LOCATING ORE UNDERCOVER USING A BACTERIAL LEACH AND OTHER GEOCHEMICAL TECHNIQUES

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Extraction Techniques

- Various methods have been employed
  - Some are novel: enzymes, buffers
  - Some are recycled: new technology with old methods
- Many extractions are not compared to other techniques

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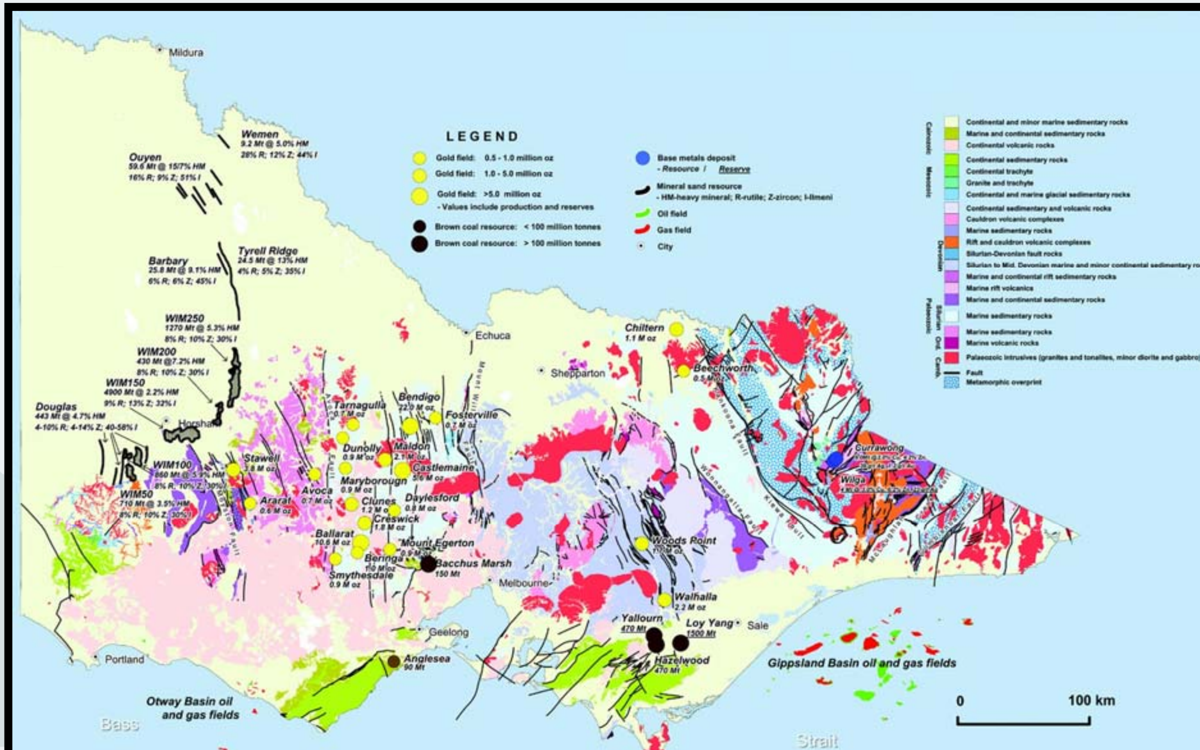
Bacterial Leach

- Developed by Curtin University, now run by SoLogic Ltd and called LocatOre®
  - Uses a non-pathogenic bacteria for the dissolution of the ultra thin surface layers of minerals
  - Advantages
    - Simple technique
    - Geochemical signature is not diluted in the matrix
  - Disadvantages
    - Lack of knowledge about the quantification/selectivity of individual elements
    - Bacteria are saturated quickly, incomplete digestion requires combining elements in suites to enhance signature

Background Problem

- Leviathan Gold Mine (Stawell) is interested in less expensive and intrusive methods to target mineralised zones
  - Western Victorian Gold deposits are known to repeat under cover to the north
- MPI (now Lionore) also had sampled soil over buried Ni deposit (Honeymoon Well)
  - Opportunity to test Bacterial Leach in another environment

Location of research



Department of Primary Industries Victoria, 2003

Mineral deposits and geology of Victoria

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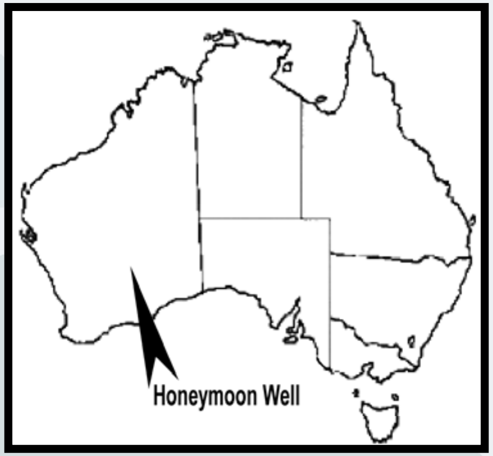
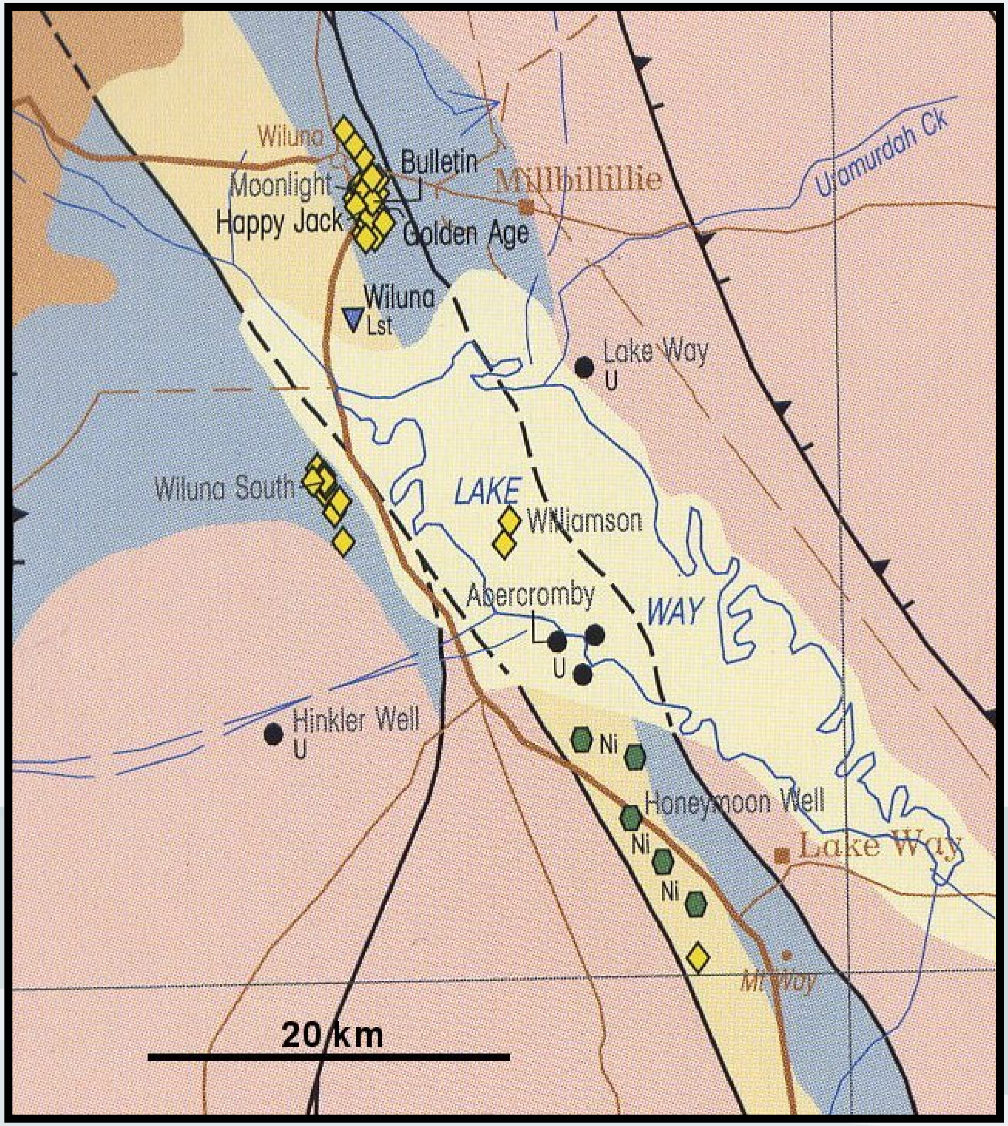
Wildwood

Honeymoon Well



Location of research



Mineral deposits and geology of HW (Dept. Industry and Resources WA, 2003)

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Honeymoon Well

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OBJECTIVES

- Assess the efficacy of the Bacterial Leach in locating mineralisation under cover in Victoria and WA
- Compare Bacterial Leach to other techniques

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METHODS

- Initial development at Kewell
- Sites investigated
  - Stawell (Wildwood): six traverses, across a known VMS Au deposit, with 20-70 m of alluvial cover
    - 80 soil samples at 30 m intervals from argillic horizon
  - Honeymoon Well: three traverses across a known Ni ore body
    - 45 soil samples, 15 from each traverse, at 20-50 m intervals from surface and approximately 35 cm depth
  - Kewell: Regolith profiles sampled at 5 m intervals down hole

Analytical Techniques

Analytical Method	Target phase
Total Dissolution	None. All phases incorporated. Useful in understanding background soil composition and interpretation of leach results.
Bacterial Leach	Non-selective, surface sorbed elements
Ammonium chloride	Water-soluble and exchangeable/surface sorbed elements
Ammonium acetate	Carbonate bound elements
0.1M Hydroxylamine hydrochloride in 0.01 M nitric acid	Amorphous/weakly crystalline Mn oxide bound elements
0.25M Hydroxylamine hydrochloride in 0.25 M nitric acid at 60ºC	Amorphous/weakly crystalline Fe oxide bound elements

- All analysis run on ICP-MS/AES for a suite of approximately 50 elements

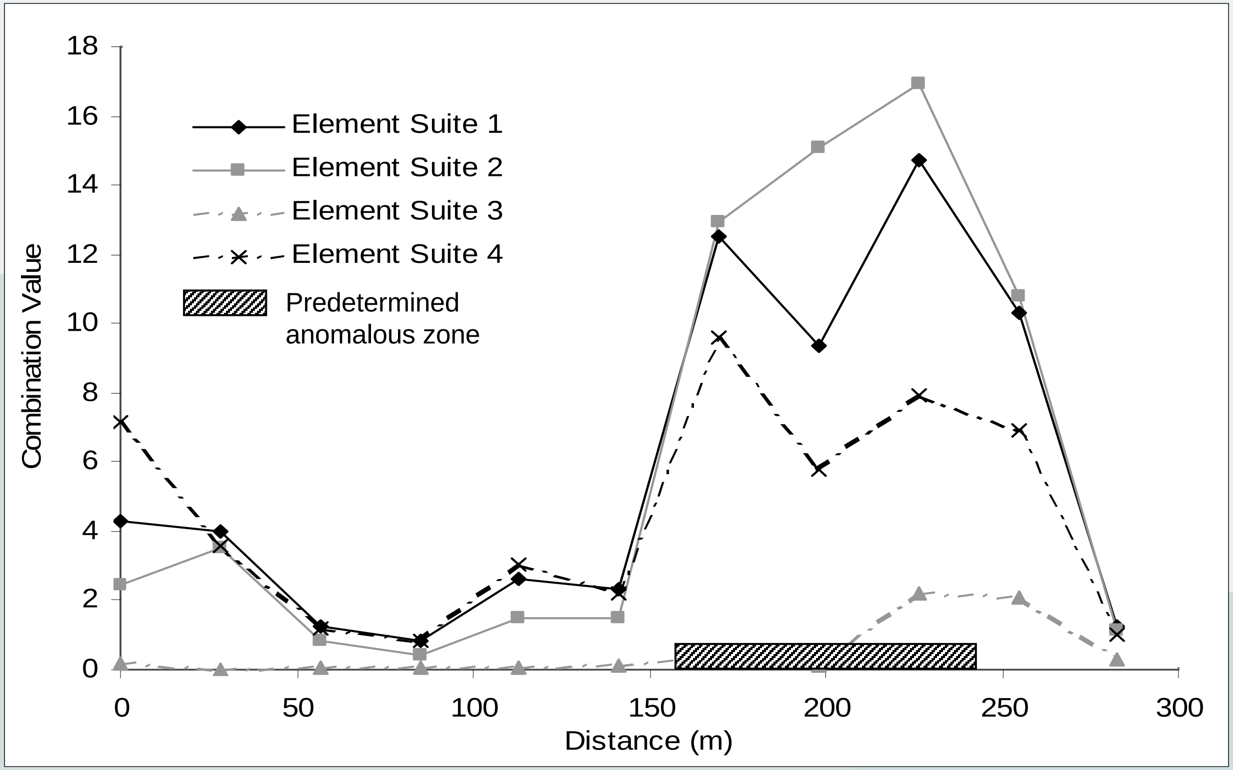
Statistical Techniques

- Correlation between elements based on laboratory techniques
- Principal Component Analysis
- Hypergeometric statistics to assess anomaly expression
  - Allows orientation survey results to be statistically compared based on probability of response through random number generation
  - Requires assumptions of expected anomalous sample points prior to getting results
  - Removes bias of viewer (Stanley 2003; Stanley and Noble 2005)

RESULTS

- Wildwood Site 1 = All listed analyses
- Honeymoon Wells= Bacterial Leach and Totals
- Kewell = Weak HA and some Totals
- Bacterial Leach uses elements suites that are combinations of Ni, Cu, As, Sb, Ga, Ge, Se, W, Te, Bi, V, Cr, Ti
- Most element suites respond similarly

Element Suite Responses



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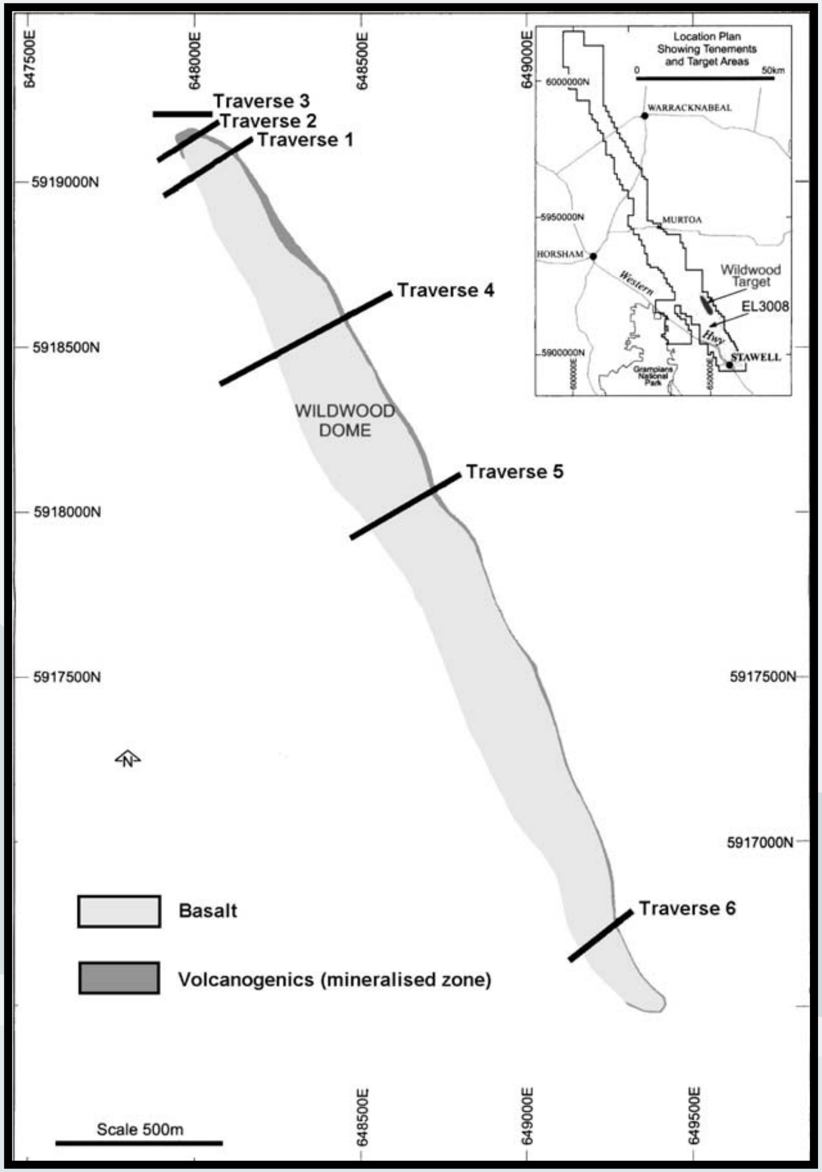
Site 1 Wildwood



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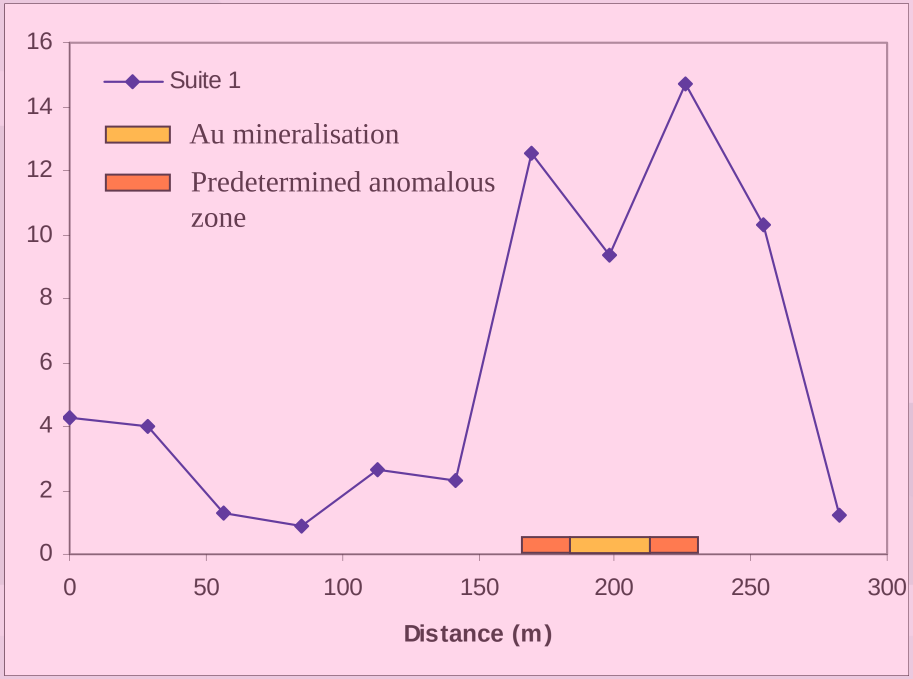
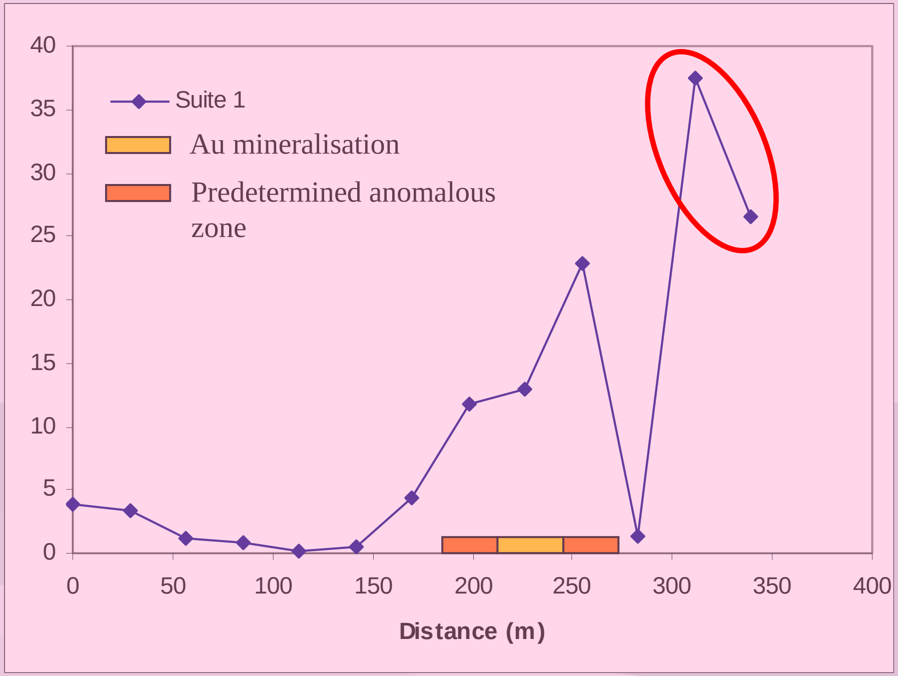
Questionable Success

- No consistent single element anomalous results for Bacterial Leach
- Not successful in 3 traverses
- Traverse #3 was not assessed as underlying mineralisation is being revised

- Combining selected element suites was successful (confirmed with hypergeometrics) in 2 of 5 traverses corresponding to the shallowest region of cover in the prospect.



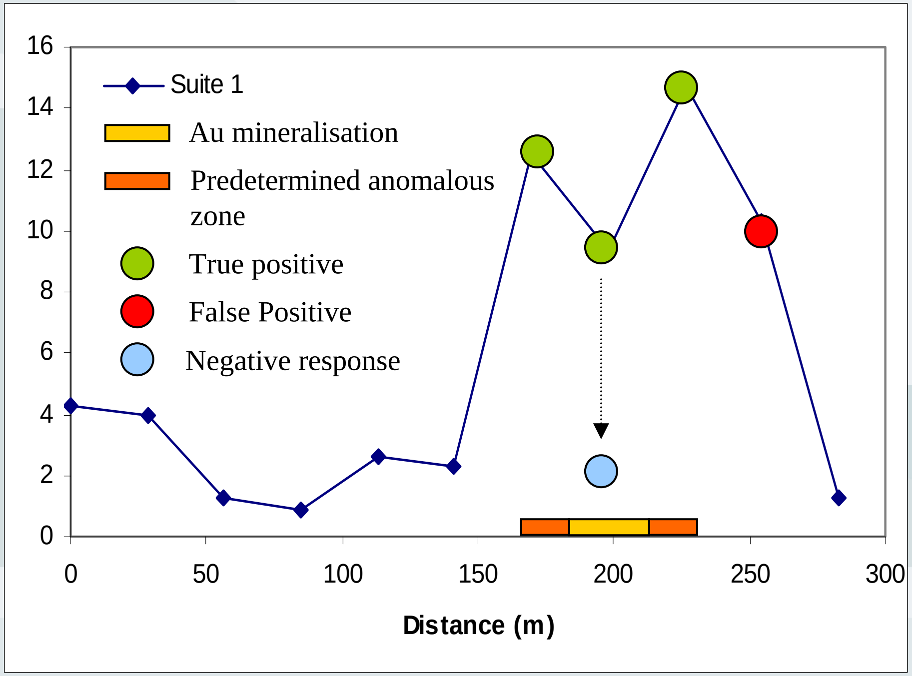
Traverse 6 LocatOre



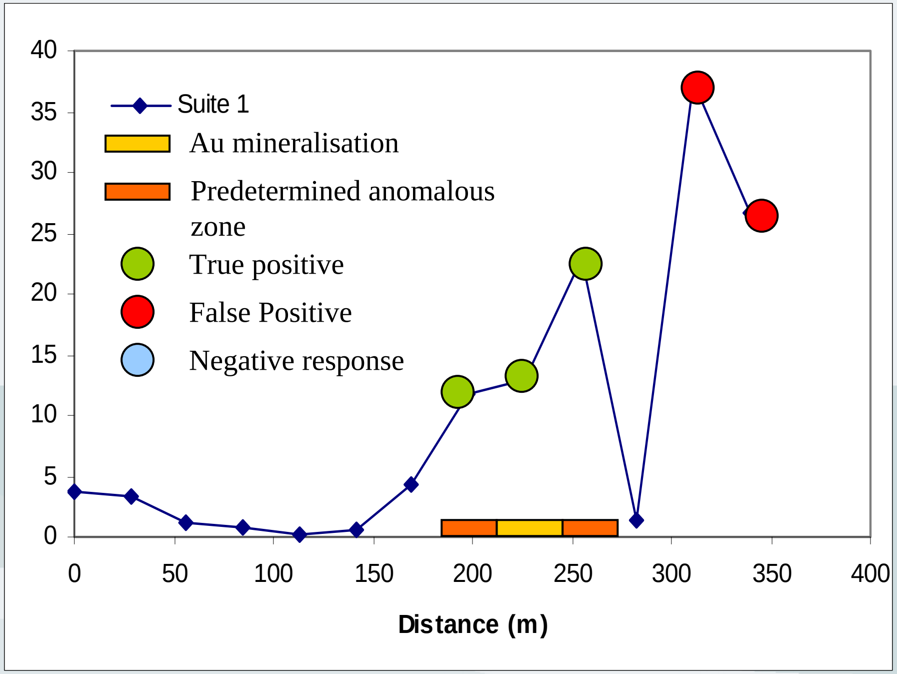
Traverse 5 LocatOre

Hypergeometric evaluation

- Pr(x) = 3 traverse 6 by chance = 2%
- Pr(x) = 3 traverse 5 by chance = 3.5%
- Add negative response Pr(x) ≥ 2 = 16% for traverse 6



WLWD Traverse 6 LocatOre



WLWD Traverse 5 LocatOre

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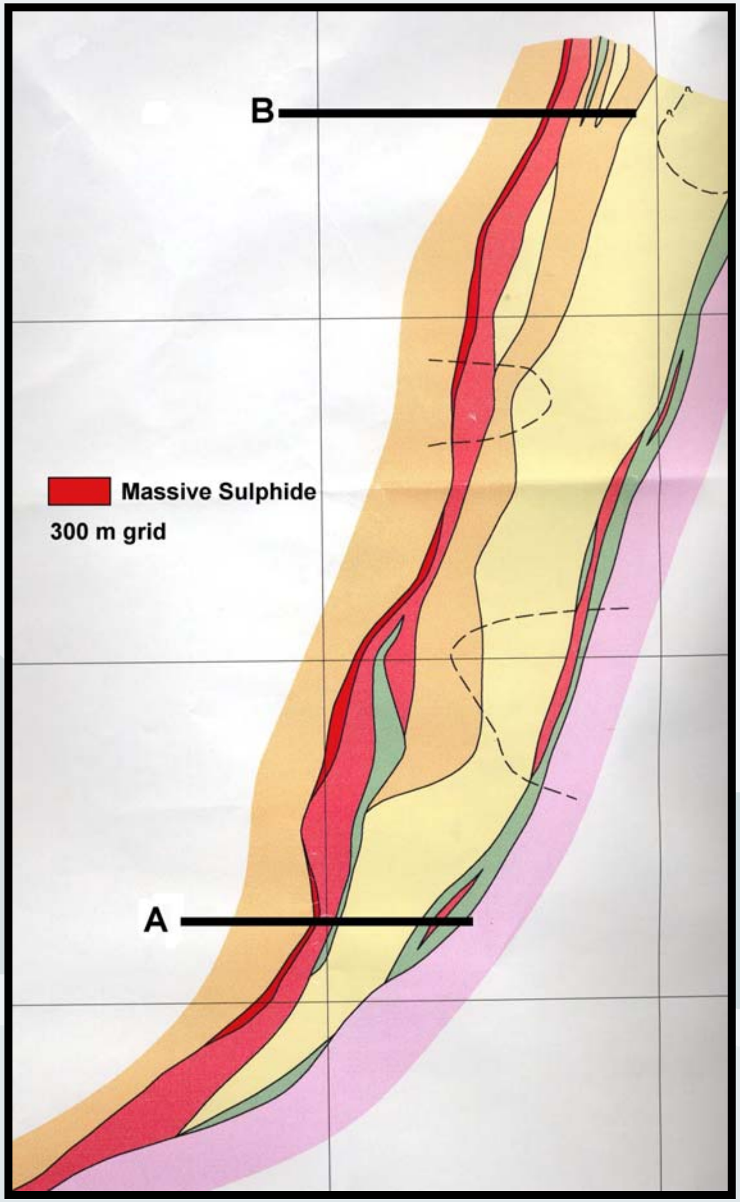
Wildwood Hypergeometric Evaluation

Traverse	Sample points	True positive	False positive	False negative	Hypergeometric Probability P(x)
1	12	0	1	4	100
2	13	0	0	5	100
4	16	0	0	4	100
5	13	3	2	0	3.5
6	11	3	1	0	2.4

Wildwood Technique Evaluation

Technique	Successful analysis P(x) < 0.05	Number of orientation surveys	Technique % success rate
Total Dissolution	0	5	0
Bacterial Leach	**2**	**5**	**20**
0.1M HA	0	5	0
0.25M HA	0	5	0
Ammonium chloride	0	5	0
Ammonium acetate	0	5	0
EC	0	5	0
pH	0	5	0

Site 2 Honeymoon Well



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Unsuccessful Exploration Geochemistry

- Single element anomalies occur, but do not correspond with mineralised zones
- Combining selected elements did not produce a significant trend in Bacterial Leach
- Values for elements taken at depth were much higher than surface samples for Bacterial Leach

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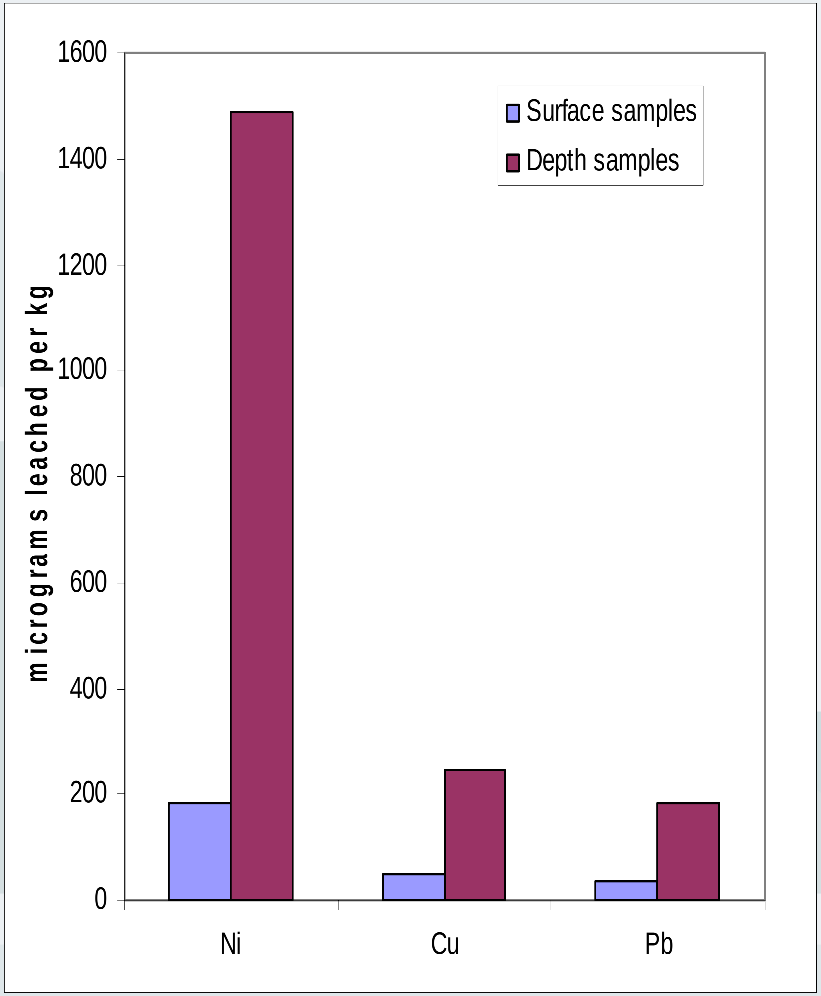
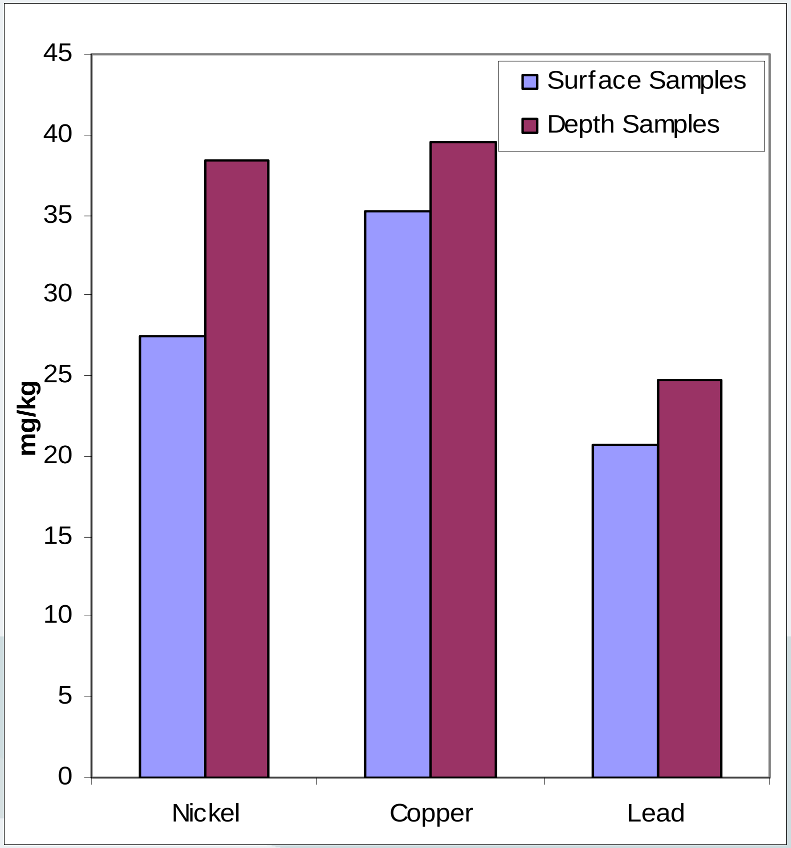
Comparison of sample depth – Bacterial Leach



- Enrichment Factors significantly higher in samples taken 30 cm lower in the profile
- Average EF for elements at depth 4.3 x
- Very important to sample consistently and on morphology
- Be aware of erosional/depositional landforms

Comparison of sample depth - Totals

- Total Digestion
  - Enrichment Factors slightly higher in samples taken 30 cm lower in the profile
  - Average EF for elements at depth 1.2 x



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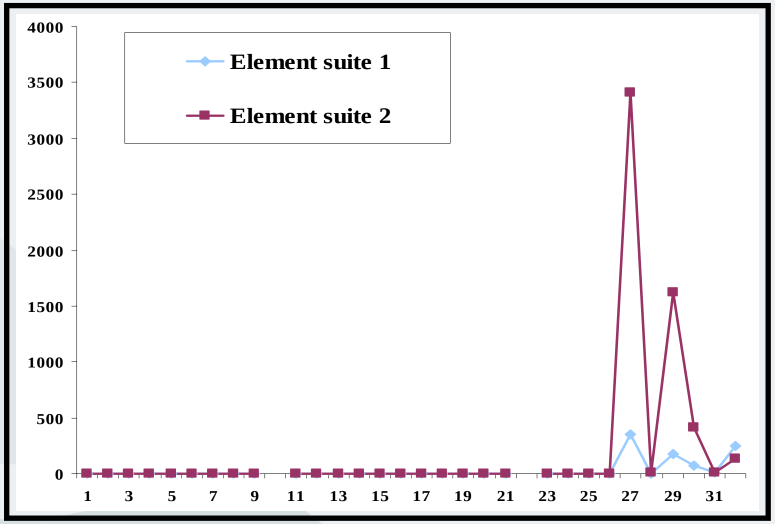
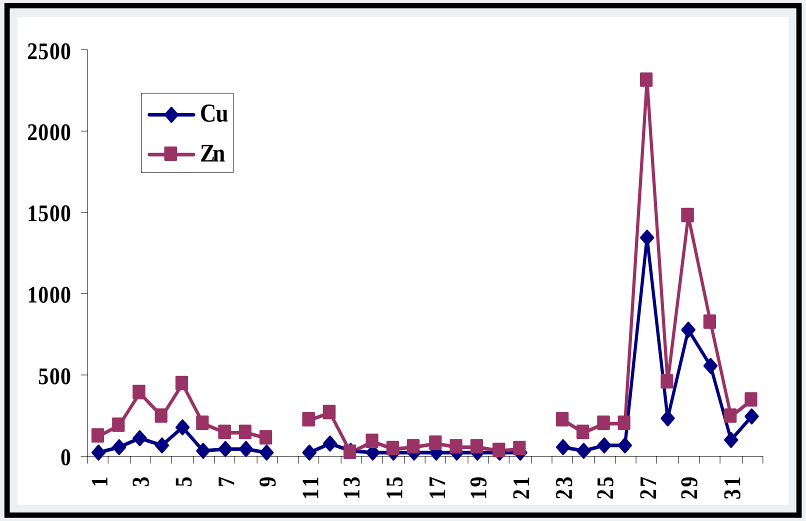
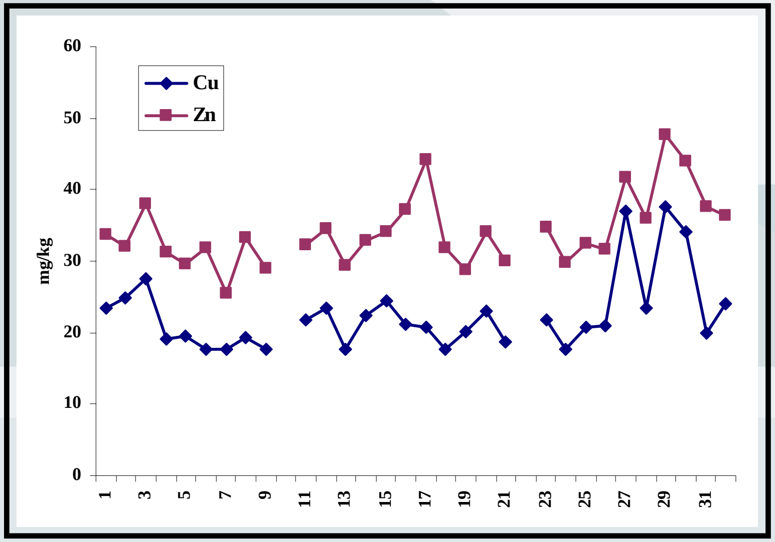
Advantage of partial/selective extractions



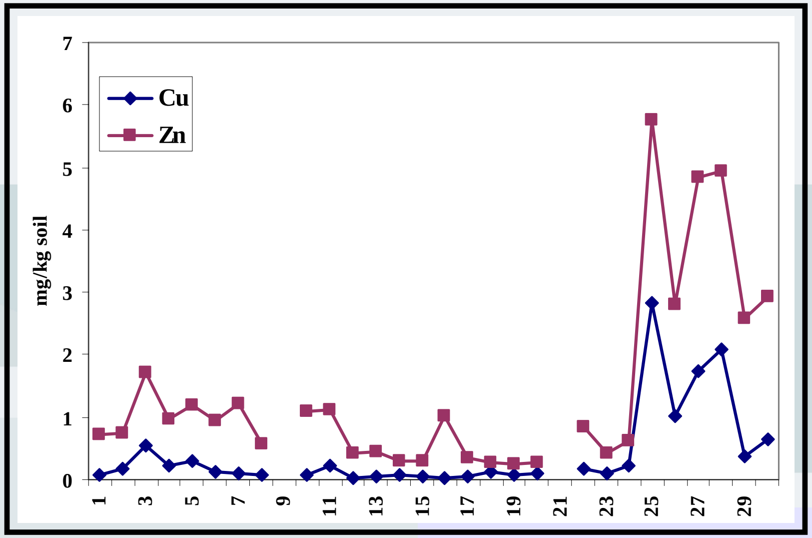
Bacterial Leach geochemical suite response



Bacterial Leach Cu and Zn concentrations



Total Dissolution Cu and Zn concentrations



NH_2OH HCl Cu and Zn concentrations

Why the poor results?

- Different climate and soil type (influence of soil properties)
- Different target ore
- Understanding dispersion direction and mechanisms of movement and anomaly formation
- Lack of understanding about technique

Comparison of techniques using Stawell samples (Wildwood, Kewell and Wartook)

- Correlation analysis to understand the different results from the different techniques
- PCA analysis

Correlation of techniques

Bacterial Leach versus total digestion

	Li T	As T	Cu T	Zn T	V T	Cr T	Mn T	Ni T
Bacterial Leach	-0.18	-0.20	0.23	-0.24	-0.24	-0.51	0.94	-0.16
	Rb T	**Sr T**	**Zr T**	**Cd T**	**Sb T**	**Te T**	**Ba T**	**Pb T**
Bacterial Leach	-0.52	0.90	-0.37	0.80	-0.40	0.13	0.12	0.29

Bacterial Leach versus hydroxylamine hydrochloride

	Li HA	As HA	Cu HA	Zn HA	V HA	Cr HA	Mn HA	Ni HA
Bacterial Leach	0.92	0.73	0.95	0.89	0.80	0.33	0.96	0.70
	Rb HA	**Sr HA**	**Zr HA**	**Cd HA**	**Sb HA**	**Te HA**	**Ba HA**	**Pb HA**
Bacterial Leach	0.91	0.97	0.69	0.87	0.67	0.89	0.58	0.85

	Strong Correlation
	Moderate Correlation
	Moderate Correlation
	Weak Correlation

Indicates Bacterial Leach may be phase selective

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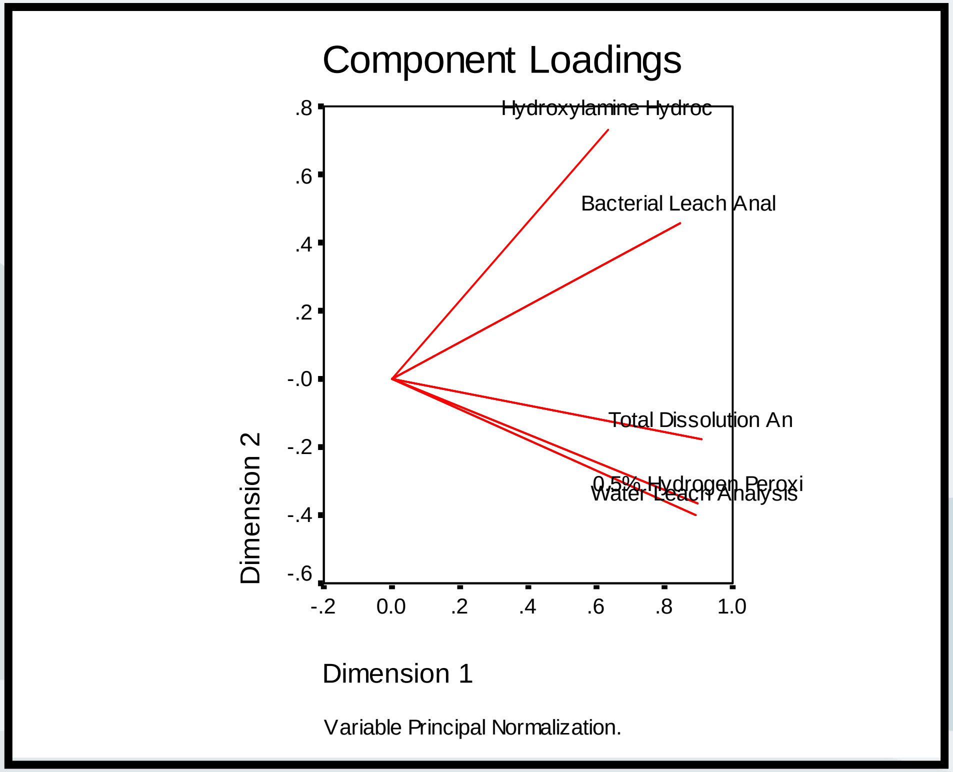
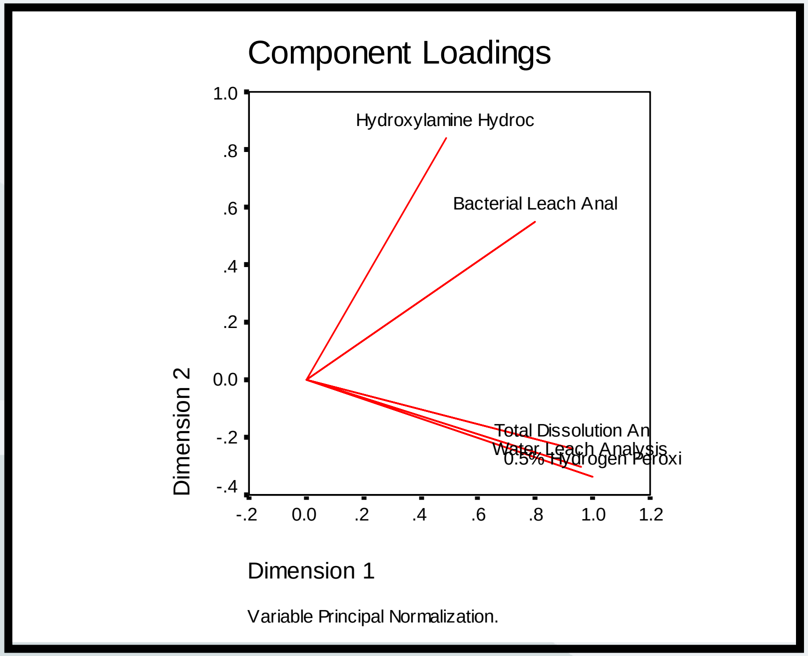
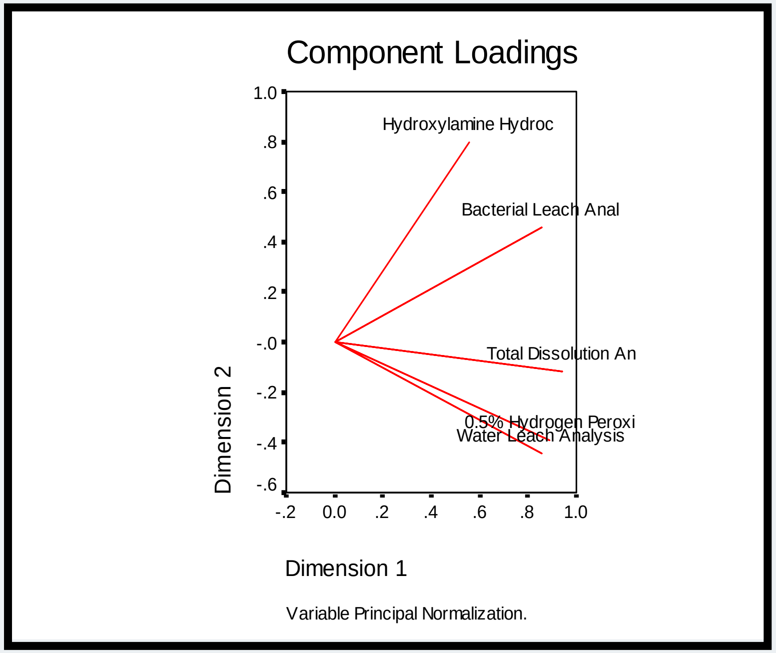
- Principal Component Analysis
  - Confirms correlation analysis about similarity of techniques and geochemical response



PCA loadings Victorian samples



Transported regolith component loadings



Residual regolith component loadings

- Technique responses between elements do not vary greatly depending on change in regolith

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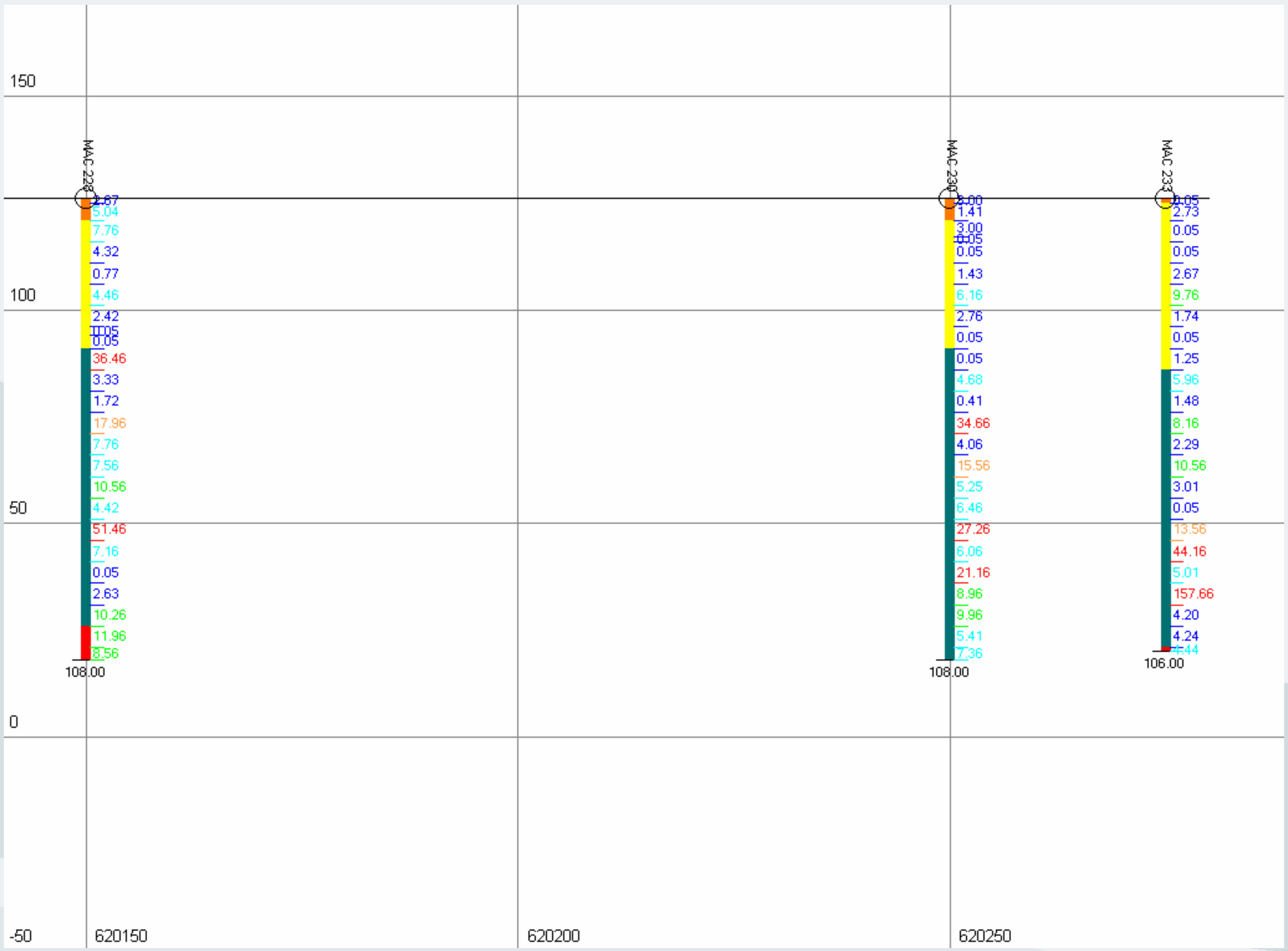
The 3D test of faith

- Do you see the distribution in 3D?
- Bacterial Leach too expensive as a first test
- Hydroxylamine Hydrochloride (and Totals) used
- Results: No clear dispersion pattern to surface

Arsenic values above Au mineralisation



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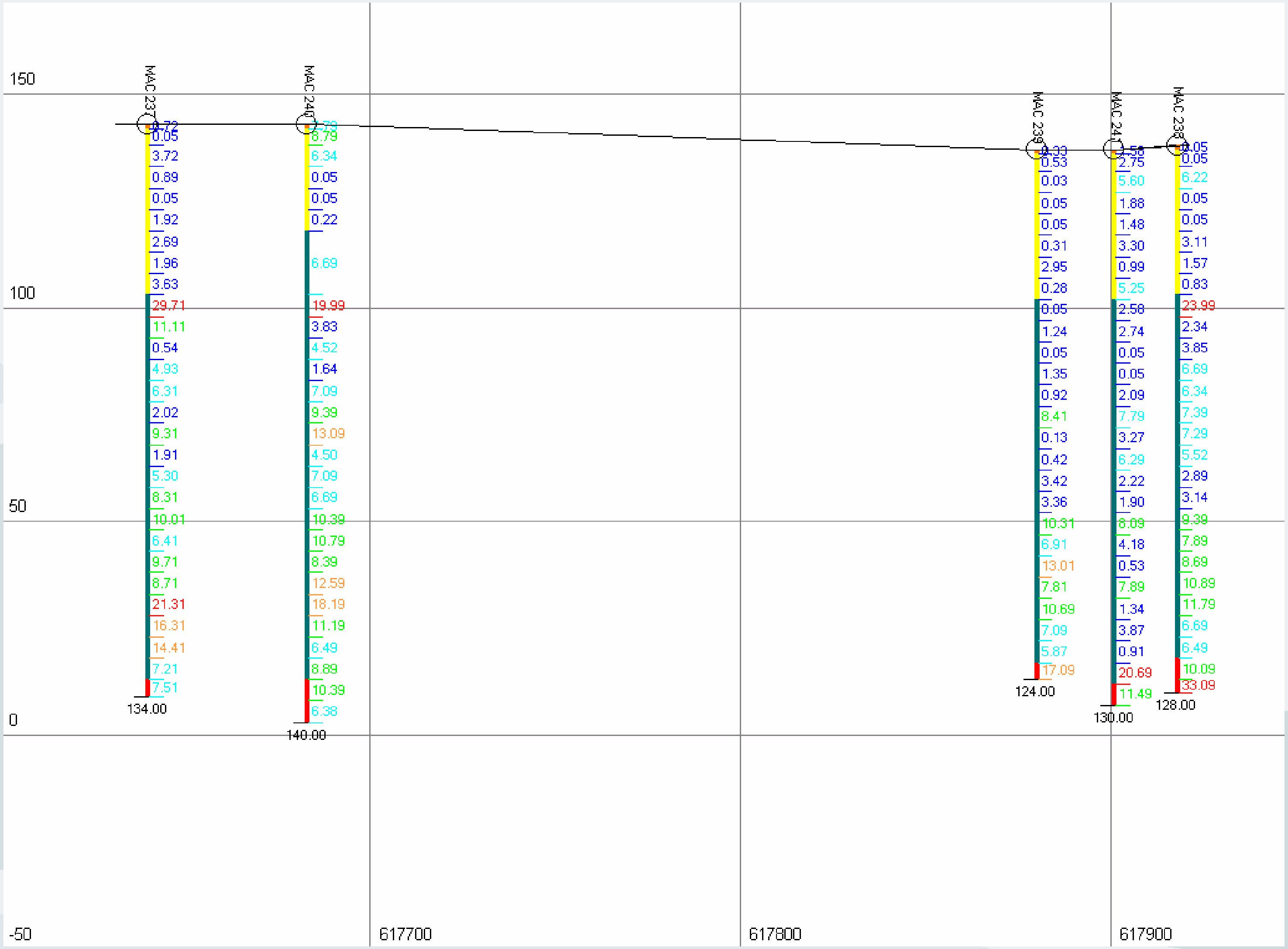
Arsenic values above barren sulphides



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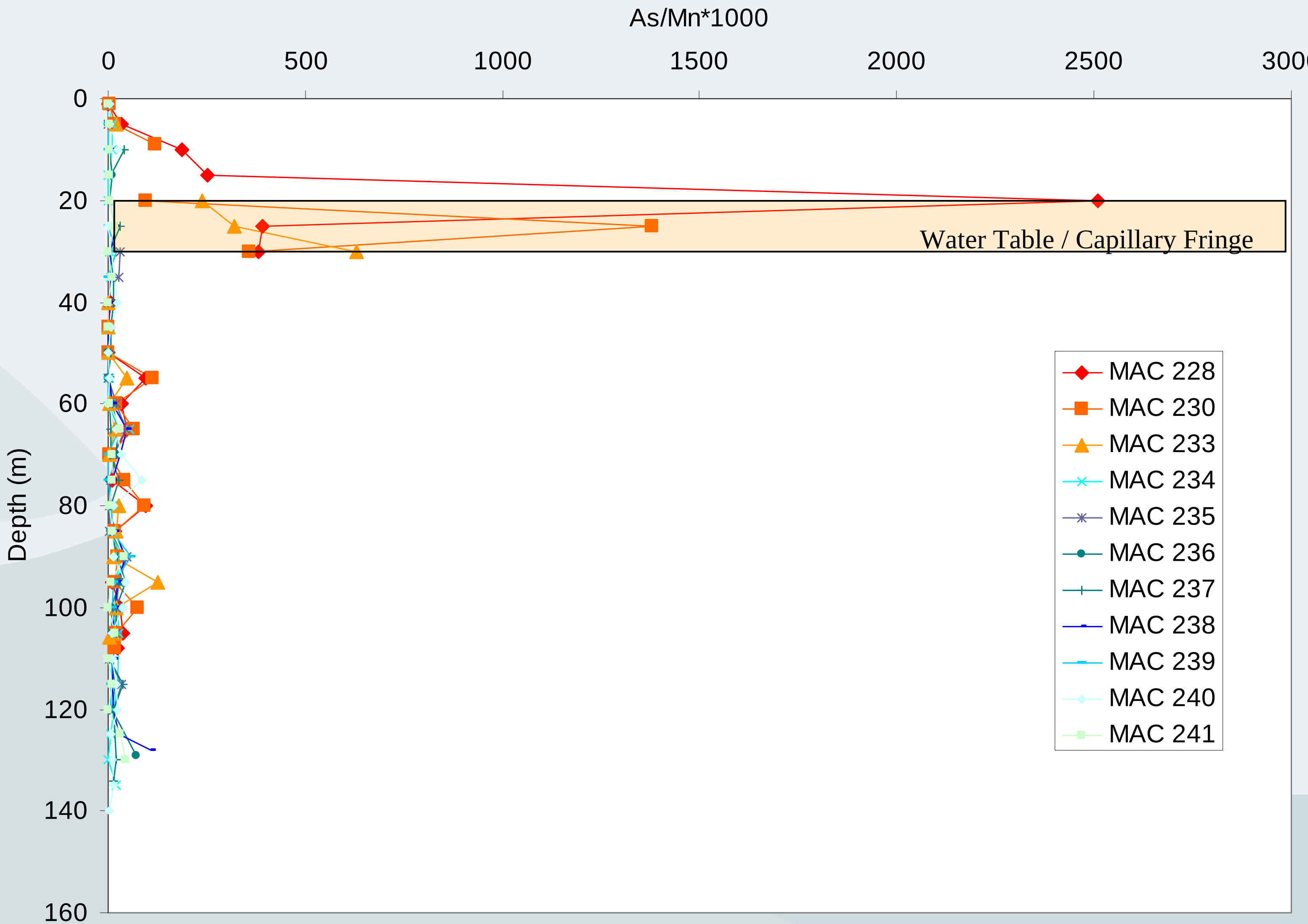
However…

- Ratio of pathfinders with Mn revealed a zone of sampling interest
- Capillary fringe/Watertable regolith samples
  - Relates to calcrete, base of hardpan, interface sampling
  - Zone of intense chemical changes and movement and element capture



Similar response from Pb and Zn

Cu, Ni and Co response evident, but less pronounced

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CONCLUSIONS

- Understanding sample media, depth and soil properties are key to getting good results
  - Depth is clearly critical at Honeymoon Well
  - Potentially new sampling zone detected at Stawell
- Hypergeometric statistics provide a method to compare techniques
- Understanding movement/dispersion mechanisms is essential to future geochemical investigation undercover

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CONCLUSIONS

- Bacterial Leach and the other analyses provided different results to each other
- Bacterial Leach does seem to have some association with Mn-oxide bound elements (HA technique)
- No method consistently identified mineralisation beneath thick cover, although Bacterial Leach was the only successful technique
- Bacterial Leach has not proved superior to the other techniques at this stage, but the element suites and increased contrast for anomalies may be beneficial

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Thank you for your attention

Thanks also to the following groups:

CRC LEME

CSIRO Exploration and Mining

Curtin University of Technology

Leviathan Resources

LionOre

Questions?

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