

Geochemistry and the challenge posed by exotic cover

David Cohen

University of New South Wales

and

Association of Applied Geochemists



SMEDG



AIG

***Recent Practical Advances
in Mineral Exploration
Technologies***

September 11, 2009



Ahmad Mokhtari

Isfahan University of Technology, Isfahan



RMRC

Neil Rutherford

Rutherford Mineral Resource Consultants, Sydney



Simon Gatehouse

Hellman and Schofield, Sydney



David Kelley

MMG – Minerals and Metals Group, Denver



Ravi Anand

CRCLEME / CSIRO Exploration and Mining, Bentley



William Coker

BHP Billiton World Exploration, Vancouver



Iain Dalrymple

Actlabs, Perth



Intro

Models

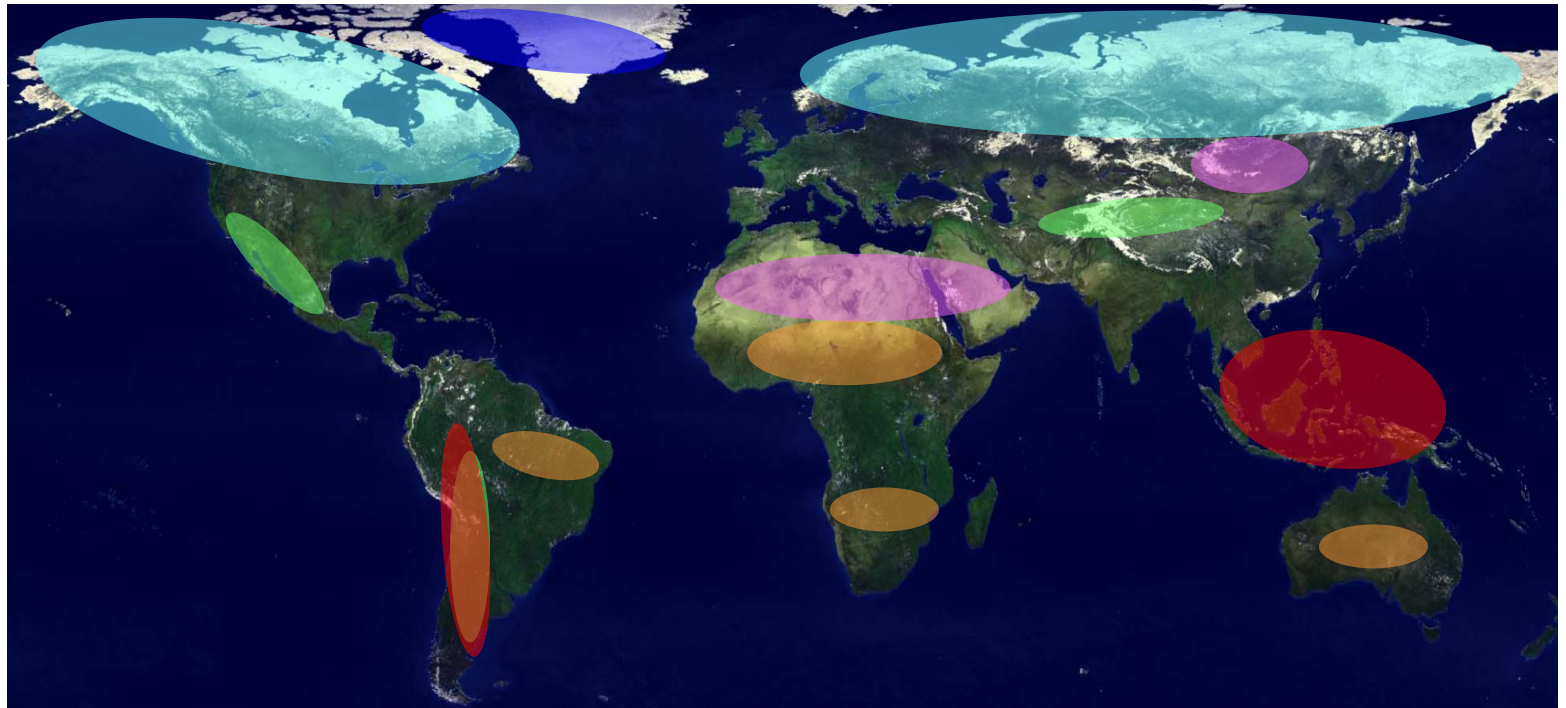
SEx

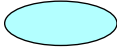





Mandy

Data

Conclusions

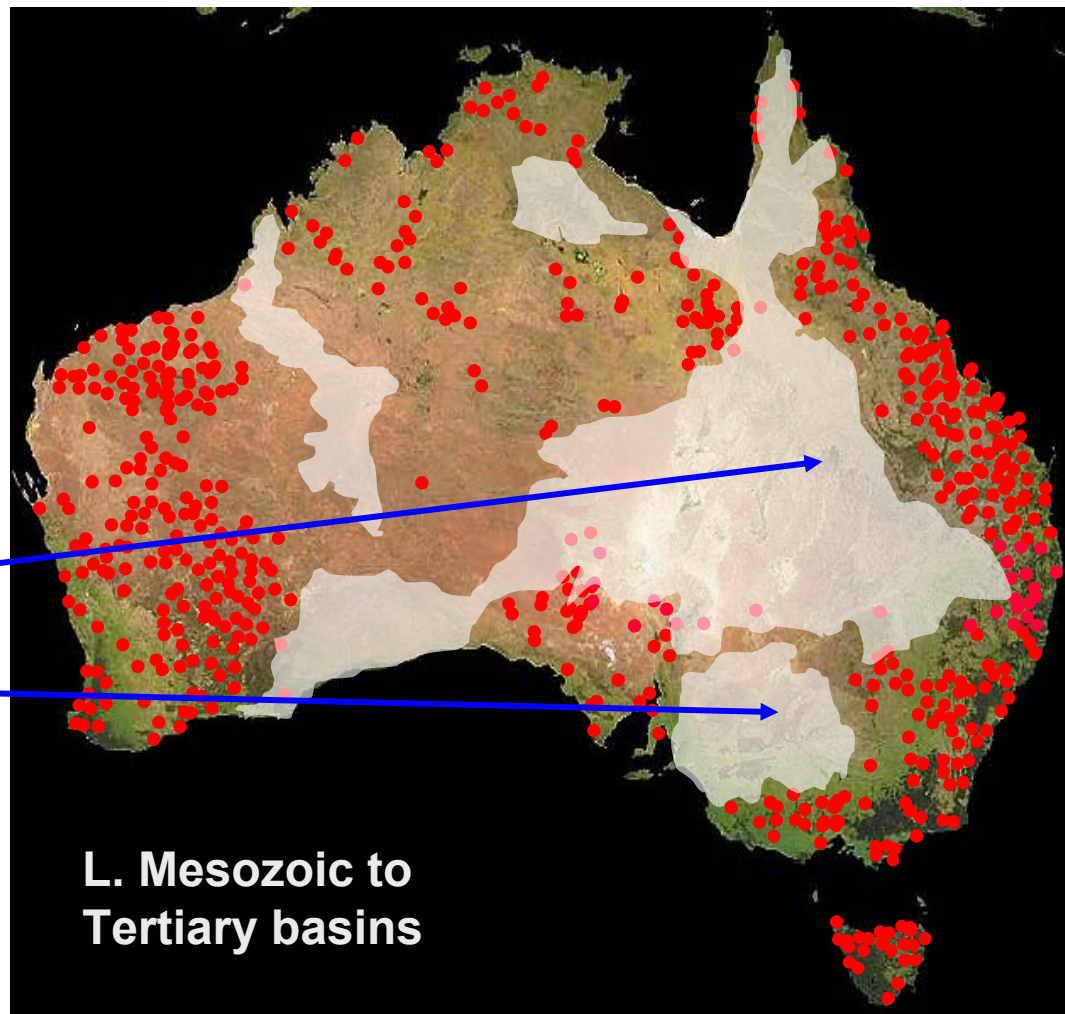
The problematic terrains for geochemical exploration



-  **Glacial deposits**
-  **Thick gravel and scree deposits**
-  **Thick alluvium or colluvium + deep weathering**
-  **Aeolian deposits**
-  **Volcanic ash**
-  **?Ice**

Thompson Orogen

Lachlan Fold Belt



• Significant mineral occurrences

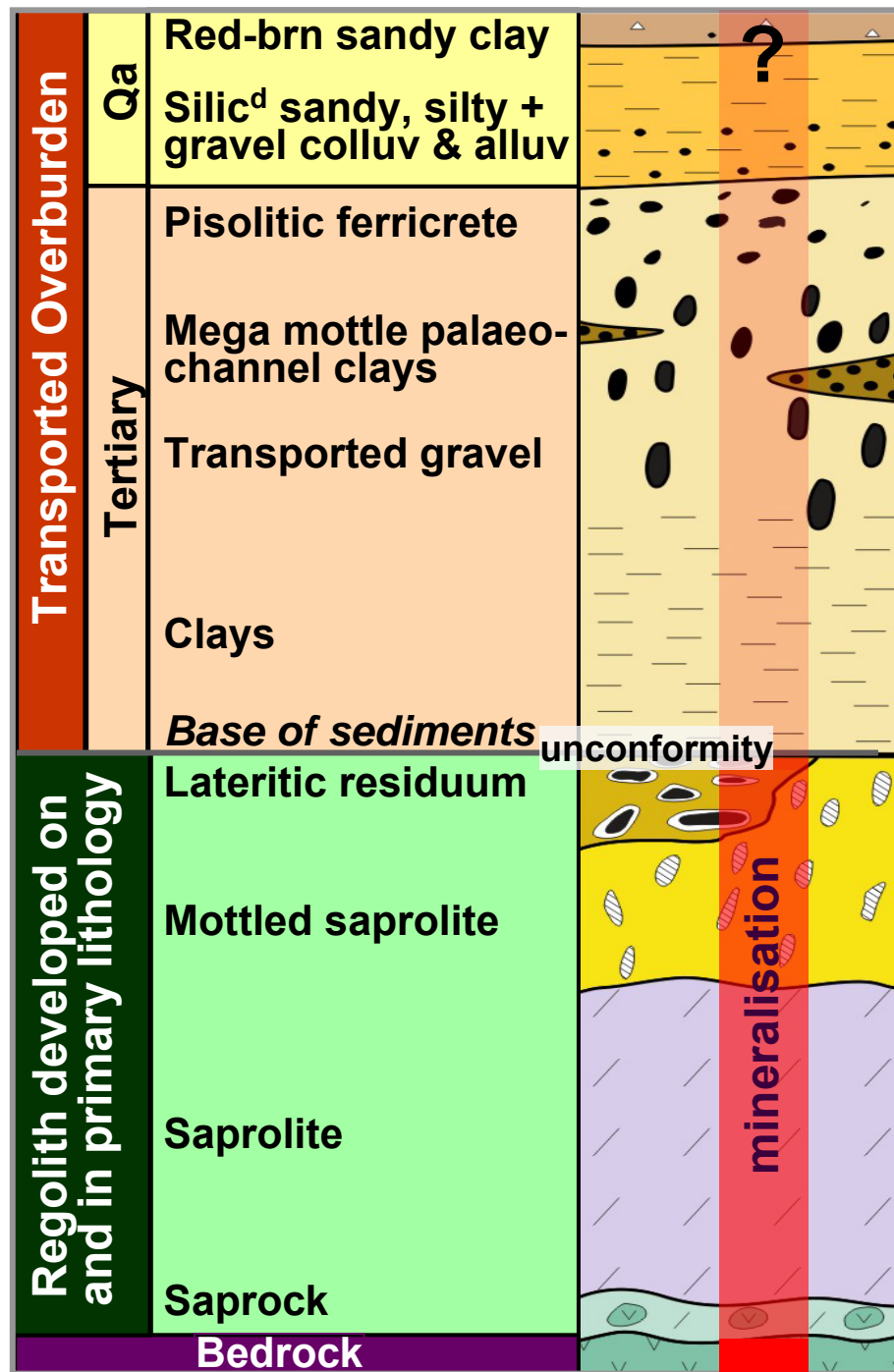
Data: Australian Minerals Atlas

Regolith Classification

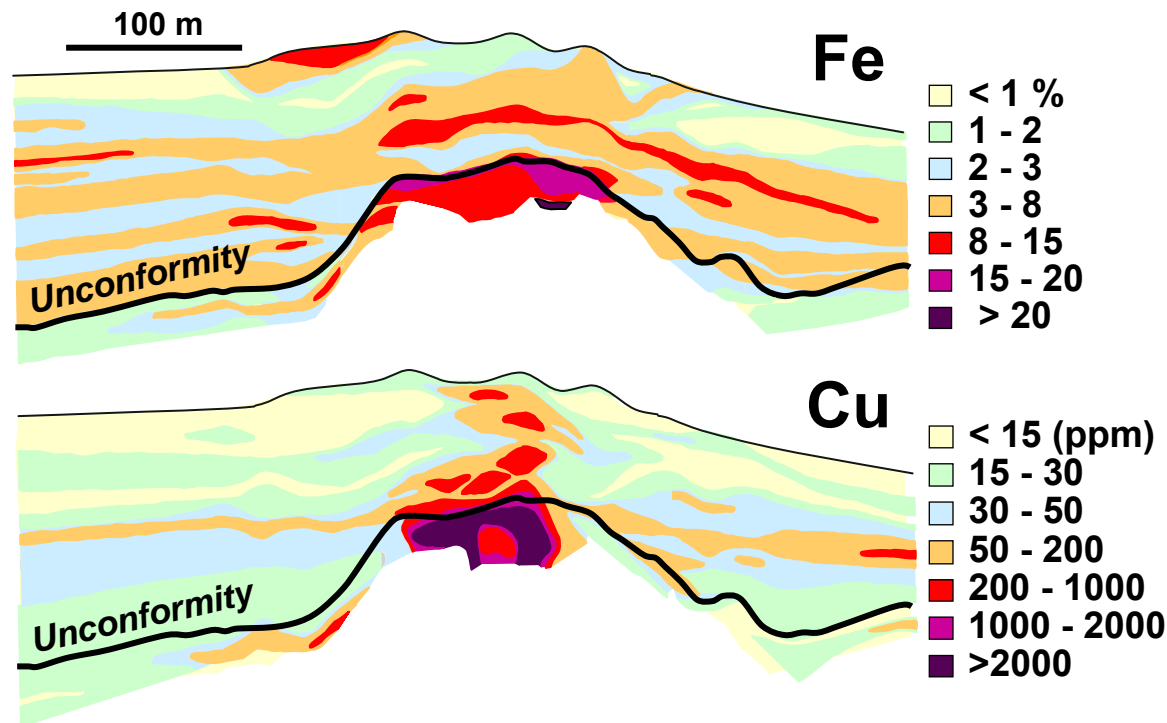
Weathered profiles typically have **RESIDUAL** and **TRANSPORTED** components of varying ages

Several distinct phases of creation and destruction of secondary Fe, Ca, Si and Al minerals – each with total or partial resetting of trace element geochemistry

- ⇒ Systematic approach to identifying regolith materials and landforms
- ⇒ Link evolution of regolith and its components to geochemical processes and sampling strategies



Does dispersion
occur through
deep, transported
cover?

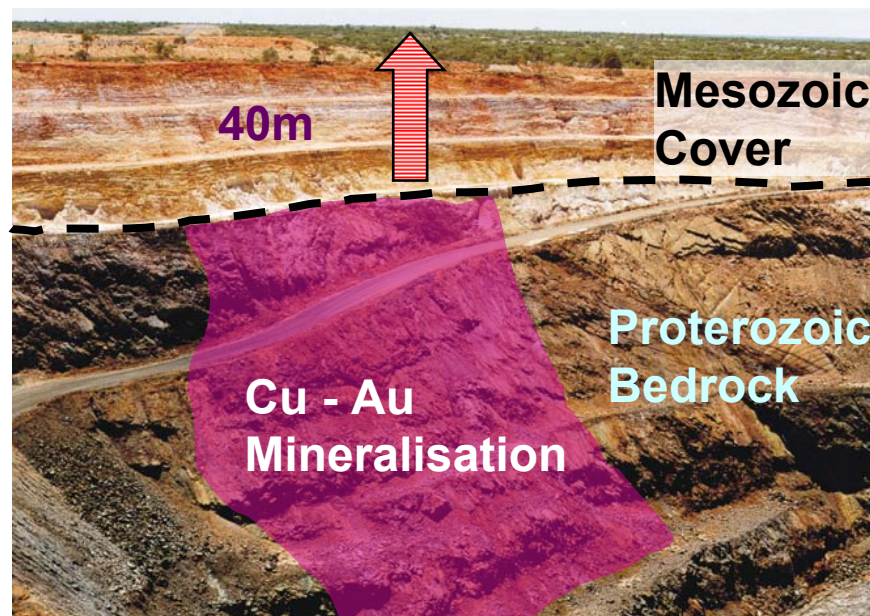


Osborne Cu-Au
deposit, Qld

Dispersion mechanisms?

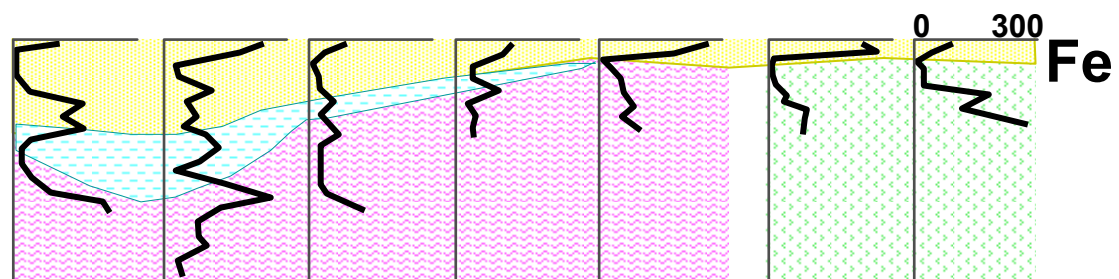
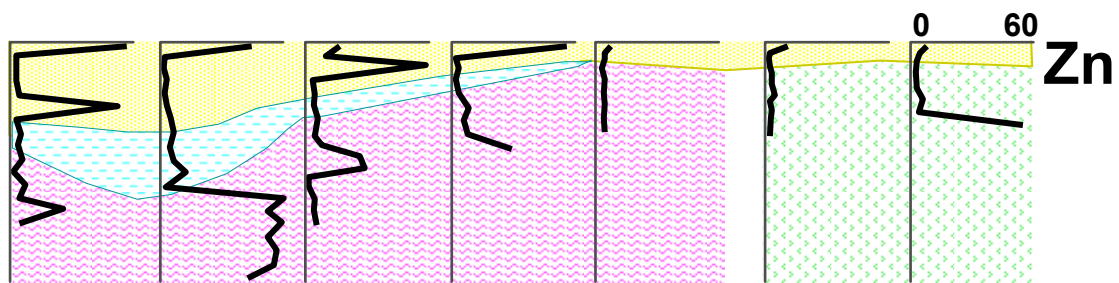
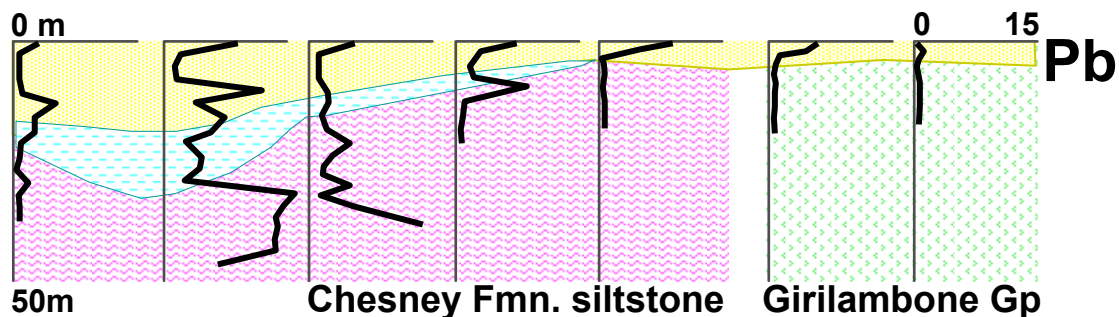
Dispersion timing?

(data: Lawrance, 1999)



Does dispersion always occur?

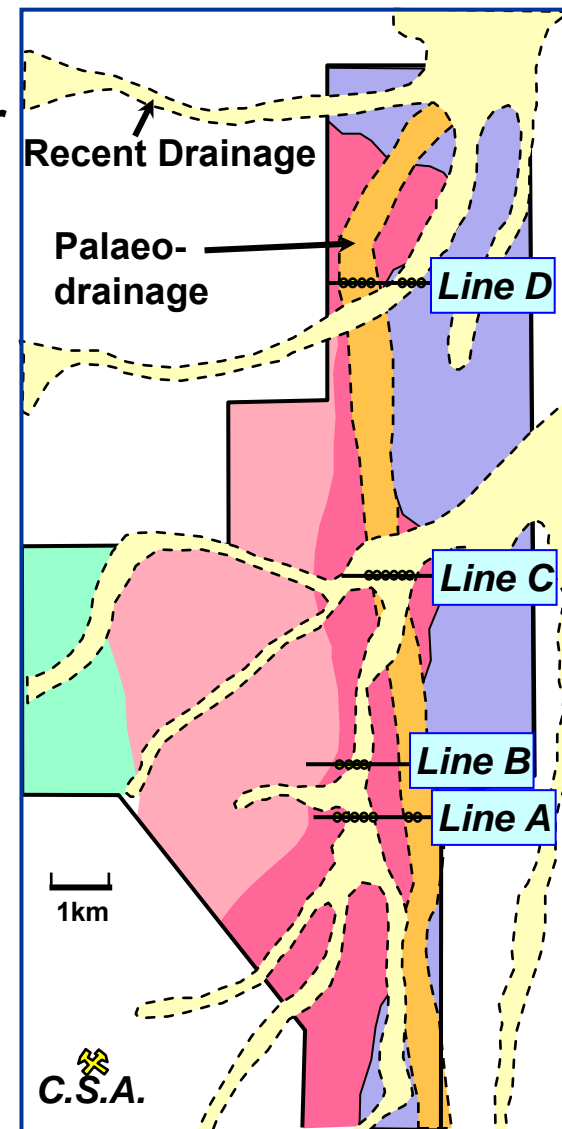
CSA Mine Lease, Cobar



- Coarse silt + lag
- Transported silt + clay
- Residual regolith

Line D

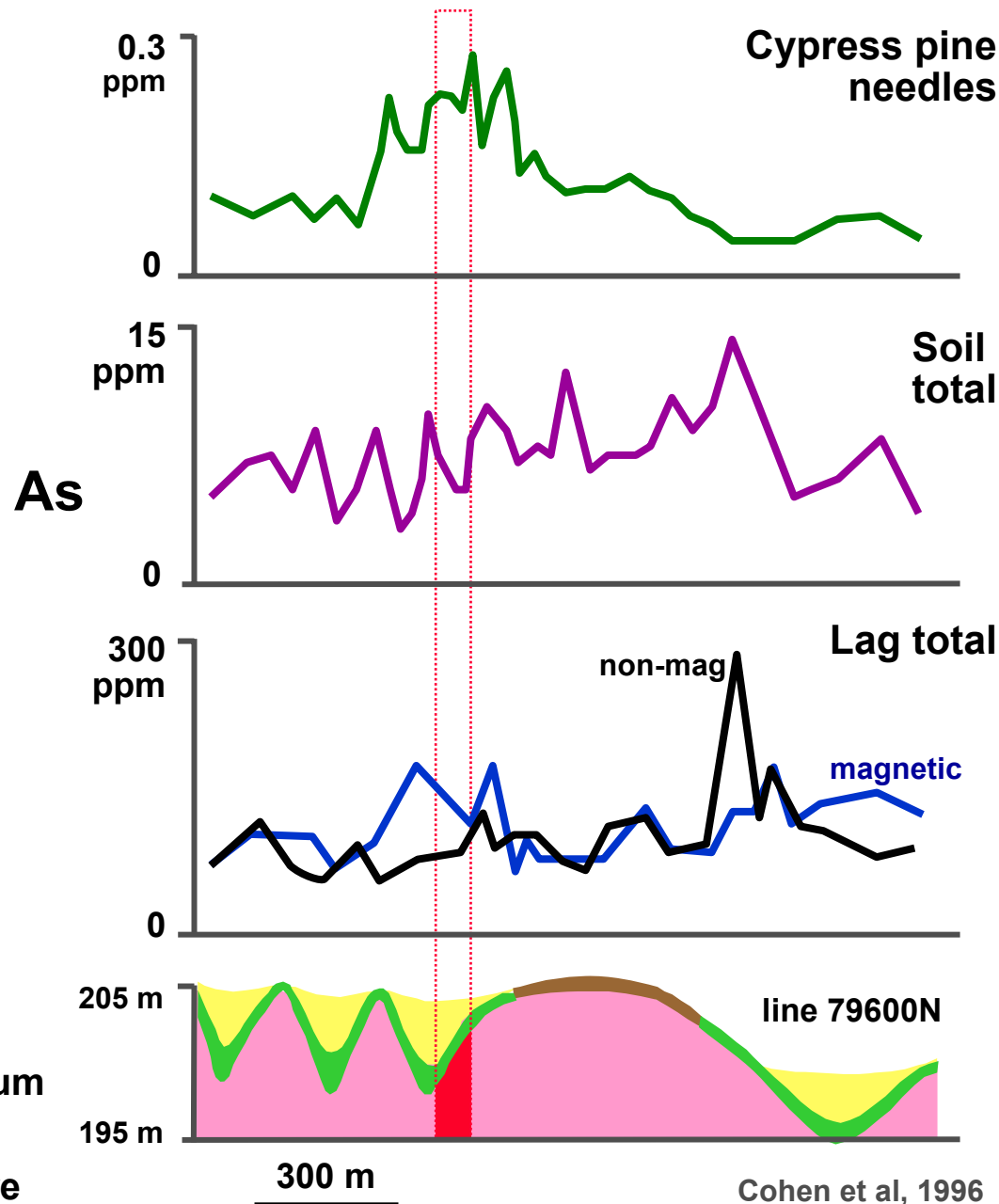
Shen and Cohen, 2005



- U. Amphitheatre Gp.
- CSA Siltstone
- Chesney Fmn. (grwk)
- Chesney Fmn. (slts)
- Girilambone Gp.

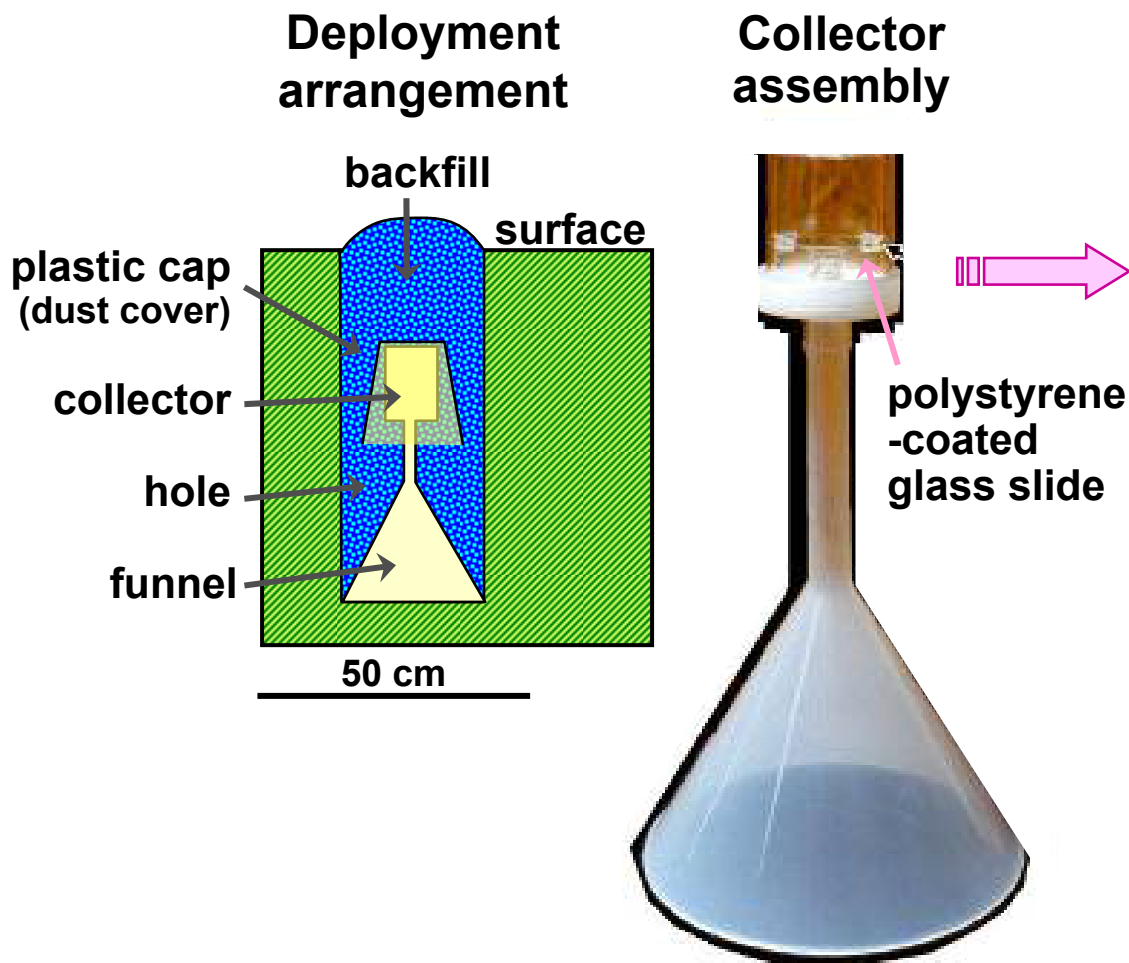
Dispersion models – vegetation effects

McKinnons deposit,
Cobar

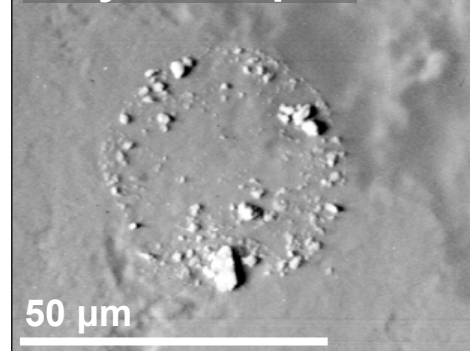


- Alluvial fill
- Pediment
- Mixed pediment / alluvium
- Saprolite
- Au mineralised structure

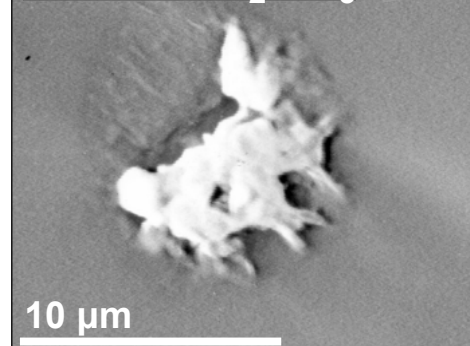
Dispersion models – gases and aerosols



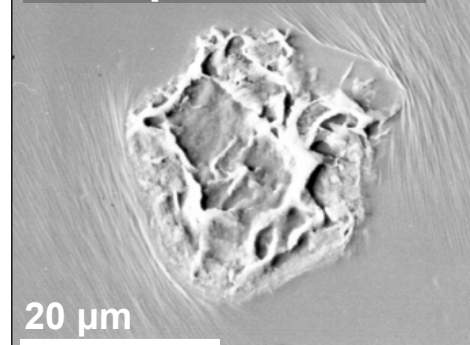
Clay in droplet



NaCl + Na₂CO₃

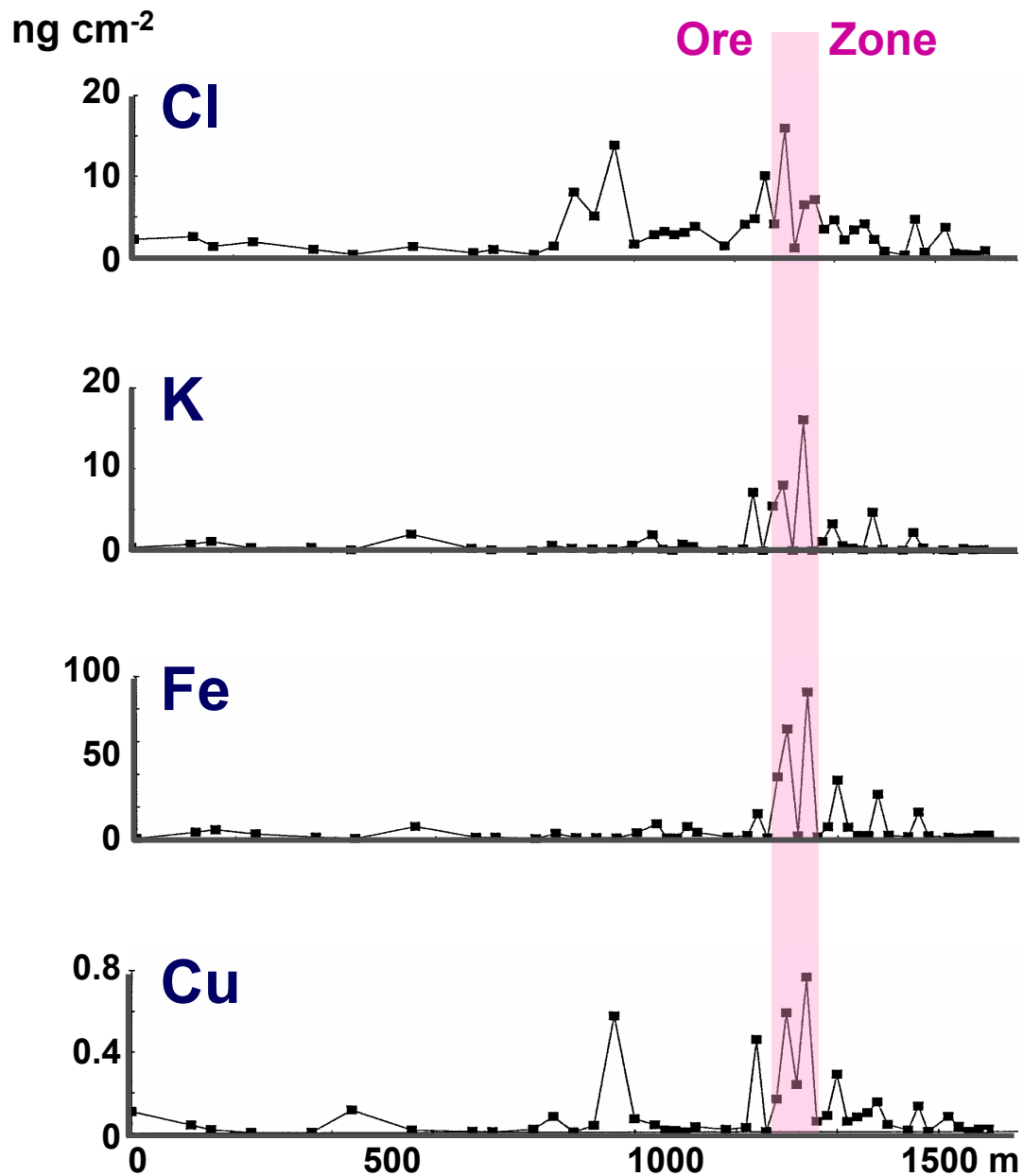


Amorphous silica



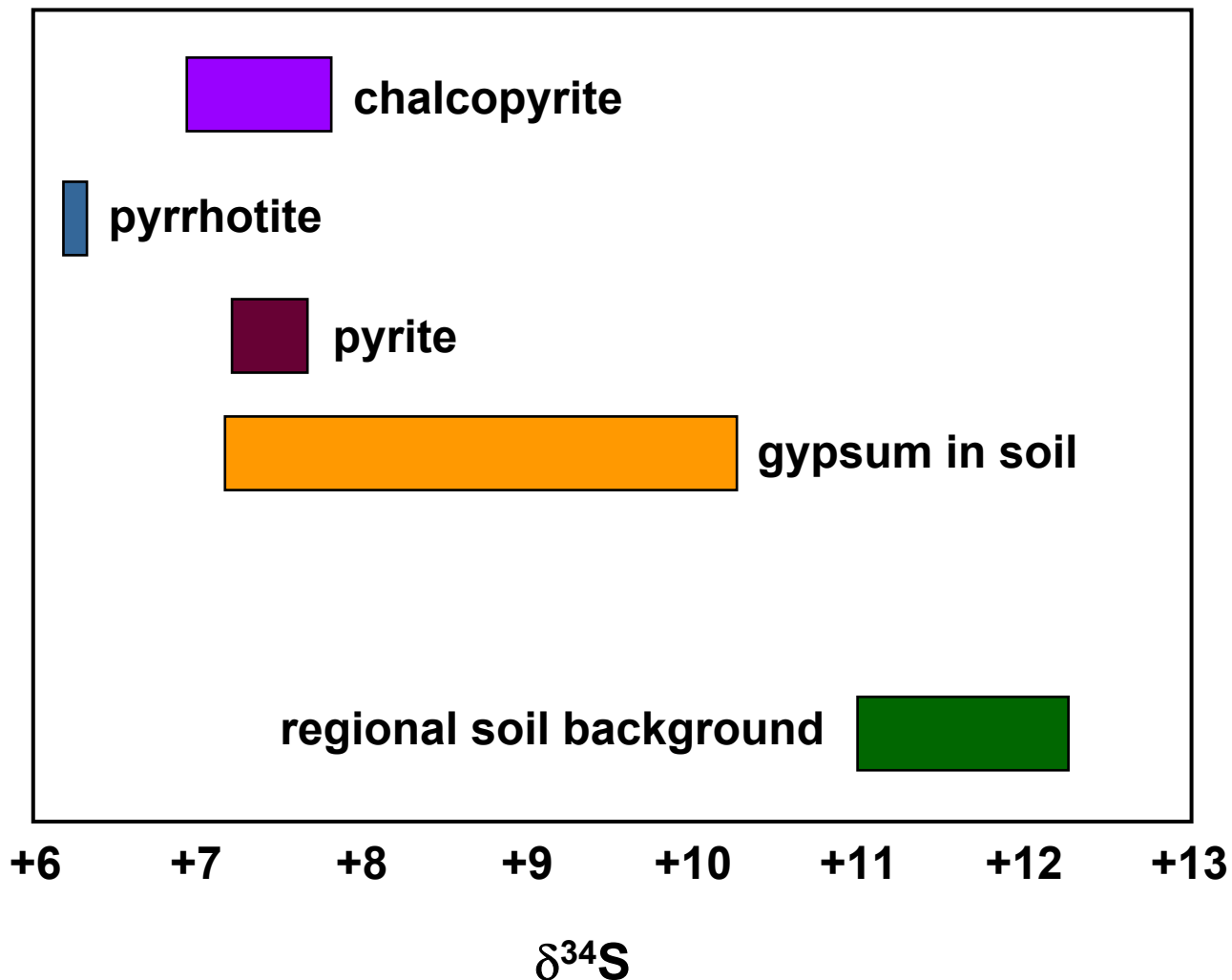
Rutherford et al., 2005

Osborne Cu-Au deposit, Qld



Plus a range of other
transition and group I
and group II elements

Osborne (Kulthor) Cu-Au deposit, Qld



Intro

Models

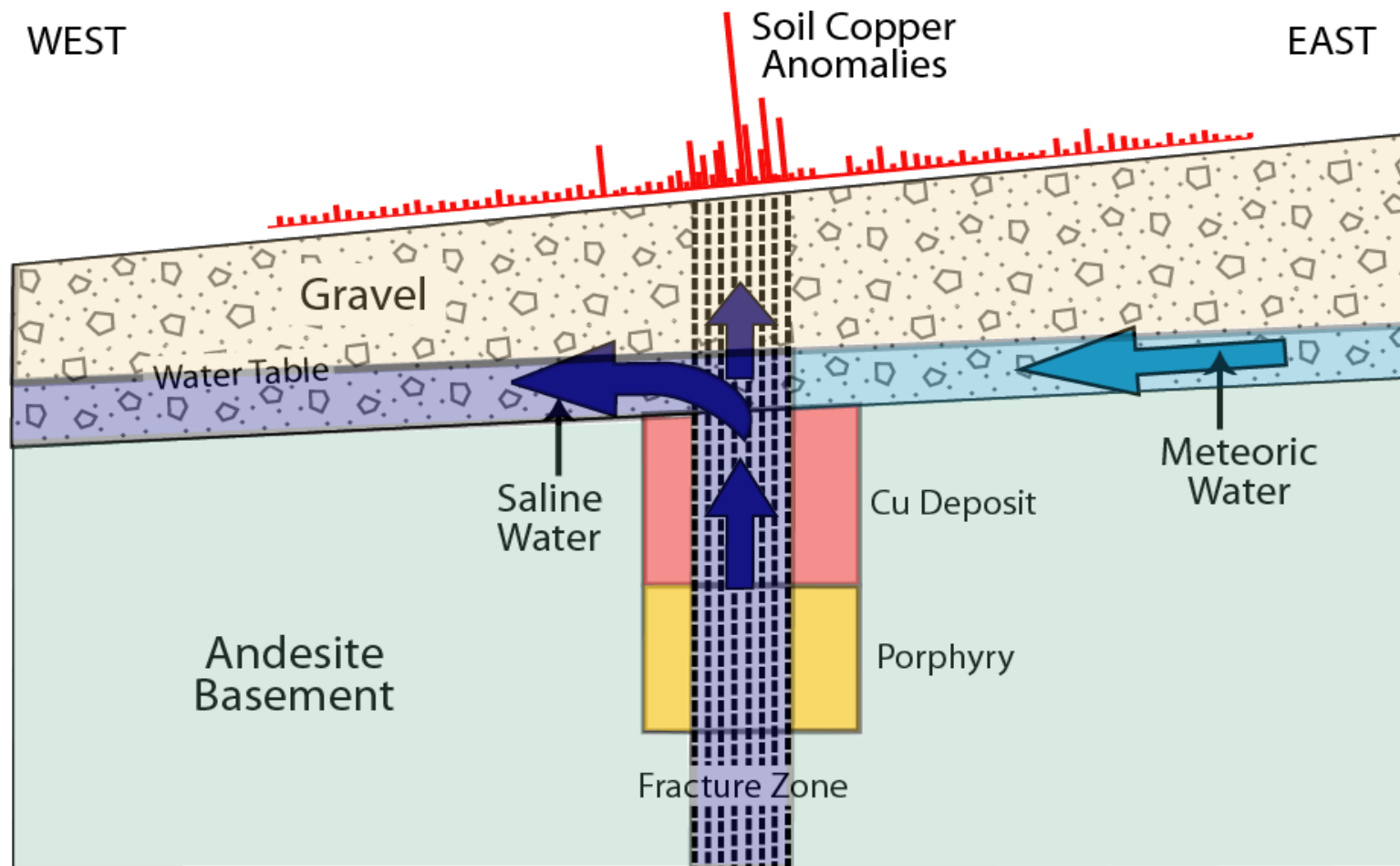
SEx

Mandy

Data

Conc

Dispersion models – dilatancy pumping



Cameron et al., 2004

Intro

Models

SEx

Mandy

Data

Conc

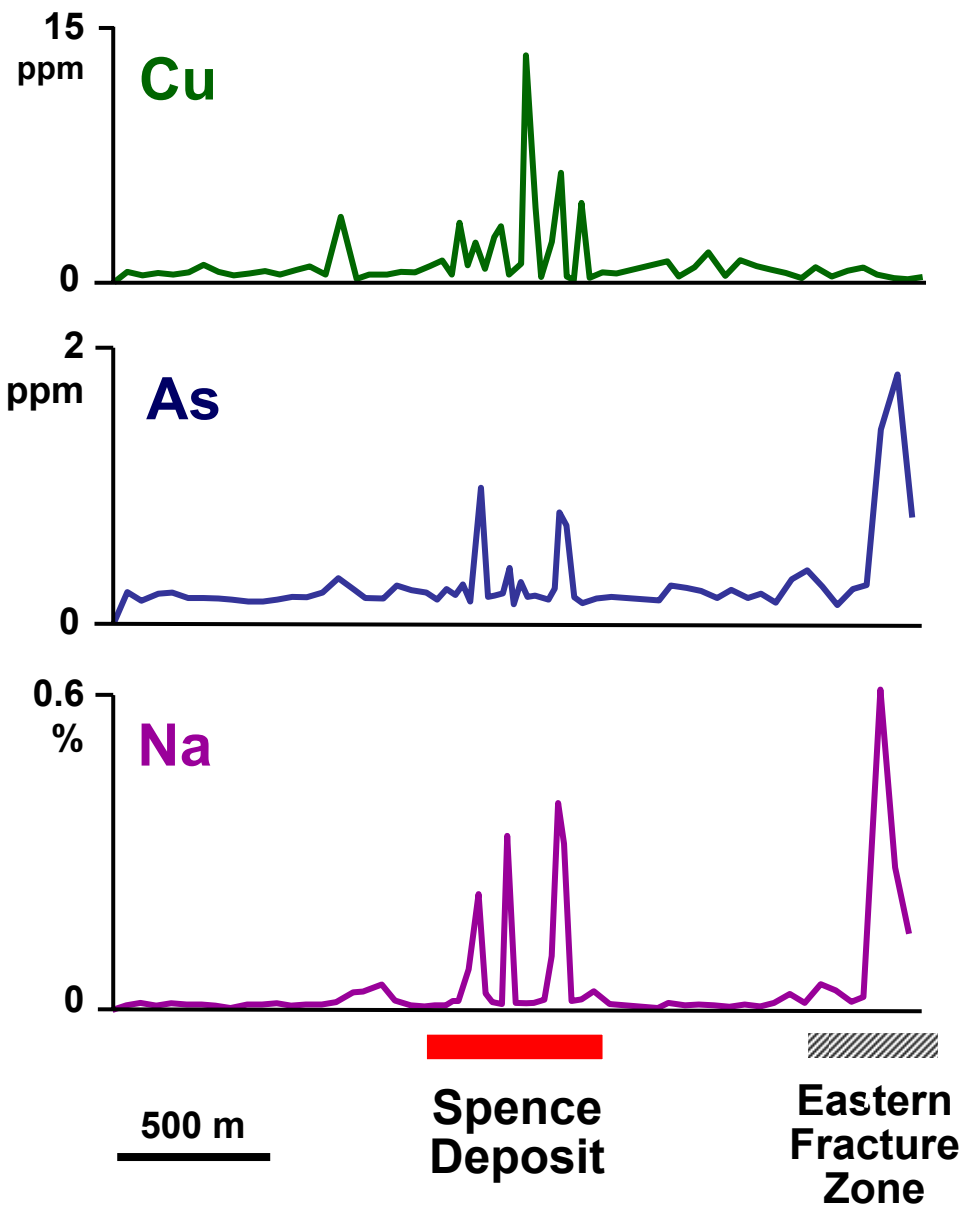
Spence porphyry Cu deposit, Northern Chile

Vertical fracture
with saline soil

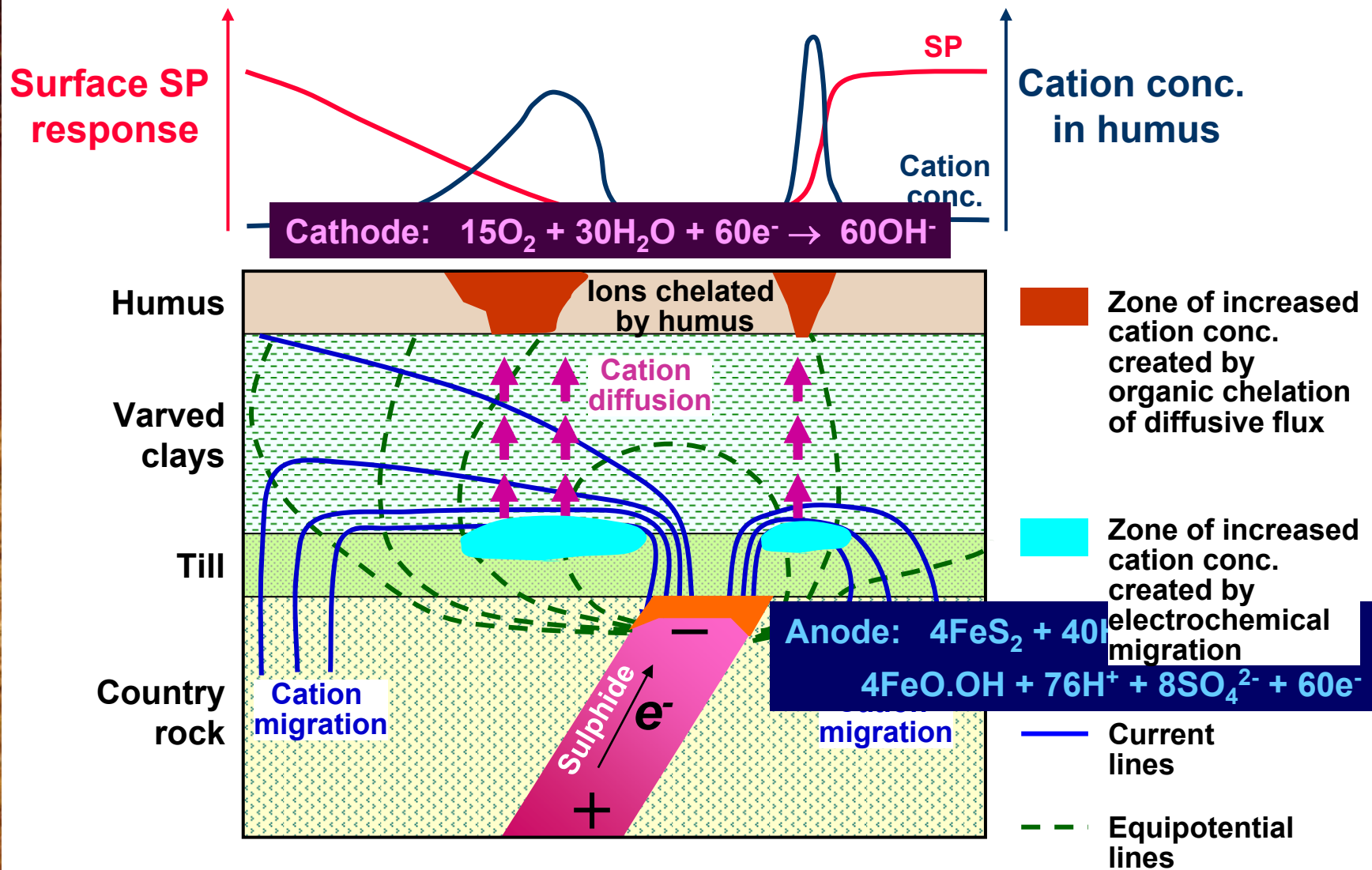


Burial under 250m of
Tertiary gravels

Surface regolith samples;
weak selective extraction

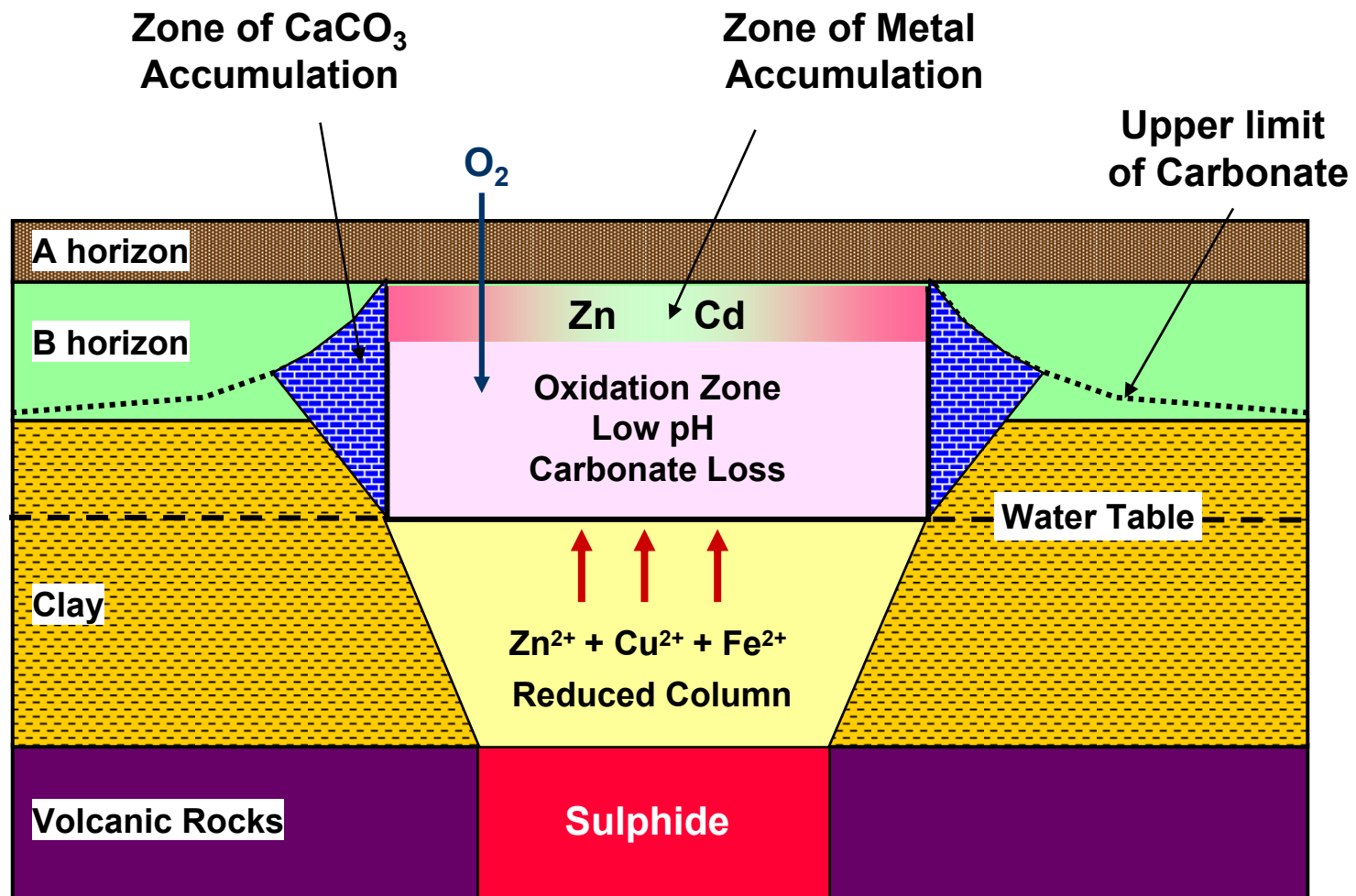


Dispersion models – electrochemical



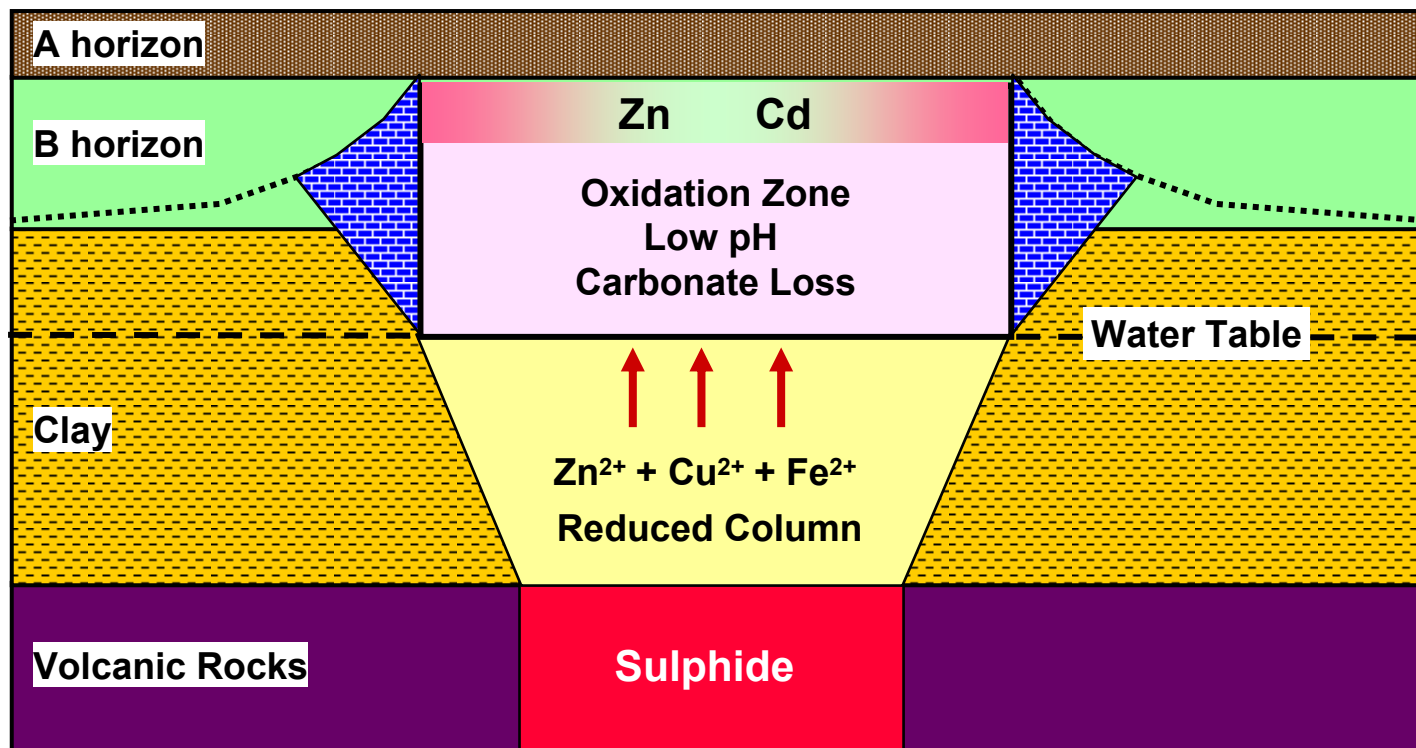
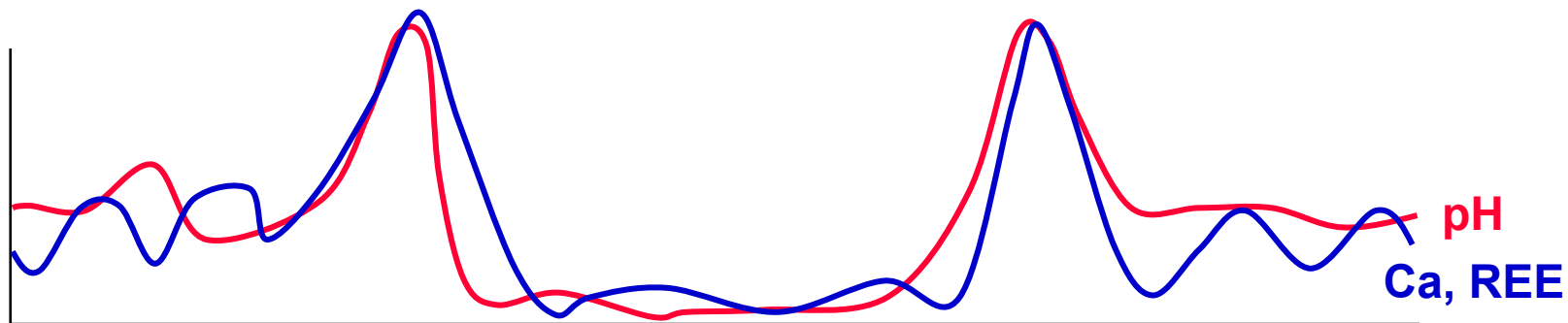
Govett, 1977
Smee, 1983

Dispersion models – electrochemical



Hamilton, 1998

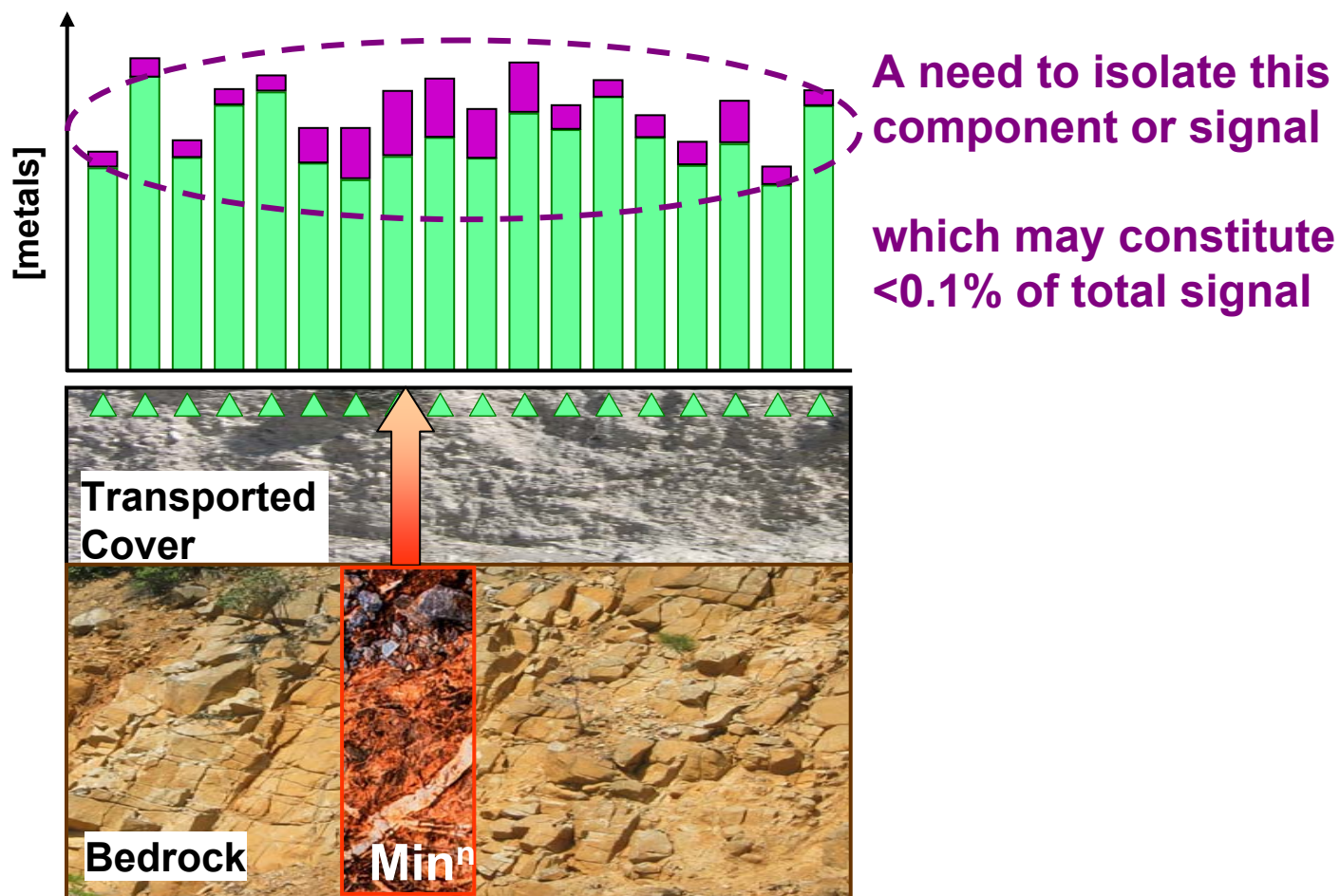
Dispersion models – electrochemical



Hamilton, 1998

A basic premise

Inherited metal content in regolith
with overprint due to dispersion away
from mineralisation OR other features



Intro

Models

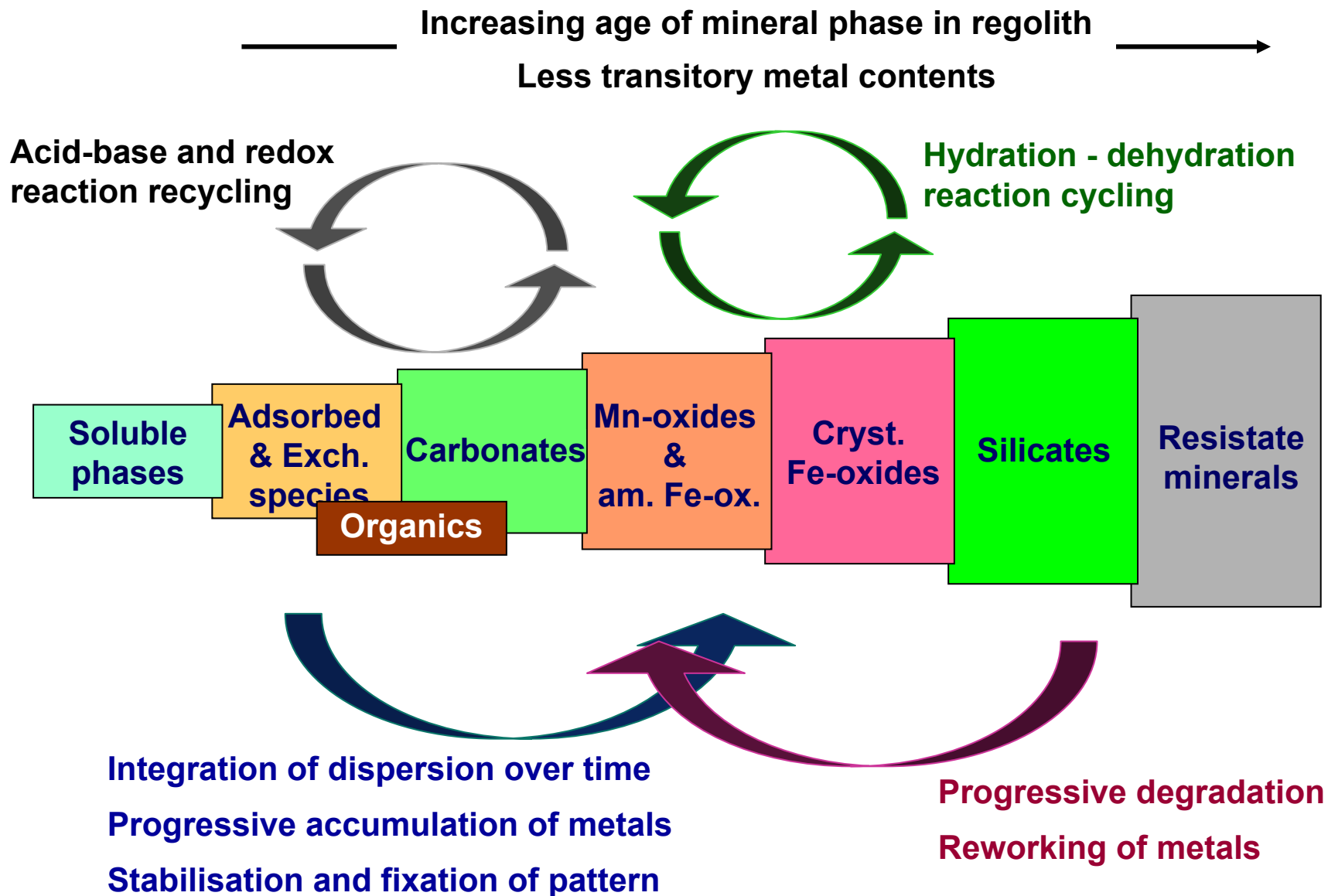
SEx

Mandy

Data

Conc

Selective Extractions



Intro

Models

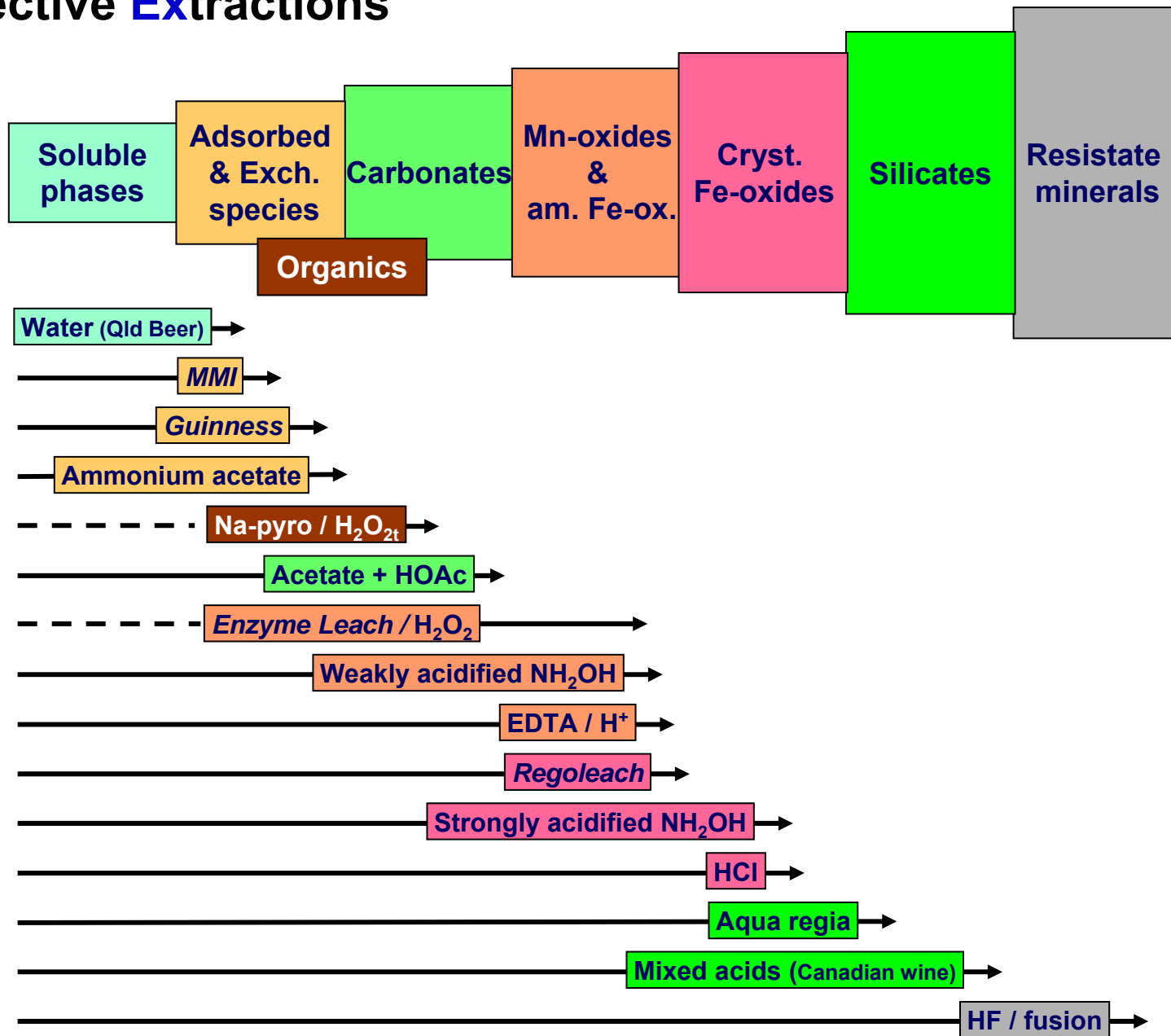
SEx

Mandy

Data

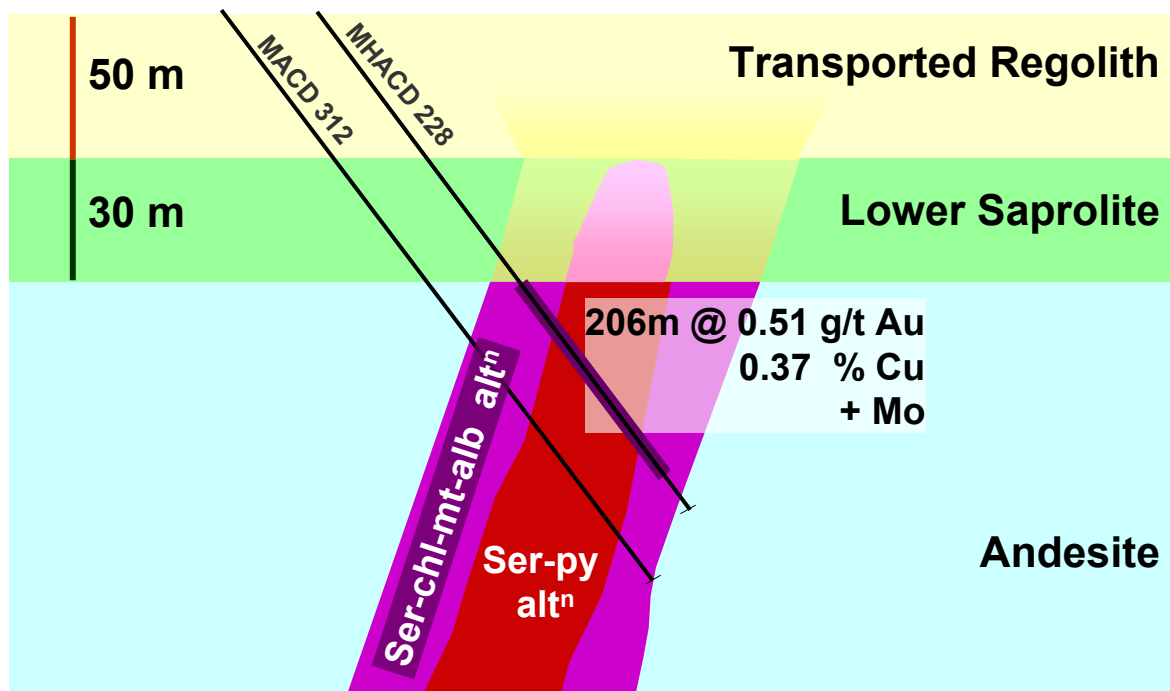
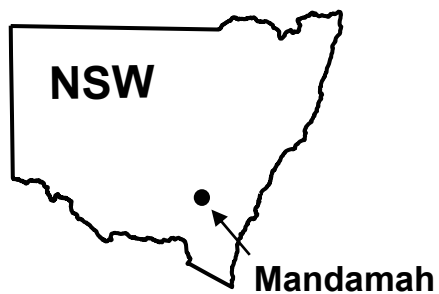
Conc

Selective Extractions



(Cohen et al, 2001; based on Gray, 1999)

Mandamah, NSW



Intro

Models

SEx

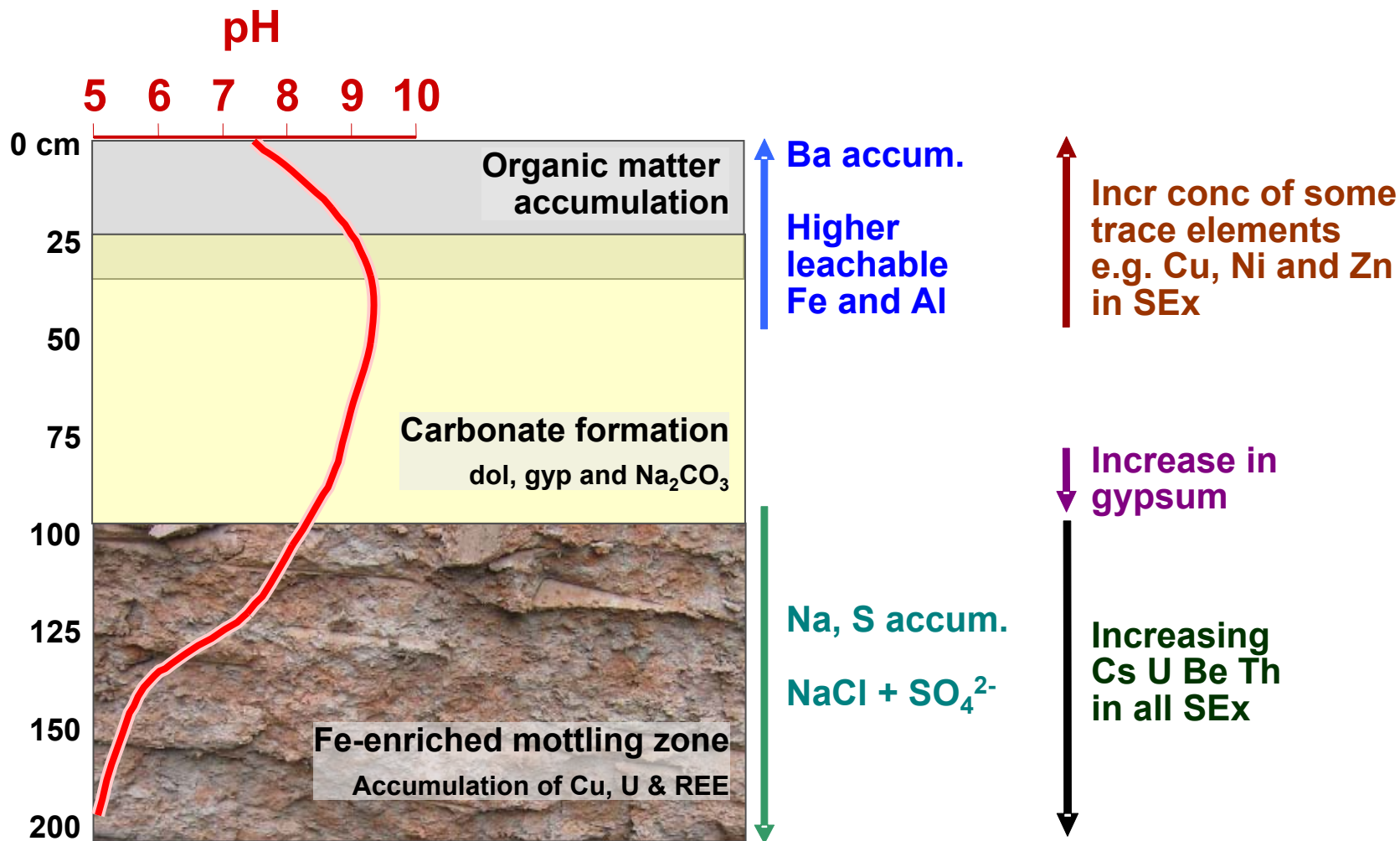
Mandy

Data

Conc



SMEDG -
AIG
'09



Intro

Models

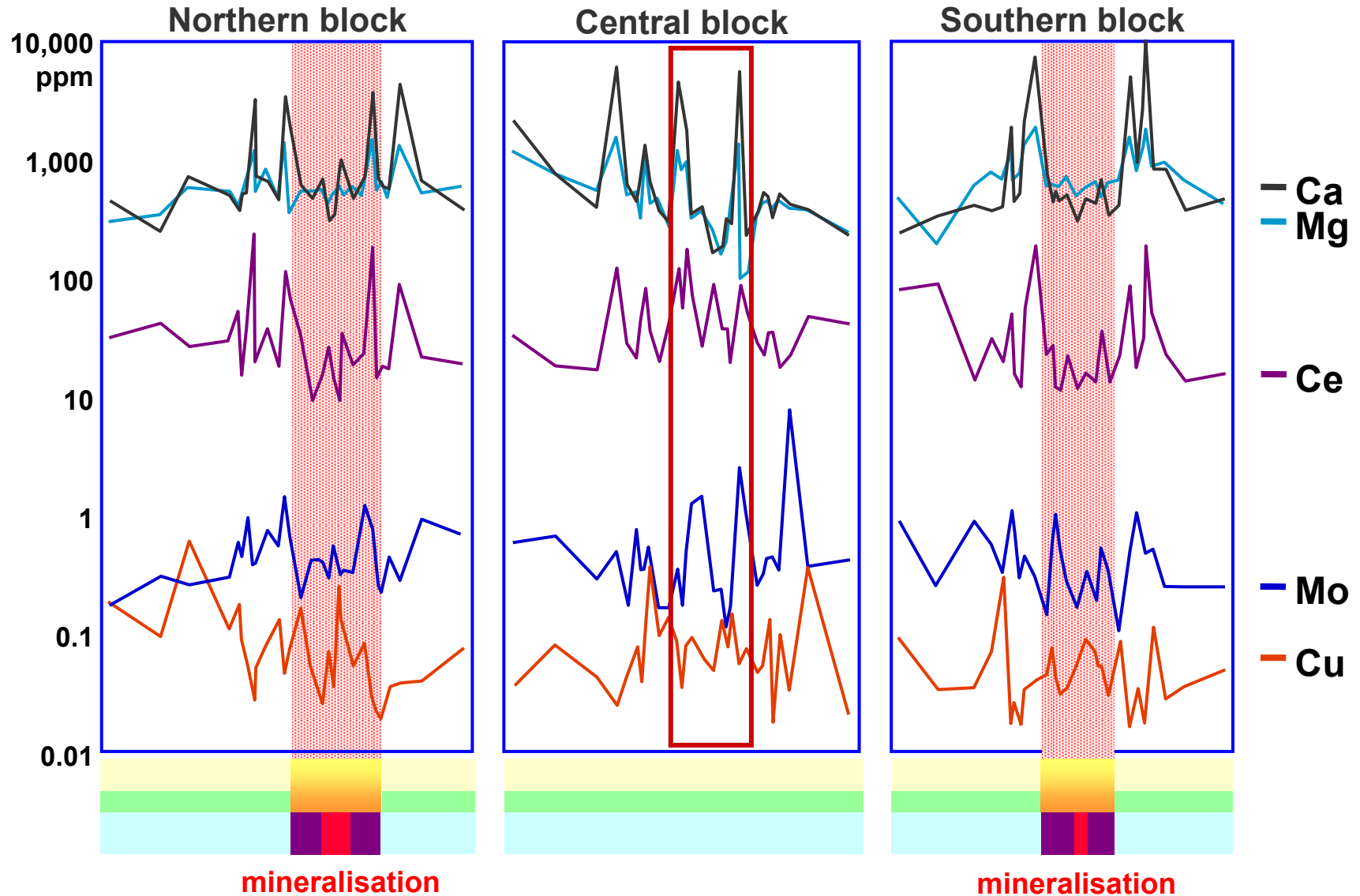
SEx

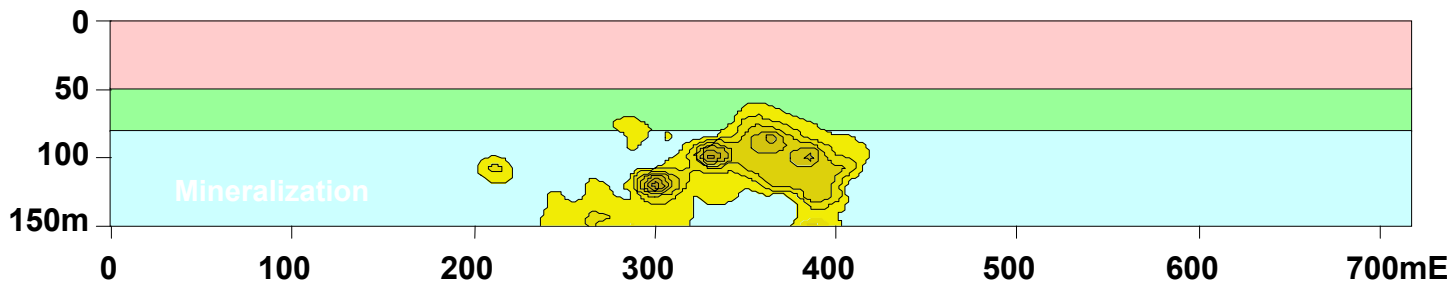
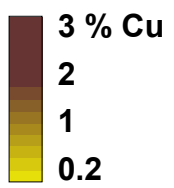
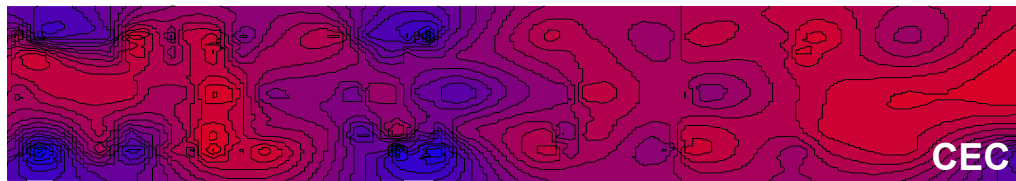
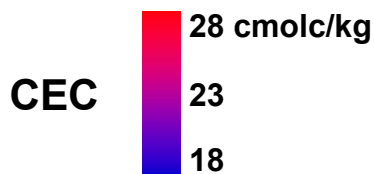
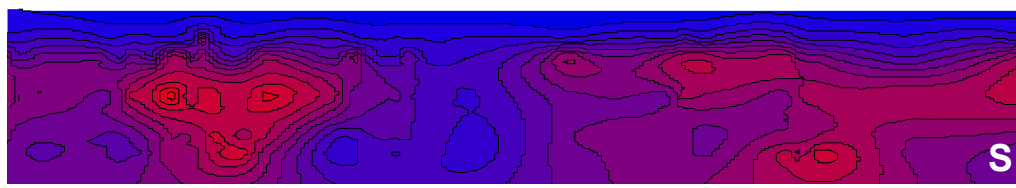
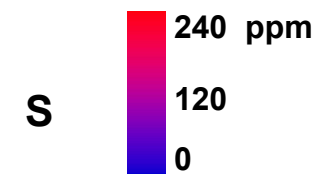
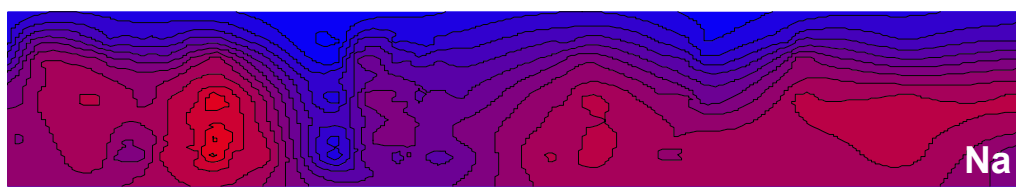
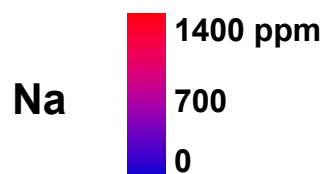
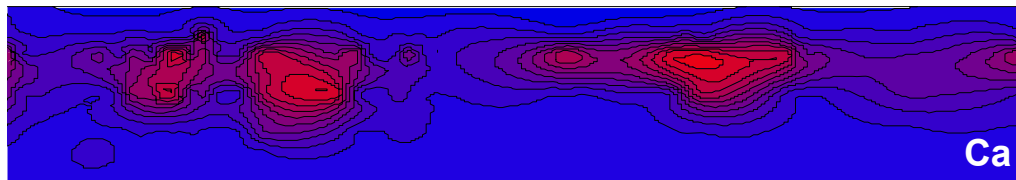
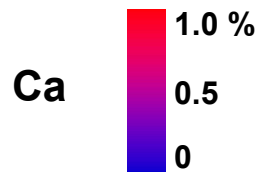
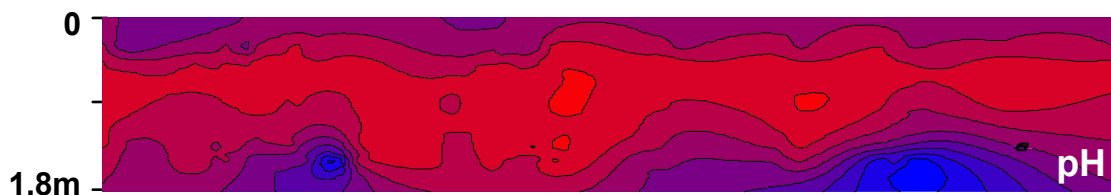
Mandy

Data

Conc

30 cm depth,
pH 5 K-acetate



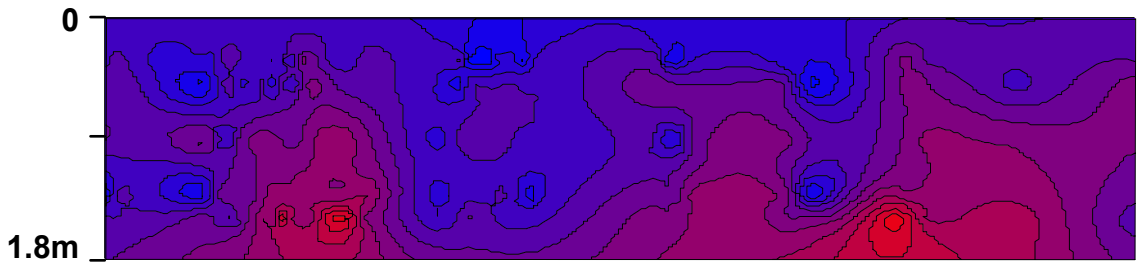
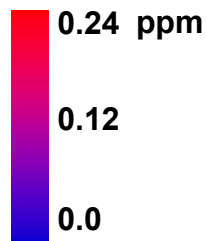


Intro
Models
SEx
Mandy
Data
Conc

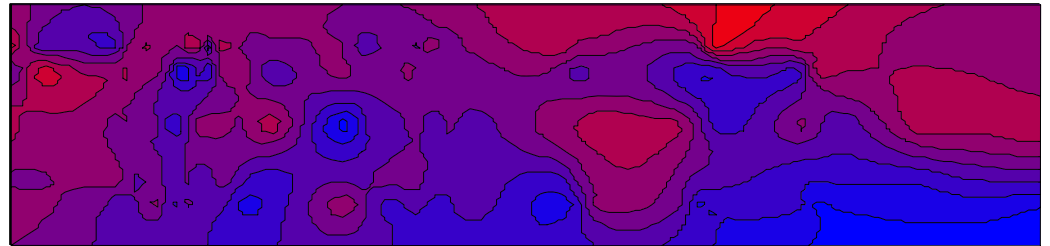
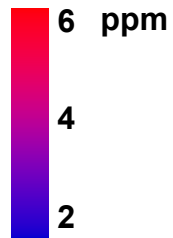


Intro
Models
SEx
Mandy
Data
Conc

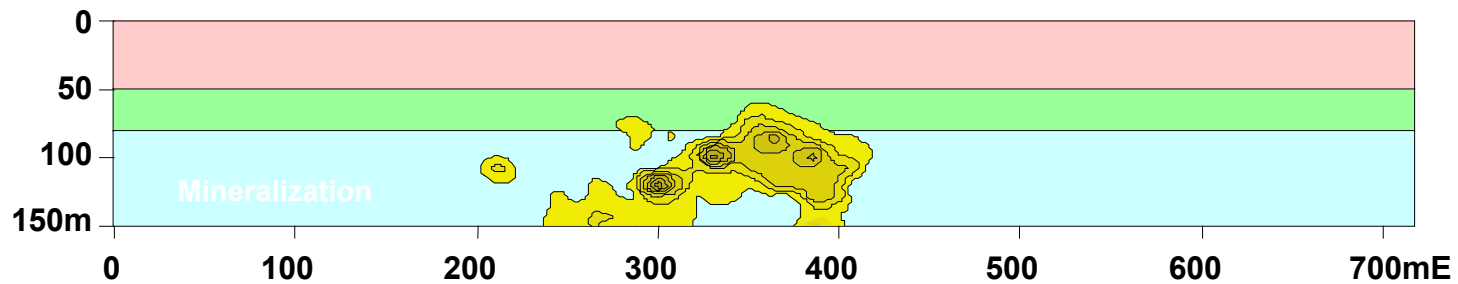
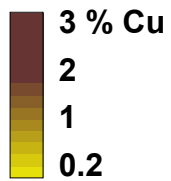
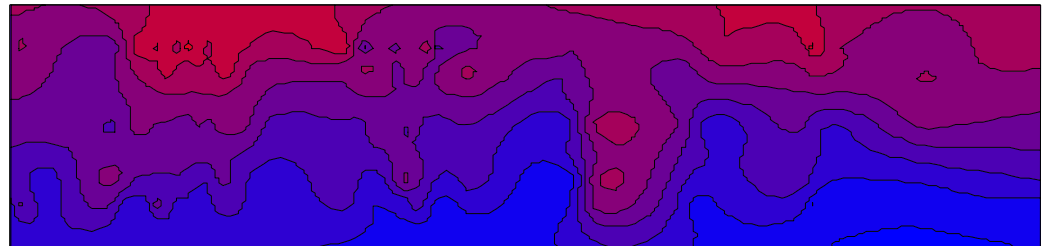
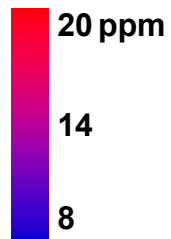
**Cu by
 $\text{NH}_4\cdot\text{OAc}$**



**Cu by
 NH_2OH**

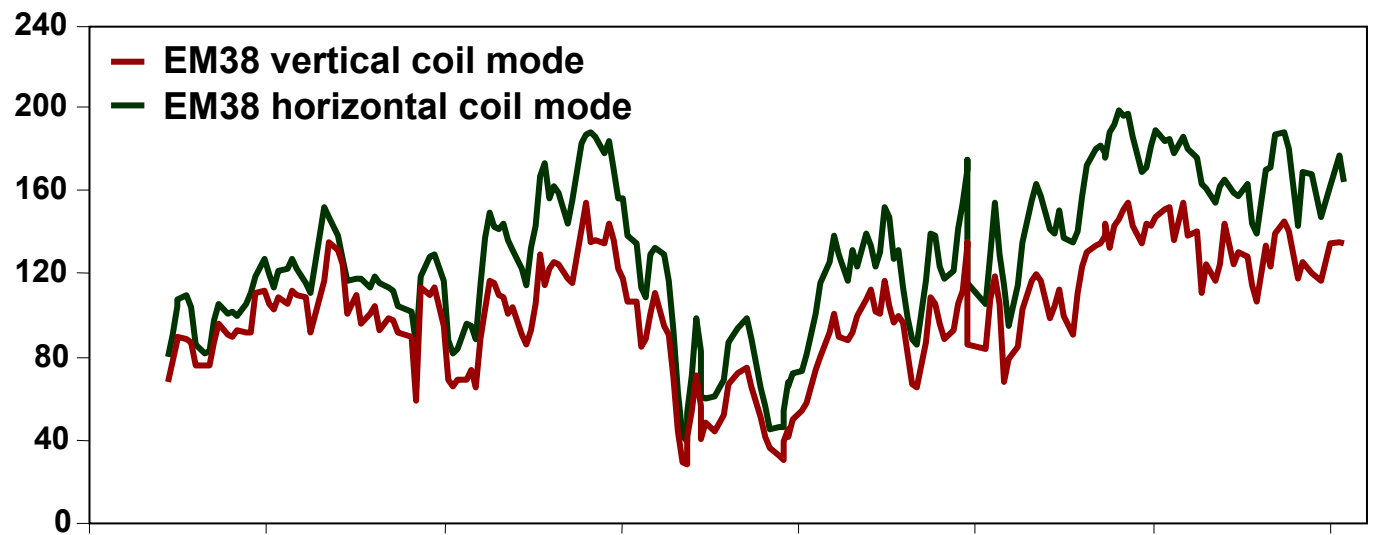


**Cu by
aqua regia**

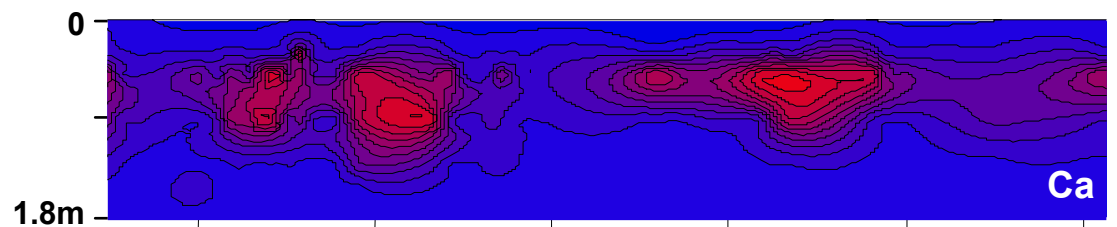
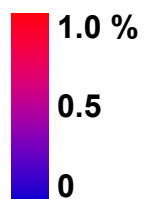




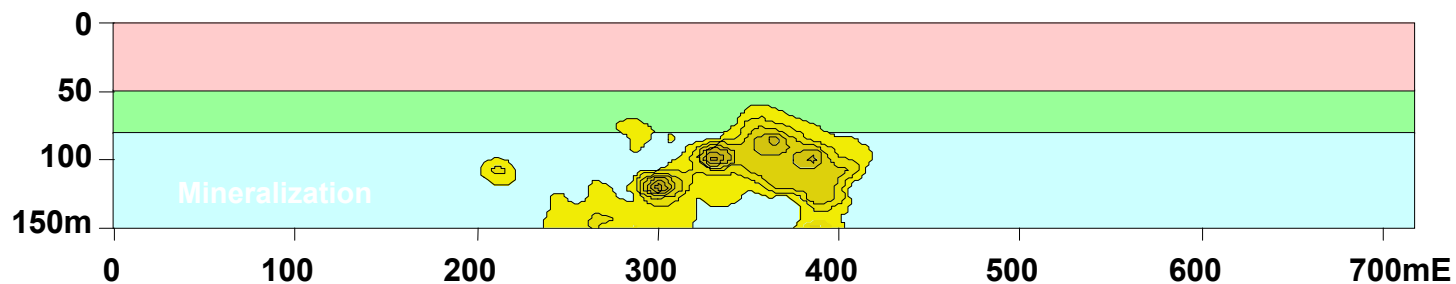
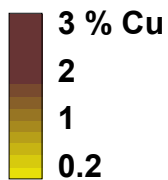
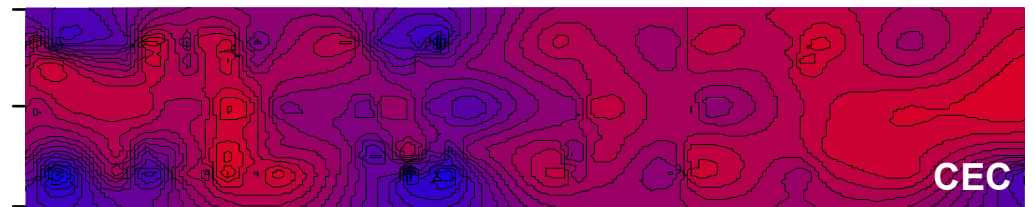
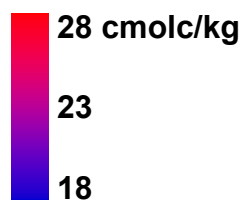
EC_a
(mS/m)



Ca

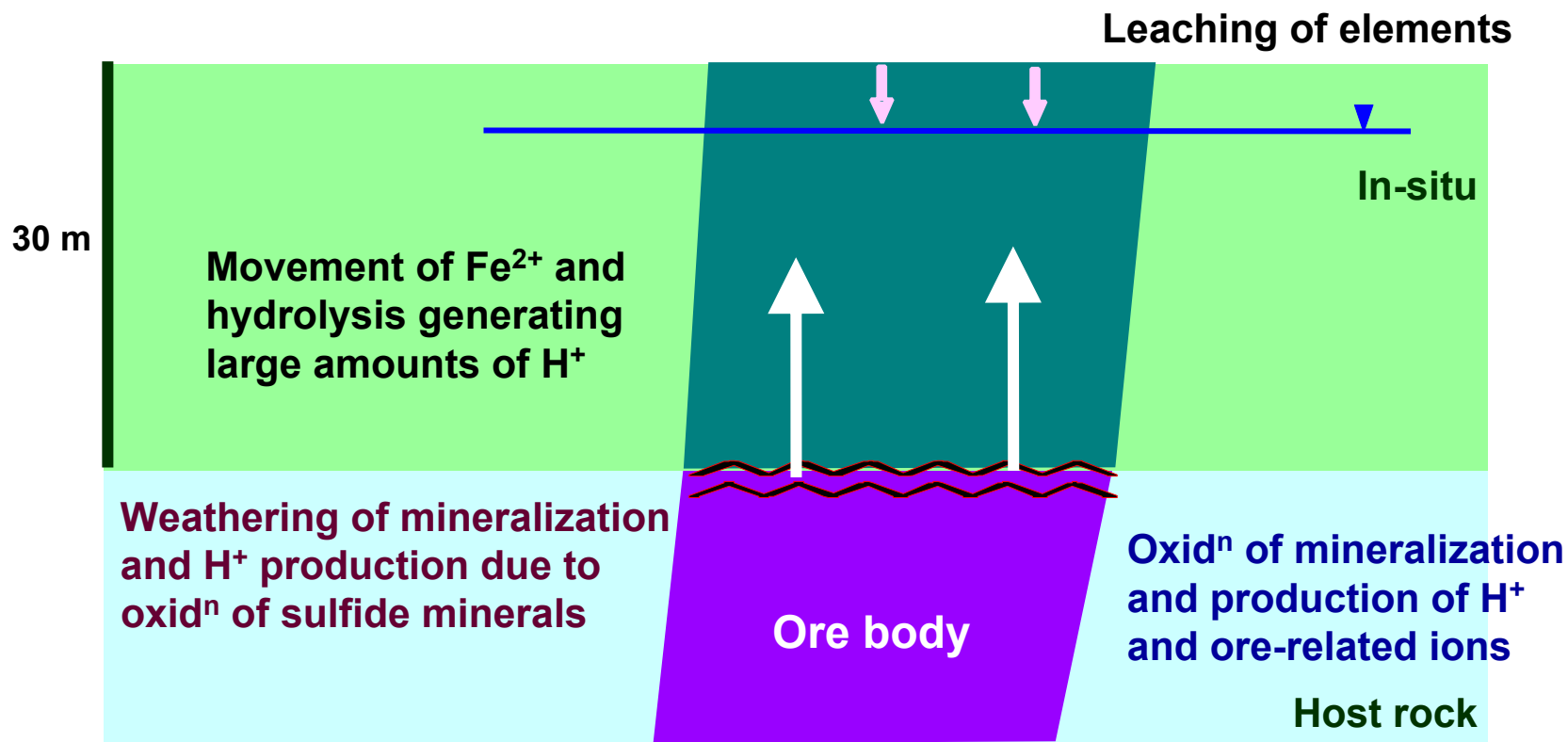


CEC



Dispersion model for Mandamah ? archaeo-electrochemical

Initial weathering phase (period of elevated rainfall)



Intro

Models

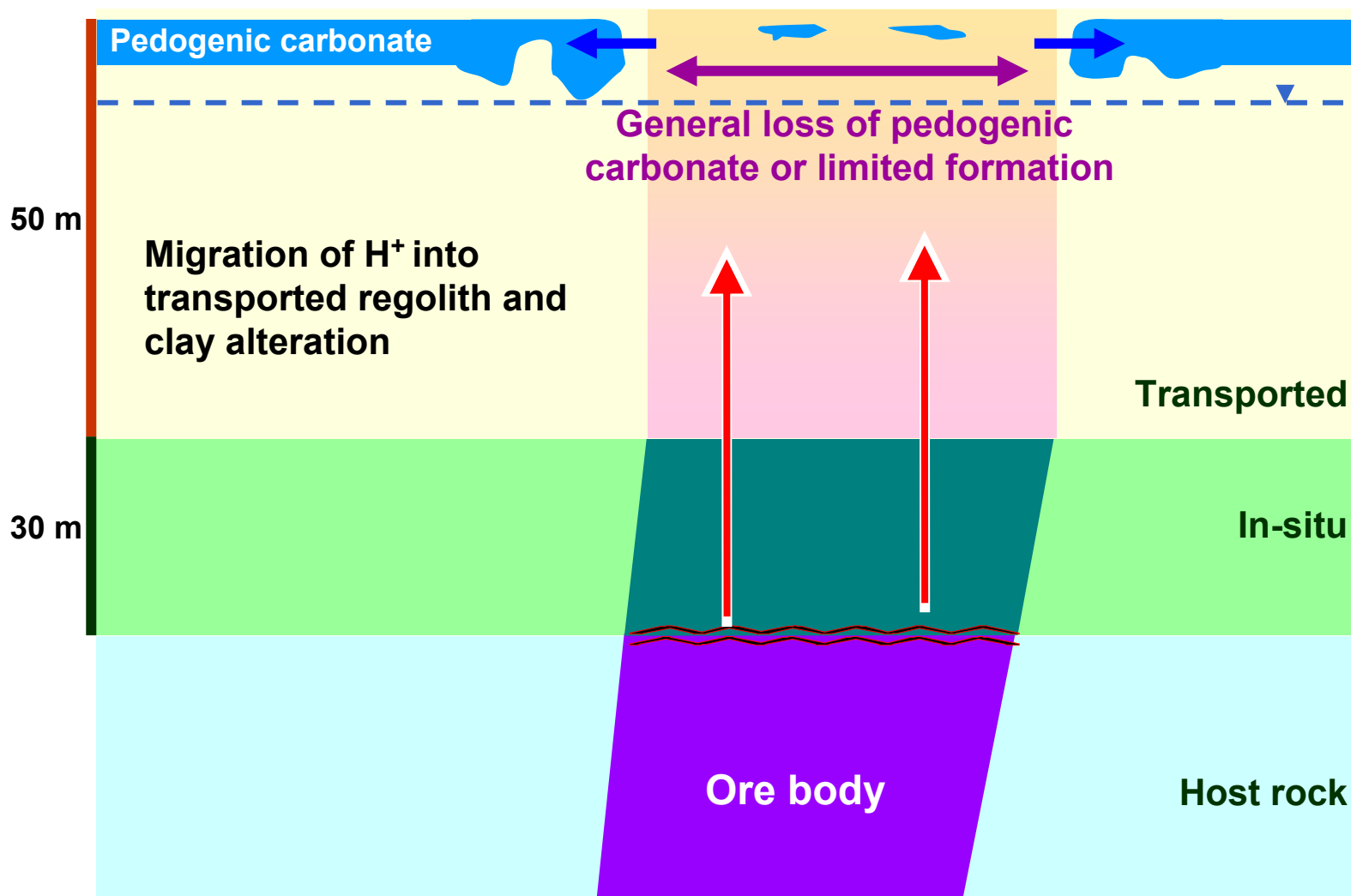
SEx

Mandy

Data

Conc

“Prograde” Phase (still high rainfall)



Intro

Models

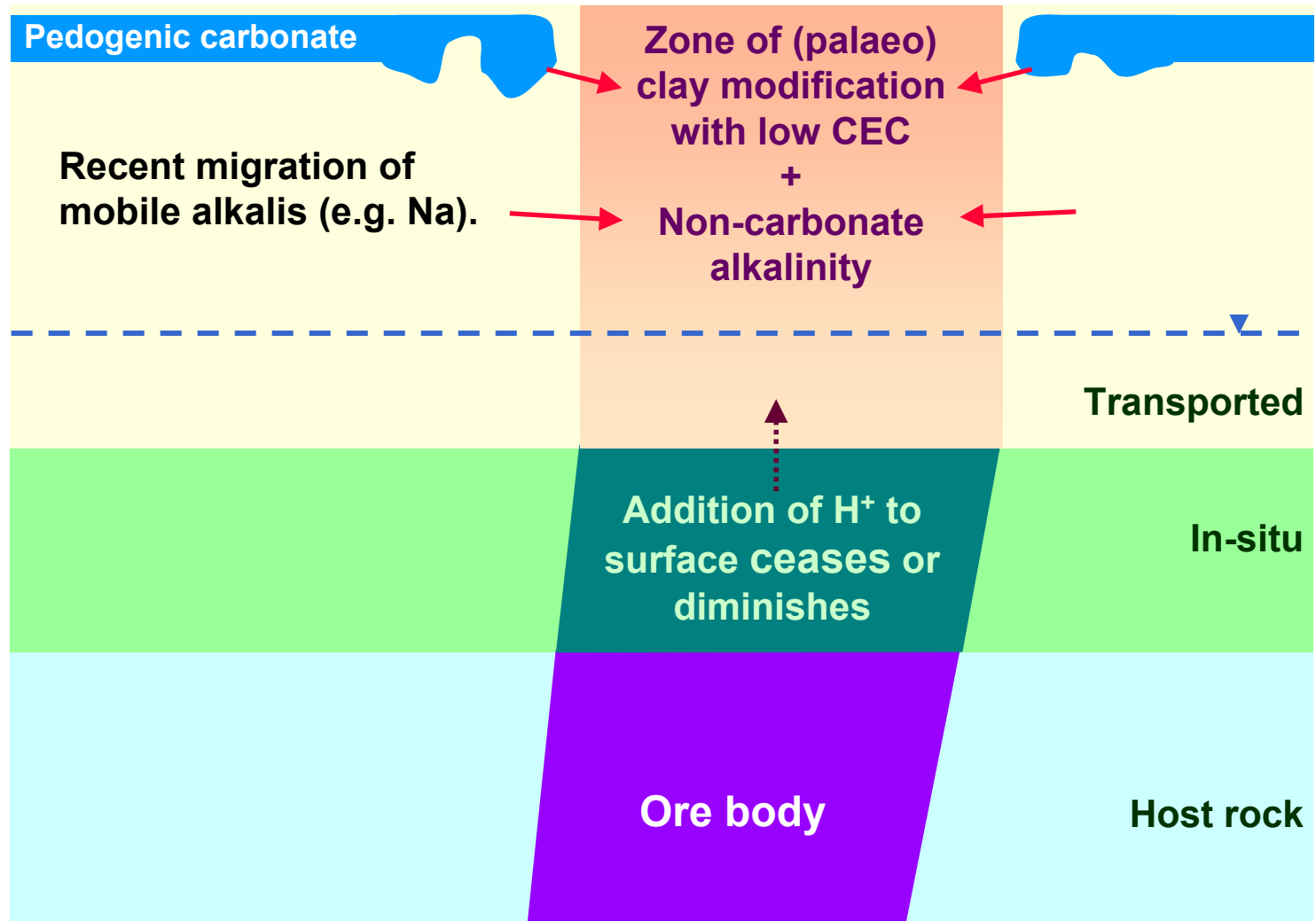
SEx

Mandy

Data

Conc

“Retrograde” Phase (Post onset of aridity)



Intro

Models

SEx

Mandy

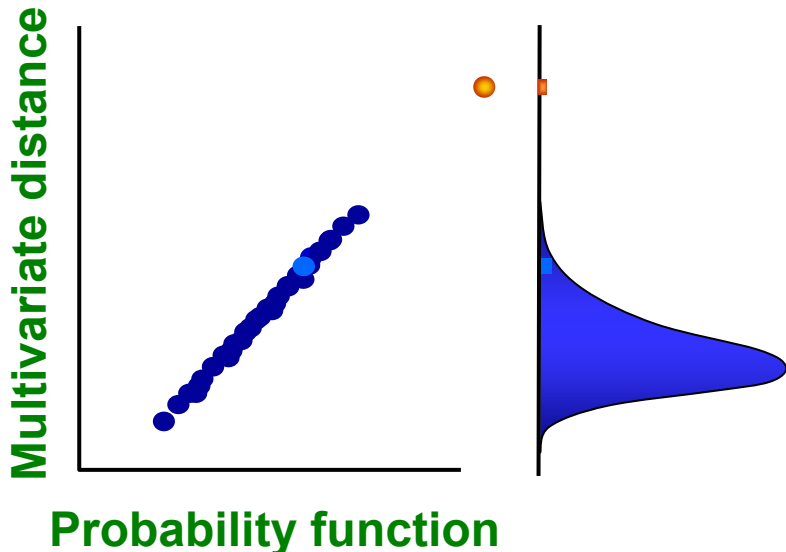
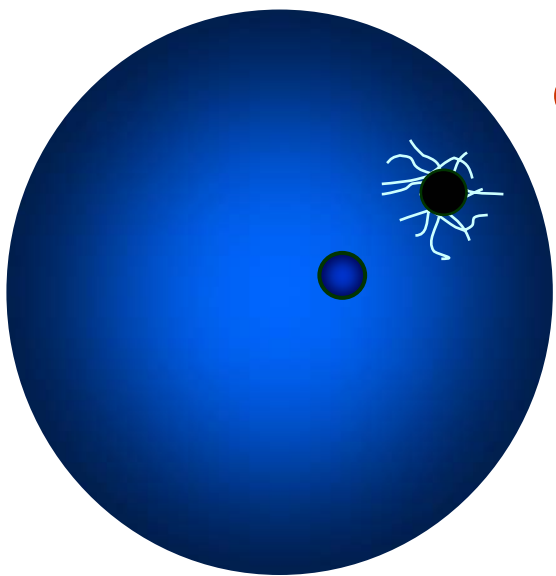
Data

Conc

Data Analysis

Objective – detecting samples whose geochemistry appears “anomalous”

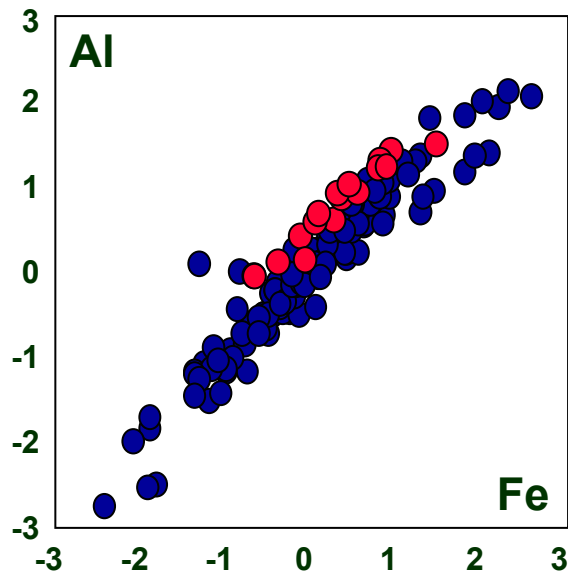
Traditional approach – satellite spotting



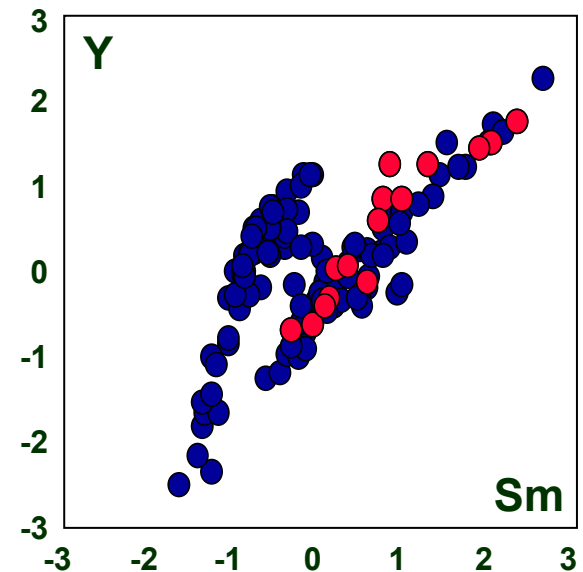
Reality for SEx data – very complex multivariate signals

Mandamah

Aqua regia



Weak hydroxylamine



- Sample from above mineralised sites
- Sample from above non-mineralised sites

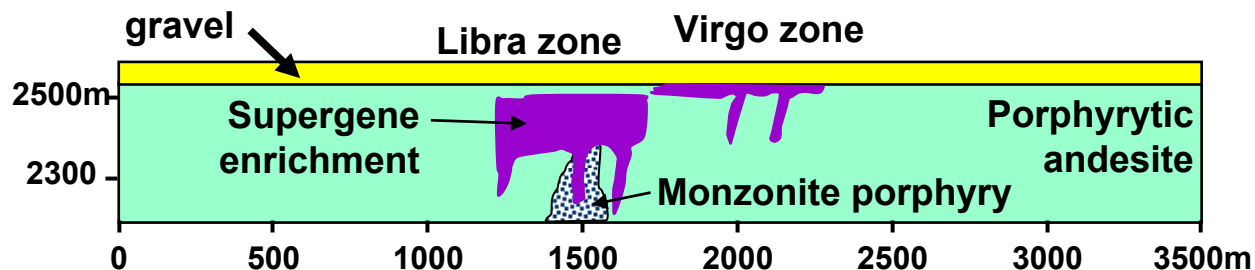
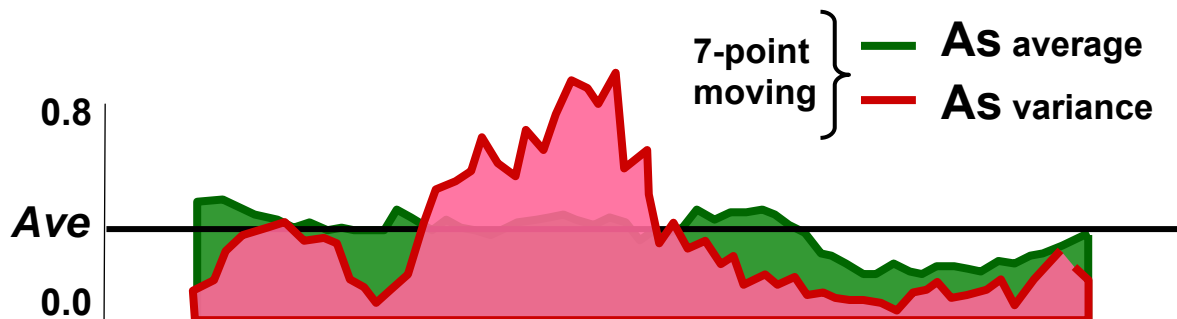
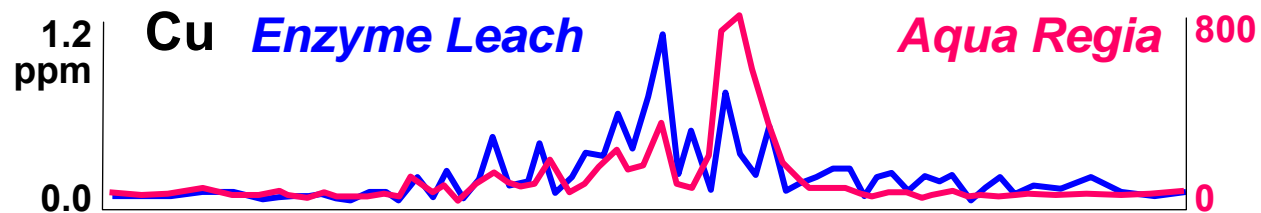
*Data transformed
and standardised*

101101001101
011001010100
010010010101
100100101100
101011001001
011000101010
010101010010
101011010100
101011010110
111111010101
011001010101
111001101011
100111111011
010111001101
110111100111
110101011110
100110001011
101011011010
010100101011
101001011010
101000010111
101000110101
111101011010
111001100011
101010110101
101010110101
000101010101
001100011110
011011011011
001110110011
100011010110
110101010110
101101100111
011010110100
010101001010

Intro
Models
SEx
Mandy
Data
Conc

101101001101
011001010100
010010010101
100100101100
101011001001
011000101010
010101010010
101011010100
101011010110
111111010101
011001010101
111001101011
100111111011
010111001101
110111100111
110101011110
100110001011
101011011010
010100101011
101001011010
101000010111
101000110101
111101011010
111001100011
101010110101
101010110101
000101010101
001100011110
011011011011
001110110011
100011010110
110101010110
101101100111
011010110100
010101001010

Chimborazo porphyry Cu, Chile



[Intro](#)

[Models](#)

[SEx](#)

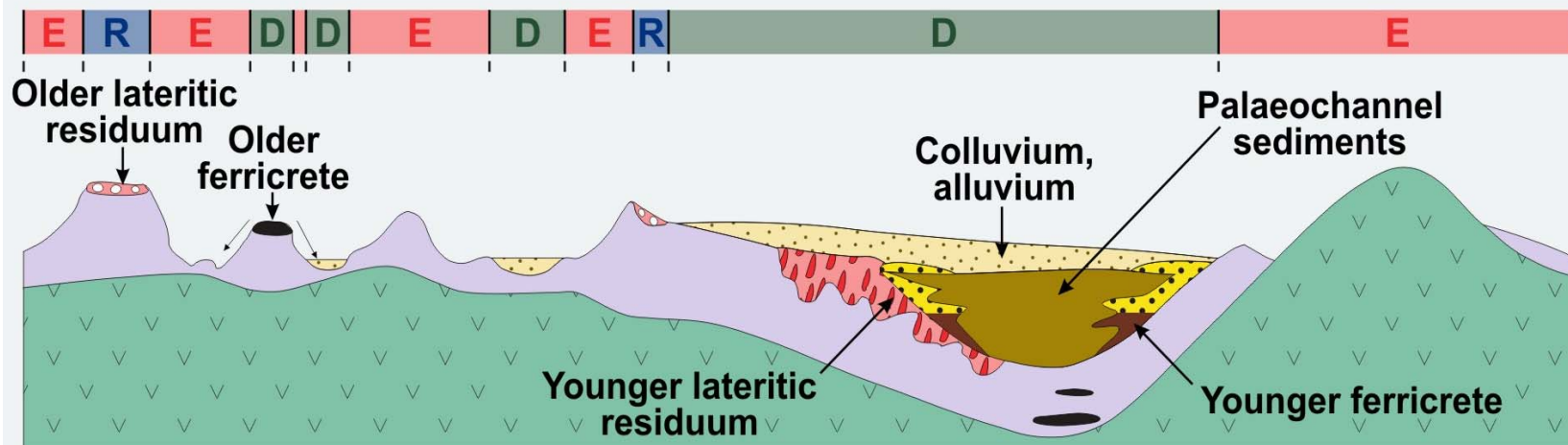
[Mandy](#)

[Data](#)

[Conc](#)

Conclusions

RED scheme (Anand et al, 1998)



Relict regime (R)

- Lateritic residuum

Erosional regime (E)

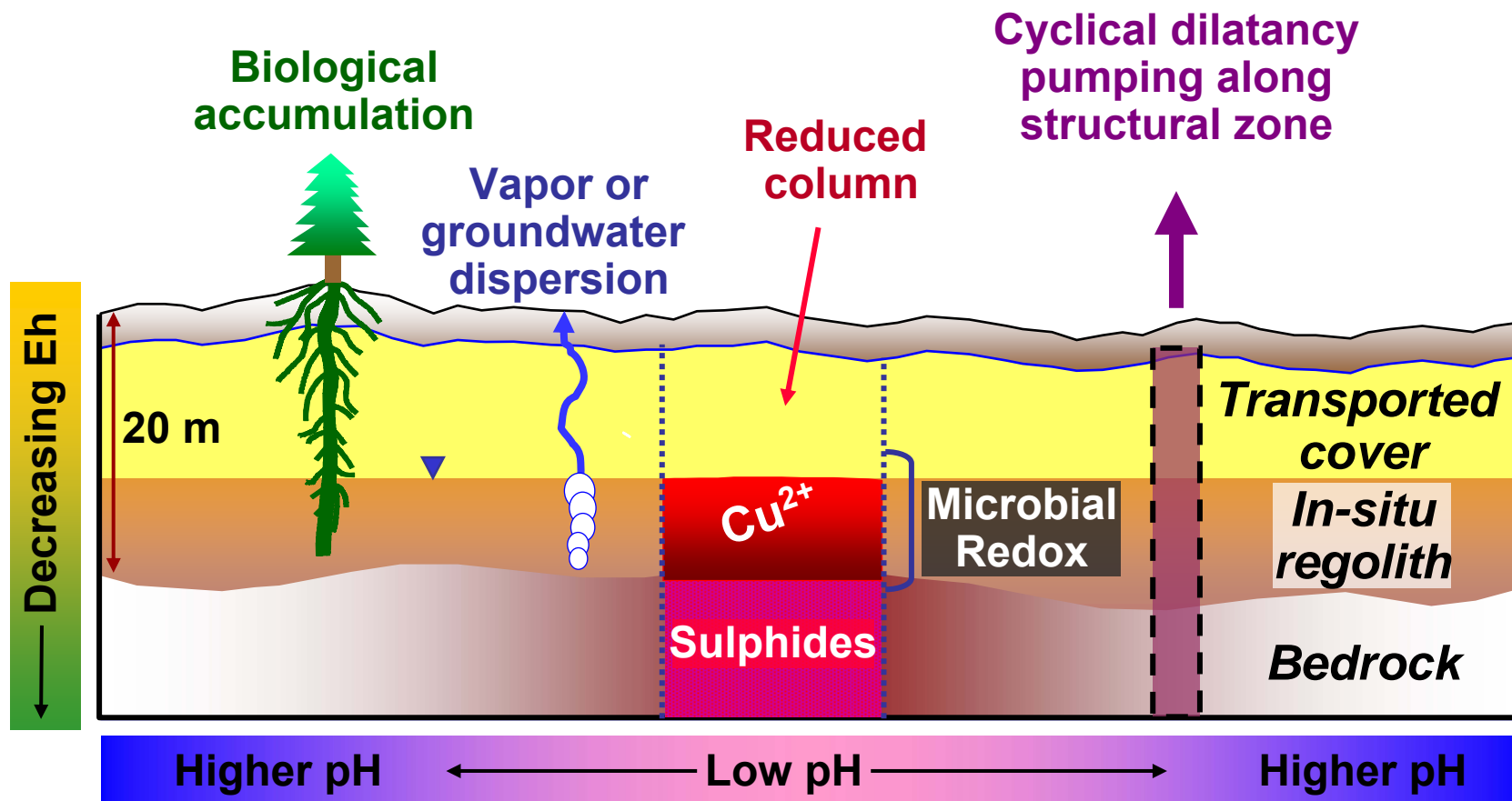
- Residual soil and ferruginous lag
- Ferruginous saprolite
- Saprolite

Depositional regime (D)

- Exposed and buried ferricrete (Fe-cemented sediments)
- Colluvium and alluvium

Conclusions

Summary of various forms of interactions of deeply buried mineral deposits with hydrosphere and biosphere



Intro

Models

SEx

Mandy

Data

Conc

Conclusions

Seeing Geochemical Dispersion Haloes

OBJECTIVE:

Separate processes that have affected the elemental and mineralogical composition of regolith (both gain and loss)



METHODS:

Isolate signals that can be related to the effects or presence of mineralisation through:

PHYSICAL (the extraction) and/or

NUMERICAL (data processing) methods

Conclusions

- **SEx not (yet) the silver bullet for thick transported or deeply weathered cover, but has prompted:**
 - research into fundamental processes of geochemical dispersion**
 - development of new approaches to definition and detection of geochemical patterns related to the effects of underlying mineralisation**
- **The bests tool for detecting deeply buried, sulphide mineralisation, may yet prove to be a simple pH meter and a bottle of dilute HCl**

Future Research Directions

- **Developments in media and analysis, based on process modelling**
- **Application of isotopes to refine understanding of dispersion mechanisms and regolith evolution models**
- **Abandoning “baselines”, “backgrounds” and “anomalies” in favour of new data processing methods that recognise geochemical signals related to processes of interest**



**General Ponsonby leads the
Scots Greys against the
Polish lancers at Waterloo**



**Field Marshal Haig
leads his troops
nowhere in particular**



**Emperor Napoleon leads
his remaining troops back
from Moscow**

Advance!

**Dispersion
models**

**Analytical
improvements**

War of Attrition

**Selective
extractions**

**Exploring in
deep transported
cover**

Data modelling

Retreat!

**Old thinking on
defining geochem
“anomalies”**

Intro

Models

SEx

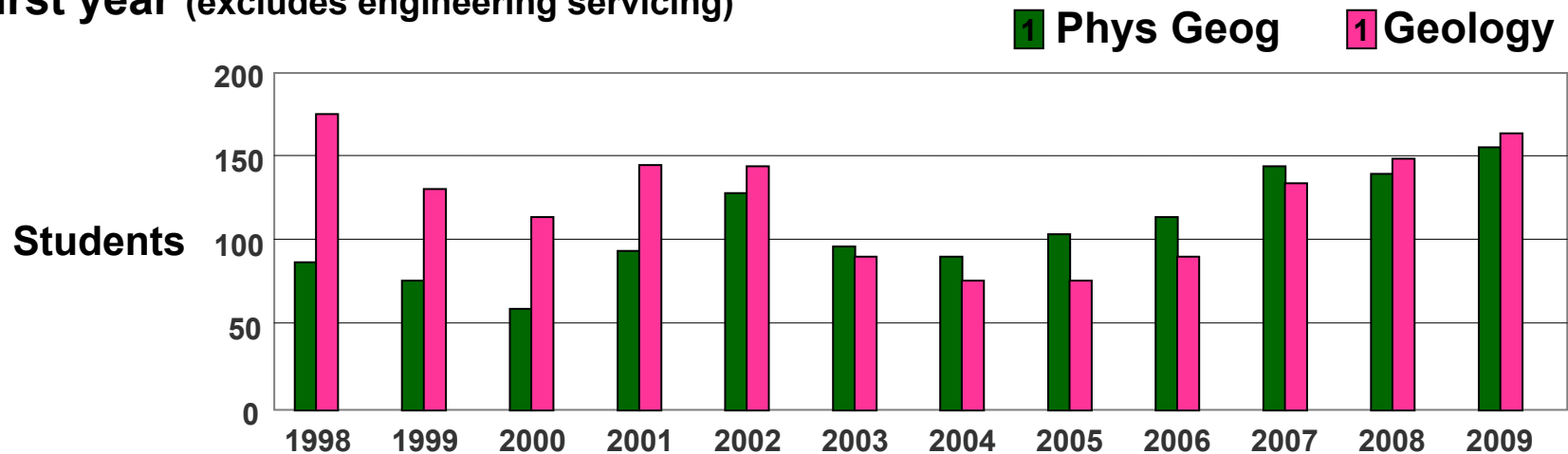
Mandy

Data

Conc

People

First year (excludes engineering servicing)



Upper years

