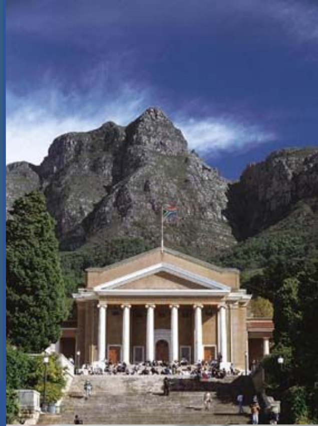
Understanding the Nature of Challenges Posed in PGM Recovery from Secondary Tailings Resources



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Reprocessing of Secondary Tailings Resources

Secondary tailings from decades of Bushveld mining contain residual PGMs — a *low-impact, low-cost* alternative to new mining

Sample History

Prior processing

Time factor

Challenges related to Tailings Resources

PGM tailings

Chromite tailings

Smelter/Converter Slags

Fine particle size, unliberated, slow-floating PGM species, low grade

Coarser particle size, not previously treated for PGMs, lower chromite content

Refractory, non-crystalline alloys and secondary minerals

Current arisings

Legacy tailings

Typically leads to *lower recovery potentials*

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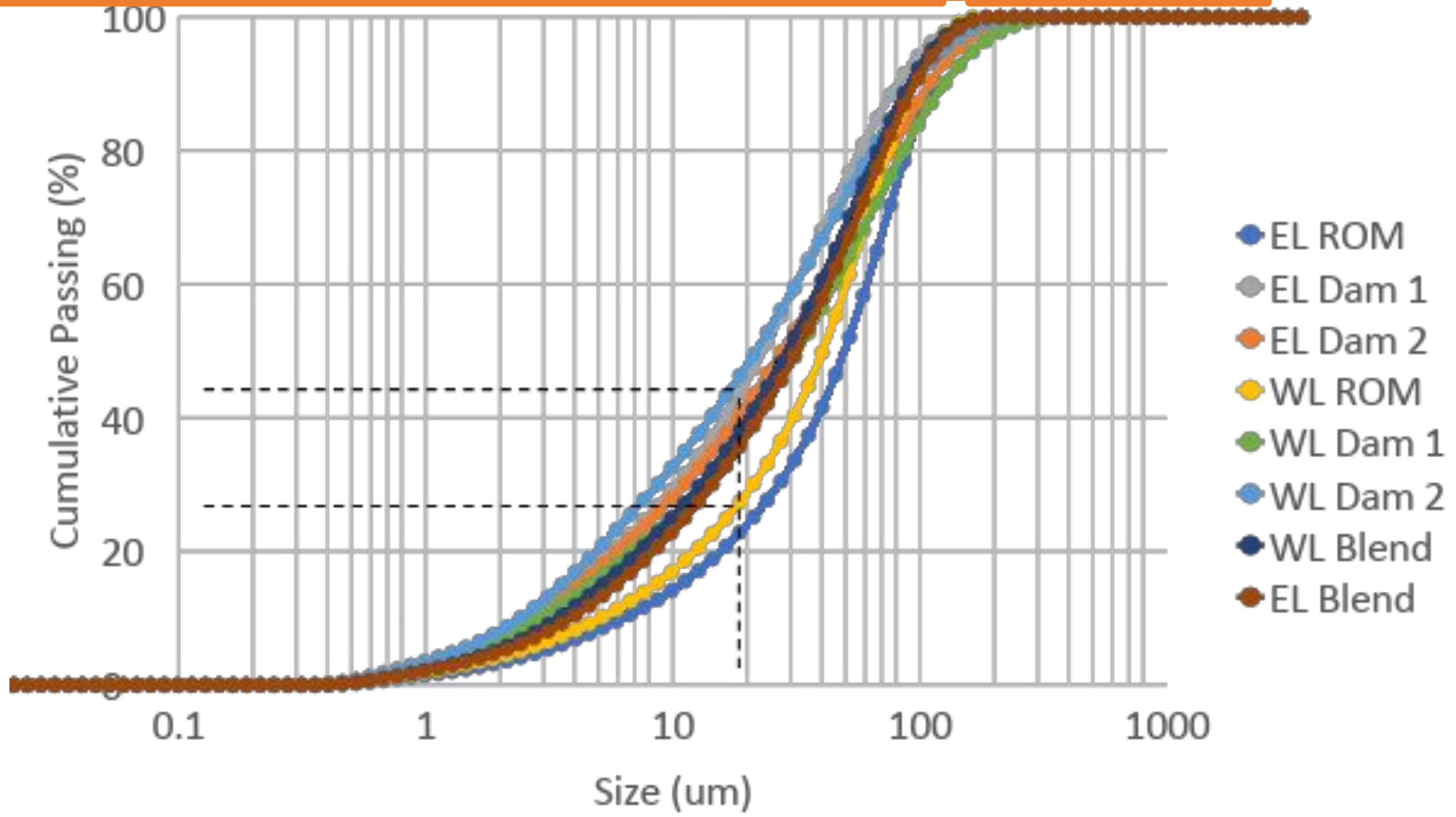
Head grades and PSDs for 6 test samples

	EL ROM	EL Dam 1	EL Dam 2	WL ROM	WL Dam 1	WL Dam 2
4E PGE (g/t)	1.22 ±0.02	3.50 ±0.02	2.39 ±0.06	1.84 ±0.10	1.98 ±0.03	2.73 ±0.08
Cr_2O_3 (wt. %)	28.88 ±0.14	23.05 ±0.14	18.80 ±0.07	26.79 ±0.16	18.53 ±0.05	18.04 ±0.08

MG

LG

Dam samples were typically much finer than ROM even though they were milled to the same target grind of 80% <75 µm



Objective: Understand reasons for differences in flotation performance of different sample types

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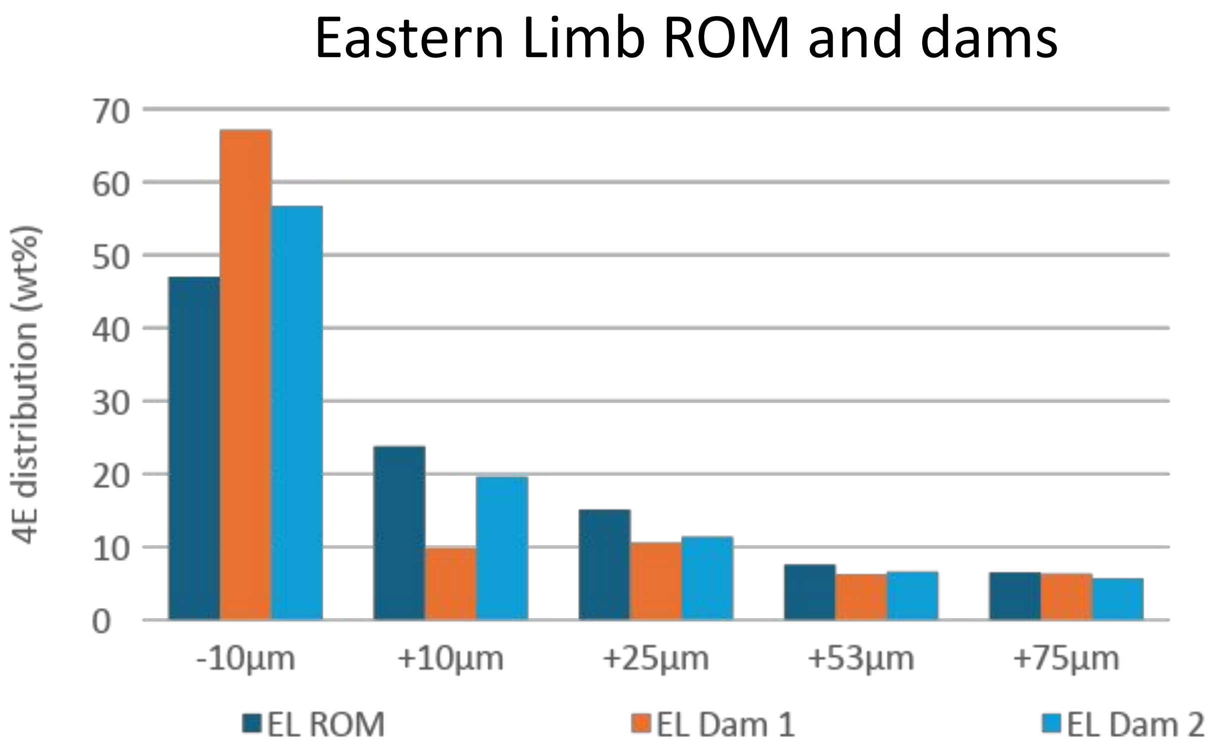
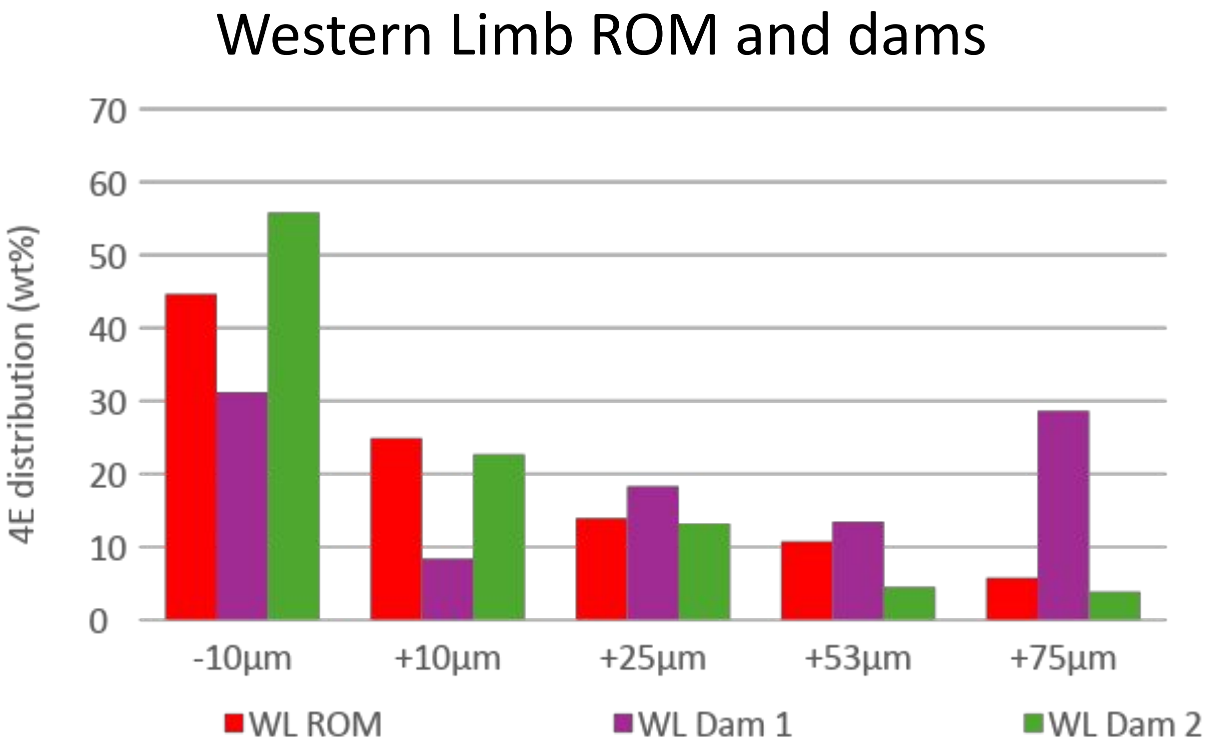
PGE distribution by size for 6 flotation feed samples





PGEs are overwhelmingly concentrated in the -10 µm size fraction

May require alternative flotation strategies such as smaller bubbles, higher energy input, higher collector dosages

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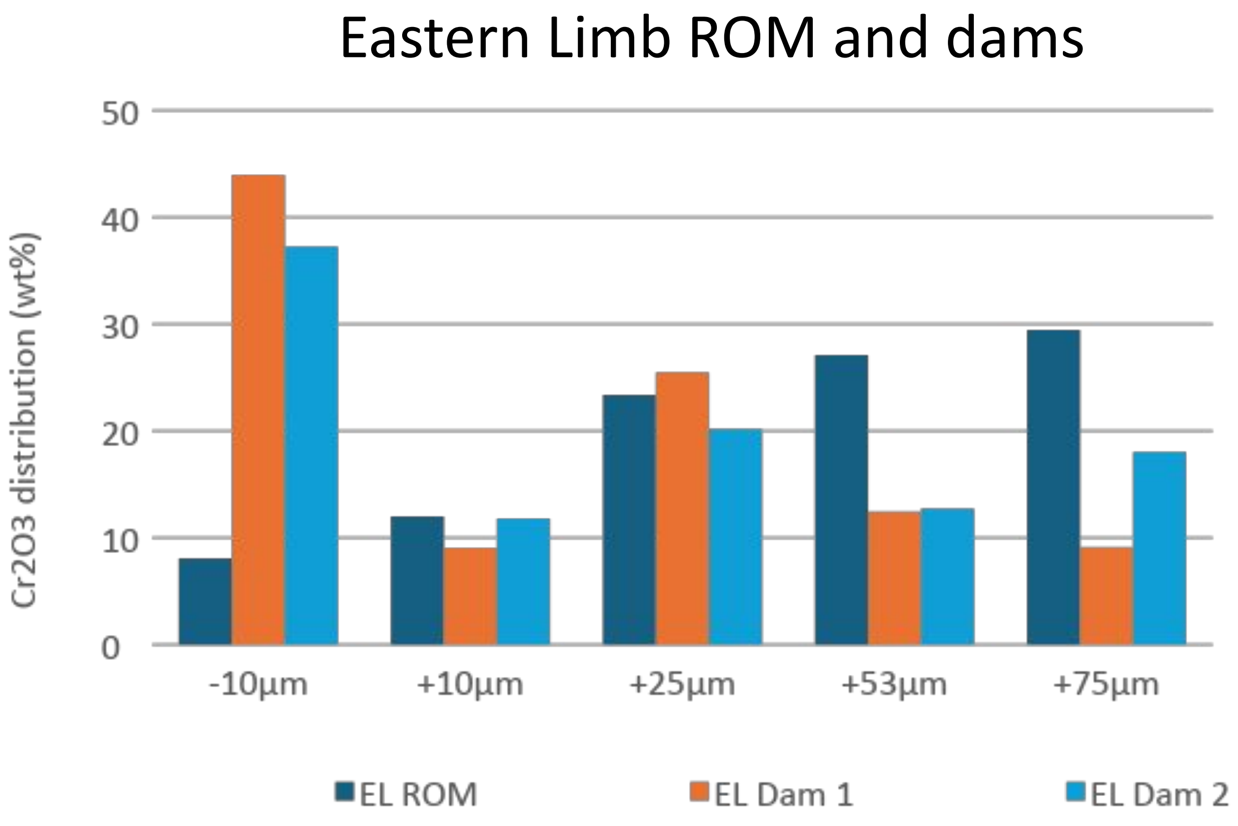
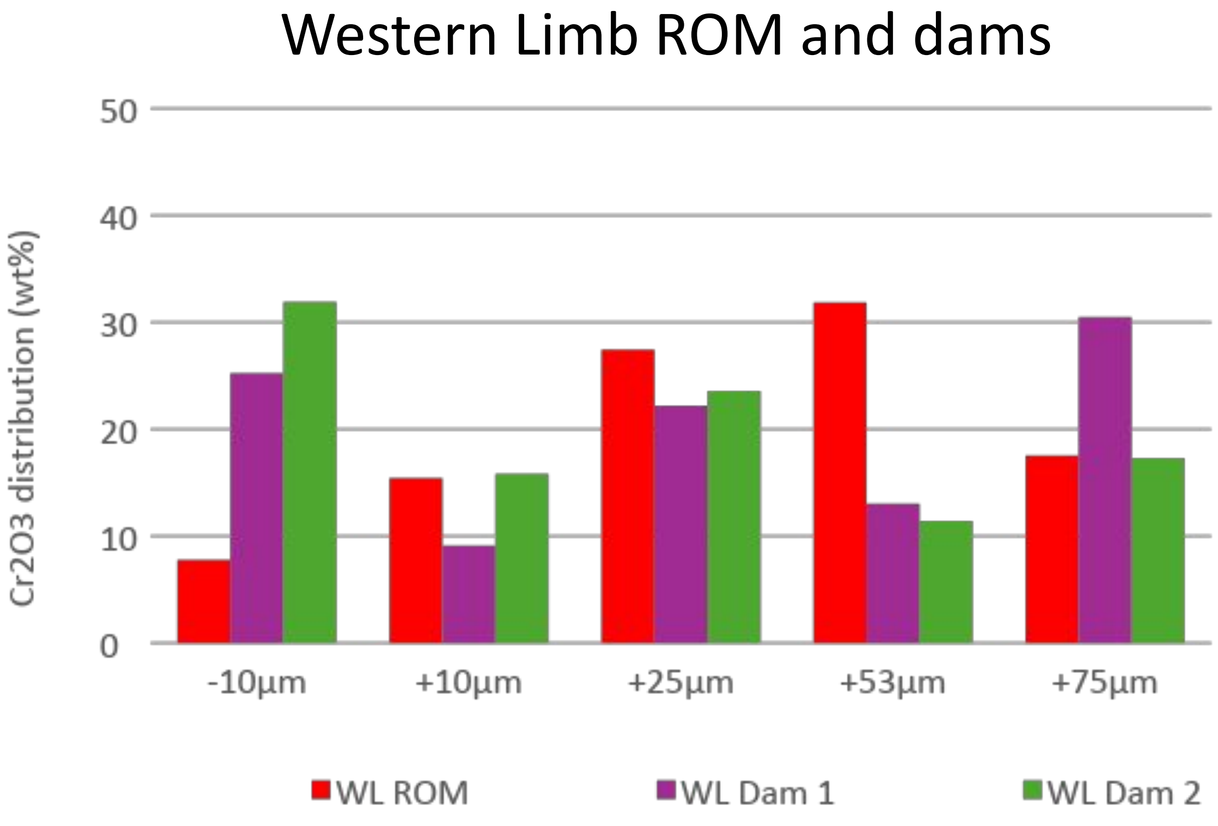
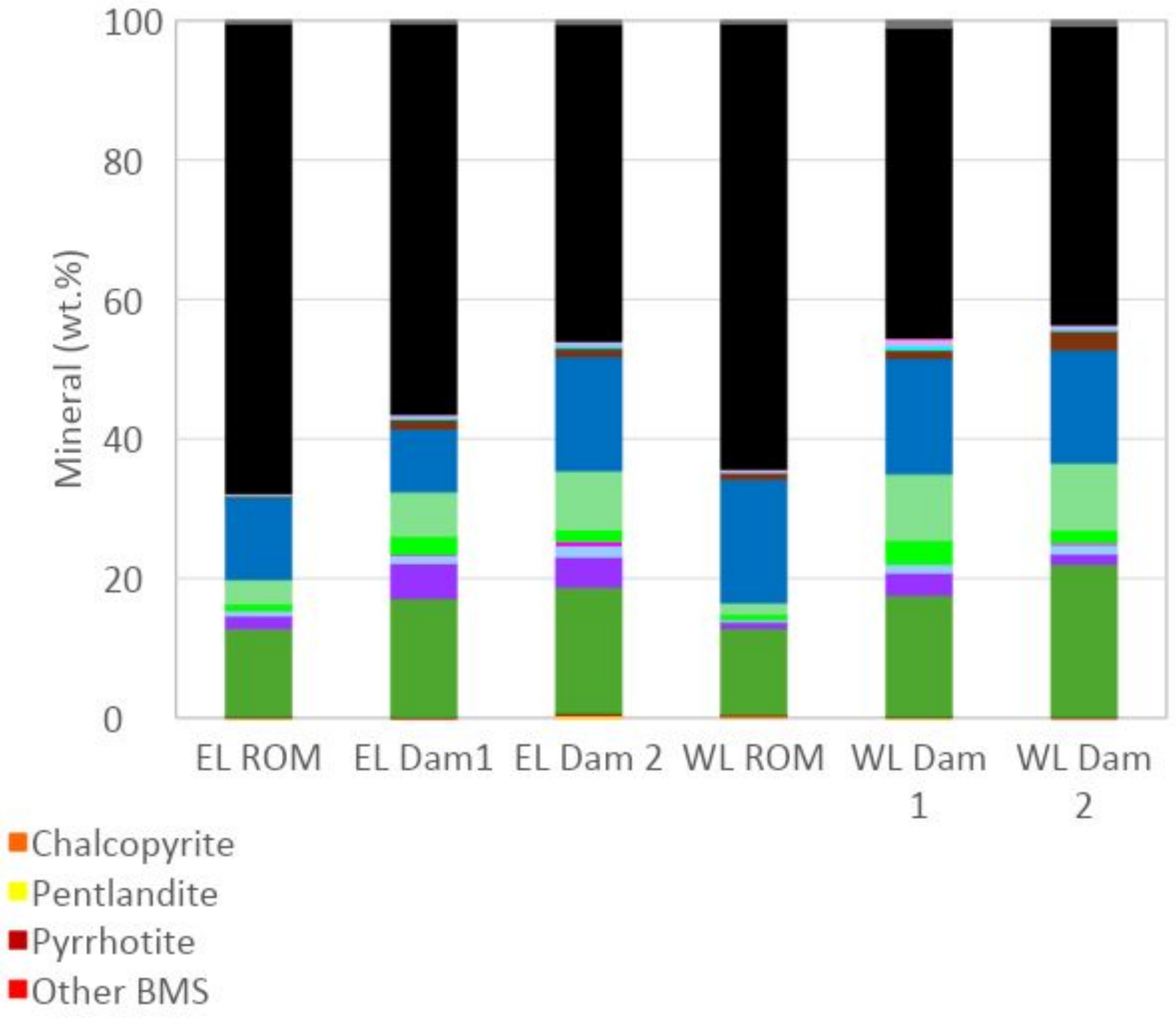
Cr_2O_3 distribution by size for 6 flotation feed samples





Cr_2O_3 is more evenly distributed throughout the size fractions
Good for limiting entrainment
Lower -10 µm in the ROM

Bulk Mineralogy



- Low BMS (0.04-0.56%)
- More chromite in the ROM (no previous chromite recovery)
- No large quantities of problematic alteration minerals

	Serpentine	Talc
EL ROM	<0.1	1.0
EL Dam1	0.2	2.6
EL Dam2	0.7	1.7
WL ROM	<0.1	0.8
WL Dam1	0.1	3.4
WL Dam2	0.3	1.9

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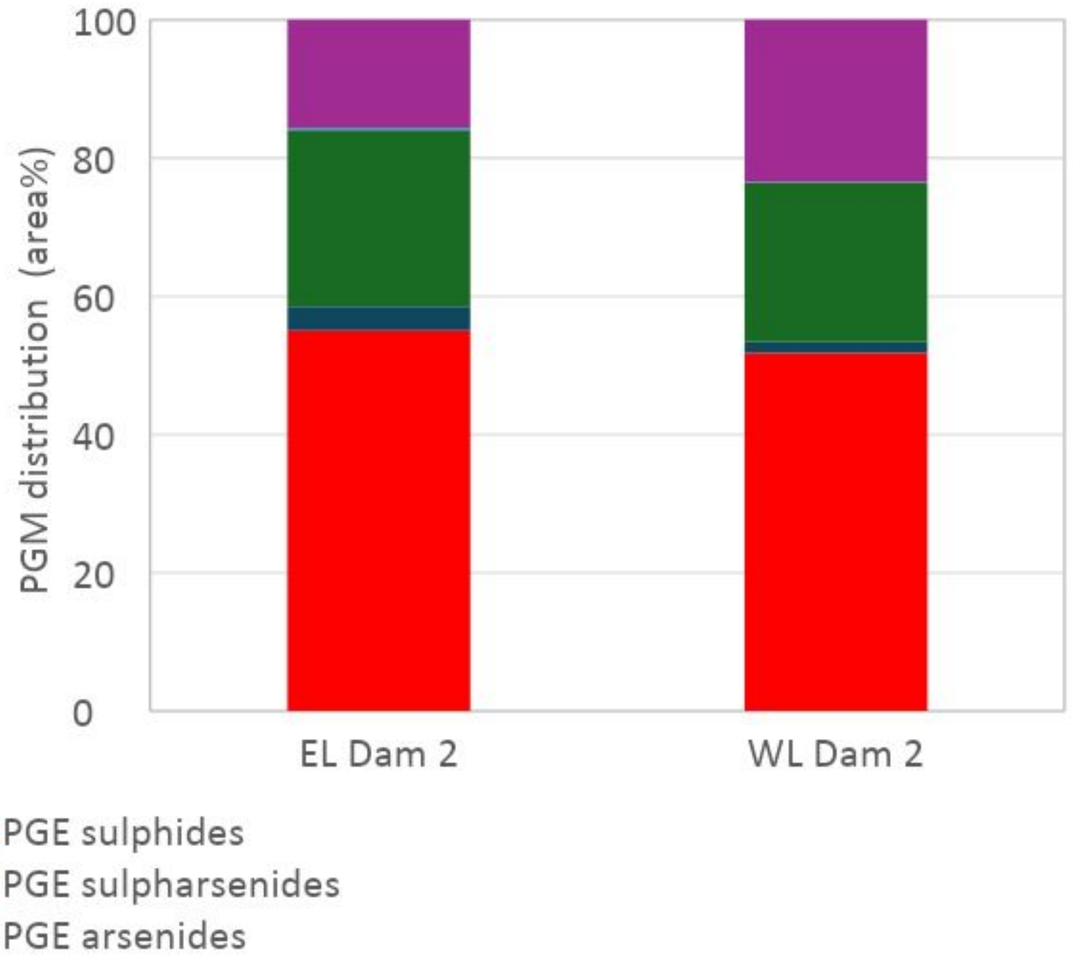
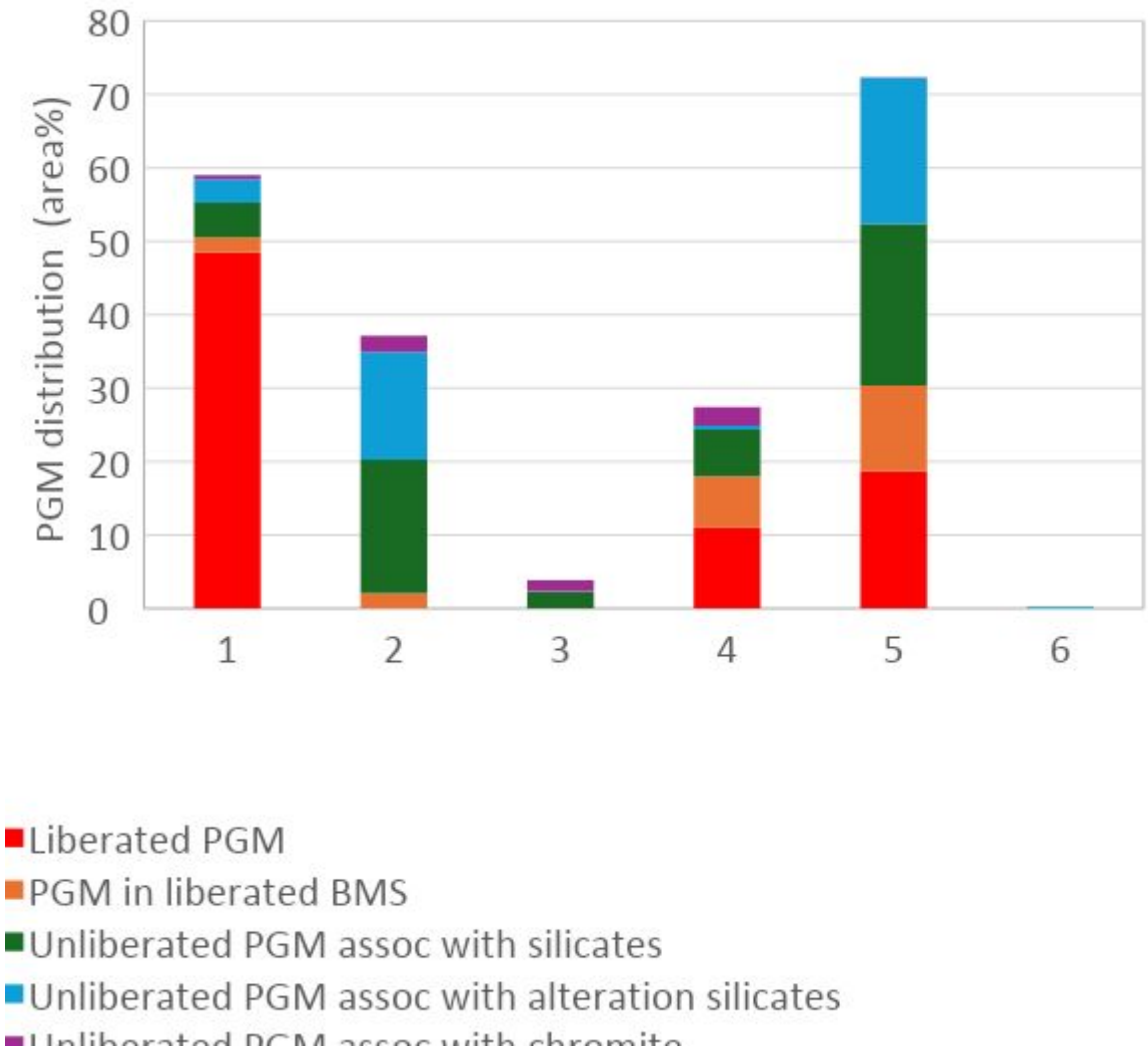
Mineralogy: PGM speciation and liberation by size

PGM speciation



~50% fast floating PGE sulfides
~50% slower floating PGE arsenides and alloys

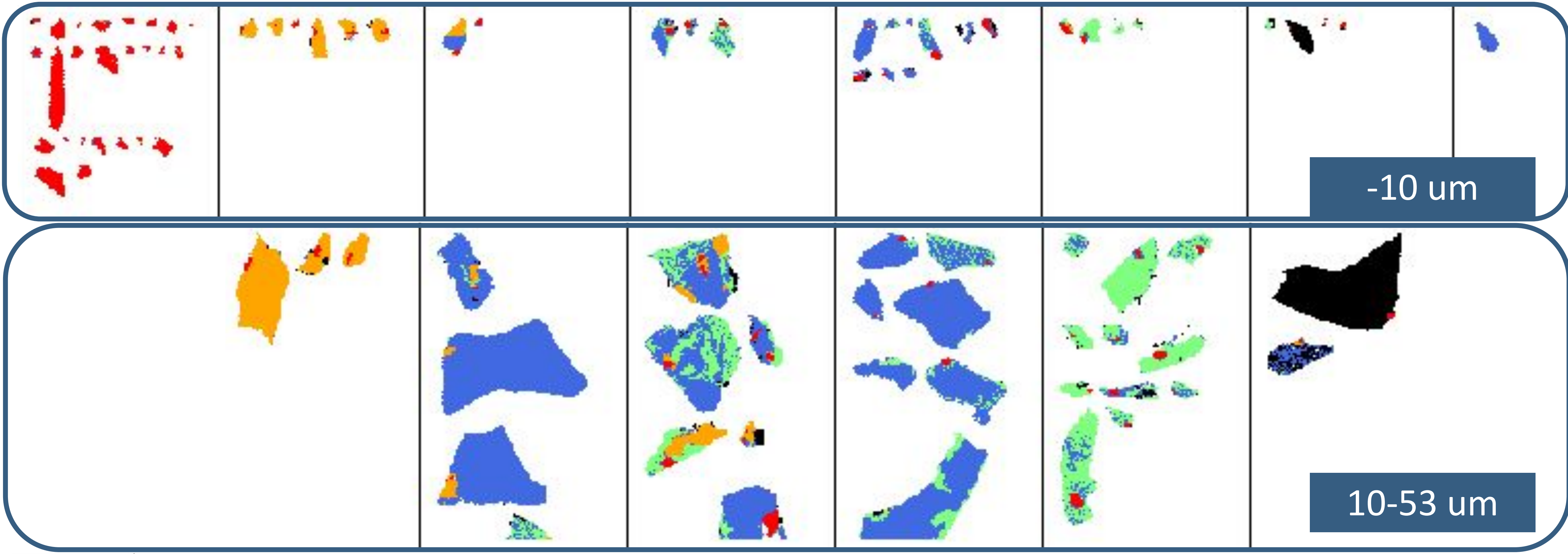
Liberation by size



-10 um size fraction is mostly liberated in EL Dam

False colour images of PGM by size by liberation class

Liberated	Liberated + BMS	PGM/BMS in silicates	PGM/BMS in alteration silicates	Attached to silicates	Attached to alteration silicates	Attached to chromite	Enclosed in silicates



EL Dam 2

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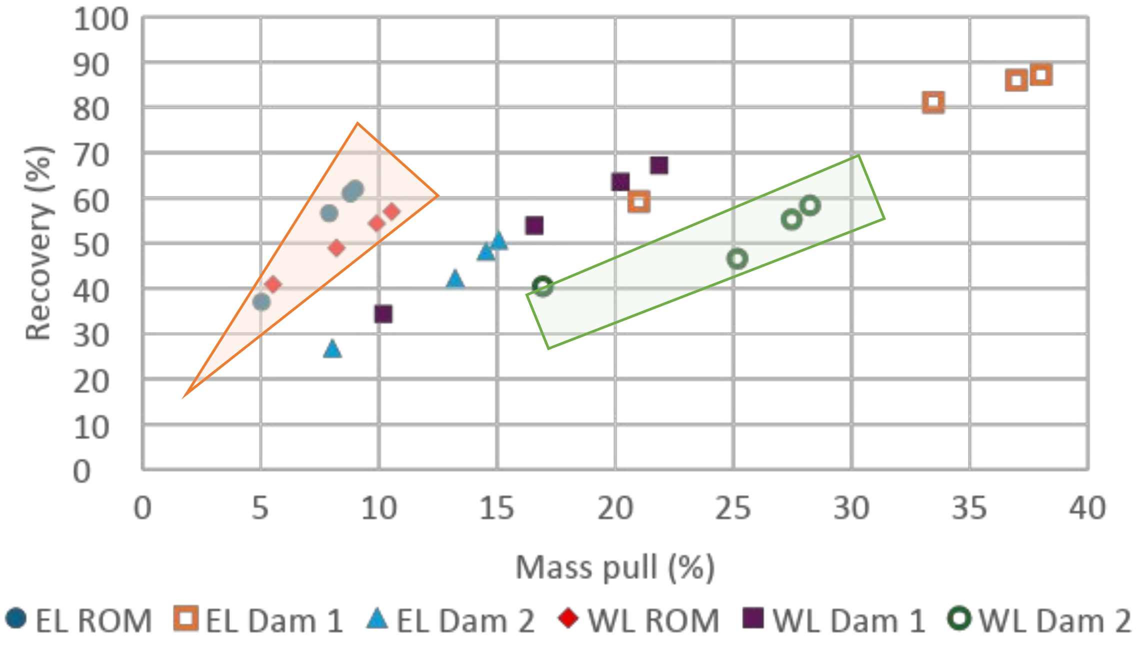
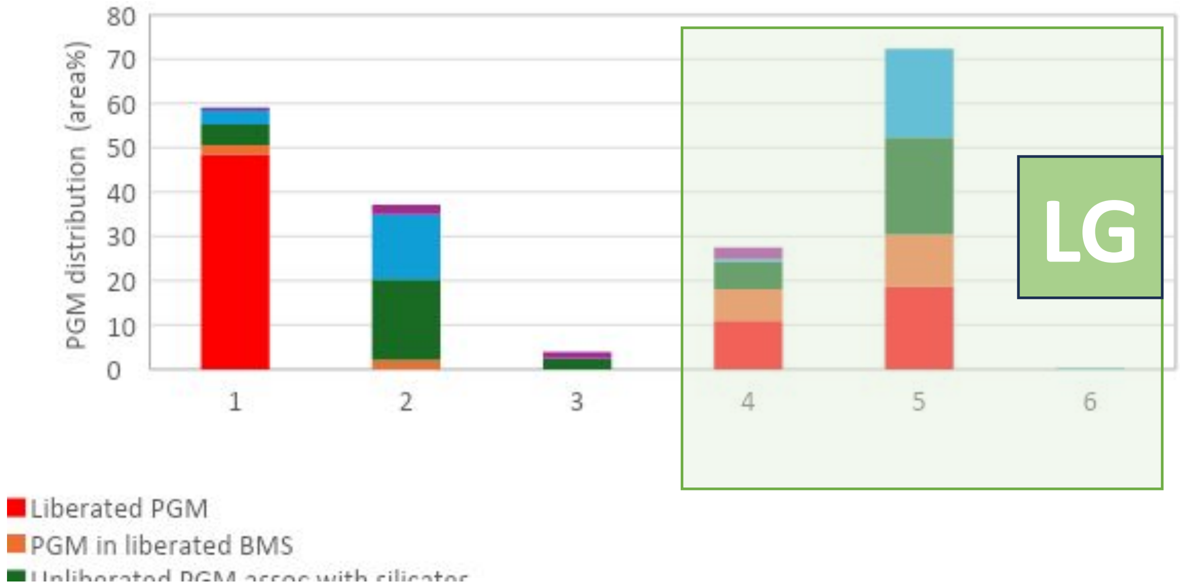
Flotation performance: 4E, Base Case





- ROMs and Dams occupy different flotation domains
- Why? PGE distribution by size; Time to flotation
- WL Dam 2 the lowest performance – LG!

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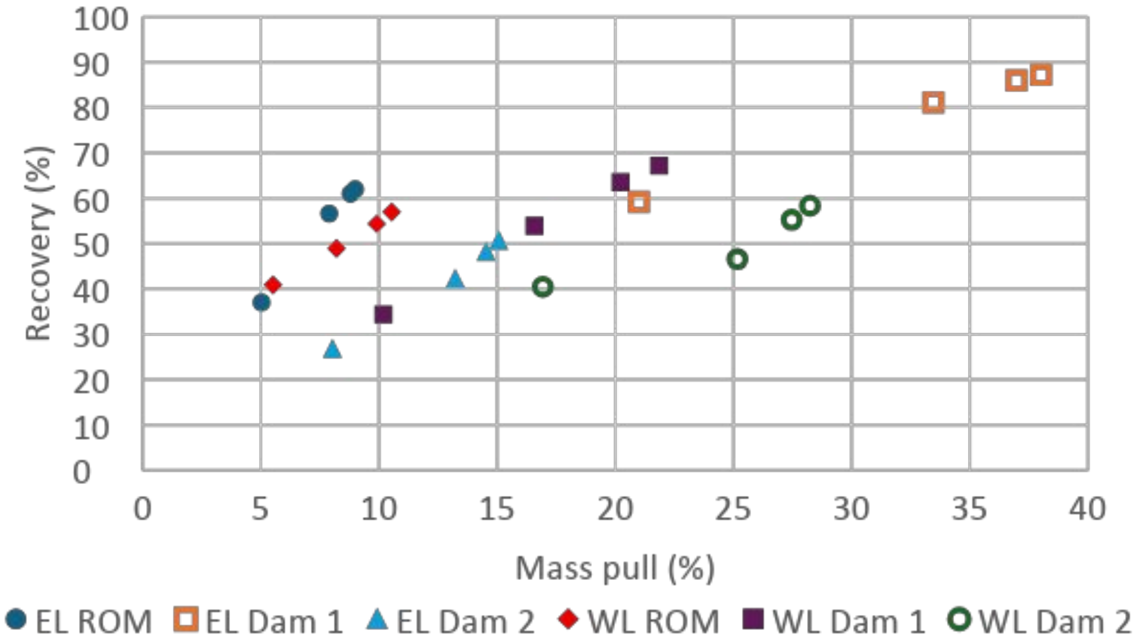
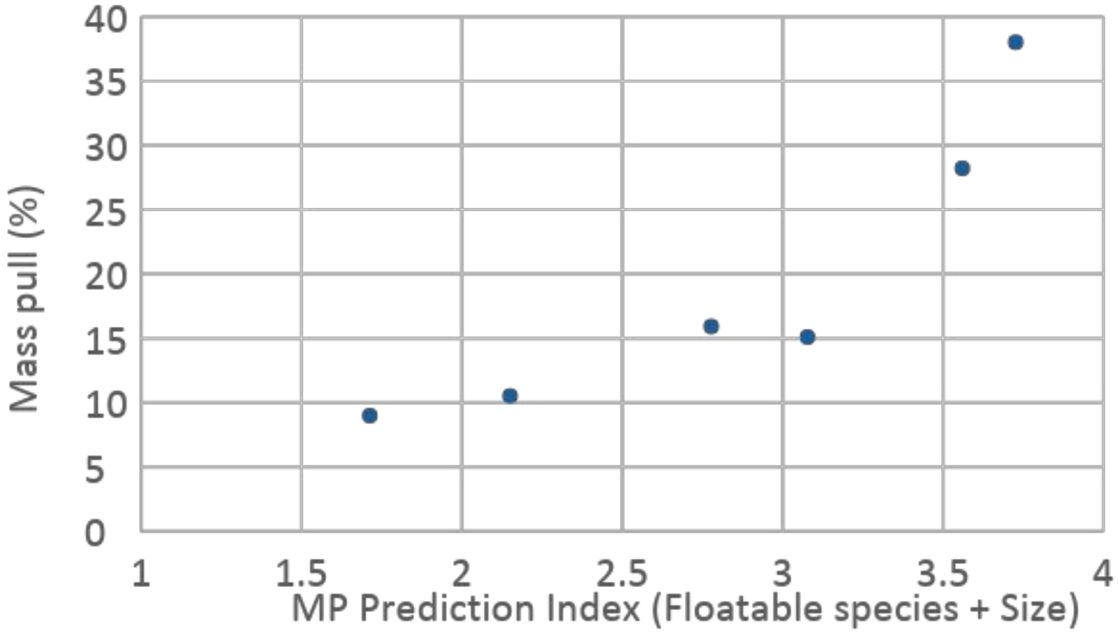
Flotation performance: 4E, Base Case



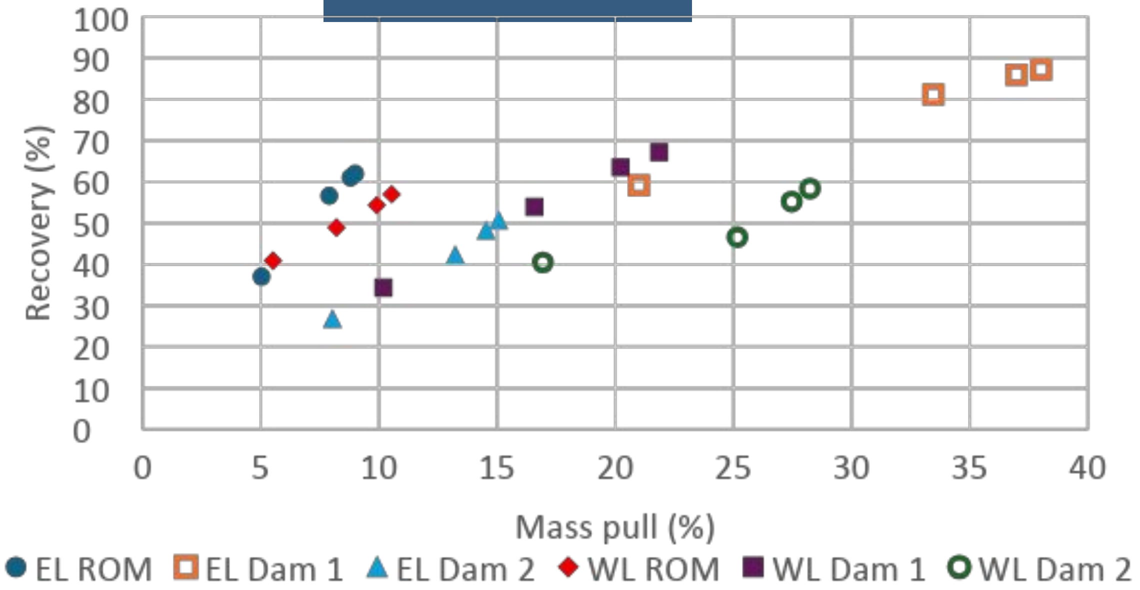


Why are there such differences in mass pull for samples floated under the same conditions?

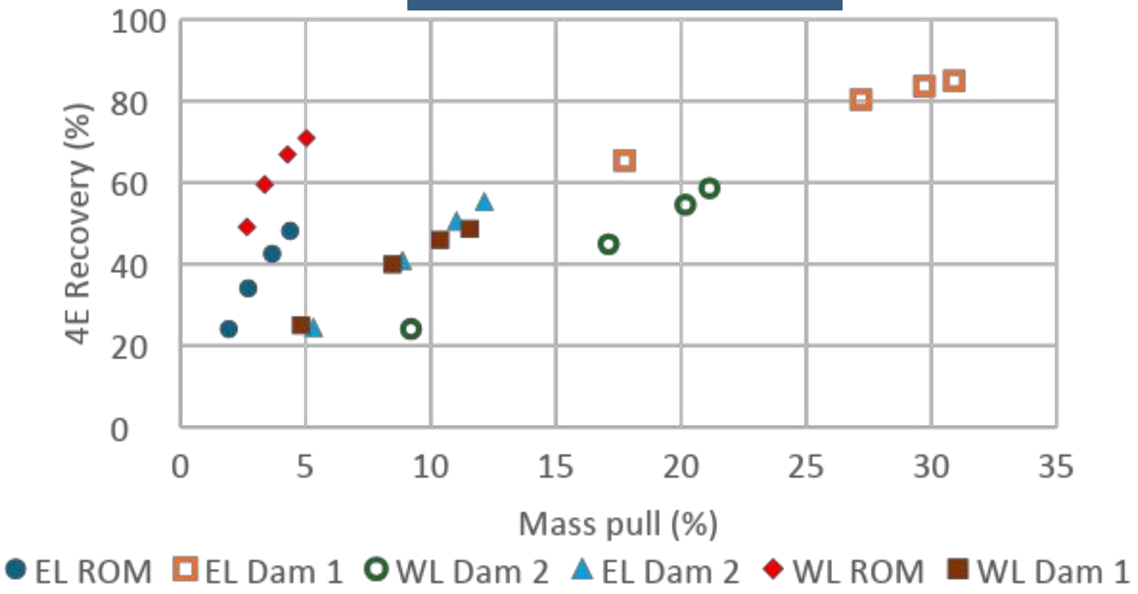
	EL ROM	EL Dam1	EL Dam 2	WL ROM	WL Dam 1	WL Dam 2
MP (%)	9.0	38.0	15.1	10.5	21.9	28.2
OPX+Talc+BMS (%)	13.6	19.6	20.2	13.5	20.8	23.8
PGE (g/t)	1.2	3.5	2.4	1.8	2.0	2.7
<10µm (%)	15.5	31.6	30.1	18.7	27.0	35.0

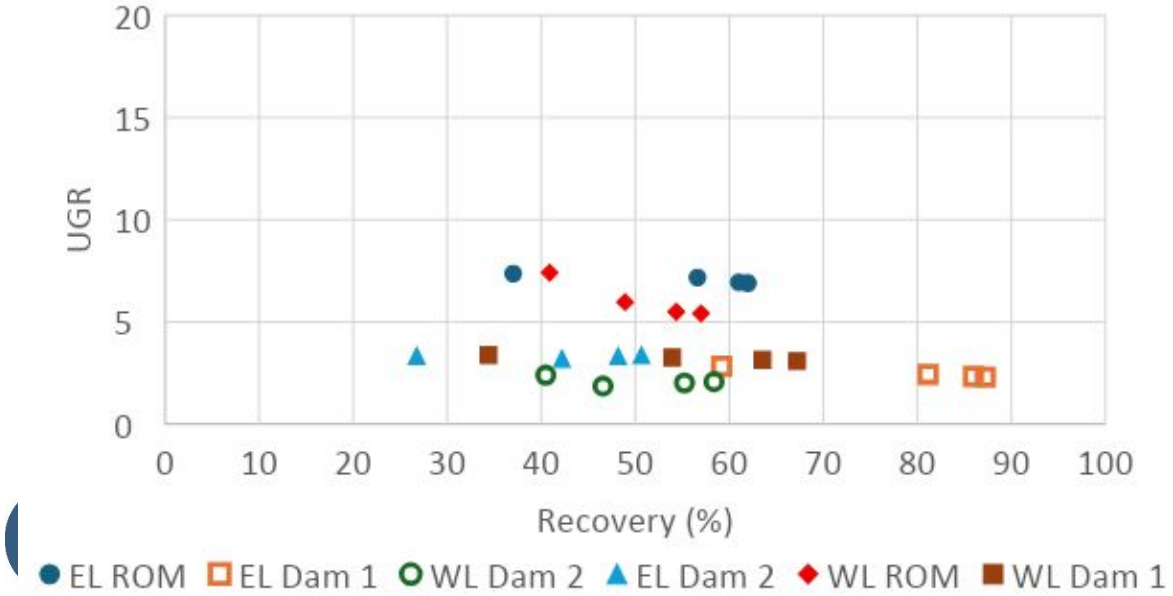
Flotation performance: 4E

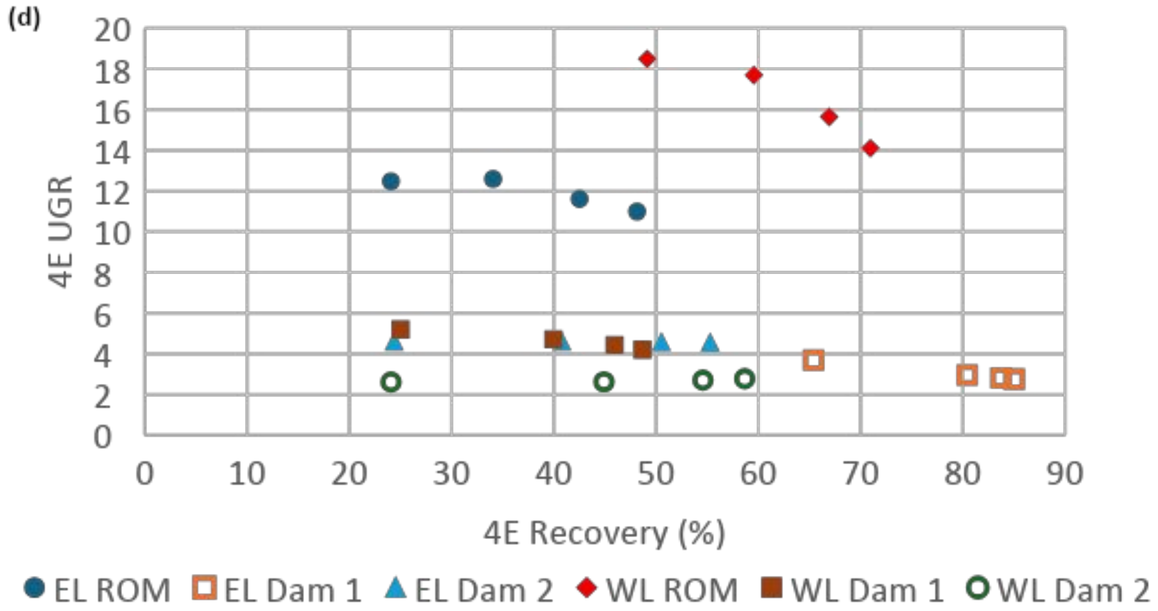
Base Case



Sodium silicate

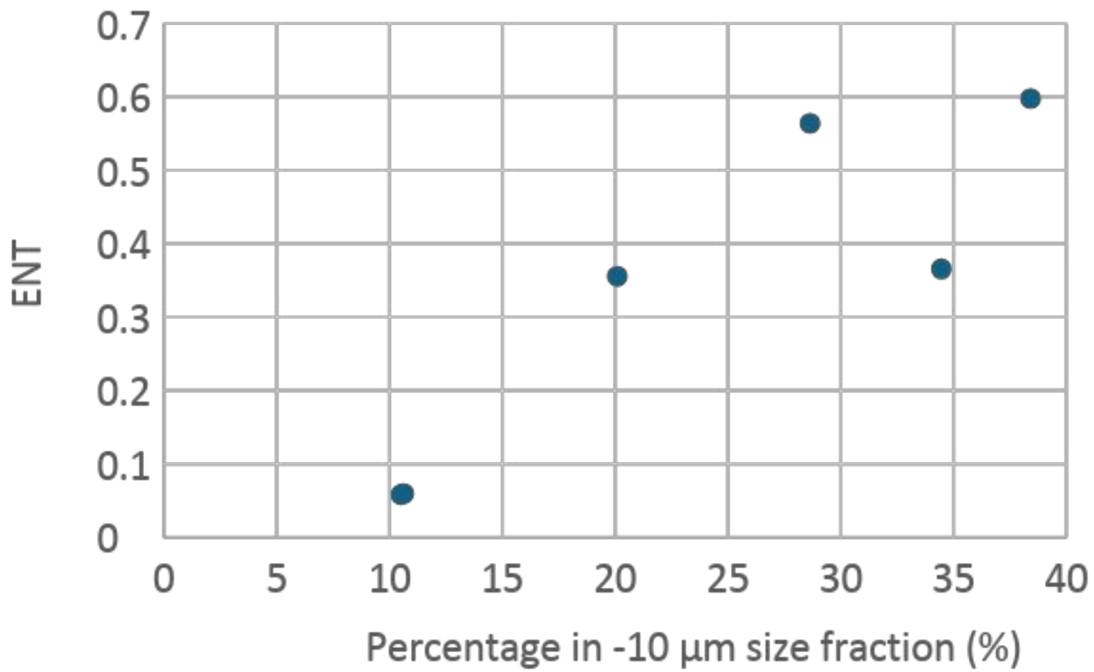






Flotation performance: Entrainment

	EL ROM	EL Dam 1	EL Dam 2	WL ROM	WL Dam 1	WL Dam 2
ENT (Solids)	0.060	0.60	0.37	0.058	0.36	0.56
R^2	1.00	1.00	1.00	0.99	1.00	1.00



- Entrainability for Dams was ~10x greater than ROM ores
- Approximately correlated with the amount of fines in the feed

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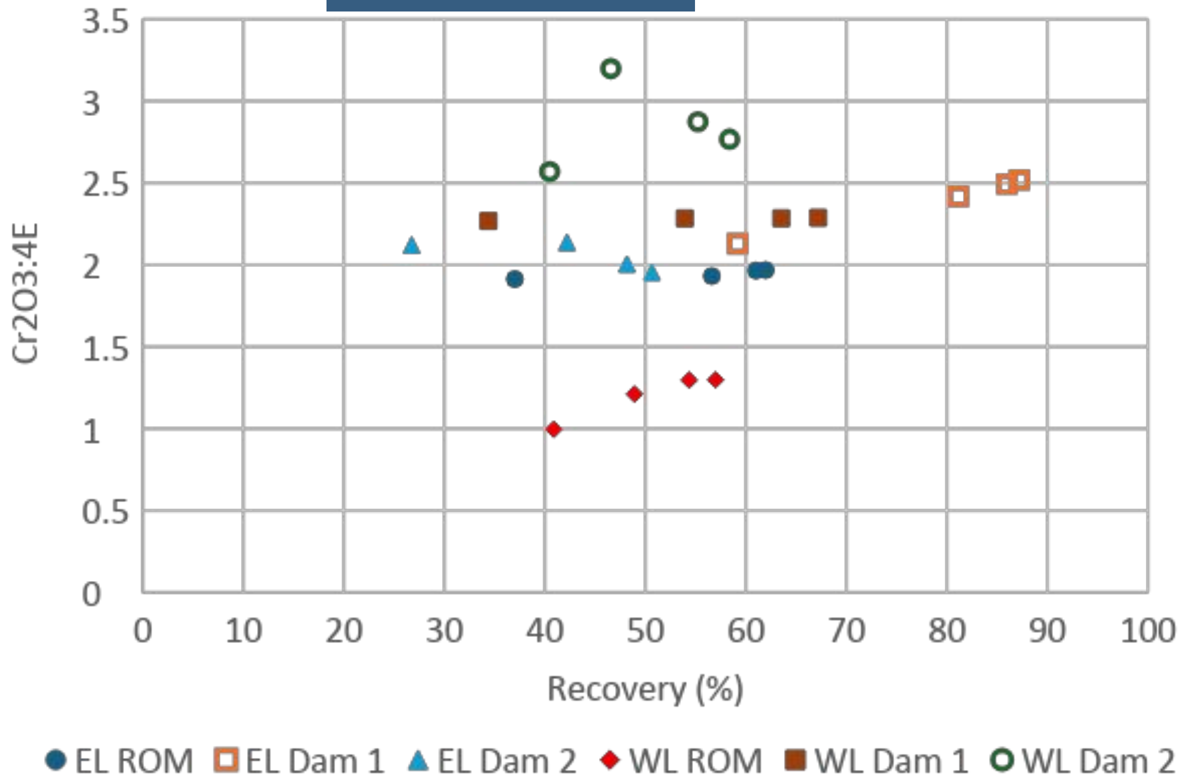
Flotation performance - Cr_2O_3:4E ratio

Base Case



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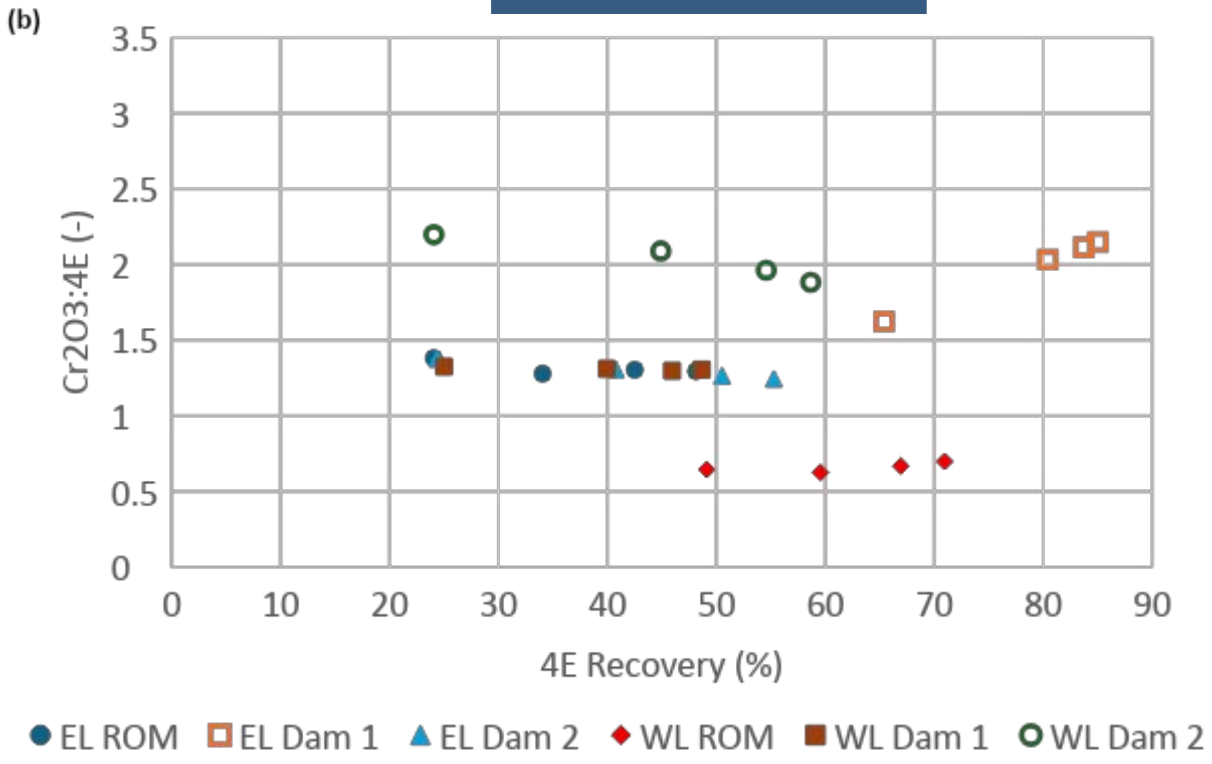

Improved Cr_2O_3:4E ratio with sodium silicate addition

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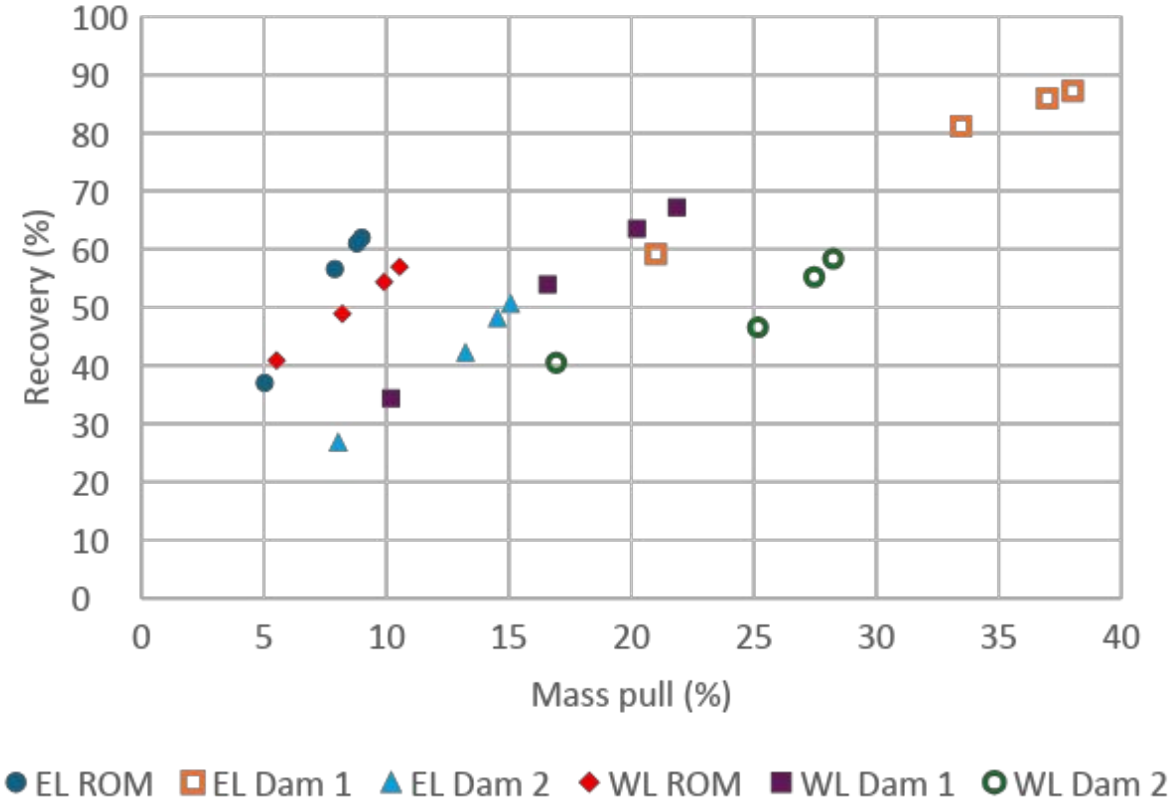
Conclusions



- Flotation recoveries for these samples were low in comparison to standard fresh PGM ores (at 10% mass pull, ROM recoveries ~60%, Dams significantly lower)
- Possible reasons:
  - PGE arsenides and alloys comprised about 50% of the PGM species
  - Very fine PGE distribution
  - Secondary mineralogy – no evidence with the tools that were used, but literature suggests the possibility

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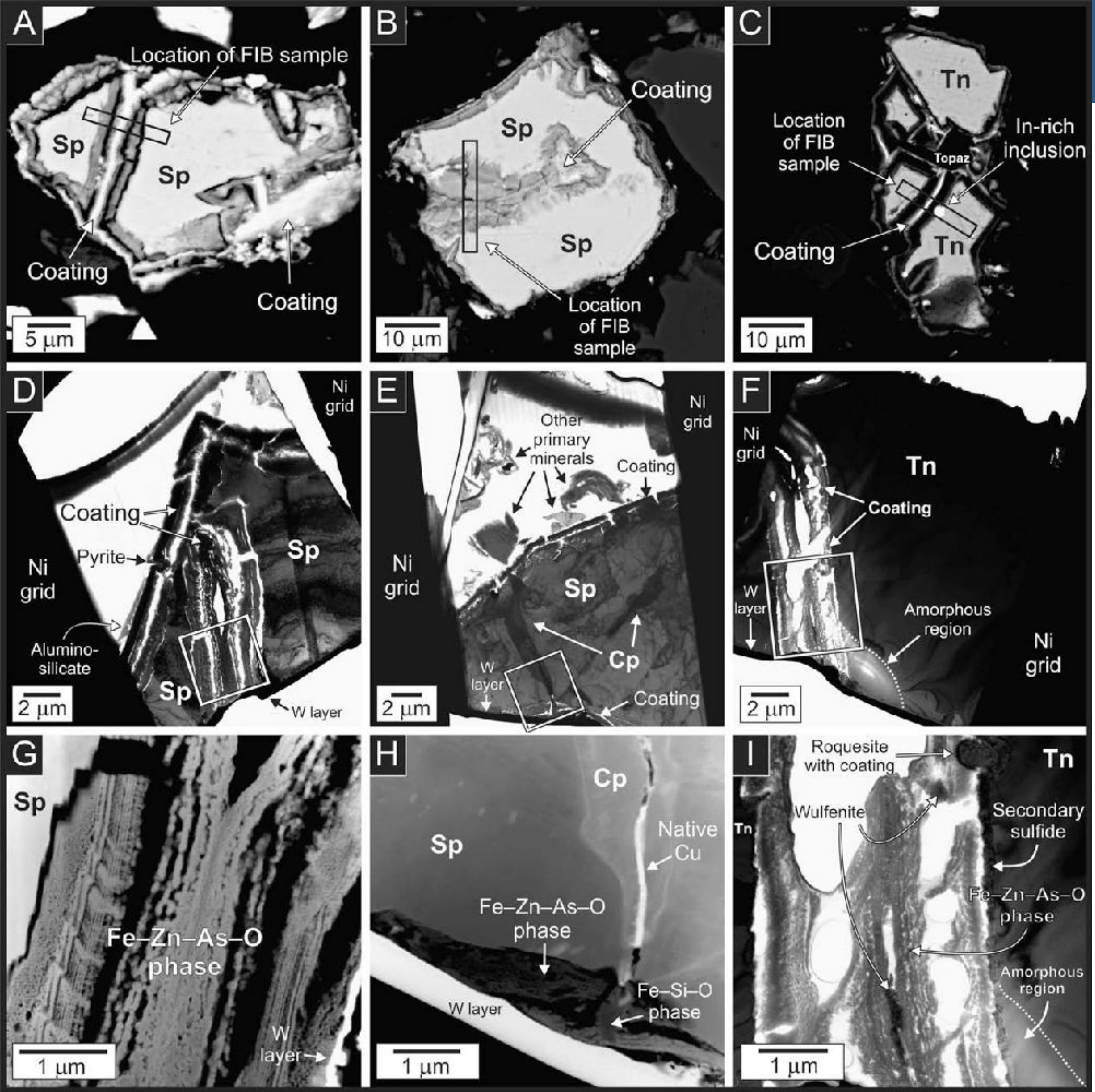
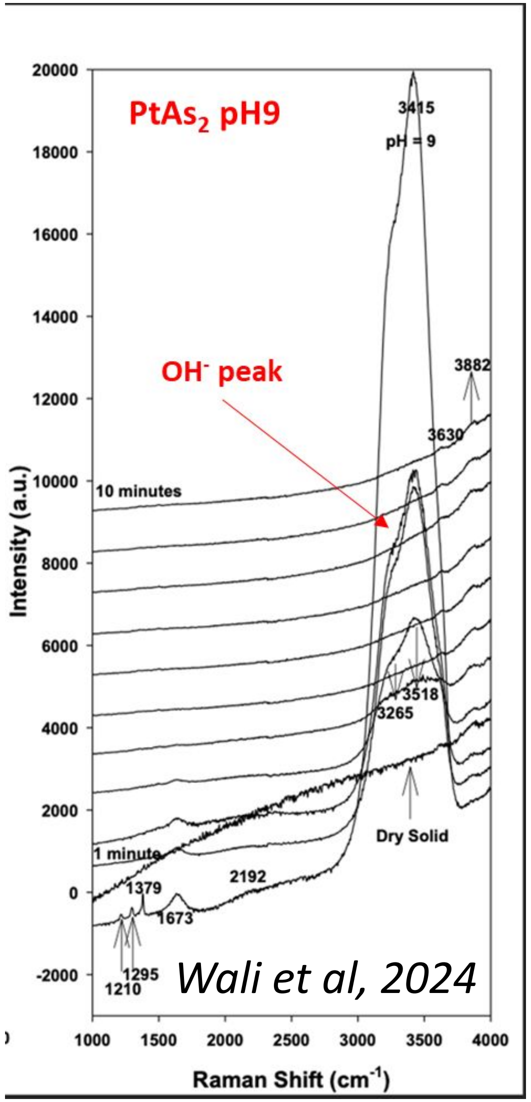
Secondary minerals formed on sphalerite and tennantite particles



SEM images

(S)TEM images

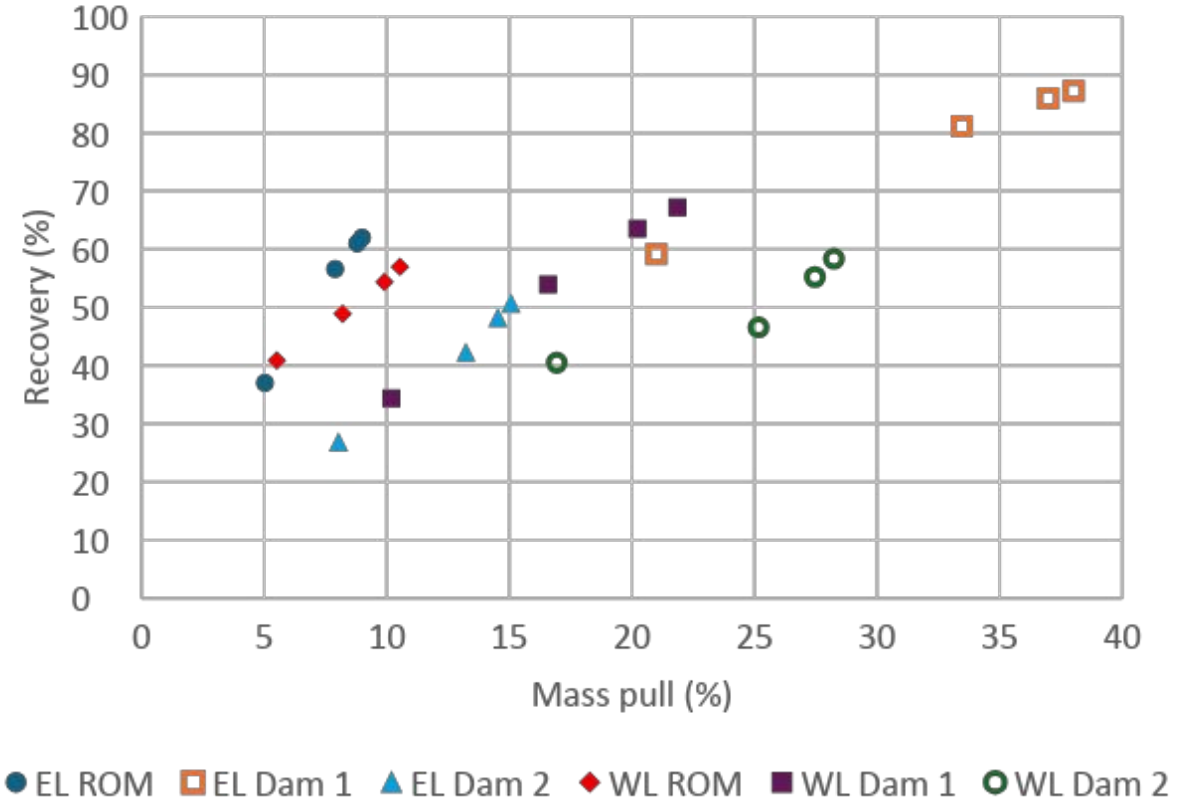
Petrunic et al, 2009



Wali et al, 2024

Oxy-hydroxide coating on sperrylite

Conclusions



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- Possible reasons:
  - PGE arsenides and alloys comprised about 50% of the PGM species
  - Very fine PGE distribution
  - Secondary mineralogy – no evidence with the tools that were used, but literature suggests the possibility
- Possible remedies:
  - Targeted reagents for slow floating species
  - High energy flotation cells for very fine particles
  - Stirred milling and low pH to dissolve and remove coatings on PGMs

Acknowledgements

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