Cost Benefit Analysis of Genomics for Mining

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Or…

An Evaluation of Potential Genomic Applications in the Mining Industry

Presentation Overview

1. Genomics as a tool
2. Evaluation Approach
3. Background on Scenarios and Outcomes
4. Concluding remarks

???

1. Genomics as a Tool

- Genomics definition: *a science that aims to decipher and understand the entirety of the genetic information encoded in an organism's DNA and corresponding complements such as RNA, proteins, and metabolites.*

1. Genomics as a Tool

- Interpreted: a tool to help better understand how biology functions
  - Identification
  - Response to change
  - Optimization
  - Etc.

- Genomics definition: *a science that aims to decipher and understand the entirety of the genetic information encoded in an organism's DNA and corresponding complements such as RNA, proteins, and metabolites.*

1. Genomics as a Tool

- Why do we need another biological tool?
  - Only 1% of microogranisms can be cultured, so we're missing 99% of the picture
  - For macro-biology, dependent on samplers schedule and experience – so species not conveniently present or mis-identification
  - Unravelling what biology can do and what impacts it

1. Genomics as a Tool

- What do you need to know?
- Many of us use ICP – but how much do we know about plasma and electron orbitals?
- Partnerships are the way forward…but then that's why many of us are here

2. Evaluation Approach

- SRK study evaluated the potential economic benefits of biological optimization *using genomics* for three scenarios:
  - Bio-oxidation (ore processing)
  - Passive Water Treatment
  - Closure and Reclamation
  - *None involve genetic modification….*

- Not a priority ranking and a suite of other opportunities identified from exploration geochemistry to baseline studies – and not just microorganisms…

3. Scenarios – Background and Outcomes

- Bio-oxidation or Bio-leaching
  - A process that uses bacteria to oxidize refractory sulphide ore
  - Bacteria are catalysts – transfer electrons from sulphide to CO_2 to make organic carbon
  - Acidic, aerated, and moderate temperature (40°C)
  - Can be in stirred tanks or heap-leach
  - Gold is most common, although any deposit that requires oxidation has potential
  - 'Competition' is pressure oxidation – higher throughput, higher recovery, but more expensive

3. Scenario: Bio-Oxidation

- Timely…
  - CIM article October 2014 – “Keep the gold bugs happy”

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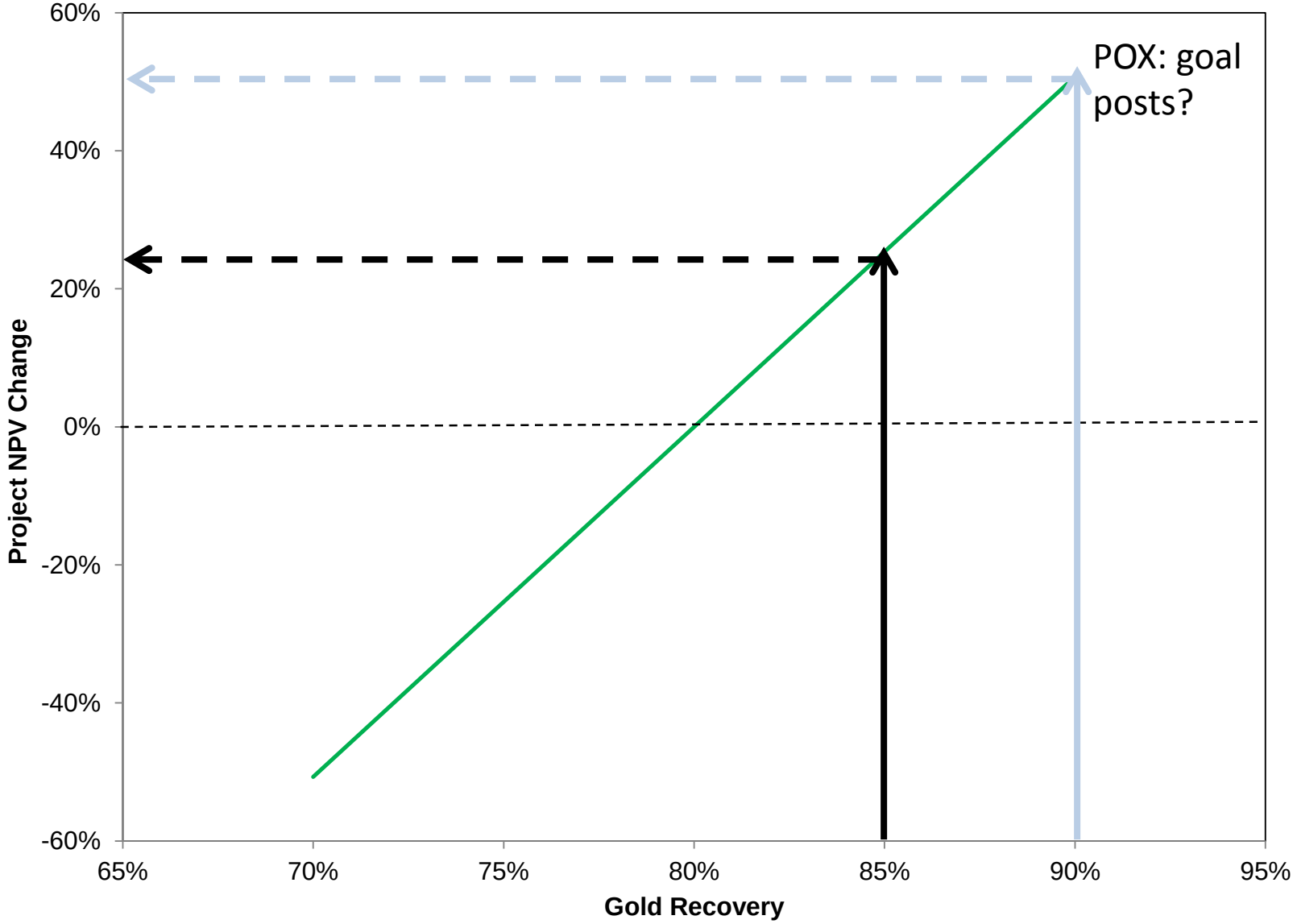
3. Scenario: Bio-Oxidation

3. Scenario: Bio-Oxidation

- Evaluation Inputs
  - Re-processing of tailings deposit – full details in paper
  - Economic model used to evaluate – hypothetical but realistic
    - 80% recovery
    - 1.5 g/t @ US$ 1,170/oz
    - CostMine (2013) inputs
    - 10 year mine life…etc

3. Scenario: Bio-Oxidation



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3. Scenario: Bio-Oxidation

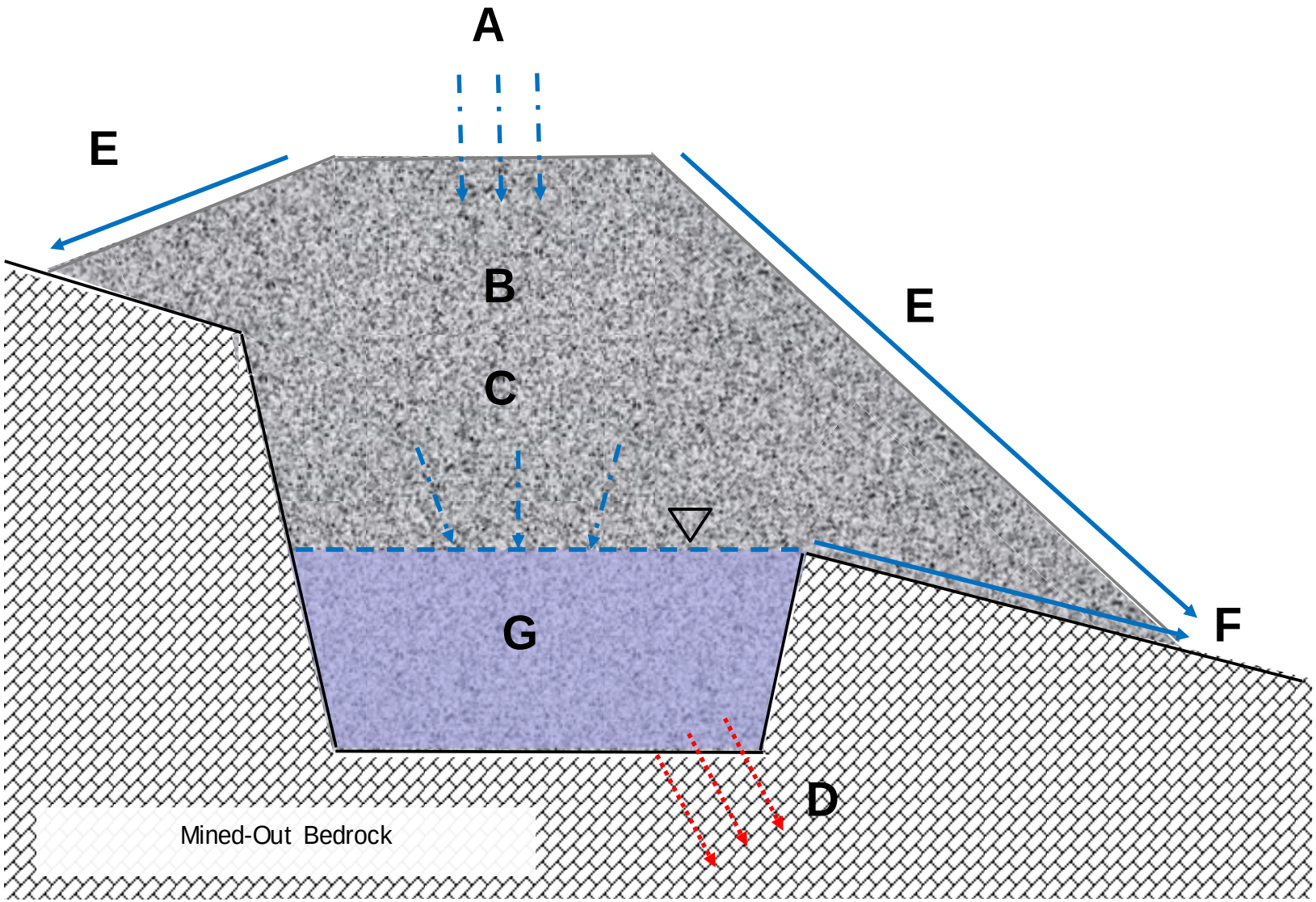
- Heap leach
  - Much lower recovery – higher potential for gain?
  - Copper – still major challenge to get much above 60%

- So where does genomics fit in?
  - Provides the means to optimize and improve rate limiting steps – to date mostly a action-reaction approach
  - For example, faster reaction rate, more complete oxidation, and faster adaption to changing ore feed

3. Scenario: Passive Water Treatment

- Bacteria as catalysts
  - ‘Reduction’ using organic carbon and respiring on oxidized constituents like nitrate, selenate, ferric iron, sulphate, etc.
  - Scenario looked at backfilled open pits that have some portion of the waste rock water saturated – aka saturated rock fill (SRF) – supports anaerobic bacteria
  - Specifically for removal of selenium from mine waste contact waters in British Columbia coal fields – selenium redox chemistry affects solubility

3. Scenario: Passive Water Treatment



3. Scenario: Passive Water Treatment

- SRF compared to Fluidized Bed Reactor (FBR)(which is also biological)
  - MEND 2014 report for FBR costs (costs quoted in Globe article double)
  - Conservative CAPEX costs for SRF – injection and monitoring wells + haulage
  - SRF technology still being developed, but based on experience with open pit configurations in coalfields

3. Scenario: Passive Water Treatment

Treatment Method	CAPEX (M)	OPEX (M)	NPV (M)
Fluidized bed reactor	$46	$12	$198
Backfilled pit	$10	$8	$112
Savings*	$36	$4	$86

* Per facility….so if you need 6 FBR plants for your operations that's $516M…

3. Scenario: Passive Water Treatment

- Where does genomics come in?
  - Full scale implementation not yet realized
  - Genomics needed to advance the research and develop process
    - Tolerance of microbial community to freshet and other chemistry changes
    - Rate limiting steps
    - Stakeholder and regulatory explanation – deciphering the black box
    - Eventually also as a monitoring tool to ensure the system operates as designed – no other tool to do this.

3. Scenario: Closure & Reclamation

- Covers often placed on mine waste at closure

- Depending on design and cost, they can meet a number of functions from dust suppression to inhibition of oxygen diffusion (sulphide oxidation)

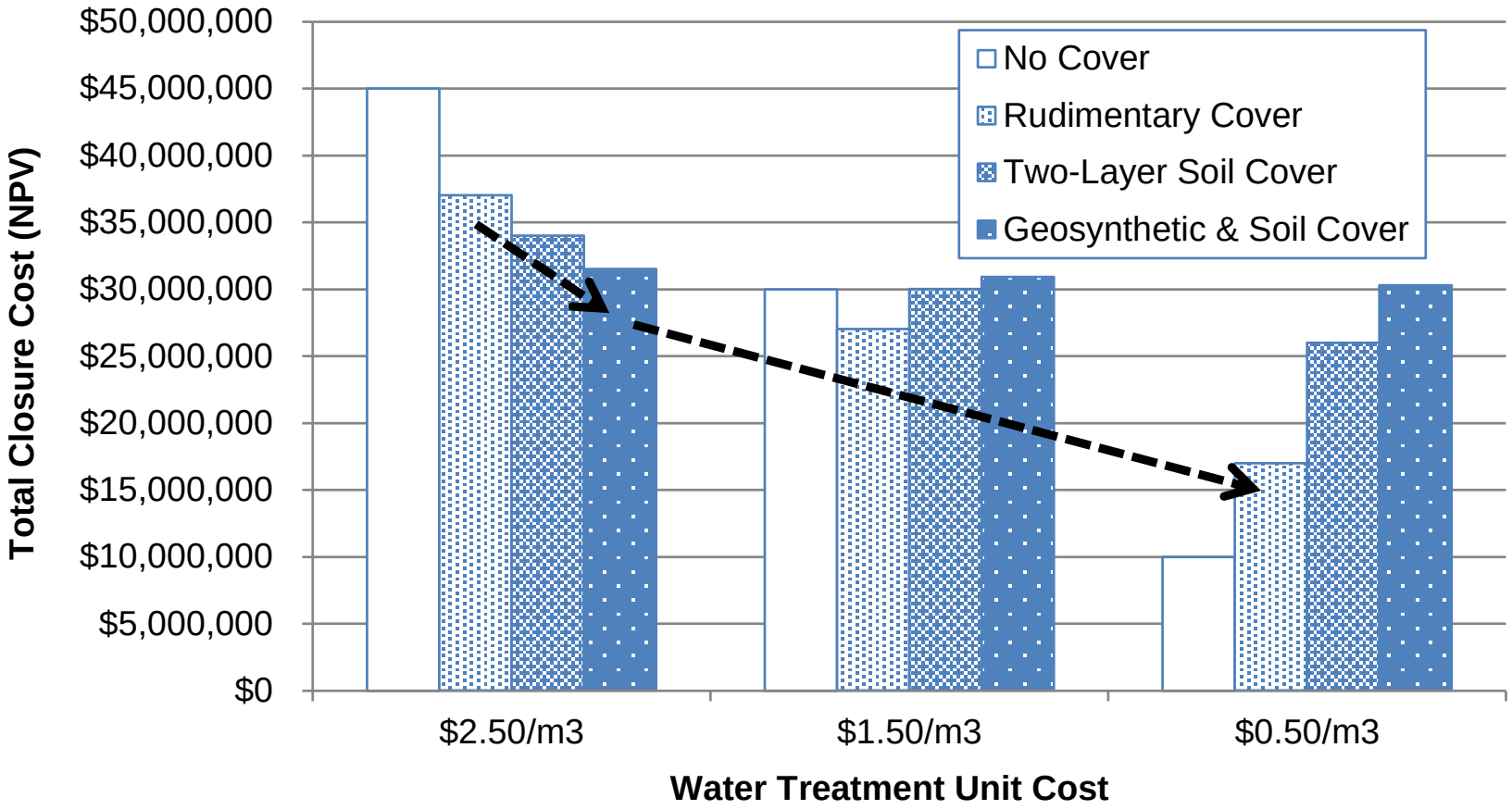
3. Scenario: Closure & Reclamation

- Covers can change moisture content and gas diffusion profile
- Changing physical conditions could support different microbial communities
- In-situ treatment (like SRF) or gas inhibition all together

3. Scenario: Closure & Reclamation

- Scenario based on experience with northern mines and covers used to inhibit ARD
- Considerations – Tailings Cover
  - 150 ha plan area
  - 800 mm of precipitation – 50% to 1.5% infiltration
  - Rudimentary cover = $80,000/ha
  - Two-layer = $160,000/ha
  - Geosynthetic = $300,000/ha (typically needed to stop sulphide oxidation)
  - Water treatment base case of $2.50/$m^3$ – but decreases with better cover performance

3. Scenario: Closure & Reclamation



3. Scenario: Closure & Reclamation

Cover Type	CAPEX (M)	OPEX (M)	Total (M)
Geosynthetic Cover	$30	$2	$32
Rudimentary Cover	$12	$0	$12
Savings*	$18	$2	$20

*per facility

3. Scenario: Closure & Reclamation

- Genomics role:
  - Provide understanding on how microbial communities in soil respond to covers – positive and negative effects
  - Opportunity is to get a rudimentary cover to perform like a geosynthetic one
  - ‘Layer cake’ of microbial communities

4. Concluding Remarks

- Role for genomics seems only limited by the number of mining-biology interactions that exist
- Project economics could be increased, or cost savings realized
- Economic benefits in addition to much more sustainable long term options
- Opening up ‘black box’ of biology to all interested parties should not be underestimated

5. Acknowledgements

- Genome BC and OGI – funding and connections
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