y, Ga.

Kimberlite Phases

- Early JoliFou
- Mid-JoliFou
- Late JoliFou
- Pense
- Cantuar
Biplot – PC’s 1-2

Process Validation
Analysis of Variance
Linear Discriminant Analysis on Kimberlite Phases – A Probabilistic Approach

Relatively low risk of misclassification because of good group separation.

<table>
<thead>
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<th>Classification Accuracy</th>
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<tbody>
<tr>
<td>Phase</td>
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<tr>
<td>eJF</td>
</tr>
<tr>
<td>mJF</td>
</tr>
<tr>
<td>lJF</td>
</tr>
<tr>
<td>Pense</td>
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<tr>
<td>Cantuar</td>
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Risk Assessment of Kimberlite Diamond Grades

- Kimberlite phases have sufficiently distinct chemistry based on:
  - Degree of fractionation
  - Mantle contamination
  - Crustal contamination
- Geochemistry of phases within kimberlite clusters show distinct differences and associated diamond grades.
- Diamond bearing phases can be identified using posterior probabilities thereby assigning a measure of risk.
Predictive Geological Mapping
Melville Peninsula, Canada
(with David Corrigan, GSC)

Lake Sediment Sampling Sites
Process Validation
Linear Discriminant Plot of Lake Sediment Geochemistry code by Lithology

87% of the discrimination is accounted for in LD1 & LD2.

Accuracy of Lithological Classification based on Lake Sediment Geochemistry

Table 2
Linear Discriminant Analysis Accuracy (%)  

<table>
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<tr>
<th>Variable</th>
<th>Agd</th>
<th>Agu</th>
<th>Akg</th>
<th>Amgn</th>
<th>APWs</th>
<th>PHg</th>
<th>Ps1/2</th>
<th>Ps3</th>
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<td>Prior Probabilities</td>
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<td>0.2</td>
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<td>Overall Accuracy</td>
<td>60.60</td>
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Variable risk in correct assignment. Risk is qualified by the tabulation of the overlap.
Predictive Mapping
Posterior Probabilities

Forced class membership.
Membership to at least one class is guaranteed.
No accommodation for observations that do not fit any of the classes.

Predictive Mapping
Typicalites

Class membership based on $\chi^2$ distribution.
No class membership is possible.
Nueltin Lake NTS 65A/B/C
Lake sediment geochemistry

With Tony Peterson, Sally Pehrsson, GSC

Identification of the Nueltin and Hudson Granites.
Geology known for NTS 65A/B
Geology unknown for NTS 65C
Geology by Eade
Linear Discriminant Analysis based on logratio transform

Classification Accuracy

Classification Accuracy is variable – variable risk in identification
Predictive Maps
Posterior Probabilities

Principal Component Analysis of Lake Sediment Data

Identification of U & Th as functions of process (stoichiometry.)
Regression of U against PC’s 1-5

PC1-PC5 account for most data variation (lithology, physical processes).

Regression of Th against PC’s 1-5
Based on ilr transform

PC1-PC5 account for most data variation (lithology, physical processes).
Anomalous U-Th Based on Regression
Hudson Granite

Residual values derived from Regression.

Anomalous U-Th Based on Regression
Nueltin Granite

Residual values derived from Regression.
Lithogeochemistry of the Abibiti Greenstone Belt

Assessing Lithogeochemistry in a Regional Mining Camp

- Abitibi Greenstone Belt is one of the world’s most productive regions for Au and base metals.
- Large databases exist with geochemistry, geophysics, geology, assessment reports.
- Can these databases be used effectively despite major discontinuities in data quality?
- Large amount of risk in assessing regional geochemical datasets that have been compiled from many sources (Grunsky, 2013).
Exploration in an established mining camp

• How can existing geochemical data be re-evaluated in an existing mining camp?
• The assembly of diverse geochemical datasets is fraught with problems (censoring, missing values, incompatible media, analytical instrumentation etc.)

Methods for exploring legacy data

• Multi-element exploratory methods
  – Principal component analysis
  – Multidimensional scaling
• Alteration indices
  – ACNK \[\frac{\text{Al}_2\text{O}_3}{\text{CaO+Na}_2\text{O+K}_2\text{O}}\]
  – Ishikawa 100*\[\frac{(\text{MgO}+\text{K}_2\text{O})}{(\text{K}_2\text{O}+\text{MgO}+\text{Na}_2\text{O}+\text{CaO})}\]\n  – Normative Corundum
  – Additive metal index (Cu+Zn)
Evaluating legacy lithogeochemical data

- Merging legacy datasets requires extensive data adjustments
  - Correct for Fe$^{+3}$ & Fe$^{+2}$
  - Determine H$_2$O$^+$ & CO$_2$ from Loss on Ignition (LOI)
  - Evaluate missing values and censored data

Principal Component Analysis
Proxy Vectors of Alteration/Mineralization

Relative S Enrichment
Carbonatization
PCA - Carbonatization
Interpolation [kriging] based on irregular sample grid

Risk: CO2 is pervasive with regional alteration.

PC5 Relative S Enrichment
Interpolation [kriging] based on irregular sample grid

Risk: S is associated with many non-VMS environments
Metal Indices (Cu+Zn)

Risk: Background values are not filtered out

ACNK Alteration Index (feldspar alteration)

Risk: Many processes alter feldspars.
Alkali Alteration Index

Risk: Many processes alter ferromagnesian minerals and feldspars.

Normative Corundum
(excess Al – feldspar destruction)

Risk: Colinearity with ACNK and Alkali Alteration indices.
Base Metal Potential: Additive Index

Carbonatization + Sulphur + Metals + alkali alteration +
feldspar destruction + corundum

*Grunsky, 2013

Minimizing Risk

- Understand the source and nature of geochemical data.
- Understand the limitations in the data.
- Recognize the assumptions made when merging and processing data.
- The application of multivariate methods generally reflect processes controlled, in part, by stoichiometry (mineralogy) and physical processes (sedimentation/erosion). This enables the recognition of patterns/trends that are associated with lithologies.
- The prediction of lithologies/resources can be carried out when sufficient data and information are available to develop a probabilistic framework.
- A probabilistic framework provides a quantitative measure of risk that can be incorporated into instruments such as NI-43101 or JORC.
Acknowledgements/References

• Bruce Kjarsgaard, David Corrigan Tony Peterson, Sally Pehrsson (Geological Survey of Canada)


Risk assessment contribution from Remote Sensing and GIS within the mine lifecycle

Michel Rheault, M.Sc., P.Geo.
Michel.rheault@effigis.com

Success of mining companies

Linked to:

- Financial risk lowering
- Deposit discovery acceleration
- Social and environmental performance
Sustainable Development in the Mining Sector

Mining companies sustainable growing → Financial, technical and environmental performance

*Build Trust Relationship* between investors, shareholders and stakeholders

*Use up-to-date IT Technologies* for mineral exploration and discovery

*Reduce Environmental Footprint* and *Rehabilitate* mining sites

*Annual Reporting on SD* in accordance with international standards

---

Mine Lifecycle

```
START - Area selection

Year 1 ...

... Year N

CLOSURE - End of activities

EXPLORATION → DEVELOPMENT → PRODUCTION → RECLAMATION

Geospatial solutions to lower risk

GEOGRAPHY / GEOLOGY / GEOPHYSICS / CONSTRUCTION / TRANSPORTATION / ENVIRONMENT / LOGISTIC PLANNING / OPERATIONS
```
Data access

- Data quality assessment
- Data selection
- Data structuring
- Ready to be used
- Lowering the risk

Worldwide Data Warehouse

- mcan.gc.ca/sciences-terre/ (GSC)
- sigeom.mmf.gouv.qc.ca (QUÉBEC)
- geologyontario.mndm.gov.on.ca/ (ONTARIO)
- empr.gov.bc.ca/mining/geoscience/ (BC)
- ngmdb.usgs.gov/ngmdb/ (USA)
- ingemmet.gob.pe/ (PEROU)
- geoscience.gov.au/ (AUSTRALIA)
- brgm.fr/ (BRGM - FRANCE)
- bgs.ac.uk/geoindex/ (BGS – ROYAUME-UNI)
- glovis.usgs.gov/ (WORLD Satellite Coverage)
- etc...
EXPLORATION
- Mapping
- Resource assessment

DEVELOPMENT
- Design
- Construction

PRODUCTION
- Extraction
- Transportation and storage

RECLAMATION
- Rehabilitation
- Monitoring

Accelerate deposit discovery

<table>
<thead>
<tr>
<th>Time (years)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
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<tr>
<td>10</td>
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<tr>
<td>15</td>
<td></td>
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<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

REGIONAL EXPLORATION (10 years)
DEVELOPMENT (5 years)
Exploration

<table>
<thead>
<tr>
<th>Exploration</th>
<th>WHAT IS NEEDED</th>
<th>HOW TO SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Baseline land conditions (access, environment, planning)</td>
<td>- Satellite product</td>
</tr>
<tr>
<td></td>
<td>- Geological information (alteration, structure)</td>
<td>- Topographical map</td>
</tr>
<tr>
<td></td>
<td>- New data (geophysics, geochemistry)</td>
<td>- Land cover map</td>
</tr>
<tr>
<td></td>
<td>- Resource assessment (targeting)</td>
<td>- Mineral map</td>
</tr>
<tr>
<td></td>
<td>- Drilling data recovery and analysis</td>
<td>- Structural map</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Target map</td>
</tr>
</tbody>
</table>

Mineral mapping

Detection of mineral indicators related to lithological units or to hydrothermal alteration based on analysis of multispectral or hyperspectral data

- Acquisition of multispectral or hyperspectral data
- Spectral analysis to extract lithological information
- Reconnaissance of hydrothermal alteration
- Production of mineral maps
- Technical report
Gossan recognition in precambrian terrain

- Ferrigenous alteration mapping – 5m vs 50cm

Classification criteria:
- Colour
- Geometry
- Texture
- Lithological relationship

(G1) Ni-Magmatic Deposit
(G2) VMS Deposit
(G3) Iron Formation (BIF)

U exploration in sedimentary basin

- Lithological mapping
- ASTER multispectral data
**Geological Mapping**

Remote predictive mapping based on the integration and interpretation of satellite and geophysical data

- Integration of satellite and geoscience data
- Lithological and structural interpretation
- Production of lithostructural map
- Geological map update
- Technical report

---

**Lithostructural mapping – 1:250 000**

Au Exploration – Africa

*Image: Landsat 7, Magnetism + Spectrometry, Faults Architecture*
Lithostructural analysis – 1:50 000
Hydrocarbon Exploration – Eastern Canada

CRITERIA USED:
- Intersection / proximity to fault
- Presence of synvolcanic fault
- Fractures density (porosity)
- Fold hinge
- Extensional structure
- Rheological contrast (permeability)
- Lithological marker
- Quartz vein
- Alteration indicator (FeO, SiO2, CO3, K)

Lithostructural analysis – 1:10 000
Au Exploration – Africa
Mineral Potential Assessment

Mineral potential assessment through the integration of mineral, structural, geophysical and geochemical data

- Integration of mineral and structural information derived from remote sensing, geophysical and geochemical data in a predictive ore deposit model
- Analysis of spatial relationships between integrated parameters and their contribution in ore deposition
- Data modeling and targeting
- Mineral potential map
- Technical report

Data modeling considerations

<table>
<thead>
<tr>
<th>PROSPECTIVE AREA</th>
<th>TARGET DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large area coverage</td>
<td>Spatially heterogeneous data</td>
</tr>
<tr>
<td>Continuous data</td>
<td>Quantitative data</td>
</tr>
<tr>
<td>Homogenous data</td>
<td>Mature mining district</td>
</tr>
</tbody>
</table>

Homogeneous data
- DEM
- Satellite Data
- Magnetism
- Gravity
- EM
- Geology map
- Geochemical data
- Drill holes data
- Mineral occurrences

Discontinuous data
VMS potential assessment

- Mature mining camp
- Multiple parameters (> 20)
- Data modeling
- Target map (<5% of total coverage)

VMS Mineral potential map

VMS Assemblage

Sub-volcanic Intrusion

EXPLORATION
Mapping
Resource assessment

DEVELOPMENT
Design
Construction

PRODUCTION
Extraction
Transportation and storage

RECLAMATION
Rehabilitation
Monitoring
Development

<table>
<thead>
<tr>
<th>WHAT IS NEEDED</th>
<th>HOW TO SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Planning of site facilities implementation</td>
<td>- High resolution satellite product</td>
</tr>
<tr>
<td>- Design of infrastructures</td>
<td>- High precision topographical map (infrastructures)</td>
</tr>
<tr>
<td>- Construction implementation</td>
<td>- High precision land cover map (sensitive elements)</td>
</tr>
<tr>
<td>- Logistic operations (access, constraints)</td>
<td>- Input to EIA</td>
</tr>
<tr>
<td>- Continuous monitoring of operations</td>
<td></td>
</tr>
<tr>
<td>- Environmental impact assessment (EIA)</td>
<td></td>
</tr>
</tbody>
</table>

Land cover mapping

Detailed land mapping in support to Environmental Impact Assessment (EIA)

- Production of thematic information (up to 1/2000 scale)
- Sensitive elements:
  - Hydrology
  - Landscape
  - Biodiversity
  - Socio-economical aspects
- Qualitative / quantitative information
- 3D visualisation
- Communication tool between operators and stakeholders
Gold mine development - Africa

- WV-2 Data (50 cm)
- 4 Spectral bands
- Site reconnaissance

Coastal forest
Infrastructures
Artisanal gold mining

Gold mine development - Africa

- Thematic classification « object oriented »
- Calculation of surfaces / volumes
- Field data validation
- Land cover map
- Integration into EIA study
Production

<table>
<thead>
<tr>
<th>Production</th>
<th>WHAT IS NEEDED</th>
<th>HOW TO SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Water source management</td>
<td>- High resolution satellite product</td>
<td></td>
</tr>
<tr>
<td>- Blasting and related volume calculation</td>
<td>- High precision topographical map</td>
<td></td>
</tr>
<tr>
<td>- Material transportation and storage</td>
<td>- Water level and contour mapping</td>
<td></td>
</tr>
<tr>
<td>- Mine tailings disposal and management</td>
<td>- Environmental change detection map</td>
<td></td>
</tr>
<tr>
<td>- Environmental monitoring (leakage, terrain movement, infrastructure stability)</td>
<td>- Surface movement map (InSAR)</td>
<td></td>
</tr>
<tr>
<td>- Logistic operations planning (access, constraints)</td>
<td>- Infrastructure movement map (InSAR)</td>
<td></td>
</tr>
</tbody>
</table>
Mine production operations

Planning and management of open pit exploitation activities

- Site visualisation
- Production of high precision topographic information (up to 1/2000 scale)
- Volume calculation (ore, stockpile, construction material)
- Production monitoring
- Environmental monitoring

Bauxite mine - Africa

- IKONOS stereo data (1 m)
- High precision topographical mapping
- Infrastructure interpretation
- Fly through simulation
**Limestone quarry - USA**

- IKONOS stereo Data (1 m)
- Digital terrain model extraction
- Multidate DTM integration (2 years period)
- Volume calculation
- Validation of production operations

**Iron mine - Canada**

- WorldView-2 stereo data (50 cm)
- High precision DTM extraction over tailings
- Elevation contours at 50 cm interval
- Detailed hydrographic mapping
- Sedimentation monitoring
Base metal mine - Canada

- Permafrost conditions modification
- InSAR Interferometry with HR radar (>15 images)
- Monitoring of soil movements
### Reclamation

<table>
<thead>
<tr>
<th>WHAT IS NEEDED</th>
<th>HOW TO SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Rehabilitation plan definition</td>
<td>- High resolution satellite product</td>
</tr>
<tr>
<td>- Rehabilitation implementation</td>
<td>- Environmental change detection map</td>
</tr>
<tr>
<td>-Infrastructures dismantling</td>
<td>- Surface movement map (InSAR)</td>
</tr>
<tr>
<td>- Vegetation seeding</td>
<td>- Infrastructure movement map (InSAR)</td>
</tr>
<tr>
<td>- Environmental monitoring (terrain movement, vegetation growing)</td>
<td>- Vegetation stress map</td>
</tr>
<tr>
<td></td>
<td>- Erosion map</td>
</tr>
</tbody>
</table>

### Reclamation operations

Monitoring of rehabilitation operations and of stability conditions after closing

- Production of high precision thematic information (vegetation, infrastructures, mineral)
- Monitoring of rehabilitation conditions (vegetation stress)
- Monitoring of soil or infrastructures movement
- Support to decision-making
Bauxite mine - Australia
- QuickBird Data (60 cm)
- 4 Spectral Bands
- Revegetation operations
- Reconnaissance of soil anomalies
- Rehabilitation monitoring

Limestone quarry - USA
- IKONOS Data (1 m)
- 4 Spectral Bands
- Rehabilitation during production
- Integration into SD annual reporting
- Rehabilitation monitoring

“Site in production and restored at 40%”
Nickel mine - Canada

- Hyperspectral Data (5 m)
- >200 channels (VNIR)
- Rehabilitation during production
- Active vs inactive zones of residues
- Lime spreading
- Seeding operations

Source: J. Lévesque, MIR Télédétection

WHAT ARE THE BENEFITS?

IMPROVE DECISION MAKING PROCESS RESULTING IN:

- Better geological knowledge
- Better field work planning
- Better monitoring of mining operations
- Risk lowering
- Cost lowering
- Acceleration of deposit discovery
- Better communication between management and stakeholders
WHAT’S COMING IN SPACE?

Next HR Sensors

- Over 40 commercial EO satellites in 2020

OPTICAL:
- SPOT 7 (2014), 2 m
- WorldView-3 (2014), 30 cm
- GeoEye-2 (reserve), 35 cm
- Sentinel 2A et 2B (2014+18mois), 10 m
- others …

RADAR:
- RCM Constellation (2014), 3 m
- TerraSAR (2014-18), 50 cm
- PAZ (2015), 50 cm
- NovaSAR (2014), 6m
- others …
**Next HR Sensors**

**WorldView-3**
- Planned for 2014
- Mono and stéréo
- 16 multispectral bands

**TerraSAR-X (suite)**
- Launch to start in 2014
- 50 cm resolution
- Multiplied observations
- Enhanced interferometry
Creating value through exploration can be thought of as the conversion of natural capital to financial capital.

This economic view of exploration presupposes that we can maintain a positive cost-risk-reward balance.

In other words, we need to overcome the various risks and challenges so that in the long run -

More money comes out of the ground than goes into the ground.
Knowing how much money goes into the ground is the easy part. Ensuring a return on those funds (overcoming the risks) is the difficult part.

Converting interesting geology into profits for companies, shareholders and governments comes down to three key challenges:

- Knowing what you need to find both geologically and economically - the challenge of discovery risk
- Dealing with commodity market and capital market volatility – the challenge of financial risk
- Realizing the potential of new discoveries – the challenge of overcoming social risk and achieving development in conjunction with local communities
Discovery Risk

- In exploration, the challenge of making new economic discoveries is one of overcoming the low probability of success each time we generate a new target.
- In addition, we are faced with the ongoing reality of depletion of “easy to find” deposits.
- The cumulative effect of more than $100 billion worth of exploration activity in the past decade has been to expand the search area to virtually all corners of the world.
- The first step in overcoming discovery risk is to understand what it is that you are looking for with respect to minimum economic and geological characteristics.
- The second step is to determine where, how and if you can make new discoveries meeting these minimum conditions.

An Economic View of Discovery Risk

Exploration is the search not for new minerals, but for new cheaper deposits whose total finding-plus-development-plus-extraction costs will be lower than the long-run incremental development-plus-extraction costs on existing deposits, which are a ceiling or maximum economic finding cost.

Adelman 1970
Exploration as Hypothesis Testing

- Within each exploration environment, program and project, each time we make a go – no go decision, we are testing the hypothesis that:

  At Least One Economic Deposit Occurs Here

- What we should be endeavoring to do is:
  - Go when the hypothesis is true
  - No go when the hypothesis is false

Source: Mackenzie

The Essence of Exploration Success

- Overcoming errors associated with highly uncertain activities
- Error 1 – The False Negative
  - No Go when the hypothesis is in fact true (an economic deposit is there)
- Error 2 – The False Positive
  - Go when the hypothesis is in fact false (an economic deposit is not there)
False Negative

- Opportunity cost of rejecting an economic discovery because we are too selective too soon in the sequential exploration process
- This error can only be completely eliminated if we are prepared to fully explore each and every exploration situation
  - Saturation exploration
- Industry mentality - incredibly embarrassing if economic deposit found later by someone else

False Positive

- Direct cost of spending money exploring barren ground because we are not selective enough early enough in the sequential exploration process
- This error can be eliminated only if we don’t explore at all
  - Minimizing cost approach to exploration
- Industry mentality - little or no embarrassment associated with over-exploring a project

**Note: the following image may be disturbing to some viewers!!**
The Red Circle of Doom?

Exploration Decision Making

• Goal is to minimize the combined total cost of False Negatives and False Positives.
• The degree of selectivity exercised at the end of each exploration stage is of critical importance.
• Historically, industry focused on avoiding False Negatives due to low chances of finding economic deposits.
Known Deposits and New Discoveries
Knowing what we need to find

- If we don’t know what we need to find, then we will not recognize when we find it. Even more importantly, from a false positives perspective, we will not recognize when we do not find it.
- On this basis, we can examine the set of known undeveloped deposits as a guide to the minimum targets for future discoveries.
- We can put this information in the context of changing market and social conditions.
- Let’s consider the copper industry. What can the set of large scale development stage copper projects tell us about what we need to find for the next generation of deposits?
- How challenging is this discovery risk?

Known Development Stage Copper Projects

- Approximately 50 large scale copper projects have been advanced to the stage of prefeasibility or feasibility.
- We will use sets of these deposits where sufficient information is available to examine geological and economic characteristics.
- What can they tell us about what we need to find for the next set of economic copper discoveries?
- First let’s consider the tonnage grade characteristics of these deposits.
Tonnage Grade Distribution of Development Stage Copper Projects

Focus between 500 Mt and 2,500 Mt
• How many of these deposits would meet a minimum threshold of 12% IRR on an after-tax basis?

• As an attempt to normalize a wide range of assumptions in the economic assessments of the projects, we have used the following price assumptions:
  • Copper – US$2.75 per pound
  • Gold – US$1,200 per ounce
  • Silver – US$ 24 per ounce
  • Molybdenum – US$14 per pound

• We have also put all assessments on a US$2012 basis necessitating some escalation estimates for capital and operation costs from earlier economic studies.
Minimum Tonnage Grade Conditions

Copper vs Gold Copper
Financial Risk

- There are many aspects of financial risk that impact the exploration business – commodity prices, exchange rates, cost escalation, availability of risk capital.
- Let’s consider the changing state of the junior exploration sector as a measure of financial risk in exploration.
- In the junior world, the challenge of overcoming the time and cost of discovery risk depends on the ability to raise funds and survive long enough to advance projects through to delineation and feasibility.
- On the basis of overall expenditure levels, the junior sector has apparently been successful as it has accounted for more exploration than the major companies for much of the last decade.

[Graph: Worldwide Exploration Budgets by Company Type (US$ millions)]

Source: SNL-Metals Economics Group
Worldwide Exploration Budgets by Target (US$ millions)

Source: Metals Economics Group
Money into the Ground – Junior Explorers

- Where do the funds for all of this junior expenditure come from?
- The number, value and trend in junior financings provide the basis for the exploration expenditures shown in the previous graph.
- The following series of slides captures a 15-year window of financings for junior exploration companies.
Number of Junior Company Proposed/Arranged Financings
Exploration Stage Companies

Value of Junior Company Financings
Exploration Stage Companies
Proposed/Arranged (millions)

Source: Gamah International
A second key element in documenting the health of the junior sector is a consideration of working capital balances. How much money do companies have at their disposal to survive and advance their projects? The perilously low working capital balances at present for many junior companies have been pointed out by numerous researchers – most notably John Kaiser as shown in the following slide.

**Working Capital Balances of TSXV Companies**

- Total net WC: $47,447,540,712
- Total with positive WC: $53,226,868,255
- Total with negative WC: $53,710,062,043
- Before 01/16: $3,832,818,000
- $0-10: $2,000,000,000
- $10-20: $2,000,000,000
- $20-40: $2,000,000,000
- $40-60: $2,000,000,000
- Above $100,000,000: $2,000,000,000
Working Capital Balances

- Working capital balances for TSXV companies as highlighted in the Kaiser Report indicate that nearly half of juniors have a working capital balance below $200,000 as of mid-January 2014.

- A strong correlation is shown between share price and working capital balances. For companies trading below 10 cents per share, the total net working capital balance was nearly negative $1.5 billion dollars. Overall, the companies on the TSXV with negative working capital balances are carrying a total of $5.8 billion in debt.

Share Price, Market Capitalization and Dilution

- By its very nature, junior company exploration leads to the continual necessity for the issuance of new equity.
- Share prices reflect the success of individual companies as well as the general market trends and underlying commodity prices.
- The following series of slides captures the changing state of the junior mining sector by focusing on the mining companies listed on the TSXV over the past 10 years as a proxy for the health of the exploration sector.
TSX Venture Exchange Summary Statistics

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of Issuers</td>
<td>974</td>
<td>1,071</td>
<td>1,103</td>
<td>1,178</td>
<td>1,275</td>
<td>1,309</td>
<td>1,285</td>
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<tr>
<td>New Listings</td>
<td></td>
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<tr>
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<td>QT</td>
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<td>RTO</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>18</td>
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<tr>
<td>Other</td>
<td>19</td>
<td>17</td>
<td>25</td>
<td>43</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>86</td>
<td>149</td>
<td>152</td>
<td>109</td>
<td>109</td>
<td>65</td>
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<tr>
<td>Equity Capital Raised (C$M)</td>
<td>3,036</td>
<td>2,798</td>
<td>5,269</td>
<td>5,893</td>
<td>2,787</td>
<td>1,283</td>
<td></td>
</tr>
<tr>
<td>Number of Financings</td>
<td>1,382</td>
<td>1,567</td>
<td>2,110</td>
<td>1,803</td>
<td>1,450</td>
<td>1,207</td>
<td></td>
</tr>
<tr>
<td>Average Capital Raised (C$M)</td>
<td>2.20</td>
<td>1.79</td>
<td>2.50</td>
<td>3.27</td>
<td>1.92</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>Volume Traded (million)</td>
<td>7.477</td>
<td>27.178</td>
<td>31.200</td>
<td>46.641</td>
<td>45.507</td>
<td>24.971</td>
<td>26.653</td>
</tr>
<tr>
<td># of Trades (million)</td>
<td>1.204</td>
<td>3.65</td>
<td>3.66</td>
<td>6.55</td>
<td>9.05</td>
<td>4.67</td>
<td>2.61</td>
</tr>
</tbody>
</table>

TSX Venture Exchange Outstanding Share Distribution

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Total Shares (million)</td>
<td>20.100</td>
<td>26.970</td>
<td>31.855</td>
<td>42.096</td>
<td>55.618</td>
<td>59.206</td>
<td>65.372</td>
<td>78.404</td>
<td>93.824</td>
<td>95.327</td>
<td>91.572</td>
</tr>
<tr>
<td>Average Shares (million)</td>
<td>20.6</td>
<td>33.2</td>
<td>31.2</td>
<td>32.8</td>
<td>33.9</td>
<td>35.0</td>
<td>35.3</td>
<td>35.8</td>
<td>36.4</td>
<td>37.2</td>
<td>37.9</td>
</tr>
<tr>
<td>Issuers above 25 million shares</td>
<td>26%</td>
<td>40%</td>
<td>47%</td>
<td>35%</td>
<td>75%</td>
<td>75%</td>
<td>74%</td>
<td>76%</td>
<td>81%</td>
<td>78%</td>
<td>74%</td>
</tr>
<tr>
<td>Issuers above 50 million shares</td>
<td>6%</td>
<td>11%</td>
<td>14%</td>
<td>26%</td>
<td>39%</td>
<td>41%</td>
<td>42%</td>
<td>47%</td>
<td>53%</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>Issuers above 75 million shares</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
<td>11%</td>
<td>19%</td>
<td>22%</td>
<td>24%</td>
<td>31%</td>
<td>34%</td>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>Issuers above 100 million shares</td>
<td>1%</td>
<td>2%</td>
<td>3%</td>
<td>6%</td>
<td>9%</td>
<td>11%</td>
<td>14%</td>
<td>18%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
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</tbody>
</table>
### TSX Venture Exchange Statistics

#### Market Capitalization

<table>
<thead>
<tr>
<th>Year</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Market Cap ($million)</td>
<td>10512</td>
<td>12300</td>
<td>17680</td>
<td>34810</td>
<td>34495</td>
<td>8804</td>
<td>20440</td>
<td>40117</td>
<td>28357</td>
<td>19251</td>
<td>10802</td>
</tr>
<tr>
<td>Average Market Cap ($ million)</td>
<td>10.79</td>
<td>13.77</td>
<td>17.33</td>
<td>35.59</td>
<td>33.43</td>
<td>8.17</td>
<td>18.14</td>
<td>34.08</td>
<td>22.25</td>
<td>14.71</td>
<td>8.41</td>
</tr>
</tbody>
</table>

#### Share of Market Cap

<table>
<thead>
<tr>
<th>Category</th>
<th>Bottom 25% of Issuers</th>
<th>Bottom 50% of Issuers</th>
<th>Top 25% of Issuers</th>
<th>Top 10% of Issuers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>78%</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>78%</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>80%</td>
<td>61%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>80%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>77%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>77%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>77%</td>
<td>64%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>77%</td>
<td>59%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>79%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>79%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>79%</td>
<td>64%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>7%</td>
<td>81%</td>
<td>66%</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>7%</td>
<td>81%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>7%</td>
<td>84%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>7%</td>
<td>85%</td>
<td>65%</td>
</tr>
</tbody>
</table>

#### Share Price Distribution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Price</td>
<td>$0.52</td>
<td>$0.45</td>
<td>$0.55</td>
<td>$0.82</td>
<td>$0.63</td>
<td>$0.14</td>
<td>$0.30</td>
<td>$0.53</td>
<td>$0.31</td>
<td>$0.21</td>
<td>$0.12</td>
</tr>
<tr>
<td>Issuers with Price ≤ $0.05</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
<td>2%</td>
<td>3%</td>
<td>47%</td>
<td>15%</td>
<td>5%</td>
<td>19%</td>
<td>38%</td>
<td>54%</td>
</tr>
<tr>
<td>Issuers with Price ≤ $0.10</td>
<td>18%</td>
<td>20%</td>
<td>20%</td>
<td>7%</td>
<td>13%</td>
<td>71%</td>
<td>37%</td>
<td>19%</td>
<td>40%</td>
<td>60%</td>
<td>74%</td>
</tr>
<tr>
<td>Issuers with Price ≤ $0.20</td>
<td>40%</td>
<td>44%</td>
<td>43%</td>
<td>28%</td>
<td>35%</td>
<td>84%</td>
<td>63%</td>
<td>42%</td>
<td>66%</td>
<td>79%</td>
<td>88%</td>
</tr>
<tr>
<td>Issuers with Price ≥ $0.50</td>
<td>27%</td>
<td>24%</td>
<td>26%</td>
<td>41%</td>
<td>31%</td>
<td>5%</td>
<td>14%</td>
<td>26%</td>
<td>14%</td>
<td>8%</td>
<td>4%</td>
</tr>
</tbody>
</table>
Major and Junior Company Comparatives

- Many of the issues discussed above are not restricted to the smallest junior explorers.
- PWC showed that the 100 largest companies on the TSXV dropped by 44% from June 2012 to June 2013.
- As shown in the following slide, mining companies on the TSX also exhibited similar if less severe decreases.

---

### Exchange Statistics

#### TSX VENTURE MINING ISSUERS

<table>
<thead>
<tr>
<th>Year</th>
<th># of Issuers</th>
<th>MC ($million)</th>
<th>Total Shares (M)</th>
<th>Average MC ($M)</th>
<th>Avg. Shares (M)</th>
<th>Avg. Price/Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>974</td>
<td>10,512</td>
<td>20,100</td>
<td>10.8</td>
<td>20.6</td>
<td>$0.52</td>
</tr>
<tr>
<td>2004</td>
<td>995</td>
<td>12,300</td>
<td>26,970</td>
<td>12.4</td>
<td>27.1</td>
<td>$0.46</td>
</tr>
<tr>
<td>2005</td>
<td>1,020</td>
<td>17,680</td>
<td>31,855</td>
<td>17.3</td>
<td>31.2</td>
<td>$0.55</td>
</tr>
<tr>
<td>2006</td>
<td>978</td>
<td>34,810</td>
<td>42,096</td>
<td>31.6</td>
<td>43.0</td>
<td>$0.82</td>
</tr>
<tr>
<td>2007</td>
<td>1,032</td>
<td>34,495</td>
<td>55,618</td>
<td>33.4</td>
<td>53.9</td>
<td>$0.62</td>
</tr>
<tr>
<td>2008</td>
<td>1,071</td>
<td>8,804</td>
<td>59,206</td>
<td>8.2</td>
<td>55.3</td>
<td>$0.15</td>
</tr>
<tr>
<td>2009</td>
<td>1,103</td>
<td>20,440</td>
<td>65,372</td>
<td>18.5</td>
<td>66.4</td>
<td>$0.31</td>
</tr>
<tr>
<td>2010</td>
<td>1,180</td>
<td>40,117</td>
<td>78,404</td>
<td>34.0</td>
<td>73.6</td>
<td>$0.51</td>
</tr>
<tr>
<td>2011</td>
<td>1,275</td>
<td>28,357</td>
<td>93,824</td>
<td>22.2</td>
<td>72.8</td>
<td>$0.30</td>
</tr>
<tr>
<td>2012</td>
<td>1,309</td>
<td>19,251</td>
<td>95,327</td>
<td>14.7</td>
<td>71.3</td>
<td>$0.20</td>
</tr>
<tr>
<td>2013</td>
<td>1,285</td>
<td>10,802</td>
<td>91,572</td>
<td>8.4</td>
<td></td>
<td>$0.12</td>
</tr>
</tbody>
</table>

Source: TMX Group
Financial Risk Implications

- 74% of issuers on the TSXV had a share price of 10 cents or less by end of 2013.
- On a global basis, about one half of all junior companies were shown to have less than $200,000 in working capital as of November 30, 2013.
- If the bottom 50% of exploration companies disappeared from the TSXV, the market cap of the mining index would decrease by only 4%.
- Financings over the past two years indicate a sharp increase in the number of very small raises (less than $500,000) as companies focus on survival.

The downturn is not restricted to the smaller exploration juniors as we sharp decreases across both the TSXV and the TSX in terms of market cap and share price.

Furthermore, major companies have been passive on the investment in and acquisition of juniors as a result of their own financial issues over the past couple of years.

Global exploration expenditures reached new heights for both senior and junior companies in 2012 but dropped by more than 20% in 2013.
Social and Developmental Risk

- The challenge of realizing the potential value of new economic discoveries has become increasingly difficult and time consuming with greater scrutiny and community/NGO engagement.
- This challenge is being met with varying degrees of success by the exploration/mining industry.
- The implications of social and developmental risks are, however, not straightforward as they directly influence the timing of new mine production and the supply/demand/price/balance.
- Consider our set of known development stage copper projects.
Conclusions

• The challenges of creating wealth from exploration are effectively the same now as in the past.
• We are still faced with discovery risk, financial risk and social/developmental risk.
• The degree of risk, however, seems to increase with time.
  • The cumulative expenditure and discovery record increases the challenge of finding new economic deposits in terms of longer time and money commitments.
  • The risk taking junior sector that performs much of the grassroots exploration is suffering a capital crisis at the same time that senior companies are cutting costs and restricting acquisition activities.
  • The number of delayed/stalled/condemned projects continues to increase with the level of public scrutiny and community engagement.
• If risks have increased, then what about our ability to quantify and mitigate those risks?
  • For most companies and countries as well as the industry as a whole, understanding exploration risk does not appear to be a priority. Why is this?
  • The animal kingdom offers two possible explanations.
Head in the Sand

Elephant in the Room
Prospectors and Developers Association Of Canada (PDAC) - March 2-5, 2014

“THE PROSPECTOR MYTH - COMING TO TERMS WITH RISK MANAGEMENT IN MINERAL EXPLORATION”
(10 years Later)
John Gingerich
Geotechnical Business Solutions

After Rose: “Cry of the Lone Wolf”

Back in 2003

“THE PROSPECTOR MYTH - COMING TO TERMS WITH RISK MANAGEMENT IN MINERAL EXPLORATION”
Gouveia, Rose, Gingerich


The “Prospector Myth” is the primary reason why explorationists persistently overestimate prospect reserves—after all, such dedicated prospectors are born optimists: they could hardly be expected to be ruthlessly objective about their prospects!

Industry has dealt with the dilemma in various ways. A common solution pits geoscientists against engineers. Another encourages executives to exercise their exploration intuition to identify which prospects are to be drilled. Today, growing adoption of consistent prospect risking methods, together with 1) continuous improvement procedures comparing geotechnical predictions vs. outcomes; 2) revised criteria for success (creating value vs. getting the prospect drilled); and 3) an appeal to geotechnical professionalism, may offer practical remedies to the problem.
Risk? What Risk?

- Pre-2003 Industry pressured by Boards & Investors to Improve Performance, reduce cost
  - Downsizing, Strategic Planning, TQM, Six-Sigma, Risk Management, etc.
- Metal Super-Cycle hits and every marginal play is now “economic” (Price masks Risk)
- Industry Leaders abandon discipline – Growth at all cost – Emergence of “Investment Tiger”
- Geoscientists: Everything can be a mine (Prospector Myth at Play)
- Global Exploration spending goes from $2.5B to $15B in 5 years peaking over $20B.
- Impact of Metal Price that encouraged this spending: Waste converted to Ore
  - e.g. Average grade of gold mines fell from 4.6 gpt in 1998 to 1.1 gpt in 2012

Impact of Market Correction

- Capital and Operating costs escalate with demands
- Supply-demand balance softens price
- Financial Crises affect access to capital
  - The wake up from the NI 43-101 placebo
  - Being a Lower quartile and mid-tier producer now important (This was always Important!)
- Redefinition of Projects: Ore becomes Waste
  - Uncertainty of future price
  - Legacy of missed targets
  - Massive write downs
  - CEO’s punted; Anglo, RTZ, BHP, Cliffs, etc..
  - Venture markets punish Junior Miners
  - “Silence of the Lambs”
The Loss of Confidence

TSX Venture drops 1500 points in 3 years (2400 to 900), >60% drop

PDAC Website:
In 2012 expenditures on exploration dropped by $700,000 to $2.2 billion compared to $2.9 billion 2011 and are projected to decline further to $1.8 billion in 2013 – an almost 40 per cent drop. The number of junior financings in 2013 has fallen by approximately 25 per cent from 2012 levels, reaching the lowest level in 15 years, while the value of financings has decreased by nearly 60 per cent.

PWC Report Nov 4, 2013: Sean Kolenko; Business Vancouver
According to the report, the market capitalization of the top 100 junior firms – of which 64 are based in British Columbia – fell 44% to $6.5 billion, as of June 30, 2013. In 2012, the top 100 juniors fell 43% over the same period. The basis for the 100 firms tracked in the report was market cap.

The drop in market cap for junior miners mirrored the performance of the TSX-V on the whole – the aggregate market cap on the exchange fell to $11.1 billion as of June 30, 2013, down from $20.8 billion last year. The mining sector represents about 35% of exchange's market cap.

Cash is also scarce. Among the companies tracked, cash and short-term investments fell to $1.2 billion this year, down from $1.9 billion in 2012. The top 100 raised $795 million through equity financings in 2013, down 50% from the $1.6 billion raised in 2012.

NOT MY FAULT!

Whose Fault is it?
- Subprime
- Quantitative easing
- Tapering
- Manipulation of Gold price
- ETF's
- China
- NI 43-101

We are no more responsible for the global events that created the surge in spending, than its collapse. We are however accountable for the wealth creation and destruction based on the projected outcomes of our exploration/development assumptions. Supply-Demand is still at play. Projects are still being developed. Note; gold, iron ore, copper still trade 3-4 times their 2003 prices.

Peter Rose;
“If portfolio management is to succeed, each prospect must be assessed consistently and objectively. Geostatistics can deal with the inherent uncertainties—what kills the portfolio is bias.”
Massive exploration investment did not translate into value creation. If anything, evidence suggests exploration performance worsened.

Note: Budget > doubled in 1986 while exploration success rate halved.

Slide from 2003 talk

1990 - Decision to end intuitive exploration practices
Exploration Risk Management

After James MacKay 2003: Rose & Associates LLP

- Requires a consistent Process for the Accurate Quantification of Forecasts and Opinions
- These tools are to be used in an economic model for Decision Support
- Main Responsibility of Explorationists
  - Identify Commercial Prospects
  - Measure them Estimating
    - Chance of Success
    - Reserves contained
    - Profitability
  - Unbiased Estimates
    - Post mortems and audits

Exploration Risk Concepts are Not New

“Exploration Success Model”
(Andy Green, CSIRO)

- ~ 5% of targets are mineral occurrences
- Of those, 1-2% will evolve into economic deposits

1000-2000 targets need to be tested!

We have long recognized there is a Probability factor in discovery…. But we have never tried to quantify it

Perhaps not so much a warning we need to get better, but a yardstick by which we can measure/justify our failures
Understanding the Difference:
Chance of discovery, versus the chance the discovery is economic

The chance a discovery is commercial/economic

Understanding where/when to explore
Understanding how/why to explore

Chance of Failure

Most Exploration Projects Failures

Exploration failure and exploration success (economic, commercial, and geologic).

Assuming we have a reasonable discovery risk.. What is the chance it is economic?

- What the petroleum sector taught us is that mother nature has no bias….
  - There is a natural (log-normal) distribution of tons and grade
  - Analyzing camp, region, deposit type, etc., statistics will yield insight to the respective distributions (right hand part of last slide)
  - Applying a business model will produce target thresholds that applied to the distribution curves gives you the probability of success

http://www.academia.edu/3486051/The_black_art_of_valuing_mineral_properties
Distribution of VMS Deposit Size within The Abitibi Greenstone Belt

Distribution of Average VMS (Grade) NSR values in the Abitibi
e.g. Porphyry Mineral exploration. Chance of a successful “Prospect” In Chile

**Geologic Requirement**
- Geology (age)
- Structural controls
- Cu porphyry intrusive
- Phyllic Overprint
- (preserved) supergene enrichment

**Chance of Success**
- Geology (age) = (0.7 - 0.95) 0.9
- Structural controls = (0.6 - 0.95) 0.8
- Cu porphyry intrusive = (0.05 - 0.15) 0.1
- Phyllic Overprint = (0.1 - 0.5) 0.3
- (preserved) supergene enrichment = (0.05 - 0.75) 0.6

Chance of a discovery = 0.9x0.8x0.1x0.3x0.6 = 1.3%

Chance of it being economic is derived from separate geostatistical analysis

---

**Chance of Success: Understanding Risk Focusing on the Right Problem**

**Cost of target opportunity in Chile**
- Comparing costs from 1997-1998 using traditional methods to 1999-2001 period using hyperspectral, there was over a 15 fold decrease in the cost to identify a new porphyry and acquire a property.

**Geologic Requirement**
- Geology (age)
- Structural controls
- Cu porphyry intrusive
- Phyllic Overprint
- (preserved) supergene enrichment

**Chance of Success**
- Geology (age) = (0.7 - 0.95) 0.9
- Structural controls = (0.6 - 0.95) 0.8
- Cu porphyry intrusive = (0.05 - 0.15) 0.8
- Phyllic Overprint = (0.1 - 0.5) 0.8
- (preserved) supergene enrichment = (0.05 - 0.75) 0.6

Chance of a discovery = 0.9x0.8x0.8x0.8x0.6 = 28%

72% chance the project will fail.

More Tools Available Today

- Borrow from the Oil & Gas Sector
  - Probabilistic tools (geostatistics, Bayesian probability, etc.)
- Borrow from GIS/Expert Systems
  - Fuzzy logic, etc..
  - Spatial tools (3D)
- Predictive Mapping (now employed)
- Fraser Institute, others (Gives us a Country Risk model)
- Use PEM (Predictive Economic Model) before PEA
- Probabilistic pricing Forecasts (structured solution for Continuous Improvement)
- Six-Sigma (has elements to be borrowed as well)
  - Philosophy - 70% rate of improvement
  - Statistical measurement - you can control what you can measure
  - Business strategy – Structured approach for characterizing, then optimizing a business process
  - DMAIC process similar structure – Business Improvement starts with Mapped Process (Define, Measure, Analyse, Improve, Control)

Learning from Others

GE’s Six-Sigma Program now widely used
Noranda, PDC, Bechtel, ..., BHP, RTZ, etc…

- Philosophy - 70% rate of improvement
- Statistical measurement - you can control what you can measure
- Business strategy – Structured approach for characterizing, then optimizing a business process
- DMAIC process similar structure – Business Improvement starts with Mapped Process (Define, Measure, Analyse, Improve, Control)

While process improvement methodologies are widely embraced in the Mining Industry as a critical factor for their operations being cost competitive, Exploration that underpins one of the most important components of corporate growth is still largely driven by the “Hero Journey” or heuristic approaches and resists the notion the unpredictable nature of discovery is in fact predictable and the Exploration process can be defined, measured, analysed, Improved and controlled.
The Future of Risk Management

• Is Mineral Exploration truly Gambling and no way to win against the house (Mother Nature)?

• Are we really looking for Solutions to our performance within or is it someone else’s fault?

• Do we believe we need to get better?

Exploration Addiction

Unfortunately DT’s Are not over

Steps to Rehab

• Denial
• Recognition
• Preparation
• Action
• Maintenance

In took over 5 years for the Oil Industry to Embrace Risk Management Strategies Are we Ready for Change?
Why I am Pessimistic. We were here before

Mineral Industry had recognized the same trends seen in the Oil Industry. Nothing like a super-cycle in metal prices to numb that pain.

![Graph showing declining world discovery rates](source)


“THE PROSPECTOR MYTH - COMING TO TERMS WITH RISK MANAGEMENT IN MINERAL EXPLORATION”

10 Years Later

Risk and Uncertainty in Mineral Exploration Implications For Valuing Mineral Exploration Properties, AIG news 2010 (Etherbridge, Kreuzer)

The argument against the use of probabilistic methods in mineral asset valuation is their apparent lack of transparency (Lawrence, 1994; Thompson, 2001). However, this statement is at odds with the petroleum industry example where the adoption of systematic risk analysis in the early 1990s has brought objectivity, consistency and greater transparency to asset valuation (Rose, 1999, 2007).

Probabilistic methods are not black box approaches. They are proven analytical tools that in the words of Murtha (2000) “combine the principles of probability and statistics with sources of data and expert opinion to try and quantify the uncertainty and risk associated with an investment opportunity […] Informed decisions require analysis of the ranges of possible outcomes and their implications” rather than a single deterministic number. As such, probabilistic methods are well suited to meet the challenges of our industry and help to increase the effectiveness of our exploration investments and decisions, and of valuations of mineral exploration properties.
**Same Conclusions: Implications of Risk Analysis and Portfolio Management**

- Geologic risk is measurable (estimating is possible).
- We can develop probabilistic models from measured geotechnical data.
- It is possible to convert geologic concepts to business models using risk analysis tools.
- You can reduce (eliminate) motivational bias. Projects (irrespective of deposit type/commodity) can then be objectively managed with respect to economic risk.
- We have tools by which to better understand/implement exploration strategies.
- Portfolio management tools can then be used to align projects with corporate/investor objectives.

*The Alternative = Definition of Insanity: Doing the same thing over and over and expecting a different outcome.*

---

**Reality Check: I will See you in 10 years**

- From 2000 to 2002 a review of Industry Trends in Exploration Indicated a need to get better. The geotechnical Community were preaching the substantial gains being made in “exploration targeting” while value creation was in fact getting worse… Seemed like we were solving the wrong problem!

- After researching what was being down in the Oil and Gas sector, I tracked down Peter Rose of Rose & Associates LLP in 2002 with the idea of championing the migration of Risk Management concepts into the Mineral Industry. Peter called me a “Lone Wolf” and expected little to come of my efforts;
  - Risk management is about making middle and senior management accountable for their exploration investment decisions. No one willing to surrender “their turn to make decisions (be the Hero)”. Not until the CEO’s and Boards invite you present is your industry ready.

  Sadly; 10 years later and nothing has changed.
The Human Factor in Mineral Exploration Risk

DMEC Workshop
PDAC March 5, 2014

Ken Witherly
Condor Consulting

The human factor

Reasons for poor technical choices

- Lack technical knowledge
- Lack of experience
- Lack of time
- Oversimplification of problem
- Too much data, not enough analysis
- “Green/red light” problem
- I can’t find the keys
The human factor

- Exploration
- Resource evaluation
- Development & production & remediation

Reward

Risk

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The human factor

Formulation of goals

Commodity

Terrain

Budget/exploration strategy

Formulation of models and gathering of information

Prediction and extrapolation

Planning of actions; decision making, and execution of actions

Review of effects of actions and revision of strategy

Commodity

• Commodity

• Terrain

• Budget/exploration strategy

\[ C + T = R \]
The human factor

- Commodity
- **Terrain**
  - Budget/exploration strategy

Brownfield  Greenfield

\[ C + T = R \]

---

The human factor

- Commodity
- Terrain
  - **Budget/exploration strategy**

\[ C + T + (B \times E) = \text{Risk} \]
The human factor

- Models
- Data

Traditional

\[ C + T + (B \cdot ES) + M = \text{Risk} \]

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Higher “risk”

\[ C + T + (B \cdot ES) + M = \text{Risk} \]

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The human factor

- Models
- Data

- What types?
- How extensive?
- Level of processing?
- In-house/external?

\[ C + T + (B \cdot ES) + M + D + I = \text{Risk} \]

Prediction and extrapolation

Interpretation

\[ C + T + (B \cdot ES) + M + D + I = \text{Risk} \]
The human factor

- Follow-up and or...
- Drilling

Planning of actions; decision making, and execution of actions

IQ vs. NQ?

\[ C + T + (B \times ES) + M + D + I + F + D = Risk \]

The human factor

- Follow-up Assessment

Review of effects of actions and revision of strategy

\[ C + T + (B \times ES) + M + D + I + F + D = Risk \]
The human factor

• Follow-up Assessment

Review of effects of actions and revision of strategy

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It's fine to celebrate success but it is more important to heed the lessons of failure. Bill Gates

© Condor Consulting 2014
The human factor

- **Case Study 1-Abitibi VHMS 1999-2007**

With declining reserves in various major base metal deposits in the Abitibi, Noranda undertook a major program of exploration that lasted 8 years.
The Strategy

• 1. New Technology
   - Re-flying of extensive regional new airborne
   - Tests and recent discoveries (Perseverance) highlighted significant step in technologies (MEGATEM system)
   - Efficient generation of drill targets with this new advanced technology
   - Involvement in technology development (Fugro).
   - Historical database.

• 2. Low cost
   - Exploration costs very low at that time.
   - The Quebec government assistance for exploration in the mining sector:
     - The exploration net cost, all deduction included in a ratio 5 to 1.
     - Capital cost for mining development relatively low due to established infrastructure.

• 3. Partnership with juniors
   - The partnership has been favored to reduce exploration cost and risk.

The largest systematic exploration project in Canada – ever!
The human factor

Historical AEM Performance
Best Case prospected ground coverage

1975 = 10%
1990 = 46%
2000 = 100%

The human factor

Perseverance - MEGATEM Discovery

Noranda Pick

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The human factor

- Early success at Perseverance was taken as a validation of the approach.
- Geological modeling was left fairly ‘basic’ with some simple statistical assumptions as to distribution of deposits at depth.
- Geochemical screening was not as reliable as hoped for.
- Follow-up drilling was limited.
The human factor

- **Case Study 2-Athabasca Basin-Where to Next?**

The Athabasca Basin produces about 30% of the world’s uranium and has the highest grade deposits being mined.

Exploration in the past decade has pushed further into the center of Basin where the sandstone depth exceeds 1 km; exploration is very expensive and has produced few returns in the past decade.
The human factor

DMEC workshop series: Risk in exploration: Measuring it and how to avoid ruin

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The human factor
Synthetic Alteration added to measured data

The human factor

Inverted Density Model

... with “Alteration Chimneys” added to data before inversion

Possible Alteration Chimneys Near Major Faults

The human factor

Discrete density highs
Located near Black Lake Shear Zone. NB under a lake

Discrete density low
The human factor

- Early success on margins of Basin and a robust targeting model using EM resulted in a number of early ‘wins’.
- As the environment matured and interest increased, new groups were forced to work in deeper parts of Basin in quest of the ‘traditional’ model.
- While new styles of model proposed, hard to break free of ‘tried and true’ even if no longer viable.
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