Waste Liberation: Improving mill feed from a miner's perspective

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CIM ICM CIM2018 CONVENTION
Vancouver, BC | May 6-9

Outline

- Introduction
- Ore Deposit Heterogeneity
- Impacts of Mining Scale
- Waste Liberation
- Mining and Pre-concentration Solutions
- Conclusions

Introduction

- Heterogeneity:
  - Inherent in ore deposits; scale varies
  - Masked in block modeling
  - Blended out for consistent mill feed
- With mass mining, increased SMU/block size means:
  - Introduction of waste
  - Further smoothing and reduction of grade
  - Reduction of heterogeneity
- But heterogeneity should be exploited to remove waste early in the mining process
- So how do we identify such waste?

Waste Liberation

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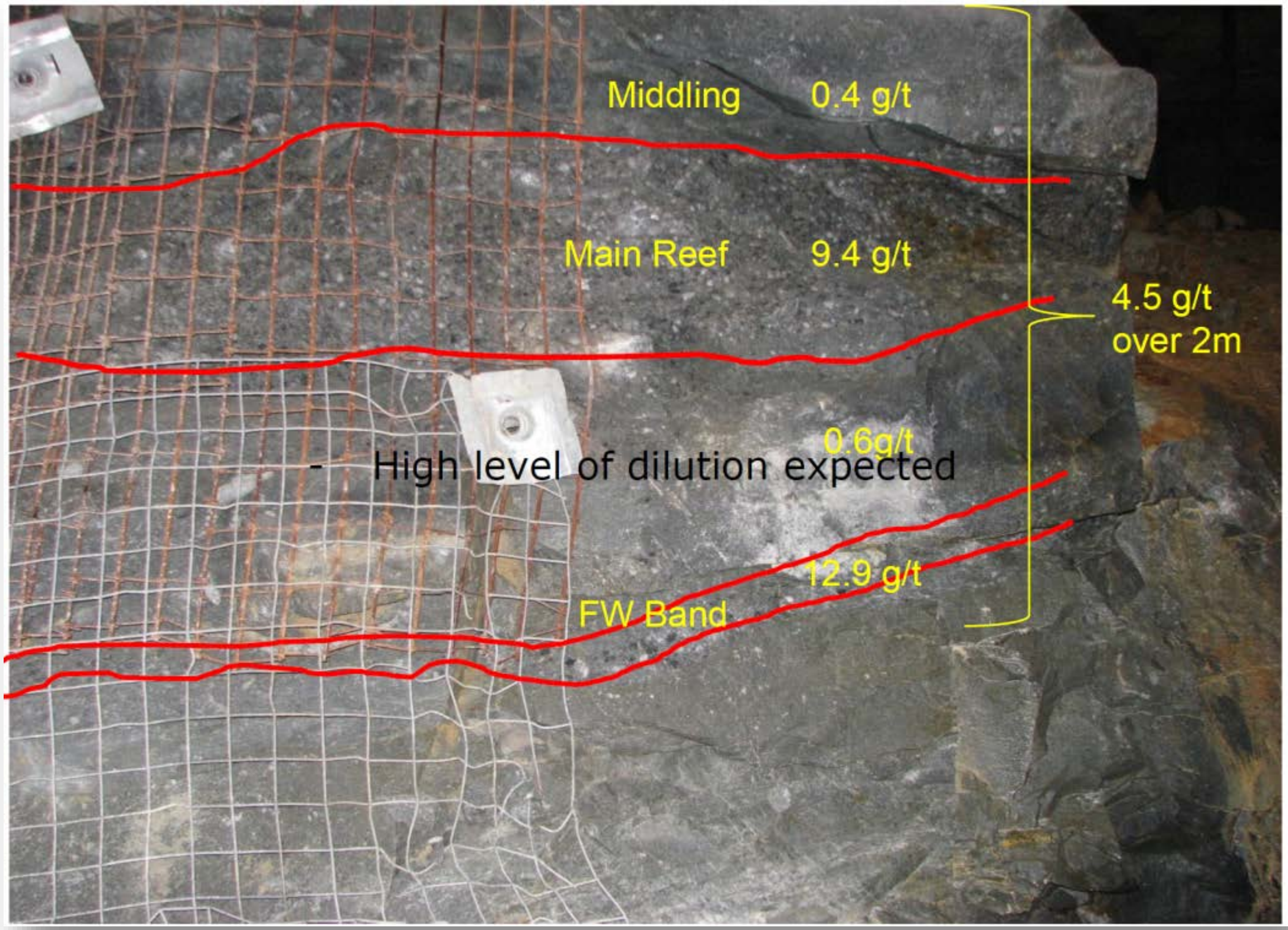
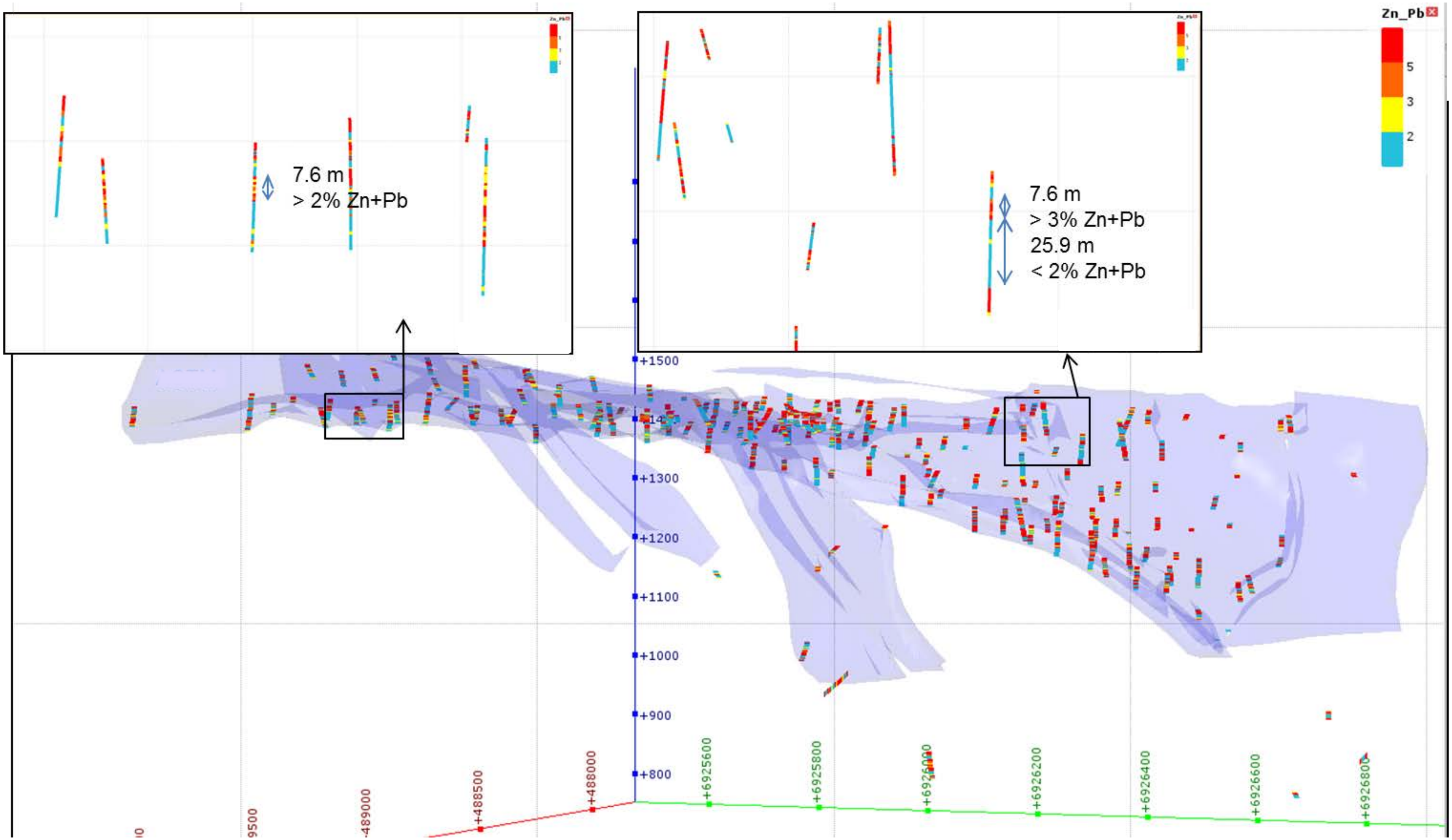
Orebody Heterogeneity – Au Reef



Source: Dance, 2015 (per Commodas Ultrasort, 2011)

Orebody Heterogeneity – Zn-Pb SEDEX

- Spatial distributions – 0-2% vs >2%



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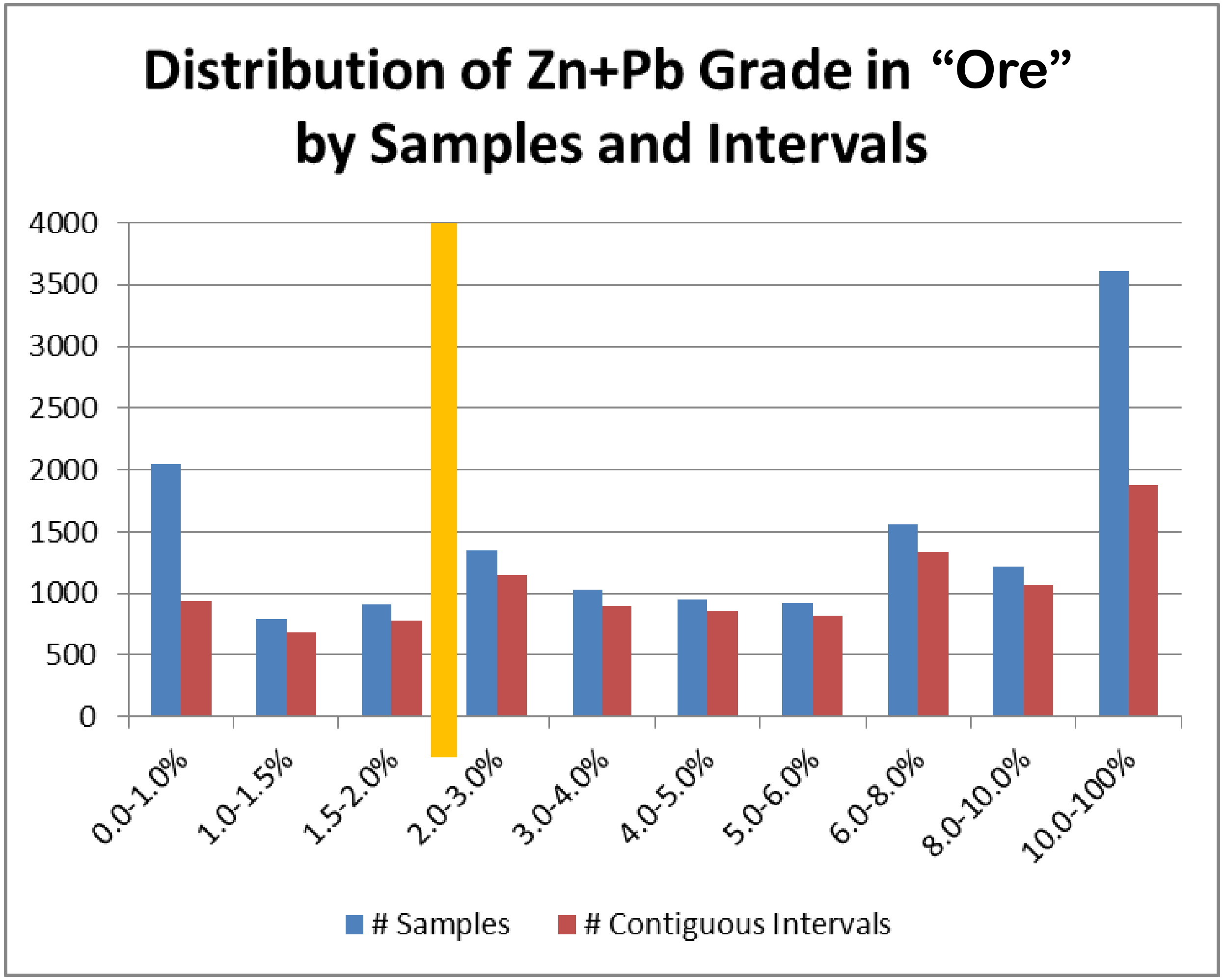
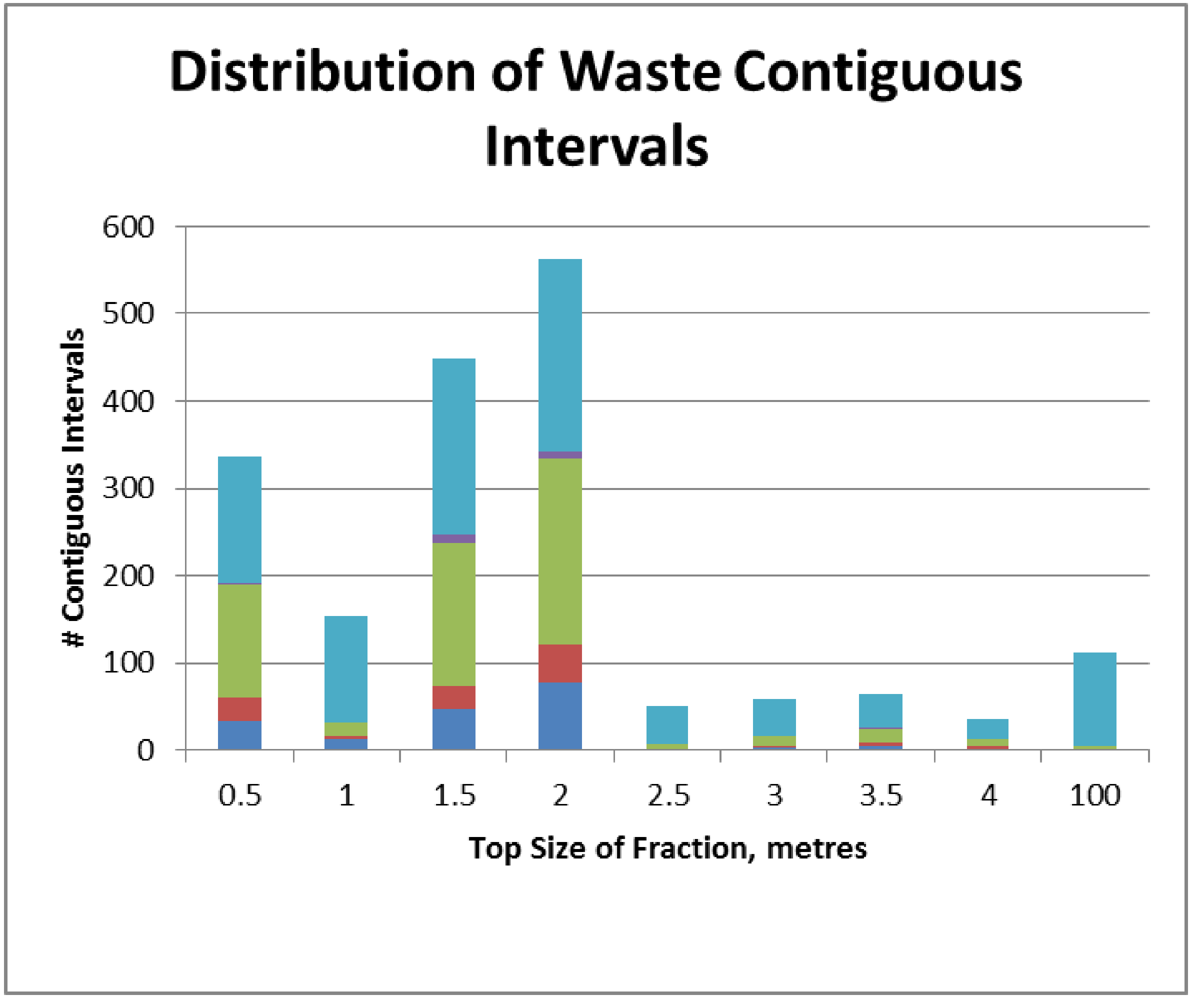
Core Hole Evidence of Heterogeneity

- Sample intervals vs Contiguous intervals in ore zone



Core Hole Evidence of Heterogeneity

- Looking only at the waste (<2% Zn+Pb) in ore zone



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Core Hole Analysis

- Down hole analysis technique:
  - Aggregating lengths of samples
  - Every sample point can be interpreted in the context of multiple aggregation lengths (similar to composites)
  - The sample point is tested as to whether it is in an aggregate of “ore” or “waste” for varying cut-offs.
  - The sample point itself is compared to the aggregations to determine if it is “waste in ore” or vice versa

- Heterogeneity Calculation:

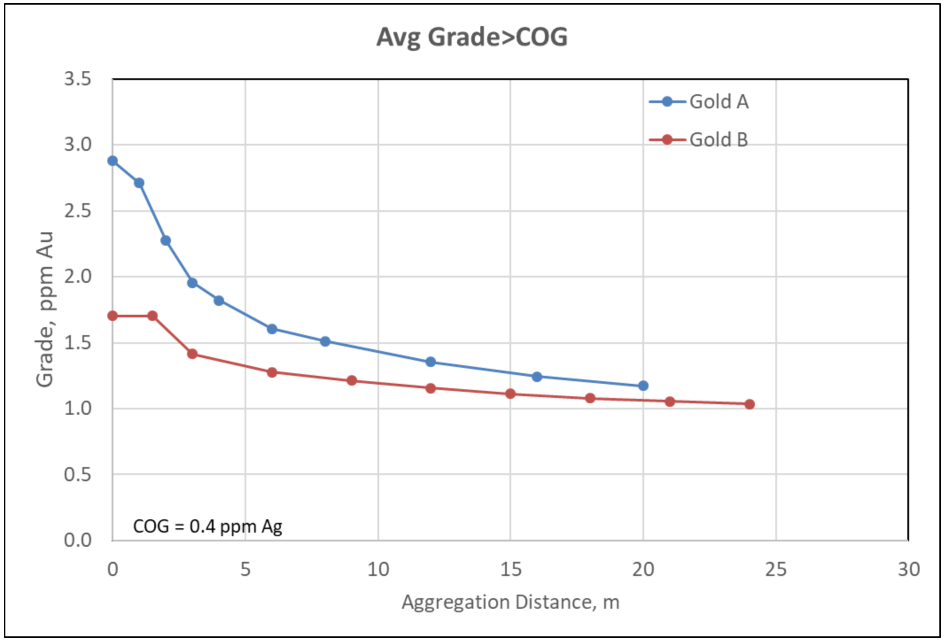
$$DH^{*} = N_g * (\Sigma (a_i - a_L)^2 \times M_i^2) / (a_L^2 \times M_L^2)$$

Where N_g is the number of groups (aggregations), α_i and α_L are the grades of group *i* and lot, respectively, while M_i and M_L are the masses of group *i* and the lot.

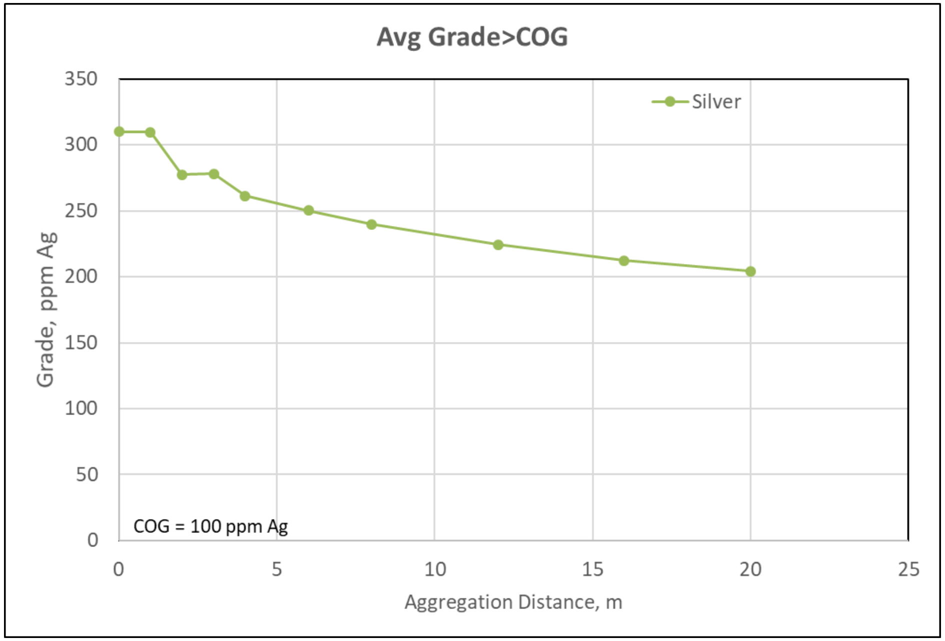
* - Distribution Heterogeneity for a dimensionless lot (per Gy, described by Pitard, 1993)

Mining Scale and Average Grade

Gold Property A&B



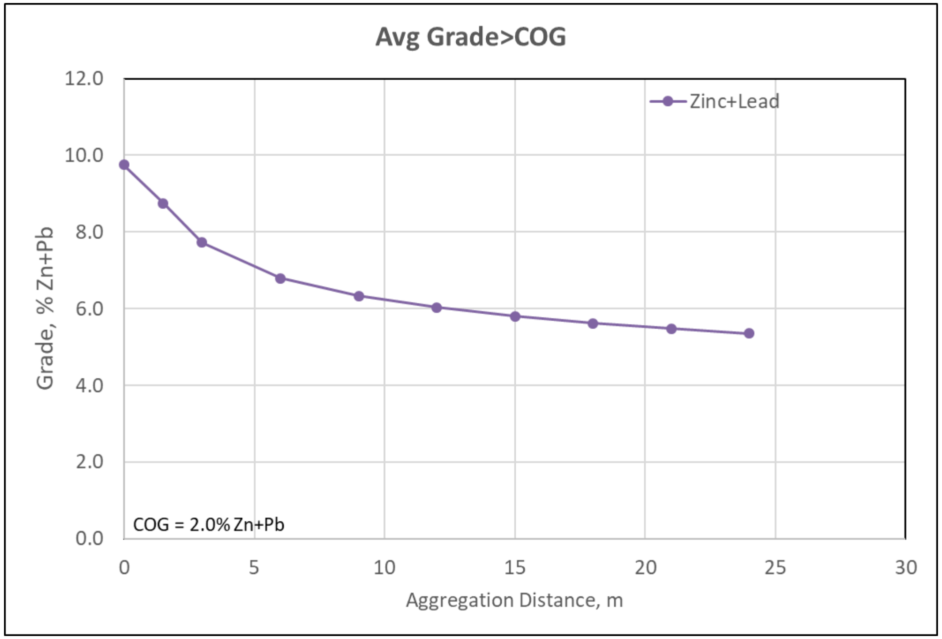
Silver Property



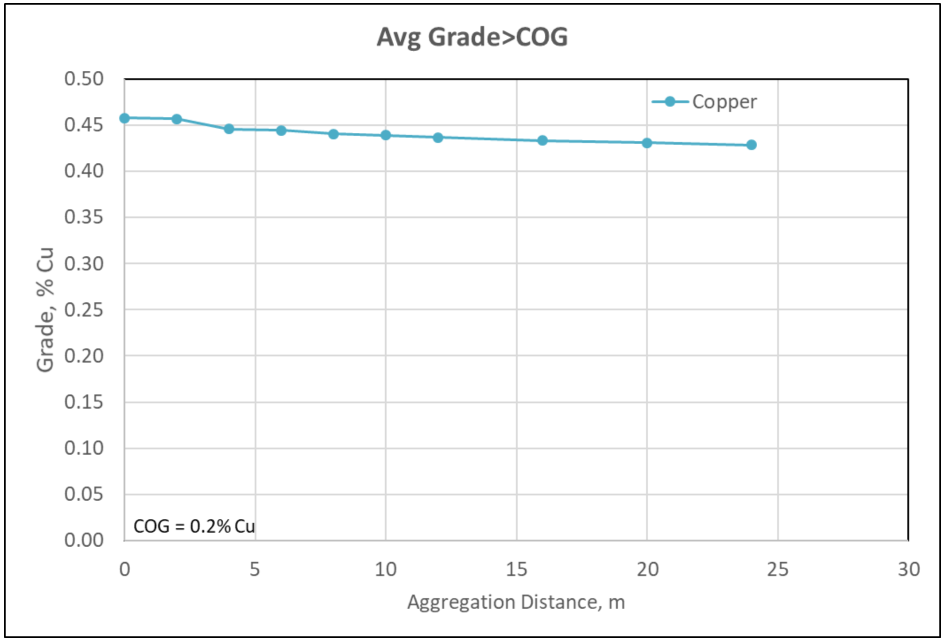
Source: McCarthy, 2017

Mining Scale and Average Grade

Zinc Property



Copper Property



Source: McCarthy, 2017

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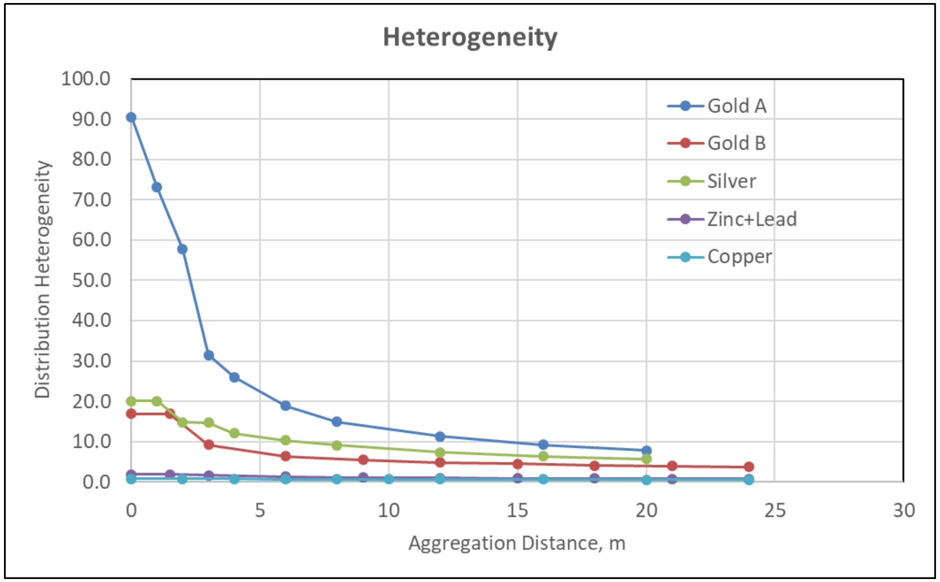
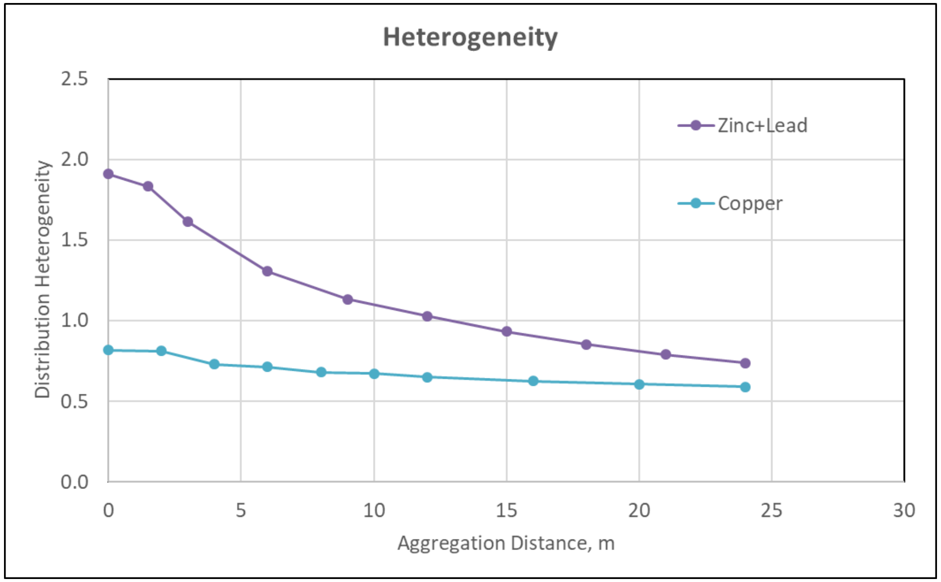
Mining Scale and Heterogeneity

All Properties

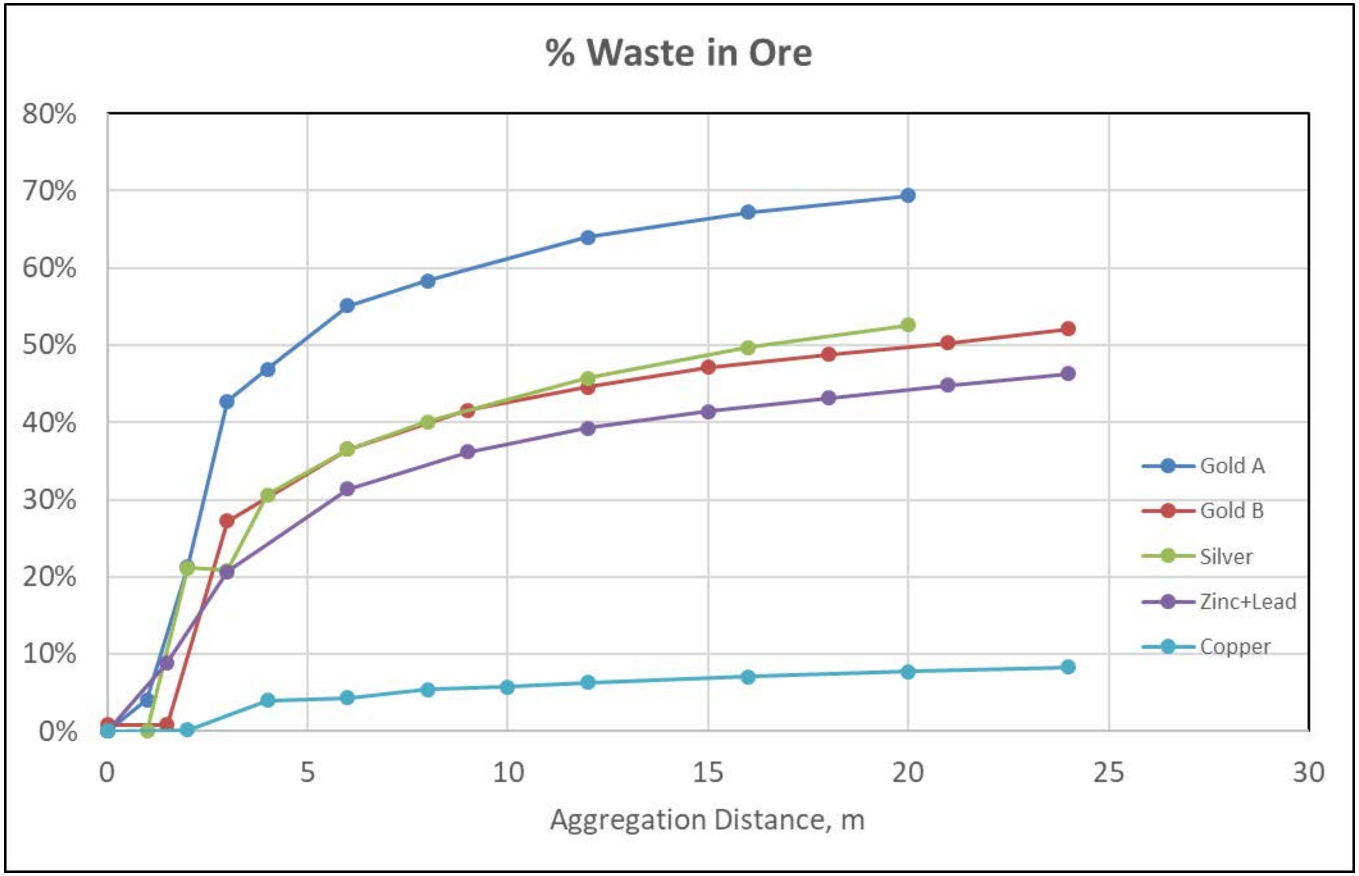
Zinc & Copper Properties





Source: McCarthy, 2017

Mining Scale and "Waste in Ore"



Source: McCarthy, 2017

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Waste Liberation

- Traditional (mineral) liberation
  - The reduction in size of particles such that the mineral of interest forms the majority of particle mass and is exposed for physical separation methods (e.g. flotation).

- Waste liberation
  - The reduction in size of ore blocks, lumps, or batches such that a point is reached where the contained amount of desired mineral is insufficient in value to pay for the further processing of the material.
  - In other words, due to heterogeneity, a volume of material at a point in the mining-milling process will, in all likelihood, be below the economic cut-off for that point in the process.
  - This can occur at a selective mining unit size (SMU), a truck size, a bucket size, and ultimately a particle size (<300 mm)

Waste Liberation

- Mineral Deportment to Size Fractions
  - For many ore deposits, valued minerals report to the finer particle size fractions (Bamber, 2008; Dance, 2016; CRC Ore, 2015)
  - Conversely, coarse fractions can have minimal mineralization or at least insufficient for these “particles” to have a grade in excess of the economic cut-off
  - Differential hardness within the ore may in some instances contribute to this characteristic when the harder material itself is not mineral-bearing
  - Is one of CRC Ore’s principal concepts underpinning their “Grade Engineering®“ - an integrated approach to coarse rejection.

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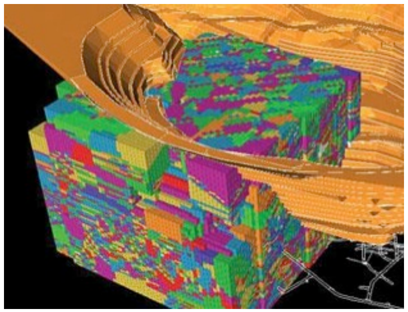
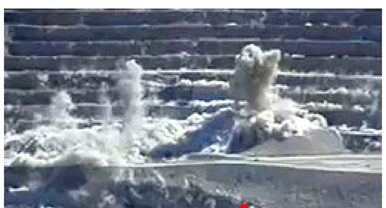
Heterogeneity/Opportunity at Every Length Scale

Mine Planning





Grinding / Flotation

Today Mining Ignores Mid-Scale Heterogeneity

Mining Block-SMU | Screening | DMS

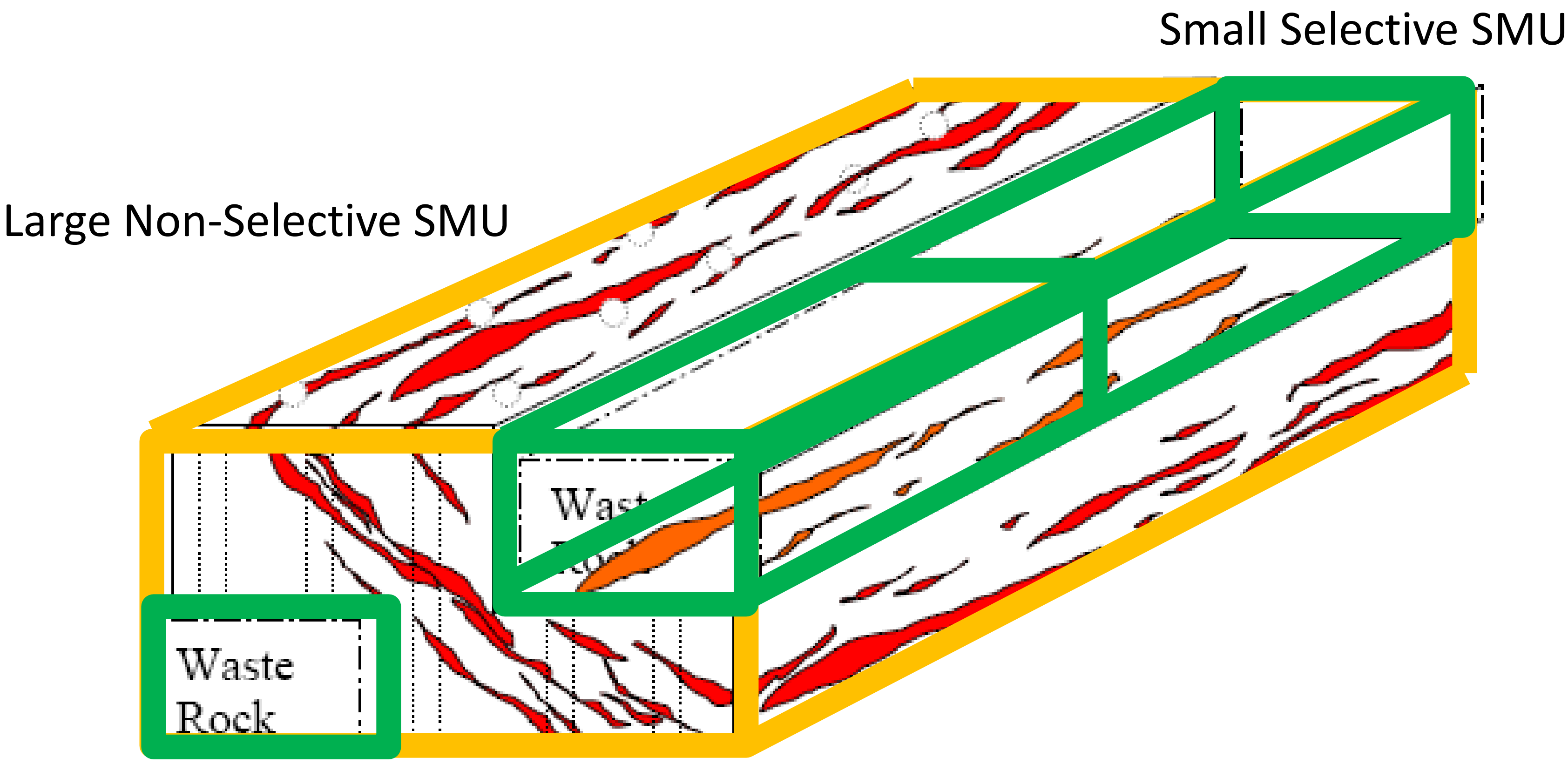
Bulk Sorting | Particle Sorting

Length Scale

>10m >1000T | **1m** | **10cm** | **<1cm <0.1kg**

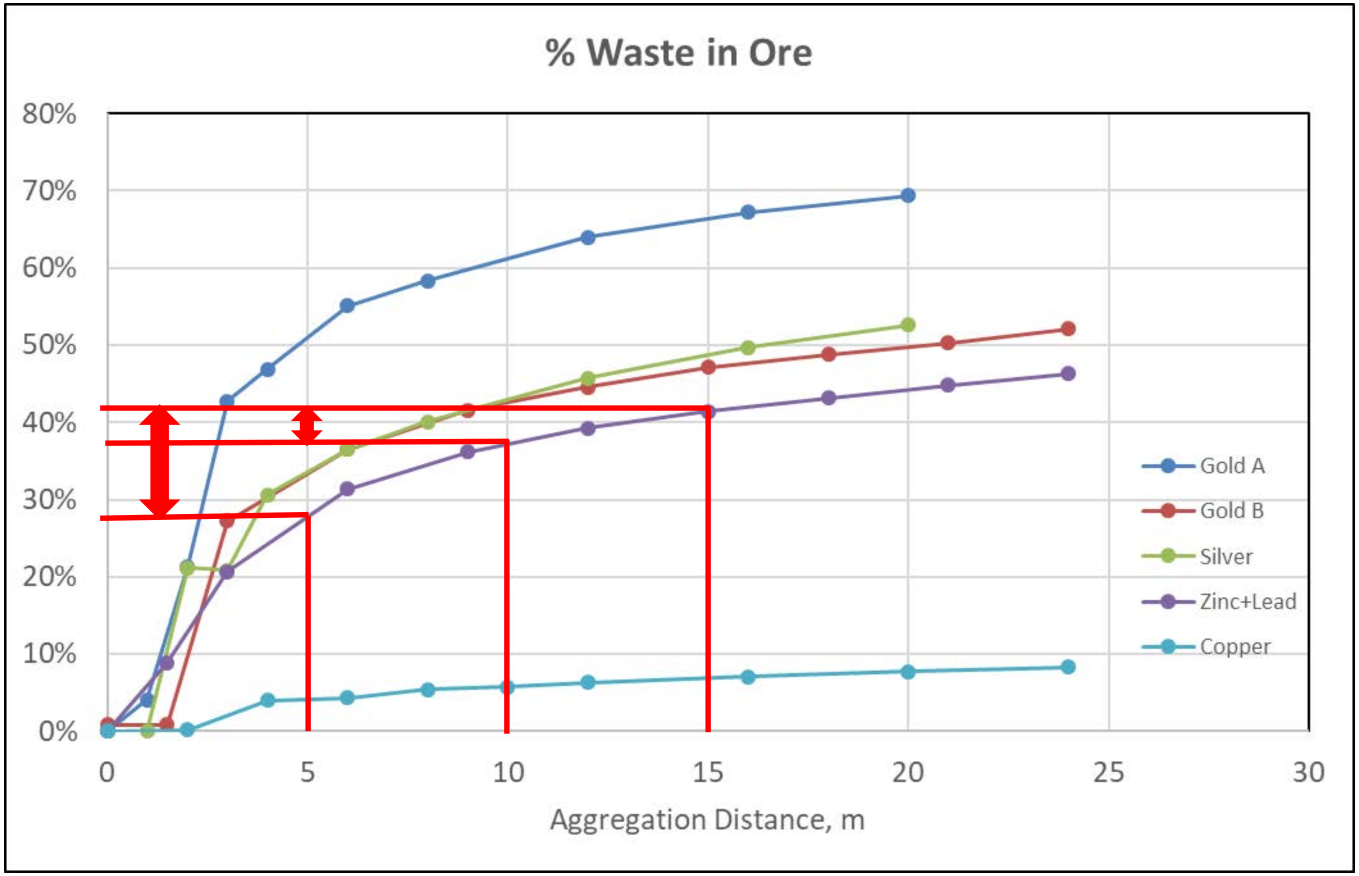
Source: Modified from Bamber, 2017

Selective Mining Unit



Source: Modified from Ebrahimi, 2015

SMU and "Waste in Ore"



Source: McCarthy, 2017

Screening

- Remove coarse fraction at or near face
  - Discard to waste
  - Or to alternate process (e.g. heap leach)

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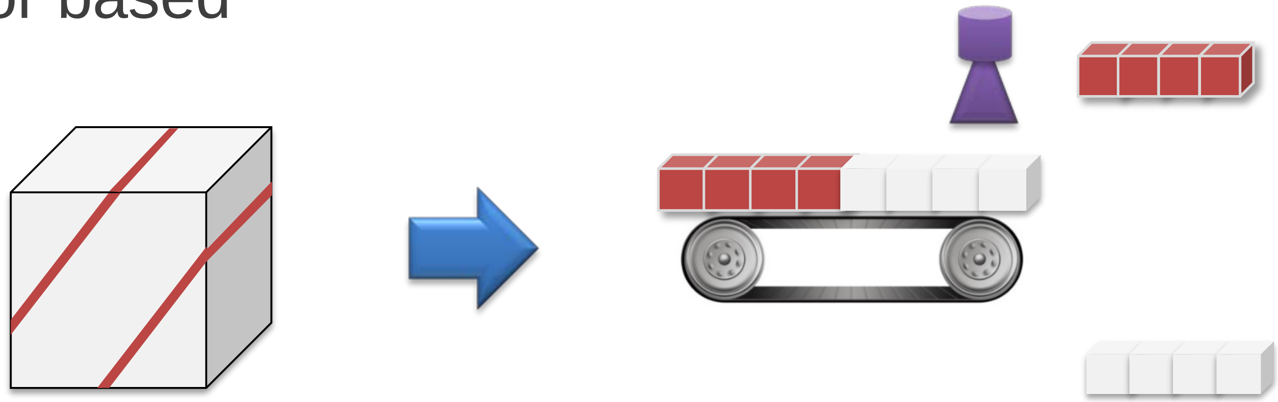
- Leverage with differential blasting
  - Use high intensity blasting in known mineralization
  - Use less explosive energy in potential internal and external dilution
  - Screening out of the coarse, un-mineralized waste pre-concentrates mill feed

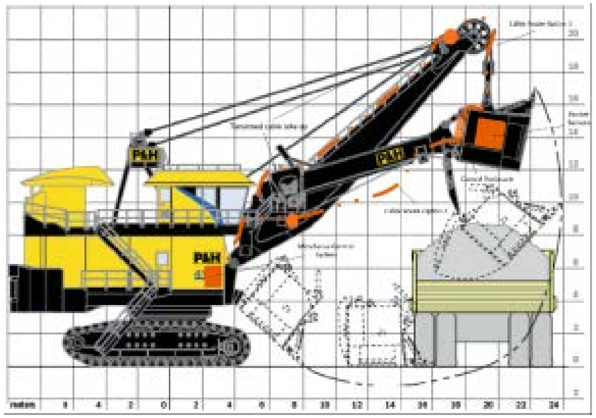
Bulk Sorting

Bulk Sorting

- Conveyor based

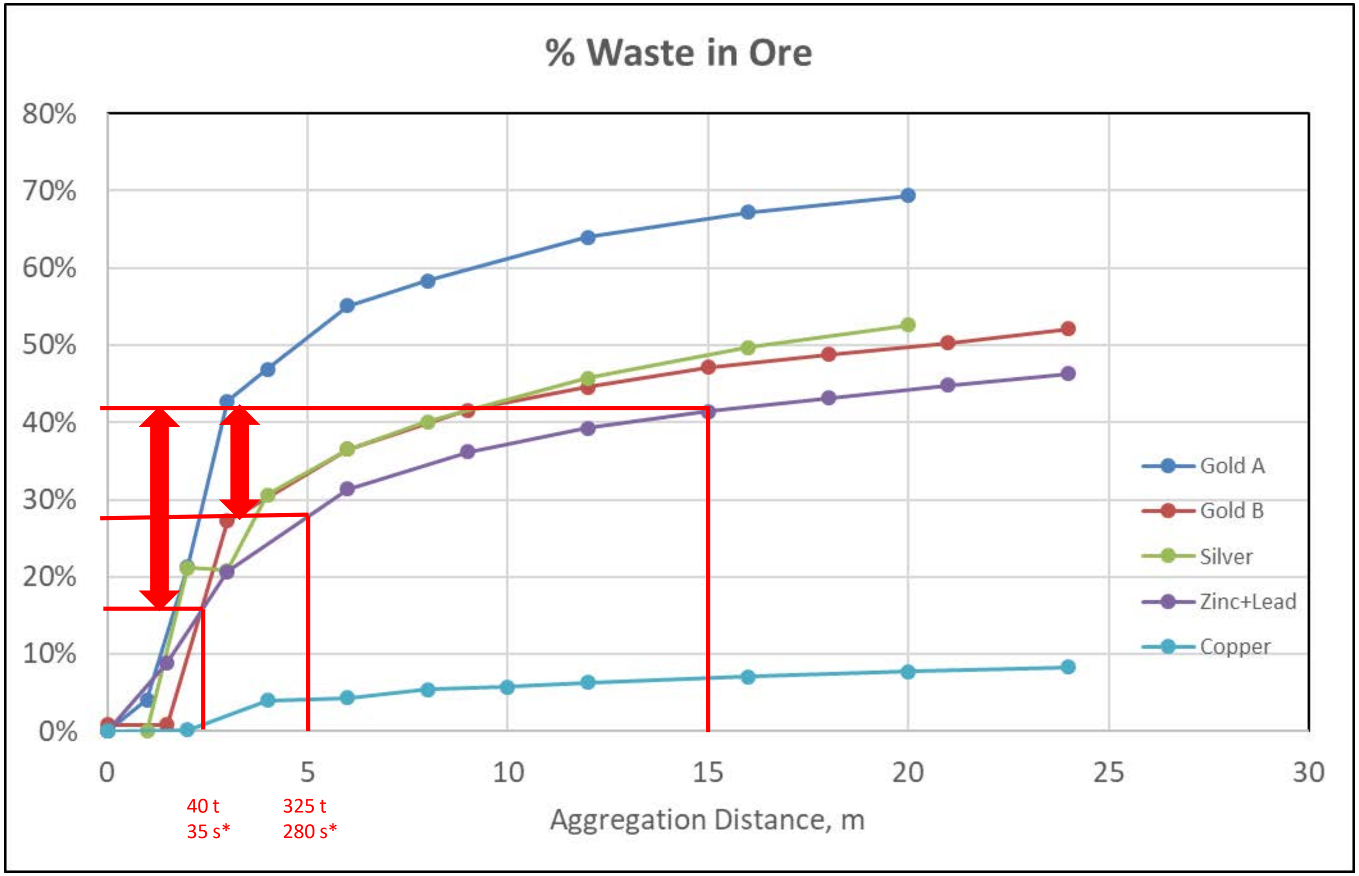


- Shovel based



From MineSense

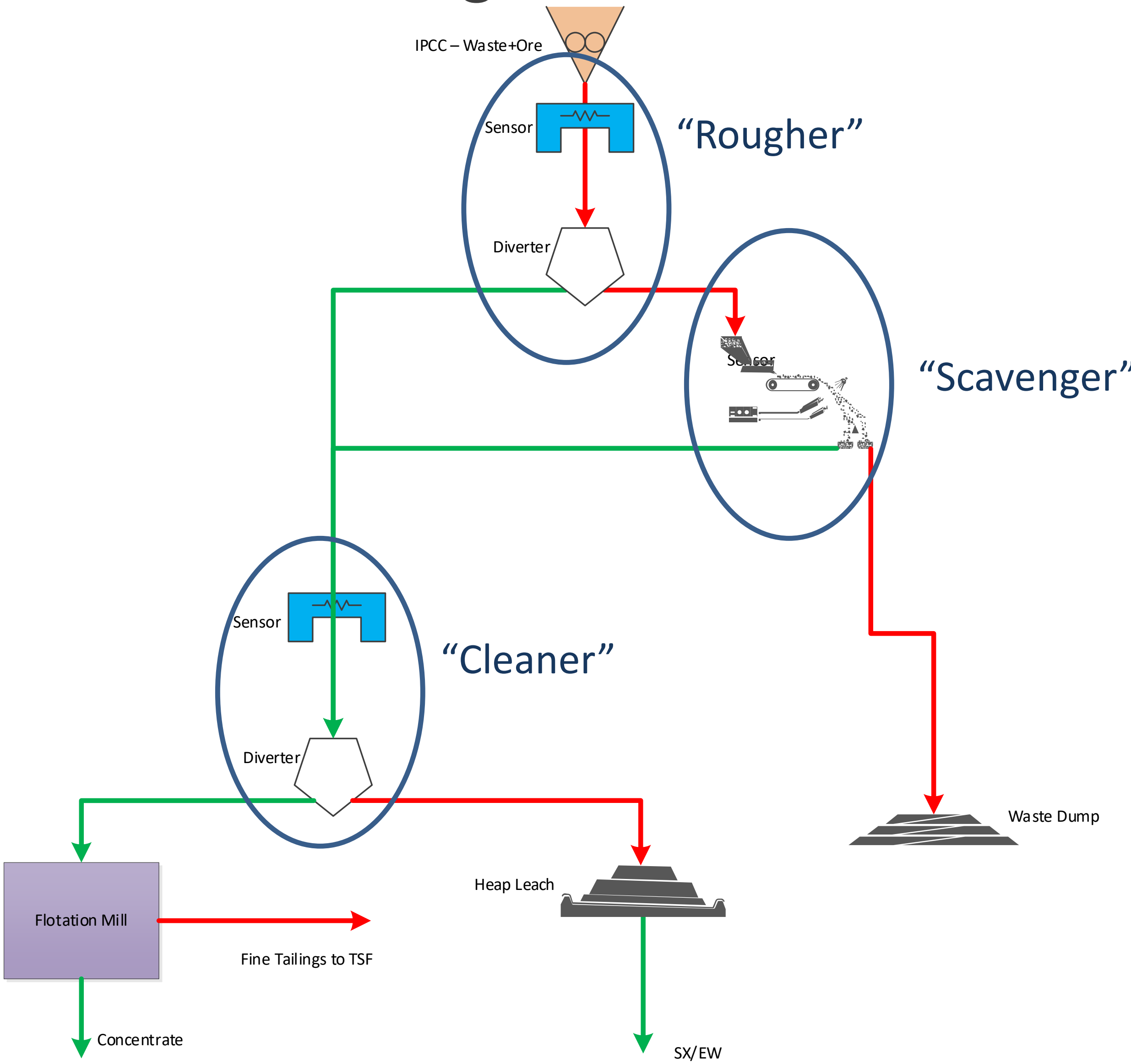
Bulk Sorting and "Waste in Ore"



* - Assumes 100,000 tpd ore feed

Source: McCarthy, 2017

Bulk and Particle Sorting



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Conclusions

- Mass mining results in resource modeling and mine planning at block sizes that mask natural heterogeneity and smooth/reduce grade.
- Waste liberation occurs at the point of fragmentation where there is insufficient mineralization to justify further processing.
- Assessing exploration data at the core hole level can indicate potential waste rejection rates.
- Waste Liberation can be achieved at mining or primary crushing scales.
- Several methods can be used to reduce or remove waste from the mill feed:
  - SMU selection
  - Screening
  - Bulk sorting (with optional particle sorting)

Thank-you!

Questions?

For more information:

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