



Mineral Hosts for Gold and Trace Metals in Regolith

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Introduction

- The geochemical dispersion of gold and base metals and their pathfinders is strongly dependent on the retention of these trace elements in the regolith.
- Which residual and newly formed regolith minerals contain Au, base metals and pathfinders?
- How much?
- Implications for exploration

Project Summary

A CRC LEME-Normandy Mining Limited (now Newmont Australia) project has investigated the element-mineral associations in the regolith of three deposits in Western Australia:

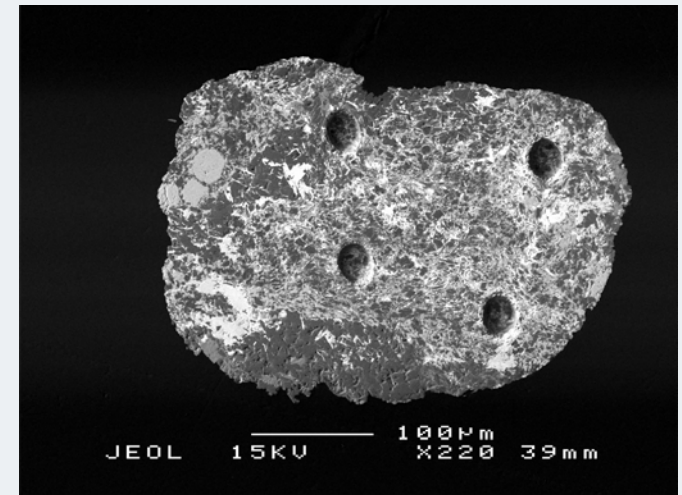
- Boddington Au deposit in the southwest of the Yilgarn craton;
- Mt Percy Au deposit in the Kalgoorlie goldfield;
- Scuddles Cu-Zn deposit in the Golden Grove district.

Methods

- A combination of mineralogical and chemical analyses
- Emphasis on *in situ* micro-analyses of clays and Fe oxides/hydroxides:
 - Bulk and clay fraction XRD
 - SEM-EDS
 - *In situ* LA-ICP-MS (Laser ablation inductively coupled mass spectrometry)

in situ LA-ICP-MS

- Samples: very little preparation
 - Thin sections > 30 μm
 - Cut blocs and polished blocs
 - Grains mounted in a binder
- Detection of element concentrations of down to 1 ppm and lower.
- About 5 minutes per analysis.
- Spatial resolution: 20 to 50 μm and down to <0.5 μm in depth.

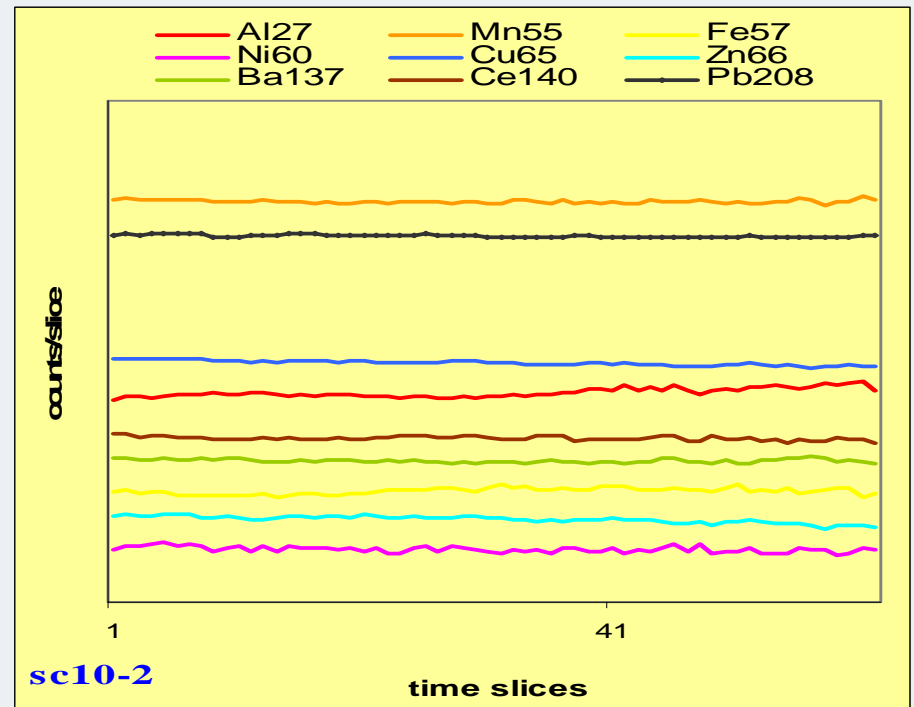
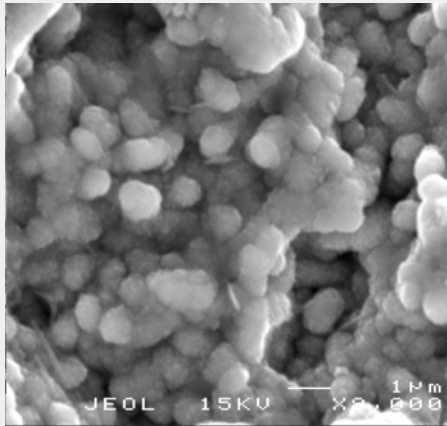
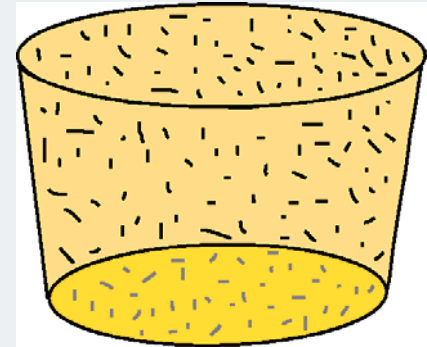


in situ LA-ICP-MS analysis of regolith material

Element concentration

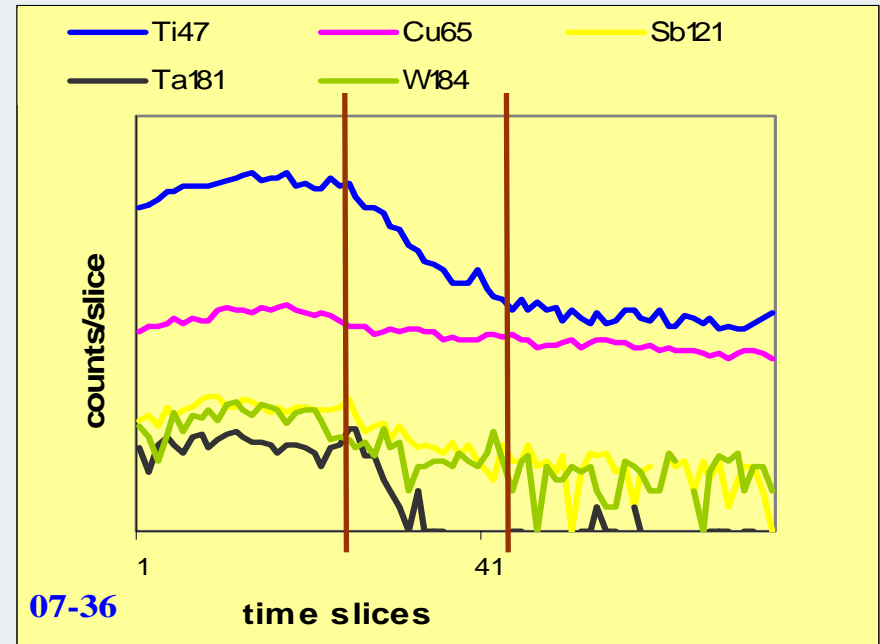
Homogeneous material

- one or several types of minerals
- Internal standard concentration : microprobe value of the concentration of a chosen element

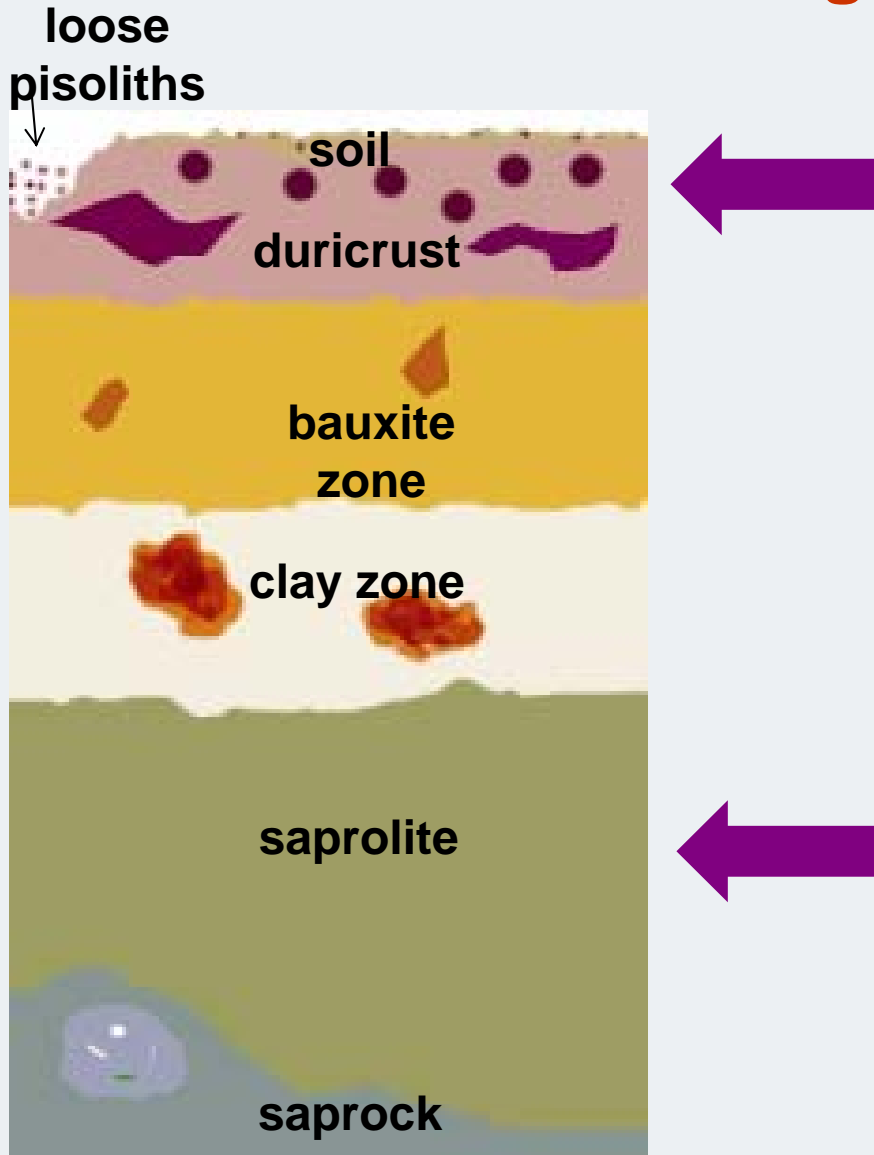


Heterogeneous material

- Internal standard concentration
 - Microprobe value cannot be used
 - The material can be “sliced”: microprobe values for each slide or elemental stoichiometry
 - Otherwise the results are normalised to 100% oxide.



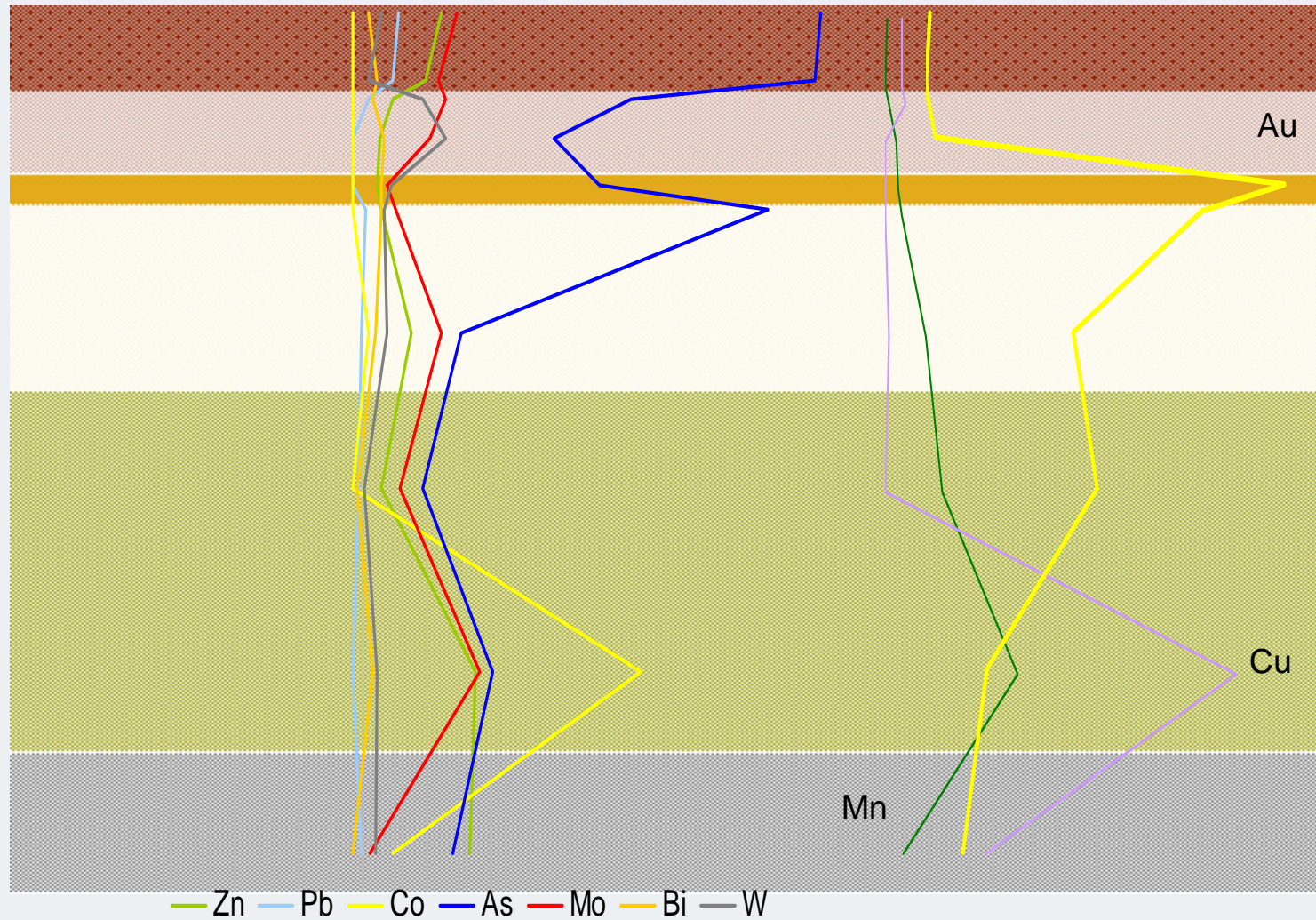
Boddington Au deposit



After Anand, 1994

CRCLEME

Geochemical composition of the regolith

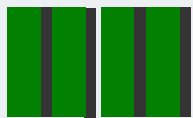


Saprolite mineralogy

- Abundant kaolinite and quartz;
- Partially weathered mica;
- Goethite + hematite replace Fe-sulphides.
 - Vermiculite, interstratified minerals chlorite/vermiculite (corrensite), and biotite/vermiculite. Vermiculite is partially weathered into kaolinite and goethite.



- Anatase grains



Chl Chl

Chlorite



Chl ver

Corrensite



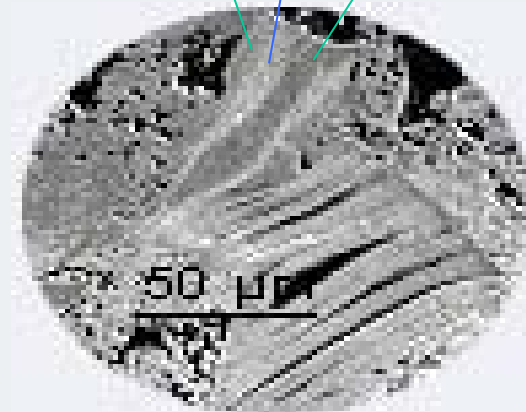
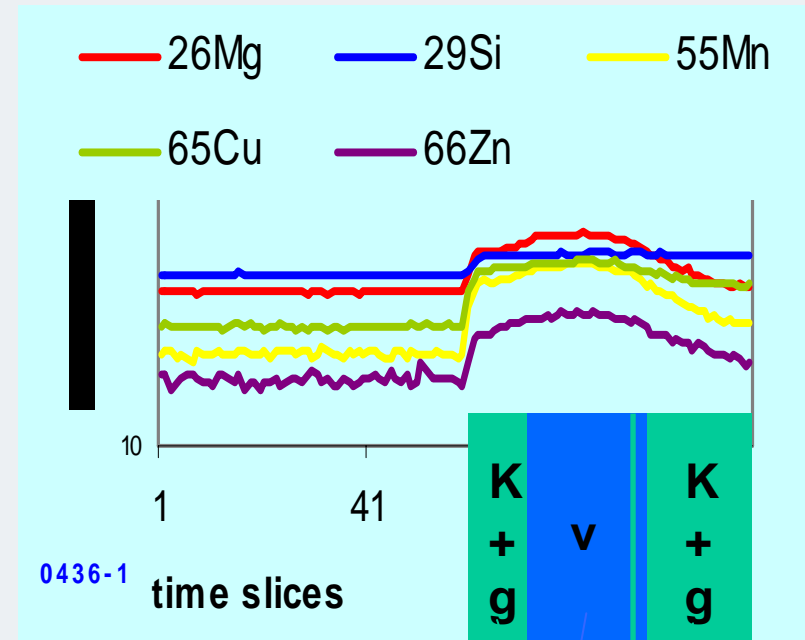
Microcrystalline
Goethite

Gt-Hm after sulphide

LA-ICP-MS

Clays

- Vermiculite: Zn (980 ppm), Mn (1.5%) and Cu (1.5%)
- Goethite + kaolinite: Cu, Zn, Mn
 - Cu, Zn and Mn % increase with goethite content
 - Goethite hosts the traces
- Kaolinite does not contain Zn, Mn, Cu

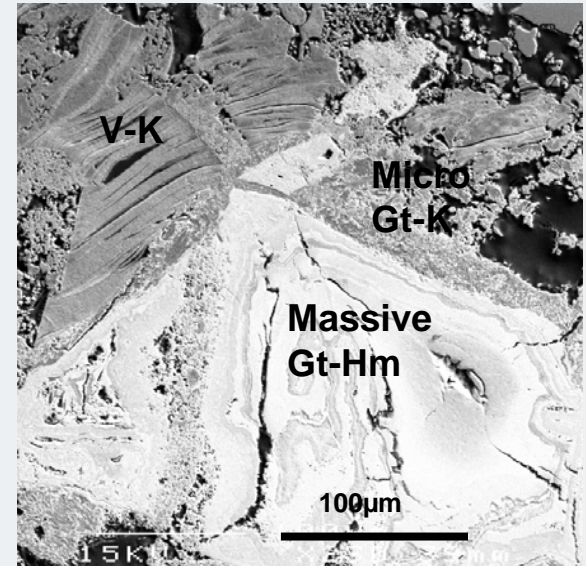


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Iron oxides

▪ Microcrystalline goethite

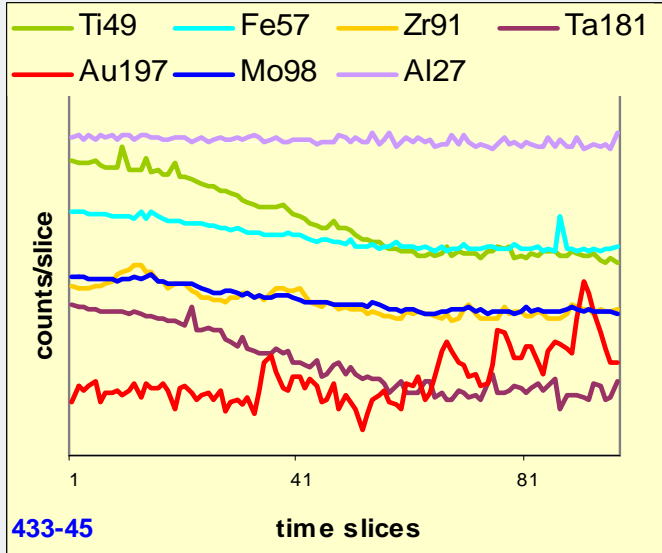
- Cu: up to 4% Cu in goethite-kaolinite
- Zn (180 ppm) and Mn (350 ppm)
- Au (>270 ppb), sub-micrometer particle
- As (0.5 %)
- Bi (>330 ppm), Mo (>210 ppm)
- W (>100 ppm) and Pb (>190 ppm)



▪ Massive goethite and hematite in iron sulfides relicts

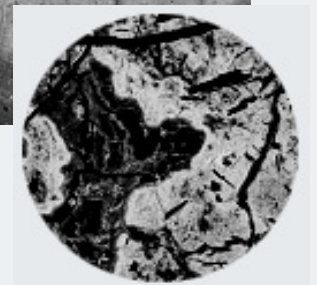
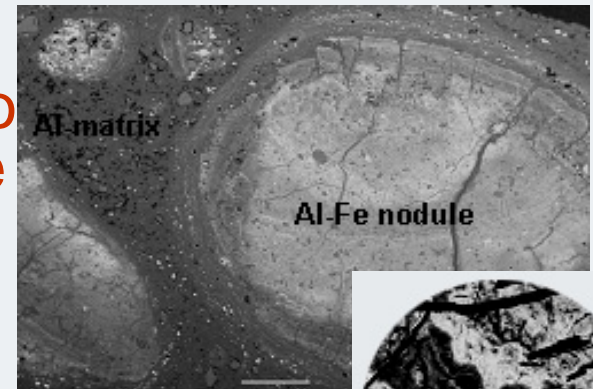
- Lower contents than in microcrystalline goethite

Boddington (Au-Cu): pisolithic duricrust



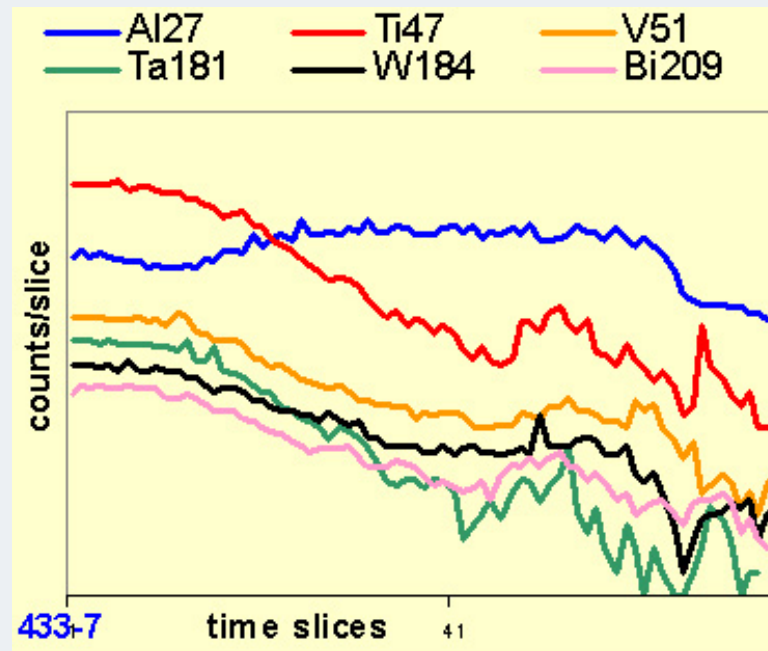
- Au (up to 1 ppm)
- Individual particles disseminated in the pisolith core and cortex and internodular matrix

- Cu (130 ppm), As (88 ppm), P and Mo (100 ppm) are concentrated in goethite in the cortex and matrix of the pisoliths
- About 110 ppm W in the core and cortex
- Gibbsite does not trap any of these elements

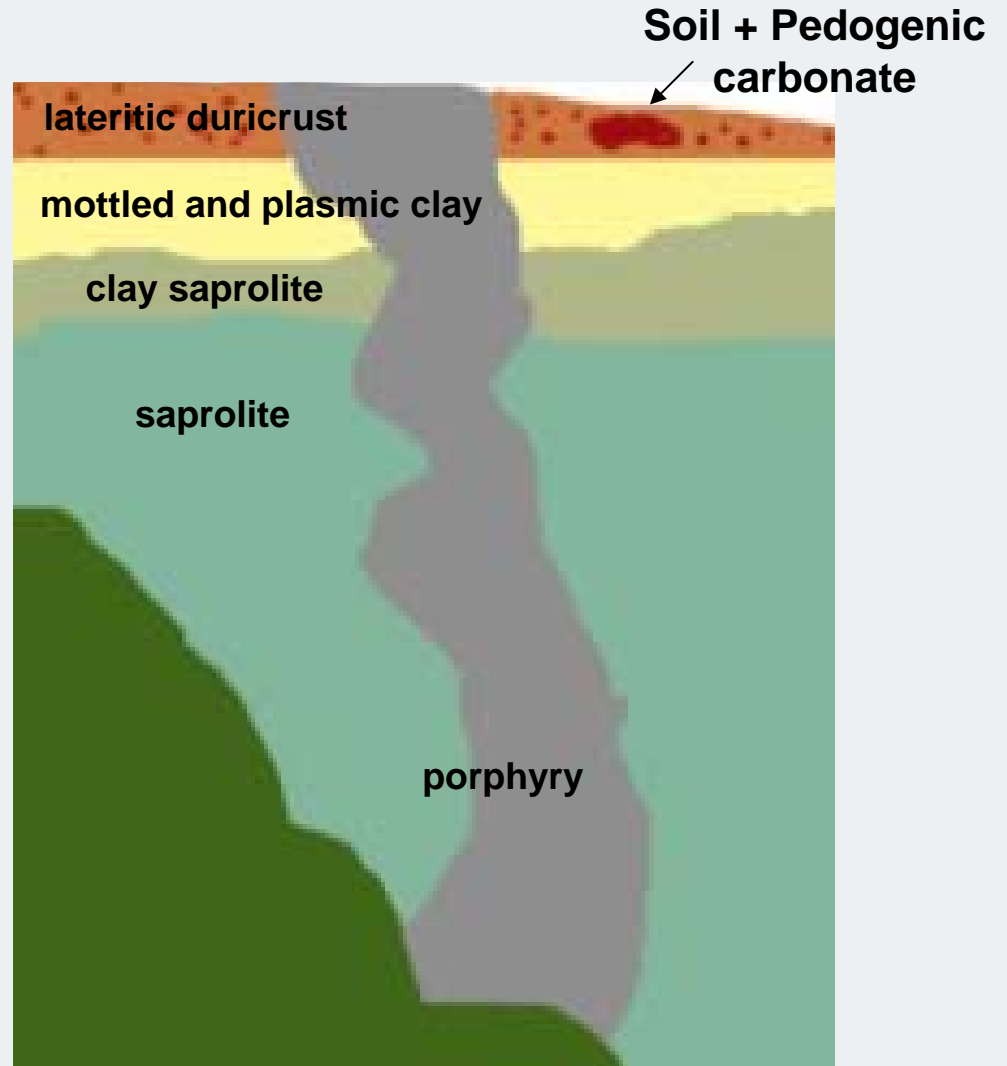
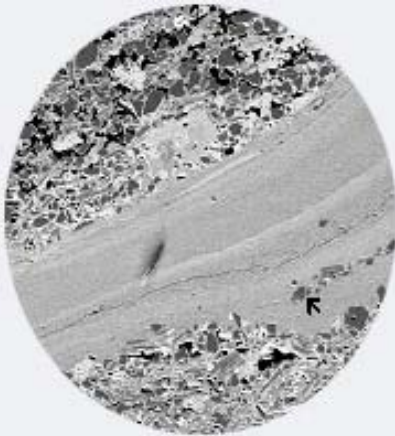


Ti-rich phases

- Anatase (titanite weathering product)
- High levels of W (>235 ppm), Ta (>271 ppm), Bi (>56 ppm) and V (885 ppm)

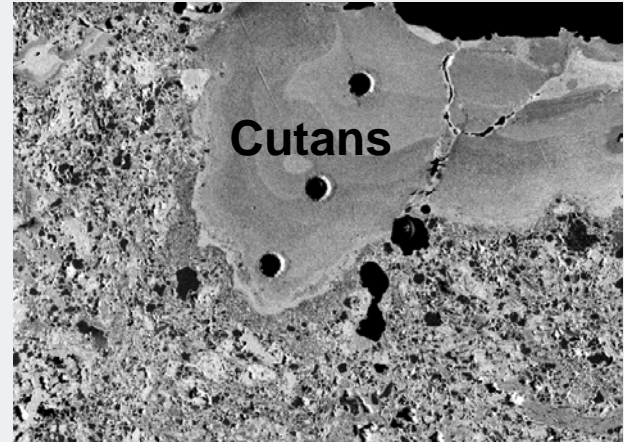
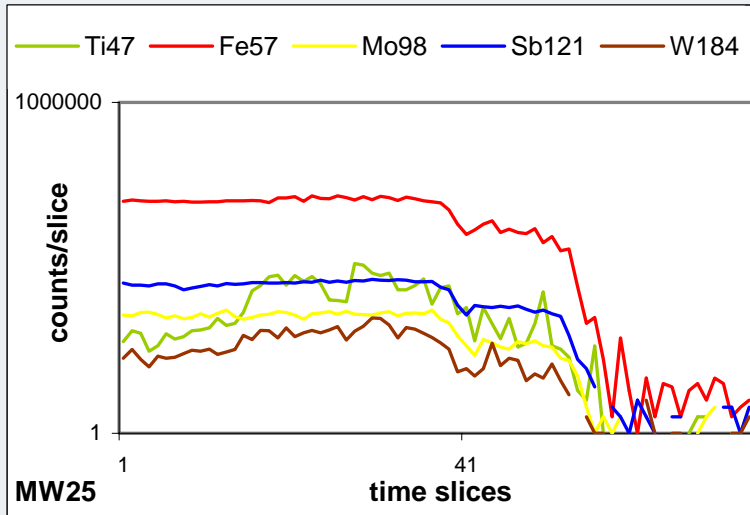


Mt Percy (Au)



(After Butt, 1991)

Mottled and plasmic clay zone



■ Goethite-rich cutans (Fe >40 %)

- high levels of Cu (up to 740 ppm), As (up to 0.1%), Mo (up to 430 ppm) and Sb (up to 900 ppm).
- W is hosted in Ti-rich grains

■ Goethite-hematite in ferruginised rock

- Comparatively depleted: Cu (140 ppm), As (370 ppm), Mo (8 ppm) and Sb (50 ppm)

Au

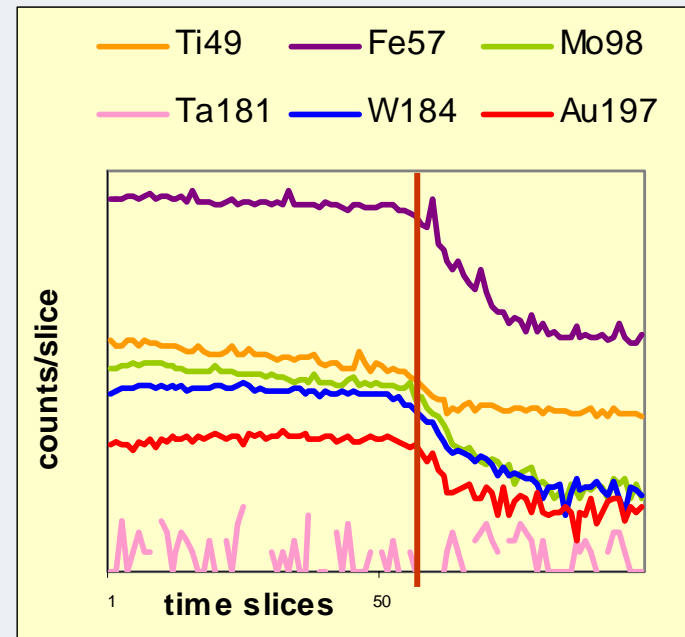
- **Cutans**

- up to 400 ppm

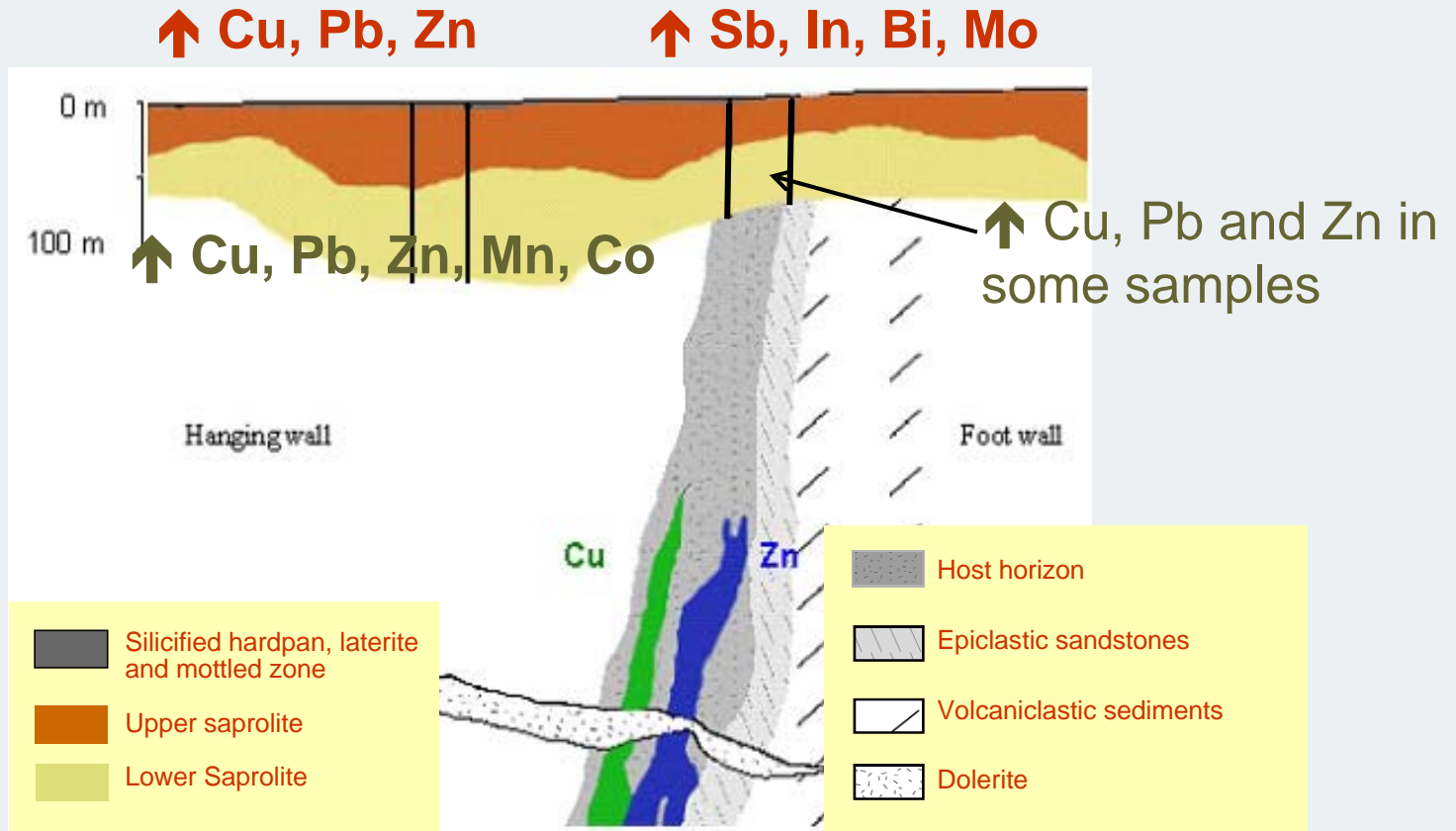
- Au occurs as crypto-crystalline particles

- **Ferruginised material**

- Au has not been detected



Scuddles (Cu-Zn)



Hanging wall

Lower saprolite

Quartz, muscovite, kaolinite

Up to 7% corrensite

Chlorite/smectite and
Chlorite/vermiculite

Mn oxides: coronadite + lithiophorite

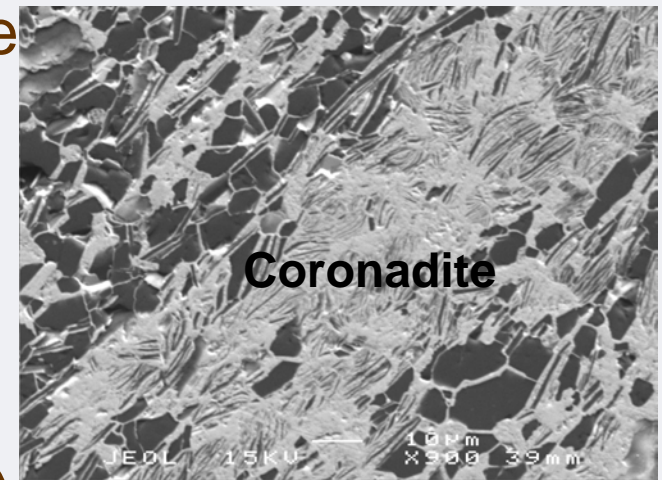
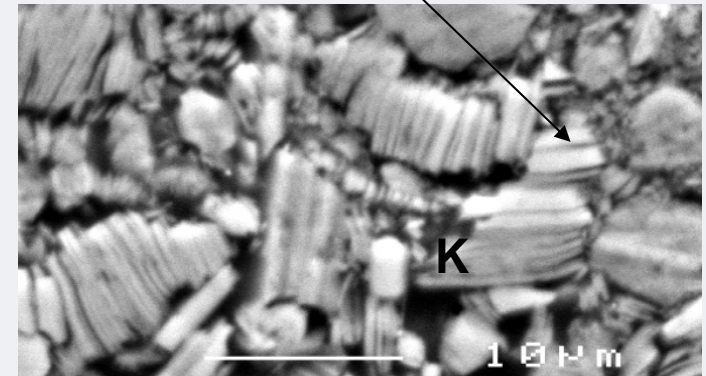
Ilmenite

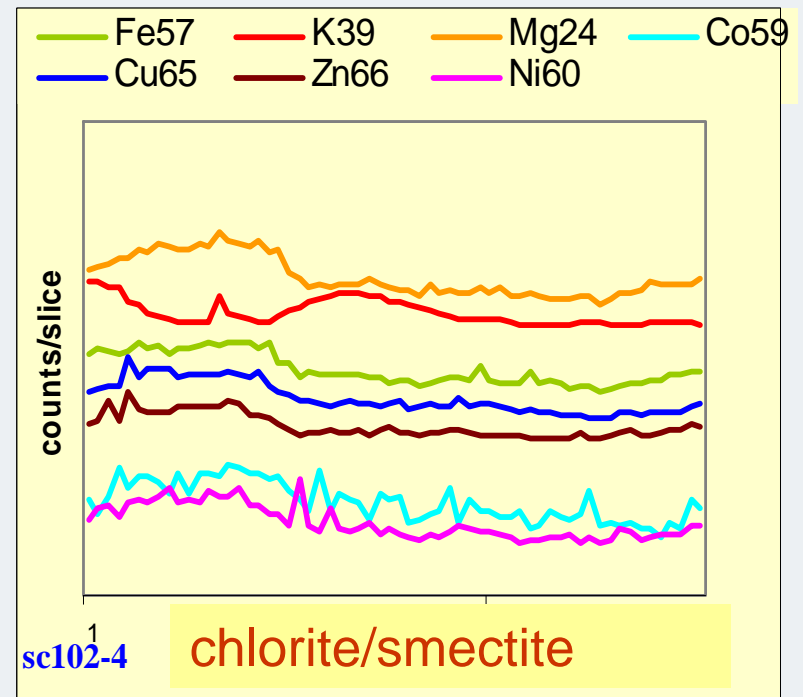
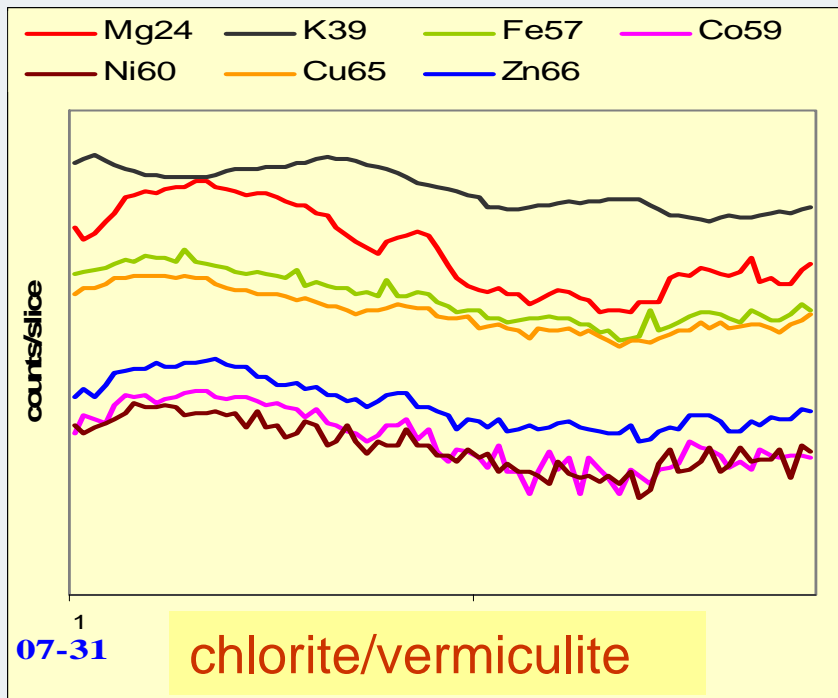
Upper saprolite

Corrensite (2 %)

Fe-smectites are present (up to 7%).

Corrensite





Lower saprolite

- Vermiculite layers of high-charge corrensite
 - About 0.30% Cu and Zn and Zn,
 - Ni (up to 340 ppm) and Co (up to 80 ppm)
- Smectite layers of low-charge corrensite
 - Lowers amounts of these elements
- Kaolinite
 - Cu, Zn, Ni, and Co are not present

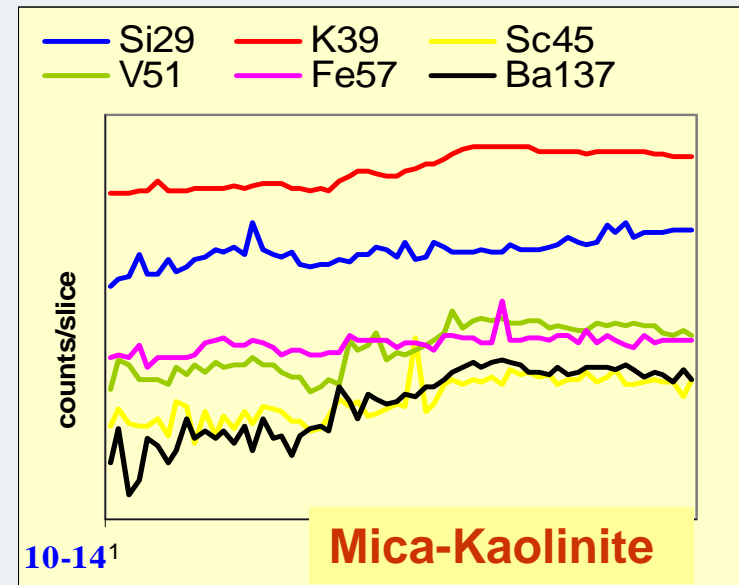
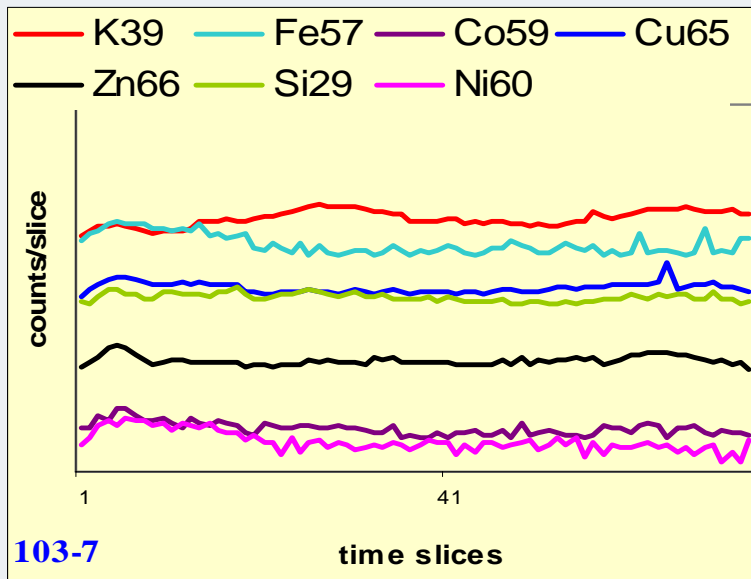
Upper saprolite

■ Smectites

- >0.25% Cu, Zn (>0.12%), Ni (>150 ppm) and Co (>50 ppm).

■ Kaolinite

- does not trap trace elements
- does not inherit cations released by the weathering of muscovite



Smectites+muscovite+ kaolinite

Over mineralisation

Lower saprolite

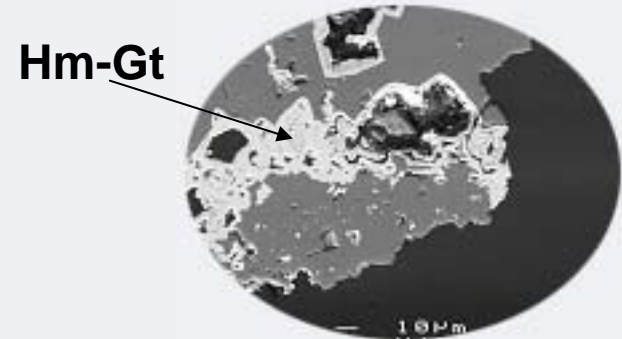
Quartz, muscovite, kaolinite

Abundant chlorite

Corrensite (1%)

Mn oxides: coronadite + lithiophorite

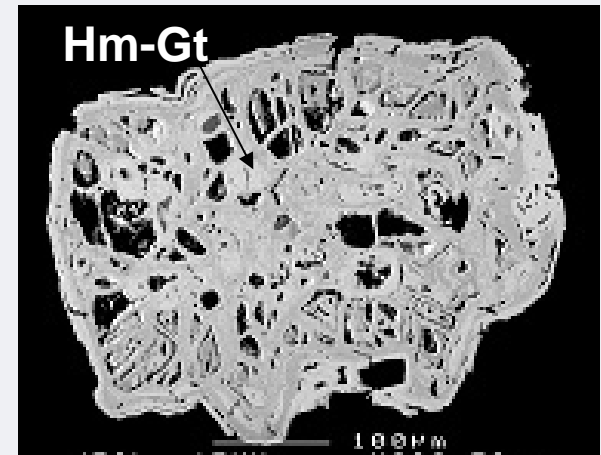
Hematite-goethite



Upper saprolite

Intensively silicified

Fe-rich banded concretions



Lower saprolite

■ Hematite-goethite assemblages

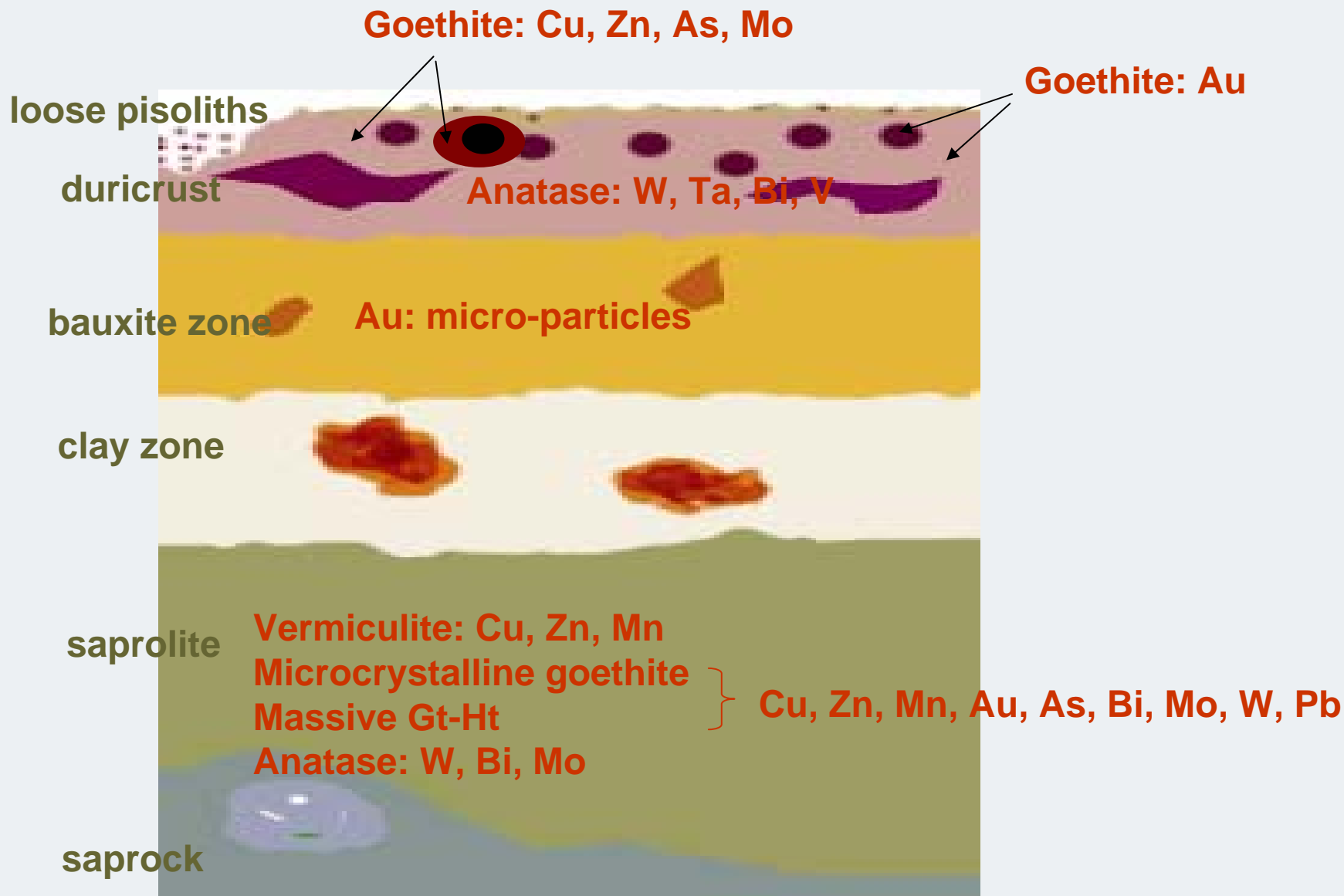
- Cu (2%), up to 0.4 % Zn and Pb, and 0.15% As
- V (220 ppm), Mn (740 ppm), Ni (130 ppm) and Co (70 ppm)
- About 40 ppm Sb

Upper saprolite

■ Fe oxides

- Depleted in Cu (0.4%), Zn (250 ppm) and As (370 ppm)
- High contents of Sb (up to 400 ppm) and Mo (up to 220 ppm)

Boddinton Au-deposit



Conclusions

- **Base metals and pathfinders are concentrated in:**
- **Clay fraction: vermiculite, smectite and interstratified minerals**
- **Microcrystalline goethite**
- **Massive goethite, hematite**
- **Cutans in voids and around pisoliths and nodules**
- **Kaolinite is barren**

Acknowledgments

- CRC LEME
- Normandy Mining Limited (now Newmont Australia)
- Steve Eggins, Australian National University, Canberra
- Juan-Pablo Bernal, Universidad Nacional Autónoma de México, México