Cooperative Research Centre for Landscape Environments and Mineral Exploration

Bugs, Trees and Minerals

- How microorganisms and Australian native plants are helping to discover new mineral deposits

Steve Rogers

Chief Executive Officer

www.crcleme.org.au

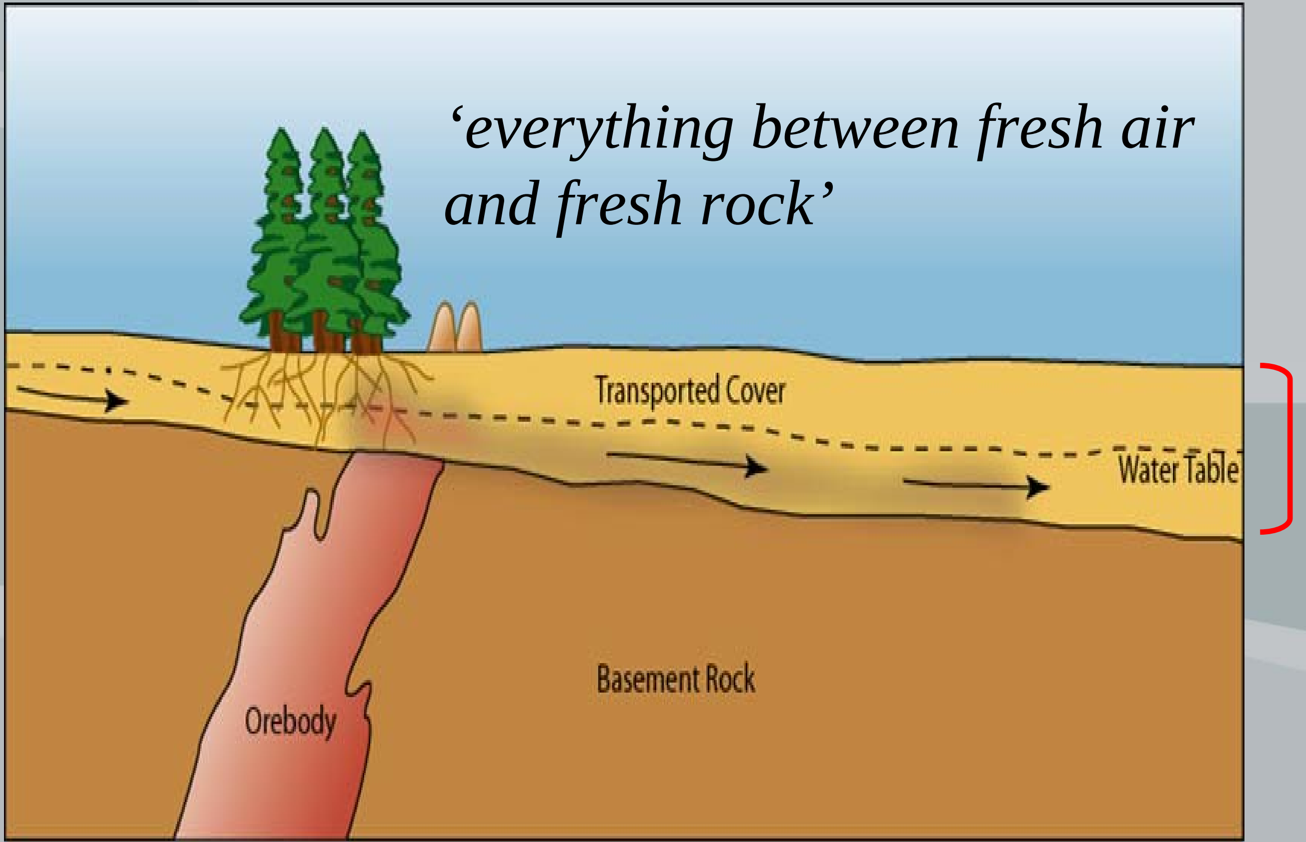
CRCLEME

Cooperative Research Centre

LANDSCAPE ENVIRONMENTS AND MINERAL EXPLORATION

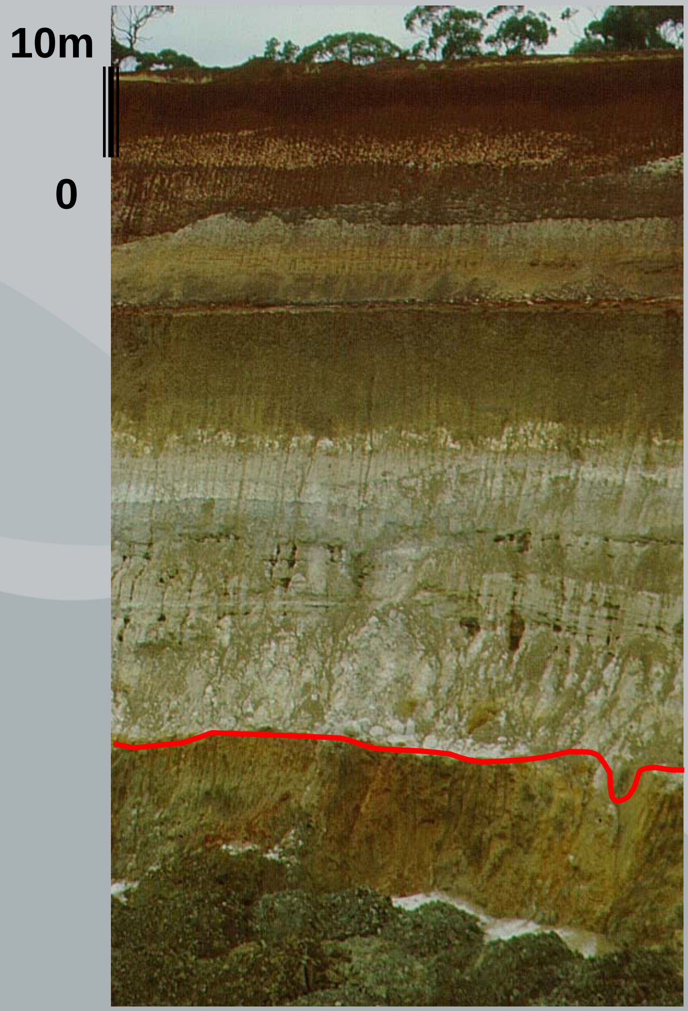
"create breakthroughs in mineral exploration and environmental management by generating and applying knowledge of the regolith" –

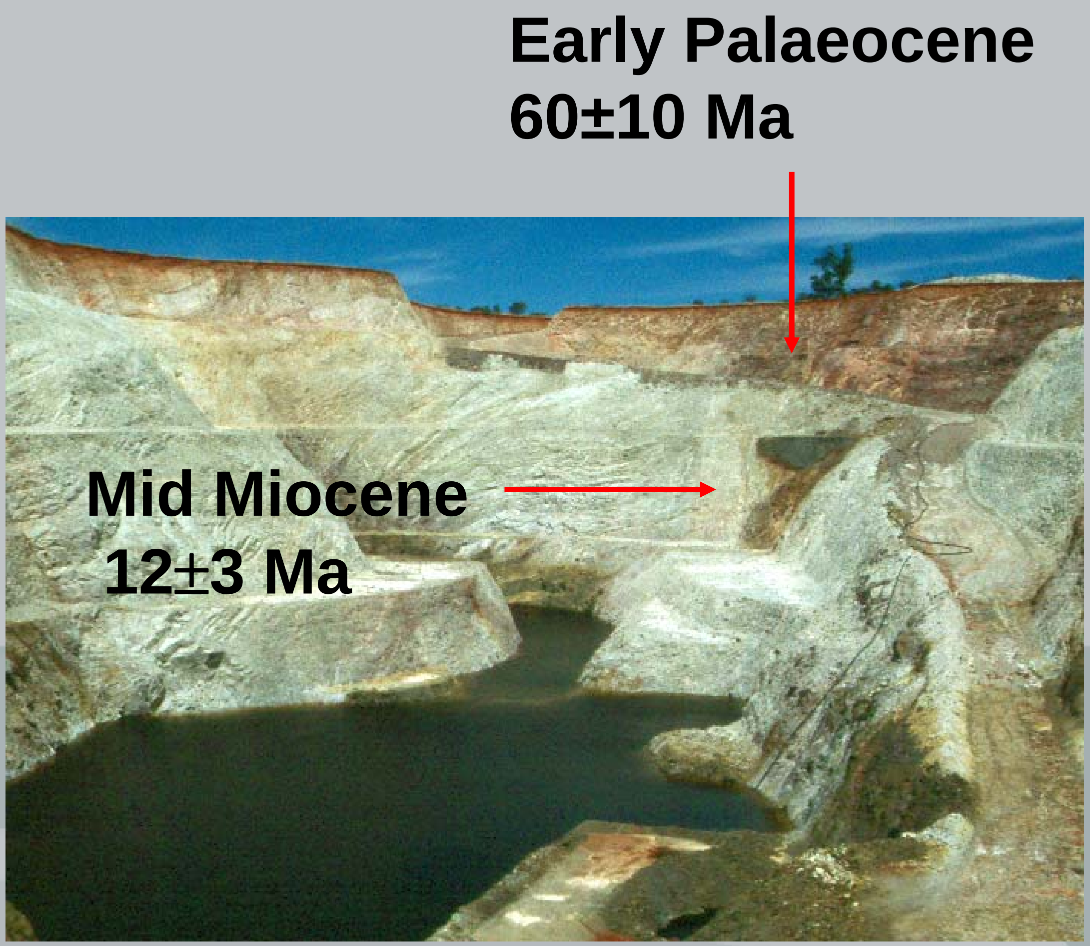
Collaborative Industry, Government and Academic R&D

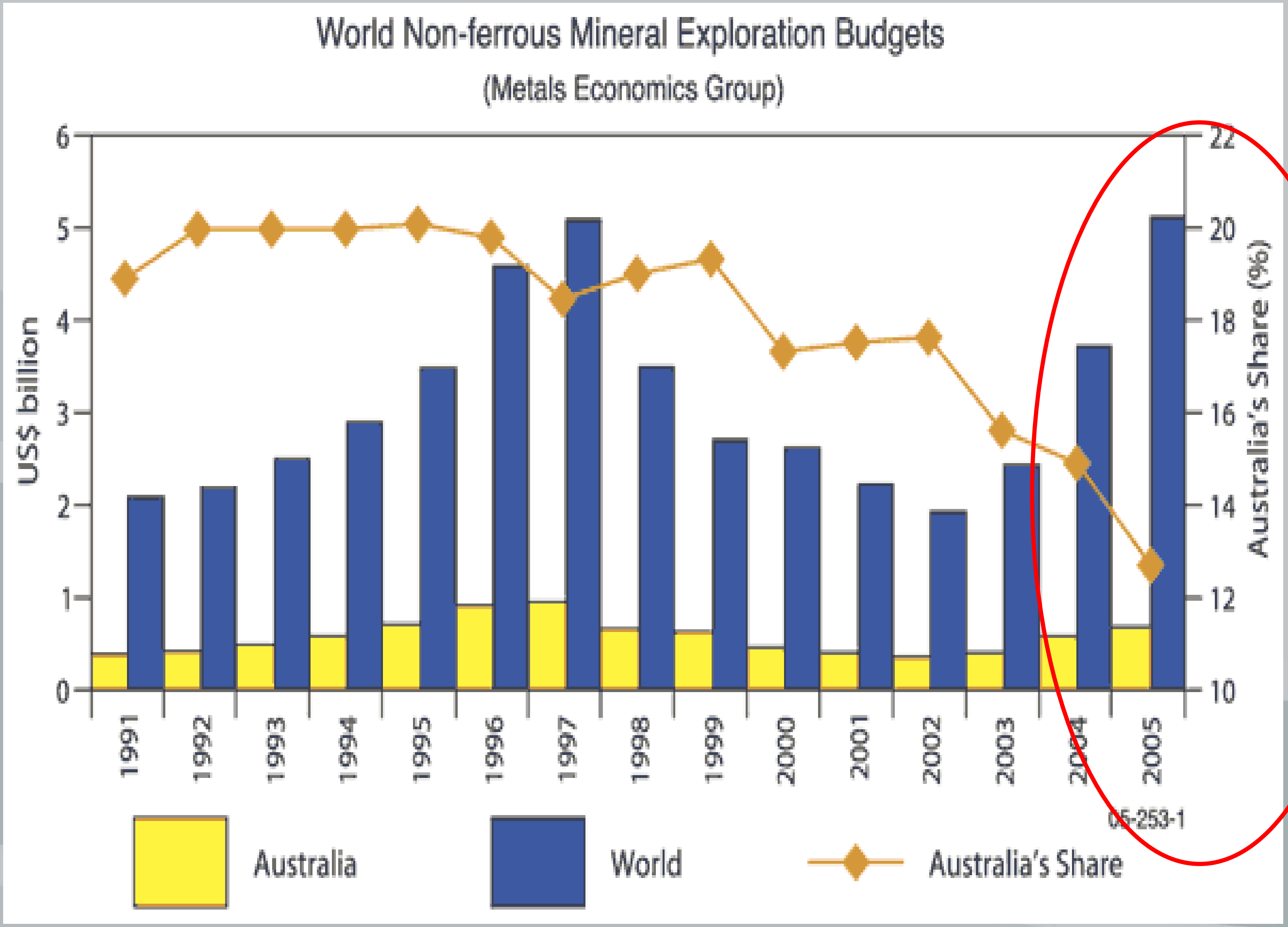


CRCLEME

Australia – Regolith Dominated Continent






World Non-ferrous Mineral Exploration Budgets
(Metals Economics Group)
US$ billion
Australia's Share (%)
0
1
2
3
4
5
6
10
12
14
16
18
20
22
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
05-253-1
Australia
World
Australia's Share

CRCLEME

1. **Mechanistic understanding of regolith landscape evolution mineral transport/transformation process**
2. **Innovative, cost effective methods of determining mineral targets through cover**
3. **Knowledge based R&D and Innovation**
4. **Researcher and Industry End-User partnerships**

LEME Approach

"Integrated multidisciplinary multi-scale approach"

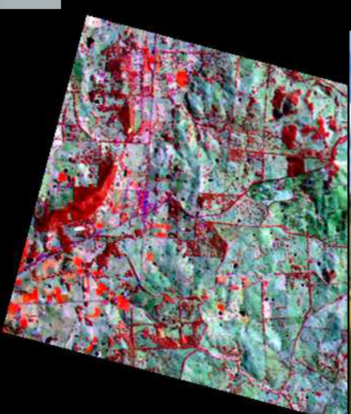
landscape to atoms

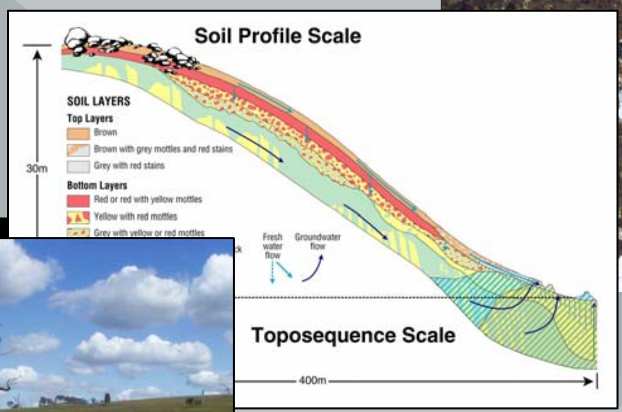
Landscape
Regional scale
National scale

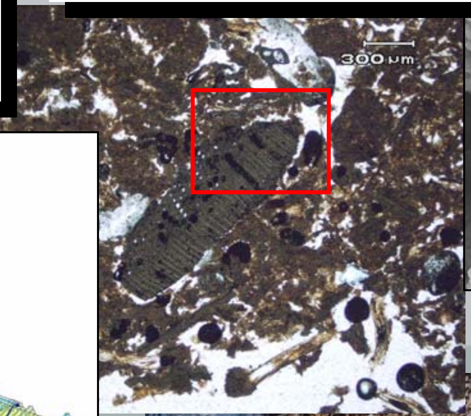
Field
Toposequence scale
e.g.Seasonal changes

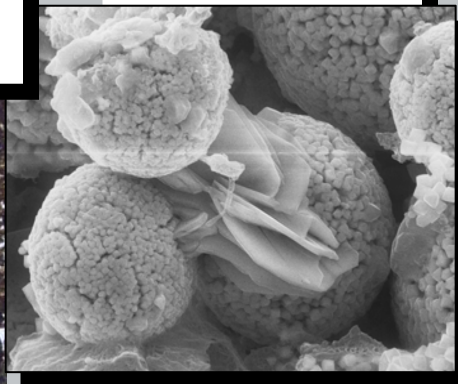
Microscopic
Macroscopic

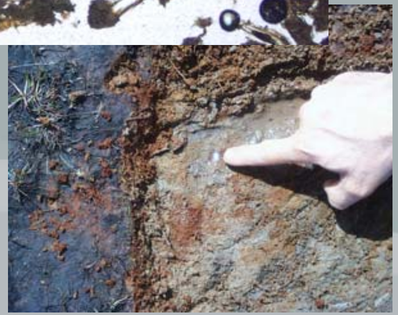
Atomistic
Molecular
Mineral











CRCLEME

EDUCATION, TRAINING & TECH TRANSFER

'Addressing the Skills Shortage'

CRCLEME

25% CRC LEME resources allocated to E&T

AUS$4.5M annually

- Critical component of R&D Innovation
- Key focus of Federal Government CRC program
- Industry ready graduates and postgraduates
- Current Minerals Boom - Skills shortages
- Maintain training through industry slumps

1. Undergraduate Teaching
2. Postgraduate Training
3. Industry/Postgraduate Short courses

2nd year undergraduate students, Fowlers Gap NSW

University Education

1. **Introduction of Regolith Geoscience Undergraduate Courses**

- The University of Adelaide, Curtin University of Technology, and The Australian National University (ANU)
- 2005-2006 over 100 students taking Regolith courses

2. **Regolith teaching materials -** On Line, Virtual Field Tours
3. **National Undergraduate Regolith Geology School (NURGS)**
4. **Honours Students**

- Graduated **<u>89 Honours</u>** students to end 2001-2006

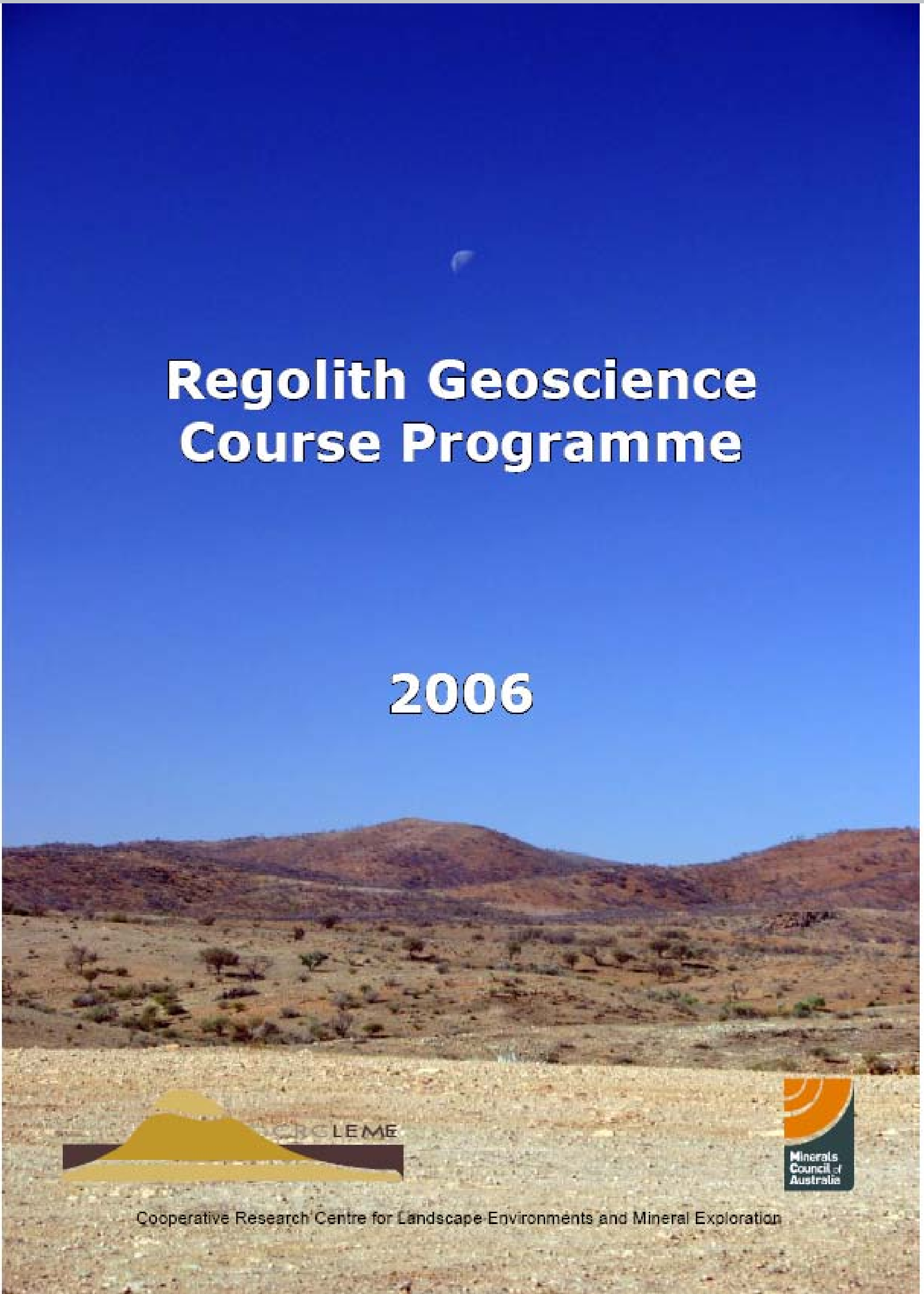
5. **PhD Students**

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

<u>Key: Provide geoscience graduates with dual career path</u>

1. Minerals Industry
2. Natural Resource Management

CRCLEME



Industry Professionals/ Postgraduate Courses

Minerals Council of Australia

- **Minerals Tertiary Education Council (MTEC)**
- **Employment of a full time MTEC/CRC LEME lecturer**

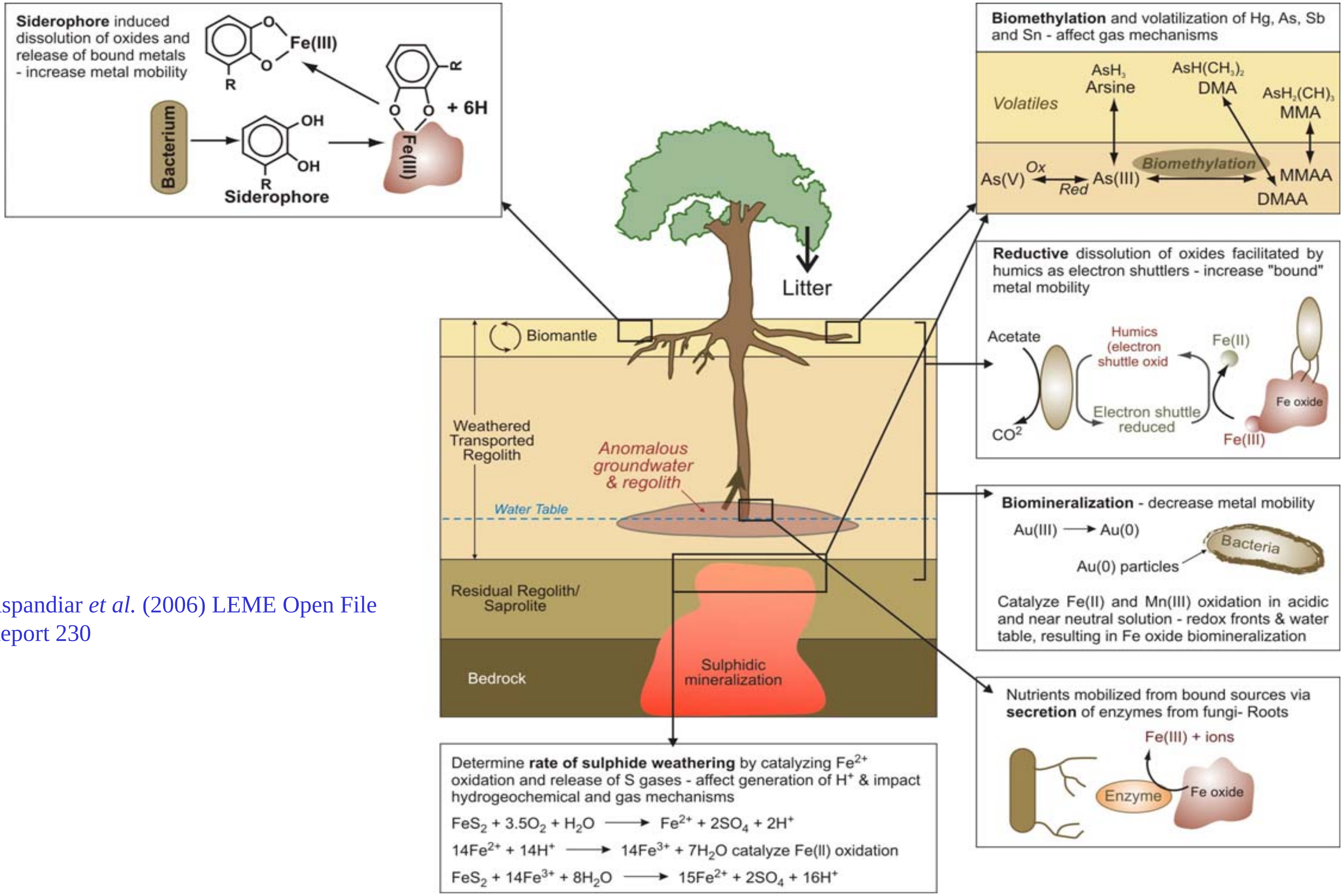
CRCLEME

Students working with practitioners

Bringing Together a range of new scientific disciplines not traditionally associated with each other

Molecular Geomicrobiology

Geomicrobial Mineralisation



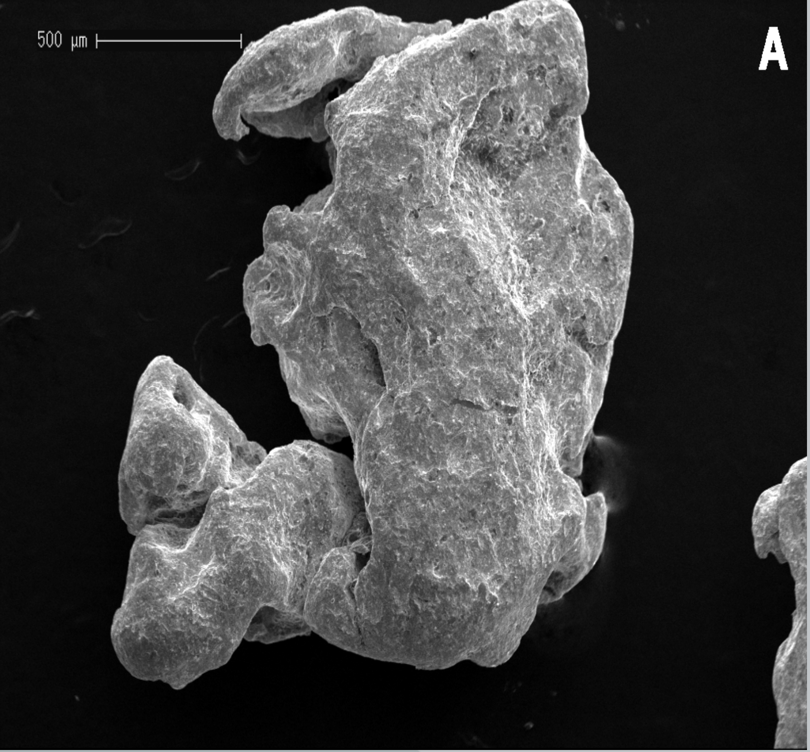
Aspandiar *et al.* (2006) LEME Open File Report 230

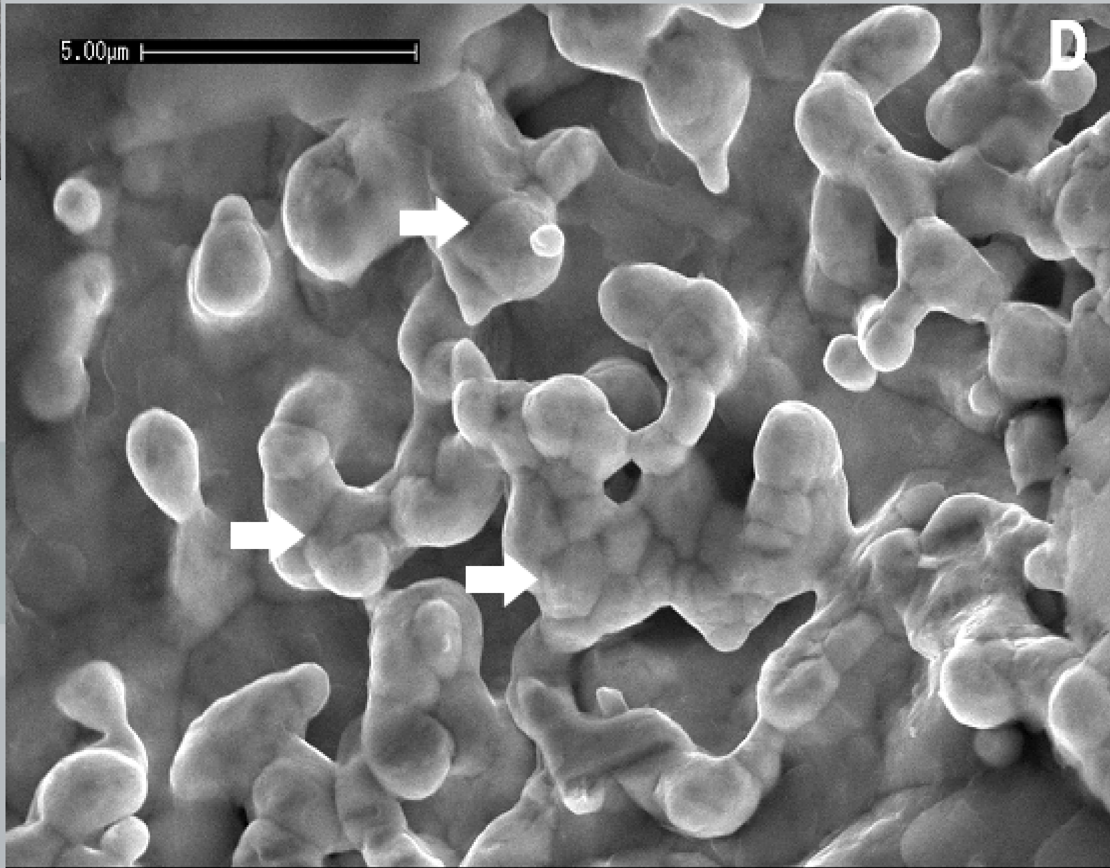
- **5000 microbial species isolated and identified**
- **Estimates 100,000 to 1 x10^6 species**
- **95% regolith microorganisms unidentified (can't be cultured)**
- **Inhabit all areas of regolith**

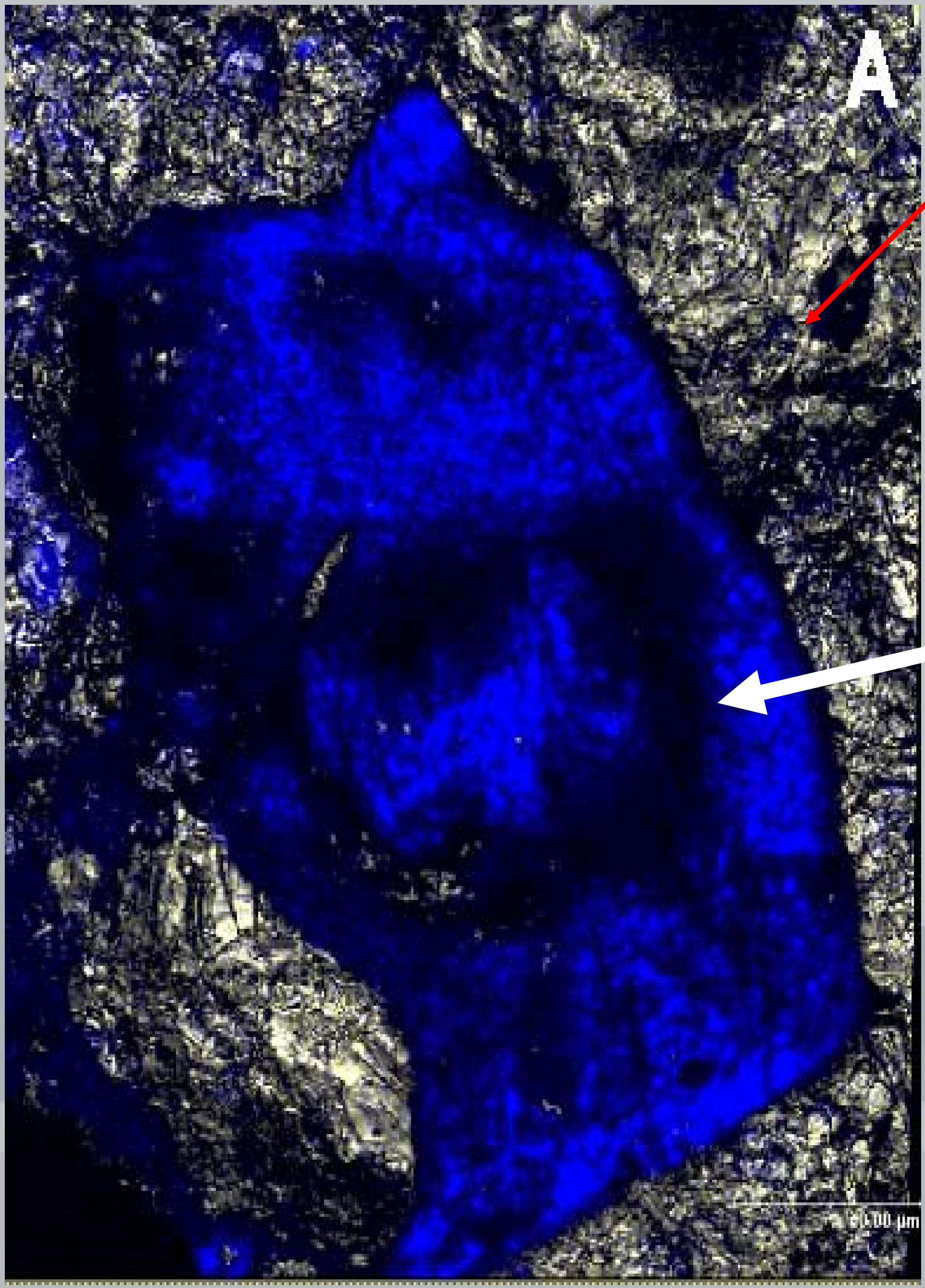
Frank Reith PhD-CRC LEME/Australian National University

Geomicrobiology of Gold

CRCLEME


500 µm
A


5.00µm
D



Gold Flake

DAPI-Nucleic Acid Stain (DNA/RNA)

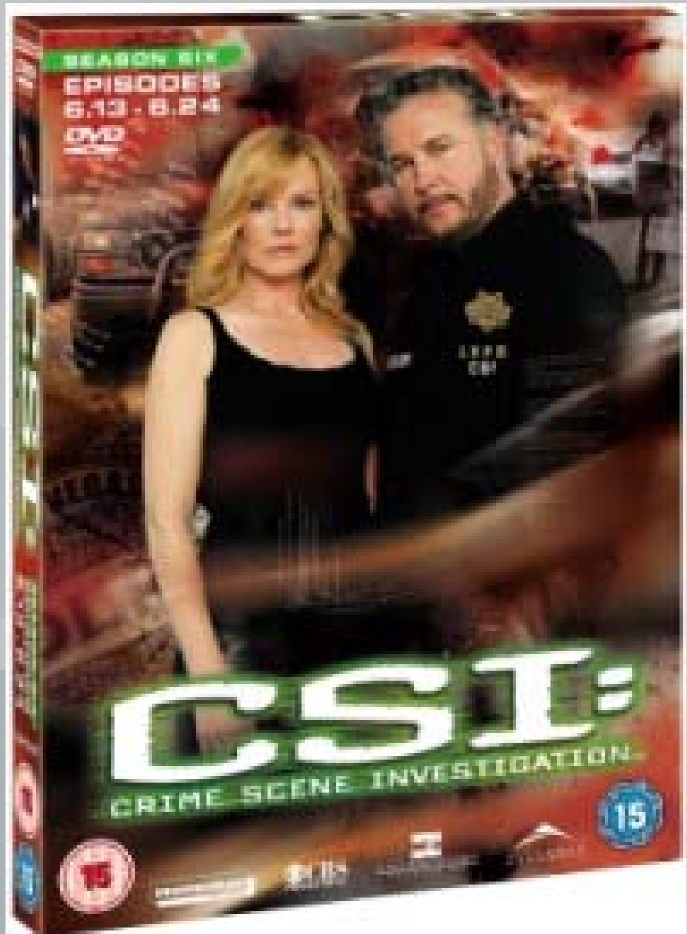
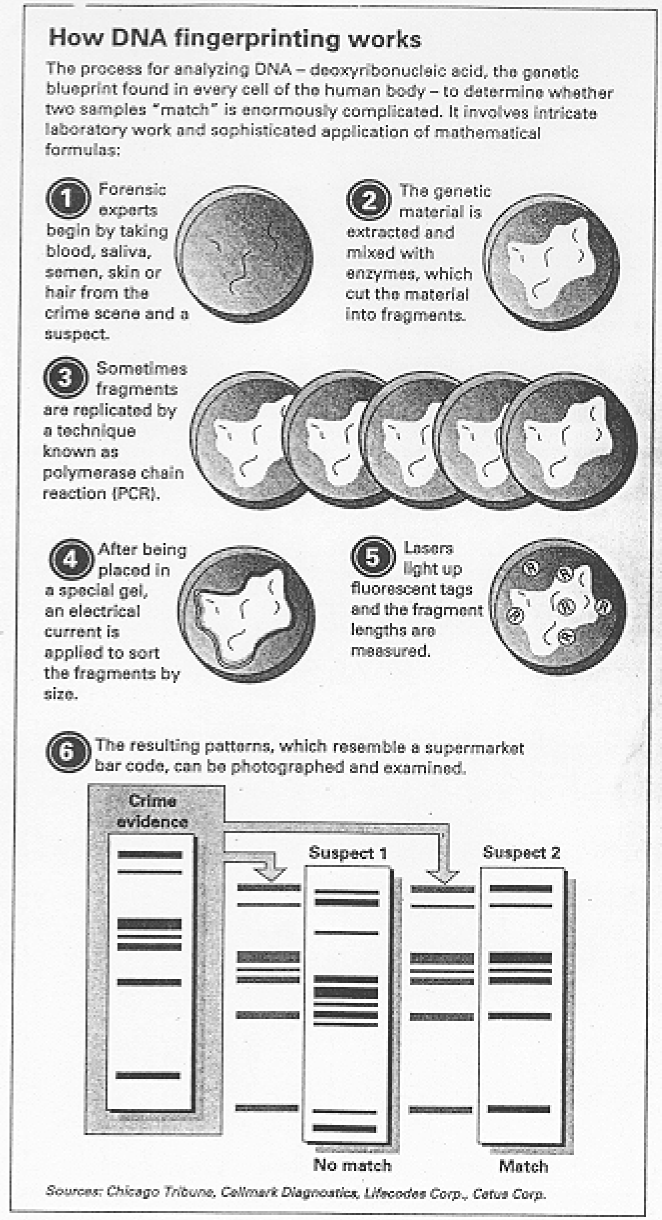
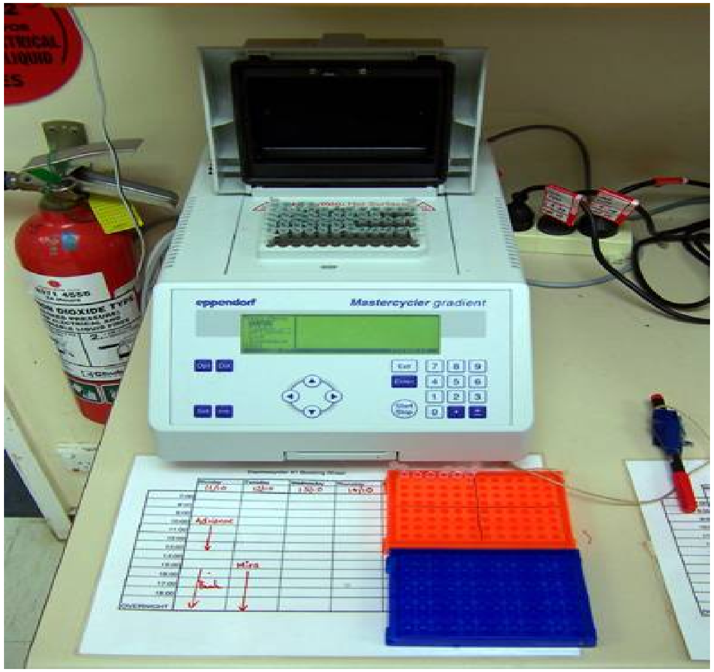


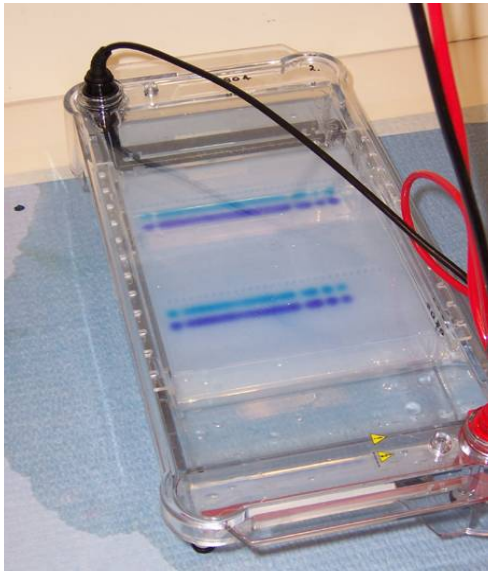
Figure 4

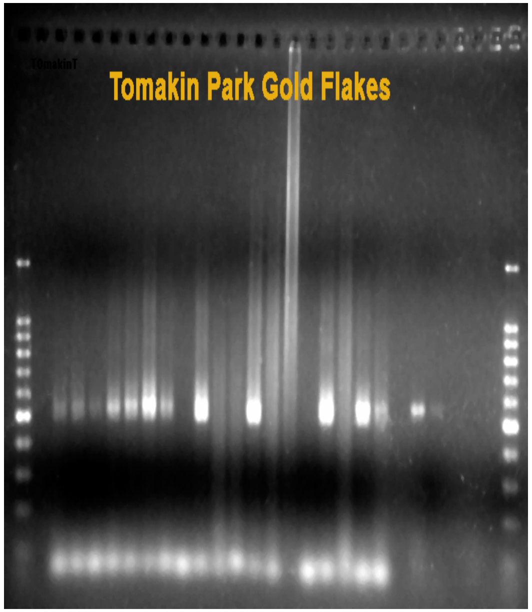


(Dallas Morning News, Knight-Ridder Tribune)

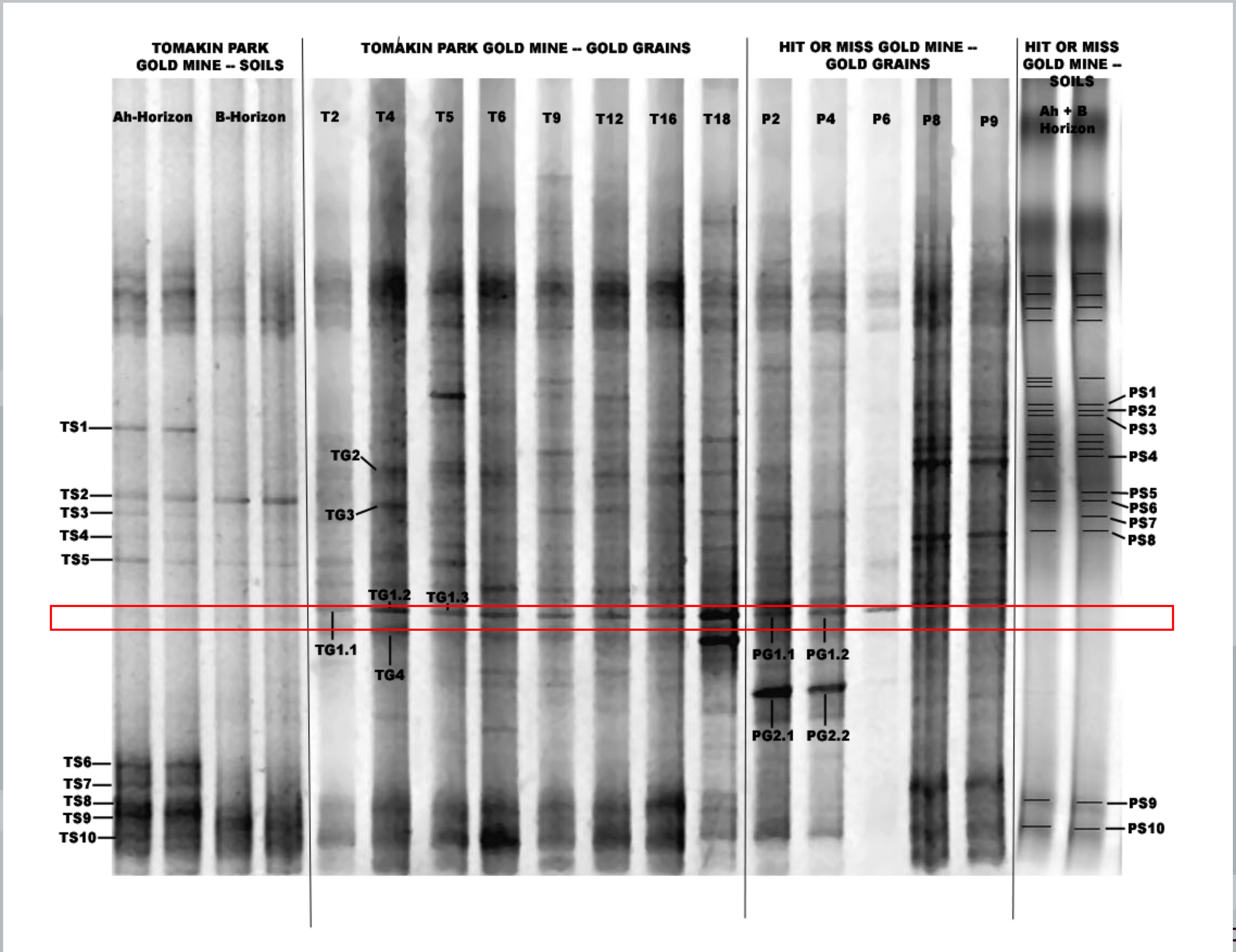
Source: The Globe and Mail, 19 July 1997, p. A6

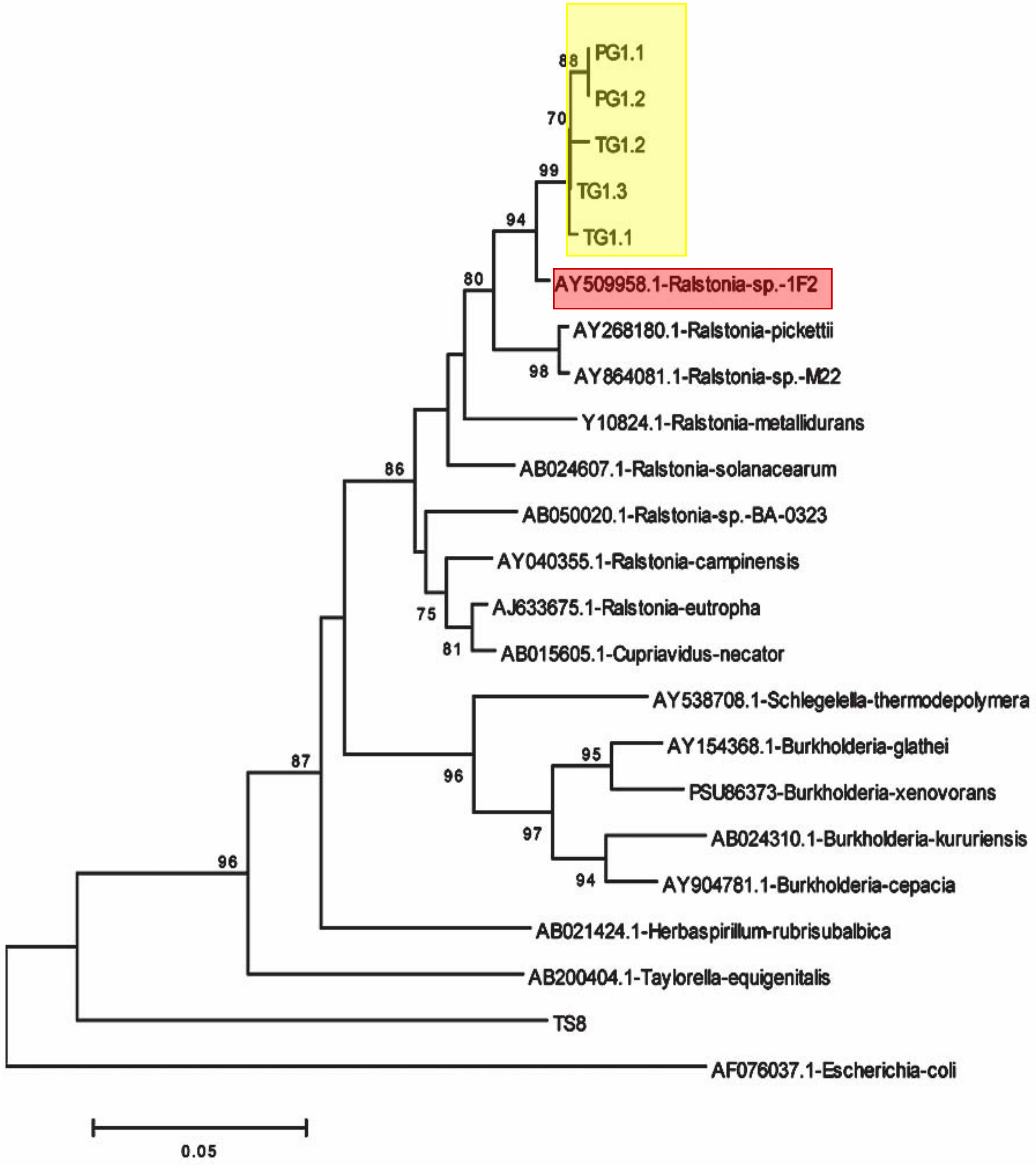

eppendorf
Mastercycler gradient




Tomakin Park Gold Flakes

16S rDNA Bacterial Diversity Analysis and Identification

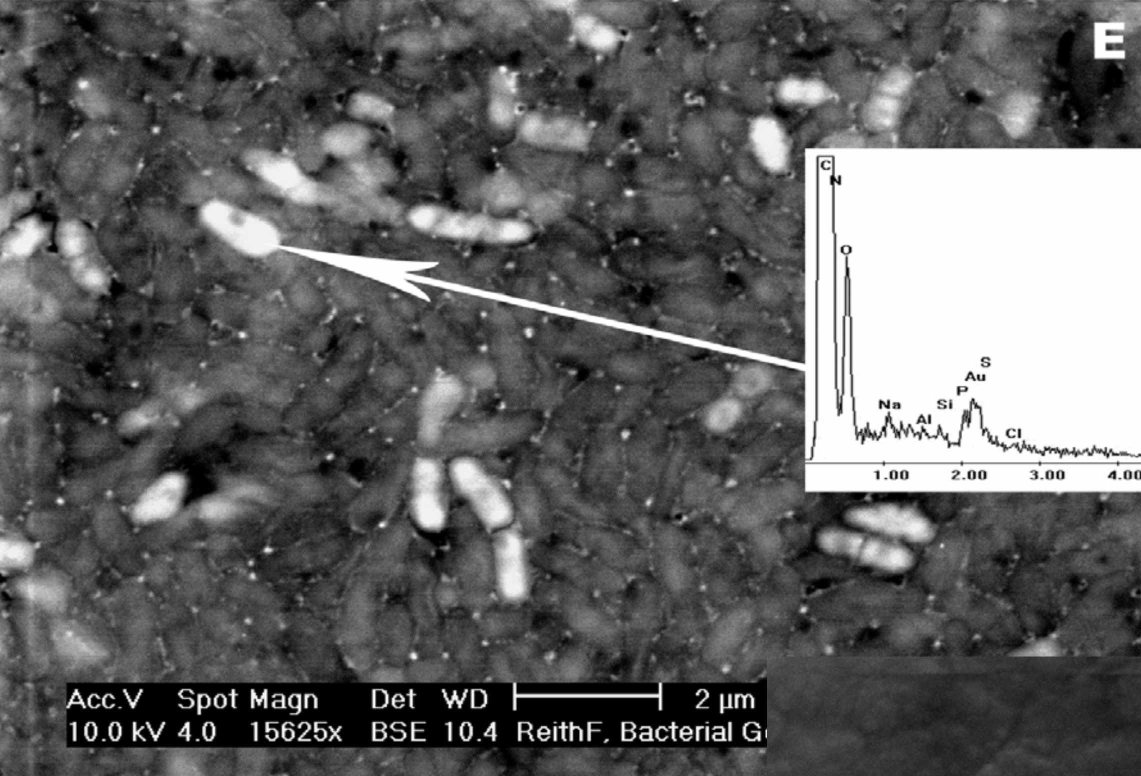


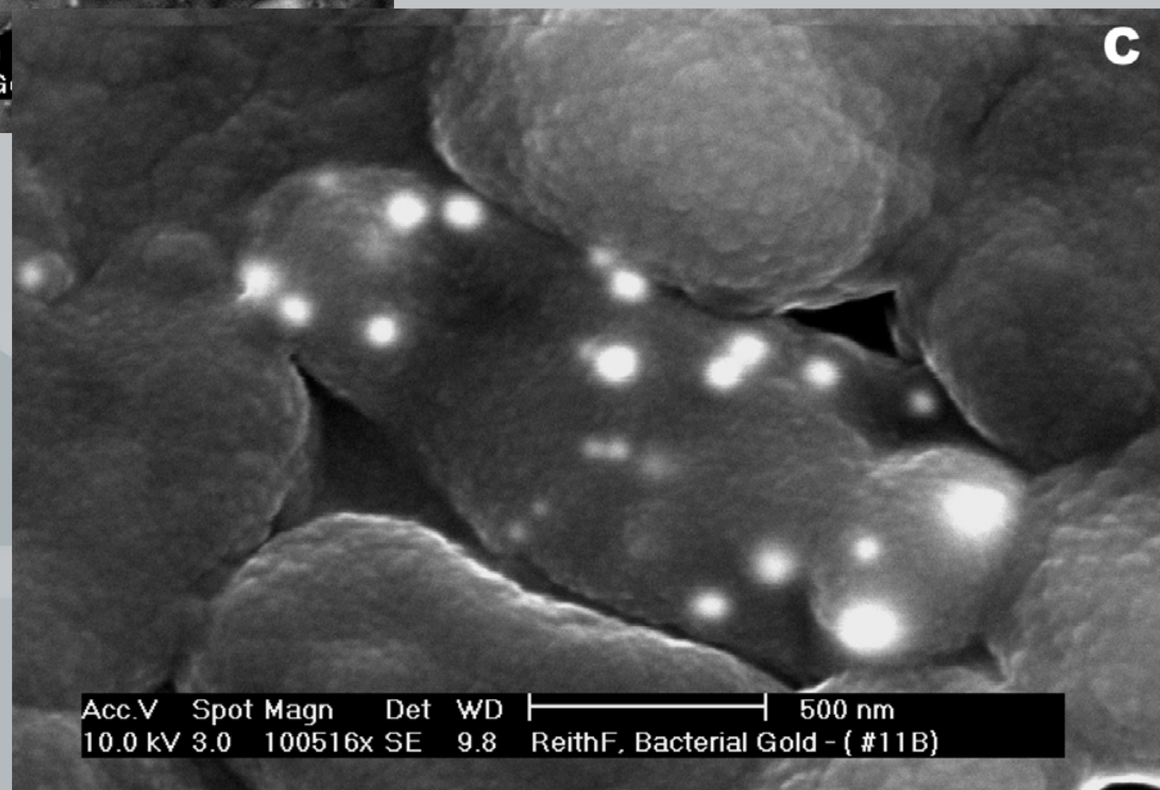


DNA Sequencing – Identification of 'Unknown Species'

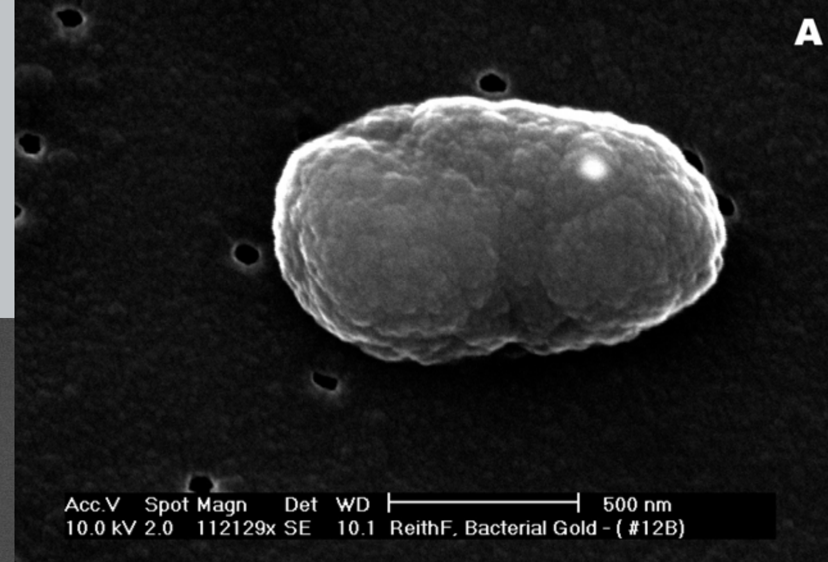
CRCLEME

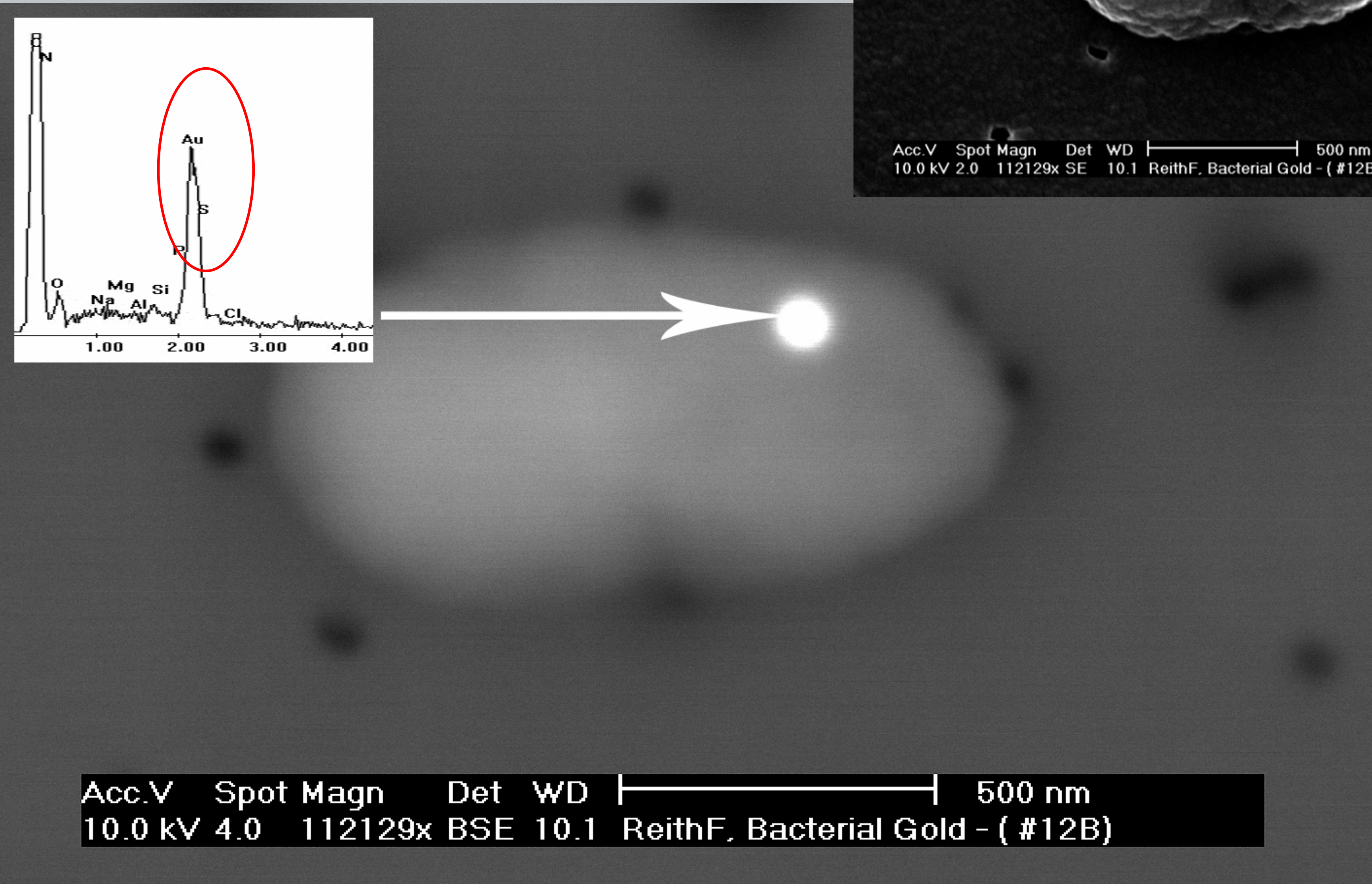
Ralstonia metalidurans





Energy Dispersive X – Ray Spot Analysis





23. I. Bezprozvanny, B. E. Ehrlich, *Neuron* **10**, 1175 (1993).
24. I. Bezprozvanny, B. E. Ehrlich, *J. Gen. Physiol.* **104**, 821 (1994).
25. I. C. B. Marshall, C. W. Taylor, *Biochem. J.* **301**, 591 (1994).
26. D. B. van Rossum *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **101**, 2323 (2004).
27. G. G. Du, D. H. MacLennan, *J. Biol. Chem.* **273**, 31867 (1998).
28. Y. Sekine-Aizawa, R. L. Huganir, *Proc. Natl. Acad. Sci. U.S.A.* **101**, 17114 (2004).
29. R. E. Dalbey, G. Von Heijne, *Protein Targeting, Transport, and Translocation* (Academic Press, San Diego, 2002).

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

Science, **313** 14 July 2006

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. 16*S* 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

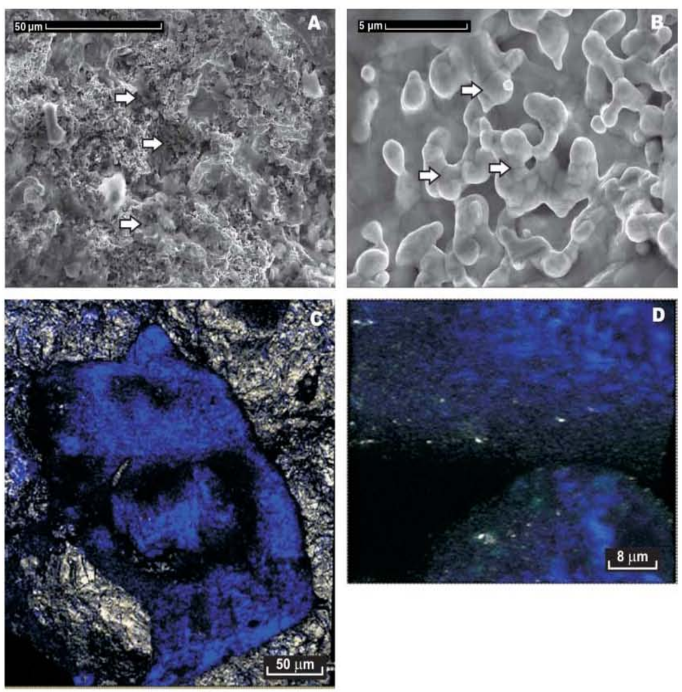
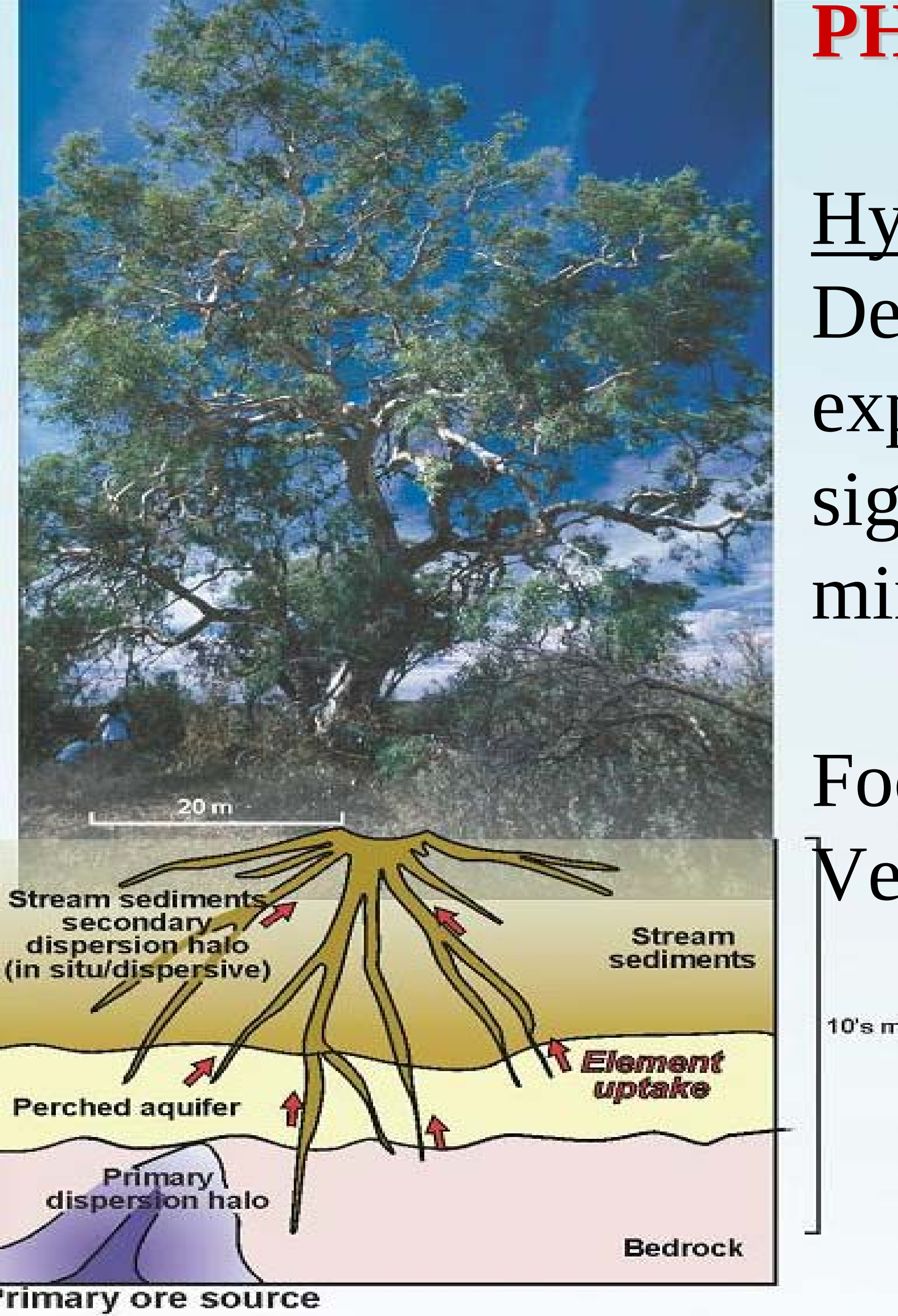


Fig. 1. Secondary electron micrographs of bacterioform gold (**A** and **B**) and confocal stereo laser microscope images (**C** and **D**) of fluorescently stained biofilms on gold grains from the Hit or Miss Gold Mine in Queensland, Australia. (A) Bacterioform gold with apparent exopolymers (white 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.

CRCLEME

PHYTO-EXPLORATION



Hypothesis

Deep rooted vegetation expresses geochemical signatures of 'Buried' mineralisation

Focus-Australian native Vegetation

To better target

Karen Hulme – PhD
CRC LEME/
The University of Adelaide

River Red Gum Phytoexploration

Lead…

- Pb up to 205 times background levels

- Geochemical footprint ~ 2.5 km

○ 0 – 36 ppm

37 – 99 ppm

100 – 190 ppm

191 – 411 ppm

Pinnacles Pb-Zn Mine Broken Hill NSW

Pinnacles - lodes extensions

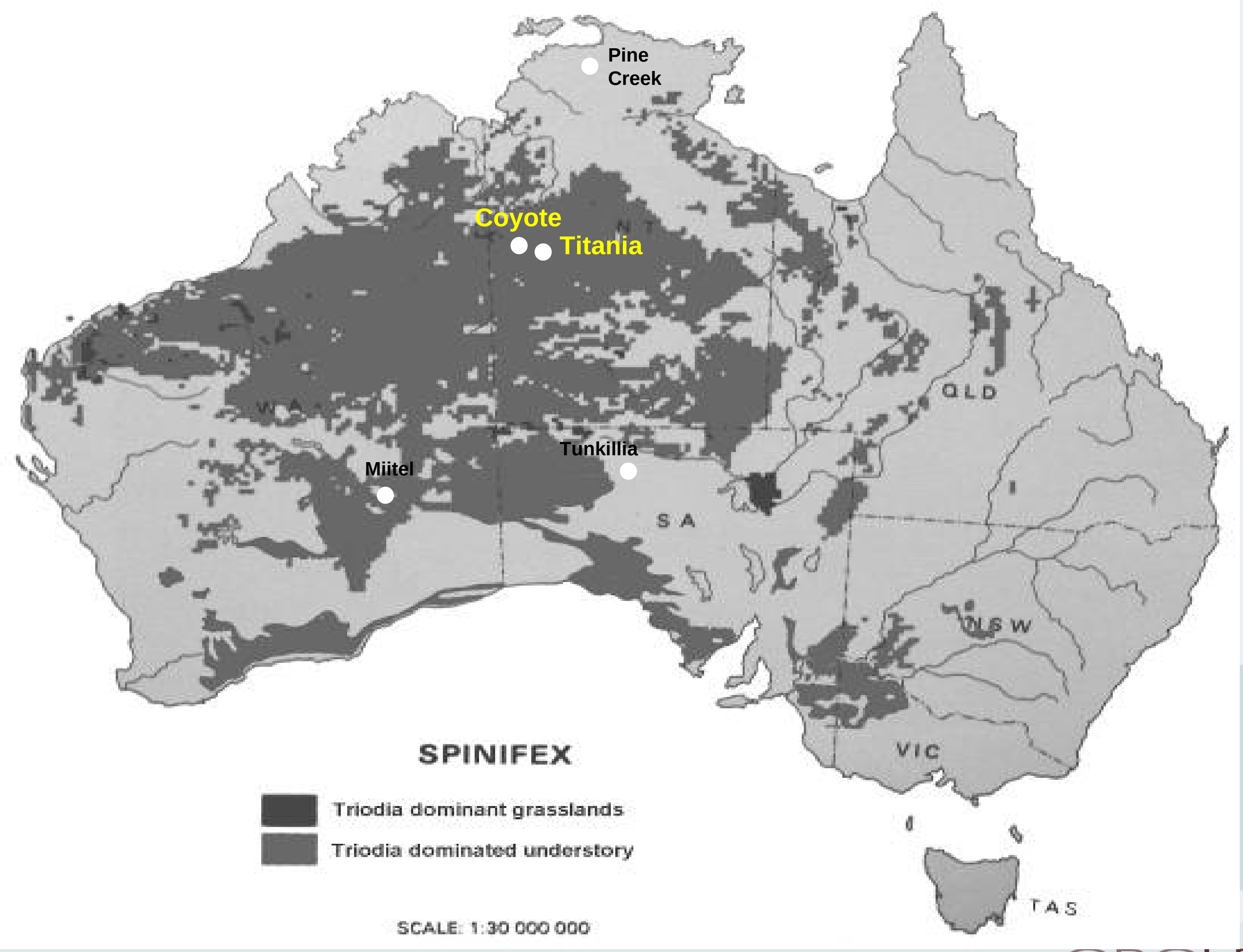
Photographs: Steve Hill

CRCLEME

Spinifex expression of buried mineralisation in the Tanami

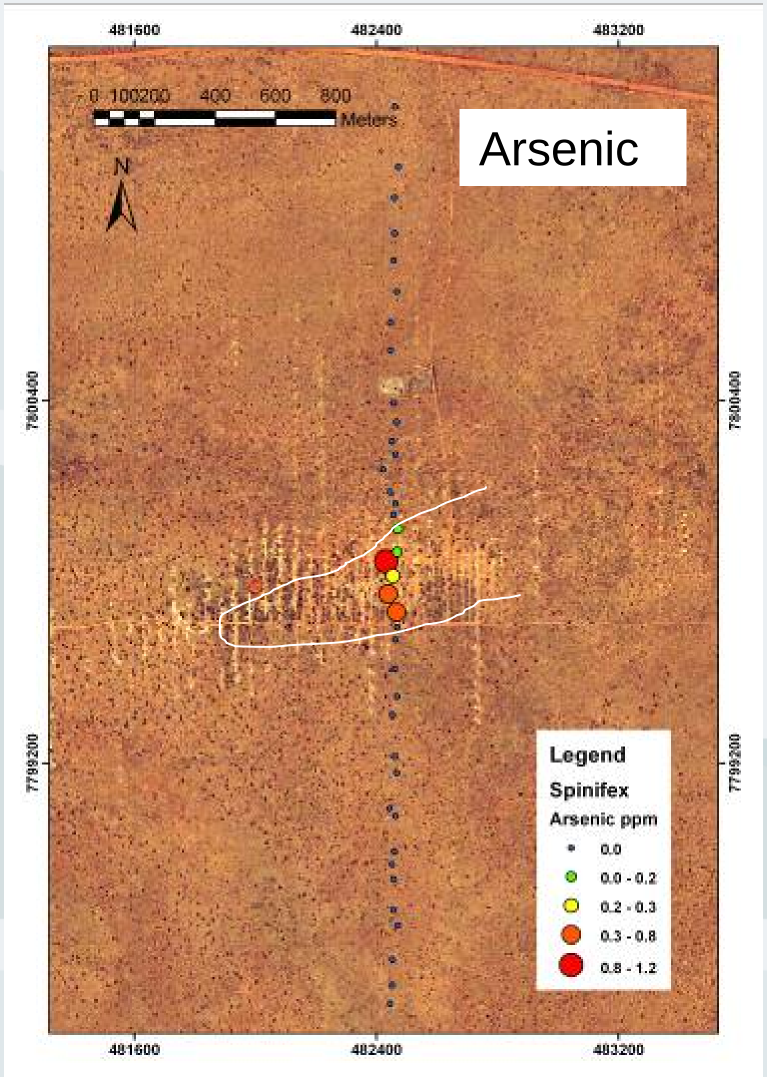
Nathan Reid – PhD CRC LEME / The University of Adelaide

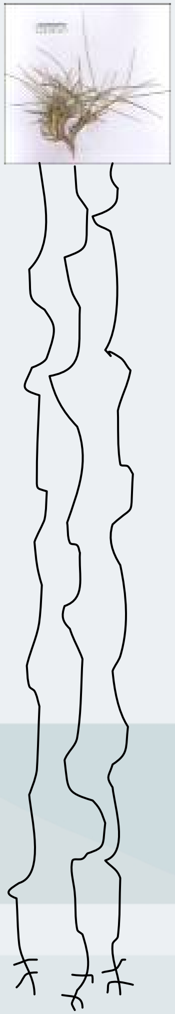
Field Sites

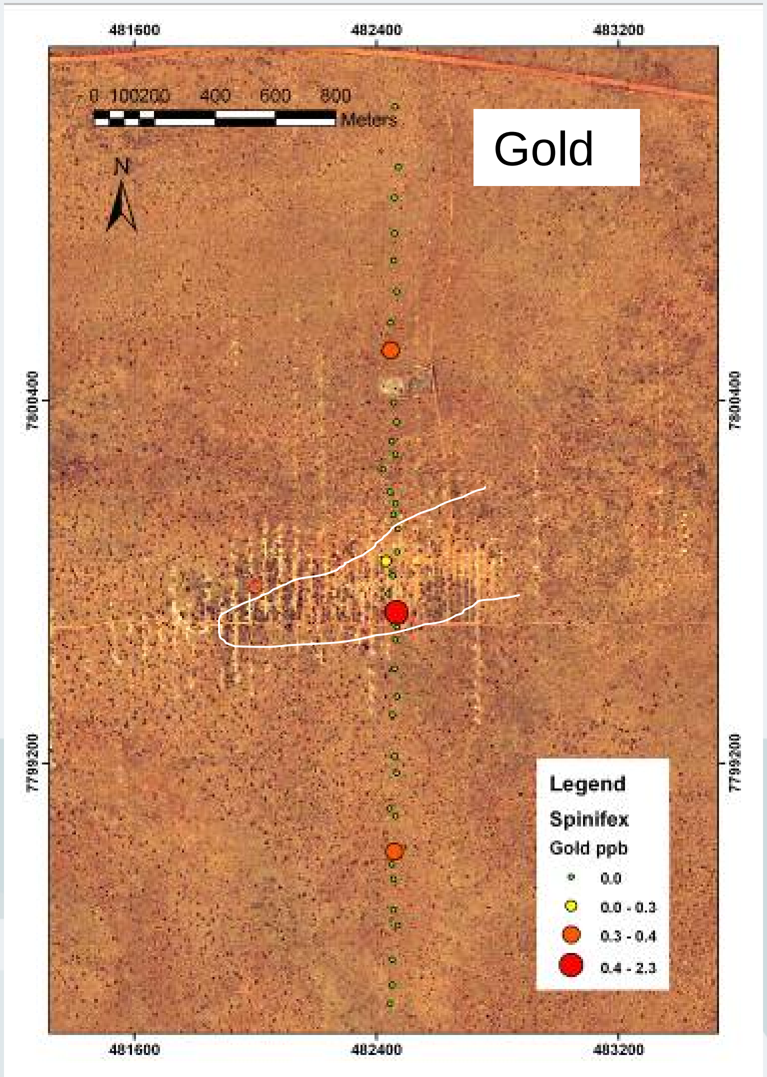


CRCLEME

Coyote Results: Spinifex

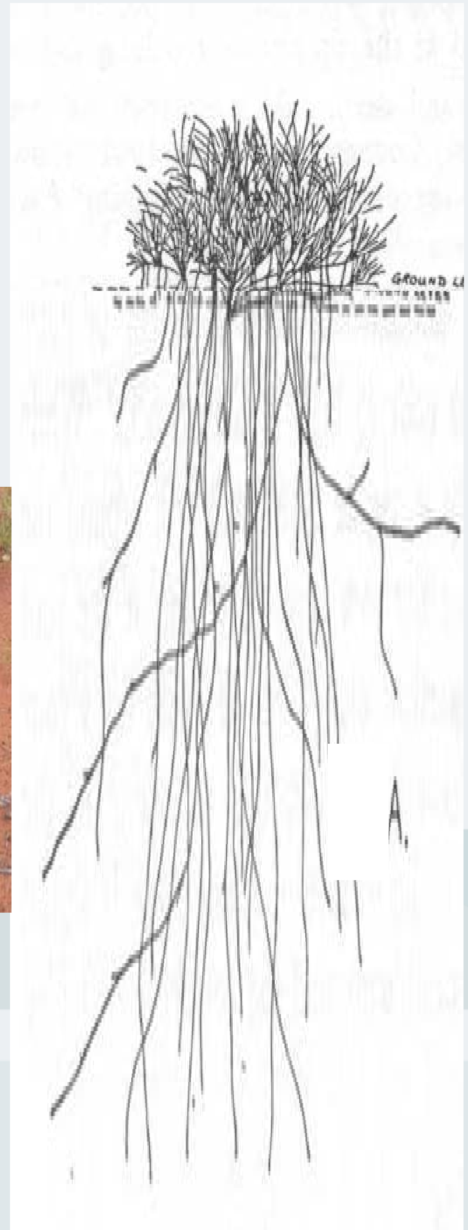






CRCLEME

Spinifex habitat



Height above ground up to 1 m

Lateral spread of roots 1-2 m

Root penetration up to 30m

To a stable groundwater source

CRCLEME

Uranium biogeochemistry

Michael Neimanis
CRC LEME/The University of Adelaide

HEATHGATE RESOURCES PTY LTD

Beverley Uranium Mine-Northern Flinders Ranges South Australia

Future work: 4 Mile Creek prospect sampling

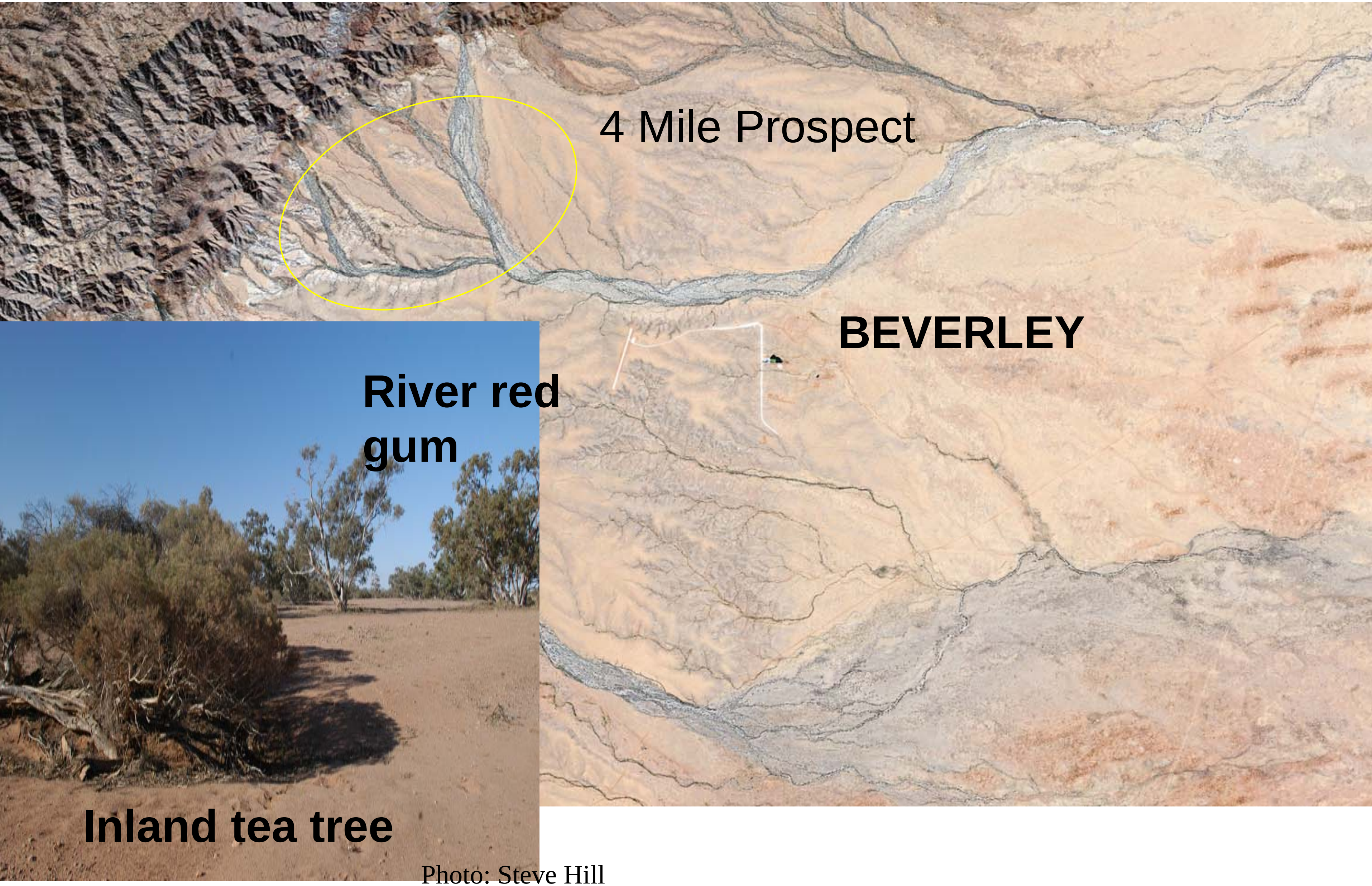


Photo: Steve Hill

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

Acknowledgements

CRC LEME Joint Venture PARTIES

The Australian National University (ANU)
CSIRO Exploration and Mining
CSIRO Land and Water
Curtin University of Technology (CUT)
Geoscience Australia (GA)
Minerals Council of Australia (MCA)
New South Wales Department of Primary Industries (NSW DPI)
Primary Industries and Resources, South Australia (PIRSA)
The University of Adelaide (U of A)

The Chamber of Minerals & Energy Western Australia

CRCLEME