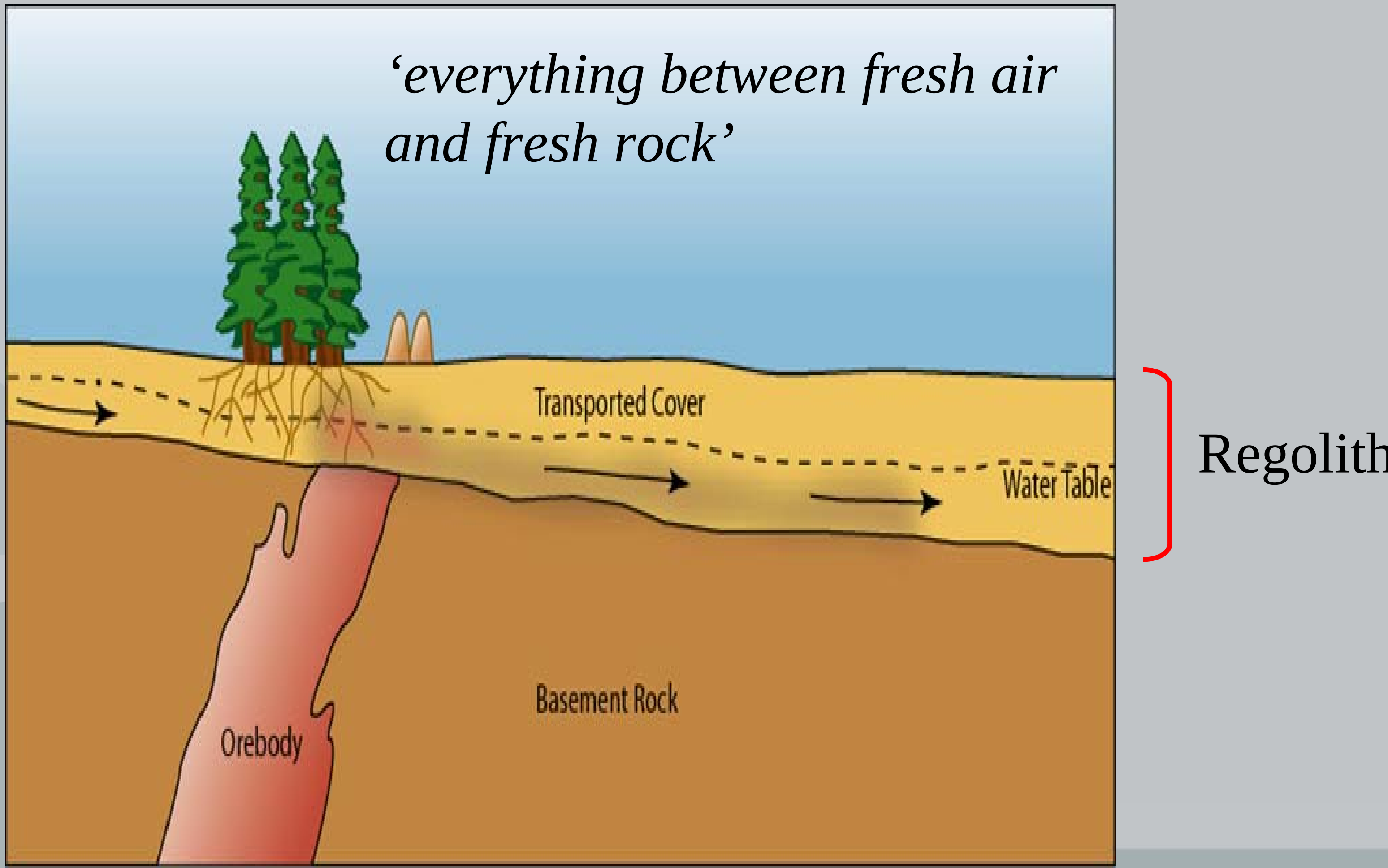
Recent Developments in Regolith Research with Application to Mineral Exploration and Environmental Management

Steve Rogers
Chief Executive Officer

www.crcleme.org.au



… **"create breakthroughs in mineral exploration and environmental management by generating and applying <u>knowledge</u> of the regolith"**

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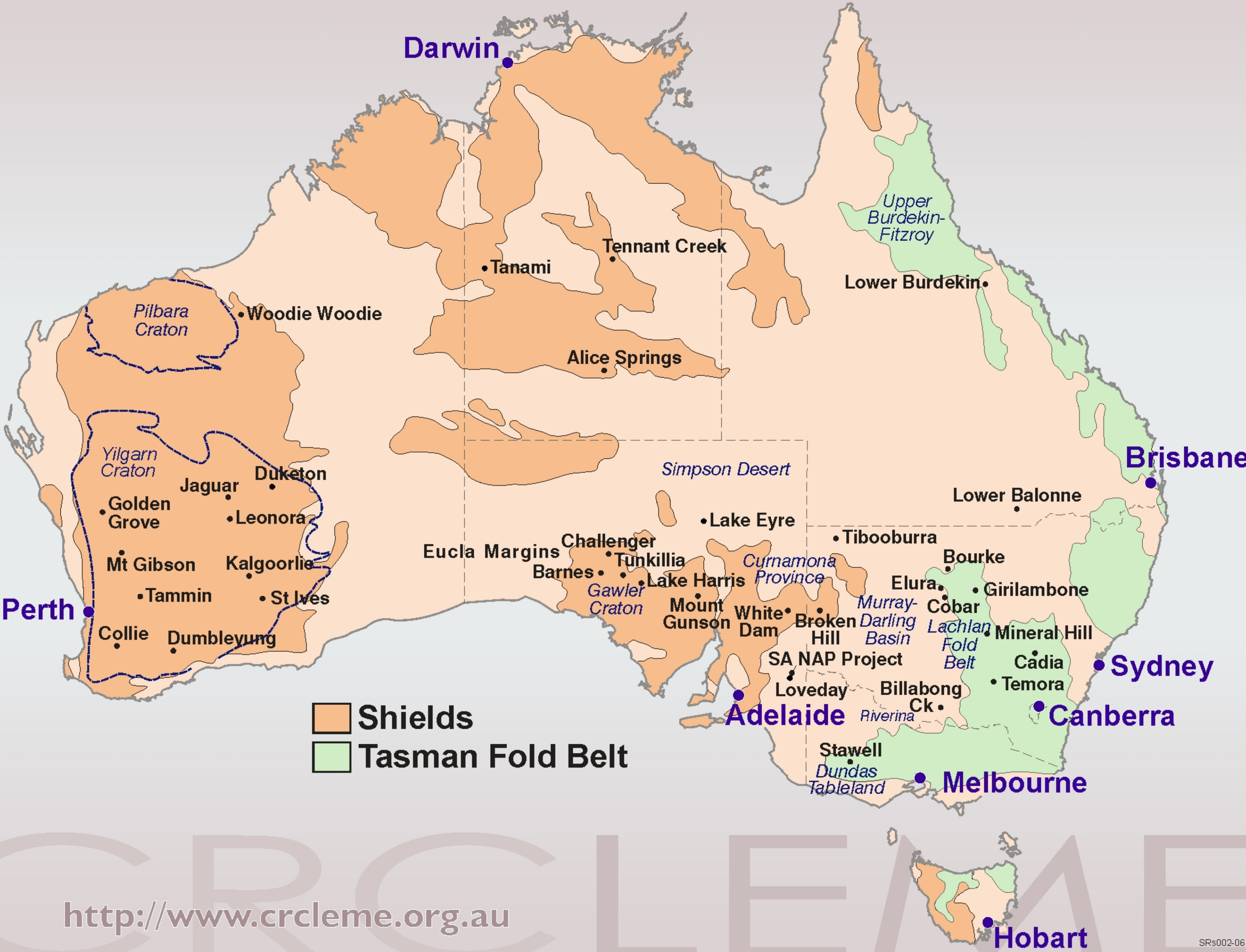
Darwin
Tanami
Tennant Creek
Upper Burdekin-Fitzroy
Lower Burdekin
Pilbara Craton
Woodie Woodie
Alice Springs
Yilgarn Craton
Duketon
Jaguar
Golden Grove
Leonora
Mt Gibson
Kalgoorlie
Tammin
St Ives
Perth
Collie
Dumbleyung
Simpson Desert
Brisbane
Lower Balonne
Lake Eyre
Tibooburra
Eucla Margins
Challenger
Tunkillia
Barnes
Lake Harris
Curnamona Province
Bourke
Elura
Girilambone
Gawler Craton
Mount Gunson
White Dam
Broken Hill
Murray-Darling Basin
Cobar
Lachlan Fold Belt
Mineral Hill
SA NAP Project
Cadia
Sydney
Temora
Loveday
Billabong Ck
Adelaide
Riverina
Canberra
Stawell
Dundas Tableland
Melbourne
Hobart
Shields
Tasman Fold Belt
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http://www.crcleme.org.au
SRs002-06

1. Mechanistic understanding of regolith landscape evolution and biogeochemical mineral transport/transformation process
2. New, innovative, cost effective methods of determining mineral targets through cover
3. Scientifically robust NRM intervention options
4. Knowledge based R&D and Innovation

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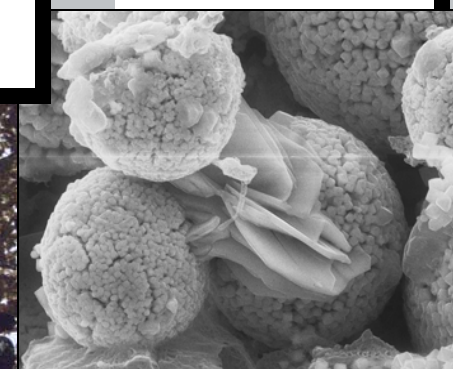
LEME Approach

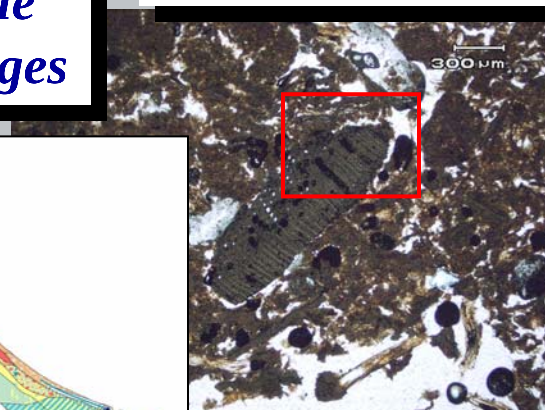
"Integrated multidisciplinary multi-scale approach"

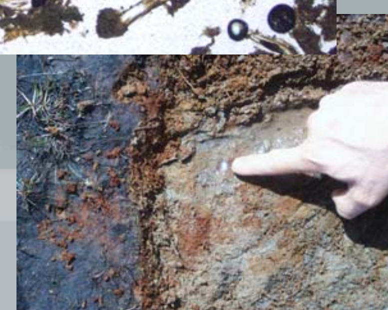
landscape to atoms

Atomistic
Molecular
Mineral

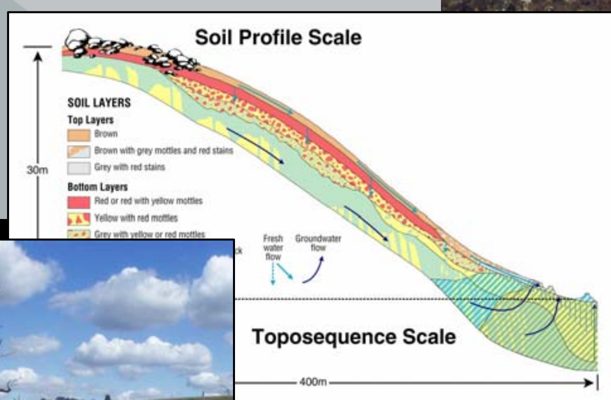


Microscopic
Macroscopic

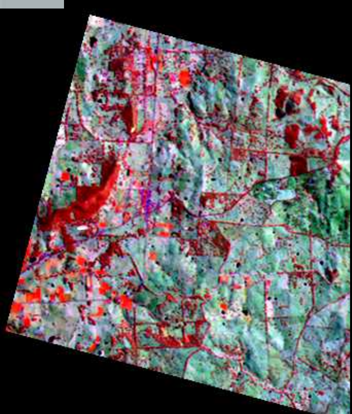




Field
Toposequence scale
e.g.Seasonal changes



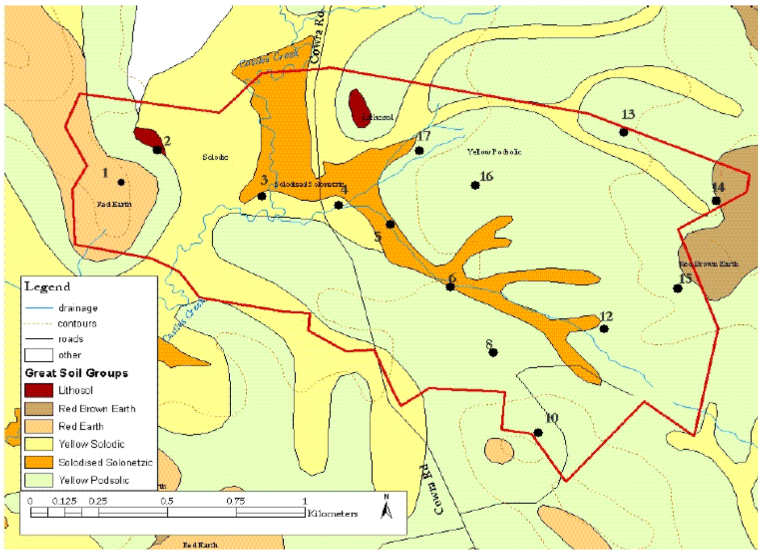
Landscape
Regional scale
National scale

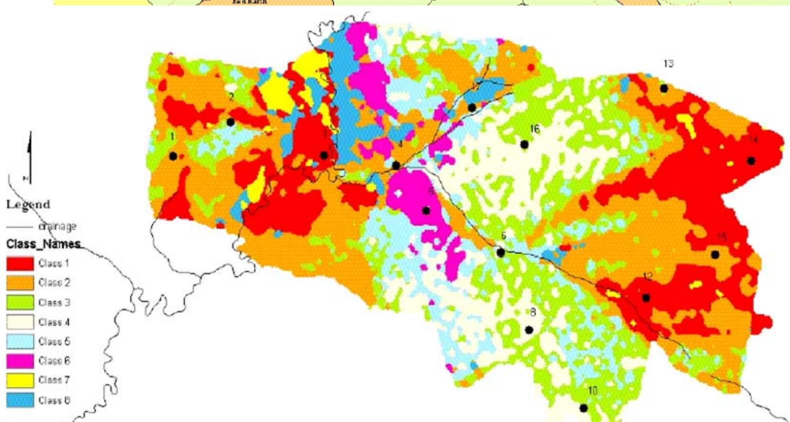


REGOLITH LANDFORM MAPS

- Radiometrics,
- DEMs,
- AEM,
- geochemistry,
- landscape evolution,
- auguring & drilling

map regolith thickness and composition.





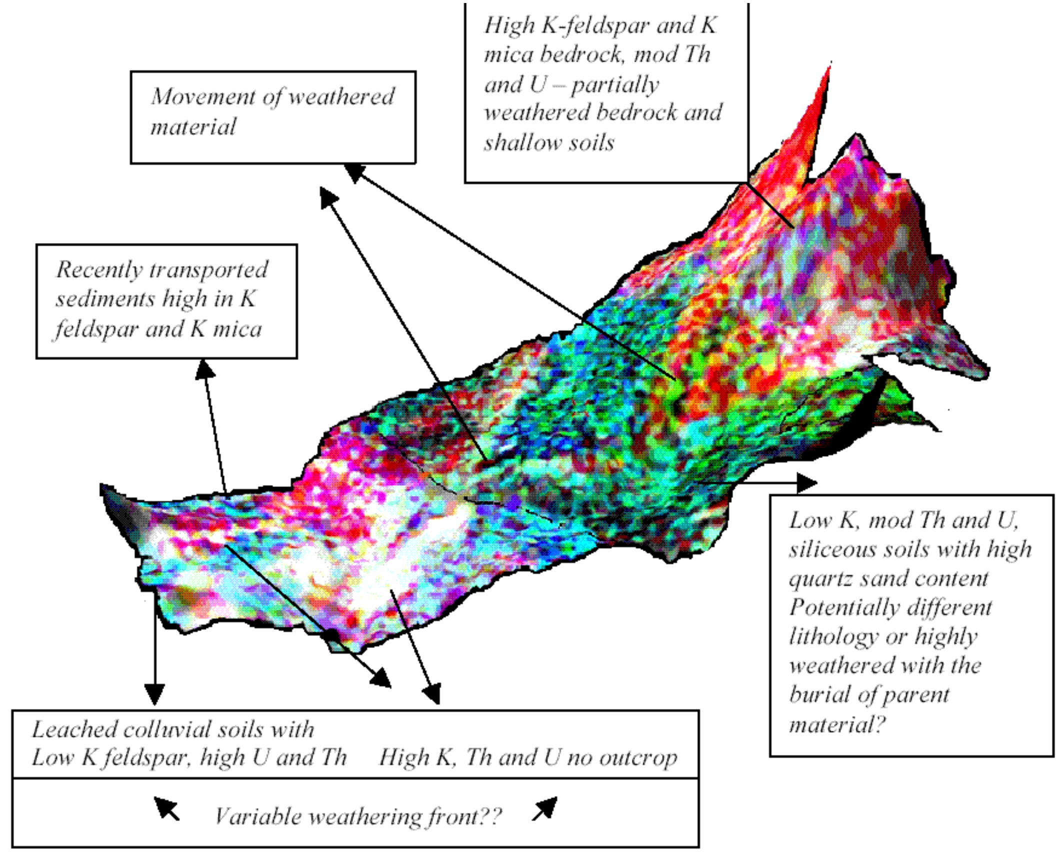
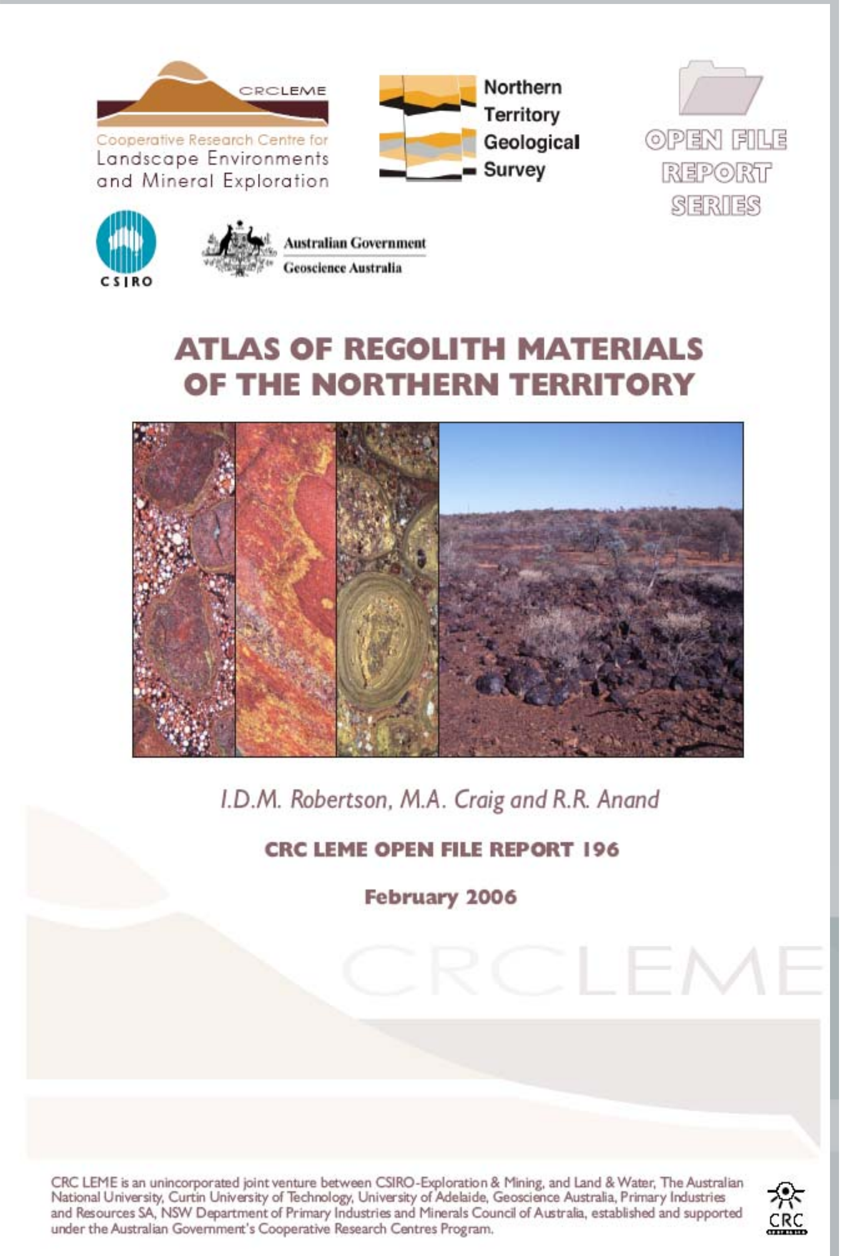


Figure 2: 3-Channel radiometrics draped over DEM and individual bands K, U and Th.

Data from Roberts et al., 2003



Cooperative Research Centre for Landscape Environments and Mineral Exploration

Northern Territory Geological Survey

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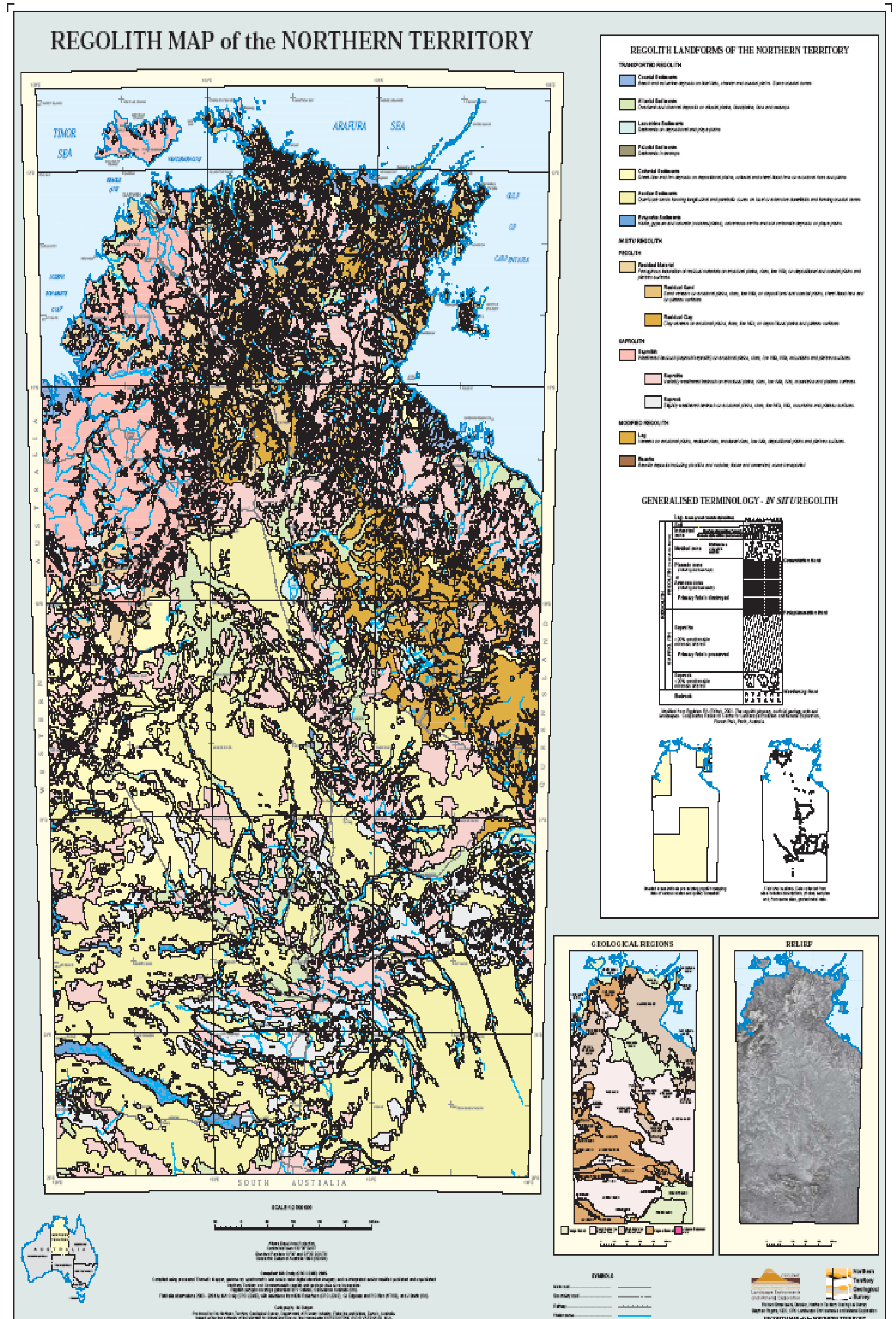
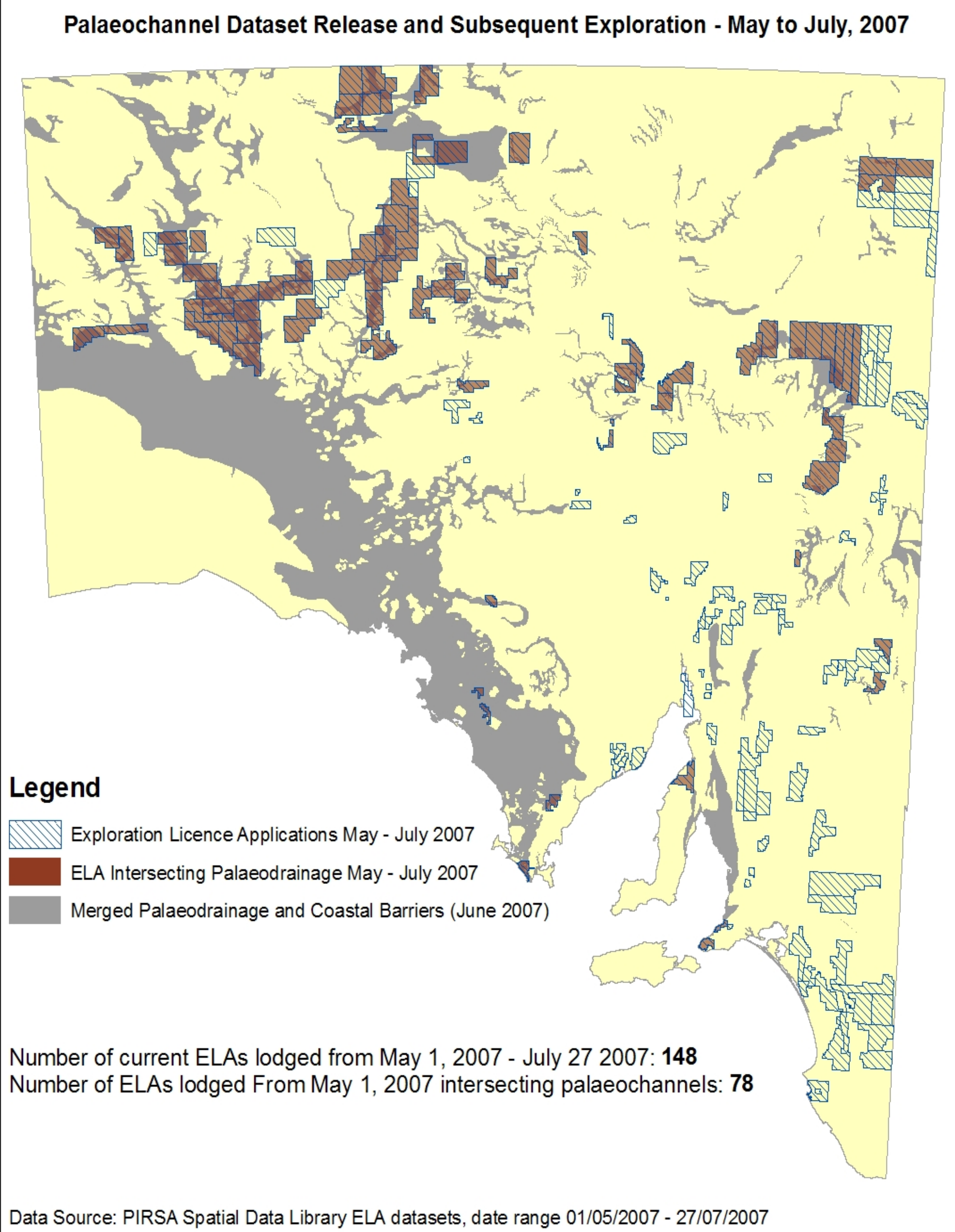
ATLAS OF REGOLITH MATERIALS OF THE NORTHERN TERRITORY

I.D.M. Robertson, M.A. Craig and R.R. Anand

CRC LEME OPEN FILE REPORT 196

February 2006





CRC LEME/PIRSA

- Revised stratigraphy of Tertiary sediments
- GIS of palaeodrainage sediments

'Major impact on Exploration Licence Applications'

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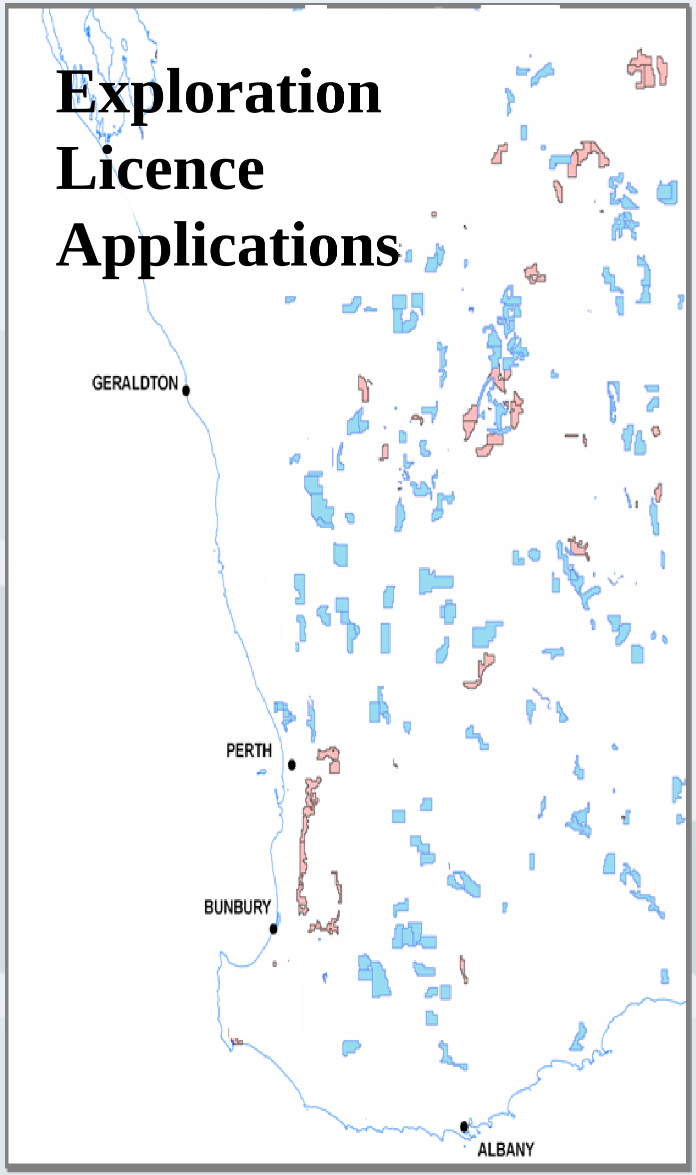
Laterite Geochemical Atlas and Database for the Western Yilgarn Craton (2007)

CRC LEME, GSWA, CSIRO, MERIWA

'Major impact on Exploration Licence Applications'



Impact of second data release

(pink)	Month prior to data release	40
(blue)	Month after data release	100

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PHYTO-EXPLORATION

Deep rooted vegetation provides a surface expression of underlying substrate – Focus Australian native Vegetation

To better Constrain

Pinnacles - lodes extensions
River Red Gum- Pb, Zn Phytoexploration

Photographs: Steve Hill

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Lead…

- Pb up to 205 times background levels

- Geochemical footprint ~ 2.5 km

Pinnacles Pb-Zn Mine Broken Hill NSW

○ 0 – 36 ppm

37 – 99 ppm

100 – 190 ppm

191 – 411 ppm

U Phytoexploration 4 Mile Creek prospect sampling

Sponsored by PIRSA PACE funding and Heathgate Resources

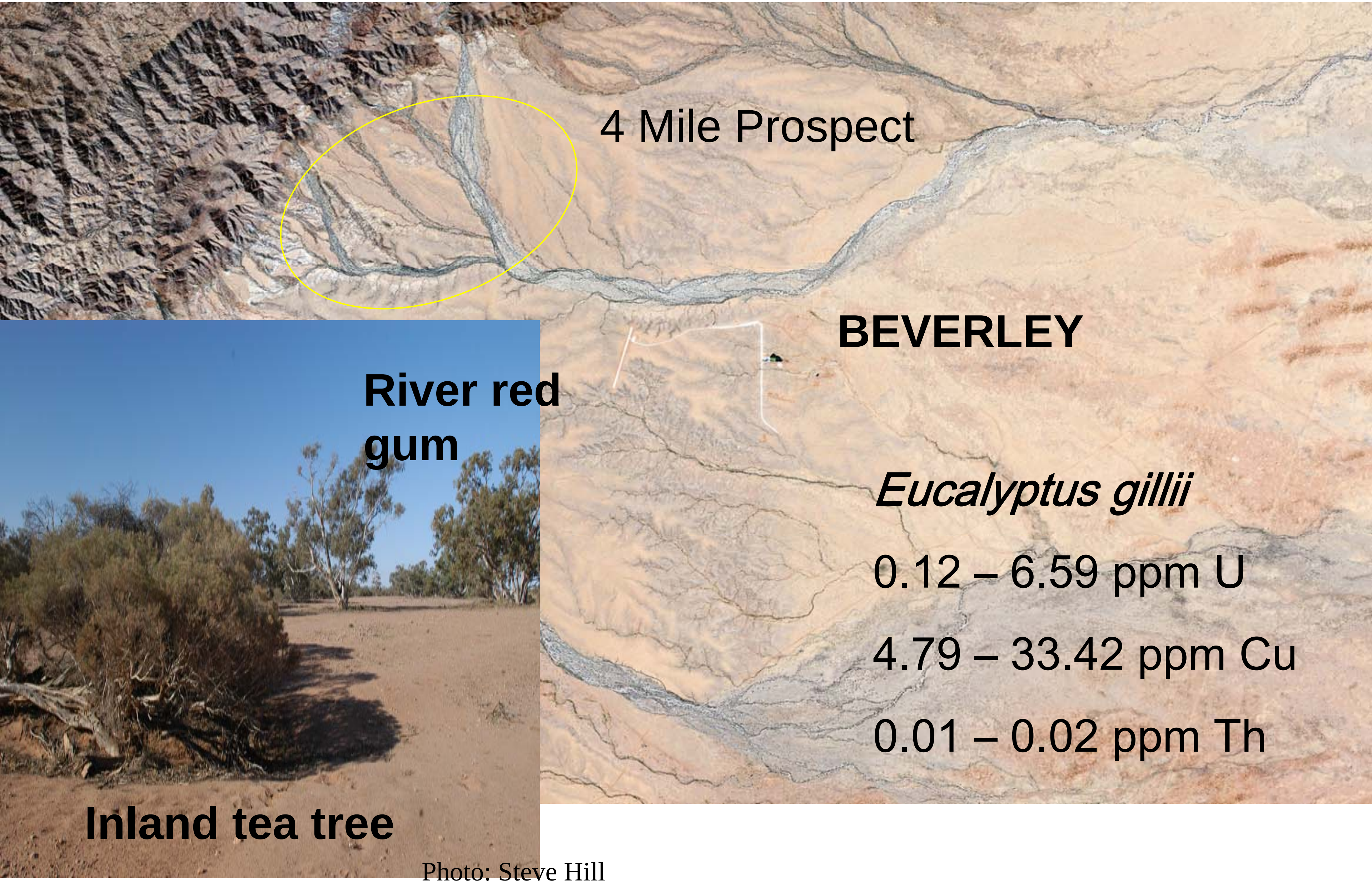
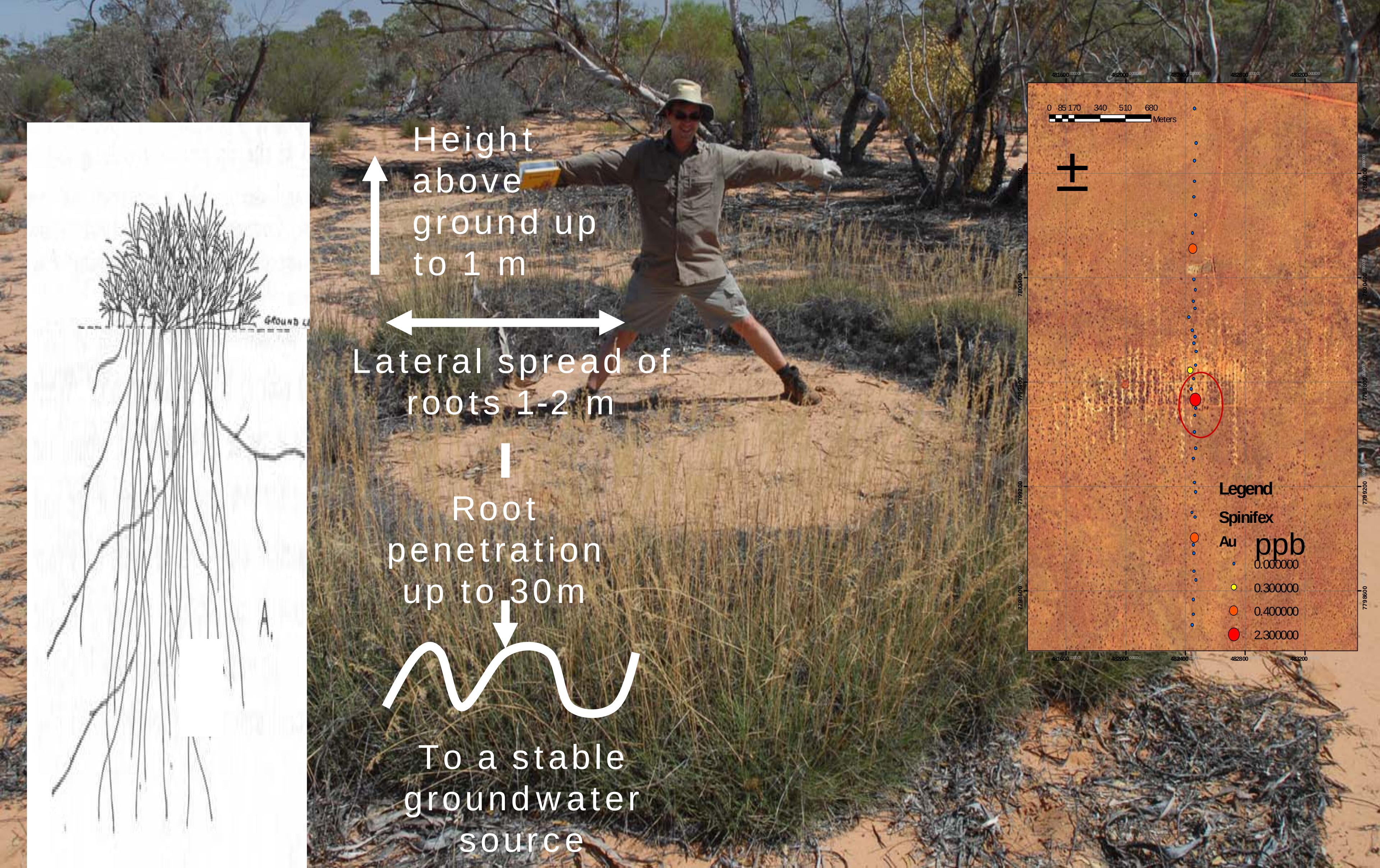
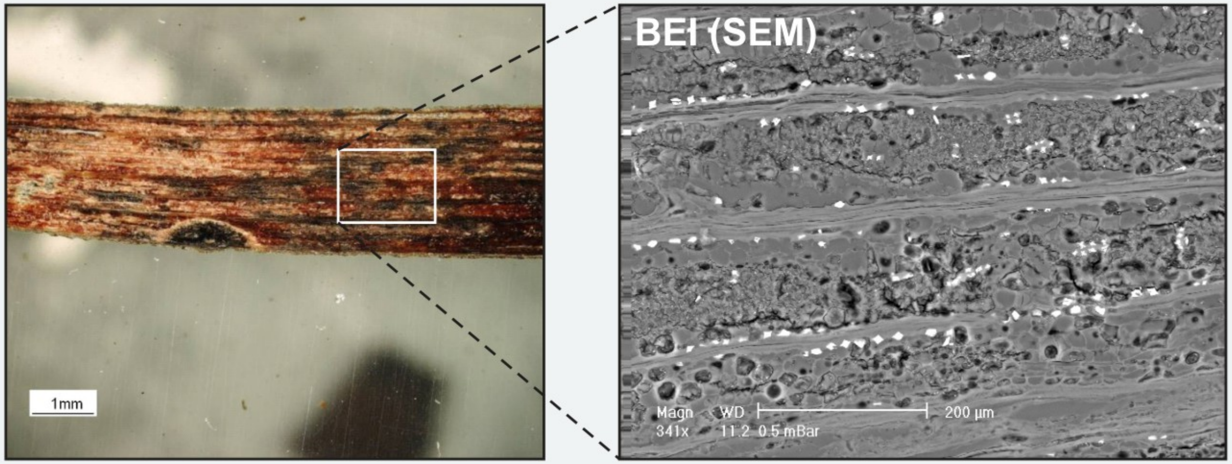


Photo: Steve Hill

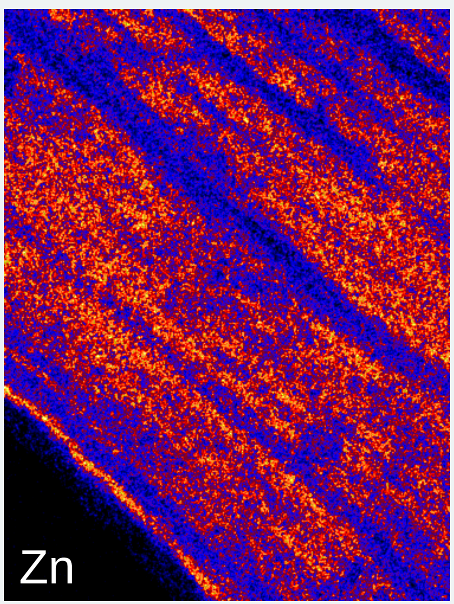
Spinifex expression of buried Au mineralisation

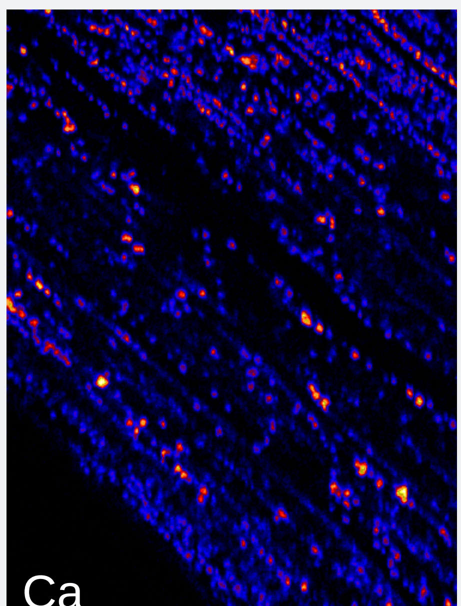


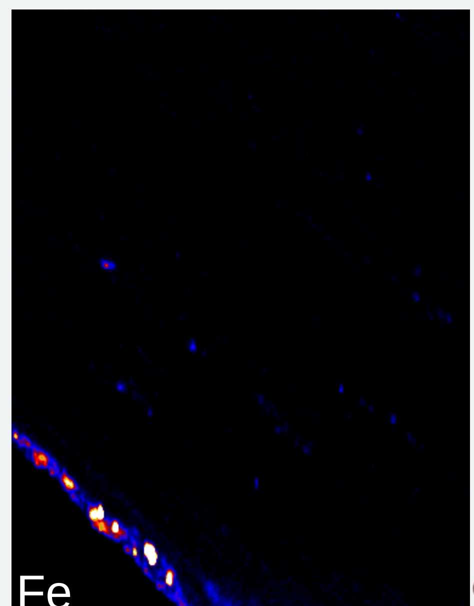
Location of metals (Nuclear Microprobe) in *Acacia aneura* leaf (Base metal deposit)



- Leaf sections show veined structure
- Bright grains under SEM are calcium oxalate crystals
- Zn present in tissues of leaves



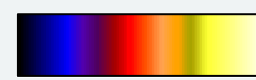




Highest Concentration

Zn 0.2%
Ca 23%
Fe 1%

Low High



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Follow that termite

Want to find buried treasure? Nature's little diggers will show you the way, says **Beth Geiger**

THE Kalahari desert in Botswana guards its geological secrets well. A layer of sand, soil and weathered rock tens of metres thick blankets all but a few outcrops of the underlying bedrock. Trying to find precious minerals embedded in the bedrock is a blind and very expensive grope.

That's why, when a geologist in the 1970s discovered a single fleck of a mineral called ilmenite on the surface, he paid attention. Ilmenite comes from a type of rock called kimberlite, and kimberlite hosts diamonds. That telltale fleck gave up an invaluable secret from the rock below: the richest diamond deposit in the world, now the Jwaneng diamond mine. But the minerals were 40 metres down, so how did a lone grain of ilmenite see the light of day? Termites hauled it.

Desert termites dig deep. They need to. In hot, arid areas, termites build large mounds above ground to help air circulation and temperature control. If a mound is damaged, it must be repaired immediately to keep out predators and protect the colony. However dry the desert, termites always need wet mud for construction. To get it the insects tunnel 30 metres or more down to the water table, clamp bits of clay or wet rock in their jaws, then climb back home to build the mound, grain by damp grain. In doing this they not only bring up samples of the soil from that depth, but also traces of water that may have flowed through rocks containing precious ores. Termite mounds are packed with clues to what lies beneath.

Now geologists and mining companies are waking up to the true potential of termite sampling. A team of Australian researchers is developing precise techniques that make the mounds, along with desert plants, reliable indicators of the rocks below. As well as scouring termite mounds for traces of gold, they are searching for chemical signatures of gold formation, brought up from the water table and concentrated in the mounds. Termites, they believe, are the ticket to new reserves of diamonds, gold and other buried treasure.

Normally, to get a sample of bedrock from beneath all the accumulated sand, soil and stones, collectively known as regolith, ▶

New Scientist 30 June 2007

Anna Petts PhD CRC LEME/The University of Adelaide

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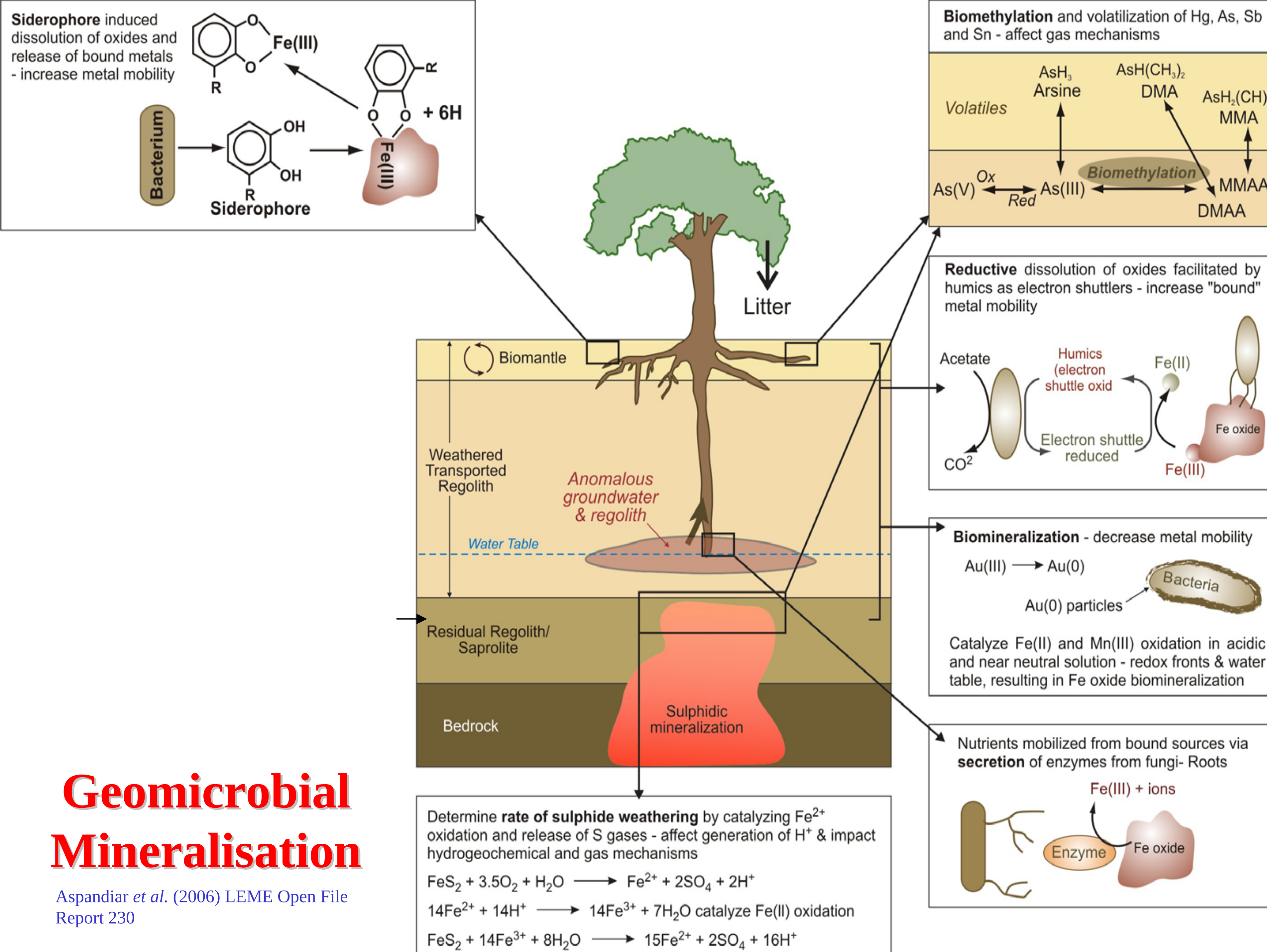
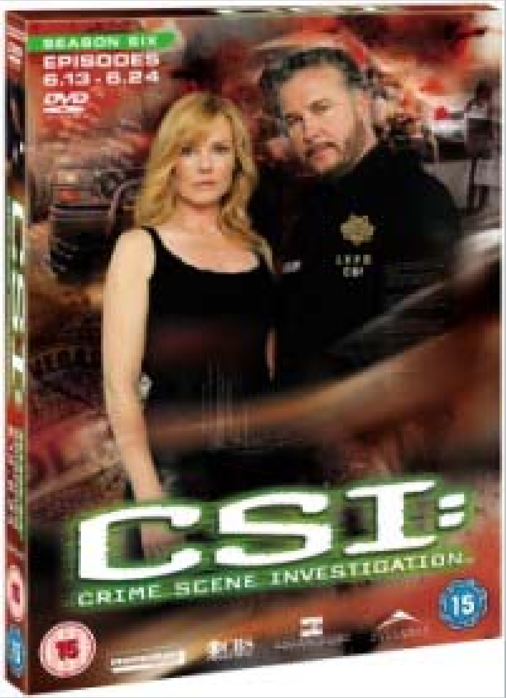


Geomicrobial Mineralisation

Aspandiar *et al.* (2006) LEME Open File Report 230

Molecular Geomicrobiology



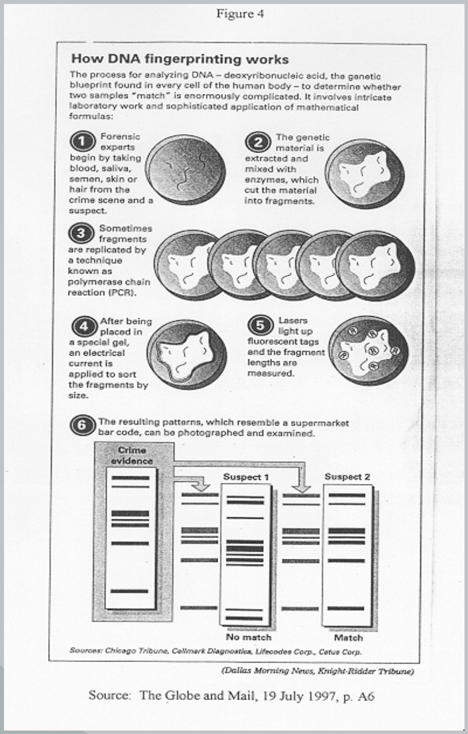


Figure 4

How DNA fingerprinting works

The process for analyzing DNA – deoxyribonucleic acid, the genetic blueprint found in every cell of the human body – to determine whether two samples "match" is enormously complicated. It involves intricate laboratory work and sophisticated application of mathematical formulas:

1. Forensic experts begin by taking blood, saliva, semen, skin or hair from the crime scene and a suspect.
2. The genetic material is extracted and mixed with enzymes, which cut the material into fragments.
3. Sometimes fragments are replicated by a technique known as polymerase chain reaction (PCR).
4. After being placed in a special gel, an electrical current is applied to sort the fragments by size.
5. Lasers light up fluorescent tags and the fragment lengths are measured.
6. The resulting patterns, which resemble a supermarket bar code, can be photographed and examined.

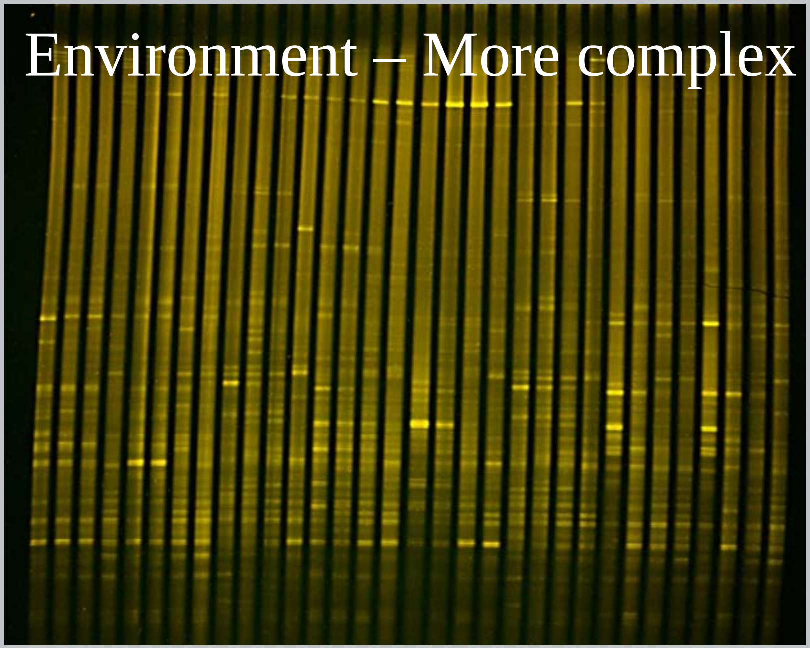
Crime evidence | Suspect 1 | Suspect 2

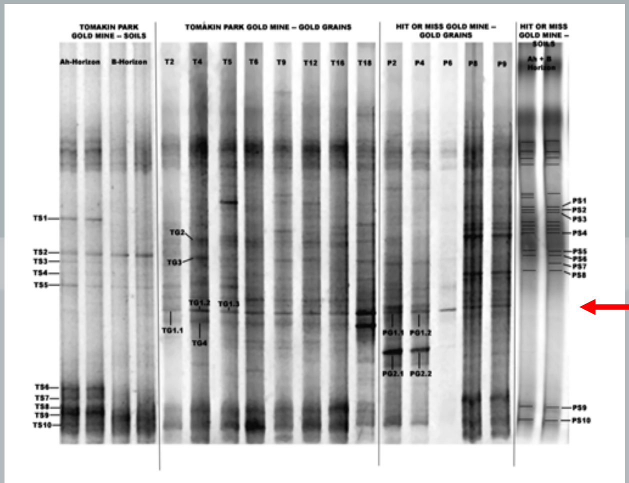
No match | Match

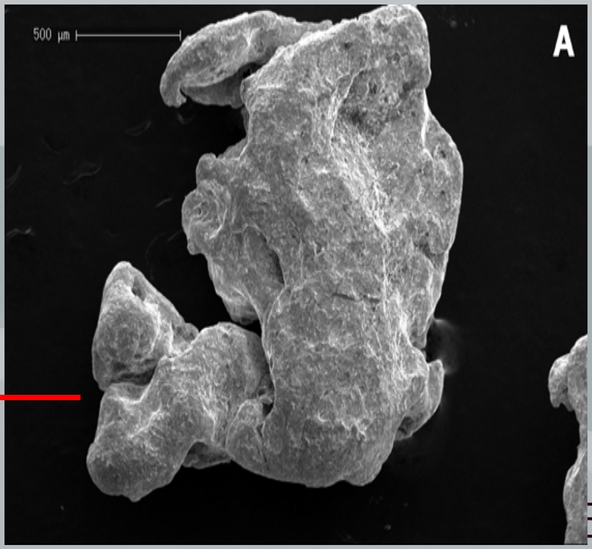
Sources: Chicago Tribune, Cellmark Diagnostics, Lifecodes Corp., Cetus Corp.

(Dallas Morning News, Knight-Ridder Tribune)

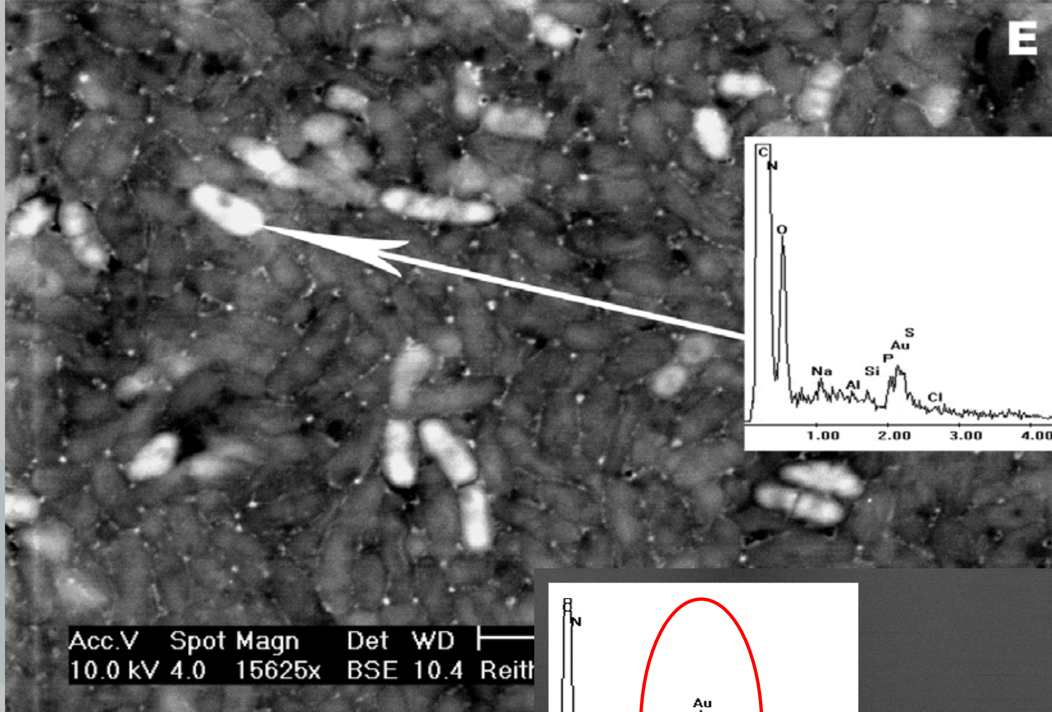
Source: The Globe and Mail, 19 July 1997, p. A6

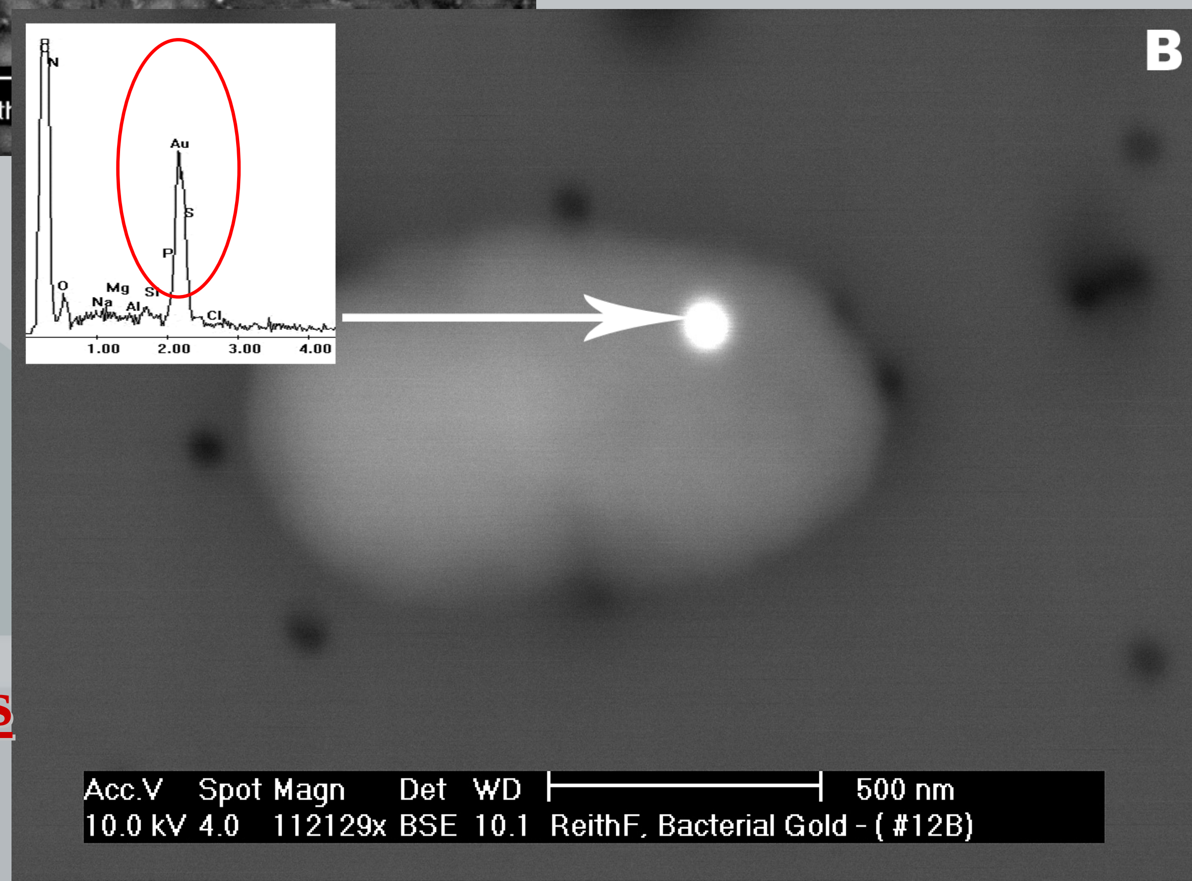






Ralstonia metalidurans





Energy Dispersive

X – Ray Spot Analysis

Geomicrobiology

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30. We thank S. Lummis (Cambridge) for use of her Flexstation and T. Kurosaki (Kansai Medical University Japan) for providing DT40 cells. Supported by the Wellcome Trust (072084), Biotechnology and Biological Sciences Research Council, and a Jameel Family Studentship (to T-U-R).

Supporting Online Material
www.sciencemag.org/cgi/content/full/313/5784/229/DC1
Materials and Methods
Figs. S1 to S7
Tables S1 to S3
References

20 January 2006; accepted 24 May 2006
10.1126/science.1125203

Biomineralization of Gold: Biofilms on Bacterioform Gold

Frank Reith,[1,2*] Stephen L. Rogers,[1,4] D. C. McPhail,[1,2] Daryl Webb[3]

Bacterial biofilms are associated with secondary gold grains from two sites in Australia. 16S ribosomal DNA clones of the genus *Ralstonia* that bear 99% similarity to the bacterium *Ralstonia metallidurans*—shown to precipitate gold from aqueous gold(III) tetrachloride—were present on all DNA-positive gold grains but were not detected in the surrounding soils. These results provide evidence for the bacterial contribution to the authigenic formation of secondary bacterioform gold grains and nuggets.

The origin of secondary gold grains is controversial and widely debated in the scientific community; the two main theories are that they are detrital or are formed by chemical accretion (*1*). However, there is growing evidence pointing to the importance of microbial processes in the cycling of gold (*2*, *3*). Common soil bacteria (*Bacillus megaterium*, *Pseudomonas fluorescens*, *Bacterium nitrificans*) are able to solubilize several milligrams of gold per liter of medium under in vitro conditions (*2*, *4*). A recent microcosm study of auriferous soils from the Tomakin Park Gold Mine in southeastern New South Wales, Australia (35°48′51.9″S, 150°10′26.4″E) showed that resident microbiota solubilized up to 80 wt % [i.e., 1100 ng per g (dry weight, soil)] of

[1]Cooperative Research Centre for Landscape Environments and Mineral Exploration, Post Office Box 1130, Bentley, Western Australia 6102, Australia. [2]Department of Earth and Marine Sciences, [3]Research School of Biological Sciences, Electron Microscopy Unit, Australian National University, Acton, ACT 0200, Australia. [4]Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water, PMB2, Glen Osmond, South Australia 5064, Australia.

*To whom correspondence should be addressed. E-mail: frank.reith@csiro.au

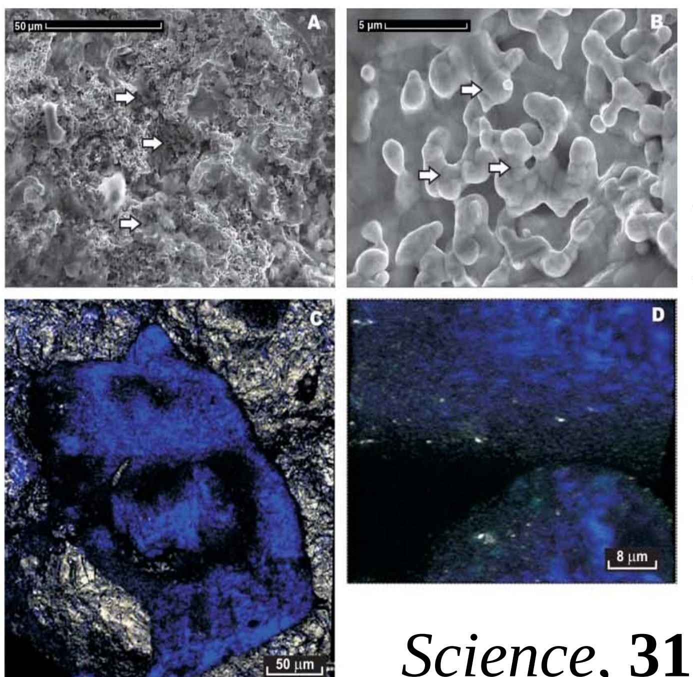

Fig. 1. Secondary electron micrographs of bacterioform gold (**A** and **B**) and confocal stereo laser microscope images (**C** and **D**) of fluorescently stained biofilms on gold grains from the Hit or Miss Gold Mine in Queensland, Australia. (A) Bacterioform gold with apparent exopolymers (white arrows) possibly derived from a microbial biofilm. (B) Detailed view of branching network of rounded and oval budding cell-like structure with apparently preserved cell wall structures (white arrows). (C) Biofilm covering an area of 200 μm by 100 μm of underlying bacterioform gold. (D) Detailed view into a small crevice in the biofilm, showing cells or cell clusters (in blue) separated by unstained interstices. Fluorescent cells are spreading predominantly over the surface of the bacterioform gold and are not present at the base of the crevice.

Science, **313** 14 July 2006

Implications

1. Transport models
2. Bioprospecting
3. Au bioprocessing (Parker CRC)

ARC Linkage 2007-10

Barrick Gold, Newmont, Adelaide University, CSIRO

AMIRA P778

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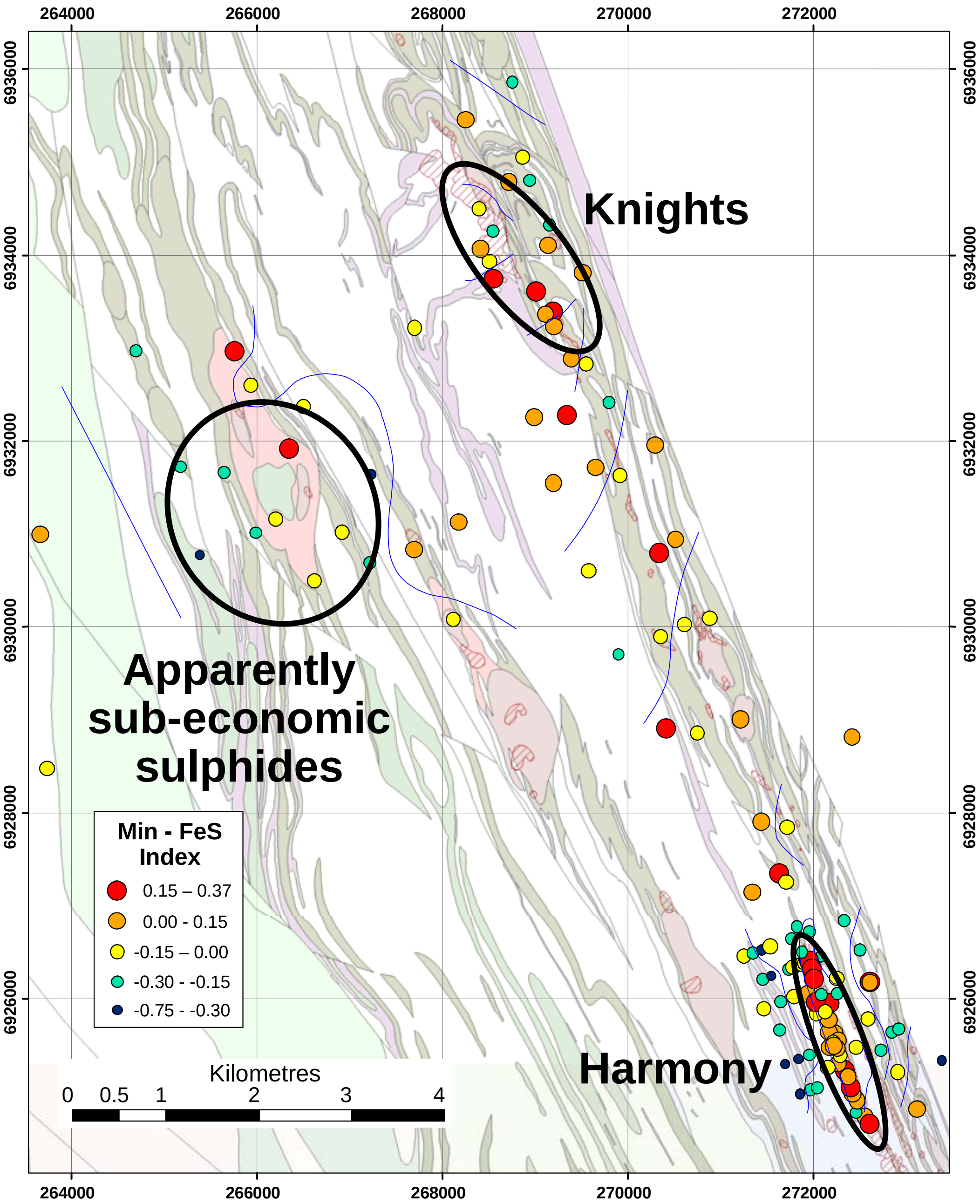

Hydrogeochemistry

- Min-FeS index strongly indicates the Harmony Ore Body in the SE, and areas of economic NiS intersections in the north (Knights) of the area, and deemphasises apparently sub-economic sulphides in the west

Source: D. Gray

Spectral Analysis – LEME/CSIRO Chip Logger

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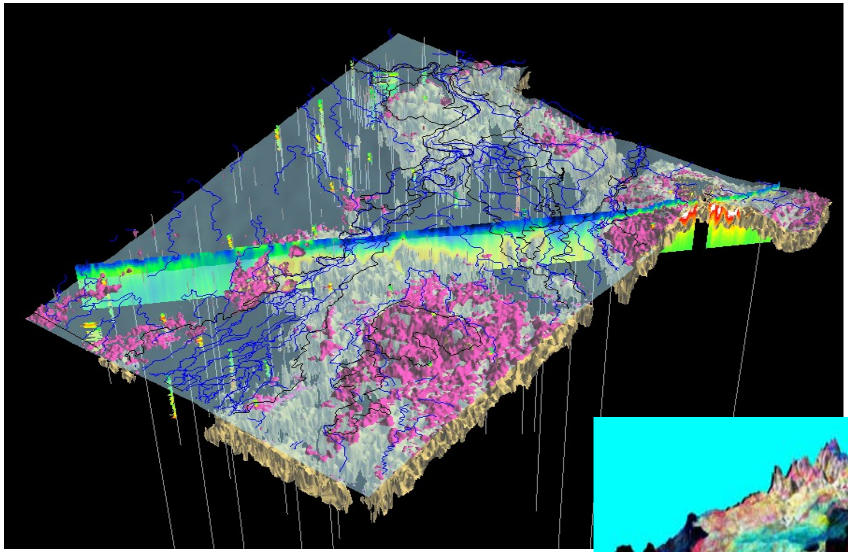
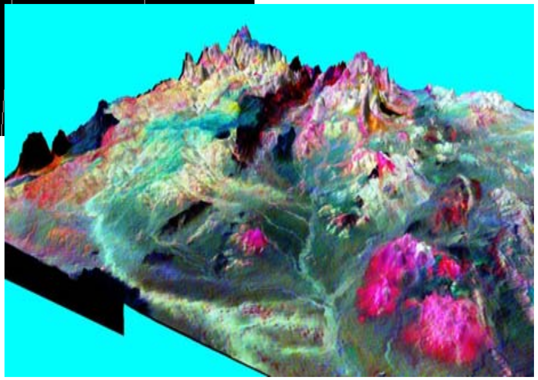
Salinity NRM Focus



1. INTEGRATED SALINITY AND GROUNDWATER MANAGEMENT IN FLOODPLAIN LANDSCAPES

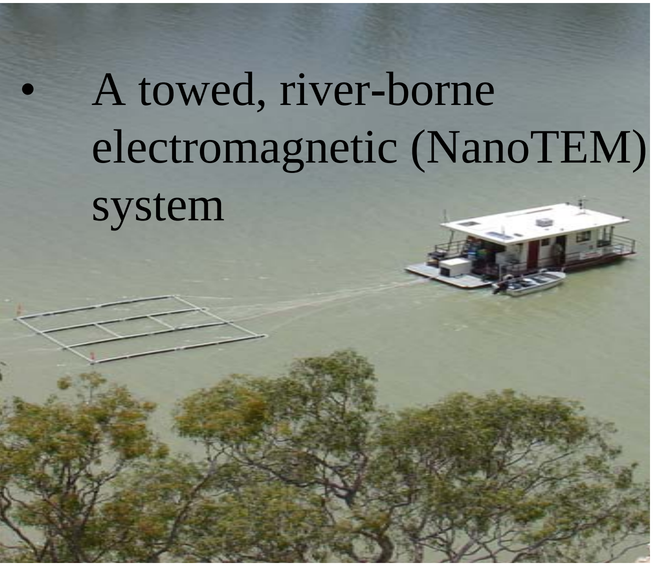


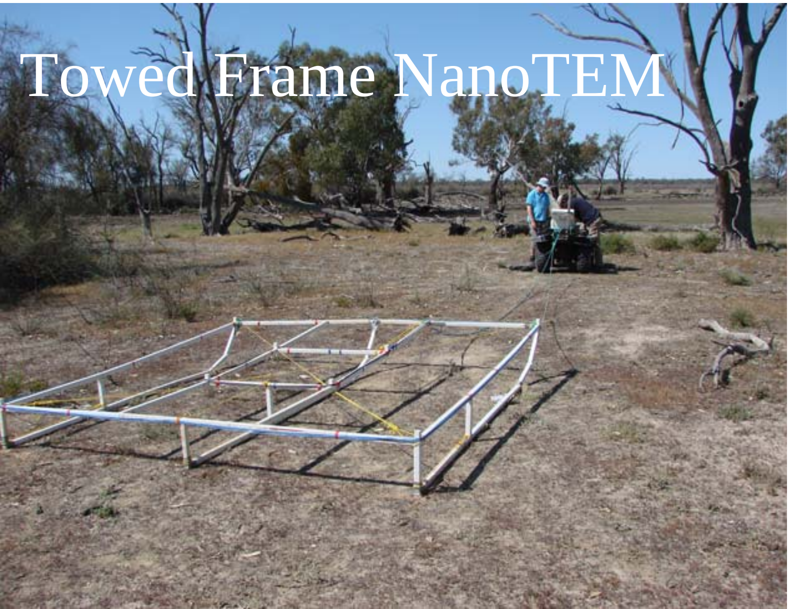
2. REDUCING SALT EXPORT FROM UPLAND LANDSCAPES

3. SALINITY MAPPING & MITIGATION IN ANCIENT SALINISED LANDSCAPES

Environmental Geophysics

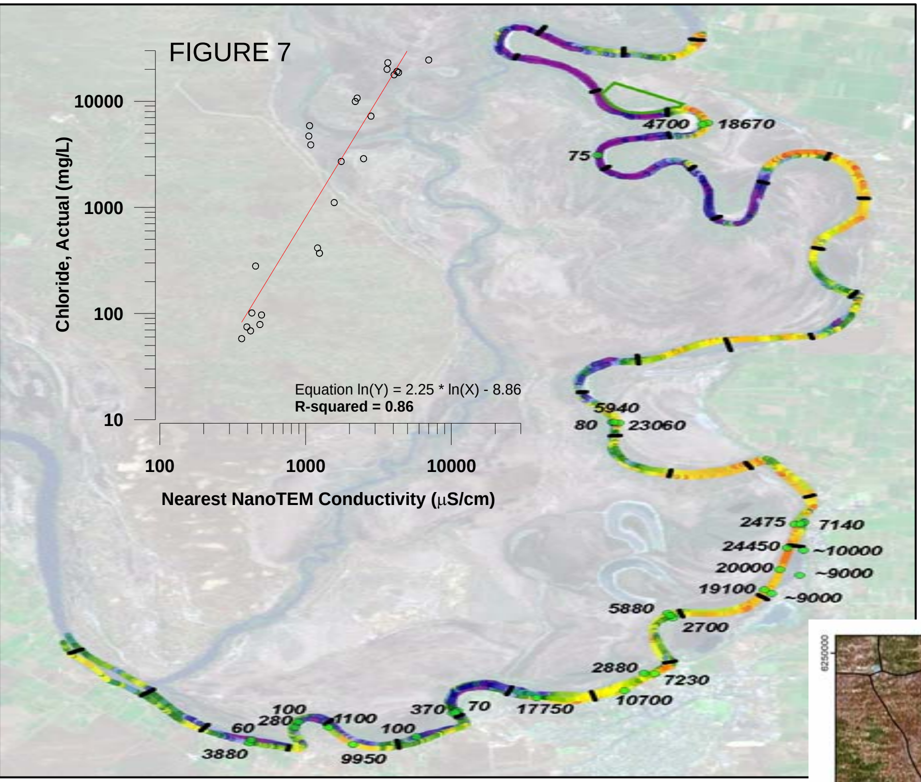
- Use of AEM and in-river EM has assisted the baseline planning of salt interception schemes in Murray Basin
- AEM data is now considered an important dataset for improving recharge models, irrigation zonation
- Floodplain studies- significant changes to understanding of floodplain processes at Chowilla with broader implication for the Lower Murray

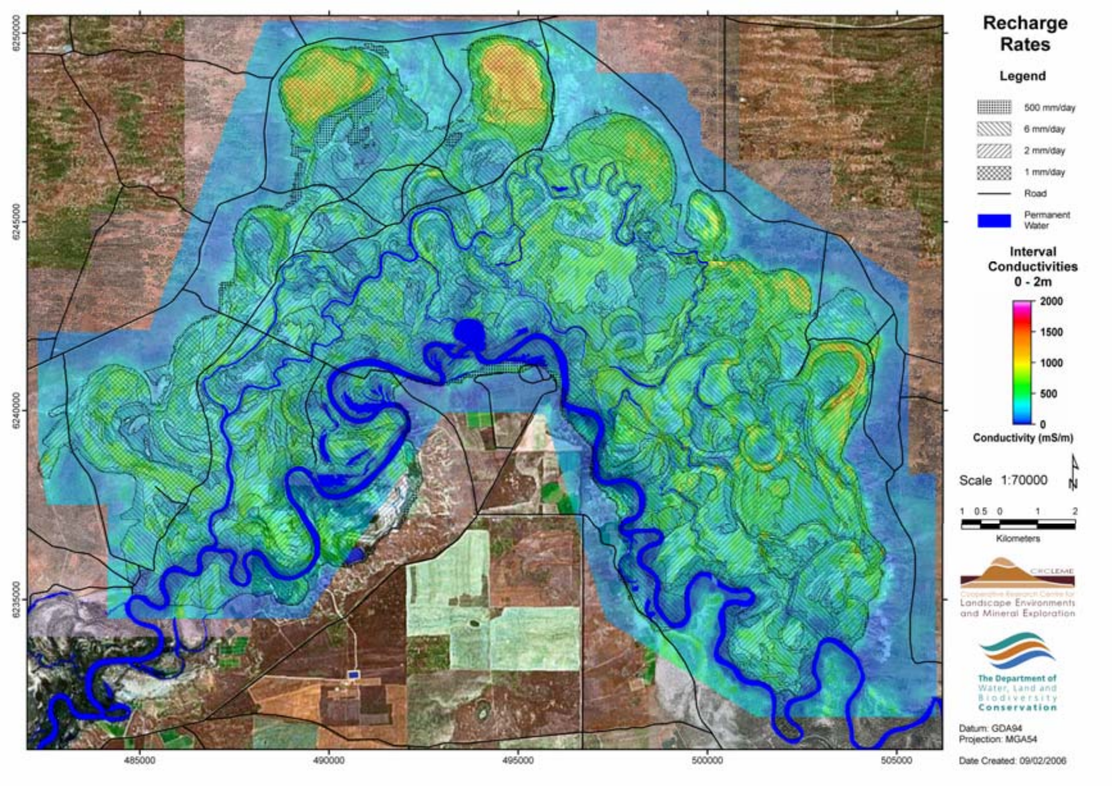




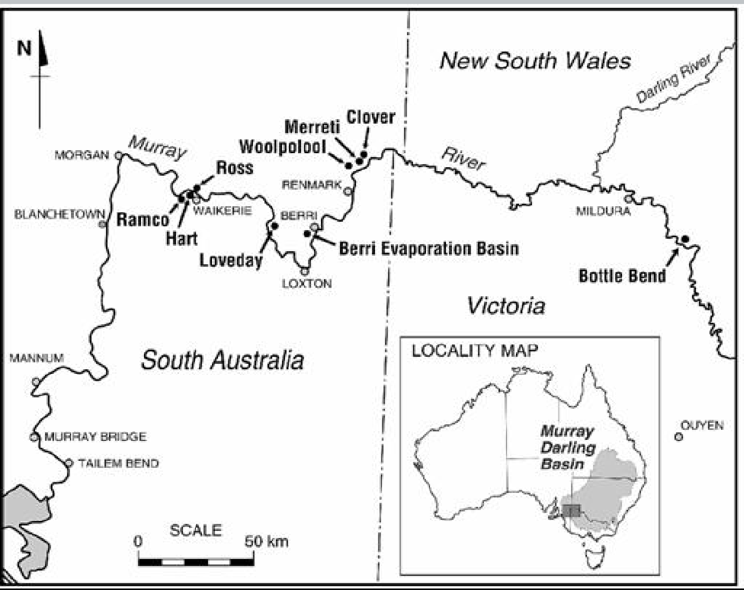
Constrained EM

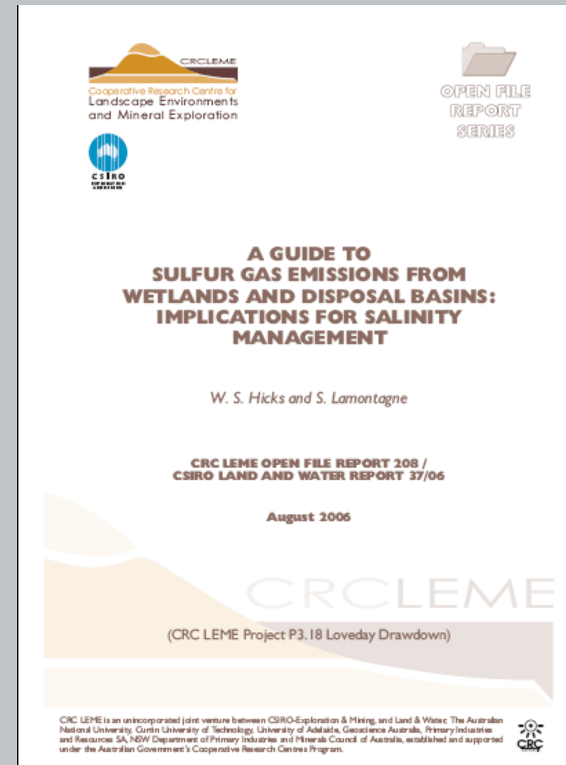
Geophysical techniques especially EM waste of $ if not constrained/ground truthed





Environmental Biogeochemistry





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OPEN FILE REPORT SERIES

A GUIDE TO SULFUR GAS EMISSIONS FROM WETLANDS AND DISPOSAL BASINS: IMPLICATIONS FOR SALINITY MANAGEMENT

W. S. Hicks and S. Lamontagne

CRC LEME OPEN FILE REPORT 208 / CSIRO LAND AND WATER REPORT 37/06

August 2006

CRCLEME

(CRC LEME Project P3.18 Loveday Drawdown)

CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, Geoscience Australia, Primary Industries and Resources SA, NSW Department of Primary Industries and Minerals Council of Australia, established and supported under the Australian Government's Cooperative Research Centres Program.

Murray Floodplain-Wetland Sulfidic Sediments

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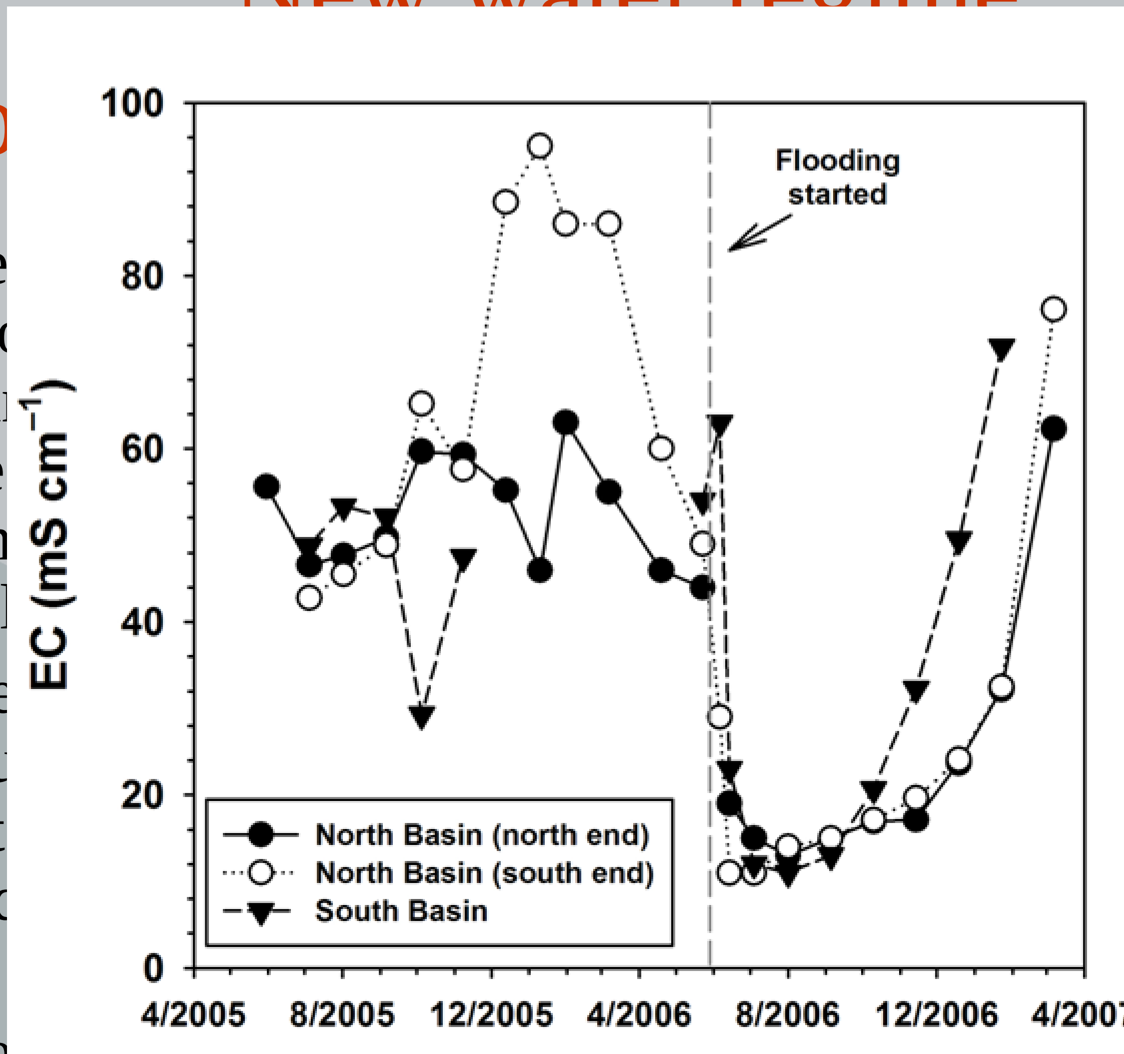
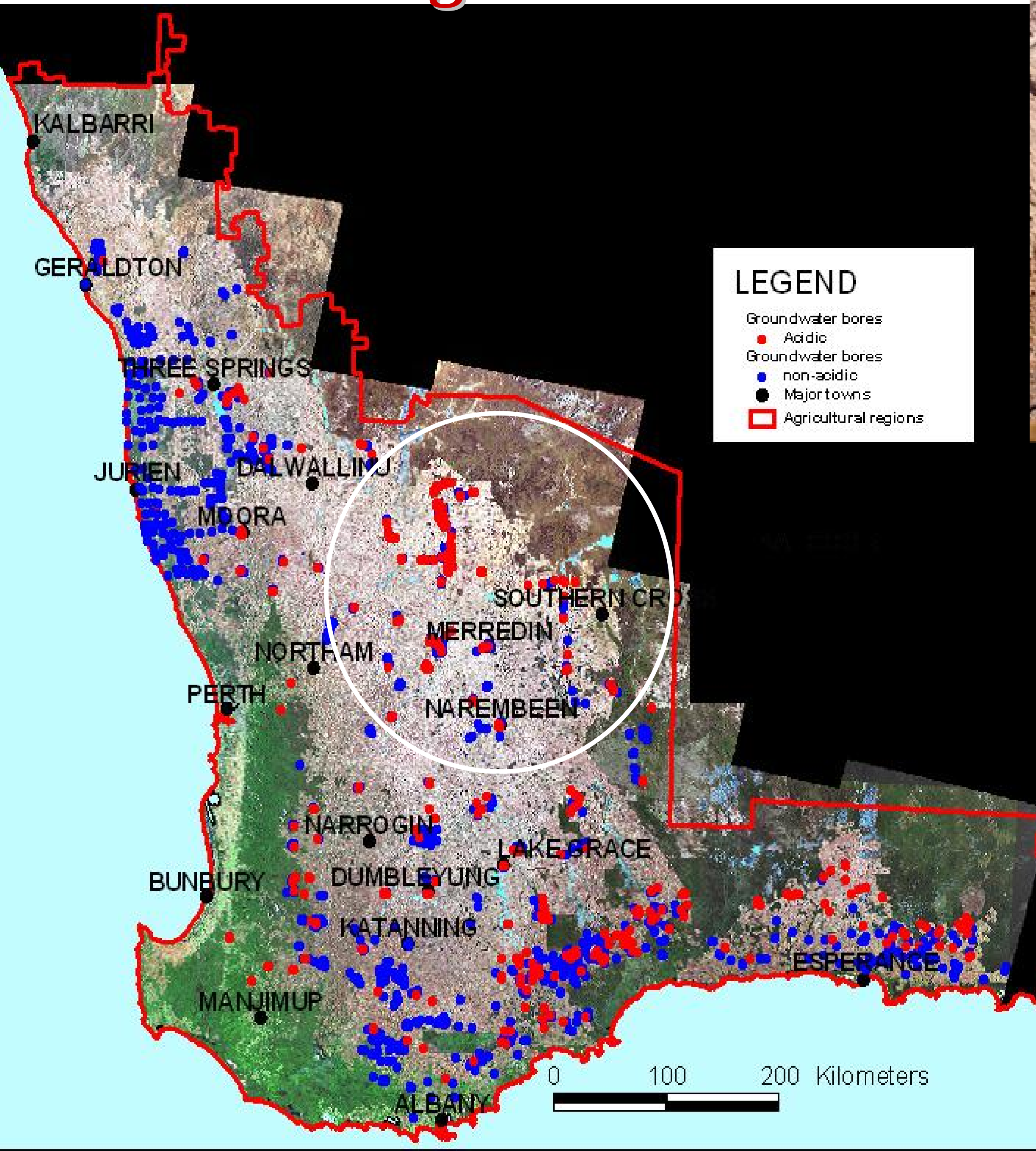
New water regime
pro WLBC

- Conne
  river t
  perma
  floode
  season
  water l
- Induce
  recircu
  export
  ground
  salts
- Where to export
  water unclear…



River?
Disposal
Basin?

Acid Drainage WA Wheatbelt



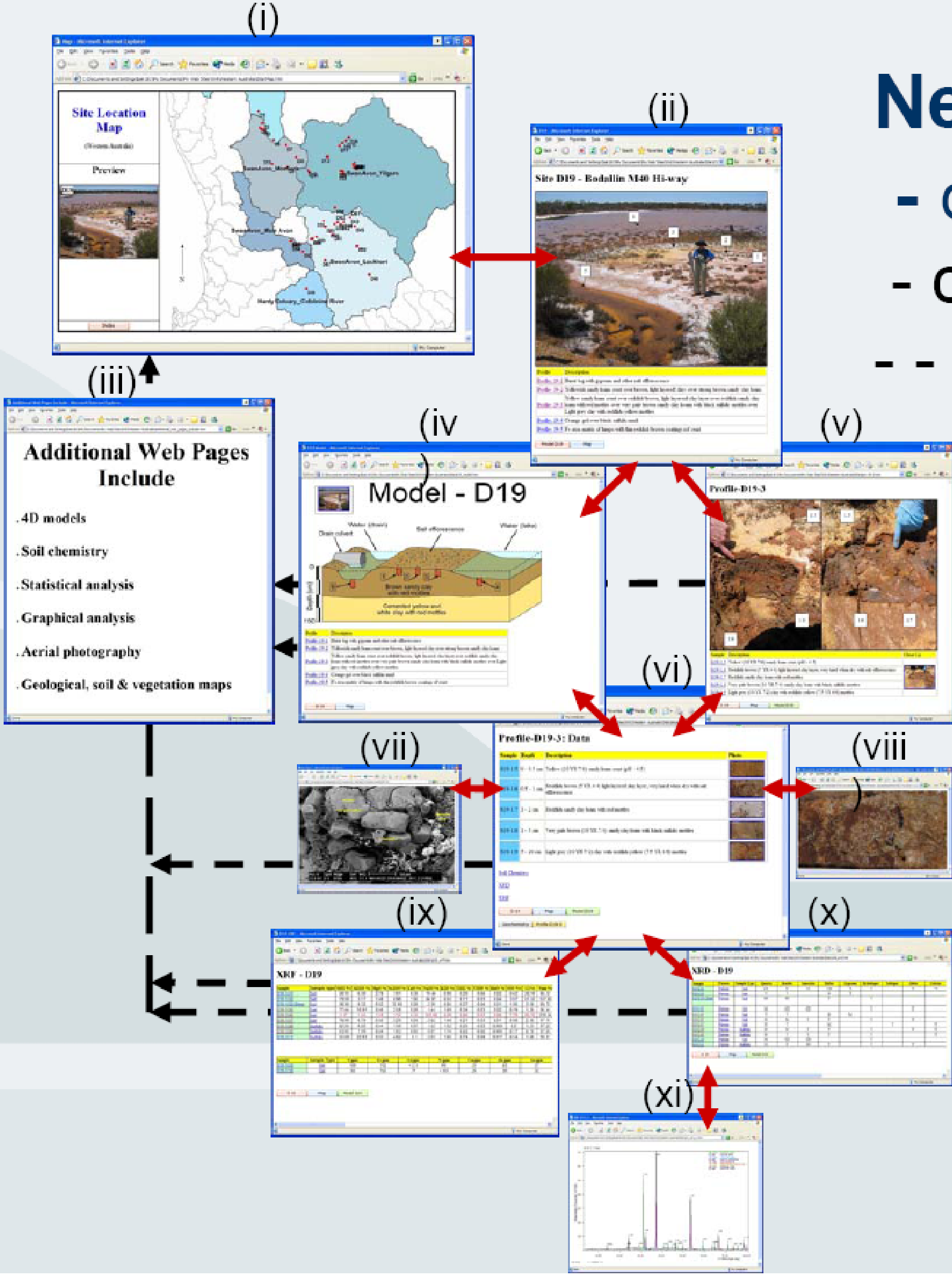
Maximum solution phase concentrations determined in drains and adjacent ground waters

Element	Maximum concentration (ppb)
Co	650
Ni	380
Cu	9000
Zn	7000
Pb	1000
As	16
U	900
Ce	2500

WA Receiving Environments

- Greater no. of lakes naturally Acid
- Alkaline lakes low buffering capacity (low total alkalinity)
- Limits acid drainage disposal options

No Drain Impact pH 3.5



New methodology for:

- data collation and
- communication

Web Based: Fully integrated/searchable package

•Advice on monitoring, identification, and management

•Hierarchical entry points

-Landholder

-Consultant

-Regulator

-Scientist

CRCLEME

EDUCATION & TRAINING

‘Addressing the Skills Shortage’

1. **Regolith Geoscience Undergraduate Courses**
2. **Regolith teaching materials**
3. **Honours Students**
4. **MTEC**

- Graduated **<u>100 Honours</u>** students to end 2006-07

5. **PhD Students**

- Graduate **<u>60 PhD</u>** students by June 2008

CRCLEME

Delivery

215 Journal Publications; 152 Books and Chapters; 317 Refereed Conference papers

- Regolith Geoscience Textbook – 2008 CSIRO Publishing
- Thematic Volumes – Inland ASS, Environmental geophysics
- Six Regional Explorers Guides
- Hydrogeochemical Exploration Field Guide
- Phytoexploration Field Guide
- Open File Reports >300 - PDF free download
- Digital compendium of LEME Regolith Maps
- Integration with AMIRA *Data Metallogenica*

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CRC LEME Joint Venture PARTIES

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New South Wales Department of Primary Industries (NSW DPI)
Primary Industries and Resources, South Australia (PIRSA)
The University of Adelaide (U of A)

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